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The Conservation of Nebraska's Water Resources

G. E. Condra

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BULLETIN 3

CONSERVATION DEPARTMENT

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CONSERVATION AND SURVEY DIVISION

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By G. E. Condra

Conservation is use without waste

Introduction.—Oxygen is the first immediate necessity of life and water is second. Both directly and indirectly and more than soil, water is our most basic resource. It is the universal solvent and without it there would be no life, and, of course, no agriculture and industry.

The largest economic use of water in Nebraska is in the growth of native vegetation and cultivated crops, and the amount of water available for these purposes in most of the state is a controlling factor in agricultural production. According to Prof. T. A. Kieselbach of the Agronomy Department of the College of Agriculture of the University, the water requirements in Nebraska for four of the principal crops for transpiration and growth are about as follows:

1. Corn, 267 to 400 pounds of water for each pound of dry matter produced or about 6.2 acre inches = 22,506 cubic feet = 168,330 gallons per acre for a crop of 50 bushels.*
2. Wheat, 264 pounds or more for each pound of dry matter or about 5.5 acre inches for a crop of 30 bushels per acre.
3. Oats, 414 pounds or more for each pound of dry matter or about 6.4 acre inches for a crop of 60 bushels per acre.
4. Alfalfa, 858 pounds or more for each pound of dry matter = about 22.6 acre inches for a yield of 2½ tons of hay per acre.

The above requirements, which represent the amount of water passed through plants by transpiration, do not include the amounts of water lost from the soil by evaporation and percolation during the growing season.

A second important use of water is by farm animals. According to Prof. H. J. Gramlich, Chairman of the Department of Animal Husbandry of the College of Agriculture of the University, the daily consumption of water by some of the farm animals is about as follows:

1. Cows, 150 pounds or about 18 gallons each.
2. Steers, 125 pounds or about 15 gallons each.
3. Horses, 75 pounds or about 9 gallons each.
4. Hogs, 15 pounds or about 1¾ gallons each.
5. Sheep, 12 pounds or about 1⅔ gallons each.

Man is the greatest water user. He requires it for drinking, bathing, cleaning, washing, heating, sewage disposal, agricultural development, manufacture, power development, and navigation. His percapita consumption for domestic purposes alone has advanced from a few gallons

* The following data may be of use in making detailed computations.
One acre = 43,560 square feet.
One square mile = 27,878,400 square feet.
One cubic foot of water=7.48 gallons.
One cubic foot of distilled water weighs 62.4 lbs. and one gallon 8.342 lbs.
One cubic foot of average ground water weighs about 62.5 lbs.
One acre inch of water = 3,630 cubic feet = 27,152 gallons.
One acre foot of water= 43,560 cubic feet = 325,824 gallons.
One square mile=640 acres or 27,878,400 square feet.
It would take 208,527,360 gallons of water to cover one square mile one foot deep.

per day among some rural peoples to seventy-five gallons or more a day in cities. We face the problem of maintaining dependable water supplies for country, town, and city.

CHANGING THE ENVIRONMENT.—Primitive people fit into nature's ways without much modification of the environment. Contagion and famine result. We adapt to the environing conditions and develop the natural resources according to technical plans and thus reduce the hazards of flood, drouth, disease, and famine. Our big problem along this line in Nebraska at this time relates to the development of certain water resources.

NATURE OF WATER RESOURCES.—Water is the greatest circulating medium, ever changing in condition of occurrence in the ocean, atmosphere, and land. It becomes vapor, cloud, rain, hail, snow, ice, lake, ground water, stream, and again the ocean. The first great reservoir and source of water is the ocean from which the lands are supplied through the atmosphere. The second important place of its concentration is on and in the land.

Bodies of water standing on the land together with the springs and streams are called surface water. Water absorbed by the soil, subsoil, and bed rock is known as ground water. All forms of water accumulation are in motion, as by wave, stream flow, capillarity, and percolation or underflow, and a knowledge of these forms and conditions of occurrence is prerequisite to an understanding of water conservation.

THE RAINFALL.—Few people realize the importance of rainfall, its volume, distribution, and relation to other forms of water accumulation. However, many of them watch the rainfall record rather closely, in the belief that the amount of precipitation is a factor in agriculture.

The precipitation has been measured in Nebraska for about sixty years, and the Government records show that the mean annual rainfall for the state is about 23½ inches, ranging from about 33 inches in the southeast corner to about 16 inches at the western border, and that of this, less than two inches comes from the snowfall.

The rainfall is the state's most important annual income. It is not subject to increase by any means known to man, yet ways are known whereby it can be better conserved and better utilized.

VOLUME OF RAINFALL.—The mean annual rainfall per acre in Nebraska is equal to a little more than a storage volume 44′ x 44′ x 44′ = 85,305 cubic feet = 638,081 gallons. This is equal to the discharge of the Niobrara River for about 1½ minutes.

The mean annual rainfall per square mile in Nebraska is 54,595,200 cubic feet = 216,371,810 gallons = the flow of the Niobrara for 12 hours.

The annual rainfall for the state is about 98,182,454 acre feet, which is more than 81 times the capacity of the Pathfinder Reservoir. It is about equal to a mass one mile wide on the length of the state with a depth of 518 feet at the east end and 259 feet at the west end. This is equal to a volume more than 263 feet high on a county 24 miles square.

DISPOSAL OF RAINFALL.—The rainfall is a mobile resource. Its mode of occurrence and seasonal distribution present interesting problems. Its natural disposal is as follows:

1. The largest portion of it sinks into the land, becoming ground water.

2. Part runs off at once, accumulating in basin-like depressions as ponds or lakes, and in the valleys as streams. This disposal is called the "direct run-off".
3. A very small portion is absorbed at once by plants and animals.
4. A small portion is evaporated directly from the surface of the land and therefore does not run off or sink into the ground.

Evaporation is comparatively high in Nebraska, from soil, free water surfaces, and the plant cover, due to the hot summers, relatively low humidity, and winds. The spring and summer evaporation loss from a free water surface, as a lake, is thought to be about 35 or 40 inches in the eastern part of the state and about 40 to 48 inches in the western counties. The ratio of ground water absorption (soak-in) to the rainfall is high, and the ratio of direct run-off to the precipitation is comparatively low. All of which means that the amount of rainfall is not the final, limiting factor in agriculture. Much depends on when it occurs and what becomes of it, whether dissipated or stored for use.

GROUND WATER.—Most but not all of Nebraska is occupied by deep soil and subsoil and thick, open textured mantle rock formations. These conditions facilitate the storage of a relatively large amount of the rainfall as ground water. The general condition is unlike that of places where the soil is shallow on impervious bedrock, causing a large amount of the rainfall to become direct run-off and not pass into ground storage.

There are two main forms of ground water accumulation; (1) the soil and subsoil moisture or capillary water, and (2) the saturated zone of freewater below the water table. This latter accumulation is very extensive, being many times the rainfall and surface water combined. It is the source of well water and springs and supplies the moisture of the capillary fringe zone just above it, from which sub-irrigated crops are grown.

In much of the state, the soils and thick subsoils have a high water holding capacity, and most of the state is underlain by thick layers of sand and gravel making abundant storage capacity for free water, which is of good quality. The importance of these favorable conditions for ground water storage is not generally understood and appreciated.

A close survey of the ground water resources of the state is being made by the Water Survey Department of the Conservation and Survey Division in cooperation with the U. S. Geological Survey. It covers such matters as the distribution of water-bearing formations, origin of ground water, direction and rate of underflow, chemical composition of water, volume of water available for well irrigation and other uses, and keeping the water table record as to depth, draw down, and seasonal fluctuation.

VOLUME OF GROUND WATER.—As has been stated, the amount of ground water in Nebraska is many times greater than the surface water. It is more than eighteen times the rainfall of an average year. This resource is more hidden from view than the surface water, hence its economic importance is not so apparent to most people.

The question has been raised from time to time regarding the depletion and permanence of the ground water supply, but no one has given the question much serious consideration, because there is no marked

depletion in most of the state. There are places, however, where the water table has been lowered several feet by wasteful practice and drainage, and on a basis of this experience, we might become unnecessarily alarmed.

On some of the uplands where alfalfa has been grown continuously for several years, the capillary water of the soil and subsoil has been exhausted down to a depth of twenty-five feet or more, and apparently none of the soak-in from the rainfall now percolates to the saturated zone from which well water is drawn. Such condition results in lowering the water table and the exhaustion of the deeper ground water except where it is supplied by underflow from other places.

Much ground water has been lost from Nebraska in late geologic time, due to the erosion of deep valleys in the broad plains of the state and the consequent underflow and drainage therefrom. This has been true of some of the table lands in which the water table has lowered 200 or more feet, and of the western part of the Loess plains area where it has dropped 100 or more feet. Similarly the valleys in all parts of the state have been the leakage ways and drainage ways of ground water. However, there are places where much river water now passes into bottomland storage from which it drains to sands under the uplands. Fortunately, there remains much ground water especially in the table lands, Loess plains, and sandhills. This does not include the water in the deeply buried formations, most of which is too heavily mineralized for domestic purposes.

It is not easy for every one to understand how the volume of ground water is determined, which, in brief, is as follows. First, the thickness and distribution of each water-bearing formation is determined largely from well logs. Second, the thickness and volume of the water-filled zone is likewise determined, and third, on a basis of the porosity or voids, the percentage of water per cubic foot or other unit is ascertained. Having these data, the amount of water for any given storage area can be calculated. The sandy bottom ground storage along the middle course of the Platte ranges between 100 and 200 feet in thickness. The water storage zone of the Loess plains area is between 100 and 300 feet or more in thickness and that of much of the Sandhill region is 300 to 600 feet in thickness. For each of these areas at least 30 per cent of the storage mass is water. So, at a point where there is 150-foot section of ground water storage, the water is equal to about fifty feet of the section and at a point in the Sandhills where the storage is 600 feet in thickness there would be 200 feet of water. However, the production of this water from wells is not so simple as it may seem, because in many places its occurrence is in deposits which vary in texture from silt to gravel, from which there is corresponding difference in the rate of delivery of the water.

The amount of ground water in the state, in the mantle rock and comparatively shallow bed rock is thought to be equal to a mass on an area 10 miles wide across the length of the state and 720 feet deep. This is our greatest water resource. Its conservation receives too little consideration.

WHEN THE WELL RUNS DRY.—In some small areas of the state, there is no ground water suitable for drinking purposes. In other small areas there is little ground water and the wells are weak, becoming

dry or nearly so at times of drouth to again increase in strength after wet years. At some of these places, the yet deeper water is saline or alkaline, making the water supply problem difficult to solve.

The proper method to follow where the conditions are as noted above, would be to conserve the well water for house purposes and make ponds for stock water or sink stock wells where water can be found on the farm. The only other alternative is to locate a water supply at some point and pipe it to the house and feed lots, if it can be done, or first develop a water supply and then erect the farm buildings near it. The whole of the difficult situation can be improved by not wasting the well water during periods of adequate supply.

ARTESIAN WELLS.—Several of the bedrock formations of the state carry water with sufficient pressure or head to cause a flow when topped by a well. The shallow flowing wells, 80 to 600 feet deep, are in the Pleistocene and Tertiary deposits and the deeper ones extend to the Dakota, Pennsylvanian, and yet older formations, some being 1,000 to 2,600 feet or more in depth.

There are at least 1,500 flowing wells in the state, many of them in the Sandhill region. They are used for about the same purposes as other wells, except those with mineralized water are used for sanitarium and bathing purposes..

Many of the flowing wells are allowed to waste their water, and many of them have ceased to flow because of the rusting of their casing. All told, the artesian waters of the state have not been used to much advantage except in places where there is scant shallow well water and in parts of the Sandhill region where the wells are shallow and not expensive. At Beaver Crossing, flowing wells are used in the development of a small stream and ponds for trout culture. There are a number of places in the state where artesian water is impounded in fish ponds and lakes.

SOIL MOISTURE CONSERVATION.—Nebraska's water problem begins with the rainfall and the attempt made by farmers to store as much of it as possible in the soil. As has been stated, the amount of rainfall is not a final check on agricultural possibilities. Rather, the ratio of soil moisture conservation to the amount of evaporation, run-off, and other water losses, is the more important.

The College of Agriculture and the Agricultural Experiment Stations have studied the soil moisture problem, especially of the sub-humid lands. This study has related to the soil section, moisture storage, evaporation, crop selection, plant spacing, soil mulch, cultural methods, and tillage equipment. It has shown that weeds rob the soil of much moisture and that they should be kept down as completely as possible as a measure in moisture conservation. Clean cultivation and early fall plowing or disking soon after the removal of a crop, such as wheat or oats, saves much moisture which otherwise would be used up by weeds and not retained for the growth of cultivated crops.

Just how beneficial the agricultural researches on soil moisture may prove to be remains to be seen, yet many farmers now use the results of these investigations, most of which have been published and made known generally through the Agricultural Extension Service.

USE OF SOIL SURVEY.—The State and Federal Soil Survey, which has been completed for sixty-seven counties of the state, maps and describes the soil types, which differ much in texture and profile and therefore in their moisture-holding capacity. Some soils are capable of holding little moisture and are drouthy regardless of the amount of rainfall unless they occupy a position near the water table and are fed by capillary fringe water; otherwise they should be retained in the native sod. Many of the soils in the sub-humid areas are quite well adapted to farming under a relative low rainfall. All of which means that the Soil Survey reports should be used more largely because a knowledge of soil texture and soil profile, which they give, is indispensable in soil moisture conservation.

DIRECT RUN-OFF AND SOIL EROSION.—A good deal has been said and written about run-off and soil erosion. Much of it has been based on hasty observation rather than on close study, with the result that only a general qualitative analysis of the subject has been accomplished. However, carefully planned run-off and soil erosion studies are now being made by the U. S. Bureau of Chemistry and Soils in cooperation with the State Soil Survey and the College of Agriculture. This co-operative investigation is to determine the nature and amount of run-off from the leading soil types. Such study is highly important, with a larger relation to agriculture than stream gaging, which has been done in the state for several years.

It is not yet known definitely what per cent of the rainfall runs off each drainage basin, let alone the amount from each leading kind of soil, which is the more important from the standpoint of general agricultural development. Ultimately, however, exact data are to be worked out and made available on soak-in, evaporation, and run-off. This will afford a technical basis for soil moisture conservation.

A few weeks since, the writer, in company with Mr. H. H. Bennett, Director of the Erosion Investigation work of the United States, and Professor J. C. Russel of the College of Agriculture, spent four days in the field in an attempt to determine to what extent soil erosion has become a problem in Nebraska. Mr. Bennett reached the conclusion that we face a rather serious situation in the Drift hill and Loess hill areas of the state where there are many examples of sheet erosion and deep gulleying. He referred, not to examples of natural erosion which are beyond the power of man to correct, but to those cases which result from bad farm management and could be prevented.

Sheet erosion, which is quite common in parts of Nebraska, removes the rich top soil, reduces the water-holding capacity and fertility of the soil, and lowers the value of the land. However, methods are known whereby much of this erosion can be prevented and relatively more of the rainfall caused to soak into the soil and not allowed to run off, digging gulleys and flooding the bottom lands and rivers with silt and sand. The only redeeming feature of the existing condition is that some of the run-off, which is most needed in the soils on the hills, passes into the ground water storage in the bottomlands.

There is a close relation between soil texture, topography, and the direct run-off. As a rule, the open-textured soils absorb a relatively large amount of the rainfall and pass it to ground storage and the

underflow or indirect run-off, whereas the heavy soils cause a higher percentage of direct run-off. Similarly, other things being equal, the flat lands have more soak-in and less surface run-off than the hilly lands. In general, a considerable part of the rainfall on most types of slopeland moves by sheet flow to the terraces and alluvial bottomlands, giving to them a relatively large soil moisture supply and therefore greater agricultural value, except where they are damaged by the excessive accumulation of sediment or by floods.

Erosion prevention means soil saving, upland water conservation, and the permanent agricultural use of more than 20,000 square miles of land in Nebraska. It means the saving of both water and soil for agricultural use.

LAKES.—There are more than 1,200 lakes in Nebraska, most of them being in the Sandhill region. Numerous depressional areas on the Loess plain and table land areas are occupied by water during periods of wet weather but they become dry during summer as a result of evaporation, plant transpiration, and percolation to deeper ground storage. These intermittent lakes have some use for duck shooting; otherwise they are largely a drawback to the country. Some of them have been drained by open ditch, but many, aggregating more than 200 square miles, are undrained. In a few places, persons have tried to drain the basins by wells sunk to layers of gravel, but with complete failure because the wells soon fill with sediment.

The sandhill lakes are largely ground water exposed in basins and valleys. They are comparatively permanent, but fluctuate in depth and area, due to the rise and fall of the water table caused by rainfall, evaporation, transpiration, and the slow adjustment of the underflow. These lakes have importance in the development of wild life, such as fish, ducks, and muskrats. Also, the sub-irrigated lands bordering them produce sure yields of grass and wild hay. The problem here is to hold the water table at the best depth for hay production, and the lakes at the required depths and best condition for wild life. Drainage lowers the water table and the lakes, and, at most places, does more damage than good.

The state has purchased and improved a few of the sandhill lakes for public fishing, shooting, and recreation under the direction of the State Fish and Game Commission. All of the state-owned lakes are kept stocked with desirable fish and some of the land bordering them has been planted to trees. Many of the sandhill lakes are now under the control of hunting clubs.

Most of the sandhill lakes are fresh, but some contain considerable potash and other alkali. The Conservation and Survey Division has analyzed the water of most of the leading lakes at different times of year in order to determine the amount of potash and the fitness of the lakes for fish culture.

Numerous cut-off lakes occur along the principal valleys of the state and several artificial lakes have been made in connection with sand production, irrigation, and water power development. These, too, have a relation to the wild life resources, and serve more or less as public recreation centers.

RIVERS.—Our rivers have been studied by University, State, and Federal departments. They have been harnessed with varying degrees of success, but are not yet well developed. This non-use applies to the many small spring-fed streams and to much of the fall, winter, and spring flow of the rivers.

The demand for stream control and the need for the conservation of river water varies greatly in the different areas of the state. To the east and southeast, where the rainfall is heaviest, the problem has been that of flood prevention. It has resulted in much drainage work and the straightening of the channels of the Little Nemaha, Big Nemaha, Salt Creek, and Logan Creek. Farther west, i.e., in the sub-humid areas, the problem is that of conserving river water for beneficial use.

The Federal Government, cooperating with state surveys, is now engaged in a close study of some of the large rivers and river basins of the United States. The War Department is in charge of the investigation, which includes the Missouri, Platte, and Republican rivers and basins of Nebraska. Fortunately the topographic, soil, and water surveys, and the stream gaging have been largely covered in the Nebraska parts of these interstate areas, and data therefrom are available for evaluation by the War Department in the comprehensive survey. All told, our state is in some respects in a better position for this cooperation than South Dakota, Kansas, Colorado, and Wyoming.

The comprehensive survey now nearing completion covers all beneficial uses of the rivers and other water resources in relation to agriculture, industry, and domestic supply. It includes special investigation on stream flow, available water, canal irrigation, pump irrigation, reservoir storage, ground water storage, flood water irrigation, return flow, stream stabilization, flood control, water power, domestic water supply, and navigation, all of which are to be evaluated and published for use by Congress in arriving at a policy to be followed in the development and utilization of interstate rivers. This fact-finding survey, which is attracting much public interest, should serve well in the conservation of Nebraska's rivers.

SPRINGS.—These are small streams of ground water escaping to the surface. They and the general seepage therewith, which constitute the indirect run-off, form the main flow of the small tributaries of certain rivers, and add much water along the main courses of the Platte and other rivers.

There are many springs in the state, especially in the Niobrara, White River, and Republican valleys. Some of them afford farm and ranch water supplies and a good many are used to fill ponds for fish culture. Several of the small spring-fed streams are stocked with trout and some of them have been improved for trout culture, which is growing in importance. The State Fish Hatcheries near Gretna, Valentine, Benkleman, and on Rock Creek are on small spring-fed streams.

At various points in the state, there are small, hill-side seepages and springs which could be developed for farm supply. This could be done by boring or trenching back above the impervious floor to the source of water and piping it to a tank, the flow to be controlled by a float valve in order to prevent the unnecessary wasting of water.

The cool, running waters, the small water falls, and the wooded lands of the tributaries of the Niobrara, between Holt county and central Cherry county are objects of beauty and of increasing importance in the development of outing places and recreation centers. Similar areas in Pine Ridge, Wildcat Ridge, and along the Republican, lower Platte, Missouri, and other water courses of the state are also places of beauty and comfort for many who enjoy the out-of-doors.

WATER POWER.—Various reports on the state's water power resources and developments have been made by the Conservation and Survey Division, and the public has become quite conversant with the subject. Two hundred and eighty-seven water powers have been built in the state of which 215 have been abandoned and 72 are in operation. This seems to be a very unfavorable record, yet most abandonments have been of small, pioneer projects, and the powers now operating are the larger hydro-electric plants built the past few years.

The Big Blue is the state's best power developed river with 22 projects. Among the largest hydro-electric powers in the state are those near Kearney, Gothenburg, Boelus, Valentine, Spencer, Fullerton, Sargeant, Ericson, Superior, and Barneston. There are undeveloped power sites on the Loup, Niobrara, and other rivers and it is quite certain that considerable hydro-electric power can be developed in connection with irrigation extension along the Platte, like those at Guernsey and Lingle, Wyoming, which serve Nebraska.

IRRIGATION.—This form of reclamation has advanced steadily in Nebraska for more than thirty years with the result that an area of about 500,000 acres of land has been brought under successful irrigation with water diverted from rivers. The irrigation structures installed, together with the reservoirs and hundreds of miles of canals and laterals, represent an outlay of millions of dollars, largely well spent as evidenced by the results. There are farm crops, homes, schools, churches, highways, railroads, and cities where formerly were short grass, prairie dogs, coyotes, and comparatively few people.

The normal summer flow of rivers in the irrigation areas has been allotted and in some cases over-allotted, and the state faces the difficult task of adjusting the distribution of the available irrigation water according to priority right, which is recognized by the statutes. The problem is to secure the most equitable distribution and the fullest duty of water, which from the nature of conditions, cannot be done to the full satisfaction of all appropriators. This is especially true with a number of the irrigation districts along the Platte, where there is always more or less misunderstanding in regard to the relation of old rights to the storage water of the Government project and the return flow developed therewith.

According to Mr. R. H. Willis, Chief of the State Bureau of Irrigation, Water Power and Drainage, the demand for irrigation water by months, on the Platte is as follows:

May, 7 per cent
June, 17 per cent
July, 28 per cent } About 57 per cent of the diversion is for
August, 29 per cent } these months.
September, 18 per cent
October, 1 per cent

The demand for irrigation water from other rivers of the state correlates rather closely in time with that of the Platte, which begins with the months of heaviest rainfall and increases as the rainfall decreases, tapering off at the end of the growing season. The big irrigation problem in Nebraska now relates to the conservation of river discharge during the months when there is little or no diversion for irrigation and much water flows to non-use. This includes the so-called flood water.

There is much seepage loss from the Platte River in connection with some of the irrigation projects between North Platte and Kearney, much of which could be prevented by canalization, across close-textured soils to the lower points of distribution in the valley, rather than to use the river channel for this distribution.

The evaporation loss from the extensive marshy areas developed in connection with irrigation is greater than from a free water surface and some of this, too, could be prevented by properly planned systems of drainage and by less extravagant use of water on certain kinds of soils from which much seepage is developed.

There are places along the Loup valleys and some other valleys of the state where sandy bottomlands are interspersed with hard land having firm soil and it is not feasible to divert from the river because the leakage loss from canals is very great where they cross the sandy land. In such areas it would probably be better to pump river water onto the tracts of land to be irrigated.

The Republican, White, and North Platte rivers are natural conservancy basins because the water diverted from them, aside from what is lost by evaporation and plant growth, becomes return flow. This is due to the topographic and structural conditions. In the middle course of the Platte valley there is leakage from the valley through sands and gravels.

Well irrigation, sub-irrigation, and the so-called flood water irrigation are discussed elsewhere in this report.

WATER STORAGE.—At first, all irrigation from rivers in Nebraska was with water diverted during the irrigation season, that during the rest of the year being allowed to run to waste. It was then learned that the flow of the non-irrigation season could be stored and released when needed. A big reservoir, known as the Pathfinder, was built on the North Platte about 45 miles southwest of Casper, Wyoming, with a capacity of 1,200,000 acre feet, and canals and reservoirs connected with this Government project were constructed in the North Platte valley of Nebraska.

The Government project means much to Nebraska in various ways. It has stored water not formerly used for irrigation, has greatly extended the irrigation area, has built up enormous ground water storage from which there is return flow all year, and has made the flow of the Platte more uniform as far down as beyond North Platte. It is now an effective demonstration of the relation reservoir storage has to river discharge, ground water storage, and irrigation. The Pathfinder storage has shown that the flow of the Platte during the inter-irrigation season can be held back and released when needed, thereby adding to the flow and diversion of the irrigation season. It shows, also, that

water not yet controlled in the Platte and other rivers can be impounded if suitable reservoir sites can be located.

RESERVOIR SITES.—A special survey has been made by the state in cooperation with the War Department, of a number of prospective reservoir sites along the Platte, Republican, and other rivers. Some of the sites seem to be feasible for development. Professor Clarke E. Mickey, who is in charge of this investigation for the state, reports that the sites available would, if developed, have storage capacity sufficient to conserve a considerable amount of the inter-irrigation season flow of the rivers.

Just how far the Government may participate in the cost of building storage reservoirs is not known. However, it is claimed by some that the cost of the project should be met by the Federal Government as a welfare measure like that of the flood prevention on the lower Mississippi. At any rate and irrespective of who participate in the cost of storing the flow of rivers during the non-irrigation season, it is now generally conceded that something should be done to conserve the wasting water, especially of the Platte, which now discharges enough water during fall, winter, and spring to irrigate several hundred thousand acres of land. This water is allowed to flow from the state practically unused and with some destruction.

FLOODWATER IRRIGATION.—It has been found that in certain areas, as near Hastings, Minden, and Holdrege, the soils and the subsoil have a high water-holding capacity and that enough water could be stored in them during the inter-irrigation season to supplement the rainfall in the growth of sure crops. Consequently, this area is strongly insistent that part of the fall, winter, and spring flow of the Platte be diverted onto their deep soils for this form of irrigation. Another area in which there is a large acreage that could be covered in this manner is in Perkins and Keith counties.

The above projects have been surveyed and recommended for flood water irrigation. Storage sites on Plum creek could be used in connection with the development of the Tri-County project at Holdrege, Minden, and Hastings.

PROTECTED WATER SHEDS.—Streams carry much sediment from basins in which there is little vegetation cover and fill the reservoirs, decreasing their capacity. Consequently, it is recognized that the catchment areas of these reservoirs should be protected with forest cover. In this connection, Nebraskans should be interested in the conservation of the forest cover not only in the area above the Pathfinder reservoir and for all reservoirs to be built in Nebraska, but they should favor forest protection and forestation on the Rocky Mountain area from which the melting snows supply much of the flow of the Platte. Also, the plant cover should be retained on all rough slope land above irrigation canals and irrigated lands because it makes the run-off less fitful and reduces erosion and sedimentation.

GROUND WATER STORAGE.—Vast amounts of irrigation water pass into ground storage. This is particularly true of the North Platte valley where the water table has risen many feet in the bench lands, and ground water storage equal to two or three times the capacity of the Pathfinder reservoir has been built up. The return flow from this

storage has made live streams where formerly were dry sand draws. This return flow enters the Platte all year, making it more uniform farther down-valley than formerly.

In the course of the Platte below North Platte, where the valley floor is underlain by thick sands and gravels, much ground water passes into storage during high stages of the river. In summer the river dwindles to a dry channel because of stream bed loss, evaporation, and diversion for irrigation, yet there is a vast amount of water underground at all times with a slow underflow down-valley and southeastward under the Loess plain at Holdrege, Minden, Hastings, and Aurora, some of it reaching the Republican and Blue rivers.

The amount of water storage in the Platte valley between North Platte and Columbus, in an area of about 2,400 square miles, with water from the river and in part from the Sandhills, is estimated as fully twenty-four times that of the capacity of the Pathfinder reservoir. Also, for the 4,000 square miles in the Loess plain area south of the Platte, which is fed by underflow from the river, the volume is about fifty times the storage capacity of the Pathfinder reservoir. More ground water than this has been built up in the Sandhill region from the rainfall.

It should be evident from the foregoing that the volume of ground water in the state is much greater than the surface water and what can be placed in open reservoirs. Although we may not have known it, a vast amount of water is being conserved in the land. Let it be known, too, that there are certain sandhill areas and sandy land areas along the Platte in which much additional river water could be stored.

SUB-IRRIGATION.—This is possible where the water table stands near enough to the surface of the land for plant roots to reach the capillary fringe water above the water table. There are extensive areas of such land in our various river valleys and in the valleys and basins of the Sandhill region.

The sandy bottom land standing at or near the water table of the broad valleys, is well suited for wild hay, whereas the firmer soils three feet or more above the water table are well adapted to alfalfa, which crop, after a catch is secured, will feed to a depth of more than 20 feet.

It would seem that it may yet become necessary to control the water table of the bottom lands at its optimum depth for sub-irrigation, this to be done by re-charging by canals during high stages of the river and by drawing down by drainage canals where necessary.

WELL IRRIGATION.—The ground water of the Platte and some other valleys of the state is pumped for irrigation at about the same cost as for canal irrigation. There are now about 700 irrigation wells in the middle course of the Platte valley and the acreage irrigated from wells is expanding.

It would seem that so long as the Platte persists there should be ground water for pump irrigation. As noted above, it would be possible, through flood water canals and by drainage, preferably by tile, to control the volume of ground water and the water table level for both sub-irrigation and well irrigation.

Thus far much of the well irrigation activity has been largely experimental, yet the success attained has given a strong impetus to this form of development in a number of districts. With more knowledge of the source and volume of water, with more efficient pumps, and the benefit of practical experience in making wells, we may expect to see well irrigation extended over a much larger area of the state.

STREAM POLLUTION.—Nebraska's tolerance of stream pollution has resulted in many unsightly views and filthy rivers, which of necessity, should be cleaned up. Town and city garbage, industrial refuse, and sewage are permitted to be thrown or run into the streams, yet nearly all agree that this should not continue because there are better and more modern methods for the disposal of such materials. Here is a very practical water conservation problem, one which should receive the attention of our citizens generally.

NAVIGATION.—The only river in Nerbaska at all suited to commercial navigation is the Missouri and there is marked division of opinion among the citizens regarding the feasibility of developing it for navigation. The subject is now under discussion with political bias cropping out in some places.

Congress has voted funds for a survey of the navigation possibilities of the Missouri. The investigation is under way, and should the engineers report favorably, we may expect the river to be developed northward to Sioux City or farther as a national project.

The question regarding what relation navigation development on the Missouri might have to certain beneficial uses of water in Nebraska has been raised. Some claim that the water requirements for navigation would interfere with the further development of irrigation. The question can be answered with assurance, in favor of navigation, because most of the flow of the Missouri comes from other states, and the flow of the Niobrara and lower Platte probably will not be appropriated for purposes which would interfere with navigation development. Also, it should be noted in this connection, that the middle course of the Platte is usually dry when the Missouri is at its lowest stage and it would not be possible, therefore, to obtain water from this source in order to build up the flow of the Missouri. So, unless other and more beneficial appropriation can be had for the Loup-Elkhorn-Platte discharge and the lower Niobrara, and such appropriations should conflict with the navigation requirements, there should be no serious conflict with the other appropriations and uses.

A problem remains, however, regarding the needs and economic feasibility of improving the river for navigation. This, too, is being investigated for report by the War Department.

Although there is practically no commerce on Nebraska's rivers, many small row boats and a good many small motor boats are used on the natural and artificial lakes, and on the rivers, for recreation and in connection with fishing and hunting.

SANITARY WATER SUPPLIES.—Most of Nebraska's drinking water of country, town, and city is drawn from the ground water, only three or four cities being supplied from rivers. Nature has given most of the state abundant drinking water of good quality, which must be conserved.

It seems that relatively few of our people have anything like a clear notion of how water enters a well and what measures should be taken to keep it free from pollution, yet the matter is not difficult to understand when one gives it some attention. The situation is about as follows: At most points in the state the spaces in the ground are completely filled with water up to a certain elevation. An opening, called the well, is made down to and into the water-filled ground. The water stands in a well up to the height of the water table and moves into the opening when by pumping, the water table is drawn down. There is a slow underflow of the ground water in the direction in which the water table slopes, which in most cases is with the general slope of a valley floor or of an upland surface. At any rate, the direction of underflow is easy to determine and should be known in order to protect a well water supply against pollution. The principles to follow in this connection are as follows:

1. Wells should be graded up and enclosed to prevent the entry of surface drainage and the trapping of frogs, mice, rats, and other animals.
2. Wells should be placed up-water gradient from privies and other places of sewage disposal in order to make sure that the underflow reaches them without contamination.
3. All sewage disposal should be placed down-water gradient from the well or wells.
4. In the case of a town or city located on a valley floor, the water supply should be drawn from the up-valley side and the sewage should be disposed of on the down valley side, where it can purify by natural filtration before reaching farm wells and municipal supplies lower in the valley.
5. In places where the shallow ground water is separated by clay layers as first, second, or third water sands, it should be the policy to sink the wells to the deeper protected water.
6. Every farm, town, or city should protect its water production area or re-locate the water supply on new ground that can be protected.
7. No spring water issuing from polluted ground should be used for drinking purposes.

The Water Survey Department of the Conservation and Survey Division of the University is required by law to serve the people of the state in an advisory way in locating and correcting water supplies, and the Health Department of the state is required to pass upon the healthfulness of water supplies. It would seem that every precaution should be taken by the people of both country and town to conserve the purity of their drinking water which is so closely related to health.

WATER RESOURCE ADMINISTRATION.—The statutes of the state cover quite adequately the administration of the surface water resources, but there is need for legislation on ground water and drainage in order to make it possible to prevent certain abuses and safeguard the public health. No doubt the needs in this line will be brought to the attention of the next legislature.

The administration of the surface water resources of the state is by the State Bureau of Irrigation, Water Power, and Drainage of the Department of Public Works. Many problems confront the Bureau in

each line of development but most of them arise in connection with irrigation. The Chief of the Bureau keeps continuous detailed records of the flow of the rivers and of the areas to be irrigated in each district and tries to secure for all appropriators an equitable distribution of water. However, this task is very difficult when the demand for water is greater than the available supply and there is a general clamor for more water.

The distribution of irrigation water involves more technical knowledge and consideration than is generally supposed. It relates to interstate rights, senior and junior appropriators, storage water, natural stream flow, evaporation loss, stream bed loss, supplemental water, the demands of irrigators and various other things. All told, the administration is difficult, at times resulting in severe criticism for the Chief of the Bureau whether justly so or not.

WATER RESOURCE ORGANIZATIONS.—Many people of the state are connected with water resource organizations, such as the State Irrigation Association, irrigation districts organizations, drainage associations, municipal water boards, and water power companies. Also, various construction companies, and the manufacturers of windmills, pumps, and other well supplies and the State Well Drillers Association have a connection and extend service in the development of water resources.

SUMMARY

1. Water, and not the soil, is our most basic resource.
2. Water is the greatest circulating medium. It is a mobile resource.
3. Rainfall is Nebraska's most important income.
4. The ratio of soil moisture absorption to rainfall is large in Nebraska.
5. The ratio of evaporation to rainfall is large in Nebraska.
6. The largest economic use of water in Nebraska is in the growth of native vegetation and cultivated crops.
7. Soil moisture is conserved by effecting the maximum absorption and storage of rainfall, and the minima of evaporation, run-off, and soil erosion.
8. Ground water in the free water zone, which is the state's most important water resource, should be conserved in quality and volume for sub-irrigation, well irrigation, and for domestic and industrial purposes. The four outstanding problems in its conservation relate to:
   a. Holding the water table at the optimum depth for agricultural development.
   b. Re-charging the bottom lands with flood water where the water table is drawn down by evaporation and under drainage, by sub-irrigation, well irrigation, and for municipal and industrial supply.
   c. The prevention of the pollution of well water supplies.
   d. The correction and extension of rural and municipal drinking water supplies.
9. There are many seepage places and springs which could be developed for rural water supply.
10. The Republican, Loup, Elkhorn, Niobrara, and the lower course of the Platte (below Columbus) flow from the state with too little utilization.

11. Much of the inter-irrigation season flow of the Platte, Republican, and other rivers of the sub-humid areas of the state is not utilized. It should be diverted to storage reservoirs and to soil, subsoil, and underground storage for irrigation and other purposes. Such diversion and storage, together with the return flow therefrom, would make the flow of the rivers more uniform by reducing their high stage discharge and increasing their low stage discharge. It would add usable water.
12. Much of the water used for irrigation in the Platte valley below North Platte is delivered to the irrigation districts through the irregular, sandy channel of the river. This delivery is slow with enormous river bed loss and evaporation loss, whereas a well-planned system of canals, extended across the close-textured soils at the edge of the valley, would give quicker delivery and conserve much water for canal irrigation in the districts served.
13. By shortening the Platte River bridges, as is done by the Burlington Railroad and the State Highway Department, the river could be held to a definite narrow channel. This practice, if followed throughout the length of the river in Nebraska, would reclaim about 150 square miles of river wash ground for agriculture and effect a benefit and saving in the distribution of water.
14. The numerous small tributaries of the Niobrara, Republican, and other rivers afford favorable places for the development of fish culture projects. This is true also with some of the 1,500 or more flowing wells in the state.
15. The sandhill region is filled with ground water up to the lake levels. The problem here is to hold the lakes and marshes at stages suitable for their best utilization, and to maintain a depth of water table in their border areas favorable for the production of wild hay. This means less drainage at places.
16. Streams heading in the Sandhills are largely fed by seepage from ground water. Their flow is uniform throughout the year.
17. Several creeks heading in the Sandhills enter the Platte, giving it a large volume of sure irrigation water.
18. Waters impounded incident to irrigation and power development enhance the value of the state's wild life resources and serve as recreation centers.
19. Through reservoir and ground storage and the return flow developed therewith, rivers are caused to assume a more uniform discharge and become better adapted to the development of wild life than intermittent streams.
20. The water power resources of the state have been investigated quite closely. Two hundred and eighty-seven water powers have been installed, of which 215 have been abandoned and 72 are now operating. Nearly all abandonments have been of small, pioneer projects. The largest powers have been built within the past few years, and some possible sites remain for development.
21. The navigation possibilities of the Missouri River are under investigation by competent engineers of the War Department for report to Congress. Fortunately, the Missouri, which is along-side Nebraska for about 460 miles, receives most of its flow from other states, which means that its development for navigation, as con-

templated by the Federal Government, will not interfere with the use of the Nebraska rivers for other purposes.

22. Storage reservoirs built in Nebraska, or in other states to serve our state, should be protected by forest cover against their filling with materials eroded from the catchment areas.
23. The rivers and other water resources should be developed for as many beneficial purposes in their natural sequence as can be had without economic interference and loss, and in view of the welfare of the state.
24. The drainage law of Nebraska should be amended to pervent abuses, and to clarify the definition of certain drainage terms.
25. Nebraska has statutes on surface water, but no law governing the allotment and administration of ground water for various important uses and to safeguard against pollution. Some states have legislated along this line and Nebraska should follow.
26. University, State, and Federal departments have participated in fact-finding investigation and contributed data for use in developing the state's water resources. ~~These investigations have related to the state's water resources~~. These investigations have related to the topography, the nature, and distribution of water-bearing formawells, reservoir sites, chemical composition of ground water, depth of water table, direction and rate of underflow, ground water storage, water power, well irrigation, drainage, soil erosion, forest relations, and the water requirements of farm crops. The Soil, Geological, and Water Surveys of the Conservation and Survey Division, and the College of Agriculture, have been active in these surveys for several years. The Conservation and Survey Division and~~of~~ the U. S. Geological Survey are now cooperating in a close study of the ground water resources, which will require a number of years for completion. The last regular session of the State Legislature voted a fund for a survey of reservoir sites and flood water utilization, and Congress has voted large sums to the War Department for the evaluation of a plan for the complete utilization of rivers. The University and state departments are cooperating with the War Department in this investigation.
27. Facts regarding the forms of occurrence together with the most feasible methods of development and utilization of the water resources, as learned by survey and practical experience, should be made known generally through bulletins, newspapers, and discussion at public meetings. Such procedure would acquaint the citizens with the relations existing between the various water resources of the state and develop a plan and agreement for comprehensive development. It would establish a sound basis for procedure.