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An Outline of the Principal Natural Resources of Nebraska and Their Conservation

George E. Condra

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By G. E. CONDRA

BULLETIN 20
CONSERVATION DEPARTMENT
OF THE
CONSERVATION AND SURVEY DIVISION
UNIVERSITY OF NEBRASKA

Reprint from the 1938 Nebraska Blue Book,
with some modifications.

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CONSERVATION AND SURVEY DIVISION

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As defined by law, the Conservation and Survey Division of the University includes the following state departments and surveys: Soil, Geological, Water, Biological, Industrial, Conservation, and Information Service. Its major purpose is to study and describe the state's resources and industries for use in development. Reports are published in three series, i.e., Nebraska Soil Survey, Nebraska Geological Survey, and the Conservation Department.

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INTRODUCTION

Nebraska is well endowed with important natural resources, such as stone, clay, sand, soil, water, prairie, forest, and wildlife. However, soil and water are our basic heritage because they, more than other resources, support native life, agriculture, industry, and social development.

Conservation has become more than theory and propaganda. It has been translated into accomplishment in the development of resources without wastage and for beneficial use in harmony with the ideal of public welfare. This practical procedure requires a technical background based on survey, research, and experience.

Survey Basis. A scientific approach is necessary to establish sound conservation policy and a basis for permanent industrial and social activity. Nebraska recognized this fact when the Conservation and Survey Division of the University was created by law to investigate and report upon the nature, occurrence, and extent of the natural resources and to serve the citizens as an information bureau regarding the development and conservation of these resources.

The activities of the Division are conducted under the Geological, Soil, Water, Biological, and Conservation surveys which cooperate with certain Federal departments. The Division, independently or with cooperating agencies, has published for general distribution more than 120 bulletins on the soil, geology, water, wildlife, industries, and conservation problems of the state.

This report, based on the work of the Conservation and Survey Division, is made to the Legislature and citizens of the state in the hope of furthering the practical conservation of our resources. It covers the environmental relations, mineral resources, land resources, land problem areas, water resources, irrigation reclamation, pump irrigation, hydro-power, water conservation, soil conservation, soil conservation service, grassland resources, agricultural forestry, wildlife conservation, conservation of service, and includes a list of references.

ENVIRONMENTAL RELATIONS

Physical Diversity. Nebraska is physically quite diverse. Its altitude ranges from 825 feet in the southeast to 5340 feet at the highest point on the western border; the mean annual rainfall decreases from 34 inches in the southeast to 15 inches in the northwest. The state has 3 climatic belts —humid, subhumid, and semiarid; 14 topographic regions; 12 groundwater regions; and 5 distinct soil regions, classed as the silty soil region, the mixed soil region, the sandy soil region, the loamy soil region, and the clay soil region. On a basis of texture, color, compaction, and other features,

there are more than 300 types of soil within the state, grouped under about 70 series. References on the climatic elements and the various regions of the state are listed at the end of this report.

Climatic Influence. Climate is a dominant factor in the development of Nebraska's agricultural resources. The high temperature and low humidity cause excessive evaporation and a high rate of plant transpiration. The amount, frequency, intensity, duration, and distribution of the rainfalls have important relations to the replenishment of soil moisture, surface water, and groundwater and thereby to agriculture and industry.

Deficiency of rainfall causes drouth which reduces excessively the soil moisture and surface water and to a less degree the groundwater, and affects destructively the wildlife and agricultural enterprises. The amount of the state's annual rainfall is variable and probably cyclic, consequently, these phases of it and the recurrence of drouth must be taken into account and reckoned with as factors in the economic life of the state. We cannot add to the rainfall, but we can effectively modify its disposal and use.

MINERAL RESOURCES

The mineral resources of our state have much greater industrial importance than is generally supposed, notwithstanding the fact that there is no production of iron or gold and very little production of coal. We do have stone, sand and gravel, clay, and some coal, volcanic ash, and potash and a chance for the discovery and production of oil and gas.

Stone. This includes limestone, chalk rock, and sandstone, and at considerable depth, granite, rock salt, and gypsum. Our limestones and chalk have been studied rather closely by the Geological Survey. Limestone and shale are used in the manufacture of cement at Louisville and chalk and shale are used in the cement plant at Superior. There are extensive deposits of cement-making materials in Nebraska.

During the past four years several new quarries have been opened on the limestones of the southeastern counties of the state to produce stone for use in the navigation development of the Missouri River between Sioux City and near Saint Joseph. The Federal government has paid the landowners and producers about $500,000 per year for this output, but unfortunately a considerable part of the stone quarried for this purpose has been wasted, due to the fact that only the larger sizes of the production were used for river control work and the rest became wastage with the quarry overburden materials, whereas, it should have been separated and piled for use in road work or for liming soils. The Geological Survey should have authority to prevent this wastage.

Some limestone is ground and shipped from Nebraska and some of it is used in the manufacture of concrete, for liming soils, or for road building. Our sandstones are generally too soft for building purposes.

Sand and Gravel. There are large sand and gravel deposits in Nebraska. They are the source of important production for road-building and the manufacture of concrete and for some shipment to other states.

The Geological Survey has published two bulletins (out of print) on the sand and gravel resources of the state. The approximate value of the state's sand and gravel output is about $1,500,000 annually.

Clay. This occurs in several geological formations at a number of places. It is used in brick and tile manufacture, as at Nebraska City, Lincoln, and Hastings. Formerly the manufacture of brick, tile, and terra cotta had considerable importance in our state, Hastings leading in volume of output, but there has been a recession in the brick and tile manufacture for about 8 years.

Volcanic Ash. This, known commercially as silica, was produced quite extensively in Nebraska about 30 years ago, but now only one operator remains, the rest having opened up deposits in Oklahoma, Kansas, and other states. Volcanic ash is used in the manufacture of "Old Dutch Cleanser" and abrasive soaps.

Coal. Several beds of coal occur in the state. They have been studied and found to be too thin for successful mining under present conditions.

Oil and Gas Possibilities. More than 1,000,000 acres of land are now under lease in our state, mainly by oil companies, for prospecting for oil and gas. Most of these blocks of leases are in the western counties. The total rentals paid to the land owners on these leases is considerable, since it runs at the rate of 10 cents or more per acre per year, and the amount spent in the state each year by the oil men in leasing, by geologists, and for seismographic survey and drilling, represents other large expenditures. It is to be hoped that oil money will continue to be used here and that oil and gas may be found in commercial quantities.

The Geological Survey collects cuttings at regular intervals from all deep wells drilled in the state and logs the wells during the progress of drilling. This service, which is required by law, is appreciated by the operators and it enables the Survey to gather valuable information on subsurface geology. No information is given out on wells during the period of their drilling.

Although our state has no law regulating how wells should be finished to prevent the pollution of the groundwater aquifers with salt water, the Geological Survey has assumed the duty of advising concerning these matters, and to date, no operator has failed to comply with our suggestions and requests.

LAND RESOURCES

Useful Materials. The land of Nebraska contains several useful agricultural materials, the most important of which are soil-forming materials, groundwater, and soil. The use that is made of land for highways, railways, airports, rural homes, industries, towns, cities, state institutions, game preserves, and parks is considerable. These uses are not considered in this report, but were reviewed by the writer in Bulletin No. 7 of the Conservation Department.

Agricultural Lands. All land in Nebraska has some importance in agriculture. However, its effective agronomic use is determined by to-

pography, soil type, erosivity of the soil, the amount and distribution of rainfall, length of growing season, crop adaptation, and cultural methods.

The outstanding favorable conditions relating to the agricultural development of Nebraska are the extensive distribution of rich soil-forming materials and the widespread water-bearing formations. Probably no state is more richly endowed with these resources and conditions.

Our state is further characterized by its broad valleys and large uplands occupied by deep, stone-free soils, making cultivation possible on a large scale. As noted before, climate is also a controlling factor in the land-use and types of farming in Nebraska. The differences in topography, soils, and climate cause diversity in the agriculture enterprises.

Survey and farming experience show that there are large areas of highly productive land within the state and that some of the land is too rough or too sandy for cultivation and that some is defective, due to lack of water supply, the presence of alkali, or to some other unfavorable condition.

Humus and Nitrogen. These were in the virgin soils of the state in relatively large amounts, but according to the investigations of Dean W. W. Burr and Professor D. L. Gross of the College of Agriculture they are being reduced under cultivation to a considerable degree in some soils.

The replenishment and maintenance of the organic matter content of the agricultural soils is a problem in parts of the state. Alfalfa, the best humus-nitrogen building crop, depletes the soil moisture at a rapid rate, but is giving way to sweet clover on the uplands and is increasing in acreage on the irrigated and subirrigated lands. This means that it should not be grown in long rotations except where there is abundant soil moisture.

Use of Mineral Fertilizers. Nebraska soils have not become deficient in mineral nutrients to the point where commercial fertilizers are used very generally, nor is this condition likely to change very much in the near future because the agricultural soils are relatively rich in the essential mineral contents. There are places in the southeastern counties, however, where the soils have become rather acid or sour, and liming of them causes increased crop yields.

Experimental work by Professor J. C. Russel of the College of Agriculture shows that some sandy soils and those containing large amounts of alkali respond favorably to phosphate fertilizer and that the beet and potato crop yields are increased very perceptibly by the use of mineral and organic fertilizers.

It is evident that fertilizers can be used more beneficially in the state than is generally supposed, and it is also true that they should be selected and applied to meet the specific requirements of the soils and crops.

Land Surveys. All of the agricultural lands of Nebraska were filed upon and plowed before their nature and adaptabilities were determined by survey. Within recent years, however, most of the state has been covered by the geological, soil, and groundwater surveys, and a second or detailed soil survey is underway.

About 30 per cent of the state has been mapped topographically, and a detailed land-use map of the state has been made. The agricultural experiment stations have accumulated valuable data on land-use and other subjects. Soil erosion control work is being done, and the agricultural extension service is carrying on an effective program in agricultural education. Many bulletins on the geology, water supply, soils, and land-use are available for farmers and others through county agricultural agents, the College of Agriculture and the Conservation and Survey Division of the University.

LAND PROBLEM AREAS

Much of Nebraska is naturally suited to agriculture, but parts of the state have defective features. The main kinds of land requiring amendment or adjustment in their agronomic use are as follows:

1. Badlands with practically no soil, 56 square miles, or 35,840 acres.
2. Rough, stony lands with little or no soil, about 1,015 square miles or 649,600 acres.
3. Tablelands, with thin, drouthy soil, due to the low capacity of the soil to hold moisture, about 2,510 square miles or 1,606,400 acres.
4. Tablelands with sandy soil subject to severe wind erosion where the plant cover is not maintained, about 1,610 square miles or 1,030,400 acres.
5. Sandhill region and its outliers, with sandy soil, subject to blowing where not grass-covered, about 22,451 square miles or 14,368,610 acres.
6. Shaly "gumbo" lands, drouthy and without well water, about 750 square miles or 480,000 acres.
7. Loess canyon areas, too rough for cultivation, about 4,270 square miles or 2,732,800 acres.
8. Blufflands, topographically unsuited to cultivation, approximately 400 square miles or 256,000 acres.
9. Eroded hillsides and gullies of the Drift Hill and Loess Hill regions, approximate aggregate area, 1,200 square miles or 768,000 acres.
10. Shallow claypan areas, with low available soil moisture, about 3,540 square miles or 2,265,600 acres.
11. Small depressional areas, subject to alternate flooding and desiccation, about 200 square miles or 128,000 acres.
12. Low-lying bottomlands with sandy soil, shallow water table and occasional flooding, about 1,260 square miles or 806,400 acres.

Badlands. These are excessively eroded small areas on the Brule clay and the Chadron formation. They occur in northern Sioux and Dawes counties and at a few places in the North Platte and Pumpkin Creek valleys and are nearly barren of vegetation. Their barrenness is due to the erosivity of the formations, caused by their fine, loose texture, and the rapid surface runoff, which has a high ratio to the rainfall.

Just how to reclaim the badlands, which are of little use, remains a problem.

Rough Stony Lands. These occur principally in the Pine Ridge escarpment, Wildcat Ridge, at the borders of the tablelands and locally along the Missouri, Republican, Big Nemaha, and lower course of the Platte. They were eroded on the Tertiary sandstone, Niobrara chalk, Dakota sandstone, and the Permian and Carboniferous limestones.

This type of land is too stony and rough for cultivation. It is best suited to grazing and forest. In places it is quite scenic due to the topography, and forest cover. Overgrazing is not good practice on this kind of land.

The federal government has purchased a large acreage of rough, stony land in the Pine Ridge region to be managed and used probably as a national forest, for wildlife development and for recreational purposes.

Tablelands with Thin Soil. Land of this type occurs widely in the western and northern counties. It is rolling to rough. The soils are classed chiefly as Epping and the shallow phases of the Rosebud and Holt series. They do not have the capacity to hold moisture sufficient for cultivated crops except during the years of maximum rainfall with favorable distribution.

Some of this land is now idle, presenting a problem in ownership, management, and use. Where its soil becomes dry and incoherent and is not protected by cover, it is removed by wind erosion, exposing the bedrock, but it recovers rapidly with increased rainfall. No doubt a considerable part of this kind of land should be seeded permanently to native grass and used for grazing.

Tablelands with Sandy Soil. This kind of land is widely scattered in the tableland regions. The soils are the sandier and less stable types of the Rosebud series, the more gravelly and sandy types of the Tripp series, and all types of the Dickinson, Anselmo, and Valentine series.

Considerable areas of this land are now out of cultivation, regaining their original prairie sod. The main problem here is revegetation which requires a period of several years. Later, there will be the problem of conservative grazing to maintain the grass cover.

Sandhill Areas. The conditions here are summarized as follows: Mantlerock and bedrock: porous, extending to depths of 300 to 800 feet and resting on impervious beds; topography: hilly, modified by basins and valleys; soil and subsoil: sandy; rainfall: 17 to 24 inches, decreasing westward; natural plant cover: grass, small shrubs and clumps of trees; rate of rainfall absorption and downward percolation: high; surface runoff for about 90 per cent of areas: nil; groundwater storage: very great with high lying water table; groundwater runoff or "run out": relatively high, making streams with uniform discharge; lakes and marshes: 2,000 or more, shallow, the depth varying with the height of the water table.

The sandhill areas are natural grasslands well suited to grazing and are used primarily for cattle raising. The hills afford pasturage; the basins and flats produce hay for winter feed, and the shallow groundwater supplies abundant well water. Plowing and overgrazing cause wind erosion.

The minor uses of the sandhill areas are as follows: For forest reserves, about 205,934 acres of which about 32,000 acres have been planted to forest by the federal government; for federal game preserve, 20,000 acres, part being in the sandhills; for game sanctuaries and wildlife sanctuaries, as for ducks, grouse, and prairie chickens, about 80,000 acres; and for three state recreational areas. Aside from grazing, the main use of the sandhills is for groundwater storage from which uniform live streams issue and are developed outside the region for irrigation, power, recreation, and wildlife.

The main conservation problems in the sandhill areas involve the maintenance of uniform grass cover on the hills, the maintenance of the most favorable depth of water table in the hay flats, the preservation of lake level, and the conservation of wildlife. Ranch management has assumed a high degree of adjustment and standardization in these areas and only high grade animals are raised.

"Gumbo" Land. An area of about 500 or more square miles of shaly "gumbo" land in northern Sioux and Dawes counties is defective for cultivation. Its natural conditions are: shale (Pierre), extending from the surface to a depth of 1,200 feet or more; topography: hilly, modified by small valleys; soil: thin, clayey, known as dark "gumbo"; rainfall: 16 to 18 inches; natural plant cover: grass and shrubs; rate of rainfall absorption and water penetration: low; surface runoff, rapid and relatively high; groundwater storage: little and of poor quality except at a depth of 2,000 feet or more.

This kind of land, of which there are small tracts in Keya Paha, Boyd, and other counties and larger areas in South Dakota, has been badly managed. Its main drawbacks are the absence of well water throughout the year and scant soil moisture during dry years. Too much of the land in Sioux and Dawes counties has been plowed and large areas of it are being abandoned as farm land. Some of the land contains selenium which is poisonous to livestock.

This land presents a problem in resettlement, involving the location of ranch buildings where drinking water can be had and where there is some soil suited to cultivation. It grows quite uniform stands of grass suited for grazing, but its overgrazing is very objectionable. Generally the "gumbo" areas of the northwestern counties could be used to best advantage by fencing large pastures, ponding stock water from the surface runoff, and by conservative grazing.

Loess Canyon Areas. These roughlands occur principally in the Republican valley region, along the south side of the Platte valley between North Platte and Lexington, also in northern Dawson County, and in Custer County. They are modified by small loess plains. The prevailing soil is the Colby silt loam.

The canyon floors of these areas are narrow, usually grass-covered and produce native hay. The canyon walls are steep, locally bare or thinly grass-covered. Most of the small irregular loess plains lying between the canyons are occupied by fertile soils and are farmed.

No doubt the canyon floors of these areas should not be plowed because their native sod prevents gullying. Also, the areas generally should be retained in the native sod. Again, farming on the small loess plains should not be extended too close to the edges of the canyons because it develops a condition favorable to the lengthening of the canyons and the erosion of the plains.

Eroded Drift Hills and Loess Hills. The up-and-down-hill plowing on the drift and loess hills, which is being done generally, is a factor in their sheet erosion and gullying, and it is now known that contour tillage and strip farming should be practiced more generally here in order to prevent the further destruction of the soil.

Under present conditions the fertile Moody, Marshall, and Carrington soils of these regions are rapidly giving way through sheet erosion to the light colored Knox and Crofton soils, and gullying is separating the farms into small tracts difficult to farm.

Although the topsoil has been eroded from many of the steep slopes in these regions, the mantlerock consists of thick soil-forming materials, and a new soil can be developed. Also, the gullies can be filled and grassed as sodded sloughs as they were originally. So, fortunately, it is possible to reclaim the depleted areas of the Loess Hill and Drift Hill regions.

The Soil Conservation Service is now studying these regions to determine how to prevent their further destructive erosion and how to correct the gullies and badly scarred hillsides. Apparently the steeper hill slopes here should be seeded to permanent grass.

Bluff Lands. These are topographically similar to the loess canyons. They were developed on mantlerock and soft bedrock, as on the loess, chalk rock, and the Dakota sandstone. Most of this kind of land occurs along the Missouri River and in the lower course of the Platte River and its main tributaries. It is generally grass-covered or forested, but is used locally for fruit farming and general farming. The bluffs are too rough for farming and should be kept in grass or forest cover for use in grazing and as park and recreational areas.

There are many fine bluffland vistas along the Missouri and Platte valleys, known as Devil's Nest, Black Bird Hill, King Hill, Queen Hill, Child's Point, Jones Point, Goose Hill, Indian Cave, Iowa Point, and Pawhuk. These and other attractive features of the bluff lands might be developed as scenic and recreational areas.

Claypan Areas. These are on the Crete and Butler soils in south-central Nebraska, the Pawnee soils in the southeastern part of the state and the Dawes soils in the western counties. They have very tight upper subsoils which limit the soil moisture storage and the availability of moisture for cropping.

Thus far no effective method has been devised to increase the amount of moisture storage in the soils of these areas. Small grains, which make the best use of the rather limited moisture supply, are grown chiefly because they mature early in the summer, usually before the topsoil moisture

stored during the preceding fall and spring is exhausted, and because these crops are less subject to severe drouth injury than corn and alfalfa, both of which require moisture in relatively large amounts and for longer periods.

As indicated above the dominant limiting factor in the use of these areas is their claypan subsoils and their unfavorable effect on the soil moisture storage. Otherwise the soils are well suited for general farming as shown by their production during seasons of normal precipitation. They are defective only during drouths. There is no water erosion problem here but some damage is done by wind erosion during dry years when the vegetative cover fails. Conservation measures on these soils are confined largely to adjustments in the cropping practices designed to make the best possible use of the soil moisture supply.

Depressional Areas. These small, inward-draining basins occur on the loess plains, tablelands, and terraces having a combined area of more than 200 square miles. The rainfall accumulates in them, usually in the springtime, making the use of the land uncertain for farming during dry years and impossible during wet years. The temporary lakes are not of much use because little of their water percolates through the heavy claypan subsoil and downward to groundwater storage and most of it evaporates, leaving bare lake beds which soon grow up to smartweeds and other undesirable plants.

Various schemes have been proposed for withdrawing the water from these depressional areas, as by dynamiting the claypan, sinking wells to the water-bearing sands and gravels and by surface drainage. Some of the depressions located where the water could be removed, have been drained by ditching but the other methods of reclamation have failed. No attempt has been made to use the water of these lakes for irrigation.

Low-lying Sandy Bottomlands. These are the low sandy lands bordering the streams, the sanded areas deposited by floods, and the sand and gravel wash on the bars and beds of streams. As a rule, they are subject to flooding from high stages of the streams and the water table is shallow. There is no soil on them in places, there being only sand wash, but the bottoms which are flooded less frequently are occupied by the sandy soil known as the Cass.

The smooth, sandy flood plains, which have wide occurrence in the state, are natural prairie lands and should be conserved for wild hay production and grazing. They are the state's best native hay lands and are better suited for this purpose than for cultivation. The shallow water table is the main factor in determining their use.

The reclamation of the flood-damaged sanded lands along the Republican, Platte, and Elkhorn rivers is being accomplished quite successfully in places. Favorable results are being obtained by deep plowing where the the sand cover is thin and the soil can be lifted and incorporated with the sand. In places where the sand cover is too thick for the application of this method, the land becomes covered with thick stands of weeds, cottonwoods, and willows, and by gathering wind-blown material and the

silt from overflows, soon builds a soil on the sand wash. Another method some are using is to seed the thinly sanded land to sweet clover and thus further soil-building.

The large areas of river wash along the Missouri River, formed by channel change incident to the development of navigation, present a problem in land-use, but since the river is to be held to its new channel, there will be constant wash onto the sandy land from the uplands and by local overflows which will build agricultural land where there are now sandbars and stretches of abandoned channel. It seems that the easiest and most inexpensive way to reclaim these sand wash areas will be to allow them to grow to weeds, willows, and cottonwoods until a soil is developed.

WATER RESOURCES

Forms of Occurrence. Water occurs in the atmosphere, on the surface of the land, in the soil and subsoil, and in the mantlerock and bedrock. Its forms of occurrence are as vapor, clouds, fog, dew, rain, hail, frost, snow, soil moisture, springs, streams, sheet water, lakes, and groundwater proper.

Volume of Rainfall. The area of Nebraska is about 77,320 square miles or 49,484,800 acres, and the mean annual rainfall, according to the United States Weather Bureau, is about 23½ inches or 96,907,735 acre feet, which would cover a county of 16 townships to a depth of 262 feet or a township of 36 square miles to a depth of more than 4,190 feet. This is the state's largest replenishing resource or physical income.

Disposal of Rainfall. Part of the precipitation falls on lakes and streams, becoming surface water at once; part is absorbed by the vegetative cover, and that which reaches the surface of the land is absorbed by the soil and subsoil or becomes surface runoff. The rates of surface runoff and soil absorption vary with the vegetative cover, soils, topography, and the intensity and duration of the rainfalls.

The amount of rainfall received and the nature of its distribution are important factors. A marked shortage in the state, as in 1934, which was 33,970,773 acre feet between January first and September first, or an unfavorable distribution, as in 1936, causes severe drouth. The most effective rainfall is supplied by frequent rains of moderate intensity.

The topographic influence in the disposal of the rainfall is shown by the runoff from hillsides and valley-slopes to the colluvial slopes, terraces, and bottomlands, which works to the disadvantage of the uplands and the advantage of the lowlands by giving the more water to the latter.

Soil Moisture. The soils of the state differ greatly in their thickness, texture, and structure and consequently in the rate of their absorption and capacity to store and release moisture. About 40 per cent of the volume of a soil is pore-space occupied by air, capillary water, and organic materials. The soils with thick topsoils and abundant organic matter receive and hold relatively large quantities of water. Sandy soils absorb much of the rainfall and pass it to groundwater storage, while the heavy soils shed relatively more of the rainfall as surface runoff.

Volume of Soil Moisture. The soils have only limited capacity for water storage which, without frequent replenishment from rains or by irrigation, is exhausted by evaporation, plant growth, and percolation. Soil moisture, though of paramount importance, is a mobile resource, subject to constant depletion, especially during hot weather.

Just what per cent of the state's mean annual rainfall passes through the soils to become groundwater has not been determined very accurately. There are places and conditions where most of it moves through the soil, whereas at other places, much of it becomes surface runoff and relatively less becomes soil moisture. For the state as a whole, however, it is estimated that more than 90 per cent of the rainfall passes into or through the soil, and that the volume of water held in the soil and subsoil at any time ranges between 5,000,000 and 13,000,000 acre feet, depending upon the degree of replenishment and loss. The largest storage is after heavy spring rains and the lowest is during late summer or after a drouth.

Surface Waters. These are the natural streams, marshes, and the natural and artificial lakes. They are formed from the rainfall, surface runoff, from groundwater or, by diversion and ponding, and are reduced by evaporation, transpiration, percolation, discharge, and water use.

Streams. The streams of the state vary considerably in quality of water and uniformity of flow, due mainly to the geologic, soil, and climatic conditions of their basins. Those fed mainly by surface runoff vary most in discharge and those heading in the groundwater of sandy lands, as in the Sandhill Region, are more uniform. Most of the larger streams have been gaged at regular intervals for several years, and their discharge is quite well known.

Our streams are used for many purposes, as for stock water, irrigation, power development, urban water supply, recreation, and in a few cases for sewage disposal. Most of them contain fish and have relations to birds and other wildlife. Some are being developed for fish culture, and the Missouri River is being developed for navigation.

Lakes. Counting those with areas of 15 acres or more, the state has more than 2,300 lakes, marshes and artificial reservoirs. Most of the natural lakes and marshes are in the Sandhill Region. They are shallow; many of them are intermittent, and more than 1,000 of them went dry during the drouths of 1934 and 1936.

The intermittent lakes on the loess plains and table lands have little economic importance. They disappear mainly by evaporation and percolation and their beds supply some grazing and at places wild hay. They become the stopping places for migrating waterfowl, giving opportunity for hunting. The more permanent lakes and reservoirs of the state afford fishing, hunting, some stock water, and recreation; many of the marshes are suitable habitats for wildlife including muskrats.

Area of Surface Water. The combined normal area of the intermittent lakes and marshes of the state is about 230 square miles; that of the more permanent streams is about 495 square miles. The maximum area of the surface waters of the state, not including floods, is about 890 square

miles. The average is about 640 square miles, but during the drouth of 1934 the combined area was reduced to about 300 square miles or 192,000 acres. The evaporation loss from the free water surfaces of the state is considerably more than the amount of rainfall on these surfaces.

The area of water surface has been increased considerably the past few years by the construction of reservoirs in connection with water power, irrigation, and erosion control work. When the reservoirs recently built and those building are filled they will add about 40,600 acres of water surface to the state.

Volume of Surface Water. The amount of surface water in the state, like the soil moisture, varies greatly through the year. Its mean volume at a given time is approximately 1,200,000 acre feet. However, the amount that moves in the streams and may occur in surface storage during the year is much greater than this. Not including the discharge of the Missouri, the annual inflow from Kansas, Colorado, Wyoming, and South Dakota through the Republican, South Platte, North Platte, and Niobrara rivers and their branches is about 1,500,000 acre feet and the outflow of the state by the Niobrara, Hat Creek, White Creek, small branches of the Missouri, the Platte, Big Blue, Little Blue, and the Republican rivers is about 6,500,000 acre feet. This shows that the outflow exceeds the inflow by about 5,000,000 acre feet, or an amount equal to slightly more than 5 per cent of the total volume of the mean annual rainfall of the state. The annual discharge of the Missouri River varies between 25,000,000 and 52,000,000 acre feet at Rulo. Of this there is a pick-up of only about 5,450,000 acre feet from Nebraska creeks and rivers.

The large reservoirs completed or building within the state were planned to have a combined storage capacity of more than 2,700,000 acre feet and the small ponds and reservoirs made by the Soil Conservation Service and the PWA will add considerably to this amount.

Groundwater Proper. This fills the porous mantlerock and bedrock up to the water table. It is supplied by rainfall and from surface waters. Its replenishment or recharge lifts the water table, and the water passing into porous layers between inclined impervious formations develops artesian pressure. Evaporation, transpiration, springs, pumpage, and drainage lower the water table and heavy draft and wastage reduce the pressure and head in the artesian aquifers.

Quality of Groundwater. As a rule, the chemical quality of groundwater is due to the nature of the aquifer containing it, and the amount of organic pollution decreases with depth. Much of the groundwater of Nebraska is medium hard and of good quality. In some of the deeper formations, however, it is quite heavily mineralized with iron, lime, salt, sulphur, etc.

Groundwater is the source of springs, considerable stream flow, well water, and subirrigation water.

Amount of Groundwater. The thick, sandy mantlerock and the younger bedrock of the state have large water storage capacity. The amount of groundwater proper in the state is vastly greater than the com-

bined surface water and soil water. The volume of that which lies above the impervious bedrock is more than ten times the mean annual rainfall or approximately 1,000,000 acre feet. This does not include the vast storage in the deeper formations, as in the Dakota sandstones and older aquifers.

Movements of Groundwater. Sandy land absorbs much of the rainfall and passes it to storage above the impervious bedrock. This groundwater so formed, moves with the gradient or slope of the water table to points of escape in the valleys. The rate of its movement is variable, but averages about 3 feet or more per day. It takes years for this water to pass from central points in the uplands to the seepage ways, springs, and major streams.

Water Table Level. Occasionally it is reported that the water level has lowered markedly at some place within a short time. Usually, however, such reports are based on observations made at wells after heavy pumpage and really mean local "draw down" and not the lowering of the water table generally.

The low rainfall of the recent drouths did not recharge the groundwater normally, and this, together with the excessive loss by evaporation, transpiration, and the excessive use of well water did lower the water table considerably in places. The water table level in the alluvial bottomlands dropped from 2 to 4 feet at many locations and 15 feet or more along-side the drainage ditches of the southeastern counties. In the sandhills, it lowered very little where the water table is deepest but dropped 2 to 4 feet or more at the lakes and in the valleys where the water table is shallow and is exposed to evaporation and transpiration. The heavier rainfall of 1938, up to the end of July raised the water table to near normal in many places, but the dry weather following has been unfavorable and the water level is now falling.

The deep water table in the upland plains and table lands does not fluctuate much, due to the slow underflow, lack of transpiration and evaporation, and the small use that is made of the water. At some places in the state, the limited amount of shallow groundwater is nearly exhausted during drouths.

Groundwater Depletion. Groundwater proper is less affected by drouth than are soil moisture and surface water. The normal rainfall, as noted before, dropped off markedly between January first and September first, 1934, and the surface waters shrank to a low minimum, but the groundwater was depleted only about 4 per cent during this period, which means that it would require a drouth of long duration to reduce it to an alarming degree in most parts of the state.

Such groundwater shrinkage as there is during drouth, influences unfavorably the flow of springs and streams, diminishes the shallow well water supplies, and lowers the lake levels. Its worst effect is the exhaustion of the drinking water supplies in certain small areas of the state.

Groundwater Level Record. The state Geological and Water surveys, cooperating with the Ground Water Branch of the United States Geological Survey, are measuring the water table level and the water temperature at 500 stations located in various parts of the state. These measurements are made at regular intervals and recorded for study and future use. It is planned to continue this activity indefinitely for about the same reasons that the rainfall is measured and the discharge of streams is gaged.

Well Water Service. Upon request, the Water Survey assists the farmers and municipalities in an advisory capacity in locating wells and in the improvement of water supplies. This service is based on the results of survey and is extended without cost to those who are served. The Department of Rural Engineering at the College of Agriculture renders a similar service in regard to types of irrigation wells, pumps and power, and conducts short courses for irrigators.

IRRIGATION RECLAMATION

Irrigation is the spread of surface water or groundwater upon dryland soils largely for increasing agricultural production. It has become an important means of developing our subhumid and semiarid lands, limited only by the availability of water and the suitability of the soils.

It is the purpose of the state to develop its irrigation possibilities as fully as possible but with every safeguard against failure. Since the amount of our land suitable for irrigation far exceeds the required amount of water available for reclamation, it has become necessary for the state to control the allocation and spread of the water in order to secure its most effective beneficial use.

Kinds of Irrigation. The forms of irrigation, based on the source of water and the way it is spread, are: (1) Canal irrigation, from streams or impounded runoff; (2) pump irrigation, with groundwater or surface water; (3) subirrigation, with groundwater supplying capillary water to plant roots; and (4) spray irrigation, spread through pipes or tubing. Pump irrigation and spray irrigation are essentially alike, differing only in the method of spreading the water.

Amount of Irrigation. The extent of irrigation in Nebraska is approximately as follows: (1) From canals with water diverted from streams, 800,000 acres; (2) by pumping from groundwater and streams, more than 60,000 acres; (3) by spraying from rural and municipal water supplies, about 40,000 acres, and (4) by subirrigation from groundwater, 1,300,000 acres; total by surface irrigation and subirrigation, about 2,200,000 acres, or 4 per cent of the area of the state. This acreage is being extended by new developments and is being reduced locally by the removal of small undesirable tracts from the existing districts.

Drouth Relations. The demand for irrigation is greatest during dry years, especially on the drouthy soils. Consequently, most land of the subhumid areas is placed under irrigation during or immediately following drouth, and there is a tendency not to irrigate it during wet years, where-

as, in the semiarid districts, irrigation is more necessary, and where available, is relied upon every year. The severe drouths of 1894 and 1934 were followed by the development of public sentiment for irrigation and the installation of new projects.

Present Conditions. Nebraskans are now irrigation-minded, due to the effects of (1) the drouths of 1934 and 1936, (2) the manifest success of irrigation in the Platte valley, and (3) to the availability of federal funds for the construction of new projects. More consideration than in the past is being given to the availability and dependability of water supplies, the suitability of the soils, and the economic factors involved in irrigation farming. However, too many people do not yet realize that as a rule irrigation is most successful where the farmers rely on it every year more than on rainfall, and that sometimes it is least successful in the subhumid areas, where the farmers hope for rain and fail to irrigate at the proper time.

Water Storage. At the start all irrigation in Nebraska was with water diverted from streams during the irrigation season, but because the flow of most streams became low when water was most needed, it was found necessary to conserve the non-irrigation season flow and the flood flow of the streams in order to obtain dependable water supplies. This condition led to the construction of regulating reservoirs, as the Pathfinder and Guernsey in Wyoming, and Lake Alice, Lake Minatare and others in Nebraska, making a total reservoir storage of about 1,300,000 acre feet in the North Platte valley in Wyoming and Nebraska prior to 1936. In addition to this, the combined capacity of the irrigation reservoirs recently completed or building in Nebraska and Wyoming is about 3,400,000 acre feet, making the total probable storage capacity of the basin in Nebraska and Wyoming about 4,700,000 acre feet. This does not include the South Platte storage.

The Pathfinder storage is released during the irrigation season to flow on the bed of the North Platte to near Whalen, Wyoming, where it is diverted for some irrigation in that state and much more in Nebraska. This spread of water builds up much groundwater storage in the terrace and slope lands of the valley, from which there is an all-year return-flow to the river.

The flow in the upper course of the North Platte is now stabilized by reservoir and groundwater storage and the middle stretch of the river between North Platte and Grand Island is being controlled for power production and supplemental irrigation.

Sandhill Storage. Nature gave Nebraska, in the sandhills, the most ideal water storage area in the Great Plains Region. The amount of groundwater here is more than 500,000,000 acre feet, equal to more than 500 times the capacity of the Pathfinder reservoir. This water is one of our most important resources. It is recharged by rainfall and is released all year at a notably uniform rate to the valleys and their streams.

The area of the Sandhill Region lying between the Platte and Niobrara valleys is about 19,332 square miles or 12,372,480 acres on which the an-

nual rainfall is about 21,600,000 acre feet, most of which enters the ground. In about 10 per cent of this area the amount of water passed back to the atmosphere by transpiration and evaporation exceeds the rainfall, and in another 10 per cent there is slightly more runoff (run out) than rainfall, whereas for about 80 per cent of the region water is released by underdrainage and streams at the rate of 20 to 25 per cent of the volume of the rainfall, in the approximate amount of about 4,000,000 acre feet per year.

The annual contribution of sandhill groundwater to the Platte valley in the stretch between Bridgeport and Gothenburg is more than the amount stored each year in the Pathfinder reservoir, and the outflow to the Niobrara, Elkhorn, and Loup valleys is equal to three times the capacity of the Pathfinder reservoir. The sandhill water is becoming a factor in power and irrigation developments.

New Irrigation and Power Projects. The following large, self-liquidating federal projects (Figure 1) have been completed or are building: (1) Central Nebraska Public Power and Irrigation District, known also as the Tri-County Project; (2) Middle Loup Public Power and Irrigation District; (3) North Loup Public Power and Irrigiation District; (4) the Platte Valley Public Power and Irrigation District, known as the Sutherland Project, which was built primarily for power but to supply some supplemental irrigation; and (5) the Loup River Public Power Project, built for power.

The areas to be irrigated by the projects listed above are about as follows: (1) 295,000 acres; (2) 45,000 acres; (3) 60,000 acres; (4) 100,000 acres; total irrigation about 500,000 acres. The allocation for number (1) was about 492,000 acres, but by a decision of the supreme court, based on a statute which prevents diversion from one basin to another, about 40 per cent of the area originally allocated was withdrawn from the district. This left about 295,000 acres to be irrigated within the basin.

Sandhill groundwater is becoming a factor in the power and irrigation projects on the Loup rivers, because it gives a uniform flow to the streams where they leave the sandhills, which discharge becomes less uniform in the hardland courses of these rivers. The Kingsley dam, being built by the Tri-County Project in the North Platte valley about 4¾ miles above Keystone, Keith County, will cost $10,000,000 or more. Its length is to be a little more than 2 miles and the height about 160 feet. The storage capacity of the reservoir is to be about 2,000,000 acre feet which should control the non-irrigation season flow and the so-called flood flow of the river and become a major stabilizing factor in the control of the Platte River and the irrigation of the valley eastward to Grand Island.

The amount of Federal funds to be allocated for the construction of the irrigation and power projects recently constructed or building in Nebraska will be $60,000,000 or more, and the cost of the rural electrification projects may be $20,000,000 or more, making the total allocation for hydro-power, irrigation, and electrification more than $80,000,000.

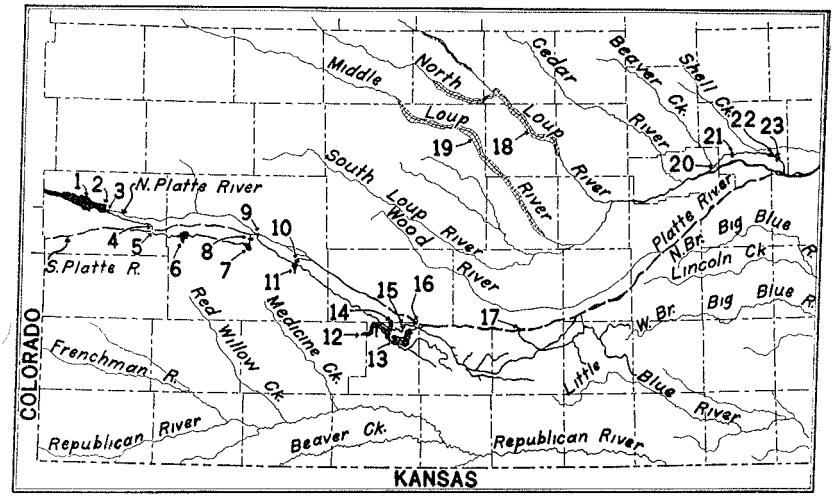

FIGURE 1. Nos. 1, 2, 9-17 show the location of the Tri-County Project; Nos. 3-8, the Sutherland Project; No. 18 the North Loup Project; No. 19, the Middle Loup Project; and Nos. 20-23 the Loup River Public Power Project.

Inter-state Relations. The Republican, Platte, Niobrara, and Missouri rivers are inter-state streams. Also, some of the groundwater, as in the flood plains of the Republican and Platte valleys and in the artesian aquifers, moves underground independently of state lines, being recharged in one or more states and released for use in another state. Consequently, the use and conservation of both the surface water and the groundwater have some inter-state or national relationships which are not adequately covered by state and federal enactments or by compacts between the states concerned.

PUMP IRRIGATION

About 3,000 pumps were operated in the state in 1938 lifting water from wells and streams to irrigate more than 60,000 acres of land, and there is considerable additional land in the state that could be pump-irrigated under proper management. It is also evident that this kind of irrigation should not be undertaken without careful consideration of the quantity, quality, and depth of groundwater, the suitability of the soils, the cost of installation and maintenance, and the economic benefit that would accrue from such development.

Following are some of the questions on pump irrigation that are often received at the office of the Conservation and Survey Division:

1. Q. What has the University of Nebraska to offer in surveys and service on the pump irrigation possibilities of the state?

   A. The Geological, Soil, and Water surveys of the Conservation and

Survey Division of the University have been active for several years in the study, mapping, and description of the geology, soils, streams, lakes, and groundwaters of the state, and the Division serves the state as an information bureau regarding the state's resources and their development.

Pump irrigation practice has been studied by the College of Agriculture and the agricultural experiment stations and the data obtained through these investigations and the surveys noted above are used in the agricultural extension service. A recent bulletin on pump irrigation at the North Platte station may be obtained free upon request by farmers and others.

The county agricultural agents of the state are conversant with the various services of the University. Persons interested in pump irrigation should consult the local agent regarding the proper agencies at the University to contact for information and guidance regarding pump irrigation.

2. Q. What is the best procedure for a farmer to follow in determining whether he has pump irrigation possibilities on his farm?
   A. The farmer should, by investigation and by reliable assistance from others, determine the following:
      (1) Whether his soil is suited to irrigation
      (2) Whether there is adequate suitable water for irrigation and the probable amount that could be pumped from a well or a stream and at what depth
      (3) The type of well or wells to put down, the kind of power and pump to use and the operation costs
      (4) The total cost of installation of pumps, casing, screens, power, etc.
3. Q. What kinds of soil are suitable for irrigation and which are not?
   A. The light, sandy soils are not suitable for irrigation because of their rapid subdrainage and low moisture-holding capacity.

   The silt loam and very fine sandy loam types are suitable. Our best irrigable soils are the silty to fine sandy loam types of the Wabash, Hall, Tripp, Marshall, Moody, Carrington, Hastings, Holdrege, Keith, Dunlap, Yale, Rosebud, Dawes, and Epping series. These are described in county soil survey reports.
4. Q. Where can information on the groundwater formations and the availability and suitability of water be obtained?
   A. From the Water Survey Department of the Conservation and Survey Division, University of Nebraska, Lincoln.
5. Q. Where can information on types of wells, pumps, and cost of operation, etc., be obtained?
   A. From the Rural Engineering Department of the College of Agriculture of the University of Nebraska, Lincoln.
6. Q. How can the amount of water and its availability for pumping be determined in the most economical manner?

A. As a rule, the farmer knows whether a stream is permanent or intermittent and about how much of its water is available for pumping. He can measure the height to which this water would be lifted and should know that allocation from the State Engineer must be secured to pump from a live stream.

The determination of the amount and availability of groundwater requires prospecting which is done in order to determine the depth and thickness of the water-bearing beds and the nature of the materials at all depths in which the water occurs. Fine, water-filled sand makes weak wells and thick deposits of water-filled gravels with wide distribution make strong wells. The complete section of the water-filled ground should be known for use in making the best location of a well, the type and diameter of permanent well to be sunk, and at what depths to place the perforations or screens and the depth to place the pump.

It is not a good plan to make a well and install a pump and power without first knowing the capacity of the ground to produce the necessary quantity of water. Persons engaged in making irrigation wells put down the test holes at a reasonable cost. They save samples of the materials encountered at all depths, and by a study of them can plan the right kind of well to make if the conditions are favorable. The State Water Survey advises regarding these matters.

7. Q. From what depth can water be lifted economically for irrigation?
   A. The depth varies greatly with the kind and value of the crops grown and with the cost of installation and the cost of power for pumping. Professors E. E. Brackett and Ivan D. Wood of the College of Agriculture can answer this question.
8. Q. Is pump irrigation desirable on farms already under canals but with inadequate water supply?
   A. Yes and no. There are places in the state where the water obtained by gravity flow from streams and reservoirs is not adequate every year and the groundwater could be pumped beneficially, but much of the pumpable water in some of these areas is passed into ground storage by percolation from the existing canals and at the expense of the irrigators. Consequently, there is a point here for consideration by those who allocate the surface waters for their most beneficial use. As a rule, it is not equitable for a land owner in an organized district to reserve his land for pump irrigation, especially if the groundwater storage results from the canal irrigation and the land in question could be served by this canal.
9. Q. Are small reservoirs preferable to wells as a source of irrigation water?
   A. The shaly lands of the state are without available well water and reservoirs serve to store rainfall for stock water and irrigation

water. All told, small reservoirs are not very satisfactory because they soon become filled with debris resulting from erosion. Generally, groundwater and permanent streams are preferable for pump irrigation.

10. Q. Will the average farm well supply water to irrigate a farm garden?

A. As a rule, no, unless the garden is small. Farm wells vary greatly in their pumping capacity. Most of them are made and equipped only for light pumping, as for the household and the livestock, whereas, the irrigation requirements are much greater. However, the need now, in most of Nebraska, is for stronger farm wells to be used for the usual purposes and for the irrigation of lawns, trees, and gardens.

Spray Irrigation. Although spray irrigation has importance, the people generally do not realize that it is irrigation. The improved municipal water supplies at Lincoln, Omaha, Grand Island, Kearney, Superior, and other cities make water available for the spray-irrigation of lawns, trees, golf courses, and gardens. As given before, the total area that is spray-irrigated in the state is estimated as 40,000 acres.

Improvements should be made in the spray-irrigation method because much of the water so spread does not enter the soil and become available to plants.

Subirrigation. This, our cheapest irrigation, is subject to control and improvement. There are many places where the groundwater table can be held at the optimum depth for native grass, forest, and cultivated crops. This can be done by distribution of flood water for the recharge of groundwater and by drainage control in which the water table is maintained at the desired depth.

There is extensive subirrigation on the low-lying sandy lands of our principal valleys, and on the hay flats and prairie plains of the Sandhill Region. The total area of the subirrigated land of the state is considerably greater than that under all other forms of irrigation.

Alfalfa is our principal subirrigated crop where the water table is comparatively shallow. Native grasses do best where the water table is near the surface and corn, wheat, and trees where it is at a moderate depth. The seepage lands with alkaline soils are best used for the production of native grass.

The sandy bottomlands and the sandy terraces conserve the rainfall by passing it to groundwater storage which facilitates subirrigation. In fact, subirrigated water is built up in this manner as seepage from irrigation canals and from streams.

Large areas in the middle course of the Platte valley are subirrigated with groundwater recharged from local rainfall, with underflow from the sandhills, and in part with underflow from the river. The problem here, as at other similar places in the state, is to maintain the groundwater table at the most effective depth for the growth of native vegetation and cultivated crops.

HYDRO POWER

The water powers of the state were described by the author in the 1930 Nebraska Blue Book, and, due to lack of space, only the new self-liquidating federal projects are reviewed in this paper.

Amount of Hydro Power. The total generating capacity of the 45 hydro-electric plants operated in the state in 1936 was about 16,000 KW, not including the Lingle and Guernsey plants in Wyoming which have a combined capacity of 7,750 KW. However, these Wyoming projects were built with federal funds assessed against irrigation lands located principally in Nebraska and their current is distributed generally in the North Platte valley.

The two federal projects recently completed in Nebraska were planned to have a combined generating capacity of about 76,700 KW or an annual production of 282,000,000 KW-hrs. of firm power and the Tri-County with its three power projects now building is expected to have a capacity of about 54,000 KW, producing about 218,000,000 KW-hrs. of firm power annually, making the probable total annual output about 500,000,000 KW-hrs. for all projects.

The purpose of the advocates of water power development is to obtain the dual use of water, i.e., for power and irrigation where possible and feasible, and with the increased growth in population and industry, develop power at the North Loup, Middle Loup, and other projects to supply the market demand. Following are summarized data on the two large new power projects.

Platte Valley Public Power and Irrigation District, known as the Sutherland Project, location shown by Figure 1, data summarized as follows:

1. Diversion dam, west of Keystone, Keith County
2. Supply canal, length 33 miles, including a big cut, and a siphon under the South Platte east of Paxton
3. Sutherland Reservoir; area 5,000 acres, capacity about 175,000 acre feet
4. Outlet canal, length 20 miles, capacity 1,400 c.f.s.
5. Regulating reservoir, area 1,600 acres; capacity 19,000 acre feet
6. Power house, southeast of North Platte; generating capacity, 29,000 KW; annual production, about 100,000,000 KW-hrs. firm power
7. Head, 206 feet
8. Turbines, 2
9. Cost of project $7,500,000, subsidized by federal government repayment to be made from the sale of power and supplemental water for irrigation

The Sutherland project had a shut-down due to a break in the siphon and is having difficulty with seepage from the reservoir located south of Sutherland. The siphon has been repaired and it is planned to control the seepage loss.

The Loup River Public Power Project, location shown by Figure 1, data summarized as follows:

1. Priority date, September 15, 1932
2. Allocation, 3,500 second-feet, diverted from the Loup southwest of Genoa
3. Length of canal, about 35 miles
4. Regulating reservoir, area 1,006 acres; capacity, about 11,000 acre feet
5. Power houses, two, known as the Monroe and Columbus plants, generating capacities 7,800 KW and 39,000 KW, total about 47,700 KW; annual production probably 182,000,000 KW-hrs. of firm power
6. Turbines at Columbus, three; diameters 20 feet, length 300 feet
7. Head, 32 feet at Monroe and 112 feet at the Columbus plant
8. Tailrace or spillway, from Columbus power house to the Platte River southeast of Columbus
9. Project construction cost about $15,500,000 subsidized by federal government, self-liquidating, repayment to be made from sale of power. This cost includes that of several hundred miles of transmission lines.

Transmission Lines and Rural Electrification. The large federal power projects are being tied together by 2,000 or more miles of high voltage transmission lines in order to avoid standby costs and to increase the dependability of service. The hookup will include the Sutherland, Tri-County, Columbus, and other projects and will serve the rural electrification districts and the institutions and municipalities of the state. The cost of this rural electrification distribution system will be $20,000,000 or more.

According to press reports, a movement sponsored by the Federal government is now underway to purchase the privately owned hydro-power plants and the fuel-using electric generating stations and their transmission lines and to combine them with the publicly owned hydro-power system to form a giant power project which, if necessary, would become a factor in national defense.

WATER CONSERVATION

The discussion under this head is a brief review of (1) water policy, (2) flood control, (3) navigation, (4) water pollution, (5) sanitary well water, (6) control of artesian wells, (7) springs, and (8) water treatment.

Water Policy. The water conservation policy of the state is based on factual surveys, conditions of occurrence, needs, vested rights and beneficial use, and as now understood, the water resources are to be allocated and developed for the maximum use and benefit to the state. This means, for example, that the waters of the Platte valley should be conserved for multiple use for wildlife, power, irrigation, subirrigation, domestic and industrial purposes, i.e., by repeated diversion, storage and use in proper sequence from the Colorado and Wyoming lines to the junction with the Missouri. Other phases of the water policy relate to the conservation and development of groundwater, soil moisture, springs, small streams, and the marshes and lakes.

Flood Control. Every large stream of the state has reached the flood stage in some part of its course. However, the 1935 flood of the Republican was the outstanding one of record in the state because of its magnitude, damage to property, and the loss of human life.

Just how to control the floods of the Republican and other rivers of the state is not agreed due to the relation their regulation might have to irrigation and other water use, and to conservation.

Reservoirs are advocated for the control of the Republican floods, but they would be emptied when the water should be held for irrigation and other purposes. Consequently, it may be advisable to compromise by planning control measures that will not conflict so strongly with water use for irrigation.

Some hold that the cost of complete flood control on the Republican would be prohibitive and therefore not feasible and that a better plan would be to adjust the land-use in the valley so that the farm homes and the towns would be placed on the terraces and slope lands and much of the floodable land would be used for grazing, native hay production, forestation, and some farming.

To straighten the Republican without the installation of river control measures would result in the erosion of a deeper channel and the drainage of groundwater from the bottomland of the valley and thus remove the well water supply.

Engineers of the War Department are now making field surveys to determine how to control the floods, and others are engaged in making a setup for irrigation. The findings of these and other groups will serve in deciding what should be done to regulate the flood hazard and the water and land use of the Republican and other valleys.

Navigation. Although a few row boats and small motor boats use our streams, lakes, and reservoirs in season, there is no navigation proper within the state. However, the Missouri river is being made navigable as far north as Sioux City. Just how beneficial this development may be to Nebraska cannot be adjudged at this time, yet, Federal engineers have reported favorably on the project.

The structures being installed to control the river within a definite course will also prevent bank erosion and thereby the destruction of agricultural land along the river. The Fort Peck reservoir in Montana, is intended to regulate the river flow by storing its flood discharge and releasing it during the low stages of the river. This, too, should prove beneficial to Nebraska.

Water Pollution. Our streams are being polluted by garbage, industrial wastes, and sewage, making them unsightly, and filthy. Pollution of the lakes makes them unsafe for bathing and in some cases too foul for wildlife and boating.

Shallow groundwaters absorb the odors and products of decaying organic materials, becoming unfit for drinking purposes. Micro-fauna and flora including bacteria live in surface waters and to some extent in ground-

water. The presence of nitrifying bacteria and Bacillus colon in water indicates that it may not be safely potable. As a rule the deeper waters filtered through sand and gravel are quite free from pollution.

Pollution, which is becoming a menace in Nebraska, should be regulated and controlled. Our state should no longer permit untreated sewage to be run into the creeks and rivers.

Sanitary Well Water. Most of the state's drinking water is drawn from groundwater through wells, only a few cities being supplied from streams. Generally, except in a few small areas, there is abundant well water in the state, yet some town wells and many farm wells are not very sanitary.

The Geological and Water surveys have been active the past few years in a survey of the water-bearing formations, and a study of the source, depth, quality, and the direction and rate of movement of the groundwater. Also, the surveys perform an advisory service in the location of sanitary wells. The following principles relate to well water conservation in Nebraska:

1. Open wells are not sanitary.
2. The well driller must know the structure of the land, the depth of the water table, and the direction of the groundwater movement in order to determine the sanitary location of a well.
3. Wells should be located where they do not catch polluted underflow from privy vaults and other sources. This means that they should be located up-gradient (water table slope) from pollution.
4. In the case of a farm home, town, or city located in a broad valley, the well or wells should be placed up-valley and the sewage disposal down-valley from the home, town, or city.
5. Every municipality should protect its water-producing ground against pollution or re-locate the water supply on clean ground that can be protected.
6. Wells should be graded up and enclosed to prevent the entry of surface drainage and the trapping in them of frogs, mice, rats, and other animals.
7. In places where the groundwater is separated by clay layers as first, second, and third waters, the well should be sunk to the lower water-bearing sands and the upper water, which may be polluted, should be cased off.
8. Spring water from polluted ground should not be used for drinking purposes.

Control of Artesian Water. There are more than 1,500 flowing wells in Nebraska, their depths ranging between 50 and 2,000 feet. Many of them supply good potable water whereas others yield saline or heavily mineralized water.

At places, as in the northeastern counties, the artesian water in the Dakota sandstones is the only dependable source of the rural and urban water supplies. Unfortunately, however, many of the wells sunk to this horizon in South Dakota, northwestern Iowa, and Nebraska in years past

have been allowed to flow unrestricted, resulting in water wastage and the reduction of artesian pressure.

The wastage of this artesian water has continued too long, with unfavorable results. North Dakota has enacted a law for the control of artesian wells, and the Nebraska legislature passed a joint resolution directing the State Geological Survey to take the necessary steps to protect the artesian waters of Nebraska. As a result, this wastage has been controlled at a number of places in Nebraska, and it seems now that the duties of the Survey in this line should be further defined by law.

Springs. Many of our springs are used for rural and some for urban water supplies. A number of them have been improved, i.e., made more sanitary and usable with less wastage. Since the summer of 1934, federal funds and relief labor have been used in the development of springs in areas where there is scant well water supply.

The average spring issuing from shallow groundwater on the hill-side or from a boggy place along a bluff line is not safe for drinking purposes and should be avoided. Only those springs coming from clean ground are safe.

Water Treatment. Polluted waters are not safe for domestic use without treatment with chlorine, iron sulphate, or other materials, and water having physical defects in color and turbidity should be corrected by sedimentation, the use of coagulants, or by filtration. Finally, water softeners are used to correct the hard waters, and certain materials are used to remove excess iron or manganese. Thus far no practical method has been found for making salt water potable.

Much of the well water of our state is naturally safe and suitable for drinking, and water treatment is less common than in other states. The careless disposal of sewage and industrial wastes pollutes our groundwater, lakes, and streams, and makes water treatment more necessary than in the past. The State Department of Health passes upon the potability of water supplies.

Well Drillers Association. The Nebraska Well Drillers Association is one of the largest of its kind in the United States. Its members cooperate with the Geological and Water surveys of the University in a program of water well improvement and groundwater conservation. The surveys offer annual short courses and extension service for the drillers, and they report to the Surveys on well logs, the depths and types of wells, and other valuable data.

SOIL CONSERVATION

Changed Conditions. Formerly much of the area of the United States States now used agriculturally was covered by prairie, marsh, or by forest. The change in landscape progressed westward with our forefathers who subdued the prairie, marsh, forest, and wildlife. Our predecessors had little technical guidance from federal and state agencies regarding the use and conservation of resources. Evidently they did what seemed to be necessary under the conditions of their day yet from our point of view some of their practices proved to be wasteful and destructive.

Following the too general removal of the prairie in Nebraska, the cultural practices that were followed generally caused much wastage of the land resources. The sandy lands in parts of the state became wind-eroded; the organic matter content of the soils was reduced under single cropping to corn or wheat; the topsoil of the hilly lands was removed by sheet erosion; the farms were gullied by accelerated runoff; the clear streams became loaded with silt; the bottomlands were sanded locally with debris washed down from the uplands; and with it all, much of the native wildlife disappeared.

The removal of topsoil from the hilly lands and the depletion of the organic matter in the subhumid regions of the state have reduced the rate of absorption of rainfall and increased the rate of surface runoff on certain types of soil. The gullying of the land carried away vast quantities of soil-forming material, drained much groundwater, and lowered the water table. Finally, the wastage of the land and water resources reduced the carrying capacity and value of much of our best farm land.

Although Nebraska has not wasted her land resources to the extent that many farms are being abandoned and there is a breakdown in agriculture, it is evident that there has been soil and water wastage and that this has caused reduced per-acre yields of farm crops. And it is now generally agreed that the unfavorable conditions that have developed can and must be corrected.

There and Here. In contrast with the unfavorable conditions found in parts of the United States and in some other countries, there are places as in England, Germany, France, and Japan, where the lands have been farmed for centuries without reduction in their producing capacity which means that we should learn from the experience of other states and other countries.

Nebraska is a young state, and fortunately the wastage of her soil has not been carried to a point beyond recovery. The conditions here are unlike those in places where the people are impoverished because the depleted soil no longer produces the necessities of human life.

Right Land-Use. There are many examples of proper land and water use in Nebraska. These are the highlights of our landscape. They are credit entries in the economic history of the state.

Recovery. The record of farming in Nebraska has been too generally a "hit and miss" proposition with respect to the conservation of the land and water resources, but fortunately the unfavorable conditions that have come about are now recognized, means for adjustment and recovery are available, and the land owners and operators generally have the purpose to conserve the soil.

SOIL CONSERVATION SERVICE

Organization. The Federal Soil Conservation Service, in cooperation with the College of Agriculture and the Conservation and Survey Division of the University of Nebraska, is engaged in a soil and water saving program in Nebraska. The cooperative work began in 1934 in Boone and

Nance counties and is now functioning through three demonstration projects, several CCC camps and three soil conservation districts, and new districts are being organized.

Soil Conservation Service Administration. This administration centers in Dr. H. H. Bennett, Chief of the Bureau at Washington, A. E. Jones, Acting Regional Conservator at Salina, Kansas, H. E. Engstrom, Coordinator for Nebraska, and in the State Soil Conservation Committee composed of W. W. Burr, Dean of the College of Agriculture, W. H. Brokaw, Director of Agricultural Extension, H. E. Engstrom (Secretary), and G. E. Condra (Chairman), Dean and Director of the Conservation and Survey Division.

The Soil Conservation Service started with demonstration projects, CCC camp work, and later districts were formed. According to present plans the demonstration projects are not to be continued indefinitely, and the CCC camps may be discontinued before long. This means that the time will come when the farmers must do most of the control work on their own farms, but will receive technical assistance from the Soil Conservation Service.

Program of Work. The complete program of soil-water conservation work in Nebraska includes the following:

1. Gully control
2. Contour farming
3. Strip cropping
4. Terracing
5. Systematic crop rotation
6. Winter cover crops
7. Pasture and range land management
8. Construction of farm ponds and reservoirs
9. Planting shrubs and trees for shade, erosion control, wildlife preservation, windbreak, fire wood, posts, and landscape beautification
10. Protection of woodlands and grasslands from fires and careless management and use

The kind and amount of erosion control work varies with farms and greatly so in the various soil regions of the state. No work is done without the approval and cooperation of the land owner.

State Soil Conservation Committee. The last legislature passed an act creating a State Soil Conservation Committee to represent the state in the organization, administration, and dissolution of the Soil Conservation Districts. The law was not entirely satisfactory to the officers of the United States Soil Conservation Service nor to some citizens who opposed the formation of districts, but most of the objections to it have been discussed generally and apparently with more agreement than at the beginning. The only difficulty now, after the organization of four districts, is our inability to secure from the Soil Conservation Service the funds and equipment that are needed. However, the Service has assigned technicians to the districts and it may be that too much was expected in the way of equipment and finance.

Since recent departmental reorganization at Washington has extended the Soil Conservation Service to include practically all phases of soil and water planning and use, and since this enlarged service is to cover both land and water conservation in Nebraska, it would seem desirable and necessary that statutory authority be given the State Committee to allocate the waters of small streams, and groundwater, for pump irrigation and other farm use. And, since farm ponds are to be made and drainage is to be installed where feasible and denied where not beneficial, authority should be given the Committee to allocate water for pondage and to pass upon the drainage of agricultural lands. In other words, the Soil Conservation Service is now planning land and water use, doing erosion control work, constructing water facilities, and covering practically the whole field of practical conservation relating to soil, water, forest, wildlife, and agriculture, and the duties of the State Soil Conservation Committee should be redefined to correlate with the services of the federal department so that the interests of the state may be represented at every point.

GRASSLAND RESOURCES

When white men reached the area now known as Nebraska, they found that the plant life, animal life, and the Indian held natural relationships closely correlated with the environmental factors. The kinds, distribution, and condition of growth of grasses, shrubs, trees, and native animals were long-time indices of natural land and water use and of climatic influence, but until recently, we, not recognizing the fact that the native grasses constitute an important resource, destroyed them and planted the seeds of grasses and cultivated crops brought from regions unlike those in Nebraska, which procedure has proved very unsuccessful in places.

It has taken severe drouth to prove the value of grassland and to demonstrate the fact that the native sod is a resource which affords grazing or hay every year whether wet or dry. The old prejudice against native prairie as expressed by terms "raw" or "unimproved" is not well founded, because some prairie lands are damaged and not improved by plowing, and because it is possible to develop grass lands to an increased capacity for grazing and hay-producing.

Fortunately large tracts of Nebraska's original grassland, as in the Sandhill Region and other sandy areas, have been preserved in the natural. The grasses protect the soil from wind erosion and support successful grazing. And, it is certain that much of our shaly land and certain other areas of the state should be regrassed and used for grazing.

AGRICULTURAL FORESTRY

Nearly three per cent of the area of Nebraska is occupied by natural and planted forest. The nature and distribution of the forest resources were briefly described by the author in the 1930 Nebraska Blue Book and are not to be discussed here because of lack of space. The trees of the state were described by Dr. R. J. Pool in Bulletin No. 7 of the Conservation and Survey Division.

The Place for Trees. Trees, like the native and cultivated grasses, have an important though neglected role in the use of land. For very obvious reasons, we should grow more shrubs and trees on our farms, ranches, rural school grounds, and recreational areas. This will require an agricultural forestry program for Nebraska as an integral part of the conservation program.

Nature has given us considerable areas of pine and hard wood forest which should be protected against destruction by fire and thoughtless cutting. Without trees and forest there can be no walnuts, hickory nuts, hazel nuts, and sylvan flowers and animals.

Forestry Program. For several years the federal government has carried on a forestry program for the conservation of timber and other resources, mostly on federally-owned land where forests occur naturally. However, agriculturists and foresters now realize that there is a phase of forestry related to the conservation of water, land, wildlife, and livestock and to those intangible social benefits relating to human comfort and the increased happiness of living.

Agricultural or farm forestry in Nebraska must cover a wide area with variations in climate, topography, groundwater, soil, population, and types of agriculture. Therefore, it is necessary that a sound program be provided not only for different types of planting, but also for different methods of application.

Cooperative Program. National, state, and industrial interests would be affected directly by such a program which should be on a truly cooperative basis: first, in the federal departments involved in conservation; second, with the state to which the program applies and where in most cases individual programs are now in operation through the College of Agriculture and, third, the commercial nurseries which are now and have been for years interested in this type of development and improvement work.

Kinds of Trees. Much has been learned through the Biological and Forest surveys regarding the kinds of trees and shrubs that will grow and survive under the Nebraska conditions. This means that in the future only those species that are adapted to the climate, water, and soil conditions should be planted in Nebraska.

Legislation. Present legislation seems to be inadequate to conduct a tree-planting program such as is needed. There should be legislative authority broad enough to include all phases of rural tree planting in Nebraska, and ample authority to include full exercise of cooperative effort between federal agencies, state, counties, municipalities, individuals, and private institutions. The statutes of our state place the forestry activities under three agencies, viz., the Conservation and Survey Division, the College of Agriculture, and the Game, Forestation and Parks Commission. It would seem that the state law should be amended to assign the research and survey phases of the work to the Forestry Department of the Conservation and Survey Division, the general educational and agricultural program to the Forest Extension Service of the College of Agriculture and restrict the forestry program of the Game, Forestation and Parks Commis-

sion to service on the state-owned recreation areas and state parks. This would prevent duplication of activity and develop a coordinated program.

Objectives. The objectives of an agricultural forestry program should be to maintain and improve agriculture and living conditions, by:

1. Conserving the soil and improving moisture relations
2. Protecting farm crops, gardens, etc., from critical hot winds
3. Improving wildlife habitat
4. Producing wood products, primarily fuel, fence posts, and rough lumber
5. Protecting people and livestock from climatic extremes and improving living conditions in general
6. Protecting the natural and planted forests for the most beneficial use that can be made of them

WILDLIFE CONSERVATION

The main wildlife resources of the state are the fish, song birds, game birds, and the game and fur-bearing mammals which were briefly described by the author in the 1930 Nebraska Blue Book. In addition to the classes of life just named, there are many kinds of micro-flora and fauna and of insects, etc., that are feed for the higher animals, and which in this respect constitute the biological base or background of the economically important wildlife. In other words there are natural resources for the fish, birds, and mammals, a knowledge of which is important in wildlife management.

When white men reached the area now known as Nebraska, the waters, prairie, and forest were thickly populated with wildlife. The plant life, animal life, and the Indian were closely correlated with the environmental conditions, but all this has been changed.

We killed most of the original stock. We destroyed the natural living conditions of fish, birds, mammals, and other forms, and are now trying to "conserve" the remaining wildlife for fishing and hunting, knowing as we must, that the only way to save this life is to make it possible for it to live and reproduce.

The destruction of brush land and forest, the burning and overgrazing of prairie, the draining of marshes and lakes, the straightening of streams, and the pollution of streams and lakes have destroyed the habitat relations of wild flowers and wild fruits, and the homes and food relations of the native song birds, game birds, fish, fur-bearers, and other forms and has changed the migration ways of the avian fauna. Consequently, the first thing to do now, if we are to really conserve wildlife, is to restore its suitable habitats. This means, for example, that for their survival there must be permanent waters suitable for fish; brush land for quail; trees and shrubs for song birds; prairie and natural feed for grouse and prairie chickens; water and feed for ducks, coots and shore birds; refuge areas for the breeding and migrant wildlife, and the close regulation of fishing, trapping, and hunting.

Cooperating with state and federal departments, the Biological Survey of the Conservation and Survey Division is making close studies of the

wildlife habitat, and the natural feed relations of fish, prairie chickens, grouse, and ducks. It has studied and mapped the Valentine Lakes Refuge and the Niobrara Game Preserve, and the Water Survey is now investigating the feasibility of impounding the waters of small streams and how to control lake levels in the Sandhill Region.

CONSERVATION OF SERVICE

During the depression and period of drouth, many new federal agencies were set up to perform temporary services in survey, agriculture, conservation, and relief. Some of them have performed efficiently in Nebraska and most of them expect to be placed on permanent status.

The salary and maintenance schedules of the new activities, as for the SCS, CCC, WPA, PWA, ACP, and the BAE, being considerably higher than those of the long-time departments, caused a shift of personnel to them which tended to disorganize some of the survey and service departments of the University and state. Some of the new activities have not been free from political bias and this has made a distinction between them and the University agencies which must not be partisan.

Although an attempt was made to coordinate the service of the new agencies with the work of the older federal, state, and University departments, this was not fully accomplished, nor was it feasible to do so in all cases because of their different objectives. Some people now claim that a better plan to have followed from the start in the placement of the new agencies would have been to affiliate them with departments that were performing the services that were to be expanded, and that this, if done, would have required smaller personnels, reduced the overhead cost, developed closer cooperation between the state and federal agencies, and have given more efficient service at less cost.

It is clear now that only those survey, research, and service activities which operate free from political influence remain in good standing with the public generally. And, it is claimed by many, that considerable retrenchment may be made in the new activities and probably some adjustment of the older activities. This, if done, will call for an evaluation of the new and older agencies and the discontinuance of those that are no longer needed, or have no definite field, or cannot show good reason for their continuance.

The purpose of the statement preceding is to call attention to the fact that in a coordinated program for the development of resources the principles of conservation should be applied to public service generally and to conservation activity in particular as well as to the natural resources. In other words the activities relating to conservation should be scrutinized very closely and standardized. This means, in effect, the conservation of conservation.

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