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BUREAU OF MINES AND GEOLOGY
Francis A. Thomson, Secretary.

GROUND WATER FOR MUNICIPAL SUPPLY
AT
POTLATCH, IDAHO.

By
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PREFACE

This report covers one of a considerable series of investigations of underground water for municipal supply made during the past few years by the Idaho Bureau of Mines and Geology.

The permanence and freedom from contamination of underground water, whether strictly artesian or not, is leading many cities in Idaho to look to this source for potable water.

In general it may be said that by a careful analysis of the surrounding geologic and topographic conditions the probability or improbability of an adequate underground water supply can be ascertained with considerable certainty.

Francis A. Thomson,
Secretary, Idaho Bureau of Mines and Geology.
GROUND WATER FOR MUNICIPAL SUPPLY
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INTRODUCTION

PURPOSE AND SCOPE OF THE SURVEY

Inasmuch as drilling activities conducted by the Potlatch Lumber Company during 1926 with the purpose of augmenting the water supply of both plant and town were relatively unsuccessful, the officials of the Potlatch Lumber Company appealed to the Idaho Bureau of Mines and Geology for geological aid.

A brief investigation consisting of five days in the field was conducted during the spring of 1927, wherein the geology and underground water conditions of a drainage area of 385 square miles surrounding Potlatch was studied by Virgil R. D. Kirkham, geologist, Idaho Bureau of Mines and Geology.

General geologic information secured by the writer in previous brief reconnaissances was extremely useful in facilitating this survey. The area is shown on an accompanying map.

ACKNOWLEDGMENTS

The writer gratefully acknowledges the assistance extended by the executive staff and officials of the Potlatch Lumber Company who facilitated and expedited the work by providing much valuable information and service.

Previous geologic literature touching on this region or the adjacent country is found in the following brief bibliography:


Some of these publications apply only generally to the area. References to them throughout the succeeding pages are made by serial number.

**GEOGRAPHY**

**LOCATION**

The region constitutes about 385 square miles of territory lying, with the exception of 20 square miles in Bonner County, in northern Latah County, Idaho. Potlatch lies in the west central part of the area. Meridian 116°30' cuts through the eastern tip of the area and Meridian 117° lies about two miles from the western border which is the Idaho-Washington boundary. The southern part of the area extends beyond parallel 46°50' and the northern part extends to approximately 47°05'. The area extends from Rs. 1 to 6 W. and from Tps. 40 to 45 N.

**TOPOGRAPHY**

The entire region lies within the drainage of the Palouse River. Three types of topography are included in the area: (1) mountainous provinces made up of metamorphosed sediments and granitic igneous intrusions in a mature and relatively rough stage of erosion; (2) plateau-like lava terraces and uplands; and (3) alluvium-covered, stream valleys. Each type is readily recognized on the accompanying geologic map. The mountainous provinces constitute part of a deeply dissected plateau which forms the western outlier of the Bitterroot and tributary ranges of the Rockies.

The area ranges from 2500 to 4800 feet above sea level and is of medium relief. The batholithic igneous intrusions usually form the highest peaks.

**SETTLEMENTS, OCCUPATIONS, AND ACCESSIBILITY**

Potlatch, which is the chief center of habitation, contains approximately 1500 inhabitants. The rest of the area examined contains perhaps 4000 additional people. Lumbering and milling, along with farming and dairying, are the chief industries. Much timber clothes the mountainous area. The plateau-like terraces and stream valleys yield excellent crops.

The area is traversed by the North and South Highway, and is adequately served by the Washington, Idaho, and Montana Railroad.

**GEOLOGY**

**STRATIGRAPHY, PETROLOGY, AND STRUCTURE**

The rocks in the region range in age from pre-Cambrian (Algonkian?) to Quaternary, and are represented at the surface by sediments of the Belt series, by granitic intrusives, by basalt lava, and by hillwash and alluvium.
The Belt series in this region appears to be Prichard in the eastern part of the area, and overlying this conformably and in natural sequence lies what is presumed to be the Burks. The rocks near Harvard are lithologically similar to the Ravalli group and north of Potlatch they closely resemble the Newland (Wallace) of the Coeur d'Alene Belt series. The entire series here is constituted chiefly of quartzites, argillaceous quartzites, and argillites.

These rocks dip consistently in a general western direction at angles varying from 25° to 60°, although the strike varies from N. 45° W. to N. 5° E. In the eastern part of the area in the lowest rock series (probably the Prichard) several basic igneous sills of varying widths were present. These sills have been correlated by the writer with the Moyie sills** which have been described in Boundary and Bonner counties, Idaho, and in British Columbia. The Belt rocks are the oldest rocks in the region and also the lowest stratigraphically. They underlie all formations shown on the map except the granitic areas.

They are exposed everywhere in the mountainous regions, except where they have been removed from the granite by erosion and where they remained uncovered by the wide-spread basalt flows which now mask the valleys, foothills, and lowlying areas. The areal outcrop of the Belt series is represented on the map by the obliquely lined areas.

Although a few minor folds and possibly some minor faults exist in the older rocks, lack of time as well as lack of pertinency to the problem in hand prevented the identification and mapping of these irrelevant features. The beds, although deposited in an approximately horizontal position, have, during the long ages of their existence, been folded, faulted, and tilted, and they are now exposed in a tilted attitude, dipping for the most part in a westerly direction at angles ranging from observed dips of 25 to 60 degrees. Jointing and bedding are well developed and with this high dip the beds immediately absorb any water which falls upon or runs over the surface. Such water, because of the prevailing westerly dip, is conducted with depth to some point far west of the mapped area.


GRANITIC IGNEOUS INTRUSIONS

The crest of the Thatuna Hills, or Moscow Mountains as they are commonly called, and of Gold Hill is made up of intruded cupola-like masses of granodiorite which have been uncovered by erosion during Tertiary and Quaternary time.

This magmatic intrusion which is part of the well known Idaho batholith is believed to have occurred in either Jurassic, Cretaceous, or Eocene times. Its phases range from granodiorite, quartz-monzonite, to granite which are assumed to be differentiations from a common magma possibly dioritic in composition.

In the field the rock shows a uniform light gray and pink color with large phenoocrysts of feldspar. An aureole of gneissic and schistose material with an average thickness of 500 feet is commonly found as a transition phase. Contact metamorphism is apparently greater at the roof than at the sides, on account of the presence there of more magmatic gases and altering agents. This formation is represented on the map by variously aligned dashes.

BASALT LAVA FLOWS

Lava flows of an age generally assigned to the Miocene and commonly thought to represent one of the more easterly embayments of the vast Columbia River lava plateau to the westward constitute the most important rocks affecting the underground water supply of the area.

The basalt, at one time molten, viscous lava, was poured out in great quantities over the old land surface. The upper surface of the flow formed a comparatively level floor to the valley. Considerable time intervals elapsed before the second and ensuing flows as evidenced by the accumulation of soil, silt, and lake bed material. The second flow poured out on a relatively level surface and its upper surface in turn presented another flat valley floor at a higher level. This was repeated until at least five flows covered part of the area. The later flows, of course, overlapped the foothills.

A fairly high relief and rugged contour had been established in the Belt sediments and granitic intrusions previous to the outpouring of the lava, and these valley flows were, therefore, confined to old established drainage depressions of considerable width. The later flows being successively at higher elevations in reality overflowed the true valleys and consequently abutted upon the flanks of the foothills.

Although not the case here, in many places this inundation of the older rocks by the Miocene (?) basalt lava permitted the higher outlying peaks to remain as uncovered islands in this "lava sea."

As a result of this investigation one discovery of considerable geologic significance can be recorded. Therefore the Columbia River basalt or Yakima basalt, as it is variously called, has never been associated with an eruption center such as a volcano, a crater, or a cone. Its origin or source has invariably been assigned to fissures and vents from which the lava was thought to have issued gently rather than by explosive action.
The writer, having worked for a number of field seasons in the extensive lava fields of the Snake River Plain where the lava sources are chiefly from local craters and cones, has long believed that similar local sources have contributed to the basalt flows of the Columbia lava plateau. With this belief in mind it was no great surprise to find an explosive center of eruption, now marked by dipping tuffs, agglomerates, and rapidly chilled lava flows, at a point on the North and South Highway one half mile east of Princeton. The old crater as exposed by erosion and by highway construction excavation shows a diameter of approximately 675 feet and the highly colored red and pink tuff and explosive material is exposed vertically for more than 15 feet. At the west edge of the cone the tuffaceous material dips notably to the west. The center of the cone is occupied by a thin flow of platy, quickly chilled lava, a phenomenon noted to be of common occurrence on the Snake River Plain. On the eastern edge of the cone the lava dips gently away from it and shows the same platy structure often characteristic of extremely small local flows.

The position of this crater in the valley and its relation to the area overlain by the basalt is such as to suggest that this center of eruption may have been responsible for a large part, but not all, of the lava.

It is not improbable, however, that much of the lava entered the valley as an eastward flowing embayment from the great inundation to the westward. Although both sources may have been instrumental in filling the present valley, it is certain that the Princeton crater contributed some of the basalt. This unique eruptive center will be more fully described with photographs and illustrations in an early number of one of the geological journals.

The basalt of the area is a heavy, dark, hard rock varying greatly in texture and characteristics in the various flows. At some places it is highly vesicular and porous. Its attitude at some distance from the crater is approximately horizontal although there is a slight tendency near Potlatch to a gentle westward inclination.

Erosion since the last basalt intrusion has of course dissected its originally level surface somewhat, but probably no more than two flows have been cut through in most of the area. This is fortunate for the water-supply since it is the lower flows which act as the chief aquifers. The basalt is represented on the geologic map by crossets.

Included in this symbol and covering the lava to varying depths in much of the area is found a loessial or wind-carried overburden generally called the "Palouse hills", "Palouse formation", and "Palouse soil". This material, whose exact origin is now being debated, probably had many sources. In many places to the west it has a thickness and character which perhaps justified the adoption of a true formation name.

Interbedded with the basalt flows in this area occurs a formation commonly found associated with the basalt along the eastern and southeastern edges of the Columbia River lava plateau. It has been called the Latah formation at Spokane by Pardee and Bryan of the United States Geological Survey. It has also been described at St. Maries.

As shown by well logs at Potlatch, this formation here shows the following members from bottom to top starting at a depth of 560 feet:

- Sandstone: 31 feet
- Coarse conglomerate: 3 "
- Alternate layers of red and brown clay: 57 "
- Basalt: 28 "
- Shale: 18 "
- Conglomerate: 21 "
- Clay: 8 "
- Loosely cemented sandstone: 14 "
- Well cemented sandstone: 15 "

Above this occur four lava flows of 91, 66, 78, and 70 feet thickness respectively. On these lies 47 feet of blue clay, which is covered by 19 feet of soil, gravel, and surficial overburden.

The total thickness of sediments represented here, exclusive of basalt flows and surficial overburden, is 213 feet. Much of this material serves as an excellent aquifer.

Considerable Pleistocene and Recent hill wash and alluvium cover some of the stream valleys. This is also included under the basalt symbol on the map.

Some Considerations of Underground Water and the Factors and Essentials for Its Occurrence with an Explanation for the Layman of Some Technical Terms

Although much water for potable and industrial purposes in supplying cities, towns, factories, farms, and irrigation projects, comes from underground, it originated from some form of precipitation such as snowfall or rainfall at the earth's surface. The melting snow or rain is eliminated by three processes - namely, evaporation, surface run-off in streams, and seepage into the ground. The water thus contained underground is generally conveniently divided into two heads to avoid confusion. These are ground water and artesian water.

Ground Water

Although some of the water which is constantly seeping into the ground is retained in the upper soil by capillarity and speedily returned to the surface again by evaporation, most of it sinks deeper into the lower soil and underlying rock masses which it saturates to a certain level. This zone of saturation represents a great body of water which furnishes water for lakes, springs, and streams, and is the water encountered by shallow surface wells. Its upper surface, which is the level maintained in a shallow well, fluctuates with the seasons and the rainfall and snowfall of the area, but actually underlies the land surface at a relatively short distance at all times. When the land surface is irregular so, also, is this upper surface or water-table, but to a lesser degree. Thus the water-table is farther from the surface beneath the hills and closer to the surface beneath the valleys. In many depressions it comes to the surface as temporary springs, as swamps, as lakes, or as seeps which insure the level of permanent streams. In regions with heavy rainfall, this water-table is close to the surface and in arid regions it may be several hundred feet below the surface. Its distance from the surface in any region, of course, fluctuates and lags behind the wet and dry seasons. The movement of this water is, as at the surface, in a down-
hills direction and it generally comes to the surface, or is concentrated in
valleys and generally follows the valley bottom where it may be in some cases
entirely separated from an overlying river by an impervious clay layer. It
is the most common source of underground water. *

ARTESIAN WATER

The various bed-rock types underlying the surficial layers of soil and
unconsolidated materials have varying degrees of porosity and thus varying
capacities for holding water. The water collects in cavities such as pores
between grains or crystals, joint cracks, bedding planes, vesicles, etc., and
saturates the rock to the best of its ability. Many rocks are relatively
impermeable to the water and others are porous and can hold or conduct a large
amount of it.

When a particularly porous rock is overlain by a relatively impermeable
layer, little water may enter it by downward seepage and it may not reach
saturation. If, however, this porous rock is folded or tilted so as to be
eroded and crop out at the surface, it may readily become filled with a greater
supply than the overlying formation.

True artesian water is that confined in rocks under sufficient hydrostatic
pressure to cause the water, when a way of escape is afforded, to rise towards
the surface although not necessarily high enough to flow out at the surface.
The essential difference then, is the tendency of artesian water to flow
toward the surface as a result of confinement and pressure whereas ground water
tends to sink away from the surface. The ideal requisite factors, then, for
artesian conditions may be stated as comprising: (1) an adequate source of
water supply such as heavy rainfall or snowfall; (2) a porous layer or rock
area, known as an aquifer, well enough equipped with cavities to contain a
large supply of water; (3) a practically impermeable retaining agent which
resists the upward progress of the water; (4) a source of pressure.
Numerous conditions exist in rock masses where a variety of water traps are
created which possess these four factors. The common one, however, is where
stratified beds of varying degrees of permeability have been warped from their
original horizontal, or nearly horizontal, depositional position to a tilted
or folded position so as to provide an artesian slope or basin wherein the
permeable beds, or aquifers, are exposed at the surface and fed therefrom
and lie between impermeable or slightly permeable beds. The entering surface
water, under these most favorable conditions, flows down hill along these
porous beds until it escapes at a lower level or, falling escarp, backs up
the slope as the pervious bed is filled, thus developing an increasing degree
of saturation until no more can be held. In an artesian slope an increasing
pressure is exerted in a saturated bed from the outcrop to the lowest position
on the slope. Should there be a natural outlet slope or lowest point, the
pressure is relieved. Although artesian conditions may still prevail up the
slope, because of the friction and slowness of movement and the size of the
reservoir area, flowing surface wells may not be expected because the lack
of pressure and true confinement. In an ideal artesian basin, water at the
low point in the aquifer receives a hydrostatic pressure from the slopes in
every direction and when tapped will flow at the surface providing it is con-
siderably lower in altitude than most points of outcrop of the aquifer.

* In the discussion which follows, the possibility of waters derived from other
than surface sources, such as certain hot springs, is purposely
omitted.
**Definitions**

**Annual ground water increment.** - The increment or recharge of ground water may be approximated by a simple calculation. From the annual precipitation of the area is subtracted the stream run-off as measured by stream gauges, and from this remainder is subtracted the loss by evaporation and vegetal usage, which usually must be approximated. The final remainder enters the ground in the catchment and intake areas and represents so many inches, or fractions thereof, which are converted then into acre-feet by multiplying by the size of the catchment area, thus making it possible to determine the amount of water that can be extracted from an artesian basin without impairing its producing possibilities.

**Aquifer.** - Any permeable, porous formation (layer, rock, or substance) which will permit water under ordinary pressure to move through it perceptibly.

**Confining bed.** - Any impermeable or impervious formation (layer, rock, or substance) which will not permit movement of ground water under ordinary pressure.

**Intake area.** - The intake area is the actual surface dimension occupied by the outcrop of the aquifer. It usually slopes away from the flanks of an elevated area where exposed by erosion or by unconformity. The outcrop may occupy a narrow belt or an irregular area and dips into the basin where it is covered by the confining bed. The size of the intake area varies with its nature, thickness, and inclination as well as the topography of the region. In a relatively flat region a gently tilted aquifer of great thickness would have an enormous intake area. In a similar region a steeply tilted aquifer of the same thickness would have a very small intake area.

**Catchment area.** - Most of the water which enters an aquifer through its intake area is water which fell elsewhere and drained to it rather than that which falls immediately thereon. That area whose drainage crosses an intake area is called the catchment area and always includes the intake area. Elevated regions near intake areas are generally catchment areas and the surface stream-drainage divide becomes also the catchment divide.

**Static level.** - The level at which water stands in an artesian well at any one point in an aquifer. It may be higher or lower at a different well in the same aquifer at some distance. It is similar to the surface watertable but is independent of it.

**Piezometric surface.** - An imaginary surface that everywhere coincides with the static level of the water in an aquifer.

**Isopotential line.** - This is a line on the piezometric surface whose every point is an equal distance above sea-level. It is a contour line.

**Hydraulic gradient.** - This is the vertical drop or rise per unit of length of the piezometric surface of an aquifer. It is a measure of the pressure drop as the water moves through the aquifer. The speed of underground flow is proportional to the steepness of this gradient. Artesian water flows from a few hundred feet to a few hundred yards per year.

* For a more adequate discussion of this subject the reader is referred to Meinzer, Oscar B. - Outline of Ground Water Hydrology - U. S. Geol. Survey Water-Supply Paper 494, 1923.
Fig 2 - Actual geologic structure section along line A-B, of Fig 1, showing local stratigraphic changes. As deduced from well logs.

Fig 3 - Generalized geologic structure section along line N-S of Plate I, showing relationships of formations.
THE GROUND WATER SUPPLY AT POTLATCH

The average annual precipitation of the mapped area is approximately 25 inches. It is known that approximately 12.5 inches of this escapes by stream run-off and it is assumed that 9 inches is used in evaporation and vegetal discharge. This leaves approximately 5.5 inches which enters the catchment area and constitutes the annual ground-water increment.

The area within the catchment divide lying east of Potlatch gives a total catchment area of 137,000. This when reduced produces approximately 40,000 acre-feet of water. When this figure is computed in cubic feet of water and in millions of gallons of water increment per year the results are so far in excess of the possible demand as to permit the annual increment factor to be totally disregarded.

The officials of the Potlatch Lumber Company are seeking a water supply which will provide them with from 400 to 425 gallons of usable water per minute. A ground-water increment of 1000 acre-feet of water will easily satisfy this demand.

Basalt flows usually make excellent aquifers inasmuch as the fine-grained part of each flow often acts as the impermeable layer and a lower vesicular, porous jointed, and broken zone is often an excellent aquifer. Where more than one flow exists another impermeable zone also exists and so on. There is usually a layer of soil or thin sediments between flows which also acts as a passageway for the water.

The intake area occurs where the basalt abuts against the rocks of the Belt series. It is relatively narrow and in this instance is on the under side and edges of the flows rather than exposed at the surface. The upper surface of the flat-lying basalt where exposed acts also as an inefficient intake area since it permits some water to descend into underlying aquifers by means of the columnar joints perpendicular to them. These are located in the fine-grained and supposedly impermeable zones between the more porous zones or layers.

Although the basalt layers can act as an agent to deter the upward rise of the water, they have no opportunity to serve this purpose here because the aquifers are drained naturally into the vast plateau to the west. Because there is no barrier in the old pre-basalt valley the accumulation of pressure is prevented. The distance from the intake area to Potlatch is long enough, however, to permit the building up of a hydrostatic head through friction and slow movement. Consequently, a well tapping these aquifers might be expected to yield as much as 400 gallons of water per minute with the water rising to within 65 feet of the surface. (See well logs following.)

Although many surface wells have been drilled within the area, many of them failed to penetrate any of the aquifers and nearly all of the others were drilled by itinerant workmen who kept no logs or who failed to properly classify the formations penetrated so that the logs are untrustworthy as guides to stratigraphy. Other drillers have left the region and are now impossible to locate.

Outside of surface evidence, the only underground evidence of a reliable nature which could be used in this investigation was the stratigraphy revealed by the logs of the four wells at the mill plant of the Potlatch Lumber Company.
These wells are grouped closely together in a fashion indicated by the accompanying sketch. They are numbered from one to four in reference to their age.

STATISTICAL DATA CONCERNING WELLS

(Supplied by courtesy of Potlatch Lumber Company)

Well No. 1.
Depth: 478.4 feet.
Water level: 63.5 feet from surface.
Casing: 478.4 feet of 4-inch steam pipe.
Pump: Harris Air Pump.
Production: 100 gal. per minute.
Log: None available.

Well No. 2.
Depth: 312+ feet.
Water level: 63.5 feet from surface.
Casing: 311 feet of 5-inch steam pipe.
Pump: Harris Air Pump.
Production: Not producing now; at one time was credited with 300 gal. per minute.
Log: None available.

Well No. 3.
Depth: 436 feet.
Water level: 90.6 feet from surface.
Casing: 8-inch hole to bottom; 70.6 feet of 8-inch steam pipe; 247 feet of 4-1/2-inch steam pipe from top of 8-inch casing.
Pump: Harris Air Pump.
Production: In 1916, 240 gal. per minute; at present, approximately 200 gal. per minute. The flow is decreasing probably due to air leak. This well has been credited with a flow of 400 gal. per minute at one time. No records show such a flow, however.
Log: 13 feet soil.
   6 " gravel.
   46 " blue clay.
   65 " basalt, black.
   First water here.
   60 feet basalt, gray.
   Second water here.
   166 feet basalt, blue.
   28 " basalt, black, porous.
   20 " red porous rock (probably sandstone).
   Third water here.
   6 feet clay; contained wood and charcoal.
   Fourth water here; chief flow.
   6 feet basalt, black, hard.
   436 feet, bottom of hole.
Wall No. 4.
Depth: 1705 feet.
Water level: Unknown.
Casing: 16-inch down 118 feet.
16-inch hole open to 462 feet.
From 462 feet 11-5/8-inch casing down 78 feet.
10-inch hole open to 612 feet.
8-inch hole starts at 612 feet down to 1400 feet.
6-inch hole starts at 1400 feet down to 1705 feet.
Pump: Lane-Bowyer Pump.
Production: 130 gal. per minute for two weeks. This decreased then to 60 gal. per minute which was maintained for three weeks.
Log: 13 feet soil.
6 " gravel.
46 " blue clay.
70 " basalt, blue and black.
First water here.
78 feet basalt, gray to blue.
Second water here.
66 feet basalt, black.
91 " basalt, blue.
15 " sandstone, cemented.
14 " sandstone, un cemented.
8 " clay.
21 " coarse grit and conglomerate.
18 " shale and clay.
28 " basalt, black.
57 " alternate layers of red and brown clay and shale.
5 " coarse grit and conglomerate.
31 " coarse grit and sandstone.
229 " quartzite with three interbedded crystallized limestone layers.*
449 " crystallized limestone probably Wallace formation.*
2 " clay.
200 " crystallized limestone.
282 " crystallized limestone including four layers of quartzite.

If the logs of wells No. 3 and No. 4 are authentic a considerable disparity in the stratigraphy is shown in the distance of 200 feet which separates the two wells. The surfaces of both of these wells are at approximately the same distance above sea level. In both wells it is 65 feet to the basalt. In well No. 3 first water appears at 130 feet and in No. 4 at 155 feet. In well No. 3 second water appears at 210 feet and in No. 4 it is 213 feet. In well No. 3 two basalt flows are credited with a thickness of 166 feet. In No. 4 the two flows total 157 feet. In well No. 3 the bottom of the upper basalt series is at 404 feet from the surface. In well No. 4 this horizon is reached at 370 feet. This shows a vertical disparity of 34 feet in a horizontal distance of 200 feet. If this is true, extremely local conditions prevail in the stratigraphy and hence in the water bearing capacity of the aquifers. In well No. 3 the lowest basalt flow is tapped at 430 feet. In well No. 4 this is tapped at 446 feet. This again shows a disparity of 16 feet. The accompanying geologic cross-section drawn from well No. 4 to No. 3 shows the probable condition existing underground, and shows two erosion stages between flows. As in the St. Maries area the Latah (?) formation was deposited after the first basalt flow and much, and in some places all, of it was removed before the second basalt flow.

* Probably Wallace formation of Belt series, or Cambrian.

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To account for the small flow of water in well No. 4 is difficult. In all probability, however, the flow from the aquifers escaped by means of the deep hole into the underlying, westward-dipping, highly jointed quartzites and limestones.

In order to increase the flow, No. 4 well was shot systematically all the way to the surface. This jammed, wrinkled, and tore the casing so that the surface waters entered the well. This causes bacterial pollution which makes the water useless. The entrance of this surface drainage also explains the production of 120 gallon per minute until the surface saturation was relieved; then the drop to 60 gallon per minute.

CONCLUSIONS

After a study of the four wells, the writer has concluded that the drilling of a new well is preferable and more economical than an attempt to repair or alter the present system so as to increase its production.

The problem resolves itself finally into the spotting of the well. The two alternatives which present themselves are: (1) the drilling of a well in the eastern part of the city on the terrace near the reservoir, and (2) the drilling of a well near the present battery of wells on the flat near the mill plant. The surface of the terrace near the reservoir rises about 175 or 180 feet above the surface of the other wells. This well, of course, requires the new well to be drilled 180 feet farther to tap the same aquifer as the wells on the flat, providing the aquifers are continuous and relatively horizontal, which is assumed. This well, lying several hundred yards away from the mill group, might have a vastly different log if underground conditions vary as rapidly as indicated by the logs of wells No. 3 and No. 4. Its advantage would be its closeness to the reservoir site. This, of course, is important because of the need for pressure in a mill town.

The advantage of the second option is small. A well drilled on the flat near the present mill group would have 180 feet less drilling and also the advantage of a known log. However, local changes are as likely to defeat success in a well nearby as one half a mile distant. The writer believes that a deep well drilled to the quartzite and equipped with perforated casing so as to be fed by the several aquifers would produce the desired supply of water at either location.

In view of the experiences of other municipalities the writer recommends that the Potlatch Lumber Company secure the type of operator who guarantees the desired amount of water for a stated price. If the contract is not fulfilled there is no cost. The wisdom of this procedure has been amply proven in several cases and the folly of the other course needs no discussion.