WESTERN GROUND WATERS and Food Production

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Today, more than ever before in American history, food is needed—food for our armed forces—food for the workers and all the people behind the lines—food for all the nations united in the fight for freedom.

Much of this food, especially sugar beets, beans, peas, beef, and mutton, will come from the soils of our Western States. A good part of it will be grown in ground-water areas of the West—areas where water from underground sources must be tapped to supplement surface irrigation supplies or the scant and erratic moisture falling direct from the skies.

Potentially, the ground waters of the West can be a most important spark plug in the total wartime machinery of food production in the United States. But now, as never before, there is need for conservative development and skillful use of the precious waters under the ground. Now, as never before, western farmers and ranchers who rely wholly or partially on ground-water irrigation cannot afford to let the well or the pump go dry.

Western Ground Waters and Food Production

By

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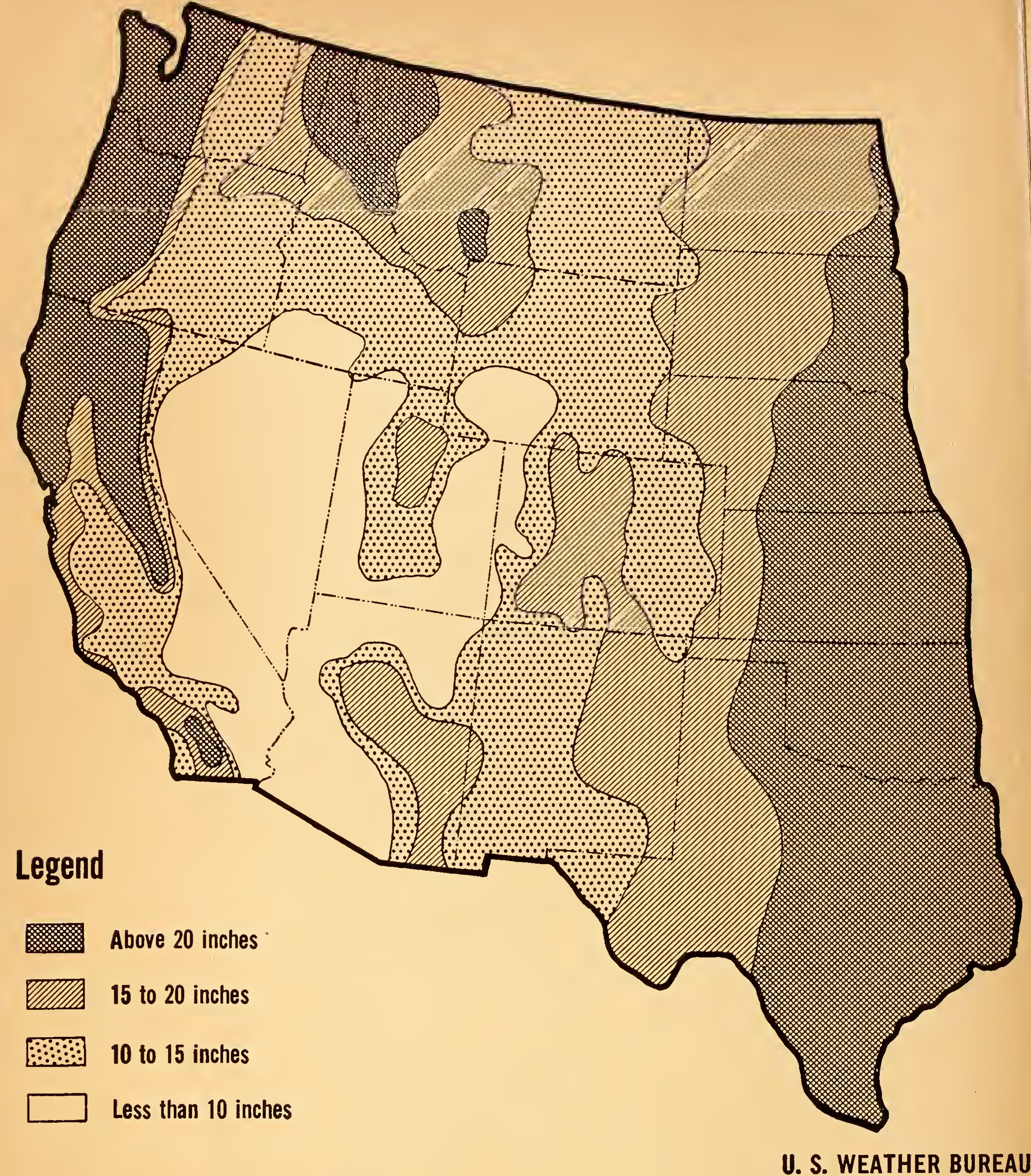
Normal Annual Precipitation

17 Western States



Where Water Rules

FOOD production in the western United States beyond the 98th meridian is inseparably linked to the story of water. Except for the humid corner of the Pacific Northwest and the favored mountain slopes that spill rain and snow from the clouds, the West is a dry country—arid and semiarid.

There is plenty of good land in the West. Here are millions upon millions of acres of rich soils that are among the most fertile on the continent—soils that can grow tremendous quantities of food for wartime needs. But they must have moisture to produce crops. And water, in comparison to the amount of potentially productive land on which to put it, is scarce.

To the traveler going West this truth unfolds in ever increasing degree. As he comes to the Great Plains, where rainfall drops to 20 inches or less a year—and that not dependable—he enters the vast country where water, not land, sets the limits of men's plans. As the dry-land farmer of the Plains well knows, rainfall hovers around the minimum with which it is possible to grow crops. Frequently—too frequently—it falls below that minimum, bringing disastrous droughts.

To the Plains farmer a dependable water supply for irrigation, even a small amount to supplement rainfall to tide him over the dry years, may mean the difference between success and failure, security and insecurity.

Farther West, rainfall declines to 12, 10, and as little as 3 inches a year—and here water supplies for irrigation become all important, the mainstay for agriculture year in and out. Here is the land of bright sunlight and sand, sagebrush, chaparral, and cactus. Without water for irrigation, much of the land isn't agriculturally usable, except for range, and even that use requires reliable water holes, stock wells, and streams.

Where water is available, as in the valleys where stream flow can be diverted for irrigation or where farmers' pumps can tap a supply of ground water, a miracle is performed. The desert is driven back by a checkerboard of green crops, the harvests of which support farm homes, provide winter feed for the herds on the upland ranges and products for the commerce of the towns and cities. Here, in the arid regions, without the life line of water coming to the land through the grid of irrigation ditches there could be no neat farm homes, no hum of traffic of the market roads, no populous towns with cotton gins, packing plants, grain elevators, shops and banks. Instead, there would be only the still, uninterrupted space of range and desert.

These summary figures indicate the vital part that irrigation plays in western agriculture:

Although the 20½ million acres of irrigated lands in the West make up only 3 percent of the land in farms, and 11 percent of the cropland, they produce about 30 percent of the crop income.

Approximately one-fifth of all farms in the 17 Western States, and more than one-half of all farms in the 11 Mountain and Pacific States, are either wholly or partly irrigated.

The investment enterprises in irrigation exceeds a billion dollars.

About 10 percent, or 1,950,000 acres of irrigated land, receives all of its supply from ground water. Another 10 percent receives its supply from mixed ground-water and surface-stream sources.

What these figures do not show is the part that irrigation plays in making possible the other 70 percent of the crop income and in providing a stable productive core, so vitally needed in wartime, around which the areal agriculture is built, with irrigated crops complementing the crops on the dry-land farms and the livestock on the range. Irrigation thus makes possible a much broader base of production and services within the area of influence of the water supply than any one of the separate agricultural segments could support alone.

Pioneers in Irrigation

The story of water use in the West goes back beyond history. When Francisco Vásquez de Coronado with his band of conquistadors made his way up the Rio Grande in 1540, he discovered Indian villages founded on a well-developed irrigation economy. Some of these villages are still inhabited today, 400 years later, and descendants of these early irrigators still bring the yellow water from the Rio Grande to their lands.

As white settlers came into the dry lands of the West, they soon learned that in order to stay they had to have water for their crops. Naturally, they turned to the nearest at hand, the water in the streams, which they diverted onto the raw land. The pioneers of modern irrigation were the Mormons, who in 1847 started spreading water from the streams on the arid lands of the Great Salt Lake Valley, with fruitful results that gave irrigation an impetus throughout the West.

Pioneers—the questing families who sought out favorable locations along the streams where they could bring the water to the land by simple direct diversions—held the center of the stage until the 1880's. Then the prosperity that seemed to come from western irrigation attracted the dollars of eastern and foreign investors. Private capital flowed into large-scale irrigation developments for some years; dams and canals were built, and vast areas of land were reclaimed from the desert. By 1900 some 9,000,000 acres were being irrigated. Toward the turn of the century, however, it became apparent that irrigation had the best chance of becoming profitable only when the family on the land had a stake in its success as buyer or owner, that irrigation development was a long, expensive, and complicated process, and further, that chances for large speculative profits were small. Private development lagged. Then, in 1902 the Reclamation Act was passed by Congress, and large-scale reclamation projects became the task of the Federal Government.

Under Federal leadership there was another great expansion in western irrigation. Larger, more difficult projects were undertaken, and previously unused stream flow was captured by huge dams and brought to lands that had been passed over in the first development period. By 1920 the acreage being irrigated had more than doubled, reaching 19,191,000. The total irrigated area has increased relatively little since then, as new developments have been offset by retirement of some older areas. The 1940 census reported approximately 21,000,000 acres of irrigated land in the 17 Western States. The Bureau of Reclamation alone has developed about 2 million acres.

Rain from Underground

In general, the surface waters were developed first, and then, as the best diversion and reservoir sites were taken up, or where water from streams was not available, the farmers began to look beneath the earth's surface for irrigation waters.

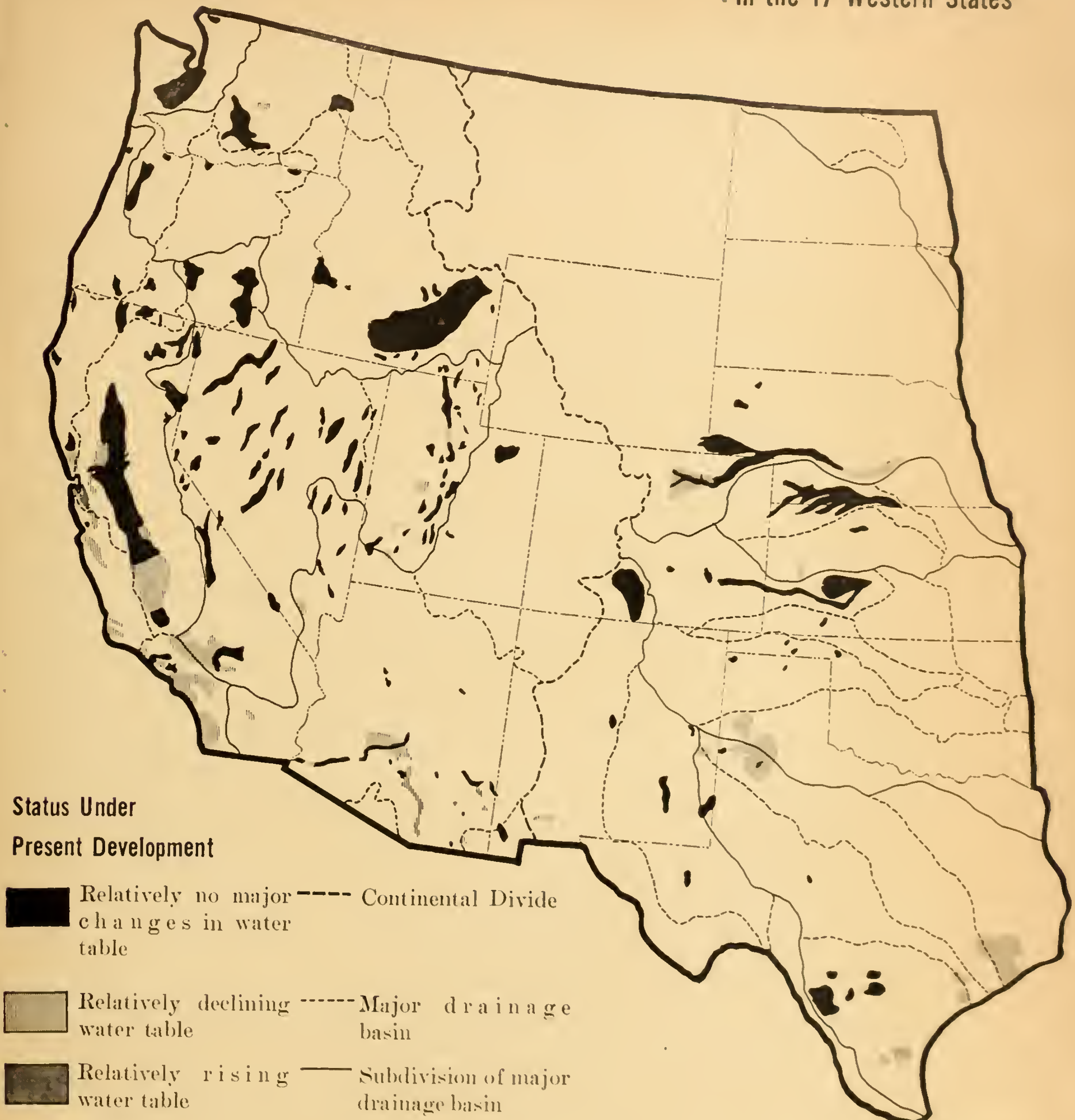
There has been some pumping of ground water or use of artesian flows for irrigation since the early days of the West. But for the most part ground water was put to work on the land only in areas where the supply was easily developed, as in the Arkansas River Valley in Kansas, where a shallow underflow was found and used shortly after the valley was settled around 1880, or in the Roswell Basin in New Mexico, where a remarkable artesian flow was discovered in 1891 and rapidly harnessed for irrigation of a large area.

Extensive use of ground water for irrigation has come within recent years and still is expanding rapidly. In 1920, in the 17 Western States, ground water was pumped for irrigation from 34,790 wells. By 1930 the number of irrigation wells had increased to over 58,000. The Census figures for 1940 indicate another tremendous increase in wells, the total being in excess of 79,000.

This development has been and is being stimulated by a number of forces, in addition to the long-time interest in irrigation in the West. Pumping equipment has been greatly improved. Modern pumps have enabled farmers to undertake irrigation from ground water in many areas

General Ground-Water Basins

in the 17 Western States



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where it was not feasible, physically nor economically, a few years ago. Deep-well turbines raise water from greater depths in larger volume at lower costs than was possible with previous equipment. The new designs in pumps have been accompanied by more efficient and dependable power units, such as small Diesel and semi-Diesel motors. Power lines have spread a web through rural areas enabling farmers to install compact, electrically driven pumps that can be operated by pushing a button. Natural gas lines have spanned many ground-water basins, bringing cheap fuel. War needs have stimulated production of many agricultural commodities.

Lesson of the Drought

Perhaps the great drought of the 1930's was the greatest single stimulant to ground-water development, particularly in the Great Plains. It drove home to farmers that even a small, dependable supply of irrigation water, sufficient to produce the basic seed supplies, feed for livestock, and a garden for the family table, is good insurance against drought and crop failure. In hundreds of communities, on thousands of farms, wells have been drilled during and since the drought, hopefully probing for a source of irrigation water.

Troubles of a "Water Rush"

All in all, the events of the past 20 years, and particularly the last 8 or 10, have created an intense interest in the underground water supply. In turn, the rush to get water has brought many critical problems.

In some localities the ground water supply that accumulated underground for generations, perhaps centuries, is being taken from the natural underground reservoir faster than it is being replenished, and is thus being depleted in the course of a few years.

In other areas, available sources of ground water are being overlooked; farmers continue to look to the skies for rain in times of drought, when they should look below their feet. Nor is ground water always used to the best advantage; in some basins a limited supply that should be carefully reserved as drought insurance for the whole community is being expended rapidly by a few growers of "water-hog" crops.

Waste is a problem too. Too much water is poured on some crops while others go dry; some free-flowing wells are allowed to pour out an uncontrolled stream of water the year around, drawing needlessly on the common supply, wasting water that might save crops or might be used by other farmers. Leaky casings, improperly designed or constructed ditches, poor preparation of land, improper timing of water application—all of these faults are too common, all contribute to waste, and all mean that the limited supply of ground water does not serve as many acres of land nor as many farm families as it should.

Underground Rivers and Forked Sticks

Much of the trouble and waste that has accompanied ground-water development, much of the lost or abused opportunity for its most productive use, comes from lack of understanding and lack of sound information regarding this vital resource.

Every farmer whose livelihood depends on use of ground water for irrigation, or who can develop an available supply to increase the productivity and the security of his farm, should have the essential facts. He should know the source of this water supply, how much there is, what his legal rights are with respect to its use, how it can best be used, and whether or not it is being depleted.

Ground water long has been surrounded by mystery and superstition that run counter to known geologic facts. One still hears of "underground rivers" that bore through solid rock; of inexhaustible, "bottomless" springs that are said to flow up from the bowels of the earth. Many folks still have faith in the magic of a forked twig that is supposed to bend down toward underground water in the hands of a person endowed with the ability to "witch" water.

The facts are available. Scientific investigation, research and experiment long ago cleared up most of the mysteries of underground water. Area by area the United States Geological Survey has determined the geology and the occurrence of ground water, getting the facts on the available supply of ground water, its origin, how it moves, where it goes, where and how it may be recovered, its quality, and its relationship to surface waters, among other things. This fund of basic knowledge is constantly being enlarged and improved by painstaking surveys.

Research on all phases of water use in farming has been carried on for more than 50 years by the Department of Agriculture and cooperating State colleges and experiment stations. Information has been made available to farmers regarding the planning of ground-water use, the types and methods of operating irrigation equipment, methods of irrigation, economics of irrigation, control of alkali, drainage, and a host of related subjects.

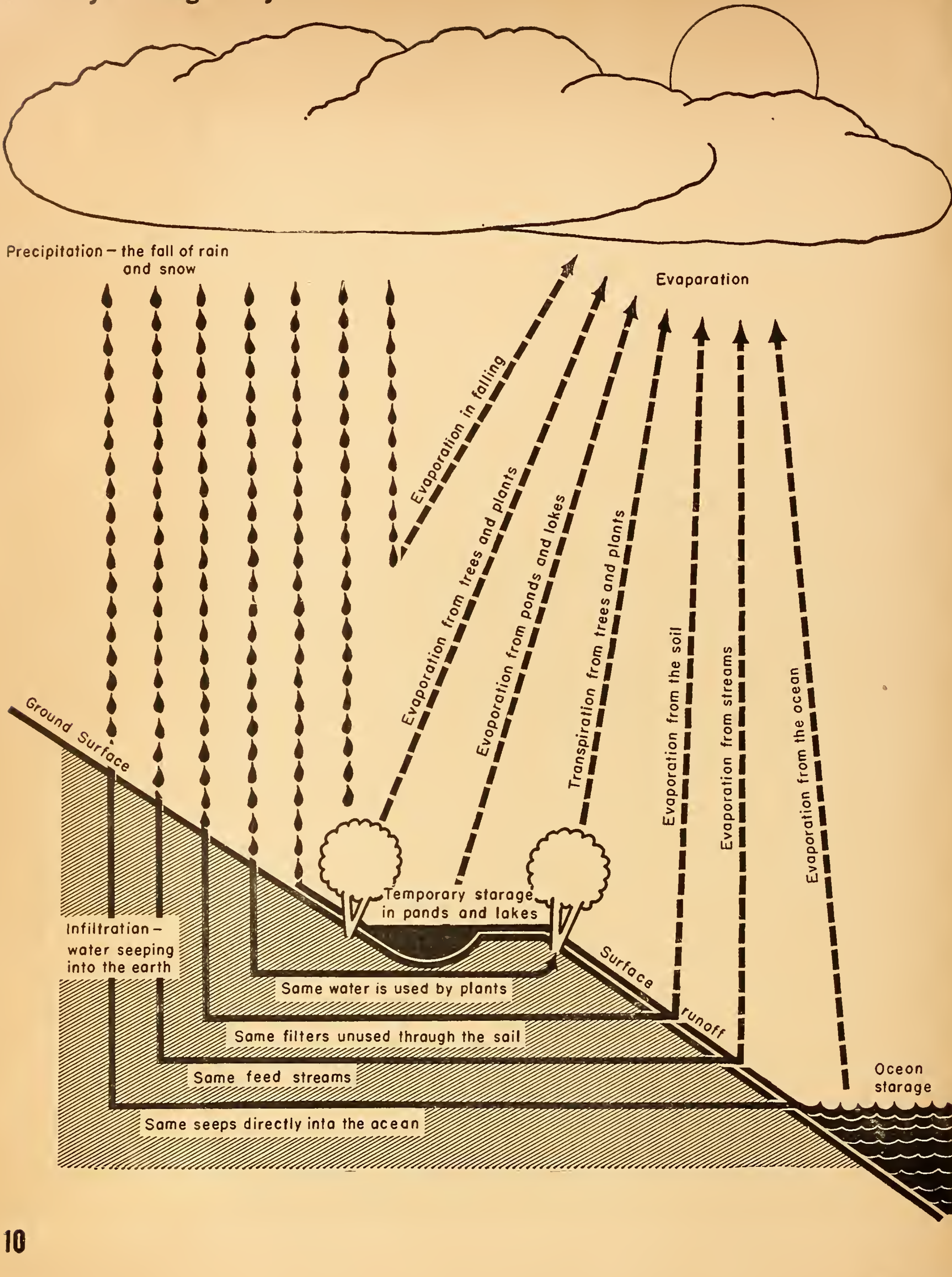
Looking Ahead

All of the facts of ground water point to one conclusion: The need for cautious, well-planned use of this extremely limited resource.

The conditions in ground-water areas vary, not only between areas but within any one area. But as a whole, it is evident that the supply of ground water in the West is distinctly limited as compared to the need for water and the amount of land that is suitable for irrigation. Each year brings the West more closely to the limit of its ground-water capacity. And each year emphasizes the need for scrupulously careful plans for the use of the ground water now available, or that which may be developed in the future. The facts on ground water are vital to the people who live, or who may come to live, in areas whose whole economy may be limited or deeply affected by the available supply of ground water, people who may develop a stable, secure agriculture through wise use of land and water, or who may be headed for disaster by improper use.

Modern pumps make irrigation cheaper and easier. This one in the Republican Valley, Nebr., delivers 750 gallons of water a minute.

The Hydrologic Cycle



Ground Water—What it is

WHEN man discovered that water sometimes could be found under dry lands by digging a hole in the ground he stumbled onto a discovery almost as important as fire. Without the art of well-drilling, man's activities would have been confined within a narrow radius of rivers and springs; he could not have ventured into the arid and semiarid regions which cover a large part of the earth.

Yet despite all of the liberties and opportunities that ground water has given man, and through all of the centuries that men have probed into the earth in search of water, surprisingly little has been known about the source of this blessing until modern times.

The ancients were inclined to take it for granted that rainfall could not sink far into the surface of the earth, and furthermore, it seemed apparent that not enough rain falls to replenish both rivers and the underground supply. Thus, they reasoned that ground water must come from some underground source, perhaps from sea water flowing inland through underground channels and in some way being purified and forced up through springs and underground streams; perhaps by condensation from the air in underground caverns.

From Fall of Rain and Melt of Snow

It remained for modern science, to marshal the facts that reveal the true source of ground water. These, of course, show that ground water comes from precipation, from the melt of snows and the fall of rain that seep into the earth's mantle of soil and rock.

Ground water is simply a part of the earth's endless and complex water cycle, through which water moves restlessly and eternally between the sea, the skies, and the land.

In the first step water goes into the atmosphere by evaporation from oceans, lakes, rivers, and the land. Water also is drawn from the ground and released into the atmosphere by plants.

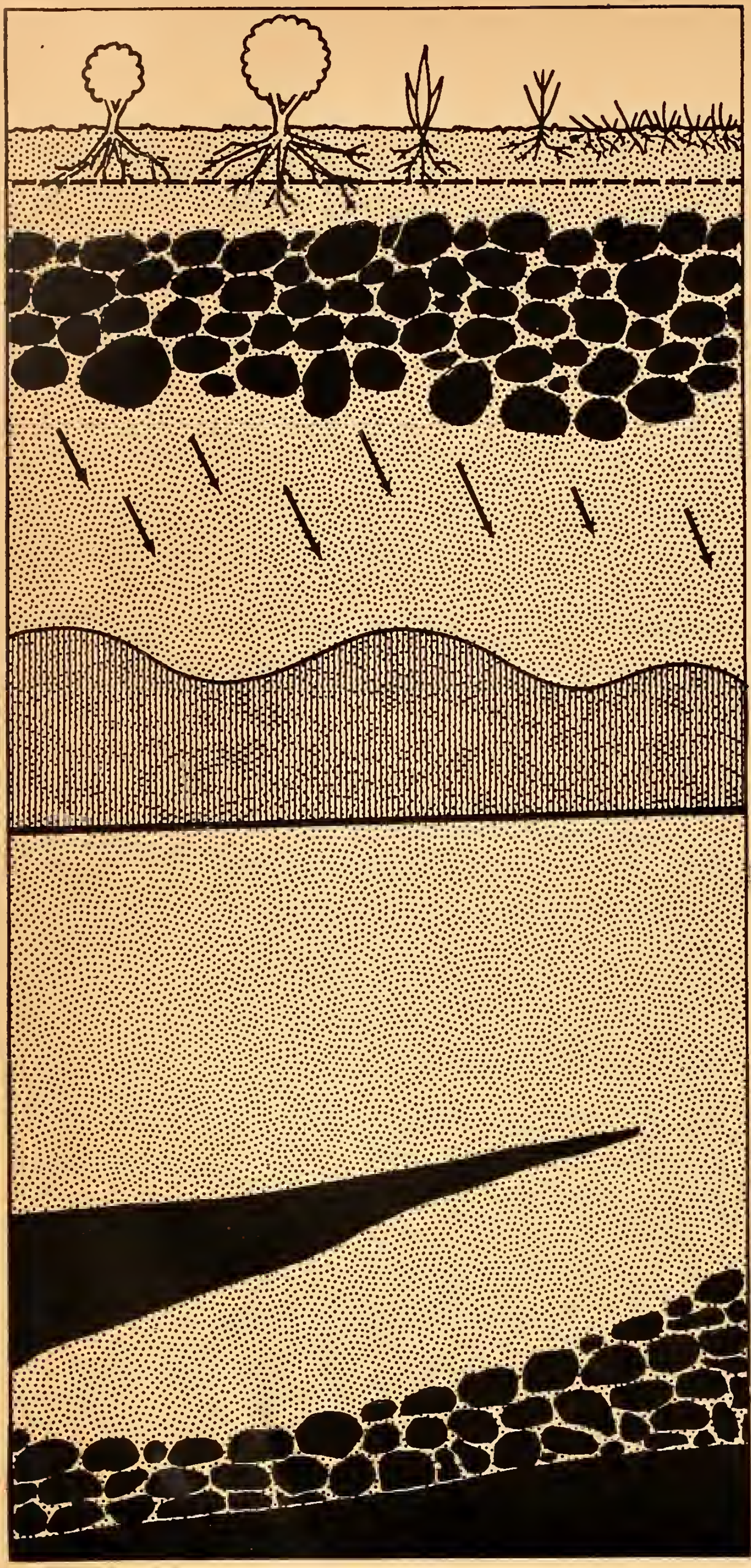
The second step of the cycle is precipitation; air masses laden with moisture may move for long distances before striking cool air currents that condense the moisture and make it fall as rain or snow, or form dew.

In the third step the precipitated water drains down grade by various routes. A part runs off the surface and is collected in gullies, branches, creeks, rivers, and lakes, and may eventually reach the ocean, or be evaporated without ever having been underground. But a part of this water is absorbed in the soil by infiltration. First, this water seeping into the soil adheres in a film to rock and soil particles, and is held there until withdrawn by evaporation or by plants. When infiltering water fulfills this first requirement, any excess moves downward to underground strata of soil, gravel, or porous rock, into the *zone of saturation*, which is a part of the natural drainage system. The water moving through this underground drainage is called *ground water*, and the top of the zone of saturation is known as the *water table*.

An Underground Reservoir

The zone of saturation, or ground-water zone, extends downward to impervious strata of rock or clay; these are the bottom of the underground reservoir.

Principal Zones of Ground Water



Soil Water
Limited to the soil zone reached by plant roots.

Pellicular Water
A film of water adhering to rock and soil particles by surface tension.

Gravity Water
Water in excess of that which can be held by surface tension moves downward by gravity.

Capillary Water
Water held above the water table by capillary action.

Water Table
The surface of the underground reservoir.

Free Water
Water moving through the natural underground drainage system unhampered by impervious confining strata.

Confined Water
Water moving underground by the confining strata or natural conduits.

Impervious Rock
The bottom of the ground-water reservoir.

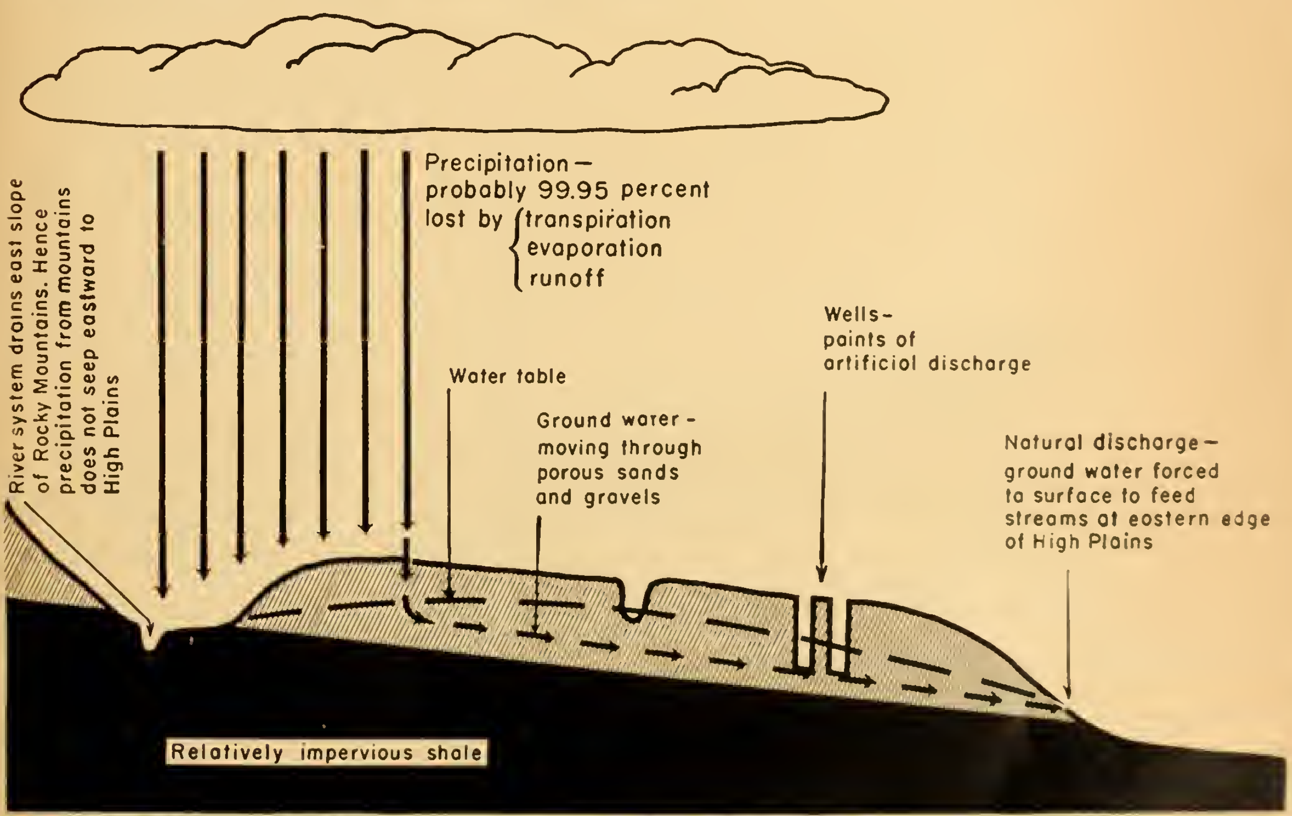
It is important to keep in mind that ground water, as much as surface streams, is a part of the natural drainage system and that it is pulled by gravity toward lower levels, but instead of flowing freely it must percolate through the space between gravel particles, or through rock crevices. Ground water constantly moves toward lower levels, just as any fluid, but this movement is far different than for free-flowing, surface water. The rate of flow varies with the slope and the porosity of the material through which the water moves. On a given grade ground water may move 6 feet a day through well-sorted alluvial gravel of high porosity, but less than a foot a day through poorly sorted, mixed silt and gravel beds. For example, in a river valley the only drainage that can be seen is the water in the stream and its tributaries which flow swiftly and unimpeded toward the sea; yet, perhaps as much water is moving more slowly underground, percolating toward the same goal through the gravels that lie at the bottom of the valley. Except in basins closed by impervious rock, ground water eventually is discharged at some lower level through springs or through "seeps" at the edge of streams which cut down into the water table.

Ground water sometimes becomes surface water, and vice versa. For example, ground water on its way downgrade may be forced to the surface by an uplifting stratum of impervious rock, to form springs that feed a stream; or, a surface stream may cut across a bed of gravel or a permeable down-dipping stratum of rock, and a part of its flow may seep away into the ground water. In some cases a stream may receive a flow from ground water when the water table is higher than the stream and may lose water to the groundwater flow when the water table sinks below the stream level.

Confined Ground Water

So far this discussion has dealt only with free ground water which uses the downward pull of gravity by percolation through porous rock, sand, and gravel, just as a surface stream uses all of its "head" for flow. In a well put down into the

The Hydrologic Cycle of the High Plains



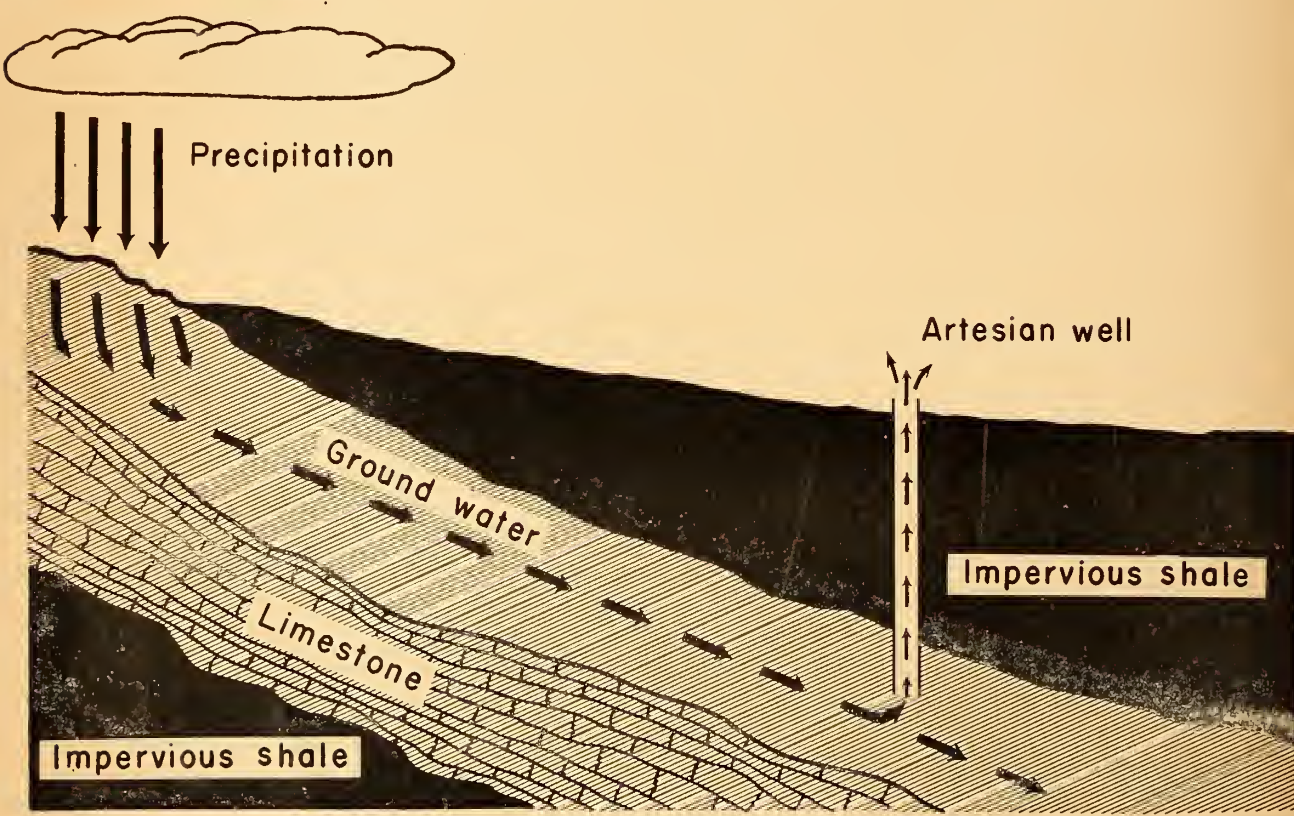
free-water table the water will stand in the casing at almost the same level as the water table, and will not rise above it without pumping.

Another type of ground water is *confined water*, that is, water that seeps into the outcrop or open end of a porous stratum of sandstone or gravel which is overlain downgrade by watertight material, as in the case of a water-carrying sandstone covered by an impervious shale. Confined water is the same as water in a pipe. If the confined stratum is pierced by a well downgrade from the intake area, the water will rise in the hole, the height of the rise depending on the amount of head developed by the slope, minus friction losses. The principle is the same as that which governs water running from a standpipe on a hill through a pipe to the valley below. Water in a pipe at the bottom should have head enough to rise nearly to the level of the water in the standpipe. When natural conditions create such a water system, flowing or artesian wells can be obtained by drilling into the confined layer of water.

Water Is Where You Find It

The capacity of the vast ground-water reservoir is tremendous. It has been estimated that ground-water supplies are sufficient to cover the earth with a layer of water 200 to 600 feet deep. But whether or not a farmer's pump will tap this reservoir at reasonable depths, and in a rock or gravel formation that will yield the needed quantity, depends on the particular geologic conditions that control the water at that spot. The character of the ground-water reservoir varies from place to place as widely as the geologic conditions. In some places, as in seeps and swamps, the water table is at the surface. Under certain conditions, as in the alluvial fill of a broad valley, it may be within 10 to 30 feet of the surface. In some areas the formations through which the ground water moves are hundreds or several thousands of feet below the surface. The layer of ground water also varies widely in thickness; it may be only a few feet thick where impervious bedrock below it rises close to the surface of the earth; it may extend down thousands of feet where condi-

An Artesian System



tions are right. The ground-water reservoir seldom is a continuous layer of water-bearing gravel or rock from top to bottom; generally, water-carrying strata or lenses are interbedded with impervious layers. A well going down through such formations may draw its water from several strata.

Aquifers and Aquicludes

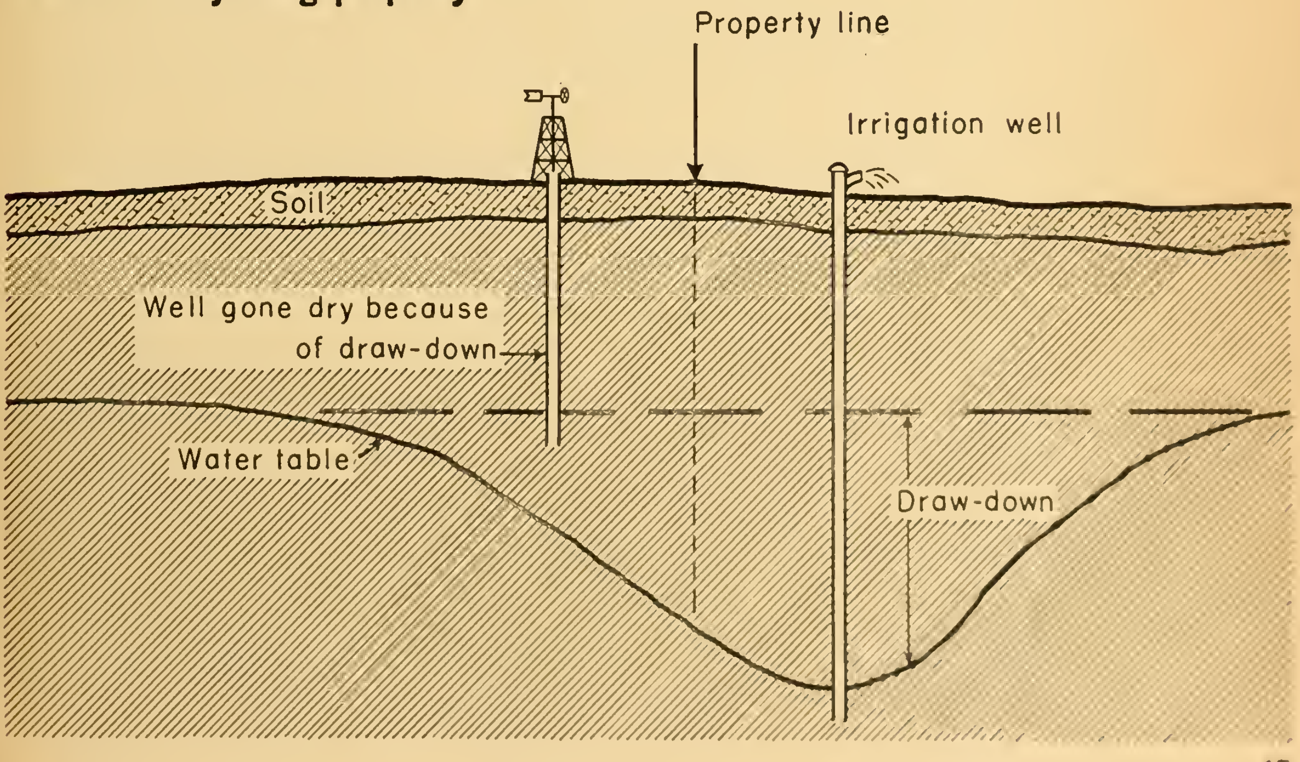
Merely drilling into a water table doesn't assure that water can be pumped from it: to produce water in worth-while quantities the drill must bore into an *aquifer*, or a formation that has the ability to carry and yield water. For example, sand and gravel, porous or fractured limestone, and fractured lava beds, generally are good aquifers and yield water readily. *Aquicludes*, however, are formations such as clays, which, although porous and capable of absorbing water, will not yield it fast enough to supply a well. Then there are formations which are impervious to water and cannot absorb it, called *aquifuges*, such as granite, and quartzite; water flows through these rocks only in fissures, fractures, and faults.

Natural Balance

Ground water, then, is a dynamic, moving film that creeps along underground slopes and valleys through sand, gravel, and porous rock, filtering through cracks and crevices: sometimes thick and sometimes thin: sometimes near the surface of the earth and sometimes far below it: sometimes capable of being recovered and sometimes not: but always finding its way back somehow into the eternal water cycle.

In its natural state, before wells pull out a part of the supply, ground water in an area or basin usually is in *natural balance*. That is, the outflow at the lower elevations through springs and seeps and losses through the roots of plants and trees, is equal to the inflow from rain and snowfall on the recharge area. Under natural balance the water table rises or falls only as the intake of water from rain and snow varies, and even then, because of the retarded movement of the water, the response is in slow motion. It may require a prolonged drought to cause the water table to drop and even then the reaction may not appear for several years.

Draw-down of an irrigation well may necessitate deepening a well on adjoining property



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However, when wells are drilled into the water table and the pumps begin to turn, the natural balance is upset and readjustments must come about. The water table declines, seeking to restore a new hydraulic balance between intake and outflow. The amount of the decline in the water table depends partly on the volume of water pumped from the underground reservoir; if the pumping is excessive, the decline of the water table will continue and wells must be deepened or they will go dry. Ultimately, overpumping can cause the water table to drop below the level from which water can be lifted economically. If on the other hand, the volume of water pumped in an area is carefully planned in relation to the supply and the recharge, a new balance can be established between intake and outflow, by stabilization of the water table at a lower level. Under such conditions, pumping may continue for a longer period at the established rate without endangering the water supply.

A Public Resource

It is apparent that by its very nature, ground water is a public, and not a private resource. If one landowner pumps too much water, or wastes water, he is not merely depleting the supply below his own land; he may be drawing water away from his neighbors' wells, or wasting a part of a common supply. For all practical purposes, communities located within the same ground-water area are drawing on a common well; if they draw too much water, everyone dependent on the supply will suffer. The situation is similar to that of a common pasture, shared by several farmers: The pasture may profitably carry 10 head of cattle and as long as only 10 are allowed to graze, they will get fat. However, if there is no plan for limiting the use of the pasture or for division of the use, each farmer may increase his number of cattle to get a larger share of the grass, with the result that 15 cattle are grazed, all of them stay thin, no farmer makes a profit, and the pasture is ruined by overgrazing.

Thirteen million gallons of water per day from underground. El Grande, probably the largest artesian well in the world, sends its carefully controlled flow over crops in the Roswell, N. Mex., Basin.

Ground-Water Law

ONE of the most vital rights a man may obtain in the West is the right to recover water from a stream or from the natural underground reservoir. As a result, a complex body of law and court decisions has grown up around water use in the western country.

Court Decisions

Many significant and perplexing questions, however, remain unsettled, particularly with regard to ground-water rights. In part this is due to the prevailing lack of understanding of the physical laws governing the occurrence and behavior of ground water. The subterranean movements of waters were so little known until comparatively recent times that the courts were loath to lay down rules governing their use; hence, the simple formula was devised that water in the ground is part of the soil and is owned by the landowner, unless proved to be flowing in a definite underground stream.

Thus the courts throughout the West generally have considered ground water as being of two classes, (1) underground streams, and (2) percolating waters. Different rules apply to each class. While this distinction has been severely criticized by competent ground-water hydrologists, the classification appears so generally throughout court decisions that it must be taken into account by anyone dealing with ground-water law.

Underground Streams

Definite underground streams, in the opinion of the courts, are subject to the same rules that apply to the surface streams in the same jurisdiction, and the underflow of a stream is governed by the same rules that apply to its surface portion. In other words, in the States where the appropriation doctrine applies, the ground waters in definite underground channels are subject to this rule alone; and in the States where the riparian doctrine applies, they are subject likewise to riparian rights.

The *riparian* doctrine, a part of the common law of England, provides that the owner of land contiguous to a stream has certain rights in its flow solely by virtue of land ownership. Originally he had the right to have the stream flow to his land undiminished in quantity and quality; and as each owner of land had the same right, this rule, if strictly enforced, would have prevented him from making any consumptive use of the water. Of necessity the doctrine was modified; the riparian owner then had the right to make whatever use of the water for "artificial" purposes, such as irrigation, as was reasonable in relation to the requirements of all other owners of land contiguous to the same stream.

The legal doctrine that has come to supplement, or in some States to replace the riparian rule, is called the *appropriation* doctrine. It has much in common with the right of discovery, or "finders keepers." This is based on priority of beneficial use, and gives the first user of the water from a stream (underground or surface) the right to continue his use as long as it is beneficial, and to use the entire supply if necessary to satisfy the right he has established. If there is any surplus water, others may use it in the order of their priority in establishing beneficial use. The right may be kept in good standing as long as the beneficial use continues, but lapses through nonuse.

Percolating Waters

Percolating waters, in legal terms, are waters in the ground other than those flowing in definite subterranean streams. With a few exceptions, there has been little legislation defining the rights of users of percolating ground waters, and the pattern of rights has been set mainly by court decisions, based on one of three primary doctrines:

1. *Absolute ownership*—English rule.—This gives the landowner unlimited right to recover ground water from under his land in any amounts and without restriction as to the manner in which it is used, or where it is used. This doctrine is accepted without specific qualifications in North Dakota, South Dakota (except, possibly, for artesian waters), Texas, Wyoming, and Oregon (with exception of ground water without reasonably ascertainable boundaries, in the eastern part of the State). It is accepted with minor qualifications in Montana; it has likewise been accepted in Arizona although the court has indicated a preference for the rule of reasonable use.

2. *Reasonable use*—American rule.—This gives ownership of percolating waters to the owner of the overlying land, but requires that such water must be "reasonably used" with regard to similar rights of other owners drawing from the same supply. This doctrine applies with varying degrees in California, Nebraska, Oklahoma, and Washington. The California rule is the most highly developed; it is an adaptation of the principle of reasonable use, known as the rule of correlative rights, under which each landowner is entitled to a reasonable proportion of the common supply in the event of shortage.

3. *Appropriation doctrine.*—This newer doctrine, developed in connection with surface streams, has been adapted in some States to the use of percolating ground waters. It recognizes that the percolating ground waters are owned by the public, but are subject to appropriation by individuals for beneficial use on a "first come, first served" basis. The waters need not be used on lands which overlie ground-water supply. Nonuse, under most of the statutes, may cause the right to be forfeited. This doctrine applies to all ground waters in Idaho, Nevada, and Utah; to ground waters with reasonably ascertainable boundaries in New Mexico and eastern Oregon; to ground waters tributary to watercourses in Colorado; to surplus ground waters above the reasonable needs of overlying lands in California.

It will be noted that the appropriation doctrine does not always apply to percolating ground waters in a State, even though it may apply to surface streams or to underground streams.

In several States the rules pertaining to percolating ground water are not well defined, or are a combination of several doctrines. In Kansas, for example, absolute ownership under common law was first recognized. Later, laws were enacted making all subsurface waters west of the ninety-ninth meridian subject to appropriation. Still later, a law was passed specifically placing ownership of ground water, underground streams, sheets, and lakes in southwestern Kansas subject to ownership of the overlying lands.

New Mexico's Laws

One of the few States with effective modern laws covering ground water, written on the basis of modern knowledge of hydrology, is New Mexico, a State that depends on its ground water for a substantial share of its agricultural production.

The Constitution of New Mexico definitely advances the appropriation doctrine for surface waters, stating:

> The unappropriated water of every natural stream, perennial or torrential, within the State of New Mexico, is hereby declared to belong to the public and to be subject to appropriation for beneficial use, in accordance with the laws of the State. Priority of appropriation shall give the better right.

And regarding beneficial use, the constitution says: "Beneficial use shall be the basis, the measure, and the limit of the right to the use of water."

New Mexico enacted a statute authorizing the appropriation of ground water in 1927, but because of a technical error this was declared unconstitutional in a decision which, however, laid the basis for the passage of an act free from technical objections. Subsequently, in 1931, in line with the court decision, the present ground-water law was passed. The law has been carefully administered and has proved to be highly beneficial in preventing overexpansion of ground-water areas, and in encouraging rehabilitation of areas that previously were on the downgrade and were threatened with serious losses through depletion of the water supply.

This act declares: "Waters of underground streams, channels, artesian basins, reservoirs or lakes, having reasonably ascertainable boundaries" to be public waters, subject to appropriation for beneficial use. The terms of the law thus apply to most of the ground water of the State, except for vagrant, diffused flows.

Under this New Mexico law, the process of obtaining a right to use ground water is as follows: Persons intending to drill wells for irrigation or industrial uses of water make application to the State engineer, who administers the water laws. The applications are published, and objections may be filed against them. If no objections are filed and the State engineer finds that there are available unused waters in the designated area he may issue a drilling permit to the applicant, subject to the rights of previous appropriators from the water source. If protests are filed, hearings are held to obtain the facts of the case, on the basis of which the permit is granted or denied. Appeals from the decision of the State engineer may be taken to the courts.

The water right so obtained is effective only as long as it is beneficially used. Water rights that are not exercised for 4 consecutive years are forfeited. The State engineer can establish ground-water districts, can set limits on the amount of water that can be appropriated in a district, and exercise police powers to prevent waste.

A bumper sorghum crop produced by irrigation in a drought year on the Plains. To the Plains farmer, a dependable water supply to tide him over the dry years may mean the difference between success and failure.

Ground Water—How It Has Been Used

Land, Water, and People

Any permanent stability of people on the land requires that they achieve a practical, long-range balance between land and water. Such balance sometimes occurs through exceptionally good luck, but usually it can be obtained only through thoughtful planning for wise use of both land and water.

In the humid and subhumid parts of the United States this land-water balance was not hard to bring about; in all except the occasional drought years the amount of rainfall is just about right for crops. In some areas drainage—getting rid of excess water—has been more of a problem than lack of rainfall.

However, in the arid and semiarid regions of the West, where water—rain, surface stream flow, and underground water—is definitely a limiting factor, where there is more good land than water, farmers must recognize the limits of their water supply and maintain a safe margin, or their security may be lost in a few swift changes of the weather, or by depletion of the water supply.

Mere luck has not proved to be very effective where pressure for development of new lands for farms, and lack of information as to the nature and amount of the water supply, have led to overdraft of this resource. The farmer whose irrigation pump begins to falter in its delivery of water and to "suck air" while his crops and orchards burn up under the summer sun, may think that his luck has run out. Actually, the trouble may go back to lack of planning for conservative use of the common water supply at the time it was being developed.

Up to the very present, the growth of ground-water irrigation, which now serves about 2,000,000 acres, has been a hit-or-miss expansion, a gamble by the individual farmer that he could find a water supply and use it profitably on his land.

Planning Needed—But How?

Until recently little information has been available as to the nature and amount of ground water as far as the individual farmer was concerned; no mechanisms were provided for planning the best use of this resource; little or no legal regulation existed to prevent permanent damage to the underground supply, or to guard against overexploitation by a few at the expense of the many. The man who takes water out of a stream—a definite, visible supply of water to be divided among a certain number of users—has long had certain rights and has had to observe the rights of others. But the man who drills a well into the invisible, slowly percolating flow of ground water has had to take his own chances; if he found water he could use it as he pleased, even though he might be draining the supply from under his neighbors' lands.

Invisible Limits

The importance of ground water in the West long has been clearly recognized. It could not be overlooked by the hundreds of communities whose only tie to the productivity of the soil is the stream of water that flows from the pump. There are hundreds of such areas, growing crops that range from avocados to alfalfa, where failure of the ground-water supply would bring im mediate break-down of a profitable farm economy, would send now self-sufficient farm families searching for new homes, and would cause now-thriving towns to wither away. In some ground-water areas, the relatively small section of irrigated land is the keystone of an economy that radiates over thousands of square miles: as for example, where the grain and the feed raised in an irrigated valley provide stability for a vast livestock industry on the ranges that surround it.

A Water savings account.—The types and conditions of ground-water occurrence vary widely. In the southern High Plains the water supply is "historic," that is, the supply underground was built up through the slow accumulation of the minute fractions of the rainfall that escaped evaporation or plant roots, and seeped into the ground-water strata. Such a "historic" supply is similar to a savings account—it is built up by small annual additions. If depleted it requires many centuries to accumulate again.

A Water income.—Other ground-water reservoirs may be recharged annually, as the Sandhills of Nebraska. The Sandhills, covering about 12⅓ million acres in north-central, central, and west-central Nebraska, act as a gigantic blotter, and absorb most of the rain that falls on them. It is estimated that the Sandhills store more than 500,000,000 acre-feet of water, 16 times as much as Boulder Dam. Part of this storage, about 4,000,000 acre-feet, is released throughout the year at a fairly uniform rate to rivers that run by the lower edge of the Sandhills and in the invisible percolation through the slopes and valleys of the underground drainage system.

Here the ground-water supply is similar to an ample but fixed income evenly distributed throughout the year. The problem of the ground-water users is to see that they live within that water income, that it is fairly divided, and not wasted.

Failure to Plan—Failing Resources

The West is crowded with examples of the need of long-range land-water planning. Even in the old days, when ground-water resources were comparatively untouched, the unplanned, ruggedly individualistic method of development did not work too well for either the individual or the community. Large investments made by hopeful pioneers frequently were wiped out because the water supply proved to be undependable. In a number of cases the first few successful wells touched off a booming expansion of irrigation far beyond the safe yield of the water supply, and today only the gaunt skeletons of ghost towns and the barren fields that have gone back to sagebrush and cactus mark what might have been a smaller but still flourishing farm community had the facts been known about the water supply and had the development been laid out with due consideration of these facts.

Santa Clara Valley

An example of tragic waste of a magnificent resource is the Santa Clara Valley in California, which within less than a generation changed from a region of plentiful water, with many free-flowing wells, to an area in which the water supply neared exhaustion, and in which huge investments in irrigated land and equipment were threatened with complete loss. In addition, startling damage resulted from settling of the valley floor, caused by depletion of the underground reservoir.

The Santa Clara Valley extends south from San Francisco Bay. Ringed by mountains, its floor covers 200,000 acres. The valley was first settled in 1777 by Spaniards, who grazed their cattle and dry-farmed, apparently unmindful of the splendid water supply beneath the soil. However, soon after the American occupation in the 1850's artesian water was discovered and used for irrigation. The artesian belt was roughly triangular in shape and extended from San Jose to San Francisco Bay. By 1910 there were about 1,000 flowing wells. In the meantime, starting in the 1890's, pumped wells were sunk in the valley fill above the artesian belt.

The climate of the valley is suitable for a wide variety of crops. Fruit growing became a major industry as long as 60 years ago. Orchards at first were dry-farmed, but when the trees developed to full size, they needed irrigation to sustain them. As no perennial streams were available, ground water was pumped for these orchards and later its use spread to many other crops. The average pumping lift originally was only 35 feet.

Nothing was done to regulate the draft on the ground water, nor to increase its recharge, which is largely dependent on percolation into the ground of intermittent storm-fed streams rising in the mountains. Much of the water of these storms was permitted to rush down the stream channels, causing severe floods, and had little chance to sink into the valley fill. Measurements during 1931-32 showed that out of 155,000 acre-feet of run-off from the watershed, only 45,000 acre-feet went into the underground storage and 110,000 acre-feet went to waste in San Francisco Bay. Twenty-nine percent was saved; 71 percent was wasted.

After 1915 the water situation became serious. Nothing was done to increase the supply. Pumping expanded rapidly. From an average of 25,000 acre-feet per year in 1915 it jumped to more than 134,000 in 1933. The water table dropped about 5 feet an irrigation season until 1933, when it fell 21 feet in a single year. In 27 years the water level dropped an average of 130 feet over the entire valley. In 1934 the average pumping lift was 165 feet. Irrigation became more precarious and extremely costly.

When the water level started declining, artesian wells gradually ceased to flow; the last one closed down in 1930. In many cases pumps were put on artesian wells, or other wells were drilled for pumping. By 1930, more than 2,000 wells were pulling water out of the valley fill.

The failure to plan and regulate the use of water in this valley has caused irreparable loss. The water in the valley fill was aiding to support the lands above it, and as it was removed the fill was compressed by the weight like a squeezed-out sponge. The valley floor settled—5 feet in 20 years.

The sinking caused great damage to buildings, pipe lines, orchards, and streets. No accurate estimate of the cost has been made, but undoubtedly it runs into millions. Worst of all, the settling compressed the aquifer and permanently reduced the storage capacity of the underground reservoir by about 500,000 acre-feet.

From the beginning, engineers, hydrologists, and others familiar with the situation sought to warn the public of the impending disaster in this valley. But popular sentiment would not support them. In 1922 a $4,000,000 conservation plan was voted down by 7 to 1.

Yet, in the 20 years that followed, farmers in the valley spent more than $16,000,000 for new wells, more powerful pumping equipment, and increased power.

Remedial action finally started in 1934 when there was no longer water available in some parts of the valley at any price, and when, as the fresh water was displaced, some of the wells began pumping salt water seeped in from the Bay.

A $3,000,000 project was undertaken in 1934 and completed in 1936 to build 5 retention reservoirs to hold back 49,000 acre-feet of flood waters. A number of percolation reservoirs, canals and water-spreading beds also were installed. Water is released gradually from these reservoirs throughout the season, and about 43,000 acre-feet annually percolates downward and becomes ground water. Through this system, the water table has been built up about 65 feet in the past 6 years. Average pumping lifts are now about 85 feet—an improvement over 1934 conditions, but still far from the conditions that originally existed in this valley.

Winter Garden Area

Another area that has gone through the process of overexpansion, followed by a disheartening slump as water supplies were threatened, is the Winter Garden area of Texas, a district covering parts of 10 southwestern counties on the Gulf Coastal Plains. As implied by the name, the Winter Garden area is blessed with an unusually favorable climate. With water for irrigation, high-value crops, such as spinach, onions, broccoli, melons, and citrus fruits, can be produced.

Although crops were cultivated in a small way near San Antonio as early as 1718 by the Spanish missions, irrigated farming is a relatively recent development, beginning during the first World War. The area is underlain by the Carrizo and associated sandstones, which absorb water at the base of the Balcones escarpment and dip southeastward below the surface, extending out below the waters of the Gulf of Mexico. In the early irrigation development period of the Winter Garden area these strata when tapped provided an excellent flow of artesian water, and the cost of irrigation was relatively low.

Despite danger signs—the physical facts regarding the water supply were fairly well known—more wells were put down and more land brought under irrigation until the peak was reached in the late 1920's when more than 58,000 acres were being irrigated with ground water. Large long-time investments had been made by landowners in irrigation plants, orchards, and improvement of their lands.

With this large an acreage drawing on it, the water supply was being depleted. The artesian flow dropped off, then stopped. Pumps were installed. The water level continued to decline, and it became necessary to pump against heads as high as 150 and 160 feet, greatly increasing the cost of irrigation. As the water level declined and costs of operation went up, many farmers—in fact nearly half of them—were forced out of irrigation, with heavy losses. The area irrigated shrunk to around 27,000 acres. At present it appears that the current reduced rate of irrigation is fairly well balanced with the water supply, and there seems to be no tendency for the water table to decline further.

In the High Plains

Nowhere is water more appreciated than in the High Plains, a land of sheer immensity that sweeps to the horizon and beyond, where everything, even the droughts, is on a grand scale. The land is plentiful and fertile, but the semiarid climate has limited the plainsman's choice of crops and made it difficult for him to build a stable agriculture. With losses and hardships of the great drought of the 1930's still fresh in mind, the Plains farmers today are more anxious than ever in their long search for dependable water supplies.

On the High Plains, one runs into the myth of "inexhaustible underground rivers." These are supposed to rise in the Rockies and flow beneath the Plains. The fact is, of course, that all of the ground water on the High Plains has a common source—the rain and snow that fall on the Plains' top. As that rain is limited—and the amount that seeps into the ground water through sinks, sandy stream beds, and sand-dune areas is but a small part of it—the yearly recharge of this underground reservoir is extremely small. The ground water does move, but hardly as a river. It seeps to the east and southeast, down the slope of the underground drainage, at a speed estimated to be 200 to 300 feet a year.

The ground water of this region was in natural balance before the pumps began to pull it out. The natural discharge, just about equalling the recharge, is through springs and seeps along the eastern escarpment, or drop-off, of the Plains, partly through trees and plants whose roots could reach into the water table in shallow-water areas, and partly through evaporation from water-table lakes.

In other words, the sand and gravels under the High Plains in this region make up a tremendous storage reservoir in which each resident has a deep and lasting interest. The natural inflow and outflow of the reservoir are balanced, so that any water taken out comes from storage, and reduces the common supply by just that much. The greater the draft on the reservoir, the faster the water level will recede. As a water table recedes the cost of pumping goes up. This puts some vital questions squarely up to the water-users:

> Do you want this capital resource to be depleted in a few years, or make it last on a "crop insurance" basis for many years? Should this resource be used intensively by a few, or should it be divided as fairly as possible for the benefit of the whole regional economy?

Scott County Basin.—From all surface indications, Scott County, Kansas appears to be as high and dry as the rest of the High Plains; its flat treeless lands lie ruler-straight against the horizon. But underneath it is different. An upthrust of impervious rock dams the sluggish eastward percolation of ground water, forming a subterranean pool under about 115,000 acres. In this shallow-water area, pumps can tap a supply at 75 feet or less, as compared to 160 to 200 feet for the surrounding country. Perhaps it has taken hundreds of years to build up this pool. It is recharged entirely from rains and snow on the High Plains to the west. The ground water escapes from the basin through natural discharge into the Smoky Hill river to the north, and northeastward through a pervious formation.

The drought of the thirties revived interest in irrigation in this area, and it was found that irrigation was profitable with modern equipment. By 1940, about 17,000 acres were being irrigated to grow sugar beets, potatoes, grain sorghums, and wheat. Pumping lifts were 50 to 120 feet, including draw-down. In that year the heavy Dieselpowered turbines pulled more than 34,000 acre-feet of water from the basin.

The limit of water use in this area is the water supply; not the land, of which there is plenty suitable for irrigation. However, at present with only a part of the land in the basin being irrigated, the water table has declined sharply, and in some places pumps are operating close to the border line of profitable recovery.

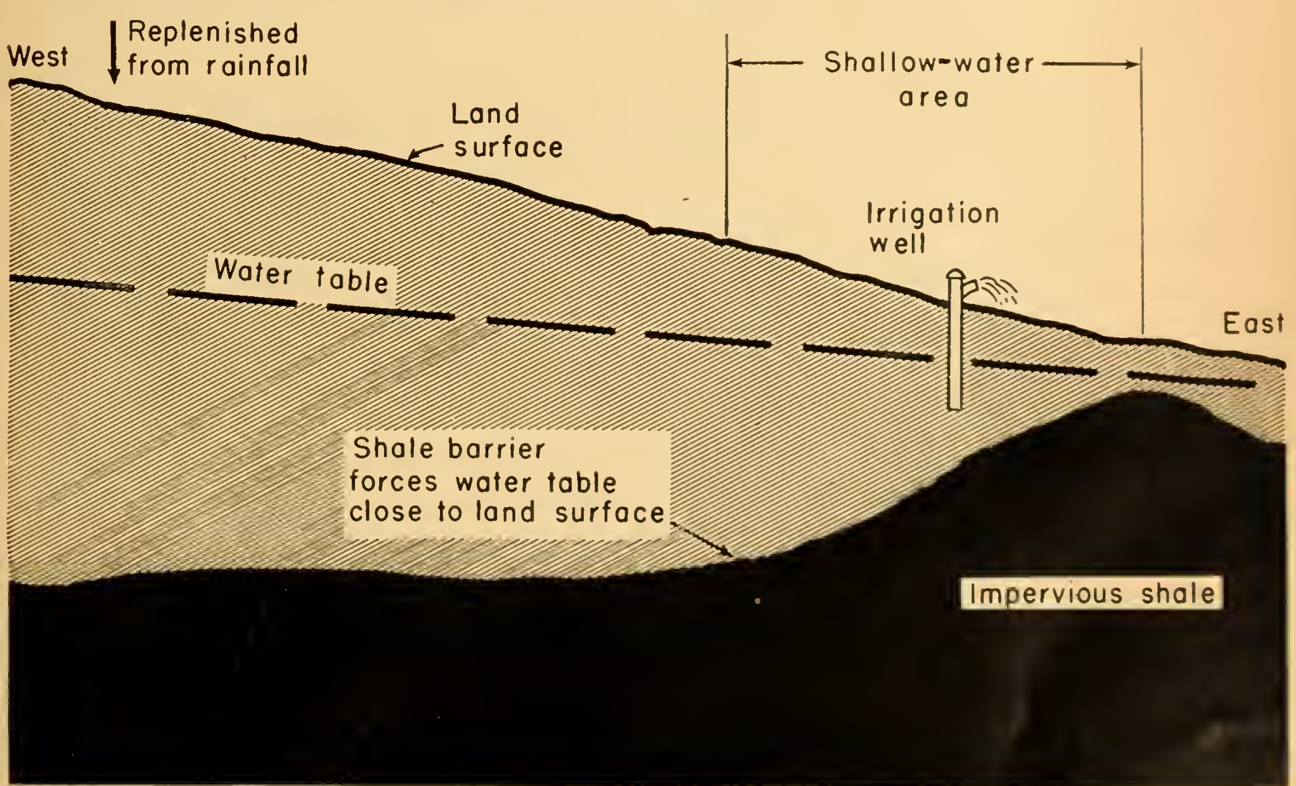
The life of irrigation in this area, where a dependable "crop insurance" water supply can do much to stabilize the whole community economy, depends for all practical purposes entirely on the rate of pumping. If sparing use is made of the water, as a supplement to dry farming and on crops that do not require a great deal of water in addition to rainfall, the supply may hold out for a long time. If, on the other hand, danger signals are ignored, and water is pumped excessively for large acreages of "heavy-duty" crops, the water table will sink rapidly, wells will have to be deepened, and eventually may not be able to reach a supply at levels from which it can be profitably pumped.

In Texas.—In the Texas portion of the High Plains, where many of the shallow-water basins of this region are found, a total of only 296 wells were drilled from 1911 to 1934. This contrasts with 300 wells drilled in 1935 and 1936, 550 in 1937, 350 in 1938, 200 in 1939, and probably 400 in 1940.

Plainview-Littlefield-Lubbock District.—This shallow-water basin covers approximately 1,500 square miles in the vicinity of the towns of Plainview, Littlefield, and Lubbock, Texas. It is one of the largest of such areas in the High Plains, and is the scene of an unusual expansion in water use. Throughout this district ground water is found in the sands and gravels at depths varying from 40 to 80 feet, and is pumped from 45 to 110 feet, including draw-down.

The first irrigation wells were sunk in this district in 1911. By 1930, only 2,500 acres were being irrigated from 100 wells. The drought of the

Cross Section of Scott County, Kans., Basin



1930's so impressed farmers with the need for irrigation that by 1937, more than 800 wells were pumping in the area, spreading water on 117,000 acres. By 1939, the number of wells had increased to 1,165, irrigating 160,000 acres.

In the early stage of the irrigation development, the water drawn from the ground was generally used for the production of crops that are important to the general economy of the area, such as feed crops, seed crops, grain, and some cotton. These also happen to be crops that can be produced with moderate use of water.

However, in recent years potato production, which on the High Plains uses more water per acre than grain sorghums, Sudan grass, wheat, or cotton, has been making heavy inroads on the established irrigated acres. In addition, most of the new wells have been sunk almost entirely to supply water for potato-growing.

Effects of Unplanned Development

The haphazard growth of ground-water irrigation has led to many maladjustments, inequities, and inefficiencies. Frequently, the use that seemed most expedient or profitable to the fortunate individual, or individuals, who first found and developed the water supply has not conserved the supply, nor has it promoted the general stability and good land use of the area in which the water was found.

In summary, the principal problems in ground-water use, are:

1. *Poor distribution.*—The development of water use has been ragged, and often the pattern of land ownership has played a more important part in determining distribution of the water supply than have the best interests of the whole basin. For example, this has sometimes resulted in overdevelopment of ground water in the upper parts of a basin, making water unavailable for use, or severely restricting the use, in lower and perhaps more productive lands of the same basin.

2. *Waste and inefficient use.*—Ground-water supplies are by no means used as efficiently as they might be. Waste is great because of lack of technical information, lack of regulation, and use of inefficient equipment and farming practices. The writer has visited areas where for 20 to 30 years, or more, flowing wells have been allowed to run all year long, pouring 6 or 7 acre-feet of water per acre on wild hay. These lands originally were devoted to cultivated crops, but constant soaking has caused alkali to seep to the surface, destroying the value of the land except for wild hay. Also, the constant outpouring of these wells has lowered the water table higher up the valley. If controlled, the supply now being in large part wasted would be available for more productive lands that now have too little water or none at all.

There is a natural tendency among new irrigators, particularly those who have been dry-land operators, to believe that if a little water is a good thing, more is even better. Experiments carried out at the Texas Experimental Substation No. 8, Lubbock, show that farmers in the High Plains, for example, usually apply too much. It is common in this region to pour approximately an acre-foot of water onto grain sorghums. But the substation's tests show that the highest yields for the least cost are obtained by applying just half that much water at the right time. It was found that under a system of irrigating with 3 inches of water just in advance of planting in late May or early June, with another irrigation in July, grain sorghums yielded an average of 52.1 bushels, as compared with 17.7 for nonirrigated. Using 9 inches of water, instead of 6, increased yields only 7 bushels an acre above the 52.1-bushel yield—not enough to pay for the extra water.

3. *Inefficient equipment and design.*—Poor layout of irrigation ditches, improper construction, and inefficient equipment contribute to high water costs. Where the land is not laid out correctly, or not properly leveled, too much water goes onto some parts of the land, and not enough on others. Faulty ditches allow water to leak away, or expose an unnecessarily large surface to sun and air, causing high evaporation losses. Inefficient equipment or poor use of equipment add to the farmers' operating costs, and sometimes result in the failure of irrigation enterprises. The farmer's pump may not be suited to the particular conditions of the area, it may be used in the wrong way, or the pump and power plant may be allowed to run down until they deliver only a part of the water needed.

4. *Lack of land-water coordination.*—Some of the most serious difficulties in ground-water irrigation come from failure to coordinate water and land use. Working out the proper relationship

between land and water use requires, first of all, assembly of the basic facts regarding the amount of available resources and the purposes for which they are capable of being used most effectively, how much land is suitable for irrigation, how much can be irrigated without impairing the water supply, and which land and crops should be given preference. Then, there must be some organizational machinery by which the land users can get agreement on these facts and needs, and plan their operations accordingly. And finally, there must be some controls to guide development along these lines. Until agricultural land use planning committees were established, the individual farmer frequently had no means of assembling the facts, of planning, or of putting plans into effect; he had no machinery for group land-water planning, and organized technical assistance.

Under these circumstances, the best long-range water-land relationship frequently has been overlooked. High-cost water has been applied on lands of low productivity while better quality lands have remained dry. The expense of developing and handling water has encouraged individual users to concentrate on intensive high-value cash crops, such as fruits and vegetables, although the welfare of the community as a whole might require entirely different crops, such as alfalfa, grains, and sorghums, to supplement or to promote a grass and livestock economy in the unirrigated region surrounding the basin. The spectacle of ranchers sacrificing foundation livestock during a drought while the irrigated lands in nearby valleys were producing sugar beets or potatoes instead of feed and forage has occurred numerous times in the semiarid Plains. The individual irrigators may make more by growing such crops, but their gain may be more than offset by the loss to the area as a whole.

In some States there has been and still is uncertainty as to who has the right to use ground water, how it may be used, and how much may be used. Wasteful exploitation of some of the most valuable ground-water basins has proceeded unchecked, not because any individual farmer wanted to wreck the resource, but because each knew that if he didn't use all of the water he could pump, others would. The lack of administrative control or regulation of ground waters in various Western States has been one of the principal obstacles to the proper planning of conservational development and use of this limited resource.

Hydrologists are well aware of the interdependence of surface and ground-water supplies, and the legislatures and courts of some States have attempted to correlate these interconnected rights of use, but in other jurisdictions there has been little or no recognition of this important relationship. Surface streams are fed in large part by seepages from the underground reservoir, and in places the streams lose water into the ground; yet the rules which govern the rights of use of surface waters and of ground waters were developed independently, at least in the early stages. A description of the evolution of ground-water law, and the various types of legal and administrative control operating in the West will be found in the section on Ground-Water Law, pages 17 to 19.

Planning Pays Dividends

Where the people in an area have thoroughly appraised their water and their land resources, and have sought to bring about balanced use they often have been able to achieve and maintain a stability of water use unmarred by wild booms and disastrous slumps. Some communities, threatened with over-exploitation of ground-water resources have been able to restore a balance before it was too late, as for example, in the Roswell basin in southeastern New Mexico.

The Roswell basin is a valley 60 miles long and six to 12 miles wide in a 15-inch rainfall belt. It was pioneered by cattlemen in the 1870's and still might be a sparsely settled ranching, dry-farming country, with a small amount of irrigation from the Pecos River, had not artesian water been discovered in 1891.

The first well flowed only a gallon a minute, but wells spurting forth 500 to 1,500 gallons a minute soon were common. By 1905 there were 485 artesian wells. As the artesian pressure did not decline, some people in the valley believed the supply was inexhaustible, that an "underground river" had been tapped, and development could continue interminably. The sight of vast fountains springing from the ground could easily lead to that impression. The largest artesian well in the valley, and probably the largest in the world, flows 9,225 gallons a minute, or more than 13 million gallons a day.

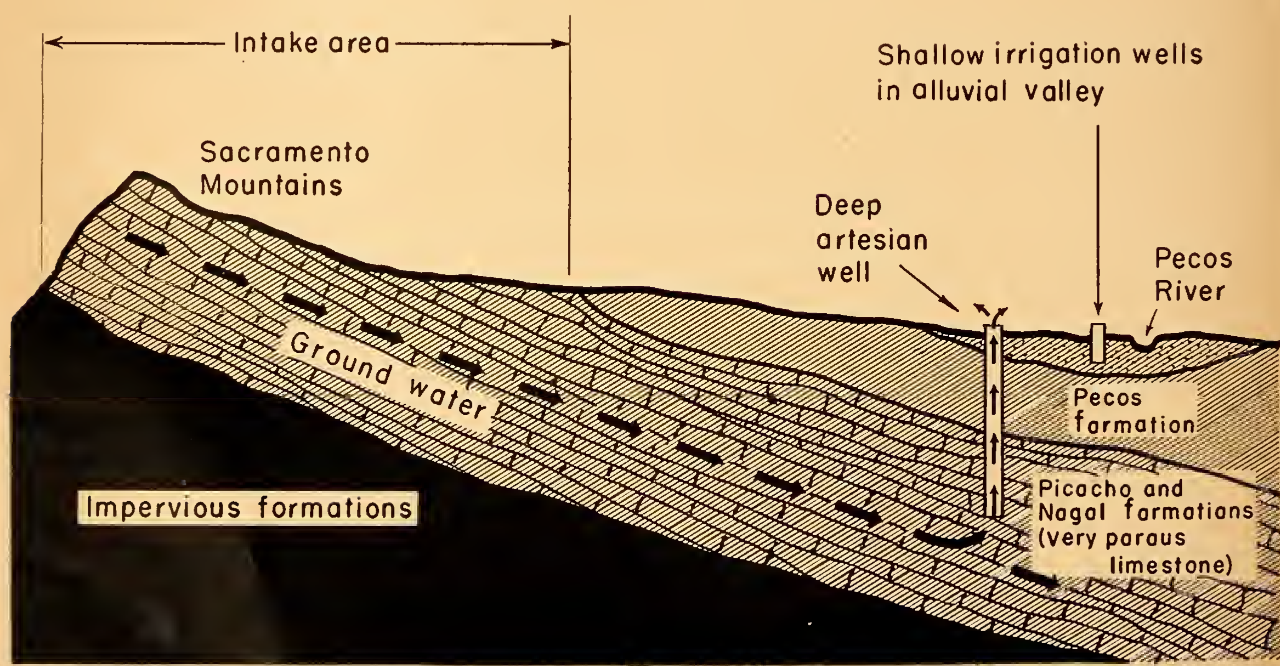
The source of the artesian flow, as shown by the United States Geological Survey investigation of the area, is a thick stratum of cavernous limestone that heads up in the extensive upland west of the valley, and slopes down under the Roswell Valley at depths of 300 to more than 1,000 feet. The limestone is an ideal natural water pipe. Water from rain and snow over the outcrop area sinks into this limestone conduit. Streams, carrying surface runoff from the mountains still farther west, pass over the outcrop and pour part of their discharge into this permeable bed. Then, as the outcrop dips down under the earth's surface, it is covered by a relatively dense stratum, confining the layer of water under artesian pressure. When tapped down in the valley, the water has pressure enough to raise it 20 or 30 feet above the surface.

The artesian water was exploited extensively from 1906 to 1910, with nearly 600 new wells being drilled. Then the myth about an endless supply was blown up. The artesian head declined rapidly, and by 1916 many wells were being abandoned and others had to be put under pump. By 1925, the area of artesian flow had shrunk from 663 square miles to 425, stranding several formerly prosperous communities.

The Roswell artesian water supply might have continued to fail had not the desperate situation stimulated enactment of a State ground-water-control law in 1927, on the basis of a carefully conducted investigation of the water-supply and land conditions. The law declared the artesian waters to be public waters under the supervision of the State engineer, and provided for establishment of artesian conservancy districts, with authority exercised concurrently with that of the State engineer, to regulate the use of artesian waters and to prevent waste. The law was later declared unconstitutional by the State supreme court because of a technical error, but was rewritten and reenacted in 1931. Under the power of this act, State engineer and the conservancy district have permitted no new wells to be drilled, except to replace existing wells which leak, the old wells then being plugged.

It also was found that a great deal of artesian water was being wasted. In many old wells the original casing had corroded, permitting water to escape into the valley fill. Many wells had been

Idealized Cross Section of
Roswell Artesian Basin



abandoned without being plugged, and these were draining away valuable water. In 1931 a well-plugging program was started by the Roswell conservancy district in cooperation with the State and WPA. By 1941 more than 500 leaking wells had been plugged. The conservancy district watches all wells closely, and if a user does not use water beneficially, that is, if it is allowed to go to waste, the well may be closed down; if a well is not used for four consecutive years it may be declared abandoned and the water right forfeited.

As a result of the elimination of waste, the plugging of old wells, and the regulation of use, the artesian head in the Roswell basin is now recovering, despite nearly a decade of generally subnormal rainfall over the intake area. A number of artesian wells that had ceased to flow are now pouring out water again. All evidence points to the conclusion that the use of water in the basin has been balanced with the supply, and the agricultural economy dependent on artesian water in the basin has been stabilized.

The farmers of the Roswell basin also irrigate from the surface flow of the Pecos River, and from shallow ground-water supplies, but the artesian flow is the most important source of water. About 115,000 acres are irrigated in the valley, of which 43,000 are watered from shallow ground water, 9,000 from surface water, and 60,000 from artesian water. Actually, some of the shallow-water supply *originates* as artesian water, as the shallow unconfined ground water is recharged in part by upward percolation of artesian water leaking through the confining stratum, and in part from return flow from artesian irrigation.

The Platte River Valley

This broad, flat valley, from 5 to 25 miles wide, cuts through the middle of Nebraska from west to east and has probably the largest supply of easily available ground water of any area in the United States. It has been estimated that from the junction of the North and South Platte Rivers in western Nebraska, on down the main valley for about 150 miles to Central City, there are about 24 million acre-feet of water under the valley at all times.

This reservoir of ground water is replenished from three sources, subsurface flow from the Sand-hills to the north and west, seepage from surface flow of the Platte River, and direct percolation from rainfall on the basin. The aquifer, or water carrier, is a coarse, porous gravel that yields water readily.

Irrigation from ground water had its start in the Platte Valley during the first World War, and has expanded steadily since. By 1930 there were 491 wells in the valley of the Platte or its tributaries, irrigating 23,400 acres. In 1940 there were 2,000 wells, irrigating about 120,000 acres.

The water table throughout the Platte Basin is within a few feet of the surface on the lower lands, and pumping lifts, including draw-down, vary from 16 to 50 feet, with the average around 30. The low lifts allow farmers to use low-head "pit" pumps and inexpensive power plants, keeping the average investment for a pumping plant down to less than $1,000.

As a rule the land use of the Platte Valley fits well into the regional agricultural economy, which is predominantly dry-land wheat farming and cattle ranching. The principal irrigated crops are corn, sorghums, alfalfa, wheat, sugar beets, potatoes, and small amounts of vegetables for local consumption.

The evolution of ground-water irrigation in the Platte Valley has been slow and unspectacular and has proceeded with regard for the large fund of information on water resources assembled by the State of Nebraska. As yet there have been no signs to indicate that the water supply is being seriously depleted.

Mud Lake Basin

This area of 2,500 square miles in southeastern Idaho is a good example of the manner in which ground water may be recovered under favorable conditions from lava beds. The basin is essentially a high plain, a part of the Snake River Plain surrounded by mountains. Its climate is distinctly arid; annual rainfall varies from 10 to 15 inches.

Underlying beds of lava are close to the land surface and yield excellent water in vast flows. More than 40,000 acres of land in the region are irrigated by artesian and pumping wells or diversion from Mud, Rays, North, Spring, and Hamer Lakes, which are in reality surface exposures of the water table. Irrigation is centered in 400 square miles around the lakes, where there are

250 flowing or partially flowing wells and 350 pumped wells.

The ground water is replenished in part by streams entering the basin from the Centennial and Beaverhead Mountains to the north, which lose a part of their flow into the fissured and cavernous lava beds. This inflow has varied from 15,000 to 80,000 acre-feet a year. Also, a part of the water from Henrys Fork of the Snake River put on lands higher up to the east, drains away into the ground water, and ultimately passes into the Mud Lake Basin.

The lakes in the basin serve as "gages" of the ground-water supply, as they rise and fall with the water table. The flow and pumping of existing wells in the basin, and drilling of new wells is carefully regulated by the State, to prevent overuse of the supply. The watermaster for the district, in charge of regulating the amount of pumping, is able to cut down or increase the

The stream of water that flows from the pump is the only tie to productivity of the soil in hundreds of communities, as in this Arizona valley where less than 10 inches of rain falls yearly.

allowable pumping on the basis of the lake level, keeping use balanced with available supply. Mud Lake also is used as a seasonal storage reservoir, from which water is diverted to large acreages. As the water level of the lake drops, pumped wells provide the needed water.

The water-bearing stratum is tapped by wells at depths of 30 to 100 feet over the area. Artesian flows range from a few gallons up to 1,000 gallons per minute. Pumping yields are high, with some wells producing more nearly 500 gallons per minute with only a few inches of draw-down. Wells sometimes are drilled as closely as 3 feet apart without interference with each other's flow.

Several unusual "gallery" type wells are operated in this basin. The gallery consists of a wide ditch dug down 20 or 40 feet to the lava bed, with a series of holes drilled into the lava to a depth of 40 feet or more. The water gushes out of the lava with artesian pressure, and is pumped up into a main irrigation ditch by a battery of centrifugal pumps. One such gallery, serving several thousand acres, delivers more than 67,000 gallons a minute.

GROUND-WATER CHECK CHART

If you plan to irrigate from ground water—

CHECK THESE IMPORTANT POINTS FIRST

A. *Availability, quality, and depth of water:*

Yes No

(1) Is a plentiful supply of water available? ☐ ☐

(2) Is available water of the right quality to permit production of the desired crops? ☐ ☐

(3) Is water available at a depth that will permit economical pumping? ☐ ☐

These are basic considerations. A farmer should know whether he has access to a dependable water supply, what types of crops can be grown with the quality of water available, and how much it will cost him to recover water from the depths at which it is found.

B. *Trend of the water table:*

(1) Is the water table stable? ☐ ☐

(2) Is it rising? ☐ ☐

(3) Is it declining? ☐ ☐

(4) Is development in the area likely to bring about withdrawals of water in excess of the natural recharge? ☐ ☐

The trend of the water table is a valuable clue to whether additional development is safe. A declining water table is a warning of danger. Water users should beware of developments that threaten to exceed the natural recharge of an area.

Merely applying water to soil does not assure abundant production. Many physical and chemical changes in the soil occur as a result of irrigation: under some conditions fertility may be leached out of the soil or may be locked in it under irrigation. Some soils lose water rapidly. A prospective irrigator should obtain complete technical advice as to the suitability of his land for irrigation before making large investments in water development.

F. *Markets for products:*

(1) Is a dependable market or use available for the types of crops to be grown under irrigation? ☐ ☐

The demand for the types of crops that can be grown on a farm under irrigation should be carefully investigated. Often local demand for specialized products can be quickly satisfied, and hence the situation in nation-wide markets should be taken into account. The irrigator should consider carefully how his irrigated production fits into the operations of the rest of his farm and the economy of his area.

C. *Legal or natural protection:*

Yes No

(1) Do the statutes or court decisions provide legal or administrative protection in your area against depletion of water supplies, or ☐ ☐

(2) Is the area protected against over-expansion and depletion by "natural" controls? ☐ ☐

The wise operator will find out the degree of legal or administrative protection available to him before he makes heavy investments in water development. Legal protection can come through legislative enactments or court decisions. The mere presence of statutes on the law books, however, is not in itself protection: It is essential to find out how effectively the laws and regulations are administered.

In some areas irrigators have "natural" protection, and legal protection may be unnecessary. This is true where the supply of water exceeds the lands suitable for irrigation. Caution: Naturally protected areas are few.

D. *Cost of operation:*

(1) Will the prospective production under irrigation bring enough returns to pay the increased costs of irrigation farming? ☐ ☐

The financial returns from irrigation must be in excess of the cost of operation, including the cost of water, or the project will fail. Many would-be irrigators underestimate the total operating costs of irrigation farming. The acre-foot cost of water is dependent upon a number of factors, including the cost of fuel or electricity, depths from which the water must be pumped, efficiency of plant design, and interest rates on investment. Each factor should be carefully investigated and the total cost of water determined before an investment is made.

E. *Land requirements:*

(1) Is the land physically suitable for irrigation from the standpoint of contour, productivity, water-holding ability? ☐ ☐

(2) Is the land suitable for the types of crops to be produced? ☐ ☐

GROUND-WATER LAW CHECK CHART

The following tabulation is merely a check chart to indicate in a very general way the water-law doctrines that govern the use of ground waters, both percolating waters and waters flowing in definite underground streams, in the 17 Western States. Because of the indefiniteness of some statutes and because in some States it is uncertain which doctrine applies or to what extent a recognized doctrine applies, it is impossible to present a tabular picture of the ground-water law situation that is brief, and at the same time precise and wholly accurate in all details.

Although limitations of space do not permit full explanation of all the variations and qualifications of the doctrines, the more important ones are indicated by explanatory notes below. The check (√) indicates the doctrine or combination of doctrines applicable to each kind of ground water and whether by reason of statute or court decision. Clearly, no development of ground waters should be undertaken in any area without further study to determine the exact legal principles that govern the use of such waters.

State	Kind of ground water	Appropriation doctrine		Riparian doctrine	Reasonable-use rule	Absolute-ownership rule	
		Statute	Court decision			Statute	Court decision
Arizona	Underground streams	√	√				
	Percolating waters				(*)		√
	*Although it was held in the decision that percolating waters are subject to rule of absolute ownership, in a dictum the court indicated it favored limitation to reasonable use.						
California	Underground streams	√	√	√			
	Percolating waters				(*)		
	*Under the correlative-rights adaptation of the reasonable-use rule, a common water supply underlying a group of lands may be apportioned to all overlying lands in the event of a shortage.						
Colorado	Underground streams		√				
	Percolating waters		(*)				
	*Percolating waters tributary to a stream are subject to appropriation, but the court has not passed directly on nontributary waters. On the basis of other decisions, however, nontributary waters are probably subject to appropriation.						
Idaho	Underground streams	√	√				
	Percolating waters	√	√				
Kansas	Underground streams	(*)	(*)	√			
	Percolating waters	(*)			(*)		(*)
	*The governing principles are not well defined. In western portion of State, by statute, all natural underground waters may be "diverted" (which may or may not mean they are subject to appropriation), but the statutes also provide that in the southwestern part of the State underground waters belong to overlying lands. By court decision, underground waters elsewhere in the State are owned by the landowner, but there is a trend away from rule of absolute ownership.						
Montana	Underground streams		√				
	Percolating waters						√
Nebraska	Underground streams		(*)	(*)			
	Percolating waters				√		
	*No definite decisions on underground streams, but they are presumably subject to the law of watercourses in the State, that is, the riparian and appropriation doctrines.						
Nevada	Underground streams	√	(*)				
	Percolating waters	√					
	*The statement as to appropriability of waters of underground streams was a dictum rather than a part of the decision.						
New Mexico	Underground streams	√	√				
	Percolating waters	(*)					(*)
	*Appropriation statute applies to underground waters having "reasonably ascertainable boundaries"; waters not having such boundaries are, under early decisions, presumably owned by the landowner.						
North Dakota	Underground streams			(*)			
	Percolating waters					√	
	*Statute provides that landowner owns waters flowing under the surface but not forming a definite stream. He may use waters of definite underground streams but may not prevent the natural flow.						
Oklahoma	Underground streams			(*)			
	Percolating waters				(*)	√	
	*Same as North Dakota. However, notwithstanding the statute apparently providing for absolute ownership of percolating waters, the court has ruled such waters subject to reasonable use by the landowner.						
Oregon	Underground streams	(*)	(*)	√			
	Percolating waters	(*)					(*)
	*Underground streams are subject to law of watercourses, by court decision. By statute, in the eastern portion of the State underground waters having "reasonably ascertainable boundaries" are subject to appropriation. By court decision, percolating waters not having such boundaries belong to the landowner.						
South Dakota	Underground streams		(*)	(*)			
	Percolating waters					√	
	*Same as North Dakota. Court decisions state that surface and underground streams are governed by the same rules, that is riparian and appropriation doctrines.						
Texas	Underground streams	(*)		(*)			
	Percolating waters						√
	*Underflow of streams is subject to appropriation, by statute, and to the riparian doctrine, by court decision.						
Utah	Underground streams	√	√				
	Percolating waters	√	√				
Washington	Underground streams		(*)	(*)			
	Percolating waters				√		
	*By court decision, underground streams are subject to law of surface watercourses, that is, the riparian and appropriation doctrines.						
Wyoming	Underground streams	(*)	(*)				
	Percolating waters						√
	*No statutes or court decisions on underground streams, but presumably they are subject to appropriation doctrine, which applies to "all natural streams."						

Planning for Better Water-Land Use

BECAUSE land and water must be used together, and because they limit each other, planning for water cannot be effective unless it is tied to land use, or vice versa. This may sound like an obvious truth, but it is one that has been largely overlooked in the past.

The *ground-water* resources of the West are particularly in need of wise planning in relation to the land. For one thing, they have not yet been fully developed; the time to accomplish the most by planning is before a resource has been depleted. At the same time, the pressure on water supplies is such that depletion is imminent if not safeguarded against. And not least is the fact that the limit and character of ground water are not generally understood, even by its users, creating the danger of unwitting overexpansion and misuse.

Objectives of Water-Land Use Planning

The objectives of sound ground-water-land use planning are to promote the welfare of both the individual and the group by the highest, most beneficial use of these combined resources consistent with conservation: to establish a ground-water policy for each area on the basis of close study of known facts regarding its *particular* situation, to guide users toward the best long-range use of water in relation to the land, for the greatest, most lasting benefit of the whole area.

Water-land use planning is not a job that the individual farmer can do alone, and it is not a job that others can do without the farmers. It requires the joint effort of farmers, technicians, hydrologists, economists, agronomists, and administrators of local, State and Federal Government programs affecting land and water.

Area Water-Land Use Planning

The process of water-land use planning is well illustrated by work under the Water Facilities Program. This program was authorized by Congress in the Water Facilities Act of 1937 to assist in providing facilities for water storage and utilization in the arid and semiarid areas of the 17 Western States. The act specifically provides that these water facilities should be located where they will promote the proper utilization of lands they are to serve and that no facilities shall be located where they will encourage the cultivation of lands that are submarginal or should be devoted to other uses in the public interest.

In proceeding under the act, the Department of Agriculture recognized that the problems of water-land use vary widely from area to area, and that each natural water-use area, or basin, must be considered as a special case. Such a natural area may be the drainage basin of a stream, or an area where particular water conditions apply because of geologic formations.

When such an area has been approved for planning work under the Water Facilities Program, the first step is to bring groups of local farmers together with land and water technicians. Together, they determine the amount of available resources, their character, and the purposes for which they can be used most effectively, to find out the proper water and land uses and the types of water facilities appropriate for the area. After this

A Picture Story of Water Development

1. Here is what Grant Lee's land near Caliente, Nev., looked like before it was irrigated—sagebrush and sand in a country where annual rainfall ranges between 0 and 10 inches.

2. A well goes down on Lee's farm under the Water Facilities program, which furnished a development loan and technical guidance.

3. The pump starts to turn. While waiting for an electric line to reach his farm, Grant Lee uses his farm tractor for power.

4. The Water Facilities installation of a 450-gallon-per-minute pump and a reservoir holding an acre-foot of water are being used to irrigate about 70 acres of alfalfa and grain.

5. It was a happy moment for Grant Lee when his Water Facilities pumping plant brought the first steady flow of water to the surface, and the promise of bountiful crops for years to come.

6. Where once the land was covered with rabbit brush and sage now grows a fine crop of rye, used to feed a dairy herd providing milk for an army of miners who recently moved into the area to mine metals needed for war production.

is done, operational plans are made to direct water use along the accepted lines, and funds are made available to finance rehabilitation of old facilities or installation of new ones in line with the plan.

Thus, water-land use planning is divided into two parts: (1) General, over-all area planning, concerned with the watershed, basin, or natural province as a whole. It provides a definite framework into which farmers can fit their individual operations. It gives a picture of the area as a unit, showing the most effective use of land and water in the interests of sustained, balanced farm production. (2) Detailed or operational planning, to point out the specific types of water use that are most practical on individual lands within the area, in view of the general plans for the area.

Planning the Republican Basin

To be specific, let us follow through on the planning process in the Republican River basin under the Water Facilities Program, from which came a "blue print" for development of much-needed irrigation on 125,000 acres of good, fertile land.

The first step—the situation.—As a first step, a general picture of the Republican basin and its problems was assembled. The Republican River and its tributaries lie like a fallen tree along the Kansas-Nebraska line. The top branches of the tree, the headwater tributaries, spread out into northeastern Colorado, northwestern Kansas, and southwestern Nebraska, joining the main trunk as it flows eastward just inside the Nebraska boundary. From the point on the main stem where it crosses southward into Kansas to the western headwaters is 350 miles. The width of the basin varies from 25 miles at the eastern end to 125 miles at the widest point westward. It covers 21,958 square miles, or about 14,000,000 acres—slightly less than the land area of West Virginia.

When the Republican basin was settled, not much was known about its climate. Early explorers thought it was a desert. However, when settlers came in the 80's and 90's, the Plains were enjoying a wet cycle, and it seemed that there was plenty of rain to raise crops. The truth, as we now know it from long-time records, falls in between. The basin ranges from subhumid in its eastern portions to arid in the extreme western parts; rainfall varies from 25 inches in the east to 14 in the west and, most important, wide fluctuations in climate occur from year to year. In fact in 1935 a rainy season, bringing the largest floods on record, was sandwiched between the extreme droughts of 1934 and 1936. In short, the climate is highly unstable, and farming is subject to frequent threat of drought.

There are 12,000,000 acres of land in farms in the basin, of which more than half are used for crop production and 43 percent for pasture. Small grains, corn, and specialty crops predominate in the east where farms are around 220 acres in size. Livestock and feed crops are most important in the western part, where farms run about 800 acres. The land generally is very fertile, requiring only water to make it produce. Much of the land is owned by absentees, and more than half of the farms are operated by tenants.

Although irrigation in the basin began as early as 1890, using water from the river, less than one-half of 1 percent of the land in farms is irrigated. About 32,700 acres are irrigated by surface water, and about 9,700 acres by pumped wells. Water supplies seem plentiful, particularly in the bottom lands, where irrigation wells can tap good flows at an average depth of 35 feet.

The shock of dry years in the Republican basin was intensified because land use and water use were not in harmony. The area was settled without knowledge of the extremes of climate. Farms followed the pattern of those of the humid eastern sections and tend to be too small for successful dry-land farming, with too much dependence on cash grain. The outward results of this maladjustment have been a heavy loss in population, an increase in tenancy, declining land values, tax- and mortgage-payment delinquency, and a heavy relief load.

How much land . . . water?—The study of the area now gets down to details, to determine the amount of available resources and the best use of them. Land is classified on the basis of its potential capabilities—is it cropland, or range land? Which cropland is suitable for irrigation, from the standpoint of physical lay-out, productivity of the soil, and water requirements?

Water supplies are measured as best they can be. What is the source of water, the amount available, its annual replenishment, its quality? Ground-water supplies are located, depths determined, and analyzed, as to quantity, quality, and replenishment.

For example, it was found that there are more than 327,000 acres of first-grade irrigable land and about 500,000 to 700,000 acres too rough or too poor to be irrigated.

Detailed investigations by hydrologists showed that about 460,000 acre-feet of water escapes unclaimed and unused from the Republican basin every year, water that could do much to increase the productivity and economic stability of the area. This water supply is made up of the surface and subsurface flow of the Republican and its tributaries, which of course represents the drainage of the rain and snow that fall over the entire watershed, plus the water that seeps into the Republican via underground water-carrying formations from the Platte Valley and the water-storing Sandhills to the north.

What is safe use?—Now, how much of this water can be used—safely? The needs of people downstream must be considered: plenty of leeway must be allowed as a safety factor, to take care of year-to-year variations and possibilities of error. The developments underway for diversion and storage of surface water must be taken into account. Even though there may be a known recharge, development should be a gradual process, governed by the long-time welfare of the basin and a deliberate and careful study of the effect of increasing development on the water supply. Ordinarily the amount of available supply and rate of replenishment cannot be completely measured until the effect of withdrawal is observed, and development should be kept in check as it goes along to allow for correction of original estimates.

When all of these factors are taken into consideration, it is found that around 238,000 acre-feet of water are available for safe use in the Republican basin.

How can this water best be recovered for use? The peculiar conditions of the Republican basin indicate that irrigation with ground water offers the best opportunity for economical irrigation. Here is a stream valley, a considerable portion of its floor underlain with porous and permeable alluvial deposits, ideally suited for storing water underground. In effect, the alluvium of the Republican is a huge, efficient underground storage basin, being kept filled by the surface runoff, and the underground leakage from the Platte Valley and the Sandhills. Why not, point out the engineers, simply put down pumps in this alluvium, pulling out the water for irrigation? This will lower the water table as supplies are drawn out of the underground reservoir, but the space vacated by the pumped water will be refilled by inflow of surface water.

Duty of water.—Next comes the question of how much and which land should be irrigated. The duty of water is taken into account—the amount per acre that will produce the best results under the type of farming that is best suited to the area. This is found to vary from 1½ to 2 acre-feet. Applying this to the safe yield of 238,000 acre-feet of water indicates that about 125,000 acres of land can be irrigated.

This does not mean that the entire basin is suitable for development: the case of each subarea and for that matter, of each farm, must be decided on its own merits. In parts of the basin the water supply is limited or believed to be limited, the rate of replenishment is slow, and it is recommended that no development be started in these areas until adequate legal controls are set up to prevent overuse. Accordingly, development is to be guided toward the parts of the basin where the possibility of depletion is least and where the amount of irrigable land is fairly well balanced with the water supply.

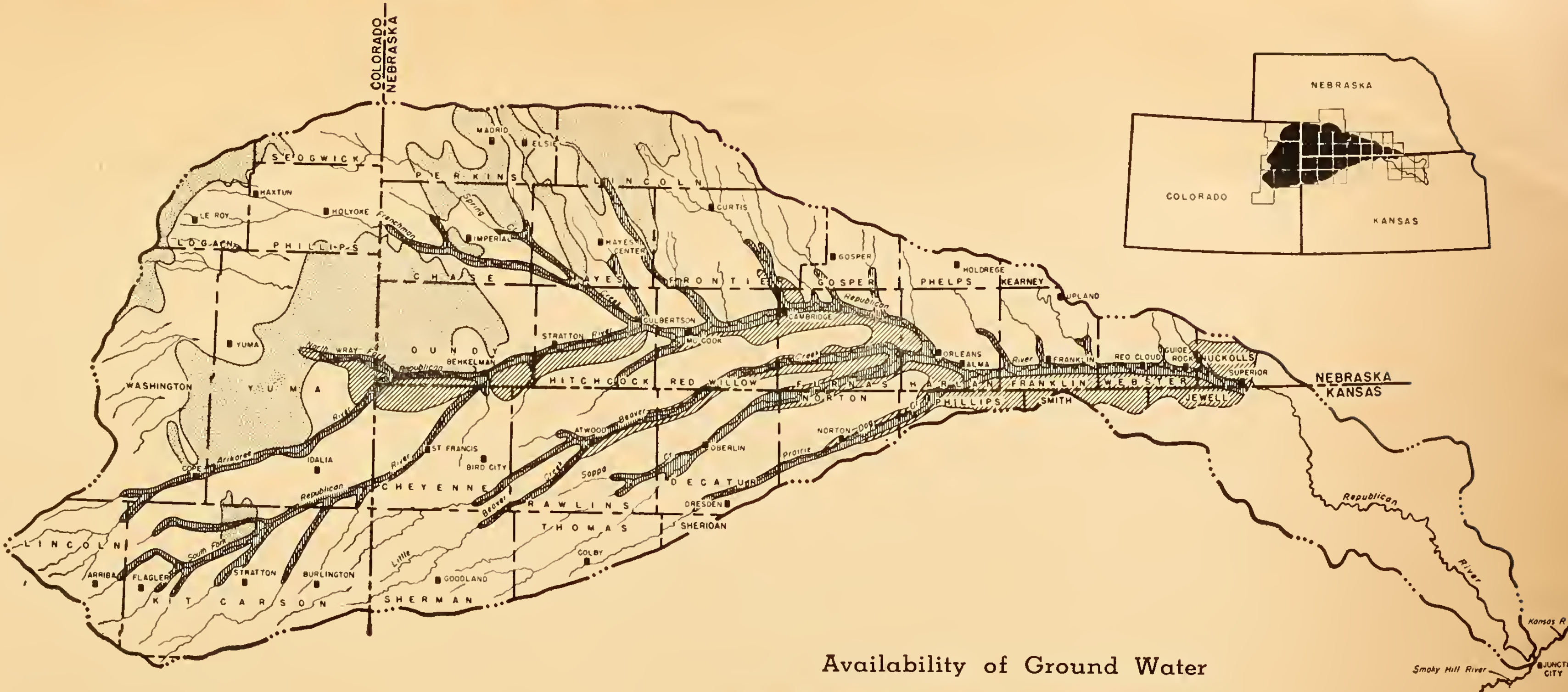
Recommendations

Out of this combined study of land and water resources of the basin, come the following recommendations for joint land-water use and development in the Republican basin:

Water use:

1. That about 125,000 additional acres of land along the main stream and the tributaries be developed for irrigation principally by recovery of ground water. The amount and location of land to be irrigated is listed and mapped for each subwatershed of the basin.
2. That careful consideration be given to establishment of percolation beds to increase the rate of ground-water replenishment when the recommended maximum rate of pumping is approached.
3. That classification of irrigable and nonirrigable land be closely followed in installing irrigation facilities and planning farms to confine irrigation investments to lands that are most productive and most easily managed.
4. That potential water users file an application to appropriate water, whether or not such applications are required by statute, to establish record of priority in water use.

Republican River Basin (Colorado, Kansas, and Nebraska)



Availability of Ground Water

- Alluvial province: Water usually very shallow. Good water generally recoverable in large quantities for irrigation.
- Dune-sand province: Adequate and potable water available at shallow depths for stock and for domestic, industrial, and municipal use.
- High Plains province: Water generally available at depths of 100 to 300 feet. Depth precludes possibilities of well irrigation.
- Nonproducing-shales province: Little or no ground water available.

5. That in the eastern part of the basin, where water will be needed only in dry years to supplement rainfall, the investment in pumping equipment be kept as low as possible by use of second-hand or rehabilitated equipment.

6. That test drilling be undertaken in several parts of the basin where information is not available on the water-yielding abilities of the alluvial sands and gravels.

Land use:

1. That irrigation developments should be encouraged where feed and crop production can be combined with the use of range. The basin is deficient in feed crops and can effectively use the increased production.

2. That irrigation serve principally to rehabilitate farm operators who are now dry-farming or ranching; that development of units entirely dependent on irrigated land is not desirable, and has been shown to be unstable.

3. That in the southwestern portion, which is suffering from more land-use difficulties than the rest of the basin, greater emphasis should be given to livestock production; that much land now used for cash grain should be shifted to grass and feed crops; that operating units should be increased where possible to a size more in line with range-livestock-feed operations; and that local public finance, mortgage indebtedness, and public services should be brought into line with less intensive, more balanced use of land resources.

4. That in the relatively stabilized Sandhills part of the area, shifts in land use should be toward reduction of cash crops, and an increase in feed crops and pasture and toward larger, more economical operating units where farms are less than 640 acres, to permit a grass-livestock-feed economy.

5. That in the "hard-land" wheat areas, the rough land be retired to permanent pasture, more livestock be raised, more of the food requirements be raised in irrigated gardens, and larger operating units be developed.

6. That population movements into the area be discouraged, particularly the type that would result in intensive irrigation on small units, or in the break-up of established units, except as opportunities are available for employment in industrial or service work.

At first glance, the goals set by such an area plan may seem too ambitious. However, all of the machinery to help farmers achieve them is already operating. An over-all plan such as this can do much to aid farmers and their local, State, and Federal agencies in realization of the goals.

Drilling an irrigation well in the Republican Valley, Nebr.

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Chief, Forest Service	Earle H. Clapp, Acting.
Administrator, Rural Electrification Administration	Harry Slattery.

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