LAND AVAILABLE FOR AGRICULTURE THROUGH RECLAMATION

PART IV

OF THE

REPORT ON LAND PLANNING

THIS PART WAS PREPARED BY THE BUREAU OF AGRICULTURAL ENGINEERING, DEPARTMENT OF AGRICULTURE
FOR THE
LAND PLANNING COMMITTEE OF THE NATIONAL RESOURCES BOARD

The National Resources Board assumes no responsibility for the views and opinions expressed herein

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PREFACE

On November 28, 1934, the National Resources Board submitted to the President, in accordance with an Executive order, its report on National Planning and Public Works in Relation to Natural Resources and Including Land Use and Water Resources. Part II of that report was the Report of the Land Planning Committee. In the course of preparing part II of the above report a large volume of basic data and information was collected which could not then be included. The publication of the present report is for the purpose of making such data and information available to interested persons and organizations.

The present land report has been organized into 11 parts according to subject matter and the contributing agencies. These 11 parts are made available as 11 separate publications. Organization and publication on this basis was done because many persons and agencies are interested only in certain parts of the present report, and the necessity of purchasing the whole report in order to obtain the desired part or parts is thereby eliminated.

The present land report, when conceived as a whole, does not purport to be a complete work on the subject of land utilization, or of its related problems and proposed lines of action; neither is it designed to be a thoroughly integrated piece of work. The primary aim here has been to set forth the facts, analyses, and the recommended lines of action as developed by each of the various contributing governmental bureaus, divisions, sections, or individuals, on the problems with which each of such agencies or persons is concerned. The points of view are, therefore, those of the contributing agencies or individuals themselves. The Land Planning Committee presents the report as information, but assumes no responsibility for the opinions expressed in it.

This report was prepared under the direction of Dr. L. C. Gray, director of the Land Section of the National Resources Board, aided by John B. Bennett, who served as administrative assistant and as secretary to the Land Planning Committee. Editing and preparation of the report for publication were under the direction of Mr. H. H. Erdmann, agricultural economist of the Land Section, National Resources Board.

Authorship by agencies and individuals is acknowledged in their respective contributions. The following governmental agencies have contributed to the whole report: The Geological Survey, the Division of Grazing Control, the Office of Indian Affairs, the National Park Service, and the Bureau of Reclamation, in the United States Department of the Interior; and the Bureau of Agricultural Engineering, the Biological Survey, the Bureau of Chemistry and Soils, the Forest Service, the Soil Conservation Service, the Weather Bureau, the Divisions of Land Economics, of Farm Management and Costs, and of Farm Finance in the Bureau of Agricultural Economics, and the Land Policy Section, the Production Planning Section, the Import-Export Section, and the Agricultural-Industrial Relations Section of the Division of Program Planning of the Agricultural Adjustment Administration in the United States Department of Agriculture. Credit also is due to the State agricultural experiment stations and extension services, State planning boards, commissions, and other State organizations and individuals for aid in preparation of several sections of the report.

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Contents

SECTION I

EXTENT OF LAND USE UNDER IRRIGATION*

Introduction

As one of the important items of inventory of national resources the Land Use Section is concerned with irrigated lands, both present and potential, in the 17 Western States. For it, the Bureau of Agricultural Engineering of the United States Department of Agriculture undertook to obtain the following data:

1. Present irrigated area.
2. Ultimate area susceptible of irrigation.
3. Water supply in its relation to the irrigated area.
4. Duty of water.
5. Grazing and other lands and their relation to irrigation.

Authorization for the collection of these data was granted August 17, 1934, with October 1 set as the date for a report. This allowed some 6 weeks to collect data, map the present and ultimate areas, tabulate the data in terms of stream basins, and write a report covering two-fifths of the area of the Nation. A summary report was submitted October 1. The statistics given therein have been elaborated in this more complete report, for the preparation of which more time was available and which includes much data not in the hands of the author when the time limitation compelled closure of the summary.

Obviously, the important data were items numbered 1 and 2 above, which called for map delineations of location and relative extent, and tabulations of acreage to show cost classification for the ultimate area susceptible of irrigation (hereinafter called the "potential" area, for the sake of brevity). The cost classification has reference to the irrigation systems alone; it does not include expenses borne by individual farmers in preparing land for irrigation and building farm ditches and small structures.

As California is the only State for which a map had been made showing the various areas, it was fully understood that both the accuracy of mapping and the definiteness of statistics would vary somewhat for the several States. It was decided that uniformity would not be insisted upon as it could be based only on the weakest available data. Each State was therefore considered as a separate unit with respect to definiteness of both mapping and tabulation. For many of the States data were mapped for the first time; hence this survey should be considered as a reconnaissance only and subject to continuous future modification, correction, and elaboration. With but 2 or 3 days allowable to each State, it was obviously impossible accurately to adjust conflicting data submitted by various authorities, and it was decided to hold the text matter to an absolute minimum, the essential data being pictured on the map and listed in the tables.

The 17 Western States: This term has been used so long in irrigation discussions in the West that it can appropriately be used here. Arranged alphabetically, the 17 States comprise Arizona, California, Colorado, Idaho, Kansas, Montana, Nebraska, Nevada, New Mexico, North Dakota, Oklahoma, Oregon, South Dakota, Texas, Utah, Washington, and Wyoming. These States do not include all of the irrigated areas west of the Mississippi River, for both Arkansas and Louisiana contain large areas devoted to rice irrigation. Both latter States receive heavy precipitation, however, and are usually associated with the Middle West and not with the 17 States named above.

Crop agriculture of Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, Utah, and Wyoming is usually considered in terms of irrigation, although there are scattered areas of grain and forage crops, large in total, that are watered by natural precipitation alone. The coast States of California, Oregon, and Washington have zones west of the Coast and Cascade Mountains where irrigation is merely supplementary to natural precipitation, although even there the increases in yields which may be brought about by irrigation are awakening a wider interest in irrigation supplies for use in the drier months of the year. East of the Coast Range in California and east of the Cascades in Oregon and Washington irrigation is thought of in the same terms as in the Mountain States listed as wholly dependent upon irrigation. The eastern tier of States—North Dakota, South Dakota, Nebraska, Kansas, Oklahoma, and Texas—includes a midway zone where irrigation might be used to advantage in excessively dry years, such as 1934, and where in most years the yields of truck crops would be improved by supplementary irrigation; but in the eastern portions of those States the rainfall, as a rule, is such as to permit farming to be conducted without irrigation.

* Prepared by Fred C. Scobey, senior irrigation engineer, Division of Irrigation, Bureau of Agricultural Engineering.

Definitions of Terms

Present Irrigated Area: In mapping irrigated lands, the usual practice throughout the West is to blanket the areas included within the exterior boundaries of constructed enterprises as showing the area irrigated at present. It is always in excess of the area irrigated in any one year, as would be assumed in most cases from comparison of the map with the figures in the second column of table I, which show the areas actually irrigated in 1929. In the third column of the same table the areas which the systems were capable of supplying with water in 1930 are shown. Both items were tabulated as part of the report of the Federal census of 1930.* Since there has been but little construction by which new lands have been placed under irrigation since 1930, it is reasonable to assume the figures obtained in the census as indicative of the area under present irrigation.

Ultimate Area Susceptible of Irrigation: These lands have come to be quite generally referred to as potentially irrigable, or "potential." The areas shown on the map and listed in tables I and II are, as a rule, blanket areas covering larger portions of the map than the figures indicate. Some 30 to 40 percent of the blanket area is usually excluded from the final irrigation project because of rough topography, poor soil, and other physical reasons. In all cases where possible, the acreage shown represents a reduction of the blanket area to what is usually termed "the net irrigable area." When the lands are finally placed under irrigation it is found that water is required for 75 to 80 percent of these net irrigable areas to form the net irrigated area for any one year.

Stream Basins: So far as practicable, the tabulation of data has been carried out to follow the scheme set up in the reports of the Federal irrigation census of 1930. Thus, the figures in the second and third columns are taken directly from the census reports, and the figures for potential and ultimate areas are listed for the same subdivisions of stream basins.

Potential Lands as Shown on the Map: These areas should not be understood to be mapped exactly, either as to location or extent. Some of them are offered as the result of definite engineering surveys, and in a few cases plans for new irrigation projects have reached the paper projection state and fairly complete estimates of cost have been made. However, there are many areas for which no definite surveys have been made and projects involving them are known to exist only in uncertain terms as to location and extent. For many potential areas the ultimate extent will be governed by the water supply available at the time of construction and the degree to which this water supply is equalized by means of reservoir storage. For many areas all the potential lands shown within any one stream basin cannot be reclaimed without a coordinated plan controlled by governmental authority, either State or National. An assured forecast cannot now be made as to what localities will be developed first and acquire prior rights to the use of the waters of the streams, perhaps definitely killing the prospects of competitive areas which have not reached construction stage.

In table II is indicated the total amount of water that would satisfy the net irrigation requirement of the present and potential lands. If detailed studies of the water resources available to any particular area indicate that there is a sufficiency of supply to satisfy this total requirement, then there is possibility of the reclamation of most of the land. If, however, detailed studies show that the water supply, modified by all feasible reservoir conservation, is still deficient, then the total area must be reduced in extent or water from other stream basins must be imported for use in the deficient area.

Duty of Water: Fortunately, the Department of Agriculture has published a series of recent bulletins showing the irrigation requirements of practically all the areas included in this survey. "Duty of water", which can be discussed in many terms, was investigated as a net water requirement under the best and most complete usage that might be assumed in a study of maximum ultimate possibilities. Investigations were made and reports written by the late Dr. Samuel Fortier, then principal irrigation engineer in the Division of Irrigation of the Bureau of Agricultural Engineering,* who was eminently equipped for the task by long association with irrigation practices and intimate knowledge of all the experimental and investigational data which existed at the time, bearing on the use of water in irrigation in various State and Federal records. Within each major region smaller areas were blocked off and assigned definite "irrigation requirements" after consideration of all the experimental data available. As these smaller areas were not separated in terms of stream basins, it has sometimes been necessary in the present study to revise the Department's figures to the

*The census definition of "area irrigated" applied only to the census year (1929), but was intended to cover all land then irrigated regardless of the nature or degree of sufficiency of the irrigation. The irrigation schedule carried the following definition: "Land should be classed as irrigated which has water supplied to it by artificial means or by seepage from canals, reservoirs, or irrigated lands, but land which has natural ground water sufficiently near the surface to support plant life should not be classed as irrigated. Land which is flooded during high-water periods should be classed as irrigated if water is caused to flow over it by dams, canals, or otherwise, but should not be classed as irrigated if the overflow is due to natural causes alone."

Of the total area reported as irrigated in 1929, about 25 percent was in land from which no crops were harvested, representing mostly irrigated pasture.

The census "area enterprises were capable of supplying with water" related to the year 1930. The figure was based on estimates by those controlling the irrigation enterprises involved, and represented "the area which the constructed works and the controlled and normally available water supply could serve, regardless of whether or not the land was farmed in the census year."

* In preparing some of these publications Dr. Fortier was assisted by Arthur A. Young, irrigation engineer, Division of Irrigation, Bureau of Agricultural Engineering.

extent of setting up a reasonable average to apply to the whole stream basin involved in specific considerations. (See table II, p. 26.)

The irrigation requirements listed in table II are usually much smaller than the amounts which must be diverted from the streams or other sources of supply, although they take account of the fact that much water used on many projects becomes available for reuse either as return flow to the stream basin or as underground water available for recovery by pumping. As a matter of fact, in areas in California and Arizona, where very high use is made of a given available flow of water, the practice is general of irrigating by surface supply and by recovery of ground water by pumping. This pumping development controls the water table so that drainage problems do not become acute. It also makes available additional water for irrigation in many localities where the natural flow of the streams has been reduced to a point at which the supply is deficient for the irrigated area, say, after July 1 or 15. The "net water requirement" as used in this report is approximately the same as "the consumptive-use duty of water."

Supplementary Irrigation and Supplementary Supply: These terms are sometimes confused. Supplementary irrigation is essentially artificial irrigation available in dry periods in regions where the natural precipitation will mature a crop of sorts. Often such irrigation, supplementing the natural precipitation, is used during all seasons, especially by truck farmers, as the additional yield obtained is commensurate with the cost involved.

Supplementary supply is usually considered as reservoir or ground water storage to be held as a reserve until natural stream flow has passed its peak and is insufficient for the areas commanded by the stream.

Waters of the Colorado River Basin: This basin is important in the present and potential irrigation activities of seven of the Western States, and mention of the agreement developed by interstate compact, bearing on the proposed distribution of water, is necessary.

Of the seven States included in the Colorado River Basin only Arizona has failed to ratify an agreement which includes terms essentially as follows: The total annual flow of the stream, assumed to be at least 15,000,000 acre-feet per annum, is allocated in two equal parts to the Upper Basin States of Wyoming, Colorado, Utah, and New Mexico and the Lower Basin States comprising Arizona, Nevada, and California, but with permission being given the Lower Basin States to increase their beneficial consumptive use by 1,000,000 acre-feet per annum. However, the compact containing this provision did not assume to divide the water further between the individual States. In 1934 the United States Bureau of Reclamation began a survey of the whole Colorado River Basin in order to locate the present and potential irrigated lands that might be commanded by this stream or its tributaries. It is proposed that the Bureau's survey shall form a basis for procedure in allocating the waters of the two basins to the individual States, or in allocating part of it and leaving the balance for future distribution. As to the exact amount of water that shall be allowed to flow on down the Colorado below Yuma and be available for the irrigation of lands in Mexico, there has as yet been no definite determination. Under the agreement, "if the United States of America shall hereafter recognize in the United States of Mexico any right to the use of any waters of the Colorado River System, such waters shall be supplied first from the waters which are surplus over and above the aggregate of the quantities specified" in the allotment to the Upper and Lower Basin States, "and if such surplus shall prove insufficient for this purpose then the burden of such deficiency shall be borne equally" by the two basins.

Grazing and Other Lands and Their Relation to Irrigation: Detailed data on this item were not obtainable within the time that could be devoted to any one State. In most of the States little or no information exists in terms of definite acreage, at least so far as the valley and desert areas are concerned. An examination of the "Natural Land Use Areas" map of the United States indicates that the description of western areas in terms of grazing is truly applicable. It is a general practice in the West to drive cattle and sheep into the higher mountain areas in the early spring and return them to the lower altitudes in the fall. Much of the areas covered by summer grazing of these animals lies in the national forest reserves, and the location and extent of such grazing areas are better known to the Department of Agriculture than grazing areas in the lowlands which lie outside the forests though constituting part of the public domain.

Sources of Data and Acknowledgments*

As stated before, the Federal census of irrigation for 1930 was accepted for the areas irrigated in 1929 and for the areas which the existing systems were capable of supplying with water in 1930. This latter item approximates the present irrigated land as pictured on the map. The areas susceptible of irrigation—the potential lands shown on the map—were determined on the basis of estimates received from many sources. The Denver office of the United States Bureau of Reclamation furnished maps showing that Bureau's major and secondary projects. The Bureau of Indian Affairs, through its supervising engineers located at

*Superior numbers refer to list of publications under "Sources of Irrigation Data," appendix.

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various western headquarters, supplied maps of the Indian reservations showing the lands now irrigated and the potential areas.

Since 1927 the United States War Department, through its Corps of Engineers, has been investigating many of the major watersheds west of the Mississippi River. For the Columbia River Basin and streams emptying into the North Pacific Ocean, the Portland office supplied published reports for the following streams: Chehalis, Columbia and minor tributaries, Coquille, John Day, Green, Puyallup, Snake, Snohomish, and Willamette. The Kansas City office supplied published reports on the following streams: Arkansas, Missouri, Niobrara, Osage, Republican, and White and Bad; and advance sheets for the main stem of the Missouri, and for the Yellowstone and Platte. The Memphis office supplied advance sheets for the Canadian and Cimarron Rivers of Kansas and Oklahoma. Since the Army reports are based on very recent investigations covering a long period of years, the potential areas located in these reports were accepted with but little modification.

The United States Geological Survey, through its Water Resources Branch, has made exhaustive studies of the basin of Snake River [54], of Green River and its utilization [310], and of the upper Colorado River and its utilization [37]. The study of the Snake was made so recently that the report has not yet been published, but advance sheets and the map were made available.

For the State of California, different reports were available as parts of the report on the coordinated State water plan. The first or Central Valley unit is described in the "State Water Plan" [17]. Still further detail is found in "The Sacramento River Basin" [20] and "The San Joaquin River Basin" [21]. Data for the region of the lower Colorado River in Arizona and California are found in "Colorado River and the Boulder Canyon Project" [7].

Data dealing with the Rio Grande, from El Paso to the Gulf of Mexico, were furnished by the courtesy of the American section of the International Boundary Commission located at El Paso, Tex.

Much data for Nebraska were taken from a recent survey report on irrigation and power [112].

For the States including the Great Plains, pertinent comments were paraphrased from Fellows' unpublished report [111].

Data regarding potential areas located by private or State enterprise, other than those acknowledged above, were obtained as follows:

Arizona: From the office of Frank P. Trott, State water commissioner, assisted by officials of the State land office.

California: From the office of the State engineer and chief of the division of water resources of the State department of public works, Edward Hyatt, who supplied data regarding the coordinated plan for the State of California and certain maps for inclusion in this report.

Colorado: From the office of the State engineer, M. C. Hinderlider.

Idaho: From the office of R. W. Faris, commissioner of reclamation, with additional suggestions from George N. Carter, former commissioner of reclamation.

Kansas: From the office of George S. Knapp, chief engineer, division of water resources.

Montana: From the office of J. S. James, State engineer.

Nebraska: From A. T. Lobdell, acting State engineer who was assisted by R. H. Willis, chief of the bureau of irrigation at Bridgeport.

Nevada: From the office of George W. Malone, State engineer.

New Mexico: From the office of the State engineer, Thomas M. McClure.

North and South Dakota: These States were not visited, as the reports of the War Department, mentioned above, were considered sufficient.

Oklahoma: There is so little irrigation here that no visit was made to the State officials in Oklahoma City.

Oregon: From the office of the State engineer, Charles E. Stricklin.

Texas: From the State board of water engineers.

Utah: From the office of the State engineer, T. H. Humpherys.

Washington: From the State supervisor of hydraulics, Charles J. Bartholet.

Wyoming: From the State engineer, Edwin W. Burritt.

Acknowledgment is also made to P. A. Ewing, irrigation economist of the Division of Irrigation, Bureau of Agricultural Engineering, for editorial assistance and pertinent comment based especially upon familiarity with statistics appearing in the reports of the 1930 Federal irrigation census, of which he had charge.

Excepting California, the various State officials listed above were furnished advance sheets of the Land Office map with the present irrigated land and potential areas shown to the extent permitted by data then available, and were requested to alter and correct these data, making such additions as were necessary. In a follow-up visit, arrangements were made for additional data. Acknowledgment is made of the courtesy extended in all the offices visited.

Conflicts of Data: Excepting California, none of the States represented in this report has a State map that purports to show the present and potential areas. In all cases it was necessary to compile these data. As built up by individual projects, there is much conflict regarding the same general areas, depending upon the group that sponsored the investigation. Likewise, differences in definition as to what constitutes irrigated

land and what constitutes feasible were a further source of disagreement between various authorities. Within the time allowed, an attempt has been made to determine the most reliable data for each area indicated but it is recognized that correction and modification will result from further and more detailed study of specific areas.

Summary for the 17 Western States

The Federal census of 1930 shows the area actually irrigated in 1929 as 18,944,856 acres within enterprises that were capable of supplying with water, in 1930, an area of 25,096,783 acres. (See table I.) There has been little expansion since 1930. It is noticeable that these figures, in round numbers 19,000,000 and 25,000,000 respectively, represent farms totaling some 77,000,000 acres. As a rule in a region where irrigation is practiced, the yield of the irrigated areas is far in excess, both in quantity and monetary value, of the yield of the unirrigated areas. Therefore, the actual picture shows irrigated lands largely supporting farms about four times their area.

The additional potential development sums up to some 26,000,000 acres. This aggregate area should be considered in terms of round numbers only, as final adjustments for various causes will remove some areas already included and will take in other areas not now in the picture. If there be added the area which the enterprises were capable of irrigating in 1930, the ultimate area—present and potential—that may be considered possible of irrigation amounts to some 51,000,000 acres.

Of the area under present irrigation, a very large portion was supplied with water at costs of less than $50 per acre and very little of it exceeded $100 per acre. However, it is noticeable that but little of the future development is possible at a charge of less than $50 per acre for water. It is quite likely that, for many projects, the costs indicated in zones in excess of $50 per acre will always be more than the lands can economically support. This means that some form of subsidy will be necessary to make many of the projects of the future acceptable from an economic standpoint.

Explanation of Map of Arable Land

An accompanying map depicts the irrigated and irrigable land in Western States, and the nonirrigated farming lands of the public-land States west of the 100th meridian.

The irrigated land embraces areas for which the soil moisture naturally available for crop production is increased by artificial means and bottom lands that are moistened by natural subirrigation. Irrigable lands are not included except where it has been impracticable to segregate undeveloped land within extensive irrigated areas because of the scale used. The total irrigated area, according to the 1930 United States census, is approximately 18,945,000 acres.

The nonirrigated farming lands embrace only the better areas of nonirrigated agricultural land. In the semiarid regions such lands comprise areas having topographic and soil conditions favorable to crop production which normally receive sufficient rainfall for the production of small grain and similar crops and during substantially every year the growing season is of adequate length to permit such crops to mature.

TABLE I.—*Summary by States of present irrigation development and ultimate possibilities of irrigation reclamation*

State	Present development		Additional irrigable area (potential area)[3]	Ultimate irrigable area [2]	Net annual irrigation requirement for ultimate irrigable area	Distribution of additional irrigable area according to estimated costs of reclamation				
	Area irrigated in 1929 [1]	Area enterprises were capable of supplying with water in 1930 [1]				Less than $50 per acre	Between $50 and $100 per acre	Between $100 and $200 per acre	More than $200 per acre	Indeterminate
	Acres	*Acres*	*Acres*	*Acres*	*Acre-feet*	*Acres*	*Acres*	*Acres*	*Acres*	*Acres*
Arizona	575,590	824,152	[3] 754,600	1,578,800	4,616,220	19,700	33,000	39,100	594,600	68,200
California	4,746,632	6,815,250	9,857,750	16,673,000	46,816,000	1,031,079				[4] 8,826,671
Colorado	3,393,619	4,678,712	957,600	5,036,300	9,616,000		12,500	246,300		698,800
Idaho	2,181,250	2,617,021	1,138,500	3,755,500	9,217,400	20,000	407,500	525,000	71,700	114,300
Kansas	71,290	83,583	1,250,000	1,333,000	2,333,000	50,000				[5] 1,200,000
Montana	1,594,912	2,276,000	[3] 1,589,600	3,865,600	6,746,200	116,000	148,900	94,000	413,700	817,000
Nebraska	532,617	703,641	1,069,600	1,773,200	2,216,400	51,500	125,300	63,400	16,200	813,200
Nevada	486,648	736,249	326,700	1,065,600	2,112,500	38,400	161,300			127,000
New Mexico	527,033	656,669	434,200	1,090,800	2,403,300	86,100	172,500	12,000	65,600	98,600
North Dakota	9,392	24,006	288,000	312,000	421,200	86,000	10,000	31,300		160,700
Oklahoma	1,573	7,331	120,000	127,400	137,500	80,000				40,000
Oregon	898,713	1,158,210	2,354,600	3,512,900	6,433,700	1,481,100	509,500	222,000		142,000
South Dakota	67,107	109,550	112,800	222,400	333,700	15,000		60,000	37,800	
Texas	798,917	1,177,415	1,130,000	2,307,400	3,615,400	139,000	820,000			171,000
Utah	1,324,125	1,542,475	622,400	2,164,900	4,331,200	56,000	26,000	186,100	88,500	265,800
Washington	499,283	631,511	2,024,000	2,655,500	7,185,080	46,000	35,400	1,345,100	26,000	571,500
Wyoming	1,236,155	1,655,008	2,405,700	4,060,600	6,622,500	508,100	888,300	392,000	42,800	574,500
Total	18,944,856	25,096,783	26,436,050	51,534,900	115,066,300	3,823,980	3,350,200	3,216,300	1,356,300	14,689,270

[1] U. S. Bureau of the Census, Irrigation of Agricultural Lands.
[2] In round numbers.
[3] Large area under "High line survey" excluded as infeasible because another part is included in another plan.
[4] Coordinated State plan for old and new lands, municipal and industrial purposes, does not segregate charges. Much of this area will cost around $100 per acre for new lands, including storage, conveyance canals, and distribution system.
[5] State authorities suggest larger acreage of potential land than Army reports which were usually accepted.

The classification on the basis of these physical conditions has been coordinated with a history of the crop yields from actual farm practice during part or all of the past 20 years. Large additional areas are physically tillable but unsuited to crop production except in occasional years, due to risks resulting mainly from climatic eccentricities or unfavorable soil conditions. In regions having an annual precipitation of 20 inches or more, all nonirrigated lands having topographic and soil conditions suitable for crop production are shown as farming land. The total area of nonirrigated farm lands shown on the map is approximately 79,000,000 acres, distributed by States as follows:

State	*Acres*
Arizona	Negligible
California	5, 900, 000
Colorado	7, 250, 000
Idaho	2, 170, 000
Kansas	10, 760, 000
Montana	12, 270, 000
Nebraska	6, 980, 000
Nevada	Negligible
New Mexico	1, 100, 000
North Dakota	11, 070, 000
Oregon	3, 750, 000
South Dakota	8, 500, 000
Utah	470, 000
Washington	7, 380, 000
Wyoming	1, 600, 000

Arizona

Irrigation Development: The 576,000 acres irrigated in 1929 [3] out of a gross area of 824,000 acres are largely contained in two major areas: on the Gila a great block blanketing the valley surrounding the capital city of Phoenix, and on Colorado River near the town of Yuma. (See table II.) Practically all the potential area, 755,000 acres, will be irrigated from Colorado River proper. The present development at Boulder Dam, the diversion dam of the Metropolitan Water District of Southern California located near Parker, and the new Imperial Heading diversion dam to be constructed a few miles above Laguna Dam afford strategic points from which future development may proceed.

Arizona is a completely arid State, requiring irrigation for practically all cropped agriculture. With the exception of one small portion, it lies wholly within the drainage basin of the Colorado River, which separates the northwestern corner of the State from the main portion by a deep canyon, impassable except at a few places. Much of the habitable portion of the State is included in Indian reservations and the Bureau of Indian Affairs has provided irrigation facilities on many of these reservations. Plans are in various stages of completion to extend this essential service to the Indians.

The largest present development lies in the great block tributary to Phoenix. Some of the potential development is based upon further conservation of waters of the Gila and its tributaries.

The river bottom lands in the neighborhood of Yuma and a small portion of the Yuma Mesa are now irrigated by waters of the Colorado diverted at Laguna Dam some 10 miles above Yuma. Immediate construction is in contemplation for a new heading for the All American Canal to serve Imperial Valley in California. The diversion dam that will be a part of this heading will be located a few miles above Laguna Dam. Water for the present Yuma project will come down the All American Canal on the California side and be carried across the river in a siphon, as at present. (See California.) The Arizona end of the dam at Imperial Heading forms a strategic point at which to divert water for reclamation of a large block of land lying between the Yuma project and the lower end of the irrigated lands in Salt River Valley.

The proposed allocation of waters of the Colorado River proper has been described (p. 3). Arizona's portion of waters allotted to the Lower Basin States has not yet been determined. Some 10 years ago the Arizona Engineering Commission [1] proposed to divert water from the Colorado River several miles above the Boulder Dam site. The proposal involved a dam 620 feet high and a very long tunnel from the dam to a reservoir on the Bill Williams River, with a second tunnel leading south to the upper end of large bodies of land north and south of the Gila. A second high line survey was reported by F. P. Trott [2].

The United States Bureau of Reclamation is conducting comprehensive surveys throughout the basin of the Colorado River to locate feasibly irrigable lands within all the States commanded by that stream. For Arizona a large portion of the land included in the project for a high-line canal is to be cared for by an entirely different method. Water released from Boulder Dam will be allowed to flow down the river to the new Imperial Heading. It will be diverted on the Arizona side and raised by pumps to command the desert areas east of the Yuma project. It is now considered that the cost of this pumping lift will be very much less than that involved in the high-line plan.

Duty of Water: In their discussion of irrigation requirements for lands of the Southwest [9] Fortier and Young set up a net requirement of 3 feet for the bulk of the area included in present and potential Arizona lands. This is about the same figure assumed for Imperial Valley in California. The Bureau of Reclamation, on its map of the Yuma irrigation project, states that "duty of water averages 3 acre-feet at the farm." Likewise, this is the figure used by the United States Bureau of Indian Affairs in its recent studies of large areas in the San Carlos project southeast of Phoenix.

Therefore 3 feet is well supported as a net irrigation requirement for Arizona lands.

Grazing: Range grazing in Arizona is largely confined to the parklike areas on the higher plateaus. Much of this land is within the national forest reserves and on Indian reservations. The low valleys of the State support few forage growths without irrigation, so figure secondarily in the grazing picture. However, the Indians and Mexicans are partial to the raising of goats, which find subsistence where cattle do not.

The Garfield report to the President (1931) on "The Conservation and Administration of the Public Domain" lists some 41,000,000 acres of grazing lands of various types in Arizona.

California

Irrigation Development: Of the total State area of 100,000,000 acres there are some 23,000,000 acres (gross) of arable land that would be benefited by irrigation, and it is estimated that a water supply would be required for about 17,000,000 acres (net). These figures [23] indicate the tremendous potential area to be affected largely by reservoir storage, when compared with the net area irrigated in 1929 of 4,746,632 acres. Of the present gross area under irrigation (some 7,000,000 acres) a large part would be benefited by a supplementary water supply. Various authorities have estimated the ultimate possible irrigation development of the arable lands of California as between 12,000,000 and 18,000,000 acres.

California is the only Western State that has made a comprehensive study of its water resources in terms of irrigation use. Dividing the State into seven major areas, the ultimate possibilities are as listed in table II. The study was not developed in terms of cost per acre for any local project of the size found in the other States, neither was a charge developed against areas now irrigated in order for them to obtain supplementary water to carry their irrigation season from, say, July 1 through to the end of the summer. The State's investigation is based on the cost of units of a great comprehensive plan, the money returns to the State to come from current water charges after the projects have been put in operation.

It is well understood that all the larger agricultural areas in California would be benefited by irrigation. Extensive areas in both the San Joaquin and Sacramento valleys have been farmed to grains for many years. The large holdings so farmed could only be made suitable for settlement in smaller tracts by making the land more productive through irrigation.

In the State's investigation it was found that there is a mean annual surplus of some 10,000,000 acre-feet of water in the Sacramento Valley [20] and a marked deficiency in the San Joaquin Valley [21]. Between the area surrounding Fresno and that tributary to Bakersfield, there is relatively little surface run-off and the irrigation at present is largely by means of pumping from ground water. As in many other similar areas, the ultimate possibilities of ground water yield were not understood in the beginning and more land was put under irrigation than the current natural replenishment can carry. Much of this development was of the highest order and the State is much concerned because of the obvious necessity to supply supplementary water to aid the present sources and thus save some 200,000 acres in this part of the Great Central Valley from reverting to a desert condition. An area of about 400,000 acres in this valley is now overdrawing the natural water supply.

*Central Valley Project:** The first unit of the coordinated State plan may be described essentially as follows: Storage of the Upper Sacramento, McCloud, and Pit Rivers is to be effected at Kennett Reservoir in the northern portion of the State. With a dam 420 feet high, some 3,000,000 acre-feet of water can be stored. In the release of this water, hydroelectric power will be generated and carried to the Bay region by means of the Kennett transmission line. The water is to be allowed to flow down the Sacramento, aiding in navigation, and diverted at various points for irrigation of lands on the valley floor, with the eventual idea of pumping lifts serving lands lying too high to be reached by the primary canals. After providing for the complete irrigation of the Sacramento Valley, a large flow of water will reach the great delta area of 400,000 highly developed acres at the junction of the Sacramento and San Joaquin Rivers. Here the surplus water will maintain a fresh water flow toward San Francisco Bay sufficient in volume to flush out salt water that has gradually encroached upon the delta islands until their agriculture is said to have been impaired in certain years.

From the Delta region to Mendota Dam, opposite Madera, the flow of the San Joaquin will be reversed. That is a series of dams will be placed in the stream bed and pumping plants will raise the water from one level to the next higher one. This flow will make an irrigation supply available to the present irrigated lands of San Joaquin Valley and to much of the area on its west side. Much of the bottom land is now irrigated by gravity flow of the San Joaquin proper. On this stream it is proposed to build Friant Reservoir, in the foothills, to store 400,000 acre-feet of water, with a dam 252 feet high. After developing power at the outlet of the reservoir, some water will flow northward

*For reference to map in this report, see map on Arable Land of the Western United States. For a more detailed presentation and maps regarding irrigation projects in California the reader is referred to the reports and bulletins published by the State division of water resources, Sacramento, Calif.

in the proposed Madera Canal, which would command by gravity most of the land of the present Madera irrigation district now receiving only ground water for irrigation purposes. Also from Friant Dam the Friant-Kern Canal would extend to Kern River below the city of Bakersfield. This high line canal would pass above most of the irrigated lands of the valley floor and would supplement the flow of various streams and canals as they are intersected, one after another. Essentially, Friant Reservoir would make possible the use of San Joaquin water, both to the north and south, on lands that do not now receive any water from that stream, and in exchange for the San Joaquin water the State would supply the bottom lands of the lower San Joaquin with surplus waters from Sacramento Valley.

The plan thus described constitutes the essentials of the present Central Valley project of the State's water plan. Further development of the coordinated State plan would involve storage reservoirs on the major streams on the eastern side of Sacramento Valley, each one to irrigate lands naturally commanded by the reservoir sites, with surplus water available for higher areas by means of pumping plants.

Another item of the Central Valley project contemplates transmountain diversion of Trinity River, now flowing into the Klamath, over to the Sacramento Valley side of the Coast Range, developing hydroelectric power in the process.

The Central Valley project is the only part of the coordinated State plan that has been worked out in considerable detail. It is proposed that only main canals and structures will be built under the plan, and water will be wholesaled by the State to the various irrigation districts and other group consumers and municipalities for definite costs, ranging from $3 to $8 per acre-foot. This project would serve areas irrigated at present with supplementary water, extending their season from, say, July 1 to the end of summer. New lands would eventually be served from these canals at the same cost per acre-foot, but they would have to supply their own distribution system, at costs ranging from $15 to $50 per acre, depending upon the terrain, the necessity of special conduits and structures, and the advantages or necessities of pumping lifts as against gravity flow. Thus the capital cost of the Central Valley project is some $167,000,000 for initial work and $580,000,000 eventually.

Colorado River Project: In 1935 water was stored for the first time in the new Boulder Reservoir, which eventually will have a capacity of 30,000,000 acre-feet. This is about twice the mean annual flow of Colorado River at this point. Discussed in terms of California alone, it is provided in the Boulder Canyon Dam act that California shall agree that annual consumptive use of Colorado River water in California shall not exceed 4,400,000 acre-feet of the water allotted to the three lower basin States, plus one-half of any excess. California's share of this water can be utilized on various areas as shown on the California map. There is at present under construction the Colorado River aqueduct to bring 1,500 second-feet of water to the city of Los Angeles and some 13 localities organized as the Metropolitan Water District of Southern California. This project, estimated to cost some $228,000,000, will strongly reinforce the waters of southern California that are at present overdrawn for irrigation, municipal, and industrial purposes. Conceivably, for some time to come, there will be excess water over the present municipal needs, and this surplus might be available for the irrigation of additional agricultural lands in this important area.

The second major diversion now under contract will take place at the new Imperial Heading some 10 or 15 miles above Laguna Dam which acts as the diversion structure for the present main canal serving the Yuma project of the United States Bureau of Reclamation. At the new heading it is proposed to divert 15,000 second-feet of water into the All-American Canal [19], returning 2,000 second-feet to the Yuma project at a point where the water can be turned into its present system. As the canal passes Pilot Knob, just north of the international line, 3,000 second-feet will be dropped back into a lower canal or the Colorado River, through a hydroelectric plant for the generation of power. This leaves 10,000 second-feet to flow on into the Imperial Valley with the eventual idea of an extension to serve Coachella Valley with gravity water. Coachella Valley now obtains all its irrigation water from underground sources. Further development of All-American Canal contemplates the conveyance of 150 second-feet over the mountains between Imperial Valley and the Pacific Ocean for use in the neighborhood of San Diego. As shown on the map, there is some irrigation along the Colorado River, particularly near Blythe, and the regulated flow of the river will make more stable the present irrigation systems.

It is contemplated that the water, as used for power at Boulder Dam, will be re-regulated by the construction of Bulls Head Reservoir between Boulder and Parker Dams. The storage at Parker Reservoir will consist merely of the upper 10 feet as a regulation zone. In other words, Parker Dam is considered more in the nature of a diversion dam than as a storage dam. Both Parker Dam and the new Imperial Heading will give diversion points for canals in both California and Arizona. (See discussion under Arizona.)

One of the difficulties of determining the cost of all potential projects in the Western States is exemplified in the distribution of charges for the construction of Boulder Dam. Of a total charge of $165,000,000,

irrigation is required to carry $38,500,000; flood control, $25,000,000; and hydroelectric power $38,200,000. If the cost of the whole project were assessed against the area of some 2,000,000 acres in California and Arizona, the eventual cost per acre for storage alone, outside of distribution systems, would be about $80. From this illustration it is evident that closely estimated costs of the development of potential projects are impossible. Nearly all projects will require storage reservoirs with accompanying power plants, and in many cases will serve irrigation, municipal, and flood-control purposes in addition to developing power. Thus it is readily seen that, even where the total cost of construction has been closely estimated, the final charge against the irrigated lands lies in the distribution of the total charges, and in many cases the irrigated lands will be charged less than their proportionate share on the ground that their development will benefit the community as a whole.

Duty of Water: In connection with the development of the comprehensive plan, one of the first investigations undertaken sought to determine net irrigation requirements, the ascertainments being needed as bases of computations of the extent of areas which might be served by the various streams of the State. Climatic conditions in California range all the way from those characterizing the lowest to those identified with the highest elevations in the United States. Specifically, the rainfall varies from a negligible amount in the southeastern section to 80 inches in the northwestern counties. In recognition of these circumstances, the State was divided into a number of sections, in each of which conditions were reasonably uniform, so that a certain definite figure could be set up as measuring its requirement. After assembling all the extensive experimental data on use of water within the State, and by careful consideration of all the circumstances typifying this use, a figure was selected for each section. The results of the investigation were then submitted to a consulting board of accepted authorities on the subject. Their ultimate findings, practically confirming the originl figures, were used in the computations of the total water requirement for potential agricultural areas in any specific part of California.[22]

Grazing: Some of the potential irrigated lands now constitute grazing areas, especially after the winter rains have made the State green with new grass. Large herds of cattle and sheep are taken in the early summer to the higher mountain areas comprised within the national forest reserves, and returned to the lower valleys in late fall. One major exception to this general practice is still represented by a portion of the San Joaquin Valley, where large areas of pasture lands are irrigated occasionally to provide year-round forage for great numbers of cattle.

The Garfield report to the President (1931) on the "Conservation and Administration of the Public Domain" lists some 36,000,000 acres of grazing land of various types in California.

Colorado

Irrigation Development: Second only to California in the extent of its irrigated areas, Colorado has 4,078,712 acres irrigable [34] under its present system, while of these 3,393,619 were actually irrigated in 1929. The additional potential areas, largely on the western slope, comprise 958,000 acres. Unlike California, the streams of which for the most part are usable wholly within its boundaries, Colorado contains the headwaters of many important rivers all of which flow into adjoining States, and the latter look to Colorado for a reasonable supply of water to cross the State lines and become available for their lands.

Colorado is one of the States in which conservation of water resources, largely in terms of irrigation, is considered essential to its future. With the decline in mining, upon which the early development of the State was based, came the rise of irrigated agriculture.

Colorado is the fountain head for the waters of the North Platte and South Platte Rivers, which finally reach the Missouri; the Arkansas River flows across the line into Kansas, eventually reaching the Mississippi; the Rio Grande flows across New Mexico, forming the international boundary line between the United States and Mexico, eventually reaching the Gulf of Mexico; the Upper Colorado, formerly called the Grand River, flows westward into Utah where it joins the Green to form the main Colorado River. In the southwest corner of the State, the San Juan drains part of both Colorado and New Mexico, reaching the Colorado River in Utah. In the northwest corner the Green, after flowing out of Wyoming and across the northeast corner of Utah, enters Colorado to receive the Yampa as a major tributary, and later on is joined by the White, all draining an extensive portion of the State. The North Platte leaves Colorado to flow northward into Wyoming, eventually joining the South Platte in Nebraska. Thus Colorado is completely surrounded by other States that are highly dependent upon water for irrigation. Its relations with Wyoming, Utah, and New Mexico in terms of Colorado River drainage are described on page 3. However, the States of Wyoming, Nebraska, Kansas, and New Mexico all look to Colorado for a continuation of the flow of the streams mentioned above so that they, too, may have a share of the water for irrigation.

The Continental Divide forms a distinct cleavage between the eastern two-thirds and the western one-

third of the State. The eastern slope is known to be so deficient in water supply as to effect complete seasonal irrigation of lands now under canal. The western slope is definitely known to have a surplus of water, and, whatever may be Colorado's final allotment of the waters of the Colorado River, the State authorities rely on the continuation of a definite surplus that can be considered as available for transmountain diversion to the eastern slope. Colorado has always operated on the doctrine of prior appropriation, and has never established a policy of arbitrarily setting a limit for the appropriation of the water of any one stream. This policy has developed senior rights that are reasonably sure of an irrigation supply for at least a portion of the irrigation season whereas the later, or junior rights, in many cases go year after year without obtaining sufficient water. The immediate concern of the State officials is to conserve fully, by means of reservoir and ground water storage, all the waters now native to the eastern slope, and to import water from the western slope to give senior rights an irrigation supply throughout the season and junior rights much more water than they now receive.

Sustaining the idea of the State engineer that there is no water available for developing additional lands on the eastern slope, only one potential area is offered, as shown on the map in the northeastern portion of the State. The potential areas in the western slope were located by reference to two water supply papers dealing with the Upper Colorado River and its Utilization [37] and the Green River and its Utilization [38] respectively, supplemented as far as possible by information developed in the survey conducted by the United States Bureau of Reclamation for the determination of present and potential areas for the whole Colorado River Basin.

Duty of Water: The irrigation requirement as set up by Fortier [42] for the eastern slope for the Missouri and Arkansas River Basins is slightly more than 2 acre-feet of water per acre of land. For the Rio Grande Basin and the western slope basins [43] it is believed that more rainfall is available during the summer months, and lesser irrigation supplies of from 1.7 to 1.9 feet are suggested, while for the extensive area comprising the northwestern corner of the State in the Green River drainage [42] a figure of but 1.35 feet is offered.

Grazing: Much of Colorado once belonged to the great cattle-range country. The fencing of range lands and the taking up of water for irrigation has changed the cattle business until now it involves summer grazing in the mountain parks largely within the forest reserves, and winter feeding of alfalfa and other forage raised on irrigated lands. Great numbers of sheep and some cattle are regularly brought to the agricultural towns north of Denver and fattened with the products residual after the refinement of beet sugar and the canning of peas and other vegetables. Throughout the mountain valleys the staple crops are the natural hays and some alfalfa. During the summer much hay is cut, stacked, and held for winter feeding. When stock is brought down from the higher mountains in the autumn, grazing is carried on in the meadows surrounding the stacks, the latter being fed under emergency only.

The Garfield report to the President (1931) on "The Conservation and Administration of the Public Domain" lists some 17,000,000 acres of grazing land of various types in Colorado.

Idaho

Irrigation Development: This State ranks third in order of present irrigation development with some 2,600,000 acres of land now under irrigation, of which 2,181,250 acres were actually irrigated in 1929.[53] The ultimate possibilities include nearly 1,100,000 acres of arable land with reasonable cost of development and another 60,000 acres of potential land for which reclamation costs are so high that they should not be included in the general potential acreage.

A glance at the map shows that both the present and potential possibilities are almost wholly within the great valley of Snake River. The major exception lies in the southeastern corner of the State where certain areas within the Great Basin are commanded by Bear River and other streams flowing into Great Salt Lake. The headwaters of the Snake lie in the high mountains of eastern Idaho and western Wyoming south of Yellowstone Park. While some of this water can be used within Wyoming, it naturally commands Idaho. State authorities say further that there is no obligation for any large volume of water to leave Idaho for use in Washington or Oregon. These circumstances permit consideration of the whole Snake River within the State, as available for use there.

State authorities are also of the opinion that the waters of the State, with the present amount of regulation, are completely used to care for the lands now under canal.[55] Much of their concern for the immediate future lies in recognition of the necessity of perfecting reservoir and ground water storage and in several major projects involving transmountain diversions to supplement the supply now available. However, the map shows great potential areas on both sides of Snake River.

It is estimated that the Upper Snake River, lying to the east of Milner Dam, will require a supplementary supply of about 500,000 acre-feet of water per annum, if potential areas under present consideration are put under canals.[55] Surveys are now under way seeking reservoir storage to regulate further the waters of the Upper Snake. However, State authorities [55] make the point that American Falls Reservoir, placed in opera-

tion in 1926, has been filled to capacity but twice since that time. Hoyt [54] shows the remarkable conservation development already attained with present storage capacity of 5,700,000 acre-feet in 68 reservoirs. This supply supplements direct-flow rights of some 2,000,000 acres of irrigated land. Of this storage 3,800,000 acre-feet is in 47 reservoirs in Idaho. There is storage possibility for another 5,700,000 acre-feet in Idaho alone. Likewise, there are certain possibilities of "exchange water", whereby certain hydroelectric power and irrigation rights on the Lower Snake might be made available on the upper river. In this State there appears a distinct conflict between hydroelectric and irrigation use, much water being used to operate hydroelectric plants, outside of the irrigation season. Water returned to the river below Milner Dam, which is the last point at which gravity diversions are now made from the Snake River proper, is below all present storage on the main stem of the Snake. Ground water accumulated in the lava beds bordering the Snake will eventually be recovered by pumping and used to supplement the surface supply.

The present major areas under irrigation lie in four great blocks. The first is along the main stem and Henrys Fork of the Upper Snake between Ashton and American Falls. The second block lies in the Bureau of Reclamation project at Minidoka. At Milner Dam diversions are made both northward and southward to irrigate the third large area under both Bureau of Reclamation projects and those organized by various group interests. Just below Milner Dam the bed of the river drops below the general level of the terrain, until the canyon several hundred feet deep renders gravity diversion out of the question. Canals on both sides of the river, from Milner Dam, have been extended about as far as is feasible. However, there is a large block of potential land between King Hill and the Boise Valley, usually described as the Mountain Home tract. Several investigations have been made looking toward the reclamation of this great body of excellent land, which is similar in many ways to the Twin Falls area, except for its distance from a natural source of water supply. One possibility for this area lies in diverting water from Salmon River by transmountain diversion into the Payette or the Boise, eventually for use on the Mountain Home tract. One plan proposes a dam and diversion works on the Salmon, thence transportation through 3 miles of tunnel to Red Fish Lake, which is to be made into a reservoir by a dam at the outlet, and thence by 14 miles of tunnel to Boise River. This project would cost some $65 per acre benefited, in addition to the present charge for the existing system. Another attractive plan involves pumping water from Snake River into Deer Flat Reservoir to supplement the present supply. The latter is wholly Boise River water which would be released for other uses.

The fourth block at the western side of the State, lying north of Snake River, is the great Boise Valley of some 200,000 highly developed acres served with direct flow of the Boise River, supplemented by extensive storage at Arrowrock Dam. In this area several possibilities of developing "exchange water" could be worked out in connection with a coordinated plan.

The valley of the Snake lends itself to the development of such a plan for the complete use of its water. The present irrigation is well divided between canals developed by local interests, those constructed by the United States Bureau of Reclamation, and the successors of an important group of projects which were promoted early in the present century under the terms of the Carey Act. Within recent years the Bureau of Reclamation has sponsored construction of extensive storage in Jackson Lake, Wyo., and at American Falls, Idaho, for the benefit of many of these projects besides its own at Minidoka. The Bureau has also made studies looking to the eventual irrigation of much of the potential area shown on the map.

Another study considers a plan for construction of extensive storage on Payette River, and a transmountain diversion from the Payette to the Boise River Basin to care for much of the area now irrigated from Boise River. This would make possible the use of the storage at Arrowrock Dam above Boise through another transmountain diversion into the Snake River Valley commanding the Mountain Home area.

Duty of Water: The net irrigation requirement as set up by Fortier and Young [59] calls for 2 feet of water for the Bear River Basin [60], and a maximum of 2.7 feet for the lands irrigated directly from Snake River, with lesser amounts for lands lying back from the river that must be economical in use if they are to receive an irrigation supply. These figures are shown in table II. Apparently these are liberal. Recent investigations of the United States Geological Survey support figures of 2 feet or less, as determined by Don H. Bark some 20 years ago. Likewise, an independent investigation made by W. G. Steward indicated that 2.2 acre-feet is about the consumptive use on Twin Falls area. Hoyt [54] makes computations based on 1.7 feet for the consumptive use on some 900,000 acres.

Sources of Data: Idaho is fortunate in the prospect of soon having available the results of a recent investigation of its irrigated and irrigable lands, which are to be published in a water-supply paper of the United States Geological Survey.[54] The map for this report was used as an index in mapping preliminary data involving the entire valley of Snake River. Certain modifications were made from maps of the United States Bureau of Reclamation for projects under primary or secondary investigation by that Bureau. The data for Indian reservations were obtained from supervising engineers of the Bureau of Indian Affairs.

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A few potential areas were rejected, under suggestion of State authorities that there was no possibility of a water supply. The totals representing ultimate irrigation possibilities are slightly less than the figures suggested by the United States Geological Survey.[54]

Drainage Requirements: At the northern end of the State there is an area of some 30,000 acres which requires artificial drainage and protection against future encroachment in order to make lands available for agricultural purposes.

Grazing: The valley of the Snake River was quite fully covered by an original growth of sagebrush, rather than forage grasses. However, the present livestock industry relies largely on summer grazing of the forest reserves that cover practically all the mountain areas, supplemented by winter feeding of forage raised on the irrigated ranches. Hoyt [54] shows some 8,000,000 acres of grazing land in Snake River Basin.

The Garfield report to the President (1931) on "the Conservation of the Public Domain" lists some 21,000,000 acres of grazing lands of various types in Idaho.

Kansas

Irrigation Development: A large part of the lands now under irrigation, aggregating some 84,000 acres, has been watered for many years from canals diverting from Arkansas River. More recent developments are by pumping from ground waters, especially in Scott County. In 1929 the area actually irrigated was 71,290 acres.[71] Assuming the ultimate development of 50,000 acres of potential lands definitely located, plus the 1,200,000 acres described below as irrigable by pumping from stream beds, the total ultimate irrigable area of the State is about 1,333,000 acres.

Kansas lies partly in the zone which is bordered on the west by the semiarid region, but the eastern part of the State ordinarily receives ample rainfall to supply the needs of most crops. The major present irrigation development is in a section tributary to Garden City. Here the greater part of the irrigated land is watered by gravity diversion from the river, but some years ago an extensive pumping system was installed to extract ground water from the sands bordering the river bed to supplement the natural flow. However, during the first years of operation water was so rapidly withdrawn by the pumps that their use became uneconomical and was practically discontinued, although other similar pumps are still operated on a smaller scale.

The gravity systems along the Arkansas were all constructed under private or group organization. Possible reservoir storage, to supplement the deficient flow of the Arkansas, is located in potential sites in Colorado. This location has not encouraged their construction by Kansas interests, as the water might have to run the gauntlet past upstream appropriators in another State. To the north of the Garden City area, in Scott County, are spots of land irrigated wholly by pumping in the midst of a potential area. State authorities say that these spots move about within the potential area from one season to another as conditions of ground water warrant changes. Irrigation developed by small pumping plants has proved very successful and, under guidance of State officials, has been extended to many areas along the Arkansas.

Various State authorities give estimates ranging from 1,000,000 to 5,000,000 acres as the area for which adequate ground-water supplies exist within a reasonable lifting distance of the surface. One study by State officials sets a figure of 1,200,000 additional acres as irrigable from such sources. While complete reliance must be placed upon irrigation for the extreme western part of the State, the use of supplementary supplies elsewhere is expected to increase materially. The location and extent of the use of these developments are not of such nature as to be closely indicated on the map. Pioneers in this supplementary practice, in this as in other States, are usually the operators of truck farms in areas tributary to the major population centers. They have found that supplementary irrigation by pumping, usually from wells, increases their crops to an extent that well repays the extra expense. The cost of these small plants runs from $15 to $25 per acre. In dry years, such as the season of 1934, supplementary pumping plants might become the mainstay of a water supply for a very large acreage, in total.

Duty of Water: As a net irrigation requirement, Fortier [77] offers 1.75 feet in depth for the western half of the State. As supporting data for this region were meager, this probably represents an expert's opinion for which there is little information either confirmatory or otherwise.

Grazing: The land classification survey for western Kansas and southeastern Nebraska [72] tabulates 1,850,000 acres under the title of grazing lands. However, State authorities point to two great blocks that are known as excellent grazing areas. The Blue Stem Hills region is said to contain 6,000,000 acres of land, covered with a luxuriant growth of blue stem grass that furnishes grazing for around 500,000 head of cattle annually. This area, which lies east of the center portion of the State, comprises Pottawatomie, Riley, Geary, Wabaunsee, Morris, Lyon, Chase, Butler, Greenwood, Elk, Cowley, and Chautauqua Counties. At the western side of the State lies the High Plains grazing region, comprising Wallace, Creeley, Wichita, Hamilton, Kearny, Stanton, and Morton Counties.

Montana

Irrigation Development: In 1929 there were 1,594,912 acres irrigated in a total area of 2,276,000 acres under canals [90]. State authorities in 1920 estimated that some 2,250,000 acres additional could be irrigated in the future, but the present compilation indicates that about 1,600,000 acres can be classed as potential area, making approximately 3,900,000 acres represent the ultimately irrigable area.

In Montana not all crop agriculture is irrigated, the irrigated land in the eastern part of the State being about half the acreage listed as farming without irrigation [91] (table II). The State is excellently watered, with major streams located in nearly all parts of it. The western part is mountainous, with long, narrow valleys ranging from ribbons but a few hundred yards wide to 8 or 10 miles in width. These mountain valleys are flat laterally, with distinct slopes rising abruptly from the alluvial field. Nearly all these western valleys are irrigated by direct diversion from their native streams. Certain areas would be benefitted by supplementary water, but the storage possibilities in mountain reservoir sites have not been extensively developed.

The northwest corner of the State lies in the Columbia River Basin. The heavy snowfall and moderate use of irrigation furnish large volumes of water to form important tributaries of the Columbia. The remainder of the State lies in the basin tributary to the Missouri River, the main stem of which extends from west to east, north of the middle half of the State, with the Yellowstone and its important tributaries flowing diagonally across the southeastern quarter.

In the Columbia Basin (Clark Fork), the Bitter Root Valley, tributary to the towns of Hamilton and Missoula, is highly developed with a small amount of constructed reservoir storage to supplement the natural water supply. In this valley the little potential land still remaining can be developed only through irrigation, and that largely by construction of additional storage, which is also needed to supplement the supply of lands now irrigated. In Deer Lodge and Flint Creek Valleys and upper Clark Fork supplementary storage is needed to carry the irrigation beyond hay and grain as a balance to the local stock industry.

The United States Bureau of Reclamation has an extensive project south of Flathead Lake. There are a few areas offered in this basin for potential development. Much of the total is not in absolute need of irrigation, especially along the Flathead and tributary streams. On the upper Clark Fork, between Missoula and Deer Lodge, there is a greater need for irrigation water to supplement the present supplies.

East of the Continental Divide the various major streams have been fully investigated by the Engineer Corps of the United States War Department and reported in various publications. Irrigation on the Milk River [96] is mostly in the eastern part of the State, but a few areas were irrigated on the Blackfeet Indian Reservation on the upper forks of the Milk. This stream heads in the region of heavy snowfall in Glacier Park and flows across the international line into Alberta, coming back into the United States 130 or 140 miles east of the point where it enters Canada.

From Chinook to the State line there is practically a continuous belt of irrigable land lying along the river. In addition, there are 6 or 8 potential areas which the War Department regards as very doubtful of final reclamation. The conclusions in its report [96] mention adjustments "whereby at least as much land will be excluded as will be taken into the projects." In order to supplement the present supply of the Milk and permit irrigation during the latter part of the season, several reservoir possibilities are definitely located. The War Department emphazises the point that many areas along the Milk are in need of flood control to protect the present agricultural investments and the towns already established.

The Marias River, a major tributary of the Missouri, flows through the country between the upper Milk and the main stem of the Missouri. That section contains numerous areas at present under irrigation, including the Valier project of 80,000 acres developed under the Carey Act. Large potential areas are also shown in the report of the War Department on this stream[95]. A water supply sufficient for 350,000 acres is indicated, which would allow the development of around 140,000 acres in addition to irrigation already existent. On the Teton River, between the Marias and the Missouri, extensive areas are already developed tributary to the town of Chouteau. Some of these areas are now served with reservoir water. The Teton enters Sun River above Great Falls. On the Sun some 56,000 acres are now under canal on the Bureau of Reclamation project near Fort Shaw, with additional areas aggregating another 51,000 acres susceptible of irrigation from the Sun and its three reservoirs, which have some 142,000 acre-feet capacity.

The main stem of the Missouri is formed by three major tributaries—the Jefferson, Madison, and Gallatin Rivers—which meet near Three Forks. The Jefferson is formed by the Big Hole and Beaverhead Rivers. These streams supply irrigation for mountain valleys as they work out toward the plains, with extensive hydroelectric development in addition to irrigation. The upper waters of the Beaverhead and the Madison are well supplied with reservoirs. Possibilities for future development along these streams are limited by the land rather than the supply of water, potential areas being much smaller in extent than those covered

by present systems. The great irrigated area on the Gallatin around Bozeman has long been noted as a practical laboratory for the development of experimental irrigation data.

Between Three Forks and the mouth of the Marias there is little present irrigation along the main valley of the Missouri, but extensive potential areas are shown. In the development of new areas, some of those already irrigated could be supplied with much-needed supplementary water. Return flow is estimated at 40 percent[95]. After crossing the one hundred and tenth meridian there is no irrigation, either present or potential, along the Missouri down to the mouth of the Milk. Here the Fort Peck Dam is now under construction. This dam was designed as a control for the Missouri, but its 17,000,000 acre-feet capacity could eventually insure a supply for 80,000 potential acres below the dam. Entering from the south are several tributaries with extensive potential irrigated lands, notably the Judith and the Musselshell. While there is now but little irrigation on these streams, extensive areas are in prospect in Judith Basin and near Harlowton and Ryegate. Present irrigation is confined to narrow ribbons closely adjoining the stream.

On the Missouri between the mouth of the Milk and the State line, there is a continuous belt of potential area, all below Fort Peck Dam, while the minor tributaries are irrigated at present in narrow strips immediately adjoining the streams.

Just beyond the State line between Montana and North Dakota, the Yellowstone enters the Missouri from the southwest. Rising in Yellowstone Park, in the northwest corner of Wyoming, this stream is of major proportions as it enters Montana. It has been pointed out that there is a possibility of additional storage a few feet in depth over the surface of Yellowstone Lake. If this could be effected without detriment to the scenic beauties of the park, there probably would be no material objection to it. (See p. 25.)

After entering Montana the Yellowstone and its tributaries flow almost continuously through irrigable land. Gravity diversions already serve the areas most easily reclaimed, and large blocks are susceptible of further improvement under reservoir regulation. Near Billings the Clark Fork enters the Yellowstone from the south, with extensive potential areas which might increase the irrigated land already tributary to Billings. Some 50 miles below Billings the Big Horn River enters, also from the south. This stream is extensively used for irrigation in Wyoming. A continuous strip of irrigated and irrigable land extends to its junction with the Yellowstone except through the canyon. Below the mouth of the Big Horn, irrigation possibilities are almost continuous to the mouth of Powder River. This stream also flows north out of Wyoming, after serving extensive areas in that State. However, only one potential strip is indicated along the Powder in Montana. Between the Big Horn and the Powder, the Tongue River enters from the south. Irrigation from that stream is largely confined to well-watered sections tributary to Sheridan in Wyoming, although minor areas are indicated in Montana. Below the mouth of Powder River irrigation possibilities on the Yellowstone extend to the State line, present irrigation being confined to the lower end of the stream in the lower Yellowstone project which is served by direct diversion.

While this State has no projects of size comparable to the Columbia Basin project of Washington, the Imperial Valley of California, or certain areas in Arizona and Colorado, a glance at the map shows that ultimate development is more likely to be controlled by economic conditions than by the supply of land or water. Necessarily, much of the agriculture of this State must be considered as a balance to the stock-raising industry, as the short growing season somewhat limits the types of agriculture that can be followed successfully. Detailed data regarding present and potential projects are found in the various reports of the War Department [92-98].

Duty of Water: The net irrigation requirements as set up by Fortier [100, 101] are indicated in table II. These figures are reasonably close to those accepted by the War Department in its studies of the various streams of this region. While considerably less than irrigation requirements of desert areas, the amounts indicated are considered adequate in view of the summer showers that are characteristic of this State during normal years.

Sources of Data: For the most part the designations of potential lands as set up in the reports of the War Department have been accepted. On this basis much acreage of highly doubtful reclamation, because of very high cost, poor land, or inadequate water supply, has not been included. If all projects offered are accepted, including some involving flood irrigation at uncertain intervals and others of cost excessive in any locality, the potential total aggregates almost twice that herein listed.

In a study conducted in 1934 some 3,500,000 acres were considered as potential land. This total includes some that the author's definition covers as irrigated land (see map). It also includes much that is of excessive cost, over $300 per acre. However, in his report on Montana Prof. S. T. Harding [102] sets a still higher figure for ultimate area that may be irrigated, as not exceeding 7,000,000 acres. He determines the water supply as sufficient for 10,000,000 to 12,000,000 acres with a duty of 3 feet per acre. Therefore it appears that land can be brought under irrigation for

many years to come, depending solely on the demand and the current economics rather than on either water supply or land as a controlling factor. Of course, local studies must still regard the water supply that can be made available to specific tracts.

Grazing: The report of the land classification of the plains area alone [91] shows some 47,000,000 acres included under various grazing groups. As the whole State has some 90,000,000 acres, this tends to verify the understanding that practically the whole State, outside of farms and rough, mountainous, and "bad" lands, may be considered as grazing areas.

The Garfield report to the President (1931) on the Conservation and Administration of the Public Domain lists some 22,000,000 acres of grazing lands of various types in Montana.

Nebraska

Irrigation Development: In 1930 the irrigation systems were capable of irrigating 703,641 acres. Of this, 532,617 acres were actually irrigated in 1929.[114] If the potential areas are taken at face value, an additional area of some 1,070,000 acres is susceptible of reclamation.

Nebraska is fortunate in having the results of a recent special survey of the resources of the State in terms of irrigation, water power, and drainage [112]. A glance at the map shows that Nebraska, like Idaho, is largely a one-stream State in terms of irrigation. It is also noticeable that practically all the present irrigation, and but little of the potential, lies west of the center of the State. Entering the State from the west are the two main forks of the Platte River. The North Platte rises in Colorado, where it serves irrigation in North Park; thence flows through extensive irrigated lands in Wyoming, where the flood waters are partly controlled by Pathfinder Reservoir, with extensive developments of both group interests and the National Bureau of Reclamation; and finally enters Nebraska in the midst of an area much of which is served by the units formerly comprising the North Platte project of the Bureau of Reclamation. In the southwest corner of the State the South Platte enters from Colorado and joins the North Platte River near the city of North Platte; from thence eastward the stream is known as Platte River.

In a supplemental report [112] Willis and McNamara, summarizing data on the Platte River, divide the stream into three sections—an upper section, from the State line to Oshkosh; a middle section, from Oshkosh to Sutherland; and a lower section, from Sutherland to Kearney. In the upper section, of 441,000 acres, about 166,000 acres have only direct-flow appropriations and the other 275,000 acres have storage rights. While the lower section has some 200,000 acres now irrigated, the greater part of the potential areas of the State, totaling nearly 700,000 acres, is tributary to this reach. The part of the State where the bulk of the present irrigation exists is in almost the same need for irrigation as is typical of States farther west. The central portion is advancing into the zone requiring supplementary irrigation, where a fuller appreciation of the increased yields obtainable under irrigation tends to encourage future construction.

On the two forks of the Loup River two potential projects are included in the reports of the War Department [119]. Present irrigation is of almost insignificant extent, but the point has been made that the extent of possible reclamation along the Loup is limited only by the economic need for irrigated agriculture in the future, as there is plenty of water for the purpose, an excellent flow, and potential storage sites to satisfy any need that may be developed. While the Army report [119] suggests but 54,000 acres as potential projects on the Loup, the State survey [112] referred to above, suggests that 207,000 acres might be considered as potential on this stream. A figure of 200,000 is used in this report.

The South Platte has its headwaters in several mountain streams rising in the eastern slope of the Rockies. After serving one of the highest developed irrigated areas in the Mountain States, both south and north of Denver, the South Platte enters Nebraska to irrigate a narrow but almost continuous ribbon of land from the State line to the junction with the North Platte. The only potential area suggested upon this fork lies to the south of Ogallala. The South Platte River has long been noted as an outstanding example of the use to be made of return waters. In years past, the upper and senior rights to irrigation in Colorado took practically all the stream, and through much of the summer season a dry sandy bed was characteristic of the Platte in northeastern Colorado and western Nebraska. In recent years the extensive development of irrigation in the upper rolling regions of the Platte and its tributaries has developed a return flow that has made rights on the lower plains in Colorado and Nebraska somewhat more secure. In the State study [112] return flow is relied upon extensively in the calculation, looking toward the maximum use of waters of the State.

In the northwestern corner of the State the Niobrara enters Nebraska from Wyoming and flows across the northern counties, entering the Missouri at the town of Niobrara. From the State line between Wyoming and Nebraska to the center of Sheridan County is a narrow and somewhat broken ribbon of irrigated land lying immediately adjacent to the stream. There are no potential areas offered for this stream. The report of the War Department [117] points out that flow in the

upper reaches is fully utilized on the present irrigated lands, and that for long reaches downstream from the present lands the adjoining tablelands rise several hundred feet above the river, so that any economic conditions reasonably to be expected appear to make irrigation, with a pumping lift of from 200 to 400 feet, out of the question. Irrigation would be further complicated by use of the water by hydroelectric plants already in operation.

Across the southern tier of counties lies the Republican River, with a continuous reach of irrigated land bordering its bed. Entering the Republican from the north at Culbertson is the stream shown on the Land Office map as Whitemans Fork, more commonly known as "the Frenchman." This stream is more nearly continuous in flow than the Republican, and it, too, has a long ribbon of adjacent irrigated land. On the Arikaree and Republican, east and west of Benkelman, no potential project to irrigate lands outside of the present irrigated area is proposed. The only other suggestions lie well to the east of McCook and are all additional narrow ribbons immediately adjoining the stream.

A marked increase in the area irrigated by pumping from wells took place between 1920 and 1930 and has continued, being accelerated especially during 1934. This development has been most notable in areas adjacent to the various rivers, because of low lifts, and has served to advance irrigation somewhat farther eastward of its former practical limits. A continuance of this advance may be expected, as the conditions favoring it are closely identical with those already described for Kansas. It will not be particularly localized, however, and cannot be mapped for that reason.

Duty of Water: The irrigation requirements set up by Fortier for Nebraska [120] assign a depth of 2 feet for that portion of the State west of the meridian marked by the eastern boundary of Colorado. From that line to a point east of Kearney a depth of 1.25 feet is suggested. It is noticeable that the State survey [112] utilizes about the same or lesser figures for net duty for the same areas.

Grazing: This State has sufficient rainfall so that forage for the grazing of livestock is available in practically all portions of the State not in irrigated or other farms. Small badland areas in northwest Nebraska are excepted.

Nevada

Irrigation Development: The meager water supply permitted irrigation of but 486,648 acres in 1929 out of a gross area under canals of 736,249 acres, [133] but reservoir regulation in the future will improve the distribution of the supply and strengthen the present irrigation. With the potential area spotted on the map, plus 60,000 acres assumed as possible of irrigation from ground water, the ultimate irrigation possibilities of the State aggregate 1,066,000 acres.

In perusing many reports on the State of Nevada it is noticeable that irrigation discussion is generally linked with the livestock industry. Likewise, mining furnishes markets for much of the produce of local irrigated lands. With the prospect of cheap power from Boulder Dam, now approaching completion, it is expected that there will be considerable extension in the development of Nevada's mineral resources and additional demands for the products of irrigated farms.

With a low rainfall, practically none of the crop agriculture of Nevada is conducted without irrigation. The present water supplies are overappropriated and the construction work of the immediate future will consist chiefly of reservoir storage to supplement the run-of-stream diversions.

Major areas under present irrigation are the valley of the Humboldt River and the narrow ribbons of its mountain tributaries, a small but highly important section directly tributary to Reno, and the larger acreage represented by the Newlands project of the United States Bureau of Reclamation.

Future development in terms of irrigation can be summarized as follows:

In Truckee River Basin there is a highly desirable project that would relieve the tense situation involved in the storage of water above the natural surface of Lake Tahoe, yet provides storage to supplement the flow of the Truckee River. The United States Bureau of Reclamation has made various investigations looking toward additional reservoir storage in Donner Lake, Little Truckee River Reservoir, and enlargement of Lahontan Reservoir, with a regulatory reservoir situated in the Truckee River proper. This prospective storage is highly desirable to stabilize the supply for the Truckee Meadows near Reno and to furnish additional water for the Newlands project.

The irrigated lands in the Carson Valley should be protected with additional storage on Truckee and Carson Rivers. On the Humboldt River cooperative investigations have been undertaken by the State and Federal Governments to determine feasible storage and river regulation to stabilize and improve this excellent irrigation asset.

On the Walker River the present irrigation, largely within an organized district, needs supplementary storage, which has been located and which will provide for the irrigation of certain additional lands surrounding the present farms.

In the extreme southern part of the State investigations are now under way to determine feasible areas upon which water may be pumped directly from

Boulder Reservoir to utilize some of Nevada's share of the allotment to the Lower Basin States. (See p. 3.)

Additional use would be found for the power to be generated at Boulder Dam, if made available to ranchers in the southern part of the State at a low charge. Substantial increases in areas irrigated by pumping will be distributed among many of the wide valleys between the mountain ranges that are scattered across most of the State. An examination by State officials indicates that many of these valleys, aggregating some 6,000,000 acres, are underlain with ground water. Estimates as to the amount of this land that could be irrigated, before exceeding annual replenishment, vary from 1 to 5 percent. If the lower figure be accepted, then some 60,000 acres of potential land would be made more than acceptable, in that supplementary feed for range stock and desert water supply could be made available over large areas now inadequately served.

Duty of Water: The irrigation requirement as set up for the State of Nevada runs from 1.7 feet across the southern end to 2.1 feet in the neighborhood of Fallon. Of the areas now most heavily irrigated, the Humboldt Valley is alloted 2 feet and the western section of the State, near Reno, 2.1 feet. While these figures appear low, it is fully appreciated that the meager run-off must be conserved to the utmost in order to irrigate the maximum area of land—in the words of Dr. Fortier, "for the largest agricultural development possible with the extremely small available water supply."

Grazing: The livestock industry is Nevada's greatest agricultural asset. Both sheep and cattle in great numbers are grazed over nearly all the State except the definitely desert areas that entirely lack natural forage. In the spring natural forage is available in the semidesert valleys. Summer feed is found in the higher mountain elevations. Under emergency pressure, alfalfa and meadow hay, raised under irrigation, are principally relied upon for winter feed.

Use of the public range is so important to Nevada that the State range commission was created by legislative act in 1929. In the findings of this commission it appears that some 53,000,000 acres, of a total of 70,000,000 acres within the State, is in unreserved public land. This is the largest area and largest percentage for any of the 11 Western States listed in the report. The chief value of the lands in the public domain is for grazing purposes, for which they are now completely utilized. In the few regions of 12 to 15 inches rainfall, grazing areas occupy all the land not now used for dry farming.

The Garfield report to the President (1931) on the Conservation and Administration of the Public Domain lists some 64,000,000 acres of grazing lands of various types in Nevada.

New Mexico

Irrigation Development: In 1930 the total area that could be served by existing works was 656,669 acres. Of this, 527,033 acres were irrigated in 1929 [148]. The potential areas spotted on the map, plus 10 percent of the underground districts definitely set aside for the purpose, plus 1 percent of the Playas Valley area mentioned below, aggregate some 434,000 acres for possible future development, making the ultimate irrigable area about 1,100,000 acres.

With the exception of scattered spots, irrigation in New Mexico is practiced chiefly in the valleys of the Rio Grande and the Pecos Rivers. The Rio Grande can be considered as comprised of four major sections: (1) that portion in Colorado irrigating the San Luis Valley; (2) the Middle Rio Grande, where irrigation has been conducted for hundreds of years, between the point opposite Santa Fe and the upper end of Elephant Butte Reservoir; (3) a portion comprising the Rio Grande project of the United States Bureau of Reclamation, irrigated by water stored in Elephant Butte Reservoir, and a narrow section along Rio Grande above Fort Quitman at the upper end of a canyon; and (4) the important reach of the river lying below the canyon section and expanding into the great Lower Rio Grande Valley. (See Texas, p. 21.)

Irrigation practice is made difficult by the great amount of silt carried by the main stream and many of its tributaries. In the Middle Rio Grande Valley, north and south of Albuquerque, irrigation has been practiced for 800 years or more, according to evidence of ancient Indian habitation. The recent work by the Middle Rio Grande Conservancy District is an excellent example of the rehabilitation that will be necessary for many of the older irrigation systems of the country. A comprehensive drainage system was installed to relieve the ground-water troubles that had rendered much of the land unfit for cultivation. Along with the drainage system a very extensive irrigation system was constructed, with several major diversion structures taking water directly from the Rio Grande. The construction of the Vado Reservoir on the Chama as a part of this project is causing some concern to the irrigators below Elephant Butte Reservoir, but there is a possibility of transmountain diversion from one of the tributaries of San Juan River to reenforce the waters of the Rio Grande by replacing any water captured at Vado Reservoir.

Scattered throughout the State are many Indian reservations where the Federal Government has developed irrigation systems for its Indian wards. The areas on most of these reservation projects are insignificant in extent but are highly important to the Indian communities dependent upon them. Certain

Indian tribes appear to take naturally to irrigation practice, others do not.

A second major irrigated area in the State extends along the Pecos River from above Roswell to 15 to 20 miles below Carlsbad. The solid irrigated area from Roswell to Lakewood is supplied with ground water, largely under artesian head. A definite boundary has been established around the artesian area, within which no new development by artesian water is allowed by State authorities. The lower area, which is comprised largely of the Federal Government's Carlsbad project, receives practically its entire supply from the river. Adjoining the present Carlsbad project is a potential area that will be dependent upon the construction of reservoir storage.

Excepting the San Juan, potential areas are mapped mainly on the basis of possible development of underground supplies, as the surface supplies are known to be fully used now. Two potential areas have been located and definite boundaries established for them, where development may take place by means of ground water. It is estimated that 10 percent of the total area indicated can be considered as actual potential irrigated areas. One of those lies in the southeastern corner of Lea County. A similar definitely bounded area is the Mimbres Valley in Luna County. Here the irrigation development is not restricted except under protest of injured parties. A similar area is known but not defined in the Playas Valley of Hidalgo County, in the southwestern corner of the State. Here 1 percent of the total area of the valley may be reclaimed by underground water. Near Tucumcari there is a large potential area to be irrigated by stored water diverted from the Canadian River. This project of some 65,000 acres appears to be highly regarded by the engineers of the War Department [150], and complete detail of the irrigation plan and contemplated reservoir storage is developed and reported in the citation given.

Duty of Water: The net irrigation requirement of the State of New Mexico as set up by Fortier and Young [149] varies from 1.6 feet in the northeastern portion of the State to 2.6 feet in the Rio Grande Valley. In their discussion of the Tucumcari area the War Department engineers [150] adopted a duty of water of 2 feet, which is 0.4 foot more than that suggested by Fortier and Young.

Grazing: Western New Mexico is well covered by mountain ranges in which torrential downpours occur at scattered periods during the summer season. This precipitation makes summer grazing highly practical. Unlike most of the Western States, New Mexico grazes cattle, sheep, and great numbers of goats, the latter being especially favored by Mexican and Indian stockmen. Certain of the Indian tribes do not take kindly to agriculture except as expressed in their herds. Others are willing to farm in much the same way as their white and Mexican neighbors.

Eastern New Mexico forms part of a great natural cattle range, along with Texas, Colorado, and western Oklahoma, but the grazing industry has gradually declined since the fencing of the open range and the utilization of local water supplies for irrigation. Much of the crop agriculture of New Mexico consists of the raising of forage crops to complement the livestock business.

The Garfield report to the President (1931) on "The Conservation and Administration of the Public Domain" lists some 39,000,000 acres of grazing lands in New Mexico.

North Dakota

Irrigation Development: North Dakota has a negligible area under supplemental irrigation, only 9,392 acres being irrigated in 1929 under systems capable of irrigating 24,006 acres.[161] Actual irrigation of much of the potential area of some 288,000 acres should be considered as very questionable. The experience of large systems in Canada and the United States indicates that it is very difficult to operate canals from which irrigation water is needed only in occasional years. However, a total of 312,000 acres may be considered as the ultimate irrigable area.

North Dakota is among the eastern tier of States that include both semiarid western parts and semihumid conditions in the eastern counties. In some years, such as the 1934 season, irrigation might be relied upon entirely, as in States farther west, while in other years it might be merely supplementary to the natural seasonal precipitation. While extensive projects are offered in the western part of the State, experience with costly systems already installed does not now encourage construction for large areas.

At the present time irrigation in this State is largely confined to the Lower Yellowstone project of the United States Bureau of Reclamation, a part of which is in Montana. The water for this area is brought by gravity from the Yellowstone River. Operation of the North Dakota pumping project of the Bureau of Reclamation, which originally contemplated the irrigation of some 25,000 acres in Williams County, has been discontinued. This project was largely completed and put under operation about 1908, but fairly adequate rainfall made irrigation unnecessary in many seasons. However, recent studies by the Corps of Engineers of the United States War Department [162] [165] indicate potential areas well over toward the center of the State which far exceed the present area of irrigated lands. It is possible that periods of dry years may result in the construction of irrigation systems in parts of the zone where precipitation alone has been relied

upon for crop agriculture, but in all likelihood only a small part of the potential areas will ever be developed.

For areas closely bordering streams or definite sources of underground water, reclamation by pumping is feasible, the possibilities representing tracts of both small and large extent. In his report on "The Irrigation Needs and Possibilities of the Great Plains" [159] Fellows mentions this possibility, particularly as regards the Missouri and its tributaries—the Heart, Knife, Cannonball, and Grand rivers. In the largest potential area offered for the State, in the Mouse River Loop, Fellows suggests that a supply may be obtained by storing the flood waters of the Mouse.

Any material increase in the irrigated area of North Dakota will come as a result of economic changes in present conditions. Where a crop "of sorts" can be raised without irrigation it is difficult to promote the development of comprehensive irrigation systems to serve large areas. However, with large increases in population and increased appreciation of possibilities of improving yields by supplementary irrigation, there will probably be a place for much additional irrigation in this State.

Duty of Water: For the western half of the State, Fortier[166] assigns a net irrigation requirement of 1.35 feet. This low figure is indicative of his recognition that irrigation is wholly supplementary to natural precipitation.

Grazing: In its report on the "Land Classification of the Northern Great Plains" [160] the United States Geological Survey lists by counties some 6,000,000 acres of nontillable grazing lands in western North Dakota, while farming-grazing lands are shown to aggregate some 2,000,000 acres. On the map they indicate as grazing lands practically all areas not included in farms or farm land.

Oklahoma

Irrigation Development: Irrigation in Oklahoma is almost negligible in extent, less than 1,000 acres being irrigated in areas adjacent to tributaries of the Arkansas and two-thirds as much in areas on Red River and its tributaries. As in the Dakotas, it is noticeable that there was material decrease during the 10 years from 1919 to 1929; in Oklahoma this amounted to 47 percent. However, about 10 years ago the United States Bureau of Reclamation reported a potential area of some 80,000 acres in Jackson, Kiowa, and Tillman counties. About 20 years ago the United States Geological Survey ([181]) reported that some 10,000 acres might be put under irrigation in the valley of the North Fork of the Canadian River near Oklahoma City. This total was to be made up of areas scattered so that not more than 80 acres would be reclaimed within a square mile. In other words, the survey estimated that about 15 percent of a large blanket area might be reclaimed by pumping from ground water.

The Oklahoma Panhandle extends far to the westward, where conditions are similar to those in western Kansas, definitely requiring a water supply for successful conduct of crop agriculture, while the main body of the State lies south of the eastern half of Kansas in a zone where extensive farming is carried on without irrigation. In the western part of the State supplementary irrigation would undoubtedly increase crops, and irrigated areas near either surface water or ground water will in all likelihood increase as economic conditions warrant the added expense.

Duty of Water: As a net irrigation requirement Fortier [184] set up 1 foot in depth for the main portion of the State west of Oklahoma City, where irrigation would be considered as supplementing the natural precipitation. Farther west, in the Panhandle, he suggests 1.25 feet, with the idea that irrigation will be less a supplementary and more nearly a primary supply.

Grazing: Before Oklahoma was thrown open for settlement it was considered part of the great cattle range of the Southwest. Encroachment of farms and fences has largely confined the open grazing to the unfenced portions of the Panhandle and the other western part of the State.

Oregon

Irrigation Development: In 1929 there were 898,713 acres irrigated from systems capable of watering 1,158,210 acres [202]. It is estimated that some 2,355,000 acres additional may be considered as potential areas. This includes more than 1,000,000 acres in the Willamette Valley, which will eventually require supplementary irrigation. The total ultimately irrigable area is therefore about 3,513,000 acres.

The Cascade Mountains divide Oregon into two distinct parts. The eastern slope is wholly dependent upon irrigation for crop agriculture, other than forage and grain crops in certain favored spots. West of the Cascade Mountains, except in the Rogue River strip from Ashland to Grants Pass, much of the agriculture has been conducted without irrigation. The greatest potential area of the whole State is in the Willamette Valley. Reports of the War Department [209] offered 513,900 acres as a potential area for supplementary irrigation in this great valley; but Powers in his "Twenty-five Years of Supplemental Irrigation Investigations in Willamette Valley" [198] establishes a case for 740,000 acres of good irrigable land and 419,000 of fair irrigable land, which are the figures published in this report. Powers estimates that some 20 percent of the valley's total area would be improved by irrigation. Much of the area offered as potential would require the installation of a drainage system as a preliminary to irrigation.

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The extreme southeastern portion of the State has used its meager water supply largely for raising hay and forage crops in conjunction with the livestock business. In the extreme east central section, where the Malheur and Owyhee join the Snake, there is a continuation of an extensive irrigated area that begins with the Boise Valley in Idaho. The United States Bureau of Reclamation is just completing works that will furnish needed supplementary water for much of the land now served by gravity from the Malheur and Owyhee rivers and by pumping from the Snake, and a full supply for the additional irrigable area.

In the north central portion of the State, south of the Columbia River, is a large block included in two possibilities. The John Day project of some 166,000 acres is considered feasible of irrigation from the John Day River when the flow of that stream is regulated by the development of known storage sites. All this area and an additional block of considerable size is included in three separate units for which irrigation is proposed by pumping from the Columbia River [207]. In this land use report the figures for areas to be irrigated by pumping from the Columbia have been accepted as against the figures for the John Day project, as they include a larger acreage.

Near the central part of the State there is an extensive area tributary to the lumber town of Bend, all irrigated under group organizations. The United States Bureau of Reclamation has conducted several studies looking toward the use of Deschutes River for further reclamation in this area. With storage of some 400,000 acre-feet possible at Benham Falls Reservoir site above Bend, and smaller sites still farther up the river, it appears that much additional area might be developed. The Deschutes River is a remarkable stream with respect to the uniformity of its flow and to the hydroelectric possibilities it offers because of its rapid fall from headwaters to its junction with the Columbia. The lower part of its course lies for miles at a time in deep canyons where direct diversion could be made only at high cost. Just below the mouth of the Deschutes, in an area tributary to The Dalles, is a potential area of some 10,000 acres where conditions are somewhat similar to those typifying the great apple and pear region a few miles farther down the Columbia. Near Hood River much of the land already irrigated is in need of more water, which can only be supplied by the development of reservoir storage.

Near La Grande is a potential area of some 25,000 acres that might be served by two possible reservoir storages with aggregate capacity of some 84,000 acre-feet. An alternate possibility for this area lies in the Grande Ronde site on the river of the same name above the town of Perry. At this site possibly 200,000 acre-feet of water might be stored.

Duty of Water: The irrigation requirements proposed by Fortier, [210] range from 2.0 to 2.7 feet east of the Cascades, with 1.2 feet for supplementary irrigation for the area including the Willamette Valley. To the southwestern corner of the State, with an area including the Klamath Falls project of the United States Bureau of Reclamation, the Klamath Indian Reservation, and the area between Medford and Grants Pass, a figure of 1.5 is assigned.

Grazing: Much of the eastern half of the State has long been used for extensive grazing of sheep and cattle. Much of the extreme southeastern portion is covered with ranches developed in the empire of the early cattle kings of California. As in the other Western States, the national forest reserves are utilized to a large extent for summer grazing, with winter feed being supplied by the products of irrigated ranches.

The Garfield report to the President (1931) on the "Conservation and Administration of the Public Domain" lists some 25,000,000 acres of grazing lands in Oregon.

South Dakota

Irrigation Development: The area irrigated in 1929 was 67,107 acres under systems capable of irrigating 109,550 acres.[227] This is a marked decrease from the figures of 1919 when the corresponding area irrigated was 101,000 acres of 151,000 acres which could be supplied. The investigations of the War Department [231 235] and unpublished reports on the main stem of the Missouri River indicate that some 71,000 additional acres can be listed as potential, including some needing supplementary water. These largely extend east from the present development, down the Cheyenne River almost to its junction with the Missouri. The great decrease in the use of irrigation during the 10 years between the last two censuses would tend to discourage extension of irrigated areas in terms of large systems, especially in the region of larger precipitation eastward. However, about 220,000 acres may be taken as the ultimately irrigable area.

South Dakota includes a semiarid western section where irrigation is almost a necessity except for wet seasons. In the eastern part of the State no irrigation is needed. The midway zone includes neither present nor potential irrigation projects.

The largest single block in irrigation at present is in the Belle Fourche project of the United States Bureau of Reclamation. In addition to the present irrigated area there are extensions of several thousand acres that may be brought under canal in the future. This project is an example of the beneficial effects of an irrigation supply, supplementary to natural precipitation, in increasing crop yields. Nevertheless, the irrigated area of the project was materially reduced

between 1920 and 1930, as was the case for the State as a whole.

The War Department [231] shows the large Angostura project on the south fork of the Cheyenne and smaller areas upstream, extending across the State line into Wyoming. Farther down the Cheyenne lies a second large project. These potential areas are considered in connection with proposed extensive reservoir storage. The War Department cites possible reservoir storage in the basin of the Cheyenne to the extent of some 400,000 acre-feet. At present there are no large reservoirs for irrigation under private enterprise. The Federal project at Belle Fourche has a capacious reservoir immediately adjacent to the irrigated lands.

Duty of Water: The irrigation requirement as set up by Fortier [236] for the western part of South Dakota allows a net depth of 1.5 feet. The War Department points out that the average duty for 15 years on the Belle Fourche project was only about 1.1 acre-feet per acre. However, it assumes a duty of 1.8 acre-feet per acre for the projects on the Cheyenne.

Grazing: In its report on Land Classification of the Northern Great Plains [228] the United States Geological Survey indicates some 10,000,000 acres of non-tillable grazing lands, some 1,400,000 acres in tillable grazing lands, and about 8,000,000 acres in farming-grazing and grazing-forage lands combined. In that report the acreage is listed by counties. It is noticeable that some 250,000 acres are listed as irrigated land. This is greatly in excess of the areas under irrigation in 1929, which, as stated above, showed a trend toward less rather than more irrigation in South Dakota.

Texas

Irrigation Development: While a very small portion of the total area of Texas is under irrigation, the areas affected are highly important to those parts of the State. Of the 1,177,415 acres that could be irrigated in 1930, 798,917 acres were actually irrigated in 1929.[251] As indicated below, much of the potential area is extremely hazy in both location and extent. However, State authorities and the American section of the International Boundary Commission estimate some 1,130,000 acres of potential land may be given over to irrigated agriculture in the future. Hence the total ultimately irrigable area is about 2,307,000 acres.

Texas extends completely across the zone bounded by the 50-inch rainfall lines at the extreme eastern side of the State and the 10-inch line in the extreme western part. However, the largest irrigated area lies in the region with 20 or more inches of precipitation. The irrigation possibilities are widely scattered over the southern half of the State, from the eastern rice fields near Beaumont to the El Paso–Juarez Valley near El Paso. In the interior the best-known area is in the neighborhood of San Antonio, where canals several hundred years old have brought water to the lands surrounding the Spanish missions. A more modern project, some 50 miles from San Antonio, depends upon storage in Medina Reservoir for a water supply.

Federal authorities have made comprehensive studies of the resources of Rio Grande and its tributary streams and have determined the acreage that might be served by their waters. However, the listing of acreages in the various counties was restricted by the placing of a limit on the total acreage that might be reclaimed from the waters of the Rio Grande. Hence, potential areas throughout the valley are largely uncertain as to definite location and extent, as ordinarily records do not come before the State authorities until claim is made for water rights.

In the El Paso–Juarez Valley practically all the irrigable area is now under canal, except certain loops in the river which will be transferred from Mexico to the United States upon completion of the works now under way. This construction will rectify the channel of the river from El Paso to Fort Quitman, shortening this part of the stream from 155 to 88 miles. The loops now in the United States, lying south of the line of channel change, will become Mexican soil, while the loops now lying to the north of the new channel will shift into the United States.

There is no potential area in the upper canyon section of the Presidio Valley. In the lower canyon section there are some 8,000 acres of potential land in excess of the area now under works, while in the hill section between the lower canyon and the Lower Rio Grande Valley there are some 153,000 acres entered as potential land. In the Lower Rio Grande Valley, with approximately 500,000 acres now under works, the total irrigable area will be almost 400,000 acres more than that area. In its report [250] the American section of the International Water Commission shows that ultimate possibilities of the river depend on reservoir storage to be developed, 4,100,000 acre-feet of storage and 1,600,000 acres of new land being set as the ultimate possibilities.

Duty of Water: The irrigation requirements set up by Fortier and Young [252] varies from 1.1 feet near Fort Worth to 2.4 feet in the western side of the State near El Paso. The section including the largest potential areas, that of Lower Rio Grande, was set at 1.75 feet. Irrigation in the Lower Rio Grande Valley is supplementary to a fairly heavy rainfall which comes at uncertain intervals through the season. Unfortunately, periods of wet weather in which no irrigation is required are simultaneous with the periods of heavy flow in the river, as there is no present storage on the Rio Grande proper below Elephant Butte Dam in New Mexico.

There are several sites for reservoir storage in the main channel. It is the present understanding of authorities familiar with the Lower Rio Grande Valley that the irrigated area in that section should not be extended without provision for reservoir water, as the present flow of the stream is fully utilized except during periods when no irrigation is required. There are certain minor reservoirs now in operation, situated away from the river, which rely on flood waters.

Grazing: The range lands of Texas have been known the country over since its earliest days. As in other range States, the building of fences, the transition from range to farm land, and the enclosure of existing water supplies have reduced the range possibilities. However, much of western Texas is still devoted to the stock industry, and practically all this portion of the State, outside of farmed areas, may be considered as permanent grazing land.

Utah

Irrigation Development: In 1929 there were 1,324,125 acres irrigated in systems which could serve 1,542,475 acres. New lands which can be classed as potential areas aggregate some 600,000 acres, but efforts for some time to come will be concentrated on construction to make more secure the water supply for the present areas under canal. It is estimated that some 900,000 acres of the area now irrigated require a supplementary supply of water. The total ultimately irrigable area is about 2,165,000 acres.

The reports of the 1930 census of irrigation [262] show figures which probably represent the ultimate efforts of the small groups that have constructed irrigation systems in Utah. Both supplementary water for the future and water necessary for the potential areas can only be made available through organization and financial assistance beyond the capacity of local interests.

Crop agriculture in Utah is quite commonly considered in terms of irrigated lands. Beginning in 1847, the Mormon settlements in the valleys east of Great Salt Lake led the way in developing irrigation practices for much of the West. The present problem of this highly developed region is comparable to that of the eastern slope of the Rockies in Colorado, in that supplementary water must be made available to augment the natural flow of the streams even before expansion is to be considered. Many studies have been made during the past few years by the United States Bureau of Reclamation looking to the development of reservoir storage, the coordination of many canal systems, and rearrangement of irrigation service for large areas. At present the Bureau is conducting a general study of the Colorado River Basin for determinations described on page 3. This has proceeded far enough to indicate that Utah's full use of its probable allotment from the 7,500,000 acre-feet allocated to to the Upper Basin States would involve several transmountain diversions. Thus far 10 of these have been definitely located, of which 5 involve tunnels from 0.1 to 11 miles in length and the other 5 involve transportation from one watershed to another through mountain passes.

Much of the present irrigated land of Utah lies in the Great Basin. It is noticeable that but little potential area is indicated there, the great concern of this State being to build reservoir storage, transmountain diversions, and additional canals to supplement the present supply for both irrigation and municipal uses. One project under present study, and subject to much local discussion, is typical of the complex nature of these rehabilitation projects. It is proposed to divert water from the upper Duchesne River through a tunnel into the upper reaches of the Provo River. Eventually a second transmountain diversion will be made to reinforce the upper Duchesne with water from the Granddaddy Lakes region now tributary to Rock Creek. Water is to be allowed to flow down Provo River, then stored in Deer Creek Reservoir on the river below Heber. As released from the reservoir, it will be diverted into a high-line canal skirting the agricultural area between Provo and Jordan Narrows. An extension of this canal will carry water above the present lands of Jordan Valley to an intersection with Parleys Canyon Creek. Various plans for the utilization of Deer Creek Reservoir differ slightly from the outline given above, but the latter shows the many complexities that enter into a complete revision of the water supply tributary to an area that long ago had utilized its run-of-stream supply.

Another item indicating the practical extremes to which the conservation of water may be carried involves irrigation surrounding Utah Lake. This is a body of fresh water connected with Great Salt Lake by Jordan River. Much of the marginal area of the lake is shallow and it is proposed to construct a dike that will confine the water to the deeper portions. This is a region of excessive evaporation, and it is believed that the water saved by the lowered evaporation resulting from the reduction of the water area will more than pay for the cost involved.

In the Colorado River Basin several potential projects are offered along the Green River above its junction with the Colorado. Some of the areas immediately adjacent to the stream are shown on the map as conflicting with potential reservoir sites, but it is believed that the areas in conflict are not of moment for many of the sites will be developed only in the distant future. Figures representing the potential areas are taken from the Geological Survey study of

the Green River[268]. It is probable that more detailed surveys included in the present study of the Colorado River Basin by the Bureau of Reclamation will result in the revision of the project areas, with possible additions and rejections for various causes. When made available, the altered data should permit proper correction of the maps.

One of the most extensive studies conducted by the Bureau of Reclamation involves the rehabilitation of the irrigation systems in Cache Valley. A number of reservoir sites on the various tributaries entering this valley offer possibilities of supplementing the present run-of-stream irrigation, but little potential area is added to that already irrigated. This study shows possibilities of bettering the water supply for some 90,000 acres.

Duty of Water: Fortier[266] sets up approximately 2 feet as the irrigation requirement for all land in the Great Basin, though showing a variation ranging from 1.8 feet in the southwest corner, where the meager water supply must be used to the utmost, to 2.2 feet in the Provo and Salt Lake Valleys.

Grazing: There is very little plains pasture in summertime. Stockmen take their herds into the mountains, largely to forest reservation areas. However, during the winter much of the southern desert lands receive precipitation so that they can furnish pasturage for both sheep and cattle in large numbers. Many of the stockmen who own ranches rely on irrigated hay crops for winter feed during seasons too severe for the stock to find their own sustenance.

The Garfield report to the President (1931) on "The Conservation and Administration of the Public Domain" lists some 38,000,000 acres of grazing lands in Utah.

Washington

Irrigation Development: Washington in 1930 had under its existing irrigation systems 631,511 acres, of which 499,283 acres were actually irrigated in 1929.[273] Of this area it is estimated that some 300,000 acres are in need of supplementary supplies to strengthen present irrigation use. The possibilities aggregate an additional 2,000,000 acres, the total ultimately irrigable area thus being about 2,700,000 acres.

Washington is divided by the Cascade Mountains into two distinct types of country. With excessive snowfall, this range is an excellent collecting ground for the water supply of many fine streams.

With few minor exceptions, the sections now irrigated are east of the Cascades, particularly in the valleys of the Yakima, Wenatchee, Methow, and Okanagan Rivers. All this area lies in the drainage basin of Columbia River. Minor areas in Spokane Valley and in the southeastern corner of the State complete the picture of agricultural development under present irrigation east of the Cascades. The potential areas lie in a few large blocks.

West of the Cascades irrigation has not been practiced to any great extent, although a few spots are indicated on the map as under irrigation at the present time and there are also a few small areas classed as potential land. The State officials emphasize the point that one small area is indicated as feasible in the extreme western side of Clallam County, in a region of 80 or more inches of rainfall. It is conceivable that the people living west of the Cascades will watch with interest the irrigation developments in the Willamette Valley of Oregon. If the additional yields in that area are commensurate with the costs of irrigation, it is conceivable that many areas in Washington would likewise benefit by supplementary irrigation.

The irrigated areas on the eastern slope lie in a few well-known sections. In the extreme east is a block tributary to the city of Spokane; on the Okanagan are several tracts in group organization and one relatively large area in the Okanagan project of the Bureau of Reclamation; on the Methow River is a long narrow ribbon adjoining the river, with certain additional spots indicated as potential. One of the well-known fruit areas of Washington is the Wenatchee Valley.

The Yakima Valley in the neighborhood of Ellensburg has been irrigated for many years under group organization, and a large area in the Kittitas project has recently been placed under canal by the Bureau of Reclamation. The Yakima Valley from above Naches to the Columbia River is a wide and almost continuous belt of land irrigated either under canals operated by groups of farmers, as several units of the Yakima project constructed by the Bureau of Reclamation, or as tracts in Indian reservations operated by the Bureau of Indian Affairs. Surrounding the present irrigated block on the Yakima are potential areas aggregating some 170,000 acres. This great valley is served by direct flow supplemented by numerous storage reservoirs constructed, in the main, by the Bureau of Reclamation. In the upper reaches of the streams along the Cascades in both Washington and Oregon are numerous lakes that would lend themselves to enlargement into excellent reservoirs.

Of the potential areas of the United States the one now attracting the greatest attention is represented by the Columbia Basin project, which was originally conceived to include from 1,000,000 to 1,750,000 acres. Several surveys have been made of it. Under construction now is the Grand Coulee Dam, which initiates a plan that looks to the reclamation of about 1,200,000 acres under pumping lift. This project incloses much of the great grain area known as "the Big Bend country." With cheap power available from Government hydro-

electric plants, it is conceivable that the present ideas of economic pumping lift can be so altered that some excellent land lying above the present project will ultimately be brought under canal.

The second great area that may be made attractive in the future is comprised of the excellent lands contained in the so-called "Horse Heaven project," north of the Columbia where it forms the boundary line between Washington and Oregon. This area is considered to contain about 200,000 acres of net irrigable land, the higher parts of it reclaimable under reservoired water from the Klickitat while the lower areas may be served from the Columbia by high-lift pumping plants. This area usually has not been considered in terms of pumping from the Columbia, but the possibility is now suggested by the prospect of cheap power.

Scattered throughout the State, as indicated on the map, are small areas of a few thousand acres each that may ultimately be brought under irrigation with more complete conservation of the streams commanding them.

Duty of Water: In setting up water requirements, Fortier and Young [286] recognize that irrigation east of the Cascades is not to be considered as supplementary to precipitation whereas for the western slopes about half as much as the eastern allotment is set up for supplementary irrigation. In the great area that includes the Yakima Valley, the Columbia Basin project, and the Horse Heaven project, a duty of 2.8 feet is offered. In the northeastern corner of the State 2.2 feet is allowed, and to the Okanogan country an intermediate amount is allotted. In a report on the Horse Heaven district an average gross duty of 2 feet is set up, which would make the net duty less than that offered by Fortier.

Grazing: Agriculture in Washington has been considered in terms of grain and fruit rather than of stock raising. Like California, eastern Washington becomes dry and brown during the summer season, which encourages the pasturing of livestock within the higher mountain areas. Heavy snowfall requires the removal of this stock during the winter, and pasturage supplemented with forage raised on irrigated farms is obtained in the lower valleys.

Wyoming

Irrigation Development: In 1929 this State contained 1,655,008 acres of land that could be irrigated under the available systems, of which 1,236,155 acres were actually irrigated during 1929 [312]. The potential area within this State comprises some 2,400,000 acres additional. Within this potential area is included that covered by the Casper-Alcova project now under construction. The total ultimately irrigable area is nearly 4,100,000 acres.

Irrigation in Wyoming is a result of a gradual transition from the old cattle range developed in the last quarter of the nineteenth century, so it is largely carried on as an adjunct of the stock-raising business.

Like Colorado, Wyoming contains the headwaters of many major streams that are used for irrigation beyond the boundaries of the State. The present irrigated areas lie in five main basins draining into North Pacific Ocean, Gulf of California, or Gulf of Mexico. In the southwestern corner the Colorado River drainage, represented by the headwaters of the Green, is used for the irrigation of mountain and plains valleys. There are possibilities for much additional area on this stream in order for Wyoming to utilize some of its share of the Upper Basin allotment of 7,500,000 acre-feet of water. (See p. 3.) The northwestern portion of the State in the Snake River drainage furnishes much of the water eventually used in Idaho, although the mountain valleys of Wyoming are almost completely irrigated. The Big Horn River drains mountainous areas of fairly heavy precipitation. Present and prospective storage will make large areas feasible of irrigation. Major tributaries of the Big Horn have larger areas in irrigation at present than the main stream. The extreme northeastern part of the State contains some possibilities but little actual irrigation. The southeastern quarter lies in Missouri River drainage and is well spotted with small irrigated areas watered by canals under private enterprise.

The largest part of the present irrigation development in Wyoming has come about through individual and cooperative effort, except for the great projects developed by the United States Bureau of Reclamation. These latter include the Shoshone project in northwestern Wyoming, served with the fine reservoir storage in Shoshone Reservoir, and the North Platte project in the extreme eastern portion of the State, which utilizes water stored many miles upstream at Pathfinder Reservoir, recently supplemented by smaller reservoirs nearer the farms. In the center of the State the Riverton project includes an area adjacent to Wind River Indian Reservation and tributary to the town of Lander. The map shows extensive potential areas in nearly all parts of the State.

The great potential area shown in Green River Basin is made up of many smaller projects which might be developed as units. The study of the United States Geological Survey [310] lists 520,000 acres of additional land as irrigable in the Green River Basin. Advance sheets of the Colorado River Basin study being conducted by the Bureau of Reclamation reduce this area to approximately 400,000 acres additional. This is no more than the reduction that is to be expected when any blanket area is subjected to the refinement of a land classification.

South of Yellowstone Park the great Jackson Hole country contains the headwaters of Snake River. (See p. 10.) Some 90,000 acres in Wyoming are now irrigated from this stream. All irrigated land in this basin pays good dividends in the raising of feed for livestock and dairy cattle.

Yellowstone National Park occupies the extreme northwestern corner of the State. From an irrigation standpoint, Yellowstone Lake, with some 90,000 acres of surface, appears to furnish an excellent opportunity for storage without marring scenic beauty. A small regulatory dam and bridge would store water some 6 feet above the present surface, or approximately 534,000 acre-feet, at a low cost and without changing the present range of fluctuations of the surface. There are also possibilities affecting some of the tributaries of the Yellowstone by way of transmountain diversions which would materially reinforce the waters of Big Horn Basin so as to permit service to its extensive areas of potential land.

East of the Big Horn Mountains the country from Buffalo to the State line, tributary to Sheridan, contains numerous large well-watered areas. The potential lands for this area form a continuous block surrounding the present ranches.

As North Platte River leaves the State to enter Nebraska, the North Platte project, situated in both States, covers an impressive area. While areas adjoining the present irrigated lands are also susceptible of development if various adjustments of water can be effected, numerous reservoir sites still to be developed in Wyoming and Nebraska might open the way to various exchanges of use of the present flow of the stream.

Construction of the system to serve the Casper-Alcova project was recently commenced, but its continuance is now threatened by interstate litigation over water rights. The planned construction includes the building of Seminoe Reservoir, the site of which offers an ultimate capacity of some 1,360,000 acre-feet, though present plans involve only about 950,000 acre-feet. By the release of water from this reservoir a large area near Casper is to be made irrigable, and cheap power is expected to encourage the development of many pumping units scattered along the Platte River in locations where gravity diversion is not feasible. The coloring on the map indicates that the Casper-Alcova project is under irrigation, but the area is listed as potential in table II.

On Laramie Plains there is extensive irrigation at present with water originating largely in Colorado. Likewise, extensive potential areas are shown as interspersed with the present irrigated lands. Leaving this area, the Laramie River passes through a canyon section to come out on the plains surrounding the town of Wheatland, which has long been under irrigation with water from several tributaries of the Laramie. Surrounding this area, under present irrigation, is a large potential block that merges into the Goshen Hole area adjoining the North Platte project.

Much of the future development of the North Platte and its tributaries in the States of Colorado, Wyoming, and Nebraska is dependent upon a final adjustment of water relations between those States.

Duty of Water: Nearly all the irrigation waters of Wyoming are used under decreed rights, at a uniform rate of 1 second-foot for each 80 acres of land. Under an assumption that the irrigation season is approximately 100 days, this would give a gross irrigation requirement of some 2.5 acre-feet per acre. Because much of this State is of geologic formations that encourage extensive return of waters to streams, a lesser amount can be accepted readily as a net duty.

The irrigation requirements as set up by Fortier and Young [298-300] appear to conform to the State requirements very closely. For instance, those investigators offer 1.6 acre-feet per acre for Green River Basin and about the same amount for Missouri River Basin lands, while the duty set for Snake River Basin by Wyoming is given as 1.7 acre-feet per acre. Considering the heavy return flow that would take place in this river and the numerous summer showers, it would appear that this amount is more than liberal.

Grazing: Agriculture in Wyoming has been built around the coordination of the livestock and dairy industries, with irrigated crops to carry the stock through the rigorous winter season. Most of Wyoming outside of the farmed areas and the more rugged mountain elevations, may be considered as grazing land, with much of the plains area grazed throughout the year except in the most severe weather. The practice of driving all the herds into the higher mountains throughout the summer is not general in Wyoming. Both cattle and sheep are grazed in great numbers.

The Garfield report to the President (1931) on the "Conservation and Administration of the Public Domain" lists some 38,000,000 acres of grazing lands in Wyoming.

TABLE II.—*Present irrigation development and ultimate possibilities of irrigation development by States and stream basins*

State and stream basin	Present development		Additional irrigable area (potential area)[2]	Ultimate irrigable area[2]	Annual irrigation requirement, additional to natural precipitation[3]		Distribution of additional irrigable area according to estimated costs of reclamation				
	Area irrigated in 1929[1]	Area enterprises were capable of irrigating in 1930[1]			Depth	Total for ultimate irrigable area	Less than $50 per acre	Between $50 and $100 per acre	Between $100 and $200 per acre	More than $200 per acre	Indeterminate
ARIZONA	*Acres*	*Acres*	*Acres*	*Acres*	*Feet*	*Acre-feet*	*Acres*	*Acres*	*Acres*	*Acres*	*Acres*
Colorado River and tributaries	572,289	819,399	754,600	1,574,000	(4)	4,603,720	19,700	33,000	39,100	594,600	68,200
Colorado River direct	54,732	67,102	577,900	645,000	3.0	1,935,000		12,000	38,700	514,600	12,600
Kanab Creek	322	667		700	2.3	1,600					
Virgin River	444	690		700	2.3	1,600					
Williams River	1,111	1,475		1,500	2.3	3,500					
Little Colorado River and tributaries	13,652	21,796	83,100	104,900	2.3	241,300	6,100	21,000	400		55,600
Little Colorado River direct	7,249	11,937	75,600	87,500	2.3	201,200		20,000			55,600
Nutrioso Creek	222	260		300	2.3	700					
Concho Creek	823	823		800	2.3	1,800					
Other tributaries	5,358	8,776	7,500	16,300	2.3	37,500	6,100	1,000	400		
Gila River and tributaries	500,169	724,283	93,600	817,900	(4)	2,412,900	13,600			80,000	
Gila River direct	104,309	218,275	13,600	231,900	2.9	672,500	13,600				
San Francisco River	781	851		900	2.6	2,300					
San Pedro River	3,956	4,428		4,400	2.6	11,400					
Santa Cruz River	24,718	39,920		39,900	3.0	119,700					
Salt River and tributaries	311,264	345,045		425,000	3.0	1,275,000					
Salt River direct	264,740	290,479		290,500	3.0	871,500					
Tonto Creek	442	442		400	3.0	1,200					
Rio Verde	6,844	9,685	80,000	89,700	3.0	269,100				80,000	
Other tributaries	39,238	44,439		44,400	3.0	133,200					
Agua Fria River	25,104	62,753		62,800	3.0	188,400					
Hassayampa River	432	650		700	3.0	2,100					
Other tributaries of Gila River	29,605	52,361		52,400	2.7	141,500					
Other tributaries of Colorado River	1,859	3,386		3,400	2.3	7,820					
Whitewater Draw and tributaries	3,301	4,753		4,800	2.6	12,500					
Total for State	575,590	824,152	754,600	1,578,800	(4)	4,616,220	19,700	33,000	39,100	594,600	68,200
CALIFORNIA											
North Pacific	68,270	104,765		337,000	(4)	1,011,000					
Sacramento[5]	696,924	1,176,770		4,266,000	(4)	[6] 15,864,000					
San Joaquin River	2,405,380	3,562,702		5,704,000	(4)	13,326,000					
San Francisco Bay	99,079	107,432		870,000	(4)	1,735,000					
Central Pacific coast	154,472	174,924		616,000	(4)	1,540,000					
South Pacific coast	585,198	744,032		2,000,000	(4)	3,340,000					
Great Basin[7]	737,309	944,625		2,880,000	(4)	10,000,000					
Total for State	4,746,632	6,815,250	9,857,750	16,673,000	(4)	46,816,000					
COLORADO											
South Platte River and tributaries	1,223,423	1,389,161	20,000	1,409,200	(4)	3,058,900					20,000
South Platte River direct	456,917	488,897	20,000	508,900	[8] 2.1	1,068,700					20,000
Bear Creek	12,824	12,908		12,900	2.2	28,400					
Clear Creek	85,676	131,778		131,800	2.2	290,000					
St. Vrain Creek	179,569	205,401		205,400	2.2	451,900					
Big Thompson Creek	92,704	100,753		100,800	2.2	221,800					
Big Beaver Creek	8,470	10,470		10,500	2.2	23,100					
Cache la Poudre River	285,160	324,523		324,500	2.2	713,900					
Lone Tree Creek	1,447	1,457		1,500	2.2	3,300					
Crow Creek	996	1,226		1,200	2.2	2,600					
Other tributaries	99,660	111,748		111,700	2.2	245,700					
Republican River and tributaries	3,375	4,465		4,500	2.1	9,500					
Smoky Hill River and tributaries	30	30			2.1						
Arkansas River and tributaries	558,072	690,955		691,000	(4)	1,508,400					
Arkansas River direct	346,178	373,943		373,900	[8] 2.2	822,600					
South Fork	10,008	10,985		11,000	2.1	23,100					
Fountain River	22,664	35,356		35,400	2.1	74,300					
St. Charles River	10,177	11,330		11,300	2.1	23,700					
Huerfano River	54,193	76,051		76,100	2.1	159,800					
Apishapa River	5,199	25,509		25,500	2.1	53,600					
Purgatoire	32,799	48,089		48,100	2.3	110,600					
Cimarron River	139	140		100	2.3	200					
Other tributaries	76,715	109,552		109,600	[8] 2.2	241,100					
Rio Grande and tributaries	551,142	674,196		674,200	1.8	1,213,600					
Rio Grande direct	356,069	379,874		379,900	1.8	683,800					
Alamosa River	30,216	43,675		43,700	1.8	78,700					
La Jara River	9,180	10,540		10,500	1.8	18,900					

[1] U. S. Bureau of the Census, Irrigation of Agricultural Lands.
[2] In round numbers.
[3] Based on Department Bulletin 1340 and Technical Bulletins 36, 185, 200, and 379 of the U. S. Department of Agriculture.
[4] Variable.
[5] Includes Sacramento-San Joaquin delta.
[6] Includes requirements for salinity control.
[7] Includes Imperial and Coachella Valleys.
[8] Average.

TABLE II.—*Present irrigation development and ultimate possibilities of irrigation development by States and stream basins*—Continued

State and stream basin	Present development		Additional irrigable area (potential area)	Ultimate irrigable area	Annual irrigation requirement, additional to natural precipitation		Distribution of add tional irrigable area according to estimated costs of reclamation				
	Area irrigated in 1929	Area enterprises were capable of irrigating in 1930			Depth	Total for ultimate irrigable area	Less than $50 per acre	Between $50 and $100 per acre	Between $100 and $200 per acre	More than $200 per acre	Indeterminate
COLORADO—Continued											
Rio Grande and tributaries—Continued.	*Acres*	*Acres*	*Acres*	*Acres*	*Feet*	*Acre-feet*	*Acres*	*Acres*	*Acres*	*Acres*	*Acres*
Conejos River	80,918	99,808		99,800	1.8	179,600					
Trinchera River	14,838	63,228		63,200	1.8	113,800					
Other tributaries	59,921	77,071		77,100	1.8	138,800					
San Juan River and tributaries	129,811	159,187	182,600	341,800	1.9	649,400			125,300		57,300
San Juan River direct	2,282	2,876	6,500	9,400	1.9	17,900					6,500
Los Pinos River	42,881	57,832	50,500	108,300	1.9	205,700			26,500		24,000
Animas River	27,283	29,374	23,600	53,000	1.9	100,700			23,600		
La Plata River	24,308	29,920	10,200	40,100	1.9	76,200			10,200		
Mancos River	13,167	16,200	15,000	31,200	1.9	59,300					15,000
Other tributaries	19,890	22,985	76,800	99,800	1.9	189,600			65,000		11,800
Upper Colorado River and tributaries	622,714	786,042	421,500	1,207,500	1.7	2,052,800		37,500			384,000
Upper Colorado River direct	64,855	96,629	46,000	142,600	1.7	242,400		12,500			33,500
Fraser River	4,164	4,652		4,600	1.7	7,800					
Muddy Creek	6,448	8,509		8,500	1.7	14,500					
Blue River	10,725	15,675		15,700	1.7	26,700					
Eagle River	12,590	13,523		13,500	1.7	23,000					
Roaring Fork	36,283	47,055		47,100	1.7	80,100					
Plateau Creek	64,833	68,486	10,000	78,500	1.7	133,400					10,000
Gunnison River and tributaries	258,872	322,837	83,000	405,800	1.7	689,900					83,000
Gunnison River direct	20,302	22,256	25,500	47,700	1.7	81,100					25,500
Taylor River	380	580		600	1.7	1,000					
Tomichi Creek	17,336	22,407		22,400	1.7	38,100					
North Fork	38,725	51,977		52,000	1.7	88,400					
Smith Fork	19,329	23,876		23,900	1.7	40,600					
Uncompahgre River	89,679	109,767	49,500	159,300	1.7	270,900					49,500
Other tributaries	73,121	91,974	8,000	99,900	1.7	169,800					8,000
Rio Dolores	80,436	106,457	237,500	344,000	1.7	584,800			25,000		212,500
Other tributaries	83,508	102,219	45,000	147,200	1.7	250,200					45,000
Tributaries of Green River	103,888	137,120	333,500	470,600	1.35	635,300			96,000		237,500
Yampa River and tributaries	74,753	103,940	255,500	359,400	1.35	485,200			91,500		164,000
Yampa River direct	22,138	28,187	22,000	50,200	1.35	67,800			10,000		12,000
Little Snake River	7,884	11,003	100,000	111,000	1.35	149,800			50,000		50,000
Other tributaries	44,731	64,750	133,500	198,200	1.35	267,600			31,500		102,000
White River	27,773	31,648	48,000	79,700	1.35	107,600			4,500		43,500
Other tributaries	1,362	1,532	30,000	31,500	1.35	42,500					30,000
North Platte River and tributaries	124,915	151,550		151,500	2.2	333,300					
North Platte River direct	7,470	7,870		7,800	2.2	17,200					
Laramie River	11,075	11,075		11,100	2.2	24,400					
Other tributaries	106,370	132,605		132,600	2.2	291,700					
Independent streams	76,249	86,006		86,000	1.8	154,800					
Saguache River	20,221	25,501		25,500	1.8	45,900					
San Luis River	37,591	42,068		42,100	1.8	75,800					
Other tributaries	18,437	18,437		18,400	1.8	33,100					
Total for State	3,393,619	4,078,712	957,600	5,036,300		9,616,000		12,500	246,300		698,800
IDAHO											
Bear River and tributaries	161,304	180,716	20,000	200,700	2.0	401,400	20,000				
Bear River direct	61,647	75,066	20,000	95,000	2.0	190,000	20,000				
Thomas Fork	3,168	3,246		3,300	2.0	6,600					
Mill Creek	16,564	17,126		17,100	2.0	34,200					
Little Malad Creek	8,858	10,502		10,500	2.0	21,000					
Other tributaries	71,247	74,776		74,800	2.0	149,600					
Tributaries of Columbia River	1,937,872	2,271,846	1,118,500	3,390,300	(1)	8,374,700		407,500	525,000	71,700	114,300
Snake River and tributaries	1,929,886	2,259,240	1,087,800	3,347,000	(1)	8,257,300					
Snake River direct	687,316	804,047	938,500	1,742,500	2.7	4,704,800		307,500	510,000	56,000	65,000
Henrys Fork	174,960	196,373		196,400	1.7	333,900					
South Fork of Snake River	161,988	181,634		181,600	1.7	308,700					
Blackfoot River	45,157	78,943	40,000	118,900	1.7	202,100					40,000
Port Neuf River	41,774	48,718	30,000	78,700	1.7	133,800		25,000			5,000
Raft River	8,935	18,115		18,100	1.9	34,400					
Goose Creek	18,126	24,191		24,200	1.9	46,000					
Salmon Falls River	28,847	36,977		37,000	1.9	70,300					
Little Wood River	19,848	21,902		21,900	1.9	41,600					
Big Wood River	83,301	117,549		117,500	1.9	223,200					
Bruneau River	18,042	21,651		21,700	1.9	41,200					
Owyhee River	8,250	8,878	5,000	13,900	1.9	26,400		5,000			
Boise River	318,496	329,322	70,000	399,300	2.7	1,078,100		70,000			
Payette River	122,468	139,495		139,500	2.7	376,600					
Weiser River	33,422	40,939		41,000	2.7	110,700					
Salmon River	93,818	110,064	3,000	113,100	2.7	305,400					3,000
Clearwater River	4,896	5,154		5,100	2.7	13,800					
Other tributaries	60,242	75,288	1,300	76,600	2.7	206,800					1,300
Other tributaries of Columbia	7,896	12,606	30,700	43,300	2.0	116,900			15,000	15,700	

1 Variable.

TABLE II.—*Present irrigation development and ultimate possibilities of irrigation development by States and stream basins*—Continued

State and stream basin	Present development		Additional irrigable area (potential area)	Ultimate irrigable area	Annual irrigation requirement, additional to natural precipitation		Distribution of additional irrigable area according to estimated costs of reclamation				
	Area irrigated in 1929	Area enterprises were capable of irrigating in 1930			Depth	Total for ultimate irrigable area	Less than $50 per acre	Between $50 and $100 per acre	Between $100 and $200 per acre	More than $200 per acre	Indeterminate
IDAHO—Continued.	*Acres*	*Acres*	*Acres*	*Acres*	*Feet*	*Acre-feet*	*Acres*	*Acres*	*Acres*	*Acres*	*Acres*
Independent streams	82,074	164,459		164,500	(4)	441,300					
Camas Creek	20,089	58,185		58,200	2.7	157,100					
Beaver Creek	806	1,536		1,500	2.7	4,000					
Medicine Lodge Creek	3,983	5,187		5,200	2.7	14,000					
Little Lost River	4,964	5,684		5,700	2.7	15,400					
Big Lost River	40,078	79,986		80,000	2.7	216,000					
Other tributaries	12,154	13,881		13,900	[9] 2.5	34,800					
Total for State	2,181,250	2,617,021	1,138,500	3,755,500		9,217,400	20,000	407,500	525,000	71,700	114,300
KANSAS											
Tributaries of Missouri River	1,411	2,406	[10] 800,000	802,000	1.75	1,404,000					800,000
Tributaries of Kansas River	1,394	2,376	800,000	802,000	1.75	1,404,000					800,000
Republican River	489	1,080	340,000	341,000	1.75	597,000					340,000
Smoky Hill River	111	296	460,000	460,000	1.75	805,000					460,000
Other tributaries	794	1,000		1,000	1.75	2,000					
Other tributaries of Missouri River	17	30			1.75						
Arkansas River and tributaries	69,879	81,177	450,000	531,000	1.75	929,000					400,000
Arkansas River direct	52,988	57,109	300,000	357,000	1.75	624,000	50,000				250,000
Cimarron River	1,098	1,115	75,000	76,000	1.75	133,000					75,000
Other tributaries	15,793	22,953	75,000	98,000	1.75	172,000					75,000
Total for State	71,290	83,583	1,250,000	1,333,000		2,333,000	50,000				1,200,000
MONTANA											
Missouri River and tributaries	1,324,486	1,871,958	1,421,600	3,293,600	(4)	5,575,200	107,300	136,900	94,000	399,700	683,700
Missouri River direct	17,069	18,234	624,500	642,800	1.7	1,092,800	6,000	42,200		16,000	560,300
Jefferson River and tributaries	363,380	403,325	7,800	411,100	1.6	657,800			7,800		
Jefferson River direct	16,393	18,940	2,700	21,700	1.6	34,700			2,700		
Beaverhead River	131,354	142,333		142,300	1.6	227,700					
Big Hole River	146,736	162,503		162,500	1.6	260,000					
Ruby River	31,071	33,526		33,500	1.6	53,600					
Other tributaries	37,826	46,023	5,100	51,100	1.6	81,800			5,100		
Madison River	30,368	37,004	8,000	45,000	1.6	72,000					8,000
Gallatin River	93,753	114,408		114,400	1.6	183,000					
Smith River	25,461	31,259	13,900	45,200	1.6	72,200			900		13,000
Sun River	28,070	67,566	50,700	118,300	1.5	177,400					50,700
Teton River	46,974	66,799		66,800	1.5	100,200					
Marias River	55,360	99,924	350,000	449,900	1.5	674,900	38,000			312,000	
Judith River	7,435	13,075	48,000	61,100	1.7	103,800		41,000	7,000		
Musselshell River	59,286	84,738	49,900	134,600	1.7	228,800			28,300	21,600	
Milk River and tributaries	88,218	190,218	36,000	226,200	1.5	339,300	20,000				16,000
Milk River direct	55,499	148,661		148,700	1.5	223,000					
Snake River	60	160		200	1.5	300					
Other tributaries	32,659	41,397	36,000	77,400	1.5	116,000	20,000				16,000
Yellowstone River and tributaries	434,550	613,707	221,500	835,200	1.9	1,587,000	35,500	53,700	50,000	50,100	32,200
Yellowstone River direct	162,312	236,401	71,900	308,300	1.9	585,800	35,500	16,200			20,200
Boulder River	11,309	12,479		12,500	1.9	23,700					
Shields River	32,866	49,462	9,800	59,300	1.9	112,700		9,800			
Stillwater River	22,162	31,087		31,100	1.9	59,100					
Clark Fork [9]	86,310	100,548	65,100	165,600	1.9	314,500		15,100	50,000		
Big Horn River	43,319	77,447	62,100	139,600	1.9	265,100				50,100	12,000
Tongue River	13,303	18,497		18,500	1.9	35,200					
Powder River	1,144	1,217	12,600	13,900	1.9	26,400		12,600			
Other tributaries	61,825	86,569		86,600	1.9	164,500					
Little Missouri River	1,462	1,962		2,000	2.0	4,000					
Other tributaries of Missouri River	73,100	129,739	11,300	141,000	2.0	282,000	7,800				3,500
Tributaries of Columbia River	270,426	404,042	168,000	572,000		1,171,000	8,700	12,000		14,000	133,300
Clark Fork and tributaries	282,836	394,610	118,000	512,600	(4)	1,052,200	8,700	12,000		14,000	83,300
Clark Fork direct	12,771	15,417	35,000	50,400	2.0	100,800					35,000
Big Blackfoot River	32,435	43,572	30,000	73,600	2.0	147,200					30,000
Bitter Root River	89,762	109,782	25,000	134,800	2.2	296,600	6,700				18,300
Flathead River	50,787	128,588	28,000	156,600	2.0	313,200	2,000	12,000		14,000	
Other tributaries	77,081	97,251		97,200	2.0	194,400					
Kootenai River	7,590	9,432	50,000	59,400	2.0	118,800					50,000
Total for State	1,594,912	2,276,000	1,589,600	3,865,600		6,746,200	116,000	148,900	94,000	413,700	817,000
NEBRASKA											
White River	8,678	13,106		13,100	1.25	16,400					
Niobrara River	3,498	4,195		4,200	1.25	5,200					

[4] Variable.
[9] Arbitrarily assumed.
[10] Additional irrigation area for each river estimated from total for entire State.

TABLE II.—*Present irrigation development and ultimate possibilities of irrigation development by States and stream basins*—Continued

State and stream basin	Present development		Additional irrigable area (potential area)	Ultimate irrigable area	Annual irrigation requirement, additional to natural precipitation		Distribution of additional irrigable area according to estimated costs of reclamation				
	Area irrigated in 1929	Area enterprises were capable of irrigating in 1930			Depth	Total for ultimate irrigable area	Less than $50 per acre	Between $50 and $100 per acre	Between $100 and $200 per acre	More than $200 per acre	Indeterminate
NEBRASKA—Continued.											
Platte River and tributaries	*Acres* 496,867	*Acres* 656,966	*Acres* 999,500	*Acres* 1,656,500	*Feet* 1.25	*Acre-feet* 2,070,600	*Acres* 44,800	*Acres* 125,300	*Acres*	*Acres* 16,200	*Acres* 813,200
Platte River direct	71,290	140,456	782,300	922,800	1.25	1,153,500		115,200			667,100
North Platte River and tributaries	373,692	450,970		451,000	1.25	563,800					
North Platte River direct	352,480	421,121		421,100	1.25	526,400					
Other tributaries	21,212	29,849		29,900	1.25	37,400					
South Platte River and tributaries	26,841	32,813	16,200	49,000	1.25	61,200				16,200	
South Platte River direct	13,975	15,745	16,200	31,900	1.25	39,800				16,200	
Lodgepole Creek	11,830	15,486		15,500	1.25	19,400					
Other tributaries	1,036	1,582		1,600	1.25	2,000					
Loup River	291	672	201,000	201,700	1.25	252,100	44,800	10,100			146,100
Other tributaries of Platte River	24,753	32,055		32,000	1.25	40,000					
Kansas River and tributaries	21,340	25,952	70,100	96,000	1.25	120,000	6,700		63,400		
Republican River	19,523	23,541	70,100	93,600	1.25	117,000	6,700		63,400		
Other tributaries	1,817	2,411		2,400	1.25	3,000					
Other tributaries of Missouri River	2,234	3,422		3,400	1.25	4,200					
Total for State	532,617	703,641	1,069,600	1,773,200	1.25	2,216,400	51,500	125,300	63,400	16,200	813,200
NEVADA											
Goose Creek	980	980		1,000	2.0	2,000					
Owyhee River	33,639	35,005	20,000	55,000	2.0	110,000	20,000				
Bruneau River	3,119	3,279		3,300	2.0	6,600					
Salmon Falls River	9,719	12,307		12,300	2.0	24,600					
Humboldt River and tributaries	138,426	287,501	8,000	295,500	2.0	591,000					8,000
Humboldt River direct	27,731	120,367		120,400	2.0	240,800					
East Fork Humboldt River	380	380		400	2.0	800					
Lamoille Creek	16,557	17,651		17,600	2.0	35,200					
North Fork Humboldt River	9,090	7,682		7,700	2.0	15,400					
South Fork Humboldt River	33,795	37,442		37,400	2.0	74,800					
Pine Creek	2,703	4,359		4,400	2.0	8,800					
Reese River	2,952	3,324		3,300	2.0	6,600					
Little Humboldt River	3,785	31,370		31,400	2.0	62,800					
Other tributaries	41,433	64,926	8,000	72,900	2.0	145,800					8,000
Truckee River and tributaries	39,028	43,424	28,000	71,400	2.1	149,900		20,000			8,000
Truckee River direct	30,417	34,625	20,000	54,600	2.1	114,700		20,000			
Steamboat Creek	3,214	3,230	8,000	11,200	2.1	23,500					8,000
Other tributaries	5,397	5,569		5,600	2.1	11,700					
Carson River and tributaries	72,872	121,784	39,000	160,500	2.1	337,000	17,400	21,600			
Carson River direct	16,062	30,220	39,000	69,000	2.1	144,900	17,400	21,600			
West Fork Carson River	2,984	2,984		3,000	2.1	6,300					
East Fork Carson River	3,205	4,133		4,100	2.1	8,600					
Other tributaries	50,621	84,447		84,400	2.1	177,200					
Walker River and tributaries	75,869	78,305	130,700	209,000	2.0	418,000		119,700			11,000
Walker River direct	72,057	74,000	119,700	193,700	2.0	387,400		119,700			
Tributaries	3,812	4,305	11,000	15,300	2.0	30,600					11,000
Colorado River and tributaries	12,308	14,849	4,600	19,400	1.7	33,000	600				4,000
Colorado River direct	249	415		400	1.7	700					
Virgin River	2,070	2,280	4,600	6,900	1.7	11,700	600				4,000
Other tributaries	9,998	12,154		12,100	1.7	20,600					
ndependent streams	100,688	138,815	36,400	175,200	2.0	350,400	400				36,000
Quinn River	8,518	10,927	8,000	18,900	2.0	37,800					8,000
Steptoe Creek	4,557	7,468		7,500	2.0	15,000					
Other tributaries	87,613	120,420	28,400	148,800	2.0	297,600	400				28,000
Ground-water area			[1] 60,000	[1] 60,000	1.5	90,000					60,000
Total for State	486,648	736,249	326,700	1,065,600		2,112,500	38,400	161,300			127,000
NEW MEXICO											
Canadian River and tributaries	68,665	108,297	65,000	173,300	1.6	277,300				65,000	
Canadian River direct	1,360	1,440	65,000	66,400	1.6	106,240				65,000	
Cimarron River	16,007	31,677		31,700	1.6	50,700					
Vermejo River	8,574	15,704		15,700	1.6	25,100					
Ocate Creek	1,102	5,800		5,800	1.6	9,300					

[1] 1 percent of 6,000,000 acres of water-bearing land in closed valley.

TABLE II.—*Present irrigation development and ultimate possibilities of irrigation development by States and stream basins*—Continued

State and stream basin	Present development		Additional irrigable area (potential area)	Ultimate irrigable area	Annual irrigation requirement, additional to natural precipitation		Distribution of additional irrigable area according to estimated costs of reclamation				
	Area irrigated in 1929	Area enterprises were capable of irrigating in 1930			Depth	Total for ultimate irrigable area	Less than $50 per acre	Between $50 and $100, per acre	Between $100 and $200 per acre	More than $200 per acre	Indeterminate
NEW MEXICO—Continued											
Canadian River and tributaries—Contd.	*Acres*	*Acres*	*Acres*	*Acres*	*Feet*	*Acre-feet*	*Acres*	*Acres*	*Acres*	*Acres*	*Acres*
Mora River	34,956	43,056		43,100	1.6	69,000					
Ute Creek	250	350		300	1.6	500					
Other tributaries	6,416	10,270		10,300	1.6	16,500					
Cimarron River	2,670	4,464		4,500	1.6	7,200					
Trinchera River	381	381		400	1.6	600					
Rio Grande River and tributaries	380,444	450,452	181,000	631,400	(4)	1,522,800		151,000	10,000		20,000
Rio Grande direct	136,114	158,486	115,000	273,500	2.6	711,100		115,000			
Rio Costilla	4,003	7,606		7,600	1.6	12,200					
Pueblo River	15,856	16,730		16,700	1.6	26,700					
Rio Chama	25,950	30,450		30,400	1.6	48,600					
Rio Santa Cruz	8,405	10,094		10,100	1.6	16,200					
Tesuque Creek	3,588	4,873		4,900	2.0	9,800					
Rio Puerco	15,202	22,245	10,000	32,200	2.6	83,700					10,000
Pecos River and tributaries	129,121	151,588	56,000	207,600	2.4	498,300		36,000	10,000		10,000
Pecos River direct	45,508	56,271	46,000	102,300	2.4	245,500		36,000	10,000		
Gallinas River	4,078	4,177	10,000	14,200	2.4	34,100					10,000
Hondo River	25,010	27,201		27,200	2.4	65,300					
Penasco River	6,833	7,993		8,000	2.4	19,200					
Other tributaries	47,692	55,946		55,900	2.4	134,200					
Other tributaries of Rio Grande	42,205	48,380		48,400	2.4	116,200					
Tributaries of Colorado River	55,310	71,495	68,200	139,700		290,900	1,100	21,500	2,000		43,600
Gila River and tributaries	9,373	10,442	22,500	32,900	1.7	55,900		16,000	2,000		4,500
Gila River direct	7,824	8,539	18,000	26,500	1.7	45,000		16,000	2,000		
San Francisco River	1,442	1,611	4,500	6,100	1.7	10,400					4,500
Other tributaries	107	292		300	1.7	500					
San Juan River and tributaries	40,253	51,703	45,700	97,500	2.2	214,500	1,100	5,500			39,100
San Juan River direct	9,772	15,075	38,900	54,000	2.2	118,800	600	5,500			32,800
Los Pinos River	160	160		200	2.2	400					
Animas River	24,425	27,325	6,300	33,600	2.2	73,900					6,300
La Plata River	4,222	5,468		5,500	2.2	12,100					
Other tributaries	1,674	3,675	500	4,200	2.2	9,200	500				
Tributaries of Little Colorado River	5,684	9,350		9,300	2.2	20,500					
Independent streams	19,563	21,580	35,000	56,000		101,100					35,000
Fresnal River	1,835	1,870		1,800	2.4	4,300					
Rio Tularosa	2,500	2,500		2,500	2.4	6,000					
Rio Mimbres	9,042	10,240	[13] 35,000	45,200	1.7	76,800					35,000
Other independent streams	6,186	6,970		7,000	(4)	14,000					
Playas Valley			[12] 2,000	2,000	1.7	3,400	2,000				
Lea County			[12] 79,000	79,000	2.4	189,600	79,000				
Torrance County			[14] 4,000	4,000	2.6	10,400	4,000				
Total for State	527,033	656,669	434,200	1,090,800		2,403,300	86,100	172,500	12,000	65,000	98,600
OKLAHOMA											
Tributaries of Arkansas River	954	5,974	40,000	46,000	(4)	56,100					40,000
Canadian River	319	556	40,000	40,600	1.25	50,700					40,000
Cimarron River	293	5,076		5,100	1.00	5,100					
Other tributaries	342	342		300	1.00	300					
Red River and tributaries	619	1,357	80,000	81,400	1.00	81,400	80,000				
Total for State	1,573	7,331	120,000	127,400	(4)	137,500	80,000				40,000
NORTH DAKOTA											
Missouri River and tributaries	7,293	21,907	188,000	209,900	1.35	283,400	86,000	10,000	31,300		60,700
Red River and tributaries	2,099	2,099		2,100	1.35	137,800					100,000
Souris River and tributaries	1,453	1,453		1,500	1.35	2,000					
Other tributaries	646	646	100,000	100,600	1.35	135,800					100,000
Total for State	9,392	24,006	288,000	312,000	1.35	421,200	86,000	10,000	31,300		160,700

[4] Variable.
[12] Irrigable from ground water, estimated as 10 percent of area in which supply is available.
[13] Irrigable from ground water, estimated as 1 percent of valley area.
[14] Estimated as 1 percent of area in which ground water may be available.

TABLE II.—*Present irrigation development and ultimate possibilities of irrigation development by States and stream basins*—Continued

State and stream basin	Present development		Additional irrigable area (potential area)	Ultimate irrigable area	Annual irrigation requirement, additional to natural precipitation		Distribution of additional irrigable area according to estimated costs of reclamation				
	Area irrigated in 1929	Area enterprises were capable of irrigating in 1930			Depth	Total for ultimate irrigable area	Less than $50 per acre	Between $50 and $100 per acre	Between $100 and $200 per acre	More than $200 per acre	Indeterminate
OREGON											
	Acres	*Acres*	*Acres*	*Acres*	*Feet*	*Acre-feet*	*Acres*	*Acres*	*Acres*	*Acres*	*Acres*
Columbia River and tributaries	504,956	658,449	2,003,500	2,662,000	(4)	5,012,400	1,220,000	476,500	222,000	.....	85,000
Columbia River direct	.....	.....	360,000	360,000	2.7	972,000	.....	310,000	50,000	.....	.....
Snake River and tributaries	288,928	370,026	197,000	567,100	(4)	1,273,300	25,000	.....	172,000	.....	.....
Snake River direct	31,814	35,881	.....	35,900	2.0	71,800	.....	.....	.....	.....	.....
Owyhee River	18,165	27,133	[15] 73,000	100,100	2.6	260,300	.....	.....	73,000	.....	.....
Malheur River	32,122	77,574	[15] 54,000	131,600	2.6	342,200	.....	.....	54,000	.....	.....
Burnt River	18,519	20,076	.....	20,100	2.0	40,200	.....	.....	.....	.....	.....
Powder River	104,089	116,492	45,000	161,500	2.0	323,000	.....	.....	45,000	.....	.....
Pine Creek	12,409	13,658	.....	13,700	2.0	27,400	.....	.....	.....	.....	.....
Imnaha River	6,838	8,190	.....	8,200	2.0	16,400	.....	.....	.....	.....	.....
Grande Ronde River	57,655	63,174	25,000	88,200	2.0	176,400	25,000	.....	.....	.....	.....
Other tributaries	7,317	7,848	.....	7,800	2.0	15,600	.....	.....	.....	.....	.....
Walla Walla River	11,123	11,526	50,000	61,500	2.0	123,000	.....	.....	.....	.....	50,000
Umatilla River	35,795	48,284	31,500	79,800	2.0	159,600	.....	16,500	.....	.....	15,000
Willow Creek	5,382	6,060	.....	6,100	2.6	15,900	.....	.....	.....	.....	.....
John Day River	40,495	44,384	15,000	59,400	2.6	154,400	.....	.....	.....	.....	15,000
Deschutes River	94,015	139,444	191,000	330,400	2.5	826,000	36,000	150,000	.....	.....	5,000
Hood River	22,370	28,352	.....	28,400	2.8	79,500	.....	.....	.....	.....	.....
Willamette River	4,250	7,022	[16] 1,159,000	1,166,000	1.2	1,399,200	1,159,000	.....	.....	.....	.....
Other tributaries of Columbia River	2,598	3,351	.....	3,400	2.8	9,500	.....	.....	.....	.....	.....
Rogue River and tributaries	58,960	74,651	33,000	107,700	1.5	161,700	.....	33,000	.....	.....	.....
Rogue River direct	11,931	14,836	33,000	47,800	1.5	71,700	.....	33,000	.....	.....	.....
Little Butte Creek	11,726	12,171	.....	12,200	1.5	18,300	.....	.....	.....	.....	.....
Bear Creek	14,862	20,293	.....	20,300	1.5	30,500	.....	.....	.....	.....	.....
Evans Creek	1,215	1,482	.....	1,500	1.5	2,300	.....	.....	.....	.....	.....
Applegate River	9,266	11,871	.....	11,900	1.5	17,900	.....	.....	.....	.....	.....
Illinois River	4,328	5,836	.....	5,800	1.5	8,700	.....	.....	.....	.....	.....
Other tributaries	5,632	8,162	.....	8,200	1.5	12,300	.....	.....	.....	.....	.....
Klamath River and tributaries	126,105	169,699	129,100	298,900	2.0	597,800	116,100	.....	.....	.....	13,000
Klamath River direct	1,841	3,672	129,100	132,800	2.0	265,600	116,100	.....	.....	.....	13,000
Lost River	60,450	75,857	.....	75,900	2.0	151,800	.....	.....	.....	.....	.....
Sprague River	7,587	13,616	.....	13,600	2.0	27,200	.....	.....	.....	.....	.....
Other tributaries	56,227	76,554	.....	76,600	2.0	153,200	.....	.....	.....	.....	.....
Other Pacific Ocean streams	1,733	3,226	.....	3,200	.8	2,600	.....	.....	.....	.....	.....
Independent streams	206,959	252,185	189,000	441,100	.....	661,800	145,000	.....	.....	.....	44,000
Deep Creek	1,906	1,937	.....	1,900	1.5	2,900	.....	.....	.....	.....	.....
Donner und Blitzen River	79,000	84,500	.....	84,500	1.5	126,800	.....	.....	.....	.....	.....
Silvies River	28,727	33,523	30,000	63,500	1.5	95,300	30,000	.....	.....	.....	.....
Other tributaries	97,326	132,225	159,000	291,200	1.5	436,800	115,000	.....	.....	.....	44,000
Total for State	898,713	1,158,210	2,354,600	3,512,900	(4)	6,433,700	1,481,100	509,500	222,000	.....	142,000
SOUTH DAKOTA											
Missouri River and tributaries	67,107	109,550	112,800	222,400	1.50	333,700	15,000	.....	60,000	37,800	.....
Missouri River direct	5	8	.....	.....	1.5	.....	.....	.....	.....	.....	.....
Cheyenne River and tributaries	66,031	108,324	110,800	219,100	1.5	328,600	15,000	.....	60,000	35,800	.....
Cheyenne River direct	.....	.....	84,300	84,300	1.5	126,400	.....	.....	60,000	24,300	.....
North Fork (Belle Fourche River)	51,342	90,359	15,000	105,400	1.5	158,100	15,000	.....	.....	.....	.....
South Fork	14,678	17,864	.....	17,900	1.5	26,800	.....	.....	.....	.....	.....
Other tributaries	11	101	11,500	11,600	1.5	17,400	.....	.....	.....	11,500	.....
Little Missouri River	.....	.....	2,000	2,000	1.5	3,000	.....	.....	.....	2,000	.....
Moreau River	60	60	.....	100	1.5	200	.....	.....	.....	.....	.....
White River	4	4	.....	.....	1.5	.....	.....	.....	.....	.....	.....
Other tributaries of Missouri River	1,007	1,154	.....	1,200	1.5	1,800	.....	.....	.....	.....	.....
Total for State	67,107	109,550	112,800	222,400	1.5	333,700	15,000	.....	60,000	37,800	.....
TEXAS											
Rio Grande River and tributaries	537,327	682,547	171,000	853,500	.....	1,543,100	38,000	133,000	.....	.....	.....
Rio Grande direct	459,557	574,817	162,000	736,800	1.75	1,289,400	32,000	130,000	.....	.....	.....
Pecos River	46,677	72,054	9,000	81,000	2.25	182,300	6,000	3,000	.....	.....	.....
Other tributaries	31,093	35,676	.....	35,700	2.0	71,400	.....	.....	.....	.....	.....
Other tributaries of Gulf of Mexico	222,520	440,048	798,900	1,238,900	.....	1,770,800	100,000	612,000	.....	.....	86,900
Nueces River	38,787	45,708	472,000	517,700	1.6	828,300	100,000	372,000	.....	.....	.....
San Antonio River	9,686	35,146	60,000	95,100	1.3	123,600	.....	60,000	.....	.....	.....
Colorado River	61,888	140,626	70,000	210,600	1.5	315,900	.....	60,000	.....	.....	10,000
Brazos River	21,560	30,061	120,000	150,100	1.1	165,100	.....	120,000	.....	.....	.....

[4] Variable.
[15] System under construction.
[16] Additional irrigable area, taken from Oregon State Agricultural College, Bul. 302; Army report (*209*) gives only 513,000 acres.

TABLE II.—*Present irrigation development and ultimate possibilities of irrigation development by States and stream basins*—Continued

State and stream basin	Present development		Additional irrigable area (potential area)	Ultimate irrigable area	Annual irrigation requirement, additional to natural precipitation		Distribution of additional irrigable area according to estimated costs of reclamation				
	Area irrigated in 1929	Area enterprises were capable of irrigating in 1930			Depth	Total for ultimate irrigable area	Less than $50 per acre	Between $50 and $100 per acre	Between $100 and $200 per acre	More than $200 per acre	Indeterminate
TEXAS—Continued											
Other tributaries of Gulf of Mexico—Contd.	*Acres*	*Acres*	*Acres*	*Acres*	*Feet*	*Acre-feet*	*Acres*	*Acres*	*Acres*	*Acres*	*Acres*
Trinity River	15,724	35,131	46,900	82,000	1.1	90,200					46,900
Neches River	28,225	60,263		60,300	1.1	66,300					
Sabine River	162	8,166		8,200	1.1	9,000					
Other tributaries	46,488	84,947	30,000	114,900	1.5	172,400					30,000
Canadian River	466	766	5,100	5,900	1.5	8,900	1,000				4,100
Red River	38,604	54,054	155,000	209,100	1.4	292,700		75,000			80,000
Total for State	798,917	1,177,415	1,130,000	2,307,400		3,615,500	139,000	820,000			171,000
UTAH											
Tributaries of Great Salt Lake	593,029	642,662	252,200	894,800	(1)	1,877,500	56,000	26,000	83,100	44,100	43,000
Bear River and tributaries	210,726	222,787	113,300	336,100	2.0	672,200	56,000	14,000	40,300		3,000
Bear River direct	99,735	100,149		100,200	2.0	200,400					
Little Bear River	41,889	44,940	45,000	89,900	2.0	179,800	45,000				
Malad River	662	668	11,000	11,700	2.0	23,400	11,000				
Other tributaries	68,440	77,030	57,300	134,300	2.0	268,600		14,000	40,300		3,000
Weber River and tributaries	109,827	113,996	5,000	119,000	2.0	238,000				5,000	
Weber River direct	66,179	66,388		66,400	2.0	132,800					
Ogden River	20,581	23,931	5,000	28,900	2.0	57,800				5,000	
East Canyon Creek	5,652	6,028		6,000	2.0	12,000					
Other tributaries	17,415	17,649		17,700	2.0	35,400					
Jordan River and Utah Lake and Tributaries	272,476	305,879	133,900	439,700	2.2	967,300		12,000	42,800	39,100	40,000
Jordan River direct	54,562	68,103	16,000	84,000	2.2	184,800			16,000		
Big Cottonwood Creek	7,101	7,751		7,800	2.2	17,200					
Little Cottonwood Creek	17,045	17,625		17,600	2.2	38,700					
American Fork River	17,787	17,500		17,500	2.2	38,500					
Provo River	57,408	65,822	18,200	84,000	2.2	184,800			9,100	9,100	
Hobble Creek	6,766	7,040	7,800	14,900	2.2	32,800			7,800		
Spanish Fork River	71,782	72,701		72,700	2.2	159,900		12,000			
Other tributaries	40,025	49,337	91,900	141,200	2.2	310,600			9,900	30,000	40,000
Sevier River and tributaries	258,929	303,757	3,000	306,800	2.1	644,300					3,000
Sevier River direct	135,783	167,574	3,000	170,600	2.1	358,300					3,000
San Pitch River	65,276	74,003		74,000	2.1	155,400					
Otter Creek	7,237	7,782		7,800	2.1	16,400					
Other tributaries	50,633	54,398		54,400	2.1	114,200					
Colorado River and tributaries	347,452	439,165	367,200	806,400	(1)	1,496,100			103,000	44,400	219,800
Colorado River direct	1,286	1,286		1,300	2.0	2,600					
Fremont River	28,655	29,284		29,300	2.0	58,600					
Virgin River	19,873	29,089	23,000	52,100	2.25	117,200			20,000		3,000
San Juan River	9,868	14,480	44,000	58,500	2.1	122,800					44,000
Green River and tributaries	278,072	351,500	300,200	651,700	(1)	1,167,900			83,000	44,400	172,800
Green River direct	1,908	2,958	35,000	37,900	1.8	68,200			35,000		
Ashley Fork River	22,314	29,519		29,500	1.75	51,600					
Duchesne River	167,022	222,094	93,000	315,100	1.75	551,400			48,000		45,000
Price River	18,059	22,953	59,000	82,000	1.75	143,500					59,000
San Rafael River	53,538	55,963	36,800	92,800	1.75	162,400					36,800
Other tributaries	14,231	18,013	76,400	94,400	2.0	188,800				44,400	32,000
Other tributaries of Colorado River	9,698	13,526		13,500	2.0	27,000					
Tributaries of Snake River	4,724	5,504		5,500	1.9	10,500					
Raft River	4,471	5,251		5,200	1.9	9,900					
Goose Creek	253	253		300	1.9	600					
Independent streams	119,991	151,387		151,400	2.0	302,800					
Beaver River	25,291	31,132		31,100	2.0	62,200					
Coal Creek	14,488	21,108		21,100	2.0	42,200					
Deep Creek	2,147	2,172		2,200	2.0	4,400					
Grouse Creek	2,408	2,578		2,600	2.0	5,200					
Other tributaries	75,657	94,397		94,400	2.0	188,800					
Total for State	1,324,125	1,542,475	622,400	2,164,900	(1)	4,331,200	56,000	26,000	186,100	88,500	265,800
WASHINGTON											
Columbia River and tributaries	481,019	601,824	1,890,800	2,492,500	(1)	6,819,190	46,000	35,400	1,345,100	26,000	438,300
Columbia River direct	10,035	13,678	[17] 1,451,200	1,464,900	2.8	4,101,720	10,400	1,400	1,341,400		98,000
Clark Fork	896	2,705		2,700	2.2	5,940					
Colville River	2,176	2,447	11,000	13,400	2.2	29,480			3,700		7,300
Spokane River	18,422	30,482	35,000	65,500	2.2	144,100					35,000
Okanogan River and tributaries	21,462	27,790	36,600	64,400	2.4	154,560					5,000
Okanogan River direct	3,895	4,552	5,600	10,200	2.4	24,480	5,600				
Tributaries	17,567	23,238	31,000	54,200	2.4	130,080				26,000	5,000
Methow River	11,720	17,346	35,000	52,300	2.4	125,520					35,000
Entiat River	1,912	2,135	1,000	3,100	2.4	7,440					1,000

(1) Variable.
[17] Including 1,199,400 acres in latest Columbia Basin project.

TABLE II.—*Present irrigation development and ultimate possibilities of irrigation development by States and stream basins*—Continued

State and stream basin	Present development		Additional irrigable area (potential area)	Ultimate irrigable area	Annual irrigation requirement, additional to natural precipitation		Distribution of additional irrigable area according to estimated costs of reclamation				
	Area irrigated in 1929	Area enterprises were capable of irrigating in 1930			Depth	Total for ultimate irrigable area	Less than $50 per acre	Between $50 and $100 per acre	Between $100 and $200 per acre	More than $200 per acre	Indeterminate
WASHINGTON—Continued											
Columbia River and tributaries—Continued.	*Acres*	*Acres*	*Acres*	*Acres*	*Feet*	*Acre-feet*	*Acres*	*Acres*	*Acres*	*Acres*	*Acres*
Wenatchee River	24,606	25,717	20,000	45,700	2.8	127,960					20,000
Crab Creek	1,761	1,885		1,900	2.8	5,320					
Yakima River and tributaries	325,299	399,726	173,000	572,700	2.8	1,603,560					119,000
Yakima River direct	257,220	317,165	173,000	490,200	2.8	1,372,560	20,000	34,000			119,000
Naches River	29,956	30,386		30,400	2.8	85,120					
Ahtanum Creek	8,172	8,936		8,900	2.8	24,920					
Other tributaries	29,951	43,239		43,200	2.8	120,960					
Snake River and tributaries	8,715	9,894	10,000	19,900	2.1	41,790					10,000
Snake River direct	1,640	1,659	10,000	11,700	2.1	24,570					10,000
Asotin Creek	3,513	4,341		4,300	2.1	9,030					
Palouse River	980	1,150		1,200	2.1	2,520					
Other tributaries	2,582	2,744		2,700	2.1	5,670					
Walla Walla River	18,508	20,000	50,000	70,000	2.1	147,000					50,000
Klickitat River	6,797	7,004	16,000	23,000	2.8	64,400					16,000
White Salmon River	4,034	4,697	4,000	8,700	2.8	24,360					4,000
Other tributaries of Columbia River	24,676	36,318	48,000	84,300	2.8	236,040	10,000				38,000
Independent streams	18,264	29,687	133,200	162,900	(1)	365,890					133,200
Dungeness River	8,960	17,607	20,000	37,600	1.4	52,640					20,000
Other tributaries	9,304	12,080	113,200	125,300	2.5	313,250					113,200
Total for State	499,283	631,511	2,024,000	2,655,400		7,185,080	46,000	35,400	1,345,100	26,000	571,500
WYOMING											
Missouri River drainage	900,523	1,217,344	1,305,400	2,522,600	(1)	4,119,700	143,400	307,300	292,000	42,800	519,900
Clark Fork (of Yellowstone) and tributaries	6,658	11,035	8,000	19,000	1.65	31,400			8,000		
Clark Fork direct	4,340	8,340	8,000	16,300	1.65	26,900			8,000		
Tributaries	2,318	2,695		2,700	1.65	4,500					
Big Horn River and tributaries	318,607	475,301	533,800	1,009,100	1.65	1,665,000	121,800	164,700	159,500	42,800	45,000
Big Horn River direct	45,379	52,318	35,000	87,300	1.65	144,000	8,700	11,300	15,000		
Popo Agie River	21,131	26,189	40,000	66,200	1.65	109,200	40,000				
Wind River	51,789	116,788	133,000	249,800	1.65	412,200		125,000			8,000
Owl Creek	16,148	18,924	2,000	20,900	1.65	34,500					2,000
Nowood Creek	15,254	19,778	39,000	58,800	1.65	97,000	15,600	23,400			
Greybull River	52,138	65,331		65,300	1.65	107,700					
Shell Creek	7,110	13,795	10,000	23,800	1.65	39,300	10,000				
Shoshone River	95,636	142,902	153,000	295,900	1.65	488,200			112,000	41,000	
Little Horn River	1,637	2,705		2,700	1.65	4,500					
Other tributaries	12,385	16,571	121,800	138,400	1.65	228,400	47,500	5,000	32,500	1,800	35,000
Tongue River and tributaries	52,195	55,453	38,700	94,100	1.7	160,000		12,700			26,000
Tongue River direct	8,914	10,534	12,700	23,200	1.7	39,400		12,700			
Goose Creek	35,455	36,884	26,000	62,900	1.7	107,000					26,000
Other tributaries	7,826	8,035		8,000	1.7	13,600					
Powder River and tributaries	49,135	55,194	118,000	173,200	1.7	294,400	2,500		24,500		91,000
Powder River direct	4,703	4,703	57,500	62,200	1.7	105,700			4,500		53,000
Red Fork Creek	450	450		400	1.7	700					
Crazy Woman Creek	2,600	4,146		4,200	1.7	7,100					
Clear Creek	35,295	35,960	20,000	56,000	1.7	95,200			20,000		
Other tributaries	6,087	9,935	40,500	50,400	1.7	85,700	2,500				38,000
Little Missouri River			18,000	18,000	1.7	30,600					18,000
Belle Fourche River	457	632	36,000	36,600	1.7	62,200		25,000			11,000
South Fork (Cheyenne River)	3,046	3,843		3,800	1.6	6,100					
Niobrara River	333	368		400	1.6	600					
North Platte and tributaries	452,752	596,125	551,900	1,148,000	1.6	1,836,800	19,100	104,000	100,000		327,900
North Platte River direct	81,313	100,287	370,800	471,100	1.6	753,900		55,900	100,000		214,900
Beaver Creek	3,132	4,176	18,000	22,200	1.6	35,500		18,000			
Grand Encampment Creek	6,906	11,522	8,000	19,500	1.6	31,200	8,000				
Spring Creek	10,825	13,197		13,200	1.6	21,100					
Pass Creek	14,681	17,860	35,000	52,800	1.6	84,500					35,000
Medicine Bow River	36,879	42,271	16,000	58,300	1.6	93,300		16,000			
Sweetwater River	6,506	8,519	45,000	53,500	1.6	85,600					45,000
Muddy Creek	400	400		400	1.6	600					
Box Elder Creek	3,742	8,486		8,500	1.6	13,600					
La Prele Creek	16,549	16,908		16,900	1.6	27,000					
Labonte Creek	4,343	4,826		4,800	1.6	7,700					
Laramie River and tributaries	179,019	257,351	18,000	275,400	1.6	440,600		15,000			3,000
Laramie River direct	98,510	168,297	8,000	176,300	1.6	282,100		8,000			
Little Laramie River	43,942	50,972		51,000	1.6	81,600					
Sybille Creek	5,237	5,387	7,000	12,400	1.6	19,800		7,000			
North Laramie River	5,979	6,360	2,000	8,400	1.6	13,400					2,000
Chugwater Creek	6,139	7,108	1,000	8,100	1.6	13,000					1,000
Other tributaries	19,212	19,227		19,200	1.6	30,700					
Rawhide Creek	225	225		200	1.6	300					
Horse Creek	29,594	30,920	30,000	60,900	1.6	97,400					30,000
Other tributaries of North Platte	58,598	79,177	11,100	90,300	1.6	144,500	11,100				
Tributaries of South Platte	17,340	19,393	1,000	20,400	1.6	32,600					1,000
Lodgepole Creek	1,595	1,725	1,000	2,700	1.6	4,300					1,000
Crow Creek	4,951	6,677		6,700	1.6	10,700					
Lone Tree Creek	9,485	9,485		9,500	1.6	15,200					
Cache la Poudre River	1,309	1,506		1,500	1.6	2,400					

(1) Variable.

TABLE II.—*Present irrigation development and ultimate possibilities of irrigation development by States and stream basins*—Continued

State and stream basin	Present development		Additional irrigable area (potential area)	Ultimate irrigable area	Annual irrigation requirement, additional to natural precipitation		Distribution of additional irrigable area according to estimated costs of reclamation				
	Area irrigated in 1929	Area enterprises were capable of irrigating in 1930			Depth	Total for ultimate irrigable area	Less than $50 per acre	Between $50 and $100 per acre	Between $100 and $200 per acre	More than $200 per acre	Indeterminate
WYOMING—Continued	*Acres*	*Acres*	*Acres*	*Acres*	*Feet*	*Acre-feet*	*Acres*	*Acres*	*Acres*	*Acres*	*Acres*
Colorado River drainage	228,699	304,057	1,004,800	1,308,900	1.6	2,094,200	296,700	566,000	95,000	----------	47,100
Green River and tributaries	228,699	304,057	1,004,800	1,308,900	1.6	2,094,200	296,700	566,000	95,000	----------	47,100
Green River direct	25,791	28,985	620,200	649,200	1.6	1,038,600	128,200	492,000	----------	----------	----------
New Fork	48,003	63,967	----------	64,000	1.6	102,400	----------	----------	----------	----------	----------
Horse Creek	5,982	6,935	----------	6,900	1.6	11,000	----------	----------	----------	----------	----------
Cottonwood Creek	9,189	10,594	18,000	28,600	1.6	45,800	18,000	----------	----------	----------	----------
South Piney Creek	1,472	1,800	15,300	17,100	1.6	27,400	15,300	----------	----------	----------	----------
La Barge Creek	4,083	4,898	4,000	8,900	1.6	14,200	4,000	----------	----------	----------	----------
Fontenelle Creek	1,607	1,680	4,000	5,700	1.6	9,100	4,000	----------	----------	----------	----------
Bitter Creek	878	1,026	----------	1,000	1.6	1,600	----------	----------	----------	----------	----------
Blacks Fork	61,397	76,875	266,100	343,100	1.6	549,000	94,000	36,000	95,000	----------	41,100
Henrys Fork	15,884	18,677	38,000	56,700	1.6	90,700	----------	38,000	----------	----------	----------
Little Snake River	11,719	12,049	----------	12,100	1.6	19,400	----------	----------	----------	----------	----------
Other tributaries	42,694	76,571	39,200	115,600	1.6	185,000	33,200	----------	----------	----------	6,000
Great Salt Lake drainage	47,379	56,221	7,500	63,700	2.0	127,400	----------	----------	----------	----------	7,500
Bear River and tributaries	47,379	56,221	7,500	63,700	2.0	127,400	----------	----------	----------	----------	7,500
Bear River direct	28,455	34,116	7,500	41,600	2.0	83,200	----------	----------	----------	----------	7,500
Tributaries	18,924	22,105	----------	22,100	2.0	44,200	----------	----------	----------	----------	----------
Columbia River drainage	59,554	77,386	88,000	165,400	1.7	281,200	68,000	15,000	5,000	----------	----------
Snake River tributaries	59,554	77,386	88,000	165,400	1.7	281,200	68,000	15,000	5,000	----------	----------
South Fork direct	1,250	1,877	35,000	36,900	1.7	62,700	35,000	----------	----------	----------	----------
Gros Ventre River	3,884	4,431	----------	4,400	1.7	7,500	----------	----------	----------	----------	----------
Little Gros Ventre River	2,274	2,294	----------	2,300	1.7	3,900	----------	----------	----------	----------	----------
Salt River	36,863	46,233	----------	46,200	1.7	78,500	----------	----------	----------	----------	----------
Other tributaries	15,283	22,551	53,000	75,600	1.7	128,600	33,000	15,000	5,000	[1]	----------
Total for State	1,236,155	1,655,008	2,405,700	4,060,600	(1)	6,622,500	508,100	888,300	392,000	42,800	574,500

[1] Variable.

SECTION II

RELATION OF DRAINAGE TO LAND-USE POLICIES*

Drainage of agricultural land is a factor of primary importance in the development of a land-use program. Lands that need drainage are usually flat and poorly provided with natural drains. Due to their lack of relief such lands are seldom subject to erosion, but if they are to be made suitable for agriculture they must be provided with drains. To keep such lands in their most productive state there must be adequate maintenance of drains after they are constructed. Fully one-sixth of the most fertile and productive farm lands have been made available for agricultural uses by artificial drainage. Of the 84,400,000 acres of land in enterprises organized to effect drainage, 63,500,000 acres are improved. There remain in the United States about 100,000,000 acres which could be improved or reclaimed by drainage. The proper utilization of this land is of importance to agriculture and the Nation as a whole.

The early settlers in this country constructed drains as a means of bringing fertile bottom lands into cultivation. Much of the prairie land of Ohio, Indiana, Illinois, Minnesota, and Iowa was wet and, in its original state, not suited for the production of crops. Some idea of the condition that existed is given in the following quotation from Long's Expedition to the Source of St. Peter's River (Minnesota) in 1823 written and published in 1825 by W. H. Keating:

> Near to this house we passed the State line which divides Ohio from Indiana * * *. The distance from this to Fort Wayne is 24 miles, without a settlement; the country is so wet that we scarcely saw an acre of land upon which a settlement could be made. We traveled for a couple of miles with our horses wading through water, sometimes to the girth * * *. We attempted to stop and pasture our horses, but this was impossible on account of the immense swarms of mosquitoes and horse flies, which tormented both horses and riders in a manner that excluded all possibility of rest.

Traveling over the same territory today and noting the well tended productive fields, the substantial and attractive farm buildings, the good roads and splendid school buildings, few recall that all of these developments have been made possible by drainage or that, if such work had not been done, the territory would still be in much the same state as when passed over by Major Long's party.

In general, the drainage enterprises inaugurated prior to 1915 were successful in that they afforded improved drainage to the lands they served, the districts met their financial obligations, and they made farming more profitable. On these projects the cost was from $5 to $10 per acre, exclusive of farm drains. Much of the land in these projects was available for cultivation when drainage was supplied. From about 1915 to 1922, and particularly during the World War period, drainage entered a new phase. More extensive and more costly gravity drainage projects were undertaken. Districts with large areas of cut-over lands that had to be cleared before the land could be cultivated were organized; many expensive enterprises from which the run-off had to be pumped were constructed; some poorly conceived enterprises were built. This overexpansion in land reclamation was due primarily to high land values and high prices obtained for products of the soil.

During the decade following the World War prices for farm products reached low levels. In 1930–33 the organization of new drainage districts stopped. Maintenance of existing drains and structures was neglected. Numerous drainage enterprises defaulted on bond and interest payments and caused losses to bond holders, mortgagors, and landowners. The number and acreage of drainage enterprises in default is relatively small compared with totals of all drainage enterprises. However, a very substantial proportion of drainage bonds now outstanding are in default. A few pumping districts were unable to operate their projects and some farmers were forced to abandon cultivation of all or part of their lands. Other districts were not able to properly maintain their drains and this caused losses of crops. Recognizing the need for Federal assistance on such projects, Congress in 1933 authorized the Reconstruction Finance Corporation to refinance drainage districts in distress and later authorized loans for maintenance purposes where necessary.

Extent of Drainage

There are 84,408,093 acres in organized drainage enterprises reported by the 1930 census and several million additional acres drained by individuals outside the organized enterprises. The percent of farms reporting drainage in the 1930 census is shown in figure 20 of the report of the Land Planning Committee to the National Resources Board, December 1, 1934, to which this report is a supplement.

* By E. W. Lehmann, Bureau of Agricultural Engineering, U. S. Department of Agriculture.

The locations of drainage enterprises in the United States are shown on the accompanying map and are compiled from data of the United States Bureau of the Census. The character and use of the land in drainage enterprises are shown in figure 1. As may be seen by this figure the largest areas in enterprises and the highest proportions of improved lands occur in the North Central States. In Ohio, Indiana, and Illinois about 93 percent of the combined acreage in enterprises is improved. In the South Atlantic States only 17½ percent is improved. This low percentage is partly due to conditions in the Florida Everglades. If the lands within the Everglades drainage district are excluded, the result in this section would show 27 percent of the land improved. As may be noted in figure 1, the largest areas of unimproved lands in drainage enterprises occur in Michigan, Minnesota, Indiana, Missouri, Florida, Mississippi, Arkansas, Louisiana, and Texas.

States having more than 100,000 acres in drainage enterprises available for settlement are as follows: Wisconsin, Minnesota, Missouri, North Carolina, Florida, Mississippi, Arkansas, Louisiana, and Texas.

The following tabulation gives the cost of different types of drainage enterprises for the United States as reported by the fifteenth census:

Kind of enterprises	Capital invested to Jan. 1, 1930	Acres of enterprises	Average cost per acre
Ditches only	[1] $277,517,731	51,860,163	$5.35
Tile only or tile and ditches	[1] 197,846,175	20,273,819	9.75
Levees with tile or ditches	[1] 104,891,569	8,631,616	12.15
Part gravity and part pumping	27,070,273	2,034,062	13.31
All drainage by pumping	79,894,531	1,608,433	49.67
Total		84,408,093	
Land protected by levees of an outside agency		7,318,167	

[1] Invested and required for completion.

Enterprises securing drainage by pumping constitute a special problem because of their high construction and maintenance costs.

Importance of Adequate Drainage to the Farmer: Adequate drainage of flat lands is of great importance

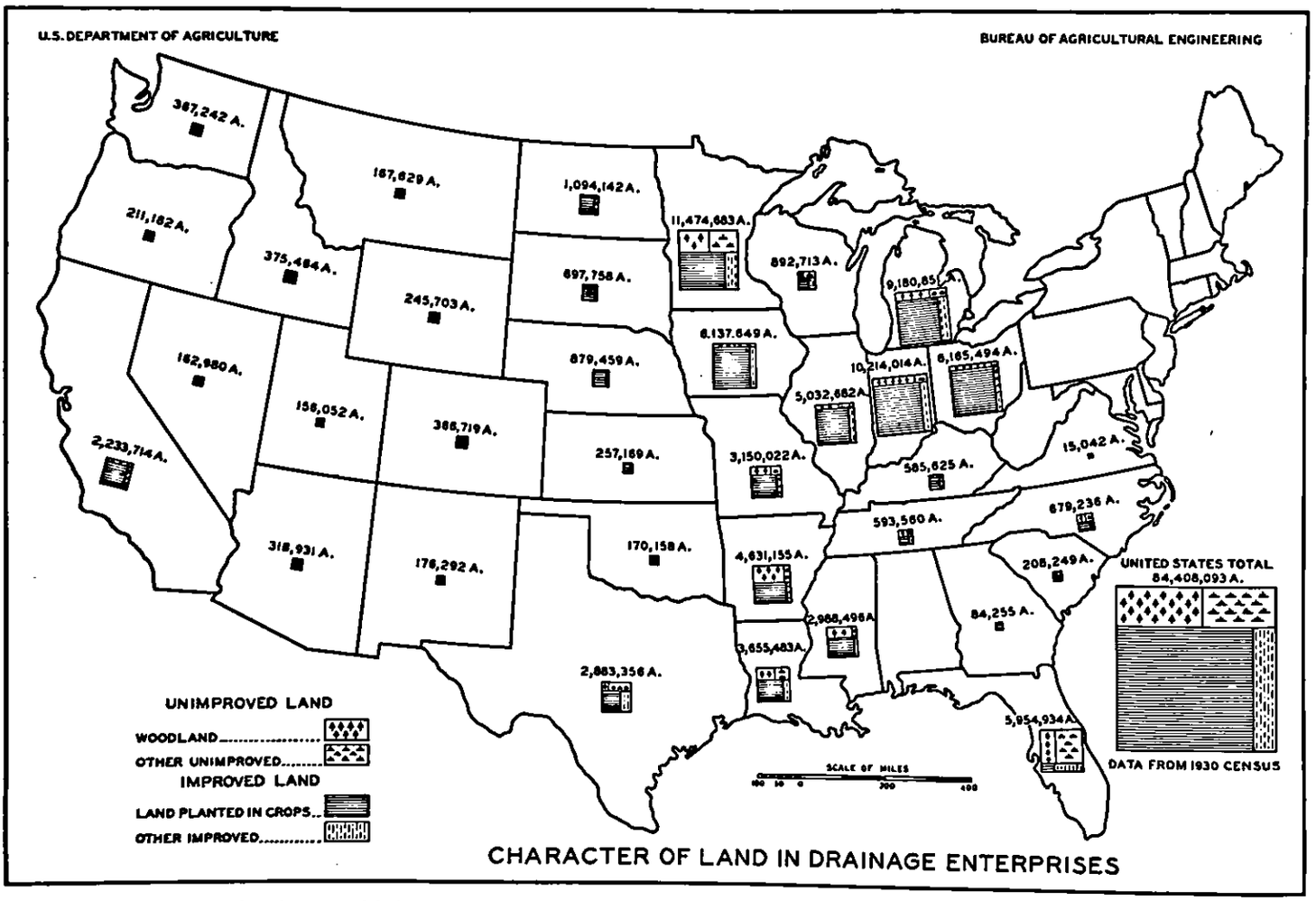

FIG. 1.—The character, use, and total acreages of the land in drainage enterprises are shown on a State basis. The largest areas in drainage enterprises and the highest proportion of improved lands occur in the North Central States.

DRAINAGE MAP
OF THE
UNITED STATES

NATIONAL RESOURCES BOARD
WATER RESOURCES SECTION

Revised from Drainage Map 1930 Census of the Department of Commerce, Bureau of Census.

Land in drainage enterprises shown in red

ENGRAVED BY U.S.G.S.

Scale 1:11,875,000.

100 0 100 200 300 400 500 600 Miles

to the farmer who cultivates such lands. Thorough drainage by removing surplus water and lowering and stabilizing the water table provides a greater depth of root zone, a warmer soil in the spring, and a better physical condition for making a seed bed and for tillage. On a field uniformly well drained, farm work can be done more timely and efficiently. Damages due to winter freezing are minimized by satisfactory drainage. The quality of nearly all agricultural crops is improved by drainage which is of particular value to cash crops since market prices vary greatly with quality. These benefits of drainage are gradually lost and lands dependent on drainage revert to marshes or even swamps when drainage improvements are not maintained.

Maintaining Drainage Improvements

One of the most important problems of existing drainage enterprises is to secure adequate and economical maintenance of existing drainage works. Many enterprises have no systematic and effective method of maintaining community drains. To accomplish maintenance in some localities new assessments or organization of a new enterprise is necessary, and overhead expenses in connection with such maintenance work appear unnecessarily large. The continued successful use of drained lands requires maintenance of both drainage district and farm drainage improvements. If drains are not maintained, the lands affected gradually become less productive and farming becomes hazardous.

The maintenance of open ditches which afford outlets for farm drainage is particularly important at the present time. The severe economic depression and a series of dry years have resulted in wide-spread neglect of these improvements which in many instances are in a poor state of repair. The seriousness of this situation will not be realized fully until one or more wet seasons result in large crop losses. Extensive maintenance work is needed during the next few years to put open ditches in good operating condition. Considerable work of this character has been done by C. W. A. and F. E. R. A. workers.

Maintaining farm drainage improvements is a necessity to the welfare of farmers on lands artificially drained. Educational and extension activities should be carried on in States where it is necessary to demonstrate the importance of adequate drainage and proper maintenance. Considerable research should be done in developing more economical methods of maintaining drainage improvements. Drainage laws of some States should be amended to facilitate adequate maintenance. Consideration might well be given to lending public funds for self-liquidating projects which are agriculturally and economically sound.

Completion of Drainage Enterprises: Many projects have large areas which are not productive because of incomplete outlet ditches or insufficient farm drainage, or because they are not cleared. An adequate land-use program should provide for the completion of those drainage enterprises which are partially complete and are economically feasible and desirable, as in their present incomplete condition a heavy burden is thrown upon the cultivated land in the district. It would seem wise to complete such enterprises and make it possible for the lands not now in use to be brought into cultivation. Such drainage enterprises apparently should be given preference when new land is needed in order that such land can bear its fair share of the cost of maintaining drainage improvements, schools, roads, and other local utilities.

The Reconstruction Finance Corporation is not authorized to make loans for the completion of new projects or for the extension of old ones, the main purpose of which would be to bring additional land into production. It will no doubt require considerable time to complete the development of such projects with private capital. This is an instance where private interests encourage the bringing of new lands into cultivation while agricultural interests at the present time generally encourage the reduction of acreage in cultivated crops. A careful study should be made of the individual areas and the opposing viewpoints harmonized.

One possibility of utilizing unimproved lands in drainage enterprises would be to relocate settlers from nearby submarginal areas. In many instances people could be kept in the same State or county by utilizing land in drainage enterprises. Such relocations could be worked out so that the farmers involved would cultivate fertile instead of submarginal lands. In the past, many farmers occupying hill land have found it profitable to move to more fertile drained lands. Available lands in drainage enterprises would in many instances offer desirable farms on which to colonize families now on relief rolls in urban areas.

Rehabilitating Drainage Districts

The problem of Federal aid for the rehabilitation of drainage enterprises that have encountered financial difficulties has been largely solved for the present. In 1933 Congress authorized the Reconstruction Finance Corporation to refinance the outstanding indebtedness of drainage enterprises in distress where a substantial reduction in principal would be made. Later, authority was granted to make loans for maintenance and rehabilitation of drainage improvements. Under the provisions of this act, 445 districts having a total outstanding indebtedness of $124,450,000 had applied for

loans amounting to $64,561,000 by October 1934.* The Drainage, Levee, and Irrigation Division of the Reconstruction Finance Corporation reported that 203 loans had been granted, totaling $25,419,000. These loans were approved to refinance $69,815,000 outstanding indebtedness. In the districts to which loans had been granted there were 6,455,200 acres of which 3,199,500 acres were in cultivation. The areas of enterprises for which loans have been approved are about 7 percent of the total area in drainage enterprises, but the amount of outstanding indebtedness which has been under consideration for refunding is a very large percent of the total outstanding indebtedness of all drainage enterprises. The loans granted averaged $3.94 per acre, and under the scheme of refinancing these drainage enterprises will have an annual cost of $1.64 per acre including local taxes, maintenance and operation charges, bond interest, and other costs. With greatly reduced annual charges and improved agricultural prices, districts which have completed such refinancing are in an excellent position to improve and develop their lands.

Abandonment of Uneconomical Drainage Enterprises.—There are occasional drainage enterprises which, under existing conditions, have proven economically unsound, have caused losses to landowners, and most likely will result in further financial losses to owners if they continue operating them. Abandonment of such enterprises will probably continue until such time as agricultural lands are more in demand. In the past, public agencies have prevented the abandonment of some districts by rendering financial assistance to keep them operating or by repairing drainage works. The policy of rendering such aid to districts which are not economically sound should be critically reviewed. Sometimes such lands can be purchased for bird and game refuges or for forest reserves. The problem of relocating or otherwise caring for farmers and settlers on enterprises which are abandoned should be given careful study.

The question of whether or not a district should be abandoned depends largely on the fertility of the land in the district, the value of the crops they produce, and the cost of providing drainage and producing the crops. Pumping enterprises are very difficult to maintain continuously under unfavorable economic conditions. The expense of operating pumping plants is so large that very few owners are willing to pay large drainage taxes on lands which are not producing revenue and offer poor prospects for future profits.

Draining Additional Land

Since there is overproduction of agricultural products, there is no need at this time for extensive development of additional areas simply to produce additional crops. However, owners of such nonproductive lands who are paying taxes and deriving no income will, as soon as agricultural conditions change and appear more favorable, be inclined to drain many of these areas if they feel they can profit by such operations. At the present time many believe that farmers on submarginal land should be placed on fertile lands and that many families on relief rolls should be colonized on small farms. These possibilities have previously been mentioned as a means of utilizing areas in uncompleted districts. This movement might even develop to such an extent that drainage of new lands will become desirable.

In considering the development of drainage enterprises it should be borne in mind that abandonment of drained lands results in no permanent national loss such as occurs when land is destroyed by erosion. When lands revert to marsh or swamp, the investors and landowners in such enterprises must shoulder the losses and the lands are in the same state as existed before reclamation. In view of these facts the formation of new drainage enterprises should not be prohibited. However, investors and the minority of landowners should be protected against abuses sometimes common to the formation of unsound enterprises. It appears that landowners and investors should assume the responsibility and expenses of developing new enterprises as long as new agricultural land is not required for public uses or as a public policy. When a district is once established, local interests become concerned with its success. Improved roads often run through drainage districts which would be flooded or made impassable in case drainage improvements were not maintained. The abandonment of the drainage enterprises also might affect school districts. In some cases State and local agencies have assisted drainage districts to continue operating because of their influence on roads and schools.

An appreciation by investors of the true costs of reclaiming lands by drainage would retard the unwise promotion of many costly projects. While large areas of land have been drained at a nominal cost, the reclamation of wet lands usually requires not only drainage district improvement, but farm drainage, clearing, farm improvements and a considerable expenditure during the development period. Another reason for developing undrained areas might be that our production of food crops would be more assured and our program of soil conservation would be more permanent if more production were carried on in flat, well-drained areas and not so much on areas that are subject to erosion.

The locations of wet lands that are drainable are shown in figure 2. The data from which this figure was prepared were compiled in 1922. Since then considerable areas have been organized for the purpose of securing

* See contribution by F. R. Kenny on land reclamation policies.

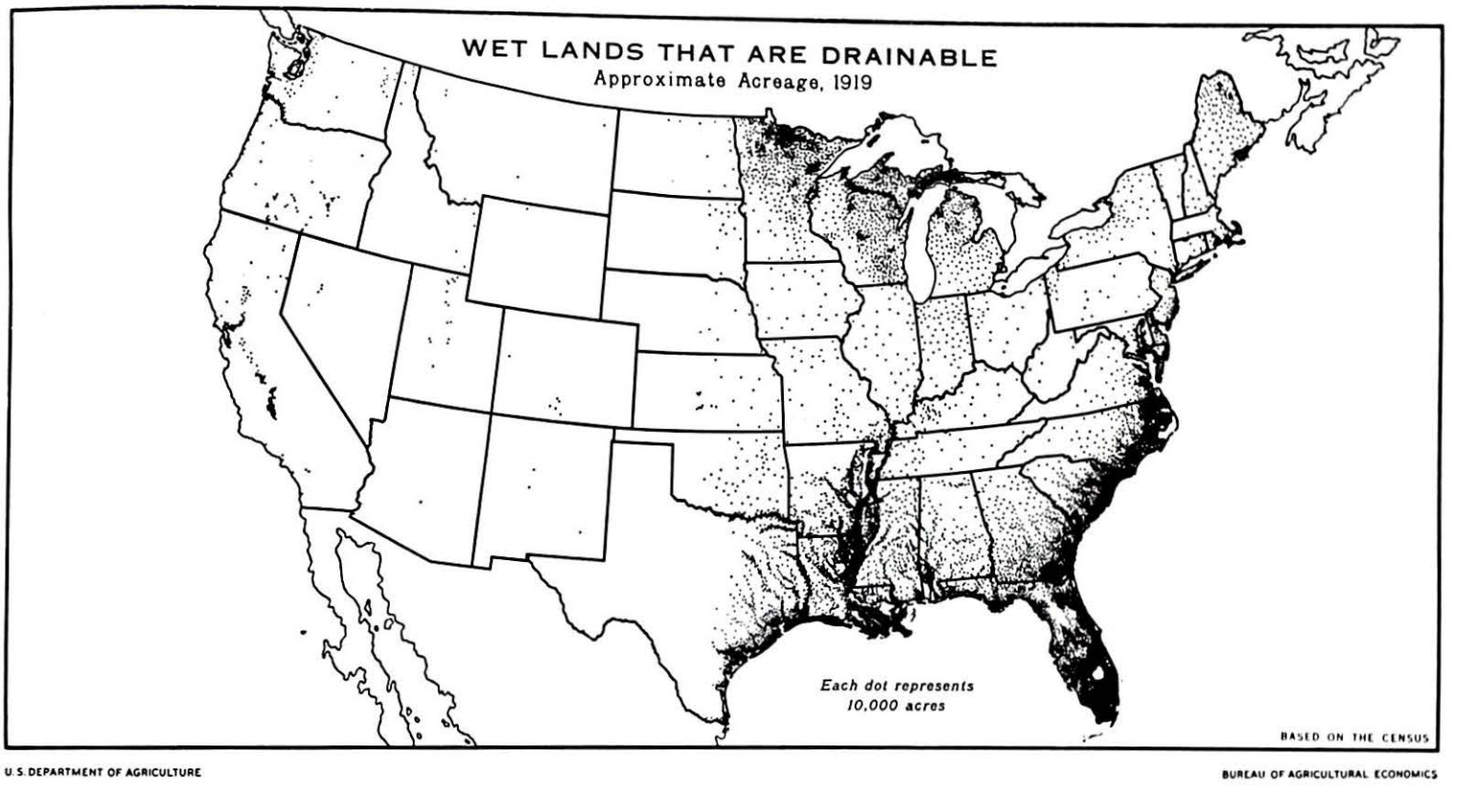

FIG. 2.—Areas of wet lands that are drainable are primarily in the eastern half of the United States. The data from which this figure was prepared were compiled in 1922. Since then considerable areas have been organized for the purpose of securing community drainage, and various other changes have been effected. After considering these changes, it is estimated that there are now about 91,000,000 acres of land which could be improved or reclaimed by drainage for agricultural purposes.

community drainage. About one-half of this acreage overlaps other drainage enterprises. Some enterprises which were drained when this map was prepared have been abandoned or maintenance has been neglected so that community drainage would be necessary to improve their productivity. After considering these changes it is estimated that there are now about 91,000,000 acres of land which could be improved for agricultural purposes or reclaimed by drainage.

This land affords a reserve of importance in the future development of this country. These 91,000,000 acres of lands, which can be drained, when needed, would support about 40,000,000 people.

Cost of Reclaiming Land by Drainage.—The cost of future drainage improvements will, no doubt, be considerably higher than the cost of drainage district improvements already constructed. Estimates of the cost of reclaiming land by providing the arterial drainage channels which are not based on detailed surveys are necessarily approximate but are of some value in connection with the working out of a land-utilization program.

From the available information it is estimated that probably one-third of these lands, or approximately 30,000,000 acres whose fertility ranges from good to high, can be drained for not more than $30 per acre. This area should more than meet the needs for new lands in the next 50 years unless there should be a marked increase in the birth rate, a lessening of the restrictions on immigration, or an increase in foreign exports. It is difficult to forecast the cost of reclaiming the other two-thirds of the wet lands. A program of development of navigation and of water resources of watersheds has been started on the Mississippi, Missouri, Ohio, Tennessee, and Muskegon Rivers and will materially affect the cost of draining agricultural lands in the watersheds of these rivers. In some instances the effect will be to decrease the cost, in others to increase the cost, of drainage. The control of floods on major streams would tend to decrease the cost of drainage on lands within the flood plain, while construction of dams to provide water for navigation will usually increase the cost of drainage. Improvements in equipment and changes in labor conditions make it impracticable to forecast cost of the development.

Legislative Problems

Drainage legislation in various States has made possible the development of drainage enterprises. However, it is generally agreed that a great need exists in many States for simplification, unification, and amendment of drainage laws to correct abuses, to reduce administrative expenses, and to increase the efficiency of construction and maintenance of drainage improvements. Before any steps are taken to change the present laws they should be carefully studied by experts.

In making changes in present drainage legislation or providing amendments, it should be borne in mind that the interest of the public, the landowner and the purchaser of bonds must be protected.

Many areas of very fertile farm land are not adequately drained due to the impossible task of getting enough of the owners to come to a common understanding of the need and to accept their part of the responsibility of making the improvement. To better these conditions some educational work is needed and probably some simplification of laws governing organization of drainage enterprises, particularly those involving small areas.

In studying legislative needs for drainage enterprises the following matters deserve consideration:

1. The advisability of a State board, a commissioner, or other officer to pass on the need, feasibility, and costs of new projects; to approve the issuance of bonds; and to approve administrative, financial, legal, and engineering fees.

2. The feasibility of revising laws relative to the organization of drainage enterprises. Study should be given to laws to determine what changes are necessary to reduce the abuses, permit landowners freedom in voting on the organization of enterprises after the cost of improvements has been determined, and discourage promoters or other interested parties from organizing enterprises which are not agriculturally sound.

3. The feasibility of improving maintenance practices.

4. The advisability of spreading benefit assessments over more extensive areas which are benefited by drainage improvements. Such benefits include business and health benefits to nearby communities; decreased cost of road construction by the county, State, and Federal agencies; and the provision of increased revenues for county and State government.

5. The desirability of permitting drainage districts to issue bonds for clearing lands and providing farm drainage in addition to outlet drains in order to bring the lands reclaimed into cultivation.

6. The advisability of continuing Government aid in the rehabilitation of drainage districts already established to a degree that will put them on a sound basis through refinancing outstanding indebtedness on a conservative basis, and providing loans for maintenance where funds are not otherwise available, and establishing an advisory service to districts which are indebted to the Government.

7. The advisability of Federal legislation being provided to take care of interstate problems of drainage organization.

8. The advisability of close financial control of districts being provided by stated audits at least once a year and reported to proper State supervisor of public accounts.

9. The collection of drainage taxes from delinquent lands which are producing crops.

10. The simplification of laws which cover the foreclosure by bondholders on delinquent districts by giving bondholders representation in the management of delinquent enterprises.

11. The problem of overlapping enterprises.

Need for Drainage Research: There is definite need for further drainage research in a long-time program of land use. Study is needed to determine the optimum requirements of drainage, and the best drainage practice in different soil types in the production of different crops as determined by yields. Such a study is essential to the establishment of a sound practice of drainage and to secure the most economical and best results. These studies should also include a study of the use of open ditches as a means of providing adequate farm drainage of certain soil types and the effect of special surface preparation of the land for a seed bed on these soil types.

There is also need for further studies on the maintenance of drainage structures and equipment under different conditions. This should include a study of open ditch maintenance, tile maintenance, levee maintenance, and the maintenance and operation of pumping plants.

There is need for studies of the run-off from areas drained and from those not drained. Finally, need exists for a study of special drainage problems such as the drainage of peat and muck soils, the drainage of tight clay soils, effect of pumping on groundwater levels, seepage into districts, and silting and erosion of channels. Research work should be done on the legal and organization problems listed in the previous section and of the possibility of improving management practices.

Need for Educational Work: In most sections there exists need for educational work and publicity on the necessity of adequate maintenance of drainage improvements and on the requirements of adequate drainage. Many farmers take it for granted that the problems of drainage are solved for all time when a ditch has been dug and tile lines installed. In most sections of the country the need for and value of drainage is thoroughly recognized. In other sections a crop failure caused by lack of drainage is accepted as an "act of the Almighty" and nothing is done about it.

In some States there is a lack of men properly trained in the theory of design and the art of drainage. In those States there is need for special drainage service which is now being met in some States through the Agricultural Extension Service. Farmers who operate

farms needing drainage should be advised as to the importance of a complete drainage plan to meet the needs of their farm, and also the importance of continued maintenance of drainage structures, just as they are now advised as to the need of using limestone to correct the acidity of the soil. County agricultural extension agents might well devote some attention to the question of adequacy and proper maintenance of drainage structures as fundamental to the satisfactory use of the land in their counties. Where there are drainage engineers stationed in a county there should be the same close cooperation between the county agents and these engineers as now exists between other professional and commercial men who serve agriculture.

Summary and Recommendations

The following is a summary of the most important drainage problems pertaining to development of a land-use program.

There are about 84,000,000 acres in organized drainage enterprises and several million additional acres which have been drained by farmers outside the organized enterprises. Of the 84,000,000 acres, 63,500,000 acres are improved lands. The continued successful use of drained lands requires a maintenance of both drainage district and farm drainage improvements. More economical methods of maintaining drainage improvements should be developed. Drainage laws should be amended in some States to facilitate adequate maintenance. Consideration might well be given to rendering public assistance to self-liquidating maintenance projects which are agriculturally and economically sound.

There are over 20,000,000 acres of unimproved lands in organized drainage enterprises. These lands are producing practically no income. They hamper the progress of the drainage districts because they cannot support their proportionate share of maintenance expenses. Districts which are agriculturally sound should be completed. In some cases it will probably be necessary to abandon uneconomical enterprises which contain large areas of unimproved lands.

The Reconstruction Finance Corporation has been authorized to refund outstanding indebtedness in drainage districts in distress. Loans totaling $25,500,000 have been approved to refinance nearly $70,000,000 outstanding indebtedness in districts containing 6,500,000 acres. Districts benefited by these loans are in excellent condition to improve and develop agriculturally. The officers of districts and landowners must exercise the best of management in order to insure rehabilitation of the enterprises even after obtaining Government loans. Loans to be used for maintenance purposes can be obtained where needed to rehabilitate or maintain drainage improvements.

There are a number of uneconomical drainage enterprises which have caused losses to landowners, and most likely will continue to result in financial losses to owners if continued in operation. The question of whether or not these enterprises should be abandoned depends largely on the success they have had in the past and the resources and ability of the owners in draining and farming the lands.

Since there is an overproduction of agricultural products, there is no need at present to encourage draining additional lands. Many farmers on submarginal lands might well be moved to more fertile lands and many families now on relief rolls could be colonized on farms in drainage districts. Should these policies become desirable, lands in uncompleted drainage districts might well be utilized for these purposes. If the movement should become so widespread that new lands are required by drainage, many tracts having good to high fertility could be drained at an average cost of not to exceed $30 per acre for arterial drainage.

The possibility of utilizing swamp and wet lands as bird and game refuges or public shooting grounds, for raising fur-bearing animals, or for recreational purposes, and taking them out of agricultural use, should be given careful consideration. Where such tracts owned by the public are available to all residents, recreational areas seem highly desirable. Owners of wet lands, who are paying taxes and deriving no income, will try to develop such lands by drainage as soon as they think they can profit thereby.

A study should be made of drainage legislation with a view of improving the organization and legislative procedure so that drainage overhead expenses will be decreased and more adequate drainage can be secured by the farmer.

Further research is desirable to develop improved methods of drainage and of maintenance of drainage works. An educational program should be encouraged to assist farmers in securing better drainage, particularly in areas depending entirely on artificial drainage for their prosperity.

SECTION III
FARM LAND AVAILABLE THROUGH CLEARING*

No surveys have been made to determine the extent of cut-over lands suitable for agricultural purposes, but the accompanying table shows the areas as given in a report on "Development of Unused Lands of the Country" (1919) transmitted by the Secretary of the Interior to the Speaker of the House of Representatives.** Although that report was made 15 years ago, it is improbable that any marked changes have taken place since the data were obtained. Any classification of cut-over lands must necessarily be somewhat indefinite because of the lack of specific information concerning the physical and economic conditions that may make these lands suitable for agriculture.

The estimated per acre costs of clearing shown in the table are intended to be representative of average conditions. The amount, species, and size of forest growth on these lands are factors that affect land-clearing costs. In size the growth may vary from seedlings on newly cut-over areas to large second growth or mature timber on the areas cleared earlier. Though the original stumps may decay with age, the second growth is continuously increasing in size and becoming more difficult to remove. The amount of growth and the species may also vary somewhat, depending on such factors as forest fires, previous growth, and location. Any estimate of land-clearing costs given in connection with these lands must necessarily be rough and general, because of the lack of information concerning the conditions which determine the cost of labor and materials involved in this work.

TABLE III.—*Cut-over lands, and estimated cost of clearing* [1]

State [2]	Area of cut-over land	Estimated cost of clearing	
		Per acre	Total
	1,000 acres	*Dollars*	*1,000 dollars*
Alabama	15,000	10	150,000
Arkansas	14,500	50	725,000
California	[3] 355	200	71,000
Connecticut	[3] 300	40	12,000
Delaware	100	40	4,000
Florida	12,500	10	125,000
Georgia	21,000	10	210,000
Idaho	[3] 476	50	23,800
Kentucky	3,250	40	130,000
Louisiana	12,000	20	240,000
Maryland	1,900	35	66,500
Michigan	[3] 4,200	50	210,000
Minnesota	[3] 5,300	50	265,000
Mississippi	13,500	10	135,000
Missouri	[3] 3,000	50	150,000
Montana	[3] 312	40	12,480
New Jersey	[3] 600	15	9,000
North Carolina	13,000	20	260,000
Oklahoma	3,000	30	90,000
Oregon	[3] 830	200	166,000
Pennsylvania	[3] Small	----------	----------
Rhode Island	[3] 185	40	7,400
South Carolina	9,500	20	190,000
Tennessee	7,800	30	234,000
Texas	12,000	20	240,000
Virginia	10,000	30	300,000
Washington	[3] 2,025	200	405,000
West Virginia	4,650	40	186,000
Wisconsin	4,900	50	245,000
Total	176,183	----------	4,862,180

[1] The areas stated are taken from H. Doc. No. 262, 66th Cong., 1st sess.
[2] For Maine, Massachusetts, New Hampshire, and Vermont the areas of cut-over land available for agriculture were reported as "unknown"; for the other States not listed, no data were given.
[3] Estimated acreage suitable for agriculture not including those lands suitable for grazing. Total cut-over area much greater.

In addition to the physical conditions obtaining, the methods used may appreciably affect the cash cost of the several land-clearing operations. Brushing costs may be reduced by pasturing with livestock, particularly goats and sheep. This process develops wild pasture, the quality of which is gradually improved as the smaller brush is killed by trampling or browsing. Brushing costs can also be materially reduced if the area is burned over a year or two before the actual removal of the brush; this is particularly true with aspen. It has been found in the Lake States that clover catches well on burned-over land, and wild pasture can be improved by seeding these areas. Where brushing has been done by cutting, further brush growth can be suppressed by pasturing until the stumps have been blasted and the land plowed.

Stump removal costs can be reduced by delaying this operation until some decay has taken place. This is practical, of course, only with those species that decay at least partially in a few years, such as hardwoods and some pines. It is not practical with such species as white and long leaf pine, which have an extremely slow rate of decay. The removal and disposal of green stumps is costly, laborious, and slow and is done only under exceptional conditions.

In the southern pine cut-over areas, the occurrence of frequent fires has almost completely consumed the forest litter and tree tops left as a result of logging operations and has suppressed much of the brush growth. Brush removal costs in those areas are practically negligible. Because of the resinous condition of many of the pine stumps they may be burned with little cash outlay, and the practice of burning stumps is rather common. In some sections of the South,

* This report covers conditions in 1934, and was prepared by N. A. Kessler, associate land-clearing specialist, Bureau of Agricultural Engineering, U. S. Department of Agriculture.

** Document No. 262, House of Representatives, 66th Cong., 1st sess.

wood distillation plants offer a market for long leaf pine stumps and down wood, and under favorable conditions the price paid may be somewhat more than the removal and haulage costs.

In the big timber sections of the West stump removal and disposal costs are high because of the size of the stumps. The usual procedure is to blast with dynamite or to pull with machinery. Under favorable conditions stumps in that region may be burned with a small cash outlay but with a considerable expenditure of time.

APPENDIX

SOURCES OF IRRIGATION DATA

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