Conservation of Natural Resources

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Editor

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Great men have been among us; hands that penn'd
and tongues that uttered wisdom—better none:

William Wordsworth

A. E. PARKINS
January 10, 1879–January 3, 1940

ELLSWORTH HUNTINGTON
September 16, 1876–October 17, 1947

RALPH H. BROWN
January 12, 1898–February 23, 1948

WALLACE WALTER ATWOOD
October 1, 1872–July 24, 1949

OLIVER EDWIN BAKER
September 10, 1883–December 2, 1949

Preface

The United States from its founding down to the present has experienced three major stages or periods in respect to the great resources of the nation. As the pioneers took possession of the continent they were first overwhelmed by abundance. Great forests stood in the way of the farmer who would cultivate the land. In the rivers and in the adjacent seas fish and other seafoods were available in great quantities. The expansive prairies of midland America were among the most productive of the world. The mineral treasures beneath the surface were largely unknown when the outer frontiers of the nation were first established. To possess the land and bring it under cultivation meant the destruction of a great forest resource. Wasteful exploitation was condoned in the midst of such abundance.

✓This rich heritage passed largely into the hands of individuals, and the development of the resources made possible the flowering of a national economy characterized by great material wealth both for individuals and for the nation. The enormous deposits of coal, petroleum, and natural gas increased greatly the power of the people to make full use of the other mineral treasures. By inventiveness and resourcefulness the machine economy has been made to yield the comforts of modern living in America. The nation by the full development of its material wealth has risen to a high place among the great powers of the world. ✓But the development, even the unwise exploitation, of the resources brought unhappy consequences. The virgin forests are largely gone. Extensive acres of land have depreciated in value through soil erosion or depletion of the plant nutrients. Rich mineral resources have been exhausted or diminished by long-continued use. Fisheries have declined because of overfishing. The great water resources remain uncontrolled. The unwise use of the material wealth of the nation has given rise to a movement to save our national heritage from further wastage. The rate at which the material wealth is being used has raised serious doubts about the capacity of the nation to maintain the same high standard of living indefinitely in the future.

The conservation movement made uncertain progress in the beginning. There existed simultaneously in the United States both abundance and the need for husbanding of resources. This is well illustrated by the need for the restoration of forests in the east while virgin timberlands remained untouched in the south and in the Pacific northwest. Progressively the need for conserving the material wealth of the nation for the future was recognized as a national problem. The idea of responsible custodianship was spread like a gospel among the people of the country. Under the leadership of Gifford Pinchot, Theodore Roosevelt, Charles R. Van Hise, and many others the conservation movement made steady progress against the wasteful and destructive exploitation of the material wealth of the nation. In the administration of Theodore Roosevelt extensive forest lands in the west were set aside as National Forests, and the timber resources were reserved for the nation. This was the first great movement on the part of the federal government to assume a major role in protecting the American people from the wasteful and destructive use of one of the nation's most essential resources. In due course the enthusiasm for conservation spread to other resources particularly soils, fisheries, wildlife, and water. The people of the nation have become aware of the need for conservation.

World War I and the high production of the 1920's made heavy demands upon the resource base to meet the needs of the mass-production economy. Immediately thereafter the difficult times of the 1930's brought on a soul-searching inquiry into the causes and the consequences of the economic prostration which had overwhelmed the country and involved much of the world. It was in this period of uncertainty and concern about the national well-being that Professor A. E. Parkins of the George Peabody College for Teachers at Nashville, Tennessee, and Professor J. Russell Whitaker, then of the University of Wisconsin at Madison, invited a group of geographers and others to join them in preparing a new book on conservation entitled *Our National Resources and Their Conservation,* first published in 1936. The book was revised in 1939 and a new chapter on fisheries was added. As the nation struggled out of the depth of the depression, this noteworthy contribution helped to inspire a new enthusiasm for the conservation of natural resources.

In the preface to the first edition Professors Parkins and Whitaker wrote that

> Conservation seeks to insure to society the maximum benefits from the use of our natural resources. . . .
>
> Conservation of natural resources is a timely field of action in the United States. The occupation of this continent has been accompanied by an unprecedented destruction of the natural landscape. Moreover, as the nation comes of age and the limits of its resources and the character of its needs begin to appear more fully, the necessity for greater care in the utilization and renewal of resources becomes impressive indeed. . . .

Since the editors of the first edition of this book made the above observations about the resource situation, this country has participated on a grand scale in the most destructive of all wars. Between 1939 and 1945 during the period of open hostilities, the United States by her great productive power and access to enormous material resources turned the tide of battle in favor of herself and her allies. And in the post-war period the great wealth of this nation has been used to restore the war-ravished areas of the world and to bring the many advantages of American economic and scientific advancements to the less fortunate peoples of the world. To attain these ends enormous sums of money have been expended. Skills and technical assistance have been shared with peoples who need help. Both war-time and post-war aid have drawn heavily upon the basic resources of the country. The needs of the nation, indeed the security of our people, not only depend on the conservation of resources yet remaining, but where important strategic materials are lacking they must be imported and stockpiled to create a resource base equal to any emergency that might confront the United States in the future. Now at the mid-century mark a re-examination of the resource situation is timely and necessary to our national security.

Conservation of natural resources is not the responsibility of a few specialists, government officials, or militant enthusiasts, but every individual, company, or organization must share in the task of preserving the resource base upon which the American economy has been built. In the schools from the kindergarten to the universities the subject matter of conservation is available for presentation in the classroom. Basic concepts are now a part of the content of botany, zoology, nature study, general science, forestry, geology, geography, economics, soil science, and many other fields of learning. Special courses and curricula on conservation are now available in many schools and universities. What is needed is an enthusiasm and an understanding of the essential nature of resources and the measures necessary to save from wasteful destruction our national heritage. The future educational leaders who are receiving their training in the colleges and the universities have an opportunity to pass along to a new generation of students the knowledge and an understanding of the resource situation as it affects the welfare of the people and the nation. This is a major responsibility of education in its broadest sense.

Conservation education cannot be narrowly graded and assigned to a particular age group in the educational system. People of all ages and occupations should be well informed about the need for conservation. This book is written primarily for college students who will be the scientists, the scholars, and the educational leaders of the future. The adult reader, whether well informed about conservation or not, will find here the essentials of the conservation movement which needs new enthusiasts and leaders.

The discerning reader of this book will note that the contributors display in their respective chapters varying degrees of concern about our natural resources. Some are more concerned than others. The language of despair may be evident here and there and may reflect the authors' genuine pessimism about the resource situation. Here and there a note of optimism may be detected. Forceful and dramatic language may be necessary on occasion to arouse a complacent people to the prospect that America's greatness is at stake.

As editor I wish to express my appreciation of the friendly and cordial spirit which prevailed during the preparation of this book. Co-operation has been magnificent over the many months we have worked together. The contributors have permitted me many editorial liberties in the preparation of the manuscript, but I have studiously avoided any change that might affect the spirit or philosophy as expressed by an individual author. It is my hope that we have brought together in one volume the many facts and ideas in the broad and diverse field of conservation so that the reader may go about his tasks with a sense of understanding of his responsibilities in the complex economy of the nation.

In the preparation of this volume Professor J. Russell Whitaker, the successor of Professor Almon E. Parkins at the George Peabody College for Teachers, generously relinquished any personal interest in the revision. Because of other commitments he was unable to continue as editor. The book retains the general organization of the original edition though most of the chapters have been entirely rewritten. Nine new authors have been added to the list of contributors. They have brought to their task a specialized knowledge of a particular resource. Since *Our Natural Resources and Their Conservation* was first published five contributors have been claimed by death. In another place their passing has been appropriately noted.

Many persons, particularly those in the government agencies, have been most helpful in finding essential data, checking sources, and supplying illustrative material. The help of these and many others is greatly appreciated. To my secretaries, Mary Jackson Neal and Evelyn E. Hard, I am especially indebted for high competence and a sincere devotion to duty.

GUY-HAROLD SMITH

Columbus, Ohio
July 4, 1950

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CHAPTER 1

The Development of Conservation in America

INTRODUCTION

Conservation, a Definition and a Problem

The United States has never been without its leaders in conservation nor have these leaders ever lacked a following. From the Mayflower Compact to the present there has developed a body of thought concerning conservation of natural resources as the foundation of our national well-being. There has been no doubt as to the generous endowment Americans have had, but there has been a great deal of difference in the attitude toward the use of that endowment.

✓ (Two world wars, an intervening depression, and a difficult period of readjustment not yet completed have given tremendous impetus to, and intensified the interest in, the conservation program. The approach to the problem has been from many angles and by many interests in our citizenry. But there has always been conflict—conflict of present versus future satisfaction, conflict in property rights, and conflict between private and social gain.) Although it now appears that conservation has thrust its unwelcome problems upon us overnight, it is much more realistic to recognize the problem as long-standing.

As parts of the environment come into the service of man we call them resources. Literally, any attempt to slow the exploitation of these resources is conservation. Historically the United States has thought of conservation as concerned with shortage in resources. (As nations go, the United States has been superlatively well endowed with resources.) Conservation has therefore achieved national importance only at certain times and with respect to certain resources. Man in America has seen great trees, thick sod, minerals, and surface streams and lakes rise from nuisance items until today they command collector's prices in the scheme of things. He has seen abandoned land, closed mines, and idle fishermen regarded as progress. For the preponderant proportion of our people con-

By Alfred J. Wright of The Ohio State University.

servation is a problem in the wise use of our resources.

How to Achieve Conservation

√ Generally speaking, there have been two schools of thought on implementing a conservation program. One group believes that in the normal operation of a price economy there will be a by-product of conservation. Others feel that manipulation of normal processes in anticipation of actual shortage is necessary in order to slow up exploitation. Whether this is achieved by one method or another, it is obvious that wise use and the elimination of waste in production, processing, and consumption are component parts of the program of the conservation of resources.

√The changing state of the arts has brought new uses for resources and even new materials into use; it alters the proportion in which resources are combined in use. The esteem in which a resource is held varies accordingly, even from place to place at any given time. This has at times given rise to optimism so great as to cause us to lose sight of the over-all picture of resource-utilization. Conservation calls for a change in the proportion of factors assembled for production. It cannot be considered apart from production practice over the years. Let us therefore turn to a consideration of the elements in our background of resource-utilization.

Characteristics of American Economy

The economy of the United States in which conservation practices must be worked out may be briefly characterized. It has developed during a period of rising technology. The frontiers of production were immeasurably expanded by the developments of the Industrial Revolution. This began shortly after the time of our westward expansion across the Appalachian Highlands, when new sources of desirable mineral raw materials were found. Unless a country had available coal or water power and iron it could not participate in the early stages of the Industrial Revolution. The timing of these discoveries in America was just right for the needs of industrializing countries on both sides of the Atlantic. America borrowed capital on the credit established by these resources. The industries thus established in turn created capital, as industrial demands followed hard upon the heels of the westward-moving settler. Cities were built and living standards raised as a result of this "having and timing." Dr. O. E. Baker has stated that in no other country has an economy been built so directly and so quickly from the "fat of the land."

For a combination of reasons the colonists were confined to the Atlantic seaboard for more than a century. French and British colonial policy, Indian hostility, inaccessibility, and the attitude of our government served to restrain these people. After the Ordinance of 1787 was enacted settlers finally crossed the Appalachian barrier to take up the first extensive area of good land they had ever seen. They were, by this time, an indigenous population with more than a century of trial and error in seaboard America, the Imperial Frontier. In contrast with subsequent migrations to western America, many of these people were educated and possessed of some means. Their first homes in the Mississippi basin were of logs, but on shelves were family silver, linen, and books. The log house was less representative of their attitudes and background than were these treasures from their former homes on the Atlantic seaboard.

This generation of Americans had mental as well as physical horizons unlike those of the earlier pioneers. They came at a time when the ideas of the Industrial Revolution were making headway in the New World. They had to wait but one generation for isolation to be dispelled by canals, roads, and railroads. Two shortages faced them at every turn: shortage of labor and of capital. In an effort to conserve these two factors of production, they naturally turned to exploitation of land and all its resources in order to get capital, and to labor-saving machines in order to accomplish the herculean task of permanent settlement. The climax may well be the overwhelming domestic market which has steadily increased throughout the years. The presence of this domestic market was the "climate" in which American resources were utilized. No nation has matched this market.

Conservation and the Frontier

Whether it was in the southern states or in the northern, all the reports from the western-moving frontier were to the effect that good land was limitless. It was level country; it was fertile, the like of which no man had seen. The effects of this great land resource upon society's welfare were not confined to the earnings of the western pioneers. It had pronounced effect upon wages even in the seaboard states; the economy here was attuned to the drawing power of the New West. The governments of the several states and the federal government used land as gold. Land provided for the means of education, religion, and compensation for fraud and damages, and was a reward for military service; it built roads, canals, and railroads. The American soldiers who went with Lewis and Clark and those who stood off the British regulars in the War of 1812 were offered land in the Louisiana Purchase. Enough frontier remains to provide equivalent rewards for a few veterans of World War II, notably in the Yakima irrigated district in Washington.

The new lands were settled more rapidly than any other part of the continent. Ohio, for instance, achieved a population of 2,000,000 within 40 years, whereas New York took a century and a half to reach the same figure. An important factor in accounting for this rapid settlement is the situation of the new lands. From the days of the first settlements in the interior, the Mississippi basin has been accessible to nearly every district of economic vitality. In many instances, the high price of land reflected its location value. In a very real sense, the resource of situation is inexhaustible.

The word frontier connotes the beginning of resource utilization. The speed with which the frontier advanced is therefore one measure of the rate of our resource use. This characteristic distinguishes the economy of the frontier from that of the older regions in the east. The difference in the relative prices of land, labor, and capital between frontier and established regions meant that the goals of agriculture were, of necessity, different. Important groups of eastern people generally favored some conservation; the enterprisers of the frontier did not. Each thought as highly of his son's future inheritance; each was concerned with the natural basis for the nation's welfare; but they did not agree on how to secure these things. Houses and barns on the frontier were built for the present generation; resource use was likewise primarily the concern of the incumbents. Careful farmers there were, many of them, but the economy of the frontier did not promote slowing up of resource utilization, and wise use meant one consistent with the prices of other factors of production.

The wide geographical extent of the frontier, together with its sustained impact upon the nation, contributed powerfully to the right of the individual to develop resources under a great variety of natural settings. In view of the dominance of these factors for so long, it is by no means strange that this right of the individual has become the "frame of reference" within which Americans have come to view the nation's resources. It became a personal privilege to benefit from the profits in farming, lumbering, and mining as these industries functioned to satisfy the nation's needs.

THE BEGINNING OF THE CONSERVATION MOVEMENT

Even during this period of unparalleled exploitation, some men attempted programs calculated to advance the cause of conservation of the foundations of national well-being. Among them were writers who sought to create an awareness of and interest in the diminishing national stock. Louis Agassiz and Arnold Guyot, coming to the United States in the prime of life, were representative of the developing liaison between the "natural historians" of the Old and the New World. Although neither wrote directly on the subject of conservation, both made significant contributions to the program in their classrooms, at Harvard and at Princeton, respectively.

George P. Marsh, a career diplomat, published his *Man and Nature* in 1863, a clear and comprehensive statement of the need for conservation on a national scale.[1] In 1891 N. S. Shaler, Dean of the Harvard Scientific School, ably reviewed the case for conservation in *Man and the Earth,* insisting that, "although the American soil made possible the greatness of the English race in America and in Europe, the frontier has disappeared and our people are driven to till the lands of second-rate quality."

Major J. W. Powell, Director of the U. S. Geological Survey (1881–94), in *Lands of the Arid Region* (1879) contributed a much more realistic appraisal of the dry lands than Professor Shaler. Unlike the others mentioned, his was a career interest in conservation.

It is difficult to see in the acts passed by Congress during the nineteenth century an awareness of the essential problems of conservation or, indeed, a willingness to deal with them. Most of the acts sought to transfer resources to private hands. Kirkland has summarized the acts as "vaguely worded, abounding in exceptions, and economically unsound." [2] Nevertheless they are milestones in the development of conservation in the United States. The first of several Homestead Acts was passed in 1862, the Mineral Lands Act in 1872, and the Timber and Stone Act in 1878. These and other acts are discussed by Professor Visher in the next chapter.

None provided the basis of a national land policy; the chief objective apparently was to create a nation of small farmers. It was not until 1879 that a beginning in land classification was made. In that year the Geological Survey was established and authorized to make a land classification. In 1891 the Forest Reserve Act was passed, authorizing the President to withdraw areas of the public domain as forest reserves. Dur-

[1] Later called *The Earth as Modified by Human Action,* New York, 1907.

[2] E. C. Kirkland, *A History of American Economic Life,* New York, 1946.

ing the administrations of Harrison and Cleveland, and especially under Theodore Roosevelt, 40,000,000 acres or more of western lands were set aside as national forests.

Forest conservation, the first emphasis. It is natural that timber resources should receive early attention. The pioneers were land hunters, but they had come from eastern states, many of which had passed some sort of law for the preservation of certain kinds of trees. They encountered in the Ohio valley a splendid hardwood forest. To land hunters these fine trees were an obstacle which had to be removed in the most economical manner. It was not all wanton destruction, but the timber was depleted at an alarming rate. Before many years every man, woman, and child could see the depletion and feel the economic pinch. The tangibility of the depletion together with the leadership of men able and anxious to do something about it set the stage for the administration of Theodore Roosevelt.

To this project President Roosevelt lent the prestige and power of his office and enlisted the interest and skills of such men as Charles R. Van Hise, President of the University of Wisconsin, James R. Garfield, Secretary of the Interior, Gifford Pinchot, career man in forestry, and a number of university professors (Figs. 1, 2, and 3). Under Roosevelt's sponsorship, a national conservation commission was formed in 1909 to make an inventory of natural resources and to ascertain the probable expectancy for the major ones. The circle widened to include the governors of every state, and eventually (1910) all countries were invited to consider the problems of conservation in a meeting at The Hague.

President Van Hise's *The Conservation of Natural Resources in the United States* (1910) served for a generation as the basic textbook in the field. In 1923 Ely, Hess, Leith, and Carver published *The Foundations of National Prosperity*, regarded by many as a companion volume to Van Hise's book. These men in their classes, their

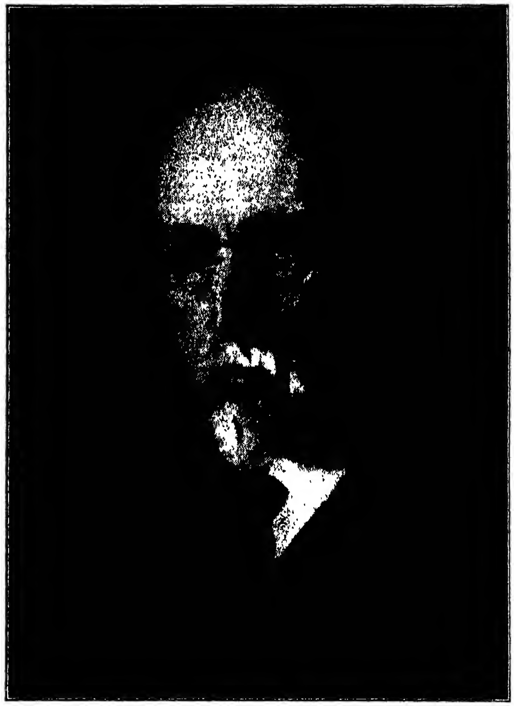

FIG. 1. Charles R. Van Hise, Professor of Geology and later President of the University of Wisconsin, was a leader in the conservation movement during the first and second decades of the twentieth century. His book, *The Conservation of Natural Resources in the United States* (1910), was an outstanding contribution to the conservation movement. (News Service, University of Wisconsin.)

books, and their public addresses, and the Chief Executive from the White House managed to arouse a large part of the American public. They were aware of the changing ratio of man to land and its resources. They had the intellectual and emotional appeal necessary to give order and vigor to the conservation movement. Forest fires, floods, soil erosion, and the spectacular phases of needless destruction were endowed with a mantle of public concern and responsibility, but the enthusiasm was not sufficiently widespread to guarantee that all bills fostering conservation would be enacted into law.

After the administration of Theodore Roosevelt, the popular appeal of conservation subsided, for a number of reasons. Some of the leaders were no longer in public office. World War I diverted attention to other pressing needs. Another reason, obviously, was the conflict in ideologies, particularly the use of resources for private gain as against society's future. A final obstacle was the failure on the part of the leaders to motivate the concept of conservation beyond the "shortage" stage. They were unwilling or unable to draw the logical conclusions from the fact that overproduction caused low prices and a wasteful use of resources. Petroleum was beginning its phenomenal rise, and the fervor aroused by this "black gold" was one of several factors that negated the feeling of "shortage."

FIG. 2. Major J. W. Powell published his *Lands of the Arid Region* in 1879, probably the first realistic appraisal of the nation's dry lands. Mainly as a result of this book an irrigation division of the United States Geological Survey was established in 1888. (American Forestry Association.)

FIG. 3. Gifford Pinchot, at one time head of the Forest Service and later Governor of the Commonwealth of Pennsylvania, was one of the leading conservationists in the United States. For many years he was closely associated with President Theodore Roosevelt who reserved for public use large areas of forest land. (American Forestry Association.)

An Optimism Based on Changing State of the Arts

The period just described may be said to have ushered in the revolution which was taking place in agriculture and manufacturing, particularly. The level land appearing to stretch interminably to the west, the nature of the crops grown, and the relatively high wages paid invited the mechanization of agriculture. In manufacturing the zeal was directed toward economy in production. The elimination of waste was almost an obsession. Higher prices fostered the utilization of scrap iron, steel, rubber, copper, wool, aluminum, and other commodities. What amounted to an electrical revolution made fundamental changes in processing ores and metals, in factory layout, and in transportation.

Whereas in 1918 the best steam-electric plants derived a kilowatt-hour of power from three and one-half pounds of coal, in 1937 only a single pound was required. The internal-combustion engine was promoting another revolution; the automobile industry, as an economy measure, initiated assembly-line production which was to spread through many kinds of industry. Chemical developments included the cracking process in the manufacture of gasoline and increased the yield from 13 to 44 per cent. Cellophane, Lucite, Bakelite, and nylon are but a few of the new materials derived by chemical processes; the list is still growing. Secondary recovery methods of petroleum extraction, deeper wells, and new methods of locating oil deposits pushed the horizon of shortage farther ahead.

On the other side of the ledger there was the fact that between 1909 and 1929 the United States used a greater quantity of earth materials than during the three centuries after the founding of the Jamestown colony. Furthermore the goal of all industry was lower prices and expansion of production which meant increased use of resources. Various devices were employed to attract buyers, and long-term credit made purchasing easier; the economies of mass production could be achieved only as a concomitant of greater consumption.

During World War I, although the American contribution was primarily agricultural, the war period heightened the desire for national self-sufficiency, particularly in the chemical industries. This war had little to do directly with the conservation movement; America's contribution, however, accelerated somewhat the trend toward conservation. (The war had increased, among other things, the size of the manufacturing establishment. With larger units and more abundant capital came the desire and ability to effect economies. Interest in conservation increased also as capital investment in the development of resources became so great as to make preservation of resources an economic consideration. A million-dollar pulp mill can take advantage of reforestation; a small sawmill cannot.)

EMERGENCE OF NATIONAL PLANNING

Herbert Hoover as Secretary of Commerce and as President furthered the conservation program in ways that were less dramatic than those of President Roosevelt but probably more realistic and enduring. Hoover's committee of experts produced the two-volume *Report on Recent Social Trends,* an important part of which was concerned with an appraisal of our national stock and plans for its future use. As chairman of the Colorado River Commission, Hoover initiated the great reclamation project which now bears his name. Some of the measures passed during the succeeding administration were the result of planning by the Hoover administration.

The Depressed Years

The production boom after World War I was followed by the national soul-searching period we know as The Depression. As nothing had done previously, this period caused us to turn inquiring eyes to the foundations of our national well-being, both natural and economic. Franklin D. Roosevelt was in the White House when this second period of widespread interest in conservation was aroused by unemployment; a conservation-minded administration set about finding a remedy for the ills in the national economy. An attitude of "It can't happen here" changed to apprehension lest even the right to earn a livelihood could no longer safely be assumed. A few years of widespread unemployment were enough to make a profound, if temporary, change in our way of doing things. For instance, power shovels were prohibited on some public works projects; in depressed America labor-saving machines were inconsistent with the goal of production, of putting everyone to work. Former goals were not entirely forgotten, however, for the continuous strip rolling mill spread throughout the steel industry. Strip mining of bituminous and anthracite coal and certain other minerals increased markedly. The planting of hybrid corn seed was widely practiced in the Corn Belt states.

The Roosevelt Era

Franklin D. Roosevelt was a conservation-minded Chief Executive. His administration came at a time when the public reaction to conservation measures was on the whole sympathetic. Even so, numerous obstacles were encountered in implementing the nationwide program, but out of the welter of planning there were many substantial gains.

Emphasis on soil conservation. Land planning may be said to have begun with this administration. The Soil Conservation Act (1933) established in nearly every state demonstration areas of more than 25,000 acres. Cropping plans and approved farming methods which farmers under contract agreed to follow for five years were put into effect. The Soil Conservation Service provided materials, heavy equipment, and labor (Fig. 4). Stimulus was given to the formation of soil conservation associations,

FIG. 4. Hugh Hammond Bennett, Chief of the Soil Conservation Service, a long-time enthusiast and leader of the movement to save soils from destructive erosion and depletion. (Soil Conservation Service.)

to be aided by advice and appropriations. Thus, although the original Agricultural Adjustment Act was declared unconstitutional, as amended under the Soil Conservation Act it made a real contribution.

The National Resources Committee (1934) provided for a National Resources Planning Board; within a relatively short time it had produced a comprehensive eleven-volume report of resource inventory and the characteristics of our economy. Although this organization was abolished in 1943, these volumes set a pattern in planning of demonstrated utility and appeal.

The Taylor Grazing Control Act (1934) established a government agency to form, manage, and supervise grazing districts on 80,000,000 acres of the public domain. In 1935 the President created the Resettlement Administration to systematize and extend existing haphazard purchases of agricultural land too poor to afford a living, to transform these lands into recreation areas, forest areas, wildlife sanctuaries, and to transfer the dispossessed population to more fertile areas. Funds to implement this program were suddenly withdrawn, and the functions of the agency were transferred to the Secretary of Agriculture. It is probable that this aspect of the Roosevelt administration's efforts to promote conservation met with the greatest opposition. This is not to be wondered at in view of the opposition of the vested interests and the conflict with the established ways of living.

Much of the work undertaken by the Civilian Conservation Corps (1933) dealt with forest improvement and flood control. At one time half a million young men were at work on these and similar projects. The over-all result was widely believed to be satisfactory; even after the interruption of the five years of war, there has been a movement to establish the program on a permanent basis.

It seems fair to observe that, taken as a whole, these measures of the Roosevelt Era represent a reversal of the American precedent. There is a great deal more government in pioneering than ever before. The fact that the public domain is increasing in nature and extent is likewise new. Although public lands were withdrawn from entry in 1934, some were opened again in 1947. The nature of the public domain changes somewhat as submarginal lands are retired, as mineral rights under continental seas are ruled part of it, and as "authorities" are created for the purpose of reclaiming land and controlling floods.

World War II

These conservation measures were interrupted or deferred by the program of World War II, with its fundamental change in goals, methods, and agencies for the nation's economy. The war was a planning period, the like of which this country had never experienced. It involved national and international planning in agriculture, mining, and manufacturing, prosaic phases of the war effort. Following immediately after the planning for The Depression in the United States, this became in effect another "Five-Year Plan." Few Americans remain unconvinced of the merit of some planning program.

War is a waster. The outstanding fact of World War II was undoubtedly its colossal waste—waste of human as well as natural resources, waste in extraction, production, and consumption, even in the homeland. The struggle over, we now face the stark fact of its appalling depletion of some of our natural resources. Experts have convinced the Congress of the necessity for the purchase and stockpiling of needed and scarce raw materials.

The research stimulated by war continues in some of its aspects. One phase is concerned with the location of manufacturing; the government spent about $20,000,000 for increased plant capacity during the war period; the conversion of these facilities to peacetime uses poses a problem in rationalization of plant location. The rate and extent of conversion have been a matter of some surprise and satisfaction. Economic regionalism is being modified somewhat by this fact. The need for and the support of conservation are thereby increased owing to its interrelations among the several aspects of the economy.

Another phase of war-induced change is concerned with the development of new power sources, new materials, and new methods of wresting minerals from their source. Whatever the pre-war trends were in our economy, the general result of the war experience has been an acceleration of these trends. The size of the producing unit has generally increased; research is therefore easier to provide. Two wars and a great depression within the active lifetime of men and women now living, must necessarily have increased the awareness of the limitations of the foundations of our national well-being.

Post-War Period

Under such headlines as "Land Rush, G. I. Style," the press gave us in 1947 the last chapter in a longtime-dominant fact in our economic development. Questionnaires circulated among soldiers by the Department of Defense showed that thousands of them wanted to own farmland. More than 20,000 arid acres which require only water to make them productive were opened by the Bureau of Reclamation to ex-service men during 1947. Another 16,000 acres were made available early in 1948. We are observing a modern version of the Oklahoma land rush, but with more applications and very much less land.

Unlike other land rushes, these applicants were screened several times. For instance, in the Klamath project along the California-Oregon boundary, of 15,000 requests for land only about 10 per cent were considered eligible for the drawings that determined the fortunate owner. Only 86 farm units were awarded!

The homestead fee is usually ten dollars. The settler must help amortize the cost of the dam or the pumping plant which puts water on his land. The charges are low during the first years while the settler is building his homestead. At the end of 40 years the costs will have been paid.

At Minidoka project in the Snake River valley in Idaho more than 5000 veterans applied for land; 996 names were finally dropped into the lottery bowl; 43 received farms. Reclamation officials hope for a larger proportion of awards when the gigantic project (1,200,000 acres) at Grand Coulee is made available. In this project, as in all others since the war, there will be no speculation in land. This is epoch-making.

Population Shifts

As a result of the war, there has been some redistribution of population. West coast states have gained in population. Press reports from California have spoken of a population of 20,000,000 within one generation. The demands for water are naturally very much greater as a result of this shift in population. Industrial payrolls have greatly increased, thus adding to the domestic and sanitation demands of a large population. Agricultural demands are greater.

The proportional increases in population and industry in states east of the Mississippi River are by no means so large, but there has been some increase in most of these states. A recent trend in industrial location has been toward smaller cities; this is true for instance in the east north central states. An appraisal of water resources is therefore a continuing process even in the humid eastern half of the country. Limited supplies of water constitute a ceiling for regional development.

Conservation is not restricted to a single objective; invariably there are interrelations with other gains. Some combination of irrigation, pollution abatement, flood control, water supply, power, and navigation benefits underlies each reclamation project. The combination varies according to geographical areas. Partly as a result of agencies established before the war, and partly because of changes in the concentration of population and industry, a gigantic flood control and reclamation program embracing more than half of the United States is envisioned. Important developmental projects are under way in the valleys of the Tennessee, Ohio, central and lower Mississippi, Missouri, Arkansas, Connecticut, and Merrimack rivers and in the Great Valley of California and the Pacific Northwest.

In addition to this there are extensive forest programs, farmland rehabilitation, and occasional attempts to introduce conservation into mining districts. Two or three states have undertaken a land classification program of their own. In areas where for generations the people have first mined the soil and then lowered their standard of living, the carrying power of land is no longer a secret of land speculators. This is conservation with man left in.

Conservation not all governmental. The activity is not all governmental. For instance, in 1947 the Natural Resources Council of America was organized. The co-operating societies include: Wilderness Society, National Audubon Society, Friends of the Land, Wildlife Management Institute, American Wildlife Foundation, American Nature Association, Ecological Society of America, Limnological Society of America, Izaak Walton League of America, National Wildlife Federation, and National Parks Association. In rural districts near large cities, the movement of urban workers to the country has stimulated conservation practices on the part of those who own acreage large enough to participate in the movement. Educational and religious institutions also have promoted conservation. One important example is the Mormon Church in Utah, which sponsored one of the earliest and most comprehensive land-use programs in the nation, embracing agricultural, mineral, and urban lands. The carrying power of the land in this isolated arid and semiarid region has been wisely planned and tremendously increased; the role of the Church in the enterprise has declined as co-operative action lessened the need for the institutional factor.

Conservation in the United States is not wholly a matter of our own needs and our resources. Many people in America are wondering what the margin is between the needs of the nation and of the countries that depend upon us and the resources of this country. Public interest in this question definitely points to a maturing not only in our economy but in our national attitudes as well. In 1947 the Secretary of the Interior submitted a report to the Chief Executive dealing with our needs and resources; the Secretary of Commerce followed with a more detailed report on the same subject. *America's Needs and Resources* appears as the title of an exceedingly comprehensive report by the Twentieth Century Fund.[8]

We have long felt that development of conservation in this country has been retarded by public apathy, abundance of resources, and private ownership. Events of the period since 1933 give every evidence

[8] J. Frederic Dewhirst and Associates, *America's Needs and Resources,* New York, 1947.

of the dissipation of much of this opposition. It is apparent that the scope of the conservation program is enormous. It will likewise be evident that on most fronts we have passed beyond the inventory stage. Stock-taking is being followed by dramatic action.

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CHAPTER 2

The Public Domain and Its Disposal

A GENERAL SURVEY

Acquisition of Areas

The term public domain applies to the land owned by the federal government. Here all land formerly belonging to the people as a whole is considered as well as that now so held.

Shortly after the adoption of the Constitution, the 13 original states ceded to the federal government all or nearly all of their claims to land beyond their borders. Thus the first public domain consisted of most of the land between the original states and the Mississippi River, except Kentucky, Vermont, and parts of Tennessee and Ohio. Other vast areas were acquired (1) by the Louisiana Purchase, (2) from Mexico, (3) by the Oregon Compromise, and (4) by the purchase of Alaska. Smaller areas were purchased from Spain, Texas, and Mexico.

Figure 1 summarizes broadly the chief additions to the public domain. It reveals that, of the total land acquired, that ceded by the original states comprised nearly one-sixth, the Louisiana Purchase and Alaska each about one-fourth, the land acquired directly from Mexico about one-fifth, and the Oregon Compromise about one-tenth. The land purchased from Texas (to the north of that state's present boundary) made up four per cent, the purchase of Florida added about two per cent to the total public domain, and land purchased from Mexico added approximately one per cent.

These lands were purchased very cheaply. The Louisiana Purchase cost about 6.5 cents an acre; Florida, 20 cents; the tract purchased from Texas, 21 cents; the Gadsden Purchase, acquired from Mexico, 68 cents; and Alaska, about 2 cents an acre.

Disposal of Areas

Their types and general distribution. Slightly more than a billion acres have become private or state property. This is about three-fifths of the approximately 1,800,000,000 acres (almost 3,300,000 square miles) which at one time or another were owned by the federal government. About half of the remaining two-fifths is in Alaska.

The chief methods of disposal of the land are summarized in Fig. 2, which reveals that about 41 per cent of the alienated land was sold; about 27 per cent was disposed of under the homestead laws; about 19 per cent was granted to the states in aid of education or for other purposes; and 13 per cent was granted in aid of the railroads, most of which was given directly to railway corporations. Nearly a third of Iowa,

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for example, was given for railway or road construction.

The land sold, except under the Timber and Stone Act (1878), was located largely east of the Mississippi River or in Iowa, Missouri, and Arkansas. The land sold under the Timber and Stone Act was, however, largely fine timber tracts of the Pacific states and of northern Idaho and Minnesota.

As the first homestead law was not passed until 1862, most of the more accessible land had already been disposed of by sale or grant. The nondesert land alienated under the various homestead laws was therefore mostly in the second and third tiers of states west of the Mississippi River, in the Dakotas, Montana, and the states south to Oklahoma and New Mexico. Considerable areas were also homesteaded in Minnesota, Arkansas, California, and Idaho, and small tracts in northern Michigan, Wisconsin, Alabama, Mississippi, Florida, and Oregon. Almost no land was homesteaded in Ohio, Indiana, Illinois, or Iowa, and none in the states south of the Ohio River, except in Mississippi, Alabama, and Florida. There was no homesteading in Texas and only a little in Louisiana. Under the several Desert Acts, which were modified homestead laws, nearly 2,000,000 acres were disposed of in Montana, nearly half as many in Wyoming, and about a fourth to a third as many in Colorado, California, and Utah, with small acreages in the other western states.

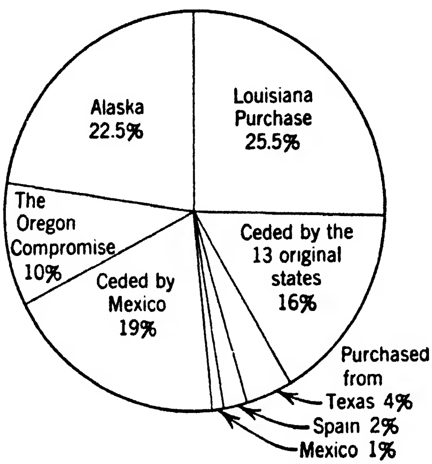

FIG. 1. Sources, percentages.

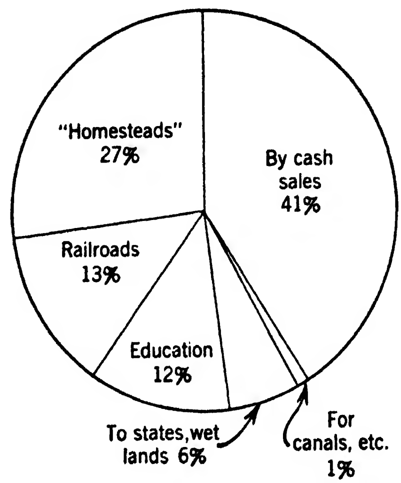

FIG. 2. How disposed of, percentages.

The Public Domain

The land granted to the states in aid of education was distributed throughout the former public domain, with, however, larger acreages in some of the poorer states. The amount, Alaska being excepted, totaled about 120,000,000 acres, nearly 200,000 square miles, an area nearly four times as large as New England. During the earlier decades of the nineteenth century only one section of each township was reserved for schools. After 1848, however, two sections to the township were set aside. In 1850 four sections (2, 16, 32, and 36) were reserved for the schools of New

Mexico and Utah. In 1864 the same provisions were made for Arizona. Moreover, liberal grants for institutions of higher learning were made after 1852. For example, "agricultural college scrip" (certificates entitling the holder to specified acreages of public land) totaled 8,000,000 acres, a tract about one-fourth as large as Pennsylvania. In addition, about 5,000,000 acres were given to state universities. The educational grants to New Mexico have been greater than those to any other state. They have totaled 9,600,000 acres, an area nearly half as large as Indiana. The next in declining order are: Arizona, Utah, California, and Montana with areas of 9,000,000 acres to 5,000,000 acres. A dozen other states in the middle west and west received about 3,000,000 acres each, and another dozen received from 1,000,000 to 2,000,000 acres. All the remaining states received smaller grants, mostly in the form of scrip chiefly in support of their agricultural colleges. The eastern states and Texas, which did not have federal land within their borders, necessarily applied this scrip elsewhere, chiefly in timbered areas in northern Michigan, Wisconsin, Minnesota, and California.

The land granted to the states for canals was mostly in Indiana, Ohio, and Michigan; grants for river improvement were largely in Iowa, Alabama, and Wisconsin; Oregon received 2,500,000 acres for roads, and Indiana and Ohio received small grants. The total grants to the states for canals, roads, and river improvement were about 10,000,000 acres, an area almost half as large as Ohio. In addition almost 65,000,000 acres of land classed as "swamp and overflowed land" were ceded to fourteen states. Florida received most, about 20,000,000 acres; Arkansas and Louisiana each received about 8,000,000 acres (roughly one-fourth of these states); and Michigan, Minnesota, Wisconsin, Missouri, and Mississippi each got from 3,000,000 to 6,000,000 acres. Illinois, Iowa, Indiana, and California were each granted 1,000,000 to 2,000,000 acres, and Oregon and Alabama were granted small acreages. (Large portions of these 65,000,000 acres were heavily timbered.) A considerable share of the proceeds from the sale of this swamp land was added by the states to their endowment of public schools.

The grants in aid of railroads, totaling 38,000,000 acres (60,000 square miles or an area almost as large as New England), were also made chiefly to the states bordering the Mississippi River. However, a few other states, Michigan, Kansas, Alabama, and Florida, each received between 2,000,000 and 5,000,000 acres. Minnesota received most: 8,000,000 acres. Of states bordering the Mississippi River, Kentucky and Tennessee received no grants in aid of railroads, and Louisiana and Mississippi, relatively little.

The grants to the railroad corporations, totaling 94,000,000 acres (an area almost as large as the east north central states), were made in the Rocky Mountain and Pacific states and in North Dakota, Nebraska, and Kansas. Two-fifths went to the Northern Pacific Railway, one-fourth to the Union Pacific, about one-seventh to the Southern Pacific, and nearly as much to the Santa Fe. Because of the large grants to the Northern Pacific Railway, the states through which this line chiefly extends, Montana, North Dakota, and Washington, contained the largest acreages of railroad grants, from 6,000,000 to 9,000,000 acres each. Nebraska, Kansas, and California each had about 5,000,000 acres.

Remaining Public Land

Types and distribution. The distribution of the land now in the public domain is shown, generalized, in Fig. 3. It is of three main types: (1) Land reserved for specific purposes and presumably to be held permanently for such uses (Fig. 4). The chief of these is the national forests; smaller areas comprise the national parks and national monuments. (2) The Indian reservations. On the basis of past experience, these Indian reservations will not be permanent. (3) The lands which were withdrawn a few years ago pending classification and further consideration of what should be done with them. This type (nearly all of it arid or semiarid) includes all land usually classed as "unappropriated public land open to settlement." The last type comprised about one-eighth of the total former public domain of the United States proper (excluding Alaska). It was withdrawn from entry by executive order in 1934 and 1935.

All three of these great types of public land are located chiefly in the Rocky Mountain and Pacific states, and in Alaska (Fig. 5). There are small areas of public land, however, in the western parts of the Great Plains states, in northern Minnesota, and Michigan.

A fourth type of public land, at present minor but likely to increase notably, consists chiefly of submarginal tracts formerly privately owned which have been purchased by the federal government to "withdraw them from agriculture," and for reforestation, range control, soil conservation, watershed protection, and wild animal refuges. Many areas of excellent land were

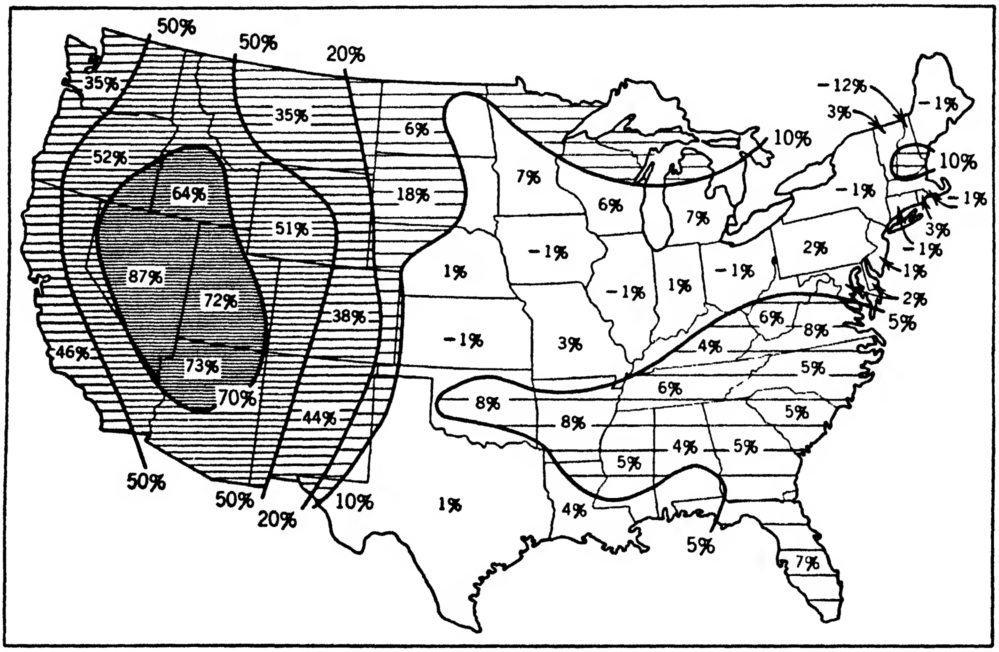

FIG. 3. Per cent of the total area of each state in federal ownership June 30, 1944. (Statistical Abstract of the United States, 1949.)

acquired for military purposes in 1941–1945; vast expanses of former public domain were closed to entry during the same period and are now used for proving grounds, bombing ranges, and other military purposes.

Considerable but temporary shrinkage of the public domain has occurred in some parts of the country when many submarginal tracts have been homesteaded that later, because of changed conditions, may become tax-delinquent. Such areas have become the properties of the local political subdivisions (the counties and states), and only a small fraction of this land has been re-ceded to the federal government. However, the return to the federal government of tax-delinquent lands has been increasing notably, largely to extend the federal forest reserves. Likewise, several extensive privately owned tracts have been donated for national parks, monuments, or national forests. Indeed, as Fig. 3 shows, all the states now contain some federally owned land in addition to building sites in cities.

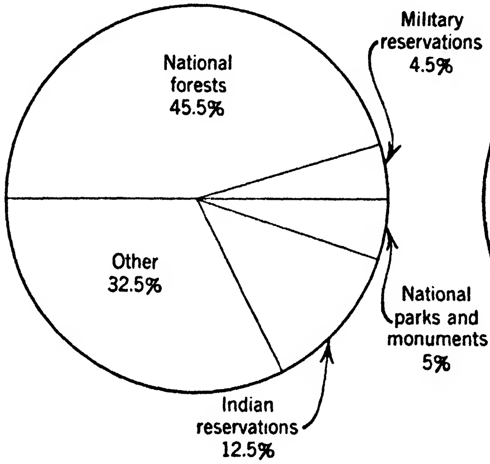

FIG. 4. Continental United States, 455,200,000 acres.

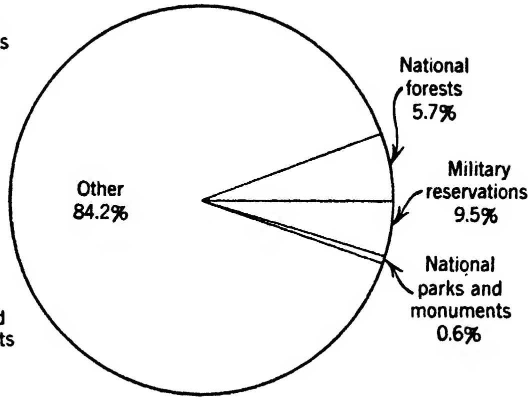

FIG. 5. Alaska, 365,000,000 acres.

Land in Federal Ownership 1944 *

* The Department of Agriculture administers about 166,000,000 acres in continental United States, and about 21,000,000 acres in Alaska. The Department of the Interior administers about 268,000,000 acres in continental United States, and about 310,000,000 acres in Alaska. The National Military Establishment administers about 21,000,000 acres in the United States, and about 34,000,000 acres in Alaska.

Types of Land Involved

The public domain has included almost all the various types of land in America. Choice agricultural land was represented, for example, by much of the Corn Belt; forest land included most of the fine forests of the middle west as well as the superb Pacific forests; mineral lands included most of the metals of the far west; the iron and copper of the Lake Superior region, and also the coal and oil fields of the interior and the west and Alaska; grazing lands have been widely represented ever since the acquisition of the Louisiana Purchase, which included much of the Great Plains. The better agricultural, forest, and mineral lands passed out of federal ownership first, and in more recent decades most of the accessible public domain has been grazing land, less valuable forest land, including cut-over and burned-over areas, and wasteland. In general, with the exception of national reservations, such as national parks, national monuments, national forests, and many of the military reservations, any public land open to settlement is either relatively worthless or so isolated as to be economically undesirable.

CHANGES IN THE POPULAR ATTITUDE TOWARD PUBLIC LANDS

At a time when the seriousness of the problems facing the American people is being widely though vaguely realized, it is desirable to consider what should be the program with respect to the remaining public domain. A preliminary step may properly be a survey of the chief historic changes in opinion as to various types of land. First the popular attitude is considered, and then the attitude of officials.

The popular attitude toward the public domain has varied as a result of five chief influences: (1) the growth of population; (2) the spread of the people made possible partly by improvements in transportation; (3) the conspicuous consequences of the exploitation of the land, especially deforestation, depletion of minerals and game animals, and, more recently, the striking effects of soil erosion; and (4) the growing realization that natural resources are limited in amount and are being used up rapidly. (5) A fifth influence is the growing sense of responsibility concerning the welfare of the populace. Formerly little was done to ease the burden of the poor, partly because people who "could not make a go of it" in one place could readily move elsewhere and start afresh. Now, however, such movements are seldom successful, as the people of each area fill nearly all the local opportunities to earn a livelihood. Consequently vast sums are expended for relief in one form or another. The seriousness of the situation is leading many thoughtful people to consider the desirability of radical changes in our land policies.

Programs concerning the American public domain have also varied widely with changes in the popular interest in agriculture, forests, minerals, and outdoor recreation and with concern for the distant future. Wild land was long considered to have little value. For example, Franklin was criticized by many prominent citizens for extending the national boundary as far west as the Mississippi River, when he negotiated the treaty at the close of the Revolutionary War. Jefferson's purchase of the Louisiana Territory likewise was widely condemned, and Seward's purchase of Alaska was often called "sheer folly."

Similarly trees were long inadequately appreciated. Indeed, few Americans, before the coming of the railroads and settlement of the prairies, considered trees much more than encumbrances to be laboriously removed and burned. The man who cleared the most land was the popular hero, and he who did not completely clear his land was called lazy. The statement, made by those less blind than their fellows, that there would soon be a timber shortage, was widely ridiculed. President Harrison was the first president who felt strongly enough the necessity of forest conservation to carve forest reserves out of the public domain (1892). Not until Theodore Roosevelt's terms (1901–1909), however, were large tracts reserved. He withdrew nearly 150,000,000 acres, in contrast to a total of about 45,000,000 acres withdrawn by all his predecessors. He included in national forests substantially all the forest lands then remaining in public ownership. Franklin D. Roosevelt (1933) was the first president effectively to encourage extensive reforestation, by means of the Civilian Conservation Corps.

Minerals, too, except gold and silver, meant little to most Americans until after 1850. Exploitation entirely without regard to the future needs was the rule. Even today persons who suggest that it is not wise to exploit immediately all mineral deposits are generally looked upon as queer. As a result, except for the reservations by Theodore Roosevelt, little mineral wealth of present value has been retained by the public.

Agriculture was the predominant source of livelihood of Americans until the 1920's. As late as 1880 two-thirds of the people lived on farms. Consequently the public land was generally evaluated in terms of its agricultural utility. The population spread westward year by year, creating tens of thousands of new farms and pushing back the frontier. Nevertheless several great westward surges were prominent. The first of these followed the Revolutionary War, when the better lands of Kentucky and Tennessee were occupied. From 1810 to 1850, during the steamboat and canal period, the large families of the first frontier generations, supplemented by many migrants from the zone from Pennsylvania to the Carolinas, crossed the Ohio and Mississippi rivers in large numbers. A third great surge into the public domain involved many people from New England and New York. It followed the completion of the Erie Canal (1825), the establishment of Great Lakes navigation, and the early railroad extension, to 1861. This wave was the first to spread over the prairies. After the Civil War there was a fourth great westward movement, facilitated by the railroads and encouraged by the free homesteads offered by the homestead law. From 1870 to 1886 hundreds of thousands of people, mostly descendants of pioneers and immigrants, moved into the prairie plains and eastern Great Plains. The dry years of the late 1880's and early 1890's checked the spread; indeed, many Great Plains counties were almost depopulated. But, commencing about 1900, a series of wet years, the enactment of legal provisions for enlarged homesteads, and the development of various inventions helpful to farmers, led to another great increase in the interest in new farms. This was heightened by the opening of various Indian reservations, notably in Oklahoma, and the withdrawal of extensive tracts for forest reserves or mineral examination.

Ten million acres of homesteads were "patented" in 1910—an area twice as large as New Jersey. Dry years, commencing in 1910, checked the spread, but the high prices for agricultural products associated with World War I again greatly increased popular interest in agriculture; but since the land capable of adequately supporting a family on a half-section was "gone," the homestead unit was increased to 640 acres in 1916, for "stock-raising" land. Almost a frenzy of filing on land followed, partly because military service reduced the residence requirements for homesteading. The collapse of farm prices after the close of the war chilled the popular enthusiasm for farming, and the droughts and low prices for farm products during 1930–1936 put an end, for this period at least, to interest in homesteading. Moreover, in November, 1934, and February, 1935, all the remaining unreserved and unappropriated land was withdrawn by executive order.

CHANGES IN THE OFFICIAL ATTITUDE TOWARD PUBLIC LANDS

The popular attitude toward the public domain, just sketched, influenced profoundly the official attitude. Nevertheless the opinions of governmental officials had sufficient independent influence so that a sketch of changes therein is desirable.

George Washington bought and sold unoccupied lands in New York, Virginia, Pennsylvania, and Kentucky to good effect. Many later government officials likewise considered that the unoccupied lands afforded opportunities for personal gain.

Alexander Hamilton and numerous other financiers of the early years thought of the public lands as potential sources of federal revenue. From their sale, much-needed revenues might be obtained with which to help pay the salaries of governmental officials, and at least the interest on the debts.

Many state officials also were interested in having their states receive grants of lands for both of the foregoing reasons. Most of the vast tracts granted to states were sold promptly, often to members of the legislature or their friends, many of whom soon resold at large profits. The funds obtained by the states were partly used to reduce the immediate tax burdens.

Allied to the concept that the sale of public land should help support the government was the realization that such lands could help supply improvements that were desirable. The first important utilization of public land for this purpose was in 1803, when Ohio was admitted as a state. One full section of each township was set aside toward support of public schools. Other tracts were given, during the early decades of the nineteenth century, to aid in canal and road construction. Ere long, increases in the grants for schools were made, and also grants for colleges. When many railroads were projected into sparsely settled or vacant regions, 1865–1885, vast areas were granted to assist in their construction.

A similar use of public lands was the granting of scrip for 65,000,000 acres as partial compensation for military services. This scrip, which in many instances was sold, may be compared with the bonus payments after World War I.

The sales of public land, however, yielded only relatively small sums—only $60,000,000 during the first half century of the nation's history and approximately $160,000,000 during the second half century, and a total to 1946 of about $250,000,000. This, to be sure, is three times as much as was paid for the land purchased from France, Spain, Mexico, Texas, and Russia, but it is pitifully small as compared with the value of the lands sold. Indeed, a competent authority has concluded that most of the land sold by the federal government yielded only a small fraction of what it was then worth (that is, readily salable for).[1] Almost none of it, even the choicest timberlands, brought more than $2.50 an acre, and the average was only 60 cents an acre. All the land sold during 160 years yielded less revenue to the federal government than the taxes on tobacco yield in an average three-month period now.

Likewise the grants in aid of internal improvements, although locally and immedi-

[1] H. H. Schwartz, *Report of the National Conservation Commission,* Vol. III, Government Printing Office, Washington, D. C., 1909, pp. 390–392.

ately helpful, nevertheless yielded results that were disappointing in many ways. For example, the 350,000 acres granted to Wisconsin in aid of the state university actually yielded less than $600,000.[2] This is much less than one-tenth of the sum it has received annually in recent years from taxes.

The failure of sales and grants to yield hoped-for results supported the conviction that the public domain was, after all, chiefly valuable as affording homes for a rapidly increasing population. The indirect taxes paid by the increased population which cheap or free land made possible would yield the chief financial returns to the government. Hence progressively fewer officials contended that the land should be held for sale at higher prices. Instead, more Congressmen and other officials came to feel that it was desirable to dispose of the land cheaply so as to encourage rapid settlement.

The strong individualism encouraged by frontier life and the conspicuous emphasis placed on real estate, partly as a result of the fact that for generations it was readily possible for any ambitious person to own land, also strengthened the conviction that private ownership was better than public ownership. The fact that public land yielded no local taxes and supported almost no population increased the strong local desire to have all public land pass into private ownership.

The desire for the alienation of public land grew until it became a firm conviction of most of the influential people in America. Numerous steps were taken to facilitate the disposal of public land, and little indeed was done to retard its disposal. An example of such an attitude is the fact that when land was sold it was almost always disposed of at the minimum price set by law, regardless of its true value. Likewise, for homesteading, the requirements were the minimum legal conditions in respect to residence and improvements, little concern being shown whether or not the man receiving the title was a bona fide settler or merely the dummy of some grasping corporation or individual.

The demand for decentralization of government and for state control tended to bring about extensive gifts of public land to the states, for no specified purpose. The feeling was that the states could dispose of certain public lands to better advantage than the more remote federal government. The gift of 65,000,000 acres of swampland to the states in 1850 was an example of this policy.

The several homestead laws with their increasingly generous provisions reflect this popular desire to dispose of the public domain. When the famous homestead law, sponsored by Lincoln, was passed in 1862, the unit was 160 acres; nevertheless settlers were soon permitted to obtain also a "pre-emption" of another 160 acres. From 1873 to 1891 in states then being rapidly settled, a "tree claim" was also possible, giving a possible total of 480 acres. The repeals, because of graft, of the pre-emption and tree claim acts, in 1891, were offset in a way by increases in the homestead unit itself. This was increased to 320 acres for "desert" land in 1877 and for "dry farming" land in 1910; it was still further increased to 640 acres for all land classified as "stock-raising homesteads" in 1916. An earlier act, in 1904, provided for 640-acre homesteads in the "sandhill country" of Nebraska.

The successive liberalizing of the homestead laws was in accord with the prevail-

[2] Van Hise, *The Conservation of Natural Resources in the United States,* New York, 1910, p. 290.

ing ideal that the public domain ought to be given to bona fide settlers who would make a permanent home upon the homestead. That larger acreages of poorer than of good land are required in order to yield a livelihood should have been obvious but was largely ignored until it was seen that few of the homesteads of the poorer agricultural land continued to be the homes of people.

The policy of the disposal of the public domain almost led to the gift to the states in 1931 of all remaining public land. Fortunately, however, there were enough congressmen whose states would have received no such gifts of land to prevent this. However, at almost every session of Congress, efforts are made to have some land now reserved made available for exploitation by lumbermen, cattlemen, miners, or others who are seeking additional personal wealth. Hence, although it is improbable that all the remaining public land will ever be allowed to pass out of federal control, constant efforts must be made to prevent local "steals."

After nearly a century during which prompt disposal was the aim, some public land was finally set aside for permanent federal ownership. The establishment of Yellowstone National Park in 1872 was a momentous event in the history of our public domain and an example to other forward-looking countries. Since then nearly 200 national parks, monuments, and reserves have been created from the remaining public domain.

The establishment of the national forests, commencing in 1891 but most extensive in 1901–1909, was even more important in limiting the alienation of public land.

Another phase of retaining part of the domain for the public was the reservation of various mineral and other rights. President Theodore Roosevelt in 1906–1909 withdrew from entry 80,000,000 acres of possible mineral lands pending their classification. Those found to have valuable minerals have been retained entirely, or the mineral rights at least have been retained to be exploited only under government control on a leasing system. Possible water-power sites were similarly withdrawn in the Pacific states and Alaska, where the potential water power is great—more than two-thirds of that for the entire country.

The alienation of public land has apparently almost run its course. During 1940–1945 only about 2,000,000 acres a year were alienated. Most of this land was homesteaded, "applied for," more than five years previously; indeed, as free lands became scarce many homesteaders have delayed "proving up," because until full title is received no taxes are levied. From 1913 to 1922, inclusive, an average of about 8,000,000 acres a year were patented; in 1910 more than 10,000,000 acres were transferred to private ownership.

Likewise the sale of public land has declined to small proportions, yielding less than $1,000,000 a year since 1921, in contrast to about $2,000,000 a year between 1913 and 1920, and $5,000,000 a year from 1900 to 1912, and about $8,000,000 a year during the 1880's.

The public domain, instead of being disposed of, is now being added to notably, by purchase, tax-delinquency, and gift. Moreover, there is much serious official discussion of the desirability of purchase by the federal government of many millions of acres of submarginal lands, especially in the more rugged, sandy, or rocky areas, formerly forested, and in the semiarid Great Plains. Indeed, an official report of December, 1935, recommended that 650,000 farms, with a total area of 101,000,000 acres, be purchased. These farm families had been unable to make a fair living from their farms. Moreover, much of their farm land was damaged by soil erosion as a result of their efforts to farm it. The official belief was that these 650,000 farms could more advantageously be used for forests or, in the drier regions, for supervised grazing. A further significant advantage expected from government ownership of submarginal lands is a reduction of the necessary payments for relief and subsidies for schools and roads in such areas. The removal of the occupants to land upon which they could be self-supporting would lighten the tax burden for the rest of the nation.

Some Ways in Which the Spirit of the Homestead Laws Was Violated

The several homestead laws were presumed to enable settlers to carve permanent homes out of the public domain. However, a large share of all homesteaded land did not afford a home for settlers. Indeed, in large tracts of the former public domain few settlers continued to reside on the land after receiving title to it. The spirit of the homestead laws was violated in five chief ways: (1) Timber land was homesteaded with no intention of making a permanent home, but merely to sell promptly to some lumber company. (2) Similarly, in the semiarid and arid states, many tracts were homesteaded for the sake of the water thereon. As soon as title was obtained, the land was sold to stockmen who could, by owning the available water supplies, monopolize large tracts of public grazing land. Often such homesteading of watering places was done by employees of livestock owners. (3) Although each individual's homestead rights were strictly limited by law, only one homestead being legal, nevertheless many individuals, moving from one land district to another, obtained more free land than they were entitled to, sometimes under assumed names. (4) Homesteading was done by dummies. Federal inspectors, during the rush of homesteading, often could not know that the man who swore that he had made the required improvement, resided on the land, etc., was not the person whose name appeared in the application and subsequently in the deed. Thus a man might "prove up" on a succession of claims, the deeds for which he turned over to another person for a fee. Not infrequently, indeed, the shacks and fences were moved to a new claim as soon as they had enabled the "proving up" of the previous claim. (5) The least reprehensible method by which the spirit of the homestead laws was violated was the selling of the homestead, which by itself was inadequate to support a family, to some adjoining settler who needed it to supplement his own too limited holdings. In semiarid regions, several hundred acres are required, on the average, to support a family.

Public Ownership of Minerals under Water

The public ownership of navigable rivers and lakes has long been recognized, but only in recent decades has the problem of the ownership of the minerals beneath such inland waters or under coastal waters been the subject of much discussion. The state's claim to coal, gravel, and oil under rivers that form boundaries as well as those officially declared navigable was first established in Indiana in 1919. Subsequently many other states have also received substantial sums paid in royalties for gravel and other minerals recovered by permit from under their rivers. When valuable amounts of petroleum were found under some coastal waters, they were likewise claimed by the states. However, since World War II the federal government has claimed the oil under the coastal waters of the Gulf Coast of Texas and Louisiana and of California. The question whether the state or the federal government owns the oil under the "three-mile zone" has not yet been settled.

SUMMARY

One of the most favored 2,000,000,000 square miles of the entire earth was spread out before the pioneers who crossed the Appalachians in 1790. The land certainly awaited settlers, and the public policy soon became the encouragement of settlement in almost every possible way. Land was sold cheaply, and vast areas were donated to the states and to corporations. By 1860 most of the better accessible agricultural land had passed into private ownership. Then, to encourage settlement further, homesteads were given free, with the result that by 1890 the frontier was officially declared gone. Nevertheless, the rapidly increasing, land-hungry people pushed on into the poorer lands until by 1920 there remained almost no public land capable of supporting an American family on even three times the original homestead unit. Except in the ephemeral Indian reservations, settlement and exploitation were almost unimpeded as long as fair agricultural land remained. But from 1892 to 1909 vast areas were reserved for national forests, parks, and monuments. Practically all alienation was stopped in 1934, and a reversal of policy was undertaken—the purchase of lands, largely submarginal, for addition to the reserved public domain.

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PART TWO

CHAPTER 3

The Great Soil Groups and Their Utilization

SOILS are a basic resource. They support the wondrous garment of vegetation which mantles the earth and without which man and his fellow creatures could not exist. This vegetation includes both the variety of domesticated crops and the many types of wild plant life—the trees, grasses, roots, and herbs—which man utilizes. The domesticated flocks and herds as well as all creatures of the wild—all that fly, walk, crawl, or swim—depend upon the land for their needs. Together, the surface configuration (land forms) and the soils constitute not only the stage but also the major source of energy for the vast drama of life which generation after generation of man, plant, and animal enacts on the earth.

Obviously the greater the variety of soils a nation possesses the greater its blessings and the better the opportunity of its people to enjoy a satisfying standard of living. That nation is particularly blessed that has large acreages of those soils suitable for the production of great quantities of the foodstuffs basic to health, and of the organic raw materials essential to shelter, clothing, transportation, and industry, such as wood, cotton, rubber, and soybeans. Of almost equal significance are numerous areas of land suited to the many forms of outdoor exercise and recreation, which are being increasingly appreciated as important to both mental and physical health.

The United States, taken as a whole, possesses soil resources unequaled by those of any other nation. Our great size has endowed us with not only a great diversity of soils but also large areas of land naturally suited to the production of both food and organic raw materials in great quantity. With our territories and possessions, we extend from the arctic into the tropics. In the far north are the tundra lands of the coastal plains of Alaska, ideal for reindeer and other northern stock. Hawaii and Puerto Rico favor the production of tropical foods and raw materials. Of greatest significance, however, is the location of the great mainland in the mid-latitudes where climate is highly favorable to mankind and

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the soils are adapted, or can readily be adapted, to a wide range of human needs and luxuries. Although Russia has a larger land area and has some types of soils that are more extensive, she lacks the highly productive soils of our middle west and south which are such a significant part of our land resources, and a larger part of her lands are more limited in productivity.

THE MAJOR SOIL DIVISIONS

When all the soils of the United States shall have been studied and classified, the number will run into the thousands. However, soils, like other natural objects, can be classified in an orderly system of classes or groups. Such a system may on one hand include all the individual types in a few broadly related and very comprehensive groups. These in turn may be subdivided successively into simpler and less inclusive subgroups until, on the other hand, only a few closely related soils comprise an elementary group.[1] The two broadest soil groups are the pedocals and pedalfers.

The pedocals occupy mainly the subhumid to arid grassland-desert regions of the west. The pedalfers occur both in the humid, dominantly forested regions of the east (their principal region) and in smaller, scattered areas in the rainy and forested parts of the western states. (See Fig. 1.)

The soils included within two such comprehensive groups are naturally very diverse. Taken as a whole, however, the soils of the two divisions are strikingly contrastive in basic characteristics, use, and the conservation problems they present.

The Pedocals

The distinguishing feature of the pedocals is the occurrence of carbonates, or so-called lime, in the lower part of the subsoil, generally in such abundance that the subsoil is gray or streaked with grayish or whitish flecks and bands.[2] The carbonates are formed in the weathering of the soil minerals. As rainwater enters the soil body, the carbonates formed in the upper part are carried downward to the depth of penetration of the water. Since the annual rainfall under which the pedocals developed was low—ranging from the light rains of the deserts to 25 or 30 inches in the subhumid areas—the individual rains seldom penetrate the soil body more than a few

[1] Such a system is similar to that employed by botanists who broadly group all plants into flowering and nonflowering plants, each of which is subdivided into phyla, classes, orders, etc., whereas the closely related species are classed into simple groups called genera. In the United States, there are several thousand elementary soils groups known as "soil series," which correspond in a general way to the genus classification of the biologists. These groups are very important locally. Each has certain specific uses, and each presents particular conservation problems connected with its use. It is impossible to include them in a single chapter in this book, however. This chapter discusses only the two broadest groups of soils, the major soil divisions, and the chief subdivisions of these divisions, known as the great soil groups. Classifying the great soil groups into two major divisions presents some problems on account of the difficulty of fitting some such groups into the two divisions, as for example the prairie soils. However, the classification serves a very useful purpose as will appear in this chapter.

[2] Carbonates are one of the more abundant chemical salts produced in the decomposition of the mineral matter from which soils are formed, especially calcium carbonate. Hence the name pedocal for this soil division, which was coined by adding the cal of calcium to the root of pedology, as soil science is formally entitled.

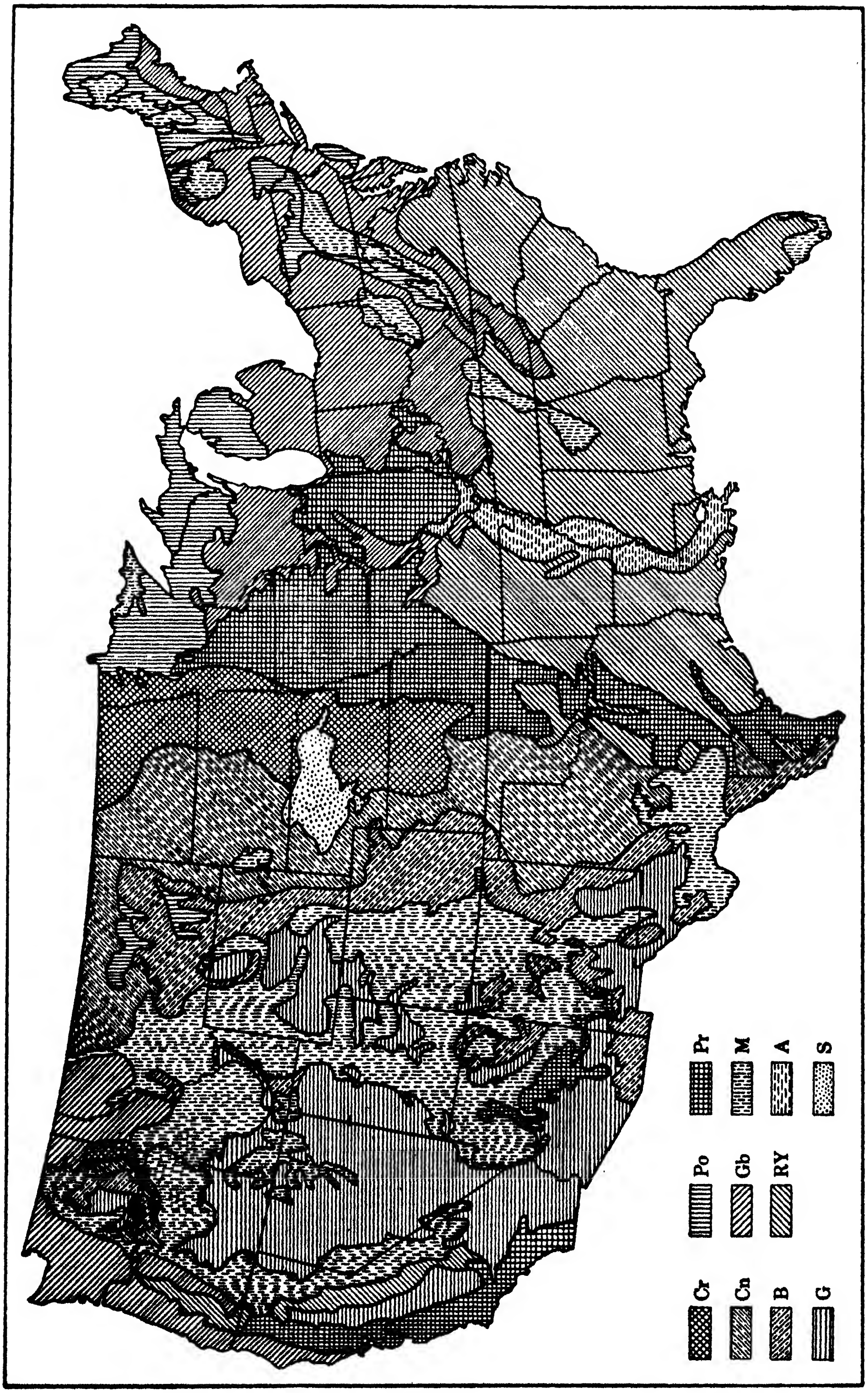

Fig. 1. Soil groups of the United States.

Chernozems	Cr	Podzols	Po	Prairyerths	Pr
Chestnuterths	Cn	Gray-brownerths	Gb	Mountain	M
Brownerths	B	Red-and-yellowerths	RY	Alluvial	A
Graverths	G			Sandhills	S

feet. The carbonates and other soluble salts released by decomposition of the minerals are thus deposited mostly at shallow depths. Since the other salts in comparison with the carbonates are relatively less abundant they are not so apparent to the eye (Fig. 2*a*).

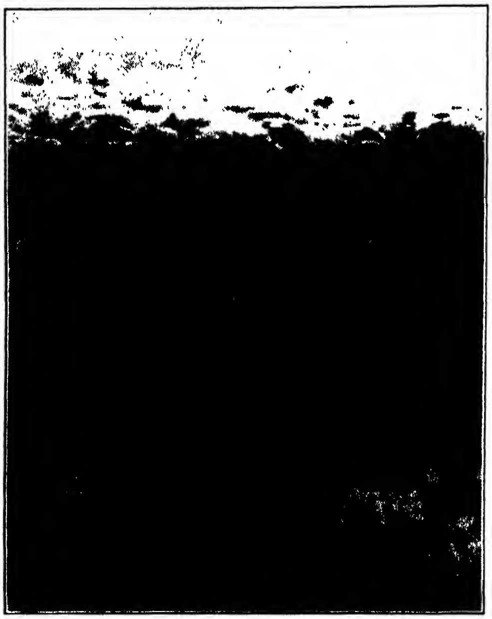

FIG. 2*a*. Road cut in the southern Great Plains showing the gray "lime zone" of the lower subsoil. Small nodular fragments also dot the upper part of the soil body. The black vertical line is a tape measure. A flat-topped mesa shows dimly in the distant background.

This movement of soluble salts, many of which are used by plants as nutrients or "plant foods," does not make the pedocals poor soils, however. On the contrary, pedocals are soils of high inherent fertility and are generally well supplied with the nutrients essential to plant growth and in turn human health. This fertility is due in part to one of the peculiar properties of the clay particles of the soils and in part to the constructive work of the natural vegetation which established itself on the soils during their formation.

Clay particles are colloidal in nature. Colloids are minute crystalline particles mostly less than 0.0002 millimeter in diameter. Depending upon their chemical composition they possess the peculiar property known as adsorption. This is the ability to remove at least part of the soluble salts from the soil solution and retain it on their myriad surfaces. The action may be roughly compared to that of innumerable tiny magnets attracting iron flecks. The colloidal clay of the pedocals possesses the power to adsorb nutrients to a high degree.

The native vegetation played an equally vital role in keeping the pedocals productive. The vegetation of the pedocalic regions consisted of two broad plant formations. Grasslands occupied the subhumid and semiarid areas, and shrub (sagebrush, shadscale, etc.), the deserts. Of the two, the grasses were the more beneficial to the soils.

Grasses develop great masses of finely divided roots. The roots not only occupy the surface layers but also are extensively expanded into the subsoils. They are heavy feeders and bring up large quantities of soluble salts from the subsoil. Each year, however, an appreciable part of the roots die off, form humus, and liberate the salts that they have taken up. Since the dead roots are *in* the soil, the humus and liberated salts are left *in* the soil body, in contrast to the forest formation of the pedalfers which makes its most significant annual contribution of organic material in its leaf fall which is deposited *on top* of the soil body (Fig. 2*b*).

The grassland pedocals were thus continually rejuvenated with both nutrients and humus, and the humus was intimately mixed with the mineral part of the soil.

Humus is all-important to a soil. Like clays, it is colloidal in nature, but weight for weight has several times the capacity to hold water and nutrients. It gives a soil good tilth, making it loose and fluffy and easy to cultivate. It makes soils dark in color and is the chief source of nitrogen. Many other important qualities depend upon its presence.[8]

The physical constitution of a soil is as important as, if not more important than, its chemical and biological properties. It is a relatively simple matter to add water, deficient nutrients, and organic matter, but it is not always easy to change basic physical properties. A dense claypan or hardpan, for example, cannot be easily converted into a loose, friable soil.

The grassland pedocals have two valuable basic physical characteristics. (1) Both surface and subsoils have essentially the same texture; i.e., the subsoils are generally not heavier or stickier than their surface soils. (2) The soils have a good structure; i.e., the individual clay particles are aggregated in the form of crumbs, granules, etc., and the aggregates are durable. They are not easily disrupted. Good structure in a soil facilitates root, water, and air movement. The space between the aggregates provides innumerable avenues for their penetration.

The desert pedocals differ from the grassland pedocals in two important respects.

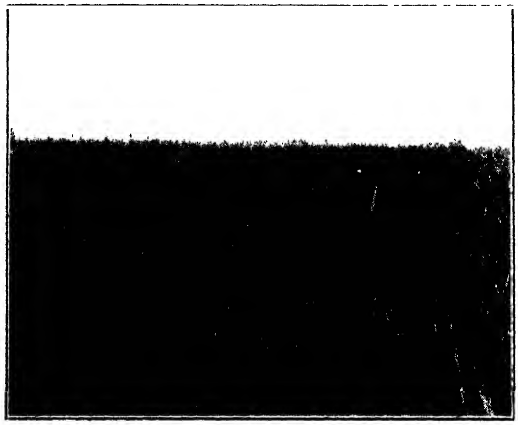

FIG. 2*b*. Native Nebraska prairie. Many people consider grasslands as dull and uninteresting, but they are our greatest builders of good soils. Their great masses of fibrous roots—often exceeding the modest volume of growth above ground—penetrate every inch of the soil and literally pack it with organic matter. The shovel stands about three feet high.

The rainfall under which they developed was light and penetrated the soils to only shallow but irregular depths. The carbonates and other soluble salts therefore are more generally distributed throughout the soil body as well as concentrated in the lower part of the subsoil. Both surface and subsoils are accordingly richly supplied with available nutrients, although the carbonate-rich layer is frequently cemented to a hardpan.

The desert soils, moreover, are low in humus and nitrogen and light in color. The more open type of plant growth of the desert shrub formation, with only a limited

[8] The basic importance of organic matter in soils is not generally appreciated. It is the organic component, however, in the continuous process of birth, growth, death, decay, formation of humus, liberation of salts, and the continued rebirth, life, and death of subsequent generations of plants that gives soils the peculiar characteristics that set them off from all other earthly materials and endow them with their peculiar productive qualities. Without organic life (chiefly plants but also the hosts of zoologic organisms) soil material is no more than disintegrated rock. It is like a dead city, complete perhaps with streets, buildings, and other structures, but without inhabitants—lifeless and unproductive. The organic environment in which a soil evolves is usually the chief factor in determining its characteristics.

proportion of grasses, if any, produced only a small amount of organic matter. The desert pedocals are, nevertheless, highly productive when irrigated because of their high percentage of soluble mineral nutrients and unclouded skies.

In brief, the pedocals are generally "good" soils. They are well supplied with lime, mineral nutrients, and humus (except as just noted), and they have a good physical constitution (except for the hardpans of some deserts). They are easily cultivated and are highly productive *when* rainfall is adequate or the land can be irrigated.

The Pedalfers

The pedalfers evolved under a relatively heavy annual rainfall—from 25 inches upwards to 80 inches and more—and under vegetation that was dominantly forest. The soil-forming processes were thus influenced by comparatively large amounts of water. Chemical weathering of the mineral particles, the growth and decomposition of organic matter, and the removal of soluble salts were accordingly greatly intensified.

The heavy rainfall carried most of the carbonates and other soluble salts to great depths, if not into the underlying groundwater. It also transferred an appreciable amount of the iron and the aluminum constituents of the surface soil into the subsoil.[4] The soils therefore have only a moderate and often small amount of available mineral nutrients. The colloidal clay of the soil has only a moderate nutrient-holding capacity.

Although the trees and shrubs of the forest formation absorbed large quantities of nutrients during their life span, a large part was lost to the soil body. The chief annual contribution of organic debris which the forest made to the soil was a *surficial* leaf deposit (Fig. 3*a*). The surface runoff carries away most of the nutrients released and the humus formed by decomposition (noticeable in the brownish waters which drain from forests), leaving only a part to be restored to the soil by soak-in waters, gravity, and the action of woodchucks, rabbits, mice, moles, worms, and other soil organisms. The pedalfers are accordingly comparatively low in humus and soluble mineral nutrients.

FIG. 3*a*. The organic debris accumulating on a forest floor consists of leaves (mainly), twigs, branches, flowers, and fruits of both the trees and their undergrowth. Measurements show that as much as a ton to a ton and a half dry weight per acre may fall annually. Since the debris is deposited on top of the soil, however, much of its potential value as a source of humus is lost. One seldom finds more than a few inches of dark, humus-rich mineral soil under the forest litter, in contrast with the foot or two of black top soil on the grasslands. (Soil Conservation Service.)

Physically, the pedalfers are also inferior to the pedocals. The subsoils are relatively heavier textured than the surface soils owing to the transfer of part of the colloidal clay from the surface by percolat-

[4] This transfer is analogous to the transfer of carbonates in the pedocals. Pedalfer was derived by adding the al of aluminum and the fer of ferrum (iron) to the root of pedology.

ing waters (Fig. 3*b*). Some of the subsoils are even claypans. Colloidal clay low in soluble salts loses its stability and is easily moved by water.

The clay forms a nutlike structure, but the aggregates are less durable. As the aggregates disintegrate under cultivation, the soil becomes stickier, harder to work, and less favorable for root, air, and water penetration.

FIG. 3*b*. Profile, or vertical section, of a Maryland pedalfer. The six-inch ruler lies at the top of the heavier-textured subsoil, the typical subsoil of pedalfers. Being lighter-textured, the surface of pedalferic soils erodes relatively easily when unprotected by vegetation, leaving the claylike subsoil exposed.

The virgin pedalfer is therefore a relatively poor soil as measured by ideal soil characteristics. It is low in lime, mineral nutrients, humus, and nitrogen. Having lost its lime, it is more or less acid in reaction. The surface soil is made up of only an inch or two of dark-colored soil material below the leaf litter, compared with the foot or two of dark-colored, organic-rich surface soils of the grass-mantled pedocals. The structural aggregates lack durability, and the subsoils are heavy.

In spite of their limitations, however, the pedalfers are productive soils. In fact, they are more productive than their richer counterpart, the pedocals, because the rainy climate which "impoverished" them also makes them highly productive when their deficiencies are remedied.

CONTRASTS IN LAND-USE

Soil groups so different in character are contrastive in land-use. They are contrastive in the problems that have arisen in their use. If we desire to conserve our land resources in the future, the differences between these two broad soil divisions are fundamental considerations. What is good sauce for the goose is not always good sauce for the gander.

Utilization of the Pedalfers

Since colonization and settlement of the United States began from the eastern coasts, it was instituted on lands of pedalferic character. The pioneer farmer began his operations on relatively poor land for the production of his crops. This was true whether he settled in New England, Virginia, or the south. At first he obtained fair and sometimes large yields, especially in comparison with those he had been able to wrest from the soils of his native country. The average virgin pedalfer had a modest reserve of nutrients, a friable, cloddy structure, and the important asset of a rainfall sufficient for a diversified agriculture.

Unfortunately, however, the small reserve of nutrients soon proved inadequate for the greater pressure his crops put on the land, the structural aggregates began to disintegrate, and yields declined year after year until they were no longer profitable.

When this happened, the field was abandoned, or even the entire farm, and a new one cleared from the wilderness.[5]

The pioneer farmer, and his successors who have continued to wear out their soils even into the present century, have been roundly condemned as "soil miners" and "soil robbers." Perhaps this characterization is a little severe. Fair judgment should not lose sight of the fact that the average pedalfer was low in nutrients and weak in structure to begin with, and that it had been depleted by the rainy climate long before any colonist set foot in the New World, and probably long before Rome, or Greece, or even Egypt flourished. In exhausting his soils the colonial farmer merely reduced them to a lower state of fertility and at worst merely robbed an impoverished storehouse.

Far worse than depleting nutrients are the management practices that have gradually led to the *physical* injury or destruction of the soil itself. Many areas in the region have been seriously damaged by water or wind erosion, and restoring land to an equivalent of its original physical condition is not so easy as adding fertilizer to replace depleted nutrients. Sometimes years are required to convert raw subsoil material into productive top soil. However, by no means have all the lands in the pedalferic region been critically injured by erosion. The damage is local, not regional.

Although instances may be cited in which some farsighted individual, like George Washington, appreciated the value of crop rotations, manure, erosion-prevention measures, and other constructive practices, it should be borne in mind that the average pioneer knew little or nothing about them and that at all times the dissemination of any knowledge, and even more important its general application, is slow—very slow. No media for popular education, such as the Extension Service, had been devised, and there were no radios. Furthermore, a huge untilled continent lay before the pioneers. They were few in numbers, and the virgin land seemed infinite in terms of the simple tools they had—the hand-wielded ax and the horse-drawn plow.

Today, the pedalfers are no longer being abandoned nor are they in a general state of nonuse. They are not all under cultivation, however. Within the variety of soils included in such a broad group are many unagricultural types, soils not well adapted to crop production in the ordinary sense of the term. Some are too sandy or too wet. Others are excessively stony. Others occupy hilly and mountainous terrain where slopes are too steep and erosive for plow crops.

The pedalfers are, nevertheless, our chief agricultural soils. They produce the greater part of our crops. An infinite number of roads, fields, orchards, and pastures now spread over the lands occupied only a few hundred years ago by great forest

[5] Under natural conditions, a kind of "working balance" develops between a forest and its soils. The nutrients released each year by further weathering of the minerals and decomposition of the organic litter are adequate to maintain the forest stand even after surface drainage waters, natural erosion, and leaching have taken their toll. But when crops are grown on the same land, this balance is destroyed, because the crop removes nutrients from the soil at a more rapid rate than they are generated. The structure breaks down as the organic matter is exhausted. The pioneer farmer did not use fertilizers to replace those his crops took from the land, nor did he maintain the organic matter of his soils through the use of manure, clover, etc.

formations (Fig. 4*a*). The roar of the tractor and the shout of the muleteer have taken the place of the call of the forest creatures.

Although the agricultural pedalfer is naturally low in nutrients and its physical constitution is not so rugged as that of the pedocals, it has the superiority of a rainfall that is generally adequate and dependable in both amount and distribution. Water, more than inherent fertility, is the irremediable limiting factor in crop production. Rainfall cannot be made to order, and water supplies are far too limited for general irrigation.

But mineral fertilizers can be profitably applied, and in about the exact proportions required for any crop adapted to the climate. Organic matter can be economically built up by means of animal manures and green manure crops, and the organic matter helps to improve the soil's structure. Where land is erosive, it can be held in place either by vegetative means, such as the use of cover crops, crop rotations, and reforestation, or by mechanical controls like contour farming and terracing. One of the epochal events of our times is the effort being put forth by agencies and organizations of all kinds, both public and private, to promote the more general use of soil conservation measures.

FIG. 4*a*. A New York lowland showing grain fields, pastures, hay lands, orchards, and woodlots—one of the highly diversified complexes of land use that characterize the pedalferic division. Compare with the simple landscape of Fig. 4*b*.

The nonagricultural pedalfers on the other hand supply many of our other important wants. We have need for many kinds of land other than agricultural, for purposes in which the quality of the soil is secondary or of minor importance. We need land for lumber and pulpwood production, and the pedalfers are natural forest lands. Obviously, the better the soil the better and faster-growing the forest "crop," but, since the growth of food is more imperative than lumber and pulp, we are reserving most of our first-class pedalfers for agriculture.

We need land for villages, towns, and cities; for rural residences, industry, and businesses; for mining operations; for water conservation and storage; and for roads, railroads, and airfields. We desire land for recreation of both extensive and intensive types. We need land for the maintenance of wildlife of many kinds.

The agricultural, unagricultural, and nonagricultural lands frequently occur in close association with each other, as within a given neighborhood or community, as well as in distinctive larger and relatively homogeneous bodies of land. Both types of occurrence have advantages. Large areas permit larger-scale development. An example is an area of forest land which may be set aside as a public-owned forest and managed and utilized as a unit for such purposes as timber production, wildlife, and extensive recreation. On the other hand, when several types of land are comingled with communities inhabited by large numbers of people, they facilitate the establishment of parks, playgrounds, and similar intensive or other recreational land uses within easy access of the population.

Since the passing of the frontier with no new lands to settle and exploit, and with the growing pressure of population on our land resources, we have been busily engaged in classifying our unagricultural and nonagricultural lands. We have been endeavoring to determine their proper ownership (public or private) and stimulating the utilization of each type for the purposes for which it is best adapted or for which it is most needed. Many agencies, both public and private, are occupied with these efforts. Some are state and federal agencies, such as the United States Forest Service or Wildlife Service, and state departments of conservation and resource utilization. Some are local political units like townships and soil conservation districts. Others are unofficial groups and organizations made up principally of interested local citizens, such as land use planning committees and conservation clubs.

Utilizing unagricultural and nonagricultural lands for the purpose to which they are best adapted is as important an aspect of conservation as maintaining agricultural lands in a productive state. Considered from this point of view, no soil is a poor soil. "Poor for what?" one might ask. For agriculture perhaps, but perhaps not for forestry, or recreation, or a bit of habitat for some type of wildlife. A more constructive question would be, "Good for what?" or "Best used for what?" When that answer is determined, then that land should be made as productive for that purpose and maintained as productive as any piece of farmland. That is complete conservation.

Utilization of the Pedocals

The pedalfers and pedocals are world types; i.e., the soils of the world may be grouped into the same broad divisions. The soils of humid forested regions are pedalfers; those of the dry grassland and desert regions, pedocals.

The world's greatest body of pedocals extends from the dry grasslands and deserts of Africa across Arabia and central and southern Asia into western China. The rainfall under which most of these soils occur is too low for satisfactory cropping without irrigation. For centuries, therefore, these natural grazing lands have been the domain of the hunter and pastoralist. The cultivator confined himself to the oases and the more humid margins, where he produced grain. Even here he generally had insufficient shelter, little or no wood for house or fuel, and a water supply limited chiefly to surface sources and shallow wells, as the chief groundwater lay deep.

The latter part of the nineteenth century inaugurated a revolutionary change in the age-old relations of pedocals and pastoralism. The agriculturist began pushing his fields into subhumid and semiarid grassland pedocals and driving the pastoralist to the arid and desert pedocals.

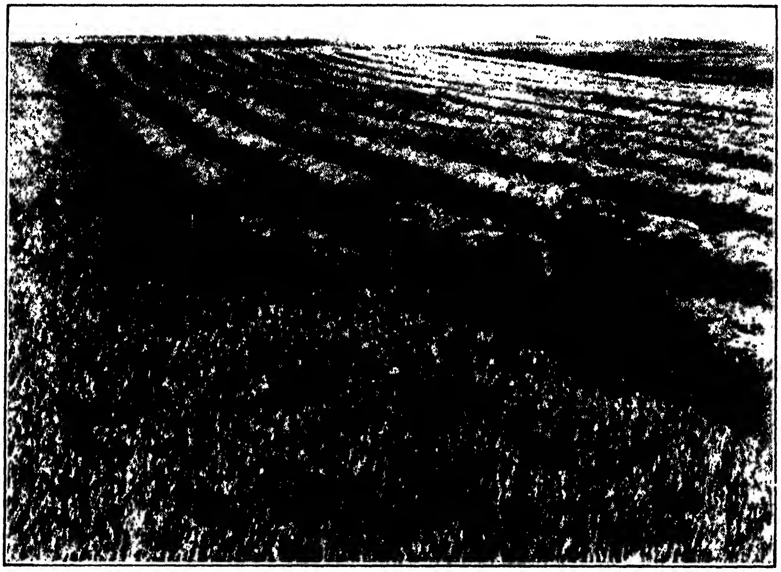

FIG. 4*b*. Harvest time in a North Dakota grainfield. Grainfields extending to the horizon and interrupted chiefly only by pastures in native grasses and occasional windbreaks symbolize the basic agriculture of the northern grassland pedocals. The grains are noted for their high nutritive value. They are rich in proteins and chemical salts essential to human health. (International Harvester Company.)

In the United States, the grassland pedocals, before the advent of the white man, were chiefly the home of the plains Indian who hunted the buffalo and other herbivora. Then came the stockman, the counterpart of the old-world pastoralist. But his days were limited. After a few decades of large-scale operations, he was forced desertward by the agricultural pioneer advancing westward through the pedalfers in search of new land.

The northern plains suddenly blossomed out in small grains, and the southern in cotton (Fig. 4*b*). Having nourished wild grasses for centuries, they proved ideal for their domesticated relatives, the cereals. Cotton, which is surprisingly resistant to low rainfall, found the rich grassland soils of the southern plains far superior to the poorer pedalferic soils of the eastern Cotton Belt. Livestock remained in the region only as an adjunct to farming, occupying chiefly the sandy lands and the rough lands bordering the occasional stream courses which have incised themselves in the plains.

A number of converging factors contributed to this revolutionary change in the economy of the pedocals. (1) The invention of the railroad provided cheap land transportation. The pedocals lay in a continental interior whose rivers offered but limited navigation. The soils are not well adapted to a highly diversified agriculture.

Cheap transportation is therefore indispensable to agricultural settlement when crop variety is limited, and all other necessities must be shipped in for the bulky crop or two that is shipped out. (2) The development of agricultural machinery provided the means of utilizing large acreages. Although the soils were rich, yields were only moderate in a land of limited rainfall. Much more land had to be cultivated to maintain adequate living standards. Of special importance in the grassland environment was the invention of a steel plow with moldboard and share of mirrorlike smoothness and with a proper curved shape to cut and invert the entire furrow slice. The straight chilled cast-iron plow with its rough-edged grain surface to resist the wear of the gritty soils of the forest was wholly unsuited to the sticky, fine-textured soils of the prairies. (3) During the period of settlement, the region experienced an unusual series of rainy years that were broken only by comparatively short droughts. The rainfall was not all that could be desired, but the nutrient-rich soils and their excellent water-holding capacity helped to compensate for the moisture limitations. (5) The invention of barbed wire met the tree shortage and stone shortage for fencing. (6) The development of deep-well drilling solved the water-supply problem. (7) Cheap land and good prices for grain and cotton offset all the other limitations.

Unlike the colonial settler, the western pioneer fashioned his cropland out of good soils and many grew grains on the same land year after year. At first the land gave promise, moreover, of remaining highly productive indefinitely. Except for variations imposed by the low and variable rains of the drought periods, yields showed little decline after some years of cultivation, even without fertilizers or any program to maintain the organic matter of the soils.

What is taken out of land beyond that which nature herself restores must be replaced. The years of one-crop agriculture eventually broke down the soil structure. Each year, when the land was prepared for the next crop, the rich humus of the soil and its teeming zoologic life were turned to a withering sun which gradually oxidized the organic matter and killed the soil population. The soil grains deprived of the binding effect of the humic colloids fell apart and turned to dust. Then the 1930's ushered in the longest and worst drought the region had ever experienced since weather records were kept. Dried out from lack of rain and left bare of all vegetation, the broken-down soil was at the mercy of every wind, and great dust storms swept through many parts of the region. The wind literally blew seeds, and sometimes seedlings, out of the land, shifted the loose soil into drifts, or stripped the land to the depth it had been plowed. Droughts and dust storms had occurred many times before. Records indicate that they had taken place again and again at least as far back as the previous hundred years, very irregularly and unpredictably. But this time the land was much more fully occupied and in poorer condition than ever before to withstand the soil-destroying winds.

The people of the plains faced ruin. Thousands migrated to the wetter lands of the Pacific Coast states. The region was not emptied of its population, however. Many stuck it out. Nor were the plains one vast "dust bowl." Thousands of fields did not blow because they were not over-exploited. On land protected with plants, dead or alive, the surface was shielded and the soil grains were held together. Moreover, the drought was irregular in time and place. It was spotty. That is a peculiar feature of the rainfall of these dry lands even in normal years.

Today, the land as a whole is tacked down again, thanks to the patient and heroic efforts of federal, state, and local agencies and of the men themselves who live on the land. Lands subject to abnormal blowing have been revegetated, and the majority of the cropland is being tilled in accordance with good soil and conservation practices.

Nature helped, too. She reinstated her normal rainfall near the end of the 1930's. But she has also issued warnings that serious droughts will come again and again. In 1945, a giant duster swept into the Dakotas from Canada, and in 1950 ominous dust clouds again swept the southern plains. Unfortunately much of the land has not as yet fully recovered its organic matter and structure since the last great drought. Many years of good farming are still needed.

The chief and cheapest insurance that can be provided for future droughts, whether they are short or long, is to husband every appreciable rain that falls and to make the most of every wet year. A single good rain, properly conserved, has carried many a crop through to maturity or to the next good rain. The wet years help re-establish needed vegetation, the organic matter, and the soil life that play such a significant role in building and maintaining structure and in storing water against the dry years.

The greatest threat now to conservation farming are the "suitcase farmers," who flock into the region during high grain prices, strip the land of its covering, live out of their suitcases during seeding and harvesting, and then abandon the bared land to the winds when prices fall.

THE GREAT SOIL GROUPS

Although the pedalfers may be briefly characterized as the high-rainfall, forested soils, and the pedocals as the low-rainfall, grassland-desert soils, the regions in which each major division occurs are made up of several climatic and vegetative types. Each climatic and vegetative regime has given rise to a distinctive group of soils which differs in a number of respects from the other groups of their respective major divisions. These broad subgroups are known as "the great soil groups." In the pedocalic regions, these subgroups may be termed chernozems, chestnuterths, brownerths, and grayerths; in the pedalferic regions, podzols, gray-brownerths, and red-and-yellowerths. In addition, there is an intermediate group, which we shall call the prairyerths (prairie soils), having characteristics of both pedalfers and pedocals.[6]

The Podzols

The podzols occupy chiefly the northern borders of the United States, extending from the Upper Lake states to New England and the northern Appalachians (Fig. 1). Small areas, not shown on the map, occur in the Rocky Mountains and the Coast ranges. The special factors in their formation were a comparatively humid climate, low temperatures, and coniferous, deciduous, or mixed forest. As the organic

[6] Several additional but closely related great soil groups are recognized by pedologists. In order to provide the general student with as simple an outline as possible of our soil groups and their relationships, however, the more closely related groups have been combined and given a simplified name based upon the more cumbersome names employed by pedologists. Soil students have not as yet devised a simple system for naming the great soil groups.

debris fell to the forest floor, it was attacked by fungi, which converted it into organic acids and humus. Rainwaters taking up the acids entered the soil, attacked the mineral particles, removed the greater part of the soluble constituents, and left the soil highly acid in reaction. The forest vegetation returned only a small proportion of the soluble salts to the surface since the nutrient requirements of most conifers is low and they draw only lightly from the soil. The hard needles, moreover, were slow to decompose, and surface drainage waters continually carried away a large part of the nutrients liberated.

FIG. 5a. A freshly plowed podzol field in north-central Michigan. One of the most striking features of a podzol is the gray-white surface soil underlying the very thin dark-colored surface layer. Although the forest floor of the virgin soil is carpeted with organic debris, it consists chiefly of "raw humus," a mat of hard needles and twigs that decompose but slowly under the cool and low-light conditions. Only a thin layer of dark-colored humus-stained mineral soil underlies the mat. The organic complexes formed from the decomposition of needles and entering the soil are carried into the subsoil and deposited there in a brown coffee-colored layer. The plowed field shows the exposure of the whitish soil layer lying between the thin humus-stained surface and coffee-colored subsoil.

The surface soil is especially lacking in the features generally associated with good soils. It is so low in organic matter that it is conspicuously whitish or gray in color.[7] The colloidal clay is very low in adsorbed nutrients and has only a limited adsorptive capacity. The subsoil is also low in nutrients but is typically a striking coffee-brown and relatively heavier in texture owing to a marked transfer of organic colloids and other fine soil particles (Fig. 5a).

During the course of exploiting the continent, the podzol region was primarily the sphere of the lumberman, that "forest plunderer," who stripped it practically bare of its excellent timber. Although his act

[7] The light-gray soil material looks like ashes. Podzol, signifying ashlike, is a folk term applied to similar gray soils in northern Russia. Pedologists adopted it to designate soils of similar character throughout the world.

was commonly censured as destructive, the timber proved a primary factor in the development of other regions. The New England timber helped develop the great shipbuilding industry of the eastern seaboard, and the Great Lakes region supplied and built up the great treeless interior farming lands south and west of the lakes. But the region was largely shunned by the farmer-pioneer. The majority of the soils were too limited in fertility, and much of the land was sandy, rocky, or poorly drained. The climate was too cool and the growing season too short for most crops. Considerable acreage was cleared in New England but generally abandoned when the west was opened up. Elsewhere clearing was only patchy, and incidental to lumbering or mining. Hay was in great demand for the workstock of the lumberman, and the lumberjack took advantage of this nearby market by turning farmer in the summer.

The chief future hopes of the podzol region are its forests and recreational resources. This is its most appropriate use. The land as a whole is best utilized for forests and wildlife, and the region is blessed with an excellent summer climate, innumerable lakes, scores of streams, and considerable rolling and rugged land. Each of these is a major recreational resource. Millions of acres of forest land, once abandoned after being cut over and ravaged by fire, have been returned to public own-

FIG. 5*b*. Although much has been said and written regarding the urgency of reforesting cutover lands, it is noteworthy that, left to themselves except for fire-protection, the cutover lands of the podzols are growing a new crop of valuable timber. Note the young conifers pushing up into the poplar which sprang up after the lumberman and the forest fire. In time, the conifers will crowd out both poplar and much of the undergrowth. As the latter shrinks, the deer population will shrink. Since deer and other herbivora are also valuable "crops" of the land, the controlled use of fire, once regarded as only an enemy, is winning increasing favor to maintain browse in selected areas.

ership and are growing a new crop of trees (Fig. 5*b*). Thousands of deer are thriving on the grasses, shrubs, and other browse that sprang up after the forest fires. Management of private forest lands is making great forward strides. Green forested lands are basic to the recreational use of a region.

The most valuable land in the podzol region is that which has a water frontage, since water has an irresistible appeal to man. Innumerable summer homes, cottages, overnight cabins, trailer camps, motor courts, boat liveries, eating establishments, night clubs, and amusement enterprises of various types line the lake shores and river banks. Many thousands are yet to be built. Although this use of land has little direct relation to the quality of the soil, it has a significant bearing upon the use of land of the broader neighborhood within which the water frontage is located. Good water frontage requires a setting of woodland or forest, and it frequently stimulates the development of local agriculture for the production of eggs or fresh vegetables.

One of the major responsibilities facing local communities in the podzol region is that of planning and directing the effective use of its water frontage and other recreational resources. Unless given some degree of direction, the ultimate pattern of land use becomes a hopeless jumble and the potentialities inherent in this important resource of the region are lost. Summer homes, overnight cabins, trailer camps, and the varied types of land uses crowding into the region injure one another and injure the community at large when indiscriminantly intermingled.

Although the podzols, taken as a whole, are low-ranking agricultural soils, they can be improved by heavy fertilization, liming, and building up their organic matter, but this is economic only under exceptional local conditions, such as a nearby or restricted market for some product. Scattered through the region, however, are a number of tracts of land, some relatively large, that are naturally quite fertile. Their soils are not true podzols but are soils derived from parent materials high in clay or lime, which retarded their podzolization. These areas comprise the valuable farm lands of the region and should be conserved primarily for that use. When moderately limed and fertilized, they make high-quality potato land and are excellent for pasture grasses and other crops basic to dairying. The summer visitor is a profitable local customer for fresh milk, and the milk truck or train and a string of cheese factories give access to the more distant markets.

The Gray-Brownerths

The climate under which the gray-brownerths developed averaged warmer and wetter than that of the podzols. The natural cover was mainly deciduous forest with an undergrowth of shrubs, herbs, and grasses.[8] This formation played an important role in the development of the soil. It produced quantities of organic matter. As both trees and understory are heavy feeders, they returned large quantities of soluble materials to the surface (Fig. 6*a*).

[8] The gray-brownerths mantling the valleys and slopes of the Rocky Mountains and the Pacific Coast Ranges were, with the exception of the Willamette valley, developed chiefly under coniferous formations some of which have dense undercovers analogous to the deciduous formations of eastern United States. Where the undergrowth is sparse or absent, the surface soil is characteristically grayish or light-colored, suggestive of the podzols.

The deciduous formation produced a heavy leaf fall each year. In contrast with the hard needles of the podzols, the soft leaves decomposed quickly and liberated their salts more readily. The humus

Fig. 6*a*. Virgin white oak on a gray-brownerth of Ohio. Such stands of virgin forest are becoming increasingly rare. Their preservation is important for future studies. Oak, maple, beech, and other deciduous trees formed the dominants in the eastern gray-brownerths. The undergrowth of shrubs and grasses common to the forest contributed materially to the characteristics of the soils. The soft leaf litter from trees and undergrowth decomposed much more rapidly than the hard needles of the podzols, and the soil supported a larger and more varied fauna (worms, mites, mice, woodchucks, etc.) which assisted in mingling more of the humus with the mineral part of the soil. (L. A. Guysel.)

formed was less acid, and the leaching solutions were less acid. The soil is therefore only mildly acid. The humus not carried away by surface drainage waters was, unlike the podzols, mingled chiefly with the surface layer, enhancing its productivity and making it brown or grayish-brown, whence the name of the soil is derived. The colloidal clay has a rather good capacity for holding nutrients and water and under virgin conditions had a moderate "reserve" of plant foods. Both surface and subsoil have a comparatively good structure, generally nutlike in form, although like all pedalfers the subsoil is the heavier textured (Fig. 6*b*).

The gray-brownerths are the top-ranking pedalfers. As a group they are the most naturally fertile and productive soils of the division. The nutrient and organic reserves of the virgin soils were only moderate, but their relatively good structure

Fig. 6*b*. Road cut exposing the brownish light-textured surface soil and the lighter brown, heavier-textured subsoil (below the six-inch ruler) of a gray-brownerth. A nutlike structure is typical of these soils in contrast to the granular structure of the grassland prairyerths and chernozems.

makes them highly responsive to liming and fertilization. Organic matter is easily improved. They are comparatively durable soils. They are easily cultivated. Climatic conditions and location are excellent. They occur in the humid mid-latitude climates with long growing seasons and generally dependable rains.

They are not inexhaustible soils, however. No soils are. They must be limed, fertilized, rotated, maintained in organic matter, and protected from erosion, like any other pedalferic soil. But the labor and cost of maintenance are not generally burdensome, and the rewards of good management are great because the soils are basically good.

Not all the soils within the group are equally desirable. Those derived from highly sandy formations, or from shales, are more readily exhausted, more difficult to maintain, and more limited in their utility. The region over which the gray-brownerths are developed includes also large areas of rugged land, particularly in the Appalachians, the Rocky Mountains, and the Pacific Coast Ranges. Except the level lowlands, these lands are primarily forest, wildlife, and recreational lands. As in the podzol region, good conservation calls for the identification of each of these types of land-use within each highland community, followed by programs and measures to implement those uses.

The gray-brownerths were the chief soils of the colonial seaboard farmer, and of the pioneer-farmer who pressed across the Appalachians into the middle west. They were soils similar to the brown soils of their North European homeland and, therefore, well adapted to the crops and livestock that they brought with them. Although many an acre was cleared, "mined," eroded, and then abandoned when newer virgin lands beckoned westward, the abandonment was only temporary during the flush of settlement of the continent. The intrinsic value of these soils was soon recognized. Their level areas now comprise one of the stable agricultural regions of our country.

One of the more valuable assets of the gray-brownerths is their marked adaptability. They can be easily and cheaply adapted to any crop climatically tolerant of their regions. Most crops are not adverse to mild acidity—many seem to prefer it—and, with a good physical constitution, the soils can readily be built up to meet the peculiar requirements of almost any crop. As a consequence, the region presents a highly checkered landscape. As economic or other conditions have warranted, it has been easy to adapt these soils to orchard or grainfield, to pasture or tobacco plot, to dairy farm, truck patch, vineyard, or forage crop. In all, the soils comprise one of the more valuable types that the United States possesses.[9]

✓Unfortunately, good lands often experience more abuse or misuse than poor lands, and the gray-brownerths have been no exception. Large areas suffered the evils of an exploitative commercial agriculture, because they were easily cultivated, productive, retained their productivity for some time, and good markets were available for their products. Too little was put back to replace what was taken out of the land. Even more serious have been the widespread losses from erosion. Millions of acres in slopes have lost millions of tons of topsoil and are scored by millions of gullies. Worst of all are the extensive areas of apparently level land—the cream of the agricultural lands—which likewise have lost millions of tons by creeping surface wash,

[9] For a fuller account of their economic utility see L. A. Wolfanger, "Economic Geography of the Gray-Brownerths of the Eastern United States," *Geographical Review*, Vol. XXI, 1931, pp. 276–296.

too slow to be seen by other than the observant eye.

The crisis in the misuse of this excellent land is now generally passed, although much still remains to be done. Its people as a whole have become aware of the problem and the need for doing something about it. This is half the battle in any situation. The other half is the invention of weapons capable of winning the battle and their employment on the battle front. Soil conservationists have now devised protective measures to hold different types of land in place under nearly every type of land-use. Radio, newspaper, magazine, and leaflet have broadcast the urgency of soil conservation. Thousands of land users are heeding the counsel in whole or in part, and each year their ranks are swelling. That the battle is not yet won, however, is attested by the floods which continue to plague these lands almost annually. Enormous quantities of muddy waters still creep down the slopes or rush pellmell into the lowlands and rivers of the region. One of the greatest problems now confronting this region is to animate every land occupant to become a soil conservationist in both principle and practice.

The gray-brownerths vary greatly in both soil and surface even in those areas generally regarded as level or only gently rolling. Prime farmland is frequently mixed with lower-grade cropland and nonagricultural lands. Many of these level lands are areas of relatively heavy population concentrations. Villages, towns, and cities have sprung up in their midst. The use of land (space) in these urban centers is a problem in itself. We are here concerned, however, with the spread of the thousands of homes, shops, and factories into the rural areas surrounding the urban centers and along the highways radiating out from them. Competition for land for many types of use is keen and growing.

Good conservation in these "rurban" communities calls for a fine degree of sorting of the land not only on the basis of physical qualities but also with respect to its social and economic utilities. Residential, commercial, industrial, recreational, educational, agricultural, and the host of other land uses that are expanding into these communities prove incompatible unless carefully analyzed and intelligently located in reference to each other.

Especially urgent is the identification of prime cropland in both these rurban communities and the gray-brownerth region at large, and its reservation for that use. Prime cropland in the United States (and in the world) is limited. Each year, as population grows, we shall feel this limitation more keenly. Prime cropland cannot be made to order, but home sites, business blocks, and playgrounds are not so critical of the type of land on which they are located.

The Red-and-Yellowerths

This great soil group forms the typical soils of the south. It embraces two closely allied and associated types. Each is named after the characteristic color of its subsoils. The rederths have reddish subsoils and yellowish-red, yellowish-gray, or yellowish-brown surface soils. The yellowerths have yellowish subsoils and yellowish-gray surface soils. The yellowerths usually occupy the more level, flat, or imperfectly drained lands, such as the Coastal Plains, whereas the rederths mantle the more undulating, sloping, and hilly lands. Rederths also cover foothills and lower mountains extending through California and western Oregon.

Both soils were subject to strong soil-forming and soil-degrading processes. The significant factors in their development were a generally warm and humid subtropical climate combined with forest vegetation.

FIG. 7*a*. A South Carolina rederth. In a virgin state, the surface soils of rederths are yellowish, as indicated by the lighter color of the top of the profile. The red, heavy-textured subsoil lies behind the bowed shadow of the tape measure. The lower part of the profile is the mottled, relatively unweathered parent material. Under cultivation rederth fields generally appear red, however, because the yellowish surface soil has either been mingled with the red subsoil in plowing or has eroded away.

The vegetation of the yellowerths was chiefly coniferous, and that of the rederths, deciduous (coniferous in the Pacific states). The relatively high temperatures coupled with the humid climate promoted intense chemical weathering, strong oxidation, and extensive leaching.[10] The result is a group of soils that is dominantly acid, some highly so, and low in plant nutrients. The mineral colloid has only a limited capacity to retain water and nutrients. The subsoils are markedly heavier in texture than the A horizons (Fig. 7*a*).

Although the land was occupied by a relatively heavy forest growth, the leaf litter and other debris which fell to the forest floor decomposed rapidly. Under the warm moist climate and the attack of legions of micro-organisms which flourish in this climate, losses of both humus and nutrients were high. The soils are, therefore, low in organic matter, and the surface soils are quite light in color. The yellowerths are the poorer agricultural soils, owing in part to their dominantly sandy texture and to the fact that they evolved mainly under coniferous forest and imperfect drainage conditions.

The red-and-yellowerths are nevertheless potentially very fruitful soils. The climate is ideal for an amazing variety of starch, protein, fat, vegetable, and forage crops, and, when generously limed, fertilized, and maintained in organic matter, the soils may be made highly productive. Their redeeming feature is their good physical constitution. It is practically impossible to change materially the physical constitution of large bodies of soils, but it is easy to improve their chemical (nutrient and acidic) con-

[10] The red-and-yellowerths are a kind of transitional soil group. The type of weathering to which they have been subject is in part similar to that under which the podzols and gray-brownerths developed (termed podzolization) and in part like that of tropical soils (termed laterization). For a brief explanation of these processes, see U. S. Department of Agriculture, *Soils and Men, The Yearbook of Agriculture,* 1938.

ditions. Both rederths and yellowerths, as a rule, are friable, i.e., are readily crumbled. This makes them easy to till and responsive to fertilizers.

In the sandy soils, the low cohesiveness is due to low coherence of the sand grains; in the finer-textured soils, to the lateritic character of the clay, a type of clay that is only slightly sticky. The soils may, therefore, be made highly productive of any of the many crops adapted to their climate, although the cost may run high. A considerable amount of labor and fertilizer is required to raise the fertility to a high level, and, under the climatic conditions to which the soils are subject, they soon lose both fertilizers and built-up organic matter, frequent replacements being necessary.

The low natural fertility of these soils is reflected in the south in the limited way in which the lands are utilized and the extensive systems of agriculture that have marked their development. The pioneer occupancy of this region roughly parallels in time the settlement of the gray-brownerths. It was the first major region to attain great commercial importance with its tobacco and cotton crops. Yet forest and cutover woodland rather than cultivated fields still characterize large parts of the region. Cropland diversifies rather than dominates the general landscape. The larger areas under general cultivation are principally either on superior local soils, which are heavily fertilized, or on younger alluvial soils, like the lowlands of the Mississippi.

Because the cost of maintaining land in a highly productive state runs high, only a few crops have reached great commercial importance in the south. They are chiefly crops that require the subtropical climate for essential or optimum growth and are able to shoulder the burden of maintaining the fertility of the soil. The demand for cotton has long made it the leading crop. Less important are local centers of tobacco, peanuts, subtropical fruits, peaches, pecans, off-season (winter) vegetables, and berries.

Subsistence agriculture is carried on, however, outside of a price economy, and the region is heavily salt-and-peppered with patch farmers who grow corn, oats, sweet potatoes, some vegetables, and a little livestock for their own use, with a bit of cotton or other commercial crop for sale. Yields do not average high, because little or no fertilizer is used, and standards of well-being of the average farmer are necessarily low. This is a region in which there is great need for human as well as soil conservation, and the problems are acute because so much of the land is incapable of carrying a heavy agricultural population on even average American standards at a low cost of soil maintenance. The deterioration of the soil is related to the long-continued cultivation of cotton, tobacco, and other crops traditional in the agriculture of the south. But new agricultural techniques, fertilization, and the introduction of soil-building crops, such as soybeans, promise to bring increasing wealth to the region.

Large areas of the south are limited agriculturally by rolling topography or poor drainage. In the southern Appalachians, the Ozarks, and the dissected uplands of the Lower Mississippi basin, there are countless slopes too steep for the plow. These are the areas well suited for permanent pasture, forests, wildlife refuges, or the playgrounds of the vacationer. Thousands of acres of poorly drained lands on the Atlantic and Gulf Coastal Plains are similarly best used for forest and wildlife (Fig. 7*b*).

Owing to their hill and mountain character, the Oregon-California areas, like much of the south, are also chiefly forest and recreational lands, although the gentler slopes are prized for apples, pears, plums, prunes, and walnuts.

The rederths have suffered immeasurably from erosion. Their topography is hilly.

FIG. 7*b*. Abandoned railroad bed of lumbermen in Arkansas. As in the podzols, nature rather than the plowman followed the lumberman in many areas of the south. The longer growing season of the south is more favorable for the rapid growth of trees, however, and one of the major growing crops is the new stand of second-growth forest that has followed the ax or sprung up on the many acres that have been abandoned because of erosion or overcropping.

For several centuries their leading crops have been cotton, corn, and tobacco planted at all angles across the hills and clean tilled. Generally, since the time of settlement the land has been left bare after the summer cropping season. In a region of heavy rainfall with mild winters and little freeze, slopes and rivers have therefore run red throughout the year with soil material stripped from the naked hills.

The rivers are now a little less red than a decade ago, thanks to the revolution in farming practices that is taking place. A large part of the south is now included in soil conservation districts. Strip cropping, contour farming, and terraces are taking the place of up-and-down-hill row cropping. Forest, grasses, and legumes are slowing up the water of the steeper slopes. The soil is being built up with lime, fertilizers, and organic matter.

Soil conservation here has two broad objectives: (1) to check erosion and (2) to bring about a gradual change in an agricultural system which has been overcommercialized. The evils of the "one-crop" system of the south are well known. The benefits of a diversified agriculture are generally appreciated. It is easy to say that the average farmer should grow less cotton and produce more crops and livestock for home consumption. But it is a challenge to human ingenuity to find the specific program adapted to the limited means and land of each individual whereby he can make the change, for he is part and parcel of a complex social and economic fabric that is not easily rewoven.

The Prairyerths

The prairie soils comprise a unique group. Their principal area, the middle west, lies in the pedalferic region, in the region of relatively high rainfall. But they are not true pedalfers. Their soils do not show the pronounced shift of iron and aluminum from surface to subsoils that is so characteristic of the pedalfers. On the contrary, they have many features in common with the pedocals.

The climate under which the middle west prairyerths evolved appears to have been similar to, if not precisely identical with, that of the gray-brownerths. If only this factor is considered, the prairyerths should therefore be similar to the gray-brown group. The soils, however, are only slightly leached, only mildly acid as a rule, very dark in color, and rich in organic matter.

The differences are due primarily to their native vegetation. It was dominantly a heavy growth of tall-grass associations, similar to those under which the chernozems developed.[11]

The tall-grass associations counteracted the weathering and leaching effects of the climate. As emphasized in earlier paragraphs on the pedocals, grass roots are powerful soil regenerators. In the prairyerth region, they crowded the soil body to depths of three and four feet and extended many of their longer fibers to six feet and more. Living, they returned large quantities of leached material which the rains carried down to the upper part of the soil, and on death they left the soil rich in these nutrients and humus and dark brown to nearly black. The rich humus improved the capacity of the soils to adsorb nutrients and retain water, and promoted the formation of a highly granular and durable structure. The subsoils of the normal soils are but slightly heavier textured, if at all, than the surface soils (Fig. 8*a*).

These are characteristics of the pedocals, and especially of the chernozems. Unlike the pedocals, however, the prairyerths have no lower horizon of carbonate accumulation, although lime is present in the parent materials underlying many of the soils. With the heavier rainfall under which the prairyerths developed, water penetrated the soil body to considerably greater depths, generally to the groundwater level, and did not deposit the carbonates in the lower part of the soil body.

As settlement pushed actively westward during the nineteenth century, the first settlers scorned the prairyerths under the delusion that land incapable of growing

FIG. 8*a*. Profile of a Nebraska prairyerth. Three feet of mellow, very dark grayish-brown organic-rich top soil overlies, at six-inch ruler, a light-brown friable subsoil. Note the thick fibrous roots of the grassland formations and the degree to which they occupy the soil body, filling it with organic matter. In the California prairyerths the grasslands were dotted with scattered trees.

trees was poor for crops. They preferred the local islands of forested uplands scattered through the prairies and the belts of forested rough land and river-bottom land running through the region. The choice of the last was in part based upon the availability of water and wood, as well as preference for the soils.

But, when settlement finally broke into the prairies, the pioneers found a seven-

[11] Considering the present climate, the natural vegetation of the prairyerths region should be deciduous forest, similar to that of the gray-brownerths, but exceptional conditions upon which natural scientists are not as yet fully agreed favored the tall-grass associations.

fold earthly paradise. They escaped the labor of clearing the forest. They found the moisture and sunshine ideal for their crops. They were able to plant in naturally rich soils. The soils having nurtured their wild kin for centuries were admirably adapted to their major crops (cereals. grasses and herbaceous). Most of the land

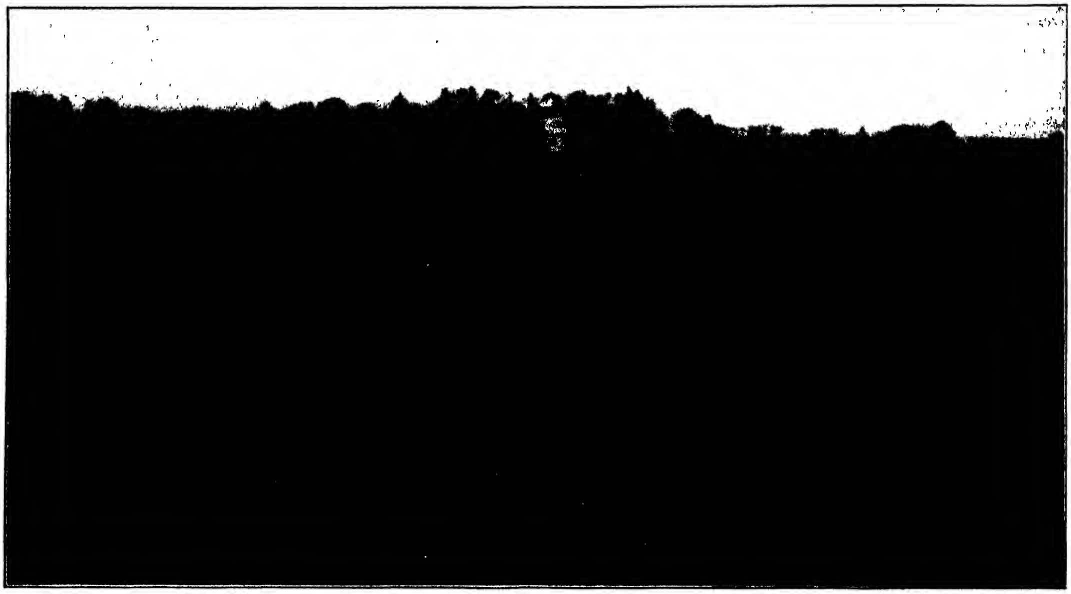

FIG. 8*b*. A level Nebraska prairyerth cornfield in early spring. Although naturally a treeless region, the farm dwelling and buildings are protected by both windbreak and fruit trees.

was level. It plowed easily with the new type of plow developed for the prairie, the granular structure forming an ideal tilth. The soils did not lose their high productivity after a bumper crop or two. The peerless grass had accumulated and thriftily preserved a great store of nutrients and invested the soil with a durable structure.

This was indeed a promised land, and its length and breadth were eagerly occupied. No widespread abandonment here, nor landscape generally dominated by the native vegetation. The northern part, which comprises the best part of the region, forms the heart of the American Corn Belt with its sweeping horizons of grain-hay-pasture-livestock farms. The soils here are darkest and richest, and the land is level. The climate is usually ideal for corn. Men can fatten many animals on rich land (Fig. 8*b*).

The Texas-Oklahoma prairies are made up of two types of land, reddish prairie soils and black prairie-like soils. The reddish prairies are less productive than their northern relatives and are used chiefly for grain, cotton, and forage. The black prairies form the so-called Blacklands and Grand Prairies of Texas. The Blacklands are famed cotton lands; the Grand Prairies, which include much rough land and shallow soils overlying limestone, grow only a small amount of cotton and more small grains, sorghum, and livestock.

The central prairyerths are a mixture of rolling and dissected land and flat lands with heavy subsoils. Their agriculture changes gradually from the corn-and-livestock type of the northern prairies to the cotton-and-corn of the south.

The California-Arizona areas are not typical prairyerths. They are best described as prairie-like soils which developed under a dominantly grass cover that is sprinkled in many places with areas of brush or thin stands of trees. Much of the land, moreover, is even more rolling than that of the central prairyerths, consisting of hills, ridges, foothills, and valleys, and the climate is a subtropical, semiarid type. Most of the rainfall which varies from 10 to 30 inches annually occurs during the mild winter. Where irrigable, the more nearly level land is intensively used for citrus or deciduous fruits or truck crops. Nonirrigable land is dry-farmed to wheat and barley or pastured.

The prairyerths have been weakened by erosion, as all humid soils have, but the injury is particularly critical with these soils because of their high agricultural quality. We can ill afford man-made erosion on any of our soils; we can least afford it on one of our most valuable soil groups. Yet millions of tons of rich dark-colored prairie soils have been washed from even the level uplands of the Corn Belt by sheet erosion, and other millions from the slopelands, and carried into the Mississippi system to be spread out by floodwaters in the lower valley. Rivulets and gullies have scored thousands of once-smooth slopes. No amount of regret will bring back the land. Happily for the future, the need for conservation farming is now generally appreciated, and both mechanical and vegetative measures are being adopted to stem these losses and rebuild the damaged land.

The greatest over-all problem of the prairyerths is the maintenance of organic matter. With the removal of the prairie associations, the soils lost their chief rejuvenating agent and supply of organic matter. The organic matter originally infused in the soil by the prairie grasslands is being gradually consumed by the soil organisms and is further oxidized with each cultivation. With loss of organic matter go loss of an important source of nutrients, loss of water- and nutrient-holding capacity, and breakdown of structure.

The system of conservation farming must, without exception, therefore, include the efficient utilization of all manure produced on the farm and the production of soil-building crops, like the legumes, to restore and maintain the organic matter of the soil. Mineral fertilizers, at first ignored for these soils, is also receiving increasing attention because the systems of grain-livestock and cotton farming draw more heavily on the soil nutrients than they are released by natural weathering of the soil material.

The Chernozems

The great soil groups comprising the pedocals form a series of north-south belts extending through a large part of the western half of the United States. Beginning in the east where the rainfall was highest and the vegetation most prolific, each successive belt to the west developed in a region of lesser rain and sparser vegetation, ending finally in the deserts between the Rockies and the Sierra-Cascade ranges.

The principal area of chernozems lies immediately west of the prairyerths, running from the eastern Dakotas southward into central Kansas. A smaller but important belt fringes the eastern edge of the Columbia Plateau. A number of valleys and lower slopes of mountains scattered through the west and having a subhumid climate and a grassland formation are underlain by small bodies of chernozems. This soil group is the American equivalent of the renowned Russian black earths, from which the name is derived, chernozem signifying "black earth" in Russia.

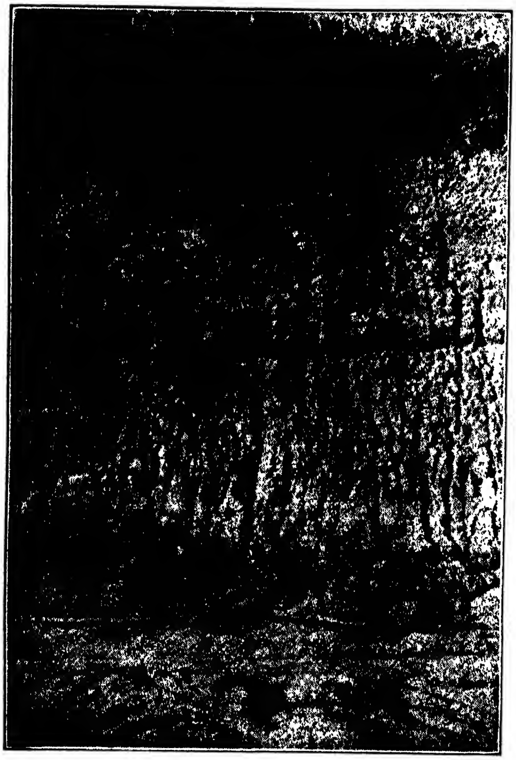

FIG. 9*a*. Profile of a Nebraska chernozem. Three feet of rich, granular, black soil, filled with grass roots, rest on four feet of limey, granular subsoil. The three-foot shovel is thrust into the thick underlying loess formation. Those who occupy and govern the chernozems are trustees of one of our priceless resources.

The chernozems developed under the highest annual rainfall, the lowest rate of evaporation (an important factor in a region of generally low rainfall), and the heaviest grassland formation of the pedocals. Although the rainfall was highest, the total averaged only about 20 to 30 inches annually and resulted in but moderate weathering and leaching of the soil material. The soil is therefore high in mineral nutrients. The layer of carbonate accumulation, the distinguishing feature of all pedocals, is usually from three to five feet below the surface. It is deeper than that of any other pedocalic group because of the heavier rainfall.

The native grass cover was chiefly tall grasses in the east, similar to those of the prairyerths, changing gradually to mixed tall and short grasses, with short grasses dominating in the western or drier part of the region. As in the prairyerths, the dense grass roots permeated the soil three, four and more feet, restored large quantities of nutrients to the upper part of the soil body, and on death and decay left the soil abounding in humus and nutrients, and very dark brown to nearly black. The upper soil commonly contains from five to ten per cent of humus. The clay colloids, moreover, are highly adsorptive of nutrients and highly absorptive of water. The soil material is excellently granulated; the structural granules are very durable; and both surface and subsoil have essentially the same texture (Fig. 9*a*).

The chernozems possess in most perfectly developed form or state the characteristics generally associated with ideal agricultural soils, although they are not well adapted to every type of crop that can be grown in their latitude. They are best adapted to the grass family, and their greatest value lies in their excellence for grain production. Because of their high content of soluble plant nutrients, they produce the highest quality of grains—highest in the nutrients essential to human health. Their nutritious native grasses nourished the great bison herds and are prized today for production of high-quality livestock. They are also well adapted for the production of forage crops like clover and alfalfa.

Unfortunately, the rainfall is not always adequate in relation to their potential productivity. It is a subhumid type in which wet and dry years follow each other in irregular and unpredictable succession. Wet years and good general rains at critical growth and fruiting periods produce bumper crops, but dry years, erratic rains, hot winds, and low-snow winters bring failures or low yields.

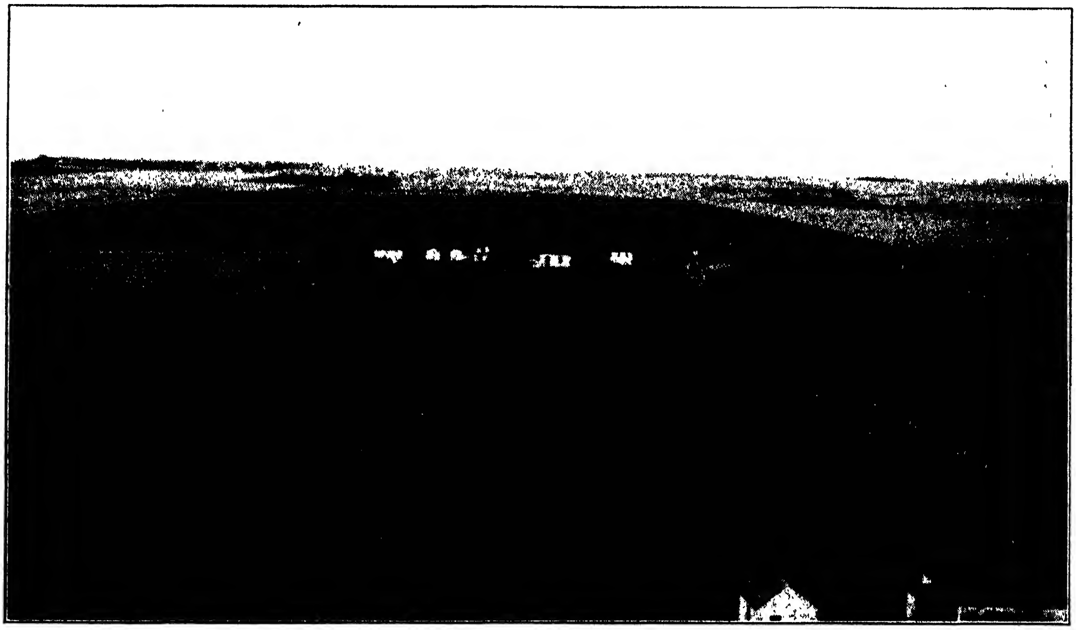

FIG. 9b. A panorama of the hard winter wheat and corn lands of the chernozems from the watertower of a small town in southern Nebraska. Only one or two shade trees and a few none-too-vigorous fruit trees stand in the average farmyard of this wholly treeless region. But a sea of peerless grains, unmatched in quality, springs out of the land when there is adequate rain.

Nevertheless, because of their high potential productivity and the fact that as a whole fair to good crops have exceeded low yields and failures, the chernozems soon became the chief pedocalic lands on which the crop producer displaced the traditional pastoralist of the grasslands. Utilizing larger and larger acreages as mechanized farming facilitated cropping more land, the chernozem farmer has now developed an extensive system of grain farming combined with at least a moderate number of livestock produced on a semi-range, semi-feeding basis. The stock are pastured principally on the rough and rolling lands bordering the natural drainageways and streams crossing the region, the poorly drained basins scattered over the plains, and the sandier lands. Most of the forage is produced on the stream bottoms and terraces under irrigation.

The cropped uplands form a gigantic grain belt whose make-up varies with latitude. The north raises a mixture of hard spring wheat, oats, barley, rye, and flax. The central chernozems raise chiefly hard winter wheat and corn, the latter a kind of westward extension of the corn economy of the prairyerths (Fig. 9*b*). The southern part forms the chief hard winter wheat region of the United States. Sorghum grains are becoming increasingly important in both the southern and central areas.

Groundwater lies deep under most of the uplands, a hundred feet or more. With the development of pump irrigation, there has been a notable and successful attempt in some areas having good groundwater supplies to extend irrigation to grains and legumes on the uplands in order to supplement deficient rainfall. Yields on such lands promptly doubled because of the high fertility of the soils, but the drain on the soils soon decreased their organic matter and necessitated the use of mineral fertilizers to restore their productivity. Groundwater supplies are not adequate, however, to convert the chernozem region as a whole into a vast irrigated garden.

The Columbia Plateau chernozems are predominantly rolling lands, in contrast with the level plains of the mid-continent region. Their rainfall approximates only 20 inches, but most of this falls in the cool seasons of the year. The land is used chiefly for large-scale wheat farming with summer fallowing every few years. The soils are very fertile, but many areas are both water and wind eroded, in many places seriously eroded, because of the rolling surface and the practice of summer fallowing.

Both wind and water have taken toll of our chernozem lands. Their complete conservation is fully as important as that of the prairyerths. They are our chief bread lands. Their great need is water and organic matter conservation, as briefly indicated in the general paragraphs on the utilization of the pedocals. Water is needed to produce organic matter and to utilize the great grain productivity inherent in this type of land. Organic matter is needed to maintain the soil structure and productivity and to help store water for the next crop of organic matter and grain. Organic matter is the cornerstone of these black lands.

The Chestnuterths

The chestnuterths occupy the second highest rainfall belt of the pedocals. They developed under a semiarid climate and a short-grass vegetation. The annual rainfall of the northern chestnuterths averages between 12 and 20 inches, and of the southern chernozems, where evaporation is greater, between 20 and 30 inches.

Under the semiarid climate, the soils were only slightly leached and the carbonate accumulation lies only a foot or two below the surface. Although the native vegetation was dominantly grass and the grasses produced all the beneficial effects of this type of formation, the growth was less luxuriant than the tall grasses of the chernozems, and the root systems less dense and shallower. The soils are accordingly lower in organic matter, less retentive of water, and lighter in color—dark brown or chestnut (Fig. 10*a*). They are well supplied with nutrients, however, and are highly productive—when rains are adequate. This, as with the chernozems, is the critical limitation of these soils, but the hazards are very much greater. The proportion of years when the rainfall is right in amount and distribution is much lower than in the chernozem belt.

The chestnuterths mark the general frontier of nonirrigated crop production, but it is a vacillating frontier swept westward and eastward by ever-fluctuating rains and the price of grain, cotton, and livestock. Yields average low. Without power machinery this region would be little more than rangeland. The large acreages that must be cropped to offset the low yields per acre are beyond the limits of the hoe and the horsedrawn implement.

FIG. 10*a*. Profile of an Oregon chestnuterth. The chestnut-colored surface soil is about one foot in thickness here and has a blocky structure. The knife is thrust into the top of the carbonate zone which lies 24 to 30 inches below the surface in this locality.

The economy of the region reflects its transitional character. Land utilization is a complex of cropped land and range (Fig. 10*b*). Crops occupy only the more productive lands. Cattle are the chief range stock. The principal crops of the north are small grains. A large part of the Montana-Dakota Spring Wheat Belt lies in this area. Corn, winter wheat, and oats occupy most of the cropland in the central states. Southward, the soils become more reddish, the climate subtropical, and cotton and sorghums form the chief crops. The Columbia basin area is almost solely wheat country. In general, these crops are merely drier-land extensions of those produced on their more humid eastern neighbors, the chernozems and southern prairyerths. Although yields run low, grain quality averages high because the nutrient content of the soils is high.

This region is the chief land of the everthreatening dust bowl. It was the target of a major attack during the 1930's. The land then devastated is not yet restored to its former productivity. Restoration of organic matter and soil structure takes much time in regions of little rain. The chestnuterths are safe for the plow only under a system of complete water conservation.

FIG. 10*b*. Cattle en route to water on a sandy chestnuterth of western Nebraska. A sprinkling of small sagebrush and other weeds has invaded this pasture, owing to overgrazing.

The Brownerths

This soil group lies desertward of the chestnuterths. It developed under an arid climate with average rainfall about 15 inches or less. Native vegetation consisted of short grasses, frequently thin of stand, mixed with shrubs and small trees in the southern part of the region (Fig. 11*a*).

The soils are relatively thin in view of the low rainfall and are practically unleached. The carbonate zone is comparatively shallow. Organic matter is relatively low because of the sparser plant cover. The surface soils are therefore brown in the north, changing to reddish-brown in

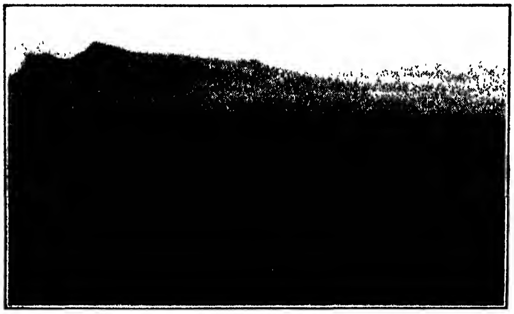

FIG. 11*a*. A thin grass, shrub-studded brownerth of Texas. Large acreages of this type of land are needed to provide a family with average American living standards, owing to its low carrying capacity.

the south (Fig. 11*b*). The brownerths are potentially highly productive, but the low rainfall limits them as a whole to livestock range. This is primarily the land of the modern ranch and the stockman, the successor to the ancient pastoralist.

Nevertheless large areas are dry-farmed to small grains and sorghums, and ribbons of irrigated land cross the dry plains or border the mountain slopes when stream flow is adequate. But yields of the dry plains are low, failures are common, and good crop years few and far between. Dry-land crop production has been most successful when conducted on the basis of large-scale operations. Erosion is even more damaging on these lands than on the wetter chestnuterths. The brownerths are submarginal croplands.

Much of the rangeland has been damaged by erosion brought on by overstocking and in turn overgrazing. When land is overgrazed, less palatable grasses, as well as weeds and shrubs of low feeding value, take the place of the more palatable and valuable native perennial grasses and herbs, and the stand of vegetation thins out. This opens the soil to erosion, and streams once

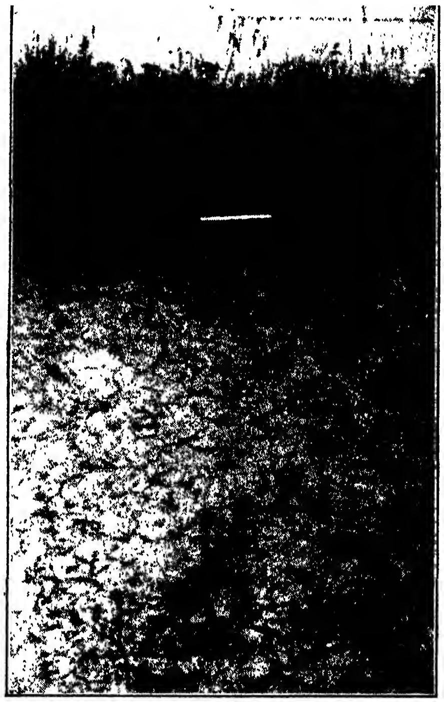

FIG. 11*b*. Profile of a Wyoming brownerth. The brown surface soil is only a foot in thickness. The carbonate zone, immediately below the six-inch ruler and speckled with lime nodules, lies relatively close to the surface. This profile is a long-time rain gauge that might well be studied by the would-be farmer. If rainfall were heavier the surface soils would be thicker and the carbonate zone deeper.

clear and well stocked with fish are now subject to floods and silting, their value for irrigation, recreation, power, and local water supply being reduced.

The Grayerths

The grayerths are the soils of the deserts and semideserts of the western intermountain plains and plateaus and their associated alluvial fans. Rainfall approximates five to ten inches. Summers are hot. Winters are cool to cold in the north but mild in the subtropical south. Vegetation is sparse and open; bare ground prevails over plant cover. The dominant forms of plant life are desert shrubs with scattered bunch grasses and short-lived grasses and herbs that spring up after rains.

FIG. 12*a*. Desert shrub on an Arizona grayerth. The light-reddish surface soil is sprinkled with gravel and is underlain by a reddish, heavy subsoil. Note the large percentage of bare ground without vegetation. Since the leaf-fall from the shrubs is also inconsequential, the soils receive little or no humus from their open plant cover.

These soils have been subject to very little leaching and are rich in soluble mineral nutrients except phosphorus. The carbonate zone is very shallow and is commonly indurated. With little or no plant life to produce organic matter, the soils have retained largely the color of their parent materials and are low in humus and nitrogen. The soils of the north are typically gray or light grayish-brown; those of the south are pink to red, the so-called red deserts of the southwest (Fig. 12*a*).

These extensive lands are the undisputed home of the sheepman and the cattle rancher. But they are low-grade grazing lands. Comparatively few animals can be stocked on the average square mile because of the sparse and low-quality vegetation. The choice rangelands are those having the best supplies of stock water (streams, springs, accessible well water) including irrigable land, where alfalfa and other feed crops can be grown to supplement the limited natural forage (Fig. 12*b*).

MOUNTAINOUS AND ROUGH BROKEN LAND

The Lithosols

The mountains, plateaus, and rough hill lands of the United States include many areas in which shallow soils overlie their rock formations. Only an inch up to a foot or two of soil mantles the bedrock. The soils are immature and more or less stony with frequent exposures of bedrock. They are known as lithosols, from the Greek work for rock, *lithos*. Although most of the land is rough and rolling, there are also areas of smooth or level land with such shallow soils (Fig. 13*a*).

A great variety of soils makes up these lands. They have little in common aside from their thin, stony character and generally rugged terrain. Each local soil strongly reflects the influence of the local rock formation from which its parent materials were derived, in addition to the conditions of soil formation at its particular site. Igneous, sedimentary, and metamorphic rocks of many types were involved.

As a whole, the lithosols and their associates in the eastern part of the United

States developed under a comparatively heavy rainfall and forest vegetation, whereas those of the west had a relatively light rainfall with vegetation varying from sagebrush, mesquite, and grass to open stands of forest or even fairly dense stands of trees on north-facing slopes (Fig. 13*b*). Although such soils show the influence of the climate and vegetation of their specific environment,[12] they are only shallow or incompletely developed. The steep slopes on which they lie retard their development.

[12] For example, the mountain soils of New England are shallow podzols, whereas the soils of the low-rainfall mountains of the west are chiefly pedocalic.

These rough and rocky lands are of value principally for forests, pasture, grazing, and recreation, depending upon the climate, vegetation, and location. Forests are dominant in the more rugged, least accessible, and rainy lands. Pastures occur chiefly in the humid eastern highlands. Here are numerous small farms which cultivate the smoother, gentler slopes and the deeper soils and utilize the lithosols for pasture or woodlot. The western unforested lands are chiefly summer livestock range. Their general carrying capacity is low but is generally higher than that of the neighboring lowlands.

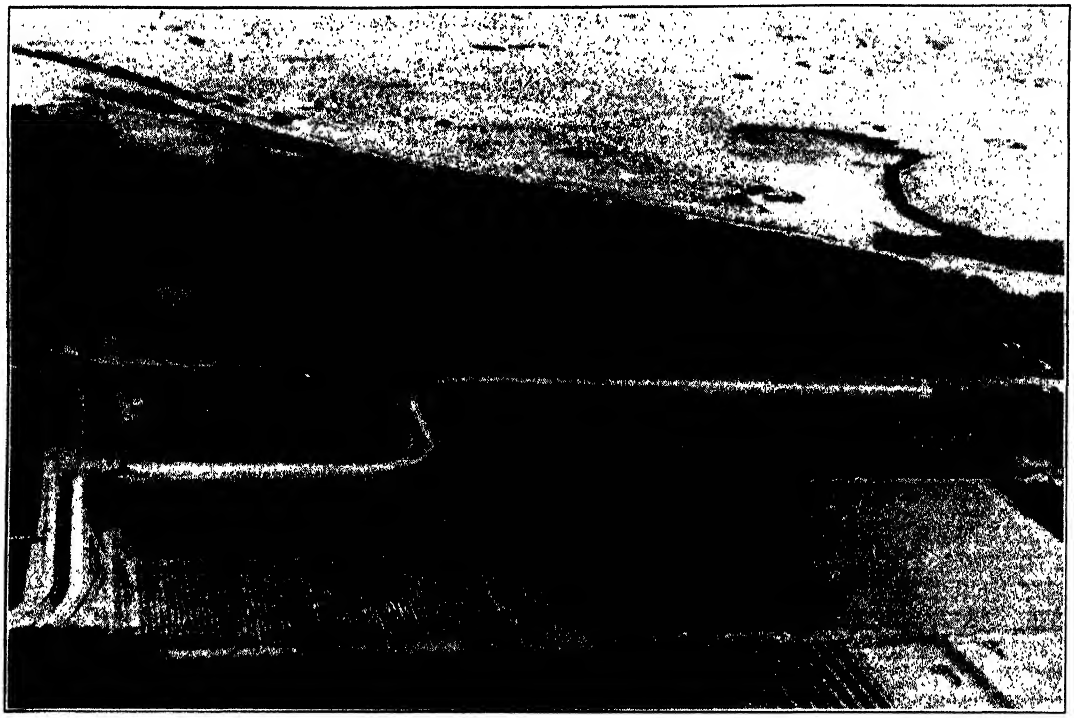

FIG. 12*b*. Irrigated land and "raw" desert in the Coachella Valley of Southern California. The crops shown include grapefruit, dates, grapes, and truck. The canal extending through the crop section is a part of the new Coachella branch of the All-American Canal. The amount of water available for irrigation of the vast area of grayerths in the west is entirely out of proportion to their needs. They are forever destined to remain low-grade rangelands dotted with occasional oases producing some high-value crop. (Hartman Studio, Indio, California. Photo furnished by R. M. Glendinning.)

These highlands comprise one of our

major recreational resources. Their rugged terrain and variously sculptured forms have universal appeal. They shelter many forms of wildlife and many varieties of plantlife. Both the desertlike vegetation of the dry mountains and the forests and alpine meadows of the rainier highlands have their enthusiastic followers. Sparkling lakes and clear-flowing streams beautify many valleys. Numerous sites provide breath-taking views.

FIG. 13*a*. Angora goats on a lithosol of the Edwards Plateau of Texas. Only patches of shallow stony soil cover the bedrock, although in places the soil is deep and supports a good growth of grass and clumps of trees. Goats, sheep, and cattle find scant grazing and browse on land of this character. (W. T. Chambers.)

The chief enemies of these lands are fires, overgrazing, timber-mining, and erosion. It is also important that the rare and choice recreational sites, the areas of exceptional natural beauty, of unusual geologic, geographic, botanic, or zoologic character, and similar lands of special interest or value be protected from haphazard and exploitative commercial and tourist "developments."

DUNE LANDS

In north-central Nebraska is a huge sand sheet of some 20,000 square miles which has been molded by the winds into a succession of billowy dunes with occasional intervening sandy valleys. Except in local "blowouts," the dunes support a mixture of tall and short grasses with scattered sagebrush, yucca, and other drought-resistant herbs and shrubs. Most of the valleys are floored with dry sands, containing slightly more clay than the dune sands, and support a more luxuriant grass cover. In a number of valleys, the underlying watertable intersects the land surface, creating small lakes and wet sands.

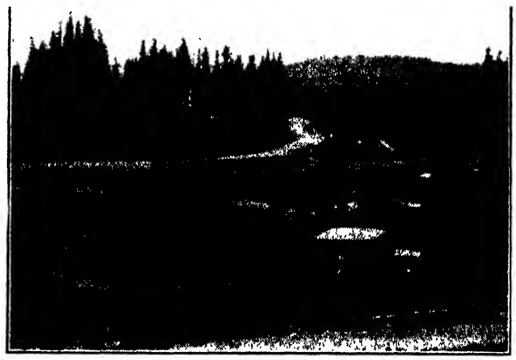

FIG. 13*b*. A highly popular Alpine meadow in the Cascades. Such meadows have long enjoyed popular favor as indicated by the antiquity of the motor vehicles that reached here in spite of the difficulty of making the steep ascent under the limited power then available. Some of the more accessible meadows are "built up" with summer hotels, lodges, and other facilities of interest to vacationists and tourists. Most Alpine meadows are utilized for grazing.

This great body of sand is a vast, unique, and excellent ranching country. Cattle are run chiefly in the dune areas during the summer and fed hay cut from the valleys during the winter. Water supplies are easily obtained from the groundwater. When the dune land was first occupied, overgrazing was common, resulting in severe wind erosion and the formation of numerous blow-outs. These are now mostly grassed over, however, because the ranchers soon came to appreciate the wisdom of limiting their stock.

The lakes and aquatic vegetation bordering them provide excellent places for the nesting and migration of waterfowl.

Similar but much less extensive areas of dry sands (not shown on Fig. 1) occur in the Dakotas, Colorado, southern Texas, and the arid western states. The western areas, however, are generally bare or covered with only sparse and inferior forage.

ALLUVIAL LANDS

The floodplains bordering the vast network of stream courses draining the United States are made up of water-laid soil material. These materials are sediments eroded [18] from the drainage basins of each stream and deposited during flood periods on the valley floor. Similar materials from the terraces adjoining the floodplains and the alluvial fans spread out at the base of many mountain slopes of the western highlands. The soils derived from these deposits are known as alluvial soils.

The features of these soils are largely determined by the type of materials laid down and the manner in which the materials were deposited. Since the sediments always consist of a mixture of materials eroded from the soils of their respective drainage basins, they resemble in a very general way the upland soils. The alluvial soils of the arid west, for example, are usually light-colored, low in organic matter, and rich in mineral nutrients and lime, whereas those of the humid northeast are generally brown or grayish-brown with at least moderate amounts of organic matter and plant nutrients.

As a group, the alluvial soils are the most productive of the nation. They are noted for their high yields and durability, although their total acreage is small and they include a number of individual types that are too wet, too sandy, or too salty or alkaline for ordinary crop production. They generally average higher in plant nutrients than the upland soils with which they are associated, have a good physical constitution, and, except where irrigation is necessary as in the arid west, suffer less from drought. Many of the older alluvial fans develop hardpans, however, necessitating blasting before crops will do well on them.

Corn is the chief cultivated crop on the alluvial soils of the humid east, with the addition of cotton in the south. Local areas are intensely cultivated for truck crops or other high-value crops like tobacco. Poorly drained lands are in forest or pasture or are cut for hay.

Alfalfa is the most important crop on the irrigated alluvial lands throughout the west, where it serves as a source of winter feed for range stock. Subtropical fruits, winter vegetables, and cotton are intensively cultivated in the southwest. Sugar beets, potatoes, beans, and small grains are grown on the alluvial soils of the central and northern mountain states.

Only the largest area of alluvial soils, the lower Mississippi, is shown on Fig. 1. This is a belt of relatively dark-colored and highly fertile soils whose parent materials were collected from the rich prairyerths and chernozems, the gray-brownerths and the topsoils of every other great soil group in its

[18] Chiefly by natural or geologic erosion. Accelerated erosion induced by man has added only a comparatively thin veneer.

far-flung basin. It has the added advantage of lying in the highly productive subtropical climate of the south: a projection of highly fertile land into a region of relatively leached soils. This lowland is therefore one of the most productive areas of the south. Its naturally well-drained lands and those easily drained artificially are intensively planted to cotton, sugar cane, soybeans, and similar high-utility crops.

But all these productive low-lying alluvial lands, those of the little rivers as well as the big, suffer the unconquered menace of periodic floods. From time to time, the rivers temporarily repossess the floodlands for their own use. Despite nearly a hundred years of organized effort to control the Mississippi River and to confine its floodwaters to its channels or to predetermined floodways, the river still overflows its lowlands. This is the major challenge to the conservationist of alluvial lands. The engineer has been basing his chief hopes upon mechanical controls such as artificial levees, temporary storage basins, and floodways along the lower courses of the river. But the answer should also be sought in the headwaters of every stream through the use of vegetation to hold both soil and water and the conservative use of all lands throughout the river system.[14]

ORGANIC SOILS

Intermingled with the major soil groups are some 80,000,000 acres of organic soils formed from the slow accumulation and decomposition of the remains of swamp, marsh, and bog vegetation. Although widespread, they are located chiefly in the south, particularly the Atlantic and Gulf Coastal Plains; the northeastern states; the Great Lake states; and the Pacific coastal valleys. They are variously known as peat, muck, and marshlands. Although some of the larger bodies of these soils, like the Everglades and the swamps and bogs of the Lake states, are extensive, the majority are individually small. This soil group is not shown on the accompanying map (Fig. 1).

The relatively undecomposed and but partially decomposed materials are generally termed peat. The more completely decomposed organic materials from which mineral matter has been released in the process of decomposition but remains commingled with the organic mass comprises muck. The organic soils, chiefly peats, accumulated along the coast lands in lagoons and along the mouths of tidewater rivers are called coastal marshes.

Only a small proportion of these soils are cultivated. The mucks are the preferred agricultural soils. They contain the highest percentage of available plant foods, although supplemental fertilization such as the addition of lime, potash, or minor elements may prove highly beneficial. The soils are mostly highly prized for special crops: onions, celery, mint, cranberries, cabbage, sugar cane, tomatoes, peppers, asparagus, rice, and other intensively grown crops. Combined grain and stock farming has proved successful on some types.

Shrinkage, fire, and wind erosion in cultivated mucks, and drainage in excess of actual need for land are major conservation problems. Following drainage, the organic matter of both cropped and uncropped land decomposes more rapidly and undergoes a more or less long period of shrinkage.

[14] One of the social devices receiving increasing attention is floodplain zoning whereby buildings and costly structures like railroads and high-class roads are excluded from lands subject to overflow. This in itself is only a negative measure, however. See chapter on floods and flood control.

Winds readily pick up the dry, fluffy muck particles from fields unprotected by windbreaks. Dry muck burns readily, and smoldering underground fires, difficult to extinguish, have destroyed many tons of this limited soil resource. Late spring and early fall frosts are cropping hazards of the northern muck lands.

The peat lands and uncultivated muck lands are utilized for pasture, hay, forest, and wildlife refuges, including migratory and local waterfowl, as the lands frequently are associated with lakes, streams, bogs, marshes, tidal waters, lagoons, and other water bodies. The preservation of an adequate and well-distributed acreage for wildlife habitation is an important conservation measure. These organic lands also play an important role in water conservation and the control of floods and erosion. They comprise one of nature's most effective storage basins.

THE SOIL FIRE

Of all the forces that break down the productivity of a soil, the soil fire is the most destructive. We make much ado about forest fires. But the soil fire—the oxidation or burning up and destruction of the organic constituents of our soils which are constantly taking place—is much more critical in its bearing upon our well-being. The organic matter and the soil organisms present in a soil determine its character and in turn its utility, in podzols as well as in prairyerths and muck lands. Reduce these organic constituents in any soil, and its productivity immediately declines. Exhaust them, and the soil will support only a token of plant life, the few hardy pioneers, we call them weeds, that are able to survive on raw land.

Soil fires burn up organic matter with nearly every crop we grow. Some of our richest soils have been losing organic matter at the rate of nearly one per cent a year! Whenever a soil is plowed, cultivated, or turned over, it loses part of its organic matter by oxidation. Obviously we cannot utilize soil without working it in some manner. We must utilize every device we know, however, to restore and maintain the organic matter, and even build it up, when possible.

KNOW YOUR SOILS

Our soils are indeed diverse. On one extreme are the podzols, too low in plant nutrients, too acid, and with too cool a climate for other than the more limited types of agriculture, and, therefore, used chiefly for forest and recreation. At the other extreme are the grayerths, rich in mineral nutrients, but strangled by a desert climate.

The arid brownerths have a little more rain, support a moderate grass growth, are rich in nutrients, but are generally too dry for nonirrigation agriculture, and are primarily pastoral lands. The chestnuterths and chernozems produce grains rich in human nutrition, although under considerable climatic hazards. The prairyerths are our big-yielding corn and cotton lands.

The gray-brownerths are our most versatile lands, with natural fertility neither high nor low but capable of being easily built up to, and economically maintained in, a highly productive state for a great variety of crops. The red-and-yellowerths are low in natural fertility but enjoy the most favorable growing climates and can be built up, at a price, to produce any crop capable of defraying the comparatively high cost of maintaining the land's productivity.

This is a broad picture, broadly painted. The preceding pages have outlined the basic differences between the soils in the various parts of our huge mainland and the chief uses we have made of them. They have indicated some of the important problems with which we must wrestle if we are going to utilize each group conservatively and improve its use for all concerned.

The best place to begin a soil conservation program is at home. Each of us should familiarize himself with the soils of his own community, their potentialities, and the problems related to their utilization. Here he can make his greatest contribution to their conservation. As in public health, safety, and other matters relating to the public well-being, the average citizen can wield his greatest influence for good in his own neighborhood. He can support a national or regional program in only a general way.

He should, of course, know the great soil group in which he lives and its place in the national and his state's economy. But after this he should get down to more local facts. What are the types of soils in his own community? What are their names, their strength, their weakness? He should know his soils and their names as he knows the names and characteristics of each type of tree, grass, crop, flower, weed, bug, and bird, so that he can make intelligent use of their capabilities and remedy their limitations. We do not lump our cattle, horses, sheep, and hogs together as mere animals and seek the same utility from each, as we do our soils. We distinguish not only each kind of animal but also their breed—Holstein, Percheron, Shropshire, Duroc, and the like.

Best use of any resource—plant, animal, soil, mineral, water, or other—can come only with knowledge of the peculiarities of each type or species. Know your basic resource, the soils of your community upon which its well-being is founded, as you know your trees and flowers. Then do something constructive about them. The more we use each individual type of soil for the purposes for which it is best adapted, the richer our nation and the more contented its people will be.[15]

Every piece of land whether it be a small tract owned and cultivated by an owner or a large region making up a major portion of a state is a trust. Man, individually and collectively, is a custodian of a capital resource. It is his responsibility to make it return enough to represent a reasonable rent, to pay the wages of the persons employed, to pay the taxes assessed by the government, and in good times to yield a profit which can be used to provide betterments and increased opportunities for the people concerned.

In the process of attaining these objectives his custodianship involves also the maintenance of the fertility and productivity of the land so that future generations may receive in their turn a rich heritage. A land resource undiminished by repeated use represents the best in soil conservation. A nation's agriculture is secure when the people who possess the land understand their responsibilities.

[15] The student interested in the soils of his community and their significance should consult the county soil survey reports and the *1938 Yearbook of Agriculture* entitled *Soils and Men,* both published by the U. S. Department of Agriculture. Not all counties have as yet been covered by such surveys. The surveys are concerned primarily with the agricultural utility; hence the student will have to make further interpretations of his own about other land uses.

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CHAPTER 4

Soil Conservation

INTRODUCTION

SOIL conservation is one of the newest agricultural sciences. The term soil conservation may have been originated by W. J. Spillman of the U. S. Department of Agriculture when he wrote *Farmers' Bulletin* 406, dated June 16, 1910. The term, as used by him at that time, meant strictly the prevention of soil erosion. The science is still sufficiently new that it means one thing to some people and something very different to others, and many of the technical terms peculiar to the science do not yet have the same meaning in all parts of the United States.

Although several leaders in various conservation movements in the nation's history have urged widespread protection of all our resources, conservation of the soil has received national recognition only since the early 1930's. Hugh Hammond Bennett, Chief of the U. S. Soil Conservation Service, is the recognized father of the movement. Since 1930, knowledge about soil conservation and acknowledgment of its need have spread rapidly. It has evolved into a recognized science. Simultaneously, the meaning of soil conservation has gradually broadened until for most people it now includes the measures and amendments involved in the protection, maintenance, and improvement of our land resources.

The science is still so new that the universities and colleges are just beginning to establish soil conservation courses. As many as 43 colleges had such courses in 1948. Formerly the teaching of this subject was handled as a side issue in established departments which were teaching closely related work. Departments of agronomy, geography, soils, range, forestry, agricultural engineering, agricultural economics, biology, and rural sociology were the chief sources of these embryonic beginnings in the teaching of soil conservation. Before 1948 no individual had a college degree as a soil conservationist. A few persons did receive agricultural degrees in 1946, 1947, and 1948 with soil conservation as their major subject. In 1948 a total of 13 colleges offered majors in conservation.

Most professional soil conservationists of today, and there are many thousands throughout the world, are made-over agriculturists, agronomists, soil and range specialists, horticulturists, foresters, geologists, biologists, and engineers. Soil conservation may embody parts of each of these and of many other sciences. Most of today's soil conservationists have been graduated in some phase of agriculture, engineering, for-

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estry, or range management. The point is that all of today's soil conservationists are retailored from their original specialties. This situation further emphasizes the infancy of the soil conservation movement.

The American Wilderness

When our forefathers landed on America's shores only a few generations ago, they found a land that was literally covered with forests and with grass. The necessity for conservation of soil or water or forests was utterly inconceivable. Sand dunes and badlands could be found, but the areas were few, generally small, and usually widely separated. There was no cultivation, no grazing except by wild game or the Indian ponies, and the only forest denudation was that resulting from an occasional fire. History tells us that land simply did not remain bare of vegetation for more than a season or two.

Then the settlers came along hunting for homes and for ways to make a living. Food for themselves, feed for their animals, fibers for clothing, logs for building houses, and fuel to keep warm were the immediate and most imperative needs. Anything that interfered with the production of those items became an arch enemy. Since all the east coast settlements were in forested territory, the pioneer there did his utmost to destroy those overshadowing forests. Trees retarded his crops and his gardens, and they also provided hiding places for the Indians. Anything he could do to drive those forests back meant greater immediate security for him and his family. Several generations came and went before these pioneers emerged at the western fringe of the forests and began to settle the prairies which lay to the westward. Here the protective mantle of grass became his immediate problem. He burned the prairie repeatedly, and then he plowed under the charred remains in order to plant his crops more easily. This is where farming in the United States really expanded. Furthermore, the areas were so vast and so fertile that practically no one thought of husbanding the soil. Only a few farsighted leaders recognized the need for better land-use, and their warnings went largely unheeded.

The universal need of the pioneer farmer, whether he was clearing grassland or forest land, always was to bare the land of its protective cover. And that is just what he has done to several hundred million acres in the United States.

In their virgin condition, the plant-covered lands were a veritable sponge. The duff which had accumulated beneath the forest cover served not only as a sponge and as a filter but also as an insulator against excessive evaporation from, and absorption by, the land surface and as a protector against puddling of the surface soil. On the grasslands, the plant litter which fell to the ground, together with the living, dead, and decaying grass roots, made such a mellow soil that it was impossible for serious erosion to occur. On the native vegetation, whether forest or grass, rainfall is readily absorbed except during the "once in a hundred years" rain. Even in such a "cloudburst," the water is at least filtered through the organic cover and reaches the streams through relatively clear springs. A few notable exceptions, such as the Missouri or "Big Muddy," as it has long been nicknamed, and the Red River in the southern Great Plains, did not run clear. The inherent muddiness of the Missouri resulted from the vast acreage of Pierre shales and considerable areas of badlands in its upper reaches; the traditional color of the Red River came from the Permian redbeds which dominate large parts of its watershed.

The settlement and clearing of America's farmlands was like a westward-moving flood or fire. It did not stop until it had swept from the Atlantic to the Pacific. From one coast to the other, the pattern of settlement and development had marked similarities. The first clearings were in the level bottomlands, then they were gradually pushed onto the gentler slopes, and finally were shoved out onto the steepest lands that could be cultivated. The growing of corn, cotton, wheat, tobacco, and other crops, the raising of cattle, sheep, hogs, horses, and goats, all have contributed to the damage that the nation's lands have already received. We have ruined vast areas in certain sections and damaged much of the land in many other sections. No section of our country has remained immune to or safe from damage (Fig. 1).

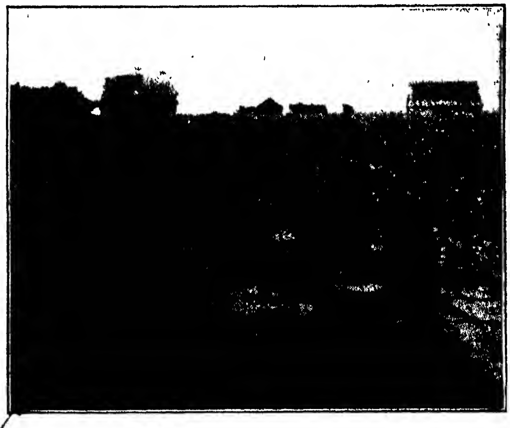

FIG. 1. Our corn has generally been grown in straight rows without regard to the slope of the land. Under such a system, erosion is inevitable. This field shows a heavy soil loss from the rain just ended. (Soil Conservation Service.)

All are familiar with the proverbial story that rocks pushed to the surface in the cleared fields. We now know that sheet erosion was invisibly removing the soil so that the rocks appeared to shove upward out of the soil.

Our Inexhaustible Soil

When this country was first settled, the soil was generally considered inexhaustible. Advertisements in early newspapers point to this fact. Such advertisements appeared, for example, in Virginia papers as late as 1800, in Ohio from 1820 to 1860, in Illinois beginning about 1830, and in Iowa beginning about 1850. They usually dominated the news sheets immediately after homesteading of a new area began, and they often continued to appear from twenty to thirty years after initial settlement. Apparently soil damage did not become obvious on most lands during the first twenty years of cultivated use.

Studied observation of virgin land near Pullman, Washington, which was first broken in 1935, showed practically no erosion on 50 per cent cultivated slopes during the first years of alternating wheat and fallow. It appears likely that erosion generally does not become a serious problem, except on the steepest lands, within ten or more years after its initial cultivation. Obviously, longer periods pass before land damage characterizes the more gently sloping lands. History shows that wind erosion also requires some similar incubation period before it attacks cultivated lands. Wind deposition from eroding lands may, of course, damage noneroding lands to the leeward at any time.

OUR LAND PROBLEMS TODAY

Today, people all over the nation are becoming conscious of damage to the land. Although our exploitative methods of land-use are the primary cause of this damage, the farmer cannot be saddled with all the responsibility. All of us, country and city people alike, share the blame. The farmer can be charged with dereliction for his exploitative methods, but the urban population is also at fault, first for permitting and later for encouraging that manner of farming. It is only natural for the farmer to resist the charge that his methods of farming are injuring the land, even when that is the major direct cause. The main indirect cause has been the lack of a constructive national land policy since the founding of this nation. Neither urban nor rural populations have realized the vital importance of the land to the nation. But, gradually, people in all walks of life are beginning to understand the relationships between the land conditions and their own circumstances.

When we look at the land of other countries, the cause for concern about our own becomes more understandable. A few nations are living examples of conservation farming, but the vast majority of them are glaring examples of exploitative use of their land. As we learn more about the conditions in other countries, and about what caused these land problems, we can more intelligently meet and correct our own land problems.

The international conflicts today are mainly an expression of either an insufficient amount of productive land or of a declining productivity from what there is. The aggressor nations need greater food production, and, since there is no longer any unclaimed territory, their only way to get more land is to take it from another nation. That usually means war.

What Has Happened to Our Land?

Through the millions of years since our present agricultural lands were formed, nature has developed a rather effective protection of the land by the thousands of kinds of plants which grow upon its surface. The processes have been in evolution for a long time, and they will continue as long as plant life grows. Man's agricultural use of the land is a relatively recent event. It is now believed that the first cultivation of the land for crops was about 10,000 years ago. It probably began with spot planting of individual seeds, much like the practice of some of the primitive tribes in various parts of the world even now. Obviously, the evolution of the farm field of today was relatively slow, because most of the changes in this regard have occurred since the United States came into being less than 200 years ago.

The over-all cropland facts in the United States are both interesting and startling. All too generally cultivation is in discord with nature's efforts to protect the land with plants. To start with, we had more than 600,000,000 acres of good tillable land in the United States. Today, we have only about 500,000,000 acres of high-class cropland left on all the farms of the nation. This includes, in addition to the suitable land now in crops, nearly 100,000,000 acres which need drainage, irrigation, or other improvements. Of these 500,000,000 acres, all but about 100,000,000 are subject to erosion whenever the land is used without protection.

Again referring to this 500,000,000 acres, about one-fourth is now being damaged by erosion at a critically rapid rate (Fig. 2). Another fourth of our cropland is being eroded at a less critical but still serious rate. A third one-fourth of our cropland is suffering from deterioration at a very slow rate, and the remaining fourth is suffering mainly from a decline in fertility.

Present estimates indicate that some 90,-000,000 acres of the land that are now cropped regularly should either be retired to permanent cover or at most should be cultivated only once in five or more years. To offset this loss in present cropland, practically an equal acreage of good land not now used for agriculture should be brought into cultivation through drainage, irrigation, clearing, or other needed improvements.

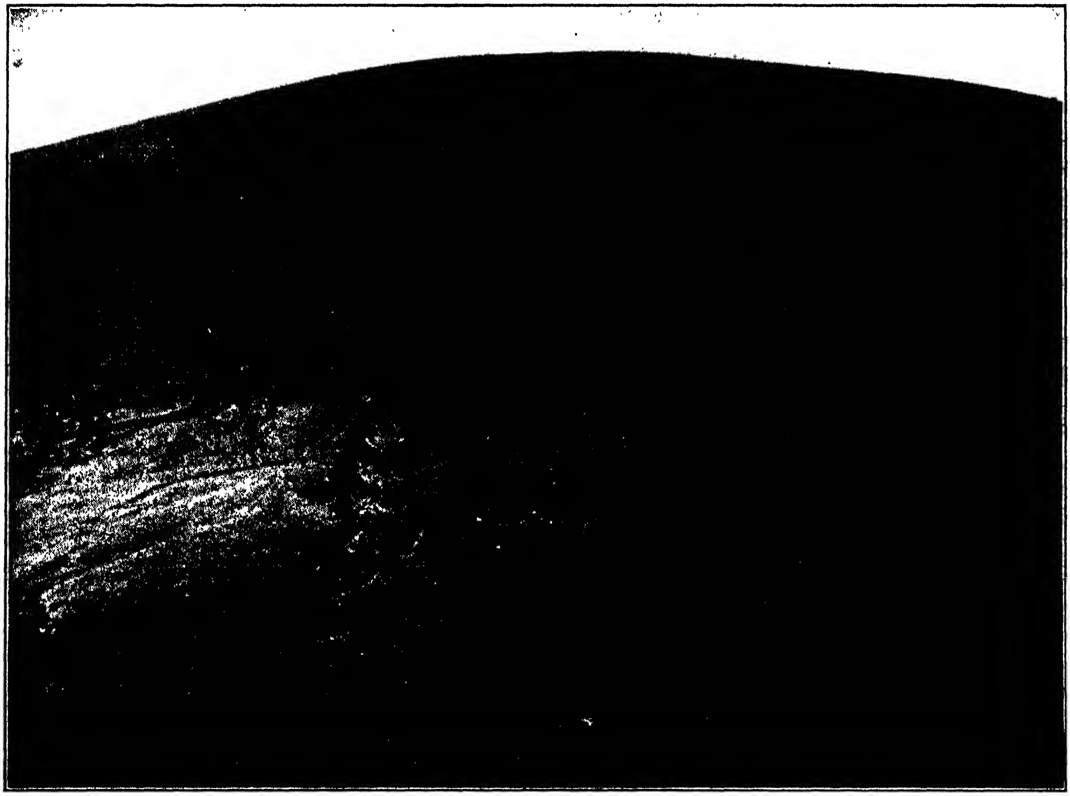

FIG. 2. Soil washing on wheat lands is one of the most serious erosion problems in the nation. This sloping winter wheat field in March, 1948, lost about one-half inch of topsoil since the wheat was seeded four months earlier. (Soil Conservation Service.)

We cannot long maintain our present standard of living if we continue to destroy land as we have since 1800. In fact, we, as a nation, cannot long survive unless we change our ways. We are allowing about 500,000 acres of our cropland to be lost by erosion each year, so that our total available area well-adapted to cropping purposes is decreasing each year under present farming practices. Similarly, our total area of land that is suited to grazing is decreasing every year under existing range practices. Our forest lands are generally eroding less severely and less quickly, so that the problem on forest lands is less acute.

Why Land Damage Occurs

✓Lands have deteriorated from four main causes: loss of soil structure, loss of organic matter, loss of plant nutrients, and loss of the soil itself. These types of land damage have been implemented through the various types of erosion, through obstructed drainage, through improper irrigation, through development of alkalinity, through floods, and through the various farming practices.

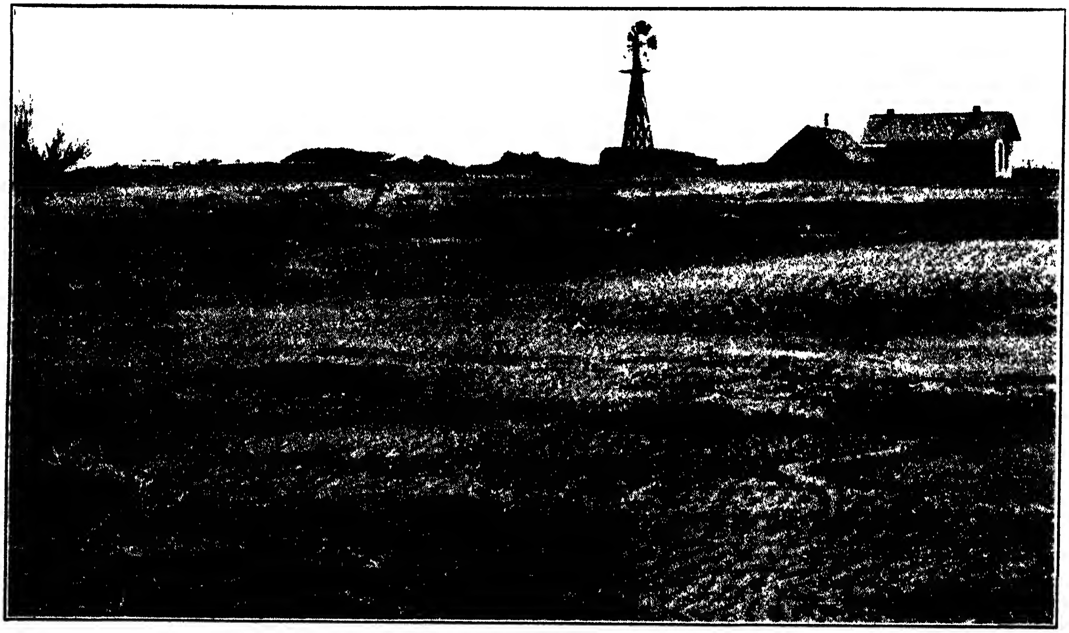

FIG. 3. Wind erosion has caused abandonment of thousands of farmsteads like this one. (Soil Conservation Service.)

LAND DAMAGE RESULTING FROM CULTIVATION

Loss of Soil Structure

When the grassland was first plowed the sod was the bugbear of the new farmer. The tough chunks of sod made the field so bumpy that a good seedbed was almost impossible. These fragments of sod persisted for many years, but gradually through the years they were broken and torn to bits by the several cultivations the land was given each year.

The principle involved is identical with the action of a meat-grinder in the making of sausage and hamburger. After the first grinding the individual pieces are relatively large. After several grindings, however, these individual bits are much smaller. With continued grindings the separate pieces become almost indistinguishable.

So it is with the soil except that, instead of only several grindings, practically all our land has suffered at least a hundred such actions. It takes only one plowing, one harrowing, and two cultivations per year for 25 years to attain the hundred mark. Most of our cultivated lands have now had several hundred such pulverizing treatments. Humid grassland soils have proved highly resistant to pulverization, but soils on cleared forest land are ground to a powder in a considerably shorter time because their soil structure is more easily destroyed.

The results upon all cultivated land, unless it has had crop residues, barnyard manure, and green manure returned to the land during its years of cultivation is a powdered soil that brings decreasing returns and increasing troubles to its owner with each decade of use. It becomes less mellow; it packs like cement; it "puddles" with every rain; and it becomes less desirable with each passing year. The rich mellow loam that had been described as inexhaustible has "worn out." It might be said to have "hardening of the arteries." The stage has been set for the terrific soil losses caused by either water or wind erosion (Fig. 3).

Loss of Organic Matter

Along with the loss of soil structure goes the loss of organic matter. Decaying vegetation, especially of grassland areas, has been adding to the amount of organic matter stored in the virgin soil for thousands of years. Only a little is added each year, but in the aggregate it is enough to transform an originally inert mass of rock fragments into a mellow living medium. In sandy soils, mellowness is attained with only two or three per cent organic matter content, but in heavier textures five and six per cent organic matter is needed to make them mellow.

Most of the cultivated soils in the United States have already lost at least half of their long-time accumulation of organic matter through erosion, stubble burning, leaching, and oxidation during their first few decades of use. After this period, loss of organic matter through oxidation usually proceeds at a slower rate, although the loss by erosion is accelerated more and more.

Loss of Plant Food

Erosion, leaching, crop removal, fire, and oxidation all contribute to the loss of plant food, though mineral salts generally are lost only through the first three processes. Plant food deficiencies are almost universal for all lands today, deficiencies of nitrogen, phosphorus, potash, sulphur, and calcium being especially common. The absence of certain trace elements, such as boron, has also proved a serious matter.

Loss of the Soil by Erosion

The losses from our soils that are mentioned in the preceding paragraphs are of considerable magnitude, but they are as nothing compared to the loss of the soil itself. Each year the average cultivated acre yields from $15 to $50 in newly created wealth. Over a century, at that price, the return from an acre would amount to $1500 to $5000, and the acre would still be on the job producing its annual profit to the nation if it were properly managed and conserved. Multiply the annual per-acre return by the 500,000,000 acres, and we have what this return means in dollars to the United States each year.

Erosion by either water or wind may remove all or any portion of the soil from a given area. If all the soil is lost, the annual harvest of wealth ceases. Its seriousness and its import to every one of us is not yet generally realized.

If the soil mantle on a farm is thin to start with or if the fertile black topsoil is an extremely thin layer, losses are more immediately noticed than if a fertile soil extends to great depths. However, the loss of the soil is a tragedy wherever it occurs, even though such loss does not entirely destroy the productivity of the land. Its ultimate effect is to destroy the resource, and the final result is abandoned land.

Most of the soils in this country are practically ruined when they have lost six inches of topsoil, and they are generally abandoned before they lose ten inches of the surface layer. Our entire farm economy is usually dependent upon that six to nine inches. Wherever we destroy that layer, we destroy the "land bank" on which our farm economy is built.

Land is actually our agricultural capital. Every acre of ruined land is one share of the bank stock thrown away. We have already thrown away about 100,000,000 acres of our land bank, which in 1945 and for every year like it meant 4 billion dollars [1] of potential wealth cut off.

✓The realization that our entire national economy is built upon and around our agricultural economy further magnifies the fundamental importance of soil conservation to every one of us.

✓As a nation, we must stop accelerated erosion!

[1] The 1945 census shows over $40 gross agricultural return for each acre of cropland.

LAND DAMAGE RESULTING FROM OVERGRAZING

The rangelands of our western states also tell a story of despoliation (Fig. 4). The story is just as dramatic as the erosion story of our cultivated lands. It differs only as to detail, for the results have been all too similar. The same land-use principles were violated, and similar land deterioration followed.

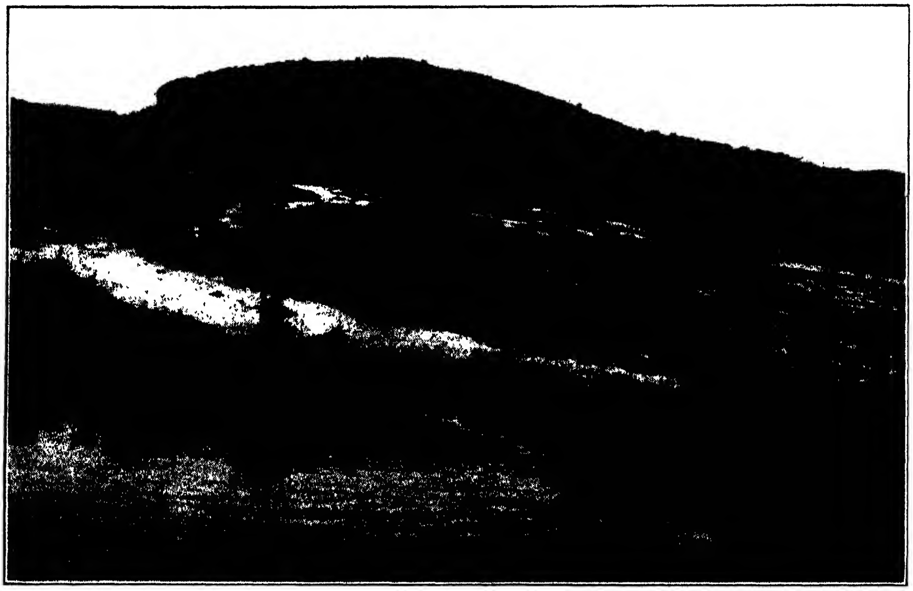

FIG. 4. When rangeland loses much of its precipitation as accelerated surface runoff, it is usually the result of overgrazing. (Soil Conservation Service.)

Essentially the error involved grazing *too many animals* on *too little land* for *too long a time* and *at the wrong times.* The hungry animals gradually ate the virgin forage species into the ground. The palatable grasses were grazed at all seasons, and the range was never rested. Gradually the more palatable plants became weaker until, in time, they died. As the good species died, other unpalatable plants filled the bare spots. Invasion of the area by weed species which not only were less tasty to livestock but also proved more aggressive on the rundown land than the original virgin species was the only possible result. With the decrease in cover, excessive trampling and packing of the soil followed. Inevitably, this sequence of events was followed by accelerated erosion.

FIG. 5. Forest fires, such as have occurred on this hillside, completely destroy the duff mantle and the forest cover. They temporarily decrease the reservoir capacity of the soil for water storage and leave the land in the most vulnerable condition. Furthermore, as the fireweed, thistle, bracken, and other weeds become dry in the fall of the year, the area, with the thousands of logs down, presents ideal conditions for another fire. (Soil Conservation Service.)

LAND DAMAGE FROM DEFORESTATION

In the land clearing which has characterized the history of our millions of formerly forest-covered acres, no thought was usually given to the land except to get rid of its cover so that it might be farmed. Later, when forest cover was being converted to lumber to build millions of homes, barns, and business buildings, the land received even less attention, if such could be possible.

The result was widespread erosion on these former forest lands (Fig. 5). Although the damage has been much greater and much faster on the clearings that became cropland, the logged-off, nonagricultural lands have also contributed greatly to the total land damage in the United States. However, there is one redeeming fact.

Most of the logged-off land now has a protective plant cover, even though it may be inadequate to protect the land against erosion. Vegetation on the land, no matter how poor that plant cover may be, does offer at least a measure of protection.

LAND DAMAGE FROM FLOODS

Most of the long-recognized losses from floods is damage not to the lands but to man's physical developments on the land. No effort is made here even to mention such damages. Instead the types of land damage resultant from floods will be indicated.

Damage by Streambank Cutting

This type of land damage results in complete destruction of the resource and leaves only desolation behind. Since the annual recurring crop loss from these destroyed acres must be capitalized on the basis of its loss to the national economy rather than on its annual profit to the farmer, the average acre of cropland thus lost represents a capital value to the nation of $2000 to $10,000 per acre.[2]

Damage by Flood Overflow

This land damage results mainly from (1) the loss of the current growing crop, (2) the cost and time of re-establishment of a replacement crop, (3) the task of mixing the compact overlaid mantle of mud with the soil beneath, and (4) the loss of soil by scouring. The current year's crop is almost always a total loss when inundated by flood. Conditioning of the muddy mantle may delay re-establishment of crops by one and occasionally by two additional crop years. In the event of severe scouring, much depends upon the nature of the newly exposed subsoil. If the subsoil is sandy or of mellow silt, it tills readily, but, if it is heavy clay, the capital value of the land is badly impaired. Crop re-establishment may prove a costly procedure, especially if an orchard or vineyard must be replaced. This cost may be further increased by the amount of debris removal necessary and the amount of leveling required.

The thin layer of silt deposited annually on the bottomlands along the Nile in Egypt has long been reported as beneficial, but most flooded communities would agree that the damages from the flood exceed the benefits from the layer of silt.

OTHER KINDS OF LAND DAMAGE

Obstructed Drainage

Many thousands of drainage projects have been organized in the United States, but all too frequently people forget that any drainage project requires constant maintenance. The result is that many, possibly most, of such projects in the entire nation have deteriorated far below their potential. Lack of tidal gates where needed, inadequate levees, filled-up drains, lack of adequate pumping facilities, and insufficient tributary ditches are common in districts that are theoretically functioning in proper drainage of land.

Securing adequate drainage in these districts is a widespread means of attaining better land-use on many of our lowland areas. In addition, we have many millions of acres of potentially good cropland that still do not have adequate drainage.

Improper Irrigation

Although there are 21,000,000 acres of irrigated cropland in the western half of

[2] Gross returns of $40 to $200 per acre annually in perpetuity capitalized at two per cent give values of $2000 and $10,000, respectively.

the United States, surprisingly little of this vast acreage is sufficiently well irrigated to produce capacity crop yields. Much of this shortcoming is due to (1) application of too much water, (2) application of water at the wrong time, (3) water applied in the wrong way, (4) water applied to land that has never been adequately prepared for irrigation, and (5) shortage of sufficient water.

Alkalinity or Salinity

The condition of alkalinity or salinity occurs almost entirely in the western half of the nation. It results from the evaporation from the land surface of considerable amounts of water where nature provides insufficient precipitation to leach the salts downward beyond the plant-root zone. It is usually intimately associated with the irrigation of arid lands.

KINDS OF EROSION

Different kinds of land, when attacked by wind and water, resist erosion in varying degrees and in different ways. Some of these man-induced types of erosion result from washing by water, others from drifting by wind, and still others from combined forces of wind and water.

Sheet erosion, gully erosion, and badlands are three degrees of soil washing, whereas dust-blowing fields, sand-drifted fence rows, and dunes are somewhat comparable damage stages of soil drifting.

Sheet erosion has reached an advanced stage over much of the sloping cultivated cropland and over some of the rangeland in the United States. With each passing decade the damage has become increasingly severe on unprotected land. The structure of the soil has been so completely destroyed on much cultivated land that with every rain the soil tends to puddle and seal from the impact of the raindrops. Runoff and rilling are the inevitable results. Lowered production follows, and ultimately gullying and abandonment occur.

On irrigated lands, rill erosion may occur with each irrigation. In certain sections on especially steep irrigated slopes, as much as 20 to 30 inches of soil has been carelessly washed away in a single decade.

Sheet erosion on rangeland results from the same cause as on cultivated areas: inadequate cover, broken soil structure, and puddling and sealing of the surface.

Snowdrift erosion is a highly localized but sometimes exceedingly severe type of sheet erosion. It occurs on the downslope side of snowdrifts where they are common on clean-cultivated sloping fields. The snowdrift itself may protect the upper part of a slope from sheet washing but may greatly increase the damage beginning at its lower edge. This is most common in the Pacific northwest states, though it may occur elsewhere.

Soil slips and earth flows. Soil slips occur only under unusual conditions, as when the bottom surface of the slipping mass of soil becomes slippery enough and fluid enough to toboggan down the slope. If this sliding material is sufficiently fluid to flow like lava—and often it is—it can also be called an earth flow or mudflow.

Such phenomena, usually on a small scale, are seen by the thousands in the steeply sloping pasture lands throughout the nation. They generally move slowly and but a short distance at any one time. They are less common on the croplands of the nation but may be both large and deep. They occur still less frequently in forested areas.

Gully erosion. In certain highly erosive soils, gullying may occur simultaneously with sheet erosion, but it is more commonly recognized and it occurs more widely as a succeeding stage of land damage. As gullies develop, they lengthen and deepen so that they truly divide and subdivide farm fields into ever smaller and less practicable land-use areas (Fig. 6). Sooner or later gullied cropland must be abandoned to some less intensive use.

Fig. 6. When the topsoil is lost, the landowner, the community, and the nation all lose. This formerly improved home was abandoned because the land would no longer produce cotton. (Soil Conservation Service.)

Badlands. When gully erosion becomes sufficiently severe that raw slopes are everywhere, with none of the original upland surface remaining, with no alluvial bottoms forming, and with all slopes approximately at the angle of repose, the topography known as badlands results.

Streambank erosion. When native vegetation covered both the bottomlands along our streams and the uplands which drained into those streams, streambanks did not erode as they do today. Logging, fires, clearing, and cultivation have decreased the reservoir capacity of our formerly forested watersheds; and overgrazing, fire, and cultivation have speeded up the runoff from the formerly grass-covered lands. The original fringe of trees along the streambank, which has been removed in considerable measure today, further retarded streambank erosion. The obvious results of all such changes is more runoff in less time from nearly all the developed or disturbed portions of any watershed.

At the same time we have cleared and farmed the usually wooded bottomlands so that, when the increased runoff reaches these lands from which nature's protective growth has been removed, the streambanks are undermined and the rich soil goes floating down the creek, river, or bayou.

And, even if the bottoms have not been cleared, the increased flood levels from the watershed area still take out the bottoms, although at a slower pace. Streambank erosion really destroys our most valuable valley lands.

Wind erosion. Research studies in the dust bowl of the 1930's have proved conclusively that long-continued cultivation of even the best soils under low-rainfall conditions is a hazardous practice. As the soil structure is more and more pulverized with each year of cultivation, it becomes increasingly vulnerable to attack by wind.

Sandy soils break down more quickly than heavier soils, but no soil is too fine-textured to blow. Therefore, any cultivated land area where strong winds occur constantly is a potential dust bowl, even under irrigation.

Dunes. As wind erosion becomes more severe the ripply land surface becomes ever more dune-like. Ultimately a typical dune topography results.

FUNDAMENTALS OF CONSERVATION FARMING

The farming methods and practices that have developed in this country through the past 200 years have been many. Some have proved beneficial, others harmful. Some have proved practicable, others impracticable. Some have been profitable, others unprofitable. The objective, more especially since the turn of the century has been to grow the largest volume of salable crops at the lowest possible cost. Too many of these new farming practices have proved exploitative. When conservation of the soil became an equally important objective after 1933, it became evident that we must find and develop safer methods of using our lands.

The essential fundamentals of conservation farming are (1) to use the land in keeping with its capabilities and (2) to protect the land in keeping with its needs. Actually the science of conservation farming has been under way for several decades, although soil conservation was not a recognized objective of most of those earlier beginnings. Many, though certainly not all, of the agricultural experiment station research projects, when adapted to this objective, have proved admirable conservation practices and measures. Their long and successful search for locally adapted green-manure crops and rotation crops was among the most notable accomplishments in this connection. Some agricultural research projects have proved to be in direct conflict with the principles of soil conservation. Such, for example, is the practice of clean-tilled summer fallow. Clean bare summer fallow is the antithesis of soil conservation.

When the soil conservation experiment stations were first established in the early 1930's, the principles of soil conservation were little more than a theory. But from the vast store of fundamental research by the agricultural experiment stations, from the experiment stations established specifically for this purpose, and from individual experimental efforts by thousands of farmers who long ago did recognize the need of better farming methods, soil conservationists developed in less than 20 years a relatively stable science.

During the primary efforts toward soil conservation it was soon recognized that good results did not follow simple, easy changes. The problem proved to be less simple than that. The land was sick in several respects, and as with a sick person a careful, continuing diagnosis of the symptoms and repeated modification of the treatments have proved necessary.

Because of the complexity of the problem, and also because it differs in detail with every change in the soil, in the slope of the land, or in the climate, progress in adapting conservation farming practices to every tract of land is slow. Early trials of applying the same treatment to all farms in a certain locality have proved just as inadequate as would good medicines administered indiscriminately.

Before making recommendations of conservation practices for the different fields of any particular farm, the doctor—in this case the soil conservationist—must first be able to classify adequately all the lands in this farm and secondly he must be able to prescribe conservation farming practices for each of the kinds of land he finds. When conservation of the soil is as far advanced as medical science is today, it may prove to be just as complex and fully as important as medical science.

In fact, there are strong indications even now that the currently increasing need for the dietary phase of medical science may be largely resultant from soil deficiencies. Soil and health are being watched more and more closely for their interrelationships.

PRINCIPLES OF CONSERVATION FARMING

Ever since the first soil conservation programs were evolved by erosion experiment station personnel in 1930 and 1931, two cardinal principles have stood out in bold relief.

The first of these two principles was then and still is as follows: *Effective prevention and control of soil erosion and adequate conservation of precipitation in any land area require that the use of the various kinds of land be in accordance with its capability and needs.* Naturally the capabilities, facilities, and adaptabilities of the landowner must be simultaneously considered. The second of these two guiding principles has always been as follows: *Efficient application of conservation measures to various kinds of land requires the assistance of a technician out on the land.*

Almost without exception, when these two principles have been carefully adhered to, the recommended use and practices have proved to be sound. On the contrary, whenever some zealous worker attempted to shortcut these principles and thereby speed up the work he found that his efforts usually brought him much trouble.

Co-Ordinated Plan of Soil Conservation

Before making any recommendations for a particular tract of land, the soil conservationist must be able to classify the different kinds of land within the tract and determine the conservation needs on each kind of land (Fig. 7). He must know how to evaluate the various ecological factors that contribute in any important way to this complicated problem, and then, finally, he must be able to apply or even create remedial measures to correct the unwise uses and methods of land management that he has encountered. In fact, he must be a geologist, soil specialist, geographer, land appraiser, agronomist, forester, range specialist, engineer, biologist, and several other scientists, all in one. The degree with which he proves able to integrate just the right amount of each science that is involved partly determines his degree of success as a soil conservationist. His success in getting the farmer to believe in, to undertake, and to maintain these procedures is another important factor. *He must be able to plan properly the integration of the dif-*

ferent practices needed on any given piece of land into a co-ordinated program. For example, on a gently sloping field, a crop rotation and crop residue utilization may be the only practices needed; a steeper adjoining hillside may need these plus terracing

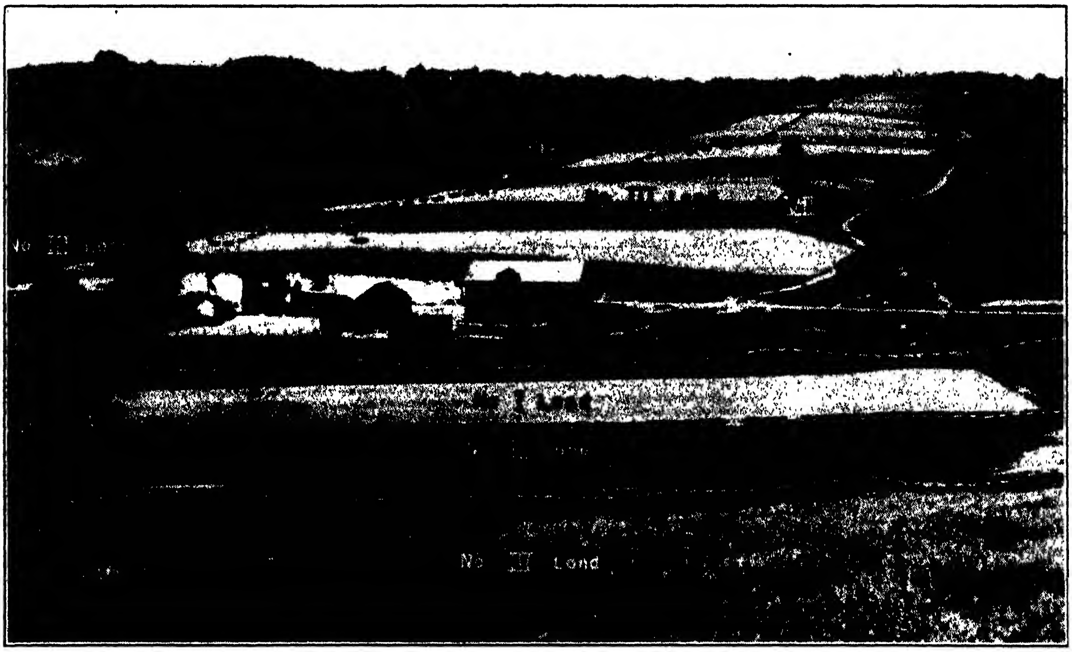

FIG. 7. Land capability is simply one way of describing the different grades (I to VIII) into which a farmer would divide his land. On this particular farm grades V, VI, or VIII are not shown in the picture. Relatively few farms have land of more than four of the eight capability classes. It is most unusual to encounter a single farm having land in each class. (Soil Conservation Service.)

and strip cropping; and on a very steep adjoining hillside the needs may sound simpler because it should not be cultivated at all. Tree planting and woodland management may represent the entire needs for soil protection on the steepest slopes.

THE CONSERVATION FARM PLAN

If land problems as complicated as these are to be solved, plans for making the needed changes must be made.

Since no two farms are identical and no two farmers alike, no two farm plans should be the same. The different soils cover varying slopes and sites under differing intensities and amounts of wind, rainfall, sunshine, humidity, and temperatures.

It must be pointed out that one soil conservation practice alone is seldom adequate to protect land against damage and deterioration. Usually three or more practices must be combined to obtain a balanced program. Both sequence and timing of each practice are important and necessary actually to stop erosion and improve the land.

Planning the Farm

When the soil conservationist tackles the planning of conservation on a farm, his first step is either to make or to obtain a map of the farm. This is commonly a vertical aerial photograph on which are shown the important physical factors. Usually these factors are limited to soil, slope, erosion and cover, although other factors may be included. From his knowledge of the many contributing factors, he evolves a particular combination of practices for each unit area on the map. The individual conservation practices, some of which are briefly described on succeeding pages, are the tools which the conservationist uses to get conservation done. The simpler jobs on gently sloping land involve only two or three simple tools, but the more difficult protection of more steeply sloping cultivated lands, generally require additional ones.

Land Capabilities

When one thinks of all the kinds of soil, all the degrees of slope, and all the kinds of climate which when combined make the different sorts of land we have in this country, only then do we appreciate that our lands differ greatly in type of use to which they are suited. This is defined as their capability, which is not necessarily related to their productivity.

Many systems of classification of the land's capability are being currently employed in the United States. The Soil Conservation Service of the U. S. Department of Agriculture has evolved a scheme that lists eight major land types. Theoretically, every acre of land in the country will fit into this scheme. These eight classes are described as follows:

Class I. Very good land that can be cultivated safely with ordinary good farming methods. It is nearly level and easily worked. Some areas need clearing, water management, or fertilization. Usually there is little or no erosion.

Class II. Good land that can be cultivated safely with easily applied practices. These include such measures as contouring, protective cover crops, and simple water-management operations. Common requirements are rotations and fertilization. Moderate erosion is common under exploitative land-use.

Class III. Moderately good land that can be cultivated safely with such protection as terracing and strip cropping. Common requirements include also crop rotation, cover crops, and fertilization. Usually it is subject to moderate to severe erosion under exploitative methods of using the land.

Class IV. Fairly good land that is best suited to pasture and hay but can be cultivated occasionally—usually not oftener than one year in six. Even when plowed only occasionally the most intensive erosion prevention practices are required.

Class V. Suited for grazing or forestry with little or no limitations.

Class VI. Suited for grazing or forestry with minor limitations; needs protective measures.

Class VII. Suited for grazing or forestry with major limitations; needs extreme care to prevent land damage.

Class VIII. Suited only for wildlife or recreation. This land usually is rough, stony, sandy, wet, or highly erodible.

With these land capabilities as the basis of the farm plan, the conservationist builds the framework of his program to fit the particular foundation on which he is working. Then he adds the necessary structural details to brace and strengthen and finish the structure adequately. The product of these procedures is a conservation farm plan designed to fit one certain farm. Probably it can be perfectly fitted to no other farm, though it will probably serve other farms having very similar measurements.

The U. S. Department of Agriculture Farm Credit Administration has a somewhat different classification in that their *Classes I* to *V* portray decreasing values of cropland. Their classification, however, is based not upon safe use of the land but rather upon its productivity.

The U. S. Department of Agriculture Bureau of Plant Industry Soil Survey uses a combination of textural, genetic, and land forms to identify their classifications. Under this system they have established thousands of different soil types.

PRINCIPAL CONSERVATION PRACTICES

The present conservation practices have gradually evolved since the early 1930's by adaptations from earlier research findings. Other practices have been developed as a result of current research, and some practices have been taken directly from trial-and-error observations and use by experimentally minded farmers. The current list of conservation practices is still in an evolutionary status and has in no sense become a set pattern.

FIG. 8. This newly contour-listed field had just been planted to forage crops before a heavy downpour left this water to soak into the ground. This has become a general conservation practice for saving water. (Soil Conservation Service.)

The current major conservation farming measures are briefly described here:

Contouring. Plowing, planting, cultivating, and harvesting sloping fields on the level; that is, farming on the contour, around hillsides with curving furrows to fit the lay of the land, instead of straight up-and-down-hill furrows. The curved furrows catch rainfall and allow much of it to soak into the ground (Fig. 8). This conserves water and greatly reduces the amount of soil that is washed away. Part of the extra water which thus enters the soil is used by crops, and part is added to the underground water supply to feed springs, wells, streams, and ponds.

Contour furrowing. Making furrows on the level to hold rainfall. This helps the growth of pasture and range grasses. Where runoff has been common, this measure decreases the runoff and in effect increases the rainfall.

Contour subsoiling. Breaking up hard subsoil so that it can absorb more rainfall. This is done mostly on pasture lands to improve the grass stand. Subsoilers follow contours, and the intervals vary with land and cover. This practice gives best results when the subsoil is dry and brittle enough to shatter when the subsoiler passes through it.

Terracing. Ridging land on or nearly on the contour. The farmer builds up low ridges or embankments of soil across sloping fields to intercept rainfall. Terraces with slight grade slow down runoff water, resulting either in increased absorption or in guiding the runoff to safe disposal at the sides of the fields. This controlled excess water runs off slowly, causing relatively little erosion. Level terraces hold all the rainfall on the land, unless they are overtopped.

Diversion channels. Channels with a ridge on the lower side. The ridges sometimes are larger than field terrace ridges and are farther apart. Otherwise they are much the same. They are built across slopes to divert damaging or wasteful runoff.

Strip cropping. Planting strips of close-growing plants, like grass or clover, between strips of clean-tilled row crops, on or nearly on the contour. The strips of close-growing plants hold water and keep it from eroding the cultivated strip below. They also strain out the soil picked up by runoff water from the plowed strips. *Field stripping* is placing alternate strips of cultivated and thick crops roughly at right angles to the main slope of the land (Fig. 9). It is really a less engineered form of strip cropping. *Wind stripping* is planting alternate strips of clean-tilled and thick crops at right angles to the prevailing wind.

Stubble-mulching or mulching. This practice is also called *trashy fallow.* It involves leaving crop residues and soil-improving crops at least partly on the ground instead of burning them or turning them under. These materials include grain stubble, straw, cornstalks, crotalaria, lespedeza, sweet clover, and other protective cover crops. Mulching protects the soil from erosion and baking, cuts down erosion and evaporation, lowers the soil temperature in summer, helps the soil to absorb more rainfall, decreases the degree of freezing, and aids growth of useful bacteria in the soil. The practice requires implements that do not turn the soil upside down.

Crop rotation. Alternating production of various crops on a piece of land. On rich land it keeps the soil productive, and on rundown land it improves the soil. In a good rotation, the soil-building crop helps the next crop. For example, nitrogen, needed for plant growth, is added to the soil by legumes, such as clover, alfalfa, and cowpeas. After they have rotted, the nitrogen can be used for growth by plants that do not have the power to fix nitrogen, such as corn, cotton, and potatoes. Rotations often are integrated with strip cropping by shifting the close-growing strips and the tilled strips at fixed periods. In this way the soil is improved by the same cropping system used to stop erosion.

Cover crops. Dense crops that prevent erosion of cultivated areas at times when there are few or no other plants to protect the land from wind and water erosion. There are summer covers, winter covers, and perennial covers. Legumes and grasses are the most common cover crops.

FIG. 9. Contour strip cropping is probably the most picturesque though not necessarily the most beneficial soil-conserving practice now in use. This field is typical of a quarter million like it in the United States. (Soil Conservation Service.)

Fertilizing land. Use of manure or fertilizer on land that needs additional plant food to stimulate plant growth.

Drainage. Removal of excess water from wet land by ditches or by tile drains. Such artificial waterways must be kept free of silt by protecting the watershed from erosion or by desilting the water as it enters. Open ditches also must be kept free of plant growth and debris that stop drainage, or the benefits will be lost.

Irrigation. Spreading water on land by safe methods to increase crop yields. Applying water with sprinkler systems is known as "overhead irrigation" and is the safest method.

Irrigation development and improvement. Management of water for irrigation. The term includes building and improving water distribution systems on farms; land preparation, such as leveling; measurement and control of water; development or improvement of springs and wells; and disposal of waste water.

Water spreading. Controlled spreading of runoff water in areas of low rainfall from the foot of slopes and from gullies and washes over nearby land that needs it. This is done by dikes, dams, and other means of directing water from one place to another. The object is to make use of all water in low-rainfall areas, rather than waste it.

Grassed waterways. Protected channels and outlets carry off excess water from terraces and near-contour crop rows. These waterways are stabilized against erosion by grasses, legumes, and vines. They include meadow strips, grassed ditches, diversion ditches, and grassed channels at the ends of field terraces.

FIG. 10. Austrian winter peas are widely grown during the winter months to protect orchard lands against erosion damage and are plowed under during the spring to build up the productivity of the land. This peach orchard is thriving under this management system. (Soil Conservation Service.)

Pasture development. Developing new pastures with selected grasses and legumes, and different combinations thereof. It may include fertilization, liming, drainage, irrigation, fencing, clipping, spreading droppings, and other measures.

Pasture improvement. Using measures that increase growth and improve quality of forage grasses. It includes such measures as deferred and rotation grazing, proper stocking, stock water ponds or wells placed to encourage better distribution of livestock, spacing of salt and bedding grounds for the same purpose, reseeding, liming and fertilizing, basin listing and contour furrowing, water spreading, weed control, clipping, spreading droppings, and fire protection.

Green manuring. Turning under grain, legume, or grass crops while green improves the soil by adding to the supply of organic matter (Fig. 10). The soil tilth is also improved.

Meadow development. Using land not suitable for cultivation to grow hay. The land should be plowed only to renew planting.

Gully control. Using plants and mechanical measures to stop eroding gullies. These measures reduce the rate of water flow. It is done by using (1) grass, vines, trees, and shrubs; (2) flumes and other devices to lessen the cutting power of waterfalls; and (3) dams for catching silt.

Field and gully planting. Planting eroded or erodible land, which is unsuitable for cultivation, to trees, shrubs, grasses, vines, or other useful plants that will help stop erosion and will also conserve rainfall.

Woodland harvesting and improvement cuttings. Cutting for lumber, pulp, and other uses according to sound forestry practices. Such cutting promotes rapid growth and makes wood a regular crop.

Pond management. Use of suitable measures (*a*) to protect ponds from erosion and siltation and (*b*) to aid production of fish and other pond wildlife.

Shelterbelts—windbreaks. Plantings of trees and shrubs in strips or belts usually one to ten rows wide. The main purpose is to deflect wind currents, thereby reducing wind erosion and snow drifting. Such strips of trees and shrubs also conserve rainfall through increased absorption by the soil, and protect fields and gardens, livestock, orchards, and buildings.

This partial list of practices shows only some of the most successful practices which are currently widespread. Additional successful practices for conserving soil and water are evolving every year. Since this science is so new, other practices will undoubtedly be recognized and added to the list with the passing years.

HISTORY OF SOIL CONSERVATION IN THE UNITED STATES

Prevention of soil erosion has been advocated by a few far-seeing persons ever since colonial times, but little has been done to accomplish control on the nation's farmlands except by those few zealous missionaries. George Washington and Thomas Jefferson advocated and practiced safer use of our cropland.

Only since the late 1920's and early 1930's have the missionaries been more than a voice in the wilderness. Dr. Hugh Hammond Bennett, Chief of the Soil Conservation Service, made the first impression on the national consciousness when, chiefly through his influence, Congress established ten erosion experiment stations in 1929, 1930, and 1931.

The immediate results of the research started at that time on these experiment farms were so striking that in 1933 the Soil Erosion Service was formed. A series of soil conservation "demonstration projects" was established in 1933–1935 at key locations throughout the nation. When the Civilian Conservation Corps was established in 1934, several hundred of the CCC camps were assigned to the Soil Erosion Service. Most of these SES-assigned camps worked either on the projects mentioned or on new projects established specifically for the CCC camps. By these means a total of several hundred demonstration projects on soil conservation were established in all parts of the nation.

In April, 1935, Congress passed the basic Soil Conservation Act (Public 46, 74th Congress), declaring it to be the "policy of Congress to provide permanently for the control and prevention of soil erosion" and authorizing the Secretary of Agriculture to establish the Soil Conservation Service to effectuate this policy. In accordance with the language of the act authorizing the Secretary to "utilize the organization heretofore established," the Secretary renamed the Soil Erosion Service the Soil Conservation Service. Much of the soil conservation work since the passage of this act has been done under that congressional authority.

In 1936, two lines of attack on the soil conservation problem appeared: the beginning of the soil conservation district movement, and the beginning of subsidy payments by the federal government for the establishment of conservation practices.

Since that time the policy of the Soil Conservation Service has been to establish conservation on the land through the medium of soil conservation districts (Fig. 11). Although the first state enabling legislation for creation of such districts was passed in 1937, the soil conservation district is now a nationwide institution. All the 48 states have enabling acts, and more than 75 per cent of the farms in the United States now are within organized soil conservation districts. Similar enabling legislation has more recently been passed in all our territories. All of Alaska was declared a soil conservation district by the territorial legislature in 1947. These districts are legal subdivisions of the states and territories and now number more than 2200,[3] with new districts being formed each month. It is now believed that practically all farmland in the United States will soon be in soil conservation districts. The evolution of the legal soil conservation district of today from the few soil conservation associations formed by farmers beginning in 1934, in connection with the Soil Erosion Service Demonstration Projects, has been an amazing development.

The initial spread of soil conservation districts centered in the main agricultural regions of the country. The vast acreage of federal lands together with the unsettled area in the eleven western states has slowed the formation of districts there. The forests of northern Michigan, northern Minnesota, and northern New York have had a similar effect in those areas. The large areas not within soil conservation districts in the states of Pennsylvania, Indiana, and Missouri are the result of a delayed passage of soil conservation district acts or the current conservation policies of those states. Most of the area within the Tennessee Valley Authority is without soil conservation districts because that administration has not considered them necessary.

The soil conservation district is a farmer-organized, farmer-operated governmental unit of the state or territory (in Connecticut, New Hampshire, and Alaska, the soil conservation district includes the entire area) in which this governing body of farmers has as the primary objective applied conservation on, and the better use of, all lands within the district.

The cash-subsidy approach began when the U. S. Supreme Court declared that the authority under which the Agricultural Adjustment Administration operated was unconstitutional. The AAA was therefore reorganized to operate under the basic Soil Conservation Act. Since that reorganization, the AAA (changed in 1946 to the Production and Marketing Administration) has paid farmers for the establishment of soil-conserving practices. This cash-subsidy program has operated closely with the soil conservation district program in some parts of the nation but has worked somewhat independently in other parts. These subsidy payments for using soil-conserving practices have been administered by a committee of farmers for each county who distributed the conservation payment money allotted to that county.

The farmers of the United States in growing numbers are asking for help in putting conservation on their land—mainly technical help. In 1940, when conservation

[3] As of January 1, 1950.

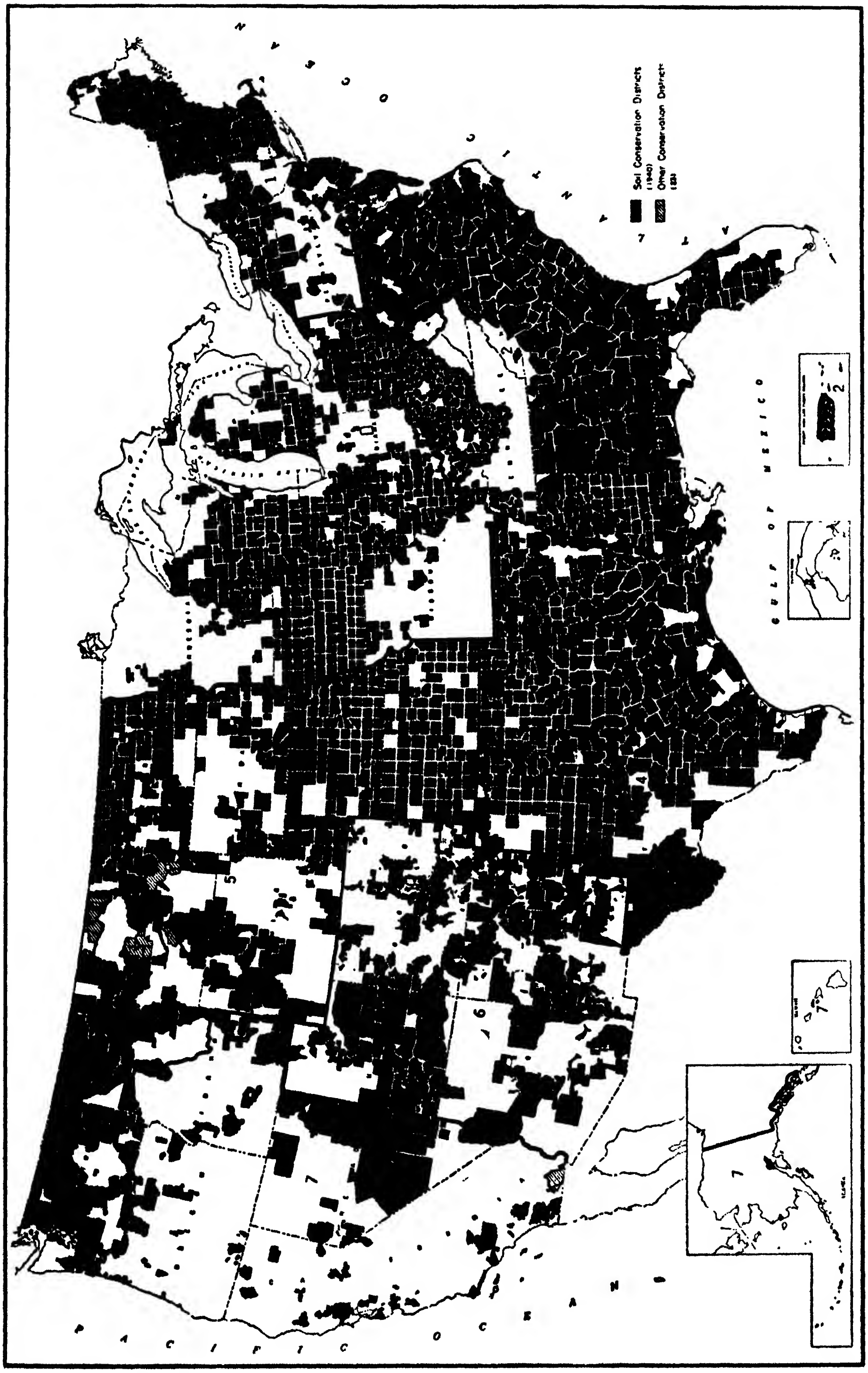

FIG. 11. Soil conservation districts established as of July 1, 1948. (Soil Conservation Service.)

farming was new, few knew about it; today millions realize its value and want it. The tens of thousands of unfilled requests on hand show that American farmers now understand much more fully than they did a few years ago the importance of conserving their own and the nation's soil and water resources.

FARMER APPLICATIONS FOR ASSISTANCE

By June 30, 1949, a total of 1,082,452 farmers had applied for farm plans on 290,577,000 acres through the 2078 soil conservation districts then co-operating with the U. S. Department of Agriculture. This does not include the large number of requests for assistance on community jobs from groups of farmers, nor does it include the hundreds of thousands of farmers who are waiting for such assistance.

Farmer Requests for SCD Assistance

	United States Farmers Applying for Assistance	*Millions of Acres Operated by These Farmers*
1943 (and before)	313,301	85+
1944	94,187	26+
1945	118,878	33+
1946	172,520	45.8+
1947	165,902	45+
1948	148,279	40+
1949 (first half)	85,764	22+

CONSERVATION WORK ON FEDERAL LANDS

The U. S. Forest Service has authority and appropriations each year to do soil and moisture conservation work on lands under its jurisdiction. The various agencies of the U. S. Department of the Interior have similar authority for work on the federal lands under their jurisdiction.

OBJECTIVE

The national objective of soil conservation is the utilization of every acre within the limits of its capability and the protection of every acre in keeping with its need.

Public Opinion

The basic concepts and objectives of the soil conservation program have met general acceptance with both urban and rural people. Public opinion usually is not immediately followed by the general application of conservation farming to the farmer's fields. A serious lag between lip acceptance and completed application still exists. The length of time varies with different localities, but a noticeable lag is almost universal. More time and a more complete understanding of the full import of the problem, on the part of the landowning public, are apparently needed before the principles for which soil conservationists are working become part of our living.

Importance of Control

The United States is destroying and damaging more land at a faster rate than any other nation. If we are to protect the stability of the American way of life, we must start soon by protecting our land resource. It cannot be left to the indefinite future. Protection of all lands against increasing damage is vital to future generations.

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CHAPTER 5

Tree Crops

THEIR RELATION TO SOIL CONSERVATION

WITH all due respect to the ladies, it is time that we developed a *man's agriculture.* In primitive societies the woman was and is usually the farmer. According to our best guess it was this ancient woman who domesticated wheat, barley, rye, corn, cotton, and nearly all the beans and other staple field and garden crops that are now the basis of European and American agriculture.

The age of science has now arrived, and therefore the time has come to develop a man's agriculture, new crops—crops that grow on trees. Tree crops are needed to help in solving one of the most menacing problems confronting the American farmer, the problem of the gully—soil erosion. We say that this is the age of science. It is in spots, but only in spots. Science has been applied tremendously to the art of killing men, and to many branches of commodity production. We have applied it but little to the distribution of what has been produced; hence we have depressions. Also we have done little about the conservation of resources, and so our civilization, as it now is, may from this cause alone be but a flash in the pan of history. It must be so unless we change and change quickly.

Every American schoolboy and schoolgirl should work on the following problem as soon as he or she has reached decimals: take the generalized data from Mr. W. A. Rockie's record of soil destruction given in the preceding chapter of this book, and estimate how long the United States will last if soil erosion continues at the present rate. The answer will shock even the fifth-grade child. He could then appreciate the gravity of a destructive force that has already caused counties in Georgia to lose half their farm population. Surveys by the Tennessee Valley Authority show that in a century 60 per cent of the land that has been cleared above the Norris reservoir has been ruined. It should make even a fifth grader shiver to think what will happen when every reservoir in the United States has silted full and become an alluvial plain subject to flooding. That is their future, and some have already reached it.

How does it happen that our much-boasted modern agriculture is so devastating? Partly because our attitude toward a distant future is like that of the cow toward tomorrow. Also, the gully is the new phenomenon. Primitive agriculture did not result in much soil erosion. The American Indian and primitive agriculturists in other parts of the world had no plow, a fact for which this generation should be

By J. Russell Smith of Columbia University.

endlessly thankful. The primitive agriculturists scratched the ground a bit in forest climates or laboriously turned a few sods in grasslands, planted a small patch, and before the soil began to wash away they abandoned the patch for another and let the healing growth of weeds and grass or briars, bushes, and trees hold the earth until clearing time came again. This was really man's first crop rotation, and it is still practiced.

The northwest Europeans do not have the gully problem. Any observing traveler can demonstrate this to his own satisfaction in almost any part of northwestern Europe. Not long ago I crisscrossed Great Britain in an automobile and rode from Copenhagen to the Alpine pastures and thence to the Channel coast of France. In the entire journey I did not see a single raw, cutting gully. There were a few old ones, but they were completely healed with grass. Other signs of erosion were almost completely absent in lands heavy with crops. The Mediterranean countries are not so blessed, however.

NEW FACTORS IN AMERICA

Why does northwest Europe escape erosion when erosion is rapidly transforming large parts of the United States into an agricultural desert? Because we have been unintelligent in transplanting European agriculture to the United States. We have resembled the pet beaver, who, with an instinct to build a dam, built one in the office where he lived as an appreciated pet. Following instinct and traditional methods, the beaver built his dam, but he built regardless of environment. Trees or office furniture were all the same to him, so he chewed up chairs and tables, took the contents of the wood box and stuffed the crevices with the pages torn from the books he found on the shelf. The dam in the office did not provide water because the beaver had built regardless of the environment.

Those who brought agriculture from Europe resembled the pet beaver in the office by not observing the proper relationship between their new environment and five things that were new to them—corn, cotton, tobacco, thunderstorms, and the absence of turf.

FIG. 1. The ruin of America. Row crops, in this field cotton with its tillage on gently sloping land, encourage soil destruction at a rate that is difficult to believe until measured details are worked out. (Soil Conservation Service.)

Row Crops: Corn, Cotton, and Tobacco

One reason why northwestern Europe is so free from soil wash is this. Corn, cotton, and tobacco are not grown to any important extent. The major crops are wheat, oats, barley, rye, and clover. These plants stand close together with scores or hundreds of plants to the square yard. Their tops cover the ground fully; their myriad roots quickly penetrate the earth and hold the soil against the force of running water. Marked differences exist where corn, cotton, and tobacco are grown, as in the United States (see Fig. 1).

The plants of these three row crops stand far apart, sometimes only two plants or even less to the square yard. There is space enough between rows to allow the cultivator to pass; sometimes it passes both ways. Many times during the period of plant growth the cultivator tears up the top layer of earth, cracking the newly formed crust and destroying any surface roots that might hold it. Soil thus loosened is ready to be carried away by the next rain. Cultivation the next week may loosen the soil that remains and prepare it for removal by the next week's thundershower, and so on through the season and the cycle.

FIG. 2. On the Piedmont of the Carolina area some of the best soils go like this with great rapidity. The slope is small, but the rainfall is heavy. The subsoil is tougher than the material below it. Thus the third layer washes out as shown here, forming what are called caves, and it falls in by the carload. This destroys the hills and destroys the valleys by putting coarse sand on top of valley soils. (Soil Conservation Service.)

The Thunderstorm

Northwest Europe has few thunderstorms. The rainfall is light. The amount of rain that falls in an hour is slight. The runoff is weak. But in this country, from the Rocky Mountains eastward, the standard type of summer rain is the thunderstorm with water pouring upon the earth at the rate of one, two, three, four, five, or even six inches in an hour. Six inches an hour nets 680 tons of water to the acre (per hour). Here are some significant figures from a recent measured erosion experiment at the U.S.D.A. Soil Erosion Experiment Station, Temple, Texas.

"The rainfall of April 2, ranging at different places from 1.09 to 1.72 inches, produced some striking results. The rate of intensity was approximately 4 inches per hour. Land planted to corn, with rows up and down a 4 per cent slope, eroded at rates ranging from 5 tons to nearly 10 tons per acre in terms of dry soil. The actual sludge of mud washed from the same areas during this single rain, ranged from 9.65 to 14.89 tons per acre. The runoff ranged from 43 to 50 per cent of the total rainfall of 1.72 inches ···

"Land having a crop of oats on a 4 per cent slope incurred soil losses ranging from only 0.01 ton to 0.2 ton per acre of dry soil. The runoff from this oat field ranged from as low as 0.4 per cent to 3.34 per cent of the total rainfall of 1.72 inches.

"Land having a cover of Bermuda grass on a 4 per cent slope sustained a soil loss of only 0.02 ton per acre, dry weight, while the runoff was 1.33 per cent." [1]

FIG. 3. This land has no more slope than that in the preceding picture, but the trees are planted on the contour. There is no soil loss. A legume growing between the trees gathers nitrogen and produces organic matter. A million peach trees are receiving this treatment near Spartanburg, S. C. This may be a permanent agriculture. (Soil Conservation Service.)

I have seen one June thunderstorm in northern Virginia which caused a little stream whose length was about half a mile, draining about 100 acres, to become 100 feet wide. As it overflowed a cornfield, it removed the soil in a wide stretch to the depth that the earth had been plowed. As this almost unbelievably swollen brook crossed the farm it ripped out seven fences, including 60 feet of stone fence. And on hillside cornfields of resid-

[1] E. B. Deeter, "One Hard Rain Did This," *Soil Conservation*, Vol. I, 1935, p. 9.

ual soil, derived from the underlying trap rock, the water removed in a few minutes probably as much soil as could be produced by many tens of thousands of years of weathering. How long can our country last? The promise is not long. (See Fig. 2 and Fig. 3.)

The clean-tilled crop and the thunderstorm are the major factors, but by no means the only ones, in the present progressive ruin of American croplands. Mr. Rockie has shown in the preceding chapter that there are also other agents of destruction.

Absence of Turf

I am not forgetting that little attention has been given to the influence of the turf-forming grasses which prefer cool climates, such as that of northwestern Europe and New England and the north Pacific coast region of the United States. Good turf is scarce in the American Cotton Belt—another reason why erosion is so bad in that land of summer thundershower, heavy winter rain, no protection by freezing, and, even to this day, the almost universal absence of winter cover crops on most of the cropland.

WE NEED TO DEVELOP CROPS THAT GROW WITHOUT TILLAGE

Unaided nature has produced many crop-yielding trees that exist in many parts of the world. It is strange that we have made so little use of them in systematic agriculture. The following paragraphs present examples of little-used crop-yielding trees.

Keawe or "Algaroba"

On the various Hawaiian Islands, with their many climates, there are thousands of acres of copse, thicket, or forest—depending on rainfall and soil—of the keawe tree, probably a mesquite (*Prosopis julifera*). It is commonly stated that all the Hawaiian keawe are descended from one tree brought from Chile in 1826 and planted by a watering trough. This leguminous tree yields beans valuable for forage. Experts at the Hawaiian agricultural station state that:

"It has taken possession of large tracts of otherwise unoccupied land, prospers where the soil is too dry for any other crop, and produces a verdure and shade where otherwise there would be an almost barren waste, and yields a pod of high feeding value ··· Thus far there has been no cultivation of algaroba. The thousands of acres of trees stand, for the most part, in rocky soil where cultivation would be practically impossible ··· It has been found that the (bean) yield per acre varies from 2 to 10 tons. This yield varies but little from year to year and occurs in two crops per year, the figures given covering the sum of both crops."

This yield is astonishing, and even more astonishing is the value of the beans. When the beans and pods are ground together to make meal, 100 pounds of it equals in feeding value 80 pounds of good barley meal. (The 10 tons = 20,000 lb. = 16,000 lb. of barley = 333 bushels.) Who ever saw an acre that yielded half as much barley even once? Some very astonishing facts were given to me by a ranch manager in charge of 21,000 acres of waste and pasture land attached to a sugar estate on the Hawaiian island of Maui. The manager was in charge of 200 dairy cows, 800 cattle, 700 horses and mules, and 250 pigs, and had a corps of accountants keeping an elaborate system of agricultural accounts.

When questioned as to the productivity of the keawe, he replied as follows: "You can take cattle, lean ones, that weigh 500 pounds; and, if you put six of them on an acre of good keawe, they will average better than 2 pounds a day on raw beans which they pick up for themselves. You can take the season from the middle of July, and the six cattle will gain 1200 pounds and sometimes will go to 1600 pounds of beef per acre on land with rainfall of 20 inches a year." Every year on this one ranch from 1000 to 1400 tons of these beans were ground into meal for feeding to livestock exactly as the American dairy farmer uses cottonseed meal, bran, or other mill feeds.

When one considers that an acre of good Kentucky bluegrass pasture or the rich pasture of old England will produce 150 pounds of live mutton per year, and an Illinois farm in corn and alfalfa will make about 450 pounds of beef and pork per acre per year, *the keawe bean tree, with 1200 to 1600 pounds of animal gain per acre per year, looms up as one of the king crops of the world.* It should be still further noted that much of the Illinois corn land is depleting rapidly by erosion and the Hawaiian hills are standing pat under their non-eroding tree cover.

The Carob

Perhaps you have wasted some sympathy on John the Baptist because he ate locusts, or on the prodigal son who desired husks. As a matter of fact, these refer to the sugary materials which the carob tree packs into the large, thick pod in which its small, hard beans are embedded. For 2000 years at least the carob bean, still called "locusts," has been a standard article of food and trade in many Mediterranean countries. Carob beans may be bought almost any day in the year from pushcarts on the lower east side of Manhattan Island, and if you should place some in a nursery school you will find that the children will eat them without invitation, unless they differ from children known to me.

I have seen carob trees growing on a great variety of rocky and other hillsides in Spain, Portugal, Algeria, Tunis, and Palestine, and found the beans selling at the same price as Indian corn and yielding the same or greater amounts per acre. The trees live for generations and perform their marvelous production of food in climates too dry for corn. In Tunis, carob trees thrive in places where the rainfall is only 10 inches a year.

American Cousins of Keawe and Carob

Since the keawe is tropical and the carob requires the orange climate, neither tree can become a major crop in the greater part of the United States. Fortunately these plants have hardy American cousins. Several species of bean-yielding mesquite thrive in the area from central Texas to Utah and southern California. The mesquite fed the oxen that pulled the caravans of the Forty-niners, as they had fed deer and Indians for unknown periods of time and also numerous herds of the white man since.

The honey locust tree (*Gleditsia triacanthos*) yields a bean that in all important economic aspects is the duplicate of the carob and the keawe. Some years ago, wishing to find out the qualities and locations of the best specimens of this large frost-resistant tree, I offered prizes through the *Journal of Heredity*. I was amazed to get a bean 16 inches long and nearly 2 inches wide. Seventeen of the dried pods weighed a pound. The sugar analysis was 29 per cent, which is much higher than in sugar cane or the sugar beet. Twenty-five per cent of this sugar will crystallize like our common sugar. The remainder is an insoluble variety from which molasses can be made. These figures indicate a potential sugar crop which, like the beet, could have a residue rich in cow feed, enough molasses to make it sweet, palatable, flesh-forming, and fat-forming. The protein of the beans provides tissue-building material.

But this prize bean has been eclipsed by beans found by Mr. John W. Hershey, who was for a time tree crops expert for the Tennessee Valley Authority, Knoxville, Tennessee. He discovered some in 1934 that carried more than 32 per cent of sugar.

I do not want to give the impression that such trees are common. They are very rare specimens of a species whose fruit varies enormously. Many of the beans have a taste that might be the same as that from the ashes of hell fire, moistened with lye.

The number of pounds of beans that an acre of good honey locust may be expected to yield is at present unknown. We know, however, that this is a fine timber tree and produces a heavy crop of beans. Some trees yield annual crops of beans. The more sugary ones are eaten greedily by farm livestock, and some of the better ones have been eaten by American children for the last 300 years. The tree grows wild from Florida to southern Canada, from New England to the Great Plains, where it ranks high as a drought resister. The honey locust has been successfully introduced into the western third of the United States—a most promising crop tree, merely awaiting intelligent experiment.

Now that Mendel's law, the real key to successful breeding, has been known to the scientific world for four full decades, it is little short of an economic crime that plant breeding of this group of bean-yielding trees, with their already established efficiency as forage plants, has not already been actively prosecuted. Anyone who is familiar with western Texas or the desert region of Arizona, California, and Nevada can recall the long stretches of the pale green foliage of the mesquite tree that jams its roots 20 or 30 feet down in the alluvium and grows along the desert water courses in which water runs for an hour or two, every year or two. I have been told of the beans lying two inches deep on the ground beneath a mesquite tree. There is some reason to believe that we could cross these hardy, frost-resistant southwestern mesquites with the still more productive allied species (or is it the same species?) now doing its marvels on the semiarid hills of Hawaii.

The astonishing results obtained by Stout and McKee with the poplar genus suggest great possibilities in crossing good specimens of every mesquite species with those from every other good mesquite species, and with the carob, if the cross can be made. Similarly, the breeding of the best honey locusts already known might be expected to give better varieties than we now have because it would be the crossing of better varieties than have ever been crossed by nature. But we have really remarkable trees already. Witness the results of the Alabama test.

A MEASURED TEST OF HONEY LOCUST

The *53rd Annual Report* (1942) of the Alabama Agricultural Experiment Station contains the following account by O. A. Atkins:

"The 5-year-old trees of the Millwood variety (honey locust) in 1942 produced an average of 58.30 pounds of pods per tree (dry weight basis) which at 48 trees per acre would be the equivalent of 2798 pounds of pods. ··· The estimated yield of 3150 pounds per acre which came from trees only five years of age had a feed value equivalent to 105 bushels of oats or 56 bushels of corn." (Page 54.)

FIG. 4. This rather small honey locust tree (*Gledetsia treacanthos*) bears its seeds in long, pulpy bean pods. About one-third of the dry weight is sugar, and there is a substantial quantity of protein also—an astounding forage producer. The crop from this tree was 258 pounds dry weight. On an acre basis it showed by test with dairy cows at Alabama Agricultural Experiment Station, Auburn, Alabama, the equivalent of 105 bushels of oats plus two and a half tons of nitrogenous hay from *Lespedeza sericea.* Corn Belt please take notice. (Alabama Agricultural Experiment Station.)

From J. C. Moore, Alabama Agricultural Experiment Station, in project work in 1945:

"In experimental studies initiated by the Hillculture Section of the Soil Conservation Service, Alabama Agricultural Experiment Station, a combination of honey locust and *Lespedeza sericea* (*cuneata*) has been very effective in controlling erosion on rough land and at the same time has furnished large amounts of feed for livestock.

"For two years preliminary feeding tests with dairy cows at Auburn, Alabama, have shown that ground honey locust pods are equivalent in feed value to oats, pound for pound. ···

"The average yield for the Millwood selection for the four years 1942–45, inclusive, was 2923 pounds of pods, dry weight, equivalent to 97 bushels of oats per acre. As the trees increase in size these yields should greatly increase.

"In addition to yields of pods from the trees the *Lespedeza sericea* (*cuneata*) (on the same ground) has averaged 2½ tons of hay per acre per year besides giving practically 100 per cent protection to the soil." (Fig. 4.)

"Pods stored three years in the dry are in fair shape. Some weevil injury is noted but the sugar content is still high. · · ·

"Two mules, one cow and one hog have been fed unground honey locust pods for 30 days on the Hillculture Farm at Auburn, Alabama, with excellent results. These animals have never failed to consume their daily allotment and no injurious effects have been noted.

"An increase in milk flow and butterfat has been observed as a result of honey locust pods in the cow's ration." (Page 55.) · · ·

"Having a combination of honey locust and *Lespedeza sericea* (*cuneata*) the following benefits are derived over a period of years:

"1. Soil is completely protected.

"2. A concentrate and hay can be produced on the same area.

"3. A good grazing and feeding-out program can be maintained.

"4. Low seed and management costs over a period of years.

"5. Weed control.

"6. Low labor requirement.

"7. Maximum production from the soil." (Page 57.)

From Mr. Moore (quoted above), 1946 Progress Report on Work Item R-1-1-3 (h), we learn that: "This year some of the 8-year-old trees produced over 250 pounds of pods per tree. With 35 trees per acre, this would be 8750 pounds of concentrates or the equivalent of 275 bushels of oats per acre." (Page 57.)

A great vista seems to be opening before the imagination. Alabama and other Cotton Belt farmers flocked to the Station to see this new miracle combination; but read the next paragraph and marvel.

The Alabama Station was inveigled into this experiment by the U. S. Soil Conservation Service (co-operating with cash). The 80th Congress economized by slashing soil service appropriations. Alabama cut down all the honey locust trees—probably the most promising experiment the Station ever had—and planted some peaches.

The honey locust is new. Growing cow feed on trees is a really new idea, and a really new idea has slim chances. After they found that they could fly, the Wright brothers rented an 80-acre field near Dayton, Ohio, for experimental flying. All summer they flew up and down that field. An interurban railway and an important highway went along one side of it. Thousands of people passed by, as the plane flew about, but no newspaper mentioned this flying until the autumn when the inventors flew over Washington City. Then enough people believed the story for it to get into print. Before that, the newspaper editors knew better, or they didn't want to get laughed at.

Grow cow feed on *trees?* Oh, no! The directors of experiment stations must be regular, and, being regular, Alabama cut down the honey locust and planted peaches. All stations have peaches, unless suburban to the North Pole, and have had them for decades.

"There are none so blind as those who will not see."

The fate of a new idea is a problem meriting serious research by the psychologists and the students of society.

For the first time in human history we now have three branches of our government with a feeble or dormant interest in developing a tree-crop agriculture. The regular horticulturists are interested (a little), the Tennessee Valley Authority is interested (a little), and the Soil Conservation Service would be interested (if it could get and keep on getting appropriations).

TREE CROPS FOR STEEP AND ROUGH LAND

The Chestnut

The chestnut tree has proved itself an excellent support for the man of the mountains. I have ridden mile after mile through chestnut orchards on steep mountainsides in Corsica (Fig. 5). In steepness and general appearance the slopes greatly resemble hundreds of mountainsides in Appalachia except for the absence of gullies. I passed through village after village of substantial stone houses. In addition to his house in the village, the average villager has the following property: a small vegetable garden, usually terraced to keep the earth from being washed away or from creeping downhill—many gardens are situated below the spring and can therefore be irrigated—a few acres of grafted chestnut trees, a few milk goats, possibly a cow, perhaps a horse or mule, and a pig or two.

FIG. 5. Characteristic mountain road in chestnut section of the Corsican Mountains. (Harcourt, Brace & Company.)

The chestnut is to him the sole crop aside from the garden, as corn is to many an Appalachian mountaineer. The chestnuts, when gathered, are dried on platforms over a slow fire in a stone dry-house. Dried, chestnuts may be kept for years as corn is kept. The horse and pig grind the dried nuts for their own food, just as they grind corn here. Gentle beating knocks off the shells, and the meats are often ground to be used for making bread, which, with goats' cheese, garden stuff, and a little pork, makes the food of the villager. The goats browse in the grass and herbage that grow beneath the chestnut trees. The pigs are fattened on the chestnuts that people have not been able to find under the leaves at harvesttime. Now comes the important part of the story. This culture has supported rather dense rural populations for generations, but the soil is intact, although the slopes are as steep as the roof of a house (Figs. 1 and 2). When a big old tree, perhaps past the century mark, begins to decline in productivity, the farmer cuts it down and takes it to the tannin extract works. A younger tree, which he has planted a decade or two before, is already well established, ready to reach into the vacant space and grow in the sunshine.

"How long has this been going on?" I asked the notary of a Corsican village.

"Oh," said he, "a hundred years—five hundred years—always."

FIG. 6. A Chinese chestnut tree well loaded with burrs. The man shows the size of the trees. This might become one of our great crops, grown without tillage.

The last assertion was a little sweeping, for chestnuts were introduced into Corsica by the Roman army in the second century. However, the permanence of this mountain agriculture puts us to shame when compared with our destructive methods in Appalachia. The Appalachian mountaineer expects to abandon a hillside clearing, mostly in corn, after five, ten, or 15 years.

The destruction of most of the native American chestnuts by a blight imported from Asia is well known to millions of Americans. It is perhaps not so well known that in the early years of the present century there were introduced into the United States chestnuts that had been exposed to the blight in China and Japan. Some of these Chinese chestnuts are superior to the native American in the following respects: They bear nuts at an earlier age; they bear larger nuts; they probably bear more of them: and some of them are of a quality quite the equal of any native nut (Fig. 6). This is not merely my personal opinion: it is the opinion of government experts who have devoted years to their study and promotion, so that America is now in a position to restore the chestnut tree, horticulturally, at least. I say horticulturally, because these trees are of a variety that has been grown in China for ages for their fruit and are low-spreading trees of the apple shape rather than the makers of tall trunks. The existing horticultural strains now growing so nicely in the United States should not be dismissed by the forester. The seedling trees vary so greatly in natural shape, and when allowed to crowd each other they behave so much like, let us say, oak trees, that they merit extensive testing for timber qualities. Selection of parent trees of better timber promise would be a good way to begin. When considering the Chinese chestnut as a timber tree one should remember the hemispherical oak that grows in the open.

Meanwhile scattered trees of this species are growing and bearing nuts on the land of several thousand owners from Massachusetts to Iowa and Michigan to Florida, and interest in them seems to be increasing rapidly.

The Cork Oak

The cork forests of Spain, Portugal, and Algeria are almost as suggestive as the widely distributed chestnut orchards of the northern Mediterranean region. The cork tree yields a stripping of bark every nine or ten years. Like the chestnut, the cork oak and its attendant grass and bushes hold the soil against erosion, while sheep, goats, and other animals forage beneath the trees. The acorn crop is harvested by pigs and goats from Portugal to Greece and Yugoslavia and produces millions of dollars' worth of pork annually, and the wood of the old tree is at last multifariously useful in lands where wood is scarce. Cork trees have grown well for decades in California and the Cotton Belt. Some 25 publications exploited them prior to 1938 urging that a cork industry be started, but there is no evidence that any forester ever heard of it. Question: "Of what are foresters' heads made?" At last a bottle-stopper manufacturer happened to see one of these trees. He was fired to take action. He started the *McManus cork project,* well worth looking up. (Write the Crown Cork and Seal Co., Inc., Baltimore, Maryland, for an account of this example of the way things happen in America.)

TREE CROPS FOR THE DRY LAND

A most interesting landscape is that of the Matmata tribe of Berbers in central Tunisia. They live on a highly dissected limestone plateau of low elevation but very rough topography resembling some parts of the Appalachian Plateau. The rainfall fluctuates from four to ten inches a year, averaging about 7.5.

These people have built loose stone dams across the gulches. The rapid runoff from the desert shower rainfall quickly fills the space back of the loose stone dams with earth. Every time the gully runs with water this earth mass is soaked and thus feeds a few olive trees or date trees that are planted in this man-collected bit of naturally irrigated alluvium. These olive trees are robust, vigorous looking, thick foliaged, and altogether compare well with those I have seen in Spain, Portugal, France, Italy, Algeria, Tunisia, Palestine, Syria, Anatolia, France, Arizona, and California

These gulch-fed and gulch-watered tree crops are the mainstay of this tribe of Berbers. Their utilization by irrigation of the water that falls during a shower is closely akin to the way the Indians of Arizona and New Mexico use shower irrigation water to feed their peach trees and their corn and pumpkin patches. If someone would bring together all the examples of this kind of agriculture in the world, it would be both surprising and instructive.

By extending this process of the conservation and utilization of a scant rainfall very large areas of arid land might have their gullies (arroyos) converted into long lines of verdant, crop-yielding trees, preferably of the forage-bean-yielding types, as this crop would fit so perfectly into the pastoral use to which these arid lands in all continents are and must be put.

NEW HILLSIDE CULTIVATION TECHNIQUES

I have been suggesting the wide possibilities that lie in the development of a plowless agriculture for dry land, for steep land, and for rough land. Opposed to these ideas is a widespread belief that trees will grow better if the ground around them is cultivated. Because of this fact many an

American orchard has been cultivated until the soil was well-nigh ruined (Fig. 7). But a discovery has been made as a result of tests of a great number of methods of managing soils in orchards. The Agricultural Experiment Station at State College, Pennsylvania, carried on a set of soil management tests over a period of 25 years. The plot which was kept cleanly cultivated almost washed away, although the slope was very slight. In about 16 years the exhaustion of vegetable matter caused the soil itself almost to collapse. The soil lost its structure, and the resulting earth became so hard that when plowed it came up in chunks the size of a man's head or even larger, and almost as hard as sun-dried bricks.

Fig. 7. A Chinese persimmon grafted on a wild persimmon in a field on an abandoned Virginia farm. With corn the land would wash away. With persimmons and grass the soil might stay indefinitely. (Sunny Ridge Nursery.)

The orchard culture almost universally recommended as ideal had been: plow in the spring, keep the soil cultivated until some time late in the summer, then sow a cover crop to grow during the late summer and autumn, to furnish vegetable matter to protect the ground through the winter, and to be again plowed under in the spring. The surprise was that this method did not do as well as was expected, apparently because the cultivation beneath the hot sun burnt out the vegetable matter.

Plots left in sod that was repeatedly mowed and allowed to rot showed that the vegetable matter had great difficulty in getting back into the earth; instead it decayed on top and passed off much virtue into the air.

The best results, to the surprise of everyone, were obtained by a thorough ripping up of the soil with harrows, spring tooth or disk, sometime between November and the beginning of spring growth. The ground was not plowed, but the sod was thoroughly ripped up and much of it turned over so that it could decay and quickly become part of the soil. Clover was sown, mowed once or twice during the summer, and the accumulation again harrowed in the next year. This annual destruction of the sod permitted the spring fertilizers to reach the tree roots rather than to be eaten up by the grass. The grass, grassroots, and chunks of sod prevented erosion, even on slopes that were steep. The vegetable matter thus worked into the soil caused it to absorb and hold moisture and carried the orchards through droughts. Successful apple orchardists in many parts of eastern United States have left off much of their plow worship, especially in Virginia.

In what climate belts is this Pennsylvania sod-buster process of orchard soil management applicable? Experiment alone will tell, but presumably it is appropriate where corn will grow, perhaps even anywhere that orchards are cultivated. Certainly it is producing excellent results on some very steep Appalachian hillside apple and peach orchards where it has been adopted as standard practice. Successful experiments in sod culture of apple orchards on the Pacific coast indicate that it may have a future in some parts of that area.

This method carries with it the possibility of the extension of a *cultivated* tree-crop agriculture on millions of acres of steep land that would be ruined by corn or by the older orchard tillage system, which was almost universally preached by the orthodox not many years ago. The new method is really a very great discovery, for it opens the way to the intensive use of millions of acres of hill lands without destroying them. This method does not preclude the use of terraces on hillsides of considerable slope.

Contour farming of row crops including trees has been greatly extended as a result of the work of the U. S. Soil Conservation Service and other groups. Spartanburg County, in the upper Piedmont section of South Carolina, has become one of the leading peach-growing counties of the United States. Nearly all the trees, almost a million in number, are planted on the contour. This cuts water runoff to an insignificant figure and permits tillage without soil loss. They are magnificent orchards.

This horticultural prosperity based on soil-saving techniques on the hill country of the American Cotton Belt is really something new and an encouragement to patriots who are concerned about the shrinking size of the United States.

Spraying orchards from airplanes may become an important practice. It is now not much more than a spectacular exception, but it is increasing rapidly. It may help tree crops to take possession of many a hillside that is not usable by the standard techniques of today.

APPLYING THE SCIENTIFIC METHOD

It is time we began to supersede the agriculture that depends upon the chance findings of the primitive woman with the agriculture that depends upon the systematic and scientific efforts of educated workers, both male and female.

There is every reason to believe that the trees of the world can give us the basis for many new crops—almost a new agriculture —if we apply the scientific method as follows:

1. Search the world's forests, groves, gulches, and fence rows for the best wild trees that nature has produced by chance. The original tree of the Red Delicious apple grew wild in an Iowa fence row.

2. Take these chance trees, and by systematic application of the laws of genetics breed far better ones. These two things have been done with the high-bush blueberry with great success.

3. Conduct experiments in farm management to make good farm plans around the chance trees that are already growing and from the better ones that can be produced by plant breeding.

The Example of the Oak

The oak tree may be cited as an example of the potential raw material with which man may deal in these three important activities. The acorns which the oak tree showers down in the autumn are nuggets of carbohydrate that differ from corn in food value by having more fat and less protein. They are good food for many kinds of animals, including man. Acorns have fattened the bear, the deer, the wild hog, and other forest denizens through millenniums and probably through geologic epochs. They are this year fattening millions of man's domestic swine, as they have done for many centuries, and certain Mexicans probably made their usual autumn journey into southern Arizona to gather up truckloads of acorns to take home—to eat, so I am told in Arizona. Mexico does not produce enough grain for its own bread.

Most acorns have a somewhat bitter taste, owing to the tannin they contain. Here and there in the United States, as well as in Spain, Portugal, and probably other countries, the acorns of a chance tree are free of tannin; then the acorn is sweet and pleasantly edible. A few of these trees here and there in the Iberian Peninsula have been propagated by grafting, like other orchard trees, and the acorns are grown and used as a crop. In Portugal and in Spain I have seen acorns roasted and eaten just as chestnuts are here.

Primitive man discovered that the bitter tannin is soluble in water, so he crushed the acorns, soaked them for a time to make them sweet, and then made bread. This bread may have been used ten times as long as man has used wheat. It is even possible that, before the coming of what we call civilization, the human race ate more tons of acorn bread than of wheat bread. John Muir, the naturalist, assured us that it is the best of bread, as demonstrated by his use of it as his chief nourishment on mountain-climbing expeditions. The acorn carries enough fat to be both bread and butter. Acorns, buried in mud, saturated by cold spring water, have been known to remain good to eat for many years—a remarkable record—and consider the simplicity of the storage method, which is one used by some American Indians.

There is a record of a California valley oak that yielded a measured ton of acorns. The ilex, or evergreen oak, native to Mediterranean climates, is a heavy yielder of acorns. One tree that I saw in southern Portugal was credibly reported to yield an average crop of 20 bushels of acorns despite the fact that it had a spread of only 51 feet.

To the shame of our agricultural experiment stations, there is no measured evidence on an acre basis to prove it, but pending disproof the writer will believe—very stoutly believe—that, if planted to the best existing oak trees, many tens of thousands of square miles of Appalachian and Ozark ridge and hill land would yield more pounds of food for man and pig by way of acorns, per decade for the next thousand years, than the same area will yield of corn in the one decade during which the mountaineer is now ruining it. This would result if it were planted to a stand of the best wild acorn trees that could now be found in that region, and plant breeding is yet to be heard from, with its, presumably, more productive trees and better quality of acorns.

It may be of interest to see if you can find out why no state or national experiment station in the United States is doing anything with oaks.

PLANT BREEDING

This new power that has so recently become available to man permits us to take two plants of the same or allied species, hybridize them, and get new combinations of the qualities of both parents and new qualities that previously existed in neither parent. For example, the late J. F. Jones of Pennsylvania, far less publicized than Luther Burbank, hybridized a European filbert and an American hazelnut and, using one-quarter acre of ground, tested offspring bearing nuts larger than those of either parent, and some smaller than those of either parent. Some of the trees were 12–15 feet high, and some of the same ancestry were so puny that they looked like sub-Arctic dwarfs.

During the nineteenth century men in many countries had been groping for knowledge in the field of heredity and fumbling in their attempts to utilize heredity by selection of breeding stock to improve farm animals and plants. Then, with the turn of the century came a flash of light, Mendel's law, which suddenly made heredity a science (genetics).

To see how far it had got in a third of a century, examine *The Yearbook of Agriculture,* U. S. Department of Agriculture, for 1937. More than a thousand pages of the record are devoted to the application of the laws of genetics for the improvement of plants and animals, mostly plants.

In the plants, naturally most of the attention was given to the annuals, which respond so much more quickly than the perennial tree.

The time has now come when plant breeding should be widely applied, especially to trees, because they are the great engines of production and permit us to utilize many hilly lands to better advantage than they can be used by annual plants or by grass.

THE WORK AND THE RESULTS

Any owner of a small plot of ground can do some of this work, and here and there individuals are having a lot of fun and also achieving important results. The chief obstacles are the cost and the fact that the individual will surely die; and it is most rare that anyone else has the interest or is in a position to carry on his work.

Tree breeding, because of the time involved, especially needs the aid of continuous institutional support. If exploration and crop creation could receive appropriations equal to the cost required to build, maintain, and operate one battleship, we could, if we wished, soon transform millions of acres of American hillsides from gullied ruin, poor pasture, or poor forest into first-class cropland, yielding grass and also honey locust beans for stock food and sugar; persimmons and mulberries for stock food and human food; acorns and chestnuts for stock food, commercial starch, and bread, made in factories as are peanut butter, lard, crackers, jam, and other canned foods. There might be scores of other crops, but if these five should be successful they could be the basis of a vast hillside agriculture. There could be a satisfactory *permanent* agriculture if we should add to them permanent pasture and a small area of noneroding hillside terraces, valley bottoms, and hilltop flats for corn, alfalfa, and gardens. America need not wash away, but both brains and conscience are needed to stop it. At present much of our agriculture appears to be conducted without either, and our agricultural resources are diminishing every day—many acres every day—because, as a Japanese visitor said to a soil conservation man while viewing American gullies, "Nobody loves this land." How can a child be made to love the land—the mother of us all?

We *sing* America, but who feels it? Who loves this land? Unless we can raise a generation that does love the land and cherish it the future of the United States as a great power promises to be short indeed as history goes. Seven-eighths of our lumber and one-third of our soil are already gone.

Someone has said, "From the Stone Age we came, and to the Stone Age we must return." But why should we hurry so to get there? The teacher has an opportunity.

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CHAPTER 6

American Irrigation

IF the length of a printed line in one column of text is taken to represent the total area classified as cropland and plowable pasture in the United States, the space, say, between any two words exceeds the portion actually irrigated in 1947. The space occupied by a three-letter word amply represents—as estimated by competent authorities, not by overenthusiastic citizens—the irrigable area of the western states. Irrigable here means the sum total of arid land which could be watered by complete storage, or as complete as other vital uses of water would permit. Again, only two farms of one hundred in this country are equipped with irrigation facilities, and a still smaller number depend on them consistently from year to year.

CONSERVATION PROBLEMS DISPROPORTIONATE TO THE AREA IRRIGATED

These proportions must seem incredibly small to one who has followed the Lincoln Highway through the lush fields of western Nebraska, approached Denver surrounded by the verdure of the Colorado Piedmont, beheld living water pouring through the Gunnison tunnel, near Montrose, Colorado, on its course to the Uncompahgre valley, or has marveled at any one of a dozen gigantic irrigation dams scattered throughout the west. One need not travel far from home to obtain an exaggerated view of the extent of the irrigated area beyond the hundreth meridian. No subject ordinarily associated with resource conservation is more widely discussed in the daily press, in popular and scientific magazines, and in government reports. The general public is quite ready to believe that the irrigated area is many times the 21,000,000 acres reported in 1939 and is likely to be astonished to learn that the much-discussed federally supported irrigation schemes furnish but 8.7 per cent of the irrigated areas with primary water supplies.

There are many reasons for the active interest shown by people, individually and collectively, in irrigation. Water is the most valuable western resource; its supply is limited in amount and distributed unevenly; and it cannot be apportioned so easily as the land which it is used to irrigate. There are also competitive uses of water in regions where irrigation is desirable or necessary. Furthermore, irrigation represents a consumptive use of water: a considerable portion is evaporated during

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use, mainly by direct evaporation into the air and the more delayed "evapotranspiration" from growing plants.

Water Supply in Constant Motion

From the irrigator's standpoint, the water supply is in a state of continuous or intermittent replenishment, never truly static, as are minerals in veins, for example. Consequently, the diversion of water from a river, or the interception of underground supplies by a well, interrupts the natural replenishment of some other available water supply. The descent of water in a stream has been likened to a marble rolling downstairs, its path a succession of descending levels. Unless provision is made to overcome losses, the flow may be seriously diminished or completely stopped at any one of the levels. Clearly, its retention at any point, as by a dam, restricts the natural water supply at a downstream position.

Irrigation, in short, constitutes a major interference with the natural downslope flow of water. Surface waters preferably follow channels of their own making or, if underground, seep and percolate more slowly and in a manner less predictable. Man has learned to his later regret that interference with natural forces or processes often leads to unexpected costs or losses. All is not clear gain. Thus the "conquest" of the arid west through irrigation projects has been partial or conditional. Many reservoirs have shrunk appreciably in capacity through the deposition of sediment in the quiet water above dams, and, as will be shown more fully later, serious problems of drainage and salt accumulation have developed in the majority of irrigated areas. Because of inadequate drainage many areas formerly irrigated have become waterlogged and saline.

CUSTOMS OF WATER USE UPHELD BY LEGAL PROCEDURES

A realization of the flowing habits of water and the possibilities of its dissipation by unwise or harmful uses account for much of the water law of the arid and semiarid west. As Mr. Justice Holmes said on one occasion, "The different traditions and practices in different parts of the country may lead to varying results, but the effort is to secure an equitable apportionment without quibbling over formulas."

Two basic formulas regulating water use in the west are the common law of riparian rights and the statutory doctrine of prior appropriation. The latter is indigenous to the region and is sometimes known as the "Colorado doctrine." In their original forms, unmodified by court rulings and judicial interpretations, these doctrines are diametrically opposed.

Common Law Doctrine of Riparian Rights

The riparian doctrine, introduced to the west with settlement, rules in essence that river-bank landowners along a nonnavigable stream have certain rights to that stream: it cannot be diminished in volume or altered in quality. Strictly applied, the common law doctrine prohibits the use of water for irrigation and has thus become progressively ill suited to western conditions.

Riparian rights have been repudiated in many states; in Arizona, for example, this action was taken by the territorial legislature in 1887. In most of the Rocky Mountain states the riparian doctrine was never recognized, whereas the courts of many of the other western states have upheld the common law, at least in restricted form. According to Samuel Wiel, authority on irrigation law, riparian rights are firmly established in California "side by side with the law of appropriation, the former for public land, the latter for private land." Under the most recent developments in California, the use of water by riparian owners must be "reasonable" with respect to the needs of appropriators of the water for use on nonriparian lands. The much-modified riparian law is sometimes known as the "California doctrine."

Appropriation Doctrine, or Possessory Rights

In the Rocky Mountain states, the Colorado doctrine is generally applicable. Under this formula, riparian rights are entirely swept aside in favor of "prior appropriation." That is to say, prior appropriation for a beneficial purpose bestows rights in streams according to the relative time of beginning use, or claim of use. "First come, first served," or "first in time, first in right," are popular phrasings of this statutory provision. When the available supply becomes inadequate for all water users, as during a drought year or late in the irrigation season, water is delivered in the order of the dates when the original rights were secured. Prior appropriation is a possessory right which, if unrestrained by interpretations of "beneficial" or "reasonable" use, could become as unsuited to the arid west as the unmodified common law.

Authorities are not in agreement as to the origin of this legalized practice. According to one view, possessory rights to water originated in the southwest among Spanish settlers from whom Anglo-Americans later borrowed the practice. The other and more widely held view is that prior appropriation had its origin among the gold miners of California who diverted water from streams high in their courses for placering, and later for hydraulic mining. The resultant pollution and sedimentation of Sierra streams was disastrous to ranchers and farmers in the lower valleys, culminating in the so-called "debris cases" fought out in the California courts in 1884. The mining interests were restrained from their damaging practices, thus marking the end, in the words of Wiel, of "upper level occupation as California's paramount industry."

Court Rulings Uphold Customs

Leading principles in water law, designed to safeguard interests of individuals and public alike, were well summarized in a federal court decision in Nevada in 1897. The plaintiffs in the action claimed that an upstream appropriator was diverting an excessive amount of water from the stream; the defendant claimed rights through prior appropriation. Said the court in this basic case (Union Mill and Mining Company *vs.* Dangberg): "Right to water flowing in the public streams may be acquired by an actual appropriation of water for a beneficial use; ··· if it is used for irrigation, the appropriator is entitled only to the amount of water that is necessary to irrigate his land, by making a reasonable use of the water. ··· If the capacity of the ditch or flume is greater than that necessary to irrigate the land, the appropriator's water will be restricted. ··· Rights acquired by appropriators must be exercised with reference to the general conditions and necessities of the community ··· measured by needs, and not for purposes of acquiring a monopoly of the water. ··· The diversion of water ripens into a valid appropriation only when it is utilized by the appropriator for a beneficial use."

The present status of water rights in irrigation in the western states is summarized in the table.

TABLE 1

PROPORTION OF TOTAL AREAS IRRIGATED, BY TYPE OF WATER RIGHT, 1939. SEVENTEEN WESTERN STATES

[From Table 18, *Census of Irrigation*]

	Per Cent of Total
Appropriation	50.1
Riparian	3.0
Appropriation and riparian	4.6
Underground	10.6
Appropriation and underground	4.5
Riparian and underground	0.6
Adjudicated by court	25.2
Other, mixed and not reported	1.4

INTERSTATE AND INTERNATIONAL CONTROVERSIES OVER WATER

Countrywide interest in irrigation problems is also sustained by continuing or intermittent conflicts between states, and between Mexico and the United States, over the distribution of water.

Conflict between Kansas and Colorado

Neighboring states, otherwise in agreement on mutual problems, have frequently come to grips over the disposal of water in rivers that flow from one into the other. Still unsolved, for example, is the longstanding dispute between Colorado and Kansas over the Arkansas River. As early as 1901 the Kansas legislature directed the attorney general to institute "such legal proceedings as might be necessary to protect the rights and interests of its citizens." Kansas claimed prior rights to the use of the water on the basis of irrigation canals said to have been constructed between 1879 and 1888 covering 200,000 acres of land—probably an area in excess of that actually irrigable. These efforts were put to nought, it was said, by the diversion in Colorado of nearly the entire flow. Only in exceptional years did enough water bypass the Colorado canals to feed, inadequately, the systems in western Kansas. Claims and counterclaims may be expected whenever water supplies are limited.

If the Kansas-Colorado dispute could be settled on general principles of water conservation, and with Olympian detachment, the ruling would probably favor Colorado. In general, water performs its greatest duty in irrigating land as near to the source of the streams as soil, climate, and other controlling factors permit. The farther upstream the point of diversion, the smaller is the loss by seepage and evaporation, according to John W. Powell, first director of the U. S. Geological Survey, in the very year, 1879, when the first canals in Kansas were being dug. Powell emphasized, often futilely, the advantage to the public in using irrigation water before a large part of it was uselessly dissipated in lengthy courses through arid lands. If this conclusion will not weigh heavily in present negotiations, it is at least possible that the completion of storage dams on the Arkansas, delayed by World War II, will permit equitable arrangements between the water users on both sides of the Kansas-Colorado line.

Mexico and the United States Contest Water Division

Various international commissions have been confronted with the solution of delicate problems involving the waters of the Rio Grande and Colorado rivers, international streams. The Mexican Commission in 1930 held that the Colorado River constituted "a common source of wealth for both countries" and claimed 4,500,000 acre-feet of water because "there were in Mexico tributary to the Colorado River 1,500,000 acres of irrigable land, for which a duty of 3 acre-feet per year was regarded as necessary." The United States Commission held for a more moderate division of waters, proposing to divert to Mexico "the greatest amount which had been delivered to irrigators in that country from the stream in any year." That year was found to be 1928 when Mexican irrigators received but 750,000 acre-feet. So many factors have been involved in the solution of the international waters problem that it is difficult to say whether or not the best purposes of conservation have been served.

LIMITED WATER SUPPLIES AND PLENTIFUL LAND

The care with which the public guards its natural water supplies through legal enactments and court decisions and by the setting up of interstate and international commissions is evidence of the value placed on these resources in the western states.

No possible form of occurrence of water is left untouched in legal or constitutional rulings. Even "diffuse surface water," escaping from irrigation canals or drainage ditches, has received its share of consideration. Underground waters flowing in definite channels as well as "diffused percolating underground water" have been covered by court decisions in various western states, which have been called the "water-conscious states" of the country. The following classification of available water supplies for irrigation has been prepared by Wells A. Hutchins.

CLASSIFICATION OF AVAILABLE WATER SUPPLIES

[Source: *Misc. Publ.* 418, U. S. Dept. of Agriculture, 1942.]

- A. Surface waters
  - *a.* Diffuse surface waters
  - *b.* Surface waters in watercourses
    - 1. Waters flowing in well-defined channels
    - 2. Waters flowing through lakes, ponds, or marshes which constitute integral parts of the stream system
  - *c.* Surface waters in lakes or ponds where evidence fails to indicate connection with stream system
  - *d.* Spring waters
  - *e.* Waste waters
- B. Subsurface waters
  - *f.* Groundwater
    - 1. Water flowing in defined subterranean channels
    - 2. Diffused percolating waters

Available water supplies in the west, as elsewhere, are broadly determined by the difference between precipitation and water losses over a given period of time. Thus far in the discussion, the phrase "arid west" has been employed; it is now necessary to distinguish between different degrees of aridity and to identify the belts of heavier rainfall in the mountainous and coastal regions.

Extent of the Arid Lands

There has been and is considerable diversity of opinion as to the definition of the terms arid and semiarid and consequently of the areal extent of these climates in the United States. In their earlier usages in this country, as Webb has pointed out, these were relative terms applied by a people entering regions of less rainfall than that to which they had been accustomed in the humid east. Later authorities have tended to define the arid and semiarid regions in terms of their suitability for normal agricultural practices. That is to say, the arid and semiarid lands comprise that part of the west in which the rainfall is insufficient, over any considerable period, for the successful production of crops by ordinary farming methods. In the absence of known methods of predetermining the amounts of effective rainfall below which agriculture becomes unsuccessful, human experimentation on a gigantic scale has been undertaken in this country. Such experimentation has resulted in some conspicuous successes as well as in stark tragedy. Many writers, in deference to the wishes of the inhabitants of the regions about which they were writing, have used, in place of the apparently libelous words arid and semiarid, the more cautious but possibly misleading word subhumid. The word subhumid has been increasingly used in a more technical sense and should not be identified with semiarid.

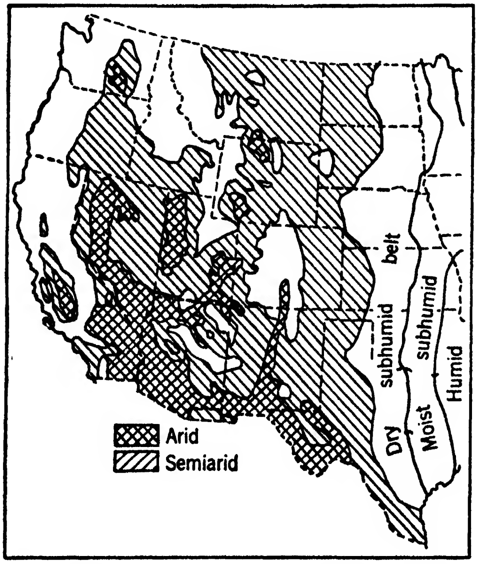

FIG. 1. Regions of arid and semiarid climate in the United States. Adapted from C. W. Thornthwaite, "Atlas of Climatic Types in the United States, 1900–1939," *Miscellaneous Publication* No. 241, U. S. Department of Agriculture, Washington, D. C., 1941.

The map of the extent of the arid and semiarid regions, much simplified from the original, commends itself for the present discussion (Fig. 1). In the first place, the extent of the dry climates has been fixed upon it by taking account not only of the annual rainfall but also of its effectiveness as influenced by evaporation. Separation of the United States into a humid east and an arid west at the 20-inch-rainfall line, though a common procedure, is not satisfactory. Very important is the precise separation of the arid area from the semiarid, because irrigation problems differ in the two and generally are more critical in the semiarid portion. This map is valuable also because its boundaries, though established in a scientific manner, closely agree with the general opinion of early-day authorities who contributed to American policies in reclamation. It appears quite probable that, if Powell had prepared a map of the arid lands in 1879 when he proposed methods of land settlement, it would have agreed closely with this one.

The dry climates, continuous as a semiarid belt in the western Great Plains, encircle the southern end of the Rocky Mountain system and overspread its lower ranges and outliers. To the west and south lies the desert, which appears as two large nuclei, one in southern New Mexico and western Texas, the other in the dry Basin and Range province of California, Nevada, and Arizona. Altogether, the deserts account for about eight per cent of the total area of the United States. Two fingers of humid climate project southward: one along the Pacific coast, the other coinciding with the northern Rockies. These islands of heavier rainfall interrupt the continuous stretch of aridity, and their proximity to the deserts favors reclamation. It is important to remember that semiaridity, rather than true aridity, dominates the west.

Lowering Estimates of the Irrigable Area

During the earlier days of western settlement, the general public was encouraged to believe that a very large proportion of the country beyond the hundredth meridian could be reclaimed by irrigation. Some would have it that all the land at moderate altitude, if it possessed good soil and favorable slope, could ultimately be watered, perhaps half a million square miles. Competent observers, however, thought otherwise. The first authentic word of caution came from the U. S. Geological Survey, delegated by Congress to investigate irrigation possibilities. The Director reported in 1890 that "the area of the arid region is about 1,300,000 square miles, one-third of the entire country. I judge that of this area there can be economically reclaimed, by irrigation, within the present generation at least, 150,000 square miles [96,000,000 acres]—an empire one-half as large as the entire area now cultivated in the United States."

The 1890 estimate was soon found to be far in excess of actual possibilities; when more adequate stream-flow records were available, the figure was reduced to 75,000,000 acres, and had descended to 60,000,000 in 1925. The estimate was again revised downward by the Bureau of Reclamation in 1942, which said, "Projects can be developed, under current standards of economic feasibility, including multiple-service projects, to conserve water for 22,120,000 acres of land in states west of the 100th meridian (or bisected by it) in addition to that irrigated in 1939 [20,395,043 acres]." The Bureau also pointed out that there are 11,700,000 acres "of presently irrigated land which will require supplemental water if their agricultural production is to be sustained and the established communities dependent on them maintained." In other words, much of the water to be impounded by irrigation dams yet to be built will be used to water lands already "under the ditch," not wholly new projects. This is a frank recognition of the fact that, in many American projects, water has been spread too thinly over the land for its proper irrigation.

Irrigable Area Limited by Water Supply

Areas remaining for future reclamation in the west lie in the proximity of highlands which provide the sources of water. Over one-half of the 22,000,000 acres now regarded as "susceptible of irrigation" are in the Pacific states and much of the remainder in the Rocky Mountain and Great Basin provinces. The Great Plains region, farther from the mountains, ranks poorly in this respect (Fig. 2).

It is generally agreed that the extension of irrigation projects will meet with increasing costs, indeed would be beyond consideration except as costs of construction are chargeable in part to flood control, water-power schemes, and other expected benefits. These are known as "multiple-purpose" projects, of which the Hoover Dam on the Colorado River is an example. Naturally enough, in the development of irrigation, the more feasible projects were attempted first; difficult and very costly schemes were not tackled. The gross per-acre cost of federal projects, which began in the present century, has been three times that of other projects, a difference accounted for in part by the more difficult physical obstacles overcome by them. Other reasons for the disproportionate cost of federal projects are (1) large outlays for storage facilities and other permanent types of construction, (2) the more accurate records of expenditures maintained by the Reclamation Service, and (3) the completion of many projects during periods of high prices.

perience of the irrigator. Common allowances for water in western projects are from two to four or five acre-feet a year. To visualize the magnitude of the reservoirs necessary, consider that 1 acre-foot is the

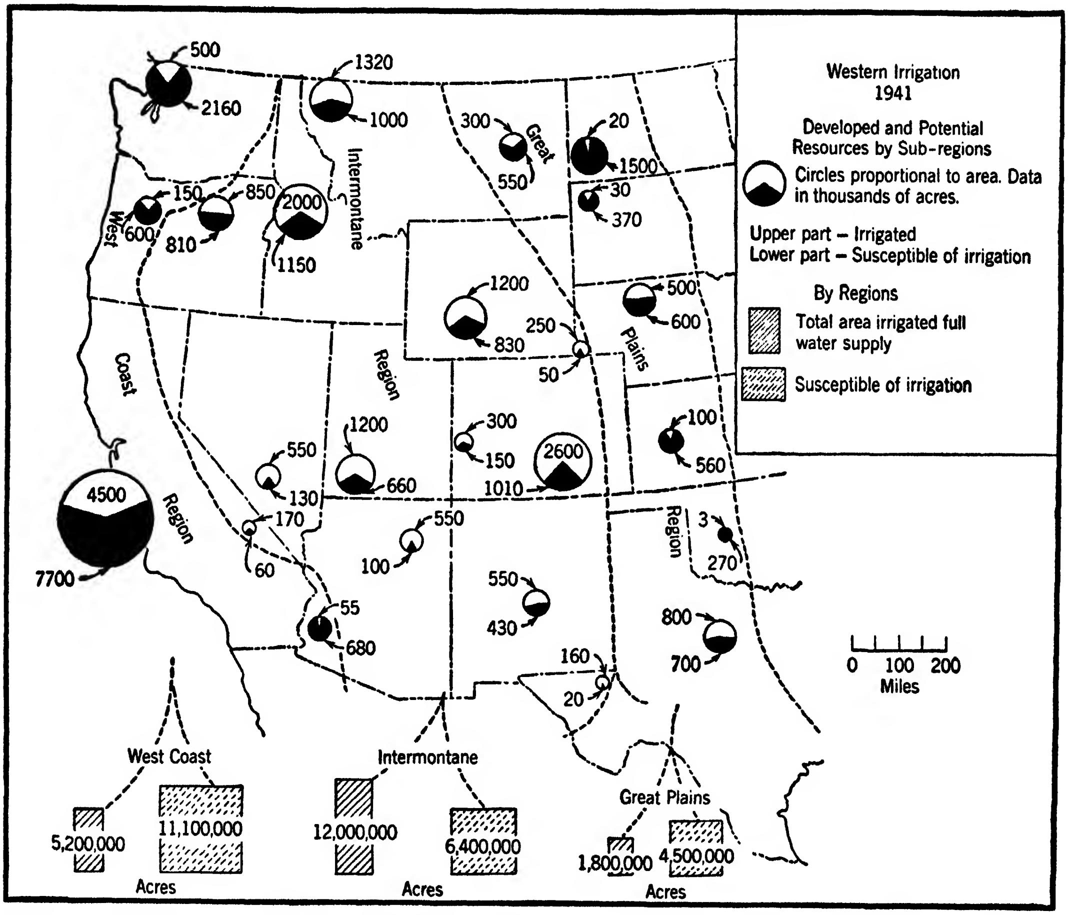

Fig. 2. Developed and potential irrigation resources in the United States. (Adapted from map in "Reclamation Handbook," *Conservation Bulletin* No. 32, Bureau of Reclamation, 1942.)

Few laymen realize the large amounts of water that must be stored to irrigate even one farm, to say nothing of 21,000,000 acres. A main determinant is the rate of evaporation, which is necessarily high in dry climates. The amount of water needed also varies with surface and soils, the kind of crop, the method of irrigation, and the experience of the irrigator.

equivalent of 326,000 gallons, sufficient to supply nine persons with water for a year. One thousand acre-feet of water would be adequate for a city of 9000 persons. An authority estimated in 1926 that the 96,000,000 acre-feet of water diverted from streams to western projects was sufficient to cover New York state to a depth of 32 inches.

Water lost in transit from the point of diversion to the farm account in part for the necessity of large storage requirements. American irrigation water is said to have "low efficiency," because of various losses and wastes. Samuel Fortier's figure of about 33 per cent efficiency is generally ac-

DEVELOPED IRRIGATION RESOURCES AND FACILITIES

Prospective developments in irrigation, beyond the immediate future, are matters of speculation; we shall now be concerned with the present status.

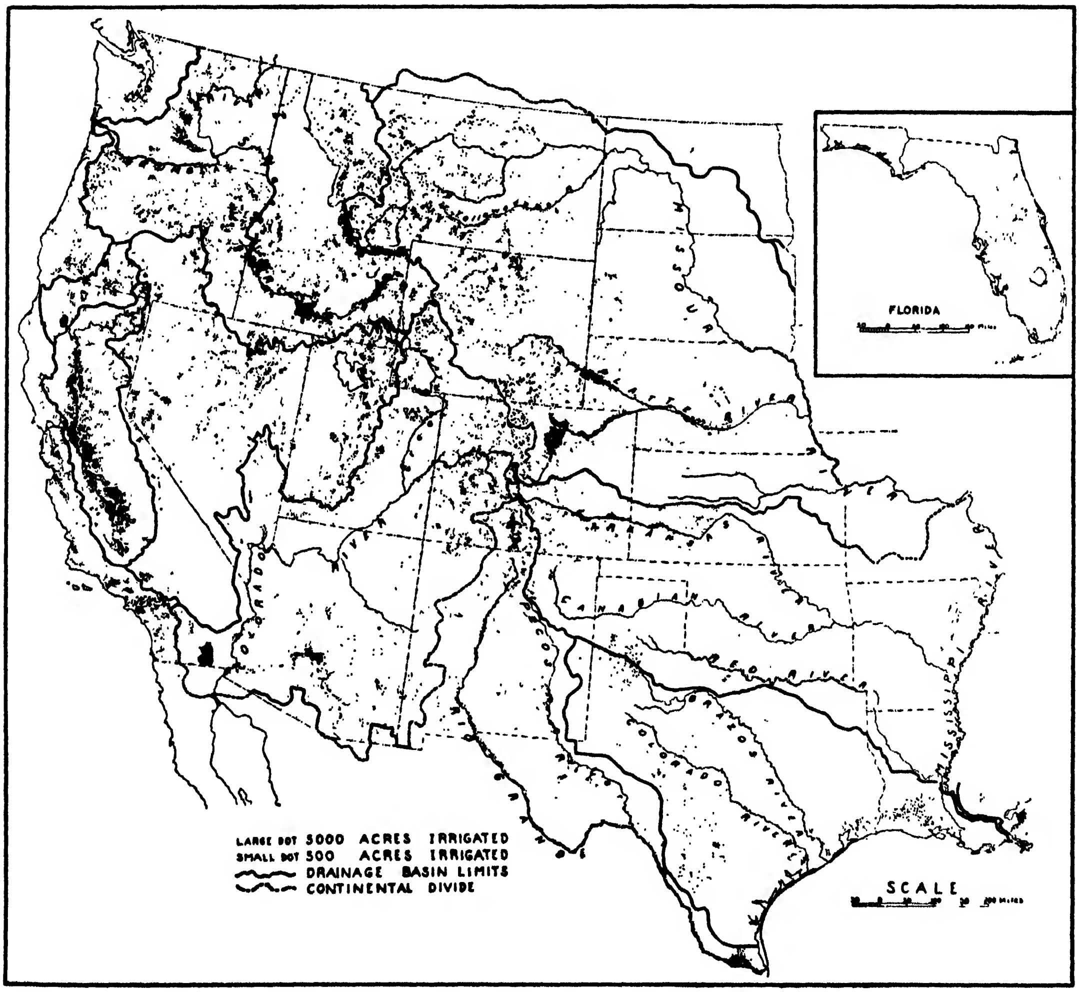

FIG. 3. Irrigated areas of the United States, 1939. (Adapted from Census of Irrigation map, Bureau of the Census, 1940.)

cepted: for every 3 gallons of water diverted from natural rivers, only about 1 gallon "subserves a useful purpose in sustaining plant life."

From the map of irrigated lands in 1939, it will be noted that most of the areas are small in extent (Fig. 3). Their linear arrangement and position indicate the derivation of the water supply mainly from rivers which originate in the higher altitudes. The most considerable bodies of irrigated land occur in the Great Valley of California, the Salt River valley of Arizona, the Snake River and its tributaries in Idaho, and the upper valleys of the Platte and the Rio Grande. Some 10 per cent of the irrigated land receives its water supply entirely or in part from wells, thus altering, here and there, the river pattern of distribution.

Small Irrigated Acreages in the East

The practice of irrigation is not wholly confined to the arid and semiarid regions. Crops such as rice, requiring more moisture than is ordinarily supplied by rainfall, are responsible for the irrigation of about 600,000 acres in Arkansas and Louisiana. In all the eastern states in 1939, only 166,000 acres were irrigated, principally by pumping plants and spray systems, with Florida accounting for over one-half of the total. There is much to be said in favor of irrigation in the humid climates of the eastern states. As Thornthwaite has pointed out, irrigation is the only sure way of combating drought, and drought is the greatest hazard in agriculture. Nevertheless, he adds, "Interest in irrigation in eastern United States is slight because farmers have not recognized the need for it. Droughts are seldom so severe as to result in complete crop failure, and the reduced yields resulting from drought are accepted as a natural feature of the region." In one sense, irrigation is a practice introduced by man to supplement rainfall and thus should find a place in nearly all climatic areas. Rainfall in humid climates, perhaps adequate as an annual amount, may not come at critical periods in the growth of plants. A farmer provided with means of applying needed water is thus in an advantageous situation. The trend seems to be toward moderate increases in irrigation in the eastern states, but it is unlikely that this practice will become institutionalized as it has in the west. Irrigation in this country has been most successful in the regions of chronic, rather than seasonal or contingent, drought.

Developed Facilities

A common error is to assume that all irrigable land in operating enterprises is watered from year to year. As a matter of fact, in 1939, there were over 7,000,000 acres in project lands in excess of the area actually irrigated in that year. In other words, installed irrigation works were capable of supplying water to an area larger than Massachusetts in addition to the 21,000,000 acres watered in that year. Conservationists have not failed to call attention to the fact that installed irrigation works are being used to about three-fourths of capacity. A full utilization of facilities already available would permit considerable increases in the area actually irrigated. This fact should be considered very carefully by those who advocate the creation of entirely new projects. There is a strong presumption that the irrigable portions of existing projects, except such land as may be occupied or reserved for town sites, buildings, and roads, could be placed under irrigation with greater economy than a completely new and untried project.

Other developed irrigation facilities are best summarized in tabular form. (Table 2.)

Organized Colonies Pioneered Irrigation

This impressive assemblage of irrigation facilities to water 21,000,000 acres of land is the result of a century of enterprise. Modern irrigation in the United States, at least by Anglo-Americans, originated in Utah in 1849 with the arrival of the Mormon people. This was the beginning of "colony

TABLE 2

IRRIGATION FACILITIES, 1940

[Source: Bureau of the Census, *Irrigation of Agricultural Lands*, 1940.]

Number of diversion dams	34,544
Number of storage dams	4,607
Number of reservoirs	7,709
Number of flowing wells	4,641
Number of pumped wells	68,279
Length of canals in miles	127,533.7
Length of pipe lines in miles	28,584.9

irrigation," a colony being defined as a more or less homogeneous group of people organized by a central authority, migrating as a body, and settling in a site chosen with a view to its irrigability. Usually the site was selected in advance of migration, but in any event the necessity of irrigation was recognized at the outset.

The Mormon colony, selecting in 1849 the piedmont alluvial fan of the Wasatch Range near Great Salt Lake, was organized around ecclesiastical authority. Later, the Colorado Piedmont was selected by numerous colonies, some of which were definitely communistic, others inspired by "land companies," and still others with the central idea of social betterment. The German Colonization Company, a communistic venture, settled in the Wet Mountain valley in southern Colorado in 1869. In 1871, the Chicago-Colorado Colony, a "land company" scheme, moved in on a predetermined site on the St. Vrain River, where the city of Longmont is now located. Most famous of all was the Greeley Union Colony, organized under the leadership of Horace Greeley. The confluence of the Cache la Poudre and the South Platte, because of ample water supply, large level areas, good soils, and other actual or expected advantages, was selected by the Greeley Union Colony.

Long since abandoned as such, the areas developed by the colonies remain today among the more successful and best-developed projects in the west. Various elements should be considered in this connection. First, the areas settled by colonies were deliberately chosen for that purpose. Of the numerous possibilities presented at the time, the choicer localities were selected. Generally speaking, sites were chosen that offered the least physical resistance to irrigation. Most desirable were relatively small but perennial streams whose waters could be diverted by small dams into easily constructed ditches and canals. In the second place, communal organization, when wisely managed, was undoubtedly an advantage. Irrigation requires the co-operation of many individuals having a community of interests. Captain C. E. Dutton in 1879 said of the Mormon colony: "This communal arrangement has been attended with great success so far as the development of water resources is concerned and the system of management has ordinarily been so conducted that the general welfare has been immensely benefited."

Other Forms of Private Enterprise

Other early enterprises were developed on an individual and partnership basis—individual farmers or, more commonly, neighboring farmers using small gravity diversions from rivers or water from wells, without formal organization. At the present time, 34.8 per cent of the irrigated land in the United States is watered under this sponsorship.

Co-operative or mutual enterprises, which distribute water to farmers according to the ownership of stock in the corporation, are also important, accounting for 31.7 per cent of the irrigated area. Also important in the development of water resources are the irrigation districts, described by the Bureau of the Census as "public corporations established under state laws empowering them to obtain funds for the purchase and construction of irrigation works" and to perform other corporate duties. Another form of organization, the commercial enterprise, which provides water to farmers who have no financial interest in the works, has dwindled in importance over the years. Between 1930 and 1940, the proportion of irrigated land supplied by commercial companies dropped from 6.5 to 4.8 per cent.

Beginnings of Federal Participation

Through these various forms of private enterprise, some 4,000,000 acres of land had been reclaimed by 1889, distributed as shown in Fig. 4. Proponents of irrigation at the time stated that the more easily irrigated lands were approaching exhaustion, although it is to be doubted that conditions were as critical as they were represented. Also approaching exhaustion were the tempers of certain western leaders; they charged Congress with failure to act promptly and decisively upon proposals to subsidize irrigation developments in one form or another. Francis G. Newlands of Nevada, later identified with the Reclamation Act, said at an Irrigation Congress in Salt Lake City in 1891, "We have, throughout the arid region, applied water to almost all the lands that are within easy reach of the rivers and streams." As a field for individual enterprise, he said, irrigation was on the way out, the time for congressional action had come. Speakers at the Salt Lake conference complained that the appropriation fund set up by Congress to finance irrigation surveys had been poorly expended. Irrigation studies, placed in charge of the U. S. Geological Survey, were made subordinate, so it was said, to other investigations.

Events such as the Irrigation Congress of 1891 were straws in the wind, pointing in the direction of government participation in western reclamation. Preliminary plans were laid between 1888 and 1891, when surveys were conducted for selection of reservoir sites. According to one authority, "The Chittenden report of 1897 was the first official advocacy of governmental participation in irrigation projects." This report recommended the construction of reservoirs, properly (it said) to be done by the federal government because (1) irrigation is an interstate problem, (2) other natural resources such as forests were directly related to water storage, (3) the federal government was the largest landowner in the west, and (4) public sentiment was in favor of such action. Between 1897 and the framing of the Newlands bill in 1901, the idea of federal aid for irrigation had extended to the point at which reservoirs were considered inadequate: provision must be made for delivering water to the land. Thus the idea of federal projects grew. In his first message to Congress in 1901, President Theodore Roosevelt said, "It is as right for the National Government to make the streams and rivers of the arid region useful to man by engineering works for the storage of water, as to make useful the rivers and harbors of the humid region by engineering works of another character." The Newlands bill became law in 1902 when the President took occasion to state his view that, since it was the duty of the government to dispose of land to settlers, it was also incumbent upon the government to place water upon it for irrigation.

Early Debates concerning Federal Reclamation

A measure so unusual as the Reclamation Act was bound to elicit much open criticism, especially from spokesmen in the humid east. Six arguments were leveled against this form of federal aid. It was said of the act that (1) it was unconstitutional and (2) it savored of paternalism. Moreover, the act was condemned because (3) it did not promote the general welfare, particularly since (4) overproduction of foodstuffs would result. Many voiced the opinion that (5) this was an unwarranted form of competition with individual effort in other parts of the country and that (6) the expenditures would be enormous, out of proportion to any benefits derived.

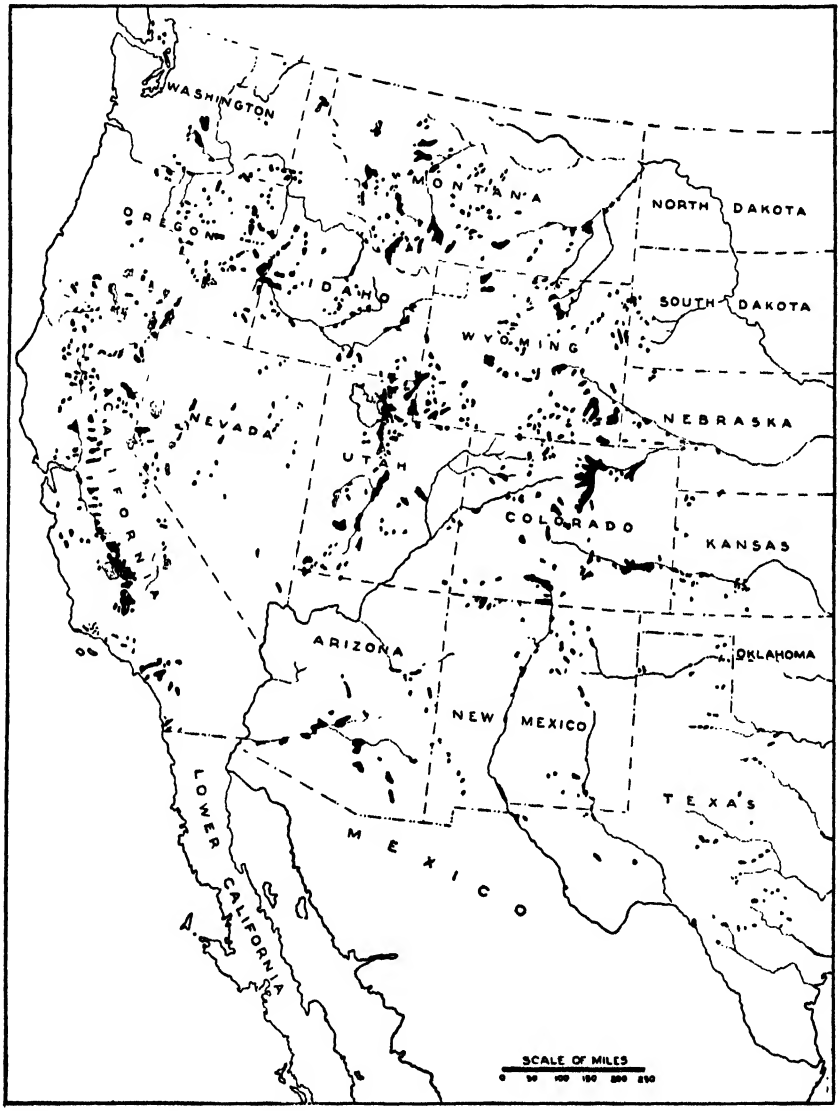

FIG. 4. Irrigated areas of the United States, 1889. (From *Statistical Atlas of the United States*, Plate 54, Eleventh Census, Washington, 1898.)

Arguments for federal reclamation took the following lines: (1) The act was constitutional because it promoted general welfare. (2) The projects would relieve dangers of overpopulation. (3) The projects would serve as pioneering outposts around which settlement could gather. (4) The act contemplated the conservation of natural resources, a necessity to which the nation was at that time becoming awakened. (5) The crops grown in the projects would be consumed locally and therefore not sold in competition with other crops on eastern markets. (6) Federal reclamation was no more paternalistic than river and harbor improvement, and it was equally general in its benefits to the nation. (7) The projects were to be self-liquidating through repayment by the settlers. Some of the arguments on both sides were obviously specious.

Criticisms of federal reclamation did not cease with the enactment of the Newlands bill; indeed, the subject remained highly controversial. Some of this controversy would have been eliminated if the parties to the debate had considered, in broad perspective, the general arid-land policy of the United States, concerning which there is, indeed, much to criticize. It should be kept in mind that federal reclamation has been only one phase of that policy, an aspect of such tangible nature as to lend itself to adverse criticism. Much of the discussion would attain a higher level if the actual accomplishments of the Bureau of Reclamation were better known.

Accomplishments of Federal Reclamation

From the material standpoint, the Bureau of Reclamation has created some 40 projects. Of these, three have been abandoned as federal schemes, although irrigation continues under other sponsorship. For example, the Garden City, Kansas, project was relinquished, but many of the facilities were taken over by private interests. Although the government pumping stations have since been abandoned, irrigation continues in the area. Many projects, in whole or in part, have been turned over for operation by irrigation districts or water-users' associations, although the government retains title to, and management of, the works.

TABLE 3

FEDERAL PROJECTS IN OPERATION, JANUARY 1, 1940

[Source: Bureau of the Census, *Irrigation of Agricultural Lands*, 1940.]

	Project Land (Primary Supply)		*Outside Projects (Supplemental Supply)*	
	Irrigated in 1939	*Works Capable in 1940 of Supplying*	*Irrigated in 1939*	*Works Capable in 1940 of Supplying*
	Acres	*Acres*	*Acres*	*Acres*
Idaho	344,638	424,840	842,715	973,656
Arizona	265,042	297,669	58,044	90,943
Montana	186,002	323,197	....	....
Washington	167,085	210,512	161,876	188,677
Nebraska	160,799	180,155	96,602	105,996
Wyoming	138,653	170,643	15,398	16,321
Oregon	130,403	175,171	85,042	117,733
New Mexico	98,064	115,695	....	....
Colorado	83,137	121,746	13,074	16,336
Texas	61,153	69,010	12,681	17,119
Nevada	57,471	66,788	11,874	41,210
California	44,581	60,297	1,709	1,709
Utah	38,623	40,812	161,455	193,021
So. Dakota	34,222	72,504	....	....
No. Dakota	14,131	19,928	....	....
Totals	1,824,004	2,348,967	1,460,470	1,762,721

The irrigated area involved, according to the 1939 census, is 3,284,474 acres, which is approximately the extent of irrigated land in the west at the time the Bureau started operations. It is estimated that 670,000 persons are supported directly or indirectly by federal projects; of this number 214,781 live on project farms. The cost of developing the land has reached $250,245,359. As explained earlier, the gross per-acre cost has been notably higher than average costs. Most of the projects include areas provided with irrigation facilities but not yet occupied by farmers. Mainly, the projects have been developed in areas presenting legal and physical obstacles such as would have discouraged private development. The more significant data are summarized by states in Table 3.

Contradictory Views of Federal Contributions

Various interpretations have been placed upon these accomplishments of the Bureau of Reclamation. Critics in condemning federal reclamation are wont to say: (1) Many, perhaps the greater number, of the projects have not been successful. This, it is said, is indicated by the failure of landholders to make repayments of original costs. (2) It follows, therefore, that federal reclamation has been a form of subsidizing agriculture that is unfair to farmers elsewhere. Such subsidizing is all the more to be deplored since it has masqueraded under the name of a home- and community-building enterprise. (3) There is no need, at least in normal times, of extending the area of farmed land; indeed, no such need existed even at the time the act became law. It is said that pressure brought to bear on Congress to pass the act was misinterpreted as a popular demand for farms and homes. The possibilities of speculation in land provided the real reason for the clamor referred to. (4) This form of paternalism has undermined self-reliance and reduced high ideals of citizenship.

On the other side, these answers are frequently heard: (1) The success of a project or of all projects together cannot be judged solely on the dollar basis. (2) Irrigation renders farming and stock raising more successful and stable. Since the country deemed it desirable, wisely or unwisely, to have the arid and semiarid lands occupied in this manner, it is logical that the settlers should be supplied with the opportunities of irrigation. Failure to take advantage of these opportunities should not be regarded as a failure of the project. (3) Many present-day difficulties within the projects are granted, but it is claimed that some of them, at least, result either from countrywide agricultural maladjustments or from residuary effects of earlier troubles which, in the light of experience, have been or are being corrected. In the last connection the National Resources Board lists these difficulties: (*a*) poor selection of settlers, (*b*) maladjustments in number and size of farms and types of farming, (*c*) tax delinquency and frequency of transfer of property, and (*d*) tenancy. It is said that the projects suffer from the undesirable forms of tenure common to those sections settled under earlier land laws. In an attempt to correct these difficulties, the Bureau of Reclamation has lately stressed soil and land classification, elimination of land speculation, and more rigid selection of settlers as to financial standing and experience. (4) It is too early to render a competent decision upon the success or failure of federal reclamation. Irrigation practice develops slowly even under favorable circumstances. Projects in the semiarid region have met with the greatest difficulty; the readjustment of farming systems under irrigation is a slow and difficult one. (5) In multiple-purpose projects, currently under development, many benefits beyond irrigation may be derived: water power, flood control, improvement of navigation, and city water supplies, in addition to recreational areas, waterfowl and wildlife refuges, and fish propagation pools. For example, the upper 72 feet of the capacity of Lake Meade, behind Hoover Dam on the

Colorado River, is reserved for flood control; the construction of Shasta Reservoir in California is justified in part by prospective improvements in Sacramento River navigation; the Parker Dam, 155 miles below Hoover Dam, supplies 13 cities with water; and the Contra Costa canal near San Francisco conveys water 16 miles for municipal purposes. Multiple-purpose projects require careful planning to achieve integration of many desired uses, as well as elaborate engineering facilities. Private enterprise can scarcely command resources sufficient to create master projects.

CONSERVATION OF WATER—IDEALS AND ACTUALITIES

The full utilization of irrigation water is an unattainable ideal. In any system, losses of water occur at all stages in its transit from the river diversion point or well to final delivery on a farmer's field.

Basic Requirements of a Project

Giving free rein to the imagination, one can conceive of an irrigation project in which perhaps seven-tenths of the water stored for irrigation actually accomplishes its mission. To minimize the two chief causes of water loss—evaporation and seepage—the canals and laterals would, in this idealized situation, be of tile or concrete and preferably laid underground. These provisions would involve prohibitive outlays of capital, except perhaps on very small installations for market-garden or horticultural production. Evaporation would continue to take its toll in the reservoir, which must lie exposed to sun and wind. Assuming that seven-tenths of the water originally stored reaches the farmer's field, there would still be no assurance that the water would perform its full duty. Factors of surface and soil, the varying requirements of different kinds of crops, and the differing skills of the operators all play decisive roles in the irrigation process.

The forehanded engineers of this idealized project would provide means of ridding the land of excess water which is bound to accumulate under irrigation. The drains would preferably be laid underground, for, if open, they would further subdivide planting fields already crossed by irrigation canals. To anticipate the correct position of drainage lines before the need for them has arisen would require more than ordinary wisdom on the part of the designers of the system. Drains are usually one of the later additions to projects, completed after damage has been done rather than before.

Changes of Soil Character

✓Experience has shown the advisability of providing drainage systems along with irrigation canal-and-lateral systems. Damages to the soil from the accumulation of water are usually of an insidious nature, not immediately evident but cumulatively serious. Soil that has lain for centuries under an arid climate is suddenly moistened with water supplies equivalent to those of humid climates. Some of the water evaporates; some of it reaches downward to the water-table or to an impervious "hardpan." A common result is an elevation of the water-table and the seepage of the water down the face of impervious layers. Eventually it may come to rest, forming water-logged or seeped land. Frequently it accumulates in quantities sufficient to form extensive swamps.

✓Furthermore, the practice of irrigation radically disturbs the normal balance of soil constituents. The incoming water carries salts in solution, later precipitated in the upper soil layers in the form of alkali. Many plants cannot tolerate even a moderate amount of salt, and cultivated crops are likely to be killed with greater accumulations. A sufficient number of properly placed drains would be an insurance against waterlogging as well as against dangerous changes in the balance of soil constituents.

The physical structure of soils may also change slowly under irrigation. Normal processes of physical weathering are altered by the new conditions. Also, irrigation water derived from rivers is likely to carry fine particles in suspension, later deposited in the fields. The suspended matter may act as a fertilizing or soil-building agent; it may also cause the soils to become less porous by the filling in of pore spaces. For example, a reconnaissance soil survey of the Salt River valley of Arizona was made by Thomas H. Means in 1899. At that time, 21 per cent of the soils around Tempe were classed as clay loams and clays. More detailed maps based on surveys in 1927 showed 82 per cent of the same soil grades. "Such great differences cannot be explained by improved methods of surveying and classification," said Mr. Means in *Science,* July 10, 1936. One result of the increased clay content is to impede the penetration of water, and this, in turn, tends to cause an accumulation of alkali in the soil. Irrigation farmers of long experience have observed changes in soils, with a healthy disagreement as to whether the changes have been beneficial or not.

Some Water Losses Contingent and Unavoidable

Under practical irrigation, unavoidable losses, such as those caused by evaporation in storage and in transit, are followed by other losses in the final act of applying water to fields. If these contingent losses exceed a reasonable figure they may be termed wastes. However, some of the "waste" water may return to the stream, or recharge the underflow, and thus serve a useful purpose to some other irrigator.

The very nature of water and the relatively low value placed upon it as a commodity limit the range of its use in irrigation. For example, water must be used in the general vicinity of its origin, more especially water derived from underground sources. To state an obvious example: surplus waters of the lower Columbia River must be used in the northwest; they cannot be turned to supply deficiencies in the thirsty plains of western Oklahoma.

On the other hand, the conveyance of water for considerable distances from its source is a firmly established practice. The early appropriation custom of directing water by ditch or flume to irrigable areas many miles from the originating river was in due time legalized in various states. Advances in engineering have made possible the construction of longer supply canals with deeper cross sections, thus extending the possibilities of matching the better soils with adequate supplies of water.

Striking instances of the diversion of water outside of its originating watershed occur in the Rocky Mountains. In Colorado and New Mexico, water is pumped across, or led by tunnel through, the continental divide in order to use the surplus water of one slope to supplement the deficient supplies of the other. A spectacular example of water diversion, but not across the continental divide, is provided by the Uncompahgre project of western Colorado. Most of the water used in this large federal project is derived from the Gunnison River by means of a seven-mile-long tunnel driven through the Mesa Incinado which separates the two rivers. The ample waters of the

Gunnison could not be used in its narrow canyon, and the small Uncompahgre River was inadequate to irrigate its wide lowland.

In some states, however, legal limitations have been placed on the extent of stream diversions. A recent case in Nebraska, where both appropriation and riparian doctrines are recognized, is to the point. The Central Nebraska Public Power and Irrigation District, in developing the Tri-County project on the North Platte River above the city of North Platte, applied for water to irrigate a very large additional acreage. To do so would have required the diversion of water from another stream. One of the senior appropriators of the nearby stream challenged this right in the Nebraska Supreme Court, which ruled that in Nebraska "water could not be supplied to land outside of the watershed of the river from which diversion was being made."

FIG. 5. The Farmers' Ditch about halfway along its 16-mile course. Like most canals, this one is an open, unlined trench.

Consideration of Losses in Transit

Generally speaking, evaporation and seepage losses increase with lengthening canal systems. It is estimated that less than 10 per cent of the length of supply canals is lined with concrete or other impervious material to prevent seepage through earthen banks (see Fig. 5). Reliance is placed on the "puddling" of excavated canals: the closing up of pore spaces with fine sediment. Fortier has found a "fairly constant" decrease in seepage losses per mile "as the capacity of the canal increases." Thus in a canal with a second-foot capacity from 1 to 5, the loss per mile averages 20.2 per cent; if the capacity is 800 second-feet or over, the loss is reduced to 1.0 per cent. Large heads of water at intakes are needed to overcome losses in transit (see Fig. 6). In other words, a portion of the water carried in a canal is expended to ensure the delivery of an adequate supply at the end of the system. This practice is probably justified on conservation grounds. Certainly it would be contrary to principles to apply water to inferior land close at hand merely to prevent losses arising from its conveyance to better soils in the same vicinity.

FIG. 6. Headgates of the Farmers' Ditch, taking water out of the Arkansas River above Garden City, Kansas, August, 1946. Because many ditches divert water at upstream points in Kansas and Colorado, there is frequently no water for this supply canal.

Much land physically suitable for irrigation and near water supplies must be excluded from consideration because such land lies above canals and laterals (Fig. 7). Water is delivered to projects largely by gravity methods. Since pumping water to higher levels is costly and rarely possible, the usual practice is to divert water at a point upstream where its elevation exceeds that of the place where delivery of the water is desired. Commonly, the gradient of the canal system exceeds that of the natural slope, thus eliminating the higher elevations from the irrigable area. Often these higher lands are physically as desirable for farming as the lower and are usually superior to the bottomlands. The practical upper limit of irrigation is thus more or less permanently fixed by the highest canals and ditches (Fig. 8).

Irrigation systems deriving water from pumped or flowing wells expend relatively little water to ensure its delivery to the desired point. Many individual farms are provided with one or more wells; thus ditches are short and evaporation is reduced to the minimum. In many well installations the water flows directly into the farm ditches, but more commonly small reservoirs impound a reserve supply, with attendant losses from evaporation. A certain amount of contingent loss is thus likely even in water-saving pump irrigation.

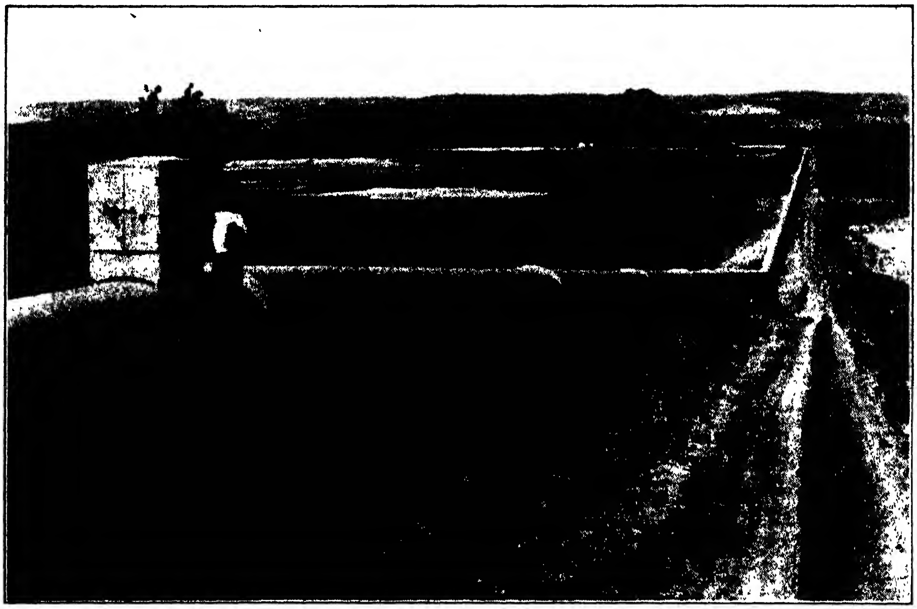

FIG. 7. Malheur River siphon, Owyhee Project, Oregon. View looking northwest showing fields in the valley. This method of water distribution is necessary where the water must be carried across relatively low areas to the upper edge of the areas to be irrigated. (Bureau of Reclamation.)

Reviews of Water Contracts Recommended

The conservation of water resources would be advanced by periodic reviews of original water rights and of contracts between irrigators and ditch companies.

Many existing water rights and contracts date back to pioneer days when there was more than enough water to go around. Liberal estimates were made in the 1870's and 1880's as to the amount of water needed during the irrigating season. Very often, excessive amounts were granted to companies or individuals. The rights once established legally continue although changes may occur in the meantime. The most common form of water right calls for the delivery of a certain quantity of water for a fixed land area, a condition not likely to encourage conservation.

Evidence suggests that the seasonal needs of irrigated areas tend to diminish with time; at least they diminish until a more or less fixed limit is reached. Powell reported in 1890 that in the San Luis valley of Colorado there was no doubt as to the increased duty of water, only about three-fourths as much being needed as during the first years of irrigation. It was stated by Fortier in 1926 that a third less water was needed in the Greeley, Colorado, area than during the beginning years of development. Furthermore, crop systems are likely to change during a period of time, and different crops are known to require varying amounts of water.

Periodic reviews of water contracts might also achieve a more equitable division among water users. Since irrigated soils may change physically and chemically, it follows that many original water rights become outdated. Rights often attach to soils which, though formerly productive, have gone out of agricultural use through waterlogging or excessive salt accumulation. In federal projects, adjustments in water contracts are taken care of more promptly than they appear to be in other types of development.

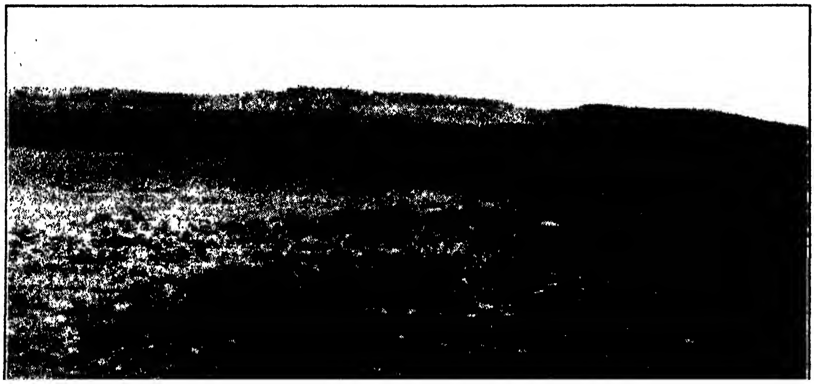

FIG. 8. This view, west of Buffalo, Wyoming, along the foothills of the Bighorn Mountains, shows the extent of irrigated land as determined by canals. The dark patch is the irrigated land, below canals. Soils that lie above, though equally good, cannot be irrigated.

Losses in Applying Water to the Land

Of the dozen methods of applying water to field crops, orchards, and pasture land, none is completely free from possibilities of water loss or soil damage (Figs. 9 and 10).

On theoretical grounds, the method called subirrigation uses water most conservatively. The objective of "subbing" is to lead water directly to the roots of growing plants, rather than to saturate the surface and thus reach the roots from above. As practiced sparingly in the west, ditches running along lines of least slope are filled with water which is not permitted to overtop the enclosing banks. The water pene-

FIG. 9. Water for the Heart Mountain Division of the Shoshone Project will reach farms by way of the Heart Mountain canal. Work was started on the canal system in 1935. A section of the canal is used to provide water for lands now farmed by veterans of World War II. Heart Mountain, from which the division derives its name, can be seen in the background. (Bureau of Reclamation.)

FIG. 10. Friant-Kern canal. View looking upstream along a lined section of the canal about two miles below Friant Dam. This canal is a part of the Tulare Basin District, Central Valley Project. Lined canals are necessary where permeable soils result in heavy losses of irrigation water. (Bureau of Reclamation.)

trates the subsoil by lateral seepage without thoroughly wetting the surface—at least that is the intent. This reduces the likelihood of high evaporation losses since the topsoil is not completely wet; some tests have shown that water loss from a thoroughly wet soil is nearly as great as from a free water surface. Subbing is rarely em-

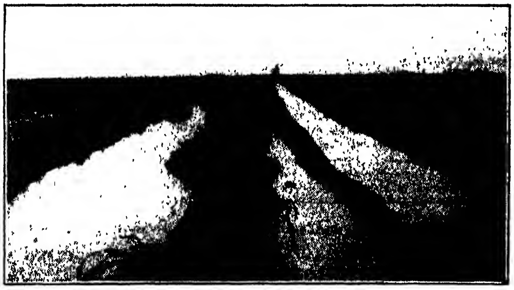

FIG. 11. Typical farm ditches carrying water for irrigation, near Garden City, Kansas, August, 1946. Ditch at the left, flowing toward observer, feeds the ditch at the right, alongside, which flows in the opposite direction.

ployed, mainly because its successful practice requires soil conditions rarely met with in one place: a porous topsoil and an impervious stratum with adequate drainage to counteract waterlogging tendencies. During the second decade of the present century a wave of enthusiasm for subirrigation swept across western Nebraska and Kansas, only to be succeeded in a few years by other enthusiasms. Continued subirrigation is identified with only a few localities, including the San Luis valley of Colorado.

Nearly one-half of the irrigated land in the west is watered by flooding from laterals, the so-called Rocky Mountain method. Contour ditches are so constructed as to command an entire field. The water flowing into them is caused to override the banks on the field side, whence it flows between crop rows (as in sugar beets) or broadside (as in wheat or alfalfa). Individual farmers have their own preferences for wetting a field by flooding: some commence with the upper ditches and move downslope, working in mud much of the time; others start with the lowest laterals and work uphill with dry land above the advancing water (Fig. 11). Water waste is likely in both methods. Unless the flow in the feeding lateral is cut off in time, the surplus washes across thoroughly saturated soil beyond the field limits, possibly filling a culvert and finally covering a nearby road. Travelers along side roads and not infrequently on main highways in irrigation projects have, on occasion, seen numerous horrible examples of water waste.

Other water application methods are known as furrow and corrugation, check, basin, and border. Each has its advocates and is variously adaptable to kind of crop, degree of slope, and type of soil. The border method, for example, depends on low levees or borders extending downslope, provided the slope is gentle. Water turned into the upper borders advances downslope in a sheet, not unlike its action in flood irrigation, but here the borders direct the flow of water. The present-day border method of irrigation is not unlike early practices of the Indians in the southwest who learned how to direct flood waters to moisten soil. Variations of "flood-water farming" are still practiced by various Indian peoples in New Mexico and Arizona.

CURRENT TRENDS IN IRRIGATION

Federal Schemes on the Increase

Chief among more recent trends is a sharp upswing in government-supported irrigation. The most comprehensive program undertaken by the Bureau of Reclamation since its origin in 1902 began in 1933. As explained by the Census, "This program resulted from an acceleration of interest in water conservation in the West, the need [during the depression years] for public works to provide employment, and the demand for newly irrigated land for settlement of the increasing population of the West." The total area of irrigated land served by the bureau increased about 20 per cent during the decade from 1937 to 1946. It was estimated on July 1, 1940, that the ultimate investment in Bureau of Reclamation projects completed or under construction was $1,350,000,000.

All-inclusive authorized or planned river developments in the west are a natural evolution of somewhat less comprehensive schemes involving major western rivers, such as the Colorado, commenced several years ago. Impetus for multiple-purpose projects was furnished also by the Tennessee Valley Authority program, a scheme that did not, however, include irrigation. Thus it has become popular to speak of plans for Missouri valley development as the TVA of the west. A Missouri valley integrated plan is generally presented as something entirely new in American thought. Looking back into history, however, we find William F. Vilas, Secretary of the Senate, saying in 1890:

"It is believed possible, by an undertaking of adequate grandeur, to seize the waters of the Missouri and its tributaries at a proper distance from their sources, and not only to apply them to the reclamation of arid lands in the upper region, but thereby also to benefit the agricultural territories adjacent to its lower currents, and even to mitigate the severity of the effect of floods of the Mississippi upon the agricultural lands of its borders."

Many uses of water in the west are complementary. Thus, water destined for use in irrigation may first be employed to generate electricity which, in turn, may be used to pump the energy-giving water to higher reservoirs and canals. Again, water caught behind a dam not only reduces flood hazards below it but may also contribute to storage facilities. It is frequently necessary, however, to equate the various desired ends. Thus, for example, in the Wenatchee valley of Washington it was found that the generation of electricity would interfere with full water utilization for irrigation. Said the U. S. Geological Survey on this point in 1922, in effect: Water from the Wenatchee River can be used to irrigate 400,000 acres of land in nearby Quincy valley, but such use will reduce power resources in the Wenatchee basin by 216,000 horsepower. The utilization of water for irrigation in this case was considered more important than generating power, a view supported by court decisions in the state of Washington.

Amalgamation of Small Projects

Now, too, heretofore separate or inadequate irrigation systems are being amalgamated into larger and more unified projects. Corporations authorized by state laws are the usual projecting agents. The Tri-County project of Nebraska has already been cited. Another development in the same drainage basin is that of the Platte Valley Public Power and Irrigation District (Sutherland project), extending between Grand Island and Ruthton. This project intends primarily to provide supplemental water to lands already under canals operated by eight different companies since about 1900.

New Activity in Well-Drilling

A third development of recent date is the more extensive tapping of underground resources. Enthusiasms over possibilities of these supplies are currently running high. The drought of the 1930's is still remembered by dust-bowl farmers who endured those years; a well on the place might mean the difference between success and failure. New methods of drilling developed in oil fields, and, in many places, lax state laws regulating the drilling of new wells have combined with other factors to initiate an almost feverish activity in Nebraska and western Kansas. Within the compass of the Hugoton oil field in western Kansas, at present in the throes of a minor boom in drilling for oil and gas, natural gas is accessible which, when piped into internal-combustion engines, provides a relatively cheap agent for lifting water from the depths. Another factor stimulating drilling for water in Kansas is the increased mobility of seasonal labor, which has permitted the production of cantaloupes and watermelons in a region which had previously depended on grain and livestock. In the middle 1930's this region was one of the dust-bowl areas.

The present enthusiasm over irrigation is probably well founded. It is well to remember, however, that there have been other, somewhat similar periods during the past century.

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CHAPTER 7

Grassland Resources

EXTENT AND NATURE OF GRASSLANDS

GRASSLAND is one of the chief kinds of vegetation that forms cover for the soil. The other kinds are forest, woodland, shrub, and scrub, which includes the fleshy and thorny desert plants and tundra. The area covered by each of these five major types or formations of vegetation is controlled largely by climatic and soil conditions. Other factors, such as recurring fires, grazing, insects, plant diseases, and human activity, often exert considerable influence.

It has been estimated [1] that the natural vegetation cover for the world as a whole was about 24 per cent grassland and savanna, 42 per cent forest, and 34 per cent desert. These vegetation formations occupied 12,670,000, 21,880,000, and 17,430,000 square miles, respectively, for a total of 51,980,000 square miles of the earth's land surface. Even now only about seven to ten per cent of the earth's land surface is cultivated, and probably not over 30 per cent can be put into cultivation in the foreseeable future.[2]

The importance of grassland as a resource is indicated by the fact that in the United States over 38 per cent of the land area is used as more or less permanent grazing land whereas only about 20 per cent is used as harvested cropland. Even in countries such as Denmark and Czechoslovakia, where farming is most intensive, 15 per cent of the total agricultural land in the former is in permanent pasture and 15 per cent of the latter is in permanent meadow and pasture. In Great Britain just before World War II almost 60 per cent of the total land area was in permanent grass and rough grazing land. Pasture lands constitute almost 45 per cent of the 689,409,000 acres comprising the total land area of Argentina.

The Flora of the Grasslands

Grassland is made up usually of a mixture of grasses, sedges, broad-leaved herbs or forbs, and occasionally some low shrubs or semishrubby plants. About 6000 species

[1] H. L. Shantz, "Economic Aspects of Conservation," *Jour. Forestry,* Vol. 39, 1941, pp. 741–747.

[2] R. M. Salter, "World Soil and Fertilizer Resources in Relation to Food Needs," *Science,* Vol. 105, 1947, pp. 533–538.

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of grasses are known, occurring in all sorts of habitats from the equator to the polar zones. The dominance of the grasses is due to a number of characteristics such as the ability to grow densely, producing as many as 500 to more than 2000 stalks to the square meter, and to develop a root

FIG. 1. Conservatively grazed mixed grass range is maintained in good condition. Blue grama grass, needle-and-thread, and western wheatgrass are the principal dominants and provide an excellent cover for the soil and good forage for livestock. (Photo by H. C. Hanson.)

system which is profuse, finely branched, and mostly deep-penetrating, often to depths of 8 and 10 feet. These roots ramify the soil so thoroughly that but few other kinds of plants can compete with them for moisture and nutrients.

Usually one to three species of grasses dominate a particular grassland area or type. In the true prairie near Lincoln, Nebraska, previous to the droughts of the 1930's the prairie flora comprised a total of 237 species, of which 38 were grasses, 18 were sedges, and the rest, broad-leaved flowering plants. The grasses and sedges, although constituting one-fourth of the total number of species, made up nine-tenths of the vegetation. Only four of the grass species were classified as dominant. Investigations in a grazed mixed prairie near Fort Collins, Colorado, showed that western wheatgrass was the dominant in a total of 109 species. In a mixed prairie area near Mandan, North Dakota, two grasses and two sedges were dominant in a flora comprising over 300 species. In remnants of the Palouse prairie in northern Utah bluebunch wheatgrass (*Agropyron spicatum*) was found to make up 95 per cent of the vegetation, all other species combined making up only five per cent.

Many species of grasses spread not only by large numbers of seeds but also by vegetative methods, especially rhizomes, as in Kentucky bluegrass (*Poa pratensis*) and western wheatgrass (*Agropyron smithii*), and stolons or runners, as in buffalo grass (*Buchloe dactyloides*). Other species, such as little bluestem (*Andropogon scoparius*) and orchard grass (*Dactylis glomerata*), propagate only by seed, forming compact bunches. Most bunch grasses are not so resistant to close grazing and excessive trampling by livestock as the rhizome-bearing or sod-forming species (Fig. 1).

Another most important characteristic of grasses is that the growth of the stems and leaves occurs at the base, so that, as the tops of the plants are grazed off, renewal takes place from near the crown of the plant. The crowns are often so low as to be partly buried in the soil, so that they are inaccessible to livestock.

After close grazing renewed growth may also arise from buds on the crowns. These features are in striking contrast to the more exposed crowns and growing parts of broad-leaved herbs, which are at the tips of the stems. Only relatively few broad-leaved herbs, such as white clover and other, similar "creeping" species, with rhizomes or runners, are moderately tolerant of continuous or frequent grazing (Fig. 2).

The creeping species of both grasses and forbs with their closely spaced stems and roots are well adapted to controlling water

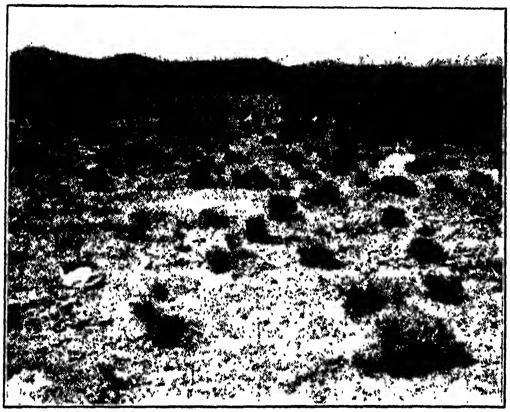

FIG. 2. Heavy grazing of this grassland has depleted the cover, bared the soil, and permitted shrubby plants of low forage value to increase. Blue grama grass has been reduced from a nearly continuous cover to the small, scattered, circular patches seen in the photo. (Photo by H. C. Hanson.)

erosion because of their ability to slow the rate of water flow, to hold the soil particles against the pressure of the water, and to accumulate water-borne debris, thus forming tiny dams which further retard the water movement. It is because of these characteristics that sod-forming species are used in seeding terrace slopes and in grassing down gullies and other areas over which drainage water from rains and floods flows. Grass-covered waterways, such as these, may provide one or more cuttings of hay during the year. In strip farming on slopes, where narrow fields of grass are planted on the contour to alternate with tilled crops, the sod grasses are most effective in absorbing the runoff from the tilled strip above as well as the precipitation received directly, thus controlling erosion of the slope. Bunch grasses are also useful in resisting erosion, particularly in the drier regions, which are less suitable for the sod-forming species.

Grasses and Wind Erosion

Grasses, too, play an important part in the control of wind erosion (Fig. 3). On cultivated fields subject to wind erosion grasses may be used in narrow barrier strips alternating with rows of crop plants. The tall and quickly growing bunch grasses

FIG. 3. Grasses are among the first invaders in areas of blowing sand. This vigorous clump of sand grass (*Calamovilfa longifolia*) is maintaining itself in an area of blowing dune sand. (Photo by H. C. Hanson.)

are most suitable for this purpose. In the plains area cultivated fields that have been damaged by wind erosion can be stabilized and reclaimed by seeding to adapted grasses. Badly depleted rangelands on which wind action has begun to remove the soil have been successfully reseeded (Fig. 4). Wind-eroded lands may be reclaimed by natural processes, as the remaining grasses spread and anchor the soil with their fine roots and their rhizome systems, and reduce wind movement at the surface of the soil with their aerial portions. Grasses are often the first invaders on sand dunes and in "blowouts." Some of these invade by rhizomes, as "blowout" grass (*Redfieldia flexuosa*), and some, by seeds, as sandhill bluestem (*Andropogon hallii*), and in time the blowing sand becomes fixed.

FIG. 4. In time the roots of the grasses bind the blowing sand and the dune becomes stabilized. These dunes in the sandhill area of eastern North Dakota have been stabilized for a considerable period of time, and bur oaks are growing in the hollows between dunes. Sandgrass and sandhill bluestem are the principal grasses. (Photo by H. C. Hanson.)

Resistance of Grasses to Drought

Because of their capacity to endure long and irregular drought periods many kinds of grasses are able to grow successfully under conditions of limited moisture. Some annual species grow and mature in the very short season when moisture and temperature conditions are suitable, such as the "six-week grasses" in the southwestern deserts. Some perennial species, like the bluestems in the moister prairies, start growth in the spring and do not mature seed until autumn; but the short grasses of the plains are restricted to a much shorter growth period because of the deficiency of soil moisture later in the summer. Cultivated grasses also show a wide range in capacity to endure drought, from Kentucky bluegrass with its high moisture requirements to the drought-enduring crested wheatgrass (*Agropyron cristatum*).

Other important characteristics of grasses that contribute to their value as a natural resource are: the capacity of some species, such as redtop (*Agrostis alba*) and reed canary grass (*Phalaris arundinacea*), to grow under very wet or swampy conditions; resistance to alkali, as salt grass (*Distichlis stricta*) and alkali grass (*Puccinellia nuttalliana*); capacity of plains grasses, like western wheatgrass, needle grasses, grama grasses, and buffalo grass, to cure on the stem, thus furnishing nutritious grazing on fall and winter ranges; and the quality of enriching the soil and improving its physical condition by adding humus derived from the decay of root and top material. The rich, deep, black soil of the chernozems with their good structure and high content of humus were developed under prairie grasses. This ability of grasses to enrich the soil has given a number of cultivated species a definite place in the rotation of tilled crops in many areas with the object of restoring soil fertility which has been reduced by tillage. In Great Britain this use of grasses (leys) is very extensive, and it is increasing in the United States.

Some species of grasses, such as wheatgrasses (*Agropyron*), needlegrasses (*Stipa*), and bluegrasses (*Poa*), start growth very early in the spring, thus providing an early "bite" for livestock; others like grama grasses (*Bouteloua*) and bluestems (*Andropogon*) start later but endure the hot summer weather better. Grasslands in which both early and late grasses grow therefore provide a longer grazing period than those in which only one kind is found. In tame pastures species differ considerably in their growth habits with respect to temperature and moisture. To furnish forage for grazing for the longest possible season, a series of pastures for early, midsummer, and autumn grazing can be attained by proper selection of species. Considerable knowledge is available regarding the growth habits of cultivated grasses, but more research is needed in order to take the greatest advantage of their distinctive characteristics.

Competition among the Grasses

Another characteristic of grasses that has not been studied sufficiently is the competitive relationship of one grass towards another under various conditions of grazing. Grazing introduces a factor that greatly alters and modifies the competitive relations of the grassland complex. Grazing on grassland containing a mixture of species is seldom, if ever, uniform either in relation to geographical distribution, time of grazing, degree of grazing, or species utilized. This nonuniform and differential grazing generally results in putting one or more species at a disadvantage in competitive relations with the other species. Usually the species that are most heavily penalized are those that are the most palatable and the most desirable from the viewpoint of maintaining the grassland at its highest possible productivity under use.

The determination of the competitive relations of grasses under grazing is properly an important field of study under management of range and pasture grasslands. Much information on the general trends of plant succession under grazing in range and pasture grasslands is now available, but the intricate relationships of individual species to associated species remain to be determined. Much of our progress in scientific management of our grasslands must await the establishment of the facts and the underlying principles governing these relationships under different types of grazing, in the many types of grassland associations, and under varying conditions imposed by climatic and weather cycles.

Kinds of Grasslands

Seven main kinds of grasslands have been classified in the United States. The *true prairie,* now mostly plowed up, extends from Manitoba into central Oklahoma and includes most of the prairie region east of an irregular line along the ninety-seventh and ninety-eighth meridians. It has been estimated that originally Iowa was seven-eighths prairie. The leading dominants, occurring as sod or bunch formers, are needlegrass, dropseed (*Sporobolus*), bluestem, switchgrass (*Panicum*), and wild rye (*Elymus*). Under good growing conditions big bluestem forms a close sod and may reach a height of 10 to 12 feet. Early settlers said that the way they located cattle in the prairie was to watch from some elevation for the waving of the tall grass as the cattle walked through it. The *coastal prairie* occupies a strip of land near the Gulf of Mexico in Texas and Louisiana. The chief dominants are a bluestem and a needlegrass. The *mixed prairie* and the *short-grass plains* occupy the area between the true prairie and the eastern limits of the Rocky Mountains. The chief dominants of the latter are the short grasses, especially grama grasses and buffalo grass. The mixed prairie, which usually lies between the short-grass plains and the true prairie, has as dominants species of medium height, chiefly western wheatgrass and western needlegrass, in association with short grasses.

The *desert plains* grassland extends from southwestern Texas westward into southern New Mexico, Arizona, and northern Mexico. The chief dominants are several species of grama grass, three-awn grass (*Aristida*), and curly mesquite grass (*Hilaria belangeri*). According to F. E. Clements, the *Pacific prairie* formerly occupied extensive areas in valleys and foothills in California and Lower California. The former bunchgrass dominants, needlegrasses, June grass (*Koeleria*), and wild ryes, have been largely replaced, owing to overgrazing and fire, by annual weedy grasses such as soft chess (*Bromus hordeaceous*), ripgut (*Bromus rigidus*), foxtail chess (*Bromus rubens*), foxtail fescue (*Festuca megalura*), and other annual grasses and forbs. The grasses of the *Palouse prairie* are in large part responsible for the productiveness of the wheat lands known as the *Palouse*. At one time this grassland occupied an extensive area in eastern Washington and Oregon, northern Utah, and southern Idaho. The major dominants are bunch grasses, bluebunch wheatgrass, Idaho fescue (*Festuca*), and giant wild rye.

In addition to dominating these major climax grassland formations, native grasses occur as associated species in many shrub and forest formations throughout the west and south. The associated grass species furnish the greater part of the forage available to grazing livestock in many of these formations. Thus, throughout much of the intermountain shrub region lying between the Rockies and the Sierra Nevada and Cascade Ranges bluebunch wheatgrass and other grasses provide an important source of forage. In the southern desert shrub region, perennial and annual grasses are of considerable importance as livestock feed. In certain of the more open chaparral types, grasses form a prominent understory of vegetation. The open "parks" and mountain meadows in the extensive coniferous forest formation of the west are grassland associations of great importance to the livestock economy of the region. Mountain meadows and subalpine grasslands in eastern Oregon and eastern Washington cover only one to two and five per cent, respectively, of the summer range of these states, but the potential production of each is 20 per cent of the summer range forage.

In the longleaf pine forest of the southern coastal plain region, extending from eastern Texas through the Carolinas to Virginia, the value of the associated grasses as a forage resource has been recognized only in recent decades. Much of the land in this area has been cut over, burned, or cultivated at some time in the past. In this type of forest the bluestems or broomsedges (*Andropogon* spp.), pineland three-awn (*Aristida*), carpet grass (*Axonopus*), dropseeds (*Sporobolus* spp.), and paspalums (*Paspalum* spp.) are important grass species.

WHAT HAS HAPPENED TO OUR GRASSLANDS?

"It was not until the white pioneer crossed the Wabash River in his westward advance that he beheld the prairies in all their splendor, and all their monotonous magnitude. These prairies presented varying aspects. The early settler avoided them at first in part for the reason that he thought them not fertile because treeless, and in part because they did not furnish the much-needed building materials, fuel, and water;

but as his experience increased, there were added to these reasons the menace of the prairie fires and terror of winter storms. But the real rich beauty of the prairie was developed only after midsummer when myriads of flowers of most varied hues were everywhere massed into one great painting, limited only by the frame of the horizon, uniform in splendid beauty, but endlessly varied in delicate detail. In the fall this in turn was followed by the rusty-red or brown expanse of drying grasses which portended the coming of the terror and the splendor of that scourge of the prairie settlers, the prairie fires, whose fascinating fury can be appreciated only by those who in earlier years had the privilege of looking upon them in hopeless helplessness." (B. Shimek.)

White Man Takes Possession of the Grasslands

Before the coming of the white man there was adjustment to a high degree between the grasslands, the native animals, especially the buffalo, the Indians, and climatic conditions. The buffalo could migrate, followed by the Indians, from areas where the grasses were suffering from drought to regions where the forage was plentiful. Undoubtedly there was overgrazing, excessive trampling, and erosion during long-continued droughts over extensive areas, which probably resulted also in the death of many buffalo. The reduction in their numbers in such drought-stricken regions afforded the grasses opportunity to recover in moister years following droughts.

The slaughter of the buffalo in the 1870's and 1880's was accompanied by the invasion of the cattlemen into the grassland areas. They soon recognized the importance of taking possession of streams and springs, thus securing control of adjoining public rangeland. The private land owned by some of the early cattle "barons" formed a fantastic pattern as it followed a winding stream. Various and devious methods were used to secure title to such streamside "homesteads." As the news spread throughout the eastern states and in Great Britain of the huge profits that could be realized from "free grass," there was a tremendous boom to invest in the cattle business, reminding one of "gold rushes" to California or Alaska. Sheepmen also appeared on the range. The grasses were nutritious the year around; it was not considered necessary to put up hay for the winter; little or no shelter was required; and the expenses were small. It was a bonanza. No wonder the industry expanded by leaps and bounds; slaughterhouses were started in various places in the range country. But droughts came; the grass was short; ranges were overstocked; no hay was available. The result was bound to be disaster, and disaster was not long in coming.

The Effects of Severe Winters

The winter of 1885–1886 was very severe in the southern plains. Losses were unusually heavy, and in the following summer large numbers of cattle were moved to the already heavily stocked ranges of the northern plains. With feed short because of a dry, hot summer in the northern plains, cattle went into the winter of 1886–1887 in poor condition. The cold came early; storm followed storms; the mercury went lower and lower. Temperatures of 60° below zero were reported. Such severe conditions had not been experienced before in the memories of the pioneer stockmen. There were no reserves of feed either on the range or in the stack. Livestock losses were terrific. Losses of more than 90 per cent were reported on some individual ranges. Many operators did not even bother to make the spring roundup. With the coming of spring most of the operators in this region found themselves facing bankruptcy. The days of big profits, big operations, and careless management on the northern plains were over. The winter of 1948–1949 was reminiscent of the extreme conditions of earlier years.

Overgrazing and Mismanagement

Many stockmen realized that the boom was over and that proper management methods would have to be worked out for the range. This would be difficult because the grasslands had been badly damaged by overgrazing and new difficulties were arising from the westward march of farmers. They were encroaching on the rangelands, the province of the so-called "nesters." The homestead laws favored the farmers. Many secured 160- to 320-acre homesteads in areas not even suited to dry farming because of insufficient moisture, poor soil, distance from markets, and shortness of the growing season. After a year, or at the most a few years, during which many depended upon the cattlemen for a living, they had to leave their homesteads. But much damage had been done to the grassland. An Indian silently watching one of these settlers plowing up the sod was asked what he was thinking. His answer was "Wrong side up." The truth of his remark is realized today because the range country is still scarred by many of these homesteaders' fields. The process of natural revegetation of these fields is remarkably slow in the range country, especially when the fields are under grazing.

The encroachment of the farmers into the range country often made it difficult for the cattlemen to prevent further deterioration of the range, and usually the cattlemen did not realize how much damage had already been done by too heavy stocking which caused too close grazing and excessive trampling, by grazing too early and too late in the season, by failure to distribute the stock properly on the range, and by general indifference to the welfare of the range. The first effects of overgrazing are so slight that only careful observations or measurements will reveal them, and it is often difficult to distinguish between the effects of overgrazing and subnormal moisture conditions.

One of the first effects of overgrazing, however, is a reduction in vigor of the most heavily grazed (most palatable) species, as indicated by the height of the stalks and diameter of the clumps. As overgrazing is continued or becomes more severe, the vigor of the most palatable species decreases rapidly, and some of them die. As their vigor and consequently their dominating effect on the area decrease, other less palatable and nongrazed species increase in vigor and size, the areas of bare soil enlarge, sheet erosion is accelerated, and seedlings of less valuable plants succeed in getting started, owing to an increased supply of moisture and light, which was not available when the palatable species were in full vigor (Fig. 5). As deterioration progresses the palatable species become weaker and die, and more nongrazed individual plants, such as annual weeds, appear. Poisonous plants often become more prominent and are grazed more, with consequent losses of livestock. In time all or most of the palatable species disappear, but the weedy species which have succeeded will be grazed only to a small extent. As this replacement of species has been occurring, the soil has become gradually more exposed to erosion by water and wind. The fine fibrous roots of the grasses, widely distributed in great numbers through the upper layers of the soil, have been replaced by the tap roots, of very limited distribution, of the weeds. The surface soil is gradually eroded away, and the area becomes progressively less fertile. Stream beds become deeper and wider; lateral gullies form; and the soil water drains away more rapidly. Unless this deterioration is halted the soil becomes incapable of supporting any kind of plants except a few low annual weed species which have practically no value for grazing. The progressive deterioration or improvement of grasslands has been analyzed and classified by ecologists into several stages, such as the climax grassland, the mixed grass-weed stage, the perennial-weed stage, and the annual-weed stage. Recognition of these successional stages is essential to proper range management.

Mismanagement caused deterioration of most of the grassland in the range country, usually resulting in a considerable decrease in grazing capacity. Even today few people realize the extent to which our range resource has become depleted and the grazing capacity of our range grasslands thereby reduced. The Forest Service has estimated that the forage on about 55 per cent of the present range area was so depleted as to have less than half its original grazing capacity. Another 30 per cent was not so seriously depleted, but the forage on this area had far less than its normal grazing value. On only about 15 per cent of the present total range area was the forage resource in reasonably good condition. An over-all estimate placed 93 per cent of the total range area as being depleted to some extent.

During World War I, because of the need for grain crops, much rangeland was again turned wrong side up, and during the droughts of the 1930's grasslands, especially those that had been overgrazed, deteriorated considerably. The great dust storms during this period originated in large part in certain mismanaged parts of the range country.

FIG. 5. This abandoned field in the Northern Great Plains has been eroded by wind and now has a sparse cover of Russian thistle. Thousands of acres of abandoned cropland such as this have been successfully reseeded with adapted native and tame grass species. (Soil Conservation Service.)

IMPROVEMENT AND CONSERVATION OF OUR GRASSLANDS

Control of the Range

Fortunately, owing to the capacity of many grassland species to take punishment in an excessive degree over a long period and to recuperate when given favorable conditions, improvement measures could be put into effect over extensive areas when the need was realized. Some of the early stockmen appreciated the value of conserving the range, but too often they were impotent against obstacles beyond their control. They contended with cattlemen, sheepmen, and new settlers for the same free range. The livestock that arrived first on the range got the grass. This led to the so-called "range wars," especially the struggles between the cattlemen and sheepmen. The necessity for control of the range became obvious.

The invention of barbed wire in 1873 made it possible for the stockman to exercise some form of range control. After 1880 the use of barbed wire spread rapidly throughout the range area. By fencing his holdings an operator could keep other livestock off his range and could regulate to some extent the distribution of his own livestock. Without doubt the availability of relatively cheap fencing in the form of barbed wire provided a strong impetus to private ownership and control of grazing lands. Actually many illegal enclosures of public land were made, which often led to bitterness and conflict. But the competition for range gave the rancher little choice in the matter; it was either fence or quit ranching. In order to fence the rancher had to acquire ownership or rights to the land that he put under fence. He naturally secured first the most valuable grazing lands and put these under fence. Most of the remaining, less valuable grazing land still continued to exist as public land. Even today almost 50 per cent of the rangeland in the west is public land.

Beginning with the setting aside by Congress in 1891 of the first public domain land into forest reserves, later known as national forests, much public grazing land has come under the control of the Forest Service. Under the Forest Service grazing is strictly controlled, with resulting improvement of the rangeland in the national forests. The Forest Service now controls grazing on 83,166,000 acres of grazable national forest land in the United States. The importance of this control and of the stimulus to better grazing management afforded by the sound management practices advocated by the Forest Service is apparent when it is realized that about 12 per cent of all the cattle and 23 per cent of all the sheep in the west are grazed on national forest lands.

Some 9,000,000 acres, comprising much grassland, is in national parks and monuments under the control of the National Park Service. About 31,000,000 acres of the 57,500,000 acres in Indian reservations, under the control of the Department of the Interior, is grassland. But there was no provision for control of a large area of grazing land in the public domain except as individual stockmen were able to exercise it locally, until the Taylor Grazing Act was enacted by Congress in 1934, amended in 1936, and supplemented by the Pierce Act of 1938. This act authorized withdrawal from entry of 142,000,000 acres of unreserved and unappropriated public domain and furnished a long-needed basis for measures to improve some of the most badly depleted grasslands. The act provides for the establishment of grazing districts under the joint management of officials of the Department of the Interior and stockmen. In 1947 the Grazing Service (now incorporated into the Bureau of Land Management) was administering sixty grazing districts comprising a gross area of 259,179,165 acres, of which 132,266,141 acres were public land.

The Campaign to Restore and Improve Grasslands

The improvement of grasslands and the development of the field of grassland management have lagged far behind the advances in arable land agriculture, such as the production of grains, corn, cotton, potatoes, vegetables, and legumes. This was due partly to the fact that the natural meadows and grazing lands were ready for use without plowing and planting and the plants continued to grow after the forage was removed. It was expected that grassland should be utilized without any special attention; but wheat, corn, cotton, potatoes, and other crops were given special study to increase yields, improve the quality, and increase the resistance to diseases. Furthermore it was more difficult to discover ways of improving grasslands because of their complex nature and because the many factors influencing the growth and development of the forage crop in native grassland could not readily be isolated and controlled. Ordinarily in a field of a cultivated crop, such as corn, there is only one species, except for weeds, in the field; but in grasslands there are usually many species, most of which have differences in habit and season of growth, in requirements upon the habitat, and in forage value.

The association of species, even on small areas, varies because of minute differences in soil moisture, texture, and nutrients and because of the competitive relationships of different species and their resistance to grazing. For example, on the northern Great Plains western wheatgrass and buffalo grass are more abundant on moister spots, but grama grass and needlegrass dominate the drier areas. Another complication arises with grasses: they are chiefly perennial whereas crop plants are annual, and consequently the latter are more subject to control. Many of the grassland species spread by vegetative means as well as by seed; and various agents are concerned with the dispersal of seeds, such as rodents and birds. Soil conditions for crop plants can be improved by employing different kinds of tillage and crop rotations, but usually this is possible to only a limited extent in permanent pastures and meadows. It has been relatively easy to select and evaluate outstanding individuals of crops, but for a long time the differences among individual grass plants were not even recognized.

At the beginning of the twentieth century the investigation and management of pastures and meadows was far more advanced in some of the European countries, for example, Switzerland, Germany, and the United Kingdom, than in the United States. The development of the science of ecology in the United States, especially in the University of Nebraska under the leadership of Dr. Charles Bessey, focused scientific attention on the natural grasslands of the west. The amount of investigational work devoted to grasslands increased slowly during the first decade of the twentieth century. In the second decade it was increasing in the field of tame pastures and meadows, and in the third and fourth decades grassland research and management were beginning to receive the attention they deserved.

The Work of Government Agencies

Early in this century the Forest Service formulated rules for improved range management and inaugurated administrative studies of range conditions in a number of different places in the western range area. In 1912, more detailed and fundamental studies of range management and grazing relations were begun in Utah and at the Jornada and Santa Rita experimental ranges in New Mexico and Arizona. The Forest Service has expanded its range research activities to include studies in all the six western forest regions of the United States and in southern and Appalachian forest regions. Major centers of grassland study are at the Santa Rita Experiment Station near Tucson, Arizona, and the Jornada Experiment Station, both in semidesert types, the Central Plains Experimental Range near Nunn, Colorado, in the short-grass type, the U. S. Range Livestock Experiment Station near Miles City, Montana, in the mixed-grass type, and at the San Joaquin Experiment Station, O'Neals, California, largely annual ranges. Other research work on grasslands is conducted in shrub or forest vegetation types, where grass is a secondary but important component.

In addition to the work of the Forest Service of the U. S. Department of Agriculture, a number of other organizations are working actively in this field. Universities and colleges throughout the midwest and western states have long had an interest in the grassland resources of the region. Many careful and important grassland research studies have been carried out at these schools, notably at the University of Nebraska, Iowa State College, Fort Hays Kansas State College, the University of Utah, and the State College of Washington.

The state agricultural experiment stations have shown much interest in the problems of grassland management, especially where grassland management is an important factor in the economic life of the state. The Bureau of Plant Industry (now B.P.I.S.A.E.) of the U. S. Department of Agriculture early began studies of grassland management and, with their present program of grass breeding and selection and grazing studies, are making contributions of immense importance to grassland management and restoration. The work of the Northern Great Plains Field Station at Mandan, North Dakota, carried on in co-operation with the North Dakota Agricultural Experiment Station and of the Southern Great Plains Field Station at Woodward, Oklahoma, is outstanding in this respect. The Bureau of Animal Industry has also carried on investigations to determine the grazing value of native grasslands and has co-operated actively with other agencies in this work.

The Soil Conservation Service has done much to call attention to the necessity of good management of our grassland resources and has implemented the application of good management practices to the land. It has also actively promoted a widespread program of grass adaptation trials, breeding, selection, and improvement designed to make available adapted grasses for reseeding.

The Production and Marketing Administration (formerly A.A.A.) of the U. S. Department of Agriculture has performed an important function in advancing the application of good management to our grassland resources. In addition to its program of providing funds to individual operators to aid them in applying good management practices, developing watering facilities, and seeding adapted grasses, it has stimulated the individual rancher to get out on his range and actually observe its condition, trend, and utilization. The individual interest developed in the basic grassland resource by this means will be of great importance to the conservation of our grasslands.

Scientific Research and the Grasslands

Scientific societies, especially the Ecological Society of America, the American Society of Agronomy, the American Society of Animal Production, the American Society of Dairy Science, and the Society of American Foresters, through their journals have done much to advance scientific research on our grassland resources. The Ecological Society and the American Societies of Agronomy, Animal Production, and Dairy Science have had committees working on different phases of grassland research, particularly on the refinement of research methods.

Certain principles and methods are essential in the research and the application of research to grassland improvement and management. One of the first requirements is knowledge of the floristic composition of the area under study, the variations in this composition throughout the area and from year to year, as well as the reasons therefor. The influence of climatic factors from year to year and the effects of various intensities of grazing by livestock should be determined. The growth habits and life histories of important species must be understood. This study of the community of grasses and intermingled herbs and shrubs is more complicated in natural grasslands than in pastures on cultivated land, which can be plowed up and reseeded when they become unproductive. But in the natural grasslands, especially in the rangeland in the western half of the United States, improvement usually depends upon what can be done with the species growing in the community. Considerable work has been done in analyzing, classifying, and mapping grassland types, but much less has been accomplished in determining the relationships of types and species to variations in soil, climate, and other environmental conditions. Long-continued studies, such as those of Dr. J. E. Weaver and associates on the grasslands of Nebraska and Kansas, are essential because of climatic changes, which were particularly pronounced during the decade 1930–1939 with consequent great effects upon the vegetation. Thorough analyses of the vegetation in relation to all environmental factors, including grazing, continued indefinitely, are required as a basis for scientific management.

Investigation of the community has led to intensive study of important individual species, such as buffalo grass, grama grass, wheatgrass, needlegrass, and bromegrass. Research on habits, palatability, productiveness, nutritive value, and genetics started first with such cultivated species as timothy, Kentucky bluegrass, orchard grass, perennial and Italian rye grasses, and smooth bromegrass. Not only are the habits of these species well known, but leafy hay strains and pasture strains have been developed for various situations and for productiveness at different seasons of the year. This type of work for range grasses was greatly advanced during the period 1930–1945, particularly by the Soil Conservation Service and the Bureau of Plant Industry. New methods of collecting, threshing, and preparing the seeds of range grasses so that they may be seeded with an ordinary grain drill have been developed.

It was found that a hammer mill removes the undesirable awns, hairs, and other appendages which prevent the seeds of many of the grasses from feeding readily through a drill. This type of treatment was especially effective with the seeds of the needlegrasses, bluestems, blue grama, Canada wild rye, Indian ricegrass, and switchgrass, and even the seeding properties of crested wheatgrass and bromegrass were improved by processing with the hammer mill. The development of this method of processing grass seeds has made it possible to reseed many desirable species that otherwise could have had only limited use.

Much attention was also devoted to the study of methods of seeding grasses so as to secure stands under a wide variety of conditions, particularly on erosion areas. With the background of knowledge based on these studies many of the hazards of establishing grass seedings have been overcome or greatly reduced.

Selection and breeding programs have resulted in the production of a number of desirable strains for both pasture and hay (Fig. 6). A taller-growing buffalo grass that carries the seed burrs at higher levels has been produced. Selections of Canada wild rye that are leafier and remain green longer

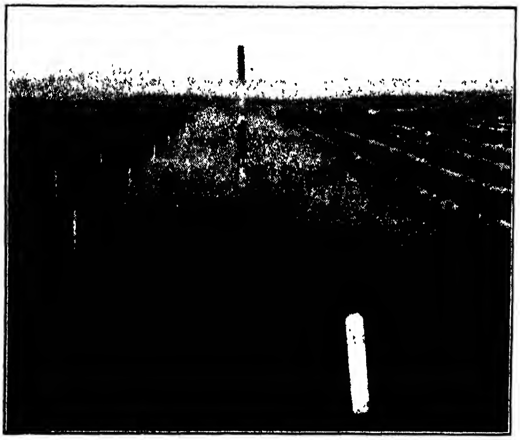

FIG. 6. An active program of breeding and selection of grasses is resulting in the development of many superior strains of both native and introduced grasses. The photo shows a selected strain of switchgrass in the grass nursery at the Northern Great Plains Field Station. (Soil Conservation Service.)

in the season have been released. Superior strains of side-oats grama and of switchgrass are now available. The wheatgrasses have provided several species and strains that have much promise for seeding under a variety of conditions, and the *Agropyron-Triticum* crosses have produced some forage hybrids that are likely to be of considerable value. The needlegrasses, too, especially *Stipa viridula* and *Stipa pulchra,* have contributed new material for selection and breeding. The program of selection and breeding with the native grasses is still new, and the major results of recent experimentation are yet to be realized.

Under the grass adaptation program which was begun in the 1930's, thousands of accessions, many from foreign countries, were grown under a wide variety of climatic and site conditions. From these widespread adaptation trials much knowledge of the adaptive ability of many native and introduced species and strains has been gained. From the results of the adaptation trials a number of species and strains have been selected for further study and improvement.

Competition among the Grasses

Much remains to be learned about the competitive relationships between different kinds of grasses and forbs under different conditions of soil, climate, and grazing. Usually plants of similar life form compete most intensely with each other for the necessities of life, so that, in the mixed prairie, wheatgrass with its erect growth, rhizome habit, and more directly penetrating roots from a few stalks succeeds in living in association with grama grass with its mat or small clumps and more spreading roots. Qualities that are advantageous in competition during dry years are resistance to desiccation, capacity to store moisture, and a deeply penetrating root system. In 1934 and 1936 western wheatgrass, grama grass, buffalo grass, western needlegrass, and other species survived even though the growth was only one-half to one inch in height over wide areas.

Interrelationships between Animals and the Grasses

Much also remains to be learned about the complete interrelationships between rodents, such as the ground squirrels, prairie dogs, kangaroo rats, and jack rabbits, carnivorous animals, such as the ferret, weasels, badger, coyote, and kitfox, and domestic livestock and the range grasses. Several studies show that the chief food of coyotes consists of rodents and carrion and that insects form an important part of their diet. Under certain conditions some kinds of rodents are more valuable than harmful because of their beneficial influence on the soil, their insectivorous habits, and the fact that they serve as food for valuable furbearers. It has been suggested that it might be possible to develop systems of rodent control by carnivorous animals, coupled with prevention of overgrazing by domestic livestock. Evidence is accumulating that some kinds of rodents increase in numbers under overgrazing. For example it has been reported by ecologists that the banner-tailed kangaroo rat in Arizona is more abundant on weedy range land than on well-grassed areas because the former provides a more abundant crop of seeds for food. Jack rabbits have also been reported to be more numerous on poor than on good range. Similar relationships have been observed for certain species of grasshoppers, which are able to injure range vegetation only under conditions of overgrazing. Since many wild animals may be more valuable than harmful in grasslands, ecologic and economic studies by well-trained scientists should be made before eradication campaigns are initiated, so that all the resources of the grasslands will be fully understood and, therefore, utilized to best advantage. It is easy to upset the intricate network of relationships, called the balance of nature, but very difficult to make adjustments after some essential elements in the network have been lost.

Restoration of the Range Grasslands

A number of cultural methods are now being used to improve range grasslands, such as contour furrowing, diversion and spreading of drainage water to areas where it will be absorbed by the grassland, application of fertilizers, destruction of shrubs such as sagebrush by burning, mechanical grubbing, or flooding, various tillage operations to hasten natural succession, fencing, and control of distribution of livestock by establishment of appropriately placed salting spots and water holes. The stockman who has no inclination for any improvement work except what he can do on horseback is rapidly becoming out-of-date. The farmer frequently walks out over his fields of wheat, potatoes, corn, cotton, etc., to examine their condition. He can readily evaluate the progress of the growth of each kind of crop because he can see the individual plants. But in grassland this is much more difficult because of the greater density of the vegetation and because of the small size of many individual plants. In order to facilitate the "sizing-up" of the grassland the stockman and administrator should have a number of small, staked sample areas which he examines periodically in order to discover the minute but highly significant changes that denote improvement or deterioration. In order to do this the stockman must know thoroughly the plants growing on his range even when they have no flowering stalks. This may seem difficult to do at first, but the technique can be readily acquired, especially if it is realized that these plants are the raw materials of the livestock industry. Some well-illustrated bulletins published by the U. S. Department of Agriculture are useful as guides in judging the condition of rangelands. Maximum values can be derived from our grasslands only by the application of thorough understanding of the nature of this important resource. To attain maximum values calls for continued research and, also, increased attention to the application of research findings to practical utilization.

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CHAPTER 8

Reclamation of Wet and Overflow Lands

OUR arable lands may be extended by irrigation of arid areas or by drainage of wet lands. These wet lands constitute the country's greatest reserve of agricultural land that is economically available when the pressure of population makes it desirable to draw upon it. In general, the term includes any land that normally has so much water in the soil that the land cannot be used for agricultural purposes. Such areas vary from swamp conditions to land that is too wet for use other than pasture, too wet during some years, or too wet during part of a growing season. Any planned economy designed for the general welfare of the nation should include some practicable system of reclaiming wet lands as large areas of these lands are potentially highly productive and capable of sustaining a large population.

DISTRIBUTION OF WET LANDS

Location and Types

Wet lands are found in every state, but by far the greater portion is in the eastern half of the country, associated with its spacious plains areas which are now highly productive and which sustain a large population. In general, wet lands fall into four classes on the basis of origin and location. The coastal swamp and wet prairie lands are found chiefly along the Atlantic and Gulf coast from Chesapeake Bay to southern Texas; the most extensive alluvial bottomlands are in the lower Mississippi basin south of the mouth of the Ohio River; the glacial swamp and wet lands are included chiefly within the Great Lakes states; and those seepage lands commonly associated with irrigation enterprises and also some river overflow and coastal lands are in the western half of the United States. The potential value of these wet lands for agricultural purposes is highly varied, as the soils range from high to low fertility. As a rule the areas having good soil that could be drained at relatively low cost have been reclaimed first and are now in use. Numerous factors have contributed to the delay of reclamation and utilization of the remainder of the wet lands, such as low fertility, cost of clearing cutover lands or timbered land, high cost of protection from river or tidal overflow, need for large-scale and costly ditch construction, and decrease in the value of agricultural land and agricultural products.

Drainable Land

Figure 1 shows the location of wet lands that are considered physically available for drainage. It is estimated that the drainable area in the United States is 91,000,000 acres.

By George J. Miller of Indiana University.

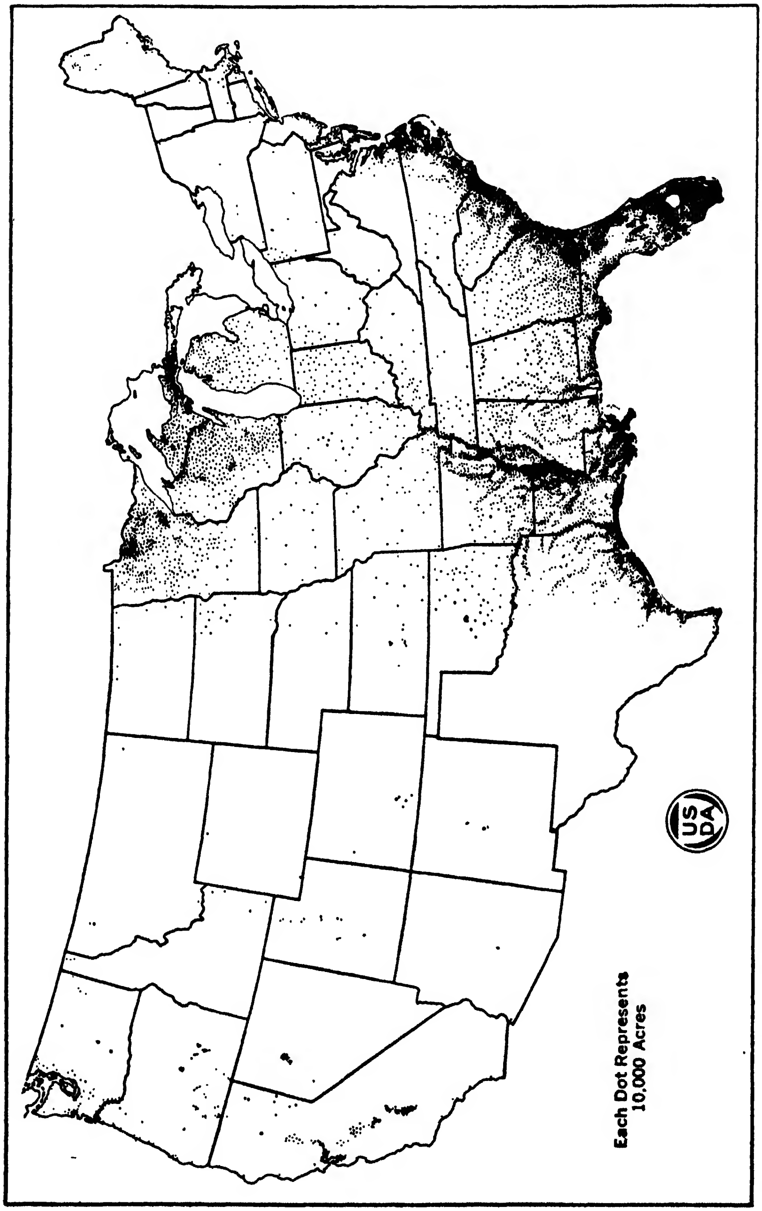

FIG. 1. Approximate location of drainable wet lands. The physically drainable raea is about 91,000,000 acres, but it is estimated that only approximately 75,000,000 acres can be drained at a cost that would justify its use for cultivated crops. (U. S. Department of Agriculture.)

When deductions are made for areas of deep peat and coastal marsh lands unsuitable for crops, it is probable that not more than 75,000,000 acres can be reclaimed at a cost that would justify drainage for cultivated crops. Although an increase in market value of crops relative to cost of drainage and maintenance might raise this estimate, let us assume the smaller figure as the practical one; it represents an area as large as the combined area of New York, New Jersey, Pennsylvania, Massachusetts, Connecticut, and Rhode Island, an area nearly as large as Italy, or the British Isles, or nine times that of the Netherlands, which now supports a population of more than 9,500,000 people. Of the total drainable land some is now utilized for pasture or for crops in favorable years, but a large proportion is swamp or timberland not yet used for agricultural purposes. Approximately 68 per cent of the area requires clearing of trees, stumps, or brush. Most of the soil would be highly productive when drained, but in some of the areas the soils are of low fertility or the soil texture is not favorable for crop production. About two-thirds of the land requiring drainage is located in the south, and one-half of the remainder is in Michigan, Wisconsin, and Minnesota. Much of the wet land in these states is peat bog without tree growth. In the south, except the tidal marshes, Gulf coastal prairies, and the Florida Everglades, and prairies, practically all the wet lands need both draining and clearing.

It is estimated that one-third of the drainable wet land may be drained at an average cost of $30 an acre.[1] However, the total cost to the individual owner would be increased in proportion to the cost of clearing the land, of farm ditches, buildings, roads, and other necessary improvements. Drained lands have certain marked advantages in that there is very little waste land, the loss by erosion is at the minimum, and such lands are relatively little affected by drought. It may be desirable from the standpoint of both individual and public welfare to transfer many farmers from some of the poor, hilly, upland farms to the productive drained land. Many of these poor upland farms offer no possibility of providing adequately for those who endeavor to cultivate them. Such abandoned farms could then be used for purposes to which they are best adapted. However, no drainage or transfers should be undertaken without adequate evidence that the probable return from the reclaimed land and the improved living conditions justify the cost. Action should be taken only after scientific investigation and careful planning based on a broad view of the problem and of the general welfare. If this is done, many of the unfortunate mistakes of the past will be avoided. We should also be sure that the value of the wet land as wildlife refuges and for recreational purposes is not actually greater, from a long-time viewpoint, than the value of that land for agricultural purposes. Evidence at hand indicates that by 1960 at least 10,000,000 acres now too wet for crops will have been drained. It is also estimated that approximately 17,000,000 acres of marshland, having little or no agricultural use, should be set aside as refuges for migratory waterfowl

THE PURPOSE OF DRAINAGE

The chief purpose of most drainage enterprises thus far undertaken has been to remove a surplus of water from lands in order that they may be used for agricultural purposes. In general, the purposes

[1] Pre-war estimate.

are to drain land already in farms and swampland that is unfit for use without removal of the surplus water, to prevent damage from seepage and alkali in irrigated areas, to prevent overflow on agricultural land, and to reduce the losses from floods, particularly along rivers or tidal marshes. All other purposes of drainage have thus far been largely secondary.

In the north central states the chief purpose has been the drainage of wet lands in cultivation so as to increase crop production. However, these states, especially Wisconsin, Missouri, and Minnesota, have extensive enterprises for the reclamation of swampland, and others for the prevention of overflow along numerous streams, as in Illinois and Kansas.

Most of the lands being reclaimed from swamp conditions are located along the Atlantic and Gulf Coastal Plains from Virginia to Texas, in the delta of the Mississippi, in Wisconsin, and in northern Minnesota (Fig. 2).

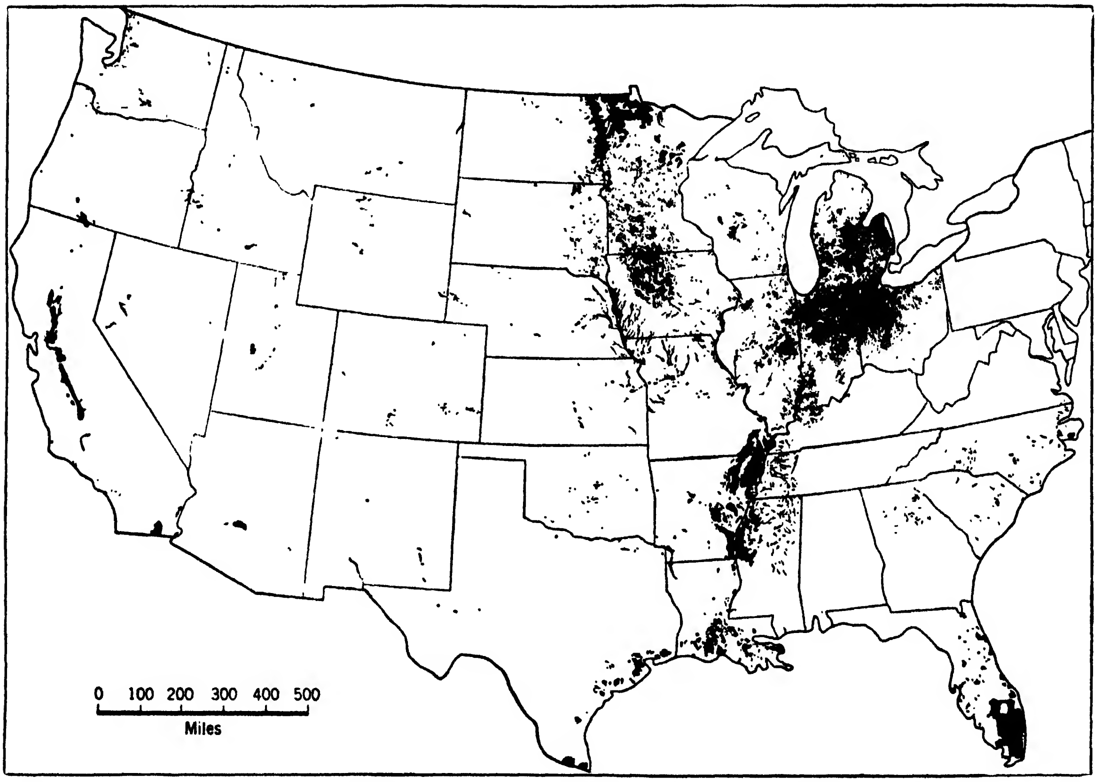

FIG. 2. Location of drainage enterprises. Nearly two-thirds of the land in drainage enterprises, in the thirty-eight drainage states, is north of the Missouri and Ohio rivers. (United States Census.)

The removal of seepage and alkali resulting from irrigation is the principal purpose of drainage in the western mountain states and of some enterprises in the Pacific states. However, reclamation of wet and swamplands has made progress in California and Oregon, and Washington has considerable areas where the primary purpose of drainage is the improvement of land in farms.

Enterprises designed to provide protection against overflow are located chiefly in the river bottoms of the central states, the Piedmont section of the South Atlantic states, the Great Valley of California, and the coastal sections of Washington and Oregon. Much of this land was in cultivation before drainage, but crop losses have resulted from occasional overflow.

PROGRESS IN RECLAMATION

State Ownership and Regulation

Under laws passed by Congress in 1849 and 1850, the federal government conveyed the swamplands to the states in which that land was located (Fig. 3). Most of this land has since passed to private ownership. At first most of the drainage was undertaken by individuals on their own farm land, largely by the construction of small ditches or by the use of tile. However, it soon became evident that satisfactory results could be obtained in many areas only by co-operative development of large units, as the main drainage ditches must pass through adjoining property, and the cost of large and long ditches was too great to be borne by an individual owner. This led many states to enact an extensive system of drainage laws so that co-operation among a large number of owners was possible and the cost could be distributed in proportion to the benefits derived. All such laws also take into consideration public welfare, such as increasing the taxable property, the betterment of public health, and improvement of public highways. The 1940 census reports 38 states having laws providing for an organized system of drainage. Removal of surplus water by drainage is legally possible in other states by individuals or by a group of individuals. The significance of the problem and public interest in drainage in the 38 states reporting drainage enterprises is indicated by the fact that the various laws in these states comprise more than 7000 pages. That public interest in the problem is evident from continued legislative activity. During the legislative sessions of 1925–1926, 79 additions were made to the drainage laws in 32 states; in 1927–1928, 121 drainage enactments were made in 35 states; and 95 statutes were added to the drainage laws in 1929. Although the state laws have many things in common, they differ to meet specific needs of the state and the type of drainage, e.g., drainage of land in farms, drainage related to flood control as well as reclamation of agricultural land, drainage of swamplands, and protection from seepage and alkali in some irrigation areas. In general, they also provide that the cost shall not exceed the benefits to be derived from the land reclaimed and that a method of assessment shall be established that will meet financial obligations. Under these laws 38 states now have 86,967,000 acres in organized drainage enterprises, representing an investment of $691,724,000 and an annual maintenance and operating cost in 1940 of $5,996,000. The latter figure averages seven cents an acre for the total acreage reporting and 19 cents for the acreage making the expenditures.[2] This huge development is distributed through 39,597 organized drainage enterprises [3] (Tables 1 and 2).

Drainage data for the 10 states reporting no organized enterprises are probably only approximate.[4] It is likely that such drain-

[2] Federal assistance was also provided.

[3] Without duplication.

[4] The states not reporting organized drainage enterprises are Connecticut, Maine, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Virginia, and West Virginia.

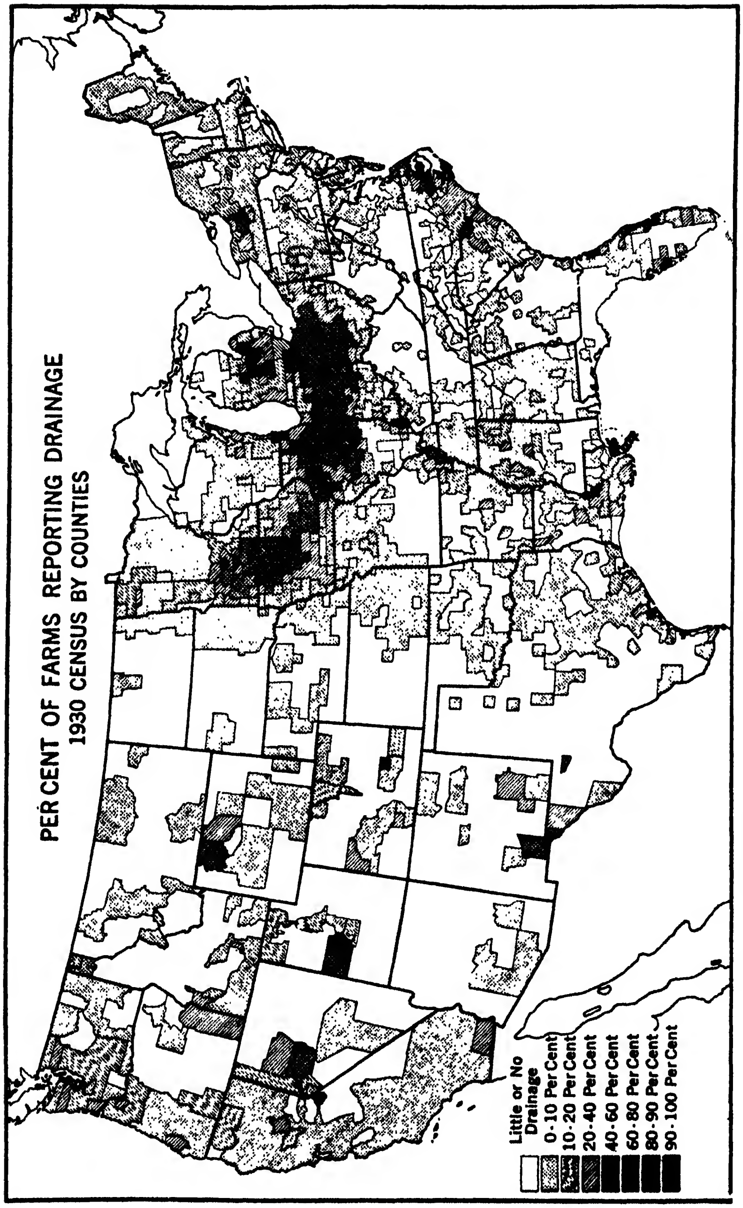

FIG. 3. Percentage of farms reporting drainage. (National Resources Board.)

age is confined chiefly to land in farms and has been provided by individual owners. In 1940, approximately a million acres of farmland were provided with drainage in these states. (See Figs. 3 and 4.) Some of these states have large areas of drainable land.

TABLE 1

LAND AND CAPITAL, BY PURPOSE OF DRAINAGE, 1940

[Source: Bureau of the Census.]

	Land		*Capital Invested to Jan. 1, 1940*	
	Acres	*Per Cent*	*Dollars*	*Per Cent*
All enterprises	86,967,039	100.0	691,724,519	100.0
Improvement of land already in farms	62,128,311	71.4	418,544,038	60.5
Reclamation of swampland not previously in farms	13,635,030	15.7	131,149,703	19.0
Protection against overflow	6,751,044	7.8	99,169,737	14.3
Removal of alkali or seepage from irrigation	4,452,654	5.1	42,861,041	6.2

Method of Organization

As previously stated, the drainage laws of the various states are designed to meet the specific needs existing in the states, and hence the methods of organizing drainage enterprises vary accordingly. In many states the legislatures have conferred the authority upon county, district, or circuit courts; in some states the authority to organize drainage districts is vested in the governing body of the county in which the larger portion of the proposed enterprise is located; in other states the clerk of the superior court is vested with the authority, or boards of drainage commissioners have jurisdiction. In 1940 approximately 94 per cent of all enterprises were either organized drainage districts having their own independent officers, or state, county, or township enterprises under control of public officials.

Of the 86,967,000 acres in organized drainage enterprises in the thirty-eight drainage states, 53 per cent was developed by the county method of organization. These enterprises represented 40 per cent of the capital investment. This type of organization is dominant in the north central states and is more common in those states where systematic drainage first began. It is probably best adapted to small enterprises

TABLE 2

PERCENTAGE OF ACREAGE IN ENTERPRISES ACCORDING TO METHOD OF ORGANIZATION (38 STATES)

[Source: Bureau of the Census.]

					Irrigation				
Groups of States	*District*	*County*	*Township*	*State*	*Federal*	*Non-Federal*	*Commercial*	*Individual*	*Others*
East north central	17.0	82.2	0.6	*				0.1	0.1
West north central	17.0	78.7	0.1	2.6	1.2		*	0.4	
South Atlantic †	98.0	0.5					0.1	1.4	
East south central	86.6	12.2						1.4	
West south central	91.8	1.5			0.6	2.0	0.5	3.6	
Mountain	31.3	0.2			44.6	22.1	*	1.8	
Pacific	45.7	0.1	0.2		10.4	40.9		2.7	
38 drainage states	40.0	53.0	0.3	0.7	2.2	2.6	0.1	1.0	*

* Less than 0.1 per cent.

† Includes two enterprises in Alabama and two in Virginia.

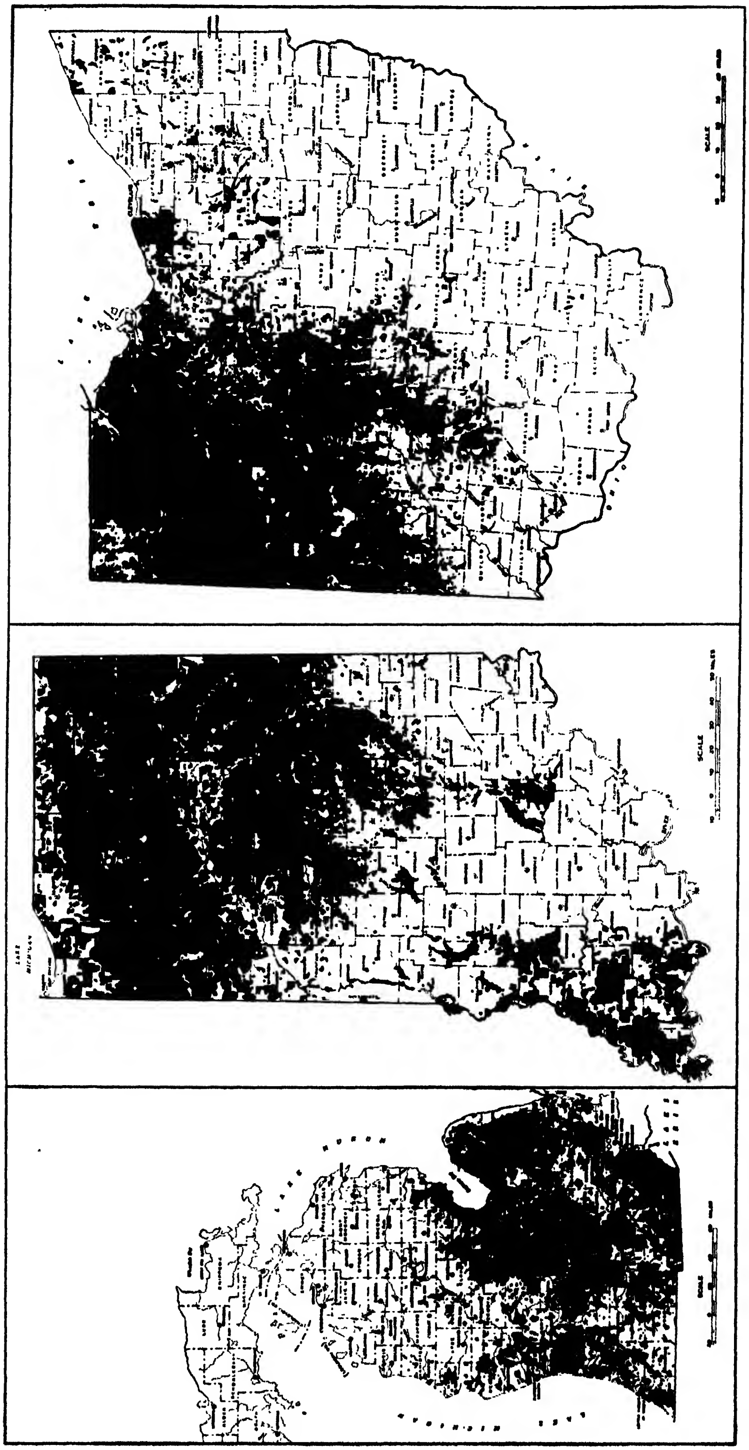

Fig. 4. Land in drainage enterprises in Michigan, Indiana, and Ohio. Michigan has 25 per cent of its land area in drainage enterprises, Indiana, 44 per cent, and Ohio, 29 per cent. (After United States Census.)

having relatively simple drainage problems. (See Table 2.)

The drainage district type of organization contains 40 per cent of all land in drainage enterprises and has 54 per cent of the capital investment. This method is well adapted to large enterprises that must establish long-time credit, with complex drainage problems that may be better handled for the whole planned area, and with one set of officers who may carry on the enterprise. This is the dominant type among the major drainage enterprises of the south.

In the Pacific and mountain states, many of the drainage enterprises are associated with irrigation districts, irrigation and drainage being coextensive in area.

Individually owned drainage enterprises are numerous and vary from the installations on a small farm to those of several thousand acres. The larger individually owned enterprises are in the Cotton Belt of the south, where many cotton plantations each containing more than 500 acres are privately drained. The largest acreage of individually owned drainage projects is in Louisiana.

Growth of Organized Drainage

Although drainage of wet lands on a small scale was undertaken early in our history, the era of rapid expansion occurred during the years 1905–1924. Approximately 70 per cent of the acreage of land in drainage enterprises was added to the total during that 20-year period. The spur of high land values and high prices for agricultural products stimulated rapid development and overexpansion, resulting in a vast acreage of unoccupied and undeveloped land. Decrease in land values and a decline in the prices of agricultural products left a very small market for the unsettled drainage areas and a correspondingly high cost of maintenance on the land occupied by farms. Though many of these enterprises were ill-advised and should not have been undertaken at the time, they do not represent a complete loss as the land that is suitable for occupancy will ultimately be settled. It is estimated that 4,569,000 acres are now available for settlement. More than three-fourths of the entire area was classified as improved land in 1940; 21.6 per cent, as idle; eight per cent, as unfit for crops owing to inadequate drainage; 12.6 per cent, as woodland; and about 9.8 per cent, as other unimproved. Most of the idle land was swampland in Wisconsin, northern Minnesota, and the south. In such land, settlement advances slowly after the principal drains are constructed. (See Table 3.)

Drainage in the Great Lakes Region

Reclamation of wet lands has been carried on extensively in the Great Lakes states. The retreating ice of the Wisconsin stage of glaciation distributed the glacial drift very unevenly, thus forming many large and small depressed areas without natural drainage lines. In some of these undrained depressions extensive swamps developed, especially in northern Minnesota and Wisconsin; in others the glacial till, which varied from heavy, stiff clay to sandy loam, remained too wet for agriculture without artificial drainage.

A large portion of northwestern Minnesota was covered by glacial Lake Agassiz. In general this ancient lake bed varies from very flat to gently rolling land with shallow depressions and was originally largely forest-covered. However, there are also many much deeper depressions of vast areal extent in the waters of which there de-

TABLE 3

GROWTH AND CONDITION OF LAND IN DRAINAGE ENTERPRISES, 1940

[Source: Bureau of the Census.]

Date of Organization	*Land in all Enterprises* *		*Land in Enterprises*					
			Condition of Land					*Land Available for Settlement*
			Improved Land		*Woodland*	*Other Unimproved Land*		
	Acres 86,967,039	*Per Cent* 100	*Acres* 67,389,440	*Per Cent* 77.5	*Acres* 11,042,630	*Acres* 8,534,969		*Acres* 4,569,205
Before 1870	171,349	0.2	132,471	77.3	33,741	5,137		4,800
1870–1879	427,759	0.5	373,450	87.3	35,197	19,112		2,086
1880–1889	2,429,435	2.8	2,173,456	89.5	146,062	109,917		7,882
1890–1899	3,742,588	4.3	3,255,998	87.0	383,194	103,396		20,016
1900–1904	5,769,509	6.6	5,133,782	89.0	452,894	182,833		23,575
1905–1909	12,191,576	14.0	10,304,430	84.8	1,054,964	796,182		416,383
1910–1914	19,573,521	22.5	12,281,391	62.7	3,168,872	4,123,258		1,404,267
1915–1919	18,012,061	20.7	14,067,404	78.1	2,589,708	1,354,949		1,241,830
1920–1924	11,272,180	12.9	8,848,443	78.5	1,680,122	743,615		762,204
1925–1929	7,410,814	8.5	6,187,542	83.5	736,562	486,710		321,089
1930–1934	2,092,568	2.4	1,787,467	85.4	205,599	99,502		14,863
1935–1939	3,873,679	4.4	2,807,606	72.5	555,715	510,358		350,210

* Land included in more than one enterprise is included in the last organized.

veloped great peat swamps or "muskeg." The reclamation of these swamps required drainage operations on a large scale, and here we find the only state drainage projects in the north central states. Drainage was stimulated by the high prices for land and agricultural products. Similar swamp conditions and ill-advised drainage efforts are found in the peat and sandy soil swamps of central Wisconsin, where some of the enterprises have been abandoned and the area returned to swamp. The deep peat soil was found to be poor for agricultural purposes because of deficiency in certain mineral plant foods essential to successful crop production. Peat soils are also susceptible to killing frost during the growing season and to fire during the dry season. Such peat fires destroy the humus covering, necessitating more drainage and increasing the difficulties of the farmer. Under drainage some of these areas returned to swamp condition through depletion of the organic material and compaction of the soils. In effect the surface of the soil was lowered to or nearly to the watertable, and as a result the land again required drainage. These conditions have led to tax delinquency and

TABLE 4

DISTRIBUTION AND STATUS OF DRAINAGE ENTERPRISES

[Source: Bureau of the Census.]

Groups of States	Number of Enterprises	Acres in Enterprises	Per Cent of Total	Per Cent Improved	Per Cent Available for Crops	Per Cent Unfit for Use	Acres Available for Settlement
East north central	32,014	32,682,172	37.6	89.2	94.6	2.0	10,460
West north central	7,106	23,468,623	27.0	85.0	94.9	2.5	1,008,960
South Atlantic *	941	7,435,448	8.5	24.2	47.6	44.3	1,687,700
East south central	710	3,957,480	4.5	65.6	63.0	20.2	93,599
West south central	918	13,228,858	15.2	63.9	77.8	11.3	1,536,529
Mountain	256	2,772,730	3.2	86.9	91.1	4.0	66,136
Pacific	418	3,421,728	3.9	88.2	85.5	4.9	165,821
38 drainage states	39,597 †	86,967,039	100.00	77.5	86.2	8.2	4,569,205

* Includes two enterprises in Alabama and two in Virginia.

† Without duplication.

reversion of some of the land to the state or counties. In the flat, fertile lands of the Red River valley drainage is needed over extensive areas of farmland. Development of drainage, however, must be associated with conservation of groundwater for stream maintenance and domestic purposes. The area presents a number of complex and interesting problems.

Nearly two-thirds of the land in drainage enterprises in the 38 drainage states is north of the Missouri and Ohio rivers. Exclusive of large swamp areas in Wisconsin and northern Minnesota, most of the land was in farms before regularly organized drainage enterprises were established. With the exception of the state drainage projects in northern Minnesota, most of the enterprises are small compared to those in the southern states, being 500 acres or less. The five states of Minnesota, Indiana, Michigan, Illinois, and Ohio have approximately 42,000,000 acres in drainage enterprises, or nearly one-half the total for the United States. A high percentage of the drained land is improved. Much of the unimproved land is included in the peat and sandy soil swamp areas of northern Minnesota and Wisconsin (Table 4). Most of the northern half of Indiana, the Maumee Plain of northwestern Ohio, and the southern part of Michigan are relatively flat or gently rolling with extensive areas of ancient glacial lake beds. Here the practice of draining excess water from farmland is widespread. Indiana has 44 per cent of its area in drainage enterprises; Ohio, 29 per cent; and Michigan, 25 per cent (Fig. 4). Drainage in this area has been installed primarily to improve the productivity of land already in farms. A similar reason accounts for the drainage in north central Iowa and much of the land of central Illinois. The Great Lakes states have more than 1,000,000 acres available for settlement in the present drainage enterprises, which represents an area four-fifths as large as the state of Delaware. This constitutes a reserve much of which will come into use as the need for additional agricultural land arises. Most of the crops suitable to the latitude may be produced on these lands.

Lower Mississippi Basin Region

South of the mouth of the Ohio River is a vast area of overflow alluvial river-bottom and delta land (Fig. 5). Much of this land will be highly productive when drained. Other areas should be reserved as wildlife refuges. At present 60 per cent of the population of the basin live in the alluvial plain, and 40 per cent on the uplands. A much larger population can be supported on the fertile lowlands, and at a far higher standard of living than now prevails, if adequate flood protection and drainage are provided and a better system of land tenure is established for the settler. About a third of the land now protected from flood is unoccupied because of inadequate drainage. Drainage is essential, not only for agriculture but also to prevent water pollution and provide sewage disposal.

The reclamation of these lands is associated with development of navigation on the Mississippi River and with protection from floods. Before the construction of levees, approximately 20,000,000 acres were subject to overflow, an area about equal to South Carolina. About three-fourths of the area is swampland, timberland, and lakes. Less than a fourth is now used for any form of cultivation. Work in progress under the Flood Control Project authorized by Act of Congress in 1928 will give flood protection to approximately 13,000,000 acres. This leaves 7,000,000 acres subject to inundation at intervals varying from one year in three to one year in fifteen. Of the 7,000,000 acres, approximately 4,400,000 are situated in the lowlands below the mouth of the Arkansas River on the west side of the Mississippi River and will receive the same protection from the existing levees at the heads of the basins as heretofore. These 4,400,000 acres comprise the land embraced in the Boeuf and Atchafalaya floodways and the Red River backwater area. Other areas that are subject to overflow and that are not likely to be reclaimed include (1) the backwater areas at the mouths of the Arkansas, White, Yazoo, and St. Francis rivers; (2) the narrow strip of land lying between the highlands and the river and extending from above Memphis to Baton Rouge on the east side of the river where the amount of land reclaimed would not justify levee construction; (3) a strip of land about five miles wide extending from near Cairo to near New Madrid on the west bank of the river. This area is likely to be flooded about once in ten years. Reclamation of these lands for agricultural purpose, as a primary objective, would not be justified.

After the disastrous flood of 1937 along the Ohio River, the Soil Conservation Service made a survey to determine the amount of sediment damage within the floodplain, covering both urban and rural areas. This survey showed that the flood covered 812,000 acres of the Ohio River floodplain between Pittsburgh and Cairo and 764,000 acres along the various tributaries. Thus 1,576,800 acres were flooded within the Ohio basin, an area that is approximately 1.2 per cent of the total area of the basin. Of the flooded area along the Ohio River, 89,000 acres were in urban areas and the remainder in rural. It is unlikely that such an extensive flood will occur more frequently than once in a century. However, the river bottomlands are flooded at least once a year. These lowlands include swamp- and marshland that might be reclaimed for cultivation if there was urgent need for more agricultural land. The reclaimable area, however, is estimated to be considerably less than 55,000 acres. It

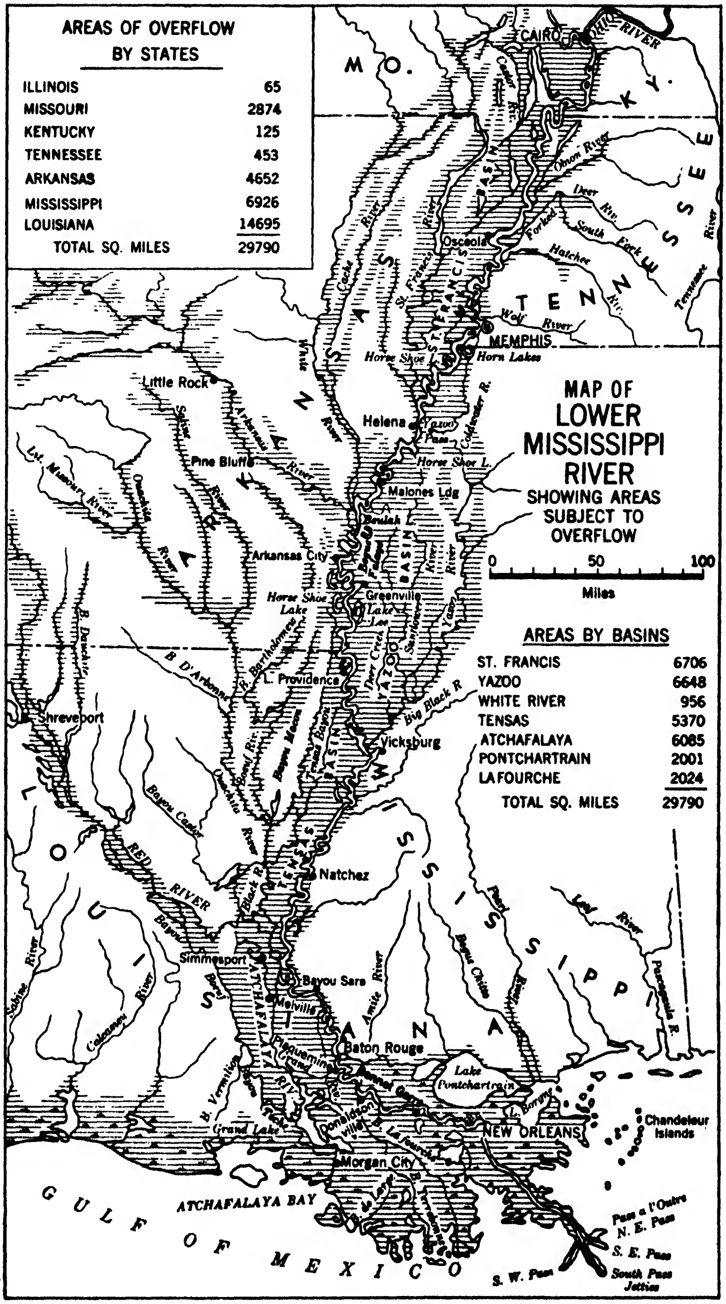

FIG. 5. The Lower Mississippi basin flood control and reclamation area. The primary purpose is flood control. However, prevention of floods, combined with drainage, will make permanently available a large acreage of fertile agricultural land. (Mississippi River Commission.)

is estimated that more than 90 per cent of the overflow land is now under cultivation.

GAINS AND LOSSES FROM DRAINAGE

The gains that may be expected from drainage accrue chiefly from the increased value of the land, the value of the products to be obtained from the drained land, the ability of the land to provide homes and to sustain an increased population, and from benefits that may be classed as public welfare such as elimination of insect-infested swamps. It is well known that swamplands are a favorite breeding ground for the malaria-carrying mosquito. From the standpoint of health the elimination of the disease-carrying mosquito from regions of human habitation would be of inestimable value.

Present drainage enterprises in the 38 drainage states have cost an average of $8 an acre. The highest acre cost has been in the Pacific ($24) and the western mountain states ($12.63); the lowest, in the east north central states ($6) and in the west south central states ($6). If we assume such reclaimed land to have an average value of $60 an acre, the total value becomes a huge figure. Even though it seems idle to speculate in such matters, it is interesting to contemplate the average annual crop production that might be expected from these lands and the millions of people who might find homes upon them. It is, however, equally idle to assume that this vast acreage of wet land will be reclaimed in the near future. The supply of agricultural land that is usable without further drainage is adequate for present needs. No new enterprise should be undertaken without the assurance that the benefits to be derived from drainage will justify the cost. Further, losses from drainage of some of the swamp areas may be greater than any gain. Some of the areas already drained were formerly splendid wildlife refuges and breeding grounds. Their present agricultural value is unimportant in comparison with their value in their natural state. It should also be borne in mind that some of these areas have a high recreational value for the hunter and the nature lover and provide excellent plant and animal habitats for scientific study.

SUMMARY

When the pressure of population upon the productive lands becomes sufficiently severe, either in the nation as a whole or locally, the drainable wet lands of the United States will be reclaimed. There should be a genuine need for such land before extensive reclamation is authorized. At present these lands represent one of the great potential assets of the nation. The development of such lands in other countries, like the Netherlands, indicates what may be done and the crop production that may be expected. The 86,967,000 acres at present in drainage enterprises is ten and one-half times the entire area of the Netherlands, including both its drained and undrained area. The assumption that any wet, swamp-, or marshland is suitable for agriculture when drained has led to the undertaking of many unwise drainage projects, and consequent disappointment and loss. Some of these enterprises should be abandoned and the swampland utilized for more appropriate purposes such as forests, wildlife refuges, or marsh-hay land. The present enterprises include an acreage available for settlement nearly as large as the estimated needs for the next quarter century. Further developments should be based on clearly demonstrated need for cropland, public welfare service such as maintenance of health and prevention of floods, ample evidence that the probable returns from drainage will warrant the investment, and careful consideration of the possibility that the wet lands, especially swamplands, may be worth more to man if left in their natural state.

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CHAPTER 9

The Agricultural Prospect*

INTRODUCTION

THE development of agriculture in the United States has been marked by an increasing control over a rich land resource and obversely by a wasteful exploitation of the soils. The frontier of settlement, in a little more than two centuries, advanced across the mountains and the plains, across the forests and the prairies, and across the steppe lands and the deserts from the Atlantic seaboard to the Pacific. Progress was not steady or uniform but was characterized by surges of rapid movement alternating with filling in and consolidating the farm lands requisitioned from nature and the aborigines. Changes in the agricultural scene have reflected the progress of scientific advancement, the stultifying effect of depression, the uneasy peace between wars, the cataclysm of war itself, and the challenging opportunities of the post-war period of readjustment.

Agriculture in the United States today, both as an industry and as a way of life, is related to a variety of conditions. In the utilization and conservation of the land resources the agricultural prospect is linked inextricably with:

1. The trends and changing character of the population.
2. The production of farm products.
3. The level of living, particularly of the farm population.
4. The improvement in rural education and culture.

THE TRENDS AND CHANGING CHARACTER OF THE POPULATION

The agricultural situation at any particular time is closely attuned to the general economic condition of the nation as a whole. The economy is sensitive to both short-range and long-term changes in conditions. When the national economy experiences a wave of prosperity agriculture generally benefits also, though there may be some differences in timing. For example in the 1920's farm prices began a downward readjustment while industrial wages still showed little or no decline. In 1948 the prices of many farm products declined months before it was reflected in a lowering of the cost of living or before the decline in employment or in wages. All

* Based in large part on the chapter originally prepared by Dr. O. E. Baker for the first edition of this book. Dr. Baker was very generous in permitting the present author to use the original title and as much textual material as seems appropriate and useful at this time.

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important features of the nation's economy may not move forward simultaneously, but the general level of prosperity and economic progress has an important bearing on the agricultural industry and the farm population.

The total number of people of all ages that collectively makes up the population constitutes a large domestic market. The high standard of living and particularly the desire on the part of the people to improve their living conditions make the American market almost unequaled from the standpoint of its capacity to consume the products of agriculture and industry. Each person added to the population enlarges by one the market of the United States and at the same time or in due course will become a part of the labor force. Without reference to the character of the population the total number at any time has important market implications for agriculture. And the future of agriculture is closely related to the prospect that a growing population will provide an expanding market for the products of the farm.

Not only has the number of people increased steadily but also there have been internal changes in the population of major importance. The birth rate has displayed significant fluctuations; the death rate has declined steadily; and the national policy in respect to immigration has been subject to important changes. Advances in medicine and nutrition have added greatly to the life expectancy of the people, and as a consequence the median age of the population has risen slowly, reaching 29.7 in 1948. The population of the United States, subjected to these internal changes over a long period of time, takes on progressively new characteristics that must be examined critically from time to time so that agriculture and other economic activities may be adjusted to the new situation. The long-term planning for the proper utilization of the agricultural resources of the nation requires a full knowledge of the population conditions now and prospectively in the foreseeable future.

The Population Prospect

The population of the United States can be predicted for a few decades in the future with greater certainty than any other factor affecting American agriculture. This high degree of certainty is related to the fact that a very high proportion of the people now living will be counted by the census taker in 1960 and 1970. The birth rate, the death rate, and the net increase in the population can be predicted with great accuracy from year to year. It is much more difficult to make long-range forecasts of the future population because a number of disturbing factors may be introduced that may affect the total population in the future. The factors that may be of major importance in the long-range forecast of the total population include a change in the birth rate, the effect of epidemics on the death rate, a long war, and the policy of the federal government in respect to immigration.

The most stable of these three factors is the death rate. Birth rates, although variable from year to year, can be forecast for relatively short periods with sufficient accuracy to meet the needs of the school authorities and others interested in the number of children under five years of age in the population. There is less certainty about the number of immigrants who will be admitted to this country from year to year. After 1945 the restrictive regulations and other checks that had been in effect for 15 years were relaxed and increasing numbers have been admitted to this country. We, as a people, are committed to a policy of selection and consequent absorption of the immigrants into the population so that a degree of homogeneity will result, particularly in respect to an attitude toward American political institutions and traditions. In the middle 1930's, when the decline in the birth rate and the great reduction in immigration became important factors in forecasting the future population, there was a disposition on the part of the forecasters to envision a static or even a declining population a few decades hence. Much of this despair in respect to the population was not dispelled by the increased birth rate of the 1940's. Whelpton of the Scripps Foundation for Research in Population Problems at Miami University, Oxford, Ohio, has made a number of forecasts, varying the assumptions so that his estimates may express the implications of fertility, mortality, and immigration as they may affect the total population at five-year intervals from 1945 to 1975.[1]

The lowest forecast is based on low fertility, high mortality, and no immigration. The average annual increase in population would decline from more than a million at present to a net loss of over 100,000 in 1975. He estimated that the total population in 1975 under these conditions would be only 151,090,000. Under conditions of medium fertility, medium mortality, and a net immigration of 1,000,000 in each five-year interval the total population in 1975 would be 169,801,000. The highest forecast, assuming a high birth rate, low mortality, and a net immigration of 1,000,000 per five-year period, would increase the population to 185,071,000 in 1975. These are challenging forecasts and American agriculture must take note of the numbers of people counted by the census taker or estimated by the demographers.

TABLE 1

POPULATION FORECAST, 1945–2000

[Source: Whelpton, Bureau of the Census.]

Year	*Total Population*	*Average Annual Increase*	*Per Cent*
1945	139,621,000	1,515,000	1.12
1946	140,840,000	1,219,000	0.87
1947	142,186,000	1,346,000	0.95
1948	143,329,000	1,143,000	0.80
1949	144,457,000	1,128,000	0.78
1950	145,460,000	1,003,000	0.69
1955	149,840,000	876,000	0.59
1960	153,375,000	707,000	0.47
1965	156,692,000	663,000	0.43
1970	159,847,000	631,000	0.40
1975	162,337,000	498,000	0.31
1980	163,877,000	308,000	0.19
1985	164,532,000	131,000	0.08
1990	164,585,000	11,000	0.01
1995	164,177,000	−82	−0.05
2000	163,312,000	−173	−0.11

The accompanying table indicates that the rate of population increase is expected to decline during the next several decades. The population controls that reduced substantially the birth rate in the period between the wars are expected to re-assert themselves and re-establish the long-time downward trend in the rate of population growth. It is generally agreed that, among the several conditions that may be regarded as the traditional controls of the birth rate, the voluntary limitation of births is the most important. This variable factor in population growth is a significant control, but in forecasting the future population of the United States it is difficult to determine accurately its effect. As a consequence, any long-term estimate of the total population

[1] P. K. Whelpton, "Forecasts of the Population of the United States, 1945–1975," Bureau of the Census, Government Printing Office, Washington, D. C., 1947, p. 41.

should be reviewed periodically so that corrections can be made from time to time.

In 1945 Whelpton made estimates of the population in respect to color, nativity, age, and sex for the thirty-year period from 1945 to 1975. Forecasts of the total population were extended to the year 2000.[2] (See Table 1.) It became evident almost at once that his estimates would be too low for the early years of the forecast period. The rise in the birth rate in the late 1940's was greater than Whelpton had anticipated. With demobilization and the return of servicemen to their homes the marriage rate and the birth rate increased notably, and as a consequence his estimates were understandably too low for the first few years of the post-war period.

The Birth Rate

Shortly after World War I the birth rate in the United States began an almost steady decline which continued into the middle 1930's (Table 2). This decline extending over a period of nearly 15 years became the despair of demographers and others who were concerned about the future population of the nation. The birth rate began to decline in the 1920's when economic conditions were generally regarded as favorable and continued its downward course into the 1930's when economic opportunities were restricted. The lowest rates came in the period from 1933 to 1936 when unemployment was very high and the marriage rate was relatively low. In this depression period marriage and the establishment of families were delayed.

Beginning in 1937 there was an upturn in the birth rate which was related in part at least to improved economic conditions. The uneasy peace in Europe may have influenced some young people to take on family responsibility. The Selective Service Act of 1940 and the prospect of war produced emotional and romantic consequences, for both the marriage rate and the birth rate increased. The birth rate continued relatively high during the war period except for 1945 when there was a slight decline. In 1944 and 1945 a large number of young men were separated from their families, and a decline was a natural consequence.

The return of thousands, indeed millions, of young men to their homes and families was followed by an increase in the mar-

TABLE 2

BIRTH RATE AND DEATH RATE, 1915–1948

[Source: *Statistical Abstract of the United States, 1948.*]

Per 1000 estimated population

	Birth Rate	*Death Rate*
1915	25.0	13.2
1920	23.7	13.0
1925	21.3	11.7
1930	18.9	11.3
1931	18.0	11.1
1932	17.4	10.9
1933	16.6	10.7
1934	17.2	11.1
1935	16.9	10.9
1936	16.7	11.6
1937	17.1	11.3
1938	17.6	10.6
1939	17.3	10.6
1940	17.9	10.7
1941	18.9	10.5
1942	20.9	10.4
1943	21.5	10.9
1944	20.2	10.6
1945	19.6	10.6
1946	23.3	10.0
1947	24.3 *	9.9 *
1948	24.6 *	9.7 *

* Estimates, Federal Security Agency.

[2] Whelpton, *op. cit.,* p. 39.

riage rate and the birth rate. In 1946 the number of births reached a total of 3,288,-672, the first time that the number exceeded three million in a single year.

The birth rate and the proportion of children in the population are somewhat higher in the rural than in the urban communities, particularly the larger cities. This long-time difference between the two groups of people has produced a population pressure or differential which has favored and maintained a consistent movement of people from the farms to the cities. This cityward migration, although not proportional to the age groups in the rural population, involves people of all ages: children taken by their parents, young people in their late teens and their twenties seeking work opportunities, and older people retiring to the city. Generally this cityward migration has been a long-time population movement in this country.[3] By this important movement the population of the cities has grown, and the farm population has been held in balance.

Urban versus Rural Birth Rate

It appears that the conditions of life in the industrial and commercial communities are not conducive to the establishment of a family with a sufficient number of children to reproduce the population. In the cities the individual is the economic unit and both the husband and the wife may be regularly employed. In the city the children can make only a limited contribution to the family income, and as a consequence the cost of rearing a large family in an urban environment is so high that it operates to limit the size of the population. It is clear that many childless couples who live in cities represent people who prefer independence and freedom from family responsibility. In the large urban centers the small living quarters which are satisfactory for a man and his wife are too small to rear a family under favorable living conditions. From data available to us it is clear that the larger cities do not rear a sufficient number of children to maintain the population but are dependent upon migration from the smaller towns and the rural areas.

In an agricultural community the wife is essential to the success of the farm operations. Her contribution is not that of a wage earner but of a helpmate who shares the work responsibility and rears the family. In the rural area, although children constitute an important cost, they are also a valuable asset and at an early age can make a contribution to the farm income by helping regularly with the daily chores about the farm and during the vacations may help with the more important farm duties. Children, particularly boys of 12 to 15 years of age, may handle certain farm machinery, such as a small tractor, with great skill and may save their father the cost of a hired hand. The busy mother and the children may care for the poultry and thus make an important contribution to the farm income.

In the rural areas the farm produces a large proportion of the food consumed by the family. Self-sufficiency or self-support is a significant feature of the farm economy. In the city, particularly in the larger urban communities, children are unable to make a major contribution to their own support unless the father is engaged in a business where his children may help. On the farm the children are an asset but in the urban

[3] See C. E. Lively and Conrad Taeuber, "Rural Migration in the United States," *Research Monograph* XIX, Works Progress Administration, Government Printing Office, Washington, D. C., 1939.

community they are a financial liability. Because of this difference in the birth rate in cities and rural areas the farm families are responsible in a measure for the maintenance and the continued growth of the urban population.

Age Composition

Not only is the total number of people important as it affects the market for agricultural products, but also the age composition or structure may have important effects upon agriculture. If and when the total population becomes stabilized at a level well below the 200,000,000 that the great resources of this country might support at a reasonable standard of living, the stimulating effect of an increasing population will be gone.

For many decades it has been evident that the median age of the population and the life expectancy have been increasing. In 1945 the median age of the population was 29.7 years.[4] Relatively the population is becoming older as represented by the distribution among the several age groups. In 1900 approximately 4.1 per cent of the population were 65 years of age and older. Decade by decade the percentage in this age group increased to 6.8 per cent in 1940, and it is estimated that the proportion will increase to 8.1 per cent by 1955.[5] This aging of the population is related to the change in the proportion of children in the population. In 1900 those under five years of age made up 12.1 per cent of the total. By 1940 the proportion in this age group had declined to 8.0 per cent. The post-war increase in the birth rate has had the effect of reversing a trend that had been in evidence for half a century. In a similar way the proportion of young people, five to nineteen years of age, declined from 32.3 per cent in 1900 to 26.4 per cent in 1940. The post-war boom in babies probably will operate to increase slightly the proportion of young people in the population during the following 15 or 20 years. In due time these relatively young people in the population will reach maturity and marry, and we may have at that time a new upswing in the birth rate. But this will not change the fact that greater and greater numbers of our people are living to ages beyond 65.

Some Implications of Population Change in Respect to Agriculture

A dynamic and growing population provides an expanding market for agricultural products. "Prior to the Civil War the population of the nation, and doubtless its consumption of farm products, increased a third each ten years. After the Civil War the rate of increase lessened, until during the World War [I] decade, and the decade of urban prosperity that followed, the increase was less than one-sixth each ten years."[6] In the decades of the 1930's and 1940's the upturn in the birth rate has not been sufficiently reassuring in respect to the future population so that a rapidly expanding agricultural industry is indicated.

It is not likely that the death rate can be reduced much more. In fact it may be expected to increase slightly as the population is made up of proportionally more old

[4] Whelpton, *op. cit.*, p. 47.

[5] "Current Population Estimates," *Bureau of the Census, Series P-25*, No. 18, Feb. 14, 1949, p. 3.

[6] O. E. Baker, "Significance of Population Trends to American Agriculture," *The Milbank Memorial Fund Quarterly*, Vol. 25, 1937, pp. 121–134.

people whose life expectancy decreases rapidly in the later years. The relatively high birth rate may be expected to decline somewhat as the post-war readjustment period comes to an end and economic conditions are less favorable for the establishment of a family. If restricted immigration continues as the established policy of the government, the prospect of a total population of 200 million, very uncertain in respect to date, probably will not be attained before the year 2000 A.D., if ever. Whatever the total population of the nation may be in the decades in the immediate future the prospect of a rapidly expanding domestic market for agricultural products is a fiction.

We may not expect a declining population in the near future, but the decrease in the rate of increase will continue. The age groups in the population change progressively with the changes in the birth and death rates. The relatively large number of young children in the population in the late 1940's will in due course require an expansion of school facilities from the kindergarten to the universities. When they attain the marriageable age there will be an increased demand for new homes, home furnishings, and other materials and facilities related to the establishment of new families. These and other characteristics of the population may affect in a number of ways the agricultural industry.

When the rate of population growth began to slacken, particularly in the 1930's, many demographers and other students of population envisioned a stable or even a declining population only a few decades in the future. After a long period characterized by a growing population and an expanding agriculture the prospect of equilibrium or stability in respect to numbers was not conducive to continued expansion. To many it suggested that agriculture should begin to make adjustments to the population conditions that would obtain only a few decades hence. No longer could the dynamic force of a rapidly expanding market be counted upon to maintain good prices and provide economic opportunities for increasing numbers of farm families. In the past the growing market at home has been related to the steady increase of the population year after year and decade after decade. Also the agriculture of the United States has long contributed large quantities of food products and industrial raw material to the overseas market. Whenever surpluses have accumulated, either because of favorable weather conditions at home or the failure of the foreign market to take the usual quantities of farm products, farm prices have declined and the farmers have suffered economic reverses. However, a steadily expanding market has always been a favorable factor in American agriculture as long as the farms were new and virgin lands were available to the plow.

The demand for agricultural products may increase in the future, and more land may be required to maintain and expand the production of a number of industrial raw materials. The manufacture of plastics, alcohol, synthetic fibers, and many other products may provide new markets for agricultural commodities. In the relatively near future the abundant petroleum resources of the United States will be materially reduced and substitutes will be sought. Immediately the extensive coal deposits and the oil shales may be utilized to make up the declining supply of natural petroleum. Alcohol made from agricultural products may make its contribution to the liquid fuel requirements of the nation. During World War II synthetic rubber was manufactured both from petroleum and from alcohol. It may be that alcohol, which can be produced from annually renewable organic substances, may help to maintain the agricultural industry at relatively high levels of production indefinitely.

In the United States, where the standard of living is relatively high, the demand for agricultural and other products will be high when the population is made up of a relatively important number of people in their twenties, thirties, and forties, the most dynamic and active decades of their lives. The total quantity of food consumed may be functionally related to the total number of people in the population. To a certain extent the relative quantities of particular foods may reflect something of the character of the population. When the population consists of relatively large numbers of children the consumption of milk will probably be high. When the proportion of mature and old people is relatively high the demand for meat will probably increase somewhat.

The character of the population in respect to age, the purchasing power of the component groups, the increasing use of materials of organic origin in manufacturing, and efforts of the federal government to improve nutrition and housing, all should operate simultaneously or in combination to maintain and expand the market for the products of agriculture. To achieve the highest possible standard of living for 175,000,000 people, or perhaps 200,000,000, the agricultural base must not be permitted to diminish.

THE PRODUCTION OF FARM PRODUCTS

In the middle of the nineteenth century the expansion of agricultural production was largely the result of bringing great areas of prairie land under the plow. The increase of farm population was related to the high birth rate on the farms and the settlement of rich new lands by agricultural pioneers, both natives and immigrants, who were seeking farms on the frontier. The middle west rapidly absorbed great numbers of new settlers who brought under cultivation the expansive and fertile prairie lands.

The expansion of agricultural production in the second quarter of the twentieth century was achieved under an entirely different set of conditions. Little or no new land has been brought under cultivation since World War I. New additions have been matched by a withdrawal of older lands from cultivation. Increased production of the 1940's was not related to changes in land under cultivation. Substantially the same area of cultivated land was made to yield a larger quantity of agricultural products.

This upturn in production was not the result of an increase in the labor force. As a matter of fact fewer workers increased agricultural production. Many farm workers left the land to enter military service. Others were attracted to war industries where wages were high and other conditions of life were satisfying. Fewer farm workers, making use of power machinery, more fertilizer, and many other improvements in technique, were able on an essentially unchanging number of acres substantially to increase agricultural production during the late 1930's and the 1940's.

The general rise in farm prices was a powerful inducement to the farmer to put forth his best efforts to make his land produce abundantly. During the long period of price decline and particularly during the depression years of the 1930's the incentive of high prices or rising prices did not function as a stimulating force. Bad years related to the extended droughts during the 1930's also had an unfortunate effect upon production. With the return of better weather conditions and higher price levels the farmer, sensitive to his new opportunity, put forth his best efforts to make his land yield abundantly.

Changes in Land Utilization

The notable increase in crop production during World War II and in the post-war years was not due to an increased acreage devoted to farm crops. In the 25-year period from 1920 to 1945 approximately 186 million acres were added to the land in farms (Fig. 1). Most of this addition to the farmlands of the nation consisted of dry semiarid and arid lands in the west and contributed little to agricultural production. In fact it was almost wholly a change in nominal ownership and did not involve a change in land use. In eastern United States about 45,000,000 acres went out of the category of farmlands. This decline was notable in the hill lands of the southeast and in the areas about the rapidly expanding industrial centers. The large increases in the dry west and new lands added to farms in Florida and Louisiana, in Wisconsin and Minnesota, and in other states resulted in a net increase in land in farms.

Cropland

Approximately one-quarter of the total land area of the United States, or about 500,000,000 acres, is classed as cropland.[7] This great area is not necessarily the sum total of the best lands for crop production. In many hill areas slope lands are devoted to crops which should be planted to permanent pasture or to forests. Many acres of land in pasture, in forests, and in other uses might be converted to cropland. In retrospect we can look back over the years to the time when the agricultural pioneers began the slow and laborious process of converting to cropland the areas that, under conditions of nature, were forest land, marshlands, prairies, and dry or subhumid lands. After a long process of agricultural development and expansion the cropland area reached a maximum of approximately 500,000,000 acres. In 1944 only 353,000,000 acres were harvested. The remaining cropland included idle or fallow land, areas of crop failure, and cropland in rotation pasture.

The cropland area does not represent in any single year the 500,000,000 acres best suited to crops. In this number are expressed the readjustments in acreage over many decades of agricultural development. In many areas the wasteful and destructive practices of agriculture have resulted in the depletion of the plant nutrients and in the physical destruction of the soil by erosion. Unhappily the process of soil wastage goes on, and additional areas may be withdrawn. On the bright side there is the hope that the ailing land may be saved and, through proper land management, may be retained as cropland. In the number, 500,000,000 acres, is expressed the dynamic character of the agricultural industry, especially in respect to the acreage that is devoted to crop production or is suitable for cultivation.

In the 25-year interval between 1920 and 1945 the total acreage classed as cropland varied little. The character of the land included as cropland has, however, changed

[7] "Graphic Summary of Land Utilization in the United States," *Cooperative Report,* Bureau of the Census, U. S. Department of Commerce, and the Bureau of Agricultural Economics, U. S. Department of Agriculture, Washington, D. C., 1947, p. 3.

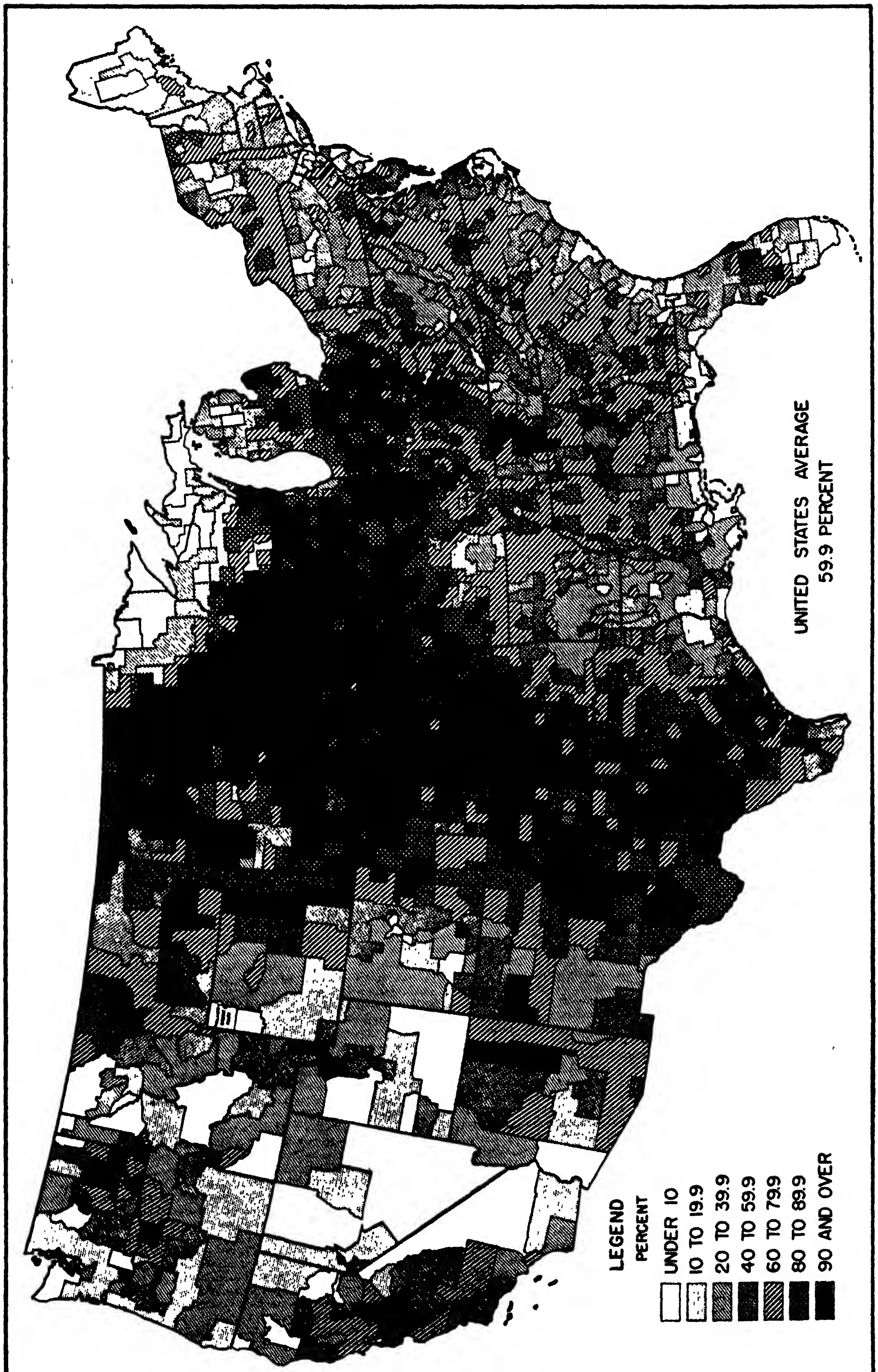

FIG. 1. Land in farms, 1945. (Bureau of the Census.)

notably. The additions and withdrawals of cropland have been substantially in balance. During the 1920's most of the increase in new cropland resulted from plowing up the natural sod of the Great Plains. The high prices for wheat and other agricultural products during World War I were responsible for this plow-up program. The expansion of cropland in this area continued even later than the 1920's. The drought years of the 1930's reversed the process, and extensive areas formerly cultivated were withdrawn from the cropland category and restored to grass where soil and other land conditions were favorable. One of the great tragedies of American agriculture was this unhappy adventure of trying to convert to croplands the native grasslands which were better suited to grazing.

During the wartime period of the 1940's, with more caution, however, cropland was again expanded in the grain-farming areas where it had been reduced in the 1930's. Again high prices for grain and other farm products and favorable crop years challenged the farmer, and he returned to the land which had once been abandoned.

The increase in agricultural production since the middle 1930's is related to conditions other than the increase of land in farms and a relatively stable cropland area. This upturn in production reflects improved technologies in agriculture, the increased applications of fertilizer material, the use of more productive animals, the farmers' devotion to their great task of feeding the hungry peoples of the world, favorable crop years, and other factors. Collectively or in combinations these factors functioned simultaneously to bring to new high levels the production of many crops. Generally the agricultural industry prospered and the benefits were widely distributed among the people at home and abroad.

The Agricultural Regions

The distribution of crops in this cropland area reflects the character of the climate, the physical nature of the land in respect to relief, and the productivity of the soil. Economic conditions, particularly market demand and prices, function as important factors in production. The combination of crops and the farm animals raised in any area are related to both the physical and economic conditions that give distinctive character to the agricultural regions of the United States. The general east-west orientation of the chief agricultural regions such as the hay and pasture belt, the corn belt, the corn and winter wheat belt, and the cotton belt has developed as the farmer has adapted his agriculture to the temperature conditions of eastern United States, particularly the length of the growing season. The regional arrangement of the agricultural areas, as represented by the dominant crop combinations, is strongly influenced by climatic conditions.

The chief cropland area of the United States is essentially triangular in shape (Fig. 2). A straight line drawn from central Ohio to the forty-ninth parallel in northwestern North Dakota, thence southward into the panhandle of Texas, and thence northeastward to central Ohio encloses a great triangular area of cropland that is probably unequaled by any other agricultural area in the world. Within this area are included parts of the spring wheat region, the hay and pasture belt, the corn belt, a part of the corn and winter wheat belt, and a small section of the cotton belt. East and west across the central section of the triangle extends the corn belt centered on what Transeau has called the prairie peninsula.[8] Most of this great cropland area is located on what was originally a great prairie land of relatively low relief and with deep black soils of high fertility. Locally, as in the Driftless Area of the upper Mississippi valley and in other unglaciated areas and along many of the streams where the bluff lands have been dissected, the terrain is irregular in configuration. Most of this productive agricultural area was originally an expansive tall-grass prairie of scant relief and under the economy of the Amerinds remained a grassland. The aborigines, by the use of fire, may have helped to maintain the prairie against the encroachment of the forest and may have extended the prairie area locally by the same means. This moot question need not be debated here. It is important, however, that the white settlers came into possession of one of the greatest agricultural areas in the world as they dispossessed the natives and, in due course of time, broke the prairie and substituted cultivated crops for the natural grasses which for thousands of years had been building the agricultural heartland of America, known as the middle west.

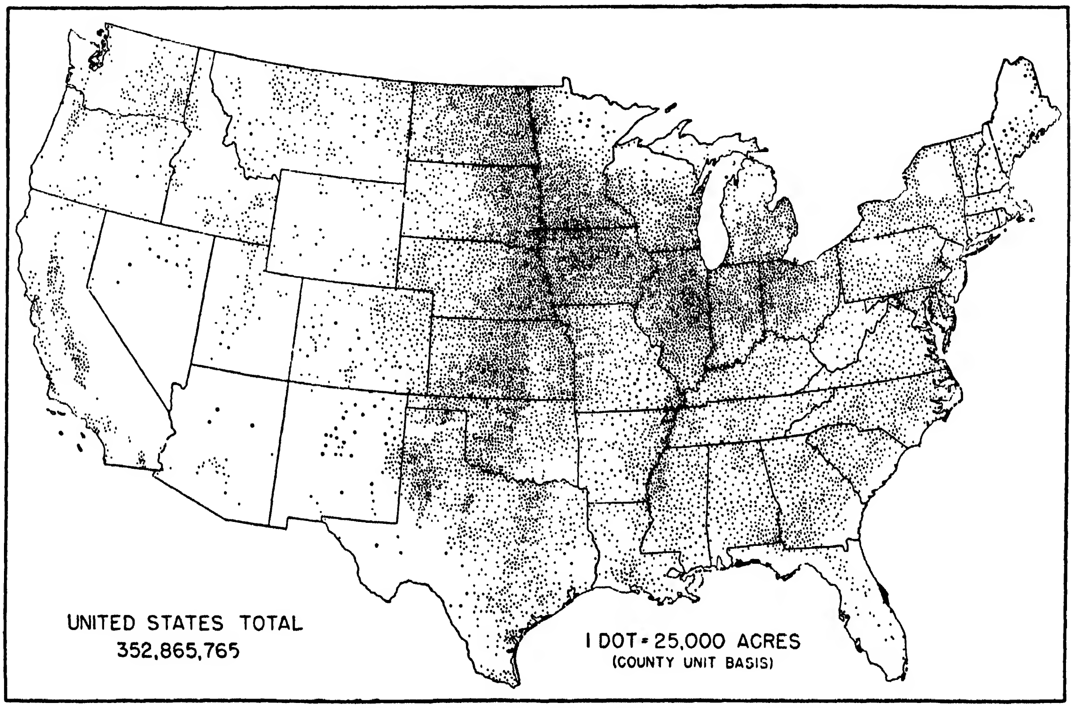

FIG. 2. Cropland harvested, 1944. (Bureau of the Census.)

In certain counties in this great triangular area as much as 85 per cent of the total area was classed as cropland in 1944, and locally 80 per cent of the land was actually in crops.[9] In the areas of slight relief the

[8] E. N. Transeau, "The Prairie Peninsula," *Ecology*, Vol. 16, 1935, pp. 423–437.

[9] "Graphic Summary of Land Utilization in the United States," *Cooperative Report*, 1947, p. 8.

mechanization of agriculture had reached a high stage of development. This is the great granary area of the United States, and in favorable years it can contribute great quantities of food to the hungry peoples of the world.

Locally in other sections of the United States there are important cropland areas that make up a great acreage of productive land, but nowhere are the fertile lands so expansive or continuous as in the middle west. In New England and in the middle Atlantic states the cropland area makes up about 20 to 80 per cent of the area in farms, depending upon location. The better lands lie in western New York along the shore of Lake Ontario and in southeastern Pennsylvania where fertile soils and low relief have favored the full use of the lands suited to agriculture. From Long Island across New Jersey and southward along the shores of Chesapeake Bay the vegetable industry is highly developed to supply the great metropolitan markets, and as a consequence the lands well suited to agriculture have been put to productive use.

In the south the irregularity of the terrain, infertile soils, swamps, and other unfavorable factors function collectively to limit the areas suitable for crops. In the more favored areas such as the inner Coastal Plain, the Piedmont, the valleys of the Ridge and Valley province of the Appalachians, the alluvial lowlands of the Mississippi, Arkansas and Red rivers, and the black prairies of Texas and Oklahoma, the proportion of farmland devoted to crops locally exceeds 60 per cent. Generally much of the land is unsuited to crops, and large areas formerly cultivated have been withdrawn from the cropland category. The south in spite of unfavorable conditions remains one of the major agricultural regions of the United States and the outstanding cotton area of the world. Its soils require careful management to prevent destructive erosion and repeated applications of fertilizer to maintain productivity. This region of heavy rainfall, erodible soils, clean cultivated crops, notably cotton, corn, and tobacco, cultivated by people not fully aware of their responsibility, is one of the great problem areas of the United States. The land resource of this area can be saved from destructive exploitation, but the proportion of the land in row crops should be reduced. The agriculture of the south may require many important changes before the area attains its proper place in the farm economy of the United States. The people must be educated to appreciate their custodianship of the land resources of one of the major agricultural areas of the nation.

Scant rainfall and extensive mountain systems restrict the croplands in the west to local areas of adequate precipitation or with water for irrigation. Large areas in the Great Plains and in the Palouse country are classed as cropland, but the practice of fallow farming reduces the area harvested each year. The Puget basin and the Willamette valley of Oregon carry on agriculture without the benefit of irrigation. The areas where the highest proportion of the lands is in crops includes the irrigated valleys of the Columbia and its tributaries, the Colorado and its tributaries, and the Great Valley and coastal valleys of California.

The expansion of cropland in the west is related to the progressive control of the rivers and the utilization of available supplies of water for irrigation. The principal areas that remain to be irrigated lie along the Columbia. When these new farmlands are brought into production important quantities of agricultural products will be added to the total supply in the United States. Thousands of new farm homes will be established in this area. In most irrigated areas the land is cultivated intensively so that the yields are high. Therefore, on these new irrigated croplands of the west the yields per acre will exceed the average for the country.

The Use of Fertilizer

The maintenance of the productivity of the soils of the United States and the upbuilding of soils that are low in plant nutrients require the application of fertilizer materials. Because new lands seemed always to be available as the frontier of settlement moved across the country the soil resources declined because erosion and leaching insidiously reduced the physical base on which the industry of agriculture was built. Many farmers were slow to realize that their lands had depreciated in quality, and productivity could be maintained only by the application of fertilizer.

In comparison with the older agricultural areas of the world fertilizer in the United States is relatively less important. In the period just before World War II Europe and Asia required "80 per cent of the nitrogen, 70 per cent of the phosphates, and more than 80 per cent of the potash used as fertilizer ..."[10] In the old agricultural areas of Europe and Asia where the intensive cultivation of land is highly developed high productivity has been maintained by the long-continued practice of supplying the essential plant nutrients through the application of mineral fertilizers. In the United States the fertilizer industry has been expanding to meet the needs of agriculture. During World War II one of the important contributing factors in attaining new high levels of agricultural production was the increased application of mineral fertilizer (Fig. 3). The nitrogen needs of the nation were met by the importation of nitrate of soda from Chile, the expansion of the synthetic ammonia industry, the recovery of by-product ammonium sulphate, and the utilization of other nitrogen-containing substances. The large resources of phosphates and sulphur were exploited to meet the needs for superphosphate. Also the loss of potash from Germany was offset by the development and expansion of a domestic industry[11] in the southwest. During World War II the production and use of fertilizers attained new levels, and agriculture under favorable weather conditions responded abundantly.

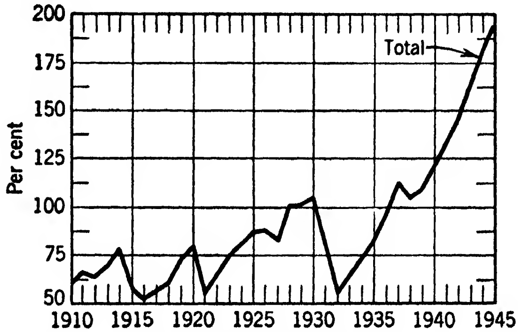

FIG. 3. Fertilizer consumption, 1910–1945. (Bureau of Agricultural Economics, U. S. Department of Agriculture.)

The geographical distribution of fertilizer consumption shows a relationship to the regional deficiencies of the soils, the crops grown, and to the availability of the fertilizer materials locally. For example phosphates and sulphur are produced

[10] K. D. Jacob and F. W. Parker, "Fertilizer in World War II," *Proceedings of the Twenty-Second Annual Meeting of the National Joint Committee on Fertilizer Application,* 1946, p. 31.

[11] *Ibid.,* p. 35.

chiefly in the south and the soils of the south require the repeated application of fertilizer for high production. Where soil depletion has not become serious fertilizers remain of less importance than in the older agricultural areas of the east and the south Atlantic (Table 3).

TABLE 3

REGIONAL DISTRIBUTION OF FERTILIZER CONSUMPTION

[Source: Jacob and Parker, *op. cit.*, p. 36.]

	Percentage of the Total		
Regions	*1918*	*1940*	*1944*
New England	4.7	3.7	3.7
Middle Atlantic	15.9	14.3	12.6
South Atlantic	53.8	42.7	38.0
East North Central	8.5	11.6	14.2
West North Central	1.6	1.5	3.1
South Central	13.2	18.6	20.9
Western	0.7	3.7	5.2
Hawaii and Puerto Rico	1.6	3.9	2.3
Total	100.0	100.0	100.0

The Minor Elements

In addition to nitrates, potash, and phosphates, which may be regarded as the great triumvirate of fertilizer minerals, lime is of great importance, and a number of minor or trace elements are known to be essential in plant and animal nutrition. These minor elements include magnesium, manganese, boron, iron, sulphur, copper, and zinc. The fact that in general only very small quantities of these substances are necessary may account for the long neglect of this aspect of soil fertility. Deficiencies of one or more of these elements in the soils have been found to be responsible for abnormalities in both plants and animals that fed upon the vegetation. As research has revealed the relation of these minor elements to the successful production of many crops certain of them have been added to the commercial fertilizers. Where the farmers are largely dependent upon manures and other organic wastes the deficiencies of these minor elements are less serious than in the areas where mineral fertilizers are used.[12]

The New Frontier of Science in Agriculture

Only limited areas of new lands can be brought under cultivation. Greater quantities of foods, fibers, and other agricultural raw materials may be produced by means other than the extension of the acreage of cultivated land. By various methods production levels can be maintained, and when the need becomes urgent the same number of arable acres can be used to greater advantage.

The application of science to agriculture is not new, but, with a realization that large areas of new lands are no longer available to meet the needs of an expanding market, it is important that the land be used to the best advantage. By various means the scientific advances in agriculture are brought to the farmer, but there is a serious time lag between the development of a new variety or an improved technique and its adoption by the practical farmer.

The United States Department of Agriculture is carrying forward a great variety of research projects at the Agricultural Research Center at Beltsville, Maryland, and at the nine regional laboratories established at Charleston, South Carolina, State College, Pennsylvania, Ithaca, New York, Ames, Iowa, Auburn, Alabama, Urbana, Illinois, East Lansing, Michigan, Dubois, Idaho, and Riverside, California. Each of

[12] Matthew Drosdoff, "The Use of Minor Elements," *Science in Farming, The Yearbook of Agriculture,* 1943–1947, Government Printing Office, Washington, D. C., 1947, pp. 577–582, reference on page 578.

these laboratories specializes in a particular aspect of agricultural science. The federal laboratories and the several state agricultural experiment stations are carrying on year after year long-range research projects designed chiefly to increase the productivity of the land with the expenditure of the least amount of energy. Research must find the ways to achieve simultaneously both high production and the conservation of the basic land resource.

Science in its application to agriculture has given the farmer more productive plants and animals, provided greater protection from insects and diseases by the formulation of new insecticides and germicides, developed methods of protecting farm products from loss in storage, and in other ways brought to the farmer the results of research. Greatest advances have been made in soil research and disease control. The farmer generally operates on a small scale and is unable to undertake scientific studies by himself. He can co-operate with a nearby research agency, such as the state experiment station, and thus participate in an important research project. But he has available to him the results of research supported by the federal and state governments and by private agencies.

Higher Yields per Acre

There have been long periods in the history of American agriculture when little or no progress was made in increasing the average yields per acre. Progress was, however, being made in the development of more productive varieties. Simultaneous with these developments in agriculture some of the older lands in the east were declining in productivity and some of the new lands of the west produced relatively low yields because of the scant rainfall and the threat of drought and crop failure. In a sense these two sets of conditions were essentially reciprocal in character and tended to keep yields stabilized. But renewed efforts to increase yields and raise total production have been successful.

The average yield of wheat in the United States was 12.3 bushels per acre in 1866–1875, 13.3 bushels per acre in 1896–1900, 13.7 bushels per acre in 1921–1925, 11.2 bushels per acre in the dry year of 1930, and ranged from 16.6 to 18.4 bushels per acre in 1940–1947. In more than three-quarters of a century wheat yields have not increased notably except when conditions of growth, particularly the weather, were favorable. Progress in wheat growing was not negligible or unimportant. New varieties, resistant to drought, diseases and insects, have been developed and grown widely and have as a consequence maintained yields as lands with greater climatic risks have been brought into production. In wheat and in a number of other crops scientific progress is reflected by the maintenance of yields as the productivity of the land declined or less productive land was planted to wheat.

For many decades the acre yield of corn resembled that of wheat but during the decade of the 1940's an upturn has been noted. In 1896–1900 yields averaged 27.7 bushels per acre, in 1921–1925 the yield was 26.7 bushels, in 1934, a particularly dry year for corn, the average declined to 15.7 bushels, but in 1940–1947 yields ranged from 28.4 to 36.7 bushels per acre. For more than a half-century scientific advances in corn growing offset factors that were operating to reduce yields. It is evident, however, that yields were increasing by the early 1940's.

Hybrid corn. Probably one of the outstanding achievements of American agriculture has been the development of hybrid corn. As with most new developments in agriculture the use of hybrid corn passed through a relatively long period of incubation. In 1933 only one acre in every thousand was planted to hybrid corn, but by 1943 more than 51 per cent was hybrid.[13] The hybrids that have increased yields from 15 to 20 per cent in the corn belt and the adjacent areas are being developed for the extensive corn areas of the south. In 1946 slightly less than 20 per cent of the corn grown in the south was hybrid. It is clear that the total corn crop of the United States can be increased still further without increasing the acreage planted to corn.

Already many of the states in the middle west are planting hybrid seed on 90 to 99 per cent of the corn acreage. Further increases cannot be expected here. The outlying corn-growing areas if hybrid seed is employed may make a substantial contribution to the total corn crop. "During the three war years of 1917, 1918, and 1919, we produced 8 billion bushels of corn on a total of 311 million acres. During the three war years of 1942, 1943, and 1944, we produced 9⅓ billion bushels on 281 million acres . . ."[14] Although it is true that favorable weather conditions during the latter period were conducive to high yields it is clear that progress in the development and use of hybrids was a major factor.

Decline in Horses and Mules

There are two ultimate consumers, so to speak, of farm products—human beings and horses or mules. All other consumers, such as cattle, swine, sheep, and chickens, are intermediate consumers and use to a large extent foods that are inedible as far as man is concerned. In a sense, since they provide food for humans, they are intermediate converters of inedible feeds and grasses into edible foods for man. Horses and mules, although they are invaluable as a source of power, ordinarily make little or no contribution directly to the total food supply.

The substitution of power machinery, particularly the tractor, for horses and mules has had the effect of releasing an extensive acreage of farmland for the production of edible farm crops or for the support of farm animals that do yield important quantities of edible animal products. The total number of horses and mules reached a maximum of approximately 29,000,000 at the close of World War I. By 1930 the number had declined to 19,124,000, and in 1940 the number had been reduced to 14,481,000. In 1948 the horses and mules on the farms of the United States were estimated at 9,151,000, less than one-third of the number at the time of the maximum 30 years earlier.

When the horse and mule population of the United States was at or near the maximum it is estimated that, in addition to pasture, the products of nearly 60,000,000 acres of cropland were required to feed them. With the number reduced to one-third of the maximum, probably 25,000,000 acres are entirely adequate to supply the necessary feed. Therefore in a period of 30 years approximately 35,000,000 acres of cropland have been made available for the production of food products or industrial raw materials for human consumption (Fig. 4). Moreover, the decrease in horses and mules was greatest in the richest agricultural regions, notably in the corn belt and

[13] Ernest G. Moore, "Men Who Went Before," *Science in Farming, The Yearbook of Agriculture,* 1943–1947, Government Printing Office, Washington, D. C., 1947, pp. 13–14.

[14] Merle T. Jenkins, "Corn Hybrids for the South," *Science in Farming, The Yearbook of Agriculture,* 1943–1947, Government Printing Office, Washington, D. C., 1947, pp. 389–394, reference on p. 394.

in the southern sections of the hay and dairy region. Gradually and progressively as these additional areas became available they were used for other cultivated crops or were withdrawn from cultivation and utilized for permanent pasture and other nonagricultural purposes.

Shift from Less Productive to More Productive Crops

Another important way of increasing the production of the available cropland without employing additional areas is the shift from the less productive to the more productive crops. The increased quantity of food crops or other agricultural products may require a greater application of labor and fertilizer, but more productive crops can be used to increase the total output of the land. For example, in North and South Dakota and in Kansas where corn can be substituted for wheat and in California where fruits and vegetables grown on irrigated land replace grains and hay, the total quantity of food produced has been, and can be, increased substantially.

Long-term trends in diet are reflected also in agricultural changes of some significance. Over a long period of years the per capita consumption of wheat has declined. This decrease in bread consumption is offset by the increased consumption of other products such as fresh fruits and vegetables, poultry, and dairy products. This change in diet reduces somewhat the dependence upon the extensively grown grain crops and increases the demand for intensively cultivated crops. Thus agricultural lands are released for other purposes. The intensification of agriculture particularly for the purposes of supplying vegetables and fruits to the great urban markets can be regarded as a major means of increasing agricultural production without extending the acreage. The increased consumption of poultry and dairy products favors the use of the grain-growing areas and the pasture lands to provide the animals with their necessary feeds. By the intensification of agriculture an unchanging acreage devoted to farm crops can be made to yield increasing quantities of food for the support of the growing population.

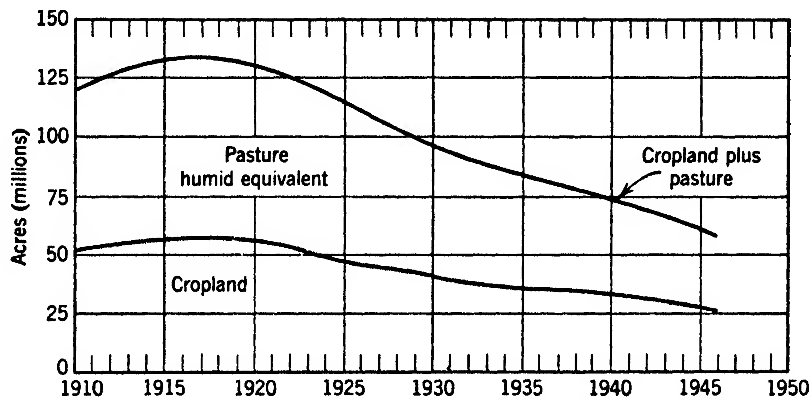

FIG. 4. Acreage required to support horses and mules. (Bureau of Agricultural Economics, U. S. Department of Agriculture.)

The shifts in American agriculture have not always been in the direction of greater intensification and greater productivity of the land. During the depression years of the 1930's when the surpluses of many agricultural products seriously depressed prices, the Agricultural Adjustment Administration restricted production by the transfer of cropland to less productive pasture or cover crops. Acreage allotments were determined for a number of crops that were plagued with surpluses, such as wheat, corn, cotton, rice, tobacco and others. To induce the farmers to transfer a portion of their croplands to soil-conserving crops incentive payments were made directly to the co-operating producers. By this means cultivated lands were set aside and planted to grass and soil-building crops so that the land could be requisitioned for cultivation at some future date when the surpluses had disappeared and when the growing demand required that these idle acres be returned to production.

More Productive Animals Increase the Food Supply

Progress in the more productive utilization of cultivated lands has been matched by the improvement of farm animals. Beef cattle, dairy animals, swine and poultry have been responsive to the improvement programs that have been developed to increase the food supply without increasing the number of animal units. Beef cattle require the products of about 11 acres of cropland, besides much pasture, to produce as much human food, measured in calories, as about 2.3 acres of cropland and 1.7 acres of pasture used to feed dairy cows, or 3.1 acres of cropland used to feed swine. The per capita consumption of beef averaged 55.2 pounds between 1935 and 1939 but during the post-war years when incomes were high consumption increased to 61.3 pounds in 1946, to 69.1 pounds in 1947, and then receded to 63.0 pounds in 1948. Pork consumption showed similar increases in the same period. An increase in the human population calls for an expansion of the animal industries to provide the increased quantities of meat products required by the people. It is important therefore that animals of great efficiency in the utilization of feed be developed and widely distributed over the farming areas so that the greatest quantities of animal products will be available to the people.

The technological developments in the animal industries have resulted in more meat per hundred pounds of feed, more eggs per hen, and have made possible the production of more milk per cow. By fertilization and the use of better lands for pasture the carrying capacity of the land has been improved. By careful breeding for greater efficiency in the utilization of feed by the dairy animals the pounds of milk per cow have increased notably. "It would be possible to raise our national level of dairy production from four thousand five hundred-odd pounds of milk a year to 7,500 or more and from 185 pounds of butterfat to at least 300." [15] This high level of production probably will be long delayed. The upgrading of a dairy herd requires many years. To extend this upbuilding, by the means now available, to the whole dairy industry will require an unknown number of years. By the development of dairy herds with high milk production per cow and the selection of those animals that are the most efficient in the utilization of feed the dairy industry can meet the increased demand for milk and milk products without requiring a comparable in-

[15] M. H. Fohrman, "Breeding Better Cows," *Science in Farming, The Yearbook of Agriculture,* 1943–1947, Government Printing Office, Washington, D. C., 1947, p. 169.

crease in crop and pasture lands to step up production.

In Praise of Grass [16]

Since the middle 1930's increased attention has been given to the place of grass in the nation's agriculture. This does not mean that the farmers of the northeastern states have been unaware of the importance of grass in the economy of this great dairy land. They have long recognized the need for adequate pasture to support their dairy herds during the summer, and the importance of meadow land to provide forage to help carry the cattle through the long cold winter. In the Great Plains many ranchers have understood the hazards of plowing up the short grass prairie for the sake of making economic progress rapidly when the price of wheat was high. They knew that a grassland economy had qualities of permanence not characteristic of the one-crop agriculture where 60 to 80 per cent of the cultivated land was devoted to wheat. But they could not resist the opportunity to cash in when the world's need for wheat was great and when the price was favorable. In other areas, particularly in the south, in the semiarid regions of the west, and on the steep slopes in the highlands there is a renewed interest in grass.

Man's eternal labors to secure adequate quantities of food, fibers, and shelter have resulted in many places in waste of the resources of the soil. Lands have been cleared and brought under the plow that should have remained in forest. In the older areas in the east certain lands have been restored to forests. Important areas have been converted into grasslands, chiefly permanent pasture and cultivated meadow. In the Great Plains and in many other areas the cultivated land has been overextended, and a reconversion of some of the plowland to permanent pasture is a means of conserving a basic resource for future generations; at the same time these pasture areas can support an important animal industry. Grass, the great healer, can do much to maintain, or even restore the productivity of the farmlands of the nation.

The agriculture of the United States in respect to its major regional characteristics does not change rapidly from year to year. Yet there are persistent forces at work that in due time may achieve significant changes. The inertia that seems to resist change may be related to the fact that the farm unit is too small to permit the individual farmer to put into practice what he knows is best for the lands. Perhaps his entire farm is in slopes that are so steep that the land should be in permanent pasture and in forest. But to make a living he must cultivate a certain percentage of the land even though he runs the risk of a gradual depreciation of the cultivated area by soil erosion. Whether the farmer has been limited by size of farm or is ignorant of the most suitable farm-management program, or for some other reason, it is generally agreed that a wider utilization of grass and the improvement of existing grasses would do much to maintain the agricultural potential of the nation.

In the United States nearly 60 per cent of the land area is used for hay and pasture. (See Table 4.) However, a relatively small proportion of the total area of the country

[16] *Grass, The Yearbook of Agriculture*, 1948, Government Printing Office, Washington, D. C., 1948. The U. S. Department is continuing a noteworthy program of issuing annually a yearbook which brings together in one place the achievements in a broad field of knowledge which has application in American agriculture. See also *Soils and Men*, 1938, *Climate and Man*, 1941, and *Science in Farming*, 1943–1947.

is in hay. The lands devoted to hay, the cropland devoted to pasture, and plowable pasture lands together make up slightly more than 10 per cent of the total land area of the country. These areas in hay and pasture are in large measure a part of the arable cropland now in use for agricultural purposes. To the extent that cultivated grasses are a part of the rotation system the greater is the opportunity to use grass or other hay crops, such as the legumes, to restore nitrogen to the soil, add organic matter, and improve the tilth. Grass as a hay crop and as permanent pasture permits the maintenance of a balanced agriculture involving both cultivated crops and meat-producing animals.

TABLE 4

LAND USED FOR HAY AND PASTURE

[Source: *Grass, The Yearbook of Agriculture*, 1948, p. 26.]

	Million Acres	*Per Cent*
Hay	74	3.9
Cropland used for pasture	48	2.4
Other plowable pasture	61	3.3
Other nonforested pasture and grazing (chiefly nonarable)	598	31.3
Woodland and forest pasture	345	18.1
Total land used for hay and pasture	1126	59.0

The rangelands of the dry west and the pasture areas in the forests and woodlands require reseeding, restoration, and careful management of grazing to protect these extensive areas from destructive erosion and loss of valuable water resources. Restoration to grass is the means of preserving these lands for future generations. In the meantime sheep and cattle pastured in the proper number can provide important quantities of animal products to a growing population. As the economy expands plowland may be extended into these areas if water is available and if the local conditions will permit cultivation of the soil.

Not only on the dry lands of the west but in the older agricultural areas of the east, the south and the middle west arable land not immediately needed to supply the food requirements of the people at home and abroad and the raw materials of industry should be planted to grass. In this way the fertility of the land would be partially restored. The cover of grass would reduce destructive erosion and would provide pasture for animals. Important areas of unneeded lands in grass or in forest would constitute an invaluable reserve of arable land which might be brought under cultivation in a national emergency or when other methods of increasing production were uneconomical.

THE LEVEL OF LIVING

The consumption of farm products, particularly the food crops, in the United States depends upon (1) the future population of the nation, (2) the per capita consumption of food, and (3) the net exports or imports of edible products. Of these three factors the most important in the immediate future, as in the past, will be the total number of people in the nation. The market for food crops is closely related to the number of mouths to feed. With the present population and the productive capacity of the arable land available for food crops the American people are well fed, but there still remains an important number whose diet is inadequate in some respect. Improving the living standard of this segment of our population will require readjustments in the production of food crops, but the rising level of living will not increase the over-all demand for food so rapidly as will the normal increase in the population. When and if the total population becomes relatively static then the changes in the demand for food will depend chiefly upon the changing standard of living of the people of the nation. The great land resources should be so managed and preserved that the underfed among our people would share at the table of abundance.

The Level of Living and the Market for Agricultural Products

The market for agricultural products is related not only to the number of consumers but to the consumptive capacity of the population. People with a high standard of living and with a high effective purchasing power can provide a very large market for the products of the land. It is recognized, however, that the consumption of certain foods does not seem to bear any significant relationship to the family income. Certain long-time trends have been established, and a change in income has little or no effect upon the general trend. For example, the per capita consumption of wheat flour averaged 224 pounds in 1880 and for more than 50 years the consumption declined until it reached only 154 pounds per person in 1938.[17] This change in the dietary habits of the nation is certainly related to the improvement of the diet of the American people, but it does not show a close relationship to the purchasing power of the consumer's dollar.

It is clear that the aggregate consumption of the agricultural products bears a significant relationship to the total number of people. It is also clear and significant from the standpoint of the total economy and the conservation of the basic resources that the higher the level of living the greater will be the quantity of goods required to satisfy the wants of the people. Enormous sums of money have been spent on advertising, propaganda, and education, all intended to stimulate or create a desire for a particular product. By various means the level of living is raised and greater quantities of goods are required to satisfy the demand. A decreasing rate in population growth or a stabilized population level may not seriously depress industry if the market continues to expand because of the progressive improvement in the level of living. As long as the people of the United States have available a large and productive acreage for agriculture, have access to large mineral treasures, employ fully the power resources available, and apply intelligence in the development and utilization of resources, the present high level of living can be maintained and improved particularly for many underprivileged groups in the population. To say that all these things can be done does not mean that they will be achieved immediately. For one or many reasons the economy may fail to make the necessary readjustments, and fear may grip the people. In spite of the opportunities for progress economic prostration may overwhelm a people, and temporarily a depression wipes out many of the gains. But when prosperity returns new levels of consumption may be attained and the stimulating effect of an expanding economy once more may bring hope to the people.

An Adequate Dietary Standard for the People of the United States

Providing an adequate diet for the people of the United States can be examined from a number of viewpoints. The diet of a

[17] Deane W. Malott and Boyce F. Martin, *The Agricultural Industries*, New York, 1939, p. 257.

family reflects somewhat the level of income or the amount of money available for the purchase of essential foods. For many families the inadequacy of the diet can be remedied by increasing the income so that more money will be available in the food budget. But an increase in income will not always provide a solution, for bad food habits tend to persist. Established culinary practices are altered slowly. By education and demonstration progress can be made particularly among the young women who may be induced to depart from the outmoded methods of their mothers. It should be a major objective of every family where there is responsible leadership to see that adequate quantities of the essential foods are available. The land resources of the United States are adequate to meet this nutritional objective of every American family.

The farmers generally have a dietary advantage over many of the people who live in the urban communities, particularly those in the villages and the small cities. Because they are producers of a variety of food products including dairy products, fruits, and vegetables, the farm families, with many exceptions among the renter class particularly, are well fed. People who live in the major cities have access to the large markets, and if the income is adequate and other conditions are favorable the families may have an adequate diet. Although many farmers may have adequate supplies of a number of foods certain protective foods may not be available in sufficient quantities or at all times of the year to maintain the physical well-being of the family. The poor farm families, especially the sharecroppers and the farm laborers, usually are inadequately fed, and the cash income of these poor families is often so low that they are unable to supplement in any substantial way their home-grown food crops. Where the land resources are suitable food production for home consumption should be sufficiently diverse to provide adequate diets. Surpluses of certain farm products may be available for sale in the market so that the cash can be used to purchase other essential foods. The farmers in the poor areas need supplementary sources of income which will permit them to purchase food that cannot be produced locally. In many instances limited land resources could be used to greater advantage if the people were adequately informed about their dietary needs and had sufficient energy and ambition to meet their food requirements. To secure adequate diets for this undernourished group of people will be difficult but possible by means of better land-planning programs.

In the cities the poor, underprivileged families live in the midst of plenty but, because of low income and little knowledge of what constitutes an adequate diet, are ill fed. These people, however, although much too large a group to receive adequate assistance, are the beneficiaries of the good works of the organized charities and the tax-supported relief agencies.

If this relatively large number of nonproducers who live in urban centers could be adequately fed the specter of agricultural surpluses would disappear. For many of these people the chance of securing a greater cash allowance is relatively remote. Food stamps or other means of distributing the foods that are in abundance may result in improved diets. This is only a partial solution of either the dietary problem of the undernourished or the problem of agricultural surpluses which must be disposed of in order to prevent a serious decline in farm prices.

Consumption of Food per Person

The character of the diet consumed by a people greatly affects the area required to feed the population. In the United States in 1944 only 353,000,000 acres of cropland were used to produce the foodstuffs and fibers used by the estimated population of 138,000,000, or approximately 2.5 acres per person. In this are included the areas used to produce fibers and other inedible products and the exportable surpluses. It is estimated that slightly less than two acres of cultivated land are required to feed each person in the United States. At the beginning of 1945 approximately 1,000,000,000 acres of pasture and grazing lands or 7.6 acres per person were available for food production. Much of this pasture land is in the west, and because of the scant rainfall the forage resources are limited. However, this western area supports during the period of growth large numbers of cattle and sheep which when fattened or finished in the grain areas of the middle west make an important contribution to the quality diets of the people of the United States.

Because of the high standard of living the area required to supply the various food products is comparatively large. The relatively low density of the population permits the use of extensive areas with relatively low average yields as compared with the older agricultural areas of Europe and the Orient. In pre-war Germany only about one acre of cropland and a half-acre of pasture were required to provide the diet of the average person. In Japan less than 0.25 acre of cropland provides the food consumed by the average Japanese. Because of multiple and companion cropping the area per person may be regarded as approximately 0.27 acre. It is obvious that the pre-war dietary standards of both Germany and Japan were below the United States, but because of intensive cultivation the yields per acre of most comparable food crops were higher than in the United States.

The Food Groups

For convenience the several food items that make up the diets of the American people are grouped as follows:

- Milk
- Potatoes, sweet potatoes
- Dry beans, peas, nuts
- Green and yellow vegetables
- Tomatoes, citrus fruits
- Other vegetables and fruits
- Meat, poultry, fish
- Eggs
- Grain products
- Fats, oils
- Sugar, sweets

These are the foods that in combination provide the inadequate, the staple, and the quality diets of the people. From these the people secure the essential nutrients of proteins, carbohydrates, fats, minerals, vitamins, and the food energy expressed in calories. Slowly and progressively, in peace and in war, in good times and bad, and as greater knowledge of foods becomes available, these several food groups increase or decrease in relative importance (Fig. 5).

From the accompanying data it is clear that there have been a number of significant changes in the diet of the American people (Table 5). Generally the changes indicate an improvement in the level of living. Since 1910 there have been notable increases in the consumption of milk, the leafy green and yellow vegetables, tomatoes, and citrus fruits, which supply the important minerals and vitamins. The carbohydrate content of the American diet has declined except sugar. Proteins and fats have changed little during the past 40 years. These data do not reveal the great improvements in food preparation and distribution which have made possible the delivery of fresh fruits and vegetables in excellent condition. Changes in the production of food crops, increased knowledge of nutrition, and advances in the marketing of foods have made possible improved living standards of the American people. By the distribution of the several groups to all classes of consumers improved nutritional standards can be attained. This is an objective worthy of our greatest scientific and economic efforts.

Food Energy

In the United States where the quantity of food is relatively abundant the number of calories is high as compared to the standards of other countries. In the 30-year period from 1909 to 1949 the energy represented by the average disappearance of food varied from 3170 to 3560 calories per person per day. The highest levels were attained in the 1909–1912 period when the food energy exceeded 3500 calories per day. After 1913 the number of calories declined reaching a low of 3170 in 1935 when economic conditions limited the quantity of food purchased by the American people. In the period just before World War II the foods consumed were equivalent to 3250 calories per person per day. During the war the calories increased slightly to 3370 in 1945. No doubt the number of calories would have been somewhat higher except for rationing which greatly reduced the per capita consumption of sugar.

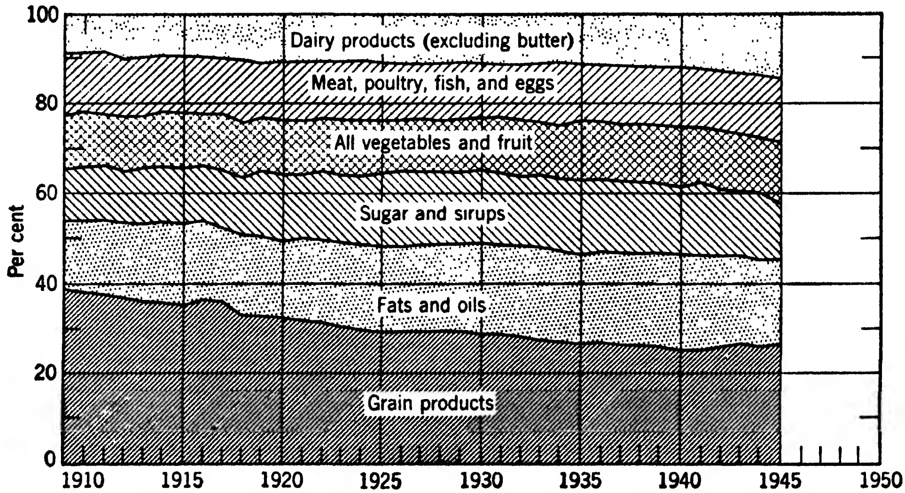

FIG. 5. Food energy derived from the major food groups. (Bureau of Human Nutrition and Home Economics, U. S. Department of Agriculture.)

The high levels of food consumption over a long period of years may be expected to continue as a distinctive feature of the family economy. Although many people may be living and working on diets that are inadequate in some significant way, the energy available from the food consumed is relatively high. A decline in food energy need not be regarded as an unfavorable trend provided that the diets are improved in other respects. The increased use of

TABLE 5

APPARENT PER CAPITA CONSUMPTION, 1910–1948

Adap ted from *Nutritive Value of the Per Capita Food Supply*, 1909–1945, U. S. Dept. of Agriculture, Washington, D. C., 1946. Data for 1945–1948 supplied by Rosalind C. Lifquist, Bureau of Human Nutrition and Home Economics, U. S. Department of Agriculture.]

	Milk Products except Butter	*Potatoes and Sweet Potatoes*	*Dry Beans and Peas*	*Leafy Green and Yellow Vegetables*	*Tomatoes and Citrus Fruits*	*Other Vegetables and Fruits*	*Meat, Poultry and Fish*	*Eggs*	*Grain Products*	*Fats and Oils*	*Sugar and Sweets*
	Quarts	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Number*	*Pounds*	*Pounds*	*Pounds*
1910–1914	165	188	12	73	46	216	155	300	297	60	91
1915–1919	178	176	15	77	50	207	147	287	275	60	94
1920–1924	185	171	14	80	58	213	147	305	242	62	108
1925–1929	195	158	17	87	61	221	143	324	234	66	118
1930–1934	196	151	16	91	66	206	141	301	212	66	113
1935–1939	205	143	19	100	84	220	137	289	197	64	109
1940–1944	232	140	21	115	102	220	152	316	201	68	107
1945	254	141	20	130	119	238	165	381	207	61	91
1946 *	265	135	22	124	113	247	168	359	192	64	92
1947 †	254	131	19	112	113	236	164	365	182	64	111
1948	250	125	19	114	109	232	158	374	174	64	109

* July, 1948, estimate.
† February, 1949, estimate.

mechanical power in industry, in commerce, and in agriculture reduces the quantity of human energy required to do the work of the nation. High standards of health and nutrition can be maintained with a static or a slightly reduced caloric intake per person per day.

The Protective Foods

As knowledge about nutrition has increased in the United States dietary standards have been established which involve more than calories, proteins, carbohydrates, fats, and oils. It is now recognized that certain minerals, such as calcium, phosphorus, and iron, and vitamins are essential ingredients of a proper diet. Foods that contain these necessary substances are classed as the protective foods, which, if consumed in proper quantities, prevent the insidious deficiency diseases. These protective substances include vitamin A and ascorbic acid (vitamin C) which are available in green and yellow vegetables, thiamine and niacin which are contained in meat, poultry, and fish, and riboflavin contributed by milk. A suitable diet must include the foods that will supply the necessary quantities of protein, carbohydrates, fats, minerals, and the protective substances so necessary to meet the energy requirements of the individual consumer and at the same time maintain his physical well-being over the years. It is important also to the individual or to the family that these dietary needs can be met by that share of the income which is available for food and that the various food products composing the diet are tasty, flavorful, and otherwise satisfying to the consumer.

In planning for a permanent agriculture for the United States many programs and objectives must be considered jointly. But the agricultural use of the land should be so organized that adequate quantities of food are produced to meet the dietary needs of the people. Where inadequacies exist the national economy must provide for the importation of the essential foods such as sugar and other tropical products from overseas source areas.

Food Consumption and Income

There is a significant relationship between the money income of the family and the consumption of food (Fig. 6). The people with the lowest incomes are unable

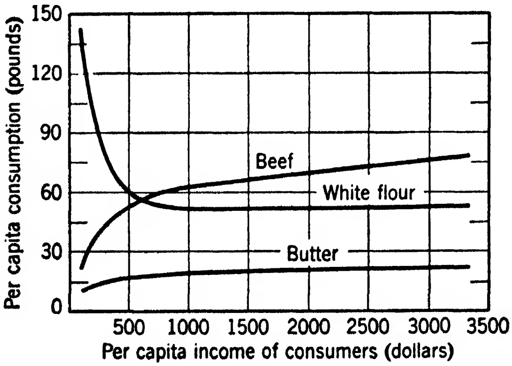

FIG. 6. The per capita consumption of beef, flour, and butter in relation to per capita income, 1941. (Bureau of Agricultural Economics, U. S. Department of Agriculture.)

to purchase the various food products that make up a quality diet but must be content with the less expensive foods that constitute the so-called staple diet. The more nutritive and protective foods usually require more money in the food budget than the families in the lowest income classes can afford. The relationship between food consumption and money income is characterized by complexities. Generally the low-income classes waste little food but families with large incomes can buy more expensive foods and may be at the same time more wasteful. Both by waste and by faulty dietary planning many people with adequate incomes are improperly fed.

The consumption of individual foods differs greatly among the several income classes. For example in the spring of 1942 urban families with an income of $5000 consumed no more milk than those who received between $1500 and $2000 annually. After a family receives a sufficient income to purchase adequate quantities of fluid milk an increase in income does not step up the consumption of milk. The quantity of meats consumed, or at least the money spent, increases with the family income.[18] Not only is there an increase in consumption of meat among families with the large incomes but there is generally a shift from pork to beef and lamb.[19] In the case of grain products, particularly flour, an increase in the family income usually means a decrease in the consumption of bread. The lowest-income classes consume flour and meal because they cannot afford the more expensive quality foods. Families with large incomes do not consume proportionately large quantities of fats. Apparently the level of income does not affect greatly the quantity of fats consumed, but people with larger incomes probably buy the more expensive fats such as butter. The per capita consumption of butter in the five-year period from 1935 to 1939 averaged 16.7 pounds per year, but rationing and the high price of butter during the war and in the post-war period reduced the quantity consumed to 10 or 11 pounds per person. In the same period the per capita consumption of margarine doubled.

The dietary use of large quantities of refined sugar has long been a significant feature of American food habits. Between 1935 and 1939 the per capita consumption of sugar averaged 96.5 pounds annually.

[18] "Family Food Consumption in the United States," *Miscellaneous Publication* No. 550, U. S. Dept. of Agriculture, Government Printing Office, Washington, D. C., 1944, p. 9.

[19] *Ibid.*, p. 15.

During the war period the quantity was reduced substantially by rationing and in 1945 was only 73.6 pounds. In 1947, however, the consumption was up to 95.9 pounds. Sugar has long been so cheap in the United States that most families are able to buy the quantities needed. Only the lowest income groups, particularly southern farm families, meet their dietary needs for sugar with relatively important quantities of molasses. It is clear that the large consumption of sugar in the United States is related to the decline in the use of other carbohydrate foods, such as bread and potatoes. Two-thirds of the sugar consumed in the United States is imported from overseas sources whereas one hundred per cent of the wheat and potatoes consumed in the domestic market is produced at home. This situation poses a significant land use problem, for the continued importation of large quantities of sugar must be counterbalanced by exports. In effect we may be exporting carbohydrates in the form of wheat in order to purchase sugar, a very digestible carbohydrate.

Fruits and vegetables are of major importance in the diet. With an increase in the family income the quantity increases. This is especially true of the protective foods such as the green vegetables and citrus fruits. Between 1935 and 1939 the per capita consumption of citrus fruits averaged 48.9 pounds annually. In 1947 the consumption had risen to 62.0 pounds per person. In the same period the use of canned and frozen fruit juices more than tripled. Much of this increased consumption probably benefited the people of the middle and higher income groups, but these protective foods are available in limited quantities to the families of the lowest income groups.

Whereas a quality diet is a privilege of the people in the higher income classes, the poorer families by careful buying and the proper preparation of food can improve their dietary situation. It should be a major objective of all people concerned with the national well-being to see that the people of the lower-income classes get a more adequate diet. One of the great paradoxes of the 1930's when agricultural surpluses were plaguing the national economy was the adoption of crop reduction while millions of people were inadequately fed. This feature of the Agricultural Adjustment Act has been adversely criticized. In recent years a philosophy of disposal of the surplus has replaced the outmoded concept of prevention of a surplus. It has become more important to find a way of distributing the surplus supplies of farm products than to use every effort to prevent the accumulation of surpluses.

During World War II when rationing was in effect meat products were in short supply and it was suggested that the consumption of grain products, particularly bread, be substituted for meat. Enriched white bread and whole wheat bread could partially replace meat and at the same time maintain high nutritive standards at much lower costs to the consumer. However, when the family income is high people in the United States prefer more meat and less bread in their diet. Under such conditions it usually is profitable to use the grain to increase the supply of meat which is in demand by the high-income families.

RURAL EDUCATION AND CULTURE

In maintaining the high production on the arable lands of the United States it is important that the people who live on the farms enjoy and share with the city dweller the comforts and advantages of our material culture. As the farmer assumes the responsibility for extending the cultivated areas by draining the wet lands, clearing the forests, and irrigating the dry lands he must secure for himself better educational opportunities for his children and improved dental and medical services for his family. Pioneer or frontier conditions of living have lasted too long in the farming areas. Farm people are anxious to have the benefits of electricity, running water, indoor plumbing, power machinery, and the automobile, so that life on the farm will be attractive, healthful, and satisfying to all members of the family. The radio, television, and other means of communication have overcome much of the isolation so long characteristic of life in the country. Farm families can participate in and enjoy the attractions of the city and still retain a strong attachment to the land which is so necessary in a long-range program of soil conservation and the maintenance of high productivity of the land.

Direction of Migration as a Factor

The prospect for rural culture, like that for a high standard of living, depends in large measure on the character, extent, and direction of rural-urban migration. If migration from the farms to the cities attains the magnitude of the pre-depression or war-time movement there will be important readjustments in the agricultural economy. Except for a brief interval in the middle 1930's and immediately at the end of World War II when demobilization returned many servicemen to the rural areas, the cityward migration has been relatively more important than the movement from the cities to the farm areas. The relatively higher birth rate in the rural areas, particularly in the poor farming areas, has tended to maintain the more or less steady migration of people from the rural areas to the urban communities.

Although people of all ages are involved in the migration to the city it is the loss of the youth from the farms that is regarded as most serious both economically and culturally. The retirement of elderly farm couples to the cities is a logical culmination of a long period of productive work on the land. In such a situation usually a son and his wife or a daughter and her husband take over the farm and continue the family enterprise. When whole families including the young children move to the city they relieve the population pressure on the land. But when the youth from the farms migrate to the cities when they attain the working age the rural areas suffer a serious loss. The farm families and the rural community have shared in the cost of their rearing and their education, and the cities become the beneficiaries without assuming a fair share of the costs. It has been estimated that it costs from \$2000 to \$5000, depending upon the price level and the standard of living of the family, to rear the average farm boy or girl until he or she is self-supporting. The migration of the farm youth to the cities without a counter movement of city youth to the country results in an important net loss to the rural areas.

The farm areas lose in other ways also, particularly when the farmer and his wife die and the estate is divided among their children.[20] In many instances part of the estate goes to the children who live in the city and part to those who remain on the farm. It usually becomes necessary for

[20] O. E. Baker, "The Outlook for Rural Youth," *Extension Service Circular* 203, U. S. Dept. of Agriculture, Washington, D. C., p. 5.

those who retain the farm to mortgage the land to pay off the brothers and sisters who have moved to the city. The interest payments represent a further drain from the farm for the benefit of city people.

Not all the benefits accrue to the urban areas. In many states the rural areas still control or wield considerable influence in the legislature. As a consequence farm areas secure important benefits. School funds and appropriations for improved highways commonly exceed the taxes collected in the rural areas. As stated elsewhere it is a good investment on the part of the cities to make an important contribution to the support of the school foundation program, for many of the children who are the beneficiaries of improved rural schools will migrate to the cities.

The migration of farm-born people to the cities is a persistent movement in the United States. In the 25-year period from 1920 to 1944 inclusive an average net migration of 600,000 civilians left the farms each year and moved to the cities.[21] This regular outflow from the rural areas helps to maintain the general upward trend of the urban population. At the same time it tends to reduce the pressure of population in the rural areas. If high farm incomes as well as production can be maintained there is an opportunity to improve the standard of living. The division of the farm income among several members of a farm family tends to limit somewhat the opportunities for betterment. Where the labor requirements can be met by the use of mechanized equipment the smaller families may have a sufficiently large per capita income to enable them to make improvements. If the income is not needed to provide the creature comforts of a large family, funds will be available for electrification of the farm, modernization of the home, an automobile, and other labor-saving equipment. Simultaneously the rural areas with higher fertility can make a significant contribution to the labor force of the urban communities and perhaps secure better living conditions for those who remain on the land.

[21] Conrad Taeuber, "Recent Trends of Rural-Urban Migration in the United States," *The Milbank Memorial Fund Quarterly,* Vol. 25, 1947, pp. 203-213, reference on p. 203.

Rural Electrification

Electricity, like good roads and the automobile, has been one of the most important factors in improved living conditions in rural areas. Electricity in the home means more than better lighting. It lightens the work of the housewife by making available to her many labor-saving appliances. The farmer's work is greatly facilitated by electric grinders, drills, feed mills, and other current-using machines. The operation of a home water system is made possible by the availability of electricity. As the Rural Electrification Administration has given its services to the extension of power lines into rural areas the material standard of living has risen. In Connecticut 91.2 per cent of the farms used electricity in 1945. In the middle west electrification lagged somewhat behind southern New England. In Indiana for example 73.7 per cent of the farms were supplied with electric current from central generating stations. The farm use of electricity has lagged still more in the south. In Florida 35.7 per cent of the farms were equipped with electricity in 1945 but in Mississippi only 18.7. California, where 92.5 per cent of the farms used electricity, reflects the high development of the power resources in the Pacific area for the benefit of all the people both rural and urban.

Effects of "Rurbanization" [22]

Should decentralization of industry and commerce increase in this atomic age the rural and the urban may merge in what has been called a "rurban civilization"; the cultural consequences would also be profound. In southern New England, where the farms are small and the cultivatable land is limited, many rural people seek employment in the nearby industrial communities. Certain members of the family may devote full time to the farming activities while others are full-time employees in industry, or an individual may divide his time between agriculture and industry. Part-time farming has become an established way of life in New England and in many other parts of the United States. Many industrial workers remembering the industrial stagnation of the middle 1930's have purchased a small tract of land in the rural area adjacent to or near their place of employment. The 40-hour week gives many of them time to cultivate enough land to make a substantial contribution to the family food supply. Many people are combining living on the land and working in the city and thus providing a measure of security.

Not only in New England but also in the industrial areas of midland America living in the country or in the small towns and working in the city have been combined as a means of providing economic security for the family. Good roads, the automobile, and the location of many of the new factories in the outlying suburbs where traffic conditions are not unfavorable have facilitated the development of commuting in industry. Many workers drive 10 to 25 miles to work each day. People who live and work under such conditions are trying to retain certain advantages of the country and the small towns and villages and at the same time to secure the high wages of industry. During World War II and in the post-war years it was difficult to secure satisfactory living quarters in the industrial communities and so many of the people remained in the nearby towns and commuted regularly to their places of employment. No doubt commuting has become an established feature of the industrial economy of the United States. As the larger farms are divided into small tracts of land to provide for large numbers of non-farm rural dwellers *rurbanization* becomes an important process.

The small part-time farms present a cultural landscape that is both attractive and depressing. Some of the older homes of New England, the middle west, and the south are spacious and attractive. Many of them are prized for their architectural beauty and, when modernized by the installation of running water and bathrooms, represent the best in rural homes. Unhappily only a limited number of such houses are available, and the division of the farms into small tracts of only a few acres has brought with it many small homes that provide the minimum in living facilities; architectural beauty is unfortunately a minor consideration.

Country living, where isolation is no longer a serious disadvantage, is attractive to many families. "To an increasing degree there are included among the people living on farms individuals who have little or no relation to the operation of the farm or the performance of the work on the farm. Per-

[22] This word *rurban* was coined by Dr. C. J. Galpin, formerly head of the Division of Farm Population and Rural Life, in the United States Department of Agriculture. It is needed, and will, it is hoped, come into general use.

sonal preference, convenience, cost, hedging against a depression, and many other factors may make a farm appear to be a desirable place of residence for persons whose major occupation is not in agriculture." [23] These country dwellers familiar with advantages of city living will not be satisfied until their homes in the country have modern conveniences.

The Migratory Farm Laborer

The benefits of improved living conditions have been unevenly distributed among the rural people. The farm owner and the tenant where tenancy is the first important step to ownership have made important progress in securing the advantages of electricity on the farm, water systems, an automobile, and labor-saving appliances and equipment. But the poorer tenants, where tenancy is a way of life, and the migratory farm laborers commonly live under primitive conditions. Many of the seasonal farm laborers, often involving whole families, have a very low annual income, are ill housed, and are denied many of the benefits of a well-established community in respect to schooling, medical service, and public relief in case of need. In 1939 John Steinbeck, in *The Grapes of Wrath,* called the nation's attention to the people of the dust bowl who were driven from their land by drought and low prices of the depression years of the 1930's. The seasonal laborer who moves from one strawberry area to another and from one fruit-picking area to another and who moves into the sugar-beet area at peak periods of work has received sympathetic consideration by Carey McWilliams.[24] These migrants as well as the land owners must share in the improved conditions of life that are spreading into the rural areas.

Economic Security

Land ownership, owner-operated farms, and the integrity of the farm family are the foundations of farm life in rural America. From time to time adverse forces have been operative and the stability of the agricultural industry has been in doubt. Farm tenancy has increased alarmingly in many areas. Corporate ownership of farm lands and large scale operation have become a challenge to the small owner-operated farm. As new patterns of agriculture are introduced into the farming areas the farmer retains his basic political and human rights to participate in the new developments and movements and to share with the other citizens the material and cultural benefits that accrue to the nation.

[23] Taeuber, *op. cit.*, p. 211.

[24] *Ill Fares the Land,* Boston, 1942.

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PART THREE

CHAPTER 10

Our Forest Resources

OUR forests are our greatest renewable natural resource. Unlike oil and minerals, our forests, if properly managed, are self-perpetuating. In addition to their importance as a source of raw material, forests also have far-reaching public benefits wholly divorced from wood substance. Over a vast portion of our land surface, forests conserve irrigation water, protect the soil, regulate stream flow, provide places of public recreation, and afford a suitable environment for wildlife.

Under proper management our forests provide not only these multiple uses but also employment and security for millions of people. In the consideration of the subject of forest conservation, attention will be directed to the economic and social importance of our forest resources and the practices necessary to maintain them at a high level of efficiency.

THE ORIGINAL FORESTS

At the time of the landing of the Massachusetts colonists in 1620 the vast expanse of original forest covered almost one-half the total area of the country and is estimated to have comprised 822,000,000 acres. This great forest area contained over 1100 varieties of trees of which about 100 have been found to have broad economic significance. Nowhere else in the world is there such a diversity of species as in the forests of the United States.

America's virgin forests were so magnificent that our pioneer ancestors considered them inexhaustible. Consequently, great quantities of high-quality timber were destroyed during the process of clearing land for agricultural purposes. However, not all this timber was wasted. Billions of board feet were used for building houses, schools, and churches, and in the development of a wide variety of industries. Our extensive forests have been important in making America great, but it was not until the 1890's that we began to realize that our forests, unless properly managed, would soon be exhausted, and a national movement of forest conservation began.

FOREST REGIONS

The forests of the United States occur in five broad regions (Figs. 1 and 2). Three

By Oliver D. Diller of The Ohio State University.

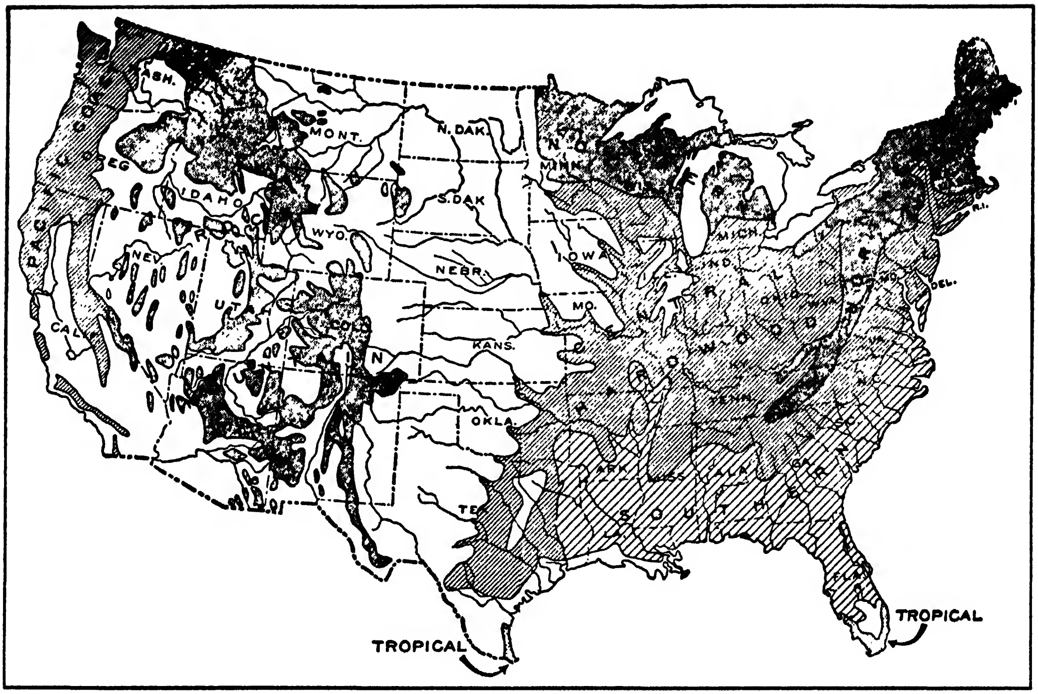

FIG. 1. Map showing the natural forest regions of the United States. (U. S. Forest Service.)

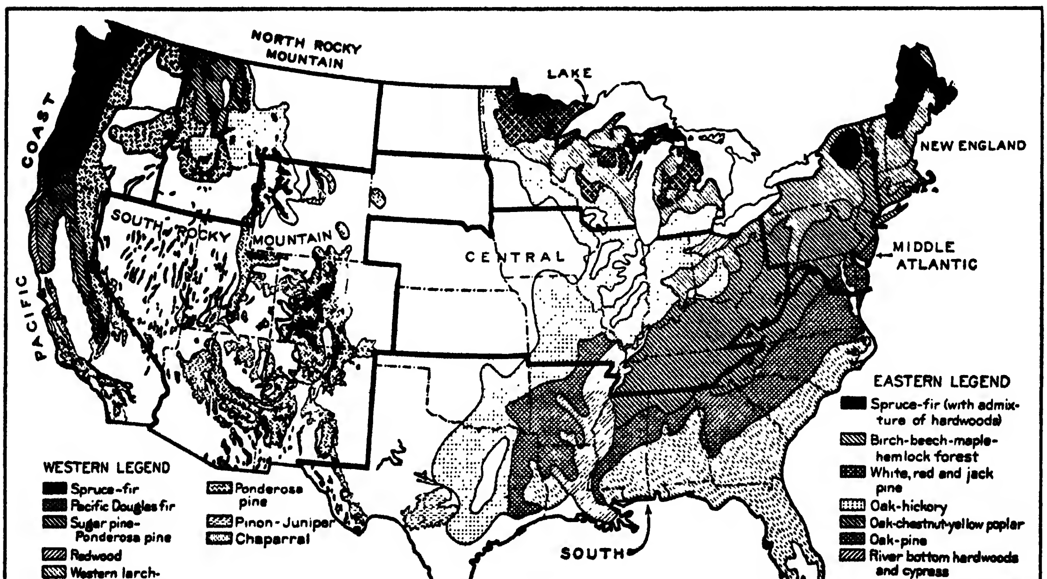

FIG. 2. A regional forest map of the United States based on groupings of forest types. (By Zon and Shantz, U. S. Forest Service.)

of these are east of the prairies: the Northern Forest, the Central Hardwood Forest, and the Southern Forest. The Rocky Mountain and Pacific Forests are west of the Great Plains, extending from Canada south to Mexico.

The Northern Forest

The Northern Forest region, shown in Fig. 1, covers almost all of New England, New York, Minnesota, Wisconsin, and Michigan. Also, it extends an arm to the southwest in the Adirondack Mountains of New York and southward along the Appalachian Highland to northern Georgia. This region includes 117,782,000 acres of forest land, supporting more than 62 billion board feet of softwoods, and nearly 80 billion board feet of hardwood saw timber. Eastern white pine, red pine, and jack pine forests are native to areas in Minnesota, Wisconsin, and Michigan. In scattered spots in the northernmost parts of these states and in the Adirondack Mountains of New York, forests of spruce-fir occur. Over most of the region hemlock is found in association with sugar maple, beech, and yellow birch. Other hardwoods found to a lesser extent are black walnut, basswood, red oak, hickories, elms, and ashes. In the southern part of the region the shortleaf, pitch, and Virginia pines are found. Before 1910 the American chestnut formed more than half of the stand in the Appalachians, but the chestnut blight has eliminated this species as a commercial tree.

The Central Hardwood Forest

This forest, principally of deciduous trees, is found in 19 states in the central eastern half of the United States, and much of it is in forest tracts intermingled with agricultural land. Its 29,328,000 acres of forest represent less than 20 per cent of the total land area in the region. Its western boundary is very irregular where it meets the prairies.

The Central Hardwood Forest consists of a wide variety of species, and, since the region covers such a wide range of soils and climate, not all of them are found throughout the region. Certain northern oaks are replaced by other species of oaks in the southern part of the area, white oak having the widest distribution (Fig. 3). American beech and sugar maple have a wider range north and south than most other species in the region. American elm is the most widely distributed tree of the deciduous forest, extending the farthest north and west. Other species found in this region are wild black cherry, cottonwood, tulip tree, shagbark hickory, red oak, yellow oak, black oak, bur oak, white ash, black walnut, red maple, silver maple, and cucumber tree.

FIG. 3. Stand of virgin hardwood in Ohio. The large trees are all white oaks. (Ohio Agricultural Experiment Station.)

The deciduous forest was most highly

developed in the Ohio and Wabash valleys and in the lower levels of the Appalachian Highland, where individual trees five feet in diameter and 175 feet in height were common.

FIG. 4. Longleaf pine north of Brunswick, Georgia. (U. S. Forest Service.)

The Southern Forest

This forest extends from Virginia through the eastern half of Texas, and from Oklahoma to the Gulf of Mexico. This vast area is characterized by four important pines: shortleaf, longleaf, loblolly, and slash. They are often referred to as hard pines because their wood is harder than that of other trees in the pine family. Of the four principal species, longleaf and shortleaf are the best known (Fig. 4). These once stood in extensive virgin forests of fabulous value, but now they occur mainly in smaller second-growth forests.

The Southern Forest is also known for its cypress swamps and bottomland hardwoods (Fig. 5). The moist lowlands support heavy stands of red and black gums and many species of southern oaks, including water, laurel, and live oak, pecan, cottonwood, ash, elm, sycamore, and soft maple.

The Southern Forest is an important source of forest products, producing more than two-thirds of all the naval stores of the world. The south produces more than one-half of the total pulpwood consumed in the United States, which amounted to 8,000,000 cords in 1946. Lumber and fuelwood

FIG. 5. Cypress brake in Louisiana containing tupelo and red maple as well as cypress. (U. S. Forest Service.)

production amounted to twice as much in wood volume as pulpwood.

Although not so widely distributed as the Central Hardwood Forest, the Southern Forest exceeds 210,000,000 acres on which approximately one-fourth of this country's saw timber is now growing.

The Rocky Mountain Forest

The forests of this region extend from Canada to Mexico and are primarily coniferous, with ponderosa pine the most common tree. In the northern part of the region the forests occur in the valleys as well as on the mountains, but in the southern portion they are limited to the higher elevations because of arid conditions in the lowlands.

At the higher elevations, Colorado blue and Engelmann spruce and Alpine and Douglas fir are dominant. At lower elevations magnificent forests of western white pine, western larch, western hemlock, and ponderosa pine flourish in various combinations. The forests of the Rocky Mountain region have been subjected to severe burning in the past, and in the burned-over areas lodgepole pine commonly has replaced the species that were found in the original forest. Quaking aspen is the most prominent broadleaf tree in this region, but owing to its short life it is not important as a saw-timber tree.

About 13 per cent of the total forest land of the United States, or some 63,000,000 acres, is located in the Rocky Mountain region. Since this is a region of low rainfall, the forests are characteristically open and the saw-timber stand is relatively light.

In spite of the fact that only 30,653,000 acres are considered to have timber that can profitably be harvested, these scattered forests are of great importance locally not only for timber products but also in the protection of watersheds for irrigation. More than fifty of our national forests and eight national parks have been established in this region.

Pacific Coast Forest

On the west coast from Washington to southern California occur the heaviest forest stands in America and probably in the world. The three Pacific coast states contain only one-seventh of the forest area of the country, but it is estimated that they contain 62 per cent of the total saw timber. The largest lumbering operations in the country are carried on in this region.

The California forest forms a natural forest unit, distinguished from the forests of Washington and Oregon. In California, east of the Cascades and the Sierra Nevadas, the forest is largely an extension of the ponderosa pine forest of eastern Oregon and merges with the south Rocky Mountain forest (Fig. 6). On the west slopes, which have higher rainfall and humidity, redwood, giant sequoia, Douglas fir, and sugar pine are important forest trees. The magnificent redwood forests contain trees varying from 175 to 225 feet in height and from three to ten feet in diameter, but many monarchs attain considerably larger sizes: heights up to 300 feet and diameters in excess of 15 feet. Although some of the virgin redwood stands have been assured continued existence through inclusion in state and county parks, most of them are in the paths of logging operations.

The Douglas fir forest of western Washington and Oregon extends 480 miles from north to south and varies in width from 100 to about 150 miles. This area covers 35,000,000 acres, of which 83 per cent is forest land. The Douglas fir forms 60 per cent or more of the stand on more than half of the forest land. Important species commonly associated with Douglas fir are western hemlock, western red cedar, Sitka spruce, Pacific silver fir, and noble fir.

The eastern-slope forest of Washington and Oregon occupies the interior of these two states and extends into Idaho and Montana, where it merges with the Rocky Mountain forest. The major species in this forest are western white pine and ponderosa pine.

FIG. 6. Virgin stand of ponderosa pine in the Deschutes National Forest, Oregon. (U. S. Forest Service.)

In addition to supporting a tremendous volume of high-quality timber, the Pacific coast forests are important for recreational purposes and for the conservation of water for irrigation, power, and municipal use.

HISTORY OF LUMBERING

The sawing of lumber began over 300 years ago along the Atlantic coast where the early colonies were first organized. The early history of lumbering in the United States is closely related to the harvesting of the white pine, which at one time was king of the primeval forests from Maine west to Minnesota and south to Georgia and Alabama. The quest for this highly prized species determined the principal course of the lumber and timber industry for more than 200 years. It created many fortunes and played an important role in the life and history of the American people.[1]

As the supply of virgin white pine declined, the principal center of timber production slowly shifted from the New England states to Pennsylvania, and thence to the Lake states. By 1904 the virgin white pine in Michigan and Wisconsin had been completely exploited, and the only remaining stands occurred in the southern Appalachians. The southern boom in white pine lasted from 1900 to 1915. During the

[1] Donald Culross Peattie, "White Pine," *Sci. American*, June, 1948, pp. 49–53.

same period others who had accumulated capital in the recently cut-out Lake states built great sawmills in the vast yellow pine forests of the southern states from Virginia to Texas.[2]

World War I created a tremendous demand for lumber, and the mills in the south were in a position to supply a large part of it very profitably. By the early 1920's the peak of the southern-pine lumber production was reached, and the big mills were either junked or moved to the far west.

During the early 1900's the manufacture of oak and other hardwood lumber also shifted from the northeast to the central and Lake states and then southward, trailing the advance of the softwood industry.

With the decline of lumbering in the Lake states, the central states, and the south, the chief producing center since 1938 has been in Oregon and Washington. In the meantime, however, the second-growth forests of formerly cutover lands have attained commercial importance, particularly in the south. The new forests lack the quality of the virgin forests, but new uses for cellulose have resulted in markets that bring in as much money to the landowner and the lumberman as did the old forests in their heyday.[3] A new outlet in the form of pulpwood has increased the value of the young crop of trees, and many timberland owners are beginning to see that a new crop of timber can be grown while the current crop is harvested and that devastation is unnecessary.

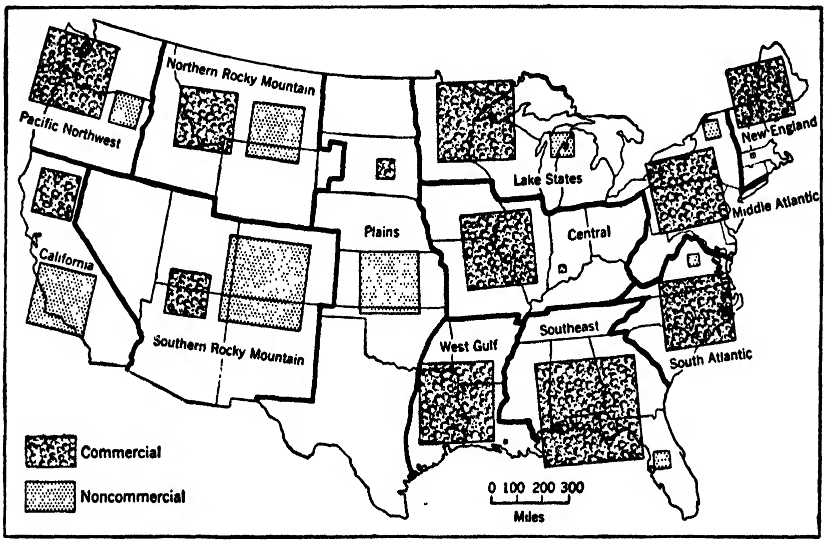

FIG. 7. Distribution of forest areas. (U. S. Forest Service.)

THE FOREST INVENTORY

Economic planning and formulation of forest policies by both public and private agencies depend upon adequate information regarding our forest resources. The U. S. Forest Service under authorization

[2] *American Conservation in Picture and in Story,* Am. Forestry Ass'n, Washington, D. C., 1941.

[3] I. F. Eldredge, *The Four Forests and the Future of the South,* The Charles Lathrop Pack Forestry Foundation, Washington, D. C., 1947.

provided in the McSweeney-McNary Act of 1928 has conducted general surveys, and additional studies have been made by individual states, the TVA, and various other agencies. Data on the extent, character, condition, and other features of American forests were obtained largely from survey reports published by the U. S. Forest Service.

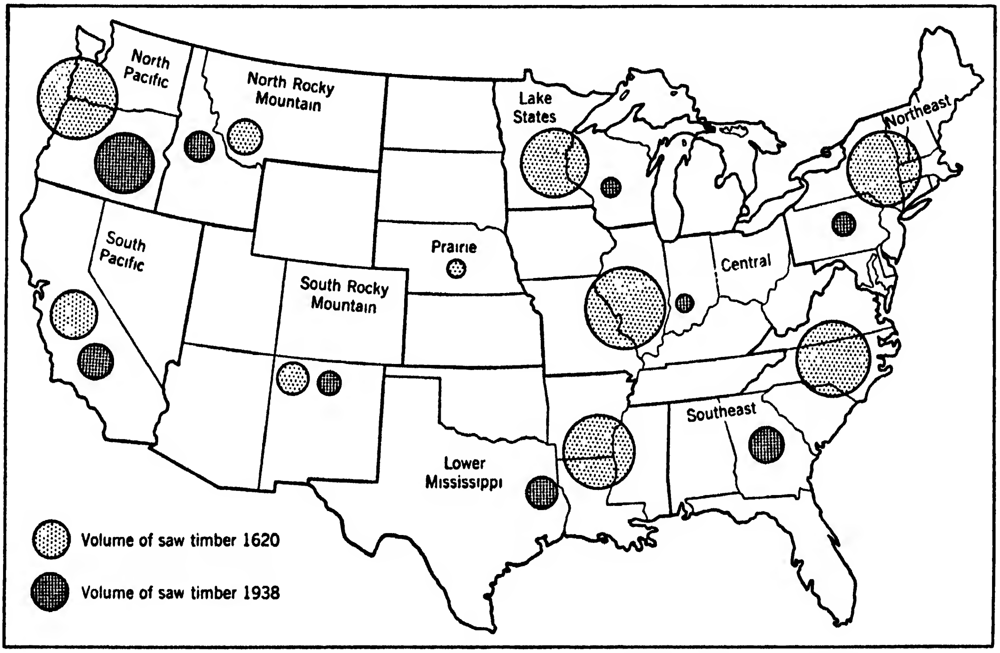

FIG. 8. Comparison of saw timber stand in 1620 and 1938. (U. S. Forest Service.)

Extent of Forests

Some 630,000,000 acres, or one-third of the total land area of this country, are primarily useful as forest land. Approximately 170,000,000 acres of this area are noncommercial, including forest land that is in rugged, mountainous country or located where climate is unfavorable or the soil is shallow. Such forests, although not suited to the production of timber of economic importance, are of great public importance in watershed protection, prevention of erosion, furnishing cover for wildlife, and providing an environment for recreation (Fig. 7).

Of the 460,000,000 acres of forest land classed as commercial or available and suited to economic production of timber and other forest products, more than three-fourths lie in the Northern, Central, and Southern Forest regions (Fig. 8).

Forest Conditions

The fact that 460,000,000 acres, or one-fourth of the area of the United States, are commercial forest land does not indicate that there will always be an abundance of timber. The condition of our existing forests must be taken into account as well as the area they cover.

Our forest lands can readily be divided into five main classes: old-growth saw tim-

TABLE 1

TOTAL COMMERCIAL FOREST AREA OF THE UNITED STATES BY CHARACTER OF GROWTH AND BY REGION *

Region	Total: Thousand Acres	Total: Per Cent	Saw-Timber Area: Total	Saw-Timber Area: Virgin Growth	Saw-Timber Area: Second Growth	Pole-Timber Area	Seedling and Sapling Area	Poorly Stocked Seedling and Sapling and Denuded
North †	170,321	36.94	48,196	2,289	45,907	41,445	49,370	31,310
South ‡	183,266	39.75	98,377	973	97,404	29,322	22,873	32,694
West §	107,457	23.31	58,603	41,356	17,247	24,246	13,309	11,299
All regions	461,044	100.00	205,176	44,618	160,558	95,013	85,552	75,303

* U. S. Forest Service, *Gauging the Timber Resource of the United States* (reappraisal of the forest situation), Washington, 1946.

† Includes New England, Middle Atlantic, Lake, Central, and Plains regions.

‡ Includes South Atlantic, Southeast, and West Gulf regions.

§ Includes California, Pacific Northwest, and Rocky Mountain regions.

ber, second-growth saw timber, poles, seedlings and saplings, and nonrestocking.

The old-growth forests are those in which no systematic lumbering has taken place and old timber predominates. Nearly 10 per cent of our total commercial forest area is in old-growth stands mostly in the Pacific coast and Rocky Mountain regions. Old-growth forests are usually thought of as heavy stands of large, high-quality trees of good species and with relatively few defects. However, only one-fourth of our so-called virgin acreage meets this standard.

In Table 1, which shows the amount of commercial forest land in the United States by character of growth and by region, the total saw-timber area, including both virgin and second-growth timber, makes up 45 per cent of our commercial forest area. These timber areas must be maintained.

The most serious deficiency in second-growth saw-timber stands is the lack of growing stock. In a well-managed forest there is not only a good stand of merchantable timber but also a good stocking of poles that provide the basis for future harvests. Stands with more than half the saw-timber trees over 18 inches in diameter occupy only one per cent of the commercial forest area in the south, and one may drive for miles in some parts of the north without seeing any merchantable saw timber. Obviously, we need to increase the proportion of large saw timber in both the northern and the southern forest regions if we are to build up the output of good-quality timber. Almost 90 per cent of our poorly stocked stands are in these two regions, indicating the degree to which the nation's forest productive capacity is underdeveloped.

The areas covered with poles (five inches or more in diameter) too small for sawlog operation make up 20 per cent of our total forest land, and satisfactory sapling reproduction makes up 18 per cent, indicating the potential increase in timber-crop yields 25 to 50 years hence if sound forestry practices are followed. The column in Table 1 headed Poorly Stocked Seedling and Sapling and Denuded shows that 16 per cent or one-sixth of our commercial forest land is virtually nonproductive. This is largely a result of destructive cutting, overgrazing, and fire.

Volume and Growth of Standing Timber

The forests of the United States are now growing annually at the rate of 13.4 billion cubic feet, including 35.3 billion board feet of saw timber. It has been suggested that an annual growth of 20 billion cubic feet of all timber and 72 billion board feet of saw timber is required for an economy of full employment in which consumers would have a free choice of readily available materials, including timber and timber products. These estimates are based on the probable demands for timber in housing programs, production of paper and paperboard, new uses for wood, a margin for export, and a margin for security in the event of war.

TABLE 2

COMPARISON OF GROWTH AND DRAIN OF ALL TIMBER AND OF SAW TIMBER ON COMMERCIAL FOREST LANDS OF THE UNITED STATES IN 1944 *

Saw Timber	*Growth*	*Drain*
	Billion Board Feet	
North	8.4	9.0
South	19.9	24.9
West	7.0	20.0
U. S.	35.3	53.9
All Timber	*Billion Cubic Feet*	
North	4.7	3.7
South	6.4	6.5
West	2.3	3.5
U. S.	13.4	13.7

* U. S. Forest Service, *op. cit.*

The significance of these growth goals is brought out by comparisons of current growth and drain as shown in Table 2. Saw-timber drain is about 25 per cent more than current growth in the south and seven per cent in the north. In the west, drain exceeds growth by a wide margin because of the virgin timber that is now being harvested.

Further analysis of Table 2 indicates an apparently favorable relation between all timber growth and drain in the north and the south. However, this balance by itself is not satisfactory because of the fact that most of these stands are in the pole stage and contain much low-grade timber. In fact, one of the major problems in the north is to find satisfactory markets for much of the inferior quality, small-size timber that should be removed from the forest to make room for more valuable growth. The same problem exists to a smaller degree in the south.

For the future economy of the west, the virgin stands should be cut in a manner that will best promote future growth. Without good forest practice in the west, this region may inherit land-use problems similar to those that occurred in the Lake states and other regions after liquidation of the forest.

In order to meet the goals that were suggested earlier, it will be necessary to increase all timber growth 50 per cent and to double saw-timber growth. The long-range solution to the problem lies in the constructive management of our second-growth forests. The actual accomplishment of this large-scale improvement in management practices in these forests, three-fourths of which are privately owned, presents a challenge which needs to be met without delay if growth and drain are to be balanced at a high level of production. No nation with vision can afford to let a renewable resource that is so vital to its welfare deteriorate.

FOREST OWNERSHIP

The character of ownership of forests is an important factor in the development of a sound forestry program. A stable type of ownership is essential because of the time element in producing trees of high quality. In the long run, the interest and ability of the landowners in the growing of trees will determine our success or failure in meeting our future timber requirements.

Private Ownership

Of the 460,000,000 acres of forest land available for commercial timber crops, approximately 341,000,000 acres or three-fourths are privately owned. About 40 per cent of the private forest lands is in farm ownership; another 40 per cent is in small nonfarm holdings; and 20 per cent is in industrial or other large holdings. As shown in Table 3, which presents the pattern of commercial forest land ownership, small ownerships are the rule in privately owned forest lands.

TABLE 3

PATTERN OF COMMERCIAL FOREST LAND OWNERSHIP IN THE UNITED STATES *

	Per Cent of Area			
	North	*South*	*West*	*U. S.*
Small private	69	66	20	57
Medium private	4	12	5	7
Large private	9	13	11	11
Total private	82	91	36	75
Public	18	9	64	25
All owners	100	100	100	100

* U. S. Forest Service, *op. cit.*

The following classification of private ownership was used: small, under 5000 acres; medium, 5000 to 50,000 acres; and large, 50,000 acres and up.

As shown in Table 3, the proportion of privately owned forest land is low in the west, where large untouched areas of the original public domain were set aside as national forests. Private holdings make up 82 per cent of the commercial forest land in the north and 91 per cent in the south.

In the early days of settlement our land policy had as its objective the building of a nation of small home owners, assuming that each owner would safeguard and develop his home property. However, our land-use history has shown that, in general, these individual property owners failed to recognize that not all their land was suitable for agricultural purposes, and the result was that vast areas of forest land wholly unfit for farming were cleared. The present intermingling of private properties, some small and some large, presents difficult problems in bringing about over-all satisfactory forest management.

The future output of forest products will be more closely related to volume of standing timber on private land than to acreage. Judged by current cutting practices, the small holdings stand out as the crux of the problem of increasing our timber growth. Results of a 1945 survey covering all public lands, all private lands of 50,000 acres or more, and a dependable sample of the smaller private holdings show that two-thirds of the cutting on private lands is poor or destructive.[4] Within the private ownership group there is a significant difference between small owners and large. Almost one-third of the cutting by large owners is good or of a high order and only one-third is poor or destructive.

About half of the acreage in small hold-

[4] *The Management Status of Forest Lands in the United States* (reappraisal report), U. S. Forest Service, Washington, D. C., 1946.

ings is on farms averaging only 41 acres of woodland each. Although such small forest acreage cannot provide the main source of income to the owner, it can and often is handled as an integral part of the farm business supplying fuel, posts, or lumber for home use as well as providing a supplementary cash income. Unfortunately, in many sections the perennial need for cash has resulted in overcutting and liquidation of the timber. However, small holdings, especially family-size farms, will continue to be an essential feature of the American scene, and we must find ways and means of helping the small woodland owner to practice better forestry if this important segment of our forest resource is to contribute its share of desirable timber products and other values.

Community Forests

The term community forest is applied to those wooded areas owned and maintained for public use by any of the subordinate units of government in given states. Local public forests have a high social value because they bring forests and forestry close to the people of the community and create a better appreciation of the relation of forests to our national economy.

There are now 2379 established community forests, with an aggregate area of 3,089,361 acres. Community forests vary in size from small woodland tracts, such as the town forests in New England, to large county forests in Wisconsin. Massachusetts, a pioneer state in the community forest movement, has 129 town forests aggregating 40,000 acres. In addition to these forests, about 160,000 acres are owned by other municipalities mainly for water protection. Wisconsin, through its county zoning laws, has acquired nearly 2,000,000 acres in county forests and has 210 school forests ranging from 20 acres to over 800 acres per school.

State Forests

During the first decade of the present century the growing conservation movement gave stimulus to state activities in forestry, centering on control of forest fires, studies of local forest conditions and problems, and education of the public to the importance of conserving forests. Eight states during this period passed legislation pertaining to acquisition and administration of state forest land.

Since 1933, considerable progress has been made in the establishment of state forests and parks. Thirty-eight states have adopted a policy of establishing and maintaining state forests, and 43 states have one or more state parks. The aggregate area of state forests is now more than 15,000,000 acres. The National Resources Committee has recommended that state ownership be eventually expanded to include 77,000,000 acres, mostly in the densely populated states.

In addition to state forests, many states maintain a system of state parks, which include areas of special scenic, historic, or recreational value. Here the emphasis is on the preservation of natural and historic features rather than commercial timber production. In some states there is an effort to preserve areas of virgin forests as examples of original conditions. An outstanding example is the California State Redwood Park, which has great scenic, scientific, and inspirational value. New York and California lead in the number of state parks and total area in parks; Minnesota, New York, Michigan, Washington, and Pennsylvania lead in area of state forests with a total of over 13,000,000 acres.

National Forests

The national forests with their 179,000,000 acres lie in 42 states and two territories. Of the total forest area 73,000,000 acres or 41 per cent are classed as commercial. Most of the national forests are in the 11 western states. These lands, including 55,000,000 acres of grazing or other nontimbered land, were permanently set aside by acts of Congress and are administered by the Forest Service of the U. S. Department of Agriculture.

The Forest Service is especially charged with the acquisition, development, and management of these public forests for economic as well as social uses. They differ from other commercial forest lands chiefly in that they are publicly owned and add to the perpetual supply of forest products.

One of the original purposes for establishing national forests was protection of watersheds. Achievement of this objective requires adequate ground cover to retard excessive surface runoff of water and to check erosion. Consequently, it has been the policy of the Forest Service to prevent overgrazing of forest and rangeland by livestock and to maintain a productive stand of timber on the lands devoted to forestry.

In the early days of federal land acquisition the federal forests were called *forest reserves.* It is significant that in 1907 the name *forest reserve* was changed to *national forest,* indicating that these lands were to be managed for the production of forest products rather than as mere reservations. The fact that the national forests make a substantial contribution in timber production is shown by the record for the fiscal year 1944. In that year the total timber cut under commercial sales amounted to 2,821,339,000 board feet, and in addition, 493,395,000 board feet were cut in exchange of timber for land. On these lands scientific forestry is being applied, and the forests are being managed for continuous production at a high level.

Other federal forests not under the jurisdiction of the Forest Service include 20,000,000 acres which still remain in the public domain, 250,000 acres of forest land on watersheds of reservoirs constructed by the Tennessee Valley Authority, 2,500,000 acres in western Oregon recovered by the government from the former Oregon and California Railroad and Coos Bay Wagon Road grants, some 12,000,000 acres in Indian forests, some 6,000,000 acres in national parks, and several million acres in wildlife refuges and military reservations. Commercial use of timber and other resources in the national parks is prohibited because the purpose is to preserve areas of distinctive scenic, historic, educational, and scientific importance in their natural condition.

INCREASING USEFULNESS OF WOOD

Since colonial times, wood has performed a vital role in the development of the United States. Wood is an extremely adaptable material. An attempted census once listed 4500 uses without even approaching a full and exhaustive classification.[5] No other material provides fuel, fiber, food, and chemical derivatives while serving in addition a wide variety of structural uses. A few of the principal products of the forest harvest are shown in Fig. 9.

World War II provided an increased appreciation of the merits and adaptability of wood and stimulated research which resulted not only in the improvement of

[5] J. A. Hall and T. J. Mosley, *Products of American Forests,* Forest Service, U. S. Dept. of Agriculture, Washington, D. C., 1939.

established products and manufacturing processes but also in the development of new and improved production techniques, new wood derivatives, and modified wood products.[6] (See Chapter 11.)

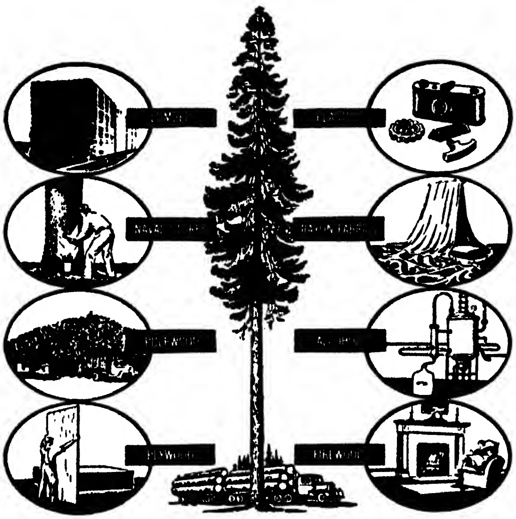

FIG. 9. Principal products of the forest harvest. (American Forest Products Industries, Inc.)

DIVERSIFIED RESOURCES IN FORESTS

Previous discussion has dealt mainly with information regarding the extent, character, condition, and ownership of our commercial forests; the relation between growth and depletion of our standing timber; and the importance of wood as a raw material. Although high standards of living require the abundant use of wood, forests include other resources of great economic and social significance that in some regions transcend their value as wood producers.

[6] "Problems and Progress of Forestry in the U. S.," *Report of the Joint Committee on Forestry of the National Research Council and the Society of American Foresters,* Washington, D. C., 1947..

Forests conserve and regulate inland waters essential for irrigation, navigation, power, aquatic life, and domestic use; they are the protecting cover that controls erosion; they are the natural home of wildlife; and, by becoming increasingly important for outdoor recreation, they promote the health and spiritual well-being of our people.

Forests in Relation to Soil and Water

In some sections of the country the value of forest cover as a regulator of stream flow far exceeds that of any other forest product or service. About four-fifths of the total forest cover of the nation is classed by the Forest Service as valuable for the protection it furnishes to watersheds. The protective ground cover of vegetation greatly aids infiltration and checks the rate of runoff from the ground surface.

The relation of forests to runoff is well illustrated by a spectacular example in the California mountains where two canyons received 12 inches of rainfall during the last days of December, 1934. One of the canyons was covered with chaparral; the other had been denuded by fire. Flood waters in the burned canyon destroyed 200 homes and took 34 lives whereas in the unburned canyon there was no serious water damage.[7]

The hydrological functions of the forest, however, are different in mountainous, hilly, and level terrain. In level to rolling topography the effect of forest cover on flood control is not so pronounced as in mountainous country. Foresters do not assert that a forest cover will prevent all floods. Certain combinations of soil and

[7] Raphael Zon, "Forests in Relation to Soil and Water," *Proc. Am. Phil. Soc.,* Vol. 89, 1945, pp. 399–402.

meteorological conditions will produce a flood despite the beneficial action of the forest cover. Any given soil can store only a certain amount of rainfall. But, without the mitigating influence of forests, floods are more frequent, more severe, and more destructive.

The processes involved in the regulation of runoff by forests may be explained largely by the fact that a well-managed forest is an integrated biological community with its own special climate, characteristic undergrowth, and topsoil.[8] The forest floor is protected by the crowns of trees and shrubs at different levels. The ground surface is a mat of dead leaves and twigs, and beneath this litter is a layer of organic matter in various stages of decay, in which there is an abundance of soil fauna and flora. All this biologic activity keeps the soil porous and gives it a crumbly structure, ideal for absorbing and filtering large amounts of water.

Snow accumulation and melt are also influenced by good forest cover. Protected against sun and wind, snow remains on the forest floor from a few days to several weeks longer than in exposed areas nearby. Also, the interception of snow by forests has received special attention because, usually, a considerable amount will stick to the trees. Measurements taken in the dense forests of Idaho show that about 25 per cent of the snowfall on the average is caught by the crowns.

Another important relation between forests and water is that forests help to hold the soil open in winter. When the surface of open fields is frozen so solidly as to be virtually impervious, that of the forest soil is still fairly open and receptive. Consequently, in cold regions, as deep snows melt, much of the water percolates gradually into the forest soil but largely runs off bare and compact frozen soil.

In addition to the above-mentioned effect of the forest in reducing runoff is the control of erosion and the consequent prevention of the silting of streams and reservoirs. Silt will eventually ruin the storage capacity of any retention reservoir. The speed of silting varies directly with the vulnerability of the watershed to water erosion.

Forests in Relation to Wildlife

The forest, when properly managed, furnishes an ideal home for many kinds of wildlife. The forest indirectly provides safe breeding places, water, food supply, shelter, and protection.

Well-managed forests are characterized by several levels or stories suitable for wildlife. Some animals live below ground, others on the forest floor, some in the lower shrub zone, and some in the trees. It is apparent, therefore, that cutting operations can be adjusted to safeguard conditions favorable to the maintenance of a wild-animal population. On the better forest soils, timber growing would logically receive the greater emphasis whereas on shallow soils and rugged mountains wildlife may be given major consideration.

That the management of our national forests on a continuous-production basis since the early years of the century has materially aided wildlife is indicated by the fact that one-third of all our big game animals and myriad smaller animals and birds claim the national forests as their home. The main objectives of the Forest Service in wildlife management are to build up the habitat, to increase wildlife population in some areas, and to keep wildlife popula-

[8] Bernard Frank and Clifford A. Betts, "Water and Our Forests," *Misc. Pub.* 600, U. S. Forest Service, Washington, 1946.

tions in proportion to the land's productive capacity. Many state and private agencies have a similar policy.

Another important program that has contributed greatly to the restoration of wildlife is the federal system of wildlife refuges. President Theodore Roosevelt set aside the first national wildlife refuge in 1903. Since then, and especially during the past decade, this program has expanded to the point where over 280 areas totaling nearly 14,000,000 acres have been set aside for this purpose under the administration of the federal Fish and Wildlife Service. (See Chapter 18.)

Value and Use of Forests for Recreation

Recreation is an increasingly important use of forest land. Before World War II no less than 40,000,000 persons visited the national forests and national parks each year. It is estimated that the total annual income derived each year from recreational use of community, state, and national forests amounts to more than $2,000,000,000. It is apparent, therefore, that recreation represents one of the major products of forests. (See Chapter 20.)

However, it must be remembered that the most important results of forest recreation cannot be estimated in terms of money. Our parks, wilderness areas, and wildlife refuges were created to preserve natural, scientific, or historical features for the enjoyment, education, and inspiration of all the people, and forests are an indispensable part of the scene. For obvious reasons, cutting of timber is prohibited or greatly restricted in such areas.

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CHAPTER 11

The Practice of Forest Conservation

THE best avenue of approach to the problem of assuring abundant and continuous wood supplies lies in the protection and management of forests and embraces all the techniques that go to make up the practice of forestry.

The United States has plenty of forest land to provide adequate forest supplies for the future. However, as was indicated in the preceding chapter, the fact that one-fourth of the area of the nation is commercial forest land does not mean that there will always be an abundance of timber. The crucial factors are the age and state of depletion of forest growing stocks. These have been adversely affected by forest fires, insects, diseases, overgrazing, and destructive cutting. Prevention of further reduction of our forest capital or growing stock is imperative if adequate future supplies of forest products are to be available.

Improved conservation practices not only are necessary for the production of more wood but also are a great reservoir for employment. A managed forest, with its continuous production of wood and its recurring needs for silvicultural treatment, can provide profitable employment to many more people than a forest that is abused or not managed at all. In Denmark 750,000 acres of forest furnish employment for about 6000 people, or one worker to 125 acres. In Switzerland the public forests give employment to one full-time worker for every 100 acres. The forests of the United States, if put under management, would give employment to over 6,000,000 people and would approximately double our annual growth of wood.[1]

FOREST PROTECTION

The most significant fact about forests is their extraordinary capacity to reproduce themselves. This was not clearly understood in the early days when the harvesting of the forest usually meant the end of the forest. We know now that there is a vast difference between forest use and forest destruction. Under modern forest management the forest crop is harvested while the forest is kept in a productive condition.

Protection from Fire

Fire is the greatest enemy of the forest. It destroys more forest growth and keeps more young trees from becoming established than any other single factor. The loss is great when expressed in terms of the useful products that might have been made

[1] *Third Report of the Governments of the United Nations,* the Interim Commission on Food and Agriculture, F.A.O., Washington, D. C., 1945.

By Oliver D. Diller of The Ohio State University.

from the forest harvest. That fire is a widespread national problem is indicated by the fact that over 18,000,000 acres of unprotected forest land were burned by 96,500 fires in 1946.[2]

One of the most serious forest fires on record occurred in Maine during October, 1947. Some 3500 people fled Bar Harbor, the famous Maine resort, when flames raced in from surrounding woodlands. Nearly 400 homes, including 60 large estates, were destroyed in this summer resort center. But the burning of Bar Harbor was only one phase of the fire disaster that struck Maine and other New England states at the peak of an extended drought period. Forest officials estimate that October fires burned more than 240,000 acres in Maine, with the timber loss and property damage amounting to millions of dollars.

American forests in every region show the effects of past forest fires. Repeated fires have converted some valuable conifer stands into brush fields and hardwood stands into ragged forests of unmerchantable trees. In addition to direct damage to timber, such fires result in the impaired condition of watersheds and the destruction of wildlife. Furthermore, after a fire, tree-killing insects and wood-destroying fungi usually increase in activity. The damage that fire does to standing timber is well illustrated in Fig. 1.

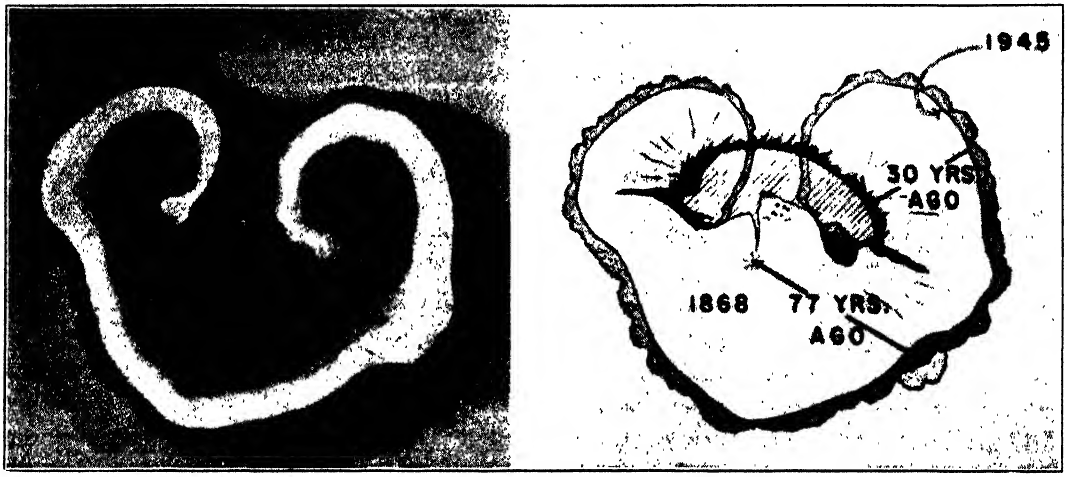

Fig. 1. Cross section of an oak which was damaged by fire in 1915. The result is a distorted, decayed trunk, useless for lumber. Annual growth rings on the tree reveal: (1) growth started in 1868; (2) fire seared side of trunk in 1915; (3) tree after so many years cannot repair damage. (Ohio Agricultural Experiment Station.)

Causes of Fires

Careless smokers who toss lighted cigarettes out of automobile windows or drop them in the dry leaves in the woods cause about one-fourth of our forest fires. "Firebugs," or incendiaries, cause as many more. Lightning and careless campers who fail to make sure that their campfires are out before they leave are the other principal causes of forest fires. These factors account for over 75 per cent of the fires each year in the United States.

[2] *Report of the Chief of the Forest Service,* U. S. Dept. of Agriculture, Washington, D. C., 1947, p. 25.

Methods of Fire Control

Fifty years' experience with the forest-fire problem has shown that, since most of the fires are man-caused, the best approach to their control is through adequate forest protection laws, efficient forest protection organizations with a system of fire wardens and fire-fighting equipment, and intensive education.

Planes and parachutes to deliver men and equipment to forest fires are the most spectacular of the new methods of combating forest fires in the United States. They have proved especially successful with fires in inaccessible places and at the same time have caught the public fancy and made people conscious of the need for protection.

Holbrook describes an example of the successful use of planes at a big fire in the Siskiyou National Forest in Oregon and California.[8] The fire was in such remote and difficult country that, if plane service had not been available, supplies and equipment would have had to be trucked 31 miles over steep mountain roads, then packed on the backs of mules 22 miles more, or a total of 53 miles. One such trip would have consumed 24 hours. A forest service plane took off from the nearest airport, at Medford, Oregon, and 15 minutes later a ton of food and supplies was parachuted safely down to the firemen.

Space will not permit detailed discussion of the many devices that are being used by efficient forest-fire organizations. Nearly all state and federal forestry agencies have a network of lookout towers and a supply of fire tools and spray pumps, and the more progressive organizations use two-way radio sets, trenching machines, and other modern equipment.

[8] Stewart H. Holbrook, *Burning an Empire,* Chapter 19, The Macmillan Co., New York, 1944.

One of the newest methods in fire control is to drop bombs containing chemicals; as these bombs crash they release a fire-killing vapor which is three times as effective as an equal weight of water. Dry Ice has also been used with success on certain types of fires.

There is no one cure-all for the fire control problem. Research on methods of control should be continued, but, at the same time, an intensive educational program must be carried on so that a subconscious will to prevent forest fires will be created in the people who are going to the forest in increasing numbers. We can cut and use our forests over and over again as long as the growing stock is protected from fires and other destructive agents.

CONTROL OF INSECTS AND DISEASES

Even though fire is considered the greatest enemy of the forest because of its effect on values other than timber, insects and diseases are causing even greater losses in standing timber than fire. During the decade 1934–1943, the estimated loss from insects and disease was 622,000,000 cubic feet each year.[4]

In addition to our native pests, the situation has been complicated still further through the accidental introduction of several highly destructive pests from foreign countries.

The major insect enemies affecting our commercial forest stands are the white pine weevil, the spruce bud worm, larch sawfly, pine bark beetle, nut weevil, the gypsy moth, and the Pandora moth.

Considerable progress has been made in methods of controlling insect pests. Air-

[4] *Report of the Chief of the Forest Service,* U. S. Dept. of Agriculture, 1947, p. 20.

plane dusting and spraying with DDT have been successful in combating a number of the leaf-eating insects. This method is promising for desperate situations, but, to date, the cost has been prohibitive for extensive areas.

Fungous diseases that have made serious inroads on our forest resources are the American chestnut blight, white-pine blister rust, Dutch elm disease, and phloem necrosis.

The greatest loss from fungous action in merchantable stands is the destruction of heartwood of living trees by decay fungi. The amount of material that has to be discarded because of rot when timber is cut often runs as high as 10 per cent of the total volume of the mature stand and occasionally amounts to more than one-third of the volume. Better fire protection and increased care in logging would minimize the attacks of these wood-rotting fungi.

Although increased research and better organization of detection and control are needed, the best possible insurance against insect and disease losses is intensive forest management. When forests are intensively managed, immature trees can be saved from attack and the mature trees that have succumbed can be salvaged. Furthermore, since so many of our most destructive pests have been imported, it would seem that quarantine regulations should be made more stringent than ever before.

RANGE MANAGEMENT AND WOODLAND GRAZING

The forage produced by herbaceous and shrubby plants under the trees and in openings in the forest is an important forest resource. This is particularly true of the forest ranges of the west and south, but much less of the central and northern forests.

Western Forest Ranges

The national forests administered by the U. S. Forest Service include more than 80,000,000 acres of land suitable for livestock grazing. In the west the forest-land grazing problem centers around the utilization of large areas of public land by many private owners of ranch property and livestock. Before these areas came into public ownership, much of this land was overgrazed and the forage so seriously depleted that fertile topsoils were washed away, slopes were cut by gullies, and irrigation works and other improvements in the valleys were seriously damaged by floods and silt.

Creation of the national forests made it possible to provide fire protection and regulation of grazing so that the forage plants and tree reproduction could be restored.

Four major principles are employed in the administration of western forest ranges to bring about the proper co-ordination of grazing with other forest uses: (1) use of the range by the class of livestock best suited to use it; (2) adjusting the number of livestock to what the range can support satisfactorily on a permanent basis; (3) adjusting the season of use to the most satisfactory period from the standpoint of correlating maintained feed production with greatest value from the use of the feed; (4) distributing the grazing over the range to ensure even utilization of all parts and to protect parts of the range needing special attention.[5]

In spite of the obvious importance of keeping grazing in balance with sustained range capacity, a small segment of the livestock industry has proposed various measures to restrict the Forest Service in its ad-

[5] "A National Plan for American Forests," *Senate Document 12, 73rd Congress, 1st Session*, Government Printing Office, Washington, D. C., 1933, p. 539.

ministration of the forest ranges and to put greater control of grazing in the hands of private individuals. Since much of the land being grazed is important watershed and some of the area is important for commercial timber production also, it would seem that the public good would best be served by permitting the Forest Service to continue to administer the national forest ranges under a system of multiple-use in which all the forest resources and values would be co-ordinated.

FIG. 2. Woodlands can be perpetuated only when there is an abundance of young growth coming on. The woodland on the left has been protected since 1932. The results are vigorous natural reproduction and improved forest soil conditions. (Ohio Agricultural Experiment Station.)

Forest Ranges in the South

The forests of the south furnish considerable feed for livestock, particularly for cattle during the spring and summer. It is estimated that nearly 150,000,000 acres of the 217,000,000 acres classed as forest land are grazed to some extent.

Since 91 per cent of the forest land in the south is held in private ownership, the grazing problem is quite different from that in the west. Among the more important problems in the grazing of southern forest lands are: the widespread practice of uncontrolled burning to remove unused grass, the serious damage by hogs in rooting out longleaf pine seedlings, and the grazing of sprouts of valuable timber species in the southern Appalachian hardwoods. Another important problem is the adequate co-ordination of forest-range grazing with improved pastures and supplemental winter feeding.[6]

[6] *Ibid.*, p. 550.

Forest Grazing in the Central and Northern Forests

On the forest lands of the central and northern States grazing is confined almost entirely to the farm woodlands. The most intensive use of forest lands by livestock occurs in the central states, where livestock population is high and most of the open land is under cultivation. Studies made by the U. S. Department of Agriculture and the state experiment stations have shown that in the central and northern regions little real forage is produced in the understory of a good forest. In most of the forest lands, timber production should be the objective and livestock grazing should be kept at the minimum in order to protect forest reproduction and ensure further timber crops (Fig. 2).

The fundamental consideration in the use of forest land for grazing in the central and northern regions is primarily one of economic values. If the land is more valuable for crops other than trees, the land should be cleared. If it is best suited to timber production, it should be protected from grazing to assure perpetuation of the forest.

PROPER CUTTING PRACTICES

As stated above, the goal of forestry is to keep in continuous production all potentially productive forest lands not used or needed for other purposes. High production is possible only when the growth is systematically harvested and the forest is protected against fire and other sources of damage.

In a virgin forest that is not disturbed, trees die and the wood rots, but young trees come in, and the two processes, growth and decay, are roughly in balance. Complete utilization of increment is approached most closely under intensive forest management, in which the selective cutting method is usually the most desirable.

Continuous Production through Selective Timber Management

In general, until the 1930's timber owners and operators thought mainly in terms

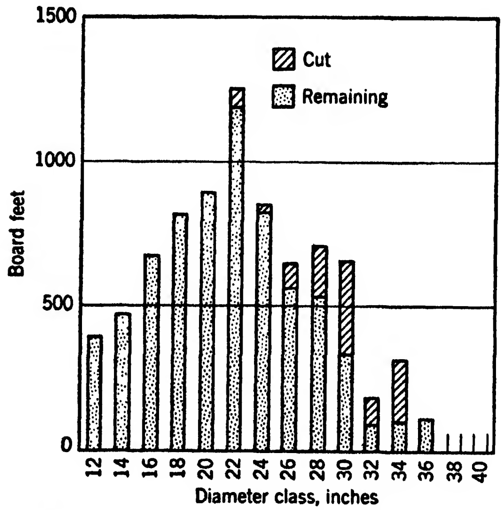

FIG. 3. How selective cutting operated in an eastern Ohio woodland. (Ohio Agricultural Experiment Station.)

of the immediate returns, and the idea of continuously productive forests was given little consideration.

The possibility of profitable, sustained yield from our forests depends upon the growing stock in them. Through judicious cutting, the growing stock can be improved, and at the same time a considerable harvest of wood products can be obtained. Selective cutting can be applied to one acre, one stand, or to a whole forest property.

Under the selective cutting method the merchantable timber stand is never cut all at once, but, instead, single trees or small groups of trees are removed. Under this system, timber can be harvested from the stand continuously, without the long waiting periods that are required after stands have been clear-cut. Also, light and frequent cutting will build up the volume and quality of the merchantable timber if the proper trees are removed. The volume can be increased by currently removing less volume than is added by growth, and the quality can be improved by removing trees of poor form and vigor and reserving the better trees until they are ready to be harvested.

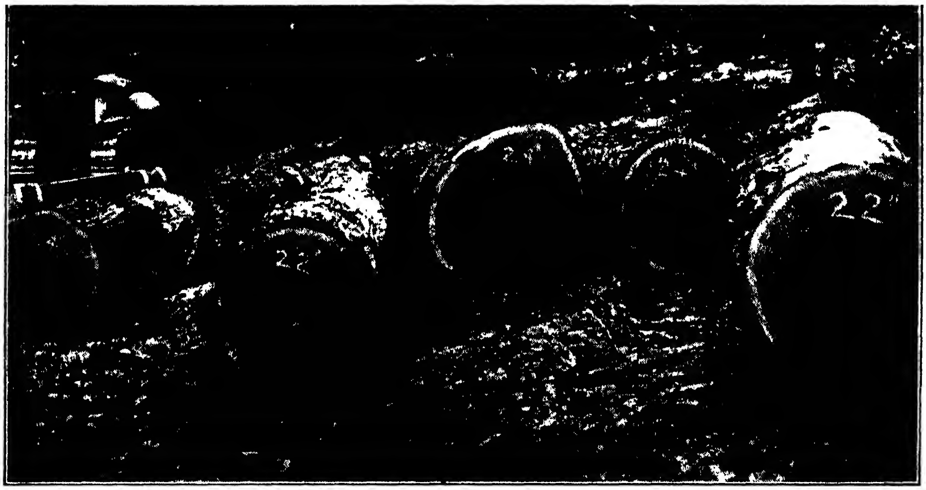

Fig. 4. An example of selective cutting. Under this method of management mature saw timber is removed every few years along with crooked, defective, and other less desirable trees. (Ohio Agricultural Experiment Station.)

Figure 3 illustrates how the selective cutting method operates. The stand structure diagram is based on data collected in a 42-acre woodland in Ohio. This is an all-aged forest having most of the timber volume in 22-inch trees. During 1943 a timber sale of 42,000 board feet of high-quality tulip poplar was made, and, as indicated in the chart, most of this volume came from the larger trees. Although the distribution of volume by diameter classes may vary for different forest types throughout the country, the same general pattern shown in Fig. 3 is maintained when forests are managed under a system of frequent, light cutting of selected trees.

Growth studies in well-managed hardwood stands such as the one mentioned above indicate that such tracts having 10,000 board feet per acre grow at the rate of about three per cent per year or 300 board feet per acre per year. At this rate, less than four years will be required for growth to replace the timber that was harvested. Under a system that removes over 50 per cent of the volume, the growing stock is so depleted that a period of 30 to 90 years must elapse before another harvest is possible.

In certain exceptional stands selective cutting may not be successfully employed. In the Pacific northwest a major problem is the transition from a timber economy based on virgin Douglas fir to one based on second growth. Here a better method seems to be clear-cutting in strips or patches with provision for natural seeding-in from uncut stands bordering clear-cut areas.[7]

Another example in which tree selection loses some of its usefulness is the area where pulpwood is the major product. Here fully mature, high-quality trees for sawlogs are not an objective of management, and a system of clear-cutting in strips would permit the growing in short rotations of a greater volume of wood at a smaller cost.

In second-growth timber throughout the country, however, the selective cutting method based on frequent, light cuts appears to be the most desirable because it produces high yields of high-quality timber on a continuous basis (Fig. 4).

Other Values of the Selective Cutting Method

Throughout this discussion little consideration has been given to the effect of selective management methods on values of the forest other than wood production. It is apparent that any management procedure that preserves a heavy growing stock and generally excludes extensive clear-cutting will promote aesthetic values, provide protection to the soil, prevent excessive water runoff, and maintain a suitable environment for wildlife.

PLANTING

Artificial reforestation through planting is a necessary adjunct to forest management because it is a means of getting barren lands back into production. Once a forest has become established, however, planting of nursery-grown trees is not a feasible method of providing successive forest harvests on a broad commercial scale. Natural reproduction is by far the cheapest and most successful method of reproducing a forest.

Interest in tree planting has increased to a marked degree since World War II. State and federal nurseries have not been able to supply the demand for planting stock because of scarcity of labor for nursery work during the war years. The continued labor shortage and a scarcity of seed retarded nursery expansion in the years immediately following the war.

There is widespread interest in tree planting to stop erosion. There are some 44,000,000 acres of farmlands in this country that should be planted to trees to reestablish forest cover and to protect watersheds.[8] To accomplish this within a reasonable time will require much more rapid progress than has been made in the past two or three decades.

In the past, the labor cost for hand planting was prohibitive to many private owners. More recently tree-planting machines have been developed which have greatly speeded up this operation and reduced costs. These machines are well adapted to level or gently rolling lands, but in steep topography hand planting or seeding from the air will be necessary.

In certain areas five-ravaged forests are reseeded by air. During the spring of 1948 some 800 pounds of white pine seed from the Champlain valley of New York state were sown across 2200 acres of the Massabesic Forest in Maine. The former Navy trainer biplane that was used flew 50 feet above surviving tree tops, seeding a 50-foot

[7] *Report of the Chief of the Forest Service,* U. S. Dept. of Agr., 1947, p. 37.

[8] *Ibid.,* p. 23. Farmlands to forests is a new and wise development in the United States.

swath with each pass. A similar experiment was conducted in Oregon, where a mixture of Noble and silver fir and Sitka spruce seeds was sown by airplane.

Air seeding costs about $3.50 per acre as compared to $35 per acre for planting seedlings by hand. This method of reforestation is still in the experimental stage, and its success will, of course, depend upon germination and survival.

Reforestation of Strip-Mined Areas

Strip mining or open-pit mining has created a new problem in the broad field of returning unproductive lands to useful crops. Strip mining is largely concentrated in the central states, where more than 100,000 acres have been disturbed.

Studies made by the Central States Forest Experiment Station[9] show that spoil banks can be afforested and that the future use of such areas will be chiefly for forestry purposes. The data show that past failures have more often been due to unskillful planting than to conditions in the spoil banks themselves. Spoil banks in the central states should eventually be covered with hardwoods, but on many of them pines or black locust must first be established to improve the soil so that hardwoods will grow.

Recent legislation in Ohio, Pennsylvania, and West Virginia calls for grading and revegetation of spoil banks. This has created a strong trend toward the use of legumes and grasses in revegetating the more alkaline spoils for livestock grazing. The acid shale areas are best suited to tree growth.

[9] A. G. Chapman, "Rehabilitation of Areas Stripped for Coal," *Tech. Paper* 108, Central States Forest Experiment Station, Columbus, Ohio, 1947.

EFFICIENT MILLING AND WOOD UTILIZATION

Whereas the most fundamental means of assuring abundant and continuous wood supplies is through protection and management of forests, another important aspect of forest conservation is proper utilization.

The process of converting round logs into square timbers is essentially a crude, uneconomic process, for the actual amount that emerges as the finished product is only a small fraction of the whole.

It is estimated that at present only 40 per cent of the merchantable timber in the forest is converted into rough lumber. Of the 60 per cent that is lost, 25 to 30 per cent is logging waste in the form of defective trees, tops, stumps, and limbs. The remaining 30 to 35 per cent consists of waste at the sawmill where the logs are converted into lumber. This waste can be broken down as follows:[10]

Items of Loss	*Log Volume Wasted (Per Cent of Total)*
Bark	13
Sawdust	13
Edgings and trimmings	12
Slabs	6
Seasoning	6
Total	50

Utilization of Wood Waste

Many technological and industrial advances have made it possible to utilize a great deal more of the tree substance than was used in the past.

[10] "Wood Utilization Problems and Possibilities in Michigan," *Report of the Consultants to the Forest Products Research Committee of the Michigan Planning Commission*, Lansing, Michigan, 1946.

The reappraisal of the nation's forest situation made by the Forest Service during 1945 and 1946 included a study of wood waste.[11] The study showed that transportation costs, lack of plant facilities, and other economic factors make the problem difficult. However, the report indicated many possibilities of waste elimination, particularly in chemical conversion.

Bark, long considered almost worthless, represents approximately 13 per cent of a sawlog. New processes have been developed that make it possible to use bark as an ingredient in plywood glues, plastics, insecticides, and soil conditioners. Shredded bark is also showing promise as a poultry litter which, when mixed with lime, makes a concentrated fertilizer high in nitrogen, calcium, and organic matter. The tannin industry is also using increasing amounts of bark from hemlock and oak trees.

More knowledge of how to reduce waste is available than it has been possible to apply, but we need to develop still better ways of utilizing what is now wasted.

Chemical Utilization of Wood

In addition to finding improved methods of using wood in its natural state or treating it with certain materials to change its properties, scientific research has made an outstanding contribution in the conversion of wood into a multitude of products that bear little or no resemblance to its original state. Most people think of lumber as the chief forest product, but sawn lumber now accounts for less than one-half of the forest harvest in cubic feet.

The most important form of wood conversion in the United States is wood pulp and paper. Approximately 21,000,000 cords of pulpwood are being used in supplying the current annual consumption of about 19,000,000 tons of paper and paperboard. It is anticipated that consumption may reach 24,000,000 tons presently.

Another important product made from wood cellulose is rayon, one of the principal yarns in the textile field. About 1,124,000,000 pounds of rayon fiber were manufactured in 1948 and 80 per cent of the raw material used was wood pulp.

The items enumerated above are only a few of the many materials that are made from mechanically or chemically converted wood. Knowledge in this field has advanced to such an extent that the immediate problems of application are, to a considerable degree, economic rather than technological.

Chemical Treatment of Wood

Pressure treatment of railroad ties with creosote has long been an accepted practice by railroads, but the initial cost of treatment has prevented the general use of chemically treated wood. Chemicals such as pentachlorphenol and copper naphthenate have been found to penetrate satisfactorily by cold soaking and in some instances by brush application. Continued improvements in the development of chemicals that will result in increased serviceability and lowered costs of treated products should make it possible to extend the use of treated wood to residential and agricultural construction. Wood preservatives have not only extended the service life of wood but also made available species of wood that were formerly avoided.

Considerable progress was also made during World War II in the development of fire-resistant treatment of wood. The chem-

[11] "Wood Waste in the United States," *Report 4 from A Reappraisal of the Forest Situation,* Forest Service, U. S. Dept. of Agriculture, Washington, D. C., 1947.

icals and methods, however, are costly and preclude the widespread use of such treated material for general construction purposes.

An entirely new group of products classified as *modified wood* has been developed through the application of synthetic resins and urea to wood. Such products as impreg, compreg, staypak, and uralloy have greater hardness, compressive strength, and abrasion resistance than untreated wood.

It is significant that many of the new and improved developments in wood utilization, particularly structural plywood, laminated wood, timber connectors, and wood preservatives, have wide application in construction and other major fields and will therefore be important in filling civilian needs in the future.

New Developments in Forest Products

As indicated above, research in wood utilization is bringing to the American public new uses of wood in many forms. One of the most dramatic and significant chapters in the history of the use of wood is the development of modern plywood. In the 1920's plywood was largely an experimental material with a narrow range of specialty uses. Today it is a standard material for wide and increasing ranges of construction and industrial uses. Its advantages lie chiefly in its nonsplitting qualities, its dimensional stability, and its availability in relatively large sizes. Furthermore, synthetic resin glues which are not affected by sun and water have made possible the bonding of boards or other relatively small pieces of wood to form great laminated arches and timbers. Such laminated structural units are prefabricated at the factory and have essentially the same properties as solid wood. This is a revolutionary development because large timbers are no longer restricted to the dimensions of logs from which solid timbers can be cut. An added advantage is that a high percentage of short-length pieces may be used and thus wood may be utilized more efficiently.

Another development in the utilization of wood is the invention of metal timber connectors which hold pieces of wood together as firmly as if they were one piece. Their efficiency is well exemplified in the construction of radio towers to a height of 400 feet and in the construction of airplane hangers with clear roof spans of more than 200 feet. Timber connectors, by making possible the extensive use of wood in railroad and highway bridges, factory buildings, and many other types of structures, were estimated to have saved 400,000 tons of critical steel in 1942.

The modern approach regards wood as a raw material that can be used in an ever-increasing number of products. Sweden in 1947 made 25 per cent of its pulp from sawmill waste. Over 90 per cent of the Swedish lumber industry's solid waste, excluding bark and sawdust, was utilized in pulp mills.

Since wood is about three-fourths carbohydrate, it is possible to convert wood waste, exclusive of bark, into sugar through wood hydrolysis. Industrial alcohol, high-protein stock and poultry feed, furfural, methanol, wood molasses, and acetic acid are products that may be obtained by this process. The chemical utilization of wood waste and inferior timber species has been receiving much attention. For example, a process has been developed for the conversion of the cellulose in sawdust into sugar, which may be used either as food or to make industrial products. In this process, containers holding several tons of sawdust are subjected to repeated percolations of dilute sulphuric acid under heat, and the filtrate is neutralized with lime. The result is a solution of glucose and pentose sugars which are the basic raw materials for ethyl alcohol and feeding yeasts. In the northwest a single commercial plant can process 200 to 300 tons of wood waste a day.[12]

Fig. 5. A remnant of a virgin loblolly and shortleaf pine stand near Crossett, Arkansas. Much of southern Arkansas was covered by such stands which averaged about 20 M per acre. (U. S. Forest Service.)

Need for Integrated Timber Use

One major need in attacking the waste problem is greater integration of the timber products industries. One-product operations tend to be wasteful.

Crossett, Arkansas, is a good example of a prosperous forest community based on properly managed forests which are co-ordinated with the manufacture of wood products (Fig. 5). A permanent sawmill, wood distillation plant, and paper mill are wood-using industries in this community that are integrated in such a way that almost complete utilization of the forest crop is possible. Encouraging developments along these lines can also be found in the Pacific northwest, the Lake states, and the west Gulf region.

Management of forests for sustained yield will be an incentive to such integration. Operators who adopt the policy of combining recurring timber growth with the manufacture of forest products can develop their plants and plan to stay in business permanently, because they have some assurance of a continuing supply of raw material.

PUBLIC ACTION IN ADVANCING FORESTRY

Although it seems certain that private owners will continue to hold the largest portion of our forest land, the public, as represented by the organized forestry agencies of state and federal governments, will have an increasingly important part to play in a nationwide forest conservation program (Fig. 6).

Practice of Forestry on Publicly Owned Lands

It is the policy of the Forest Service and state forestry agencies to utilize timber and other forest products for the benefit of consumers, to support industries on a continuous basis, and otherwise to contribute to stable local and national economy.

[12] *Trees, The Yearbook of Agriculture,* U. S. Department of Agriculture, Washington, D. C., 1949, p. 642.

Cutting operations on public forests are of great significance in determining and demonstrating methods of silvicultural practice. Great progress has been made in our knowledge of forest management procedures in publicly owned forests through research and experimentation. In addition to assuming the responsibility of ownership and rehabilitation of idle lands that are not attractive to private capital, our public forests have an important place in demonstrating better forest practices.

FIG. 6. Stand of government-owned virgin mixed hardwood timber consisting of maple, elm, and black ash in the Nicolet National Forest in Wisconsin. (U. S. Forest Service.)

Public Regulation of Cutting on Private Lands

Public regulation of cutting on private forest lands has been recommended by the Forest Service and several state agencies as an essential step in continued forest production. Individual owners are handicapped in adopting good forestry practices if other owners continue their "cut-out-and-get-out" policy of exploitation (Fig. 7). Many economic obstacles disappear when all owners handle their forests under the principles of continuous forest production.

However, many owners and operators oppose the idea of public regulation on the ground that it would be an unwarranted encroachment on private enterprise.[18]

In spite of the rather general distaste for further public regulation, there is a growing public recognition throughout the nation that, if the forest resource is to be saved from further waste and degeneration, some type of control over timber harvesting practices is essential. Many of the more far-sighted industrial leaders feel that the time has arrived when steps should be taken to replace destructive measures by sound silvicultural practices on all forest lands.

Federal versus State Regulation

Although the idea that some regulation is desirable and necessary is accepted by many people, they believe it can and should be imposed and administered by the states and that it is a state responsibility and function. These individuals feel that for the federal government to take upon itself such a responsibility is to deprive a state of opportunity to develop initiative and resourcefulness and that a strong nation can rest only on a foundation of strong states.

Already 15 states have enacted regulatory laws, but most of them have been in effect too short a time for their effectiveness to be

[18] "Problems and Progress of Forestry in the U. S.," *Report of the Joint Committee on Forestry of the National Research Council and the Society of American Foresters,* Washington, D. C., 1947.

judged. Legislation in Maryland and California[14] sets forth the need and objective of regulation, defines in broad terms the provisions for woods practice designed to ensure the constructive use of forest lands and to prevent injurious exploitation, provides authority for enforcement of the law, with provisions for an organization adequate in character and size for efficient administration, and grants authority for appropriation of funds large enough to achieve in practice the purposes of the legislation. In these laws the details of the proposed cutting practices are formulated by local forest committees of timber owners and operators with the result that the rules come up from the bottom, rather than being imposed at the top and passed down. With the maximum of local rule and a higher agency determining the adequacy of the rules, the operation of public regulation on private lands to a large degree reflects industry regulating itself in the interest of preserving its own basic resource.

FIG. 7. An example of destructive cutting. (Ohio Agricultural Experiment Station.)

[14] "The Forest Situation in California," *Report to the Legislature by California Forestry Study Committee,* 1945.

Taxation of Forest Lands

Forestry is inseparately linked with taxation. The burden of taxation is often given as the reason for failure to practice forestry. In individual instances this is undoubtedly an important factor, but, where forests are under light selective management with regular returns annually or at short intervals, taxes are not a serious obstacle to forest management.

Generally speaking, the tax problem is most serious in areas that have been clear-cut and require considerable time for restoration to a productive condition.

Several states have enacted special tax legislation designed to encourage the building up of the growing stock in immature stands. Such legislation has usually taken the form of abolishing the ad valorem system of taxation and imposing a yield tax at the time of harvest.

For young growth, a combination of a low, fixed annual fee, in lieu of a tax, and a yield tax collectible at the time of harvest, has been tried and has been the law in Oregon for several years. Indiana, a hardwood state, assesses classified forest lands at $1.00 per acre and collects a yield tax at time of cutting equal to the tax rate times the difference between assessed value at time of classification and assessed value at time of harvest.

In those sections of the country where chronic tax delinquency is a serious problem, the best solution seems to be absorption of such lands into public ownership, federal, state, or county.

There is need, however, for continued research in forest taxation. The guiding principle should be that forest land must contribute its share in support of public activities and institutions. Where woodlands are managed properly, taxes are seldom a serious obstacle.

Public Assistance to Private Owners

Public officials, generally, consider it sound policy to make good forest practice attractive to private owners. This attitude has been reflected in public assistance to private operators in co-operative fire protection, forest research, assistance to the states in the production and distribution of forest planting stock, in the educational program of the Extension Service, in woodland demonstration projects, and in farm forest marketing projects. The federal government is also giving aid directly to individuals through federal land banks and through complete farm plans furnished by the Soil Conservation Service.

An important development in public assistance to private woodland owners was started during World War II as the Timber Production War Project. In order to stimulate increased output of timber products, several federal and state agencies besides the Forest Service provided foresters to assist sawmill and logging operators and timberland owners in meeting production problems. The help given operators and woodland owners in more efficient operation of equipment and better forest management was especially valuable.

Since the war, forest management assistance to private owners has been continued under the Norris-Doxey Act of 1937. During 1947, 153 co-operative farm woodland management projects in 39 states were operated. Where the states put up 50 per cent or more of the cost the co-operating state agencies had direct supervision of the projects. The technically trained Norris-Doxey foresters provide specific in-the-woods advice and assistance to individual farm woodland owners.

Since more than 3,000,000 farmers own woodlots and it is estimated that less than one in ten knows how to give his woods skillful care, the importance of on-the-ground technical assistance is apparent.

PROGRESS IN PRIVATE FORESTRY

Since approximately 75 per cent of the nation's forest land is in private ownership, the importance of good forest practice on privately owned land is self-evident (Fig. 8).

The great demand for wood products during the 1940's has shown that forests can be grown for profit, and many private owners, particularly the lumber, paper, and pulp industries, have come to realize that their own best interests will be served by maintaining their forests in a productive condition.

FIG. 8. A stand of sugar maple, beech, black cherry, and hemlock in Pennsylvania. (U. S. Forest Service.)

Industrial Forestry

Korstian has estimated that about 153,000,000 acres in 37 states may be classed as "industry forests," or forests under industrial management.[15] Within the past few years industry has initiated such movements as "Tree Farms" and "Trees for Tomorrow" in which the major emphasis is on growing more trees. These programs call for continuous growing of trees on every acre of land best suited for that purpose and bringing the widest possible area under permanent forest management. Leaders in the forest industries realize that the timber supplies that they will need in order to stay in business will have to be grown as a crop. Furthermore, they have developed an appreciation of the necessity for good forest practice to meet their responsibilities to the general public inherent in their custody over a great natural resource.

Whether a sufficient acreage of industry-owned land will be managed as a crop soon enough to protect the public welfare with-

[15] Clarence F. Korstian, "Forestry on Private Lands in the United States," *Bulletin* 8, Duke University School of Forestry, Durham, N. C., 1944.

out some form of regulation is problematical. Nevertheless, it is highly important that recognition and encouragement be given to forest owners and operators who have initiated sound forest practices.

Farm Forestry

As was indicated in the preceding chapter, 57 per cent of the commercial forest land in the United States is in small private holdings, and about one-half of this is in farm woodlands averaging slightly over 40 acres each. Where farm tenure is reasonably stable, the resident farm owner is usually interested in managing his woodland properly, but, as a group, farmers owning small areas are not handling their forests to the best advantage. As a rule, farmers having a substantial amount of merchantable timber have sold their timber "lump sum" without provision for proper cutting. After such liquidation of the growing stock, there follows a long waiting period before another sale can be made.

In certain areas, the handicaps that farmers and other small woodland owners face have been met by co-operative effort. There are numerous forms of co-operative arrangements, whether or not they are called "co-operatives." Pooling of interests by woodland owners has helped in many regions to maintain stable manufacturing concerns and in obtaining regional sustained yield management. Each small tract properly managed is an essential element of the aggregate of all contributing properties.

In view of the economic difficulties that small woodland owners have in practicing forestry, it is apparent that added education and technical assistance in forest management and marketing are needed.

There is no one answer to the problem of making sound forest conservation a reality on a nationwide scale. The solution lies in a positive, aggressive attack on the problem from many angles, including proper cutting practices, restoring forest cover on barren lands through planting, more efficient utilization of wood, public assistance in the control of destructive fires, insects, and diseases, in education and on-the-ground technical assistance, in continued research and demonstration, and the adoption by private industry of practices that will result in continuous production. Public regulation can be justified only when the forest resource is not being protected and managed for the public good.

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PART FOUR

CHAPTER 12

Water Supply for Domestic and Industrial Uses

SIGNIFICANCE OF WATER RESOURCES

"WASTE not! Want not! We never miss the water until the well goes dry." These are the words of an old adage which, although often quoted, have seldom if ever been taken literally. No doubt the universal need of water, its worldwide distribution, and apparent inexhaustibility have led to various human attitudes towards its utilization, one of which is not the conservation of that important natural resource. It is indeed an anomaly that a resource that not infrequently creates a deluge of extremely destructive proportions needs on occasion to be conserved. Both too little and too much water are, in part, the result of the unwise use of all natural resources. The universal importance of water as a basic necessity of all forms of life makes its utilization a most complicated problem of conservation. Water, a biological necessity, is also of great economic importance.

DOMESTIC AND INDUSTRIAL USES OF WATER RESOURCES

The various ways in which water is utilized are such that interests conflict and numerous problems arise. All life is completely dependent upon water, which includes drinking water for man and beast, soil water for vegetation, and surface water for the habitat of all types of aquatic life. On the other hand water is a source of power, an industrial ingredient, a medium of transportation, a waste removal and purification agent, as well as a recreational asset, and a marker of boundaries. Of this array, domestic and industrial uses are but a small part, and even these are varied and conflicting in the ways in which water resources are used. Domestic uses alone, which vary widely from place to place, consist of at least two major groups which can be designated as primary and secondary uses. These become manifest in areas of permanent or temporary water shortage.

By John H. Garland of the University of Illinois.

Primary Domestic Uses

By far of greatest importance is water for human consumption, drinking water, cooking, and the like, without which mankind would perish. Under most dire conditions of water shortage this usage is given first consideration. Closely akin is the use of water for sanitary purposes. The demands of modern civilization for water for personal cleanliness, laundry, and other hygienic needs within the home and within public and private institutions, although not so great as the per capita consumption of the Romans in the incipient stages of decay of that civilization, are enormous. In the United States public water works deliver over 7,500,000,000 gallons of water (1,000,000 cu. ft.) per day to approximately 80,000,000 people. Although the rate varies widely from 70 to over 400 gallons per person per day, the average for cities of more than 100,000 population is about 140 gallons. Ancient Rome's consumption of 300 gallons has given rise to the observation that the decline of the Roman Empire and the present time are the two great bathing eras of all historic time.

Secondary Domestic Uses

The distinction between primary and secondary domestic uses of water, in some instances, is difficult to determine. For purposes of discussion it will be necessary to draw arbitrary lines and to limit the observations to these conditions. It is obvious that great quantities of water are utilized in the sanitary sewage systems of all towns and cities, most of which has already been utilized as a primary domestic supply. Additional water is necessary to dilute and treat sewage or in many cases to carry the treated sewage away.

Water for fire protection is of greatest importance to towns and cities. Periods of water shortage are always menaced with the danger of a severe fire. Innumerable villages and towns as well as portions of many large cities in this country have been destroyed by fire because their supply of water was insufficient to meet the emergency. The volume of water consumed is not a crucial factor, since it is very small; it is the necessity of having a large flow of water available when needed that is the important factor for fire protection.

Closely associated is the utilization of water to lay dust and wash debris from city streets as well as to flush accumulations from the catch basins of the storm sewers in periods of dry weather. In a like manner lawn sprinkling systems and overhead irrigation make a demand upon the secondary domestic water. Thus, at least in the humid portion of the country, the sprinkling of lawns and gardens and the forcing of vegetables by overhead irrigation or other types of "rain makers" constitute a domestic type of water utilization.

The introduction of air conditioning of department stores and large public buildings has placed a heavy demand upon the water for secondary domestic purposes which has, however, been limited by the sewer system. About 15 per cent of the per capita water consumption in northern cities is consumed by air-conditioning systems.

One of the lesser secondary domestic uses of water is for recreational purposes. In the present discussion utilization refers to the direct consumption of water for that purpose rather than the recreational uses made of streams, lakes, and the like. It includes the consumption of water for fountains, public and private swimming pools, and other types of ornamental and recreational uses of water which must come from the water supply. Both indoor and outdoor swimming pools have become users of the domestic water supply.

Industrial Uses

Numerous types of manufactures require large quantities of water in their industrial processes other than the water consumed by the employees of the plants. Thus the amount, the quality, and the cost of water are important factors of industrial localization for some types of manufacturing. The utilization of water for direct water power or hydroelectric power is not considered here since it is discussed at length elsewhere.

The industrial uses of water fall into three broad but somewhat interrelated categories: (1) water is an important ingredient of the finished product; (2) it is used as an agent for cooling, removing impurities, preparing solutions, and the like; and (3) it is important in the diluting and removal of industrial waste.

The several industries using water directly as an ingredient of the finished product include the food canning and preserving industries, dairies and creameries, the beverage and bottling manufactures, the distilleries, and commercial ice plants. It is also obvious that these industries will require large quantities of water for cleansing, for raw materials, for cooling, and for the removal of waste. The food and beverage manufacturers are among the highest users of water for the removal of industrial waste. The stockyards and meat-packing industries, where water is not important as a direct ingredient, consume millions of gallons of water per day, whereas a modern distillery consumes millions of gallons of water per day for steam, for cooling, and as an ingredient.

Many other industries, especially paper and pulp making, leather tanning, textile manufacturing, bleaching, dyeing, and printing of cotton textiles, oil refineries, electrical generating plants, coke plants, steel mills, and related types of industries, use enormous quantities of water both as cleansing, cooling, or solution media, and to flush away industrial waste. The paper and pulp industries utilize water to wash away impurities as well as to reduce the wood to pulp. In the mechanical grinding process, which produces most of the coarse paper and newsprint, about 15,000 gallons of water are utilized for every ton of paper produced, and in the sulphide and the soda processes as much as 100,000 gallons of water per ton of paper are utilized.

The steel industries are tremendous users of water chiefly for cooling purposes. An adequate supply of water is of greater importance in the location of a modern steel mill than transportation. On an average the daily consumption of water of the nation's steel mills is 4,600,000,000 gallons or about four and one-half times the consumption of the 8,000,000 people of New York City. Two of the largest steel mills [1] of the nation consume about 500,000,000 and 350,000,000 gallons of water each day, respectively. Most of the water is used to cool essential parts of the blast furnaces and open hearths as well as the rolls of the rolling mills. Blast-furnace slag is quenched and granulated, a process requiring great quantities of water. The associated coke and gas plants also utilize enormous volumes of water to cool gas washers and to clean the gases as well as to quench the coke. As much as 50,000,000 gallons of water are used daily by an individual coke plant. Electrical generating plants are also great consumers of water for cooling.

[1] Herbert Fredman, "Steel's Niagara," *Steelways*, May, 1947, p. 31.

The utilization of water to flush away industrial waste is usually associated with the pollution of streams and rivers. The type of waste varies with the industry, some being more harmful than others. The steel mills contribute, among other wastes, an acid solution known as "pickle liquor." An important operation in the making of rolled and sheet steel, tin plate, wire, and galvanized pipe is the removal of flakes produced by the rolling process. The best method of removing the scale is to treat the steel in an acid bath, usually sulphuric acid. The removal of the oxide scale by the acid reduces the bath to an aqueous solution of free acid and metal salt known as "spent pickle liquor" since the process of scale removal is known as "pickling." The problem of disposing of this type of industrial waste is an enormous one, for about 600,000,000 gallons [2] of spent pickle liquor are produced yearly by the nation's steel plants.

Numerous other industrial demands are made upon the water supply to generate steam in locomotives and in ships as well as to operate hydraulic mechanisms. The so-called "hydraulic" water pumped to a pressure of 750 pounds is used in steel mills for the removal of scale as well as for the operation of hydraulic mechanisms that open and close furnace doors and move other heavy pieces of equipment. Large quantities of water are also used in connection with the pumping of salt, sulphur, and some oil wells.

SOURCES OF WATER SUPPLY

The amount of water utilized each day for both domestic and industrial purposes immediately raises the question of the supply, its amount, and its quality as well as the probability of an adequate and continuous supply. To the average individual of our modern civilization water is taken for granted; it is always available at the tap. It is the source of supply behind the tap that is the critical factor. Without tremendous water supplies concentrated on small local sites, it is doubtful that modern urban development could have taken place.

With the exception of the connate and magmatic waters our water supply falls as some form of precipitation. Thus in general the supply is related to distribution of precipitation. The map (Fig. 1) indicates the unequal distribution of precipitation over the United States. In general, east of the 100th meridian the precipitation is adequate, increasing from 20 inches per year on the Great Plains to 50 to 60 inches on the east coast and 60 to 80 inches on the Gulf coast. Westward, except on the Pacific northwest coast where the rainfall is very heavy, precipitation decreases to desert proportions over much of the intermontane region. Of the precipitation that falls a portion is evaporated from the surface of the ground. The amount thus lost depends upon the temperature of the air, the nature of the surface, and the vegetational cover upon which it falls. A portion is absorbed by the surface materials of the earth, and a portion drains off to the sea. Thus the water that enters the surface of the earth, known as "groundwater," and the water that flows off or remains on the surface, known as "surface water," are the two sources of water for domestic and industrial uses.

Surface Water

Surface water or runoff is available in three forms: streams and rivers, lakes, and

[2] John D. Greene, "Can We Clean up Our Rivers?" *op. cit.*, pp. 6–9.

reservoirs and tanks. Drainage features, especially permanent streams, are among the most conspicuous physical features of a humid region. The larger the area drained and the heavier the precipitation the larger is the volume of the master stream. Although streams and rivers are an important supply of domestic and industrial water in the humid part of the United States, most of the large reclamation projects, which furnish water for irrigation and hydroelectric power as well as domestic water, are in the semiarid and arid portion of the country. Even in humid areas it is necessary to impound the water of the smaller streams to ensure an adequate water supply for larger towns and cities.

Inland fresh-water lakes, especially the Great Lakes, are outstanding sources of water for the many towns and cities along their shores, as are many of the smaller lakes in the glaciated portion of the United States.

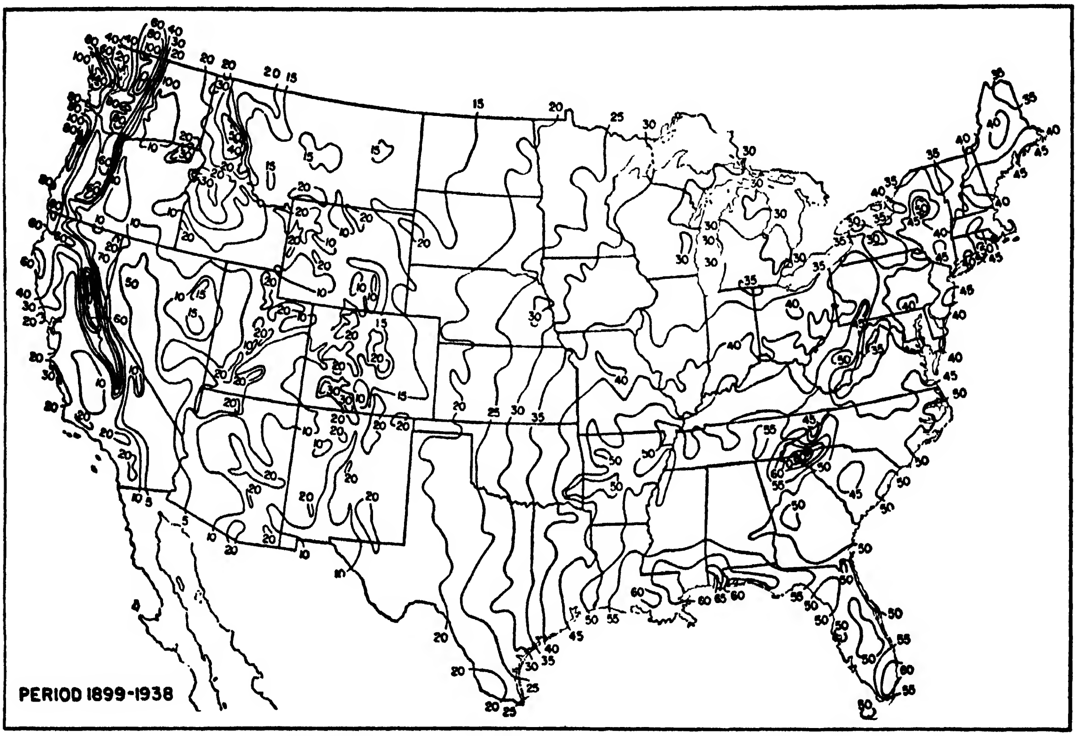

Fig. 1. Average annual precipitation in the United States. With the exception of the Pacific northwest the average annual precipitation of western United States is inadequate. (*The Yearbook of Agriculture,* 1941, U. S. Department of Agriculture.)

Although the impounding of water of a tributary stream is a common practice of ensuring a water supply, reservoirs and tanks serve to store runoff, usually referred to as "rain or storm water" to supplement the water supply. These range in size from the cistern and rain barrel of humid lands to the large dams and reservoirs in the mountains designed to impound melting snow and storm water to provide a domestic supply as well as water for stock and irrigation in the semiarid lands of the west.

In the rural areas of the United States, especially in the regions of hard groundwater, the "drinking" water well and the cistern or soft-water pump are conspicuous features of the water supply of each home.

Groundwater

The precipitation that soaks into the earth is known as the "groundwater." The force of gravity causes the water to percolate downward through the unconsolidated soil and mantle rock and into the crevices and interstices of the underlying bedrock until a depth is reached where the density of the rock and the lack of crevices prohibit any further penetration. The greater portion of rock porous enough to contain water is within a few hundred feet of the surface. The groundwater is maintained by the portion of precipitation that seeps into the earth; additional water percolates downward until it meets the water already there. If the water is not of sufficient volume to fill all the interstices, the upper portions of the mantle rock may be damp whereas the areas below are saturated. The upper limit of the saturated zone is known as the "groundwater table."

The groundwater table or groundwater level is not a horizontal surface, nor is it at a constant depth below the earth's surface. Since the water tends to seek a level by slow outward movements from its higher positions, the watertable tends to assume a position between true surface configuration and a horizontal surface. Thus the watertable is close to or at the surface of the ground in the valleys and at greater depths beneath the hills. Likewise the watertable is at greater depths in subhumid and dry regions or after lengthy periods of drought in humid regions, whereas in humid regions, especially after periods of heavy precipitation, it may be near the surface.

Unlike surface water, groundwater is not generally available for use until some device has been constructed to reach the watertable, except in those places where the watertable reaches the surface of the ground in springs. Much of this water goes directly into the streams, lakes, and marshes and for all practical purposes is a part of the surface-water supply. Many springs, however, are a direct source of water.

Springs. The location of springs depends upon terrain and rock structure in relation to the position of the watertable. In its simplest form a valley eroded below the watertable, especially in glacial till, is the locus of a series of springs which will cease to flow if drought or other causes reduce the watertable below the valley floor. A horizontal layer of impervious material, if exposed on a hillside, would allow the perched watertable to escape in a series of springs along the hillside. Fault and joint planes are also important features in permitting groundwater to rise to the surface, some of which may have been in contact with igneous rocks of sufficient temperature to produce hot springs and geysers.

Many springs are of such limited volume or of intermittent nature that they are of value as a source of water supply only for individual houses, especially isolated farmsteads, and small villages. There are, however, in the United States several areas of springs of enormous volume (Fig. 2). The U. S. Geological Survey [8] has located 60 springs each with a flow sufficient to supply completely a city of 500,000 inhabitants and at least six others any one of which would supply a city of 2,000,000 with

[8] O. E. Meinzer, "Large Springs in the United States," *Water Supply Paper* 557, U. S. Geol. Survey, Washington, D. C., 1927.

all its water requirements. Large springs develop in regions of cavernous limestone and in porous lavas where groundwater from relatively large areas drains into subterranean channels of large capacity. The areas of large springs in the United States are northern Florida, the Ozark region of Missouri, central Texas, the Upper Snake Plains of Idaho, western Oregon and northern California, and central Montana. The springs of the northwestern portion of the country are largely in the porous lavas, whereas the rest of the large springs are associated mainly with cavernous limestone. It is notable that the water supplies from large springs are remote from the urban concentrations of the nation.

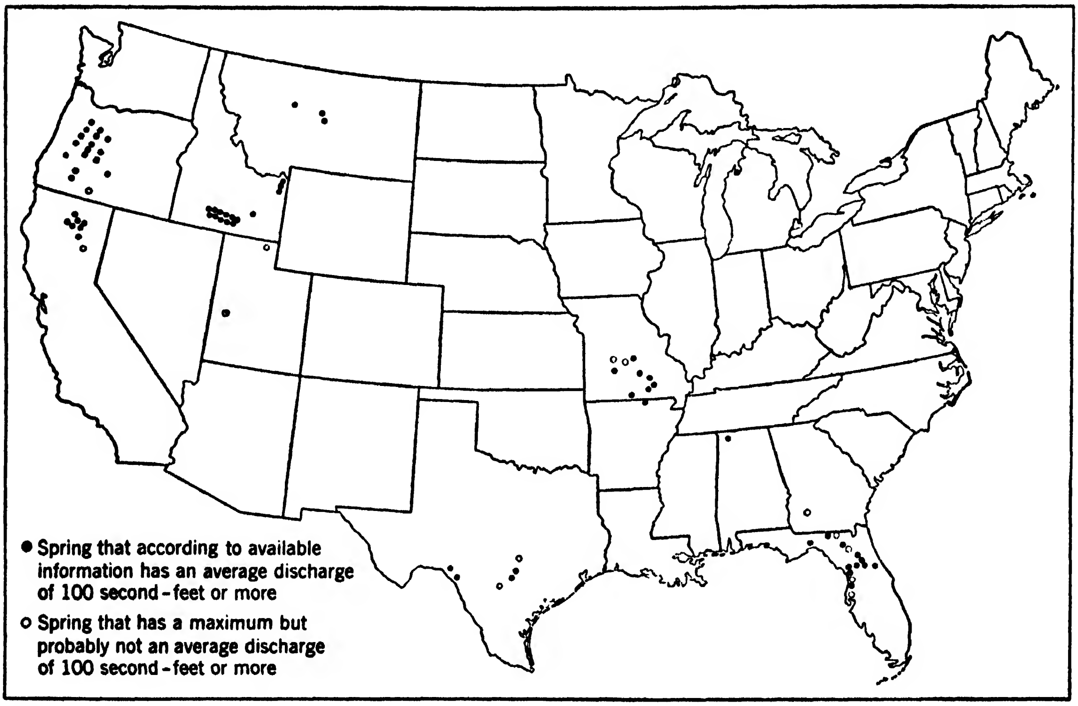

FIG. 2. The large springs of the nation which are capable of supplying large cities with all their water needs are remote from urban concentration. (After Meinzer, *Water Supply Paper* 577, U.S.G.S.)

Wells. A supply of water may be obtained by digging or drilling from the surface of the ground to the watertable. Dug wells of necessity are shallow and are constructed in glacial drift or other unconsolidated material. The well, although curbed, is open and thus is subject to contamination from the surface. The water is lifted by a windlass, or sweep, or a simple lift pump. Supplies of this type, although numerous, are suitable only for isolated homes in rural areas, and even there, a summer's drought may lower the watertable sufficiently to cause the well to go dry.

Dependable supplies of water for towns and cities, and even individual homes, are obtained by drilling deep wells, cased against pollution from surface seepage, into the drift or underlying bedrock. Water from most deep wells must be brought to the surface by force pumps.

Artesian wells. Under special conditions large supplies of water are obtained from deep, flowing artesian wells. The water in a well which flows sufficiently to require little or no pumping is confined in such a manner that hydrostatic pressure sufficiently great to lift the water in the well has been developed. Hydrostatic pressures develop only under special conditions of terrain, underlying bedrock, and climate. The conditions consist of a porous formation, generally sandstone, exposed to sufficient precipitation to fill it, which gently dips below a layer of impervious material. If the water-bearing formation is closed off at its lower elevation the water is entrapped and is therefore under pressure. A well drilled into the water-bearing layer from any point on the surface lower than the exposed portion of the porous formation will flow, or at least will rise in the well owing to the weight of the water in the higher portion of the porous strata.

In the United States artesian wells have been drilled on the Gulf Coastal Plain and on the Great Plains and central lowlands to depths of 3000 and locally to almost 5000 feet.

SETTLEMENTS AND WATER SUPPLY

It is convenient to think of the population of the United States as being composed of three settlement groups each of which contains about one-third of the total population. The first group is metropolitan and is made up of the 92 cities with populations of 100,000 and over; the second is composed of small cities, towns, and villages; and the third is composed of the farm population. The last two groups depend largely on groundwater, whereas the metropolitan group depends on surface supplies supplemented for secondary domestic and some industrial uses by groundwater. Thus the problems of the quantity and quality of water supply and the conservation thereof vary from group to group.

Metropolitan Group

By far the greatest consumers of water are the metropolitan areas, for it is there that great concentrations of people make a tremendous demand upon the domestic supply. Likewise the presence of industry within the cities places an industrial demand upon the water supply that in most districts greatly exceeds the domestic use.

Although a variety of systems both private and municipal have been developed to supply the water needs of metropolitan areas, the volume required is so large that most urban areas depend upon surface water supplemented for certain uses with groundwater. For some large urban districts it has been necessary to transport water long distances at great cost. Interstate conflicts over water rights have arisen in connection with the water supply of some of our large metropolitan areas.

The relationship of population density and distribution to humid climatic conditions in the United States is clear. The relationship of the cities of the metropolitan group to drainage features within the humid regions is likewise conspicuous. As the map (Fig. 3) indicates, most of the cities of the metropolitan group are located upon rivers or lakes which may be utilized as a source of domestic and industrial water.

Conspicuous among the city groups are those associated with the Great Lakes and with the Mississippi drainage system. Less conspicuous are the associations of the cities with the streams of the Gulf and Atlantic Coastal Plain, and those of the Pacific northwest and the mountains. Thus only a few of the cities, those in the semiarid portion of the country such as Los Angeles, San Diego, and Salt Lake City, and those on bays and estuaries along the seacoast, such as Boston and New York City, have insufficient surface water supplies at their immediate sites. Although all urban groups have innumerable problems concerning the conservation of their water supply, these cities have the added problem of ensuring an adequate supply.

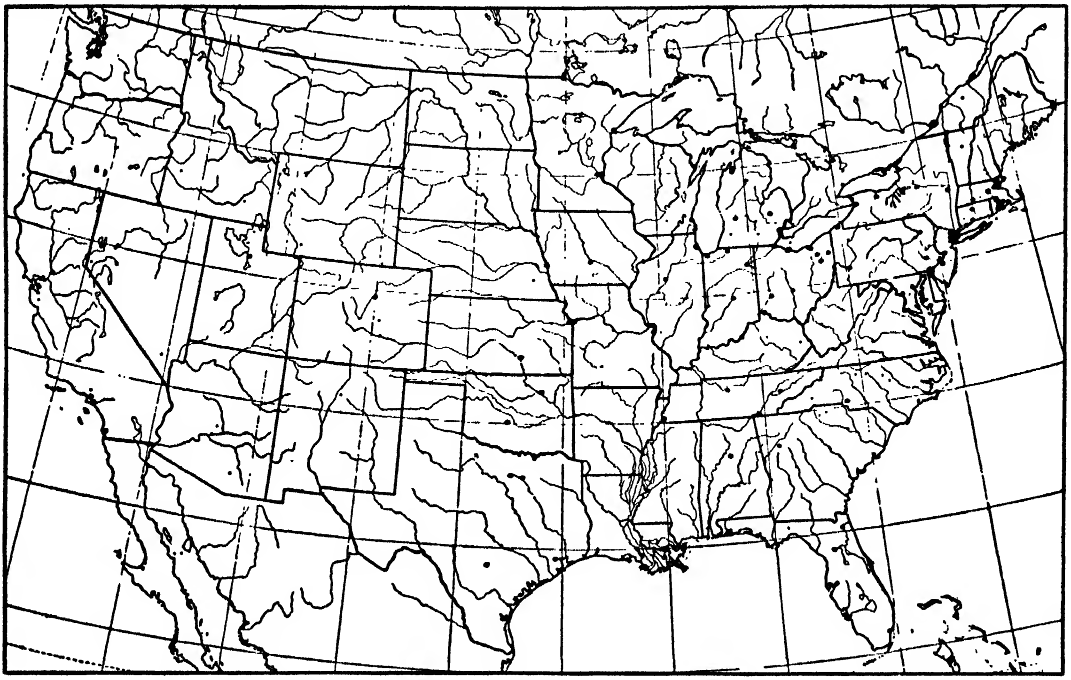

FIG. 3. Most of the major cities of the metropolitan group are located on rivers or lakes which may be utilized as a source of domestic and industrial water.

Los Angeles, the only city of over 1,000,000 outside of the humid section of the United States, is entirely dependent upon a water supply from beyond its local area, in part beyond the limit of the state. The Los Angeles River, the subject of many jokes, was the original source of water for the first 125 years of the city's existence. By 1908 efforts were being made to increase the water supply since the growth of the city was limited by the local water supply. In 1914 the Los Angeles aqueduct was completed to the Owens River east of the Sierra Nevadas 238 miles away. At a cost of $25,000,000 the water was brought by canal, siphon, and tunnel through the desert and under the mountains into the Los Angeles basin. Since one of the conditions by which the water of Owens Lake was obtained was the requirement that all the water be used within the city, Los Angeles enlarged by incorporating 50,000 acres of the San Fernando valley immediately north of the city. The population of the city increased to more than 500,000 by 1920, industries came to the area in increasing numbers, some of which required guarantees of several millions of gallons of water per day. Additional water was secured from Mono Lake north of Owens valley. By 1930 the population of Los Angeles had passed 1,000,000 with another million people in the metropolitan district of the basin.

In 1934 the Colorado Compact was arranged to secure an additional supply from the Colorado River at a cost of $220,000,000 to the Metropolitan Water District of Southern California. The water, which now supports a population of over 3,000,000 within the Los Angeles basin, is conducted from the Colorado River at the Parker Dam 155 miles below Hoover Dam through 241 miles of aqueduct. There are 92 miles of tunnels, and the water must be raised 1617 feet by five pumping stations operated by electric power generated at the Hoover Dam.

Within the humid portion of the United States the New York metropolitan district is the largest that must reach out for a sufficient domestic and industrial water supply. Both private and municipal ownership supply water to the metropolitan district. The Ringewood system supplies groundwater from an elaborate system of infiltration galleries laid 10 to 15 feet below the watertable for six miles in the glacial sands of Long Island. The other systems supply surface water impounded in reservoirs at varying distances from the metropolitan district. The oldest is the Croton Reservoir in Westchester County, which was in operation in 1842. The Catskill system, which conducts water from the Ashokan Reservoir in Greene County, was in use by 1915. In 1930 the State of New Jersey attempted unsuccessfully to enjoin the State of New York from diverting the water of the Delaware River for an additional water supply for New York City.

Boston, likewise, having outgrown the supplies of the Framingham and Wachusett reservoirs, now receives an additional water supply from the Quabbin Reservoir in the Connecticut valley, where several of the tributaries of that river have been impounded. Likewise the State of Connecticut filed a bill of complaint with the Supreme Court against the Commonwealth of Massachusetts for planning to divert the waters of the tributaries of the Connecticut from their natural flow into that river.

Other cities on secondary streams have ensured themselves a supply of surface water by impounding the rivers. Those cities on the major rivers and on the Great Lakes pump their water directly from the source with less danger of the supply diminishing acutely. Chicago and Milwaukee draw their water directly from Lake Michigan; Duluth, from Lake Superior; Detroit, from Lake St. Clair; and Toledo, Cleveland, and Buffalo, from Lake Erie, whereas Syracuse takes its water from Skaneateles Lake and Rochester from Hemlock and Canadice lakes.

Wells supply much of the water for 18 of the 92 cities of the metropolitan group as well as supplement the supplies of those largely dependent upon surface water. Dayton, Ohio, Tacoma, Washington, and Lowell, Massachusetts, cities of the humid portions of the United States, depend upon groundwater for their supply from wells ranging in depth from 25 to 70 feet. Houston and San Antonio, Texas, and Memphis, Tennessee, depend upon artesian wells for their water supply, whereas Pittsburgh and St. Louis utilize deep wells for a part of their supply.

Second and Third Groups

The remaining two-thirds of the people of the United States live in towns and cities with less than 100,000 population and on individual farmsteads. The water supply for this portion of the population is obtained chiefly from groundwater. On the farms and in the villages individual wells, dug or drilled into the watertable, are pumped by hand, windmill, gasoline engine, or electric motor.

In the larger towns and small cities the individual wells have given way to water companies or municipal water supplies where groundwater is pumped from a deep well or a series of wells into a high tank or other type of storage to develop sufficient pressure to circulate the water to all consumers. As the demand for domestic and industrial water has increased, groundwater has not been adequate and many small cities have added surface supplies by pumping directly, if they were located on large rivers or lakes, by impounding small streams, or by purchasing water from nearby large cities that already had established an adequate surface supply. Mountain towns depend upon the melting snow and rain to keep open reservoirs filled.

CONSERVATION PROBLEMS

The two major conservation problems affecting water for domestic and industrial purposes are the quantity of water available and its quality for the purpose for which it is to be used. It is upon these two conditions that the entire program of water conservation rests.

As cities have grown and running water for domestic purposes has been made available to greater and greater proportions of the population, the per capita consumption has risen. With urbanization came tremendously increased utilization of water for industrial purposes. Likewise the greater number of people and especially their concentration in urban groupings have caused a problem of sewage disposal which together with industrial waste has helped to pollute many of the existing sources of water supply. It is well to note that urbanization and industrialization are not the sole causes of polluted and diminished water supply. The conditions of deforestation, erosion, floods, and declining watertables are also contributing factors in the complete conservation problem.

Pollution

The disposal of sewage and industrial waste is an important problem of water conservation especially in the metropolitan districts. Great Lakes cities draw domestic water from the lakes and return sewage to them; Chicago discharges sewage into the Sanitary Canal, dilutes it by water diverted from Lake Michigan, and then the Illinois River delivers the city's waste to the Mississippi. River cities draw their domestic supply from the river above the town and return the sewage, partially or entirely untreated, into the river below the city. Industries likewise withdraw water for numerous industrial uses and return various types of industrial waste. The Ohio, the largest of the interior rivers flowing through the populated, industrial portion of the United States, is our most utilized river. From Pittsburgh at its source to Cairo at the Mississippi confluence, it is lined with industrial and commercial cities and towns, all of which draw their water supplies from the river and return domestic sewage and industrial waste. The tributaries of the Ohio are likewise utilized. The Mahoning River, which flows through the Youngstown, Ohio, steel district, is so extensively used and reused that the hot, rusty liquid has little resemblance to a river.

The Ohio River Valley Sanitation Compact. With the industrial and commercial development of the Ohio River valley, like that of many other valleys in the United States, has come increased utilization of the water in the streams. The Ohio is used for commerce, particularly for a heavy barge traffic in coal, sand and gravel, and iron and steel products. Many industries require enormous quantities of water in their industrial processes or for cooling. For example, 65,000 gallons of water are needed in the manufacture and finishing of one ton of steel. In aluminum 960 gallons are used per pound of ingot metal. In by-product coke 3600 gallons are used per ton of coal.[4] Many other industries use and reuse the water of the Ohio and its tributaries.

The Ohio is the source of water for culinary purposes of the people who live in cities that are located on the river. These same cities dispose of their wastes by discharging them directly into the river. In times of drought when the river is low the condition of the river becomes a menace to health.

After many years of study and repeated efforts on the part of health officers and others concerned with the quality of the water in the river the Ohio River Valley Water Sanitation Compact was signed in Cincinnati on June 30, 1948. The interstate compact ratified by Ohio, Indiana, West Virginia, New York, Illinois, Kentucky, Pennsylvania, and Virginia is an important step forward. The river waters cannot be purified immediately, but the cooperation of the several states may do much to reduce eventually the pollution of the Ohio and its tributaries.

[4] C. V. Youngquist, "Ohio's Water Resources," *The Ohio State University Engineering Experiment Station Circular* 48, Columbus, Ohio, 1946, p. 7.

Although flowing water exposed to the sunlight and air tends to purify itself, the problem of pollution has become more complex as domestic and industrial uses have placed an ever-increasing drain on the volume of water. Sewage and industrial wastes have increased enormously; aquatic life has been partially destroyed; silting due to increased erosion has been accelerated; and floods and droughts have become more acute, owing in part to deforestation and improper utilization of the watersheds. Likewise groundwater is polluted, especially in shallow and open wells. Seepage from barnyards and from cesspools in more thickly populated areas is a source of contamination.

It has long been known that polluted water resources were among the most dangerous of disease carriers. Typhoid fever is one of the epidemic diseases that has been traced directly to the domestic water supply. City after city using raw river water cut the typhoid death rate steadily after filtration plants and later sterilization of water were adopted. The typhoid death rate in the United States fell to one-ninth of its former significance after water-purification practices were adopted by the major cities using surface water. It is probable that other epidemics are spread by means of the water supply or faulty sewage disposal.

Purification of water and the processing of sewage and industrial waste are two of the important steps in the program of conservation of surface water, since sewage and industrial waste in the rivers and lakes are among the major causes of pollution. Beginnings have been made by both cities and private industry to process sewage and industrial waste, returning only harmless residues to the streams and lakes. If these processes are carried to their logical ends, reclaiming usable materials from industrial waste and producing fertilizers from sewage, only pure water would be returned to the streams and lakes, and one of the conservation problems would be solved.

sterilization processes must be followed than are necessary in the lake cities to ensure clean, tasteless, pure water for domestic use.

Among the numerous processes that have been developed to remove the various undesirable and dangerous substances from

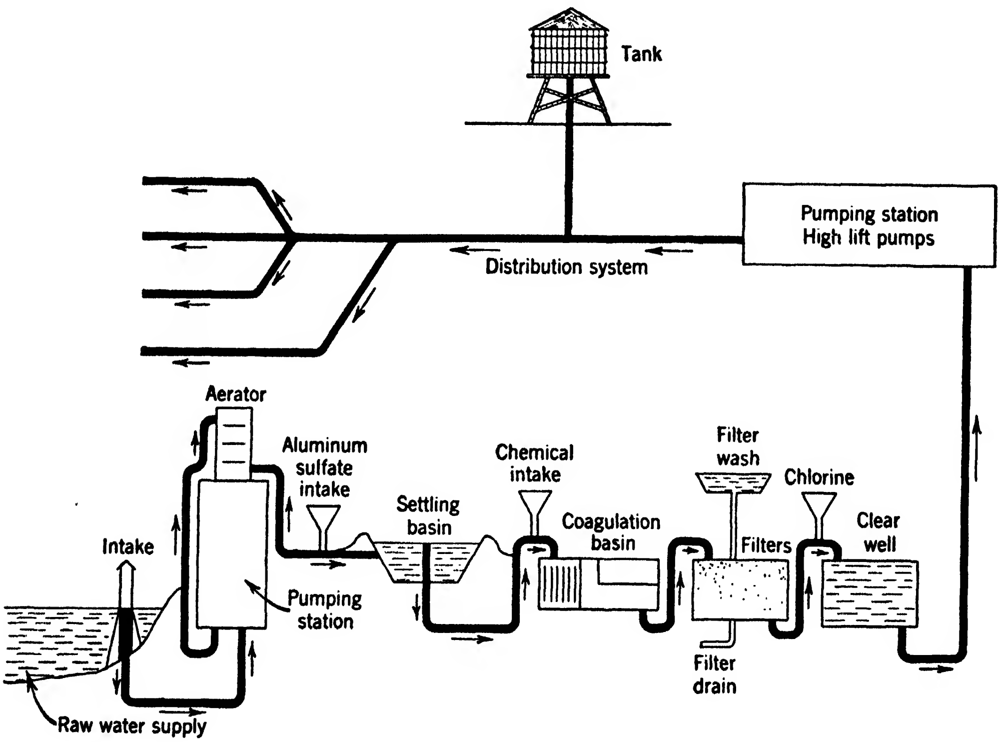

FIG. 4. Generalized diagram of the numerous processes that have been devised to remove undesirable and dangerous substances from water that is unsafe in the untreated state.

Since most surface water is polluted, domestic supplies taken from streams and lakes are purified according to the nature of the pollution (Fig. 4). Because the water of the Great Lakes is potable in its natural state, the cities drawing their water supply from the lakes have placed their intakes far out in the lake in deep water to overcome in part the pollution from sewage and industrial plants along the lake shore. Most rivers have a much higher degree of pollution, and more extensive purification and

water of polluted sources that are intended for domestic consumption are sedimentation, coagulation, filtration, aeration, chlorination, and coppering (Fig. 5).

River water is usually turbid or muddy from the amount of material carried in suspension by the flowing water. Much of the suspended material is the result of excessive erosion in the watershed of the river, but a portion is due to industrial waste. The water of lakes and reservoirs tends to be relatively clear, except in times of severe storm, since the water is not in motion and the suspended particles are allowed to settle. Reservoirs on turbid streams fill with sediment—a situation that may be too costly to correct if the construction of a new reservoir farther upstream is necessary. The more excessive erosion becomes, the greater is the problem of dealing with turbidity, the silting of reservoirs, and the like. Turbidity ranges all the way from 100 to 5000 parts of suspended material in a million in the various rivers of the United States.

Much of the suspended material is removed from turbid water in settling basins, after which sulphate of alumina is introduced to coagulate organic matter and entangle bacteria. Turbidity is further reduced and harmful bacteria are removed by both mechanical and bacterial filtration. Odor and taste due to the destroyed bacteria are removed by aeration. Coppering prevents the growth of algae, which tend to cause taste and odor in the water. Especially in water that has not been subjected to other processes of purification chlorination serves as a germicide and effective safeguard.

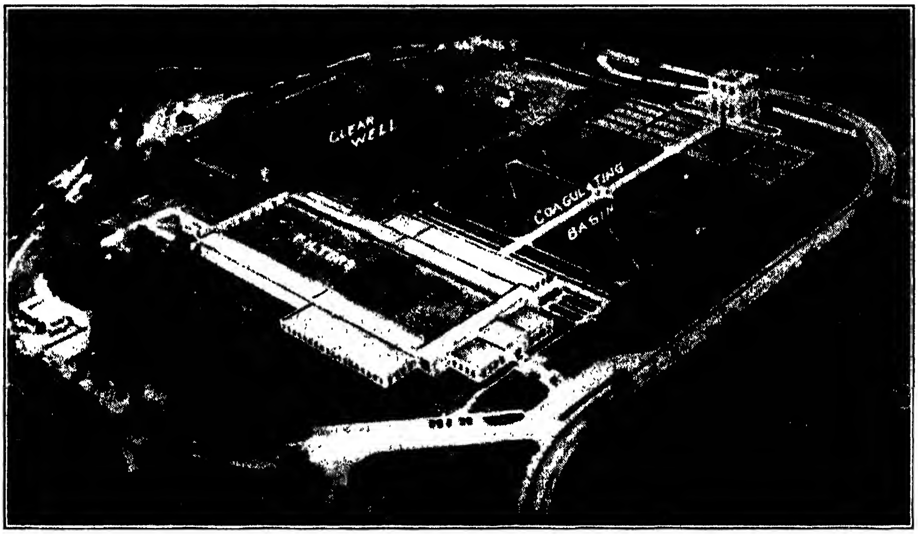

Fig. 5. A modern filtration plant, Cincinnati, Ohio. (Cincinnati Water Works.)

Mineral Content

Groundwater supplies, especially from deep wells, are less likely to be polluted but usually present two equally perplexing problems. One is the presence of minerals in solution in the water; the other is a diminished supply due to falling watertables. Much of the groundwater, as well as some surface water that has been in contact with calcareous material, contains magnesium and calcium salts and other soluble material in solution in sufficient quantities to cause the water to be hard and therefore less desirable for many purposes. Hardness is a measure of the calcium and magnesium salts in solution in the water. Soft water contains less than 60 parts of salt per million; temporarily hard water contains from 60 to 120 p.p.m., and permanently hard water contains more than 120 p.p.m.

Temporary hardness may be removed by simple softening processes, but permanent hardness cannot be removed without extensive and likewise expensive permutite operations. Communities that depend upon a supply of permanently hard groundwater are faced with the problem of using the water untreated or assuming the added cost of softening the water. Municipal or water company softeners are sometimes employed, but in most towns and cities depending on hard groundwater the softening is at the discretion and expense of the user. Both industrial and domestic consumers install water softeners. Soft-water services have been established in hard-water communities, both the softener and the regenerating service being conducted on a rental basis. Since hard water does not permit the proper detergent action of soap, it is not desirable for household purposes or for laundries. Likewise various types of textile mills, breweries, photographic establishments, and steam boilers, especially railroad locomotives, require large quantities of soft water. The saving in soap alone takes care of the cost of water softening for domestic and commercial laundries.

Manganese, iron, sulphur, and sodium chloride are other harmful or undesirable mineral properties of groundwater that affect the taste or odor of the water. Sulphur water and salt water from deep wells are not potable but are suitable for cooling. If the salt water is dense enough the brine is usable in the chemical industry. Sulphur water is suitable for air-conditioning plants. The spent water, however, is or should be returned to a dry well rather than the sewer.

Declining Watertable

One of the conservation problems confronting towns and cities that depend upon groundwater as a source of supply is the declining level of the watertable. Especially in the dry regions where numerous wells tap the groundwater for both domestic and irrigation water, the level of the watertable has fallen a number of feet, making it necessary to deepen many of the wells. In humid areas likewise groundwater is being removed faster than it is being replaced by precipitation. In like manner the hydrostatic pressure of artesian wells has been reduced until some of them have ceased to flow above the level of the ground.

Any well drilled into the groundwater and pumped continuously lowers the watertable in a great cone in the vicinity of the well into which the water must percolate from the surrounding area. If the water-bearing formation is composed of coarse, porous material the water will flow in rapidly, but if it is fine-grained material the replacement will be slow and it will be relatively easy to pump the well dry temporarily. Thus it is necessary to drill a series of wells at rather widely spaced intervals to ensure an adequate water supply for a town or city entirely dependent upon wells. More and deeper wells are drilled as the demand for water increases, and many communities turn to surface water for their supply. If water is pumped out faster than it is replaced by percolating rainwater, a valuable water supply will diminish.

CONSERVATION ATTITUDES

The problem of water conservation is not one that can be solved independently of the conservation of the other natural resources. It is possible to restrict the use of water by various devices of metering, checking leaks, and raising the price. Although desirable and necessary at times and in various places restricted use is not a solution.

The total volume of water will always depend upon the amount that falls as precipitation, whereas the available surface and groundwater will depend upon the nature of the earth's surface materials. Sufficient forest and grass cover will retard runoff and floods, reduce erosion, and raise the level of the groundwater. It is doubtful if impounding water raises the watertable anywhere except in the vicinity of the lake, and even there silting may produce a watertight lake bottom. With a proper balance of evaporation, runoff, and groundwater maintained by adequate reforestation and soil conservation programs an enduring source of water for everything but the most fantastic demands can be ensured.

To complete the conservation program the problem of pollution must be solved by disposing of domestic sewage and industrial waste in a manner that will not contaminate water supplies. Likewise the problem of cleaning up our streams and lakes and maintaining clean watersheds is a vital part of the conservation of water for domestic and industrial purposes. The best conservation program to ensure a water supply for domestic and industrial purposes is a good reforestation and natural vegetation program, an intelligent soil conservation program, an adequate flood control program, as well as an enlightened wildlife conservation program, for they are all the same—the intelligent and continuous utilization of our natural resources.

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CHAPTER 13

Water Power and Its Conservation

INTRODUCTION

IN the cultural evolution of man he has striven to gain mastery over his environment, and in a large measure his achievements reflect an increasing use of mechanical power. In primitive societies man was limited to the strength of his own muscles. But in due time the domestication of animals gave him greater power and, as a consequence, increased control over his environment. The wheel, the lever, and other simple but fundamental inventions made possible the mechanical revolution which was to come. In a period of human slavery the man power available in a community or in the possession of a slaveholder was a measure of economic strength. It may be significant that the liberation of human slaves came when mechanical power was multiplying man's control over nature. Gradually and inevitably the work of the world was shifted from the muscles of man to the untiring machine driven by mechanical power. No longer was man power, particularly slave power, at a premium; hence man's moral attitudes in respect to his slaves overtook his economic demands and the slaves were set free.

This statement of the relation of slavery and the liberation of the slaves to the increased use of mechanical power is a half-truth, for slaves were used chiefly in agriculture where mechanical power was not so important as it was in manufacturing. But the rapid development of power-using machinery created a virtual revolution in manufacturing. The utilization of power was largely responsible for the series of developments that resulted in transferring the processing of raw materials from the home to the factory.

Water Power and the Hydrologic Cycle

In the operation of the hydrologic cycle, water that falls upon the land returns to the sea from which it was derived originally. In its return it fulfills its destiny, and man in his understanding of the ways of water may make full use of this essential resource. Wherever precipitation falls upon elevated areas potential power is available along the streams, depending on the quantity of water and the declivities along the watercourses. As long as the energy of the sun continues to evaporate the waters from the seas, and the vapor-laden winds penetrate the continents deeply, the precipitation that falls in elevated areas will flow back to the sea. This perennially renewable power resource should be developed wherever it is economically feasible, so that the nonrenewable fuels may be conserved for future generations.

By Guy-Harold Smith of The Ohio State University.

Frontier America and the Early Development of Water Power

The aboriginal Americans who lived along the watercourses used the streams for their personal needs and for transportation, but they were unmindful of the power available in the rushing waters. The legends of the Indians contain many references to falling waters but there is little evidence that they had any appreciation of water power as a factor in their primitive economy.

The establishment of the colonies along the Atlantic seaboard preceded the great mechanical revolution. The early settlers, although they were compelled to live under relatively primitive conditions, brought to America a greater understanding of the value of resources than that possessed by the Indians. From New England to the Piedmont farms were being cleared, homes built, and at favorable locations water wheels were installed to utilize the local power resources. Many of these first-used power sites proved to be of temporary usefulness; others helped to localize settlements and to develop them into expanding mill towns, which today look back to their founding at the water's edge and where falling water provided power.

Frontier America and the Water Wheel

Almost as soon as the colonists set foot on American soil they turned not only to the land for the production of food but also to the watercourses as a source of power. As people moved from the seaboard westward across America to settle along the moving frontier they developed the power sites to turn the wheels of pioneer industry. These little water wheels at numerous power sites ground meal and sawed the timber into lumber. These were the important industrial products of the frontier. Gradually, as the farmer became more concerned with the cultivation of the land, he left the responsibility for the utilization of local power to people who sought to make their living at this occupation. Larger wheels at the more important power sites, often requiring the construction of dams, replaced the little water wheels. Here was a division of labor and, in consequence, a division of responsibility. The farmers with their greater concern about food production were clearing the land and cultivating the fields and generally were changing the character of the headwater area so important in maintaining a regular supply of water power. Dams were built to provide the necessary head to turn the water wheels, but the reservoirs were soon silted up with the fertile soil from the farms in the upstream areas.

Eventually many of the old mills were abandoned. It was cheaper to use the more reliable steam engine which burned coal. The development of transportation made coal relatively easy to secure, and the local water wheels declined in importance. But the moving frontier, as it progressed westward across America, gave the water wheel a temporary place in the economy of the pioneers.

Evolution of the Water Wheel

The manner in which water power was first utilized is unknown to us, but available evidence indicates that the first water wheels were crude devices. Probably the first was simply a paddle wheel which turned slowly in the current. The efficiency of such a water wheel was only three or five per cent of the total available power, and in time the undershot wheel which had an efficiency of 25 to 30 per cent was developed. The moving water was confined to a flume or channel constructed so that the paddles received the full impact of the moving water. The efficiency was further increased to 50 or even 70 per cent when the flume was deepened so that the full surface of the paddles received the impact of the moving water. This was known as the "breast wheel."

A more efficient use of falling water was made possible by the development of the overshot wheel which utilized a system of buckets so that little energy was lost. The best wheels of this type were 80 to 85 per cent efficient and were in wide use in the early part of the nineteenth century.

Gradually the overshot wheel was replaced by the water turbine, which, after a number of improvements were made, utilized the energy of falling water more efficiently, particularly at the large power plants. The old overshot water wheel used a head of no more than 40 feet, but the turbine made possible the use of a head up to 1000 feet. Many of the old water wheels are still turning the wheels of industry and give some indication of their efficiency and their usefulness in certain power situations. But the modern turbine is more satisfactory for the utilization of the power available at large dams.

The Steam Engine

With the invention and development of the steam engine the stage was set for coal-generated steam power to dwarf the power generated from falling water. The wheels of industry still were turned by water power, but steam power became increasingly important during the nineteenth century. By 1900, 70 per cent of the total mechanical energy produced in the United States was derived from bituminous coal, 20 per cent from anthracite,. five per cent from petroleum, and three per cent from water. The remaining two per cent was contributed chiefly by wind and animals. This gives some indication of the relative position of water power among the other power resources. In the 50 years since the turn of the century the proportion of the power developed from coal has declined to less than 45 per cent; petroleum has risen to approximately 30 per cent; natural gas supplies nearly 15 per cent; and water power yields less than 10 per cent of the total power developed (see Chapter 17).

THE ECONOMICS OF WATER-POWER DEVELOPMENT

Considered from a purely physical point of view the total amount of water power available along a watercourse or in a particular region is related to the quantity of water available in the streams, the vertical fall of the water, and the efficiency of the water wheels or turbines used in the development of the power resource. A number of conditions or circumstances, operating either in conjunction or singly, influence the installations necessary for the generation of the power available from falling water. The gradient of a stream may be so gentle that power sites are limited and the necessary head difficult to obtain without the construction of expensive reservoirs. Another stream discharging a similar quantity of water may have a gradient characterized by long reaches of low fall interrupted by rapids and falls where power development is economically and physically feasible. The seasonal irregularity of precipitation may set definite limits to the utilization of a stream for power purposes. The dams and other engineering works necessary for the full utilization of a stream for power may affect adversely the use of the stream for navigation and other purposes. The physical characteristics of a stream should be thoroughly examined in terms of the several purposes for which water may be used immediately and prospectively when the stream is fully developed.

Water Power and the Localization of Industry

Before the invention of the steam engine or the development of electric generators and motors, power from falling water led to the location of many manufacturing establishments at the power sites. Many of the older industrial cities of the United States were founded at the river's edge and at the falls or rapids where the power could be used directly in manufacturing. Among the many such cities, Rochester, New York, Minneapolis, Minnesota, and the fall-line cities at the contact of the Coastal Plain and the Piedmont may be mentioned. The location of the falls, the result of the processes of nature, did not everywhere satisfy the economic requirements of the region or the nation. But throughout New England and in many other sections of the country the power-located cities have continued to grow, though today little or none of the power is used directly.

Although the invention and development of the steam engine resulted in the abandonment of many water-power installations, riverside location was still important, for it was easy to obtain water for the boilers or for manufacturing processes. In some areas, such as the Ohio valley, important quantities of coal are still transported by water. The steam engine produced power for direct use in industry and eventually became relatively more important than water power. Where water power continued to be used the supply was too restricted to meet the needs of the flourishing industrial cities. Many cities in the older sections of eastern United States were founded at a water-power site, developed and expanded under steam power, and now are making use of both and of other sources of power. Some of the smaller power sites have been abandoned as uneconomic.

Electricity and Water Power

The electrification of industry and transportation in the latter part of the nineteenth century and the first quarter of the present century permitted a revaluation of the localization factors. No longer was it necessary to locate the mill at the water wheel or adjacent to the boiler which generated the steam. Within limits, which have been gradually extended, electrical power could be generated in one place and transported by high tension lines to the power-consuming centers.

The development of electric energy from falling water makes possible the utilization of the power a hundred or more miles from the place where it is needed. Many of the most important power sites are located in or near mountain areas but the places where the power is needed may be many miles away. The effects of isolation of power-producing sites are being diminished by the continued development of transmission facilities and efficiencies.

Transmission of Electrical Power

In the early stages of electrical power development the distribution of current was confined to the local areas where it was generated. Many small and large communities were served by power plants located at the waterfalls of a through-flowing stream. In others the electric current was steam generated. In either event the distribution was usually confined to the local municipality or to some industrial or private consumer. Localization of use was related to technical limitations, to long distance transmission, and to excessive costs of the lines in terms of anticipated returns. In many situations it was cheaper to transport the coal to the market area and generate the electricity there instead of constructing the necessary lines to transmit or transfer the electric current from a generator to a distant market.

Progressively through the years the transmission distance has increased until power generated at a central station may be distributed to a consuming market 200 or 300 or in particular situations 500 miles away. Transmission distance has increased with technological improvements in the electrical field, the development of major blocks of power in remote areas, and the necessity of delivering electric current to a distant market, as in the case of surplus power produced in the TVA, at the Hoover dam, and at Grand Coulee. These great public projects produce power in excess of local requirements and during World War II and in the post-war period have delivered power to distant markets.

Interconnection of Electric Power Facilities

The expansion of certain electrical facilities resulted in the absorption of smaller and financially weaker systems. These consolidations generally improved electrical service by providing greater diversity of load, a reduction of costs, and greater flexibility within the system. The integration of local units into major power systems leads inevitably to interconnection within the major systems. In spite of certain charges of monopoly and the concentration of financial control in a few hands, interconnection makes possible the transfer of surplus power to deficient areas. Interconnection, operated in the best interests of consumers, should provide uninterrupted service in times of emergency.

The irregularity of rivers, only partially alleviated by the building of dams, requires steam-generating plants to provide continuous service. A prolonged interruption of service caused by floods may be offset by interconnection with a nearby power system.

The Federal Power Commission has encouraged interconnection. During the war years, and particularly in the post-war period, the demands for electric power have tended to expand faster than could be met by the utilities. In certain areas the supply and demand have been essentially out of balance, so that interconnection became a virtual necessity. The national welfare is dependent upon the willingness of the private and the public power interests to cooperate in order to secure the benefits of interconnection.[1]

POTENTIAL WATER POWER IN THE UNITED STATES

Water Power and Storage

The potential water-power resources of the United States were estimated in 1949 at 43,841,000 horsepower available 90 per cent of the time or 59,625,000 horsepower available 50 per cent of the time. This estimate made by the U. S. Geological Survey is based upon storage now available and other facilities that might logically be constructed in the future. The total power available therefore is related to the construction of reservoirs which will regulate the discharge of the streams at the power sites. These resources are subject to revision upward

[1] *Energy Resources and National Policy,* U. S. National Resources Committee, Washington, D. C., 1939, pp. 263–268.

when it becomes evident that storage facilities may be constructed at a number of small local sites. The inclusion of these relatively small powers will not greatly increase the total (Table 1).

TABLE 1

POTENTIAL WATER POWER IN THE UNITED STATES, 1949

[Source: U. S. Geological Survey.]

	Available 90 Per Cent of the Time		*Available 50 Per Cent of the Time*	
Division	*Horsepower*	*Per Cent*	*Horsepower*	*Per Cent*
United States	45,155,000	100.00	59,625,000	100.00
New England	1,078,000	2.39	1,781,000	2.99
Middle Atlantic	4,553,000	10.08	5,890,000	9.88
East north central	869,000	1.92	1,640,000	2.75
West north central	1,891,000	4.19	2,553,000	4.28
South Atlantic	2,936,000	6.50	4,058,000	6.81
East south central	2,673,000	5.92	3,848,000	6.45
West south central	943,000	2.09	1,236,000	2.07
Mountain	11,524,000	25.52	13,537,000	22.70
Pacific	18,689,000	41.39	25,082,000	42.07

Storage in a drainage basin is not everywhere related to the regulation of the flow simply for power purposes but involves also other uses of the water for irrigation, the maintenance of minimum depth for navigation, and for flood control. Water control for all purposes in a river basin is an ultimate objective of water-resource planning, but it may be necessary in certain drainage basins to achieve these several objectives successively instead of simultaneously.

WATER-POWER DEVELOPMENT IN THE UNITED STATES

The water-power plants of the United States have more than one-quarter of the producing capacity of the generators installed in all parts of the world. Progressively, and in spite of some wartime destruction of generators, the installations have increased steadily. The accompanying table shows the total capacity of water-power plants at the year's end from 1920 to 1947 (Table 2). The United States leads all other nations in the capacity of water-power plants with 24,206,000 horsepower. The capacity in Canada is 10,490,923 horsepower, in Japan 8,600,000, in Italy 6,250,-000, and in France 6,100,000. These five countries, on the basis of the installed capacity of the hydroelectric generators, can produce nearly two-thirds of the world's hydro-generated power. Some of the other important producing countries include Sweden, Norway, Switzerland, Germany, Austria, Spain, and the Soviet Union. The movement to make fuller use of water-power resources is worldwide and is not confined to the United States or any other country.

TABLE 2

CAPACITY OF THE WATER-POWER PLANTS OF THE WORLD

[Source: U. S. Geological Survey.]

Year	*Total Capacity of Water-Power Plants (Horsepower)*	*Comparison with 1920 (Per Cent)*
1920	23,000,000	100
1923	29,000,000	126
1926	33,000,000	143
1930	46,000,000	200
1934	55,000,000	239
1936	60,000,000	261
1938	63,900,000	278
1940	69,400,000	302
1941	71,600,000	311
1945	77,800,000	338
1947	86,900,000	378

Hydroelectric Power in the United States

The capacity of hydroelectric generators in the United States has continued to increase year after year with one or two exceptions. The construction of new dams and the installation of new turbines and generators has gone forward in peace and war, in good times and bad, and bids fair to continue until the water-power resources are more fully developed and utilized.

TABLE 3

CAPACITY OF HYDROELECTRIC GENERATING PLANTS IN THE UNITED STATES, DECEMBER 31, 1920–1947

[Source: Federal Power Commission.]

Year	*Capacity in Kilowatts*	*Year*	*Capacity in Kilowatts*
1920	3,703,531	1935	9,398,662
1921	3,901,661	1936	10,037,165
1922	4,128,476	1937	10,175,663
1923	4,507,020	1938	10,657,162
1924	5,023,872	1939	11,003,939
1925	5,921,965	1940	11,223,729
1926	6,405,462	1941	11,817,374
1927	6,802,351	1942	12,841,933
1928	7,702,433	1943	13,883,583
1929	7,813,448	1944	14,586,324
1930	8,585,164	1945	14,911,617
1931	9,090,613	1946	14,848,491
1932	9,257,651	1947	14,970,274
1933	9,333,695		
1934	9,344,933		

The capacity of electric utility generating plants in the United States was 50,303,660 kilowatts on December 31, 1947. Nearly 29 per cent or 14,970,274 kilowatts were hydro-generators (Table 3). Relatively the hydro-generators were most important in the Rocky Mountain and Pacific coast states where competition from coal and other fuels is reduced. In the Rocky Mountain states nearly 75 per cent of the installed capacity of the electric utility plants is hydro. In the Pacific states the capacity is nearly 70 per cent hydro. In areas where coal and other fuels are abundant and readily available the installed capacity of the generators is chiefly steam or internal combustion.

At the end of the year, 1947, of the total capacity of the electric utility generating plants, 14,970,274 kilowatts were hydro-generators, 35,939,017 were steam plants, and 1,302,197 were internal combustion generators. The steam-generated electricity (174,501,312,000 kilowatt-hours) required 89,543,867 tons of coal. It is clear, therefore, that the use of hydro-generators saved the equivalent of 40,000,000 tons of coal. Only about half of the water-power resources of the United States have been developed. Ultimately when full development and utilization have been achieved the annual saving in coal may be approximately 80,000,000 tons. Thus an undiminishing and renewable resource could make a substantial contribution to the conservation of an expendable resource. (See Table 4.)

TABLE 4

PRODUCTION OF ELECTRIC ENERGY IN THE UNITED STATES

[Source: The Federal Power Commission.]

	Total 1000 kw. hrs.	*Hydro 1000 kw. hrs.*	*Steam 1000 kw. hrs.*	*Internal Combustion 1000 kw. hrs.*
1925	61,451,091	21,797,874	39,367,118	286,099
1930	91,111,548	31,189,554	59,293,363	628,631
1935	95,287,390	38,372,154	56,144,412	770,824
1936	109,316,033	39,057,647	69,359,153	899,233
1937	118,912,675	44,012,945	73,890,698	1,009,032
1938	113,812,371	44,279,309	68,423,122	1,109,940
1939	127,641,804	43,563,627	82,783,741	1,294,436
1940	141,837,010	47,321,278	93,001,735	1,531,997
1941	164,787,878	50,862,952	112,319,000	1,605,926
1942	185,979,476	63,870,575	120,478,951	1,629,950
1943	217,758,831	73,632,223	142,380,595	1,746,013
1944	228,188,844	73,945,184	152,327,495	1,916,165
1945	222,486,283	79,970,312	140,435,268	2,080,703
1946	223,129,669	78,397,320	142,379,987	2,352,362
1947	255,725,173	78,419,811	174,501,312	2,804,050

Installed capacity of electric utility generating plants December 31, 1947, in kilowatts:

Hydro	14,970,274
Steam	35,939,017
Internal combustion	1,302,197
Total	50,303,660

THE GEOGRAPHICAL DISTRIBUTION OF WATER POWER

The pattern of water-power distribution in the United States reflects chiefly the terrain conditions and the amount of precipitation. Where the land is elevated and the precipitation heavy the potential water power is great. In areas that are low with streams of slight gradient the available power is also low. In dry areas the water power is generally restricted. Maps of annual precipitation and relief are basic to an understanding of the geographical distribution of water-power resources.

The distribution of water power in the United States can be examined in terms of the topographic areas of the country such as the Appalachian Highlands, the Rocky Mountains, and the Sierra Nevada-Cascade Mountains, or hydrographic areas such as the Susquehanna, the Colorado, the Columbia, or the Mississippi drainage basin. However, it has become conventional to examine the power situation in terms of statistical areas or census divisions.

New England

New England which contains slightly more than one per cent of the total area of the United States and has between six and seven per cent of the population has only 2.31 per cent of the potential water power in the United States. However, the development and utilization of water power is well advanced in New England which has approximately 11 per cent of the capacity of water wheels in the United States. As one of the oldest industrial areas in the nation New England originally used her water power directly in manufacturing processes. With the coming of electricity an important proportion of the available water power was used in the generation of electricity. "At the end of 1937 about 29 per cent of the generator capacity of New England plants producing electricity for public use was water driven ···"[2] Ten years later the proportion had been reduced to 27 per cent. The industrialization of New England makes heavy demands upon other sources of power such as coal from the Appalachian Plateau.

Water power in New England both before and after the development of electrically driven equipment has been extensively used in the woodworking and in the textile mills. With the growth of the larger urban centers the domestic use of electricity has increased and water-wheel capacity has increased also. In the period between 1921 and 1938 water-wheel capacity increased 53 per cent.[3]

Continued development in New England is related to the competitive position of the area in respect to manufacturing. Certain industries, particularly textiles and shoes, have moved out of New England. During World War II New England's share of government-built or government-financed construction was somewhat below her relative position as a manufacturing area.[4] This may be interpreted as a significant fact of prophetic importance to industrial New England. The industrial readjustments consequent upon the transformation of the United States from a major agricultural to the greatest industrial nation in the world have wrought changes in the economic character of New England. This does not mean a decline in manufacturing or a reduced demand for hydroelectric power. It is expected that further use will be made

[2] *Ibid.*, p. 246.

[3] *Ibid.*, p. 248.

[4] Alfred J. Wright, "Recent Changes in the Concentration of Manufacturing," *Annals Assoc. Amer. Geogrs.*, Vol. 35, 1945, pp. 144–166.

of the power resources of New England as greater control of the rivers becomes urgent and economically feasible. Extensive development of the power resources of the major rivers provides New England with hydroelectric power, and the reservoirs supply water for industrial and municipal purposes and in a measure alleviate the danger of floods.

The chief rivers that supply power to New England, and can be developed further, include the Connecticut, the Kennebec, the Penobscot, and the Androscoggin. The construction of single-purpose dams for power alone probably should be restricted until the several water problems have been examined and it has been determined how water supply, navigation requirements, flood control, and power can be linked into a single water-control project. On many of the smaller streams the power resources are restricted, but the recurring floods are a major economic hazard. Water-power development in this area therefore may be secondary to the solution of a more urgent water problem (Fig. 1).

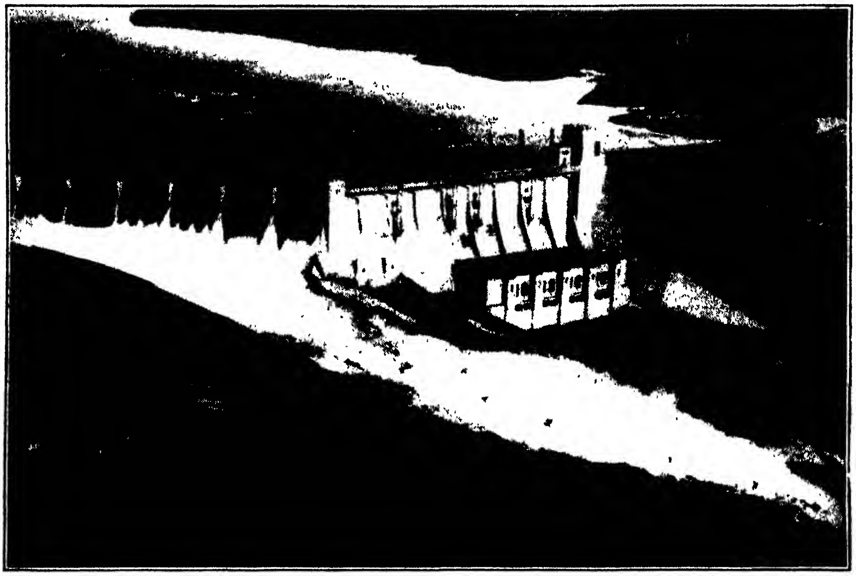

FIG. 1. Comerford Station, Monroe, New Hampshire, and Barnet, Vermont, is the largest hydroelectric plant in New England. Its four generating units have a capacity of 150,000 kilowatts. (New England Electric System, Photo by Fairchild Aerial Surveys, Inc.)

The Middle Atlantic

New York, Pennsylvania, and New Jersey together make up the middle Atlantic division. This area is economically one of the most important sections of the country because of the density of the population and the high development of the power resources for industrial and commercial purposes. Few sections in the United States, in spite of the restricted area devoted to industry and commerce, are so highly developed as the narrow strip extending from New York to Baltimore.

In the United States as a whole more than 36 per cent of the electricity produced for public use is generated by hydroelectric plants. In the middle Atlantic division the percentage is only 18 which means that access to coal results in steam-generated electricity for the public utilities. Along the seaboard the use of petroleum reduces somewhat the dependence on other sources of energy.

Most of the power is developed along the Niagara, the St. Lawrence, and the Susquehanna rivers. Important power sites have been developed at the northern edge of the Appalachian Plateau and along the margin of the Adirondacks. Except for a very small part New York was glaciated, and as a consequence the drainage was disorganized producing many sites where power can be developed.

Important supplies of undeveloped power are still available along the Niagara and St. Lawrence rivers. When and if the St. Lawrence project is authorized and developed hydroelectric energy will be available to areas within transmission distance of the sources. The largest demand for power is in the seaboard area which may be beyond the limits of economic transmission. But the important power resources will be available in up-state or northwestern New York, particularly along the Mohawk valley.

The chief hydroelectric plants in Pennsylvania are in the southeastern part of the state. These hydro-plants interconnected with fuel generators provide most of the electrical energy for the municipal, industrial, and commercial users. The relative accessibility of coal in western Pennsylvania has retarded somewhat the full utilization of water power, but in the future, multiple-purpose water-control projects will result in an increased use of hydro-generated electricity.

East North Central

The division that consists of Ohio, Indiana, Illinois, Michigan, and Wisconsin is an area of relatively low relief and moderate rainfall; hence the power resources of these east north central states are not great. In Ohio, Indiana, and Illinois the unglaciated and the older drift areas have limited water-power resources. Michigan and Wisconsin are somewhat more elevated and glaciation disorganized the drainage so that numerous sites are available. This in effect is an area of little powers which collectively total only two per cent of the potential water power of the country.

In the upper lakes region the high percentage of the land in forests, the extensive swamp areas, and the numerous lakes regulate the discharge of the streams. In Wisconsin and Michigan the potential resources will permit a 75 per cent increase in the capacity of installed water wheels.

When the frontier of settlement first invaded this area as in many other sections of the country water-power resources were utilized locally at numerous sites to run the flour and saw mills. Later these small mills gave way to larger installations which permitted the direct use of the power or the development of hydroelectric power for the tributary area. An increased need for power will require the construction of reservoirs and the utilization of many unused sites.

South Atlantic

The south Atlantic division consists of the District of Columbia and the eight states of Delaware, Maryland, Virginia, West Virginia, North Carolina, South Carolina, Georgia, and Florida. This area embraces slightly more than nine per cent of the land area of the United States, has approximately 13 per cent of the population, and also has seven per cent of the potential water power.

The low-lying Coastal Plain with its through-flowing streams of low gradient has little available water power. But inland along the Piedmont and at the margin of the Southern Appalachians the several major streams provide numerous sites for the development of power.

A major part of this area was for a long time largely agricultural. As a consequence, rapid or full utilization of the water resources lagged behind industrial New England. But with the shift of many of the textile mills to the Piedmont and with the growing demands for power in other industries, particularly woodworking, tobacco, and chemicals, the installed capacity of the water wheels increased rapidly.

It is estimated that the available undeveloped energy resources will permit doubling the present output of power without exhausting the potential water power available in the area. Full development cannot come at once, for power generation is related to other water problems such as municipal and industrial supplies of water, stream pollution, navigation, and flood control.

On the east slope of the southern Appalachians the chief power rivers include the Savannah, the Santee, Roanoke, Potomac, Saluda, Warrior and Tombigbee, Yadkin-Pee Dee, the Chattahoochee, and many smaller streams. One of the largest reservoirs in this area is the Saluda, on the Saluda River in South Carolina.

Water-power development in the area is related to the availability of fuel-generated electrical power particularly in the coal-producing state of West Virginia. Also natural gas and petroleum are competing fuels in this area.

Full development of the water-power resources must take into account the occasional dry years which greatly reduce the discharge of the streams. Reservoirs to provide storage of great quantities of water in periods or seasons of abundance and interconnection with fuel-generator systems are necessary to assure the consumer that adequate power will be available at all times.

East South Central

The four states of Kentucky, Tennessee, Mississippi, and Alabama which lie south of the Ohio and east of the Mississippi comprise the east south central division. Mississippi which is largely in the Coastal Plain is least important in respect to water-power resources. A high percentage of the area is in the drainage basin of the Tennessee River and as a result has experienced, since 1933, a rapid development of the water-power resources under the jurisdiction of the Tennessee Valley Authority.

Within the drainage basin of the Tennessee the federal government has undertaken a notable experiment in government-supported regional planning. Multiple-purpose planning extends into other phases of the economic life of the region as well as those related to the river. The manufacture of chemicals for agriculture and for industry is an important development. Planning for better land use so that the people may live a richer and more healthful life is a major objective. To achieve this desirable good the government has participated in the life of the people by sponsoring housing projects, by helping in the resettlement of people displaced from lands required for the public projects, by bringing better medical facilities to the people, and in other ways contributing to the welfare of the people.

The Tennessee River, largely an uncontrolled stream before the initiation of the TVA program, had a number of small reservoirs in the headstream area and the

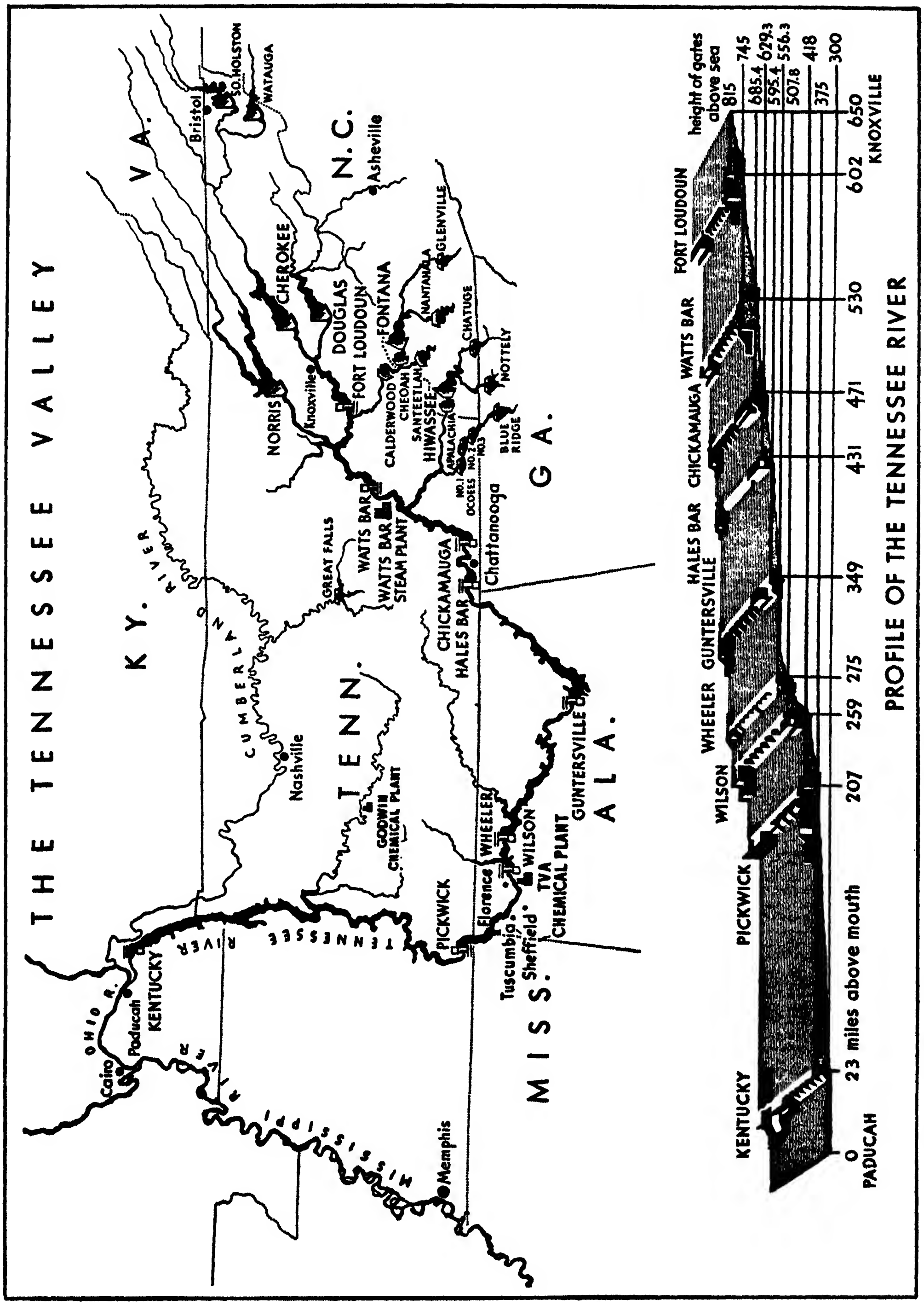

FIG. 2. The Tennessee River and the principal reservoirs of the Tennessee Valley Authority. (Tennessee Valley Authority.)

great Wilson dam at Muscle Shoals. A program of acquisition of dams already built and the construction of new dams has brought the Tennessee largely under control. The impounded waters make the Tennessee a navigable stream at all times; the power developed at the several dams is available within the Valley and to the tributary areas; the floodwaters resulting from excessive precipitation are held back and contained within the reservoirs and the stream channel; and as a by-product the impounded waters provide fishing and recreational opportunities for great numbers of people (Fig. 2).

Up to 1948 the Tennessee Valley Authority had built 16 dams and had secured ten other dams, the largest of which was Wilson dam built during World War I. The great dams on the Tennessee include in upstream order the Kentucky, Pickwick Landing, Wilson, Guntersville, Hales Bar, Chickamauga, Watts Bar, and Fort Loudoun. Other multiple-purpose dams on the tributaries are the Hiwassee, Norris, Cherokee, Douglas, and Fontana. The total generator capacity of the TVA system, both hydro and fuel, was 2,567,402 kilowatts for the fiscal year ending June 30, 1948. The fuel-generated power represented only 17 per cent of the output.[5]

Full utilization of the water-power resources of the east south central division will require interconnection with steam-generated systems. The abundant coal resources of Kentucky, Tennessee, and Alabama will make it possible to maintain steam stand-by generators which can be used when demand exceeds hydro-generated power or when an extended drought reduces the available water power. Jointly the hydro- and steam-generated power is entirely adequate to meet the industrial and domestic requirements of the area.

[5] Tennessee Valley Authority, *Annual Report*, 1948, pp. 83–84.

West North Central

The seven states of Minnesota, Iowa, Missouri, North and South Dakota, Nebraska, and Kansas make up the west north central division. Contained within these states is 17.18 per cent of the total area of the United States but only four per cent of the potential water power. Minnesota was largely glaciated and resembles Wisconsin and Michigan in the character of its water-power resources. The Dakotas and Kansas with low rainfall and great expanses of nearly level land have very limited water-power resources. Nebraska, Iowa, and Missouri are somewhat better situated. The relief is greater and the rainfall is heavier in Iowa and Missouri.

Inadequate hydroelectric power is available in this area for industrial purposes, municipal users, and the rural electrification program. Much of the electrical energy will have to be fuel-generated. Coal and petroleum are available in the southern part of the area and are used extensively in the generation of electricity. Multiple-purpose water-control projects in the eastern part of the area might be developed chiefly to control the floods and incidentally may permit the development of hydroelectric power.

The through-flowing rivers such as the Missouri have important power resources in the sparsely populated headstream area. It is not economically feasible to transport the power to the Dakotas, Nebraska, and Kansas. These areas will probably continue to meet their power needs chiefly from the local or nearby fuel resources. In Nebraska and in the Black Hills area of South Dakota small water-power installations can contribute a limited supply of hydroelectric energy in an area of scant water resources.

The two largest power installations in this area are at Keokuk, Iowa, on the Mississippi, and at the Lake-of-the-Ozarks on the Osage in Missouri. When and if the co-ordinated water-control projects of the Missouri valley are realized more important installations for the generation of water power may be constructed.[6]

West South Central

The west south central division consisting of the four states of Arkansas, Louisiana, Oklahoma, and Texas contains 14.45 per cent of the area of the United States but has less than two per cent of the potential water power, and approximately the same percentage of the population. This is one of the least important water-power areas in the United States. Approximately half of the resources have been developed. Here as in many other sections of the country the movement to bring the great rivers and the little waters under control may result in the installation of generators at some of the dams built partly for flood control and navigation.

Mountain

Geographically this is the largest census division and includes Montana, Idaho, Wyoming, Colorado, New Mexico, Utah, Arizona, and Nevada. This large area contains approximately 25 per cent of the water-power resources of the United States. Here the generation of water power is closely associated with other water uses, particularly irrigation. Generally these two major uses are not in conflict, for the melt water of the winter snows can be impounded during the spring and early summer. The water can first be utilized power and then distributed to the thirsty land.

The major centers of power development are in the Northern Rockies or the adjacent plains where mining and mineral processing require a large amount of electrical power. The headwaters of the Missouri, particularly at Great Falls, provide power for western Montana. In Idaho the Snake River generates power for the southern part of the state and adjacent areas. The largest installation is at the Hoover dam on the Colorado River below the Grand Canyon. An important block of the power generated here is allocated to California where the need is great. Other power resources such as petroleum and natural gas are used to generate electricity in many local communities thus eliminating the need for long-distance transmission of hydro-generated electricity.

Pacific

Washington, Oregon, and California include within their boundaries only 10.7 per cent of the area of the United States but contain approximately 42 per cent of the potential water power. Approximately one-half of the available power is in Washington, and the other half is divided almost equally between Oregon and California.[7] The availability of water power and the relative scarcity of competing fuels, except in southern California where petroleum is abundant, have been conducive to the development and use of hydroelectric energy. Coal produced in Oregon and Washington

[6] Morris Llewellyn Cooke, "Plain Talk About a Missouri Valley Authority," *The Iowa Law Review,* Vol. 32, 1947, pp. 367–390.

[7] *Energy Resources and National Policy,* National Resources Committee, Washington, D. C., 1939, p. 260.

while economically important is not competitive to the extent that water-power development is seriously retarded. In view of the scant supplies of high-grade coal the development of perennially renewable water-power resources will prolong or extend the life of the limited reserves. In Washington wood waste from the sawmills and woodworking mills is also used to produce fuel-generated electricity.[8]

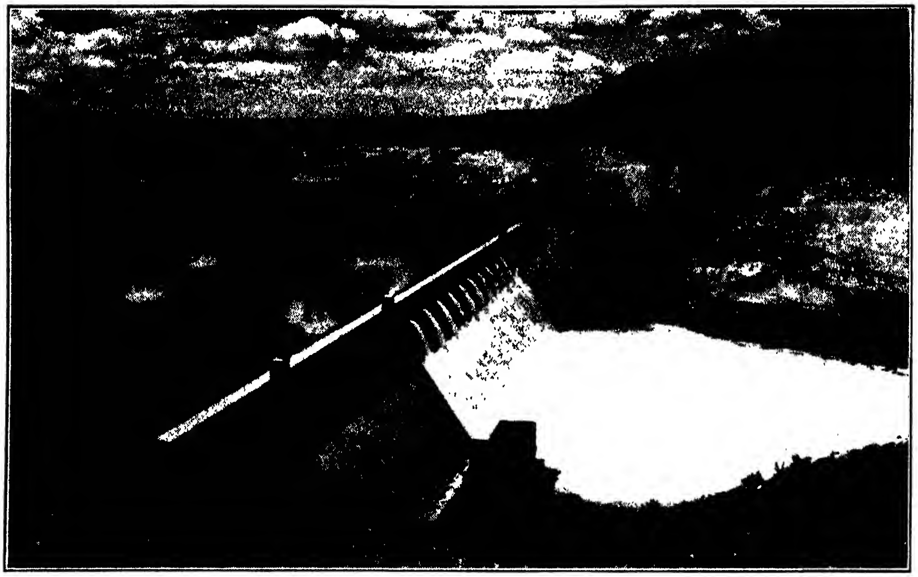

FIG. 3. The Grand Coulee dam is the largest concrete dam in the world and kingpin for the Bureau of Reclamation's million-acre Columbia Basin Irrigation Project. Power generated by the dam will be used to operate the world's mightiest irrigation pumps that will start Columbia River water on its way to a million-acre expanse of farming land. The world's biggest hydroelectric generators are operated at the dam. Its ultimate power installation will be the greatest in the world. The west powerhouse, farthest from the camera, already contains the greatest installed capacity of any single powerhouse in the world. (U. S. Bureau of Reclamation.)

Great reserves of undeveloped power remain in the Pacific northwest where the relatively high mountains and the heavy precipitation, particularly in the form of snow during the winter, are favorable conditions. This seasonality of the precipitation will require many relatively large reservoirs to even out the discharge of the streams and to provide a continuous and uniform delivery of electric current to the consumers. East of the Cascades and in the agricultural valleys of California water is also needed for irrigation. The dual uses of water for power and irrigation are not generally in conflict, and it may be expected that continued economic development of the Pacific area will require both the expansion of irrigation agriculture and the utilization of the water-power resources.

Before 1930 most of the power development was along the west slope of the Cascades and the Sierra Nevada, but the Columbia, one of the great power rivers of America, is now contributing its power to the consumers of the tributary area. The

[8] *Ibid.*, p. 260.

construction of the Bonneville dam where the Columbia breaches the Cascades and the Grand Coulee dam more than 400 miles upstream has made available power which served well the wartime industries (Fig. 3). In the post-war period the power is available for peacetime projects which will enrich the life of the people by providing current for their electrical equipment and appliances.

In addition to the numerous reservoirs that have been constructed on the west slope of the Cascade-Sierra Mountains, some of which rank among the highest in the world, the Shasta dam on the Sacramento was completed in 1945 (Fig. 4). This great dam will serve the multiple purposes of supplying water for the dry plains of the Sacramento valley, of holding back the floodwaters which in times past have been so destructive, and of generating power for the tributary area.

FIG. 4. Shasta dam. General view of dam and lower reservoir area as seen from hill about one mile downstream. Mt. Shasta is plainly visible on the horizon. (U. S. Bureau of Reclamation, photo by B. D. Glaha.)

Probably the developed water power in the Pacific division is approximately ten per cent of the total feasible undeveloped resources. Rapid development is largely dependent on the expansion of market and the ability of the power-producing companies or agencies to deliver cheap electrical energy to the consumer. The expansion of agriculture requires both water and power because irrigation water in many places, particularly in the Columbia Plateau, must be lifted to the farmlands to be irrigated. The Bureau of Reclamation which is one of the most important producers of power is also an important consumer. The need and the demand for power will require further development of the unused resources as population growth and industrial expansion continue as major regional trends.

THE FEDERAL CONTROL OVER WATER POWER

From the foundation of the federal government it was generally understood that the Constitution gave the government jurisdiction over the navigable waters of the United States. There existed some doubt in respect to the extent of this jurisdiction. However, by 1866 it became evident that the jurisdiction was being acknowledged. The River and Harbors Act of 1884 gave the United States Government control of structures on navigable waters. In 1901 Congress passed a bill giving the Secretary of the Interior the power to grant rights of way over public lands for water-power plants, dams, reservoirs, and transmission lines. After large areas of public land had been set aside as national forests, the Secretary of Agriculture gave easements for rights of way across forest lands. The interest of the Forest Service was related to the important relationship between the flow of streams and the forest cover. Under the leadership of Gifford Pinchot the Forest Service was much interested in protecting the watershed areas and controlling the streams in the national forests. Since the jurisdiction of the navigable waters came under the Department of War, the national forests under the Department of Agriculture, and large areas of public land were still administered by the General Land Office of the Department of the Interior, these three departments were most concerned with the problem of government control over water resources, particularly power and water-power sites.

In the period between 1906 and 1920 a number of attempts were made to consolidate the interests of the three departments of the federal government and at the same time to satisfy the private power interests who were anxious to develop certain power sites on public lands. This was a period of searching in order to determine the appropriate way for the government to facilitate or control the development of the water-power resources. The National Conservation Congress of 1913 urged Congress to provide the necessary legislation to permit the utilization of navigable streams for power. At a conference in 1914 governors of the states of Utah, Colorado, Nevada, Washington, Oregon, Idaho, Wyoming, New Mexico, and North Dakota claimed the waters in their respective states as state waters and therefore under their jurisdiction. Here was a conflict between the interests of the several states and the federal government. In 1912 the Commissioner of Corporations had recognized the futility of divided authority and had recommended either public ownership or public control of the power sites. In this period of experimentation a number of bills related to the problem of power development and control of the water resources were introduced in the Congress. Certain of these bills passed one House or the other, President Theodore Roosevelt vetoed one bill that had passed both Houses, and President Taft vetoed another. Both presidents clearly were in favor of public control of power resources, but neither was satisfied with the particular bill presented for his signature. The chief engineer of the Forest Service in June of 1917 recommended the creation of a federal power commission consisting of the Secretaries of Agriculture, Interior, and War, the Attorney General, and one appointed member to serve as executive officer.

The Federal Power Commission

During the first two decades of the present century it had become evident that federal jurisdiction over the power resources, or at least public control, was a necessity. A bill, introduced in the House by Congressman John J. Esch in the special session of the 66th Congress, was passed by the House on May 4, 1920, was passed by the Senate on May 27, and was signed by the President thus becoming the Water Power Act of June 10, 1920. This act created the Federal Power Commission giving it "... general administrative control over all water-power sites and kindred establishments that are located on the navigable waters on the public lands and on the reservations of the United States." [9] The Federal Power Commission became an investigative and judicial agency of the federal government. Its activities include co-operation with state agencies concerned with water control. It can investigate water-power resources, issue permits and licenses, evaluate properties, and fix rates. From this beginning in 1920 when the basic legislation became a part of the law, the Federal Power Commission has continued to function very effectively in the development and control of the water-power resources of the nation.

While the original Federal Power Act prescribed the jurisdiction of the Federal Power Commission as applying to the power resources on navigable rivers and on public lands, it was evident that, in time, its function would be somewhat extended. The internal organization required the setting up of particular divisions such as engineering, accounting, statistical, regulatory, licensing, and legal. The authority of the commission was also extended to supervision of the sale of securities where there was no state agency authorized to carry out this function. The various activities of the commission could easily be justified when it is understood that approximately 85 per cent of the water-power resources of the United States were subject to the jurisdiction of the federal government and could be utilized only under the provisions of the Federal Water Power Act.

During the first 10 years from 1920 to 1930 it became evident that the commission required reorganization. The cabinet members who had previously served on the commission were aware that their duties should be transferred to full-time commissioners. They would be relieved of this responsibility which would give them more time to handle the other affairs of their respective departments.

Reorganization of the Federal Power Commission

An act passed by the Congress reorganizing the commission was signed by President Hoover on June 23, 1930. A five-man commission was appointed by the President and promptly took over the duties of the commission. The first chairman was George Otis Smith, formerly Director of the U. S. Geological Survey. At the time of reorganization the capacity of water-power installations on public lands or on navigable waters had reached 3,000,000 horsepower. This was 24 per cent of the total hydroelectric generating capacity of the United States. In 10 years from 1920 to 1930 there had been 100 per cent increase in capacity. In this interval the rates for electric current had declined from 7.52 cents to 6.06 cents per kilowatt hour. There still remained much to be done in

[9] Milton Conover, "The Federal Power Commission," *Service Monograph No.* 17, Institute for Government Research, Baltimore, 1923, p. 1.

the field of electrification. The commission reported in 1929 that 90 per cent of the farms were without electrical service and only two per cent of the railroad mileage was electrified. It was evident that the Federal Power Commission, or some other agency, might take up the responsibility of promoting the utilization of water power and other power resources.

President Roosevelt was inaugurated in 1933; he realized the need for further investigations in the fields of power utilization and in the regulation of the power industry. Issuing an executive order on August 19 of that year he called for a power survey. During the depression years when the need for public works programs which would provide employment was urgent, the Federal Power Commission became an active agency of the government. Its duties extended to the investigation of holding companies, and the President called upon the commission not only to survey the water resources of the country but to consider also the problem of rates and to formulate a program of public works. The power survey ordered by President Roosevelt was one of the most comprehensive investigations of the power situation in the United States made either by a private or federal agency.[10] The problem of appropriate rates became a major concern of the commission which has co-operated with state agencies in determining fair rates to the consumer of electric current.[11]

The passage of the Public Utility Act of 1935 extended the jurisdiction of the commission to electrical energy regardless of the method of generation if the electric current was involved in interstate commerce. The commission then had power to facilitate interconnection and co-ordination of power facilities where the two were geographically and economically feasible.

By 1938 the Federal Power Commission was operating under six major acts of Congress including first, the act which created the commission in 1920, the amendatory act of 1930, the Public Utility Act of 1935, the Natural Gas Act of 1938, the Flood Control Act of 1936 as amended in 1938, and the act that created and authorized the TVA.

During World War II the Federal Power Commission was able to facilitate the allocation of power to a great variety of war industries. The commission kept a close check on the supply of electrical current in relation to the expanding market. New generator capacity was installed wherever possible to meet the wartime requirements. Between 1940 and 1947 the installed capacity of the electric power industry increased from 40,000,000 to more than 50,000,000 kilowatts.

Since 1920 the work of the commission may be divided into four rather distinct periods. Between 1920 and 1930 the licensing function was a distinguishing feature of its work. The second period from 1930 to 1935 was characterized by the power and rate surveys. During the next five-year period the regulation of interstate commerce in power was an absorbing duty. Since 1940 the demands of the war and the postwar readjustment period brought to the commission the complex problems of resource utilization for the benefit of all the people.

The need for multiple-purpose projects on many of the great streams and the little

[10] Federal Power Commission, National Power Survey, *Interim Report, Power Series No.* 1, Washington, D. C., 1935.

[11] See *Opinions and Decisions of the Federal Power Commission,* Washington, D. C., Vol. I–V, 1931–1946.

waters of the United States requires that the commission make comprehensive surveys of the drainage basins requiring engineering works to control stream flow. Both the River and Harbors Act and the Flood Control Act of 1946 provided for the installation of penstocks in the dams when approved by the Secretary of War upon the recommendation of the Chief of Engineers and the Federal Power Commission. At last the Federal Power Commission can participate fully in the multiple-purpose projects as well as those devoted exclusively to the generation of power.

Rural Electrification

The federal government is actively engaged in the promotion of consumption of electric power in rural areas. Under the jurisdiction of the Rural Electrification Administration the government has facilitated the organization of power-distribution systems. The REA has secured low-cost power from a number of the large public power projects such as the Tennessee Valley Authority, the Southwest Power Administration, the Bureau of Reclamation, and the Bonneville Power Administration. The REA has made few loans for the development of hydroelectric power projects, but has been more interested in the distribution of low-cost electric current to people in rural areas, so that the farmers can have power for home lighting, the electric appliances in the home, and power-driven equipment on the farm. It has been estimated that at least one-third of the power distributed through REA-financed systems is hydro-generated.[12]

[12] Personal communication from George W. Haggard, Acting Administrator, Rural Electrification Administration.

The Advantages of Public Control of Water Power

Most of the economic activities of this country are carried on by private enterprise. This is an American tradition, and there is every indication that this essential feature of our economy will be continued. However, the public interest is vitally important in those enterprises where the welfare of the people is directly involved. In the development and distribution of power derived from falling water the public interest is evident. Development of a major water-power site under private auspices confers upon the company a quasi monopoly, and to protect the interests of the public some kind of control or regulation either by the state or by the federal government is essential.

The development and utilization of water power for the generation of electricity is unlike the mining of coal for the production of power. Water power is a natural resource inexhaustible in character, in which the public interest is continuous. One generation which uses the power is under some obligation to pass it on to the next in such a manner that the public welfare will be served. The use of exhaustible and diminishing resources does not imply the necessity for public control except for fair rates to the ultimate consumer of the power generated. The relative abundance of coal, petroleum, and natural gas has been conducive to the private development of these power resources. The great size of some of the water-power projects has required public financing, for private capital could not be expected to undertake development with the necessary long-term amortization of the cost at the low rates determined by the regulatory commissions. Venture capital has been reluctant to invade this field of power development.

Numerous arguments can be advanced for public control of water-power resources. It is important that the people of the country have available at all times adequate power at reasonable rates. The facilities may be privately owned but reasonable rates must be subject to determination by a state or federal agency thus guaranteeing to the consumer the best electrical service for the least cost. This does not mean that private interests and the public welfare are seriously in conflict. A fair-minded state utility commission will see to it that a privately owned power company gets a reasonable return upon its investment and at the same time will be mindful of the need of the people for adequate and cheap electric service.

There is always the danger that a large share of power may be controlled financially by a few major power companies which in turn may be largely dominated by a few persons whose desire for personal gain is inimicable of the welfare of all of the people. Public control is necessary to give to the people a feeling that their best interests are protected by the government.

The monopolistic character of water-power development and particularly the generation and distribution of electric current eliminates competition as an effective force in the determination of fair and equitable rates. It would be very uneconomical and unwise to try to achieve fair rates by competition between two or more companies. Competition would require duplication of facilities which probably would result in higher costs for electrical service than would be obtained from a publicly owned utility or from a privately owned company whose rates were established by the state utility commission.

The impounding of waters in reservoirs and the discharge of the waters downstream calls for an agency whose jurisdiction transcends the local interests of a power company developing the power resources at a single site. Over-all basin control by a government agency is necessary to see that all interests, both private and public, are served.

State Commissions

In the various states there are commissions, or other agencies, that exercise jurisdiction over the intrastate power resources. These several agencies may not have the necessary personnel and financial resources to carry out all the investigations, and generally they are dependent upon the fact-finding agencies of the federal government, particularly the Federal Power Commission and the United States Geological Survey.

Generally most of these state commissions are concerned with the determination of rates based upon the fair appraisal of the assets of the power companies or in the determination of actual cost. The fixing of a fair rate for electric current in the market areas is a necessary and useful function, and the state utility commissions have usually operated with reasonable success in this area. However, in the development and distribution of power, which are interstate in character, the state agencies must co-operate with the Federal Power Commission.

In this matter, as in a number of others, individual states have been jealous of their respective rights. On occasion there has been objection to federal participation. In those cases involving the interstate commerce in power, and where the federal government has corresponding jurisdiction, as in the case of power developed on navigable waters and on the public lands, co-operation of the state water-control agencies and the Federal Power Commission has usually been achieved without serious difficulty.

Private versus the Public Interest

In the United States to permit individuals and private companies and corporations to develop resources has been a long-standing tradition, based largely upon the principle that the public lands should be distributed to relatively small landowners. From the time of the first Homestead Act in 1862 until the end of the nineteenth century it was regarded as a major objective of this government that the land resources be transferred to the hands of individuals. Thus the development of a strong economy for the nation and personal security for the individual was possible. The same tradition or principle was applied also to minerals, to forests, and to waters. Great abundance permitted the wide distribution of resources to many people, but as scarcity developed there tended to be a reversal of this trend, and great areas of land were held in perpetuity by the federal government in national forests, national parks, and national monuments. The reservation of certain mineral lands to protect the public interests also came about.

The situation in respect to water power has been a little different from that of farmlands and mineral deposits on public lands. Water power is derived from precipitation which falls widely on the land. The water then is concentrated in a watercourse, and because of fortuitous or other circumstances the water power can be developed only in a limited number of favorable locations. The wide distribution of precipitation would seem to give to all the people, particularly those residing in the drainage basin, an interest in all the water problems of the drainage system. Water power, therefore, is a right that belongs to all the people, and, if the privilege of developing the power resources is granted to an individual or to a private company, it seems logical that a license and an appropriate fee should be required. This is the logic behind the idea that water-power resources are invested with a public interest which requires either public ownership and consequent development or private development under governmental regulation.

Interstate Compacts

Most water-control projects transcend the state boundaries and require joint or multiple state agreements for their development. Water power in all its aspects is not limited to the site where the generator is located but extends to the headstream area where the water begins its flow to the sea. This is the area of water storage, either natural or man made, which regulates, as far as possible, the supply of power where the turbines and generators are installed. A lake in one state and a reservoir in another regulate the discharge of a stream, the power developed in the lower section of the river may be in a different state, and the electric current generated may be distributed in an interstate market. A proper and full development of the power resources of a drainage basin would require an interstate compact as a means of securing the co-operation of the several states and the Federal Power Commission. The development of such interstate compacts requires a number of stages before the compacts can be given final effect. (1) They must be authorized by Congress which provides the enabling legislation; (2) state legislatures must also authorize the project and provide the personnel and agencies that are to carry out the negotia-
states must proceed to draw up the com-
tions; (3) the commissioners of the several

pact; (4) the compact must now be submitted to the legislatures of the several states for approval and ratification; and (5) Congress must also ratify the compact. Any break in this series of five steps may mean the ultimate failure of a project applicable to a drainage basin. However, the defection of a single state, depending somewhat on its location in the drainage basin, may or may not affect the proposed project.

CONSERVATION OF WATER POWER

Water power is a nondiminishing resource. Unlike the fuels, it is not depleted by use and once used can be re-used time and time again. The fuel minerals are extractable and expendable, but water power is perennially renewable. It must be used as the water seeks its lowest level, or the power is lost forever. This distinguishing feature of water power has led many people to believe that we should make every effort to make immediate and full use of water-power resources. Unhappily, this is hardly possible when considered in the light of both the physical characteristics of the streams and the economic conditions under which the power must be developed and utilized.

In a free economy, or in a partially controlled economy, competition of water power with power developed from fuels may be uneconomic, or at least full use of the water power is not feasible.

The irregular discharge or flow of the streams introduces a serious limitation to the development and use of water power. Storage may achieve reasonable regularity, but the dams may be very expensive and add greatly to the cost of the power. Since full use of the power is economically unwise, it may be possible, however, to utilize a high percentage of the power available and use stand-by steam plants to maintain a satisfactory flow of electric current to the consumers. Where competing fuels are not available it may be economically feasible to develop the water power to the fullest. In other areas, such as the upper Ohio valley where enormous quantities of coal are available, the development of the water resources for the production of power may be quite uneconomical. Only where control of the rivers for multiple purposes and where the cost can be distributed among several beneficiaries would it be wise to develop to the fullest the power resources. The conservation of water-power resources therefore is not a simple engineering problem of bringing a river completely under control and utilizing the total power available. Development must take place in a context of the local and national economy: at a particular time it may be inadvisable to install water wheels to utilize the power of falling water; in a later period it may be entirely possible and economically very desirable to make at least a partial, if not a full, use of the water-power resources. Conservation is therefore both an engineering and an economic problem and may require the solution of the several water problems *seriatim* instead of simultaneously according to a grandiose plan.

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CHAPTER 14

Our Waterways and Their Utilization*

BODIES of water—oceans, seas, gulfs, sounds, lakes, and rivers—provide the cheapest form of transportation for man if they are used in their natural form, and under the most favorable conditions; man-made waterways may also provide cheap transportation, if these canals are dug in areas requiring them. Unfortunately many canals have been constructed without due consideration of their costs and relative values when completed, and this has caused an apprehensive attitude in the mind of the general public toward inland waterway transportation that is not always justified.

Other than the digging of canals, the chief improvement that has been made in water transportation is in the carrier itself. When primitive man first learned to use a floating log to transport himself from some point on a river to some other downstream place dates far back in prehistoric times, yet there is no doubt but that this primitive navigator began to think of ways to improve his craft. The dugout canoe and the raft were some of the earliest improvements on the floating log. In the evolution of the boat from log to leviathan over the thousands of intervening years, man has made the water carrier swifter, larger, and more efficient and has reduced thereby the cost of water transportation. The development of the power-driven boat or raft, whether propelled by man power, wind, steam, or modern diesel engine, was perhaps the greatest improvement in the carrier in that it allowed man to ascend a stream against a current as well as to drift downstream with the current.

Improvements in the carrier of commerce, however, were not all that was needed to make waterways useful to man. Nature herself had been somewhat niggardly in her gifts to navigation on some streams, while she was lavish on others. Some handicaps placed in the way of cheap water transportation were: (1) streams frequently flowed in the wrong direction, with a circuitous and tortuous course, which needed straightening and widening; (2) obstructions in streams in the form of falls and rapids presented hazards, if not complete barriers to navigation, and had to be by-passed by canal or other means of transportation to link the separate parts of a

* The author of this chapter owes a deep debt of gratitude to the late A. E. Parkins, of George Peabody College for Teachers, the author of the original chapter on Our Waterways and Their Utilization in the First and Second Editions of *Our Natural Resources and Their Conservation,* New York, 1936 and 1939. Although some of the material has been rewritten and brought up to date, the original chapter has been drawn upon freely.

By Edwin J. Foscue of Southern Methodist University.

waterway; and (3) ice on some streams caused a complete cessation of the use of a waterway for a period during the winter. In attempting to overcome the natural handicaps so as to make the waterway more serviceable as a carrier of commerce, man has built portage trails, railways, and canals and has spent money lavishly on many projects that never should have been attempted. However, these mistakes should not cause one to condemn all waterway projects nor overlook those that have been successful in the past or those that may be desirable in the future. According to A. E. Parkins, in making improvements, either in the carrying agents or the navigated waters, man must adapt his work to:

1. The physical condition of the water bodies.
2. The types of commodities to be carried.
3. The ever-increasing commercial demands resulting from an increasing population and a changing economic order.
4. The mechanical developments and improvements that are continually being made under the spur of competition.

Large sums have been spent by the United States government for improvements in harbors and rivers and in constructing canals. Although the period of canal building was at its peak in the first part of the nineteenth century prior to the beginning of the railroad era, appropriations for waterway improvements in the twentieth century are many times as great as those of the steamboat era of the 1850's. Today, improvements in navigation are linked so closely with the development of water power and flood control on streams, as in the case of the Tennessee Valley Authority, that it is perhaps unreasonable to charge the large appropriations to navigation alone. The various valley authorities that are being proposed should be analyzed from all points of view before they are either approved or condemned. It is true that the ultimate consumer pays the transportation bill, but, when certain parts are charged off to national defense as in World War I and World War II, perhaps this cost is not too great. In future, all forms of transportation by land and water should be studied so that the available facilities may be fully utilized by the people of the United States both in time of war and in time of peace. Waterway carriers, railroads, motor-truck lines, and airlines should be made to realize that they all have a place in the development and growth of a modern nation. If and when this is done, our combined arteries of transportation will be able to withstand the shock of any commercial demand or the emergency of war.

OUR WATERWAY RESOURCES

The United States ranks high among the nations of the world in its navigation resources (Fig. 1). The types of "waters" used for the movement of commodities are:

1. Ocean waters.
2. Seacoast harbors (the deeper intracoastal waters).
3. Intracoastal waters, other than harbors.
4. Lakes.
5. Rivers.

Ocean Waters

The length of the "general" coastline of the United States is as follows: on the Atlantic Ocean, 1888 miles, on the Gulf of Mexico, 1629 miles, and on the Pacific Ocean, 1366 miles; total, 4883 miles. The tidal shoreline (reaching into harbors to points where such waters narrow to a width of three statute miles) is 7314 miles. The

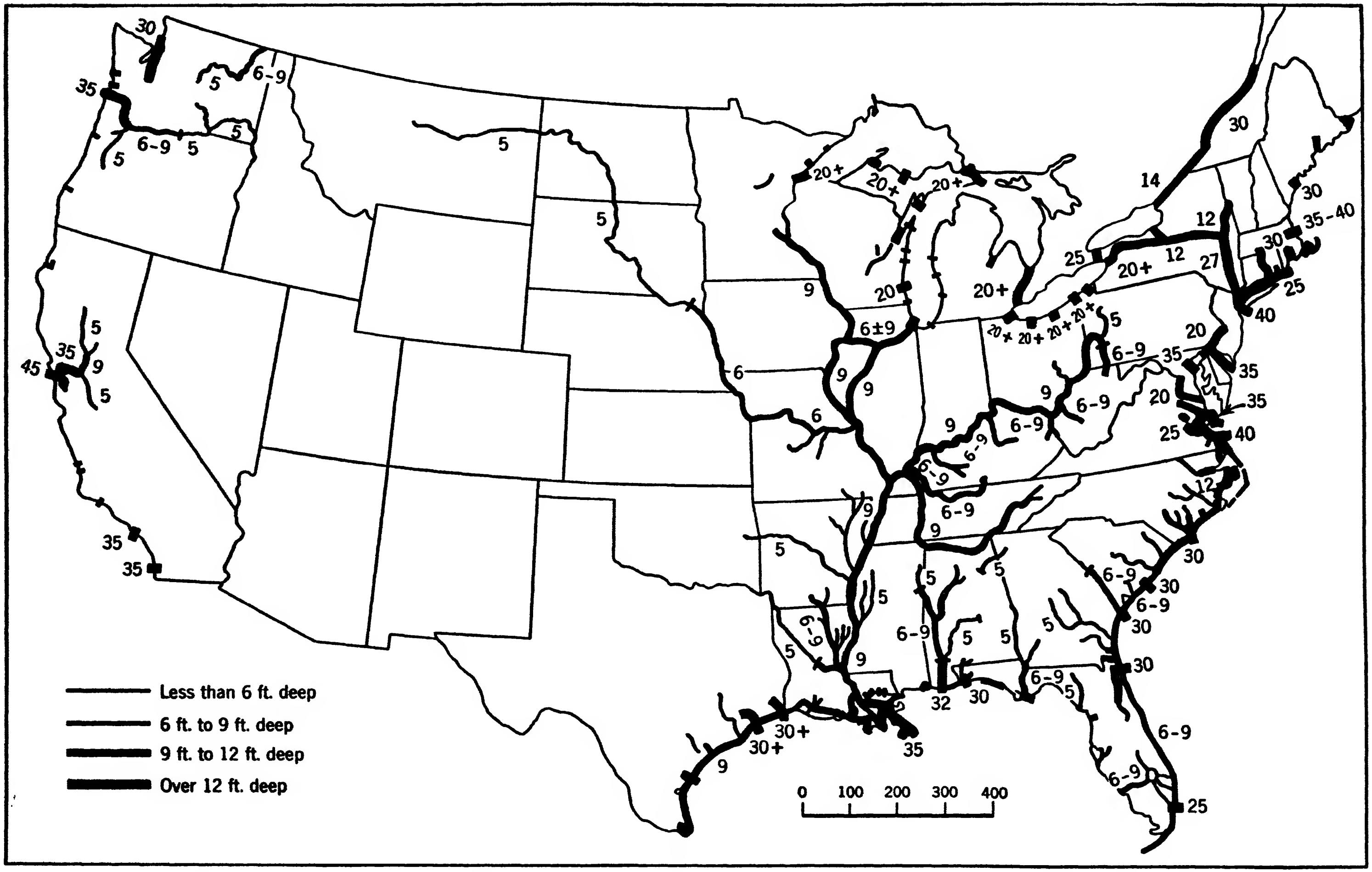

FIG. 1. Principal waterways of the United States, 1946. (After Office of the Chief of Engineers, U. S. Army.)

shorelines of islands are not included. Our jurisdiction over coastal waters, of course, extends only to the three-mile limit, except by special agreement with other nations. We can thus include the ocean waters contiguous to our coast as a part of our waterway resources. Improvements for ocean and coastwise navigation—lighthouses and lightships, lifesaving stations, and coast guard patrol boats and airplanes—are for the safety of vessels and men. These, though contributed by our federal government, are international in their benefits.

Seacoast Harbors (the Deeper Intracoastal Waters)

The effectiveness of a coastline is measured more by the number and usableness of the harbors than by length. The Atlantic coast harbors of our country are numerous. Those north of and including Chesapeake Bay are spacious. From Sandy Hook northeastward they are largely the result of glacial action and drowning. Shifting bars are uncommon, for the currents are strong, the offshore waters deep, and the supply of sands meager. The southern shore of Long Island is an exception. Boston Harbor is separated from the ocean by drumlins. New York Harbor is largely the drowned lower Hudson valley.

From Sandy Hook southward to the tip of Florida and all around the Gulf of Mexico the harbors for the most part are estuaries, the result of the drowning of valleys carved in the unconsolidated muds, sands, and gravels of the Coastal Plain. At Philadelphia, Baltimore, and Richmond the estuaries cut completely across the Coastal Plain to the Fall Line. Most estuaries are ill adapted, in their natural condition, to modern commerce. They are shallow and thus require much dredging to provide navigable channels for modern vessels. Moreover, they call for continual attention owing to the tidal shifting of estuarine sediments.

The Pacific coast harbors, though excellent in general, are few in number. The harbor at Los Angeles is largely man-made. Two shallow, marsh-bordered water areas have been dredged into a very serviceable harbor, which ranks high in commerce among the great ports of our country. San Francisco Bay and Puget Sound are most excellent natural water bodies. They require only the minimum of improvement. Both are classed as drowned harbors. San Francisco Bay is a drowned mountain valley; Golden Gate which leads out to the ocean is a drowned mountain pass. Puget Sound besides being drowned has been glaciated. The lower Columbia River is also drowned. There are shifting bars at the mouth that require constant attention even with fairly permanent improvements. It was the shallow water of these bars that deterred Vancouver from claiming the Columbia as a British river. Gray, shortly after, in a smaller vessel, sailed many miles inland from the ocean and took possession in the name of the then young United States of America.

A harbor to be serviceable should be spacious enough to meet the demands for anchorage space and freedom of movement of the vessels visiting the harbor. Since anchored vessels shift their position with changes in the wind and the tide each vessel must have a space allotment greater in radius that the length of the vessel. The additional space demanded is proportional to the length of anchor chain used. Deep harbors are not essential, but the depth should be at least five to ten feet deeper than the draft of the vessel at the lowest tide. Most American harbors in their original condition are too shallow to meet the demands of the large seagoing vessels of today. Until well into the nineteenth century the depth demands of ocean vessels were modest and little dredging of channels and archorage space was called for. The large harbors today have 25- to 30- and even 40-foot channels with a width of 300 to 600 feet. Harbor improvements that have to do with serviceable channels, anchorage space, and turning basins are, as a rule, provided by the federal government. State, city, and private companies ordinarily provide the freight piers and channels to state, city, or private wharves or to dry dock and ferry slips.

Harbors with broad mouths on low coasts call for breakwaters or piers to form protecting headlands. The artificial harbor produced is commonly known as a "harbor of refuge." Ice harbors also, employing breakwaters, are needed in some northern rivers. Delaware Bay has both a harbor of refuge and an ice harbor.

Lagoon harbors like the one at Miami require much dredging of the lagoon to secure the requisite depth and also frequent clearing of the entrance through the barrier beach, because of active tidal scour and wash and deposition. Most estuarine harbors are shallow in their original state. At Baltimore, at the head of the Patapsco estuary, a channel 20 miles long has been excavated from the city harbor to the 35-foot contour in Chesapeake Bay. Far down the bay near the mouth of York River another channel 4.5 miles long has had to be dredged to provide 35 feet of water needed for the large ocean-going vessels bound to or from Baltimore. As cities such as New York, Philadelphia, Baltimore, and others expand their overseas commerce, additional wharf space, anchorage basins, and channels are called for.

The silt-laden Mississippi makes the maintenance of a deep channel for ocean vessels from the Gulf to New Orleans a costly project. It is at the head and at the mouths of the channels, "passes," as they are called, of the bird-foot delta that silting is a problem that calls for continual supervision and frequent dredging. Jetties [1] have not entirely solved the problems of providing a usable channel.

An interesting harbor development in late years on the Gulf Coast is the Houston Ship Channel that extends 50 miles northwesterly from the ocean across Galveston Bay, and thence along San Jacinto River and Buffalo Bayou. This channel, with a depth of 34 feet and a width varying from 250 to 400 feet, ends in a turning basin at Houston (Fig. 2).

Even San Francisco Bay has had to have federal aid in deepening and widening its main ship channel. The State of California also has made generous contributions to fit San Francisco to handle large volumes of commerce.

To cross the bars at the entrance to the Columbia River, jetties and frequent dredgings are necessary to maintain a 40-foot channel at mean low tide. The lower Wil-

[1] This device was used by Eads in South Pass in 1879 (jetties completed). He and some associates contracted to maintain the channel 26 feet deep and 200 feet wide at the bottom for a term of 20 years. The total sum paid them by the government was $8,000,000. Although the jetties are probably more effective than any other method known, other devices are needed to control the silt (400,000,000 tons a year) that is deposited where river currents meet tidal waters of the Gulf.

The Mississippi from New Orleans to the Gulf is treated by the engineers of the United States Army as a harbor, that is, a deeper intracoastal waterway.

lamette and lower Columbia are here considered intracoastal. From Portland to the ocean is 110 miles. In its original condition this section of the Columbia had controlling depths of only 10 to 15 feet at low water, but it now has a 30-foot channel from Portland to the head of the estuary.

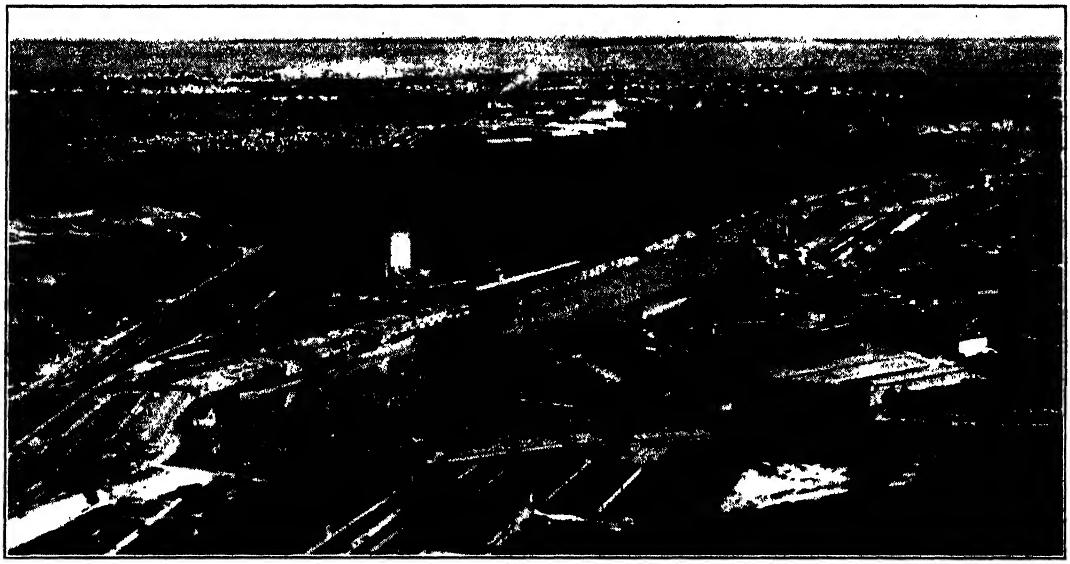

FIG. 2. Turning basin near Houston, Texas. (Robert L. Browning.)

Intracoastal Waters, Other Than Harbors

Besides the major harbors, several other conspicuous deep intracoastal water bodies in the United States, such as Narragansett Bay, Long Island Sound, Delaware Bay, Chesapeake Bay, Tampa Bay, Mobile Bay, Galveston Bay, San Francisco Bay, and Puget Sound, have required but little improvement to fit them to handle ocean and coastwise traffic. The drowned portion of the Hudson River with tidal waters to Albany, and the Mississippi to New Orleans, may rightfully be classed with these deeper intracoastal waters.

Many hundreds of square miles of lagoons, estuaries, and shallow intracoastal waters have been improved to meet the needs of shallow-draft crafts, too small to brave the coastal waters. Lagoon waters are almost continuous from New York Harbor southward to the tip of Florida and also border almost the entire Gulf coast. Most of these shallow intracoastal waters and several deep intracoastal water bodies have been connected by short canals, here and there, to form the great Intracoastal Waterway that extends from Cape Cod Bay to Key West. The Gulf Intracoastal Waterway is largely completed except for the southwest section between Corpus Christi and Port Isabel.[2] These waterways are shown in Fig. 1.

Lakes

The connected Great Lakes form the greatest inland body of navigable waters in the world, measured by area of water surface, depth of water, and volume of commerce. This great waterway, in its

[2] The last part of this waterway through Laguna Madre was completed in July, 1949.

original condition, had two distinct barriers to continuous navigation, one between Lakes Superior and Huron and the other between Lakes Erie and Ontario. Lake Superior is connected with Lake Huron by the St. Marys River, but at the St. Marys rapids there are only two or three feet of water plunging over resistant red sandstone ledges. The current is so strong that even skiffs and canoes must be cordoned upstream. The first American ship canal (with one lock) at the St. Marys rapids was completed in 1855. A canoe and bateau canal, however, had been constructed on the Canadian side of the river in 1798. It was destroyed by Americans in 1814. There are now four chambers on the American side of the St. Marys River at Sault Ste. Marie, in two canals. The depths of water at the locks are 12.6 feet, 18 feet, 34.5 feet, and 24.5 feet, respectively. The Canadians have a ship canal (and lock) that accommodates the largest lake vessels. All the locks are free to either domestic or foreign vessels in either country. The St. Marys River has been improved. Two channels 20 and 24 feet, respectively, have been provided, one for upstream, the other for downstream navigation. In the St. Clair and Detroit rivers, the connecting waters between Lakes Huron, St. Clair, and Erie, much dredging and blasting of hard rock has been necessary to provide a 20-foot channel. Between 1824 and 1833 the Canadian government constructed the Welland Canal connecting Lake Erie with Lake Ontario. The chambers in later years were deepened to 14 feet and lengthened to 270 feet, and by 1931 the Welland Canal had been greatly improved to accommodate large lake and ocean freighters. This canal is several miles west of Niagara River. Lake Ontario is distinctly a Canadian lake in its commercial activity. In the others, United States commerce dominates.

Lake Michigan, the second of the Great Lakes in size, is connected with Lake Huron by the broad, deep Strait of Mackinac.

There are few natural harbors on the Great Lakes. Every harbor has had some improvements, which, in general, are similar to those of ocean harbors.

Navigation improvements of the Great Lakes in comparison with those of the Mississippi and ocean harbors are fairly permanent features. Tides are scarcely discernible even with a tide gauge. The lake levels are fairly constant, varying not more than one or two feet during the year and three or four feet in a decade or two. The changes in the level are correlated fairly closely with the relative amount of rainfall of the Lakes Region. The velocity of the currents in the connecting waters varies but little from season to season. The connecting waters carry little silt, hence bar-forming is not active in these channels. Nor is bar-forming so active in the harbors of the Great Lakes as on the South Atlantic and Gulf coasts. River harbors, like those at Cleveland and Toledo, however, require close attention to maintain a uniform channel depth.

The total shoreline of the Great Lakes, in American waters, is nearly 4700 miles (8345 miles, total length). As a result of navigation improvements in the channels connecting the lakes and the numerous harbors, large vessels (many 600 feet long drawing 17 to 18 feet of water) can sail 1000 miles from Buffalo to Duluth-Superior, and about the same distance to Chicago, carrying loads larger, in tons of cargo, than those in most ocean carriers. Some of our largest cargo carriers can transport 12,000 to 15,000 tons of iron ore or an equal volume of coal or grain. The commercial possibilities of the Great Lakes, however, are not measured by the length and width of each of the lakes. Were the demand great enough, hundreds of traffic routes, rather than a few as at present, could be developed, so vast is the expanse of water.

Rivers

The navigable rivers of the United States may be grouped as follows: rivers of the Atlantic slope, rivers of the Pacific slope, the Mississippi and its tributaries, and the Gulf slope rivers. Those of the Great Lakes basin are short. The Red River in the Hudson Bay basin drains northward into Lake Winnipeg.

In their original condition, most of the Atlantic slope rivers were navigable for only short distances upstream from their mouths. The navigable sections of New England rivers measure but a few miles, for the rock of the upland comes nearly to the ocean's edge. The only exception is the Connecticut, which has a 12-foot channel to Hartford, 52 miles from the mouth. Southward from New York Harbor the navigable sections lie between the Fall Line and the intracoastal waters, and it is largely in these sections that improvements have been or are being made under "existing projects." The riverways (to be distinguished from intracoastal shallow waters) are very short in Virginia and North Carolina. Fayetteville on the Fall Line in North Carolina is 115 miles from Wilmington; and Augusta on the Savannah is 219 miles from the ocean. The Alabama is navigable to the edge of the Piedmont, 364 miles from Mobile Bay. In the past, some of the West Gulf slope rivers have been used to float commercial products, and now and then there is some agitation to canalize the Trinity (to Dallas), but today water navigation is restricted, largely to intracoastal waters, natural or dredged.

Only a few rivers on the Pacific slope are navigable. The Sacramento will be navigable to Red Bluff, 261 miles from Suisun Bay, when existing projects are completed, and the San Joaquin is navigable for about 100 miles. Since the region was settled river craft have used the Columbia from Portland to the Cascade Water Gap about 160 miles from the mouth, or 50 miles above Portland. Canals and locks at the water gap of the Cascades open up long stretches of shallow water for navigation (Fig. 1). The Willamette has long been available for shallow-draft river steamers.

In certain respects the greatest of all river systems of the world is the Mississippi. The Missouri-Mississippi from the Rockies to the Gulf is 4200 miles long, the longest river in the world. It is 2475 miles from Lake Itasca, the source of the Mississippi, to the Gulf of Mexico. The Missouri is 2945 miles long, the Arkansas 1460 miles, the Ohio (including its longest headwater tributary) 1283, the Tennessee nearly 1000, and the Cumberland more than 700.

There are some 15,000 miles of riverways that have been navigated within the Mississippi River basin. The mileage of the "existing projects," however, is far less than this (Fig. 1). It is more than a thousand miles from Cairo, near the mouth of the Ohio to the Gulf, and nearly a thousand miles from Pittsburgh to Cairo. St. Paul, at the head of navigation on the Mississippi, is 874 miles by river from the mouth of the Ohio. Fort Benton in Montana, once the head of navigation on the Missouri, is 2285 miles by water from the mouth of the Missouri.

When forest and grassland were still

dominant and men too few to construct roads, and railroads were unknown, many of the tributaries of the Mississippi now but little used were active arteries of trade and travel. The navigable lengths of the rivers were far longer than now—not that there is less water but the present standards of efficiency, and even necessity, are higher. Many rivers listed as navigable in the past were navigable only during seasons of high water, three to seven months of the year. The Ohio, for example, in low-water periods had only one to two feet of water in portions of the navigable channel. Boulders and snags were common. Work of removing some of these obstructions was begun about 1825. The first locks and dams were provided for by Congress in 1879. Other dams were constructed at later dates by special appropriations. No consistent plan of river improvement was followed. Improvement to fit the river to handle modern barge traffic began about 1910, at which time a general plan was adopted by Congress.

Before improvements were made, the Mississippi just below Cairo had a minimum depth of only 4.5 feet. Above Cairo the Mississippi was about as navigable, before improvements were made, as the Ohio. Even though the fluctuations in depth of water are not great in the upper Mississippi (most of the tributaries flow out of the lands covered by the ice in the Wisconsin glacial epoch and thus abound in lakes and marshes), navigation was frequently interrupted, if not suspended, during the dry season. Intermittent service was discouraging to shippers and led to loss of patronage and finally to complete cessation of traffic. An attempt is now being made to modernize the transportation facilities and provide dependable service.

MAN'S USE OF THE WATERWAYS

Use of the Riverways

Explorers, fur traders, colonizers, farmer-settlers, all in their turn, have found our waterways almost indispensable. Our ocean harbors welcomed the first explorers and colonizers. On some of them were founded the first settlements from which began the conquest of the land now included in the United States. The fur traders, the advance guard of civilization, used the Hudson, the Connecticut, several of the Maine rivers, and the St. Lawrence for their operations. Up the Hudson, the Mohawk, and on to the Great Lakes went British and Dutch fur traders. The St. Lawrence and Ottawa led the French in their birchbark canoes to the same Great Lakes, once the greatest fur-producing region on the continent. The low divide between the Mississippi tributaries and the Great Lakes favored the wide wanderings of the French voyageurs in their trading operations with the Indians. After them into the heart of the continent went the British and British-American trader along the same routes. Navigable waterways to them meant rivers and creeks of a foot or so of water as a minimum.

The birchbark canoe was the carrying agent, particularly in the Great Lakes region. It could be carried over portages and even pushed through marshes in wet seasons. On the Great Lakes and the St. Lawrence as commerce expanded bateaux, pushed, cordoned, or sailed, carried European commodities to the French trading posts at Detroit, Mackinac, and elsewhere, and returned laden with furs.

Both the canoe and the bateau were used on the Ohio, Mississippi, and Missouri by fur traders. When the farmer-settler began the conquest of the Mississippi basin, larger craft were employed to carry them westward to new homes on or near the many rivers and afterward transported their products downstream to markets. These primitive craft were the raft, the flatboat, and the keelboat (Fig. 3). Some flatboats, suitable only for downstream navigation, were 50 to 60 feet long, and 20 feet wide. They could carry 250 to 300 barrels of flour or an equal weight of other products. The journey from the Ohio to Natchez or New Orleans took 25 to 30 days. The flatboat used the cheapest form of propulsion—the river currents. Since the marketable products were ready for shipment during the off-season on the farms, the farmers or farmers' sons generally manned the boats, and thus the cost of transporting the products to market was low, so low, indeed, that flatboat traffic continued long after the coming of the vastly superior steamboat. Stern necessity forced the majority of farmers to transport their own products to market, but there developed rivermen who carried products on commission or bought them outright much as auto-truck men do today.

The keelboats, fewer in number and much smaller than the flatboat, and therefore in downstream navigation not so efficient a carrier, could, with much labor, be poled, "bushwhacked," or cordoned upstream. It was the express boat of the Mississippi. The journey from New Orleans to Louisville took from 70 to 90 days.

Sailing boats were not adapted to the meandering forest-bordered rivers where in the course of 20 or 30 miles the boat must sail toward every point of the compass. Besides, the tall trees tended to check the winds, and strong currents interfered.

All forms of river carriers were eclipsed by the steamboat when it appeared in the early part of the nineteenth century. The first steamboat on interior rivers, the *New Orleans,* made its first trip in 1811 from Pittsburgh, where it was built. But it never

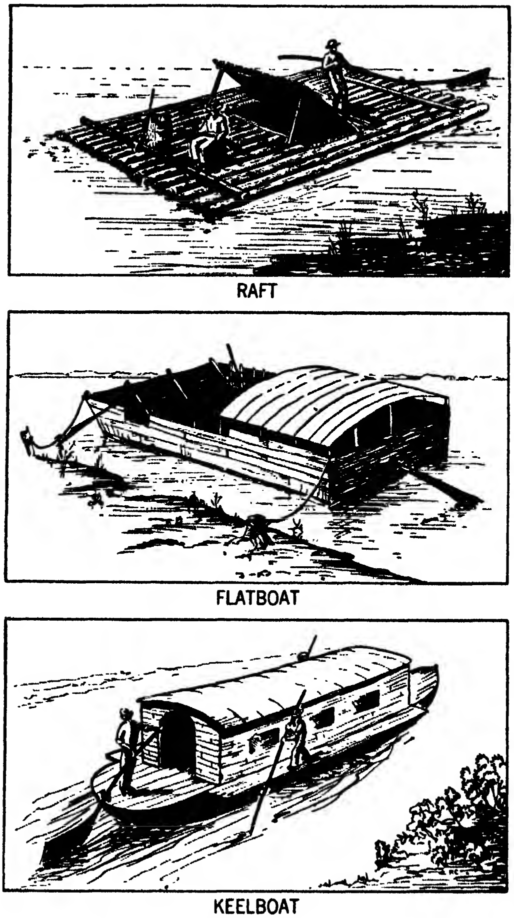

Fig. 3. Early means of transportation on the rivers of the United States. (From "A History of Navigation on the Tennessee River," *House Document* 254, 75th Congress, 1st Session, pp. 18–19.)

returned, for its boiler and engine were not powerful enough to cope with the strong currents of the Mississippi and Ohio. It was used for many years in the trade on the quiet waters between Natchez and New Orleans. Effective steamboat navigation on the Mississippi and its larger tributaries dates from about 1815–1820. The first river steamboats had hulls like the *Clermont* on the Hudson. In time the designers of river steamers found that the hull of their vessels must be patterned after the flatboat—long and broad, thus enabling a shallow draft. In reality the river steamers were flatboats with engines added. They sailed on not in the water. Someone jokingly declared that they could sail in a heavy dew. As time went on the engines and boilers of the steamboats were improved and the speed increased. In 1815 the *Enterprise* steamed from New Orleans to Louisville in 25 days and 2 hours. In 1828 the *Tecumseh* ran the same distance in 8 days and 4 hours, and in 1852 the *Eclipse,* in 4 days and 18 hours. The fastest time ever made—even to date—on the Mississippi was by the *Robert E. Lee* in 1870. This steamer made the 1200 miles between New Orleans and St. Louis in 3 days, 18 hours, and 14 minutes.

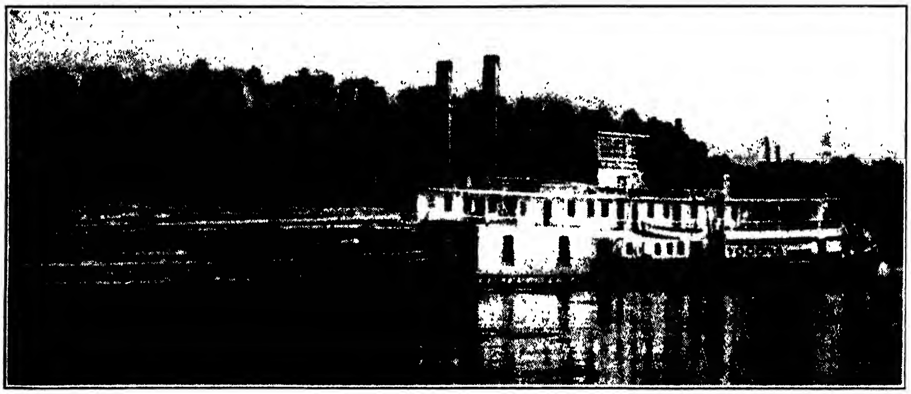

Fig. 4. A towboat on the Mississippi pushing a line of barges loaded with logs. (Fenno Jacobs from Three Lions.)

Most of the river steamers on the interior rivers between 1840 and 1870 were excellent passenger and packet boats, large, spacious, grand, veritable floating palaces (Fig. 4). The keelboat, as previously stated, took from 70 to 90 days to cover the distance that river passenger and packet boats did in 5 to 9 days. No wonder, then, that the steamboat in its maturity was treated with respect, for to the people of that time it did actually "annihilate" space and greatly reduced the costs of transportation. Besides, it was the only comfortable and speedy means of travel for long distances. It served, except in low-water seasons, a large part of the Mississippi basin within 50 or so miles of the navigable rivers. Ice gave no trouble south of the Ohio and very little on that river. The steamboat hastened the settlement of the basin. It carried settlers westward and afterward kept them in touch with friends, relatives, and markets that they had left behind. The increasing population in turn called for more steamboats.

In 1820 there were 72 registered steamers on the Mississippi, by 1842 the number had reached 400, and five years later there were 1200. It was estimated that in 1840 some 40,000 men were employed in river transportation—some of course ran the flatboats —and that more than 7,000,000 people were dependent on the rivers for transportation.

The steamboat brought many economic advantages to the people served. The Mississippi basin for the first time was brought into connection with national and international channels of trade. The producers received more for their products, and consumers paid less for their merchandise. There was a rapid increase in wealth. Products that heretofore had been considered worthless now came to have economic value. The merchants were benefited. Their money turnover was more rapid than before and they were not obliged to carry so large a stock as formerly and thus less capital was tied up in goods. Formerly the replacement of stock was a matter of six or eight months; after the steamboat came, only a month or so. That there ever could be greater efficiency in transportation, greater speed, and greater luxury in travel was undreamed of in the 1840's.

The Decline of the Steamboat and Riverway Transportation

By 1850 a new form of transportation began to dispute the supremacy of the steamboat. Railways using steam locomotives were first used in the United States about 1830. At first railroads were not considered competitors of steamboats. Many of them were laid out to supplement steamboat transportation, to fill in the gap here and there between rivers and lakes and tidal waters. In Michigan, for example, the earliest railways projected were to extend from the head of navigation of rivers flowing eastward into Detroit River or Lake Erie and the head of navigation of those flowing into Lake Michigan. The Baltimore and Ohio was projected to connect the Ohio River with the Patapsco at Baltimore.

In the late 1830's railways became a subject of such importance that many state governments and private corporations projected lines to connect navigable rivers or to extend from seaports to navigable rivers in the interior. Railway planning and building were active in New York, Pennsylvania, Maryland, South Carolina, Illinois, and elsewhere. But the panic of 1837, caused partly by the boom in railway construction, checked railway expansion in many states and stopped it entirely in others. It was not until the 1850's that railway building was resumed. At first all the lines were short and in few instances competed with steamboats. When consolidation and the building up of through lines took place and rivers were paralleled as the extension continued, the struggle for supremacy between steamboats and railways became active. Not always did the railroads fight honorably. They often cut freight rates to starve out the boat lines. The Interstate Commerce Commission, empowered to supervise railway rates and finances, was the public's reaction to such unfair activities. The practice of lowering rates on lines competing with waterways and advancing them on others became so common that the public in general today accuses the railways of such unfair methods even where investigations show that they no longer exist. The railways frequently purchased large urban tracts of land with river frontage that they did not and could not use.

Undoubtedly the greatest factor, however, in the decline of river transportation from the 1860's to recent decades was the changing conception on the part of the public of what constitutes efficient transportation. Standards of transportation were advanced. The railways were able to improve their service and meet the more exacting demands of the public. The river craft did not. The old generalized passenger-packet boat had reached its highest stage of development in speed, carrying capacity, efficiency in loading and unloading, and operation. A spirit of conservatism seemed to have become ingrained in the managerial personnel. It had lost the ability of adaptation. The river steamer of 1920 differed but little from that of 1840. But many improvements were made in the transportation equipment of the railways during the period. New personnel with new ideas was needed on the riverways.

Many adverse natural conditions existed on the waterways of the United States, particularly on the Mississippi and its tributaries, which caused a decline in river transportation, and practically none of these affected the railroad. Among these handicaps were:

1. Falls, rapids, and snags in the river.
2. Swift currents.
3. Fluctuating volume and seasonal variations in depth.
4. Ice in northern rivers.
5. Meandering courses.
6. Wrong general direction.
7. Relatively small tributary area.
8. Difficulty of expanding branch lines or feeder lines.

In addition to these natural handicaps, the rivers also suffered in competition with the railroads because:

1. The flow of commodities was variable. The steamboat for the most part served agricultural regions whose marketable products were highly seasonal. In addition, on the Mississippi, there was very limited return, or upstream, cargo.

2. At best river steamers were slow in comparison to railroads.

3. Terminal facilities were usually inadequate.

These adverse conditions and many others brought about the near extinction of the old-time passenger-packet steamboat on our rivers. Only a few are now engaged in the transportation of freight. Many river cities have one or more that are in the excursion business. Though the grandeur of these old steamers may attract excursions they are wholly unfit to function in modern transportation.

Again these adverse conditions have had to be recognized and avoided or eliminated in the new era in river transportation that is now upon us, before river transportation can hope for success. Not all people who know the riverways and their shortcomings are certain that they can stage a comeback. The railways which were so successful in the struggle of the nineteenth century are still with us, and moreover are improved. Auto-trucks and good roads, which in certain types of traffic are more serviceable, are offering keen competition to both railroads and waterways, and the freight-carrying airplane is surpassing all of them for high-value, small-bulk commodities, because of its greater speed and its ability to go in any direction.

TABLE 1

REASONS WHY NASHVILLE SHIPPERS DID NOT USE THE CUMBERLAND RIVER

Reason Given	*Per Cent*
Speed and convenience of truck and railroad	43
Requests of customers for shipment by truck or railroad	16
Reliability of truck and rail service	14
Slowness and irregularity of river service	13
Trucks saved drayage and storage	6
Other reasons	8

In 1928 a survey was made at Nashville, Tennessee, to determine why shippers did not use the Cumberland River. Many business men were interviewed, with results as shown in Table 1. A similar survey at

Memphis brought practically the same replies.

The use of the other navigable rivers of the United States was similar to the story just sketched. The Cumberland had its first steamboat in 1818. A steamboat reached Arkansas Post on the Arkansas in 1820. A steamer on the James River that ran between Richmond and Norfolk was described in 1818 as being "a floating hotel, fitted up with much taste and neatness, with accommodations for both board and lodging." Steamboats on the James, Potomac, and other Virginia rivers "were crowded with passengers." The Roanoke, Cape Fear, Savannah, Alabama, and other rivers in the south were the main arteries of commerce. The Savannah about 1835 had 20 steamboats of large size and 50 steam towboats with scores of barges. The river towns and nearby farming sections of most of the tributaries of the Ohio were served by steamboats. The Missouri at times was navigated as far as Fort Benton. Sioux City, Omaha, and Kansas City had more regular service. On the Pacific slope the Columbia, Snake, and Sacramento were used actively after the frontier reached the far west, two decades or more after the beginning of the steamboat era on the Mississippi.

Riverway transportation on the Mississippi was at its highest in 1859, just before the hostilities between the north and the south severed commercial relations and the trade of the upper Mississippi basin turned eastward.

Use of the Great Lakes

The Great Lakes have never experienced the decline that characterized the history of navigation on the rivers. Railways for the most part tend to increase lake traffic. They act as feeders from the farming regions to the west of the lakes and connect the lakes with the Atlantic. Even if the cost of navigation improvements are considered in determining "real" rates, railways can hardly compete with the large lake vessels. The great size and specialized character of the carriers, their speed and lack of interruption en route, and the numerous labor-saving devices used in loading and unloading at the lake terminals make for efficiency in modern transportation equivalent or superior to that of ocean transportation (Fig. 5).

Steam navigation on the lakes began in 1818 when the steamer *Walk-in-the-Water* made its first trip between Buffalo and Detroit. As with the steamboats on interior rivers to the south, this ship and the scores of craft that followed stimulated the western movement. Travel from Buffalo to Detroit was reduced from five, sometimes 10 days, to 48 hours, and the journey was accomplished with much greater comfort. By 1826 there were six steamers on Lake Erie. As on the rivers, great improvements were made as time went on in size, speed, and efficiency, and improvements are still being made. From Lake Erie steamers entered the commerce of Lake Huron and Lake Michigan, though the sailing vessels long continued to carry a large part of the commodities of these lakes where the services of tugs were scarcely needed. Sailing vessels found some difficulty in navigating the St. Clair and Detroit rivers unassisted, but a large percentage did use these waters. In 1852 there were 80 steamboats, 50 barges, and 270 schooners on the Great Lakes. The completion of the "Soo" Canal in 1855 extended the active traffic lines into Lake Superior, and soon iron ore became one of the important articles of lake commerce.

The increase in the size of lake vessels has kept pace with the increase in the depth of navigable channels. The first waterway improvements were made in the harbor at Erie, Pennsylvania, in 1825. By 1851 nearly $3,000,000 had been spent on harbor and river channel improvements. For many decades improvements were desultory as to time and location. A 20-foot channel project was adopted by Congress in July, 1892. In 1905 Congress authorized a preliminary examination and survey with a view to enlarging the channel to 22 or 25 feet. The Board of Engineers suggested after careful consideration that the enlargement be deferred. Subsequently, however, appropriations have been made to deepen channels to 25 or 26 feet. This work is now being carried on. In certain channels where the currents are strong, and especially where fogs are frequent, as in the St. Marys River, two channels are provided, one for upbound and one for downbound vessels.

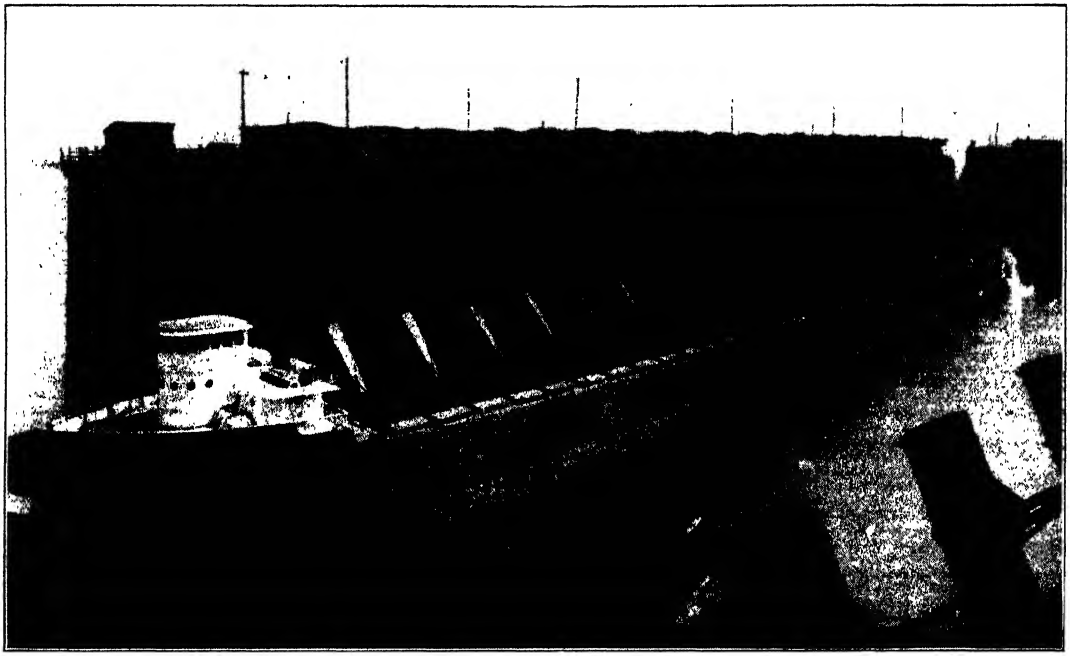

FIG. 5. A giant freighter ready for gravity loading at the great iron-ore docks at Duluth, Minnesota. In three hours this freighter can be loaded with 14,000 tons of ore and begin immediately its trip down the lakes to the ore-receiving ports. (Barkley Schroeder, Duluth Chamber of Commerce.)

Today the greatest physical obstacle to navigation on the Great Lakes is ice. The season of navigation varies from 225 to 240 days. For about a third of the time each year all movement must cease except for the ice breakers that operate across Lake Michigan, the Strait of Mackinac, and Lake Erie. The long period of inactivity is not so serious to the continued success of water transportation as such a period would be on the Lower Mississippi, for the great bulk of the commodities carried are iron ore, grain, and lumber. The grain can be transported to eastern markets in the fall before the navigation season closes.

iron ore, coal, and lumber can be stored readily. The importance of the Great Lakes in the domestic and to some degree in our foreign commerce lies, as previously stated, in the large dimensions of the channels provided by the federal government, the large size of the lake carriers, the efficiency of the loading and unloading devices, and the location of the Lakes between great mineral deposits, forests (now about depleted), and large grain-producing areas on the one hand and a densely settled industrial region on the other. In the industrial region are produced large quantities of coal. Its blast furnaces consume most of the iron ore produced in our country, and its demands for the grain of the west are great. Moreover, the industrial region extends to the Atlantic seaboard and thus has contacts with the world traffic routes.

In no other region of the world is man utilizing and thus conserving navigation resources as in the Great Lakes region.

RECENT DEVELOPMENTS IN RIVER TRANSPORTATION

Transportation on the Mississippi reached its lowest point, measured by tonnage moved, some time between 1900 and 1920. There had been roughly a half-century or more of rise followed by a period of decline in riverway transportation.

Our harbors, the deeper coastal waters, and the Great Lakes show a fairly steady rise in traffic movement. No matter what improvements were made in land transportation, they "carried on." There has been a gradual and profound advance in the capacity and efficiency of the carriers and freight and passenger terminals. The growth in importance of railways aided overseas commerce and also, to a certain degree, coastwise and lake commerce. Deep-water transportation like that of our Great Lakes or coastal waters has little to fear from railway competition.

The Federal Barge Line

The new era in river transportation was ushered in about 1918 when the federal government took over the railways and the director general of transportation appointed a committee to study the possibilities of reviving or increasing commerce on the rivers, canals, and deep waterways. The committee in 1918 recommended that a fleet of modern river carriers be created on the lower Mississippi River and another on the Warrior-Tombigbee-Mobile riverway. Congress that year authorized the War Department to proceed with the development, and thus the Mississippi-Warrior River Barge Line was created. Large appropriations were made to develop efficient water carriers, and the work in channel improvement was speeded up. By 1920 the beginning of a fleet of modern tugboats and efficient barges was in operation on the Mississippi and on the Warrior-Tombigbee riverways. The Inland and Coastwise Waterways Service, under the direct control of the War Department, was created to operate the steadily increasing fleet.

This venture was far from successful. The federal government lost on the average $1,000,000 a year between 1920 and 1924. Congress was informed by Major General Ashburn that in his opinion "this loss could be stopped under certain conditions and a net income accrue within five years of corporate activity, failing which it would become the duty of the Secretary of War to inform Congress that the whole project of creating navigable streams to afford the people of the United States cheaper transportation was a colossal failure."[8] To give the experiment further trial Congress in 1924 created the Inland Waterways Corporation, a quasi-independent organization, with Ashburn as director. The federal government purchased capital stock in the corporation from time to time and made donations or special appropriations.

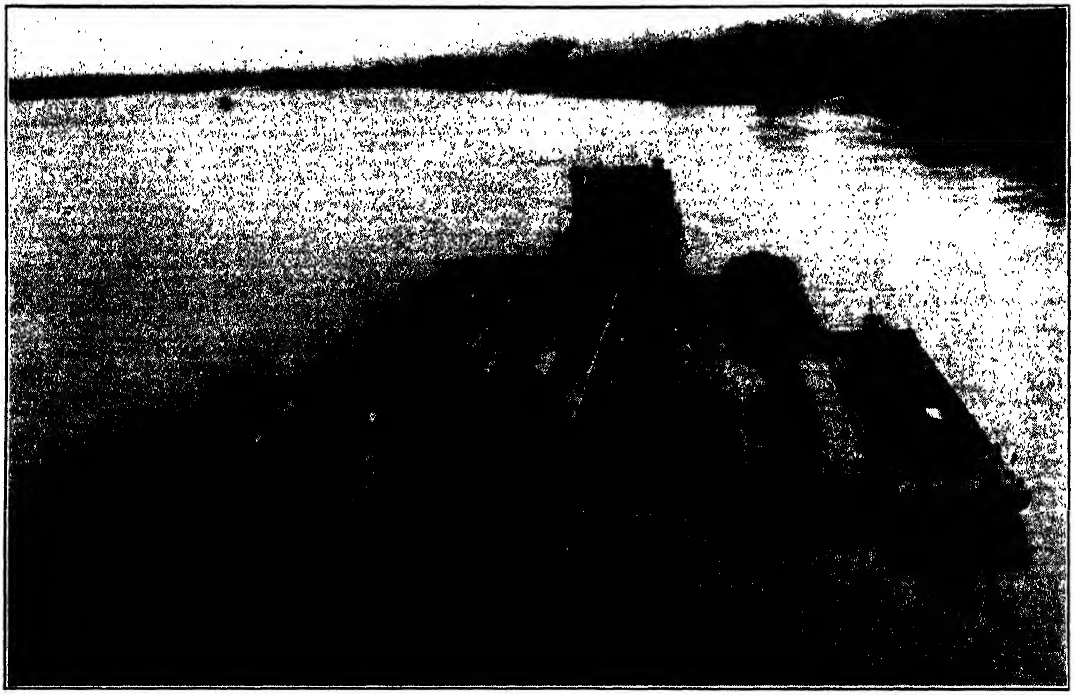

Fig. 6. View showing a tow of eleven oil barges moving downstream from Vicksburg, which can be seen in the distance. (Mississippi River Commission.)

The major function of the Inland Waterways Corporation is, as the articles of its creation state, to demonstrate to private companies the feasibility of inland water transportation; when success has been demonstrated and private corporations show a willingness to utilize the waterways, the federal government is to retire from the field. The IWC's engineers have exhibited much enterprise and intelligence in developing efficient carriers. The freight barges are of steel. They vary in size, the large number on the lower Mississippi being 230 feet long, 47 feet wide, and 11 feet deep, and drawing three to six feet of water when fully loaded. They have a capacity of 2000 tons of freight each. Some of the larger have a capacity of 3000 cargo tons, the smaller 400 to 1000. They have watertight compartments that make them as unsinkable as ocean vessels. The barges may be loaded or unloaded either through top hatches or side doors. The towboats are among the most powerful ever constructed on inland rivers. The largest are of steel, twin-screw tunnel type, powered by Diesel engines with an indicated horsepower of 1800. The corporation also owns several

[8] *Report of Inland Waterways Corporation*, 1928, p. 1.

car floats, a few oil tankers, some derricks, and terminal and landing barges (Fig. 6). The numbers in the various types are increasing. No money has been spared to provide the most efficient equipment. The federal government through the IWC now maintains federal barge lines on the lower Mississippi (New Orleans to St. Louis), the Warrior-Tombigbee (New Orleans to Port Birmingham), the Illinois River (St. Louis to Chicago), the upper Mississippi (St. Louis to Minneapolis), and the Missouri River (St. Louis to Kansas City). Congress has empowered the IWC to extend services to any waterway that, it is thought, can bring favorable returns. The equipment on the upper Mississippi, the Missouri, and the Warrior River divisions is smaller than that used on the lower Mississippi. (See map, Fig. 1.)

Efficient terminal facilities have been provided at most large river ports. Loans were made by the IWC to many cities to provide the necessary terminal equipment.

In 1929 the IWC achieved what it had been desiring for some time—the co-ordination of river and rail transportation. The Interstate Commerce Commission ordered the railways connecting with the barge lines "to establish a sweeping system of barge-rail and rail-barge-rail rates and routes" for shippers who desired to combine water and rail facilities.

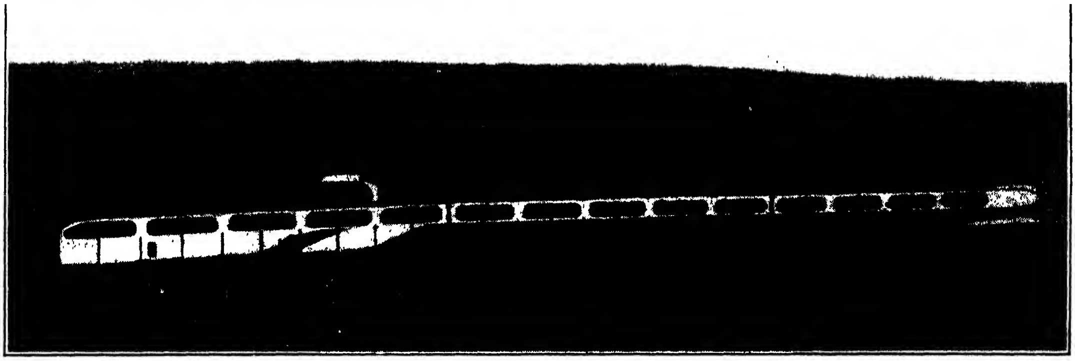

FIG. 7. A modern type of craft built for river commerce. (St. Louis Shipbuilding and Steel Co.)

A Specialized Commercial Barge Line

For some time a growing traffic on the inland waterways of the nation consisted of the handling of thousands of automobiles between the factories in the Great Lakes area and the distributing centers of the south and southwest. Experiments were made with many types of craft, but the great demands of World War II for the transportation of jeeps, ambulances, reconnaissance cars, and trucks led to the construction of perhaps the most modern and most efficient river carrier that ever navigated inland waterways. This type of craft known as the "Commercial Clipper" (Fig. 7) is being operated on the Illinois, Ohio, Tennessee, and Mississippi rivers, as well as on the Gulf Intracoastal Canal, by the Commercial Barge Lines, Inc., of St. Louis. Because of its efficiency, it has largely revolutionized the specialized shipping of motor vehicles.

Waterway Improvements

Since the middle of the last century, but chiefly since about 1875, desultory improvements have been made in various rivers of our country. Sometimes improvements in one part of a river bore no relation to those in another. The appropriations secured depended largely on the initiative and activity of the congressman, or congressmen, in whose district or districts the waterways lay.

As a general statement it may be said that even moderate federal appropriations were not asked for until a decade or two after the decline in river transportation set in. This decline supplied the argument for seeking public money. The lower the traffic figures sank on the riverways the more insistent became the demands. If a few locks and a three-foot channel did not bring the desired results in increasing traffic, then more locks and a five-foot channel were demanded. At the same time the railways were extending their lines and improving their service. The good roads movement got under way in the last two decades or more, and the auto truck has entered as a serious competitor with the railway.

One may make the generalization that the greater the funds spent on most of our rivers the smaller the movement of commodities on them. This state of affairs is due largely to the public's turning away from waterways to railways and trucks, which give more efficient and speedier transportation.

Existing River Projects

Only a few of our scores of rivers now being improved will be considered here. Nearly every river that has been navigated in recent decades, if by nothing more than motorboats, is included in the list of rivers receiving federal funds. The waterways map (Fig. 1) shows most of the larger existing projects.

The works and improvements necessary to provide navigable riverway channels vary, of course, with the nature of the channel. In previous projects when the appropriations were small improvements consisted largely in narrowing the channel by dams of loose rock extending from the bank or shallow water to the edge of the channel, in removing rocks and snags, and in constructing devices to protect the caving of the banks. When large appropriations became available more permanent works were possible. Dredging and the construction of substantial dams and locks are now the order of the day. These provide slack-water navigation. The gradient of the river and the number of rock ledges determine the number of dams and locks required. On the Ohio and the upper Mississippi immense sums have been spent, or are being spent.

THE ADVISABILITY OF RIVER AND HARBOR IMPROVEMENTS

The question of the advisability of waterways involves a consideration of (1) the total cost of improvements, (2) the financial returns, and (3) a comparison of the relative costs of providing water and rail transportation, where such comparison is possible. Statistics are not available to present a complete picture of the domestic and foreign commerce of our country that moves by water. Although in normal times the total water-borne commerce of the United States is valued at more than $17,000,000,000.

There seems to be little question about the advisability of the improvements that the federal government has made in most of the ocean and lake harbors. The expenditure of large sums on ocean harbors and channels to fit them to function for scores of years is certainly good business, though there are, no doubt, many ports at which the expenditures can hardly be justified. One must agree also that the amount used on the harbors and the channels connecting the Great Lakes is money well spent. There are many people in our country, however, who question the advisability of spending great sums of money on the Mississippi River system for construction and maintenance, to move freight that has a relatively small value. They declare also that the improvements of the Missouri between Kansas City and the mouth can hardly be considered feasible.

Costs of Transportation, Riverway versus Railway

Riverway advocates without exception claim that the riverways give shippers far lower rates than the railways. That the shipper is given a lower rate by river carriers than by the railway is a fact, but river carrier rates are not based on the same complex of items as railway rates. Railways must purchase the right-of-way, construct roadbeds and tracks, and provide depots and terminals. They must provide traffic equipment, a large part of which is idle many weeks each year because of the seasonal variation in the flow of traffic; pay immense sums in taxes on its tangible properties; and hire a veritable army of employees to keep the right-of-way in perfect condition, to man the traction equipment, and to keep the proper records demanded by efficient operation and by the Interstate Commerce Commission. They also pay heavy attorneys' fees to fight the numerous suits brought by persons who look upon the railways as easy picking. All these items are reflected in the rates the public is called upon to pay.

In contrast, waterway rates are based only on the cost of the operation of the powerboats and barges. With privately owned common carriers the shipper pays for the craft. The way is provided and maintained, the locks (if any) are operated, and the channel lighted to make navigation safe and reduce insurance rates, all by the federal government at no cost to the carrier. Cities usually furnish terminals. Only the traffic equipment is taxed. The very expensive "way" pays no taxes. If the shipper does not recompense the federal government the general public must. The taxpayers of the United States pay the entire cost of transportation, directly or indirectly, whether by rail or water or air. They have the right to demand the cheapest form of transportation available, consistent with adequate service. If the common carriers on the Ohio, for example, were operated on the same basis as the railways, that is, if they were called upon to meet these hidden costs and amortize the capital investment through a 50-year period, their actual rate would thus be considerably higher than that of the railroads. In fact, the freight moved on the Ohio River costs the public annually from $8,000,000 to $10,000,000 more than if the railways paralleling the river handled it. The commodities carried on the Ohio, by class and percentage, are coal and coke about 44 per cent; gravel and stone 43 per cent; logs, lumber, oil, gasoline, metallic ores, metals, and manufactures 11 per cent; and package freight 2 per cent.

If the capital investment of the federal government in the Ohio riverway had been spent in the building of roads, more people might be benefited directly. This amount would build four parallel, two-lane roads from Pittsburgh to Cairo, and if we add the money spent to improve navigation on the Mississippi from Cairo to New Orleans the four roads could be extended on to New Orleans. They would pass through every one of the major cities on the Ohio and the Mississippi touched by riverway craft.

This sum would construct two parallel, double-track railways, completely equipped, between Pittsburgh and New Orleans and in addition build a similar double-track line from Cairo to Chicago by way of St. Louis. The total distance that freight would have to travel by railway would be only about two-thirds to one-half of that by river. A round trip by train or truck, between Pittsburgh and New Orleans, could be made in less than four days. It would take the modern tug and barges 30 days with no delays or stops. Four days at least, however, would have to be added to pass the 100 locks in the up and down voyages on the Ohio. Measured on the basis of time the hypothetical railways mentioned above, as movers of freight, are equivalent to sixteen "tracks" on the Ohio and Mississippi.

In this discussion of the relative costs of riverways, roads, and railroads, no consideration has been given to the possible allocation of some of the costs of navigation dams to flood control and power development. The reason for not considering these other uses is that, so far, federal appropriations on the Ohio, Illinois, upper Mississippi, and the Missouri have been made specifically for navigation.

The Federal Barge Line

In a previous section in this chapter the activity of the federal government in advancing riverway transportation has been discussed. Between 1920 and 1924 about $1,000,000 a year were sunk, as Senator Warren once remarked, into "the deep black mud of the Mississippi." Even Congress developed a resentment to appropriating further money, and so in 1924 the Inland Waterways Corporation came into being. For some years it operated at a loss. In 1935 its net operating profit was $651,-802.83. At the end of twelve years there was a net profit of $781,238.29.[4]

In 1927 the federal investment in the Inland Waterways Corporation, which paid no interest on the loans from the federal government, was $24,000,000. It paid no taxes except indirectly in the rents to municipalities for the use of their terminals; it paid no corporation taxes, no insurance, and no office rent.[5] Private operators would be called upon to meet these costs. The "way" over which the Federal Barge Lines boats travel is also a federal contribution. The railways that compete, however, have no such advantages.

Apparently the Federal Barge Line has not yet demonstrated that private corporations can successfully operate common carriers on the Mississippi riverway.

The Intracoastal Waterway or Canal

The location and depth of the various parts of this waterway are shown on Fig. 1. Cape Cod Canal, Long Island Sound, and Chesapeake Bay belong, in our classification, to the deeper intracoastal waters. It is on these that most of the commerce of the Intracoastal Waterway is carried. These deeper sections, without a doubt, as previously stated, represent proper investments. The Chesapeake-Delaware Canal carries a fair commerce, mainly between Baltimore and Philadelphia. Its cost is far less than

[4] *Annual Report of Inland Waterways Corporation,* 1935, p. 13. The net income for the year ending Dec. 31, 1937, was $253,935.29. (Report for 1937, p. 1.)

[5] *Annual Report of the Inland Waterways Corporation,* 1933, pp. 16–18.

the value of the commodities moved annually. The channel from Norfolk to Beaufort, North Carolina, has much less traffic. Commerce on the shallower channels to the south is largely local. Only a small amount of through-freight could be expected, for the larger ports are served by large, deep-draft coastwise vessels and are also connected with three very efficient railways on the Coastal Plain and the Piedmont. The chief beneficiaries of the shallow Atlantic Intracoastal Waterway as a "through-route" are owners of private yachts who migrate between northern ports and Florida resorts. Parts of the Gulf Intracoastal Waterway in Louisiana and Texas carry a large commerce. Oil and oil products bulk largest in quantity and value.

FIG. 8. A lock along the Chesapeake and Ohio canal which was never completed. (National Park Service.)

CANALS OF THE UNITED STATES

About a century ago the United States was in a canal-building boom. The Middlesex Canal in Massachusetts was opened for service in 1808, the Erie in 1825, the Pennsylvania about 1840, and the Chesapeake and Ohio about 1840 (Fig. 8). The favorite pastime of many dreamers in the early nineteenth century was to connect rivers with canals, no matter where, over plateaus or mountains, without a thought of the topographic difficulties, the supply of water at the crest of the watersheds, cost of operation, and amount of traffic that would tend to flow to the artificial waterway.

One enthusiast about 1820 wrote, "Astonishing as it may seem, 75 miles af canal are all that is necessary to give water communication between Market Street bridge (Philadelphia) and the Pacific Ocean at the mouth of the Columbia." By the time the railway mesh had become quite thoroughly spread over American landscapes east of the Mississippi, many states and private corporations had constructed about 4000 miles of canals. Figure 9 shows the location of the more important canals about 1850. New York and Pennsylvania, Maryland, and Virginia, each projected canals in the latter part of the eighteenth traffic route. Pennsylvania had to use portage railways to connect east-flowing and west-flowing canalized rivers. Neither Maryland nor Virginia got its canal over

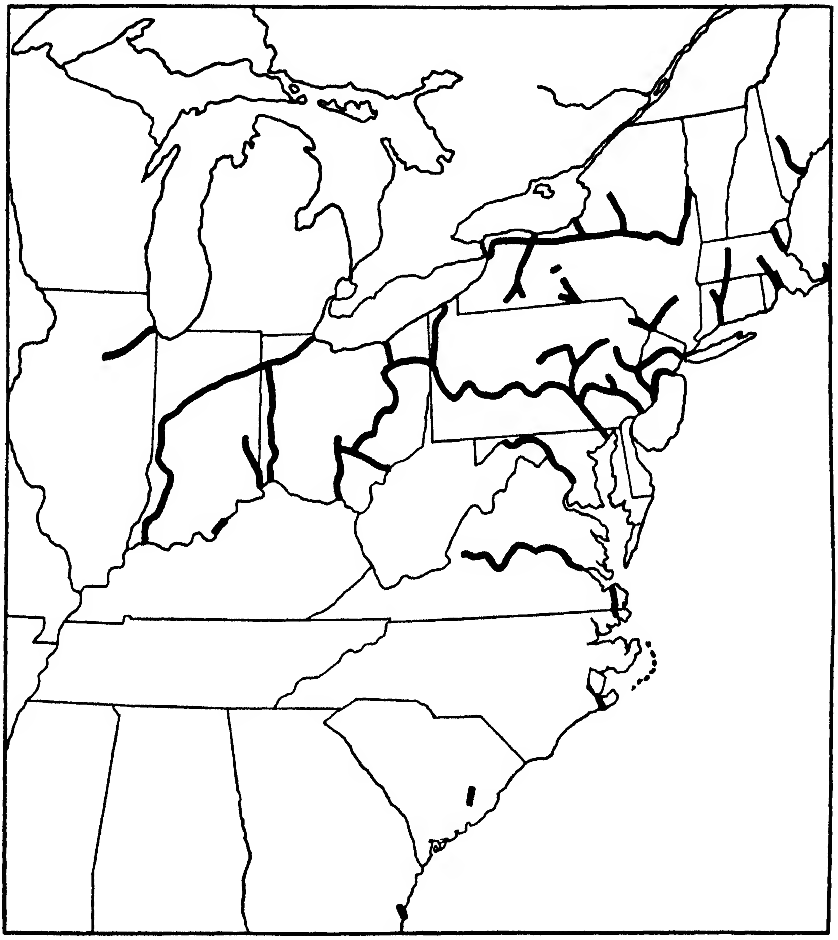

FIG. 9. Barge canals about 1840–1850. (Data from R. S. Tanner, *Canals and Railways of the United States*, 1940, and Coulton's *Atlas of the World*, Vol. 1, 1856.)

century from the Atlantic seaboard cities westward to the Great Lakes and toward the Ohio. New York's canal is the only one that has survived to our day, and that only after two expensive enlargements. Topographic conditions were more favorable than in most states, and the New York canal occupied a natural and strategic the bold Allegheny front and the Appalachian Plateau. The Chesapeake and Ohio canal in Maryland went no farther than Cumberland, and the James River canal only a few miles west of Buchanan, both towns being in the Great Valley.

The Chesapeake and Ohio canal was being used but little in 1890 to float coal to tidewater. The James River canal went into disuse nearly a century ago; and the Pennsylvania canal was no longer used after the early 1860's. Since the 1870's, 4000 miles of canals that probably cost upward of $200,000,000 have been abandoned.

In the early part of this century the State of New York greatly enlarged the Erie canal [6] and some of its branches at a cost of more than $120,000,000.[7] Being toll free, it was estimated that the enlargement would enable the canal to transport 20,000,000 tons of freight a year. The 1936 volume of 5,014,206 tons declined steadily, however, throughout the boom period of World War II to a low of 2,908,082 tons [8] in 1945, showing that, in spite of many supposed benefits and much publicity, the New York shippers still prefer to use railroads and motor trucks to haul their commodities.

The only other barge canal (except canals as part of riverways and the intracoastal waterways) now in operation is the 7-foot Hennepin canal in Illinois that connects the Illinois River with the Mississippi. Its construction was authorized by Congress in 1890. The annual cost of operation is much greater than the total value of the commodities carried on the canal. This means that the public of the United States is spending a large sum each year to move a very limited number of commodities for the shippers along the waterway.

Ship canals, like the one in St. Marys River, because they accommodate large carriers, are in an entirely different category from the almost "extinct" barge canals. The "Soo" canals carry more tonnage annually than either the Suez or the Panama canal.

There is some doubt about the feasibility of the proposed trans-Florida canal (Fig. 1) whose construction was begun on September 19, 1935. Some question the saving of time that is claimed—two and a half days between the Atlantic and the Gulf. It should be remembered that the speed of vessels will need to be reduced to 6 or 8 miles an hour and insurance charges will be increased. Numerous expensive bridges must be provided ready for servicing vessels day and night. The freedom of movement on land will be greatly curtailed and the watertable lowered in the section of the state crossed. Florida is divided in opinion as to the feasibility of the canal. Congress early in 1936 refused to vote money to continue the project. However, the great loss of shipping, particularly of tankers with their valuable cargoes of petroleum, during World War II, due to the fact that vessels were forced to go around Florida and expose themselves to German submarine attacks, would more than have paid for the construction of the trans-Florida canal.

A century or so ago men thought of wheeled vehicles as supplementary to the river steamer. We are living in quite a different age. River and canal traffic is slow. Man and goods now move by modern means of land transportation as far in an hour as they did a century ago in a long day. The river was dominant when there was no other form of "rapid transit." It was dominant when speed and efficiency were measured by the oxcart and the Conestoga wagon. It now is economically possible only where immense quantities of heavy freight with an all-year movement are available and where the cost of channel improvement is low. The railway brought

[6] The title now is the New York State Barge Canal—Erie Division.

[7] Capital cost to the state as of June 30, 1933, was $173,500,000.

[8] *Annual Report of the Chief of Engineers, U. S. Army*, 1946, p. 283.

about the decline of river transportation because it was more efficient. Today on short hauls, and on long hauls under certain conditions, the truck and the bus are more efficient than the railways, and a large part of our population is turning to them. The river steamboat now has to compete with modern means of transportation that are more efficient than even the new type of river carrier.

Speed is a dominant condition of our age. The speed of locomotives has been materially increased in recent years in the face of competition offered by fast-moving automobiles, auto buses, auto trucks, and airplanes. The rate of movement of freight has been increased. Fast freight express trains that handle package freight have been put on many railways leading out of the great distributing centers. Inexpensive adjustments in design of power units and the widening of the tracks will enable railways greatly to increase their speed. Streamlining is an aid. Since water is 800 times as dense as air, it is quite evident that increase of speed of freight carriers on the riverway can be obtained only at a tremendous increase in the consumption of power.

From the few facts presented, it seems that the riverways and barge canals are definitely outmoded.

THE CANADIAN-AMERICAN ST. LAWRENCE SEAWAY[9]

Although the five Great Lakes constitute the finest inland waterway of the world, they are handicapped by being landlocked. The Niagara escarpment separates the four upper lakes from Lake Ontario and a series of rapids separates that body of water from the mouth of the St. Lawrence. The possibility of a deep-water route from the Great Lakes to the sea has attracted attention since almost the beginning of settlement in the New World. When Jacques Cartier reached the rapids above the site of Montreal in 1535 in his futile attempt to find a route to China, he appropriately named them Lachine Rapids. From his day until recent times considerable thought was given to the project, but nothing was done until the Canadian Government began the construction of a 14-foot canal around the rapids of the upper St. Lawrence. This project was completed in 1901 but it was soon considered obsolete since the locks were only 270 feet between gates and the over-all depth of 14 feet proved to be too shallow for most vessels.

The modern St. Lawrence seaway project was inaugurated when the new Welland ship canal was completed by the Canadian Government in 1931. It has a controlling depth of 25 feet, with a 30-foot depth over the sills of the locks. This canal now permits large ships to scale the Niagara escarpment between Lake Ontario and Lake Erie, a vertical distance of 323 feet. The Welland canal was not a local improvement but an integral part of the proposed Great Lakes–St. Lawrence seaway. The entire cost of the canal was borne by the Canadian Government, but with the new treaty Canada will be given credit for this amount in her total expenditures on the St. Lawrence seaway (Table 2).

As might have been expected, considerable opposition has arisen to the seaway by interests who feel that they may be harmed by its completion. One of their chief

[9] Much of the data of this section was taken from *The St. Lawrence Survey* of the United States Department of Commerce, Washington, D. C., 1941, particularly Part VII.

TABLE 2

ESTIMATE OF COST OF ST. LAWRENCE SEAWAY

[Source: Hearings on H.R. 4927, statement by Brig. Gen. Thomas M. Robins, Assistant Chief of Engineers, United States Army, No. 12, p. 966.]

	Canada	*United States*	*Total*
Great Lakes section:			
New lock at Sault Ste. Marie with approach channels	....	$ 8,000,000	$ 8,000,000
Connecting channels	....	66,029,000	66,029,000
Welland canal	$ 133,000,000	....	133,000,000
St. Lawrence River:			
Thousand Island section	772,000	516,000	1,288,000
International Rapids section:			
(*a*) Works solely for navigation	....	48,857,000	48,857,000
(*b*) Works primarily for power	37,950,000	78,550,000	116,500,000
(*c*) Works common to navigation and power	22,414,000	100,210,000	122,624,000
Canadian section:			
St. Francis Lake channel	1,330,000	....	1,330,000
Soulanges reach	25,785,000	....	25,785,000
Lachine reach	55,839,000	....	55,839,000
Total	$277,090,000	$302,162,000	$579,252,000
Expenditures to date	132,672,000	17,105,485	149,777,485
Cost to complete	$144,418,000	$285,056,515	$429,474,515

arguments against the seaway is that it will not justify its costs, but the joint commission of the two governments has pointed out that the trade territory to be served by this seaway contains more than 40,000,000 people, produces $25,000,000,000 worth of manufactured goods each year, and yields over 50 per cent of the agricultural wealth.[10] This seems sufficient to supply the additional tonnage that the seaway could handle. Opposition to the project has come largely from four separate spheres of economic activity: (1) the Great Lakes carriers, (2) the coal-mining industry, (3) existing harbors along the eastern shores of the Great Lakes, and on the Atlantic and Gulf coast, and (4) the railroads. Although opposition from these interests is natural, their claims are somewhat exaggerated.[11]

[10] *The St. Lawrence Survey,* Part VII, p. 21.

[11] *Ibid.,* pp. 35–54.

The St. Lawrence seaway not only contemplates a deep waterway from Duluth to the entrance of the St. Lawrence River near Newfoundland, a distance of 2350 miles, but also, in the several short sections where dams and locks must be constructed, will develop a considerable amount of hydroelectric power which will be of immense value to both nations. The details of the project are clearly shown on the accompanying map (Fig. 10).

World War II emphasized the need of the St. Lawrence seaway as an essential item in the defense of Anglo-America and also the desirability of development of greater hydroelectric power in the region served by the seaway. With these points in mind the President of the United States issued an Executive Order on October 16, 1940, creating the St. Lawrence Advisory Committee. After an exchange of notes between the United States Government and the Ca-

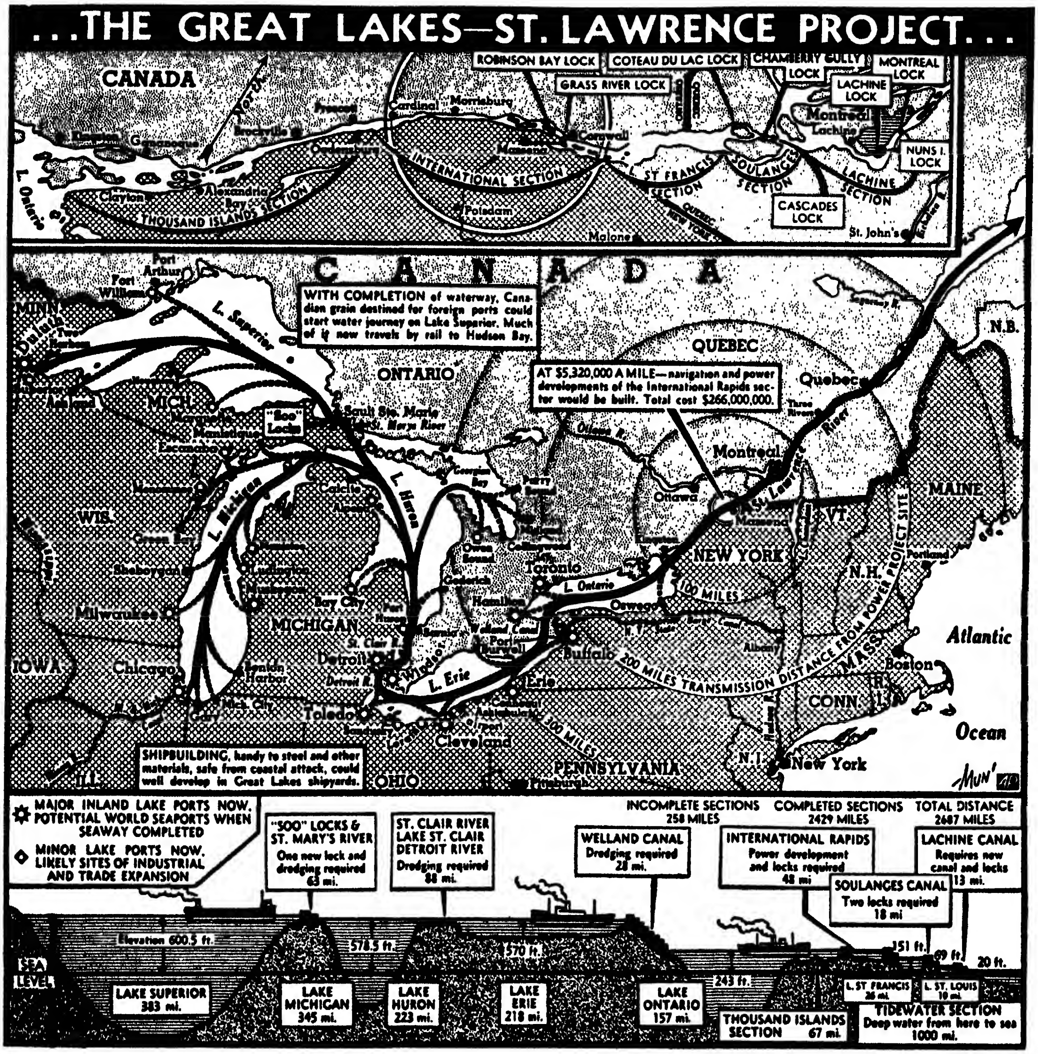

FIG. 10. Map of the Great Lakes–St. Lawrence project. (The St. Lawrence Survey, U. S. Dept. of Commerce.)

nadian Government the following year, the Great Lakes–St. Lawrence agreement was signed by the two nations on March 19, 1941. This international agreement set up the machinery for the completion of the project. However, the war ended before any considerable work was accomplished, and it remains to be seen whether a postwar United States Congress will appropriate sufficient funds to make the seaway a reality.

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   Part II. Shipping Services on the St. Lawrence River.
   Part III. Potential Traffic on the St. Lawrence Seaway.
   Part IV. The Effect of the St. Lawrence Seaway Upon Existing Harbors.
   Part V. The St. Lawrence Seaway and Future Transportation Requirements.
   Part VI. The Economic Effects of the St. Lawrence Power Project.
   Part VII. Summary Report of the St. Lawrence Survey, including the National Defense Aspects of the St. Lawrence Project.
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CHAPTER 15

Floods and Flood Control

INTRODUCTION

THE control and useful development of water in our streams constitutes an important segment of the larger problem of water conservation. In the operation of the hydrologic cycle the return of the water to the sea from which it was originally derived provides an opportunity to use the water beneficially and as far as possible to prevent destructive floods. Rivers come into existence as the result of precipitation falling on the land and have as their ultimate destiny the return of the waters to the sea. Because the lands receive their precipitation at irregular intervals and because the amount varies from place to place the streams resulting from the runoff are markedly irregular in their discharge. In fact, a stream with a uniform flow does not exist.

If all of the precipitation that falls could be absorbed into the earth and then discharged more or less steadily or uniformly most streams could be confined to their channels. But an important proportion of the precipitation that falls never becomes a part of the reservoir of underground waters but flows quickly to the water courses, swelling the streams beyond their constraining banks. The placid stream which between rainstorms is so attractive and useful becomes in times of flood a raging torrent. With its carrying capacity and its competency greatly increased, a river in flood becomes a powerful agent of destruction. The satisfactory solution of the flood problem may be beyond the engineering skill and the economic resources of our people, but partial control may yield results commensurate with the expenditures in effort and money.

The fertile alluvial lands of the Nile, the Tigris-Euphrates, the Hwang Ho, and the Mississippi, the creation of their respective rivers, have been repeatedly inundated. These and other great rivers are, at the same time, the givers and the destroyers of life and property. In the plaintive song, "River Stay 'Way from My Door," is epitomized the feelings of fear and respect of a people for the power of a great river. Recurrent floods are characteristic of small streams as well as of the large, and locally the resulting damage may be great. The flood problem may be said to have its beginning when the excessive waters derived from runoff and from underground sources spread beyond the banks of the stream channel. On occasion, torrential rains may produce flooding of local areas by the runoff from highland areas to the adjacent lowlands, the water not having reached the channels of either the permanent or inter-

By Guy-Harold Smith of The Ohio State University.

mittent streams. Usually such floods due to sheet-wash are of short duration and cause little water damage. The principal damage is done by rill-erosion and sheet-erosion on the slope lands and by burial of the lowland areas under a layer of sediment. It is the rapid runoff of waters resulting from heavy rains that is the chief cause of floods.

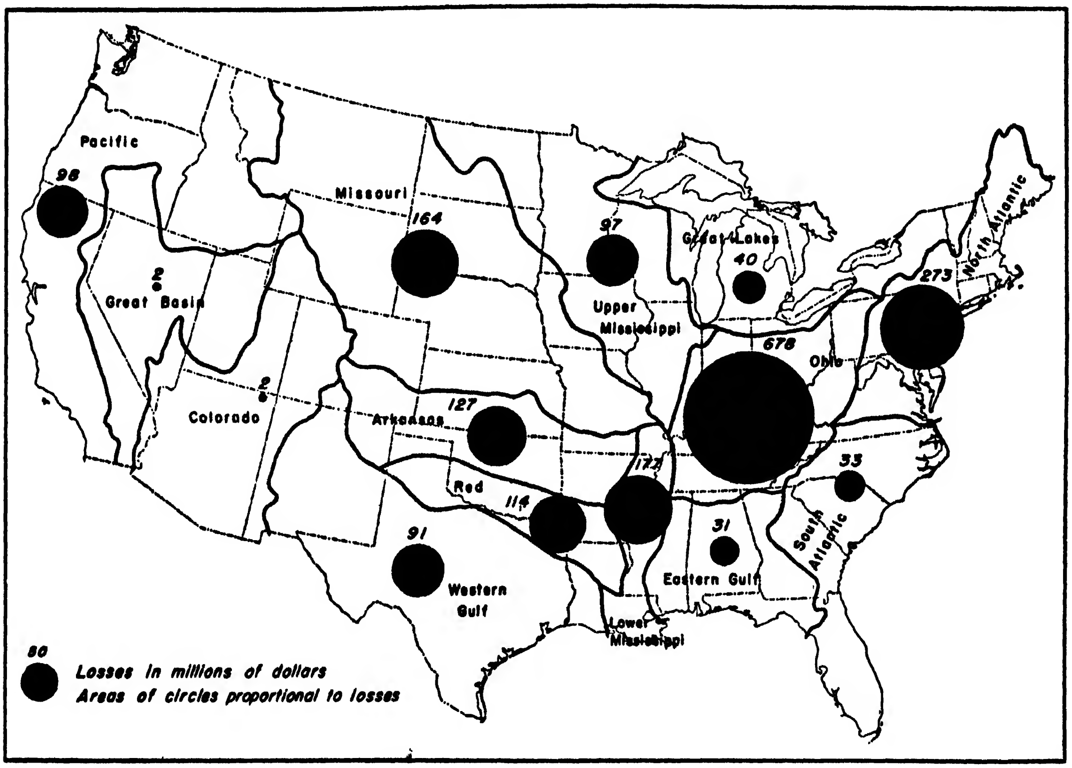

FIG. 1. Distribution of flood losses in the United States over a period of twenty years. (Weather Bureau, U. S. Dept. of Commerce.)

FLOOD DESTRUCTION

It is difficult to determine exactly the extent of flood damage and to compare in a satisfactory manner one great flood with another (Fig. 1). This is due in part to the tendency to overestimate flood damage, particularly at the time of the flood. Another complicating factor is the changing value of the dollar in which the damage is expressed. However, it appears that the floods are becoming more destructive in the United States. In 1913 the damage from floods along the Mississippi and Ohio rivers was computed to be in excess of \$162,000,000. The great flood of 1927 caused a total loss of more than \$284,000,000 within the Mississippi drainage basin. The unprecedented flood of 1937 along the Ohio caused damage estimated at \$417,000,000, not including soil losses. The "duck drownder" flood along the Mississippi and the tributaries in the St. Louis area in the summer of 1947 caused an estimated damage of $160,000,000 to agriculture alone. Within the Missouri basin the average annual loss has been estimated at $2,800,000. The long-continued flooding of the low-

FIG. 2. The inundation of Westminster Flats along the Connecticut River in 1936. Note the large tobacco sheds standing partially submerged by the floodwaters. (New England Electric System. Photo by Fairchild Aerial Surveys, Inc.)

lands of the Columbia during the early summer of 1948 caused an estimated damage in excess of $100,000,000.[1]

Disastrous floods are not confined to the Mississippi and its major tributaries but are characteristic of practically all major streams in the United States. Occasionally flood damage is particularly heavy west of the Cascades, in the Sacramento–San Joaquin basin, and in the Los Angeles area. In 1927 New England suffered from one of the most disastrous floods in her history, and in 1936 heavy rains, falling on frozen ground in northeastern United States, locally caused extensive damage (Fig. 2). The Atlantic slope from New England to Florida is subject to occasional floods which damage riverine property amounting to millions of dollars. Along the coast of Florida flooding also results from the hurricanes which are accompanied by heavy precipitation and high winds. These strong on-shore winds drive the tidal waters inland causing inundation of lowlying areas. In the autumn of 1947 southern Florida ex-

[1] Douglas W. Polivka, Chief, Technical Information Branch, Office of the District Engineer, Portland District. Personal communication.

perienced two hurricanes which caused heavy wind and water damage.

Flood Damage to Transportation Facilities

The predisposition of the people to preempt the rich riverine lands for agricultural, industrial, and commercial purposes subjects them to the hazards of recurring floods. Railroad builders found the water courses nicely graded and therefore well suited for the railway lines, and as a consequence the flood damage to railway property is high. However, the damage is lessened by the studied relocation of the tracks and the redesign of bridges. Complete information on the destructive character of floods, particularly the great floods, was not available when the original routes were surveyed and the tracks laid. As data on floods have become available the railways in order to protect their large investment have spent millions on the relocation of tracks and bridges.

Flood Damage in Urban Areas

Many of our large cities such as New Orleans, Cincinnati, St. Louis, Pittsburgh, and Nashville were located on rivers when the water courses were the principal highways of commerce. The utilization of the low-lying lands adjacent to the rivers for industrial and commercial purposes has resulted in heavy damage in times of flood, owing both to the destruction of property and to the suspension of business for periods varying from a few days to several weeks (Fig. 3). Lands once used for private

FIG. 3. Property of the Lawrence Gas and Electric Company showing the gas plant and the boiler house flooded by six feet of water from the Merrimack River (1936). (New England Electric System. Photo by Fairchild Aerial Surveys, Inc.)

purposes are not easily relinquished, for the owners, especially if individual land holders, can hardly afford to abandon the properties to the river. In such areas the recurring floods cause increased damage, owing to an increase in property values

FIG. 4. The Missouri River breaking through the railway dike near Glasgow, Missouri, on June 26, 1947. Efforts to prevent the break-through by the use of piling proved futile. (Press Association, Inc.)

through the years. Urban areas subject to floods are abandoned only with great difficulty, for industries seeking low land values and people in the low-income group seeking low rentals are likely to locate on these cheaper lands along the river. Usually protection against floods is sought before abandonment is considered. If protective levees, generally built at public expense, prove adequate, property values increase and the utilization of the land is intensified. Then an unprecedented flood overtops or breaks through the levees and causes enormous damage. The increased property damage reported from many cities is due to man's encroachment upon the rivers.

Flood Damage to Agricultural Lands

In agricultural areas the amount of damage depends upon the season and whether intensive economic use is made of the land. A winter flood may cause little damage to farm lands, but in southern California where the intensive cultivation of vegetables is an important winter industry the occasional winter floods may be very destructive. The floods of spring may inundate planted fields and delay replanting until it is too late to secure a fully matured crop. The floods of late spring and early summer of 1947 in the lowland areas of Iowa and Missouri caused heavy damage to crops (Fig. 4). The immediate losses in a single season may be offset somewhat by the enrichment of the lowland by the deposition of silts.

PHYSICAL CONDITIONS AFFECTING FLOODS

Causes of Floods

Floods are the result of many conditions working singly or in combination. Usually no single cause can be assigned the whole responsibility. The immediate cause of most floods, however, is the excessive runoff from precipitation of high intensity, though many other conditions may be necessary to cause a great flood. Although most floods are related directly to heavy precipitation and the immediate surface runoff, floods are also caused by dam failures, ice obstructions, high tides, and gales.

Precipitation Features

Rainfall is not a continuous but a recurrent phenomenon. In the United States the results of the occasional rains can be combined into several distinct types. The long-time averages give the normal annual rainfall régimes for the several sections of the United States. Ward [2] resolved the thousands of individual rainfall records into fourteen major types, but these may be further reduced in number.

In northeastern United States the annual precipitation of 40 to 45 inches is quite evenly distributed throughout the year. During each month sufficient precipitation is received to maintain a continuous flow of water in the streams, though occasional droughts may reduce some to insignificant trickles. This is the *New England type* and is characteristic not only of New England but also of much of the northeastern part of the country.

Farther west the quantity of precipitation is reduced and the régime becomes characterized by a late spring-early summer maximum. Since this distinguishing feature is common to extensive areas within the Missouri basin it is known as the *Missouri type.* Toward the Rocky Mountains the quantity of precipitation is reduced to 10 to 15 inches annually, but the régime remains essentially the same.

Along the Gulf coast the annual precipitation of 55 to 60 inches is so distributed as to produce a monsoon-like maximum in the summer with two periods of minimum rainfall in May and October. This is the *north Gulf coast type,* which is modified along the south Atlantic coast by the late summer-early autumn hurricanes which displace the summer maximum forward toward the early autumn.

In much of the semiarid and arid interior of North America the seasonal régime of the precipitation is of little significance as a flood factor, for the quantity is too small. The floods are due chiefly to melting snows or to torrential downpours falling upon barren ground or upon steep slopes.

Along the Pacific slope of western United States the numerous rainfall records may be resolved into the *north Pacific type* and the *south Pacific type.* Both are characterized by a winter maximum and a summer minimum. Along the north Pacific the months of July and August are usually so dry as to be deficient in moisture, though irrigation is not necessary for general agriculture. In the south Pacific area the winter precipitation is much less than in the north and the summer minimum becomes an extended dry season. The limited moisture is inadequate for agricultural needs, and most crops require irrigation. Floods are generally confined to the rainy season or to the spring and early summer.

The intensity of precipitation. The surface runoff which is the chief source of floodwaters is dependent not only upon long-continued precipitation but also upon heavy storms of short duration. A two-inch fall of rain would hardly produce a flood if it fell in a drizzle extending over several days, but if it were concentrated within an hour or two the resulting runoff would in areas of steep slopes produce local flooding. In a large section of eastern United States a ten-minute rain of more than an inch may be expected once in twenty-five years.[3] Such heavy rains of

[2] Robert De C. Ward, *The Climates of the United States,* New York, 1925.

[3] David L. Yarnell, "Rainfall Intensity—Frequency Data," *Misc. Pub.* 204, U. S. Department of Agriculture, 1935, p. 33.

short duration are the cause of considerable flood damage in limited areas (Fig. 5).

The great floods of the Ohio River, such as the disastrous inundation of 1937, are generally related to the conjunction of two major air masses. Usually a mass of relatively cold air stagnates over the upper Mississippi valley with its southern margin fronting upon the Ohio. The continuing flow of warm moist air from the Gulf of Mexico northward over the edge of the stationary air mass results in heavy frontal rains, which, if long continued, cause excessive runoff and destructive floods.[4]

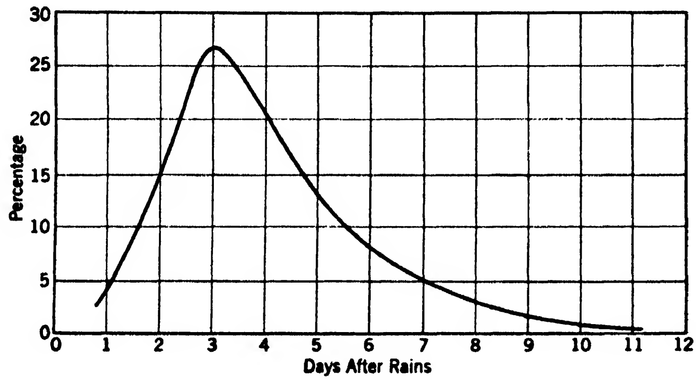

FIG. 5. A composite distribution graph for eight storms in Muskingum River basin above Dresden, Ohio. The surface runoff, as shown by the graph, produced the greatest rise in the river on the third day following the precipitation in the tributary area and then gradually declined to normal by the twelfth day. (Data from W. G. Hoyt and others, "Studies of Relations of Rainfall and Runoff in the United States," *Water Supply Paper* 772, U. S. Geological Survey, Washington, D. C., 1936, p. 141.)

In the Rocky Mountains the floods are of two principal types: those which are due to heavy general rains, and those due to the so-called cloudburst type of rainstorm. Rains of the first type are infrequent, and the resulting floods are confined to the principal streams which receive the waters of large drainage areas. The long-continued rains accompanied by rapidly melting snows cause a steady rise in the streams until the flood stage is reached, and then gradual retreat to the water course follows. Such floods are characteristic of the major tributaries of the Missouri such as the Yellowstone, Milk, North and South Platte, and Big Horn rivers. The cloudburst type seems to localize principally in the open basins along the front of the Rocky Mountains and along the valleys within the mountain mass. The high intensity of the rainfall results in rapid runoff, swelling the local streams to flood proportions. Such floods quickly subside, but their suddenness usually causes heavy damage particularly to roads, railroads, and reclamation projects.

Occasionally the two types are combined into a single flood, for there is no sharp distinction between the two. In the Big Horn basin the heavy rains of July 21 to 27, 1923, produced an unprecedented flood on the Big Horn as recorded or measured at Thermopolis, Wyoming. The local but heavy showers of July 21 and 22 were fol-

[4] Charles F. Brooks and Alfred H. Thiessen, "The Meteorology of Great Floods in the Eastern United States," *Geogr. Review*, Vol. 27, 1937, pp. 269–290.

lowed by veritable cloudbursts on the 23rd and the 24th. The total fall for a seven-day period was estimated at several inches. The resulting flood caused enormous damage, the railroad alone sustaining a loss estimated at more than $1,000,000.

Forms of precipitation. When precipitation falls as rain we may expect the streams to reflect in their discharge the increased supply of water. But when the precipitation comes in the form of snow there will be no immediate response in the runoff unless the snow melts quickly. A heavy snow cover lying upon deeply frozen ground or upon well-saturated ground is a potential flood hazard particularly if the melting is rapid and accompanied by a heavy rain.

The impending floods from a dangerously heavy snow cover may be prevented by recurring cold periods which check the runoff. If the night temperatures fall well below freezing the runoff may be so delayed as to give ample time for the flood crest to flatten out. Also short cold periods may be very effective in delaying the runoff set in motion during the warm periods.

In northern United States and in the higher areas in the west, where a cold winter season holds temperatures well below freezing for long periods, spring floods may be expected annually. In New England the winter snows are particularly heavy and yield upon melting sufficient runoff to cause devastating spring floods. In the period between 1880 and 1933 there were 153 floods recorded for the Merrimack River at Lawrence, Massachusetts. Of this number 44 were in March, 56 in April, 17 in May, and the remaining 36 in the months of June, July, October, November, December, January, and February. Since the precipitation of northeastern United States is quite evenly distributed throughout the year, it is evident that the floods of the Merrimack are caused chiefly by heavy spring rains falling on the snow-covered highlands.

The Columbia River, deriving a large proportion of its waters from melting snow, was in flood at The Dalles, Oregon, 120 times in the 57-year period between 1878 and 1934. The month of June had 51 floods; May, 31; and April, 21. The remaining 14 floods came in the months of January, February, March, July, November, and December. The increased discharge of the Columbia River in late spring and early summer is due very largely to the progressive melting of the snow in the mountain sections of the drainage basin. The great flood of June, 1948, was related to the rapid melting of the heavy snow cover in the headstream area.

Runoff Characteristics

Every drainage basin has a characteristic runoff pattern, but from year to year there is considerable variation due to the amount and the seasonal irregularities in precipitation, the rate of melting of the snow cover, and many other conditions. In much of eastern United States the maximum runoff comes in the spring months chiefly because the winter snows upon melting add their contribution to the spring rains and the frozen condition of the ground prevents sink-in. The runoff is usually least in late summer when occasional droughts and high evaporation reduce the amount of water that reaches the streams, and in the mid-winter when sub-freezing temperatures maintain a snow cover, thus delaying runoff until the spring. The winter minimum is quite characteristic of the more northern states because of the severity of the winter season. In the interior of the country where the late spring-early summer maximum is a characteristic feature of the rainfall the maximum discharge of the streams becomes more sympathetic with the rainfall régime.

In New England, where the precipitation is quite evenly distributed throughout the year, the runoff shows both a spring and an autumn maximum. The most disastrous floods are associated with the melting snows of spring, as illustrated by the floods of early March, 1936, and with the occasional but heavy rains of autumn (Fig. 6).

utaries joining the main stream at or near a common point would be conducive to floods at times of widespread and heavy rains. In eastern United States general rains covering extensive areas are common enough to be an important cause of floods. Recurring storms in a more or less circular drainage basin would result in a simultaneous discharge of the tributaries into the master stream, probably resulting in flood

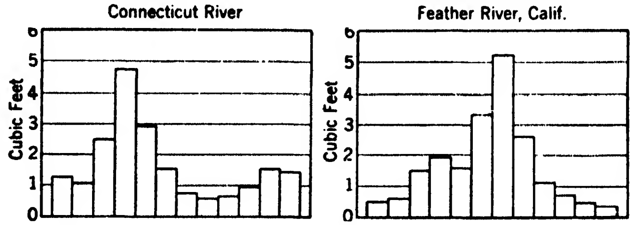

FIG. 6. Runoff hydrographs for the Connecticut and Feather rivers. The ordinates show the average monthly runoff in cubic feet per second per square mile. The Connecticut River shows the spring maximum so characteristic of northeastern United States, and the Feather River illustrates the discharge of rivers along the Sierra-Cascades where the melting snows from the high mountains produce an early summer maximum. (After the National Resources Board, Part III, *Report of the Water Planning Committee.*)

In the western part of the United States the maximum runoff comes chiefly in the early summer. Along the Pacific coast the winter precipitation may produce floods immediately, as was true within the Sacramento basin during the winter of 1936 and along the Willamette in the winter of 1948, but usually the precipitation falls as snow in the mountains and is not released until spring and early summer (Fig. 7). As the snow fields are reduced the discharge of the streams is greatly diminished by late summer and early autumn except for a few major rivers such as the Colorado, the San Joaquin, the Sacramento, and the Columbia which tap never-failing sources in the mountain areas.

Shape of the Watershed

By *a priori* reasoning it is evident that a circular watershed with the several trib-

damage. Regardless of the shape of the drainage basin heavy rains in the tributary areas may occur in such a manner as to produce a serious flood along the bottomlands of the main stream. Distribution of the heavy rains locally and timing are significant elements in the development of a great flood.

If the whole drainage basin of any river system is subject to general and recurring storms, floods may be expected along the master stream. In long linear basins a single storm of high intensity may produce a flood in a limited section of the stream, and unless there are reinforcements from other sources the flood crest will flatten out sufficiently to recede to the channel in the downstream section of the main stream.

Also, floods on such major streams as the Mississippi, the Missouri, the Ohio, the Columbia, and the Susquehanna may be caused by a number of storms so distributed within the watershed and spaced at the proper time intervals that coincidence of crests in the lower course of the master stream results. This was true of the 1933 flood of the Ohio River [5] when general rains over the drainage basin had saturated the ground and filled the channel. An earlier storm of March 13 to 15 moving eastward across the Ohio basin yielded its greatest precipitation in the Wheeling area. A few days later a second storm followed, accompanied by heavy rains centered over the lower Miami valleys and the Cincinnati area, and as a result the flood crests from the two areas reached Cincinnati simultaneously.

FIG. 7. The Willamette River between Corvallis and Salem during the spring flood of 1948. Note how the course of the river, roads, and field boundaries are marked by trees. (Portland District, Corp. of Engineers, U. S. Army.)

Configuration of the Terrain within the Watershed

On relatively flat lands each field becomes to a limited extent a catchment basin retarding the discharge of water to the watercourses. Water drains slowly from the lands of low relief, giving time for the stream to discharge its waters continuously within its confining channel, unless successive storms fall upon saturated ground. The excess water from these later storms cannot be absorbed and quickly seeks the watercourse endangering the riverine prop-

[5] Wallace T. Buckley, "The Ohio River Flood of March, 1933," *Ohio Journal of Science*, Vol. 35, 1935, p. 75.

erty when the stream passes flood stage. In areas of low relief and gentle slopes runoff is delayed sufficiently to permit infiltration, but in regions of steep slopes there is a rapid streamward movement of the surface water unless precipitation is light and spread out sufficiently to give time for infiltration to the reservoir of underground waters. In rugged areas with steep slopes torrential rains usually are accompanied by rapid runoff and flooding of the lowlands along the watercourses. A heavy protecting cover of vegetation may somewhat reduce the runoff and consequently the flood damage, but forested areas are not free from floods. All other factors being equal, the steeper slopes in a drainage basin yield the greater surface runoff. Slope, stream density, and other terrain conditions are important factors in determining the flow or discharge of a river.[6]

In the Red River basin as measured at Grand Forks, North Dakota, the annual precipitation averages approximately 21 inches and the surface runoff is only 1.25 inches. The light rains in the area no doubt are partly responsible for the low runoff, though an important consideration is the extremely flat terrain. For the Mississippi basin above Keokuk, Iowa, the precipitation averages 29.51 inches, of which 6.98 inches or approximately 23 per cent are lost by surface runoff. Here the slightly more rugged terrain and the increased precipitation are conducive to a greater runoff than is characteristic of the nearly level Red River plain. As illustrated by the Tennessee River, the steeper slopes of the southern Appalachians cause even greater runoff. The proportion escaping to the streams without having become a part of the groundwater reaches nearly half of the average annual precipitation of 50.36 inches.

[6] Walter Langbein and others, "Topographic Characteristics of Drainage Basins," *Water Supply Paper* 968-C, U. S. Geological Survey, Washington, D. C., 1947.

Orientation of Rivers

The orientation of streams is a significant factor in the flooding of the adjacent floodplains. In Siberia the northward courses of the Ob, the Yenisei, and the Lena are favorable to flooding because spring comes to the headstream areas while the northern and downstream sections are still frozen. In North America the Mackenzie presents a similar situation, except that the larger lakes tend to flatten out the flood crests. This condition causes the inundation of extensive areas along these streams in late spring and early summer. To a limited extent the Red River of the north is affected in a similar manner because of its south to north orientation. Fortunately very few major rivers in the United States are so oriented as to suffer from the type of floods so characteristic of the great Siberian rivers.

In much of continental United States the general rains of cyclonic origin and the local thunderstorms move from the west toward the east. The Ohio drainage basin is so oriented that frontal rains may occur simultaneously and repeatedly over the full length of the watershed. Fortunately most of the storms move upstream, and precipitation falls first in the lower section of the watershed and a part of the runoff is discharged downstream before the waters from the headstream area reach the lower course of the river. Along sections of the Missouri and other western tributaries of the Mississippi storm movement is downstream. In slow-moving storms the torrential rains and the floodwaters may move progressively downstream with serious consequences. Generally the storms move more rapidly than the flood crests. Watercourses that are oriented transverse to the paths of local thunderstorms may escape serious damage, for the flooded area is likely to be restricted.

Soil and Rock Conditions

Floods occur in part because the soil and the soil material are unable to absorb the precipitation as fast as it falls or before it escapes as sheet wash. This failure to absorb the water depends upon the nature of the soil, slope, degree of saturation, the amount and intensity of the precipitation, and other conditions. Where the surface soil consists of coarse sands and gravels which permit a high proportion of the precipitation to infiltrate to the underground reservoir, floods seldom occur unless the ground is saturated or frozen, or the intensity is so great that excessive runoff results. In the Coastal Plain of the Atlantic and Gulf coasts where the underlying formations are particularly porous, there is little danger from floods of local origin. Though much of the area receives an annual precipitation of 40 to 60 inches, the surface materials readily absorb a high proportion of the rainfall.

In the Great Lakes states where the glacial drift consists of sand and gravel the danger from floods is not great. Here also the slight relief of the glacial landscape is conducive to infiltration. These sandy and gravelly areas are particularly characteristic of Michigan, central and northern Wisconsin, and northeastern Minnesota.

Where the surface soil is clayey and more or less impervious to infiltration, the runoff will be heavy in all storms of great intensity. Usually such areas suffer extensive denudation from sheet wash and rill erosion, and great quantities of soil are carried to the watercourses. In the Piedmont and the Southern Appalachians both the surface soil and the underlying crystalline rocks have limited storage capacity, and, as a result, the many rivers are subject to flood. At times of heavy storms destructive floods may spread beyond the protecting channels and progress seaward causing damage in the Coastal Plain, where floods of local origin are rather uncommon. The most disastrous floods are inherited from the Appalachians and are confined to the major streams that rise in the crystalline areas to the west and north.

Physiographic Aspects of Floods

Streams that are lowering their courses into bedrock usually are bordered by rather steep slopes and the floodwaters do not inundate extensive areas. And many streams that flow on more gentle gradients are commonly bordered by narrow alluvium-covered flats which are subject to limited flooding when the rivers rise above the protecting banks. Along such streams little damage results from inundation, but bridges, roads, and other structures that lie close upon the rivers suffer from the rush of the floodwaters.

The recent erosional history of northeastern United States, disturbed as it has been by glacial and post-glacial changes in level, has been characterized by a Pleistocene filling of once deeper valleys. This partial filling was terminated at the close of the glacial period, and re-excavation of the valleys began. The erosion of this alluvial material has produced a series of terraces along many streams with the main stream confined to a meandering channel within a low floodplain. In the lower sections of a valley the terraces are most numerous and upstream may converge into only one, or in some instances may be nonexistent. In the upstream section the incision made in the alluvial plain may have served to limit the flooded areas at times when the stream spreads beyond its confining channel. The single but low terrace was originally a haven of refuge from the floodwaters. With the settlement of the land and the clearing of the forest, runoff has increased, carrying with it sufficient soil to fill the shallow incision in the alluvial plain, thus setting the stage for more extensive damage in times of subsequent floods. Along the lower sections of such terrace-bordered streams the narrow floodplain is frequently inundated, but the flood damage is confined to the lower plain, the terrace areas being high enough to escape inundation.

The construction of weirs across gullies serves the dual function of preventing and reducing soil erosion and rapid runoff at the same time. The checking of the runoff should also prevent the deposition of coarse débris over the nearby alluvial plains. In many rugged areas the best agricultural land is found along the alluvial lands of the master stream, and its major tributaries. When the forests were cut from the adjacent slope lands, runoff was increased and as a result the capacity and the competency of the streams were increased. Sand, gravel, and even large boulders were carried downstream in torrential currents and strewn across the alluvial lowlands, thus reducing if not destroying the agricultural utility of the land. A protective cover on the slope lands will do much to prevent the despoliation of these limited areas of agricultural land.

Rivers such as the Mississippi, Missouri, Red, Illinois, and many others flow seaward on a broad alluvial plain. Where the gradient is very low the stream follows a meandering course. The most notable example of such a stream in the United States is the lower Mississippi, though streams of all sizes may be characterized by meanders.

The large streams that flow along broad alluvial plains are commonly bordered by important natural levees of their own creation. The streams in time of flood spread beyond their banks, and as their velocity is checked a thin veneer of sediment is deposited in a narrow strip along the watercourse. By repeated floodings this riverside strip is built up into a protecting natural levee. The river is then confined, except for the major floods, between the protecting levees. The land slopes away from the river to lowlying back swamps partially drained by smaller rivers which flow more or less parallel to the master stream. Such streams are known as the Yazoo type, the name being derived from the stream of that name in the alluvial plain of the Mississippi above Vicksburg.

Since the natural levees that border the streams are made by the rivers it may be expected that in times of great floods the water will rise above the levees and inundate extensive areas beyond the levees. Where the levees are low or weak the floodwaters may break through to the back swamp areas by way of crevasses.

The system of meanders is continually shifting as the river erodes the banks on the outer bends. This weakens the protecting levee, and in time of high water there is always the danger that crevasses will be formed. By this process of levee building and silting of the back swamp areas the alluvial plain is built up with the main stream swinging slowly across the plain and the meanders moving progressively downstream.

The seaward extension of the delta of the Mississippi results in a gradual lengthening of the stream. As a consequence the river bottom is built up slightly to maintain the necessary gradient. Subsequently floods will build up the adjacent levees, confining all but the greatest floods to the levee-bordered channel. A great river flowing seaward is a powerful physiographic agent, ever changing the configuration of its alluvial plain.

FLOOD CONTROL

To escape the danger of floods various control measures either singly or in combination have been utilized to provide the necessary protection. Probably one of the earliest methods was to evacuate the area at the first warnings of impending danger. Flight to safe areas could hardly be interpreted as flood control, but it did mean the protection of life and a limited amount of property. This method is still used when there is a failure of other protective measures. Throughout the history of civilized man the fertile alluvial lowlands have been preferred areas of habitation; and, as high water menaced periodically the homes of the people, the protecting dike or levee became one of the first methods of defense against floods.

Channel Improvements

One of the simplest and most individual methods of flood protection is channel improvement. Along relatively small streams riparian owners may without a great deal of expense improve a stream channel by clearing out obstructions such as brush and trees. Accumulated débris from previous floods may be removed, facilitating the discharge of floodwaters, thus preventing the stream from overspreading its banks and inundating adjacent lands. This simple method is usually accompanied by a straightening of the channel by cutting across meanders and other sharp bends in the river (Fig. 8). The clearing and straightening of the channel make for a rapid discharge of the floodwaters, preventing inundation of riverine properties.

Such local flood-prevention methods are effective unless the stream is aggrading its channel and building up its floodplain. There the puny efforts of man may be wasted in a futile attempt to prevent flood damage. A stream that is building up its course will continue to do so in spite of local protective works. The control of such a stream will require preventive works in the headstream areas and perhaps along the lower course of the stream as well. Channel straightening has the effect of steepening the gradient, thus increasing the velocity. The stream is then able to carry along its course both a larger quantity of sediment and larger fragments. Unless it is loaded to capacity it will deepen and perhaps widen its channel sufficiently to carry the water of subsequent floods if the course is not allowed to become clogged by débris.

Local improvements in the channel planned to protect only the adjacent property may actually increase the flood hazard downstream. Improvements designed to facilitate the rapid downstream movement of water along the tributaries may heighten the flood crests along the master stream. It is because of the conflicts of interests within a drainage basin that all flood-control works should be co-ordinated, so that preventive measures applied in one area may not nullify the works in another.

Protection by Levees

Levees are very commonly associated with other local preventive measures used along the smaller streams as well as along such major streams as the Mississippi tnd the Missouri. Short levees are usually constructed where the banks are low to maintain a uniform channel height. Channel straightening will require fill-ins and protecting levees to make sure that the stream in time of flood is confined to its new channel. Along streams that have been gauged over a long period of time the flood crests may be so well known that protective dikes for the drainage of the lowlands outside of the dikes in time of low water. In times of flood the gates will have to be closed, preventing drainage of the lowlands. To avoid local inundation it may be necessary to install pumping machinery to lift the water over the levee to the main stream.

FIG. 8. Aerial view showing the Leland and Tarpley cut-offs on the Mississippi River in the vicinity of Greenville, Mississippi. The closely spaced meanders known as the "Greenville Bends" can be easily identified. The man-made cut-offs decreased the navigational distance by many miles and increased the carrying capacity of the river. (Mississippi River Commission. Aerial photo by U. S. Army Air Forces.)

may be constructed to contain all but the great floods between them. Here the levees or dikes should not be placed too close to the river's edge, but set back somewhat, leaving room for other preventive works along the stream and providing a safety margin in anticipation of unprecedented floods. Such a system of protecting dikes will require a correlated system along the tributaries and a series of gates to provide

The confinement of a river between closely spaced levees creates a dangerous situation because the floodwaters, no longer having access to the floodplain, rise above former levels and increase the danger of breaks or crevasses. This danger may be lessened somewhat by a scouring and a deepening of the channel which becomes a restricted floodway in time of high water. At the time a river is in flood and restricted to a levee-protected channel the increased velocity, while it scours and enlarges the channel, eats away the banks, forming crevasses through which the floodwaters may escape to the low back swamps. Temporarily, at least, levees give protection to riverine property, but there is no general agreement as to the effectiveness of the method.

Levees as a protective device have been most extensively used along the lower Mississippi, but they are necessary along many of the major tributaries such as the Red, the Arkansas, and the Illinois. Many of our principal cities are located upon the larger rivers, and wherever there is likely to be extensive damage to valuable urban property by inundation protecting levees have been constructed. Though rather expensive, the levees, if properly constructed and maintained, may give adequate protection against all floods except those classed as the great and unprecedented floods.

It is estimated that the flood damage along the Illinois River averages more than $2,000,000 annually. The watercourse is bordered by expensive levees which in many places are located too close to the river, resulting in disastrous breaks and extensive inundation. The fertility of the plain invited settlement of lands that should have been dedicated to the river. Because of the high cost involved in the maintenance of the system of levees, limited areas once used for farms have reverted to their former condition and now are used for floodways and game refuges. What is true of the Illinois is also true of the Mississippi, except that the scale is greater both in the levee system required and in the destruction of property when the levees fail.

Along the Red, the Arkansas, the White, and the Ouachita rivers the construction of levees has given inadequate protection to more than 2,000,000 acres of alluvial lands. The system of levees needs to be reorganized and co-ordinated into a unified project not only for the sake of the 2,000,000 acres now receiving partial protection but also to give increased security to the 7,000,000 acres subject to inundation in times of high floods.

Levees along the Mississippi River

Levee construction along the Mississippi was begun at New Orleans in 1717. The first single mile of levee was gradually extended upstream, the individual planters assuming responsibility for their respective sections along the river.[7] Since the early settlers along the Mississippi were interested in navigation as well as flood protection, the levees were so placed as to serve the dual function of facilitating commerce and giving protection to the rich alluvial lands (Fig. 9).

Recurring floods along the river called for additional levees constructed chiefly by riparian landholders, by counties, parishes, levee boards, and the several states. But it soon became evident that adequate protection was beyond the means of the local organizations. There were many areas which, because of sparse population and limited resources, were unable to assume their full share of the responsibility, and as a result floodwaters overtopping the natural levees spread downstream inundating farmlands locally well protected. As a result of the lack of co-ordination of the levee systems and the absence of protective works in the sections still remaining in the public domain, there developed very early a movement for flood control by the federal government.

[7] Andrew A. Humphreys and Henry L. Abbot, *Report upon the Physics and Hydraulics of the Mississippi River,* War Department, Washington, D. C., 1874, p. 150.

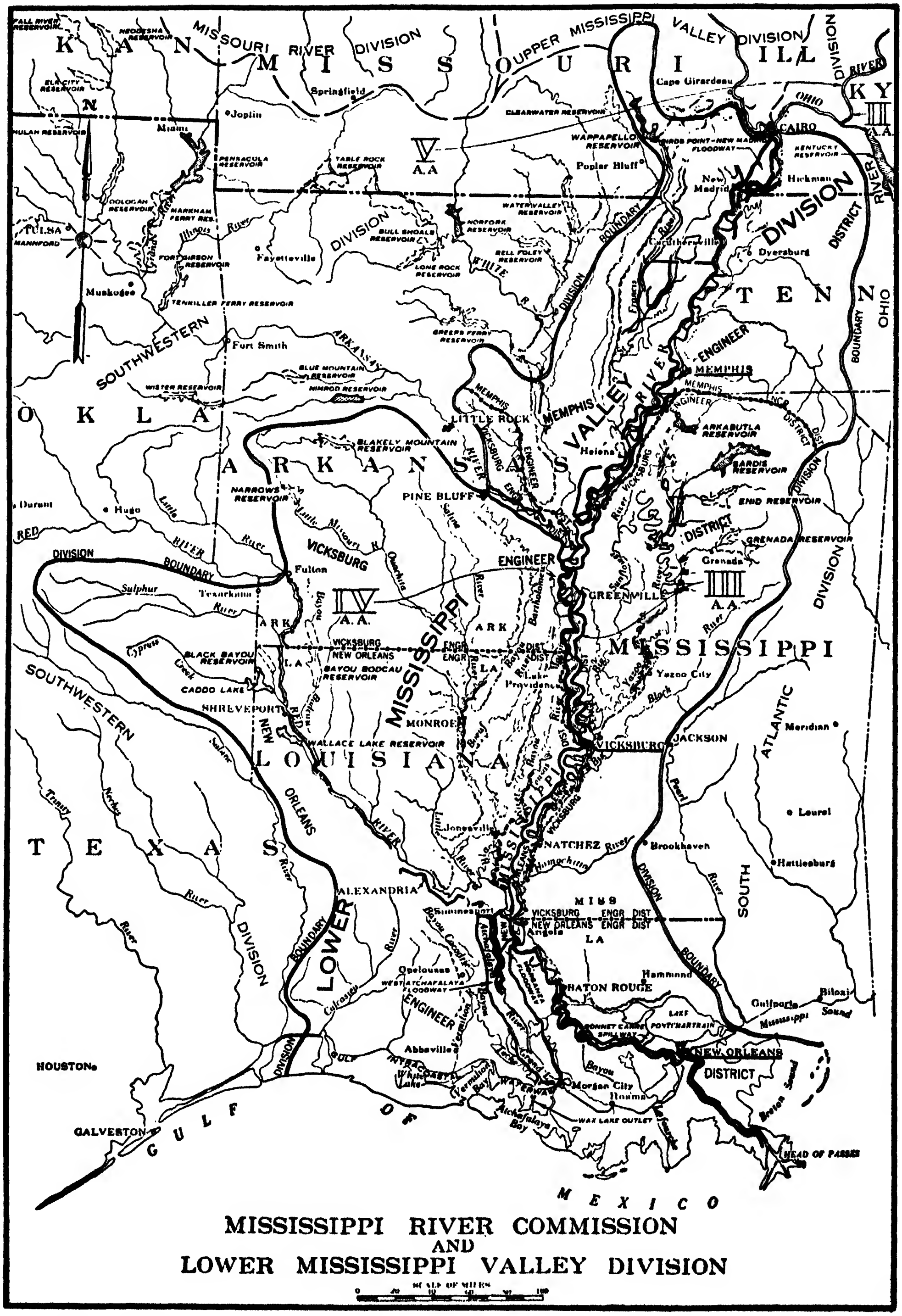

FIG. 9. Map showing the location of the major levees, floodways, spillways, and other flood control works in the alluvial lowland of the lower Mississippi basin. (Mississippi River Commission.)

The ever-growing levee system was severely tested by the disastrous flood of 1859, which destroyed important sections of the system. Before adequate repairs could be made the Civil War, like a series of destructive floods, had as one of its unfortunate consequences a deterioration of the levees. And during the reconstruction period recurring floods culminating in the great flood of 1882 aroused the nation to the need for adequate protection. In 1879 Congress created the Mississippi River Commission which became the federal agency for carrying out the program of flood control, though the first money appropriated for use by the commission was for the improvement of the river for navigation, and flood protection was only incidental.

The commission after careful study of the problem established the standards for levee construction and otherwise co-operated with local agencies, such as levee boards, in providing the necessary protection. Specifications for levees and other control works have been revised from time to time, but continual efforts toward standardization and co-ordination of systems have resulted in constructive though inadequate protective works, as was demonstrated by the great floods of 1922, 1927, and 1937.

Congress by a succession of acts from 1917 to 1946 has provided funds for the control of floods on the Mississippi and at the same time authorized the use of other methods than levee building to protect the alluvial bottomlands. The federal government also assumed a larger share of the costs. The use of floodways, created by the set-back of major levees, indicated recognition of the need of the river for a larger share of the bottomland. The Flood Control Act of 1936 authorized the construction also of retarding basins in the upper reaches of the alluvial basin.

Spillways and Floodways

The natural history of a river confined to a levee-protected course includes not only an overtopping of the levees in time of flood but also the breaking of wide gaps in the levees permitting the floodwaters to escape to the back swamp areas. Because a large river may at times need more of the floodplain than is available between the levees, an additional floodway may be provided in the lower back swamp areas. Such floodways should be protected by dikes and coordinated with the levee system of the master stream and its major tributaries. Well-protected floodways should be an effective means of lessening the danger of breaks in the levees where too much water is confined to a narrow watercourse. Old crevasses may be used for the spillways through which the waters may be diverted to the floodways. This adaptation of the man-modeled watercourses to the natural courses of the river is a recognition of the behavior of the river.

In the lower section of the Mississippi the river is held between high natural and artificial levees. The water that seeps through or overtops the levee does not return to the river but flows to the Gulf of Mexico by way of the Atchafalaya River and the Bayou Lafourche. The latter is a levee-guarded channel extending from Donaldsonville, Louisiana, almost to the Gulf. This condition along the lower Mississippi illustrates how the diversion of waters from the main stream may lower flood crests in the downstream section of the river and for a limited distance upstream.

The Mississippi River Commission from its inception in 1879 to the disastrous flood of 1927 when 23,573 square miles [8] were in-

[8] *Monthly Weather Review,* Supplement 29, 1927, p. 34.

undated stood rather firmly for flood control largely by levees. One of the important reasons for this support of a single method was the matter of cost. After the 1927 flood the commission's policy was broadened to include a more comprehensive scheme of levees as a first line of defense to be supplemented by spillways, floodways, and other protective measures.

FIG. 10. The Bonnet Carré spillway, which in times of high water discharges into Lake Pontchartrain and reduces the hazard of floods in the New Orleans area. View shows the spillway in operation during the high-water period of 1945. (Mississippi River Commission. Aerial photo by U. S. Army Air Forces.)

In 1928 Congress recognized the validity of the floodway method of alleviating the flood danger and provided for a system of floodways to supplement the levees along the Mississippi. By the time of the 1937 flood levees, floodways, upstream reservoirs, and other protective measures were accepted as essential in the over-all control of the river.

Above New Orleans the Bonnet Carré floodway can be used to discharge the floodwaters of the Mississippi into Lake Pontchartrain and thus provide a measure of protection to the downstream communities (Fig. 10). The Morganza floodway above Baton Rouge can be used in time of emergency to divert floodwaters to the Gulf of Mexico by way of the levee-guarded Atchafalaya basin.

Retarding Basins

Along the larger rivers that have broad natural levees and expansive back swamp areas, retarding basins may be developed as a means of reducing the flood crests. Certain back swamp areas along the middle sections of an alluvial plain cannot be drained easily and might well be set aside as retarding basins. Water discharged from the constricted channel of a major river in flood may raise the level of the water in the swamp area very slightly and at the same time may reduce the flood crest sufficiently to prevent serious flooding or damage to other protective works. Such retarding basins may be constructed in headstream areas with good results. The retarding dams are usually constructed of earth except for the spillways or the gateways and so designed that local floodwaters accumulate behind the dams and are discharged automatically, maintaining a bankfull condition along the watercourse. A series of retarding dams functioning in this manner may be a very effective means of preventing floods. If such retarding basins are equipped with outlet structures and control gates the normal emptying progress may be arrested. Control gates increase materially the effectiveness of the retarding reservoir as a flood-control measure.

After the Dayton flood of 1913 the Miami Conservancy District of Ohio was organized to protect the valley from such disastrous floods. A series of five retarding dams across the Great Miami River and its tributaries were constructed. Two of the dams are on the Miami and Loramie Creek above Dayton, two are on the Mad and the Stillwater which join the Miami at Dayton, and the fifth is on Twin Creek, which enters the Miami above Middletown. This flood project with its retarding dams, levees, and channel improvements has been regarded as one of the most successful flood-control methods, though there has been no flood equal to the 1913 inundation to test its effectiveness.

Flood Control Moves Upstream

The success of the retarding dams in the Miami basin has resulted in the adoption of a system of reservoirs in the Muskingum Watershed Conservancy District in eastern Ohio. During the depression years the program of public works included the construction of a large number of reservoirs in the upstream areas. A change in the attitude of the water-control engineers and the appropriation of large sums of money made possible the upstream movement of water control.

The construction of storage reservoirs for flood prevention alone is a costly method of control unless the reservoirs may be used for other purposes, such as water supply, power, recreation, and the regulation of the low-water level of the master stream. Multiple-purpose reservoirs are recommended unless there are conflicts that cannot be easily resolved. For example, a reservoir to be useful for water power must be kept as nearly full as possible, but the same reservoir to be effective in the prevention of floods must be kept empty so that the floodgates can be closed in time of emergency. This conflict may be resolved by a series of dams some of which are built primarily for flood control and others designed for the generation of power. A large dam, which in effect is two dams in one, may serve both purposes. The lower section of the dam may be used for power and be kept as nearly full as possible while the upper section may be available for water storage if a flood threatened.

Many of the reservoirs that now serve as flood-prevention works were constructed for other purposes, and flood control was a secondary though an important consideration. For example, the Wilson dam on the Tennessee was constructed for power purposes, but it also helps to regulate the flow of the lower course of the river. This dam is now a part of the Tennessee Valley Authority which includes several multiple-purpose reservoirs.

In the Cascades and the Sierras the many dams constructed for power purposes and for the storage of irrigation water minimize the flood hazards resulting from melting snows. Such dams not only reduce the flood crests but also may improve the low-water stage of the rivers. The great dams such as the Hoover dam on the Colorado, the Bonneville and the Grand Coulee dams on the Columbia, and the proposed reservoirs on the Missouri are all a part of a long-range water-conservation program.

The construction of many small dams in the headstream area of certain major streams not only will serve in flood prevention but also will provide recreational opportunities. If the stored water is not needed for culinary purposes these numerous reservoirs may be used by a large number of persons if they are easily accessible to the public. Complete control may be beyond the means of the nation, but where the reservoirs serve multiple purposes the expenditure of public money may be justified.

The flood problem has its origin where the rain falls upon the land, and if there is to be effective downstream control of floods there must be flood prevention at the sources. The Flood Control Act of 1936 committed the federal government to a program of reservoir construction in the upstream areas of rivers subject to floods.

In order that reservoirs may have a long life and serve the function of flood prevention, efforts should be made to prevent their silting up. The drainage basin above a reservoir should be so protected from erosion that maximum capacity of the reservoir can be maintained. If the runoff carries great quantities of sediment into the ponded waters of the reservoir, the capacity may be greatly reduced. Not all sedimentation can be prevented, but if the watershed is forested or grass covered, the load of silt carried by the stream is reduced to the minimum.

To be most effective reservoirs should not be placed too far upstream, for such placement will require more dams and will intercept only a small proportion of the runoff. A downstream location as near as possible to the area to be protected is to be preferred. One major dam across the master stream just above the area subjected to floods will give greater protection probably than ten smaller dams in the headstream area. It is not recommended, however, that the large dams be substituted for small dams in the tributary areas but that a co-ordinated system of reservoirs be considered not only for flood prevention but for other water needs as well.

Forests and Floods

It has been often stated that a forest cover in a drainage basin materially reduces floods, but forested areas are not free from the hazard of flood damage. There is conclusive evidence that the eastern tributaries of the Mississippi and the lower section of the master stream suffered from great floods before the land was settled and the forest was largely removed.

Adequate flood protection is largely dependent upon engineering structures, but the forest cover should be considered as a supplementary protective measure. A closely forested area with its absorptive leaf-litter delays runoff somewhat and gives greater seasonal uniformity to the discharge of the streams.

"The litter-covered forest floor is generally recognized as the best protection against erosion of soil. · · · A mere comparison of the forest soil made porous by these agents and by the penetration of tree roots, with the packed soil of adjacent fields will convince any one of the value of this cover in retarding runoff." [9]

This slight retardation of runoff may serve to reduce floods provided that the subsequent rains are delayed a sufficient length of time to permit the lowering of the water-table and a drying out of the litter. If the absorptive capacity of both the litter and the soil is reduced because of saturation heavy recurrent storms will cause floods. Probably the most important effect of the forest cover is not in its effect upon surface runoff but upon its protection of the soil, which in rugged areas is susceptible of removal; when both the forest cover and the absorptive topsoil have been removed, all rains, no matter what their spacing, yield rapid runoff. These indirect results are of major importance in the prevention of floods and in the maintenance of reservoir capacity whether the reservoirs be used for flood prevention or for other purposes.

THE RESPONSIBILITY FOR FLOOD CONTROL

Introduction

The control of floods is a responsibility that extends beyond the limits of the inundated areas. The calamitous floods of the Mississippi and other major streams of the United States always arouse widespread public interest in the causes of floods and their control. To charge the whole cost of protective works to the immediate beneficiaries would burden them with taxes beyond their capacity to pay. Conversely, to charge the cost to people who in no way receive any of the benefits directly from flood control is to misplace the responsibility for control. These two conflicting concepts can be harmonized by expecting the local beneficiaries to accept a share of the costs in proportion to their capacity to pay and charging the remaining costs to the general public by means of federal and state taxation. In this way the per capita cost of flood control is so small that the individual willingly assumes his share of the national responsibility.

Floods have no respect for political jurisdictions, just as political boundaries show little relation to hydrographic boundaries. Since flooded areas seldom coincide precisely with political areas the existing minor civil divisions such as townships and counties are unable individually to cope with the flood problem. This inadequacy of the political units as originally delimited has led to the organization of levee boards, conservancy districts, water-control boards, reclamation districts, and other legally constituted bodies for the practical solution of many water problems including the control of floods. The magnitude of the problem of the lower Mississippi transcends the local jurisdictions and consequently becomes invested with a public interest national in scope.

Individual Responsibility

The flood problem begins with the formation of a tiny rivulet in the farmer's field. Its control is both a personal and a social responsibility. His personal interest is not confined to the hazard of floods on his farm but to the associated loss of soil as the runoff gathers into rivulets which converge into larger and more devastating streams, producing both water and soil damage.

The individual landowner, though he may have a humanitarian interest in the

[9] E. F. McCarthy, "Forest Cover as a Factor in Flood Control," *American Society of Civil Engineers, Trans.*, Vol. 93, 1929, pp. 718–719.

flood hazards of the drainage basin in which he lives, can do little toward the solution of the problem, especially if he lives beside a large stream. In rural areas where streams are small, individual farmers may by channel improvements and the construction of levees give protection to their lowlying lands. The clearing of a stream channel of driftwood, trees, and other obstructions may so facilitate the flow during high water that the channel is widened, thus increasing its capacity.

The individual interest may be inimicable to the public interest, however, in the matter of flood control. The farmer who hastens the downstream movement of water across his farm may be contributing to floods in the lower section of the river. With an understanding of his individual responsibility the farmer may by altering his farm practice so delay runoff as to contribute to the solution of the flood problem, and all farmers working collectively may materially reduce flood crests in downstream areas.

Imperceptibly the personal responsibility of many individuals enlarges to a regional responsibility co-extensive with each important drainage basin. If the whole watershed lies within a single state the flood-control agency or conservancy district may be organized under the laws of the state and, if the problem is of sufficient moment, may deserve the blessing of the state in the form of financial aid.

Regional Aspects of Flood Control

Planning for the best use of water resources is essentially a regional responsibility, the region being coincident with the drainage basin of the streams concerned. This concept of the planning region cannot be adhered to rigidly, for the transmission of water power in the form of electricity and the distribution of water for irrigation and municipal purposes extend far beyond the limits of the drainage basin, and require a modification of the hydrographic region to include adjacent areas that constitute the peripheral sections of an economic region (Fig. 11).

The problem of flood control, however, is rather strictly confined to the drainage basin. So long as control measures involve only riverine works the plan would require the co-operation of river-side communities, but as control is extended to include preventive measures the whole drainage basin should be organized into a unit. The obstacles that make difficult the realization of this ideal are many and probably will stand in the way of a strictly regional organization based upon the hydrographic basin. Practically this ideal may not be necessary, for levee boards, conservancy districts, and other water-control organizations may serve as the legally constituted agencies to deal with state and federal authorities.

One of the most notable experiments in regional planning in the United States is the Tennessee Valley Authority authorized in 1933. Flood control is only one of the objectives of the multiple-purpose plan for the Tennessee River basin. The Columbia River basin with its several water conditions should have a plan that embraces and integrates all aspects of the water problem. In a similar manner the waters of the Missouri whether used for power, recreation, or irrigation should be made to serve as many people as possible, and the proposed Missouri Valley Authority should be authorized as the planning agency which, as Congress provides the necessary funds, should proceed to the orderly development

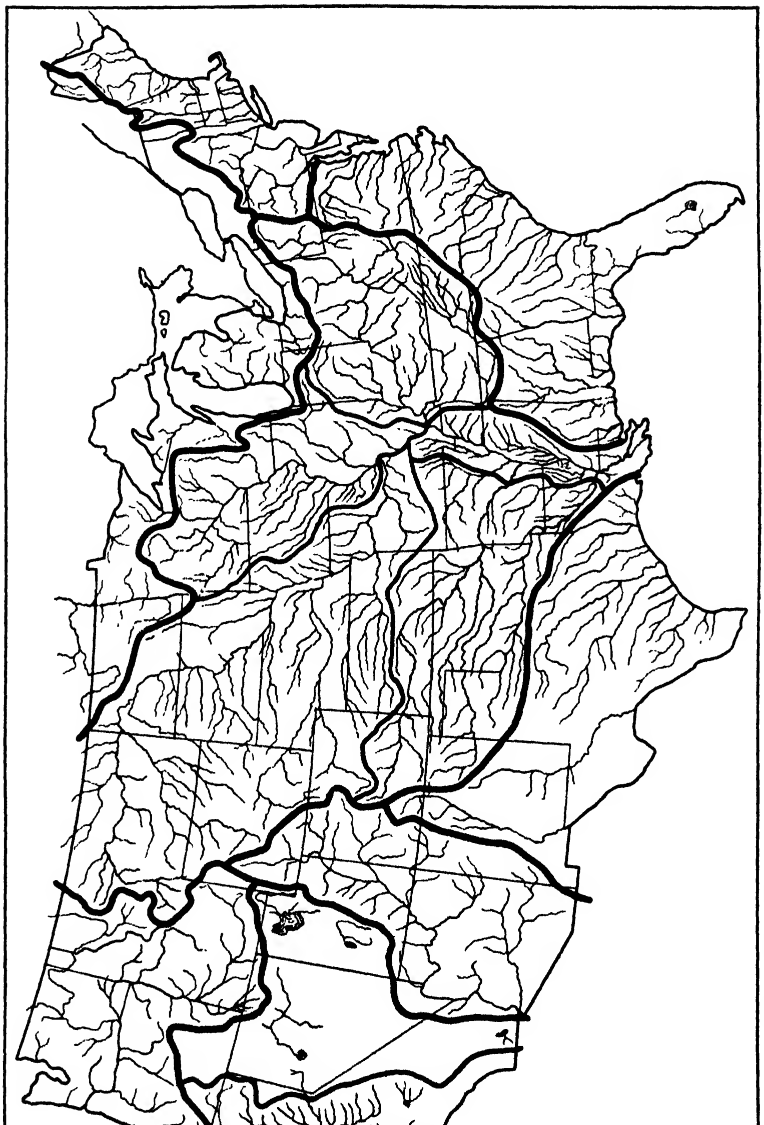

FIG. 11. Major drainage areas of the United States. (After National Resources Board, Part III. *Report of the Water Planning Committee.*)

and utilization of the water resources of the basin.[10]

Flood plain zoning.[11] One neglected but very important aspect of water control is the authority of planning commissions and similar agencies to regulate the use of land along watercourses. It may be trite but very truthful to say that the flood plain belongs to the river, and people, individually or collectively, who pre-empt the bottomlands may expect on occasion extensive flood damage. Effective zoning of bottomlands may result in dedicating large areas to use by the river in times of flood. Only the higher and easily protected lands should be approved for residential and industrial purposes.

The Responsibility of the States

Where a drainage basin lies entirely within a single state, a conservancy district or flood-control board may be authorized by the legislature or by a conservation board charged with the responsibility of handling the many water problems of the state.

Flood problems that involve two or more states may require interstate co-operation in order that a flood-control program may be extended to all parts of the drainage basin. The co-operation should include not only an interstate agreement but also a uniformity of laws to facilitate the work of the organization charged with the responsibility of flood control. Such interstate pacts are rather difficult to secure for the reason that the benefits to be derived from flood-protection works are not equally distributed among the several states. The apportionment of costs in a manner that appears equitable to one state will not be acceptable to another. Flood-prevention works such as storage reservoirs may be located in one state and the area thereby protected from floods may lie in another. An interstate compact that provides an acceptable distribution of costs is difficult to attain. In addition to the economic difficulties the legal requirement of authorization and ratification of interstate compacts by Congress and the legislatures of the states concerned practically precludes their wide use. One of the most notable interstate agreements is the Colorado River Compact involving the interests of seven states. Flood control was, however, a minor consideration in the negotiations of this interstate compact. The engineering aspects of this problem are relatively simple. The placement of engineering works and other preventive measures could be determined without unnecessary conflicts of opinion, but an equitable distribution of benefits and a fair apportionment of costs have been very difficult.

Conservancy districts authorized by a single state may be empowered to borrow money to carry out a flood-control program and levy assessments against the benefited properties to finance the project. The state's responsibility extends to a supervision of the financing operations and the retirement of the outstanding bonds. Where the cost of protecting bottomlands is so high that farmers have difficulty in making payments the state should maintain a conservative policy in authorizing flood-control projects. Only those projects that are self-liquidating or in which there is an important public interest should be authorized. It may be necessary to appropriate what appear to be unduly large sums to protect such utilities as water-supply plants

[10] Morris Llewellyn Cooke, "Plain Talk About a Missouri Valley Authority," *The Iowa Law Review*, Vol. 32, 1947, pp. 367–390.

[11] See Ralph B. Wertheimer, *Flood-Plain Zoning*, California State Planning Board, Sacramento, 1942, 43 pages.

in order that there be no interruption of the service. For such purposes excessive expenditures may be justified, but there should be a careful scrutiny of all flood-control plans to make certain that the benefits to be gained equal or exceed the cost of the protective works.

In those projects in which the federal government is a participant the responsibilities may be shared by the two jurisdictions. Whatever may be the share assumed by the federal government, the state can best undertake the purchase of right of way, flowage rights, the relocation of roads, and the settlement of damage claims. The representatives of the state can negotiate with local property owners to better advantage than can the federal government. The landowners are disposed to accept the evaluation of their property as fair and just if it is made by their neighbors and friends who are familiar with local values, and at the same time the government benefits both by lower costs and by the resulting good will created by fair evaluations.

Federal Responsibility

During the early history of the United States the many functions of the federal government did not extend to the construction of flood-control projects, partly because such works were not considered within the jurisdiction of the government. Flood damage was restricted in area, and, so far as protection or control was regarded as a public responsibility, the costs were shared locally by the beneficiaries of the protective works. But as recurring floods inundated an increasing acreage of valuable farmlands along the lower Mississippi there developed a strong sentiment in favor of the federal government assuming a share of the financial burden.

Where state boundaries transect a watershed, interstate co-operation becomes necessary to control floods. Federal responsibility begins first with the government's control of legally navigable streams where state and national co-operation is essential to an effective control program. The navigation needs and the flood-control requirements should be welded into a common program. The collateral uses of water should also be given careful consideration in any flood-control project. Though there may be some conflicts in purpose as represented in the construction of reservoirs, the essential unity of the flood-control problem and that of the conservation of water must be recognized.

It required many years for the concept of national responsibility to develop, but the magnitude and recurrence of the Mississippi floods kept the question before the public. After each great flood the people of the lower Mississippi appealed to Congress for aid. Among many people there was some doubt as to the constitutional authority for the federal government to undertake the building of levees for the protection of private property. With the creation of the Mississippi River Commission in 1879 the United States Government began to participate actively in the program of flood control, though the first moneys expended were primarily for the improvement of navigation and flood protection was an incidental consideration. Therefore the federal government entered upon a program of flood control under the guise of the constitutional authority to promote navigation.[12] With the settlement of the rich alluvial lands along such rivers as the Mississippi, the Sacramento, and other

[12] National Resources Board, Part III, *Report of the Water Planning Committee,* Washington, D. C., 1934, p. 378.

major streams, and the development of our complex system of railroads, highways, and postal system, the federal government became empowered under the commerce clause to build flood-control works to maintain and facilitate interstate commerce. The early doubts on the constitutional authority have largely been removed and the government has extended its jurisdiction to include flood-prevention projects in the headstream areas.

After the great Mississippi flood of 1927 the people of the United States were awakened to the need for a comprehensive plan of protection against the recurrence of such a disaster. The limited participation of the federal government in the period immediately after the establishment of the Mississippi River Commission has been extended. From this limited participation responsibility has been expanded to an assumption of 100 per cent of the costs of labor and materials in the construction of levees and other protective works.

As the question of constitutional authority has been settled and as engineers have come to recognize that flood control involves also flood prevention, government participation has moved upstream from flooded areas to the headstream areas. Every great flood on the lower Mississippi is related to a flood of major proportions on the Ohio, though a flood on the Ohio does not always cause a flood on the lower Mississippi.[18] With a recognition of the importance of the Ohio as a contributing cause of floods on the lower Mississippi, there has developed a sentiment for flood-prevention works in the headwater area of the Ohio basin, and the federal government is participating in the control works.

The Tennessee Valley Authority, though it is a plan involving multiple objectives, will by its system of reservoirs control the flow of the Tennessee River. In a similar manner the Muskingum Watershed Conservancy District with its fourteen reservoirs and retarding dams is primarily a flood-control project, though other water uses are included in the plan. The Tennessee Valley Authority is chiefly a federal project, but the Muskingum Watershed Conservancy District was financed by the federal government, the State of Ohio, and the District. In these two projects is epitomized the government's participation in the flood-control works now being constructed in the headstream areas.

In order to circumvent the extravagant use of federal money for flood-control works the Water Planning Committee of the National Resources Board recommended

"... the policy of requiring appropriate contributions from localities benefited as a most satisfactory general test whether a particular project is meritorious."

The Committee further recommended

"... that federal contributions be made (*a*) only where there is reasonable protection against maximum floods; (*b*) only where the total benefits justify the expense; (*c*) only where there are responsible and legally constituted authorities with which to deal; (*d*) to an extent not greater than 30 per cent of cost of labor and materials where the benefits are chiefly local; (*e*) to an extent greater than 30 per cent only in proportion to benefits definitely applicable to recognized national interests; (*f*) to a full 100 per cent only where the benefits are almost wholly of national interest."[14]

[18] *Monthly Weather Review,* Supplement 29, 1927, p. 7.

[14] National Resources Board, Part III, *op. cit.,* p. 273.

The above recommendation expressed the general policy of the federal government until the Flood Control Act of 1936 and the amendatory act of 1938 made possible the waiving of local contributions previously required. After 1938 the federal responsibility for flood-control projects was acknowledged as a government obligation. Local participation was not entirely abandoned, but a century of levee construction, channel improvement, and the development of multiple-purpose projects reflect a broadening of federal authority in the control of the nation's water resources.[15]

International Control of Floods

Fortunately the boundaries of the United States are so located that floods of international character are not beyond the control of man. An important section of the Canadian boundary lies within the Great Lakes–St. Lawrence system which is relatively free from floods. Our conflicts with Canada have involved the low-water stages of the Great Lakes rather than high levels. The diversion of water from Lake Michigan for the purpose of sewage disposal at Chicago has at times of low-water stages on the Great Lakes drawn vigorous protests from Canada.

Another section of the Canadian boundary, from Lake of the Woods to the Rocky Mountains, lies across a region of slight rainfall where the problem of floods is very local and minor. Also a long section of the boundary from the Red River to the Rockies lies very near the water parting between the Missouri River and the Assiniboine River which joins the Red River at Winnipeg.

The Red River of the north rises within the United States and flows northward across the Canadian boundary to Lake Winnipeg. Spring advancing from the south sometimes opens the headstream area while the northern and lower course is still blocked by ice. These occasional spring floods overspread the flat alluvial plain across which the river flows, damaging the adjacent farm lands and a number of small urban centers. The drought conditions of the period between 1930 and 1936 turned the attention of people to the problem of water deficiency, though floods such as the inundations of 1882, 1897, 1916, and 1950 may recur when the wet phase of the climatic cycle returns. In 1912 a treaty between the United States and Canada created the International Joint Commission which serves for the adjudication of the many water problems of interest to the two countries, and if the problem of floods becomes critical the commission stands ready to facilitate negotiation and arbitration.

Along the boundary between the United States and Mexico there are two areas requiring international co-operation for the control of floods and the apportioning of the water resources. The lower course and the delta of the Colorado were long subject to recurring floods, but the construction of the Roosevelt reservoir on the Salt River and the Coolidge reservoir on the Gila River somewhat reduced the flood hazard, and the completion of the Hoover dam has greatly reduced the danger of inundation in the delta. The apportionment of water remains as the critical unsolved water problem of the Colorado.

More than 800 miles of the Mexico–United States boundary lies along the Rio Grande. The water of the upper course is derived exclusively within the territorial limits of the United States. Above El Paso the control of the river is essentially an

[15] Gilbert Fowler White, *Human Adjustments to Floods,* Chicago, 1945, pp. 5–24.

American problem, though Mexico is vitally concerned with the quantity and the quality of the water that enters Mexican territory. Below El Paso additions to the Rio Grande are drawn chiefly from the Sierra Madre of Mexico. Floods in the lower course so far as they are the result of increments from the south can be controlled only by the co-operation of the Mexican government. The construction of the Elephant Butte dam across the Rio Grande at Hot Springs, New Mexico, practically prevents the danger of floods in the 125-mile section above El Paso.

The water problems of Mexico and of the United States are not so susceptible of arbitration as the Canadian-American problems. In the dry regions of southwestern United States the shortage of water has often precipitated disputes under the doctrine of prior right, and an equitable distribution of the limited water resources is very difficult to obtain. It has been suggested that a commission similar to the Canadian-American International Joint Commission be provided for the solution of Mexican-American water problems.[16]

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[16] National Resources Board, Part III, *op. cit.,* p. 382.

PART FIVE

CHAPTER 16

Conservation in the Mineral Kingdom

MINERAL CONSERVATION

MINERALS differ from other natural resources in one fundamental way. They are irreplaceable. Plants and animals may be bred in successive generations, depleted soils may be restored to fertility, and barren wastes may be afforested to productive maturity. A mineral deposit that has been truly exhausted is beyond restoration. An appreciation of the inorganic nature of the mineral kingdom is of the utmost importance in any consideration of the problems of conservation associated with the utilization of mineral products. The necessity of true conservation or actual preservation of the material itself is greater than that encountered in the treatment of other resources. The imperishable nature of the minerals themselves or their products makes this possible.

Mineral conservation has been defined many times. Most definitions have been concerned with intelligent utilization. The general thought behind such a definition is that intelligent use implies efficiency in production and the minimum of waste in processing and use. Such definitions fail to emphasize any element of preservation and actual saving. Therefore, it seems desirable to define mineral conservation as the intelligent utilization of mineral resources plus a proper regard for the rights of coming generations. The future is entitled to some equity in our mineral inheritance. Mineral conservation is concerned with the preservation of this inheritance for as many generations as possible and at the same time with the maintenance of a steady flow of mineral raw materials for the support of present industry. Our present resources are adequate in nearly all types for one more generation of the most profligate use and abuse, and fortunately some of them exist in tonnages sufficient for many generations. The wisdom with which these materials are employed will control the economic future of the country.

THE HISTORICAL DEVELOPMENT OF THE MINERAL INDUSTRIES

The intelligence and mechanical ability of man to make and use tools are the most significant characteristics distinguishing him

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from other animals. Many varieties of rock were employed as primitive tools as the examination of any collection of Indian relics will disclose. Gradually it was recognized that certain minerals possessed distinctive properties which could be utilized for special purposes. The hardness and conchoidal fracture of flint permitted the production of sharp edges which were produced on arrowheads, spears, and other edged tools. The softness of soapstone permitted carving it into pipes and bowls. The plasticity of clay allowed it to be formed into pots which aided in the cooking and storage of food. Mineral pigments produced colors attractive to the eye of primitive man. The necessity of salt in human diet was recognized. The minerals important to the prehistoric people increased in number, and some knowledge as to the occurrence and properties of these materials must have accumulated. The remnants of these materials that have survived the passage of thousands of years supply the archaeologist with the only evidence from which the conditions of early life may be reconstructed. Perishable materials obtained from plant and animal life unfortunately have vanished. Mineral terms, the Paleolithic or old stone age and the Neolithic or new stone age, are therefore employed to designate certain periods in the development of human culture.

Metals in the Economy of Primitive Man

A knowledge of metals was acquired gradually owing to the small number that can be found in elemental form and the irregularity of their distribution. It is probable that gold was the first metal with which man was acquainted. This is due to the fact that practically all gold occurs geologically in elemental form. Its combination with other elements to form minerals is rare, the tellurides of gold being the only important commercial exception. Gold has been distributed geographically with extraordinary profusion, unrivaled by any of the rare metals and equaled only by such common metals as iron and aluminum. Its liberation from enclosing rocks by the processes of erosion permits the metal to concentrate, particularly in the beds of streams. Its high specific gravity causes it to separate from the lighter worthless minerals with which it is associated, and to collect in valuable concentrations. The occurrence of such deposits must have been noticed by early man at his drinking places. The brilliant and untarnishable yellow color of the metal falls in the spectrum near the color values to which the human eye is most sensitive. It is possible to detect the presence of gold in remarkably minute amounts, a speck worth but one five-hundredth of a cent being clearly visible to the eye. The early recognition of this metal and the attachment of desirability or value to it has contributed to its present position as a universally accepted monetary standard by which the value of other commodities is measured.

Native copper, which is found in the outcrops of many copper deposits, was collected and its use initiated the copper age in which tools and weapons made from this metal were in widespread use. It was replaced by bronze, an alloy of copper and tin, of superior hardness and possessing a better cutting edge. The use of bronze indicates that some knowledge of ores and metallurgy had been attained. It is likely that metallurgy had its birth in some primeval campfire in which ores containing copper or tin were exposed to the reducing action of the flames. The recognition that the exposure of certain rocks to fire produced metal and the reasoned repetition of the experiment marked the birth of metallurgical science. Native iron is a metal of exceptional rarity. Such supplies as were available to early man were obtained from meteorites; the Greenland Eskimos still follow the practice. The superiority of the metal was recognized, and it was highly prized, many legends having been preserved concerning swords of mythical origin falling from the skies. The art of reducing iron ores to crude metal was known in the 14th century B.C. A knowledge of the direct smelting of iron ores and finally of the production of steel, the most useful alloy of iron, followed at a much later date. The recognition of the superiority of metal over stone and the superiority of one metal over another established a pattern of political and economic procedure that is still active. The tribe with the most modern weapons won its wars and exercised domination over less advanced peoples. The first genuine interest in conservation was connected with the desire for a secure supply of those minerals essential to national defense.

Minerals in the Colonial Period

Minerals continued to play an expanding role in a growing civilization. The desire for mineral products became a powerful motivating force in the exploration and settlement of new lands. This demand for minerals also became the basis of a barter in goods leading to an established commerce. The Athenian civilization blossomed to heights of accomplishment in art, architecture, and philosophy at a time when the principal source of wealth was a silver mining operation located at Laurium. The peace imposed by Rome within the limits of the Empire permitted the discovery and operation of metal mining on a scale unequaled in the past. Roman engineering skill was directed toward the production of gold, silver, copper, tin, lead, and iron with the greatest energy. The metal produced made the army formidable and the excess, diverted to civilian uses, created improved living standards. The fall of the Roman Empire and the division of political power which followed it led to the onset of the Dark Ages. Mining operations languished or ceased entirely. Owing to their scarcity the value of metals increased. Unfortunately much of the accumulated knowledge of the occurrence of ores, methods of mining, and treatment of the derived metals was lost or retained only by a few people in restricted localities. This regrettable state of increasing ignorance and lower standards of living obtained until it was broken by an intellectual awakening which had its origin in part in the Crusades which brought the barbarians of western Europe in contact with the Arabian civilization in which the elements of astronomy, chemistry, metallurgy, and mathematics had been preserved and amplified. European thought and action reflected the stimulus of this event, and the forces of civilization started forward again. The discovery of the Americas released a flood of gold and silver most of which came to Spain and made that country a formidable power in European politics for a short time. The defeat of Spain by England led to the creation of the British Empire and the control of a substantial portion of the world's mineral resources. Interest in conservation was first noted in Elizabethan England.

It is a curious example of a dual interest in which the competition of minerals with other products produced a conflict of interests. The smelting of iron ores was done with charcoal. The inroads of the charcoal burners in the hardwood forests produced a shortage which threatened the oak timbers necessary for the maintenance of the Royal navy. The burning of charcoal in certain forests was therefore prohibited. As a result the introduction of coal and coke as smelting fuels was hastened. The problem of what should be conserved in the interests of national defense and how it should be done was recognized at this date. The problem is still acute and the solution illusive. Great Britain provides an example worthy of study of the effects of mineral depletion, attempts at conservation, and a declining economy induced by exhaustion of natural resources. It is frequently forgotten that at times Great Britain has led the world in the production of silver, lead, tin, iron, and copper. With the exception of iron the depletion of these deposits is now almost complete. Those social and economic problems connected with mineral depletion and the lack of any well-organized program of conservation have been encountered at a date many years earlier than their appearance in the United States of America.

Minerals and the Industrial Revolution

The first industrial use of the steam engine was in pumping water from mines. Flooded properties were restored to use, and deep mining made possible. The potential tonnage of minable ore was tremendously enlarged. Iron mines and coal lands increased in value and began to exert a localizing influence on the population, leading eventually to the development of cities near the mineral deposits. The invention of machines for spinning and weaving nearly destroyed the handicrafts and the cottage industries. The productive capacity of the individual worker was increased vastly, and wealth began to accumulate. The transformation from a rural to an industrial economy was initiated. The discovery that wealth could be obtained from manufacturing and distribution of the goods through trade led to the establishment of the factory system. The development of the locomotive and the steamship facilitated the movement of peoples and goods at rates unknown in the past. The machinery was being installed which was to lead to a wasteful and merciless exploitation of mineral resources. The same machinery made possible the production of mineral commodities in large quantities and in localities in the most remote parts of the earth.

The Rise of a Mineral Economy

The so-called Industrial Revolution originated almost contemporaneously with the American Revolution. The two movements had a profound influence on political thinking and economic development. The Industrial Revolution began with the development of a steam engine in useful form. The basic principles of steam power had been known for hundreds of years. But for all practical purposes the steam engine was invented in 1768 by James Watt who added those adjuncts necessary to change an ancient toy into a working machine of almost unlimited possibilities. It introduced the co-operative use of minerals. A coal fire beneath an iron boiler, partially filled with water, produced steam whose energy was employed to turn wheels. The impact of this simple device on the social and economic structure of society produced changes and pressures whose ultimate effects are still being introduced and even at the present time are not entirely understood. For the first time in history man had controlled energy at his disposal. Not the energy of a few domesticated animals with their incessant requirements for food, or the energy of erratic winds, or of small waterfalls, but energy derived from the combustion of mineral fuels existing in the earth in untold millions of tons.

Approximately one hundred years after the introduction of the steam engine another source of energy was released which was to have equally profound effects on the economic structure. This was the generation and distribution of electricity to the home and to industry. The first central power plant was erected in New York City in 1882. Copper, a metal of limited usage before this date, came into universal demand as a conductor. The high conductivity, low price, and ductility of this metal, permitting the production of wire with ease, immediately placed it in first rank as a necessity in the electrical industries. The replacement of steam by electricity was gradual and almost imperceptible at first. It still continues and is now conspicuous in the railroad systems. The electrification of industry is leading to a dispersal of industry, tending to counteract the concentrations of populations near coal mines. The invention of the telegraph, telephone, radio, electrical appliances, and the evolution of the automobile with its dependence upon electrical ignition created an unprecedented market not only for copper but for an increasing variety of other metals in constantly expanding tonnages.

The production of food has been considered the most basic of all human activities. And the inadequacy of supply has plagued many nations for generations; at times it has fallen to such low levels as to cause widespread starvation. The farm tended to be a small unit, generally a family affair, operated primarily for subsistence. Such surpluses as existed at times were marketed locally. This pattern still exists to a remarkable degree. Larger operations became possible only as unoccupied areas, such as the American west, were thrown open to settlement.

The shift of workers from the farm to the industrial city would have caused a serious depletion in the food supply of the nation if the productive capacity of the single worker had not been substantially increased. This increase is due to mechanization of the farm, a development that arrived with the twentieth century. The tractor, a metallic device, powered with mineral fuel, is now a common sight on many farms. It has multiplied the output per worker many times. It has also made the farm operator dependent on such machines.

The maintenance of soil fertility has grown steadily in social significance as new lands have become more difficult to obtain. It is no longer possible to abandon exhausted soils and move on to newer fields. Fertilizers have been employed for centuries. Among the most useful were manure, sea weed, wood ashes, bones, and animal and plant refuse. The quantities of such materials available for farm use simply were not sufficient for the growing acreage coming under cultivation to support a growing population. It became necessary to use minerals to supply the four most valuable substances, nitrogen, potash, lime, and phosphate. Fortunately these elements exist in mineral form in quantities large enough to satisfy the requirements of soil restoration for many years. Gradually, and with little public recognition of the fact, the agricultural industries have become dependent upon minerals for their continued existence.

The chemical industries have become a conspicuous and influential index of industrial activity in modern commerce. Nothing has contributed more to precision in manufacturing processes, the development of new goods, and the maintenance of American living standards than these industries. From an obscure origin largely concerned with early metallurgy and the manufacture of gunpowder they have grown into industrial giants of the first rank. They are dependent on minerals for over 90 per cent of their raw materials. And it must be remembered that in the field of organic chemistry much of the carbon, the basic nucleus of organic compounds, is derived from coal or petroleum. As stated by the U. S. Bureau of Mines, "The chemical industries depend upon minerals for a substantial part of their essential raw materials. Sulphur, salt, and lime are outstanding examples of well-known mineral substances employed in enormous quantities either for active reagents or as components of finished products. Chemical processes form the backbone of industrialization. In no nation or community can diversified manufacturing and processing industries become dominant unless chemical raw materials are available in adequate quantities at moderate prices. The United States has been richly endowed with most of these essential commodities, and their abundance and availability have been decisive factors in the enormous growth of the chemical industries that has marked the past 30 years." [1]

The consumption of mineral raw materials in the chemical industries has been great and the problems of conservation of growing importance, but it is significant that the application of chemical knowledge is providing the means by which conservation may be made effective. Research has developed new materials which may be substituted satisfactorily for familiar commodities of totally different origin. Thus, nylon, produced from minerals, may be used in place of silk from the worm, or rubber made from petroleum may replace the juice from the tree. The silicones, in which silicon is substituted for the carbon of organic compounds, produce many new and remarkable commodities. The conservation attained may benefit either the mineral or the organic field.

Minerals since 1900

It is apparent that the stage was being set for a demand for minerals without precedent in world history. The twentieth century has become the period of the greatest exploitation and waste of minerals ever known. It has also become the first period in which conservation has become a matter of paramount importance to the well-being of the country. The statement is made frequently that more minerals have been produced since 1900 than during all previous history. This statement actually falls far short of the truth. This is illustrated in Fig. 1 in which the production of the common metals in the United States from the date of earliest record through 1900, and the production from 1901 through 1945 are represented graphically. A similar condition exists for minerals not represented.

This acceleration in production has been made possible by a combination of factors. Among the most important are improvements in transportation by which remote areas have been made productive, the development of the automobile and good roads, expansion in electrification, invention of the airplane, and advancements in mineral engineering and technology. Among the contributions of science the de-

[1] Oliver Bowles and Ethel M. Tucker, "Trends in Consumption and Prices of Chemical Raw Materials and Fertilizers," *Information Circular* 7320, Bureau of Mines, Department of the Interior, Washington, D. C., 1945.

velopment of improved explosives, the invention of the air drill, and the application of the flotation process have been noteworthy. The size of the United States, with its millions of consumers living in 48 states without tariff walls, has permitted the development of that extraordinary American phenomenon, mass production. It has been developed to its highest state in the manufacturing industries. Concentrations of large tonnages of low-grade ore are amenable to similar techniques. Such operations have been successful in the porphyry coppers and in certain iron mines and limestone quarries. The economies of such operation are such that they have contributed large tonnages of material to industry at low cost.

The first half of the twentieth century witnessed wars which for violence, destruction, number of people, and area involved were without parallel. The amounts of mineral products consumed and the controlling influence which they exerted on the strategy and final outcome of the conflicts were also without precedent. Huge and uncontrollable wastages of irreplaceable material resulted. Shortages, particularly of metals, brought about the salvaging of old material, rationing of critical materials, prohibition of civilian use, and an intensive search for new sources. The importance of minerals in the economy of the country and the necessity for conservation in their use were brought to the attention of millions of citizens for the first time. Wars, because they are horribly wasteful, tend to publicize the desirability of conservative use of natural resources and are followed by a period in which interest in conservation increases.

The population of the United States has almost doubled since 1900. Population in 1900 was reported to be just under 76,000,000 as compared with approximately 149,000,000 in 1949. This increase has created markets that strained the productive capacity of the country. The basic problem of industry during part of this time has been one of production and not distribution.

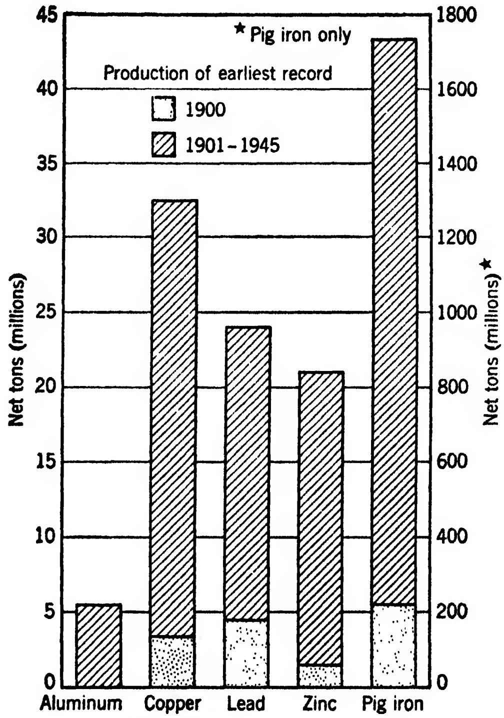

FIG. 1. Production of common metals in the United States.

tion. Efficient recovery of mineral raw materials frequently was sacrificed for speed and profit. Many wasteful processes were ignored or tolerated to the detriment of conservative practice. The first change in the production-distribution pattern was noted after the close of World War I when excess capacity, originating in wartime expansion, produced more goods than the market could absorb. Overcapacity to produce tended to be the problem rather than actual overproduction. This condition was obscured during the rising tide of prosperity in the 1920's and did not become prominent until the depression years of the 1930's. World War II again utilized all the country's capacity to produce and expanded it. Certain problems associated with overproduction may be present again in the post-war years of economic adjustment.

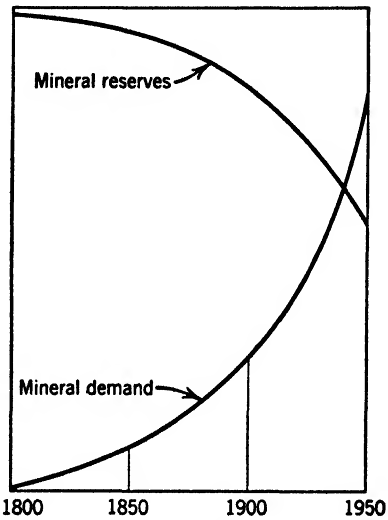

FIG. 2. Nature of ore reserves.

Mineral production increases at a far more rapid rate than population growth. This is shown by the remarkable increase in the value of mineral wealth produced per capita. In 1900 this amounted to $14; in 1945 it was $62. In part an increase in price as well as in production is reflected. Expansion in production will undoubtedly continue for an indeterminate period in the future, provided that the mineral resources exist in adequate quantities to support such a productive flow. They will not be sufficiently abundant unless proper measures are devised and applied to increase the efficiency of mineral utilization and the conservation of our mineral reserves.

The per capita trend of all mineral consumption with the outstanding exception of coal has been upward. Actually the tremendous increase in per capita consumption has been the cause of depletion of mineral resources to a degree unpredictable in the past. There is no evidence of any marked decline in this trend. Predictions as to the future life of reserves at the present rate of consumption are likely to be of little value and may be seriously in error. The consumption will be greater than anticipated, and, unless conservative measures are applied, the demands of the future cannot be met. A decline in per capita consumption of a mineral commodity of major importance may serve as a clue to an increased efficiency in use or the emergence of a competitive material.

The estimated relationships of mineral reserves and demand for a 150-year period are shown in Fig. 2. It will be noted that the decline in mineral reserves and increase in demand have accelerated with greatest rapidity since 1900. The demand for minerals would have long since exhausted the reserves as understood in 1800 if there had not been a constant readjustment in ideas as to what constitutes a mineral resource. These readjustments have been caused by the application of new technologies by which the grade of ore has been lowered allowing great tonnages of material, previously considered worthless, to be added to reserves.

THE NATURE OF MINERAL RESOURCES

In their entirety mineral resources represent the complete mineral endowment of the earth. In actual usage the term is applied commonly to materials of commercial significance. That is, the tendency is to calculate resources in tonnages of raw materials suitable for use by the standards of the time. As these standards shift constantly it is desirable to consider the ultimate composition of the earth. This composition and the relative abundance of the elements represented will exert a controlling influence over the employment of minerals in any long-range program and over the urgency with which conservative measures must be applied to individual items. The data in Tables 1, 2, and 3 are taken from Clarke and Washington.[2]

TABLE 1

ESTIMATED AVERAGE COMPOSITION BY ELEMENTS OF THE EARTH'S CRUST

[Source: *Prof. Paper* 127, U. S. Geological Survey.]

	Per Cent
Oxygen	46.710
Silicon	27.690
Aluminum	8.070
Iron	5.050
Calcium	3.650
Sodium	2.750
Potassium	2.580
Magnesium	2.080
Titanium	0.620
Hydrogen	0.140
Phosphorus	0.130
Carbon	0.094
Manganese	0.090
Sulphur	0.052
Barium	0.050
Chlorine	0.045
Chromium	0.035
Fluorine	0.029
Zirconium	0.025
Nickel	0.019
Strontium	0.018
Vanadium	0.016
Cerium, yttrium	0.014
Copper	0.010
Uranium	0.008
Tungsten	0.005
Lithium	0.004
Zinc	0.004
Columbium, tantalum	0.003
Hafnium	0.003
Thorium	0.002
Lead	0.002
Cobalt	0.001
Boron	0.001
Beryllium	0.001
Total	100.000

Composition of the Earth's Crust

Examination of Table 1 discloses that eight elements are present in the earth's crust in quantities over one per cent. These eight make up 98.58 per cent of the total. It appears inevitable that over a long period of time these elements will come into increased use simply because of their abundance. The so-called common metals, nickel, copper, zinc, and lead, are far from common. They are actually among the very minor constituents of the earth's crust. It is also noteworthy that such well-known and commercially useful metals as gold, silver, platinum, antimony, bismuth, tin, mercury, and many others occur in such extremely small amounts in the earth's crust that they are not represented at all in a percentage treatment.

Ores in the Earth

Most of these metals have become known because by an extraordinary sequence of geologic processes they have been concentrated in quantities sufficient to attract attention and ultimately to permit economic extraction. Ore bodies are rare not only because they are formed by unusual events but also because these events must have occurred in the proper order. Many ore bodies are formed at great depths and the

[2] Frank Wigglesworth Clarke and Henry Stephens Washington, "The Composition of the Earth's Crust," *Prof. Paper* 127, U. S. Geological Survey, Washington, D. C., 1924.

possibility of their discovery is improbable until erosion has removed sufficient thousands of feet of overlying rocks to bring the ore or the indications of its presence near the surface. It is probable that undiscovered mineral deposits exist at great depths, and it is also more than probable that many ores have been destroyed completely by erosion and only traces of their most insoluble and resistant constituents remain.

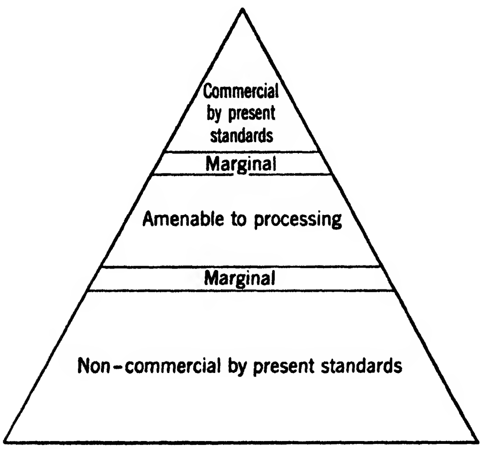

FIG. 3. Mineral reserves and mineral demand.

Man's advent on the earth and his interest in certain minerals introduce an element of timeliness in respect to geologic time. Hence, many of the most productive mineral areas in the United States, such as the copper deposits of Arizona, the mother lode gold ores of California, and the lead ores of Missouri may be considered geologic rarities which were formed in ancient time, exposed to enough erosion so that their presence was visible, and were then discovered and exploited before destruction by natural forces. An ore has been defined many times as mineral matter minable at a profit. It might be defined with greater meaning as mineral matter whose extraction is believed to be profitable.[3] The factors that actually control profit may be remote from the ore, and the same deposit and material may be profitable or unprofitable, depending upon many varying and at times uncontrollable conditions. The profit motive or hope of profit tends to classify mineral matter as ore or gangue, its worthless associate.

The true nature of mineral resources has been altered constantly by the utilization of new technologies permitting the use of lower grade material. The minimum percentage content of metal permissible to classify mineralized matter as ore has been lowered steadily since 1800. As stated by Corry and Kiessling, "Grade tends to vary inversely with tonnage." [4] The large tonnage producers of gold, copper, and iron ores have been able to effect such economies in operation that the grade of ore that could be called commercial constantly drops. Increases in the efficiency of operation allow the treatment of lower grade ore. Conversely an increase in price for the product mined will also increase the tonnage of reserves by permitting treatment of material formerly considered worthless.

The nature of ore reserves is illustrated by Fig. 3. Exact separations between the different grades of ore cannot be drawn and a marginal zone exists in all classifications. The tonnage is approximately proportional to the area. The peak of the pyramid has already suffered violent depletion and for certain metals has been nearly destroyed.

[3] W. M. Myers, "Additional Concepts of Ore Reserves," *Mining and Metallurgy,* Vol. 27, 1946, pp. 180–181.

[4] Andrew V. Corry and O. E. Kiessling, "Grade of Ore," *Report No.* E-6, Works Progress Administration. National Research Project, August, 1938.

The tonnages of material of lower tenor constantly increase for almost all minerals. It is in this area that the application of new technologies can be most effective as a conservative force.

Minerals from the Sea and the Atmosphere

The last frontiers of the planet have been invaded in the search for minerals. The ocean and the atmosphere are now prolific sources of certain materials. The composition of the ocean is given in Table 2.

TABLE 2

COMPOSITION OF THE OCEAN

[Source: *Prof. Paper* 127, U. S. Geological Survey.]

	Per Cent
Oxygen	85.79
Hydrogen	10.67
Chlorine	2.07
Sodium	1.14
Magnesium	0.14
Calcium	0.05
Potassium	0.04
Sulphur	0.09
Bromine	0.008
Carbon	0.002
Total	100.000

All elements are present in small quantities not easily represented on a percentage basis. The recovery of sodium chloride, magnesium, magnesia, and bromine is carried on as a commercial venture. Iodine and potassium have been recovered indirectly. Other elements may become significant with the passage of time. The reserves of magnesium and bromine have been expanded enormously by the use of sea water as a primary source.

The composition of the atmosphere is shown in Table 3.

TABLE 3

VOLUMETRIC COMPOSITION OF THE ATMOSPHERE

[Source. *Prof. Paper* 127, U. S. Geological Survey.]

	Per Cent
Nitrogen	78.03
Oxygen	20.99
Argon	0.94
Carbon dioxide	0.03
Hydrogen	0.01
Neon	0.00123
Helium	0.0004
Krypton	0.00005
Xenon	0.000006
Total	100.001686

The industrial recovery of nitrogen and its compounds and the recovery of oxygen have become important industries. Neon, argon, and other rare gases are recovered in commercial quantities.

Reserves for the Future

Estimation of the tonnage and quality of mineral resources available for future use cannot be determined with satisfactory accuracy, partly because of the geologic nature of the resources. They are buried in the ground or dispersed in solution. They cannot be seen readily nor can their magnitude be measured with ease. The mineral deposits themselves, with the exception of such bedded structures as exhibited by coal, salt, clay, gypsum, and similar materials, may display unpredictable irregularity in size, shape, and mineral content. The concept of what qualifies as a reserve is subject to constant revision by the applications of new techniques in discovery, production, and processing. The concept of an economic reserve is subject to further modification by variations in price, extension of transportation systems by which remote areas may be tapped, and new discoveries.

It is a significant fact that no new discoveries of primary magnitude have been made in the United States since 1910. It is obvious that the easily located mineral deposits, whose presence has been disclosed at or near the surface, have been found.

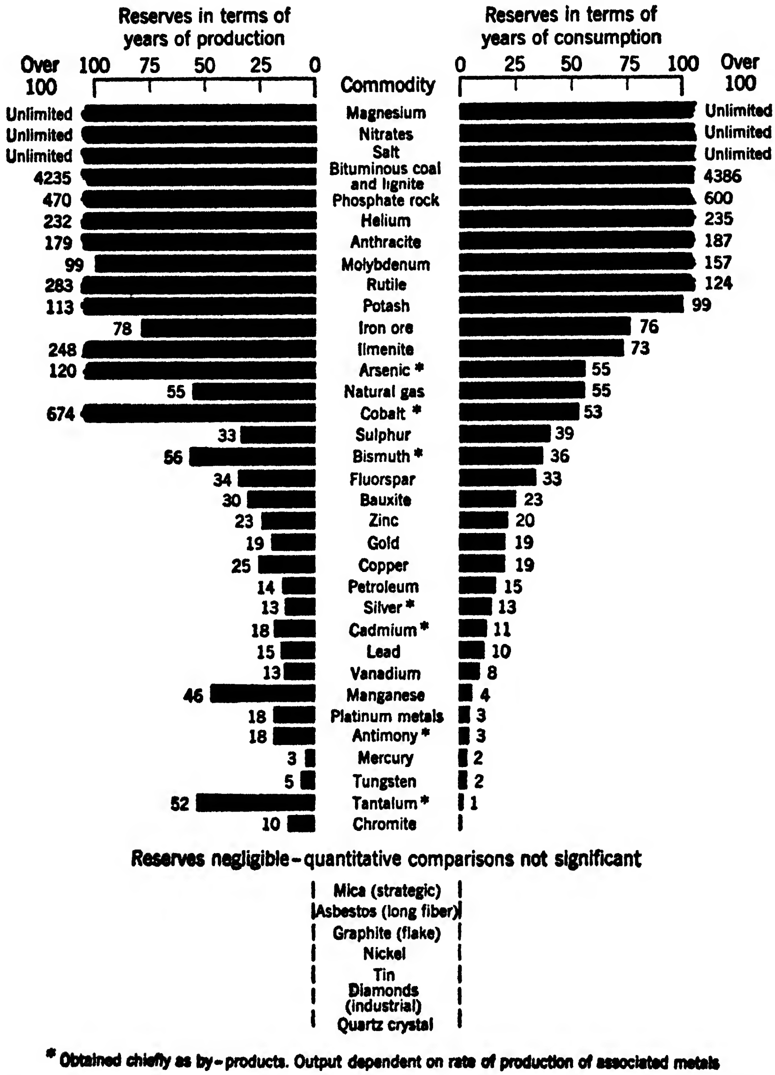

FIG. 4. Estimated "commercial" reserves as of 1944. (*Eng. Mining J.*, Vol. 148, 1947.)

As nearly accurate an inventory as possible of the minerals left for the support of future generations is necessary for the intelligent solution of the problems involved in conservation. The size and financial requirements of such an undertaking on a national basis are such that individual action is neither feasible nor economically possible. Therefore, inventorying of resources has been assumed by the government operating through the Department of the Interior. This department, with the

Bureau of Mines and the Geological Survey, contains one of the nation's most complete combinations of scientific personnel and equipment competent to deal with an undertaking of such exceptional magnitude. A report with data relative to the estimated reserves and the degree of American self-sufficiency in its principal minerals was prepared and presented to Senator Malone's subcommittee on mines and mining of the Senate Public Lands Committee, in May, 1947. A summary of this report by Elmer W. Pehrson, chief of the economics and statistics branch of the Bureau of Mines, and S. G. Lasky, principal geologist of the Geological Survey, was published in the June, 1947, issue of the *Engineering and Mining Journal* by whose kind permission

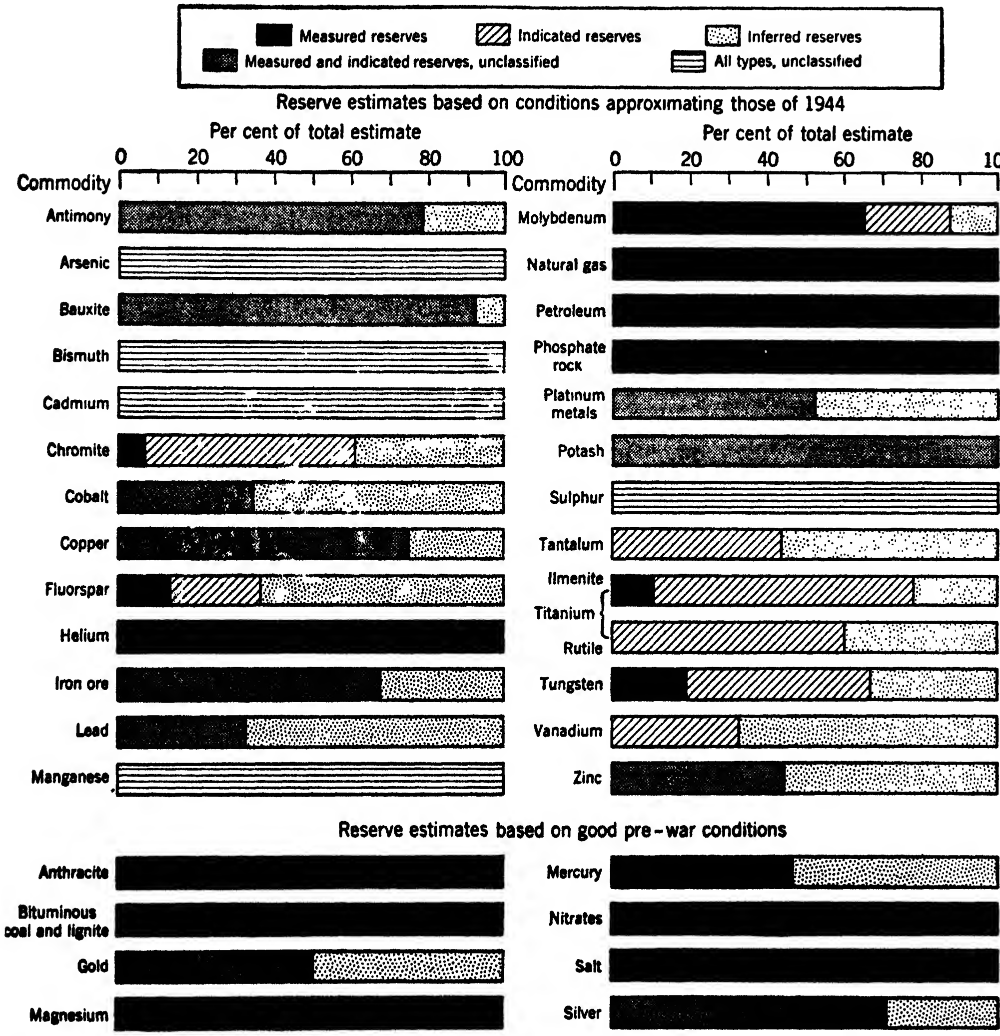

FIG. 5. Percentage of measured, indicated, and inferred reserves included in estimates of "commercial" reserves in the United States. (*Eng. Mining J.*, Vol. 148, 1947.)

TABLE 4

U. S. Mineral Position—Actual, Impending, and Potential

Based on known "commercial" reserves, outlook for noteworthy discovery, and the possibility that known submarginal resources can be made available by technologic progress and improved economic conditions.

[Source: *Eng. Mining J.*, Vol. 148, 1947.]

Relative Self-Sufficiency

Actual and Impending

(Based on present technologic and economic conditions and on known "commercial" reserves.)

A. Virtual self-sufficiency assured for a long time:

Bituminous coal and lignite	Molybdenum	Nitrates
Anthracite	Fluorspar (metallurgical)	Phosphate rock
Natural gas	Helium	Potash
Magnesium	Magnesite	Salt
		Sulphur

B. Complete or virtual dependence on foreign sources:

1. Small or remote expectation of improving position through discovery:

Chromite	Platinum metals	Quartz crystal
Ferro-grade manganese	Tin	Asbestos (spinning quality)
Nickel *	Industrial diamonds	

2. Good expectation of improving position through discovery:

Cobalt *	Graphite (flake)

C. Partial dependence on foreign sources, actual or impending:

1. Good expectation of improving position through discovery:

Petroleum	Iron ore	Zinc
Arsenic *	Lead	Fluorspar (acid-grade)
Bismuth *	Mercury	
Cadmium *	Tantalum *	
Copper	Tungsten	

2. Little hope of improving position through discovery:

Antimony *	High-grade bauxite	Strategic mica
Vanadium		

Potential

(If technologic and economic changes permit use of known submarginal resources.)

A. Virtual self-sufficiency:

Bituminous coal and lignite	Magnesium	Helium
Anthracite	Manganese	Magnesite
Natural gas	Molybdenum	Nitrates
Petroleum	Titanium	Phosphate rock
Aluminum ore	Vanadium	Potash
Copper	Fluorspar (all grades)	Salt
Iron ore	Graphite (flake)	Sulphur

B. Complete or virtual dependence on foreign sources:

Platinum metals	Industrial diamonds	Asbestos (spinning quality)
Tin	Quartz crystal	

C. Partial dependence on foreign sources:

Antimony	Chromite	Tungsten
Arsenic	Lead	Zinc
Bismuth	Mercury	Strategic mica
Cadmium	Nickel	
Cobalt	Tantalum	

* Domestic production chiefly by-product.

Figs. 4 and 5 and Table 4 are reproduced.[5]

The estimated commercial reserves as of 1944 are shown in Fig. 4, in terms of years of production and years of consumption. It is apparent immediately that, apart from the first five items, the reserves as represented are adequate for only very limited periods of time, the actual number of years involved at the maximum amounting to

[5] Elmer W. Pehrson, "Interior Department Revises Mineral Reserve Estimates," *Eng. Mining J.*, Vol. 148, 1947, pp. 80–83.

only a few generations. The metals, particularly, are in short supply, and the future life of iron ore, bauxite for aluminum, gold, silver, copper, lead, and zinc exhibits a brevity of shocking import. Fortunately the most important nonmetallics, nitrates, phosphate rock, potash, and salt, are among the most abundant reserves. Sulphur and fluorspar are in relatively short supply. It is noteworthy that the reserves of the very useful and strategically important nonmetallics, particularly mica, asbestos, graphite, industrial diamonds, and crystal quartz, are available in such negligible quantities that significant comparisons cannot be made. Pehrson and Lasky state that the present knowledge of mineral resources is entirely inadequate to permit an accurate appraisal of total mineral wealth. The data presented are restricted to known mineralized areas as appraised by accepted methods. The estimates include measured, indicated, and inferred reserves. Measured reserves have been exposed sufficiently to permit quantitative measurement. Indicated reserves are calculated from indications of reasonable accuracy. Inferred reserves include material for which there is little visual evidence but whose presence may be inferred from geologic evidence of reasonable acceptance. Commercial reserves include mineral material workable under the conditions obtaining in 1944. The distribution of reserves according to the per cent included under each degree of assurance is shown in Fig. 5.

No allowances have been made for discoveries in the future. Therefore, it is probable that during the life of the reserve, as now known, developments will appear that will alter and prolong its longevity. These developments may be new discoveries, improvements in technology, increases in price, or stimulation of production by subsidy The important lesson to be derived from Figs. 4 and 5 is that official government agencies attempting to arrive at the truth have estimated the future life of domestic reserves of many of our most useful metals to be a few decades at most. The necessity of a conservative attitude in the utilization of these materials requires no further demonstration.

No nation is entirely self-sufficient with regard to its mineral requirements. The degree of self-sufficiency worsens with time due to depletion of domestic supplies and the creation of demands for minerals not available locally. Normal commerce in times of peace permits the import of foreign materials with benefits to both parties concerned. In wartime this may become impossible owing to alignment of the supplies with the opposition, enemy action, or lack of shipping facilities. The desire for mineral self-sufficiency invariably displays itself before and during periods of hostilities. It is evident that those materials for an adequate supply of which we are partially dependent upon foreign sources should be used with caution. The position of the United States with regard to self-sufficiency is shown in Table 4.

Practice of Conservation

The practice of conservation tends to be popular in theoretical appeal but distasteful in application, because it requires special effort and interferes with normal operations. It is concerned with a conflict between the future with its indefinite and unknown requirements and the present with its positive and immediate demands for minerals of specified quality in established tonnages. There is also a conflict between profits of the present age and the social welfare of future generations. To be successful the practice of conservation must emphasize actual saving of material, encourage the re-use of all products possible, and decrease all wastes. And such activities must be practical economically. Sufficient profit must accrue from the operations to justify their continuance. Where this is not possible the government may absorb the pecuniary loss in the best interests of the country as a whole. The practice of conservation has not been a conspicuous feature in the American scene. The reverse has been more evident and the development of the country to its present pre-eminence in industrial production has been accompanied by an appalling waste of natural resources without parallel in history. Such savings as have been practiced are the basis of particular industries, such as the collection of junk and the recovery of secondary metal. Also in periods of national emergency the people, under the stimulus of patriotic appeal, have been induced to collect and save as much metal as possible.

Research

Research has been termed a national resource.[6] It is acknowledged to be essential to the conduct of government. Under government sponsorship it rose to its most spectacular heights in the development of the atomic bomb. The term "research" is used in a broad sense meaning all activities connected with the discovery, collection, assembly, and interpretation of facts. It includes economic studies connected with the production and marketing of minerals, as well as laboratory and engineering studies associated with their production and processing, and fundamental research in the basic properties of the minerals themselves. Intelligent action can be based only on facts. All the facts concerned with the relationship of reserves to production and consumption must be assembled. Production data are relatively abundant, complete, and reasonably accurate. Data dealing with consumption are incomplete or lacking and frequently do not supply the information necessary for the solution of the closely related problems of marketing. The ultimate consumption of some mineral commodities is at times so obscure as to make impossible an accurate appraisal of the requirements of such markets. The interpretation of the extraordinarily complex effects of technological progress on the economic structure and the mineral market will be possible only when factual data are assembled. Research is the foundation of technical advancement. The increased utilization of minerals requires an expansion in the knowledge of their basic properties. The same knowledge may permit more efficient utilization and the development of substitutes in the best interests of conservation.

Discovery

It is desirable to broaden the base of mineral supplies by new discoveries. The rate of consumption has been far greater than the rate of discovery for years, and only the remarkable magnitude and richness of mineral areas known before 1900 has made possible the production which has characterized this century. The search for minerals during this period has been

[6] National Resources Committee, *Research—A National Resource, I. Relation of the Federal Government to Research,* U. S. Government Printing Office, Washington, D. C., 1938. National Resources Planning Board, *Research—A National Resource, II. Industrial Research,* U. S. Government Printing Office, Washington, D. C., 1940.

acute, but most of it has been carried on by the oldest method, examination of the surface by the prospector. It is improbable that any areas of appreciable size or known promise have been neglected. It is evident that this method of discovery has reached its maximum usefulness. Further discoveries appear dependent upon the application of geologic techniques and geophysical methods, by which certain physical properties of the earth may be measured and the possible presence of ore bodies deduced. These methods are still in a state of change and development. Their potential usefulness has not yet been disclosed. An actual inventory of the mineral resources of the country by such methods and by the use of exploratory drilling is of such formidable size that it can hardly be undertaken by agencies other than the federal or state governments. A re-examination of mineralized areas in the eastern states that have been nearly forgotten owing to the evolution of the huge western producers is also in order.

REDUCTION OF WASTE IN EXTRACTION AND PROCESSING

Waste has been defined by Rockefeller as follows: "Whenever the word is used thoughtfully, 'waste' denotes an unfavorable comparison between an actual situation and another possible or ideal situation. Quantitative measures of waste must necessarily be expressed as ratios of the actual compared with the possible or the ideal. Waste is a degree, not a magnitude." [7] The reduction of waste to the minimum degree is a prime objective of conservation. The maximum recovery of values and efficiency of operation in metal mines has been attained in the large open cuts such as are associated with the porphyry coppers. Recovery approaches 100 per cent in extraction and over 90 in processing. Such margin as exists for improvement lies only in concentrating and smelting operations. And in these operations such proficiency has been attained that there is little economic margin for improvement.

Substantial increases in metal prices would justify additional treatment at further cost and the recovery of some metal values now lost. In underground mines there may be some loss due to the necessity for leaving pillars, which may or may not be recovered at a later date. There have been occasions when poor recovery was made simply because of ignorance of the form and attitude of the ore body, which was so complex that valuable ore concentrations were missed by the first operators because their presence was not suspected. The principal cause of loss in metal mining tends to originate in the cut-off point at which the material ceases to be ore. That is, if material containing less than one per cent of values, or whatever the cut-off value is, cannot be mined it is left undisturbed. Its recovery at a later date when values are higher is as likely to be hindered as facilitated by the fact that the material lies near mine openings. These openings instead of being an asset as a means of entry may become a liability because of caving, flooding, and the fact that the ground may be in unworkable condition. It will be recalled from the nature of ore reserves as exhibited in Fig. 3 that the tonnage of low-grade, noncommercial material may be large and in the aggregate contain a desirable and theoretically valuable amount of metal. Basic differences between the problems of

[7] David Rockefeller, *Unused Resources and Economic Waste*, The University of Chicago Press, Chicago, Ill., 1941.

conservation of the metals and the fuels become apparent. The fuels display notoriously high losses in extraction and complete destruction in use. The metals and many of the nonmetallics enjoy a reasonably high percentage of recovery and if properly used may be reclaimed for repeated use.

Reduction of Waste in Use

A certain amount of waste is unavoidably connected with the utilization of metals, even the most valuable which are protected with care. Certain metals are so employed that a substantial percentage of the metal is consumed with little or no opportunity for recovery and re-use. It is unfortunate that the metals so used are among those possessing the smallest reserves for the future. Tin, lead, and zinc are outstanding examples in this category. The consumption of tin in the United States is presented in Table 5.

TABLE 5

CONSUMPTION OF TIN IN THE UNITED STATES, 1945

[Source: U. S. Bureau of Mines.]

	Long Tons		
	Primary	*Secondary*	*Total*
Tin plate	26,080	.....	26,080
Terneplate	493	248	741
Solder	10,930	3,399	14,329
Babbit	4,144	3,684	7,828
Bronze and brass	9,093	17,972	27,065
Collapsible tubes	515	44	559
Tinning	2,390	202	2,592
Foil	181	64	245
Chemicals	196	448	644
Pipe and tubing	204	89	293
Type metal	10	1,281	1,291
Bar tin	963	131	1,094
Miscellaneous alloys	378	228	606
White metal	65	151	216
Total	55,642	27,941	83,583

Primary metal is that derived directly from the ores. Secondary metal is that reclaimed from material previously used. The table indicates that not all common tin-consuming commodities require some primary metal. Unavoidable losses in use eliminates the possibility of reliance on secondary metal alone. Tin plate, of prime importance to the canning industry, is manufactured directly from primary metal. Tin-plate scrap may be saved and detinned and the secondary metal employed in the manufacture of chemicals. It is of interest that the largest single consumer, bronze and brass, obtains nearly two-thirds of its tin from secondary sources. However, the tonnage used in the production of tin plate, terneplate, solder, collapsible tubes, and foil is subject to excessive loss. The tin scrap produced in the manufacture of cans may be reclaimed but a large number of the cans themselves are thrown away as may be noted by the examination of any city or village dump. The disposal of collapsible tubes and tinfoil is equally wasteful except in wartime when special efforts have been made to induce the public to effect savings.

The consumption of refined lead in the United States in 1945 as reported by the U. S. Bureau of Mines is shown in Table 6.

The most conspicuous totally consuming uses in the above list are ammunition, solder, terneplate, white lead, red lead and litharge, tetraethyl lead, chemicals, and insecticides. The amount of material that may be recovered for secondary use from this list is small at best. As these uses comprise 37 per cent of the total it is apparent that a large proportion of the annual lead production is being diverted to uses where recovery is impossible. The superiority of white lead as a paint pigment, red lead for

TABLE 6

CONSUMPTION OF REFINED LEAD IN THE UNITED STATES, 1945

[Source: U. S. Bureau of Mines.]

	Short Tons
Ammunition	29,315
Bearing metals	14,104
Brass and bronze	7,069
Cable covering	86,158
Calking lead	13,374
Casting metals	5,322
Collapsible tubes	7,428
Foil	2,185
Pipe, traps and bends	24,061
Sheet lead	30,624
Solder	27,475
Storage batteries	60,179
Terneplate	2,178
Type metals	1,401
White lead	35,611
Red lead and litharge	157,171
Tetraethyl lead	75,890
Chemicals and insecticides	8,567
Annealing	5,525
Galvanizing	988
Lead plating	1,130
Weights and ballast	9,539
Other	32,205
Total	637,499

TABLE 7

CONSUMPTION OF SLAB ZINC IN THE UNITED STATES, 1945

[Source: U. S. Bureau of Mines.]

	Short Tons
Galvanizing	
Sheet and strip	135,383
Tubes and pipe	63,163
Wire and wire rope	46,083
Fittings	10,014
Other	82,538
Total	337,181
Brass products	
Sheet, strip, and plate	146,375
Rod and wire	67,299
Tube	21,507
Castings and billets	12,942
Copper-base ingots	9,893
Other copper-base products	1,361
Total	259,377
Zinc-base alloy	
Die castings	121,966
Alloy dies and rods	8,286
Slush and sand castings	584
Total	130,836
Rolled zinc	97,589
Zinc oxide	18,113
Other uses	
Wet batteries	1,790
Desilverizing lead	2,095
Light-weight alloys	1,469
Other	3,861
Total	9,215
Total, all uses	852,311

metal protection, and tetraethyl lead in reducing knock in gasoline is undisputed, but it remains a regrettable fact that so much of one of the most useful and scarcest metals should be so employed as to be destroyed beyond reclamation.

Galvanizing, the process of coating steel with zinc for rust protection, is the largest single consumer of the metal. Zinc so employed is eventually dissipated and irretrievably lost. Little zinc is recovered as such; most of the metal reclaimed for secondary use is found in its most common alloy, brass. The consumption of zinc in the United States in 1945 is shown in Table 7.

Recovery of Secondary Metals

The greatest opportunity for the conservation of metals lies in their re-use. The collection of such metal has become a well-organized industry. The terms secondary and scrap are used interchangeably, and at times the entire industry is referred to as the junk business. The degree to which metals enter the secondary market is controlled by value, properties, how they are employed, and at times where they are employed. Gold, silver, platinum, and other precious metals are protected from loss and excessive wear and pass through many cycles of utilization. A portion of the gold stock of the United States is undoubtedly of ancient origin and has appeared in many forms during its long existence. Metals that resist corrosion may be exposed for long periods of time with little loss and later be used again. Copper and lead belong to this class; long exposure to the weather produces little change other than the development of a surface coating of oxidation products which protects the metal from further attack. Lead used in the storage battery or in the form of cable may be recovered and re-cycled many times. The same metal employed as a pigment in paint or in gasoline in the form of tetraethyl lead is lost beyond recovery. Unfortunately the great problem of rust protection for ordinary steel is yet to be solved, and rust losses continue to amount to many millions of dollars annually. Metals used in densely settled and highly industrialized areas tend to accumulate in large tonnages and can be recovered for secondary use owing to their proximity to transportation and a market.

The loss of metallic equipment during the war was disastrously large because so much of it was located in geographic areas beyond the limits of economic transportation, or was sunk at sea. The recovery of secondary material effects economies beyond the saving of the metal itself. It also saves time, transportation, costs of raw material, fuel, labor, and expense. A ton of steel scrap represents two tons of iron ore, 2600 pounds of coke, a substantial amount of fluxing stone, and at times important ferro-alloy elements. Therefore the savings produced by the use of such material affects many operations. Small steel companies depend entirely on its use in making steel. An increase in the metal-saving habits of the public is desirable and can be accomplished as was demonstrated during the war. However, such a program will meet with little success unless the public is convinced of its necessity and the necessary organization is ready to provide for the prompt and convenient removal of accumulated material.

Use of Substitutes

Direct substitution of metal by-products obtained from replaceable resources, plants and animals, exists in a small degree. Such substitution is rarely made because the metals have demonstrated such superior qualities that any change is likely to be marked by poorer performance. Wooden beams may replace steel but rarely do except for ornament as they lack tensile strength, permanence, and fire resistance. As noted earlier in this chapter, fertilizer elements of organic origin can be used but are not available in tonnages sufficient to provide for the large areas now under cultivation. The development of many new plastics is changing the competitive picture, and an increased competition and substitution of metal by plastic bonded materials may be expected. Some of these plastics are of mineral origin and serve to indicate the ultimate possibilities in the use of minerals. The extraordinary strength and performance exhibited by planes constructed of bonded wood veneer and the remarkable properties of glass fibers when bonded with plastics indicate that they will become increasingly competitive with metals in some fields and their use will effect some conservation. They are not likely to displace large tonnages or produce any drastic changes in the metal markets.

TABLE 8

METAL PRODUCED IN THE UNITED STATES IN 1945

[Source: U. S. Bureau of Mines.]

	Short Tons Primary Metal	*Short Tons Secondary Metal*	*Value of Secondary Metal*
Aluminum	496,487	298,387	$ 85,297,005
Antimony	1,930	17,148	5,432,487
Copper	782,726	1,006,516	237,537,776
Lead	356,535	363,039	46,468,992
Magnesium	32,792	9,247	3,791,270
Nickel	1,155	6,483	4,538,100
Tin	0	35,133	36,538,320
Zinc	467,084	360,444	61,996,368
Steel	79,701,648	56,191,085	Ferrous scrap consumed
	Fine Ounces	*Fine Ounces*	
Gold	954,572	885,483	30,991,905
Silver	29,024,197	58,360,767	41,494,505

Within its limitations one metal may replace another satisfactorily as has been shown by the substitution of aluminum for copper as an electrical conductor, and aluminum for iron and copper in cooking utensils. The scarcity of ferro-alloy elements during the war resulted in some substitution. In the general program of conservation of such important alloying elements as nickel, molybdenum, chromium, manganese, and vanadium, the aim was to produce steels of low alloy content with essentially the same properties as steels containing larger amounts of these elements. The development of the NE (National Emergency) steels originated from a general program of conservation coupled with a careful selection of the usable alloying elements. Reduction in the amounts used and substitution of elements was found possible although the usual difficulties were encountered which are associated with any program of substitution that involves some sacrifice of certain desirable characteristics in a definite steel. Over a long period of time as shortages become more acute a replacement of the less abundant by the more abundant elements may be expected. The relative abundance of elements in the earth's crust is shown in Table 1.

A comparison of the production of primary metal and secondary metal and its value is exhibited in Table 8.

Quality Conservation

Quality conservation implies the use of the lowest grade material that can be employed satisfactorily for a definite operation and the saving of superior materials for such purposes as can benefit by superior quality. Opportunity for the application of such conservation exists in the use of the fuels with their high variations in composition, behavior, and heating value. Little opportunity exists with the metals because the introduction of similar technologies of production and processing throughout the world has leveled quality. That is, a pound of copper is identical in performance whether it originated in Rhodesia, Chile, or Montana. Second-quality metals can scarcely be said to exist. Choice in the use of certain metals and in the use of many alloys is usually made on the basis of cost rather than on the basis of conservation.

NATIONAL POLICIES AND INTERNATIONAL RELATIONS

The basic problems of conservation are so universal in distribution and so closely associated with the well-being of the country that they can be investigated and solved only on a national basis. Unfortunately no unified national policy has been adopted nor has any long-range program directed toward conservation been made a part of any policy. Those activities connected with exploration, production, processing, marketing, and the conservation of minerals are scattered in a number of bureaus in various departments of the federal government. The number of these agencies increases in wartime when problems of supply become acute.

The Application of Science

Research in fundamentals and the development of new processes through the pilot-plant stage has proved to be one of the most desirable and profitable of governmental activities. The government through its diversified scientific agencies is justified in undertaking abstract research of remote promise of practical results. It has been demonstrated repeatedly that the most abstract research of one generation becomes the basis of industry in the next. Research in the basic properties of minerals, their crystals and their atoms, and the geologic environment in which they occur may supply the necessary data by which substitutes may be prepared, economies in use attained, and new supplies added to the waning reserves.

Inventory

An intelligent application of the principles of conservation can be made only with an accurate knowledge of the reserves remaining for future use. The difficulties of such an operation have been mentioned. A useful inventory of national scope requires continual revision in the light of new discoveries, new technologies, shifting demands, and changing prices. Such an inventory eventually should expand to the extent of including the geologic mapping of the entire country and actual exploration to depths of economical mining by drilling or other approved methods.

Strategic Minerals

All minerals are of the greatest importance in war and those in which the United States has led the world in production, such as coal, oil, and iron, are at the top of the list. The term "strategic" has been applied more commonly to those materials that are totally lacking or are present in inadequate supply within the political boundaries of the country. They might be defined more exactly as the deficiency minerals. Tin, manganese, chromium, tungsten, vanadium, bauxite, mica, industrial diamonds, and quartz crystals are conspicuous examples. The degree of self-sufficiency is shown in Table 4. The feasibility of the purchase of these deficiency minerals by the government and their storage in stockpiles for times of emergency has been the subject of debate, appropriation of funds by Congress, and a certain amount of action.[8] The problem is a part of the general program of national defense. The decision as to what should be stockpiled, where and how stored, presents more complications than the fundamental simplicity of the problem would indicate. The presence of a diversified and adequate stockpile for emergency use would not only be reassuring but also serve as a conservative measure preventing the hasty and wasteful exploitation of our partial supplies under the impetus of the demands of industry engaged in the production of the machines of war.

Taxes

A system of taxation of mineral resources and the industries based on them satisfactory to all concerned has never been

[8] John B. DeMille, *Strategic Minerals, A Summary of Uses, World Output, Stockpiles, Procurement*, McGraw-Hill Book Company, Inc., New York, 1947, 626 pp.

evolved. The fact that mineral resources are wasting assets, exploitation of which consists of a liquidation of capital, presents a situation not encountered in ordinary industry. The tax structure is now complex and extends from federal acts to those of the local community. Excessive taxation induces rapid and wasteful exploitation. A comprehensive study and possible reorganization of the regulations controlling mineral taxation and the appraisal of reserves possess possibilities for an increase in conservation.

Foreign Mineral Policy

The discovery and operation of mineral deposits in many foreign countries together with the establishment of proper transportation systems have created an intricate international flow of mineral raw materials on a global basis. It has created also a growing interdependence among the nations with regard to their mineral supplies. This interdependence tends to increase because of the rise in importance of special materials which may be used in small tonnages but nevertheless are essential to the most important industries.[9] Interest in conservation therefore assumes an international and world-wide aspect. The final fabrication of mineral products is concentrated in a comparatively small number of geographic areas and is dependent upon the co-operative and synchronous employment of many materials. The tendency of mineral raw materials to flow toward fuels and markets is noteworthy. Alteration of this pattern will appear slowly. American investment in foreign countries concerned with the production of minerals represents billions of dollars. These investments were made not only because the funds were available but also, more significantly, because American leadership in mineral technology made their employment practical. The protection of such investments becomes increasingly difficult with the growth of industrialization and nationalism in many parts of the globe. Investors have been subject to harassment through imposition of special taxes, export tariffs, cancellation of concessions, imposition of discriminatory legislation, and outright appropriation. The necessity of more conservation of those minerals within domestic control is apparent. Entry of minerals of foreign origin into the United States is controlled in part by the extent to which similar materials are produced domestically. Little opposition exists to the introduction of materials that we do not produce. Those that compete with domestic production create an economic problem concerned with the differential in wage rates that exists between the United States and foreign countries. The solution and control of this problem are attempted by means of import tariffs. A re-examination of the relationship of domestic reserves and future consumption to foreign supplies should develop data that would be useful in the conservation of any resource showing signs of dangerous depletion.

Domestic Subsidies

In an aging mineral economy the limit of economic operation is frequently attained. That is, the oil well or mine ceases to produce profit dollars although the mineral resource itself is by no means exhausted. Further operation is dependent upon a price in excess of that current in the market. Should such properties be abandoned with the probable complete loss of the re-

[9] C. K. Leith, "Principles of Foreign Mineral Policy of the United States," *Mining and Metallurgy,* Vol. 27, 1946, pp. 6–17.

serves remaining or should their life be prolonged so that the maximum in total recovery may be obtained? Prolongation is dependent upon a compensatory payment or bonus which in effect serves to subsidize production and ensure the recovery of material which otherwise would be wasted. Marginal producers operating with costs so high as to make profits trifling or nonexistent are in a similar situation. The subsidization of high-cost producers during the war, when demand for metal was acute, demonstrated that substantial tonnages of metal can be obtained under the stimulus of a bonus. The total benefit derived from the services of such metal may outweigh the increased cost.

Time for Action

The time for a conservation program for minerals is not after the depletion incurred by use and waste has reduced our national heritage to the vanishing point. The time is while reserves still exist which if wisely conserved will endure for many years. That time is now.

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CHAPTER 17

The Mineral Fuels

INTRODUCTION

ENDOWED with a rich heritage of mineral wealth, the United States has for decades led the world in production and consumption of fuels, metals, and nonmetallic minerals. The industrial and military strength of our nation depends increasingly on its capacity to develop these resources. Without its wealth in mineral reserves the United States could not be one of the leading nations today, nor could the citizens of our country have attained the highest standard of living approached anywhere in the world. This progress has been brought about directly by the tremendous use of our power facilities. To the present the four primary sources of energy have been coal, petroleum, natural gas, and water power. Now we are on the threshold of the development and use of a new source of power in atomic energy. Its possibilities are still largely unknown, but basic industrial research promises a wide utilization of this energy to supplement the traditional fuels within the next few decades.

At present the mineral fuel production represents more than 60 per cent of our total value of minerals produced in the United States and is more than 50 per cent of the world's output. The nation in 1948 produced nearly 40 per cent of the world's coal, 65 per cent of the petroleum, 90 per cent of the natural gas marketed, and had approximately 28 per cent of the developed water power. The total energy produced in the United States averages the equivalent of 1,000,000,000 tons of bituminous coal annually. In 1946 the total value of our mineral fuel industries was $5,725,000,000 with bituminous coal valued at $1,806,153,000 and petroleum at $2,441,810,000. Our energy consumption has increased from 8009 trillion Btu's[1] in 1900 to 35,977 trillion Btu's in 1946.

The mineral fuel reserves are exceedingly unequally proportioned (Table 1). When all mineral reserves are expressed in equivalent tons of coal of 1300 Btu's per pound of calorific value, it is found that the total of all ranks of coal amounts to approximately 2556 billion tons, whereas the proved petroleum reserves are equivalent in heating value to only 5.9 billion tons of coal and the proved natural gas reserve is equivalent to 6.4 billion tons. Information is not available on the national reserves of fissionable materials—uranium and thorium.

[1] Btu, British thermal unit, is the quantity of heat required to raise the temperature of one pound of water one degree Fahrenheit at or near its point of maximum density.

By E. Willard Miller of The Pennsylvania State College.

TABLE 1

ESTIMATED MINERAL FUEL RESERVES OF THE UNITED STATES

[Compiled from numerous sources.]

			Equivalent Billions of Net Tons of Bituminous Coal of 1300 Btu/lb. Calorific Value		
Fuel Reserves	*Reserves Jan. 1, 1948*	*Assumed Annual Production*	*Reserves Jan. 1, 1947*	*Per Cent of Total Fuel Reserves*	*Reserves Divided by Annual Production and Loss †*
Anthracite	15	0.06	15	0.6	165
Low volatile bituminous	52	0.115	56	2.2	317
High volatile bituminous	1351	0.467	1403	54.2	2024
Subbituminous	818		598	23.1	
Lignite	939		484	18.7	
Total	3175		2556	98.8	
Billions of Barrels					
Petroleum *	24.7	1.7	5.9	0.2	14.2
Oil from shale *	92	1.7	21.2	0.8	54.1
Trillions of Cubic Feet					
Natural gas *	165	4.0	6.4	0.2	40.0

* Proved reserves only.
† 35 per cent loss for anthracite; 30 per cent loss for bituminous.

Relative Importance of Energy Resources 1800–1946

During the early days of our country water and wind power, wood, and work animals provided the principal sources of power. However, between 1800 and 1870 there was a gradual shift from the predominance of nonfuel energy sources to mineral energy sources. About 1830 coal began to play an increasing role as a source of energy and reached its relative peak of importance in 1899 when bituminous and anthracite accounted for 89.1 per cent of the total 7900 trillion Btu's of energy contributed by both mineral fuels and water power in the United States. In that year oil and gas accounted for only 7.7 per cent of the total (Fig. 1).

The relative importance of coal as a source of energy has been declining since the early 1900's. In 1918, the peak production year of World War I, coal supplied 82 per cent of the energy resources whereas petroleum and natural gas supplied 13.4 per cent. The relative value of coal as a source of energy decreased rapidly after 1918 to 63 per cent of the total in 1929, and to 43 per cent in 1946. In public utilities and domestic consumption coal has been replaced by oil and natural gas. In 1946, 95 per cent of the locomotives on order were Diesels burning fuel oil. Also many industrial plants are turning to petroleum as a source of energy.

With the coming of motor transportation the production of petroleum increased rapidly. Petroleum's share of the energy produced increased from 4.6 per cent in 1899 to 29 per cent in 1946. The upward trend of petroleum is still in progress. Natural gas has followed the same trend as petroleum except to a lesser degree, increasing from 3.3 per cent of the total in 1899 to 14.2 per cent in 1946. The production of water power has closely followed the total consumption of energy, increasing many times, but maintaining about the same relative position.

The trend of coal has been downward in recent years, but the exhaustion of petroleum and natural gas will occur long before the coal reserves are depleted. There will consequently be a subsequent return to coal in the near decades and no doubt a growing dependence on nuclear energy.

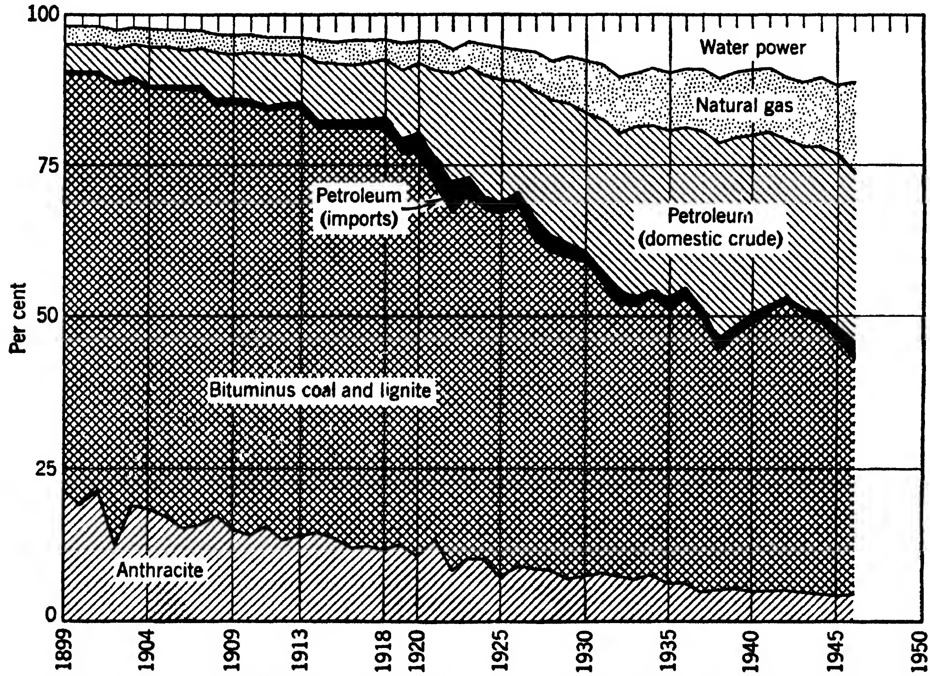

FIG. 1. The relative importance of the power resources in the United States. (Data from U. S. Bureau of Mines.)

COAL RESOURCES

Importance of the Coal Industry

Coal is the wonder mineral of the world. It provides man with more of the comforts and necessities of life than all the other minerals of the earth. It has been a vital factor in the growth of modern world powers. England, long-time undisputed mistress of the land and sea, attained her position as the result of intelligent use of coal. Germany, before World War I, owed to coal her rapidly acquired distinction as an industrial nation. The United States can attribute her world leadership largely to this dynamic power resource. The availability of coal is, truly, the greatest single factor in the development of our industrial life.

In relation to the importance of coal in the nation's economy, it employs a comparatively small number of workers. In 1945 there were only 383,100 men employed in the bituminous coal mines. Although this was the year of highest coal production in our history, the number of workers has been steadily declining since 1923 when

704,793 were employed. The great technical advances in mechanization have been largely responsible for this trend. However, in many regions coal mining is still one of the principal occupations. In West Virginia, the number of coal miners nearly equals the total number of workers in manufacturing, and the coal industry of Illinois employs twice the number in the meat-packing industry.

The annual value of bituminous coal, which usually exceeds one billion dollars, was $1,810,900,452 in 1944, the highest in coal history except for 1920 when coal reached a peak value of $2,139,933,000. Investments in coal mining total billions of dollars. The coal industry also spends millions of dollars for equipment, tools, and incidentals each year. The anthracite mines of Pennsylvania produce wealth far greater each year than the total value of the gold and silver production for the entire nation. The United States coal industry is the largest bulk-handling industry in the world. Every day more than 30,000 carloads of coal move from more than 7000 mines. It is the sole supporter of economic life in many regions and of great importance in others. Consequently, the coal industry affects directly a large segment of the entire population.

Origin and Nature of Coals

Coal is a combustible earth material composed of fixed carbon, volatile matter, moisture, and ash originating from the alteration of plant life. In every geologic age since the Pre-Cambrian period great swamps have existed where layer upon layer of vegetation have accumulated to form peat bogs. Peat develops into coal in a number of stages.[2] The first is the burial of peat under sediments, and the resulting types of coal depend upon the depth of burial, time since burial, and, consequently, the pressure resulting from compression and/or crustal disturbances. It is estimated that it takes 100 years to form one foot of peat and from three to eight feet of peat to produce one foot of coal. Pressure, therefore, is one of the great factors in coal development. Lignites are characteristically found where burial is shallow with little crustal distortion whereas anthracite and high-carbon coals are formed by great compression related largely to crustal disturbances.

[2] Elwood S. Moore, *Coal*, New York, 1940, pp. 136–193.

Coal is composed of a number of different materials. Fixed carbon is the most essential constituent of coal. It gives the black color to coal and burns with a short flame giving almost no smoke. There is a close correlation between fixed carbon and heat value. The volatile matter, consisting of compounds of carbon and hydrogen, is important because of its high heat content and the number of by-products that are obtained from it in the destructive distillation of coal in coke ovens.

Besides fixed carbon and volatile matter there are a number of waste materials in coal. The moisture content of coals varies from as little as less than one per cent in anthracite to more than 40 per cent in lignite. The ash in coals comes from foreign matter in the original plant material or from sediments washed into the swamp as the peat was formed. The ash content varies from less than one per cent to as much as 55 per cent in some coals. Ash and water are diluting substances so that they are an economic waste factor in storage, handling, transportation, and consumption.

Ranks of Coal

Rank indicates the differences in coal in its progressive evolution from lignite to anthracite. This alteration is marked by a decrease of volatile matter and an increase in fixed carbon from the low- to high-rank coals. The standard classification of coal as devised by the United States Geological Survey is based on the chemical and physical properties of each coal.[8] The composition of each of the coals, as to fixed carbon, volatile matter, moisture, and heat efficiency, is summarized in Fig. 2.

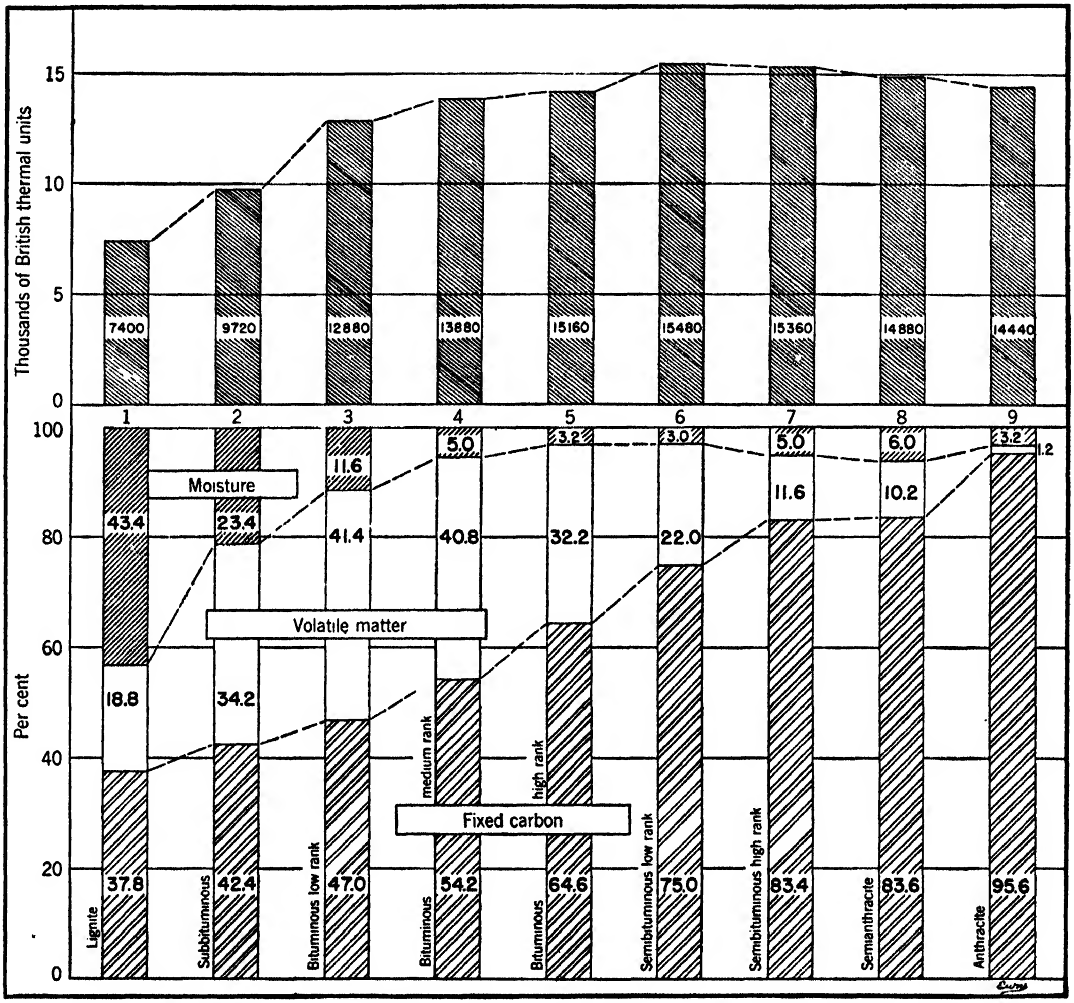

FIG. 2. The heat efficiency and the composition of the different types of coal. (After U. S. Geological Survey.)

[8] Marius R. Campbell, "The Coal Fields of the United States," *Professional Paper* 100-A, U. S. Geological Survey, Washington, D. C., 1922, pp. 3–10.

Lignite, frequently called brown coal, is the lowest rank. It is characterized by a moisture content of 30 to 43 per cent and fixed carbon ranging from 30 to 55 per cent. The structure is fibrous and woody. It disintegrates readily on exposure and must be stored carefully to prevent spontaneous combustion. These qualities make lignite the poorest of all coals for most purposes.

Subbituminous coal is black and may be dull or lustrous, but it still retains the woody appearance of lignite. Its moisture content also may be high, ranging from two to 40 per cent. Fixed carbon varies from 35 to 60 per cent. On weathering it slacks and has a tendency toward spontaneous combustion. Subbituminous coal has a fairly high heat value and serves an important local market, particularly in western United States.

Bituminous coal is the most important industrial and heating coal in the world and makes up about 52 per cent of the total world reserve. It may be dull black to highly lustrous. The moisture content is small, and the fixed carbon content varies from 48 to 73 per cent. This coal stores well and burns with a yellow flame, frequently giving off a penetrating odor. There are many varieties of bituminous coal of which the most common are coking, cannel, noncoking, torbanite, and bogshead.

Semibituminous has a high fixed-carbon content and has the highest heating value of all ranks of coal. It is an excellent steam coal and is used for general manufacturing where a high degree of heat is required. This coal is, however, friable, and disintegrates readily on storage. It can be used easily where mechanical stokers are used.

Semianthracite differs from anthracite only in that it is more friable. It has a fixed carbon content of 83 to 93 per cent and is thus a smokeless fuel with a high heat value, free from soot, and burns slowly, making an excellent domestic fuel when used with a stoker system.

Anthracite is a hard dense coal with the highest fixed carbon and lowest hydrocarbon content of all coals. It is characterized by a jet black color, freedom from ash and moisture, excellent coherence, and burns with a short blue flame. It is an ideal domestic fuel because of its smokelessness and steadiness in burning.

Coal Reserves and Centers of Production

The nation's coal reserves are extensive but are unevenly distributed and highly variable in quality and accessibility. The coal areas, located in 31 states, have been classified into six major provinces: Eastern, Interior, Gulf, Northern Great Plains, Rocky Mountain, and Pacific coast (Fig. 3).

The original reserves of coal, computed by the United States Geological Survey, were placed at 3214 billion tons of which on January 1, 1948, it was estimated that 3185 billion tons still remained unmined. The estimates of reserves are based on a combination of factors that have been established to determine the commercial value of coals. The minimum thickness of coals that can be mined commercially was placed at 14 inches for bituminous, two feet for subbituminous, and three feet for lignite. All coals with an ash content to 30 per cent are included. Six thousand feet was considered the ultimate limit of coal mining, and coal below this depth was not considered as a reserve. The average specific gravity of coal was estimated at 1.3, and tonnages were computed on this basis.

The Eastern province, containing the Atlantic coast, the Anthracite, and the large Appalachian regions, is the oldest mining area in the United States. The Atlantic coastal region in Virginia and North Carolina is of little importance. The Anthracite region of northeastern Pennsylvania is the most important in the country, producing 98 per cent of our anthracite and containing 95 per cent of our reserves.

The Appalachian region is the largest

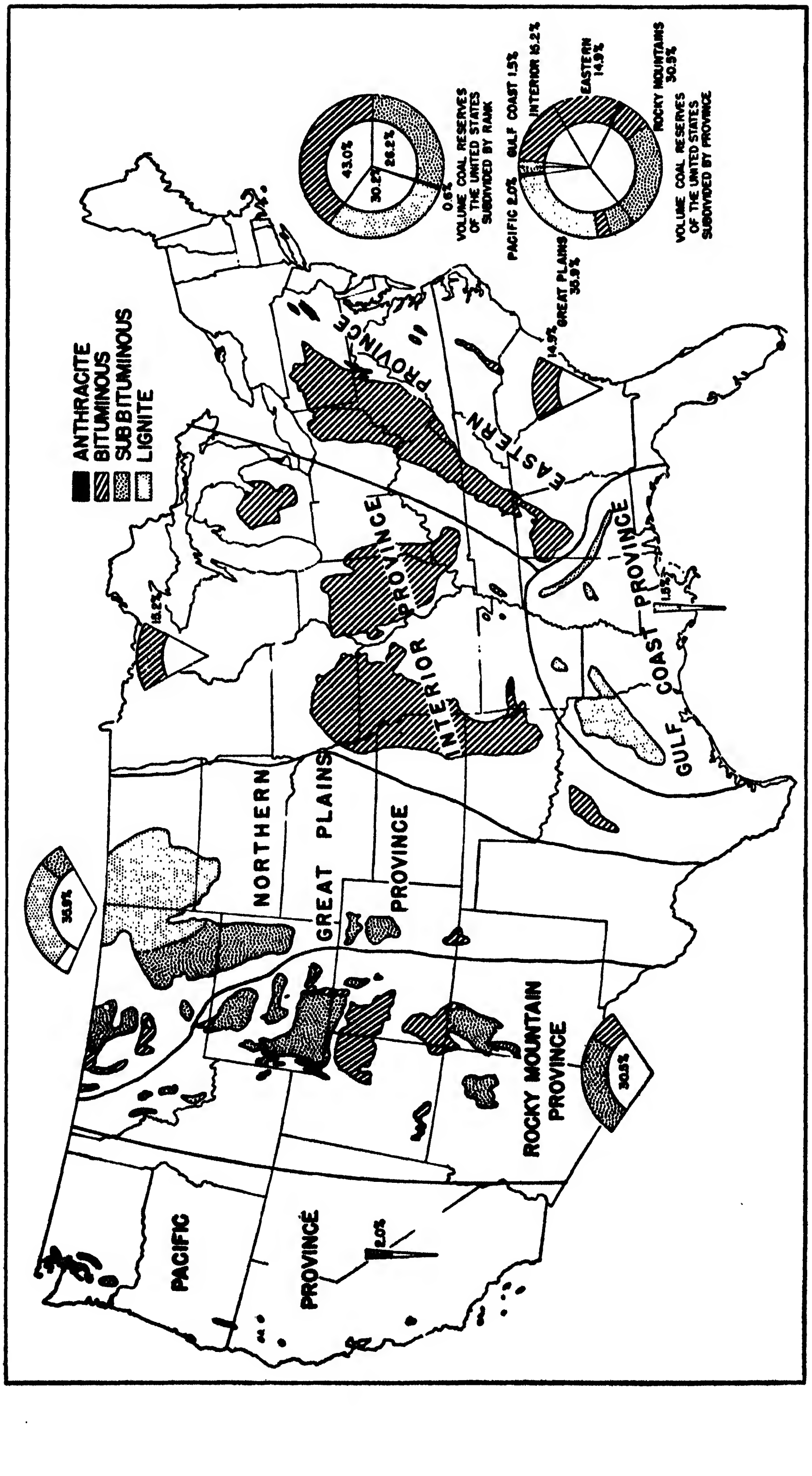

FIG. 3. Coal-producing areas in the United States. (U. S. Geological Survey.)

area of high-grade bituminous coal in the world. An area of approximately 50,000 square miles is underlain with coal. West Virginia has the greatest amount of high-rank bituminous and is followed by Pennsylvania. Essentially every variety of bituminous coal is found. The coal in much of the area is easy to mine for the seams are nearly horizontal and in many places outcrop on the sides of the valleys, making possible low-cost drift operations, shallow shaft mines, or strip mining. The famous Pittsburgh coal seam of western Pennsylvania, eastern Ohio, and West Virginia is the world's largest single deposit of high-volatile bituminous coal. It supplied the coal for the furnaces of Connelsville which was the primary source of coke in the early development of the iron and steel industry of Pittsburgh.

The Interior province consists of four regions: Eastern, Western, Northern, and Southwestern. The coal of the Interior province is largely bituminous, but the quality is not so good as in the Appalachian fields. The coal of the Eastern region, Illinois, Indiana, and western Kentucky, has been mined most extensively and has been one of the prime factors in the growth of manufacturing in the central lowlands. Illinois, with 77 per cent of its area underlain by coal, has the greatest reserves east of the Mississippi River and because of low-cost mining and good-quality coal has become the third largest producer. The coal deposits of the Western region, which extends from Iowa to Arkansas, are large but mostly low-rank bituminous which consequently burns with considerable soot and smoke. It has little coking value but does have a high heat content and is therefore used locally for domestic heating and as a steam coal for railroads. Only limited mining activity occurs in the Northern region of Michigan and the Southwestern region of Texas.

The Gulf province which extends along the coast from Texas to Louisiana has mostly lignite. The coal is in a region of young, undisturbed rocks so that it has remained of low rank. The lignite is of highest quality in northern Texas and southern Arkansas where some mining is practiced locally. Since the coal has a high volatile content it has a potential use in coal hydrogenation.

The Northern Great Plains province includes all the coals of the Great Plains of the United States and extends into the Prairie Provinces of Canada. This province has tremendous quantities of lignite and subbituminous coal. Wyoming has 590 billion tons of subbituminous coal of the total United States reserves of 818 billion tons. North Dakota has 600 billion tons of lignite of the total United States reserves of 939 billion tons. Wyoming, North Dakota, Colorado, and Montana are the four leading states in total reserves. However, these reserves are largely low-rank coals with only about two-thirds of the heating value of bituminous, and the coals are essentially noncoking. At present mining is very limited, supplying only local needs.

The Rocky Mountain province is composed of a large number of noncontiguous fields extending from Montana to New Mexico. The province contains all ranks of coal from lignite to anthracite. The coal is found in great basins, and the rank depends largely on the crustal disturbances. The principal mining centers are in Utah, Colorado, and New Mexico, where the coal is used locally by railways, by ore smelters, and for domestic heating.

The coal of the Pacific province is limited largely to Washington, with minor deposits in Oregon and California. Although Washington has a good supply of subbituminous and bituminous coal, mining is difficult because the rocks were folded and faulted in many places and subsequently were covered by deep deposits of glacial drift. Mining is limited to a few million tons annually for local use.

The coals of the Appalachian and Interior provinces are the foundation of the great manufacturing districts of eastern United States. Approximately 85 per cent of our bituminous production is in Pennsylvania, Ohio, West Virginia, Kentucky, Indiana, and Illinois. Most of our high-quality coal is found in these states. At present 12.3 per cent of the output consists of anthracite which makes up only 0.5 per cent of the tonnage reserves. Another 16.6 per cent of the output is semibituminous or low-volatile bituminous, which constitutes only 1.7 per cent of the tonnage reserves. The fourteen northeastern states consume over 70 per cent of the coal produced but have only 15 per cent of the reserves. For the most part the nation's best coals are being depleted at a rapid rate. The famous Pittsburgh coal bed has an estimated life of about 100 years. The reserves in beds thicker than 42 inches in the fields of southern West Virginia have an estimated life of only 75 years at present extraction rates.

The reserve supply will begin to disappear near our greatest industrial centers. The industrial pattern of the United States is directly related to the location of the high-grade bituminous coal. Present production centers in coal fields nearest the consuming markets, where transportation charges are at the minimum. At present half of the cost of bituminous coal, delivered at the purchaser's siding, consists of freight. Extensive transportation of coal would make the delivered price prohibitive for many users. One may well contemplate the increase in cost of products manufactured with costly western low-rank coals or the migration of industry, leaving whole areas stranded with complete economic disarrangement.

Production Trends and Problems of the American Coal Industry

Coal was discovered in the early colonial period, but the modern coal-mining industry began only about 1820. Although the relative growth was rapid the output remained small until the Civil War period. In 1840 production was 2,070,039 tons and by 1860 only 14,610,042 tons. Anthracite exceeded the production of bituminous until 1869, and until 1873 the United States imported more coal than it exported.

From 1850 to 1910, during the great industrial expansion of the United States, coal production virtually doubled every eight or nine years (Fig. 4). The peak rate occurred between 1860 and 1870 when the increase was 168 per cent. This rate of gain was maintained almost unabated until 1890, but after that there was a tendency toward retardation. From 1890 to 1900 the gain was 91 per cent, but from 1910 to 1920 only 36 per cent. Production increased to a peak output of 579,385,820 tons in 1918. From 1850 to 1920 was the most rapidly growing industrial period of our country, and coal was the principal fuel upon which this growth was based.

From 1918 to 1923 the production curve was approximately horizontal, but from 1923 to 1940 the general trend was downward. As a result the coal industry has been in a chaotic condition since World War I because of lack of adjustment to changing economic conditions. The declining market has been caused by a number of factors. Excessive capacity to produce and consequent cutthroat competition is the outstanding problem. Coal mining is carried on by a large number of independent companies in widely distributed fields. bama, and some of the western states. The southern fields, although farther from the large markets, possessed high-quality coals and enjoyed a lower ton-mile freight rate;

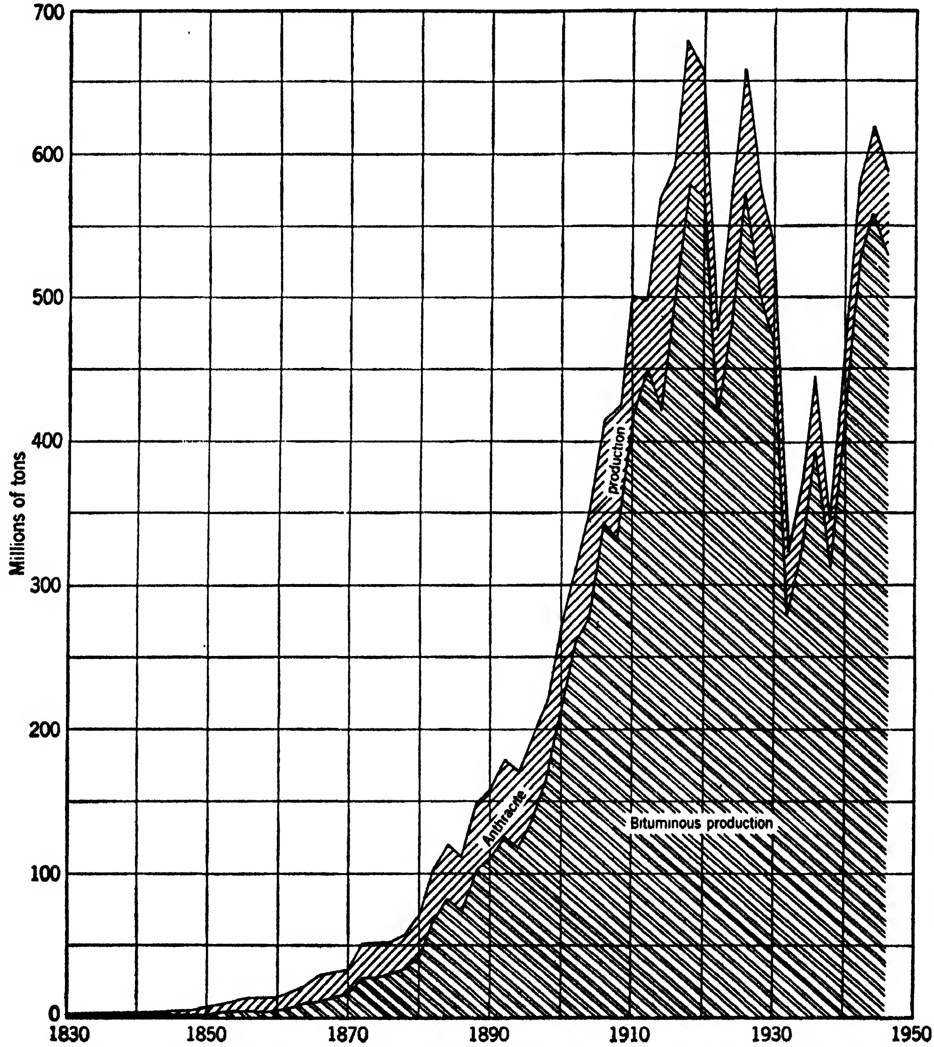

Fig. 4. Coal production of the United States, 1830–1946. (Data from U. S. Bureau of Mines.)

The coal areas of western Pennsylvania, Ohio, Indiana, and Illinois were the first to be developed and the first to be unionized. As strikes occurred in the union fields, coal production increased in the nonunion areas of West Virginia, eastern Kentucky, Alamoreover, the scales of wages were lower than in the northern fields. By 1927 the expansion was so great in the nonunion fields that they could supply the entire country's needs without the aid of the union mines. Although all fields have been unionized the excessive production and competition have remained.

Mechanization and continuous operations were also important factors in the increased output at a time of a declining market. Cutters and loaders can now mine seams of coal one foot in thickness.[4] The replacement of hand labor by machines has increased the productive capacity of the mines. In 1900 the average output per man per day was 2.98 tons. At that time 24.9 per cent of the coal was cut by machines and underground mechanical loaders were unknown. In 1944 the average daily output per man was 5.67 tons with 90.5 per cent of the coal cut by machines and 52.9 per cent loaded underground by mechanical loaders.

Irregular demand also has created conditions favoring overproduction. Coal consumption varies by year and by seasons. Production facilities must be available to meet peak conditions. This creates a surplus in certain years and in particular months. Other factors influencing the coal market include advances in fuel efficiency and decrease in coal demand owing to competition from other fuels. These were the major factors causing the coal industry to be in a depressed condition from 1920 to 1940.

World War II once again created tremendous demands for coal so that production grew rapidly from 1940 to 1944. In 1944, a total of 619,576,240 tons were produced of which 559,000,000 tons were bituminous. Production declined temporarily at the close of the war, primarily as a result of prolonged strikes in the industry. However, in 1947 the coal production of 676,000,000 tons, of which 619,000,000 were bituminous, surpassed the wartime peak by nine per cent. It would now appear that a large coal production will continue for a considerable number of years if labor disputes can be settled before strikes result.

[4] C. Robinson, "Mechanization in Thin Coals," *Mining Congress Journal,* Vol. 31, 1945, pp. 41–44.

Principal Uses of Coal

Most of the 50,000,000 tons of coal produced monthly in the United States is consumed in the nation's factories, transportation facilities, electric power utility plants, and for domestic heating. Industrial consumers, taking 40 per cent of the total, are the largest users. Of the industrial users, manufacturing industries, taking over 20 per cent, are the largest single consumers, followed by the coke furnaces which require about 17 per cent of the coal output. In the coke industry by-product ovens consume over 90 per cent and beehive ovens the remainder. Domestic heating, consuming nearly 25 per cent, is the second largest single user. Railroads use an additional 22 per cent and public utilities 12 to 15 per cent of the total coal production. Other minor purposes are for colliery fuel, bunker coal, and a small foreign trade.

COAL CONSERVATION PROBLEMS

Mining Practices and Losses

There are two principal methods of mining coal: underground workings and open-pit or stripping. In underground mining the coal seam may be entered either by the drift, slope, or shaft method. In drift and slope mining the coal seam which outcrops on a hillside is entered by digging a tunnel into the side of the hill. If the coal is deep a shaft is sunk to the coal seam in order to enter it.

The loss of coal in underground mining has been declining in recent years, but it is still of great importance. The average percentage of loss from both avoidable and unavoidable causes has declined from about 64 per cent in 1850 to about 35 per cent. In a survey by the United States Coal Commission, it was found that unavoidable losses averaged 15.3 per cent and avoidable losses 19.4 per cent.

A number of causes lead to underground mining losses. Present mining methods, utilizing only the best coals, leave millions of tons of coal untouched in the ground in a condition that makes future recovery unlikely, even at a markedly higher price. Coal left on the roof and bottom, in rooms, in entries, and in panel pillars causes other losses. Formerly, the greatest loss in mining came from coal left in pillars to support the roof of the mine. Modern methods employing the long-wall or panel system avoid much of this loss for the coal is mined in retreat and the roof allowed to fall as soon as the coal is recovered. Other wastes involve coal lost under buildings, railroads, in boundary pillars, in cemeteries, and around oil and gas wells. Coal may also be wasted in handling and in its preparation underground. Economic pressure and insufficient margin between the cost of mining and the selling price of coal are other reasons for leaving large areas of coal unmined. The suspension of mine operations at times of strikes and shutdowns frequently results in great loss of coal, especially on pillar lines. When the mines are not in operation, pillars become crushed, resulting in squeezes, and even the roofs may collapse. Then the operators usually decide to leave the coal in place and start a new room or entry rather than restore the old one. A continuously operated mine will aid materially in the conservation of available coal still left in the ground.[5] In a year when the United States uses 600,000,000 tons of coal the total additional quantity lost is about 210,000,000 tons of which 118,000,000 tons could be recovered.[6]

Since the early 1930's open-pit mining has increased greatly in importance. It is practiced where the coal lies near the surface and the overburden of earth can be removed. Coal stripping began before World War I but was relatively unimportant until large steam shovels were developed. Before 1926 the largest stripping shovels had a dipper capacity of only one to three cubic yards. The largest shovels now hold 30 to 40 cubic yards, and it is possible to dig with them to a depth of 80 to 90 feet. The amount of coal mined by stripping has risen rapidly from one per cent of the total in 1917 to nearly 20 per cent in 1948.

The advantages of strip mining are many. In 1948 the average surface miner produced twice as many tons per day as the subsurface worker. Although investment in stripping machinery is high the salvage value of this equipment is much greater than that of subsurface equipment. The return of money invested in surface operations is quick. The danger in open-pit operations is minimum. The recovery of coal is from 75 to 95 per cent of the original total.

The great problem of strip mining is the restoration of the land after the power shovels have worked to uncover the coal. The great furrows of rocky materials, commonly called spoil banks, have often become major areas of desolation. A num-

[5] Richard Maize, "Coal Conservation Requirements of Pennsylvania," *Mineral Industries*, Vol. 16, 1946, pp. 1–4.

[6] "Planning for Progress in Coal Mining; Opinions of Industry Leaders; Problems and Opportunities," *Coal Age*, Vol. 50, 1945, pp. 82–91.

ber of states have passed legislation requiring that the land be leveled and improved. However, restoration to the original contour is now questioned. Usually the cost of such operations is prohibitive. The leveling processes often pack the soil so firmly that seedling trees do not survive. With few exceptions it has been found that the best restoration is the planting of trees on the original spoil bank. In many mines the last open cut can be made into small lakes with excellent recreation facilities. In hill country the furrows, which are usually on the contour, hold the runoff water effectively and are thus highly beneficial to the growth of trees. Excellent timber stands have been developed in Illinois, Ohio, and Pennsylvania on the banks. In some instances the income from the land is greater after such treatment than it was before the stripping operations. However, no two spoil-bank areas can be subjected to the same treatment. Some spoil banks have high lime content and can support various grasses and deciduous trees. Pasture and forage use, however, is usually impossible because the steep slopes prevent mowing. Other banks are highly acid and will support only conifer plantings at best. Each area is a problem in itself and much careful study and experimental work is needed before even general restoration rules and principles can be formulated. Apparently, however, because of its many advantages, strip mining is here to stay. Therefore the cost, of such study, and experimental work is more than justified.[7]

Losses in Processing

The processing of coal into coke resulted in tremendous losses when the beehive oven was employed. With the introduction of the by-product coke oven in the early 1900's these losses have been largely eliminated. A ton of bituminous coal coked in a beehive oven will yield about 1300 pounds of metallurgical coke whereas the same amount of coal, coked in a by-product oven, will yield 1500 pounds of coke as well as 22 pounds of ammonium sulphate, nine gallons of tar, two and a half gallons of light motor oil, and 10,000 cubic feet of gas. In 1905 less than 10 per cent of the coke was produced in by-product ovens. Since then the growth has been rapid, and in 1948 over 90 per cent of the coke was produced in this way. Some of the by-products obtained in coking are lost, however, for the United States does not provide a large market for these products. For example, only about 40 per cent of the tar produced is sold for by-products, and the remainder is used as a fuel.

When coal is processed in low-temperature carbonization and gasification ovens for the production of liquid fuels a serious problem of waste once again arises. A change in the form of fuel, particularly to the liquid state, is accomplished only with heavy losses of the potential heat value under existing technical methods.

Conservation in Consumption

There has been a remarkable gain in efficiency of coal utilization by the principal consumers. This substantial reduction in consumption of coal per unit of work is an important form of conservation, for it increases the potential usefulness of our coal resources. These improvements have been due largely to the following advancements: (1) growth of knowledge of the composition and properties of coal; (2) improvement of the physical processing of coal for specific uses; (3) introduction of econo-

[7] W. L. Burt, "Future of Strip Mining in the Northern Appalachian Fields," *Mining Congress Journal,* Vol. 30, 1944, pp. 25–27.

mies in conversion of coal to heat energy; (4) introduction of economies in conversion of coal to mechanical energy; and (5) reduction of energy required for a given purpose.

Improved Knowledge of the Nature of Coal

A knowledge of the composition and properties of coal is fundamental before improvements in efficient utilization can be accomplished. Coal is a highly complex substance which is the source, in part, of thousands of products from aspirin tablets to dyes. The first survey of the composition and properties of coals was made in this country in 1904. This work has been continued by the United States Geological Survey and the Bureau of Mines. Special attention has been placed on phases of research, such as reactions involved in the utilization of coal in conservation processes, classification of coals as they occur in the ground, development of standard grades and specifications for most efficient utilization in marketing, and utilization of the coal as a raw material in the chemical industry.[8]

Physical Processing of Coal for Specific Uses

Coal as it comes from the mines usually has impurities and is not the best size for efficient utilization.[9] Nearly all the anthracite and more than 25 per cent of the bituminous in 1948 was sized and cleaned before it was marketed. Most of this work, particularly sizing, is now done mechanically, but, when the pieces of slate are large, hand picking is still more effective. The mechanical method of separation is done by taking advantage of differences of specific gravity. The tendency of lighter particles to separate from heavier particles when subjected to a current of air or water, or to centrifugal force, and when floated in liquids of proper density is aptly applied in mechanical coal-cleaning plants.

The washing of coal to reduce its ash and sulphur content has developed largely since 1920. The keen competition and introduction of mechanical methods of mining has encouraged this development. The percentage of coal washed has increased from 5.3 per cent in 1927 to over 25 per cent in 1948. The cleaning of coal is a conservation measure for it permits the crushing of lumps of impure coal and recovers a considerable portion of the coal. Clean coal can also be used more efficiently.

Conversion of Coal to Heat Energy

Most modern home furnaces are inefficient producers of heat energy. Efficiency tests by the Battelle Memorial Institute in Columbus, Ohio, have revealed wide variations in effective utilization, summarized as follows: 45 per cent efficiency for hand-fired bituminous, 55 per cent for stoker-fired bituminous, 50 per cent for hand-fired semibituminous, 70 to 75 per cent for natural gas, and 60 to 70 per cent for oil. The largest losses are due to escape of heat in dry flue gases, ranging from one-third to two-thirds of the total. Other losses are from moisture, carbon monoxide gas, and unconsumed carbon in the ash.

Most of the prevailing losses can be prevented by improved firing methods. Stoker firing gives higher efficiency and eliminates a large percentage of the smoke. In hand

[8] George S. Rice, A. C. Fieldner, and F. G. Tryon, "Conservation of Coal Reserves," *Third World Power Conference,* Vol. VI, Section IV, Washington, D. C., 1936, pp. 706–709.

[9] G. B. Southward, "Fundamentals of Modern Coal Preparation," *Mining Congress Journal,* Vol. 26, 1940, pp. 38–39.

firing, efficiencies depend to a large extent on the personal factor. The public needs to be educated in the handling of coal furnaces. The schools of the nation can contribute greatly to the saving of coal by educating the coming generations in the most economical and efficient manner of using the particular coal available in the different parts of the country. Rules compiled by combustion engineers, familiar with the characteristics and behavior of each type of coal, could serve as lesson material. Maximum efficiency as great as 90 to 92 per cent can be attained by proper firing of pulverized coal in stokers.

Conversion of Coal to Mechanical Energy

Efficiency when coal is converted to mechanical energy has been increasing steadily but is still remarkably low. By the end of World War I the most efficient steam engines consumed a little more than a pound of coal per horsepower hour, and by 1945 this figure had been reduced nearly 50 per cent.[10] The central electric power stations have made the most spectacular gains in fuel efficiency. From an average in 1902 of 6.4 pounds of coal per kilowatt hour, the level was reduced to 1.3 pounds in 1945. In 1919 steam engines consumed 170 pounds of coal per 1000 gross ton miles of freight service and in 1945 only 116 pounds, a reduction of 31.8 per cent. The quantity of coking coal consumed per ton of pig iron was reduced from 3194 pounds in 1918 to 2635 pounds in 1945, a decrease of 17.5 per cent.

Although these examples of increasing fuel efficiency are important, most users of coal to produce mechanical energy are still highly inefficient. Coal-burning steam turbine plants have been able to attain an efficiency of only 31 per cent, and mercury-vapor plants have a maximum efficiency of 38 per cent. Most locomotives built since 1920 have a thermal efficiency of probably not more than 11 or 12 per cent. Industrial boilers have an efficiency of 60 and 65 per cent. One of the great needs is for more extensive and better utilization of insulation materials to eliminate these wastes. The requirements for mechanical energy can be reduced to a fraction of present needs.

The Future of Coal

The future of coal in the coming decades will depend on two important factors. The first, and more important, is the availability and utilization of petroleum, natural gas, water power, and atomic energy, and second, the development of technical improvements that will continue to raise the efficiency of coal-burning furnaces. Although, since about 1900, coal has lost its position relatively among the mineral fuels as a supplier of energy, the absolute consumption has risen from 7123 trillion Btu's in 1900 to over 17,000 trillion Btu's in 1948. Coal is still our cheapest fuel, and it is now an essential in the processing and manufacture of practically all items needed in both a peace and a war economy. These factors alone will assure a continued high production.

Industry has continually carried on a research program in order to improve coal-burning equipment. Although more efficient stokers, boilers, and fire boxes will lessen the demand for coal per unit of work performed, these improvements will tend to overcome the competition with petroleum and consequently increase the total coal

[10] R. F. Stilwell, "More Steam from Less Coal," *Chemical Industries*, Vol. 59, 1945, pp. 59–62.

consumption. Because of the limited supplies of petroleum and natural gas, the great invasion of these fuels carried long distances in pipe lines for burning under stationary boilers may be, in one sense at least, considered anti-conservational.

Many new uses of coal are developing at present. Super power plants located at the mine for the conversion of coal to electric energy have been planned to eliminate the expensive charges for transporting the bulky coal. By-products from coke ovens have frequently been wasted because of the limited market. The production of synthetic rubber, plastics, nylon, explosives, and hundreds of other products in which coal can be a basic material was greatly expanded in World War II, and markets are still growing.[11] By-products from coking of coal could become of primary importance. The Germans are known to have produced edible fats and cooking oils from low-grade coal. Experimentation has indicated the possibility that coal's largest market, except as fuel, in the future may be as a fertilizer, for many types of coal are excellent soil builders.

Coal as a basic source of energy is likely to be needed for generations to come so that it is our obligation to use this power resource with the minimum of waste. Because of the great abundance of coal, we have been extremely wasteful. Continued waste will destroy one of our greatest natural heritages.

PETROLEUM

Importance of the Petroleum Industry

Petroleum is probably our most indispensable and limited mineral fuel. It has been one of the most significant minerals in shaping our modern civilization. With petroleum products used for illumination, power, heating, and lubrication it has grown to be one of our largest industries. No industry has shown itself more characteristically American than the oil industry, with private enterprise and initiative holding sway from its very beginning. The industry has grown until today it is valued at more than $20,000,000,000. In 1948 the wholesale value of petroleum products consumed was more than $3,200,000,000. To produce these products the petroleum industry employs more than 160,000 workers in drilling and production, 40,000 are engaged in transportation, 100,000 in refining, 120,000 are employed in wholesale marketing, and 600,000 men attend to service stations and retail outlets. More than 200 taxes have been imposed on various forms of petroleum products of which approximately 200,000 federal, state, and local tax collecting authorities receive an average of one and a half billion dollars in taxes each year.

The petroleum industry had one of its greatest struggles in supplying the fuel needs of World War II. The consumption was appalling. For example, it took 60,000 gallons of gasoline a day to keep a single armored division fighting, the large bombing raids over Germany used 10,000 gallons of 100 high octane per minute, one hour's flight of a Navy Hellcat fighter consumed enough gasoline to drive a car from New York to Denver, and to fill the fuel tanks of one battleship took enough oil to heat an average home for more than 500 years.

In order to meet these needs an almost unbelievable expansion of the American petroleum industry was necessary. The plan for this vast industrial enterprise had its inception on May 27, 1941, when Presi-

[11] H. L. Ickes, "Coal's New Horizons," *Coal Age*, Vol. 48, 1943, pp. 54–61.

dent Roosevelt appointed Secretary of the Interior Harold L. Ickes, as Petroleum Coordinator. In this great endeavor, the government's part was to point out what problems had to be solved and to give aid and guidance in getting them solved. The solving of the problems was left to the practical experience and initiative of the industry itself. On June 19, 1941, the issue was presented to the leading oil men of the country, and co-operation was at once pledged. Within sixty days a pattern had been established for teamwork between industry and government which continued throughout the war.

Out of this concerted effort a total of 13,400 wildcat wells were drilled—more than in any like period of history; 5,000,000,000 barrels of oil were produced, or one-fifth of the total oil produced in this country; a billion dollars of new refineries were built in the United States, plus approximately 280 million dollars' worth abroad; the industry built, relaid, or reversed the flow of more than 10,000 miles of pipe lines; the flow of oil to the east coast with the help of railroad tank cars increased from the pre-war level of 5000 barrels daily to over 1,000,000 barrels a day at the peak; and the American tanker fleet, despite all losses, grew by more than four and one-half times. The war effort was a tremendous drain on our oil resources, for the United States supplied more than 80 per cent of all petroleum products consumed, although we have only an estimated 40 per cent of the known oil reserves of the world. The great question now before the nation is, "How long can the United States continue to produce at this accelerated pace?"

The Nature of Petroleum

Crude petroleum is a complex mixture of oily hydrocarbons which also frequently contains small quantities of oxygen, nitrogen, and sulphur with varying amounts of natural gas, water, and dirt. A large number of different mixtures make possible wide variations so that crude oils may range from gasoline to pitch or asphalt. Petroleums, in general, are divided into three classes—paraffin, asphaltic, and mixed base—according to their dominant chemical composition.

Petroleum may be colored a light straw, green, brown, or black. Usually the light-colored oils are high-grade crude, and the darker-colored oils produce the lower-quality products. The density of crudes is expressed in specific gravity which is the ratio of the weight of a given volume of oil to the weight of the same volume of water under standard conditions. The specific gravity of crudes varies from 0.77 to 1.00. Since the specific gravity scale is expressed as a fraction and the numbers are read with difficulty, an arbitrary scale, known as the Baumé, is used. On the Baumé scale a specific gravity of 1.00 is read as 10°. Oils are tested by means of hydrometers constructed for liquids lighter than water, and therefore the readings are given in integral numbers larger than 10. Oils nearly as heavy as water have readings close to 10°, whereas those lighter than water have much higher readings. A crude is said to be heavy if it tests below 20° Baumé or light if the reading is above 30° Baumé. In general the value of crude rises as the Baumé reading increases, for light oils are usually rich in gasoline and light naphthas.

Occurrence of Petroleum

Petroleum is generally considered to have originated from organic material, either animal or plant, which was first deposited in sedimentary rocks of marine origin. This material was then covered, and by a process of earth distillation petroleum was formed. The process of origin is an important key to exploration, for petroleum is found in sandstones and limestones, and in igneous or metamorphic rocks only if it has migrated there from sedimentary rocks. Many structures are favorable to the accumulation of petroleum. Of these the anticline is best known with the typical arrangement of natural gas at the top of the anticline, oil beneath and on either side, and water at the base.

Products of Petroleum

The petroleum industry produces a wide variety of products. Each product performs a peculiar and distinctive function which has not been adequately met by any substitute or competitive material.

The earliest important product obtained from crude oil was kerosene, providing inexpensive artificial illumination which was superior to all illuminants of its day. Kerosene contributed greatly to the spread of information, for it gave the opportunity to more and more people to read and learn. Kerosene also became an illuminant in the field of transportation, contributing greatly to the world's safety. Although kerosene has been replaced by gas and electricity in most sections of our country, it is still the chief illuminating and cooking agent in many rural areas and foreign countries.

Gasoline, which has replaced kerosene as the most important product, is the most fundamentally necessary fuel of the modern world. The outstanding achievement of the petroleum industry has been keeping pace with automobile manufacturing which uses a large percentage of the total oil output. The proportional yield of gasoline from crude has risen greatly as a result of improvements of refining technology, recovery of gasoline from natural gas, and cracking of heavy crudes. Increasing motor transportation has been a fundamental factor in molding American life.

The lubricating materials suitable for high-speed, high-temperature machinery are obtainable in sufficient quantities only from petroleum. To meet the needs of hundreds of different machines and engine designs, lubricating oils and greases are produced in infinite varieties. Each lubricating problem has been solved by a special type of oil. The power and production machine, which characterizes our civilization, has been made possible by petroleum lubricants.

After gasoline, kerosene, and light lubricating oils have been extracted from the crude there still remain the heavy, less volatile oils in the form of gas oils and fuel oils. These oils may be used as a raw material for cracking gasoline or directly as a fuel in industry, transportation, agriculture, and for domestic heating.

Geographic Distribution of Petroleum

Petroleum is widely distributed in the United States where eight major districts cover 26 states (Fig. 5). Although the petroleum areas are widespread, the really large yields of oil are obtained from a few states.

The Appalachian province, which extends from southwestern New York through Pennsylvania and from southeastern Ohio to Tennessee, is the oldest producing region in the world. The first well was drilled in 1859 near Titusville, Pennsylvania, and, with the discovery of oil on August 28, the modern oil industry was born. The first oil boom soon followed and has been repeated a hundred times in most of the new oil areas. Pennsylvania was the principal supplier of the world's

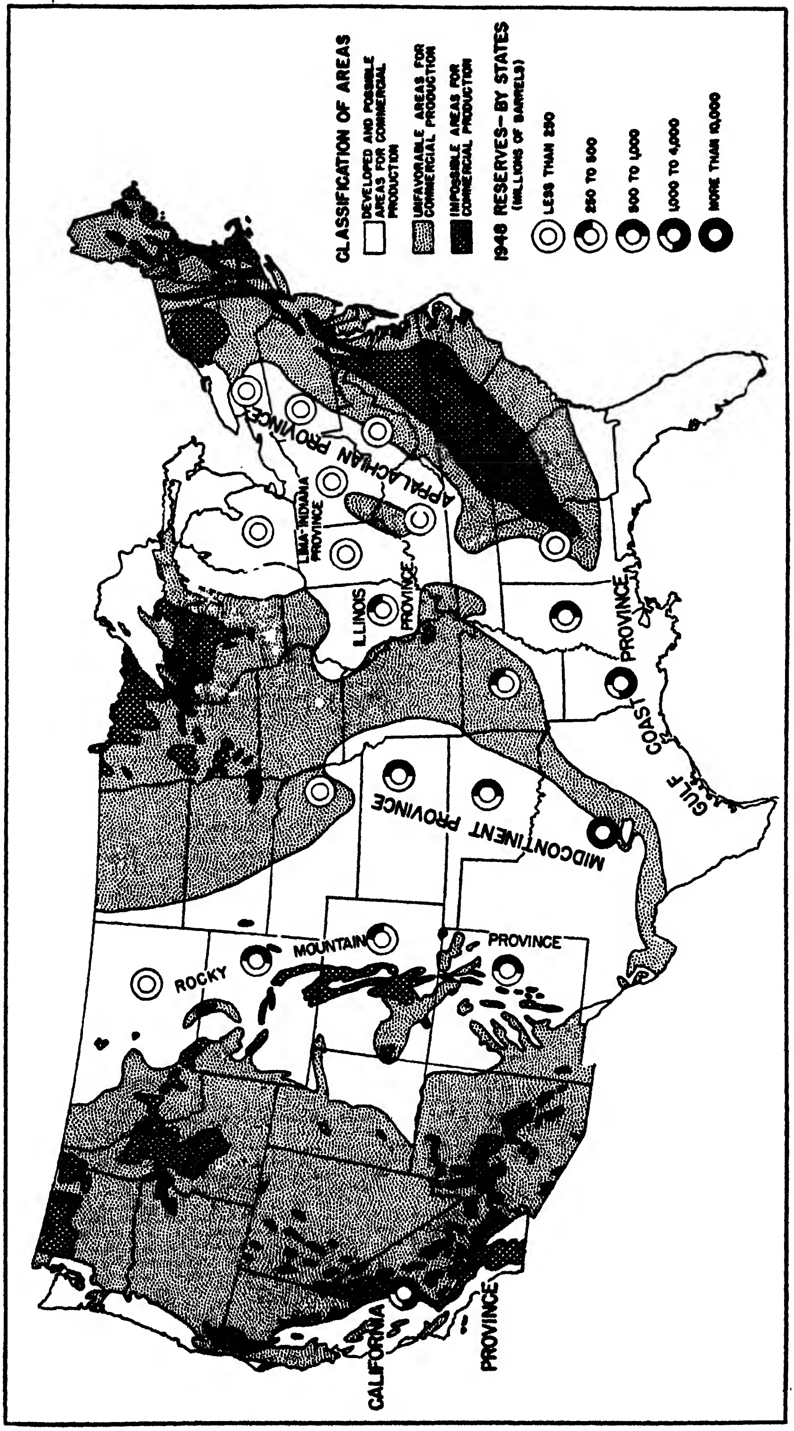

FIG. 5. Petroleum areas in the United States. (U. S. Geological Survey.)

oil until the Lima–Indiana province was discovered in 1884. The maximum for the Appalachian province was reached in 1891 when more than 33,000,000 barrels were produced. Production has declined slowly since that date, and most wells in the province are now extremely small. Some areas average only one-fourth of a barrel per day, and the average production of all wells in Pennsylvania is now less than three-tenths of a barrel daily. Over 140,000 wells have been drilled in the province. A number of fields have developed secondary recovery methods in order to secure a greater yield of petroleum. The Bradford field has applied water repressuring measures since the early 1900's and is the principal area of production, as well as the most important experimental center, of secondary recovery efforts in the United States. The oil is high grade, ranging from 35° to 50° Baumé. It is paraffin base with few impurities and consequently commands the highest price of all petroleums. It is of particular value in the making of high-quality lubricants.

The Lima–Indiana province extends from the northwestern corner of Ohio to Indianapolis, Indiana. It was discovered in 1884, and peak production occurred in Ohio in 1896 and in Indiana in 1906. The oil is paraffin base but contains sulphur and water which has lowered its value. The province was developed at a time when conservation principles were disregarded so that production rose and declined rapidly. From 1884 to 1931 more than 60,000 wells were drilled. No doubt one-tenth of this number could have recovered more petroleum. Today the province is nearly exhausted.

The Michigan province was discovered in 1925, and most of the production has come from the Saginaw and Muskegon fields. In 1939, the peak year, production was only 23,500,000 barrels. The output has declined since then, and there is little indication of future growth.

The Illinois province, lying in southeastern Illinois and western Indiana, was discovered in 1905, and output reached a peak in 1910 when 33,000,000 barrels were produced. Production declined to less than 5,000,000 barrels annually by 1937 when deep drilling discovered new sources of petroleum. The output again increased rapidly until 1940 when 146,484,000 barrels were produced but gradually declined to a production of 66,440,000 in 1947. The production curve in Illinois illustrates the effects of new discoveries on output when no effective conservation legislation had been enacted. In both periods of new discoveries the basic philosophy was to secure the largest possible production in the shortest possible period. Conservation principles have largely been ignored; consequently, the ul. timate yield has been greatly reduced as a result of such factors as overdrilling and rapid depletion of the original reservoir. This petroleum, largely paraffin base testing about 30° Baumé, is sulphur free and is easily refined. The natural gasoline content is only 15 to 20 per cent and consequently the value of the oil is rather low.

The Midcontinent province, which includes the oil fields of Kansas, Oklahoma, Arkansas, northern and west-central Texas, and northern Louisiana, is the largest and most productive area in the United States. Large-scale developments began in 1905. Between 500,000,000 and 800,000,000 barrels of oil have been produced annually for the past 15 years. This tremendous production is due to the large petroliferous area, the complexity of structural conditions, and the variety of sources of origin of the petroleum. All grades from light paraffin to heavy asphaltic oils are produced. This province has had many spectacular developments. The discovery of the Glenn pool in Oklahoma in 1905 increased the state's production from 1,367,000 barrels in 1904 to 43,524,000 in 1907. The wildcat exploration in Kansas in 1916 to 1918 with the discovery of such fields as Eldorado, Augusta, Florence, and Peabody increased the state's production from 3,000,000 to 45,000,000 barrels. The discovery of each new field has stimulated the search for others so that production has continually risen. A number of times the production has been so great, as a result of new discoveries, that the oil market has been flooded and prices fell temporarily. In each instance, however, peak production has rapidly subsided, and the market has recovered. Early efforts to control production by conservation methods failed. However, greater conservation efforts are now being practiced.

The Gulf coast province came into production in 1900 with the discovery of oil in the famous Spindletop well. Production has at times declined temporarily but the general curve has been upward to the present. The province ranks third in the United States and will probably continue to be a large producer for a considerable period. The oil is usually associated with domal rock structures and thus is frequently under great pressure, resulting in many gushers.

The crude oil is of heavy asphaltic base with sulphur impurities and contains little natural gasoline. Fuel oil is the major refined product which is used extensively in ships. With the use of cracking in refining, the heavy oils have become a good source of gasoline. Some of the oils are excellent for the preparation of heavy cold-test lubricants.

The Rocky Mountain province is composed of scattered fields from Montana to New Mexico. Nearly all grades of oil are present, but light high-quality oils dominate. Production began about 1916 but has always been small. In view of the large area and varied structural conditions, petroleum may be found in larger quantities in the future. A more intensive search is necessary if the petroleum areas are to be thoroughly explored.

The California province ranks second in the annual output of petroleum. There are only two large producing districts, the Los Angeles basin and the southern portion of the San Joaquin valley. Evidence of oil from surface seeps had long been known but the first successful well was not completed until 1887 at McKittrick. Production increased rapidly until 1903 when California became the largest oil-producing state. California has been either in first or second place since then.

The oil pools are characterized by high gas pressure so that individual well production is usually large. The oil is predominantly asphaltic in character, but smaller quantities of high-quality crude are produced. Because of great flush production and competition, excessive drilling has characterized the area. After much waste the oil producers have finally recognized that conservation practices pay dividends. California now has a state conservation law which helps to prevent the waste of natural gas. This gas is conserved not only for industrial uses but also to maintain pressure in the wells, thus increasing the amount of oil that can ultimately be recovered from the producing sands.

Trends in Production

The petroleum industry has experienced a continuously rising production curve

(Fig. 6). The increase from 1859 to 1900 was relatively modest with a yearly average of only 25,000,000 barrels and a total production of 1,000,000,000 barrels. The great demands for petroleum were created by the development of automotive transportation. Domestic consumption rose rapidly after 1900 from 209,500,000 barrels in 1910 to a peak of 1,007,300,000 barrels in 1929. After a temporary recession in the early 1930's the 1936 production exceeded the 1929 peak and output has continued to rise to an all-time high of 2,000,000,000 barrels in 1948. The rate of production has been greatly accelerated in recent years. More oil was produced in 1948 than the total between 1859 and 1907. From 1930 to 1948 more than 25,000,000,000 barrels were produced, which was 71 per cent of the total production since 1859.

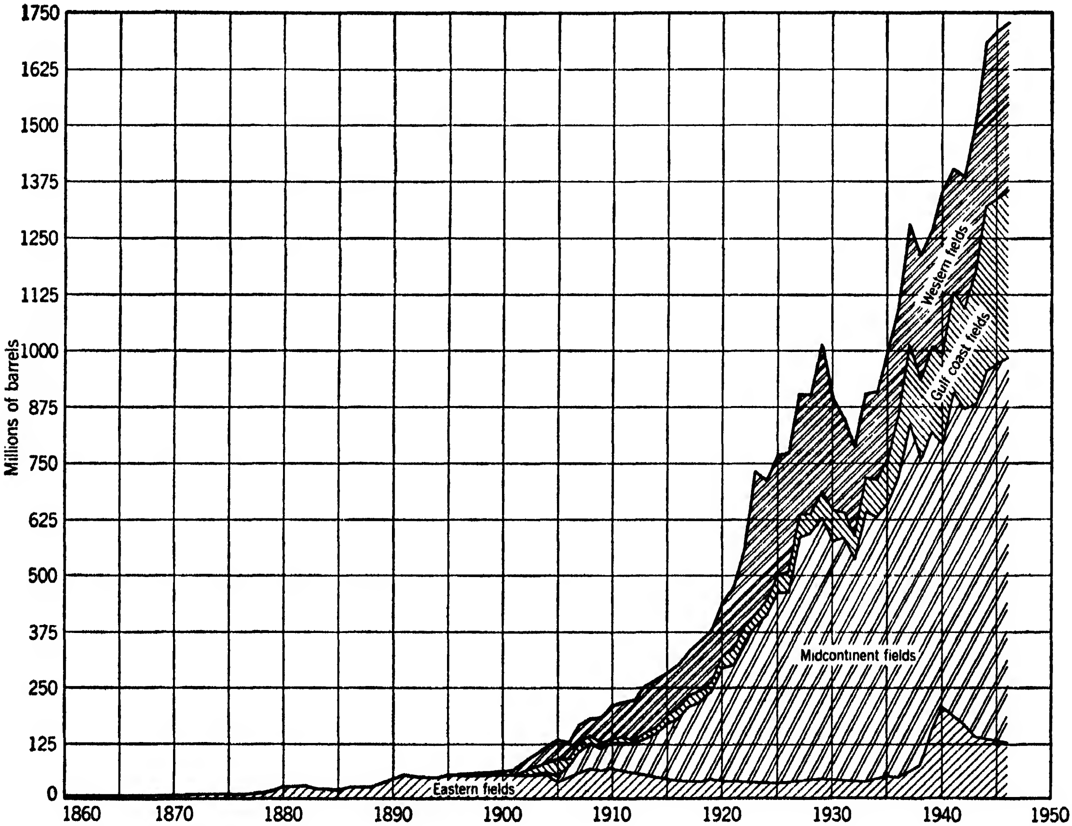

FIG. 6. Petroleum production of the United States, 1860–1946. (Data from the U. S. Bureau of Mines.)

This tremendous production has been caused primarily by the demands for gasoline and fuel oils. The consumption of gasoline has risen from 75,000,000 barrels in 1918 to 913,000,000 barrels in 1948. The domestic demand for fuel oil has risen from 150,000,000 barrels in 1918 to 920,000,000 barrels in 1948.

Migrational Trends

Peculiar to all mineral exploitation is the characteristic of exhaustibility; oil and gas pools are notoriously short lived, particularly when exploited under the wasteful practices of competitive drilling. Today the computed centers of oil and gas production are far from the areas where the industry was first important. The line of march has been to the west and south, following closely in the wake of discovery.[12]

The center of oil production was located in western Pennsylvania from 1859 to 1889, the longest period in which it has been in one spot. Commercial production began in Ohio, West Virginia, and California in 1876, and in 1889 the center of output was in northeastern Ohio; a decade later it had moved to northwestern Ohio close to the Indiana border. In 1900 more than 57 per cent of the crude oil came from the Appalachian district, more than one-third from the Lima-Indiana district, and the remaining eight per cent from California and the Gulf coast.

From 1900 to 1910 the center of production shifted westward from western Ohio to central Kansas as a result of the remarkable discoveries of new oil pools in the Mid-continent field. By 1919 the center had shifted slightly southward to the Panhandle of Oklahoma. At this time a secondary center of production had developed in California. California was the leading state from 1903 to 1915. From 1915 to 1927 California and Oklahoma were about equal in output, and first place shifted between them. In 1927 Texas became the largest producer and has maintained the lead since then, producing over 44 per cent of the national total in 1948. The center of production has consequently shifted, first southwestward in 1929 to northwestern New Mexico and then into the Panhandle of Texas as a result of the outpouring of oil from these fields in the early 1930's. The center remains today in the Panhandle of Texas. In 1948 more than 60 per cent of the crude oil produced came from the Mid-continent fields, about 20 per cent from California, and over 12 per cent from the Gulf coast fields. The Illinois fields' share of production in 1948 was about four per cent, and less than two per cent was supplied by the Lima, northeastern Indiana, Michigan, and Appalachian fields.

[12] O. E. Kiessling and others, "Technology, Employment, and Output per Man in Petroleum and Natural Gas Production," *National Research Project, W.P.A. Report E-10*, 1939, pp. 34–50.

United States Petroleum Reserves

From the earliest period the conviction of an early exhaustion has haunted the petroleum industry. In periods of stress these fears have aroused public opinion and have colored national policy. Since petroleum is a liquid deeply buried in the earth the only way to measure reserves is to drill into them and estimate possible recovery. The proved petroleum reserves of the United States have constantly been revised upward to the present (Fig. 7). The first estimates were made in 1909 when the automobile industry was beginning to make its first great demands for gasoline. It was estimated that the total petroleum yield of the United States might be as low as 10,000,000,000 barrels or as high as 24,500,000,000 barrels. The first estimates in which the proved reserves were separated from estimates of undiscovered fields were made in 1921. In this estimate, 5,000,000,000 barrels were classified as oil "in sight" on January 1, 1922, and 4,000,000,000 barrels additional as prospective and possibly recoverable by current methods of production. In 1925 the American Petroleum Institute estimated proved reserves to be 5,321,427,000 barrels. The Federal Oil Conservation Board stated in October, 1932, that new discoveries raised the known reserves to 10,000,000,000 barrels, and the American Petroleum Institute on January 1, 1939, reported that proved reserves were 17,348,146,000 barrels.

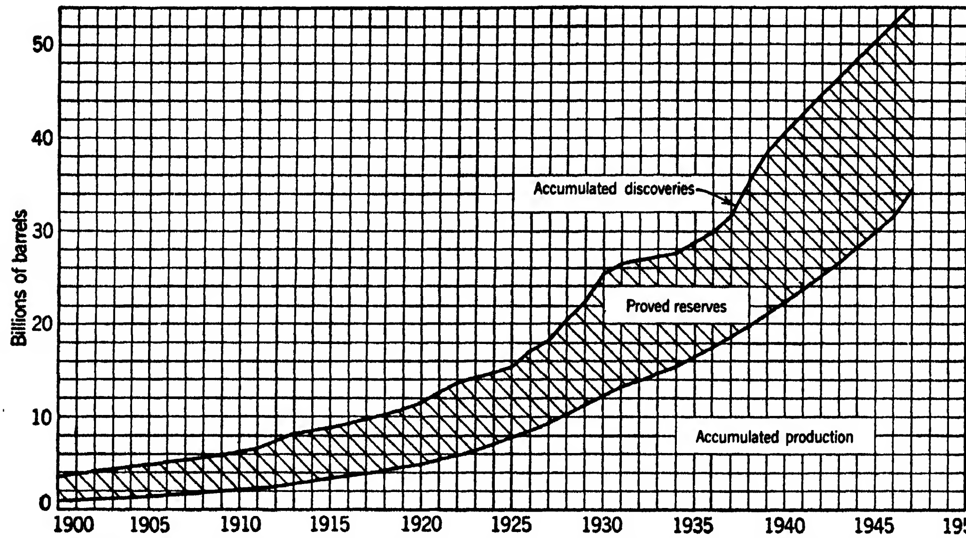

FIG. 7. Accumulated production and proved reserves of petroleum in the United States, 1900–1947. (American Petroleum Institute.)

The proved reserves have continued to mount until on January 1, 1948, the American Petroleum Institute and American Gas Association reported proved reserves of 21,487,685,000 barrels of crude oil and 3,253,975,000 barrels of natural-gas liquids, making total reserves of 24,741,660,000 barrels, the largest in the country's history.[18] Despite a record output of 1,988,000,000 barrels of oil in 1947, the net gain in proved oil reserves of the country amounted to 614,125,000 barrels of crude oil and natural-gas liquids. Texas, with reserves of 14,765,000,000 barrels has 59 per cent of the United States oil reserves, with California, Louisiana, Oklahoma, Kansas, Wyoming, and New Mexico following in the order named.

Proved reserves in any pool include both drilled and undrilled oil recoverable under existing economic and production systems now in operation. For a one-well field, where development has not gone beyond the discovery well, the area assigned as proved is usually small in regions of complex geological conditions, but possibly larger where the geology is simple. In a sparsely drilled field the area between wells is considered to be proved only if the information regarding the geology of the field and the productive horizon is adequate to assure that the area will produce when drilled. Thus the total of new oil through discoveries estimated as proved in any given year will be comparatively small and the total new oil by extension comparatively large.

[18] *Proved Reserves of Crude Oil, Natural Gas Liquids and Natural Gas, December 31, 1947,* American Gas Association and American Petroleum Institute, New York, Vol. 2, 1948.

Trends of Petroleum Reserves

The ultimate survival of the petroleum industry depends on the discovery of new fields and deeper oil-bearing zones. The extent to which new sources will be found will depend greatly on whether the price of oil will permit the heavy and increasing expenses of new exploration and still maintain a profit. Although new oil regions will still be discovered, the number of new fields is definitely limited; each newly found field leaves one less to be discovered.

The proved reserves are about twelve times the present rate of production. The trend of discovering additional reserves of petroleum in new fields in the United States has been downward since 1939 and was at its lowest level in more than 20 years in 1946. The rate at which the United States can produce oil is primarily dependent on the finding of new fields, for we have relied in the past on relatively new flush fields for about half of our requirements. The decrease in the finding of new oil reserves during the past several years is shown in Fig. 8.

The decrease in new discoveries is exceedingly serious for exploration has increased in recent years. Over 15,000 wildcat wells were drilled from 1940 to 1945. This activity resulted in the discovery of a record number of new fields and of new producing horizons in old fields, but the importance of these discoveries, measured in terms of volume of new oil, has gradually diminished. Between 1919 and 1939 three major fields, averaging more than 100,000,000 barrels annually were discovered each year. Since 1940 only one such major field has been discovered; therefore, the petro-

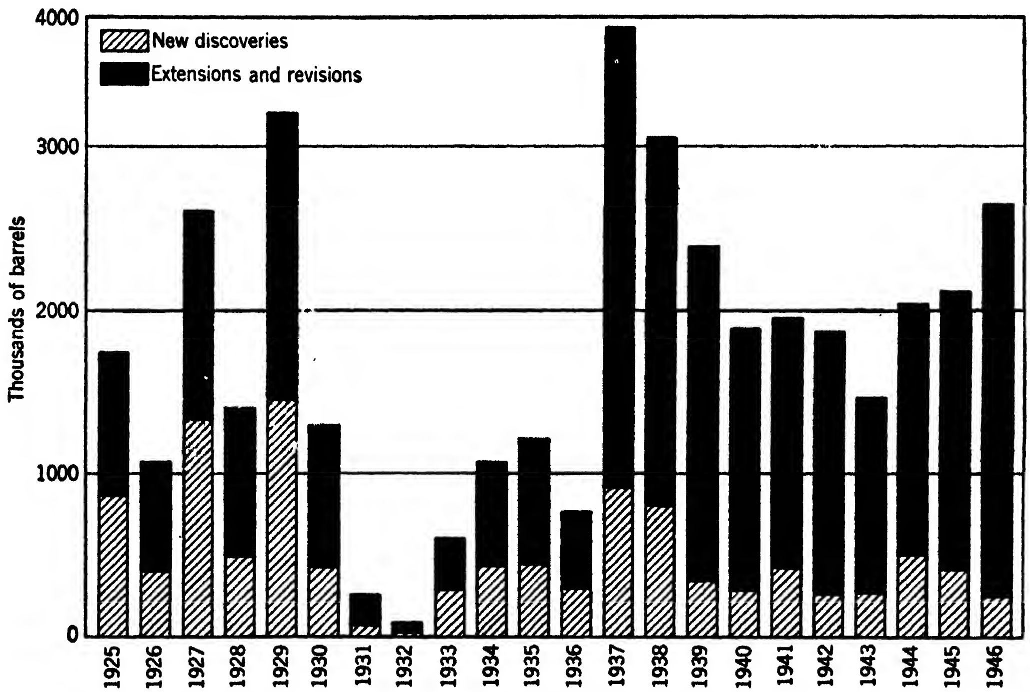

FIG. 8. Annual new reserves of petroleum, 1925–1946. (American Petroleum Institute.)

leum industry has been drawing heavily on reserves.

Although the rate of discovery of new oil fields has greatly decreased compared with pre-war years, geologists estimate that more than 150,000,000,000 barrels of oil may yet be found in the Western Hemisphere. About 50,000,000,000 barrels of this is placed in the United States. In addition, the country has yet to exploit fully the underwater sources of the continental shelf. Secondary recovery of domestic supply from apparently depleted oil fields and synthetic fuels are further sources barely touched to date.

PETROLEUM CONSERVATION PROBLEMS

Applied petroleum conservation lies largely in wise utilization and an advancing technology in order to achieve maximum recovery with minimum waste. In each of the technical branches—exploration, drilling, production, and refining—new scientific advancements have added millions of barrels to our reserves. If our petroleum industry is to serve adequately for its maximum period of existence, a continuing and expanding program in public education and technical research is a necessity. It has been estimated that perhaps 17,000,000,000 barrels of the ultimate recovery of 50,000,000,000 barrels from present known fields can be credited to improved technology.

PETROLEUM EXPLORATION

Development of Scientific Exploration

The first oil fields were discovered either on surface evidence, such as seepages or gas bubbles, or on pure luck. It was not until after 1900 that the industry considered geological interpretation a definite aid to oil exploration. Beginning about 1912 geologists started to map outcrops to locate favorable drilling locations. By 1920 various kinds of cross sections, subsurface contour maps, and peg-models in three dimensions were being used extensively. The results of the initial explorations were encouraging, and soon the known structures had been drilled to depths permitted by existing equipment.

The most radical change that has come about in exploring for oil and gas has been the introduction of geophysical methods in the early 1920's.[14] One of the earliest was the refraction seismic method developed by German scientists. In this method, scientific use is made of the fact that seismic or earth waves, caused by a charge of explosive detonated at or near the surface, will travel with greater speed through dense rocks than through the surface formations between the starting and recording device. The refraction method was successful in locating a large number of salt domes in the Gulf coast but was largely unsuccessful in locating small deeply buried structures that are so common in the Mid-continent fields. As a result, Americans developed the reflection seismic method which employs ranging principles. In the reflection method the depth and configuration of deeply buried beds are determined from records of waves that originate at the blast and are reflected back to the surface, similar to the echoes that result from reflection of sound waves. The results of this method were phenomenal and the method is used

[14] W. M. Rust, Jr., "Evaluation of New Geophysical Methods," *Bulletin of the American Association of Petroleum Geologists,* Vol. 29, 1945, pp. 865–871.

today in practically all oil-producing countries. This method of exploration has been applied particularly to areas where no surface indications are present. It can be used for the deepest drilling possible today. In 1930 there were a few crews in the field; by 1935 the number had increased to about 50, and by 1944 to about 250.

The gravity methed of exploring for oil, which by means of a torsion balance measures local variations in the intensity of the earth's gravitational field, was also introduced in the early 1920's. This instrument has been particularly helpful in discovering salt domes and for reconnaissance surveys. In 1944 there were more than 60 gravity-meter teams operating in the United States. Other geophysical methods of exploration include apparatus measuring the magnetic phenomena in the earth's crust caused by certain mineral deposits and the conductivity or resistivity and other electrical properties of rocks constituting the earth's crust.

The use of aerial photographs is advancing rapidly in oil exploration for interpretation of structural features such as anticlines, faults, and other features. Plane table mapping still is of value, but aerial photographs present a direct view of the terrain and make it possible to establish easily the exact position of objects. Today aerial photography is on a scientific basis. Aerial maps can be made with a contour interval of five feet which are equal in accuracy to many transit and plane table surveys.

Results of Planned Exploration

The development of geophysical and other methods of surveying has greatly increased the possibilities of discovering oil. From 1937 to 1942 one out of every six wildcat wells drilled on technical information discovered an oil pool, whereas only one out of eighteen wildcat wells that were drilled without technical advice discovered oil.[15] The reserves of the United States have greatly increased since the introduction of scientific exploration about 1925. If the trends from 1920 to 1925 had been maintained to the present day, the 1948 proved reserves would have been under 15,000,000,000 barrels; actually they are nearly 25,000,000,000 barrels.

The problem of finding additional oil for our expanding market demands an active exploration program. The industry is now spending several million dollars a year in research to develop new techniques and improve old ones. Some of the current problems involve direct oil finding by geophysical and geochemical methods, adaptation of the seismic method, the origin of petroleum, and intensive studies of subsurface data collected from old and new wells. Oil exploration is a dynamic phase upon which the entire industry is dependent.

DRILLING

Trend toward Deeper Drilling

Drilling advancements, which have permitted the penetration of all types of formations at ever-increasing depths, have been significant factors in extending the life of the petroleum industry. The pioneer wells were exceedingly shallow, many not exceeding several hundred feet. Gradually the depth increased. By 1890 the deepest well was over 5000 feet and by 1925 nearly 8000 feet. In 1938 a test well in California reached a depth of 15,004 feet, and in 1947 a new record was established with a well

[15] Leonard M. Fanning, *Our Oil Resources*, New York, 1945, pp. 75–76.

nearly 18,000 feet deep. Today a 5000-foot well is considered relatively shallow, and many wells are producing from below 10,000 feet.

Deeper drilling has been responsible for the discovery of new fields in areas where shallow drilling had proved unsuccessful, and of new sands underlying old producing fields in which the existence of such sands, if known, was previously considered beyond the limit of drilling. The most reliable estimates now available indicate that the ultimate recovery from reservoirs already discovered and 5000 feet or more in depth will be in excess of 11,000,000,000 barrels, or almost a quarter of the total ultimate recovery from fields discovered to the present time.

Improvements in Equipment

The outstanding change in drilling technique, directly responsible for reaching greater depths, was the shift from the cable tool method to the rotary method. The rotary method differs from the cable tool method in that the formation through which the wells are drilled is abraded and chipped by an auger-like, "fishtail" bit attached to a rapidly rotating pipe, instead of being hammered and pulverized into small particles by the pounding of heavy tools suspended on a cable. Greater speed is an important advantage of the rotary drill. It is not uncommon for a modern rotary rig to drill as much as 1000 feet of soft formation in one day. As a result of the development of "hardrock" bits and hard-surface alloys, the rotary system has been adapted to practically all formations.

The success of the rotary system has been due to scientific control of the circulating mud fluid and the ability to drill a hole of uniform size. The mud coats the walls of the hole, and the water sands are sealed without using numerous strings of steel casing. In cable tool drilling each water horizon must be shut off by a separate string of casing. Thus, in rotary drilling a hole of uniform size can be maintained to any depth whereas with cable tools the hole gets progressively smaller, eventually leading to "running out of hole," a condition that prohibits further drilling. The rotary drill can maintain a uniformly large hole which makes deep drilling possible.

Other major advancements in drilling include improvements in cements and cementing techniques, and development of methods to control high subsurface pressures and temperatures. The application of directional drilling has made it possible to develop off-shore fields, such as those in the Gulf of Mexico and along the California coast, where the derricks are on the shore and the oil reservoirs underlie beach resorts or deep water. There has been a general improvement in the design, strength, and power of drilling equipment. With increased depth the trend has been to heavier rigs. The cable tool derrick has increased in height from 64 to 122 feet, and rotary derricks vary from 122 to 178 feet. Efficient gas-pressure control equipment has been invented which permits drilling in high-pressure areas. The development of these drilling techniques has added thousands of square miles of prospective oil area and has added substantially to our crude oil reserves.

PETROLEUM PRODUCTION

The techniques of producing oil from wells have been revolutionized. A scientific analysis of traditional methods has indicated many desirable modifications, for the life of an oil field depends to a large extent on its method of development. Improvements in well spacing, efficiency of reservoir operations, increased importance of production engineering, and secondary recovery methods have enabled constantly larger proportions of the gas and oil in the underground reservoir to be recovered.

Well Spacing

Petroleum, unlike solid minerals, moves underground with shifting pressures. Thus, oil will move toward a well where there has been a release in pressure. The long-established rule of capture in oil and gas regions gives the owner of an oil well the right to produce all oil that flows into his well. As a consequence, as soon as an oil well is drilled in an area owned by small landholders, each owner is forced into an intensive drilling campaign if he is not to lose his oil. In most of our fields the fact is wholly ignored that oil and gas pools are single units and that for maximum production they should be developed and operated without reference to surface property lines. In hundreds of our oil fields thousands of needless wells have been drilled because of the competitive character of the American oil industry. The greatest disadvantage of uncontrolled drilling is maximum production within a short period of time with resultant loss of the gas pressure and consequently a low ultimate recovery of the oil.

No general rule of well spacing has been devised for each pool must be considered separately.[16] There has, however, been a tendency toward wider well spacing. During World War II the federal government required a spacing of one well to 40 acres. In some fields physical conditions require closer spacing, in others an even wider spacing. Wider spacing with efficient methods has reduced the cost of developing pools and is reflected in lower producing costs. Thus, the consumer benefits from this new pattern of development.

Efficiency of Reservoir Operations

The increased knowledge of the principles of reservoir behavior and factors affecting recovery have contributed more to our present reserve position than any other single development. The most efficient operation results from maximum use of natural energy. In the early oil industry, and the practice still exists in certain areas, it was common procedure to produce the oil as rapidly as possible, now recognized as extremely wasteful. Controlling the production rates and conserving the reservoir energy increase the ultimate recovery.

Fundamental research on the physical properties of the oil reservoirs has been considerable since 1925.[17] The knowledge of the reservoir energies, free gas, oil and dissolved gas, and free water, has been greatly increased. Since oil in itself has no inherent energy, its recovery depends on its displacement by either gas or water. It is now generally recognized that there are three ways in which these fluids behave to release energy: through a simple expansion of gas released from solution in the oil, through displacement of the oil from the sand by downward expansion of a free gas cap, and through displacement of oil by upward influx of water from below the oil sands.

The adoption in recent years of methods

[16] W. V. Vietti and others, "Relation Between Well Spacing and Recovery," *Petroleum Engineer,* Vol. 17, 1946, pp. 51–60.

[17] Park J. Jones, *Petroleum Production,* 2 volumes, New York, 1946.

to maintain as nearly as possible the original reservoir pressures has proved successful in all operations. For example, in the Cook Ranch field of Texas pressure maintenance has raised the ultimate recovery from 7,500,000 barrels to 20,000,000 barrels, and in the Tepetate field of Louisiana the ultimate yield has increased by at least 40 per cent. Thus the problem is to maintain natural pressures or, if these are exhausted, to create new energy by water or gas repressuring.

Increased Importance of Production Engineering

Upon completion of a well in most new fields, an efficient production organization has been planned to give the largest ultimate recovery possible. Advances have come so rapidly that oil-producing operations have become highly specialized.[18] A few of the more important engineering developments follow. From the standpoint of efficient recovery and the conservation of reservoir energy, the use of tubing in flowing wells—particularly where natural gas is the chief propulsive agent—is probably one of the most important technical advances. When wells are produced at considerably less than open flow rates, as under proration schedule, higher efficiencies of flow are attained through tubing of smaller diameter than would be obtained through large casing. Modern oil and gas separation, operating under pressure, effect efficient separation of fluids and gases and allow virtually complete recovery of the gas accompanying the oil. This permits the gas to be reinjected into the oil sand, maintaining the reservoir pressure and increasing the ultimate yield. More effective technical procedures, both for lifting and pumping oil, have increased the total amount recovered. In 1928, a depth of 5000 feet was regarded as the maximum from which oil could be lifted by plunger pumps. By 1934 the advancement in sucker rods and pumping units made it practicable to lift oil commercially from depths of 7000 to 8000 feet, and today this has been increased to more than 10,000 feet. These and numerous other technical efficiencies have also added millions of barrels of petroleum to our known reserves.

Secondary Recovery Developments

By the primary production methods practiced in the United States as much as 50 to 90 per cent of the original oil remained in the oil sand when the wells were abandoned. As a result the oil industry is developing processes by which a greater recovery of oil can be obtained after the free flow has ceased and pumping is no longer profitable. Secondary recovery practices are growing in importance, and consequently millions of barrels of additional oil have been added to our reserves.[19]

In secondary recovery the reservoir energy must be restored by some method of repressuring the oil sands. Water flooding, first applied in the Bradford field of Pennsylvania about 1900, was the first repressuring method. The water is injected into the oil sand, and as it spreads out from the injection well it drives the oil ahead of it into oil-producing wells. This method recovers an additional 15 to 30 per cent of the original amount of oil. About 30 to 45 per cent of the original quantity of oil

[18] S. E. Buckley, "Trends and Developments in Petroleum Production Engineering," *Bulletin of the American Association of Petroleum Geologists,* Vol. 30, July, 1946, pp. 1131–1139.

[19] *Drilling and Production Practice—1945,* American Petroleum Institute, New York, 1946.

is still left in the sands. "How can this additional oil be recovered?" is one great question in the oil industry today.

Gas and air repressuring has had a wider application than water flooding. This method is now in use in practically all producing states. Production has been greatly increased. For example, in central Pennsylvania production on certain leases has been increased more than 700 per cent by gas drive. In the Bartlesville field of Oklahoma the original reservoir pressures yielded a total of 4000 to 6000 barrels per acre over a period of 20 years. With the introduction of gas drive an additional output of 1000 to 1500 barrels per acre have been recovered for a period of more than ten years.

Secondary recovery methods are usually more expensive than primary operations and have therefore been limited to the most promising areas. As our supply of oil is exhausted and prices increase, secondary recovery methods will be more widely practiced. The oil industry now estimates that possibly as much as 5,000,000,000 additional barrels of oil may be obtained by secondary recovery. These estimates are not considered as part of our 24,000,000,000 barrels of oil recoverable from present proved fields.

REFINING

Advances in Refining

The technological advances in refining in the twentieth century have also added millions of barrels of oil to our reserves. The greatest advancement in refining has been the development of the cracking process since 1913, by which heavy hydrocarbon molecules can be broken into lighter fractions by the application of comparatively high temperatures and pressures. By this method the amount of gasoline from a barrel of crude oil has been increased from 18 to 45 per cent of the total yield. With the development of catalytic cracking, of which several units have already been built, the average yield of gasoline will be increased to about 57 per cent and could be increased greatly beyond this figure.[20]

If it were not for the increased yield of motor fuel made possible by cracking, more than twice as much crude oil would be needed to supply the present demands. Besides lengthening the life of our petroleum resources, the conversion of the heavy fraction of petroleum to gasoline by cracking has tended to retard the extent to which coal has been replaced by oil as an industrial fuel. Without cracking the heavier fractions would have been available in constantly larger quantities from ordinary distillation processes and would have been placed on the market at prices in competition with coal.

The cracking process is most important, but other techincal advancements have been significant. The polymerization process makes it possible to produce thousands of barrels of gasoline daily from refining gases that were once wasted, and this process has also contributed largely to the making of 100-octane gasoline. The use of tetraethyl lead has produced a better anti-knock gasoline. Owing largely to refining improvements the modern airplane engine is about ten times as powerful, weighs about one-fourth as much per horsepower, and has about 40 times as great thermal efficiency as those used in 1920. Refining technology has increased our reserves and at the same

[20] G. Armistead, "Modern Refining Processes," *Oil and Gas Journal*, Vol. 44, 1946, one of a series of 15 articles.

time made available a product of greater efficiency.

Synthetic Liquid Fuels

As the natural petroleum supplies are depleted substitute liquid fuels can be produced to supplement the declining crude oil. This supply can come from a number of sources, such as (1) alcohols from vegetable matter, (2) distillation of oil shales, (3) conversion of natural gas by the gas synthesis process, (4) liquefaction of coal or lignite by the hydrogenation process, (5) conversion of water gas from coal by the Fischer-Tropsch synthesis process, and (6) by-product light oils and tars from coking coal.

Alcohol, distilled from vegetable matter, has proved satisfactory when blended with motor fuels. At present its production cost is greater than that of gasoline from petroleum, but if the price can be lowered its use may increase greatly.

Petroleum can be obtained from oil shales that contain little or no liquid oil or hydrocarbons but from which large quantities of oil can be obtained by destructive distillation. Detailed surveys of the oil shales of the United States have never been prepared, but a preliminary report in 1928 estimated that there were 400,000,000,000 tons of oil shales which would yield 92,000,000,000 barrels of oil. More recent estimates indicate that this approximation may be low. The greatest reserves of shale are in western Colorado, southwestern Wyoming, and eastern Utah. Secondary deposits are found in Nevada, Indiana, Ohio, Kentucky, West Virginia, and Pennsylvania. The oil yield from these shales varies from 15 to 60 gallons per ton of shale, and yields of gasoline from 35.2 to 55.3 per cent have been obtained by the cracking process. Estimates of total costs for producing a barrel of crude shale oil varies from $1.75 to $2.50. Only small trial plants have utilized oil shales to the present.

Natural gas can be converted to liquid hydrocarbon by first changing it to carbon monoxide and hydrogen which are the raw materials for the gas synthesis process. From 10,000 to 12,000 cubic feet of gas are required for one barrel of gasoline. With natural gas costing five cents per 1000 cubic feet a gallon of gasoline will probably cost between five and nine cents. Small commercial plants are now operating in Kansas and Oklahoma. Although gas reserves are fairly large natural gas is usually considered too valuable a substance in its own form to supplement the petroleum reserves.

In the manufacture of coke and coal gas, 10 to 12 gallons of tar and three gallons of light oil are obtained in the high-temperature carbonization of one ton of coal, and 20 to 35 gallons of tar are obtained in the low-temperature carbonization of one ton of coal. Coal tar averages about 16,500 Btu's as compared with 19,000 Btu's per pound for petroleum. Much of this tar is now used as a liquid fuel at the steel plants. At present, however, this is not a practical method to produce large quantities of liquid fuels, for the yield of oil is too low in relation to the quantity of coal consumed.

Two processes for the direct production of synthetic fuels from coal or lignite are receiving widespread attention: the coal hydrogenation, or Bergius-I.G., process, and the gas synthesis, or Fischer-Tropsch, process. Liquid fuel is the primary product of both processes with combustible gases and waxes as by-products.[21]

[21] A. C. Fieldner and others, "Hydrogenation and Liquefaction of Coal and Lignite," *Technical Paper* 666, U. S. Bureau of Mines, 1944, 69 pages.

In the coal hydrogenation process the large reserves of high-volatile coal of Ohio, Indiana, western Kentucky, and Illinois and the subbituminous and lignite of western United States are potentially of value, but subbituminous coal is the only grade that can be used at present until improved processes are developed. One ton of high-volatile bituminous coal will yield from 1.43 to 1.79 barrels of gasoline, one ton of subbituminous coal will yield approximately 1.11 barrels of gasoline, and one ton of lignite will yield 0.8 barrels of gasoline. At present there are 800,000,000,000 tons of subbituminous coal in the United States which would yield approximately 888,000,000,000 barrels of gasoline. For the present the large reserves of high-volatile bituminous and lignite should be regarded as only secondary sources. Ordinarily coal will be hydrogenated directly to gasoline, but it is possible to produce Diesel fuels as well as some grades of lubricating oil and wax. By conventional high-pressure hydrogenation a gasoline of 70- to 75-octane rating can be produced in 20 to 25 per cent yield.

The gas synthesis, or Fischer-Tropsch, process has a much wider application to greater varieties of raw material, including coal, coke, lignite, coal gas, natural gas, charcoal, and wood. They are converted to carbon monoxide and hydrogen which are combined in their conversion to liquid hydrocarbons. The yield of gasoline from bituminous coal is about 2.3 barrels per ton and from subbituminous about 1.7 barrels. The gasoline from American reserves of coal alone would be approximately several thousand billion barrels. The cost per gallon of gasoline would be about eight or nine cents. The straight-run gasoline, constituting about 60 per cent of the total, would have an octane number of about 50 to 55. Other products include Diesel oil, lubricating oils, and waxes.

PETROLEUM CONSUMPTION

Use without Waste

In using petroleum and its products motorists frequently forget that they are using an irreplaceable natural resource. Largely because of the cheapness of cars and of motor fuel, the United States has become the world's greatest per capita consumer of petroleum. Motoring within the United States during 1946 was equivalent to nearly 12 million trips around the earth. The ordinary motorist could institute many economies in waste if he thought only a little about the valuable product he is destroying. It is commonly known that greater mileage per gallon of gasoline can be obtained if the speed is moderately fast. Yet we persist in building higher and higher speed automobiles. Through reasonable reduction of speed it is estimated that 10 per cent of the nearly 20,000,000,000 gallons of gasoline consumed in 1946 could have been saved.

It is also estimated that another ten per cent could have been saved by eliminating much needless driving such as short drives in cities and seeking a parking place, and by keeping pleasure riding within reasonable limits. The conservation of nearly 70,000,000 barrels of motor fuel would have a value of nearly $500,000,000 saved for worth-while projects. It is also common practice for filling station attendants to destroy oil that has motor sludge and dirt in it. This oil has nearly as much fuel value as new oil and should be used in heating plants and incinerators. Most carburetors on American cars are inefficient utilizers of gasoline. It is asserted that if carburetors were properly adjusted on all cars there would be a saving of another $250,000,000 on our annual fuel bill. Conservation is the effort to ensure the maximum present and future benefits from the use of natural resources. It cannot be practiced by a few specialists. It is the obligation of every citizen to use our rich heritage with maximum efficiency and minimum waste.

NATURAL GAS

Value and Uses of Natural Gas

Natural gas has been called "Nature's most perfect fuel." Its use as a raw material in industry and as a domestic fuel has been expanding greatly in recent years. The value of marketed natural gas has risen from nearly $200,000,000 in 1920 to $900,000,000 in 1948. The industrial users consume 80 per cent of the total marketed natural gas for the manufacture of carbon black, production of gasoline, as a fuel for Portland-cement and electric-power utility plants, and in oil and gas field operations. Domestic heating was the second largest outlet for natural gas followed by the commercial market. This increase in use is due largely to new gas discoveries, new uses for gas, and the development of long-distance natural gas pipe lines. In 1948 four states, Texas, California, Louisiana, and Oklahoma, consumed over 60 per cent of the natural gas marketed, but millions of cubic feet of gas were transported from the southwestern gas fields to the northeastern market.

Trends of Production, Distribution, and Reserves

It has been estimated that commercial gas production from the early 1800's to January 1, 1949, was 77 trillion cubic feet of which 71.5 trillion cubic feet were sold commercially from 1906 to 1944. The trend of production has been constantly upward from nearly 339 billion cubic feet in 1906 to a peak of 5.9 trillion cubic feet in 1945.

The United States has an abundant supply of natural gas. Production has been developed in 25 states but Texas produces 50 per cent of the total. The proved, recoverable reserves of natural gas as of January 1, 1948, were 165 trillion cubic feet, the largest in our history. The reserves were classified as follows: 118 trillion cubic feet of free gas not in contact with crude oil, 28 trillion cubic feet of free gas in contact with crude oil, and 19 trillion cubic feet of gas in solution in crude oil.[22] Reserves have greatly increased since 1925, largely as a result of discoveries in the southwest and in California. From 1925 to 1948 reserves increased at the average rate of 6.5 trillion cubic feet per year, about two and one-half times the average rate of withdrawal.

There are now four important natural gas regions in the United States, Appalachian, Mid-continent, Gulf coast, and California. The Appalachian gas fields include all areas east of central Ohio and northeast of central Alabama. This is the oldest gas-producing area in the United States, and many fields have passed their peak production. West Virginia is the largest producer followed by Kentucky and Pennsylvania.

The Mid-continent and Gulf coast fields have increased from 19 per cent of the total production in 1906 to 78 per cent in 1948. Development has been most rapid in Texas where 57 new fields were discovered in 1945.

[22] *Proved Reserves of Crude Oil, Natural Gas Liquids, and Natural Gas,* December 31, 1947, American Gas Association and American Petroleum Institute, New York, Vol. 1, 1947.

The California natural gas production has risen from 0.03 per cent in 1906 to 18 per cent in 1948. Production is centered in the Rio Vista and Kirby Hills fields. These fields have had a tremendous gas wastage each year mounting to untold billions of cubic feet, because of a lack of markets.

CONSERVATION OF NATURAL GAS

Waste of Natural Gas

The ease of recovery and the bountiful supply of natural gas, frequently with a limited market, have often resulted in a criminal waste of this valuable mineral fuel. Until 1918 the waste of natural gas was usually equal to the consumption. Although in recent years the value of natural gas is gradually being recognized, tremendous waste still continues. In 1944 there was a recorded waste of natural gas of more than 1,010,285 million cubic feet. It has been estimated that, if the gas wastage in the oil and gas fields of the Texas Panhandle alone were utilized as a fuel for a large electric generating plant, 2,575,000 horsepower could be produced every hour. This power would be almost four times the total output of the Grand Coulee dam and power plant.

The wastes of natural gas are many and have usually been intentional. One of the most important causes of waste lies in the common practice of allowing gas to escape freely from oil wells for this usually increases the immediate yield of oil. Since many oil fields have no facilities for marketing this gas, it is allowed to escape into the atmosphere. In some areas the natural gas has been withdrawn from the reservoir as quickly as possible in order to prevent its capture by adjacent producers. In the making of by-products from natural gas, such as carbon black and gasoline, the residue gases are frequently wasted although they may contain as much as 97 per cent of the original heating value of the gas.

Conservation Measures

With the realization that natural gas is one of the most efficient agents in extracting oil from the ground, conservation practices are being applied in many areas.[28] Most states have now passed laws partially controlling the waste of natural gas. Also with the expansion of facilities for distributing natural gas the demands by domestic and industrial consumers have increased. Natural gas is now recognized as one of the best fuels available. Our supply is still fairly large but many problems of efficient utilization remain unsolved in many areas.

ATOMIC ENERGY

Fundamental research and the study of atomic energy have been going on for several decades. However, the great concentration of effort has come since July, 1942, with the expenditure of $2,000,000,000 in the construction and operation of atomic bomb facilities. While the mineral fuels have been conspicuously developed by private enterprises, it has been recognized almost unanimously from the beginning that nuclear energy must be socialized. In 1946 when the Atomic Energy Commission was established, complete government control of the industry was not disputed. The only question was which government agency should handle this new source of power.

[28] "Conservation of Petroleum and of Natural Gas," *Third World Power Conference,* Vol. VI, Section IV, Washington, D. C., 1936, pp. 766–774.

Sources of Nuclear Energy

Atomic energy is developed chiefly from uranium.[24] Thorium and other radioactive minerals may be used in the future as fissionable material. Uranium is one of the more common minerals. It constitutes 0.008 per cent of the earth's crust and is therefore twice as abundant as zinc, four times as abundant as lead, and many times more common than tin, silver, or gold. The spectograph and Geiger-Müller counter detect it in most granite and sedimentary rocks. However, the mineral is rarely found in concentrated form, but ore containing a low content of uranium is practically limitless.

The largest known deposits of uranium in the United States are in the carnotite ores of western Colorado, eastern Utah, and northeastern Arizona. These ores were first developed between 1910 and 1920. In the 1920's as a result of the lowered radium prices, operations were reduced, and in the 1930's the uranium was recovered only as a by-product of vanadium. The ore contains two to four per cent U_3O_8. Low-grade uraninite deposits located in pegmatites are found in New Mexico, Colorado, Wyoming, Texas, North Carolina, Pennsylvania, New York, and New England. Uranium may be recovered from oil shales, coal, and bitumen.

The national reserves of fissionable materials are not known, but the total quantity would not need to be large to equal the total mineral fuel reserve. On the basis of 1600 tons of coal being equivalent to one pound of fissionable uranium, only about 800,000 tons of the latter are required to be equivalent to the total coal reserve of 3.2 trillion tons.

[24] "Uranium Supply Will Be Hard to Control," *Engineering and Mining Journal,* Vol. 146, 1945, pp. 80–82.

Peacetime Uses of Atomic Energy

The spectacular development and use of the atomic bomb have frequently overshadowed the peacetime uses of atomic energy. Research on this phase of the work has not been neglected, and a number of practical benefits have already developed. Radioactive materials for medical and biological uses are already being produced in commercial quantities. Another product of nuclear energy has been the separation of isotopes. Isotopes are forms of an element that differ principally in their weight and somewhat in minor respects from the normal forms. Study and use of them may lead to important new developments in chemistry and metallurgy.

Research in the use of atomic energy is now directed to its application in chemistry, propulsion of movable objects, and its use as a fuel in power plants. The development of the first atomic energy power plant is now considered to be equal in importance to that of constructing one of the major atomic bomb material plants. The first atomic energy power plant will have conventional turbines, electrical generators, and electrical transmission lines, but the furnace will be replaced by a chain-reacting power pile. There are many technical problems to be solved before atomic energy can be used to supply fuel to a power plant. The size and shape of the fuel unit, the method of transferring heat from the power pile to the engine or prime mover, the problem of loading and unloading the pile, and the problem of automatic control of the pile and its accessory equipment including the steam turbine and generator are some of the plant problems. Another significant problem involves the distance of the plant from populous regions in order to dispose of the radioactive wastes. Since there is a continual emission of radioactive waves which penetrate a considerable thickness of metal or rock, workers must be protected from the destructive rays.

Although no power plant using atomic energy has yet been constructed, the Baruch Report to the Atomic Energy Commission gave estimates on cost of nuclear energy for power uses. It was estimated that a nuclear power plant of 75,000-kilowatt capacity could be built and equipped at 1946 prices for $25,000,000 and that, operating at 100 per cent capacity and with interest charges of three per cent, the plant would produce power at eight cents per kilowatt hour. A similar coal plant would cost $10,000,000 for installation and produce power at six and a half cents per kilowatt hour. The cost of an atomic-powered plant is only 23 per cent more than a modern utility plant using coal costing $7.00 per ton. With coal at $10.00 per ton, the operating costs would be the same. These initial estimates of atomic power are high, but advancements in techniques can be expected to lower costs considerably.

Advantages of Atomic Energy

It now seems likely that economically sound atomic power plants soon will be built for commercial operation. The first experimental plant for the generation of steam is planned for the early 1950's. It is believed that a small nuclear power plant can be perfected which, with the modern gas turbine, will act as a stand-by plant on established utility systems. This would greatly reduce power transmission costs and ensure partial operation if the standard super power station were inoperative.

In the conventional fuel generating plant, coal constitutes 60 per cent of the total operating cost. This is one of the most important factors determining the industrial pattern of the United States. Since a nuclear power plant will consume a trivial amount of fuel, a greater decentralization of industry is possible. This may be a most desirable factor in our present world economy.

As our present sources of power from petroleum, natural gas, and coal dwindle, nuclear power may supplement these. If our demand for power continues to grow as in the past our needs will absorb all the uranium that will be produced and at the same time keep the mineral fuels output at a high capacity. Atomic energy will supplement, but will not supplant, existing forms of power.

GENERAL SUMMARY

Our high industrial productivity has been made possible largely by the availability and utilization of our power resources. Our energy consumption has increased sevenfold since 1870, so that today every man, woman, and child has the equivalent of 84 slaves working eight hours each day for him. This has resulted in high productivity which is the first essential of a high standard of living.

Our mineral fuels are still abundant, but nevertheless they are irreplaceable and limited in quantity. Coal, our largest mineral reserve and our cheapest fuel, will retain a substantial position in supplying the nation's fuel. Technical advancements will continue to develop further economies and conveniences in utilization. Because we have a relatively small quantity of coking coals, these should be reserved for metallurgical uses where other coals cannot be substituted. The use of all other coals for steam generation should be encouraged. Our petroleum supply will be depleted relatively soon. Therefore, our natural petroleum should be reserved for motor fuels and lubricating needs, and its use as a boiler fuel should be discouraged. This will delay the time when our petroleum needs will have to be satisfied from synthetic oils at possibly considerably higher costs. Natural gas should be reserved for domestic and specialized industrial uses, including conversion into chemicals in regions where coal is lacking. The development of atomic energy in the coming decades may change the energy pattern of the United States. However, this change will be gradual and atomic energy will supplement, rather than displace, our mineral fuels for years to come.

The use of our power facilities can be expected to increase in the future. This will mean a rise in the production of capital and consumer goods to heights never before reached. Consequently, we can expect a higher standard of living to be attained than in any previous period of history.

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P A R T S I X

CHAPTER 18

Conservation of Wildlife*

INTRODUCTION

THE conservation of wildlife means the wise use and management of nondomesticated animals for the benefit of all the people. Both game and nongame species and those that sometimes are inimical to man's interest are included in this definition. Game and fish management are specialized branches of the field of wildlife conservation. Their objective is the maintenance of an adequate supply of game, fish, and fur to meet the demands of those who seek wild animals for sport and profit. This is the primary function of most state fish and game departments.

Nongame species are usually considered incidental by-products of game management. Their welfare otherwise is largely dependent upon the efforts of interested individuals, private organizations, and such government agencies as the United States Fish and Wildlife Service and the National Park Service, which are supported by funds available through taxation.

IMPORTANCE OF WILDLIFE RESOURCES

Early History

Native wild animals are an integral part of our American heritage. Their utilization for food, clothing, and barter was vital to the success of the colonists and later to the opening of the west. They made possible the establishment of many pioneer settlements. Many of the early explorations and discoveries which opened up the interior of the United States were made by trappers seeking new sources of fur for foreign trade. Wild animals were an important source of food for man as recently as the westward expansion of the railroads during the two or three decades following 1830. During this period, for example, about 250,000 bison were killed annually,

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By Charles A. Dambach of The Ohio State University.

largely to supply meat for crews building the railroads.

Food

We have long since passed the time when wild animals were of importance in meeting our total food or clothing needs. Although the annual kill of present-day game species is enormous in the aggregate (an estimated 250,000,000 pounds yearly), it falls far short of meeting total food needs. During the 1945–1946 hunting season the estimated kill for Pennsylvania, one of the leading game states, totaled 10,631,387 pounds live weight.[1] After dressing, this amount would provide less than one pound of meat per inhabitant of that state or less than one per cent of its per capita needs.

Fish for Food and Pleasure

Based on a four per cent yearly return, the capital value of the United States fishery resources, including both fresh- and salt-water fisheries, was estimated in 1943 to be $5,855,000,000.[2] Harvesting the annual fish crop upon which this figure is based provided full-time employment to 65,000 fishermen and part-time employment to 60,000 more persons. The average annual catch totals 4,400,000,000 pounds of fish for which the public in 1943 paid $230,200,000 for canned fish, $60,400,000 for oil meal and fish by-products, $137,600,000 for fresh fish, $106,700,000 for packaged fillets, $20,300,000 for frozen fish, and $40,900,000 for cured, smoked, and pickled fish.

The principal fisheries industries are located along our Atlantic and Pacific coasts and the Gulf coast. The Pacific region and Alaska alone produced 82 per cent of the canned fish pack. The Atlantic coast produced 16 per cent, and the Gulf states two per cent. Our fresh-water fisheries exclusive of the Great Lakes are of importance primarily for recreational fishing. In these waters, commercial fishing produces about 85,000,000 pounds of fish per year, whereas recreational fishing brings in approximately 260,000,000 pounds of coarse and game fish. The Great Lakes fisheries produce annually about 100,000,000 pounds of fish, thus providing employment for 5000 commercial fishermen.[3] (See Chapter 19.)

Fur

Wild furs, though no longer a home necessity, still provide the major source of income for thousands of trappers and part-time income for many farmers. The aggregate value of the annual take of furs in the United States since 1940 has ranged from $100,000,000 to $125,000,000. Most of the fur-bearing animals are trapped on the farms and ranches of the country, with more than 50 per cent being harvested by farm families. The remainder is taken by professional trappers, who in many instances own none of the land on which they trap.

Fur prices have fluctuated greatly as styles, economic conditions, and supplies have changed and as acceptable substitutes have been developed. The advent of fur farms on which carefully selected superior strains of fox and mink are raised has also been a factor in determining the price of some wild furs. Probably 15 per cent of present fur sales consist of pen-reared animals.

[1] Pennsylvania Game Commission, "Summary of 1945–46 Game Kill," *Mimeographed News Release,* April 9, 1947.

[2] Lionel A. Walford, *Fishery Resources of the United States of America,* Washington, D. C., 1945, pp. 126–132.

[3] *Ibid.,* pp. 117–118.

Since the end of World War I, the United States has been the leading producer of furs among the countries of the world and is now the center of the fur industry. The chief wild-fur producers are the United States, Soviet Russia, and Canada. The retail fur trade in the United States which results from processing native and imported furs annually exceeds $400,000,000.[4]

Biological Value

Many scientific and popular articles have been written about the value of birds, mammals, and other forms of wildlife in the control of insect, rodent, and weed pests. Most of these were written before the development of modern insecticides, rodenticides, and herbicides. Such materials as DDT for insects, 2-4D for weed control, and ANTU for rodents have made possible some control of pests heretofore reduced largely by natural enemies. Forest insects such as the spruce budworm, larch sawfly, bark beetles, and many others have been controlled. Many of our native and introduced wild animals consume great quantities of injurious insects, weed seeds, and rodent pests. The following are only a few of the many examples that appear abundantly in the literature of economic zoology. Forbush estimated that birds in 1921 reduced the cost of insect damage in this country by $444,000,000 annually.[5] Bryant credited the meadowlarks in the Sacramento valley of California when feeding their young with the daily consumption of 193 tons of insects.[6] McAtee estimated that on a single North Carolina farm native finches daily ate more than 900,000 aphids during an outbreak of these insects.[7] During their lifetime, insect-eating mammals, particularly moles and shrews, also consume great quantities of insects.

Many of our hawks and owls feed primarily on such destructive rodents as house mice, rats, meadow mice, ground squirrels, and gophers. Larger mammals like foxes, skunks, and weasels also feed extensively on these injurious animals as do some kinds of snakes. Unfortunately some of these predators occasionally feed on beneficial species of wild animals and domestic livestock, particularly poultry.

Although many birds feed extensively on weed seeds, it is doubtful if they are as valuable in destroying the seeds as are field-inhabiting rodents, which thoroughly grind their food before swallowing it. The seeds of such plants as red cedar, dogwood, and hackberry, for example, pass unharmed through the digestive tract of birds and may in this manner become established in places where they are unwanted.

Farmers and biologists have found that, although natural enemies contribute to the control of crop pests, they are not to be depended upon to afford the degree of protection necessary for commercial production of many crops.

Injurious Habits

Not all wild animals are beneficial to man. House mice, rats, and other rodents

[4] Frank G. Ashbrook, "Fur—An Important Wildlife Crop," *Wildlife Leaflet* 314, Fish and Wildlife Service, U. S. Department of the Interior, Washington, D. C., 1945, pp. 1–6.

[5] Edward H. Forbush, "The Utility of Birds," *Massachusetts Department of Agriculture, Bulletin* 9, 1921.

[6] Harold C. Bryant, "Economic Value of the Western Meadowlark in California," *University of California Agricultural Experiment Station, Bulletin* 236, Berkeley, 1913, p. 12.

[7] W. L. McAtee, *Yearbook*, United States Department of Agriculture, Washington, D. C., 1912, pp. 397–404.

are charged with an annual destruction of $500,000,000 worth of crops in the United States. Predatory animals take their toll of livestock also. Throughout the country, poultry farmers suffer from raids by rats, weasels, mink, skunks, foxes, and predatory birds. The cattle and sheep men of the western plains and mountain ranges suffer losses from large predatory animals including coyotes, wolves, mountain lions, and an occasional marauding bear. Because of their burrowing habits, muskrats are sometimes responsible for breaks in dams and levees; ground hogs, badgers, gophers, and prairie dogs cause considerable damage by digging dens in crop fields, pastures, and road fills.

Even the city gardener is often chagrined to find his ornamental shrubs girdled and his prize garden plants trimmed by groundhogs and rabbits; his corn, beans, and lawn cut off from contact with moisture-laden soil by moles; his squash, cucumber, and melon seeds eaten by white-footed mice and gophers; and his choice tomatoes spoiled by pheasants, starlings, and rats.

Wild animals are known to serve as reservoirs of disease for both man and domestic livestock. Probably the best known is tularemia or rabbit fever, a sometimes fatal disease contracted by human beings from infected rabbits or other wild animals.

Recreational Value

The United States Fish and Wildlife Service has estimated that the annual business turnover in this country resulting from our wildlife resources amounts to between one and two billion dollars. Most of this is derived from expenditures for hunting and fishing equipment, ammunition, transportation, lodging, meals, guides, and other expenses related to hunting and fishing trips. At least 13,000,000 hunting and fishing licenses are purchased annually in the United States. Many who hunt or fish do not secure licenses because of exemption for age, military service, or land ownership or because of nonenforcement of the license law.

Many others enjoy wildlife for aesthetic reasons only and gain their pleasure through observation and study. This interest contributes to the economic importance of wildlife resources and provides a market for the makers of photographic equipment and supplies, for the binocular, field-glass, and telescope manufacturers, the publishers of natural history books, the manufacturers of outdoor clothing, and many other businesses large and small that are dependent on wildlife resources in part, at least, for marketing their services and products. Expenditure for fishing tackle alone (exclusive of boats and live bait) exceeds equipment for playgrounds, baseball, tennis, skating, tobogganing, billiards, and pool tables. It is only slightly exceeded by the money spent for golf.[8]

The total recreational value of wildlife resources, however, is not to be measured in terms of jobs and money income alone. Probably of far greater importance is the healthful relaxation that is the reward for participation in their use

INVENTORY OF WILDLIFE RESOURCES

The Past

The first white men to set foot on what is now the United States entered a country that abounded with wild animals of many kinds. They found in the eastern seaboard areas an abundance of white-tailed deer,

[8] United States Department of Commerce, *16th Census of the United States, Manufactures,* Washington, D. C., 1941.

elk, wild turkey, and such smaller animals as ruffed grouse, heath hen, and gray squirrel, which provided food in quantities limited only by the hunter's ability to capture them. A like abundance of fish in the streams and natural lakes also provided food for those who sought to take them by net, spear, poison, and hook. Wild ducks of many kinds, geese, and shore birds frequenting the waterways during their spring and fall migrations and their nesting season afforded another source of food. Inhabiting the waterways and wilderness areas were fur bearers such as beaver, otter, fisher, marten, muskrat, and mink, whose pelts were shipped in great numbers to European ports in exchange for goods needed by the early colonists. Also present were bears, mountain lions, wolves, wildcats, lesser predatory animals, and rodents, which raided the herds of livestock and ravished the gardens and fields of the pioneers.

Under these conditions, there developed a public attitude that wildlife resources were limitless, that they could be utilized fully without restraint or concern for the future, and that wildlife inimical to the interests of man was to be eliminated by the most effective means at hand. Laws were passed to encourage or make mandatory the killing of predatory animals and rodents that were known to damage livestock and crops.

This pattern of unrestraint was repeated again and again as civilization spread westward. When the Ohio valley was reached, large numbers of grouse, wild pigeon, waterfowl, and the furs of beaver, otter, muskrat, and other animals were sent to the eastern markets. The supply appeared to be limitless.

Pushing still farther westward, the pioneers found on the great prairies and plains in the heart of America an abundance of grass-feeding animals. American bison in great droves extended as far as a man could see; estimates of their numbers ranged from 15,000,000 to more than 50,000,000. Prong-horned antelope lived on the plains in numbers equal to, if not greater than, the bison. Elk, deer, and small game including quail, prairie chicken, and sharp-tailed grouse were present the year around. In the sloughs, marshes, and waterways, vast flocks of waterfowl and shore birds congregated, some tarrying only in migration but some nesting there. Small birds and mammals abounded, as did wolves, coyotes, hawks, and other animals that preyed upon them. This vast abundance of wildlife was quickly reduced by killing for food, sport, and clothing. Grain production and grazing also contributed to the loss until the region is now one of the poorest big-game areas in all North America.

The wilds of the western mountains were opened and exploited before the vast herds of buffalo and antelope had been reduced on the plains. Here animals were fewer but more varied than on the plains. There were elk, mule deer, black and grizzly bear, mountain sheep, mountain goat, wild turkey, grouse, beaver, many kinds of squirrels, and other lesser animals, and large predators such as wolves and mountain lions wherever deer herds were found. In the desert regions game was scarce except for trout in some of the cold streams which had their sources outside the desert area and except for vast flocks of waterfowl in marsh areas like the Great Bear River marsh. As the westward expansion reached the Pacific Ocean, the last remaining virgin populations of wild animals were tapped. The trout of high mountain streams, the salmon of coastal rivers, the waterfowl of the Pacific flyway, and the sea otters and seals of the Pacific coast were rapidly exploited.

The Vanished and the Survivors

The heavy heel of civilization crushed deeply into our once vast stores of wildlife resources. Many species declined greatly in numbers, some approaching extinction; others vanished completely. Among the victims of our expansion were the great auk, the Labrador duck, the heath hen, the Carolina paroquet, the passenger pigeon, the Pennsylvania bison, several races of the grizzly bear, the Audubon bighorn sheep, the big plains wolf, the big sea mink, the Gull Island meadow mouse, and probably the Eskimo curlew, and the Cape Sable seaside sparrow. At the present time about 50 species of wild animals are declining or are in actual danger of extinction. In a few species, the trend has been reversed. Pronghorned antelope, white-tailed deer, furseals, and egrets are examples of animals that have partially or wholly recovered from low population levels.

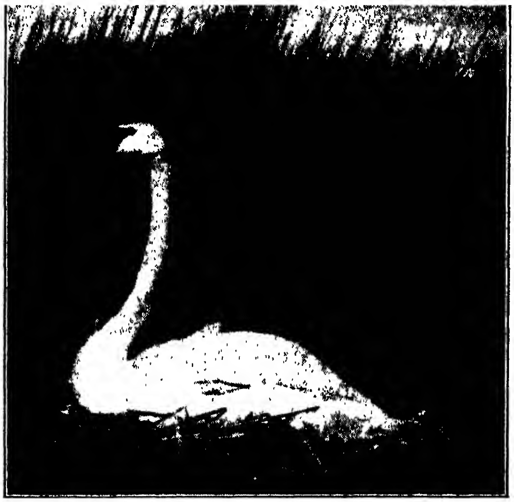

FIG. 1. The trumpeter swan is numbered among the vanishing species of American wildlife. It is still in danger of extinction although complete protection is now afforded in both the United States and Canada. Shooting, collecting the birds for down, and destruction of nesting sites are important reasons for the decline. (United States Fish and Wildlife Service.)

No single cause can explain the decline of all American wildlife. Market hunting was probably the chief cause for the decline of gregarious birds like the passenger pigeon, Eskimo curlew, and many species of ducks. Passenger pigeons were killed by the thousands in their roosts at night, and their bodies were prepared for market in processing plants set up for that purpose. Eskimo curlews were killed in great numbers during their spring and fall migrations and hauled by the wagonload into town for marketing. Ducks and shore birds were killed with specially constructed guns capable of bringing down dozens of birds at a single shot. From some ports along the Great Lakes they were shipped to nearby and eastern markets in carload lots. The great buffalo herds were decimated by hunters seeking the hides for sale or the choice parts for food. Many were killed merely for sport. The whaling, sealing, and fishing industries accounted for the decline of fish, seals, whales, and manatees, and fishermen along the North Atlantic coast were responsible for wiping out the colonies of the great auk and the Labrador duck. Plume hunters nearly caused the extinction of the snowy egret and the reddish egret and reduced many other species before their activities were outlawed. Aquatic resources declined because of the pollution of streams and lakes by industrial and mine wastes, raw sewage from cities, silt from eroding farm fields, and overfishing of some species. Draining of swamplands, clearing of forests, and the development of grasslands for agricultural purposes so altered the environment that animals unable to adjust to the changes could not survive. Misuse of the land accelerated erosion and intensified the effects of floods and drought. As a consequence, the capacity of the soil to support both human and wildlife populations was reduced. These factors are of equal or greater importance than the more evident ones previously considered (Fig. 1). Among other factors are adverse weather, disease, parasites, and man-induced accidents such as forest and grassland fires and destruction by agricultural implements.

Although the toll of wildlife that fell before the guns, clubs, nets, and traps of man was enormous, not all of it was wasted. Much of the kill was used in helping to meet the food needs of a growing nation and in aiding the development of commerce. We must recognize also that the vast herds of bison which roamed the plains, the deer, elk, bear, wild turkey, the grouse of the eastern forests and central hardwood region, and the mule deer, panthers, and grizzly bear of our western forests could not, even with complete protection, exist now under the cultivation and grazing of land necessary to our civilization.

Present Wildlife Resources

Despite the decline of many species, the wildlife resources of the United States are still vast, and some species are more plentiful today than at any time in recorded history, especially on farms and ranches. The several races of cottontail rabbits, quail, muskrats, field-inhabiting songbirds, and introduced game birds (pheasants and Hungarian partridges) have been benefited by the clearing of the forests and the development of mechanized agriculture. In the State of Michigan, for example, with its millions of acres of forested and cutover lands, about three-fourths of the total value of the fur crop is produced by the better agricultural areas of the southern half of the lower peninsula.[9] More than 80 per cent of the land available for wildlife production in the entire United States is farm or ranch land.[10] We probably now harvest annually most of the surplus crop of upland game, much of which previously went unharvested for lack of interest or need. Some animals are still being overused, whereas others are not utilized sufficiently to keep their numbers within the capacity of their environments to support them. Fish abound in our inland ponds and lakes, and big-game mammals such as deer and elk under too rigid protection soon overpopulate their range.

Known wild vertebrate animals total more than 35,000 species.[11] Of these about 18,000 are fish; 5500 are reptiles and amphibians including frogs, toads and salamanders, snakes, lizards and turtles; 8600 are birds; 3500 are mammals. The North American fauna, especially that of the United States, is unusually rich in number of species. Even in the intensively farmed and highly industrialized midwestern states, the variety and abundance of wildlife is surprising. The State of Ohio, for example, is known to have at least 183 kinds of fish, 32 kinds of frogs, toads and salamanders, 39 kinds of reptiles, 180 kinds of nesting birds, and at least 65 kinds of mammals. On a single well-managed 100-acre farm in the same state, we can expect to find 50

[9] Michigan Department of Conservation, *Ninth Biennial Report*, 1939, p. 230.

[10] J. Paul Miller and Burwell B. Powell, "Game and Wild-Fur Production and Utilization on Agricultural Land," *Circular No.* 636, United States Department of Agriculture, 1942, pp. 1–58.

[11] Ernst Mayr, "The Number of Species of Birds," *Auk*, Vol. 63, 1946, pp. 64–69.

to 60 kinds of wild animals totaling 2000 to 3000 individuals.

Farm Wildlife

Our present wildlife resources can probably best be understood by considering the abundance and variety of animals in relation to the class of land that they occupy.

FIG. 2. The cottontail rabbit is the most important game mammal in the United States. It is well adapted to living on land used for agricultural purposes and provides the bulk of the small game hunting over much of the country. (Charles A. Dambach.)

Of first importance in this classification is farm wildlife, which provides approximately 68 per cent of the total game kill.[12] The principal kinds of farm game are the cottontail rabbit, squirrels, bobwhite quail, the ringnecked pheasant, and the Hungarian partridge (Fig. 2). These species annually provide the bulk of the recreational hunting throughout the country (Fig. 3). Farm wildlife also includes many of our songbirds and other nongame animals which are enjoyed by great numbers of people and such fur bearers as opossums, skunks, and weasels. Farm game animals primarily occupy land owned privately and managed for profit and are often only a by-product of farming operations.

[12] Miller and Powell, *op. cit.*, p. 29.

Wildlife of the Forest and Range

Forest and range wildlife includes most of the important big-game animals: white-tailed deer, mule-deer, black-tailed deer, antelope, and black bear (Fig. 4). More than half of the total are white-tailed deer, one-half of which are in eastern states (Table 1). This group also includes wild turkey, sharp-tailed grouse, ruffed grouse, sage hen, western quail, and gray and other squirrels (Fig. 5). The coyotes, wolves, cougars, gray foxes, bobcats, and black

FIG. 3. Cottontails, though providing many hours of recreation to the hunter, often cause considerable damage to farm crops. Girdling of this tree by rabbits resulted in its death. There is little incentive for farmers to encourage rabbits and other kinds of wildlife where such injury is liable to occur. (United States Fish and Wildlife Service.)

TABLE 1

INVENTORY OF BIG GAME IN THE UNITED STATES IN 1946

[Big Game Inventory of the United States, 1946, *Leaflet* 303, Fish and Wildlife Service, U. S. Department of the Interior, Washington, D. C., pp. 1–13.]

Species	*Individuals*
White-tailed deer	4,965,000
Mule deer	2,007,900
Columbian black-tailed deer	402,300
Woodland caribou	40
Elk	288,900
Moose	23,300
Prong-horned antelope	233,900
Rocky mountain bighorn	16,000
Desert bighorn	7,600
Mountain goat	15,700
Peccary or javelina	116,600
European wild boar	1,700
Black bear	155,100
Grizzly bear	1,400
American bison	5,000
Total	8,240,400

bears that enter the fur trade come largely from forest and range land. Although they and the big-game animals are principally species of forest and range land, they are relatively abundant on land that is used in part for agricultural purposes. The range and forest land of the west and the forests of the Great Lakes states and of the northeast are the principal producers of this kind of wildlife. These areas provide about 21 per cent of the total annual game kill.

The Wilderness Refuge

Wilderness wildlife includes those animals that occupy relatively remote and inaccessible areas like the high mountain ranges and unexploited forested or swampy land. They are greatly restricted in distribution and are nowhere abundant owing to the limited amount of such land and to the inability of the land to provide adequate food and shelter for a high population of animals. Many of our rare and vanishing species are limited to this class of land. Among the better-known species are elk, grizzly bear, moose, mountain sheep, mountain goat, ivory-billed woodpecker,

FIG. 4. The white-tailed deer is the most important big-game animal in the United States. They are becoming more abundant in areas recently retired from agricultural use. Where such areas border land used for agriculture, deer damage to crops frequently results. (United States Soil Conservation Service.)

and trumpeter swan, and such fur bearers as the lynx, fisher, marten, and wolverine.

Migratory Wildlife

Migratory wildlife inhabits all classes of land. It includes most of our common song and insectivorous birds and such game species as shore birds, ducks, geese, and doves (Fig. 6). Although providing only about 11 per cent of the total annual game kill, these game birds, because of their spectacular migratory flights and the national and international problems involved in their management, often attract more interest than more abundant species. Such management problems are well illustrated by our various species of waterfowl most of which nest in the wet prairies and marshes of northern United States or Canada and winter in the coastal marshes of southern United States, Mexico, and Central America. Thus at least three countries are frequently involved in the production, protection, and utilization of a single mobile resource. Four well-established flyway routes are followed by these birds in their flights to and from breeding and wintering grounds: the Atlantic flyway along the Atlantic coast, the Mississippi flyway through the Mississippi valley, the Central flyway through the Great Plains, and the Pacific flyway along the Pacific coast.

FIG. 5. The ruffed grouse is a highly prized game bird of forested land. Once common over most of its range, it is now largely confined, in huntable populations, to areas of rather extensive forests. Efforts to replenish it by transplanting wild trapped birds or by artificial propagation on game farms have met with failure. Over the northern part of its range, it is subject to cycles or periodic declines and rises in abundance. (United States Soil Conservation Service.)

Unless drained, the nesting and wintering grounds of waterfowl and shore birds are usually of little or no agricultural or industrial value. Many millions of acres of former duck marshes have been drained and put to agricultural use, with a resultant decline in the area available for breeding and wintering grounds. The remaining areas are called upon to produce a crop of waterfowl adequate to satisfy the demands of more than a million hunters in the United States alone.

Resident Aquatic Wildlife

Resident animals which inhabit our swamps, marshes, sloughs, lakes, ponds, streams, and ditches include some of the most important fur-bearing animals. To this group belongs the muskrat, which is the most remunerative fur bearer in the United States. Beaver, mink, otter, and raccoon also occupy waterways and, like the muskrat, do much of their feeding either along the margins of water areas or in the adjacent agricultural land. Three of these animals (muskrat, raccoon, and mink) make up two-thirds of the total annual fur production in the United States, about 15,000,000 to 20,000,000 pelts.

FIG. 6. Comparatively little is known about the habits and living requirements of many of our important wild animals. Banding of waterfowl (a female mallard duck) to determine their migratory behavior is but one phase of the research work necessary for a sound wildlife conservation program. (United States Fish and Wildlife Service.)

Our fishery resources are represented by a great many species, inhabiting a wide variety of habitats ranging from cool mountain streams to stormy coastal waters. Included in this group are both fresh- and salt-water fish, lobsters, crabs, shrimp, oysters, scallops, clams, sponges, whales, fur-seals, walrus, and sea otters. Many of these animals are utilized primarily as food; others, particularly the fish of inland waters, are used largely for recreational fishing.

BASIC PROBLEMS IN WILDLIFE CONSERVATION

Problems of Ownership

Present concepts of ownership and legal title to wildlife were established during our early history when nearly all wild animals were produced and harvested on publicly owned land. Now more than 75 per cent of the annual harvest of game and fur comes from privately owned agricultural land. One of the basic problems in the management of wildlife stems from this change in land ownership. By common law the states hold wildlife in trust for all the people, and the people have the right to use wildlife subject only to restrictions set up by the states. Thus the responsibility for the welfare of wildlife rests not with each individual but with the state government which has practically no opportunity to act beyond limiting the time and manner in which animals can be sought and the number that can be taken. In effect, the states can enforce regulations designed to distribute fairly the wildlife crop among the citizenry, but they can do little directly to improve the crop size since it is produced mainly on land in private ownership—primarily farms and ranches. (See Table 2.)

Farmers and ranchers have the best opportunity to provide for the welfare of wildlife but are given little or no incentive to do so. The farmer who encourages wildlife production on his land runs the risk of abuse by rowdy hunters, personal inconvenience occasioned by even the most considerate hunter, and damage to livestock and crops by both hunters and wildlife; yet he has no greater legal right to use the wildlife he produces than the city sportsman. The only means at his disposal to protect himself from the hunter nuisance is to exercise his trespass rights by closing his land to hunting, trapping, or fishing. A growing number of farm and ranch operators use this means to prohibit hunting on their property or to obtain a nominal fee for their trouble and for hiring more property and personal protection than state game and fish law enforcement provides. This movement has developed because the public attitude until recently had not generally supported enforcement of trespass laws adequate to afford the farmer the protection to which he is entitled.

Unfortunately many sportsmen still feel that holding of a hunting or fishing license entitles them to full pursuit of their sport wherever they may find it as long as they abide by the regulations pertaining to bag limits, seasons, and legal manner of taking game.

The problem of wildlife ownership is further complicated by the fact that nearly all the state game and fish departments are financed largely by money received from the sale of hunting and fishing licenses. To enforce trespass rights with game protectors or wardens paid from these funds would in effect lead to the closing of more land to hunting and thus to a decline in the number of license-buying hunters. This conflict of interest between sportsmen and landowners is of considerable and increas-

TABLE 2

HUNTING PRESSURE IN THE UNITED STATES IN RELATION TO LAND USE AND LAND OWNERSHIP

[Columns 2 to 8 inclusive are based on Table 5, "Game and Wild-Fur Production and Utilization on Agricultural Land," *United States Department of Agriculture Circular* 636, 1942. Column 9 is from "Handbook of Game and Fish Management," Walter W. Gresh, Minneapolis, Minnesota, 1945.]

State	*Approximate Total Land Area by United States Agricultural Census, 1935*	*Areas on Which Public Hunting Is Prohibited by Law (Rights of Way, Cities, Refuges, etc.)*		*Total Potential Huntable Area Devoted to Agriculture*		*Estimated Total Potential Huntable Area*		*Hunting Licenses Issued 1944–1945*	*Estimated Potential Huntable Area per License*
(1)	*(2) Acres*	*(3) Acres*	*(4) Per Cent*	*(5) Acres*	*(6) Per Cent*	*(7) Acres*	*(8) Per Cent*	*(9) Number*	*(10) Acres*
Alabama	32,818,560	3,458,626	10.54	16,926,278	57.65	29,359,934	89.46	107,877	272
Arizona	72,838,400	24,719,273	33.94	37,905,482	78.77	48,119,127	66.06	40,095	1,201
Arkansas	33,616,000	3,586,790	10.67	15,211,497	50.66	30,029,210	89.33	64,545	465
California	99,617,280	9,648,887	9.69	43,015,708	47.81	89,968,393	90.31	319,410	281
Colorado	66,341,120	6,190,935	9.33	48,255,342	80.22	60,150,185	90.67	226,963	265
Connecticut	3,084,800	689,152	22.34	1,597,578	66.69	2,395,648	77.66	33,859	71
Delaware	1,257,600	218,554	17.38	765,536	73.68	1,039,046	82.62	15,256	68
Florida	35,111,040	5,269,239	15.01	5,319,836	17.83	29,841,801	84.99	68,366	436
Georgia	37,584,000	3,777,624	10.05	22,796,582	67.43	33,806,376	89.95	57,094	592
Idaho	53,346,560	5,150,149	9.65	32,357,656	67.14	48,196,411	90.35	126,809	380
Illinois	35,867,520	5,249,718	14.64	28,191,525	90.08	30,617,802	85.36	300,144	102
Indiana	23,068,800	4,104,942	17.79	17,506,220	92.31	18,936,858	82.21	398,903	47
Iowa	35,575,040	4,766,216	13.40	30,808,824	100.00	30,808,824	86.60	226,113	136
Kansas	52,335,360	3,953,652	7.55	45,390,935	93.82	48,381,708	92.45	101,852	475
Kentucky	25,715,840	4,900,621	19.06	16,524,040	79.38	20,815,219	80.94	76,785	271
Louisiana	29,061,760	2,672,851	9.20	8,742,128	33.13	26,388,909	90.80	124,485	212
Maine	19,132,800	1,333,207	6.97	4,093,237	23.00	17,799,593	93.03	115,821	154
Maryland	6,362,240	1,023,931	16.09	3,717,461	69.64	5,338,309	83.91	83,090	64
Massachusetts	5,144,960	1,147,025	22.29	1,669,304	41.75	3,997,935	77.71	85,075	47
Michigan	36,787,200	4,392,502	11.94	15,512,167	47.88	32,394,698	88.06	784,604	41
Minnesota	51,749,120	8,418,690	16.27	29,770,381	68.71	43,330,430	83.73	328,057	132
Mississippi	29,671,680	3,681,960	12.41	16,538,583	63.64	25,989,720	87.59	95,999	270
Missouri	43,985,280	5,575,640	12.68	30,877,732	80.39	38,409,640	87.32	229,096	168
Montana	93,523,840	12,020,511	12.85	62,663,286	76.88	81,503,329	87.15	100,294	812
Nebraska	49,157,120	3,803,841	6.92	45,753,279	100.00	45,753,279	93.08	141,088	324
Nevada	70,285,440	7,970,582	11.34	47,166,520	75.68	62,314,858	88.66	16,509	3,774
New Hampshire	5,779,840	438,145	7.58	1,850,123	34.64	5,341,695	92.42	65,146	82
New Jersey	4,808,960	888,829	18.48	1,473,485	37.59	3,920,131	81.52	125,866	31
New Mexico	78,401,920	9,851,223	12.57	63,376,071	92.45	68,550,697	87.43	35,170	1,949
New York	30,498,560	3,970,709	13.02	16,030,366	60.43	26,527,851	86.98	545,299	48
North Carolina	31,193,600	4,611,922	14.78	16,926,637	63.68	26,581,678	85.22	115,978	229
North Dakota	44,917,120	5,723,458	12.74	39,120,632	99.81	39,193,662	87.26	56,803	690
Ohio	26,073,600	5,076,689	19.47	19,030,502	90.63	20,996,911	80.53	523,040	40
Oklahoma	44,396,160	7,896,910	17.79	32,936,874	90.24	36,499,250	82.21	121,278	301
Oregon	61,188,480	6,664,118	10.89	37,024,381	67.90	54,524,362	89.11	138,964	392
Pennsylvania	28,692,480	4,583,362	15.97	12,986,083	53.86	24,109,118	84.03	607,096	40
Rhode Island	682,880	165,503	24.24	242,820	46.93	517,377	75.76	9,154	56
South Carolina	19,516,800	2,255,717	11.56	10,674,918	61.84	17,261,083	88.44	65,369	264
South Dakota	49,195,520	7,786,521	15.83	39,437,124	95.24	41,408,999	84.17	137,739	301
Tennessee	26,679,680	5,008,592	18.77	16,348,007	75.44	21,671,088	81.23	131,112	165
Texas	167,963,520	12,901,900	7.68	132,066,774	85.17	155,061,620	92.32	146,148	1,610
Utah	52,597,760	5,054,397	9.61	33,615,172	70.70	47,543,363	90.39	90,603	525
Vermont	5,839,360	581,068	9.95	3,635,743	69.16	5,258,292	90.05	47,797	110
Virginia	25,767,680	2,853,272	11.07	15,668,578	68.38	22,914,408	88.93	151,814	151
Washington	42,775,040	6,892,205	16.11	17,405,766	48.50	35,882,835	83.89	287,167	125
West Virginia	15,374,080	1,550,367	10.08	8,376,185	60.59	13,823,713	89.92	179,651	77
Wisconsin	35,363,840	4,894,209	13.84	20,461,048	67.15	30,469,631	86.16	298,478	102
Wyoming	62,430,720	8,024,305	12.85	48,727,916	89.56	54,406,415	87.15	43,040	1,264
United States	**1,903,176,160**	**244,998,539**	**12.87**	**1,216,493,322** **1,453,493,322***	**73.36** **87.65***	**1,658,178,421**	**87.13**	**8,190,901**	**202**

*** Includes 237,000,000 acres of private nonfarm grazing land.**

ing importance. The problem is particularly acute in the eastern and midwestern states where the amount of available, publicly owned land is small and where the human population is great. (See Table 2.)

A paradoxical situation exists in that a crop produced by the landowner is widely advertised to the sportsmen by state game departments seeking revenue from license fees and by business interests which profit from the manufacture and sale of sporting goods or services. South Dakota, for example, with but 100,000 resident hunters has been at or near the top among the states in total revenue from license sales because it has encouraged out-of-state hunters to take part in harvesting the pheasant crop produced on its farms. In 1945 it ranked third in income with $1,087,122 in license sales to 99,684 residents and 45,755 nonresidents. Hunting license sales for the entire United States increased from 5,988,064 in 1935 [13] to 12,066,763 in 1948.[14] Thus we have a growing army of hunters and fishermen who annually buy more and more equipment and seek places where it can be used. Economic and social changes leading to fewer working hours, the short work week, more and longer vacations, and better transportation facilities have all influenced this trend.

Hunting Pressure

The resulting pressure on wildlife and the land is particularly great in heavily populated states. Some states have less than 50 acres of total land area for each hunting license sold. New Jersey with 125,866 licensed hunters in 1945 had but 31 acres of potential huntable land per license holder, Indiana but 47, and only a small number (five western states) had more than a thousand acres of huntable land per license holder. For the country as a whole, there were only about 200 acres of potentially huntable land per licensed hunter for the 1944–1945 hunting season. (See Table 2.) These data do not take into account the many thousands of hunters who do not buy licenses, such as farmers when hunting on their own land, exempted veterans in states granting this privilege, and local people in rural areas in those states where hunting law enforcement is lax. The figures also do not reflect the relative amount of game available per unit of area. The abundance of game is a direct function of the productiveness of the land, and for this reason more game is produced per unit of area in the midwest than in the rougher and less fertile parts of the country. In few, if any, areas is the supply adequate to provide every hunter with all the game his license permits him to take.

In general, hunting pressure is greatest where the population is highest, but the percentage of the population that hunts and fishes is in inverse ratio to population density. This suggests that the quality of hunting declines as hunting pressure increases.

Although it is becoming increasingly apparent that hunting pressure is not the chief factor affecting the abundance of most species of wildlife, some species are especially susceptible to reduction by this means, particularly wilderness-inhabiting species and those that are intensively sought because of their superior sporting qualities or high trophy value. Big horn sheep, grizzly bears, and moose are examples.

[13] *Ibid.*, p. 37.

[14] J. R. M. Rutherford, *Ten Years of Pittman Robertson Wildlife Restoration*, Wildlife Management Institute, Washington, D. C., 1949, p. 68.

Waterfowl, too, are subject to drastic population reduction by overshooting because of the high-quality sport they provide and because of their gregarious and migratory habits, which subject them to gunfire while en route from their breeding areas to their wintering grounds. During the droughts of the early 1930's the North American waterfowl population dropped to the dangerously low level of 30,000,000 birds. With stringent hunting regulations and the return of favorable weather, the waterfowl population rose to about 140,000,000 during World War II, when hunting pressure was low. The substantial rise in the number of duck hunters from 1,380,000 in 1942 to an estimated 2,000,000 in 1946 has once more reduced their numbers below the average annual increase and below the carrying capacity of their breeding grounds.[15] During this period the waterfowl bagged each year increased from 16,000,000 to 26,000,000, and the population after hunting declined from 120,000,000 to 80,000,000.

Pollution

Fortunately, the reproductive capacity of most kinds of fish is so great that their numbers are seldom seriously depleted by ordinary recreational fishing, although commercial fishing has reduced many once abundant fish of both coastal and inland waters. However, the rendering of streams and lakes uninhabitable for fish because of pollution is a problem of considerable magnitude. Many of our streams are now inhabited only by species of fish such as the carp which is tolerant of the sewage they carry.

[15] Clarence Cottam, *Transactions of the 12th North American Wildlife Conference*, American Wildlife Management Institute, Washington, D. C., 1947, pp. 67–86.

The chief sources of pollution are domestic sewage, industrial and mine wastes, and fine particles of soil washed from farms. Oxidation of domestic sewage exhausts the water-borne oxygen necessary to fish life and results in the production of materials toxic to fish. Industrial and mine pollution results from the emptying into bodies of water of waste products which may poison fish directly or interfere with their respiration, thus causing death. Minute quantities of such waste materials may be sufficient to kill fish directly or indirectly by destroying their food supply. For example, phenol, a waste product of gas plants and oil refineries, is toxic to trout at concentrations of but five parts per million of water, and potassium cyanide, a waste product of coke ovens, at concentrations as low as 0.1 to 0.3 part per million. Silt in streams covers up spawning beds and bottom-inhabiting organisms which fish feed upon and also reduces light penetration below that necessary for plant growth.

Although some kinds of pollution have been alleviated, the problem still exists on a large scale in many states. Some large waterways like the Illinois River are said to be polluted continuously for distances of 100 miles, whereas the Ohio River is subject to pollution at many points along its entire length. Only a few of the many cities along the Ohio shore treat their sewage before it is dumped into the river. Chemicals from coal mines in the principal coal-producing states and the wastes that drain into streams from iron, copper, lead, and other mines, and industrial plants have made hundreds of streams uninhabitable to fish. The treatments necessary to render pollution harmless to animal life are often expensive and imperfectly developed. For this reason, many states are slow to enforce pollution-abatement measures because they fear loss of important industries to states where pollution laws are less strict. Uniformly applied pollution-abatement measures in all the states would help to correct this situation. Passage of the federal Water Pollution Control Act in 1948 opened the way for the states to attack this problem co-operatively.

Land-Use

Among other conditions affecting the welfare of wildlife are the overgrazing of forested lands and the burning, both intentional and accidental, of forest, range, swamp, and other wildlife habitats. Unwise drainage of vast marsh and swampland areas has also been a factor contributing to the decline of some species, although it must be kept constantly in mind that much of our best agricultural land owes its high value to judicious use of drainage ditches. Tractor-powered mowers, binders, combines, and other farm machinery have greatly increased wildlife mortality in crop fields during the reproductive season. Roadside mowing during the same period has also caused severe losses. The electric fence and effective weed-killing chemicals have further accelerated the removal of brushy fence rows which often are the only permanent source of wildlife cover on farms. Decline in productivity of land due to overcropping and erosion has also had a profound effect on reducing wildlife production over large areas of formerly good game lands.

Public Apathy

Prejudice, tradition, misunderstanding, and selfishness are other important problems in wildlife conservation. Many sincere people lacking basic biological knowledge still cling to management of our wildlife resources by outmoded and biologically unsound programs of predator control, bounty payments, "vermin-control" campaigns, introduction of exotic species, and artificial propagation and release of originally wild stock. Vociferous minorities of such uninformed persons sometimes prevent state conservation departments from putting sound wildlife conservation programs into effect until public support for enlightened management is mobilized. Some states, for example, are forced to continue providing protection to female deer during the hunting season in the face of overwhelming evidence that the herd is becoming too great for its food supply.

Because many state fish and game departments are still subject to political maneuvering by the party in power, it is expedient for them to practice programs of appeasement. However, those fish and game departments that operate under the guidance of truly nonpolitical conservation commissions are generally undertaking farsighted programs of wildlife management based on sound biological concepts and principles.

Lack of technically trained personnel on the staff of conservation agencies is also a problem. Agencies under political domination offer even qualified personnel insecurity of tenure and low salaries. A tendency to improve this situation by employing college-trained men for permanent positions carrying moderate salaries has become evident. The colleges and universities have responded by providing professional training in this field; at least 16 colleges and universities in the United States were offering the necessary course of study in 1948. They are gradually building up a force of professional wildlife managers to whom the management of this resource may safely be entrusted.

MANAGEMENT OF WILDLIFE

Three Basic Concepts

The three basic concepts upon which any sound program of wildlife conservation must be built are set forth by Gabrielson,[16] formerly director of the United States Fish and Wildlife Service:

1. Soil, water, forest, and wildlife conservation are only parts of one inseparable program.
2. Wildlife must have an environment suited to its needs if it is to survive.
3. Any use that is made of any living resource must be limited to not more than the annual increase if the essential seed stock is to be continually available.

It should be clear from these concepts that wildlife is primarily a by-product of land use. Except on public and private hunting or fishing preserves or wildlife sanctuaries, it is seldom the primary object of land use. For this reason, its management must be integrated with and largely subordinate to the management of land for agricultural, forest, and mineral use. Management under these conditions requires intimate knowledge of the habits and living requirements of all forms of wildlife.

The basic living requirements of all wild animals are food, water, cover, and a climate to which they are adapted. Certain species have special requirements such as salt for deer and grit for quail, pheasant, and partridge. The particular kind of food, water, and cover required by different animals is usually a fixed characteristic of each species. For example, quail feed primarily upon seeds of grain and weeds, fruit, and insects, whereas many birds such as the warblers and vireos, feed almost entirely upon insects and near relatives of insects.

[16] Ira N. Gabrielson, *Wildlife Conservation*, New York, 1942, p. vi.

Food Requirements

To be adequate, not only must the food supply be of the right kind but also it must be available at all seasons of the year and within the daily traveling range of the animal. One of the most serious wildlife conservation problems occurs in areas where some food is abundant during the spring, summer, and fall months but is deficient during the winter. This problem is particularly acute on the western range where deer, elk, and antelope find abundant food in high mountain ranges during the summer months but are often unable to secure sufficient food to ward off starvation when driven by heavy snows to the valleys where they must compete for food with domestic livestock.

On many of our farms and ranches today there is a greater abundance of food suitable for small animals like quail, pheasant, other seed-eating birds, rabbits, ground hogs, and ground squirrels than was present when the land was covered with forests or unbroken grassland, because of the growing of grain and forage crops, which are utilized by these animals. Although most of these crops are grown for domestic purposes, large quantities of waste grain, forage plants, and weed seeds are left in the fields. For example, mechanically harvested corn fields may contain several bushels of grain and a hundred or more pounds of weed seeds per acre after harvesting is completed. In such areas, lack of cover is frequently the most important factor limiting abundance of wildlife.

Cover Requirements

The specific cover requirements of many animals are varied and complex. Thus the introduced ring-necked pheasant requires for nesting over much of its range open herbaceous cover such as sweet clover, alfalfa, and bunch grasses; dense thicket cover into which it may escape when pursued by natural enemies; tall corn, small grain stubble, or weeds in which it may feed unmolested; weedy or thicket roosting cover; and exposed ground where it can pick up grit. The lack of one or more elements of the cover requirements of a species may be the factor limiting its abundance. The common bluebirds and wrens of our farms and gardens, for example, are limited by the availability of such nesting sites as holes in trees and fence posts and artificially constructed bird houses.

An important aspect of the cover needs of wild animals is its distribution in relation to available food and water. To be fully effective, cover must be so distributed that it can be utilized during travel to and from sources of food and water and as refuge which can be quickly reached if an animal is threatened with attack.

Water Requirements

The water needs of aquatic or semi-aquatic animals like fish, frogs, ducks, geese, and swans are readily apparent. Not so apparent, however, are the needs of individual species.

Trout require clear, cool water with high oxygen content, whereas bullheads, catfish, and carp are tolerant of silt-laden, moderately warm water. Muskrats are most abundant in shallow water in which cattail, bur reed, and other aquatic plants grow profusely. Waterfowl also favor shallow waters where puddle ducks such as the mallards obtain food by probing the stream or lake bottom with their bills, and where fish-eating birds such as the mergansers and herons find an abundance of small fish. Nearly all species of animals that live in or on bodies of water are dependent upon water that is clean, free from toxic substances, and sufficiently rich in mineral nutrients to support a high population of plants and animals.

Many terrestrial animals like deer, elk, and moose require clear, open water for drinking. Others like quail and pheasant are able to meet their water needs from dew and by eating available succulent plants and fruits. When these are absent, they, too, must have access to open water if they are to be abundant. Fortunately, some animals including the western quails are able to obtain adequate water from the food they regularly eat.

The absence of suitable water the year around is often the most important factor limiting the abundance of wildlife in areas of low rainfall, particularly in marginal areas where an occasional drought wipes out populations built up during periods of normal or heavy precipitation. Ducks and geese which nest in the marshes of north central United States and the Prairie Provinces of Canada suffer great losses when such droughts occur. In contrast, wildlife of the more humid regions sometimes suffers from an excess of precipitation, especially when it occurs during the nesting season. During such a period, the eggs and young of many ground-nesting species become chilled from drenching rains or are drowned by flood waters.

Capacity to Reproduce

The biotic potential or reproductive capacity of most kinds of wild animals greatly exceeds the carrying capacity of the environment they occupy. If all lived and reproduced, the potential progeny from a single pair of adult bobwhite quail would in three years' time number at least 1000 individuals. Even deer which per year produce but one to three young may overpopulate their available range under suitable conditions: theoretically, a density of one pair of adult deer per square mile (640 acres) may in only fifteen years result in a population of one deer per acre. Although truly phenomenal increases in population occasionally occur, it is doubtful if the full biotic potential is ever attained under natural conditions. Usually only a small fraction of the potential increase results, even when the necessary welfare factors of food, water, and cover are present.

Decimating Factors

Full attainment of the biotic potential of wild animals is prevented in part by one or more decimating factors: diseases, parasites, predation, starvation, accidents, and hunting. The importance of each factor varies with respect to species, environmental conditions, and human activities; frequently one factor or a combination of factors is more important than any of the others. Thus ducks are generally more subject to losses from overshooting and disease than are ràccoon, which suffer from inadequate woodland habitat. Bobwhite quail and deer are subject to losses from starvation during severe winters. Because of their nesting in hay and grain fields, ring-necked pheasants are subject to high mortality from accidental encounters with mowing machines, grain binders, and combines.

Wildlife Management Practices

The primary responsibility of the wildlife technician is to determine whether the decimating and welfare factors are in proper balance with the needs of the species and, if they are not, to devise ways and means of correcting them. This necessitates carefully conducted research into the life history and habits of animals with respect to their natural and potential environment. Although only a beginning has been made in this field of investigation, a considerable body of information useful in prescribing guiding principles is now available. From these data and past experiences, our present sound wildlife conservation programs and our knowledge of unsolved problems have been developed.

Regulating the Use of Wildlife

Since Biblical times, limiting the harvest of wildlife to not more than the annual increase has been recognized as a management measure.[17] This is the fundamental purpose of all hunting laws and other regulations restricting the use of wild animals the world over. To accomplish this purpose, various methods have been employed ranging from simple tribal taboos against disturbing the female during the breeding season to the complex regulations in force in the United States at the present time. Although regulations vary greatly from state to state, all are largely based upon limiting the period when animals can be taken to the nonbreeding season (open season); limiting the length of time during which they can be taken (length of season); limiting the number that can be taken in a day (daily bag limit) and in a season (season bag limit); and regulating the manner in which they can be taken (restricting caliber and load of gun, preventing use of decoys, bait, ferrets, fire, snares, nets, and dynamite).

All states now require separate licenses for hunting and fishing or a combined license for both sports. Some states require special licenses of commercial fishermen, live-bait dealers, fur dealers, and game-

[17] Deuteronomy, 22:6.

farm operators. In some states scientific collectors and taxidermists also are required to have permits.

The federal government is responsible for fixing regulations protecting migratory species of wildlife and requires the purchase of a federal duck stamp for hunting waterfowl. The United States has entered into international treaties for the protection of migratory species of wildlife and certain endangered ocean fisheries such as whaling and fur-seal industry, the North Atlantic fisheries, and the Northern Pacific halibut fisheries. One of the most important federal laws protecting the welfare of wildlife is the Lacey Act of 1900, prohibiting both the importation of any foreign wild animal without approval of the Department of Agriculture and the interstate shipment of the dead bodies of illegally killed wild animals. The latter provision virtually ended the market hunting of wildlife and the wild-bird feather trade which were threatening extermination of many species. Federal protection of migratory species is authorized under the Migratory Bird Treaty Act of 1918, which replaced the Migratory Bird Act of 1913.

Predator Control

Destruction of animals that prey upon game species and domestic livestock has long been a duty of private game managers and of public employees charged with the welfare of wildlife. Many state game-law enforcement officers spend much of their time killing hawks, owls, crows, foxes, coyotes, and other predatory animals in the belief that the welfare of desirable species is thus promoted. Some states encourage the destruction of predators by paying bounties for each animal killed; Pennsylvania alone has paid out over a million dollars for this purpose. State agencies promote local predator-control campaigns by 4-H Clubs, Future Farmers of America, youth groups, and sportsmen's clubs.

Scientists have accumulated convincing evidence that these efforts not only fail sometimes to promote the welfare of wildlife generally but may actually be harmful. For example, destruction of predators was an important contributing factor in the increase of the Kaibab deer herd in Arizona to the point where it exhausted the available food supply resulting in starvation of much of the herd, serious damage to young trees, and decline in the capacity of the range to support future deer populations.

Some conservation departments, after studying the effectiveness of bounty payments for predator control in their states, have concluded that the money spent neither reduced the predators nor appreciably benefited wildlife. However, these same agencies are often forced by public opinion to continue bounty payments.

Unfortunately, our knowledge of prey-predator relationships is not adequate for a satisfactory solution of the many problems involved in this controversial subject. It is common knowledge that predatory animals do kill many desirable species. It is also well known to biologists that a limited amount of predation may be beneficial to some kinds of wildlife by killing off diseased individuals, by preventing overpopulations, by encouraging wariness, and by holding in check less valuable species that may compete with desirable animals for food, shelter, and water. There is no evidence that promiscuous killing of predators is either effective or desirable; effective predator control should be directed only at those species and those individual animals actually known to be doing harm.

Artificial Propagation and Introduction of Exotic Species

Since historic times, man has been interested in exotic animals and has attempted to substitute them for native animals displaced by his occupancy of their environment. Of the many attempts to introduce exotic game species into this country, only the introduction of the ring-necked pheasant and the Hungarian partridge can be termed successful. Yet even the latter species has dropped to such low population levels over much of its established range in the United States that its future status is in question. Although the ring-necked pheasant has declined somewhat, it seems to be a permanent addition to the farmland of the nation particularly in the midwest, the northern Great Plains, and parts of the Pacific northwest. Filling with foreign introductions gaps left by declining native species does not appear to present a very promising solution to the problem.

In some instances, foreign introductions have caused considerable harm and unexpected displacement of native species. The European starling and the English sparrow, introduced to control certain injurious insects, not only have failed in that mission but also have become a pest of city and country alike where they occupy nesting sites of bluebirds, woodpeckers, and other hole-nesting birds. The common carp, introduced as a food fish, roil the water in many of our lakes and streams making the habitat unsuitable for other species.

Closely allied to the introduction of exotic game animals are attempts to increase by artificial propagation their numbers and that of native species. This phase of game management originated in the Old World, where since the sixteenth century it has been practiced to sustain for the privileged classes the sport of hunting. In the United States it has been used both to secure exotic or native stock for establishing new areas or replenishing areas thought to be overshot or overfished and to supply stock for bird-dog field trials, for commercial hunting and fishing preserves, and for sale as food. Many state conservation departments operate one or more game and fish farms and spend as much as one-fourth or more of their total income for this purpose. Ring-necked pheasants and native quail are the game birds generally raised for stocking purposes. Trout, several kinds of bass, bluegills, whitefish, and a number of other fish are commonly reared in artificial ponds for restocking. Most of these are planted in natural bodies of water as fry (recently hatched fish) or fingerlings (fish with one season's growth). Some states attempt to provide public fishing by stocking streams with hatchery-reared adult fish.

Artificial propagation, particularly of upland game species, is an expensive way of providing public recreation. Its chief value lies in replenishing suitable areas that have been depleted by overshooting, severe winter losses, and such accidents as fire or flood. Artificial stocking of fish is usually practical only in new bodies of water. Unfortunately, much of the artificially reared game and fish are released in already adequately stocked areas or in areas not adapted to occupancy by the species released. For many years, artificially reared ring-necked pheasants were distributed equally in all Ohio counties in response to demands by local sportsmen groups. Despite these repeated plantings, huntable populations of pheasants have developed only in the intensively farmed, glaciated parts of that state. A similar approach to stocking fish has been followed in many states. Millions of fry and fingerling fish have been stocked in waters to which they were not adapted or in waters already overpopulated with adapted species. Usually the newly planted fish either succumb to the new environment or provide expensive food for the fish already present.

Wildlife Preserves and Refuges

Although hunting preserves have been used for hundreds of years to provide exclusive shooting privileges to the titled classes of Europe and Asia, they are of comparatively recent origin in this country. A few states, Pennsylvania and Michigan for example, have set aside large areas of publicly owned land for public shooting grounds; many states have also acquired and developed lake sites to provide public fishing waters. Some extensive preserves in this country are privately owned by wealthy persons or by clubs with exclusive memberships. Frequently these areas encompass the finest hunting territory, such as the Lake Erie marshes which are largely controlled by gun clubs for waterfowl shooting. Various systems of leasing exclusive hunting rights on farms in the best hunting areas have also become popular. This practice has been highly developed in the southern and southeastern states and is gaining headway in the good pheasant hunting areas of the Corn Belt.

On some preserves much effort is being made to increase wildlife production. But on many privately owned and managed tracts, the sole management measure employed is to divide fairly the natural increment of game according to privileges paid for.

The development of any system of paid hunting has been opposed by organized sportsmen and conservation departments because they fear that it will restrict hunting privileges to those with better than average incomes and that it will reduce income to conservation departments through the sale of fewer licenses. Landowners in general, however, have organized paid hunting preserves more for protection from hunter abuses than for profit. The fees charged amount to but a few cents per acre of huntable land.

Unlike preserves, refuges are developed primarily for wildlife preservation. Their history in the United States is of comparatively recent origin, although a few such private areas were probably in existence when the first official refuge was authorized by the California legislature in the 1869–1870 session. The first federal wildlife refuge was established by presidential order on March 17, 1903, when Pelican Island in Indian River, near the east coast of Florida, was set aside for the protection of a waning population of brown pelicans. Under the dynamic leadership of Theodore Roosevelt, Gifford Pinchot, E. W. Nelson, William T. Hornaday and, more recently, Jay N. Darling, Aldo Leopold, and other conservationists, the refuge movement has so developed that the United States has the greatest wildlife refuge system in the world: 272 federal wildlife refuges aggregating 17,643,915 acres in continental United States and Alaska. The greatest number of areas (184) is for protection of migratory waterfowl; more than half of the land (10,601,364 acres in 16 tracts) has been acquired for big game. Other purposes of federal refuges are the protection of nongame birds that nest in large colonies, wildlife in general, and research. Most of the present and anticipated funds for maintenance and development of the federal wildlife refuge system are derived from the sale of the federal duck stamp required for hunting migratory birds.

The states, too, have developed a system of wildlife refuges, although the intent has often been to preserve breeding stock of huntable species to establish on adjacent overshot areas. This has proved to be a most useful management method to maintain huntable populations of game in areas of intense hunting pressure but it is practical for only a few species such as waterfowl, deer, turkey, and pheasant, which are able to spread out quickly into the surrounding territory, are tolerant of crowding, and can be maintained on cheap land.

Two outstanding private waterfowl refuges are the Andrew Clark Refuge at Santa Barbara, California, and the W. H. Kellogg Bird Sanctuary at Battle Creek, Michigan. Other refuges of outstanding importance are Lake Merritt maintained by the city of Oakland in California, Hawk Mountain Sanctuary in Pennsylvania, Bird City at Avery Island in Louisiana, and the extensive system of refuges maintained by the National Audubon Society. The most important of the latter group are located in Florida with eight refuges and in Texas with 17 refuges where colonies, chiefly of herons and ibises, are protected. There are probably many more than a hundred other private refuges of value to wildlife in the country.[18]

Management of Food, Cover, and Water

The foregoing wildlife management measures are designed to control those factors that decimate wildlife populations. Except in relation to refuges, they have little to do with providing the food, water, and cover necessary for these animals to live and reproduce. This phase of wildlife management has been left largely to the landowner, without guidance and without incentive. Yet the wise solution of this problem is the key to the future recreational use of the wildlife resources of our farms and ranches (Fig. 7).

A partial solution to the problem lies in the fact that good soil, water, and forest conservation contribute greatly to the welfare of wildlife. Fertile soil protected by any needed conservation practices such as long crop rotations, contour cultivation, strip cropping, terraces, and good tillage methods provides more food and cover for wildlife than does less fertile, less well-managed land. Permanent reservoirs developed for farm and ranch water supplies, for flood control, and for urban use also provide water for fish, waterfowl, and the many animals that inhabit stream, lake margins, and the shallow fringes of impounded waters. Only profitable forest management can assure the future of the farm woodlot, which is the permanent home of much farm wildlife and the safe retreat of other kinds. All these measures are vital to the economic security of the farmer and rancher, and they are carried out because it is profitable to do so.

Fortunately a vast program of soil and water conservation has already been initiated on the nation's farms under the leadership of the United States Soil Conservation Service. This agency, working through locally organized soil conservation districts and with the aid of the state agricultural extension programs, has helped thousands of farmers and ranchers to conserve and restore their soil and water and to make their woodlots more productive. As these practices are extended, wildlife will benefit proportionately.

Additional measures are needed, however, to develop fully the potential wildlife productivity of land in agricultural ownership. It is to be expected that some of these measures, such as gully control and range

[18] Ira N. Gabrielson, *Wildlife Refuges*, New York, 1943, pp. 3–39.

or pasture improvement, may be carried out as part of regular farm operations. But other measures of considerable value to wildlife will probably not be carried out on a significant scale unless it becomes profitable for the farmer to undertake them or unless he is safeguarded against the inconvenience and abuse that often attend hunting on his land.

According to estimates made by the Soil Conservation Service, at least 100,000,000 acres of land in continental United States are best adapted to wildlife use, of which at least 33,000,000 acres are in farms and ranches. About one-half of this area is now making its maximum contribution to wildlife and will continue to do so if it is not disturbed by fire, grazing, or cultivation. The remaining area, in need of some improvement to make it fully productive, includes 6,500,000 acres suited for marsh management, 1,000,000 acres of ponds, 1,000,000 acres of streambanks, 3,000,000 acres of crop-field borders, 6,000,000 acres of oddly shaped fields unsuited to other uses, and 250,000 acres of spoil banks resulting from various surface mining operations.[19]

To become fully productive of wildlife, these areas must support vegetation that provides erosion-resistant ground cover, and food and cover, useful to wildlife. The establishment of such vegetation requires technical knowledge not ordinarily available to farm owners. In some instances material assistance such as nursery stock, fence to protect wildlife areas, and some financial inducement may be necessary. Agencies such as the Soil Conservation Service which work with farmers are in the best position to offer the necessary technical direction for wildlife improvements on farmland, and agencies supported by hunting and fishing license funds are best able to provide needed material aid.

Careful management of the wildlife areas on the nation's farms can establish the cover necessary to hold a wildlife population adequate to utilize fully the food supply that is so often produced as an incidental by-product of highly mechanized agriculture. Such areas are the only land on farms that can be justifiably managed solely for wildlife. They offer the best opportunity for providing the three basic wel-

FIG. 7. Management of land to produce food, water, and shelter adequate for wildlife needs is one of the basic steps in wildlife management. This field border of *sericea lespedeza* (an introduced legume) serves as an erosion control strip and a turn row for farm equipment, utilizes the nonproductive strip between woodland and crop field, and provides wildlife cover and food in abundance. Such practices to secure widespread adoption must be practical. Hundreds of miles of borders like these have been established on farms planned for soil and water conservation in the southeastern states. (United States Soil Conservation Service.)

[19] Edward H. Graham, *The Land and Wildlife,* New York, 1947, p. 52.

fare factors of food, water, and shelter which, together with control of the important decimating factors, are the building stones of any successful wildlife conservation program.

Management of food, water, and cover are equally important on other lands if wildlife is to be benefited. The intensity of such management, however, must be based on the major use to which the land is adapted. Timber production, for example, is given first consideration on both public and private forested land; yet modification of timber management practices can be employed to increase materially forest-wildlife production. These modifications include the leaving of den trees for squirrels, raccoons, and other tree-dwelling animals, the favoring of desirable seed- or fruit-producing trees, the selective or group harvest method of cutting timber to provide a variety of forest growth from small seedlings to large trees, and the leaving of open areas in reforestation projects for the securing of mixed stands of natural growth and planted trees.

WILDLIFE CONSERVATION PROGRAMS AND RESPONSIBILITIES

The development of a sound national program of wildlife conservation is dependent upon three basic steps:

1. An adequate research program to establish the status of important wildlife species, their needs, and measures necessary for their continued welfare under predicted use.

2. An educational program to acquaint the citizenry with the basic needs of wildlife and with the biological, social, and economic problems involved in its use and to train adequate personnel to administer and manage this resource.

3. An action program to provide the food, water, cover, and protection from decimation needed by wildlife.

Considerable progress has already been made in the field of wildlife management. It is now a well-established profession for which at least 16 colleges and universities in the United States offer training at either the undergraduate or graduate level or both.

The states through their divisions of conservation spend for wildlife management purposes the annual revenue from sale of fishing and hunting licenses, totaling about $25,000,000. This amount is supplemented by federal appropriations to the states from an excise tax on arms and ammunition; during the period 1938–1949, this tax yielded $48,175,431 of which $23,431,274 were appropriated. Approximately 30 per cent of this amount was expended for research, 30 per cent for development projects, 35 per cent for land acquisition, and 5 per cent for administration of the fund.

The United States Fish and Wildlife Service is the federal agency charged with responsibility for migratory species of wildlife and the federal wildlife refuge program. It conducts important wildlife researches in fields ordinarily untouched by state and private institutions. It also participates in a co-operative research program with the American Wildlife Management Institute, state universities, and state divisions of conservation.[20] This

[20] There are 17 co-operative wildlife research units in the United States. In most cases the Fish and Wildlife Service, the co-operating state university or college, and the state department of conservation contribute an equal amount of money or the equivalent in services for the

agency is also charged with responsibility for a program of injurious-animal control, which is carried on largely in the western ranges.

Other federal agencies play a leading part in the management of wildlife resources. Of these, the National Park Service and the Forest Service work entirely on public land, whereas the Soil Conservation Service through its technicians develops programs for wildlife restoration on farms managed for soil and water conservation.

Among the many private organizations that contribute to the welfare of wildlife are the National Audubon Society, the American Wildlife Management Institute, the American Wildlife Federation, and the Izaak Walton League of America. These and other agencies carry on the important educational work of informing the general public of wildlife problems and act as the watchdogs of governmental activities which affect the well-being of our wildlife resources.

SUMMARY

Wildlife is a renewable resource which is subject to management by man. The basic needs of wild animals are adequate food, water, and cover to meet their specific requirements and protection from decimating factors which reduce their numbers. These needs can be met only by proper management of the land upon which they live and by control of such decimating factors as overhunting. Application of these measures on publicly owned land is now largely in force.

Although many species formerly common or abundant are now rare the aesthetic value of those remaining is great. Public demand for recreational use of wildlife exerts enormous pressure on the supply and in some species necessitates complete protection and drastic restrictions on the use of others to ensure their welfare.

Most of the recreational use of wildlife is provided by agricultural land where the proper incentives for adopting practices beneficial to wildlife are often lacking. Widespread application of soil and water conservation practices may in part fulfill this need. Where these measures are not feasible or adequate, other inducements must be provided if wildlife production is to be maintained at a high population level.

Considerable advancement has been made in the field of wildlife management. Further progress is dependent upon continual research and sound educational and action programs unhampered by political interference and the clamor of uninformed or selfish pressure groups.

operation of each unit. Part of the Fish and Wildlife Service's contribution is met by funds provided by the Wildlife Management Institute which is a private-non-profit organization. Co-operative Wildlife Research Units are at the present time maintained at the following institutions: Alabama Polytechnic Institute, University of Alaska, University of Arizona, Colorado A. and M. College, University of Idaho, Iowa State College, University of Maine, University of Massachusetts, University of Missouri, The Ohio State University, Oklahoma A. and M. College, University of Oregon, University of Montana, The Pennsylvania State College, Texas A. and M. College, Utah State Agricultural College, and Virginia Polytechnic Institute.

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CHAPTER 19

Fisheries for the Future

INTRODUCTION

The Changing Viewpoint

The American attitude toward fisheries is typical of a pioneer society attuned to an era of plenty. The easy-going assumption that man can never exhaust the sea placed upon nature the entire responsibility for replenishment. Public reliance upon this comfortable theory, which demanded neither care nor restraint on the part of the fishermen, was based on general ignorance concerning most types of underwater life. Halibut might be abundant on one bank and entirely absent in a neighboring area, but no one knew why. Schools of mackerel would be plentiful one season and fail to appear a year later. The biologic history of most food fishes was a complete mystery, and reputable scientists, unable to make accurate underwater studies, assumed that there was an inexhaustible reservoir of fish in the oceans. Knowledge concerning marine life was extremely meager until early in the twentieth century, and even today little is known concerning the abundance, habits, growth, reproduction, and migration of many valuable food fish. Fortunately, biologists and oceanographers have now developed various techniques of marine investigation, and their research on problems of fish life is providing exact data of great value.

The old-fashioned biologists, in considering fisheries inexhaustible, also underestimated the ingenuity of modern fishing methods. It was impossible to foresee the effect of otter trawlers, large-scale operations, and numerous improvements in fishing gear—all of which added to the efficiency of production but also intensified the pressure upon the basic resource. The theory of inexhaustibility has now been abandoned or, at least, modified. The modern biologist prefers to think of fisheries as a replaceable resource, needing scientific study and responding readily to good management.

Public Responsibility for Conservation

Good management, however, has been a goal difficult to attain.

"From a conservation viewpoint, the fisheries are perhaps the most poorly managed of all our national resources. Legislative regulations governing them, where they exist at all, are piecemeal, localized and often based on lay opinion, superstition or snap judgment. ··· Yet there is a science of fishery conservation, which is highly specialized and exact. That it has not been more fruitful in this country is no reflection on the science or scientists but

By Howard H. Martin of the University of Washington.

rather on the public's failure to back them up. True, fishery science is costly · · · but it more than pays for itself in increased value and security of wealth which it strives to protect. Nevertheless, federal and state conservation agencies have everywhere been required to do their fishery conservation work on a financial shoestring. Small wonder that they have obtained shoestring results!"[1]

Distribution of Fish in the United States

With a maximum of shallow continental shelf waters in addition to bays, river mouths, and other coastal indentations, the United States has an ideal setting for a large and valuable fishery. It also has a greater variety of fish than any other nation. The North Atlantic and the North Pacific, with their warm and cold currents in close proximity, are natural plankton feeding grounds for nearly all the fish that are most important in commerce. The value of these well-stocked waters has been greatly increased since the 1920's by the enlargement of the list of varieties considered good for food. The annual catch exceeds 4,000,000,000 pounds, for which the fishermen are paid $152,000,000. When fish are fresh-frozen, filleted, smoked, canned, dried, salted, pickled, or otherwise packaged and prepared for final consumption, the value of the catch is several times this figure. The capital value of the United States fishery is estimated at $5,855,000,000 (see Table 1).

New England, by far the oldest commercial fishing center in America, still regards the cod as its most characteristic sea food. This historic fish has shown some fluctuations from year to year, but New England still takes nine-tenths of the American cod, much of it now entering the fresh fish trade. Speedy and efficient trawlers have increased the catch of both haddock and cod; haddock is now the leading commercial variety on the Atlantic seaboard, accounting for one-quarter of the total New England catch. Other valuable bottom fish taken by the trawlers include rosefish, flounder, and pollock. The lobster, chiefly a New England product, is now third in value, Maine alone catching more lobster than all other states combined. Other leading shellfish include clams, oysters, and scallops. Herring and mackerel provide the largest catches among pelagic varieties. Although certain individual species have declined in numbers, the ports of Boston and Gloucester market a greater variety of food fish than can be found in any other section of the United States.

TABLE 1

FISHERIES PRODUCTION BY REGIONS, 1942

[Source: U. S. Fish and Wildlife Service]

Region	*Million Dollars*	*Percentage of Total*	*Million Pounds*	*Percentage of Total*
New England	36.3	23.8	705	18.3
Middle Atlantic	12.4	8.2	319	8.3
Chesapeake Bay	10.0	6.6	202	5.2
South Atlantic and Gulf	14.6 *	9.6	575 *	14.9
Great Lakes	8.6	5.7	75	1.9
Mississippi River and tributaries	2.9 †	1.9	82 †	2.1
Pacific coast	49.2	32.4	1375	35.7
Alaska	17.9	11.8	522	13.6
Total	151.9	100.0	3855	100.0

* Data for 1940.
† Data for 1931

The many tidewater bays, inlets, and sunken rivers of the Middle Atlantic states are especially suitable for shellfish, including oysters, crabs, and clams. Chesapeake Bay in particular is famous for its extensive public and private oyster beds; two-thirds

[1] Lionel A. Walford, *Fishery Resources of the United States of America,* Washington, D. C., 1945, p. 131.

of the United States oyster production comes from the Middle Atlantic area. Alewives, or river herring, are taken freely in tidewater streams from Chesapeake Bay to the Carolinas. Menhaden, caught with purse seines by the thousands of tons, are processed into meal, oil, and fertilizer.

FIG. 1. Fisherman's Wharf, Los Angeles, home port and outfitting center for sardine purse seiners and tuna clippers. Los Angeles leads all other ports in the United States in tonnage of fish landed. (Los Angeles Harbor Department.)

Along the low-lying Gulf coast from Key West to the Rio Grande, shrimp-trawling, now a $5,000,000 industry, is the most profitable single fishing activity. The highly migratory red snapper, a favorite warm-water species, is handled in quantity through Pensacola. Other fisheries of the South Atlantic and Gulf include mullet, alewives, sea trout, oysters, and crab. Florida waters account for practically all the sponges.

The Great Lakes have their own special food fishes, the more valuable being herring, lake trout, blue and yellow pike, yellow perch, and whitefish. The Mississippi River system, more limited than the Great Lakes, markets almost entirely buffalo fish, carp, and catfish.

Since 1880 the New England and Middle Atlantic fisheries have shown a general decline in volume. The Pacific coast and Alaska, in contrast, now produce about six times as much as in 1880, when salmon was almost the only fish taken commercially on the west coast. In value salmon now accounts for one-third of the total Pacific fisheries. Sardines (pilchard) and tuna are landed in huge quantities, mainly in California (Fig. 1). Other leading west coast varieties are the halibut of the northwest, mackerel, flounder, and herring—the last mainly from Alaska. With the discovery of high-potency vitamin A in shark livers, this fishery has become a major industry in Pacific waters. A large part of the salmon and almost all the tuna and sardines are used for canning purposes. The California tuna pack increased from 75,000 cases in 1912 to 6,460,000 in 1949, an all-time record. Tuna canning is divided between San Diego and the port of Los Angeles. Two-thirds of the American mackerel supply now comes from California waters, with the Los Angeles area as the landing center. Several varieties of bottom fish such as flounder and the rockfish are taken by deep trawling for the fresh fish market. Crabs and oysters are the most valuable shellfish of the Pacific coast.

TABLE 2

FISHERIES OF THE UNITED STATES AND ALASKA, 1942

[Source: U. S. Department of the Interior.]

Fish	*Value*	*Pounds*
Salmon	$ 23,459,000	508,598,000
Tuna *	13,086,000	129,065,000
Pilchard	10,419,000	974,680,000
Haddock	8,806,000	145,687,000
Flounders	6,273,000	116,858,000
Halibut	5,992,000	52,935,000
Sharks (including grayfish)	5,618,000	35,060,000
Cod	3,798,000	73,456,000
Rosefish	3,755,000	128,107,000
Mackerel	3,715,000	103,628,000
Menhaden	2,881,000	518,784,000
Lake trout	2,425,000	10,175,000
Shellfish		
Oysters	10,676,000	64,646,000
Oysters, western	1,129,000	10,768,000
Shrimp	5,934,000	152,090,000
Clams	4,785,000	28,291,000
Crabs	3,363,000	87,957,000
Lobster	2,926,000	12,932,000
Scallops	2,709,000	8,238,000
Total	$152,172,000	3,856,548,000

Note: Data are for fisheries having a value of $2,000,000 or more. Other varieties having a value of half a million dollars or more were, in order of value of catch, whiting, pollock, (sea) herring, sea trout, mullet, buffalo fish, shad, croaker, whitefish, sablefish, yellow pike, sponges, lake herring, yellow perch, ling cod, scup (or) porgy, red snapper, butterfish, striped bass.

* Among varieties listed as tuna are the yellowfin, bluefin, skipjack, bonito, albacore.

Exploitation and Depletion in Atlantic Waters

Evidences of decline or exhaustion in specific American fisheries are so numerous that they can be selected almost at random, either from popular accounts or from scientific studies. In colonial days salmon were plentiful from the mouth of the Hudson River as far north as Labrador; they were a staple food fish taken in large quantities during the annual run and used either fresh or salted. Today only a few scattered rivers, such as the Penobscot in Maine, have runs of any size, and the Atlantic salmon is regarded as a sports fish, with hatcheries in New England trying to increase the available stock. The Atlantic halibut is still a commercial fish but is now far below its former production (Table 2).

Cod has been taken in quantity for two or three centuries without exhausting the stocks, but statistical records show that present-day catches are far below those of the past. The old-fashioned schooner and handline fishing from dories produced 294,000,000 pounds of cod in 1880. Today with the addition of the latest and most efficient devices, the annual cod catch is about 85,000,000 pounds. Atlantic mackerel are still plentiful but have been subject to wide fluctuations, with large catches during the latter half of the nineteenth century, small ones during the first quarter of the twentieth century, and again in 1937. Since then the Atlantic catch has again increased. Weakfish (known as squeteague in southern New England) were formerly taken in quantity along the Massachusetts coast but finally lapsed into insignificance in New England, most of the catch now coming from the middle and south Atlantic states, particularly from Chesapeake Bay.

A favorite example of ruthless exploitation is the giant sturgeon of Chesapeake Bay which at one time was slaughtered indiscriminately for the roe, the bodies frequently being left to decay along the shore. Sturgeon are still taken occasionally but are in danger of extinction. New England is now marketing only one-half as much lobster as in 1890. Alarmed by the decline of this popular sea product, several of the New England states adopted severe size-limit laws and have begun artificial propagation by means of hatcheries. Runs of alewives are seriously curtailed because of overfishing and the many dams and other obstructions that hinder access to former spawning grounds. The shrimp situation is recognized as basically unsound, with too many small and immature shrimp being caught in certain Texas, Louisiana, and Florida waters. Intensity of shrimping has caused virtual extermination in some areas. Evidences of decline in abundance are presented by the Atlantic herring, red snapper in the Gulf of Mexico, oyster beds from Chesapeake Bay to the Carolinas, and the sponge grounds near Tarpon Springs, Florida.

Overfishing in the Great Lakes and Interior Rivers

Sturgeon, bluefin, and cisco (Lake Erie herring) are gradually disappearing from the fish markets of the lake cities. The U. S. Fish and Wildlife Service has published an impressive list of fish once plentiful in the Great Lakes which are declining, have become commercially insignificant, or are actually extinct. In every instance the reason is bad management, mainly overfishing and the use of destructive types of gear. Production of whitefish, once the recognized leader in the lake catch, has dropped steadily in recent years.

"The process of depletion has been gradual in most areas, but the stock in Lake Huron became virtually exterminated in the 1930's by overfishing with a new and ruinously efficient gear, the deep-trap net. This gear took whitefish in prodigious quantities from the offshore waters where they concentrate in summer. Unfortunately, its use was not prohibited until after the fishery of Lake Huron had reached a state of collapse."[2]

Concerning cisco, the same account says

"Up to 1924 this resource had supported a United States fishery producing 8 to 39 million pounds a year. Beginning about 1925 the total annual catch declined rapidly until in 1928 it was only 600,000 pounds; it has remained below a million pounds ever since. In 1938, when the catch went up to 810,000 pounds, it looked as though the cisco population might be recovering. But in the absence of any adequate effort to nurture this recovery the fishery quickly reduced the stock. Fishermen took 717,000 pounds in 1939, only 25,200 pounds in 1942."[3]

In an attempt at rehabilitation a two-year study of Great Lakes fisheries has been made by a joint Canadian-American board. Its report found that several species had reached low levels of abundance and recommended that regulations for their management be formulated and tested.

[2] Walford, *op. cit.*, p. 113.
[3] *Ibid.*

The interior lakes and rivers have also been overexploited. Valuable native game fish, such as the black bass, striped bass, perch, and crappie, have declined in the Mississippi. They have been replaced in quantity but not in quality by the sluggish and prolific German carp, introduced into American waters in 1877 and now caught by the millions of pounds.

FIG. 2. Razor clams are a valuable commercial fishery in Washington, Oregon, and Alaska. Dug by hand at low tide, they are dropped into a surf sack attached to the belt. Heavy inroads on the stock resulted in state regulation which now includes size limits, bag limits, an annual quota, and a curtailed season. (*Pacific Fisherman.*)

Declines in Pacific Coast Production

Fishing is of high importance in the regional economy of the Pacific states. Faced with a sharp decline in salmon runs and the possible extinction of the halibut resource, west coast interests have been quick to accept drastic remedial measures. Many less significant sea products are faced with similar declines. The lowered stock of razor clams has necessitated size limits, quotas, and restricted seasons (Fig. 2). Abalone, spiny lobster, shrimp, yellowtail, and white sea bass, to mention only a few, have become problem fisheries subject to varying degrees of regulation.

Biologists for some time have been concerned about the intensity of sardine fishing in California waters. During 1946 and 1947 this hitherto reliable fish failed to appear in its usual enormous numbers in the Monterey and San Francisco Bay district. Alarmed by the disappearance of sardines, the industry asked the state legislature for greatly increased appropriations to study the problem.

Space will permit a detailed discussion of conservation problems for only a few selected fisheries. Information concerning many important commercial types is available in *Fishery Resources of the United States of America,* published by the Fish and Wildlife Service. This comprehensive study is actually an atlas of all important American fish.

SHAD OF THE ATLANTIC SEABOARD

The Spring Run

The increasing pressure upon fish abundance is particularly noticeable in a study of the Atlantic shad. This highly popular market fish has been caught in nearly every river along the Atlantic littoral from Florida to Newfoundland, but it is most abundant from the Carolinas to Long Island. In colonial days Chesapeake Bay and the rivers tributary to it had enormous runs every spring. The early settlers along the Delaware and the Hudson also caught shad by the thousands, and throughout the middle Atlantic states it held approximately the same place in public esteem that cod enjoyed in New England.

Like the salmon, the shad is anadromous, with a life cycle that includes both salt and fresh water. Fingerlings hatched in Atlantic rivers spend their first summer in fresh water, attain a size of three to five inches, and then migrate to the ocean. Little information is available concerning their oceanic feeding grounds, as they are seldom taken in deep water even by trawls. After spending three to five years in the sea adult shad return to the parent stream to spawn.

Causes of Decline

So severe were the inroads upon the shad population that as early as 1860 there was a marked decline in the catch. Seines and gill nets in Chesapeake Bay at the mouths of the Potomac and other tributaries sometimes cut off entire runs, so that the level of replacement dropped sharply. Millions of fry were destroyed by sewage and industrial wastes. Power dams cut off many spawning waters, fishways proving of limited efficacy. Hatcheries began artificial propagation in the latter part of the nineteenth century, planting millions of larvae in streams where runs had been decimated, but the decline continued. The catch of 50,000,000 pounds in 1900 has dropped to an average of 9,000,000 pounds with resultant higher prices for shad and the ever popular shad roe.

Remedial Measures

Rehabilitation of the shad is still a controversial question along the Atlantic seaboard. Fishery experts believe that data on the life history of shad are now adequate and that regulation to ensure a larger spawning escapement is the most practical approach to the problem.

"Shad runs can be increased, as has been demonstrated in the Hudson River since 1935. There, by the simple expedient of fishing shad at a moderate instead of an excessive rate, enough spawning adults have been spared to rebuild the runs by natural reproduction. In 1944 Hudson River fishermen took less than 40 per cent of the run, yet they caught more pounds of shad than at any previous time when fishing rates were much higher." [4]

The results attained in New York could be duplicated by other shad-fishing states. Maryland has likewise adopted measures to reduce overexploitation, but in many of the Atlantic states the traditional attitude still prevails—give the fisherman a free hand to fish as he pleases. State legislatures are reluctant to pass laws firm enough to be effective. All interests agree, however, that the shad supply is too low and that a way

[4] *Ibid.*, p. 3.

should be found to raise production and stabilize it at three or four times the present level.

THE SALMON OF THE NORTH PACIFIC

The Annual Salmon Run

Every spring and summer the rivers of the Pacific, from California to the Bering Sea, are the scene of one of the world's most spectacular fish runs. Millions of salmon appear at the river mouths, swarm across the bars, and move steadily upstream. Rapids and waterfalls are no deterrent. Driven by the spawning urge, salmon dart through swift water and around great boulders, leaping falls of considerable height. A long run of a thousand miles up the Columbia to the headwaters of the Salmon River in Idaho generally begins in March or April. The short runs of Vancouver Island, where the spawning beds may be only a few hours from salt water, may not begin until late in the autumn. The salmon finally reach the original stream or lake where they were hatched several years before. Scooping out a shallow nest they deposit and fertilize the eggs, then cover them with a layer of protecting gravel. Pacific salmon take no food after leaving salt water. Spent by the journey and the final act of reproduction, the parents lie quietly in eddies and die within a short time.

The eggs generally hatch in about two months, the fry emerging from the gravel in the spring. Depending upon species the young salmon remain several months, sometimes as long as three years, in fresh water before beginning their trip to the ocean. The salt-water phase of their life cycle lasts from two to six years, again depending upon the variety of salmon. Over 95 per cent of their growth is made in the sea, but their marine feeding grounds are not definitely known. Coho and Chinook salmon have been taken by trawls at depths as great as 90 fathoms. Chinook from the Columbia have been tagged off the Queen Charlotte Islands and later recovered in the Columbia again, and other varieties migrate long distances through the passages of southeastern Alaska.

The Salmon Pack

When adult salmon reach the coasts prior to the annual spawning run, they are in prime condition. Packing plants are located from northern California to western Alaska, usually near river mouths. By means of traps, purse seines, and gill nets the fish are caught by thousands and taken to canneries where machinery now does most of the work. The average annual salmon pack for the United States and Alaska over a period of twenty-five years, 1918 to 1942, usually exceeded 6,000,000 cases (48 pounds to the case), but production declined to 5,000,000 cases after 1946. In addition to canned salmon several million pounds are marketed fresh or quick-frozen, smoked, and mild-cured.

Species of Salmon

Five species of salmon are found in Pacific waters. Sockeye or red salmon, weighing from four to 10 pounds, have long been the favorite. An ideal cannery fish from the standpoint of size and color, the sockeye formerly provided most of the American pack and still accounts for over one-quarter of the take. The great Chinook or king salmon, averaging over 20 pounds and sometimes weighing up to 100, are sold fresh as well as canned. Coho or silver are less popular for canning because of their lighter-colored flesh. Humpback or pink

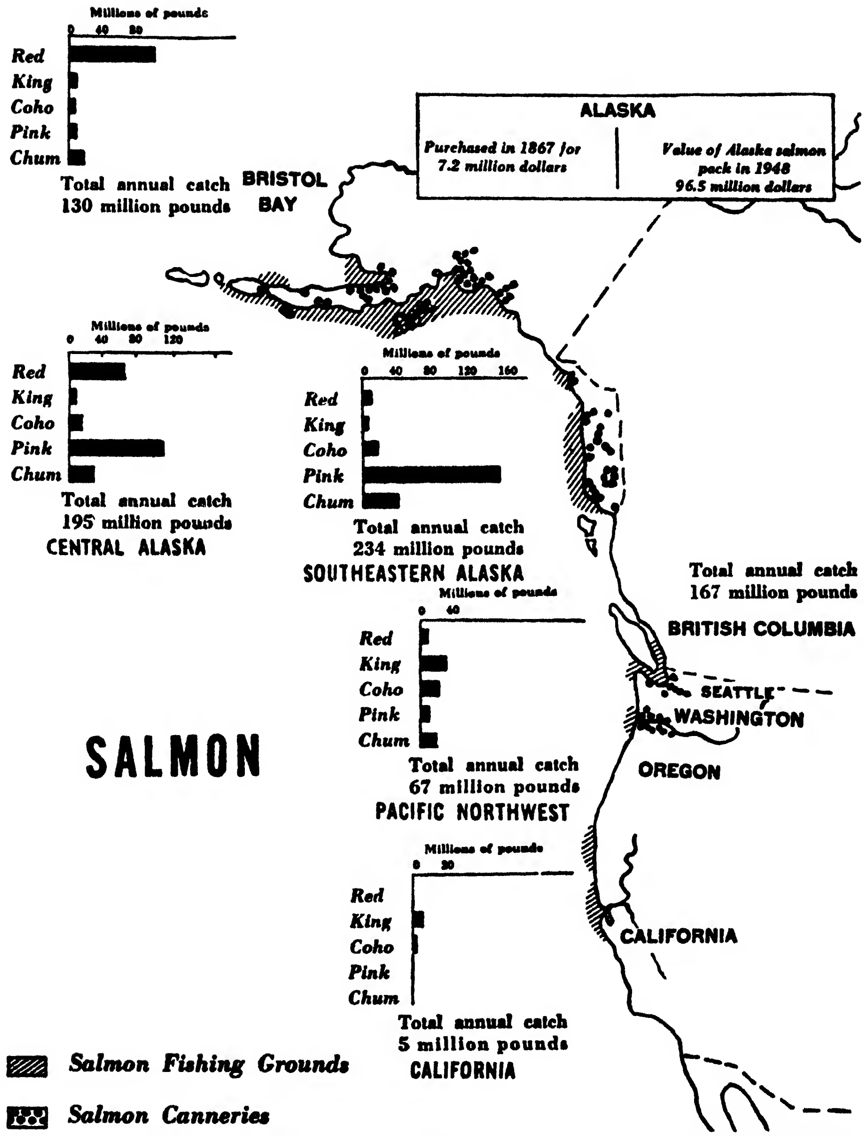

Fig. 3. The salmon pack of the Pacific coast and tributary streams. (*Pacific Fisherman.*)

salmon, weighing three to five pounds, are the most plentiful, particularly in southeastern Alaska where they are caught in great numbers, and now provide approximately one-half of the pack. Chum or keta, light in color and formerly regarded as inferior, are also a standard cannery item. Steelhead trout are frequently caught and sold as salmon.

Decline of West Coast Salmon Runs

Salmon canning began on the Sacramento River in 1864. The runs at that time were excellent, and the pack increased to 200,000 cases in 1882, then dropped steadily until it disappeared. The decline was caused, first, by overfishing to the point where the adult escapement was insufficient to replenish the stock and, second, by the obstruction of rivers by power and irrigation dams. The Sacramento and the San Joaquin are now insignificant as salmon streams.

Salmon canning along the small coastal rivers of northern California, Oregon, and Washington reached a peak of about 250,000 cases in 1911; the 1949 pack in the same areas was 19,000 cases. The Columbia River, a steady producer for over sixty years, reached its maximum of 634,000 cases in 1895. Since then the teeming sockeye runs in the Columbia have shrunk to a fraction of their former size. Canning has held up fairly well through the substitution of other varieties, especially the Chinook, but the present average production of 250,000 cases is only about one-half of that of the 1920's. The Puget Sound area, with the richest salmon waters within the United States, has had an even more drastic decrease. Salmon canning started here in 1877 and reached its maximum in 1913 with 2,500,000 cases. Minimum output for a 52-year period occurred in 1944 with 38,950 cases, but the annual average pack, 1945–1949, was over 500,000 cases, pinks and churns predominating.

The steady decline of salmon in the United States was offset by the rapid rise of Alaskan fishing, which was more than sufficient to keep up the total supply (Fig. 3).

THE ALASKAN SALMON FISHERIES

Growth of the Canning Industry

The salmon fisheries of Alaska located along 10,000 miles of coast line, are one of the richest natural resources of the North Pacific. They have an average fresh-fish value of $15,000,000 to $18,000,000 annually; the bulk of the catch is packed and is then valued at approximately $45,000,000.

The first salmon cannery in the far north was established on Prince of Wales Island in 1878, and by 1888 the Alaska pack exceeded that of the Columbia River. More and more canneries were established in the north to take advantage of the seemingly inexhaustible supply, the industry finally reaching a peak of 6,677,000 cases in 1918 under the stimulus of wartime prices. During the ensuing decade the pack dropped to an average of 4,500,000 cases per year, then began to increase reaching an all-time peak of 8,454,000 cases in 1936, decreasing gradually to about 4,400,000 cases in 1949.

Decrease in Abundance

In its early years this industry was almost entirely unregulated, and cut-throat competition was rife among canners operating in the northern territory. The legislation enacted by Congress in 1906 for the protection of Alaskan salmon was not effective. Certain streams were blocked so completely by traps that virtually no fish reached the spawning beds. After a few years of heavy packs and scant returns of young salmon, the runs stopped and canneries had to be abandoned. There was also a decrease in many other rivers, and apprehension was felt lest the profitable Alaskan fisheries might gradually follow the Atlantic salmon industry into oblivion.

Government Regulation Adopted

Behind the scenes there was for many years a struggle between interests in favor of unrestrained operations and fishery experts who pointed out the necessity of restriction if the industry was to be preserved. The proponents of stronger regulatory measures were, as usual, accused of "trying to lock up the resources of Alaska." After three years of controversy the White Act was passed by Congress in 1924. Under this new act the Bureau of Fisheries was given supervisory and enforcement powers over all fishing in the northern territory. The most important feature of the bill provided for at least a 50 per cent escapement of all salmon entering the rivers to spawn; thus no cannery was permitted to take more than half of any salmon run.

Management of Depleted Areas

Since salmon, with few exceptions, return to the home stream, each of the Alaskan rivers is now managed as a separate area. The Fish and Wildlife Service has discretionary powers, so that a badly depleted area may be closed for a term of years and the regulations relaxed when the run again approaches normal. For instance, under this provision the regulations for 1934 provided for the closure of 93 fish-trap sites, at the same time opening a number of previously closed fishing grounds to seines and other forms of gear. Despite the seemingly drastic character of these restrictions, the 1934 pack exceeded that of 1933 by 2,000,000 cases.

One of the problem areas has been the red (sockeye) salmon waters of Bristol Bay, one of the most valuable fisheries in Alaska. The Bristol Bay sockeye matures in a five-year cycle, and there was a steady decline in the 1920, 1925, and 1930 runs, although other years remained close to normal. In order to give this particular cycle a chance to rebuild, red salmon canning in Bristol Bay was sharply restricted in 1935 on the supposition that a large spawning escapement would restore this run. The hope was realized in part, and larger packs were permitted both in 1940 and in 1945; this particular cycle has apparently been stabilized. As a further measure of conservation in this area, traps were prohibited in favor of gill nets.

General Supervision and Scientific Control

The service has authority to regulate types of gear and the location of traps and also collects data on general conditions in each area. Humpback or pink salmon supply one-half of the annual Alaskan pack, but little information was available on the life history of this prolific fish. Biologists verified the fact that it matures in a two-year cycle and collected other data concerning its life history so that regulation could be put on a scientific basis. Patrol vessels prevent poachers from invading forbidden waters.

Under these wisely flexible regulations, the Alaskan salmon fishery has been stabilized at a profitable level, and with a minimum of interference with individual fishing rights. Although it is difficult to satisfy all interests, regulation has met with general approval. However, the gradual decrease in the salmon pack since the high year of 1936 may require sharper regulatory measures in the near futue.

SALMON PROBLEMS IN CANADA AND THE UNITED STATES

Puget Sound and the Fraser River

Although the Alaskan salmon situation improved steadily after 1924, the Puget Sound catch showed an alarming decrease to one-third of what was formerly regarded as the normal supply. All species of salmon are caught in the Sound, but the sockeye is rightly regarded as the most important to the canning industry. The sockeye entering Puget Sound are generally regarded as migrants on their way to the Fraser River basin of British Columbia, which is exceptionally well supplied with suitable spawning lakes and headwaters. Poor spawning in the upper Fraser is inevitably reflected in a poor pack four years later. in both Canadian and American canneries. On their way through Puget Sound to the Fraser the sockeye were exposed to an array of cannery traps, to numerous purse seiners clustered around the entrance to the straits of Juan de Fuca and the Gulf of Georgia, and to gill netters in the mouth of the Fraser.

Since both Canada and the United States had a vital stake in the imperiled Fraser runs, a treaty was proposed in 1907; it provided for a joint commission to investigate the problem and recommend legislation. The measure, passed by the Canadian Parliament, was defeated in the United States Senate. During the ensuing thirty years two similar treaties were approved by Canada but held up by certain American interests, while intensive fishing continued and the Fraser River-Puget Sound sockeye pack sank to new low levels.

International Sockeye Salmon Treaty

It was not until 1937 that a revised treaty was finally ratified by both countries. By this time ruthless overfishing and poor escapement had reduced sockeye runs to a point where drastic rehabilitation was necessary. The treaty provided for the creation of the International Pacific Salmon Fisheries Commission, with three representatives from each country.

"The Commission is empowered to investigate the natural history of the sockeye salmon of the Fraser River, hatchery methods, spawning ground conditions and related matters. It may conduct fish cultural operations, improve spawning grounds or stock the Fraser with sockeye by such methods as it may deem advisable and recommend removal of obstructions to migration. It is empowered to limit or prohibit the taking of sockeye in Convention waters. · · · Only such fishing gear may be used in any open season as the Commission may approve. The catch of sockeye shall be distributed as equally between the two countries as is practicable." [5]

Canada agreed to make the entire Fraser basin available for restoration and propagation, the cost to be borne jointly. The research staff of the commission began its investigation in 1938 and studied the sockeye salmon through two complete cycles lasting eight years. With the data obtained the commission drew up the necessary measures for control.

[5] International Pacific Salmon Fisheries Commission, *Annual Report,* 1945, p. 3.

Fluctuation in the Sockeye Salmon Runs

Both the American and the Canadian pack of Fraser-spawned sockeye was for many years dependent on a "big year" cycle, i.e., 1901–1905–1909–1913, and three lesser runs in the intermediate years (Fig. 4). In the "big year" both the pack and the spawning escapement were enormous. There was a tendency toward overfishing in the leaner years. Tomasevich says: "A mistake made in the exploitation of the sockeye salmon fishery of the Fraser River system ··· was the exploitation of the 'off year' runs with the same (or greater) intensity as those of the 'big year.' The consequence was the overfishing of these runs instead of letting more spawning fish escape with a view to gradually building up these runs in the end, possibly to the level of the big-year runs." [6]

Rockslide at Hell's Gate

During the building of a railroad through the Fraser River canyon in 1913 a rockslide was dumped into the river at Hell's Gate (Fig. 5). The stoppage was so complete that most of the sockeye escapement of that year was cut off from the spawning lakes and streams of the upper Fraser basin and perished below the blockade. As a resuit, the sockeye pack of 1917 dropped to 500,000 cases. With a poor adult escapement

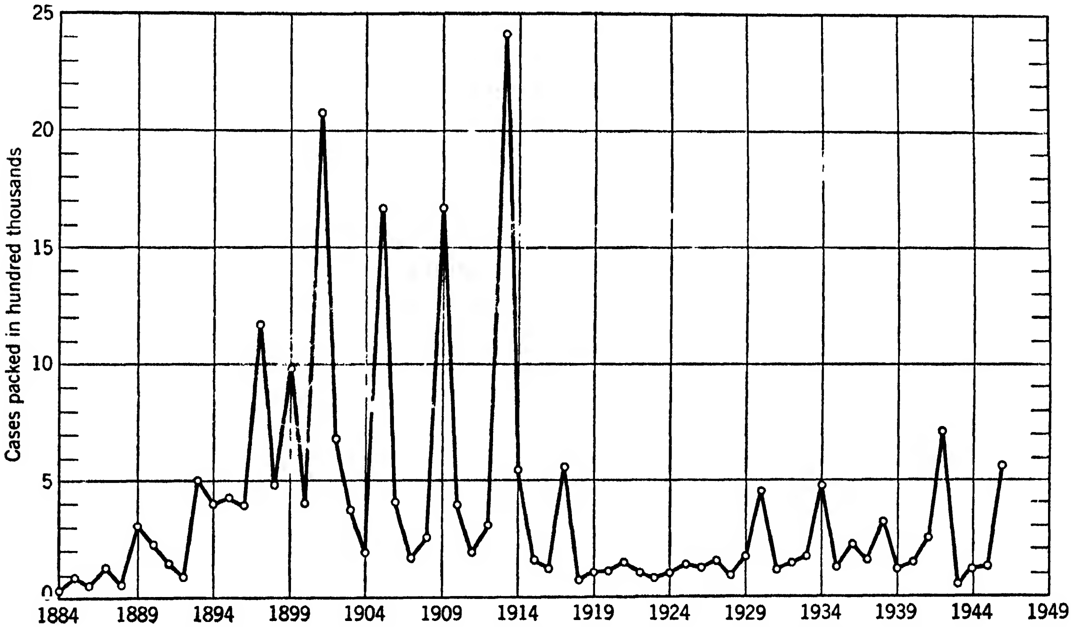

FIG. 4. Pack of sockeye salmon, spawned in the Fraser River system. Fraser sockeye mature in a four-year cycle; prior to 1914 the 1897–1901–1905–1909–1913 runs made Puget Sound one of the world's richest fishing grounds. The average pack for 1894–1913 was 755,000 cases annually. The "big-year" run vanished after the disastrous rock slide at Hell's Gate. All other runs also declined, the average pack for 1927–46 being 240,000 cases. The best producing cycle at present is 1930–1931–1938–1942–1946. This graph illustrates the mismanagement of a rich resource. (International Pacific Salmon Fisheries Commission.)

[6] Jozo Tomasevich, *International Agreements on Conservation of Marine Resources*, p. 239.

that year, the "big" run was a thing of the past. All years were now "off years."

Attempted removal of the rockslide in 1914 was only partially successful. At certain water levels some of the runs, particularly those of the late fall, got through Hell's Gate each year. During times of heavy runoff, the remnants of the rockslide plus the velocity and turbulence of the torrent caused great damage to spawners. An estimated 65 per cent of the 1941 sockeye were lost below the narrows during a critical water stage which lasted 60 days.

Fishways for a Larger Escapement

Concluding that the Hell's Gate blockade should be regarded as a permanent obstacle, the commission decided on a permanent remedy—concrete fishways on both sides of the canyon. Begun in 1943, the first pass was ready for the 1945 run, and both were in operation the following season (Fig. 6). Success was immediate. For the first time since 1913 salmon in maximum numbers were able to reach the spawning beds of the upper Fraser and Lake Quesnal. The escapement in 1945 and 1946 was approximately four times as large as in the previous cycle years of 1941 and 1942. In addition, sockeye were arriving at the spawning grounds in better physical condition.

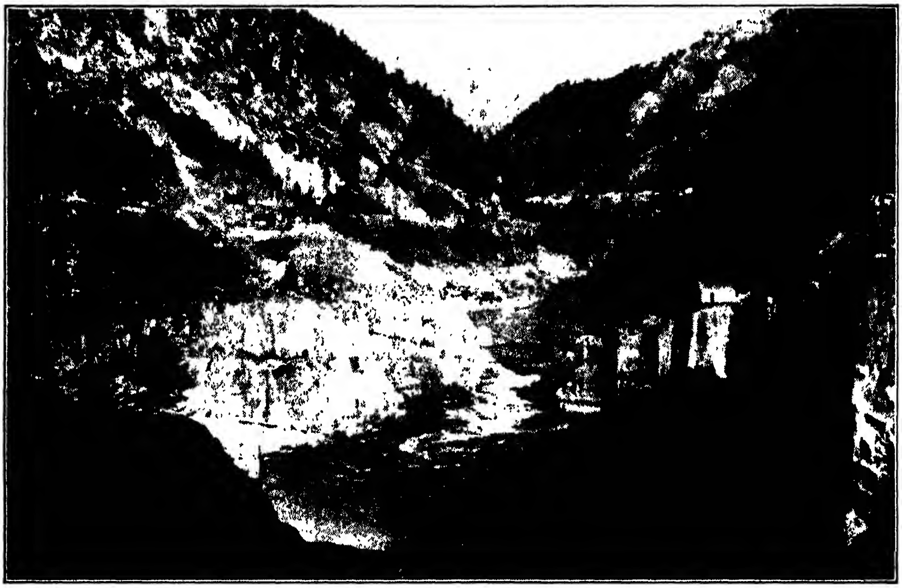

FIG. 5. Hell's Gate in the Fraser River canyon, where a constricted channel was further blocked by a rock slide. From 1913 to 1945 the spring sockeye runs to spawning beds in the upper Fraser lake system were almost destroyed, and the fall runs greatly reduced. (International Pacific Salmon Fisheries Commission.)

"As the loss of fish since the original catastrophe could be valued at half a billion dollars, these results in two successive years contributing toward a restoration of a great run are obviously of great financial value." [7]

[7] W. F. Thompson, 12th North American Wild Life Conference, San Antonio, Texas, February 5, 1947.

The commission is planning additional fishways particularly at Bridge River Rapids. Formerly productive lakes and streams where salmon are practically extinct will need to be restocked by fingerlings reared in hatcheries. Many years of carefully restricted catches and generous spawning escapements will obviously be part of the rehabilitation plan in Convention waters.

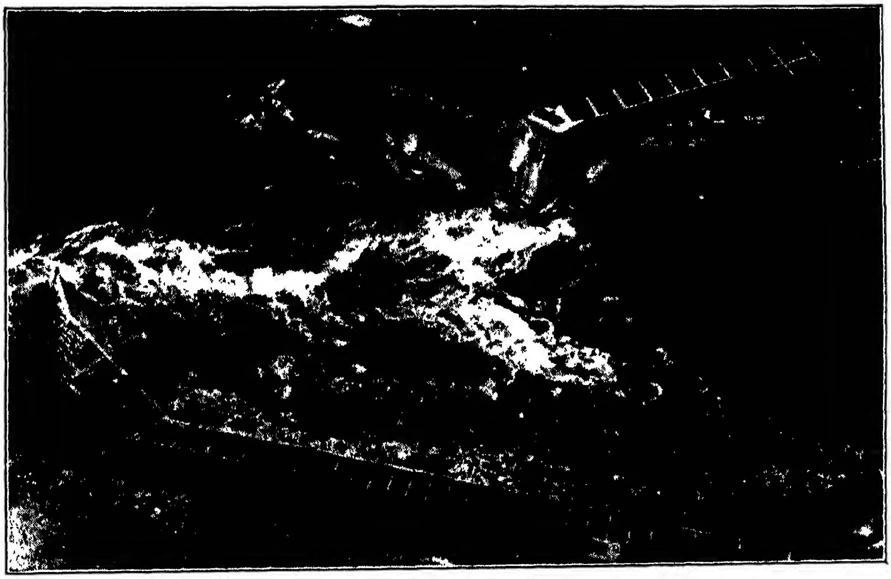

FIG. 6. Two fishways nearing completion during the low-water period at Hell's Gate. These ways will facilitate passage through the narrows at all stages of the river. The year construction began, 1943, the pack of Fraser-spawned salmon sank to 51,000 cases, the lowest figure in 50 years. (International Pacific Salmon Fisheries Commission.)

The ultimate objective is a steadily augmented return of adult salmon until all runs have been rebuilt to profitable size. Under proper management the Fraser system might easily become the world's most productive salmon river.

Conflict of Interests—Power Dams on the Columbia

According to the Department of Fisheries, State of Washington,

"The fishery in the Columbia River has been decreasing slowly since the turn of the century. The constant inroads of civilization have continually worked to the detriment of the fish populations. First irrigation diversions, then small hydroelectric dams on several tributaries, then more and larger irrigation diversions, over-fishing by the commercial interests, increase in sport fishing, gaffing of fish on the spawning grounds and increasing industrial and domestic pollution bringing pressure constantly against the fish populations, have slowly decreased their former abundance."

Included in the future problem of salmon conservation on the Columbia are two gigantic dams, Bonneville and Grand Coulee, each of them higher than any obstacle previously surmounted by anadromous fish. The 30-foot Rock Island dam on the middle

Columbia is equipped with three fish ladders which have provided passage for salmon on their way to the spawning grounds. The 55-foot Bonneville dam on the lower Columbia has an elaborate system of fish ladders, also elevators by which salmon can be lifted over the top into quiet water. (Passes have been constructed so that fingerlings on their way to the sea can reach the lower side of the dam safely.) First placed in operation in 1938, the Bonneville fishways have proved completely successful, spawning salmon having the usual access to tributary waters, including the entire Snake River system.

The 550-foot Grand Coulee dam on the middle Columbia, however, is an impassable obstacle. Since it is economically impracticable to convey fish over a barrier of this height, salmon runs are completely blocked at this point. It is estimated that 1100 linear miles of salmon streams in the upper Columbia basin of Washington, Idaho, and British Columbia were lost as spawning grounds. To counteract the effect of this reduction a large federal hatchery with acres of rearing pools was built at Leavenworth, Washington. Adult salmon on their return journey to the upper Columbia were intercepted at Rock Island dam, stripped of their eggs, and the eggs were fertilized. Fingerlings reared in the hatchery pools were taken by tank truck to suitable planting areas in understocked rivers such as the Wenatchee, Entiat, Okanogan, and Methow, streams tributary to the Columbia below Grand Coulee dam. The young salmon thus artificially propagated and planted in new home streams joined the down-river migration to salt water, later returning as adults to the parent stream to spawn naturally. By careful management augmented runs are being built up in various middle Columbia tributaries, and artificial propagation has become a permanent part of the effort to sustain spawning stocks.

CONSERVATION OF PACIFIC HALIBUT

One of the most popular food fishes in America is the halibut, found in both the North Atlantic and the North Pacific. This great deep-sea flounder, dark on its upper or right side, white on the left or under side, early became one of the staples of the Atlantic coast fish trade. It was not until some sixty years ago, however, after the inauguration of fast transcontinental rail service between Puget Sound and eastern United States, that Pacific halibut began to reach the market in quantity. Once landed to the extent of 14,000,000 pounds per year, Atlantic halibut has been heavily overfished and has decreased to about 1,000,000 pounds annually. In the United States the ratio of Pacific to Atlantic halibut is now approximately 40 to one.

The Pacific Halibut Catch

The Pacific halibut banks follow the continental shelf from northern California to the Bering Sea. Halibut are caught on long bottom lines on which are strung a series of shorter lines baited with herring; a unit of gear of this sort, called a "skate," is usually set at depths varying from 35 to 200 fathoms. The larger and better-equipped vessels with considerable cruising radius operate in the Gulf of Alaska and along the Alaska peninsula. The industry is in the hands of American and Canadian fishermen, with Seattle, Vancouver, Prince Rupert, and Ketchikan as the principal base ports and shipping centers; fishing boats from Petersburg, Juneau, and Sitka take part. Cleaned, iced, and landed at one of the northwest ports, halibut reach United States markets fresh or frozen; canning is relatively unimportant.

The halibut lives to an age of more than 25 years and generally weighs 5 to 200 pounds. Every season a few giants are taken that weigh 250 to 350 pounds. During the period of abundance in the early 1900's most of the fishing was done off the coast of British Columbia and southeastern Alaska, within a radius of about 500 miles from Seattle and Vancouver, B. C. Gradually, as the numbers declined within this area vessels pushed farther to the north and west, returning with even larger cargoes of fish. Peak production was reached in 1915 when the total catch was 63,254,000 pounds. Any catch between 50,000,000 and 60,000,000 pounds was considered normal, and in order to maintain this figure both Americans and Canadians went to more and more distant grounds.

Concealed Depletion

Production figures may give no indication of impending depletion until after much of the damage has been done. This is especially true of demersal fish which have a long life cycle and late maturity. Salmon mature in two to five years, depending upon the species, but most female halibut do not arrive at the spawning stage until 12 to 16 years old; about half of them mature by 12 years, and only a small proportion as early as 8 to 10 years. Depletion therefore may be even more insidious than in a salmon run, where the actual shortage of spawners will appear sooner.

Evidence of Depletion

For many years the decline of halibut in the North Pacific was partially concealed by the fact that as an area was depleted the fishermen widened their radius of operations and still managed to bring in the usual poundage. Little was known about actual sea-bottom conditions, many fishermen contending that there was still an abundance, but that halibut migrated from one bank to another and that it was necessary to shift fishing operations to follow them. Finally the limits of lateral expansion were reached, and, with a greatly increased fishing fleet at work, three definite evidences of depletion began to appear.

1. Despite increased fishing the annual catch was declining on the southern grounds, which had been worked longest and hardest.

2. The proportion of mature fish brought to market was decreasing, a larger share of each catch consisting of "chicken" or small, immature halibut.

3. The catch per skate or unit of gear had declined and was continuing to decline at an alarming rate. The average catch per skate in 1906 was 250 pounds, but in 1930 it had dropped to 35 pounds per unit of gear.

The International Fisheries Commission

Though the normal amount of fish continued to reach the market, the industry became concerned. Fishery experts pointed out the basic unsoundness of the situation and the possibility that the Pacific banks were faced with a decline similar to that of the Atlantic. The authorities, both in the United States and in Canada, were convinced that this situation could not continue indefinitely without destroying the Pacific halibut fisheries or at least reducing them to insignificance.

Accordingly, the International Fisheries Commission was appointed in 1924 with a membership of two Americans and two Canadians and was given authority to investigate and recommend halibut conservation measures. A staff of scientists headed by Dr. W. F. Thompson began the necessary biologic and economic research. In 1925 and thereafter comprehensive surveys of the banks were made, using chartered fishing vessels. Thousands of fish were caught, measured, tagged with a metal clip on the cheek, and returned to the water. By offering a bounty for each tagged fish caught, they obtained recoveries and information on as high as 40 per cent of the fish released. It was ascertained that there were distinct populations of halibut each living, spawning, and dying within its own area of the coasts with little migration between areas. Hence it is difficult for a depleted area to be restocked from an adjoining one. Artificial propagation of deep sea fish such as halibut is impracticable; it is also impossible to control the food supply or enemies of the fish. Each stock must be managed so that the catch from it will be fully balanced by natural propagation and growth.

Life History of the Halibut

Considerable difficulty is involved in securing accurate data concerning spawning habits and early growth of any demersal fish. Consequently little was known in 1927 about the first stages of development of either the Atlantic or the Pacific halibut. Despite the fact that depletion had already gone far on the Atlantic banks, no attempt had been made to investigate the younger stages of the halibut's cycle. In order to obtain a complete life history of the Pacific halibut, the commission research staff spent several winters in the Gulf of Alaska and off the Alaska peninsula where mature halibut were most plentiful.

The mature fish gather in schools to spawn along the edge of the continental shelf during the winter season, December to March. By the use of fine-meshed silk plankton nets, this North Pacific expedition took numbers of large translucent halibut eggs and also of baby halibut. The free-floating eggs are deposited in 150 to 200 fathoms of water; after hatching, the larvae gradually rise to moderate depths and drift with the currents. In late spring the tiny halibut move toward shore and settle to the bottom in relatively shallow water where they spend the early part of their life cycle. Later the small adult fish move out to depths of 50 to 100 fathoms. Halibut usually spend their entire life before maturity in or near one bank but move about freely within their particular area after reaching maturity.

These biologic data concerning habitat, spawning, and rate of growth were later correlated with other data, particularly those of ocean currents, and by 1930 it was possible to present a fairly comprehensive life history of the Pacific halibut. With the commercial information already in hand, it was possible to make recommendations for control and restoration.

Regulatory Measures Applied by the Commission

The 1923 treaty established a closed winter spawning season and provided for investigation. A new treaty giving the International Fisheries Commission authority to regulate the halibut fisheries was signed by Canada and the United States in 1930.[8] The main regulatory measures applied to the industry include:

1. The division of the fishing grounds into four areas which may be regulated

[8] A third treaty giving the commission somewhat broader powers was ratified by both countries in 1937.

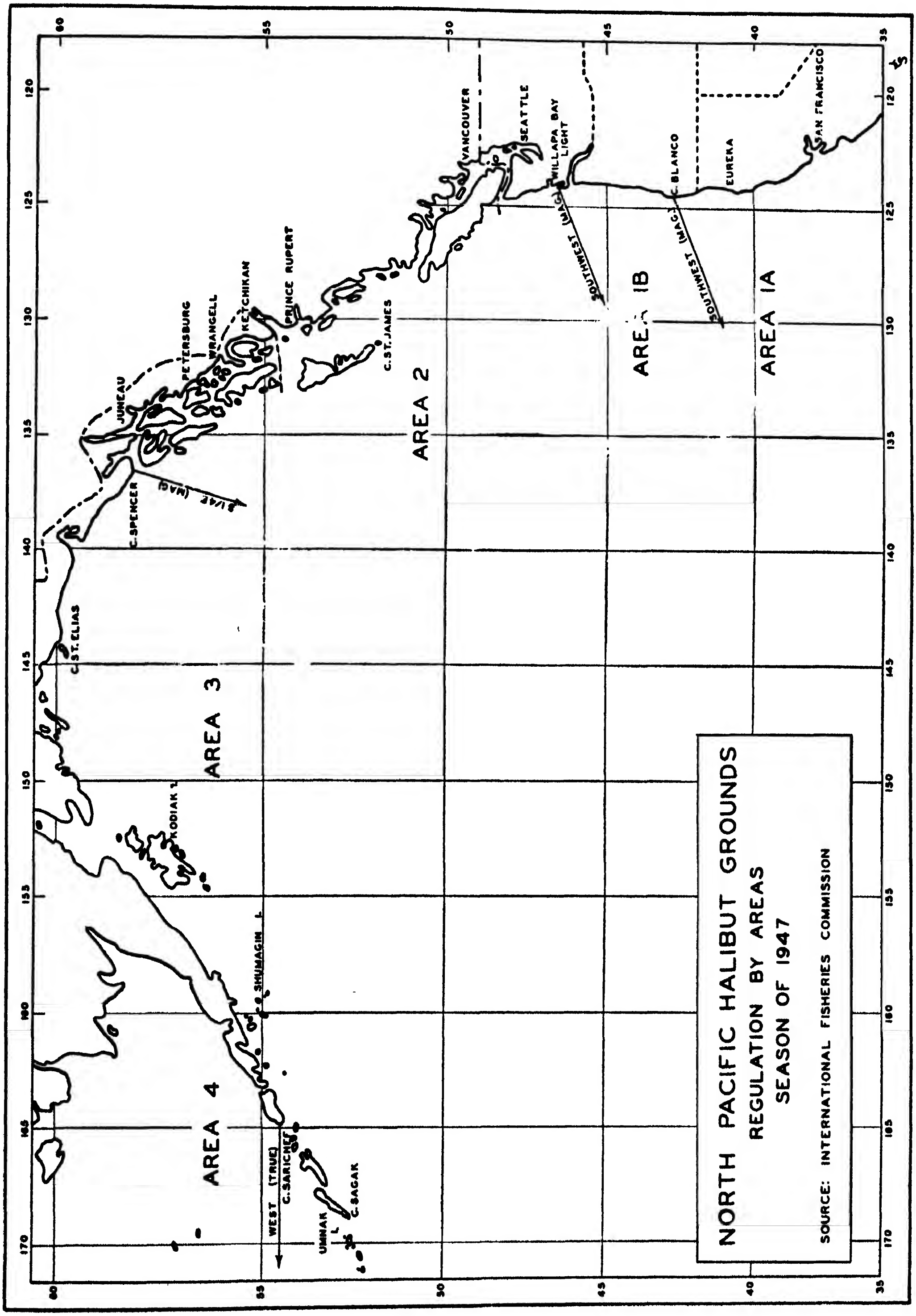

FIG. 7. The halibut banks of the North Pacific are divided into five areas. Catch limits are applied in Areas 2 and 3 which provide over 98 per cent of the catch at present.

separately. In 1946 these were increased to five (Fig. 7).

2. The application of annual catch limits which may be raised or lowered at the discretion of the commission. Originally set at 46,000,000 pounds (dressed, heads-off weight), the limits have been gradually increased. Landings in 1949 from all Pacific areas totaled 55,379,000 pounds, two-thirds of which was American and one-third Canadian.

3. The closure of each important area when the catch limit specified for it has been taken. In 1932, the first year of regulation, the fishing season lasted a full nine months until the winter closed season intervened. In 1949, the catch limit for Area 2 was reached in 34 days and for Area 3 in about 75 days.

4. The creation of certain nursery areas where fishing is entirely prohibited. These areas serve much the same purpose as wildlife refuges.

Campaign of Education

In exercising its new enforcement powers the commission held numerous public hearings open to all who were interested—fishermen, large and small boat owners, and the wholesalers who handle the shipment of fresh and frozen fish. The research staff assisted the commission in a campaign of education, demonstrating the facts of depletion by means of maps, charts, and graphs, and stressing the need for regulation and restoration of the fishery to its former position, with as little restriction of individual fishing rights as possible. A certain amount of opposition by the fishermen, at the beginning of regulation, gradually declined as rehabilitation went on.

The restrictions adopted were so successful that by 1933 the United States Fish and Wildlife Service stated in its annual report:

"The practicability of the commission's regulations involving division of the convention waters into areas, limiting the catch from each area, licensing of vessels for the halibut fishery, collection of statistics of abundance and locality of capture, modification of the closed season, and closing of nursery grounds has been satisfactorily proved."

Return to a High Level of Abundance

As a result of more than twenty years of concerted effort, halibut is now regarded as the best example of successful management of a major underwater resource. Discussing U. S. fisheries in general, the Fish and Wildlife Service reported in 1945:

"There is only one example of a fishery resource that has been successfully studied and conserved over most of its range; that is the Pacific halibut, administered by the International Fisheries Commission since 1930. This is the only fishery conservation agency that has come even close to being adequately supported in money and personnel." [9]

The industry has also indicated its approval of halibut rehabilitation and regulation. The *Pacific Fisherman* states:

"More fish with less fishing. In five words that tells the story of the 1946 North Pacific halibut season. Halibut production of the North Pacific banks passed the 60-million-pound mark. The catch was the largest taken in any year since 1915, and it was caught in the shortest season in the history of the fishery." [10]

Today few halibut fishermen would care

[9] The Fish and Wildlife Service, *Fishery Resources of the United States of America,* 1945, p. 131.

[10] *Pacific Fisherman, Yearbook,* 1947, p. 227.

to return to the cut-throat competition of the 1920's. Production stabilized at a high level gives them immediate profits as well as an assured future.

Reviewing results to date, Henry A. Dunlop, Director of Investigations of the International Fisheries Commission, said in an interview:

"Regulation by the Commission has brought about remarkable changes in the halibut fishery. The abundance is twice as great as it was in 1931, the year before regulation began; annual catches are 12,000,000 to 15,000,000 pounds greater; and these larger catches are taken with one-third less fishing effort. Rehabilitation is well under way.

"The Commission's future objective is to increase the supply of halibut to the point where the maximum permanent yield will be secured. This will require continued regulation, guided by scientific study. Any relaxation of control would immediately result in overfishing, producing a few highly productive years but returning the fishery to its earlier unprofitable condition."

PELAGIC SEALING

Seal Herds of the Pribilof Islands

Like the whale the Alaska seal (in reality a sea lion) has long been a problem in conservation. The rocky Pribilof Islands of the Bering Sea are the largest seal rookery in the world. In winter the seals swim far south in the ocean, returning in early summer to their home grounds where the pups are born. Seal skins have long brought high prices and from 1880 to 1911 seal hunters of all nations congregated around the Pribilofs to indulge in indiscriminate killing. There was grave danger that the herd would be exterminated. After an unsuccessful attempt in the early 1890's to have the Bering Sea recognized as a closed area subject to its sole jurisdiction, the United States in 1911 negotiated a treaty with Great Britain, Russia, and Japan. This agreement, the North Pacific Sealing Convention, which prohibited pelagic sealing was signed just in time the herd having been reduced from an estimated 3,000,000 to a scant [illegible]50,000.

Control and Restoration

United States control includes both protection and scientific management. Coast Guard cutters accompany the herd on its annual migration. Since seals are polygamous and sexes are born in equal numbers, a large proportion of the bachelor seals are surplus and can be killed without impairing the natural increase. Three-year-old bachelors provide the bulk of the 55,000 or more skins taken annually. The carcasses are made into meal and oil, and some are fed to blue foxes, which supply about 2000 skins per year. The entire "take" is worth some $1,500,000 annually, the other signatory nations sharing in the profits. Under this sensible system of control by international agreement the seal herd in 1947 had regained its original size of 3,000,000.

Claiming that the seals injured her fisheries, Japan denounced the sealing treaty in 1941. After 1942, pending the negotiation of a new treaty, sealing operations were carried on by the United States and Canada under a provisional agreement.

THE WHALING INDUSTRY

Shift in Whaling Centers

Another type of marine life, the whale, is also in need of protection from too efficient methods. The great deep-sea mammal has been pursued so ruthlessly for more than a century that a reliable estimate of the whale population is less than 350,000, a mere remnant of the hordes which once frequented the seas.

The shift of whaling centers—from Norway and Iceland to the shores of New England, thence to the North Pacific with headquarters in the Hawaiian Islands, and finally south to New Zealand, the Falkland Islands, and the Antarctic—provides an interesting study in the progressive exhaustion of a world resource. Active whaling long ago disappeared from the North Atlantic and is now only a minor activity in the North Pacific.

Factory Ships in the Antarctic

The most active center of present-day whaling is in the Antarctic waters, particularly around Ross Sea. Most of the world's whaling is now done in this area, where the cold waters are especially rich in the tiny crustacea and other minute sea organisms which make up the food supply of whales. During the short Antarctic summer, November to February, the great mammals feed along the edges of the southern ice floes and have attracted the modern whaling fleets of several fishing nations, especially Norway and Great Britain.

Large steel vessels, powerful enough to plow their way through pack ice, have been turned into veritable floating factories, completely outfitted for modern whaling. Each of these mother ships employs a number of small but high-powered chaser boats. Equipped with a Norse invention, the Foyn harpoon gun, which shoots a harpoon carrying a bomb in its tip, the chaser hunts down a whale and then tows it back to the mother ship. The carcass is dragged up a runway to the cutting floor inside the vessel where it can be completely processed in a few hours. Present-day whalers are required to utilize every part of the carcass. Not only is oil reduction greatly improved, but the Antarctic factory ship is equipped with canneries for whale meat which has long found a ready market in the Orient; whale meat is also frozen or dehydrated for the European market. Bone and scrap are made into poultry feed or fertilizer. At the end of the season the mother ship returns to the home port to dispose of its cargo. Much of the oil goes into the manufacture of margarine, soap, cosmetics, or lubricants.

The Conservation Problem

A high degree of mechanized efficiency is making heavy inroads into the remaining whale supply. Japanese scientists report that the gray whale is seldom seen in the North Pacific; several other varieties are now quite rare. Sperm, right, and humpback whales are diminishing all over the world, finback and blue whales accounting for the bulk of today's catch. Too many immature whales are being taken, and it is generally admitted that all varieties are being killed faster than they can reproduce.

Unfortunately there is no sign of decreasing pressure upon the supply. The Norwegians and the British who had a virtual monopoly in the Antarctic for a number of years were operating 14 and 13 reduction vessels, respectively, in 1938; the Japanese with six and the Germans with five floating factories were active competitors. The Norse oceanographer, Hjort, estimates that there are probably not more than 300,000 whales still available in all Antarctic waters. Since whales range the oceans freely from arctic to tropical waters and are not under the direct jurisdiction of any country, the preservation problem is difficult. Nationally speaking, whale conservation is nobody's business.

International Control Needed

Faced with the prospect of virtual extinction of many species, biologists and oceanographers proposed an international agreement to protect the remaining whales against indiscriminate killing. The League of Nations made a beginning by sponsoring an international conservation agreement for the protection of the right whale, which was becoming scarce. Signed by 26 nations, including all the whaling countries except Japan, this treaty went into effect in 1935. Coast Guard officers of the signatory nations were assigned to Antarctic whaling fleets to see that treaty provisions were observed. The 1937 Agreement for the Regulation of Whaling went further in that it forbade the killing of certain whales and set size limits for others. It forbade the use of floating factories south of 40° S. latitude except during the open season from December 8 through Marth 7; it also established a sanctuary where no whaling was permitted. This agreement was not successful, however, chiefly because it did not include all the whaling nations and because greater efficiency in exploitation more than compensated for the short season.

After temporary cessation during World War II, active whaling was resumed. In 1947 the floating factories of seven nations (Norway, England, Netherlands, U.S.S.R., Australia, New Zealand, and Japan) were operating in the vicinity of the Falkland Islands and Ross Sea. The 1947 catch was to be limited by international agreement to 16,000 whales and 1,600,000 barrels of oil. Since the Antarctic has the last known reserve of whales, continued large-scale exploitation will inevitably lead to depletion or even to extinction.

The need is for an international whaling agreement to be signed by all nations concerned which will protect all species for a term of years. With a longer closed season, the killing of immature whales prohibited, and a production quota set for whale oil, this unique mammal might have a chance to survive.

MANAGEMENT OF FISHERIES

The Abundance-Depletion Cycle

The foregoing accounts of shad, salmon, halibut, seals, and whales may be regarded as fairly typical of the conservation problem inherent in most American fisheries, as well as illustrative of the methods by which restoration may be achieved. In most commercial operations, where fish are regarded as free goods provided by nature and the only law is the law of capture, a certain well-defined pattern is now recognized.

1. A period of abundance, with large catches per man, per boat, or other unit of effort. The apparently inexhaustible supply at this stage is frequently a temptation to indulge in reckless overfishing.

2. A period of declining catches, with the return per unit of effort falling off to a marked degree.

3. Intensification of fishing efforts. This understandable attempt of the fishermen to keep up the poundage generally means more and larger boats, more efficient gear, and a wider cruising radius. Intensification helps to keep up the amount marketed but makes still deeper inroads into the remaining parent stock.

4. Depletion and abandonment of the grounds. Depletion often occurs with scant warning, since, by the more intensive combing of the sea or by taking constantly larger percentages of schooling fish such as mack-

erel or anadromous runs of shad or salmon, the impending exhaustion may be concealed for some time. When operations become unprofitable the "fished-out" area is usually abandoned.

Many varieties of fish have gone through this cycle, which begins to operate just as soon as the original abundance drops below a certain level. In some instances, if a scant spawning stock remains, a ground may rebuild naturally but slowly to a point where fishing may be resumed years later. Rejuvenation of this type probably accounts for the fact that the records frequently show that fish have returned to abandoned banks.

Even though certain fluctuations in abundance of marine life are caused by biologic factors or by physical and chemical conditions within the sea, overfishing is still the outstanding cause of depletion. Consequently restriction on overfishing is the most direct remedy which can be applied to marine life management.

The Pollution Problem

Industrial development has placed an additional handicap on the many streams and rivers formerly utilized as fishing areas. (See also Chapters 12 and 18.) Sewage from cities, oil from ships in harbors, and mill wastes of all kinds have been poured into streams and bays, particularly along the heavily industrialized North Atlantic seaboard. Among the more destructive to fish life are the effluents from coal and metal mines, chemical plants, rayon mills, pulp mills, fruit and vegetable canneries, and sugar refineries. One of the recognized causes for the decline of shad runs is the contamination of streams flowing into Chesapeake Bay, thus limiting the fresh-water area where spawning is possible. The lessened herring, pike, and perch catch in Lake Erie is partly the result of industrial pollution which is practically unrestricted. The disappearance of fish in many other waters has also been traced directly to sewage or mill wastes.

Factories and fisheries are undoubtedly conflicting interests, and the industrial necessities of a given locality may prove to be greater than its need for uncontaminated shad waters or oyster beds. Certain regions are already industrialized to such an extent that any idea of restoring fishing probably should be abandoned. In the future, however, it may prove feasible to have purity of waters without placing any real handicap on industry. Scientific research has already solved some of the problems of factory wastes, and industrial plants are increasingly willing to co-operate in keeping streams free from poisonous or offensive materials. The fouling of coastal waters by oil-burning and oil-carrying ships is now prohibited by federal laws. Since stream pollution is also undesirable from the social and aesthetic standpoint, public opinion will undoubtedly call for considerable future improvement.

Agencies for Scientific Research

Modern control work in fisheries falls into two broad divisions: (1) investigation, and (2) regulation. The restoration of any declining species must always be preceded by a thorough investigation of the life history and habitat; these studies are done best by the marine biologist.

Concerning investigational work there is little difference of opinion. The accumulation of biologic facts about fish as well as economic facts about their exploitation is usually favored by all interests. Research of this type is generally done by a governmental or state agency, or by a special commission. Within the limitations of its appropriations, the Fish and Wildlife Service has made innumerable studies; similar studies have been made by international commissions for halibut and sockeye salmon control. The commercial fishing interests, with millions of dollars invested, are only too glad to have scientific investigators assist in safeguarding their industry. Usually they are ready to co-operate with survey work and frequently to assist in financing it.

Many states have fishery commissions with research staffs, most of them specializing on local problems. California began the study of the valuable sardine industry about 1919. The Washington State Department of Fisheries, originally interested only in salmon problems, has made numerous studies of shrimp, oysters, herring, and razor clams (Fig. 2). Virginia with its contributions to oyster culture in Chesapeake Bay, Maine with its research on lobster, Oregon on crab, and Michigan on trout are other examples. Among the valuable agencies is the North American Council on Fisheries Investigation, which includes the countries especially interested in the North Atlantic littoral and the Newfoundland banks. This council carries on biologic and economic investigations, collecting and correlating all data that are valuable to its members. A number of other laboratories are making contributions to marine research, including Scripps Institution of Oceanography in California, the Oceanographic Laboratories of the University of Washington, the Chesapeake Biological Laboratory at Solomons Island, Maryland, and The Franz Theodore Stone Institute of Hydrobiology of The Ohio State University at Put-in-Bay.

Restrictive Legislation and Its Enforcement

On the question of regulatory measures there is still a wide difference of opinion. Fishing is an outgrowth of the old hunting economy, and there is probably no occupation in which the worker is more intensely individualistic and more opposed to any type of restriction. The natural tendency on the part of the fisherman, as an area begins to decline, is to fish even harder. Individuals or small companies with a heavy investment in boats and gear, with families to support and taxes to meet, are in no position to agree voluntarily on any conservational policy that calls for a restricted catch. The industry, therefore, is generally unable to take a long-range view of the matter.

For many years any attempt to follow investigation with restrictive legislation was fought by groups that felt that their interests demanded wide-open fishing. Even after carefully planned legislation was secured it was often difficult to enforce it. Opposition to control measures has gradually declined largely through the realization that most of the regulatory agencies are using their powers with the utmost discretion and permitting the industry to take the maximum amount of fish commensurate with a sustained supply for the future. The possibility of reversing the previously mentioned abundance-depletion cycle so as to rebuild the stock is also better appreciated. In certain areas the industry has been educated to accept as necessary a carefully regulated catch, a larger escape of spawning fish, more eggs, more fingerlings, a larger stock of mature fish, and eventually a larger surplus available for commercial capture.

Control of an entire fishery by a single bureau or commission with discretionary powers, such as the Fish and Wildlife Service exercises in Alaska, has so far proved to be the most effective type of regulation. In the United States the legal control of fisheries is vested in the several states, and various commissions have been successful in regulating the fishing season, the types of gear, and irrigation diversion, and in operating state hatcheries.

In many states there is a sharp legislative conflict between the commercial and the sports fishermen over the allocation of fishing rights and privileges. Most states have laws forbidding the commercial sale of recognized game fish, either fresh- or salt-water. Atlantic salmon are now so few that they have become essentially a sports fish. Certain coastal rivers in Oregon, such as the Rogue, have also been closed to commercial salmon operators. In general, any declining species tends to become the subject of a determined legislative drive to reserve it exclusively for the sportsman, a somewhat doubtful interpretation of the principle of conservation.

Interstate Control of Fishing Waters

Some of the richest fishing rivers, bays, and coastal waters of the United States are administered under two or more sets of rules, sometimes at cross purposes. Regardless of political boundaries New York shares certain fishing grounds with Connecticut, others with New Jersey. A similar situation prevails in the Great Lakes and elsewhere. Stocks of fish may migrate across a state line, sometimes spawning in one state and feeding in another.

The several states traditionally exercise full jurisdiction over their coastal and interior waters, setting up the regulations under which fisheries are operated. The legislative approach to interstate migration of fish has been quite unrealistic, and its results often controversial. The Maryland-Virginia friction over oyster beds is of long duration; when migratory species are involved, the difficulty increases. "Maryland crabs migrate to Virginia waters to spawn, and hence legislation established in the upper state will have little effect on crab rehabilitation unless corresponding and co-operative enactments and enforcement can be instituted by the lower state." [11] Oregon and Washington face each other across the Columbia River but have entirely different regulations for the protection of Columbia salmon. Washington deplores Oregon laws and believes that Idaho has failed to provide satisfactory legislation to improve spawning in the Snake and other Columbia tributaries. The Atlantic coast shrimp, a highly migratory crustacean, moves south in winter through state waters with diverse regulations and, while still undersized, are taken in excessive quantities along the Florida coast.

Under the present system progressive laws of one state may be nullified by obsolete laws of a neighboring commonwealth. There is a growing tendency, however, for states sharing the same stocks of fish to strive for greater uniformity in their legislation.

For maximum efficiency interstate waters, such as Chesapeake Bay, Long Island Sound, the Great Lakes, and the Columbia River, should be managed as unit areas with uniform rules and regulations throughout. It may be advisable to create a Chesapeake Bay Authority, a Great Lakes Authority, with complete jurisdiction over all fishery questions.

[11] Julian D. Corrington, "Reorganization of Conservation Work in Maryland," *Science*, February 5, 1943.

The Three-Mile Limit versus Continental Shelf Sovereignty

One of the still unsolved problems of fishery management is that of jurisdiction over marine grounds extending beyond the three-mile limit. Under the generally accepted usages of international law it is permissible for aliens to operate fishing boats in coastal waters just outside that limit. Many disputes have arisen in the past over the interpretation of this rule, but it was not until the rapid increase in the use of floating canneries, particularly by Japanese interests, that the problem became acute. During the summer of 1937 Japanese canneries of this type entered the red salmon area of Bristol Bay, Alaska, catching and canning part of the inbound salmon run. Using deep curtain nets it is possible to remain outside the three-mile limit and still intercept part of an anadromous fish run on the continental shelf.

Alaskan salmon abundance has so far been carefully preserved by conservation measures previously described. It is a question whether alien interests which have borne none of the cost and are not bound by the 50 per cent escapement rule of the Fish and Wildlife Service should be allowed to share in the catch and perhaps nullify the conservation work.[12]

In the future the United States should probably enter into a number of international agreements similar to the one that abolished pelagic sealing. Canada and the United States have been unusually successful in working out joint treaties for the management of halibut and sockeye salmon.

[12] For a detailed discussion of international control of fisheries see Jozo Tomasevich, *International Agreements on Conservation of Marine Resources,* Food Research Institute, Stanford University, 1943.

There is a growing sentiment in favor of abandoning the three-mile limit for fisheries, substituting in its place the continental-shelf limit. Since the continental shelf is actually a highly productive underwater extension of the land area, it may become necessary for nations to assert jurisdiction over it in order to preserve their hard-won fisheries. President Truman's proclamation of September 28, 1945, claiming control over areas of the high seas contiguous to the coasts of the United States wherein fishing activities have been or may in the future be developed, is an assertion of continental-shelf sovereignty.

Aquiculture for the Future

The science of land utilization has progressed rapidly since about 1900, and agriculture is now in possession of a body of exact knowledge concerning food production. Nothing comparable has so far been done for the great salt-water margins of the continents, rich in marine life and plankton food supply. The technique of underwater research has been gradually perfected to the point where it is now possible to make reasonably accurate and extensive examinations of the ocean floor at any given depth. Scientists hope that it will thus be possible to lay the basis for agriculture's companion industry, farming the continental shelves so that fishing will develop into real aquiculture.

Scientific fish farming in the United States is on the increase, including the construction of artificial ponds that are stocked with suitable varieties of game or pond fish, such as bass, crappie, bluegill, and catfish. Hatcheries supply millions of fry to stock ponds of this type. By adding chemical fertilizers to the water microscopic plants and insects multiply, serving as the

8. Rousenfell, G. A., and G. B. Kelez, "The Salmon and Salmon Fisheries of Swiftsure Bank, Puget Sound, and the Fraser River," *Bulletin, Bureau of Fisheries*, Government Printing Office, Washington, D. C., 1940.

9. Russell, E. S., *The Overfishing Problem*, Cambridge University Press, 1942.

10. Thompson, W. F., and N. L. Freeman, "History of the Pacific Halibut Fishery," *Report 5, International Fisheries Commission*, Vancouver, B. C., 1930.

11. Thompson, W. F., *The Effect of Fishing on Stocks of Halibut in the Pacific*, University of Washington Press, Seattle, 1950.

12. Tomasevich, Jozo, *International Agreements on Conservation of Marine Resources, with Special Reference to the North Pacific*, Stanford University Press, 1943.

13. Walford, Lionel A., editor, *Fishery Resources of the United States of America*, Fish and Wildlife Service, U. S. Departme[illegible] the Interior, Washington, D. C., 1945.

PART SEVEN

CHAPTER 20

Recreational Resources

THE RECREATIONAL MOVEMENT

THE increased interest and participation of the American public in outdoor recreation during the period since 1910 has resulted in expansion of facilities, acquisition of land and natural resources for recreational use, and an annual expenditure of time and money that is phenomenal as compared to the period before the turn of the century. Except for the war years 1942–1945, the expansion of the recreation business has continued from year to year. During the first half of the 1930's, recreational interests claimed a $300,000,000-a-year business in Michigan alone which made this activity second only to the automobile manufacturing industry in dollar value. It is further claimed that seven per cent of the national income in 1939 was spent on travel and outdoor recreation.[1] "This was more than Americans spent—on the basis of wholesale prices—for all motor vehicles manufactured in 1939 and was nearly twice the value of our exports. Recreational travel equaled the output of the meat-packing industry, petroleum refining, printing and publishing, and the products of our iron and steel blast furnaces combined."[2] Is this a temporary phenomenon or a lasting change in the American way of life? What is the situation regarding future needs for resources to take care of the people's demand?

Relatively little research has been done in the recreational use of land with the result that even the most elemental statistical data are lacking except for projects owned and operated by governmental agencies. Private organizations have been promotional in nature and usually have maintained a studied disregard for releasing, if by chance they should have them, statistical facts about their business. Accordingly, some important phases of the recreational industry will have to be treated in generalities rather than with exactness.

Even the most casual examination of the

[1] Don Thomas, President of the National Association of Travel Officials, *Proceedings Annual Membership Conference,* National Association of Travel Officials, Duluth, Minnesota, November, 1945, p. 73.

[2] *Ibid.*

By Edward C. Prophet of Michigan State College.

causes of growth in this industry indicates that the expansion is fundamentally sound and that continued expansion and demand are in order for a number of years. Space permits only a limited discussion of a few of these causes of expansion.

The population shift from farms to towns and cities, which became significant about 1910 and has continued to the present time, is of great importance. Urban dwellers feel a greater need for outdoor recreation than do rural people who spend much of their work-hours in the open. Congested urban living seems to create a psychological demand for an occasional change of scenery. Census data indicate that the percentage of rural population is continuing to shrink and that the smaller and medium-sized towns and cities are continuing to gain. Aside from the increase of facilities related to the net yearly gain in total population, an increasing proportion of people in urban centers are demanding outdoor recreational opportunities. Even the rural people are asking for their share of recreation resources provided by public funds.

The composition of the population has changed and is continuing to change. Census data indicate that this country is rapidly approaching the point at which about one-third of the population will be over fifty years old, about one-third will be twenty-one to fifty years old, and about one-third will be under twenty-one years old. The oldest and youngest groups have both time and the desire for recreation to utilize leisure hours. Each year more of the older population group will have funds to finance recreation as Social Security and retirement systems affect more people.

Trends in industry and business are toward shorter work days, shorter work weeks, and longer vacation periods, frequently with full pay benefits. The Boy and Girl Scout movements, the physical education programs in the schools, and the educational work of those interested in preventive medicine have all educated the American public to the idea of getting outdoors and of engaging in recreational activities.

Some of the promoters of both publicly and privately financed recreation projects have become so enthusiastic about expanding facilities that they assume that most of the land not now in economic use will be absorbed and utilized for recreation. Unfortunately land may be submarginal for recreational use, just as land is submarginal for agriculture, forestry, and other purposes. The law of supply and demand must be considered in discussing recreational resources and in determining whether the areas are marginal or submarginal. What today is submarginal may in a few years be in great demand. Accordingly, then, one phase of the conservation of recreational resources is to see that areas not now in economic use are not materially disturbed but are left in their present condition until the future demands for this type of resource may be properly and fairly determined.

What Are Recreational Resources?

At the outset, it is frankly admitted that no two students of recreational affairs have exactly the same viewpoint, and so their definitions will vary. This general field of recreation is a new one, and its limits have not been established. In this discussion only the phases of the recreational industry that deal with land will be considered. Land is used here in the sense in which the geographer-economist employs it, meaning not only land surface but also all natural conditions such as location, climate, water, and vegetation. To give the reader some idea of the wide range of recreational resources a few are listed: mountains, forests, rivers, lakes, ravines and glens, hilly belts, landscaped parks, ocean shores, areas with warm climate in winter, areas with cool temperatures in summer, and even cutover forest lands for hunting.

Some of these recreational areas are to be found in our national forests, some in the national parks, some in state parks and forests, and some under private ownership (Fig. 1). In the pages that follow, the discussion of recreational lands and their utilization is arranged according to the basis of the ownership of the land and the uses to which it is put.

The reader should be warned that dependable statistical data, especially of an inventory nature, are generally lacking for this industry. For those phases of the industry for which data are available they will be presented, but in most cases there is no summary for the nation as a whole but merely information limited to local areas derived from scattered type studies. Many of these have been made in Michigan, where a number of investigators have been exploring this field.

HUNTING AND FISHING LANDS

If area used were the basis of measurement, hunting and fishing would be the most important recreational uses of land. If the number of people involved, or better still, man-days of use, were the basis, hunting and fishing lands would still rank with the foremost recreational lands. Only if we consider the amount of investment in recreational resources and the expenditures of the recreationalists would this phase of the industry take a secondary position.

Need for Public-Owned Lands

In the past it has not been necessary for the hunter or fisherman to own the land on which he hunts or fishes. In the United States we have a heritage that hunting and fishing are free to all men, but we have had to modify that by license laws as the amount of game and fish has become more limited. The problem of trespass has become sufficiently acute that a demand for publicly owned hunting grounds has resulted in the setting aside of such tracts.

Changes in Number of Animals

The damage done to our wildlife by the destruction of its original habitat and the destruction accomplished by unregulated hunting and fishing have been covered in a previous chapter and will not be repeated here (see Chapter 18). Sound principles of conservation of game and fish and their propagation and protection by societies and commissions in various states are producing more than gratifying results. In spite of a change in habitat, related to lumbering, that at first was thought to be very damaging, game populations as large as, or even larger than, existed before the lumbering operations are present in some areas. Members of the Game Division of the Department of Conservation of Michigan agree that the deer population is as large today as it ever was and that some sections are actually overpopulated. With the removal of the forest there is far more summer forage than in the days before these areas were cut over. The amount of winter forage—cedar swamps—is limited, so that with an increasing number of deer, winter feeding has been necessary in some areas. However, such results have been attained only where strict enforcement of the game laws is in effect and where the hunters make a

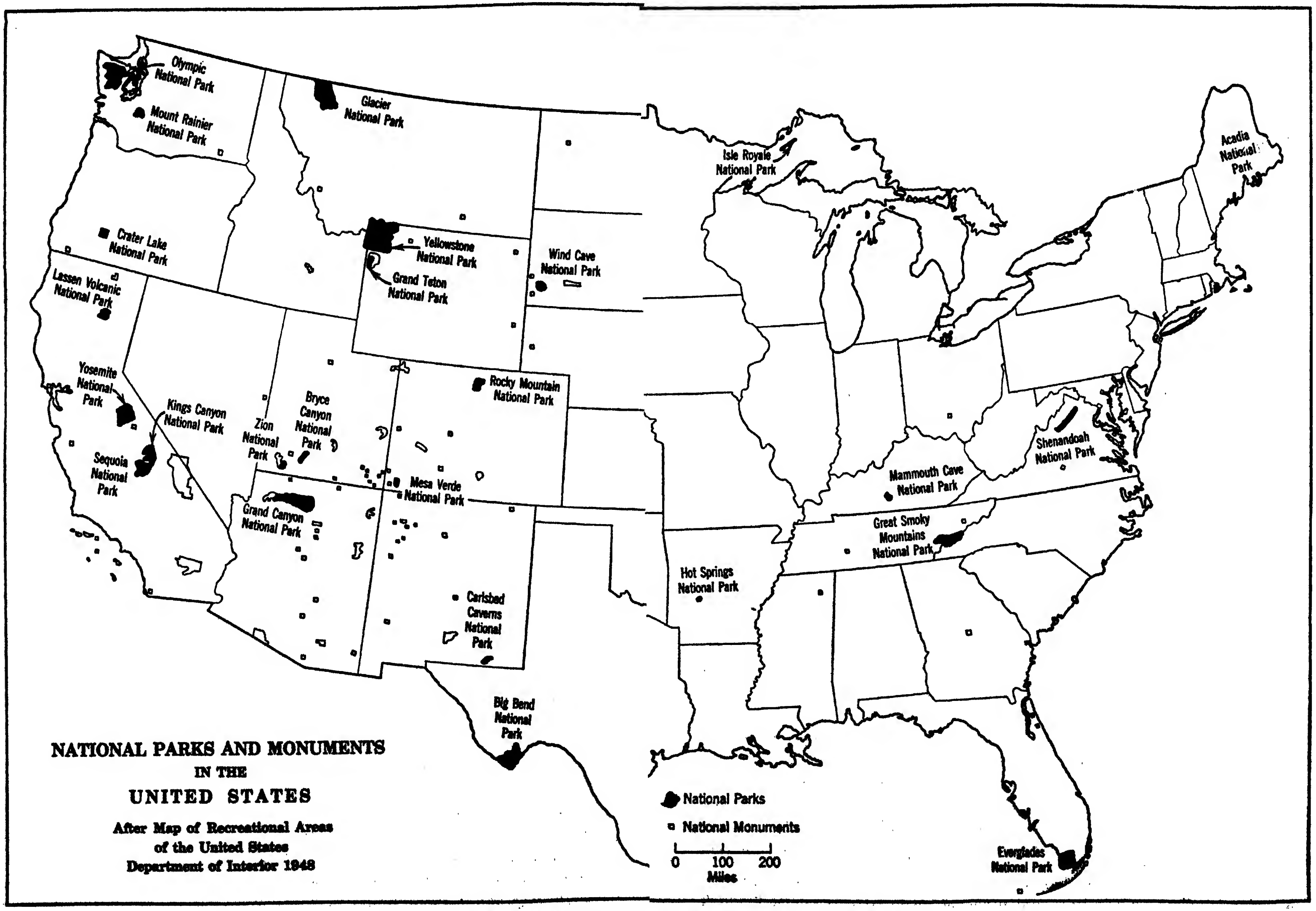

FIG. 1. National parks and monumented States. (After National Park Service.)

reasonable effort to co-operate with the game management and propagation organizations.

Hunting and Fishing Lands Classified

Game exists in areas exhibiting two distinctly different settlement patterns: first, in the sparsely populated areas made up of forest, cutover, and abandoned lands, and secondly, in more densely settled farm areas. Small game predominates in the farm areas. Woodlots, fence rows, and uncultivated fields provide cover and some food, and the cultivated fields provide the remainder. Many more people hunt small game in the farming section than attempt to hunt for larger game in the sparsely settled areas. In 1946 more than 632,000 small-game hunting licenses were sold in Michigan, whereas 350,000 deer licenses were sold.[3] The income from hunting licenses has been used to acquire land for preserves and public hunting and to finance game propagation, management, and research. Michigan has pioneered in this field, and some other states are patterning their work after this example. In Pennsylvania, large areas of the Allegheny Plateau and the Folded Appalachians which are generally not suited to agriculture provide a hunting area for both deer and small game that is relatively near large cities. The importance of hunting in Pennsylvania is comparable to that in Michigan. Since 1930 many farmers in the northeastern prairie states have developed a profitable secondary source of income by providing room and board to sportsmen who are attracted to that area by upland game-bird hunting. This type of game has become plentiful due to propagation and management co-operation among state agencies, sportsmen's organizations, and the farmers. Several species of birds were introduced and propagated in the area after the native stock had been practically exterminated. Throughout the Rocky Mountains and westward to the Pacific coast hunting is widespread and a major attraction for sportsmen both local and from distant regions. In our southern states small game hunting is indulged in by a large number of the residents in rural areas.

Many more individuals engage in fishing as a sport and recreation than in hunting. In 1946 in Michigan alone over 1,000,000 noncommercial fishing licenses were sold.[4] The fishing season is much longer than that for hunting so that the man-hours spent fishing are many times those devoted to hunting. On a participation basis, fishing is a much more important recreational activity than hunting. Fortunately, fishing resources are more widespread in their geographical distribution and availability to population centers. All streams and bodies of water not seriously polluted, if they are not now utilized, can be developed for this type of recreation.

The total number of licensed sportsmen in all states was estimated at 24,000,000 in 1946.[5] Since hunting and fishing take place on most of our land and waters, it might be said that for practical purposes the entire area of the United States should be included as part of this resource.

Private Hunting and Fishing Lands

In some states, Michigan for example, private ownership of hunting lands has

[3] Statistics furnished by the Education and Public Relations Division of the Michigan Department of Conservation, Lansing, Michigan.

[4] *Ibid.*

[5] B. Ray Keifer, Vice-President, *Outdoor Life,* New York, N. Y., *Proceedings Annual Membership Conference,* National Association of Travel Officials, Duluth, Minn., 1945, p. 7.

been encouraged. Groups of hunters form a club, purchase or lease cutover land, and post it, closing it to other hunters. Some of the clubs have been instrumental in increasing the deer population in their territory by enforcing even stricter game laws on their members than those imposed by the state. There are 220 such hunting and fishing clubs in the northern half of the lower peninsula of Michigan.[6] One has an area of 18,000 acres, two have more than 10,000 acres each, and there are 32 in all owning more than 1000 acres each. Statistics are not available on the total area of privately owned hunting and fishing land held for that specific purpose in the United States, but the total area is much larger than is generally realized.

Government Hunting and Fishing Lands

Government-owned hunting and fishing lands should include the national forests, some of the national parks, waterfowl refuges and public hunting areas adjoining them, state-owned game refuges and hunting grounds, and the state forests. Most of the national parks allow fishing but prohibit hunting. States have had to purchase lands for public hunting as privately owned lands have been closed to the public by their owners. The demand for more and larger areas of public hunting land and property with access to streams and lakes is very pressing in several states, among them Michigan, Ohio, Pennsylvania, and New York. The usual procedure with hunting lands is to establish a game preserve in the center of a tract of state-owned land and allow public hunting on the remainder of the tract.

On August 30, 1934, the Bureau of Biological Survey of the Department of Interior reported over 42,000,000 acres in game refuges administered by local and state authorities and over 2,700,000 acres administered by federal agencies.[7] The area under federal jurisdiction has expanded so that in 1941, the Fish and Wildlife Service of the Department of Interior had primary jurisdiction over 7,250,000 acres of national wildlife refuges and secondary control over 6,250,000 acres administered by other federal agencies.[8] These data give an idea of the expansion in the federal program aimed at maintaining and propagating game. Several states have expanded their activities and the area in refuges since 1934 but summary data are not available.

Uncontested Trespass Lands

Today most hunting is done on privately owned land where trespass by hunters is not contested. Hunting in the farm sections takes this form except when the hunting is done by the farmer and his family on his own farm. Farmers object to the damage done to their property by many hunters, but it is difficult to keep them off the property even when posted. Cutover lands, held by absentee owners, are more or less free hunting areas, but as this land is sold out to governmental agencies or acquired by hunting clubs it may be closed to the public. The land-ac-

[6] Wilbur O. Hedrick, "Recreational Use of Northern Michigan Cut-over Lands," *Special Bulletin* 247, *Agricultural Experiment Station,* Michigan State College, East Lansing, Michigan, 1934, p. 26.

[7] "Recreational Use of Land in the United States," *Report on Land Planning,* Part XI, National Park Service, Washington, D. C., 1938, p. 76.

[8] "A Study of the Park and Recreation Problem of the United States," *National Park Service,* Department of the Interior, Washington, D. C., 1941, p. 54.

quisition activities of several branches of the federal government since 1933 have added many million acres of hunting lands to those held by governmental agencies. If this trend continues and the farmers become more effective in prohibiting trespass, the hunter will be able to hunt only on public lands or lands that he owns for that purpose. If the American public is to have ready access to hunting land, then public agencies must acquire far more land than they now control in order to provide for the demand. Fortunately, hunting conflicts little, if at all, with the use of the land for forestry and some of the other conservation projects.

THE USE OF NATIONAL FORESTS FOR RECREATIONAL PURPOSES

The national forests constitute the largest area of potential recreational land in the United States. Their location, however, is not in the best interest of the majority of the recreationalists. The major population centers are in eastern United States whereas most of the large national forests are in the western part of the country. In 1947 the national forests contained 228,525,883 acres.[9] Their recreational use has just begun.

Why Recreational Use Is Now Secondary

The *Use Book of the Forest Service* definitely gives recreationalists rights and privileges in the forests, but in most areas the recreational use is secondary and subservient to that of the forest use. It is natural, but unfortunate, that this is true. In most areas, more fires are caused directly by carelessness or malicious intent by man than by any other single means (see Chapter 10). The forester is not anxious to increase the hazards of fire by encouraging visitors in remote sections of the forests, especially during the fire season. Selected spots of limited area are set aside for camps along the main roads where fires may be controlled easily if they start and where the activities of the visitors can be supervised Care has been used to select spots that are attractive and are near either good fishing or hunting areas. Nature study trails have been laid out in some forests and, where winter snow conditions warrant, a program of winter sports has been started. Such a program has been started in the Manistee National Forest near Cadillac, Michigan. In 1938, the Forest Service maintained 6000 public campgrounds and reported that 32,600,000 people visited national forests in that year not including individuals that merely passed through a forest while traveling on an automobile road routed into the forest.[10] Forest Service appropriations for recreational administration increased from $65,000 in 1929 to $588,000 in 1938.[11] These figures give only a partial idea of the extent to which the national forests are serving the recreational needs of the nation but they indicate that much greater use can be made of these areas as facilities are provided and visitors are encouraged.

Unless the visitor is interested in fishing, hunting, or hiking there is not much to keep him entertained while camping in a national forest. As a result the campers usually stay for a limited time only. Camp sites along main state or national high-

[9] *Statistical Abstract of the United States,* Bureau of the Census, Washington, D. C., 1948, p. 718.

[10] "A Study of the Park and Recreation Problem of the United States," *idem,* p. 53.

[11] *Ibid.,* p. 94.

ways that pass through the forests are the most used, but enough visitors wish to get away from the beaten path to make the camp sites on the lesser-used forest highways justifiable. Undoubtedly it will be necessary to provide more of these.

The average recreationalist has to travel a long distance to reach the larger national forests that still have virgin timber. Unless he is primarily interested in hunting or fishing he can as easily go to a national park where the entertainment opportunities are more plentiful, and where better facilities are arranged to take care of him. This is the main reason why the national forests have not attracted and kept for longer visits a large number of recreationalists.

How Some Forests Are Used

As an example of the fact that intensity of use depends on distance from populated centers, Angeles National Forest which lies just to the north of the Los Angeles metropolitan area can be cited. Picnickers visit it on week ends and holidays. A number of private camps have been allowed within the forest which provide entertainment of various sorts. Traffic patrols have to be maintained on the main roads in this forest to regulate traffic and keep a safe speed limit. Steep grades, sharp curves, hard surfaced roads, and visitors, just released from the limitations of city driving, set up traffic conditions that are hard to control. Throwing of lighted tobacco from cars is also a serious problem. An effort is made to prohibit smoking except at designated camp sites, private camps, or sight-seeing grounds. These prohibitions have not diminished the volume of traffic. The majority of the visitors confine their activities to motoring through sections of the forest to enjoy the altitude, coolness, and beautiful scenery. It is used more like a large city park than the other national forests.

Leased Building Sites in National Forests

The Forest Service grants leases and permits for the erection of cottages and permanent camps. These are usually in selected areas where danger from fire is not great or where fires can be controlled easily. In southern California the demand for this type of permit is great. People wish to spend part of the year at a higher elevation than where they live near the sea, or they are driven to the higher elevations by the summer heat. In most parts of the country, however, the demand for summer cottage sites in the national forests has not been as pressing as one might expect. Because of the lack of national forests in the east or the recentness of their establishment there, big summer colonies have not as yet developed, but the movement is under way. In 1931 when the Hiawatha National Forest located in the upper peninsula of Michigan was dedicated, and, before even a reasonable amount of land had been acquired, demands began to pour in for cottage sites. By the end of 1931 more than three hundred such requests had been received by the forester in charge. Leases for cottage sites were held up until the forester could determine a satisfactory management scheme for the forest under his supervision. This is merely an example that shows the volume of recreational use that may be made of some of the national forests in the east.

More National Forests in the East

During the middle 1930's impetus was given to the acquisition of lands for national forests in eastern United States by the desire of government agencies to retire submarginal farmland from agricultural use and to put under forest management large areas of cutover and burntover lands. Purchase areas for national forests have been designated in most of the states east of the 100° meridian with a concentration in the Great Lakes states, the Gulf states, and the Southern Appalachians. These new national forests are located within a few hours' driving distance from large cities and densely settled agricultural regions so their attractiveness as recreation sites will improve as the land comes under proper forest management. This will provide a real opportunity for most of the people in this country to make use of the national forests as recreation areas. It may be that recreational uses will need to be given first consideration and forestry uses secondary consideration in some of these eastern forests.

State forests comprised some 15,780,000 acres in 1935.[12] In general their management and operation are patterned after that in the national forests, and their service as recreational areas is about the same as in the national forests except that a proportionally larger area lies in eastern United States.

THE NATIONAL PARKS AS RECREATIONAL GROUNDS

Why National Parks Were Founded

The national parks are recreational areas par excellence. The facilities for handling the visitor are as fine as any, better than most, and are set in a background of unique scenic splendor. The two main purposes underlying the founding of the national parks were: (1) to set aside areas having unusual natural features so that they may be kept undisturbed for all time, and (2) to allow ready access to these areas to all citizens without exploitation for private gain. Some of the incidental results, which are of great importance from the standpoint of recreation conservation, are: exploitation of game and forests has been prohibited in these areas; first-class fire protection has been provided for areas otherwise more or less unprotected; game preserves have been set up, protecting and providing a permanent home for some species that were facing extinction (bison, Rocky Mountain goats, antelope, etc.); and the opportunity has been provided to educate millions of people on sound conservation policies (see Fig. 1).

The Need of Parks in Eastern United States

With the exception of a few parks that were recently created, most of the national parks are located in the western states, too distant from the homes of the majority of our people to be visited regularly. This is very unfortunate, but efforts to remedy this situation have been made. The year 1919 saw the opening of Acadia National Park in Maine, 1931 the opening of Great Smoky Mountains National Park in the Southern Appalachians, 1935 the opening of Shenandoah National Park in Virginia, and 1936 the acquisition of Mammoth Cave as a national park. Since then Isle Royale in Lake Superior and the Everglades in Florida have been added as national parks. World War II delayed the completion of facilities to handle visitors in the Isle Royale Park, but limited numbers can now be accommodated. The eastern parks will attract and handle far more visitors than those in the west because of the nearness to population centers (Fig. 2).

[12] *Ibid.*, pp. 50 and 51.

Most national monuments are similar in function to the national parks, but smaller in area, and the facilities for taking care of visitors are more limited. Battlefields, historic spots, and national cemeteries in the eastern states also serve as tourist attractions, but details of their use as recreation by 2,566,000, and 2,691,000 visited the national historical and military parks. Most national historical and military parks are located in eastern United States and give some indication of the popularity of properties administered by the National Park Service even when they do not contain spectacu-

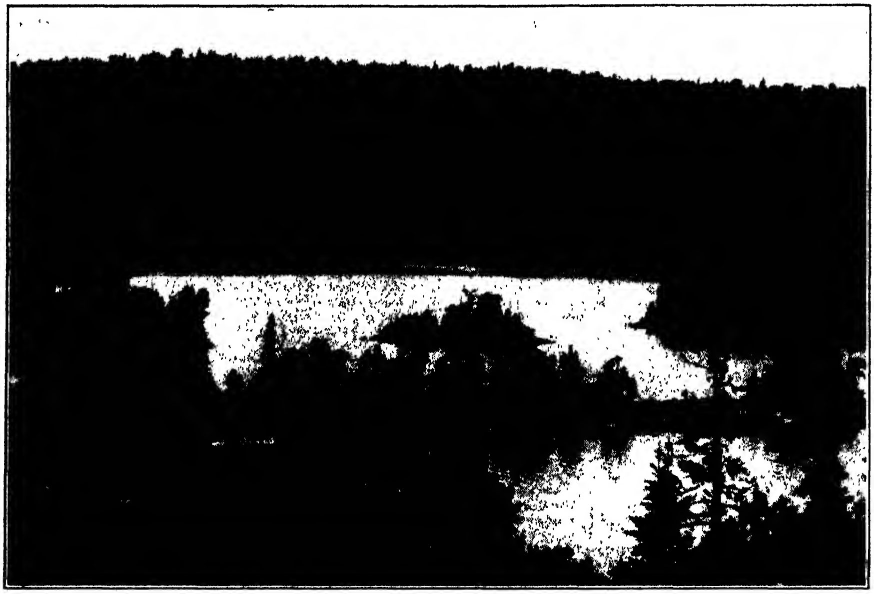

FIG. 2. Tobin's Harbor, Isle Royle, in Lake Superior. This is the type of wilderness area that is attractive to the recreationist who wishes a vacation in isolation. (Michigan Department of Conservation.)

centers are omitted in this discussion as the general function is much the same as that of the national parks.

The National Park Service administered 203 areas containing 21,882,770 acres in 1940. Of these areas 26 were national parks with over 10,000,000 acres and 82 areas were national monuments with over 9,000,000 acres.[18] During the 1939 travel season 15,454,000 people visited the areas administered by the National Park Service. The national parks led with 6,800,000 in attendance, national monuments were visited

[18] *Ibid.*, pp. 52–53.

lar scenery. (For recent travel data see Table 1.)

In acquiring lands east of the Rocky Mountains a question of basic policy has been raised. The purpose of the national parks is to preserve for present and future use some natural feature or features of great interest and rarity so that it will not be damaged or exploited for private gain, as well as to provide recreational grounds for visitors. Originally recreation was of secondary importance as some of the parks were little used owing to inaccessibility. Now the matter of serving the public has

TABLE 1

VISITORS TO NATIONAL PARKS, ETC.

[Source: National Park Service.]

	National Parks	National Monuments	National Historical Parks	National Military Parks and Cemeteries
1920	919,504	138,951		
1925	1,762,666	292,256		
1930	2,774,561	472,095		
1935	4,056,362	1,332,221	510,264	1,624,014
1940	7,358,080	2,816,912	915,410	1,907,756
1941	8,388,909	3,749,452	1,078,541	2,021,380
1942	4,263,409	2,094,788	644,766	943,807
1943	2,172,706	1,604,050	355,923	417,178
1944	2,566,729	1,842,938	438,471	454,821
1945	3,994,504	2,301,585	411,278	668,037
1946	9,351,973	3,571,882	886,404	1,341,392
1947	11,024,068	3,943,577	1,149,912	1,572,112
1948	11,307,826	4,392,549	1,212,409	1,542,444

become or is becoming uppermost. Accordingly, pressure is being exerted by local residents to have national parks created near their communities whether the natural features are worthy of such a project or not. Also local interests wish to capitalize on the prestige of the National Park Service. The National Park Board has fought against this, but Congress has been responsive to local demands. The problem is being met in part by having the National Park Service aid the local authorities by consultation and advisory work so as to bring to them methods of administration that have been successful in the national parks and types of facilities that have proved popular. Such an arrangement does not lower the standards of national parks and has resulted in improvements in the locally administered parks.

Intensive Use of Parks Near Large Population Centers

The parks in the east have shown very excellent attendance records, even if they lack the grandeur of many of those in the west. Acadia in Maine recorded a steadily increasing attendance, from 64,000 in 1919 to 237,000 in 1932.[14] Since then new attendance records have been set. Great Smoky Mountains National Park attracted 150,000 the first year that a road was opened into it (1931) and doubled this number in 1932. Since then the number of visitors has steadily increased. We may expect that the limited number of eastern parks will soon attract more visitors each year than the large parks in the west.

Yosemite, located near the greatest concentration of people in the west, shows a yearly attendance of about 500,000.[15] In 1917 only 34,000 visited it. Since then the gain has been steady. It affords a refuge to many Californians from the heat in the Great Valley and the Coast Ranges during the summer. Actually it is a summer resort in many respects. It appears that most of the visitors are interested in the entertainment features and the relief from the heat rather than the opportunity to observe and enjoy natural phenomena. The number of visitors desiring the use of camp sites is so great that limited camping privileges are granted in order that no one may monopolize the facilities provided by the government and camp sites may be made available to more individuals. During the peak of the season (July) in 1935 more than 8000 people encamped in an area of a few square miles in the main valley where most of the facilities for campers are located. In most of the other parks the visitor is attracted by unique natural features which were the original reasons for the setting aside of the park area.

[14] *Annual Report of the Director of the National Park Service*, United States Department of the Interior, Washington, D. C., 1932, p. 85.

[15] *Ibid.*, p. 85.

Accommodations for and Care of Visitors

In the majority of the larger parks accommodations of four kinds are provided to take care of the visitors: (1) hotels, (2) cabin camps, (3) tourist cabins, and (4) tourist camping grounds (Fig. 3).

Hotels were established as the first step in opening the parks to visitors. They were first served by horse-drawn stages, and more recently by motor buses or stages co-operating with the railroads. The hotels and the stages are operated as concessions from the government, and a certain amount of regulation is imposed so that the service is good and the safety of visitors is assured. The cabin camps are operated on the same basis, providing accommodations at a lower price than the hotels. These cabin camps usually consist of elaborate rustic buildings devoted to lounges, dining rooms, and entertainment halls, and the visitors are put up for the night in individual cabins clustered around the main buildings.

FIG. 3. Rustic cabins so necessary to the tourists who are on the move most of the time. (Michigan Tourist Council.)

The tourist cabins are a relatively new feature, having made their appearance since 1934. Because many travelers utilize cabins in traveling by automobile and do not carry camping equipment, but desire accommodations at a nominal price where they can prepare their own meals and have comfortable sleeping quarters, it has been necessary to provide that type of accommodation in the national parks.

The tourist campgrounds have been a familiar sight in the parks for a long time. The majority of the visitors utilize them. Travel by automobile, camping en route and at the parks, is the most inexpensive way to visit the national parks and is within the means of the majority of the people in this country. Some of the parks furnish free wood for camp fires and about the only expense is the entry fee into the park, which is very low. Cabin trailers are coming into vogue and may in a few years exceed the number of campers with tents.

The government provides services of various kinds to visitors: free guide service to the main features of the park, maps of the park, police protection, camp fire programs, lectures on natural science, and museums.

Creating a Sentiment for Conservation

The ranger-naturalists direct the visitors' attention not only to the special geological features of the park but also to the animal life, the plants, the flowers, and the trees. A real interest in natural phenomena is developed, and at the same time the visitor is shown why man should not exploit them. Some of the most effective work in getting the public to realize the true value and importance of conservation is being done in our national parks.

The operational cost of the National Park Service has been nominal. In 1929 the budget was $4,500,000 and has been increased steadily as more functions and areas have been added.[16] By 1949 the budget reached $13,129,000, which was a very small amount in relation to the large area under administration and the number of visitors served.

STATE PARKS

Their Function

Since 1920 state parks have become recreation areas of very great importance (Fig. 4). Their primary purpose is to provide outing places for city dwellers and densely settled rural areas. Some are small, being only picnic grounds with an area as small as three or four acres; others are large, like Ludington State Park, in Michigan, with more than 3000 acres. Twenty-seven states have one or more parks that exceed 3000 acres in area, and Texas has the largest individual state park with an area of 225,000 acres.[17] These parks may be divided into two groups: (1) the picnic areas near big cities, and (2) parks having natural features of special interest which may be located in wildland areas.

FIG. 4. State Park, Grand Haven, Michigan. The public beaches along the Great Lakes are great resort areas for the water enthusiasts who seek relief from the heat of the middle west. (Michigan Department of Conservation.)

County parks and state forests are utilized by recreationalists in the same manner as the state parks and the national forests and will not be given separate consideration here.

The small picnic parks serve more people than the larger state parks. On week ends and holidays having favorable weather con-

[16] "A Study of the Park and Recreation Problem of the United States," *National Park Service*, U. S. Department of the Interior, Government Printing Office, Washington, D. C., 1941, p. 94.

[17] *Ibid.*, pp. 134–271.

ditions, there is actually hardly standing room at most of the parks in southeastern Michigan around Detroit, at those in northern New Jersey, and at those near New York City. Additional areas are being set aside as parks in these areas since the problem is so acute.

The larger parks might be considered miniature national parks. Some of them have been located so as to preserve special natural features and provide campgrounds, playground equipment, picnic equipment, and nature trails. Caretakers not only attempt to keep the parks clean but act as police officers and nature guides if they have the time.

The State Park Movement

In 1939, forty-six states had state parks, but some had very few.[18] Two states had only one park each, two others had two parks each, and five others had three or four parks each. Seven states had more than 40 parks each. These were Connecticut with 45, California with 35, Iowa with 45, New York with 61, Oregon with 52, Washington with 42, and Michigan with 72. This tabulation does not include campgrounds provided in state forests or other types of state-supported recreational grounds. It appears that Michigan has done more in the way of setting up a state park program and carrying it out than any other state. There is need for many more, or at least much larger, state park areas in the southeastern part of the state as indicated above. The director of parks in Michigan has had two objectives in picking out sites: (1) to serve the largest number of people, and to have the parks spaced at reasonable distances and scattered over the state to serve tourists; and (2) to try to include samples of each type of topography, vegetation, and animal life that occurs within the state. In other words, the idea in part is that followed in the national parks.

[18] *Ibid.*, pp. 134–271.

The Pacific coast states, the middle west, the lake states, the northeastern states, and the middle Atlantic states are the areas where state parks are most numerous and where they are best supported. There is a decided lack of state parks in the south, in the prairie states, and the mountain and intermontane states. However, in the mountain states there are adequate vacation grounds in the national forests and national parks but they are not usually well located to meet the local need for picnic and outing parks (Fig. 4). In the south state parks of the picnic type are inadequate, particularly for the Negroes.

In 1939 state parks totaled 1397 areas with 4,342,863 acres.[19] Most states had picked definite sites for additional parks that will be acquired and developed as funds become available. In some states over a hundred per cent expansion in areas and acreage is planned.[20]

The estimated attendance for 1941 was 84,000,000 visitors of which 2,859,000 stayed overnight.[21] The state park systems of the nation, in 1942, employed 1518 workers on a year around basis and 2107 individuals seasonally. Their budgets amounted to $9,372,000 of which $2,598,000 represented capital investment in land and facilities.

As indicated above in the attendance figures, only a small percentage of the visitors to state parks stayed overnight. The primary usage is for picnic and outing

[19] *Ibid.*, p. 50.

[20] *Ibid.*, pp. 134–271.

[21] *National Conference on State Parks, Appendix, Yearbook,* Park and Recreation Progress, Washington, D. C., 1943.

parks. Where bathing facilities are available near large cities very large attendance figures may be recorded for a single park. Before World War II two such parks (Bay City and Grand Haven) in Michigan regularly recorded annual attendance of between 900,000 and 1,500,000 visitors.[22]

The Administration of State Parks

Beginning in the early 1930's California has charged a fee of fifty cents a night for camping in the state parks. This has had an adverse effect on the number of campers or potential campers. Innumerable camping parties in the national parks located in California stated in the summer of 1935 that they usually utilized the state parks, but since the fee has been charged they have crowded into the national parks. That was one cause of the congestion in Yosemite National Park in 1935.

Though the right or justification of the states to charge camping fees in their parks is not questioned, it is regrettable that it tends to discourage people from using them and also encourages campers to camp along the roads, in out-of-the-way places, on private lands causing numerous trespass problems, to create hazards to the forests in the form of fires, and hazards to health due to lack of sanitary facilities. In some sections the cost of fighting fires and protecting water supply seems to justify the abandonment of the camping fee. It is better to have the campers concentrated where they can do little damage by fire, and where protective measures may be put in force with a minimum cost, than to force the campers to scatter to out-of-the-way places where they may do considerable damage.

The state appears to be the best administrative unit for parks that serve local needs. The state can locate parks in the areas where needed, it can administer them all with a trained staff, and it runs into fewer legal barriers in acquiring land than smaller governmental units do when they go beyond their own legal limits. Also, in most state budgets the funds needed to maintain the parks are not so large a percentage of the total budget, whereas the reverse may be true in smaller governmental units.

RECREATION OR OUTING PARKS

A new type of park is being contemplated. It will be a combination of "Coney Island" and a national park. It resembles the former in that special features are to be installed to entertain properly the visitor from either city or farm while he is on an outing. It resembles a national park in its size and the fact that the federal government is providing the funds to create it. Three such projects are under way in Michigan. Two of them are in the southern part of the state; one, the Yankee Springs project, is located in the southwestern part about 100 miles from Chicago by automobile, the second, the Allegan project, is located about 30 miles southwest of Grand Rapids and is easily reached from Chicago, and the third is in the Waterloo area. These three projects are within 350 miles of more than 28,000,000 people, most of whom are living in areas with poor facilities for outdoor recreation in forested areas. The fundamental purpose is to provide a suitable and attractive park for an outing as well as overnight accommodations.

Parks of this type may be started in other sections of the United States. They should not be confused in any way with the na-

[22] *Biennial Reports,* Michigan State Department of Conservation, Lansing, Michigan.

tional parks, and so another name is needed. Suggested names are either "recreation parks" or "outing parks." A park of this type will not eliminate the need for state parks or locally owned parks more accessible to the big cities than the "outing parks."

FIG. 5. The desert landscape of the dry southwest appeals to many tourists who like the colors of the rocks and the brilliant flowers of the many cacti. (Union Pacific Railroad Co.)

AESTHETIC AND OTHER USES OF LAND

Recreational Areas for Nature Lovers and Others

By aesthetic use of land is meant the use made by the sightseer who enjoys the beauties of the landscape but who does not tamper with or destroy the resource (Fig. 5). The national parks fall under this category, but they have already been covered at some length as a separate type of land-use. Wilderness areas, scenic areas, canoe routes, hiking and bicycle trails, and riding trails make up this type of recreational resource (Fig. 6).

Many Americans are learning that it is as enjoyable or more so to hunt with a camera as with a gun. They desire places where game and other wild animals may be observed in their natural habitat undisturbed by man. Such areas are becoming a real attraction to tourists. Nature trails are also popular. On these the visitor may observe, or have pointed out for his observation, various natural phenomena which he does not have an opportunity to see at home. Such trails are very popular in the national parks and experiments in state parks may prove popular. No great effort has been directed along this line elsewhere. Possibly, special areas may have to be set aside near population centers for this type of park, but only limited areas have been devoted exclusively to this use.

Accommodating Hikers

Hiking trails need not involve the ownership of much property. During 1934 and 1935 a series of inns or hostels was established in southern New England to accommodate hikers. Public roads and byways were used for routes, which pass through areas of beautiful scenery. The operators of these inns reported successful seasons until the entry of this nation into World War II, which shows that many of our citizens desire this type of facility and use it when it is provided. Several hiking and bicycle routes with hostels were located in southeastern Michigan and were operated successfully until they were discontinued because of the war. The popularity of hiking in the Austrian and Bavarian Alps shows how this phase of the recreation business may be developed in this country. Accommodations need to be very moderately priced to attract vacationists. A vacation of this sort is not costly; it is very enjoyable to those who like to walk but do not care to dodge automobiles on the highways, and it gives the individual a chance really to observe the scenery. It may be necessary to locate these trails on government-owned property in order to avoid highways and trespassing on private property. They should be located near population centers if good scenery exists there. The nearer they are to where people live the greater will be the use made of them. It may be necessary to purchase land for this purpose as the demand becomes greater. The New England experiment shows that it pays from a purely business standpoint.

Short hiking trails may be constructed along river banks actually within city limits if river beautification plans are carried out. Such resources are largely overlooked and undeveloped.

Meeting the Demands of Equestrians and Canoeists

Riding trails are in much the same category as the hiking trails in the east but are unimportant except for short bridle paths in some of the city parks. The present scheme of highway and road layout makes it inadvisable for a rider to utilize them even in farming sections. Also, accommodations spaced one day's journey apart for riders and mounts are not available in the more settled areas. This type of recreational resource has remained undeveloped. Camping parties utilizing horses are not uncommon in the mountainous areas of the west, but facilities for this type of travel are not provided in the east-

FIG. 6. Franconia Range in the White Mountains of New Hampshire. In summer and winter the mountains of New England have their enthusiasts. Here each year thousands of people enjoy their annual vacation, a brief respite from their work-a-day life. (E. D. Putnam, Antrim, N. H.)

ern part of the country except in a few sections of the Southern Appalachians where the local residents travel on horseback.

The dude ranches of the west are capitalizing on this idea. Some now gain most of their income from the visitors rather than from the ranching activities, and in these instances the land use may well be considered recreational rather than grazing. This trend in land-use should be encouraged.

of recreation. If necessary, temporary subsidization of commercial liveries by local interests can very soon determine where such liveries will pay, and thereafter no subsidy will be needed.

Ownership of Aesthetic Lands

No extensive areas need be owned outright by the public in order to make use of the aesthetic values that they contain. The

FIG. 7. Mount Hood, Oregon. Each year thousands of tourists derive pleasure by traveling within sight of the snow-capped mountains of the west. A few take up the challenge of the mountains and scale the heights. (Union Pacific Railroad Co.)

total amount of land owned for this use is not large, but its utilization in terms of the enjoyment it yields to the public is great. Public agencies need not even own the lands through which scenic highways pass, but the scenery really constitutes the resource which causes the road to be used by tourists. It is possible to make this resource available to the public in some places where it is not now available by merely re-routing some of our main highways or constructing branches that may be used by the visitor who desires scenery and letting the through traffic continue on the present more direct routes (Fig. 7). The cost of such roads is largely the cost of construction and main-

Canoe trip routes could be put to more use if canoe liveries were provided at suitable points on our better canoe waters. These liveries are lacking on most of the better routes except in New England. Canoeing has become much more popular in Michigan since 1940, and a number of private liveries have been established on a profitable basis. Some were established in 1945 and 1946 by discharged war veterans seeking a small privately owned business opportunity. Most of these have proved successful. The Michigan State Department of Conservation publishes a booklet with a map of canoe routes and liveries which has done much to encourage this type tenance once the highway route is purchased.

An All-Purpose Park

The Adirondack Mountains project, in New York, is in some respects a mammoth recreation park under state ownership. However, it also carries out the functions of a game preserve and wilderness park. It is large enough so that these various uses do not conflict, as they can be isolated from one another. The primary object has been to provide an area where the aesthetic uses are given first consideration.

FIG. 8. A small private beach along the coast of southern California near La Jolla. (All Year Club of Southern California.)

RESORTS

Summer, winter, and health resorts are among our most-valued and best-appreciated recreational land uses. Under this category are included resort subdivisions, colonies of cottages, seasonal hotels, clubs, and health centers (Fig. 8). The placing of health centers in this list might be questioned as they represent an organized business, but, except on public lands, most phases of the recreational use of land are organized business enterprises. The health center is exploiting a natural resource just as much as the owner of a cottage or the owner of hunting land.

Recreation at Health Centers

Health centers individually occupy large acreage but taken as a group do not utilize enough land to justify an attempt to estimate the area. A few outstanding health resorts are French Lick, Indiana, Hot Springs, Arkansas, Saratoga Springs, New York, Excelsior Springs, Missouri, and Asheville, North Carolina. In each instance, an entire city has been built up to take advantage of either a mineral spring or a comfortable climate. Entertainment, especially outdoor exercise, is provided in order to keep the patients occupied and to aid in the cure. The larger hotels provide golf courses, riding stables and bridle paths, swimming pools, spacious lawns, and woodland trails for hiking. An individual establishment may have a thousand acres or more, but the total number of such establishments throughout the country is limited. Recreational facilities of such excellent quality have been provided that many people come to these health resorts to make use of them rather than for the medical services provided.

Resort Subdivisions

Resort subdivisions occupy at least 1,500,000 acres in the United States. There are no accurate figures for the country as a whole, or for any one state. The author has made investigations and tabulations for some counties in Michigan and, on the basis of these surveys, conservatively makes the estimate given above. A thorough tabulation and check might show double that acreage. In Michigan alone more than 100,000 acres are included within resort subdivisions. Wisconsin, Minnesota, Maine, California, and Florida are a few of the other states in which this type of subdivision is popular. Much more land is subdivided into resort plats in Wisconsin or Minnesota than in Michigan. Just how much of the Florida subdividing and real estate promoting should be charged to recreational use of land is a moot question, but a vast area should certainly be included irrespective of how limited the definition of a resort subdivision is that serves as the basis for classification.

Most of these lots have not had cottages built on them, but may have. In Roscommon County, Michigan, there were more than a thousand cottages in the summer of 1929.[23] On the average about 100 cottages per year have been added since then. In 1946 alone on the south side of Houghton Lake in this county, 257 new cottages were built. A conservative estimate is that there were in 1947 over 3000 cottages in the county which has three lakes and is located in the center of the northern half of the lower peninsula of the state. In 1931 there were more than 2100 cottages in the upper peninsula of Michigan. The number had almost doubled by 1947. There are no accurate figures for the number of cottages in the state, but a conservative estimate will place the total at 35,000. The larger colonies of summer cottages are located along the shores of Lake Michigan, the inland lakes in the southwestern part of the state, inland lakes within 60 miles of Detroit, and on the shores of Lake Huron and Lake St. Clair.

The Taxable Value of Resort Subdivisions

From the standpoint of local taxation, the cottage is a valued asset. If an individual can afford to own a cottage he can certainly afford to pay the taxes. On some cutover lands this is the most important source of local taxes.[24] Data for 1931 indicate that in West Traverse Township, Emmet County, Michigan, recreation facilities represented 86.5 per cent of the total property tax. In Denton Township, Roscommon County, Michigan, they represented 85 per cent of the tax. There were 17 townships in the northern part of the lower peninsula of Michigan where over 50 per cent of the total tax burden was borne by recreational facilities, largely cot-

[23] Data obtained from surveys made by the author. Reports of some of these surveys are on file with several Michigan state commissions but are not in published form.

[24] Wilbur O. Hedrick, "Recreational Use of Northern Michigan Cut-over Lands," *Special Bulletin* 247, *Agricultural Experiment Station,* Michigan State College, East Lansing, Michigan, 1934, pp. 51–55, 60.

tages and resort hotels. These figures are presented to show how important recreation may be to a locality even in terms of its tax rolls.

New construction of cottages and other recreation properties since 1931 has increased materially the percentage of the tax roll carried by recreational property in northern Michigan. For example, in Forest Home Township in Antrim County, 15.7 per cent of the tax load was on recreational lands in 1931, but had increased to 52 per cent of the total by 1946.[25] Less than three per cent of the area in this township was carrying 52 per cent of the tax load. It should be mentioned that there had been no reduction in taxation on other types of property and that this township has little or no waste or unutilized land in it.

Cottages represent one of the most stable forms of the recreation business. They involve a long-time investment, they bring a definite number of visitors to the area each year, and they help to support the local community by providing a market for goods and services, as well as bearing a fair share of the local taxes. The same can be said for resort hotels.

Some summer colonies are operated as clubs, drawing their members from the same community and strata of society. These developments are very similar to resort associations of cottagers.

RECREATION CLUBS

The name "recreation club" is here used to connote a resort and hunting club which in its origin is little more than a real estate promotion scheme. Enough of them have survived in spite of the nationwide financial depression of the 1930's, to involve several hundred thousand acres of land that might otherwise have been either abandoned or absorbed in some governmental project. The basic plan of most of these clubs is for the promoters to acquire several thousand acres of land (usually 10,000 to 20,000) in an undeveloped area, but within one or two days of easy driving from large population centers, and then to organize a club. A clubhouse is constructed and possibly a number of cottages. Memberships are sold, giving privileges to use the clubhouse and the cottages for a week or two each year, to hunt and fish on the club's land, and to buy a lot and have the club build a cottage for that member's exclusive use. Fundamentally, the idea is to sell some of the land at subdivision prices and hold the bulk of the land as bait to get more members. The original cost of the land is very low, and, if enough members join and buy lots, the project may pay the promoters very well. They usually expend some of the dues to provide reasonable fire protection and possibly to stock the streams with fish.

This is one way to keep on the tax rolls large acreages of land and at the same time have private interests maintain good fire protection and forest management policies. However, from the member's standpoint, he could get most of the benefits and privileges he obtains here from the average resort development or in the national forests and not have to pay dues or membership fees.

ORGANIZED CAMPS

Organized camps require the same general resources that summer cottages and hotels do. The use of the land is the same as in any resort area. They act as a force

[25] *Ibid.* The 1946 figure is from unpublished data gathered by the author.

encouraging physical well-being, as the youth of the country are being trained in these camps to appreciate outdoor recreation. They are doing much to build up a future demand for recreational resources. An astonishing number of camps can afford to advertise in magazines with a national circulation, such as *Harper's* or *Cosmopolitan.* Many of the directors of physical education in our high schools operate summer camps. Such organizations as the Y.M.C.A., the Y.W.C.A., luncheon clubs, chambers of commerce, Scout troops and numerous other organizations sponsor summer camps. No estimate is available of the total investment in such properties or the area of land involved, but it is sufficiently large to merit consideration in evaluating the recreational use of land.

TOURIST CAMPS FOR RECREATIONISTS

Mention should be made of types of land-use that are minor in area, but very important in some phases of the recreation industry. These are tourist camps, roadside picnic grounds, lodging houses, and tourist inns. They do not involve large areas of land, either for the individual establishments or in total, but they provide necessary facilities for some classes of recreationists.

The tourist camp has exhibited a marvelous transformation in the period since 1933. At that time no community was complete without a public campground where visitors could pitch their tents. Today, the majority of these campgrounds have either been abandoned or are no longer kept up since the traveling recreationist demands another type of accommodation. The tourist taste in accommodations has shifted from tents and campgrounds to overnight cabins except for the use of cabin trailers which has been accelerated since the close of World War II.

How strong this will be no one can foresee. The use of trailers as temporary homes during the war near all industrial centers has educated millions to their use and has created a boom for the companies making them. In Florida some communities have special accommodations to take care of as many as 3000 trailers in a single trailer park. Generally, throughout the south the trailer is popular. The state parks in Michigan have had to build trailer stalls in the parks that permit overnight stops. During the war years and continuing to 1947, most of the spaces in trailer parks near cities have been occupied on a semipermanent basis by individuals who have had to utilize trailers as homes because of the housing shortage. As a result tourists with trailers have had a difficult time finding places where they could park their trailers.

From a land utilization standpoint, the trailer makes less use of land and permanent installations than do other forms of accommodations. The owner of a cottage is assessed for taxation on both the land and the building, and, furthermore, the property may last a lifetime, whereas the trailer can be placed on a small part of a trailer park and occupies little land area. The owner of the trailer may never return again to the area so that the trailer does much less than a cabin or cottage to create permanent values.

The overnight cabin, the motor court, and the motel have been developed on a profitable basis since 1925 when those phases of the tourist industry were in their infancy. There were about 20,000 motor courts and motels in the country in 1947 with about 440,000 rental units.[26] The *Tourist Court Journal* estimates that from 8000 to 10,000 new modern courts averaging 50 rental units each would be built between 1947 and 1952.[27] The bulk of the better motor courts and motels are located at the outskirts of cities and towns from Maryland south to Florida, west to southern California, and along the Pacific coast to the Canadian border. The capital investment in some motels runs over a million dollars, and very few motor courts or motels have been developed for less than $25,000. Standards for equipment, service, and operation have risen steadily so that about 38 per cent of the motor travelers questioned in 1946 indicated a preference for this type of overnight accommodation. In January, 1947, one California motor court operating 210 rental units and several restaurants in connection with the establishment had 151 employees and a payroll of $23,895.[28] The owners of this establishment have refused twice to sell for $1,500,000. This gives some idea of the investment, employment, and volume of business activity represented by a tourist court.

The overnight cabin either alone or operated as a small motor court is widely distributed. There is no estimate of the number of cabins or operators for even a single state, much less for the country as a whole. The overnight cabin represents supplementary income for hundreds of thousands of individuals throughout the country. If business becomes brisk enough and adequate capital can be obtained, the owner may develop a motor court. Most of the overnight cabins are equipped for housekeeping which reduces the over-all expense of travelers as they can prepare their own meals. Considerably more land is utilized by a group of cabins or a motor court than is used by a city hotel to accommodate the same number of people.

Roadside picnic grounds do not account for any appreciable acreage and usually utilize small strips of land acquired with the road right-of-way. Their value lies in alleviating the trespass problem by providing a comfortable and attractive place for picnickers to stop.

GOLF COURSES FOR RECREATIONISTS

Although all the golf courses in the country do not occupy a large acreage as compared to national forests or national parks, they do utilize a large enough area to be included in any discussion of recreation from the land-utilization standpoint. Possibly more than a million acres are devoted to golf courses. From the standpoint of man-days of use, golf courses deserve a high rank among our recreational lands. Also, most courses pay their own way as private clubs, contributing taxes for the support of the local governments. The fundamental idea of recreation land is human enjoyment, and, judged on this basis, golf courses should be ranked at present as one of the more important types of this land-use.

URBAN PARKS

Establishment of a Belated Movement

Practically all the cities of 100,000 population or more have park facilities, but, with the exception of a very few cities, these

[26] A. J. Cutting, "The Courts Are in Session," *Motor News,* June, 1947, Automobile Club of Michigan, Detroit, Michigan.

[27] *Ibid.*

[28] Frank J. Taylor, "Just What the Motorist Ordered," *Saturday Evening Post,* July 5, 1947.

facilities are not adequate. Even where there is an adequate area in parks, the parks are not well located to serve the people. All our cities are relatively young, and for most of them the period of great growth has been since 1900. If the American people had been alert to the fundamental need for recreational space, adequate, well-located park space could have been set aside. Unfortunately, the real demand for park areas on the part of the public has come since 1920, after the more desirable sites had been given over to other uses. A few notable examples of foresight in regard to recreation sites would include: Lincoln Park and the Midway in Chicago, Central Park in New York City, Audubon Park in New Orleans, and the Zoological Park in St. Louis.

Most cities in the United States of 100,000 population or more are located either on a river or lake, but either industry or transportation has been given first choice in the better recreational sites and have been entrenched there so long that it is virtually impossible to recover land for badly needed recreational facilities. Pollution of waters with industrial wastes and city sewage has made rivers undesirable for recreation, and railroads have utilized the easy routes along their banks. Industry has occupied the sites undesirable for homes or business along the lowlands near the rivers which were especially desirable because of nearness to the transportation routes. The public callously stood by or actually encouraged the industrial use of this land, not realizing that it was giving away its birthright. Any foresighted individual objecting to the utilization of the water frontage for transportation or industry, and foolish enough to raise a protest, was looked upon as a menace to the city's progress and was ridiculed and condemned.

Almost any American city that the reader can mention is an example of this principle of giving transportation and industry the first choice of the water frontage. A few random examples would include Seattle, Portland, Oregon, San Francisco, New Orleans, Tampa, St. Louis, Kansas City, Denver, Minneapolis, Duluth, Detroit, Buffalo, Pittsburgh, New York, and Philadelphia.

The few exceptions to this rule are found in nonindustrial cities like Miami, St. Petersburg, and Atlantic City. In each of these cities, the main business is catering to recreationists, and ready access to the water is desired.

Lake and River Front Parks

At great expense and with much labor Chicago has provided itself with a lakefront park in the heart of the city. This has been accomplished by creating a new shore line by filling in part of Lake Michigan. The new land lies between the railroad lines and the lake, and has brought into being several thousand acres of land now used as a park and several miles of lake frontage. Most cities have neither the physical sites to permit such a project nor the financial resources to pay for it. The other recourse to obtain frontage already used for other purposes than recreation is to buy it, but that involves costs beyond the means of most urban communities. In addition, the question is raised of the practicability of devoting vast sums of public money to a use the results of which cannot be measured directly in dollars and cents.

Urban Marginal Parks

The general practice in our larger cities is to acquire large acreages for park purposes at their outskirts where land can be purchased at a nominal cost and where structures do not have to be removed. Some cities have even gone beyond their corporate limits in acquiring park lands. Chicago has a number of forest preserves located in Cook County, outside the city limits; Detroit has a zoological park and a golf course located in an adjoining county, as well as the large new River Rouge Park, extending for several miles along its western border. Several other cities, including San Francisco, New Orleans, and St. Louis, have new parks on their outskirts. These large parks usually provide several types of facilities: golf courses, tennis courts, baseball diamonds, football fields, bridle paths, and outdoor theatres, as well as expanses of lawn, shrubbery, and forest.

The Urban Playgrounds

Another type of recreational use of land in the cities is the playground, usually located adjoining the school. As individual playgrounds only a few acres are involved, but as a group they embrace many thousands of acres. Unfortunately, most of them are too small and should be enlarged, but the high cost of land and the buildings that would have to be razed practically prohibit much expansion in area. Here, again, is a fine example of our short-sightedness. Sooner or later most of these playgrounds will need to be enlarged, for children need to be kept off the streets, and, as these playgrounds are located in the neighborhoods in which the children live, they will be fully used.

The Problem of Golf Courses in Urban Parks

The demand for public golf courses has further complicated the urban park problem because a golf course requires a relatively large acreage. These have been constructed either in large existing parks or in new parks at the outskirts of the city. Lansing, in central Michigan, has four public golf courses. In addition, three privately owned courses are open to the public at very low green fees. Here is a city of 100,000 people, the majority of whom are factory workers and their families, supporting seven golf courses by very nominal green fees. In addition, there are two private clubs taking care of those who desire club membership and more privacy. This example shows the number of golf courses that can be supported by an industrial population of this size. There is a decided lack of such facilities in most of our cities. Many more public or quasi-public courses are needed throughout the country.

Municipal and county parks had an estimated attendance of 600,000,000 in 1938.[29] Data on these types of parks are very spotty. The National Recreation Association of New York City has found that many local officials do not answer questionnaires that have been distributed to secure accurate data for a nationwide survey. The following data for 1940 give some idea of the importance of municipal and county parks: 1465 cities out of 3464 cities and towns of more than 2500 population reported 444,000 acres in parks, 1031 cities reported a total value of parks at $1,654,000,000 which averaged $4685 per acre reported, 909 cities reported 28,228 year-around employees, 1056 reported 24,666 seasonal workers, and 1367 cities expended $83,000,000 on their parks in 1940.[30] A total of 779 county

[29] *A Study of the Park and Recreation Problem of the United States,* National Park Service, U. S. Department of the Interior, Washington, D. C., 1941, p. 49.

[30] George D. Butler, "Municipal and County Parks in the United States," *National Recreation Association,* New York, 1940, pp. 1, 9, 25, 37, 49, and 56.

parks contained 197,000 acres, 138 counties reported expenditures of $12,000,000, and 109 counties valued their parks at $183,-829,000.

Inadequacy of Urban Recreational Facilities

In spite of the splendid efforts made by a few of our large cities to provide a sufficient area in parks and playgrounds during the middle 1920's, they are still very inadequately supplied. We have turned our best recreation sites, those that are well located in the urban areas, over to other uses and in some instances damaged them beyond repair. The misuse of a natural resource stands out vividly here. Today we have the need for these resources but are in a poor position to make them available to the public except at unjustifiably great expense. We can provide parks, but they are not located where they will receive the maximum use or serve the public best. Drives are staged regularly to clean up the river fronts or lake fronts of our cities, but usually the efforts fall far short of their objectives. Possibly the best example of success along this line is a portion of the river bank at Minneapolis. It is hoped that these periodic drives to clean up what is left of the river frontage in many of our cities not only will be continued but will yield real results as the public becomes better informed and demands better recreational facilities. There is still enough frontage within city limits to be worth saving, and it is hoped that it will become worth-while recreational land instead of an eyesore as it is in many cities.

MISCELLANEOUS CONSIDERATIONS

From 1934 to 1939 emergency agencies of the federal government expended over $1,000,000,000 for recreational facilities and improvements.[31] The Work Projects Administration to January 1, 1939, accounted for $681,000,000, and the Civilian Conservation Corps for over $300,000,000. These funds were in addition to normal allocations from the federal, state, county, and municipal governments. The National Park Service was consulted in the expenditure of these funds so that the publicly financed recreational areas had greatly improved facilities at the beginning of World War II.

Touring has become a major recreation for Americans. In 1936, 40,000,000 Americans took automobile trips of a week or more in length, and in 1941, approximately 53,000,000 took pleasure trips of varying duration.[32] The competition between resort operators and others interested in serving the traveling public is exceedingly keen, and every effort is being made to attract business. In addition to the advertising funds supplied by the actual operators, the majority of the states have a substantial travel-promotion appropriation. The amounts vary from $5000 to $500,000 annually, averaging $90,000 per state.[33] State governments are sufficiently interested and concerned in the continued well-being of the recreation industry within their borders to be willing to spend taxpayers' money to help promote this industry.

Every year thousands of families take up residence in their summer cottages. In the

[31] *A Study of the Park and Recreation Problem of the United States,* National Park Service, U. S. Department of the Interior, Washington, D. C., 1941, p. 94.

[32] Don Short, Travel Editor, *New York Journal-American, Proceedings Annual Membership Conference,* National Association of Travel Officials, Duluth, Minnesota, 1944.

[33] *Idem,* Research Committee Report, 1945, p. 34.

mountains, in the northern woods, and at the seashore, these regular residents give a stability to the recreational industry. Many of them are content to enjoy the quiet of a peaceful and unhurried vacation. They become taxpayers and as a consequence take a protective interest in recreational facilities.

CONCLUSION

In the foregoing pages an effort has been made to show the characteristic uses of recreational land. This classification of the different types of recreational lands is not intended to be all-inclusive but suggestive to the reader. The comments are made with the hope of stimulating further interest in this phase of conservation and of showing the magnitude and importance of outdoor recreation in our society. It is impossible to estimate the actual amount of damage already done to recreational lands by mismanagement or utter failure to manage the land. However, we still have adequate resources for the recreational needs of our people except in the cities and more densely settled rural areas. The really important need is to make the existing resources available to the people. Since the early 1920's great progress has been made, and it must continue at an accelerating rate. Lands now available and suitable for recreation should be acquired before they are taken over for less worthy purposes.

The student of land use may find numerous suggestions for research problems in the foregoing pages. Accurate and detailed information is lacking for nearly every topic discussed. Until more information of an inventory nature is assembled, it will be difficult to know fully the extent to which our recreational resources have been utilized at present or the real needs of the future. The present trend for shorter hours of labor in industry and business and a limited number of working years for most of our citizens is forcing leisure time on many people so that they will have more time to indulge in outdoor recreation. The demands on our recreational lands have just begun. Adequate plans for the future need to be formulated now while we still have vast resources in the form of reserve recreational lands that have not been utilized for other purposes.

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CHAPTER 21

The Conservation of Man

OUR MAJOR CROP

THE greatest of America's resources is in many ways the most neglected. We have long had accurate information as to the average size of litters among the main varieties of swine, but we still have only approximate knowledge as to how large the families are in each economic, social, and educational class of human beings. We know with considerable certainty what kind of lambs will result from any given mating, but we can only guess the kind and value of the children born to any given pair of human parents. We raise steers that provide the best beef with the least food, but we cannot produce a human community in which honesty, industry, intelligence, self-control, altruism, artistic appreciation, and a sense of social responsibility prevail among the great majority.

Such ignorance seems almost incredible when we consider the cost of rearing the children of each generation. Our children are a sort of crop. The harvest begins when a child becomes a full-time worker, at the age of 18, let us say. The children born in the United States numbered 2,070,000 in 1932 and 3,440,000 in 1946. The number varies from year to year, and eight or ten per cent die before reaching maturity. For the sake of convenience, let us assume that from 1950 to 1970 approximately 2,500,000 young people will reach the age of 18 each year. They are our annual human crop, ready for harvest.

The Cost of Rearing Children

Dublin and Lotka of The Metropolitan Life Insurance Company have carefully estimated the cost of producing this valuable crop. Table 1 is based on their esti-

TABLE 1

COST OF AN EIGHTEEN-YEAR-OLD YOUNG AMERICAN *

[Adapted from Dublin and Lotka, *The Money Value of a Man*, N. Y., 1946, 2nd Edition.]

1. Cost of birth, including physician, hospital, nurse, etc.	$ 420
2. Food	3,185
3. Clothing	995
4. Shelter (the child's fair share of rent, etc.)	1,966
5. Education, mainly at public expense	1,795
6. Household expenses (child's proportional share)	1,740
7. Health (partly at public expense)	420
8. Recreation and transportation (partly at public expense)	1,576
9. Miscellaneous	457
Total	$12,554

* The figures here given are 40 per cent higher than those of Dublin and Lotka, which were based on an annual income of $2500 and on the prices prevailing in 1935–1936. The increase is made in order to bring the data into better accord with the prices and national income prevailing after World War II.

By the late Ellsworth Huntington of Yale University.

mate of what it costs to bring a child into the world, and feed, clothe, protect, and educate it up to the age of 18. The figures are based on a family income which reaches $3500 during the father's most productive period. A family with such an income may begin with only $1500 and end with little except help from our social security system. As thus interpreted, Table 1 is near enough to the national average so that we may use it to illustrate our faulty system of human conservation.

According to this table, the 2,500,000 young people who reach the age of 18 each year have cost the country at least $30,000,000,000, equivalent to a fifth, more or less, of our normal national income. To this large sum we must add something to represent the part played by mothers in producing, feeding, and training their children. If we include reasonable pay for the mothers, the real cost of bringing up an average child must be considerably greater than we have estimated. An 18-year-old boy or girl is evidently a most valuable young animal, worth as much as a hundred young cows or horses. One would expect any sensible community to make sure that every such animal was kept in perfect health, was trained with the greatest care, and was of good stock to start with.

TABLE 2

HUMAN REPRODUCTION ACCORDING TO OCCUPATION

[Source: U. S. Census, 1940.]

Occupation of Husband	*Per Cent of Population*	*Children under 5 Years per 1000 Wives under 50 Years of Age*
1. Farm laborers	3	722
2. Other laborers (except in mines)	4	686
3. Farmers	14	577
4. Factory operatives, etc.	20	537
5. Skilled workmen, foremen, etc.	17	421
6. Professional and semi-professional	7	388
7. Service workers	4	384
8. Clerks, salesmen, etc.	14	367
9. Businessmen, managers, officials, etc.	11	321

SOCIAL CONDITIONS OF THE HUMAN CROP

The Size of Families

The human crop comes largely from social groups that have large families. The size of families varies greatly according to the father's occupation (Table 2). Laborers and farmers have many children; white collar workers have few. In rural areas farm laborers (line 1 in the table) have 25 per cent larger families than the farmers who hire them (line 3). In urban areas laborers (line 2) have 114 per cent more children per family than businessmen (line 9). Differences of this kind are incompatible with the most effective human conservation. Such conservation must aim at preserving and improving two kinds of qualities—those that people possess as the result of biological inheritance and those derived from cultural environment. Therefore, human conservation has two fundamental requirements. One is the long, slow process of altering the birth rates of the various classes of society so that the nation will have the greatest possible number of children with a good biological inheritance both physically and mentally. The other is the more immediate work of seeing that every child grows up under really good conditions of health, home training, and general education. These two requirements are met by some families in each of the nine groups of Table 2, but that fact alone has little significance. We need also to know what percentage of each occupational group is of this desirable kind. Unless the percentage among farmers and laborers is higher than among the white-collar groups numbered six to nine in Table 2, the United States is by no means practicing a wise policy of human conservation.

The imperative need of human conservation is shown with special clearness in Table 3. We are sometimes told that

TABLE 3

INTELLIGENCE RATINGS AND SIZE OF FAMILY BASED ON THE INTELLIGENCE QUOTIENTS (IQ) OF 4330 CHILDREN COLLECTED BY LENTZ IN AMERICAN CITIES

[Source: Lorimer and Osborn: *Dynamics of Population*, p. 196.]

Intelligence Quotient	*Quality of People*	*Percentage of Measured Children*		*Children in 100 Families*	
60–69 (under 60 omitted)	Feeble-minded	4		540	
70–79	Morons	10	32	530	503
80–89	Dull and backward	18		480	
90–99	Lower average	21	41	420	398
100–109	Higher average	20		355	
110–119	Somewhat superior	13		345	
120–129	Distinctly superior	7		310	
130–139	Highly superior	4	27	300	318
140–149	Extremely superior	2		250	
150 and up	Suggesting genius	1		220	

superior people have inferior children, whereas geniuses often are born in stupid families. Both of these conditions occur sometimes, but repeated investigations prove beyond question that among the children born in families of superior intelligence (27 per cent in Table 3), the proportion showing unusual ability and strength of character is far greater than among those born in families of the feeble-minded, moron, and dull types (32 per cent in Table 3). Although we cannot yet determine how much of the difference between these two types of families is ascribable to biological inheritance and how much to training and opportunity, it seems certain that the superior types ought to have at least as many children as the inferior types instead of not much more than half as many.

Education of Parents and Size of Family

A division of the population on the basis of education likewise indicates that our present system of differential birth rates fails to conserve many human values. Table 4 is based on all native white women

TABLE 4

FAMILY SIZE AND EDUCATION OF NATIVE WHITE WOMEN

[Source: U. S. Census, 1940.]

Amount of Schooling	*Percentage of Women*		*Children per 100 Women*	
1–4 years of grade school	5		430	
5–6 years of grade school	10	27	370	363
7 years of grade school	12		330	
8 years of grade school	28	46	290	270
1–3 years of high school	18		240	
4 years of high school	16		180	
1–3 years of college grade	7	27	170	169
4 or more years beyond high school	4		120	

aged 45–49 years. The decline from 430 children per 100 families where the mothers had less than five years of schooling to only 120 where the mothers have studied four years beyond high school is truly startling. Part of the decline is due to differences in rates of marriage and sterility. In 1940 among native white women aged 45–49 who had had only one to four years of schooling scarcely 4 per cent were unmarried and 14 per cent childless. Among college graduates of the same age 30 per cent were unmarried and 49 per cent were childless. Among women born since 1895 the contrast between the educated and uneducated has diminished somewhat, but it is still alarmingly large. Women who do not finish grade school have twice as large families as those who finish high school. Even if there were no difference in heredity between these two groups of women, there surely is a great difference in their fitness to train children. The early training given

by mothers is universally recognized as of supreme importance in forming children's character and preparing them for later achievements. It can scarcely be doubted that, on an average, mothers who have gone through high school train their children better than those who do not finish grade school. From the standpoint of human conservation the habits illustrated by Table 4 are amazingly foolish.

Still other data re-enforce this disquieting conclusion. Table 5 shows that the quarter

TABLE 5

All Children Born to Native White Women Aged 45–49 Years in 1940 Compared with Rental Value of Home

[Source: U. S. Census, 1940.]

Monthly Rental Value of Home	*Per Cent of Total*		*Children per 100 Women*	
Under $5	7		450	
$5 to $9	11	29	393	383
$10 to $14	11		331	
$15 to $19	10		293	
$20 to $29	19	44	252	249
$30 to $39	15		215	
$40 to $49	9		190	
$50 to $74	11	27	175	181
$75 to $99	3		171	
$100 or more	4		185	

or more of our people who live in the poorest homes have families about twice as large as the quarter living in the most expensive homes. The poorest quarter of the people in the United States produce more than twice as many children as the richer half. Here, just as in our study of education, it should be noted that our data include unmarried women and childless married women, as well as those who have children. Among both the richer and the better educated in our population, which to a considerable extent are identical, there are many more unmarried women and childless married couples than among the poorer and less well educated. Such a condition arises partly from deliberate choice, partly from preoccupation with matters outside the home and the family, and largely from late marriages. It does not appear to be due to any lack of innate physiological ability to produce children, although the mode of life among the rich may tend toward such disability in later years.

Late marriages systematically reduce the birth rate. They also increase the average length of a generation, thus diminishing the rate of natural increase to a degree that is rarely realized. Suppose that at the ages of 18, 20, and 22 an uneducated woman bears daughters. These survive and follow their mother's example, as do their daughters in turn. When the woman reaches the age of 74 she will have 9 grandchildren, 27 great-grandchildren and three great-great-grandchildren. Another woman, highly educated, postpones marriage so long that her three daughters—if by rare chance she has so many—are born when she is 33, 35, and 37 years of age. Her daughters behave likewise. When she is 74 she will have 9 grandchildren, but there will be no children to match the other woman's 30 great- and great-great-grandchildren. Although this illustration is extreme, it emphasizes a most important point. Because of delayed marriages, the contrasts among groups that differ in occupations, intelligence, education, and economic status are really much greater than appears in the tables. It is often and truly said that one-third of the present population produces two-thirds of the children. A better idea of the conditions of human conservation is gained from the statement that, if the present differential birth rates continue, a quarter of the people now living will be the ancestors of at least three-quarters of the people fifty years hence.

The lowest line of Table 5 gives a hint of an interesting change. It indicates that the most prosperous 4 per cent of our families have slightly more children than the 14 per cent who come next in the scale of prosperity. Studies of the graduates of Harvard, Yale, Princeton, and other colleges point in a similar direction. They indicate a higher birth rate among people who achieve much than among those who achieve little. The Yale data are especially significant. The members of three classes that had been out of college more than 25 years were classified by several of their classmates according to their success in making themselves useful members of society.[1] Then they were divided into ten groups according to their average ratings on the scale of usefulness. The number of children per man in each group was next ascertained. The least successful tenth had the fewest children, and the size of the families increases steadily from the least to the most successful tenth. Unfortunately, even the most successful group does not have enough children to replace itself from generation to generation. Nevertheless, if the tendency for successful and useful people to have larger families than the less successful should increase, and should prevail among all classes, it might become of primary importance in human conservation.

An equally important and opposite tendency at the other end of the scale may perhaps be promoted by such events as the phenomenal improvement in the economic situation of American miners during and after World War II. In less than ten years their average wages rose from less than $15 to $65 per week. According to the normal pattern the miners' new prosperity ought to result in a decline in the size of their families, which have hitherto been extremely large. If these two opposed tendencies persist long enough, the contrasts in all our tables will diminish and perhaps disappear. Progress in this direction will be desirable regardless of whether the differences between miners or laborers and successful high school or college graduates are purely cultural or are also biological. No one class of society ought to produce most of the children unless we discover that a single class is really the one best fitted for parenthood.

[1] Ellsworth Huntington and Leon F. Whitney, *The Builders of America*, p. 253.

THE GEOGRAPHY OF THE HUMAN CROP

Regional Differences in Birth Rates

The production of the human crop shows strong contrasts geographically as well as economically and socially. Figure 1 indicates how far the number of white children born in each state departs from the number needed to maintain the population unchanged from generation to generation. It is based on the Census Bureau's estimates of the birth rate after allowance for such conditions as the tendency for young unmarried women to congregate in cities. In Fig. 1 the number 120 (South Carolina) means that a generation hence, if there is no migration, the population will have increased 20 per cent, whereas 80 (California) means a decline of 20 per cent. The human crop is evidently coming in very diverse degrees from different parts of the United States. In proportion to its population, West Virginia (144) produces twice as many children as New York State (71). If these rates of reproduction should continue for a century, the population would increase threefold in West Virginia and diminish by two-thirds in New York. The increase in births from 1932 to 1947 has reduced the geographical contrasts in birth rates, but their general character has not changed. Although Fig. 1 is based on births from 1935–1940, it represents a condition that is not likely to disappear for a long time.

Because of the differential birth rates, the quality of the population of the United States during the next half century will depend more and more upon persons born in the south (the heavily shaded parts of Fig. 1), the Rocky Mountain states, and a far northern strip from North Dakota to Maine. Young people already born in those regions, or who will be born there in the next decade or two, are practically certain to migrate in large numbers to the manufacturing sections in the east and to the Pacific coast, which contain about half the country's population. The leadership of the United States in industry, commerce, and world affairs is bound to be greatly influenced by the quality of the surplus population that comes to industrial sections from other parts of the country.

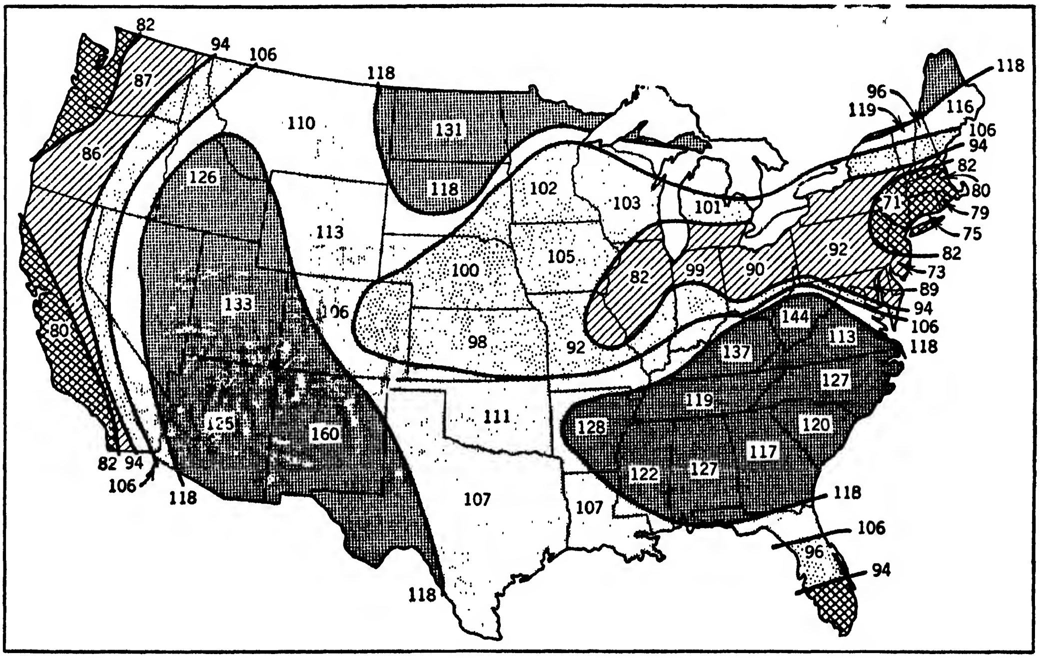

FIG. 1. Adjusted net reproductive rate of white women, 1935–1940. (Based on report of the Census Bureau.)

Differences between Urban and Rural Communities

Urban and rural communities provide another type of geographical contrast in birth rates. In each state shown in Table 6, and in practically all others, there is an almost regular increase in the number of children compared with the number of women as one goes from the largest cities to smaller ones and then to the villages and farms. In order to equal the birth rate of

TABLE 6

CHILDREN UNDER FIVE YEARS OF AGE PER 100 WHITE WOMEN AGED 20–44 YEARS

[Source: U. S. Census, 1940.]

	Louisiana	*Michigan*	*Pennsylvania*	*California*
Cities over 400,000	278 *	414 †	336 ‡	280 §
Cities of 100,000–400,000	...	410	359	310
Cities of 10,000–100,000	311	406	346	316
Cities of 2,500–10,000	407	507	376	431
Rural nonfarm (villages)	547	595	515	491
Rural farm	680	666	581	568

* New Orleans.
† Detroit.
‡ Philadelphia and Pittsburgh.
§ Los Angeles and San Francisco.

the farms the city birth rate would have to be multiplied by 2.4 in Louisiana, 1.6 in Michigan, 1.7 in Pennsylvania, and 2.0 in California, and by similar figures in other states. Among Negroes the contrast in the birth rate in cities and on farms is greater than among white people. Everywhere the birth rates in the larger cities are so low that, if there were no migration and the rates of marriage, sterility, and death remained as now, the cities would decline rapidly in population, whereas the rural districts would increase.

The extent to which the cities recruit their numbers from the rural districts may be judged from the relative growth of the two types of areas. Between 1920 and 1930 the native white population of the cities (all towns with 2500 or more inhabitants) increased by 12,000,000—that is, from 40,000,000 to 52,000,000. The corresponding farm population decreased by nearly a million, dropping to less than 24,000,000. The rural nonfarm, or village, population increased by only 3,000,000, and in 1930 was under 20,000,000. All this means that among the native white population at least 10,000,000 people—a yearly average of 1,000,000—came to the cities from the rural districts, especially from the farms. In 1930, one person out of five in our cities was a gift, so to speak, from the villages and farms.

The financial depression which began with the crash of 1929 checked and even reversed the cityward tide for a while, but after 1934 the old tendency reasserted itself. During World War II the contribution of the rural districts to the cities became much more than 1,000,000 persons each year. Left to themselves without recruits from elsewhere, the cities would today have much less than the 40,000,000 native white inhabitants that they had in 1920—certainly no more than 35,000,000. Yet actually they have more than twice this number. Foreign immigration has contributed only a little to this increase. Most of it has come from farms and villages, especially those of the south, the Rocky Mountain states, and the far northern strip from North Dakota to Maine.

THE CULTIVATION OF THE HUMAN CROP

In some respects great progress has been made in the conservation of human resources. The marvelous improvement in the cure and prevention of disease is well known. A classic example is the reduction of the annual tuberculosis death rate from about 250 per 100,000 persons in 1910 to only 35 in 1947. During this same period diphtheria, which in 1910 took 80 lives per 100,000 children, almost disappeared. Education has also made progress. Children seem to be trained more wisely now than in the old days of severe repression and cruel punishment. We recognize that each stage of a child's development needs its own particular form of training. Other methods of improving and conserving our human resources include the clearing of slums, the spread of social welfare work, the improvement of government, the ministrations of religion, the care of defectives, the movement to do away with war, and the spread of saner ideas as to diet, exercise, and sex. Such activities and attitudes indicate that the problem of human conservation receives much constructive attention.

In spite of this good record, the efforts devoted to both health and education are pitifully small and badly distributed. In 1946 Americans devoted almost as much time and effort to supplying the country with tobacco as to teaching their children. Less than 1,000,000 schoolteachers worked for the children about nine months of the year. Approximately 500,000 farmers made tobacco their main cash crop; another 100,000 persons were engaged in making cigarettes and other tobacco products; uncounted hundreds of thousands spent part of their time in transporting or selling tobacco products. Including taxes, the cost of such products amounted to $3,700,000,000. And what did we pay for the education of our children in elementary and secondary schools? Less than $3,000,000,000 in 1944, but increases in the post-war years brought education into parity with the tobacco industry. And many taxpayers strenuously object to further taxation for schools!

Progress in Medicine

As for health, World War II showed that one-third of our young men were so handicapped physically or mentally that they were rejected for ordinary military service. About one-sixth of the rejections were due to easily remedied defects such as bad teeth or poor posture, but more than one-third arose from emotional instability—psychoneurosis. The physicians tell us that most of the minor physical ailments of the men in the draft, and many of the major disabilities, would never have existed if all our children had been properly fed and had received good medical and dental care from infancy onward. The psychologists say that the greater part of the varied mental and nervous defects that go under the name of psychoneuroses might likewise have been avoided if children had received firm, affectionate, intelligent care in early childhood.

Most children are born with the capacity of becoming healthy, efficient adults if rightly cared for, but we fail to give them the necessary care. The amount spent to preserve their health is distressingly small. According to the estimates of Dublin and Lotka (Table 1) the cost of medical care for 2,500,000 children up to the age of 18 is $1,050,000,000. Another way of estimating this cost is seen in Table 7 based on the work of Dr. L. S. Reed in the United States Public Health Service.[2] The total pay-

[2] Dr. Reed's original table is based on the year 1940. In order more nearly to represent conditions as they now are, his figures have been increased by 40 per cent.

TABLE 7

THE ANNUAL COST OF MEDICAL CARE IN THE UNITED STATES

Physicians ($1,500), dentists ($475), other practitioners ($170)	$2,145,000,000
Nurses in private duty; graduate ($205), practical ($85)	290,000,000
Hospitals (including payments to doctors and nurses)	1,235,000,000
Drugs ($940), supplies ($60), glasses ($105)	1,105,000,000
Organized services; public ($250), private ($55)	305,000,000
Total	$5,080,000,000

ments to 170,000 physicians, 70,000 dentists, and 360,000 nurses, and for all our hospitals, drugs, eyeglasses, and health services by governments, factories, universities, military organizations, and so forth, is $5,000,000,000. Persons aged 18 years or less form about 40 per cent of our population, but we spend relatively little to preserve their health. If we assume that, on an average, their medical expenses are half those of older people, we again get $1,000,000,000 as the total annual cost of preserving the health of our children. The sum of $1,000,000,000 for the health of children looks painfully small compared with the $8,770,000,000 that we spent in 1946 for alcoholic drinks. Incredible as it may seem, the net result is that we, who claim to be the most advanced of nations, spend approximately three times as much on tobacco and alcoholic beverages as on educating our crop of children and keeping them in good health from infancy to maturity.

Human life might be conserved by a forceful and effective drive against accidental death. It is particularly important that children, young people, and people in their middle years be saved from crippling and fatal accidents. The death of people over 65 years of age from accidents is particularly high, especially from accidents caused by motor vehicles and from falls. A serious accident to an old person may bring to an end a highly useful life but the loss to society is not so great as that of a young person entering on a productive career.

The chances of meeting death by accident are much greater for the venturesome male than the female. In 1946 fatal accidents among white males was 2.3 times that of white females.[3] The male from birth to the age of 75 runs the greater risks not only because he is more venturesome but also because his occupations generally are more hazardous than those of the female.

The motor vehicle is one of the chief causes of accidental death. In 1947 exactly 100,000 people suffered fatal accidents, and nearly one-third were caused by motor vehicles. In 1933 the deaths caused by motor vehicles numbered 25.0 per 100,000 population. In 1947 the rate was 22.5 per 100,000. In the same period the number of deaths per 100,000,000 vehicle miles declined from 16.2 to 8.6.[4] Human life can be saved if fatal automobile accidents can be greatly reduced.

Progress in Education

The geographical distribution of our expenditures for both education and health is almost as faulty as their small amount. Where children are born in largest numbers, the payments for both purposes are least. If the birth rates indicated in Fig. 1 were to continue, the white population

[3] "Fatal Accidents and the Venturesome Male," *Statistical Bulletin,* Metropolitan Life Insurance Company, Vol. 30, 1949, pp. 6–8.

[4] Data from *Accident Facts,* 1948 Edition, National Safety Council, Chicago, 1948.

of the ten southern states that are most heavily shaded would increase about one-quarter in each generation. The colored population would increase still more. According to Fig. 2, the average expenditure on each child in the schools of these same states is only $69. In the ten states where the families are smallest—so small that there would be a natural decline of one-fifth if present conditions continued for a generation—the expenditure is more than twice as great. In the United States as a whole, relatively low expenditures for education prevail in essentially the same Rocky Mountain, southern, and far northern regions (Maine) where the birth rate is high. New York and New Jersey spend three or four times as much per pupil as Mississippi, Alabama, and Arkansas, and more than twice as much as Maine.

If we consider only the white population, all the southern states rank somewhat higher than in Fig. 2, but the general appearance of the map is not changed. Virginia alone receives a darker shading than at present. Nevertheless, Negro education is dangerously neglected in many states. The amount spent per white child in 1944 was approximately twice as great as per Negro child in Arkansas and Florida, three times as great in Alabama, Georgia, Louisiana, and South Carolina, and six times as great in Mississippi. Many Negroes migrate away from these states. Their poor education is, therefore, a detriment to large parts of the country. The white people of the south say truly that they are poorer than those elsewhere and cannot afford good education for their own children to say nothing of Negro children. This raises

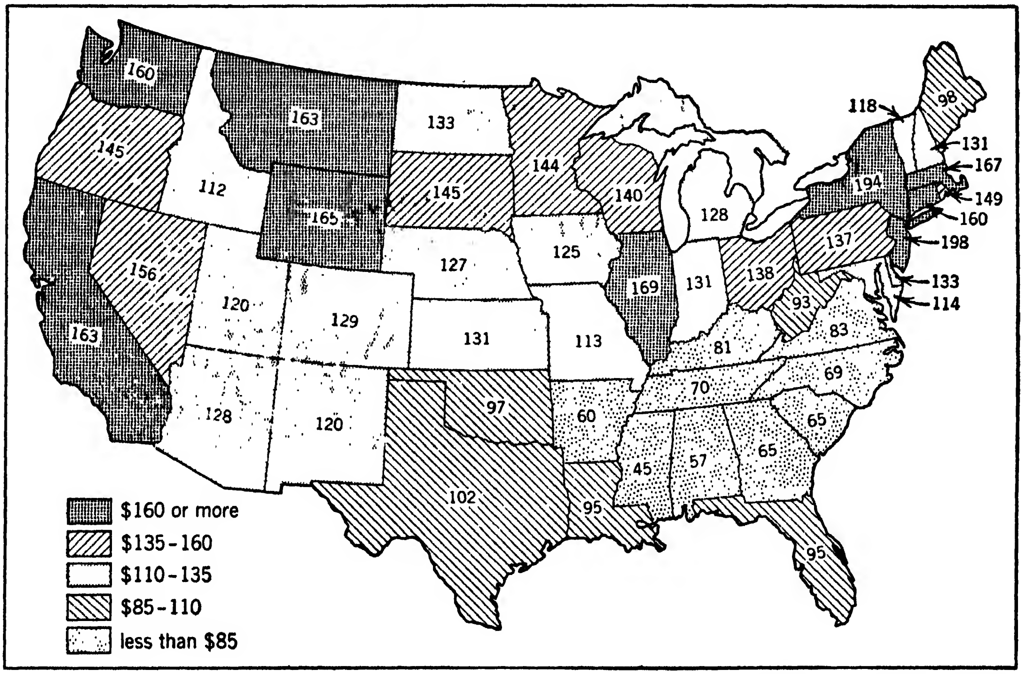

FIG. 2. Current expense per pupil in average daily attendance, 1944–1945 (not including interest). (Federal Security Agency.)

the much-disputed question of how far the taxes paid by the richer states, with their relatively few children, ought to be used to help the schools of the poorer states. This question is usually regarded as political, but it also lies in the realm of human conservation.

major features are alike and are the opposite of those of the map of reproduction. From the maps alone it is difficult to judge how nearly the care of education and the care of health have a geographical distribution exactly the opposite of that of rates of reproduction. A diagram like Fig. 4 helps in this respect. At the top the states are named in order, from left to right, according to the rates of reproduction among their white population. New York with a rate of 71, New Jersey (73), and Connecticut (75) are at one end, and Kentucky (137), West Virginia (144), and New Mexico (160) at the other. Dots connected by a solid line are placed at the proper height to represent these rates according to the scale on the left. Inasmuch as the care of health and the care of education have almost the same geographical

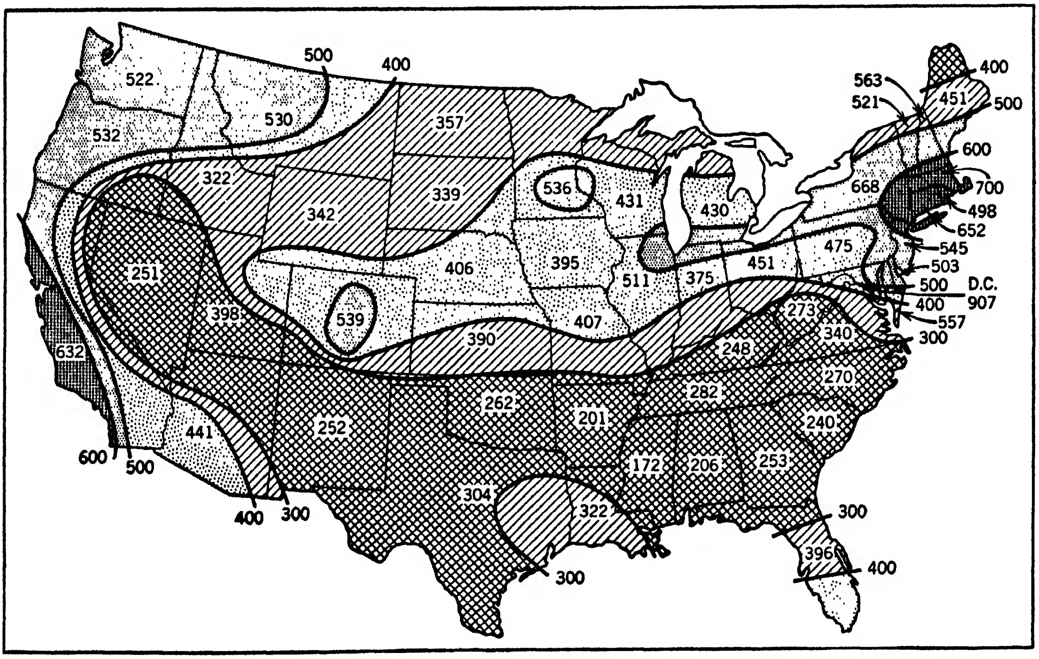

FIG. 3. Physicians, dentists, and nurses per 100,000 population, 1940. (Data from the Bureau of the Census.)

The care of health shows a geographical distribution as unfavorable as that of education (Fig. 3). Comparatively speaking, physicians, dentists, and nurses are least numerous in the south and the Rocky Mountain states aside from Colorado and Montana. They are also few in number in the northern states of Maine and North Dakota. For a given number of inhabitants, Mississippi has only one of these guardians of health whereas Massachusetts has four. Although the maps of education and care of health differ in detail, their distribution, we can combine the two into a single index number, giving equal weight to each. Little crosses connected by a zigzag line indicate these index numbers. New York's index, according to the scale on the right, is 670, and New Jersey's 605, whereas that of Mississippi (eleventh from the right) is only 150. If reproduction and Minnesota, Montana, Maine, and Vermont are all cool, northern states. Prominent low points, on the other hand, are found in warm and generally humid states—Florida, Louisiana, Oklahoma, Georgia, Mississippi, and Arkansas.

Urban and rural communities differ in their care of education and health quite as

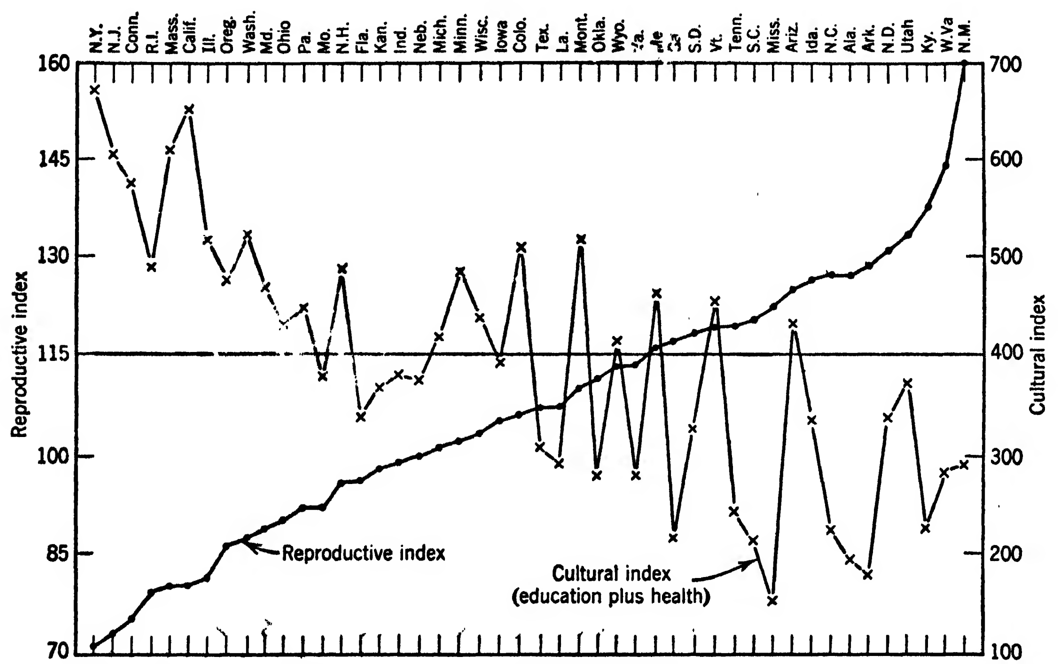

Fig. 4. Comparison of reproductive and cultural indexes. (Based on data from the Bureau of the Census and the Federal Security Agency.)

the care of education and health varied in exactly opposite ways, the crosses would form a line that would fall from left to right in just the same way that the line of dots rises. Although there is no perfect agreement of this kind, the line for health and education evidently has a general slope downward from states with few children to those with many. Its irregularities indicate the effect of such factors as cities and climate. Among the states that form peaks, California, Colorado and much of Arizona have cool, dry climates; New Hampshire, much as in their birth rates. Urban communities almost always spend much more per pupil than the neighboring rural areas (except rural suburbs of large cities). They also have many more physicians, dentists, and nurses. In 1942 the average expenditure per pupil for all purposes in the cities of the United States was $132, and in the rural sections only $84. The contrast between urban and rural conditions is especially marked in the south, where the birth rate is highest. In Kentucky, where the rural schools are almost wholly attended by white children, the annual cost of instruction in the public schools was $86 in the cities and only $42 in the rest of the state. In the District of Columbia, the annual cost in 1945 was $161 against only $83 in the whole state of Virginia and approximately $47 in rural Virginia. Even in a highly progressive state like Ohio, the rural part of the state spent only $98 per pupil against $171 in Cleveland.

In the care of health, the contrast between urban and rural territory is even greater than in education. City people can generally get a physician or reach a hospital inside an hour, whereas millions of rural people may need a day. Physicians, dentists, and nurses, especially the experts, show an increasing tendency to practice in cities. In proportion to population, the city of Washington has more than three times as many doctors as the state of North Dakota. On his daily rounds in Chicago, a physician rarely drives more than ten miles; in rural Montana he may average one hundred. An additional advantage of cities is that, where many people live close together, they can maintain health services which are impracticable in rural territory. Cities spend great sums on prevention of epidemics, food inspection, housing, medical examination of school children, water supplies, and sewage systems.

In spite of these advantages, migration to the cities is harmful to health. According to a census report issued in 1943 the chances that an urban and a rural white child born in the same part of the country will survive to the age of 40 are almost identical.[5] After the age of 40, however, the death rate increases far faster in cities than in rural districts. If present conditions continue, only 402 out of 1000 persons born in a given year will survive to the age of 70 in cities of more than 100,000 population, whereas 444 will survive in smaller cities, and 526 in rural territory. All the doctors, dentists, nurses, health inspectors, and hospitals of the cities are able to keep the city people in as good health as the rural people only up to the age of 40. Thereafter, they are increasingly unable to overcome the bad effects of the city. Cities are great enemies to health, and thus to the conservation of man.

[5] "United States Abridged Life Tables, 1939, Urban and Rural," *Vital Statistics—Special Reports*, Washington, D. C., Vol. 23, No. 15, 1943.

IS THE QUALITY OF THE HUMAN CROP CHANGING?

Quality is more important than quantity. What, then, is the quality of the children who fill the void left by the low birth rate of our cities? We have seen that, as a rule, children's education and the care of their health are relatively backward in the mountain sections and the rural areas almost everywhere; but how about inherited capacities and aptitudes? Does the advantage in these respects lie with the rural districts or with the manufacturing sections and the cities? Has the steady cityward migration since 1850 had any effect upon the innate quality of the American people?

There are grave differences of opinion as to the answers to these questions. Some people assert that biologically inherited traits have nothing to do with the diversity of character and achievements among people who live and work under various geographical, social, and economic conditions. This view seems extreme and illogical. There is not space here to argue the matter, and the evidence is not yet sufficient to give full certainty. The sound view seems to be that both heredity and culture enter into the problem. Sometimes one is more important and sometimes the other. The way in which the two factors seem to combine to influence the relative status of cities and rural districts is set forth in the following paragraphs.

Migration, a Selective Process

One of the laws of migration is that if a region offers few and poor opportunities, the brighter, more alert, more ambitious, and more energetic young people tend to migrate away from it.[6] Suppose that a poor rural area, including poor villages and the surrounding farms and mines, has the same population as a neighboring city. The birth rate in the city is so low that its population would decline by one-third in each generation if not recruited from outside. The rural area has so many births that its population would increase by more than half in a generation if no one moved away. It affords so few opportunities that, each year, a third of the young people who reach maturity migrate to the city. Thus, the rural population remains stationary whereas that of the city increases by at least one-sixth. Among the relatively bright, energetic cityward migrants the great majority are better educated than the average of those who remain at home. They generally come from the homes where the training is most conducive to good citizenship and leadership. Their inherited capacities are presumably greater than those of their comrades who stay at home. The word "presumably" is used because, as yet, we have not been able to develop tests that give any great degree of certainty as to how far the character of a given population depends on heredity and how far on training. In these pages we accept the idea that, on the whole, the families in which practically all the children go through high school are better endowed by heredity and get a better home training than those in which practically all the children fail to finish the eighth grade. If this idea is accepted, there seems to be no escape from the conclusion that cityward migration generally, although not always, depresses the quality of the rural population. The city gets relatively good material both culturally and biologically even though formal education in the rural area may not be so good as in the city.

What, now, will happen to the next generation? Because of the quality of their parents, the urban children of the cityward migrants will presumably have a better home environment and inherit greater capacities than their rural contemporaries. Because of their urban environment they will have better schools and greater opportunities than the rural children of the same age. Unfortunately, however, if the present rates of birth, marriage, sterility, and death continue, they will be 30 per cent too few to replace their parents. The rural children, on the other hand, will presumably receive from their parents a less favorable biological inheritance than that of the children of the cityward migrants. They will grow up in relatively inferior homes and will have a relatively poor education. When they become old enough, most of the more competent, better trained, and more highly educated among them will go to the cities. The cream will once more be skimmed off for the benefit of the city, but it will not be such rich cream as before. In the city, part of this new cream will fill the void arising from the low birth rate of the previous city migrants; the rest will in-

[6] Ellsworth Huntington, *Mainsprings of Civilization*, New York, 1945, p. 93.

crease the urban population. Thus the city is the gainer in comparison with the rural districts, but the quality of the later migrants is presumably lower than that of the earlier ones.

With each new generation this process of deterioration is repeated. If it continues too long, it may lead to a collapse of civilization. The cityward migrants doubtless strengthen the cities, but their migration sterilizes them so that their stock gradually dies out. Each generation of rural nonmigrants is slightly less competent than its predecessor because it comes from a less desirable type of home. If the sterilizing effect of city life really leads to a deterioration biologically as well as culturally in both the urban and the rural population, its effect may prove most sinister. It may help to account for the intensity of some of our present social and political problems. And it may intensify such problems as time goes on. If conservation is needed anywhere, it is surely needed in the human crop on which we spend a third or more of our effort.

REGIONAL QUALITIES OF THE CROP

In considering the quality of this same human crop another great question arises: Do constant migrations from place to place tend to concentrate certain types of ability in one section rather than in another? An answer is suggested by a study of the 85,000 American leaders mentioned in *American Men of Science,* Poor's *Register of Directors,* and *Who's Who in America.*[7] The scientists, businessmen, and notables included are clearly superior to the average American in mental ability as well as in achievement. Their superiority arises from a combination of cultural and biological advantages, although no one knows how much should be ascribed to each. Three sections of the United States have played an especially im-

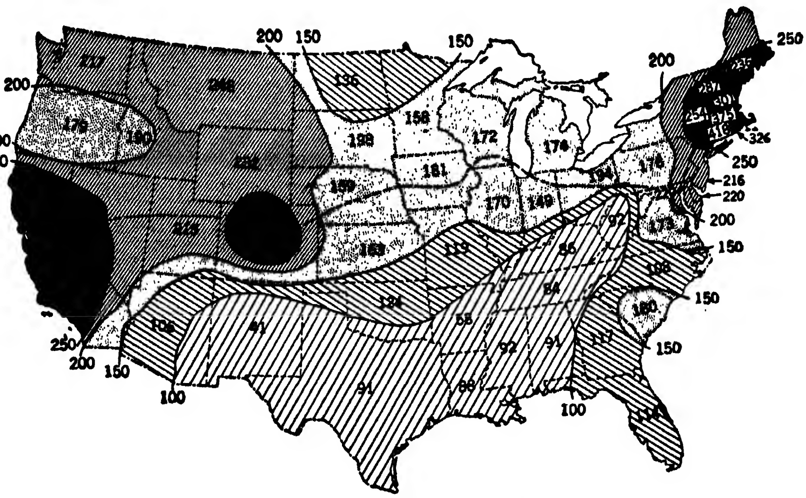

Fig. 5. Approximate number of leaders among an average 100,000 white children born in each state. Based on *Who's Who* (1936–37), *American Men of Science* (1938), and *Poor's Register of Directors* (1938). (*Mainsprings of Civilization.*)

[7] *Ibid.*, pp. 80–97.

portant part in the production of recent American leaders (Fig. 5). By far the most important section centers in Connecticut, with an index number of 418, but includes the rest of New England and New York. The others are Utah and California (with Nevada). South Carolina rises conspicuously higher than the neighboring states—that that state still leads the country, and, in proportion to its population, still has more than seven times as many leaders as Arkansas, which stands lowest (Fig. 6). North Dakota has lost ground, presumably because it is so purely agricultural and subject to frequent crop failures. As a birthplace of leaders it ranks half as high

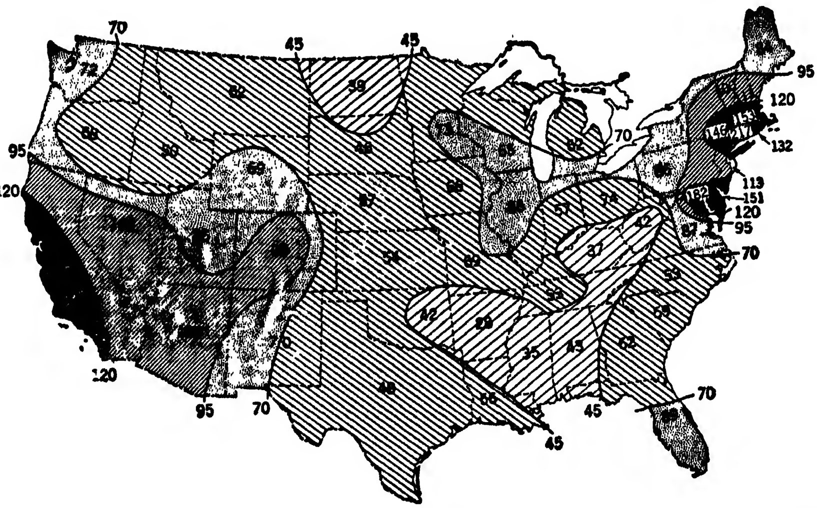

FIG. 6. Leaders living in each state in 1937 per 100,000 white population in 1930. (*Mainsprings of Civilization.*)

twice as high as any of the largely rural states from West Virginia to New Mexico. North Dakota ranks lower than any other northern state and is the most rural state in the Union. In general, the degree of productivity in the matter of leaders is high in the north, low in the south, higher on the coasts than in the interior, and higher in urban than in rural communities.

Persistence of Regional Characteristics

As leaders reach maturity and move to new homes, there is little tendency to equalize the uneven distribution that prevailed at the time of their birth. Although half of the leaders born in Connecticut have gone elsewhere, others have come in, so as California, but as a residence of such persons only one-third as high. South Carolina has lost similarly. Although it is three times as productive as Arkansas (Fig. 5), it has only twice as great a proportion of leaders (Fig. 6). This drop to a level like that of its neighbors strongly suggests that South Carolina's high record as a birthplace of leaders arises from the presence of families with unusually fine hereditary traits, and not from opportunities or general education superior to those of its neighbors. New Mexico shows an opposite condition. Its native population, with its high percentage of Mexicans, has not produced many leaders—less than one-fourth as many as South Carolina in proportion to births. It stands at the very bottom in Fig. 5. Its opportunities, however, are so promising that in Fig. 6 it outranks half the states and even excels Wisconsin.

Figure 7 shows that parts of the United States may lose persons of a particular type although gaining in other types. In all the shaded states the number of scientists listed in *American Men of Science* is less than two-thirds as great as would be expected on the basis of those who were born there. South Dakota is very heavily shaded because its scientists and prospective scientists have gone elsewhere in especially large numbers. They are now less than one-third as numerous as they would have been if scientists had been relatively as abundant among migrants into that state as they were among persons born there. In similar fashion, Oregon, Montana, North Dakota, and Maine have scarcely more than half their fair share. All the shaded states taken together have supplied several thousand scientists to centers like New York, Washington, and Chicago, and to southern states which have produced relatively few of their own. Businessmen—directors—have also migrated in such a way that, aside from Nebraska, Utah, and Washington, all the states shaded in Fig. 7 have a deficiency which averages 22 per cent.

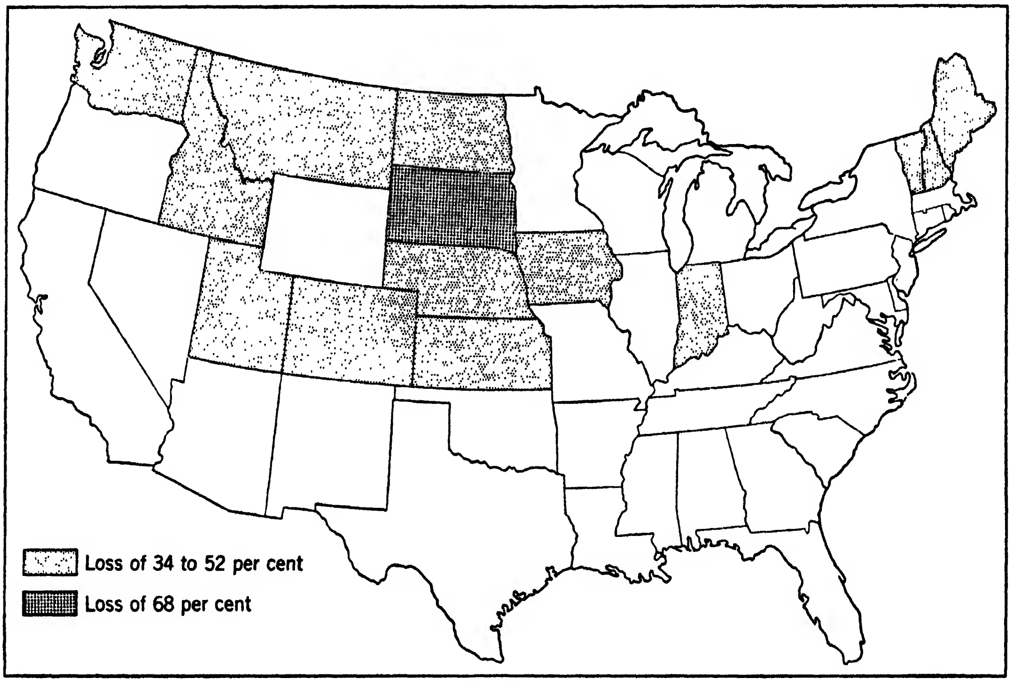

FIG. 7. States with serious loss of scientists.

Before drawing final conclusions as to the migration of leaders, we must take account of the fact that science and business are by no means the only occupations. A map based on 50,000 unusually successful farmers would almost certainly be more or less the reverse of Fig. 7. It would presumably show that Iowa and the surrounding states have attracted unusually competent agriculturists from other parts of the country and have much more than their fair share. Leaders of all kinds and of all grades of competence are continually migrating from place to place, thereby altering the geographical distribution of different kinds of ability.

If we knew as much about people's abilities as we know about the egg-laying capacities of hens, we could make maps showing the distribution of human competence in farming, in trade, in science, in politics, and in many other lines. We could ascertain to what extent internal migration is concentrating certain kinds of ability in particular parts of the country. Something of this kind is evidently taking place. The percentage of competent businessmen is certainly greater in Chicago and Philadelphia than in the rural population of southern Wisconsin and Minnesota, but these rural areas surpass the two great cities in their percentage of competent dairymen.

The word "competent" again raises a vital question that we have already encountered. Are the businessmen and the dairymen well-fitted for their respective kinds of work solely by training, or is there also a biological factor? Do competent businessmen, scientists, and followers of other professions differ from one another and from competent farmers in any innate combinations of the genes that control the structure and functioning of the glands, nerves, brain, and other organs upon which mental as well as physical activities depend? The common answer just now is "No." That answer is in accord with the fashion of the times, but there is no proof that it is right. We simply do not yet know the exact facts. The wise man will recognize that both heredity and environment are basic factors. In any given problem, however, he will withhold judgment as to the importance of each factor until more reliable information is available. In the entire field of conservation few problems are more urgent than that of the relative parts played by heredity and environment.

SUMMARY AND CONCLUSIONS

This study of our most valuable crop is unsatisfactory and, in many ways, depressing. It is unsatisfactory because our information is so scanty and the divergence of views so great. It is depressing because it suggests that the quality of the American people is declining, and that little attention is being paid to this decline. Human material is overwhelmingly the greatest asset of the United States. This material, as we fondly believe, is fundamentally good. It is produced in very uneven amounts in different geographical regions, and in different classes of society. As a rule, the largest supply comes from the regions and classes where the educational and economic conditions are least favorable. During the nineteenth century the differences in the birth rates of the various geographical sections and social classes of America gradually increased until the urban, the wealthy, the educated, and the intelligent parts of the population were in danger of dying out unless replaced by children springing from the rural, the poor, the uneducated, and the unintelligent sections. Now there are slight indications that the size of families is beginning to increase among the best educated and most socially minded types of people. There is similar evidence of a decline at the other end of the social scale, but the contrast between the birth rates of the mentally inferior and the mentally superior is still extreme.

This unfavorable situation is rendered worse by the fact that each year more than 600,000 young people pour out of the less-favored rural environments into the cities and industrial areas. They ought to come with every advantage of health and training. Yet the cities and the industrial areas, rich as they are, begrudge even the small share of their taxes that goes to support education and health in the less-favored areas. For their own sake, if for no other reason, the cities and the more prosperous regions and classes of society ought to show far more interest in helping the rural and less-favored regions and classes from which they draw so much of their human material.

Another aspect of the matter is even more portentous. Is the human crop, to which we devote at least one-fifth and perhaps one-third of our time and energy, growing better or worse from generation to generation? The honest answer is that we do not know. We know beyond the shadow of a doubt that our yield of corn per acre has increased notably because of the introduction of improved strains and hybrid seed. We know equally well that there has been a similar improvement in the number of eggs laid by the average hen, and in the amount of beef produced from a given amount of animal feed. But our children? Even if they are given better schools and better medical care than formerly, do their parents train them better, and are they better biological specimens than their ancestors were?

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PART EIGHT

CHAPTER 22

State and Local Planning

INTRODUCTION

GEOGRAPHY as a subject, and geographers as individuals and as a group, have long been interested in various aspects of planning. This is largely the result of geography's interest in regions as areas of the earth's surface, and of the fact that much of planning has to do with areas of the surface. Thus, very naturally, some members of the field of knowledge that deals with area have been drawn into planning. There has arisen, however, a technical profession of city planning, manned by professional city planners, some of whom entered the planning field after preliminary work in engineering and others of whom were directly trained for the planning of cities. At the present time many geographers and city planners are engaged in the more recently developed field of regional planning.

THE PLANNING REGION

A geographical area of almost any size can be the subject of a plan. Among the common planning units are (1) subdivisions of a city, (2) the city, (3) the county, (4) the metropolitan region, (5) the state, (6) groups of states, (7) a regional unit not associated with states, and (8) the nation.

The City a Unit

The region that is the subject for planning may be of almost any size. Perhaps an example of a small region which is the subject of planning is the city subdivision, although as a matter of fact every lot is the subject of a plan, and even the house and landscaping adjuncts to the lot are planned. The whole neighborhood of a city may very properly be the subject of a plan, for it usually includes several subdivisions, and as a result creates problems of wider interest than those of a given subdivision.

Planning for the entire village, town, or city is a natural outgrowth of smaller plans. Thus there has arisen the need of a broad, well-conceived city plan to care for both present and expanding needs of the metropolitan area. This is one phase of local planning that is well understood and permanently rooted. The ancients had city plans. Medieval castles and their adjacent

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villages were planned, although an adequate defense of the area from outside attack was the prime object of the plan. Many of our American cities were planned from the start, excellent examples being Philadelphia, Washington, Detroit, and Salt Lake City. Others of our cities, objects of intensive planning at present, grew rather aimlessly from small centers or grew in mushroom fashion by the continued addition of subdivisions, each subdivision being perhaps planned by itself, but the entire area was not co-ordinated into a well-thought-out whole.

The Metropolitan Area a Unit

The metropolitan area or the county plan were outgrowths of city planning. The formulation of plans for a wider region than the city itself was the result of continued urban growth. Suburbs were growing rapidly and had many interests in common with the main city. However, political separation of the suburbs from the city made it impossible to apply the city plan to them, for that kind of plan must halt at the city borders on account of political exigencies. Planning regions for these urban and urban-rural areas larger than the city itself have primarily assumed two forms: (1) the metropolitan district, and (2) the county. In the former the entire metropolitan area is the subject for the plan. This type of planning region includes the city and its satellite suburbs, the surrounding rural and rural-urban districts, and it commonly crosses county and even state lines. Thus the New York regional plan includes portions of New York State, New Jersey, and Connecticut; the Philadelphia Tri-State plan crosses from Pennsylvania to New Jersey and Delaware; planning for greater Cincinnati involves part of Kentucky; and a broad plan for the Chicago metropolitan region includes surveys and suggestions for portions of Illinois, Indiana, and Wisconsin.

The County as a Unit

The second type of larger area surrounding a city is the county, and many of the planning organizations and commissions of the United States have been organized on this political basis. Examples of a county planning region are furnished by some of the New Jersey counties, by Monroe County, New York, the larger area for the city of Rochester, and by Milwaukee County, Wisconsin. The county planning region of this type functions best when the city is near the center of a county so that the county and the metropolitan region become essentially synonymous. It has advantages in that the planning is made for but one or two units of government, thus often circumventing difficulties offered by different and sometimes conflicting governmental administrations when county and state lines are crossed.

The State or Region a Unit

Two additional regions, both larger in area than all those previously mentioned, are areas subject to planning. One is the state itself, and the other a large entity crossing state lines, larger than counties or metropolitan regions, and comprising all the territory within arbitrary limits. Any one of the forty-eight states, of course, is an example of the first. The Tennessee Valley Authority is an example of the second type of larger region, the arbitrary borders of which were furnished by the watershed of the Tennessee River. Another such regional unit is the proposed Missouri Valley Authority. A group-of-states arrangement can also be and is used as the subject of a plan, such as the six New England states, or the Pacific northwest region, which comprises Washington, Oregon, and Idaho. The larger-than-state regions, and the regions of considerable area that cross state lines, are, however, primarily subnational units, and as such are practical subdivisions of national planning rather than state planning. Consequently they will be treated more fully in the section on national planning (see Chapter 23).

For many reasons the state is an ideal unit for planning, primarily as a result of its political unity. For many planning purposes the state is the geographic unit, the master region. The major natural resources of the state can be studied and inventoried, conservation problems can be approached from a statewide basis, and the geographic distribution of the resources and problems can be adequately recorded and catalogued within the limits of the state. Uniformity and similarity of government, from both practice and personnel, within the state also permit considerable uniformity of approach to the planning problem. The collection of basic data, the formulation of a plan, and the eventual carrying of the plan into practice are also facilitated by state arrangements.

It must ever be kept in mind, however, that even though the state is for many purposes the geographic unit for planning there are regional diversities involved. The regional concept, the breaking down of the master state region into subregions, is essential. A planned attack on any of the problems of an American state forces recognition of the regional diversities within state boundaries, exactly as national planning involves breakdown of the nation's territory into subnational regions.

Conversely, some state problems transcend state lines, and thus state planning merges into the field of regional planning. The states of southern New England, realizing their small size individually, as well as the similarity of their problems, united with the states of northern New England to form a New England Regional Council. This organization promotes the welfare of all six states along certain lines. The governors of the southern states united to form an organization which promotes certain unifying interests of the entire region, and the organization advertises the advantages of the region in national magazines. Although many organizations of this type are not strictly planning groups comparable to a city planning commission or the Tennessee Valley Authority, nevertheless they perform certain functions that identify them with state and local planning.

The state is usually a good region for planning because of several inherent American qualities. Among these is the theory of state's rights, an idea which has been very strong at several periods of our history, which has been dormant and quiescent at other periods, but which is ever present; it may at any time come to vital life and is a major factor in both our state and national life. In addition the state, under our American form of government, has certain functions to perform, functions not expressly delegated to the national government. The question of planned land-use, water-use, highways, and other features is one within the several states which ranks in the forefront among state problems. The people of a state may accomplish much toward realization of a fuller life in their regional planning.

How State Planning and Conservation Are Related

Intelligent conservation of natural resources involves knowing the resources, the problems of inventory, preservation, efficient utilization, and their renewal. Thus state planning in every sense, and on all sides and aspects of its philosophy, strikes at the essence of modern conservation in its broadest implications.

The major natural resources of the United States are located, of course, within the borders of the several states. Many of these resources are of utmost significance to state and nation. The state as an entity is interested in planning for continuation of these resources so that the state may profit from their existence, perhaps directly in the form of taxes or indirectly through the welfare of the citizens most immediately concerned with the resource. No state wants its soil destroyed by needless soil erosion. Intelligent planning and active conservation will save the soil. Wise and efficient use of minerals will bring the greatest good to the greatest number, even though the mineral may be exhausted at some future time. A wise and planned use of the forests of the state, coupled with intelligent reforestation, will permit the continuation of industries dependent upon forest raw materials, and save the state from possible loss of manufacturing plants, impoverishment of workers, and the stranding of inhabitants in the formerly forested areas. Examples of the type of the three just cited might be multiplied at length. The need for state planning is evident. It is necessary to correct mistakes of the past, to help with present problems, and to serve as a guide to wiser utilization of resources in the future.

EXTENT AND NUMBER OF PLANNING REGIONS

Planning regions of all the types previously listed exist in the United States. In addition, the entire country may be considered a single planning region, the subject of national planning projects.

City Plans

The National Resources Committee in 1937 undertook a survey of the planning commissions engaged in city and town planning within the United States.[1] Their survey and report indicated a total of more than 1700 city and town planning agencies in existence at that time. Many more have been added since.

Metropolitan Plans

Metropolitan and county plans have been developed in numerous places within the United States. The Boston metropolitan area was among the first to be organized for planning, especially for its water, sewer, and park system.[2] New York City and its environs have been the subject of one of the largest metropolitan plans set up in the country.[3] Some dozen or more large and major metropolitan regions have been organized for planning, among them the regions surrounding such cities as Philadelphia, Chicago, St. Louis, Toledo, Washington, Los Angeles, Cincinnati, and many others.

County Plans

More than 400 counties have been organized for regional planning, and the total is growing constantly. In some of these planning units the county is used as the political basis of a metropolitan-area plan,

[1] *Progress Report,* National Resources Committee, Washington, D. C., 1937, p. 3.

[2] *State Planning: A Review of Activities and Progress,* National Resources Board, Washington, D. C., 1935, p. 3.

[3] *Regional Plan of New York and Its Environs,* Russell Sage Foundation, 1931.

as previously explained. In others, and by far the larger number, the county is a unit for county planning in the rural sense, that is, the county itself is the basis of the planning and reason for the planning, and is not used as synonymous with a metropolitan area. Mercer County, New Jersey, Los Angeles County, California, and Monroe County, New York, are examples of "county-metropolitan" planning. Counties first organized for rural regional planning were primarily those within Wisconsin and California. Each of these states has an enabling law permitting the county to be the subject of land zoning and permitting the county board to enact a rural zoning law designating various types of land-use within the area of the county. Not all the counties of either state have taken advantage of the enabling act. Counties possessing "problem" areas within their borders, such as counties in the northern cutover region of Wisconsin, have, however, taken advantage of the act of 1923, and most of the 19 northern counties primarily affected by the problem of cutover land have enacted rural zoning ordinances.

In the 1930's there was a movement to unite some of the county planning boards into "district" planning agencies, some 27 of which were organized in various parts of the United States prior to the outbreak of World War II.

State Plans

State planning organizations in June, 1936, were located in 47 of the 48 American states. The state planning movement received tremendous impetus between 1933 and 1935 as a result of federal assistance, and the large percentage of the United States subjected to state planning reflects the rapid spread of the regional planning movement as an aid in the solution of the problems of conservation and the orderly development of resources.

Post-War Planning

World War II served as the stimulus for a second era of state planning. The state planning boards, well established during the 1930's, served as clearing agencies for the development of post-war plans in practically all states. The states realized the need of additional inventories, and proceeded to obtain them. The great redistribution of inhabitants during World War II made necessary a period of "stocktaking," and the formulation of plans for the future of the state. Nearly every American state now possesses a post-war plan. (See the bibliography.)

STATE PLANNING

What Is State Planning?

The National Resources Planning Board, when it functioned as a planning agency, defined state planning as "the systematic, continuous, far-sighted application of the best intelligence available, to programs and problems of state development and organization, in order to provide higher standards of living and greater security for the people of the state. Planning is the use of scientific and technical skills, coupled with imagination, to determine and influence trends or changes which can be helpful to this larger purpose."[4] State planning thus consists of gathering all necessary data about the state, of recording and analyzing these data, and of bringing all possible intelligence to the study of the data with a view to discovering trends so that the even-

[4] National Resources Board, *State Planning, op. cit.,* p. 4.

tual plan will be more accurate and have a greater chance of success.

The Need for State Planning

The need for state planning is evident. Previous chapters have discussed usage of the individual resources, and examples of unplanned land-use, water-use, forest-use, and others have been given and are well known to every intelligent citizen. One basic objective of state planning is to correct the mistakes of the past, or to help correct them as far as possible; a second is to help with present state problems; and a third is the service that planning can perform for a wiser utilization of resources in the future.

The planners can serve to collect the data, take inventories, analyze data, suggest changes, guide legislation, and correlate isolated plans suggested by individual state administrative departments.

The state itself is a natural planning unit for problems within its borders. Different states are affected in dissimilar ways by similar problems, for conditions are not constant in all American commonwealths. The states are the most important framework of the nation. As such, each state as an individual unit cannot help being vitally interested in planning for its own welfare. One of the basic needs for planning is related to the fact that our nation consists of 48 commonwealths. Each state must thus plan for itself and for resource utilization within its area. The correlation of individual state plans and common action on these plans lies either with a group-of-states arrangement or with national planning organizations.

Development of State Planning

State planning grew naturally, the result of its need. Preliminary growth was slow but sure, and growth after 1933 was aided by federal assistance. Nevertheless, planning evolved as a necessary function, and the impetus state planning received after 1933 pushed it more quickly to the forefront.

State planning in a sense has been going forward ever since formation of the states themselves. State governments were planning before the term "state planning" had arisen, and when most individuals who called themselves "planners" were engaged in city planning.

In the 1890's planning movements were instigated for the preservation of historic and scenic sites, and a great deal of public interest was aroused. Forest and game planning followed about 1900 and was an important factor in the formation of several state conservation commissions as units of state government. Health problems, city water supply problems, and allied fields of planning led to organization of state health departments. The advent of the automobile led to the movement for good highways and resulted in the formation of highway commissions. These bodies undertook the planning for highway needs of the state. State governments today are replete with various departments and commissions, each of which is a planning agency for some particular function of the government.

State planning for land-use grew apace during the 1920's, for, particularly in that decade, there arose the need for planning for "land problem" areas within the several states. It had been previously supposed that most of the land surface of the country, other than very rough land or dry lands, would eventually be devoted to agricultural land-use. That had been the preceding history throughout most of the eastern United States—the passage of an area from forest land to farm land. Gradually the realization came that such changes were not occurring in the Laurentian Upland portions of the Lake states. Northern Minnesota, northern Wisconsin, northern Michigan, and the Adirondack region of New York had not passed through the cycle from forest to farm, but had been left as cutover land, burntover land, and land covered with poor second-growth timber. Very few farmers had followed the lumberman in the region. As long as lumber and real estate companies held this cutover land in the hope of selling it to future settlers, the problem was not serious, for the companies paid taxes on the land and consequently local and state governments received an income from it. As soon as the companies allowed large areas of their former holdings to become tax delinquent, and eventually to pass to county or state ownership, with resulting removal from the tax rolls, the problem became acute. People gradually came to realize that a new era had set in, that much of the northern type of glaciated, stony land located in a region of short growing season was not potential agricultural land and that plans for the wisest use of this marginal and submarginal land would have to be developed.

The New England states and New York were faced with the problem of abandoned hill farms. Vermont and New Hampshire had literally been moving downhill.[5] In New York the hill farms of the southern plateau counties had been abandoned in large numbers, and population had been moving toward the lowlands of the Hudson-Mohawk valleys and the Lake Ontario plain. The study of the New York State situation resulted in a 1926 report by the New York State Commission of Housing and Regional Planning, considered by many authorities to be the first comprehensive state planning report in the United States.[6]

The large areas of cutover tax-delinquent lands in the northern portions of the Great Lakes states of Michigan, Wisconsin, and Minnesota became serious problems for these individual states. The land problem of the north finally precipitated investigations, field studies, and administrative control in these states, and each in turn developed planned efforts to meet the problem, such as the detailed inventory studies of the Michigan Land Economic Survey, the Land Economic Inventory of the State of Wisconsin, and the county studies of the College of Agriculture. It was evident that knowledge of existing conditions was essential before the wisest use of the land could be determined.

The need for planning that resulted in various functional surveys was well recognized. The stage was now set for inclusive state planning projects, involving several functions of the state. This last stage, the fostering of a more rapid development of state planning, received prime impetus under the National Planning Board in 1933 and its successors, the National Resources Board in 1934, the National Resources Committee in 1935, and the National Resources Planning Board in 1939. The latter was eventually terminated by Act of Congress on June 26, 1943, and was abolished on August 31. The groundwork for effective state planning was thus laid between 1933 and 1943.

The National Planning Board conducted preliminary surveys of the planning bodies

[5] J. W. Goldthwait, "A Town That Has Gone Downhill," *Geog. Rev.*, Vol. 17, 1927, pp. 527–552. See also H. F. Wilson, "The Roads of Windsor," *Geog. Rev.*, Vol. 21, 1931, pp. 379–397.

[6] National Resources Board, *State Planning, op. cit.*, p. 4.

in the United States and aided in having planning boards organized in states that did not possess them. To the state planning boards the National Planning Board assigned regional planning consultants, men actively engaged in the planning profession, and capable of guiding the newly organized state committees and planning boards in the field of planning. The immediate result was the taking of the preliminary state inventories and the issuance of preliminary reports. These activities, fostered by federal aid to the states, gave state planning rapid momentum, and resulted in the awakening and quickening of planning interest within the states.

The professional planners continued their services to the state planning boards, the results of which were embodied in final state planning reports. Primarily these were inventories of the resources of the states, but they also contained preliminary recommendations for wiser and fuller use of the natural and human assets of the respective areas. The National Resources Board also undertook the study of the land resources, the mineral resources, water resources, and other basic resources of the United States in order to correlate the work of the separate states into a nationwide inventory and report. To this end additional consultants were assigned, each charged with special detailed investigation of a single resource. Completion of the preliminary studies of these basic resources of the individual states, and correlation in Washington of the separate reports, resulted in the National Resources Board report to the President in December, 1934, the most complete inventory and study of the United States undertaken to that date. State planning in each state was thus capped by a national inventory. State planning boards now continue intensive work and make recommendations within their respective states.

Fields of State Planning Work

State planning in the United States covers a wide range of subjects. The regional character of the United States is one of the factors largely responsible for this, since obviously one of the western intermontane states is most interested in the water resource from the standpoint of storage and control for irrigation, whereas a lower Mississippi valley state approaches primarily the flood-control aspect of the water resource, and a densely peopled eastern state is primarily concerned with reservoir storage facilities for city water supplies and the control of stream pollution. In still other states the water power aspect of the water resource may be most urgent, and within the geographic regions of any one state all these water problems singly or in combination may be critical factors.

The National Resources Board in a study of state planning activities fostered by the individual state planning boards and commissions found that a dozen or two major headings form the primary activities and interests of the state organizations.[7] Among these fields are: (1) population studies, involving present population distribution, and forecasts of the human resource at some future date, and future population trends; (2) basic mapping of the state, including topographic, aerial, soil maps, cover maps, and others; (3) planning the land resources of the state in all its various aspects; (4) water resources; (5) minerals and mineral land planning; (6) power resources and projects; (7) transportation planning, including highways, airways, railroads, water-

[7] National Resources Board, *State Planning*, 1935, pp. 5–7, 111–289.

ways, and other types of transportation; (8) housing programs and studies of existing housing conditions; (9) recreation; (10) conservation of natural resources; (11) distribution of industry; (12) fiscal programming; (13) unemployment; (14) relief; (15) education; (16) public works programming; (17) governmental reorganization; and (18) governmental relationships. Other conceivable subjects also enter the realm of state planning, and not all the boards within the several states have studied all the above subjects.

State planning boards and commissions also serve in many states as agencies to plan industrial development. Many of the boards, such as that of Tennessee, maintain an Industrial Development Division This division answers inquiries about industrial sites within the state, lists industrial plants that are for sale, and attempts to interest outside manufacturers in a Tennessee location. These "promotional" aspects of state planning have become of increasing importance during the post-war period, an outgrowth, no doubt, of the war and post-war population redistribution within the United States. To the extent that this aspect of planning has developed, the various state boards come into competition with each other.

How State Planning Is Carried Out

The planner in planning for a state must have before him an adequate and detailed picture of present natural and human resource conditions before he can analyze data and before he can formulate a state plan for the future. It cannot be too strongly emphasized that the existence of adequate basic data is essential to the formulation of a regional plan. It is in the collection and interpretation of these data that the geographer is primarily interested. State planning consists of at least four significant stages:

1. *A statewide inventory of regional assets and endowments.* This includes an inventory survey of both physical features (features of natural earth) and cultural features (man-made features). Included within the survey should be as complete a study as possible of the human resources of the state, for after all it is man that is using the state's natural resources, and it is man himself for whom the plan is made and for whom it is eventually to be put into effect.

2. *Analysis of the data collected in the surveys.* This second stage is most important but cannot be carried to complete fruition without adequate preliminary data.

3. *Planning proper.* Planning includes measures, tools, new ways of doing things which may promote orderly development, and fuller use of our resources.[8]

4. *The administration of the plan.* The state planning boards originally investigated primarily the first point in order to have an effective groundwork for an intelligent analysis. In other words, they have collected a great body of inventory and survey material and have laid the groundwork for effective state planning, a process which is well under way in the individual states. In the years immediately following World War II new studies were made in many states because it was obvious that the war had altered the resource situation and plans made in the middle 1930's were outdated. Readjustments in the economy could best be made in terms of the resources remaining after a wasteful war and in relation to a wise plan of development.

Rural Land Zoning

Regional planning involves the making of a plan, the application of the plan to

[8] *State Planning, op. cit.*, p. 4.

the region, whether the plan be for water, land, or people, and finally the administration of the plan by existing state agencies or duly appointed administrators. Rural method for achieving the objectives in planning. Zoning has been called "the use of the police power to bring the utilization of privately owned land into harmony with

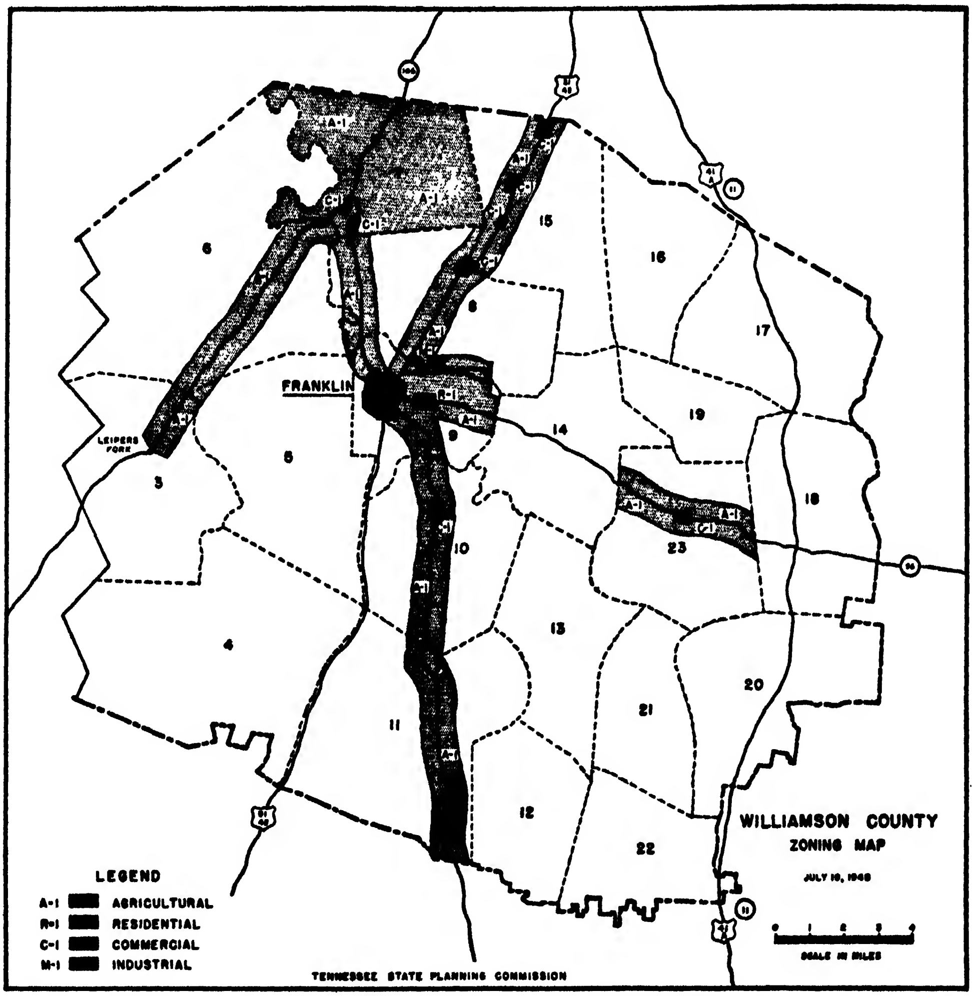

FIG. 1. Rural zoning in Williamson County, Tennessee. The Williamson County Planning Commission has worked out a plan for the development of the land fronting upon the major routes running north and south across the county. (Tennessee State Planning Commission.)

zoning has proved an effective means of transferring land plans from paper into actuality, and as such it deserves a place in modern American thinking (Fig. 1).

Zoning of rural territory is in reality a public purposes." [9] Wisconsin and California permit zoning in rural areas under general state enabling acts; some other

[9] *Wisconsin Regional Plan Report,* 1934, p. 271.

states have extended the zoning power to counties under individual or special acts. Oneida County in northern Wisconsin is considered to have passed the first rural zoning ordinance in the United States. The typical rural zoning law is not related to metropolitan planning but has as its objective the zoning of land for agriculture, forestry, recreation, and commercial purposes. Zoning permits enforcement of the land-uses through the police power and consequently is more than merely classification of land.

Successful zoning, as in Wisconsin, has come about through state direction and supervision combined with local classification of the lands for zoning purposes.[10] The procedure has usually been for the county board to recommend the instigation of a study leading to the eventual passage of a zoning ordinance. Township meetings are held after this declaration of intent, and the inhabitants of the local government units actually zone the land within their political divisions. This comes about through township discussion of zoning problems in town meetings. After all townships have zoned their land the county board takes final action, passes the zoning ordinance, and issues an official land-use map of the county. In many respects the practices followed in rural zoning are thus quite similar to urban zoning, the major differences being only in types and classifications of land-use. The strength of the rural zoning movement to date has been in the local township meetings, the final zoning ordinance being the summation of local knowledge. Rural zoning has thus "come up from below" and has not been spread as a mantle from higher governmental authorities, a practice often leading to local dissatisfaction.

[10] W. A. Rowlands, "Rural County Zoning in Wisconsin," in *Wisconsin Blue Book*, 1937, pp. 169–183.

Human resource planning of necessity accompanies land zoning. The setting up of forest districts, for example, may remove land from agricultural use and may result in movement of the population from the forest district. This fact involves readjustments in local governments, readjustments in roads, schools, and school districts, and perhaps even a change in the community pattern. A change in one major land-use thus commonly promotes a series of succeeding changes. Under an ideal arrangement agricultural zones in a territory such as northern Wisconsin, Michigan, or Minnesota should consist of well-blocked lands of fair to good quality located on good roads in a "going" community, and near markets, schools, churches, and community centers. Resettlement of scattered population in the forest zones may be necessary if the entire population is not able to obtain employment in the forests. These resettled people should be concentrated on farmlands in existing communities, a practice permitted in Wisconsin counties if the settler is willing. Planning for the region may also involve major changes in political units and may result in consolidation of school districts or townships, the dissolution of small districts, the abandonment of unnecessary roads, changes in rural mail routes, and a host of other changes. The ramifications of regional planning thus are numerous and diverse, but extremely critical and necessary.

Planning for a regional unit involves the same general aspects. The files of the Tennessee Valley Authority are replete with practical problems that had to be solved—resettlement of farmers who lived in areas that were to be flooded, changing the road patterns, shifting the marketing zones of rural communities, and others.

Geographical Aspects of Regional Planning in the State

The regional point of view places emphasis upon regions of the earth's surface. A region is an areal convenience selected for a purpose. Various purposes require regions of unlike definition, and, since nature seldom creates areas of any great size that are uniform throughout and have sharp boundaries, it is necessary to limit many areas arbitrarily. The region, however transitional it may become toward its margins, may nevertheless be recognized by the nature of its central complex or core, about which it is defined. Many regions, especially those of subnational character, as previously noted, transcend state boundaries, whereas numerous regions are entirely within the political borders of one state or else are state units for state planning purposes.

The regional aspect of planning is important in the several states. Land resources and land planning have received regionally different treatments within the country. Some state planning boards have made land ownership surveys. In some of the western Corn Belt states, where corporations frequently hold large blocks of land, the state planning boards have studied the effects of this type of ownership. In Idaho a harmonized state reclamation program had an important place in the land studies. In the eastern and midwestern states the problem of submarginal agricultural land is critical. Iowa, a major agricultural state, studied the land resource as one of its primary endeavors, a good example of a regional interest. In Maine, on the other hand, the planning board studies correlated the land with the state's recreational problems. Wisconsin and Michigan, faced with the cutover submarginal land problem, interested themselves in inventory and zoning to take stock of the land problem and to attempt to solve it.

Regional aspects of the water problem have been cited in another connection in the present chapter. Flood control and water conservation are paramount in the southwestern United States; flood control and stream pollution, in the lower Mississippi and the Ohio valleys; watershed examination, both for public water supplies and for danger from industrial wastes, is a critical feature of water resource planning in densely peopled Connecticut, Massachusetts, and parts of New York and Pennsylvania; hydroelectric power is an important item for planning in Maine; irrigation problems interest Nevada; and water diversion, storage, and irrigation are fundamental in Colorado.

Practically all the individual items of state planning have been and are being approached regionally within the states. States possessing large cities within their borders have stressed recreational needs, as in the Chicago and New York areas. States with large natural recreational areas, such as the Great Lakes section, Missouri with its Ozark Highlands, or Maine and New Hampshire with their seacoast, lakes, and wilderness areas, have stressed private commercial resort planning and public parks planning. Missouri contemplates an Ozark Parkway; New York State believes that about nine million acres, or one-fourth of the land area of the state, might be considered for public ownership; whereas Maine plans to acquire beaches and headlands that may be developed for public use.

Forest land and forest resources have been stressed in practically all states. However, those with large forest areas or with important lumber industries or critical watershed problems have emphasized the subject. New York State wishes reservoirs in all headwater areas, with an appropriate proportion of the land in forest.

The New Jersey planning board has instituted a field survey of the larger industries of the state. Connecticut has made very detailed cover maps of the state. These types of planning studies have been carried on in small, densely populated states, obviously with a regional orientation different from that of the western states.

Human resources may also be approached from the regional standpoint. Population forecasts, for example, call for intensive regional studies in order that regional potentialities may be foreseen and possible changes noted.

Regionalism, both on the national and state scale, is critical. A realization of the regional method is necessary for the complete understanding of state planning and is desirable in helping to interpret various aspects of the state planning movement within the United States.

LOCAL PLANNING

City and town planning have been well established for a long period of time. The ancients planned centers of defense; medieval peoples planned their towns and fortresses; and modern peoples have planned many types of areas. City and town planning has been defined as a science and an art concerned with the shaping and guiding of the physical growth and arrangement of towns in harmony with their social and economic needs.[11] City planning as a profession, and as a means to an end, has assumed a major place in the United States and is accepted by citizens as desirable. The end toward which city planners are working is the development of a physically well-balanced city in which health, safety, and human welfare are well cared for by the structure of the city (Fig. 2).

Major problems in city planning have to do with such subjects as (1) means of communication, including streets, railways, and waterways; (2) housing facilities; (3) recreational and educational needs; (4) the regulation of city land-use and of population density through zoning; (5) protection of health; (6) the development of civic centers, civic art, and so on, and a host of additional subjects. It will thus be seen that city planning includes far more than merely the physical alignment of certain features, or the patterns of transportation and sewerage systems. The future development of parks, schools, streets, the relationship of residence districts to commercial and industrial areas, the protection of health, the zoning of land—all involve public improvements. The city planner must be broadly educated and able to cope with a variety of problems (Fig. 3).

City planning commissions in the United States are often empowered by statute with authority to regulate the location of industries, to regulate the location of buildings designed for specific uses, as for example an apartment house, to regulate the areas of courts or yards, which in effect permits the commission to control the density of population in parts of the city, and to exercise authority for measures that are designed for public health, safety, and

[11] Thomas Adams, *Outline of Town and City Planning*, New York, 1935, p. 21.

welfare. The kind of regulation that may be imposed by the various city planning commissions under general state statutes is not arbitrary but usually must be based upon a scientific study or inventory of the

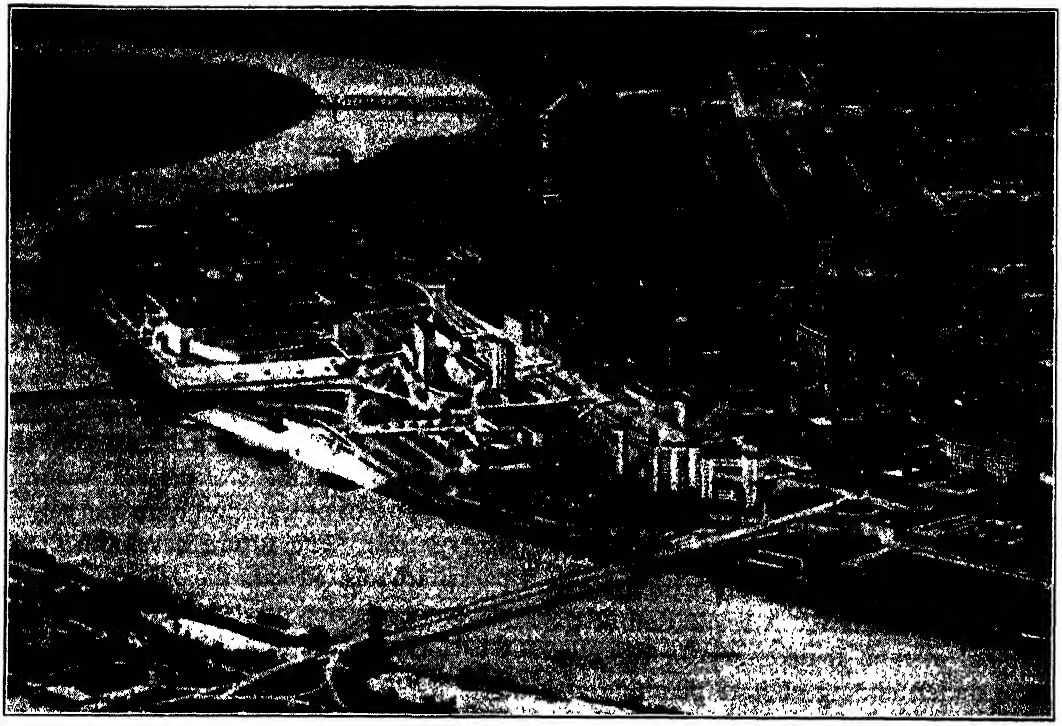

FIG. 2. The redevelopment plan for the river front of Cincinnati, Ohio. The bold plan for the redevelopment of the river front area of Cincinnati provides for an expressway system to speed up the flow of traffic, recreational areas including a stadium, a heliport, an administrative center, and other facilities so necessary in a large well-planned city. (City Planning Commission, Cincinnati, Ohio.)

municipal development, and ordinarily it requires several public hearings before adoption. Changing of regulations and of zone districts from time to time is permitted, for a city is constantly in a process of evolution and the plan must be adjusted to changes which the urban center itself may have helped to bring about.

City zoning ordinances, enacted under permissive state statutes and designed to protect various land-uses within the city, have commonly been upheld in the courts when such ordinances are reasonable. The designation of definite land-uses for given city areas is well known and accepted by the public. City planning calls for co-ordination of an entire area into a well-conceived plan. Past planning of American cities has too often been carried on in piecemeal fashion, each subdivision added to the city having been planned by the realtor at the time of its development, but planned perhaps only for the best interest of the operator and not with a thought to a co-ordinated whole. Modern city planning is consequently not a substitute for no planning at all but is rather a development of co-ordinated planning to take the place of unrelated and unregulated scattered planning. City planning has reached its present stage of development as a result of public demand. Residence districts wish to be protected from encroachment by factories. Residents of areas that are devoted to single-family homes want protection of their property from encroachment by large apartment houses. An apartment-hotel district in turn does not wish to be encroached upon by tenements or by industrial plants. Public sentiment is strongly in favor of city zoning ordinances, most of which designate specific land-uses to specific areas. Changes in zoning ordinances usually require public hearings and frequently require consent of interested parties. For example, a change of a city block from a single-family unit residence zone to a double- or multiple-family dwelling zone commonly requires consent of the landowners within the block, since they are the interested citizens affected by the change.

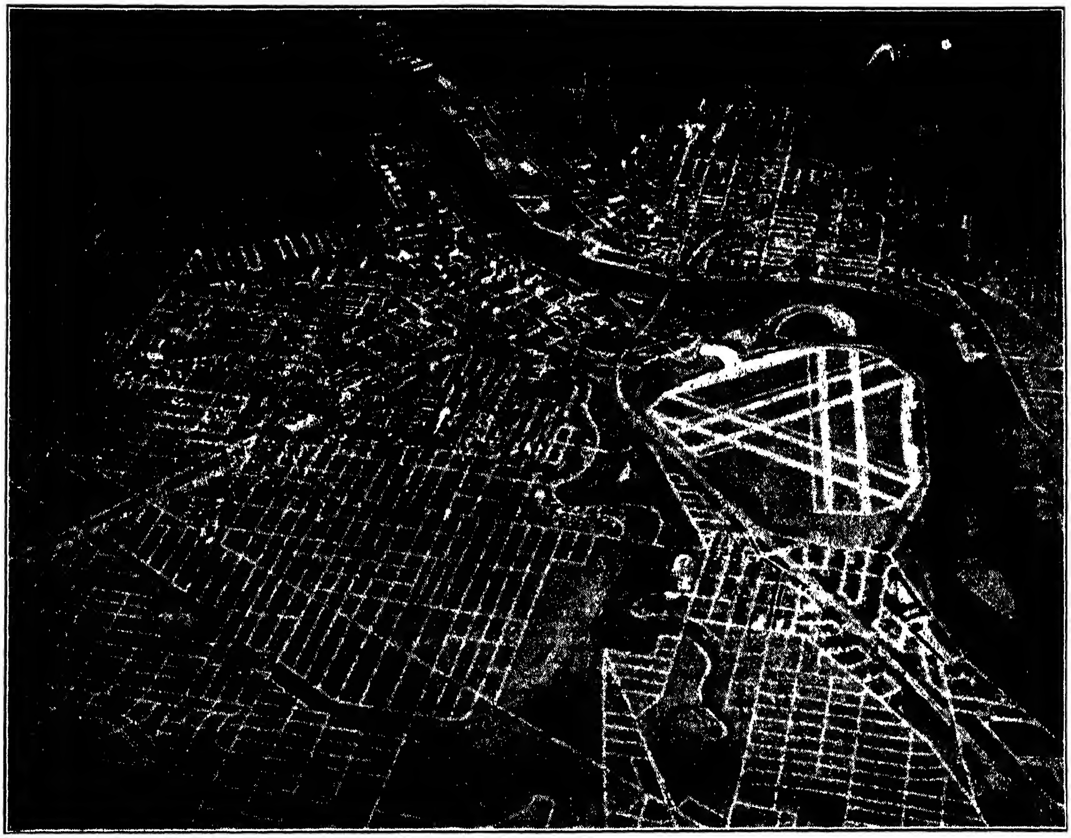

FIG. 3. An oblique view of Toledo tomorrow. In Toledo, Ohio, the people have been conscious of the need for a comprehensive plan well suited to the future needs of the city. The model of the city has attracted nationwide attention as a dramatic method of visualizing the needs of an urban community. (Photo courtesy *Toledo Blade*.)

Physical aspects of city planning extend beyond the city borders and link city with metropolitan-county planning. The highway system, for example, must connect with important arteries that lead from the city to its surroundings. Bridge approaches, water-supply, and dozens of similar items are of utmost significance. The complexity of planning for a large city, and of connections between the city and its surrounding region, is well illustrated by the admirable redevelopment plan of Cincinnati and environs carried out and published under the auspices of the City Planning Commission.

The human element is important in local planning. The human resources of the area are among the reasons for the planning; and a fuller life for future generations may be realized if the population characteristics and population trends are known. Educational planning, hospital planning, parks and recreation, for example, are all items that depend upon as accurate forecasts of future population as possible. Population trends, the shift of population within cities, the size of the families, and other pertinent facts that can be obtained in the human inventory are all of significance to the city planner. The environs of the business district may have a large population, for example, but if the largest child population is in the outskirts of the city the effect upon educational and school-need planning is profound. On the other hand, the park and recreational needs may be the reverse of the school needs in the instance just cited.

City planning commissions and state planning boards have worked in close cooperation. Both local and state planning appear to be permanent features of the economic and social structure of the United States.

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CHAPTER 23

National Planning and the Conservation of Resources

INTRODUCTION

THE national government, by its legislative acts, administered by the chief executive and tested in the highest tribunal of the people, provides equal opportunity for all the people of the United States The government in all its branches generally operates in the best interests of the nation as a whole and not selectively for the benefit of a few. Since the founding of the Republic the Congress has given attention to the needs of the nation, but inevitably certain acts of Congress have been advantageous to selected groups or particular areas. But in the government there have always been men of high principles whose great ambition has been to contribute to the general welfare of the nation.

The Responsibility of Congress

In the Congress, both in the House of Representatives and in the Senate, the members in general may be said to entertain two major objectives. As would be expected these elected representatives of the people are the protectors of the interests of the people whom they serve. At the same time they are aware of the needs of the nation, and their legislative actions reflect their interests in the national welfare.

The improvement of rivers and harbors, the reclamation of lands requiring irrigation, the control of floods, the development of power, the protection of coastal areas against erosion, the conservation of the soil resources, the preservation of the dwindling forest resources, and the conservation of the mineral treasures have required Congressional action. On occasion some of the beneficial acts may have been achieved through voting agreements. In this way a number of regional projects may be linked in a program of development which results in general benefits to the nation as a whole.

Inequality in the Distribution of Resources

The abundant resources of the country have not benefited all the people equally. Many people have been enriched because they have been successful in securing control over the material resources of the country. Others in humble circumstances have not shared in the great wealth of the nation. Certain pioneers settled the new farmland when the rich prairies were available. At a later period the settlers were not so for-

By Guy-Harold Smith of The Ohio State University.

tunate, for the richer lands were gone. The abundant timber and mineral resources were developed and exploited by private capital, and a fortunate few were enriched. Other people for one reason or another came into possession of poor land and found it difficult to earn a decent living. The material resources distributed unequally over the country have benefited the people of the country unequally.

Private Enterprise and National Planning

Concurrently with the political growth of the United States private enterprise and personal initiative were responsible in a large measure for the development of the natural resources. Because of the great abundance rapid and wasteful use of resources became a characteristic feature of the national economy. From the time of settlement and particularly after the frontier moved westward beyond the Appalachians, there was for many decades a prodigality about the exploitation of the great resources of timber, grass, coal, iron, and oil. But in the twentieth century, when the major outlines of the national economy had been established and when the great wealth of the nation had passed into private hands, the problem was no longer one of resources in America but of resourcefulness of the people in making a wise use of our material wealth for the benefit of all. Two world wars with their enormous wastefulness and a great economic depression have made us aware of the necessity of husbanding our resources and of examining our economy to see that it functions without injury to great numbers of our people. National planning among other things must be directed toward the wise use of resources and the ordering of the economy in the best interests of all the people. Planning is both a public and a private responsibility. People as property owners, whether as private citizens or as shareholders in large corporations, must join with the federal government in reducing the wasteful exploitation of natural resources.

In times past there have been periods of economic stress with widespread unemployment and insecurity. In spite of our great resources there have been periods of economic prostration. Fear has replaced hope and people have entertained doubt about the stability and the soundness of the national economy. The American economy characterized by the operation of the free enterprise system has been the envy of other peoples. Its great capacity for growth and expanded production has been outstanding. Nevertheless the national economy has been unable to achieve by itself certain necessary reforms and particularly to attain stability and full employment; as a result the federal government has participated increasingly in the economic life of the nation.

It has become evident that the federal government has an important responsibility in the development and the utilization of the natural resources of the country. The government has in the past provided a set of rules for the conduct of business and functioned as an umpire watching to see that the fundamental rules of the economy were not violated.

The federal government has become more paternalistic and now takes a leading part in planning for the full use and conservation of the material resources of the country. The national government has become in effect a gigantic planning agency and participates in many ways in the economic life of the nation.

THE NATURE OF NATIONAL PLANNING

Planning on a Nationwide Basis

It is not always evident that certain acts of Congress may change in a significant way the utilization of natural resources. The tariff regulations or duties applied to imports may affect all the people in much the same way. The import duty on foreign sugar increases the price of sugar everywhere in the United States. The duty on wool has a similar effect on the price of all woolen products whether they are made of imported wool or wool of domestic origin. In these instances the government was not primarily concerned with the increased price of sugar and wool to all the people but in the protection provided for the domestic producers of these products. In spite of the selective beneficiaries of Congressional action the federal government is interested in the general welfare of all the people.

While certain acts of Congress may operate selectively for the benefit of the few, many laws have nationwide application. The Pure Food and Drug Act, the insuring of bank deposits, the establishment of uniform postal rates, the operation of the Federal Reserve System, and many other acts and regulations apply more or less uniformly to all the people (Fig. 1).

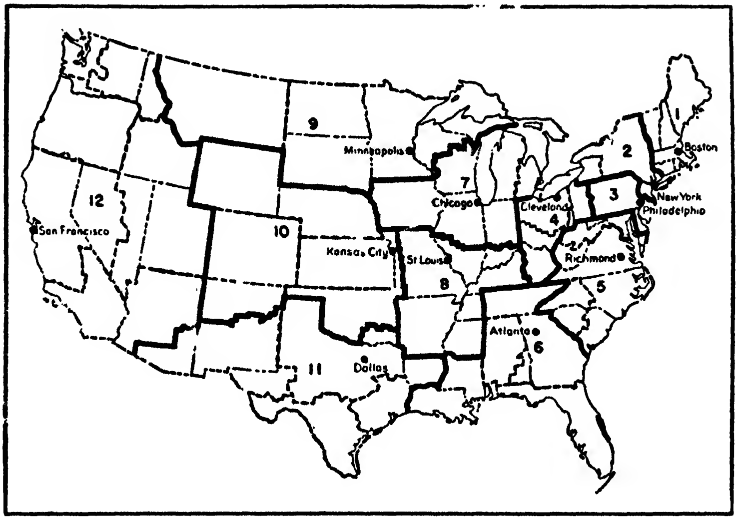

FIG. 1. The Federal Reserve Board: Districts. These divisions were originally set up to serve the banking and financial interests of the country. The boundaries are essentially political and arbitrary in character. (National Resources Committee.)

Benefits or disadvantages may accrue selectively to certain people, but the national welfare requires on occasion that the federal government take definite action. No doubt the best interests of the people were served when the federal government prohibited the export of helium gas, placed an embargo on the export or re-export of tin, endorsed stockpiling of strategic materials, or required that all uranium-bearing ores be sold to the government. During World War II a large number of resources and industrial materials were brought under control of the federal government. The jurisdiction of the government extended from production and procurement through processing and allocation to civilian and military agencies. This was well illustrated by rubber, linseed oil, copper, aluminum, and a great number of products. In times of national stress the participation of the federal government in the economic affairs of the nation is greatly expanded in the best interests of all the people.

National planning is regarded by many as a step toward a kind of totalitarianism which is in conflict with free enterprise and personal liberty. It is in the national interest, however, to use some of the wealth of the richly endowed areas for the benefit of the poorer sections of the country. Frequently the states that pay more into the federal Treasury in taxes than they receive in benefits are disposed to complain about inequities. Within the states a similar complaint is heard in the rich counties because the poorer counties receive in state aid more than their share of the funds available for roads and schools. Generally it is accepted as good governmental planning to use the greater wealth and resources of richer and more fortunate counties or states for the benefit of the poorer areas. In respect to schools this policy of good government can be easily defended, for the surplus population of the poor areas generally migrates to the more prosperous areas, and it is in the best interests of the richer region to receive people who are well educated and trained to make their contribution to the local community.

In the broad field of planning for the security and the defense of the nation, and planning for the social security of the people individually and by groups, the federal government must be concerned with the physical or material resources that are fundamental in security planning. The government extends its protection to all the people and otherwise recognizes the nationwide application of its laws and regulations. The conservation and wise use of the material heritage of the nation require vigilance and dynamic action against waste of the physical base of our national economy.

Government Must Take the Long View

In the long-range development of the economy of the United States the material resources have been or will be depleted unequally. Certain industrial raw materials occur in such great abundance that there is little danger of immediate exhaustion, for example, sand and gravel and perhaps even coal. The use of enormous quantities of iron and petroleum, on the other hand, has threatened our ultimate supply of these basic resources. The heavy demand for such metals as aluminum, lead, zinc, and copper has made us aware of the possibility of exhaustion of these essential raw materials.

The federal government and other agencies, both private and public, are giving and must continue to give attention to the conservation of our natural resources through research and investigations to extend the productive life of many of the sources of the raw materials so necessary in the complex economy of the United States and the world. Although most advances may benefit people selectively by professional group or occupation or in some region where the resources occur, the ultimate objective of the research should be to help all the people of the country to maintain or raise their standard of living.

A full and wise use of the human and material resources of the United States will require the co-operative efforts of many agencies both private and governmental. This great problem should engage the attention of agriculture, industry, and labor; a great variety of societies and associations must be ever mindful of their responsibilities in this great field of resource utilization; each family, the school, the church, and each person must share in the drive to prevent the waste of our material heritage; and every planning agency, local and national, and particularly the federal government must assume the role of leadership to the end that the material heritage of this nation shall be preserved from wanton destruction.

Standard of Living and Resource Utilization

The high standard of living attained by the people of the United States is due to a number of factors. The volume and value of material resources in relation to the number of people is conducive to the development of a high standard of living But in America the capacity of the people, with an urge to improve their physical well-being and raise their cultural standards, has been an important factor. The inventive genius of the people made possible the development of machines that can utilize the great power resources of the country for the welfare of the people. In spite of wastefulness and an imprudent drain upon the material base of our economic life, the economic and political leadership has been equal to its opportunity to bring favorable conditions of life and security to the American people. To maintain these conditions is the challenge which recurrently confronts the people and their government.

Planning, a Definition

Planning is the development of a program of ultimate objectives and a schedule of operations to achieve the desired results. In the development and wise use of resources a clear statement of the objectives to be attained is essential to the execution of a plan. It is also very important that the several operations in the plan be scheduled so that the key projects are given priority. This simple statement encompasses most of the essentials of planning whether local, state, regional, or national. The objectives and mode of operation are similar. The scale is different, as are the objectives and the operations required to attain the desired results.

Planning is not regimentation or may not be. In the United States democratic planning should emerge from the community or national discussion of issues that require collective action. Planning should be continuous, or at least there should be a periodic review of previous plans so that obsolete objectives may be abandoned. Also it may be necessary to reschedule the projects in terms of recent developments. A long-term plan characterized by rigidity instead of flexibility may be doomed to failure. It is important that planning, as a community program, should be responsive to the will of the people who may wish to re-examine their earlier plans and revise their schedule of projects. For example, a schedule may have called for the early construction of a series of navigation dams to maintain a minimum depth of water to facilitate commerce. A disastrous and unprecedented flood may demonstrate the need for the immediate construction of reservoirs in the headstream area to provide adequate protection to the structures planned earlier for navigation control.

REGIONAL PLANNING

In an area as large as the United States where the geographical diversity is so great it was inevitable that resource development and use would be distinctly regional in character. For example, the harvesting of the great white pine forest of the Great Lakes states placed upon the lumber markets one of the finest building materials in the latter decades of the nineteenth century and the first decade of the twentieth. When this harvest was consumed the lumber industry moved on to other forests, and the cutover lands became a problem area. In a similar manner the grasslands of the Great Plains were first the natural grazing lands of the indigenous buffalo. Then overpasturing by cattle and the breaking of the sod for agriculture weakened the natural defenses of the area, and in the dry years of the 1930's the dust bowl in its turn became a problem area.

Whether clearing the forest, breaking the prairie, mining coal, or irrigating the land are involved, the economic character of the country varies greatly from region to region.

What Is a Region?

There are many kinds of regions. Some regions are essentially physical in character such as soil regions, physiographic regions, climatic regions, and drainage basins. Others are cultural regions such as language areas, regions with a dominant religion, and areas with a particular mode of government. Whether physical or cultural a region must have one or more distinguishing characteristics that are more or less co-extensive with the area, and it should be set apart from other regions with distinct or arbitrary boundaries.

Many well-recognized regions in the United States have emerged because of certain dominant characteristics that have distinguished the area over a long period of time. In many instances the exact boundaries are very indefinite and ill defined, but the areas or regions are familiar to the professional planner and to the laymen as well. A region, to have validity and usefulness as a planning area, should emerge from the physical and cultural landscapes of America without consciously defined boundaries or enumerated common characteristics. Certain areas may be largely physical in character, and others chiefly cultural. In still other regions the physical and cultural characteristics are inextricably intermingled.

No matter how the regions may have evolved or taken on their identifying attributes, most Americans are familiar with New England, the Piedmont, the south, the middle west, the Great Plains, the Driftless Area, the Columbia Plateau, the Great Basin, and many more restricted areas or regions such as the Mohawk valley, the Delta country, the Tennessee valley, the Salt Lake oasis, the Great Valley of California, or the Puget Basin. Some of these are physical regions or were originally, but many of them have taken on composite characteristics reflecting something of the natural conditions in combination with the economic and cultural attributes. People living, working, and shaping the destiny of an area give to it characteristics that transcend the natural conditions which at the outset may have been dominant.

Most regions have a central or core area which may be regarded as the type location. However, the core may not represent all the characteristics of a large area or in the same proportion. No small area in New England could be truly representative of the forested highlands of northern Maine, the truck farming area of the Connecticut lowland, the sandy beach areas of Marthas Vineyard, or the industrial community of Worcester, Massachusetts. With all its regional or sectional differences New England is a region. The states that constitute the region are contiguous; they have a common heritage; they are confronted by similar problems; and, what is most important, there is an awareness of regional unity on the part of the people. New England is a psychological as well as a geographical region.

The same type of analysis can be applied to other major regions with much the same results. In regional planning which in effect is national planning by regions it is necessary that the areas set up as planning regions should have something of the unity of spirit that characterizes New England, the south, or the middle west. From this sense of regional unity will come the leadership and the energy that will achieve results.

Frederick Jackson Turner, historian of the frontier, recognized the importance of pioneer life as a significant force in the development of fundamental political character of the United States. Although the moving frontier tended to bring some common experiences, the pioneers were adventuring into different geographical regions. Sectionalism was from the outset a concomitant characteristic of the settlement and development of the United States.

Regionalism or sectionalism in a narrow provincial sense may be an undesirable characteristic of the national economy. But regionalism, if it is a unifying force which transcends the restricted limits of a small area, may be a vital factor in the development of national character. Out of the diversity of states and regions a spirit of national responsibility emerges. Fortunately in the Congress and in other branches of the federal government the national welfare has been paramount, and as a result sectional interests usually have not prevailed. "The diversity of regions rather enriches the national life than impoverishes it · · ·"[1] Regional planning is in effect national planning expressed or developed areally.

Regional Divisions of the United States

The federal government has found it desirable, and in particular cases almost a necessity, to decentralize or regionalize certain functions. The concentration of many agencies in Washington has been looked upon as undue centralization of administrative activities in a single urban center. The rapid expansion of governmental agencies in wartime and during the difficult depression years placed a heavy burden upon the metropolitan area of Washington. Housing for government employees, transportation to and from work, office space for personnel, and related problems became the insuperable difficulties of a rapidly expanding metropolitan area. There was no time for planning, but it was obvious that decentralization of certain governmental functions was an urgent necessity.

The Census Divisions

The Bureau of the Census has established a number of arbitrary but statistically useful regions. Each of these divisions includes a number of states that are contiguous and have many characteristics in common. They include New Engand, middle Atlantic, south Atlantic, east north central, west north central, east south central, west south central, mountain, and Pacific groups of states. These are not regions of functional or administrative im-

[1] Donald Davidson, "That This Nation May Endure, The Need for Political Regionalism" in Herbert Agar and Allen Tate, *Who Owns America?*, Boston, 1936, p. 116.

portance. They have statistical convenience and through long use have become well established.

Functional Divisions of the United States

For the purpose of decentralizing certain administrative functions of the government a number of agencies have a regional pattern of organization. This is well illustrated by the United States Circuit Court of Appeals which consists of ten Circuit Districts and the District of Columbia. These regions or districts are judicial areas and serve this function only (Fig. 2).

In 1914 during the administration of President Woodrow Wilson and while Carter Glass was Secretary of the Treasury, the Congress enacted the legislation that created the Federal Reserve System. For the purpose of carrying out the provisions of the act the United States was divided into 12 Federal Reserve districts each consisting of a number of states or parts of states and each having a Federal Reserve bank to serve the banking, industrial, and commercial interests of its area.

Many other agencies of the federal government have been organized on a regional basis, or have established outpost or field offices to facilitate their administrative activities. The Veterans Administration, in spite of the need for a gigantic central office in Washington, has established a great number of regional or local offices. The Social Security Administration maintains regional offices in 11 cities in the United States, one in Alaska, and one in Hawaii. The Federal Trade Commission in addition to the headquarters office in Washington has branch offices in New York City, Chicago, New Orleans, San Francisco, and Seattle. These agencies illustrate a degree of decentralization and the regional organization of certain activities of the federal government. In 1938 it was reported that more than 70 federal agencies found regional organization necessary and that there were 108 different ways of or-

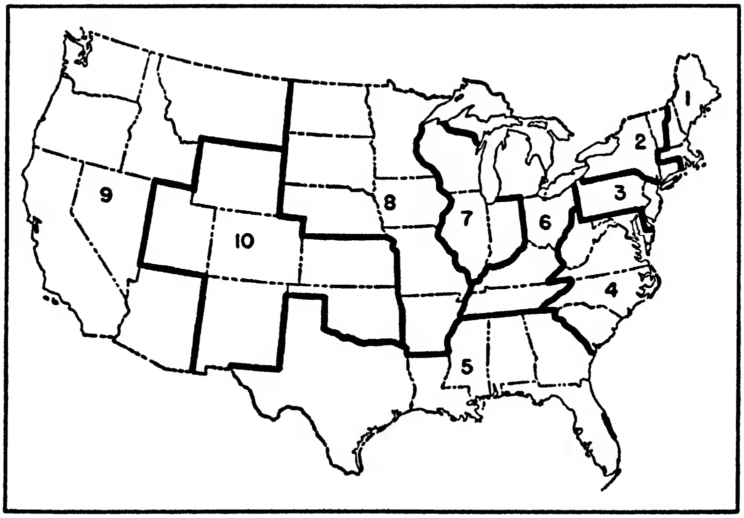

FIG. 2. The United States Judicial Circuit Court: Districts. Certain functions of the federal courts are handled in ten circuit districts delineated by selected state boundaries. (National Resources Committee.)

ganizing the country regionally for the purpose of administering the federal services efficiently.[2] No doubt the war years required a regional organization of numerous war agencies, and a number of government bureaus moved their central offices from Washington to other cities where living and working conditions were favorable.

Planning Regions

The establishment of regions for the planned development and use of resources emerges as a necessary concomitant of national planning. Certain steps have already been taken and may indicate the nature of the regions that are most suitable for planning and developmental programs. It is obvious that no single type of region will be suitable for all purposes. Several kinds of regions, differing in dimensions, overlapping perhaps in certain instances, and encompassing a number of vital activities, may be necessary to achieve the several objectives of a well-balanced program of national development.

The Watershed as a Planning Region

It has been recognized that the hydrographic basin or watershed is an appropriate and manageable planning area.[3] In many of the drainage basins of the United States the principal problems that require constructive action are closely related to the river in each watershed. The river and its several tributaries are continually carrying away the top soil of the area; floods frequently inundate the bottomlands; low water conditions interrupt commerce; and in other ways the problems focus attention on the river. The control of the master stream becomes the key project in a basin-wide program of resource development which will under proper management extend to other problems not directly related to the river (Fig. 3).

The Tennessee River basin, developed under the administrative jurisdiction of the Tennessee Valley Authority, may be regarded as the model drainage-basin planning region. Other watersheds have been designated as well suited for regional development. These include the Ohio valley, the Missouri valley, the Colorado valley, the Columbia valley and others (Fig. 4). Regional planning by drainage basins cannot be realized in a few months or a few years. It is important in the over-all planning for the nation as a whole that certain great public-works projects be reserved for development when the labor force is not fully employed in private industry. For this reason it is important that plans be prepared well in advance of need so that they may be used to provide employment as soon as it becomes evident that unemployment has become so serious as to affect the national economy adversely.

The Tennessee valley development is an achievement that has been the envy of other regions. People in other areas are reluctant to wait until adversity initiates a program of action. The full development of the resources of the Missouri valley, the Columbia valley, the Ohio valley, and many other valleys will be delayed until certain other war-delayed activities have caught up with the public demands. The requirements of the United States in respect to housing, automobiles, and new productive equipment to meet consumer needs are so great that material, the labor force, and the

[2] National Resources Committee, *Regional Planning*, Washington, D. C., 1938, p. 1.

[3] Alvin H. Hanson and Harvey S. Perloff, "Regional Resource Development," *National Planning Association*, No. 16, Washington, D. C., 1942, p. 29.

managerial skills are not available for major public-works projects.

Before the need arises for immediate action the comprehensive surveys can be made so that plans will be ready when the need arises. As an integral part of the plans a schedule of projects should be developed. It may be necessary to proceed immediately with certain plans for a region or watershed and reserve for later periods the completion of the project. That is well illustrated in the signing of the Ohio River Valley Water Sanitation Compact at Cincinnati, Ohio, on June 30, 1948. Navigation on the Ohio has long been a part of the program of river development. Floods remain a great menace, and many years will be required before the excess waters can be brought under control. But the Ohio is more than an artery of commerce. It is a source of water for millions of people, and at the same time it is a great sewer. It is the problem of sanitation on the agenda of Ohio valley projects that requires solution soon.

Groups of States as Planning Regions

Other types of areas have been suggested as suitable for regional development. Some of these include a number of drainage areas, and their boundaries are not in all areas coincident with the water parting or the divide between watersheds. The New England area consists of a group of states rather than a number of drainage areas, yet the water problems of the several major streams such as the Connecticut and the Merrimack require a number of multiple-purpose projects to meet the situation.[4] The Middle

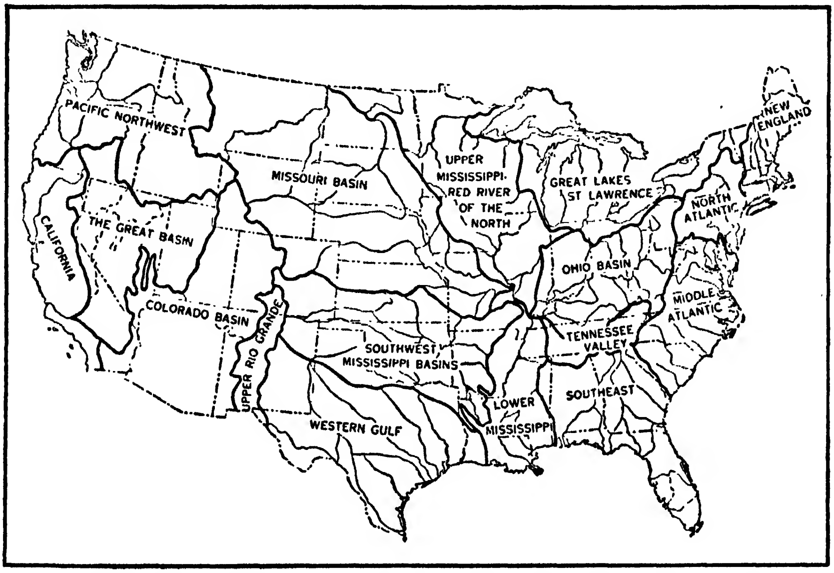

FIG. 3. Major drainage basins of the United States. Drainage basins are naturally well suited for water planning, but in spite of their limitations they are being considered appropriate for the more inclusive regional planning programs. (National Resources Planning Board.)

[4] National Resources Planning Board, *Development of Resources and Stabilization of Employment in the United States, Part II. Regional Development Plans,* Washington, D. C., 1941, p. 14.

Atlantic area like New England is largely a group of states extending from New York to North Carolina and fronting on the Atlantic. It is an area with many problems, of action that will rehabilitate the unfortunate people who live in such areas and redesign the land-use pattern in terms of the long-range needs of the urban areas.

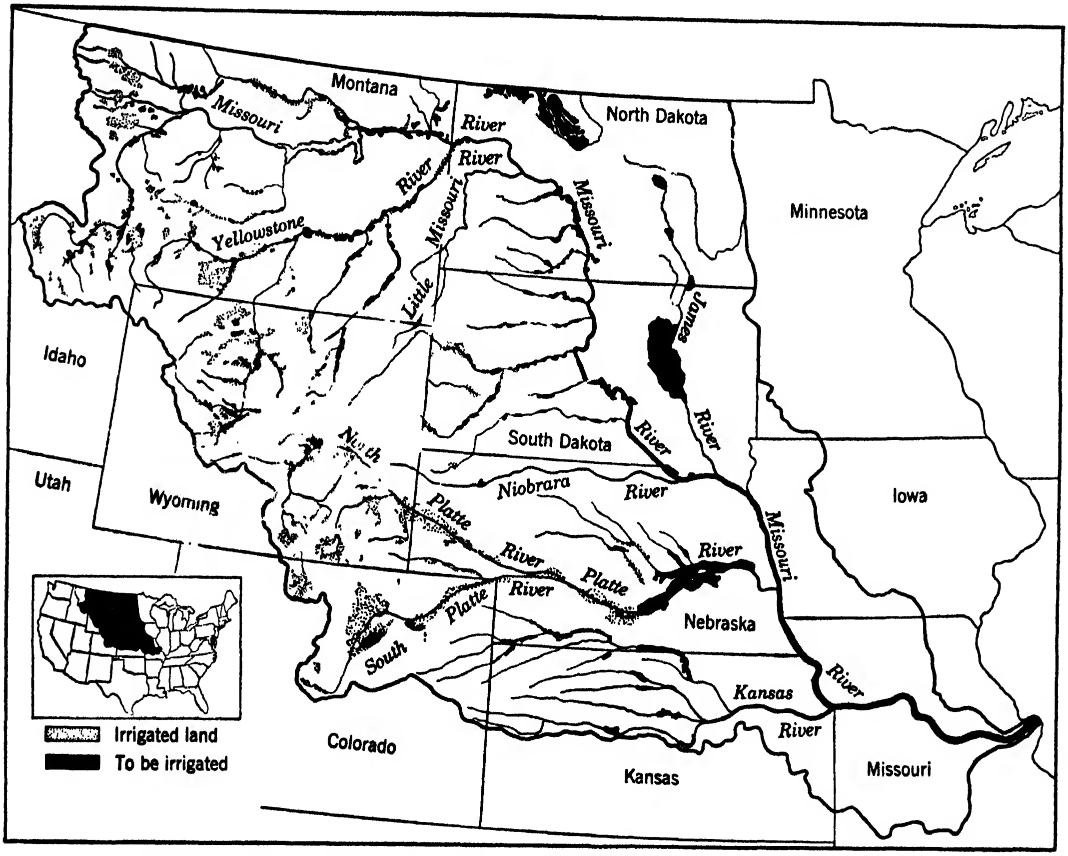

FIG. 4. The Missouri River basin. The basin of the Missouri River presents a series of problems which seem to require careful regional planning for their proper solution. (After the Bureau of Reclamation.)

but it lacks the regional consciousness so characteristic of New England.[5] This is a region highly developed industrially and commercially, and many of the most urgent problems of today are related to the lack of careful planning in the past. Urban blight and the related ills of the industrial communities require plans and programs

[5] *Ibid.*, p. 29.

Other groups of states have been considered appropriate planning regions. Some of these include the southeast consisting of South Carolina, Georgia, Florida, Tennessee, Alabama, and Mississippi. Part of this area is already included within the Tennessee valley project. In spite of industrial developments in the Piedmont, in the Birmingham district of Alabama, and in the Tennessee valley, this is an agricultural area with some of the agrarian problems associated with the cash crops of cotton and tobacco.[6] This region like the Middle Atlantic consists of a group of states with a sufficient number of common characteristics to suggest that they be considered a planning region.

The mountain states planning region consists of Colorado, New Mexico, Wyoming, and parts of several other states in the Rocky Mountain area. This large area, because of the character of its resources, has been exploited rather than developed. Minerals have been mined until the rich treasures have been exhausted; grasslands have been overgrazed to supply meat products to the eastern markets; and in many areas the limited timber resources have been cut so that watershed protection has been reduced.

The one great resource of this area that requires the careful attention of the planning agencies is water. The scant rainfall, in most places inadequate for either forest or agriculture, becomes a resource of great importance in the water courses where the water is available for power and for irrigation. The co-ordination of the several water-use projects is the major regional problem of the mountain states.[7]

The Pacific southwest and the Pacific northwest regions are similar planning regions because each consists of a number of states and parts of states. In both areas large tracts of dry land without adequate water are characteristic, though the southwest has less rainfall than the northwest. The southwest has access to the power and the water of the Colorado while the northwest taps the resources of the Columbia. Both regions as described by the Regional Planning Commission of each area have many of the characteristics of a drainage basin so well adapted to the needs of regional planning.

In the Pacific southwest water is the universal need. "Cities, farms, mines, and factories depend directly on perpetuation of their water supplies, which must often be brought from distant sources. The desert is ever striving to recapture the territory that has been wrested from it." [8] In such an area the individual, whether he is a farmer, a miner, or a city dweller engaged in activities that seem to bear little relationship to the basic industries, may be unmindful of the fact that he is in a large measure dependent upon projects sponsored and developed by collective action. Water is brought in from distant sources, and also the power developed on the same rivers that supply the water. Certain projects have been developed by private corporations, but others had to wait for governmental action. Where the resources are relatively scant in terms of the number of people who wish to share in their development and use the public interest transcends the personal or individual. In the southwest there is a genuine need for a comprehensive and long-range plan or series of plans for the appropriate development of the resources.

The Pacific northwest as a planning region consists approximately of the three states of Washington, Oregon, and Idaho, though the regional limits have not been sharply defined. The several problems related more or less directly to the natural resources include the settlement and reclamation of arable lands, the utilization of water for irrigation and power, flood control, the

[6] *Ibid.*, p. 50.

[7] *Ibid.*, p. 174.

[8] *Ibid.*, p. 198.

establishment of the sustained yield principle in the lumbering industry, forest protection and rehabilitation, and the preservation and development of the scenic resources.

NATURAL RESOURCES AND NATIONAL SECURITY

The basic raw materials so necessary in maintaining the highly developed economy of the United States are available in very unequal quantities. Fortunately America is richly endowed with most of the essential raw materials of industry, but there are notable exceptions. The rapidly expanding economy has increased greatly the demand for raw materials and hastened the exhaustion of certain resources initially in short supply. An immediate or prospective shortage of basic raw materials produces a sense of insecurity. A people mindful of the real or ultimate scarcity of the resources that are essential to the national economy should take the necessary steps to attain security. The economy of peace should be convertible to war in all possible haste in times of emergency and with the least possible interruption of normal civilian activities. Whether the United States is a neutral or a belligerent the nation's best interests will be served if the economy is based upon adequate supplies of the essential raw materials.

It may be observed that complete independence in respect to the basic resources of industry is an impossibility for the United States. Dependence upon resources imported from other countries is and has been a significant feature of the American economy. Staley has stated clearly and forcefully, "There is no escape from international raw material interdependence ···" [9] and this applies to the United States as well as to other richly endowed countries.

New Discoveries

The available supply of many important resources will be increased by new discoveries if the history of mineral exploration can be used to forecast the future. In spite of the prospect that new discoveries will add substantial supplies of many resources to the total available for industrial use, there is also the grim truth that the rate of discovery will fall below the rate of use. New and more economical ways of using low-grade deposits may extend greatly the life of many known resources. This may be regarded as one of the important means of increasing the ultimate supply of many important mineral resources. National security is related to the continued search for additional supplies of essential resources and to an expanded program of research designed to make available industrial raw materials from deposits now known.

Energy Resources and the Strength of the Nation

The fuel and power resources of the United States have made possible the high development of power-driven machines and have been responsible in a large measure for the highly mechanized productive facilities that have brought material conveniences and comforts to the American people. Human toil has been reduced substantially through the decades. Inanimate energy released by the consumption of coal, petroleum, gas, and water power has multiplied many fold the energy of human hands. The continued use of these power resources

[9] Eugene Staley, *Raw Materials in Peace and War*, New York, 1937, p. 238.

should give the United States a material civilization of a high order. Human energies thus released could be devoted to activities of great cultural value to the country and to mankind.

The coal deposits of the United States are so extensive and so abundant that it has been estimated that the resources of bituminous coal alone will last a thousand years. The reserves of anthracite are much smaller, and the productive life of the mines may not exceed 175 years. Petroleum is being consumed at a very rapid rate, and the known reserves may last only 15 to 30 years, depending upon whether the reserves can be expanded by new discoveries or by improved methods of recovery. The known reserves of natural gas are being developed rapidly and probably will be exhausted in approximately fifty years. The relative abundance of coal in relation to the known reserves of petroleum and natural gas makes it obvious that the experimental work on the liquefaction of coal and the recovery of liquid fuel from oil shales must be intensified. The enormous demand for liquid fuels will require somewhat of a revolution in the power industry. In addition to the liquefaction of coal to replace the dwindling supplies of petroleum it may be necessary to turn to organic sources of power in the form of alcohol derived from agricultural and other plant materials. Higher prices for liquid fuels and the necessity of securing new materials should provide the incentive to achieve the desired results. If the United States is to maintain its high position in respect to the productive use of inanimate power it must be ready also to adjust the nation's economy to the changing character of the energy resources available for industrial use.

It is difficult to state with any degree of assurance just how atomic power may be used as a source of energy. The ultimate importance of atomic energy as a power resource is related to the supplies of fissionable materials that are available in this country or can be secured and the progress made in the development of the means of making the energy available for practical use. In only a decade or two it may be possible to supplement, perhaps even replace, other sources of energy with the enormous energy resources of the atom.

The Metals in a Power-Using Economy

The United States has long been essentially self-sufficient in respect to iron ore. The rich ores of the Lake Superior area have supplied in large measure the needs of the nation. But expanded use during World War II has reduced the available supply of the high-grade ores. Small quantities of ore from Cuba, Chile, Sweden, and other oversea's sources have long been imported advantageously. With the depletion of the high-grade ores in the Lake Superior area increasing quantities may be imported from these foreign sources and from recently discovered deposits in Canada and Labrador. The present ratio of domestic to imported ore may require adjustment in favor of more foreign ores. This is a resource situation that the United States must face as the national economy recovers from the effects of the war.

The increased use of specialty steels requires a number of ferroalloy metals such as manganese, chromium, nickel, tungsten, vanadium, molybdenum, and others. The United States has adequate supplies of only one of the essential alloy metals, molybdenum. The steel industry on its own responsibility may build up inventories of these ores or metals to protect itself temporarily against shortages if supplies should be cut off. The metal industries cannot be charged with full responsibility for assuring for themselves sufficient supplies to meet both the requirements of peace and the emergency of war. In a large measure the federal government is responsible for meeting the emergency of war. Stockpiling or substitution may be the alternative solutions to this national problem.

Many of the nonferrous metals are being used so rapidly that domestic supplies are inadequate or will soon be so reduced in quantity that dependence upon foreign sources will be a sobering fact. The United States has always been dependent upon foreign areas for tin, mercury, and a number of metals of lesser importance. Available and known reserves of lead, zinc, and copper have been so reduced during World War II that imports are immediately necessary. A substantial increase in price or a new and cheaper method of recovering the metals from low-grade ores may delay the shift to foreign sources. The industries concerned and the federal government should be alert to the importance of this group of metals in the national economy and particularly in reference to national security.

The rapid expansion in the utilization of light metals such as aluminum and magnesium and their alloys is a part of the revolution in the metal economy. These light metals may be used extensively in the manufacture of machinery and transportation equipment. The reduction of dead weight may result in a more efficient use of power and at the same time reduce the demand for steel. In a similar way the increased use of plastics may replace important quantities of metals formerly used for decorative purposes. Although inexhaustible quantities of aluminum occur in common clay it cannot be produced economically from this source.[10] The high-grade bauxite ores are being used rapidly and oversea's sources of ores are meeting at least half of America's aluminum requirements. Magnesium produced from brines, magnesium-bearing minerals, and from sea water is essentially a domestic industry, and the resources may be regarded as inexhaustible.

In order to protect the position of the United States in respect to the nonferrous metals both industry and government should encourage the recovery of secondary metal and the development of substitutes and support research in the hope of improving the techniques of metal recovery from the more abundant low-grade deposits. Industry's objectives should be the development of adequate domestic supplies to maintain high-level production with reasonable profits to the shareholders. Most of these metals are essential materials in time of war, and the objective of the national government should be security based upon the knowledge that domestic supplies and the accumulated stockpiles would be adequate to meet the immediate needs of a wartime economy.

The problem of the metals has many facets. Each metal, or closely related metals such as lead and zinc, must be examined in terms of current production, known reserves, importance of secondary recovery, the proximity of foreign sources, and the necessity for stockpiling. These problems separately and collectively are of major importance to the professional conservationist, the industries which use them, and the federal government which must plan for the

[10] Wilbert G. Fritz, "Natural Resources," in J. Frederic Dewhurst and Associates, *America's Needs and Resources*, New York, 1947, p. 583.

security of the nation. In fact it is the duty of every citizen to be fully informed about the mineral situation so that he may participate in the solution of this important resource problem.

Resources of Organic Origin

The United States is normally dependent on imports for an important list of products of organic origin. During World War II fats and oils were in short supply. The expansion of the production of peanuts and soybeans offset in large measure the loss of supplies of coconut and palm nut oil regularly imported from the Far East. The cordage fibers such as henequen, Manila hemp, and jute are not only important in civilian industries but are essential in time of war. Other fibers such as kapok, bristles, and wool are imported to meet domestic requirements.

The list of materials of organic origin can be extended to include timber and wood pulp, condiments, tanning materials, rubber, and hides and skins. Our dependence upon oversea's sources may be reduced by the development of substitutes, particularly rubbers developed from petroleum and alcohol. The increased use of plastic wood, resin-impregnated woods, wallboard, and preservatives may extend greatly the forest resources of the country.

Unlike the nonperishable mineral resources these organic materials cannot be stockpiled without danger of deterioration and perhaps complete loss if they are stored over a long period of time. Stockpiling requires continual renewal of supplies to meet or offset withdrawals from the nation's hoard of essential materials.

The National Security Resources Board

The National Security Act of 1947 created the National Security Resources Board, the National Security Council, the Central Intelligence Agency, the National Military Establishment, and the Munitions Board. All these agencies of the federal government, particularly the National Security Resources Board and the Munitions Board, are concerned with the material resources that in a national emergency should be available for both civilian and military purposes.

The National Security Resources Board is a permanent civilian agency of the government and consists of the chairman of the board, the secretary of state, the secretary of the treasury, the secretary of defense, the secretary of the interior, the secretary of agriculture, the secretary of commerce, and the secretary of labor. The board is charged with the responsibility of securing the co-operation and support of industry, agriculture, labor, and the personnel of the universities, professional societies, and all other organizations which can make a contribution to full and continuous utilization of the material, man power, fuel, electric power, transportation facilities, and all finished products involved in total mobilization.

Continuous planning is an essential responsibility of the National Security Resources Board. Plans once regarded as adequate must be re-examined frequently for technological changes in production, and changes in strategy and tactics, which in war may alter the power potential without any significant change in the quantity of materials available. The board has recognized eight major categories of responsibility.[11] 1. The board will maintain *balance sheets of the resources and require-*

[11] Background material about the National Security Resources Board, a memorandum dated September 1, 1948.

ments of the economy fully mobilized to meet any emergency. 2. A series of *economic readiness measures* must be prepared for use of the President and the Congress in meeting the immediate and long-term requirements of the emergency. 3. Planning must include *integrated policies and programs* which will recognize the necessity of maintaining the civilian economy at the same time the nation mobilizes its resources for war. 4. *Plans for the mobilization of industries* must be in readiness for immediate use in converting to war. 5. Mobilization of the productive facilities would require, for maximum efficiency and flexibility, a carefully developed plan of *controls, methods, and procedures.* 6. The board shall advise the President on *organization plans for an emergency* so that all federal agencies and department may make their maximum contribution to the nation's needs in an emergency. 7. Recommendations in respect to *emergency legislation* must be kept in readiness in case war should come suddenly. The President could, by a series of executive orders, take the first necessary steps to meet the emergency. 8. A *roster of key personnel* must be maintained and constantly revised so that mobilization may be attained quickly with well-qualified persons available for assignment to the most important positions.

The responsibilities of the board extend beyond the realm of resources as expressed in quantities of raw materials either as reserves or the production of strategic resources. But in all its activities the situation in respect to resources is of fundamental importance, particularly in recommending full mobilization to meet a national emergency.

By Executive Order, dated November 13, 1947, President Truman called upon all agencies and departments of the federal government to co-operate with the National Security Resources Board by supplying essential data in their possession and to make such studies as the board may request. On its own responsibility the board and its staff members may make special studies and a number of such reports have been completed.

The National Security Resources Board by the Act of Congress which created it must give its attention to the material requirements of the peacetime economy as well as the wartime needs of the nation. All contingencies in respect to resources properly come under the jurisdiction of the board.

The Munitions Board [12]

The National Security Act created the Munitions Board as the successor to the Army-Navy Munitions Board. This agency is under the jurisdiction of the secretary of defense and is charged with responsibility in respect to certain matters assigned to the board by law and others that may be referred to it by the secretary. Among its many responsibilities the board will maintain up-to-date estimates on the economic and military potential of the nation. The board shall give particular attention to the requirements of the National Military Establishment in respect to man power, matériel, services, and facilities involved in economic and military mobilization to meet a national emergency.

The Munitions Board consists of a chairman, who serves as the executive officer, an

[12] This section is based largely on published reports and press releases of the Munitions Board, particularly on a report entitled "The National Stockpile, a Non-confidential Supplement to the Stockpiling Report," issued by the board on July 23, 1948.

undersecretary or assistant secretary of each of the three military departments, and other essential personnel. The board as thus constituted has jurisdiction over a variety of activities which affect in a very vital way the national security. Specifically the board must give attention to the position of the United States in respect to the raw materials so necessary for the security of the nation. There must be a formulation of procedures for the procurement, the production, the allocation, and the distribution of the basic resources. All plans must be continually reviewed in order that the resources and facilities may be mobilized with greatest effectiveness in an emergency.

The regular appraisal of the situation in respect to resources is a major function. The stockpiling of certain strategic resources that are in short supply is an important activity of the board. A great variety of materials from agar to zircons and including quartz crystals, mica, and uranium have been classified in respect to the urgency of stockpiling. Three major categories or groups of materials have been set up. Group A includes those materials that must be stockpiled. This is the only means of meeting an emergency with adequate supplies on hand. In this list are included such materials as bauxite, chromite, mercury, natural rubber, tungsten, and many others. Group B includes a number of materials in which the supply situation is less urgent but which should be stockpiled. Included in this list are such materials as cryolite, graphite, platinum, and wool. The C group consists of materials that pose difficult problems of storage. The danger of fire and deterioration while in storage make long-time stockpiling impossible or at least extremely difficult. This list includes such materials as bristles, jute, leather, balsa wood, scrap metal, and uranium. This grouping is subject to revision as the supply situation changes. It is the duty of the board to re-examine from time to time the resource situation so that the National Military Establishment may be fully informed about the supplies, the production, and the distribution or allocation of strategic resources.

RESEARCH AND THE PROBLEM OF DIMINISHING RESOURCES

In the conservation of the natural resources of the nation one of the great hopes of the future is the intensive search for the solution of the problems related to the exhaustion or decline of the material wealth long so abundant and easily available to us. Organized research must be brought to bear upon this problem, and human talent must be mobilized so that the basic needs of our economy can be satisfied to the end that security of the nation will never be in doubt for want of the essential raw materials.

Individual Research

It is traditional that the individual scholar at work in his laboratory or in his study represents scientific progress in a free society. Scientists working alone in their laboratories or in the field have found ways of utilizing more fully or more cheaply our material resources. Certain scholars will always be more effective as lone workers, and they should be encouraged to make full use of their research ability. The scholar in isolation has become relatively less important, but his work should be encouraged and supported. It will be difficult to integrate the researches of many individuals into a planned program of investigation covering adequately all aspects of the national problem of resource utilization and preservation.

Industrial Research

Many years ago certain industries anxious to maintain their competitive position established research laboratories and employed a staff of scientists to carry out their investigations. Initially the industrial research laboratories or divisions were largely concerned with practical problems related to the industry that sponsored or supported them. But industrial research has become both practical and fundamental. The findings do not always need to have immediate and practical usefulness. At the outset research carried on by industry was largely directed toward more economical manufacture of commercial products or the development of new and better products. In the United States these industrial developments have usually resulted in the increased use of the basic raw materials.

Some of the best-known industrial research organizations include the Research Laboratories Division of General Motors Corporation headed by Charles F. Kettering, the General Electric Research Laboratories, the chemical, development, and engineering departments of the E. I. du Pont de Nemours & Co., The Standard Oil Development Co., Monsanto Chemical Company, the Mellon Institute, the Battelle Memorial Institute, and many others.[18] These research organizations have become increasingly important in the industrial progress in the United States. Research activities have moved forward from the restricted objectives to more comprehensive programs. Better products for the ultimate consumer remain important, but research is being directed toward the solution of the raw material problems. The beneficiation of low-grade ores is an important development and indicates the direction of research in the field of natural resource utilization. The recovery of aluminum from common clays and other aluminum-bearing minerals is a research enterprise of major importance. As essential raw materials have become scarce or for one reason or another difficult to obtain, industrial research has been re-oriented. The transformation of the rubber industry as a result of the loss of access to adequate supplies of natural rubber is a notable example of the capacity of American industry to solve a raw material problem.

In the field of industrial research integration can be achieved for the reason that government-sponsored programs have been allocated to those research foundations or organizations best qualified to carry on the investigations. Continually there emerge from the industrial laboratories achievements which the National Security Resources Board can examine and appraise in terms of the needs of the nation.

Research in Colleges and Universities

Research in the major educational institutions of this country has been overshadowed by the great industrial research organizations. In fact research in the universities is in many instances indistinguish-

[18] For a comprehensive listing of industrial research laboratories see Callie Hall (assisted by Mary Timms and Lois Wilson), "Industrial Research Laboratories of the United States Including Consulting Research Laboratories," *Bulletin No.* 113 (Eighth Edition), The National Research Council, National Academy of Sciences, Washington, D. C., 1946.

able from the research in industry. Many universities receive support from industry for their research progams, and generally the achievement of practical results is a major objective. In the universities there can be a detachment that is conducive to long-range research of fundamental character where practical application is not immediately envisioned. The universities are peculiarly well suited for this type of research.

It is appropriate that certain research programs in the universities should be concerned with the many aspects of the resource problem. In the physical and biological sciences, in political science, and in economics both the scientific and the social aspects of natural resources may be investigated with scholarly objectivity.

The Government and Research

The federal government and to a lesser extent states and municipalities have conducted and supported research activities over a long period of time. During World War II and in the post-war period research in agencies of the federal government has been greatly expanded. In a similar manner research in the universities and in private research organizations has been generously supported by the federal government. Much of the research is related directly or indirectly to the problem of national security and in one way or another is concerned with the resource situation.

The Agricultural Experiment Stations, the Bureau of Mines, the Soil Conservation Service, the Bureau of Animal Industry, the Forest Service, the regional laboratories and the Agricultural Research Center of the Department of Agriculture, the Research and Development Board, and many other bureaus and agencies of the federal government are devoted to research programs which will lead eventually to a wiser use of our basic resources. In such organizations the advantages of group research are obvious. The exchange of ideas among scientists concerned with a common problem is a fruitful experience and generally yields important results.

In a nation of diminishing material resources there are still new frontiers to be explored. New lands are no longer available to challenge the pioneering spirit of the youth of America, but the new frontiers of science present an opportunity for adventure and achievement for those who would serve the needs of their country. Through the resourcefulness of our people in making a full and appropriate use of the more abundant materials available to us and in searching continuously for new resources we shall achieve the security we desire.

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