CLALLAM COUNTY TEST OBSERVATION WELL

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30N/2W-17G

Testwell #14

Test obs well #14

ABSTRACT

(T.30N, R 2 W. - Sec 17G1)

A 1000-foot test observation well was drilled near the town of Sequim, Washington, by the Washington State Department of Ecology in cooperation with the U.S. Geological Survey. The well is the tenth drilled to date under the State of Washington's test observation well drilling program. Information on groundwater conditions and geologic lithology was obtained and analyzed to establish adequate guidelines for the management of groundwater resources within the Clallam-Jefferson County area.

The Clallam County well penetrated unconsolidated materials - till, clay, sand, and gravels of predominantly glacial derivation. No bedrock was encountered.

Three pump tests were conducted, one on the middle aquifer, 489 to 531 feet, another on the lowermost zones, 814 to 877 feet and 970 to 1000 feet, and the last on the shallow aquifer, 245 to 265 feet. The first two tests drew saline water into the hole after pumping several minutes. The upper aquifer produced fresh water and was pumped at 50 gpm for over 8 hours with approximately 20 feet of drawdown.

The results would indicate that salt water intrusion may be encountered by wells that penetrate deeper materials along the straits even if they are situated 1/8 to 1/4 mile or more from the coastline. Fresh water is available from the shallower aquifers and may be pumped at 50 gpm or more.

Under normal circumstances, the well is favorably located to monitor changes in water levels with increased development in the area. However, because of the salt water influx to the more regional lower aquifers and the type of materials the hole penetrates, the well can be used to monitor only local groundwater conditions.

Clallam County Test Observation Well

Well Construction

Work began on the Clallam County test observation well on June 14, 1977. Tom Ketzenberg, driller for Richardson Well Drilling Company, operated a Koehring Speedstar rotary rig for the initial drilling and casing of the test well. By 1335 hours, a ten-inch steel casing had been placed to 36 feet. The top 65 feet consisted of glacial till; glaciofluvial clay, silt, sand, and gravel made up the balance of the lithology penetrated.

An 8-3/4 inch bit was used to drill from surface to the bottom and the hole was held open by drilling mud (Revert, formaldehyde and water) mixed to a viscosity of between 40 and 60 seconds. By June 17 the hole was down to 1015 feet.

On Saturday June 18, the geophysical logging equipment from Washington State University was on the site and the first log run, starting at noon of that day. Logs were spontaneous potential - resistivity, caliper, natural gamma, neutron gamma, gamma gamma, and neutron neutron. Fluid temperature and fluid resistivity logs were not run because the water in the hole was that introduced during drilling operations. The geophysical logs, analyzed by James Crosby and Jeff Brown, were used along with the geologist's log to determine depths of the various aquifers. Promising intervals were located at 245-260 feet, at 485-520 feet, at 820-880 feet, and at 970-1000 feet. It was decided to pre-perforate the casing at 970-1000 feet, 820-880 feet, 680-710 feet (for grout) and 485-520 feet, pump-test the middle aquifer (485-520 feet) first and the lower two aquifers (820-880 feet and 970-1000 feet) second and then mill-knife cut 320-330 feet (for grouting) and 245-260 feet, grout-off this upper aquifer and test-pump it last. The original contract had called for testing the lower aquifers first, the middle second (after mill-cutting perforations) and the upper aquifer last; limitations in using the mill knife at depths greater than 400 feet negated this plan.

On June 29, the first section of six-inch casing (21 feet) with drive shoe was placed in the hole. Each section of casing was welded to the next as it was added. By July 1, casing was in hole. Perforated intervals were at 489-531 feet (a full 42 feet rather than 35 feet), 672-702 feet, 814-877 feet, and 970-1000 feet. The hole was then flushed with chlorine, 2 bottles (11 lbs.) for each 2000 gallons of water in mixing tank, to break down the "revert" and collapse the hole against the casing. The chlorine was circulated throughout the hole to produce complete mixing with the "revert".

By July 5 the hole had been backfilled with pea gravel and 8 feet of bentonite pellets to the 715 foot depth. Cement was mixed with bentonite using a 94-lb. sack of "Portland Cement" to 5 lbs. bentonite and 5 to 6 gallons of water. A total of 13 sacks was mixed in the mud tank and pumped through the rods set at a depth of 540 feet. The grout was allowed to set overnight and then checked the next day with the rod. The grout had not settled sufficiently and, therefore, another 5 sacks of cement were added through the rods; however, this time from a depth of 660 feet.

On the morning of July 7 a water level measurement was made with the rods in the hole. The static water level (SWL) was determined to be 94.15 feet below top of the 6-inch casing. The grout, however, was still soft and it was decided to allow the grout to set an additional night. The next day the water level was down to 178 feet. July 11 was spent in developing the aquifer with air and water. On July 12 the SWL was measured at 0945 hours and was 85.5 feet below the top of the casing. A pump column was installed in preparation of pump testing.

The turbine pump was started on July 13 at 1115 hours with SWL at 97.29 feet. The initial discharge rate, measured by timing the filling of a 55-gallon drum, was 108 gallons per minute (gpm) and by 1245 hours the water level had dropped to 251.55 feet. A conductivity meter and Hach testing kit indicated the water was brackish with 2500 parts per million (ppm) chlorides. At 1330 the pumping rate was increased to 146 gpm and the water level dropped to 254 feet. At 1340 the discharge was increased to 170 gpm and the water level dropped to 256.5 feet. At 1415 water was sampled for lab testing. At 1510 hours, the pumping rate was 203 gpm and the water level was at 267 feet. At 1555, the discharge rate was 235 gpm and the water level had dropped to the bowl intake level at 290 feet. The pump was turned off at 1700 hours. The last water quality sample taken indicated a chloride content of 7000 ppm. The maximum acceptable concentration of chloride in drinking water is 250 ppm.

On July 14 the water level had risen to 242.01 feet below the top of casing. Time and "recovery" was as follows:

Time	SWL
0925	242.23 feet
0943	242.28 feet
1000	242.36 feet
1020	242.46 feet
1040	242.46 feet

These water levels probably reflect tidal influence since the tide was ebbing during the interval of measurement. Thus the aquifer pumped in the previous day's test was hydraulically connected with the Strait of Juan de Fuca. It was decided to grout-off this aquifer and test the lowest and then the uppermost aquifers.

From July 20 to the end of the month, work on the well consisted of grouting and regrouting to seal off the middle aquifer. Problems with bridging of cement and loss into the aquifer prolonged the final completion of the well.

August 1 through August 3 was spent in drilling and bailing with the cable-tool rig down to the lowest aquifer. However, at 700 feet where the perforations for grouting to separate the lowest and middle aquifers ead been cut, grout was pulled in through the perforations and sand entered the hole. The day of August 4 was spent in grouting the hole at approximately 700 feet to seal off sand. The grouting was not successful; however, it was decided to pump water from sand and gravels at the bottom of the hole. On August 8, 9, and 10 a pump column was placed in the well to 340 feet. The pumping test was to start early the next morning. However, hazardous fire conditions forced closure of the forest and postponement of the aquifer test. Not until August 18 was an attempt made to continue testing and then under "hoot owl", (late night conditions), when pumping would begin at 0200 hours. Mechanical problems cancelled this test. On August 22 a bailing test was conducted and samples collected. The bailing rate was 21 gpm and, as before, water was brackish, with chloride concentrations ranging from 480 ppm at the beginning of the test to 3530 ppm and salinity from 5.6‰ to 6.8‰. Specific conductivity ranged from 10,300 μmhos/cm at the beginning to 11,000 μmhos/cm.

By September 16, 1977 a rotary rig had been moved in and preparations were made to grout-off perforations at 700 feet. Sand, however, prevented grouting until the casing had been cleared to 710 feet. On September 21 the hole had been cleared and 3.5 yards of cement was added to the hole and water pressure was applied to push cement through perforations and out into hole. The cement was allowed to set. When drilling began again the cement was at 341 feet. By October 13 the hole had been drilled out to 1000 feet and developed for several hours. A pump test was conducted on the lower aquifer, October 19 and 20; again salt water was encountered. A total of 16 samples were taken and specific conductivity ranged from 37,600 to 44,000 μmhos/cm with pH of 7.7 to 8.7. Pumping rates were increased from 115 gpm to 317 gpm as the test progressed. The bowls had been placed at 348 feet; static water level measured 241.35 feet below the top of the casing. Because the airline diameter was not large enough for the electric tape, water level measurements could not be made. A larger airline would not fit between the column and the casing and any attempt to measure with the E-tape outside the airline while the pump was running resulted in a crushed electric line. By noon of October 21 the column had been removed and a static water level measurement indicated water to be 242.3 feet below the top of the casing.

October 24 through October 26 was spent in filling the well to 300 feet with pea gravel and grouting off approximately 280 feet to 300 feet. Mill knife cuts were then made in the casing (4 cuts per foot from 260 feet up to 245 feet). Water was added to the well to determine any loss. Within the first half-hour, the water level dropped from 200 feet to 218 feet and the next morning the static water level had dropped to 241 feet. The well was then developed by bailing until the pump and column arrived. Bailing down 30 feet brought cascading water from the perforations; however, after several hours of bailing 20 gpm the water level remained static. A water sample taken from the bailer indicated conductivity at 450 μmhos/cm, (under 250 ppm chlorides), much better than the previous samples from the two lower aquifers.

On October 28 the pump had been placed over the column and the bowls set at 287 feet. Five minutes into the test the water level was fluctuating around 272+ feet. Discharge varied from 30 to 60 gpm. The water level eventually dropped to the bowls where the pumping rate fluctuated from 50 to 60 gpm, depending on the amount of air that was being pumped. Water samples collected and then analyzed later disclosed chloride concentrations that varied from 25 to 44 ppm and specific conductivity of 419 to 461 μmhos/cm. After one hour, the pump was cut back to 3500 rpm and the water level stabilized at 261.5 feet with a consistent discharge rate of 50 gpm.

Clallam County Well in Retrospect

The Clallam County test well was one of only two deep observation wells drilled west of the Cascade Mountains by the Department of Ecology. Because of the lack of experience in drilling deep test wells in unconsolidated materials, using rotary methods, a number of mistakes were made which can be eliminated in future operations.

First and probably of primary importance, the mud rotary method is not the best system for drilling observation wells when lithologic information and aquifer identification and accessibility are essential. The movement of cuttings up the drill hole does not allow for enough accuracy in logging lithologic intervals and sloughing from previously drilled sections of the hole may further confuse the logs. The "revert" mud used in rotary drilling has a tendency to conceal potential aquifers and may even seal them off if it does not break down completely when rinsed with chlorine. The cable tool drilling method, although much slower, would probably be much more useful and accurate than rotary. The cable tool or churn drill allows for more precise logging. Since casing is driven as the well is drilled, individual aquifers may be pumped and tested as they are encountered. The specifications for drilling the Clallam County test well called for either rotary or cable tool drilling; it should have specified cable tool method since consolidated geologic formations were not anticipated and lithologic and aquifer conditions were important considerations.

Grouting delays became an important part of the Clallam County project. The need for grouting-off and isolating individual aquifers and the lack of a good system for doing so, postponed the final completion of this well for at least one month. The drillers either mixed the cement in the mud tanks and pumped it down through the drill rods or, when the cable tool was on the site, they mixed it in a cement mixer and poured it into the well from the surface. The former allowed for the water pressure to force grout out into the annular space between casing and hole and might have been adequate if enough cement had been forced down the hole by setting the rods just above the interval to be grouted. The latter method of grouting was inadequate in both respects and allowed the grout to bridge within the casing before reaching the area to be grouted. In both cases bentonite was mixed with the Portland Cement in the ratio of 5 pounds of bentonite to each 94-pound sack of cement and 5 to 6 gallons of water. The bentonite was unnecessary as it not only increased the setting time for the grout but decreased its initial and final strength and durability. The grout, sans bentonite, should have been pressure-grouted into the annular space. One method would entail welding a flange, able to accommodate 6 to 8 bolts, to the surface casing. A matching plate with pressure gauge and inlet pipe, as used under flowing artesian conditions, would be attached to seal off the well. One would then backfill the hole with sand or gravel to the level of grout perforations, pour the quantity of cement needed to grout the annular space plus 15 percent or 25 percent in case of loss and then place a wiper plug in the hole. The seal would be placed over the well and tightened down. Enough water to fill the casing to the surface would be pumped through the pipe inlet and the pressure monitored by the pressure gauge. The water pressure would force the wiper plug and grout down the casing to the perforations. The grout would then be allowed to set for 72 hours.

Another problem was obtaining airline or piezometer water level measurements during pump testing of the well. Because 6-inch casing was installed the entire length of the well, the diameter of the measuring pipe or airline was limited. A 3/8 inch diameter pipe, installed alongside the pump column to measure fluctuating water levels should have been adequate. However, the galvanizing in the pipe and the constriction at each joint prevented access of the electric tape used in water level measurements. A larger, 1/2-inch pipe would not fit in the annular space between the pump column and the 6-inch casing. An 8-inch or larger casing should have been installed and reduction to smaller size could have been done at either the 500-foot or 600-foot depth. The airline should not be set directly on the pump bowls; the vibrations from the pump will cause the water level to fluctuate within the airline.

In summary, a cable-tool type drilling rig should be used for the drilling of deep test observation wells in unconsolidated to poorly consolidated materials. The specifications should have allowed for larger diameter casing; perhaps 12 or 16 inch as surface seal with reduction to 10 or 8 inch and perhaps 6 inch diameters as the well progressed. A more adequate method of pressure grouting should have been incorporated to seal off individual aquifers.

Lithologic Log of Clallam County
Test-Observation Well (30N/2W-17G)
Drilled and Grouted June 14 to October 28, 1977

Material	Thickness	Depth
Till, brown, weathered	22	22
Sand, silty, brown	26	48
Till, brown, weathered	2	50
Gravel, pea size fragments, clay	20	70
Sand, fine, silty, brown, w/some gravel	35	105
Sand, silty, brown	5	110
Sand, fine, silty, brown w/some pea size gravel, sub-angular to rounded	10	120
Sand, fine, silty, brown w/some pea size weathered gravel, clay	10	130
Sand, fine, silty, brown w/some pea size gravel, sub-angular to rounded	25	155
Sand, fine, silty, brown w/some gravel slightly more coarse and more angular	10	165
Sand, fine, silty, brown w/less gravel	15	180
Silt, sand, fine, brown w/some clay	10	190
Silt, sand, fine, brown, more clay	5	195
Silt, sand, fine, brown, clay more Fe discoloration	5	200
Clay, brown-gray w/some silt	8	208
Clay, greasy, brown-gray, some silt	3	211
Peat, brown	4	215
Clay, greasy, brown, w/some silt	5	220
Clay, greasy, interlensing blue-gray and brown clay	3	223
Clay, blue (gray) w/some clay, brown	8	231
Clay, blue, fine sand, brown	4	235
Sand, fine, brown, blue clay lensing out	8	243
Sand, fine, brown, blue clay, w/some gravel	2	245
Sand, coarse, brown clay w/angular pea size gravel - may be till	2	247
Clay, tan, blue w/silt, gravel	3	250
Clay, brown (orange), blue, rig compressor pressure up (dense materials)	3	253
Sand, brown, some pea size gravel	7	260
Clay, brown, some silt, pea gravel	8	268
Clay, brown, pressure up	2	270

Upper aquifer

Material	Thickness	Depth
Clay, brown w/some fine sand, pea gravel	10	280
Clay, brown w/coarse brown sand	10	290
Silt, brown w/brown clay and some coarse sand and gravel	10	300
Silt, sandy, brown w/brown clay	10	310
Sand, fine, brown w/some silt, brown clay and gravels	10	320
Clay, brown w/silt, some pea gravel	10	330
Clay, brown, blue-gray w/some silt	10	340
Sand, brown, brown silt, light to dark brown clay	10	350
Clay, and silt, brown w/some light and black pea size gravel	10	360
Sand, brown w/some coarse sand and pea gravel, small amount of silt	10	370
Sand, coarse, brown w/black, green and light colored clasts	10	380
Sand, coarse, brown, black, some light colored w/some fines, silt, clay	10	390
Sand, coarse, brown, black, light colored, rounded to sub-rounded, some fines, silt, clay	10	400
Sand, coarse some pea gravel, brown, black, white weathered clasts	10	410
Sand, coarse, brown, black w/silt, brown clay	15	425
Sand, fine, brown, brown clay and silt, some light and dark gravel clasts	5	430
Sand, medium to coarse, brown to black, light colored, w/some silt present	10	400
Sand, medium to coarse, brown to black w/some silt	10	450
Sand, fine to medium, brown, black, green to light w/clay and silt and some pea gravel	10	460
Sand, medium to coarse, brown, black, green w/some brown silt	8	468
Cobbles, as reported by driller	2	470
Sand, medium to coarse, brown, black, green w/some brown silt, and pea gravel	10	480
Clay, silty, brown, some pea gravel	10	490
Sand, medium to coarse, black, brown, browy clay w/some pea gravel	5	495
Cobbles, gravel, angular to rounded, black, green, light colored w/some silt, clay	5	500
Sand, medium to coarse, angular to rounded, brown, black, green, light, w/silt and brown clay, some pea gravel, less clay than above	10	510
Sand, medium to coarse, sub-angular to angular, some rounded clasts, various colors, some clay, silt, pea gravel	10	520

Middle aquifer

Material	Thickness	Depth
Sand, coarse, various colors, fine gravel, silt, brown clay	10	530
Sand, medium to coarse, angular to subangular, some rounded, various color - more silt, clay than last sample, pea gravel	10	540
Sand, fine to medium, angular to rounded, various color, much silt, brown clay, some pea gravel	5	545
Silt, clay, brown, less sand	5	550
Silt, clay, brown, fine sand w/pea gravel of various colors	10	560
Silt, clay, brown w/some coarse sand or fine gravel, various colors	10	570
Silt, clay, brown, fine sand mixed w/coarse sand of various colors	10	580
Silt, clay, brown, some medium-coarse sand, pea gravel, rounded to subangular, various colors	10	590
Sand, medium to coarse, rounded to subrounded, various colors, silt, brown clay, not as abundant as in previous sample, some pea gravel	10	600
Sand, medium to coarse, rounded to subrounded, various colors, silt, brown clay, some pea gravel	10	610
Sand, medium to coarse, w/fine gravel, rounded to angular, various colors, almost no silt or clay	5	615
Sand, medium to coarse, silts, brown clay (also oxidized orange-brown), fine gravels	5	620
Sand, medium to coarse, angular to subrounded, various colors, pea gravels, some silt	10	630
Sand, coarse, various colors, angular and subangular to rounded pea gravel, some silt and brown clay	10	640
Sand, medium to coarse, various colors, silt, brown clay, subangular to rounded pea gravel	10	650
Sand, medium to coarse, various colors, silt, some brown clay of greater quantity than previous sample, pea gravel	10	660
Sand, fine, various colors, silt, some clay, pea gravel	10	670
Silt, fine sand, brown, some brown clay, some coarse sand of various colors	10	680
Silt, brown clay, some coarser sand of various colors	10	690
Silt, fine sand, brown clay, a few coarser sand particles	10	700
Silt, brown clay, very few coarser sand particles	10	710
Silt, clay, fine brown sand, very few coarse sand grains	10	720
Sand, fine, silt, some brown clay, samples becoming coarser, some medium sand	10	730
Sand, fine to medium, brown, silt, some brown clay, some coarse sand, various colors	1	731

Material	Thickness	Depth
Sand, fine to coarse, some pea gravel and brownish-gray silt and clay	9	740
Same	5	745
Sand, fine to coarse, pea gravel, angular fragments of broken pebbles, a little silt and brown-gray clay	5	750
Same with less clay and silt, more fragments of pea gravel	7	757
Same, increasing amount of brown to gray clay	3	760
Sand, fine to coarse, pea gravel size angular fragments, brown clay and silt, increased clay content	3	763
Clay, silt, brown, fine to coarse sand, fragments of pebble size gravel	7	770
Same	10	780
Clay, silt, brown, fine to coarse sand, pea gravel of various colors, angular and some broken fragments, probably 50/50 fines to coarse volume	10	790
Sand, coarse, angular, various colors, silt, brown clay, angular/broken pea gravel present	10	800
Clay, silt, brown, fine to coarse sand of various colors, predominantly fines	10	810
Clay, silt, brown, some fine to coarse sand	2	812
Sand, coarse angular to subrounded, various colors some silt, brown clay, pea gravel, faster drilling-coarser material	8	820
Sand, coarse, varied colored fine gravel, angular to subrounded, some brown silt	10	830
Same with some brown clay	10	840
Sand, very coarse, fine to medium gravels of various colors, angular to subrounded, some brown silt and clay	10	850
Sand, coarse, varied colored fine to medium gravel, angular to subrounded, some brown silt and clay	10	860
Sand, coarse, many colored fine to medium grain gravels, angular to subrounded, brown silt and clay. A Higher percentage of fines than previous samples	10	870
Same	10	880
Silt, clay, brown, coarse sand and fine gravels, angular to subrounded, varied in color, more fine materials than sand and gravel	10	890
Silt, clay, brown, coarse sand, gravels as above, greater percentage of fines	10	900
Clay, silt, brown w/some gray-blue clay some coarse sand, various colors present	10	910
Clay, blue-gray, some silt and medium to coarse sand, various colors	10	920

Material	Thickness	Depth
Silt, brown, less clay, some coarser sand, overall fraction more coarse than previous sample	10	930
Silt, brown, some clay, coarse sand, some multi-colored pea gravel, angular to rounded	10	940
Silt, clay, brown, very little gravel, some medium to coarse sand of various colors is present	10	950
Silt, brown, blue clay, also coarse sand of various colors	5	955
Clay, blue, some coarse angular sand fragments	5	960
Clay, silty, blue, fine to coarse sand, angular to subrounded, various colors	10	970
Sand, coarse, angular to subrounded, various colors, some brown silt	10	980
Sand, coarse, w/fine, angular to subangular gravel of various colors, and some brown silt	10	990
Sand, coarse, fine multi-colored, angular to subrounded gravel, some brown clay and silt	10	1000
Same	10	1010

aquifer (970–1000)

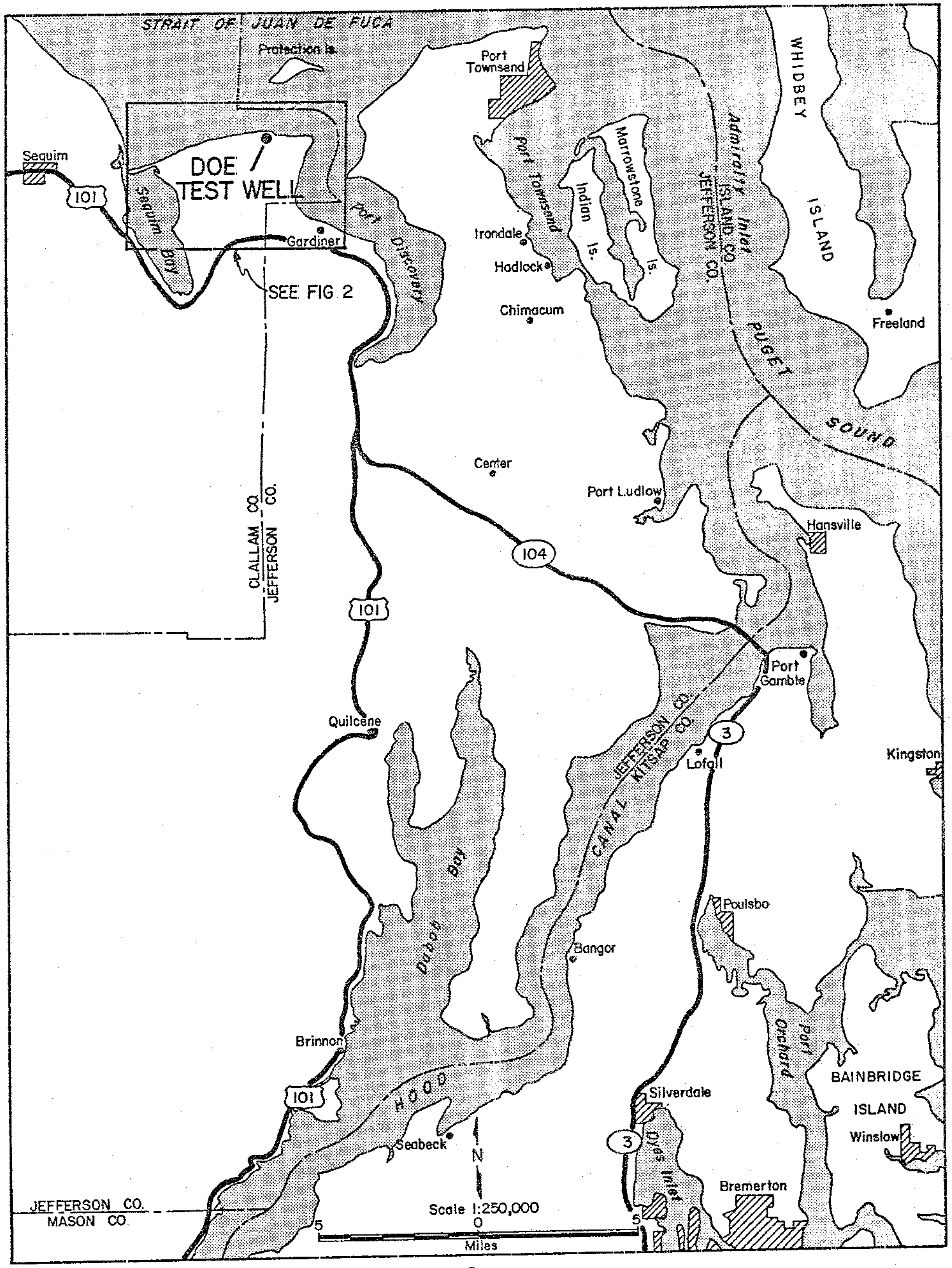

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Figure I. GENERAL LOCATION MAP, HOOD CANAL AND VICINITY.

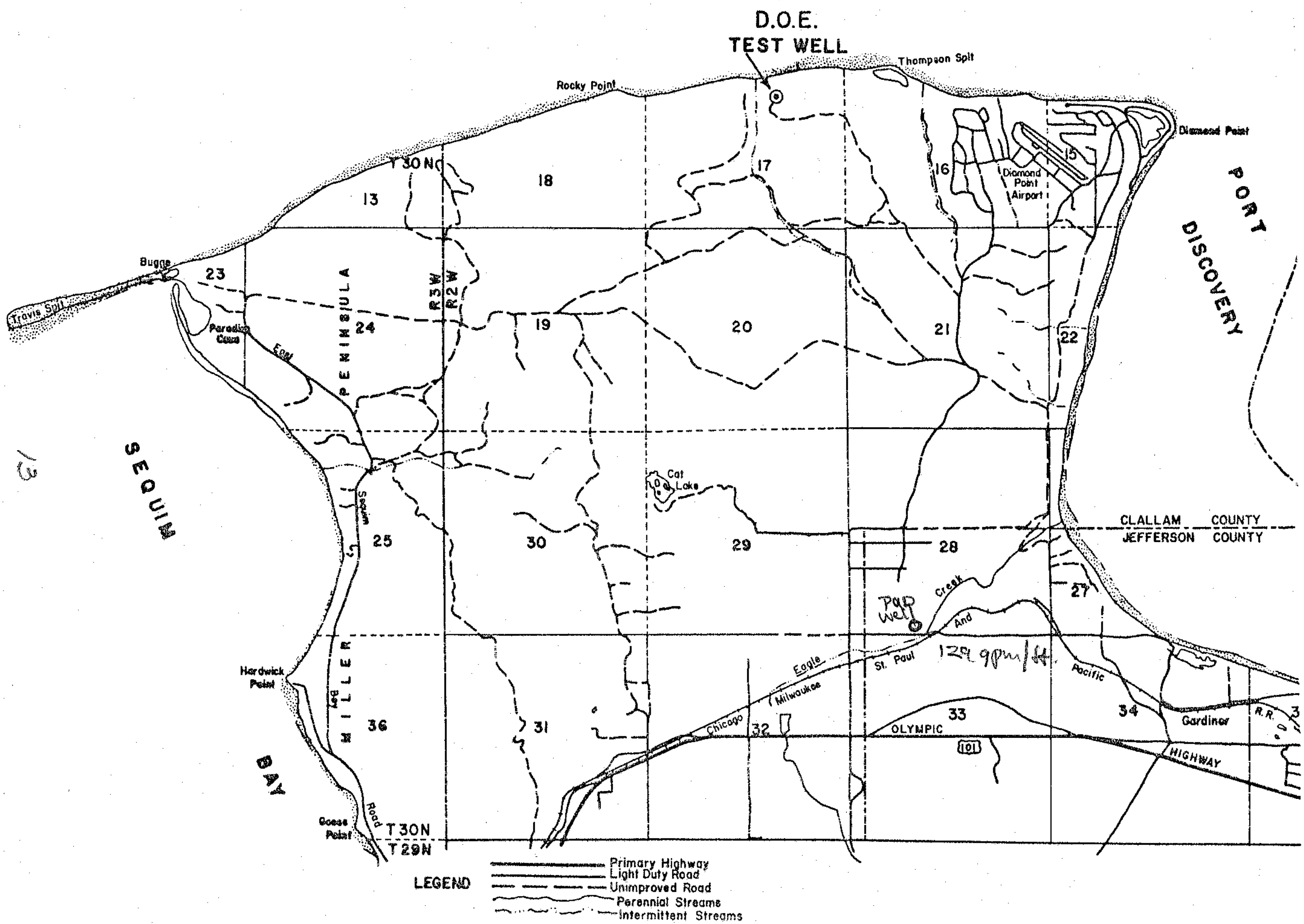

Figure 2. LOCATION MAP, MILLER PENINSULA, TEST OBSERVATION WELL NO. 14.

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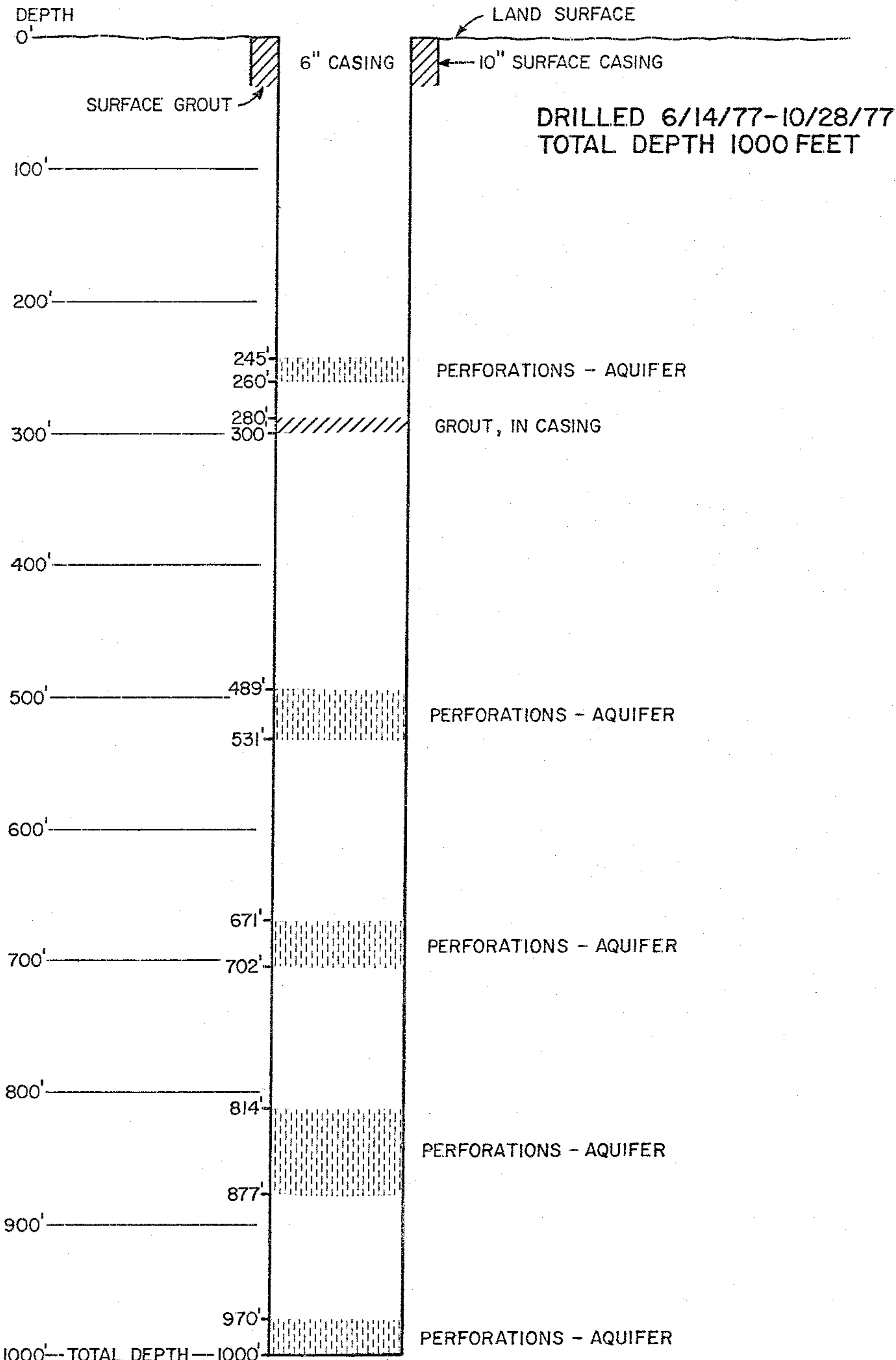

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Figure 3. TEST OBSERVATION WELL NO. 14, CLALLAM COUNTY.