UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

GROUND-WATER SITUATION IN OREGON

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R. C. Newcomb

Geologist, U. S. Geological Survey

Prepared in cooperation with the State Engineer of Oregon

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INTRODUCTION

The water that occurs beneath the land surface follows definite and well-known rules of hydraulics, the same as water on the surface. However, ground water must be studied by methods, some of which are unique to that type of water occurrence, in order to evaluate the part it plays in the over-all water scheme.

Water that falls on the land surface as rain or snow and water that rests upon the surface may in places pass laterally or downward through the pores of the earth materials. There it may take one or more of a variety of paths before again flowing out on the surface or being expelled to the atmosphere by evaporation and by the transpiration of plants. Water so diverted underground is delayed or diverted from its course toward the sea and that digression results in many services of prime importance to mankind. Underground, the water generally exceeds in total quantity the water present on the land surface at any one time.

The discussion of ground water can be clarified somewhat by a description of the major parts or phases of the normal path of water underground.

Just below the land surface is the belt of soil water in the soil zone. Beneath that generally occurs the next zone called the intermediate or vadose belt. The soil-zone belt and the intermediate belt have one thing in common -- they are generally undersaturated. The whole together is aerated and is appropriately called the zone of aeration. In some relatively fine-grained materials water is held by capillarity in a thin zone just above the water table. When present, that capillary fringe also belongs to the zone of aeration. Beneath the zone of aeration all available pores of the earth are saturated; the upper limit of that saturated zone, where not under pressure greater than that of the atmosphere, is called the water table.

The relation of the water table to the land surface has special significance. If it is too deep, the water may lie beyond economic recovery; if it is too close to the surface, the zone of aeration may be missing, or be too thin to prevent direct evaporation and the concentration of salts in the soil. The water table may even coincide with the surface or stand above the surface where the water may emerge, drain off as springs, or stand as lakes or swamps.

Bodies of ground water having a water table are not under pressure other than the weight of the atmosphere, and are called unconfined ground water. Unconfined ground water held above the true water table by an underlying impervious bed is called perched ground water. Ground water prevented by tight overlying rock from rising as high as the pressure head of the adjacent unconfined water would allow, is under pressure and is called confined, or artesian, ground water. As hydrologists use it, the word "confined," or "artesian," ground water means any ground water under pressure great enough to rise in a well above the point at which it enters the well bore, whether or not it rises to land surface.

The hydrologist's use of the word artesian is thus hydraulically correct, though it differs from one widespread use of the word artesian which denotes ground water that flows at the surface.

The fundamental factors that control the existence, movement, and behavior of ground water are the size, shape, and arrangement of openings in the earth materials. Some rock and earth, such as shale and clay, contain pores so small that they are virtually impermeable and do not readily transmit water underground. Other materials, such as unconsolidated sand and gravel, porous sandstone, fragmental volcanic rocks, and fractured rocks like basalt and gneiss, transmit and store water in various amounts. Those porous rocks, when saturated, are known as aquifers and are the sources of the ground water economically recoverable and useful to man. Consequently, the location and evaluation of ground-water supplies require a full understanding of the succession, extent, thickness, and form of the porous and nonporous layers of rock that make up the earth's outer crust.

It may be summarized that the three basic considerations controlling the usable ground-water resources of any region are the supply of water available for infiltration into the ground, (determined largely by the climate), the form and shape of land-surface features (the gentler the slope, the more chance for water to get into the ground), and the geologic fabric of the region concerned. Study of these basic factors shows that the magnitude of the ground-water resources may differ greatly from district to district. Even though ground water follows the basic rules of hydraulics, its mode of occurrence will vary and must be appraised separately in each general area in order to get workable answers to questions of economic development and wise management.

OCCURRENCE OF GROUND WATER IN OREGON

General divisions of the State

A general appraisal of ground water in Oregon necessitates partition of the over-all area into divisions that differ one from another. Such informal divisions of the State are:

1. Southeastern plateaus
2. Columbia plateau slope north of the central mountains
3. Central and central-eastern mountains
4. Cascade Range
5. Klamath Mountains
6. Willamette Valley
7. Coast Range
8. Coastal belt

If these divisions are graded as good, fair, and poor in each of the three basic considerations just outlined -- namely, precipitation, porous rocks, and gentle topography -- a general classification according to ground-water potentiality results, as follows:

Division	Precipitation	Porous rocks	Gentle topography
Southeastern plateaus	Poor	Good	Fair
Columbia plateau slope	Fair	Fair	Fair to poor
Central and central-eastern mountains	Fair	Fair	Poor to fair
Cascade Range	Good	Good to fair	Poor
Klamath Mountains	Good	Poor	Poor
Willamette Valley	Good	Good to poor	Good
Coast Range	Good	Poor	Poor
Coastal belt	Good	Poor to fair	Fair

Specific character of the larger divisions

The Coast Range and Klamath Mountain divisions, with their relatively impervious rocks, steep slopes, and narrow valleys, afford probably the poorest general environment for large ground-water supplies. The Cascade Mountains differ therefrom in having large areas of young fragmental volcanic rocks that absorb and store water. Such storage is significant to streams like the Deschutes River, whose sustained flow, supported by ground-water discharge, makes the stream one of the least variable in the United States.

The central mountains division, including the several groups that extend through east-central and northeastern Oregon, has large areas of steep slope, impermeable rocks, and narrow river valleys where ground water is of relatively little consequence; however, the division also has several intramountain basins like Baker, Wallowa, and Union Valleys, where the ground-water resources are moderate to large.

The southeastern plateaus are, in general, composed of fairly permeable volcanic rocks that are receptive to ground water. Much of the land there lies high above its corresponding levels of ground-water storage and much of the area has low rainfall and small annual infiltration. The volcanic rocks there direct a large part of the infiltration to lower levels where it lies deep beneath the plateaus. However, because the ground water drains off to the valleys, the water table lies at shallow depth below the valleys. In places the ground water flows out in springs such as Roaring Springs of the Catlow Valley and Ana Springs of the Summer Lake basin as well as flowing out into the beds of the lakes and streams.

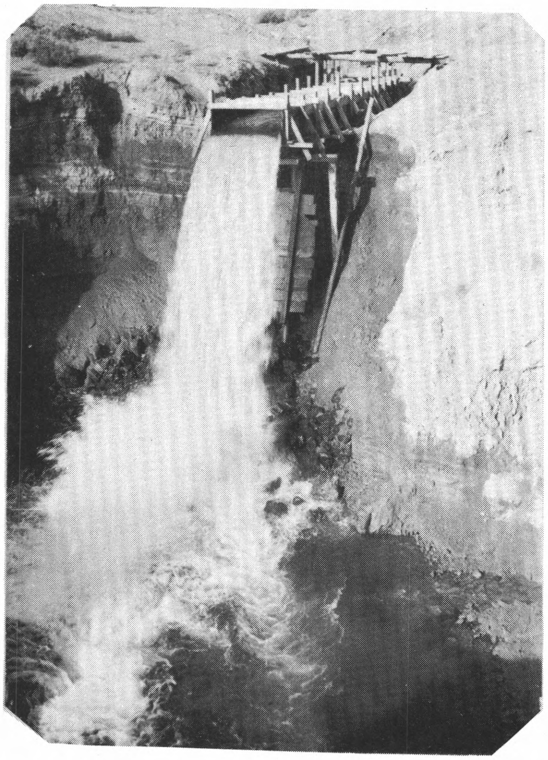


Figure 1. Discharge from Ana Springs at the north end of Summer Lake valley. This natural escapement for the artesian water in the volcanic rock is apparently the outlet of the large ground-water body beneath Fort Rock and Silver Lake basins farther north. Its volume averages about 80 to 100 cubic feet per second and forms Ana River, the main flow into Summer Lake.

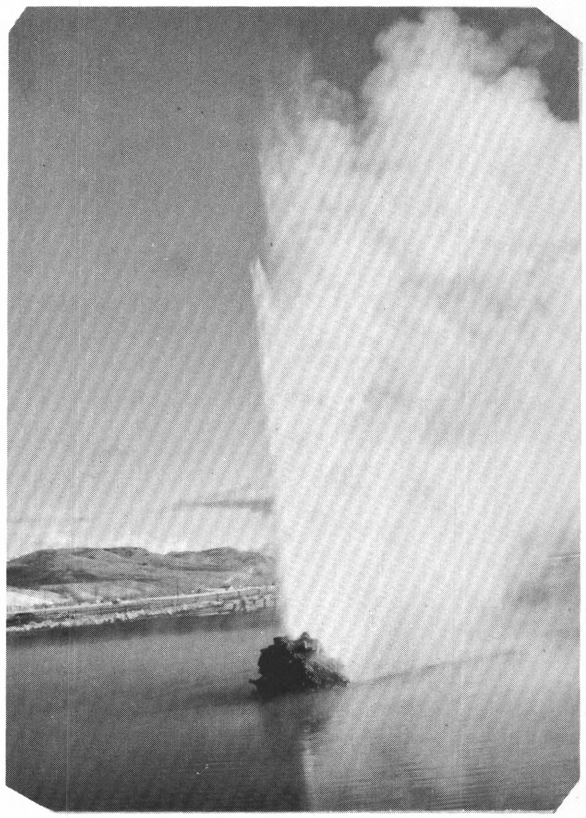


Figure 2. A 38-foot well at the Hunters' Lodge at Lakeview. Superheated water is tapped near a large fault zone which there parallels the mountain front.

The Columbia plateau slope north of the central and central-eastern mountains is composed largely of the Columbia River basalt. There most of the land is in high plateaus, and deep river canyons drain the ground water to lower levels; however, some basinlike areas such as the Umatilla Valley and The Dalles syncline area are locations of potentially important ground-water supplies.

The coastal belt is a narrow band of steep, hilly topography lacking any real coastal plain and composed of rather impervious rocks that commonly reject water that would otherwise infiltrate. Consequently, the streams are flashy during the rainy season and low in summer. A narrow band of beach sand is present at some places, and where thick enough, this sand stores some fresh ground water in what is known as the Ghyben-Herzberg lens floating upon saline water.

The Willamette Valley, the largest low-lying valley in the State, affords a large ground-water resource in the aggregate. However, despite its favorable topography and rainfall, it lacks large ground-water supplies at some places for two main geologic reasons: (1) The bedrock beneath the valley fill, particularly in the southern half of the valley, consists mostly of non-water-bearing or saline-water-bearing sedimentary rocks; and (2) the older alluvial deposits are in part a poor source of ground water because they are too fine grained or because of the clayey condition that has resulted from the decomposition of the old sand and gravel fill.

Some principal geologic features

In the Willamette Valley the most productive ground-water zone occurs in the young alluvium along the main flood plains, but there is a secondary extension into much of the older alluvial deposits that underlie the adjacent higher terraces. At some places, as along the western edge of the valley south of Corvallis and in the area near Independence, those older alluvial deposits are mostly fine grained and do not yield large quantities of ground water. In the whole valley area the ground water in the alluvium is largely unconfined and is tributary to the streams. South of the Waldo-Salem Hills the bedrock beneath the valley alluvium is mostly impervious; north therefrom the basalt formation of miocene age that underlies much of the valley area, and rises above valley level at places such as the Red Hills of Dundee, Petes Mountain, Cooper Mountain, and Palatine Ridge, furnishes ground water to wells over a widespread area. Most of the ground water in that basalt also is unconfined and is tributary to the streams; however, at a few places near Farmington, Mulloy and Clackamas it is confined and flows above land surface from some wells.

Over the Columbia plateau slope north of the central mountains, ground water occurs in the Columbia River basalt and drains toward the Columbia River and its tributaries. At some places where the Columbia River basalt is downwarped into structural basins or synclines -- as at The Dalles, Milton-Freewater, and Umatilla -- moderately large amounts of ground water are stored in some aquifers, even in places at relatively high level above the local streams. However, elsewhere in that area, as in the Deschutes Valley farther southwest, the base level of the streams, and consequently of the water table, is so far below the plateau surfaces that for most uses ground water in large quantities cannot be developed economically now.

Figure 3. View eastward across Pine Creek flat west of Umapine where drilling machine is constructing a well in the Columbia River basalt. The well was started in the upper, hanging-wall side of the fault zone (shown as dark vertical zone and escarpment on the hill beyond) and tapped flowing artesian water in the lower, foot-wall side.

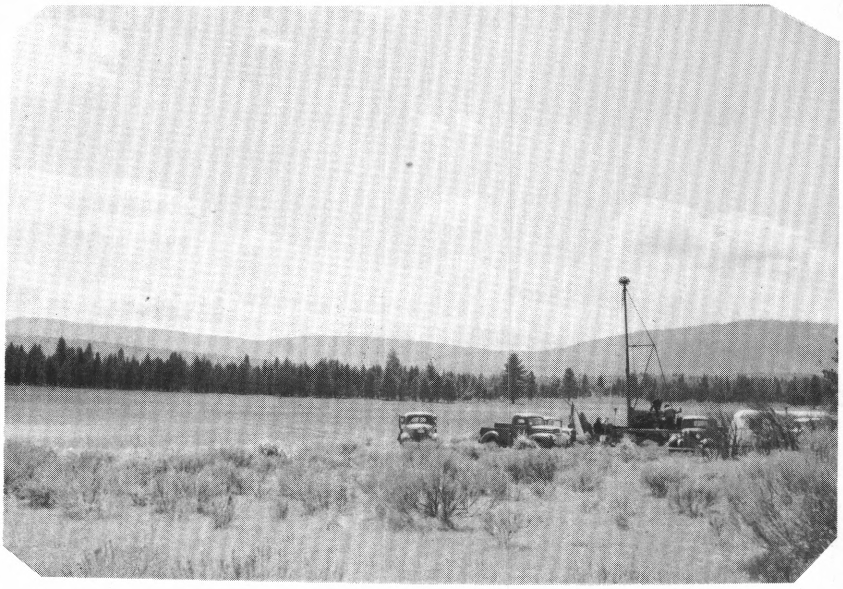


Figure 4. Drilling machine constructing a well to irrigate field on the Guy Barton farm on Pine Flat, Klamath County.

In the mountain areas of central Oregon the ground water occurs under a variety of conditions. In the Union, Baker, and Prineville Valleys it is mainly unconfined and occurs in the alluvial valley fill, though some is confined in volcanic bedrock of the Baker and Union Valleys and in the older alluvial deposits of the Prineville Valley. Many smaller basins, like those along the Powder, Grande Ronde, and Wallowa Rivers, have potential ground water, but little is known now about those occurrences. For the most part, the mountain valleys are narrow and the stream gradients are relatively steep. Under existing conditions in such valleys there has been little incentive for the development of ground water, even when it is known to be present, as in the lower John Day River valley.

In the lower basins of the southeastern plateau area -- such as those of the Malheur River, Harney Lake, Warner Valley, Goose Lake, Chewaucan River, Lost River, and Fort Rock -- important ground-water supplies occur at relatively shallow depths. The rock formations there vary so that at different places and depths different ground-water yields are obtained. In the smaller basins, like those near Brogan in the Malheur River basin, the annual infiltration is small, and wise development will necessarily avoid the overexploitation of stored ground water. In valley areas like the Warner Valley, Goose Lake, Chewaucan, and Lost River basins, the ground water, though also limited as to annual recharge, is tributary to large evapo-transpiration areas where it may be considered by some to be partly lost from beneficial use. Under some such conditions, advantage might be gained by pumping both to salvage water and to drain the subsoil.

Quality of the ground water

Nearly everywhere in the State the chemical and physical quality of the ground water is good, two exceptions being the salt waters in marine sedimentary rocks that occur in places at depth beneath the Willamette Valley, the Coast Range, and the Klamath Mountains, and the highly mineralized water that occurs along fault lines in the Southeastern plateau division. Otherwise, essentially all the ground water is nonsaline, of good color and normal temperature, and relatively low in dissolved chemical content. There are some relatively high alkali concentrations in the soil of some of the valleys, but much of the underlying ground water is not excessively alkaline.

In the high-rainfall, western part of the State the ground water generally contains more dissolved solids than the adjacent surface water. In the arid eastern part of the State, on the other hand, the ground waters in many places contain less chemical matter than do the corresponding surface waters. Excessive amounts of possibly harmful constituents like boron and fluorine are generally lacking in ground waters over most of the State. One ground-water analysis showing fluoride in excess of 1 part per million is known in the Union Valley near Imbler. Two or three wells just east of Baker yield water containing a moderately injurious boron content and ground water of similar boron content is reported in the Tule Lake area south of Klamath Falls. In Bear Creek valley near Medford fluoride and boron occur in harmful amounts in ground water withdrawn from strata of the Umpqua formation.

Only two serious cases of artificial contamination of ground water are known -- that from pea-cannery wastes in the Milton-Freewater area, and that from the aluminum-sulfate wastes at Keezer Bottom north of Salem. If manufacturers can be persuaded to avoid underground disposal of noxious by-products and wastes, it will help prevent future contamination.

The deep underground disposal of sanitary wastes has been practised for many years in some plateau areas of porous volcanic rocks and has rendered certain areas, like that east and northeast of Bend, unsuitable for ground water development.

Use of ground water

Present development

In Oregon, ground water now is used principally for domestic, stock-watering, public-supply, industrial, and irrigation purposes. There are an estimated 100,000 domestic and stock-watering wells. Most of these are shallow dug wells or small-diameter drilled wells. They are of various depths with a maximum of about 1,500 feet; their water levels range from above the land surface, in certain flowing wells, to about 1,000 feet below the land surface. Though these domestic and stock wells are generally of small yield, they afford information on the ground-water conditions in many areas where the ground water is not otherwise developed. Many highly productive wells have resulted from information gained only from wells of small yield.

Ground water furnishes the public supply for about 250,000 people or about one-fifth of Oregon's population. Most public-supply wells are of the deeply drilled type; shallow ground-water resources have been overlooked in many places. Where facts are known so that costs may be accurately compared, ground water has been chosen in some places in preference to surface-water sources for public supply because of its lower first cost (large expenditures for filtration or other purification plants and long conduit pipes are avoided), its smaller storage-reservoir requirements, its greater susceptibility to automatic control with lesser operating costs, its more uniform chemical character and temperature.

The industrial uses of ground water are greatest near the cities where industrial plants are concentrated. Wood-processing operations, canneries, and various food-processing plants are the largest users. Less water is used for air conditioning than in the warmer parts of the Nation. However, though the actual amount is small so far, Oregon is one of the largest users of ground water for space heating. Both the hot water that occurs along fault lines in the south-central plateau area and the normal-temperature water serves reverse-cycle heat-pump installations are used for that purpose. The Equitable Building in Portland is now the largest building in existence heated entirely by a heat-pump system based on ground-water temperatures.

Irrigation is, of course, the principal use of ground water in Oregon. In an area of such diverse topography as the State, a suitable soil, a favorable growing climate, and a relatively high-level ground-water supply do not coincide over wide areas. However, the floors and lower slopes of basin and valley areas commonly are so favored. About 50,000 acres were irrigated wholly by ground water in 1950. As little as a foot of irrigation water was used in the northwestern part, and as much as 3 feet of water was used in the southeastern part of the State.

In all, possibly 75,000 acre-feet of water was so applied in 1950. The pumping lift ranges from zero in a few flowing artesian wells to about 600 feet in the Cherry Heights well near The Dalles -- the irrigation well with the greatest artesian pressure above land surface is but a few miles from the irrigation well having the greatest pumping lift.

The development of ground water for irrigation in Oregon has come about largely in three epochs -- the first during the original period of intensive farming in the nineties and at the turn of the century, the second during the first World War, the last during the second World War and the ensuing years of high farm prices. The increase in recent years has probably about doubled the acreage that was under irrigation with ground water in 1940.

The first period resulted in the use of much of the spring discharge and shallow ground water that was close to areas of suitable soils. A few deep wells were constructed, but those which failed to flow were considered useless at the time. Those wells that did yield flowing artesian water were commonly left to flow unchecked.

During the second period, which centered about World War 1, a few wells were constructed and better pumping equipment was put into use. Electricity was more widely transmitted and pumping installations and power were relatively cheaper. However, not all ground-water areas were reached by power lines, and steam engines were still used to drive pumps in some areas (using sagebrush fuel in the Fort Rock basin). During the period between the first and second World Wars many loan-appraisal authorities considered 75 feet the maximum feasible water lift for field crops of the Pacific Northwest, where electricity was employed for power.

The third period of ground-water development is continuing. Not only have favorable prices made it possible for the farmer to attempt development of ground water, but the lower cost of electric power and better pumping equipment have encouraged this operation. To those lands at a distance from any unappropriated surface water, either ground water or imported surface water involving long conduits and large storage works provides the only hope for irrigation.

Some potential future benefits from the development of ground-water resources are evident; doubtless there are others as yet unforeseen. As an example, it appears from a non-technical agricultural appraisal that, in places where our ranges have become depleted until nonforage plants now predominate, cattle no longer make a proper growth or gain and the wool industry has diminished alarmingly, the development of ground-water sources to irrigate forage crops and so to stabilize those livestock industries now has an urgency out of all proportion to the expense of constructing the necessary wells. Likewise, it may be found desirable to reapportion water use in certain irrigated areas developed in the past without using available ground-water supplies. In many of our irrigation districts some lands have both the surface-water right and the economically feasible ground-water lift. In some valleys there has even been resultant loss of land from waterlogging. For certain of these, probably it would be entirely feasible to develop ground water supplies on the lower lands and thereby not only to help drain those lands but also to free canal water for use on higher, fertile lands not now irrigated.

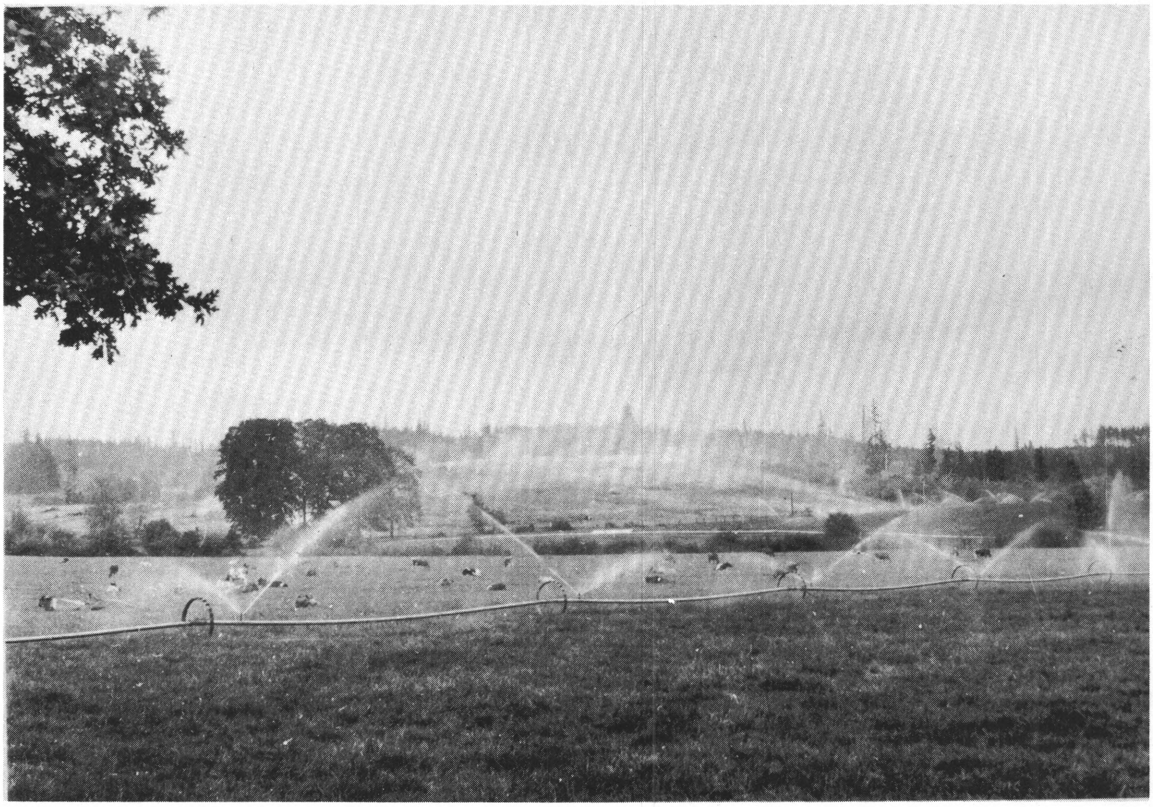


Figure 5. View showing water, from a 590-foot well in the Columbia River basalt beneath the south slope of Cooper Mountain, being applied by sprinklers to pasture on the Bierly Brothers farm in the Tualatin Valley, Washington County. (Photo by Clyde Walker.)

Potential additional sources

Three obvious ways by which the amounts of ground water used for irrigation might be increased are (1) construction of additional wells in areas now known to contain available ground-water supplies, (2) exploratory well construction in areas where ground-water conditions are unproved but inferred to be favorable, and (3) improvement of the techniques for well construction.

Ground-water information indicates that many areas are underlain by ground-water supplies suitable for fairly large-scale development. Among these are parts of the lower Willamette Valley, Union and Baker Valleys, north Warner Valley, and Goose Lake, Fort Rock, and Swan Lake Basins. Even though the economic advantage of putting that ground water to use has been demonstrated at certain places, extensive development has not followed universally. There are still many favorable opportunities even in the proved areas. In some districts geologic conditions are favorable but no exploratory wells have been drilled to determine the presence or absence of adequate supplies.

Improved well-construction techniques, particularly to fit known local conditions of ground-water occurrence, could be used to advantage in Oregon. For example, many districts, such as the Tualatin Valley and Goose Lake basin, have fertile soils but are underlain by fine-grained deposits -- silt or fine- to medium-grained sand -- from which ground water can be extracted economically only by properly constructed wells. Suitable construction practices and devices not generally in use include proper gravel packing, prefabricated well screens with openings sized according to the texture of the water-bearing material, thorough surging and cleaning of the aquifer materials adjacent to the well, and provision of entry ports and measuring devices through which water levels may be measured in the well (see pl. 1). Some well owners and operators do not have an adequate log of the materials penetrated or a suitable description or sample of the materials from which the ground water must be extracted. That the well-construction industry means to correct such deficiencies is apparent. Their efforts can be encouraged by a small reading knowledge on the part of the investor prior to having awell constructed. Many private and public bulletins, books, and pamphlets are available for the guidance of the public and the well-construction industry on the matter of improvement in our techniques for extraction of our ground-water resources. A more modern concept of well construction technique is needed in Oregon where well construction alone now amounts to a million-dollar-a-year industry.

Status of public ground-water information

The ground-water resources of Oregon are being studied under a cooperative program of modest proportions between the U. S. Geological Survey and local agencies, the principal one of which is the Office of the State Engineer. Direct cooperation with the State Engineer in these investigations has been small but growing since 1936.

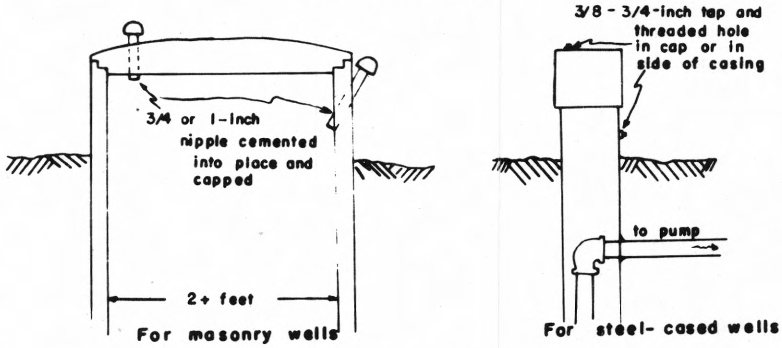
Three districts now are covered by published water-supply papers: the Willamette Valley, Harney Basin, and The Dalles area. Several are covered by unpublished typewritten reports on public file and others by unpublished data available in public file. The Geological Survey office supervises a State-wide net of observation wells, so far an incomplete but growing net, to observe trends in ground-water levels.

During the 15-year period for which the Geological Survey has kept records of ground-water levels in Oregon, there has been no general lowering of ground-water levels--only minor changes in some districts. In a few localities there is now some interference of adjacent wells, such as those in the Columbia River basalt aquifers near The Dalles and at Milton, those in the confined-water stratum of the older valley alluvium at Prineville, and in places, those in the deeper alluvium of the Willamette Valley.

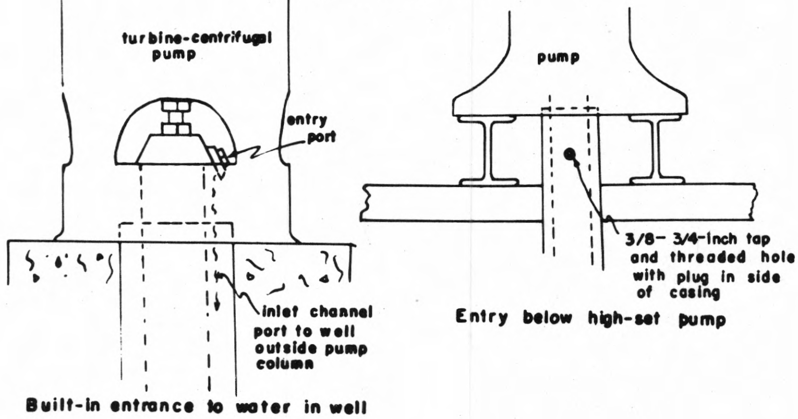
Though of minor volume as regards the total quantity of our usable water resources, ground water is due to play an increasingly important part in the development of Oregon and to exercise a vital influence on the lives and well-being of the inhabitants. A full realization of the benefits offered by the development of ground-water resources can be obtained most economically through the use of the progressively increasing fund of public information.

SKETCHES OF ACCESS PORTS TO SOME WELLS FOR THE MEASUREMENT OF WATER LEVELS

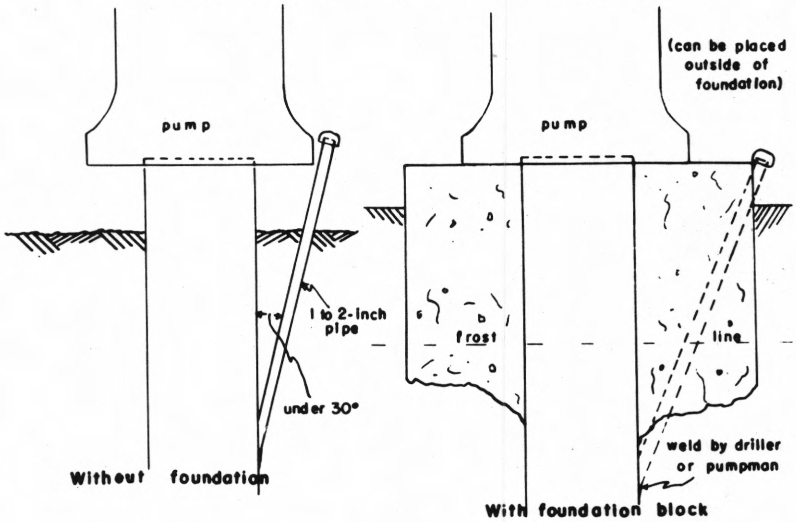
Wells open above



Pump-covered wells



External pipe entry to well casings



Entry to artesian flowing wells