Irrigation development, institutional blocks to ground-surface-water integration in the Gallatin Valley, Montana
by Ramon Wesley Sammons

A dissertation submitted to the Graduate Faculty in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Agricultural Economics
Montana State University
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Abstract:
This research problem is concerned with the blocks to an integrated irrigation system in southwestern Montana, The reasons for choosing the Gallatin Valley for study are: (1) the valley needs additional water to assure adequate irrigation throughout the irrigation season, (2) a large ground water reservoir exists 10-40 feet below certain parts of the valley, (3) the valley has 100 years of irrigation history, (4) no serious agriculture-industry or agriculture-municipal water conflicts have been experienced, and (5) both ground and surface water resources are used for irrigation.

Mail questionnaires sent directly to farmers and personal interviews with local ditch company officials is the method used to establish the blocks to ground-surface water integration. The Bureau of Reclamation, 1958, established the benefit-cost ratio for a valley wide integrated system to be greater than 1.52. Analysis of collected data indicates the blocks to development are physical, historical and legal. Physical blocks exist because the farm land and the surface and ground water are in different locations. Historical blocks are a result of the way surface water rights have been established in Montana, The lack of a ground water code prior to 1962 created a legal drag on ground water development.

The blocks to integration could possibly be overcome by a project demonstrating the merits of-ground-surface water integration, A 25 well pumping system is proposed. This system would supply water to one area of the valley, The High Line .Canal Company, for the 45 days during which they usually have little or no‘irrigation water. Hydro-logical data for this system is taken from secondary sources. Estimated costs of construction and operation of the project were submitted by various irrigation supply companies, well drilling companies and construction companies in Montana, The pumping system is designed to be owned and operated by The High Line Ditch Company, Total head for the 25 wells varies from 30 feet to 259 feet. The estimated pumping cost for the designed system averages $0.0326 per acre foot of lift.

The overall average cost of delivering water to the ditch is $4.17 per acre foot.

The decision to install a pump irrigation system is a management function of The High Line Canal Company, A study budgeting the costs for typical farms under The High Line Canal would be helpful in making this decision, A management study could establish the value of additional water, indicate the opportunities to grow crops with high water requirements and show the effects of increased fixed liabilities on the net capital ratio of The High Line Canal Company farmers.

IRRIGATION DEVELOPMENT

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by

RAMON WESLEY SAMMONS

A dissertation submitted to the Graduate Faculty in partial fulfillment of the requirements for the degree

of

Doctor of Philosophy

in

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Approved:

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ABSTRACT

This research problem is concerned with the blocks to an integrated irrigation system in southwestern Montana. The reasons for choosing the Gallatin Valley for study are: (1) the valley needs additional water to assure adequate irrigation throughout the irrigation season, (2) a large ground water reservoir exists 10-40 feet below certain parts of the valley, (3) the valley has 100 years of irrigation history, (4) no serious agriculture-industry or agriculture-municipal water conflicts have been experienced, and (5) both ground and surface water resources are used for irrigation.

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The blocks to integration could possibly be overcome by a project demonstrating the merits of ground-surface water integration. A 25 well pumping system is proposed. This system would supply water to one area of the valley, The High Line Canal Company, for the 45 days during which they usually have little or no irrigation water. Hydrological data for this system is taken from secondary sources. Estimated costs of construction and operation of the project were submitted by various irrigation supply companies, well drilling companies and construction companies in Montana. The pumping system is designed to be owned and operated by The High Line Ditch Company. Total head for the 25 wells varies from 30 feet to 259 feet. The estimated pumping cost for the designed system averages $0.0326 per acre foot of lift. The overall average cost of delivering water to the ditch is $4.17 per acre foot.

The decision to install a pump irrigation system is a management function of The High Line Canal Company. A study budgeting the costs for typical farms under The High Line Canal would be helpful in making this decision. A management study could establish the value of additional water, indicate the opportunities to grow crops with high water requirements and show the effects of increased fixed liabilities on the net capital ratio of The High Line Canal Company farmers.

CHAPTER I

The Study in Perspective

Ground water development is generally conducted individually on a well-at-a-time basis. Locations, timing, volumes pumped, and use are most frequently individual decisions unrelated to prior development and resource potential. Surface water, in contrast, is usually developed by water companies, public districts, municipalities, or state and federal government in connection with a long history of water rights. For the most part, ground water and surface water have been brought into use independently of each other, legally and economically. Yet, surface water and ground water are but two parts of the same resource.

In 1961 four western states, recognizing this common water problem, jointly agreed to make an "Economic Analysis of Integrated Ground-Surface Water Resource Management." The 1961 reports of the Senate Select Committee on Water Resources brought the urgency of this study into focus by pointing out that new irrigation development between 1900 and 1909 included only 8 percent ground water. In a similar nine-year period, 1950-1958, 69 percent of the new irrigation was accomplished using ground water. Continued development along these lines would produce a system void of the benefits of integrated management.

The goal of the regional study, begun in 1961, is to provide the West with valuable information needed in counseling legislative committees, private organizations and others about the development of ground and surface water as one common resource. Montana has a unique posi-

tion in the regional mosaic since water development here is in its infancy. Only 13 percent of the hydroelectric power potential has been developed, vast possibilities remain in recreation development, and countless opportunities remain for agricultural and industrial uses. Montana is fortunate in that a critical water shortage has not yet developed. In the future water is expected to become an increasingly important resource in Montana's social and economic development with more pressing demands for water being made by rapidly expanding agricultural, industrial and recreational development.

Montana's unique contribution to the regional economic study is focused on the Gallatin Valley, Figure 1. This valley has irrigation history dating back to 1864. Currently the valley relies on both surface and ground water as a source of irrigation water and there is a wealth of hydrological data available about the ground and surface water resources. The valley has never experienced serious agriculture-industry or agriculture-municipal conflicts over water usage. The valley does experience irrigation water shortages but it possesses water resources sufficient in quantity to fill its needs. These characteristics make the Gallatin Valley an ideal case study area for ground-surface water integration.

Objectives

The objectives for this study are:

1. To estimate the amount of agricultural water usage that can be expected to develop within the Gallatin Valley in the foreseeable future.

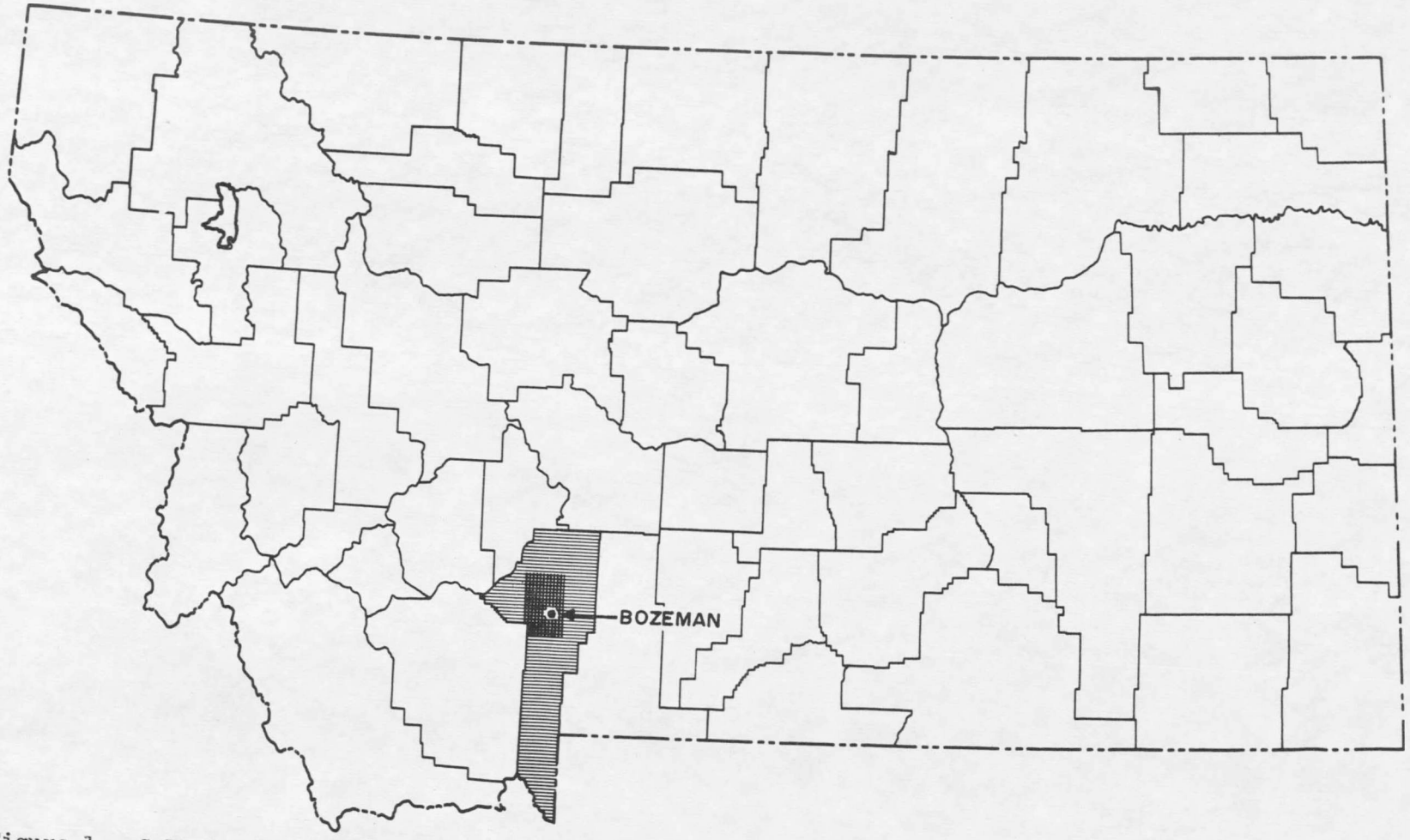


Figure 1. Gallatin County and Gallatin Valley, Montana, 1964.

2. To identify and delineate the present institutional, legal and technological blocks to the development and coordination of ground-surface water integration.

3. To recommend policies and programs to coordinate the use of ground and surface water.

Procedures

The procedures for pursuing each objective are as follows:

Objective 1.--Future agricultural needs for irrigation water will be estimated using primary and secondary data.

Objective 2.--The interest groups involved are farmers, ditch companies, local courts and others. Each of these groups can contribute unique information to the mosaic pattern of this study.

1. Farmers

The farmers will be divided into those with a full supply of water and those needing additional irrigation water. By means of personal interviews, present water costs can be established for both groups and these costs will allow some limits to be set, if there are any, on the technical and economic possibilities of private development of the local ground water resource. Secondly, from the farmers that actually have a need for more water, the amount of water needed and the price they can afford to pay for more water will be determined.

A third area to be explored is the attitude of both groups of farmers toward integration of ground and surface water. Reactions here may set some limits upon the institutional alternatives that can be considered.

2. Ditch Companies

Ditch companies can roughly be divided into those with a full or nearly full supply of water and those with mostly flood water rights. These two groups will be interviewed regarding their interest in and ability to carry out a ground-surface water exchange.

3. Local Courts

The local court has jurisdiction over the decreed water rights of the valley. The legal status of ground-surface water integration is paramount in this study, therefore the court will be consulted in order to determine any existing legal blocks to integration, or to future expansion of industrial and other uses.

Objective 3.--A study of the economic feasibility of privately developing a pumping project will be made. The feasibility of such a project will give direction to recommended policies and programs to coordinate the use of ground and surface water.

CHAPTER II

National Importance of Water

Water is deemed so important that plans are being made for a 10-year study of the earth's water resources. Plans include an International Hydrological Decade to begin January 1, 1965 with scientists from 100 nations gathering data on the earth's water cycle with special emphasis on infiltration, evaporation, streamflow, underground reservoirs, and erosion. Some of these projects may continue for a century in an effort to know more about our water.1/

Present Water Supply

As a nation we have acknowledged the importance of water to the extent that during the past 50 years our national government has authorized over 20 commissions or committees to examine our national water policies and problems. Until fresh water can be taken from the ocean, precipitation will remain the world's only supply of fresh water. For the United States as a whole the present precipitation supply is staggering. In a normal year, mother nature delivers enough water onto the United States to cover the whole country to a depth of 30 inches! However, about 21 of these 30 inches, after supporting our forests and non-irrigated farms, return to the atmosphere by evaporation and transpiration and are not available for human use, Figure 2. The nine inches remaining go into surface run-off or ground water storage. These nine

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1/Bozeman Daily Chronicle, November 3, 1963, p. 13.

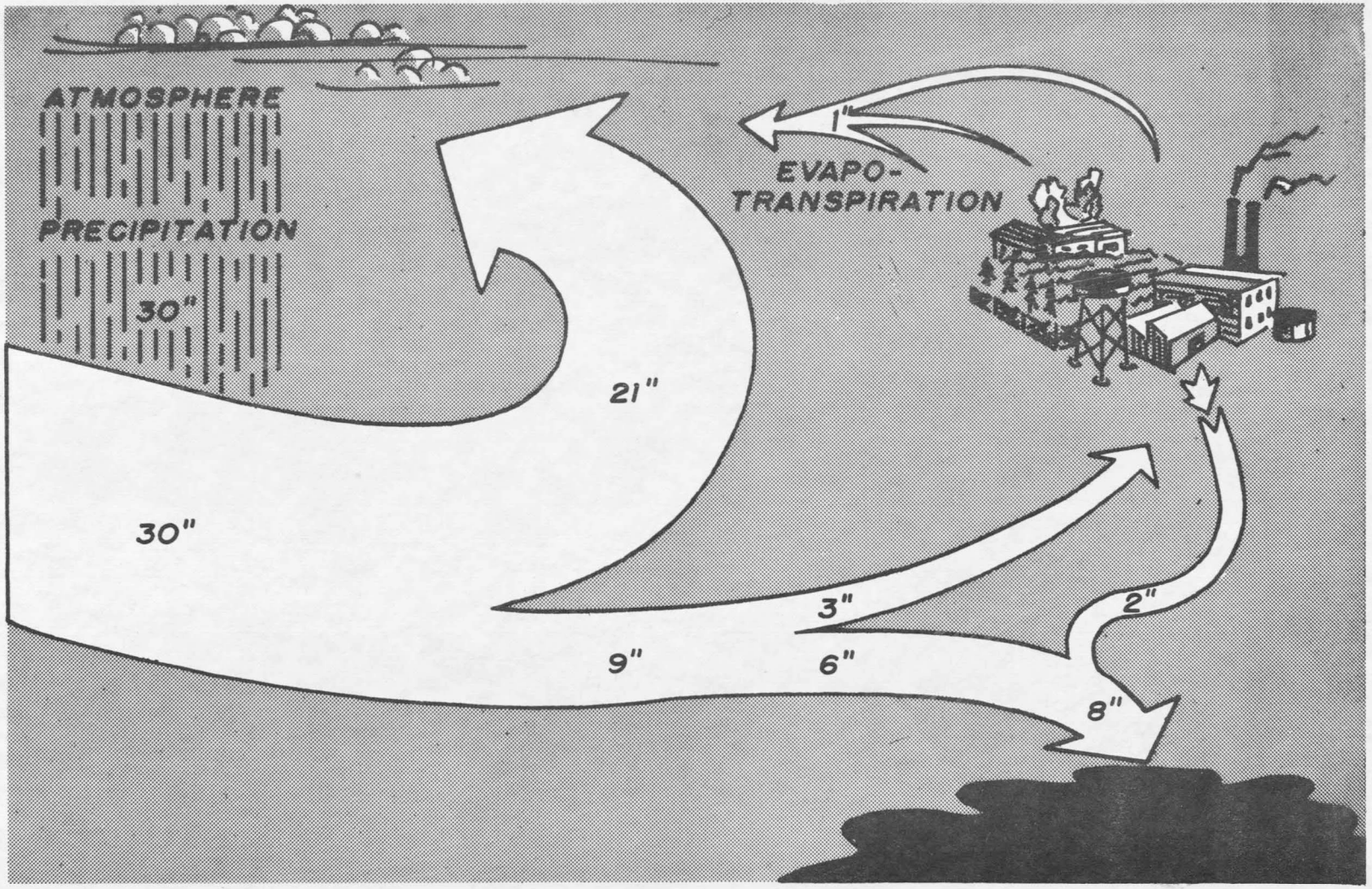


Figure 2. The National Water Supply.*

*Source: Select Committee on National Water Resources, United States Senate, Water Resources Activities in the United States, U. S. Govt. Printing Office, Washington, D. C., 1959, p. 4.

inches, about 1,160 billion gallons per day, constitute our manageable supply of water. Under present conditions we utilize about three of the nine manageable inches and allow the other six to run off or be stored underground. One inch of the three we utilize is consumed either through evaporation, transportation or incorporated into products. Two of the utilized inches dilute wastes, are used as coolants, create power, etc., but are returned to stream flow.

National averages misrepresent our water problem by showing our daily supply to be 1,160 billion gallons and our use to be only 250 billion gallons. We expect to use only slightly more than one half, 600 billion gallons daily, of our average manageable supply by 1980. This seems to present a favorable picture but overall figures are very misleading. There is a wide variation in the distribution of the average annual precipitation in the United States--about two-thirds of the total precipitation falls on one-third of the land area, Figure 3. To further complicate the situation, there are wide yearly variations in the precipitation received in most areas of the United States.

Present Water Usage

Human life depends upon water. A human can survive on about six pints of water daily but the average American has become accustomed to using over 60 gallons daily for household and lawn watering purposes.

In 1960 the United States utilized about 250 billion gallons of water each day. The way water is used affects the total supply. Consumed water, that which is evaporated or incorporated into a product,

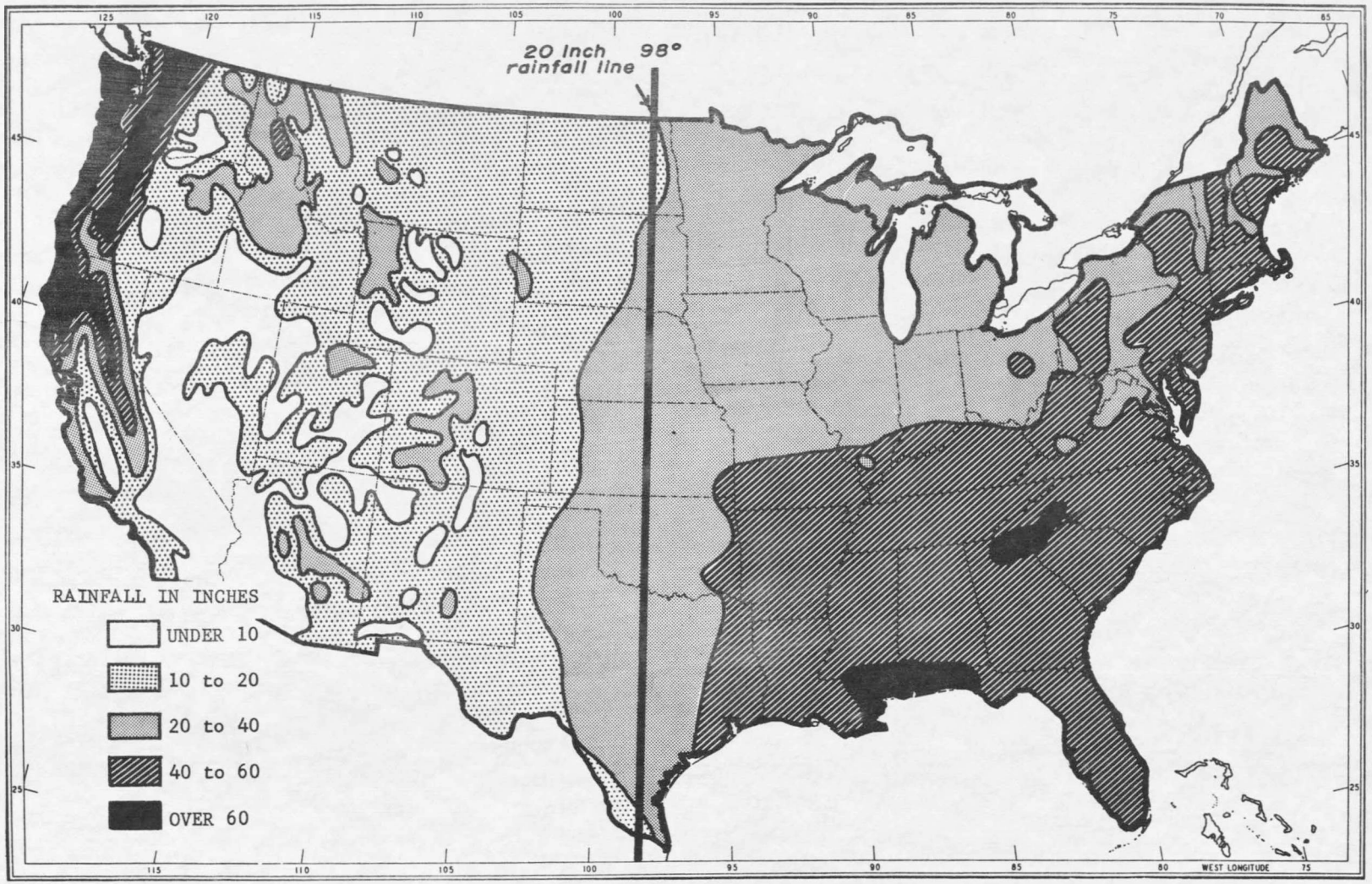


Figure 3. Approximate Average Annual Precipitation in the United States.

is removed from our total supply. Irrigation using 46 percent of our supply is one of the most consumptive uses of water, evaporating about 60 percent of the water used, Figure 4. Irrigation accounts for 80-90 percent of all consumed water.2/ Industry also uses 46 percent of our total water supply but only 2 percent of this water is evaporated. Rural and municipal supplies account for 8 percent of the total usage and are 10 percent consumptive.

Most industrial water is used in Eastern United States and most irrigation occurs in the West, Figure 5. Comparing Figures 3 and 5 we find industry, a low consumptive use, is located in a high rainfall area. Irrigation, a high consumptive use, draws its water from the low rainfall area of the United States. The relationship of consumptive uses and rainfall areas intensifies the national water problem.

Institutional Water Conflicts

Our national water supply is presently 4.5 times greater than our consumption. Our other natural resources are not found in the same places water is found and as a result the population of the United States is not always located where the fresh water is most abundant. Partly because of this mismatch an institutional problem has developed around the question of who owns the water within the boundaries of a state or nation and who has the right or privilege of its use.

2/Select Committee on National Water Resources, United States Senate, Water Resources Activities in the United States, Committee Print No. 1, United States Government Printing Office, Washington, D. C., 1959, p. 9.

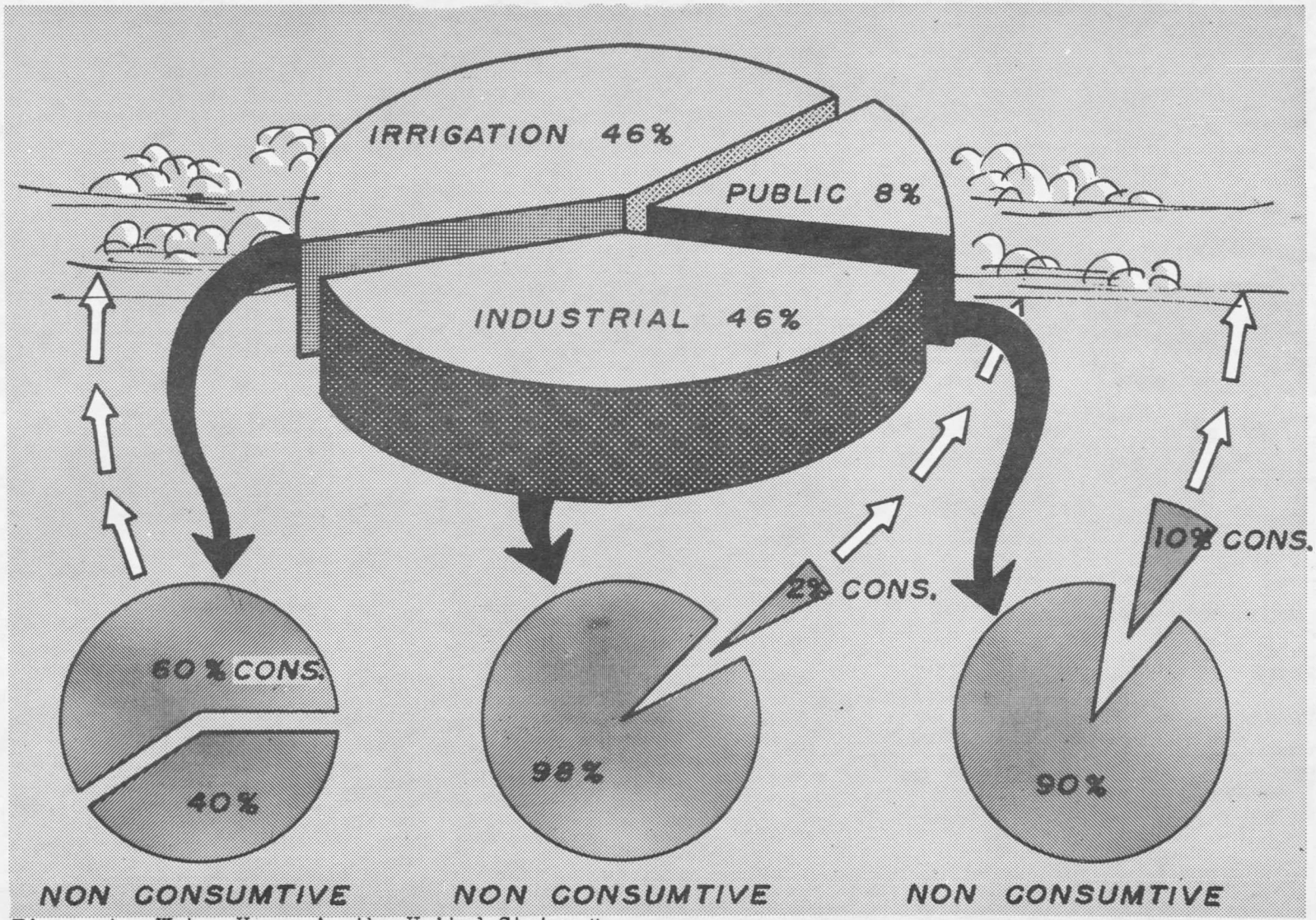


Figure 4. Water Usage in the United States.*

*Source: Select Committee on National Water Resource, United States Senate, Water Resources Activities in the United States, U. S. Govt. Printing Office, Washington, D. C., 1959, p. 8.

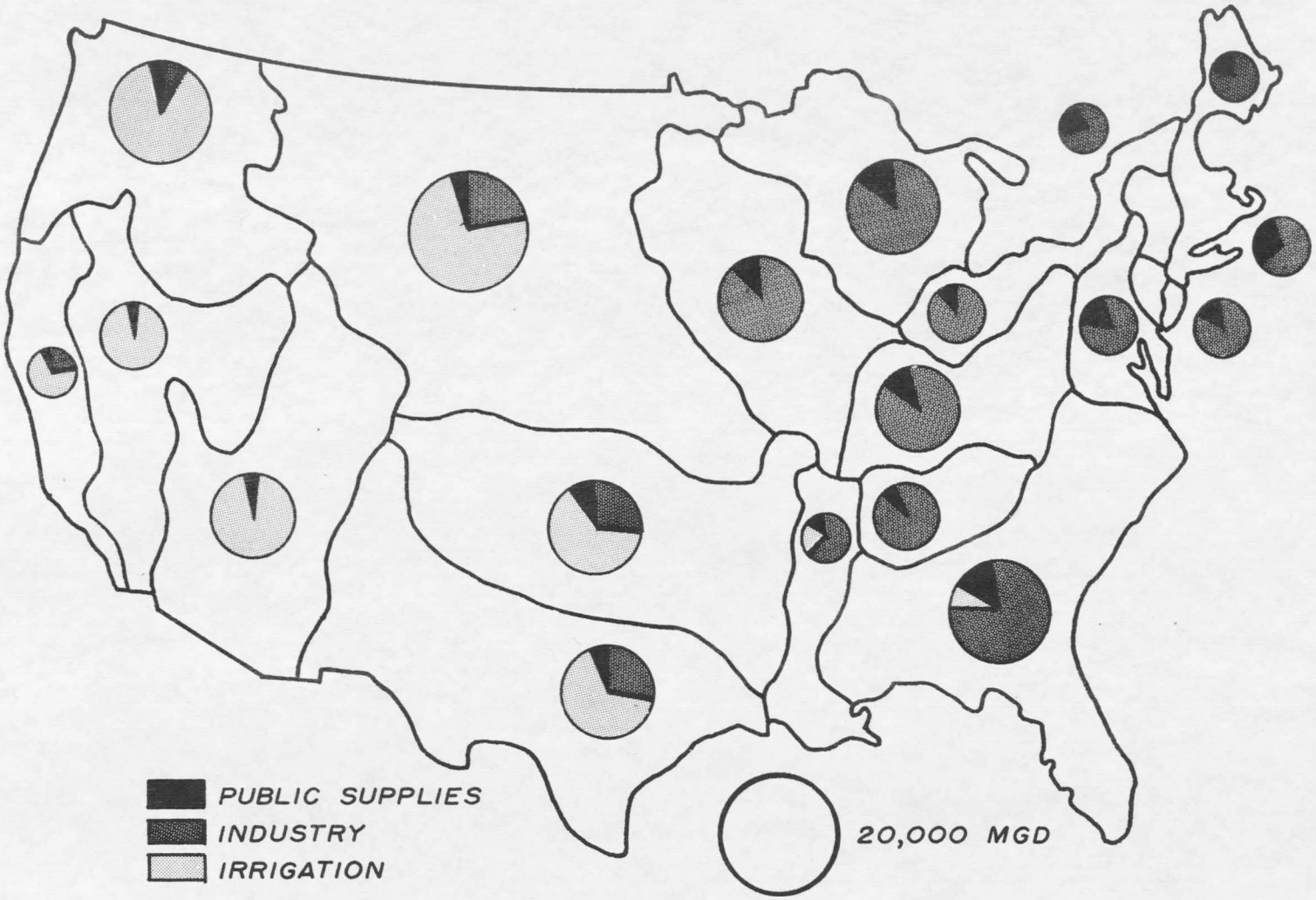


Figure 5. Regional Water Usage in the United States.*

*Source: Select Committee on National Water Resources, United States Senate, Water Resources Activities in the United States, U. S. Govt. Printing Office, Washington, D. C., 1959, p. 14.

An example of the difficulties that arise over rights-of-water-usage is the 10-year old conflict between Arizona and California over who has the right to the water in the Colorado River that forms the boundary between California and Arizona. In Southern California the population increases at the rate of 1,000 people every day and these people need water, the industries that employ these people use water, and the agriculture that feeds them uses water. Southern California is an arid region and must bring in water to support its industry, agriculture, and cities.

Arizona's population has doubled in the past 10 years and the Phoenix and Tucson areas have been pumping more water from the ground than rainfall has made available for recharge. The irrigation ruins near Phoenix suggest another civilization may have exhausted the water supply in centuries past. Phoenix and Tucson are looking for a new source of water.

Each of these two developing states on opposite sides of the Colorado River have considered themselves entitled to the water. A decision from the highest court in the land was required to settle the long dispute between these two states. The Supreme Court decision delivered on June 3, 1963 was split five to three in favor of Arizona getting more and California getting less water than they each received at that time. This institutional decision will force California to bring water 700 miles from Northern California to replace the water presently piped 250 miles from the Colorado River.

Since the Supreme Court decision, Arizona can legally lift her share of the Colorado River 985 feet to a ridge 25 miles from the river and gravity-flow it through pipes 220 miles to a large, as yet unconstructed, distribution system in the Phoenix-Tucson complex. This development will involve still other institutional problems. Arizona cannot develop her project without Federal aid and California has 40 congressmen who probably will do what they can to stop such aid. Obstructing Arizona's development will allow California to use the water from the Colorado River for a few more years until she can find some replacement water.

This institutional conflict is not confined to California and Arizona as is evident from the following editorial:

> California doesn't want any of its water going to Arizona, but proposes an aqueduct and pumping stations to get water from Idaho's Snake River for California. Governor Robert Smylie of Idaho doesn't think much of that idea, as could have been predicted.
>
> Governor Smylie suggests that California tap the Columbia River at Astoria and pipe the water south. The pipe presumably would be submerged off shore. Oregon doesn't like that pitch either. The Oregonian comments that if people and industries want Northwest water, let them come to the Northwest.
>
> No state wants to be the supplier of water for another. This applies to Montana as well as to Idaho and Oregon. We want, and should have, first call on the water that arises within Montana borders. And we want prior rights to the power produced within the state.
>
> Unless population growth is restrained, Southern California and perhaps Arizona will have to get water from the sea by conversion from salt to fresh. The Federal government is doing a lot of research on this in an effort

to get the cost down.

If the cost problem can be licked as a number of scientists think it can be, this makes more sense than trying to move rivers from one section of the country to another.3/

3/Editorial, Great Falls Tribune, December 6, 1963, p. 6, Col. 1-2.

CHAPTER III

History of Irrigation

Early Irrigation

The record of the first irrigation project is lost in antiquity. No one seems to know if the first irrigation was in Asia, Africa, Europe, or even America. Egypt had a project which diverted water from the Nile River in a channel 12 miles long as early as 2000 B.C. This channel may not have been a part of the first irrigation project but it probably created the first man-made lake, Lake Moeris. Egypt had other probably firsts, e.g., the first artesian well, the milometer for guaging streams, a system of canals for irrigation and navigation; and the first mechanical means for lifting water from one level to another. Many of these "pumping" methods developed first by Egypt are still in use today.4/

Another ancient irrigation project worthy of mention because of its size and historical importance is that of Babylonia. Included in her system was a lake 42 miles around and 35 feet deep used for irrigation water storage. Their Nehrawn Canal was 400 miles long diverting water from the Tigris River and varied in width from 250 to 400 feet. These facilities supported the large cities of Babylon and Ur.5/ Failure to keep these facilities clean and useable aided in the destruction

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4/Huffman, Roy E., Irrigation Development and Public Water Policy, The Ronald Press Company, New York, 1953, pp. 7-8.

5/Ibid., p. 9.

of these great cities.

China and India also had irrigation systems very early in their culture, possibly as early as Egypt's, and their use of the art of irrigation went through differing stages of development through the centuries.

Irrigation practices in the Mediterranean area probably spread from the early Egyptian usage. The Greeks, Phoenicians, and Arabs all used irrigation in their cultures. The Romans and especially Julius Caesar, spread the practice wherever he went. The Romans introduced a type of flood irrigation into England that is still used today. The Arabs took irrigation into Spain with their conquest and the practice remained and developed long after they were driven out.6/

Irrigation in the Western Hemisphere dates back to before the time of Christ. In South America extensive irrigation was practiced in Peru, Mexico, Chile, and Argentina. The Incas of Peru probably had the largest irrigation system in the Americas, with one canal over 400 miles long. They used long aqueducts which displayed their engineering skill. Early irrigation in North America was confined to what is now Southwestern United States and dates back to the beginning of the Christian era. The most elaborate prehistoric developments were in the Salt River Valley, Utah, where it is estimated canals and laterals exceeded 1,000 miles. Approximately 250,000 acres were at one time under irrigation. This vast civilization vanished about 1400 A.D. New Mexico, Arizona

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6/Ibid., p. 11.

and Kansas also show remains of early irrigation systems but they too had vanished before the Spanish came in the early 1700's.7/

Modern Irrigation

The modern irrigation era in the United States starts with the establishment of the first Mormon Settlement in the Great Salt Lake Valley in 1847. The Mormon Settlement is not given this honor because they were the first group in modern times to practice irrigation, far from it. The Spanish missionaries of the Roman Catholic Church established missions in Arizona, New Mexico, and California and each included a small irrigation system for survival and instruction. The mission at San Diego, established in 1768 included an irrigation system and an irrigation community was initiated at Santa Cruz, California in 1776. At the time of the Mormon Settlement irrigation was a common practice at Sante Fe, New Mexico and some feel the Mormon freighters and teamsters may have observed irrigation first hand while freighting into New Mexico from Missouri.8/

The Mormon pioneers were Anglo-Saxon people and heirs of the long centuries of culture and civilization known to the Anglo-Saxons. The Mormons were pioneers in their own right. They moved from the humid east into a desert to settle down and live. Living in this desert was a challenge not known to the Anglo-Saxon pioneers before them who only

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7/Ibid., pp. 12-14.

8/Ibid., p. 15.

passed through this desert on their way to California and Oregon. The Mormon pioneers came to stay and somehow they must subdue the land and at the same time keep their civilized life and standard of living. Their social, economic and spiritual possessions they had to preserve. Their society in the desert must be as good or better than they had had in the humid region. "That was the challenge to the pioneers of 1847—to build communities of modern, civilized people under the ditch, comparable or superior to those in the rainfall regions from which they came. That accomplishment is in mind when we speak of modern irrigation."9/

The Mormon experience proved modern irrigation was possible and other groups soon took up the art. The 1849 gold rush gave a big push to irrigation water usage as ill fated miners turned to agriculture. In 1857 a settlement was started in what is now Anaheim, California, and in the 1870's irrigation projects were started in Greeley, Boulder, Longmont, Fort Collins, Loveland, and Colorado Springs, Colorado. Success in these adventures stimulated national interest in the possibilities of irrigation and the result has been a series of judicial decisions and legislative acts from the 1870's until 1963. Examples are, The Desert Land Act of 1877, The Carey Act of 1894, The Reclamation Act of 1902 10/ and The 1963 Supreme Court judicial decision on California vs. Arizona.

9/Ibid., p. 15 (citing "A Century of Irrigation", by John A. Widtsae, Reclamation Era, XXXIII, No. 5, May, 1947).

10/Ibid., pp. 16-27.

CHAPTER IV

The Development of Modern Water Rights

Water rights are different in the various parts of the United States and much of the difference is a result of topography and climate.

The Transitional Zone

A plenary understanding of present United States water rights is impossible without some knowledge of the climatic and topographical differences within the United States.

An imaginary line drawn north and south across the United States at the 98th meridian would cross North and South Dakota, Nebraska, Kansas, Oklahoma and Texas dividing the United States into the humid east and the arid west, Figure 6. These states bisected by the 98th meridian form a transitional zone and great changes are seen in the vegetation, topography, climate, and animal life when crossing the zone from east to west.

The variations in elevation west of the transitional zone are extreme, starting from 1,000 feet mean sea level (MSL) near the 98th and increasing steadily to the Continental Divide, about 14,000 feet. Beyond the divide elevations remain high until the western coastal range of mountains are crossed where a sharp descent is made to the Pacific Coast.

Vegetation in the transitional zone changes from the eastern timbered region to the western grasslands. This vegetational shift forces a shift in the animal life on the plains where the buffalo roam, the

antelope play and for the lack of a tree the chickadee becomes a ground squirrel. A typical eastern reaction to changes in vegetation and animal life west of the 98th are vividly described by Mark Twain in his first stage trip west. He describes his first "jackass rabbit", sage brush--a gnarled and venerable live oak tree reduced to a little scrub, prairie dog villages, antelope, coyote and buffalo with all the surprise of an eastern resident. His first impressions of the South Platte were:

> We came to the shallow, yellow, muddy South Platte with its low banks and its scattering flat sand-bars pigmy islands--a melancholy stream straggling through the center of the enormous flat plain and only saved from being impossible to find with the naked eye by its sentinel rank of scattering trees standing on either bank. The Platte was "up", they said--which made me wish I could see it when it was down, if it could look any sicker and sorrier.11/

Mark Twain's surprise and derision were justified since the climatic changes experienced in the transitional zone are the most important as far as man is concerned. The seasonal temperature-ranges west of the transitional zone are extreme but by far the most important climatic difference is the lack of precipitation. East of the transitional zone average rainfall is 20-60 inches per year, Figure 6, which is sufficient for abundant agriculture, while most of the area west of the 98th receives a sparse 10-20 inches of rainfall.

11/Clemens, S. L., Roughing It, Rinehart and Company, Incorporated, New York, 1957, pp. 33-34.

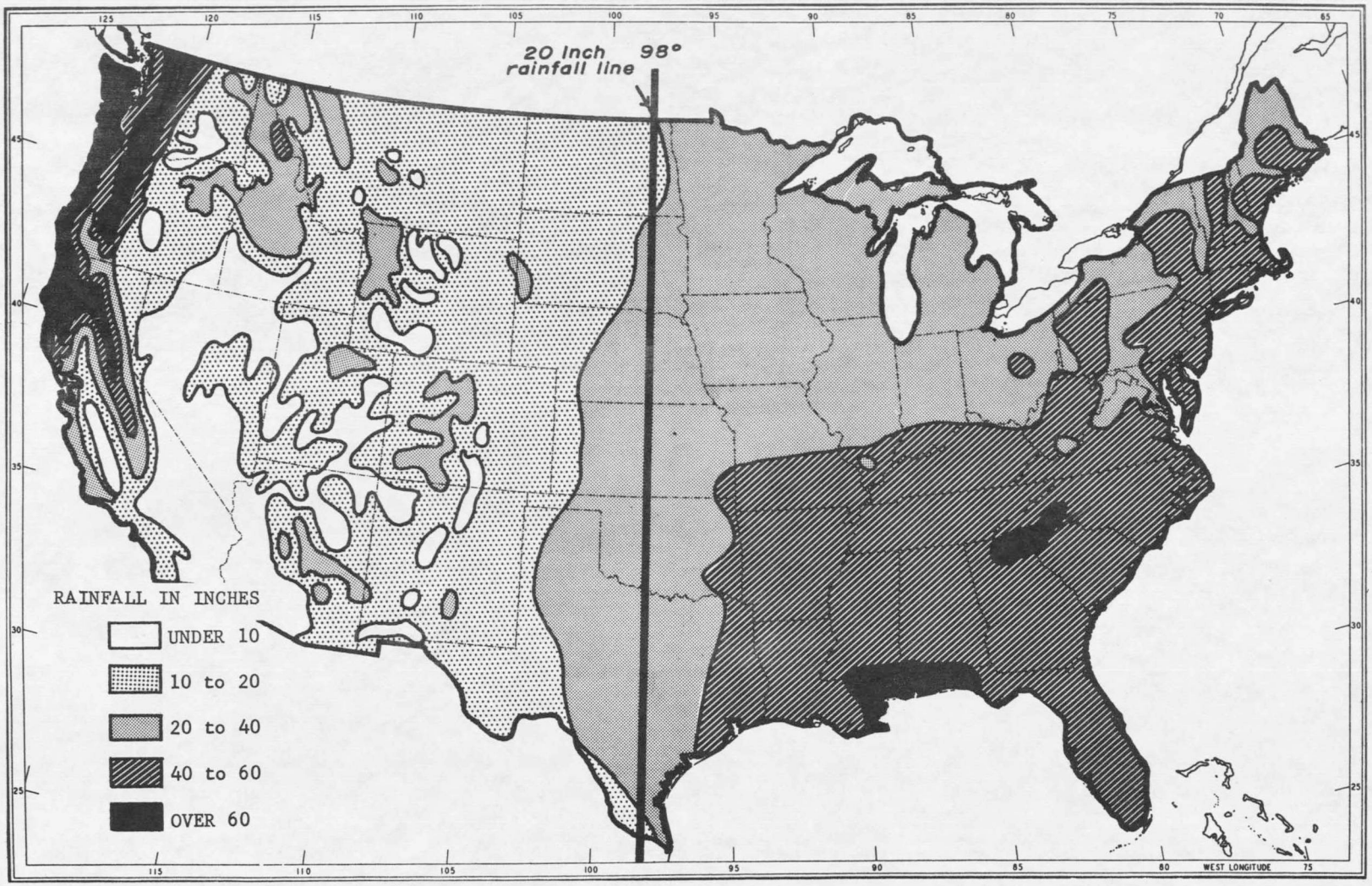


Figure 6. The 98th Meridian—The Transitional Zone.

The difference in annual precipitation between the east and west has had a marked affect upon the respective attitudes regarding rights to run-off water. East of the transitional zone land is scarce and water is free. The institutional and legal structures of the expanding United States were formed in the east under the assumption of the universality of these conditions. West of the transitional zone however, pioneers found land to be free (as evidenced by the great lengths to which the government went to give it away to railroads and homesteaders) and water to be scarce (as evidenced by the great length the settlers and later the government went to preserve it).

In summary then it was the climatic and topographical changes experienced when crossing the transitional zone that forced the early settlers to alter most of their social and legal institutions. This alteration is clearly attested to in the difference in water rights between the east and west.

Eastern United States Water Rights

Eastern United States was settled by people directly from Europe where moisture was sufficient for farming and continued irrigation was not necessary. Water there was used primarily for domestic, power, and recreational purposes and their laws and institutions were developed around these three. The amount of rainfall in eastern United States is comparable to western Europe and the traditional water law was applicable to both regions.

The Doctrine of Riparian Rights

The Doctrine of Riparian Rights, the title given to the water right system brought to the United States via the transfer of English Common law, was developed by people living in humid areas and evolved naturally as a solution to their needs.

The central theme of this doctrine is:

> Access to the water is the key point. The lands must somehow touch the stream or lake... Those who do not own lands touching the water body,..., do not have rights to use those defined waters... Once the land is completely severed by lawful means from access to the body of water, it may never again under the common law recover water rights in the natural water course. That is a basic point that makes the riparian system ever contracting never expanding... Another limitation of the riparian system... arises out of the main concept that each piece of riparian land is entitled to have the full flow of the stream come by substantially undiminished in quantity or unimpaired in quality...
>
> The riparian landowner is not held to any measure of beneficial use and conservation of the water supply. His right does not arise by reason of use... His rights arise by reason of ownership of land--nothing more.12/

Another writer explains the riparian rights as follows:

> The common law riparian right is comparatively simple, as far as the law with reference to it is concerned. It is an incident of the ownership of land which borders upon a stream. It is not shared in any way with those whose land does not abut upon the stream. Except for the right of the riparian owner to use so much water from the stream

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12/Busby, C. E., "Regulation and Economic Expansion," Yearbook of Agriculture, 1955, The United States Department of Agriculture, The United States Government Printing Office, pp. 669-670.

> as he reasonably requires for his own riparian purposes, the stream must be left undiminished in quantity and unimpaired in quality. He enjoys his riparian rights on a plane of complete equality with other riparian owners.13/

This riparian concept of water usage then would allow only for domestic use, power (if no polution), and recreational water uses by those who owned the banks containing the water. This concept inherently creates many blocks to eastern development even today but suffice it to say, such a concept of water usage could not meet the needs of western United States.

Western United States Water Rights

The gold rush of 1849 brought many people from the East into California. These people crossed the transitional zone and passed westward to a humid area much like the one they knew in the East. Once in California these "miners" were out of reach of the established law and riparian water rights. They found land, water, and gold and they "were free to make any use of the land and the water (in neither of which they held any proprietorship) that they could agree upon among themselves."14/ When they found gold they took the water to the gold because water was a must to separate the precious metal from the rocks and dirt. Water for mining was scarce, the demand greatly exceeded the supply, so the miners

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13/Patten, George Y., "Water Rights in Montana", Rocky Mountain Law Review, Vol. 23, No. 2, December, 1950, pp. 2-3.

14/Webb, Walter Prescot, The Great Plains, Grosset and Dunlap, New York, 1931, p. 443.

worked out a practical institution to allocate the water among themselves. This institution is The Doctrine of Prior Appropriation.

The Doctrine of Prior Appropriation

The early California miners agreed among themselves that the first person to develop a use for water held a priority for its use over later developments regardless of relative positions on a stream. From this idea comes the phrase—"first in time, first in right", and once a priority was established the "right" was valid as long as use was continual and beneficial.

As the gold rush in California diminished it increased in Montana, Colorado and other western states. As the miners moved from California they naturally took their new doctrine with them to other states. When gold fields failed, many turned to farming. Much of the new farming areas needed irrigation and it was only natural for them to apply their mining water doctrine to irrigation water. The Doctrine of Prior Appropriation has gone through many stages of development in several states but the important features are:

1. It gives an exclusive right to the first appropriator and in accordance with the doctrine of priority, the rights of later appropriators are conditioned upon the prior rights of those who have preceded.

2. It makes all rights conditioned upon beneficial use. The doctrine of priority was adopted for the protection of the first settlers in time of scarcity. The doctrine of beneficial use became a protection to later appropriators against wasteful use by those with earlier rights.

3. It permits water to be used on non-riparian lands as well as on riparian lands.

4. It permits diversion of water regardless of the diminution of the stream.

5. Continuation of the right depends upon continued beneficial use. The right may be lost by nonuse.15/

The eight mountain states have found they could not follow the riparian doctrine and they completely abrogated it in favor of the Doctrine of Prior Appropriation, Figure 7. These states are bordered on the West by the humid Pacific Coast States and on the East by the transitional zone states. These two groups of states modified the riparian doctrine to fit their own needs. Only the humid east has followed the common law doctrine.

Montana Water Rights

January 11, 1965 will mark 100 years since the Bannock Assembly, territorial government for Montana, adopted "The common law of England" and in so doing adopted the riparian doctrine of water rights.16/ From that time to this the laws affecting uses and rights to use both surface and ground water have been shaped and reshaped in an effort to find a stable useable water right code.

Before the doctrine of riparian rights was adopted as law the

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15/Huffman, Roy E., op. cit., p. 43.

16/Dunbar, Robert G., "The Search for a Stable Water Right in Montana", Agricultural History, Vol. 28, October, 1954, p. 139.

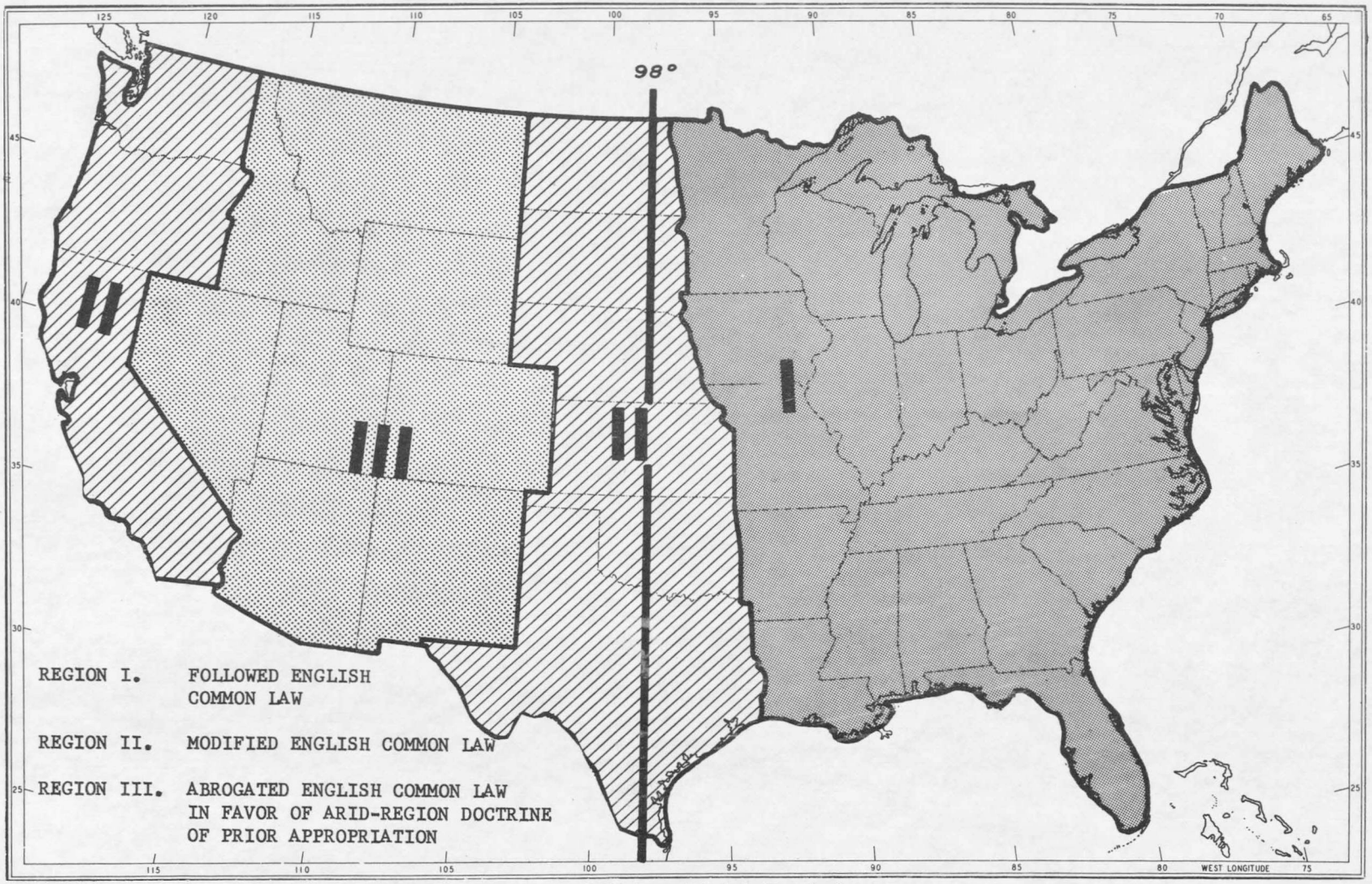


Figure 7. The Geographical Distribution of Water Right Doctrine.

miners and ranchers were actually using a prior appropriation approach to their common water problems. This doctrinal dichotomy in water rights continued in Montana until 1921. In 1919 after three dry years the Ames Reality Company, near Helena, decided to change the point of their diversion on Prickly Pear Creek from a point below the ranch of one Anna Mettler to a point above her ranch. This change took all of the water from the creek and the Mettler ranch was without water. A necessary fact of the case was that the Mettler ranch used water from the creek but had never made an appropriation or diversion of the creek. The case of Mettler vs. Ames Reality Company came before the court. Anna Mettler wanted water on the basis of her riparian right while Ames Reality Company based their case on prior appropriation. The decision of the court was, "Our conclusion is that the common law doctrine of riparian rights has never prevailed in Montana since the enactment of the Bannack Statutes in 1865, and that it is unsuited to the condition here..."17/

Surface Water Rights

Since the 1921 Supreme Court decision the Doctrine of Prior Appropriation has been the valid Montana water right law. Montana water is public property and rights to the use of water may be established in one of three ways. The first method applies only to unadjudicated

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17/Ibid., p. 141, citing Mettler vs. Ames Reality Company, Montana, 61: 152-71 (1921); Pacific Reporter, 201:702-08 (1921); Montana Supreme Court Library Briefs, Vol. 128, No. 4475, Brief of Appellant.

streams and requires a notice to be posted at the point of diversion and a copy of the notice to be filed within 20 days in the county clerk's office of the county in which the appropriation is being made. Construction of the diversion must begin within 40 days after the posting and continue with reasonable diligence until completion.

A second method, not provided for by law, is simply to dig a ditch and apply the water to beneficial use. The Supreme Court has ruled an appropriator may acquire a right by this method.

The third method applies to those streams where water rights and priorities have been determined by adjudication by the District Court. Once the streams are adjudicated the court decree becomes the effective deed of the appropriator to his water right. If a new appropriator wants to obtain water from an adjudicated stream he must petition the District Court having jurisdiction over the stream for permission to make the appropriation. If the other water users make no objections the court will give permission and a supplemental decree granting the right. This new right is then subject to the rights of the prior appropriators.

Ground Water Rights

In 1961 the Montana legislature passed an Underground Water Code. Prior to this time the use of ground water was not recorded, controlled or regulated. The Underground Water Code provides the machinery whereby a person or persons wanting to develop a ground water resource can establish a right to use said ground water and can determine who has

use priority. Certain sections of the code are reproduced in Appendix A. The basic philosophy of the code follows the Doctrine of Prior Appropriation and ranks water rights in the following manner:

1. Any surface water right appropriated before January 1, 1962 has priority over any ground water right, prior or subsequent to said date.

2. Any beneficial application of ground water prior to January 1, 1962 is recognized as a water right.

3. Any appropriation of ground water on or after January 1, 1962 is based upon the provisions of the code.

In establishing rights "between all appropriators of surface or ground water on or after January 1, 1962, the first in time is first in right."18/

The code makes provisions for the appropriation of ground water after January 1, 1962 in the following manner:

1. Before construction is started file a "Notice of Appropriation of Ground Water" with the county clerk in the county where the appropriation is contemplated. This notice gives the right its earliest possible date.

2. After filing the above notice construction of the well or other development must begin within 90 days and be continued till completion of the project.

3. Upon completion of the project a "Notice of Completion" must be filed with the county clerk stating the project is finished.

18/Underground Water Code, Montana Session Laws 1961, Chapter No. 237, Section 2.

This "Notice of Completion" is very important. If this notice is filed upon completion the date of the right is related back to the filing data on the "Notice of Appropriation." If the "Notice of Completion" is not filed after completion then the privilege of "relation back" is forfeited and the water right will be dated when the "Notice of Completion" is filed rather than the earlier date. Fifteen days difference in dating surface rights makes a big difference in the Gallatin Valley and the demand may create the same pressure on ground water rights.

CHAPTER V

History and Characteristics of Gallatin Valley

History

The southwestern portion of Montana was put-on-the-map by Lewis and Clark in 1805 when they discovered the source of the Missouri River. English, Canadian and American fur traders traversed the area for 50 years following Lewis and Clark, but it was the discovery of gold in the 1850's and 60's that began to bring people into the area. Gallatin County's first settlement was established near the mouth of the Gallatin River in 1862 when the Gallatin Town Company laid out a town site later known as Gallatin City. Gallatin City, located near the present town of Three Forks, and the Gallatin Town Company were incorporated and chartered respectively by the first legislature in 1865. The first house in Gallatin County was constructed at Gallatin City in 1863.

Bozeman was laid out and the first house built in 1864. That same year the first irrigation ditches were dug and the first wheat crop produced by John Thomas. Grain production took hold rapidly and as a result several flour mills, a malting plant, and a brewery were constructed. The first water right in the valley dates back to May 1, 1864 and water rights were established every year from 1864 to 1927. In the 88 years from 1864 to 1952 (the year the Bureau of Reclamation study was completed) water rights were dated in all but six years (1928, 1930, 1941, 1944, 1946, 1949). In less than 20 years after the

first water was diverted from the Gallatin River all of the normal surface run-off had been claimed. The first two court cases involving water rights were held in June, 1884. These first two cases established a trend and in the 68 years from 1884 to 1952, 44 cases, an average of .65 each year, are on record.

Immediately after the first settlement the population of the Gallatin Valley began to grow and in 1865-66 the first school was taught, 1867 brought a military post, Fort Ellis, and 1869 saw the first newspaper--The Montana Pick and Plow. Progress then was slow as we know progress today. Telegraph connections came to Bozeman from Helena in 1871, in 1878 the two principal hotels in Bozeman registered 14,000 guests. Even with all of this development the valley waited until 1883 for the first railroad and 1893 for Montana State College.19/

Geography

Gallatin County, Figure 8, is located in the southwest portion of Montana, Figure 1. The county spans 50 miles from east to west and 116 miles from north to south, totals 2,517 square miles and ranks, according to area, 25th of 56 counties in the state. The elevation of the county ranges from 4,000 feet near Trident to 11,293 feet at Koch Mountain north of Hebgen Lake.

19/Water Resources Survey, Gallatin County, State Engineer's Office, Helena, Montana, January, 1953, pp. 6-8. United States Department of Interior, op. cit., addendum to Appendix B, Vol. 1, Part III and IV, Ibid., Appendix A.

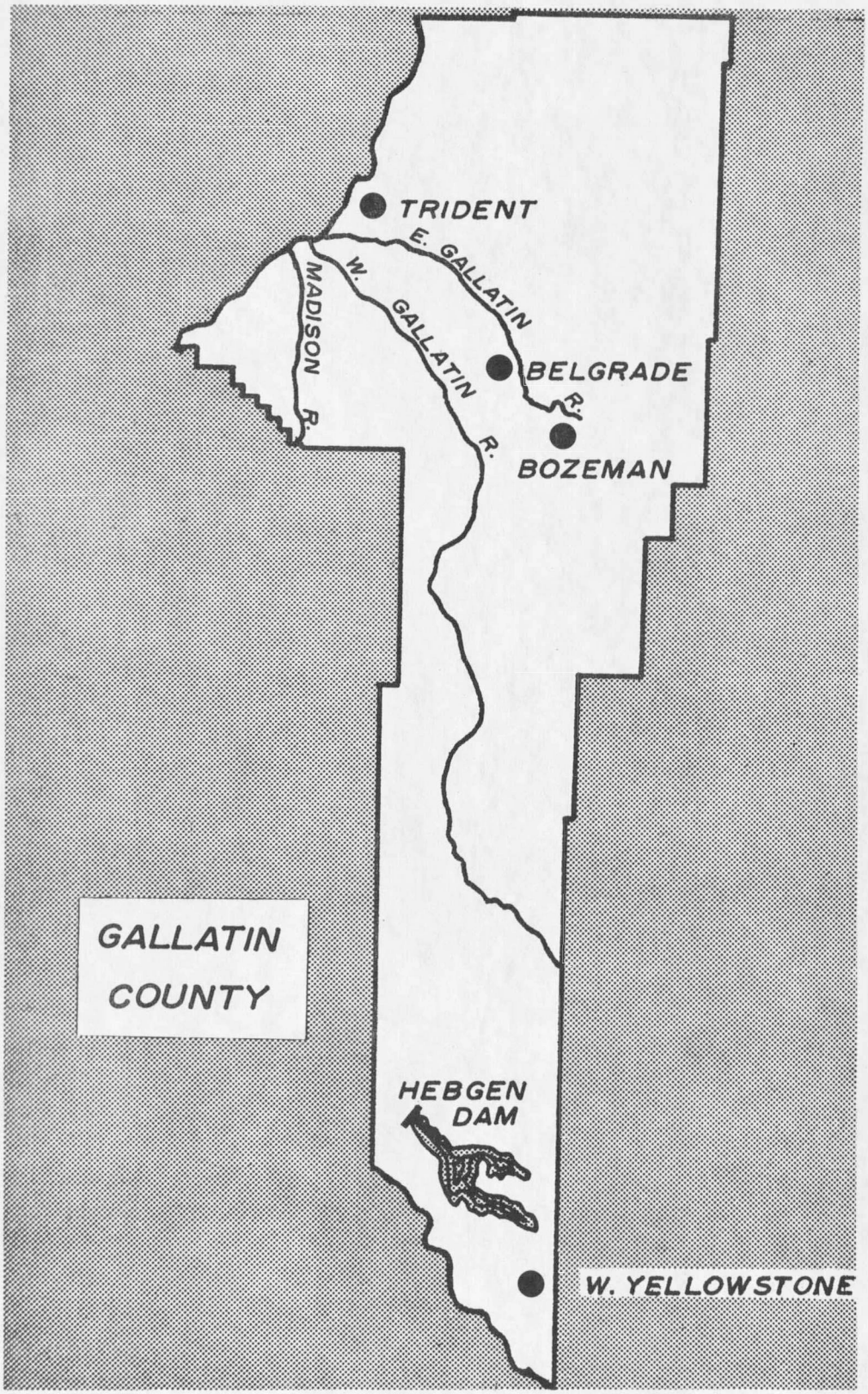


Figure 8. Gallatin County, Montana.

Although four rivers have drainage within the county only the Gallatin River and its tributaries are of any irrigation significance. The West Gallatin River has its origin in the southern reaches of the county and flows northward for about 110 miles, draining 1,840 square miles and emptying into the Missouri River above Trident. About 80 miles north of its lofty origin the Gallatin River enters the Gallatin Valley, south of Gallatin Gateway, and flows north-northwesterly 28 miles through the valley before passing through a tight gorge near Logan and then on into the Missouri River.

The Gallatin Valley, the most important agricultural sector in the county, is about 25 miles long and 20 miles wide and has an area of about 540 square miles. The valley is bounded by hills and mountains on all sides. The 7,000 feet Horseshoe Hills on the northwest, the 9,000 feet Bridger Range on the northeast, the 10,000 feet Gallatin Range on the southeast, and 11,000 feet Madison Range on the southwest, and the low Camp Creek Hills on the west. The valley floor is comparatively smooth, sloping northerly on an average of about 40 feet per mile. The altitude within the valley ranges from about 5,400 feet on the southern border down to 4,100 on the north.20/

20/Hackett, et. al., Geology and Ground Water Resources of the Gallatin Valley, Gallatin County, Montana, Geological Survey Water-Supply Paper 1482, United States Government Printing Office, Washington, D. C., 1960, pp. 12-13.

Climate

The climate in Gallatin County is characterized by large variations in temperature and precipitation. These are due, at least in part, to the difference in elevation of the various parts of the county, Table I. In general the County is characterized by long cold winters and short cool summers. The mean annual temperature at Bozeman is 42.1 degrees Fahrenheit, the highest temperature on record is 112 degrees and the lowest is -53 degrees Fahrenheit. The May-September average temperature is 58.1 degrees Fahrenheit. There is an inverse relationship in Table I between the elevation and the May-September average temperature. Trident the lowest MSL station has the highest average temperature while Hebgen Lake the highest MSL station has the lowest average temperature.

The last killing frost in the spring in Bozeman averages about May 24 and the first killing frost in the fall comes on the average about September 16 allowing a growing season of about 115 days. At Hebgen Dam the last frost is expected about June 15 and the first frost of the fall rushes in by September 11 allowing for a growing season of only 88 days. Killing frosts come every month of the year, however, at the higher elevations.21/

Precipitation in the Gallatin County is unevenly distributed. The annual average precipitation varies 12.5 inches, from a high of 25.17 inches at Hebgen Dam down to 12.65 inches at Trident, Table II. Elevation and average annual precipitation are directly related with the

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21/Water Resources Survey, Gallatin County, op. cit., p. 10.

TABLE I. TEMPERATURES AT SELECTED STATIONS, GALLATIN COUNTY, MONTANA.*

Station	No. of Years on Record	Average Annual Temp.	Highest Temp. on Record	Lowest Temp. on Record	May-Sept. Average Temp.	Elevation MSL
Belgrade	15	41.3	100	-43	58.3	4451
Bozeman	61	42.1	112	-53	58.1	4856
Hebgen Dam	41	36.6	99	-60	54.4	6489
Trident	19	45.5	105	-45	62.0	4036

*Source: Adapted from United States Department of the Interior, Report on Three Forks Division, Missouri River Basin Project-Montana, Bureau of Reclamation, Upper Missouri Projects Office, Great Falls, Montana, September, 1958, Appendix A, pp. 9, 11.

TABLE II. PRECIPITATION AT SELECTED STATIONS, GALLATIN COUNTY, MONTANA.*

Station	No. of Years on Record	Inches of Annual Average Precipitation	May-Sept. Average Inches	May-Sept. Percent of Annual Average	Elevation MSL
Belgrade	16	14.11	8.40	60	4451
Bozeman	62	17.55	9.47	54	4856
Hebgen Dam	44	25.17	9.61	38	6489
Trident	20	12.65	8.51	67	4036

*Source: Adapted from United States Department of the Interior, Report on Three Forks Division, Missouri River Basin Project-Montana, Bureau of Reclamation, Upper Missouri Projects Office, Great Falls, Montana, September, 1958, Appendix A, pp. A9, 10.

highest annual average recorded at Hebgen Dam, 6481 MSL, and the lowest annual average recorded at Trident, 4036 MSL. Precipitation during the growing season, May through September, is inversely related to the elevation with Trident receiving 67 percent of its annual precipitation during that season while Hebgen Dam only receives 38 percent of its annual average precipitation during May-September season. Within the valley proper the 1952 record shows a 8.76 inch difference in precipitation received within a 13 mile range with 10.81 inches recorded west of Belgrade and 19.57 inches recorded at Bozeman. Obviously then it follows that the precipitation for the valley is unevenly distributed and the heaviest amounts are recorded in and nearest the mountains.22/

Agriculture

The terrain of much of Gallatin County is high and mountainous. The total land area is about 1,618,800 acres and approximately 65 percent of it is mountainous and much of it is included in the national forests. Roughly 58.3 percent of the total land area is included in farms and only 16 percent, 262,000 acres plus, is presently used as crop land. The ratio of dry land to irrigated land in the county is about 1 to .75, approximately 150,000 and 112,000 acres respectively.23/

The number of harvested irrigated acres in the county varies from year to year. In 1961, 68,923 irrigated acres were harvested in

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22/Hackett, op. cit., pp. 14 and 18.

23/Water Resources Survey, op. cit., pp. 11-12.

Gallatin County. In 1960, 66,521 were harvested. In these two years Gallatin County ranked third among Montana counties in number of irrigated acres harvested. In 1961 the value of the irrigated harvest was $4,412,400 or an average of $64.02 per acre. There were only 12 counties in the state that had a per-acre-average higher than Gallatin County and only two counties had a higher gross value of production from irrigated acreage.24/

Various crops are grown on the irrigated land in the valley. Almost all the cropland in Gallatin County is in the area designated as the Gallatin Valley. Using 1961 as a representative year we find 200 acres of durum wheat, 300 acres of rye, 500 acres of corn, 823 acres of potatoes, 2,600 acres of spring wheat (other than durum), 8,800 acres of winter wheat, 11,100 acres of barley and 41,000 acres of hay (all types). Plainly wheat, barley, and hay are the most important irrigated crops in the valley.25/ The Montana Department of Agriculture does not record irrigated pasture acreages or production-per-acre. For the Gallatin Valley irrigated pasture acreages would be high.

Many of the Gallatin Valley farmers summer fallow irrigated land. Even though farmers can irrigate all their land and some of them have the water they need, many of them summer fallow one half of their land

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24/Montana Department of Agriculture, Montana Agricultural Statistics, Montana Department of Agriculture and United States Department of Agriculture, Helena, Montana, Vol. IX, December, 1962, pp. 9-10.

25/Ibid., pp. 29-60.

claiming their long run average production per acre is higher using summer fallow.

CHAPTER VI

Bureau of Reclamation Report on The Three Forks Division

Appendix B, "Volunteer Comments," of this thesis include several references to various alternative methods of supplying water for the Gallatin Valley. All of the alternatives have some merit and most of them have been considered at one time or another. It is the author's opinion that many of the people who submitted these alternative suggestions withheld their support from the program proposed in Chapter VII because they considered their alternatives far superior. In this chapter a detailed summary of the Bureau of Reclamation Report is presented in order that comparisons can be made.

The United States Department of Interior was created by an act of the United States Congress in 1849. The Department of Interior is responsible for advancing certain domestic interests and includes the Bureau of Indian Affairs, the Geological Survey, National Park Service, Bureau of Mines, Bureau of Land Management, and the Bureau of Reclamation. The Bureau of Reclamation was set up under the Reclamation Act passed by Congress in 1902 and since its establishment its primary interests have been flood control, development of power, and irrigation.

The Missouri River Basin Project is a plan authorized under the Flood Control Act of 1944 and 1946 for the coordinated development and control of the Missouri River and its basin lands. Senate Document No. 191, Missouri River Basin (report by Secretary of the Interior, Harold L. Ickes on Bureau of Reclamation plan for Basin Development), dated

April, 1944 coins the phrase "Three Forks Unit" for the Jefferson, Madison, and Gallatin River basins, Figure 9. In September, 1958 the Bureau of Reclamation published a "Report on Three Forks Division, Missouri River Basin Project--Montana."

Previous Studies

Investigation in the Three Forks Unit began as early as 1905-1906 by the Reclamation Service, some private studies were conducted in the 1920's, but the first comprehensive inventory of the water resources in the area was made between 1928 and 1933 by the War Department. Two reports were made by the War Department, House Document 193, 1931 and House Document 238, 1933.

The Bureau of Reclamation began an investigational program in 1938 aided by private and state funds that culminated in the afore mentioned report, Senate Document 191 dated April 1944. This report contained the original plan for the Three Forks Division which was submitted subject to modifications that might be indicated as a result of more detailed surveys and studies. The modifications made later were several and extreme. To indicate the intention of the original plan a quotation is taken from Senate Document 191, page 63:

> ...after Canyon Ferry Reservoir has been built, it will be possible to utilize the Montana Power Company's Hebgen Reservoir, on the Upper Madison River, with its capacity of 345,000 acre-feet, chiefly for irrigation. In the past it has been used for power. A long diversion canal from the Madison River will deliver the regulated flow of that river to a bifurcation works in the vicinity of Norris, Montana, where the main canal will divide into two branches, one

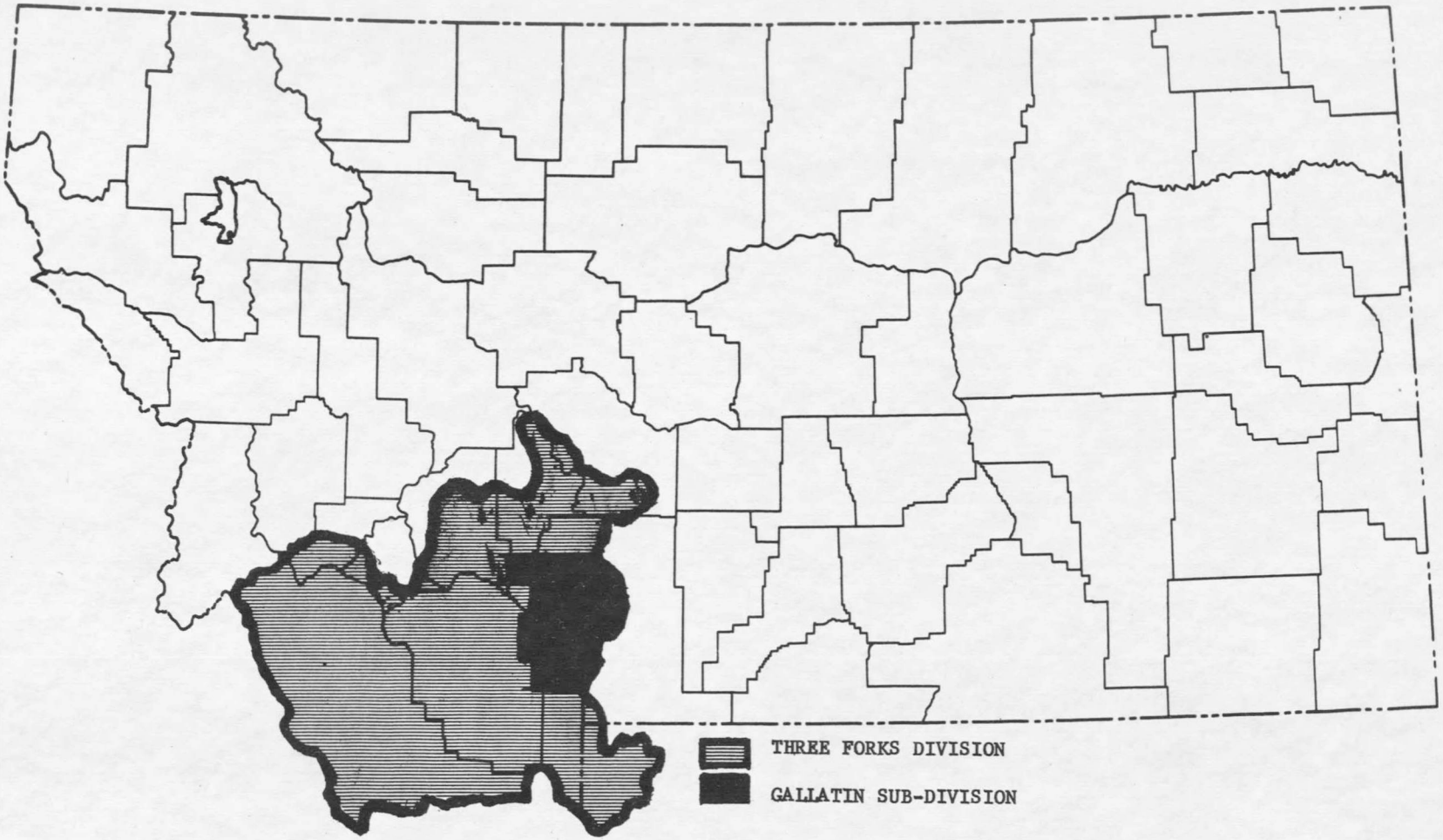


Figure 9. The "Three Forks Unit", of the Missouri River Basin Project, Bureau of Reclamation, Department of Interior.

branch crossing the Madison River and entering the Gallatin Valley, where 124,000 acres of irrigated land have suffered frequent shortages of water. Importation of Madison River water will preclude the necessity for constructing a large, expensive reservoir on Gallatin River, as heretofore proposed, and will permit the expansion of the irrigated area in the Gallatin Valley by some 40,000 acres of land. Reservoirs of 20,000 acre-foot capacity, on the Taylor Fork of the Gallatin River, and 15,000 acre-foot capacity, on Bridger Creek, will be required to supplement the water supply, in addition to an 8,000 acre-foot reservoir on Middle Creek, which has been under construction by the Montana State Water Board.

After conducting their study in 1958 and analyzing the data received the Bureau of Reclamation reports:

> The original basic plan to utilize the Madison River through transbasin diversions to irrigate a great portion of the development areas has been modified to limit the use of that stream to the Madison Sub Basin only... It is recognized that considerable change has been made in the original plan authorized in Senate Document 191 and modification of the original authorization may be required.26/

Reported Alternatives by Bureau of Reclamation

Each of the following alternative plans submitted by the Bureau of Reclamation's 1958 report on the Three Forks Division require the construction of a dam at the mouth of the Gallatin Canyon below Spanish Creek.27/

Alternative No. 1.--The Spanish Creek Dam and Reservoir location

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26/United States Department of Interior, Report on Three Forks Division, Bureau of Reclamation, Upper Missouri Projects Office, Great Falls, Montana, September, 1958, Appendix A, p. A-33.

27/Ibid., Appendix M.

seven miles up stream from Gallatin Gateway as shown in Figure 10 is the same for all four of the alternatives studied. For each alternative the dam was to be an earth and rock fill structure and for Alternative No. 1 it was to be 332 feet high and 1,260 feet long at the crest elevation of 5,469 M.S.L. Total storage capacity of this size structure was estimated to be 260,000 acre-feet.

The dam construction is the main feature of this alternative. It would supply water to the existing ditch structure and would service 76,942 acres. The total cost of the dam, including interest and miscellaneous charges came to $24,495,000 in 1957 dollars. The annual costs of the project was established at $680,160. The benefits were estimated at $1,034,800 (allowing for a $7,200 loss to recreation because of the construction) yielding a benefit-cost ratio of 1,034,800/ 680,160 = 1.52.

This 1.52 benefit-cost ratio is less than the program proposed by the 1958 report. Any dam on the Gallatin River, says the report, will meet with objections from naturalists and conservationists. Because of the lower benefit-cost ratio and the local objections, Alternative Plan No. 1 was not proposed.

Alternative No. 2.--This plan utilizes a dam located in the same area as Plan No. 1, Figure 10. Plan No. 2, however, calls for a earth-rock filled dam 390 feet high, 1,500 feet long at the crest and storage of 382,000 acre-feet. The larger storage capacity was needed because of the extended ditching system as shown in Figure 11. The proposed

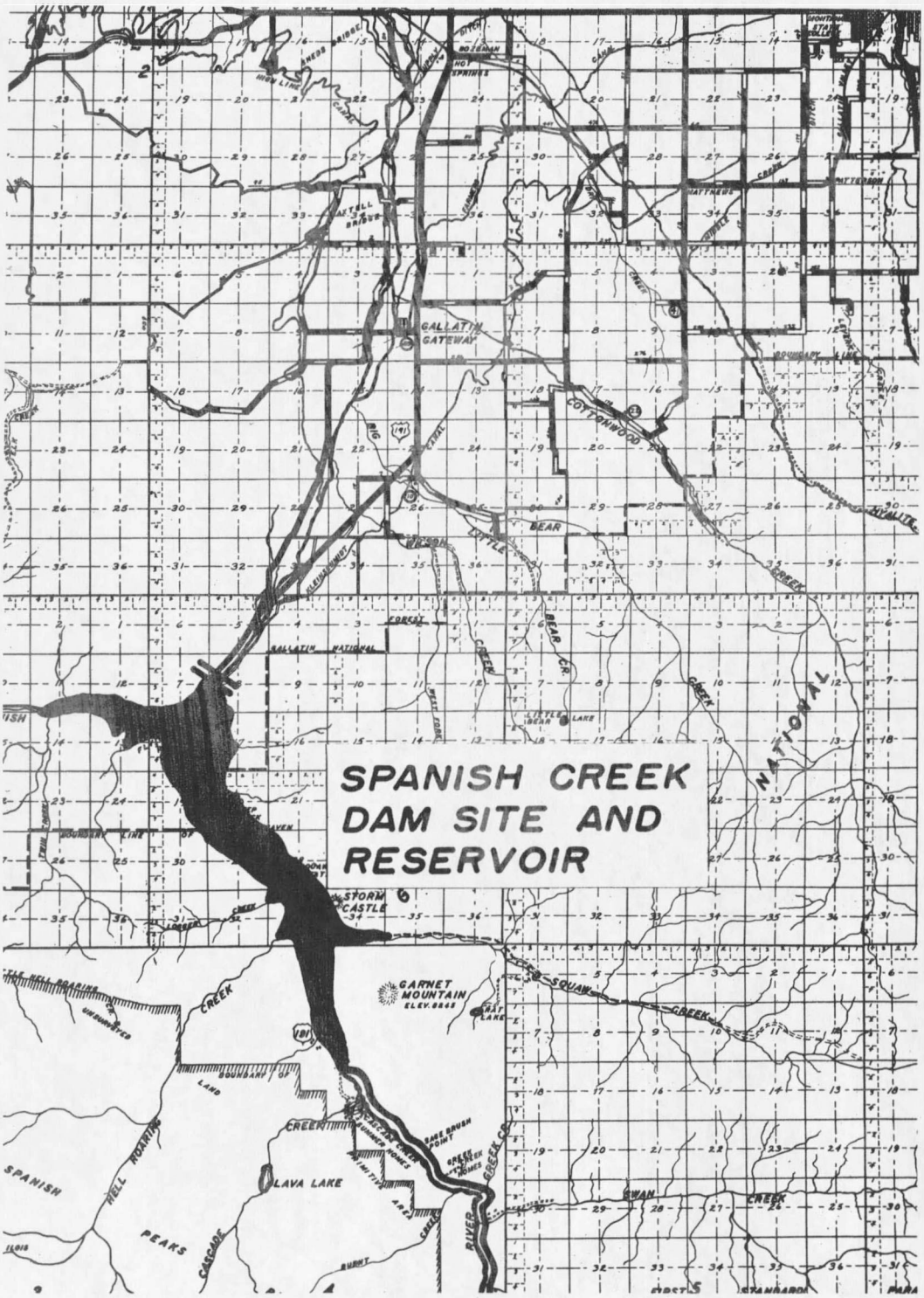


Figure 10. Spanish Creek Dam Site and Reservoir, proposed by Bureau of Reclamation, 1958.



Figure 11. The Anceney and Kleinschmidt Canals proposed by the Bureau of Reclamation, 1958.

Kleinschmidt Canal, Figure 11, would be a 67 mile long supply works and would abandon the present eight mile long Kleinschmidt Canal.

Anceney Canal would begin with a diversion dam about two and one-half miles below the Spanish Creek Dam and would service lands on the west bench of the Gallatin River. The canal would be about 41.2 miles long with no arable land located between the start and Mile 19 of the canal.

The increased dam size, and construction of the two canals with their laterals is the major differences between Plan 1 and Plan 2. The total cost of Plan 2, including interest and miscellaneous charges comes to $56,932,000. Annual costs were estimated to be $1,665,140 and annual benefits $1,871,800 yielding a benefit-cost ratio of 1.12.

Although the total benefit-cost ratio was greater than 1, some of the areas within the system have a ratio of less than one when evaluated separately. The increased dam size reportedly brought increased opposition from local interests, conservationists, and naturalist groups. Due to these and other factors Plan 2 was considered less favorable than the proposed plan.

Alternative No. 3.--Plan No. 3 utilizes the same dam location and size as described in Plan No. 1 and the same extensive ditch structure as described in Plan No. 2. The 260,000 acre-feet of storage from Plan No. 1 is insufficient to supply enough water for the extended ditch system proposed in Plan No. 2. The unique feature of Plan No. 3 is the use of ground water pumping to furnish the additional water.

The general working of this plan would use the storage water from the Spanish Creek Dam to supply the needs of the Kleinschmidt and Anceney Canals while supplying the needs of the Gallatin Valley proper from 193 wells located along the existing irrigation ditches.

This pumping system is the same as that used in the suggested plan of development and is described in detail below under Proposed Bureau Plan. The ground water supply for this pumping system was established in a study conducted in 1953 by the U. S. Geological Survey at the request of the Bureau of Reclamation.

The total cost for Plan No. 3 in 1957 dollars including interest and miscellaneous charges was set at $55,731,400. The annual cost was set at $1,771,720 and the expected benefits were $1,871,800 yielding a benefit-cost ratio of 1.06.

The objections to this plan are basically the same as for the previous two plans. The local people object to a dam site in the Spanish Creek area, and some of the land under the extended canal sections when considered separately has a benefit-cost ratio of less than one and therefore should not be developed. The overall benefit-cost ratio for Plan No. 3 is less than for either No. 1 or No. 2 and therefore has a lower priority.

Alternative No. 4.--Plan No. 4 is a modification of Plan No. 3 attempting to eliminate the areas of low benefit-cost ratios. The 21,755 acres to be serviced by the Anceney Diversion Dam and Canal had a ratio of .56 to 1.00 and are removed from this plan. The remainder

of the plan is the same as No. 3. Water from the 260,000 acre-feet storage project would be used for irrigation in the 67 mile long Kleinschmidt Canal and also some would be released into the Gallatin River proper to maintain a fish supply. This latter use would reduce some of the local objection to the development plan as a whole.

The total cost of this project would be $40,026,100. Total annual cost was set at $1,284,300 with the annual benefit of $1,495,200 thus yielding a benefit-cost ratio of 1.16.

The same local opposition to the dam itself still applies to this project. There still remains some land under the 67 mile Kleinschmidt Canal that carries a benefit-cost ratio of .73 to 1.00. Because of these this plan was rejected in favor of the plan suggested in the "Report on Three Forks Division".

Proposed Bureau Plan

Water Requirements.--(1) Acres needing water. The Bureau of Reclamation established the area of the Gallatin Basin needing additional water as bounded on the south by the Kleinschmidt and High Line Canals (diverted south of Gallatin Gateway) and on the north by the land under the White Ditch, Figure 12, heading on the West Gallatin River, and land under the Aagrad Ditch on the East Gallatin River. This area includes 67,434 productive acres irrigated from the West Gallatin River and 1,737 productive acres irrigated from the East Gallatin River. Within this area the bureau established a "Gallatin Unit" that would supply supplemental water to 59,096 acres. These acres are to be

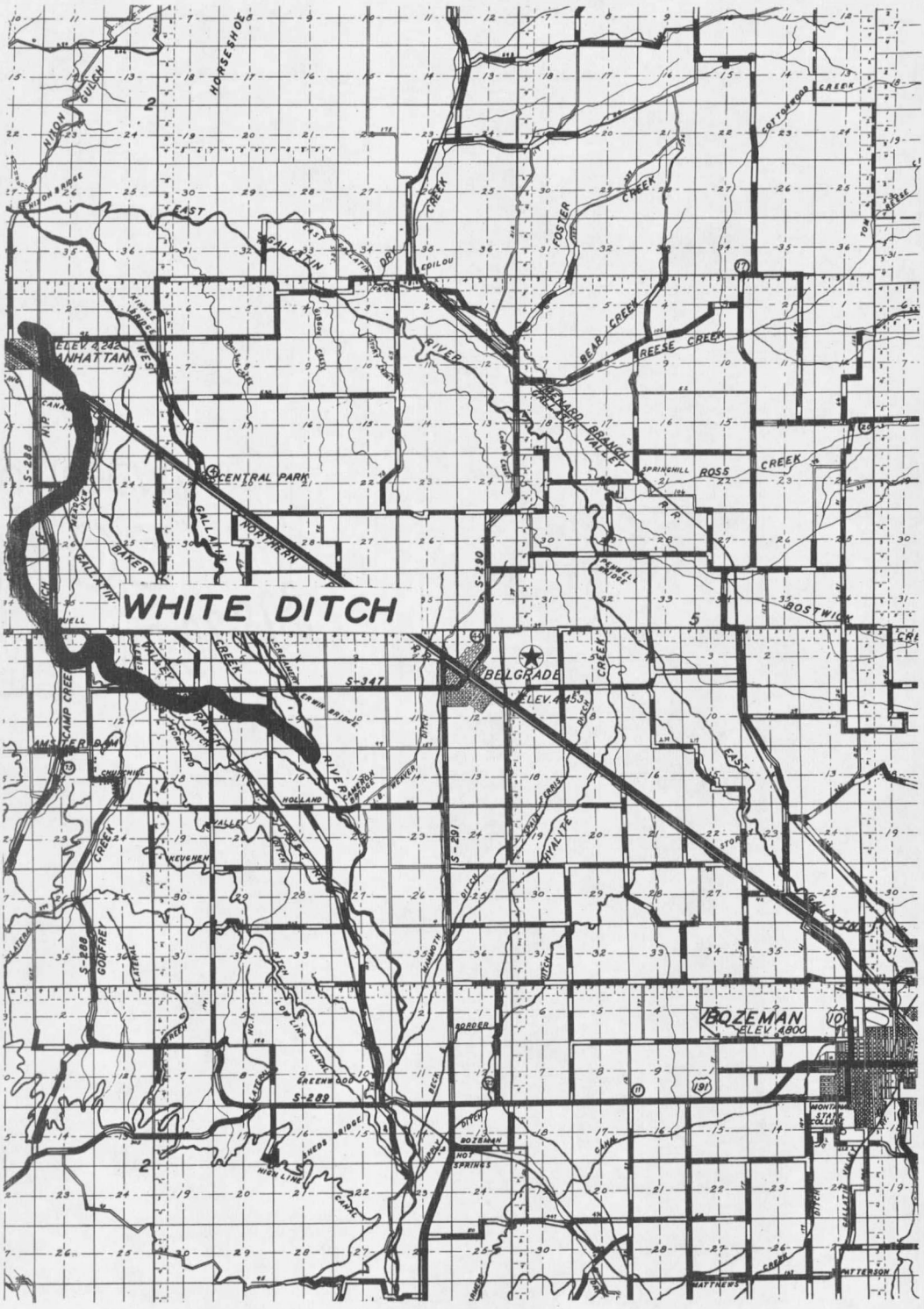


Figure 12. The White Ditch, Gallatin Valley, Montana, 1958.

serviced by ground-surface water integration and are divided into 51,139 irrigable acres (50,601 productive acres) presently supplementally irrigated and 7,957 irrigable (7,614 productive acres) intermittently irrigated. This is a total of 58,215 productive acres included in the Gallatin Unit.28/

Water Requirements.--(2) Water needed per acre. Not all of the streams in the Gallatin Unit have been adjudicated but for those that have been the general rule was to allow one miner's inch (1/40 of a second-foot in Montana) for each acre irrigated. To determine legal requirements the Bureau assumed all water rights could be satisfied by one miner's inch per acre.

For development purposes the Bureau used a static measurement in acre feet. The Bureau estimated the soil in the Gallatin Unit would use 2.03 acre feet annually. The effective precipitation for the Unit is .72 with a farm efficiency of 65 percent. The farm delivery requirement is estimated to be 2.02 feet.

It was estimated 42 percent of total water diverted would be lost by transportation and wastes in the main canals and laterals in an efficient system, and even greater losses would occur in the Gallatin Unit. The Bureau estimated a total diversion of four acre feet per acre would be required and they divided it as follows:

28/Ibid., Appendix B, pp. 148-157.

	Acre-feet per acre
Annual consumptive use	2.03
Effective precipitation (80% of five dry years)	-.72
Consumptive use of irrigation water	1.31
Farm waste and deep percolation losses (35%)	+.71
Farm delivery requirement	2.02
Canal losses and wastes (42%)	+1.48
Gross diversion requirement (efficient systems)	3.50
Additional requirement for unit lands (average)	.50
Gross diversion requirement for unit lands	4.00

Using the bureau's estimate of four A.F. per acre and the 58,215 productive acres the gross diversion requirement would be about 233,000 acre-feet annually.29/

Water Supply.--(1) Surface water. Continuous records of run-off for the Gallatin River are available since 1929 and correlated records have been determined from 1926. Permanent stream-gauging stations have been located on the West Gallatin, near Gallatin Gateway, since 1930, and at Logan, including both East and West Gallatin, since 1928. The records at Gallatin Gateway show a low run-off in 1934 of 295,700 acre-feet, a high in 1952 of 714,600 acre-feet, and an annual average in 1926-1952 of 520,000 acre-feet.

The head of the White Ditch, three miles west and two miles south of Belgrade, Figure 12, is the point of minimum flow on the West Gallatin River. Due to irrigation run-off all ditches with diversion points north of this point have sufficient water supplies from surface water sources and these lands were not considered by the Bureau of Reclamation for

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29/Ibid.

development. The point of minimum flow on the East Gallatin is just below the head of Aagard Ditch. All ditches diverting water below this point were considered to have sufficient supplies of surface water.

The average annual run-off of 520,000 acre-feet is greater than the estimated need of 233,000 acre-feet gross diversion. Because of the down stream rights the total flow can never be diverted. The unregulated flow of any stream is not constant throughout the year and as a result water is not available in the late summer when it is most needed.

On the West Gallatin the Bureau estimated there would be sufficient water for all 67,434 acres above the controlling point (based on one miner's inch per acre) for full irrigation until July 1-5 on an average. By the end of July more than 30,000 acres would have their supply cut off and by August 31 over 45,000 acres lose their supply of water.

The East Gallatin was estimated to have a full supply of water until between August 25 and 31 during the worst years and a long time average full supply until mid-September.30/

Water Supply.--(2) Ground water. At the request of the Bureau of Reclamation the Geological Survey conducted a study of the ground water resource of the Gallatin Valley in 1953-54. Their findings were published in Geology and Ground Water Resources of the Gallatin Valley,

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30/Ibid.

Gallatin County, Montana.31/

This study points out there are large quantities of ground water available in certain parts of the Gallatin Valley. Ground water is not stationary and the "flow" of ground water in the Gallatin Valley varies from 120,000 acre-feet to 320,000 acre-feet with a 240,000 acre-feet average annual supply for the period 1934-1953. The average annual ground water supply of 240,000 acre-feet is only 20,000 acre-feet short of the amount of water that would have been stored behind the 332 foot Spanish Creek Dam as shown in Figure 10. The average specific yield for the valley as a whole is .15. The aquifer for the Gallatin Valley is an alluvial deposit ranging from 20 to 400 feet thick carrying a coefficient of transmissibility varying from 38,000 gpd per foot to 670,000 gpd per foot. The U.S.G.S. report divided the valley into three major sections for the purpose of analyzing the available ground water, Figure 13.

(a) Gallatin Gateway Subarea.

This land area is about 10 miles long and comprises an area of about 16 square miles. The average depth of the aquifer throughout the area is 55 feet with coefficients of transmissibility ranging from 170,000 to 380,000 gpd per foot. The water table in the subarea at the time of the study was 10-15 feet below the land area. The average

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31/Hackett, et. al., Geology and Ground Water Resources of the Gallatin Valley, Gallatin County, Montana, United States Department of Interior Geological Survey, Geological Survey Water Supply Paper 1482, United States Government Printing Office, Washington, D. C., 1960.

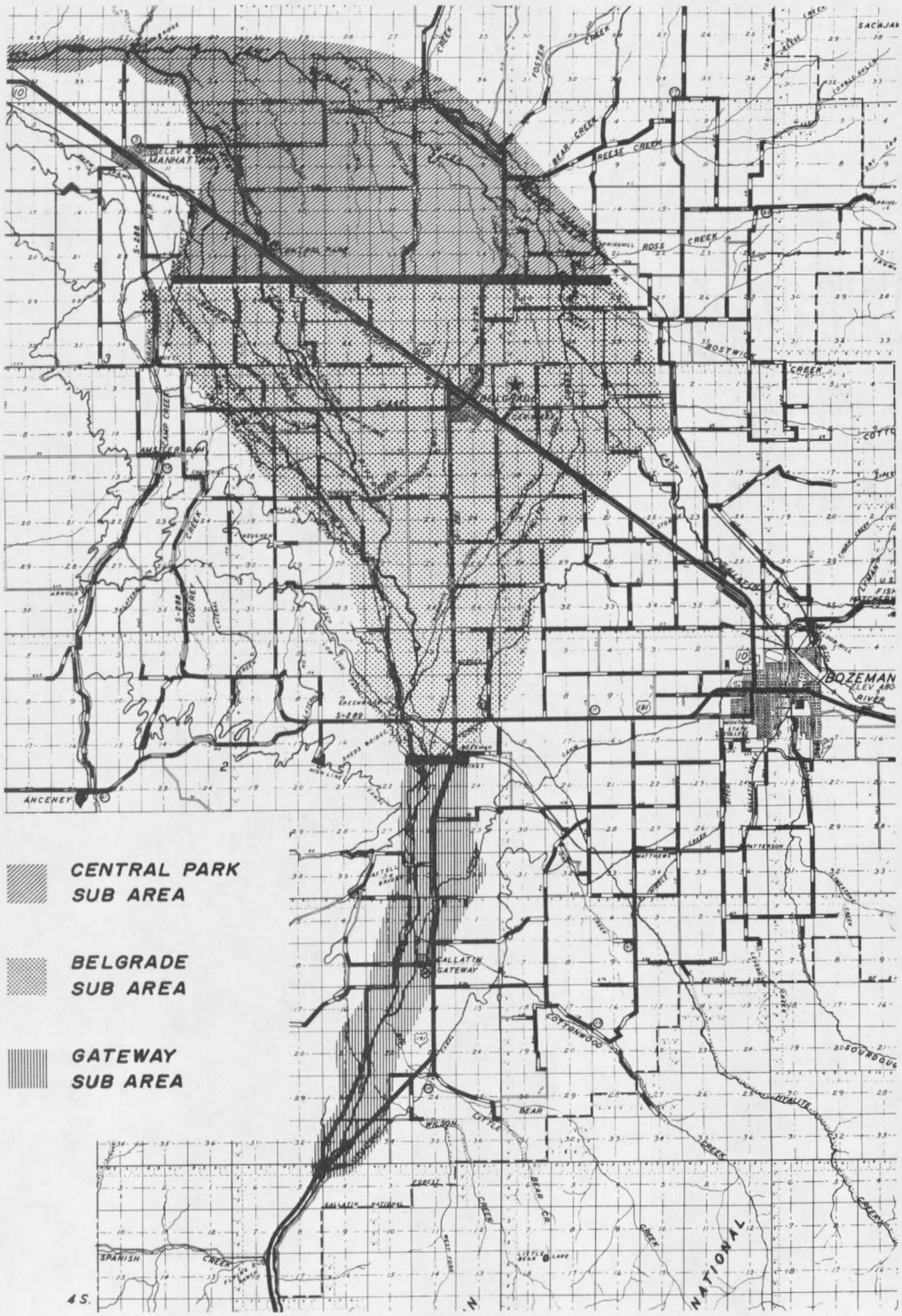


Figure 13. Gallatin Valley Ground Water Subdivisions.
Established by the USGS, 1957.

annual discharge of ground water to surface flow for the area was estimated to be 20,000 acre-feet.

(b) Belgrade Subarea.

The Belgrade subarea is a triangular shaped area comprising 67 square miles of the valley, Figure 13. The alluvium under the Belgrade subarea is the principal ground water reservoir in the Gallatin Valley. The thickness of the alluvium ranges from 68 feet near the south boundary to over 400 feet at the north boundary. Coefficients of transmissibility in the subarea vary from 50,000 to 670,000 gpd per foot. It was estimated that at least 100,000 acre-feet of water are discharged from the subarea via ground and surface water flows. The water table variations show the extent of the storage capacity in the subarea. The water table varies 10 feet or less near the edges of the area and over 40 feet near Belgrade. During the 1953 irrigation season the water table south of Belgrade came up 40 feet as the reservoir filled up with excess irrigation water.32/

(c) Central Park Subarea.

This northernmost section of the ground water area comprises about 48 square miles and generally has a high water table making most of the area swampy. The alluvium varies from 31 to 300 feet thick and the coefficients of transmissibility vary from 38,000 to 480,000 gpd per foot. It is estimated that 300,000 acre-feet of water enter the area

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32/Ibid., plate 7.

annually by underflow and because of this underflow more ground water is returned to surface water in this area than in any other part of the valley. The water table over much of the area is five feet or less below the surface. Pumping in the upper regions of the valley would lower the water table only slightly. Artificial drainage would be required to lower effectively the water table over most of the area.

The Pumping System.--In light of their total study, the water resources available and the local opposition to the four alternative plans mentioned above, the Bureau of Reclamation's proposed plan of development utilizes only the available ground water resource and does not recommend surface water storage. Surface water storage is feasible having a benefit-cost ratio of greater than one, but ground water utilization has the highest benefit-cost ratio and according to the bureau's findings does not carry local opposition to the development.

The bureau's plan was to pump about 92,300 acre-feet of water annually using 193 irrigation wells, 180 wells on ditches diverting from the West Gallatin River and 13 on ditches diverting from the East Gallatin. These wells would range from 16 inches to 24 inches in diameter and from 30 to 120 feet deep. The water was to be pumped by deep-well turbine pumps with capacities of one to four cfs and powered by electric motors ranging from five to 40 horsepower. Electric power for this system was to come from the Bureau of Reclamation power plant at Canyon Ferry Dam and wheeled over the Montana Power Companies high-

power lines.33/

One hundred ninety-three irrigation wells distributed over the Gallatin Valley certainly would affect the priority water right system. These wells were to be located along existing ditches and pumping would maintain flows that would normally have been diverted from the river. Since the existing flow would be maintained in existing ditches from ground water sources the stream flow (surface flow) could be diverted onto other lands not over the ground water reservoir. This well location would allow for a transfer of the surface water diversion but would not require a transfer of water rights.34/ The bureau recognizes the water right problem of the project will not be easy to solve. I quote:

> ...water exchange agreements must be executed before the ground water development is started so that full coordinated use can be made of both ground and surface water supplies. This does not mean that an individual would relinquish his water right. It would only mean that he would be agreeable to a substitution of pumped water for "right" water where necessary. In order for the ground water development to succeed, it is essential that there be 100 percent acceptance of this principle of water exchange, always subject, of course, to the priority of the private water rights.35/

The total annual OM and R (Operation, Maintenance and Replacement)

33/United States Department of Interior, op. cit., pp. 68-69.

34/Ibid., p. 69.

35/Speech by H. E. Aldrich, "Summary of Report on Three Forks Division", presented to Montana Reclamation Association, November 12, 1958, p. 9.

costs for the project, 1957-58 dollars, were estimated to be $140,700. Using their estimated 59,096 acres, this amounts to $2.38 cost per acre.

Pumping for this project was to be limited to July, August and September since there usually is sufficient surface water to meet all requirements through June. Pump capacities were to be limited to 25 percent of the annual demand for any particular ditch and they would pump a maximum of 60 percent of the total annual requirement. Their pumped water would be distributed 25 percent in July, 25 percent in August, and 10 percent in September.36/

36/United States Department of Interior, op. cit., Appendix B, pp. 13-178.

CHAPTER VII

ANALYSIS OF INSTITUTIONAL BLOCKS

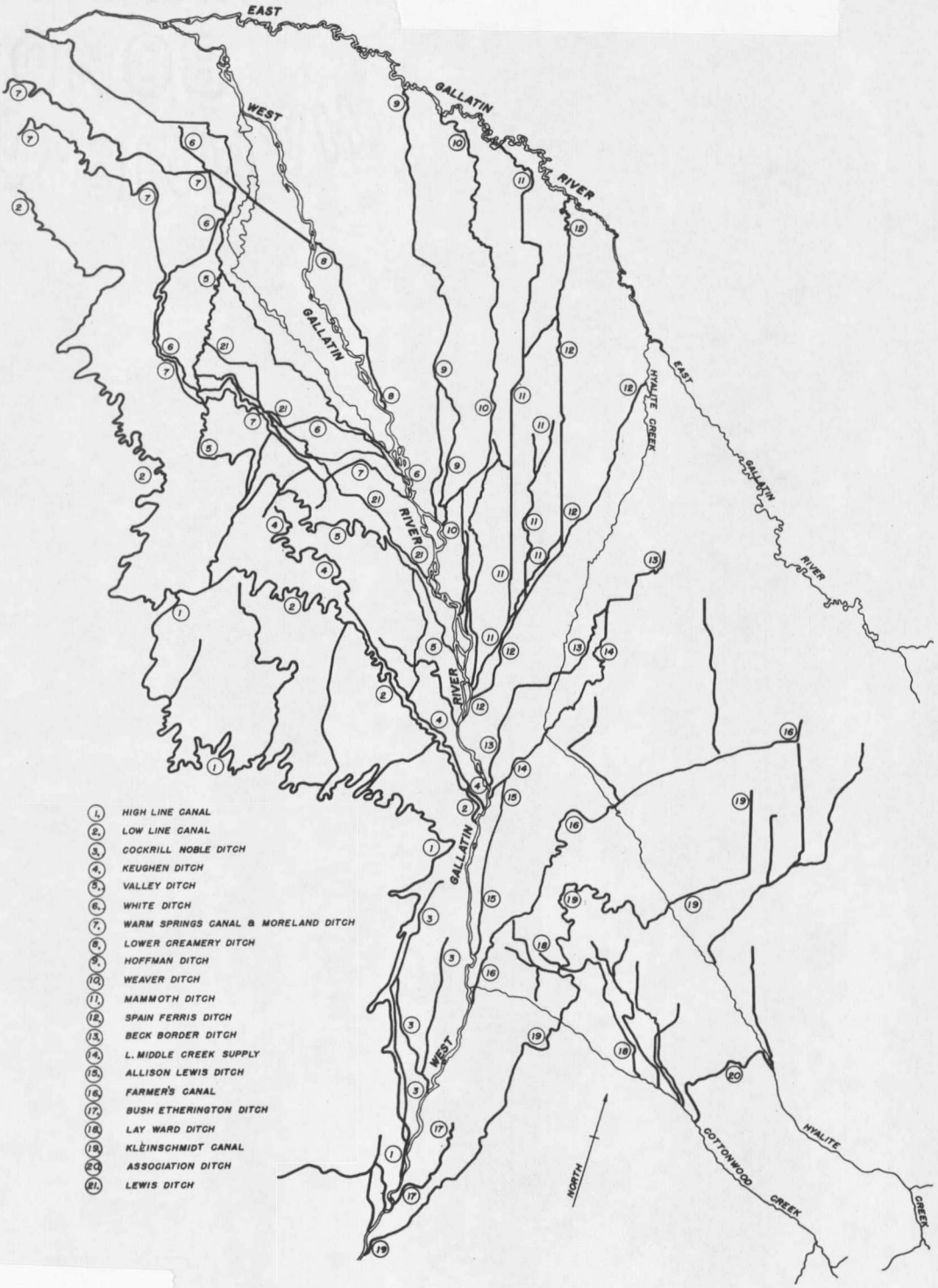
The Setting

The irrigation system presently existent in the Gallatin Valley is the product of 100 years of private development. The first irrigation ditch was dug in 1864 and other ditches were added as the population grew. The result of this development is an irrigation maze, Figure 14. The Gallatin Valley ditch system is poorly organized, ditches cross each other, some ditches use natural streams or slough channels for conveying water and some ditches run parallel for long distances. The overall result is a very inefficient system of irrigation. Many recommendations have been made, by government and private organizations trying to rectify the inefficiencies but very little progress has been made.

In addition to, or as a result of, the inefficiencies listed above the Gallatin Valley also experiences need of additional irrigation water and at the same time allows water to flow from the valley unused. Chapter VI delineates the ground water supply established by the Geological Survey. One of the aims of this study is to determine the factors blocking the development of this resource.

Procedure

There are 22 ditch organizations in the valley plus many privately owned and operated ditches. Tracts of land in the valley having water rights range from fractions of an acre to hundreds of acres. In light



The Gallatin Valley Irrigation System

of these wide differences the study area was limited to water diverted from the West Gallatin River onto tracts of land 40 acres and larger. The West Gallatin River was selected in order to put some geographical limits on the study area and at the same time include most of the valley's irrigation water. The 40-acre limitation was established to eliminate the farmers that do not receive a significant amount of their income from irrigation.

Stratification of water users for analysis could not be developed. Obviously every one used water but the users had differing water rights, applied their water to different types of soil, topography, crops, and at different times of the year. Facing the lack of meaningful homogeneity the consulting statistician advised against stratification in favor of contacting as many of the delineated water users as time and money would permit. The "time" of the study was such that farmer contacts were to be made during the summer months, the farmer's busiest season. In view of the season, and numbers involved it was decided to contact the farmers by mail questionnaire, and to contact the ditch companies by personal interviews. The questionnaire and schedules used are included in Appendix C. Mail questionnaires are notorious for their low percentage of return and in order to increase gross return the identification material, items 1-6 and 14 were filled out in advance. The advance work seemingly paid off. The gross questionnaire return was 47 percent.

The mail questionnaire was logically arranged so data accumulation

would yield the amount of water presently applied per acre, the amount the farmers need per acre and the price they are willing to pay for additional water. Once the additional water needed and the price they could pay was established the economic feasibility of supplying the water could be determined. The necessary institutional organizations would follow and development could proceed smoothly.

In the planning stages of this study it was hypothesized that the ditch organizations themselves might be a block to development. In order to compare the ditch company officials attitude against individual member attitude, as well as obtain other information, the "Schedule-Ditch Companies" was developed. Using this schedule officials of the major ditch companies using Gallatin River water were contacted.

Present Water Usage

Questionnaires were sent to 184 Gallatin Valley farmers. Useable questionnaires representing 26 different organized and private ditches were returned. In several cases only one or two questionnaires were returned by farmers using private ditches. All private and organized ditches represented by two questionnaires or less were grouped in a "Miscellaneous Ditches" section. Where three or more questionnaires were received for any one ditch or ditch company separate tabulations were made, Table III.

Most of the West Gallatin River was decreed by the court in Case Number 3850, 1909. In the Gallatin Valley decreed water has been granted on the basis of one miner's inch for each acre of irrigated

TABLE III. NUMBER OF FARMERS BY DITCH COMPANIES USING VARYING AMOUNTS OF WATER AND THEIR INDICATED NEEDS FOR ADDITIONAL WATER, GALLATIN VALLEY, 1963.

Ditch Company	Miner's Inches of Water																					
	Under .49		.5-.74		.75-.99		1.-1.24		1.25-1.49		1.50-1.74		1.75-1.99		2.00-2.24		2.25-2.49		2.50-2.74		2.75-2.99		3.00 Over	
	a/	b/	a/	b/	a/	b/	a/	b/	a/	b/	a/	b/	a/	b/	a/	b/	a/	b/	a/	b/	a/	b/	a/	b/
Farmers Canal Co.			1	1	3	2	1		3	1	2				1	1	11	5						
High Line Canal Co.	1	1	4	4	4	4	5	4			1	1			1	1	16	15						
Kughen Ditch Co.					1						2						3							
Kleinschmidt Canal (West Gallatin Canal Co.)	1	1	3	1			2	2			1						7	4						
Lewis Ditch					1		2										3							
Low Line Canal Co.	1		3	3	4	4	1										9	7						
Lower Middle Creek Supply Ditch									2						2	2	4	2						
Spain Ferris Ditch Co.			1	1	2	1	1	1									5	3					1	
Valley Ditch Co.			1				1												1		3			
Miscellaneous Ditches			2		4		6	3	1	1			1		1	1			1		16	5		
TOTAL	3	2	15	10	19	11	19	10	6	2	6	1	1		5	5	58	36	2		19	5	1	

a/This column represents the number of farmers applying water at the specified rate.

b/This column represents the number of farmers indicating they want or can use additional water.

land at the time of the decree. Many farms in the valley have been sold several times since 1909 and the number of irrigated acres per water right could have changed over the years. One section of the questionnaire was designed to establish the amount of water presently applied per acre. It was hoped this section of the questionnaire would give some indication of the adequacy of this one inch per acre limitation. Tabulation of the questionnaires and a few personal interviews revealed farmers do not know how much water they apply per acre. The reason for this is twofold.

The organizational complex of ditch companies is one reason no record is kept of the amount of water applied per acre. For example, if 15 farmers belong to one ditch company and the company has rights to a "ditch-full" of water, then the ditch is kept full and each farmer draws from it as required, or when no one else is irrigating. No record is kept to see who uses exactly how much water for how long. The second reason no one knows how much water is used stems from flood water usage. Early in the spring when the river is high every ditch company and private ditch carries a ditch full of water and everyone uses all they need and no records are kept of this water. Only when the river gets low and the court appoints a water commissioner, July 1-15, is any thought given to the amount of water diverted from the river.

It is assumed that few farmers, if any, apply water at a rate less than they have water rights to cover. For example, if a farmer owns two shares of Ditch "X", then over the course of the irrigation

season he will receive at least two shares of the water in Ditch "X". Using this assumption then, the present-use-of-water was tabulated by dividing the number of acres each farmer recorded into the number of miner's inch or equivalents to which he was entitled, Table III.

Irrigation water application in the Gallatin Valley varies from under .49 to over 3 miner's inches per acre, Table III and Figure 16. Forty (40) percent of the reporting farmers apply water at the rate of 2.00-2.74 miner's inches per acre. In contrast only 29 percent of the reporting farmers apply water between the rates of .75-1.49 miner's inches per acre. This percentage spread suggests the 1 miner's inch per acre decree stipulation no longer holds for the entire Gallatin Valley.

A majority of the Gallatin Valley farmers indicate a need for additional water. This need is shown by the shaded area of Figure 15. The need for additional water is not limited to any specific segment of the miner's-inches-per-acre continuum. All ranges with 3 or more farmers reporting indicate a need for more water. The 2.25-2.49 is the modal range (that which occurs oftenest) and 65 percent of these farmers indicate a need for additional water. Many of the farmers, 34 percent of those reporting, apply water between the .5-1.24 ranges and 58 percent of this group want additional water. The majority, 53 percent, of all reporting farmers indicate a need for additional water.

Present Water Costs

The reported cost of water in the Gallatin Valley is irregularly

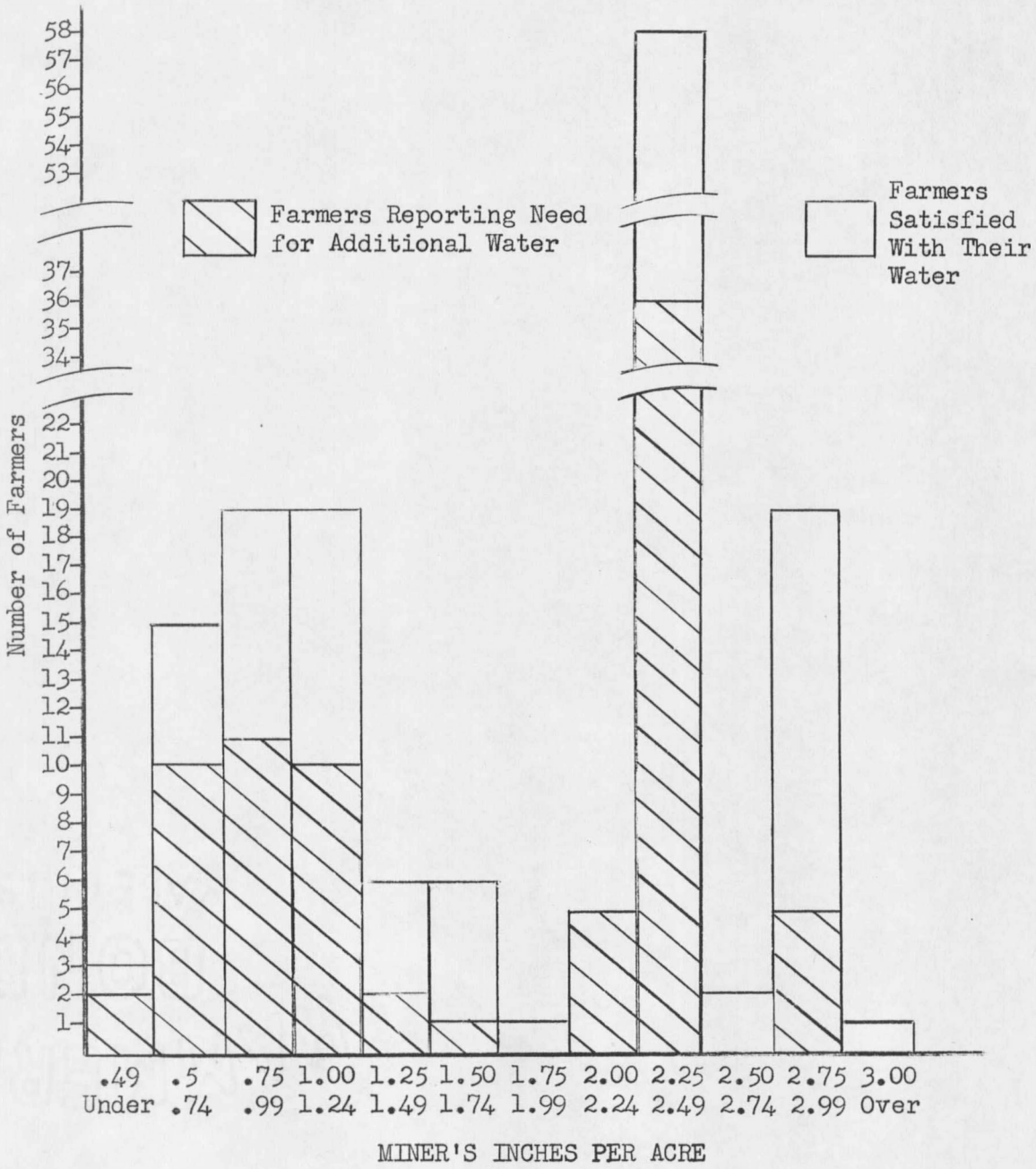


Figure 15. Number of Gallatin Valley Farmers Reporting Using Varying Amounts of Water and Their Need for More Water, 1963.

spread between less than $.24 to over $3.99 per-miner's-inch, Table IV and Figure 16. The "cost-per-miner's-inches" of Table IV and Figure 16 is a fabricated cost used for comparison of Gallatin Valley water costs. The cost-per-miner's-inch is termed "fabricated" because of the way it is derived. Few, if any, of the Gallatin Valley farmers know the amount of irrigation water they use per season. During the "flood water" season every ditch runs full and farmers use all the water they need. No record is kept on this water. When the river water supply gets low July 1-15 ditch flows are reduced to their legal limits. It is assumed, as in the previous section, all farmers will receive at least their legal share of available water. Using this assumption, the number of miner's inches or equivalents to which each farmer is entitled is divided into his annual average cost. This yields a fabricated "cost-per-miner's-inch".

The modal cost range is $.50-.99 with 23 percent of the reporting farmers represented. The $2.00-2.49 range contains 22 percent of the reporting farmers. This large representation at a high cost is due to High Line Canal Co. Eighty-eight (88) percent of High Line Canal Co. is within this range.

Fifty-six (56) percent of the Gallatin Valley farmers pay less than $1.50 per miner's inch for their water. Although a majority of farmers pay less than $1.50 for their water 22 percent of the reporting farmers pay $2.00-2.49 for their water and 39 percent pay $2.00 and over per miner's inch. Even this wide variation in costs does not

TABLE IV. NUMBER OF GALLATIN VALLEY FARMERS BY DITCH COMPANY REPORTING COST OF WATER PER MINER'S INCH, 1963.

Ditch Company	Cost of Water Per Miner's Inch									
	$.00-$.24	$.25-.49	$.50-.99	$1.00-1.49	$1.50-1.99	$2.00-2.49	$2.50-2.99	$3.00-3.49	$3.50-3.99	Not Given
Farmers Canal Co.		2	6		3					2
High Line Canal Co.				1		15	1			
Kughen Ditch Co.		1	2							
Kleinschmidt Canal (West Gallatin Canal Co.)			1		2	2		1	1	
Lewis Ditch		2								1
Low Line Canal Co.				1			3	4		1
Lower Middle Creek Supply Ditch Co.		1	1				1			1
Spain Ferris Ditch Co.			4	1						
Valley Ditch Co.		2	1							
Miscellaneous Ditches	4	1	3	3	1					
TOTAL NO. OF FARMERS	4	9	18	6	6	17	5	5	1	5

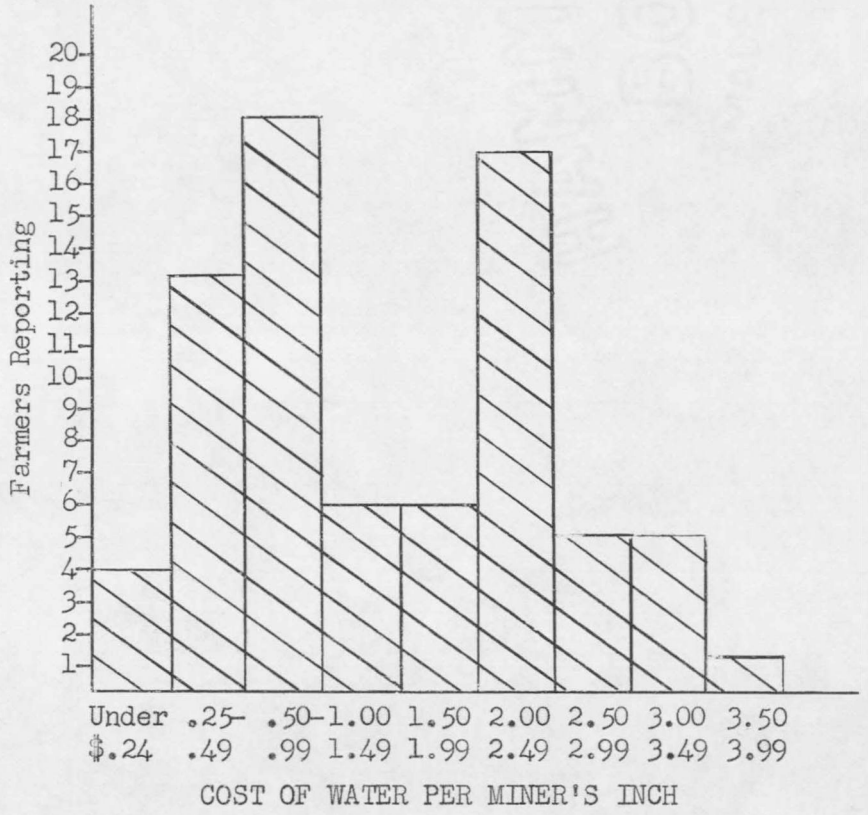


Figure 16. Total number of Gallatin Valley farmers reporting water costs per miner's inch, 1963.

tell the complete story.

Using this fabricated cost, two farmers may have the same "cost-per-miner's-inch" and yet not be paying the same price per acre foot of water. A difference in per acre foot costs would be a function of the water right. If one farmer has an old right he will receive a "miner's-inch-flow" all summer long while another farmer, with the same "miner's-inch-cost" and a late right may have his water shut off by July 15. Their costs per miner's inch would be the same yet their cost per acre-foot would be very different. This divergence in cost per acre-foot is magnified when the old right has a very low cost per miner's inch and the later early-cut-off right has a high cost per miner's inch. The latter is typical in the valley with the Baker Ditch Company and the High Line Canal Company being examples. The Baker Ditch Company has an average annual cost of $.50 per miner's inch and very seldom has its water shut off. The High Line Canal Company on the other hand has an average annual cost of $2 per miner's inch and has its water shut off each year by July 1-15. If a Baker Ditch Company water user would allow his water to run constant from June 1 to August 31, his water would cost 11 cents per acre-foot. If a High Line Canal Company water user would allow an equivalent amount of water to flow from June 1 to July 15 his water would cost 90 cents per acre-foot.

Another facet of the cost structure not presented by the fabricated costs is the different ditch company policies. In the Kughen Ditch Company each water user helps maintain the ditch from his property to

the headgate. Using this system the farmer on the extreme end of the ditch has a higher water cost than the farmer nearest the headgate. Another company policy affecting costs is the manner in which ditch repairs are made. Some ditches with only a few users can be cleaned by three to four days joint effort while other long ditches with 50-60 users will require special expensive equipment. Some ditch companies make annual repairs and thereby keep their annual costs at about constant levels while others allow the ditch to "run down" for 10 years and then incur high annual costs for five years putting the ditch back into repair. Again some ditch companies have "overcharged" for water through the years and carry large cash reserves for special emergencies and others only charge for actual expenses.

Attitudinal Expressions

The mail questionnaire was designed to check the attitudes of the valley farmers to find out if the farmers over the ground water areas would be willing to accept pumped water in place of their surface water rights. If the farmers were agreeable, this exchange would allow the upstream farmers to divert additional surface water. The upstream farmers were queried regarding their willingness to share the cost of pumping water in the lower regions of the valley for the privilege of diverting more surface water. If both areas were agreeable to such a transfer an institutional organization could be developed to facilitate the exchange and at the same time protect prior rights.

Farmers Over the Ground Water Area

The ground water area lies along the river and includes much of the central part of the Gallatin Valley, Figure 17. Thirty-eight percent (38 percent) of the reporting farmers have land over the ground water area, Table V. Two of the ditches, Spain Ferris Ditch Company, Figure 19, and Lower Middle Creek Supply Ditch, Figure 23, reported all of their land is over ground water and two companies, High Line and Low Line Canal Companies, Figure 19 and 21, reported no land over the ground water. An interesting phenomenon is evident from Table V. The ditch companies that cover large areas of the valley have little or no land over the ground water area. The magnitude of this phenomenon is apparent by comparing Figure 17, Table V and the location maps, Figures 18-23. Besides the High Line Canal, Figure 19, and the Low Line Canal, Figure 21, which have no land over the ground water area, there are other canal companies representing large blocks of the valley with very little land over the ground water area, e.g., the Farmers Canal, Figure 18, Kughen Ditch Company, Figure 20, and the Kleinschmidt Canal.

The majority, 53 percent, of the farmers having "ground water land" reported they would not accept pumped water in place of their surface water rights. The Lower Middle Creek Supply Ditch, Figure 22, is the only ditch where all reporting farmers were over ground water and all refuse to accept pumped water. This is probably a result of the sub-irrigation in that area and the fear that pumping would lower the water table. All of the farmers from the Farmers Canal, Kleinschmidt Canal,

TABLE V. ATTITUDE OF GALLATIN VALLEY FARMERS OVER THE GROUND WATER AREA, 1963.

Ditch Company	Total Farmers Reporting	Farmers Over Ground Water Area b/	Those Accepting Pumped Water c/	Farmers Not Accepting d/	Farmers Not Committed	Ditch Location Figure No.
Farmers Canal Co.	13 a/	2	2			19
High Line Canal Co.	17					20
Kughen Ditch Co.	3	1		1		21
Kleinschmidt Canal (West Gallatin Canal Co.)	7	1	1			22
Lewis Ditch	4	3	2	1		
Low Line Canal Co.	9					23
Lower Middle Creek Supply Ditch	4	4		4		24
Spain Ferris Ditch Co.	5	5	2	2	1	20
Valley Ditch Co.	3	2	2			25
Miscellaneous Ditches	18	14	5	9		
TOTAL	83 d/	32	14	17	1	
Percent of Total Farmers	100	38	(44) e/	(53) e/	(3) e/	

a/One farmer has land in both areas--over and not over ground water.
b/Number of farmers that replied in each company or under the ditch with land over the ground water.
c/Number indicating they would accept pumped ground water so others could use their surface water.
d/Number not willing to exchange ground surface water.
e/Percent of farmers in ground water area.

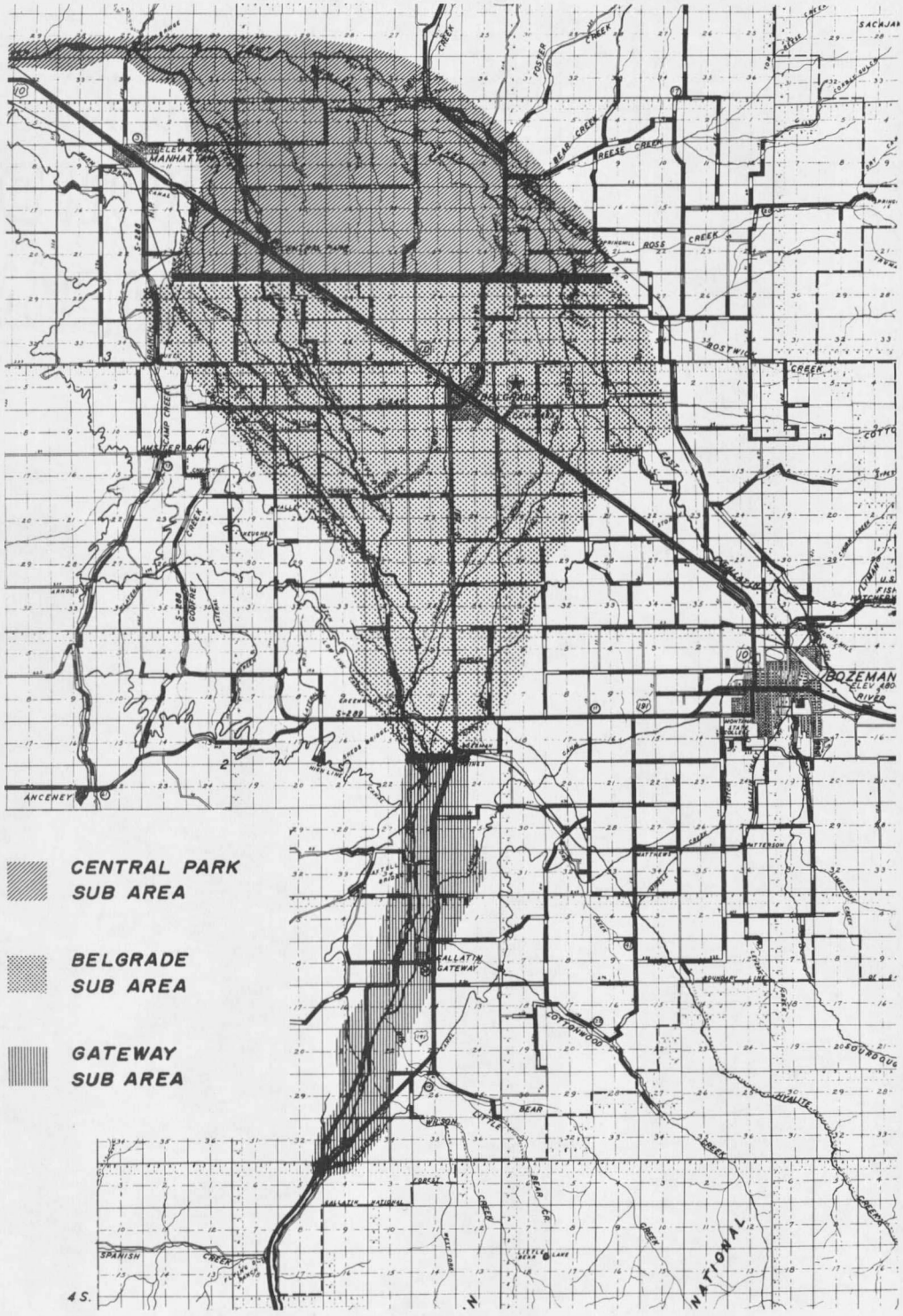


Figure 17. Ground Water Location, Gallatin Valley, 1957.

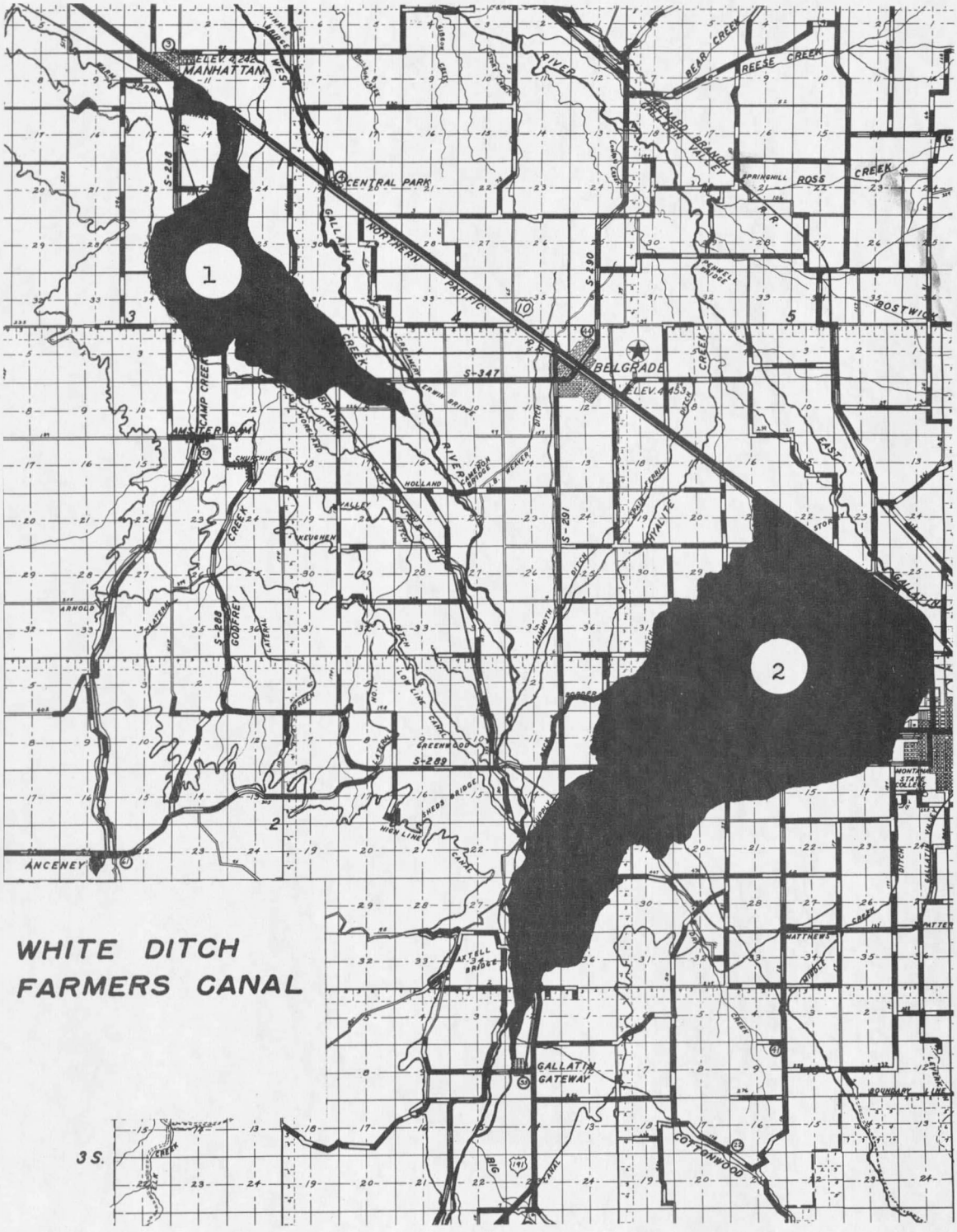


Figure 18. (1) White Ditch and (2) Farmers Canal.

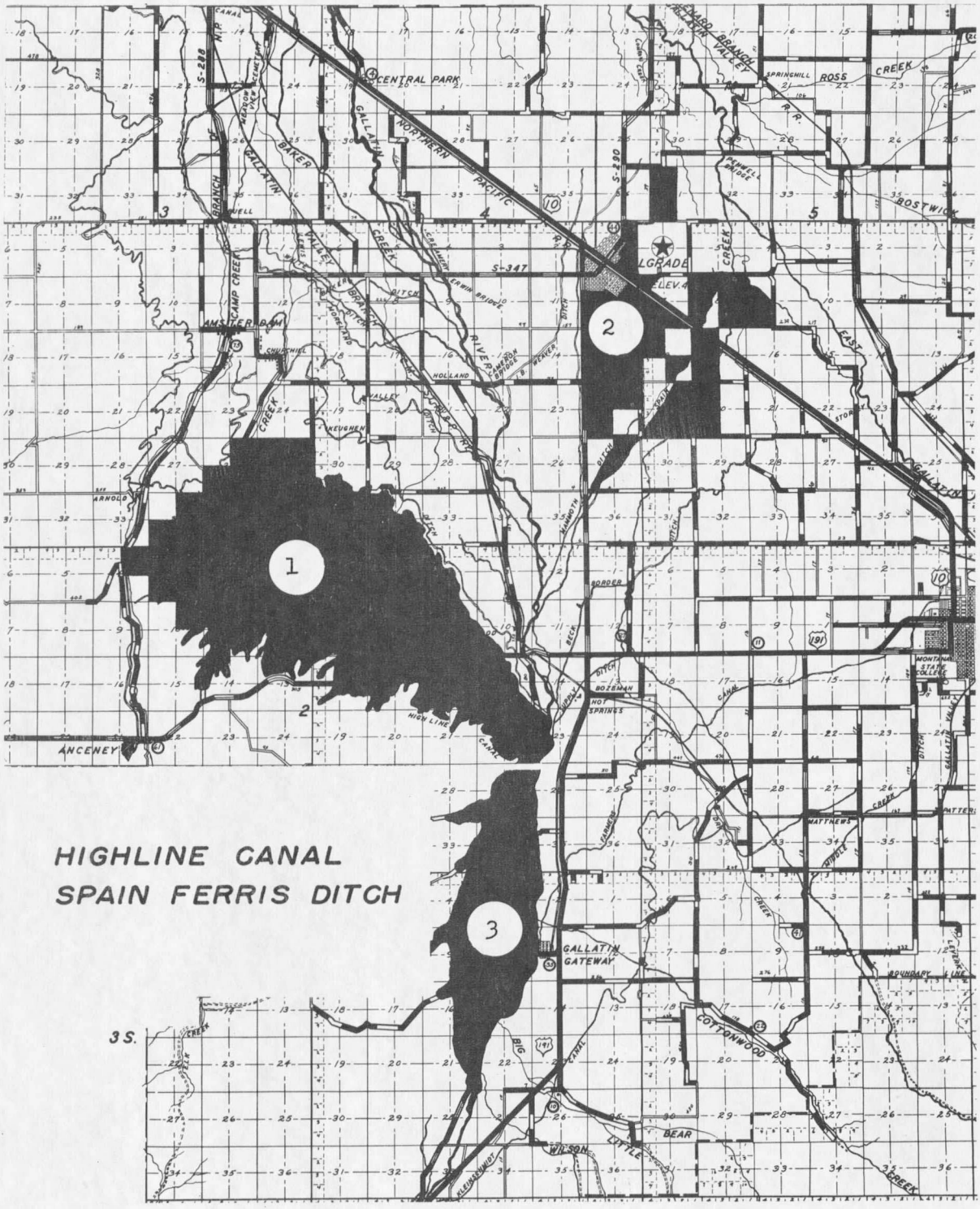


Figure 19. (1) High Line Canal, (2) Spain Ferris Ditch, and (3) Under High Line Canal but not irrigated from it.

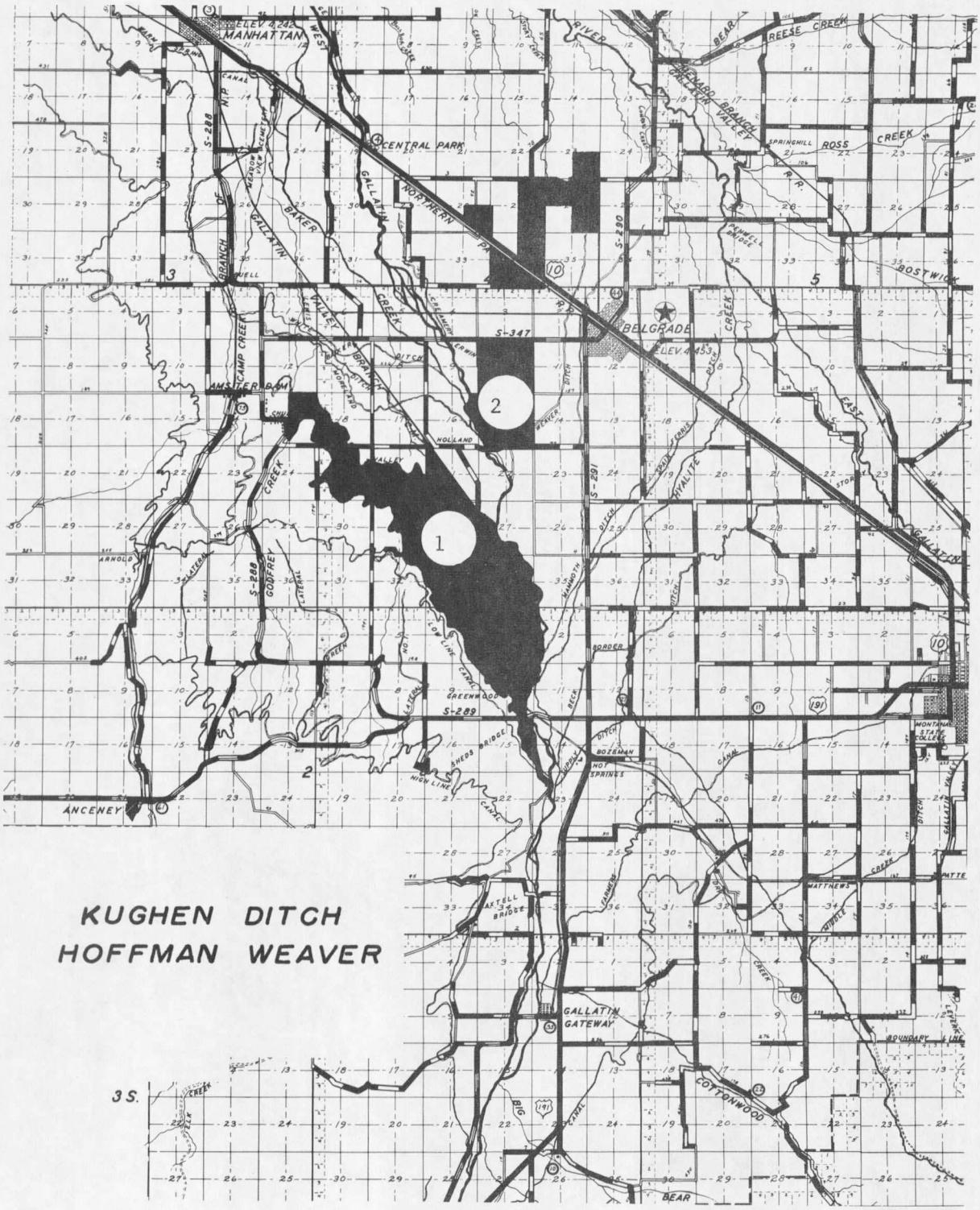


Figure 20. (1) Kughen Ditch and (2) Hoffman Weaver.

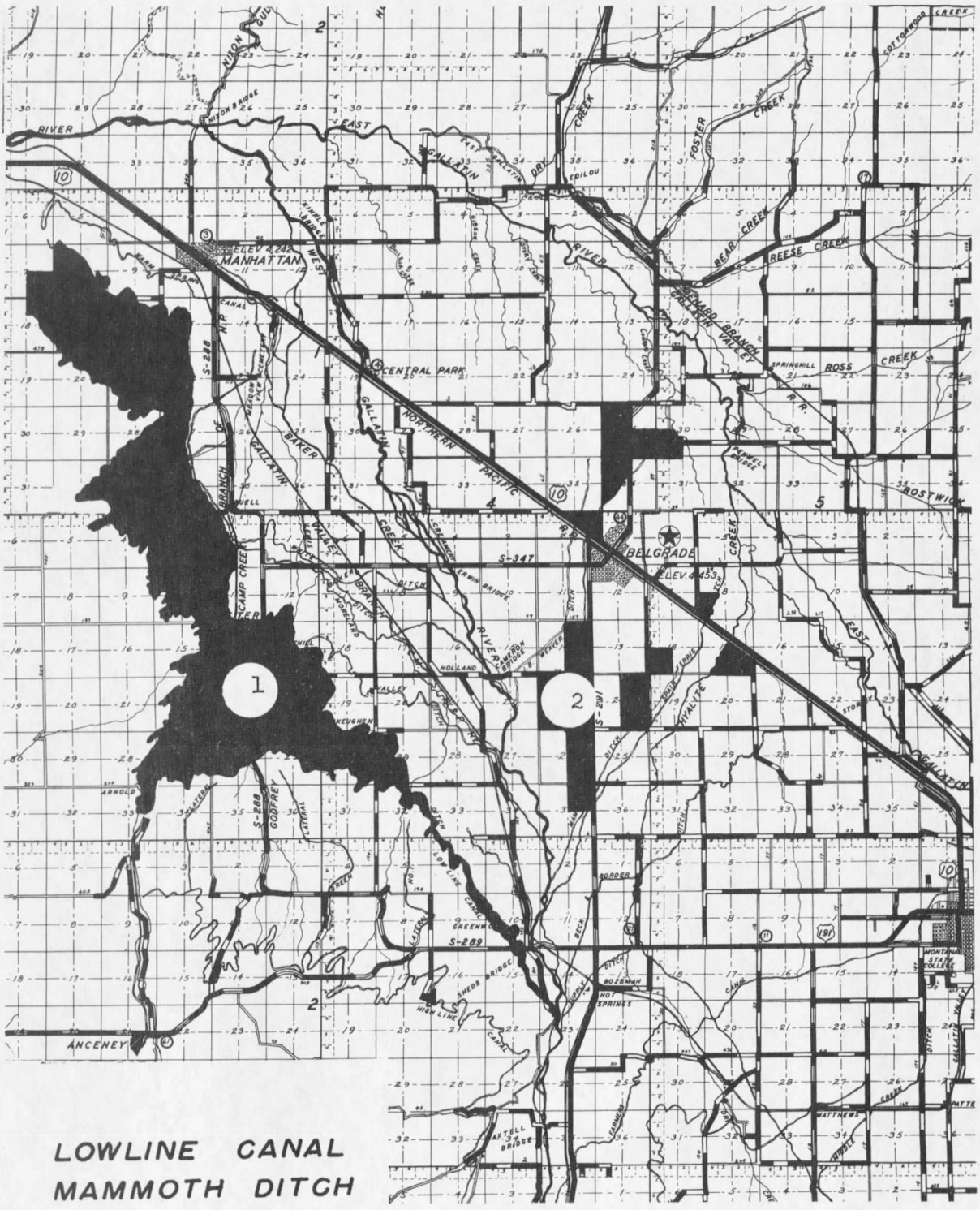


Figure 21. (1) Low Line Canal and (2) Mammoth Ditch.

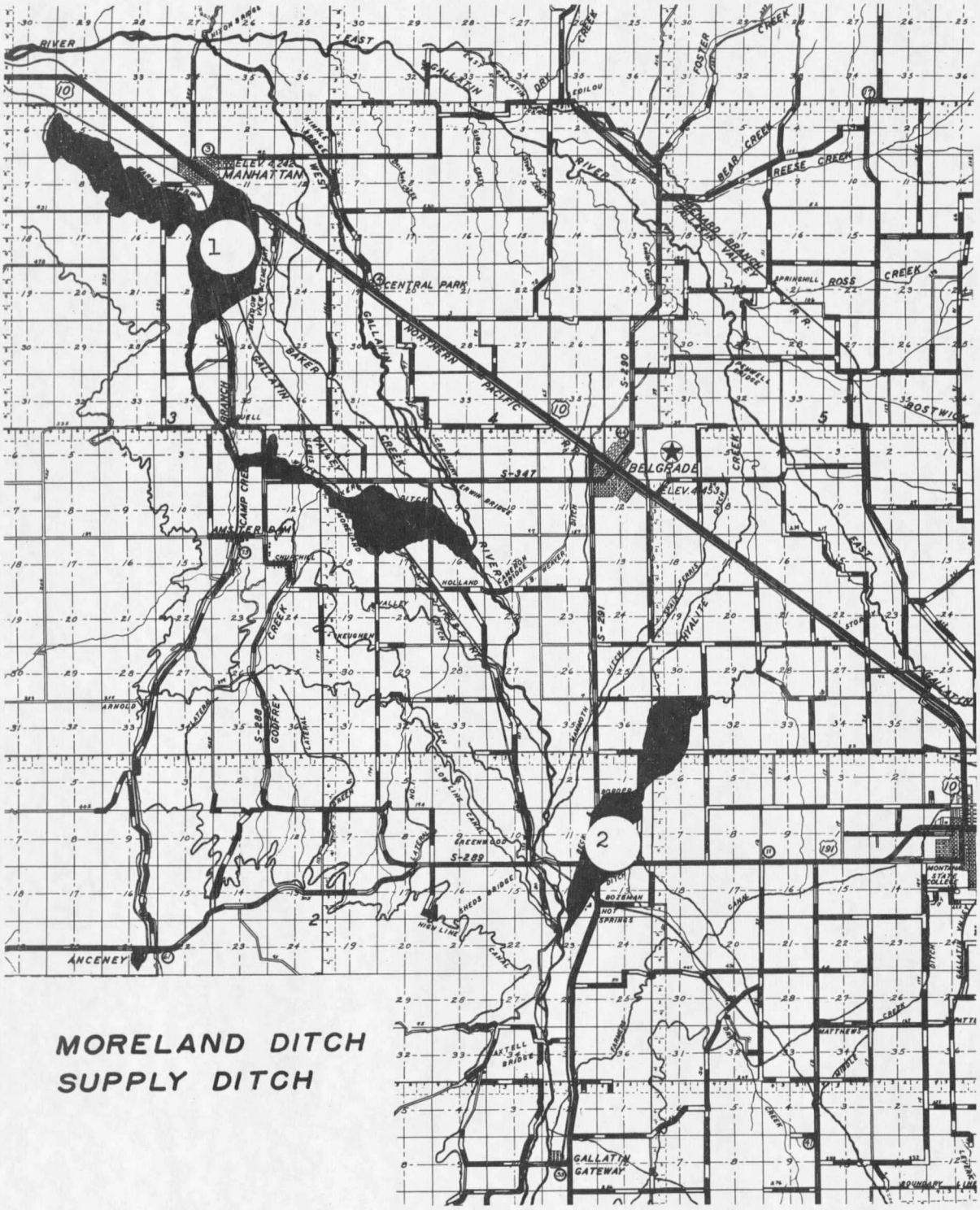


Figure 22. (1) Moreland Ditch and (2) Supply Ditch.

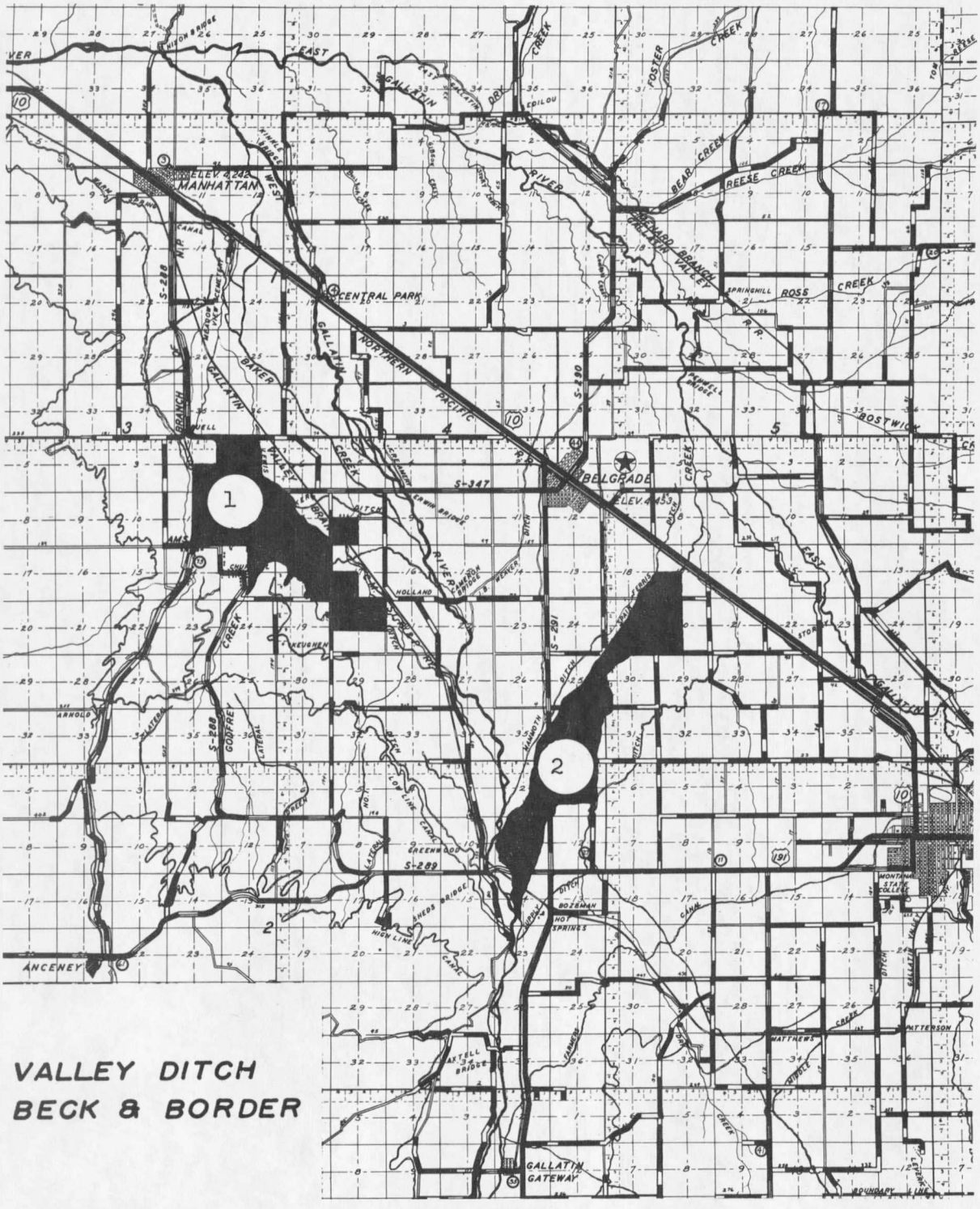


Figure 23. (1) Valley Ditch and (2) Beck and Border.

and Valley Ditch Company reporting land over the ground water would accept pumped water.

In summary, the attitudes of farmers over the ground water area is negative toward accepting a ground-surface water exchange with 53 percent voting against it. The attitudes of individual companies exhibit extreme variances with members of some companies being 100 percent against accepting an exchange, e.g., Lower Middle Creek Supply Ditch. Whereas members of other companies voted 100 percent to accept a ground-surface water exchange, e.g., Farmers Canal Company.

Farmers Not Over the Ground Water Area

Sixty-two percent (62 percent) of the reporting farmers have land that is not over the ground water area. All of the land in High Line and Low Line Canals is away from the ground water, Figures 20 and 23. In addition, all but two of the farmers reporting in the Farmers Canal, Figure 19, all but one of the farmers reporting in the Kughen Ditches, Figure 21, and all but one of the farmers reporting under the Kleinschmidt Canal, own land away from the ground water area.

Although 53 percent of the valley farmers stated they needed additional water, only 42 percent of those not over ground water are willing to share pumping costs to receive the additional water. The absence of general consent to share pumping cost may be the result of the farmers not knowing what is involved in the water exchange process and therefore unwilling to express cooperation. Some information meetings in the valley might increase the percentage of cooperators but it is

doubtful if 100 percent cooperation in a ground-surface water exchange could be attained.

The High Line and Low Line Canal Companies, Table VI, are the only two ditch companies in which a majority of the reporting farmers are willing to pay for additional water. This is probably due to their long history of being critically short of water and their separate efforts to increase their water supplies.

Implications

Through the course of this study we have established the existence of a large supply of ground water and a need within the valley for more irrigation water. This section is a summarization of the apparent blocks to the integrated development of the existing supply to satisfy the expressed need.

Economic

In this study no positive economic blocks to integrated ground-surface water development were discovered. There are certainly no blocks to integrated development as far as economic theory is concerned. Given a situation sterile of existing institutions an integrated irrigation system can be developed using economic theory where the marginal cost of applying water is just equal to the marginal benefit received from the application of the water or a system where the return/price ratio is equal to the return/price ratio of all other production inputs.

The benefit-cost ratio of developing the ground water resource is

TABLE VI. ATTITUDE OF GALLATIN VALLEY FARMERS NOT OVER GROUND WATER AREA, 1963.

Ditch Company	Total Farmers Reporting	Farmers Not Over Ground Water b/	Farmers Willing to Share Costs c/	Farmers Not Willing to Share Costs d/	Farmers Not Committed	Ditch Location Figure No.
Farmers Canal Co.	13 a/	12	3	9		19
High Line Canal Co.	17	17	9	8		20
Kughen Ditch Co.	3	2		2		21
Kleinschmidt Canal (West Gallatin Canal Co.)	7	6	1	4	1	22
Lewis Ditch	4	1		1		
Low Line Canal Co.	9	9	5	4		23
Lower Middle Creek Supply Ditch	4					24
Spain Ferris Ditch Co.	5					20
Valley Ditch Co.	3	1		1		25
Miscellaneous Ditches	18	4	4			
TOTAL	83 d/	52	22	29	1	
Percent of Total Farmers	100	63	(42) e/	(52) e/	(2) e/	

a/One farmer has land in both areas--over and not over ground water.
b/Number of farmers that replied in each company or under a ditch that did not have land over the ground water area.
c/Number willing to share cost of pumping water elsewhere to increase their own supply of surface water.
d/Number not willing to share pumping costs.
e/Percent of farmers not over ground water area.

greater than one as submitted by the Bureau of Reclamation and nothing in this study indicates it should be otherwise. Many of the farmers submitting reasons for not wanting to go along with any type of ground water development gave the high-cost-of-pumping as a reason, and many of those with very low water costs said they could not pay more for water. At the same time the High Line Canal users, which have a relatively high cost of water per miner's inch, Table IV, indicated they wanted more water and would pay more money for it. The real monetary value of water in the valley seems to be set or suggested by those who have very little of it or apply it to marginal land.

Physical

One of the apparent present blocks to ground water development is the location of the ground water supply. The Belgrade Subarea, Figure 17, is the valley's main source of ground water and in this same area are located some of the oldest surface water rights in the valley. Those farmers with plenty of inexpensive surface water certainly do not want to increase their costs by pumping their irrigation water. These farmers with old water rights do not want to risk losing their rights via some pumping scheme. Therefore, they refuse to cooperate and block any attempts to development of the ground water resource.

Another physical block to development is the high water table through much of the area. This high water table causes much of the land to sub-irrigate and this benefit has been incorporated into many farm operations and even capitalized into the value of the land. If farmers

owning this land would develop their own pump irrigation or agree to allow someone else to supply their present surface rights from pumps they run the risk of losing their "sub" and they are not going to allow this to happen if they can block it.

The comments submitted by the reporting farmers indicate the prevalent animosity to loss of "sub-water".

Typical comments are:

101 - We try to start irrigating early in the season to get the water table up and make the lower ground to sub. If we put pumps in there would be no sub. Crops would burn up.

Maybe a dam could be built up the canyon somewhere to hold some of the spring run-off.

110 - The underground water table is high only when there is plenty of water in the river. We believe the present water laws are fair, and should not be changed.

119 - Our irrigation system is very simple and economical to operate. Besides I have some ground that subs and if I pumped I would probably have to irrigate more land and my costs would rise. Why would I want to increase my costs, when our supply is perfectly adequate and our costs are low. We always have all the water we need. We having one of the oldest rights in the valley, have never been cut at the river when the water gets low except to our decreed right.

236 - (This comment is paraphrased to conceal identity of writer). Because of uneven nature of my land leveling is too expensive, sprinkling is too expensive, therefore I use most of my water raising the water table. I would consider legal action against anyone pumping on or near my property.

Other adverse comments are recorded in Appendix B 050, 192, 265 and 905.

Historic and Legal

The history of the valley as it developed within the legal framework has produced a water right system rigid to change. The first water was diverted from the Gallatin River in 1864 and in less than 20 years all of the reliable river flow had been claimed. The farm population in the valley increased and even though the normal surface water run-off had been claimed the new farmers claimed a right to the use of surface water. The natural result of this action was a series of court cases to settle the disputes. The first two court cases were held in June, 1884 and from then to 1952, a period of 68 years, 44 court cases are on record.

There are three methods of establishing water rights in Montana and over the years these have created a resistant attitude toward water development and change. The courts have allowed any farmer to dig a ditch, put the water to beneficial use and acquire a water right on an unadjucated stream. This construction and diversion can be done without respect for those who have prior rights. If the late comer can fend the opposition and continue using the water he can establish a water right. The legends are legion about the strife and struggles, both verbal and physical, between neighbors and otherwise-friends regarding the rights and use of water. During the course of this study the author received a first hand account of one water user who had personally barged into the Montana Supreme Court and in his rage announced his intention to kill his neighbor if something was not done legally to

stop the man from illegally using water. This strife was resolved legally but a system developed by such strife and existing on such a legacy is resistant to change. This attitude is evident in the volunteer comments submitted:

086 - The upgoing taxes, plus increase in price of water will break every farmer.

Don't want anybody interfering with our water rights.

060 - I am not interested in this in any way, shape, or form.

210 - We have plenty of water and don't need to pay more if government don't interfere and take it away. Leave our water alone, use flood control and help two ways out on expense. We have plenty of water, why take the underground water. Why don't the government put dams in these canyons and hold the flood water and have flood control and irrigation water at the same expense. Our taxes are too high now. Save some money. We don't want to lose our water we need it.

223 - Present system satisfactory for 75 years--can get along without Bureatric (bureaucratic) interference.

Other similar comments, 110, 160 and 296 are recorded in Appendix B.

Another legal drag if not a block to development has been the lack of a ground water code in Montana. Until January 1, 1962, the effective data of the Underground Water Code, Montana did not have legal structures for governing priority of ground water usage. The 1962 code allows those persons who put ground water to beneficial use prior to January 1, 1962 to file claims on this ground water on or before January 1, 1964. The clerk and recording offices in most counties of the state

received a rush of claims in December, 1963, and it remains to be seen if this code will remove the drag on development. Beneficial use is the extent and limit of appropriative rights that are established under the code. The application of ground water for beneficial use before January 1, 1962 is stated in the code to be sufficient to establish a ground water right. Perhaps the most significant statement in the code regarding priorities and development is in Section 2 which states "Rights to surface water where the date of appropriation precedes January 1, 1962 shall take priority over all prior or subsequent ground water rights."

Summary

Surface-ground water integration for the Gallatin Valley, Montana appears to be potentially beneficial and feasible with only two exceptions. Integration is feasible from both the standpoint of economic theory and benefit cost ratios. Integration would be possible within the present legal structure with only minor adjustments. Physically the points of surface water diversion and ground water pumping can be integrated to increase total water supply.

The first restriction to ground-surface water integration comes from the possible lowering of the ground water table and thus decreasing the sub-irrigation in parts of the valley.

The second and most important block to ground-surface water development seems to be the emotional or attitudinal set of the farmers in the valley. Their system of water rights has been won by many per-

sonal and ancestoral fights with courts, water commissioners, and neighbors and they are loath to enter into any governmental, organizational, or contractual arrangements that may endanger one of their most precious possessions--an early water right.

One action that is physically possible and institutionally permissible and which hopefully would remove some of the attitudinal blocks to development would be the establishment of a small privately organized and financed pumping project in the valley. The feasibility study in Chapter VIII is presented with the dual purpose of supplying some greatly needed supplemental water to the High Line Canal and at the same time providing the valley with a demonstration project that may serve as a stimulation for further ground-surface water integration.

CHAPTER VIII

PROPOSED DEVELOPMENT PLAN

Introduction

As this project developed it seemed the blocks to the initial proposal were paramount. A demonstration project appeared necessary to give the farmers an opportunity to observe what can be done via pump irrigation in the Gallatin Valley.

The High Line Canal, Figure 24, is the most logical area for a proposal since more farmers responded from that ditch than any other, thus showing their interest. The water cost to the High Line Canal users is among the highest, $2.00 to $2.49 per miner's inch, therefore they know the value of the water they buy. The High Line Canal has a flood-water-right of 6,800 miner's inches which is cut off each year about July 1-15. All but one of the 17 farmers reporting said they could use water for a longer period of time to irrigate pasture and hay. Nine of the 17 High Line farmers, 53 percent, indicated they would be willing to pay for additional water. The project under study consists of 25 wells to supply 3,400 miner's inches of water to the High Line Canal during the last of July and most of August.

The proposed development plan takes the form of a feasibility study. First consideration is given to the physical resources available, next comes the needs of the canal, then a plan of development of the resources is presented, followed by the problems of water rights, and last is the cost structures of the proposed development.

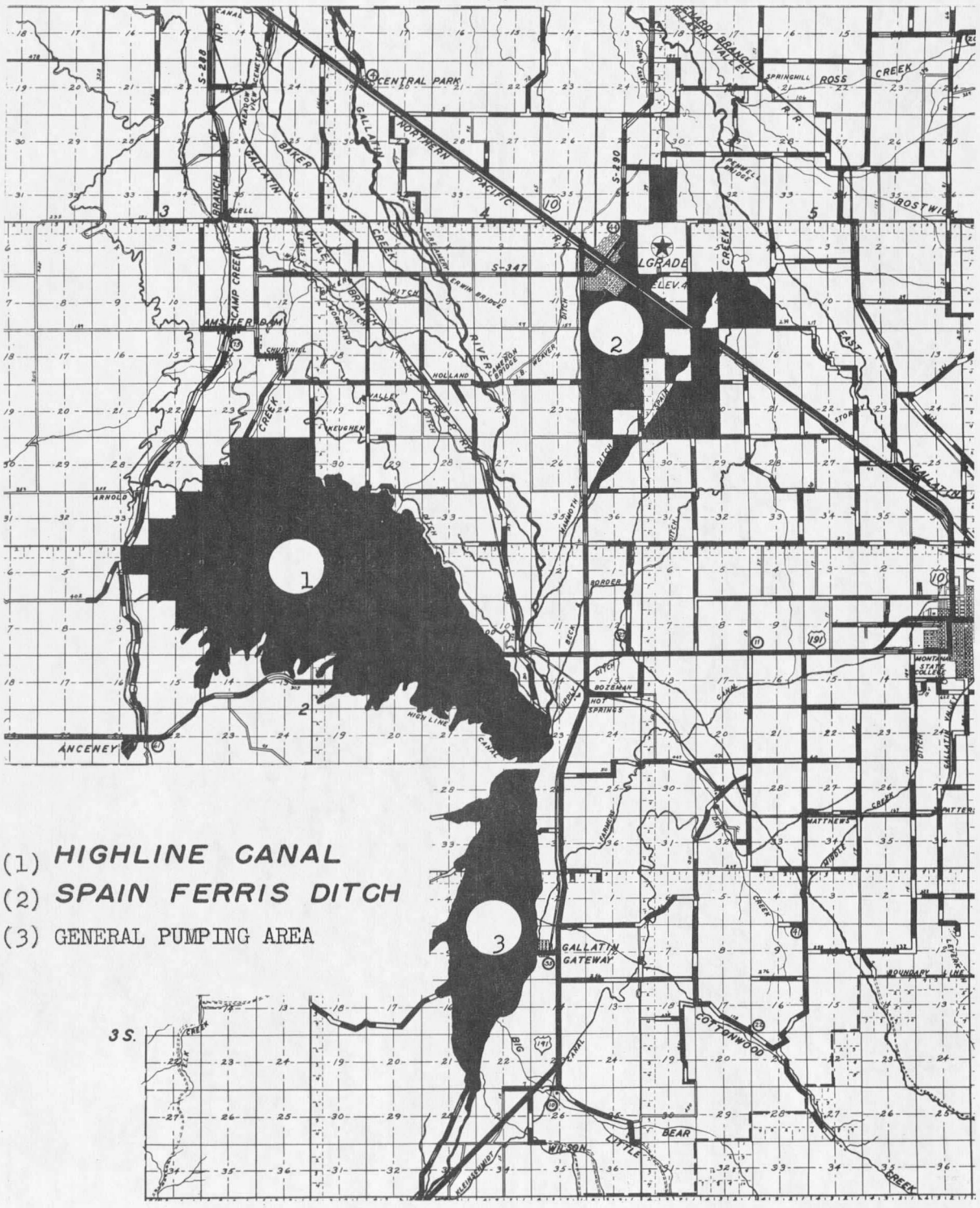


Figure 24. Gallatin Valley Irrigation Feasibility Study Area, 1963.

Characteristics of Soil

Anyone who has dug post holes or observed the road side cuts knows there are several types of soil diffused over the face of the earth. We are concerned here mainly with the water bearing capabilities of the earth's surface and shall confine our descriptions within these limits.

Some surface material such as sands, gravel, and some rocks, such as sandstone, have the ability to "hold" water (or allow it to pass through slowly). Water-bearing rocks that will yield enough water to be a source of supply are known as aquifers. The various characteristics of aquifers are very important to hydrologists and much study has gone into the measurement and comparison of them. Let us examine only a few.

Specific yield is one important concept. A strict definition is given in Appendix D--Definitions, but broadly speaking it is a measure of the quantity of water that a saturated aquifer will yield when drained by gravity. The opposite of specific yield is specific retention which is a measure of the quantity of water retained by a saturated aquifer against the pull of gravity. The quantity of water which drains out, specific yield, plus the quantity retained, specific retention, equals the total volume of interstices in the aquifer, i.e., the porosity.

Another important characteristic of any aquifer is its ability to transmit water. This capability is termed "transmissibility." The coefficient of transmissibility is "the number of gallons of water per

day, at the prevailing water temperature, that is transmitted through each (one) mile strip extending the full saturated thickness of the aquifer under a hydraulic gradient of one foot per mile."37/

Permeability is the characteristic of porous material that allows it to transmit water. Experimentation on permeability was carried on as early as 1856, and today the Geological Survey uses a standard coefficient of permeability defined "as the rate of flow of water in gallons a day at 60 degrees Fahrenheit through a cross-sectional area of one square foot under a hydraulic gradient of 100 percent."38/ This is a laboratory concept so a related coefficient was developed called the field coefficient of permeability which in "the rate of flow of water, in gallons per day, under prevailing conditions, through each foot of thickness of a given aquifer in a width of one mile, for each foot per mile of hydraulic gradient."39/

Characteristics of Ground Water

First let us understand "ground water." Not all water below the surface of the earth is "ground water." "Ground water" occurs only where all of the pores in the earth are saturated. Thus ground water is found only in the "zone of saturation." The saturation zone may be level with the land surface in some areas or may be hundreds of feet

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37/Hackett, op. cit., p. 181.

38/USDA, Water, op. cit., p. 298.

39/Hackett, op. cit., p. 101.

below the surface in other areas. If the zone of saturation is below the land surface then a "zone of areation" exists between the land surface and the zone of saturation. Water always exists in the zone of areation by molecular attraction and this water will not be given up to wells. Well water is obtained by drilling through the zone of areation to the zone of saturation. Thus not all water in the ground is "ground water" by definition.

Water in the zone of saturation usually is in constant motion "downhill" via the pull of gravity. The rate of flow of surface water is measured in feet per second but the rate of ground water flow is measured in feet per day or even per year. One factor that affects the flow of ground water is the slope of the water table. This slope is known as the hydraulic gradient and is measured by variations in the height of water in wells divided by the distance between wells, Figure 25.

The water table is a common term which refers to the upper surface of the zone of saturation. If a well is drilled into the zone of saturation, water will fill the hole and the water level in the well will also be the water level in the zone of saturation, (except for artesian water). The water level in the well will also be the level of the water table. We have all heard the phrase "water seeks its own level" yet this is not necessarily true of ground water in the sense that the water table is a certain number of feet above sea level for any large area. The water table usually approximates the surface terrain or "land

Hydraulic Gradient = $\frac{H}{L}$

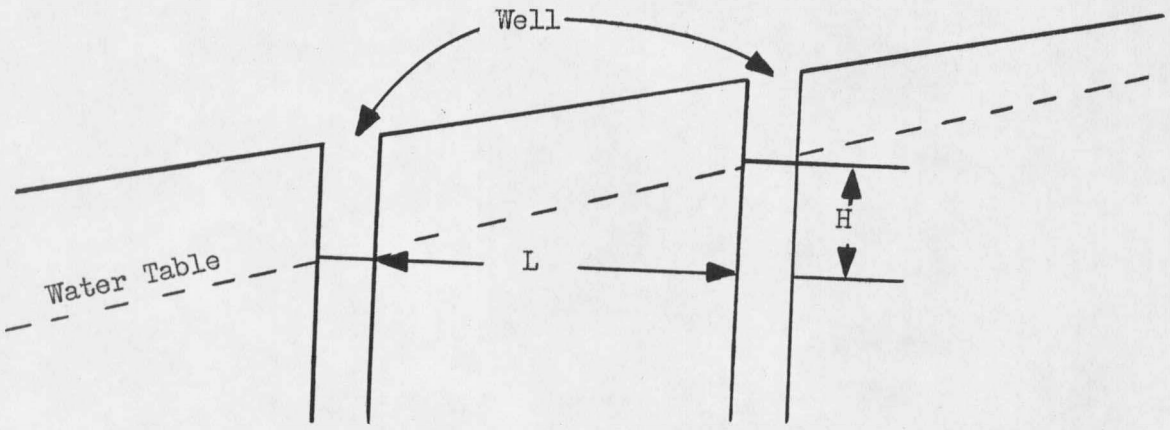


Figure 25, Hydraulic Gradient.

table." Also, since a ground water reservoir is subject to the same gravitational forces as a surface reservoir, the water table will fall as water flows out or is drawn out of the reservoir and the water table will rise as water flows into the reservoir (recharge).

Not all ground water is free or unconfined. Some water is under an impervious layer and when tapped by a well the water rises in the well higher than this impervious layer, Figure 26, and under some conditions the water will even rise onto the land surface and become surface water. Water under an impervious layer which will not allow the water table to raise is called confined or artesian water. Obviously the level of water in a well that taps confined or artesian water would

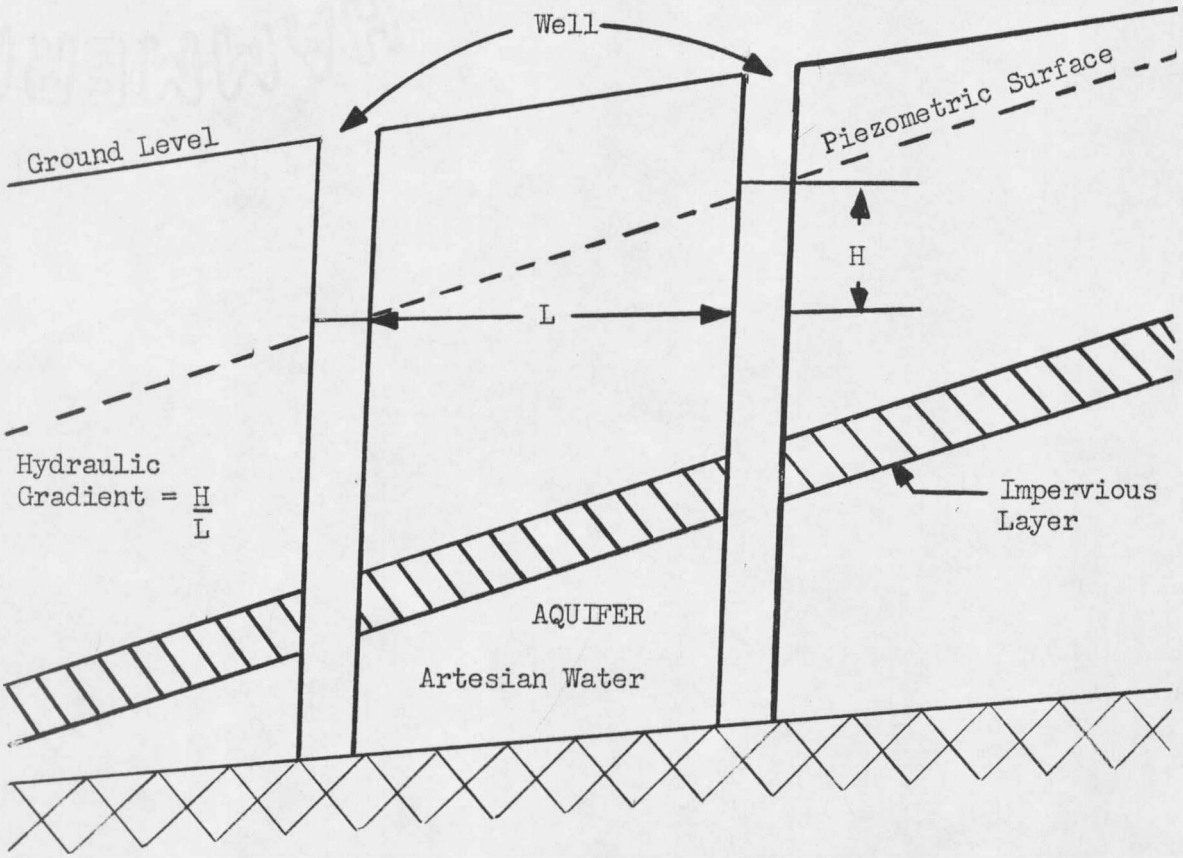


Figure 26. Piezometric Surface.

not correspond with our definition of the water table. Hydrologists say the height of water standing in a well tapping confined water corresponds to the hydrostatic pressure under which the water is confined. Further "an imaginary surface that coincides everywhere with points to which this confined ground water will rise is called piezometric surface," Figure 26.

There is another defined type of ground water which is trapped

above an impervious layer or hard pan and cannot seep deeper into the ground. This confined water is referred to as perched water.

In conclusion, let us consider the total supply of ground water. Underground reservoirs are reportedly the largest supply of fresh water our nation has. The capacity of ground water reservoirs exceeds that of surface reservoirs and streams including the Great Lakes. Our supply has been estimated at 10 year's annual precipitation or 35 years run-off![40/] The reason for concern regarding ground water usage does not involve the total supply but rather smaller basins. Many of the ground water reservoirs, especially in the western states, are being pumped at a faster rate than the long run average precipitation can be expected to recharge them. This dilemma arises when heavier and heavier demands, via population increase and industrial and agricultural growth, are placed on ground water supplies without regard for the amount of precipitation that is available for recharge.

Characteristics of Wells

When a well in an unconfined ground water supply is pumped, the water level in the well is lowered, and water from the immediate saturated area will flow into the well casing. Continued pumping will cause continued lowering of the water in the well which in turn causes the flow from the saturated zone to increase until the inflow equals the

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40/Thomas, Harold E., "Underground Sources of Our Water," in Yearbook of Agriculture, 1955, p. 62.

discharge. The amount the well's water level is lowered below the water level in the saturated zone is called draw down.

Water moving toward a well must pass through millions of small pores in the aquifer and as the water approaches the well its velocity must accelerate because the area through which it travels decreases approaching the well. For example, a well with a 12 inch diameter will have a 37.7 inch circumference (circumference $= \pi d$, $\pi = 3.14$, d = diameter). An imaginary circle three inches away from the well (d = 18 inches) has a circumference of 56.6 inches and just like the increase in the velocity of water as it passes through a nozzle on the end of a garden hose, the velocity of the water approaching the well must increase as the area through which it passes becomes smaller and smaller, i.e., from the larger circles through smaller ones.

Water runs faster as it goes down hill so it naturally follows that the velocity of water in an aquifer is directly proportioned to the slope of the water surface. Since the velocity of the water increases as it approaches the well the slope of the water surface also increases as the water approaches the well. The result of this bit of physics is a funnel shaped water surface around a pumped well. This funnel shape is known as the cone of depression, Figure 28. The area of influence, a term nearly synonymous with cone of depression, is the total area under which a drop in the water table is experienced as a result of pumping a well. An average area of influence has a 1,000 foot radius at usual rates of pumping.

Specific capacity is a measurement for evaluation of wells. It is the discharge in gallons per minute per foot of draw down. To establish specific capacity it is assumed that wells penetrate the full depth of any aquifer, therefore the capacity of a well is directly proportional to the thickness of the aquifer. Specific capacity is directly proportioned to the draw down of a well so long as the draw down is small when compared with the water depth in the well. For example if we have two wells, one with a water depth of four feet and the other with a water depth of 12 feet, a pumped draw down of three feet will not yield the same amounts of water. The first well will be drawn down three-fourths its water depth while the second well will only be drawn down one-fourth of its water depth.

The size of a well affects its capacity but not as much as one might expect. If we assume an area of influence of 1,000 feet and a constant draw down, a two foot well will theoretically produce only 10 percent more discharge than a one foot well. A four foot well will increase discharge only 21 percent over a one foot well.

If we want to develop wells of maximum capacity we must make them as deep as the aquifer or at least deep enough so the draw down is small when compared to the water depth in the well. The casing size of deep wells need be only large enough to accommodate the pumping equipment since the cost of increasing size will not be offset by increasing yields.

Water Measurement

Comparisons of water volume are impossible without some common unit of measure. Water can be measured either standing or flowing. Standing water is measured by specific volume, for example: (1) An acre inch, the volume of water required to cover one acre one inch deep, 3,630 cubic feet, and (2) an acre foot, the volume of water required to cover one acre one foot deep, 43,560 cubic feet. Acre inches and acre feet can also be expressed in gallons. One gallon is equal to .13386 cubic feet and by simple division, an acre inch equals 27,117.8 gallons and an acre foot equals 325,852.8 gallons.

Flowing water has several types of measure such as gallons per minute, cubic feet per second, acre-inches per hour, acre-feet per day, and the miner's inch. Each of the flowing measurements, except the miner's inch, are stated as a volume per unit of time. The miner's inch is defined as the quantity of water that will flow through a one inch square hole when the hole is made in a vertical wall four to seven inches below the surface of flowing water. The western states have each defined the miner's inch in cubic feet per second. Southern California, Idaho, Kansas, New Mexico, North and South Dakota, Nebraska, and Utah each define the miner's inch as 1/50 of a cubic foot per second. Arizona, Northern California, Nevada, Oregon and Montana each define it as 1/40 of a cubic foot per second. In Colorado 38.4 miner's inches equals one cubic foot per second.41/

41/Isrealsen, op. cit., p. 20-21.

All of the flow and standing measurements are interchangeable. Listed below are some equivalents.

Standing Measurements

1 acre inch = 3,630 cubic feet

1 acre foot = 43,560 cubic feet

1 gallon = .13386 cubic feet

1 cubic foot = 7.481 gallons

1 cubic foot = 1,728 cubic inches

Flowing Measurement in MINER'S INCHES

1 mi = 1/40 of a cubic foot per second (cfps)

= .025 (cfps)

1 mi = .025 X 60 sec. = 1.50 cfp minute

1 mi = 1.5 X 60 min. = 90 cfp hr.

1 mi = 90 X 24 hr. = 2,160 cfp day

1 mi = 2,160/43,560 = .0496 AF per day

40 mi = 1 cfps

50 mi = 90 X 50 = 4,500 cfp hr.

50 mi = 4,500 X 24 = 108,000 cfp day

50 mi = 108,000/43,560 = 2.48 AF per day

100 mi = 216,000/43,560 = 4.96 AF per day

200 mi = 432,000/43,560 = 9.92 AF per day

Physical Resources

The Gateway ground water subarea covers an area of about 16 square

miles and includes the head of the High Line Canal and the proposed pumping project, Figure 27. Under the Gallatin River is a water bearing alluvial bed one and one-half to two miles wide and an estimated 55 feet thick. The alluvium is considered to be uniformly coarse and permeable and three aquifer tests gave the following coefficients of transmissibility: 380,000 gpd per foot, 270,000 gpd per foot, and 170,000 gpd per foot.42/

The water table in Gateway subarea is 10-15 feet below the land surface yet it is higher than the water level in the river and water flows from the ground into the river, Figure 30. It is estimated the Gateway subarea discharges an annual average 20,000 acre feet of water into the Gallatin River. This estimate is based upon the gain in flow of the Gallatin River between gauging stations located near Gallatin Gateway and Axtell Bridge two miles north of Gallatin Gateway in Section 34. Measurements of the change in flow were made in November and December of 1952 and January and February of 1953. These were months of very little surface run-off and when no irrigation diversions were made.43/

It is estimated that the 20,000 acre feet of annual discharge from the Gateway subarea should be available for consumptive use. By drawing

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42/Hackett, et. al., Geology and Ground Water Resources of the Gallatin Valley, Gallatin County, Montana, United States Department of Interior, Geological Survey, Geological Survey Water-Supply Paper 482, United States Government Printing Office, Washington 25, D. C., 1960, p. 136.

43/Ibid., p. 139.

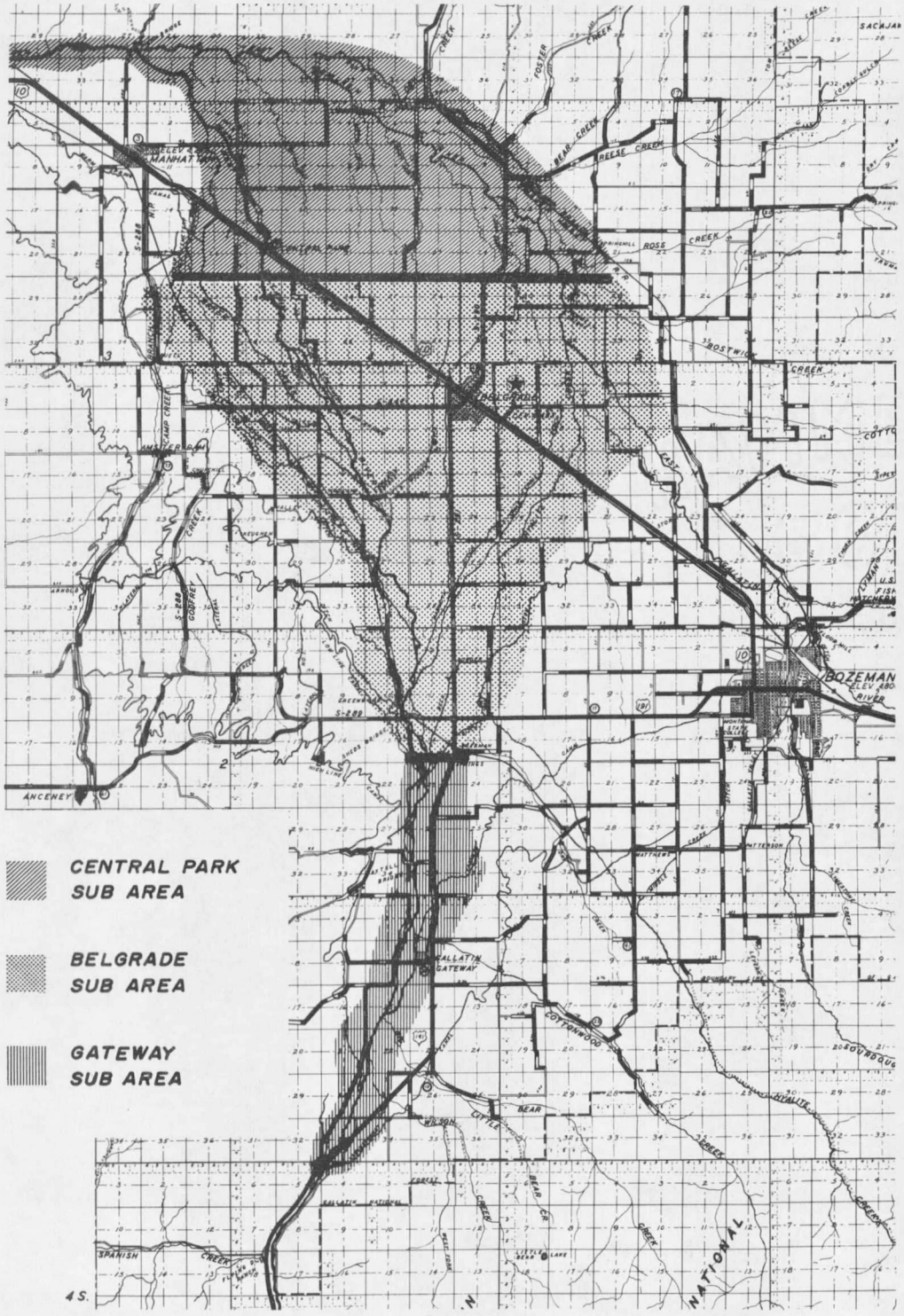


Figure 27. Ground Water Area for Pumping Project.

on this supply for consumptive use the annual flow of surface water across the north boundary of the subarea would be reduced by about an equivalent amount.44/ It is important to note that the annual flow would be reduced. This does not mean that water pumped in July and August will necessarily reduce the river flow by an equivalent amount in July and August. It means that some of the water that would normally be discharged into the river in September and October is being brought to the surface a month or two earlier.

Pumping 20,000 acre-feet or less in the subarea will naturally lower the water table but not below that of the river. As long as the water table remains above the river water level the surface-water outflow from the subarea will always be equal to or greater than the surface-water inflow.

In summary the physical resources of the subarea are estimated at 20,000 acre-feet of ground water that can be used consumptively. Withdrawal of 20,000 acre-feet or less will allow all of the surface-water inflow to cross the north boundary of the subarea undiminished. Consumptive use of ground water will decrease the annual surface water outflow by an amount equal to or less than the amount withdrawn. Not all of this decrease will necessarily be evident in the same months that the withdrawals are made.

44/Ibid., p. 139.

High Line Canal Needs

The High Line Canal is long and expensive to maintain. The canal serves 37 farmers that currently irrigate about 8,300 acres. There are about 1,800 potentially irrigable acres under the ditch making a total of about 10,100 irrigable acres under the canal. The canal has three decreed water rights: (1) 3,400 miner's inches appropriated May 9, 1890; (2) 3,400 miner's inches appropriated June 1, 1901; and (3) 700 miner's inches appropriated June 1, 1913.45/ The dates of these rights are very late, making them only "flood rights" and the ditch company official interviewed reported one-half of their supply was usually cut off on July 1 and the rest about July 15.

Questionnaires were sent to 72 percent (27 of 37) of the members of the canal and 63 percent (17 of 27) responded. This high response shows the interest these farmers have in alleviating their water shortage. Ninety-four percent (94 percent) of the farmers (16 of 17) reported they needed water for a longer period of time and 56 percent of the farmers (9 of 16) said they would be willing to pay for additional water.

On the basis of supply available and the need expressed the feasibility study proceeded. It was assumed that grain irrigation would be complete by July 15 and an assured supply of 3,400 miner's inches, roughly one-half their decreed right, during July and August would be

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45/Water Resources Survey, op. cit., p. 38.

adequate for hay and pasture needs.

A Development Plan

We have established a physical resource of 20,000 acre-feet annually in the Gateway subarea and the High Line Canal Company needs 3,400 miner's inches for 30-60 days during July and August. The problem now is to develop a plan to utilize the resource to satisfy the need.

Number of Wells Required

First we shall consider the quantity of water needed. Under the Hydrology section we defined one miner's inch of water

$$1 \text{ mi} = 1/40 \text{ cfs} = .025 \text{ cfs}$$

The quantity needed for the High Line Canal is 3,400 mi or

$$3{,}400 \text{ mi} = 3{,}400 \times .025 = 85 \text{ cfs}$$

Based upon the Bureau of Reclamation's study it is assumed that wells drilled the full depth of the aquifer in the Gateway subarea will produce an average of 3.5 cfs per well. Under this assumption 25 wells are required to produce 85 cfs.

$$\frac{85 \text{ cfs}}{3.5 \text{ cfs/well}} = 24.3 \text{ wells}$$

Spacing of Wells

A battery of 25 irrigation wells must have proper spacing to maintain a constant flow of 3.5 cfs. The equation

$$Q = \frac{\pi P_m (h_e^2 - h_w^2)}{2.303 \log_{10} (r_e/r_w)}$$

Q = Quantity of water pumped in gallons per day

$h_e - h_w$ = drawdown

P_m = permeability factor

π = 3.1416

r_e = radius of influence

r_w = radius of the well in feet

was used to calculate well spacing for this project. The equation assumes certain data are known for the well and Figure 28 helps visualize the data required.

The shape of the drawdown curve or cone of depression was discussed earlier. It has been calculated that in a thick water-bearing medium a well will drawdown one foot for each 100 gallons pumped per minute.46/ The wells in this project produce 3.5 cfs or

3.5 cfs X 60 sec = 210 cfp minute

1 cf = 7.48 gallons

210 X 7.48 = 1,570 gallons per minute

1,570 $\cong$ 1,600 gpm

Under the assumption, of one foot drawdown for each 100 gpm, wells in this project will have 16 feet of drawdown,

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46/Israelson, op. cit., p. 110

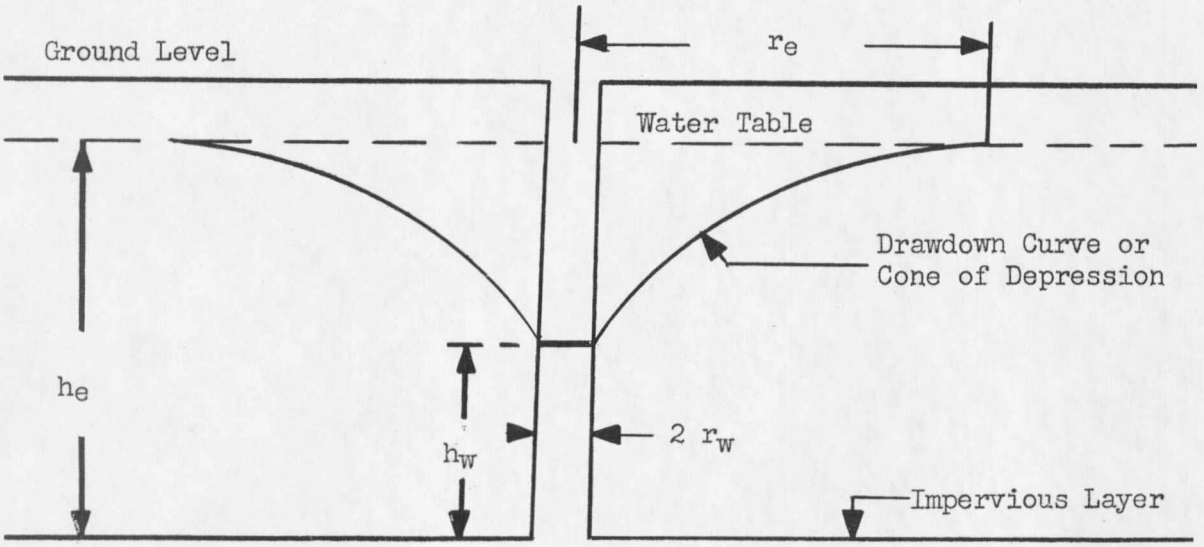


Figure 28. Well Profile.

$$\frac{1{,}600 \text{ gpm}}{100 \text{ gpm}} = 16 \text{ feet}$$

Assuming an aquifer depth, h_e, of 50 feet h_w will equal 34 feet,

$$h_e - 16' = 50-16' = 34',$$

$$h_w = 34 \text{ feet}$$

Well size is another important factor. It is assumed the project wells would be 16 inches in diameter. This diameter will allow a smaller casing to be lowered inside the 16 inch casing should the larger one rust out in future years. A 16 inch well has an eight inch radius which gives us

$$8/12 = .666$$

$$r_w = 0.67 \text{ feet}$$

The quantity of water pumped is assumed 3.5 cfs which, as established above, yields about 1,600 gpm.

$$1{,}600 \text{ gpm} \times 1{,}400 \text{ minutes per day} = 2.304 \times 10^6 \text{ gpd},$$

therefore,

$$Q = 2.304 \times 10^6 \text{ gpd}$$

Summarizing the data used to calculate well spacing we find

$Q = 2.304 \times 10^6$ gpd

$\pi = 3.1416$

$P_m = 4{,}000$ gpd/ft^2 see Appendix E

$r_w = 0.67$ ft.

h_e = for an average well 50 feet

drawdown = 16 feet

$h_w = h_e$ - drawdown = 50' - 16' = 34 feet

and using the above equation to solve for r_e we get

$$2.30 \times 10^6 = \frac{(3.1416)(4.0 \times 10^3)(50^2 - 34^2)}{2.303 \log_{10} (r_e/0.67)}$$

$$\log_{10} (r_e/0.67) = \frac{(3.1416)(4.0 \times 10^3)(1.344 \times 10^3)}{(2.303)(2.304 \times 10^6)}$$

$$\log_{10} r_e = \log_{10} 0.67 = 3.18247$$

$$\log_{10} r_e = 3.18247 + (9.82607 - 10)$$

$$\log_{10} r_e = 3.00854$$

$$r_e = 1{,}202 \text{ feet}$$

Minimum well spacing using this method is approximately 2,000 feet.

Location of Wells

The Gateway subarea is very narrow near the head of the High Line Canal. Careful planning was required to locate 25 wells west of the Gallatin River, over the aquifer, and always 2,000 or more feet apart. It seemed apparent most of the recharge for the area must flow toward and in the same direction as the river. Using this assumption it seemed logical that wells should not be placed in three rows parallel to the river. If wells are located "three deep" the middle row would be "robbed" by the two "outside" rows of its share of recharge. Incorporating this assumption into the well-location required considerable more pumping area than was originally considered necessary.

Wells could have been located on the east side of the river but the expense of crossing the river was considered too great for the benefit received. Another reason for no wells east of the river was the possibility that other companies would want to use that area if this project is successful.

Considering the aquifer location and the above assumption it was decided the 25 wells should be located (1) west of the river, (2) above the ditch where possible, (3) a reasonable distance from the river, and

(4) in no more than two parallel rows along the river. The result of the planning located the 25 wells as shown in Figure 29 and Figure 30.

Pipe Requirements

Wells 1-5.--Under the proposed project water is to be piped from the well location to the High Line Canal. Water from wells one to five could be delivered to the canal in an open ditch but this would require right of way, ditch construction and increased evaporation loss. If the water was piped to the canal the pipe could be laid underground, or along fence rows, and not be a menace to the property crossed.

It was desired that the water from wells one to five would flow freely via gravitational pull from the wells to the canal, Figure 31. This would allow the water to remain enclosed and yet not require any pump horsepower to force it through the pipes. The equation

$$d' = \frac{2.159\ Q_n}{s^{1/2}}^{3/8}$$

where

d' = diameter

Q = quantity flowing

n = 0.012

s = slope of the pipe

was used to calculate the approximate pipe diameters required. The actual calculations for each well can be found in Appendix E. The

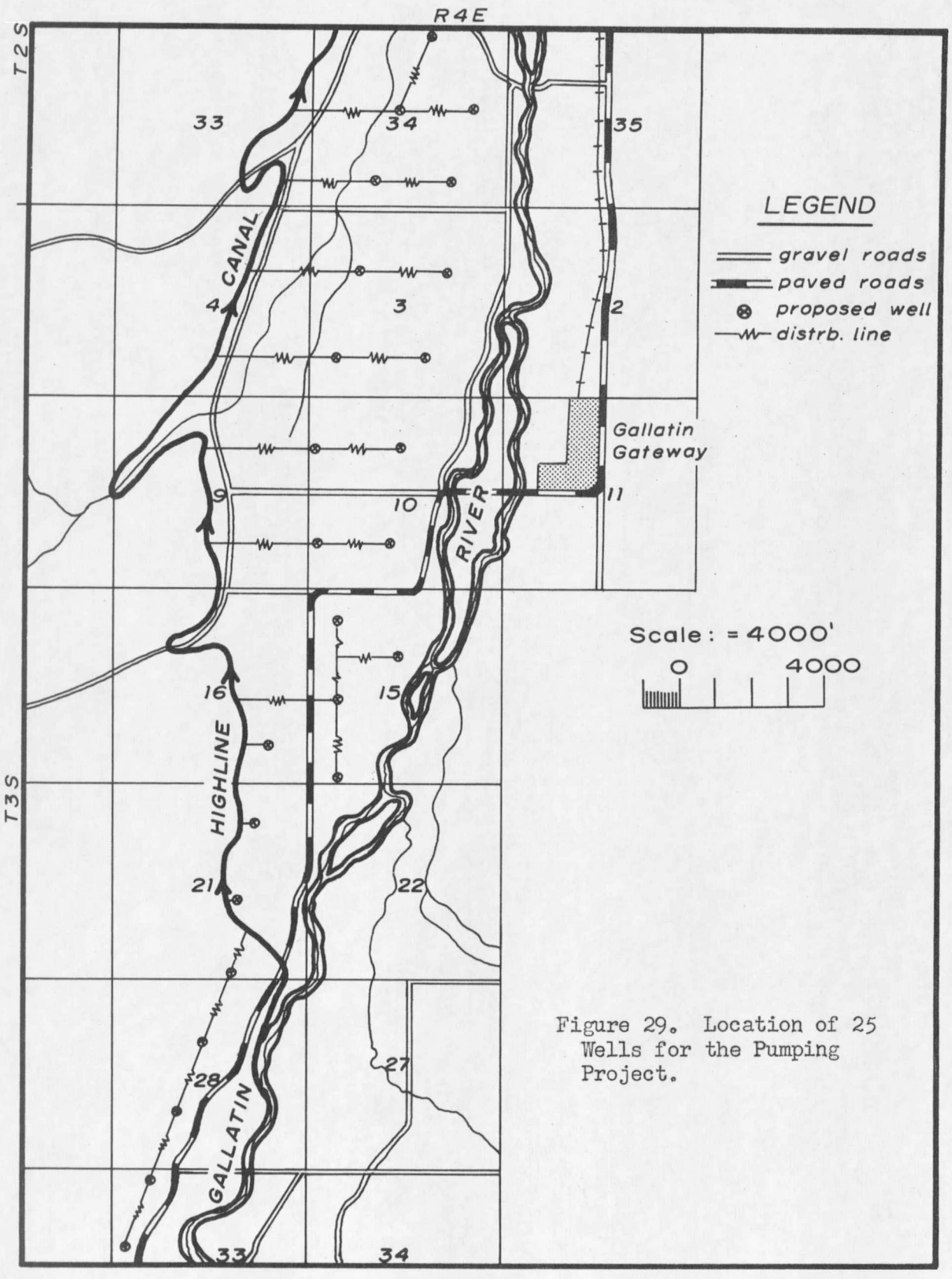


Figure 29. Location of 25 Wells for the Pumping Project.

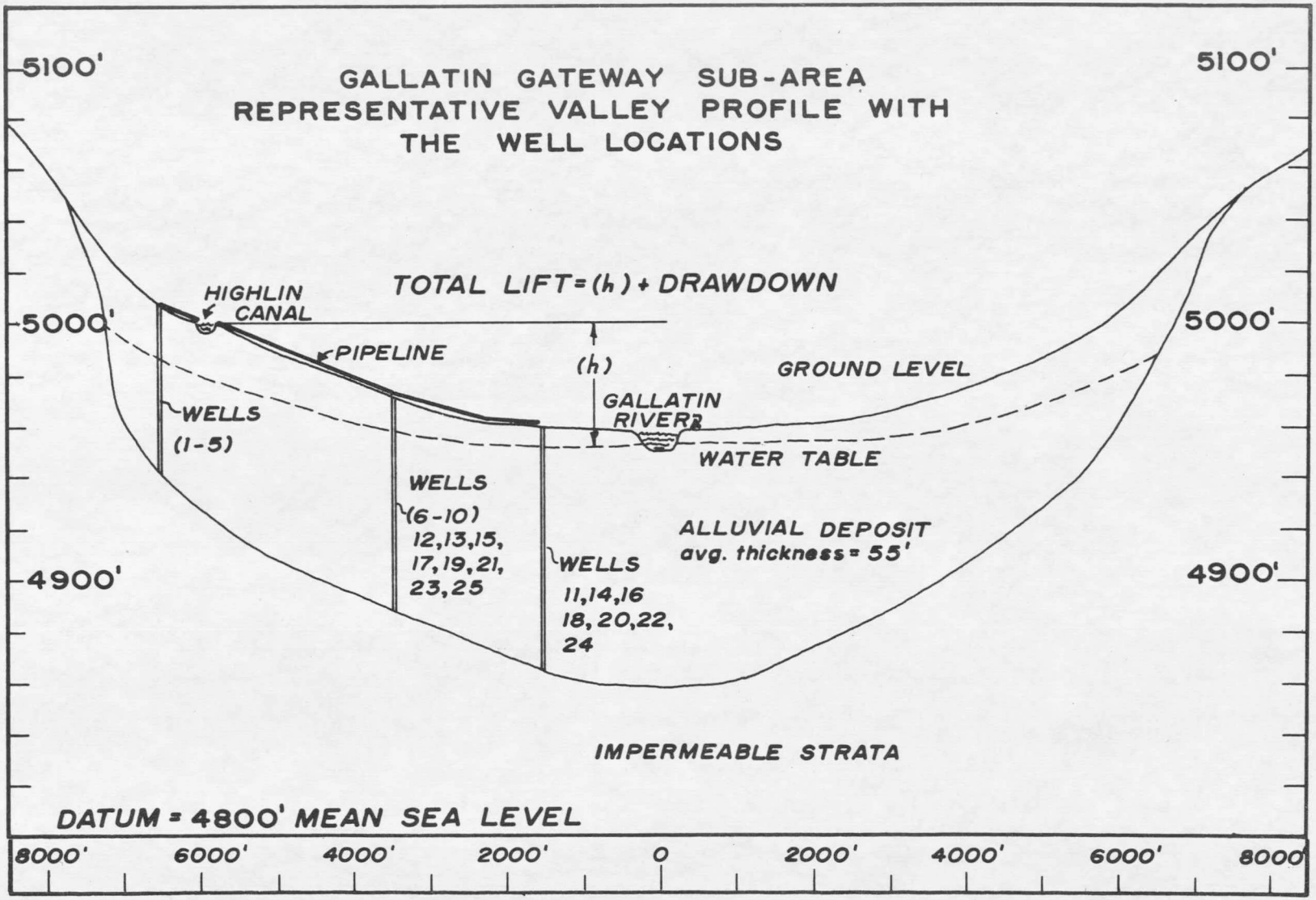


Figure 30. Representative Profile of Gallatin Gateway Subarea.

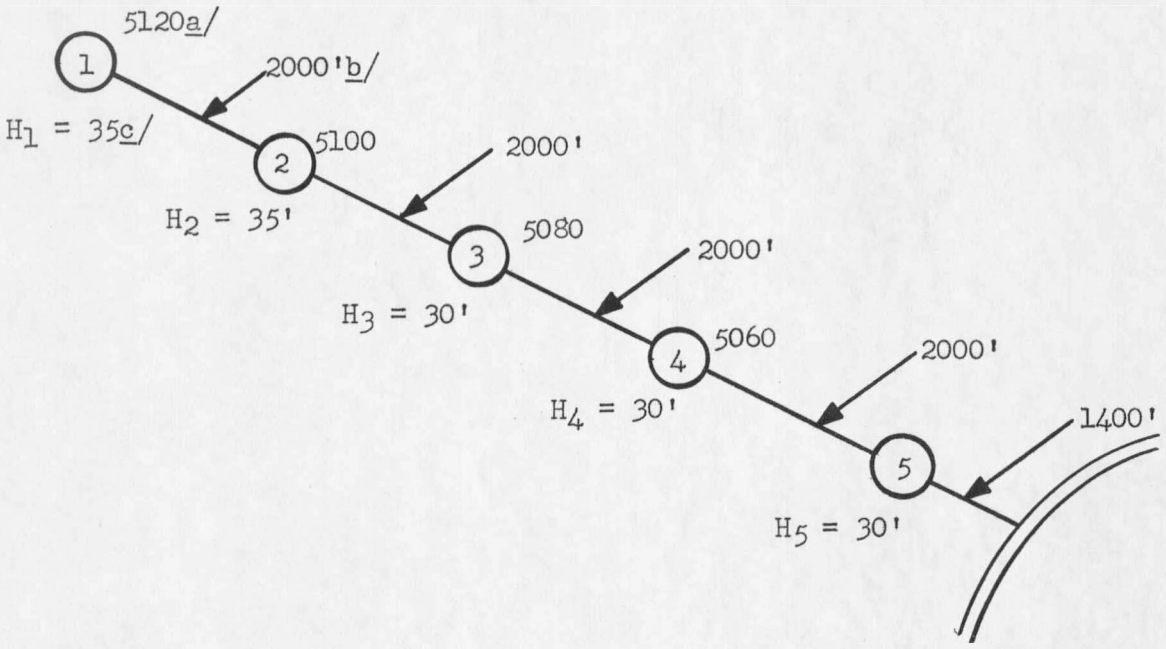


Figure 31. Location of Wells 1-5 With Respect to the Ditch.

a/Approximate mean-sea-level and elevation.

b/Approximate distance between wells.

c/Approximate distance to water when pumping at full capacity.

actual calculated sizes were in inches and fractions of inches and in every case the recommended size was increased to the next largest number.

A summary of the required pipe size and lengths is given in Table VII.

Wells 6-8.--Wells six to eight are located near and just below the ditch. For planning purposes these wells were individually connected

to the ditch using 10 inch pipe. This pipe size was used because of the velocity and friction factors for 10 inch pipe allow for the lowest friction head-loss. The calculations for these wells using 10 inch pipe are included in Appendix E. Figure 32 shows the location of these wells with respect to the ditch and Table VIII shows the pipe required.

Wells 9-12.--Wells nine to twelve are grouped in such a way that it seemed logical to deliver their output through one common pipe from well number 10 to the ditch. The calculation regarding pipe size for this group of wells is included in Appendix E and Figure 33 shows the location of the wells with respect to the ditch. Table IX shows the pipe requirements.

Wells 13-22.--Wells thirteen to twenty-two are located in two rows parallel to the ditch and the river. The odd numbered wells are closer to the ditch and the even numbers are closer to the river. These wells are located so every two wells have a common delivery pipe to the ditch. These wells, like all the rest, use 10 inch pipe for one well and 14 inch pipes for two wells. The calculation for these wells are included in Appendix E. Figure 34 shows the location of the wells with respect to the ditch and Table X shows the pipe required.

Wells 23-25.--Wells 23-25 are grouped so they can deliver to the ditch through one common pipe. These three wells form the northern-most boundary for the pumping project. Calculation for these three wells are included in Appendix E. Figure 35 shows the location of the wells with respect to the ditch and Table XI shows the pipe required.

TABLE VII. PIPE REQUIREMENTS, WELLS 1-5.

Pipe	Q	Inside Diameter	Length
(1-2)	3.5 cfs	12"	2000'
(2-3)	7.0 cfs	16"	2000'
(3-4)	10.5 cfs	18"	2000'
(4-5)	14.0 cfs	20"	2000'
(5-D)	17.5 cfs	22"	1400'

TABLE VIII. PIPE REQUIREMENTS, WELLS 6-8.

Pipe	Q	Inside Diameter	Length
(6-D)	3.5 cfs	10"	300'
(7-D)	3.5 cfs	10"	400'
(8-D)	3.5 cfs	10"	600'

TABLE IX. PIPE REQUIREMENTS, WELLS 9-12.

Pipe	Q	Inside Diameter	Length
(9-10)	3.5 cfs	10"	2200'
(10-D)	10.0 cfs	20"	2800'
(C-10)	7.0 cfs	14"	1100'
(11-C)	3.5 cfs	10"	1700'
(12-C)	3.5 cfs	10"	1100'

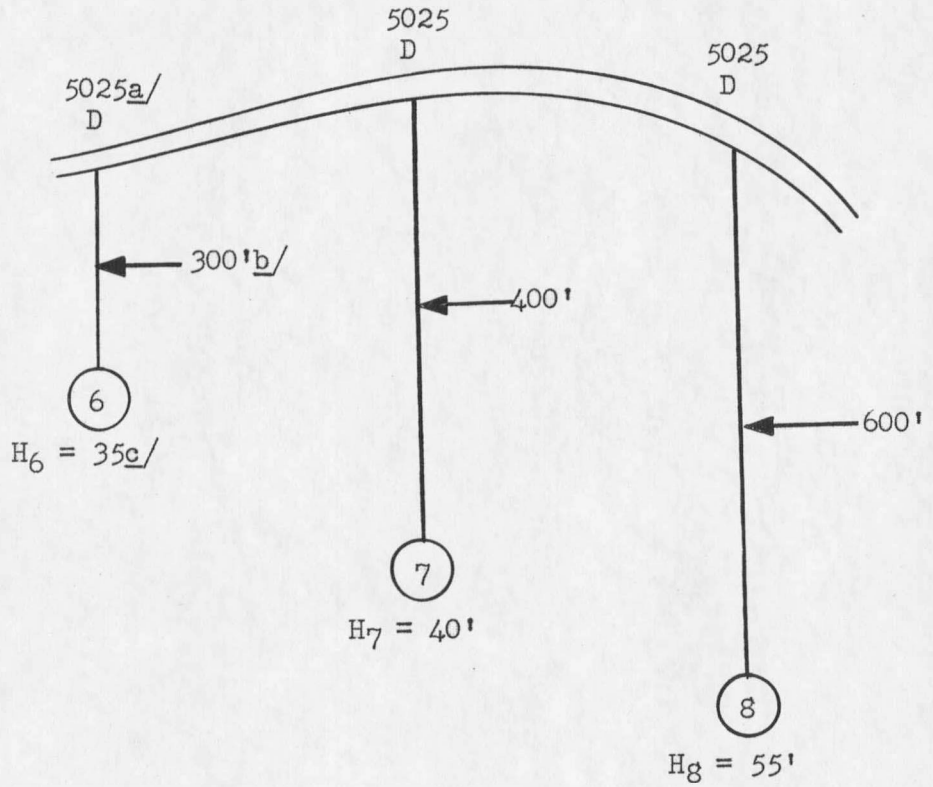


Figure 32. Location of Wells 6-8 With Respect to the Ditch.

a/Approximate mean-sea level elevation.

b/Approximate distance.

c/Approximate depth to water when pumping at full capacity vertical distance from the ditch to water when pumping at full capacity.

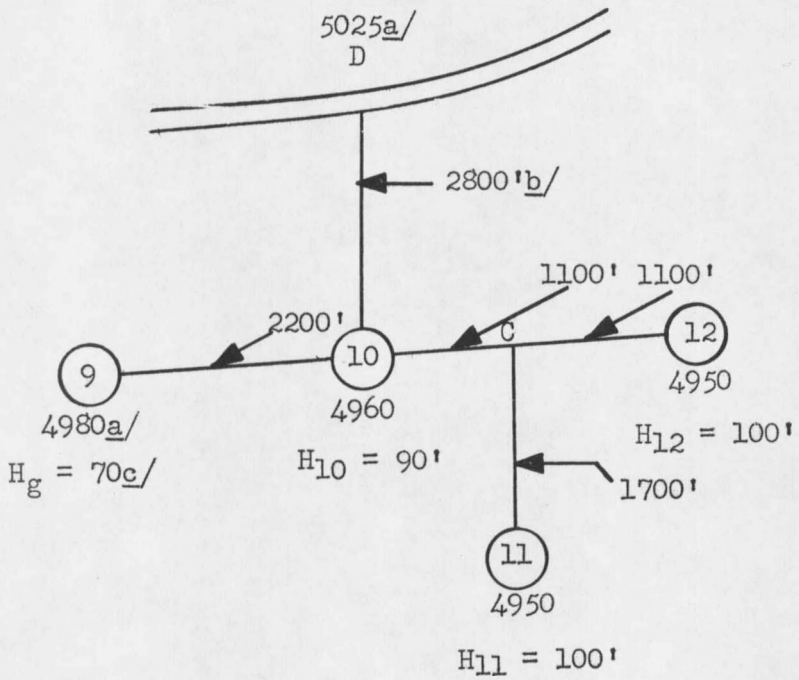


Figure 33. Location of Wells 9-12 With Respect to the Ditch.

a/Approximate mean-sea-level elevation.

b/Approximate distance.

c/Approximate vertical distance from the ditch to water when pumping at waters full capacity.

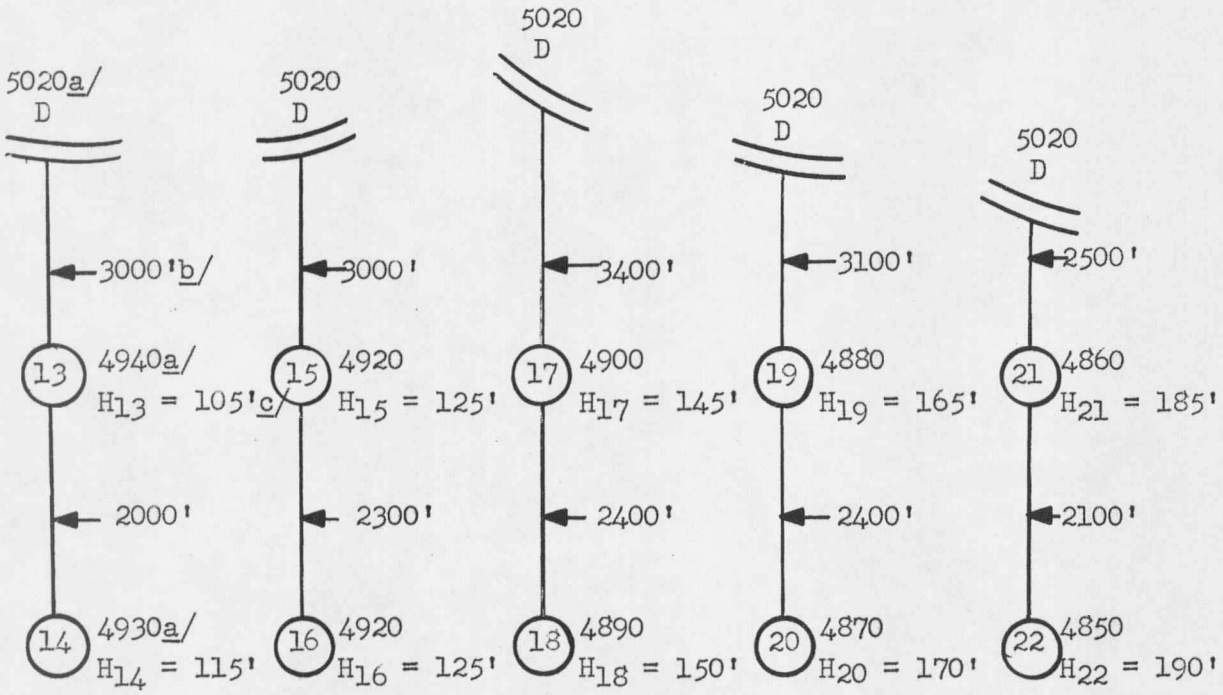


Figure 34. Location of Wells 13-22 With Respect to the Ditch.

a/Approximate mean-sea-level elevation.

b/Approximate distance.

c/Approximate vertical distance from the ditch to water when pumping to full capacity.

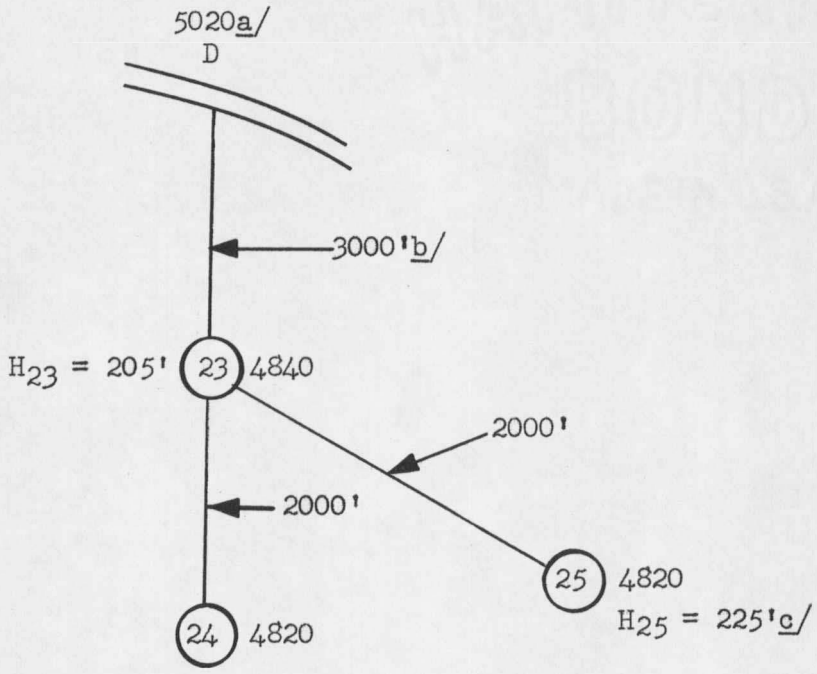


Figure 35. Location of Wells 23-25 With Respect to the Ditch.

a/Approximate mean-sea-level elevation.

b/Approximate distance.

c/Approximate vertical distance from the ditch to water when pumping at full capacity.

TABLE X. PIPE REQUIREMENTS, WELLS 13-22.

Pipe	Q	Inside Diameter	Length
(13-D)	7.0 cfs	14"	3000'
(14-13)	3.5 cfs	10"	2000'
(15-D)	7.0 cfs	14"	3000'
(16-15)	3.5 cfs	10"	2300'
(17-D)	7.0 cfs	14"	3400'
(18-17)	3.5 cfs	10"	2400'
(19-D)	7.0 cfs	14"	3100'
(20-19)	3.5 cfs	10"	2400'
(21-D)	7.0 cfs	14"	2500'
(22-21)	3.5 cfs	10"	2100'

TABLE XI. PIPE REQUIREMENTS, WELLS 23-25.

Pipe	Q	Inside Diameter	Length
(23-D)	10.5 cfs	17"	3000'
(24-23)	3.5 cfs	10"	2000'
(25-23)	3.5 cfs	10"	2200'

Horsepower Requirements

Deep well turbine pumps were assumed throughout the entire project. These pumps have a large range of adaptability for capacity and total head. Turbine pumps can be lubricated by either water or oil and do not need to be primed before they will start pumping. A typical pump installation is shown in Figure 36.

The horsepower requirements vary for most of the 25 wells in this proposed pumping system. The most common unit for measuring horsepower requirements for irrigation pumping is "water horsepower." Water horsepower is defined "as the power theoretically required to lift a given quantity of water per second to a specified height."47/ The equation used in this project to calculate water horsepower is

$$H_p = \frac{QH_t}{550E}$$

where

H_p = Water horsepower;

Q = Quantity discharged in cubic feet per second;

= 62.4, the weight of one cubic foot of water;

H_t = Total vertical lift in feet plus the head loss of piping in feet;

550 = 550 ft.-lb. per second, the measurement of one horsepower;

E = The pumping plant efficiency. This was assumed to be 1.00.

47/Israelsen, op. cit., p. 82.

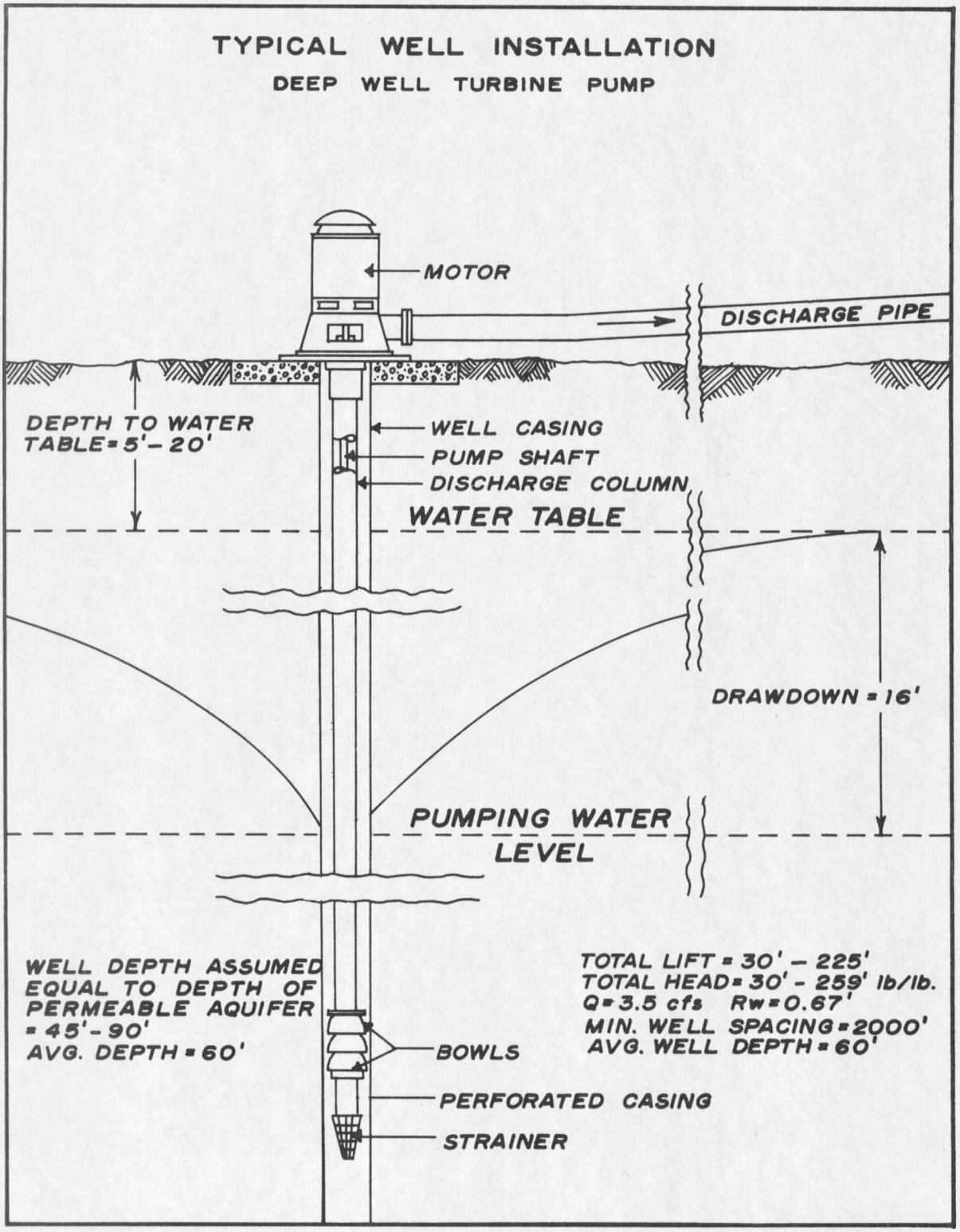


Figure 36. Typical Well Installation.

Using this equation the water horsepower for well number one would be,

$$H_p = \frac{(3.5)(62.4)(35)}{550} = 13.9$$

where

$Q = 3.5$ cfs

$H_t = H_1$ = approximate depth to water when pumping at full capacity

$E = 1.00$

This same equation was used for wells one to five where the water was brought to the surface and allowed to flow, gravity-pull, through pipes to the ditch. The individual calculations for these wells are included in Appendix E. The calculated horsepower requirements for these wells are included in Table XII.

Wells 6-25 have two factors, vertical lift and pipe friction, included in their total horsepower requirements. The vertical lift factor is computed in exactly the same manner as it was for wells one to five, i.e., it is the vertical distance the water must be lifted from the well when pumping at full capacity to the ditch. The pipe friction comes from <u>forcing</u> the water through the pipe from the well to the ditch. To force the water through the pipe requires additional horsepower. This additional power is referred to as head-loss and can be computed by

TABLE XII. WATER HORSEPOWER FOR WELLS NO. 1-25.

Well Number	Horsepower	Well Number	Horsepower
1	14	14	61
2	14	15	55
3	12	16	66
4	12	17	64
5	12	18	77
6	16	19	71
7	18	20	85
8	25	21	78
9	40	22	90
10	38	23	85
11	52	24	93
12	48	25	106
13	47		

$$H_L = f\frac{LV2}{d2g}$$

where

H_L = Friction head-loss;

f = A friction factor (for computation of this factor see Appendix E);

L = The length of the pipe;

V = Velocity in feet per second;

d = Diameter of the pipe in feet;

g = Pull of gravity.

Using this equation the water horsepower for well number six is

$$H_p = \frac{3.5 \times 62.4 \times H_t}{550 \times 1.0} = .397\ H_t$$

$$H_t = 35' + H_L$$

$$H_L = 0.016 \times \frac{300}{834} \times \frac{(6.42)^2}{64.4}$$

where

E = 1.00

f = .016

L = 300

d = diameter of 10 inch pipe in feet = 0.834

V = 6.42

g = 32.2

therefore

H_L = 3.7 feet 4 feet

H_t = 35' + 4' = 39 feet

H_p = .397 X 39 = 15.5

In allocating the head-loss for wells 9-23, it was assumed that since the wells were all connected with one or more other wells, the head-loss would be equally distributed between the connected wells. The total head-loss was divided by the pumps involved and each water horsepower increased proportionally.

The calculation of horsepower for each individual well is included in Appendix E and a summary of the calculated horsepower is given in Table XII.

Rights to the Ground Water

Rights to the use of the ground water required for this project must be established in two steps. First a "Notice of Appropriation" should be filed with the clerk and recorder of Gallatin County and actual work on the project must then begin within 90 days. The second step in establishing the ground water right is filing a "Notice of Completion." After the second notice is filed, the effective date of the water right becomes that of the first notice. If the first notice is not filed, the effective date of the right is the date on the second notice.

Once established, the ground water right for this proposed project will have priority over any subsequent ground water development. Accord-

ing to Montana Under Ground Water Code, Appendix A, Section 2, surface water rights have priority over ground water rights. The Attorney General's office, Helena, Montana, indicates this proposed project does not need to fear being forced to stop pumping because of injury to surface water rights down stream. It is their opinion the proof required by down stream users to establish a claim against the proposed project is all but impossible to obtain.48/

Installation Costs

To establish cost estimates for the entire development project information was submitted to three contractors and their cost estimates were solicited. Each company was given the size and amount of pipe required and the total lift of the water from each well. The companies were then asked for their recommendations about the type of pipe, type of pumps and horsepower requirements. The companies were asked to make estimates separately on pipe and pumps so the lowest cost unit from each company could be used. The composite estimate of the lowest cost units from each company is given in Table XIII.

Cost of Wells

The number and location of wells was submitted to three well drillers and each asked for their recommendations about test wells, casing thickness, etc. The lowest cost estimate was submitted by Van

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48/Interview with L. Forsell, Attorney General's office.

TABLE XIII. COMPOSITE OF THE LOWEST COST UNITS FOR EACH OF 25 WELLS IN THE PROPOSED HIGH LINE PUMPING PROJECT, 1963.

Well No.	Horse Power	Cost of Wells	Cost of Pumps	Cost of Pipe	Cost of Laying Pipe	Cost of Electric Installation	Cost of Land	Total Cost
1	20	1,800	1,884	4,250	1,400	750	500	10,584
2	20	1,800	1,884	6,990	1,600	750	500	13,524
3	20	1,800	1,884	6,990	2,000	750	500	13,924
4	20	1,800	1,884	8,690	2,000	750	500	15,624
5	20	1,800	1,884	6,170	1,400	750	500	12,504
6	20	1,800	1,884	542	210	750	500	5,686
7	25	1,800	1,984	626	280	750	500	5,940
8	30	1,800	2,362	794	420	750	500	6,626
9	50	1,800	2,763	2,138	1,540	750	500	9,491
10	50	1,800	2,763	12,050	2,800	750	500	20,663
11	60	1,800	3,185	5,066	2,070	750	500	13,371
12	60	1,800	3,185	1,214	880	750	500	8,329
13	60	1,800	3,185	8,630	2,400	750	500	17,265
14	75	1,800	3,500	1,970	1,400	750	500	9,920
15	75	1,800	3,500	8,630	2,400	750	500	17,580
16	75	1,800	3,465	2,222	1,610	750	500	10,347
17	75	1,800	3,635	9,742	1,120	750	500	17,547
18	100	1,800	4,110	2,306	1,680	750	500	11,146
19	100	1,800	4,150	8,908	2,480	750	500	18,588
20	100	1,800	4,110	2,306	1,680	750	500	11,146
21	100	1,800	4,275	7,240	2,000	750	500	16,565
22	125	1,800	4,575	2,054	1,470	750	500	11,149
23	100	1,800	4,275	10,340	2,400	750	500	20,065
24	125	1,800	4,575	1,970	1,400	750	500	10,995
25	125	1,800	4,900	2,138	1,540	750	500	11,628
Totals		45,000	79,801	123,976	40,180	18,750	12,500	320,207

Dyken Drilling Company of Bozeman, Montana. Their estimate for twenty-five wells with 16 inch perforated casings, developed and test pumped was $1800 per well.

Cost of Pumps

Total lift and water volume data were submitted to three companies asking for recommendations and cost estimates. The lowest estimate was submitted by the Midland Implement Company of Billings, Montana, Table XIV. Their estimate includes five feet of suction pipe, 10 feet of pump bowl submergence, five feet of discharge pipe, plus the installation of pumps and motor control panels. Their pumps have 12 inch bowls and vary from one to six stages in proportion to the lift. The horsepower requirements submitted by the commercial companies was higher than the water horsepower calculated by formula. This was expected since actual efficiencies range from 70-85 percent and the formula assumed the efficiency to be 100 percent.

Cost of Pipe

Pipe cost estimates were submitted to three companies asking for their recommendations and approximate costs. The lowest estimate was submitted by Van Dyken Drilling Company, Bozeman, Montana, Table XV. Their recommendation was for reinforced concrete pipe connected by rubber "O" rings. Included in their estimate was the cost of pipe, "O" rings, and 25 joints, elbows, valves, etc. to connect the pumps to the discharge pipe.

TABLE XIV. RECOMMENDED PUMP SIZE AND ESTIMATE COST--MIDLAND IMPLEMENT COMPANY, 1963.

Well No.	Total Lift	Pump Size	No. of Stages	Horse Power	Pump Cost	Control Panel Cost	Total Pump Cost
1	35	12"D	1	20	1,690	194	1,884
2	35	12"D	1	20	1,690	194	1,884
3	30	12"D	1	20	1,690	194	1,884
4	30	12"D	1	20	1,690	194	1,884
5	30	12"D	1	20	1,690	194	1,884
6	39	12"D	1	20	1,690	194	1,884
7	45	12"D	1	25	1,790	194	1,984
8	62.5	12"D	2	30	2,115	247	2,362
9	101	12"D	3	50	2,485	278	2,763
10	94	12"D	3	50	2,485	278	2,763
11	130	12"D	3	60	2,650	535	3,185
12	120	12"D	3	60	2,650	535	3,185
13	117.5	12"D	3	60	2,650	535	3,185
14	152.5	12"D	3	75	2,965	535	3,500
15	137.5	12"D	3	75	2,965	535	3,500
16	166	12"D	4	75	2,930	535	3,465
17	159.5	12"D	4	75	3,100	535	3,635
18	194	12"D	5	100	3,535	575	4,110
19	178	12"D	4	100	3,575	575	4,150
20	212.5	12"D	5	100	3,535	575	4,110
21	195.5	12"D	5	100	3,700	575	4,275
22	226.5	12"D	5	125	4,000	575	4,575
23	212	12"D	5	100	3,700	575	4,275
24	232	12"D	5	125	4,000	575	4,575
25	259	12"D	6	125	4,325	575	4,900
Total					69,295	10,506	79,801

TABLE XV. PIPE SIZE AND ESTIMATED COST--VAN DYKEN DRILLING COMPANY, 1963.

Well No.	Pipe Size	Length of Pipe in Feet	Cost Per Foot	Pipe Joints	Total Cost
1-2	12"	2,000	1.98	290	$ 4,250
2-3	16"	2,000	3.35	290	6,990
3-4	18"	2,000	3.35	290	6,990
4-5	20"	2,000	4.20	290	8,690
5-D	22"	1,400	4.20	290	6,170
6-D	10"	300	.84	290	542
7-D	10"	400	.84	290	626
8-D	10"	600	.84	290	794
9-10	10"	2,200	.84	290	2,138
10-D	20"	2,800	4.20	290	12,050
C-10	14"	1,100	2.78	290	3,348 a/
11-C	10"	1,700	.84	290	1,718 a/
12-C	10"	1,100	.84	290	1,214
13-D	14"	3,000	2.78	290	8,630
14-13	10"	2,000	.84	290	1,970
15-D	14"	3,000	2.78	290	8,630
16-15	10"	2,300	.84	290	2,222
17-D	14"	3,400	2.78	290	9,742
18-17	10"	2,400	.84	290	2,306
19-D	14"	3,100	2.78	290	8,908
20-19	10"	2,400	.84	290	2,306
21-D	14"	2,500	2.78	290	7,240
22-21	10"	2,100	.84	290	2,054
23-D	17"	3,000	3.35	290	10,340
24-23	10"	2,000	.84	290	1,970
25-23	10"	2,200	.84	290	2,138
Total		53,000			$123,976

a/These total $5,066.

Cost of Laying Pipe

Gardner Construction of Bozeman, Montana was the only firm submitting an estimated cost for laying the pipe in this project, Table XVI. Their estimate calls for all ditches to be dug two feet wide and four feet deep. This size ditch allows for work space and the required hand covering of the pipe. Their estimate was 70 cents per foot to dig, lay and back fill the 10-12 inch pipe, 80 cents per foot for 15 inch pipe and $1.00 per foot for the 18-21 inch pipe.

Cost of Electric Installations

The Montana Power Company has agreed to supply the power for this project, but at the time of writing, their final estimate was not available. Previously, they estimated the cost for a similar project and this previous estimated figure has been used here as an estimated cost pending the final figure from the Montana Power Company.

Cost of Land and Easements

Some land will be required for the proposed project. The well drillers estimate a plot 100' x 100' will be required for setting the drilling rigs and a permanent plot 20' x 40' for the pump and discharge pipe. This land can be purchased or leased. For purposes of the feasibility study it is assumed the land will be leased on a long-term basis with the privilege of developing a water right. It is assumed a lease agreement would be negotiated with the necessary access and development privileges.

TABLE XVI. ESTIMATED COST OF LAYING PIPE--GARDNER CONSTRUCTION COMPANY, 1963.

Well No.	Pipe Size	Length of Pipe in Feet	Cost Per Foot	Total Cost
1-2	12"	2,000	$ .70	$1,400
2-3	16"	2,000	.80	1,600
3-4	18"	2,000	1.00	2,000
4-5	20"	2,000	1.00	2,000
5-D	22"	1,400	1.00	1,400
6-D	10"	300	.70	210
7-D	10"	400	.70	280
8-D	10"	600	.70	420
9-10	10"	2,200	.70	1,540
10-D	20"	2,800	1.00	2,800
C-10	14"	1,100	.80	880 a/
11-C	10"	1,700	.70	1,190 a/
12-C	10"	1,100	.70	880
13-D	14"	3,000	.80	2,400
14-13	10"	2,000	.70	1,400
15-D	14"	3,000	.80	2,400
16-15	10"	2,300	.70	1,610
17-D	14"	3,400	.80	1,120
18-17	10"	2,400	.70	1,680
19-D	14"	3,100	.80	2,480
20-19	10"	2,400	.70	1,680
21-D	14"	2,500	.80	2,000
22-21	10"	2,100	.70	1,470
23-D	17"	3,000	.80	2,400
24-23	10"	2,000	.70	1,400
25-23	10"	2,200	.70	1,540
Total		53,000		$40,180

a/These total $2,070.

Drilling the wells and laying the pipe can be done in the late fall and winter. This will cause minimal damage to meadows and crop land. Access roads and well drilling will disturb very little land. The trenches for laying pipe will be long and cross several fields. It is assumed an average cost of $500 per well will reimburse farmers for damages incurred in well drilling and laying the pipe.

Once the pumps are installed and operating, maintenance will be the only reason to visit specific well sites. Pipe lines will be buried and require infrequent maintenance. For the right to visit pump sites and pipe lines when necessary, an annual rent of $100 per well is assumed.

Financing

The Agricultural Stabilization and Conservation Service is authorized to financially assist farmers who make certain types of developments. The ASC cannot share the cost of drilling irrigation wells but they will share up to 50 percent of the cost of permanent distribution line. In addition, they will contribute 10 cents per cubic yard toward digging ditches, two cents per cubic yard for back fill, and 75 cents per hour toward any hand labor required for back filling.

The financing and cost sharing of these wells is calculated for groups of wells in order to examine the marginal cost and returns of each group.

Wells 1-5.--These wells require 9,400 feet of pipe to deliver their water to the ditch. The ditches for this project are two feet by four

feet and contain .2963 cubic yards per linear foot,

$$9,400 \text{ X } .2963 = 2,785.2 \text{ Cu. Yds.}$$

The ASC pays 10 cents per cubic yard to dig the ditch and two cents per cubic yard for back fill, making a total of 12 cents per cubic yard.

$$2,785.2 \text{ X } .12 = \$334.22$$

The ASC will pay 75 cents per hour towards back fill labor and the contractor suggests this would amount to about two cents per foot.

$$9,400 \text{ X } .02 = \$188$$

The total ASC contribution toward installing the 9,400 feet of ditch for Wells 1-5 is \$188 + \$334.22 = \$522.22. The total estimated cost of the digging of the ditch and laying the pipe is \$8,400. The actual cost to the ditch company is:

$$\begin{array}{r} \$8,400.00 \\ -\ 522.22 \\ \hline \$7,877.78 \end{array}$$

The ASC will share 50 percent of the pipe cost. Pipe costs for Wells 1-5 is \$33,090. The ASC share is \$16,545 and the company share is \$16,545. The total cost of these wells to the ditch company is:

Five wells at \$1,800	\$ 9,000.00
Five pumps	9,420.00
One-half pipe cost	16,545.00

Ditch and laying pipe	7,877.78
Electric line	3,750.00
Land and easements	2,500.00
	$49,092.78

The Farmers Home Administration loans money for this type development at five percent simple interest. If any project meets Soil Conservation Service standards, they will loan 100 percent of the cost, amortized over a 40-year period. The annual amortized cost for these wells is:

$$49,092.78 \times .05828 = \$2861.13.$$

Wells 6-8.--These wells require 1300 feet of pipe.

1300 X .2963 = 385.2 Cu. Yds.	
385.2 X .12 =	$46.23
1300 X .02 =	$26.00
Total ASC share	$72.23

Total estimated cost of laying pipe is $910.

	$910.00
	-72.23
Cost to ditch company	$837.77

The total cost of pipe is $1,962.00. SCS will share one-half, leaving the ditch company share...

$$\frac{\$1,962}{2} = \$981.00$$

The total ditch company cost for these wells is:

Three wells at $1,800	$ 5,400.00
Three pumps	6,230.00
Ditch and pipe cost	1,818.77
Electric line	2,250.00
Land and easement	1,500.00
Total	$17,198.77

The total cost amortized yields an annual cost of:

$$\$17,198.77 \times .05828 = \$1,002.34$$

Wells 9-12.--These wells require 8900 feet of pipe.

$$8900 \times .2963 = 2,637.07 \text{ Cu. Yds.}$$

$$2637.07 \times .12 = \$316.45$$
$$8900 \times .02 = \$178.00$$

Total ASC share $494.45

The total cost of laying this pipe is:

$7,290.00
- 494.45

Total ditch company cost $6,795.55

The total cost of pipe for these wells is $20,468, leaving the ditch company a cost of:

$$\frac{\$20,468}{2} = \$10,234.$$

The total cost of these wells to the ditch company is:

Four wells at $1,800	$ 7,200.00
Four pumps	11,896.00

Ditch costs	6,795.55
Pipe costs	10,234.00
Electric line	3,000.00
Land and easement	2,000.00
Total	$41,125.55

The annual amortized cost of these wells is:

$$\$41,125.55 \times .05828 = \$2,396.80$$

Wells 13-16.---These wells require 10,300 feet of pipe.

$$10,300 \times .2963 = 3,051.89 \text{ Cu. Yds.}$$

$$3,051.89 \times .12 = \$366.23$$
$$10,300.00 \times .02 = \$206.00$$

Total ASC share $572.23

The estimated total cost of laying this pipe is:

$7,810.00
- 572.23

Total ditch company cost $7,237.77

The total pipe cost for these ditches is $21,452, yielding a ditch company cost of:

$$\frac{\$21,452}{2} = \$10,726.$$

The total cost of these wells to the ditch company is:

Four wells at $1,800	$ 7,200.00
Four pumps	13,650.00

Ditch cost	7,237.77
Pipe cost	10,726.00
Electric line	3,000.00
Land easement	2,000.00
Total	$43,813.77

The annual amortized cost for these wells is:

$$\$43,813.77 \times .05828 = \$2,553.47.$$

Wells 17-20.--These wells require 11,300 feet of pipe.

$$11,300 \times .2963 = 3,348.2 \text{ Cu. Yds.}$$

3,348.2 X .12	= $401.78
11,300 X .02	= $226.00
Total ASC share	$626.78

The total cost of laying pipe is:

	$6,960.00
	- 627.78
Total ditch company cost	$6,332.22

The total cost of the pipe for these wells is $23,262, yielding a ditch company cost of $11,631.

$$\frac{\$23,262}{2} = \$11,631.$$

The total cost of these wells to the ditch company is:

Four wells at $1,800	$ 7,200.00
Four pumps	16,005.00

Ditch cost	6,332.22
Pipe cost	11,631.00
Electric line	3,000.00
Land and easement	2,000.00
Total	$46,168.22

The annual amortized cost of these wells is:

$$\$46,168.22 \times .05828 = \$2,690.68.$$

Wells 20-21.--These wells require 4600 feet of pipe.

$$4600 \times .2963 = 1,362.98 \text{ Cu. Yds.}$$

$$1326.98 \times .12 = \$159.24$$
$$4600 \times .02 = \$92.00$$

Total ASC share $251.24

The total cost of laying the pipe is:

	$3,470.00
	- 251.24
Total ditch company cost	$3,218.76

The total cost of pipe for these wells is $9,294.00, yielding a ditch company cost of:

$$\frac{\$9,294}{2} = \$4,647.00.$$

The total cost of these wells to the company is:

Two wells at $1,800	$ 3,600.00
Two pumps	8,850.00

Ditch cost	3,218.76
Pipe cost	4,647.00
Electric line	1,500.00
Land and easement	1,000.00
Total	$22,815.76

The annual amortized cost of these wells is:

$$\$22,815.76 \times .05828 = \$1,329.12.$$

Wells 23-25.--These wells require 7200 feet of pipe.

$$7200 \times .2963 = 2,133.36 \text{ Cu. Yds.}$$

$$2133.36 \times .12 = \$256.00$$
$$7200 \times .02 = \$144.00$$

Total ASC share $400.00

The total cost of laying pipe is:

$$\$5,340.00 - 400.00$$

Total ditch company cost $4,940.00

The total pipe cost is $14,448.00, yielding a ditch company cost of:

$$\frac{\$14,448}{2} = \$7,224.00.$$

The total cost of these wells to the ditch company is:

Three wells at $1,800	$ 5,400.00
Three pumps	13,750.00
Ditch cost	4,940.00
Pipe costs	7,224.00

Electric line	2,250.00
Land and easements	1,500.00
Total	$35,064.00

The annual amortized cost of these wells is:

$$\$35,064 \times .05828 = \$2,043.53.$$

Operation Cost

The 25 wells in the project are assumed to operate 24 hours per day for 45 days each season, producing 7 acre feet per well, per day.

One acre foot = 325,872.36 gallons

$$\frac{325,872.36}{1600 \text{ gpm (well production)}} = 204 \text{ minutes per AF}$$

$$\frac{204}{60} = 3.4 \text{ hours per AF}$$

$$\frac{24}{3.4} = 7 \text{ AF/24 hours/well}$$

Electrical Charges

Electricity is sold by the watt hour or kilowatt hour (kwh.). The Montana Public Service Commission allows the Montana Power Company to sell electricity at different rates for different purposes. Residential electricity both rural and urban is sold at the following rates:

Schedule R-57—Residential Electric

85 cents for the first 12 kwh, or less.

3.9 cents per kwh. for the next 88 kwh.

2.6 cents per kwh. for the next 100 kwh.

1.3 cents per kwh. for all additional kwh.

The minimum bill for residential electricity is 85 cents per month.

In contrast to household usage, general electric service is available for "all electric service required when supplied through one meter at one point of delivery. Not available for standby, breakdown, supplementary, resale or shared service."49/ Pumping for irrigation comes under this "general service" category and is charged according to the following schedule:

Schedule GS-57--General Electric Service

90 cents for the first 12 kwh., or less

3.9 cents per kwh. for the next 280 kwh.

2.8 cents per kwh. for the next 1,500 kwh.

1.7 cents per kwh. for the next 3,200 kwh.

1.0 cents per kwh. for the next 15,000 kwh.

0.8 cents per kwh. for the next 200 kwh. per kilowatt

55 cents per kwh. for all additional kwh.

The minimum bill under this schedule is 90 cents per month.

In addition to the above rate schedule the company also levies a monthly demand charge. On all general service lines the Montana Power

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49/From data published by the Montana Power Company--a copy of this material is included in the appendix.

Company permanently installs a meter that registers the kilowatts drawn through the line at all times. For example, if three, 20 horsepower motors were running on a metered line and another was turned on, the kilowatt demand register (kilowatts being used) would increase from 51 kilowatts to 68 kilowatts (at 17 kilowatts per 20 horsepower motor). To establish a demand charge the company selects the 15 minutes of highest use recorded on the meter, averages the use for this 15 minute period and sets their demand charge according to the following schedule:

First 10 kilowatts--no charge

Next 20 kilowatts--$1.00 per kilowatt

All additional kilowatts--.90 per kilowatt

For example, a 20-horsepower motor draws 17 kilowatts under full load. The monthly demand charge for running this motor 15 minutes is $7, i.e., the first 10 kilowatts are free and the next seven kilowatts cost $1.00 each. If another 20-horsepower motor would be turned on (longer than 15 minutes) it would cost $13.00 for the first thirteen kilowatts, (making a total of $20 for 30 kilowatts) and 90 cents per kilowatt for the remaining 4 kilowatts or $3.60. The total monthly demand charge for running these two 20-horsepower motors is $7 plus $13 plus $3.60 or $23.60. This is a flat rate charge incurred by turning the motors on. In addition to the demand charge, the kilowatt hours used by these two motors must be paid for according to the regular GS-57 schedule.

A second rate schedule is available from the Montana Power Company for irrigation or sprinkling service. This rate is known as Rider-3 and reads as follows:

> Where a customer has an irrigation pumping or sprinkling outfit which is operated only during the irrigation season and which may be discontinued during the remainder of the year, service will be billed at a rate of 1.5 cents per kilowatt hour, subject to a minimum seasonal bill per point of delivery of $7.50 per horsepower connected. Customers must select to take service under this rider or the standard schedule GS-57 at the beginning of the season and cannot change rates during the season.50/

An example of how this Rider-3 schedule operates may be helpful. A person with a 20 horsepower irrigation motor would be charged a minimum seasonal bill or 20 X $7.50 or $150. This $150 would purchase 10,000 kilowatt hours for the season at 1.5 cents per kilowatt hour. A 20 horsepower motor demands, under full load, about 17 kilowatts therefore the farmer could run his pump 10,000/17 = 588 hours for the minimum charge. Tables XVII and XVIII supplied by the Montana Power Company show the company charge for motors of various horsepower. A 20 horsepower motor under schedule GS-57, their general service rate, would cost $151 for three weeks of operation (504 hours) while the same motor could run 588 hours for $150 under Rider-3. The Rider-3 advantage is four weeks operation for $1.00 less than three weeks operation under schedule GS-57.

50/Ibid.

TABLE XVII. HOURLY OPERATING COSTS PER HORSEPOWER--ONE MONTH.

Horsepower	Kilowatt Demand Full Load	GS-57 Schedule One Month (720. Hrs)		
HP	KW	¢/KWH	¢/Hp.Hr.	Bill
10	8.8	1.92¢	1.68¢	$ 122.
15	13.0	1.66	1.44	155.
20	17.0	1.54	1.30	188. a/
25	21.1	1.45	1.22	222.
30	25.2	1.41	1.19	255.
40	33.5	1.31	1.09	315.
50	41.7	1.22	1.02	365.
60	50.0	1.14	0.95	410.
75	62.2	1.06	0.88	475.
100	82.3	0.98	0.81	583.
125	103.0	0.94	0.77	694.
150	123.0	0.91	0.74	801.
175	143.0	0.88	0.72	909.
200	163.0	0.87	0.70	1,016.
300	240.0	0.83	0.66	1,429.
400	320.0	0.81	0.65	1,855.

a/Horsepower above this line could be more economical on Rider-3 if the seasonal minimum of $7.50 per horsepower can be used.

TABLE XVIII. HOURLY OPERATING COSTS PER HORSEPOWER--THREE WEEKS.

Horsepower	Kilowatt Demand Full Load	GS-57 Schedule Only Three Weeks (504 Hrs.)		
HP	KW	¢/KWH	¢/Hp.Hr.	Bill
10	8.8	2.23¢	1.96¢	$ 99.
15	13.0	1.94	1.69	127.
20	17.0	1.77	1.50	151.
25	21.1	1.65	1.39	176.
30	25.2	1.58	1.33	201. a/
40	33.5	1.49	1.24	251.
50	41.7	1.41	1.18	297.
60	50.0	1.34	1.12	338.
75	62.2	1.27	1.05	401.
100	82.3	1.17	0.96	485.
125	103.0	1.10	0.90	569.
150	123.0	1.06	0.87	655.
175	143.0	1.02	0.84	738.
200	163.0	1.00	0.81	820.
300	240.0	0.95	0.76	1,144.
400	320.0	0.92	0.74	1,475.

a/Horsepower above this line could be more economical on Rider-3 if the seasonal minimum of $7.50/horsepower can be used.

Table XIX, also supplied by the Montana Power Company, is a useful guide in comparing the cost of electric motors with other fuels as sources for pumping power.

Wells 1-5.--Motors of 20 horsepower or less have their most inexpensive operation under Rider-3, page 149. The pumps on this project will run:

$$24 \text{ hours} \times 45 \text{ days} = 1080 \text{ hours}$$

Under a full load, a 20 horsepower motor has a 17 kilowatt demand; therefore, it has

$$1080 \times 17 = \underline{18,360 \text{ kilowatt hours}}$$

for the season. Under Rider-3, the first 10,000 ilowatt hours cost $150.00 and the balance cost $.015/kilowatt. Therefore,

$$\begin{array}{r} 18,360 \text{ total kilowatts} \\ -\underline{10,000} \text{ Rider-3} \end{array}$$

$$8,360 \times \$.015 = \underline{\$125.40}$$

The seasonal charge per 20 horsepower motor running 1080 hours under full load is:

$$\$150 + \$125.40 = \underline{\$275.40}$$

Maintenance charges are allowed for each pump at two percent of the purchase price, therefore,

TABLE XIX. COST OF OTHER FUELS FOR IRRIGATION PUMPING.

Type of Fuel	Horsepower per Gallon
Diesel	14.5 Hp.Hr./Gal.
Gasoline	11.6 Hp.Hr./Gal.
Propane	9.0 Hp.Hr./Gal.
Natural Gas	100.0 Hp.Hr./Gal.

For converting horsepower-per-gallon into cents-per-horsepower-hour, use the following formula:

$$¢/Hp.Hr. = \frac{¢/Gal. \text{ of Fuel}}{Hp.Hr./Gal.}$$

For example: Gasoline at 21.5¢/Gal.

$$¢/Hp.Hr. = \frac{21.5¢/Gal.}{11.6 \text{ Hp.Hr./Gal.}} = 1.8¢/Hp.Hr.$$

Use the local-area fuel cost for converting any of the above.

$$1{,}690 \times .02 = \$33.80$$

Summarizing the operation costs for Wells 1-5:

$$\frac{5 \text{ wells } (275.40 \text{ Electrical Charge} + \$33.80 \text{ Maintenance}) + 2{,}861.13 \text{ Amortization}}{(7 \text{ AF/day} \times 45 \text{ days}) \; 5 \text{ wells}} =$$

$$\frac{\$4{,}407.13}{1{,}575 \text{ AF}} = \$2.80/\text{AF}$$

Wells 6-8.--Operational cost:

Demand Charge

#6	Rider-3	
#7	(21.1-10) $1.00 =	$11.10
#8	(25.2-10) $1.00 =	15.20
		$26.30

Kilowatt Charge

#6	Rider-3		$275.40
#7	(1080 X 21.1)	.0145	330.42
#8	(1080 X 25.2)	.0141	383.75
			$989.57

Maintenance Charge

$5595 \times \$.02 = \$111.90$

Total cost per acre foot is:

$$\frac{(989.57 + 26.30) + 111.90 + \$1{,}002.34}{(7 \text{ AF} \times 45 \text{ days}) \; 3} =$$

$$\frac{\$2{,}130.11}{945} = \$2.25/\text{AF}$$

Wells 9-12.--Operational cost:

Demand Charge

#9	(41.7-30) $.90 + $20.00	$ 30.53
#10	(41.7-30) $.90 + $20.00	30.53
#11	(50-30) $.90 + $20.00	38.00
#12	(50-30) $.90 + $20.00	38.00
		$137.06

Kilowatt Charge

#9	(1080 X 41.7) .0122	$ 549.44
#10	(1080 X 41.7) .0122	549.44
#11	(1080 X 50) .0114	615.60
#12	(1080 X 50) .0114	615.60
		$2329.08

Maintenance Charge at two percent of pump cost:

(10,270) $.02	$ 205.40

Total cost per acre foot is:

$$\frac{(2,329.08 + 137.06) + 205.40 + \$2,369.80}{(7AF \times 45 \text{ days}) \ 4 \text{ wells}} =$$

$$\frac{\$5,068.34}{1,260.00} = \$4.02/AF$$

Wells 13-16.--Operational cost:

Demand Charge

#13	(50-30) $.90 + $20.00	$ 38.00
#14	(62.2-30) $.90 + $20.00	48.98
#15	(62.2-30) $.90 + $20.00	48.98
#16	(62.2-30) $.90 + $20.00	48.98
		$ 184.94

Kilowatt Charge

#13	(1080 X 50) .0114	$ 615.60
#14	(1080 X 62.2) .0106	712.06
#15	(1080 X 62.2) .0106	712.06
#16	(1080 X 62.2) .0106	712.06
		$2751.78

Maintenance Charge

(11,510) $.02	$ 230.20

Total cost per acre foot is:

$$\frac{(\$184.94 + \$2,751.78) + \$230.20 + \$2,553.47}{(7AF \text{ X } 45 \text{ days}) \text{ 4 wells}} =$$

$$\frac{\$5,720.39}{1,260.00} = \$4.54/AF$$

Wells 17-20.--Operational cost:

Demand Charge

#17	(62.2-30) $.90 + $20.00	$ 48.98
#18	(82.3-30) $.90 + $20.00	67.07
#19	(82.3-30) $.90 + $20.00	67.07
#20	(82.3-30) $.90 + $20.00	67.07
		$250.19

Kilowatt Charge

#17	(1080 X 62.2) .0106	$ 712.06
#18	(1080 X 82.3) .0098	871.06
#19	(1080 X 82.3) .0098	871.06
#20	(1080 X 82.3) .0098	871.06
		$3325.24

Maintenance Charge

$13,745 X $.02 $274.90

Total cost per acre foot is:

$$\frac{(\$250.19 + \$3,325.24) + \$274.90 + \$2,690.68}{(7AF \times 45 \text{ days}) \ 4 \text{ wells}} =$$

$$\frac{\$6,541.01}{1,260.00} = \$5.19/AF$$

Wells 21-22.--Operational cost:

Demand Charge

#21	(82.3-30) $.90 + $20.00	$ 67.07
#22	(103-30) $.90 + $20.00	85.70
		$132.77

Kilowatt Charge

#21	(1080 X 82.3) .0098	$ 871.06
#22	(1080 X 103) .0094	1045.65
		$1916.71

Maintenance Charge

7,700 X $.02 = $154.00

Total cost per acre foot is:

$$\frac{(\$132.77 + \$1916.71) + \$154.00 + \$1,329.12}{(7AF \times 45 \text{ days}) \ 2 \text{ wells}} =$$

$$\frac{\$3,532.60}{630} = \$5.60/AF$$

Wells 23-25.—Operational cost:

Demand Charge

#23	(82.3-30) $.90 + $20.00	$ 67.07
#24	(103-30) $.90 + $20.00	85.70
#25	(103-30) $.90 + $20.00	85.70
		$238.47

Kilowatt Charge

#23	(1080 X 82.3) .0098	$ 871.06
#24	(1080 X 103) .0094	1045.65
#25	(1080 X 103) .0094	1045.65
		$2962.36

Maintenance Charge

11,700 X $.02 $234.00

The total cost per acre foot for these wells is:

$$\frac{(\$238.47 + \$2,962.36) + 234.00 + \$2,043.53}{(7AF \times 45 \text{ days}) \ 3 \text{ wells}} =$$

$$\frac{\$5,478.36}{945} = \$5.80/AF$$

Summary of Operational Costs

The total cost of operation is:

	Cost	Acre Feet
Wells 1-5	$ 4,407.13	1,575
Wells 6-8	2,130.11	945
Wells 9-12	5,068.34	1,260
Wells 13-16	5,720.39	1,260
Wells 17-20	6,541.01	1,260

Wells 21-22	$ 3,532.60	630
Wells 23-25	5,478.36	945
	$32,877.94	7,875

The average water cost for the whole project is:

$$\frac{\$32,877.94}{7875} = \$4.17/AF$$

The cost of water per acre foot of lift is an indication of the efficiency of a pumping system. Figured on an average per well basis, this project pumps water for:

$$\frac{3194 \text{ total lift}}{25} = 127.8 \text{ feet of lift per well,}$$

$$\frac{7875 \text{ total acre feet}}{25} = 315 \text{ AF/well,}$$

$$\frac{\$32,877.94 \text{ total operation cost}}{25} = \$1,315.12 \text{ per well,}$$

$$\frac{\$1,315.12}{315 \times 127.8} = \$0.0326 \text{ per acre foot of lift.}$$

It is estimated a modern plant pumping 1,000 hours or more per season should pump water for a total cost of $.05 per acre foot of lift and the cost could double for older or inefficient systems.51/ Using this criterion, the proposed project is very efficient and is an inexpensive source of additional irrigation water.

51/Carl Rohuer, "Wells and Pumps for Irrigated Lands," Water, op. cit.

CHAPTER IX

SUMMARY AND FURTHER RESEARCH

Summary

The Gallatin Valley

The largest supply of fresh water in the United States is stored underground. There is more ground water in the United States than all surface streams and dams including the Great Lakes. The Gallatin Valley, between 4,000 and 5,500 feet mean sea level, in southwestern Montana, is over one of these ground water reservoirs. The Gallatin Valley reservoir stores more than 240,000 acre-feet of water. A survey of the valley farmers regarding their irrigation water needs shows 53 percent of those reporting need additional water. Many of these farmers have adequate irrigation water early in the year but their supplies are shut off by July 1-15. These farmers cannot irrigate again until late August or September. The Gallatin Valley is unique because it uses both ground and surface water for irrigation, has need for additional irrigation water and at the same time, water flows from the valley unused.

The majority of the reporting farmers in the valley do not own land over the ground water and therefore cannot satisfy their need for additional water by pump irrigation. The farmers over the ground water area are not willing to share their surface water with the "have not" farmers and allow their own water supplies to be pumped. Ground surface water integration is blocked.

Blocks to Integration

The reasons the farmers will not accept a surface-ground water exchange, are physical, historical and legal. Economically, the development of a valley wide integrated irrigation system is possible. The benefit-cost ratio for such a system is greater than 1.52.

The physical block to development exists:

(1) because the old inexpensive water rights are located over the ground water reservoir; and

(2) because much of the land in the valley is subirrigated.

These farmers with "sub" will not co-operate in an integration plan because they fear pumping would lower the water table enough to eliminate their "sub".

Legally, a development drag has existed because Montana did not have a ground water code prior to 1962. Present evidence gives no indication of the effect the 1962 law will have on integrated development.

A "historical block" is inherent in Montana's water right structure. Water rights can be established in three ways in Montana and because of this, otherwise-friends and neighbors have been put-at-odds. Once water rights have been established through such a system, people are very reluctant to change.

A Proposed Development Plan

A project to demonstrate the benefits of ground-surface water integration through a private pumping enterprise is proposed. The High

Line Canal Co. needs additional water. Their water costs are high, their supply is limited and their needs can be supplied through a pumping project. Twenty five (25) irrigation wells pumping 45 days can supply enough water to irrigate hay and pasture during that part of the irrigation season when they normally receive little or no water. The 25 well project can supply 7875 acre feet of water for an average cost of $4.17 per acre foot.

Suggestions for Further Research

A farm management study budgeting the costs for typical farms under the High Line Canal would help them establish the value of additional irrigation water. Such a study would consider their present farm organizations and their ability to incorporate more water and water using crops. A second management factor would be their financial positions. The net capital ratios these farmers' have and how these ratios would be affected by an increase in fixed liabilities sufficient to install the proposed project, is of utmost importance. A study of this type would be a help to the farmers under the canal.

The effect of a valley-wide pumping project on the valley water table, needs to be established. After the proposed project has established the merits of ground-surface water integration, the effect on the general water table must be determined before a valley-wide project can be developed. Studying the water table for the whole valley will point out the benefits of lowering the table in some areas to allow some swampy ground to come into full production.

A model of an institutional organization that would allow farmers to exchange surface water for ground water without endangering their present water rights is needed. This institutional structure would delineate legal responsibilities for both parties during its operation and dissolution. This model would be the apex of what is physically possible and institutionally permissible.

APPENDICES

APPENDIX A

SELECTED PORTIONS OF THE UNDERGROUND WATER CODE

CHAPTER NO. 237

MONTANA SESSION LAWS 1961

HOUSE SUBSTITUTE FOR SENATE BILL NO. 78

AN ACT RELATING TO AND PROVIDING FOR THE APPROPRIATION AND REGULATION OF GROUND WATER; DEFINING TERMS USED IN THE ACT; PROVIDING FOR THE APPROPRIATION OF GROUND WATER; PROVIDING FOR THE FILING OF CLAIMS OF VESTED GROUND WATER RIGHTS WITH THE STATE ADMINISTRATOR AND COUNTY CLERK AND RECORDER; PROVIDING FOR THE FILING OF NOTICES OF APPROPRIATION OF GROUND WATER AFTER THE EFFECTIVE DATE OF THE ACT WITH THE STATE ENGINEER AND COUNTY CLERK AND RECORDER; PROVIDING FOR PRIOR RIGHTS; PROVIDING FOR THE DESIGNATING AND MODIFYING OF BOUNDARIES OF GROUND WATER AREAS AND SUB-AREAS BY STATE ADMINISTRATOR; AUTHORIZING STATE ADMINISTRATOR TO MAKE SURVEYS, INVESTIGATIONS AND STUDIES OF GROUND WATER; PROVIDING FOR THE LIMITING OF WITHDRAWALS FROM GROUND WATER AREAS OR SUB-AREAS BY THE SUPERVISOR; PROVIDING FOR CHANGE OF LOCATION OF GROUND WATER WELLS AND OTHER WORKS; PROVIDING FOR ABANDONMENT OF GROUND WATER RIGHTS; PROVIDING AGAINST WASTE OF GROUND WATERS AND PROVIDING FOR THE REGULATION OF WELLS TO PREVENT WASTE: PROVIDING FOR A HEARING BEFORE THE DISTRICT COURT TO CONFIRM THE ORDERS OF THE STATE ADMINISTRATOR; PROVIDING FOR APPEALS; AUTHORIZING COUNTY ATTORNEYS TO PERFORM CERTAIN SERVICES; AUTHORIZING STATE ADMINISTRATOR TO ADMINISTER OATHS AND TO PRESCRIBE REASONABLE RULES AND REGULATIONS; PROVIDING FOR FEES; PROVIDING PENALTIES

FOR VIOLATIONS OF THE ACT; AND REPEALING SECTIONS 89-2901 TO 89-2910, INCLUSIVE, REVISED CODES OF MONTANA, 1947, AND ALL ACTS AND PARTS OF ACTS IN CONFLICT WITH THE PROVISIONS OF THIS ACT; PROVIDING FOR A SAVING CLAUSE; AND PROVIDING FOR AN EFFECTIVE DATE.

BE IT ENACTED BY THE LEGISLATIVE ASSEMBLY OF THE STATE OF MONTANA:

Section 1. DEFINITIONS. As used in this act or regulations issued hereunder:

(a) "Ground water" means any fresh water under the surface of the land, including the water under the bed of any stream, lake, reservoir or other body of surface water. Fresh water shall be deemed to be water fit for domestic, livestock or agricultural use. The Administrator, after notice and hearing, is authorized to fix definite standards for determining fresh water in any controlled ground water area or subarea of the state.

(b) "Aquifer" means any underground geological structure or formation which is capable of yielding water or is capable of recharge.

(c) "Well" means any artificial opening or excavation in the ground, however made, by which groundwater can be obtained or through which it flows under natural pressures or is artificially withdrawn.

(d) "Beneficial use" means any economically or socially justifiable withdrawal or utilization of water.

(e) "Person" means any natural person, association, partnership, corporation, municipality, irrigation district, the State of Montana or any political subdivision or agency thereof, and the United States or

agency thereof.

(f) "Administrator" means the State Engineer of the State of Montana.

(g) "Ground water area" means an area which, as nearly as known facts permit, may be designated so as to enclose a single and distinct body of ground water, which shall be described horizontally by surface description in all cases and which may be limited vertically by describing known geological formations should conditions dictate this to be desirable. For purposes of administration, large ground water areas may be divided into convenient administrative units "known as subareas."

Section 2. RIGHTS TO USE. Rights to surface water where the date of appropriation precedes January 1, 1962 shall take priority over all prior subsequent ground water rights. The application of ground water to a beneficial use prior to January 1, 1962 is hereby recognized as a water right. Beneficial use shall be the extent and limit of the appropriative right. As to appropriations of ground water completed on and after January 1, 1962, any and all rights must be based upon the filing provisions hereinafter set forth, and as between all appropriators of surface or ground water on and after January 1, 1962, the first in time is first in right. The right to use ground water may be obtained without a well, as a sub-irrigation and other natural processes, and appropriations by such means are provided for under section three hereof. Appropriative rights shall relate only to quantities of water for beneficial uses and not to water levels, means of use, or ease of withdrawal;

and appropriative rights shall not apply to minimal household use as provided in section five hereof.

Section 3. FILING--NOTICE OF APPROPRIATION--NOTICE OF COMPLETION.

(a) The administrator shall prepare and publish forms for the filing by appropriators with the county clerks. They shall be known as a "Notice of Appropriation" and a "Notice of Completion", respectively. The Notice of Appropriation shall require, and provide space for answers to such questions as: (1) the name and address of the appropriator; (2) the beneficial use for which the appropriation is made, including a description of the lands to be benefited if for irrigation; (3) the rate of use in gallons per minute of ground water claimed; (4) the annual period (inclusive dates) of intended use; (5) the probable or intended date of first beneficial use; (6) the probable or intended date of commencement and completion of the well or wells; (7) the location, type, size and depth of the well or wells contemplated; (8) the probable or estimated depth of the water table or artesian aquifer; (9) the name, address and license number (if any) of the driller engaged; and (10) such other similar information as may be useful in carrying out the policy of this act.

The Notice of Completion shall require answers to the same sort of questions as required for the Notice of Appropriation, except that for the most part it shall inquire as to accomplished facts concerning the well or means of withdrawal, including information as to the static level of water in the casing or the shut-in pressure if the well flows

naturally; the capacity of the well in gallons per minute by pumping or by natural flow; the approximate draw down or pumping level of the well; the approximate surface elevation at the well head; the casing record of the well; the drilling log showing the character and thickness of all formations penetrated; the depth to which the well is drilled; and similar information.

For the benefit of persons obtaining (or desiring to obtain) ground water without a well (as by sub-irrigation and other natural processes) a specially prepared "Notice of Completion" shall be provided, enabling such persons to describe the means of using ground water and to estimate the amount of water so used, and requiring such other similar information as shall be pertinent to this particular class of user. The administrator shall distribute said forms to the county clerks.

(b) On and after January 1, 1962, any person desiring to appropriate ground water may complete a Notice of Appropriation and file it with the county clerk of the county in which the appropriation is located.

(c) Upon the filing of a Notice of Appropriation, the county clerk shall transmit a copy thereof to the Administrator, and to the Montana Bureau of Mines and Geology, retaining the original on file locally.

(d) After filing a Notice of Appropriation, in order to acquire a right based thereon, the person must, within ninety (90) days, commence actual excavation and diligently prosecute construction of a well and, upon its completion, file a Notice of Completion with the county clerk

of the county in which the appropriation is located. The county clerk shall handle and transmit such filed notices as in the case of a filed Notice of Appropriation.

(e) A failure to file a Notice of Appropriation deprives the appropriator of his right to relate his date of appropriation back, and results in the dating of his appropriation as of when he files a Notice of Completion. Until a Notice of Completion is filed with respect to any use of ground water instituted after January 1, 1962, no right to that use of water shall be recognized. However, in the case of uses instituted prior to January 1, 1962 and diligently prosecuted to completion on or after that date, the date of appropriation shall relate back to the date of commencement of construction, upon the filing of a Notice of Completion.

(f) Persons required to file well logs and other information under the laws governing the conservation of oil and gas and who do so in compliance therewith, shall be deemed to have complied with all of the filing requirements of this act insofar as it applies to such particular oil and gas wells, salt water disposal wells, and injection wells. The date of appropriation in such cases shall be the date that written notice of intention to drill is given to the oil and gas conservation commission of the State of Montana.

(g) It shall be the responsibility of the driller of each well to fill out the Notice of Completion for the appropriator, and the latter shall be responsible for its filing.

(h) Persons who have put ground water to a beneficial use, including sub-irrigation or other natural process, prior to January 1, 1962, shall within two (2) years after January 1, 1962, file a declaration in the office of the county clerk of the county in which the claimed right is situated. The declaration shall be made on a form known as a "Declaration of Vested Ground Water Rights" and shall contain the following information: (1) the name and address of the claimant; (2) the beneficial use on which the claim is based; (3) the date or approximate date of the earliest beneficial use, and how continuous the use has been; (4) the amount of ground water claimed; (5) if the beneficial use has been for irrigation, the acreage and description of the lands to which such water has been applied and the name of the owner thereof; (6) the means of withdrawing such water from the ground and the location of each well or other means of withdrawal; (7) the date of commencement and completion of the construction of the well, wells or other works for withdrawal of ground water; (8) the depth of water table; (9) so far as it may be available, the type, size and depth of each well or the general specifications of any other works for the withdrawal of ground water; (10) the estimated amount of ground water withdrawn each year; (11) the log of the formations encountered in the drilling of each well; and (12) such other information of a similar nature as may be useful in carrying out the policy of this act.

The county clerk shall transmit copies to the office of the Administrator and the Bureau of Mines and Geology. The Administrator shall

attend to filing copies in any other counties affected by the appropriation.

The Declaration of Vested Ground Water Rights herein provided for shall be taken and received in all courts of this state as prima facie evidence of the statements therein contained.

Failure to comply with this requirement shall in no wise work a forfeiture of such rights, or prevent any such claimant from establishing such rights in the courts, but he must maintain the burden of proving such unrecorded rights. Provided, however, that persons who have filed the water well log form, provided for in Section 1 and 2 of Chapter 58, Session Laws of Montana, 1957, shall be deemed to have complied with the requirements of this section. These latter forms may be returned to the county clerks by the Administrator for the purpose of correction or for the entry of material facts necessary to fully complete the filing.

Section 15. APPROPRIATION MUST BE FOR A USEFUL PURPOSE--ABANDONMENT. The appropriation must be for some beneficial purpose and when the appropriator or his successor in interest abandons and ceases to use the water for such purpose, the right ceases; but questions of abandonment shall be questions of fact and shall be determined as other questions of fact.

Section 16. WASTE AND CONTAMINATION OF GROUND WATER PROHIBITED--EXCEPTION--DUTIES OF ADMINISTRATOR. No ground waters shall be wasted

without beneficial use. The Administrator shall require all wells producing waters which contaminate other waters to be plugged or capped. He shall also require all flowing wells to be so capped or equipped with valves that the flow of water can be stopped when the water is not being put to beneficial use. Likewise, both flowing and non-flowing wells shall be so constructed and maintained as to prevent the waste, contamination or pollution of ground waters through leaky casings, pipes, fittings, valves, or pumps either above or below the land surface, provided however, in the following cases the withdrawal or use of ground water shall not be construed as waste under this act:

(1) the withdrawal of reasonable quantities of ground water in connection with the construction, development, testing, or repair of a well or other means of withdrawal of ground waters;

(2) the inadvertent loss of ground water owing to breakage of a pump, valve, pipe, or fitting, if reasonable diligence is shown by the person in effecting the necessary repair;

(3) the disposal of ground water without further beneficial use that must be withdrawn for the sole purpose of improving or preserving the utility of land by draining the same, or that removed from a mine to permit mining operations or to preserve the mine in good condition;

(4) the disposal of ground water used in connection with production, for reduction, smelting and milling metallic ores and industrial minerals, or that displaced from an aquifer by the storage of other mineral resources.

The Administrator at any time may hold a hearing on his own motion, or upon petition signed by a representative body of users of ground water in any area or subarea, to determine whether the water supply within such area or subarea is used in compliance with this act.

Section 17. INSPECTION--ENTRY ON PREMISES. The Administrator or any assistant, any representative of the State Bureau of Mines and Geology or the State Board of Health, shall have the right of entry on the property of any appropriator, where a well is situated, at any reasonable hour of the day, for the purpose of investigating any matters in connection with this act.

Section 18. INFORMATION AVAILABLE TO PUBLIC. Such information as is required or secured under the provisions hereof shall constitute public records, and as such shall be available to the public at all reasonable times.

Section 21. RULES AND REGULATIONS. The Administrator may prescribe and enforce reasonable rules and regulations concerning and providing for inspection and entry for that purpose by the Administrator or his official representative; the circumstances under which the construction of weirs or other measuring devices may be required; and such other similar matters as are required by, and consistent with the administration of this act.

Section 25. FEES. For the filing of any notices, declarations,

applications for a license, petition, or other matters with the county clerks, or Administrator, a fee of two dollars ($2.00) for each such document shall be paid. Fees paid to the Administrator shall be paid by him to the General Fund of the State; fees paid to the county clerks shall be paid by them to the General Fund of their respective counties.

Section 26. PENALTIES. Any person who violates or refuses or neglects to comply with any provision of this act, or of any order, rule or regulation promulgated by the Administrator, or who commits waste, shall be guilty of a misdemeanor, and upon conviction shall be fined not less than twenty-five dollars ($25.00) nor more than two hundred and fifty dollars ($250.00) for each offense.

Section 29. EFFECTIVE DATE. This act shall take effect on and after January 1, 1962.

APPENDIX B

VOLUNTEER COMMENTS

Code No.

003 - I start irrigating as soon as possible in the spring and use my water in the best possible manner. Most of my irrigating is finished by July 15.

I think that when the water supply gets short and when (our ditch) goes dry there should be more work done on seeing whether the old right ditches are wasting water and if they are using their water in the best possible manner. If we could keep water an extra 10 days or two weeks that would be all that is necessary.

020 - We haven't irrigated on our farm since 1959. We are in Soil Bank!

048 - My water supply is adequate. I would not care to change to some scheme which at this time we know nothing about.

I don't need any more water. Although, of course, I would be willing to cooperate to help some other person to get an adequate supply.

050 - We would probably lose our sub-water here which really helps us. I have considered drilling a well which I would use when (our ditch) went dry. When the ditch goes dry our water table drops several feet in a day or two. I thought if I had a well that

would pump 150 inches of water I could save my pastures and hay meadows with flood irrigation. I have my doubts if this water would help my sub-irrigation any, because it would probably lower the water table at the upper end of the farm.

060 - I am not interested in this in any way, shape or form.

065 - Our present setup is so convenient and so adequate.

080 - It would in my estimation change the water flow to divert the water from this part of the valley.

We need a storage dam in the Gallatin Canyon, and at the present cost of electrical power it would be impractical to pump water to irrigate this valley.

085 - Putting a pump some other place you would not help this farm. When the ditch runs dry in July and there is no water in the river.

086 - The upgoing taxes, plus increase in price of water will break every farmer.

Don't want anybody interfering with our water rights.

100 - The price for drilling a well is too high and water is too far down. What we need is a dam up the Gallatin River some place to increase our water about 30 to 40 days.

101 - We try to start irrigating early in the season to get the water

table up and make the lower ground to sub. If we put pumps in there would be no sub. Crops would burn up.

Maybe a dam could be built up the canyon somewhere to hold some of the spring run off.

110 - The underground water table is high only when there is plenty of water in the river. We believe the present water laws are fair, and should not be changed.

119 - Our irrigation system is very simple and economical to operate. Besides I have some ground that subs and if I pumped I would probably have to irrigate more land and my costs would rise. Why would I want to increase my costs, when our supply is perfectly adequate and our costs are low. We always have all the water we need. We having one of the oldest rights in the valley, have never been cut at the river when the water gets low except to our decreed right.

131 - Don't think someone else should pump water to take place of what I already have. Productivity of land would not justify too much additional expense. I don't understand the purpose of this setup--I can't see any advantage in pumping water above and cutting off supply I have. Would be glad to have any additional information you get from these questionnaires.

136 - I am well pleased with our system.

152 - I am satisfied with what I got.

156 - I think we should have laws passed to protect our water for Montana use and development. Also to protect existing water rights.

158 - I am satisfied with the water I have. What is the purpose of all this information? I would like to know.

160 - We have enough water as it is. And when it is a little less we have learned to get along with that.

170 - In normal years we couldn't use more water then we now have. The "X" acres we cultivate is cropped and summer fallowed every other year and mostly seeded to winter wheat. It often has no need of irrigation. We irrigate the barley and pasture so our water supply usually is adequate. It could all be irrigated by sprinkler if necessary and we had the necessary pipe.

177 - I don't think it is necessary to pump water elsewhere. A good water commissioner to see to it that less water is wasted would give everybody enough water the year around.

181 - Have sold all but five acres, but kept all the water, 5/16 share in "X" Canal and 20 AF in Hyalite Reservoir.

191 - If (our canal) could be kept three-fourths full through the season I would have plenty with the shares I have.

192 - I have more than enough water now, quite a lot of sub-water.

209 - In the first (place) we have to drill 90 feet to get a sufficient supply for winter stock water and for domestic use. In the second place there is no one can predict or give an accurate estimate as to what the additional output of water and (what) the cost would be. So I don't feel free to sign my rights away on the strength of estimates.

210 - We have plenty of water and don't need to pay more if government don't interfere and take it away. Leave our water alone use flood control and help two ways out on expense. We have plenty of water, why take the underground water. Why don't the government put dams in these canyons and hold the flood water and have flood control and irrigation water at the same expense. Our taxes are too high now. Save some money. We don't want to lose our water we need it.

213 - Depending upon the weather, we are short of water after July 1, usually. Enough water to use border dike irrigation would save a lot of labor, expense and increase production of hay and pasture in which we are mainly interested.

215 - The only way I would want to change the water right is to have a larger right in the same ditch as I would rather flood irrigate then sprinkle.

216 - Do not know (the amount of water used at present). We do not employ a rider on ditch. When one neighbor is not using any water another may use all water contained in ditch. If proper management is used (we) do not need any more water.
If we had a reliable water commissioner there would be enough water for most ditches. As it is run now there is too much waste and run off into East Gallatin.
We have "X" inches of water in (our ditch) and all of the years we had the farm have had to fight with the water commissioner as he says we only have "Y" inches. Seems to be too good a friend of Judge Lessley's.
(NOTE: Actual number of minus inches and name of ditch withheld to conceal identity.)

217 - The cost of maintaining these ditches is only a two or three day job a year, so I wouldn't want to pay cost of pumping also I'm afraid if much pumping is done in the valley I might lose this water as a lot of it is surface water and seepage.

223 - Present system satisfactory for 75 years--can get along without Bureatric (bureaucratic) interference.

227 - Water supply now adequate but could use more at times.

236 - (This comment is paraphrased to conceal identity of writer). Because of uneven nature of my land leveling is too expensive, sprinkling is too expensive, therefore I use most of my water

raising the water table. I would consider legal action against anyone pumping on or near my property.

258 - As I understand your plan, it was all worked out several years ago by the Water Board, Reclamation and the S.C.S.--and I answered the same questions at that time.

260 - Dear Sir: I am not interested in trading '66 water for pumps.

265 - We already own one of the oldest underground water rights--we can't see changing it for a 1963. Well, also it is questionable if this water could be used upstream, that is if these springs could be tapped by wells somewhere else. If it would be possible to tap these springs at the present moment, and it was done this well or wells would have to stop operation if our water supply was cut down or stopped. Now if we were given wells that produced the water we have and also give us an 1881 right on them then this would of course be a different story.

279 - Would want more information.

287 - I would like to see a student engineer appointed as an assistant to the water commissioner. His duties to study the water and be sure that it is all used farther down the river. It has been reported to us that thousands of inches go to waste on down the river.

293 - I can irrigate all the land below the ditch with the water I now have.

294 - I feel the cost of pumping, etc., would be too high and the results too small to make it practical. My main need on this place is for extra water from July 10 or 15, on to the first of September. Up to that time I am not limited to just 80 inches inasmuch as there is extra water. However, from about the middle of July on I could beneficially use another 50 inches of canal water.

296 - Sirs: I feel these questions are personal and of no concern to others unless they are cooperating in some scheme to junk the rights of priority and useage and substitute another Federal project with its wasted millions.

299 - I'd prefer dams up the river to hold the run off in spring and prevent flood damage. I'd be satisfied if I could have 120 miners inches (his allotted share) all season. As it is (our ditch) has its water turned (off) early in July each year as water gets low in river and the early rights take all the water.

308 - We would have an excellent farm if we had a little better water right. Most years we run out of water from the 6th to the 15th of July.

310 - You should have given a definition or example in regards to

miners inches per acre.

I think the more surface water used for upstream use, is most beneficial for all concerned. It would help keep the downstream water level more normal and also would be more economical to supplement.

311 - If you would drill a well, what ground would you have to stand on if some other company would claim the underground water. For instance some other state I do not know if this is facts but was told that it could happen.

313 - The possibility of pumping water for (my place), has been checked into and does not promise to be too possible.

316 - The theory behind this is very good. But if other people are going to pay for their water, I am afraid there will be a large amount of wasted water, with this thought in mind--If the other fellow is going to pay for my water I will use all I can. . .

318 - I believe water could be diverted from the Madison River through a canal from the West Yellowstone area, to the Gallatin or a dam enlarged at the Hebgen Area to generate power to pump water over the Grayling Pass into the Gallatin River from Hebgen Lake. This water would then be picked up by our canals, even if only half of our water shares are available we could benefit.

331 - Satisfied with the water I control. With growing only one crop

of hay or grain per season I couldn't afford to pay more for water. If farm crops were up in price like everything we buy, things would be different.

348 - We do not care for more water because the cost would be too high. We paid already $180 for 90 inches of water a year.

350 - Why increase our production when we cannot move (at a profit) that which we already produce.

905 - I have a decreed rite of 283 inches; but at the flood stage I use possibly 500 inches or more and by pumping I would receive but the decreed rite which would reduce the amount of water available.

Under the present circumstances this amount of water has proven very satisfactory and under no circumstances do I wish it changed.

The underground water table is at present at a favorable height and many farms have been arranged to use this to an advantage therefore, I do not wish to lower our water table by pumping.

APPENDIX C

SURVEY SCHEDULES
MAIL QUESTIONNAIRE

Project W-75 June, 1963

1. Name: _____

_____ Code Number Address: _____

_____

2. Your land is located in: (Please correct)

Section(s) _____

Township(s) _____

and Range(s) _____

3. You are a member of _____

_____ ditch company.

4. You are served by the following major ditches:

1. _____

2. _____

3. _____

4. Others _____

5. You own the following shares of the above named ditch company:

	Shares	Approximate inches of water
a.	_____	_____
b.	_____	_____
c.	_____	_____
d.	_____	_____

6. You own the following water rights:

	Date	D-Decreed N-Notice U-Use	Stream	Amount Allowed
a.	_____	_____	_____	_____
b.	_____	_____	_____	_____
c.	_____	_____	_____	_____
d.	_____	_____	_____	_____
e.	_____	_____	_____	_____

7. The total annual cost of your water is:

5 year estimated average

a. Operation and Maintenance $ _____ . _____

b. Special assessments $ _____ . _____

FOR OFFICE USE ONLY:

Total Water Cost _____

Cost per miners inch _____

8. Total number of acres in your farm _____

9. Number of acres irrigated (estimated average of last 3 years) _____

10. Total possible number of irrigable acres _____

11. About how much water do you use per irrigated acre at present (an average amount)

Check one:

_____ a. .75 miners inches per acre

_____ b. 1.00 miners inches per acre

_____ c. 1.25 miners inches per acre

Check one (continued)

_____ d. 1.50 miners inches per acre

_____ e. 1.75 miners inches per acre

_____ f. 2.00 miners inches per acre

_____ g. Other—write in amount _____

12. About how much water would you use IF THE SUPPLY WAS PLENTIFUL AND CONSTANT: (on the average)

Check one:

_____ a. 1.00 miners inch per acre

_____ b. 1.50 miners inch per acre

_____ c. 1.75 miners inch per acre

_____ d. 2.00 miners inch per acre

_____ e. 2.25 miners inch per acre

_____ f. 2.50 miners inch per acre

_____ g. Other—write in amount _____

13. If a plentiful supply could be delivered constantly to your farm about how much <u>COULD</u> you pay for the additional water:

Check one:

_____ a. $ .50 per miners inch

_____ b. .75 per miners inch

_____ c. 1.00 per miners inch

_____ d. 1.25 per miners inch

_____ e. 1.50 per miners inch

_____ f. 1.75 per miners inch

Check one (continued)

_____ g. $2.00 per miners inch

_____ h. 2.25 per miners inch

_____ i. 2.50 per miners inch

_____ j. Other--write in amount _____

If one (1) is written in the box at the right of this page fill in Question 15.

If two (2) is written in the box at the right of this page fill in Question 16.

14. (Location with respect to ground-water resource) [ ]

15. The location of your farm makes it possible to supply your irrigation water from wells.

If farmers upstream paid the cost of wells and pumping your present supply of water--AT NO COST TO YOU--would you allow them to divert your present surface water supply for upstream use? CHECK ONE

NOTE--NOTE: You would NOT in any way change your present water right!!

Yes	No
___	___

If no, state why:

_____

_____

_____

_____

16. The location of your farm makes it possible for you to increase your irrigation water supply by sharing the cost of pumping water for some other farm.

Would you be willing to share the cost of pumping water elsewhere in the valley to increase your own supply?	CHECK ONE Yes	No
	___	___

If "no" please briefly state why:

_____

_____

_____

_____

Use this space for any additional comment you wish to make--all information and comments are confidential.

_____

_____

_____

_____

_____

_____

/wd

SCHEDULE--DITCH COMPANIES

W-75: Economic Analysis of Integrated Ground-Surface Water Resource
June, 1963

1. Name:

a. Of the company _____

_____

b. Of the person being interviewed and title _____

_____

c. Legal structure (co-op, corp., etc.) _____

_____

2. Present operation:

a. Number of farmers served _____

b. Number of irrigable acres served _____

c. Water:

1) Amount supplied

a) Company water _____

_____

b) Private water _____

_____

_____

_____

2) Cost of water supplied

a) Company water

(1) Operation and Maintenance costs _____

_____

(2) Other--specify _____

_____

_____

b) Private _____

_____

_____

d. Water rights owned by company

1) Dates and type (decree, notice, use, etc.) _____

_____

_____

_____

_____

_____

_____

_____

_____

_____

2) Amount of each right _____

_____

_____

_____

_____

_____

_____

_____

_____

3) Date when water is shut off (average for each right) _____

_____

_____

_____

_____

_____

_____

_____

_____

3. Optimum operation

a. How much water can your ditches supply? _____

_____

_____

b. On an average, how much water is needed for the land served by your company.

1) Per irrigable acre _____

2) In total _____

c. In your opinion, what is the maximum charge farmers under your ditches can afford to pay for additional water? _____

_____

_____

How much water would they use at the additional price? _____

_____

_____

d. What development is needed to irrigate all irrigable acres under your ditches? _____

_____

_____

_____

4. General:

a. In 1958, the Bureau of Reclamation published a study of the Gallatin Valley and made several proposals to increase the total supply of irrigation water. The next few questions are to record your knowledge of their study.

Do you know?	Yes	No
1) The Bureau had conducted the study	___	___
2) There is enough ground water available for irrigation plus some industrial uses	___	___
3) The "ground water" area is about one mile wide near Gallatin Gateway and 12 miles wide near Belgrade	___	___
4) They suggest the development of 193 irrigation wells	___	___
5) That under their system present water rights would not be changed	___	___
6) That under their system most of the valley now under irrigation would receive a full supply of water.	___	___

b. Reaction to the Bureau study — Yes ___ No ___

1) It is a very good study and should be developed ___ ___

2) A good study but no more water is needed ___ ___

3) There are better ideas for development (specify) ___ ___

c. Water development: Number according to priority

1) If more water is to be developed, who do you feel should develop it?

a) Ditch companies

b) Federal Government

c) Others--specify

2) Disregarding question "1)":

a) Could this ditch company finance the digging of irrigation wells, is the organization strong enough to do this? ____

_____

_____

If you feel this company could develop the water, do you feel they will? _____

_____

_____

_____

b) If additional water was developed, could this ditch company distribute the additional water? _____

_____

If not, why? _____

_____

APPENDIX D

Definitions

Acre inch - An acre inch of water is the amount of water required to cover one inch deep or 3,630 cubic feet of water.

Acre foot - An acre foot of water is the amount of water required to cover one acre one foot deep or 43,560 cubic feet of water.

Aquifer - Water-bearing rocks (formations, groups of formations, or parts of formations) that will yield sufficient water to be a source of supply.52/

Coefficient of Transmissibility - The capacity of an aquifer to transmit water is termed "transmissibility." The coefficient of transmissibility is the number of gallons of water per day, at the prevailing water temperature, that is transmitted through each mile strip extending the full saturated thickness of the aquifer under a hydraulic gradient of one foot per mile.53/

Drawdown - The difference in feet between the static water table and the water level in a well being pumped at full capacity. Drawdown is necessary to establish the cone of depression.

Head - Pressure head, the height of water in feet.

52/Hackett, op. cit., p. 100.

53/Ibid., p. 101.

Hydraulic gradient - The difference in head between two points divided by the distance between the same two points in the slope of the water table.

Miner's inch - The miner's inch is a flow measurement equal to the quantity of water that will flow through an opening one inch square in a vertical wall under a pressure head ranging from four to seven inches. The western states also define the miner's inch in terms of cubic feet per second. In Montana one miner's inch is equal to 1/40 cubic feet per second.54/

Permeability - The characteristic of a porous material that allows to transmit water is called permeability. The standard coefficient of permeability of a material . . . is defined as the rate of flow of water in gallons a day at 60 degrees Fahrenheit through a cross-sectional area of one square foot under a hydraulic gradient of 100 percent.55/

Recharge - The hydrologic term for the addition of water to the ground water reservoir.56/

54/Israelsen, op. cit., pp. 20-23.

55/Dean C. Muckel, "Pumping Ground Water So As To Avoid Overdraft", Water, Yearbook of Agriculture, 1955, The United States Department of Agriculture, United States Government Printing Office, Washington, D. C., 1955, p. 298.

56/Irving F. Davis, Jr., Colorado's Ground Water Problems--The Economic Picture, Colorado State University Experiment Station, Bulletin 506-S, Fort Collins, Colorado, June, 1960, p. 5.

Specific capacity - The rate of discharge of a well per unit of drawdown. The specific capacity can be determined by dividing the discharge of the well, generally in gallons per minute by the water level drawdown, generally measured in feet.57/

Specific yield - The ratio of 1) The volume of water that a saturated aquifer will yield by gravity to 2) The volume of the aquifer. It is a measure of the quantity of water that a saturated aquifer will yield when drained by the gravity.58/

Water Table - The upper surface of a zone of saturation, if the zone is not confined. In general, the water table is not a level surface, but conforms, in subdued relief, to the irregularities of the overlying land surface . . .59/

Zone of saturation - Sub-surface water occurs in the pores and chinks of the rocks. When these interstices are completely full with water the area is referred to as the zone of saturation.60/

57/Hackett, op. cit., p. 100.

58/Ibid., p. 100.

59/Ibid., p. 100.

60/Dean C. Muckel, op. cit., p. 296.

APPENDIX E

Wells No. (1-5)

Given:

$H_1 = 35'$, $H_2 = 35'$, $H_3 = 30'$, $H_4 = 30'$, $H_5 = 30'$ — H = The approximate depth to water when pumping at full capacity

$Q = 3.5$ cfs (each) $Q_T = 17.5$ cfs

Formulas:

$$Q = AV \quad V = \frac{0.590}{n} \; d^{2/3} \; s^{1/2}, \quad n = 0.012$$

$$d' = \left(\frac{2.159 \, Qn}{s^{\frac{1}{2}}} \right)^{3/8}$$ (For approximate pipe diameter to allow water to flow freely without pressure)

$$Hp = \frac{Q\rho H_t}{550 \, E}, \quad E = 1.0 \text{ (assumed)}$$

Well 1:

$$Q = 3.5 \text{ cfs}, \; s = \frac{20'}{2000'} = 0.01$$

$$d' = \left(\frac{2.159(0.012)}{(0.01)^{\frac{1}{2}}} \, Q \right)^{3/8} = (0.259 \, Q)^{3/8}$$

$$d' = (0.259 \times 3.5)^{3/8} = 0.964' = 11.6'' \rightarrow \underline{\underline{12''}}$$

*Pipe 1→2: $d = 12'' = 1.00'$, $Q = 3.5$ cfs $A_1 = 0.785$ sq. ft.

$$V_1 = \frac{0.590}{0.012} (1)^{2/3} \; (0.01)^{1/2} = 4.91 \text{ fps} \quad Q = (0.785)(4.91) = 3.86 \text{ cfs}$$

$$\text{Pump 1: } HP = \frac{(3.5)(62.4)(35)}{550} = 13.9$$

---

*Check equation to be sure calculated pipe diameter will carry the required amount of water.

Well 2:

$Q = 7.0$ cfs, $s = \frac{20'}{2000'} = 0.01$

$d' = (0.259\ Q)^{3/8} = (0.259 \times 7.0)^{3/8} = 1.250' = 15" \rightarrow \underline{\underline{16"}}$

*Pipe 2→3: $d = 16" = 1.33'$, $Q = 7.0$ cfs, $A_2 = 1.39$ sq. ft.

$V_2 = \frac{0.590}{0.012} (1.33)^{2/3} (0.01)^{1/2} = 5.95$ fps, $Q = (1.39)(5.95) = 8.26$ cfs

Pump 2: HP = 13.9

Well 3:

$Q = 10.5$ cfs, $s = \frac{20'}{2000'} = 0.01$

$d' = (0.259\ Q)^{3/8} = (0.259 \times 10.5)^{3/8} = 1.455' = 17.5" \rightarrow \underline{\underline{18"}}$

*Pipe 3→4: $d = 18" = 1.50'$, $Q = 10.5$ cfs, $A_3 = 1.77$ sq. ft.

$V_3 = \frac{0.590}{0.012} (1.50)^{2/3} (0.01)^{1/2} = 6.45$ fps, $Q = (1.77)(6.45) = 11.4$ cfs

Pump 3: $HP = \frac{(3.5)(62.4)(30)}{550} = 11.9$

Well 4:

$Q = 14.0$ cfs, $s = \frac{20'}{2000'} = 0.01$

$d' = (0.259\ Q)^{3/8} = (0.259 \times 14.0)^{3/8} = 1.605' = 19.3" \rightarrow \underline{\underline{20"}}$

*Pipe 4→5: $d = 20" = 1.67'$, $Q = 14.0$ cfs, $A_4 = 2.19$ sq. ft.

$V_4 = \frac{0.590}{0.012} (1.67)^{2/3} (0.01)^{1/2} = 6.92$ fps, $Q = (2.19)(6.92) = 15.2$ cfs

Pump 4: HP = 11.9

---

*Check equation to be sure calculated pipe diameter will carry the required amount of water.

Well 5:

$Q = 17.5$ cfs, $s = \frac{14'}{1400'} = 0.01$

$d' = (0.259\ Q)^{3/8} = (0.259 \times 17.5)^{3/8} = 1.761' = 21.1" \rightarrow \underline{\underline{22"}}$

*Pipe 5→D: $d = 22" = 1.84'$, $Q = 17.5$ cfs, $A_5 = 2.66$ sq. ft.

$V_5 = \frac{0.590}{0.012} (1.84)^{2/3} (0.01)^{1/2} = 7.39$ fps, $Q = (2.66)(7.39) = 19.6$ cfs

Pump 5: HP = 11.9

---

*Check equation to be sure calculated pipe diameter will carry the required amount of water.

Wells No. (6-8)

Given:

$H_6 = 35'$, $H_7 = 40'$, $H_8 = 55$; H = the approximate vertical distance from the ditch to water when pumping at full capacity

$Q = 3.5$ cfs, $Q_T = 10.5$ cfs

$Q = AV$

3.5 cfs → 10" Pipe (Assumed)

$d = 0.834'$, $A = 0.546$ sq. ft., $V = 6.42$ fps

$$N_R = \frac{d \rho V}{\mu} = \frac{0.834 \times 1.94 \times 6.42}{2.735 \times 10^{-5}} = 380{,}000$$

$e = 0.00015$ Commercial Steel or Wrought Iron

$$\frac{e}{d} = \frac{0.00015}{0.834} = 0.00018$$

$f = 0.016$

$$H_L = f \frac{L}{d} \frac{V^2}{2g}$$

Well 6:

$$H_L = 0.016 \times \frac{300}{0.834} \times \frac{(6.42)^2}{64.4} = \underline{3.7'}$$

$H_t = 35' + 4' = 39'$

$HP = \frac{Q \rho H_t}{550E}$, $E = 1.0$ (Assumed)

$$HP = \frac{3.5 \times 62.4 \times 39'}{550} = 15.5 \text{ HP}$$

Well 7:

$$H_L = 0.016 \times \frac{400}{0.834} \times \frac{(6.42)^2}{64.4} = 4.9'$$

$H_t = 40' + 5' = 45'$

$$HP = \frac{3.5 \times 62.4 \times 45}{550} = 17.8 \text{ HP}$$

Well 8:

$$H_L = 0.016 \times \frac{600}{0.834} \times \frac{(6.42)^2}{64.4} = \underline{\underline{7.4'}}$$

$$H_t = 55' + 7.5' = 62.5'$$

$$HP = \frac{3.5 \times 62.4 \times 62.5}{550} = 24.8 \text{ HP}$$

Wells No. (9-12)

Given:

$H_9 = 70'$, $H_{10} = 90'$, $H_{11} = 100'$, $H_{12} = 100$; H = the approximate vertical distance from the ditch to water when pumping at full capacity.

$Q = 3.5$ cfs (each), $Q_T = 14.0$ cfs

$Q = AV$

3.5 cfs 10" pipe

$d = 0.834'$, $A = 0.546$ sq. ft., $V_1 = 6.42$ fps, $f = 0.016$

Pipe 9-10:

$$H_L = f \frac{L}{d} \frac{V^2}{2g} = 0.016 \times \frac{2200}{0.834} \times \frac{(6.42)^2}{64.4} = \underline{\underline{27.0'}}$$

Pipe 11-C:

$$H_L = 0.016 \times \frac{1700}{0.834} \times \frac{(6.42)^2}{64.4} = \underline{\underline{20.9'}}$$

Pipe 12-C:

$$H_L = 0.016 \times \frac{1100}{0.834} \times \frac{(6.42)^2}{64.4} = \underline{\underline{13.5'}}$$

7.0 cfs $V_1 = 6.42$ fps, $A_2 = 1.090$ sq. ft.

$d = 1.178' \cong$ 14" pipe $\{ d = 1.168'$, $V_2 = 6.55$ fps

$$N_R = \frac{d \rho V}{\mu} \quad \frac{1.168 \times 1.94 \times 6.55}{2.735 \times 10^{-5}} = 542{,}000$$

$$\frac{e}{d} = \frac{0.00015}{1.168} = 0.00013$$

$f = 0.0146$

Pipe C-10:

$$H_L = 0.0146 \times \frac{1100}{1.168} \times \frac{(6.55)^2}{64.4} = \underline{\underline{9.2'}}$$

14.0 cfs $V \cong 6.5$, $A_4 = 2.154$ sq. ft.

$d = 1.655' \cong 20"$ pipe $\{d = 1.667', V_4 = 6.41$ fps

$$N_R = \frac{1.667 \times 1.94 \times 6.41}{2.735 \times 10^{-5}} = 749,000$$

$$\frac{e}{d} = \frac{0.00015}{1.667} = 0.00009$$

$f = 0.0137$

Pipe 10-D:

$$H_L^* = 0.0137 \times \frac{2800}{1.667} \times \frac{(6.41)^2}{64.4} = \underline{\underline{14.7'}}$$

$$HP = \frac{Q\rho H_t}{550E}, \quad E = 1.0 \text{ (assumed)}$$

Well 9:

$H_t = 70' + 27' + 4' = 101'$

$$HP = \frac{3.5 \times 62.4 \times 101'}{550} = 40.0 \text{ HP}$$

Well 10:

$H_t = 90 + 4 = 94'$

$$HP = \frac{3.5 \times 62.4 \times 94}{550} = 37.3 \text{ HP}$$

Well 11:

$H_t = 100' + 21' + 4.5' + 3.5' = 130'$

$$HP = \frac{3.5 \times 62.4 \times 130}{550} = 51.6 \text{ HP}$$

---

*Assumption: H_L distributed evenly to branch laterals.

Well 12:

$$H_t = 100' + 13.5' + 4.5' + 4' = 120'$$

$$HP = \frac{3.5 \times 62.4 \times 120}{550} = 47.6 \text{ HP}$$

Wells No. (13-22)

Given:

$H_{13} = 105'$, $H_{14} = 115'$, $H_{15} = 125'$, $H_{16} = 125'$, $H_{17} = 145'$, $H_{18} = 150'$, $H_{19} = 165'$, $H_{20} = 170'$, $H_{21} = 185'$, $H_{22} = 190'$; H = the approximate vertical distance from the ditch to water when pumping at full capacity.

$Q = 3.5$ cfs each, $Q_T = 35.0$ cfs

$Q = AV$

3.5 cfs 10" pipe: $d = 0.834'$, $A_1 = 0.546$ sq. ft., $V_1 = 6.42$ fps, $f = 0.016$

7.0 cfs 14" pipe: $d = 1.168'$, $A_2 = 1.090$ sq. ft., $V_2 = 6.55$ fps, $f = 0.0146$

$H_L = f \frac{L}{d} \frac{V^2}{2g}$ (3.5 cfs) $H_L = 0.016 \times \frac{L}{0.834} \times \frac{(6.42)^2}{64.4} = 0.0123L$

(7.0 cfs) $H_L = 0.0146 \times \frac{L}{1.168} \times \frac{(6.55)^2}{64.4} = 0.00834L$

Pipe 13-D:

$H_L^* = 0.00834\ (3000) = \underline{\underline{25.0'}}$

Pipe 14-13:

$H_L^* = 0.0123\ (2000) = \underline{\underline{24.6'}}$

Well 13:

$H_t = 105' + 12.5' = 117.5'$

$H_P = 0.397\ H_t = (0.397)(117.5') = 46.6$ HP

---

*Assumption: H_L distributed evenly to branch laterals.

Well 14:

$H_t = 115' + 25' + 12.5' = 152.5'$

$H_P = 0.397\ H_t = (0.397)(152.5) = 60.5$ HP

Pipe 15-D:

$H_L = 0.00834\ (3000) = \underline{\underline{25.0'}}$

Pipe 16-15:

$H_L = 0.0123\ (2300) = \underline{\underline{28.3'}}$

Well 15:

$H_t = 125' + 12.5' = 137.5'$

$H_P = 0.397\ H_t = (0.397)(137.5') = 54.6$ HP

Well 16:

$H_t = 125' + 28.5' + 12.5' = 166.0'$

$H_P = 0.397\ H_t = (0.397)(166.0') = 66.0$ HP

Pipe 17-D:

$H_L = 0.00834\ (3400) = \underline{\underline{28.4'}}$

Pipe 18-17:

$H_L = 0.0123\ (2400) = \underline{\underline{29.5'}}$

Well 17:

$H_t = 145' + 14.5' = 159.5'$

$H_P = 0.397\ H_t = (0.397)(159.5) = 63.4$ HP

Well 18:

$H_t = 150' + 29.5' + 14.5' = 194'$

$H_P = 0.397\ H_t = (0.397)(194) = 77.0$ HP

Pipe 19-D:

$H_L = 0.00834\ (3100) = \underline{\underline{25.8'}}$

Pipe 20-19:

$H_L = 0.0123\ (2400) = \underline{\underline{29.5'}}$

Well 19:

$H_t = 165' + 13' = 178'$

$Hp = 0.397\ H_t = (0.397)(178) = 70.7\ HP$

Well 20:

$H_t = 170' + 29.5' + 13' = 212.5'$

$Hp = 0.397\ H_t = (0.397)(212.5) = 84.5\ HP$

Pipe 21-D:

$H_L = 0.00834\ (2500) = \underline{\underline{20.8'}}$

Pipe 22-21:

$H_L = 0.0123\ (2100) = \underline{\underline{25.8'}}$

Well 21:

$H_t = 185' + 10.5' = 195.5'$

$Hp = 0.397\ H_t = (0.397)(195.5) = 77.6\ HP$

Well 22:

$H_t = 190' + 26' + 10.5' = 226.5'$

$Hp = 0.397\ H_t = (0.397)(226.5) = 90.0\ HP$

Wells No. (23-25)

Given:

$H_{23} = 205'$, $H_{24} = 200'$, $H_{25} = 225'$; H = The approximate vertical distance from the ditch to water when pumping at full capacity.

$Q = 3.5$ cfs each $\quad Q_T = 10.5$ cfs

$Q = AV$

3.5 cfs 10" pipe: $d = 0.834'$, $A_1 = 0.546$ sq. ft., $V_1 = 6.42$ fps,

$f = 0.016$

$H_L = 0.0123L$

Pipe 24-23:

$H_L = 0.0123\ (2000) = \underline{\underline{24.6'}}$

Pipe 25-23:

$H_L = 0.0123\ (2200) = \underline{\underline{27.0'}}$

10.5 cfs $V_3 \cong 6.5$ fps, $A_3 = 1.615$ sq. ft.

$d = 1.434 \cong$ 17" pipe $\begin{cases} d = 1.417', \\ V_3 = 6.65 \text{ fps} \end{cases}$

$$N_R = \frac{d \rho V}{\mu} = \frac{1.417 \times 1.94 \times 6.65}{2.735 \times 10^{-5}} = 669{,}000$$

$$\frac{e}{d} = \frac{0.00015}{1.417} = 0.00011$$

$f = 0.014$

Pipe 23-D:

$$H_L = f \frac{L}{d} \frac{V^2}{2g} = 0.014 \times \frac{3000}{1.417} \times \frac{(6.65)^2}{64.4} = \underline{\underline{20.4'}}$$

Well 23:

$H_t = 205' + 7' = 212'$

$H_P = 0.397\ H_t = (0.397)(212) = 84.1$ HP

Well 24:

$H_t = 200' + 25' + 7' = 232'$

$H_p = 0.397\ H_t = (0.397)(232) = 92.1$ HP

Well 25:

$H_t = 225' + 27' + 7' = 259'$

$H_p = 0.397\ H_t = (0.397)(259) = 106.0$ HP

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