Artificial Recharge of Ground Water—Grand Prairie Region, Arkansas

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By KYLE ENGLER, F. H. BAYLEY 3d, *and* R. T. SNIEGOCKI

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By KYLE ENGLER,[1] F. H. BAYLEY 3d,[2] and R. T. SNIEGOCKI [3]

ABSTRACT

The Grand Prairie region of Arkansas is unique in many respects. It is peculiarly adapted to rice cultivation because of an abundant supply of irrigation water, an extensive "clay cap" that holds the water without excessive loss by downward percolation, and relatively level land which permits the construction of well-spaced levees.

The cultivation of rice began in the Prairie in 1904. The annual withdrawal of large quantities of water from deposits of Quaternary age to irrigate rice since that time has resulted in a gradual decline of water levels, until the Prairie is now considered a water-problem area.

In 1951 the U.S. Congress authorized the U.S. Army Corps of Engineers to undertake studies of artificial ground-water recharge in the Grand Prairie region. In 1953 the U.S. Geological Survey began a research study in the Grand Prairie to investigate the fundamental principles of artificial recharge to an aquifer. These two factors, coupled with the interest of the University of Arkansas in artificial recharge, marked the beginning of the project. To avoid duplication of effort, the three agencies pooled resources and cooperated excellently in the exchange of information throughout the course of the study.

The purpose and scope of study differ slightly for each agency. Generally, however, the objective is to determine the feasibility of relieving ground-water shortages by injecting surface water through wells.

INTRODUCTION

PURPOSE AND SCOPE

In 1953 the Grand Prairie region of Arkansas was selected for an investigation of the fundamental principles of recharging ground-water reservoirs through wells. The work since that time has consisted of the collection of detailed hydrogeologic information in the vicinity

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of the recharge site, drilling two experimental recharge wells, constructing water-treatment and conveyance facilities, and making a series of injection tests utilizing the two wells. As data and interpretive analyses become available, different elements of the project are to be released in a series of reports. This report, the first of the series, presents general information about the Grand Prairie region, as related to the studies of artificial recharge, and describes the development of the region that has caused it to become a water-problem area.

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Layne-Arkansas Co., Stuttgart, Ark.
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Peoples National Bank, Stuttgart, Ark.
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DESCRIPTION OF THE GRAND PRAIRIE REGION

LOCATION

The Grand Prairie region in east-central Arkansas is in the Coastal Plain physiographic province. It is an irregular, but nearly continuous, tract of prairie lying principally between the White River and Bayou Meto. It extends northwestward from near the confluence of the White and Arkansas Rivers to a short distance beyond Lonoke, Lonoke County. Nearly all of Arkansas County and parts of Lonoke, Prairie, and Monroe Counties are included in the Grand Prairie region. (See fig. 1.) The region consists of approximately 1,000 square miles, of which roughly 700 square miles, or 450,000 acres, is developed riceland.

CLIMATE

The Grand Prairie region is humid and has long, hot summers and short winters. The mean annual temperature at Stuttgart is 63.3° F. The mean temperatures for December, January, and February are 45.1°, 44.2°, and 46.6° F, respectively. The mean temperatures for June, July, and August are 79.2°, 82.3°, and 81.9° F, respectively. The temperature rarely falls to zero and seldom rises above 98°. High humidity makes summer days seem sultry. The cold is penetrating in winter and is felt much more than in less humid regions. Excessively cold weather is exceptional and of short duration. As a result, the ground seldom freezes to a depth exceeding 4 inches. Seasonal changes are not sudden, each season blending into the next.

The average annual precipitation at Stuttgart for the period of record (1888–1958) was 51.78 inches; the recorded minimum was 31.58 inches in 1943, and the maximum, 74.84 inches in 1945. January is the wettest month and September, the driest.

The last killing frost in the Grand Prairie region generally occurs during the first week in April, and the first killing frost occurs in

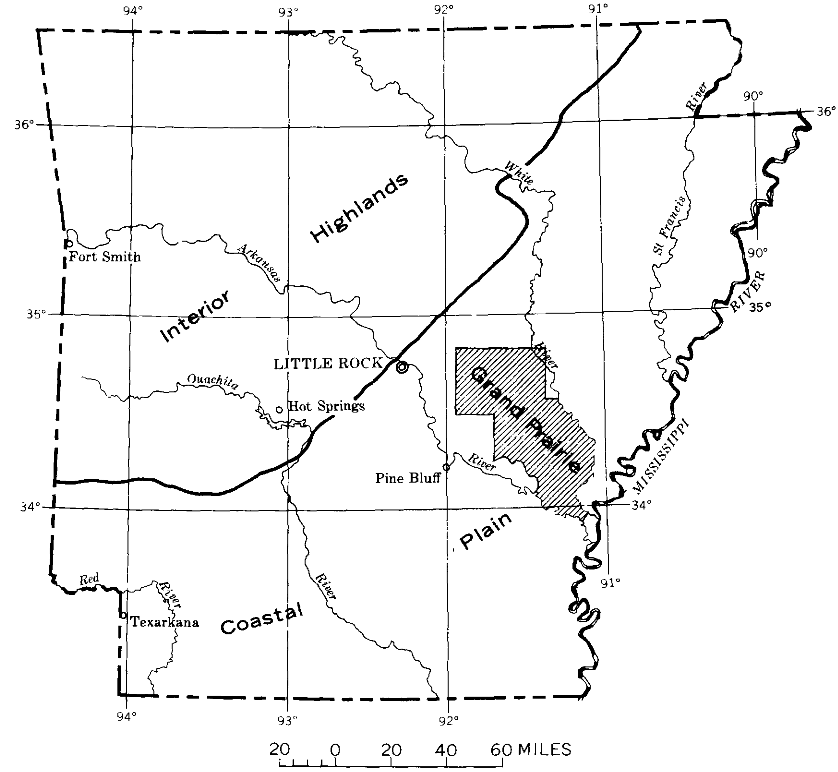

FIGURE 1.—Map of Arkansas showing the location of the Grand Prairie region.

about the third week in October. The average growing season is approximately 210 days.

There is no appreciable difference in climate among the different parts of the Grand Prairie region because of relatively level topography and the absence of bodies of water large enough to cause climatic changes. As a result, climatological data shown in figure 2 for Stuttgart, Ark., are fairly representative of conditions throughout the Prairie.

TOPOGRAPHY

Topographically the Grand Prairie region can be divided into four general divisions—low ridges and intervening valleys, gently rolling uplands, level plains, and alluvial belts along streams. The differences between divisions are not marked, and, in broad terms, the Prairie can be considered to be an area of low relief made up of prairies and timberlands.

The Prairie slopes southeastward; the highest altitudes, in the northwest corner are 250 feet above sea level. The lowest altitudes

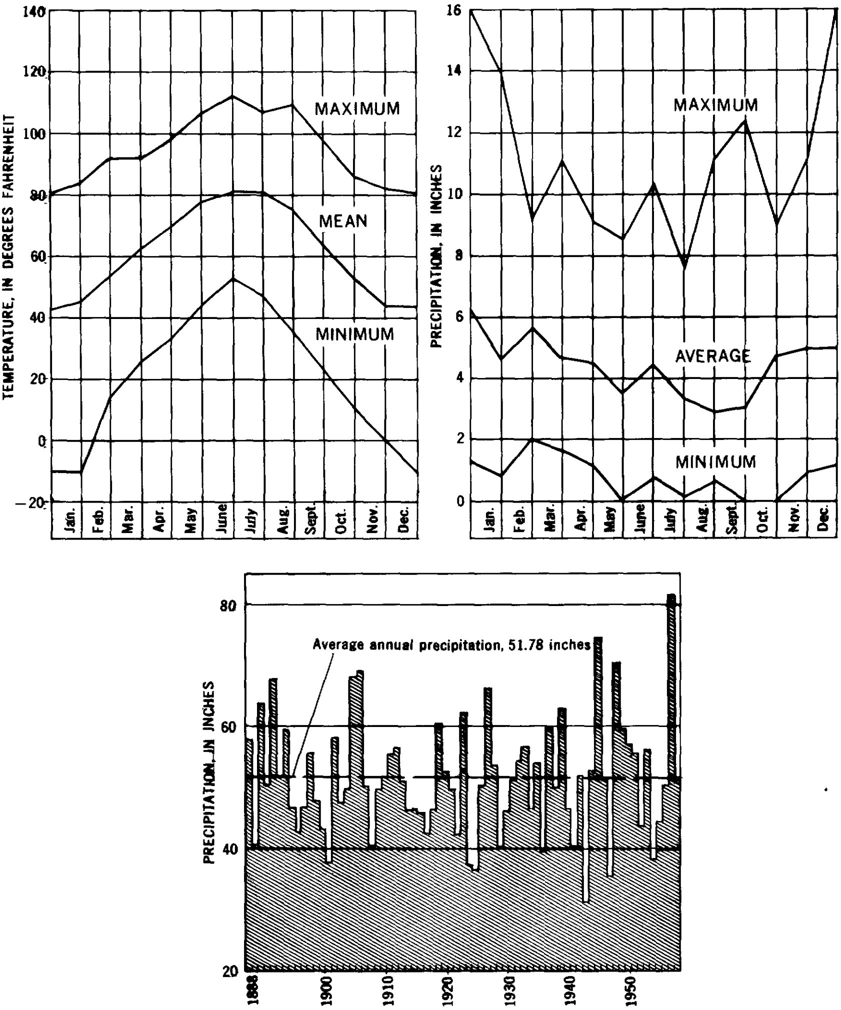

FIGURE 2.—Selected climatological data for Stuttgart, Ark.

are about 150 feet above sea level. The average southeastward slope is about 1 foot per mile. The maximum relief is less than 10 feet in a square mile.

DRAINAGE

Drainage of the Grand Prairie is sluggish except in the southwestern part of Arkansas County, where it is good. Most of the bayous are intermittent, but one of the exceptions is the lower part of LaGrue Bayou, which is fed by seepage springs.

The principal natural streams that drain the Prairie are LaGrue, Little LaGrue, Mill, King, and Two Prairie Bayous. The Arkansas

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and White Rivers and Bayou Meto drain the small parts of the Grand Prairie that are adjacent to them. Many lowlands near the rivers and bayous are swampy and contain much timber. Such areas, called islands, stand out on the landscape as more or less isolated patches.

OCCURRENCE OF NATURAL PRAIRIES

D. G. Thompson of the Geological Survey (written communication, 1933) has postulated a theory to account for the occurrence of natural prairie lands and timbered areas (islands) in the Grand Prairie region, as follows.

The Grand Prairie contains the largest area of prairie land in Arkansas. The prairies, elevated 20 to 60 feet above low-water stages of the Arkansas and White Rivers, are the highest land in the region. They are rather level, poorly drained, and topographically immature. A characteristic feature of the prairies is a relatively impervious clay cap in the subsurface at a depth of 1 to 2 feet. This clay cap makes the land ideally suited for rice growing because little water can percolate through it.

A few streams have worked back into the prairies, cutting valleys a few hundred feet wide down to the level of the Arkansas and White Rivers near those streams; but near their headwaters they have cut only a few feet below the surface of the prairies. For the most part, the timbered areas lie along these streams. Obviously, the soils along the streams are different from those on the prairie surfaces, because the relatively impervious subsurface clay has been breeched. The boundary between the prairies and timbered areas seems to coincide closely with the change in soil.

The historic absence of timber on the prairies may have been due to the clay bed and its effect on the moisture supply. In some seasons of the year the ground is saturated with water, at other times it is dry and hard—conditions not favorable for giving seedlings a good start. If tree roots extended through the clay, moisture might be sufficient to sustain growth. There is some doubt, however, that tree roots could penetrate the clay, and if they did, that sufficient moisture would be available for growth. Clay collected from test holes is remarkably dry.

Other factors, such as differences in soil pH and fertility, may be related to the location of the timbered areas and the prairies. The original prairie soil is acid; but, because much subsurface material is calcareous, the soil in the eroded stream bottoms may have a higher pH.

A few trees are now growing on the prairies in or near ricefields, probably because rice irrigation creates an abundant moisture supply and, in places, a pH change in the soil (Sniegocki, 1963). Tree growth near ricefields tends to support the theory that native trees cannot grow until the clay cap has been breached and soil-moisture and pH conditions have changed.

CULTURE

CITIES AND TOWNS

There are 41 small cities and towns in the Grand Prairie region. None has a population exceeding 10,000, and the prosperity of all depends upon the prosperity of the farmer. Industry is becoming established in the area and should create diversification of the economy.

ELECTRIC POWER

A significant amount of electric power is used each year in the Grand Prairie to operate irrigation wells. In 1958, an average of about 30 percent of the total kilowatt-hours metered was used to pump water for irrigation. The average cost of rice-irrigation power in 1958 was about 2.3 cents per kilowatt-hour.

TRANSPORTATION AND HIGHWAYS

The Grand Prairie region is serviced by the St. Louis Southwestern (Cotton Belt) Railroad and the Chicago, Rock Island and Pacific Railroad. Ample freight service is provided the Prairie area by rail and truck combinations. Bus service is provided by the Southwestern Greyhound and Midwest Trailways. Private transportation or taxi service must be used to reach the southern part of the Prairie. A network of Federal and State paved highways connects the principal municipalities. This network of paved roads and many graveled secondary roads provide the area with a satisfactory road system.

AGRICULTURE

HISTORY OF RICE DEVELOPMENT IN THE AREA

The following description of rice development in the Grand Prairie region is quoted from Stephenson and Crider (1916, p. 144–145).

> Rice has been grown commercially in Arkansas since 1904 and conditions are ideal for the rapid development of the industry. The soils of most of the prairie land in the interstream areas of the advance lowland between Crowleys Ridge and Arkansas River are peculiarly adapted in composition and distribution to the raising of this cereal, and large quantities of the water necessary for irrigation lie at relatively shallow depths beneath the prairies. [This statement has proved true, as a large proportion of the rice produced in the State is grown in this area.]

In August and September, 1896, Mr. [W. H.] Fuller and H. H. Puryear made a wagon trip from Lonoke southward through Arkansas and Louisiana to the Gulf of Mexico. Eight miles north of Crowley, La., they saw rice fields owned and operated by Abbott Bros., of Crowley. As this was the first rice either of them had seen growing, they spent two days studying the plantations of Abbott Bros. and of W. W. Duson and became convinced that the conditions under which rice was grown in the prairies of southwestern Louisiana were essentially like those existing in the prairies of Lonoke County, Ark.

After his return to Lonoke, Mr. Fuller made preparations to raise an experimental crop of rice on his farm, 8 miles southeast of Lonoke (in the NW. ¼ sec. 8, T. 1 N., R. 7 W.). He drilled two 4-inch wells, installed a pumping plant, and in the spring of 1897 planted 3 acres of rice. Some of the seed germinated, grew, and headed out, but because of an accident to the pumping plant and consequent failure to apply the necessary amount of water to the crop the grain did not reach maturity. Yet the experiment, so far as it went, was successful, for it demonstrated that the grain, if properly irrigated, could be raised on the prairies of Arkansas.

In 1898 Mr. Fuller moved to Louisiana and engaged in rice culture on the prairies of that State for four seasons; he familiarized himself in a practical way with the methods employed in preparing the soil, planting the seed, irrigating the growing plants, and harvesting the grain; he also learned how wells were drilled and equipped for supplying water for irrigation. During 1903, while Mr. Fuller was in Louisiana, 5 acres of rice was grown in Lonoke County by the Johnson Morris family; no detailed information has been obtained concerning this crop.

In the fall of 1903 Mr. Fuller returned to Arkansas, and with the financial backing of citizens of Carlisle and Hazen, he made preparations to raise a crop of rice on a commercial scale. A well was drilled and equipped for pumping on Mr. Fuller's farm, and 70 acres was planted to rice in the spring of 1904; at the end of the season 5,225 bushels were harvested. The total cost of producing this crop, including the cost of drilling and equipping the well, was $3,147, and the crop sold for $1 a bushel. During the same season a branch station of the Arkansas Agricultural Experiment Station was established 1½ miles west of Lonoke, where 750 bushels of rice were raised on 10 acres of land. Rice was also raised during the same season by the Morris family, but no statistics concerning this crop are available.

The completely successful efforts of Mr. Fuller and the experiment station to raise rice demonstrated beyond a question that this cereal could be grown at a profit on the prairies of Arkansas, and the lessons taught by these demonstrations were quickly learned.

Rice acreage in Arkansas increased rapidly, and 60,000 acres was reported in 1910. By 1913, the rice acreage of the State had reached 104,700 acres. The peak acreage was reached in 1954, when 243,000 acres was grown in the Grand Prairie region and 690,000 acres was grown in the State. The total acreage of rice irrigated in the Prairie from 1905 through 1957 is shown in table 2. Every county in the State has reported rice grown at one time or another, but the lowlands of eastern Arkansas are the largest producers.

MODERN RICE CULTURE

Temperatures, growing season, and other climatic factors are generally favorable for rice production in Arkansas. Other favorable factors in the Prairie are: (1) a relatively impervious subsoil close to the surface, which reduces the water requirements; (2) good field drainage to permit water removal before harvest; and (3) an ample supply of irrigation water.

An excellent seedbed is required to insure a good stand of rice free from grass and weeds. Procedures followed vary from year to year and from farm to farm. However, a common practice is to cut straw or other stubble into the soil with a heavy disc and then to plow 5 to 6 inches deep, as soon as possible after harvest. This may be in the fall or as early in the following spring as weather will permit. A firm, weed-free seedbed is developed by using disc harrows, field cultivators, springtooth harrows, and smoothing harrows in any order—according to weather, soil conditions, and farmer preferences.

Land leveling is extremely desirable and removes potholes by moving soil from high to low spots. Properly leveled land surfaces permit shallower water in irrigation, thus saving water and providing better weed and grass control. Leveling also provides more complete surface drainage and facilitates seedbed preparation, insect control, and harvesting.

Rice is grown on land which is flooded to a depth of 4 to 6 inches throughout a large part of the growing season (fig. 3). The levees are high enough and firm enough to hold half a foot of water or more on the deep side.

After the land is leveled, levees are surveyed with an engineer's level and then marked off and built to about half of their final height. After the seeding on a dry seedbed is completed, the levees are finished to full size (about 18 inches high). However, where rice is water seeded, the levees must be built to full size before flooding. In both methods, the completed levees also are seeded.

A high-germination, pure-seed rice that has been treated with a fungicide to protect the young plants from seed-borne diseases is planted between April 20 and June 30. The planting date depends on the weather, soil conditions, variety selected, and method of planting.

General practice followed in water seeding is to apply a full 4- to 6-inch flood just before seeding. After airplane seeding, the water depth is allowed to decline until the rice plant is well anchored and has grown up through the water. Then, water is gradually added until full flood is again reached.

FIGURE 3.—Photograph of rice field, showing rice plants, irrigation water, and levees.

Normally, each plot is drained once during the growing season to help control water weevils and to permit the application of fertilizer on dry soil. The application of fertilizer on dry soil has proved to be more efficient than application on wet soil.

When the heads of rice droop and turn yellow, the fields are again drained to permit the land to dry before the harvest. Generally, slightly less than 2 weeks is required for drying.

Rice is planted by a grain drill or is broadcast by airplane or endgate seeder. Planting by grain drill places the seed at a relatively uniform depth, which results in a high percentage of germination and permits the use of less seed than in other methods. Seed planted on dry soil by airplane or endgate seeder is covered to a depth of 1 to 2 inches by light disking or harrowing.

Seeding rice in water, which is always done by airplane, aids in controlling grass and may result in greater yields. Fields usually are harrowed or cultivated just before flooding, and the resulting shallow furrows in the soil reduce the movement of seed and seedlings on flooding, and a more uniform stand of rice is obtained.

Rice that has been seeded on a dry seedbed (about 90 percent is seeded in this manner) is flooded to a depth of about 2 inches when the seedlings are 4 to 6 inches high. As the plants grow, the depth of the flood is increased to 4 to 6 inches.

The time and depth of the first watering generally depend on the amount of weed and grass infestation. Grass that is completely covered with water is kept well under control. Therefore, the depth of the first flooding is mainly determined by the height of the grass.

Only the binder-thresher method of harvesting was used from the start of rice production in 1904 until 1942. In 1942 the Rice Branch Experiment Station harvested 700 bushels of rice by the combine-drier method.

When the binder-thresher was used in harvesting, more men and man-hours of labor were required. The rice was cut by a tractor-drawn binder at a rate of about 12 acres per 10-hour day. Two men were required to operate the binder and tractor, and four additional men were required to shock the rice. The rice was left shocked in the field until it was dry enough to be threshed and stored.

The threshing crew usually consisted of about 14 men and 8 teams and wagons; 2 additional men were used to haul the grain to the storage elevator. On an average, such a crew could thresh and store about 25 acres of rice in a 10-hour day.

Labor and power used for harvesting by the binder-thresher method averaged 11.2 man-hours, 1.2 tractor-hours, 0.8 truck-hour, and 6.4 horse-hours per acre (Slusher and Mullins, 1948).

Self-propelled combines are now (1960) used for almost all the rice harvesting. These machines are generally of 12- or 14-foot cut and rubber-tire or crawler-track design (fig. 4) and have a daily capacity ranging from 15 to 17 acres. Although the combine completes the cutting, threshing, and straw spreading in one operation with a minimum of hand labor, it creates another operation; all the rice harvested by the combine must be artificially dried. Therefore, this method of harvesting commonly is called the combine-drier method.

Normally, combining begins when the moisture content of the grain is about 23 percent and is completed by the time the moisture content reaches 17 percent, if at all possible. Harvesting before a 23-percent moisture content is reached is likely to result in light, chalky kernels that lower the yield of head rice. Harvesting after a 17-percent moisture content is reached is likely to result in considerable loss from shattering in the field, and the yield of head rice is lowered owing to checking of the kernels.

Although combining characteristics of rice are better at a moisture-content range of 17 to 23 percent, milling and storage characteristics are poor. To further reduce the moisture content to 13 to 14 percent, the rough rice (rice as it comes from the combine) is artificially dried by heated air forced through thin columns or layers of the high-moisture rice. Heated-air temperatures commonly range from 110° to 135° F. A large part of the rice is dried on a custom basis at the

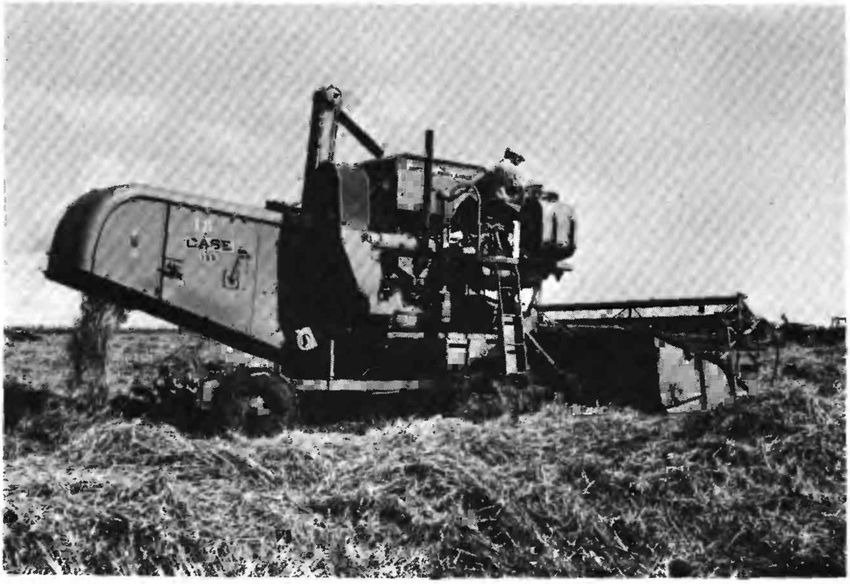

FIGURE 4.—Photograph of a rice combine in operation.

rice mills; however, a sizable portion of the rice combined is dried by the farmer in his own drier and stored on his farm until marketed.

When rice was threshed, the mills received grain directly from the thresher over a period of 4 months or longer, which made the problem of rough-rice storage of minor concern. With the combine, a large part of the rice crop is harvested and must be dried in about 2 months. Consequently, storage bins are constructed in conjunction with the driers.

At least 36 driers and storage units are available in the Prairie. As of 1958, ample drier and storage capacity was available in the Prairie to dry and store the normal rice crop of the area. At least 10 million bushels of storage capacity is available in conjunction with driers, in addition to storage facilities on farms.

The following table indicates the rapidity and completeness with which the combine-drier method has taken over in rice harvesting.

TABLE 1.—*Rice harvested by combining*

Year	*Percent of crop combined*
1942	700 bushels, <0. 1
1943	0. 3
1944	3. 3
1945	20. 6
1946	50. 6
1949	75. 0
1958	99. 9+

In 1947 it was reported (Slusher and Mullins, August 1948) that it required 2.8 man-hours, 0.7 tractor-hour, and 1.4 truck-hours to combine an acre of rice. These requirements have been reduced since that report, but the amount of reduction is not known, as recent research in this field has not been reported.

The combining of rice is treated in more detail in the following reports:

Hall, O. J., March 1948, The operation of rice driers in Arkansas 1946: Arkansas Agr. Expt. Sta. Bull. 474, 34 p.

McNeal, Xzin, December 1950, When to harvest rice for best milling quality and germination: Arkansas Agr. Expt. Sta. Bull. 504, 41 p.

———October 1957, Rice aeration, drying, and storage: Arkansas Agr. Expt. Sta. Bull. 593, 41 p.

Slusher, M. W., February 1955, Enterprise costs and returns on rice farms: Arkansas Agr. Expt. Sta. Bull. 549, 34 p.

Slusher, M. W., and Mullins, Troy, October 1949, Production items and costs for enterprises on rice farms: Arkansas Agr. Expt. Sta. Bull. 489, 35 p.

OTHER CROPS

Although rice is the principal crop in the Grand Prairie region, soybeans, cotton, oats, and lespedeza are grown extensively, particularly in the "off years" when rice is rotated with other crops. No extensive discussion of these crops is given in this report, inasmuch as their water requirements for irrigation are considerably less than for rice.

DEVELOPMENT AND USE OF WATER

GENERAL STATEMENT

Ground water is pumped from two aquifers in the Grand Prairie region. Wells deriving their water from deposits of Tertiary age are known locally as deep wells, and wells screened in deposits of Quaternary age are called shallow wells. The use of these terms is based on the fact that the so-called deep wells range in depth from about 450 to 1,100 feet, whereas shallow wells range in depth from about 85 to 200 feet. More extensive discussions of the hydrogeology of the region are given in other reports on the area (Engler, Thompson, and Kazmann, 1945; Sniegocki, 1963).

DOMESTIC SUPPLIES

Most of the farm homes of the area are supplied with water pumped from deposits of Quaternary age; a few domestic wells obtain water from Tertiary deposits. Water from Quaternary deposits is high in calcium and magnesium salts and is hard; in some water the iron content may be excessive. Water used in the farm home generally is

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untreated, but the use of zeolite water softeners is becoming more prevalent.

Typical domestic wells are cased with 2-inch galvanized-iron pipe and finished with a drive-point screen. Larger wells, 4 to 6 inches in diameter, are becoming more common as the quantity of water required increases and the use of jet and submersible pumps becomes necessary.

About 4,300 farm homes in the Grand Prairie use approximately 1,800 gpm (gallons per minute) of water, or the equivalent pumpage of three rice-irrigation wells. Domestic pumpage thus obviously constitutes only a small percentage of the total pumpage in the Prairie.

INDUSTRIAL SUPPLIES

Self-supplied industry is a minor user of ground water in the area. Most industries are supplied by municipalities. Exceptions are as follows: Two rice mills in Stuttgart use shallow wells for a standby and fire-protection water supply; a rice mill in DeWitt uses a well having a capacity of about 200 gpm; ice plants in Lonoke and Gillett use their own wells; the Arkansas Power and Light Co. uses a well for the water supply at its headquarters just southeast of Stuttgart; and the Southern Rice Produce Co. of Carlisle uses a 50-gpm well for its water supply at the warehouse and drier. No doubt there are a few other industrial supplies of ground water in the area, but the pumpage is small.

Some industrial users of ground water in the area chlorinate the water, but most do not. The industrial processes are such that the chemical-quality requirements of the water are not rigid.

MUNICIPAL SUPPLIES

All cities and towns of the Grand Prairie region that have municipal water systems are supplied by wells. Generally, the water needs treatment, particularly in the northern part of the Prairie. However, several of the smaller towns do not treat the water. Stuttgart, the largest city in the Prairie, uses one deep well and three shallow wells that have a total output of about 3,000 gpm. The water is treated in a well-designed modern plant by aeration, lime, alum, filtration, and chlorination.

Lonoke has a population of about 2,000. Its water supply is obtained from one shallow well with a capacity of approximately 300 gpm. A reservoir and elevated storage tank are used in the distribution system.

Carlisle's population of about 1,400 is supplied with water from two shallow wells that yield about 750 gpm. The water is aerated and filtered.

The Hazen water plant aerates, filters, and chlorinates the water it pumps from two shallow wells. The total capacity is about 300 gpm.

DeWitt, the second largest town in the Prairie, obtains its water from one deep well with a capacity of about 500 gpm. Two shallow wells are used on a standby basis. Treatment consists of aeration and chlorination.

The water supply for Gillett is furnished by one deep well, having a capacity of 250 gpm, and one shallow well that is operated on a standby basis. The water receives no treatment and is pumped directly into an elevated storage tank.

The total population of cities having a municipal water supply is about 20,000. Maximum total plant capacity for these cities is estimated to be 5,000 gpm. Based on per capita consumption of 100 gpd (gallons per day), the total daily pumpage is approximately 1,400 gpm.

IRRIGATION SUPPLIES

GROUND WATER

The principal use of ground and surface water in the Grand Prairie region is for the irrigation of an average 127,000 acres of rice per year. Deposits of Quaternary age supply 90 percent of the ground water used in rice cultivation, with an average of approximately 115,000 acres of rice being irrigated each year with water from shallow wells. About 12,000 acres of rice per year has been irrigated with ground water from deposits of Tertiary age and surface water stored in reservoirs or pumped from bayous. The total acreage of rice irrigated each year (1905 through 1957), the source of water, and the acreage irrigated by each source are shown in table 2. How these data are used to estimate the annual quantity of water withdrawn from deposits of Quaternary age, is discussed below.

Information about the yearly consumption of water per acre of rice was obtained from studies made in 1928 and 1929 (Clayton, 1930). Additional determinations of the duty of water for rice were made from 1937 through 1940 by the Agricultural Engineering Department and the Rice Branch Experiment Station of the University of Arkansas. It was determined that the average total depth of water applied to irrigate rice was 32.9 inches, of which 22 inches was applied by pumping, and 10.9 inches fell as rain. On the basis of available data and factors indigenous to rice culture, as well as farming practices, no correlation could be made between required pumpage and variations in rainfall. From these studies, it was concluded that an average duty of water for rice in the Grand Prairie region is about 1.8 acre-feet per year.

TABLE 2.—*Water requirements for rice irrigation in the Grand Prairie region, 1905–57*

Year [1]	Total area irrigated (acres)	Irrigated from surface water and deep wells (acres)	Irrigated from shallow wells (acres)	Estimated quantity pumped from shallow wells (acre-feet) [2]
1905	460	----------	460	1, 000
1906	4, 000	500	3, 500	6, 000
1907	6, 000	500	5, 500	10, 000
1908	11, 000	500	10, 500	19, 000
1909	27, 000	500	26, 500	48, 000
1910	48, 000	1, 500	46, 500	84, 000
1911	57, 000	3, 000	54, 000	97, 000
1912	73, 000	3, 000	70, 000	126, 000
1913	84, 000	3, 000	81, 000	146, 000
1914	74, 000	3, 000	71, 000	128, 000
1915	80, 000	3, 000	77, 000	139, 000
1916	100, 000	7, 000	93, 000	167, 000
1917	122, 000	7, 000	115, 000	207, 000
1918	136, 000	7, 000	129, 000	232, 000
1919	126, 000	7, 000	119, 000	214, 000
1920	149, 000	7, 000	142, 000	256, 000
1921	112, 000	7, 000	105, 000	189, 000
1922	130, 000	8, 000	122, 000	220, 000
1923	116, 000	8, 000	108, 000	194, 000
1924	131, 000	8, 000	123, 000	221, 000
1925	143, 000	8, 000	135, 000	243, 000
1926	161, 000	8, 000	153, 000	275, 000
1927	144, 000	9, 000	135, 000	243, 000
1928	131, 000	9, 000	122, 000	220, 000
1929	129, 000	9, 000	120, 000	216, 000
1930	141, 000	9, 000	132, 000	238, 000
1931	146, 000	9, 000	137, 000	247, 000
1932	127, 000	9, 000	118, 000	212, 000
1933	120, 000	9, 000	111, 000	200, 000
1934	110, 000	10, 000	100, 000	180, 000
1935	105, 000	12, 000	93, 000	167, 000
1936	119, 000	14, 000	105, 000	189, 000
1937	115, 000	14, 000	101, 000	182, 000
1938	129, 000	15, 000	114, 000	205, 000
1939	113, 000	15, 000	98, 000	176, 000
1940	126, 000	17, 000	109, 000	196, 000
1941	135, 000	18, 000	117, 000	211, 000
1942	162, 000	22, 000	140, 000	252, 000
1943	157, 000	20, 000	137, 000	247, 000
1944	163, 000	20, 000	143, 000	257, 000
1945	158, 000	20, 000	138, 000	248, 000
1946	175, 000	21, 000	154, 000	277, 000
1947	185, 000	21, 000	164, 000	295, 000
1948	188, 000	21, 000	167, 000	301, 000
1949	195, 000	21, 000	174, 000	313, 000

TABLE 2.—*Water requirements for rice irrigation in the Grand Prairie region, 1905–57*—Continued

Year [1]	Total area irrigated (acres)	Irrigated from surface water and deep wells (acres)	Irrigated from shallow wells (acres)	Estimated quantity pumped from shallow wells (acre-feet) [2]
1950	169, 000	21, 000	148, 000	266, 000
1951	216, 000	22, 000	194, 000	349, 000
1952	215, 000	22, 000	193, 000	347, 000
1953	220, 000	23, 000	197, 000	355, 000
1954	243, 000	23, 000	220, 000	396, 000
1955	185, 000	23, 000	162, 000	292, 000
1956	164, 000	22, 000	142, 000	256, 000
1957	147, 000	21, 000	126, 000	227, 000
Average	127, 000	12, 000	115, 000	207, 000

[1] Data for years 1905–42 from Engler, Thompson, and Kazmann, 1945, p. 24.
[2] Based on 1.8 acre-feet of water per acre of rice per year.

Multiplying the average total rice acreage irrigated each year with water from shallow wells by a duty of water of 1.8 acre-feet, an average of 207,000 acre-feet of water is computed to be withdrawn annually from deposits of Quaternary age. Such a quantity of water would cover a section of land to a depth of about 3¼ miles.

Water-level measurements are made in about 300 shallow wells in the Prairie each spring. These have been used to construct the maps of the ground-water surface shown in plates 1 and 2. The average annual decline in water levels over the region for the period 1939–59 is shown in plate 3. Obviously, the average annual withdrawal of 207,000 acre-feet of water from the Quaternary deposits exceeds the annual replenishment.

Fewer data are available on deep wells. However, water-level measurements show an annual decline of about 1 foot in deposits of Tertiary age; the decline becomes greater as more wells are drilled and withdrawals of water increase.

A typical shallow well and pump are shown in figure 5. The well consists of a pit casing, or outer casing, ranging in diameter from 18 to 28 inches, which extends from the surface into the water-bearing sand and gravel. From near the bottom of the pit casing, a smaller casing and screen, usually 12 inches in diameter, extends to the bottom of the aquifer and is surrounded by a gravel pack. The overlap of 5 to 15 feet between the two casings provides a reservoir for the gravel pack.

The pump consists of several stages (bowls), which include the suction pipe (tail-pipe), the discharge pipe, and the pump head. Impellers inside the bowls are driven by a vertical shaft from the pump head.

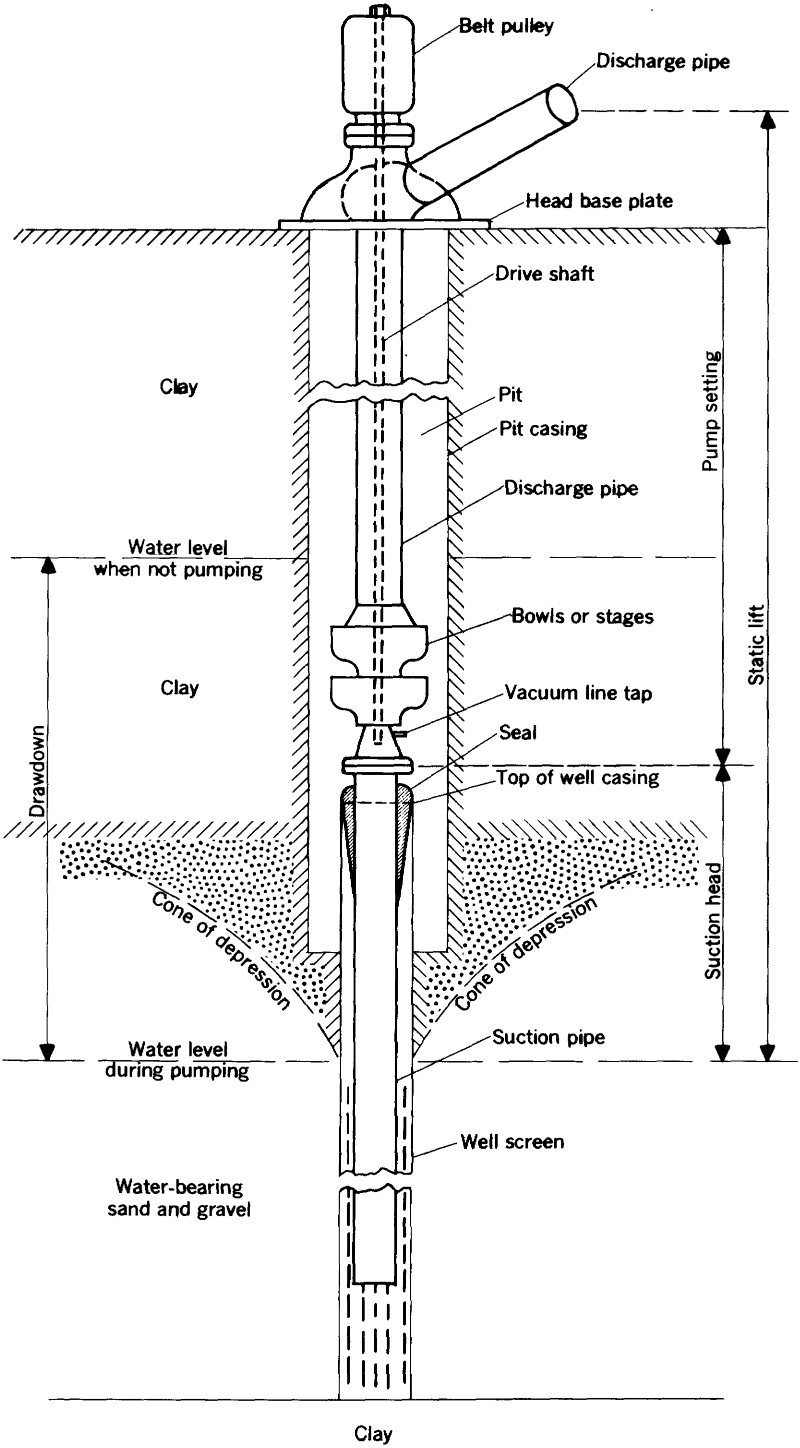

FIGURE 5.—Typical shallow well and pump installation.

The space between the top of the smaller casing and the pump column is commonly closed with a seal made of metal or sacking dipped in hot asphalt. The seal prevents air from entering the smaller casing and permits a partial vacuum to exist during pumping, the intent being to increase the flow of water through the screen.

Before about 1936, pump bowls were slow speed types of large-diameter (as much as 24 inches) and had low efficiencies (30 to 60 percent). These were sealed to and set on top of the smaller casing, as shown in figure 5. As the water level dropped below the pump setting, it became necessary to construct a new well with a shorter well casing and, in some cases, a shorter screen. The development of small-diameter, high-speed bowls permitted their placement inside the screen, with a seal between the pump-discharge pipe and the smaller casing above the bowls, thereby saving the trouble and expense of drilling a new well.

Deep wells are constructed similarly, although the use of casings of two different diameters may be less common.

The yield of shallow wells in the Prairie ranges from 400 to as much as 3,000 gpm. The average well yield is estimated to be 650 gpm and will irrigate an average of 70 acres of rice.

Water from both shallow and deep wells is chemically suitable for irrigation. In a few places, salt water has been found beneath the fresh water in the deposits of Tertiary age. The source of the salt water is not known, but local well drillers attribute the contamination to deep oil-well tests that were not properly sealed off.

In general, the deep-well water is considered to be better for irrigation of rice than that from deposits of Quaternary age. This is because the shallow-well water contains greater amounts of calcium, which is thought to accumulate in the soil, raise the pH, and lower rice yields. More extensive discussions of the chemical quality of the water are given in other reports on the area (Engler, Thompson, Kazmann, 1945; Sniegocki, 1963).

SURFACE WATER

The use of surface water for rice irrigation started in the Grand Prairie soon after the beginning of rice cultivation. Irrigation of rice with surface water increased from about 500 acres in 1905 to a maximum of nearly 20,000 acres by 1955. Most of the water is from bayous and drainage ditches that receive runoff from rainfall.

In some places, surface water is pumped from streams directly to the ricefield. However, as the streams are dry or their flows are low during the latter part of the irrigation season, such a practice is undependable. As a result, many storage reservoirs have been constructed;

the first completely enclosed type was built in 1910 on the Tindall farm about 5 miles south of Stuttgart.

The number of reservoirs constructed has increased rapidly, and in 1958 about 200 individual reservoirs were in use. The capacity of many of these reservoirs is small, and most of them cover only 20 to 30 acres and are shallow. The increase in the number of reservoirs has not resulted in a large increase in acreage irrigated from surface water because of their small size and capacity.

Reservoirs are entirely enclosed by levees or only partly enclosed, according to topography. A few dams have been constructed across stream channels, but generally the water is pumped from the stream into the reservoir by large-capacity relift pumps.

The loss of water by evaporation from surface storage is about 48 inches annually (pan evaporation in reservoir at Experiment Station), of which nearly 17 inches evaporates during June, July, and August. Consequently, enough water must be stored to supply irrigation needs and to provide for evaporation losses. It is desirable, therefore, to store water in reservoirs as deep as possible. Many of the partly enclosed reservoirs store water that is about 8 feet deep on the levee side and decreases in depth to a featheredge at the upslope, or nonleveed, edge. Generally, water is 5 to 7 feet deep in the completely enclosed reservoirs.

The older and larger reservoirs were constructed in undeveloped woodland areas of low value. These areas gradually have been depleted, and the use of cropland for reservoir sites is now practiced to a great extent. More than half the reservoirs constructed in the past few years have been built on cropland. This has increased the cost of the reservoirs.

A recent study of the reservoir systems in the Grand Prairie (Gerlow, 1958) presents an economic appraisal of reservoir construction and use and compares the costs of using surface and ground water for rice irrigation.

Surface water generally is of better chemical quality for rice irrigation than water pumped from shallow wells. Increased rice yields are reported where surface water is used. Not only is the quality better, but the quantity available for rapid flooding is greater, which results in better weed control.

BEGINNING OF THE STUDIES OF ARTIFICIAL RECHARGE IN THE GRAND PRAIRIE REGION

BACKGROUND

Although withdrawal of water from the Quaternary aquifer for rice irrigation began in 1904 and by 1916 had exceeded the natural recharge, decline of water levels was regarded with little concern in the early years of rice production. However, the possibility that the Grand Prairie might be faced with a shortage of water for rice irrigation through depletion of the underground reservoir caused some concern by 1927, as indicated by the following article, quoted from the Arkansas Democrat, January 25, 1931, entitled, "Grand Prairie Faces Shortage of Rice Water."

This problem began to be sensed by leaders in the rice territory several years ago. Senator T. H. Caraway brought it to the attention of the U.S. Geological Survey in April 1927. Arrangements were made with Dr. George C. Branner of the Arkansas Geological Survey for a co-operative study of the situation. Funds were also provided by the Stuttgart Chamber of Commerce, by the State experiment station, and through a deficiency proclamation by Gov. Harvey Parnell for money from State funds.

David G. Thompson of the U.S. Geological Survey, Washington, D.C., was assigned to study the irrigation-water supply in the Grand Prairie. By July 1930, the water level in the shallow wells was declining 10 to 14 inches a year, and complete exhaustion of a few shallow wells had been reported. Further results of studies made in the first 2 years were included in a press release by the U.S. Department of Interior dated January 26, 1931. Extracts from the release are as follows:

A very large quantity of water is used in the Grand Prairie region for irrigating rice. It is estimated that in 1929 more than 200,000 acre-feet of water was so used. * * * The total flow, if spread over an irrigating season of 90 days, would average more than 1,100 cubic feet a second. * * *

As a result of the annual withdrawal of such large quantities of water from the ground, there has been a gradual lowering of the head as indicated by the water in observation wells, in almost all parts of the region [pl. 4]. This loss of head has amounted to only a few feet in some places, but over a large area it has been from 20 to 35 feet or more. A natural result has been that the cost of pumping increased. An even more serious problem relates to the permanency of the ground-water supply. * * *

The safe yield of a water-bearing bed may be defined as the rate at which water can be withdrawn from it for an indefinitely long period without depleting the supply to such an extent that withdrawal at this rate is no longer economically feasible. * * *

The principal factors that determine the safe yield of a water-bearing bed are the quantity of water available to recharge the bed, the area of the intake zone in which the surface water gains access to the beds, and the permeability of the bed. * * *

As there is practically no recharge by direct downward percolation of rainfall in the Grand Prairie region and the ground water moves in from beyond its borders, a controlling factor in the safe yield of the Pleistocene [now called Quaternary] beds in this region is their permeability. * * *

A careful study of the available information relating to the head and the depth to the top of the water-bearing beds shows that in several areas the water levels in wells had dropped below the top of the water-bearing beds. * * * This condition is significant, for it indicates definitely that the consumption of water from the beds in these areas has exceeded the quantity that has flowed into them. * * * It is estimated that draining occurred over a total area of about 100 square miles. The thickness of the drained portion of the water-bearing beds ranges from a few inches to 30 feet or more. The numerical average of the recorded thickness is about 13 feet. It is roughly estimated that the total volume of water removed from storage by the draining process has been about 333,000 acre-feet. This figure cannot be considered exact, but the volume is probably at least 250,000 acre-feet and may considerably exceed 333,000 acre-feet. * * *

The records in regard to water levels seem to indicate that in 1928, when estimated consumption was 177,000 acre-feet, the pumpage was in excess of the inflow. As the inflow does not vary much from year to year, it would appear that the safe yield is less than 177,000 acre-feet a year. According to the estimates * * * that number has been exceeded in every year since 1916, except 1921 and 1923. If the safe annual yield were 175,000 acre-feet, the total excess above that quantity would have been about 345,000 acre-feet. If the safe annual yield were only 150,000 acre-feet, the excess would have been about 600,000 acre-feet, which is considerably more than the quantity estimated to have been removed from storage by unwatering. The excess, based on a safe yield of 175,000 acre-feet a year, more nearly corresponds to the estimate of the quantity of water drained. * * *

The data obtained in the present investigation lead to the conclusion that the large quantities of ground water that have been used for irrigation in the Grand Prairie region have for the most part been replaced by percolation of new water into the area, and that in the future, replenishment of the ground water supply may be expected each year by natural processes. It has been shown, however, that the consumption of water from the principal source of supply—namely, the Pleistocene beds—is somewhat greater than the quantity that is annually added to it. It is therefore imperative that consideration be given to methods for remedying the situation by increasing the supply or reducing the consumption.

Some of the local leaders were not satisfied with the 1928 and 1929 studies. The June 25, 1931, issue of a newspaper, the Arkansawyer, stated:

The Arkansawyer is of the opinion that the Federal government is giving the water situation more adverse publicity than conditions actually justify. In fact, the law bulletin on the subject appears to have been a hurry-up effort to offset reports published in the Arkansawyer and other papers quoting farmers to the effect that the water level was coming back rapidly.

The Arkansawyer obtained the reports from farmers, many of whom kept tap on the water levels from year to year. They may be accepted as fairly indicative of the conditions in the neighborhoods they represent.

The shallow water sands of the prairie were subjected to the greatest demand upon them in the history of the rice industry last year. The supply this year seems to be standing up remarkably well, in spite of the past winter being one of the driest in many years. * * *

This country is in no immediate danger of drying up and blowing away.

To be certain that the trend indicated in the cooperative studies of 1928 and 1929 was not temporary, further investigations were approved in 1932 and 1933.

The Grand Prairie Leader, in an article dated October 19, 1933, entitled "Water Survey to be Continued Here," stated:

G. C. Branner, State Geologist, has been notified that the U.S. Geological Survey has made an allocation from its public works fund to continue the ground-water investigation in the irrigated rice district of Arkansas. * * *

Mr. Branner said work to be done under the new allotment of funds will relate largely to the problem of the safe yield for rice irrigation by pumping from the water-bearing formations. It will involve a study of the relation between the consumption of water and the fluctuation of water level since the mimeographed report was issued. An effort will be made to obtain more detailed information in regard to consumption of water in the earlier years of the investigation.

Much of the information collected in these early studies was included in Bulletin 457 of the Arkansas Agricultural Experiment Station (Engler, Thompson, and Kazmann, 1945). The statement that the withdrawal of water from the water-bearing beds had exceeded the natural recharge was repeated in this report. The annual inflow was estimated to be 135,000 acre-feet, as compared to the 1928–29 estimate of 150,000 to 175,000 acre-feet.

Although continued observation of water levels in the Grand Prairie region has shown a gradual decline, there have been years of exception, such as 1933–34.

An increase in the height of the water level in wells in the rice irrigation district has ben recorded, W. C. Mendenhall, Director of the U.S. Geological Survey, informed George C. Branner, State Geologist, Monday.

Mr. Branner said the information is of great importance to rice growers of eastern Arkansas, because of reports which had shown that the water level had dropped considerably in previous years. * * *

* * * * * * *

In the fall of 1933, for the first time since the measurements (taken every spring and fall) were begun, the water level was higher in a majority of the wells than on corresponding dates a year ago. Because of its great interest to rice growers, a preliminary report was immediately sent out.

'This rise in water is presumably due to a reduction in the quantity of water pumped during the irrigation season,' Mr. Mendenhall wrote, 'but it is not yet certain as to the cause of this reduction, whether to heavy rainfall at critical times in the irrigation season, to an increased substitution of water from surface sources, or to a reduction of acreage irrigated.

'Any reduction due to the first and third causes may be only temporary. The higher water level in the fall of 1933, nevertheless, is a favorable position, for it appears to definitely establish the fact that recovery from the overdraft in recent years is possible, if there is a sufficient reduction of water pumped.' (Grand Prairie Leader, "Water Level Goes Higher Tests Show," January 25, 1934.)

This rise in water level came at a critical time for the rice interests in the Grand Prairie. In view of data collected in the cooperative studies of the ground-water situation, the Federal Land Bank and

Farm Credit Association refused to make loans in a part of the Grand Prairie. Groups representing rice interests protested this action, and the rise in water level provided a basis for these protests. In December 1934, much of the Grand Prairie was reopened for loans. Under the new plan, farms were considered individually; farmers having land in unfavorable locations with regard to the ground-water supply had to provide a supplemental supply of irrigation water.

The Federal Land Bank contributes to the cost of water-level measurements made in the Grand Prairie each spring by representatives of the Geological Survey and the University of Arkansas. A water-table contour map is compiled from these measurements. The elevation of the bottom of the aquifer subtracted from the elevation of the water table indicates the thickness of the saturated section and provides a basis for considering farm loans.

The 1957 measurements again showed a general rise in the water table; however, the rise was slight, and such changes are an exception rather than the rule.

As it became apparent that natural recharge to the shallow aquifer of the Grand Prairie was sufficient only to supply about 120,000 acres, alternate methods of water supply were proposed.

Interest in methods of alleviating the water shortage has increased continously as the situation has become more critical. Congressman D. D. Glover wrote to the Office of the Chief of Engineers, U.S. Army, in 1930 concerning plans to construct a canal from DeValls Bluff on the White River to Bayou Meto and to build a dam on the White River for irrigation. General Lytle Brown, Chief of Engineers, replied that the plan, which proposed a system of canals to distribute water supplied by a pumping plant at DeValls Bluff, required 1,000 cfs of water during periods when the total flow was frequently as small as 5,000 cfs. He pointed out also that it was impractical to raise the water elevation the required 30 feet above the 1927 flood level, because the land on the east side of the White River was only 2 or 3 feet above the 1927 flood level at the proposed location of the reservoir. In addition, preliminary reports did not indicate a suitable damsite in the DeValls Bluff area. This plan was revised several times, and in the Flood Control Act of 1950 Congress authorized a similar plan; however, appropriation of funds was not authorized. This plan incorporates a pumping plant rather than a dam.

On February 9, 1932, Congressman Glover introduced a bill in the U.S. House of Representatives which directed the Department of the Interior to make a study to find the most economical way to get a supplemental water supply for the Grand Prairie.

Another proposal called for construction of a dam on the Little Red River near Heber Springs and diversion of a part of the flow into the

Grand Prairie through a gravity canal. The same difficulty was found in this plan as in others of similar type. No local body was organized to furnish the required assurances of land availability, project maintenance, and repayment of construction costs to the Government. A diversion dam and gravity canal on the Little Red River were included in a 1948 study by the Corps of Engineers and were found to be more expensive than the DeValls Bluff plan.

A canal connecting Little Rock on the Arkansas River and DeValls Bluff on the White River was proposed in 1932 and 1933. The primary purpose of this canal was to provide a route for boats; however, some interests considered the water-supply feature to be of primary importance. Farmers in the region voiced objections to the proposal and generally condemned it.

Construction of large reservoirs for storage of surface runoff has been proposed for several locations. Generally, it was considered that the cost of delivering the water to the individual user would make the price of water extreme. Many small reservoirs have been constructed by individual farmers and supply approximately 10 percent of the water required for irrigation. Most of the natural sites for small reservoirs are already in use. High evaporation losses are also a major problem.

"Deep wells" solved the water-shortage problem at a few places in the Grand Prairie region. However, deposits of Tertiary age will support only a limited number of wells and cannot be considered to be an answer to the problem.

The Department of the Interior's memorandum for the press, "Ground-Water Supplies for Rice Irrigation in the Grand Prairie Region, Arkansas," January 26, 1931, offered another possible solution to the water shortage.

> A method that has been widely suggested to prevent overdraft and raise the head is the process of artificial recharge. This consists primarily of introducing surface water into the water-bearing beds through wells or in other ways. Artificial recharge has been practiced in certain localities where geologic conditions favor the process. However, the writer [D. G. Thompson] knows of no locality where this process has been used under conditions similar to those in the Grand Prairie region, and there is no precedent by which to judge whether recharge could be practiced here economically. Because of the considerable depth to the water-bearing beds, recharge by means of wells is believed to be the only method to be considered for adding water to them. There is no doubt that large quantities of water could be introduced, but the cost might be prohibitive. A properly constructed well should be capable of carrying into the beds at least as much and probably considerably more water than can be pumped from them; for it should be possible to create a head during the recharge process that would be greater than the drawdown needed to provide the discharge by pumping. However, the water used for recharging will at times carry more or less fine sediment, which may clog the recharge well. Moreover,

algae or bacterial growth may develop in the material near the outlet of the well, which may also clog it. For these reasons, it will probably be necessary to filter the water and perhaps treat it with sterilizing agents before it enters the recharge well. Attention must also be given to the question of pollution of the water supply and to the sanitary efficacy of filtration or other treatment of the introduced water. * * *

* * * * * * *

It is not certain whether the cost of adding water by means of recharge wells will be low enough to warrant the use of the method merely to reduce the cost of pumping. The use of such wells to prevent further depletion of the supply may be practicable, and it is believed that investigation of the cost of such wells and experimentation with one or more of them are warranted.

Mr. Thompson's surmisal of the Grand Prairie irrigation situation has proved to be excellent. At first, only a few people were willing to accept the fact that the ground-water supply was limited, but as pump bowls were lowered and well yields declined, more people became concerned about the water problem. Inasmuch as a rice-acreage reduction would result in a reduction in income, a supplemental water supply was more desirable, and interest in recharging the deposits of Quaternary age artifically continued to grow.

Two methods of recharging through wells were considered. One involved the use of a small number of large horizontal-collector wells, which would be operated throughout the year and have an outside water supply such as the White or Little Red River. The other involved the use of existing irrigation wells to inject local surface runoff that would be stored temporarily in small reservoirs. Several proposals have attracted widespread attention. An example is quoted from the February 22, 1952, issue of the Arkansas Democrat, headlined "Stuttgart Pair Would Recharge Water Supply."

A pair of Arkansans want Congress to pick up a $250,000 tag to quench a big thirst. They'll make the request Monday in Washington before a House Appropriations Sub-Committee (civil functions).

It's the sections of the country where irrigation is used in farming that need the big drink of water. A couple of Stuttgart engineers, Brooklyn-born Raphael Kazmann and Texas-born Tom Fricke, have a plan to remedy the dwindling supply of sub-surface water—simply pump water back into depleted underground storage strata of sand and gravel. They think they can do it by recharge wells.

* * * * * * *

Fricke and Kazmann have been working on the recharge theory for years and have expounded it before government agencies. They contend their system eventually will restore ground water to desirable levels at well as cut the cost of irrigation and remove the danger and hazard of a drought.

This is how their plan works:

They would sink a well about 20 feet in diameter and 130 feet in depth. In the center would be a shaft with perforated distributor pipes at the bottom, arranged like spokes on a wheel. The pipes would be forced into the aquifer (water-bearing sand and gravel) and water forced down the shaft and through the pipes into natural water-storage vaults.

The Kazmann-Fricke idea reverses the operation of the horizontal-collector type of well.

The surface-water source for underground distribution would come from nearby streams by means of a canal. One recharge well is designed to feed water wells within a 2-mile radius and thus eliminate the need for intricate canals connecting rice farms.

The two engineers want Congress to finance the first test project. If it works here, they are confident that the recharge well idea would be successful in other parts of the nation that need a shot-of-water.

The plan above recommends an experimental pilot plant; however, some proposals envisioned a large-scale operational pilot plant. The following is quoted from "Greers Ferry Dam Brings New Interest in Recharge" (Daily Leader, July 14, 1954):

Army engineers are going to take a closer look at a plan—partly old, partly new—to recharge the underground water supplies for the rich Grand Prairie region of Central Arkansas.

The most recent plan, worked out by Col. John E. Buxton, Little Rock consulting engineer, would take water from the Little Red River below the proposed Greer's Ferry Dam and run it southward by means of pipes and natural ditches into the Grand Prairie region. * * *

Buxton's (1954) plan is this:

A low dam would be built on the Little Red in the vicinity of Judsonia and a huge conduit would be constructed to carry water southward through the oval-shaped Grand Prairie region to a point west of DeWitt. Water would be released from this pipeline at intervals along the route so that it might seep back into the earth and recharge the underground supplies. (See figure 6.)

Buxton said that once Greer's Ferry is built there would be a constant supply of water for the project since the reservoir back of the big dam will have a capacity of 294 billion gallons for flood-control storage and 622 billion gallons for power generation.

Water would flow along the 60 miles of the pipeline entirely by gravity—no pumps would be needed. Buxton figured a pipe about 10 feet in diameter would be needed at the head of the line. This would decrease in size as the line progressed southward. He estimated that about a third of the Little Red River stream flow would pass down the line yearly.

The project, he said, would be a pilot plant for a study of ground-water recharge since the flow of water through the pipe and the level of the water in the area's wells could be accurately measured.

Although some interests thought that the horizontal-collector well would be the best facility for artificial recharge, others proposed tests of vertical wells as a preliminary to the costlier studies of the large well.

COOPERATING AGENCIES

The Committee on Flood Control of the U.S. House of Representatives adopted a resolution of December 18, 1945, which directed the Corps of Engineers to review certain outstanding reports concerning

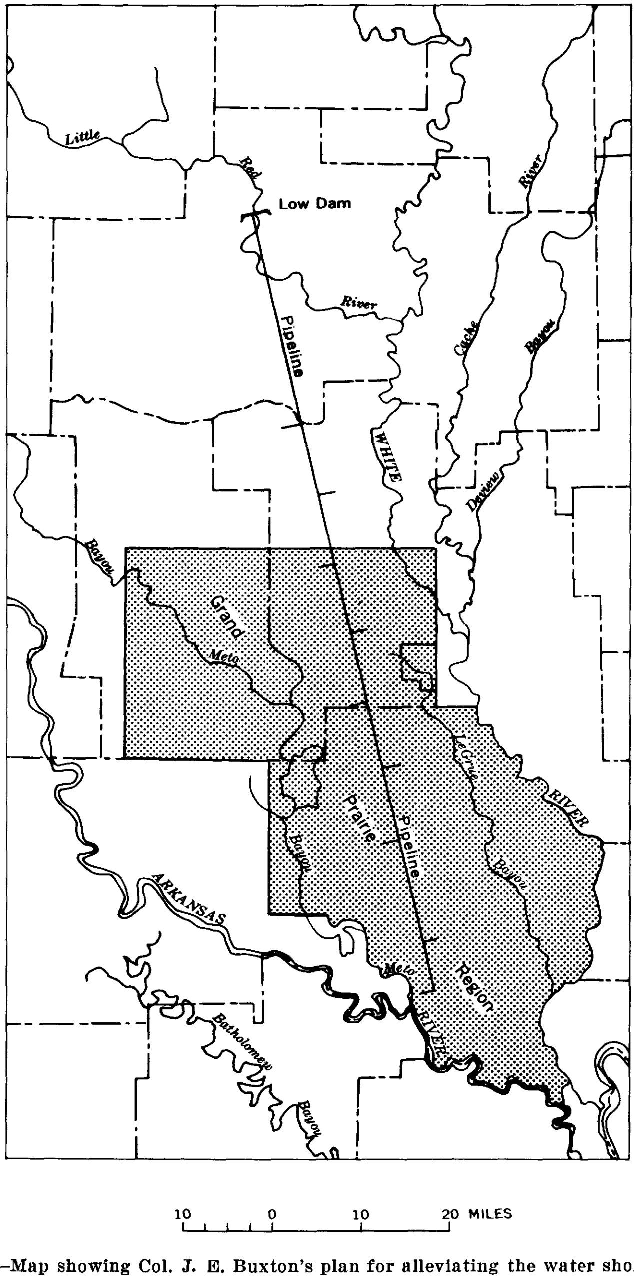

FIGURE 6.—Map showing Col. J. E. Buxton's plan for alleviating the water shortage in the Grand Prairie region.

drainage and water supply for irrigation in the Grand Prairie region of Arkansas. In response to this resolution, the Corps of Engineers made a study of the feasibility of constructing works for the importation of water into the Grand Prairie from the Arkansas, White, and Little Red Rivers. A plan for withdrawal of water from the White River at DeValls Bluff and for its distribution through a system of canals was presented in the Review of Reports for the Grand Prairie region and Bayou Meto Basin, submitted on July 1, 1948. This plan was authorized by the Flood Control Act of 1950. However, local interests have never pressed for implementation of the authorized plan. On September 28, 1951, the Committee on Public Works of the United States Senate adopted a resolution directing the Corps of Engineers to review outstanding reports on the Grand Prairie region of Arkansas to determine if any changes in the water-supply plan were warranted and to make such on-site tests as were necessary, but no funds for the tests were made available until fiscal year 1954.

In 1946 the University of Arkansas organized its first artificial-recharge project, but no field studies were made. In 1953 the University prepared plans for an artificial-recharge project based on the use of a horizontal well for injection. (See figure 7.) The horizontal water collector incorporates a concrete casing approximately 13 feet in diameter that is allowed to sink by its own weight as excavation proceeds slightly ahead of the casing. A system of screens is driven horizontally, thus resembling the spokes of a wheel; these screens have an average length of 200 feet. These plans were presented to private interests in an effort to obtain the necessary financing; however, because of the large first cost, no private backing was received.

In 1953 the U.S. Geological Survey began a research study of the fundamental principles of artificial recharge. The Grand Prairie region of Arkansas was selected as the area of study because it provided a large natural laboratory for general recharge investigations. The large volume of aquifer, dewatered by pumping for irrigation, provided an ideal medium for recharge experiments.

Being cognizant of the Congressional resolution directing the Corps of Engineers to conduct water-supply studies in the Grand Prairie, and of the University of Arkansas' interest in recharge, the Geological Survey invited representatives of the Corps' Vicksburg District and the University of Arkansas to meet with its representatives in Little Rock on January 6, 1954. The purpose of this meeting was to discuss the possibility of beginning an artificial-recharge project on a joint basis, thus pooling the resources of the three interested agencies and at the same time avoiding duplication of effort. The Corps of Engineers and the University of Arkansas considered such a study

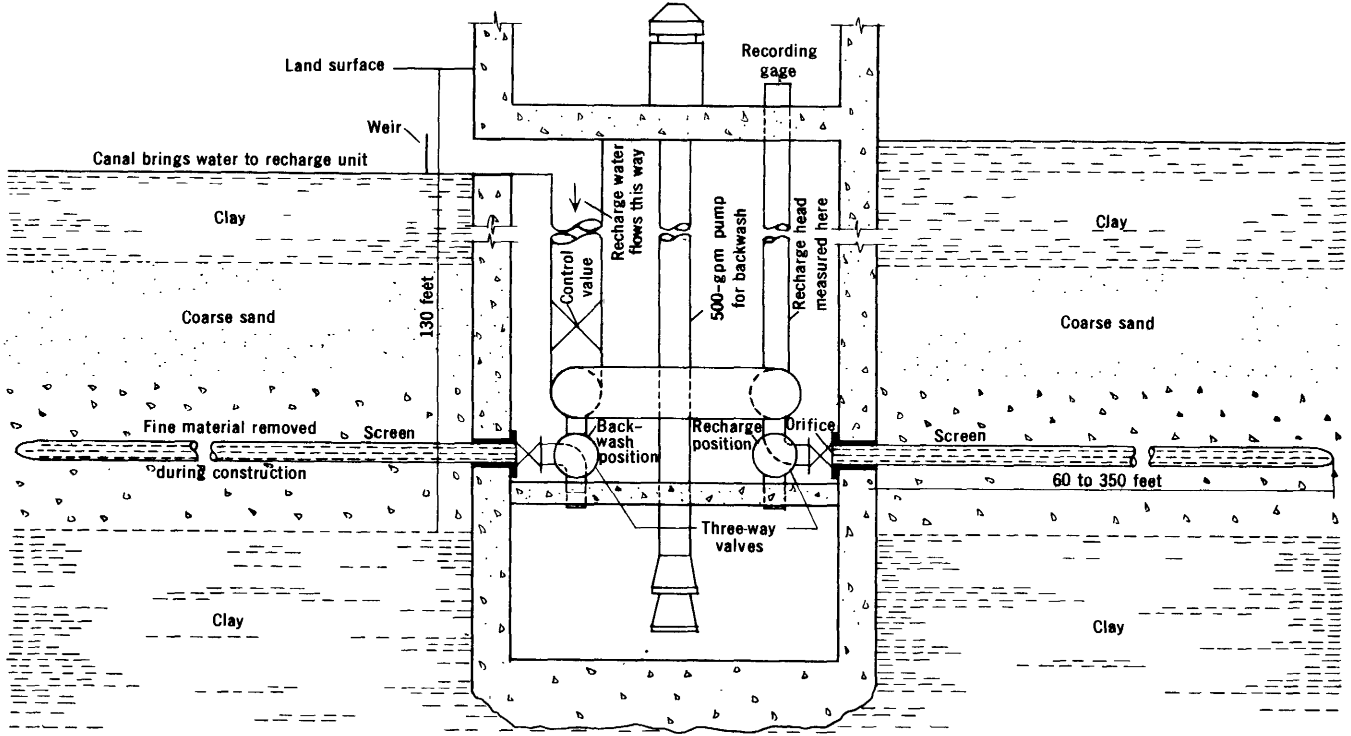

FIGURE 7.—Diagram showing the radial collector as a recharge well.

desirable and agreed to participate on an informal basis to the extent of available funds.

LOCAL INTERESTS AND PARTICIPATION

The Stuttgart Chamber of Commerce formed a Recharge Committee composed of the following men: Messrs. Ralph King, executive vice president of the Layne-Arkansas Co.; H. L. Leftwich, district manager, Arkansas Power and Light Co.; A. N. Spicer, rice farmer; and Leo Galvin, manager of the Stuttgart Division of the Fairbanks-Morse Co. Mr. Leftwich was succeeded as district manager by Mr. Clyde Martin, who also replaced Mr. Leftwich on the Recharge Committee. The purpose of this committee was to implement the recharge studies by obtaining materials and funds to be channeled through the University of Arkansas. Solicitation of funds and materials was highly successful, and contributions came from people concerned with the economy of the Grand Prairie as well as those interested in the fundamentals of artificial recharge. (See Acknowledgements, p. A2.) This group has continued to function throughout the life of the project and has been most helpful in obtaining local services as well as funds and materials.

SELECTION OF THE ARTIFICIAL-RECHARGE TEST SITE

The University of Arkansas offered land on its Rice Branch Experiment Station as a site for field experiments. The Experiment Station is 7 miles east of Stuttgart, on the northeast flank of the area of greatest ground-water decline. Little LaGrue Bayou, adjacent to the Experiment Station on the east, offered an adequate surface-water supply and a natural reservoir site if such proved necessary. Other advantages were permanence of site and assistance of Experiment Station personnel. This site was adopted by the participating agencies.

PURPOSE AND SCOPE OF THE PROJECT

Artificial recharge has been attempted in several locations and accomplished under certain conditions. However, few data are available on the hydraulics and economics of recharging with surface runoff under field conditions.

The purpose of this investigation differs slightly for each participating agency; generally, however, the objective is to determine the feasibility of relieving ground-water shortages by injection of surface water through wells. Both the quality of the water and the type of well will be varied in an effort to evaluate the potentialities and limitations of injection through wells. To provide water of different characteristics, it is necessary to apply basic water-treatment principles with special adaptations for field use. Studies should be made to determine the most practical method of providing water of suitable chemical and physical quality. The condition of the well and the affected aquifer must be determined for each test. The cost of the resulting plan will be analyzed with the accompanying benefits to determine the feasibility of artificial recharge in any particular area. It is possible that similar experiments should be made in other localities with different aquifer characteristics. The studies to date (1960) are based on the use of local runoff stored temporarily in small reservoirs and on recharge through vertical wells similar in construction to irrigation wells. If a project based on a water supply from outside sources such as the White or the Little Red River is considered, then tests of wells of other types such as the horizontal collector well would be worthwhile.

It is emphasized that all phases of this project must be considered experimental and not operational. Until such time as testing is finished and data are analyzed and reported, operational recharge will not be considered by the participating agencies.

Additional phases of the studies will be described in subsequent chapters of this water-supply paper. The second chapter describes the regional hydrogeology. The third and succeeding chapters will describe the results of tests.

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