Geology and Ground-Water Features of the Smith River Plain Del Norte County California

By WILLIAM BACK

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CONTENTS

ILLUSTRATIONS

[Plates 5-7 in pocket]

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By William Back

ABSTRACT

Smith River plain, in the Klamath Mountains physiographic province of California, borders the Pacific Ocean in the northwest part of Del Norte County, 400 miles northwest of San Francisco. The area of investigation, 20 miles long, comprises about 110 square miles. Agriculture, mining, logging and lumbering, and commercial fishing are the principal industries in the county.

Cool summers and mild winters characterize the climate of the plain. Normal annual precipitation is about 75 inches. Precipitation is heaviest during the five coldest months, from November through March.

Smith River plain is a broad, subrectangular emerged marine terrace of low relief at the base of a range of rugged mountains. The surface of the plain is underlain by marine-terrace deposits, alluvial fill, and sand dunes.

The area is drained principally by the Smith River and its tributaries from a small watershed, 613 square miles, that has the exceptionally high annual runoff of about 2,600,000 acre-feet, or 80 inches. Lakes Earl and Talawa, shallow brackish-water lakes in the west-central part of the plain, form a collection basin for runoff from several minor streams.

Rocks that crop out in the area range in age from Jurassic to Recent. Jurassic arkose, graywackes, chert, and serpentine and other intrusives underlie the plain and form the mountains to the east. Overlying these rocks, in a small area around Crescent City, is the marine St. George formation of Pliocene age, composed of 350 to 400 feet of sand and clay. Marine sand and clay of the Battery formation of Pleistocene age overlies the St. George formation and overlaps onto the Jurassic rocks. Locally, the Jurassic rocks are directly overlain by unconsolidated river-terrace deposits or Recent flood-plain deposits.

The Battery formation, which averages about 35 feet thick, is the aquifer for most of the domestic water supplies on the Smith River plain. Most of the ground water for irrigation is from wells that penetrate Recent flood-plain deposits, although a few irrigation wells obtain water from river-terrace deposits.

Recent flood-plain deposits have the highest water-yielding capacity. The coefficient of permeability for these deposits ranges from 5,000 to 20,000 gallons per day (gpd) per square foot. The coefficient of permeability of the terrace deposits of the Smith River is 1,000 to 2,000 gpd per square foot, and the terrace deposits of Rowdy Creek are even more permeable. The coefficient of permeability for the Battery formation is about 500 gpd per square foot.

Recent sand dunes along the coast constitute a catchment area for storage and recharge of ground water. These deposits are a potential source of water for water-deficient Crescent City.

The Jurassic rocks and the St. George formation generally do not bear water. Coefficients of permeability of two samples from the coarser facies of the St. George formation were 2.6 and 13.7 gpd per square foot.

Wells are shallow—few exceed a total depth of 35 feet. Depths to water

commonly range from 5 to 25 feet below the land surface. Seasonal fluctuation probably averages 5 feet. The total annual pumpage of ground water on the Smith River plain is about 2,400 acre-feet, of which some 1,700 acre-feet is used for irrigation. The gross ground-water storage in the Smith River plain, from 10 feet to 35 feet below the land surface, is about 100,000 acre-feet.

Both surface water and ground water in this area are of low mineral content and are generally of excellent quality for all uses. The only natural detriment is the high content of iron in some areas. There is no evidence of sea-water encroachment into this coastal basin.

INTRODUCTION

LOCATION AND EXTENT OF AREA

The Smith River plain borders the Pacific Ocean in the northwest part of Del Norte County, Calif., 400 miles northwest of San Francisco (fig. 1). Comprising about 110 square miles, the area has a north-south length of 20 miles and a general east-west width of 5 miles; it lies between 41°40′ and 42°00′ north latitude, and between 124°00′ and 124°15′ west longitude. The area is shown on the United States Geological Survey's topographic maps of the Klamath (formerly Requa) and the Crescent City (formerly Point St. George) quadrangles, 15-minute series, scale 1:62,500.

United States Highways 101 and 199 make the area readily accessible from Eureka, 85 miles to the south, from Oregon coastal towns to the north, and from Grants Pass, Oreg., 90 miles to the northeast.

PURPOSE AND SCOPE OF THE WORK

The Geological Survey, in cooperation with the Division of Water Resources of the State of California Department of Public Works, made a reconnaissance investigation of the Smith River plain, the major ground-water basin in Del Norte County, as a part of a cooperative program for reappraisal of the State's ground-water resources. The investigation was designed to determine the geologic features of ground-water occurrence, quantity, and movement; the location and extent of the ground-water areas; and the influence of hydrologic and geologic factors on the chemical quality of the ground water.

The report summarizes the basic data of 213 wells, including water-level measurements, estimates of pumpage, drillers' logs, and chemical analyses. A geologic map of the area shows the distribution of the geologic formations.

This investigation was made under the general supervision of A. N. Sayre, chief of the Ground Water Branch, Water Resources Division, United States Geological Survey, and J. F. Poland, district geologist in charge of the ground-water investigations of the Geological Survey in California. The project was under the direct supervision of A. R. Leonard, geologist, Ground Water Branch.

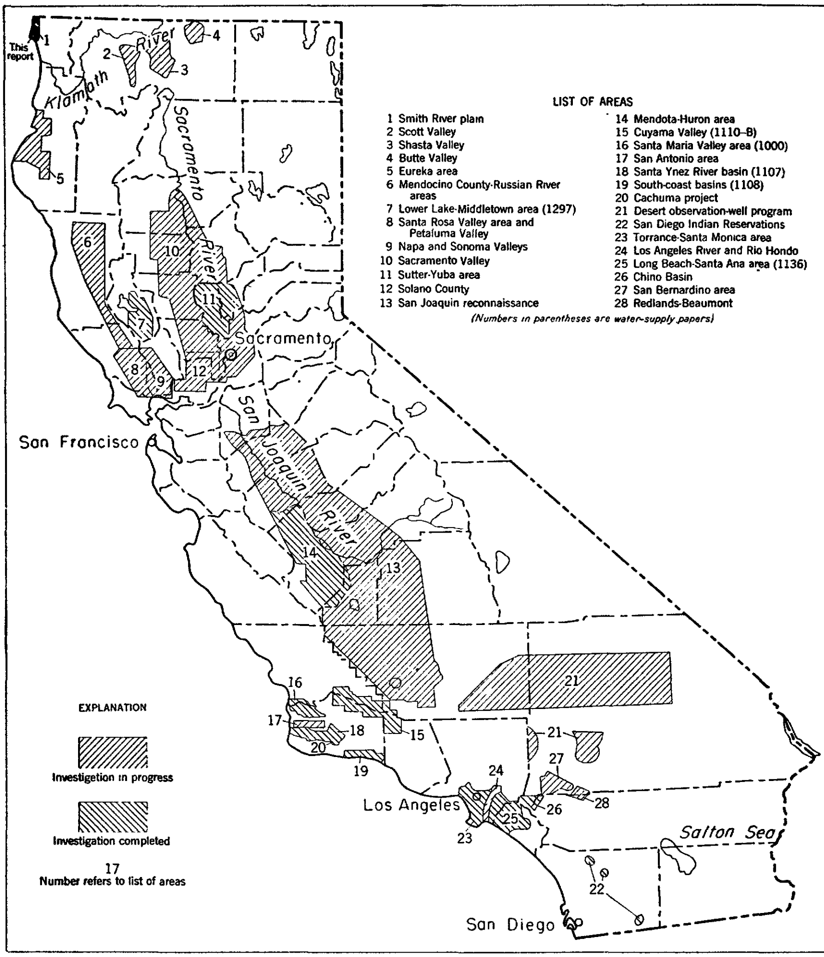


FIGURE 1.—Map of California, showing the location of the Smith River plain.

PREVIOUS INVESTIGATIONS

The first description of the physiography and general geology of the area was prepared by Diller in 1902. A very brief report on the economic geology of Del Norte County was written by Hershey (1911), based upon a reconnaissance made in 1907. Mineral resources of the mountain region not covered in this report have been described by several writers. Maxson (1933) described the mineral deposits of Del Norte and Siskiyou Counties, primarily with regard to geological setting and genesis. In 1952 Salem Rice included the Cresent City (formerly Point St. George) quadrangle in the reconnaissance study that he made of northwestern California. His report is to be published by the Division of Mines, State of California Department of

Natural Resources, as a guidebook of the Redwood Highway. McCullough,[1] Division of Water Resources of the State of California Department of Public Works, prepared an unpublished report for the Regional Water Pollution Control Board, based on a week of field work in May 1952.

METHODS AND PROCEDURES

During a total of 3 months of field work between July and December 1953, 213 wells were located. These wells are described in the Records section of this report. Water levels in the wells were measured whereever possible. Wells were plotted on preliminary copies of the maps of the Crescent City (formerly Point St. George) and Klamath (formerly Requa) quadrangles, scale 1:40,000.

Wells were located by means of an odometer to within 0.10 mile, shorter distances were estimated, and wells were then plotted in reference to the culture shown on the map. Aerial photographs were used for some locations. Locations are accurate to within about 100 feet. All water-level measurements were made from a fixed measuring point at the top of each well, using a steel tape graduated to hundredths of a foot, and are accurate to about 0.10 foot. The altitude of each measuring point was estimated by use of an aneroid barometer. A few field tests indicated that the error of the aneroid measurements was less than 2 feet; therefore, the error in relative altitudes of any two measuring points probably is not greater than 4 feet.

Drillers' logs of 89 wells (not included in this report) were obtained from the Division of Water Resources; the well locations reported by drillers were checked in the field.

Irrigated acreage was obtained by totaling the irrigated acreage reported by each farmer. Several farmers also furnished data on their annual use of water per acre. By assuming uniform irrigating practices for other farms, an estimate was made of the amount of water used for irrigation in 1953.

The yield of each irrigation well under operating conditions was estimated by determining the number and size of sprinklers, assuming an average pressure, and correcting with published data for friction losses in pipes and sprinklers. By dividing the yield (gallons per minute, *gpm*) by the measured drawdown (*dd*), a rough approximation was made of the specific capacity, in gallons per minute per foot of drawdown.

The "yield factor," expressed simply as a number, was estimated by dividing the specific capacity by the saturated thickness of material

[1] McCullough, C. A., 1952, Ground-water conditions, Smith River plain, Del Norte County: Calif. Dept. Public Works, Div. Water Resources, unpub. rept.

(total depth of well minus depth to water) and multiplying by 100.[2] From this, a crude estimate of the field coefficient of permeability, in Meinzer units (p. 15), can be obtained by multiplying the yield factor by some figure between 15 and 20. (See p. 16.) In formulas:

$$\text{Specific capacity} = \frac{gpm}{dd}$$

$$\text{Yield factor} = \frac{\text{Specific capacity}}{\text{Saturated thickness}} \times 100$$

Ground-water storage beneath the Smith River plain was estimated by computing the total footage of each of five types of sediment, applying a specific-yield figure [3] for each type (p. 43), and calculating storage for each of five lithologically distinct subareas, which were delineated by a peg model. The peg model was constructed by indicating the lithology with a color symbol on quarter-inch dowels. Lithology was based on reports by well drillers. At locations representing the wells, the colored pegs were stuck into holes in a plywood table on which a map of the area had been glued. The color symbols grouped the material according to its hydrologic properties—pegs of similar color represented logs of wells drilled into material of similar water-yielding properties.

Two permeability tests and four grain-size analyses were made in the laboratory of the Geological Survey at Lincoln, Nebr. The permeability tests were made of samples from the St. George formation, Pliocene age, by using a permeameter. The grain-size analyses were made of two samples from the St. George formation and two samples from the Battery formation of Pleistocene age.

Technicians of the Division of Water Resources, using a portable refraction seismograph (pl. 1*A*), estimated the thickness of alluvium and depth to bedrock at 2 selected localities and the thickness of Pleistocene sediments, Pliocene sediments, and depth to bedrock at 3 other localities.

The geology was mapped in the field on base maps at a scale of 1:40,000, supplemented by aerial photographs of the United States Department of Agriculture, which were at a scale of 1:20,000.

Hydrographs of two wells were drawn from records obtained from recording gages for the period July to December 1953. Another hydrograph was drawn from weekly measurements made by E. C. Johnson, a local resident, in his own well.

[2] Poland, J. F., Sinnott, Allen, and others, 1945, Withdrawals of ground water from the Long Beach-Santa Ana area, California, 1932–41: U. S. Geol. Survey open-file rept.

[3] The specific yield is the ratio of the quantity of water that will drain by gravity from a saturated water-bearing material to the total volume of the material.

Most of the 36 ground-water analyses in the table on page 66 were of samples collected during the field season and analyzed at the laboratory of the Geological Survey at Sacramento, Calif. The other analyses were furnished by the Division of Water Resources.

Samples of Smith River water have been collected monthly by the Division of Water Resources and analyzed in part by it and in part by the Geological Survey. Chemical analyses of 36 samples of surface water are included in this report.

All precipitation and temperature records were obtained from published records of the United States Weather Bureau.

WELL-NUMBERING SYSTEM

The well-numbering system used in California by the Geological Survey and the Division of Water Resources shows the location of wells (or other features) according to the rectangular system for the subdivision of public land. For example, in the number 16/1W–17A1, assigned to a well 2 miles north of Crescent City, the part of the number preceding the slash indicates the township (T. 16 N.); the number between the slash and hyphen indicates the range (R. 1 W.); the digit between the hyphen and the letter indicates the section (sec. 17); and the letter following the section number indicates the 40-acre subdivision of the section, as shown in figure 2.

D	C	B	A
E	F	G	H
M	L	K	J
N	O	P	R

FIGURE 2.—Diagram showing 40-acre subdivisions of a standard section.

Within each 40-acre tract the wells are numbered serially, as indicated by the final digit of the number. Thus, well 16/1W–17A1 is the first well to be inventoried in the NE¼NE¼ sec. 17. Inasmuch as all the Smith River plain lies north of the Humboldt base line, the township letter designation (N) can be omitted, and the foregoing abbreviation of the number is adequate.

ACKNOWLEDGMENTS

Appreciation is expressed to the many persons who cooperated and assisted in the collection of field data used in the preparation of this report. The State of California Department of Public Works, Division of Water Resources, helped in many ways. Nearly all the drillers' logs and past water-level records used in this report are from the files of the Division of Water Resources. The seismograph survey was made by R. E. Slyfield, W. D. Fuqua, and D. M. Hill, under the supervision of E. C. Marliave, all of the Division of Water Resources.

Records of test-hole borings for bridges over Rowdy Creek and the Smith River were made available by the Division of Highways of the Department of Public Works.

Salem Rice, geologist of the Division of Mines of the State of California Department of Natural Resources, furnished information about the Jurassic rocks in the vicinity of the Smith River plain.

L. G. Hertlein, California Academy of Sciences, identified marine invertebrate fossils and gave valuable assistance in the interpretation of the stratigraphy of the Smith River plain.

The cooperation of the Del Norte County Board of Supervisors, road commissioner, and county chamber of commerce facilitated this work. Assistance given by Joseph Creisler, sanitarian of the Humboldt-Del Norte County Department of Public Health, is greatly appreciated.

C. H. Pyles, district manager of the California-Oregon Power Co., furnished information on irrigation installations that was most helpful. Personnel of the Crescent City Water Co. and Smith River Water Co. made available the records of water yield and use. P.T. Starr and Douglas Purdue, well drillers, and the management of Olson Drilling Co. permitted the use of their well logs.

Wholehearted cooperation and support were given by the residents of the area. Miss Emma Gwerder, E. C. Johnson, Edward Berquist, and Frank Patton made weekly water-level measurements in their wells during the period of investigation.

GEOGRAPHY

ECONOMIC DEVELOPMENT

Crescent City, population 1,706 (1950 census), is the county seat of Del Norte County. The population of the county is 8,078, of whom nearly 7,000 live on the Smith River plain. The only other towns in the area are Fort Dick, population 500, 8 miles north of Crescent City on U. S. Highway 101, and Smith River, population 400, 12 miles north of Crescent City and also on Highway 101.

According to a 1953 report of the county chamber of commerce, the chief economic activities are agriculture, mining, logging, lumbering, commercial fishing, and maintenance of recreational facilities. Agricultural income is derived mainly from dairy products and livestock, and to a minor extent from flower culture. About 2,200 acres of pasture land is irrigated.

The chief ores mined in Del Norte County are those of chromium, copper, manganese, and mercury. Fir and redwood lumber and plywood veneer are the main products of the logging and lumbering industries. Commercial fishermen obtain most of their income from the catch and sale of crab, salmon, and sole.

Tourists are attracted by recreational facilities that provide for hiking or driving through the many miles of redwood trees (*Sequoia sempervirens*) and the profusion of wildflowers, including rhododendrons and azaleas that grow to heights of 20 to 30 feet. Among other attractions are camping, picnicking, and swimming in Jedediah Smith State Park, located in a grove of redwoods on the banks of the Smith River; fishing for trout, steelhead, and salmon in the streams; and fishing in the surf and open sea.

CLIMATE

Following Köppen's system, Trewartha (1937) classified the climate of the Smith River plain as being of the marine west-coast subdivision of the humid mesothermal type. According to Trewartha, this mild marine climate is characteristic of regions on the western or windward sides of middle-latitude continents, poleward from about 40°, where the onshore westerly winds have a strong marine influence. This type of climate is characterized by mild summers and, considering the high latitude, abnormally mild winters. The coldest month is January (fig. 3), with an average temperature of 46° F. During the three summer months of June, July, and August, the average temperatures are from 57° to 60° F. The growing season (last killing frost to first killing frost) averages about 230 days.

The normal annual precipitation recorded at a weather station 8 miles northeast of Crescent City at an altitude of 125 feet is 75.80 inches. Precipitation is heaviest in the five coldest months, from November through March. The maximum, minimum, and normal rainfall for each month, based on 63 years of record, are shown in figure 3. The minimum recorded seasonal precipitation (for the climatological year from July 1 to June 30) was 34.52 inches, in 1923–24, and the maximum was 109.59 inches, in 1885–86. The precipitation is much greater in the uplands to the north and east, as shown by the average annual runoff of 80 inches from the basin of the Smith River.

PHYSIOGRAPHY AND DRAINAGE

The Smith River plain, or the Crescent City platform, as it was called by Maxson (1933), is a broad, subrectangular emerged marine terrace, bordered on the south and west by the Pacific Ocean and on the north and east by the Klamath Mountains. Smith River plain, the name given this ground-water basin by the State Division of Water Resources (fig. 1), is in the Klamath Mountains physiographic province of California. On the east and north the low relief of the

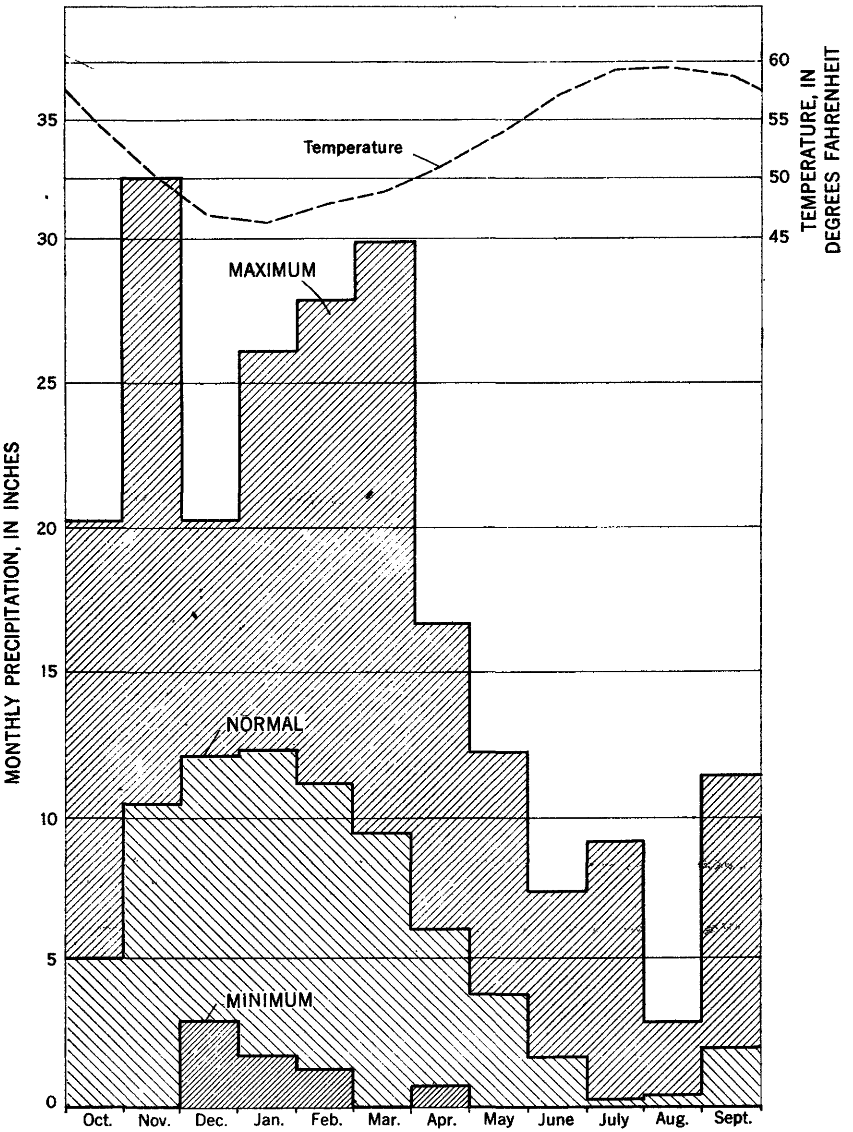


FIGURE 3.—Normal monthly temperature and maximum, normal, and minimum monthly precipitation near Crescent City.

plain gives way abruptly to the high relief of rugged mountains of moderate altitude (2,500 feet), which rise steeply to the Siskiyou Divide at 6,000 feet.

Smith River plain is drained by the Smith River and its tributaries and by Robinson, Jordan, and Elk Creeks. The major tributary of the Smith River north of the main stream is Rowdy Creek, which is joined at the town of Smith River by Dominie Creek and which joins the Smith River about 3 river miles upstream from its mouth.

Robinson Creek (not shown on map) flows on the Fort Dick terrace near the contact of the Battery formation for nearly its entire course; it drains into Lake Earl. Jordan Creek flows northwestward from the mountains to drain into the southeastern part of Lake Earl. A low, hardly perceptible, divide separates the drainage area of Elk Creek from the Jordan Creek drainage area. Elk Creek flows southwestward and drains into the Pacific Ocean near Crescent City.

The platform, varying from almost flat to undulating, has a relief of 75 feet (pl. 2*A*). One major exception is the series of steep alluvial fans, adjoining the mountain front, which reaches altitudes exceeding 100 feet above the plain. The fans are nearly continuous along the mountain front from east of Crescent City to the Oregon State line. Inasmuch as the fans form at the mouths of minor streams, an integrated drainage pattern has not developed on them.

Along the coast from Crescent City to approximately a mile northeast of Point St. George, a sea cliff rises to about 50 feet above the narrow, pebbly beach. Both south of this reach and north to the Smith River the beach is wider and sandy, with no sea cliff. South of Crescent City the sandy beach ends abruptly against the steep scarp of the mountainous headland. North of the Smith River the shoreline is marked by a sea cliff that is also about 50 feet high. This sea cliff continues to about three-fourths of a mile north of the State line, in Oregon, where it gives way to the flood plain of the Winchuck River.

The most striking physiographic features of the marine-terrace deposits are the many elongate sand ridges that were formed in Pleistocene time. Each ridge is about 500 feet wide at the base and rises about 30 or 40 feet above the plain. These ridges, which strike northwest, are generally parallel to one another and to the coastline southwest of Crescent City. They are best exposed in the road cuts along Highway 199 northeastward from the junction with Highway 101 to the flood plain of Jordan Creek. The road cuts are crescent-shaped escarpments rising approximately 20 to 30 feet above the highway. At many places the interridge areas are swampy and lie about 30 feet below the road. To the west, on Highway 101, the ridges are not so prominent, but they occur nearly as far north as

A. REFRACTION SEISMIC EQUIPMENT LAYOUT AND EXPLOSION

B. ST. GEORGE FORMATION ALONG PEBBLE BEACH

A. SURFACE OF MARINE TERRACE

B. ANCIENT SEA STACK OF JURASSIC ROCKS

C. ESCARPMENT OF FORT DICK TERRACE

Fort Dick, where the marine terrace is terminated by the river terrace. East of Crescent City the ridges are readily visible from the rolling county road that traverses Elk Valley.

Sand dunes form a narrow strip, averaging about a mile wide, along the coast from Point St. George to the mouth of Smith River. The surface is undulating, and the highest dunes rise as much as 60 feet above the interdune areas. The more stable dunes are covered with spruce trees, and interdune areas are covered with native grasses. Several large, rapidly moving sand dunes (pl. 3) are encroaching on the runways of the County Airport and on office buildings of the Paragon Plywood Corp. in 16/1W–18 (built since the photograph in pl. 3 was taken). The high permeability of the dunes permits infiltration of almost all the precipitation, thereby preventing any surface runoff. Consequently, no integrated drainage pattern has developed in the dune area.

In the west-central part of the plain are two shallow, brackish-water lakes. Lake Talawa, 1½ miles long and half a mile wide, joins larger Lake Earl, 3 miles long and more than a mile wide, by a dredged channel through a narrow sand ridge. This channel, 10 feet deep, is reported to be the deepest part of the lakes. The lake shores are covered with a dense growth of marsh grasses. To the southwest, east of the airport, is a smaller lake, Dead Lake.

Lake Earl is a collection basin for drainage from Jordan Creek and several minor streams from the southeast and for Robinson Creek and Talawa Slough from the north and northeast. From the west, seeps and springs drain from the sand-dune area into the lakes. During floods the Smith River overflows its channel and discharges through Talawa Slough to Lake Earl. The topographic gradient between Lake Earl and the Smith River is very low, and residents report that at times the hydraulic gradient is reversed, so that water flows from Lake Earl to the Smith River. Attempts have been made to drain flood waters from the two lakes by dredging a channel through the low sand ridge between the western extremity of Lake Talawa and the sea; however, the channel was soon filled with sediment deposited by onshore currents and waves.

The Smith River has formed terraces along its course as far east as the junction of South Fork and the main stream. This easternmost terrace segment in the mountain area, locally called Hiouchi Valley, is the location of Jedediah Smith State Park. The largest terrace along the Smith River is the one on which the town of Fort Dick is situated, and hence is referred to in this report as the Fort Dick terrace. This terrace is separated, except locally, from the flood plain by a 20-foot escarpment (pl. 2*C*). The terrace extends westward from Highway 101 for some 2 miles and extends southeastward about 2 miles, where it ends against the mountain. North of the river a remnant of the Fort Dick terrace is partly covered by Recent alluvial fans. Terraces extend about a mile on either side of Rowdy Creek. The oldest and highest is at approximately the same altitude as the Fort Dick terrace and may correspond to it. The town of Smith River is built on the northernmost remnant of this terrace. North of the terrace alluvial fans border and overlie the flood plain of the Smith River.

The flood plain of the Smith River is a few feet wide in Hiouchi Valley and about a mile wide near Fort Dick. In the lower reaches the flood plain widens to some 4 miles and merges with the flood plain of Rowdy Creek near the tidal mouth of Smith River. To the southwest the flood plain joins the lacustrine plain of Lake Earl (included in the area mapped as Qfu on pl. 5).

Jurassic rocks occur on the Smith River plain as small outliers surrounded by the more recent sediments (pl. 2*B*). These masses of rock range in size from a few feet to several hundred feet at their bases. A few rise to nearly 200 feet above the plain, but others are barely visible above the soil. These outliers are inferred to be remnants of sea stacks that formed offshore during Pleistocene time.

DISCHARGE OF THE SMITH RIVER

Since October 1931, the Geological Survey has maintained a recording gage on the Smith River, a mile downstream from the junction with South Fork. The average annual runoff from the 613-square-mile drainage basin for the period from October 1931 to December 1952 is about 2,600,000 acre-feet, or nearly 80 inches per year.

Figure 4 shows the yearly runoff, reported by the Geological Survey, plotted with the precipitation recorded by the U. S. Weather Bureau at the weather station 8 miles northeast of Crescent City. The plotted discharge figures are for the water year, October 1 to September 30· the plotted precipitation figures are for the climatological year, July 1 to June 30. In general, the two graphs show a rather good correlation. However, during 1941–42, 1945–46, and 1949–50 precipitation decreased from the previous year, but surface runoff increased. This apparent anomaly can probably be explained by noting that this area is susceptible to storms with heavy precipitation in short periods of time; consequently, there is a rapid runoff of large amounts of water which might otherwise be absorbed into the ground. Therefore, even with an annual decrease in total precipitation, the storm-frequency pattern of rainfall could result in an abnormally high stream runoff. Also, the precipitation recorded at the weather station near Crescent City is not representative of the precipitation throughout the Smith River drainage basin.

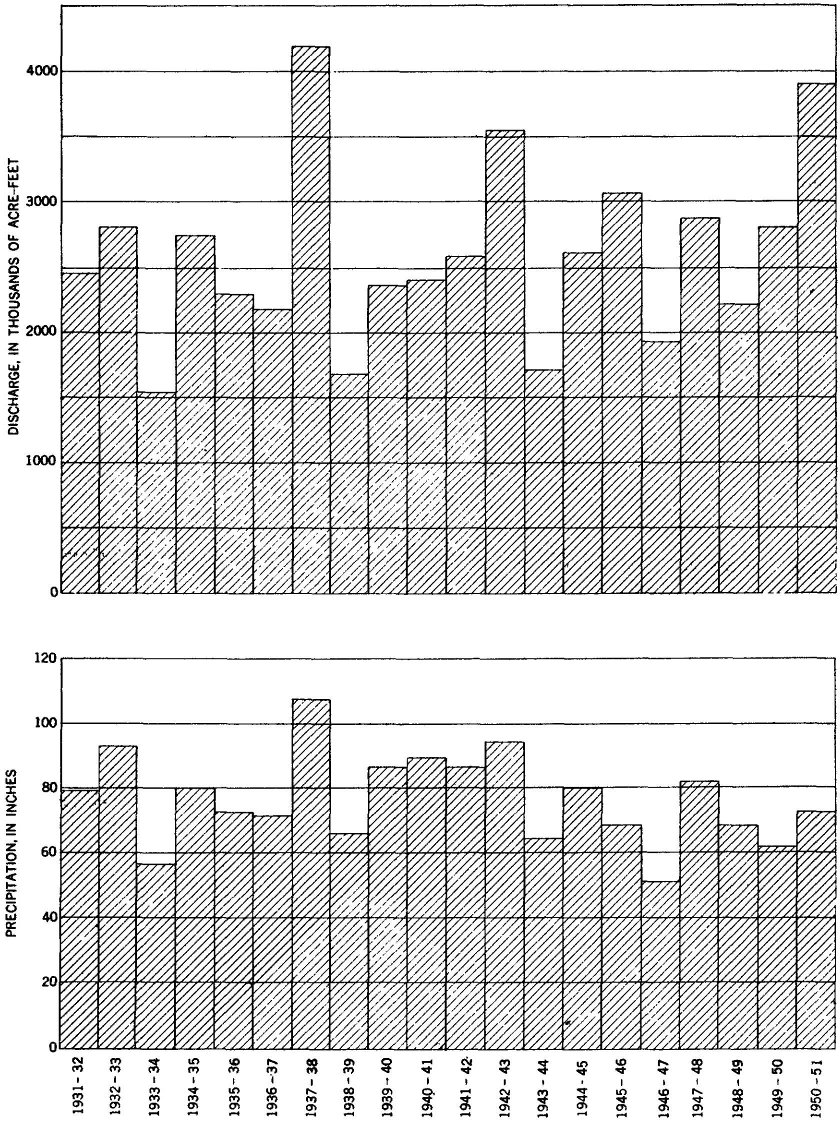


FIGURE 4.—Annual discharge of the Smith River and annual precipitation near Crescent City.

The general distribution of precipitation in the drainage basin is shown in figure 5. Normal annual precipitation increases inland, with increase in altitude, from about 50 inches on the plain at Crescent City (altitude less than 50 feet) to about 75 inches at the weather station (altitude 125 feet) 8 miles northeast of Crescent City, and as

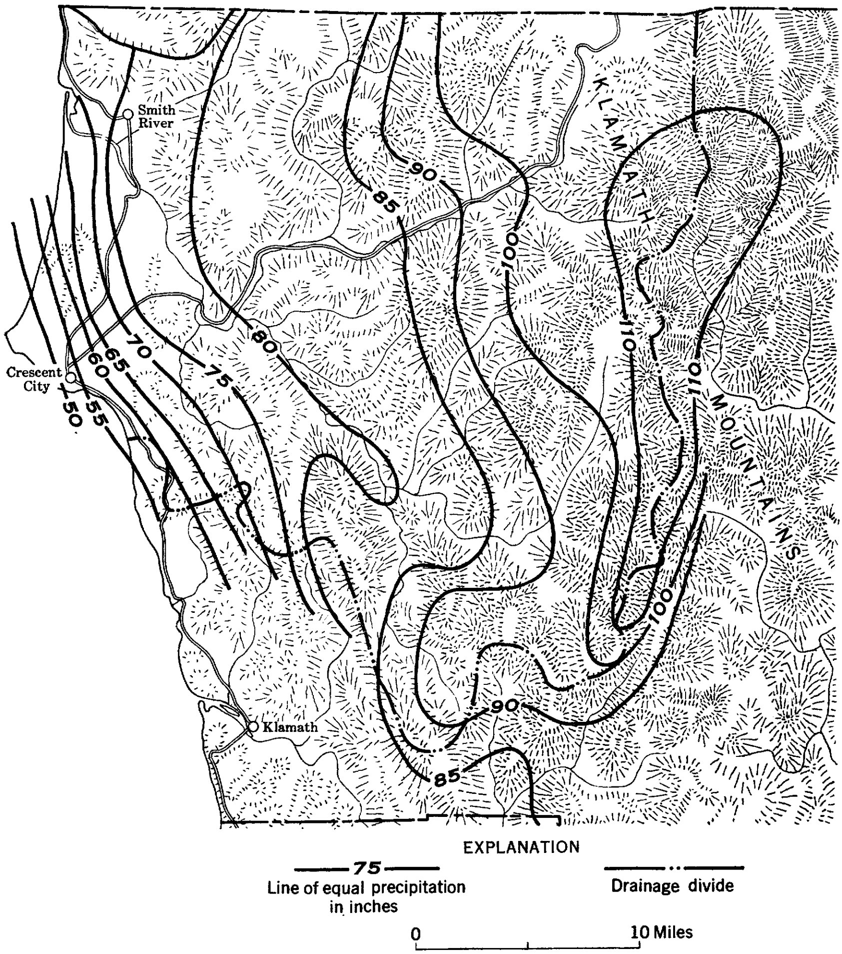


FIGURE 5.—Geographical distribution of precipitation in the Smith River drainage basin.

much as 110 inches along the crest of Siskiyou Mountain (5,000 to 6,400 feet). The precipitation on the basin probably averages more than 90 inches.

GEOLOGY

GROUND WATER

The quantity and quality of water in any ground-water basin are dependent upon the amount of precipitation and the geology of the basin. A geologic study of a basin is concerned primarily with the extent, thickness, and permeability of aquifers or potential aquifers, including the location and physiography of their outcrop areas, and the way in which these factors control the occurrence, quantity, and quality of the ground water. The extent of formations is determined by geologic mapping. The lithologic character is determined by the examination of outcrops and the records of wells. Average thickness and probable extent of the formations on the Smith River plain were determined by areal mapping, interpretations of logs from wells and test holes, and geophysical interpretation of five seismic probes.

The permeability of a rock is its capacity to transmit water under pressure (Meinzer, 1923a, p. 28). Approximate permeability of any formation can be determined or estimated by several laboratory or field methods. The coefficient of permeability, expressed in Meinzer units, is determined in the laboratory by measuring the number of gallons of water that will flow in 1 day through an undisturbed sample, 1 foot square, under a hydraulic gradient of 100 percent (loss of head of 1 foot per foot of travel) at a temperature of 60° F. The coefficient of permeability may be expressed also as the number of gallons of water a day that will percolate through a section of water-bearing material, 1 mile wide and 1 foot thick, for each foot per mile of hydraulic gradient.

The quantity and rate of movement of ground water are dependent, in part, upon the permeability of the rocks, which is primarily controlled by the size and degree of interconnection of voids, or interstices, in the rocks in the zone of saturation. In unconfined aquifers, the top of the zone of saturation is the water table, represented by the level at which water stands in an unpumped well. In fragmental rocks, the size of interstices through which ground water moves is dependent upon the size, shape, and degree of sorting of the individual grains forming the sediments. The size and degree of sorting may be determined by means of grain-size analyses of representative samples of the aquifer. Grain-size analysis of granular material consists of separating into groups the grains of different sizes and determining the percentage by weight that each group constitutes. Therefore, a grain-size analysis gives some indication of the permeability of a sediment.

Although determining the permeability of rocks in the field requires controlled pumping tests, it is possible to determine properties that are in large part controlled by the permeability of the rocks. The yield and specific capacity of a well are generally controlled by the permeability and thickness of the material penetrated in the well. The specific capacity is the ratio of the yield of a well to the drawdown. Drawdown is the difference between pumping water level and standing water level. Specific capacity is generally expressed as gallons per minute (gpm) per foot of drawdown. All other factors being equal, a well penetrating a permeable rock will have a higher yield and higher specific capacity than a well penetrating a rock of low permeability.

A number designating the specific capacity per foot of saturated material tapped is called the yield factor.[4] This factor is a rough comparative index of the permeability of the sediments inasmuch as

[4] See footnote 2, p. 5.

it is a unit value, independent of the thickness of the section penetrated. In order that the yield factor may be expressed in whole numbers, the quotient, derived from dividing the specific capacity by the saturated thickness, is multiplied by 100. In practice, it has been found that an approximate permeability, expressed in Meinzer units, may be estimated by multiplying the yield factor by 15 to 20, depending on the size and method of construction of the well and conditions of ground-water occurrence.

Another indication of the relative permeability is the slope of the water table, which is controlled in part by the permeability of the materials saturated. Consequently, the spacing of the contours on a water-level map is indicative of the permeability of the aquifer, if the thickness is known to be essentially constant. Darcy's law of laminar flow expresses this concept by the equation:

$$Q=PIA$$

in which Q is the quantity of water discharged in a unit of time; P is a coefficient of permeability for the material; I is the hydraulic gradient; and A is the cross-sectional area of the material through which water percolates (Wenzel, 1942, p. 3–7). Hence, if P decreases, and A and Q remain constant, I must increase in proportion to the decrease in P, in order that the same amount of water may be transmitted. Therefore, the water-table gradient is very flat in a highly permeable gravel, and it becomes quite steep in a poorly sorted, silty sand of low permeability. On plate 6, an area of high permeability is indicated in the downstream section of the Smith River flood plain, and an area of low permeability is indicated at the foot of the mountains east of the plain.

The slope of the water table also will steepen if the aquifer becomes thinner and the same amount of water is to be transmitted. From Darcy's law, if A (cross-sectional area) decreases, and P remains constant, I must increase in proportion to the decrease of P in order for Q to remain constant.

SUMMARY OF STRATIGRAPHY

The rocks that are exposed in the area discussed in this report range in age from Jurassic to Recent. The oldest are Jurassic arkose, graywacke, chert, glaucophane schist, and serpentine. Overlying these rocks, in a small area around Crescent City, are beds of Pliocene sand and clay (St. George formation), which in turn are overlain by Pleistocene sand and clay (Battery formation). Throughout the rest of the platform, the Jurassic rocks are directly overlain by poorly consolidated sand and clay of the Battery formation, unconsolidated river-terrace deposits, or Recent alluvium. Recent eolian deposits border the coast.

The lateral extent of the geologic units and the stratigraphic relations are shown on plate 5. A general description of the geologic units and their water-bearing properties is given in the following chart.

Stratigraphic units of the Smith River plain area

System	Series	Formations and symbols		Thickness (feet)	General character	Water-bearing properties
QUATERNARY	Recent	Dune sand (Qd)		0–70±	Loose eolian deposits bordering the shoreline; fine- to medium-grained subangular quartz and ferromagnesian minerals.	Moderately permeable, readily available water supply; very little development at present.
QUATERNARY	Recent	Alluvium	Alluvial fans (Qaf)	0–50±	Weathered debris from Jurassic rocks, generally angular fragments in sandy clay matrix; includes some slope wash. In places associated with landslides (Ql).	Locally yields water in sufficient amount for domestic use; in other areas too impermeable for successful wells.
QUATERNARY	Recent	Alluvium	Flood-plain deposits (Qfy) (Qfu)	0–100±	Unconsolidated clay, sand, and gravel, forming alluvial plains; includes lacustrine deposits in vicinity of Lake Earl. Includes Qfy, coarse, loose sand and gravel 0–50 feet thick, mapped in channels of the Smith River and Rowdy Creek.	Generally very permeable; best aquifer in area; wells commonly yield 200–500 gpm; coefficient of permeability ranges possibly from 5,000 to 20,000 gpd per sq ft. Qfu, very permeable but not penetrated by wells.
QUATERNARY	Pleistocene	Terrace deposits (Qt)		0–50±	Unconsolidated deposits of older river alluvium, consisting of sand and gravel and clay.	Nearly everywhere permeable enough for domestic supply; yields of irrigation wells range from 140 to 400 gpm. Coefficient of permeability is about 1,000 to 2,000 gpd per sq ft.
QUATERNARY	Pleistocene	Battery formation (Qb)		0–60±	Compact marine-terrace deposits of fine sand and clay; contains 1-foot pebble zone at base.	Most extensive aquifer; well yields range from less than 10 gpm to 50 gpm. Coefficient of permeability is probably less than 500 gpd per sq ft.
TERTIARY	Pliocene	St. George formation (Tsg)		?–400±	Consolidated marine sand, silt, and clay stone. Locally highly fossiliferous, very lenticular; probably bay or lagoonal deposits.	Not tapped by wells; generally too impermeable for successful wells.
JURASSIC		Undifferentiated rocks (Ju) Serpentine (Jub) Schist (Js)			Consolidated, slightly metamorphosed arkoses, shales, ultrabasic intrusives (Ju), phyllite, and semischists (Js).	Yield little water to wells. Some springs along the mountains discharge water from joints.

GEOLOGIC FORMATIONS AND THEIR WATER-BEARING PROPERTIES

ROCKS OF THE JURASSIC SYSTEM

CHARACTER

Arkose, chert, and schist of late Jurassic age are exposed in the Smith River plain area. Intrusive into these rocks are ultrabasic rocks altered to serpentine, which are considered to be part of this system. Jurassic rocks form the mountains that bound the plain on the east and north, constitute the bedrock which underlies the semiconsolidated and unconsolidated Cenozoic sediments of the plain, and protrude through the younger sediments as scattered irregular rock masses rising above the general level of the plain (pl. 2*B*).

The Jurassic rocks are principally thick, massive arkosic sandstones containing abundant shale fragments. In most exposures bedding is obscure, fractures are common, and the arkose is weathered light brown. Along the coast the section consists principally of blue arkose that weathers gray and contains less shale fragments than the characteristic brown arkose. This coastal section contains an assemblage of diverse rock types, such as conglomerate, chert, greenstone, black shale, and graywacke.

In general, the Jurassic rocks are slightly metamorphosed and resistant to erosion. They have been eroded to form a series of sea stacks, shown on plate 5 as rock islands a short distance off the coast south of Crescent City, near Point St. George, and north of Smith River. Scattered across the plain are small outcrops of arkose of Jurassic age, which stand as resistant masses as much as 200 feet above the general level of the plain. These masses have the shape and appearance of sea stacks and are interpreted as having been so formed when the Pleistocene sea covered the Smith River plain. The easternmost of these ancient stacks are at the foot of the steep mountain front that forms the eastern edge of the plain. Rocks of the same lithologic character form this mountain front and extend for almost 3 miles eastward.

East of the arkose, a band of metamorphosed rocks about a quarter to half a mile wide (pl. *5*) separates the arkose from a wider band of serpentine, representing an ultrabasic intrusive. Salem Rice (oral communication, December 1953) described the metamorphosed rocks as metasediments, largely phyllites and semischists. Both the schist and serpentine form linear outcrop patterns across the Hiouchi Valley area and, according to Rice, extend for several miles north and south of the Smith River.

AGE AND CORRELATION

In a report for the Division of Mines on the geology of Del Norte County, Maxson (1933) divided the Jurassic rocks into the Galice formation, Dothan formation, "Serpentine," and Siskiyou granodiorite. Inasmuch as Maxson's Galice formation and Siskiyou granodiorite occur in the eastern part of the county and do not crop out in the area of investigation, this paper is concerned only with Maxson's Dothan formation and "Serpentine."

The Dothan was named by Diller (1907, p. 407–411) from a locality in southern Oregon about 65 miles northeast of this area. Diller assigned the Dothan to the Jurassic period, on the basis of the pelecypod *Aucella erringtoni.* He indicated (p. 412) that the Dothan contrasted strongly with the Knoxville and suggested (p. 420) that it may correlate with the Franciscan. Diller stated that the Dothan was overlain by the Galice, but he suggested that the beds were overturned and the Dothan actually was younger than the Galice (p. 410–11). Butler and Mitchell (1916, p. 2) traced the Dothan to near the southwestern corner of Oregon, and Maxson's use of the name was apparently in deference to their work.

In southwestern Oregon, Louderback (1905, p. 522–550) described a series of sandstones containing shale, conglomerate, and chert, associated with greenstone, serpentine, and schist. He named these rocks the Dillard series and stated that they were identical in lithology and character with the Franciscan of the California Coast Ranges (p. 548–549). In the same area, he named the Myrtle group and described sedimentary rocks as belonging to this group which overlies unconformably the Dillard (of Diller, 1907) and contains the Knoxville fossil *Aucella.*

Taliaferro (1942, p. 88–89) considered the Franciscan of the north Coast Ranges to extend into Oregon, to be equivalent in part to the Dillard (of Diller, 1907), and to be younger than, and overlap, the Dothan and Galice. He based this conclusion, in part, on the relatively unmetamorphosed character of the Franciscan compared to the older rocks.

Wells, Hotz, and Cater (1949) mapped rocks of Jurassic age in the Kerby quadrangle in southwestern Oregon and, concerning their age, state (p. 9)—

> The writers think it best to follow the conclusion of Diller, namely that the Dothan is younger than the Galice, and is equivalent in age to the Franciscan group of the California Coast Ranges. The lithologic similarity of the Dothan and Franciscan can be attested to by the writers.

In a recent report on the Gasquet quadrangle, which is south of the Kerby quadrangle and several miles east of the Smith River plain, Cater and Wells (1953, pl. 11) extended the Dothan of the Kerby quadrangle about half a mile into California. This outcrop is about 12 miles northeast of the town of Smith River and is separated from the Smith River plain by a belt of intensively folded and faulted intrusive and metamorphic rocks, which Cater and Wells assign in part to the Galice.

As described by Cater and Wells, the Dothan formation has a marked lithologic similarity to the Jurassic rocks of the Smith River plain and to rocks that have been classified as Franciscan farther south in the California Coast Ranges. Cater and Wells do not discuss the age relations of the Dothan and Franciscan, but agree (p. 85) with Taliaferro that the Dothan is older than the Galice.

Because of the lack of agreement concerning the classification of the Jurassic rocks in this area, they are not assigned formational status in this report. The various workers (Diller, Maxson, Taliaferro, and Cater and Wells) agree that these rocks are of Late Jurassic age and similar lithologically. No fossils have been found in these rocks, and a detailed study of their stratigraphy is beyond the scope of this report.

WATER-BEARING PROPERTIES

Rocks of the Jurassic age are dense and crystalline and contain no appreciable amount of interstitial water. Some water is contained in the joints and other fractures in the formation, and along the mountain front many small springs flow from these openings.

The one well completed in the Jurassic rocks, 17/1W–14C1, at the Redwood Union School, is 215 feet deep, produces 5 gpm and has a reported drawdown of more than 150 feet.

Several unproductive wells have been drilled into the Jurassic rocks. Wells 16/1W–27C2 (total depth 500 feet) and 17/1W–11B2 (total depth 325 feet) are examples. The owner of the latter reported that he drilled three other dry holes on the same property.

TERTIARY SYSTEM

PLIOCENE SERIES

ST. GEORGE FORMATION

Character.—The marine sand and shale exposed in the sea cliff at Point St. George was named the St. George formation by Maxson in 1933. These beds consist principally of massive, poorly bedded siltstone and shale containing discontinuous irregular lenses and thin beds of sand and scattered pebbles and carbonized wood fragments. In fresh exposures most beds of the formation are characteristically a dull gray blue, although locally they contain lenses of sand of lighter color or they may be stained violet. Weathered exposures may be rust colored or have brown-mottled iron staining. At Pebble Beach the lowest beds exposed at low tide are massive sandy clay, locally highly fossiliferous, that have a well-developed joint system (pl. 1*B*). In that area beds of the St. George formation strike N. 50° W. and dip about 12° NE.

The thickness of the St. George was not determined, but the thickness of exposed strata near Point St. George is about 75 feet, and the maximum thickness is estimated to be about 400 feet. In test well 16/1W–21D1, drilled for the Crescent City Water Co., 213 feet of the St. George formation was penetrated without reaching the base. The refraction seismograph survey indicated the thickness along the south side of Jordan Creek to be 125 feet and at Washington Boulevard, 225 feet.

Rocks of the St. George formation were examined in 1901 by Dall (*in* Diller, 1902, p. 34–35), who correlated them in part with the Miocene "Empire Beds" of Cape Blanco, Oreg. Beds of similar lithology that cropped out under the wharf at Crescent City were considered by him to be Pliocene and were named "Crescent City beds." Dall described the "Crescent City beds" as "Soft bluish sandstone containing pebbles and worn fragments of carbonized wood * * * a few invertebrates occur sparsely." Although the outcrop of the "Crescent City beds" no longer remains above the sand and water, the lithology described by Dall is very similar to that of rocks in the southernmost outcrop of the St. George formation on Pebble Beach. In this report the "Crescent City beds" are considered to be a facies of the St. George formation.

The St. George formation crops out for about 1½ miles south from Point St. George along Pebble Beach and for a short distance to the north of Point St. George. Salem Rice reported (oral communication, December 1953) that at low tide the Pliocene sands crop out for a few hundred feet on the low sandy beach 1½ miles south of Crescent City.

Although no outcrops are visible on Fort Dick Beach (17/1W–17), many fossiliferous slabs as large as 2 feet by 2 feet and approximately 2 inches thick, of apparently the same formation, occur on the beach. For several miles to the north and south from this locality, the beach is very sandy and there are no outcrops. Several individuals who collect the float for ornamental stone reported that the slabs are larger and more abundant on the landward side of the first low sand dune. An explanation for the occurrence of these slabs is that during storms and high tides waves waft the light fossiliferous siltstone (specific gravity 1.77) onto the beach from a submarine outcrop.

Hertlein (written communication, October 29, 1953) identified the following fossils from the fossiliferous siltstone float on Fort Dick Beach: *Panomya ampla* Dall, *Siliqua patula nuttalii* Conrad, *Yoldia strigata* Dall, and *Polinices* sp. Hertlein states—

This assemblage of fossils, as well as their preservation, is similar to others occurring in the Pliocene in northern California. In connection with this locality, one might take into consideration the fact that an extinct species of sand dollar, *Anorthoscutum* cf. *A. oregonense quaylei* Grant and Hertlein, has been found in similar float material in the same area. That echinoid is known to occur in the upper Wildcat formation [Wildcat series of Lawson, 1894] in northern California.

The major lithologic feature of the St. George formation is the pronounced facies change in the outcrop along Pebble Beach. At the southernmost exposure (loc. 1, pl. 3), 5 feet of massive blue sandstone contains a haphazard scattering of pebbles and rounded fragments of carbonized wood. The sandstone includes a few thin bright-violet lenses of coarser, frosted quartz sand and red and black silt particles. The main part of the formation is a fine- to medium-grained clean bluish-gray quartz sand. (See grain-size analyses, fig. 6.) The exposure is weathered to a smooth, rounded surface with a brown-mottled iron stain.

Toward locality 2 the sandstone gradually loses all wood fragments and pebbles and changes to a very dense, fine-grained siltstone with minor jointing. Two small fossils found at this locality were identified by Hertlein as of *Cardium* cf. *C. corbis* Martyn. In reference to these fossils, Hertlein (written communication, October 29, 1953) states:

This species has been recorded as occurring from upper Miocene to Recent. The present specimens are incomplete and poorly preserved, but their general appearance suggests a Pliocene age for the beds from which they came.

At locality 3 the formation is principally well-jointed clay stone, containing some wood fragments at the base. The clay contains a few 1- to 2-inch concretions.

At locality 4 the massive blue sandstone reappears and contains scattered pebbles. A resistant brown sandstone lens 100 feet long, of medium-grained, rounded quartz, overlies the blue sandstone.

About 15 feet of well-cemented blue sandstone is exposed at locality 5. At this place the sandstone is broadly crossbedded.

The formation is a massive well-jointed blue clay stone at locality 6. The two sets of joints intersect at angles of approximately 120° and 60° (pl. 1*B*). The clay stone breaks with a conchoidal fracture and shows spheroidal weathering.

Approximately 40 feet of the St. George formation is exposed at locality 7; it has about the same lithology as at locality 6. This extremely fossiliferous exposure contains the following assemblage: *Cardium corbis* Martyn, ?*Cryptomya* sp., *Macoma nasuta* Conrad, *Protothaca* cf. *P. staleyi* Gabb (juvenile), ?*Saxidomus* sp., *Solen* cf. *S. sicarius* Gould, ?*Ocenebra* sp. (cast). Hertlein, who made the identifications, reported that the fossils from this locality are identical with others found in the Pliocene in the same area.

At locality 8 the lithology is very similar to that at the southernmost outcrop (loc. 1). The sand is a little whiter and contains a lens of clay and a lens of purple and black sand. Pebbles and rounded fragments of carbonized wood are abundant. The weathered surface is mottled with brown iron stains.

The Pliocene sands and clays exposed along Pebble Beach probably represent deposition of sediment in a bay or lagoon. At the northern and southern outcrops, the presence of coarser sediments, containing pebbles and fragments of carbonized driftwood, suggests that these deposits are littoral facies. The clays and silts, which contain many fossils, may be the deposits from the slightly deeper part of the Pliocene bay that is represented on Pebble Beach. Sediments exposed along Pebble Beach, however, are all relatively near-shore deposits, the major part of the bay probably having lain seaward from the present shoreline.

Water-bearing properties.—Although the hydrologic properties of the St. George formation have not been tested throughly, the fineness of grain of the sediments and lenticular character of the deposits seem highly unfavorable for the development of a deep water supply near Crescent City. On the basis of bailer tests, the Olson Drilling Co. recommended abandonment of the two test holes (16/1W–17P1 and 21D1) that were drilled into the St. George for the Crescent City Water Co. The following log of test hole 16/1W–21D1, drilled in 1953, illustrates the lithologic character of the St. George formation. Altitude is 25 feet. The lithologic terms are as given by the driller; the geologic correlations are by the writer.

	Thickness (feet)	*Depth (feet)*
Battery formation (Pleistocene):		
Top soil	2	2
Sand	34	36
Gravel, pea, shells	1	37
St. George formation (Pliocene):		
Gray clay	1	38
Blue clay	22	60
Blue sand	190	250

Two representative samples of the coarser facies of the St. George formation show coefficients of permeability of 2.6 and 13.7 Meinzer units, respectively. By inspection of the results of the grain-size analyses of these two samples, one (*A* in fig. 6) is classified as a poorly sorted silty fine to medium sand, and the other (*B* in fig. 6) as a silty fine sand. However, inasmuch as the base of the Pliocene sediments is nowhere exposed in the area, the lowest part of the formation may possibly be coarser. However, even if coarser deposits occur at the base, recharge would be through the upper fine-grained sediments because the basal part does not crop out. Some water may percolate through the formation along the locally numerous joint planes (pl. 1*B*), but the amount of recharge by this process probably would be small.

QUATERNARY SYSTEM

PLEISTOCENE SERIES

BATTERY FORMATION

Character.—The Battery formation was named by Maxson (1933), presumably from the section of silty clay alternating with fine- to medium-grained quartz sand exposed at Battery Point, southwest of Crescent City. Maxson defines the formation as "A thin marine-terrace capping of unconsolidated sands exposed over the southern portion of the Crescent City platform." He also says, "Much of the surface of the Crescent City platform has been reworked by wind." With the Battery, Maxson also mapped Recent sand dunes along the coast. These dunes are mapped separately in this report.

The Battery formation, as considered in this report, includes related continental deposits consisting of contemporaneous stream gravels and elongate sand ridges. These ridges may not be of aqueous origin, but they are composed of reworked marine sediments and therefore are closely related to the Battery formation.

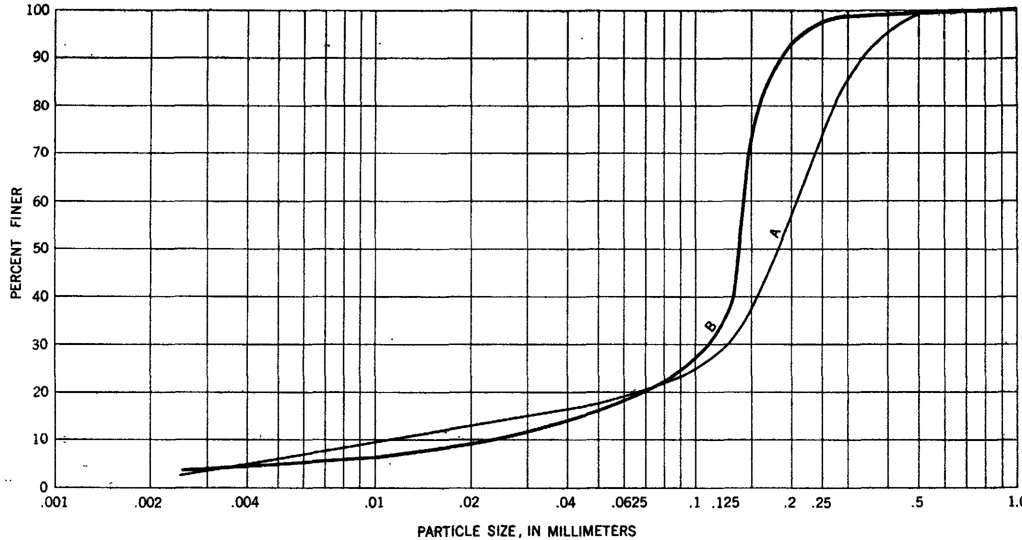
Where the Pliocene sediments remain, the Battery formation overlies them with a slight unconformity. In the rest of its area of outcrop, the Battery overlies the Dothan rocks of Jurassic age with an angular uncomformity.

The best exposures of the Battery formation are along Pebble Beach. However, the vertical section can be observed in many streambanks and road cuts. The Battery immediately underlies the surface in the southern two-thirds of the area. Recent sand dunes and Lake Earl conceal the western limit, and along the mountains Recent alluvial fans cover the eastern margin. The northern limit of the main exposure is the contact with deposits of the Fort Dick terrace.

Hertlein identified the following fossils that were collected from the Battery at a locality on Pebble Beach (pl. 3): *Macoma inquinata* Deshayes, *Saxidomus giganteus* Deshayes, *Spisula* sp., and *Balanus* sp. In reference to these fossils he states: "The two species definitely identified live in the waters in this region at the present time. The general appearance of the fossils suggests a Pleistocene age."

Regarding the age of the Battery, Maxson (1933, p. 136) writes: "A fossiliferous lens contains a small fauna whose general aspect is that of the upper San Pedro stage." The San Pedro is generally considered to be lower Pleistocene.

The Pleistocene age of the Battery formation seems to be well established, but its position within the Pleistocene is not clearly indicated. The horizontal attitude, low degree of induration, and Recent aspect of the fauna identified by Hertlein suggest a late Pleistocene age for these deposits.



Size groups (percent by weight)

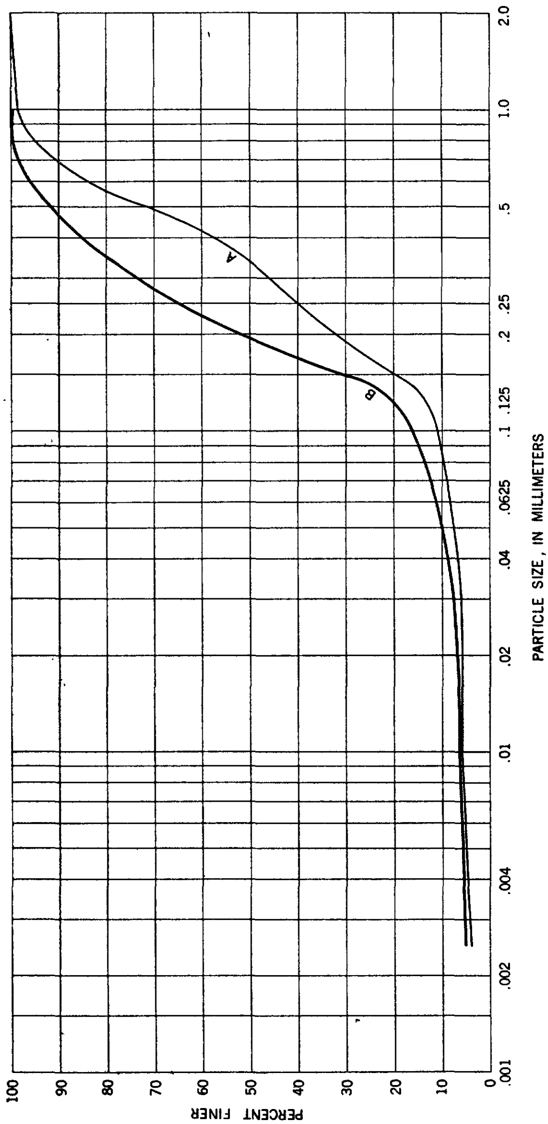
Sample	Clay size	Silt size	Sand size			
			Very fine	Fine	Medium	Coarse
A	5.0	13.8	10.0	43.6	27.4	.2
B	4.3	15.1	16.0	62.6	1.8	.2

FIGURE 6.—Grain-size analyses of two samples from the St. George formation.

Where present, the Battery ranges in thickness from about 28 to 66 feet. A 28-foot section of the Battery was measured on Pebble Beach (pl. 3). In the Pebble Beach area a zone of gravel in a matrix of sand and sticky clay makes up the lower few feet. Most wells in the Battery formation are not drilled through the formation but are completed in the lower part, at a depth of about 35 feet. Test holes 16/1W–21D1 and 35P1, drilled by the Crescent City Water Co., encountered the top of the basal gravel zone at depths of 36 and 25 feet, respectively. The seismic probe made along Washington Boulevard (pl. 6) indicated a possible thickness of 66 feet for the Battery. The thickness could not be estimated from the data obtained from the seismic probe along Jordan Creek. In the exposures along Pebble Beach the Battery consists principally of lenticular, poorly stratified beds of silty sand alternating with thin clay layers. There the section is composed of about one-third clay and two-thirds sand. The sand is generally buff, blue, or gray but weathers yellow to give a rusty appearance to the entire exposure.

The following section, measured on Pebble Beach at 16/1W–19Q, is representative of the formation.

	Thickness (feet)
Battery formation:	
Soil, dark-brown; contains shell fragments	1.4
Sand, buff, quartz, and rounded black minerals, rather well sorted, medium-grained; appears to have microcrossbedding. (Near the base of this bed, about 50 ft north, is a 6-in. violet clay layer banded at top and bottom by 1½ in. of iron oxide)	1.8
Clay, white; contains a 6-in. lens of poorly sorted well-cemented sand	2.2
Clay, bluish-gray, hard, minor jointing; many organic fragments decomposed to iron oxide	3.7
Sand, buff to gray, fine- to medium-grained; fine and better sorted toward the top	4.0
(Section continued 20 ft south)	
Clay, brown from iron oxide, very sticky	.1
Sand, blue, fine to coarse, larger grains predominantly well-rounded quartz; contains small amount of clay and silt and some plant fragments; one 1-in. layer of iron oxide, otherwise iron free. (Mechanical analysis, *A* in fig. 7)	7.6
Clay, blue, sticky; contains decomposed plant fragments	.4
Sand, buff, fine to medium grains of rounded and frosted quartz; contains small amount of coarse sand, silt, clay, and irregular streaks of iron oxide. (Mechanical analysis, *B* in fig. 7)	1.8
(Section continued 100 ft northwest)	
Sand; lower 2 ft contains large pebbles and shale fragments	5.0
Total exposed thickness of Battery formation	28.0
Jurassic rocks:	
Chert, white to buff	2.0
Shale, bluish-black, fissile, soft, weathers friable to sticky. To base of sea cliff above rocky beach	8.0



Size groups (percent by weight)

Sample	Clay size	Silt size	Sand size				
			Very fine	Fine	Medium	Coarse	Very coarse
A	4.3	4.1	5.0	25.2	30.8	30.0	.6
B	5.5	6.1	7.8	45.8	27.4	7.4	

FIGURE 7.—Grain-size analyses of two samples from the Battery formation.

In the sea cliff north of the mouth of Smith River, 20 feet of stratified indurated marine sand, containing abundant pebbles in layers and stringers (pl. 4*B*), overlies the bedrock of Jurassic age. The sand is overlain by about 3 feet of poorly stratified yellow sandy clay containing lenses of gravel.

Drillers' logs of wells near the intersection of Elk Valley Road and Highway 199 report several feet of "clean river gravel." The peg model shows that this gravel forms a rather continuous layer roughly parallel to Jordan Creek and from about a mile south of the creek extends around the northeastern shoreline of Lake Earl. Although this gravel is continental in origin, it interfingers and is interbedded with the marine deposits of the Battery; therefore it is included in that formation in this report.

The following log of well 16/1W–3P1, drilled by Peter T. Starr, Jr., in 1951 for Ray Miller, illustrates the character of the Battery formation in that area.

Battery formation:	*Thickness (feet)*	*Depth (feet)*
Top soil	3	3
Yellow clay	13	16
Sand, gravel	12	28

An estimated minimum thickness of 60 feet of continental gravels (pl. 4*A*), exposed along Highway 199 in 16/1W–1, are tentatively correlated with the Pleistocene gravels along Jordan Creek and are included in the Battery formation. The gravels are poorly sorted, ranging in size from granules to 4-inch cobbles. They are cemented with a matrix of sandy clay. Several lenses of sticky blue clay contain many carbonized fragments of wood and abundant rather well-preserved leaves.

The lenticular nature of the deposits and the abundant plant material indicate that the sediments were deposited near shore, possibly in a lagoon.

Water-bearing properties.—The marine-terrace deposits of the Battery formation are the principal source of ground water in the Crescent City area and in most other parts of the plain. In general, wells in these deposits yield water sufficient for 1- or 2-family dwellings. The Patterson Water Co., at the north edge of Crescent City, supplies water for 10 families from 1 well. The Crescent City Water Co. has 2 wells for its main supply of water in winter. In the summer these wells are used only as emergency standby supply, because they can be pumped dry in a few hours.

Properties of wells tapping the Battery formation are given in the table on page 30. The largest yield reported for any well that derives its water from the marine-terrace deposits was 50 gpm. Of 13 wells for which information was available, the yields ranged from 8 to 50 gpm and averaged about 20 gpm. Drawdown ranged from 2 to 10 feet and averaged about 5 feet. The reported specific capacity for these wells ranged from 1.3 to 12 gpm per foot of drawdown and averaged about 4. Capacity and drawdown figures are reported from drillers' logs and probably do not represent stabilized conditions; therefore, the higher reported values may not represent sustained yields.

The log of well 16/1W-3N1, which reported a specific capacity of 10 gpm per foot of drawdown, showed sand and gravel in the bottom of the hole, presumably gravel of the Pleistocene channel of Jordan Creek.

Coefficients of permeability for the Battery formation, based on the data given in the table on page 30, were found to average about 500 gpd per square foot. The yield factor, and consequently the permeability reported, may be higher than the actual values, owing to the possible inaccuracies of the assumptions involved in the system of estimating yield factor and permeability. (See p. 16.)

The two factors that most critically control the validity of the final results are the observed specific capacity and the reported saturated thickness. Because of the common irrigation practice of shutting down the pump to move sprinklers every 4 hours, it was impossible to measure the pumping level at any well after it had been pumping longer than 4 hours. Therefore, the pumping level may still have been declining at the time reported, and the measured drawdown would be too small, thereby increasing the reported specific capacity of the well.

The yield factor, as reported, would also be too high if the well penetrates the aquifer only partly, so that a large part of the water entering the well is derived from beneath the bottom of the well. Therefore, if the saturated thickness, as reported, is too small, it follows that the yield factor and estimated permeability will be too large.

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Properties of wells in the Battery formation

Well no. on pl. 5	Yield (gpm)	Drawdown (feet)	Specific capacity (gpm per foot of drawdown)	Saturated thickness (feet)	Yield factor [1]
16/1W-3N1	30	3	10	28	36
17H1	50	4	12	13	92
18F1	10	5	2	10	20
16/2W-24A1	8	6	1.3	13	10
16/1W-20E1	10	3	3.3	9	36
20H1	30	8	3.7	20	18
20H3	10	2	5	13	38
20P1	25	4	6.2	10	62
21F1	15	10	1.5	15	10
27B2	30	6	5	12	42
28G1	20	6	3.3	12	28
17/1W-27Q1	15	5	3	12	25
18/1W-17B1	10	4	2.5	5	50
Average	20	5	4.5	13	36

[1] Yield factor $= \frac{\text{Specific capacity}}{\text{Saturated thickness}} \times 100$

RIVER-TERRACE DEPOSITS

Character.—River-terrace deposits are older (Pleistocene) alluvium in a raised position with respect to Recent flood plains. In general, the terrace deposits consist of sand and gravel mixed with clay. Drillers' logs indicate that finer material is more prevalent in the upper part and that cobbles several inches in diameter are common in the lower part. The terrace deposits that are shown on the map (pl. 5) are of late Pleistocene age, and in most places they directly overlie the bedrock of Jurassic age. The inferred relations of the terrace deposits to the Battery formation, alluvium, and rocks of Jurassic age are shown on plate 5.

The log of well 17/1W-14F1, drilled by Peter T. Starr, Jr., in 1953, illustrates the character and thickness of the deposits underlying the Fort Dick terrace.

	Thickness (feet)	*Depth (feet)*
Terrace deposits:		
Gravelly soil	13	13
Sand, gravel, and boulders	17	30
Jurassic rocks:		
Solid rock	4	34
Blue shale	6	40

Terrace deposits lie on both sides of the Smith River upstream from where Highway 101 crosses the Smith River. The Fort Dick terrace is the largest on the plain and covers 5 to 6 square miles. North of the Smith River is a narrow strip of terrace deposits which have been deposited in part by the Smith River and in part by Rowdy Creek. These northern deposits are overlain in places by Recent alluvial fans.

A topographic break marks the contact of all the terrace deposits with the younger sediments, with the exception of the western margin of the Fort Dick terrace. Along that contact the escarpment is very subdued, probably because of the erosion and alluviation by floodwaters of the Smith River and Lake Earl. In that area, the windblown deposits from the dunes, a short distance west, are a ready source of sediment for redistribution by the floodwaters.

The log of well 16/1E–9N1 in Hiouchi Valley shows the thickness of the terrace deposits to be at least 50 feet. Logs of several wells near Fort Dick indicate a thickness of about 40 feet.

Water-bearing properties.—In general, the river-terrace deposits are permeable enough to yield sufficient water for domestic wells. However, the well drilled for the Redwood Union School (17/1W–14C1), through the entire thickness of 40 feet of sediment, was not reliable during early fall. Three successful irrigation wells have been developed in the river-terrace deposits. These wells have yields estimated at 140, 200, and 400 gpm.

The following table shows the properties of a few selected wells on which it was possible to obtain information regarding the water-bearing characteristics of the terrace deposits.

Properties of wells in the river-terrace deposits

Well no. on pl. 5	Yield (gpm)	Drawdown (feet)	Specific capacity (gpm per foot of drawdown)	Saturated thickness (feet)	Yield factor [1]
Fort Dick terrace:					
17/1W– 9J1 (irrig.)	200	12	17	21	81
14F1	50	3	17	15	113
14L2	20	4	5		
15E2 (irrig.)	400	7	57	36	158
15M1	30	2	15	10	150
Rowdy Creek terrace:					
18/1W–35C1 (irrig.)	140	2.26	61	15	407
Hiouchi Valley terrace:					
16/1E–9K1	15	2	7.5	11	68
Average	122	4.6	26	18	163

[1] $\text{Yield factor} = \frac{\text{Specific capacity}}{\text{Saturated thickness}} \times 100$

The coefficients of permeability of the terrace deposits of the Smith River are probably 1,000 to 2,000 gpd per square foot. Available information indicates that the terrace deposits of Rowdy Creek are more permeable than those of the Smith River and are probably about as permeable as the less permeable facies of the Recent flood-plain deposits—that is, about 6,000 gpd per square foot.

RECENT SERIES

FLOOD-PLAIN DEPOSITS

Character.—The flood-plain deposits, mapped as Qfu and Qfy on plate 5, form and underlie the present flood plains of Smith River, its major tributaries, and Jordan, Lopez, and Gilbert Creeks. With the mapping scale used, it was not possible to show the alluvium along the smallest streams. In the mountain area the Smith River flood plain is less than a quarter of a mile wide, but on the platform the flood plain ranges in width from half a mile to several miles.

Except in the stream channels, the flood-plain deposits are exposed only locally, but their lithology is known from the drillers' logs of wells for these deposits. They consist largely of sand and gravel intermixed in places with silt. As in the terrace deposits, boulders and cobbles are probably common in the flood-plain deposits mapped as Qfu. They are observed to be common in the river-channel deposits (Qfy).

The following log of well 17/1W–3C1, drilled by Starr & Purdue in March 1953, illustrates the lithologic character of the flood-plain deposits. Altitude of the well was 15 feet, and depth to water at the time of drilling was 3 feet.

	Thickness (feet)	*Depth (feet)*
Recent flood-plain deposits:		
Soil	2	2
Sand	3	5
River gravel	20	25

Seismic probe 2, upstream from the bridge where Highway 101 crosses the Smith River (pl. 5), indicated that the surface of the Jurassic rocks slopes about 2 degrees toward the northeast; the thickness of alluvium was shown to be about 42 feet on the southwest end and 60 feet on the northeast end of the line of penetration.

Seismic probe 3, near the mouth of the Smith River, indicated a 1-degree slope to the east on the Jurassic rocks; the thickness of alluvium was shown to be about 65 feet on the west end and 95 feet on the east end of the line of penetration.

Along small tributary streams the thickness of the alluvium ranges from a featheredge to some 50 feet.

Water-bearing properties.—The flood-plain deposits are the most productive aquifers in the area of investigation. Yields of irrigation wells that penetrate these deposits range from 200 gpm to more than 500 gpm. The following table shows the properties of a few selected wells on which it was possible to obtain information regarding the water-bearing characteristics of the flood-plain deposits.

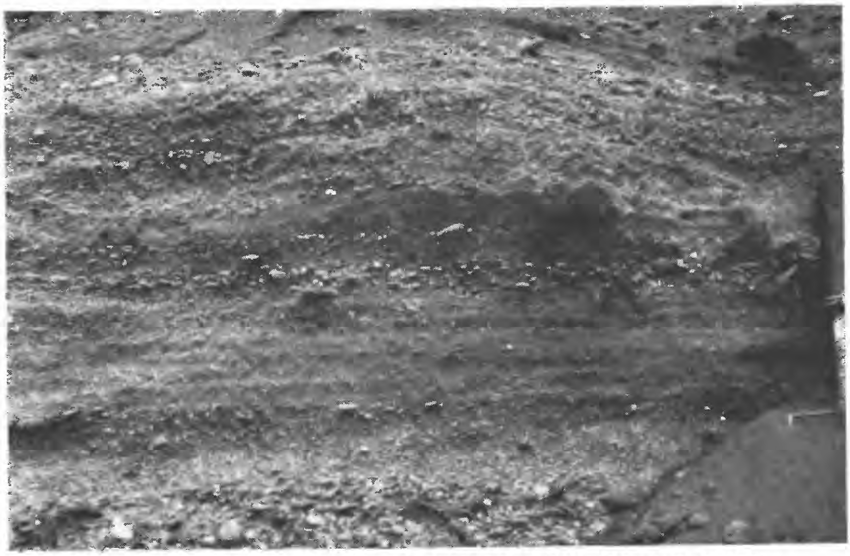
Properties of wells in the flood-plain deposits

Well no. on pl. 5	Yield (gpm)	Drawdown (feet)	Specific capacity (gpm per foot of drawdown)	Saturated thickness (feet)	Yield factor [1]
18/1W–26P1	180	1.12	160	14	1,140
34M1	525	1.50	350	14	2,500
35K1	240	2.73	88	24	370
17/1W– 3C1	420	3.44	123	18	680
Average	340	2.2	180	17	1,170

[1] Yield factor $= \frac{\text{Specific capacity}}{\text{Saturated thickness}} \times 100$

AERIAL PHOTOGRAPH OF THE PEBBLE BEACH AREA, SHOWING OUTCROPS (1–8) AND FOSSILIFEROUS LOCALITY (7) OF THE ST. GEORGE FORMATION AND MEASURED SECTION AND FOSSIL LOCALITY OF THE BATTERY FORMATION

A. CONTINENTAL GRAVELS OF THE BATTERY(?) FORMATION



B. GRAVEL FACIES OF THE BATTERY FORMATION ALONG SEA CLIFF

Although the properties of these wells are representative of most wells drilled into the flood-plain deposits, the values are relative and should be used only to compare water-bearing characteristics of the several aquifers in the Smith River plain. However, the coefficients of permeability for the flood-plain deposits are very high, probably in the range of 5,000 to 20,000 Meinzer units but possibly higher.

It would appear from these estimates that properly constructed large-diameter wells could produce yields in excess of 1,000 gpm.

ALLUVIAL-FAN DEPOSITS

Recent alluvial-fan deposits form a narrow strip, almost continuous, along the mountain front. In general, these deposits consist of poorly sorted fragments of the Jurassic sandstone embedded in a very weathered silty to clayey matrix. Individual fans from small streams draining the mountain front have coalesced so that the typical fan shape is no longer apparent. The surface of the fans has a steep slope (pl. 5) compared with the nearly flat surfaces of the adjoining marine and stream terraces.

In the northern and southern parts of the Crescent City platform alluvial fans overlie marine-terrace deposits of the Battery formation. From the Smith River to a short distance north of Rowdy Creek the fans overlie river-terrace deposits. From this area north to the marine terrace the fans have been deposited directly onto the flood plain of Smith River and its local tributaries.

Although several domestic wells produce water from the alluvial fans, at many localities these deposits are poorly sorted and contain such a high proportion of fine material that they do not yield water of sufficient quantity for domestic use.

Associated with the alluvial fans are several landslides, mapped as Ql on plate 5.

DUNE SAND

The eolian sand deposits form a pronounced topographic feature adjacent to the ocean along the west edge of the Smith River plain. The sand dunes cover an area more than 10 miles long and about 1 mile wide, from Point St. George north to the mouth of the Smith River.

Although the total thickness of the eolian deposits is unknown, the ridges are locally 60 to 70 feet above the surfaces of the marine terrace and alluvium. Where they border the sea, they stand as much as 60 feet above sea level.

The sand composing the ridges is gray, fine- to medium-grained, angular to subrounded, and predominantly quartz but containing abundant ferromagnesian minerals. The near-surface material in the interdune area is poorly sorted but is generally finer grained.

The loose, unconsolidated dune sand is so susceptible to wind erosion that it is unsuitable for cultivation, and consequently no irrigation wells have been developed in this area. However, several dairy herds graze on the native grasses that surround Lake Earl and grow in the interridge areas.

Surface drainage is poor, and a large part of the precipitation that falls on the dune area infiltrates the ground and becomes recharge, moving eventually to the adjoinging Battery formation and alluvium. The water table crops out locally in pools that occupy some of the interdune depressions.

Water-bearing properties.—The dune sand is moderately permeable and contains water of good quality; however, only a few dozen stock and domestic wells are now used in the area. Hydrologic properties should be investigated further to determine the feasibility of developing large water supplies.

STRUCTURE

The major structural feature of the area is the Del Norte fault, along which the Smith River plain has been dropped from the adjacent mountains. According to Maxson (1933, pl. IV), this fault lies near the base of the mountain escarpment and separates the Jurassic rocks from the plain. In the mountains the complexly folded Jurassic rocks strike in general toward the northwest. The surface beds on the plain are practically undisturbed and are underlain by Pliocene rocks which dip gently northeastward.

According to Maxson (1933, pl. IV), the strike of the Del Norte fault south of Rowdy Creek is nearly north, but north of Rowdy Creek the strike curves northwestward along the base of the hills and is due west at the mouth of the Smith River. If Maxson's mapping of this fault is correct, then the narrow band of the Battery formation north of the Smith River represents sediments deposited on a wave-cut terrace carved directly in the mountain headland and formed independently of the main part of the Smith River plain. However, the similarity of the bedrock surface and the superficial deposits in the two parts of the area suggest that they might have originated contemporaneously under identical conditions. The area north of the Smith River, like the main part of the plain, probably is faulted down from the adjacent mountains. That area is apparently offset to the west along a cross fault that generally follows the westward-striking trace of Maxson's Del Norte fault. The valley of Rowdy Creek and its south fork follows the zone of weakness of this cross fault. Mapping of the Rowdy Creek drainage area in more detail than was possible for this report may reveal more evidence indicating the presence of such a fault.

Near Point St. George, Dall (*in* Diller, 1902, p. 35) observed dips as much as 20° N. in the St. George formation and concluded that they were initial dips. He suggested that the beds of the St. George were deposited as a broad arch over the irregularly eroded surface of the Jurassic rocks. The author, however, observed a strike of N. 50° W. and dip of 12° NE. in those beds along Pebble Beach and agrees with Maxson (1933, p. 137) that this dip is the result of structural movement. Tilting of these beds by the structural movement that dropped the Smith River plain seems to be logical and consistent with the structural history of the area. Thus, the beds of the St. George were tilted gently northeastward by downward movement of the Crescent City block, with respect to the adjacent mountain front, prior to the deposition of the overlying Battery formation, which is undisturbed. This tilting indicates that movement along the Del Norte fault occurred during one or more intervals before and after deposition of the St. George formation. The first lateral movement along the Rowdy Creek cross fault probably occurred before deposition of the St. George.

GEOLOGIC HISTORY AND GEOMORPHOLOGY

After the deposition of Jurassic rocks, the area was uplifted and probably remained above sea level during the Cretaceous period and the early part of Tertiary time. During Miocene time the area evidently was covered by the sea, or at least the sea extended eastward from the area, because a few hills east of the Crescent City platform are capped by marine sand and clay of probable Miocene age—the "Wymer beds," as they were named by Diller (1902, p. 32). The total area submerged by the Miocene sea is unknown, but the widespread occurrence of marine rocks in California suggests that it was probably very extensive. Absence of Miocene rocks on the platform may be explained by inferring that the platform area was an island composed of Jurassic rocks or that the Miocene sediments were later eroded from the platform area.

During the period from about the middle of the Miocene to the part of the Pliocene preceding deposition of the St. George formation, the Crescent City platform was dropped by faulting. The gradual movement along the Del Norte fault and the hypothetical Rowdy Creek cross fault caused the platform to be lowered somewhat below sea level. At that time the Jurassic rocks were eroded and sculptured by the ocean, forming a wave-cut terrace marked by the prominent sea stacks that remain today as small outcrops of Jurassic rocks protruding through the Pleistocene and Recent sediments.

During the Pliocene epoch the ocean covered at least the southern two-thirds of the platform, and deposits of the St. George formation accummulated in a bedrock trough. The ancestral Smith River was probably a major source of sediment as it flowed through the low gap, now elevated and crossed by U. S. Highway 199. Later, the newly deposited Pliocene beds were eroded and possibly were completely removed from areas they once covered. During the geologically active middle Pleistocene time, structural movement tilted the Pliocene beds slightly landward. The late Pleistocene sea spread over the platform area and formed a wave-cut terrace, on which the Battery formation was deposited. At that time the Smith River was still flowing through the saddle now crossed by Highway 199; the mouth of the river was near the present intersection of Highway 199 and the Elk Valley Road. As the Pleistocene sea retreated, the river extended its course across the platform and flowed in the ancestral channel now occupied by Jordan Creek.

Lake Earl was at the mouth of Smith River at the end of the Pleistocene and during early Recent time. According to Davis (1933, p. 231), Lakes Earl and Talawa are lakelike bays "enclosed by a long, wave-built, smoothly beached sand reef" which swings southwestward to the low, rocky headland of Point St. George. The two lakes are separated by a narrow strip of sand, which may be an older reef of somewhat sharper curvature than the outer reef.

Prominent elongate sand ridges on the marine-terrace surface of the Battery formation probably originated near the shore as the Pleistocene sea withdrew from the Smith River plain. These ridges might have been formed by ocean waves and currents, or they may be transverse dunes formed of sand blown from successive beaches of a withdrawing sea. Emery (1950, p. 219) described similar ridges in San Diego County, Calif., and concluded that they were of eolian origin.

These ridges are about 500 feet wide at the base, 30 or 40 feet high, nearly symmetrical in cross section, and trend northwestward parallel to the coastline at Pebble Beach. The material forming the ridges is subrounded to subangular quartz sand. Thin horizontal clay layers occur in the upper part and some material of finer grain is distributed throughout the sand. Cursory examination of road cuts along Highway 199 seemed to indicate parallel bedding in these deposits, but broad crossbedding was visible after a heavy rain had removed loose debris from the cuts.

The elongate character of these ridges, their symmetry, and their parallelism with the present shoreline suggest that they were deposited by wave action. The broad crossbedding and frosted sand grains, however, indicate an eolian origin. The sand grains are subangular because, like the Recent dunes, their source was probably a nearby beach and they were not transported far enough to become well rounded. The clay layers and the finer material dispersed through the sand were probably derived from the weathering of clay-forming feldspars and concentrated in lenticular beds by soil-forming processes. Similar fine-grained material and thin clayey zones were observed in cuts in the Recent dunes. The occurrence of swampy undrained interridge areas is more consistent with an eolian than an aqueous origin for these ridges.

An eolian origin for these ridges, as postulated by Emery for the ridges in San Diego County, seems to be the more logical explanation.

During early Recent time the Smith River was pirated or deflected toward the north, where it debouched from the mountainous area at the present location. The Crescent City platform was lower in relation to sea level than it is now; the surfaces now represented by the Fort Dick and equivalent terraces were the flood plain of Smith River.

Perhaps part of the Battery formation was eroded by the river immediately prior to the deposition of these terrace deposits. The terraces in Hiouchi Valley, about 150 feet above the present river channel, may indicate that the river gradient was far steeper than it is now. The escarpments of these terraces also suggest at least three periods of sea-level lowering in relation to the land surface since the deposition of the deposits now forming the highest terrace. Fort Dick terrace is the youngest terrace of the Smith River. Since the deposition of these latest terrace deposits, the sea level has lowered and the sediment load of the Smith River is now being deposited on the present flood plain at an altitude lower than the Fort Dick terrace.

GROUND WATER

GENERAL HYDROLOGIC PRINCIPLES

"Subsurface water" is the term used to designate all water that exists below the land surface (Meinzer, 1923b, p. 17–32). Ground water is the part of subsurface water that is in the zone of saturation.

Except for minor amounts of water from magmatic solutions (juvenile or primary water), the source of ground water is precipitation. However, only a fraction of the total precipitation that falls on a given area infiltrates to become part of the ground-water body. A part of the remainder of the precipitation returns to the atmosphere by evaporation, and by transpiration through the leaves of plants—that is, by processes collectively called evapotranspiration. The water that is neither absorbed into the soil and underlying formations nor evaporated at the point of precipitation becomes direct surface runoff. This runoff, in the form of sheet wash and streamflow, continues to flow downslope on the surface until it either evaporates, seeps downward to become subsurface water, collects in basins, or flows to the ocean.

The term "hydrologic cycle" is used to describe this movement of water from the atmosphere to the land, to the oceans, and again back to the atmosphere.

Ground-water recharge is the addition of water to the ground-water reservoir and may take place in several ways. Ground water in the Smith River plain is derived from direct infiltration of precipitation, subsurface inflow of water that fell as precipitation on the mountains or in the dune area, and infiltration of runoff in the lower reaches of the Smith River and other permeable stream channels.

The three principal factors controlling the proportion of precipitation that becomes recharge are depth to the water table, permeability of material underlying the land surface, and topography.

In the Smith River plain, the relief and the depth to water are generally consistent throughout the area; therefore, the permeability of the sediments is the critical factor that determines the favorable places of recharge from precipitation. In general, the upper beds of the Battery formation are rather impermeable and permit only a small amount of infiltration. Terrace deposits are somewhat better for infiltration. Permeable sand dunes and flood-plain deposits are the most favorable recharge areas. The hydrograph of well 16/1W–17K1 (fig. 8), in the Battery formation, shows no change in rate of downward trend following the late summer rains; however, the hydrograph of well 17/1W–15M2, in terrace deposits, shows an almost immediate rise in water level after the August rains.

Ground-water discharge, the withdrawal of water from the ground-water body, may occur in several ways. In the area covered by this report, natural discharge is primarily through springs and seeps that discharge into the ocean or into effluent streams draining into Lakes Earl and Talawa or the ocean, or it is by evaporation and transpiration. Springs and seeps discharge ground water from the lower part of the Battery formation in the sea cliffs along Pebble Beach and north of the Smith River. Other springs are along the eastern edge of the sand dunes at the south end of Lake Earl. Many of the numerous springs along the mountain front are developed for domestic water supplies. The flow of Elk and Jordan Creeks is sustained by ground-water discharge along their courses (pl. 6).

Artificial discharge in this area takes place by pumping from wells. When a well is not pumped, equilibrium exists between the head of water in the well and the head of water in the aquifer outside the well. When water is withdrawn from the well, the head inside the well is reduced and a difference in head is created for some distance from the well. In the process of establishing hydraulic equilibrium, the water table develops a cone of depression. The apex of the cone is at the water level in the well during pumping, the height is equal to the drawdown, and the base is the original water surface. The area affected by a pumped well (area of influence) is controlled largely by the rate of pumping and rate of recharge. A higher pumping rate in a well produces a greater drawdown, and thereby increases the depth and diameter of the cone and the area of influence. The local rate of recharge is controlled primarily by the permeability of the water-yielding beds tapped by the well.

WATER TABLE AND MOVEMENT OF GROUND WATER

The lateral movement of ground water is shown by contour maps of the water table. Ground water moves from points of higher to points of lower head; therefore, contours, or lines connecting points of equal altitude on the water surface, may indicate the areas of recharge (water-table highs) and areas of discharge (water-table lows).

Plate 6 shows water-level contours for the ground-water body of the Smith River plain. The general north-south alinement of contours along the mountain front indicates that the predominant direction of movement is from the alluvial fans toward the most extensive aquifers, the Battery formation and the river terraces. The alluvial-fan deposits have a low permeability, and most of the recharge in that area is probably by infiltration in the channels of the small streams.

About 1½ miles north of Crescent City on Highway 101 is a ground-water divide. North of this divide water flows to Lake Earl; south of the divide water either discharges by seepage along the sea cliff south and west of Crescent City or is drained to the ocean by Elk Creek. Therefore, the water that is recharged to the ground-water body in the headwaters area of Elk Creek discharges in part to Lake Earl and in part as surface water in the lower reaches of Elk Creek, thence to the ocean.

Although few water-level measurements have been made in the sand-dune area northwest of Crescent City, projected contours indicate that recharge is entirely from precipitation on that area and that the ground water moves from the higher dunes outward in all directions: to Myers Creek drainage (northwest of Crescent City, not shown on base map), to Lakes Earl and Talawa, and directly to the ocean.

Along the Smith River the shape of the 20-foot contour, which crosses the river about three-fourths of a mile upstream from Highway 101, indicates that from this point to approximately the point of the crossing of the 10-foot contour the river gains ground water. And also upstream from this crossing the river is probably gaining. The shape of the 10-foot contour indicates that the river is gaining ground water on its north bank and losing water to the ground on its south bank. The bend of the 5-foot contour in the downstream direction shows that the river is losing water to the ground on both sides in secs. 33 and 34, T. 18 N., R. 1 W. Underflow moves through the swampy marshes to Talawa Slough.

North of the Smith River the control is poor, but the contours indicate that recharge is from the mountain front and discharge is either to the Smith River or to the tidal area near the mouth.

Cross sections *A–A′* and *B–B′* (pl. 5) show the relation of the water body to the land surface. These cross sections indicate that the river is gaining ground water because of its entrenchment below the water table.

On the Smith River plain the depth to water below land surface ranges from zero to slightly more than 30 feet. Within any local area of the Battery formation the topography is the factor controlling depth to water. Under the many ridges and swells of the undulating surface the water is farther below land surface than in the draws and swales between the topographically high areas.

The deepest water levels are generally found along the mountain front and near the Smith River (pl. 6). The water levels along the mountains are deep because the land surface slopes more steeply than the water table. The depth to water adjacent to the river is as great as 20 feet because of the entrenchment of the stream and the discharge of ground water into the river. From about the north quarter-section corner of 17/1W–11, the river, in effect, has the same influence as a battery of wells along the river channel in lowering the water levels in wells adjacent to this reach.

FLUCTUATIONS OF WATER TABLE

Fluctuation of water levels is due to several causes. Among the reasons for fluctuations noted on recorder charts from this area are daily variation of barometric pressure, which causes a small change; infiltration of irrigation water; infiltration of rain either near the well or up the water-table gradient from the well; pumping from wells; and natural discharge.

Recording gages were installed on two wells during the 1953 field season. One record obtained is from July 21 to December 3; the other is from July 25 to September 18, ending at that time because of well failure. E. C. Johnson, resident of the area, furnished weekly water-level measurements on his well for this period. Hydrographs of these wells, daily cumulative rainfall, and daily discharge of the Smith River are plotted in figure 8.

The record for well 16/1W–2J1 shows that the downward trend of water levels ceased shortly after the 2.31-inch rain on August 25.

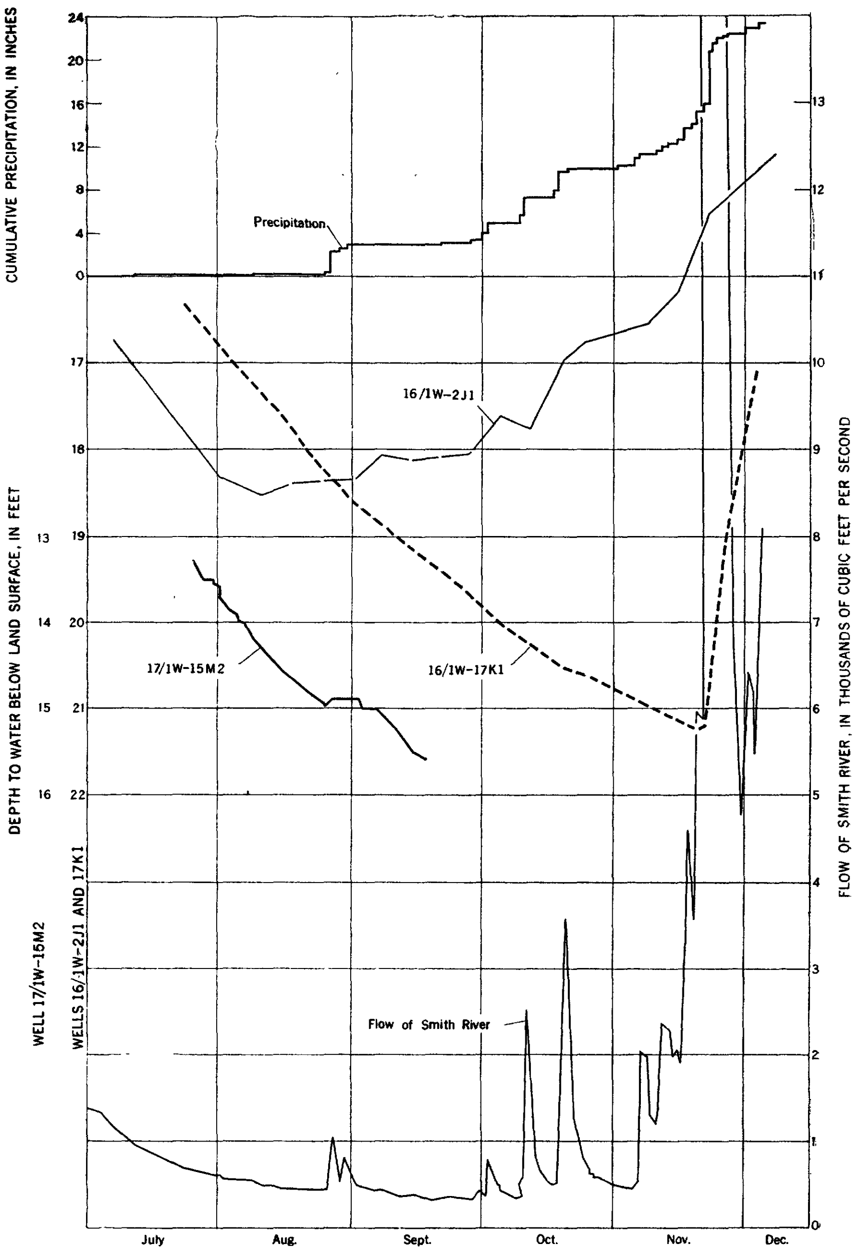


FIGURE 8.—Hydrographs of three wells in the Smith River plain.

Also, the hydrograph for recorder well 17/1W–15M2 shows a slight rise in water level at the same time.

Well 16/1W–17K1 is on a ground-water divide (pl. 6) which underlies the local drainage divide. The hydrograph of this well, shown in figure 8, is a plot of the daily high-water level for the period of record. This hydrograph shows the downward trend of water levels in the vicinity from July to November 10. During the last 10 days of record the water level rose to within less than a foot of the late July water level. The summer and fall water-level decline, recorded in this well, is due to the flattening of the ground-water mound by natural discharge northward to Lake Earl and southeastward to Elk Creek drainage and also to depletion of water in storage by pumping for local use. The 2.31-inch rain in late August did not affect this record, probably because the amount of precipitation was not sufficient to infiltrate to the zone of saturation; instead the water was held as soil moisture or left the area as surface flow. The recovery beginning on November 20 was primarily the result of precipitation entering the aquifer in an area of higher permeability, very likely at some distance from the well, and thence percolating underground to the well. Undoubtedly some precipitation infiltrated directly to the water body in the vicinity of the well.

In well 16/1W–2J1, the rapid rise in water level in response to rainfall, beginning about August 10, evidently was due to the geological location on an alluvial fan at the mouth of the ancestral Smith River. Starting with the first rain in August, the water level rose throughout the period of record, and it must have continued to rise until withdrawal exceeded replenishment.

The hydrograph of well 17/1W–15M2 shows a downward trend, resulting from irrigation pumping from well 17/1W–15E2 and natural outflow from the deposits underlying the Fort Dick terrace into the river alluvium to the northwest. The change in slope of the hydrograph on July 28 resulted from the shutdown of irrigation pumping because of a broken pump. Local rainfall on August 26 caused pumping to stop again, permitting the cone of depression around the pumped well to refill. This water-level recovery and the contemporaneous recharge from the rainfall filtering through the relatively permeable gravel of the river terrace is reflected by the rise in water level shown in figure 8. On approximately September 6 irrigation pumping started again, and the water level continued its downward trend. The record ended abruptly when a gopher dumped the dirt from its burrow down the well, sinking the recorder float and filling the well.

Cross section *B–B′* (pl. 5) shows the position of the water table for July and for September 18, 1953. During this period the average decline of the water table in the Battery formation and deposits of the Fort Dick terrace was about 6 feet. In the alluvium and the deposits underlying terraces along Rowdy Creek, the decline in water levels averaged about 4 feet. Because by July water levels have declined from the spring high and are not yet at their lowest by September, the seasonal fluctuation is somewhat greater than is represented by the 4 to 6 feet of fluctuation shown.

GROUND-WATER STORAGE

In order to estimate the underground storage capacity of any ground-water reservoir, it is necessary to know the areal extent of the aquifer, the thickness of the deposits saturated with fresh water, and the specific yield of the sediments. The specific yield of a rock saturated with water is the ratio of the volume of water it will yield by gravity to its own volume.

On the Smith River plain, ground-water storage was computed for the interval from 10 feet to 35 feet below the land surface. The 10-foot upper limit was chosen because it most nearly approaches an average depth to water. Average depth of wells is about 35 feet, and data were insufficient to compute storage to a greater depth.

The area of investigation was divided into 5 separate storage units (fig. 9). Each unit, as selected, has a relatively consistent lithology throughout and differs from other units in the water-yielding properties of its sediments. The areas occupied by Lakes Earl and Talawa and the tidal mouth of the Smith River were excluded from the storage units.

The lithologic subdivisions were made on the basis of information obtained from the areal geologic mapping and inspection of the peg model.

Specific yields assigned to deposits on the Smith River plain were modified from specific-yield values used in a report on the Sacramento Valley (Poland, Davis, Olmsted, and Kunkel, 1951). The following table shows the specific yields, in percent, used to estimate ground-water storage for the Smith River plain.

Specific-yield values for the various lithologic materials used in estimating ground-water storage on the Smith River plain

		Specific yield (percent)
Class 1:	Gravel; boulders; sand and gravel	25
Class 2:	Dune sand	15
Class 3:	Sand; clay and sand; fine sand	10
Class 4:	Clay and gravel; sandy clay	5
Class 5:	Clay; blue shale	1

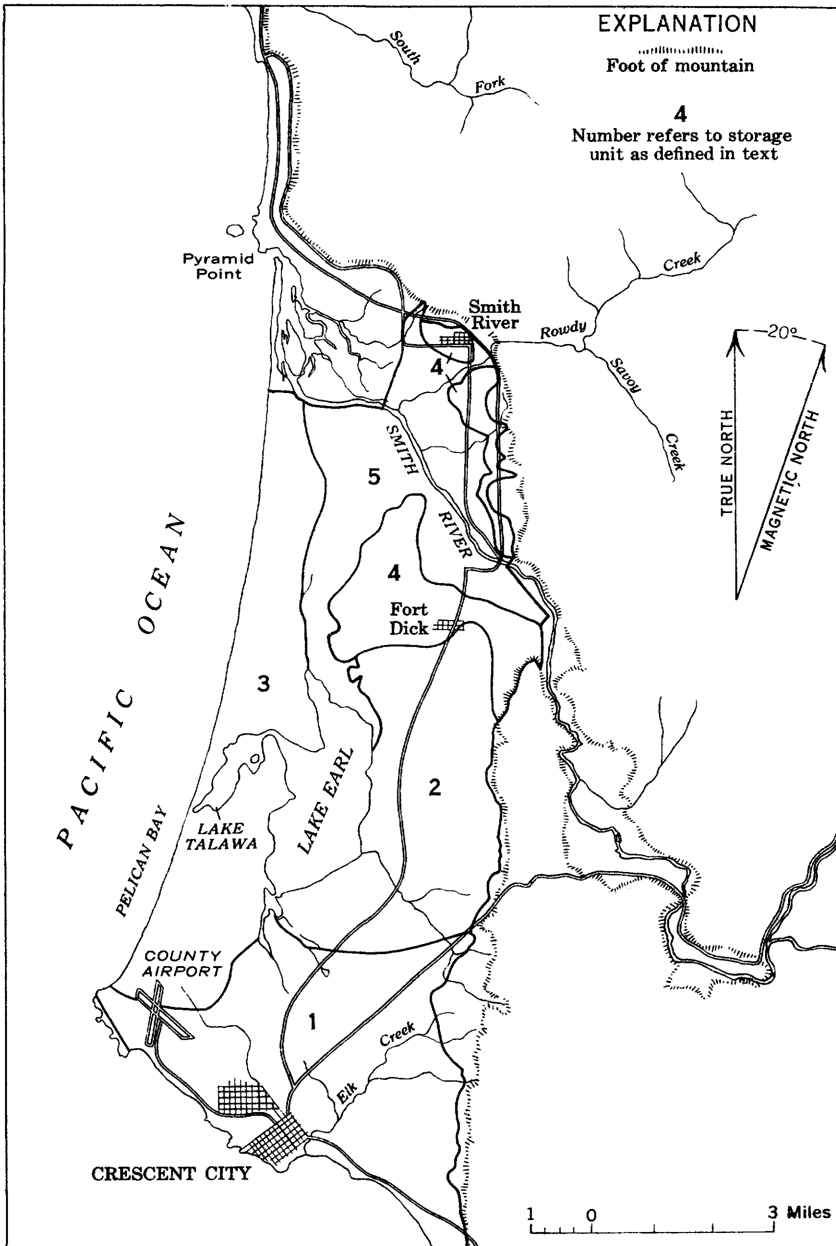


FIGURE 9.—Map of the Smith River plain area, showing ground-water storage units.

For each unit shown in figure 9, the drillers' logs were examined and the thickness of each class of material between 10 and 35 feet below the land surface was totaled. The total thickness for each class was divided by the total thickness for all classes to determine the percentage represented by each class. Each percentage was multiplied by the specific-yield value for that class; then these products were totaled and divided by 100 to determine the average specific yield for the sediments in that storage unit.

In storage unit 1, for example, well logs reported a total of 275 feet of class 3 material, 109 feet of class 4, and 75 feet of class 5, for a total of 459 feet of material between 10 and 35 feet below the land surface. Classes 3, 4, and 5, therefore, made up, respectively, 60.0, 23.7, and 16.3 percent of the total footage. The products obtained by multiplying these percentages by the assigned specific-yield values are 600, 118, and 16. The sum of these three products divided by 100 equals 7.3 percent, the estimated average specific yield of sediments from 10 to 35 feet below the land surface in unit 1. Unit 1 comprises an area of 9,260 acres. By multiplying this acreage by the 25-foot thickness, a total of 231,500 acre-feet of sediment is obtained. This quantity of sediment multiplied by the average specific yield of 7.3 percent equals 16,900—the estimated number of acre-feet of ground water stored in unit 1. The following table shows results of similar computations for all units in the area. The ground-water storage in the Smith River plain between depths of 10 and 35 feet is about 100,000 acre-feet.

Areas, average specific yield of sediments, and estimated ground-water storage for storage units shown in figure 9

Storage unit	Geomorphic unit	Area (acres)	Average specific yield (percent)	Ground-water storage (acre-feet)
1	Marine terrace	9, 260	7.3	16, 900
2	Marine terrace	6, 430	11.3	18, 200
3	Sand dunes	6, 450	15	24, 200
4	River terraces	3, 300	11.7	9, 650
5	Flood plain	5, 630	21.6	30, 400
	Total	31, 070		99, 350

USE OF WATER

The total use of water on the Smith River plain in 1953 was about 4,800 acre-feet. Probably half of this amount was derived from wells and the other half from diversion from the Smith River and other streams of the area. Irrigation supplies required the largest amounts of both surface water and ground water. Each source contributed about 1,700 acre-feet. Water used for municipal purposes was about

200 acre-feet from ground water and 150 acre-feet from surface water. Almost all domestic and stock requirements, some 500 acre-feet, were supplied from ground water. The industries used surface sources for most of their water requirements.

Irrigation.—Irrigation on the Smith River plain, which is primarily for pasture, has developed principally since 1947. Rotating sprinklers are used for irrigation, and the area of irrigation is generally confined to the flood plains and terraces of the Smith River and Rowdy Creek. Of the 41 irrigation pumps operating in the area in 1953, 23 pumped ground water; the other 18 pumped surface water, either directly from the perennial streams or from seeps or spring-fed sloughs.

The amount of pasture irrigated per well, as reported by the owner of each irrigation well, ranged from 7 acres to 100 acres and averaged about 50 acres. The total acreage irrigated by ground water was approximately 1,100, and about the same total acreage was irrigated by surface water.

The general practice seems to be to irrigate for 10 to 15 hours a day from the last week in June to the last week in September. Most farmers try to irrigate their entire fields 2 or 3 times a year. Nine farmers supplied information sufficient to estimate the amount of water used annually per acre of land. The computations based on these data showed the amount of water in acre-inches, used on each acre for the entire season, to be 6, 8, 11, 12, 20, 24, 25, 30, and 33, the median being 20 inches and the average 18 inches. Therefore, about 1½ acre-feet per acre per season for the entire area is probably a reasonable figure. Thus the total pumpage of ground water for the 1,100 acres irrigated is about 1,700 acre-feet per year.

Municipal supplies.—The municipal supplies of both Crescent City and the town of Smith River are furnished by privately owned water companies.

Crescent City is served primarily by surface water in the summer and ground water in the winter. During the summer Crescent City's ground-water source is not dependable, and during the winter the surface water has a brown discoloration impractical to remove. This discoloration is presumably from organic debris of the heavily vegetated slopes of the watershed. The total annual use of water is about 300 acre-feet; some two-thirds of this amount, or 200 acre-feet, is ground water. The peak use for a summer day was reported to be 1,300,000 gallons.

The four sources of supply are the Griffin well, Tower well, Myers Creek, and a tributary of Elk Creek. The Griffin well, 24 feet deep and 8 feet in diameter, is equipped with a 2-inch centrifugal pump powered by a 5-horsepower electric motor. Production is about 50 gpm, and the well is used 8 hours a day in the summer and 24 hours a day in the winter. The Tower well, 22 feet in diameter and 32 feet deep, is used only as emergency standby in summer but is pumped continuously in winter. During the summer the average flow of the tributary of Elk Creek is reported to be about 625 gpm and the flow of Myers Creek to be 350 gpm, all of which is diverted into two separate pumps. The water is chlorinated and pumped through filter tanks.

The town of Smith River obtains its water supply from a reservoir made by a small dam on Dominie Creek, a tributary of Rowdy Creek. The water moves by gravity flow through an 8-mile line from a 96,000-gallon filter basin to a distribution system composed primarily of 2-inch pipes. The amount of surface water used is about 50 acre-feet a year.

Domestic and stock supplies.—Domestic wells supply water to homes for household use and for irrigation of lawns and gardens. Stock wells supply water for livestock. Most of the 213 wells on which information was obtained for this investigation, however, are used for both domestic and stock supplies. Wells developed for these supplies are constructed by rotary or cable-tool drilling, by driving sand points, or by digging with pick and shovel. These wells are generally equipped with electric motors, ranging from ¼ to 1 horsepower. Most of the wells in the sand-dune area are driven sand points equipped with hand lift-pumps.

In the alluvial-fan deposits along the mountain front, many unsuccessful attempts have been made to obtain domestic water supplies from wells. As alternatives, many springs piped into houses furnish adequate water supplies. Some residents use gravity flow to pipe the spring water to catchment basins, from which they pump the water into pressure systems to serve the houses.

In the reaches of the Smith River upstream from the mountain escarpment, many residents obtain their water supplies from the river. They pump water into pressure tanks by mounting the electric motors and pumps above flood level and laying pipes to the river bed. They do not treat the water. The maximum late-summer lift involved in the arrangement ranges from 50 to 175 feet.

The estimated annual pumpage of ground water for domestic use in the Smith River plain is about 500 acre-feet.

Industrial.—Only a very small part of the water used for industrial purposes is ground water. The major industrial use of water is to fill the sawmill log ponds, which are used to float the logs in order to maneuver and sort them. Inasmuch as most of the mills are near Crescent City, they are on the marine terrace. Owing to the low yield of wells in the Battery formation, the mills have been situated so as to obtain surface water from the many small streams and sloughs. Several mills have made unsuccessful attempts to drill wells of sufficient yield to supply the log ponds. Most mills have wells to supply water for drinking and other uses that require minor quantities. Yields of these wells are comparable with those of domestic wells.

QUALITY OF WATER

The quality of water in any area is determined largely by the geology and climate. In general, rainfall, by exerting a diluting effect, controls the degree of concentration of mineral constituents. The kind and relative proportion of each constituent are controlled by the types of minerals composing the rocks and soils with which the water comes in contact. Water direct from the atmosphere contains only small amounts of minerals, principally dissolved gases and a little dust. Consequently, water from perennial streams, particularly in regions of high rainfall, is generally less concentrated than ground water. The greater the distance water moves underground, and the longer it stays underground, the greater is the opportunity to dissolve minerals from the rocks.

Being in an area of extremely high rainfall, both the stream waters and ground waters on the Smith River plain are of low mineral concentration and are excellent for irrigation and domestic use. The only natural detrimental feature of the water is the high content of iron, found locally. Several wells in and around Crescent City have a high nitrate content. This may indicate sewage contamination, for nitrate is commonly an end product of the decomposition of organic matter. The chloride content of water contaminated by sewage also is somewhat higher than that of uncontaminated water from the same aquifer.

One of the notable contrasts between the ground water of this area and the water of most of California is the low pH values, generally ranging from 6.0 to 7.2. These low pH values are presumably due to the presence of carbonic acid from the atmosphere and vegetation and organic acids from vegetation.

Most of the waters are of the magnesium bicarbonate type. The bicarbonate ion is derived in part from carbon dioxide gas from the atmosphere dissolved in rain water. However, in general, the largest amount is from the carbon dioxide gas released by decomposition of vegetative matter. The principal source of the magnesium is the ferromagnesian minerals of the Jurassic rocks, especially serpentine.

EXPRESSION AND ILLUSTRATION OF CHEMICAL ANALYSES

Chemical analyses of waters are quantitatively expressed as parts per million (ppm), equivalents per million (epm), and percentage of reacting value. The chemical analyses of ground water of the Smith River plain area are given in the table on p. 66 and the surface-water analyses in the table on page 70. One part per million equals one part, by weight, of the constituent to one million parts by weight of water. The unit "equivalent per million" is defined as one equivalent weight of an ion or compound in one million weights of solution. The equivalent weight of an element or a compound is that quantity that will exactly react with another element or compound. The third, and in some ways most useful, method of expressing the chemical analyses is the percentage reacting value of the cations (basic ions) and anions (acidic ions). This value is the ratio of the equivalents per million of the individual cation or anion to the sum of the equivalents per million of the cations or anions, respectively.

In plate 7, circular diagrams representing chemical analyses have been superimposed on the geologic base map. The area of each circle is proportionate to the concentration, expressed in total parts per million of cations and anions. Each separate wedge represents the percentage reacting value of each constituent, the cations being on the left side and the anions on the right side.

The water-analysis diagram (fig. 10) used in this report was developed by Piper (1945) and has been used extensively in geochemical studies. The diagram contains three fields for plotting: (1) a diamond-shaped field; with (2) a triangular field on the lower left in which percentage reacting values of the cations are plotted; and (3) a triangular field on the lower right in which percentage reacting values of the anions are plotted. Therefore, a point in each of the two triangles indicates the relative percentages of the several dissolved constituents. The central diamond-shaped field is used to show the overall chemical character of the water by a third single-point plotting, which is at the intersection of lines projected from the plottings of cations and anions.

Analyses of ground and surface waters in the Smith River plain have been plotted in figure 10. In general, this diagram shows a grouping of the water samples from each formation, illustrating the influence of geology on the chemical character of the water. The relation of geology to water quality is discussed in the sections that follow. Waters from Lake Earl and the Pacific Ocean plot near the right margin, in the area characteristic of brines and sea water.

The specific conductance furnishes an approximation of the total mineral content, although it does not give any indication of the relative quantities of the different constituents in solution. The relation of specific conductance to the sum of the determined ionized constituents (calcium, magnesium, sodium, potassium, carbonate, bicarbonate, sulfate, chloride, and fluoride) is shown in figure 11.

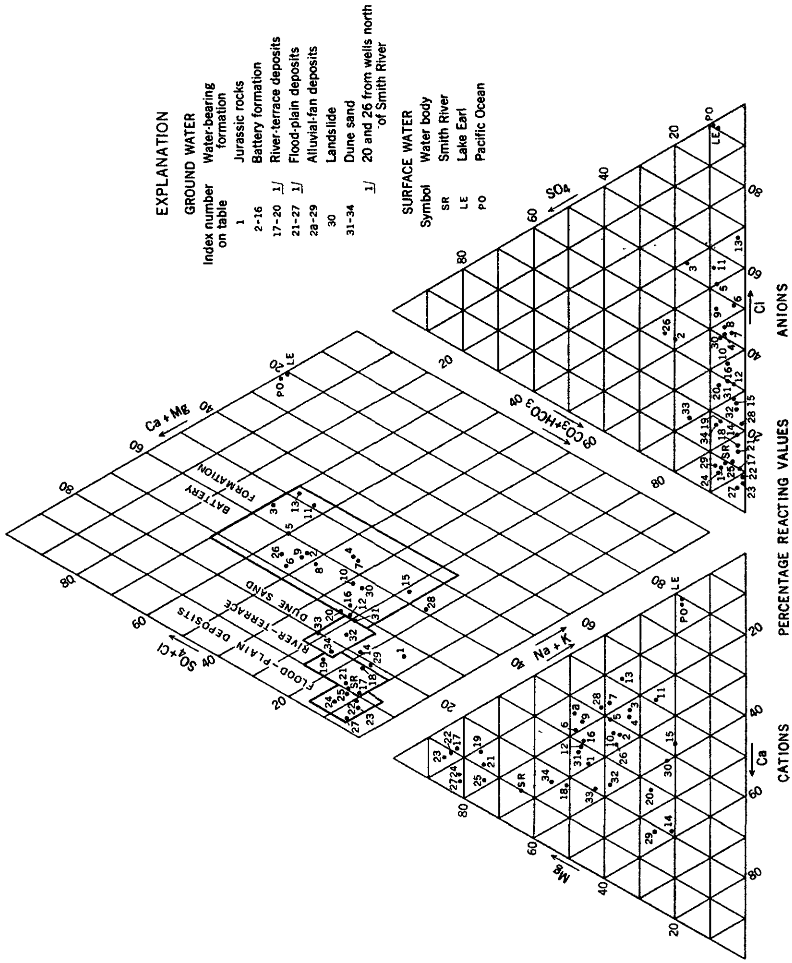


FIGURE 10.—Water-analysis diagram.

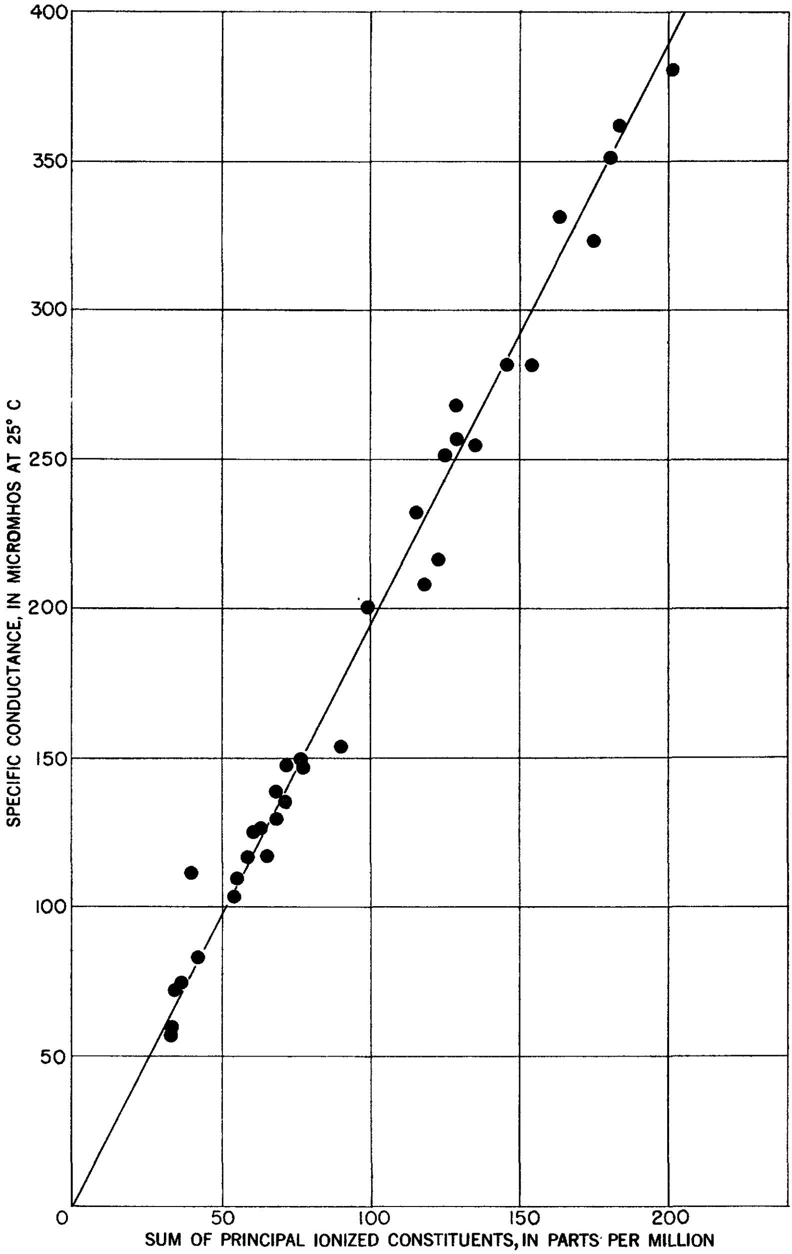


FIGURE 11.—Relation of specific conductance to the sum of the principal ionized constituents.

The mean curve is shown on the plot of 34 analyses of ground water. The sum of the ionized constituents as used on the illustration is less than the sum of dissolved solids (table on p. 66) because it does not include silica, iron, and other minor constituents.

For most ground water beneath the Smith River plain, the curve shown in figure 11 can be used with reasonably accurate results to estimate the sum of principal ionized constituents from the measured specific conductance. The curve can be expressed approximately by the formula:

$$S=0.52\ (K\times 10^6)$$

where S=sum of ionized constituents in parts per million; $K\times 10^6$= specific conductance in micromhos at 25° C.

CHEMICAL QUALITY OF SURFACE WATER

Surface water of this area has a far greater range in total concentration than the ground water. Smith River water often contains less than 50 ppm of dissolved solids, and Lake Earl water contains in excess of 6,800 ppm (pl. 7 and table on p. 70).

The water sample from Lake Earl was collected at the eastern shoreline. Presumably the deepest part of the lake may have water of higher concentration. Therefore, the analysis probably represents the least concentrated water present in the lake at the time of collection. During periods when floodwater enters the lake, the concentration of dissolved solids may be appreciably less.

Lake Earl contains sodium chloride water of nearly the same relative percentage of constituents as sea water, but of less concentration; consequently, in figure 10 it plots at nearly the same point as sea water.

The change in quality of Smith River water compared to the variation in the amount of discharge is shown in figure 12. The flow plotted for the river was measured at the time of collection of the monthly water samples. During periods of low flow the water is slightly more concentrated than during high flow. In 1953 the specific conductance ranged from about 80 micromhos during winter flows to nearly 140 micromhos during the summer low flow of less than 400 cfs.

Analyses represented by the bar diagrams in the top part of figure 12 indicate that during both high flow (analysis for January) and low flow (analysis for August) the water of the Smith River is of the magnesium bicarbonate type and of low concentration. As would be expected, the Smith River water groups with the water from Recent alluvium in figure 10.

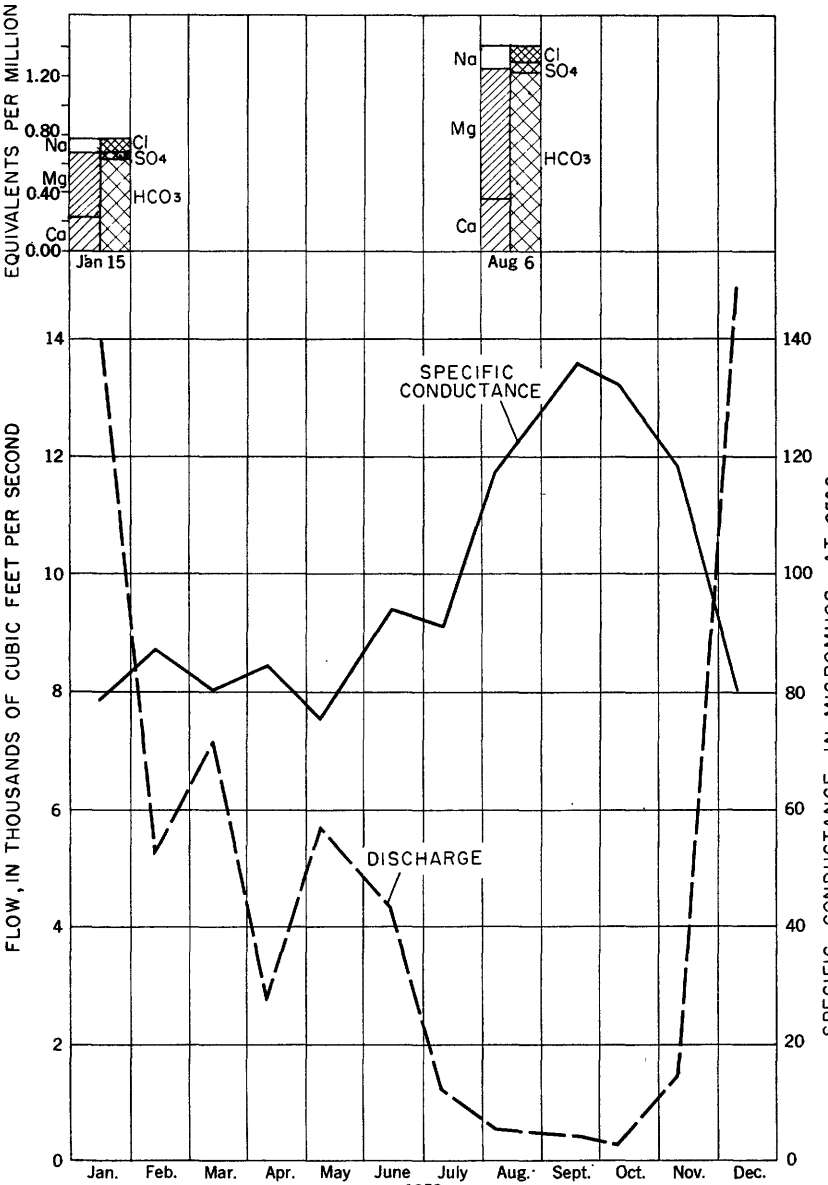


FIGURE 12.—Relation of specific conductance of Smith River water to discharge.

RELATION OF CHARACTER OF WATER TO GEOLOGY

In general, types of water and the concentration of dissolved solids relate to the geologic formations in which the water occurs or through which it has moved. Inasmuch as the aquifers beneath the Smith River plain are shallow, the water types are practically coexistent with the areal distribution of the formations, and the differences in the quality of water are not due to vertical change in the quality of water in any one formation. Therefore, the analyses represented on the geochemical map (pl. 7) indicate the concentration and kind of soluble minerals in the waters of each aquifer throughout its penetrated thickness at that particular location.

Waters north of the Smith River are distinctly different from the waters immediately south of the river, particularly in concentration and calcium-magnesium ratio (pl. 7). These northern waters from the Rowdy Creek drainage have very low concentrations and a relatively high calcium-magnesium ratio. The explanation of this difference is that drainage from Rowdy Creek does not come in contact with a serpentine exposure (Salem Rice, oral communication, December 1953). The sheared and fractured serpentine is relatively soluble to slightly acid waters, and magnesium is readily taken into solution.

The three analyses available for waters from the drainage basin of Rowdy Creek, irrespective of their aquifers, show a marked similarity to one another and to waters from the Battery formation (fig. 10). A minor difference is that these northern waters have a higher percentage of calcium. One analysis, 17/1W–27F1, is for water from the flood-plain deposits; another, 17/1W–35G1, is for water from the terrace deposits; and the third, 17/1W–36D1, is for water from the landslide and alluvial-fan deposits.

The water-analysis diagram (fig. 10) shows the general similarities and differences of the waters from one aquifer to another. Analyses are grouped in figure 10 as waters from flood-plain deposits, river-terrace deposits, dune-sand deposits, and the Battery formation (marine-terrace deposits). Analyses of waters from alluvial fans show a diversity of waters. Also, the analyses from wells in the flood-plain and terrace deposits at Rowdy Creek show a marked difference from the analyses of water from the flood-plain and terrace deposits of the Smith River.

Except for about half of the analyses from the Battery formation, all waters plot in the left quadrant of the diagram, which indicates that carbonate hardness exceeds 50 percent; that is, the chemical properties of the water are dominated by the alkaline earths (calcium, magnesium) and anions of weak acids—in this area, the bicarbonate ion.

Five of the remaining analyses for the Battery formation (wells 15/1W–2D1, 16/2W–13E1–2, 16/1W–9H1, 15C1, 20Q1) plot in that part of the diamond-shaped diagram in which no one cation-anion pair exceeds 50 percent; that is, the percentage reacting values of sodium, magnesium, and calcium are nearly equal to one another, and no one anion exceeds 50 percent.

Two analyses (index nos. 11 and 13) plot in the portion of the diagram which indicates that noncarbonate alkali exceeds 50 percent; that is, the chemical properties are dominated by the alkali metal sodium and anions of strong acids—here, the chloride and nitrate ions. The high chloride and nitrate content in these two wells possibly results from contamination by surface seepage.

Figure 10 shows that, of the four geologic classifications of water, the waters of the flood-plain deposit have the highest percentage reacting values of calcium, magnesium, and bicarbonate. The percentage reacting values of calcium and magnesium together in the flood-plain waters range from 88 to 98 percent. These values decrease through the river-terrace waters (82 to 90 percent) and sand-dune waters (70 to 84 percent) to the lowest value for waters of the Battery formation (48 to 72 percent). Ranges overlap for percentage reacting value of bicarbonate for the four subdivisions of the geologic classification, but the units are in the same order. Flood-plain analyses have the highest proportion of bicarbonate, 82 to 94 percent; river-terrace analyses, 74 to 90 percent; sand-dune analyses, 68 to 76 percent; and the Battery formation, 30 to 72 percent.

JURASSIC ROCKS

The only well on the Smith River plain that obtains water from the consolidated Jurassic rocks is well 17/1W–14C1, at the Redwood Union School. Water from this well, moderately hard, is of the magnesium bicarbonate type; it has a dissolved-solid concentration of 175 ppm, relatively high for the Smith River plain area.

BATTERY FORMATION

The fine-grained marine deposits of the Battery formation have the most diverse water types of all the aquifers on the Smith River coastal plain. Bicarbonate water of low concentration is the most common, magnesium and sodium being the predominant cations. One analysis (16/1W–26E1) shows bicarbonate water of high calcium content, and several analyses show nearly equal amounts of the cations. Sodium chloride water is not uncommon in the Battery formation.

In general, the waters of higher concentration of dissolved solids in the Battery formation are near the sand dunes or alluvial fans. Waters near the center of the marine terrace tend to have the lowest concentration of dissolved solids of any waters on the Smith River plain. The relatively higher concentrations near the dunes and fans are probably due to the freshness of the fragments of minerals in these deposits, which are weathering now. Soluble minerals of the marine-terrace deposits were dissolved and removed at an early time, and only the more stable weathered products now remain. The low concentration of dissolved solids in the water, therefore, is due to dilution by precipitation and lack of addition of mineral matter. Waters range in hardness from soft to moderately hard.

RIVER-TERRACE DEPOSITS

The three analyses of water from terrace deposits of the Smith River (pl. 7), 16/1E–9K1, 17/1W–14F1, and 15E1, show a magnesium bicarbonate water low in sodium. Water from the Fort Dick terrace is soft to slightly hard. Water in the terrace deposits in Hiouchi Valley is moderately hard.

FLOOD-PLAIN DEPOSITS

Waters from the flood-plain deposits south of the Smith River are of the bicarbonate type and have the highest percentage of magnesium of any water on the Smith River plain. These waters are slightly to moderately hard. The water of the highest concentration of dissolved solids is in the reaches farthest downstream (pl. 7). This water has been in contact with the sediments for a longer period of time and has taken into solution a greater amount of minerals. Wells 17/1W–4L1 and L2 are also being recharged by mineralized water from the dune area immediately to the west. Iron content in the water from these two wells is high, 6.5 and 9.7 ppm, respectively. Sodium content of the water in the flood-plain deposits is very low, owing to the flushing and diluting action of the large amounts of Smith River water that recharge this area and remove the cyclic salts from these very permeable sediments.

DUNE SAND

All four analyses of water from the sand-dune area (pl. 7) are nearly identical to one another in percentages of the constituents. However, water from the northern well (17/1W–20P1) and the southern well (16/1W–7F1) contains more than twice as much dissolved solids as water from wells 17/1W–32M1 and 16/1W–5L1. Water from the four wells has been in contact with the same kind of minerals in the dune sediments. A possible explanation for the different concentrations of dissolved solids may be that the wind blows unweathered minerals from the beach to the recharge area of wells 17/1W–20P1 and 16/1W–7F1, thereby furnishing a constant source of soluble minerals to these two wells. Also, salt spray is carried inland and deposited in the soil, forming an additional source of mineral matter. Lake Talawa, on the windward side of wells 32M1 and 5L1 (pl. 7), may prevent any new minerals or salt spray from being deposited in the recharge area of these two wells.

Water of higher dissolved-solids concentration in the sand dunes is of the calcium magnesium bicarbonate type and is moderately hard. Water of lower concentration of dissolved solids is of magnesium bicarbonate type and is soft.

RECORDS

The first of the following tables (p. 58) contains descriptive data on the water wells that were located and identified in the field. Included are most irrigation, industrial, and public-supply wells, and also many domestic and stock wells for which logs, chemical analyses, or water-level measurements were available.

The second table (p. 64) contains water-level measurements for selected wells in the Smith River plain area.

The third table (p. 66) contains analyses of ground water from wells in the Smith River plain. Water samples dated prior to July 1953 were collected by the Division of Water Resources, State of California Department of Public Works; all others were collected by the Geological Survey. The chemical analyses were made by the Geological Survey.

Analyses are listed by aquifers and are arranged in geographical order on the basis of the well-numbering system. Most of these analyses are shown diagrammatically in plate 7, and all are plotted on the water-analysis diagram, figure 10.

The fourth table (p. 70) contains chemical analyses of surface water on the Smith River plain. These data consist of one analysis of Lake Earl water; one analysis of water from the unnamed tributary of Elk Creek, from which Crescent City obtains part of its water supply; and analyses from the Smith River.

Smith River analyses, arranged chronologically, are the results for samples collected at the Geological Survey gaging station by personnel of the Division of Water Resources in connection with the State monthly stream-sampling program.

All surface water samples included in this table were collected by the Division of Water Resources. The complete analyses were made by the Geological Survey; the partial analyses were made by the Division of Water Resources.

Records of wells

Well no.: See p. 6 for description of well-numbering system.
Depth of well: Depth was obtained from the well owner or the driller's log.
Type of well: D, dug; P, percussion or cable tool; R, rotary; Sp, sand point; A, auger.
Stratigraphic unit: The symbols in this column are the same as those used on the geologic map, plate 5, and they refer to the stratigraphic unit or units from which the well obtains all or most of its water.
Measuring point: Tc, top of casing; Tcc, top of concrete curb; Tb, top of boards; Tp, top of pipe; Tcr, top of concrete rings; Ls, land surface, top of hole with no casing.
Type of pump: J, jet; L, lift; T, turbine; P, pitcher; W, windmill; C, centrifugal.
Use: D, domestic; I, irrigation; S, stock, T, test hole; PS, public supply; Ind., industrial supply; U, unused well; A, abandoned well; F, fire protection.
Other data available: C, chemical analysis; L, driller's log; W, miscellaneous water-level measurements. All are in files of the Geological Survey.
Discharge, drawdown: The discharge, in gallons per minute, and the drawdown, in feet, are listed as reported by the owner or well driller or as estimated from field data.

Well no.	Owner or user	Year completed	Altitude of land-surface datum (feet)	Depth of well (feet)	Type of well and diameter (dug wells, feet; other, inches)	Stratigraphic unit (pl. 5)	Measuring point and distance above or below (—) land-surface datum (feet)	Water level: Date measured	Water level: Depth below land-surface datum (feet)	Type of pump and horsepower	Use	Other data available	Discharge (gpm) / Drawdown (ft)
15/1W- 2D1	T. F. McNamara	1951	23	30	P,12	Qb, Qfu	Tc 0.0	July 17, 1953	[1] 22.90	T,15	I	C,L	50/4
										C,2	D		300/11
16/2W-13E1	U. S. Coast Guard		56	30	D,4	Qb	Tcc .0	Sept. 3, 1953	13.95	J,1	D	C	
13E2	do		54	30	D,4	Qb	Tcc .0	do	10.65	J,1	D	C	
24A1	Garth McNamara	1952	45	31	P,6	Qb				C,¼	D	L	8/6
16/1W- 1D1	Verle Coalson	1952	160	56	P,6	Qaf				C,½	D	L	
2D1	A. G. Rosa	1915	54	20	D,7	Qb	Tb .0	July 27, 1953	8.86	C,½	D	L	
2J1	Edward C. Johnson	1953	127	36	P,6	Qaf		July 6, 1953	16.70	J,¾	D	L,C,W	
2J2	Ed. Lesina		131	43	P,6	Qaf	Tc .0	do	20.40	J,½	D		
2K1	Ben Lesina	1952	69		P,6	Qb	Tc 1.0	do	2.82	C,⅓	D		
2M1	K. P. Cunningham		55	32	P,6	Qb	Tc .0	do	10.37	J,½	D	C	
2Q1	J. H. Hill	1952	100	30	P,6	Qaf					D	L	
2R1	Redwood View Court	1952	116	35	P,8	Qaf	Tb .0	July 19, 1953	14.12	C	D	L	
3B1	Annie M. Nelson		32	28	D,4	Qb	Tb .5	May 27, 1952	17.9	C,¼	D		
3G1	J. Little	1952	33	34	P,6	Qb				C,½	D	L	
3H1	Ocean Drive-in Theater	1951	45	37	P,6	Qb	Tc .0	July 2, 1953	17.60	C,½	D		
3N1	Broadfoot & Sweeney	1953	24	30	P,6	Qb	Tcc .0	July 18, 1953	9.76	C,¼	D	L	30/3
3N2	W. C. Gilcrest	1953	27	28	P,6	Qb				T,1	D	L	
16/1W- 3N3	H. Sweeney	1953	25	32	P,6	Qb				J,¼	D	L	
3P1	Ray Miller	1951	32	30	P,8	Qb	Tc 0.0	July 18, 1953	18.50	C,1	D	L	
4J1	Henry J. Post	1951	15	28	P,8	Qb	Tc .0	do	10.30	L,¼	D	L	
5L1	Ed. Cadra	1910	13	12	D,2.5	Qd	Tcr 3.0	do	8.60	C	D	C	
7A1	Elmer Hight	1953	33	10	D,4	Qd	Tb .0	do	10	Not completed		L	
7F1	Lawrence Cadra	Old		15	D,4	Qd	Tcc .0	Dec. 2, 1955	6.05	C,⅓	D	C,L	
8M1	Wm. Stewart	1951	14		P,8	Qb	Tc 1.0	June 1, 1955	[2] 8.3				

								Aug. 25, 1955	[2] 10.6				
								July 26, 1953	3.40	J,1/4	D	...	...
8Q1	Ralph Galliher	1953	29	...	A,6	Qb	Tb .0	July 25, 1953	10.81	C,1/3	D	...	...
9G1	George Endert	1953	26	32	P,6	Qb	...	...	...	...	D	L	...
9H1	Nat S. Allen	(3)	32	...	D,4	Qb	Tc 2.0	May 27, 1952	10.0	J,1/2	D	C	...
								July 2, 1953	9.08				
								June 1, 1955	[2] 9.7				
								Aug. 25, 1955	[2] 11.6				
9N1	Zimmerman	1952	36	25	P,6	Qb	Tc .0	July 18, 1953	8.00	C,1/2	D	L	...
10B1	Bar K Ranch	...	38	...	D,2.5	Qb	Tb .0	do.	16.3	C,1/2	D,S	...	...
10D1	Lula Sargent	1924	34	20	D,4	Qb	Tb .0	July 2, 1953	10.67	J,1/3	D	...	...
10L1	Wendel Moore	1888	44	18	D,6	Qb	Tb 1.0	do.	6.92	J,1/3	D	...	...
10R1	Frank Love	1953	45	20	D,4	Qb	Tb 1.0	July 4, 1953	4.10	New	D	...	...
11B1	F. K. Scholl	1951	99	23	...	Qb	Tc 2.0	July 18, 1953	8.70	L	D	L	...
11B2	Lyle Riddle	1951	83	21	P,6	Qb	Tc .0	July 4, 1953	7.03	C,3/4	D	L	...
16/1W-11B3	E. M. Weaver	1952	90	30	P,6	Qb	...	...	Dry	...	U	L	...
11F1	Lloyd Trickey	1952	75	30	P,6	Qb	...	...	...	C,1/2	D	L	...
11F2	do.	1952	75	30	P,6	Qb	...	...	Dry	...	U	L	...
11G1	Lawrence Oliver	1952	90	20	P,6	Qaf	Tcc 0.0	July 19, 1953	3.50	C,1/4	D	L	40/4
11G2	J. Pozzi	1951	92	35	P,8	Qaf	Tc .0	do.	5.38	C,1/4	D	L	...
11G3	J. K. Cooke	1952	83	23	P,8	Qb	...	...	...	...	U	L	...
11K1	N. Huffman	1940	81	13	D,4	Qaf	Tb .0	July 6, 1953	7.70	C,1	D	...	...
15C1	L. L. Early	1952	39	27	P,6	Qb	Tc 1.0	July 4, 1953	10.35	C,1/3	D	C	...
16J1	J. C. Mather	...	44	20	D,5	Qb	Tb .0	do.	9.64	J,1/2	D	...	...
16R1	F. H. Borath	...	31	...	D,5	Qb	Tcc 1.0	do.	7.40	C,1/4	D	...	...
17A1	Arthur Kelly	...	37	21	D,5	Qb	Tcr 3.0	July 2, 1953	8.7	J,1/2	D	...	...
17A2	Pine Grove School	...	33	20	D,4	Qb	Tcr 2.0	July 23, 1953	7.73	C,1	D	C	...
17G1	W. C. Johnston	1951	50	40	P,6	Qb	...	...	...	...	U	L	...
17H1	R. A. Elledge	1952	44	36	P,12	Qb	Tcc .0	July 20, 1953	[1] 22.29	C,3/4	D	L	50/4
17J1	W. H. McCarger	1952	41	40	P,6	Qb	...	...	...	...	D	L	...
17K1	Dan Berquist	1953	48	40	P,6	Qb	Tc 1.0	do.	16.10	...	U	L,W	...
17P1	Crescent City Water Co.	1953	...	60	...	Qb	...	...	...	...	T	L	...
16/1W-17Q1	Norman Mathews	1944	...	30	D,5	Qb	...	...	...	...	D	...	...
18F1	Sunset Logging Co.	1952	54	35	P,8	Qb	Tcc 1.0	July 28, 1953	13.84	P	D	C,L	10/5
20E1	Marvin Crank	1952	50	39	P,6	Qb	...	...	...	J,1/4	D	L	10/3
20H1	George Jacobs Co.	1952	32	42	P,6	Qb	Tc .0	July 2, 1953	3.56	J,1/2	D	L,W	30/8
20H2	Ole Hellekson	1952	40	28	P,6	Qb	...	...	...	...	D	L	...
20H3	Meadows Plymouth Agency.	1951	37	30	P,6	Qb	Tc 1.0	July 21, 1953	8.75	C,1/2	D	L	10/2
20J1	Crescent City Water Co.	...	...	24	D,8	Qb	...	...	...	...	PS	...	50/?
20P1	John Aguire	1952	50	30	P,6	Qb	...	...	...	...	D	L	25/4
20Q1	Crescent City Water Co.	...	...	30	D,20	Qb	...	...	...	...	PS	C	...
21D1	do.	1953	...	250	...	Qb	...	...	...	...	T	L	...
21E1	R. H. Hichens	1953	36	31	A,5	Qb	Tc .0	July 28, 1953	17.10	J,1/4	D	L	...
21E2	Johnson Paradise Cafe	...	29	30	P,6	Qb	Tc .0	May 26, 1952	11.8	J,1/2	D	...	...
								July 28, 1953	11.50				
21F1	Jack Lees	1952	28	35	P,6	Qb	Tc .0	do.	14.20	J,1/2	D	L	15/10
21K1	Moore	1952	20	70	P	Qb	Ls .0	July 21, 1953	8.42	...	T	L	...
21M1	Del Norte Infirmary	...	19	...	D,4	Qb	Tcr. 0	May 1, 1953	2.0	C,1 1/2	D	C	...
								July 29, 1953	6.74				
22J1	Harold Nelson	1950	58	32	D,5	Qb	Tb .0	July 6, 1953	13.92	J,1/4	D	...	...

See footnotes at end of table.

Records of wells—Continued

Well no.	Owner or user	Year completed	Altitude of land-surface datum (feet)	Depth of well (feet)	Type of well and diameter (dug wells, feet; other, inches)	Stratigraphic unit (pl. 5)	Measuring point and distance above or below (—) land-surface datum (feet)	Water level: Date measured	Water level: Depth below land-surface datum (feet)	Type of pump and horsepower	Use	Other data available	Discharge (gpm) / Drawdown (ft)
16/1W-22Q1	Frank Patton		39	22	D,5	Qb	Tb 0.0	May 26, 1952	11.7	C,2¾	D	C,W	
23D1	Joe Nunes	1935	62		D,6	Qb	Tb 2.0	July 6, 1953	17.70	J,½	D,S	C	
26D1	H. C. Keikland		63	17	D,5	Qb	Tb .0	Apr. 30, 1955	7.5	C,⅓	D	C	
								July 5, 1953	9.87				
26E1	J. C. Buchanan		40	18	D,4	Qb	Tcr 1.0	May 26, 1952	2.8	J,½	D	C	
								July 28, 1953	10.60				
26L1	Maud Parson	1947	123	52	P,6	Qaf	Tcc .0	do.	10.52	J,¼	D		
26M1	O. E. Holloway	1952	59	35	P,6	Qb	Tb .0	July 21, 1953	23.27	J,¼	D	L	
26M2	B. Swanson	1951	60	39	P,6	Qb				C,½	D	L	
26M3	Crescent City Water Co.	1953		20		Qb					T	L	
26M4	do.	1953		20		Qb					T	L	
26N1	H. D. McClane		23	18	D,4	Qb	Tcr .0	July 28, 1953	8.25	C	D	C	
26N2	C. V. Burtis		31	16	D,6	Qaf	Tcr .5	May 26, 1953	0.6	C,½	D		
								July 28, 1953	7.40				
26P1	Tracy Smith	1952	44	26	P,6	Qaf	Tc .0	July 21, 1953	7.02	P	D,U	L	
27A1	C. E. Gable	1953	54	45	P,8	Qb				C,½	D	L	
27B1	O. T. Bevis		38	27	D,4	Qb	Tb .0	July 5, 1953	[1] 13.65	C,⅓	D		
								do.	10.25				
27B2	James Lees	1953	40	36	P,6	Qb	Tc .0	July 21, 1953	13.30	J,¼	D	L	30/6
16/1W-27C1	Castle Mills		31		D,4	Qb	Tcr 0.0	July 28, 1953	8.34	J,1	Ind.		
27C2	do.		31	500	R,12	Qb,Tsg(?)Ju			Dry		U	L	
28G1	Ross Howard	1953	15	24	P,6	Qb	Tcc .0	do.	7.42	J,½	D	L	20/6
29H1	Ralph E. White			18	D,4	Qb	Tcr 1.0	May 26, 1952	7.9	C,½	D		
								July 28, 1953	7.60				
34G1	G. C. Harmer		8		D,4	Qb	Tb 1.0	May 26, 1952	4.8	C	D		
								July 17, 1953	7.35				
35P1	Crescent City Water Co.	1953		40		Qb,Ju					T	L	
16/1E-4M1	Ed. Lesley	1951		40	P,6	Qt	Tcr .0	July 26, 1953	25.3	J,½	D	L	
8B1	Jedediah Smith State Park	1951		34	R,12	Qt		June 16, 1951	13		PS	L	50/?
8H1	H. B. Wilkinson	1952		30	P,6	Qt					U	L	35/?
9K1	James Jamison	1952		47	P,6	Qt	Tc .0	July 30, 1953	36.00	J,¾	D	C,L	15/2
10N1	Charles Selig	1953		30	A,4	Qt	Ls	do.	26.4	P	T	W	
17/1W-1M1	Joe Rose	1952	135	60	P,12	Qaf,Qt			Dry	T,15	I,U	L	
1P1	Conner Bros.	1952	150	50	P,8	Qaf	Tc .0	July 20, 1953	7.60	T,¾	D,S	L	5/10
2G1	Evo Mello			50	P,12	Qfu				T,30	I,S		

17/1W-2L1	U. L. Rich		29		D,4	Qfu	Tb .0	Sept. 19, 1953	19.90	J,½	D		
2L2	Parks		26		D,5	Qfu	Tb 2.0	do	16 88	None	U		
2M1	Wm. Buckner		26	30	P,6	Qfu	Tc 3.0	July 7, 1953	17.76	J,½	D		
2P1	Homer Martin		31	27	P,8	Qfu	Tb .0	May 28, 1952	19.2	J,¼	D	C	
								July 3, 1953	18.60				
								Sept 19, 1953	21.93				
2R1	L. A. Ulrich			54	D,6 P,12	Qfu				C,20	I		
3C1	Tedson Bros	1953	15	25	P,12	Qfu	Tc 2.0	Sept 18, 1953	7.35	C,25	I	L	
3E1	Jepsen-Tedson	1950	20	25	P,8	Qfu	Tc .0	July 8, 1953	12.12	C,¾	D,S		
								June 1, 1955	[2] 12.6				
								Aug. 25, 1955	[2] 14.7				
3J1	R. H. Emerson		24		D,2	Qfu	Tcr 2.0	July 7, 1953	15.10	C,¾	D,S		
4L1	Manuel Silva	1950	12	33	P,12	Qfu	Tc .0	July 8, 1953	6.50	C,20	I	C	
4L2	do	1953	12	19	P,8	Qfu	Tc .0	do	8.39	C,1	D	C	
9B1	Grace Drew		12		P,6	Qfu	Tc .0	May 28, 1952	4.6	W	S		
								July 30, 1953	6.07				
9G1	do	1952	12	21	P,6	Qfu					U	L	
9H1	Marlin Tryon		15	30	D,3	Qfu	Tc 3.0	July 7, 1953	6.90	W	S		
9H2	do	1952	15	22	P,12	Qfu				C,3	F	L	
9J1	F. L. Mauzey	1949	17	31	P,12	Qt	Tc .0	July 8, 1953	9.48	C,15	I		250
								Sept. 17, 1953	10.32				
9K1	do		13	13	D,3	Qfu	Tcr 1.0	July 8, 1953	7.53	C,1	D		
10G1	Alvin Henry		27	50	P,8	Qt	Tc .0	July 20, 1953	19.00	J,¾	D		
11A1	L. H. Simonson	1952	34	36	P,8	Qfu	Tc .0	July 3, 1953	13.47	J,1	D		
17/1W-11B1	Harvey Zoon	1950	34	33	P,6	Qfu				J,1	D		12–15
11B2	L. H. Simonson	1952	34	327	P,6	Qfu,ju	Tc .0	July 3, 1953	12.67		U		
11E1	Pressly Tryon	1945		16	D,20 by 30	Qfu				C,25	I		
11F1	do	Old	32		D	Qfu	Tb .0	July 23, 1953	18.30			C	
								Sept. 19, 1953	19.00				
11G1	Joe Paradise		33	30	P,6	Qfu	Tc .0	July 17, 1953	17.55		D		
11J1	O. E. McNutt	1950	31	30	D,4	Qfu	Tcr 1.0	July 3, 1953	19.02	J,1	D		
11L1	Murray Tryon	1940	32		P,6	Qfu	Tcc .0	July 2, 1953	13.55	C,½	D,S		
								Sept. 19, 1953	[1] 15.88				
12C1	Glen Spencer	1952	140	35	P	Qaf			Dry		U	L	
12P1	Ronel Bolen		41		D,4	Qfu	Tb 1.0	July 27, 1953	21.86	T,1½	D		
13B1	do				D,5	Qfu	Tb .0	Nov. 28, 1953	21.10	C,¼	S		
13G1	Alice Henry		44		P,6	Qfu	Tc .0	July 27, 1953	22.75	J,½	D	C	
13R1	Norman Case	1953	52	40	P,6	Qfu	Tc .0	do	24.50		D	L	
14C1	Redwood School	1950		215	P,6	Ju,Qt					D	C	5
14F1	Walt Kindel	Old	45	36	D,4	Qt	Tb 1.0	May 28, 1952	21.2	J,½	D	C	
								July 23, 1953	18.25				
								Sept. 19, 1953	26.87				
14F2	Fort Dick Community Church.	1953	45	40	P,6	Qt					D	L	50/3
17/1W-14J1			74		D,4	Qb	Tc 0.0	July 6, 1953	9.22	½	D		
14L1	Jay Coggins	1951	50	20	P,6	Qt	Tc .0	May 28, 1952	15.8	J	D	L	
14L2	Stapleton	1952	45	17	P,12	Qt					D	L	20/4

See footnotes at end of table.

Records of wells—Continued

Well no.	Owner or user	Year completed	Altitude of land-surface datum (feet)	Depth of well (feet)	Type of well and diameter (dug wells, feet; other, inches)	Stratigraphic unit (pl. 5)	Measuring point and distance above or below (—) land-surface datum (feet)	Water level: Date measured	Water level: Depth below land-surface datum (feet)	Type of pump and horsepower	Use	Other data available	Discharge (gpm) / Drawdown (ft)
17/1W-14L3	Jay Coggins	1953	50	37	P,6	Qt	Tc .0	July 2, 1953	14.70	J,½	D	L	15/?
								Sept. 19, 1953	22.67				
15E1	Paul Johnson	1941	20	18	D,4	Qt	Tb 1.0	July 2, 1953	10.15	C,1	D	C	
15E2	do		19	50	D,6	Qt	Tc 12.0	do	13.50	C,15	I		
					P,12			Sept. 18, 1953	16.61				
15K1	W. E. Hopper	1952	26	20	D,5	Qt	Tc .0	July 2, 1953	11.38	J,⅓	D		
15M1	Ottinger	1952	21	23	P,6	Qt				L,¼	D	L	30/2
15M2	Pressly Tryon		21	30	P,6	Qt	Tc .0	July 25, 1953	13.30		U	W	
16C1	Roy Tryon		14	21	D,4	Qt	Tb .0	July 8, 1953	9.38	C,¼	D		
16G1	W. A. Mitchell	1951	11	11	D,3	Qfu	Tb .0	July 7, 1953	6.10		D		
16L1	Layton	Old	10	12	D,4	Qfu	Tb 1.0	July 2, 1953	6.34	L,1½	D,S		
17Q1	H. A. Kortie	Old	17		D,3	Qd	Tb .0	July 8, 1953	3.30	W	S		
20P1	do	1920		18	SP	Qd				C,1	D	C	
21B1	C. B. Crossley	1948	12		D,4	Qt	Tb .0	July 7, 1953	6.86	C	D		
21H1	Gene Tison	1951	19	18	D,5	Qfu	Tcc.0	do	13.22	C,½	D		
17/1W-22E1	George Price	1952	50	50	D,4	Qb	Tb 1.0	July 2, 1953	22.70	L	D		
22E2	L. L. Wheeler	1952	35	40	P,6	Qb				J,½	D	L	
22E3	Frackers	1951	35	40	P,6	Qb				J,¼	D	L	
22E4	Hubert O. Cole	1950	35	45	P,6	Qb				J,½	D	L	
22Q1	Anna Cantlon	1945	56	18	D,7	Qb	Tb 2.0	July 29, 1953	12.65	L	D		
23A1	V. R. Swanson		109	25	P,6	Qb	Tb 2.0	July 6, 1953	7.12	C,¼	D		
23J1	F. G. Riley	1951	121	13	D,4	Qb	Tb .0	do	6.65	C,½	S		
23N1	Ethel Arnett	1953	75	25	P,6	Qb	Tc .0	July 29, 1953	10.17	C,¼	D		
24B1	Dan Boraggie	1953	68	20	D,5	Qt	Tb .0	July 27, 1953	12.73		D	L	
24J1	Bertha Edlund	1950	65	22	P,6	Qt		July 1953	14	J,½	D		
26R1	O. B. Herrick		140	24	D,4	Qaf	Tcc 2.0	July 27, 1953	13.73	J,¼	D	C,L	
27E1	Wm. C. McKay	1946	51	28	D,5	Qb	Tb .0	July 7, 1953	23.45	J,⅓	D	L	
27F1	Lionel Borough	1945	39	19	D,16	Qb	Tb .0	do	2.51	C	I	L	200/?
27Q1	B. E. Newman	1953	55	28	P,6	Qb	Tc .0	July 21, 1953	10.33	C,½	D	L	15/5
27Q2	Charles Newsome	1953	55	25	P,6	Qb	Tc .0	Sept. 21, 1953	10.13	C,¼	D	L	
32M1	Ed. McLaughlin	1874	15	12	D,5	Qd	Tb .0	July 18, 1953	4.12	C	D,S	C	
34C1	A. S. Hunter		37	25	D,5	Qb	Tb 1.0	May 27, 1952	21.0	C,½	D	C	
								July 23, 1953	21.12				
17/1W-34D1	do			10	D,50	Qb							
34J1	C. A. Munger	1952	31	24	P,6	Qb	Tc .0	July 22, 1953	6.55		D	L	
34K1	Francis Bolman	1952	30	24	P,6	Qb	Tc .0	do	8.40	J,½	D	L	
34K2	C. L. Krettinger	1952	28	24	P,6	Qb	Tc .0	do	8.12	J,½	D	L	
34K3	Hennebeck	1951	30	22	P,6	Qb	Tc .0	May 28, 1952	8.1	C,½	D	L	
								July 23, 1953	8.49				
34K4	Wm. Bregers	1953	30	25	P,8	Qb				C,½	D	L	
35F1	Hennebeck		67		D,5	Qb	Tcc 1.0	July 27, 1953	10.35	P	D		

35N1	T. Haun	1952	55	20	P,8	Qb				C,1	D	L	
36M1	Finley		190		D,5	Qaf	Tb .0	do.	8.12	C,¼	D		
17/1E-31R1	Tom Peacock	1952	60	30	P,8	Qfa		Sept. 1952	Dry		D	L	
18/1W- 8G1	W. L. Woodward		60	54	P,6	Qb	Tcc .0	July 24, 1953	24.2	J,½	D		
8Q1	R. E. Erickson		52	19	D,4	Qb	Tcc .0	do.	10.00	C,½	D		
8R1	Wm. Reeves	1946	112	39	P,6	Qaf	Tc 1.0	do.	22.00	C,½	D		
16N1	G. M. Bobst	1943		30	P,6	Qaf				C,¼	D,S		
17B1	Walter Richards	1952	76	40	P,6	Qb				J,½	D	L	10/4
17R1	M. J. Sierka		18	26	P,8	Qb	Tb .0	do.	7.47	D,1	D		
21D1	Bruno Brado	1952	25	23	P,8	Qfa				J,½	D	L	4/3
18/1W-22C1	C. E. Hixson	1952	150	13	D,5	Qfu	Tcr 1.0	do.	5.68		D	L	
22Q1	Valley View Court	1937	36	43	P,8	Qaf,Qfu	Tc .0	May 28, 1953	14.0	C,1	D		
22R1	Tod Westbrook	1953	75	35	P	Qaf			Dry		A	L	
23N1	Wm. Owens		67	56	P,6	Qaf				C	D	L	
26B1	Del Norte Creamery	1953	60	38	P,8	Qfu,Ju			Dry		A	L	
26D1	Arnold Samuelson	1949		38	P,8	Qt	Tc .0	May 28, 1952	20.4	J,1½	D,I		
								July 23, 1953	19.77				
26E1	Maris Dairy			38	P,8	Qt	Tb.0	Sept. 29, 1953	24.06	C,15	I		
26L1	do.			20	D,4	Qfu	Tb −7.0	do.	12.10	C,15	I		
26L2	do.			35	P,12	Qfu				C,15	I		
26P1	Merlin Goodlin	1946	38	28	P,12	Qt	Tc 1.0	May 28, 1952	8.5	C,10	I,D,S	W	
26R1	H. D. Strackbein	1950	93	41	P,8	Qt,Qaf						L	
26R2	Don Haite	1952	93	30	P,6	Qt						L	
27B1	Tod Westbrook			23	P,14	Qfu					I		
27F1	Brogan		22	35	D,3	Qfu	Tcc 1.0	May 28, 1952	7.6	C,1	D	C	
					P,8			July 9, 1953	7.95				
27F2	do.		22	12	D,20 by 40	Qfu	Ls .0	do.	4	C,20	I		500/?
27P1	Robert Sarina		14	13	D,30	Qfu	Ls 0.	May 28, 1952	2.0	C,30	I		200/?
								July 9, 1953	1.5				
18/1W-28F1	Westbrook				P,6	Qfu	Tb 3.0	do.	9.48	W	D,S		
32J1	M. C. Johnson	1925	50	30	D,3	Qd	Ls .0	July 7, 1953	25	L	D,S		
					SP								
34C1	Robert Sarina	1951	8	28	P,10	Qfu	Tc .0	July 3, 1953	5.56	J,1	D		
34M1	Jepson-Tedson	1946	18	28	D,6	Qfu	Tc 6.0	Sept. 18, 1953	14.22	C,20	I		
					P,12								
34M2	Jepson	1946	18	27	P,10	Qfu	Tc .0	July 29, 1953	16.27	J	D,S	C	
34P1	Jepson-Tedson			32	P,12	Qfu				C,30	I		
35A1	Irwin McIndoe	1951	60	60	P,12	Qt,Qaf				T,30	I	L	300/?
35B1	do.	1949		55		Qt				T,20	I		{400(July)/?
35C1	Fred Haight	1947	47	37	P,12	Qt	Tc .0	Sept. 18, 1953	20.07	T,15	I		250(Aug.)/?
35E1	Doyle T. Garvin	1952	27	36	P,12	Qfu	Tc .0	July 9, 1953	12.35	T,20	I		
35G1	Irwin McIndoe	1946	69	50	P,12	Qt	Tc .0	do.	24.47	J,1	D	C	
35K1	Morris Jergensen	1946	40	38	P,12	Qt	Tp .0	Sept. 17, 1953	14.40	C	I		
35K2	Wm. McIndoe	1850	41	23	D,5	Qt	Tcc .0	July 9, 1953	14.15	J,⅓	D		
35M1	do.	1947		40	P,12	Qfu				T	I		
35Q1	R. L. Moore		30		D,4	Qfu	Tcc .0	Sept. 18, 1953	6.63		D		
18/1W-36D1	A. W. Pemberton	1950	100	50	P,8	Qaf,Ql	Tcc 0.0	May 28, 1952	36.8	J,½	D	C	
								July 23, 1953	31.45				
19/1W-32Q1	Paul Bowen		132	30	P,6	Qaf	Tc .0	July 22, 1953	[4] 22.41	([5])	D		
								July 30, 1953	14.12				
32Q2	do.	1953	92	55	P,6	Qaf	Tc .0	do.	27.1	J,⅓	D,S		

[1] Pumping at time of measurement.
[2] Measurement furnished by the U. S. Bureau of Reclamation.
[3] Completed before 1947.
[4] Being siphoned at time of measurement.
[5] Gravity flow.

Water-level measurements for selected wells in the Smith River plain area

[Depths to water below land-surface datum are in feet. Measurements for 1955 were furnished by the U. S. Bureau of Reclamation]

Date measured	Depth	Date measured	Depth	Date measured	Depth
Well 16/1W-2J1					
1953		*1953*—Continued		*1954*	
July 6	17.71				
July 30	16.70	Oct. 18	17.05	Jan. 10	15.2
Aug. 9	18.28	Oct. 25	16.74	Jan. 17	14.7
Aug. 16	18.5	Nov. 7	16.56	Jan. 23	14.5
Aug. 23	18.37	Nov. 15	16.16	Jan. 31	14.38
Aug. 30	19.97	Nov. 22	15.27	Feb. 7	14.76
Sept. 6	18.33	Nov. 29	14.96	Feb. 14	14.7
Sept. 13	18.04	Dec. 6	14.69	May 30	17.49
Sept. 20	18.10	Dec. 13	14.70		
Sept. 27	19.29	Dec. 20	15.0	*1955*	
Oct. 4	18.03	Dec. 27	15.14	June 1	16.8
Oct. 11	17.60	Jan. 3	15.2	Aug. 25	19.7
Well 16/1W-17K1					
1953		*1953*—Continued		*1953*—Continued	
July 20	16.10	Sept. 20	19.39	Nov. 20	21.23
July 25	16.46	Sept. 25	19.59	Nov. 21	21.21
July 30	16.74	Sept. 30	19.80	Nov. 25	19.40
Aug. 5	17.07	Oct. 5	20.02	Nov. 30	17.91
Aug. 10	17.31	Oct. 10	20.23	Dec. 3	17.03
Aug. 15	17.60	Oct. 15	20.37		
Aug. 20	17.98	Oct. 20	20.51	*1954*	
Aug. 25	18.24	Oct. 25	20.61	May 31	17.2
Aug. 30	18.52	Oct. 30	20.75		
Sept. 5	18.76	Nov. 5	20.89	*1955*	
Sept. 10	18.96	Nov. 10	21.00	June 1	15.2
Sept. 15	19.20	Nov. 15	21.15	Aug. 25	20.0
Well 16/1W-20H1					
1953		*1953*—Continued		*1955*	
July 2	3.56	Sept. 11	6.5	June 1	3.9
July 30	5.65			Aug. 25	9.0
Aug. 14	6.6	*1954*			
		May 27	7		
Well 16/1W-22Q1					
1952		*1953*—Continued		*1953*—Continued	
May 26	11.7	Sept. 2	14.1	Nov. 12	14.8
		Sept. 9	12.1		
1953		Sept. 16	15.5	*1954*	
July 28	12.20	Sept. 24	17.8	May 28	12.6
July 30	12.95	Sept. 30	16.0	Aug. 20	10.0
Aug. 7	12.9	Oct. 7	15.0		
Aug. 12	12.82	Oct. 14	15.0	*1955*	
Aug. 22	10.34	Oct. 29	14.4	June 1	10.8
Aug. 27	14.0			Aug. 25	15.8
Well 16/1E-10N1					
1953		*1953*—Continued		*1954*	
July 30	26.4			May 25	22.0
Aug. 11	22.5	Aug. 16	22.0		

Water-level measurements for selected wells in the Smith River plain area—Continued

[Depths to water below land-surface datum are in feet. Measurements for 1955 were furnished by the U. S. Bureau of Reclamation]

Date measured	Depth	Date measured	Depth	Date measured	Depth
Well 17/1W-15M2					
1953		*1953*—Continued		*1953*—Continued	
July 25	13.30	Aug. 25	14.90	Sept. 18	15.55
July 30	13.51	Aug. 30	14.88		
Aug. 5	13.98	Sept. 5	15.00	*1955*	
Aug. 10	14.28	Sept. 10	15.16	June 1	11.3
Aug. 15	14.55	Sept. 15	15.43	Aug. 25	15.4
Aug. 20	14.78				
Well 18/1W-26P1					
1952		*1953*—Continued		*1955*	
May 28	8.5	Sept. 20	12.84	June 1	9.1
1953		*1954*			
July 23	10.50	Aug. 20	13.35		

Chemical analyses of ground water

[Analyses are in parts per million, except as otherwise indicated]

Index no. in fig. 10	Well no.	Date sampled	Temperature (°F)	pH	Specific conductance (micromhos at 25°C)	Sum of determined constituents	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Hardness as calcium carbonate ($CaCO_3$)	Percent sodium
									Parts per million (upper number), equivalents per million (middle number), and percent of total reacting value (lower number) for indicated cations and anions												
									Rocks of Jurassic age												
1	17/1W-14C1	Sept. 28, 1953	------	8.0	324	175	------	0.03	21 1.048 29.6	19 1.562 44.2	20 0.870 24.6	2.1 0.054 1.5	185 3.032 85.8	0 ------ ------	10 0.208 5.9	8.5 0.240 6.8	------ ------ ------	3.3 0.053 1.5	----	130	25
									Battery formation												
2	15/1W-2D1	July 17, 1953	57	6.9	147	64	-----	0	7.7 0.384 26.8	6.3 0.518 36.1	12 0.522 36.4	0.4 0.010 0.69	41 0.672 46.9	0 ------ ------	[1] 14 0.283 19.7	17 0.479 33.4	------ ------ ------	------ ------ ------	----	45	36
3	16/2W-13E1 and 13E2.	Sept. 23, 1953	------	6.7	380	190	------	.02	15 .749 22.0	14 1.151 33.8	34 1.478 43.4	1.0 .026 0.76	65 1.065 30.7	0 ------ ------	27 0.562 16.2	64 1.805 51.9	------ ------ ------	2.5 0.040 1.2	----	95	43
4	16/1W-2M1	July 7, 1953	------	6.4	111	53	------	.3	4.7 0.235 22.7	4.2 0.345 33.3	8.7 0.378 36.4	3.1 0.079 7.6	34 0.557 53.7	0 ------ ------	[1] 2.7 0.057 5.5	15 0.423 40.8	------ ------ ------	------ ------ ------	----	29	36
5	16/1W-9H1	Aug. 27, 1953	------	6.4	57.3	33	------	.03	2.1 0.105 20.4	2.4 0.197 38.3	4.8 0.209 40.7	0.1 0.003 0.10	15 0.246 39.9	0 ------ ------	2.1 0.044 7.1	8.8 0.248 40.2	------ ------ ------	4.9 0.079 12.8	----	15	41
6	16/1W-15C1	do	53	6.4	117	65	------	.17	4.2 0.210 19.6	6.3 0.518 48.4	7.7 0.335 31.3	0.3 0.008 0.7	34 0.557 47.3	0 ------ ------	1.8 0.037 3.1	11 0.310 26.3	------ ------ ------	17 0.274 23.2	----	36	31
7	16/1W-17A2	------------	------	6.6	147	88	16	------	4.9 0.245 18.3	6.3 0.518 38.6	13 0.565 42.1	0.5 0.013 0.97	46 0.754 54.4	0 ------ ------	2.0 0.042 3.0	19 0.536 38.7	0 ------ ------	3.3 0.053 3.8	0.01	38	42

8	16/1W-18F1	Aug. 27, 1953	53	7.0	251	127	-----	2.3	7.6 0.379 1.0	14 1.151 48.6	19 0.826 34.9	0.4 0.010 0.0	79 1.295 52.2	0 ----- -----	5.5 0.115 4.6	36 1.015 40.9	----- ----- -----	3.4 0.055 2.2	-----	76	35
9	16/1W-20Q1	Apr. 30, 1953	-----	6.8	232	135	19	.3	8.0 0.399 18.6	12 0.987 46.0	17 0.739 34.4	0.8 0.020 0.93	61 1.000 46.5	0 ----- -----	6.7 0.139 6.5	28 0.790 36.7	0.2 0.011 0.51	13 0.210 9.8	0.11	69	34
10	16/1W-21M1	May 1, 1953	-----	7.3	149	91	14	.5	7.8 0.389 26.0	6.7 0.551 37.3	12 0.522 35.3	0.7 0.018 1.2	56 0.918 61.4	0 ----- -----	3.4 0.071 4.8	17 0.479 32.0	0 ----- -----	1.6 0.026 1.7	.04	47	35
10a	16/1W-21M1	Aug. 20, 1954	57	7.2	161	103	20	-----	7.3 0.364 23.2	8.2 0.676 43.0	12 0.522 33.2	0.4 0.010 0.64	56 0.918 56.0	0 ----- -----	4.5 0.094 5.7	21 0.592 36.1	0.3 0.016 0.93	1.2 0.019 1.2	0.25	52	33
11	16/1W-22Q1	May 26, 1952	-----	6.8	109	64	8.6	-----	4.8 0.240 24.6	2.9 0.238 24.4	11 0.478 49.0	0.8 0.020 2.0	22 0.361 36.0	0 ----- -----	3.7 0.077 7.7	18 0.508 50.7	0 ----- -----	3.5 0.056 5.6	.04	24	49
12	16/1W-23D1	Aug. 27, 1953	59	7.1	72.4	38	-----	.27	3.4 0.170 23.9	4.1 0.337 47.4	4.5 0.196 27.6	0.3 0.008 1.1	32 0.524 68.0	0 ----- -----	0.7 0.015 1.9	7.2 0.203 26.3	----- ----- -----	1.8 0.029 3.8	-----	25	28
13	16/1W-26D1	Apr. 30, 1953	-----	6.6	154	101	10	.3	4.0 0.200 13.2	6.4 0.526 34.7	18 0.783 51.7	0.2 0.005 .33	30 0.492 31.8	0 ----- -----	1.6 0.033 2.1	23 0.649 42.0	0 ----- -----	23 0.371 24.0	.06	36	52
14	16/1W-26E1	do	-----	7.2	255	147	12	.4	31 1.547 58.5	6.7 0.551 20.8	12 0.522 19.7	1.0 0.026 .98	127 2.081 79.6	0 ----- -----	3.3 0.069 2.6	14 0.395 15.1	0 ----- -----	4.3 0.069 2.6	.02	105	20
15	16/1W-26N1	do	-----	8.1	216	139	15	.8	17 0.848 37.0	5.5 0.452 19.7	22 0.957 41.8	1.3 0.033 1.4	104 1.704 72.0	0 ----- -----	3.6 0.075 3.2	18 0.508 21.5	0.3 0.016 0.68	3.9 0.063 2.7	.03	65	42
16	17/1W-34C1	May 27, 1952	-----	6.9	103	70	16	-----	4.8 0.240 23.3	5.8 0.477 46.4	6.0 0.261 25.4	2.0 0.051 5.0	42 0.688 65.7	0 ----- -----	2.1 0.044 4.2	9.5 0.268 25.6	0 ----- -----	2.9 0.047 4.5	0	36	70
	Terrace deposits																				
17	16/1E-9K1 (Hiouchi Valley).	Aug. 28, 1953	-----	7.6	201	99	-----	0.05	5.1 0.254 11.5	22 1.809 82.2	3.2 0.139 6.3	0 ----- -----	120 1.967 88.8	0 ----- -----	1.3 0.027 1.2	7.0 0.197 8.9	----- ----- -----	1.5 0.024 1.1	-----	103	6
18	17/1W-14F1 (Fort Dick).	May 28, 1952	-----	7.2	136	96	24	-----	9.6 0.479 31.3	9.5 0.781 51.0	6.0 0.261 17.0	0.4 0.010 0.65	76 1.246 83.2	0 ----- -----	1.7 0.035 2.3	7.5 0.212 14.2	0 ----- -----	0.3 0.005 0.33	0.16	63	17

[1] Sulfate estimated by difference, approximate only, and includes the equivalent amount of anions, which was not determined.

Chemical analyses of ground water—Continued

Index no. in fig. 10	Well no.	Date sampled	Temperature (°F)	pH	Specific conductance (micromhos at 25°C)	Sum of determined constituents	Silica (SiO_2)	Iron (Fe)	Parts per million (upper number), equivalents per million (middle number), and percent of total reacting value (lower number) for indicated cations and anions										Boron (B)	Hardness as calcium carbonate ($CaCO_3$)	Percent sodium
									Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)			
									Terrace deposits—Continued												
	17/1W-15E1 (Fort Dick)	July 30, 1953	------	7.0	126	57	------	------	2.8 0.140 10.7	12 0.987 75.2	4.1 0.178 13.6	0.3 0.008 0.60	60 0.983 74.9	0 ------ ------	[1] 4.3 0.090 6.8	8.5 0.240 18.3	------ ------ ------	------ ------ ------	------	56	14
20	18/1W-35G1 (Rowdy (Creek).	July 29, 1953	------	6.6	83.2	38	------	.3	7.2 0.359 44.9	2.6 0.214 26.8	5.0 0.217 27.1	0.4 0.010 1.2	32 0.524 65.5	0 ------ ------	[1] 3.8 0.079 7.2	7.0 0.197 27.3	------ ------ ------	------ ------ ------	------	29	27
									Flood-plain deposits												
21	17/1W-2P1 (North of Smith River).	Aug. 27, 1953	------	6.8	130	68	------	0.07	4.2 0.210 14.6	13 1.069 74.5	3.4 0.148 10.3	0.3 0.008 0.6	78 1.278 85.0	0 ------ ------	1.5 0.031 2.1	5.8 0.164 10.9	------ ------ ------	1.9 0.031 2.1	------	64	10
22	17/1W-4L1	do	59	7.1	363	190	------	6.5	6.4 0.319 7.7	42 3.454 83.3	8.5 0.370 8.9	0.1 0.003 0.10	228 3.737 90.8	0 ------ ------	0.5 0.010 0.2	12 0.338 8.2	------ ------ ------	2.0 0.032 0.80	------	189	9
23	17/1W-4L2	do	67	7.0	352	190	------	9.7	6.0 0.299 7.2	43 3.536 85.4	7.0 0.304 7.3	0 ------ ------	231 3.786 92.9	0 ------ ------	0.7 0.015 0.4	9.5 0.268 6.6	------ ------ ------	0.4 0.006 0.1	------	192	7
24	17/1W-11F1	July 30, 1953	57	7.1	257	119	------	0	7.7 0.384 13.6	28 2.303 81.4	3.1 0.135 4.8	0.3 0.008 0.28	150 2.458 86.8	0 ------ ------	[1] 10.0 0.208 7.3	5.8 0.164 5.8	------ ------ ------	------ ------ ------	------	134	5
25	17/1W-13G1	Aug. 27, 1953	------	7.2	139	68	------	.13	5.5 0.274 18.9	13 1.069 73.8	2.3 0.100 6.9	0.2 0.005 0.34	79 1.295 87.3	0 ------ ------	1.7 0.035 2.4	4.8 0.135 9.1	------ ------ ------	1.2 0.019 1.3	------	67	7
26	18/1W-27F1 (North of Smith River).	July 30, 1953	------	6.0	72.2	27	------	------	3.6 0.180 28.7	2.8 0.230 36.7	5.0 0.217 34.6	0.3 0.008 1.3	17 0.279 44.5	0 ------ ------	[1] 7.0 0.145 23.1	7.2 0.203 32.4	------ ------ ------	------ ------ ------	------	20	35

27	18/1W34M2	do	56	7.2	332	160	------	0	11 0.549 15.0	36 2.961 80.6	3.4 0.148 4.0	0.5 0.013 0.35	208 3.409 92.9	0 ------ ------	[1]4.2 0.087 2.4	6.2 0.175 4.7	------ ------ ------	------ ------ ------	------	176	4
27a	18/1W-34M2	Aug. 20, 1954	55.5	8.0	341	212	38	------	8.9 0.444 11.6	39 3.236 84.4	3.2 0.139 3.6	0.5 0.013 0.34	216 3.540 90.7	0 ------ ------	6.6 0.137 3.5	6.0 0.769 4.3	0.1 0.005 0.13	3.2 0.052 1.3	0.05	184	------
									Alluvial-fan deposits												
28	16/1W-2J1	July 30, 1953	------	6.9	268	148	------	9.0	10 0.499 17.8	14 1.151 41.2	26 1.131 40.5	0.5 0.013 0.46	134 2.196 78.0	0 ------ ------	------ ------ ------	22 0.620 22.0	------ ------ ------	------ ------ ------	------	82	40
29	17/1W-26R1	Aug. 27, 1953	------	7.0	208	121	------	3.0	26 1.297 55.9	7.3 0.600 25.8	9.4 0.409 17.6	0.6 0.015 0.6	123 2.016 85.2	0 ------ ------	8.2 0.171 7.2	6.2 0.175 7.4	------ ------ ------	0.2 0.003 0.1	------	95	18
									Landslide												
30	18/1W-36D1	------	------	6.6	58.4	43	9.6	------	4.8 0.240 39.2	1.7 0.140 22.9	5.0 0.217 35.4	0.6 0.015 2.5	21 0.344 54.8	0 ------ ------	1.9 0.040 6.4	8.0 0.226 36.0	0 ------ ------	1.1 0.018 2.9	0.1	19	35
									Dune sand												
31	16/1W-5L1	Aug. 27, 1953	------	6.7	126	61	------	0.20	6.0 0.299 25.1	6.8 0.559 46.8	6.3 0.274 23.0	2.4 0.061 5.1	52 0.852 70.8	0 ------ ------	2.3 0.048 4.0	10 0.282 23.4	------ ------ ------	1.3 0.021 1.7	------	43	23
32	16/1W-7F1	Sept. 28, 1953	------	7.6	282	146	------	.02	22 1.098 37.5	14 1.151 39.3	15 .652 22.3	1.1 0.028 0.96	128 2.098 72.7	0 ------ ------	5.2 0.108 3.7	22 0.620 21.5	------ ------ ------	3.7 0.060 2.1	------	112	22
33	17/1W-20P1	July 98, 1953	------	7.5	282	132	------	------	22 1.098 36.4	16 1.316 43.6	12 0.522 17.3	3.2 0.082 2.7	126 2.065 68.4	0 ------ ------	[1,2]22.8 0.474 15.7	17 0.479 15.8	------ ------ ------	------ ------ ------	------	121	17
34	17/1W-32M1	Aug. 27, 1953	------	6.7	117	59	------	.47	6.8 0.339 28.5	8.0 0.658 55.4	4.1 0.178 15.0	0.5 0.013 1.1	55 0.901 75.2	0 ------ ------	4.3 0.090 7.5	6.5 0.183 15.3	------ ------ ------	1.5 0.024 2.0	------	50	15

[1] Sulfate estimated by difference, approximate only, and includes the equivalent amount of anions, which was not determined.
[2] Probably includes some nitrate.

Chemical analyses of surface water

[Analyses are in parts per million, except as otherwise indicated]

Date sample	Gage height	Discharge (cfs)	Temperature (°F)	Dissolved oxygen	pH	Specific conductance (micromhos at 25° C)	Sum of determined constituents	Silica (SiO_2)	Iron (Fe)	Parts per million (upper number) and equivalents per million (lower number) for indicated cations and anions: Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Hardness as calcium carbonate ($CaCO_3$)	Percent sodium
Lake Earl																						
Apr. 28, 1952	----	----	----	----	7.5	11,700	6,800	3.5	----	79 3.94	261 21.46	2,110 91.75	4.0 0.10	84 1.38	0 ----	508 10.58	3,790 106.89	0.1 0.01	1.2 0.02	1.1	1,270	78
Unnamed tributary to Elk Creek																						
May 1, 1953	----	----	----	----	7.5	187	117	22	----	4.2 0.210	11 0.905	17 0.739	1.0 0.026	61 1.000	0 ----	4.8 0.100	24 0.677	0 ----	2.9 0.047	0.09	56	39
Smith River																						
Apr. 11, 1951	7.8	2,310	52	11.4	7.4	79	----	----	----	----	----	----	----	----	----	----	2.0 0.056	----	----	----	39	----
May 13, 1951	10.84	6,100	48	12.2	7.4	86	----	13	----	3.6 0.180	8.7 0.715	1.3 0.056	0.3 0.008	52 0.852	0 ----	2.0 0.042	1.8 0.051	----	0 ----	.18	43	6
June 20, 1951	5.00	600	64	9.0	7.8	121	----	----	----	----	----	----	----	----	----	----	2.4 0.068	----	----	----	54	----
July 17, 1951	4.41	450	68	8.8	>8.0	137	----	----	----	----	----	----	----	----	----	----	0	----	----	----	61	----
Aug. 7, 1951	4.04	340	68	8.8	>8.0	140	----	----	----	----	----	----	----	----	----	----	6.0 0.169	----	----	----	62	----
Sept. 12, 1951	3.78	250	66	9.6	8.0	139	----	13	----	7.2 0.359	1.3 0.106	2.9 0.126	0.2 0.005	8.3 0.136	0 ----	3.9 0.081	2.5 0.070	.0 ----	0 ----	.05	71	8

Oct. 14, 1951	5.88	1,070	61	9.8	7.6	121	------	------	------	------	------	------	------	------	------	------	3.5 0.099	------	------	------	57	------
Nov. 15, 1951	11.02	7,100	48	12.2	7.4	86.1	------	------	------	------	------	------	------	------	------	------	2.8 0.079	------	------	------	4.2	------
Dec. 13, 1951	8.98	3,600	45	12.0	7.4	88	------	------	------	------	------	------	------	------	------	------	3.0 0.085	------	------	------	44	------
Feb. 6, 1952	------	------	45	12.8	7.4	72.9	------	------	------	------	0.700	1.5 0.065	------	41 0.672	0	------	2.5 0.071	------	------	------	35	8
Mar. 5, 1952	9.67	4,840	43	11.6	7.4	92.8	------	------	------	------	------	------	------	------	------	------	4.5 0.127	------	------	------	39	------
Apr. 15, 1952	8.89	3,820	48	11.8	7.5	78	------	------	------	------	------	------	------	46 0.754	------	------	0	------	------	------	38	------
May 22, 1952	7.83	------	52	10.8	7.5	75.0	55	16	0	5.2 0.259	5.6 0.461	1.2 0.052	0.1 0.003	44 0.721	0	2.7 0.056	2.0 0.056	0	0	.05	36	7
June 9, 1952	5.74	1,010	59	9.8	7.8	95.8	------	------	------	------	------	------	------	62 1.02	------	------	3.0 0.085	------	------	------	49	------
July 10, 1952	4.91	574	65	9.4	8.1	119	------	------	------	------	------	------	------	68 1.11	------	------	3.0 0.085	------	------	------	56	------
Aug. 7, 1952	4.25	358	68	8.6	8.4	142	------	------	------	------	------	------	------	76 1.24	------	------	2.0 0.056	------	------	------	62	------
Sept. 18, 1952	3.88	261	61	9.2	8.2	136	------	------	------	------	------	------	------	79 1.29	------	------	2.3 0.065	------	------	------	66	------
Oct. 9, 1952	3.76	238	59	10.5	7.4	141	------	12	------	8.0 0.399	12 0.987	4.1 0.178	0.4 0.010	81 1.33	0	3.6 0.075	3.1 0.087	0	1.5 0.024	.03	69	------
Nov. 5, 1952	3.74	229	57	12.9	7.8	147	------	------	------	------	------	------	------	82 1.34	------	------	3	------	------	------	66	------
Dec. 4, 1952	6.47	1,380	44	12.0	6.4	124	------	------	------	------	------	------	------	60 0.983	------	------	2 0.056	------	------	------	52	------
Jan. 15, 1953	14.57	14,000	46	14.4	7.2	79.0	------	------	------	4.1 0.205	5.8 0.477	2.0 0.087	.3 0.008	40 0.656	0	------	3.8 0.107	------	------	------	34	11
Feb. 12, 1953	10.27	5,260	51	13.1	7.4	87.2	------	------	------	4.3 0.215	6.3 0.518	2.0 0.087	.1 0.003	46 0.754	0	------	2.0 0.056	------	------	------	37	11
Mar. 12, 1953	11.45	7,150	45	11.3	7.6	80.9	------	------	------	3.7 0.185	7.2 0.592	3.8 0.165	------	48 0.787	0	------	3.5 0.099	------	------	.14	39	18

Chemical analyses of surface water—Continued

Date sampled	Gage height	Discharge (cfs)	Temperature (°F)	Dissolved oxygen	pH	Specific conductance (micromhos at 25° C)	Sum of determined constituents	Silica (SiO_2)	Iron (Fe)	Parts per million (upper number) and equivalents per million (lower number) for indicated cations and anions										Boron (B)	Hardness as calcium carbonate ($CaCO_3$)	Percent sodium
										Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)			
Smith River—Continued																						
Apr. 9, 1953	8.18	2,760	47	12.6	7.4	84.1	......	......	......	4.4 0.220	7.3 0.600	2.0 0.087	......	50 0.819	0	......	2.5 0.071	......	......	.01	41	10
May 7, 1953	10.26	5,620	50	12.1	7.3	75.3	51	13	0	4.2 0.210	6.2 0.510	1.7 0.074	0.1 0.003	43 0.705	0	1.9 0.040	2.5 0.071	0	0.2 0.003	0	36	9
June 11, 1953	9.59	4,310	55	12.5	7.5	94.3	......	......	......	......	......	......	......	50 0.819	......	......	2 0.056	......	......	.01	40	10
July 8, 1953	6.12	1,210	67	10.2	7.3	91.4	......	......	......	......	......	......	......	52 0.852	......	......	1 0.028	......	......	.02	48	7
Aug. 6, 1953	4.84	556	65	9.8	7.5	118	......	......	......	7.5 0.374	9.8 0.806	2.4 0.104	0.2 0.005	67 1.098	0	......	3.2 0.090	......	......	0	59	......
Sept. 17, 1953	4.19	400	66	8.6	7.9	136	79	13	0	7.4 0.369	11 0.905	2.8 0.122	0.2 0.005	76 1.246	0	3.7 0.077	3.5 0.099	0	0.3 0.005	.06	64	9
Oct. 8, 1953	4.15	300	57	10.2	8.0	133	......	......	......	7.0 0.349	11 0.905	2.8 0.122	0.2 0.005	75 1.229	0	......	3.0 0.085	......	......	.06	63	49
Nov. 8, 1953	6.61	1,400	52	11.5	7.5	118	......	......	......	......	......	......	......	54 0.885	......	......	2 0.056	......	......	0	60	9
Dec. 9, 1953	15.57	14,900	52	12.5	7.7	80.9	......	......	......	4.4 0.220	6.6 0.543	1.8 0.078	0.2 0.005	47 0.770	0	......	1.8 0.051	......	......	.01	38	9
Jan. 7, 1954	11.65	......	47	12.8	7.5	81.3	......	......	......	4.4 0.220	7.0 0.576	1.5 0.065	0.3 0.008	49 0.803	0	......	2.2 0.062	......	......	0	40	7
Feb. 4, 1954	13.2	......	45	12.4	7.7	72.3	......	......	......	4.0 0.200	5.6 0.461	1.8 0.078	0.2 0.005	42 0.688	0	......	1.8 0.051	......	......	.04	33	10

LITERATURE CITED

Butler, G. M., and Mitchell, G. J., 1916, Preliminary survey of the geology and mineral resources of Curry County, Oreg.: Oreg. Bur. Mines, Min. Res. Oreg., no. 2.

Cater, F. W., Jr., and Wells, F. G., 1953, Geology and mineral resources of the Gasquet quadrangle, California-Oregon: U. S. Geol. Survey Bull. 995–C, p. 79–132.

Davis, W. M., 1933, The lakes of California: Calif. Jour. Mines and Geology, v. 29, no. 2, p. 175–236.

Diller, J. S., 1902, Topographic development of the Klamath Mountains: U. S. Geol. Survey Bull. 196.

——— 1907, The Mesozoic sediments of southwestern Oregon: Am. Jour. Sci., 4th ser., v. 23, p. 402–421.

Emery, K. O., 1950, Ironstone concretions and beach ridges of San Diego County, Calif.: Calif. Jour. Mines and Geology, v. 46, no. 2, p. 213–221.

Hershey, O. H., 1911, Del Norte County geology: Mining and Sci. Press, v. 102, p. 468.

Jenkins, Olaf, 1938, Geologic map of California: Calif. Div. Mines.

Lawson, A. C., 1894, The geomorphogeny of the coast of northern California: Calif. Univ., Dept. Geol. Sci., Bull. 1, p. 255–263.

Louderback, G. D., 1905, The Mesozoic of southwestern Oregon: Jour. Geology, v. 13, p. 514–555.

Maxson, J. H., 1933, Economic geology of portions of Del Norte and Siskiyou Counties, northwesternmost California: Calif. Jour. Mines and Geology, v. 29, nos. 1 and 2, p. 123–160.

Meinzer, O. E., 1923a, The occurrence of ground water in the United States, with a discussion of principles: U. S. Geol. Survey Water-Supply Paper 489.

——— 1923b, Outline of ground-water hydrology, with definitions: U. S. Geol. Survey Water-Supply Paper 494.

——— 1936, Movements of ground water: Am. Assoc. Petroleum Geologists Bull., v. 20, no. 6, p. 704–725.

Piper, A. M., 1945, A graphic procedure in the geochemical interpretation of water-analyses: Am. Geophys. Union Trans. 25th Ann. Mtg. pt. 6, 1944, p. 914–923, discussion, p. 924–928.

Poland, J. F., Davis, G. H., Olmsted, F. H., and Kunkel, Fred, 1951, Ground-water storage capacity of the Sacramento Valley, Calif.: Calif. Dept. Public Works, Water Res. Div. Bull. 1, p. 618–632.

Taliaferro, N. L., 1942, Geologic history and correlation of the Jurassic of southwestern Oregon and California: Geol. Soc. America Bull., v. 53, no. 1, p. 71–112.

Trewartha, G. T., 1937, An introduction to weather and climate: New York, McGraw-Hill Book Co., 373 p.

Wells, F. G., Hotz, P. E., and Cater, F. W., Jr., 1949, Preliminary description of the geology of the Kerby quadrangle, Oregon: Oreg. Dept. Geology and Min. Industries Bull. 40, 23 p.

Wenzel, L. K., 1942, Methods for determining permeability of water-bearing materials, with special reference to discharging-well methods: U. S. Geol. Survey Water-Supply Paper 887.

INDEX