A BRIEF DESCRIPTION OF THE GROUND-WATER RESOURCES of PACIFIC AND WAHKIAKUM COUNTIES, WASHINGTON

By

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TABLE OF CONTENTS

ILLUSTRATIONS

TABLES

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ABSTRACT

Pacific and Wahkiakum Counties, in southwestern Washington, have an area of about 1,200 square miles. This semimountainous area is bordered by the Pacific Ocean. The area has a marine climate with precipitation averages ranging from 70 to over 120 inches per year, most of which occurs in winter.

For purposes of this study, rocks in the area are divided into three unconsolidated Quaternary units and two Tertiary bedrock units.

Alluvium, consisting of peat, clay, silt, sand and gravel, occurs mainly in the lower parts of valleys, where it is relatively thin, and in a narrow strip near the beach north of Willapa Bay, where it may exceed 200 feet in thickness. The alluvium in the valleys generally yields only small amounts of water, but yields may vary from none to a few hundred gallons per minute. Irrigation pits in alluvium along the coast north of Willapa Bay yield from 100 to 500 gpm.

Beach and associated marine deposits consist mostly of sand, but also have clay, silt, and some gravel at depth. These deposits lie along the ocean and also form North Beach Peninsula. The unit exceeds 1,000 feet in thickness in places, and yields up to 2,000 gpm, to wells and irrigation pits.

Terrace deposits consisting of unconsolidated to semiconsolidated beds of clay, silt, sand, and gravel which overlie the bedrock in the

northwest part of the area, and are more than 800 feet thick in places. These deposits yield up to 220 gpm to wells.

The basalt of the Columbia River Group consists of as much as 1,400 feet of nearly flat-lying flows with minor amounts of interbedded sandstone and conglomerate, and occurs in the southeastern part of the area. Yields of water from the unit vary from small to as much as 1,200 gpm from some wells.

Older sedimentary and igneous rocks underlie the entire area and crops out over most of it. Yields to wells from this unit generally are small.

Nearly all of the ground-water withdrawal occurs on North Beach Peninsula and along the coast north of Tokeland and is used mainly for domestic and irrigation purposes. The amount of ground-water withdrawn from wells in the project area is small.

Most of the ground water is good quality, soft to moderately hard; and is the calcium bicarbonate type. Excessive amounts of chloride and iron occur in some of the water. Some of the high chloride water may be incipient sea-water intrusion, and some is connate water.

INTRODUCTION

Purpose and Scope

As part of an interagency study of the water resources of the Pacific Coast region of Washington, the U.S. Geological Survey was requested in April 1969 to make a reconnaissance-type study of the ground-water resources of Pacific and Wahkiakum counties in southwestern Washington.

The investigation and the writing of this report was done during May and June 1969 by D. R. Cline. Existing data and various reports were collected and selectively synthesized into this report.

Most of the wells and ground-water development in the project area are in Pacific County on the North Beach Peninsula and along the narrow coastal plain from Tokeland to the Grays Harbor County line. Data are presently available for less than one half of the wells in these areas, and less than one half (130) of the wells for which data are available are included in this report. Nearly all the wells in Pacific County from Raymond south to the Columbia River were inventoried by the writer from August through October 1968 for another project.

This report describes, on a reconnaissance basis, the ground-water resources of Pacific and Wahkiakum counties. The geologic principal units, their distribution, and water-yielding characteristics, as well as the availability, use, and chemical quality of ground water are discussed.

Previous Work

A number of reports and maps deal with the geology of various parts of the two-county area, among these are work by Williams (1952), Henriksen (1956), Pease and Hoover (1957), Gower and Pease (1965), Livingston (1966), Beikman, Ran, and Wagner (1967), Wagner (1967a, b), and Wolfe and McKee (1968). A report by Rigg (1958) discusses the peat resources of the area, and Livingston (1958) listed oil and gas test wells.

Reports that pertain to ground water in the project area are much fewer in number. Ground water in the Grayland area is discussed by Wegner (1956), in the Willapa River valley briefly by Walters (1963), and in adjacent coastal Oregon by Frank (1968). A few chemical analyses are given by Van Denburgh and Santos (1965), and some water use data by Laird and Walters (1967). An unpublished report by A. O. Waananen in 1965 briefly discusses ground water in the Willapa Bay area, and a reconnaissance report by K. L. Walters (in review), for which this writer collected much of the data in Pacific County, discusses salt-water intrusion along the coastline.

Acknowledgments

Information and data that were supplied to the writer by well owners and various other individuals and organizations is gratefully acknowledged. Thanks is given in particular to the Washington State Division of Mines and Geology for geologic information.

Well Numbering System

The well numbers used herein give the location of the well. The first part of the numbering system gives the township and range; the number following the hyphen gives the section; and the letter gives the 40-acre tract within that section, as shown in the diagram. The last number is the serial number, and is assigned in the order that the wells are inventoried in each 40-acre tract, thus the second well inventoried in the NE1/4 of the NW1/4 of Sec. 32, T. 9 N., R. 5 W. was designated well 9/5W-32C2.

PHYSIOGRAPHY AND CLIMATE

Pacific and Wahkiakum Counties are in southwestern Washington and are bordered on the south by the Columbia River and on the west by the Pacific Ocean. Willapa Bay is a large nearly enclosed bay that occupies most of the western side. North Beach Peninsula is a barrier bar, 1-2 miles wide, extending north over 20 miles from the mouth of the Columbia River and enclosing most of Willapa Bay. Along the east and north side of the area no natural boundaries occur, and the hills, rising to 3,000 feet above sea level, extend into the adjacent counties.

The interior of the area includes most of the Willapa Hills and is mostly uninhabited except along the main river valleys. The valleys are narrow generally in the upper reaches, but broaden moderately near the mouths of the rivers. On the west side the hills stop abruptly at or near the coast. Inland a mile or so from the coast north of Willapa Bay an escarpment rises to a terrace about 200 feet above the narrow coastal plain.

The area has a marine climate with wet winters and distinctly drier summers. About   percent of the precipitation occurs in the   month period   to   Precipitation averages about 70 to 80 inches per year along the coast and increases inland with altitude, probably exceeding 120 inches per year on the higher peaks.

GEOLOGIC UNITS AND THEIR WATER-YIELDING CHARACTERISTICS

The rocks of the area are divided into five units for the purpose of this report, three units are of Quaternary age and two are of Tertiary age. The Tertiary units form the bedrock of the area. Overlying the bedrock in places, are minor deposits of unconsolidated material, such as landslide deposits and silty clay beds. These are omitted from discussion in this report because they yield little or no water, and so are not important for the purposes of this report.

Quaternary Deposits

Deposits of Quaternary age in the area are unconsolidated to semi-consolidated, and consist of peat, clay, silt, sand, gravel, and boulders. These deposits contain the major ground-water resources, and are the main sources of supply of ground water in the area. North of Willapa Bay the identification of, and relationships between these deposits at depth are uncertain. Unconsolidated deposits probably underlie some of southern Willapa Bay and may underlie much of the rest of the bay. The relationship and continuity, if any, between the Quaternary marine deposits beneath North Beach Peninsula and the terrace deposits on Long Island is unknown; however, because the distance between the two localities is less than two miles, unconsolidated deposits probably extend continuously under the bay in this area.

Alluvium

Alluvial deposits in the project area consist of peat, clay, silt, sand, gravel, and boulders that are poorly to well sorted. The alluvium was deposited by streams mainly in the bottoms of the major valleys, on the peninsula at Tokeland, and the strip between the beach sand and the terrace deposits north of North Cove (Figure 2). The latter area probably was a lagoon that has been filled with eroded terrace deposits and now has, in places, a thin layer of peat on top. Much of the peat is roughly five feet thick; maximum thickness is less than 10 feet probably (Rigg, 1958).

The alluvium is generally thin in the river valleys, less than a few tens of feet thick, and in some places a stream, such as the Willapa River, has cut down to bedrock, leaving only a thin mantle of alluvium on the flood plain. Alluvial deposits along the Columbia River probably are considerably thicker, at least in some places, although information is lacking in this area. In the Tokeland area unconsolidated deposits are more than 200 feet thick; how much of this material is alluvium is uncertain. North of North Cove the alluvium, which perhaps here includes other unconsolidated deposits, changes in thickness from a few tens of feet to more than 200 feet within very short distances.

North of Willapa Bay the alluvium overlies semi-consolidated terrace deposits (as shown by wells which have no casing in the lower part, Table 2), and probably also overlies beach and associated marine deposits, particularly along the western side of the coastal alluvial strip. Elsewhere alluvium overlies bedrock mostly; in the Elochoman River valley by Cathlamet, alluvium overlies the basalt of the Columbia River Group.

Yields range from little or no water to moderately large amounts from wells and irrigation pits tapping the alluvium. Much of the alluvium in the river valleys yields only small amounts of water to wells. In places the permeability of the alluvium is very low or the alluvium is unsaturated, at least part of the time, so that it yields little or no water. Conversely at other places in the river valleys the alluvium will yield as much as a few hundred gallons per minute to wells. Along the coast north of Willapa Bay are many irrigation pits tapping the alluvium; most of these pits yield 100 to 300 gpm, -- a few yield up to 500 gpm.

Beach and Associated Marine Deposits

Beach and sand constitutes most of the beach and associated marine deposits, but much silt and clay and some gravel occur at depth (Table 2). At places on North Beach Peninsula a thin layer of peat overlies the beach sand; generally the peat is one to five feet thick, but locally may be as thick as 10 feet (Rigg, 1958). The beach sand, which commonly has drift-wood associated with it, occurs at the surface over the whole outcrop area (Figure 2), and overlies beds containing various amounts of sand, silt, clay, and some gravel. The beach sand in the project area has been blown into longitudinal north-south-trending dunes that average about 25 feet in height, although some rise to 50 feet.

The beach sand is more than 100 feet thick in places, excluding the height of dunes, and the combined thickness of the beach sand and associated marine deposits probably is many hundreds of feet through much of the area of their occurrence. Maximum thickness of these deposits is apparently more than 1,400 feet at the north end of North Beach Peninsula. The deposits thin to the south, as shown by the decreasing depth to bedrock in wells (Table 2) and the cropping out of bedrock by Seaview, Washington (Figure 2). Bedrock also crops out on the east side of Long Island, and some continuity probably exists between the Quaternary deposits of Long Island and the peninsula.

Along the coast north of Willapa Bay, the beach and associated marine deposits probably extend eastward beneath the alluvium, and wedge out against the underlying terrace deposits. The beach deposits apparently thicken rapidly toward the west. An oil test well about one quarter of a mile inland from the ocean went through just over 1,000 feet of unconsolidated sediments before reaching bedrock (well 15/11W-31G1, Table 2).

The beach and associated marine deposits will yield moderate to large amounts of water (as much as 2,000 gpm) to wells and irrigation pits on North Beach Peninsula (Table 1). No information on yields from the deposits north of Willapa Bay is available, but yields there probably are similar to those from the adjacent alluvium and from deposits of North Beach Peninsula. Nearly all the wells tapping the beach sand are shallow, small-diameter sand points which produce enough water for house and yard use. Most of the wells producing large quantities of water are large diameter irrigation pits.

Terrace Deposits

The terrace deposits consist of semiconsolidated to unconsolidated beds of clay, silt, sand, and gravel (Table 2). These form a sea cliff more than 200 feet high north of Willapa Bay. The deposits directly underlie most of the northwestern part of the project area and extend south along the shore of Willapa Bay to the south end of Long Island (Figure 2).

The terrace deposits overlie bedrock surface that is quite hilly and underlie alluvium in the stream valleys and adjacent to the sea cliff extending north from Willapa Bay. The terrace deposits may also underlie beach deposits at depth; the relationship between terrace and marine deposits is unknown.

The maximum thickness of the terrace deposits is unknown, but is more than 700 feet in the district north of Willapa Bay, and more than 800 feet near South Bend, and apparently more than 600 feet at Bay Center. Records of wells north of Willapa Bay show that the terrace deposits extend to more than 300 feet below sea level, and the nearby sea cliff and hills rise to 400 feet above sea level. At South Bend a well on the ridge adjacent to well 14/9W-29Q1 (Table 1) reported penetrated more than 800 feet of terrace deposits.

The terrace deposits yield small to moderate amounts of water to wells, up to 220 gpm (Table 1); and wells tapping some sand and gravel zones possibly could yield as much as 400 gpm. Most of the terrace deposits above sea level are unsaturated along the coast and in valley walls. Inland from the coast, and back from the valley walls where there is now (1969) virtually no development, much more of the terrace deposits lying above sea level are probably saturated and would yield at least small amounts of water from sand and gravel zones.

Tertiary Deposits

The rocks of Terrtiary age are consolidated and form the bedrock which underlies the whole area. These rocks consist of thick sequences of various sedimentary rocks, lava flows and volcanic debris, and some intrusive igenous rocks. Generally the bedrock yields little water and is tapped for ground-water supplies only if supplies from other sources are not available; the exception is basalt of the Columbia River Group, which is more productive in places.

Columbia River Group

Basalt of the Columbia River Group comprises a series of nearly flat-lying lava flows and some generally minor interflow beds of sandstone and conglomerate. To the west sedimentary rocks markedly increase and lava flows decrease in abundance, according to Livingston (1966).

Within the study area the basalt occurs in the southeastern part and is all in Wahkiakum county (Figure 2). In the present compilation, some minor amounts of this unit were included with the older sedimentary and igneous rocks where the small areal extent and the topographic position of the basalt are not favorable for yields of more than small amounts of ground water, similar to yields from the underlying bedrock.

The basalt of the Columbia River Group is overlain by alluvium in the Elochoman River valley and along the Columbia River west of Cathlamet. To the southeast of the Elochoman River overlying the basalt on the high ground are some unproductive silty clay beds that are relatively thin, generally less than 40 feet thick, including weathered basalt (Livingston, 1966). These beds are not shown on the map nor discussed further becasue they will yield little water and have little effect on the hydrology of the area.

The thickness of the basalt ranges considerably because of the undulating erosional surface of the underlying rock, and the irregular erosional surface on the top of the basalt. The thickness of the basalt may be as much as 1,400 feet in places (Livingston, 1966, p. 37).

The basalt of the Columbia River Group yields small to large amounts of water to wells in the project area, as much as 1,200 gpm. Yields of closely adjacent wells tapping the basalt can be very different (Table 1) because of differences in the number and character of fractures and the flow zones that are intersected. Basalt flows of small extent and higher present positions, as on the narrow ridges, are apt to be unsaturated; more extensive basalt, especially at the lower positions tend to be more productive.

Older Sedimentary and Igneous Rocks

The older sedimentary and igneous rocks constitute the bedrock in the area except for the Columbia River basalt. This unit comprises shale, sandstone, conglomerate, volcanic flows and breccias, and minor amounts of intrusive igneous rocks. It is the most widespread of all the units, extending through the whole area and directly underlying most of it, particularly inland from the coast and the Columbia River. All fo the other units overlie this bedrock unit. The thickness of the older and sedimentary igneous rocks is many thousands of feet, at least.

Although many different rock types are included in this rock unit, all appear to have nearly similar water-yielding characteristics. Wells topping this unit generally have yields that range from small amounts of water to virtually none. Data concerning the water-yielding characteristics of this bedrock unit are scarce; however, yields to wells of more than 20 gpm are probably rare.

GROUND WATER

Although ground water occurs in all five rock units in the study area, the Quaternary age deposits constitute the most important reservoir of fresh ground water. The basalt of the Columbia River Group yields large amounts of water locally, but more than small yields from this unit are largely unpredictable.

Recharge

The ground-water reservoir is recharged largely by precipitation that falls on the area and infiltrates the ground surface. Most of the recharge is in the winter and spring when precipitation is greatest. During the summer and early autumn little or no recharge occurs; evapotranspiration returns what little rain that does fall to the atmosphere. Ground-water levels rise naturally during the winter and spring and decline during the summer and autumn in response to the rate of recharge.

Rain that falls on the beach deposits soaks in quickly; very little surface runoff occurs in this area. Bedrock areas, on the other hand, have rather large amounts of surface runoff because the normally steep slopes and low permeability of the rocks prevents much infiltration. Thus, areas underlain by beach deposits receive much more recharge from precipitation than do bedrock areas even though less precipitation falls at the lower altitudes. Areas covered by the alluvium and terrace deposits generally receive intermediate amounts of recharge from precipitation. Where near-surface materials are silty and clayey, the recharge might diminish to near that of bedrock; where they are clean sand and gravel they absorb much water.

Some of the water running off the hills into the valleys would be available for recharging the alluvium also.

Movement

Ground water in the project area moves generally from the hills toward the valleys where it discharges largely as seepage to streams, and toward the coast, where it discharges into the ocean. Ground water in the beach sand on North Beach Peninsula moves toward the ocean on the west side and toward the bay on the east side. If the terrace and marine deposits are continuous eastward beneath the bay, ground water may possibly move west from the mainland at depth beneath the bay and the peninsula to discharge into the ocean. On the peninsula, water levels in the shallow wells are about the same as in deeper wells, indicating very little vertical movement of ground water in this part of the area. In the coastal district from Tokeland to the Grays Harbor County line, water levels in the deep wells tend to be a little higher than those in the shallow wells and a number of wells flow indicating some upward movement of hydraulic gradient in ground water system. The artesian head originates from ground water in the high terrace deposits to the north and east.

Discharge

Ground water in the area is discharged by means of springs, seepage into streams and the ocean, evapotranspiration, and wells. Ground-water flow into streams is probably the major means of discharge although a large amount of ground water must discharge directly into salt water of the ocean, particularly from North Beach Peninsula but also from unconsolidated deposits in other areas. Spring flow and the ground-water portion of streamflow are the lowest in autumn when ground-water levels are low and at the highest, when ground-water levels are high, generally in spring. An analysis of streamflow data for streams draining mostly bedrock areas in the two counties shows that the discharge of ground water from the bedrock to the streams is small (E. G. Nassar, U.S. Geol. Survey, oral communication, 1969). This situation is due to the low permeability of the bedrock which does not absorb much of the precipitation.

The discharge of ground water by evapotranspiration is relatively small; it is significant only in summer when the climate is hot and dry and at places where the water table is at or near the land surface. Areas where evapotranspiration from the ground water reservoir can be appreciable are the lakes, peat beds, and lowlands between the dunes on North Beach Peninsula, the peat beds and lowlands north of North Cove, and the stream valleys, particularly near their mouths.

The amount of water discharged by pumping from wells in the area is small because much of the area is undeveloped, and because surface water supplies are used for the larger communities. The major ground-water withdrawals occur on North Beach Peninsula, excluding the north end, and along the coast from Tokeland north to the Grays Harbor County line. The towns of Ilwaco, Seaview, and Long Beach are supplied by surface water, however. On North Beach Peninsula and north of Tokeland most of the ground water is withdrawn from April to October and only a small amount is withdrawn during the winter. Elsewhere also, more ground water is withdrawn during the summer than the winter, but the difference is not so marked.

CHEMICAL QUALITY

Ground water in Pacific and Wahkiakum Counties is mostly good-quality water that is soft to moderately hard. Some water contains excessive iron, chloride, or dissolved solids. The main constituents in the good-quality ground water are silica, calcium, and bicarbonate (Table 3); the hardness of water from 11 wells ranges from 12 to 91 milligrams per liter (mg/l, same as ppm), with the water from 4 wells being soft (0-60 mg/l) and the other 7 being moderately hard (61-120 mg/l). Dissolved solids from these wells ranged from 44 to 163 mg/l, considerably less than the U.S. Public Health Service recommended limit of 500 mg/l. Other recommended concentrations limits, within which the water from these wells lie, are iron 0.3 mg/l, chloride 250 mg/l; sulfate 250 mg/l; and nitrate, 45 mg/l. Specific conductance is a measure of the concentration, degree of ionization, and ionic strength of the dissolved-solids constituents; as a rough guide in the project area, water exceeding 1,000 micromhos is considered to be of poor quality.

Dissolved constituents that are excessive in the water from a few wells include iron, chloride, dissolved solids and hardness mainly. The chemical analyses of water from one well in Table 3 (11/11W-34P1) show that the water is of very poor quality, having excessive values for all parameters. The water from this well is used only for washing cranberries. This well, which taps deposits from 139 to 149 feet below sea level, probably is drawing saline water into it during pumping. According to the Ghyben-Herzberg principe saline water normally would be encountered about 320 feet below sea level for a water level in the well of 8 feet above sea level. However, by drawing the water level down, during pumping to 3 1/2 feet above sea level, which is only 4 1/2 feet of drawdown, saline water would rise high enough to enter the well. Determinations of chloride concentrations of ground water in the two county area ranged from 3.2 to 1,840 mg/l. However, only 16 of the samples analyzed had concentrations greater than 50 mg/l. Fresh ground water normally contains less than 25 mg/l chloride. Because salt spray probably adds some chloride to the ground water, On North Beach peninsula water containing more than 50 mg/l chloride generally is not considered to be indicative of sea-water intrusion by K. L. Walters, U.S. Geol. Survey (written commu., 1969).

North of Willapa Bay saline water occurs in various zones (Table 3). K. L. Walters (written commun., 1969) postulates that in this former lagoonal area the salty zone contain incompletely flushed connate water. At places in the project area and elsewhere in southwestern Washington the bedrock contains saline water, which certainly must be relic sea water.

Excessive iron in the ground water is a problem locally; of the 12 wells samples and listed in Table 3, five yielded samples that had dissolved iron concentrations greater than 1 mg/l. In the area from Chinook to the north end of North Beach Peninsula many well owners reported to the author that their water contained excessive iron and many others reported their water contained no noticeable iron. The only relationship discernable to the author concerning the occurrence of iron from the reports of the local people is a seeming tendency for the water from wells located in between the dunes to contain excessive iron, and wells on the dunes to contain little iron. In the coastal Oregon sand dunes immediately south of the Columbia River about three dozen analyses for iron ranged in concentration from 0.05 to 53 mg/l (Frank, 1968). No pattern to the distribution of the iron concentrations is readily apparent.

WATER USE

Ground water is mostly used for domestic and agricultural purposes in the project area (Table 1). The two areas of greatest use of ground water -- North Beach Peninsula and from Tokeland to the Grays Harbor County line -- contain many homes, resorts, and cottages, and many acres of cranberry bogs. By far the largest number of small supply wells are used for domestic use and lawn and garden watering. A number of irrigation pits withdraw moderate to large amounts of ground water for irrigating cranberries and for controlling frost and excessive heat so as to prevent damage to the berries. The amount of ground water withdrawn in 1965 for irrigation in Pacific County was 105 acre-feet, and in Wahkiakum County was 9 acre-feet (Laird and Walters, 1967).

Water is used from a few wells in the project area for public supplies. Most of the wells supply less than two or three dozen homes; Bay Center was the only community larger than this to be supplied with ground water in 1968. Bay Center had a population of 600 people in 1960. In the fall of 1968 a privately owned public-supply system was being readied to serve Ocean Park and Nahcotta (population, 1,000 people in 1960).

Only a small amount of ground water is used in the project area for industrial purposes -- about 7 million gallons in 1965 (Laird and Walters, 1967). Seafood processing is the main industrial use of ground water. Small amounts are used for commercial purposes, stock watering, and fish hatcheries.

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