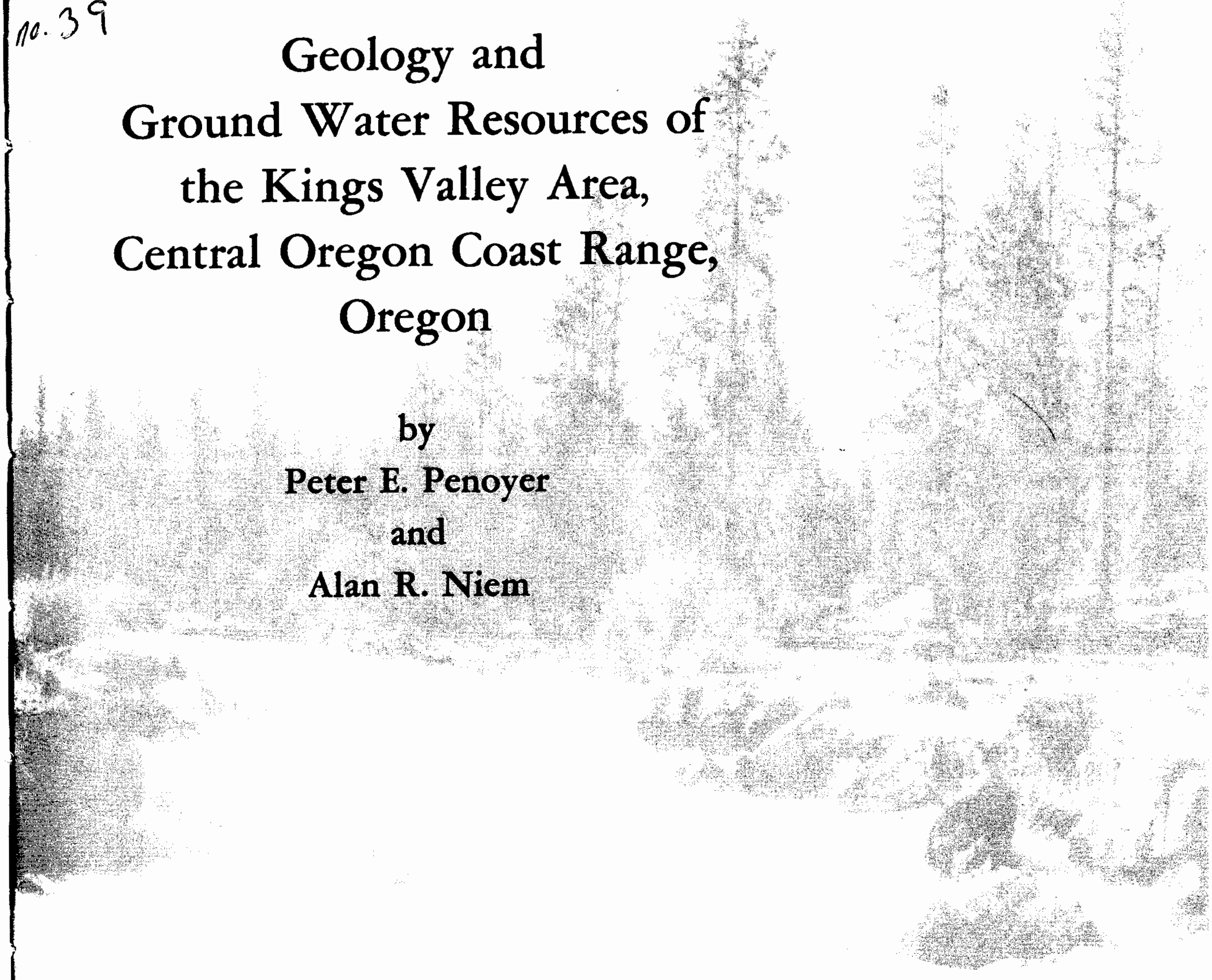

Geology and Ground Water Resources of the Kings Valley Area, Central Oregon Coast Range, Oregon

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Water Resources Research Institute
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ABSTRACT

The occurrence, movement, and chemical composition of ground water in Kings Valley is directly related to the geology. The Eocene Kings Valley Siltstone underlies Kings Valley and is the principal aquifer in the study area. Artesian wells in this tuffaceous unit penetrate one or more confined water-bearing fracture zones. Water in storage, specific capacities, transmissivities, and well yields are low in the siltstone. Highest yields occur near the eastern recharge area composed of rugged hills of fractured Siletz River pillow lavas. Ground water flows northwestward from this basaltic recharge area down dip through the Kings Valley Siltstone.

In the valley, ground water has low hardness, is more saline with depth, ranges from sodium bicarbonate to sodium chloride type water and is generally good to excellent quality. Poorest quality water (some brackish) occurs in some of the Kings Valley Siltstone, suggesting that connate water is being encountered and that the flushing action on ground water by recharge is very slow. Some unusually low calcium and magnesium concentrations indicate that confined ground water is undergoing natural softening by cation exchange of Na^{+} for Ca^{++} and Mg^{++} ions in zeolites and clay minerals in an alkaline environment. A few wells contain excess iron, unpotable sodium chloride contents, or have too high sodium adsorption ratios (SAR) for irrigation use, and/or have high concentrations of coliform bacteria due to surface water contamination.

Key words: ground water, Kings Valley Siltstone, artesian aquifer,
fracture zones, water quality, cation exchange.

TABLE OF CONTENTS

ABSTRACT Page

INTRODUCTION

Purpose and Scope of the Investigation 1
Acknowledgements 2
Location and Extent of the Area 2
Previous Investigations 4
Methods of Investigation 4
Well- and Spring-numbering System 6

GEOGRAPHY

Topography 8
Climate 8
Vegetation 10
Drainage 12
Culture and Industry 14

GEOLOGY

Geologic Setting 15
Structure 17
General Description, Relationship, and Water-Bearing Properties of Rock Units 18
Siletz River Volcanic Series
Siletz River Volcanics 19
Kings Valley Siltstone Member 20
Tyee Formation 23
Post-Eocene Igneous Rocks 25
Valley Alluvium and Colluvium 26
Soils 29

GROUND WATER

Modes of Occurrence 30
Unconfined Water 30
Confined Ground Water 31
Perched Ground Water 32
Source and Movement of Ground Water 33
Eastern Upland Recharge Area 33
Central Lowland Discharge Area 36
Pump Test 40
Transmissivity 40
Water in Storage 42
Unconfined Water Zones 43
Water Table Fluctuations 44
Northern and Western Uplands 45

GROUND WATER (continued)

Chemical Quality of the Water 48
  - Sodium 48
  - Calcium 51
  - Magnesium 54
  - Carbonate and Bicarbonate Alkalinity 54
  - Dissolved Gases 57
  - Potassium 58
  - Iron 58
  - Chloride 59
  - Silica 60
  - Sulfate and Nitrate 61
  - Fluoride 62
  - Temperature and pH 62
  - Hardness 63
  - Total Dissolved Solids 66

  - Suitability of Water for Irrigation 67
  - MPN-Bacteria Contamination of Water Wells 70
  - Areal Variations in Chemical Quality 72

SUMMARY AND CONCLUSIONS 73

REFERENCES CITED 75

Tables 80

Appendix A 82

Appendix B 92

LIST OF ILLUSTRATIONS

Figure		Page
1	Location of Kings Valley.	3
2	Well- and spring-numbering system.	7
3	View of Kings Valley looking west from high ridge underlain by Siletz River Volcanics	9
4	Annual precipitation (1949-67) at Hoskins, Dallas, and Philomath, Oregon.	11
5	Average monthly precipitation for the years 1857-64 and 1944-54. Average monthly discharge for the Luckiamute River near Pedee, Oregon for the water years 1941-68.	13
6	Quarry in fractured Siletz River basalts.	21
7	Typical exposure of dipping Kings Valley Siltstone.	21
8	Bedded Kings Valley Siltstones with thin light-colored tuff lamina and thicker resistant basaltic sandstone rib.	24
9	Interbedded graded light gray sandstone and well indurated darker gray siltstone of the Tyee Formation.	24
10	Stream alluvium consisting of poorly sorted basalt gravels overlain by thick structureless clayey silts.	28
11	Ground water subareas of Kings Valley area.	34
12	Water well yields map of the Kings Valley area.	38
13	Close-up of sample of fresh well indurated Kings Valley Siltstone.	39
14	Time-drawdown diagram of pumping well.	41
15	Hydrograph of well 10S/6W-21abb in Kings Valley Siltstone for the period 1970-75.	44
16	Quarry exposure of resistant Tyee Formation.	47
17	Calcite equilibrium diagram.	52
18	Classification of irrigation waters.	68

Purpose and Scope of the Investigation

Although there have been a few hydrogeologic studies along the Oregon coast by the U. S. Geological Survey (Frank, 1970; Hampton, 1963) mainly involving unconsolidated coastal dune and beach deposits, there have been no hydrogeologic studies conducted within the Oregon Coast Range dealing exclusively with the hydrologic character of the geologic units that form the range. Intermontane valleys in the range have a large potential for population growth. Therefore, a ground water policy is imperative to orderly development of the ground water resource. This study will be useful to formulation of such a policy. In addition, the sedimentary and volcanic rocks that underlie Kings Valley typify the major rock types in the coast ranges of Oregon and Washington, and this study has wider applications by characterizing the water resources and water chemistry of tuffaceous and volcanic rocks in this high rainfall region.

Historically, the search for adequate supplies of potable ground water in the Oregon Coast Range has met with unpredictable success. Often, considerable expenditures by land owners on well construction have met with unsatisfactory results. Dry wells, wells which yield marginally adequate quantities of water for domestic use, and wells yielding water of poor chemical quality are not uncommon in Kings Valley and in the Oregon Coast Range in general. It is essential that information be compiled and interpreted pertaining to the geology, position, quantity, and character of the water-bearing units and on the chemical quality of ground water for efficient use and future economic development of water supplies in the Kings Valley area. It is the purpose of this report to provide as much of this information as possible so that future searches for adequate water supplies will become a more rewarding exercise.

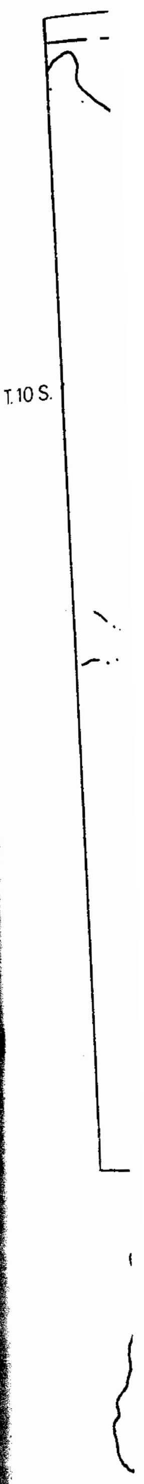
Acknowledgements

The cooperation and assistance of state and federal officials, particularly W. S. Bartholomeuw of the Oregon Water Resources Department and A. R. Leonard of the U. S. Geological Survey Water Resources Division in Portland, greatly facilitated this study. James Robison of the U. S. Geological Survey Water Resources Division critically reviewed the hydrogeolog section of this report. We thank the well drillers and friendly residents of Kings Valley for their patience and cooperation. A special thanks goes to Raymond Gellatly of Philomath, Oregon, whose experience and well drilli expertise in Kings Valley led to many fruitful discussions for which the authors are indebted.

Chemical anaylses for sulfate would not have been completed were it not for the help and cooperation extended by William Griffis at the Environmental Protection Agency Water Quality Laboratory in Corvallis. X-diffraction analyses of mudstone units were conducted by David M. Cooper o the Department of Geology, Oregon State University, for this study and for this the authors extend their appreciation. Funds for this study were granted by the U. S. Department of Interior, Office of Water Resources Res (grant number OWRR A-034), as authorized under the Water Resources Act of 1964 through the Oregon Water Resources Research Institute.

Location and Extent of the Area

Kings Valley occupies an elongate area of approximately 8 square mile on the eastern flank of the central Oregon Coast Range (Figure 1). It is located in the northwestern part of Benton County in T. 10 S., R. 6 W. It is bounded by McDonald Forest on the east, by the Marys River - Luckiamute River drainage divide on the south and west, and on the north by the Polk County - Benton County boundary. Oregon State Highway 223 traverses the valley from south to north.



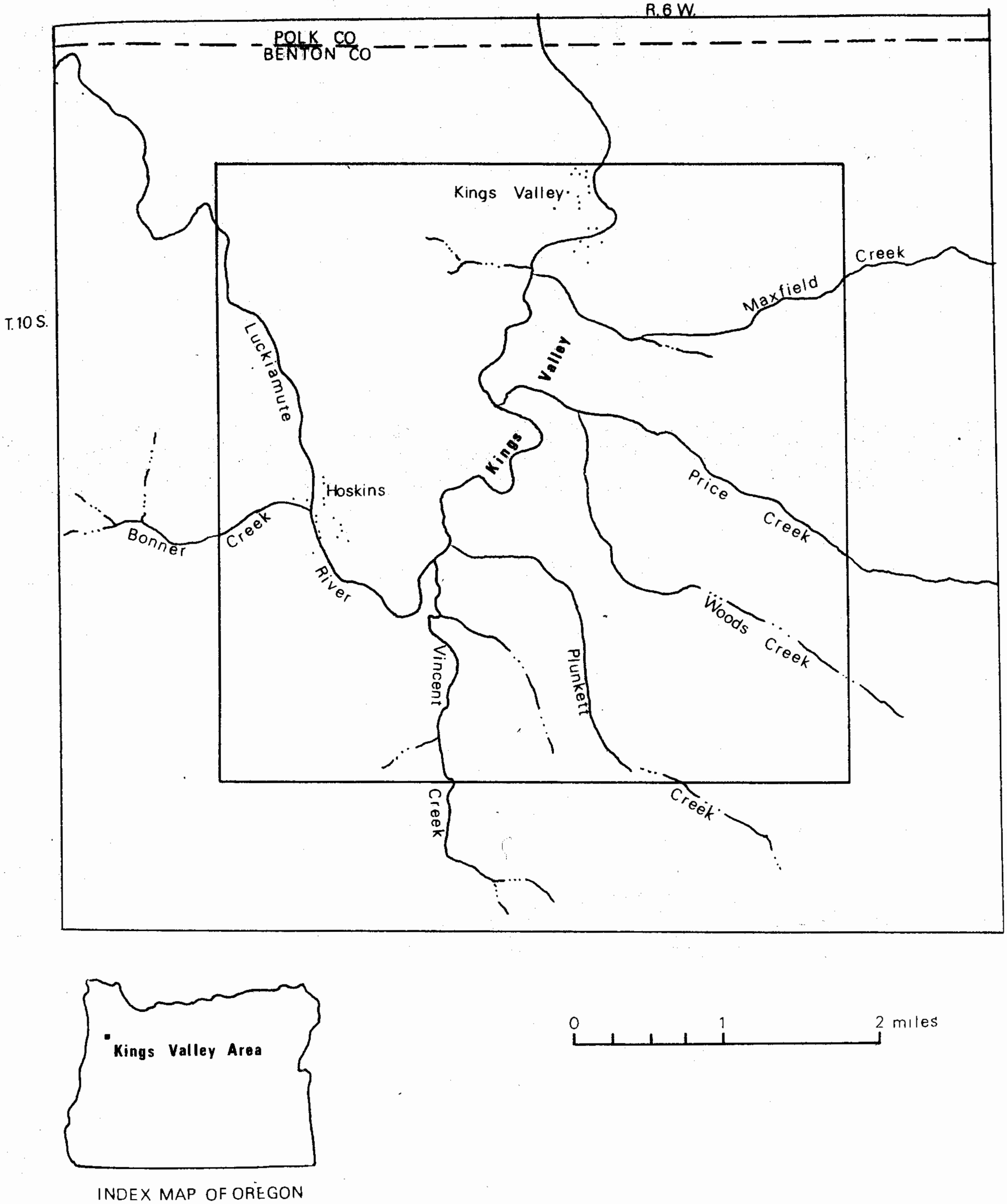


Figure 1. Location of Kings Valley.

Previous Investigations

No previous investigation of ground water resources in the Kings Valley area has been conducted. Ground water studies in nearby areas in the Willamette Valley have been reported by Piper (1942) for the general Willamette Valley, by Frank and Johnson (1972) for the Eugene-Springfield area, and by Frank (1973) for the Corvallis-Albany area. Hampton (1972) and Hart and Newcomb (1965) reported on the geology and ground water in the Mollala-Salem slope area and in the Tualatin Valley near Portland, respectively. A geologic reconnaissance map (1:62,500) of the Kings Valley area was constructed by Vokes and others (1954). Baldwin (1955) mapped the Marys Peak quadrangle southwest of Kings Valley. Balster and Parsons (1965, 1966) have described the soils and geomorphology of Kings Valley.

Methods of Investigation

This report is based on well data (from drillers' logs filed with the Oregon Water Resources Department), on previous geologic mapping, and on geologic and hydrologic information collected during the spring and summer of 1975. Field work included locating wells in the project area, measurement of well elevations and water levels with an altimeter and a Fisher M-scope, respectively, and collection of water samples at selected wells. A pump test was also conducted to determine specific yields and transmissivities of the aquifer.

The methods of collection and treatment of water samples in the field discussed by Rainwater and Thatcher (1960) and by Brown and others (1974) were employed in this study. At each location, two one-liter water samples were collected. One sample was acidified with 10 ml of concentrated nitric acid; the other sample was left untreated and chilled. Water temperature, specific conductance, and pH at each water well were measured in the field using a thermometer, lectro Mho meter (model MC-1), and a portable Orion pH meter. A second set of pH readings was made in the lab prior to alkalinity determinations to check if equilibrium changes due to air trapped in the small space near the cap of the sample bottles had altered the concentration of the carbonate species.

Detailed geologic mapping, petrographic study of thin sections, and clay X-ray diffraction analysis of representative formational samples added details to the earlier reconnaissance geologic studies completed in the area. The U. S. Geological Survey topographic map of the Corvallis quadrangle (scale 1:62,500) was expanded to a scale of 1:12,000 and was used to map the geology in detail and to map well localities. The 1:12,000 scale was also used on the base maps for the final presentation of data (Plates I through III).

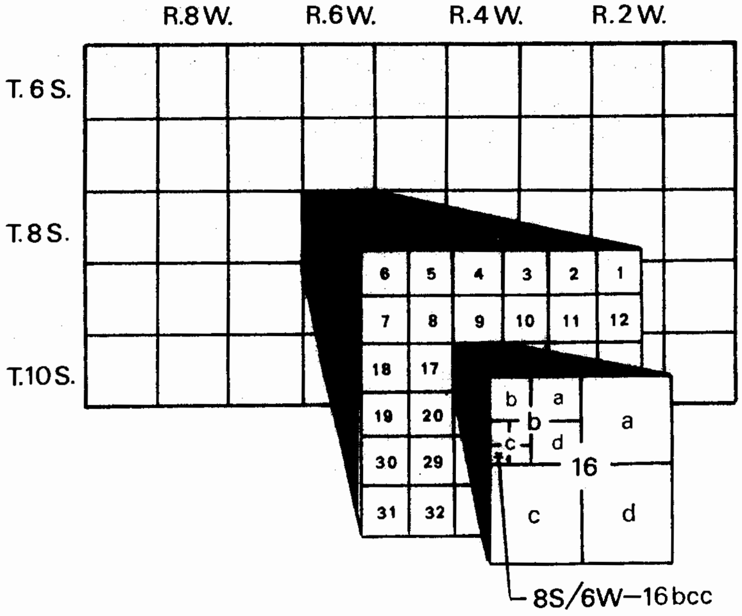
Thirty water samples (25 from wells, 2 from springs, 3 from streams) were analyzed for total dissolved solids for all major ionic constituents (sodium, calcium, magnesium, silica, bicarbonate, sulfate, chloride) and secondary ionic constituents (iron, potassium, carbonate, nitrate, and fluoride). With the exception of sulfate, all analyses were made by the principal investigator in a water quality laboratory established for this purpose in the Department of Geology at Oregon State University. Sulfate was determined by the federal Environmental Protection Agency Water Resources Laboratory in Corvallis, Oregon. MPN tests for coliform bacteria counts on water well samples were conducted by the Department of Microbiology at Oregon State University. Laboratory analyses of water samples were begun in May, 1975. Less than two months elapsed between collection of the samples and completion of all chemical analyses. Alkalinity determinations were made within five days of sample collection.

Procedures outlined in "Standard methods for the examination of water and waste water" published by Taras and others (1971) and methods described by Brown and others (1974) were followed for chemical analyses for major and minor ionic constituents in the water samples. Calcium, magnesium, sodium, and potassium ion concentrations were determined using a Perkin-Elmer model 103 atomic absorption spectrophotometer in the Department of Geology at Oregon State University. Silica and iron ion concentrations were determined with a Turner model 350 visible light spectrophotometer. Carbonate and bicarbonate alkalinities were determined by potentiometric titration with a strong acid to pH endpoints of 8.3 and 4.5, respectively. Chloride, fluoride, and nitrate concentrations were determined with an Orion model 407A specific ion meter and appropriate electrodes. Procedures for these analyses using the appropriate ion electrodes were supplied by the manufacturer. Total dissolved solids, the sodium adsorption ratio, and the two forms of hardness (carbonate and non-carbonate) were then calculated from the cation and anion data obtained in the procedures outlined above.

Well- and Spring-numbering System

Well and spring locations are designated by township, range, section, and position within the section of the rectangular land survey system. Figure 2 illustrates the method of locating wells and springs used in this report and recommended by the U.S. Geological Survey Water Resources Division. In the symbol 8S/6W-16bcc, for example, the two numeral-letter combinations preceding the hyphen denote the township and range, respectively (i.e., T. 8 S., R. 6 W.). The number after the hyphen (16) indicates the section, and the three letters which follow locate the well or spring within that section. Quarter sections (160 acres) are designated by the first letter; quarter-quarter sections (40 acres) are designated by the second letter, and the quarter-quarter-quarter sections (10 acres) by the third. A numeral subscript following the third letter indicates that two or more wells occur in the same 10-acre parcel whereas the lower-case letter(s) indicates a spring. For example, if two wells occur in the SW¼, SW¼, NW¼ sec. 16, T. 8 S., R. 6 W., they would be designated 8S/6W-16bcc$_1$ and 8S/6W-16bcc$_2$. The occurrence of a spring in the same quarter-quarter-quarter section would be designated 8S/6W-16bcc(s).

Figure 2. Well- and spring-numbering system.



GEOGRAPHY

Topography

Kings Valley, an intermontane valley located in the Pacific Border physiographic province (Fenneman, 1931), is approximately 2 miles wide by 4 miles long (Figure 1). Relatively high, rugged north-south trending forested ridges reaching elevations of nearly 2,000 feet separate this narrow valley from the much broader Willamette Valley to the east (Plate I). The less rugged and highly dissected forested 1,200-foot high mountainous uplands of the Oregon Coast Range flank the western side of the valley (Figure 3). The valley floor slopes gently northward although the slope is steeper in the southern part of the valley. Above the average elevation of the valley floor of approximately 320 feet, several small forested hills rise 200 to 300 feet (Figure 3).

Climate

The Kings Valley area has a humid temperate climate largely moderated by mild moist marine air masses which move in from the Pacific Ocean (50 miles to the west) throughout much of the year. Most precipitation falls during the cool cloudy winter months, whereas summer months are generally dry, warm, and clear. Temperatures average 36° F in January and 65° F in July. The growing season is long (more than 180 days) and frost-free usually lasting from April through late September. Periods of subfreezing temperatures generally last less than a week, and subzero temperatures are rare.

Complete precipitation records from Hoskins are available only for the years 1858-60, 1862-64, and 1949-53. These scant data indicate that this intermontane valley apparently receives significantly more rainfall

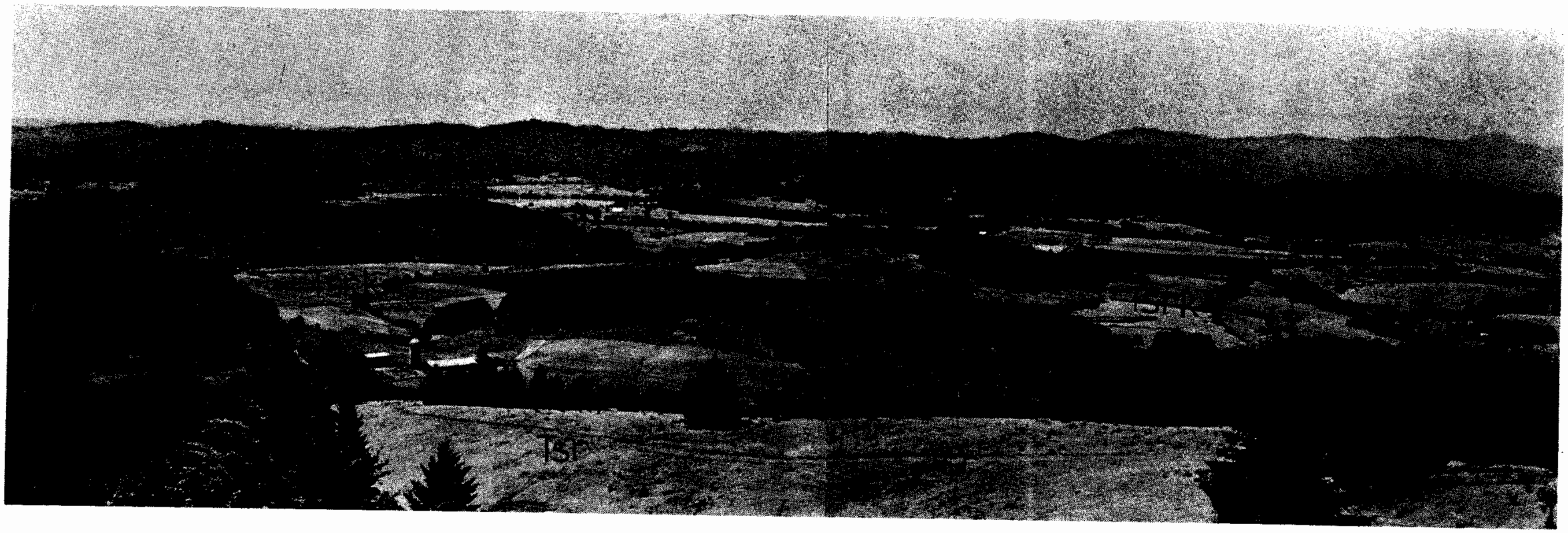


Figure 3. View of Kings Valley looking west from high ridge underlain by Siletz River Volcanics (Tsr) in foreground. Kings Valley Siltstone Member (Tsrk) underlies gently rolling forested hills in central portion of figure. The Tyee Formation (Tt) forms the far valley wall and distant ridges. Trace of Kings Valley fault is approximately from upper left to lower right through center of the photo.

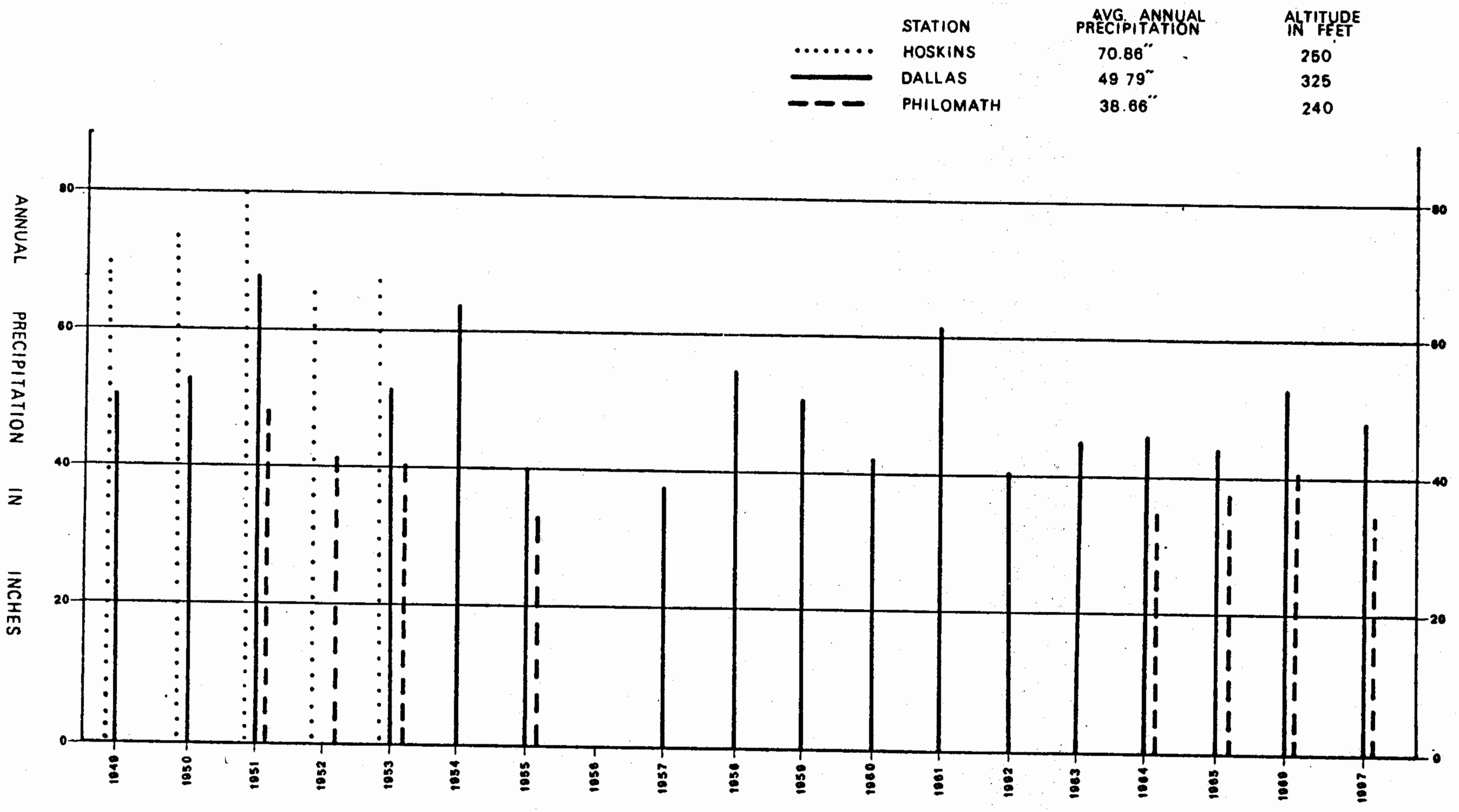
than areas of comparable elevation to the northeast and southeast in the Willamette Valley. The composite average annual rainfall at Hoskins for the three periods on record is 67.28 inches. In comparison, annual precipitation at Philomath (12 miles south-southeast) and Dallas (18 miles north-northeast) has averaged 30.30 and 48.53 inches, respectively, since 1936. Figure 4 presents the annual precipitation at these stations for the period 1949-67. Data are available from all three stations only for 1951 and for 1953. For these two years, the average annual rainfall at Hoskins was 13.60 inches greater than at Dallas and 29.41 inches greater than at Philomath. The average monthly rainfall for the wettest month (January) and for the driest month (July) at Hoskins during the period shown in Figure 4 was 11.77 inches and 0.35 inches, respectively. The amount of rainfall in the Kings Valley area increases with increasing elevation and probably well exceeds 70 inches at the highest elevations (approximately 1850 feet) on the surrounding hills (Balster and Parsons, 1966).

Vegetation

The native vegetation of the Kings Valley area was dominantly Douglas-fir (Pseudotsuga menziesii) and Oregon white oak (Quercus garryana) which was cleared for agriculture by Chinese laborers approximately one hundred years ago (Parsons and Balster, 1965). The valley is now predominantly pasture except on low hills in the valley and on the higher ridges surrounding the valley where groves of second growth Douglas-fir, Oregon white oak, and bigleaf maple (Acer macrophyllum) occur.

Figure 4. Annual precipitation (1949-67) at Hoskins, Dallas, and Philomath, Oregon. Data from "Climates of the States - Oregon" and "Climatological Data" by

Figure 4. Annual precipitation (1949-67) at Hoskins, Dallas, and Philomath, Oregon. Data from "Climates of the States - Oregon" and "Climatological Data" by U. S. Dept. of Commerce.



Drainage

The principal stream in Kings Valley is the Luckiamute River. It has six tributaries in the valley: Bonner Creek, Vincent Creek, Plunkett Creek, Woods Creek, Price Creek, and Maxfield Creek (Figure 1). With the exception of Bonner Creek, the tributaries drain westward and northward off the high ridge on the eastern and southern side of Kings Valley (Plate I). The flow of all the tributaries in late summer is very low and generally ephemeral at higher elevations. The average August flow of the Luckiamute River near Pedee, Oregon (5 miles north and downstream of Kings Valley) is 29.5 cubic feet per second (Oregon Water Resources Board, 1975), much below the average January maximum flow of 1100 cubic feet per second.

It is evident from Figure 5 that highest stream flow occurs during the winter coincident with periods of greatest precipitation and that a steady decline in streamflow and precipitation characterizes the period of February through September. Apparently ground water does not contribute significant quantities of water to stream flow to maintain even moderate base stream flow during the dry late summer months.

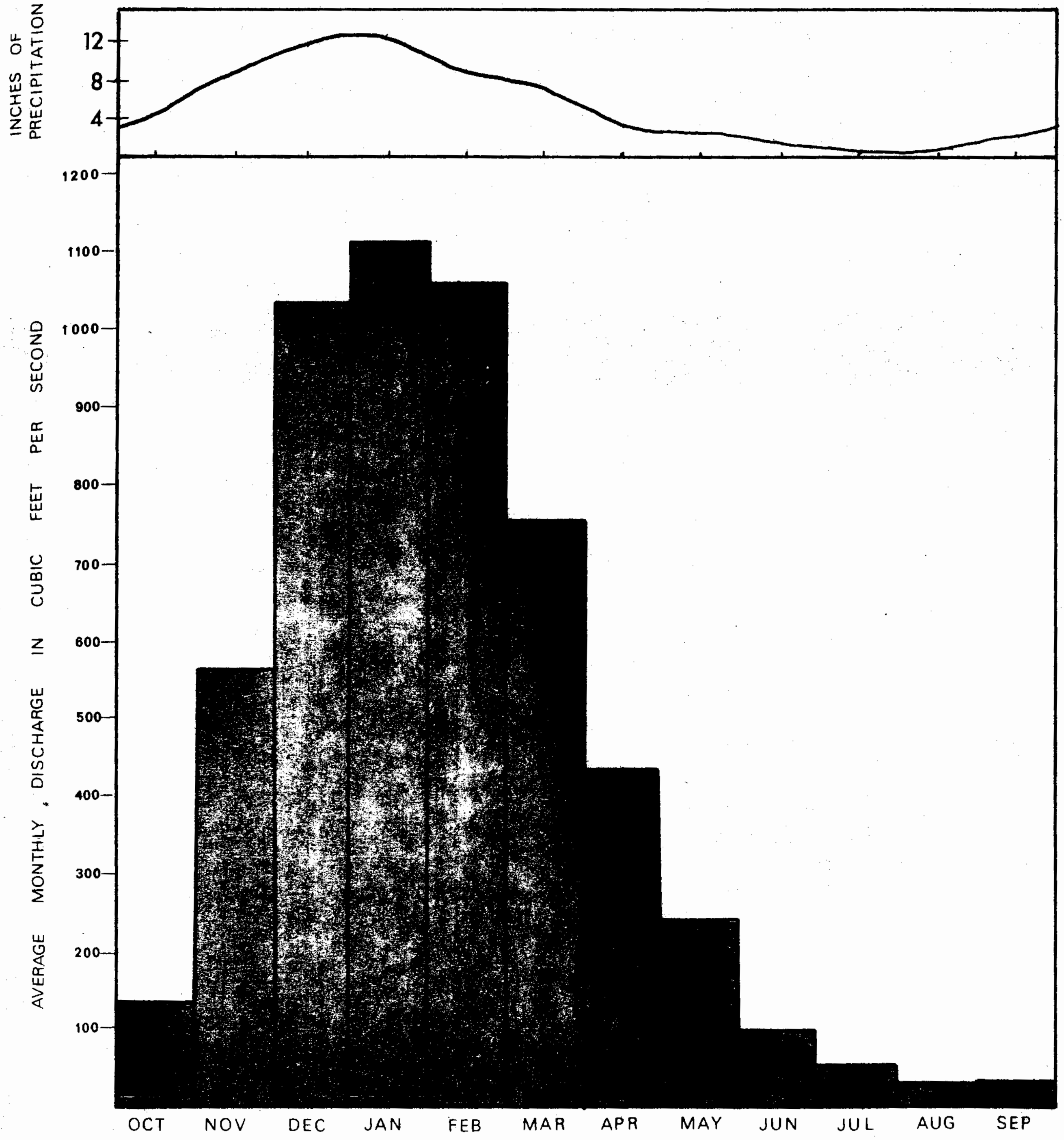


Figure 5. Average monthly precipitation for the years 1857-64 and 1944-54. Average monthly discharge of the Luckiamute River near Pedee, Oregon for the water years 1941-68.

Culture and Industry

The principal centers of population are the town of Kings Valley located in the northern part of the valley and the village of Hoskins located in the southwestern part of the valley (Figure 1). Farms and single-family residences are scattered throughout the valley. Small scale farming, cattle ranching, and occupations associated with the lumbering industry are the principal sources of income for the approximately 600 residents of the Kings Valley area. There is one operating sawmill, a small railroad, and an elementary school. No major industries are located in the area. Generally poor soils limit the variety of crops that can be raised in the valley. Hay, cattle, and Christmas trees are the most common agricultural products.

GEOLOGY

Hydrogeology is defined as "the study of ground water with particular emphasis given to its chemistry, mode of migration, and relation to the geologic environment" (Davis and DeWiest, 1970, p. 1). Thus, an understanding of the areal distribution and physical character of the rocks and of the interrelationships of rock units to the movement and chemistry of ground water are prerequisite to evaluating the ground water resources of a given area.

Geologic Setting

The geologic history of the Kings Valley area can best be summarized beginning in early Eocene time with widespread voluminous outpouring and accumulation of submarine basaltic lavas and breccias of the Siletz River Volcanics in a deep marine geosyncline (Snavely and Wagner, 1963; Vokes and others, 1954). Rapid quenching of these lavas by sea water resulted in the formation of the fractured and glassy textures and distinctive pillows in the lavas. Concomittant hydrothermal alteration produced abundant secondary minerals, particularly chlorite and zeolites (chabazite, morderite, and natrolite). After burial, interstices between individual pillows and vessicles in the basalt flows were partially filled with calcite and zeolites by pore fluids migrating through the lavas.

During later stages of volcanism in middle Eocene time, local submarine volcanic vents erupted fine pyroclastic debris accompanied by smaller quantities of basaltic pillow lavas (Vokes and others, 1954). Much of this pyroclastic material intermixed with terrigenous clays and silts derived from a nearby volcanic terrain (probably the ancestral western Cascades) to produce the deep-marine tuffaceous siltstones that form the Kings Valley Siltstone Member of the Siletz River Volcanics.

Late middle Eocene time was characterized by an end of submarine basaltic volcanic activity and a great influx of micaceous, arkosic, and lithic sands and silts transported from the south by turbidity currents into the deep marine basin (Snavely and others, 1964). These distinctively graded and rhythmically bedded units of turbidite origin now comprise the Tyee Formation.

Local post-Eocene basaltic volcanicity (probably Oligocene) of a dominantly intrusive nature followed deposition of the Tyee strata. Texturally, the intrusive basalts are finely to medium crystalline (locally porphyritic to diabasic) and form sills and dikes.

Late Miocene to late Pliocene uplift of the Coast Range deformed the stratigraphic units into broad synclines and anticlines cut by a series of high-angle normal and reverse faults.

In Pleistocene and Holocene time, the Luckiamute drainage pattern was superimposed on the uplifted Coast Range strata and carved a deep wide valley in the Kings Valley Siltstone between the resistant ridges of Tyee rocks on the west and Siletz River Volcanics on the east. Most of the sediment was transported out of Kings Valley into the Willamette Valley to the northeast. However, some local stream gravels, sands, and silts were deposited along the Luckiamute River and its floodplain. At present, the Luckiamute and its tributaries have entrenched below the alluvial terrace deposits and are downcutting through the siltstone bedroc Landslides and weathering continue to form a thin colluvial cover mantling the surrounding Tyee and Siletz River Volcanics hills and ridges.

Structure

Kings Valley lies on the southeast limb of a syncline which plunges gently northeast and whose axis lies in the Dallas and Valsetz quadrangles to the northwest of Kings Valley (Vokes and others, 1954; Baldwin, 1947). Strata in the western part of Kings Valley dip gently (7° to 16°) to the northwest but are more steeply dipping (27° to 78°) in the eastern part of the valley (Plate I).

The Kings Valley Siltstone which floors the valley is cut by a northeasterly striking normal fault known as the Kings Valley fault (Vokes and others, 1954)(Plate I). The trace of the Kings Valley fault can be followed over 12 miles. Immediately south of the study area, the Kings Valley fault is offset by a smaller fault known as the Plunkett Creek fault (Vokes and others, 1954). The amount of displacement on the Kings Valley fault is unknown, but it is thought to be considerable. North of the study area, a northeastward trending branch of the fault downdrops the Tyee Formation in the northwestern block against the Siletz River Volcanics on the southeastern block (Vokes and others, 1954). On the basis of rapid gradient changes of magnetic anomalies across the Kings Valley fault, Bromery (1965) suggested that the volcanic rocks on the west side of the fault have been downdropped 1,000 to 2,000 feet.

Balster and Parsons (1965, 1966), in a soil-geomorphic study, noted the occurrence of sag ponds, springs, and landslides adjacent to the buried trace of the Kings Valley fault in the southeastern quadrant of the valley. These springs and landslides occur on the Kings Valley-Siletz River Volcanics contact, approximately ¼ mile east of the trace of the Kings Valley fault drawn by Vokes and others (1954). It is probable that this is the trace of another northeast-southwest fault(s) that parallels the Kings Valley fault. There are anomalously steep dips (as much as 78°

to the northwest) in the Kings Valley Siltstone in the vicinity of this possible fault trace near the Kings Valley-Siletz River Volcanics contact perhaps due to drag along a fault (Plate I). Balster and Parsons (1965, p. 5) also reported exposed fault planes at the head of Price Creek. Another set of faults, according to their study, strikes N 50° W and locally forms slickensides and gouge and controls the orientation of Woods Creek and Price Creek canyons (Figure 1 and Plate I).

Bromery (1965) postulated from the results of an aeromagnetic survey of the central Oregon Coast Range the existence of a large subsurface north-south trending fault 1 mile west of the Kings Valley fault through the entire length of the valley from Plunkett Creek on the south to the northeast side of the village of Kings Valley.

General Description, Relationship, and Water-Bearing Properties of Rock Units

Rock units are distinguished using a wide variety of criteria including age, lithology, stratigraphic position, and chemical and mineral compositions, to mention a few. Hydrologic units, on the other hand, are separated on the basis of their water-yielding and water-bearing properties such as specific yield, porosity, permeability, transmissivity, and storage capacity. In general, geologic units agree rather well with hydrologic units, but the occurrence of a geologic unit containing two or more hydrologic units (and vice versa) is not uncommon. In this report, stratigraphically defined geologic units are equal to hydrologic units. For example, the Siletz River Volcanic Series is divided on the basis of geologic and hydrologic criteria into a volcanic unit and a siltstone member (Kings Valley Siltstone).

Siletz River Volcanic Series

Siletz River Volcanics

The oldest rocks exposed in the Kings Valley area and in the core of the Oregon Coast Range comprise a thick resistant sequence of early to early middle Eocene basaltic pillow lavas and pillow breccias called the Siletz River Volcanic Series. Snavely and others (1968) and MacLeod and Snavely (1973) determined on the basis of petrography and chemical analyses that this volcanic sequence consists of two petrologic basalt types, a lower tholeiitic basalt unit and an upper alkalic, porphyritic basaltic sequence of more local extent. The lower unit comprises the high ridges of basalt on the east side of Kings Valley (Snavely and others, 1968). The upper alkalic basalt unit has not been recognized in this area. Snavely and Baldwin (1948) and Vokes and others (1954) noted subordinate tuffaceous siltstones and basaltic sandstone interbeds in the lower basalt unit in the Marys Peak quadrangle to the south and near Coffin Butte north of Corvallis, respectively. No evidence of interbeds was observed in limited exposures (2 square miles of outcrop) of the lower unit in the Kings Valley area, however. Fresh exposures of the lower unit occur in a quarry on the east side of Kings Valley (center E½ sec. 22 T. 10 S., R. 6 W.) and crop out more extensively along the ridges further east (Plate I). The Siletz River basalts in this area are characterized by closely packed ellipsoidal pillows 1 to 3 feet in diameter (Figure 6). Individual pillows display well developed radial jointing patterns and chilled altered dark glassy tachylyte rims. The pillows are extensively fractured and are composed of very dark gray aphanitic to finely crystalline basalt. Fractures and interstices between pillows are commonly filled with fibrous zeolites (including natrolite, morderite, and chabazite) or are calcite-cemented which would inhibit ground water movement through the rock. Pillow breccias in the Siletz River Volcanics consist of closely packed angular aphanitic basalt fragments 1 inch to 6 inches in length and small isolated broken and unbroken pillows tightly cemented by calcite and zeolites. In thin section, the Siletz River basalts are generally holocrystalline with an intersertal texture composed of interlocking zoned plagioclase laths (labradorite An_{50} to An_{55}) and augite with scattered patches of magnetite and ilmenite and minor apatite, altered olivine, and basaltic glass. The glass groundmass is altered to fibrous green nontronite and yellow-brown chlorophaeite.

The base of this volcanic sequence is not exposed in the Coast Range, but estimates of thickness for this unit and associated epiclastic deposits, based on geophysical studies, exceed 20,000 feet (Snavely and Baldwin, 1948; Snavely and others, 1968).

Kings Valley Siltstone Member

Overlying and possibly interfingering with the Siletz River Volcanics is the early middle Eocene Kings Valley Siltstone, a well-bedded, dark brownish gray tuffaceous siltstone and waterlaid tuff of marine origin. Vokes and others (1954) were first to name and describe this 3,000-foot thick unit as a member of the Siletz River Volcanic Series. The non-resistant siltstone underlies much of Kings Valley with more than 5.1 square miles of outcrop area (Plate I). In road cut exposures, the relatively "soft" thinly-bedded siltstone rapidly weathers to small crumbly medium gray siltstone chips (Figure 7). Fresh exposures also occur in the stream beds and banks of the Luckiamute River and its tributaries. Elsewhere, the unit is covered by stream alluvium, terrace deposits, and thick soils. The siltstones appear to conformably overlie the Siletz River Volcanics in a quarry on the east side of the valley (center E½ sec. 22 T. 10 S., R. 6 W.).

Figure 6. Quarry in fractured Siletz River basalts. Note spheroidal pillows (⟵) and thin immature soil, mostly basalt fragments, developed on top of pillow basalts (⇦) (center E½, sec. 22, T. 10 S., R. 6 W.).

Figure 7. Typical exposure of dipping Kings Valley Siltstones in road cut along Oregon State Highway 223. Note the abundance of mudstone chips in foreground.

The Kings Valley Siltstone contains some thin, white, tuff laminae and 1 to 4-inch thick resistant calcareous lenses of medium-grained basaltic sandstones (Figure 8). In thin section, the argillaceous siltstones are composed of abundant dark clay minerals and the opaque iron oxides, hematite and limonite, along with scattered angular silt-sized clasts of albite twinned plagioclase laths, rare foraminiferal tests, quartz, augite, apatite, and finely disseminated carbonaceous debris. Clay minerals are dominantly montmorillonite with lesser amounts of a mixed layer montmorillonite-mica and chlorite. Zeolites infill silt-sized intraparticle pore spaces, and the zeolite clinoptilolite and calcite infill micro-veinlets in the siltstones. Small irregular laminae of basaltic sandstone are locally interstratified with the clayey siltstones. Sand-sized basalt clasts consist of labradorite laths and augite in an intersertal texture similar in mineralogy and texture to the Siletz River basalts from which they were probably derived. The basalt clasts are partially altered to calcite, iron oxides, clay minerals, and zeolites.

South of the study area, Vokes and others (1954) determined that the Kings Valley Siltstone interfingers with the upper part of the Siletz River Volcanics. No evidence of an interfingering relationship between the two units was observed in the limited exposures in Kings Valley, however. Snavely and others (1968, p. 467) determined that the Kings Valley Siltstone Member is probably equivalent in age (Ulatisian) to the upper alkalic basalt unit of the Siletz River Volcanics. This upper alkalic unit, however, has been recognized only in the Ball Mountain area, near Kernville on the Oregon coast. If only the older lower tholeiitic basalt unit is exposed on the ridge on the east side of Kings Valley as Snavely and others (1968) have reported, it is possible that the Kings Valley Siltstone merely overlies and does not interfinger with the older Siletz River tholeiitic basalts in the Kings Valley area. More geologic study in the area will be necessary to determine the exact stratigraphic relationship between these two units.

Tyee Formation

The youngest sedimentary rocks exposed in the Kings Valley area are the rhythmically bedded and graded deep-marine sandstones and siltstones of the Tyee Formation. These middle Eocene rocks crop out over 6 square miles in the western part of the study area (Plate I). Diller (1896) first named and described this formation in the southern part of the Coast Range in the vicinity of Tyee Mountain northwest of Roseburg, Oregon. Later workers involved with regional mapping of the Tyee (Baldwin, 1947, 1955, 1956, 1961; Vokes and others, 1949, 1951, 1954; Snavely and Vokes, 1949; Snavely and others, 1963, 1964, 1969) extended its formational use throughout much of the central and southern Oregon Coast Range.

The sandstones are principally arkosic, lithic, and feldspathic wackes, containing approximately 30% silt- and clay-sized detritus. In outcrop, the well-indurated sandstone beds are medium greenish gray, fine- to medium-grained, 2 feet to 5 feet in thickness, and are characterized by ubiquitous abundance of carbonaceous plant fragments and mica flakes. The sandstones are generally structureless, except for the rare occurrence of siltstone rip-ups, parallel laminations in the upper two or three inches of the sandstone beds, and sole marks. Grading is defined by sharp bottom contacts and gradational silty upper contacts (Figure 9). The interbedded siltstones and silty mudstones are 1 inch to 4 feet thick, structureless, dark greenish gray, micaceous, and carbonaceous. Sandstones are composed predominantly of angular grains of quartz, euhedral plagioclase (mostly andesine) and volcanic rock fragments (dominantly andesite) with lesser amounts of muscovite and biotite flakes, chert, siltstone rip-ups, microcline,

Figure 8. Bedded Kings Valley Siltstone with thin light-colored tuff lamina (←) and thicker resistant basaltic sandstone rib (⇦) (east stream bank of the Luckiamute River near Kings Valley cemetery). One-foot hammer for scale.

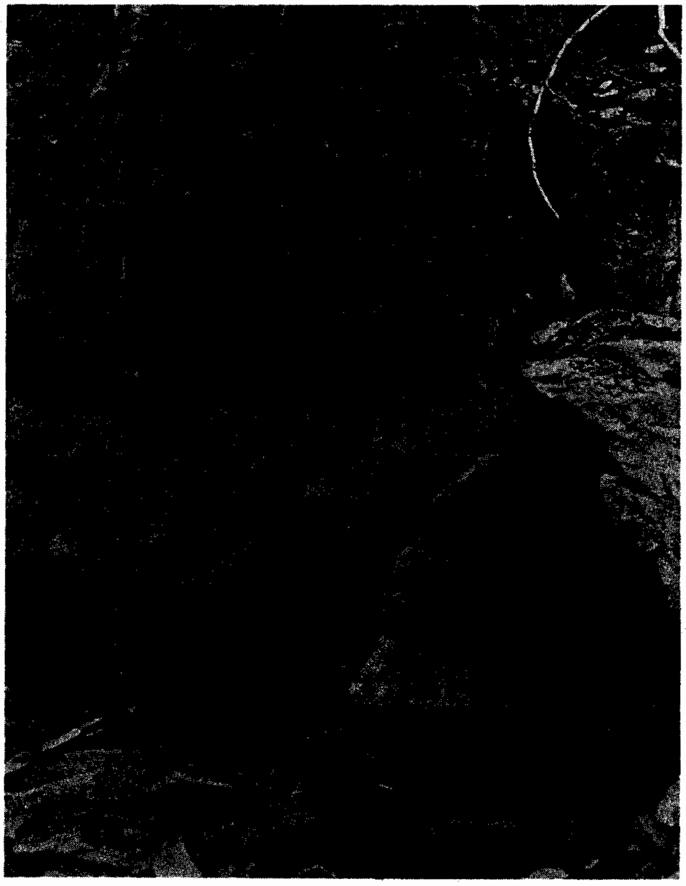


Figure 9. Interbedded graded light gray sandstone (A) and well indurated darker gray siltstone (B) of the Tyee Formation. Note the sharp bottom contact of the sandstone bed and the less distinct upper contact. Quarry on west side of Kings Valley. One-foot hammer in lower right for scale.

orthoclase, basalt, quartz-mica schist and quartzite (polycrystalline quartz) clasts, magnetite, ilmenite, hornblende, and a variety of heavy minerals. Montmorillonite, illite, and mixed layer montmorillonite-mica are the most abundant clay minerals in the sandstone matrix and in the muddy siltstone interbeds between sandstones. The clay matrix in the sandstones appears to be, in large part, diagenetic in origin from the breakdown of chemically unstable volcanic rock fragments. The abundant clay matrix, and locally calcite, act as pore-filling cement between framework grains, creating a well indurated sandstone with little porosity and permeability.

Tyee strata locally disconformably overlie "paleohighs" of Siletz River Volcanics in the Oregon Coast Range (Snavely and others, 1969), but in the Kings Valley area, a general concordance of dips suggests that the Tyee Formation conformably overlies the Kings Valley Siltstone Member of the Siletz River Volcanic Series in this area (Plates I and IA). Estimates of the thickness of the Tyee Formation in the Oregon Coast Range range from 6,000 feet to 10,000 feet (Snavely and others, 1964). In the study area, located on the eastern margin of the outcrop area, only 600 feet of the basal part of the formation are exposed.

Post-Eocene Igneous Rocks

In this report, basaltic and gabbroic intrusive igneous rocks which crop out locally and intrude middle Eocene sedimentary strata (the Tyee and Kings Valley Siltstones) are referred to as post-Eocene intrusive rocks (after Vokes and others, 1954). They are probably Oligocene in age (Baldwin, 1955). Field studies and drillers' logs of wells 10S/6W-15cdc and 10S/6W-22acc$_1$ (Table 1) suggest that these intrusive bodies are nearly concordant tabular sill-like bodies less than 100 feet thick. They crop out in sections 15 and 22 T. 10 S., R. 6 W. (Plate I) where they form low rounded hills. Post-Eocene dikes and sills are more abundant in the Monroe and Marys Peak quadrangles to the south (Vokes and others, 1954; Baldwin, 1955). Petrographically, these rocks are finely to medium crystalline and locally have porphyritic to diabasic textures. Scattered dark green augite phenocrysts are common in an intersertal groundmass of euhedral calcic andesine (An_{30} to An_{50}) and anhedral crystals of augite and magnetite/ilmenite.

These intrusives are dark greenish gray when fresh but commonly weather to a light brownish gray. They also contain closely spaced horizontal and vertical joints. Weathered surfaces are locally pitted due to selective removal of augite phenocrysts. Weathering along joint surfaces forms brownish orange iron oxides and dark metallic gray manganese stains. Insufficient data are available on the hydrologic character of the post-Eocene basalt intrusives in the Kings Valley area because few wells have penetrated these intrusives. Intrusive rocks of this general composition, however, have yielded little water to wells throughout the northern Oregon Coast Range (Illian, 1973).

Valley Alluvium and Colluvium

Stream alluvium and terrace deposits in Kings Valley are very variable in thickness and overlie all but the older volcanic unit. The largest area of terrace deposits and stream alluvium is 4 square miles along the west side of the valley paralleling the length of the Luckiamute River (Plate I). The thickest terrace alluvium is found along the Luckiamute River in the southwestern part of the valley. There, a 65-foot water well south of Hoskins failed to completely penetrate the stream deposit (Table 1 and Plate IA). The floodplain of the Luckiamute River is narrow there and is incised 10 to 30 feet below adjacent terraces. Lateral undercutting of the terrace deposit by meanders of the Luckiamute has locally widened the floodplain. Balster and Parsons (1965) in a soil-geomorphic study of the Kings Valley area recognized and mapped three terrace levels along the Luckiamute. Two low terraces, with a difference in elevation of only 8 feet, parallel the floodplain and comprise most of the terrace deposits. The third, a higher locally preserved terrace, occurs 100 feet above the present level of the Luckiamute River. Balster and Parsons also recognized small pediments developed on the Kings Valley Siltstone which lies between the stream terrace deposits and the steeper highlands to the east and west.

Thin alluvium and terrace deposits (less than 10 feet thick) locally occur along tributary streams on the eastern valley slopes (not mapped on Plate I). Stream alluvium and terrace deposits consist of interbedded chocolate brown, structureless, micaceous silts, clays, minor sands, and thick basalt gravels (Figure 10). The gravels consist of poorly sorted angular to subrounded basalt cobbles and pebbles in a basaltic sand-silt matrix (Plate IA and Appendix A).

Locally, 1 to 20-foot thick colluvium deposits are associated with old landslides and downslope creep of weathered material developed on the Tyee Formation and Siletz River Volcanics along the west and east sides of Kings Valley, respectively. Colluvium on Siletz River Volcanics consists of weathered dark reddish brown iron-stained angular basalt blocks and clays. Tyee colluvium contains weathered broken angular blocks and fragments of sandstone and mudstone in a matrix of light brownish clay.

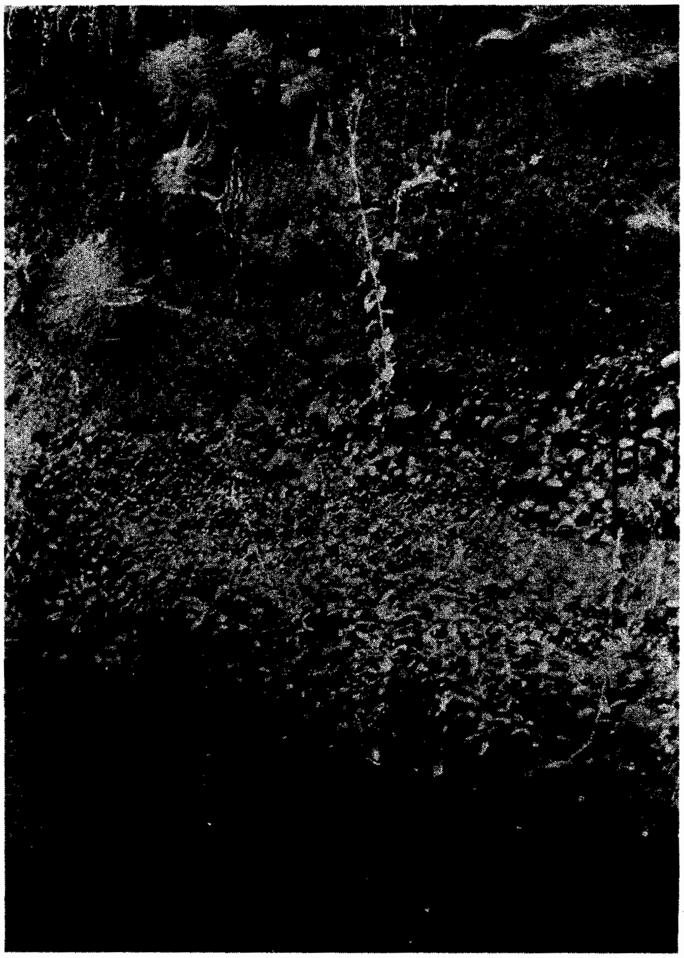


Figure 10. Stream alluvium consisting of poorly sorted basalt gravels (approximately 3 feet thick) overlain by thick structureless clayey silts. Alluvium directly overlies Kings Valley Siltstones in the creek bed. East streambank of Maxfield Creek. Bar scale is one-foot high.

Soils

The Kings Valley Siltstone, the alluvial floodplain, and terraces of the Luckiamute River and its tributaries in Kings Valley are dominated by moderately to well-drained dark brown silty clay loams of the McAlpin-Abiqua association (Knezevich, 1975). The soil is sticky, plastic, medium to strongly acidic, and contains a subsoil of dark reddish brown silty clay to very dark gray-brown silty clay. This subsoil may extend to a depth of 60 inches or more. The McAlpin series is formed in alluvium mainly derived from Siletz River basalts and occurs on lower slopes of areas capped with the Abiqua soil. The Siletz River Volcanics highlands on the east side of the valley are overlain by the Jory-Bellpine association soils which are deep, well drained dark red to reddish brown silty clay loams developed on the basalt colluvium (Knezevich, 1975). The highlands composed of Tyee Formation on the west side of the valley contain deep, dark brown to dark reddish brown silty clay loam and moderately deep, gravelly loams of the Apt-Honeygrove-Bohannon association (Knezevich, 1975). The Apt subsoil is dark yellow brown and is strongly acidic. The dark brown Bohannon series soils are dark brown, 20 to 40 inches deep, and are sandy being developed from weathering of Tyee sandstones. Runoff is very high in these soils.

Detailed soil mapping and investigation of the relationship between soils and geomorphic floodplain and terraces between Price Creek and Woods Creek in Kings Valley was undertaken by Balster and Parsons (1968). In a related study, Parsons and Balster (1965) showed that Ca- and Mg-rich ground water seeping from a fault on the east side of the valley resulted in enrichment of calcium and magnesium in soils downslope from the fault.

GROUND WATER

Modes of Occurrence

All water that occurs beneath the earth's surface in the zone of saturation is called ground water (Davis and DeWiest, 1970). Ground water may have three modes of occurrence, either as unconfined, confined, or perched water.

Unconfined Water

Unconfined ground water is in direct contact with the atmosphere through interconnected pore spaces of the host rock or alluvium. In the Kings Valley area, unconfined ground water occurs locally above the indurated rock units in stream alluvium and terraces covering the valley floor (Plate I). Only where thickest deposits of valley alluvium occur, as in the southwestern part of Kings Valley (Plate I), do unconfined ground water sources yield useable quantities of water to wells throughout the year. In winter months floodplain alluvium and terrace deposits locally may be nearly saturated to the surface and a significant proportion of a few well yields in the thick valley alluvium may be from this source. In summer months the saturated zone within the alluvium is much thinner or may be entirely absent. However, the minimum casing requirements of the well-drilling regulations effectively prevent developing of ground water from the alluvium and stream terraces at most places in the valley.

Confined Ground Water

Confined ground water occurs in an aquifer which is separated from the atmosphere by one or more impermeable layers (aquicludes). In some geologic situations, no clear division may exist between ground water classified as confined water and that classified as unconfined water. In this study, water-bearing zones separated from the surface by a leaky aquitard which permits some recharge directly from infiltration from above are interpreted to constitute zones of semi-confined water. Ground water in most wells in Kings Valley occurs under semi-confined and/or confined conditions in the Kings Valley Siltstone Member.

Most of the wells penetrating the Kings Valley Siltstone are artesian in character. Drillers' logs indicate that typically in most wells, over a period of several hours after the first penetration of a semi-confined or a confined water-bearing zone 40 to 220 feet below the surface, the water level in an artesian well will rise to within 4 to 60 feet of the land surface (Table 1). Well logs suggest that confined ground water generally occurs more than 100 feet below the surface in more sandy or fractured thin-bedded siltstone units (Appendix A). Water-bearing zones less than 100 feet below the bedrock surface contain semi-confined water. These zones of semi-confined water probably are recharged in part from slow leakage of unconfined water from overlying alluvial and terrace deposits and streams during rainy winter months down into the underlying siltstones. Locally, joints and fractures in the siltstones may aid in conducting water to more permeable fracture zones below.

Perched Ground Water

Perched ground water is ground water in an aquifer that occurs above the regional ground water table. The position of perched ground water is commonly controlled by structure or the stratigraphy of the rock units in an area. Perched zones are recharged by downward percolation of water through the zone of aeration and by lateral movement of ground water along the upper surface of less permeable strata. Springs commonly result from the intersection of the surface of the earth with perched water zones.

In the study area, perched water is commonly associated with the Tyee Formation in the hilly area on the west side of Kings Valley. Many residents in the Hoskins area obtain domestic water supplies from shallow dug wells (less than 20 feet deep) or from springs which flow from one or more perched water bodies in the colluvium overlying the relatively impermeable Tyee strata. These perched aquifers generally have limited water storage and recharge areas and in general yield small to moderate quantities of water to wells and springs. These springs occur approximatel 200 feet above the nearby piezometric surface in the Kings Valley Siltstone (Plate II).

Source and Movement of Ground Water

The source, abundance, mode of occurrence, and movement of ground water is a function of the geologic and hydrologic characteristics of the rock units and unconsolidated sediments present. For purposes of discussion, the Kings Valley study area is divided into three subareas having different geologic, hydrologic, and physiographic characteristics. These subareas include (1) the eastern upland recharge area underlain predominantly by the Siletz River Volcanics, (2) the central lowland discharge area covered locally by thin alluvium and terrace deposits and underlain entirely by the Kings Valley Siltstone, and (3) the northern and western upland area underlain by Tyee strata. The boundaries of these subareas coincide with the outcrop patterns of the geologic units in the valley (Plate I and Figure 11).

Eastern Upland Recharge Area

The eastern upland subarea covers approximately 2 square miles and consists of north to northeasterly trending ridges composed of Siletz River Volcanic breccias and basaltic pillow lavas which are covered by the thin red residual Ritner soil of basalt fragments, iron oxides, and clays. The thin pebbly well-drained soil permits rapid infiltration of a substantial part of the more than 70 inches of annual precipitation which falls in this area. The highly fractured and jointed nature of the basalts further allows water to migrate to the ground water table. For this reason and because of the low infiltration rate in the relatively impermeable Kings Valley Siltstone, the eastern upland area is probably the principal source of recharge for the ground water in the valley plain below. Some recharge also occurs in the western upland area underlain by the Tyee strata.

Most of the recharge occurs in the rainy winter and spring seasons (Figure 5). No quantitative measurement of annual recharge has been attempted due to the lack of information on precipitation, evapotranspiration, and runoff rates in the area. Due to the lack of residences, domestic water wells are absent from the forested eastern upland area. In addition, no water wells in Kings Valley have penetrated the Siletz River Volcanics below the Kings Valley Siltstone in the adjacent valley plain. Thus, little information is available as to the hydrological character of these basalts.

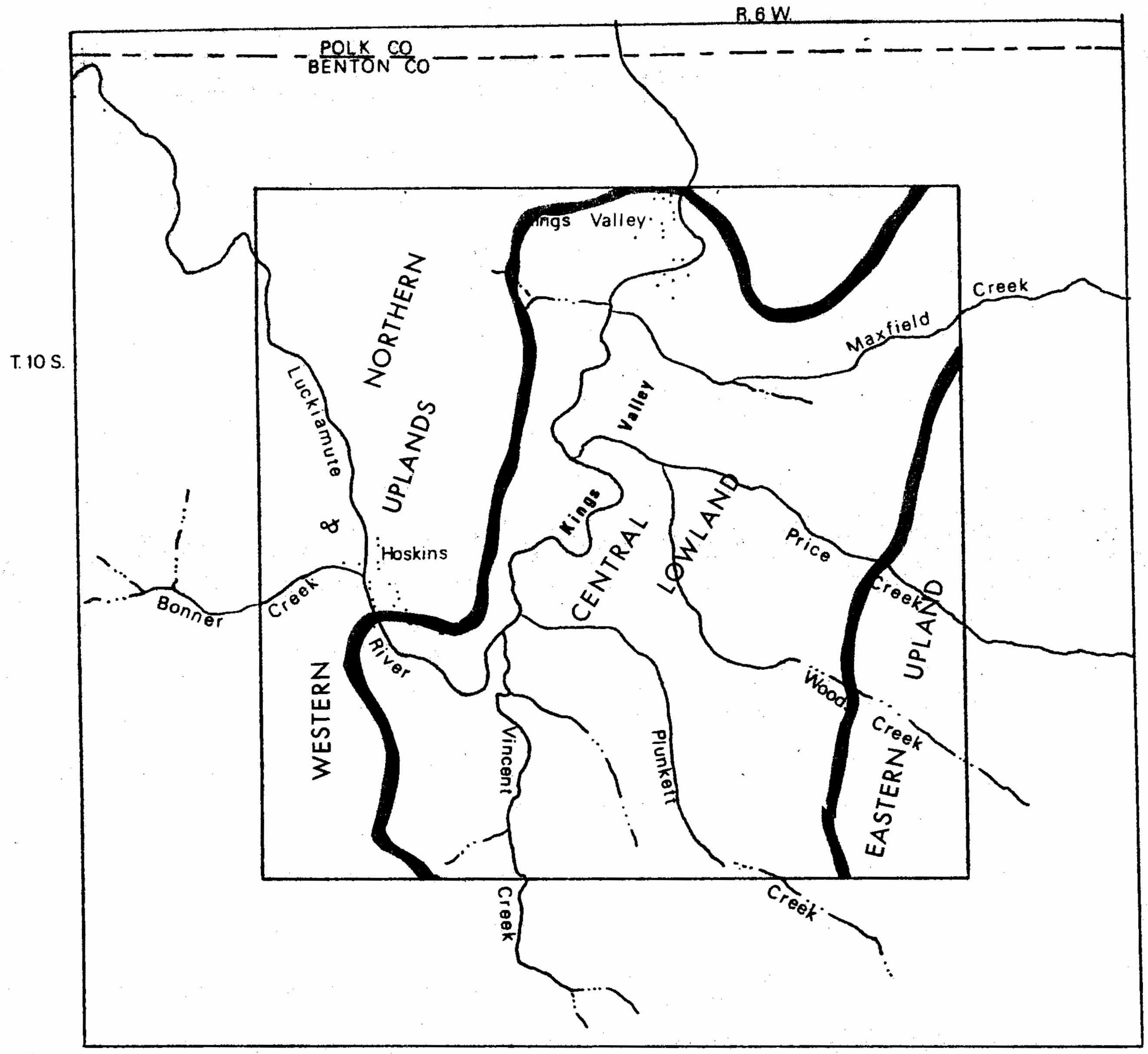


Figure 11. Ground water subareas of Kings Valley area.

Moderate well yields in the range of 15 to 60 gpm have been obtained from these volcanic rocks in the Philomath-Corvallis area, 12 miles to the southeast (Frank and Johnson, 1972; Ray Gellatly, well driller, 1975, personal communication). In general, the yield from the volcanic rocks exceeds yields from the Tertiary sedimentary sequences in that area. A similar yield should be expected in the eastern upland area of Kings Valley.

Because basalt lacks primary intercrystalline porosity, ground water probably flows through poorly developed interconnected fractures related to the pillow jointing pattern, through interstices between pillows, and along many small high-angle normal and reverse faults that cut the basalts. Such fractures are well-exposed in a quarry on the east side of the valley (center E½ sec. 22 T. 10 S., R. 6 W.). Many fractures, however, have been partially filled by secondary mineralization by zeolites, calcite, and chalcedony. Some perched water concentrated along these fractures has created springs and seeps along the steeper hills on the east side of Kings Valley. These springs and seeps supply base flow to the several streams that drain this subarea.

Central Lowland Discharge Area

The central lowland subarea is locally overlain by stream alluvium and terrace deposits and underlain by the Kings Valley Siltstone Member. The siltstone member is the principal aquifer in Kings Valley, and nearly all wells in the lowland area obtain their water from this unit. Most discharge occurs either artificially by pumping through wells or naturally by evapotranspiration where the water table is near the surface and by springs and seepage into nearby streams.

The configuration of the regional piezometric surface within the Kings Valley Siltstone for May, 1975, is shown on Plate III. The piezometric surface probably reflects the mean potentiometric heads of several confined water-bearing zones in the Kings Valley aquifer because it is likely that there has been water circulation between confined and shallow semi-confined water-bearing zones with different heads via the uncased wells. Contour lines on Plate III connect points of equal potentiometric surface elevation. Ground water moves down gradient at right angles to the contours from the Siletz River Volcanics eastern uplands area down dip in a northwesterly direction through the Kings Valley Siltstone underlying the valley plain. Although the hydraulic gradient calculated from the slope of the piezometric surface is steep (154 feet per mile), the rate of ground water movement in the central lowlands is probably very slow due to the low permeability of the Kings Valley Siltstone. No effect of the Kings Valley fault is noted on the position or shape of the piezometric surface (Plates I and III).

Low permeabilities in the Kings Valley Siltstone are suggested because well yields and specific capacities, although variable, are generally low at most places in the valley. Bailer tests by well drillers indicate that most well yields range from ½ to 40 gpm and average 11.6 gpm (Table 1). Specific capacities determined regionally from bailer tests on logs of 19 wells in the Kings Valley Siltstone are low, ranging from 0.01 to 2.0 gpm/ft average 0.35 gpm/ft. Most yields are adequate for domestic or stock uses. Because the Kings Valley aquifer yields water slowly to wells, there is little probability of regionally dewatering the aquifer by domestic over-pumping. However, most wells probably could not sustain more than moderate withdrawals (e.g. > 50 gpm) for more than a few hours. Distribution of data on well yields in the valley (Figure 12) suggests that the highest yields may be expected on the eastern valley slopes adjacent to the Siletz River Volcanics ridge whereas lower well yields (generally less than 10 gpm) are probable in the southwestern part of the valley. For example, eight wells with a total penetration of 1,342 feet in the Kings Valley Siltstone located south of Hoskins yield in total 32 gpm whereas an equal number of wells which penetrate nearly the same thickness of strata in the eastern part of the valley yielded a total of 130 gpm. It is not clear whether the cause of these greater yields can be attributed to differences in well construction or that the upper part of the Kings Valley Siltstone in the eastern part of the area has greater transmissivities. Well log data (Table 1 and Appendix A) also suggest that domestic wells drilled deeper than 150 to 200 feet into this aquifer generally have not significantly increased the yield and were less likely to produce ground water of good chemical quality.

Fresh samples of the muddy siltstones are well indurated (Figure 13) and relatively impermeable. Drillers' logs (Appendix A) indicate that confined ground water is supplied to wells by the intersection of the well with several zones of fracture or sandstone layers within the Kings Valley Siltstone. One water-bearing fracture zone occurs between 40 and 80 feet below the surface and two or more zones are intersected between 100 and 400 feet. These fracture zones do not appear to be laterally continuous from one well to the next. Closely spaced 1/32 inch to 1/4 inch wide fractures can be traced for several inches on outcrops of the siltstones and are generally subparallel to bedding or are nearly vertical joints (Figure 8).

Water movement between surface streams and confined water-bearing zones in this area is probably minimal because of the low permeabilities of the siltstones.

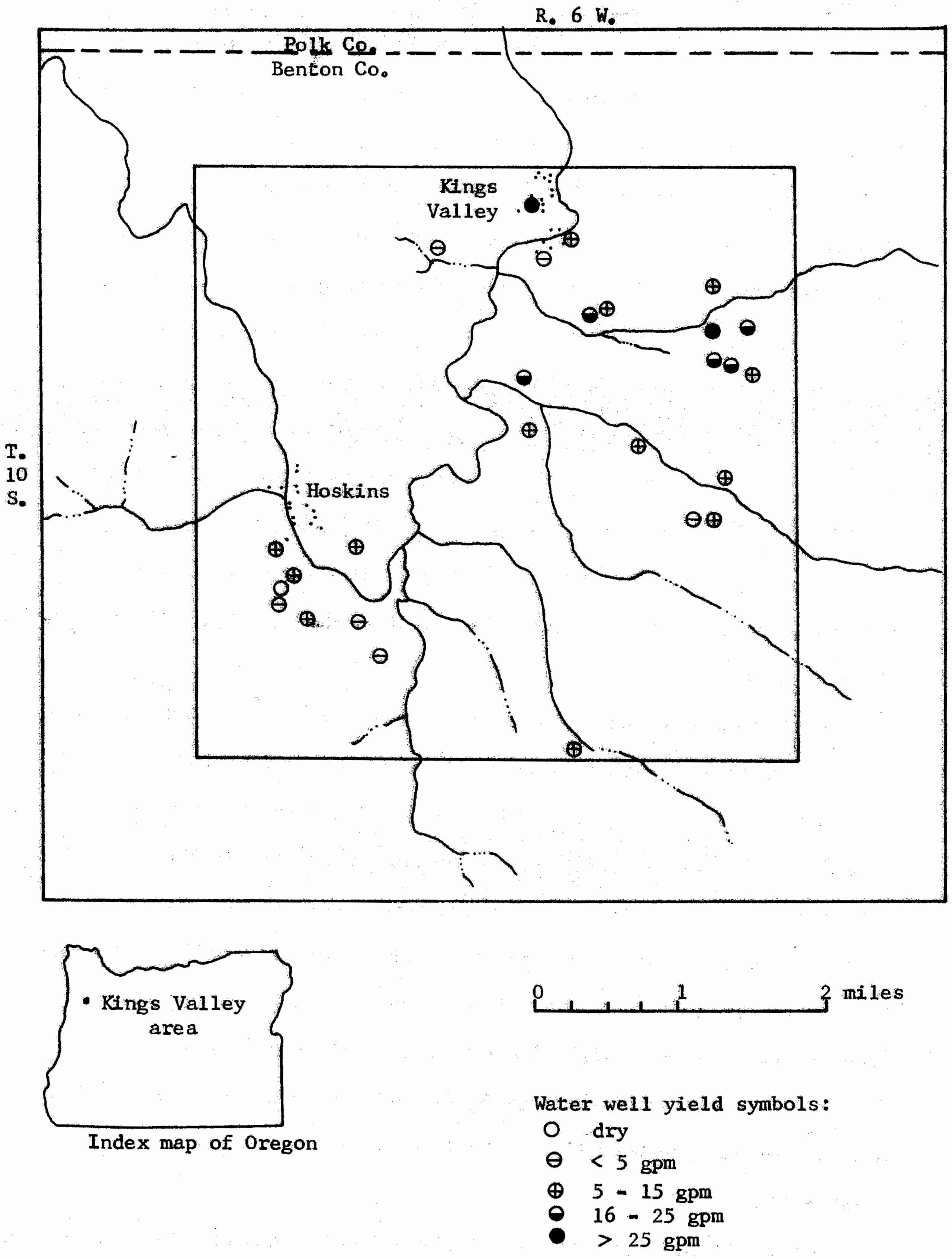


Figure 12. Water well yields map of the Kings Valley area.

Figure 13. Close-up of sample of fresh well indurated Kings Valley Siltstone, from roadcut on east side of Oregon State Highway 223

Pump Test

A pump test was conducted on well 10S/6W-27bab$_2$ to determine aquifer characteristics such as transmissivity and storage coefficients of the Kings Valley Siltstone. The pump-tested well is 6 inches in diameter and 122 feet deep in Kings Valley Siltstone with one fracture zone. The observation well (an older abandoned well) is 25 feet away and 15 feet deep. Both wells had approximately the same water table level before pumping. During the 2 hour-40 minute period in which the test was conducted with a constant pumping rate of 7.1 gpm, there was a total drawdown of 40.38 feet in the pumping well, but no change in the water level in the observation well. Because there was no drawdown in the observation well, the Theis equation (1935) modified by Cooper and Jacob (1946) for calculating storage and transmissivity coefficients of the Kings Valley Siltstone could not be used.

The pump test gives the magnitude of drawdown of a pumping well at a constant rate over a short period of time in the Kings Valley Siltstone. Figure 14 is a time-drawdown graph of the pumping well constructed from the results of the test. The specific capacity (rate of yield of well in gallons per minute per unit of drawdown at the stated yield) of the pumping well in a 2-hour 40-minute period in the Kings Valley Siltstone was 0.18 gpm/ft. This specific capacity is low and reflects the relatively low permeability of the Kings Valley Siltstone at this well.

Transmissivity

Walton (1970) published a modified non-equilibrium formula for estimating transmissivity of an aquifer using data from a pumping well only. The formula expresses the following relationship:

$$T = \frac{264Q}{\Delta S} \quad \text{in gpd/ft} \quad \text{or} \quad T = \frac{35.3Q}{\Delta S} \quad \text{in ft}^2\text{/day}$$

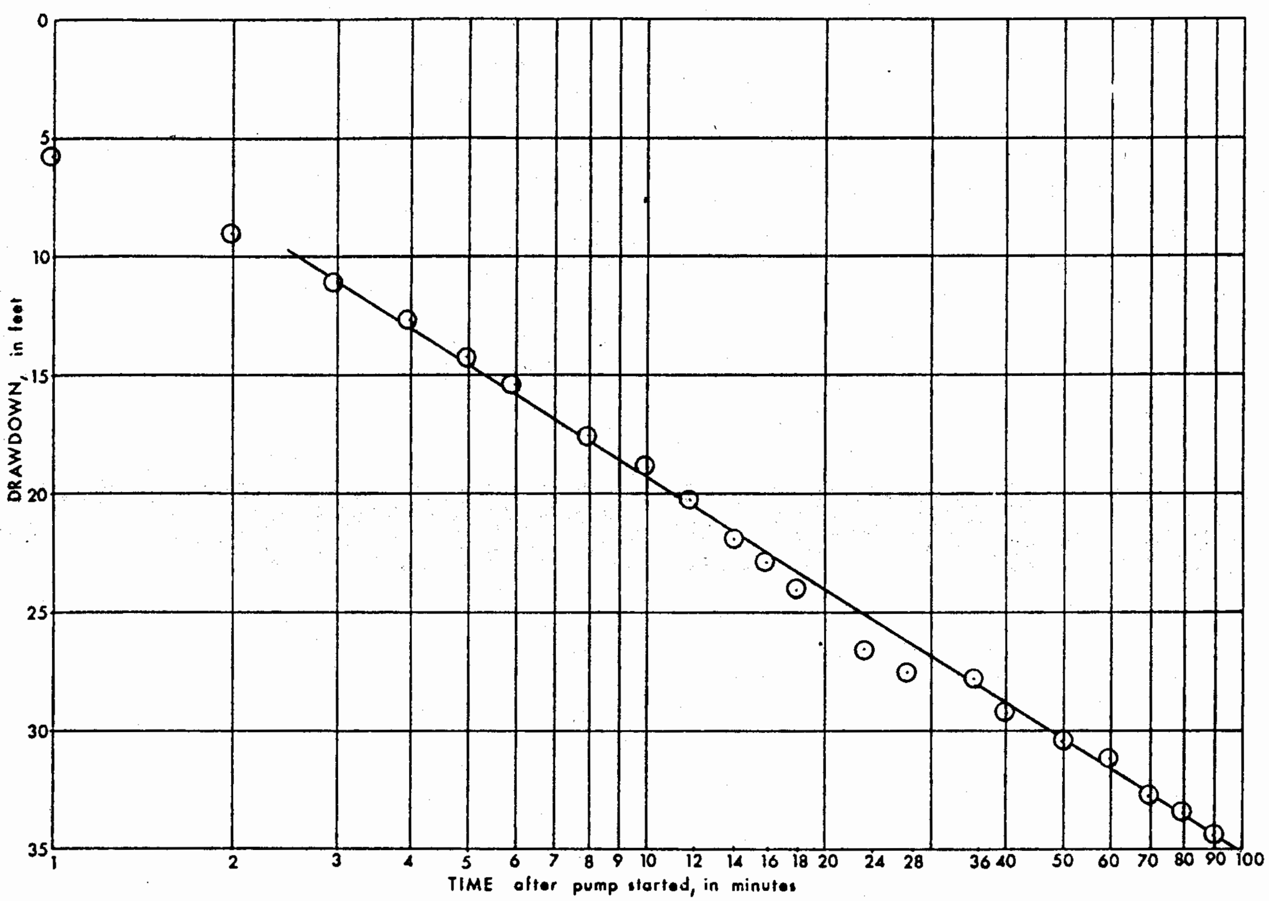


Figure 14. Time-drawdown diagram of pumping well.

Using the data from the time-drawdown graph of the pumping well (Figure 14):

$$S = 16 \text{ ft}; \qquad Q = 7.1 \text{ gpm}$$

Thus,

$$T = \frac{264\ (7.1)}{16} = 120 \text{ gpd/ft}$$

or

$$T = \frac{35.3\ (7.1)}{16} = 16 \text{ ft}^2/\text{day}$$

Thus, field pump test data indicate that transmissivity in the Kings Valley aquifer is low as one would expect in these siltstones. A problem is that these equations depend upon several theoretical assumptions: namely, the aquifer is not stratified, aquifer is not variable in thickness, the aquifer is homogeneous, the aquifer is infinite in extent, and the discharging well penetrates the entire thickness of the aquifer. The Kings Valley Siltstone may not fulfill these theoretical assumptions.

Water in Storage

Because data are not available to determine the storage coefficient in the locally fractured Kings Valley Siltstone, only a rough estimate as to the total ground water available in storage (to a depth of 200 feet) in the siltstones under Kings Valley has been attempted. Most confined aquifers have storage coefficients that range from 10^{-5} to 10^{-3} and are approximately 10^{-6} per foot of thickness (Lohman, 1972, p. 8 and 53). Assuming a storage coefficient of 10^{-6} to 10^{-4} for aquifer thicknesses of 1 foot to 100 feet, respectively, in the siltstones, the volume of stored water which can be released from the Kings Valley Siltstone with a 200-foot head decline throughout 5.1 square miles of the valley is approximately 0.64 to 64.0 acre-feet. Since the Kings Valley Siltstone is not homogeneous in fracture porosity, the storage coefficient and total water in storage in the siltstones could be conceivably much higher in different areas of the valley.

Unconfined Water Zones

An unconfined water-bearing zone occurs locally in the stream and floodplain alluvium and in the surrounding terrace deposits that overlie the Kings Valley Siltstone in the central lowland area. It is this local zone that is probably responsible for maintaining a base flow to the streams in the area year-round. Water yields from the alluvium and terrace deposits are generally variable (from less than 5 gpm to greater than 20 gpm). Low yields can be expected in the alluvium and terrace silts and clays because of their poorly sorted nature and abundant clay matrix. The terrace and stream gravels with higher porosities and permeabilities will provide much higher yields but have limited storage. Since most steel well casings completely penetrate these alluvial and terrace materials, little or no water can flow into these wells from these unconfined aquifers. Commonly, the higher terrace deposits are located in the zone of aeration.

Water Table Fluctuations

Ground water levels fluctuate from year to year and seasonally in response to natural and man-induced changes in recharge and discharge. Water table fluctuations in the central lowland area underlain by the Kings Valley Siltstone and valley alluvium were determined by periodic measurements of an observation well (no. 10S/6W-21abb) by the Oregon State Engineer's Office in the years 1970 through 1975. Figure 15 illustrates a hydrograph of this well. It is apparent from comparing Figure 15 and Figure 5 (precipitation curve for Kings Valley) that water levels are highest (January through April) following periods of greatest precipitation and greatest recharge and are lowest (August through October) following periods of least precipitation and least recharge. Annual water table fluctuation for these years is approximately 10 feet. The well does not show any obvious long-term fluctuation in water levels for the years 1970 through 1975.

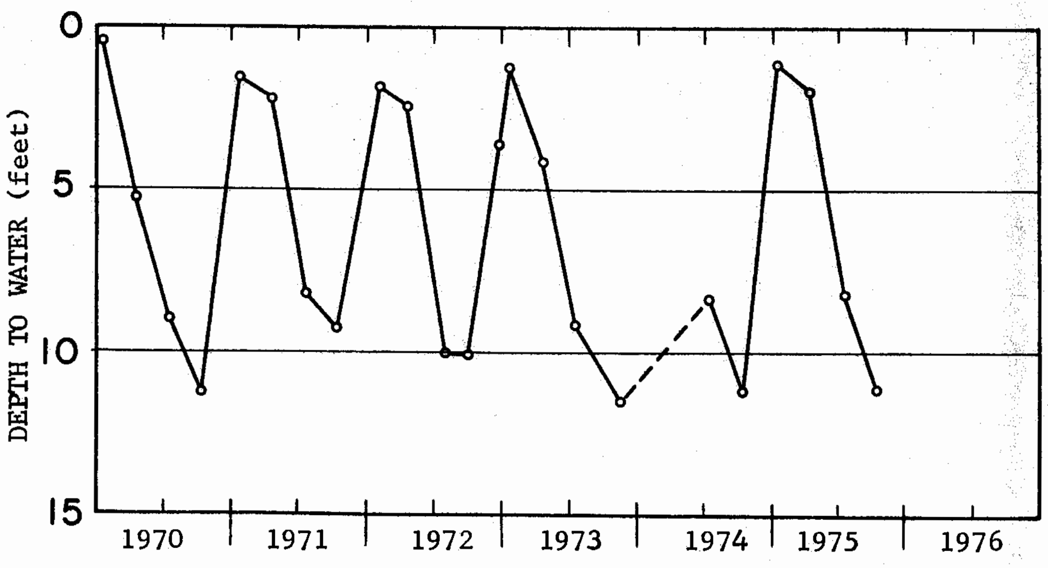


Figure 15. Hydrograph of well 10S/6W-21abb in Kings Valley Siltstone for the period 1970-75.

Northern and Western Uplands

The northern and western upland subarea covers approximately 6 square miles consisting of the hilly area underlain by Tyee strata (Plate I). Some ground water recharge to the valley probably occurs in this upland area. However, in general, the rocks found in this area are the least permeable of any in the study area and yield very small quantities of water to wells. Four wells penetrating both the Tyee Formation and the Kings Valley Siltstone yield 1 to 12 gpm and average 6 gpm. Specific capacities of these four wells calculated from bailer tests are also very low, ranging from 0.01 to 0.10 gpm/ft, average 0.05 gpm/ft. Frank (1973) determined that, in the Eugene-Springfield area, water-bearing zones in the Tyee are generally discontinuous lenticular beds of sandstone and shale with well yields generally less than 10 gpm. Study of Tyee sandstone thin sections indicates that extensive diagenetic breakdown of the unstable mineral and volcanic rock fragments in the sandstones has produced abundant quantities of montmorillonite, illite, and mixed layer clay matrix and calcite and iron oxide cements. These materials have almost completely filled and cemented interparticle pore spaces in the sandstones, virtually destroying any primary porosity and permeability. Snavely and others (1964, p. 468) determined from 17 representative samples collected throughout the Coast Range that effective porosity of the Tyee sandstones is low (average 14%) and permeabilities are very low (average 2.7 millidarcies), ranging from 0.2 to 4.5 millidarcies. The low permeabilities in these sandstones is unusual compared to much higher permeabilities typical of many sandstones (Davis and DeWiest, 1970). The unstable mineralogical character of these compositionally immature lithic sandstones and associated extensive diagenetic alteration can account for these very low permeabilities and should be expected in areas underlain by volcanic sandstones throughout the Oregon and Washington coast ranges.

Examination of Tyee rocks in quarry exposures in the study area suggests that ground water moves through these rocks principally along bedding planes between sandstones and mudstones and by permeating down and through joints or fractures (Figures 16 and 9). The Tyee contains two sets of nearly vertical joints striking N 30° E and N 57° W. Joints are 1/16 inch to 1/4 inch wide with a spacing 1/2 inch to 5 feet apart. The highest yields in the unit probably will be obtained where joint or fracture systems are concentrated in the subsurface. Well log data from the few wells that penetrate these rocks in this area suggest that ground water is being derived from a fracture system.

The majority of residents in the area underlain by Tyee rocks near Hoskins obtain their domestic supplies from springs. These springs commonly form on the unit along hillsides where perched unconfined water has seeped down through the overlying soil and colluvium to the contact of the underlying nearly impermeable Tyee Formation and the overlying colluvium and soil. There, it flows along this contact until it intersects the hillside, forming a spring. Seasonal flow in these springs can be expected to be variable because of the limited storage and dependence on rainfall. Lower yields can be expected during the long dry summers. Well 10S/6W-30bbc is a shallow, old, dug well in colluvium and the Tyee Formation that yields adequate quantities of ground water of excellent chemical quality (Table 2) for domestic use.

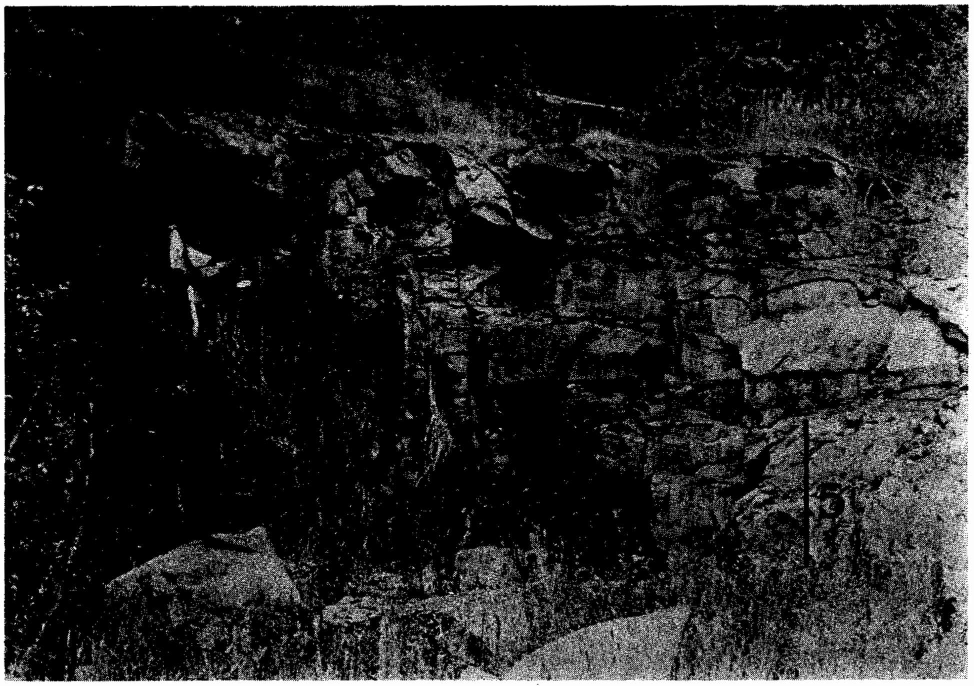


Figure 16. Quarry exposure of resistant Tyee Formation on southwest side of Kings Valley (SW¼ NE¼ NW¼ sec. 30, T. 10 S., R. 6 W.). Note joint-fracture system in strata and seep in center of photograph (arrow). Bar scale is 5 feet high.

Chemical Quality of the Water

The overall chemical quality of ground water in Kings Valley is satisfactory for most purposes with the exception of one deep well (10S/6W-21aba) where brackish water was penetrated in the marine Kings Valley Siltstone. Most water samples are potable and within the desirable range of salinity and hardness for public uses as prescribed by the U.S. Public Health Service (Davis and DeWiest, 1970, p. 121). Springs and surface water in Kings Valley are also of excellent quality within the limits of the 14 chemical and biological constituents that were analyzed.

Water chemical analyses are reported in Table 2 in milligrams per liter (mg/l).

The following chemical constituents were analyzed and related to mineralogical composition of the rocks: ionic concentrations of sodium, calcium, magnesium, carbonate, bicarbonate, potassium, iron, chloride, silica, sulfate, nitrate, and fluoride; temperature, pH, hardness, and total dissolved solids. The suitability of ground water for irrigation (SAR index), MPN-bacte count, and the areal variations in water chemistry are then considered.

Sodium

Sodium, unlike silica, calcium, and magnesium, is not an abundant constituent of the common rock-forming minerals. The primary source of most sodium in ground water is from the weathering of plagioclase feldspar (Davis and DeWiest, 1970). For example, one such chemical reaction is:

$$\underset{\text{albite}}{2NaAlSi_3O_8} + 2CO_2 + 3H_2O \rightleftharpoons \underset{\substack{\text{clay}\\\text{(kaolinite)}}}{Al_2Si_2O_5(OH)_4} + \underset{\text{aq}}{2Na^+} + 2HCO_3^- + 4SiO_2$$

Concentration of sodium in natural waters ranges from 0.2 mg/l in some rain to more than 100,000 mg/l in brines in contact with salt beds.

Sodium concentrations in well water range from 5.2 to 640 mg/l and average 121 mg/l in the Kings Valley area (Table 2). The highest concentrations occur in the northern and southwesternmost part of the valley (Plate II). In those locations, high sodium concentration is associated with high concentrations of chloride. Sodium concentrations are lowest in an east-west band across the center of the valley and in the southeastern part of the valley (Plate II).

The lowest sodium concentrations (3.2 to 7.8 mg/l) are in streams and springs in Kings Valley (Table 2).

Sodium concentrations exceeding 200 mg/l and 300 mg/l are considered objectionable for drinking purposes and for general household use and irrigation, respectively (Davis and DeWiest, 1970, p. 121). Sodium in concentrations of 200 mg/l or more may have adverse physiological effects. Water from three wells (10S/6W-16cdd, -16cab, -21aba) in the northern part of Kings Valley have objectionable concentrations of sodium (300 to 640 mg/l) (Table 2).

One deep well (no. 10S/6W-21aba; 243 feet) in the valley encountered the highest concentrations of sodium (640 mg/l) and chloride (1,690 mg/l), suggesting that connate water is being encountered and/or that permeability is sufficiently low in the Kings Valley Siltstone to prevent much active circulation and flushing of meteoric water over long periods of time. A relatively shallow well (10S/6W-16cdd, less than 50 feet) in the northern part of the valley also encountered sodium and chloride-rich water.

In the Tertiary mudstones of the California Coast Ranges, saline sodium chloride water is also encountered at depths of only a few tens of feet below the bottoms of stream valleys, probably due to little flushing action due to the low permeability of these fine-grained sedimentary rocks over hundreds of thousands of years according to Davis and DeWiest (1970,

p. 370). It is suggested that drilling below 200 feet in the central lowland of Kings Valley increases the possibility of encountering water with highly unsuitable sodium contents.

Davis and DeWiest (1970, p. 105) noted that ground water with total dissolved solids ranging from 1,000 to 5,000 mg/l generally has more than 100 mg/l of sodium. It is interesting to note that in the nine wells in Kings Valley that have sodium concentration greater than 100 mg/l (ranging from 120 to 313 mg/l), total dissolved solids are significantly less than 1,000 mg/l (ranging from 316 mg/l to 804 mg/l, Table 2). In addition, these wells have sodium concentrations that are 2 to 7 times that of chloride concentrations (Table 2), suggesting that not all of the sodium is associated with connate sodium chloride water in the formation. These unusual, higher than normal, sodium concentrations relative to total dissolved solids coupled with lower than normal Ca^{++} and Mg^{++} concentrations (some with only tenths of a percent, Table 2) suggest cation exchange of Ca^{++} and Mg^{++} for Na^{+} in the abundant clays and zeolites in the tuffaceous Kings Valley Siltstone.

X-ray diffraction analysis shows that montmorillonite clays are an abundant clay group in the Kings Valley Siltstone. The montmorillonite clays have high capacities for cation exchange due to their 2:1 expandable lattice structure and chemistry (Grim, 1953). One such reaction would be:

$$2\ \text{Na mont. clay} + Ca^{++}_{aq} \longrightarrow \text{Ca clay} + 2\ Na^{+}_{aq}$$

(modified from Verhoogen, Turner, Weiss, Wahrhaftig, and Fyfe, 1970, p. 403)

Ground water studies have shown that clay minerals are also known to release large quantities of exchangeable sodium (Renick, 1925; Piper and others, 1953; Foster, 1942). Zeolites are also well known for cation exchange capabilities (Hay, 1966). The Ca-Na-rich zeolite clinoptilolite

$((CaNa_2)(Al_2Si_7O_{18}) \cdot 6H_2O)$ has also been recognized in Kings Valley Siltstone thin sections and X-ray diffraction analysis. Other zeolites, including sodium-rich natrolite ($NaAlSi_5O_5 \cdot H_2O$), identified in the vug interstices of the Siletz River Volcanics in the eastern highland recharge area are also possible sources for sodium by solution and cation exchange.

Calcium

The concentration of calcium in normal potable ground water generally ranges from 10 to 100 mg/l (Davis and DeWiest, 1970, p. 103) although concentrations up to several hundred mg/l are not uncommon. Calcium concentrations in ground water samples from Kings Valley are quite low relative to that normally expected in ground water. More than two-thirds of the samples contain less than 10 mg/l calcium, and four samples contain less than 1 mg/l calcium (Table 2). Cation exchange and removal of calcium in solution for sodium in the montmorillonite clay minerals and zeolites in the presence of organic matter and alkaline pH conditions in the Kings Valley Siltstone may account, in part, for these low values. This exchange reaction is further discussed in the sections on sodium and hardness. Further evidence of preferential cation removal of calcium in solution in the subsurface is that calcium concentration in the Kings Valley streams is higher than in many of the wells (Table 2). It has been shown that calcium solubility increases with higher salinity (Davis and DeWiest, 1970, p. 103). This relationship probably accounts for the anomalously high calcium concentration in the brackish water from the Albright well (10S/6W-21aba, Table 2).

Ground water in rocks containing some calcite typically is saturated or nearly saturated with respect to calcite whereas most streams tend to be undersaturated (Stumm and Morgan, 1970). Figure 17 from Stumm and Morgan shows the comparison of the Kings Valley water samples in terms of

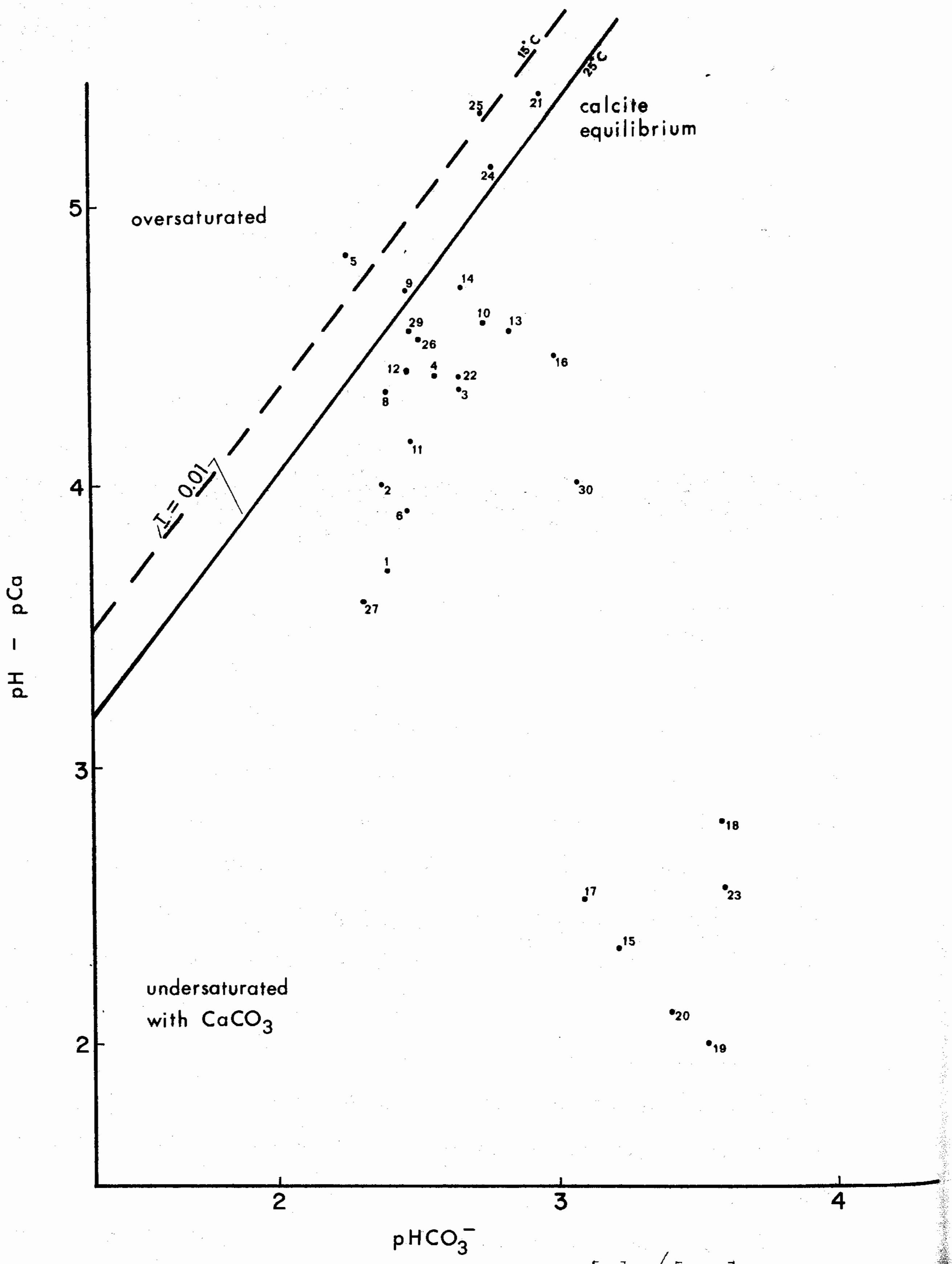


Figure 17. Calcite equilibrium diagram. $[H^+] / [Ca^{++}]$ is plotted as a function of $[HCO_3^-]$ in terms of their negative log concentrations. I=0.01 is the ionic strength and 25°C is the temperature of the solution for which the calcite equilibrium condition is defined (after Stumm and Morgan, 1970, p. 410).

bicarbonate, hydrogen, and calcium ion concentrations (Table 2) with the calcite equilibrium composition for the reaction:

$$CaCO_3 + H^+ \rightleftharpoons Ca^{++} + HCO_3^-$$

The dashed line and the solid line in the figure represent the calcite equilibrium at saturation at 15° C and 25° C, respectively. Although the siltstones contain some calcite cement, this plot indicates that most of the ground water in Kings Valley is somewhat undersaturated with respect to calcite and that precipitation of calcite under the high pH and moderately high bicarbonate conditions probably cannot alone account for the low calcium in ground water (see section on hardness for further explanations of low calcium concentrations). Only two samples are oversaturated at 15° C, roughly the temperature of ground water in Kings Valley (see section on temperature and pH). Figure 17 also shows samples from springs (samples no. 17 and 18 in Table 2) and two wells (samples no. 15 and 19) that are undersaturated and plot in the same region as surface water samples. It was observed in the field that surface water enters well 10S/6W-30bbc (sample no. 12) which suggests that surface water may enter well 10S/6W-28bbb also and may thus account for the undersaturated condition. The springs are probably fed by near surface unconfined perched water and not from deeper confined water-bearing zones.

Probable primary sources of dissolved calcium in these rocks would be from the weathering, predominantly hydrolysis, and diagenetic alteration of calcium-rich plagioclase and clinopyroxene (as in the labradorite and augite in the Siletz River Volcanics in the recharge area and basaltic sandstone laminae in the Kings Valley Siltstone). The concentrations of calcium in Kings Valley are very low and should present no problem for drinking and household use.

Magnesium

Although magnesium compounds have higher solubilities than calcium compounds, magnesium is generally found in lesser concentrations in ground water than calcium, probably due to the greater abundance of calcium in the earth's crust (Davis and DeWiest, 1970, p. 104). Common concentrations in natural ground water range from 1 to 40 mg/l. Similar to the Ca^{++} concentrations, Mg^{++} in all but one of the ground water samples in Kings Valley is low (0.1 to 11.0 mg/l) averaging 1.9 mg/l. This average excludes the single relatively high magnesium sample from well no. 10S/6W-22acc which is located near the Kings Valley fault. This well may have encountered some of the Mg^{++} and Ca^{++} rich water percolating up along the fault postulated by Balster and Parsons (1965). Considering the abundance of ferromagnesian source minerals (such as augite) in the Siletz River Volcanics in the recharge area, more dissolved magnesium might be expected. Ten wells contain ground water having less than 0.5 mg/l magnesium (Table 2). Generally, the lowest Mg^{++} concentrations occur in wells having highest sodium and lowest calcium concentrations (Table 2). This relationship and the occurrence of higher Mg^{++} concentrations in surface water and spring samples (av. 2.8 mg/l) than in many ground water samples (Table 2) substantiates probable cation exchange of Na^{+} for both Mg^{++} and Ca^{++} ions by the abundant montmorillonite clays and minor zeolites in the Kings Valley Siltstone. Similar low values of Mg^{++} and Ca^{++} ions are found in well water from Gulfport, Mississippi, which are thought to also have undergone natural softening by cation exchange in the clays (Davis and DeWiest, 1970, p. 104).

Carbonate and Bicarbonate Alkalinity

The alkalinity of a solution is its capacity to neutralize acid (Hem, 1970). Any ion in solution that enters into a chemical reaction with strong acid can contribute to titrated alkalinity. In natural waters, alkalinity is most commonly attributable to the concentrations of the carbonate and bicarbonate species. Other species such as hydroxide, iron, silicate, or phosphate contribute to titrable alkalinity but are insignificant due to their low concentrations in most natural waters.

The dissolution of CO_2 gas derived from the atmosphere, from the soil, or released in the carbonation reaction of limestone and dolomite is a principal source of carbonate and bicarbonate ions titrated in alkalinity determinations. Four chemical reactions describing the dissolution of CO_2 gas and the formation of carbonate and bicarbonate ions are:

1. $CO_2\ (g) \rightleftharpoons CO_2\ (aq)$

2. $H_2O + CO_2\ (aq) \rightleftharpoons H_2CO_3$ (carbonic acid)

3. $H_2CO_3 \rightleftharpoons \underset{\text{(bicarbonate)}}{HCO_3^-} + H^+$

4. $HCO_3^- \rightleftharpoons H^+ + CO_3^{=}$

If abundant carbon dioxide is present (e.g. soil water), the above dissociation will proceed only as far as the bicarbonate stage. Increasing the pH increases the ratio of carbonate to bicarbonate and favors the precipitation of $CaCO_3$.

5. $Ca^{++} + CO_3^{=} \rightleftharpoons CaCO_3$

Thus, the concentration of total carbonate in solution is largely dependent on the hydration equilibrium of CO_2 (equation: $H_2CO_3 = CO_2(aq) + H_2O$) and to a lesser extent on the pH and the concentration of metal cations (e.g., Ca^{++}, Mg^{++}) capable of precipitating as a solid carbonate phase (e.g., calcite).

Ground water samples from Kings Valley contain from 7 to 305 mg/l bicarbonate ion. Generally, where chloride levels are low, well water is of the sodium bicarbonate type (see Plate II). Bicarbonate is the most abundant anion in more than half of the water samples.

Alkalinity determinations were made in the laboratory from 3 to 5 days after the samples were collected. A second set of pH measurements made at that time showed an average decrease of 0.6 pH units (changes in pH ranged from maximum decrease of 3.35 units to a maximum increase of 0.25 pH units). Also iron precipitated in some samples during this period. These changes attest to a changing chemical equilibrium during storage, apart from natural conditions. Roberson and others (1963) have shown that field determinations of alkalinity, pH, and specific conductance are generally higher than laboratory determinations. Rainwater and Thatcher (1960) explained such differences between field and laboratory data as possibly caused by changes in temperature of the sample, by precipitation of iron compounds, and other changes in equilibrium between the time of field analysis and laboratory analysis (for example, loss of CO_2 from the sample to air trapped under the cap of the bottle).

Examination of laboratory analyses (Table 2) for ground water samples from Kings Valley suggest that most samples are alkaline, moderately to weakly buffered by $Na^+HCO_3^-$, and unstable (i.e., adjust to a new equilibrium rather quickly with corresponding changes in pH) once removed from their natural environment. Consequently, in this report determinations of the bicarbonate species made in the laboratory are probably somewhat low for most samples, represent concentrations of these species one might expect after storage, and should be used with these limitations in mind for geochemical interpretation of this aquifer system. It should be noted also that in some samples all of the carbonate ion concentration was lost in the shifting of equilibrium during storage and that calculated total dissolved solids values may also be slightly low.

Dissolved Gases

Dissolved gases were not analyzed, but from pH values and the bicarbonate alkalinity determinations, an approximation of the free carbon dioxide content is possible. From Table 3, it is evident that free carbon dioxide content is probably low (less than 6 mg/l) in ground water in the study area (range 2 to 6 mg/l) due to the alkaline condition of the ground water ($pH > 8.0$) and moderately high to low bicarbonate ion levels (generally < 300 mg/l) in the water. Numerical values shown in the table are subject to slight correction for temperature and total dissolved solids. Greater concentrations of CO_2 are possible under increased pressures. Most of the ground water in the study area is under confined conditions, and the foaming nature of water from a recently drilled water well (10S/6W-16bdc) suggests that CO_2 content may be higher than values shown in Table 3 for the corresponding bicarbonate and pH values. Methane was also apparent in this well because the gas burned when exposed to a flame (Ray Gellatly, 1975, personal communication).

Table 3 (after Johnson, 1966, p. 77)

Bicarbonate alkalinity, mg/l as $CaCO_3$	Free Carbon Dioxide - mg/l		
	at pH = 7.0	at pH = 7.5	at pH = 8.0
100	22	6	2
200	43	12	4
300	63	17	6
400	82	22	7

Potassium

Most potable ground water contains less than 10 mg/l potassium, and potassium concentrations commonly range from 1.0 to 5.0 mg/l (Davis and DeWiest, 1970, p. 106). Potassium concentrations in Kings Valley ground water are relatively low, ranging from 0.1 to 2.2 mg/l with an average of 0.8 mg/l (Table 2).

Common sources of potassium are the weathering (hydrolysis) and diagenetic alteration of orthoclase, microcline, muscovite, and biotite, and volcanic glass. One such reaction is:

$$\underset{\text{(orthoclase)}}{2KAlSi_3O_8} + H_2O \rightleftharpoons Al_2Si_2O_5(OH)_4 + 2K^+$$

In these mudstones and in the basalts, the relative abundance of potassium minerals is very low. Some muscovite ($KAl_2(OH)_2(AlSi_3O_{10})$) occurs in the Kings Valley Siltstones. Microcline ($KAlSi_3O_8$) and orthoclase are found in the Tyee sandstones. Most potassium released during diagenetic alteration of potassium-rich minerals probably is bonded tightly in the illite clay structure and thus is not available for solution. Illite has been identified in X-ray diffraction analysis as a minor clay constituent in the Kings Valley Siltstones.

Iron

Iron is an abundant element in the earth's crust, but concentrations exceeding a few milligrams per liter in natural waters are rare. Iron concentrations exceeding 0.3 mg/l are considered objectionable for domestic use by the U.S. Public Health Service (1962). Above this level, iron stains laundry, porcelain, and other plumbing fixtures. At slightly higher concentrations, it imparts an objectionable taste to the water.

the ferrous ion, Fe^{+2}. The solubility of the ferric species, Fe , is relatively low compared to Fe^{+2}, and above pH of 4.8 the solubility of ferric iron is less than 0.01 mg/l (Hem, 1970). Iron in solution may have been derived from hydrolysis and solution of ferromagnesian minerals, iron oxides, and clays in the Kings Valley Siltstone and adjacent Siletz River Volcanics in the recharge area.

Water from four wells (10S/6W-17ddc, -29cdb, -16bbd, -16bba) in Kings Valley has objectionably high concentrations of iron for domestic use (Table 2). The fact that these four wells yield water characterized by relatively lower pH values (iron is more soluble at lower pH values) and are located in an arcuate strip along the northwest side of the Luckiamute River suggest that this is a local phenomenon (Plate II). The Moser Lumber Company well (10S/6W-16bbd) had the highest iron content (6.7 mg/l) of all wells sampled. Commercial iron removal equipment is available and should be sufficient to remove excess concentrations of iron where it occurs in ground water in the valley.

Surface water samples contain low to moderate amounts of iron, probably in the form of particulate ferric hydroxide.

Chloride

The element chlorine is not a major constituent of rock-forming minerals. However, the mobility of the chloride ion once in solution and its tendency not to form solute complexes with other ions, or to form salts of low solubility, and to enter into biochemical reactions contributes to its disproportionately high concentration and ubiquitous nature as a solute in ground water (Hem, 1970).

The amount of chloride in waters from the Kings Valley area ranges from 11 to 1,690 mg/l and averages 121 mg/l for the wells sampled. Davis and DeWiest (1970, p. 121) recommend a maximum chloride content in water of 250 mg/l for public consumption and a maximum of 300 mg/l for irrigation. Four wells (10S/6W-16cab, -16cdd, -21aba, -32bac) in Kings Valley exceed these limitations.

Generally, water from deeper wells located on the lower northern valley slopes and bottom have the highest chloride concentrations (Plate II, Table 2) although one 50-foot well (10S/6W-16cdd) encountered water with high sodium chloride (Table 2). Water from these wells is of the sodium chloride type. It is hypothesized that because of the low permeabilities and very slow recharge or flushing action of fresh surface water into the Kings Valley aquifer that some of the deeper brackish ground water with high chloride content may be of connate origin. Ground water in the northern lower part of the valley has the longest flow path from the recharge area (Plate III) and thus is least likely to be flushed by infiltration of fresh water. The chloride may be derived, in part, from slow devitrification of basaltic volcanic glass fragments and diagenetic alteration of Cl-bearing micas and apatite in the tuffaceous Kings Valley Siltstone and in the Siletz River Volcanics.

<u>Silica</u>

Silica in solution is probably present in the form of monomeric silicic acid (H_4SiO_4) in the normal temperatures and pH ranges of natural water (Krauskopf, 1959). Ground water commonly contains between 5 and 40 mg/l silica (Davis and DeWiest, 1970, p. 101), reflecting the low solubility of silica compounds in water and the slow rate of solution of common silicate minerals such as quartz, clay minerals, and feldspars.

Silica in ground water samples from Kings Valley fall within these typical values, ranging from 8.5 mg/l to 31 mg/l, averaging 18 mg/l (Table 2). Silica concentration in the ground water probably represents near saturation conditions relative to the silicate minerals present (Krauskopf, 1959). The range of pH (5.45 to 9.2 in the field) appears to have little effect on silica concentrations. Silica concentrations in springs and stream water are as high or higher than silica concentrations in well water in Kings Valley (Table 2).

Sulfate and Nitrate

A common source for sulfate in natural waters is oxidation of sulfides in sedimentary and igneous rocks by circulating aerated waters (Hem, 1970). The sulfate ion, once in solution, is chemically stable in aerated water except in the presence of a few uncommon metal cations.

Sulfate concentrations in ground water samples from Kings Valley were below 30 mg/l except in two wells closely associated with post-Eocene basaltic intrusives. The Moore well, 10S/6W-22acc, and the Randles well, 10S/6W-22bbb, had sulfate concentrations of 106 mg/l and 110 mg/l, respectively (Table 2). No log is available for the Randles well but a 10- to 20-foot thick basalt sill crops out near the location of this well, and the bore hole probably penetrates this sill. The Moore's well completely penetrates a 63-foot thick basalt sill (see Plates I and IA). The fact that these were the only two wells with sulfate concentrations far in excess of all others in the valley suggests that locally high sulfate concentrations may be attributable to the close proximity of intrusive rocks which either bear metallic sulfides or have chemically (thermally) altered the sulfur species (e.g., pyrite) in the host sedimentary rocks.

A concentration of 45 mg/l nitrate is basis for rejection of a water supply (U.S. Public Health Service, 1962). High nitrate concentrations in ground water suggest surface water contamination from animal wastes, fertilizers, or industrial chemicals (Hem, 1970). Nitrate concentrations vary little in ground water sampled from the valley and range from 0.7 mg/l to 6.2 mg/l, average about 1.7 mg/l (Table 2), suggesting that safe levels of nitrate exist in the ground water supply although water samples containing the higher levels of nitrate should be checked for the presence of coliform bacteria.

Fluoride

Fluoride concentrations in most natural waters are generally less than 1 mg/l; concentrations near this level are considered beneficial to children's teeth (U.S. Public Health Service, 1962, p. 8). In water with high total dissolved solids, fluoride may occur in amounts exceeding 1.5 mg/l; at that level fluoride may cause mottling of tooth enamel (Hampton, 1972). Suggested limits of fluoride concentration are computed on the basis of the average daily maximum air temperature. For temperate climates similar to that of the Kings Valley area, the U. S. Public Health Service (1962, p. 8) recommends 1.3 mg/l as the maximum allowable fluoride content. Well water sampled in the Kings Valley area contained an average of 0.5 mg/l fluoride and ranged from 0.1 to 1.2 mg/l and thus are beneficial rather than hazardous to health. Diagenetic alteration of apatite is a possible source of fluoride.

Temperature and pH

Ground water temperatures range from 13° to 15° C (Table 2). Surface water averages 14° C. Field pH readings range from a low of 5.45 to a high of 9.6, averaging 8.0. Laboratory pH of the same samples measured three to five days after collection is generally lower, probably due to temperature changes, precipitation of iron compounds, and loss of CO_2 in the sample (see further discussion under section titled alkalinity, carbonate, and bicarbonate).

Hardness

Hardness reflects the soap-consuming capacity of water produced by the effect of the alkaline earth cations. Usually only calcium and magnesium cations are present in significant amounts in natural waters so hardness is typically attributed to these ions in most ground water studies. In this report, hardness is computed from the concentrations of the calcium and magnesium ions and expressed in terms of $CaCO_3$ equivalents in milligrams per liter as "calcium and magnesium hardness" (Table 2). Non-carbonate hardness is computed for samples in which the calcium and magnesium hardness exceeds that portion of the hardness equivalent to the bicarbonate and carbonate alkalinity (Table 2). The following scale is commonly used to express the relative hardness of water (Dufor and Becker, 1964, p. 27):

Hardness as $CaCO_3$ (mg/l)	Classification
0 - 60	Soft
61 - 120	Moderately hard
121 - 180	Hard
> 180	Very hard

The hardness of water from 27 wells and springs averaged approximately 54 mg/l as $CaCO_3$. Water from wells 10S/6W-22acc and 10S/6W-21aba were very hard (225 mg/l and 579 mg/l in samples 9 and 7 in Table 2). All other wells yielded moderately hard to soft water. Approximately 45 percent of the wells sampled (11) from the Kings Valley

Siltstone Member had very low hardness values (10 mg/l or less). Even stream and spring water in the area has higher hardness values than these very soft ground water samples (Table 2).

These data suggest that some natural phenomenon occurs in the ground water environment which causes well water to become, in time, extremely soft. Foster (1950), Carroll (1959), Ames (1960), Hay (1966), and numerous others have discussed chemical criteria and geologic environments which favor natural water softening in the subsurface by selective ionic adsorption and ion exchange. Briefly, the important chemical and geologic factors favoring cation exchange and ionic adsorption include:

1. An abundance of certain clay minerals that have high capacities for cation exchange and ionic adsorption;
2. The occurrence of zeolites in association with a tuffaceous sandstone or fine-grained rock;
3. An abundance of silt-sized quartz;
4. The presence of organic matter;
5. Alkaline conditions.

All of these chemical and geologic conditions for cation exchange and ionic adsorption are present, to some extent, in the Kings Valley Siltstone Member. It is a tuffaceous, fine-grained rock containing abundant montmorillonite clays, zeolites (probably clinoptilolite), and carbonaceous organic matter. Angular quartz in the silt-sized fraction is present in thin section. Field pH measurements show that ground water from most wells is alkaline (pH > 8).

Cation exchange by clay minerals can be simply stated as:

$$\mathrm{Na}^{+} + \mathrm{H\ clay} \rightleftharpoons \mathrm{Na\ clay} + \mathrm{H}^{+}$$

Since most clays behave as weak acids, metal cations (e.g., Ca^{++}, Mg^{++}, Na^{+}, K^{+}) in solution commonly exchange with hydrogen protons in clay interlayers to maintain electroneutrality of the clay structure. These exchange reactions take place in the thin film of water in contact with the minerals. Although the mechanism of exchange might be quite variable from mineral to mineral, the end result is always the same (i.e., the cancellation of negative charges on the surfaces of the minerals). For example, cation exchange in montmorillonite is caused by the isomorphous substitution of Al^{+3} for Si^{+4}. The resulting negative charge on the clay structure is neutralized as cations (e.g., Ca^{++}, Mg^{++}, K^{+}, Na^{+}) are attracted to the flat surfaces, the edges, and between the silica and alumina layers of the clay micelle (Carroll, 1959). The relative exchange capacities of clay minerals, zeolites, and other rock-forming minerals and rocks vary greatly.

Carroll (1959) has determined that montmorillonite group clays and zeolites exceed exchange capacities of other common clays and rock-forming minerals by a factor of ten or more. Also, quartz, although it has a relatively low exchange capacity (5.3 meq/100 g at pH = 7), may be significant in cation exchange reactions where it is volumetrically abundant in the less than two-micron size fraction, such as in siltstones.

The relative ease of ionic replacement of calcium and magnesium is less than that of other common cations ($Ca^{++} < Mg^{++} < K^{+} < H^{+} < Na^{+} < Li^{+}$) so once adsorbed or held in an exchange position in a solid clay phase these cations are less likely to return to the aqueous phase in later exchange reactions. This may explain why Ca and Mg hardness is low while Na^{+} content is high in Kings Valley water samples. Ca^{++} and Mg^{++} ions that have been adsorbed or exchanged in the clay structure and are tightly held, but Na^+ ions which also can be exchanged for hydrogen protons in the clay minerals are more readily released into the aqueous environment. Clay minerals have long been known to release large quantities of exchangeable sodium in the ground water environment (Renick, 1925; Foster, 1942; Piper and others, 1953).

Total Dissolved Solids

Water may be classified based on the total concentration of dissolved solids. A common classification suggested by Davis and DeWiest (1970, p. 118) is:

Types of Water

Name	Concentration of total dissolved solids in ppm
Fresh water	0 - 1,000
Brackish water	1,000 - 10,000
Salty water	10,000 - 100,000
Brine	greater than 100,000

Total dissolved solids (calculated) in Kings Valley ground water range from a low of 39 ppm (mg/l) to a high of 2,584 ppm (mg/l), averaging 377 ppm (mg/l) (Table 2). Most well water is very fresh (less than 500 ppm or mg/l). Only in one well (10S/6W-21aba) in the northern part of the study area is the water brackish (2,584 ppm or mg/l). Four wells in the area exceed the limit (500 mg/l) recommended for drinking water used in interstate commerce according to U.S. Public Health Service standards (1962) (Table 2). However, it does not necessarily mean that water in these four wells is unsuitable for private use. At least two other older wells in the area have been abandoned due to encountering brackish water. Streams, springs, and wells suspected of mixing with surface or perched unconfined water have generally lowest total dissolved solids whereas deeper wells (those exceeding 200 feet) in confined zones are more likely to have high total dissolved solids (Tables 1 and 2).

Suitability of Water for Irrigation

The chemical quality of water suitable for irrigation has been extensively studied and described by the U.S. Department of Agriculture (U.S. Salinity Lab Staff, 1964). Important parameters for determining suitability of water for irrigation include: (1) the salinity hazard (total dissolved solids); (2) the alkali hazard (proportion of sodium to other principal cations); and (3) the concentration of possible toxic substances such as boron.

A general relationship between the specific conductance (micromhos/cm) and the total dissolved solids makes it possible for a rapid measurement of the salinity hazard of water for irrigation based on the conductivity measurement (Table 2; Figure 18). The relationship is: total dissolved solids are approximately 0.5 to 0.65 times the specific conductance.

The second parameter, the sodium (alkali) hazard is determined by the proportion of sodium ions to calcium and magnesium ions (expressed in milliequivalents per liter) in solution. The sodium adsorption ratio (SAR) is the index used for designation of the sodium hazard and may be computed for any natural water using the following formula:

$$SAR = \frac{Na^{+}}{\sqrt{\frac{Ca^{++} + Mg^{++}}{2}}}$$

If calcium and magnesium concentrations are proportionally high and sodium concentrations relatively low, then the sodium hazard is low. If calcium and magnesium are low with proportionally high sodium, then the hazard is high (Figure 18). The alkali hazard is a problem in water used for irrigation because if sodium in solution (which may be more

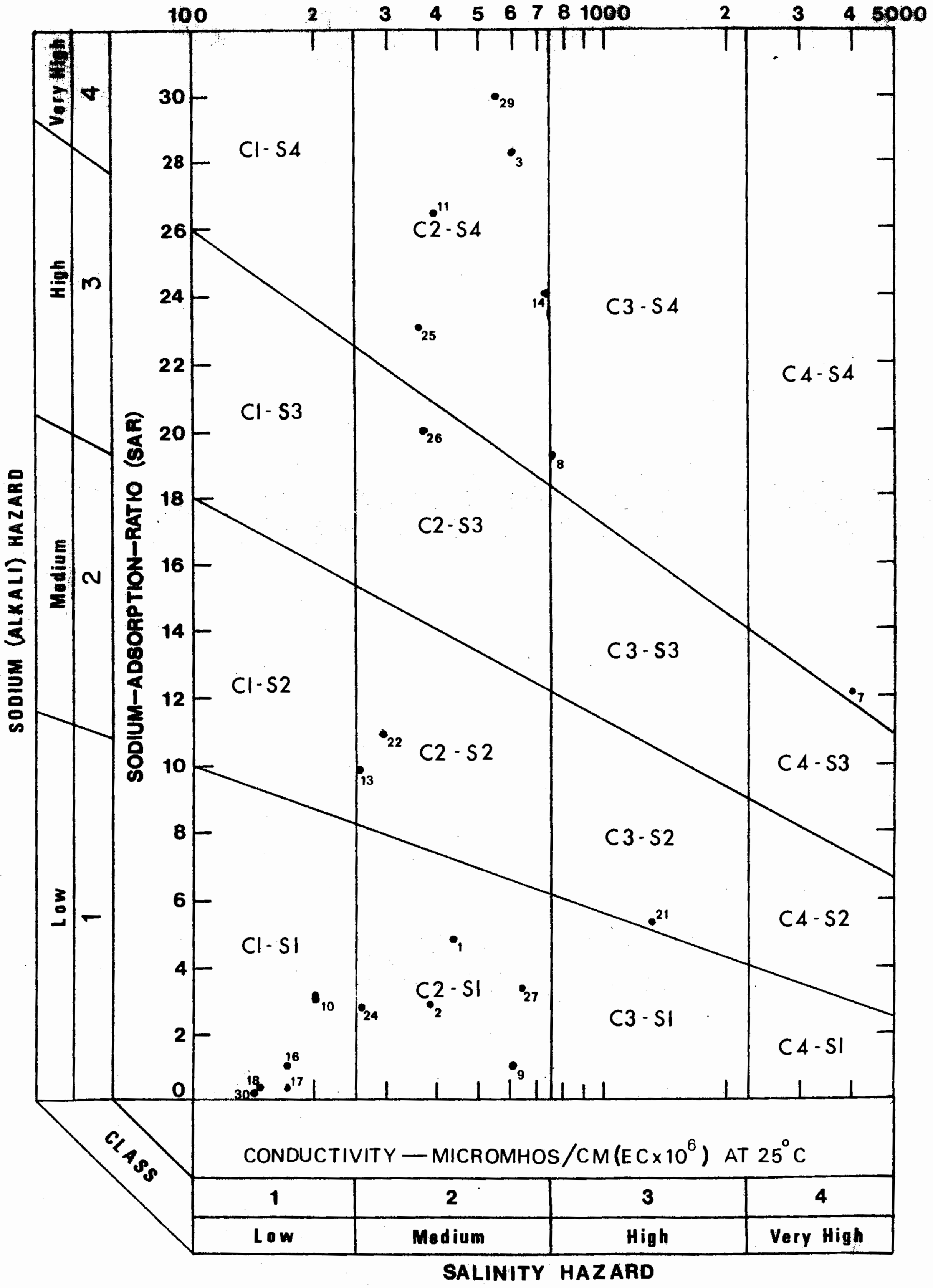


Figure 18. Classification of irrigation waters (after U.S. Salinity Lab Staff, 1954, p. 80). Numbers of plotted circles correspond to sample numbers in Table 2.

strongly hydrated) replaces in time the less hydrated calcium and magnesium in soils, the resulting swelling of soil clays adversely affects the permeability of soils which in turn affects the usefulness of the soil in growing crops.

The well water conductivity measurements and SAR index calculations are used in conjunction to determine the suitability of water for irrigation (Figure 18). The divisions in the classification diagram (Figure 18) correspond to the 16 different classes of irrigation waters which range from low sodium and low salinity (C1-S1) to very high sodium and very high salinity (C4-S4). The higher the number, the more damaging the water is to soil structure and the less suitable the water is for irrigation. Waters classified as C4-S4 are not suitable for irrigation of any crops in any soil, except under special conditions.

SAR values were computed for 27 ground water and 3 stream samples (Table 2). Twenty-one of the values plotted on the diagram. Of the 21 samples, 5 samples plotted in each of classes C1-S1, C2-S2, and C2-S4. Two samples lie in class C2-S2, and one sample plotted in each of classes C2-S3, C3-S2, C3-S4, and C4-S4. An unexpected number of samples (four) plotted off the top of the diagram, above 32 SAR. Eleven water samples have a very high sodium hazard, but only one sample has a very high salinity hazard. These unusually high SAR values reflect the disproportionately high relationship of sodium to calcium and magnesium. These data also suggest that some cation exchange and/or adsorption phenomenon may be operating in the subsurface to selectively remove calcium and magnesium from the ground water. Such phenomena could explain the high sodium hazard results observed for ground water from the Kings Valley Siltstone Member. It is possible that the high rainfall in the area would tend to preclude any large build-up of sodium salts in the soils where high sodium or high alkali hazard ground water was used. All of the spring samples have both low alkali and low salinity hazards.

Although some of the ground water in the Kings Valley area is unsuitable for irrigation, the chemical quality and SAR index of surface water samples is generally excellent (Table 2) and where available surface water should be used in place of ground water for this purpose.

MPN-Bacteria Contamination of Water Wells

The standard bacteriological test for the purity of water is a test for the presence or absence of coliform bacteria (coli-aerogenes). These particular bacteria are commonly found in the intestines and intestinal discharges of humans, birds, and other warm-blooded animals and in soils. The standard test (MPN) for determining the presence of coliform bacteria was carried out by the Department of Microbiology at Oregon State University on May 16, 1975. In this test live coliform bacteria from water samples will ferment lactose with gas formation within an incubation period of 48 hours at 35° C and will constitute a positive test (Taras and others, 1971). The test results are also expressed in terms of most probable number (MPN) which is a statistical estimation of bacteria density (Taras and others, 1971). Animal or human contamination of a water supply is indicated by a positive test. It should be emphasized that this test makes no distinction between harmless species and those species of coliform bacteria potentially infectious to man. A positive test indicates a water supply is unsafe, and this situation should be remedied as quickly as possible.

In general, most surface waters show the presence of some coliform bacteria and for this reason should be avoided for domestic consumption when possible. On the other hand, ground water is usually free of coliform bacteria except where surface water moves directly down into the ground water supply and is unimpeded (i.e., is not naturally filtered by movement through soil or rock).

Coliform bacteria counts were determined for 7 domestic wells, 1 spring, and 4 streams in Kings Valley (Table 2). All the domestic wells, the spring, and one of the streams were being used for drinking supplies. Of the 7 water wells tested, six showed positive tests with MPN values ranging from 1.8 to 2400^{+} (Table 2). All streams sampled were positive with MPN values ranging from 33 to 2400. The spring also gave a high positive MPN value of 2400+.

High concentrations of coliform bacteria in water samples probably indicate surface water contamination of the water well by (in many instances) imperfect well seals or cracks in the casing such that surface water can drain into the well. A publication by the Oregon State Board of Health (1971), "The Protection and Purification of Rural Water Supplies", outlines some of the necessary precautions in the construction and operation of rural water wells.

Some of the wells with highest coliform concentration in the study area are located near fields where livestock are present; and animal wastes may be, in part, the source of high concentrations of coliform bacteria. It is suggested that these wells be inspected for possible avenues of contamination, sterilized with chlorine, and, if a second test is positive, then a chlorinator should be installed following the guidelines established by the Oregon State Board of Health (1971).

It should be pointed out, however, that only one sample from each well was submitted for a MPN test and that additional tests are necessary over a period of time to form a conclusive opinion.

Areal Variations in Chemical Quality

Areal variations in chemical quality of ground water in the principal aquifer, the Kings Valley Siltstone, and variations in spring water quality in the Tyee Formation are shown on Plate II. In the north central and southwestern part of the area, most of the ground water (excluding springs in the southwest) is of the sodium chloride type, is relatively high in dissolved solids, low in hardness, and is unsuitable for irrigation (see section on suitability for irrigation) and in some wells unsuitable for domestic consumption. Springs in the southwestern part of the area developed along the contact of the colluvium and the Tyee Formation are very low in total dissolved solids and are excellent chemical quality.

On the basis of field measurements of specific conductance and laboratory chemical analyses, water in the south and southeastern side and northwesternmost part of the valley is of sodium bicarbonate type, contains low total dissolved solids, is low in hardness, and is of good chemical quality for most uses. Well number 10S/6W-22acc is an exception to this generalization, being relatively higher than most wells in magnesium and sulfate concentrations than sodium chloride or bicarbonate.

Water quality generally changes progressively from the topographically higher parts of the valley from a sodium bicarbonate type with low total dissolved solids to a sodium chloride type with higher total dissolved solids in the topographically low areas of the valley located in the north and in the southwest (Plate II). These chemical variations suggest that m cations and anions particularly Na^+ and Cl^- are dissolved into the ground water from diagenetic reactions with host rock minerals as ground water slowly moves through the Kings Valley Siltstone toward the topographically low center of the valley where older ground water, possibly in part connate, occurs in deeper wells.

SUMMARY AND CONCLUSIONS

Ground water recharge in the Kings Valley area occurs primarily through infiltration of precipitation directly on the Siletz River Volcanics ridges flanking the east side of Kings Valley. In this area, thin rocky soil overlies fractured and jointed basaltic breccias and pillow basalts. Ground water moves from this area under hydraulic pressure into the interfingering Kings Valley Siltstone Member under confined and semi-confined conditions and proceeds down dip largely through more permeable zones of jointed and fractured siltstone. Ground water movement is very slow due to the low transmissivities of the siltstones, thus resulting in meager yields in most wells. Higher yields occur on the upper slopes of the eastern part of the valley, but it is not apparent whether the cause for this can be attributed to differences in well construction or that the upper part of the siltstone unit has greater transmissivities. Unconfined water occurs locally in the thick alluvium in the southwestern part of the valley, and perched water which forms springs occurs in the colluvium overlying the nearly impermeable Tyee Formation on the hillsides on the western side of the valley. Ground water quality is generally good for the 12 ionic constituents analyzed except in the northern part of the valley where some connate unpotable brackish sodium chloride water with high total dissolved solids is encountered in the Kings Valley Siltstone.

In its movement through the tuffaceous siltstone, confined ground water undergoes natural softening by cation exchange with zeolites, with clays of high exchange capacity, and, to some extent, with silt-sized quartz in the siltstones in an alkaline environment. The small volume of water in storage and slow rate of movement have the combined effect of prolonging contact between exchangeable cations and their geologic environment. Consequently, sodium concentrations are increased at the expense of magnesium and especially calcium ions which are selectively removed and preferentially held by montmorillonite clays and in the crystal structure of zeolites.

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Table 1.--Records of selected wells in the Kings Valley Area

Well number: See p. for description of well-numbering system.
Type of well: B, bored; Dg, dug; Dr, drilled.
Finish: P, perforated; S, screened; X, open hole.
Altitude: Altitude of land surface at well, in feet above mean sea level. *Indicates altitude determined accurately with altimeter.
Water level: Depth to water given in feet (to nearst .1") reported by authors, all others well driller. F, flowing well whose static water level is not known.
Specific conductance: Field measurements made by authors May 8-13, 1975.

Well performance: Yield, in gallons per minute, and drawdown, in feet, generally reported by driller.
Use: H, domestic; I, irrigation; N, industrial; S, stock; U, unused.
Remarks: C, chemical analysis reported in table 2 ; B, bailed for indicated time to determine yield under "Well performance".

Well or spring number	Owner	Type of well	Year com-pleted	Depth of well (feet)	Diameter of well (inches)	Depth of casing (feet)	Finish	Character of material	Alti-tude (feet)	Water level		*Depth at which water first found	Well performance		Use	*Specific conduct-ance of water	Remarks
										Feet below datum	Date		Yield (gpm)	Draw-down (feet)			
								T. 10 S., R. 6W.									
15cdc	M. Randles	Dr	1973	150	6	50	X	Claystone, basalt	452*	55.0	5/8/75	70	10	25	H	-	M, B
16bab	E. Raw	-	-	-	-	-	-	-	325	-	-	-	-	-	H	550	C
16bba	E. Raw	-	-	-	-	-	-	-	331*	2.7	5/13/75	-	-	-	H	76	C, M
16bbd	Moser Lumber Co.	Dr	1967	50	5	-	X	Gravel claystone	322	15	8/10/67	-	40	20	N	646	C, B
16bdc	C. Berrest	Dr	1975	200	6	20	X	Siltstone, claystone	308*	9.1	8/9/75	195	-	-	H	-	M, B
16bcd	J. Moore	Dr	1952	60	6	-	-	-	312	-	-	-	-	-	H	730	C
$16cab_1$	L. Frank	Dr	-	-	-	-	-	-	300*	22.9	5/8/75	-	-	-	H	1,370	C, M
$16cab_2$	E. Moore	Dr	1972	131	6	127	X, P	Claystone	304	6	7/20/72	-	5	108	H	-	B, perforated 63-127'
$16cab_3$	T. Moore	Dr	1967	60	6	20	X	Claystone	310	16	6/21/67	-	3	40	H	-	B
16cdd	R. Taylor	Dr	-	50	-	-	-	-	320*	8.5	5/8/75	-	-	-	H	1,420	C, M
17aca	G. Hill	Dr	1974	195	6	20	X	Claystone	405	F	5/16/74	57	1 3/4	195	H	-	B
17dba	F. Stephens	-	-	-	-	-	-	-	340*	11.0	5/8/75	-	-	-	H	389	C, M
17ddc	E. L. Berklund	-	-	-	-	-	-	-	315*	16.4	5/8/75	-	-	-	H	445	C, M
21abb	T. Maloney	Dr	1968	140	6	116	X, P	Siltstone, claystone	361*	9.8	7/11/75	-	20	60	H	-	M, B
21aba	M. Albright	Dr	1960	243	6	96	X	Siltstone, claystone	365*	F	5/23/60	-	6	-	I	3,920	C, B 18 psi pressure at well head
21bca	C. Moser	Dr	1952	112	6	19	X	Claystone	346*	3.4	5/8/75	38	20	-	H	749	C, B, M
$21cac_1$	H. Kaplan	Dr	1965	74	6	20	X	Claystone	356*	15.5	8/9/65	64	12	44	H	250	C, B
$21cac_2$	H. Kaplan	-	-	-	-	-	-	-	356*	5.0	5/8/75	-	-	-	U	-	M
21dda	D. Brewer	Dr	1974	200	6	29	X	Shale	435	24	8/29/74	80	15	56	H	535	C, M, B
22aba	T. Moore	Dr	1967	250	6	46	X	Claystone	558*	50.0	5/13/75	-	20	170	H	403	C, M, B
$22acc_1$	E. Moore	Dr	1965	100	6	18	X	Claystone, basalt	538*	34.2	5/13/75	57	20	45	H	612	C, M, B
$22acc_2$	E. Moore	Dr	1973	91	6	91	P	Claystone	540	36	5/21/73	58	20	30	H	-	C, B
22baa	E. Moore	Dr	1967	150	6	42	X	Claystone	415	40	3/15/67	-	30	35	H	-	B
22bbb	M. Randles	Dr	-	33	6	-	-	-	403*	4.8	5/8/75	-	-	-	H	759	C, M
22dab	E. Moore	Dr	1974	60	6	32	X	Claystone	578*	3.3	5/13/75	45	7	40	S	-	M, B
$27bab_1$	R. Windgate	-	-	-	-	-	-	-	475*	9.2	5/8/75	-	-	-	U	-	M
$27bab_2$	R. Windgate	Dr	1965	122	6	34	X	Claystone	475*	22.9	5/21/65	57	7	98	H	390	C, B
27bbd	R. Hunter	Dr	1973	95	6	20	X	Claystone, shale	498*	13.5	8/10/75	72	9	55	H	-	B
27bdb	R. Hunter	Dr	1973	410	6	20	X	Siltstone, claystone	488*	50	10/11/73	120	1/2	350	U	-	B
28bbb	C. Chambers	-	-	-	-	-	-	-	410	-	-	-	-	-	H	87	C
28bac	R. Moser	Dr	-	-	-	-	-	-	418	-	-	-	-	-	H	165	C
28dcd	N. Chambers	Dr	-	-	-	-	-	-	490	-	-	-	-	-	H	258	C
29cdb	O. E. Frantz	Dr	-	-	-	-	-	-	332*	9.4	5/13/75	-	-	-	H	600	C, M
30acc	M. Lorshbaugh	Dr	1972	115	6	30	X	Claystone	350	25	5/8/72	45	6	85	H	-	B
30add	J. Cox	Dr	1973	115	6	56	X	Sandstone, claystone	374*	20.0	5/9/75	58	6	89	U	-	B, M
30bad	L. Probst	Dr	-	-	-	-	-	-	363*	13.6	5/8/75	-	-	-	-	-	M
30bbc	K. Stanton	Dg	-	-	-	-	-	-	441*	2.0	5/9/75	-	-	-	H	43	C, M
30dbb	J. Owen	Dr	1971	65	6	49	X	Gravel, silt	371*	15.7	5/8/75	48	10	45	H	-	B, M
30dbc	H. Clay	Dr	1972	345	6	62	X	Sandstone claystone	392	-	11/27/72	dry	0	-	U	-	
30dca	J. Gibson	Dr	1973	180	6	55	X	Claystone, sandstone	410*	19.2	5/8/75	147	6	136	U	-	B
30dcb	H. Clay	Dr	1972	165	6	63	X	Siltstone, claystone	395*	33.4	5/8/75	82	1	140	U	-	B
$30dda_1$	J. Johnson	Dr	1973	245	6	30	X	Sandstone, shale	345	60	7/11/73	220	1 1/2	170	U	-	B
$30dda_2$	J. Johnson	-	-	-	-	-	-	-	-	-	-	-	-	-	U	-	
32bac	R. MacRae	Dr	1959	112	6	16.7	X	Siltstone	383*	68.8	5/8/75	100	2	86	H	1,180	C, M, B
33caa	T. Turner	Dr	1962	128	6	51	X	-	578*	6.1	5/8/75	51	-	-	H	330	C
33dcc	D. Passon	Dr	1967	90	6	28	X	Claystone	656*	26.6	5/8/75	54	7	66	H	360	C, M, B
								T. 11 S., R. 6W.									
5bcc	E. F. Pankalla	Dr	1971	120	6	27	X	Claystone, sandstone	410*	2	9/7/71	42	12	118	H	283	located just south of map area C, B

Table 7.--Chemical Analyses of water from representative wells in the Kings Valley Area

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Table 2.--Chemical Analyses of water from representative wells in the Kings Valley Area

Sample no.	Location number	Owner	Depth of well (feet)	Date of collection	Milligrams per liter													Hardness as $CaCO_3$				Temperature					
					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)	Dissolved solids (calculated)	Calcium magnesium	Noncarbonate	Specific conductance at 25°C	Field pH	(°C)	(°F)	Sodium adsorption ratio (SAR)	Lab pH	MPN	Remarks
1	10S/6W-17ddc	E.L. Berklund	-	5-8-75	17	1.3	14	4.5	83	1.7	224	0	29	17	.4	2.6	281	53	0	445	7.2	13	55	4.9	6.9	-	1/
2	10S/6W-17dba	F. Stephens	-	do	24	1.3	21	7.8	58	2.2	225	0	<5	24	.6	3.1	253	84	0	389	7.2	13	55	2.7	6.8	-	1/
3	10S/6W-29cdb	O. Frantz	-	5-13-75	21	.06	2.8	.1	175	.4	133	6	<5	196	.6	2.2	470	8	0	600	8.45	14	57	2.7	8.7	14 pos	-
4	10S/6W-16bcd	J.F. Moore	-	5-8-75	17	.03	0.5	.2	167	.6	174	0	<5	157	.8	2.3	431	2	0	730	9.1	14	57	46	7.9	-	2/
5	10S/6W-16cab	L. Frank	-	do	10	.06	3.6	.7	313	1.2	297	0	<5	302	1.2	2.7	781	12	0	1,370	8.8	15	59	39	6.95	-	2/
6	10S/6W-16cdd	R. Taylor	-	do	8.5	.14	2.4	1.2	300	1.1	195	0	<5	396	1.2	2.6	809	11	0	1,420	8.1	14	57	39	7.9	-	2/
7	10S/6W-21aba	M. Albright	243	do	11	.10	232	.1	640	1.9	19	0	<5	1,690	.5	-	2,584	579	563	3,920	9.6	15	59	12	6.25	-	2/
8	10S/6W-22bbb	M. Randles	50	do	16	.06	5.2	.3	160	.5	233	0	110	43	.4	1.3	452	14	0	759	8.2	16	61	19	7.4	-	-
9	10S/6W-22acc	E. Moore	100	5-13-75	28	.06	44	28	36	.9	192	0	106	31	.2	1.1	369	225	68	612	7.6	15	59	1.0	7.9	0 Neg.	-
10	10S/6W-22aba	T. Moore	250	do	29	.07	7.2	1.2	35	.2	102	2	<5	12	.2	1.1	138	23	0	203	8.3	14	57	3.2	8.4	-	-
11	10S/6W-27bab	R. Windgate	122	5-8-75	13	.06	0.5	.1	86	.1	199	0	6	13	.6	0.8	218	2	0	390	8.95	16	61	26	7.2	3.7 pos	2/
12	10S/6W-21dda	D. Brewer	200	do	14	.17	0.8	.1	120	.1	185	22	21	31	1.2	0.9	302	3	0	535	9.1	16	61	33	8.9	-	-
13	10S/6W-21cac	H. Kaplan	74	do	21	.22	1.6	.6	58	.3	126	0	8	16	.2	0.8	169	7	0	250	8.9	14	57	9.9	8.0	-	2/
14	10S/6W-21bca	C. Moser	112	do	9.8	.13	2.8	.5	165	.6	159	0	16	160	.9	1.4	435	9	0	749	8.7	13	55	24	7.5	-	2/
15	10S/6W-28bbb	C. Chambers	-	do	17	.06	7.2	4.3	5.2	.4	36	0	<5	12	.1	6.2	70	35	6	87	6.2	14	57	0.4	6.3	-	2/
16	10S/6W-28bca	R. Moser	-	5-13-75	17	.02	9.2	2.2	19	.2	61	0	12	13	.1	0.7	103	32	0	165	8.1	14	57	1.5	8.35	1.8 pos	-
17	10S/6W-29bac(s)	G. Bush	Spring	5-9-75	23	.06	13.2	3.8	7.8	1.6	50	0	10	16	.1	0.8	101	48	7	154	6.1	17	63	0.5	6.1	2400+ pos	-
18	10S/6W-30ada(s)	J. Cox	Spring	do	22	.03	9.6	2.7	6.8	.9	30	0	8	16	.1	0.8	82	35	11	123	6.45	15	59	0.5	6.45	-	-
19	10S/6W-30bbc	K. Stanton	-	do	19	.15	2.0	1.1	8.8	1.0	19	0	<5	11	.1	0.7	53	10	0	43	6.2	14	57	1.2	6.2	3.7 pos	-
20	10S/6W-18cbb	LR_1	stream	5-13-75	13	.18	2.4	.9	3.2	.5	23	0	<5	8.8	.1	0.7	41	10	0	36	6.3	13	55	0.5	6.3	2400 pos	-
21	10S/6W-32bac	R. MacRae	112	5-9-75	21	.06	34	2.2	120	.3	215	0	10	303	.3	2.0	599	94	0	1,180	8.4	14	57	5.4	7.5	14 pos	-
22	11S/6W-5bbc	E. PanKalla	120	do	23	.02	2.0	.1	59	.2	129	0	<5	22	.4	0.8	171	6	0	283	8.65	15	59	11	7.15	-	2/
23	10S/6W-16baa	LR_2	stream	5-13-75	15	.21	3.2	1.4	3.9	.5	15	0	<5	9	.1	0.3	42	14	2	47	6.65	14	57	0.5	6.3	430 pos	-
24	10S/6W-28dcd	N. Chambers	-	5-8-75	21	.02	9.2	2.8	34	.5	89	0	9	19	.2	2.9	143	34	0	258	8.6	13	55	2.7	7.2	-	2/
25	10S/6W-33caa	T. Turner	-	5-9-75	18	.07	0.5	.1	74	.1	121	28	<5	16	.8	1.0	199	2	0	330	9.2	15	59	23	9.2	-	-
26	10S/6W-33dcc	D. Passon	90	do	20	.01	1.2	.1	84	.1	179	0	6	16	.6	1.0	217	4	0	360	9.0	14	57	20	7.9	-	2/
27	10S/6W-16bbd	Moser Lumber Co.	50	5-13-75	31	6.7	30	11	90	2.0	305	0	20	53	.2	2.6	397	120	0	646	6.75	15	59	3.6	6.8	-	1/
28	10S/6W-16bba	E. Raw	-	do	13	.50	1.6	.9	5.5	.8	7	0	<5	11	.1	1.1	39	8	2	76	5.45	15	59	0.9	5.5	2400+ pos	-
29	10S/6W-16bab	E. Raw	-	do	15	.17	1.2	.1	130	.6	223	37	<5	23	.6	1.3	319	4	0	550	9.1	15	59	30	9.3	-	2/
30	10S/6W-27aba	PC_1	stream	do	25	.25	10	5.0	6.4	.3	51	0	<5	13	.3	0.9	84	45	3	145	7.6	14	57	0.4	7.6	33 pos	-

1/ Iron precipitated in untreated sample
2/ Carbonate alkalinity lost during sample storage

Drillers' Logs of Representative Wells

Appendix A contains 27 lithologic logs of water wells in Kings Valley. All but one of the logs were obtained from drillers' reports submitted to the Oregon State Engineer. One log was obtained from Ray Gellatly, a well driller in the area. Many well log records are not available because many wells were drilled prior to the passage of the Groundwater Act of 1955 (ORS 537.505 to 537.795) which made it mandatory that such logs be filed with the State of Oregon.

Descriptions of rock materials penetrated by well drillers have been edited and re-interpreted to provide a consistency in terminology and to correlate with geologic data obtained from field and laboratory work. Terminology used to describe quite similar rock units may be very different depending on the background of the individual compiling the log. For example, in the study area the Kings Valley Siltstone Member is a lithologically homogeneous fine-grained tuffaceous siltstone unit containing a few silica cemented (or more siliceous) siltstone zones and thin basaltic sandstone beds and laminae, yet some logs record penetrating thick hard sandstone units. No evidence of thick sandstones has been found in exposures of this member anywhere in the valley. Occasionally adjacent wells separated by only a few tens of feet and penetrating indurated materials to similar depths have been logged differently such that one may record only shale and claystone whereas the other is reported to penetrate "hard sandstone" at many horizons. This perplexing situation is largely due to misinterpretation of hard siltstone units (carbonate or zeolite cemented) within the member as sandstone. Often white zeolites are called "white quartz" in the logs.

APPENDIX A.--Drillers' logs of representative wells

Materials	Thickness (feet)	Depth (feet)
10S/6W-15cdc. M. Randles. Altitude 452 ft. Drilled by R. C. Gellatly, 1973. Casing: 6-in. diam to 50ft; unperforated.		
Soil	1/2	1/2
Clay, light brown	5 1/2	6
Clay, light gray	12	18
Clay, yellow	7	25
Clay, gray	7	32
Claystone, gray, hard	33	65
Claystone, gray, broken, "water-bearing" 2 gpm	26	91
Siltstone, gray	23	114
Basalt, gray, hard	10	124
Siltstone, light gray, "water-bearing" 8gpm	26	150
10S/6W-16cab. T. Moore. Altitude 558 ft. Drilled by R. C. Gellatly, 1967. Casing: 6-in. diam to 20 ft; unperforated.		
Boulders, small	3	3
Clay, yellow with large and small boulders	12	15
Claystone, hard-packed	10	25
Claystone, dark gray	14	39
Claystone	16	55
Claystone, loose	5	60
10S/6W-16cab$_2$. J. V. Price Store. Altitude 310 ft. Drilled by R. C. Gellatly and R. S. Witham, 1972. Casing: 6-in. to 24 ft; 5-in. to 127 ft. 5-in; perforated 63 to 127 ft.		
Soil	2	2
Clay, brown	15	17
Clay, brown and boulders	6	23
Claystone, light gray	6	29
Claystone, gray, hard	47	76
Siltstone, gray	14	90
Claystone, gray, hard, with zeolites	41	131
10S/6W-16cac. R. G. Murphy, Altitude 354 ft. Drilled by Bill Howell, 1962. Casing: 6-in. diam to 28 ft; unperforated.		
Clay, brown	17	17
Claystone, gray	193	210
Claystone, blue	40	250

Materials	Thickness (feet)	Depth (feet)
10S/6W-17aca. G. Hill. Altitude 405 ft. Drilled by L. W. Mutschler Well Drilling, 1974. Casing: 6-in. diam to 20 ft; unperforated.		
Clay, yellow	12	12
Claystone, gray, hard	38	50
Siltstone, gray, hard, with quartz	7	57
Claystone, gray	138	195
10S/6W-21aba. M. Albright. Altitude 365 ft. Drilled by R. C. Gellatly, 1960. Casing: 8-in. diam to 33 1/2 ft, 6-in. diam to 96 ft; unperforated.		
Soil	2	2
Clay and boulders	16	18
Shale, gray	72	90
Shale, gray, hard	140	230
Siltstone and shale	10	240
Sandstone, porous	3	243
10S/6W-21abb. T. Maloney. Altitude 361 ft. Drilled by Babcock Well Drilling, 1968. Casing: 6-in. diam to 116 ft; perforated 70 to 100 ft.		
Soil	4	4
Clay, yellow	9	13
Siltstone, blue	37	50
Shale, blue, broken	60	110
Siltstone	32	142
10S/6W-21bca. Carl Moser. Altitude 346 ft. Drilled by R. C. Gellatly, 1952. Casing: 8-in. to 19 ft; perforated 14 to 16 ft.		
Clay and loose rock	14	14
Loose rock	2	16
Shale, gray	22	38
Shale, gray with zeolites, "water-bearing"	17	55
Shale, gray and claystone with streaks of gray clay	57	112

Drillers' logs of representative wells--Continued

Materials	Thickness (feet)	Depth (feet)
10S/6W-21cac. H. Kaplan. Altitude 356 ft. Drilled by R. C. Gellatly, 1965. Casing: 6-in. to 20 ft; unperforated.		
Soil	1	1
Soil and boulders	1	2
Clay, gray	7	9
Claystone, gray	9	18
Claystone, gray, hard white quartz	46	64
Claystone, broken, "water-bearing"	10	74
10S/6W-21cca. Don Ayers. Altitude 355 ft. Drilled by R. C. Gellatly and R. S. Witham, 1971. Casing: 6-in. diam to 24 ft; unperforated.		
Soil	1	1
Sand, brown and grit	4	5
Clay, yellow	7	12
Clay, reddish brown	3	15
Clay, light gray	5	20
Clay, dark gray	25	45
Claystone, dark gray	12	57
Siltstone, light gray	10	67
Claystone, gray broken (bearing 7gpm)	5	72
Claystone, gray	9	81
Claystone, light gray (bearing 13gpm)	8	89
10S/6W-21dda. D. J. Brewer. Altitude 435 ft. Drilled by Art Clinton Well Drilling Co., 1974. Casing: 6-in. diam to 29 ft; unperforated.		
Soil	3	3
Gravel, small and brown clay	21	24
Boulders, large	8	32
Shale, blue	134	166
Hard rock, gray, "water-bearing"	34	200

Drillers' logs of representative wells--Continued

10S/6W-22aba. T. Moore. Altitude 558 ft. R. C. Gellatly, 1967. Casing: 6-in. diam to 46 ft; unperforated.

Materials	Thickness (feet)	Depth (feet)
Boulders	3	3
Boulders, sandstone, large with red grit	8	11
Boulders, large with brown grit	9	20
Siltstone, brown, broken	17	37
Siltstone, gray hard	22	59
Shale, dark gray	54	113
Shale, medium hard	72	185
Shale, gray, broken, "water-bearing"; 3gpm	3	188
Siltstone, gray, hard	15	203
Shale, light gray	14	217
Shale, dark gray	22	239
Shale, gray, broken, "water-bearing"; 17gpm	6	245
Siltstone, gray, hard	5	250

10S/6W-22acc. E. Moore. Altitude 583 ft. R. C. Gellatly, 1965. Casing: 6-in. diam to 100 ft; unperforated.

Materials	Thickness (feet)	Depth (feet)
Soil	2	2
Clay, gray and broken brown rock	16	18
Shale, hard gray	9	27
Basalt, black with white zeolites, "water-bearing"	63	90
Shale, gray, "water-bearing"	10	100

10S/6W-22acc$_2$. E. Moore. Altitude 525 ft. Drilled by R. C. Gellatly and R. S. Witham, 1973. Casing: 6-in. to 25 ft. 5-in., 5-in. to 91 ft. 2-in.; perforated 58-90 ft.

Materials	Thickness (feet)	Depth (feet)
Soil	2	2
Clay, brown	13	15
Clay, gray and boulders	6	21
Claystone, gray	70	91

Drillers' logs of representative wells--Continued

Materials	Thickness (feet)	Depth (feet)
10S/6W-22baa. E. Moore, Altitude 415 ft. Drilled by R. C. Gellatly and R. S. Witham, 1967. Casing: 6-in. to 42 ft; unperforated.		
Boulders, small	3	3
Boulders, large	12	15
Boulders, large and yellow clay	10	25
Clay, brown	11	36
Claystone, light gray	12	48
Claystone, dark gray	12	60
Claystone, gray, medium hard	60	110
Claystone, dark blue	40	150
10S/6W-22dab. E. Moore. Altitude 578 ft. Drilled by R. C. Gellatly, 1974. Casing: 6-in. diam to 32 ft; unperforated.		
Boulders and clay	15	15
Clay, red	5	20
Clay, lt. gray, with grit	5	25
Shale, dark gray, hard	15	40
Shale, gray, broken, bearing 4gpm	15	55
Shale, gray, broken, bearing 3gpm	15	60
10S/6W-27bab$_2$. R. Windgate. Altitude 475 ft. Drilled by R. C. Gallatly, 1965. Casing: 6-in. diam to 34 ft; unperforated.		
Soil	1 1/2	1 1/2
Gravel and clay	13 1/2	15
Shale, gray	15	30
Siltstone, gray	27	57
Shale, gray	65	122

Drillers' logs of representative wells--Continued

Materials	Thickness (feet)	Depth (feet)
10S/6W-27bda. R. Hunter. Altitude 488 ft. Drilled by Corvallis Drilling Co. Inc., 1973. Casing: 6-in. diam to 20 ft; unperforated.		
Soil	4	4
Siltstone brown	4	8
Shale, blue gray	62	70
Siltstone, blue	40	110
Shale, blue	30	140
Shale, gray	32	172
Siltstone, hard gray	7	174
Siltstone, dark blue	15	194
Shale, dark blue	48	242
Siltstone, gray	18	260
Shale, dark blue	50	310
Shale, dark gray	100	410
10S/6W-30acc. M. Lorshbaugh. Altitude 350 ft. Drilled by R. C. Gellatly and R. S. Witham, 1972. Casing: 6-in. to 30 ft; unperforated.		
Soil	2	2
Clay, red	6	8
Clay, yellow	7	15
Clay, light gray	10	25
Clay, dark gray	9	34
Claystone, gray, broken "water-bearing" 4gpm	38	72
Siltstone, light gray	8	80
Claystone, gray, broken, bearing 2gpm	23	103
Claystone, gray	12	115

Drillers' logs of representative wells--Continued

Materials	Thickness (feet)	Depth (feet)
10S/6W-30add. J. Cox. Altitude 374 ft. Drilled by R. C. Gellatly and R. S. Witham, 1973. Casing: 6-in. diam to 56 ft; unperforated.		
Boulders, large	19	19
Clay, brown	6	25
Sandstone, gray	11	36
Sandstone, gray, hard	4	40
Conglomerate, sandy, light gray	5	45
Sandstone, gray, hard	7	52
Sandstone, dark gray "water-bearing" 6gpm	20	72
Claystone, dark gray	30	102
Claystone, light gray, hard	102	115
10S/6W-30dbb. J. Owen. Altitude 410 ft. Drilled by Casey Jones Well Drilling Co. Inc., 1971. Casing: 6-in. to 49 ft; unperforated.		
Soil	1	1
Clay, brown silty	30	31
Clay, blue silty	3	34
Gravel and sand, coarse	5	39
Silt, gray, hard	2	41
Gravel and sand, coarse	2	43
Silt, gray, hard	4	47
Conglomeratic rock, gray, brown	18	65
10S/6W-30dbc. H. Clay. Altitude 392 ft. Drilled by Corvallis Drilling Co. Inc., 1972. Casing: 6-in. diam to 62 ft; unperforated.		
Soil	1	1
Clay, brown, sticky	17	18
Clay, blue, sandy	25	43
Clay, blue-gray, silty	13	56
Claystone, dark gray	61	117
Siltstone, blue-gray, hard	90	207
Siltstone, brown, gray, medium hard	54	261
Siltstone, blue-gray, medium hard	84	345

Drillers' logs of representative wells--Continued

Materials	Thickness (feet)	Depth (feet)
10S/6W-30dcb. H. Clay. Altitude 395 ft. Drilled by Corvallis Drilling Co. Inc., 1972. Casing: 6-in. diam to 63 ft; unperforated.		
Soil	1	1
Boulders and clay, brown	25	25
Clay, blue, silty	20	25
Siltstone, blue, medium hard	38	93
Claystone, gray, medium hard	34	127
Siltstone, blue gray, medium hard	38	165
10S/6W-30dda. J. Johnson. Altitude 345 ft. Drilled by Corvallis Drilling Co. Inc., 1973. Casing: 6-in. diam to 30 ft; unperforated.		
Soil	6	6
Clay, yellow	13	19
Sand and gravel, brown	4	23
Siltstone, blue gray	27	50
Shale, blue gray	90	140
Siltstone, blue gray	35	175
Siltstone, gray	20	195
Shale, gray	50	245
10S/6W-32bac. R. MacRae. Altitude 383 ft. Drilled by R. C. Gellatly, 1959. Casing: 6-in. diam to 16 ft. 8-in; unperforated.		
Soil	1	1
Clay	14	15
Siltstone, light gray	15	30
Shale, gray	50	80
Siltstone, gray	20	100
Siltstone, gray, hard "water-bearing"	12	112

Drillers' logs of representative wells--Continued

Materials	Thickness (feet)	Depth (feet)
10S/6W-33dcc. D. Passon. Altitude 656 ft. Drilled by R. C. Gellatly and R. S. Witham, 1967. Casing: 6-in. to 28 ft; unperforated.		
Soil	2	2
Shale, brown	7	9
Claystone, light gray	22	31
Claystone, blue, medium hard	2	33
Claystone, dark gray	13	46
Claystone, light gray	8	54
Claystone, broken gray "bearing 2 1/2-3gpm"	2	56
Claystone, dark blue	19	75
Claystone, gray, hard, broken "bearing 4gpm"	2	77
Claystone, light gray	13	90
11S/6W-5bcc. E. F. Pankalla. Altitude 410 ft. Drilled by Schoen Electric and Pump, 1971. Casing: 6-in. diam to 27 ft; unperforated.		
Soil	2	2
Clay	18	20
Claystone	22	42
Siltstone, with zeolites	51	93
Siltstone	27	120

20
15
.4

APPENDIX B

Well Construction

The majority of wells in the Kings Valley area tap only terrace alluvium and the Kings Valley Siltstone Member of the Siletz River Volcanic Series. A few wells penetrate the Tyee Formation, and just one chemical analysis was made from a dug well that penetrates that unit. No wells are constructed in the pillow basalts that form the ridges on the eastern side of the valley (see Plate I for well locations in relation to geologic units). Most wells in Kings Valley have been drilled by cable tool. The cuttings loosened by the bit are removed with the bailer. Nearly all wells are 6 inches in diameter and are cased with steel pipe to a depth of at least 20 feet. This effectively seals off the valley alluvium because the thickness of non-indurated materials does not generally exceed 20 feet. Well 10S/6W-30dbb is an exception and is shown in Plates I and IA.

The indurated nature of the units penetrated below the thin valley alluvium allows open hole finishing in most cases. Well screening is rarely necessary. Only wells 10S/6W-30add and 10S/6W-16bdd have, at times, produced excessive amounts of fine sand, but problems of this nature are rare throughout the rest of the valley.