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Geochemistry, Alluvial Facies Distribution, Hydrogeology, and Groundwater Quality of the Dallas-Monmouth Area, Oregon

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AN ABSTRACT OF THE THESIS OF Rodney R. Caldwell for the degree of Master of Science in Geology/Hydrogeology presented April 23, 1993.

Title: Geochemistry, Alluvial Facies Distribution, Hydrogeology, and Groundwater Quality of the Dallas-Monmouth Area, Oregon.

APPROVED BY THE MEMBERS OF THE THESIS COMMITTEE:

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The Dallas-Monmouth area, located in the west-central Willamette Valley, Oregon, consists of Tertiary marine and volcanic bedrock units which are locally overlain by alluvium. The occurrence of groundwater with high

salinities has forced many rural residents to use public water supplies. Lithologic descriptions from driller's logs, geochemical (INAA), and x-ray diffraction analyses were used to determine alluvial facies distribution, geochemical and clay mineral distinctions among the units, and possible sediment sources. Driller's log, chemical and isotopic analysis, and specific conductance information from wells and springs were used to study the hydrogeologic characteristics of the aquifers and determine the distribution, characteristics, controlling factors, and origin of the problem groundwaters.

Three lithologic units are recognized within the alluvium on the basis of grain-size: 1) a lower fine-grained unit; 2) a coarse-grained unit; and 3) an upper fine-grained unit. As indicated by geochemical data, probable sediment sources include: 1) Cascade Range for the recent river alluvium; 2) Columbia Basin plutonic or metamorphic rocks for the upper fine-grained older alluvium; and 3) Siletz River Volcanics from the west for the coarse-grained sediment of the older alluvium.

The Spencer Formation (Ts) is geochemically distinct from the Yamhill Formation (Ty) and the undifferentiated Eocene-Oligocene sedimentary rock (Toe) with higher Th, Rb, K, and La and lower Fe, Sc, and Co concentrations. The clay mineralogy of the Ty is predominantly smectite (86%) while the Ts contains a more varied clay suite (kaolinite, 39%;

smectite, 53%; and illite 8%). The Ty and Toe are geochemically similar, but are separated stratigraphically by the Ts. The Siletz River Volcanics is distinct from the marine sedimentary units with higher Fe, Na, Co, Cr and Sc concentrations. The Ty and Toe are geochemically similar to volcanic-arc derived sediments while the Ts is similar to more chemically-evolved continental crust material.

Wells that encounter groundwater with high salinities (TDS>300 mg/l): 1) obtain water from the marine sedimentary bedrock units or the older alluvium; 2) are completed within zones of relatively low permeability (specific capacities ≤5 gpm/ft); and 3) are located in relatively low-lying topographic settings. The poor quality waters occurring under these conditions may be due to the occurrence of mineralized, regional flow system waters. Aquifers of low permeability are less likely to be flushed with recent meteoric water, whereas upland areas and areas with little low permeability overburden are likely zones of active recharge and flushing with fresh, meteoric water.

The most saline waters sampled have average isotopic values ($\delta D = -6.7\ ^{o}/_{oo}$ and $\delta O = -1.7\ ^{o}/_{oo}$) very near to SMOW, while the other waters sampled have isotopic signatures indicative of a local meteoric origin. The Br/Cl ratios of most (10 of 14) of the waters sampled are within 20% of seawater. A marine connate origin is proposed for these waters with varying amounts of dilution with meteoric waters and water-rock interaction. The problem waters can be classified into three chemically distinct groups: 1) $CaCl_2$ waters, with Ca as the dominant cation; 2) NaCl waters with Na as the dominant cation; and 3) Na-Ca-Cl waters with nearly equal Na and Ca concentrations. The NaCl and $CaCl_2$ waters may have similar marine connate origins, but have undergone different evolutionary histories. The Na-Ca-Cl waters may represent a mixing of the NaCl and $CaCl_2$ waters.

GEOCHEMISTRY, ALLUVIAL FACIES DISTRIBUTION, HYDROGEOLOGY, AND GROUNDWATER QUALITY OF THE DALLAS-MONMOUTH AREA, OREGON

by

RODNEY R. CALDWELL

A thesis submitted in partial fulfillment of the
requirements for the degree of

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in
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TO THE OFFICE OF GRADUATE STUDIES:

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TABLE OF CONTENTS

APPENDICES

LIST OF TABLES

LIST OF FIGURES

FIGURE PAGE

LIST OF PLATES

INTRODUCTION

Groundwater with naturally occurring high concentrations of total dissolved solids occurs at several localities in the Willamette Valley, Oregon. Piper (1942) proposed that salty groundwater is likely to be encountered along the eastern foothills of the Coast Range or within the sedimentary rocks in the western half of the central lowland of the Willamette Valley. In places, the water is not only too saline for human consumption but also for stock watering and irrigation uses. The lack of fresh groundwater has forced many rural residents to obtain potable water from public water sources, drill numerous wells in the hope of obtaining useable water, or treat the poor quality water and repeatedly repair or replace pumps and plumbing.

The Willamette Valley is a structural and erosional basin composed of sedimentary marine and volcanic bedrock units overlain by unconsolidated fluvial sediments. The hydrogeologic and geochemical characteristics of these units may be factors in the distribution of groundwater with high total dissolved solids concentrations.

The purpose of this project is to investigate the geology, hydrogeology and groundwater quality of the Dallas-Monmouth area, Oregon. The project has four objectives:

1) determine the thickness and distribution of lithologic units within the unconsolidated sedimentary deposits and determine the geochemistry and clay mineralogy of the bedrock and unconsolidated units;

2) determine the hydrogeologic characteristics of the bedrock and unconsolidated sedimentary units, determine their relation to groundwater quality, and develop a potentiometric surface map;

3) determine the distribution, chemical and isotopic (hydrogen/deuterium and oxygen-18/oxygen-16) composition, and temporal variations of the poor quality groundwater; and

4) propose possible origins of the saline groundwater.

LOCATION AND GEOGRAPHY OF STUDY AREA

The study area encompasses approximately 140 square miles (360 sq. km) of the west-central Willamette Valley in Polk County, Oregon (Figure 1). The area is primarily agricultural with some industry and logging and includes the towns of Dallas, Monmouth, Independence, Rickreall and Buena Vista. The boundaries of the study area were chosen as features that were probable constraints of the local groundwater flow regime. The boundaries include foothills of the Coast Range to the west, topographic highs to the north and south, and the Willamette River along the eastern margin. The area lies within 44° 45' and 45° 02' north latitude and 123° 05' and 123° 30' west longitude.

Topography ranges from low relief to gently rolling in the eastern portion to mountainous terrain in the west. Elevations range from less than 125 feet (38 m) to over 1600 feet (488 m).

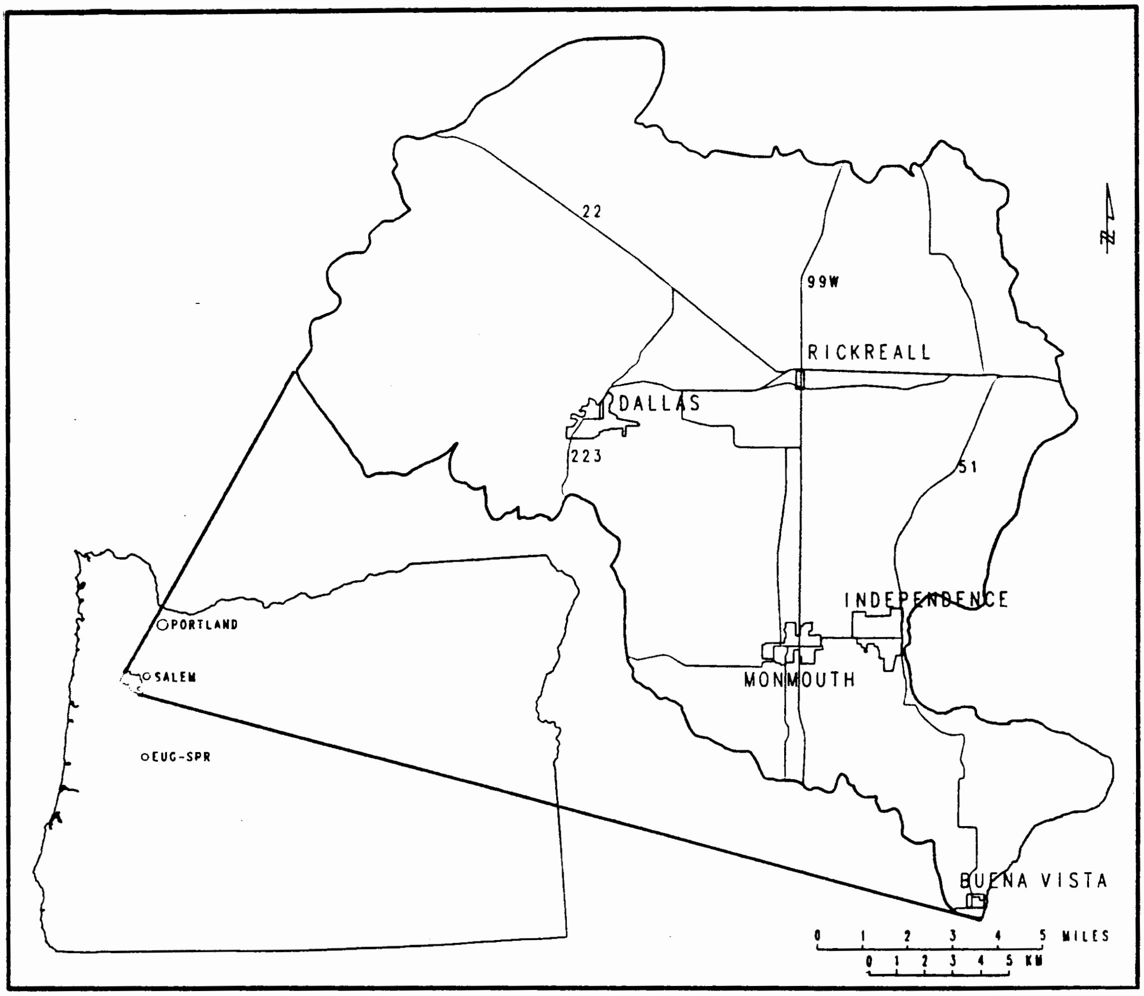


Figure 1. Location of the study area.

The climate is mostly warm and dry in the summer to cool and moist in the winter. Annual precipitation, with the majority occurring in the winter months, varies from less than 40 inches (1 m) in the valley flat near the Willamette River to over 100 inches (2.5 m) in the foothills of the Coast Range (Gonthier, 1983).

Access is provided by a dense network of state, county and local roads, except in the Siuslaw National Forest in the western portion. Due to the abundant vegetation, bedrock exposures are primarily limited to stream banks and roadcuts.

PREVIOUS WORK

The geology of the Dallas-Monmouth area has been mapped and revised numerous times. Mundorff (1939) mapped the Salem quadrangle as part of an Oregon State College master's thesis. Piper (1942) mapped the Willamette Valley as part of a U.S. Geological Survey Water Supply Paper. Baldwin (1964) mapped and discussed the geology of the Dallas and Valsetz 15 minute quadrangles, which includes much of the western portion of the study area. Oil and Gas Investigations maps of portions of the Coast Range by Vokes and others (1954) and Baldwin and others (1955) cover portions of the northern and western study area. Bela (1981), Brownfield and Schlicker (1981) and Brownfield (1982a, 1982b) revised previous maps, added greater detail and produced 7 1/2 minute quadrangle maps covering over 50% of the area. Price (1967), Gonthier (1983), Wells and others (1983), Walker and Duncan (1989) and Walker and MacLeod (1991) produced maps and compilations which also included portions or all of the study area.

In addition to the geologic maps mentioned above, several geologic investigations include the study area. The Siletz River Volcanics, which forms the basement and is exposed west of Dallas, was petrochemically and petrographically described by Snavely and Baldwin (1948) and Snavely and others (1968). Boggs and others (1973) studied the petrographic and paleontologic characteristics of the Rickreall Limestone Member of the Yamhill Formation and suggested a relationship between its accumulation and volcanic activity. Gaston (1974) and McKeel (1984) used foraminifera data to determine the age and depositional setting of marine bedrock units. Baker (1988) investigated the depositional setting and stratigraphy of the Spencer Formation in the west-central Willamette Valley, which included isopach maps of units within the Yamhill and Spencer Formations. Cunderla (1986) petrographically separated the Spencer Formation into a lower arkosic sandstone member and an upper arkosic to lithic arkosic sandstone member.

Balster and Parsons (1968) studied soils and geomorphology of the Willamette Valley and designated a high gravel terrace north of Dallas as the type section for their Dolph Geomorphic surface. Glenn's (1965) Ph.D. thesis on the late Quaternary sedimentation and geologic history of the north Willamette Valley describes the stratigraphy, mineralogy and depositional setting of the Willamette Silt deposits which he determined may represent over 40 episodic flood events. McDowell (1991) summarizes the Quaternary geology of the Willamette Valley.

Master's theses of Graven (1990) and Werner (1990) investigated the structure of the southern and northern Willamette Valley, respectively. These theses, summarized as part of a U. S. Geological Survey open-file report by Yeats and others (1991), include a structure contour map of the bottom of the unconsolidated sediments, cross-sections, a structure contour map of the top of the Spencer Formation and previously mapped structure within the project area. Niem and Niem (1984), Snavely (1987) and Snavely and Wells (1991) summarize the Cenozoic geologic history of western Oregon and Washington.

The groundwater resources and hydrogeologic characteristics of portions or all of the study area have been investigated in U. S. Geological Survey Water-Supply Papers and Oregon Water Resources Department Groundwater Reports (Piper, 1942; Price and Johnson, 1965; Price, 1967; Gonthier, 1983). These reports contain information concerning the hydrogeologic characteristics of specific hydrogeologic units (hydraulic conductivity, yield, specific capacity, coefficient of storage and recharge), water levels, hydrographs of water level fluctuations in specific wells, water chemistry, well log information from driller's reports, and water well and spring locations. Data from Gonthier's (1983) report, including well locations, field measurements (specific conductance, pH and water levels), and water chemistry are an important part of the database for this study. The collection of field data for Gonthier's report was primarily conducted in 1976. Newton's (1969) report on saline water of Oregon, includes locations and chemical analyses of saline wells in western Oregon.

METHODS OF INVESTIGATION

Literature research was the initial phase of the investigation. Hydrogeologic and lithologic information was acquired from U. S. Geological Survey Water-Supply Papers and Oregon Water Resources Department Ground Water Reports.

Field work for this study was conducted primarily during the summer of 1990 through the summer of 1992. The field work included: location and inventory (water level, specific conductance, temperature, and pH measurements) of water wells and springs, return visits and inventory of previously located wells and springs, reconnaissance of the surface geology, water sample collection, and collection of bedrock and unconsolidated sediment samples from surface exposures and drill cuttings from water wells.

Information from over 300 field-located water wells, oil and gas wells, and springs was used for this study (Plate 1). Seventy-six water wells and eight springs were located by the author for this study. The well and spring locations were plotted on 7 1/2 minute quadrangles and elevations were determined within ±10 feet (3 m) accuracy. Twenty previously located wells (Gonthier, 1983) were revisited and inventoried. Several of the wells and springs were visited two or more times during the investigation.

Where there was access, water levels of the wells were measured to an accuracy of 0.05 feet (1.5 cm) with the use of a 200 (61 m) or 500 (152 m) foot steel tape. The water levels were adjusted relative to land surface datum (lsd). The time since the well was last pumped was noted in order to determine if the water level was under static conditions.

Field measurements including specific conductance, temperature, and pH were made at the water wells and springs where possible. Most of the wells were purged by pumping at least three bore volumes or until the specific conductance and temperature values stabilized. Care was taken to bypass water treatment mechanisms such as water softeners or filters. For a few of the wells, which didn't have pumps, samples were retrieved with a teflon bailer or specific conductance and temperature measurements were made by lowering a probe down the well. YSI model 32, YSI model 3000 TLC with a cable reel, and an Orion model 124 temperature and specific conductance meters and a VWR Scientific Cat. No. 34100-674 pH-MV-Temperature meter were used in the field. The meters were checked before and after use, and sometimes in the field, with specific conductance standards ranging from 74 to 12,900 μmhos/cm and pH standards of 4, 7, and 10.

Lithologic descriptions from the driller's logs of nearly 300 field-located water wells and oil and gas wells were input into a database. With the use of Arc/Info geographic information system (GIS) software and a program by Leonard Orzol of the USGS, each well's lithologic units and basal unit elevations were graphically depicted in map view. From this, elevation designations were made for the top of the bedrock and the top and bottom of significant, spatially traceable, unconsolidated sedimentary units. Structure contour and isopach maps of the bedrock, unconsolidated sediments and lithologic units within the unconsolidated sediments were hand drawn and digitized. The GIS program was also used to construct cross-sections.

Previous geologic maps (Baldwin and others, 1955; Baldwin, 1964; Bela, 1981; Brownfield, 1982a and 1982b; Brownfield and Schlicker, 1981; Gonthier, 1983; Yeats and others, 1991), with an emphasis on larger scale more recent maps, were compiled and digitized. Modifications were made as a result of the interpretation of outcrops and driller's logs collected for this report (Plate II).

Surficial bedrock and unconsolidated sediments, drill cuttings from water wells, and drill cuttings from oil and gas exploration wells archived at the Oregon Department of Geology and Mineral Industries were collected for instrumental neutron activation analysis (INAA) and x-ray diffraction analysis. INAA of 71 samples was conducted to determine distribution and trends of major and trace elements within and among geologic units. The INAA procedures are included in Appendix A. The clay mineral suites of seven outcrop and drill cutting samples from water wells were determined with X-ray diffraction analysis. The x-ray diffraction analysis was performed by Reka Gabor, Research Associate, Department of Geology, Portland State University. Percent of mineral component was determined by using the peak-height normalized technique of Chung (1974).

Specific capacity values were calculated with the use of pump test data from the Oregon State Water Resources Department (OWRD) and data recorded on driller's logs. Static water level measurements by the author, OWRD and USGS personnel, and recorded on driller's logs were used to construct a potentiometric surface map of the alluvial-fill.

Samples from wells and springs were collected to ascertain the chemical and isotopic characteristics of the groundwater and the possible origin of the water with high salinities. Analysis of the water samples included: 1) δD and $\delta^{18}O$; 2) Br^-, Cl^-, and I^-; and 3) major ions. After the initial specific conductance values were measured in the field, sites were chosen for further investigation. The sites chosen for additional analysis had specific conductance values ranging from 270 to over 55,000 μmhos/cm.

Thirteen samples were collected for oxygen and deuterium isotopic analysis. A peristaltic pump with teflon tubing was used to fill the 100 ml glass sample bottles. The bottles were then immediately sealed with a polyseal cap to reduce the escape or entrance of gases. Twelve of the samples were analyzed by standard mass spectrometer methods at Krueger Enterprises Inc., Geochron Laboratories Division, Cambridge Massachusetts. The isotopic data is expressed relative to standard mean ocean water (SMOW). For quality assurance, one replicate sample was sent to the USGS Water Resources Division, National Laboratory in Arvada, Colorado and analyzed by mass spectrometer methods. Also used in this study was isotopic data from the Luckiamute River collected by the USGS Water Resources Division (written communication, M. Crumrine, 1992).

Samples submitted for ionic concentration analysis were filtered through a .45 μm millipore filter with the use of a peristaltic pump with teflon tubing and a pancake filter system. The specimens were placed in 250 ml nitric acid-rinsed polyethylene bottles. Samples to be submitted for cation concentration analysis were acidified with 1 ml of nitric acid per 250 ml of solution.

Fourteen sites were sampled for Br^-, Cl^-, and I^- ionic concentrations and were analyzed at the USGS Water Resources Division, National Laboratory in Arvada, Colorado. For quality assurance, two samples from one site and a sample of Pacific Ocean water (collected near the town Neskowin, Oregon) were analyzed. The USGS lab used fluorescein, thiocyanate, and ceric-arsenious oxide colorimetry methods. The lab also measured the specific conductance of the samples which were compared to the field measured values.

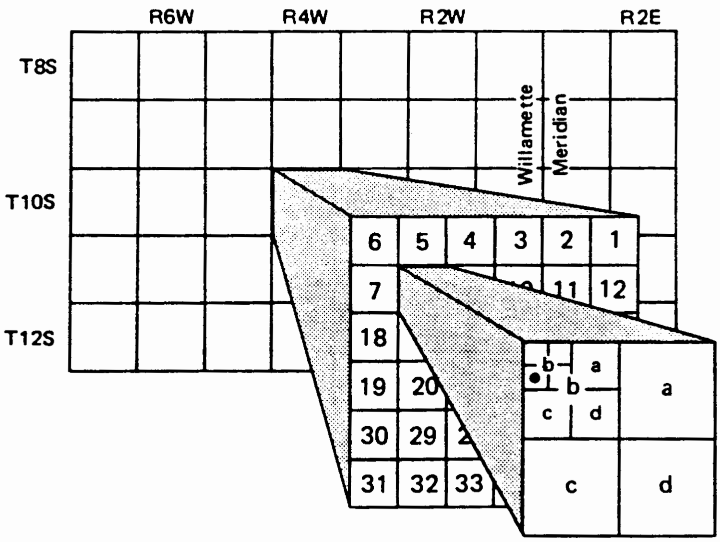
The concentrations of CO_3, HCO_3, Al, B, Ca, Fe, Mg, Mn, Na, Si, I, F, Cl, Br, NO_3, and SO_4 from two saline spring samples were analyzed at Keystone/NEA Environmental Resources in Portland, Oregon. Keystone/NEA analytical methods included inductively coupled argon plasma (ICP)(EPA 6010) for the metals and iodide, ion chromatography (EPA 300.6) for anions other than iodide, and titration for carbonate/bicarbonate (ASTM D513 Method C). Acid digestion (EPA 3050) was used to keep ions in solution.

Chemical data from study area wells and springs and western Oregon oil and gas wells were input into a version of the program WATEQ (Plummer and others, 1976) to determine if distinctions among the waters exist with respect to degrees of saturation with various mineral species. Output from the program also included charge balances to determine consistency of the analyses.

A database was compiled with the following information from study area wells: specific conductance, water-bearing unit, specific capacity, topographic setting, water level depth and elevation, and open interval depth. These parameters were then compared to their respective specific conductance values to determine if possible relations to water quality exists among them.

The water wells, springs, and sample sites are identified, based on their location, according to the rectangular system for the subdivision of public lands

(Figure 2). The series of alphanumeric characters represents the township, range, and section, respectively. A series of three lower case letters (a-d) after the section number are used to designate the quarter-quarter-quarter section subdivision. If more than one well is within the same section subdivision, a delimiting number is attached to the end. Therefore, 10S/4W-8bbc2 is the second site located in township 10 south, range 4 west, and the southwest 1/4 of the northwest 1/4 of the northwest 1/4 of section 8.



● Well 10S/4W-8bbc2

Figure 2. Site location system. Modified from Gonthier (1983).

REGIONAL GEOLOGIC HISTORY

The Cenozoic era continental margin of western Oregon and Washington was marked by underthrusting, transcurrent faulting, block rotation, magmatism, and extension during oblique convergence between North America and oceanic plates (Snavely and Wells, 1991). Concurrently, the Oregon Coast Range, Willamette Valley and adjacent continental shelf were part of a 400 mile (640-km) long forearc basin (Niem and Niem, 1984). Confusing the geologic history, paleomagnetic data indicates a greater than 50° clockwise rotation in the Coast Range and Klamath blocks about a pivot in northwest Oregon or the Klamath Mountains from early to possibly late Eocene (Simpson and Cox, 1977; Magill and others, 1981).

A thick sequence of early to mid-Eocene oceanic basalts and associated seamounts and islands, which includes the Siletz River Volcanics within the study area, form the basement rock of the Oregon and Washington Coast Range (Duncan, 1982). These basalts may be the result of *in situ* eruption during a period of continental-margin rifting, extension, and rapid, highly oblique, northeast motion of the Kula and Farallon plates (Snavely and Wells, 1991).

During the early to middle Eocene subsidence created a deep forearc basin on the Coast Range basaltic crust (Niem and Niem, 1984). In the southern Oregon portion of the basin, thick turbidite deposits of sandstone and siltstone of the Tyee Formation were derived from an uplifted Klamath terrane and Jurassic-Cretaceous arc complexes in Idaho, northern Nevada and adjacent areas (Heller and others, 1985). In the northern Coast Range, locally derived basaltic sandstone, lavas and limited impure limestone lenses accumulated (Niem and Niem, 1984). Deformation, subsidence and marine sedimentation, except around local volcanic sources which formed islands and shoals, continued throughout most of the Eocene (Snavely and Wagner, 1963). During the latest Eocene the forearc basin was separated into a number of smaller basins that deepened westward as a result of regional uplift marked by a period of head-on convergence (Snavely, 1987).

The Oligocene and early Miocene were marked by deformation in Western Oregon and Washington and rapid subsidence in the forearc basin. Thick sequences of bathyal tuffaceous siltstone and arkosic sandstone were deposited in the axial parts of the basin (Snavely, 1987). Volcanic activity of the Cascade arc contributed large quantities of ash and tuff-breccia to the fore-arc basin (Snavely, 1987). Thirty to 34 Ma igneous intrusions into marine sediments of the Coast Range represent the final episode of rift-related magmatism (Snavely and Wells, 1991). Renewed regional underthrusting in the early to mid Miocene caused extensive folding and faulting along northeast and northwest trends. Uplift resulted and restricted marine deposition to the west flank of the Oregon Coast Range and the adjacent continental shelf (Snavely and Wells, 1991).

Basalts of the Columbia River Basalt Group were erupted from fissures in eastern Washington, Oregon, and Idaho during the Miocene. The Grande Ronde and Wanapum Basalt Formations flowed through a 40 mile (60 km) wide gap, the Columbia trans-arc lowland, in the western Cascades and into the northern Willamette Valley (Beeson and others, 1989).

Differential uplift, folding, and faulting of the Oregon Coast Range and Cascade arc intensified in the late Miocene and Pliocene (Niem and Niem, 1984). This resulted in the formation of the Willamette Valley, bordered on the west by the Coast Range and on the east by the Cascade Mountains. The Willamette Valley has since been the depocenter of fluvial and lacustrian sediments (McDowell, 1991).

Bedrock highs, such as the Eola-Salem Hills and the Tualatin Mountains, may have divided the Willamette Basin into a series of closed basins during the Miocene (Snavely and Wagner, 1963). Through drainage occurred by middle Pliocene when the Willamette River became superimposed on the Tualatin Mountains and Salem Hills as a result of aggradation (Baldwin, 1981). During the Pleistocene, incision caused the formation of terraces and pediments

(McDowell, 1991). Fluvial and glaciofluvial gravels (Cascadian origin) and mudflows formed terraces and fans along the eastern margin of the Willamette Valley. Terraces and fans from streams draining the unglaciated Coast Range occur on the western margin (McDowell, 1991).

Allison (1953) identified three gravel units in the southeastern Willamette Valley and tentatively correlated them with glaciations. The oldest and highest gravel was termed the Lacomb gravel (pre-Kansan), the next highest was the Leffler gravel (Kansan), and the lowest and youngest was termed the Linn gravels (Illinoisan or early Wisconsin) which underlies much of the valley floor.

Much of the Willamette Valley floor is underlain by horizontally bedded silt and associated deposits up to an elevation of 400 feet (122 m) (McDowell, 1991). These late Pleistocene deposits have been termed the Willamette Silt (Treasher, 1942; Allison, 1953) and the Willamette Formation by Balster and Parsons (1969). These deposits, which are herein termed the Willamette Silt, are the result of glacial outburst floods from Lake Missoula in western Montana which produced the channeled scablands of Washington, traveled down the Columbia River Gorge and into the Willamette Valley (Allison, 1935, 1953, 1978; Bretz, 1925). Associated with the Willamette Silt are up to boulder size granite, granodiorite and other material of extrabasinal origin that may have been ice-rafted into place (Allison, 1935).

A two phase model of the deposition of the Willamette Silt has evolved (Allison 1932, 1935, 1978; Glenn, 1965; Schlicker and Deacon, 1967; Roberts, 1984). The first phase consists of a thick body of low energy, silt and sand deposits probably laid down by multiple floods. The second phase consists of a single very large flood resulting in erosion and deposition of smaller volumes of coarse-grained, high-energy deposits near gaps where the flood waters entered the valley and fine-grained, low-energy deposits across the valley floor (McDowell, 1991).

Approximately 13,000 years ago, after the regression of the flood waters, drainage networks and the main channel of the Willamette River became re-established on the floor of the Willamette Valley (McDowell, 1991). In response to changing local base level, shifts in the Willamette River's position and the piracy and diversions of valley floor tributaries occurred about 11,000 years ago (Glenn, 1965). Fluvial deposition has been primarily restricted to channels and floodplains of major rivers and their tributaries during the Holocene (Yeats and others, 1991).

STRATIGRAPHY

The study area stratigraphy consists of sedimentary marine and volcanic bedrock units which are locally overlain by unconsolidated sediment deposits. The stratigraphic relationships and characteristics of the individual units are discussed in this section. Plate II is a surficial geologic map compiled from previous works with some minor modifications as a result of findings from this investigation.

BEDROCK GEOLOGIC UNITS

Stratigraphic Tertiary bedrock correlations for areas within western Oregon are illustrated in Figure 3. The mineralogy of the individual bedrock units are listed in Table I.

Siletz River Volcanics (Tsr)

The early to mid Eocene Siletz River Volcanics, first named by Snavely and Baldwin (1948), is the basement rock in the central Oregon Coast Range. Based on K-Ar radiometric dating techniques, the age has been determined to be 50.7±3.1 to 58.1±1.5 Ma (Duncan, 1982). Snavely and others (1968) suggested an average thickness of 10,000 feet (3 km),

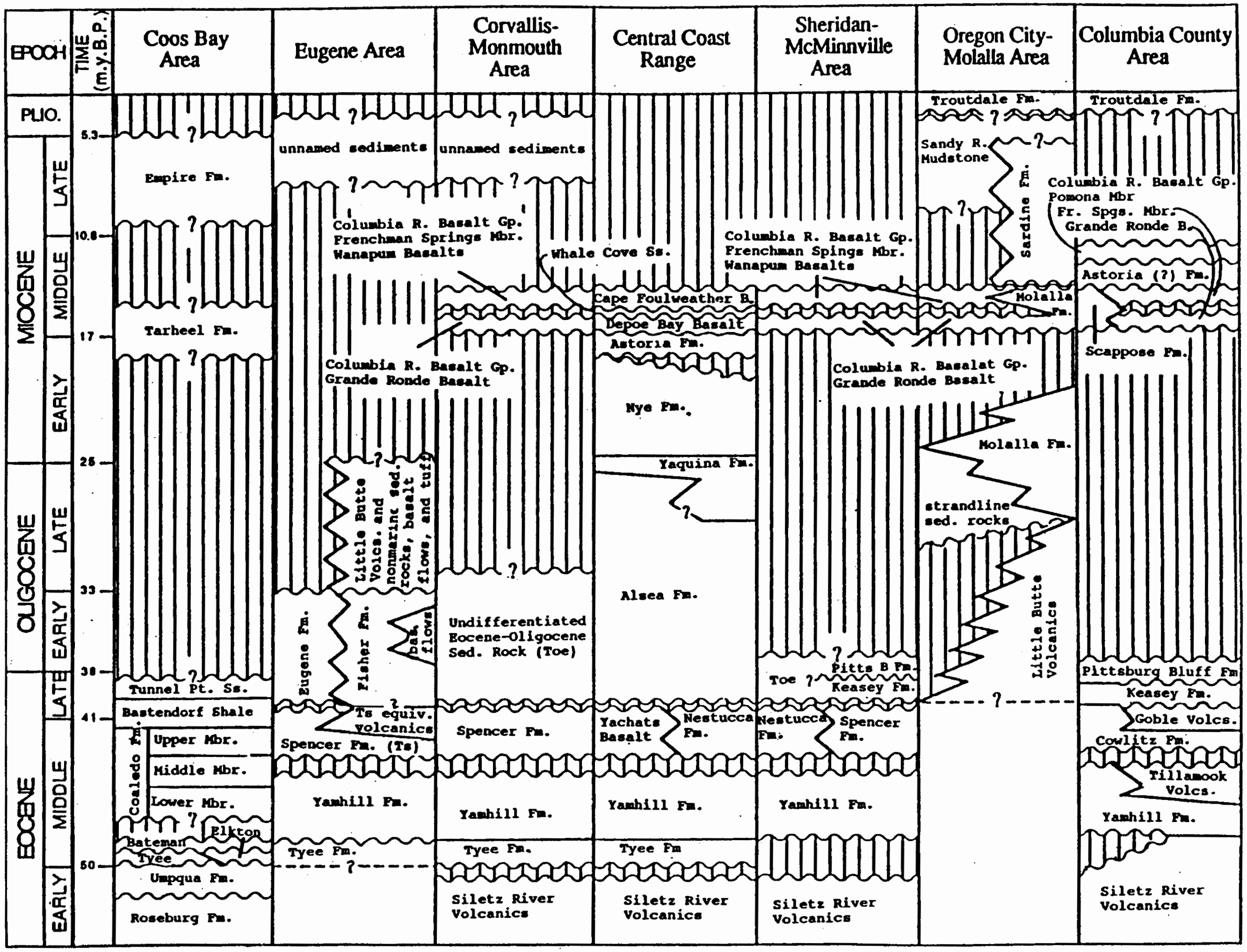


Figure 3. Stratigraphic correlation chart for Tertiary rocks of western Oregon (modified from Yeats and others, 1991).

TABLE I

MINERALOGY OF THE BEDROCK UNITS

UNIT	MINERALOGY	REFERENCES
Columbia River Basalt (Tcr)	Primary: Ca–Na plagioclase, augite, magnetite, ilmenite Secondary: chlorophaeite	Beaulieu (1971)
Intrusive Rocks (Ti)	Primary: plagioclase (varied), magnetite, olivine, augite, apatite, biotite, quartz Secondary: chlorite, calcite, zeolites, nontronitic clay minerals	Brownfield (1982), Bela (1981), MacLeod (1981)
Undif. Eocene–Olig. Sed. Rock (Toe)	No analysis	
Spencer Fm. (Ts)	Primary: plagioclase (oligoclase to calc–andesine), quartz, K–feldspar (orthoclase, with minor microcline and perthite), with lesser amounts of muscovite, biotite, green hornblende, magnetite, pyroxene, chert, zircon, sphene, glauconite Secondary: smectite, zeolites, calcite, quartz, chlorite, K–feldspar, Fe–oxides	Gandera (1977), Cunderla (1986), Al–Azzaby (1980)
Yamhill Fm. (Ty)	Primary: plagioclase (oligoclase and andesine), hornblende, quartz, glauconite, chlorite, limonite, biotite, muscovite Secondary: calcite, glauconite	Baldwin and others, (1955), Al–Azzaby (1980)
Rickreall Limestone Mbr.	Primary: calcite, quartz, augite, mica, feldspar Secondary: heulandite, chert, quartz, pyrite, mixed layer clays	Boggs and others, (1973)
Tyee Fm. (Tt)	Primary: plagioclase, quartz, biotite, muscovite, chert Secondary: calcite	Baldwin (1964)
Siletz River Volcs. (Tsr)	Primary: plagioclase (mostly labradorite), augite, magnetite, olivine Secondary: smectite, pyrite, palagonite, thomsonite, calcite, chlorite, natrolite, analcime, scolecite, mesolite, heulandite, apophyllite, chabazite, mordenite, stilbite, laumonite, amethystine quartz	Baldwin (1964), Snavely and others, (1968), Beaulieu (1971), Keith and Staples (1985)

laumontite

with some areas near former volcanic centers possibly over 20,000 feet (6 km). Baldwin (1964) assumed an average dip to the southeast at 15° to 20°. Local variations in the strike and dip are ascribed to faulting. The Tsr is exposed in the Ellendale basalt quarries west of Dallas.

Snavely and others (1968) divided the Tsr into two units. The predominant lower unit consists of dark greenish gray, aphanitic tholeiitic to olivine tholeiitic, amygdaloidal, submarine pillow lava and flow breccia. Closely packed ellipsoidal pillows make up the majority of the lower unit. Massive to columnar jointed basalt sills and basalt-filled lava tubes occur in the tuff-breccia sequences (Snavely and others, 1968). The thinner, less extensive upper unit is comprised of submarine and subaerial alkali basalt, associated porphyritic rocks with olivine basalt flows and interbedded breccia. In both units, secondary minerals have been precipitated in vesicles, between breccia clasts, and along fractures in the basalt (Table I).

The Kings Valley Siltstone Member overlies and is interbedded with the Siletz River Volcanics (Volkes and others, 1954). The member is marine in origin and is comprised of brownish gray tuffaceous siltstone with some thin, white, tuff laminae and calcareous lenses of medium-grained basaltic sandstone (Penoyer and Niem, 1975).

Tyee Formation (Tt)

The middle Eocene Tyee Formation does not crop out nor has it been detected in the subsurface within the project area. It has been mapped in the Kings Valley area to the southwest where it unconformably overlies the Siletz River Volcanics. Burky and Snavely (1988) estimated an age of 50 to 52.5 Ma based on coccoliths.

The commonly eastward dipping marine strata are composed of bluish-gray, fine to medium-grained, feldspathic, lithic, or arkosic sandstone and micaceous carbonaceous siltstone with minor dacite tuff interbeds near the top (Baldwin, 1964, Walker and Duncan, 1989). The sediment was deposited in middle bathyal or deeper waters and to a lesser extent, inner neritic water depths (McKeel, 1984).

Yamhill Formation (Ty)

The middle to late Eocene Yamhill Formation, first named by Baldwin and others (1955), unconformably overlies the Siletz River Volcanics within the study area. To the south near Falls City, the Yamhill Formation overlies the Tyee Formation.

The eastward dipping Yamhill Formation consists predominantly of siltstone and shale with fine-grained sandstone and tuffaceous material (Baldwin, 1964). The type section, located along Mill Creek near Buell, Oregon, consists of a thinly bedded 500 foot (150 m) basal unit of dark-gray shale and siltstone with occasional beds of lime-cemented sandstone overlain by 500 feet (150 m) of massive to thick bedded gray to greenish gray sandstone (Baldwin and others, 1955). Approximately 4,000 feet (1200 m) of massive to faintly bedded micaceous siltstone and mudstone overlie the sandstone. In the west-central Willamette Valley, Baker (1988) recognized a tuffaceous mudstone and siltstone unit overlain by a sandy to conglomeritic volcaniclastic unit (termed the Miller sandstone member) which is overlain by faintly bedded micaceous siltstone and mudstone.

Gaston (1974) and Mckeel (1984) used microfossils to determine the environment of deposition. The upper and lower mudstone units were deposited in lower to middle bathyal marine depths while the prominent Miller sandstone member is shallow-marine to non-marine in origin.

The Rickreall Limestone Member of the Yamhill Formation occurs locally at or near the base of the Yamhill Formation (Baldwin, 1964). The low grade limestone is bioclastic with rounded fragments of basic volcanic rock and minor amounts of micrite (Boggs and others, 1973). The limestone generally occurs as lenses that grade laterally and vertically into fossiliferous sandstone and siltstone. The prevalence of the Foraminifera Amphistegina, which are generally restricted to shallow water depths in modern environments, is indicative of deposition in a shallow nearshore environment (Boggs and others, 1973). The Rickreall Limestone Member is exposed in the abandoned Oregon Portland Cement Company quarry southwest of Dallas (8S/6W-12).

Spencer Formation (Ts)

The late Eocene Spencer Formation, first named by Turner (1938), comprises approximately one half of the exposed Eocene sedimentary rocks within the Dallas-Monmouth area. The Ts, similar to all of the marine bedrock strata in the Willamette Valley, is usually deeply weathered at the surface. The Ts is gently deformed and dips easterly at angles of about 15° (Beaulieu, 1971). An angular unconformity occurs between the Spencer Formation and the underlying Yamhill Formation, the result of a marine regression (Graven, 1990). Suggested thicknesses within the study area range from nearly 2,500 feet (640 m) near Dallas (Yeats and others, 1991), at least 1,500 feet (460 m) near Monmouth (Baldwin, 1964), and about 800 feet (240 m) in the Balston 7 1/2 minute quadrangle (Brownfield, 1982b).

The Ts has been divided into a lower predominantly sandstone member and an upper mudstone and siltstone member. The lower member consists of very fine to fine-grained arkosic, micaceous and tuffaceous sandstones and siltstones with some carbonaceous or glauconitic units (Baker, 1988). The upper member is predominantly mudstone, silty mudstone and tuffaceous siltstone (Baker, 1988).

Mckeel (1984) suggests inner to middle neritic depths for most of the lower member and middle bathyal for the upper member. A metamorphic and plutonic source for much of the lower member and a more proximal volcanic source for the upper mudstone member is suggested (Cunderla, 1986: Baker, 1988). The best exposures of the Spencer Formation within the study area are at the Willamette River cut bank south of the Buena Vista ferry and a roadcut on Fishback Hill west of Monmouth.

Eocene-Oligocene Sedimentary Rock (Toe)

A marine sedimentary unit, termed the Eocene-Oligocene sedimentary rock by Bela (1981) and the undifferentiated Tertiary rocks of Gonthier (1983), is exposed west of the Eola Hills in the northern part of the study area. The Toe is subdivided into a light-gray to tan, sandy tuffaceous siltstone lower unit and a light-brown to gray, fine- to coarse-grained tuffaceous sandstone and siltstone upper unit (Baldwin and others, 1955; Bela, 1981; Brownfield and Schlicker, 1981). The lower unit is approximately 1,000 feet (300 m) thick and the upper unit is approximately 1,350 feet (410 m) thick (Brownfield and Schlicker, 1981). Mckeel (1984) determined that the sediment was deposited near to shore, in shallow shelf to middle bathyal water depths.

Intrusive Rocks (Ti)

Oligocene mafic dikes, sheets, and laccoliths intrude marine sedimentary rocks throughout much of the Coast Range. A large population of the intrusions of variable thickness occur southwest of the study area in the Falls City vicinity. The intrusions are composed of dense basalt, diabase, andesite, diorite and gabbro (Baldwin, 1964; Bela, 1981; Brownfield, 1982a; MacLeod, 1981). The age of these igneous intrusions has been determined to be approximately 30 Ma (Walker and Duncan, 1989).

Columbia River Basalt Group (Tcr)

Subaerial basalt flows of the Miocene Columbia River Basalt Group are exposed in the Eola Hills in the northeastern portion of the study area and in the Salem Hills to the east. The basalt has a maximum thickness of 400 to 500 feet (120 to 150 m) with individual flows of 40 to 100 feet (12 to 30 m) (Bela, 1981). An age of 16 Ma has been determined isotopically for this section of the Tcr (Beeson and others, 1989).

The basalt is of the Grande Ronde Basalt formation as is the case with most of the flows in the Willamette Valley. Included in the Eola Hills are: (1) a basal, reversed polarity member, possibly the Grouse Creek Unit; (2) the "low Mg" , normal polarity (N_2) Winter Water Unit; and (3) the "high Mg", normal polarity (N_2) Sentinel Bluffs Unit

(Beeson, 1992, personal communication).

The Tcr consists of weathered to unweathered basaltic lava flows and interflow zones. The interflow zones are marked by ash, baked soils and flow-top breccia. The flows are generally dense, fairly crystalline, dark-gray to black, fine-grained to aphanitic, even-textured to slightly porphyritic tholeiitic basalt exhibiting massive columnar jointing near the base to diced or hackly jointing in the entablature (Bela, 1981). Weathered zones are reddish-brown to grayish-brown, crumbly to medium-dense basalt. As a result of intense weathering, thick, clay-rich lateritic soils and local bauxite mantle much of the hilltops and slopes.

UNCONSOLIDATED SEDIMENTS

Unconsolidated sediments overlie marine and volcanic bedrock units over most of the valley floor and some upland areas. Figure 4 illustrates the correlations of these units throughout the Willamette Valley.

High Terrace and Alluvial Fan Deposits (Qt)

The Pleistocene to Holocene high terrace and alluvial fan deposits include the higher terrace deposits of Bela (1981), the terrace gravels of Baldwin (1964), the terrace deposits of Gonthier (1983), and the terrace, pediment, and lag gravels of Walker and MacLeod (1991). The unit

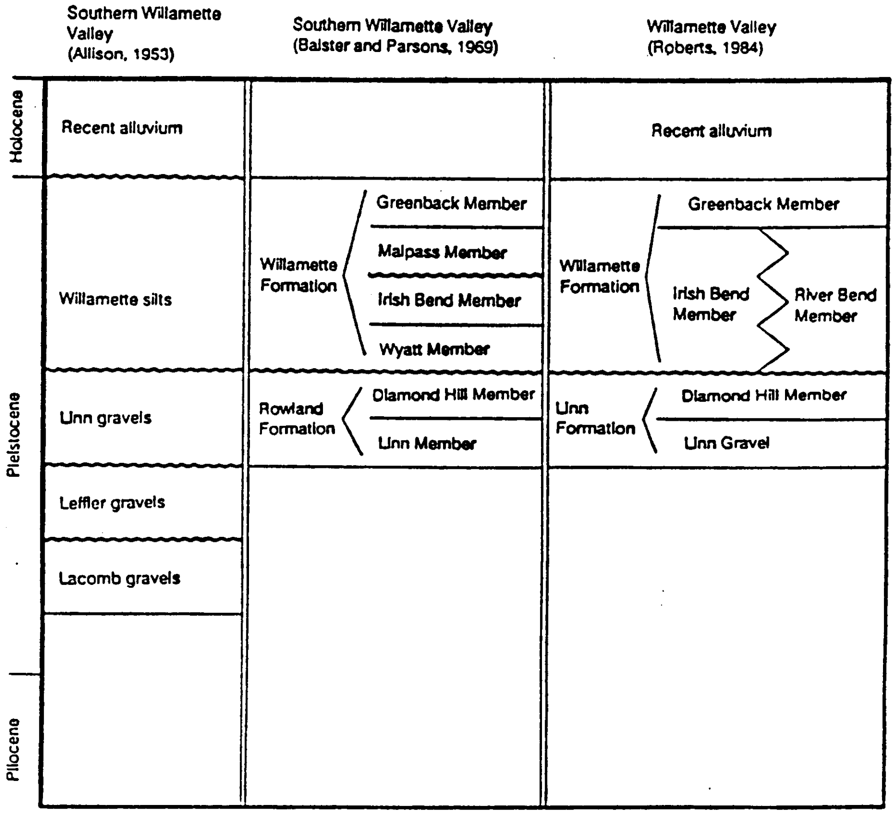


Figure 4. Correlation of Willamette Valley Quaternary stratigraphic units (modified from McDowell, 1991).

underlies elevated terraces, and consists of alluvial fans, colluvium and slope wash near bedrock foothills.

The Qt is composed of poorly sorted, light-brown clay, silt and sand with some gravel layers weathered to variable degrees. The gravels are basaltic in composition and were probably derived from the Siletz River Volcanics to the west. Thicknesses range from more than 80 feet (24 m) near Dallas to thin veneers overlying marine bedrock. Portions of the Qt may be equivalent to the Lacomb and Leffler gravels of Allison (1953) (McDowell, 1991).

The Qt may be locally mantled by the Willamette Silt of Allison (1953), the Willamette Silt Formation of Glenn (1965), or the Willamette Formation of Balster and Parsons (1968) and Roberts (1984) with a possible intervening paleosol. These deposits, herein referred to as the Willamette Silt, are composed of bedded to massive clay, silt and sand found at elevations of up to 400 feet (122 m) (McDowell, 1991). Glacial erratics of granite, granodiorite, slate, gneiss and other material of non-Willamette Valley provenance are also associated with the Willamette Silt.

The Qt is exposed north of Dallas near the intersection of Dyck and Perrydale roads (7S/5W-15), the type section for the Dolph geomorphic surface (Balster and Parsons, 1968) (Figure 5). At that location, highly weathered clay, silt, sand and gravel directly overlie fine-grained, fossiliferous sandstone of the Spencer Formation. Intensely weathered gravel, can easily be cut with a shovel near the top of the section.

Older Alluvium (Qoal)

The Pleistocene to Holocene older alluvium is the most extensive of the unconsolidated geologic units in the valley flat of the study area. This material includes the middle terrace deposits, the lower terrace deposits of tributary rivers and streams and the lower terrace deposits of alluvial bottomlands of Bela (1981), the older alluvium of Gonthier (1983) and Walker and Duncan (1989), and the alluvium of Baldwin (1964). The Willamette Silt also mantles this unit.

Figure 5. Weathered Qt gravel overlying Spencer Formation sandstone.

The Qoal is composed of poorly sorted and unconsolidated clay, silt, sand and interbedded gravel. The Qoal may be equivalent to the Linn gravels of Allison (1953), the Rowland Formation of Balster and Parsons 1969), or the Linn Formation of Roberts (1984). In general, the upper part of the older alluvium consists of fine-grained sediments (clay, silt and fine-grained sand) which overlies layers of fine and coarse-grained sediments. The unit is transitional to the high terrace and alluvial fan deposits. Gonthier (1983) reported thicknesses up to 85 feet (26 m), but that may have included part of the Qt.

Yeats and others (1991) report nonmarine, fine-grained sediments ("blue clay") throughout much of the Willamette River Valley. This unit may underlie or be included in the Qoal in some areas.

Recent River Alluvium (Qal)

The recent river alluvium (Holocene) comprises the sediment deposited in the active Willamette River channel and floodplain. This unit includes the recent river alluvium and the lower terrace deposits of the Willamette River of Bela (1981) and the younger alluvium of Gonthier (1983).

The Qal is composed of generally poorly sorted, fresh cobbles, gravel, sand, silt and clay. Gonthier (1983) reported thicknesses of up to 55 feet (18 m). Generally, 5 to 30 feet (1.5 to 9 m) of silt and very fine sand overlie 10 to 45 feet (3 to 14 m) of sand and gravel (Gonthier, 1983). The sand and gravel layers appear to be areally extensive and are quarried throughout the Willamette Valley. Some driller's logs indicate that fine-grained sediments, which may correlate to the non-marine fine-grained sediments of Yeats and others (1991), occur under the coarser-grained sand and gravel layers.

RESULTS

THICKNESS AND DISTRIBUTION OF UNCONSOLIDATED UNITS

Outcrop and well log information enabled determination of the thickness and distribution of lithologic units within the deposits of unconsolidated sediment. These lithologic units are based on predominant grain-size and are not time stratigraphic units. The information is presented in cross-sections (Plate III) and a series of isopach and contour maps (Figures 6 to 11). The driller's logs used to construct the cross-sections are included in Appendix B.

With hydrologic properties in mind, the unconsolidated sediment was divided into either predominantly coarse-grained or fine-grained lithologic units. The coarse-grained aquifers within the unconsolidated deposits, composed primarily of sand and gravel, have much higher water producing capabilities than their fine-grained counterparts. The distribution, thickness, and upper and lower elevational extent of the coarse-grained unit may be of benefit to drillers when determining the placement and depth of future water wells.

Elevation of top of bedrock

Tertiary marine and volcanic bedrock units crop out along much of the northern, western and southern boundaries of the study area. However, most of the units at those localities are highly weathered and mantled by thick regolith. In approximately half of the area, primarily in the valley flat below an elevation of 300 feet (91.4 m), the bedrock material is overlain by unconsolidated sediment.

Lithologic descriptions from the driller's logs of 181 field located water and engineering wells were used to determine the elevation of the bedrock beneath the alluvial fill (Figure 6). Eighty-seven of the wells penetrated the top of the bedrock. Ninety-four of the wells did not penetrate bedrock, but were used to constrain its maximum possible elevation.

The elevation of the upper bedrock surface gradually increases to the north, west and south of the Willamette River, which lies on the eastern margin of the study area. The elevations are lowest, less than 100 feet (30.5 m), under most of the Willamette River floodplain. The elevation of the top of the bedrock could be less than 80 feet (24.4 m) at some locations near the Willamette River since the majority of the wells there are shallow and do not penetrate bedrock.

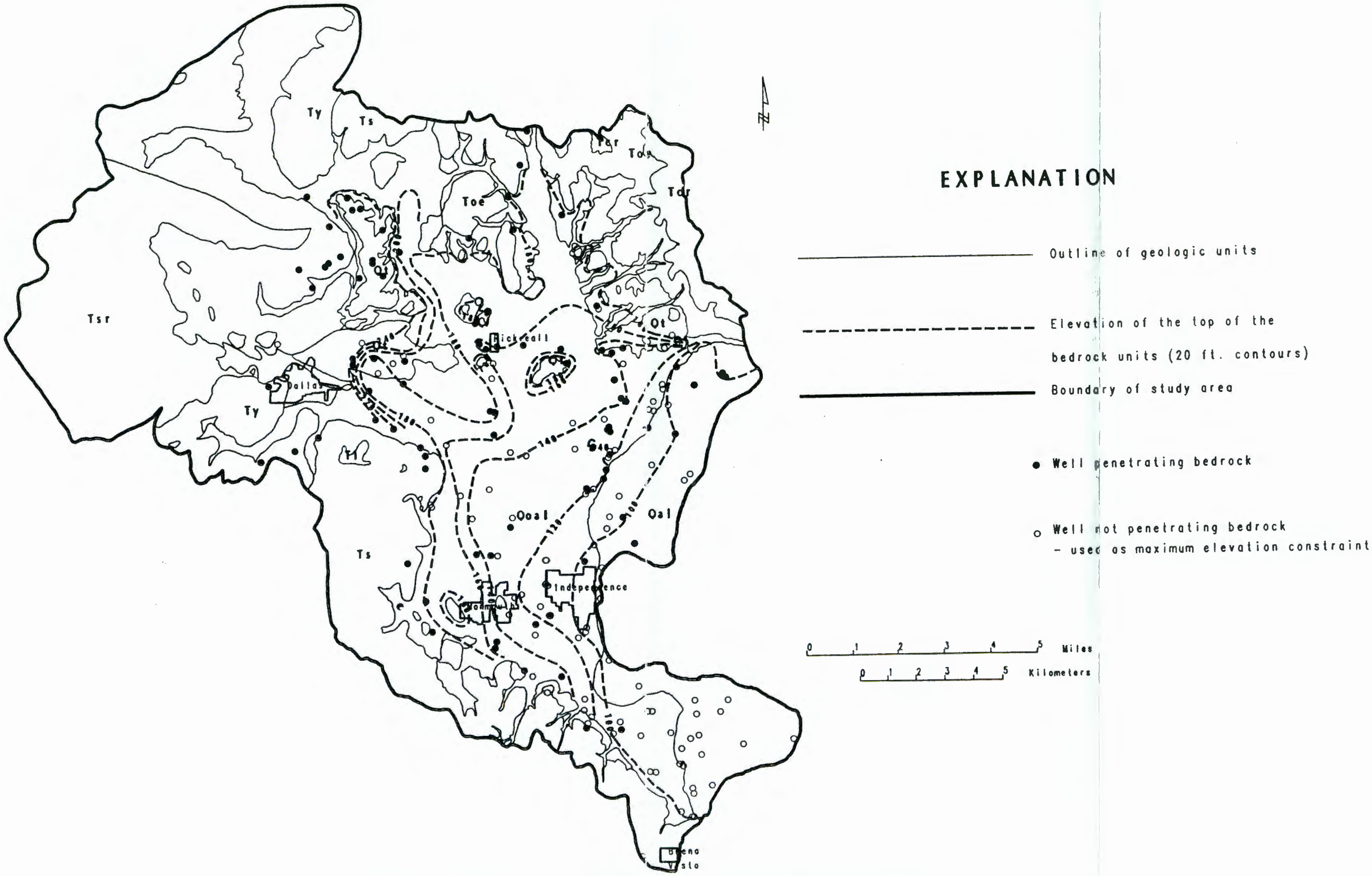


Figure 6. Elevational contours of upper bedrock surface.

Thickness of Alluvial Fill

The majority of the unconsolidated sediment deposits occur at elevations of less than 300 feet (91 m). The deposits consist of clay, silt, sand, gravel, pebbles and cobbles. Individual layers within the unconsolidated sediments vary from homogeneous to heterogeneous in grain size distribution.

One hundred seventy-five wells were used to determine the thickness of the unconsolidated material (Figure 7). Eighty-two of these wells extended through the alluvial fill and penetrated the underlying bedrock. Ninety-three of the wells did not fully penetrate the alluvium, but were useful in constraining a minimal thickness.

In general, the unconsolidated material thins coincidentally with increasing elevation of the upper bedrock surface. The greatest thicknesses, up to and over 80 feet (24.4 m), occur near the Willamette River between Buena Vista and Independence and along a northwest trend between Independence and Dallas. The majority of the wells with lithologic records in the valley flat and floodplain north of Buena Vista are less than 80 feet (24.4 m) deep and none of them reportedly encounter bedrock. Therefore, the thickness of unconsolidated sediment in that area may actually be well over 80 feet (24.4 m) thick, but conclusive data are lacking.

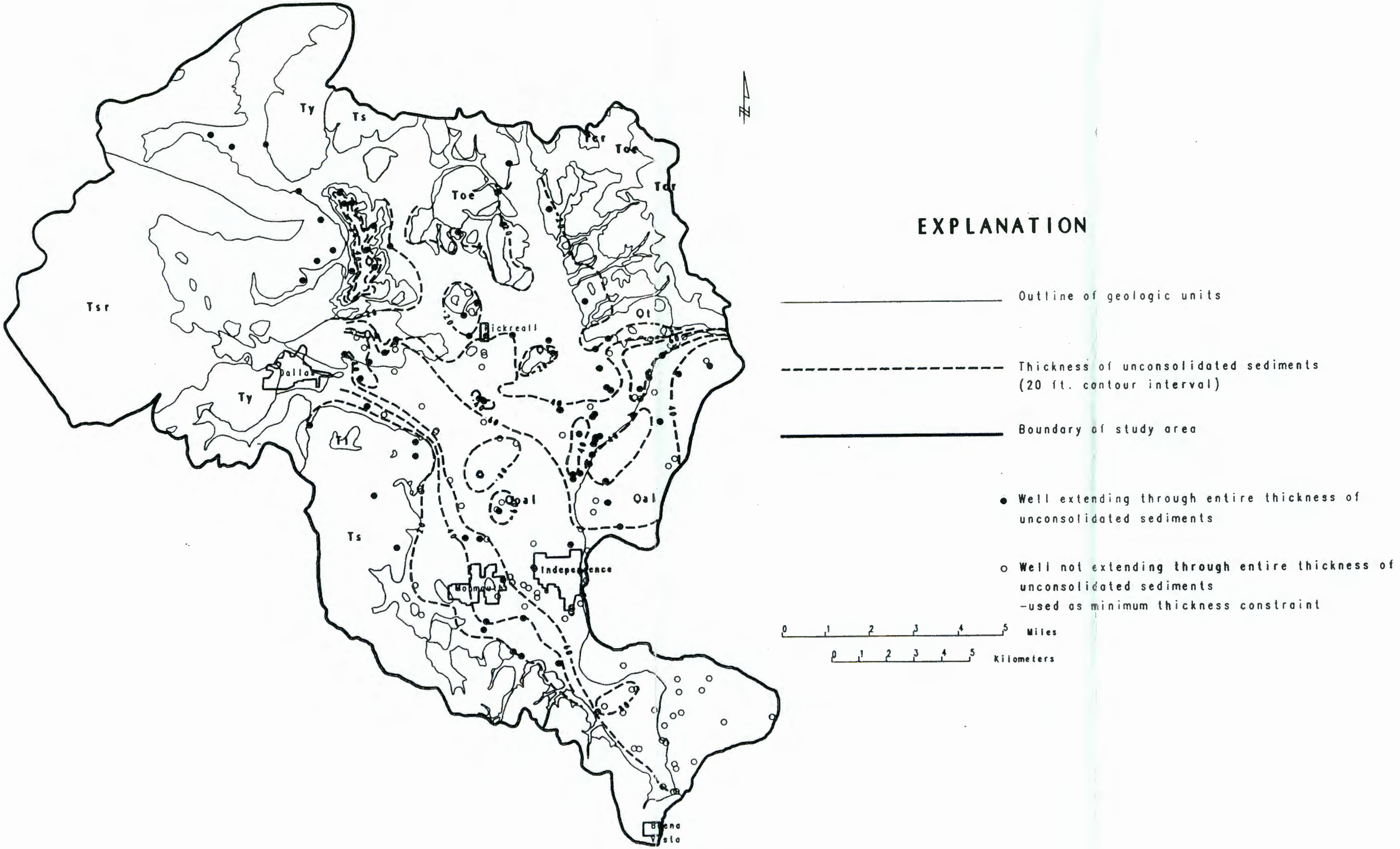


Figure 7. Isopach map of alluvial fill.

Thickness of lower fine-grained unit

A sequence of clay and silt deposits, commonly termed "blue clay" by drillers, occurs under some of the lowermost sand and gravel layers and above the bedrock in the Dallas-Monmouth area. Most of the lower fine-grained unit appears to be less than 20 feet (6 m) thick. Siltstone and claystone of the marine bedrock units often weathers to a chemically reduced, gray to blue, fine-grained material. This causes difficulty in differentiating between the weathered bedrock and the lacustrian or alluvially derived "blue clay" from descriptions in drillers' logs. It was not possible to confidently trace this unit within much of the basin fill and therefore, an isopach map was not constructed.

Although the lower fine-grained unit appears to be thin or absent over much of the area, a significant thickness may underlie the valley flat and the recent Willamette River floodplain north of Buena Vista. There, four relatively deep wells reportedly penetrate up to 94 feet (28.6 m) of blue clay. The close proximity to an exposed ridge of Spencer Formation raises the question of whether this is weathered marine bedrock or alluvial or lucustrian deposits. Cross-section E-E' (Plate III) represents lithologic data from wells in this area.

Bottom of Coarse-Grained Unit

Layers of coarse-grained unconsolidated sediment, comprise much of the unconsolidated basin fill. This unit is predominantly composed of sand and gravel and in some cases, pebbles and cobbles. The coarse-grained material is poorly to moderately well sorted, moderately to well rounded, and chiefly of basaltic and andesitic composition. Locally, clay and/or silt occurs as a matrix or as interlayers between the coarse-grained layers.

One hundred forty wells were utilized to determine the elevation of the bottom of the lower-most, significant coarse-grained sedimentary deposits (Figure 8). For the purpose of this study, the coarse-grained deposits were determined to be significant if they were greater than 10 feet (3 m) thick and were laterally traceable among neighboring wells or outcrops. Ninety of the wells extended through the sand and gravel deposits. Forty-nine of the wells did not, but they were utilized in constraining a maximum basal elevation.

Some areas lack coarse-grained material within the basin fill sediments. A case in point is the valley flat area north of Rickreall Creek in the north central portion of the study area. Although up to 40 feet (12.2 m) of unconsolidated sedimentary deposits occur there, virtually no sand and gravel layers are present. The maximum extent of significant coarse-grained material is represented by the

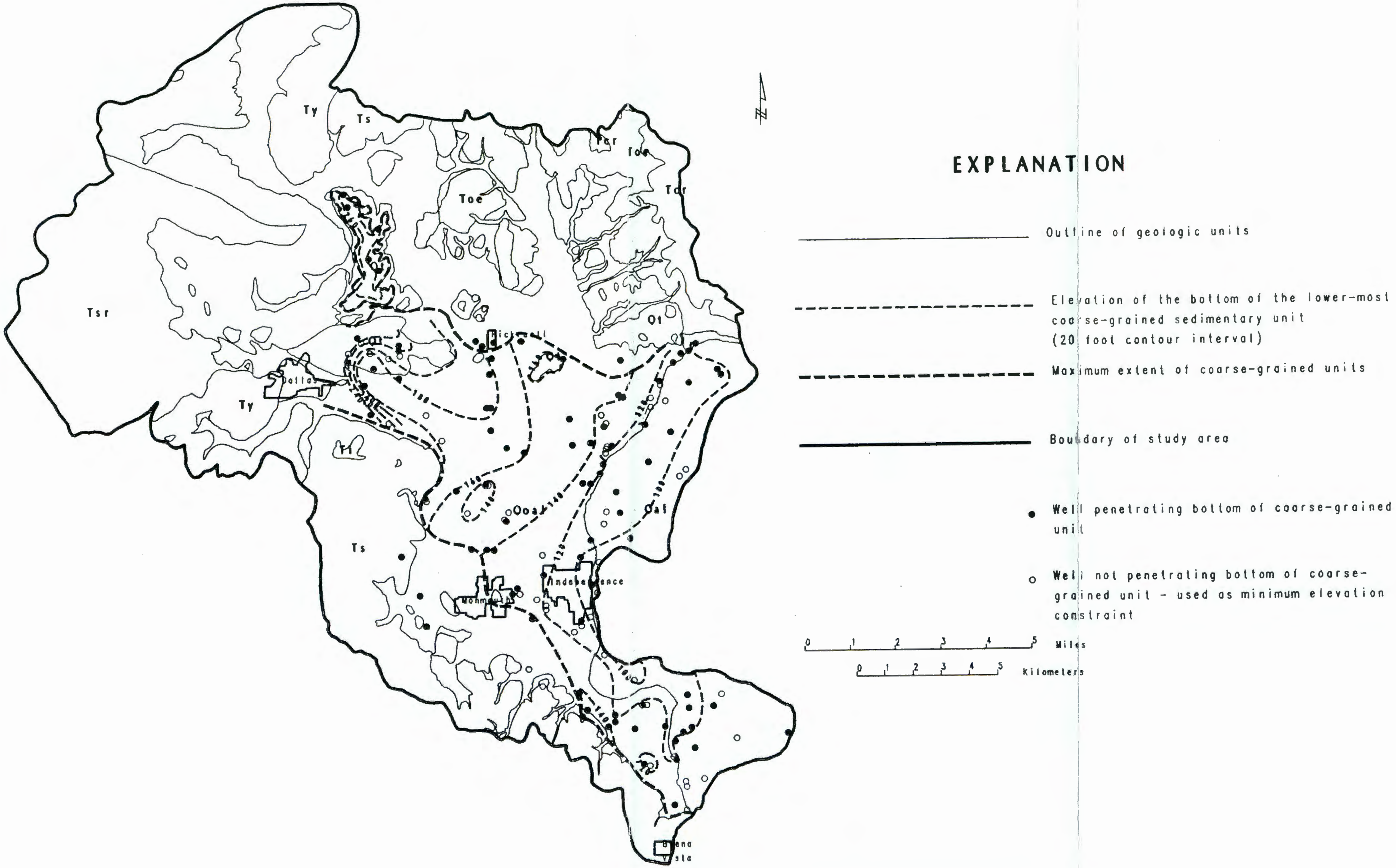


Figure 8. Elevational contours of the bottom of the coarse-grained unit.

thick dashed lines in Figures 8,9, and 10. Drillers have reported sand and gravel layers beyond these lines, but they are relatively thin and discontinuous.

Commonly, the coarse-grained unit directly overlies the bedrock (cross-sections C-C' and D-D', Plate III). Consequently, the basal elevation contours of the unit are very similar to those of the upper bedrock surface. However, where a fine-grained unit occurs between the bedrock and the coarse-grained unit, there is a marked difference between the contours. This occurs in and near the recent Willamette River floodplain where wells have reportedly encountered up to 94 feet (28.6 m) of blue clay (cross-sections A-A' and E-E', Plate III).

Top of Coarse-Grained Unit

The top of the uppermost significant coarse-grained unit was determined with the use of the driller's reports of 150 wells, all of which penetrated the top of the unit (Figure 9). The elevation of the top of the unit is the lowest, commonly less than 150 feet (46 m), adjacent to the Willamette River. The highest elevations, over 280 feet (85 m), occur in the upper terrace and fan deposits northeast of Dallas. The top of the coarse-grained material slopes gently to the east from Dallas to the Willamette River.

Figure 9. Elevational contours of the top of the coarse-grained unit.

Thickness of Coarse-Grained Unit

One hundred sixty-one wells were used to determine the thickness of the coarse-grained unconsolidated material (Figure 10). Of these wells, 129 extended through the entire unit. Thirty-two of the wells did not extend through the entire thickness, but were used as a minimal thickness constraint. In most cases, the thickness of the coarse-grained sediment unit is accurately indicated by the difference in elevation of the top of the uppermost and the bottom of the lowermost significant gravels. Individual clay, silt and fine-grained sand layers are locally included in the total thickness of the coarse-grained material. These fine-grained deposits were only included in the coarse-grained unit if they constituted less than 25% of the overall thickness of the unit and were bounded on the top and bottom by significant coarse-grained material. Cross-sections B-B' and C-C' (Plate III) represent this situation.

The sand and gravel deposits are thickest near the Willamette River and in an area east and southeast of Dallas. Near Dallas, thicknesses exceed 80 feet (24.4 m) (cross-section c-c', Plate III). Although the unit is the thickest near Dallas, it includes several interlayers of fine-grained sediment up to nearly 20 feet (6.1 m) thick. The sand and gravel deposits at and northeast of Independence are less than 60 feet (18.3 m) thick, but they are coarser-grained and contain less fine-grained material

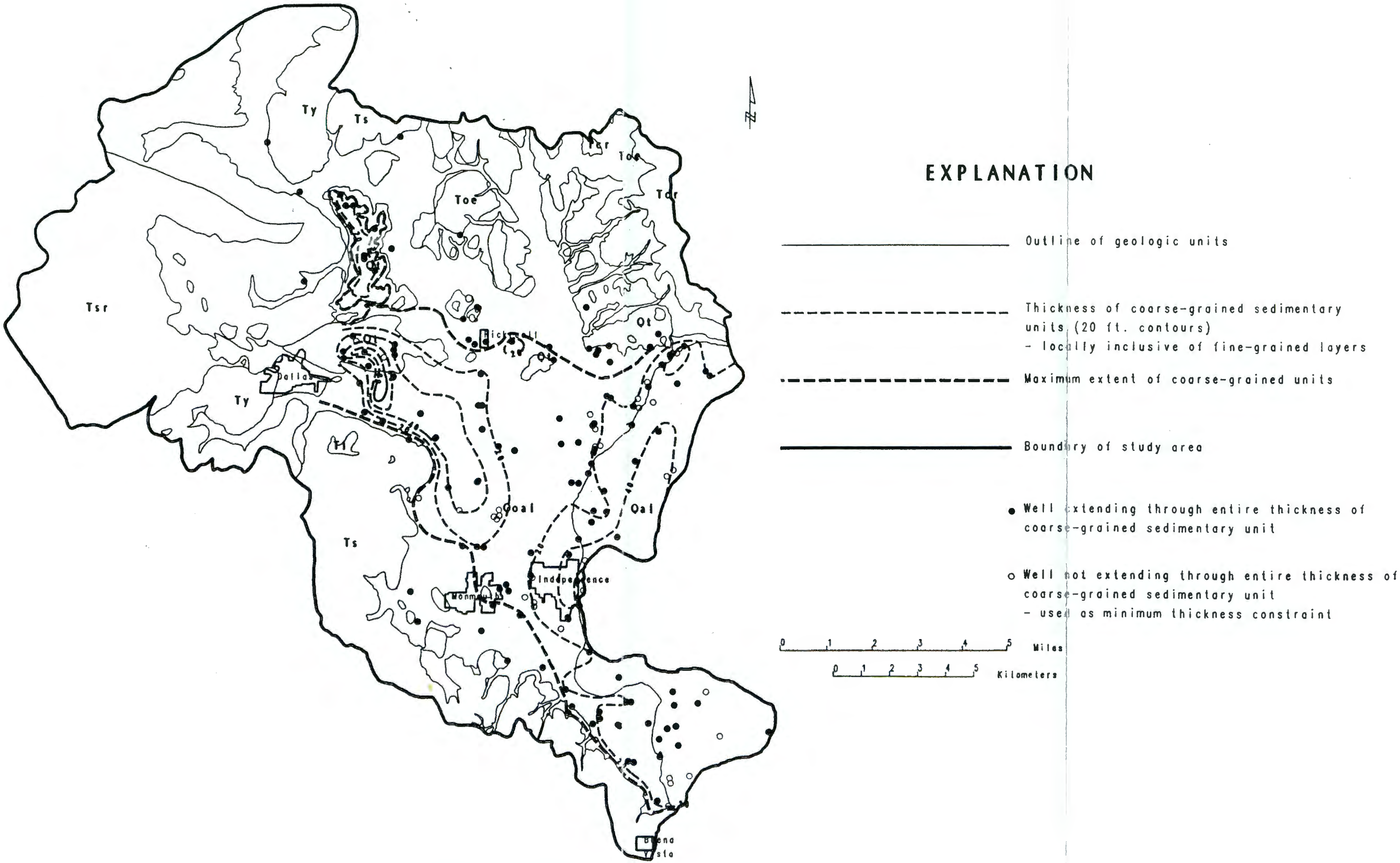


Figure 10. Isopach map of the coarse-grained unit.

than those near Dallas. Some of the thinnest deposits, less than 20 feet (6.1m), occur in the older alluvium in the valley flat between Rickreall and Monmouth. Cross-section C-C' (Plate III) extends through the thickest coarse-grained deposits near Dallas, the relatively thin deposits in the central portion of the valley flat, and the moderately thick deposits north of Independence.

Thickness of Upper Fine-Grained Unit

One hundred fifty-six fully penetrating wells were used to determine the thickness of clay and silt overlying the coarse-grained deposits or bedrock where the coarse-grained material was absent (Figure 11). The upper fine-grained deposits are composed of clay, silt and fine-grained sand. In the driller's logs, the material is commonly referred to as "brown clay". Thicknesses range from 0 to nearly 40 feet (12.2 m) with the greatest thicknesses occurring in the older alluvium near Independence and Monmouth. The material is less than 20 feet (6.1 m) thick, and locally non-existent, over most of the recent Willamette River floodplain.

It was often difficult to discern between weathered marine bedrock and fine-grained alluvial deposits. Therefore, confidence in the isopach contours decreases beyond the extent of the coarse-grained material.

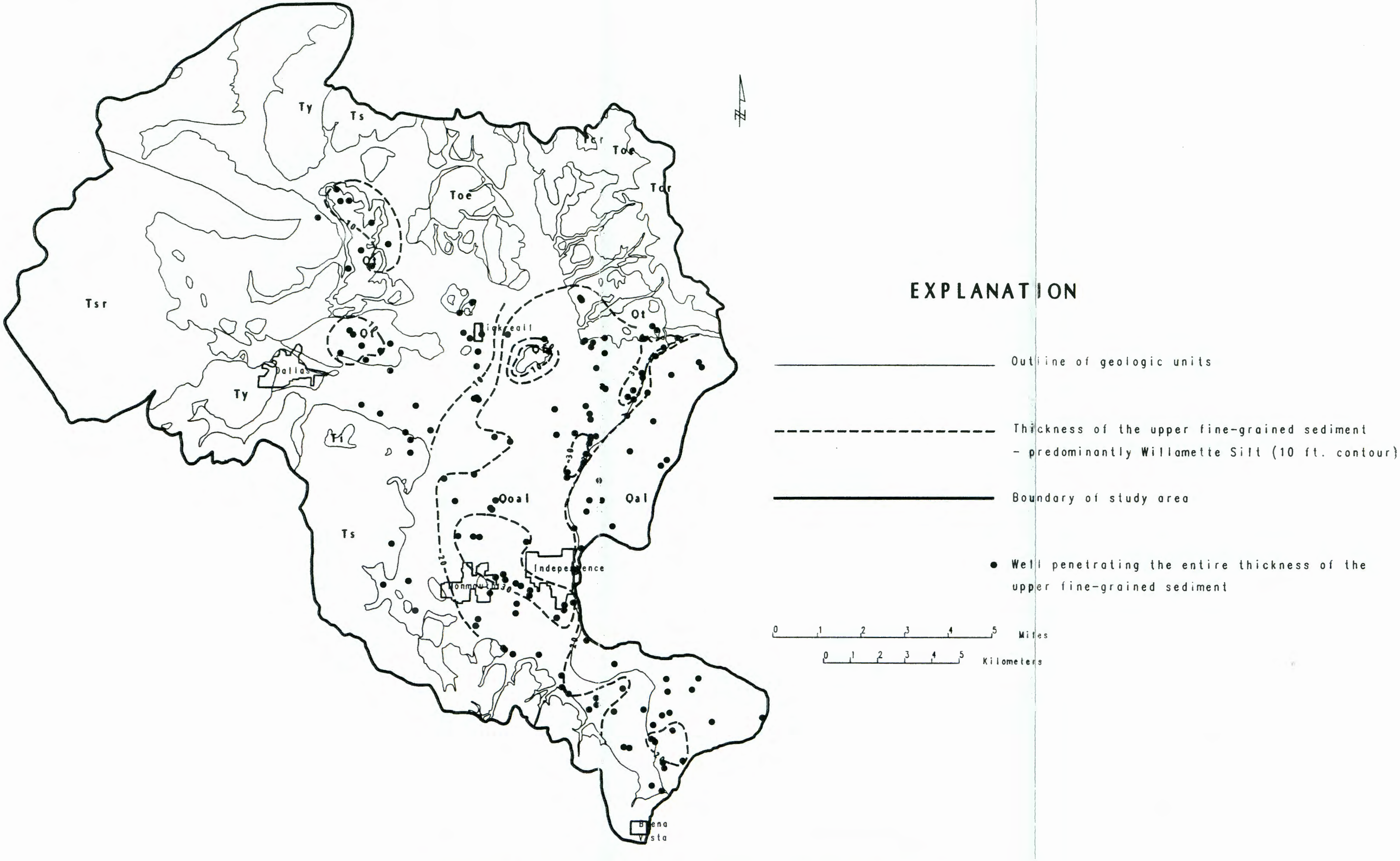


Figure 11. Isopach map of the upper fine-grained unit.

Because of this, the isopach contours rarely go beyond the extent of the coarse-grained deposits. However, the fine-grained unconsolidated material is certain to occur beyond the extent of the sand and gravel deposits.

Geologic Map Modifications

The surficial geologic map (Plate II) produced in this study is primarily a compilation of previously published work. However, as a result of the data compiled for this study, there have been some modifications. Portions of the bedrock-alluvium boundary, particularly in the western half of the study area, were shifted slightly on the basis of well log information. In most cases, the alluvium was extended slightly beyond where it had been mapped before.

An area northeast of Dallas (7S/5W) was previously mapped entirely as terrace deposits (Qt). Surface exposures and well log data indicate that the area consists not only of weathered sand and gravel, but also of marine bedrock. Baldwin (1964) mapped a bedrock exposure at 7S/5W-15bbb as Spencer Formation (Ts). Accordingly, the marine bedrock unit in this area has been tentatively assigned to the Ts.

GEOCHEMISTRY OF ALLUVIAL AND BEDROCK UNITS

The elemental concentrations of 71 samples from oil and gas exploration wells, water wells and surface grab samples were determined by instrumental neutron activation analysis

(INAA). The results are tabulated in Appendix A and sample locations are indicated in Figure 12.

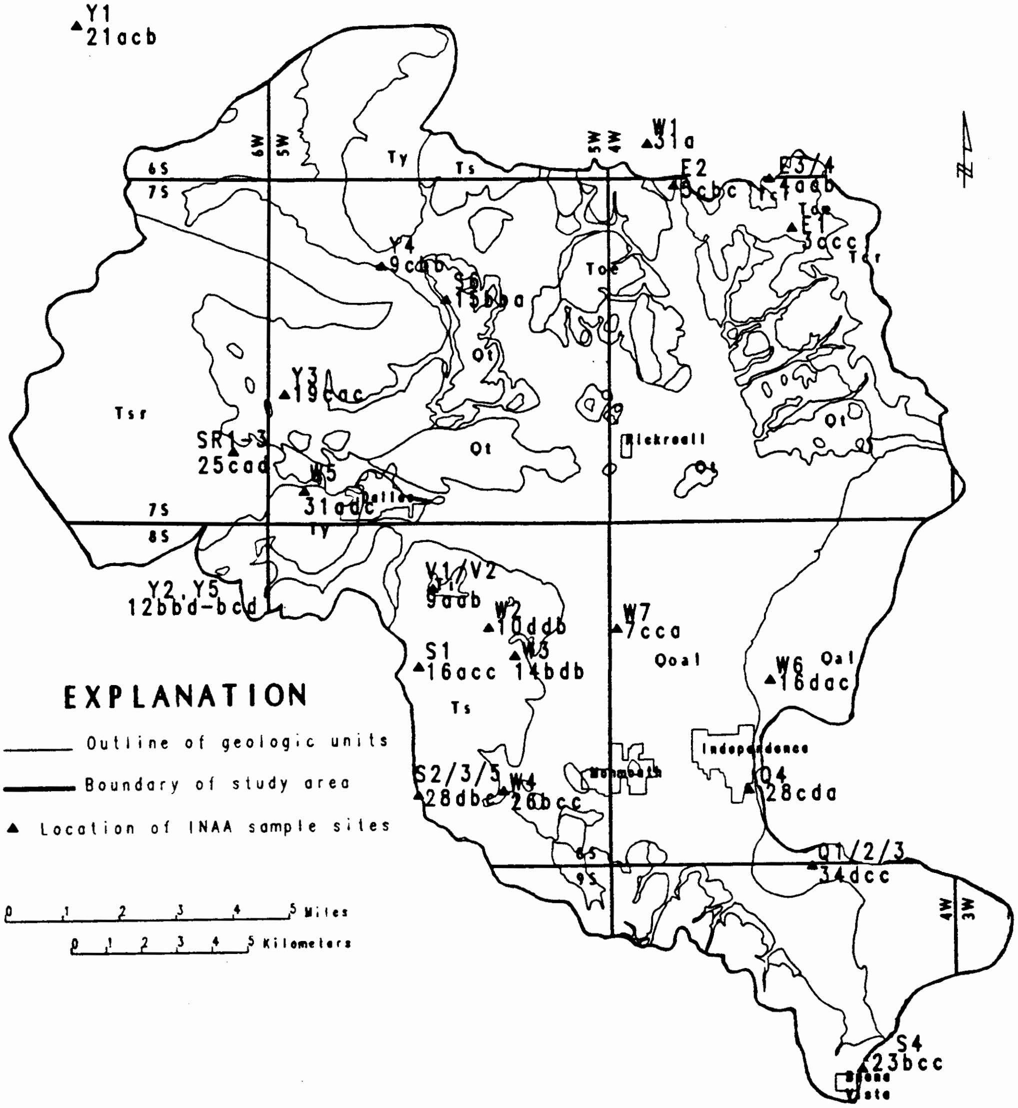


Figure 12. INAA sample locations.

Bedrock Units

Graven (1990) and Werner (1990) used logs (mud, lithology, and electric) and biostratigraphic correlations (McKeel, 1984, 1985) of petroleum wells to study the subsurface stratigraphy of the Willamette Valley. The geochemistry of four of these oil and gas exploratory wells was investigated with the use of INAA. Table II contains the elevations of the contacts between the stratigraphic units encountered by these wells as determined by Graven (1990) and Werner (1990). Lithologic descriptions of samples from the wells are included in Appendix A.

TABLE II

STRATIGRAPHIC CONTACT ELEVATIONS
FOR WELLS W1, W2, W3, AND W4

RESERVE OIL AND GAS,
Bruer 1 (W1)

	elev (ft)
Toe	-226
Ts	-1293
Ty	-4193
Tsr	

MIRIAN OIL CO.,
Bliven 3 (W2)

	elev. (ft)
Ts	-269
Ty	

MILLER,
Bursell 1 (W3)

Ts	-305
Ty	

MILLER,
Stump 1 (W4)

Ts	-308
Ty	

The author has the greatest confidence in the stratigraphic picks for the Reserve Oil and Gas, Bruer 1 well (W1) because it was the only one of the four wells where biostratigraphic constraints were available (McKeel, 1984). Well W1 encountered the undifferentiated Eocene-Oligocene sedimentary unit (Toe), the Spencer (Ts) and Yamhill (Ty) Formations and the Siletz River Volcanics (Tsr).

Iron, K, Na, Co, Cr, Rb, Sc, Ta, and Th were useful in characterizing the units in well W1. The geochemical distinctions between the units are apparent when these elements are plotted versus elevation (Figure 13). The Siletz River Volcanics has relatively high Fe, Na, Co, Cr, Sc and Ta concentrations in comparison to the marine sedimentary units. Samples from the Spencer Formation interval have comparably higher concentrations of K and Rb. The range of Fe, Co, and Ta concentrations from the sampled Yamhill Formation section of the well are distinct from the other units. The Fe, K , Rb and Th values of samples from the Toe are distinct from those of the underlying Ts.

Cluster analysis (Davis, 1986) of W1 samples, based on Fe, K, Na, Co, Cr, Rb, Sc, Ta and Th concentrations, was used to produce the dendrogram in Figure 14. Samples with the highest correlation coefficient (r) or similarities are clustered together. Correlation coefficients are greater than .98 for samples determined to be of the same geologic

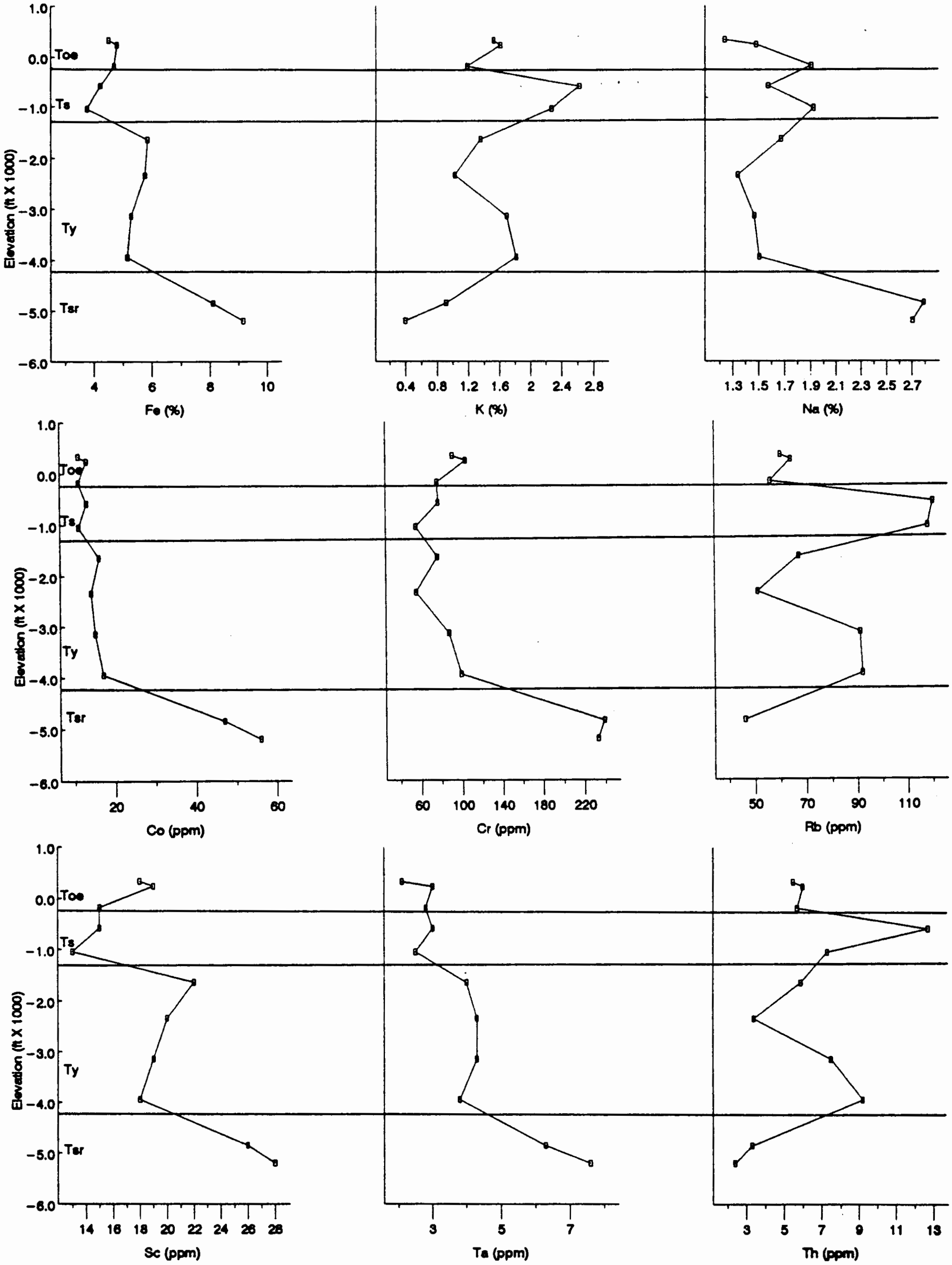


Figure 13. Selected elemental concentrations vs elevation in Reserve Oil and Gas, Bruer 1 exploration well. Horizontal lines represent the elevation of the stratigraphic picks of Werner (1990).

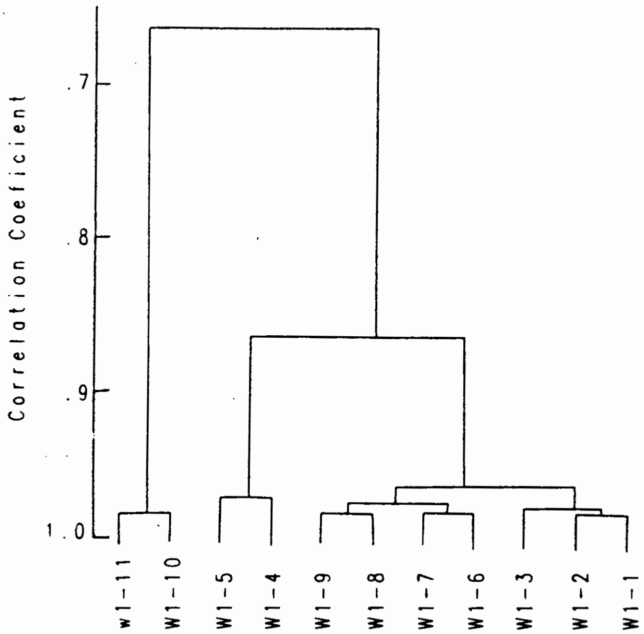


Figure 14. Dendrogram of well W1 samples based on INAA data.

unit. The cluster family of the Toe portion (W1-1, 2 and 3) have a high similarity (r>.97) with samples from the Ty (W1-6, 7, 8 and 9). Spencer Formation samples (W1-4 and 5) have a similarity level of .88 with samples from the Toe and Ty group. The Tsr samples (W1-10 and 11) and the sedimentary bedrock units have a relatively low similarity (r=.67).

The other petroleum wells (W2, W3 and W4) are thought to encounter the Spencer and Yamhill Formations exclusively (Graven, 1990). The elements Fe, K, Co, Rb, Sc, and Th sufficiently distinguish the Ts and Ty in W1 and were therefore used to delineate the formations in the Mirian Oil Co.-Bliven 3 (W2), Miller-Bursell 1 (W3) and Miller-Stump 1 (W4) exploration wells. The concentrations of the selected elements for these wells are listed in Table III.

TABLE III

SELECTED ELEMENTAL CONCENTRATIONS, ELEVATIONS, AND GEOLOGIC UNIT DESIGNATIONS OF WERNER (1990) AND GRAVEN (1990) OF OIL AND GAS WELLS W1, W2, W3 AND W4 SAMPLES

Sample	Elev. (ft)	Fe %	K %	Co ppm	Rb ppm	Sc ppm	Th ppm	Unit
W1-4	-583	4.21	2.62	13	120	15	12.7	Ts
W1-5	-1043	3.75	2.27	11	118	13	7.3	Ts
W1-6	-1643	5.84	1.35	16	67	22	5.9	Ty
W1-7	-2343	5.76	1.02	14	51	20	3.4	Ty
W1-8	-3143	5.27	1.69	15	91	19	7.5	Ty
W1-9	-3943	5.14	1.81	17	92	18	9.2	Ty
W2-1	165	4.41	2.18	12	146	15	12.4	Ts
W2-2	63	4.04	1.94	13	95	14	8.5	Ts
W2-3	-242	5.17	2.14	18	75	18	11.2	Ts
W2-4	-540	5.23	1.73	14	89	20	7.3	Ty
W2-5	-837	5.79	1.34	17	68	22	5.0	Ty
W2-6	-1137	7.58	1.19	27	45	23	4.5	Ty
W2-7	-1430	5.84	0.89	18	78	22	4.2	Ty
W3-1	300	4.34	2.47	14	127	16	14.0	Ts
W3-2	200	4.86	2.13	12	133	16	12.1	Ts
W3-3	0	4.97	1.31	12	100	15	8.6	Ts
W3-4	-200	4.43	2.35	17	144	16	11.1	Ts
W3-5	-400	6.24	1.76	18	82	21	7.4	Ty
W3-6	-630	6.27	1.45	18	102	23	6.1	Ty
W3-7	-765	6.26	1.61	17	70	22	5.5	Ty
W4-1	100	10.75	2.09	22	108	13	10.0	Ts
W4-2	0	3.75	1.37	8	59	13	11.0	Ts
W4-3	-295	4.46	2.65	17	117	16	11.3	Ts
W4-4	-600	5.62	1.39	15	55	19	7.3	Ty
W4-5	-895	6.79	1.59	21	64	25	5.4	Ty
W4-6	-1200	7.02	1.46	25	65	28	3.6	Ty
W4-7	-1265	6.79	1.40	22	63	26	4.2	Ty

The upper two (W2-1 and 2) and the lower four samples (W2-4, 5, 6 and 7) of well W2 group geochemically into the Ts and Ty units as Graven (1990) had assigned. However, sample W2-3 has some geochemical characteristics of both units. The K and Th concentrations more closely match the values for the Spencer Formation in well W1, while the Fe, Co, Rb and Sc concentrations are more similar to those of the Yamhill Formation. The elevation of sample W2-3 is at -249 feet (-76 m) and Graven (1990) picked the Ts-Ty contact at -269 feet (-82 m). The cluster dendrogram (Figure 15), based on the selected elements, illustrates that W2-3 has a greater similarity with W2-4 of the Yamhill Formation than with the other Spencer Formation samples.

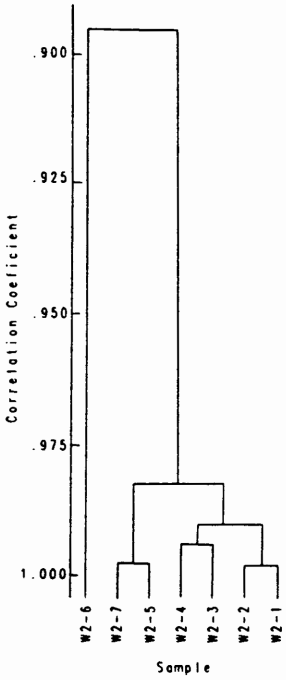


Figure 15. Dendrogram of well W2 samples based on INAA data.

Geochemically, samples from wells W3 and W4 generally support the unit designations assigned by Graven (1990). In both wells, the samples (W3-4 and W4-3) from the basal portion of the Spencer Formation, as assigned by Graven (1990), have Co concentrations similar to that of the Yamhill Formation in well W1. The other elemental concentrations of samples W3-4 and W4-3 are within the ranges of the Spencer Formation in well W1. For each well, the samples are separated into two distinct cluster families (Figure 16). The samples within each of these clustered families correspond to a common, previously specified geologic unit (Ts or Ty).

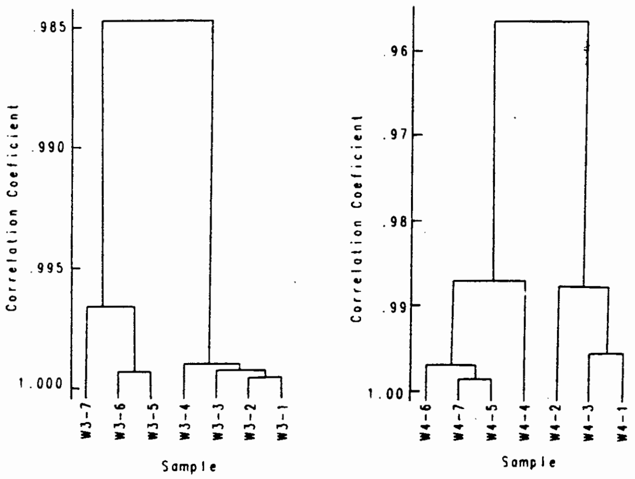
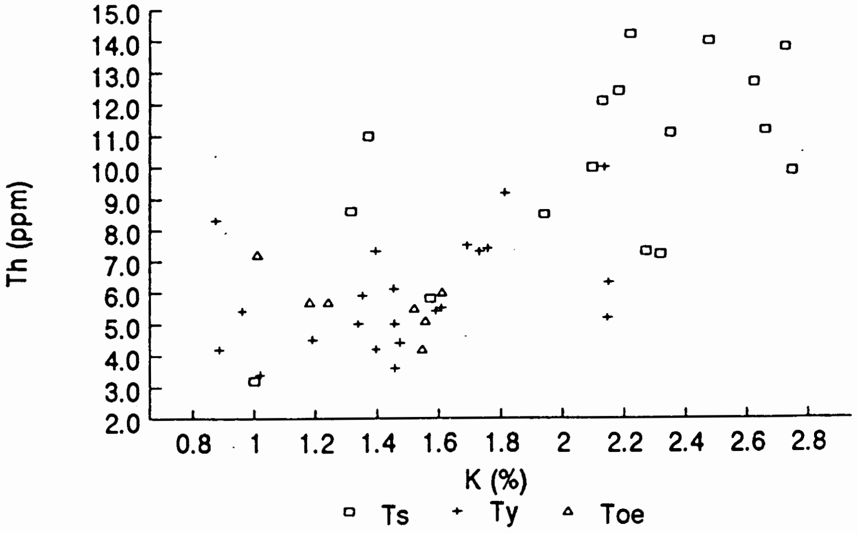


Figure 16. Dendrograms of samples from wells W3 and W4 based on INAA data.

Applying techniques used by Kadri and others (1983) in northwestern Oregon, the K, Th, La and Sm concentrations of samples from the sedimentary bedrock units were examined as possible provenance indicators. The majority of Spencer Formation specimens have relatively high Th and K values in comparison to the Yamhill Formation and the undifferentiated Eocene-Oligocene sedimentary unit (Figure 17). Thorium is more concentrated in continental igneous and metamorphic terranes than it is in volcanic arc material or oceanic areas (Moore, 1972). Taylor (1964) suggests an average Th value of 9.6 ppm for continental crust and a granite average of 17 ppm. Condie (1976) suggests a 0.18 to 5.5 ppm range of Th values for volcanic arc derived material. The Spencer Formation samples from this study have an average Th concentration of 10.2 ppm. The average Th concentrations for the Yamhill Formation and the Toe were 6.03 and 5.62 ppm, respectively.

Samples from the Spencer Formation commonly have higher La/Sm ratios, indicative of granitic and metamorphic source material, than the majority of the samples from the Yamhill Formation and the undifferentiated Eocene-Oligocene sedimentary unit (Figure 17). The range of Th, La, Sm and K concentrations overlap among the sedimentary bedrock units as depicted in Figure 17.



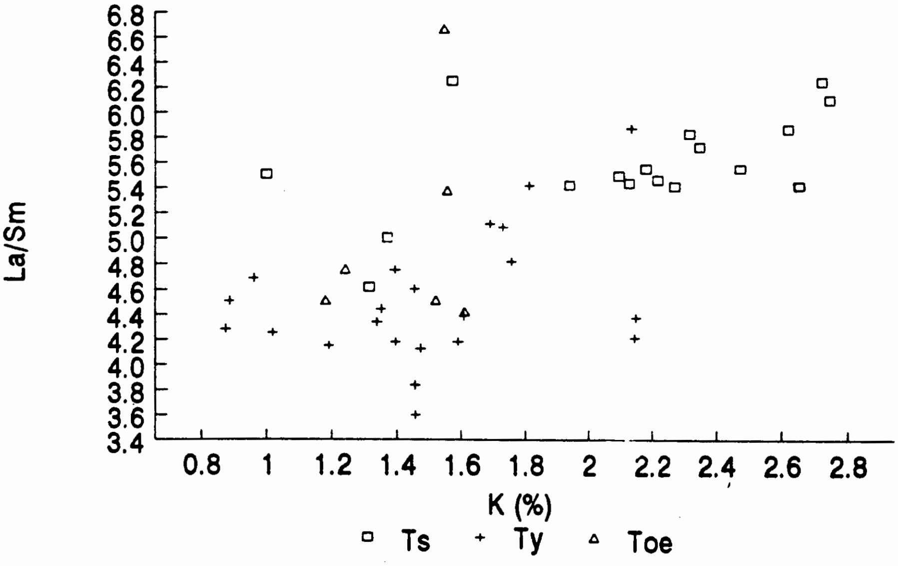


Figure 17. K vs Th and K vs La/Sm for the sedimentary bedrock units.

Two surficial samples of the Rickreall Limestone Member of the Yamhill Formation were analyzed (Y-2 and Y-5). The limestone occurs in the basal portion of the Yamhill Formation, overlying the Siletz River Volcanics (Tsr). The limestone specimens have lower K, Cs, Th, La and Fe, and higher Cr and Sr concentrations in comparison with other samples of the Yamhill Formation. The Th concentrations, which range from 0.4 to 2.1 ppm, are well below the average for continental crust (Taylor, 1964) and are more similar to the average concentration of basalt (2.2 ppm) (Taylor, 1964).

Basaltic boulders, previously mapped as Siletz River Volcanics (Baldwin, 1964), cap the summit of Mt. Pisgah southeast of Dallas (Figure 18). These boulders have been tentatively assigned to the Tertiary intrusives (Ti) for this study. The Fe, K, Na, Cr, Sc and Sr concentrations of two samples from these boulders (Ti) were compared with those of the Siletz River Volcanics (Tsr) and the Winter Water (Tcrww) and Sentinel Bluffs (Tcrsb) units of the Columbia River Basalt Group (CRBG) (Table IV). The cluster analysis of these values was used to produce the dendrogram in Figure 19. The CRBG units are the most similar to one another (r>.99). The next highest similarity (r>.98) is that of the Tsr with the CRBG units.

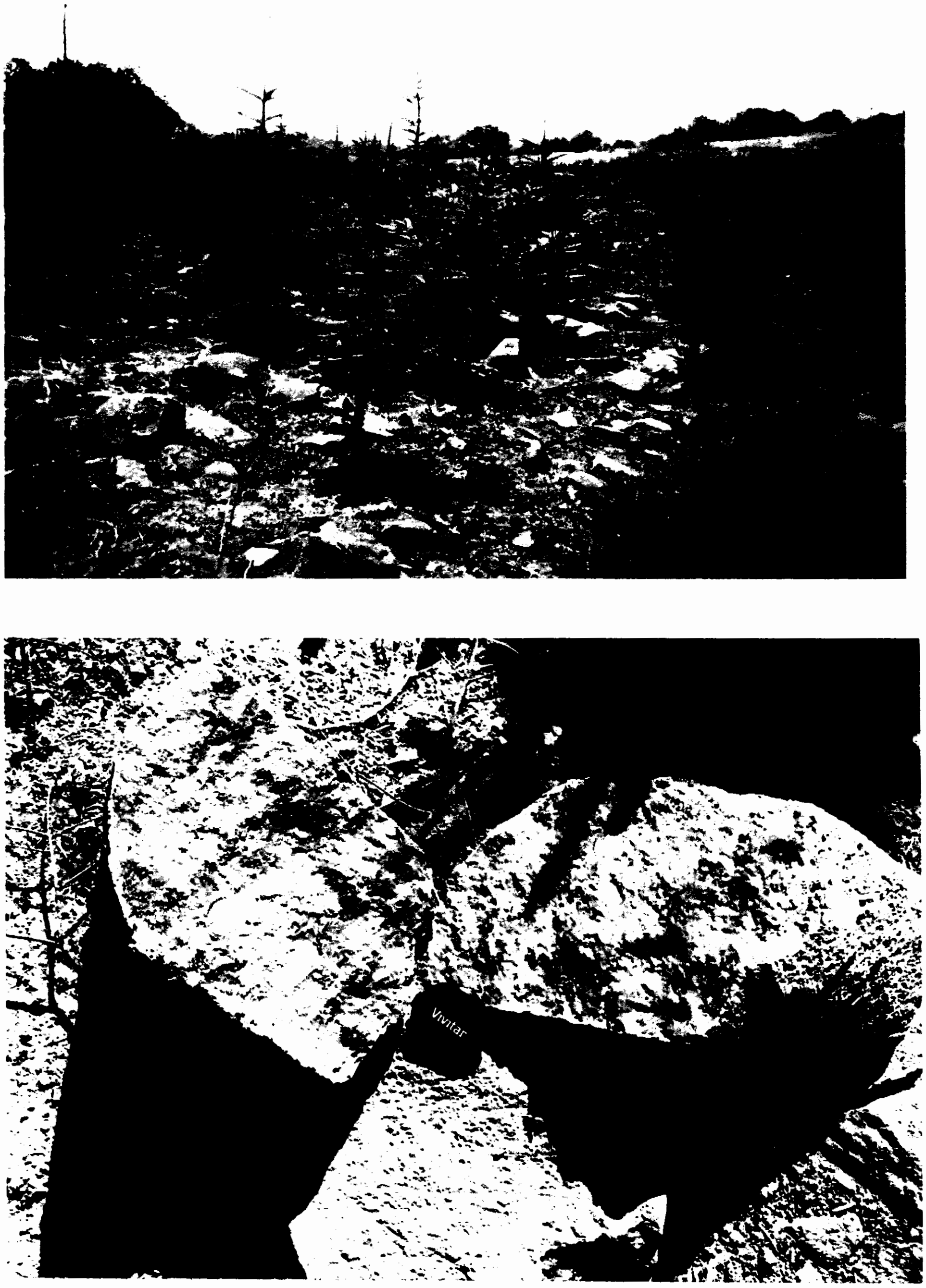


Figure 18. Basaltic boulders overlying Spencer Formation sandstone on the summit of Mt. Pisgah (8S/5W-9aab).

TABLE IV

SELECTED ELEMENT CONCENTRATIONS FOR THE SILETZ RIVER VOLCANICS (Tsr), MT. PISGAH BOULDERS (Ti), AND BASALT OF THE COLUMBIA RIVER BASALT GROUP (Tcrww AND Tcrsb)

Element	Tsr	Ti	Tcrww*	Tcrsb*
Fe (ppm)	8.10-12.98	7.17-7.67	11.62	11.42
K %	0.40-0.91	0.53	1.76	1.19
Na %	1.97-2.79	2.02-2.03	3.11	3.0
Cr (ppm)	93-239	235-231	17	43
Sc (ppm)	26-47	39-41	31	34
Sr (ppm)	363-1118	271-605	322	318

* Beeson and others (1989)

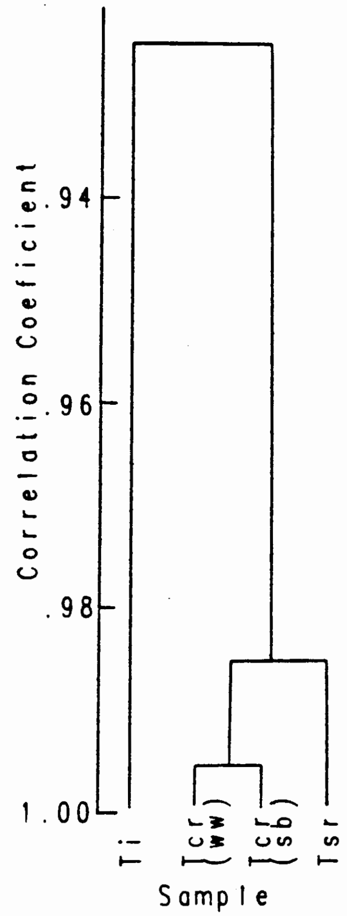


Figure 19. Dendrogram of Siletz River Volcanics (Tsr), Columbia River Basalt Group (Tcrww and Tcrsb), and Mt. Pisgah basaltic boulder (Ti) based on INAA data.

Unconsolidated Sediments

The elemental concentrations of fifteen unconsolidated sediment samples from this study were compared to basin-fill sediments of the Tualatin Valley (unpublished data, Caldwell, 1990) and the Portland basin (Lite, 1992). Lite (1992) reported two distinct sources, the Cascade Range and the Columbia River Basin, for the sedimentary units within his southeast Portland basin study area. Comparably high La and Th concentrations, in response to detritus from plutonic and metamorphic rocks within the drainage basin, are diagnostic of a Columbia River Basin source (Lite, 1992). Sediment from a well near the west flank of the Tualatin Mountains in the Tualatin Valley was probably derived from a granitic or metamorphic Columbia River Basin source (unpublished data, Caldwell, 1990). Lite (1992) also separated sediments with Cascade Range sources into three distinct chemical groups: 1) basalt; 2) basaltic andesite: and 3) andesite.

Silt and clay from the upper portion of the older alluvium (W7-1 and Q-4) and blue clay (W6-5) from below the sand and gravel layers of the recent river alluvium (Qal) have relatively high La concentrations. In a graph of the Na versus La concentrations for unconsolidated sediment samples within this study area and sediment from the Tualatin Valley and Portland basin, samples W7-1, W6-5, and Q-4 plot among the Columbia River Basin source sediments of the Tualatin Valley and the Portland basin (Figure 20).

The relatively high Th concentrations of samples W7-1 and Q-4 again places them among the Columbia River Basin derived sediments of the Tualatin Valley and Portland basin on a Na vs. Th graph (Figure 20). A lower Th concentration for sample W6-5 places it within the realm of the Cascadian derived sediments. The majority of the unconsolidated sediments from this study plot within the region dominated by sediments determined to be of Cascade Range provenance.

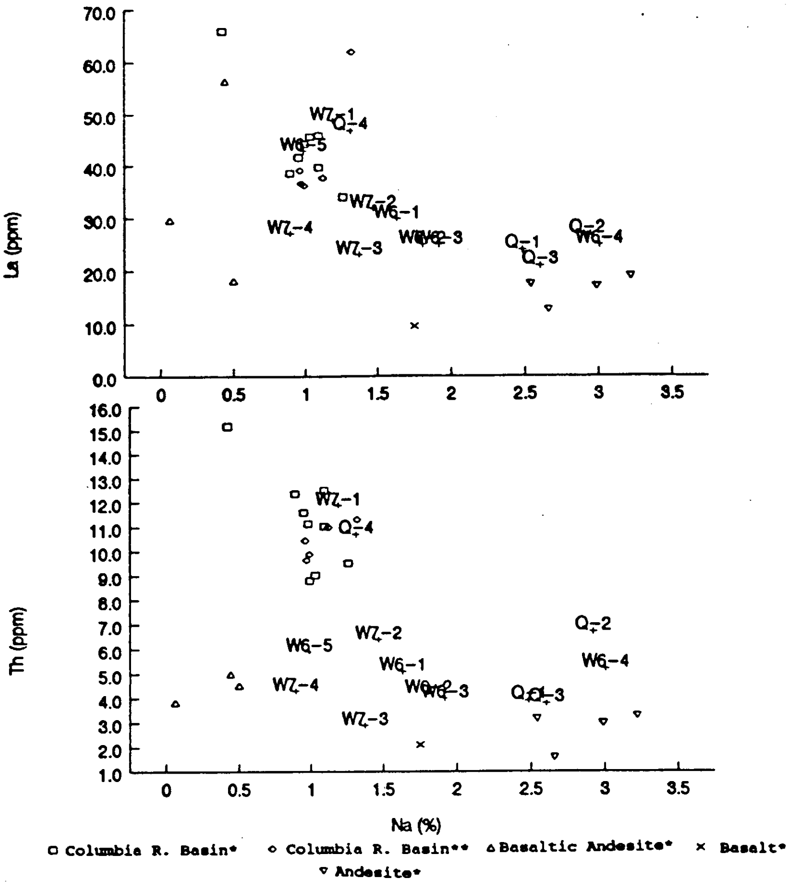


Figure 20. Comparison of Na vs La and Na vs Th concentrations of unconsolidated sediment samples from this study and sediment samples from the Portland basin (Lite, 1992)* and the Tualatin Valley (Caldwell, 1990)**.

In a Na vs. Sc graph, W7-1, Q-4 and W6-5 values again lie in the proximity of the Columbia River Basin derived sediments (Figure 21). Sand-size and less splits from sand and gravel deposits (W7-2 and W7-3) and a lower coarse sand, silt and blue clay layer (W7-4) within the Qoal have relatively high and closely similar scandium concentrations. The Na and Sc concentrations for these samples plot near a Portland basin sediment sample determined to be of Cascade Range basalt provenance (Lite, 1992). The gravel within samples W7-2, W7-3 and W7-4 appeared to be of basaltic composition in hand specimen.

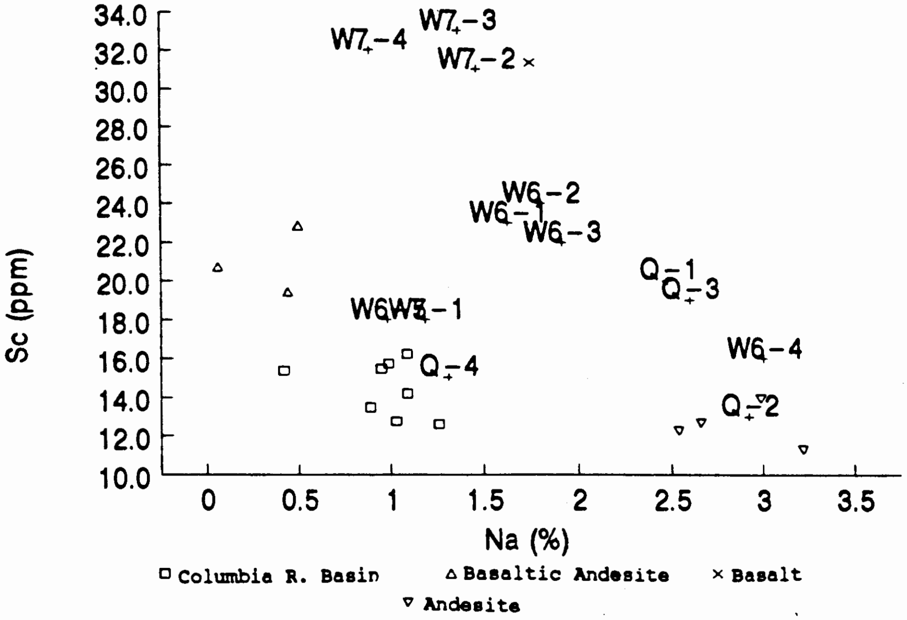


Figure 21. Comparison of Na vs Sc concentrations of unconsolidated sediment samples from this study and sediment from the Portland basin (Lite, 1992).

Samples from well W7 in the older alluvium (Qoal) provide an interesting situation in which differing sediment provenance may be present. The upper silt (W7-1) has Th and La concentrations that resemble plutonic or metamorphic provenance and the lower samples (W7-2, 3 and 4) have Sc concentrations near that of sediment from basalt of the Cascade Range. The chemical variation of the sediment encountered by well W7 is visually apparent by graphing Co, Cr, and Fe versus elevation (Figure 22). In all three cases, the lower two samples (W7-3 and W7-4) have the greatest concentrations. The second highest sample (W7-2) has concentrations transitional between those of the uppermost sample (W7-1) and the samples W7-3 and W7-4.

A cluster analysis was performed on the sand-size and less fraction of the lower two samples in well W7 (W7-3 and W7-4) and basaltic bedrock units in the area. Average Fe, K, Na, Cr and Sc concentrations of the Siletz River Volcanics (Tsr) and boulders from the summit of Mt. Pisgah (Ti) from this study and the Winter Water (Tcrww) and Sentinel Bluff (Tcrsb) units of the Columbia River Basalt Group (Beeson and others, 1989) were utilized. W7-3, W7-4 and the Tsr appear to be the most similar as they cluster together with a distance coefficient of less than 10 in the dendrogram (Figure 23).

Samples (W7-1 and Q-4) from the upper fine-grained section of the older alluvium (Qoal) are the only

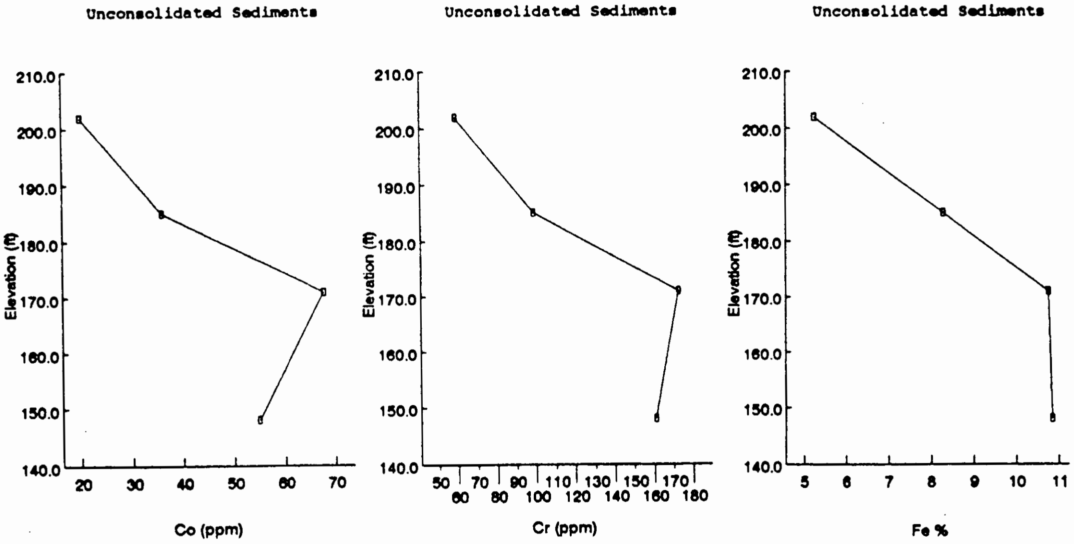


Figure 22. Co, Cr, and Fe concentrations vs elevation in well W7.

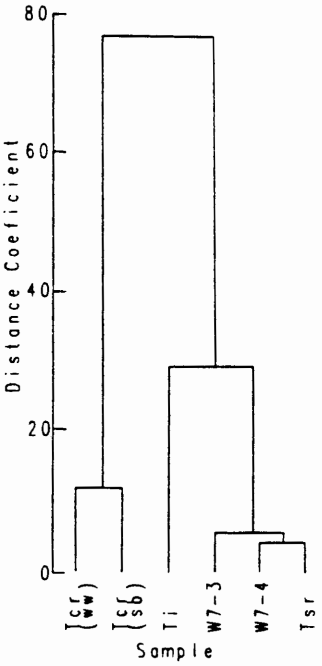


Figure 23. Dendrogram of Siletz River Volcanics (Tsr), Columbia River Basalt Group (Tcrww and Tcrsb), Mt. Pisgah basaltic boulder (Ti), and Qoal basaltic sand and gravel (W7-3 and W7-4) samples based on INAA data.

unconsolidated sediment samples in which all of the elemental concentrations are within the range of those of the Spencer Formation (Ts). Cobalt, however, may be a fairly reliable element to use to differentiate the upper-fine grained Qoal from the Ts. Only one Ts sample (W4-1) has a higher Co concentration than samples W7-1 and Q-4. W4-1 is unique among the Ts samples with anomalously high Cr, Fe, and Co concentrations.

All of the elemental concentrations, with the exception of Co, determined for the unconsolidated sediment samples are within the range of those determined for the undifferentiated Eocene-Oligocene sedimentary rock unit (Toe). A blue clay sample (W6-5) from below a sand and gravel section in the recent river alluvium (Qal) is the only unconsolidated sediment sample that has a Co concentration within the range of those of the Toe. The other unconsolidated sediment samples have Co concentrations higher than those of the Toe unit. No geochemical distinction between the unconsolidated sedimentary deposits and the Yamhill Formation was evident.

CLAY MINERALOGY

The clay mineralogy of seven samples from four sites was determined by x-ray diffraction. Table V provides brief descriptions of the samples and their locations. Splits of these samples were also analyzed by INAA. Semi-quantitative analyses of the <2μ clay minerals are represented in Table VI.

TABLE V

LOCATION AND DESCRIPTION OF CLAY MINERAL ANALYSIS SAMPLES

SAMPLE	LOCATION	DESCRIPTION
S-3	8S/5W-28dbc	Spencer Formation (Ts), weathered outcrop, light brown silt
W5-1	7S/5W-31dab1	Yamhill Formation (Ty), water well drill cuttings from surface to 17 feet below surface, brown clay
W6-1	8S/4W-16adc	Upper fine-grained unit of the recent river alluvium (Qal), water well drill cuttings from surface to 5 feet below surface, brown topsoil
W6-2	8S/4W-16adc	Upper fine-grained unit of the recent river alluvium (Qal), water well drill cuttings from 5 to 11 feet below surface, brown clay
W6-5	8S/4W-16adc	Lower fine-grained unit below the sand and gravel of the recent river alluvium (Qal), water well drill cuttings from 37 to 42 feet below surface, blue clay
W7-1	8S/4W-7cca2	Upper fine-grained unit in the older alluvium (Qoal), water well drill cuttings from surface to 17 feet below surface, brown clay
W7-4	8S/4W-7cca2	Lower fine-grained unit in the older alluvium (Qoal), water well drill cuttings from 54 to 77 feet below surface, blue clay and silt split from blue clay, silt and sand

TABLE VI

RELATIVE PERCENT OF CLAY SUITES

SAMPLE	RELATIVE % OF CLAY MINERALS				
	KAOLINITE	ILLITE	VERMIC- ULITE	SMECTITE	EXPANDABLE MIXED LAYER
W5-1	---	---	---	86	14
W7-1	18	18	26	29	7
W7-4	14	3	---	73	10
W6-1	22	---	18	41	19
W6-2	14	---	26	46	14
W6-5	---	---	---	100	---
S-3	39	8	trace	53	trace

Smectite and expandable mixed layer (kaolin/smectite) are the most abundant clay minerals in all samples. Samples W6-5 and W5-1 are overwhelmingly dominated by smectite. Sample W5-1 is a bedrock sample from the Yamhill Formation while W6-5 is from a "blue clay" layer in or below the recent river alluvium (Qal).

Sample W7-1, brown clay from the upper section of the older alluvium (Qoal), has measurable concentrations of kaolinite, illite, vermiculite, smectite, and expandable mixed layer clay. The material from which W7-1 was sampled is commonly referred to as Willamette Silt.

W7-4 is from the lower portion of the Qoal which overlies either the Spencer Formation (Ts) or the undifferentiated Eocene-Oligocene sedimentary rock unit (Toe) in the area of sampling. Kaolinite, illite, smectite, and expandable mixed layer clay are noted in both W7-4 and S-3, a Spencer Formation sample. The same clay species plus chlorite were recognized by Cunderla (1986) in his study of the Ts.

Samples W6-1 and W6-2 are from the upper fine-grained layer of the Qal. They have similar concentrations of kaolinite, vermiculite, smectite and expandable mixed layer clay.

GROUNDWATER

Hydrogeology

Information from 302 water wells (Plate I) comprise the database used to examine the hydrogeology of the study area (Appendix C). The hydrogeologic characteristics of the stratigraphic units including water level, yield, and specific capacity, are summarized in Table VII. The hydraulic conductivity, storage coefficient, recharge and median specific capacity values determined by Gonthier (1983) are also included in Table VII. The hydrogeologic characteristics are not given in Table VII for the Columbia River Basalt Group and the Tertiary Intrusive Rocks because of the limited number of wells in these units.

TABLE VII

HYDROGEOLOGIC CHARACTERISTICS OF THE GEOLOGIC/AQUIFER UNITS

AQUI-FER	WELL DEPTH (ft) MEAN	STATIC WATER LEVEL (ft) MEAN	YIELD (gpm)		SPECIFIC CAPACITY (gpm/ft)						HYDR.* CONDUC. (ft/d) MED.	STORAGE* COEFFI-CIENT	RE-* CHARGE (in)
			MEAN	MED.	no. of wells	LOW	HIGH	MEAN	MED.	MED.*			
Qal	48	19.5	302	75	36	1.10	607.1	59.9	40.0	40.0	170.0	0.2	8–15
Qoal	68	21.1	79	30	80	0.02	175.0	7.3	2.0	0.59	19.0	.001–0.2	2–5
Qt	95	12.8	13	8	13	0.04	2.4	0.5	0.3				
Toe	119	34.8	15	10	20	0.01	2.3	0.5	0.2	0.10	0.3	.00001–.001	2–5
Ts	134	37.9	11	8	41	0.01	30.0	1.6	0.1				
Ty	174	22.1	22	9	33	0.01	1.7	0.3	0.1				
Tsr	171	36.4	18	8	16	0.01	12.5	1.1	0.1	0.11	0.2	.00001–.001	2–5

*From Gonthier (1983)

The specific capacity of a well is defined as the pumping rate divided by the drawdown in the well (Freeze and Cherry, 1979). Most of the pump tests were of short duration, generally less than 4 hours, and well efficiency is not known. However, specific capacity values offer a coarse estimate of relative aquifer capabilities. For example, the unconsolidated alluvial units are far more productive than the bedrock units. Wells within the recent river alluvium (Qal) have the highest mean and median specific capacity values and corresponding yields, followed by the older alluvium (Qoal) and the high terrace and alluvial fan deposits (Qt). The mean and median specific capacities are the lowest among the bedrock units.

The median specific capacity values calculated for this study are similar to those determined by Gonthier (1983). Gonthier (1983), however, grouped the Qt and the Qoal units together and the marine sedimentary bedrock units together. The median specific capacity value for the Qoal unit is over six times greater than that of the Qt. The median specific capacity values of each of the marine bedrock units are quite similar to one another. The similar specific capacity values of the marine sedimentary bedrock units appear reasonable due to their similar grain-size characteristics.

The specific capacities of each of the aquifer units are highly variable. This variability may be due to pump test inconsistencies, dissimilarity in the construction of the wells, or hydrogeologic characteristic variation within each unit. The specific capacities of the older alluvium (Qoal) vary the most with a range of .02 to 175 gpm/ft.

Water Levels

The average static water level depth, as indicated in Table VII, is the shallowest among wells completed in the Qt. Static water levels of the Qal and the Qoal are similar to one another and are the next closest to land surface. The measured static water levels of wells completed in the Yamhill Formation approach those of the unconsolidated sediment. The mean static water levels of the other bedrock units are similar to one another and considerably deeper.

The water levels in several of the wells used for this study have been repeatedly measured (Appendix C). This has allowed analysis of water level fluctuations through time. Hydrographs compiled from several years of water-level measurements of six Oregon Water Resources Division observation wells are included in Appendix D.

The hydrographs indicate water level fluctuations within the unconsolidated and consolidated water bearing units. The hydrographs, as well as water-level measurements from less consistently measured wells, indicate that the highest water levels occur in the winter and spring and the lowest in the late summer and early autumn months. Water levels from 101 water wells measured during the inferred low water-level period, from August through October (1961-1991), were used to construct a potentiometric surface map for the basin-fill sediments of the Dallas-Monmouth area (Figure 24). Assuming that rivers and streams are a representation of the water table during the late summer months, the elevations of the topographic contour-surface drainage intersections on USGS 7 1/2 minute quadrangle maps were incorporated into the potentiometric surface map. Due to the limited number of measured water-levels in the bedrock units, the potentiometric surface of the bedrock units was not mapped. The direction of groundwater flow was interpreted and represented as flow lines (Figure 24).

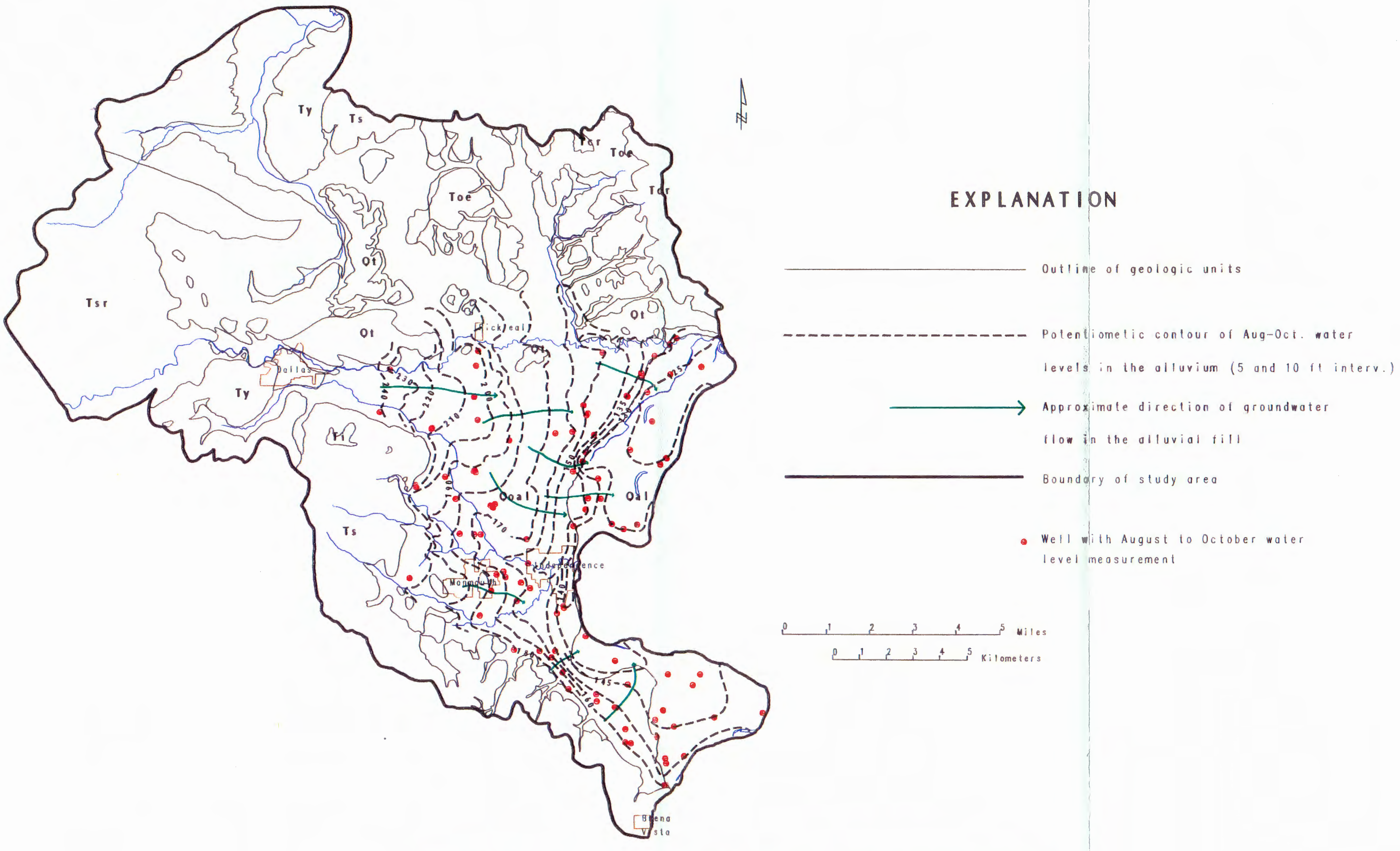


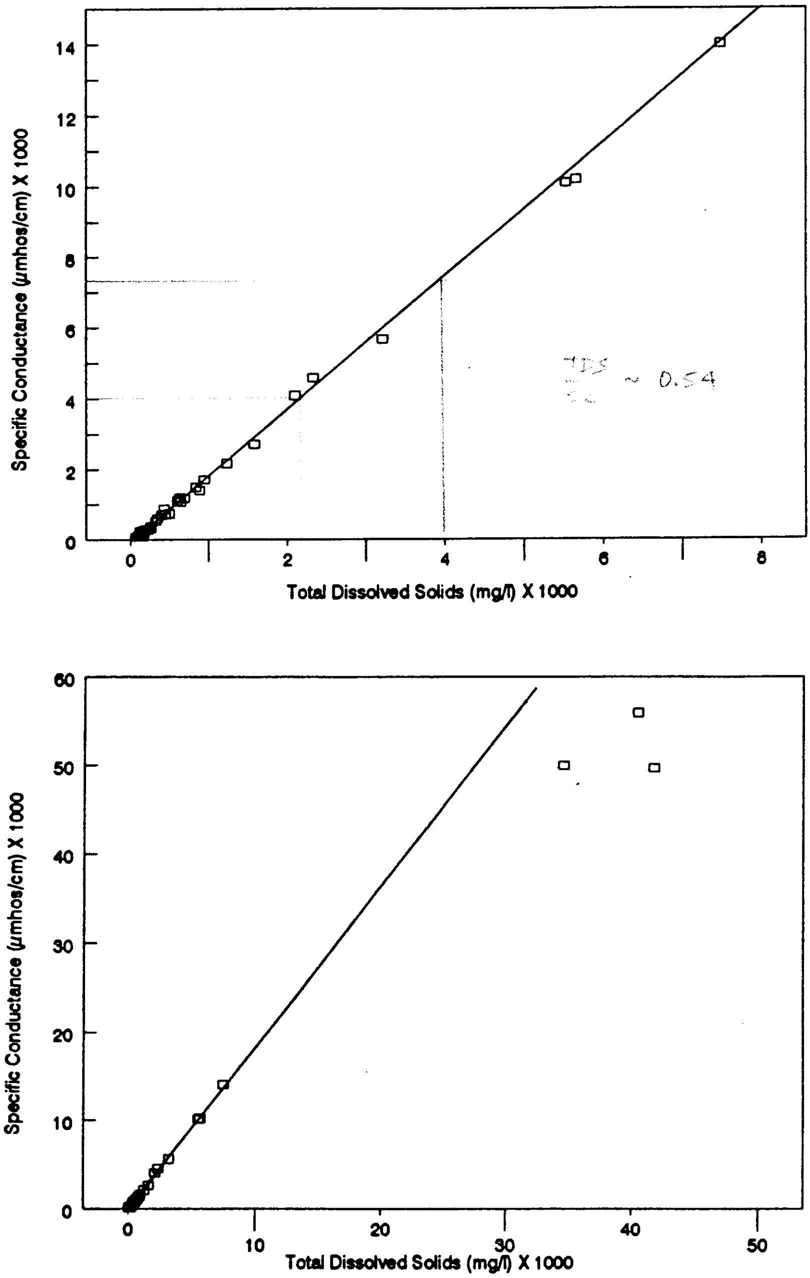
__Figure 24__. Potentiometric surface map of the alluvial aquifers.

GROUNDWATER QUALITY

In 1962 the United States Public Health Service (USPHS) non-mandatory total dissolved solid (TDS) concentration standard for drinking water was set at 500 mg/l (Hem, 1985). In 1981 the American Water Works Association (AWWA) suggested a <200 mg/l TDS water quality goal for potable water (Hem, 1985). The TDS of precipitation is generally less than 40 mg/l and seawater is around 34,500 mg/l. A widely used scheme for categorizing waters based on TDS, commonly referred to as salinity, is as follows (Freeze and Cherry, 1979):

	(mg/l)
Fresh water	0-1,000
Brackish water	1,000-10,000
Saline water	10,000-100,000
Brine water	>100,000

Figure 25 represents the salinity versus specific conductance values for waters from the Dallas-Monmouth area (Gonthier, 1983), an oil and gas well at 6S/4W-6bd (Price and Johnson, 1965), ocean water (Hem, 1985), and springs (6S/4W-21cad1 and 7S/6W-2add) from this study. As indicated by Figure 25, a linear trend exists between specific conductance and dissolved solid concentration, especially at the lower concentrations. However, the values for the most saline spring (6S/5W-21cad1), the oil and gas well (6S/4W-6bd), and ocean water plot below the best-fit line representing the more dilute waters.



<u>Figure 25</u>. Plots of TDS versus specific conductance for Dallas-Monmouth area groundwater and seawater.

Hem (1985) recognizes similar TDS concentration versus specific conductance trends, with a slight decrease in slope with increased concentrations, in single salt solutions. He states that the slope of the straight part of the line and the degree to which it flattens with increasing concentration varies with different salts. A linear relationship does not always exist in natural waters because they may contain a variety of ionic and undissociated species and the amounts and proportions of each may widely vary (Hem, 1985).

Using Figure 25, the maximum TDS standards for drinking water of the AWWA and the USPHS correspond to specific conductance values of approximately 300 and 850 µmhos/cm, respectively. The conductance for the lower limits of the brackish and saline waters correspond to approximately 1750 and 18,000 µmhos/cm, respectively. In comparison, precipitation commonly has values near 50 µmhos/cm and seawater is near 50,000 µmhos/cm (Hem, 1985).

Distribution of poor quality groundwater

The specific conductance values reported in Gonthier (1983) and measurements by the author, were used to determine the distribution and relative dissolved constituent concentrations of groundwater in the study area. Appendix C lists the specific conductance values and dates measured for many of the wells and springs.

The specific conductance values, adjusted to 25°C, from 174 water wells and eight springs were used to construct Figure 26. Figure 26 is fundamentally a hazard map for the occurrence of poor quality groundwater. The greater likelihood of encountering saline water occurs within the shaded areas. A value of 500 μmhos/cm, roughly equivalent to 300 mg/l TDS, was used as an approximate break between potable water and water for which one should be concerned about the TDS concentrations. The patterns in Figure 26 indicate that the groundwater with the lowest specific conductance values occurs in the recent river alluvium of the Willamette River floodplain (Qal), in much of the older alluvium (Qoal) in the central and eastern valley flat, and in the bedrock units along topographic highs.

Since Figure 26 is based only on the data available, it does not mean that groundwater with high salinities could not be encountered within the non-shaded areas. For example, since data are only available from shallow wells within the Qal, it does not rule out the possibility for the occurrence of brackish or saline groundwater at greater depths beneath the Willamette River floodplain.

Since water with high salinities is inappropriate for human consumption, there is little reason to complete a well that has encountered such water. Therefore, opportunities to obtain samples of brackish or saline water are limited. The darkened triangles in Figure 26 represent sites that

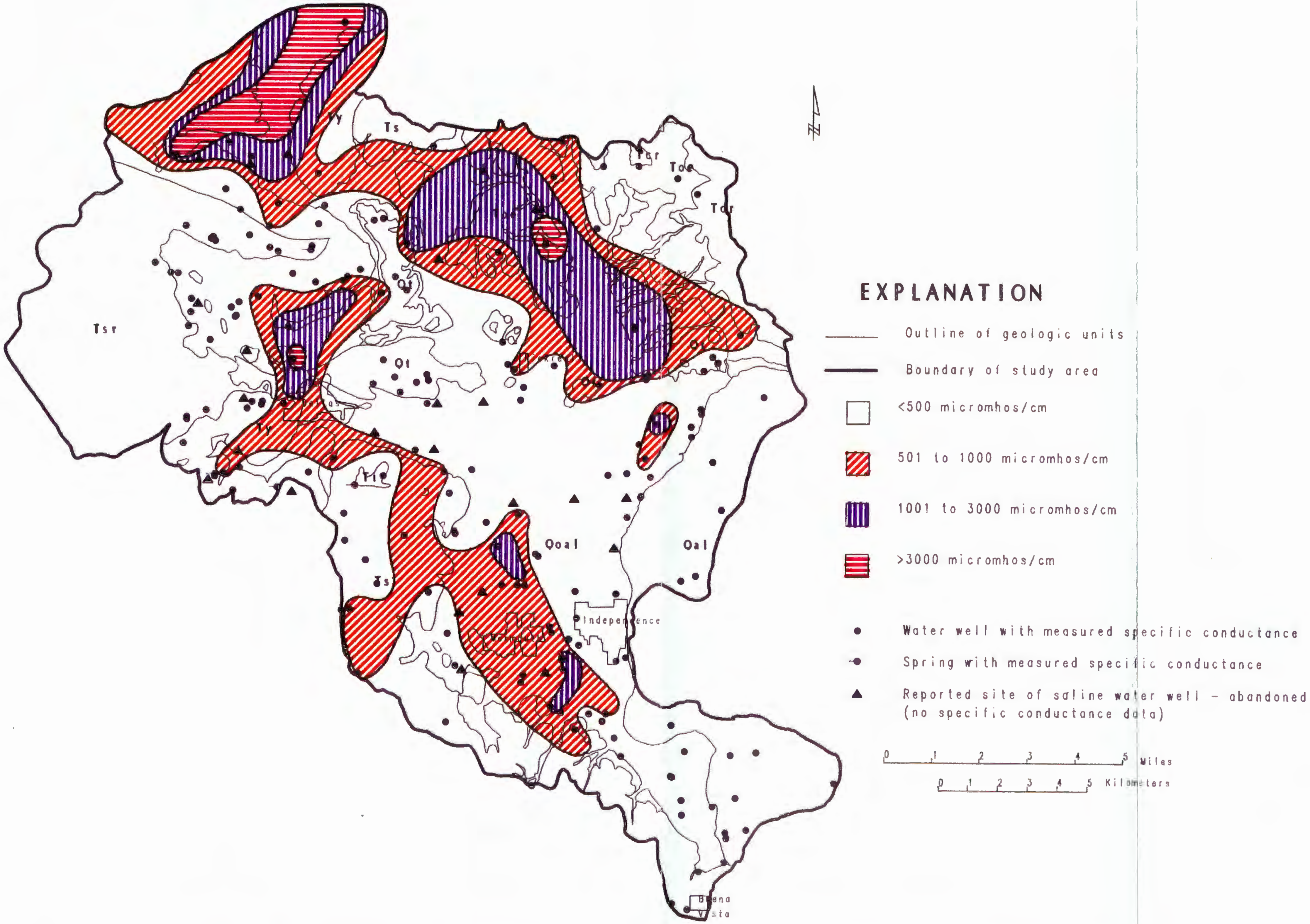


Figure 26. Groundwater salinity hazard map based on specific conductance measurements.

"salt" water was reported by residents or drillers. All of these wells have been abandoned or the "salt" water bearing zones have been sealed and no specific conductance values were obtained. These sites were not used to constrain the specific conductance isocons, but they should be taken into consideration when evaluating the distribution of poor quality groundwater.

An example of a site where there was a reported occurrence of high salinity groundwater that can not be confirmed by this study is located at 8S/5W-26dc. There, a long-time resident explained the details of a shallow, less than 30 feet (9 m) deep, hand-dug well. The well, completed in sandstone of the Spencer Formation, was used only for stock water. After a period of time, cows began to give birth to an unusual number of stillborn calves. Eventually, cows started dying at an uncommonly high rate. A taste of the well water indicated that the water had "turned salty". The well was immediately abandoned and filled in. The suggested safe upper TDS concentration limit for beef cattle stock water is 10,100 mg/l (Hem, 1985). Using Figure 25 as a reference, a TDS concentration of 10,100 mg/l would be equivalent to a specific conductance of approximately 18,000 μmhos/cm.

Another example of the reported occurrence of poor quality groundwater is located at 7S/5W-5 in the valley flat of Salt Creek. At that locale, four shallow wells drilled for members of one family all reportedly encountered "salty" groundwater. All of the wells, the deepest being 51 feet (15.5 m), were completed in the Yamhill Formation. The wells were abandoned and thus no samples were obtainable. Residents claim that few wells have encountered potable water in this vicinity.

A series of small springs located near Salt Creek at 6S/5W-21cad had the highest measured specific conductance values which averaged over 57,000 μmhos/cm (Figure 27a). Previously unknown to the scientific community, they may be among the most saline in western Oregon. The discharge from these springs appear to be less than one gpm. As apparent in Figure 27a, the local flora's intolerance to the saline water is indicated by the lack of vegetation in close proximity to the discharge points. There is abundant evidence of the use of these waters by wildlife, apparently as a source of salt. The springs were flowing at approximately the same rate when visited in the months of January, February, April and August of 1992 and are probably perennial.

Another series of springs, with average specific conductance values near 14,000 μmhos/cm are located along Salt Creek at 7S/6W-2add (Figure 27b). These springs, discharging at about 5 gpm, are also thought to flow year-round as they were flowing in January and August of 1992.

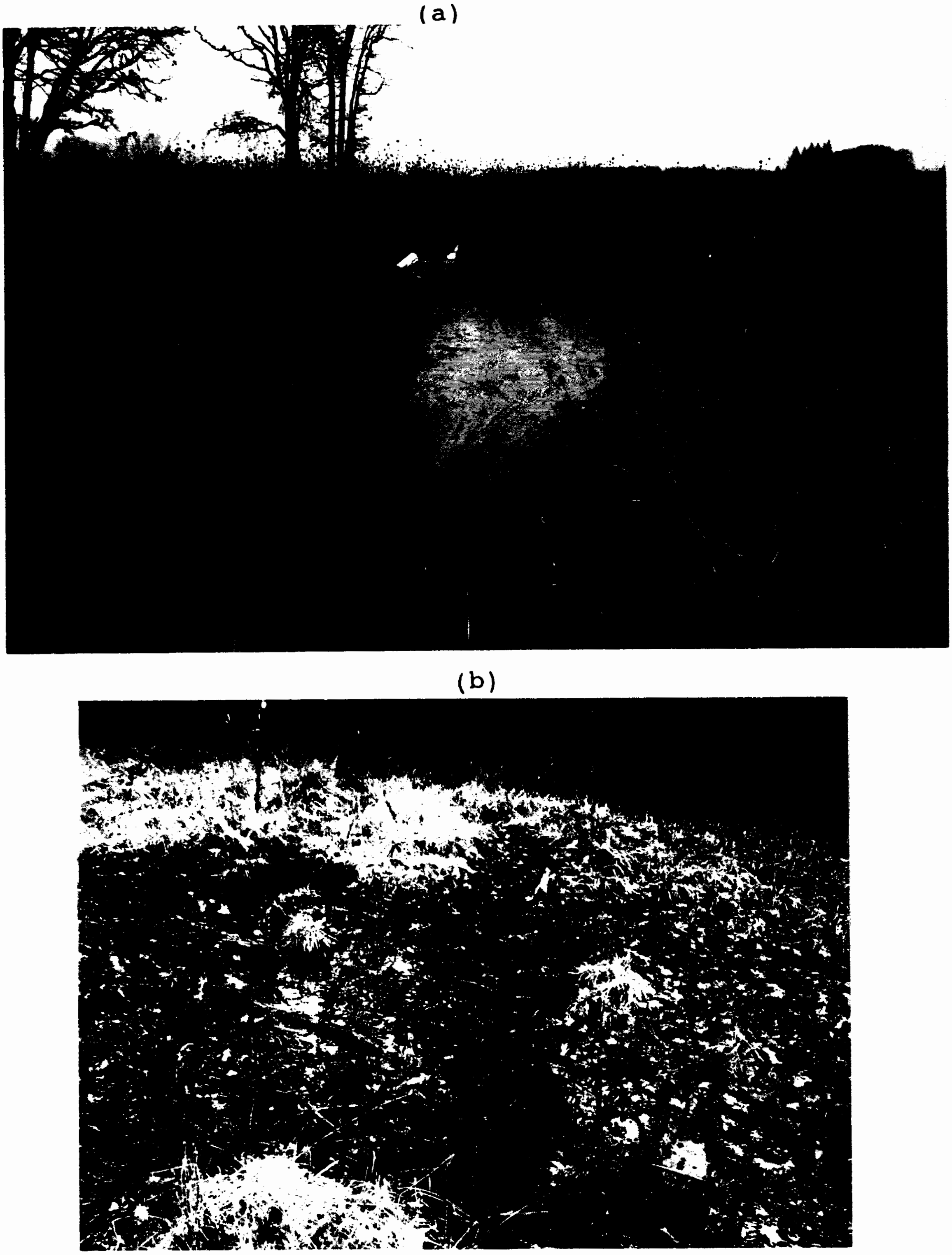


Figure 27. Springs with high salinities near Salt Creek at 6S/5W-21cad (a) and 7S/6W-2add (b).

Temporal Groundwater Quality Variation

Many of the wells and springs have had multiple specific conductance measurements made at various times (Appendix C). This allows for the determination of specific conductance variations through time.

The temporal variation in specific conductance values appears to be small. For example, in well 8S/4W-31dda1 the measured field values range between 2400 and 2650 μmhos/cm over a period of 18 years. The author considers these values to be fundamentally the same. The range of values is surprisingly small, especially considering that different sampling personnel and meters were used. The length of time the well was purged could also explain the small variation in these values. While sampling the well on one occasion, the author noted a variation of values from 2750 μmhos/cm after one minute of pumping to 2400 μmhos/cm after the values stabilized following 20 minutes of pumping.

Chemical Analysis

The water chemistry of 22 wells (Gonthier, 1983) and two springs within the study area was examined for this investigation. Their respective locations are included in Plate I. Table VIII contains the water chemistry for these sites as well as ocean water (Hem, 1985) and a 2985 ft (910 m) deep oil and gas exploration well (6S/4W-6bd) located five miles (8 km) north of the study area (Price and Johnson, 1965).

TABLE VIII

CHEMICAL ANALYSIS OF SELECTED WATERS

SITE			AQUIFER				(mg/l)										Spec. Cond.	pH	T(C)
SIO2	Al	Fe	Mn	Ca	Mg	Na	K	HCO3	SO4	Cl	F	N	P	B	As	TDS			
WATER WELLS																			
8S/4W-2cac2*			Qal																
34		0.03	0.01	20	11	8	1.1	89	15	6.3	0.1	4.9	0.01	0.007	0.001	161	225	8.2	17
8S/4W-22abd*			Qal																
38		0.21		21	9	6.1	1	76	17	3.7		4.6	0.09	0.007		154	90	7.3	12
9S/4W-2dca*			Qal																
48		0.07		25	16	8.2	0.7	98	21	7	0.1	11	0.09	0.005	0.001	223	292	7.7	13
9S/4W-10bad1*			Qal																
52		0.02	0.01	14	8	9	1.3	82	5.9	4.3	0.1	0.66	0.21	0.002	0.001	139	191	8.3	13.5
9S/4W-10bad2*			Qal																
43		0.09		14	1.5	13	1	75	5	3	0.4					144		6.6	
9S/4W-14dbb*			Qal																
44		0.01	0.02	23	14	10	0.9	90	24	8.7	0.1	9.5	0.21	0.01		211	287	7.2	13
7S/4W-31bcd*			Qoal																
37		0.17	0.27	21	9.6	15	0.3	132	2.3	2.9	0.1	0.09	0.57	0.009	0.001	156	223	8.5	12
7S/4w-32aab*			Qoal																
27		0.02	0.01	9.8	1.8	230	2.8	213	0.1	250	0.1	0.63	0.07	0.25		630	1180	8.3	13
7S/4W-34ddc*			Qoal																
46		0.06	0.04	18	11	16	2.8	111	13	5.9	0.2	2.7	0.57	0.007		118	244	7.9	13.3
8S/4w-18dbd*			Qoal																
24		0.03	0.13	25	12	17	0.9	157	10	7.8	0.2	0.22	0.2	0.01	0.001	176	273	8.1	11
8S/4W-19bdb*			Qoal																
23		0.82	0.33	62	26	150	1.5	418	1.4	160	0.1	1.9	0.02	0.08	0.001	640	1080	8.1	14
8S/4W-28cdb*			Qoal																
45		0.03	0.01	33	17	25	2	221	3.8	13	0.2	0.3	0.41	0.007	0.002	251	386	8.7	12
8S/4W-33bbb*			Qoal																
39			0.52	34	134	38	2.8		2	0.4						268			
6S/4W-6bd**			Toe/Ts																
4		1.5	0.4	11500	51	4060	22	14	12	26000						41800	49700	6.1	
7S/4W-7acc*			Ts																
29		0.6	0.39	44	8.5	250	3.9	286	300	100	0.2	1.1	0.05	0.48		883	1390	8.6	14
7S/4W-26ccb*			Ts																
56		2.2	0.41	25	12	31	3.5	202	2	10	0.3	0.7	0.22	0.02	0.006	246	330	8	14.5
7S/5W-2bac*			Ts																
3.2		0.13	0.03	7	1.4	50	1	133	0.7	13	0.3	0.59	0.02	0.22	0.001	145	254	8.3	14
8S/4W-31dda1*			Ts																
23		3	0.46	60	20	500	5.4	286	1.6	810	0.2	2.7	0.02	1.1	0.001	1580	2700	8.4	14.5
8S/5w-21dca*			Ts																
7.8		0.04		1.9	0.3	280	0.8	503	3	75	0.6	0.75	0.27	1.7		691	1170	8.6	13
7S/5W-6bdd*			Ty																
12		0.16		18	3.5	460	2.5	422	10	500	0.1	2.2	0.07	1.9		1230	2170	8	16
7S/5W-15acc1*			Ty																
16		0.24	0.02	19	5	340	3.5	274	1.3	400	0.3	2.1	0.12	1.8	0.001	942	1700	7.8	14
7S/5W-29cad*			Ty																
4.7		19	0.58	1200	210	1500	11	3		5200		0.12	0.02	2.6			14800	4.9	14
8S/5W-7bbb*			Ty																
22		0.03	0.02	51	0.7	70	0.7	94	27	120	0.3	0.68	0.08	0.46	0.001	342	611	7.9	14
SPRINGS																			
6S/5W-21cad***			Qoal/Ty																
7.24	0.13	8.3	0.32	9700	4.4	4700	17	<1		26000				2.4		40500	56000	6.8	9
7S/6W-2add***			Qoal/Ty																
11.2	0.085	0.043	0.011	1800	0.5	840	3.8	8.42		4800				1.5		7482	14000	8.2	9.5
Ocean****																			
6.4	0.001	0.003	0.002	410	1350	10500	390	142	2700	19000	1.3	0.67	0.09	4.5	0.003	34580	50000		

* Gonthier (1983)
** Price and Johnson (1965)
*** Analyzed by Keystone/NEA
**** Hem (1985)

Samples from waters with the highest salinities, the springs (6S/5W-21cad1 and 7S/6W-2add) and the oil and gas well (6S/4W-6bd), have higher concentrations of Ca relative to Na. Most of the samples with relatively low TDS (≤251 mg/l) are also enriched in Ca relative Na. The majority of the other samples, with intermediate salinities, have higher concentrations of Na relative to Ca.

Of particular interest is the concentrations of the major ions (Na, Ca and Cl) of the oil and gas exploration well (6S/4W-6bd) and the two springs (6S/5W-21cad1 and 7S/6W-2add) (Table IX). Also notable is the chemical dissimilarity of this well and the springs with that of ocean water. The Na, Ca and Cl concentrations of spring 6S/5W-21cad1 and well 6S/4W-6bd are very similar. The Na:Ca, Na:Cl and Ca:Cl ratios of the springs are nearly identical to one another and closely similar to the well.

TABLE IX

Na, Ca, AND Cl CONCENTRATIONS, THEIR RESPECTIVE RATIOS, AND SPECIFIC CONDUCTANCE OF STUDY AREA SPRINGS WITH HIGH SALINITIES, A LOCAL OIL AND GAS WELL, AND OCEAN WATER

SAMPLE LOCATION	SPEC. COND.* (µmhos/cm)	Na (mg/l)	Ca (mg/l)	Cl (mg/l)	Na/Ca	Na/Cl	Ca/Cl
SPRINGS 6S/5W-21cad	56000	4700	9700	26000	0.48	0.18	0.37
7S/6W-2add	14000	840	1800	4800	0.47	0.18	0.38
WELL (Price and Johnson, 1965) 6S/4W-6bd	49700	4060	11500	26000	0.35	0.16	0.44
OCEAN (Hem, 1985)	50000	10500	410	19000	25.61	0.55	0.02

Ionic concentrations (ppm), pH and temperature values from two springs (6S/5W-21cad1 and 7S/6W-2add) and two water wells (7S/5W-29cad and 8S/4W-31dda1) from the study area were input into a Fortran version of the program WATEQ (Plummer and others, 1976). For comparison, the analyses of $CaCl_2$ water from the oil and gas exploration well at 6S/4W-6bd (Price and Johnson, 1965) and NaCl brines from two oil and gas exploration wells in the Mist area of northwestern Oregon (written communication, Northwest Natural Gas, 1992) were also input into WATEQ.

Output from the WATEQ program includes molalities, activities, possible complex ions or molecules, ion ratios, log activity ratios, ion activity products, solubility products and a list of the state of saturation of the water with respect to several mineral phases. The degree of saturation of these waters with respect to several mineral phases is listed in Appendix E. The program also performs a charge balance to determine if the analysis is consistent. The WATEQ program calculated charge balance discrepancies of up to 4.15% for these analyses.

The $CaCl_2$ waters of the brackish and saline springs (6S/5W-21cad1 and 7S/6W-2add) and the oil and gas well at 6S/4W-6bd and the NaCl waters of the Mist Gas Field are saturated with respect to the majority of silica phases examined. Together, these waters are undersaturated with respect to most Mg and Mn phases. However, distinctions do exist between the two groups. The NaCl waters are saturated/supersaturated with respect to a greater number of mineral phases than the $CaCl_2$ waters. Specifically, the NaCl waters are saturated/supersaturated with respect to more Na and Ca mineral phases than the $CaCl_2$ waters.

The major ionic components of waters from the domestic wells (7S/5W-29cad and 8S/4W-31dda1) are Na and Cl, but 7S/5W-29cad is much more concentrated and has nearly equal Ca-Na concentrations. Both wells are saturated with respect to most of the silica phases. Well 7S/5W-29cad was saturated with respect to the fewest mineral phases, this may be directly attributed to its anomalously high acidity (pH = 4.9).

Water from well 8S/4W-31dda1 is unique among the waters analyzed in that it is saturated/supersaturated with respect to most magnesium and manganese mineral phases. Like the NaCl waters of the Mist Gas Field wells, domestic well 8S/4W-31dda1 is saturated/supersaturated with respect to the majority of Ca mineral phases. However, unlike the Mist Gas Field wells, it is undersaturated with respect to most Na phases.

Bromide, Iodide and Chloride Concentrations

Chloride, bromide and iodide are among the most conservative constituents in natural waters, with chloride being the most conservative. However, bromide and iodide concentrations can be affected by the alteration of organic matter (Fabrika-Martin and others, 1991). Samples from two springs and twelve water wells were analyzed for Br, Cl, and I concentrations. Two replicate samples and a sample of ocean water from Neskowin Bay, Oregon were analyzed for quality assurance. In addition to analyzed samples from this report, previously reported concentrations from an oil and gas well located at 6S/4W-6bd (Price and Johnson, 1965) and seawater (Hem, 1985) are included in Table X.

The ratios of these halides are often useful in determining possible groundwater or contaminant sources. The chloride-bromide ratios of the samples analyzed for this study are of particular interest. Eleven of the fourteen sites sampled have Cl:Br values which are greater than that of seawater. Ten of these sites have Cl:Br values within 20% of that of seawater. All of the Cl:I values are at least one order of magnitude less than that of seawater.

The graphical representation the log Br versus log Cl concentrations is a commonly used method in groundwater source identification (Whittemore, 1988; Walter and others, 1990). Data from this study, plotted on a log Br versus log Cl graph, represent a relatively tight array for which a straight line can be fitted (Figure 28).

The data were also plotted on a log Cl vs log Br/Cl x 1000 modified mixing boundaries graph of Whittemore (1988) (Figure 29). Whittemore (1988) constructed the graph from

TABLE X

Cl, Br, AND I CONCENTRATIONS, THEIR RESPECTIVE RATIOS, AND LAB AND FIELD SPECIFIC CONDUCTANCE VALUES FOR SELECTED AREA WELLS AND SPRINGS, A LOCAL OIL AND GAS WELL, AND SEAWATER

SAMPLE LOC.	AQUIFER	Cl mg/l	Br mg/l	I mg/l	Cl/Br	Cl/I	Br/I	SPEC. COND.	
								LAB (µmhos/cm)	FIELD (µmhos/cm)
SPRINGS									
6S/5W-21cad1	Ty	27000	41		659			57400	56000
6S/5W-21cad1*	Ty	26000	56.22	7.1	462	3662	7.9		56000
7S/6W-2add*	Qoal/Ty	4800	14.11	1.9	340	2526	7.4		14000
WELLS									
6S/4W-6bd***	Toe/Ts	26000	63	14	413	1857	4.5	49700	
7S/4W-21dcc	Toe	270	0.86	0.36	314	750	2.4	1610	1580
7S/4W-30ccb	Ts	380	0.53	1.8	717	211	0.3	1430	1430
7S/5W-1cad	Toe/Ts	47	0.1	1.6	470	29	0.1	1200	1210
7S/5W-5dda	Ty	8.5	0.03	0.005	283	1700	6.0	540	550
7S/5W-6bbc	Ty	410	1.7	1.6	241	256	1.1	1710	1610
7S/5W-31dab2	Ty	47	0.09	0.051	522	922	1.8	400	397
8S/4W-7cca	Qoal	15	0.04	0.005	375	3000	8.0	340	335
8S/4W-11cad	Qal	9.9	0.03	0.002	330	4950	15.0	270	262
8S/4W-11cad	Qal	9.4	0.03	0.001	313	9400	30.0	270	262
8S/4W-19bca	Qoal/Ts	110	0.38	0.34	289	324	1.1	960	946
8S/4W-30ada	Qoal	17	0.05	0.083	340	205	0.6	620	610
8S/4W-31dda1	Ts	570	2.3	1.5	248	380	1.5	2450	2400
9S/4W-5bda	Ts	68	0.29	0.004	234	17000	72.5	700	704
SEAWATER - NESKOWIN BAY, OREGON									
5S/11W-25cbc		15000	53		283			40800	
AVG. SEAWATER**		19000	67	0.06	284	316667	1116.7	50000	

* Analyzed at Keystone/NEA ** Hem (1985) *** Price and Johnson (1965)

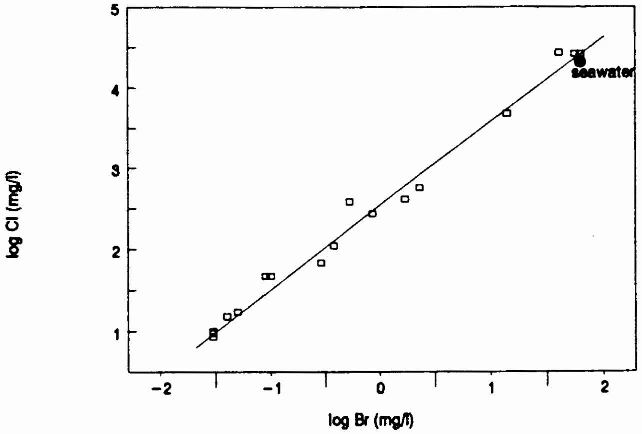


Figure 28. A plot of log Br versus log Cl concentrations for waters of selected study area wells and springs, a local oil and gas well, and ocean water.

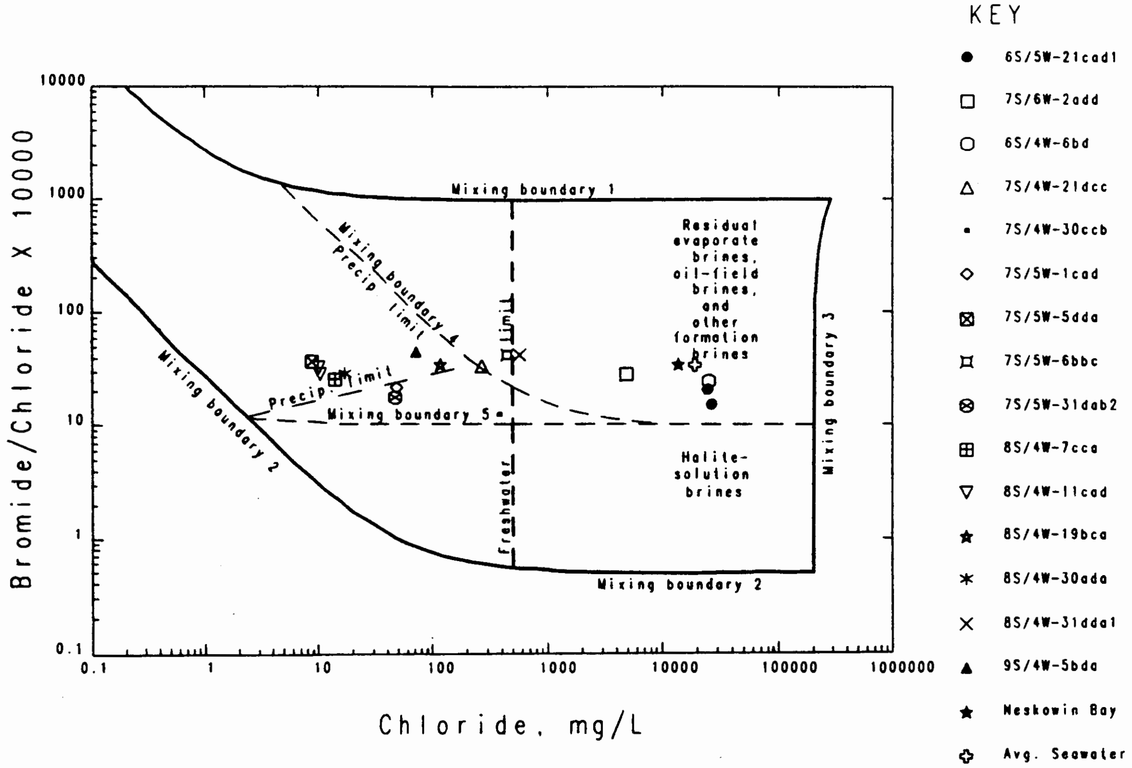


Figure 29. Br and Cl concentrations of waters from selected study area springs and wells, a nearby oil and gas well, and seawater represented in the mixing boundaries of natural waters graph of Whittemore (1988).

bromide and chloride data of world-wide natural waters. Boundaries 1, 2 and 3 represent the maximum extent of determined bromide and chloride concentrations in natural waters. Values within the precipitation limit boundaries in the upper left portion of Figure 29 depict the extent of measured Cl and Br concentrations in precipitation, globally. The zone between mixing boundaries 1 and 5 represents the mixing of most fresh waters with formation brines and residual evaporite solutions. The area between mixing boundaries 2 and 4 characterize the mixing of most fresh waters and halite solution brines. The freshwater limit line marks the 500 mg/l concentration of chloride.

All of the bromide and chloride concentrations for this study plot between mixing boundaries 1 and 5 (Figure 29). The springs with high salinities (6S/5W-21cad1 and 7S/6W-2add) and the saline oil and gas well (6S/4W-6bd) values plot near that of seawater. Data from six wells with chloride concentrations less than 200 mg/l lie within the precipitation limit. All of the waters exceeding the fresh water limit fall outside of the zone bounded by mixing boundaries 2 and 4. Samples from ten of eleven sites under the fresh water limit have bromide and chloride values that graphically lie within the area bounded by mixing boundaries 2 and 4.

$\delta^{18}O$-δD Isotopic Concentration

Water samples from three springs, six wells and one surface drainage were analyzed for D/H and O^{18}/O^{16} isotopic ratios. Table XI contains data from this study, the Luckiamute River (collected by the USGS), standard mean ocean water (SMOW), and pre-Miocene SMOW (Sheppard, 1986).

TABLE XI

δD AND $\delta^{18}O$ OF SELECTED WELLS, SPRINGS, AND PRE-MIOCENE AND MODERN SEAWATER (SMOW)

SAMPLE LOCATION	WATER BEARING UNIT	D (o/oo)	O (o/oo)
SPRINGS			
6S/5W-21cad1*	Ty	-8	-1.6
"	"	-6	-1.8
"	"	-6	-1.6
7S/6W-2aad*	Qoal/Ty	-62	-9.4
8S/5W-8bca*	Ty	-66	-9.3
WATER WELLS			
7S/4W-21dcc1*	Toe	-72	-10.8
7S/4W-30ccb*	Ts	-74	-11.1
7S/5W-1cad*	Toe/Ts	-73	-10.6
8S/4W-11cad*	Qal	-67	-9.5
8S/4W-19bca*	Qoal	-66	-9.7
8S/4W-31dda1*	Ts	-80	-11.1
8S/4W-31dda1**	"	-75.5	-10.7
SALT CREEK			
6S/5W-21cad4*		-62	-9.1
LUCKIAMUTE RIVER			
9S/4W-18ccc**		-61	-8.4
9S/4W-18ccc**		-57	-8.6
STANDARD MEAN OCEAN WATER (SMOW)		0	0
PRE-MIOCENE SMOW***		-7	-1

* Analyzed by Krueger Enterprises, Inc.
** Analyzed by USGS NATIONAL LABORATORY
*** Sheppard (1986)

The isotopic ratios were plotted in relation to the meteoric water line of Craig (1961) (Figure 30). All of the values lie on or near the meteoric water line. Most are isotopically lighter than -8 ($^{o}/_{oo}$) $\delta^{18}O$ and -55 ($^{o}/_{oo}$) δD and plot near the meteoric water line except for the values of the highly saline springs. Three samples collected from the salt spring at 6S/5W-21cad1 cluster between the meteoric water line and the value for SMOW and pre-Miocene SMOW.

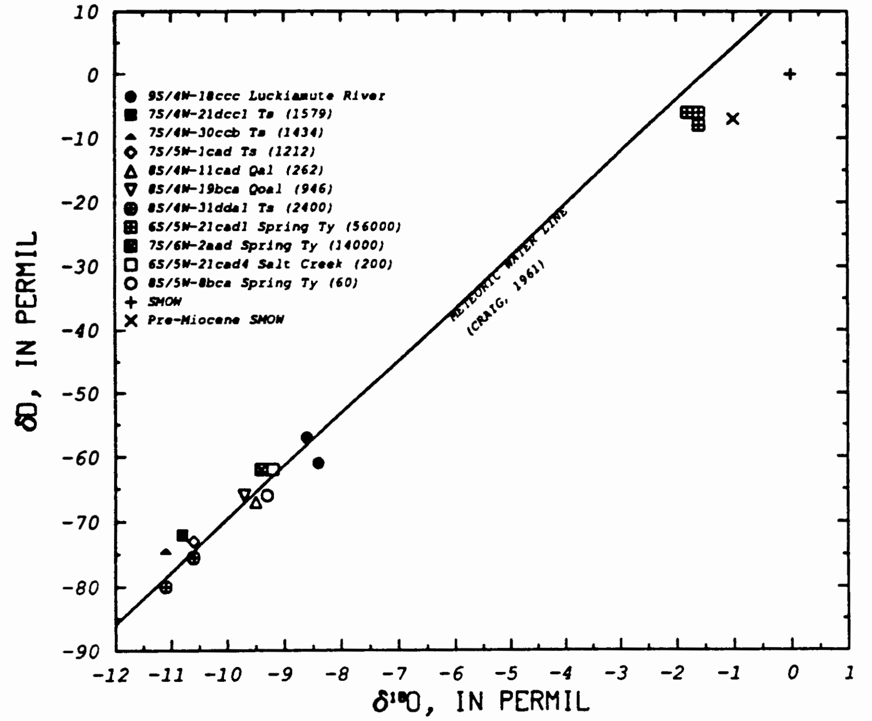


Figure 30. δD and $\delta^{18}O$ plot of waters from selected study area wells, springs and streams, pre-Miocene SMOW, and modern SMOW in comparison to the meteoric water line of Craig (1961).

Possible Groundwater Quality Relationships

Aside from determining the areal distribution of groundwater with high TDS concentrations, possible relationships between water quality and various physical factors were investigated. Hydrogeologic aspects, such as the water-bearing unit, specific capacity, and the depth to and elevation of the static water level, were compared to their respective specific conductance values. A possible relation between specific conductance and the topographic setting and the depth of the open interval was also examined. The specific conductance values were from Gonthier (1983) or were measured by the author for this study.

The mean, standard deviation, median and range of measured specific conductance values for the major water-bearing units are in Table XII. The average and median specific conductance values for the Siletz River Volcanics (Tsr), recent river alluvium (Qal) and high terrace and alluvial fan deposits (Qt) are among the lowest of the water bearing units. The highest mean and median specific conductances occur in the marine sedimentary bedrock units (Toe, Ts, and Ty) and the older alluvium (Qoal). The variations in the specific conductance values are minor among waters obtained from the Qal, Qt and Tsr when compared to the other units.

TABLE XII

SPECIFIC CONDUCTANCE INFORMATION FOR EACH OF THE MAJOR WATER BEARING UNITS

Aquifer	Specific Conductance (μmhos/cm)				Sites
	Mean	Stand. dev.	Med.	Range	
Qal	246.1	55.6	235	160-330	21
Qoal	447.7	257.4	375	160-1300	43
Qt	162.5	90.1	160	75-375	8
Toe	744.5	690.2	710	45-3000	19
Ts	422.6	482.0	390	70-2650	36
Ty	595.8	935.3	330	130-5500	33
Tsr	195.0	84.6	195	50-410	14

None of the wells in the Qal, Qt, or Tsr produce water with measured specific conductance values of 500 μmhos/cm or more. However, Gonthier (1983) did report specific conductances of up to 10,200 μmhos/cm from wells completed in the Tsr to the southwest of the study area. Wells in the sedimentary marine bedrock units and the Qoal yield waters of both satisfactory and poor quality. With the exception of the Toe, the majority of the wells within these units provide acceptable quality water with specific conductance measurements of less than 500 μmhos/cm.

One hundred forty-one wells with both specific conductance and specific capacity data were used to generate Figure 31. The specific conductance values range from less than 100 to over 3000 μmhos/cm for wells with specific capacities ranging from nearly zero to approximately 180 gpm/ft. The greatest range of the measured specific conductance values occur at specific capacities of less than one gpm/ft. With increasing specific capacity, the range of specific conductance values narrow and are generally lower.

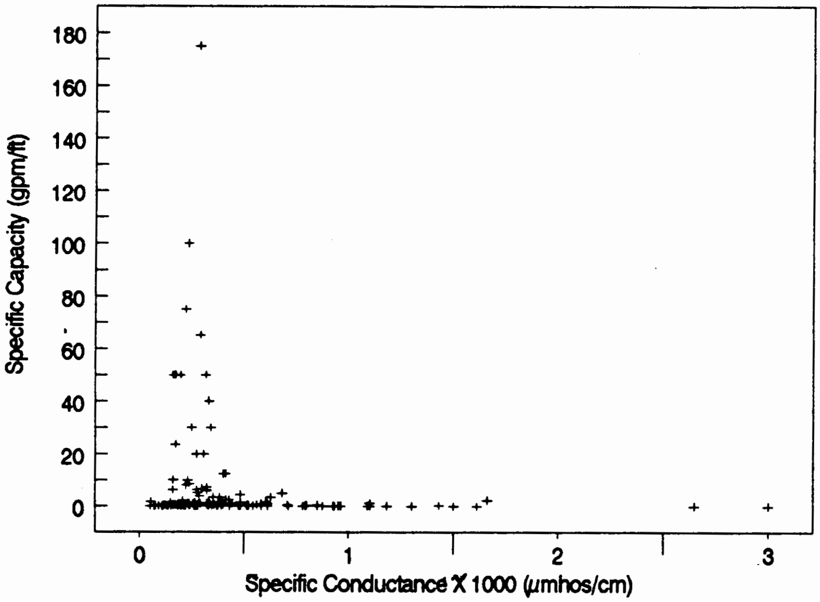


Figure 31. A plot of specific conductance vs. specific capacity for selected wells.

Only wells with specific capacity values of five gpm/ft or less have measured specific conductances greater than 500 μmhos/cm. However, the majority (69%) of these wells also yield groundwater of acceptable quality with specific conductance values of 500 μmhos/cm or less. Of the wells with specific conductances of over 500 μmhos/cm, nearly half (47%) have specific capacities of 0.1 gpm/ft or less.

One hundred seventy-one wells in the database have both specific conductance and static water level information. The static water levels range from near surface to almost 240 feet (73.1 m) below lsd (land surface datum) and have associated specific conductance values ranging from 45 to 5500 μmhos/cm. The depth to water for the well with the highest specific conductance value was 3.98 feet (1.21 m). All but one of the wells with specific conductance values of over 1000 μmhos/cm have static water levels of less than 60 feet (18.3 m) below lsd. However, the majority (78%) of the wells with static water levels of less than 60 feet (18.3 m) have specific conductances of 500 μmhos/cm or less.

The elevations of the static water levels range from 108.4 to 1110.0 feet (33.0 to 338.3 m). Specific conductance values of 1000 μmhos/cm or more occur only at static water level elevations below 400 feet (121.9 m). However, 71 percent of the wells with similar water level elevations of 400 feet (121.9 m) or less have specific conductance values of 500 μmhos/cm or less.

The topographic setting and elevation of 174 wells with specific conductance measurements were determined with the use of topographic maps. Each well was assigned to one of three topographic settings; valley flat, hillside, and at or near hilltop. Table XIII represents the mean, standard deviation, median and range of specific conductance values for each of the topographic settings.

TABLE XIII

TOPOGRAPHIC SETTING OF WELLS AND RESPECTIVE SPECIFIC CONDUCTANCE INFORMATION

Topographic Setting	Specific Conductance (µmhos/cm)				Sites
	Mean	Stand. Dev.	Med.	Range	
Valley Flat	543.6	674.4	320	45-5500	106
Hillside	384.1	275.0	305	90-1500	43
Hilltop	277.3	201.7	230	50-925	25

Wells located within valley flat settings have the highest average and median specific conductance values. The wells from that group also have the largest variation in specific conductance values as indicated by the standard deviation. Wells located at or near hilltops have the lowest average and median conductance values.

The majority (61%) of the wells with specific conductance measurements are located in the valley flat. Correspondingly, the majority (57%) of wells with specific conductances of 500 µmhos/cm or less are found in the valley flat. At higher salinities a greater, disproportionate percentage of wells occur in the valley flat. Seventy-three percent of the wells with specific conductance values of over 500 µmhos/cm and 94% of the wells with values of over 1000 µmhos/cm are found in the valley flat.

One hundred sixty-six of the wells have both open interval information and measured specific conductance values. The depths to the top of the open intervals range from 11 to 205 feet (3.4 to 62.5 m) below land surface with a specific conductance range of 45 to 5500 μmhos/cm. Only wells with open interval depths of less than 100 feet (30.5 m) had specific conductance values of over 1000 μmhos/cm. However, 75 percent of the wells with open interval depths of less than 100 feet (30.5 m) obtain good quality water with specific conductance values of less than 500 μmhos/cm.

Several area wells reportedly encountered "salt" water at depths greater than 100 feet (30.5 m) and were either abandoned or backfilled to obtain useable water at shallower depths. A well at 8S/4W-19bca encountered "salt" water in hard gray claystone, probably the Spencer Formation, at a depth of 120 feet (36.6 m). The well was sealed off with cement to a depth of 90 feet (27.4 m) and now obtains water from sand and gravel layers in the older alluvium (Qoal). However, the problem is not completely resolved for this well as recent specific conductance measurements by the author range from 931 to 941 μmhos/cm. Table XIV lists 16 both field located and non-field located wells that, according to driller's reports, encountered "salt" water at depths greater than 100 feet (30.5 m). No wells reportedly encountered fresh water below an occurrence of "salt" water.

TABLE XIV

WELLS THAT REPORTEDLY ENCOUNTERED "SALT" WATER

Well Location	Depth (ft)	Unit	Remarks
7S/4W-7	169	Toe	Abandoned
7S/4W-16	127	Toe	Abandoned
7S/4W-26ccb	190	Toe	Backfilled to 83 feet
7S/5W-6	220	Ty	Abandoned
7S/5W-30	395	Ty	Backfilled to 345 feet
7S/5W-31	330	Ty	Abandoned
7S/5W-35	195	Ts	Abandoned
7S/5W-36	100	Ts	Abandoned
7S/6W-1	143	Ty	Abandoned
8S/4W-19bca	120	Ts	Backfilled to 90 feet
8S/4W-31a	305	Ts	
8S/5W-3b	320	Ty	Backfilled to 180 feet
8S/5W-7bbb	141	Ty	Backfilled to 97 feet
8S/5W-8	163	Ty	Backfilled to 146 feet
8S/5W-24	205	Ts	Backfilled to 190 feet
8S/6W-12	240	Ty	Backfilled to 200 feet

DISCUSSION

GEOLOGY

Similar lithology, interfingering facies, and the generally weakly consolidated character of the Tertiary marine sedimentary units often frustrate identification of units in outcrop and in drill cuttings. Likewise, it is oftentimes difficult to distinguish between fine-grained alluvium and weathered marine bedrock. The geochemistry of trace and selected major elements were used by Kadri (1982) and Lite (1992) to differentiate sedimentary units and to suggest possible provenances. Instrumental neutron activation analysis (INAA) data accompanied by x-ray diffraction data and lithologic descriptions from drillers logs were used in this study to: 1) determine the extent and thickness of various lithologic units within the unconsolidated sediment; 2) differentiate units within the bedrock and unconsolidated material; 3) differentiate the bedrock units from the unconsolidated sediments; and 4) determine possible sediment sources for both the bedrock and the unconsolidated material.

Bedrock

In the study area, the Spencer Formation (Ts) is generally characterized by higher Th, Rb, K, and La and lower Fe, Sc, and Co concentrations in comparison with the other sedimentary bedrock units. The Ty and Toe units are geochemically similar, but are separated stratigraphically by the Ts. The Siletz River Volcanics (Tsr) are readily distinguished from the sedimentary units by relatively high Fe, Na, Co, Cr, and Sc.

Geochemistry of sediment (INAA) from four oil and gas wells support the unit designations of Graven (1990) and Werner (1990) for these wells. However, near the Spencer-Yamhill contact, the units are less geochemically distinct. The geochemistry suggests a gradational contact between the Ts and Ty. The contact between the Ts and Ty is thought to mark a marine regression (Graven, 1990).

The Spencer and Yamhill Formations may also be distinguishable on the basis of clay mineralogy. A sample of the Yamhill Formation is composed predominantly of smectite (86%) (Table VI), while a sample from the Spencer Formation has a more varied clay mineral suite (smectite, kaolinite and illite with trace amounts of vermiculite and expandable mixed layer clay).

The geochemistry of the marine bedrock units may be useful as provenance indicators. INAA data as well as previous lithologic and petrographic work (Baldwin and others, 1955; Baker, 1988) suggest differing sediment sources during deposition of the Yamhill Formation. Most of the Ty samples have elemental concentrations typical of volcanic arc-derived sediments. A minority of samples, such as a gray claystone sample near the type section along Mill Creek, have Th concentrations similar to those of more chemically-evolved igneous and metamorphic rocks.

A change of provenance for the Yamhill Formation may be recorded in the Reserve Oil and Gas, Bruer 1 exploration well. Thorium concentrations of two samples in the upper half of the 3360 foot (1024 m) Ty section are within the range found in volcanic arc derived sediments, while two samples in the lower half of the section have concentrations similar to continental crust (Taylor, 1964).

The Rickreall Limestone Member of the Yamhill Formation is bioclastic with volcanic fragments and limited amounts of micrite (Boggs and others, 1973). The volcaniclastic component is not only apparent in hand specimens, but also geochemically as indicated by Th concentrations near those of oceanic crust (Taylor, 1964). The likely source of these volcaniclastics is the underlying oceanic basalts of the Siletz River Volcanics.

The Th and La concentrations of nearly all of the Spencer Formation samples are indicative of continental crust material (Taylor, 1964). However, two of the Ts samples have elemental concentrations approaching those found in volcanic arc derived sediments. Baker (1988) and Cunderla (1986) suggested a distal plutonic and metamorphic, possibly the Idaho batholith, and proximal volcanic sediment sources for the Spencer Formation.

The undifferentiated Eocene-Oligocene sedimentary rock unit (Toe) is composed of tuffaceous siltstone and sandstone (Baldwin and others, 1955; Bela, 1981; Brownfield and Schlicker, 1981). Correspondingly, all of the Toe samples have Th concentrations within or slightly higher than the range Condie (1976) has suggested for volcanic arc derived sediments. The sediment was probably deposited during late Eocene-early Oligocene time from a Western Cascade volcanic source.

Basaltic boulders overlying Spencer Formation sandstone on the summit of Mt. Pisgah southeast of Dallas had been previously mapped as Siletz River Volcanics (Tsr) (Baldwin, 1964; Gonthier, 1983; Walker and MacLeod, 1991). Samples from these boulders are geochemically distinguishable from the Tsr as well as Columbia River Basalt (Tcr). Baldwin (1964) suggested that the boulders may be the remains of a basalt flow (or flows) that interfingered the Spencer Formation at the time of deposition. Basalt and diabase constitute much of the Coast Range intrusives (Ti), accordingly the Mt. Pisgah basalt is tentatively assigned to this group.

Unconsolidated Sediment

On the basis of grain-size, the unconsolidated alluvial material is separated into the following lithologic units: 1) a lower fine-grained unit, composed primarily of blue clay and silt; 2) a coarse-grained unit, composed primarily of sand and gravel; and 3) an upper fine-grained unit consisting of tan to brown clay, silt and fine-grained sand. The lower fine-grained unit is not laterally extensive, but deposits possibly exceeding 94 feet (28.6 m) thick may occur beneath the sand and gravel deposits in the valley flat north of Buena Vista. It is difficult to determine from driller's logs if this material is equivalent to the nonmarine fine-grained sediments that overlie bedrock throughout much of the Willamette Valley (Yeats and others, 1991) or is poorly lithified or weathered marine bedrock. No samples were available for chemical analysis.

The greatest thicknesses of the coarse-grained unit, exceeding 80 feet (24.4 m), occur in the high terrace and alluvial fan deposits (Qt) and the older alluvium (Qoal) near Dallas. The deposits are the thinnest to non-existent in the Qoal in the central and northern portions of the valley flat. The coarsest deposits with the fewest fine-grained interlayers occur in the recent river alluvium (Qal), which are over 40 feet (12.2 m) thick near Independence.

Thicknesses of the upper fined-grained unit range from near 0 in portions of the recent Willamette River floodplain to a maximum of nearly 40 feet (12.2 m) overlying older alluvium (Qoal) sand and gravel near Independence and Monmouth. Because of similarities in grain size between this unit and weathered marine bedrock, the thickness directly overlying bedrock was rarely determined.

X-ray diffraction and INAA data were useful in the characterization of the unconsolidated sediment. The upper fine-grained, coarse-grained, and lower fine-grained units of the Qal are geochemically distinct from those of the Qoal. Clay analyses also indicate differences among the upper fine-grained unit of the Qoal, the upper fine-grained unit of the Qoal, the lower fine-grained unit within the Qoal, and a blue clay from below sand and gravel of the Qal.

The use of INAA to distinguish the unconsolidated sediment from the marine bedrock units was moderately successful. The Spencer Formation is geochemically distinct from the unconsolidated sediments, with the possible exception of the upper fine-grained unit of the Qoal. The similar geochemistry of the upper fine-grained unit of the Qoal and the Ts are the likely result of similar provenance material type. All but one sample of the unconsolidated sediments, a sample of blue clay from beneath the Qal sand and gravel section, have Co concentrations higher than those of the Toe. No geochemical distinction between the basin-fill sediments and the Yamhill Formation was apparent after examination of the INAA data.

The La and Th concentrations of the upper-fine grained sediment of the Qoal are similar to Portland basin (Lite, 1992) and Tualatin Valley (unpublished data, Caldwell, 1990) sediments that were proposed to have a continental (plutonic or metamorphic) Columbia Basin source. Baldwin (1964) and Bela (1981) mapped portions of the study area and suggested that the upper brown clay and silt of the Qoal are catastrophic flood deposits commonly referred to as Willamette Silt. An influx of catastrophic flood deposited Columbia Basin sediment could explain the distinct geochemistry of the upper fine-grained Qoal.

A volcanic or Cascadian provenance is likely for the unconsolidated Qal sediments. The upper fine-grained and coarse-grained Qal units have elemental concentrations similar to Portland basin sediments of Cascade Range provenance (Lite, 1992). A sample of blue clay from below the sand and gravel of the Qal, is composed entirely of smectite and is interpreted as a volcanic ash deposit.

Samples from the coarse-grained unit of the older alluvium (Qoal) are geochemically similar to the Siletz River Volcanics basalt exposed in the Coast Range to the west. It is proposed that much of the Qoal coarse-grained unit had a Tsr source from the west and is not a result of Willamette River deposition. A Tsr source is supported by the fan-like morphology of the top of the coarse-grained unit that slopes eastward from the foothills west of Dallas (Figure 9).

Cross-section C-C′ (Plate III) shows the thickest, Tsr derived sand and gravels to the west near Dallas, relatively thin deposits in the central valley flat, and moderately thick deposits in and near the recent Willamette River floodplain. Cross-section D-D′ (Plate III) represents a thickening of the Qoal coarse-grained unit in the direction of the Willamette River. Since it is unlikely that the Tsr derived sediments would thin and then thicken again going eastward away from the source, the Qoal sand and gravel adjacent to the Willamette River floodplain may be the result of Willamette River deposition. If Willamette Silt mantles the Qoal, as indicated by geochemical and lithologic data, Willamette River derived Qoal sediments had to have been deposited prior to Willamette Silt deposition. An area may exist, probably near the eastern margin of the Qoal, in which the distal extent of the Tsr-derived coarse-grained material interfingers with or is truncated by Willamette River deposits.

INAA of the basin-fill material, may provide insight into the evolution of the Willamette Valley. Within this study area, sediment with a Cascadian signature occurs within the recent floodplain of the Willamette River. The fine-grained sediment (Willamette Silt) overlying the sand

and gravel deposits of the older alluvium appears to be derived from a plutonic or metamorphic provenance and not from the surrounding marine bedrock units. The majority of the coarse-grained sediments of the Qoal and Qt are probably derived from Coast Range basalts and were not deposited by the Willamette River.

HYDROGEOLOGY

Groundwater is obtained from bedrock and unconsolidated alluvial deposits in the project area. The unconsolidated sediments are generally more permeable than the bedrock units as indicated by higher reported yields and calculated specific capacities (see Table VII).

The coarse-grained sections, primarily sand and gravel, are the most significant groundwater sources in the unconsolidated sediments. The sand and gravel aquifer of the recent river alluvium (Qal), which reaches thickness of over 40 feet (12.2 m), is the most productive of the unconsolidated sediment units with shallow wells capable of producing over 1,000 gpm. Fine-grained deposits, primarily clay and silt, are used as a groundwater resource where the coarse-grained layers are not present. Adequate yields for domestic purposes have been obtained in fine-grained sediments in the central valley flat northeast of Rickreall.

Although sand and gravel deposits of the older alluvium (Qoal) are much thicker, exceeding 80 feet (24.4 m) near

Dallas, they are generally less productive than the coarse-grained Qal aquifer. Most of these wells have reported yields of less than 100 gpm. This may be explained by the overall finer grain size and the presence of clay and silt interlayers. However, near Independence, the sand and gravel aquifer of the Qoal is approximately 40 feet (12.2 m) thick, with several wells yielding over 400 gpm. This portion of the Qoal may be hydraulically connected with the adjacent Qal sand and gravel aquifer to the east.

The terrace and alluvial fan deposits (Qt) are the least productive groundwater resource of the unconsolidated sediments. Where sand and gravel deposits are present, they are oftentimes highly weathered, discontinuous, and less than 20 feet (6.1m) thick. Most of the Qt, such as the area on the west flank of the Eola Hills, lacks gravel and is rarely utilized as an aquifer.

Basalt flows of the Columbia River Basalt Group (Tcr) are an important regional hydrogeologic unit over much of the northern Willamette Valley. Substantial quantities of groundwater are obtained from fractured, brecciated and interflow zones. The Tcr is used for small-scale public supply and domestic purposes in the Eola Hills in the northeast portion of the study area.

Very few data are available concerning the hydrogeologic characteristics of the Tertiary intrusive rocks (Ti). No wells are known to penetrate the Ti within the study area. Similar intrusive rocks in the northern Oregon Coast Range have yielded little water to wells (Penoyer and Niem, 1975; Frank, 1974; Frank and Collins, 1978).

The marine bedrock units including the Eocene-Oligocene undifferentiated sedimentary rocks (Toe), the Spencer (Ts), Yamhill (Ty) and Tyee (Tt) Formations, and the Kings Valley Siltstone Member of the Siletz River Volcanics are widely used for domestic purposes. The marine units have similar lithologies and subsequently, similar hydrogeologic characteristics. The permeability of these units are relatively low, but because of the large saturated thickness, a deep uncased well allows enough water to enter the well bore to meet domestic needs.

Basalt of the Siletz River Volcanics (Tsr) is used primarily as a domestic groundwater supply source in the western portion of the study area. The hydrogeologic characteristics of the Tsr basalt are very similar to the other bedrock units with low yields and specific capacities.

Gonthier (1983) estimated annual groundwater recharge due to precipitation for the aquifers in the Dallas-Monmouth area (see Table VII). The sand and gravel aquifer of the Qal has the highest annual recharge of 8 to 15 inches (20 to 38 cm). Since there is little or no fine-grained, low permeability material overlying the Qal sand and gravel, much of the precipitation that falls on the surface directly infiltrates into the underlying sand and gravel aquifer. The estimated annual recharge of 2 to 5 inches (5 to 13 cm) for the Qoal and Qt aquifers is lower due to the occurrence of an extensive fine-grained, relatively impermeable unit that overlies most of the sand and gravel deposits. Gonthier (1983) estimated recharge rates of 2 to 5 inches/year (5 to 13 cm/year) for the low permeability bedrock units.

Groundwater flow occurs primarily through the pores or interstices between the particles that compose the unconsolidated sediment aquifers. In addition to groundwater movement through porous media, significant flow may occur in fractures and joints in the bedrock units. Interflow zones between lava flows are also major pathways for fluid migration.

The Siletz River Volcanics (Tsr) is highly fractured due to extensive folding and faulting. Keith and Staples (1985) suggest that the abundant zeolite minerals that line the fractures in the Tsr may be the result of cold (≈10°C) meteoric water-basalt interactions over a long period of time or low-temperature (60-70°C) basalt-seawater interaction. The presence of these zeolites within fractures and joints may actually inhibit modern groundwater movement within this unit. Fluid flow within fractures in the marine sedimentary bedrock is also indicated by the occurrence of secondary minerals lining fractures.

Secondary mineralization, which appears to be Fe or Mn oxides, occurs in a series of fractures within sandstone of the Spencer Formation on the west bank of the Willamette River north of the Buena Vista ferry (Figure 32).

Figure 32. Secondary mineralization within fractures of Spencer Formation sandstone (9S/4W-23bdd).

A significant range in discharge and subsequent specific capacity values is evident for each of the bedrock and alluvial aquifer units. Since facies changes occur within the bedrock and alluvial units, grain-size, degree of sorting, and the thickness of the aquifer material is variable. These variations directly influence the hydraulic characteristics of the respective units. The degree of weathering and the occurrence of paleosols would also influence the hydrogeologic characteristics of the unit. In the case of the bedrock units, the occurrence, orientation, and continuity of fractures, joints and interflow zones may also be responsible for the range of discharge and specific capacity values.

Wells penetrating the same aquifer material with identical hydraulic properties may have significantly different specific capacity values as a result of differing well construction and pump test methods. Several factors can influence the accuracy of pump test data including the duration, method of discharge and water level measurement, the degree in which the aquifer was stressed, and different personnel performing the pump test. The construction of the well, including the length of the open interval and whether the open interval is uncased, screened, perforated casing, or open ended casing influences the effectiveness of the well to remove water from the adjacent aquifer. Therefore, the water level and yield of the well bore may not be wholly representative of the aquifer.

The hydrographs for wells in both bedrock and alluvial units indicate annual water level fluctuations can be correlated to normal precipitation cycles (Appendix D). The highest water levels occur in the winter and spring months which correlates to the normal periods in which the majority of the local precipitation occurs. The hydrographs, along with water levels from less consistently measured wells, indicate a recharge-discharge equilibrium with no apparent water level declination over the past several years.

A potentiometric surface map, based on August to October water level measurements over the past several years, was generated for the basin-fill sediments (Figure 24). The groundwater flow, inferred from the potentiometric surface map, is in the direction of the Willamette River which forms the eastern boundary of the study area. The potentiometric surface roughly mirrors topography with an inferred down slope flow direction. The potentiometric surface contours generally V-upstream at their intersection with the tributaries to the Willamette River. This is an indication that the streams are discharge areas in relation to the local groundwater flow system.

The potentiometric surface contours V-downstream with respect to the Willamette River. If this is truly the case, the Willamette River is acting as a recharge area to the local flow system. This is contradictory to the conclusion that the Willamette River is acting as a discharge area as indicated by the inferred flow direction towards the Willamette River for the majority of the area (Figure 24).

River levels of the Willamette River may fluctuate several feet during the year. The potentiometric surface was constructed with late summer water levels which correlates to a period of low flow in the Willamette River.

If the river surface elevation represented on the USGS 7 1/2 minute quadrangle maps was determined from a period of high flow, the intersections of the potentiometric contours with the Willamette River represented in Figure 24 are not valid. If the river elevations were only approximately two feet (.6 m) lower than they are represented on the topographic maps, it would alter the potentiometric contours to be indicative of a gaining rather than a losing stream. A way to clear up this problem would be to measure the relative elevations of the Willamette River and the static water levels in wells adjacent to the river to determine if the gradient is towards or away from the river.

The potentiometric surface gradient of the Qal in the floodplain of the Willamette River is commonly less than that of the Qoal. The steeper Qoal gradient suggests that it is less permeable than the Qal. This is supported by the lower average specific capacity values observed in wells completed in the Qoal.

GROUNDWATER QUALITY

The following discussion will provide inference based on the available data for conditions in which groundwater with high salinities occurs in the study area. Of the factors examined, groundwater with relatively high salinities occurs almost exclusively under the following conditions; 1) sedimentary marine bedrock and older alluvium water-bearing units, 2) specific capacities of less than 5 gpm/ft (an indication of low permeability), and 3) valley flat or relatively flat lying topographic settings. The groundwater quality is highly variable under these conditions individually, but when all of these conditions occur together, the likelihood of encountering saline water is high.

Groundwater with relatively high measured specific conductance (>500 μmhos/cm) was only found to occur in the sedimentary marine bedrock units (Toe, Ts and Ty) and the older alluvium (Qoal). Within these units, only wells completed in zones of low hydraulic conductivity or transmissivity, as inferred from specific capacities of less than 5 gpm/ft, produced the relatively poor quality water.

Although poor quality water occurs only in wells of relatively low specific capacity in the marine sedimentary bedrock and Qoal units, the majority of the wells under these conditions produce acceptable quality water. However, where these conditions occur and the wells are located in a valley flat or relatively low lying area, a high percentage of the wells produce low quality water. Thus, the topographic setting of the wells appears to be extremely important from a groundwater quality standpoint.

None of the wells obtaining water from the Siletz River Volcanics (Tsr) had measured specific conductance values of >500 μmhos/cm within the study area. Gonthier (1983), however, reported several problem wells to the south near Kings Valley and Adair Village. These wells also predominantly occur in relatively flat lying areas and have specific capacity values of less than 5 gpm/ft. In general, the conditions in which groundwater with relatively high salinities exist within the study area, also exist in Gonthier's study area. Gonthier's (1983) report includes most of this study area, but is over twice as large and extends to the south and southwest.

As groundwater moves along its flow paths in the saturated zone, increases of total dissolved solids and most of the major ions normally occur (Freeze and Cherry, 1979). Active flushing with meteoric water exists in areas of recharge, while increasingly older, more sluggish water occurs with depth. Therefore, shallow groundwater in recharge areas is lower in TDS than the water deeper in the same system and water in shallow zones in discharge areas.

The author suggests that the model illustrated in Figure 33 may represent the fundamental basis of the distribution of fresh and poor quality water within the study area. Figure 33 represents a topographically driven groundwater flow system in which cross-formational discharge is taking place (Domenico and Schwartz, 1990). The zones of fresh water occur as a result of local recharge and more highly mineralized waters occur with distance from the outcrop or recharge areas. As indicated by the salinity hazard map (Figure 26) generated from specific conductance values, primarily satisfactory quality groundwater (≤500 μmhos/cm specific conductance) occurs within topographically high areas. These areas are likely areas of active recharge and subsequent flushing with fresh meteoric water.

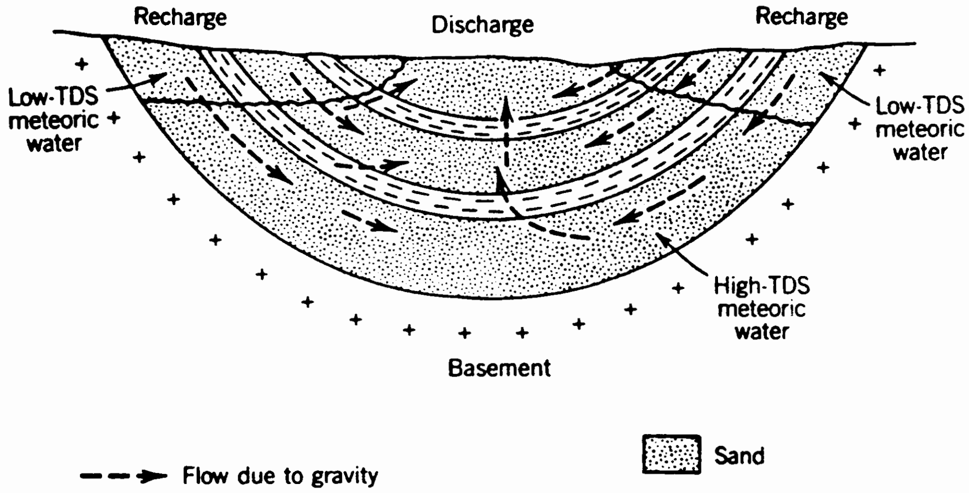


Figure 33. Topographically driven groundwater flow with cross-formational discharge (modified from Domenico and Schwartz, 1990).

Wells located on hillsides were found to commonly produce acceptable quality water. However, some wells north of Rickreall and west of Monmouth, do produce water with slight salinity problems on hillsides. The moderate slopes may contain waters of local to intermediate flow zones with slightly increased TDS concentrations.

The valley flat regions, especially near streams, are plausible zones of discharge and, depending on the flow path length and residence time, variably high salinities. Supportive of this is the occurrence of the brackish and saline springs in the northwest portion of the study area. These springs are obviously areas of discharge, and possibly the surficial emanation of older, deeper waters from the regional flow system.

Although the recent river alluvium (Qal) is located in the valley flat topographic setting, the water encountered there is of acceptable quality. Impervious overburden is generally lacking, unlike the Qoal, thus allowing for a large proportion of precipitation and run-off from nearby sources to directly infiltrate the system and therefore flush it with fresh, meteoric water. The waters encountered in shallow wells may actually be from a local flow system which overwhelmingly dilute the mineralized waters from the regional flow regime discharging into the area.

Similarly, the high terrace and alluvial fan deposits (Qt) are also a source of favorable quality groundwater. The Qt deposits are located in uplands or in areas of moderate slope and are plausible areas of recharge and active flushing with meteoric water. The average static water levels of the Qt are the shallowest of the water-bearing units. This may be indicative of a perched condition in which a lens of fresh water is trapped in the sand and gravel above relatively impermeable bedrock.

Wells completed in the sedimentary marine bedrock and

Qoal units have a large variability in specific capacity values which indicates a variation in the permeability within these units. Wells with low specific capacities may be obtaining water from zones of low permeability. In comparison with highly permeable material, waters within the zones of low permeability are likely to have higher TDS concentrations. With increased residence time, the waters have a greater chance to interact with the aquifer material and pick up dissolved constituents. Material of low permeability, in particular the marine sedimentary bedrock, may contain water trapped in the unit at the time of sediment deposition (connate water) that has not been completely flushed with recent meteoric water.

The Siletz River Volcanics (Tsr) is only exposed in upland areas in the study area. As a result, the exposed Tsr is plausibly an area of active recharge. Water with high salinities in the Tsr to the south of the study area (Gonthier, 1983), may be the result of encountering older waters from a regional flow regime at depth or near areas of regional discharge in the flat-lying areas.

The depth at which water with high salinities is found is highly variable. Although all of the wells with measured specific conductances of greater than 500 μmhos/cm have open interval depths of less than 100 feet (30.5 m), drillers reported several other wells that encountered "salt" water at much greater depths.

Theoretically, from the examination of the basin groundwater flow model (Figures 33), wells at progressively greater distances from the areas of recharge and discharge encounter waters of the same flow path at progressively greater depths. Supporting evidence of this may occur along Soap Creek. There, Gonthier (1983) noticed a situation in which a shallow well near the stream was highly saline. Wells progressively deeper and farther from the stream had decreasing salinities. The author suggests that the wells deeper and farther from the stream were obtaining water of a slightly younger age and shorter flow path. With increased depth, it is hypothesized that the same wells would encounter the same saline water as that of the shallow well near the stream.

The isotopic composition (oxygen-18 and deuterium) of all the waters analyzed, with the exception of the saline springs at 6S/5W-21cad, were fairly similar to one another. The δD and $\delta^{18}O$ values from these samples plot on or near the meteoric water line of Craig (1961). It is suggested that the main component of these waters is relatively recent meteoric water.

The isotopic values of saline springs at 6S/5W-21cad, by far the most saline of the waters encountered, are dramatically distinct from the other waters sampled. A non-recent meteoric source for these waters is proposed. Located less than 50 feet (15.2 m) from Salt Creek, these springs may represent the discharge of older, mineralized waters of a regional flow system.

It is also proposed that other waters with high salinities, such as the brackish springs (7S/6w-2add) near Salt Creek, contain a proportion of older, mineralized waters or waters from an intermediate flow path. In these cases, the isotopic signature of the older waters may be masked by significant dilution with recent meteoric waters.

The saline springs at 6S/5W-21cad and saline water from a 2,985 feet (910 m) deep oil and gas well (6S/4W-6bd) are chemically similar. The relative proportions of the major ions of these waters are also quite similar to the brackish springs at 7S/6W-2add. These waters are chemically distinct from other waters sampled in the area with Ca rather than Na as the major cationic species. The highly mineralized waters of the oil and gas well, which at one time flowed at 5 gpm (Price and Johnson, 1965), may represent old, deep waters of a regional flow system within the sedimentary basin. The chemical similarities of the springs and the oil and gas well may indicate that at least portions of these waters are from the same source or flow system.

If the springs with high salinities are indeed the surface emanation of waters from a regional flow system, the conditions which brought these waters to the surface is of interest. The springs may be a result of gravitational flow and cross-formational discharge to the surface.

However, the springs may also be the result of upward flow along fracture or fault zones to the surface. This situation is thought to occur in the Rumsey Hills area, southwestern Sacramento Valley, California (Unruh and others, 1992). There, perennial saline springs, which are isotopically distinct from area meteoric waters, emerge along thrust faults and are thought to represent non-meteoric formation waters which have had significant residence time in the subsurface.

Figure 34 shows the locations of the $CaCl_2$-rich brackish and saline springs discovered during this study, a $CaCl_2$-rich saline water producing oil and gas well, and an unverified saline spring reported by local residents. Although there are no faults mapped within the immediate vicinity, an argument can be made for the upward flow of mineralized waters along a structural pathway. The relative locations of these sites occur along a northeast trend. Northeast-striking faults have been mapped displacing Columbia River Basalt and material equivalent to the undifferentiated Eocene-Oligocene sedimentary unit (Toe) to the northeast and the Siletz River Volcanics and Yamhill Formation to the west and southwest (Walker and Macleod, 1991).

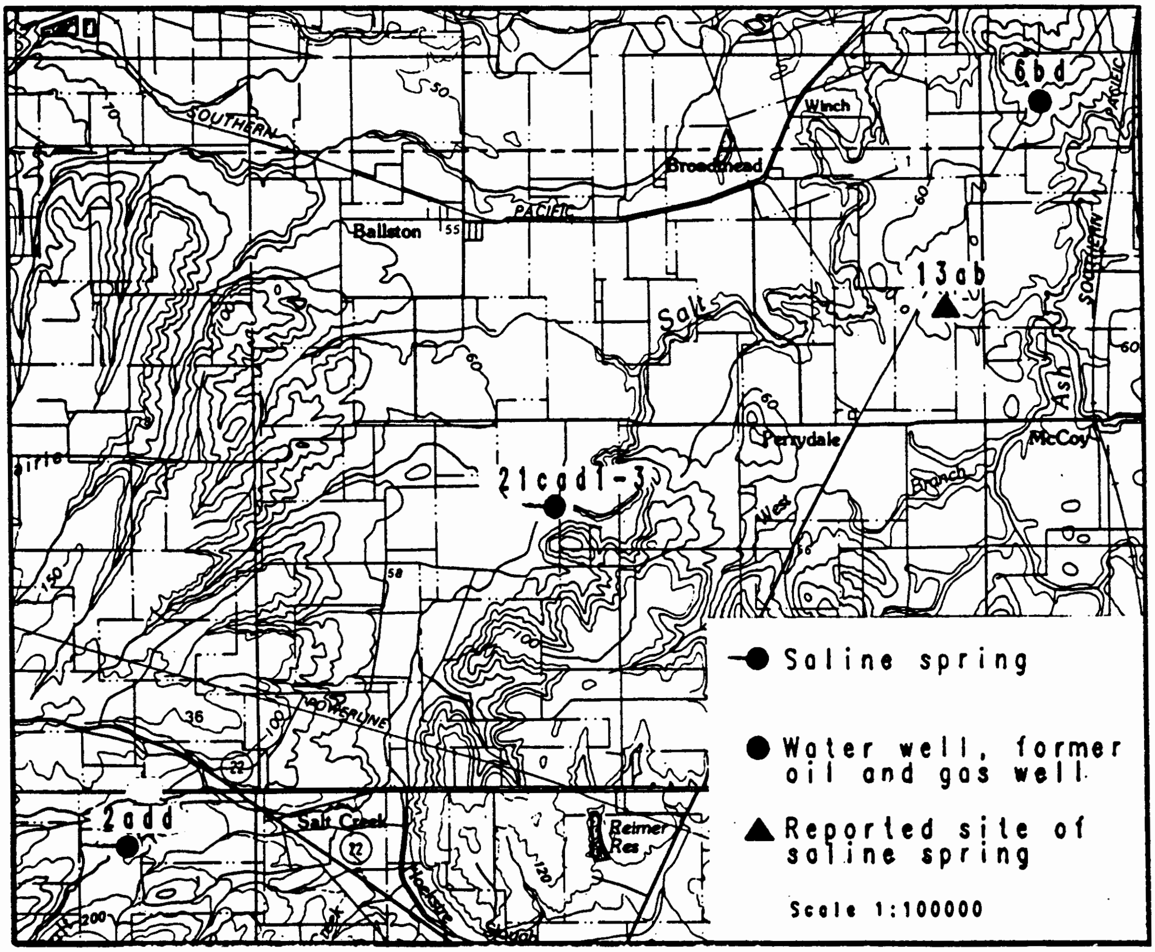


Figure 34. The location of $CaCl_2$ springs, a $CaCl_2$ water bearing oil and gas well, and an unverified saline spring.

ORIGIN

The origin of groundwater with high salinities has been a topic of ongoing study and debate for decades. Excellent reviews of this subject are provided by Kharaka (1986) and Hanor (1983). Commonly proposed origins for groundwater with high salinities include; dissolution of halite, connate marine water, incorporation of subaerially evaporated seawater (bitterns), membrane filtration, and a combination of several sources (Hanor, 1983; Kharaka 1986; and Drever 1988). The problem waters within the study area, over 300 mg/l TDS, can be separated into three groups: 1) water with Na as the dominant cation, herein referred to as NaCl waters; 2) water with Ca as the dominant cation, herein referred to as $CaCl_2$ waters; and 3) the least common water with nearly equal Na and Ca concentrations, herein referred to as Na-Ca-Cl waters. The following section will discuss the possible sources and evolution of the NaCl and $CaCl_2$ waters and possible relations between these groups.

The dissolution of evaporites does not appear to be a likely source of salinity in the study area. Firstly, there are no reported evaporites within the Willamette Valley. In addition, none of the waters sampled had both Na and Cl concentrations proportionally greater than that of seawater, as would be expected with halite dissolution (Drever, 1988).

The Br/Cl ratio of evaporating seawater remains fixed until saturation with respect to halite is reached. As halite precipitates, Br preferentially remains in solution and the Br/Cl ratio of the water increases. In contrast, a brine formed by simple dissolution of NaCl will have a Br/Cl ratio lower than that of seawater because halite has a low Br/Cl ratio (Hanor, 1983).

The majority of the waters sampled (10 of 14) have

Br/Cl ratios similar to seawater. The Br and Cl concentrations of all of the sampled waters plot within the region of mixing of freshwaters, formation brines (which includes marine connate water), and residual evaporite solutions (Figure 29) (Whittemore, 1988).

The Br and Cl concentrations in Figure 35 plot along a linear trend, adequately defined by the seawater dilution-evaporation trajectory of Carpenter (1978). The trajectory line has been extended to include much lower concentrations than the line defined by Carpenter (1978). The author is unsure of whether this projection to low concentrations is valid. Figure 35 could be interpreted as a mixing line between two separate sources, seawater and fresh or meteoric water. Points above the seawater dilution-evaporation trajectory line generally indicate solution of halite and samples that plot below the line result from mixing of bittern and meteoric waters (Kharaka, 1986). Therefore, the Br and Cl concentrations point to a seawater source rather than halite dissolution or the incorporation of bittern connate water. This method has been used in the Illinois Basin and in the foothill suture zone, Sierra Nevada Range, California to distinguish the role of seawater as a source for the salinity in groundwaters (Walter and others, 1990; Mack and Ferrell, 1979).

The variation of the Br/Cl ratios seen in this study (Table X) may be explained, at least in part, by interaction

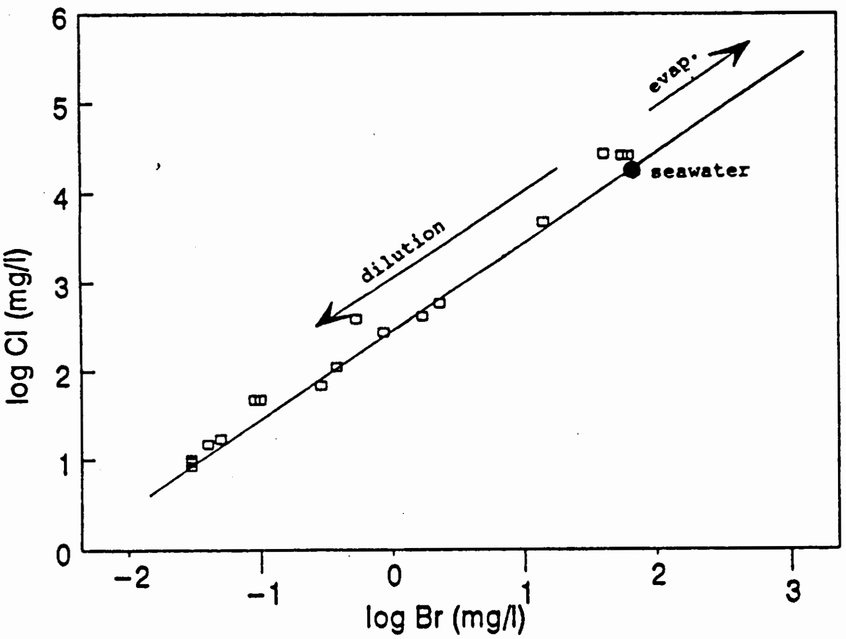


Figure 35. Log Cl vs log Br concentrations of study area waters with a modified version of the seawater evaporation-dilution trajectory of Carpenter (1978).

with organic material. Alteration of organic matter within sedimentary rocks during diagenesis may cause a release of Br with larger amounts of Iodine to pore waters (Fabryka-Martin and others, 1991). This organic influence is consistent with all of the waters analyzed from this study in which Iodine is greatly enriched relative to Br in comparison with seawater. The alteration of unevenly distributed organic matter throughout an aquifer could produce small local differences in the halogen ratios of the pore waters.

Clayton (1966), using isotopic data, was the first to show that the waters from many petroleum well fields were predominantly of local meteoric origin. As indicated in Figure 30, most of the groundwaters sampled have $\delta^{18}O$-δD signatures similar, but isotopically lighter than the local streams. It is suggested that the streams are closely representative of recent, local precipitation. Isotopic values of precipitation are likely to be variable through time and even among different storm events. It is suggested that the isotopic values of the majority of the groundwater samples, although highly variable in chemical composition, are within the range of local meteoric water and have a strong, relatively recent, local meteoric water component.

Isotopic data have been used to determine a connate seawater origin component for many fluids in sedimentary basins (Hitchon and Friedman, 1969; Peters, 1993; Kharaka and others, 1973). The proximity of the isotopic values of a $CaCl_2$ spring (6S/5W-21cad1) to SMOW and even more closely to Pre-Miocene (Pre-glacial) SMOW (Sheppard, 1986) are consistent with a connate seawater origin. These waters may represent seawater trapped in the Eocene marine sediments or the early Eocene basalts and associated sediments of the Siletz River Volcanics with little mixing with recent meteoric water.

The similar chemical compositions of the two most saline waters suggests a common source or at least a common chemical evolution for waters expelled at these sites. However, the isotopic data for the saline (6S/5W-21cad1) and brackish springs (7S/6W-2add) are quite different. The brackish springs have isotopic compositions interpreted to be very similar to local, recent meteoric water. It is suggested that the same original saline source water is present in both cases, but with varying degrees of dilution with meteoric waters.

The waters with the greatest TDS concentrations within the study area are within the $CaCl_2$ group. Sodium is commonly the dominant cation in sedimentary basin pore fluids, but increasing relative proportions of Ca are often associated with increasing TDS (Kharaka, 1986). Several processes may dramatically change the chemical composition of meteoric or formation waters. Processes that may be responsible for increased Ca concentrations include; dolomitization, ionic exchange, albitization of plagioclase, membrane filtration, and interaction with basalt.

High concentrations of Ca in sedimentary basin pore fluids may be explained by the dolomitization of limestone (Graf and others, 1966; Carpenter, 1978). In this reaction, Mg is reacted with limestone to release an equivalent amount of Ca to solution. The Rickreall Limestone Member of the Yamhill Formation occurs in the area. Since the deposits are of limited thickness and extent and are limestone rather than dolomite, a large-scale dolomitization source of pore fluid Ca is not likely.

Changes in fluid composition and temperature will both cause redistribution of ions between solution and exchange sites on clay minerals and oxides (Drever, 1988). Under most dilute conditions, Ca and Mg exchange with sorbed Na as groundwater moves through clayey material (Domenico and Schwartz, 1990). Under more concentrated conditions, such as in ocean water, the dominant exchangeable cation is sodium, which may displace Ca into solution (Drever, 1988).

Another possible source of Ca may be the albitization of plagioclase (Land and Milliken, 1981; Boles, 1982; and Middleton, 1972). In this process, original feldspars are altered to Na-plagioclase (albite) and Ca is released into solution during the action of sodium-rich pore waters. The albitization reaction can be described as:

$$CaAl_2Si_2O_8 \text{ (anorthite) } + 2Na^+ + 4H_4SiO_4 =$$
$$2NaAlSi_3O_8 \text{ (albite) } + Ca^{2+} + 8H_2O$$

Interstitial marine connate water is a plausible source of Na needed for the reaction.

The differential permeability of clay and shale, which are abundant in the study area, may be a factor in the behavior and composition of groundwater. Because shales contain tightly-packed charged particles of clay, they permit the flow of neutral water molecules but retard the passage of dissolved ions (Freeze and Cherry, 1979; Hanor, 1983). This process, known as osmosis, occurs if two aqueous solutions of different concentrations are separated by a selectively permeable membrane which results in the tendency for water molecules to migrate through the membrane from the more dilute solution into the more concentrated solution (Hem, 1985).

If the differences in hydraulic head across the shale membrane are sufficient, water molecules can be forced to flow in the opposite direction of osmosis. This process is known as reverse osmosis, membrane filtration, reverse chemical osmosis or hyperfiltration (Hanor, 1983). As flow continues, the salty fluids become saltier and the less salty fluids become fresher. Possible origins of pressure gradients needed to drive reverse osmosis include; uplifted recharge areas relative to the basin interior, rapid deposition of fine-grained sediments, and post-depositional tectonic compression (Bredehoeft and others, 1963; Graf, 1982).

The chemical composition of water that has flowed through a geological membrane (effluent water) will be lower in total dissolved solids and have a different chemical composition from the original input solution or that of the solution remaining in the aquifer on the input side of the membrane (hyperfiltrated water). The membrane effluent characteristics include the following chemical markers; lower TDS, Ca/Na and Br/Cl ratios and higher B/Cl, HCO_3/Cl and F/Cl ratio (Kharaka 1986). In comparison to one another, the $CaCl_2$ waters from this study have characteristics more similar to waters held back on the influent side of a membrane, while the NaCl waters have characteristics of membrane effluent.

$CaCl_2$ brines have been found to be produced by basalt-seawater interaction (Hardie, 1983; Mottl and Holland, 1978; Drever, 1988). Basalts exposed to seawater at relatively low temperatures undergo alteration that results in the uptake of potassium by the basalt and loss of calcium, silica, and usually magnesium from the basalt. The basalt may take up magnesium, rather than release it, if the circulation of seawater is restricted so that the pH rises as a result of alteration reactions (Drever, 1988).

Modern rift zone hydrothermal brines, such as those found in the Reykjanes, Iceland geothermal system, are typically $CaCl_2$ brines (Hardie, 1983). These brines are thought to be the result of high temperature interactions of basalt with seawater. Mottl and Holland (1978) conducted experiments in which fresh mid-ocean ridge basalt was reacted with seawater. The reactions resulted in removal of Mg and Na from seawater, balanced largely by leaching of Ca from basalt. The resulting brines closely matched those from the basalt-seawater geothermal system at Reykjanes, Iceland. The zeolites found in the Siletz River Volcanics may be evidence of hydrothermal basalt-seawater interaction (Keith and Staples, 1985).

The relatively low concentrations of sulfate found in the most saline of the waters in this study may be the result of bacterial reduction (Drever, 1988 and Kharaka 1986). Reducing conditions are prevalent in deeper waters. Under these conditions, bacteria use the oxygen in sulfate to oxidize organic matter, producing sulfide species. High to moderate temperature basalt-seawater interaction could also remove sulfate from solution, resulting in the formation of pyrite or anhydrite (Drever, 1988).

If the $CaCl_2$ and NaCl waters have a unified or common origin, the differences in chemical composition may be explained, at least in part, by membrane filtration. The $CaCl_2$ waters may represent waters held back on the influent side of the membrane while the NaCl waters represent the effluent waters. Hypothetically, the $CaCl_2$ waters could be tapped by wells on the influent side of the membrane or they could have bypassed the membrane through fractures.

If the NaCl and $CaCl_2$ waters are derived from different sources, the NaCl waters are readily accounted for by the release of marine connate water possibly due to flushing by modern meteoric water. The $CaCl_2$ waters could be generated near the time of eruption of the Siletz River Volcanics (Tsr) by moderately high temperature reactions between hot basalt and seawater. The $CaCl_2$ waters could also be generated by lower-temperature albitization reactions of the plagioclase in the Tsr or the Eocene sedimentary rocks.

These $CaCl_2$ waters may be issuing along deep seated structures and are forced to the surface by tectonic processes active in the Cascadia subduction zone.

Figure 36a is a plot of Na versus Ca concentrations of the problem waters (>300 mg/l TDS) from this study, western Oregon groundwaters with salinities of greater than 10,000 ppm (Newton, 1969), saline waters from Mist Gas field wells (written communication, Northwest Natural Gas, 1992), seawater (Hem, 1985), and average inland precipitation (Hem, 1985). Nearly all of the waters plot on two well-defined trends, especially at Ca and Na concentrations of greater than 2000 mg/l. The same data is plotted in Figure 36b, only with inferred dilution trajectories of the $CaCl_2$ and NaCl waters with freshwater. An estimated 50/50 mixing line between the NaCl and CaCl waters is also included in Figure 36b.

The author favors the hypothesis that the NaCl and $CaCl_2$ waters within the study area, and quite possibly extending throughout western Oregon, are two distinct groups of waters with different evolutionary histories. The NaCl waters, which closely approximate a linear trend between precipitation and seawater, may simply be marine connate seawaters with varying degrees of meteoric water dilution. Although waters from the $CaCl_2$ group may have also originated as seawater, they appear to have undergone a more complex evolutionary history. The Na-Ca-Cl waters with relative Na and Ca concentrations intermediate between the $CaCl_2$ and NaCl groups, which occur at Na and Ca concentrations of less than 2,000 mg/l in Figure 36, may be the result of mixing between the two groups.

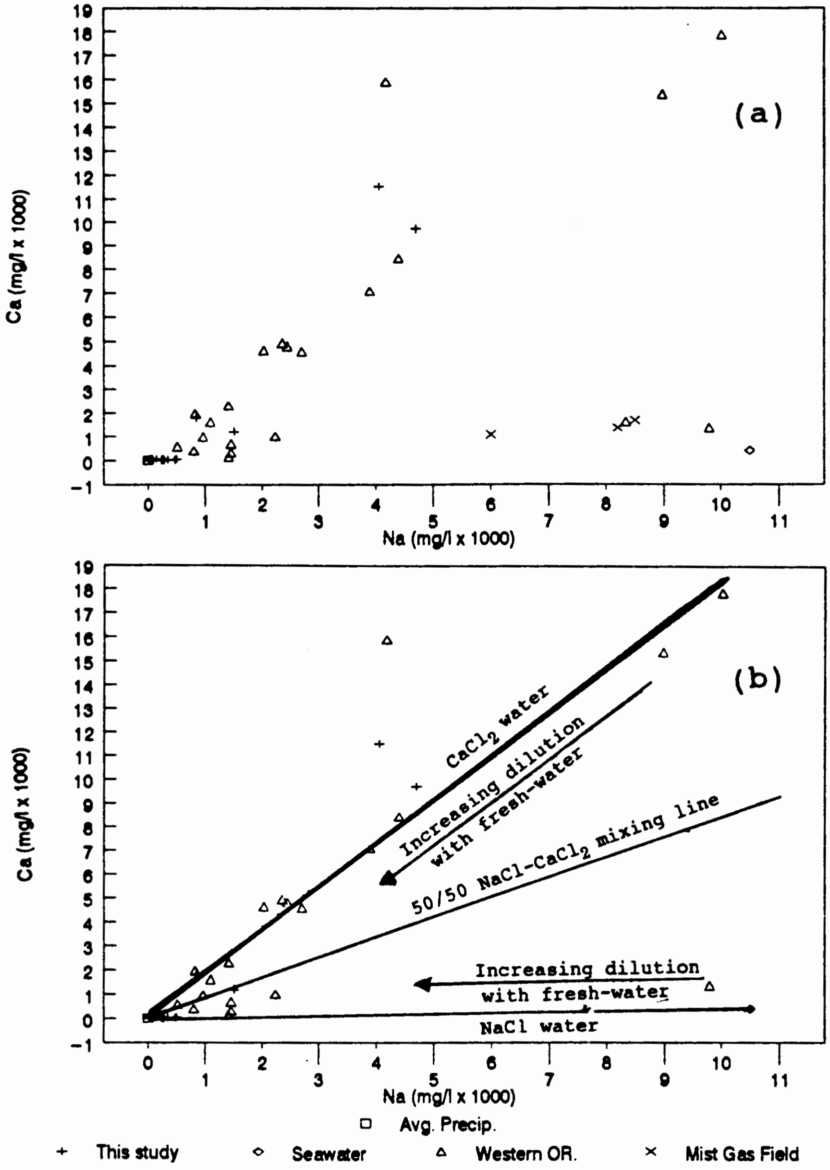


Figure 36. Plots of Na vs Ca concentrations of seawater, average inland precipitation, study area problem waters, and saline waters of western Oregon (a and b), with estimated freshwater dilution trajectories and a 50/50 $CaCl_2$-NaCl water mixing trajectory (b).

SUMMARY AND CONCLUSIONS

Unconsolidated alluvial sediments, consisting of clay, silt, sand and gravel, reach thicknesses of over 80 feet (24.4 m) within the study area. A lower fine-grained, a coarse-grained, and an upper fine-grained lithologic unit are recognized within the unconsolidated sediments. The lower fine-grained unit, commonly termed "blue clay" in driller's reports, is not areally extensive, but significant thicknesses (>80 feet (24.4 m)) may exist in the valley flat north of Buena Vista. The coarse-grained unit, composed primarily of sand and gravel, reaches thicknesses of over 80 feet near Dallas within the high terrace and alluvial fan deposits (Qt) and older alluvium (Qoal), is relatively thin in the central portion of the valley flat and is coarser-grained and over 40 feet (12.2 m) thick in the recent river alluvium (Qal) near Independence. The upper fine-grained unit, composed primarily of brown clay and silt, is the thickest, nearly 40 feet (12.2 m) within the Qoal and is thinner to non-existent within the Qal.

The geochemical (INAA) similarity of the coarse-grained lithologic unit of the Qoal and Siletz River Volcanics (Tsr) basalt, together with the fan-like morphology of the upper surface of the coarse-grained unit, indicate a Tsr source of these sediments from the west. The geochemically distinct upper fine-grained sediments of the Qoal, which are geochemically similar to Columbia Basin source sediments within the Portland basin, are probable catastrophic flood deposits (Willamette Silt). The Qal sediments are likely to be of Cascade Range provenance as they are geochemically similar to sediments of that provenance in the Portland basin. A blue clay sample from the coarse-grained unit of the Qal is composed entirely of smectite and is interpreted as volcanic ash.

Basalt of the Tsr is geochemically distinguishable from the marine sedimentary bedrock units with higher Fe, Na, Co, Cr and Sc concentrations. The Spencer Formation (Ts) is distinguished from the Yamhill Formation (Ty) and the undifferentiated Eocene-Oligocene sedimentary rock unit (Toe) by higher Th, Rb, K, and La and lower Fe, Sc, and Co concentrations. Samples from the Ty and Ts also differ on the basis of clay mineralogy, with the predominant smectite composition of the Ty and clays of a more varied suite for the Ts. The Ty and the Toe are geochemically similar, but stratigraphically separated by the Ts.

Yamhill Formation and Toe samples have geochemical characteristics mostly typical of volcanic arc-derived sediments, while a minority had Th concentrations more similar to those of more chemically-evolved igneous and metamorphic rocks. Due to chemical similarities, the volcanic component of the Rickreall Limestone Member of the Ty appears to have been supplied by the underlying Tsr. Elemental concentrations, particular Th and La, of the Ts samples are indicative of continental crust material, although two samples have concentrations approaching those of volcanic arc-derived sediments.

The alluvial sediments, with the exception of the upper-fine grained Qoal sedimentary unit, are geochemically distinct from the Spencer Formation samples. A geochemical distinction between the unconsolidated sediments and the Toe and Ty is not as apparent. Cobalt may be a delimiter with respect to the Toe, but there was no apparent distinction between the unconsolidated sediments and the Ty.

Unconsolidated sediments, particularly those of the coarse-grained lithologic unit, are the most productive groundwater aquifers within the study area. The marine sedimentary and volcanic bedrock units are the least productive and have similar hydrologic characteristics resulting from similar lithologies and related porosity and permeability. A potentiometric surface map of August through October water levels of wells within the unconsolidated sediments shows a predominant flow direction towards the Willamette River with discharge to local streams.

Groundwaters with measured TDS concentrations of up to 40,500 mg/l occur in the study area. Water with salinities of 300 mg/l or greater have been found to occur only in the older alluvium (Qoal) of the unconsolidated sediments, the undifferentiated Eocene-Oligocene sedimentary rock unit (Toe), and the Spencer (Ts) and Yamhill Formations (Ty). Although acceptable quality water also occurs in these units, wells completed in zones of low permeability (<5gpm/ft specific capacity) and located in valley flat or low-lying topographic settings are most likely to encounter water with high salinities.

The majority of the Br/Cl ratios of the sampled waters are near that of seawater. Isotopic data from the majority of the waters sampled are interpreted as that of local meteoric origin with δD ranges from -57 to 80 $^{o}/_{oo}$ and $\delta^{18}O$ ranges from -8.4 to -11.1 $^{o}/_{oo}$. The most saline waters sampled (40,500 mg/l TDS) have isotopic values very near SMOW and pre-Miocene SMOW with δD ranges of -6 to -8 $^{o}/_{oo}$, and δ^{18} ranges of -1.6 to -1.8 $^{o}/_{oo}$. Although there is an understanding that water-rock interactions could cause significant isotopic shifts, these saline waters, although chemically distinct from seawater, are interpreted as marine connate seawater with little dilution with recent meteoric waters.

It is suggested that the salinity problem in the area may be the result of original seawater trapped in sediments during deposition with subsequent dilution with meteoric waters and significant water-rock interaction. The occurrence of poor quality waters within relatively impermeable units in low-lying areas may be the result of regional flow system waters discharging to these areas with little flushing with recent meteoric water. The occurrence of relatively fresh water near upland highs and in material of high permeability may be the result of recent flushing with meteoric water. The similar specific conductance values of common wells, measured in 1976 (Gonthier, 1983) and during this study, are indicative of little temporal variation in salinity during this time period.

Groundwaters with high salinities can be divided into three groups: 1) NaCl waters with Na as the dominant cation; 2) $CaCl_2$ waters with Ca as the dominant cation; and 3) Na-Ca-Cl with nearly equal amounts of Na and Ca. Processes that may occur in the area to alter the relative Ca-Na concentrations within the groundwaters include: membrane filtration, albitization, high and low temperature basalt-seawater interaction, and cation exchange. Although all of these waters may have a marine connate source, distinct evolutionary histories for the $CaCl_2$ and NaCl waters are favored.

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APPENDIX A

GEOCHEMICAL ANALYSES

INAA METHODS

Drill cuttings and samples from surface exposures were selected for instrumental neutron activation analysis (INAA). In each case, care was taken to obtain a representative sample of the material available. Oil and gas well drill cuttings were acquired from the archive collection at the Oregon Department of Geology and Mineral Industries. Samples from water wells were collected by the author and water well drillers. Fresh or non-weathered outcrop specimens were chosen for analysis where possible a notations were made where only weathered material was available.

Foreign matter such as modern plant material, metal and sample bag fibers was removed in the preliminary phases of sample preparation. Samples containing gravel were sieved with a no. 30 sieve and the medium sand size and smaller grain-sizes were retained for analysis. Oxidized or weathered material was removed and discarded when possible. The harder samples, such as the limestones and basalts, were first crushed with a chipmunk jaw crusher. All of the samples were then crushed by hand with a hardened steel mortar and pestle. The mortar and pestle were cleaned with ethanol and compressed air between samples. A small amount of the next sample was then crushed and discarded to reduce the chance of cross contamination between samples.

An approximate 1 gram split from each sample was placed into a clean 0.5 dram polyvial and weighed to 0.0001 gram precision with a Mettler H10T balance. To reduce the effect of varying geometries with respect to the gamma ray detector, the volume was similar in each vial. The polyvials were then heat sealed and placed in 2 dram polyvials for irradiation.

Two sets of samples were independently irradiated at the Reed Reactor Facility, Reed College, Portland, Oregon and at the Oregon State University Reactor, Corvallis, Oregon. The samples were subjected to a constant neutral flux of $2x10^{12}$ at 250 kw for one hour. The samples were counted with the high-purity Germanium Coaxial Photon Detector System, GE&G ORTEC at three different periods after irradiation; 4 to 5 days, 13 to 16 days, and 92 to 111 days.

Peak analysis error computation were obtained with use of the EG&G ORTEC 92X Spectrum Master program package. Elemental concentrations and errors were calculated with comparison to four reference materials; the National Bureau of Standards Coal Fly Ash Standard Reference Material 1633a, the National Bureau of Standards Bituminous Coal Standard Reference Material 1632b, Geological Survey of Japan rhyolite reference sample JR-1, and the U.S.G.S. granite reference material G-2.

INAA SAMPLE1 LOCATIONS

Sample ID.	T.R.S.	Comments
W1	6S/4W-31a	Oil and gas exploration well, Reserve Oil and Gas Co., Bruer 1
W2	8S/5W-10ddb	Oil and gas exploration well, Mirian Oil Co., Bliven 3
W3	8S/5W-14bdb	Oil and gas exploration well, Miller, Bursell 1
W4	8S/5W-26bcd	Oil and gas exploration well, Miller, Stump 1
W5	7S/5w-31dab2	Butch Meyer water well
W6	8S/4W-16dac	Setnicker Farms irrigation well
W7	8S/4W-7ccd	Willamette Pollen Co. irrigation well
Q1-Q3	8S/4w-34dcc	Valley Concrete gravel pit
Q4	8S/4w-28cda	Outcrop in ditch
V1,V2	8S/5w-9aab	Summit of Mt. Pisgah
E1	7S/4W-3ccc	Tile trench at Brunker Winery
E2	7S/4W-5cbc	Road cut on west side of 99W
E3,E4	7S/4W-4aab	Road cut on west side of Oak Grove road.
S1	8S/5W-16acc	Road cut south of Bursell road
S2,S3,S5	8S/5W-28dbc	Fishback hill road cut on Monmouth Highway
S4	9S/4W-23bcc	Cut bank of Willamette River
S6	7S/5W-15bba	Intersection of Dyck and Perrydale roads
Y1	6S/6W-21acb	Cut bank of Mill Creek
Y2	8S/6W-12bbd	Former Portland Cement Limestone Quarry
Y3	7S/5W-19cac	From 6' deep pit
Y4	7S/5W-9cbb	Highway 22 road cut
Y5	8S/6W-12bcd	Former Portland Cement Limestone Quarry
SR1-SR3	8S/5W-25cad	Ellendale Quarry

INAA SAMPLE DESCRIPTIONS

Sample ID.	Elevation (ft)	Stratigraphic Unit/Description
W1-1	327	Toe, light gray siltstone
W1-2	237	Toe, light gray siltstone
W1-3	-183	Toe, " " "
W1-4	-583	Ts, light gray siltstone
W1-5	-1043	Ts, light gray siltstone and fine sandstone
W1-6	-1643	Ty, Gray shale
W1-7	-2343	Ty, light blue silty shale
W1-8	-3143	Ty, light brown to gray silty shale
W1-9	-3943	Ty, light brown to gray silty shale
W1-10	-4843	Tsr, volcanic clastics, containing olivine, chlorite, ferrous iron compounds, siltstone, quartz and ash
W1-11	-5192	Tsr, basalt with secondary mineralization
W2-1	165 to 120	Ts, gray siltstone or claystone
W2-2	63 to 43	Ts, " " " "
W2-3	-242 to -249	Ts, " " " "
W2-4	-540 to -553	Ty, gray claystone
W2-5	-837 to -845	Ty, " "
W2-6	-1137 to -1160	Ty, " "
W2-7	-1430 to -1453	Ty, " "
W3-1	300 to 295	Ts, gray siltstone or claystone
W3-2	200 to 195	Ts, " " " "
W3-3	0 to -5	Ts, " " " "
W3-4	-200 to -205	Ts, gray siltstone or claystone
W3-5	-400 to -405	Ty, " " " "
W3-6	-630 to -635	Ty, " " " "
W3-7	-765 to -770	Ty, " " " "
W4-1	100 to 95	Ts, blue shale
W4-2	0 to -5	Ts, blue shale
W4-3	-295 to -300	Ts, blue shale
W4-4	-600 to -605	Ty, gray sandy shale
W4-5	-895 to -900	Ty, gray sandy shale
W4-6	-1200 to -1205	Ty, gray sandy shale
W4-7	-1265 to -1270	Ty, gray sandy shale
W5-1	538 to 521	Ty, brown clay
W5-2	521 to 516	Ty, brown claystone
W5-3	516 to 511	Ty, blue claystone
W5-4	511 to 468	Ty, gray claystone
W5-5	468 to 440	Ty, blue clay
W5-6	440 to 416	Ty, gray claystone
W6-1	150 to 145	Qal, brown topsoil
W6-2	145 to 139	Qal, brown clay

W6-3	139 to 138	Qal, clay and silt split from brown silty clay with small gravel
W6-4	138 to 113	Qal, clay and silt split from predominately sand and gravel
W6-5	113 to 108	Qal, blue clay
W7-1	202 to 185	Qoal, brown clay
W7-2	185 to 174	Qoal, clay and silt split from predominately sand and gravel
W7-3	171 to 160	Qoal, clay and silt split from blue clay, sand and gravel
W7-4	148 to 125	Qoal, clay and silt split from blue clay and sand
Q1	150 to 148	Qal, light brown sand and silt
Q2	148 to 146	Qal, clay and silt split from predominately sand and gravel
Q3	140	Qal, clay and silt split from predominately sand and gravel
Q4	170	Qoal, light brown silt and very fine sand
V1	830	Ti, angular basalt boulder
V2	830	Ti, angular basalt boulder
E1	300	Toe, light brown to tan tuffaceous siltstone
E2	200	Toe, " " " "
E3	460	Toe, "
E4	480	Toe, "
S1	600	Ts, weathered light brown siltstone
S2	680	Ts, light brown siltstone and sandstone
S3	700	Ts, weathered, light brown, silt
S4	160	Ts, light brown sandstone, highly fractured with iron staining
S5	640	Ts, gray siltstone or fine sandstone, plant fossils
S6	280	Ts, dark brown siltstone and sandstone, fossiliferrous
Y1	340	Ty, gray claystone
Y2	500	Ty, Rickreall Limestone member, fossiliferrous
Y3	600	Ty, weathered, reddish brown clay and silt
Y4	240	Ty, light brown, weathered clay and silt
Y5	500	Ty, Rickreall Limestone member, massive
SR1	520	Tsr, dense basalt
SR2	500	Tsr, basalt with secondary mineral veins of calcite
SR3	530	Tsr, serpentized basalt with

zeolites

STD1 - Standard, rhyolite, JR-1 GSJ reference sample

STD2 - Standard, coal fly ash, National Bureau of Standards, standard reference material 1633

STD3 - Standard, G-2, USGS reference material

STD4 - Standard, bituminous coal, National Bureau of Standards, standard reference material 1632b

ELEMENTAL CONCENTRATIONS

SAMPLE	Na %	Error	K %	Error	Rb ppm	Error	Cs ppm	Error	Ba ppm	Error	Sr ppm	Error	Fe %	Error	Co ppm	Error
	Reserve Oil and Gas Co., Bruer 1, exploration well															
W1-1	1.24	0.22	1.52	5.60	60	16.26	4	7.07	664	8.37			4.50	0.78	11	1.77
W1-2	1.48	0.21	1.61	7.83	64	20.15	4	6.32	550	9.87	438	20.10	4.78	0.89	13	2.02
W1-3	1.91	0.19	1.18	8.57	56	27.99	2	6.78	2111	2.65	404	20.03	4.68	0.87	11	2.23
W1-4	1.57	0.20	2.62	4.93	120	11.38	6	7.36	1400	4.21	210	37.15	4.21	0.84	13	2.15
W1-5	1.92	0.19	2.27	7.93	118	15.22	4	5.68	1245	3.82	358	20.62	3.75	0.85	11	1.69
W1-6	1.67	0.20	1.35	11.13	67	23.50	3	6.37	741	7.14	409	26.74	5.84	0.76	16	1.47
W1-7	1.34	0.23	1.02	9.33	51	31.51	2	8.10	592	8.11	343	26.92	5.76	0.73	14	2.04
W1-8	1.47	0.23	1.69	7.61	91	18.42			867	6.19	260	32.81	5.27	0.72	15	1.90
W1-9	1.50	0.23	1.81	6.05	92	13.70	7	4.55	808	8.06	332	24.90	5.14	0.86	17	2.48
W1-10	2.79	0.16	0.91	15.25			2	16.17	909	7.03	363	29.01	8.10	0.62	47	1.00
W1-11	2.71	0.14	0.40	29.45									9.16	0.57	56	1.06
	Mirian Oil Co., exploration well															
W2-1	1.23	0.22	2.18	5.79	146	13.59	5	3.95	846	6.58	400	20.29	4.41	0.85	12	2.14
W2-2	2.02	0.18	1.94	5.56	95	19.15	4	4.68	742	7.30	429	19.16	4.04	0.88	13	1.64
W2-3	1.37	0.21	2.14	4.25	75	32.39	6	3.41	801	7.64	328	26.89	5.17	0.82	18	1.75
W2-4	1.53	0.20	1.73	7.71	89	26.74	5	6.04			574	39.18	5.23	0.92	14	2.01
W2-5	1.90	0.17	1.34	9.45	68	22.03	3	11.56	625	10.12	314	32.55	5.79	0.74	17	1.48
W2-6	1.73	0.21	1.19	8.14			3	7.78	532	10.12	428	24.31	7.58	0.71	27	1.36
W2-7	1.56	0.20	0.89	14.90	78	20.03	3	10.98	571	11.23	189	49.43	5.84	0.69	18	1.34
	Miller, Bursell 1, exploration well															
W3-1	1.05	0.28	2.47	4.59	127	10.12	7	3.17	946	6.85	302	32.95	4.34	0.92	14	1.51
W3-2	1.22	0.27	2.13	4.91	133	13.79	6	3.32	847	7.23	271	33.67	4.86	0.84	12	2.47
W3-3	1.96	0.20	1.31	12.04	100	23.33	4	5.01	840	7.67	270	33.36	4.97	0.79	12	2.38
W3-4	1.48	0.23	2.35	5.14	144	15.28	6	3.10	735	6.87	281	31.28	4.43	0.86	17	1.78
W3-5	1.68	0.21	1.76	9.78	82	19.47	5	5.44	634	10.18	233	40.00	6.24	0.85	18	1.78
W3-6	1.94	0.22	1.45	11.43	102	25.05	4	7.22	572	10.42	308	32.51	6.27	0.65	18	1.86
W3-7	1.83	0.21	1.61	11.29	70	22.28	3	5.54			378	25.10	6.26	0.70	17	1.84
	Miller, Stump 1, exploration well															
W4-1	1.04	0.34	2.09	7.90	108	14.52	5	3.82	875	9.09	233	39.01	10.75	0.51	22	1.62
W4-2	1.29	0.30	1.37	11.98			3	6.41	636	8.92	372	23.13	3.75	0.96	8	2.05
W4-3	1.43	0.28	2.65	6.35	117	18.96	7	6.87	745	8.13	251	42.37	4.46	0.80	17	1.83
W4-4	1.60	0.18	1.39	4.96	55	26.08	4	6.49	653	8.31			5.62	0.72	15	1.89
W4-5	2.25	0.23	1.59	13.05	64	30.76	3	10.69	703	10.20	533	20.74	6.79	0.70	21	1.60
W4-6	2.57	0.21	1.46	13.03	65	35.33							7.02	0.77	25	1.81
W4-7	2.44	0.23	1.40	16.66			2	8.95	690	9.34	363	30.41	6.79	0.72	22	1.36
	Butch Meyer, water well															
W5-1	0.12	1.89	9.77	8.33			5	17.01	436	10.57			7.42	0.70	31	1.81
W5-2	0.03	4.95	4.64	16.02			3	23.31	439	11.82			6.82	0.70	6	5.26
W5-3	0.69	0.58	1.46	14.89	61	27.50	3	11.98					7.19	0.70	20	2.34
W5-4	0.92	0.53	1.47	13.68	55	18.34	3	19.75	461	12.39			5.80	0.83	16	2.55
W5-5	0.97	0.51	2.14	10.45	84	20.76	5	13.37	497	10.31	238	43.67	6.63	0.71	20	1.76
W5-6	0.80	0.51	2.15	10.42	66	20.52	5	10.98	589	8.72			6.13	0.69	18	2.47

Error = % cumulative related to data processing

SAMPLE	Cr ppm	Error	Hf ppm	Error	Ta ppm	Error	Sc ppm	Error	Th ppm	Error	U ppm	Error	W ppm	Error	Ga ppm	Error
	Reserve Oil and Gas Co., Bruer 1, exploration well															
W1-1	91	5.91	6	4.79	2.1	6.98	18	0.62	5.5	3.75					29	17.84
W1-2	104	4.49	6	5.20	3.0	14.50	19	0.58	6.0	3.74	6	24.68			22	28.43
W1-3	76	3.96	5	7.58	2.8	7.34	15	0.80	5.7	3.38			2	29.12	33	22.88
W1-4	77	3.22	7	3.32	3.0	4.81	15	0.70	12.7	1.68	7	16.14	4	23.62	28	28.29
W1-5	55	7.15	5	4.63	2.5	13.46	13	0.71	7.3	2.61					21	38.45
W1-6	76	5.67	5	6.26	4.0	8.34	22	0.54	5.9	3.60					28	19.50
W1-7	55	7.12	5	5.31	4.3	9.52	20	0.68	3.4	6.51					27	21.57
W1-8	87	4.83	5	5.11	4.3	5.86	19	0.56	7.5	2.80	5	19.49	3	34.48	35	18.61
W1-9	99	4.83	5	5.24	3.8	14.36	18	0.97	9.2	2.35	6	21.17			27	26.69
W1-10	239	2.95	5	7.12			26	0.51	3.3	6.83					38	28.99
W1-11	233	2.27	6	6.04	7.6	5.67	28	0.61	2.4	12.24					37	19.28
	Mirian Oil Co., exploration well															
W2-1	83	3.04	6	3.38	4.7	4.52	15	0.78	12.4	1.74	4	13.84	6	10.06	19	31.17
W2-2	66	5.10	7	3.11	3.7	15.56	14	0.70	8.5	2.44					29	27.64
W2-3	83	3.29	7	4.21	4.1	6.36	18	0.59	11.2	2.15	4	13.76	2	33.50	34	21.01
W2-4	79	3.66	5	4.41	4.0	16.27	20	0.67	7.3	3.19					39	27.01
W2-5	70	6.97	5	4.84			22	0.62	5.0	4.26					32	25.17
W2-6	824	0.56	4	5.19	4.7	3.95	23	0.50	4.5	5.02			5	16.18	36	23.39
W2-7	63	7.74	5	6.28	3.0	8.74	22	0.54	4.2	4.73			5	14.27	34	26.43
	Miller, Bursell 1, exploration well															
W3-1	70	3.63	7	3.98	2.7	4.50	16	0.46	14.0	1.64	4	11.76			32	21.59
W3-2	69	4.12	6	4.64	2.5	6.54	16	0.73	12.1	2.05					28	23.68
W3-3	46	4.91	9	2.45	3.1	3.45	15	0.62	8.6	2.39						
W3-4	68	3.45	7	4.00	2.4	4.84	16	0.61	11.1	1.99			2	35.67		
W3-5	83	5.14	5	5.29	2.4	13.11	21	0.60	7.4	3.19	6	36.39	2	48.73	39	23.08
W3-6	70	3.87	5	5.32	2.4	16.85	23	0.35	6.1	3.76	5	25.65			37	22.40
W3-7	73	5.79	5	7.05	2.5	7.86	22	0.37	5.5	4.06	6	22.98			31	22.30
	Miller, Stump 1, exploration well															
W4-1	900	0.57	6	4.87	1.8	6.64	13	0.58	10.0	2.31	4	14.43	5	11.02	56	16.30
W4-2	37	9.18	9	2.89	1.7	12.01	13	0.68	11.0	1.90	4	14.84			44	21.29
W4-3	82	3.20	7	4.07	2.0	12.67	16	0.75	11.3	2.12	5	21.23			41	22.61
W4-4	82	2.97	6	5.05	2.8	6.04	19	0.63	7.3	3.05			1	36.96	25	20.53
W4-5	68	6.91	6	5.82			25	0.54	5.4	4.24			2	43.88		
W4-6	53	11.41	5	6.70	4.7	7.30	28	0.49	3.6	6.19						
W4-7	52	15.64	6	5.97	5.0	20.07	26	0.53	4.2	5.37	7	40.36				
	Butch Meyer, water well															
W5-1	76	8.05	6	6.00	3.9	7.84	30	0.62	5.2	4.27	2	26.52			53	15.36
W5-2	37	6.81	5	6.19	4.1	18.34	30	0.60	3.2	6.34					47	16.33
W5-3	64	7.59	5	6.13			24	0.77	5.0	4.65	1	47.71			49	19.23
W5-4	67	4.84	5	6.30	2.6	16.79	21	0.73	4.4	4.35						
W5-5	77	5.93	6	5.85	2.8	6.46	24	0.70	5.2	3.92						
W5-6	68	5.26	5	6.44			20	0.82	6.3	3.45	2	34.95	2	39.17		

SAMPLE	Sb ppm	Error	As ppm	Error	Br ppm	Error	Zr ppm	Error	Zn ppm	Error	La ppm	Error	Ce ppm	Error	Nd ppm	Error
	Reserve Oil and Gas Co., Bruer 1, exploration well															
W1-1	1.6	19.87	14	5.99	2	31.07	243	40.39	110	25.42	23	2.93	56	23.47		
W1-2	2.2	28.81	17	5.93			180	35.74	114	24.72	23	2.88	60	19.77		
W1-3	2.9	24.85	15	6.77	5	19.04	241	21.59	177	14.45	23	3.61	54	22.82		
W1-4	3.2	16.75	14	8.00	3	28.05	180	32.04	142	17.96	41	2.00	92	13.68	36	17.11
W1-5	2.4	47.35	12	11.49			184	42.96	89	26.06	27	3.61	56	19.96		
W1-6	1.7	25.63	19	5.92	6	27.06			117	25.41	24	3.51	67	20.93		
W1-7	1.7	27.02	16	5.86			170	32.57	126	23.06	20	3.51	45	27.24		
W1-8	2.6	18.24	16	5.61	4	26.88			159	18.47	24	3.70	45	31.89		
W1-9	2.5	13.49	17	5.78					139	28.98	33	3.29	63	6.81		
W1-10			7	27.10					146	22.53	22	5.59	46	30.77		
W1-11							413	38.07	160	22.41	24	4.33	46	36.52		
	Mirian Oil Co., exploration well															
W2-1	1.4	16.34	16	6.91	6	34.28	325	21.05	96	26.24	41	1.61	75	17.30		
W2-2	1.5	45.49	7	15.95			192	28.37	82	31.18	33	2.77	67	19.26		
W2-3	2.3	17.94	14	7.96			210	25.90	115	24.43	41	1.93	103	14.07		
W2-4	4.8	24.60	16	5.94			224	22.75	111	26.53	32	3.62	64	23.40	34	43.83
W2-5	2.6	38.90	12	8.73			353	39.80	121	26.27	23	3.17	43	36.82		
W2-6	4.2	33.74	15	6.51					130	25.39	22	4.02	60	25.54	35	29.70
W2-7	2.2	35.84	14	6.48			321	27.75	114	27.02	23	3.47	36	37.20		
	Miller, Bursell 1, exploration well															
W3-1	1.8	14.12	13	7.42			231	23.31	104	25.49	46	1.50	109	12.52		
W3-2	1.7	20.40	21	4.92			280	38.68	112	25.65	38	1.89	93	14.92		
W3-3	2.5	21.22	9	11.22			237	21.57	110	23.29	42	1.93	99	14.77		
W3-4	2.0	16.55			5	13.78	254	21.08	123	19.22	40	2.11	108	13.96	38	17.02
W3-5	2.4	43.83	21	5.49	5	46.37	199	28.54	118	26.09	26	4.31	69	19.82		
W3-6	2.0	24.73	21	5.02			215	35.35	132	23.02	23	5.48	66	23.16	28	24.02
W3-7	2.4	26.33	21	5.43			221	29.38	119	25.81	25	2.98	60	24.73		
	Miller, Stump 1, exploration well															
W4-1	3.9	6.07	23	4.14	5	23.60	230	34.37	515	4.74	34	2.18	55	28.08		
W4-2	2.4	20.44	11	14.91			322	25.59	96	24.65	44	2.00	96	15.25		
W4-3	1.0	19.22	11	11.62			367	27.45	108	24.92	41	2.48	83	17.19	44	28.72
W4-4	3.1	39.16	18	5.78			262	25.97	107	25.88	28	3.09	57	25.25		
W4-5	1.6	36.08	11	9.92			173	43.47	138	21.35	23	4.59	55	26.21		
W4-6			12	11.09					129	26.18	18	4.42	47	30.44		
W4-7			12	10.88					131	25.45	23	4.57	58	24.93		
	Butch Meyer, water well															
W5-1	0.7	22.15	13	6.87	6	26.69	479	46.11	154	32.68	24	2.18	44	9.35		
W5-2	0.4	40.05	10	9.40			412	27.37	118	42.64	31	1.49	23	19.57		
W5-3	0.9	19.56	15	6.23	8	23.26	621	35.10	140	32.35	28	2.06	54	7.59		
W5-4	1.1	34.59	14	7.95			665	47.51	124	33.67	26	2.47	52	7.79		
W5-5	0.6	28.58	16	5.62			363	38.40	141	31.97	24	3.52	52	8.24		
W5-6	0.6	25.91	14	6.64					130	32.04	21	3.03	39	9.33		

SAMPLE	Sm ppm	Error	Eu ppm	Error	Gd ppm	Error	Tb ppm	Error	Tm ppm	Error	Yb ppm	Error	Lu ppm	Error
	Reserve Oil and Gas Co., Bruer 1, exploration well													
W1-1	5.1	1.19	1	5.86	1	27.39	0.7	9.02	0.49	28.40	2.6	12.35	0.35	6.97
W1-2	5.2	1.06	1	7.24	1	31.40	0.8	8.16	0.54	25.87	2.7	15.33	0.37	7.24
W1-3	5.1	1.74	1	7.03	2	18.97			0.50	26.39	2.6	11.63	0.35	8.01
W1-4	7.0	0.86	1	5.37	4	10.70	1.0	6.06	0.51	26.63	3.0	12.54	0.38	12.94
W1-5	5.0	1.15	1	6.48	2	18.02	0.7	8.08	0.46	26.03	2.2	12.49	0.28	7.09
W1-6	5.4	1.12	2	7.23	1	29.70			0.35	37.31	2.1	13.11	0.30	8.63
W1-7	4.7	1.73	1	6.17	2	17.93	0.6	10.88	0.43	29.80	2.3	16.46	0.30	8.53
W1-8	4.7	1.11	1	7.29	3	15.71	0.7	8.27	0.53	23.87	2.1	16.30	0.27	9.14
W1-9	6.1	0.99	2	8.08	6	27.34	0.8	9.04	0.32	44.24	2.3	12.20	0.31	8.08
W1-10	5.7	1.45	2	6.25	1	28.11	0.9	9.89	0.58	25.12	2.2	18.39	0.28	9.94
W1-11	6.9	1.49	2	5.46	1	35.17	0.9	8.26	0.74	20.46	2.2	19.96	0.32	10.11
	Mirian Oil Co., exploration well													
W2-1	7.4	0.77	2	5.45	3	12.47			0.65	22.08	3.1	12.24	0.38	6.91
W2-2	6.1	1.21	1	6.18	2	17.31	0.8	7.38	0.47	28.13	2.6	11.32	0.30	13.07
W2-3	7.9	0.75	2	5.57	3	13.26	1.1	6.82	0.66	22.74	3.6	10.05	0.45	11.26
W2-4	6.3	1.12	2	6.71	3	19.68	0.9	7.93	0.48	32.62	2.6	12.52	0.37	7.84
W2-5	5.3	1.64	2	8.53	2	19.69	0.8	10.86	0.45	33.54	2.5	14.09	0.32	8.52
W2-6	5.3	1.75	2	7.25	2	25.29			0.66	21.74	2.7	16.15	0.37	8.36
W2-7	5.1	1.58	2	5.99	1	29.36	0.8	8.96	0.52	25.97	2.7	15.58	0.32	13.63
	Miller, Bursell 1, exploration well													
W3-1	8.3	0.70	2	5.98	3	11.38	1.1	5.56	0.73	19.02	3.4	11.34	0.44	6.37
W3-2	7.0	0.84	1	5.29	3	13.64	0.9	7.09	0.54	26.26	2.8	11.49	0.38	7.96
W3-3	9.1	0.73	2	4.35	2	16.70	1.4	5.00	1.06	13.07	4.7	9.02	0.62	9.41
W3-4	7.0	1.10	2	5.45	3	12.94	0.9	6.33	0.55	24.50	2.7	12.51	0.38	13.11
W3-5	5.4	1.10	2	6.30	3	16.64	0.8	8.88	0.54	23.99	2.5	13.00	0.34	9.10
W3-6	5.0	1.17	2	5.57	1	27.92	0.8	9.24	0.48	28.15	2.1	17.91	0.27	10.05
W3-7	5.7	1.04	2	6.56	2	21.22			0.54	26.42	3.1	12.63	0.29	8.83
	Miller, Stump 1, exploration well													
W4-1	6.2	0.93	1	5.44	2	16.08	0.8	9.41	0.41	34.91	2.7	13.40	0.37	9.81
W4-2	8.8	0.69	2	5.47	3	14.00	1.1	5.40	0.66	20.26	3.7	10.04	0.45	11.34
W4-3	7.6	0.82	2	6.89	2	15.81	1.0	6.75	0.58	23.83	3.1	12.57	0.39	6.90
W4-4	5.9	1.37	1	5.79	2	19.03	0.7	8.86	0.64	20.76	2.4	12.73	0.31	8.50
W4-5	5.5	1.55	2	5.15	1	36.25	0.9	8.69	0.55	26.59	2.6	16.94	0.31	10.03
W4-6	5.0	2.30	2	7.60			0.7	9.85	0.43	31.13	2.7	14.47	0.42	9.87
W4-7	5.5	1.24	2	6.17	1	37.37	0.8	8.52	0.45	32.38	2.6	14.19	0.31	15.83
	Butch Meyer, water well													
W5-1	6.3	0.83	2	8.19			1.0	8.72	0.60	30.55	2.8	14.53	0.44	7.09
W5-2	9.4	0.72	3	4.75	7	29.22	1.3	8.01	0.51	40.92	4.4	8.93	0.64	9.34
W5-3	7.3	0.82	2	2.71			1.0	9.31	0.65	29.52	3.1	12.81	0.51	6.27
W5-4	6.3	1.12	2	3.58					0.41	43.48	2.8	15.37	0.40	7.52
W5-5	5.7	1.11	2	4.10			0.8	10.16	0.73	25.38	2.6	14.53	0.40	7.19
W5-6	4.8	1.08	1	5.31					0.40	41.08	1.7	14.80	0.31	8.59

SAMPLE	Na %	Error	K %	Error	Rb ppm	Error	Cs ppm	Error	Ba ppm	Error	Sr ppm	Error	Fe %	Error	Co ppm	Error
	Setnicker Farms, water well															
W6-1	1.63	0.39	1.31	15.30	68	24.52	4	9.79	665	8.42	366	30.52	6.85	0.72	26	2.00
W6-2	1.81	0.33	0.90	24.10			4	13.63	673	7.39	496	44.18	6.57	0.76	28	1.93
W6-3	1.91	0.33	1.09	21.22			3	13.02			555	18.51	6.32	0.78	26	1.94
W6-4	3.01	0.25	1.49	31.81	70	18.03	3	9.93	638	7.36	356	30.15	4.62	0.85	16	2.64
W6-5	0.98	0.48	1.24	12.50			4	16.33	777	6.09			5.20	0.79	11	3.72
	Willamette Pollen Co., water well															
W7-1	1.19	0.49	2.18	11.21	117	15.28	7	4.55	849	5.66	672	32.13	5.24	0.84	20	1.77
W7-2	1.47	0.36	1.08	0.00	75	22.20	5	10.77	628	8.71	379	29.36	8.29	0.62	36	1.65
W7-3	1.37	0.36	1.31	16.19	56	31.61	2	21.40					10.77	0.52	68	1.20
W7-4	0.89	0.51	1.06	25.81	60	29.87	5	19.71	699	8.72	272	48.51	10.85	0.60	55	1.07
	Alluvium, surficial deposits															
Q-1	2.48	0.27	1.38	19.43	86	22.48	2	15.15	678	6.84	735	14.67	6.23	0.80	27	1.96
Q-2	2.93	0.27	2.02	15.56	74	21.79	6	4.47	728	6.13			4.29	0.91	16	2.03
Q-3	2.61	0.27	1.42	23.73	49	20.15	3	17.00	636	7.18	490	18.83	5.65	0.70	25	1.64
Q-4	1.31	0.37	2.05	13.77	92	8.93	5	9.91	835	6.44	242	36.68	3.98	0.92	17	2.58
	Tertiary intrusives, surficial exposures															
V-1	2.03	0.25									271	37.77	7.17	0.51	46	1.60
V-2	2.02	0.36											7.67	0.68	49	1.26
	Undif. Eocene-Oligocene Sed. Rock, surf. exp.															
E-1	0.47	0.62	1.24	10.87			3	15.09	382	12.10			4.31	0.87	8	4.27
E-2	1.08	0.40	1.55	10.70	74	20.75	4	10.91			576	40.49	4.39	0.94	11	3.57
E-3	0.94	0.40	1.56	17.43	68	16.37	3	10.31	626	7.70	1107	8.45	3.24	1.06	4	5.11
E-4	0.35	0.73	1.01	11.78	6	25.57	4	8.32	478	11.08			4.56	0.91	4	5.22
	Spencer Formation, surficial exposures															
S-1	1.25	0.34	2.32	7.99	92	8.71	3	13.44	651	5.89	219	33.55	2.28	1.36	6	3.64
S-2	1.39	0.31	2.75	8.40	109	9.96	6	4.47	789	5.59	253	29.85	3.58	1.00	14	2.03
S-3	1.20	0.41	2.72	7.30	116	8.89	6	4.47	778	6.04	238	38.94	2.50	1.47	11	3.52
S-4	0.86	0.45	2.22	6.34	125	11.01	8	6.59	758	6.88	193	47.13	2.73	1.20	14	2.92
S-5	0.95	0.29	1.57	5.81	91	12.81	4	5.22	550	6.97	290	21.52	3.93	0.93	9	2.50
S-6	0.64	0.35	1.00	9.99			3	11.86	484	9.99			5.18	0.83	10	3.60
	Yamhill Formation, surficial exposures															
Y-1	0.62	0.32	2.13	8.12	95	14.22	15	2.32	628	8.31	197	42.43	4.53	0.84	39	1.65
Y-3	0.05	2.22	0.87	8.16	66	14.75	6	12.53					6.99	0.71	6	5.45
Y-4	0.16	1.24	0.96	9.60			4	13.00	656	11.12			5.48	0.91	42	1.59
	Rickreall Limestone Member															
Y-2	0.62	0.42	0.77	14.67							736	13.56	4.46	0.91	28	1.31
Y-5	0.09	1.78	0.00	0.00	28	24.87							2.10	1.86	13	2.08
	Siletz River Volcanics, Ellendale Quarry															
SR-1	2.30	0.25	0.70	30.88	49	49.19							12.98	0.53	61	1.29
SR-2	1.97	0.27	0.77	0.00	40	49.98					326	39.66	10.12	0.60	43	1.53
SR-3	2.64	0.22	0.75	0.00							1118	15.71	11.36	0.54	42	1.51

SAMPLE	Cr ppm	Error	Hf ppm	Error	Ta ppm	Error	Sc ppm	Error	Th ppm	Error	U ppm	Error	W ppm	Error	Ga ppm	Error
	Setnicker Farms, water well															
W6–1	83	7.86	6	5.84	3.1	18.33	23	0.70	5.1	3.99						
W6–2	91	2.82	5	5.07	3.6	23.81	24	0.63	4.2	4.73	3	27.70				
W6–3	91	3.67	5	5.66	3.9	20.14	22	0.73	4.0	4.82					55	21.37
W6–4	59	3.49	5	4.90	2.9	18.43	16	0.80	5.2	3.63	5	39.80			55	26.62
W6–5	59	3.86	6	4.06	4.3	14.28	18	0.79	5.9	3.34						
	Willamette Pollen Co., water well															
W7–1	59	3.73	7	3.88	3.5	4.42	18	0.87	11.9	1.75			4	35.01	37	23.63
W7–2	99	4.85	6	5.20	3.8	5.38	31	0.62	6.4	3.40			18	10.73	46	18.02
W7–3	173	1.79	5	6.09	3.7	16.92	33	0.76	2.9	8.79					71	13.96
W7–4	161	3.88	7	5.38	3.8	5.63	32	0.63	4.3	5.58					63	16.60
	Alluvium, surficial deposits															
Q–1	92	5.32	5	5.71	2.5	23.85	20	0.80	3.9	4.92					59	20.63
Q–2	35	6.20	6	4.41	1.8	6.45	13	1.07	6.7	3.30	6	39.45				
Q–3	79	3.09	5	5.24	2.2	7.05	19	0.73	3.8	4.66	4	43.96	3	44.59	39	20.54
Q–4	59	3.91	9	3.09	2.4	4.94	15	0.88	10.7	1.93					25	28.34
	Tertiary intrusives, surficial exposures															
V–1	231	1.86	3	8.37	2.3	17.72	41	0.62	1.8	27.55					69	20.66
V–2	225	2.27	2	9.27			39	0.71	0.9	23.86					62	21.21
	Undif. Eocene–Oligocene Sed. Rock, surf. exp.															
E–1	60	4.15	7	4.49	3.0	7.12	24	0.70	5.7	3.49					39	18.59
E–2	74	3.04	5	5.06	2.5	16.28	19	0.72	4.2	5.00	3	17.34				
E–3	51	4.05	6	4.16	2.1	7.08	18	0.93	5.1	3.34	3	17.91			27	21.25
E–4	62	10.30	7	3.58	3.0	18.82	27	0.77	7.2	4.77	3	12.47			40	17.51
	Spencer Formation, surficial exposures															
S–1	63	3.19	5	3.76	1.7	5.71	13	0.87	7.2	2.24	3	14.67				
S–2	58	3.30	6	3.83	1.8	5.04	12	1.07	9.9	1.95					32	23.16
S–3	78	2.82	7	2.87	2.1	4.75	16	0.81	13.8	1.57	4	11.04				
S–4	75	2.84	8	3.47	2.5	4.67	17	0.96	14.2	1.44	4	9.69	2	47.62	20	27.07
S–5	37	4.52	4	4.60	1.4	7.79	7	1.39	5.8	2.57					19	23.38
S–6	39	5.36	4	5.83	2.6	16.70	16	0.81	3.2	5.36					16	20.89
	Yamhill Formation, surficial exposures															
Y–1	68	7.23	6	4.98	3.3	6.52	21	0.82	10.0	2.19	4	24.13			58	21.71
Y–3	93	5.08	5	6.43	3.2	9.23	27	0.65	8.3	3.20					29	16.07
Y–4	74	3.93	5	6.00	3.7	9.50	31	0.61	5.4	4.75			2	45.09	39	13.69
	Rickreall Limestone Member															
Y–2	184	2.28	3	9.35			16	0.76	2.1	12.13	2	49.23	2	45.17	27	19.91
Y–5	87	2.65	1	18.97			17	1.10	0.4	27.21	1	37.36			15	31.65
	Siletz River Volcanics, Ellendale Quarry															
SR–1	120	4.79	6	7.03	7.4	14.72	47	0.57	1.5	16.54					56	16.48
SR–2	93	8.21	5	8.20	6.4	18.78	35	0.64	1.1	20.52						
SR–3	124	2.59	7	3.89	7.9	5.56	37	0.53	2.6	9.91					54	19.82

SAMPLE	Sb ppm	Error	As ppm	Error	Br ppm	Error	Zr ppm	Error	Zn ppm	Error	La ppm	Error	Ce ppm	Error	Nd ppm	Error
	Setnicker Farms, water well															
W6-1	1.2	18.50	11	12.71	14	10.07			139	31.55	30	2.82	55	7.65		
W6-2	2.6	31.59	10	13.51			209	40.20	165	23.97	25	2.64	47	10.03		
W6-3	4.3	28.89			11	8.25	340	24.52	154	22.90	25	3.98	48	8.28		
W6-4	2.8	23.78	11	18.01			309	19.93	95	38.34	25	4.28	42	8.14		
W6-5	1.4	27.69	2	37.96			442	30.34	105	37.01	43	1.52	78	4.95	44	13.45
	Willamette Pollen Co., water well															
W7-1	1.2	18.60	9	11.00	4	17.80	352	37.07	142	26.11	49	1.78	86	4.89	42	25.93
W7-2	0.7	34.43	8	14.84			522	34.64	198	26.15	32	2.51	64	8.29		
W7-3	0.5	49.84	9	15.63			215	45.30	192	28.63	23	4.20	54	9.65		
W7-4			6	15.89					177	30.77	27	2.24	59	9.57		
	Alluvium, surficial deposits															
Q-1	2.2	32.03	7	19.78	9	42.39	260	31.20	116	36.86	24	3.53	45	9.39		
Q-2	1.8	32.76	9	22.58			280	35.84	122	23.10	27	3.77	83	5.57	24	20.50
Q-3	2.4	39.57	9	19.17	7	27.91			128	26.60	21	6.43	41	10.07	27	41.51
Q-4	0.9	27.48	9	13.16			345	18.26	92	39.56	47	1.64	78	5.46	40	14.56
	Tertiary intrusives, surficial exposures															
V-1			25						129	43.70	10	10.68	19	5.34		
V-2			39						127	45.28	9	6.70	18	7.50		
	Undif. Eocene-Oligocene Sed. Rock, surf. exp.															
E-1	0.9	16.81	8	10.18			284	23.86	132	34.67	29	1.92	49	8.19	34	37.93
E-2	1.9	25.31	7	12.12			311	41.02	107	39.17	18	2.76	34	12.10	16	42.85
E-3	0.6	34.62	7	18.70			296	39.49	110	34.07	29	2.45	47	7.76		
E-4	0.6	26.76	3	19.01					141	35.66	15	3.06	21	19.96		
	Spencer Formation, surficial exposures															
S-1	1.7	36.75	8	10.72			192	45.28	93	27.82	32	2.28	58	5.64	34	32.06
S-2	2.2	16.29	18	7.18					110	23.10	39	1.90	75	5.57	35	33.33
S-3	2.2	22.19	9	13.79			263	25.61	118	32.61	58	1.31	106	4.18	5	12.52
S-4			9	7.81			252	22.97	136	27.60	54	1.31	117	3.96	53	11.61
S-5	1.3	30.43	7	9.91			231	22.33	63	38.31	25	3.39	41	7.57	21	41.47
S-6			9	8.75					96	38.70	33	1.98	58	7.25		
	Yamhill Formation, surficial exposures															
Y-1	1.7	15.90	16	6.09			171	34.87	161	25.95	34	1.97	65	18.98		
Y-3	0.8	17.08	15	4.38	8	11.95	262	38.40	108	44.85	27	1.39	43	11.45		
Y-4	0.6	25.21	13	5.48	5	27.59			171	32.26	37	1.35	58	9.30		
	Rickreall Limestone Member															
Y-2			10	6.70			289	27.19	88	29.91	12	4.21	35	33.73		
Y-5	0.2	33.61	4	9.68							10	2.37	360	22.77		
	Siletz River Volcanics, Ellendale Quarry															
SR-1			35						238	27.52	21	4.63	53	11.42		
SR-2			40						163	33.92	15	5.15	35	14.26		
SR-3			2	49.65			525	39.54	163	33.40	34	2.78	75	7.20	51	13.26

SAMPLE	Sm ppm	Error	Eu ppm	Error	Gd ppm	Error	Tb ppm	Error	Tm ppm	Error	Yb ppm	Error	Lu ppm	Error
	Setnicker Farms, water well													
W6-1	7.1	0.93	2	4.11	4	49.27			0.47	40.57	3.0	13.89	0.55	5.97
W6-2	6.2	1.01	2	3.32	6	28.82	0.8	10.15	0.53	31.09	2.6	13.67	0.46	7.37
W6-3	6.0	1.29	2	8.41					0.54	31.48	2.8	15.43	0.44	6.75
W6-4	5.2	1.28	2	2.82			0.8	8.80	0.52	30.28	2.6	10.27	0.39	10.29
W6-5	9.8	0.77	2	5.94	5	29.09	1.3	5.82	0.76	23.30	4.1	11.16	0.62	5.41
	Willamette Pollen Co., water well													
W7-1	8.6	0.77	1	7.04	9	18.31	1.2	6.30	0.71	25.65	3.8	11.88	0.52	11.37
W7-2	7.4	0.95	2	8.13	7	26.17	1.0	8.57	0.73	27.59	2.9	14.32	0.45	6.74
W7-3	6.8	1.04	2	3.59					0.89	22.59	2.8	16.95	0.48	7.65
W7-4	8.0	0.89	3	6.66	7	26.85	1.2	8.20	0.86	24.53	3.5	12.90	0.60	6.49
	Alluvium, surficial deposits													
Q-1	5.3	1.50	2	9.47			0.8	9.36	0.57	28.47	2.3	16.16	0.34	8.20
Q-2	5.8	1.24	2	4.70					0.37	34.64	2.9	9.57	0.46	18.14
Q-3	5.0	1.31	2	4.85			0.7	11.31	0.38	41.44	2.1	14.07	0.37	8.12
Q-4	8.2	0.93	2	3.25			1.0	7.05	0.69	24.80	3.5	10.29	0.59	9.08
	Tertiary intrusives, surficial exposures													
V-1	4.1	1.89	2	10.22					0.21	47.22	2.2	13.12	0.33	6.26
V-2	4.0	2.37	3	10.30			0.5	18.74			2.0	13.43	0.40	7.95
	Undif. Eocene-Oligocene Sed. Rock, surf. exp.													
E-1	6.1	0.83	2	7.88			0.8	8.47	0.54	30.16	2.9	12.48	0.43	17.37
E-2	2.7	1.79	1	11.47					0.39	36.95	1.7	16.92	0.28	9.47
E-3	5.4	0.93	2	4.26			0.6	9.93	0.30	46.19	1.9	13.10	0.28	9.65
E-4	1.8	2.40	1	18.59					0.32	44.00			0.29	24.69
	Spencer Formation, surficial exposures													
S-1	5.5	0.95	1	4.26	4	32.30	0.6	8.08	0.46	29.16	2.2	11.87	0.36	6.67
S-2	6.4	1.03	2	4.70			0.9	7.37	0.71	21.96	2.9	10.32	0.44	11.58
S-3	9.3	0.70	2	2.90			1.3	5.64	0.78	23.02	3.8	9.28	0.63	8.67
S-4	9.9	0.59	2	6.81					0.79	23.40	3.8	7.90	0.55	14.11
S-5	4.0	1.55	1	4.99			0.6	30.88	0.40	33.72	1.7	13.56	0.25	7.82
S-6	6.0	0.87	2	3.56			0.8	8.09	0.53	31.03	3.1	9.70	0.46	11.07
	Yamhill Formation, surficial exposures													
Y-1	5.8	0.94	4	1.87	7	29.43			0.23		2.4	10.94	0.31	8.80
Y-3	6.3	0.76	1	8.59							2.9	14.90	0.41	8.42
Y-4	7.9	0.84	2	3.43					0.50	41.45	2.6	14.13	0.42	8.24
	Rickreall Limestone Member													
Y-2	3.0	1.35	1	8.29	1	49.21			0.20	42.03	1.2	22.05	0.16	16.77
Y-5	1.9	1.61	1	11.20			0.2	20.70			0.9	17.68	0.12	15.79
	Siletz River Volcanics, Ellendale Quarry													
SR-1	8.4	1.52	3	2.58					0.83	27.43	3.8	13.29	0.71	7.26
SR-2	6.2	1.89	2	6.17			1.0	9.64	0.67	29.19	2.9	11.52	0.45	7.41
SR-3	11.3	0.88	3	2.41	7	28.92	1.6	6.36	0.97	22.15	4.5	10.68	0.70	6.07

MEASURED AND PUBLISHED ELEMENTAL CONCENTRATIONS FOR STANDARDS

SAMPLE	Na %	Error	K %	Error	Rb ppm	Error	Cs ppm	Error	Ba ppm	Error	Sr ppm	Error	Fe %	Error	Co ppm	Error
	First Irradiation															
	Rhyolite, JR-1, GSJ reference sample															
STD-1	2.80	0.12	3.67	4.59	229	3.35	19	0.81	137	22.92	99	45.42	6.16	2.23	1	7.85
	Coal fly ash, NBS, SRM 1633															
STD-2	0.17	0.82	1.80	2.78	154	9.95	12	3.21	1614	3.82	853	12.47	9.29	0.51	46	0.80
	Granite, G-2, USGS reference material															
STD-3	3.11	0.13	3.92	3.68	163	5.16	2	7.03	1818	2.28	467	10.43	1.92	1.53	5	2.44
	Bituminus coal, NBS, SRM 1632b															
STD-4	0.54	1.14					1	13.77					8.17	1.63	2	4.01
	Second Irradiation															
	Rhyolite, JR-1, GSJ reference sample															
STD-1	2.89	0.09	3.42	3.33	233	3.11	19	1.08	216	21.85			0.68	3.23	1	11.07
	Coal fly ash, NBS, SRM 1633															
STD-2	0.18	0.83	2.00	4.21	136	12.41	11	2.69	1608	3.47	867	14.09	9.78	0.47	46	1.08
	Granite, G-2, USGS reference material															
STD-3	3.15	0.09	3.78	4.34	188	4.54	2	13.24	1790	1.98	460	10.07	2.05	1.07	5	2.79
	Bituminus coal, NBS, SRM 1632b															
STD-4	0.05	0.83	0.08	12.31	9	36.34	1	28.73	85	18.95			0.67	1.91	2	9.89

Error = % cumulative related to data processing

SAMPLE	Cr ppm	Error	Hf ppm	Error	Ta ppm	Error	Sc ppm	Error	Th ppm	Error	U ppm	Error	W ppm	Error	Ga ppm	Error
	First Irradiation															
	Rhyolite, JR−1, GSJ reference sample															
STD−1	2	47.36	5	3.21	1.6	5.42	5	0.88	25.2	0.71	9	5.65	2	28.95	13	38.59
	Coal fly ash, NBS, SRM 1633															
STD−2	174	1.72	9	4.53	5.8	3.50	39	0.32	23.9	1.11	11	3.45	3	14.72	58	5.65
	Granite, G−2, USGS reference material															
STD−3	7	17.56	9	2.22	1.2	4.64	4	1.07	24.9	0.78					27	25.80
	Bituminus coal, NBS, SRM 1632b															
STD−4	13	11.06	1	20.76	0.3	27.02	2	1.01	1.4	5.35					5	25.15
	Second Irradiation															
	Rhyolite, JR−1, GSJ reference sample															
STD−1	3	33.33	5	2.73	1.9	3.23	5	1.09	24.8	0.70	9	4.29			13	29.07
	Coal fly ash, NBS, SRM 1633															
STD−2	196	1.43	7	3.32	8.2	7.09	39	0.38	25.1	0.95	10	3.10	4	14.06	58	6.70
	Granite, G−2, USGS reference material															
STD−3	8	13.44	9	3.34	1.3	15.09	4	1.34	25.6	0.72	6	22.37	4	38.28	32	23.84
	Bituminus coal, NBS, SRM 1632b															
STD−4	11	18.36	1	15.60			2	2.01	1.3	5.30	1	25.44			2	23.21

SAMPLE	Sb ppm	Error	As ppm	Error	Br ppm	Error	Zr ppm	Error	Zn ppm	Error	La ppm	Error	Ce ppm	Error	Nd ppm	Error
	First Irradiation															
	Rhyolite, JR−1, GSJ reference sample															
STD−1	2.5	15.09	16	5.26	6	24.05	130	21.27	33	32.37	21	2.87	52	14.09	27	41.20
	Coal fly ash, NBS, SRM 1633															
STD−2	6.8	1.99	148	0.55	3	16.89	240	27.01	240	12.35	86	0.59	194	7.63	91	22.89
	Granite, G−2, USGS reference material															
STD−3			16				248	13.64	75	11.50	97	0.83	153	5.59	60	8.42
	Bituminus coal, NBS, SRM 1632b															
STD−4	0.4	16.69	5		17	1.21			22	30.50	5	3.17	15	30.89		
	Second Irradiation															
	Rhyolite, JR−1, GSJ reference sample															
STD−1	2.9	14.70	18		3	19.61	97	31.35	39	39.71	22	2.75	50	5.09	26	33.76
	Coal fly ash, NBS, SRM 1633															
STD−2	7.8	1.72	145	0.55	4	17.89	387	21.56	261	15.06	94	0.50	164	2.54		
	Granite, G−2, USGS reference material															
STD−3			13				358	27.30	75	18.85	104	0.64	163	1.75		
	Bituminus coal, NBS, SRM 1632b															
STD−4	0.2	16.11	6		17	1.23					5	2.36	11	37.59		

SAMPLE	Sm ppm	Error	Eu ppm	Error	Gd ppm	Error	Tb ppm	Error	Tm ppm	Error	Yb ppm	Error	Lu ppm	Error
	First Irradiation													
	Rhyolite, JR−1, GSJ reference sample													
STD−1	5.8	0.84	0.5	9.37	5	4.38	1.1	4.53	0.73	12.66	4.6	6.40	0.53	5.94
	Coal fly ash, NBS, SRM 1633													
STD−2	17.7	0.28	4	3.19	6	7.37	2.3	3.16	1.24	13.20	7.0	7.52	0.84	11.07
	Granite, G−2, USGS reference material													
STD−3	7.8	0.80	1	3.13	5	3.90	0.7	11.29			1.7	21.46	0.15	11.62
	Bituminus coal, NBS, SRM 1632b													
STD−4	0.9	1.80	0.3	13.51	0.3	44.03	0.2	15.02	0.16	33.67	0.5	20.43	0.05	17.67
	Second Irradiation													
	Rhyolite, JR−1, GSJ reference sample													
STD−1	6.1	0.68	0.6	12.29	5	20.57	1.1	6.78	0.73	17.36	4.6	5.73	0.68	3.82
	Coal fly ash, NBS, SRM 1633													
STD−2	19.1	0.26	4	1.66	13	15.96	2.5	3.11	1.34	15.19	7.4	6.40	1.13	5.41
	Granite, G−2, USGS reference material													
STD−3	7.9	0.54	1	5.17	5	22.30	0.8	12.16			1.4	24.36	0.17	12.18
	Bituminus coal, NBS, SRM 1632b													
STD−4	0.8	1.28	0.2	12.85							0.5	17.15	0.07	13.70

APPENDIX B

SELECTED DRILLER'S LOGS

7S/4W-19ccd. Harry Fast. Altitude 211 ft. Drilled by J. A. Sneed and Sons, 1965. Casing 6-in diam to 20 ft; unperforated

Materials	Thickness (feet)	Depth (feet)
Topsoil	2	2
Clay, yellow	16	18
Claystone, gray hard	151	169

7S/4W-21dcc1. Hollis Bice. Altitude 175 ft. Drilled by Art Clinton, 1962. Casing 8-in diam to 55 ft; perforated 25-45 ft

Materials	Thickness (feet)	Depth (feet)
Clay, gray	5	5
Clay, sandy brown	20	25
Clay, blue	45	70
Sandstone, blue	20	90

7S/4W-26ccb. Virgil Myers. Altitude 169 ft. Drilled by Marion West, 1970. Casing 6-in diam to 45 ft; perforated 43-45 ft

Materials	Thickness (feet)	Depth (feet)
Brown Clay	40	40
Black sand and small gravel with cemented blue clay	6	46
Blue-gray claystone with thin strata of white rock	144	190

7s/4W-30ccb. Hubert Grimsbo. Altitude 215 ft. Drilled by Willamette Drilling, 1966, Casing 6-in diam to 95 ft; perforated 82-95 ft

Materials	Thickness (feet)	Depth (feet)
Topsoil	3	3
Clay, brown	32	35
Clay, gray	20	55
Clay, brown	10	65
Shale, gray	30	95

7S/4W-31bcd. Dallas Equipment Co. Altitude 213 ft. Drilled by Muntschler Drilling, 1971. Casing 6-in diam to 28 ft; perforated 22-27 ft

Materials	Thickness (feet)	Depth (feet)
Soil	2	2
Silt-clay, yellow	4	6
Gravel and sand, coarse	22	28
Clay, yellow	9	37

7S/4W-31ccd. Paul Wedel. Altitude 175 ft. Drilled by Miller-Robinson and West, 1967. Casing 10-in diam to 40 ft; perforated 28-29, 32-34 ft

Materials	Thickness (feet)	Depth (feet)
Clay, brown	15	15
Clay, gray with small gravel	20	35
Claystone, gray	64	99
Claystone, brown	2	101
Claystone, dark gray	14	115
Claystone, light gray	5	120

7S/4W-32aab. Garfield Roth. Altitude 200 ft. Drilled by Robinson Eola Drilling, 1973. Casin 8-in diam to 19 ft; unperforated

Materials	Thickness (feet)	Depth (feet)
Clay, brown	9	9
Clay, brown and gravel	7	16
Shale, blue	67	83
Sandstone, blue	27	110

7S/4W-34ddc. Rickreall Water Assn. Altitude 172 ft. Drilled by Robinson Eola Drilling, 1971. Casing 12-in diam to 41 ft; screened from 40-57 ft

Materials	Thickness (feet)	Depth (feet)
Soil	1	1
Clay, brown	30	31
Gravel with clay binder	10	41
Sand and gravel	20.5	61.5
Claystone, hard gray	3.5	65

7S/5W-2bac. George Beyerle. Altitude 226 ft. Drilled by Art Clinton, 1959. Casing 12-in diam to 20 ft; perforated 14-20 ft

Materials	Thickness (feet)	Depth (feet)
Topsoil	1	1
Clay, brown	19	20
Shale, blue	20	40

7S/5W-5dda. Donald Hoekstre. Altitude 510 ft. Drilled by Robinson Well Drilling, 1991. Casing 10-in diam to 29 ft; unperforated

Materials	Thickness (feet)	Depth (feet)
Clay, brown and claystone	28	28
Claystone, gray	112	140

7S/5W-6bbc. W. F. Anderson. Altitude 240 ft. Drilled by Eola Well Drilling, 1979. Casing 6-in diam to 22 ft; unperforated

Materials	Thickness (feet)	Depth (feet)
Soil	1	1
Clay, brown	10	11
Clay and gravel	3	14
Claystone, gray	144	158

7S/5W-6bdd. Darrel Sexton. Altitude 217 ft. Drilled by Robinson Eola Drilling, 1974. Casing 6-in diam to 19 ft; unperforated

Materials	Thickness (feet)	Depth (feet)
Topsoil	2	2
Clay, brown	8	10
Clay, gray	10	20
Claystone, gray	27	47

7S/5W-15aac1. Don Schellenberg. Altitude 272 ft. Drilled by J. A. Sneed and Sons, 1969. Casing 6-in diam to 21 ft; unperforated

Materials	Thickness (feet)	Depth (feet)
Topsoil	1	1
Clay, yellow	2	3
"Basalt, weathered soft"	9	12
Clay, gray	10	22
Claystone	107	129

7S/5W-27dcc. Ed Sims. Altitude 290 ft. Drilled by Eola Well Drilling, 1978. Casing 6-in diam to 67 ft; perforated 63-66 ft

Materials	Thickness (feet)	Depth (feet)
Clay, brown	14	14
Clay, brown and gravel	30	44
Clay, gray	20	64
Sand, coarse and pea gravel	3	67
Sand, gray and clay	9	76
Gravel, cemented	11	87
Sand, fine	3	90
Clay, gray	2	92
Gravel, cemented	15	107
Sand and pea gravel	3	110
Claystone		>110

7S/5W-29cad. Merle Bitikofer. Altitude 370 ft. Drilled by Robinson Eola Drilling, 1974. Casing 6-in diam to 19.5 ft; unperforated

Materials	Thickness (feet)	Depth (feet)
Soil	1	1
Broken rock and clay	5	6
Clay, orange	3	9
Claystone, gray	29	38

7S/5W-31dab2. Butch Meyer. Altitude 540 ft. Drilled by P. Dickerson, 1990. Casing 10-in diam to 29 ft; liner 4-in diam to 215 ft; perforated 30-215 ft

Materials	Thickness (feet)	Depth (feet)
Topsoil	2	2
Clay, brown	17	19
Claystone, brown	5	24
Claystone, blue	15	39
Clay, blue	33	72
Clay, gray	28	100
Claystone, gray	24	124
Clay, gray	18	142
Claystone, gray	73	215

7S/5W-34bbd. Jerry Reeves. Altitude 295 ft. Drilled by Marion West, 1971. Casing 6-in diam to 57 ft; perforated 48-54 ft

Materials	Thickness (feet)	Depth (feet)
Clay, brown	5	5
Clay, brown and gravel	2	7
Clay, sandy brown	9	16
Sand and gravel, black and cemented with blue clay	25	41
Clay, blue	5	46
Gravel, cemented brown	12	58
Claystone, blue-gray	2	60

7S/5W-35cab. Sand Strip Golf Course. Altitude 245 ft. Drilled by Robinson Well Drilling, 1988. Casing 8-in to 80 ft; liner 6-in diam 55-75; perforated 25-35, 45-75 ft

Materials	Thickness (feet)	Depth (feet)
Topsoil	6	6
Clay and gravel	6	12
Gravel, cemented	8	20
Gravel, small and loose clay	15	35
Gravel, cemented	10	45
Clay, loose and gravel	7	52
Gravel, sandy	5	57
Clay, loose and gravel	5	62
Claystone, soft	13	75

7S/6W-12add. Bob Green. Altitude 620 ft. Drilled by Dickerson Well Drilling, 1983. Casing 6-in diam to 65 ft; unperforated

Materials	Thickness (feet)	Depth (feet)
Topsoil	2	2
Clay, brown	15	17
Clay, yellow	41	58
Claystone, gray	27	85
Sandstone, gray	52	137
Claystone, gray	11	148
Sandstone	28	176
Claystone	4	180
Sandstone	31	211
Basalt	185	396
Basalt with sandstone	130	526

8S/4W-2cac1. Green Villa Farms. Altitude 150 ft. Drilled by Robinson Eola Drilling, 1975. Casing 12-in diam to 52 ft; perforated 35-48 ft

Materials	Thickness (feet)	Depth (feet)
Clay and gravel	20	20
Gravel, small and medium	9	29
Sand	2	31
Gravel, small and medium	17	48
Sand	1	49
Shale, gray	4	53

8S/4W-2cac2. Green Villa Farms. Altitude 150 ft. Drilled by Robinson Eola Drilling, 1975. Casing 6-in diam to 46 ft; unperforated

Materials	Thickness (feet)	Depth (feet)
Gravel and clay	20	20
Gravel, small to medium	9	29
Sand	2	31
Gravel, pea gravel to medium	15	46

8S/4W-3dba. Charles Evans. Altitude 150 ft. Drilled by J. A. Sneed and Sons, 1960. Casing 8-in diam to 45 ft; perforated 33-45 ft

Materials	Thickness (feet)	Depth (feet)
Topsoil	1	1
Clay, blue	1	2
Silt, yellow	6	8
Clay, yellow	15	23
Gravel, cemented	10	33
Gravel	2	35
Gravel, cemented	7	42
Sand, fine	3	45
Shale, blue	7	52

8S/4W-3bcc. Bruce Dalke. Altitude 186 ft. Drilled by Robinson Eola Drilling, 1973. Casing 6-in diam to 39 ft; unperforated

Materials	Thickness (feet)	Depth (feet)
Clay, brown	20	20
Clay, blue	6	26
Clay, brown and gravel	3	29
Gravel and sand	5	34
Gravel, medium	7	41
Sandstone, gray	6	47
Claystone, soft	2	49

8S/4W-4cdd. Louis Peterson. Altitude 177 ft. Drilled by Todd's Drilling, 1971. Casing 6-in diam to 31 ft; unperforated

Materials	Thickness (feet)	Depth (feet)
Topsoil	2	2
Clay, brown and yellow	8	10
Gravel, sandy	10	20
Claystone, blue	19	39
Gravel, consolidated	2	41
Claystone, blue hard	37	78
Clay, blue hard	2	80

8S/4W-6bac. Walter Boyer. Altitude 222 ft. Drilled by J. A. Sneed and Sons, 1959. Casing 6-in diam to 42 ft; unperforated

Materials	Thickness (feet)	Depth (feet)
Topsoil	2	2
Clay, yellow	16	18
Gravel, cemented	23	41
Shale, gray	56	97
Sandstone, white	1	98
Shale, gray sandy	17	115
Sandstone, white	1	116
Shale, gray	5	121

8S/4W-6cac1. Katherine Herrara. Altitude 222 ft. Drilled by J. A. Sneed and Sons, 1955. Casing 6-in diam to 47.5 ft; unperforated

Materials	Thickness (feet)	Depth (feet)
Topsoil	2	2
Clay, gray	25	27
Gravel, cemented	7	34
Shale, blue	3	37
Gravel, cemented	10	47
Shale, blue	2	49
Shale, blue diced	1	50

Materials	Thickness (feet)	Depth (feet)
8S/4W-7cca2. Willamette Pollen. Altitude 205 ft. Drilled by Eola Well Drilling, 1980. Casing 10-in diam to 75 ft; perforated 55-75 ft		
Clay, brown	22	22
Clay, brown and gravel	12	34
Clay, blue-green	21	55
Clay, blue-gray with layers of pea gravel and gray sand	25	80
8S/4W-7ccd. Willamette Pollen. Altitude 202 ft. Drilled by Dickerson Well Drilling, 1991. Casing 8-in diam to 92 ft; perforated 63-78 ft		
Topsoil	1.5	1.5
Clay, brown	17	18.5
Clay, gray with medium gravel	12.5	31
Clay, sandy blue	3	34
Gravel, cemented in gray clay	11	45
Clay, gray	12	57
Clay, blue-gray with pea gravel and fine sand	33	90
Clay, sandy blue-gray	5	95
8S/4W-9cdb. Hugh Rogers. Altitude 169 ft. Drilled by Miller-Robinson and West, 1966. Casing 6-in diam to 37.5 ft; perforated 27-35 ft		
Clay, brown	14	14
Clay, blue	13	27
Gravel, small loose	1	28
Claystone, gray	3	31
Clay, brown and small gravel	4	35
Claystone, gray	155	190
8S/4W-11cad. John I Haas Inc. Altitude 150 ft. Drilled by Floyd Sippe, 1989. Casing 8-in diam to 36 ft; perforated 30-46 ft		
Soil	2.5	2.5
Clay, brown	3.5	6
Clay, sandy brown	5	11
Clay, brown and gravel	8	19
Sand, dirty and gravel	3	22
Gravel, loose	8	30
Sand and gravel with some brown clay	4	34
Gravel, loose	2	36
Sand with some gravel	3	39
Gravel, loose	2.5	41.5
Clay and gravel	8.5	50
8S/4W-16dac. Setnicker Farms. Altitude 150 ft. Drilled by Michael Waldroop, 1991. Casing 12-in diam to 42 ft; perforated 20.5-37 ft		
Topsoil, brown	1	1
Clay, brown with some sand	4	5
Clay, brown	6	11
Clay, silty brown with some small gravel	1	12
Gravel, small-medium with fine-coarse brown sand	25	37
Clay, with pieces of claystone	5	42
8S/4W-18dbd. Tel LeBec. Altitude 187 ft. Drilled by Art Clinton, 1957. Casing 10-in diam to 33 ft; perforated 23-33 ft		
Loam	3	3
Clay, yellow	18	21
Gravel	16	37
Shale, blue	23	60
8S/4W-19bca. Wesley Jepson. Altitude 192 ft. Drilled by Floyd Sippe, 1968. Casing 6-in diam to 56 ft; perforated 33-35, 40-41 and 51-53 ft		
Soil with gravel	2	2
Clay, brown	13	15
Clay, brown silty	6	21
Clay, green	11	32
Clay, green with small gravel	1	33
Gravel, small	3	37
Clay, dark green with gravel	3	40
Gravel and green clay	1	41
Clay, green with a small amount of gravel	6	47
Clay, green and gray	3	50
Clay, gray with sand and gravel seams	3	53
Claystone, gray with some gravel seams	3	56
Claystone, gray	39	95
Claystone, hard gray	25	120
8S/4W-19bdb. Loren Reynolds. Altitude 184 ft. Drilled by Art Clinton, 1964. Casing 8-in diam to 55 ft; perforated and gravel packed 26-47 ft		
Topsoil	2	2
Clay, brown	16	18
Clay, blue	15	33
Clay, blue, and medium gravel	7	40
Gravel, blue	4	44
Clay, sandy, blue	11	55
8S/4W-20bdd. Earl Renninger. Altitude 182 ft. Drilled by Todd's Drilling, 1974. Casing 6-in diam to 32.5 ft; perforated 27-30 ft		
Topsoil	2	2
Clay, brown	5	7
Silt, brown	7	14
Silt, sandy brown	3	17
Clay, blue, soft-sticky	10	27
Gravel, medium fine	5	32
Sandstone, hard brown	0.5	32.5
8S/4W-21bdc. Boise Cascade. Altitude 169 ft. Drilled by Art Clinton, 1959. Casing 8-in diam to 71 ft; perforated 41-71 ft		
Topsoil	3	3
Clay, brown	23	26
Sand and gravel	45	71
Shale, blue	14	85
8S/4W-21dba. Pacific Power and Light Co. Altitude 154 ft. Drilled by Art Clinton, 1957. Casing 16-in diam to 50 ft; perforated 20-45 ft		
Soil, alluvial	5	5
Clay, brown	5	10
Sand	5	15
Gravel, loose	15	30
Gravel and sand	20	50
8S/4W-26cdb. City of Monmouth. Altitude 173 ft. Drilled by Art Clinton, 1968. Casing 12-in diam to 66 ft; perforated 47-66 ft		
Topsoil	2	2
Clay, gray	32	34
Coarse sand and medium gravel	32	66
Clay, blue	6	72

8S/4W-28cdc1. City of Monmouth. Altitude 173 ft. Drilled by Art Clinton, 1966. Casing 12-in to 66 ft; perforated 45-65 ft

Materials	Thickness (feet)	Depth (feet)
Topsoil	2	2
Clay, gray	21	34
Sand, coarse and medium gravel	32	66
Clay, blue	6	72

8S/4W-30ada. Lloyd Crabb. Altitude 181 ft. Drilled by Todd's Drilling, 1969. Casing 6-in diam to 47 ft; perforated 36-45 ft

Materials	Thickness (feet)	Depth (feet)
Topsoil	5	5
Clay, brown silty	15	20
Clay, blue soft	4	24
Sand, fine brown	4	28
Clay, blue	11	39
Gravel	6	45
Clay, blue	25	70
Clay, brown	5	75
Clay, blue sandy	5	80

8S/4W-31bac. Allen Henry. Altitude 191 ft. Drilled by Todd's Drilling, 1973. Casing 8-in diam to 43 ft; perforated 22-42 ft

Materials	Thickness (feet)	Depth (feet)
Topsoil	2	2
Clay, brown	7	9
Clay, silty brown	12	21
Clay, sandy blue	5	26
Clay, blue	4	30
Sand, fine and blue clay	7	37
Clay, blue	6	43
Claystone, blue hard	37	80

8S/4W-31dda1. Daniel McClean. Altitude 200 ft. Drilled by Art Clinton, 1966. Casing 8-in diam to 122 ft; perforated 92-116 ft

Materials	Thickness (feet)	Depth (feet)
Topsoil	3	3
Clay, brown	23	26
Shale, blue	74	100
Rock, gray	22	122

8S/4W-33bbb. City of Monmouth. Altitude 175 ft. Drilled by Art Clinton, 1970. Cased 12-in diam to 60 ft; perforated 28-58 ft

Materials	Thickness (feet)	Depth (feet)
Topsoil	3	3
Clay, brown	23	26
Clay, blue	6	32
Gravel, medium	18	50
Clay, blue	5	55
Gravel, large	5	60

8S/5W-7bbb. Paul Olliff. Altitude 405 ft. Drilled by J. A. Sneed and Sons, 1972. Casing 6-in diam to 40 ft; unperforated

Materials	Thickness (feet)	Depth (feet)
Topsoil	1.5	1.5
Clay, yellow	5.5	7
"Basalt, weathered"	16	23
Claystone, gray firm	100	123
Sandstone, light gray	18	141

8S/5W-21dca. Alton Falk. Altitude 395 ft. Drilled by Robinson Eola Drilling, 1976. Casing 6-in diam to 51 ft; unperforated

Materials	Thickness (feet)	Depth (feet)
Soil	1	1
Clay, brown	9	10
Clay, gray	36	46
Claystone, gray	24	70
Sandstone, gray	164	234
"Old land" and wood	9	243
Claystone and sandstone, gray	57	300

8S/5W-24adb. Harry Brown. Altitude 195 ft. Drilled by J. A. Sneed and Sons 1964. Casing 6-in diam to 47 ft; unperforated

Materials	Thickness (feet)	Depth (feet)
Topsoil	2	2
Clay, yellow	21	23
Clay, blue	11	34
Conglomerate	11	45
Claystone, gray hard	30	75
Claystone, white hard	10	85

8S/5W-26bcd. John Stump. Altitude 215 ft. Drilled by J. T. Miller, 1960. Casing 12-in to 130 ft; an oil and gas exploration well

Materials	Thickness (feet)	Depth (feet)
Shale, blue	139	139
Sand	36	175
Shale, blue and gray sand	133	308
Sand and sandy gray shale	140	448
Shale, sandy gray	170	618
Sand and gray sandy shale	192	810
Shale, blue sandy	102	912
Sand and gray sandy shale	330	1244
Shale, gray sandy and hard gray shale	258	1502

9S/3W-7adc. Alluvial Farms. Altitude 170 ft. Drilled by Willamette Drilling, 1981. Casing 10-in diam to 49 ft; perforated 29-44 ft

Materials	Thickness (feet)	Depth (feet)
Topsoil	4	4
Clay, brown	10	14
Sand, brown and gravel	31	45
Clay, brown	8	53

9S/4W-2dca. Robert Fitts. Altitude 159 ft. Drilled by Todd's Drilling, 1974. Casing 12-in diam to 50 ft; perforated 39-49 ft

Materials	Thickness (feet)	Depth (feet)
Topsoil	2	2
Silt, brown, with clay	16	18
Gravel, medium coarse	32	50
Clay, red	8	58
Clay, blue	2	60

9S/4W-4bcd. Kenneth Nelson. Altitude 188 ft. Drilled by Robinson Well Drilling, 1971. Casing 12-in diam to 48 ft; perforated 30-36 ft

Materials	Thickness (feet)	Depth (feet)
Clay, brown	20	20
Sand, brown	7	27
Gravel, small and brown sand	9	36
Clay, blue with brown streaks	12	48

9S/4W-5bda. Ben Magill. Altitude 245 ft. Drilled by Robinson Drilling, 1991. Casing 6-in diam to 94 ft; perforated 69-93 ft

Materials	Thickness (feet)	Depth (feet)
Soil	1	1
Clay, brown	17	18
Clay, orange	28	46
Clay, brown	10	56
Clay, gray	6	62
Clay, gray with thin layers of small gravel and sand	33	95

9S/4W–9aac. Charles Bowman. Altitude 187 ft. Drilled by Willamette Drilling, 1964. Casing 10–in diam to 124 ft; perforated 46–55 ft

Materials	Thickness (feet)	Depth (feet)
Topsoil	2	2
Clay, brown	6	8
Clay, gray	4	12
Clay, blue	3	15
Clay, green	5	20
Silt, brown	10	30
Sand, black and wood	10	40
Sand, black and gravel	7	47
Clay, blue and sand	6	53
Clay, green and sand	2	55
Clay, gray	10	65
Clay, green	5	70
Clay, gray	10	80
Sand, black	34	114
Clay, green	10	124

9S/4W–9bab. Larry Smith. Altitude 197 ft. Drilled by Paul Dickerson, 1984. Casing 6–in diam to 35 ft; liner 4–in diam 27–140 ft; perforated 35–140 ft, gravel packed 1–140 ft

Topsoil	3	3
Clay, brown	17	20
Sandstone, brown	8	28
Clay, blue	21	49
Sandstone, blue	2	51
Claystone, gray	16	67
Sandstone, blue	2	69
Claystone, blue	22	91
Sandstone, blue	24	115
Clay, blue	6	121
Sand, blue	17	138
Clay, blue	2	140

9S/4w–10bad1. Luckiamute Water Coop. Altitude 168 ft. Drilled by Todd's Drilling, 1969. Casing 10–in diam to 59 ft; perforated 22–49 ft

Topsoil	2	2
Clay, gray	3	5
Clay, brown	8	13
Clay, green	5	18
Gravel, medium	32	50
Clay, blue	25	75

9S/4W–10bad2. Luckiamute Water Coop. Altitude 167 ft. Drilled by Todd's Drilling, 1974. Casing 12–in diam to 46 ft; perforated 35–45 ft

Topsoil	2	2
Clay, gray	2	2
Clay, brown	9	13
Clay, green	5	18
Gravel, medium coarse	27	45
Clay, blue	10	55

9S/4W–10bbb. Charles Bowman. Altitude 180 ft. Drilled by Willamette Drilling, 1965. Casing 12–in diam to 132 ft; perforated 50–60 ft

Topsoil	2	2
Clay, gray	33	35
Sand, black and gravel	23	58
Clay, blue	32	90
Clay, gray	40	130
Shale, gray	32	162

9S/4W–11acd. Wigrich Farms Inc. Altitude 162 ft. Drilled by Michael Waldroop, 1990. Casing 12–in diam to 49 ft; perforated 24–43 ft

Materials	Thickness (feet)	Depth (feet)
Clay, brown sandy	6	6
Clay, brown with some sand	6	12
Clay, brown sandy	5	17
Sand, brown fine–medium	1	18
Gravel, small–medium with fine–coarse brown sand	11	29
Sand, brown and gravel	9	38
Gravel, small–large with brown sand	5	43
Clay, blue	6	49

9S/4W–11bbd. Robert Fitts. Altitude 170 ft. Drilled by Todd's Drilling, 1975. Casing 6–in diam to 50 ft; perforated 35–48 ft

Topsoil	2	2
Clay, brown	10	12
Clay, sandy brown	6	18
Gravel with sand	30	48
Clay, blue	7	55

9S/4W–12acd. Gerald Morlan. Altitude 167 ft. Drilled by Ace Drilling, 1963. Casing 12–in diam to 38 ft; perforated 33–38 ft

Clay	4	4
Loam, sandy	4	8
Clay, sandy	10	18
Gravel, sand and clay	2	20
Gravel, "river run"	18	38

9S/4w–14dbb. Cecil Hultman. Altitude 168 ft. Drilled by Art Clinton, 1962. Casing 12–in diam to 36 ft; perforated 23–34 ft

Willamette soil	2	2
Clay, brown sandy	8	10
Clay and medium gravel	12	22
Gravel, large	14	36

APPENDIX C

RECORDS OF SELECTED WELLS AND SPRINGS

EXPLANATION

Well number: See page 7 for description.
Aquifer: Water bearing unit contributing to well.
Elevation (ELV): Elevation of land surface at well, determined from 1:24,000 scale topographic maps.
Depth of well (DPT): Depth of completed well in feet.
Diameter (DIA): Diameter of well bore in inches.
Open Interval: Top and bottom of open interval in feet.
Yield: Discharge in gallons per minute during pump test.
Drawdown (DD): The lowering of the water level (in feet) as a result of pumping.
Pumping Period (PP): Length of pump test in hours.
Method of discharge measurement (M): B, bailer; P, pump; A, air; R, reported.

Specific Capacity (SPEC. CAP.): Pumping rate divided by drawdown during pump test, reported values of 0 have been assigned <.1.
Water Level: Depths to water in feet, depths reported in decimal fractions were likely measured others were reported by owners or drillers, F denotes a flowing well.
Specific Conductance: Field measurements.
Use (U): Use of water: H, domestic; N, industrial; C, commercial; S, stock watering; I, irrigation; P, public supply; E, engineering; F, fire; G, oil and gas; U, unused.
Remarks (REM): B, Br analysis; C, Cl analysis; I, Iodide analysis; OD, oxygen-deuterium analysis; CA, chemical analysis; Salty, reported occurrence of salt water; HYD, hydrograph; Filled, back-filled.

WELL NUMBER	OWNER	YEAR COM-PLETED	AQUI-FER	ELV ft	DPT ft	DIA in	OPEN INTERVAL TOP ft	OPEN INTERVAL BOT ft	DEPTH CASED ft	YIELD gpm	DD ft	PP h	M	SPEC. CAP. gpm/ft	WATER LEVEL ft	DATE MEAS. YYYYMMDD	SPECIFIC CONDUC. µmhos/cm	DATE MEAS. YYYYMMDD	U	REM.
06S/05W –																				
33ACC	DESCHLER, TIM	1989	Ty	477	120	8	42	117	120	100	58	3	A	1.7	42.00	19891019			H	
															30.05	19910523				
07S/04W –																				
03CCC	KLIMCZAK, STAN	1987	Toe	250	200	6	100	200	200	14		1	A		17.00	19870813			H	
03CDA	BRUNKER, GRANT	1990	Toe	405	71	6	39	71	39	75	52	4	A	1.4	24.23	19901101	147	19911101	H	
O4DBA	ERICKSON, K	1987	Toe	450	147	6	39	147	147	40	24	1	B	1.7	39.77	19901111	53	19901111	H	
05BBB	COVILLE, MERTON	1968	Toe	248	72	8	40	71	40	12	40	1	B	0.3	43.27	19760721	800	19760721	H	
05DAA	ELLIS, VERTA	1967	Toe	468	248	6	37	248	37	1	231	1	A	<.1	23.93	19760722	45	19760722	H	
06DDB	LEPPIN, ARTHUR	1956	Toe	248	89	6	17	89	17	3	73		B	<.1	27.83	19760721	710	19760721	S	HYD
07ACC	LOWERY, JERRY	1973	Toe	195		6									22.56	19760721	1100	19760721	H	CA
08DDB	BOATWRIGHT, M	1973	Toe	202	120	6	25	120	25	7	95	1	B	0.1	21.93	19760722	430	19760722	H	
10AAD	JENSEN, KELTON	1978	Toe	615	245	6	205	245	245	20		2	A		183.98	19910120	223	19910120	H	
10BBB	GRIMSBO, DON	1957	Toe	225	78	6	61	78	61						10.00	19570300			H	SALTY
15AAA	FARM, NILA	1957	Tcr	545	110	6	69	110	69	26	90	2	B	0.3	10.00	19570613			H	
15DBD	BISHOP, ARTHUR	1958	Toe	315	61	6	39	40	41	19	30	2	B	0.6	29.00	19580721			H	
							41	61												
18ABD	ARMS, R	1965	Toe	215	118	6	26	118	26	8.3	60	1	P	0.1	50.65	19760722	3000	19760722	H	
19CCD	FAST, HARRY	1965	Ts	211	169	6	20	169	20	1	130	1	P	<.1	34.00	19651012			U	
21DCC1	BICE, HOLLIS	1969	Toe	175	78	12	32	36	47	30	27	1	B	1.1	37.77	19760722	1100	19760722	U	B,C,I,OD
21DCC2	BICE, HOLLIS	1962	Toe	175	90	8	25	45	55	25	11	2	B	2.3	14.00	19620811	1661	19910919	H	
							55	90							16.69	19910919	1580	19911130		
23DCC	HEINRICHS, JOHN	1963	Toe	305	180	6	172	180	172	20	120	2	B	0.2	58.00	19631010			H	
26AAB	RALSTON, DOUG	1979	Toe	400	258	6	38	258	38	10	100	1	A	0.1	154.00	19790913	791	19910120	H	
26CAB	SUNDBORG, E	1959	Toe	210	130	8	20	130	20	9	78	2	B	0.2	32.00	19621008	210	19761005	H	
26CAC	WADE, GUY	1969	Toe	240	86	6	68	86	86	15	50	2	A	0.3	39.26	19910917	186	19910917	H	
26CCB	MYERS, VIRGIL	1970	Toe	169	83	6	43	45	45	6	30	1	A	0.2	15.54	19760723	320	19760723	H	CA
							45	83												
26DCC	KENNEDY, DAVID	1975	Qoal	170	85	8	50	78	79	45	4	1	B	11.3	45.00	19750731			H	
							79	85												
26DCD	WHITEMAN, EDDIE	1966	Qoal	150	42	10	29	40	42	300	11	5	P	27.3	20.00	19660811			U	

WELL NUMBER	OWNER	YEAR COMPLETED	AQUIFER	ELV ft	DPT ft	DIA in	OPEN INTERVAL TOP ft	OPEN INTERVAL BOT ft	DEPTH CASED ft	YIELD gpm	DD ft	PP h	M	SPEC. CAP. gpm/ft	WATER LEVEL ft	DATE MEAS. YYYYMMDD	SPECIFIC CONDUC. µmhos/cm	DATE MEAS. YYYYMMDD	U	REM.
26DDB	CONVERSE, GRACE	1962	Qoal	160	85	8	45	75	84	250	46	4	P	5.4	29.00	19620108			I	
															35.90	19910917				
27CCB	SPLANE, ELZA	1962	Qoal	160	97	6	81	97	81	10	70		B	0.1	14.00	19620710			H	
28DCA	SAVAGE, BEN	1963	Toe	170	69	6	47	69	47	15	50	1	B	0.3	10.00	19630227			H	
28DCD	STINNETT, B	1958	Toe	165	62	6	46	62	46	3	45	1	B	0.1	15.00	19580909			H	
28DDC	BEYERS, LYLE	1960	Toe	171	111	6	51	111	51	10	80	1	B	0.1	17.47	19760723	1090	19760723	U	
29DDB1	SMULL, PAUL	1962	Toe	175	60	6	33	57	60	2			B		11.00	19620418			H	
29DDB2	BRAMAN, W	1958	Toe	175	48	6	28	33	48	2.5	30	1	B	0.1	16.00	19581010			H	
							45	46												
30CAC	RICKREALL	1966	Qoal	209	50	10	18	35	35	50	10		B	5.0	5.00	19660119	275	19760722	U	
	FARM SUPPLY						35	50							6.88	19760722	255	19901106		
30CCB	GRIMSBO, HUBERT	1966	Ts	215	95	6	82	95	95	1.5	7	2	B	0.2	20.00	19661208	1430	19911203	H	B,C,I,OD
															19.37	19911203				
30DAD	POLK COUNTY	1968	Ts	194	100	6	21	79	80	15	88	1.5	B	0.2	6.88	19760722	275	19760722	N	
	COOP						80	100									255	19901106		
31BAB	NORMAN, RICHARD	1969	Qoal	210	65	8	22	28	30	70	58	1	B	1.2	7.00	19690814			U	
							28	65												
31BAC	SHIER, ROBERT	1969	Qoal	211	51	6	31	41	51	15	17	1	B	0.9	5.58	19760723	260	19760723	H	
31BCD	DALLAS EQUIP.	1971	Qoal	213	28	6	22	27	28	40	4	2	B	10.0	6.70	19761006	230	19761109	C	CA
32AAB	ROTH, GARFIELD	1973	Ts	200	110	8	19	110	19	7	65		B	0.1	69.80	19760722	960	19760722	S	CA
33AAB	BEYERS, LYLE	1967	Toe	172	176	6	20	59	60	1.7	154	1	P	<.1	11.41	19760723	370	19760723	H	
							60	176												
33ADD	STEELE, RAYMOND	1975	Ts	171	100	6	32	100	32	20	90	2	B	0.2	20.25	19761006			H	
34BBD	FREEBORN, CLYDE	1970	Qoal	171	50	6	39	45	45	8	23	2	B	0.4	20.65	19761006			H	
							45	50												
34CCC1	VANDEROFF, DAVE	1969	Qoal	175	100	6	23	27	32	5.5	60	1	B	0.1	15.00	19690623	1300	19761005	H	
							32	100												
34CCC2	VANDEROFF, DAVE	1975	Toe	175	130	6	46	130	46	45	30	1	B	1.5	22.00	19750106			I	
34CCD	WEDEL, PAUL	1967	Qoal	176	120	10	28	29	40	11	90	1	B	0.1	12.05	19761005			U	
							32	34												
							40	120												
34DDC	RICKREALL WATER	1971	Qoal	172	65	12	40	54	41	125	33	24	P	3.8	27.00	19710427	285	19761012	P	CA
	ASSOCIATION						54	57												
							57	65												
35ABB	MUELLER, THOMAS	1973	Qoal	172	61	6	60	61	60	30	5	4	B	6.0	39.00	19730202			H	
35BAC	MUELLER, MRS E	1967	Qoal	176	79	10	57	78	79	300	16	1	P	18.8	45.43	19761005			I	
35CBB	BROWN, WALTER	1960	Qoal	175	58	6			58	30	3.5	1	B	8.6	40.00	19600928	236	19761005	H	
35CBC	RICKREALL WATER	1973	Qoal	169	60	12	40	52	60	110	15	48	P	7.3	36.40	19761012	320	19761012	P	
	ASSOCIATION						52	60												
35DBD	BROWN, W	1966	Qal	138	40	12	19	38	40	400	15.	1	P	25.9	10.32	19761013			I	
															11.43	19911202				
36BDB	GREEN VILLA	1957	Qal	135	39	10	21	35	35	500	5	0.5	P	100.0	15.00	19570122	232	19910912	I	
	FARMS						35	39												
36BDD	KENNEDY, DAVID	1964	Qal	141	43	12	22	31	34	510	14	2	P	36.4	18.87	19761013			I	
							34	43												
07S/05W –																				
01CAD	DRISCOLL, C	1970	Ts	240													1210	19911130	H	B,C,I,OD
02BAC	BEYERLE, GEORGE	1957	Qoal	226	40	12	14	20	20	0.1		12	B		1.43	19760427	250	19760427	U	CA
							20	40												
05BDB	HOEKSTRE, FRANK	1960	Ty	220	45	12			45	5			P		7.00	19600627			H	SALTY, FILLED

WELL NUMBER	OWNER	YEAR COMPLETED	AQUIFER	ELV ft	DPT ft	DIA in	OPEN INTERVAL		DEPTH CASED ft	YIELD gpm	DD ft	PP h	M	SPEC. CAP. gpm/ft	WATER LEVEL ft	DATE MEAS. YYYYMMDD	SPECIFIC CONDUC. µmhos/cm	DATE MEAS. YYYYMMDD	U	REM.
							TOP ft	BOT ft												
05DDA	HOEKSTRE, DON	1991	Ty	510	140	6	29	140	29	30	61	1	A	0.5	69.00	19911015	516	19911020	H	B,C,I
															68.47	1991202	550	19911202		
06BBC	ANDERSON, W	1979	Ty	240	158	6	22	158	22	1	128	1	A	<.1	12.00	19790731	1611	19911130	H	B,C,I
															5.38	19911130				
06BDD	SEXTON, DARREL	1974	Ty	217	47	6	19	47	19	3	32.	1	B	0.1	19.79	19760428	1180	19760428	H	CA
07CAB	JOHNSON, JUDY	1973	Tsr	555	242	6	34	242	34	2.5	197	1	A	<.1	15.07	19760505	220	19760505	H	
07DAD	MINAHAN, GARY	1990	Ty	540	175	6	6	175	175	20	60	4	B	0.3	60.00	19901214			H	
07DDA	SCHIERLING, A	1979	Ty	450	293	6	19	293	293	1		1	A		60.00	19790611			H	
07DDD	SCHIERLING, A	1979	Ty	500	113	6	11	113	113	8		1	A		10.00	19790613	258	19911103	H	
08BCC	HEVNER, C	1965	Ty	275	163	6	20	163	20	4	150	1	P	<.1	11.00	19650521	480	19760430	H	
08DDA	SCHROCK, ALLEN	1990	Ty	420	119	6	59	119	59	30		1	A		37.80	19911002	225	19911002	H	
08DDD	WYNIA, CLIFFORD	1973	Ty	480	218	6	59	218	59	22	130	1	A	0.2	86.69	19760504			U	
09BCC	HOEKSTRE, HENRY	1960	Ty	218	36	12	16	36	16	3.3			P		2.49	19760504	130	19760503	H	
09CCB	WYNIA, CLIFFORD	1975	Ty	360	118	6	60	112	61	30	60	1	A	0.5	55.75	19760504			U	
						5			114											
10BCC	WALL, FRANK	1965	Ts	300	140	8	20	140	20	1					20.00	19651115			H	
10CAC	HARRIS, VERN	1967	Ts	305	143	6	56	143	56	4	104	1	A	<.1	11.87	19760505	130	19760505	H	
10CBD	SIMPSON, W	1960	Ts	315	55	10	12	55	12	3.3			P		4.47	19760428	130	19760428	U	
13ACA		1955	Toe	245	100	6	37	45	45	5			P		19.78	19760429	810	19760429	S	
							45	100												
14CBD	HAINSWORTH, C	1968	Ts	190	114	6	21	114	21	1					37.00	19680829			H	
15AAC	SCHELLENBERG, D	1969	Toe	272	129	6	21	129	21	0.3	84	1	A	<.1	4.95	19760429	1100	19760429	U	CA
15DCB	VANWINKEL, C	1971	Qt/Ts	290	173	6	27	46	47	8	150	1	A	0.1	14.00	19710401			H	
							47	173												
15DCC	WIEBE, HARRY	1965	Qt	290	65	6	27	32	38	8	50	1	B	0.2	5.93	19760429	90	19760429	H	
							38	65												
16AAB	TRUSSELL, DON	1981	Ty	260	311	6	19	311	19	1.5		1	A		4.00	19810922			H	
16ABB	FRIESEN, EDWARD	1989	Ty	310	131	6	24	131	24	6	91	1	A	0.1	40.00	19891102			H	
16CDD	KOLSKI, JOHN	1973	Ty	348	176	6	29	176	29	15.5	146	1	A	0.1	13.45	19760430			U	
16DCB	DAVIS, TOM	1990	Ty	390	198	6	28	198	28	28		1	A		66.00	19900814			H	
16DCC	DALKE, GERALD	1969	Ty	335	132	6	40	132	40	120	90	1	A	1.3	30.34	19760430	265	19760430	H	
16DDB	SIMPSON, ROSS	1974	Ty	302	240	10	20	240	20	200	171	1	A	1.2	9.92	19760504	330	19760504	U	
17ADB	JOHNSON, RICK	1985	Tsr	420	150	6	27	150	27	50	4	1	P	12.5 F		19910913	410	19910913	H	
17BCD	AIME, GEORGE	1970	Tsr	680	117	6	40	117	40	6	62	1	A	0.1	21.41	19760506	150	19760506	H	
17CDD	SIEROSLAWSKI, E	1972	Ty	720	178	6	41	178	41	60	69	1	A	<.1	94.20	19760506	310	19760506	H	
18AAB	DOMASCHOFSKY, J	1979	Tsr	610	65	6	36	65	44	30			A		24.00	19790719			H	
18ABB	FRESH, LARRY	1972	Tsr	738	202	6	85	202	85	9	120	1	B	0.1	70.30	19760505	140	19760505	H	
18ADA	MILLER, ROBERT	1972	Tsr	675	71	6	40	71	40	50	23	1	A	2.2	40.32	19760505	205	19760505	H	
18ADB	STULL, W	1969	Tsr	706	370	6	44	370	44	2	369	1	A	<.1	2.05	19760505			U	
19ACA	UNRUH, EDWARD	1971	Ty	614	250	6	110	230	10	3	200	1	B	<.1	56.76	19760506	580	19760506	H	
						5			250											
19BDC	DUNMIRE, ERNEST	1973	Ty	622	157	6	26	157	26	18	137	1	A	0.1	26.79	19760507	375	19760507	H	
19CBB	PORTER, RICHARD	1974	Ty	570	135	6	39	135	39	30	100	1	A	0.3	34.18	19911014	356	19911014	H	
19CCA	SEYMOUR, LYLE	1969	Ty	602	323	6	31	323	31	3	250	1	A	<.1	235.23	19760509	925	19760507	H	
19CDB	SEYMOUR, LYLE	1971	Ty	603	554	6	27	554	27	14			A				300	19760507	H	
19CDC	LUCHAU, JOHN	1990	Ty	560	238	6	25	238	25	10		1	A		43.00	19900920			H	
20AAA	DICKERSON, PAUL	1971	Ty	412	100	6	80	100	80	32		1	B		22.24	19760506	330	19760506	H	
20CDC	TRAINOR, W	1974	Ty	430	218	6	19	218	19	2	155	1	A	<.1	110.40	19760507	1500	19760507	H	
21BCD	DICKERSON, PAUL	1975	Ty	322	110	6	21	110	21	45	30	1	B	1.5	27.41	19760430			U	
22AAC	VOGEL, LEE	1969	Qt	295	50	6	35	41	44	5	32	1	B	0.2	12.00	19690313	75	19760518	H	
							44	50												
22BDB	DUNN, ALLEN	1968	Ts	305	191	6	27	191	27	0.5	166	1	A	<.1	27.87	19760518	530	19760518	H	
25AAC	FLEMING, H	1966	Ts	205	36	6	23	32	36	15	21	1	B	0.7	5.56	19760519	265	19760519	I	

WELL NUMBER	OWNER	YEAR COM-PLETED	AQUI-FER	ELV ft	DPT ft	DIA in	OPEN INTERVAL		DEPTH CASED ft	YIELD gpm	DD ft	PP h	M	SPEC. CAP. gpm/ft	WATER LEVEL ft	DATE MEAS. YYYYMMDD	SPECIFIC CONDUC. µmhos/cm	DATE MEAS. YYYYMMDD	U	REM.
							TOP ft	BOT ft												
25DAD	LARSEN, RUSSELL	1968	Ts	205	47	6	22	44	47	22	20	1	B	1.1	13.09	19760519	235	19760519	H	
26CDB	COOK, LELAND	1970	Qt	270	85	6	33	53	54	2.5	70	1	A	<.1	14.75	19700605			H	
							54	85												
26CDC	LESTER, LARRY	1974	Qt	265	120	6	113	125	113	10	20	2	B	0.5	12.59	19760519	205	19760519	I	
27CAC	RUGGLES, CLARK	1973	Qt	322	78	6	33	39	41	20	69	1	A	0.3	10.88	19760519	170	19760519	H	
							41	78												
27CCD	FRINK, CHARLES	1981	Qt	310	113	6	38	113	113	10		1	A		10.00	19810526			H	
27CDA	GAINS, CLYDE	1969	Qt	315	51	6	21	33	42	17	33	2	B	0.5	12.83	19690721			H	
							42	51												
27DCC	SIMS, ED	1978	Qt	290	110	6	63	66	67	36	15	1	B	2.4	15.00	19780718			H	
							66	110												
29CAD	BITIKOFER, M	1974	Ty	370	38	6	20	38	20	3			A		3.98	19760520	5500	19760520	U	CA
31DAB1	HUTCHINSON, W	1990	Ty	490	260	6	40	240	260	3		2	A		30.00	19900718	338	19911014	H	
31DAB2	MEYER, BUTCH	1990	Ty	540	215	6	30	215	29	3.5	180	1	B	<.1	35.00	19901206	346	19910919	H	B,C
						4			215						77.60	19911203	397	19911203		
31DBB	BROWN, DENNIS	1990	Ty	570	198	6	39	198	39	14		1	A		65.00	19900418	232	19921014	H	
31DBC	FREISEN, ALTON	1971	Ty	595	191	6	40	191	40	2.5	165	1	A	<.1	26.08	19760811	265	19760811	H	
32CBA	TEAL, ORVAL	1971	Qt	380	80	6	40	80	40	5	80	2	B	0.1	22.00	19710730			H	
34ACA	KROEKER, MARTIN	1959	Qt	270	56	6	25	52	52	25	16	1	B	1.6	4.51	19760520	375	19760520	H	
							52	56												
34BBD	REEVES, JERRY	1971	Qt	295	60	6	48	54	57	14	25	1	B	0.6	6.97	19760520	160	19760520	H	
							57	60												
34DBC	DALLAS ASSEMBLY OF GOD	1980	Qt	275	213	10	90	213	231	18		2	A		30.00	19801101			I	
35BAB	ANDERSON, W	1971	Qt	260	71	6	34	71	71	6	59	1	A	0.1	12.99	19760519	110	19760519	H	
35BBB	SHARP, T	1973	Qt	276	95	6	63	95	63	8	77	1	B	0.1	7.27	19760520	115	19760520	I	
35CAB	SAND STRIP GOLF COURSE	1988	Qoal	245	75	8	25	35	60	40	5		B	8.0	15.00	19881031	220	19910913	I	
						6	45	58	75						14.32	19910913				
							55	75												
07S/06W –																				
12AAD	WOODRUM, W	1970	Ty	450	272	6	55	272	55	19	95	1	A	0.2	97.30	19760505	240	19760505	H	
12ADD	GREEN, BOB	1981	Ty/Tsr	620	526	6	65	526	65	6		1	A		420.00	19830809			H	
12CCD	DHABOLT, J	1970	Tsr	1115	45	6	25	45	25	8.3	33	1	B	0.3	4.95	19760511	235	19760511	H	
13AAC	BELTZ, DAVID	1970	Tsr	925	402	6	50	402	50	5	310	2	A	<.1	107.10	19760511	195	19760511	H	
13ABD1	KING, LEROY	1970	Tsr	857	98	6	64	98	64	45	50	2	A	0.9	37.15	19760511	260	19760511	H	
13ABD2	JONES, C	1974	Tsr	855	160	6	80	160	80	50	138	1	A	0.4	32.67	19760511	280	19760511	H	
13CCC1	BRIGGS, HARRY	1976	Ty	890	103	6	31	103	31	14	48	1	A	0.3	53.21	19760520	200	19760520	U	
14DBC	MERRYMAN, LARRY	1969	Tsr	990	161	6	21	161	24	1	141	1	A	<.1	43.00	19760513	180	19760513	H	
14DDC	WILSON, NORMAN	1956	Tsr	800	160	6	21	160	21	2	143		B	<.1	25.69	19760512	180	19760512	H	
24BDC	TERRY, HOWARD	1972	Ty	778	118	6	23	118	23	6	80	1	A	0.1	26.71	19760513	265	19760513	H	
24CAC	WYSCAVER, ELDON	1974	Ty	758	161	6	23	161	23	2	143	1	A	<.1	8.22	19760512	260	19760512	H	
24CDB	TOMPKINS, KEN	1990	Ty	780	210	6	24	210	210	5	155	1	P	<.1	5.00	19900607			H	
24CDC	JOHNSON, F	1963	Tsr	681	130	6	28	48	67	30	62	2	B	0.5	40.00	19630726	120	19760512	H	
							67	130												
25ACA	HUDSON, ROBERT	1970	Ty	630	82	6	40	80	40	20	37	2	B	0.5	25.71	19760512	165	19760512	H	
25CBD	BOWMAN, THOMAS	1990	Ty	540	340	6				1		1	A						H	
36CCA	HAYES, ROBERT	1973	Tsr	692	116	6	31	116	31	7.5	82	1	A	0.1	45.48	19760514			H	
36CCD	PARSONS, TOM	1974	Tsr	680	271	6	54	271	54	3	229	1	R	<.1	35.56	19760514	105	19760514	H	
36DBD	SPENGLER, MIKE	1973	Tsr	642	162	6	59	162	59	8	115	1	A	0.1	38.00	19760514	50	19760514	H	

WELL NUMBER	OWNER	YEAR COM–PLETED	AQUI–FER	ELV ft	DPT ft	DIA in	OPEN INTERVAL TOP ft	OPEN INTERVAL BOT ft	DEPTH CASED ft	YIELD gpm	DD ft	PP h	M	SPEC. CAP. gpm/ft	WATER LEVEL ft	DATE MEAS. YYYYMMDD	SPECIFIC CONDUC. µmhos/cm	DATE MEAS. YYYYMMDD	U	REM.
06S/04W –																				
02BBA	SETNIKER, FRANK	1961	Qal	144	45	12	33	43	45	640	11	7	P	58.2	20.10	19760929			I	
02CAC1	GREEN VILLA FARMS	1975	Qal	150	53	12	35	48	52	1700	10		P	170.0	24.00	19750731	215	19910912	I	
							52	53												
02CAC2	GREEN VILLA FARMS	1975	Qal	150	46	6			46	30			B	30.0	24.00	19750923	248	19761013	N	CA
															29.26	19910912				
03AAC	MULLER, T	1968	Qoal	164	48	8	27	45	48	60	10		B	6.0	20.00	19680614	320	19760929	H	
03ABD1	MULLER, T	1962	Qoal	169	60	12	38	56	60	400	28	6	P	14.3	26.00	19620414			I	HYD
															34.79	19910913				
03ABD2	MULLER, LEO	1975	Qoal	169	51	8	42	45	51	50	2		B	25.0	30.00	19751004			H	
03DBA	EVANS, CHAS	1960	Qal	150	52	6	33	42	45	70	19	1	B	3.7	21.00	19600219			H	
							45	52												
04ACA	KNAUPP, DAVID	1963	Qoal	171	50	10	38	47	50	18	13	2	B	1.4	22.00	19630802	480	19760930	S	
04BCC	DALKE, BRUCE	1973	Qoal	186	49	6	39	49	39	12	38	1	B	0.3	11.00	19730625			H	
04CCC	RAIBLEY, LEE	1966	Qoal	186	51	6	35	45	51	20	19	1	B	1.1	20.00	19661012	440	19761005	H	
04CDD	PETERSON, LOUIS	1971	Qoal	177	80	6	31	80	31	7	72	2	B	0.1	12.06	19760929	330	19760929	H	
04DAB	PETERSON, JOHN	1975	Qoal	171	65	6	38	65	38	10	41	2	B	0.2	24.00	19750918			H	
04DAC	WATTENBERGER, D	1969	Ts	162	65	6	37	65	37	30	30	2	B	1.0	25.64	19760930	610	19760930	H	
04DBA	PETERSON, GROVE	1971	Qoal	168	80	6	31	37	40	9	62	2	B	0.2	18.00	19710823			H	
							40	80												
06BAC1	BOYER, WALTER	1959	Ts	222	121	6	42	121	42	8	100	1	B	0.1	12.00	19591019			H	
06BAC2	BOYER, WALTER	1955	Ts	225	141	6	26	141	28	6	132		B	0.1	14.00	19550909			H	
06BBD	KESTER, W	1959	Ts	224	75	12	36	75	36	9.2			B		15.71	19761006			H	
06CAC1	HERRERA, K	1955	Ts	222	80	6	48	80	48	5	65		B	0.1	18.30	19761006			H	
06CAC2	KOPPENSTEIN, C	1969	Qoal	222	58	8	25	45	50	5	40	2	B	0.1	14.00	19690701			H	
							50	58												
07ABA	HANSON, D	1972	Qoal	208	40	6	22	31	32	3	5	2	B	0.6	5.00	19720705			H	
							31	40												
07CCA1	OAKES, ROD	1973	Qoal	201	77	8	63	73	76	25	22	1	B	1.1	38.00	19730827			H	
							76	77												
07CCA2	WILLAM. POLLEN	1980	Qoal	205	80	10	55	75	75	40	52	1	B	<.1	18.00	19800709	540	19910917	I	B,C,I
							75	80							15.97	19910917	335	19911202		
															7.63	19911202				
07CCD	WILLAM. POLLEN	1991	Qoal	202	95	8	63	78	82	36	60	2	B	0.6	30.00	19911025			I	
08BBC	ROGERS, JOE	1969	Qoal	201	73	6	22	40	66	3	50	2	B	0.1	12.00	19690909			U	
							56	64												
							66	73												
09AAA1	DUNCAN, W	1969	Qoal	165	45	8	37	43	45	35	6	1	B	5.8	25.34	19760930	320	19760930	H	
09AAA2	BISBEE, DONALD	1965	Qoal	165	45	12	34	43	44	70	19		P	3.7	22.00	19651022			H	
															21.80	19910919				
09AAB1	EDMONDS, EARL	1973	Ts	167	43	6	42	43	42	30	4	1	B	7.5	28.00	19730731			H	
09AAB2	KNAUPP, DAVID	1968	Qoal	167	50	12	35	44	45	80	23	3.5	P	3.5	30.00	19680515			I	
09AAC	GEISBRECHT, E	1972	Qoal	165	55	8	34	53	55	100	29	1	B	3.5	19.00	19720715			I	
09ACD1	HARDMAN, GLEN	1970	Qal	165	46	6			46	22	20	1	B	1.1	23.25	19700813	320	19760930	H	
09ACD2	EDIGER, DONALD	1970	Ts	165	54	6	42	54	42	25	20	1	B	1.3	23.00	19700815	260	19760930	H	
09CDB	ROGERS, HUGH	1966	Qoal	169	190	6	27	35	38	4	160	1	B	<.1	25.00	19660926			S	
							38	190												
09CDC	ROGERS, HUGH	1963	Qoal	168	65	8	26	38	42	6.7	42	2	B	0.2	24.00	19630304			H	
							42	65												
09CDD	ALDERSON, W	1965	Qoal	167	51	8	28	43	44	35	8	1	B	4.4	23.90	19760930	480	19760930	H	
							44	51												

WELL NUMBER	OWNER	YEAR COM- PLETED	AQUI- FER	ELV ft	DPT ft	DIA in	OPEN INTERVAL TOP ft	OPEN INTERVAL BOT ft	DEPTH CASED ft	YIELD gpm	DD ft	PP h	M	SPEC. CAP. gpm/ft	WATER LEVEL ft	DATE MEAS. YYYYMMDD	SPECIFIC CONDUC. µmhos/cm	DATE MEAS. YYYYMMDD	U	REM.
09DBA	GREEN VILLA FARMS	1962	Qoal	160	89	6	45	89	45	16	50		B	0.3	27.00	19620906			H	
10ADC	MADJIK FARMS	1990	Qal	150	38	12	19	35	38	65		1	B		14.00 26.24	19901205 19910911			I	
11CAD	HAAS, JOHN	1988	Qal	150	46	8	36 41	41 46	36	47	5	1	B		17.00 21.75	19880104 19910911	241 262	19910911 19911202	I	B,C,I,OD
11DBB1	HASS, JOHN	1991	Qal	145	39	8	24	36	39	66	2	1	B		15.00 20.42	19910318 19910911			I	
11DBB2	JOHN I HAAS INC	1950	Qal	145	37					425	0.7	4	P	607.1	22.50	19910715			I	
15BBB	GREEN VILLA FARMS	1969	Qal	148	34	12	18	30	34	500	7	2	P	71.4	14.00	19690914			I	
15BCC	GREEN VILLA FARMS	1973	Qal	151	41	18	21	41	21	400	23	5	P	17.4	16.67 16.90	19761013 19900806			I	
16ADC	GREEN VILLA FARMS	1973	Qal	155	38	8	18	38	18	800	20	4	P	40.0	15.58	19761013			I	
16DAC	SETNICKER FARMS	1991	Qal	150	42	12	21	37	42	75	7	1	B	10.7	11.00	19911018			I	
18ACD	ROBERTS, HERB	1972	Qoal	191	32	6	24	29	31	18	15.	2	B	1.2	8.00	19720204			H	
18DBA	ROBERTS, HERB	1972	Qoal	188	56	6	26 44	38 56	44	40	12	3	B	3.3	6.00 14.58 12.91 13.25	19720306 19761006 19900807 19900911			I	
18DBD1	LEBECK, TED	1957	Qoal	187	60	10	23 33	33 60	33	140	21	2	P	6.7	13.30	19761109	295	19761109	I	CA
18DBD2	FOX, CARIE	1978	Qoal	185	40	6	30 34	34 40	34	10		3	B		14.34	19910911	260	19910911	H	
19BCA	JEPSON, WESLEY	1988	Qoal	192	90	6	33 40 51	55 41 53	56	2	68	1	B	<.1	17.00 23.90 21.89	19880829 19911019 19911202	931 946	19911019 19911202	I	BCI,OD SALTY AT DEPTH
19BDB	REYNOLDS, LOREN	1964	Qoal	184	55	8	28	47	55	15	31	1	B	0.5	15.90	19761015	850	19761015	H	CA
20BDD	RENNINGER, EARL	1974	Qoal	182	33	6	27	30	33	25	10	2	B	2.5	10.00	19740821	410	19761015	H	
20CDD1	MELANDY, PAT	1961	Qoal	163	36	6	28	34	36						10.90	19761015	375	19761015	R	
20CDD2	ODOT.	1962	Qoal	162	60										9.00	19620408			E	
21BAA	RIDENOUR, L	1976	Qoal	160	60	8	42	50	51	50		1	B	50.0	27.00	19760527			I	
21BDC	BOISE CASCADE	1959	Qoal	169	85	6	41 71	71 85	71						27.00	19590703			N	
21DBA	PACIFIC POWER	1957	Qal	154	50	16	20	45	50	1200	14	25	P	85.7	18.00	19570714			U	
22AAA	SETNIKER, FRANK	1960	Qal	141	26	17				350			R		10.81 14.17	19761007 19910911	225	19761007	I	
22ABD	SETNIKER, FRANK	1960	Qal	155		12				500			R		29.97 25.01	19900807 19910911	224 294	19761007 19900809	I	CA
22BAB	SETNIKER, FRANK	1956	Qal	150	63	12	20 60	 63	60						18.43 20.07	19761007 19910911			I I	
28ABC	VALLEY CONCRETE AND GRAVEL	1972	Qal	152	49	10	39	47	47	50		2	B	50.0	21.50	19720512			N	
28BAA	ODOT.	1979	Qoal	151	63										14.00	19790424			E	
28CDA	WEBBER, JOHN	1990	Qal	168	60	12	60		60	40	2	1	B	20.0	39.00	19900605	272	19911019	H	
28CDB	CITY OF MONMOUTH	1968	Qoal	173	72	10	47 66	66 72	66	270	22		P	12.3	37.50	19680329	400	19761109	P	CA
28CDC1	CITY OF MONMOUTH	1968	Qoal	173	72	10	45 66	65 72	66	165	12		P	13.7	36.00	19680318			P	

WELL NUMBER	OWNER	YEAR COM–PLETED	AQUI–FER	ELV ft	DPT ft	DIA in	OPEN INTERVAL TOP ft	OPEN INTERVAL BOT ft	DEPTH CASED ft	YIELD gpm	DD ft	PP h	M	SPEC. CAP. gpm/ft	WATER LEVEL ft	DATE MEAS. YYYYMMDD	SPECIFIC CONDUC. µmhos/cm	DATE MEAS. YYYYMMDD	U	REM.
28CDC2	CITY OF MONMOUTH	1969	Qoal	174	62	12	41	60	62	170	12	4	P	14.2	39.00	19690925			P	
28CDC3	CITY OF MONMOUTH	1969	Qoal	174	62	12	40	60	62	280	14	9.5	P	20.0	38.00	19691016			P	
28CDC4	CITY OF MONMOUTH	1978	Qoal	173	65	***	51	62	51	230	10	24	P	23.0	38.58	19900803			P	
28DBB	ODOT.	1984	Qal	145	67														E	
29BCA	PEBLEY, CLAY	1981	Qoal	182	50	6	37	45	49	10	26	1	B	0.4	20.00	19801121			H	
29BDC	DUGGER, J	1968	Qoal	177	46	8	32	42	46	20	18	1	B	1.1	14.30	19761014	320	19761014	H	
29CAA	HUMPHREY, C	1964	Qoal	175	61	10	47	59	61	40	12	1	B	3.3	41.60	19761014	350	19761014	C	
29CCA	CURRIE, JEROME	1969	Qoal	171	80	6	37	40	42	1.5	74	2	B	<.1	15.30	19761014	1100	19761014	H	
							42	80												
29DBB	RICHARDS, MATT	1989	Qoal	175	61	6	59	61	59	60		1	A		24.00	19890618			H	
30AAD	GORNICK, P	1972	Qoal	181	65	6	39	40	63	30	20	2	B	1.5	13.90	19761013	600	19761013	H	
							51	53												
							63	65												
30ABD	SACRE, A	1959	Qoal	185	60	6	40	52	56	10	44	1	B	0.2	6.00	19591005			H	
30ADA	CRABB, LLOYD	1969	Qoal	181	80	6	42	45	47	40	12	2	B	3.3	16.50	19761013	625	19761013	H	B,C,I
							47	80							25.79	19900808	564	19900808		
															28.02	19910917	610	19911202		
30DBB	PURVINE, DANE	1975	Ts	187	63	6	22	37	40	10	51	2	B	0.2	12.00	19751014			U	
							40	63												
31BAC	HENRY, ALLEN	1973	Qoal	191	80	8	22	42	43	5	64		B	0.1	17.00	19761013	510	19761013	H	
31BDB	PESANO, JAMES	1957	Qoal	190	55	6	19	25	40	30	6		B	5.0	19.70	19761013	680	19761013	H	
							40	55												
31DDA1	MCLEAN, DANIEL	1966	Ts	200	122	8	92	116	122	8	90	1	B	0.1	30.30	19761008	2650	19761008	S	B,C,I,OD,CA
							116	122							39.70	19911019	2601	19911019		
																	2400	19911201		
31DDA2	MCLEAN, DANIEL	1959	Ts	203	132	12	40		72	4.2			B		94.60	19761008	483	19761008	H	
							72	132							108.73	19911012	430	19911012		
32BBA	MULL, GWANE	1967	Ts	168	73	8	32	70	73	2	48	1	B	<.1	19.80	19761014	875	19761014	S	
32CCD	GILLIAM, MAX	1964	Qoal	193	57	6	47	55	57	15	31	2	B	0.5	11.80	19761008	560	19761008	H	
32DCD	LAMERS, BILL	1976	Ts	185	100	4	40	100	100	2	94	2	B	<.1	12.60	19761008	390	19761008	H	
33BBB	CITY OF MONMOUTH	1970	Qoal	175	60	12	28	58	60	153	15.		P	9.8	35.00	19701015			P	CA
33CCC	CASCADE FARM SERVICE	1969	Qoal	182	70	6	50	70	70	15	18	1	B	0.8	34.20	19761007	580	19761007	N	
33DAB	CITY OF MONMOUTH	1990	Qal	155	50	6	26	38	39	90	6.6	7	P	13.6	23.01	19900803				
							39	50												
08S/05W –																				
01CCD1	WARKENTIN, H	1970	Qoal	223	55	6	51	53	55	50	20	2	B	2.5	8.02	19760810	425	19760810		
01CCD2	WARKENTIN, H	1973	Qoal	223	64	8	54	59	60	50	15	2	B	3.3	8.46	19760810			U	
							60	64												
02ADA	GIESBRECHT, M	1979	Qoal	235	55	6	46	56	55	10	40	4	B	0.3	5.00	19790719			H	
02CBB	SCHAECHER, DON	1990	Qoal	50	125	6	29	125	125	15	60	1	P	0.3	7.00	19900808			H	
02DCD	CLENDENIN, CHET	1970	Ts	313	216	6	80	216	80	9	119	2	A	0.1	136.65	19760810	540	19760810	H	
03ACA	TRIPPLE T. DAIRY	1990	Ts	270	100	6	20	100	100	10	75	1	B	0.1	15.00	19900327			H	
04CAC	ALBRECHT, H	1970	Ts	407	131	6	20	39	40	12	110	1	A	0.1	39.57	19760813	520	19760813	H	
							40	131												
05DDC	FORSBERG, NORM	1969	Ty	515	110	6	33	110	33	9	70	1	B	0.1	30.00	19690707	480	19760811	I	

WELL NUMBER	OWNER	YEAR COM– PLETED	AQUI– FER	ELV ft	DPT ft	DIA in	OPEN INTERVAL TOP ft	OPEN INTERVAL BOT ft	DEPTH CASED ft	YIELD gpm	DD ft	PP h	M	SPEC. CAP. gpm/ft	WATER LEVEL ft	DATE MEAS. YYYYMMDD	SPECIFIC CONDUC. µmhos/cm	DATE MEAS. YYYYMMDD	U	REM.
06CDC	DICKEY, JAMES	1973	Ty	515	161	6	38	161	40	6	129	1	A	0.1	36.33	19760812	280	19760812	H	
07BBB	OLLIFF, PAUL	1972	Ty	405	97	6	40	97	40	11	88	1	A	0.1	18.45	19760728	610	19760728	H	CA, SALTY AT DEPTH
07BCD	HANSEN, TOM	1974	Ty	724	161	6	52	161	52	50	71	1	A	0.7	99.78	19760813	210	19760813	H	
08BBC	PATZLAFF, IRVIN	1967	Ty	435	99	6	40	99	40	2.5	75	1	P	<.1	23.76	19760813			U	
09DCB	BRANDT, VICTOR	1970	Ts	655	100	6	78	100	78	11	38	1	B	0.3	59.96	19760813	210	19760813	H	
10BAB	FLEMING, JERRY	1984	Ts	580	200	6	11	200	200	9		1	A		14.00	19840301	243	19920229	H	
11ABD	CLENDENIN, CHET	1973	Ts	316	311	6	40	59	60	4	296	1	A	<.1	11.23	19760810			U	
							60	311												
11ACD	NALL, FRANK	1973	Ts	416	251	6	58	80	81	5	236	1.5	A	<.1	20.09	19760810	70	19760810	H	
							81	251												
12DCC	HASSLER, EARL	1975	Qoal	212	57	6	39	42	55	20	39	2	B	0.5	16.19	19760810	400	19760810	H	
							55	57												
13ADC	CASTLE, FLOYD	1962	Qoal	201	59	6	58	59	59	25	20	1	B	1.3	15.64	19760811	1100	19760811	H	
14AAC1	CARMICHAEL, C	1972	Qoal	259	89	6			86	10	59	1	B	0.2	22.00	19720128	280	19760811	H	
14AAC2	HILL, WALLACE	1966	Qoal	262	72	8	42	62	72	15	42	1	B	0.4	32.85	19760811	165	19760811	H	
15ADB	SEVIER, ROBERT	1965	Ts	290	175	8	57	97	99	3	158	1	B	<.1	100.28	19760812	780	19760812	H	
							99	175												
15CCB	ELLIS, DEAN	1971	Ts	516	244	6	46	244	46	4	183	1	B	<.1	54.98	19760812	270	19760812	U	
16ACC	GORMAN, KENNETH	1974	Ts	635	85	6	33	85	33	30		2	B	30.0	63.66	19760812	340	19760812	H	
21DCA	FALK, ALTON	1970	Ts	395	300	6	51	300	51	12	210	1	B	0.1	93.30	19760805	950	19760805	H	CA
21DCB	HUXFORD, GARY	1974	Ts	505	185	4	120	185	185	4	95		B	<.1	105.00	19760805	470	19760805	H	
					185	6			33											
22BDB	ROSS, NORMAN	1973	Ts	422	90	6	20	90	20	20		2	B	20.0	77.00	19760806	305	19760806	U	
23BDC	ZIMMERDAHL, R	1969	Ts	303	82	6	70	82	70	45	67		A	0.7	48.00	19760806	350	19760806	H	
24ADB	BROWN, HARRY	1964	Ts	195	85	6	47	85	47	35			B		22.10	19760806	500	19760806	H	
26ACA	KIRSHNER, ROGER	1971	Qoal	254	80	6	73	78	80	30	35	2	B	0.9	23.80	19760806	255	19760806	H	
26BCD	MILLER, JOHN	1980	Ts/Ty	215	1502	12	130		130										G	
26DDD	BORK, ELMER	1981	Ts	265	72	6	52	70	72	17		1	A		23.00	19810924	458	19900930	H	
33AAD	KEGGIN, BILL	1975	Ts	685	258	5	39	258	39	1	140		A	<.1	109.00	19751104	850	19760804	H	
						6			20											
08S/06W –																				
01BCD	KENYON, R.	1972	Ty	895	186	6	34	39	40	7	143	1	A	0.1	103.55	19760727	265	19760726	H	
						4	136	175	176											
							176	186												
12AAB	WILLIAMS, FRED	1973	Ty	585	154	6	24	154	24	75	91	1	A	0.8	63.27	19760728	335	19760728	H	
09S/03W –																				
07ADC	ALLUVIAL FARMS	1981	Qal	170	49	10	29	44	49	600	5	2	P	120.0	24.00	19810629	329	19910913	F	
09S/04W –																				
01BDD	SCHMIDT NURSERY	1967	Qal	163	34	12	28	33	34	30	4	1	B	7.5	20.90	19760923			I	
															21.34	19760923				
01CBD	HADLEY, DOUGLAS	1975	Qal	161	37	12	25	35	37	50			B	50.0	14.40	19760923	195	19760923	I	
02ACD	FITTS, ROBERT	1967	Qal	157	44	12	23	43	43	20		1	B	20.0	8.00	19670311			I	
															15.71	19910913				
02DCA	WIGRICH FARMS	1974	Qal	159	60	12	39	49	50	50		2	B	50.0	14.00	19740103	317	19760923	I	CA
							50	60												
03BAD	KRAUGER, FRANK	1966	Qal	145	47	12	35	45	47	300	4	4	P	75.0	11.40	19760924	220	19760924	U	
03CCC	BOWMAN, CHARLES	1957	Qoal	178	97	12	30	61	61	1000			P		23.20	19760930			U	
							61	97												

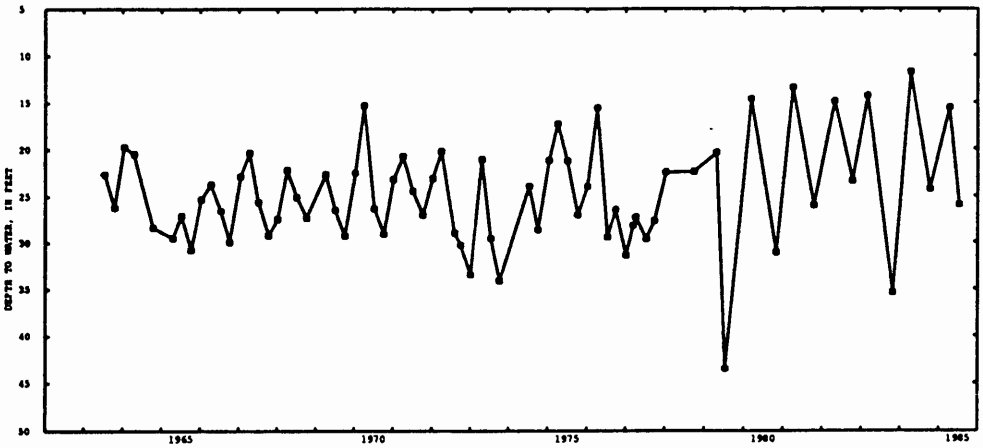
WELL NUMBER	OWNER	YEAR COM-PLETED	AQUI-FER	ELV ft	DPT ft	DIA in	OPEN INTERVAL TOP ft	OPEN INTERVAL BOT ft	DEPTH CASED ft	YIELD gpm	DD ft	PP h	M	SPEC. CAP. gpm/ft	WATER LEVEL ft	DATE MEAS. YYYYMMDD	SPECIFIC CONDUC. µmhos/cm	DATE MEAS. YYYYMMDD	U	REM.
03DBD1	SMITH, ARTHUR	1974	Qoal	171	150	6	53	55	60	40	4	2	B	10.0	20.00	19760924	160	19760924	H	
							56	150												
03DBD2	SMITH, ARTHUR	1972	Qoal	175	52	8	38	42	47	40	4	1	B	10.0	22.00	19720717			H	
04BCD	NELSON, KENNETH	1971	Qoal	188	48	12	30	36	48	80	24	3	P	3.3	13.10	19760924	380	19760924	I	
04CBD	OLSEN, H.	1968	Qoal	196	55	8	45	53	55	30	15	2	B	2.0	15.00	19680729			H	
04CDA	BOWMAN, CHARLES	1967	Qoal	197	93	8	31	45	80	50	55	2	P	0.9	18.50	19760930	290	19760930	U	
							65	70												
							72	78												
04CDC	BOWMAN, CHARLES	1967	Ts	212	80	8	30	35	80	10	60	2	P	0.2	7.00	19670305			U	
							50	55												
							64	69												
05AAA	MAGILL, FULTON	1961	Qoal	186	75	8	59	75	75	8	34	1	B	0.2	26.00	19611006	380	19761008	H	
05BDA	MAGILL, BEN	1991	Ts	245	95	6	69	93	94	20	39	1.5	P	0.5	29.00	19910617	704	19911201	H	B,C,I
07ACC	RIDENOUR, G	1970	Ts	272	140	6	120	140	120	30	30	2	B	1.0	26.10	19760910	230	19760910	H	
09AAC	BOWMAN, CHARLES	1964	Qoal	187	124	10	46	55	124	225	47	3	P	4.8	20.00	19640428			U	
09BAB	SMITH, LARRY	1964	Ts	197	140	6	35	140	140	7.5	119	1	P	0.1	8.00	19640910			H	
10BAD1	LUCKIAMUTE	1969	Qal	168	75	10	22	49	59	970	41		P	23.7	14.50	19760930	171	19760930	P	CA
	WATER COOP						49	75												
10BAD2	LUCKIAMUTE	1974	Qal	167	55	12	35	45	46	50		2	B	50.0	25.50	19760930	162	19760930	P	CA
	WATER COOP						46	55							19.52	19900806	209	19900806		
10BBB	BOWMAN, CHARLES	1965	Qoal	180	162	12	50	60	132	350	51	8	P	6.9	35.00	19650729			I	
							132	162							27.13	19910919				
10DBD	LUCKIAMUTE	1978	Qoal	173	42	12	25	35	42	350	2	24	P	175.0	16.36	19900806	284	19900806	P	
	WATER COOP																			
11ACD	WIGRICH FARMS	1990	Qal	162	49	12	24	43	43	65		1	B	65.0	10.50	19901227	288	19910913	I	
							43	49							17.70	19910913				
11ADB	FITTS, ROBERT	1974	Qal	163	60	6	39	49	50	50		2	B	50.0	14.00	19740103			I	
							50	60												
11BBD	FITTS, ROBERT	1975	Qal	170	55	6	35	48	50	50		2	B	50.0	15.00	19751209			H	
11CAB	COBINE, DONALD	1964	Qal	159	37	12	24	34	35	600	12	2	P	50.0	15.96	19760923			U	HYD
							35	37												
11CDB	MURPHY, PAUL	1985	Qal	172	42	6	32	40	42	50	8	1	B	6.3	16.00	19850223	273	19911019	H	
11CDD	WESSEMAN, C	1973	Qal	170	70	6	35	50	55	40	5	1	B	8.0	23.00	19730904			H	
							55	70												
11DAC	SCHMIDT NURSERY	1957	Qal	167	48	12	27	37	37	150			R		16.00	19570425	327	19910917	I	
							37	48							20.00	19900926				
															19.01	19910917				
12ACD	MORLON, GERALD	1963	Qal	167	38	12	33	38	38	550	3.5	2.5	P	157.0	21.60	19761001			I	
															22.25	19900803				
															22.36	19910913				
13BCB	SPINAS, DON	1970	Qal	171	40	6	32	38	40	25	4	1	B	6.3	23.50	19760923	160	19760923	H	
14ACC	HULTMAN, CECIL	1961	Qal	169	40	12	27	38	38	640			P		18.40	19760922	235	19760922	I	
							38	40												
14CDC	LARWOOD, JAMES	1974	Qal	182	58	6	40	48	50	50	0	2	B	50.0	21.00	19740514			I	
14DBB	HULTMAN, CECIL	1962	Qal	168	36	12	23	34	36	700					19.90	19760922	230	19760922	I	CA
15AAB	LUBBERS, RICH	1990	Qal	177	58	12	49	57	58	150		1	P		19.01	19910919			I	
15ABA	YOUNG, PAUL	1975	Qal	173	64	10	42	57	59	50	0	2	B	50.0	14.90	19760929	170	19760929	I	
							59	64												
22CDD	PRATHER, LELAND	1969	Ts	361	191	6	91	110	60	5	118	1	A	<.1	72.00	19760929	90	19760929	H	
						4	152	190	191											
22DDC	JOHNSON, REED	1979	Ts	295	245	6	97	245	97	4	161	1	A	<.1	91.76	19911027	197	19911027	H	
23ABB1	WELLS, PERRY	1971	Qal	192	50	6	45	48	50	40		2	B	40.0	36.40	19760922	330	19760922	H	

WELL NUMBER	OWNER	YEAR COM–PLETED	AQUI–FER	ELV ft	DPT ft	DIA in	OPEN INTERVAL TOP ft	BOT ft	DEPTH CASED ft	YIELD gpm	DD ft	PP h	M	SPEC. CAP. gpm/ft	WATER LEVEL ft	DATE MEAS. YYYYMMDD	SPECIFIC CONDUC. µmhos/cm	DATE MEAS. YYYYMMDD	U	REM.
23ABB2	WELLS, NINA	1990	Qal	188	53	12	27	45	53	120	19		P	6.3	21.50 25.33	19901110 19910913			I	
23BBC	GODFREY, RAY	1967	Ts	235	157	6	57 156	136 157	156	5	140	1	A	<.1	10.60	19760929	90	19760929	H	
09S/05W –																				
02ABD	BOWMAN, CHARLES	1969	Ts	370	323	6	24	323	24	4	293	2	A	<.1	10.70	19760901	215	19760901	U	
12AAD	THOMAS, WILLARD	1956	Ts	350	120	6	60	100	100	10	70		B	0.1	69.96	19760901			U	

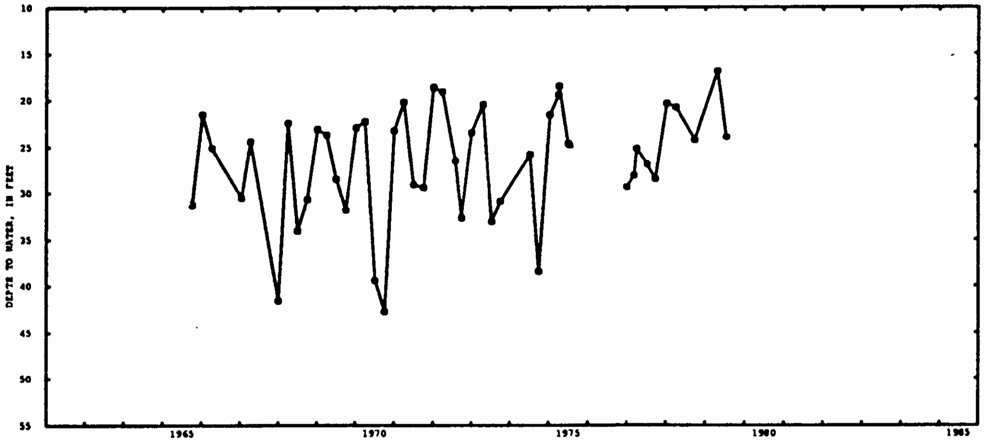
SPRING NUMBER	OWNER	SOURCE	ELEV	EST. YIELD (gpm)	SPECIFIC CONDUC. µmhos/cm@25C	DATE VISITED YYYYMMDD
06S/5W–21CAD1	BUSH, RICK	Qoal/Ty	170	<1	56316 56850 59600	19920206 19920418 19920802
06S/05W–21CAD2	BUSH, RICK	Qoal/Ty	170	<1	53988 56210 59700	19920104 19920206 19920802
06S/05W–21CAD3	BUSH, RICK	Qoal/Ty	170	<1	58300	19920802
07S/05W–17ADC	B&D TIMBER	Tsr	360	5–10	258	19910913
07S/06W–02ADD	LUCERO, RICHARD	Ty/Tsr	350	~5	16302 12551 13340 12876	19920105 19920106 19920106 19920106
08S/05W–08BCA		Ty	460	?	63	19920106
08S/05W–09ADB	FLEMMING, JERRY	Ts	780	~2	113	19920229
08S/06W–12AAB		Ty	460	~10	115	19920215

APPENDIX D

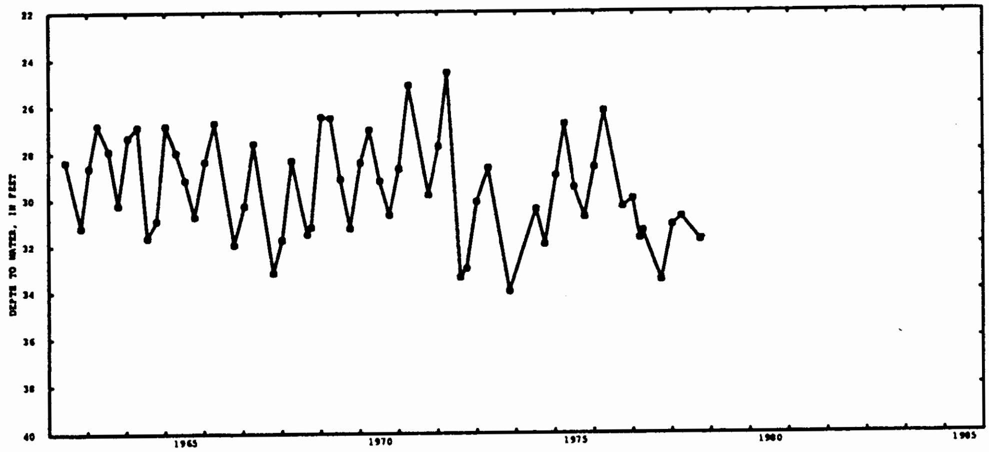
HYDROGRAPHS FOR SELECTED WELLS



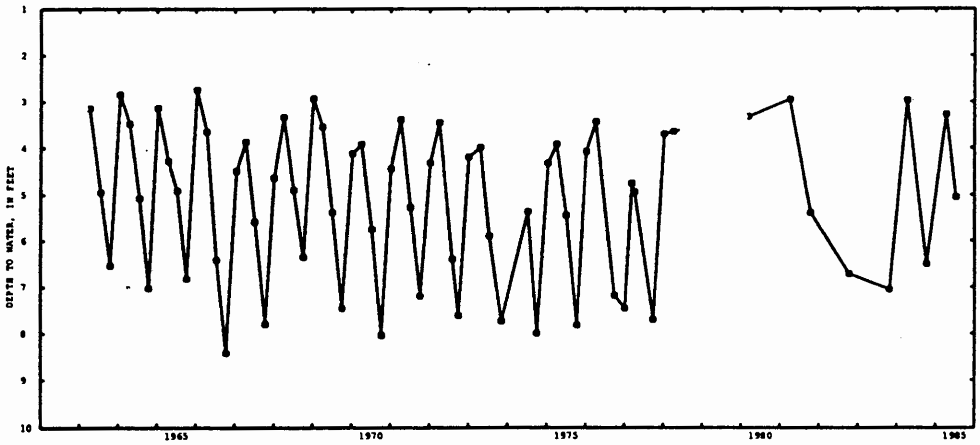
6S/4W-17aac, 270 feet (82.3 m) deep in Eocene-Oligocene undifferentiated sedimentary rock (Toe) or Spencer Formation (Ts).



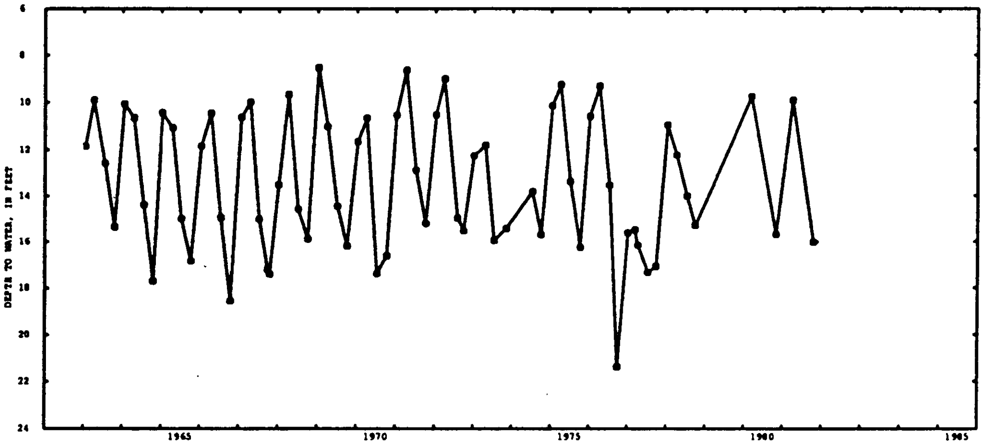
7S/4W-6ddb, 89 feet (27.1 m) deep in Eocene-Oligocene undifferentiated sedimentary rock (Toe).



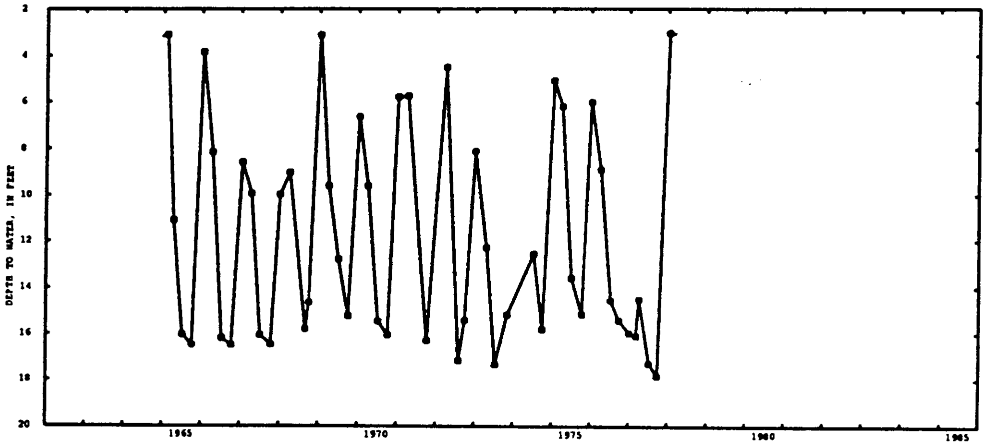
8S/4W-3abd, 60 feet (18.3 m) deep in older alluvium (Qoal).



8S/6W-25ddd, 52 feet (15.8 m) deep in Yamhill Formation (Ty).



9S/4W-8ccc, 120 feet (36.6 m) deep in Spencer Formation (Ts).



9S/4W-11cab, 37 feet (11.3 m) deep in recent river alluvium (Qal).

APPENDIX E

CHEMICAL EQUILIBRIA OF SELECTED WATERS

6S/5W-21cad	Ca-Cl Spring	Spec. cond. > 57,000 µmhos/cm	
supersaturated log IAP/KT > +1	near equilibrium -1 < log IAP/KT < +1	undersaturated -10 < log IAP/KT < -1	greatly undersaturated log IAP/KT < -10
annite	adularia	alunite	chlorite
boehmite	albite	analcime	chrysotile
diaspore	AlOH3a	anhydrite	clinoptilolite
goethite	chalcedony	anorthite	erionite
hematite	halloysite	aragonite	forsterite
illite	MnHPO4	brucite	hausmannite
kaolinite	pyrophyllite	calcite	huntite
k-mica	quartz	clinoenstatite	hydromagnesite
laumontite	Si glass	diopside	manganite
magnetite	Si gel	dolomite	MnCl2,1w
Montmoril-AB		FeOH3a	Mn2SO4,3
Montmoril-BF		greenalite	Mn3PO4,2
Montmoril-Ca		gypsum	MnCl2
		halite	MnCl2,2w
		hydroxlapatite	MnOH3
		maghemite	MnSO4
		magnesite	mordenite
		mirabilite	phlogopite
		MnCl2,4w	pryolusite
		MnOH2	rhodonite
		nahcolite	sepiolite
		phillipsite	talc
		prehnite	tephroite
		rhodochrosite	tremolite
		siderite	trona
		thenardite	
		vivianite	
		wiarakite	

7s/6w-2add	Ca-Cl Spring	Spec. Cond. 14,000 µmhos/cm	
supersaturated log IAP/KT > +1	near equilibrium -1 < log IAP/KT < +1	undersaturated -10 < log IAP/KT < -1	greatly undersaturated log IAP/KT < -10
boehmite	ALOH3a	adularia	brucite
fluorapatite	chalcedony	albite	chlorite
kaolinite	goethite	alunite	chrysotile
mont-Ca	halloysite	analcime	clinoptilolite
mont-BF	hematite	anhydrite	diopside
	illite	annite	erionite
	K-mica	anorthite	forsterite
	laumontite	aragonite	greenalite
	montmor-BA	calcite	hausmanite
	pyrophyllite	clinoenstatite	huntite
	quartz	diaspore	hydromagnesite
	Si gel	dolomite	manganite
	Si glass	FeOH3a	Mn2SO4,3
		fluorite	Mn3PO4,2
		gypsum	MnCl2
		halite	MnCl2,1w
		hydroxlapatite	MnCl2,2w
		maghemite	MnCl2,4w
		magnesite	MnOH2
		magnetite	MnOH3
		mirabilite	MnSO4
		MnHPO4	mordenite
		Nahcolite	phlogopite
		phillipsite	pyrolusite
		prehnite	rhodonite
		rhodochrosite	sepiolite
		siderite	talc
		wairakite	tephroite
			thenardite
			tremolite
			trona
			vivianite

6s/4w-6bd Ca-Cl Former Oil and Gas Well Spec. Cond. 49,700 µmhos/cm

supersaturated log IAP/KT > +1	near equilibrium -1 < log IAP/KT < +1	undersaturated -10 < log IAP/KT < -1	greatly undersaturated log IAP/KT < -10
goethite	chalcedony	anhydrite	chrysotile
hematite	quartz	aragonite	forsterite
magnetite	Si glass	brucite	greenalite
		calcite	hausmanite
		clinoenstatite	huntitite
		diopside	hydromag
		dolomite	manganite
		FeOH3a	Mn2SO4,3
		gypsum	MnCl2
		halite	MnCl2,1w
		maghemite	MnCl2,2w
		magnesite	MnOH3
		mirabilite	MnSO4
		MnCl2,4w	pyrolusite
		MnOH2	rhodonite
		Nahcol	sepiolite
		rhodochrosite	talc
		Si gel	tephroite
		siderite	tremolite
		thenardite	trona

7s/5w-29cad	Na-Cl Water Well	Spec. Cond. 5500 μmhos/cm	
supersaturated log IAP/KT > +1	**near equilibrium** -1 < log IAP/KT < +1	**undersaturated** -10 < log IAP/KT < -1	**greatly undersaturated** log IAP/KT < -10
	chalcedony	aragonite	brucite
	goethite	calcite	chrysolite
	quartz	clinoenstatite	diopside
	Si glass	dolomite	forsterite
		FeOH3a	greenalite
		halite	hausmanite
		hematite	huntitite
		magnesite	hydromagnesite
		magnetite	hydroxlapatite
		MnCL2,4w	maghemite
		MnHPO4	manganite
		nahcolite	Mn3PO4,2
		rhodochrosite	MnCL2
		Si gel	MnCL2,1w
		siderite	MnCL2,2w
		vivianite	MnOH2
			MnOH3
			pyrolusite
			rhodonite
			sepiolite
			talc
			tephroite
			tremolite
			trona

8s/4w-31dda1	Na-Cl Water Well	Spec. Cond. 2650 μmhos/cm	
supersaturated log IAP/KT > +1	near equilibrium -1 < log IAP/KT < +1	undersaturated -10 < log IAP/KT < -1	greatly undersaturated log IAP/KT < -10
dolomite	aragonite	anhydrite	hausmanite
FeOH3a	calcite	brucite	hematite
fluorapatite	chalcedony	clinoenstatite	Mn2SO4,3
goethite	chrysotile	fluorite	Mn3PO4,2
greenalite	diopside	forsterite	MnCl2
maghemite	hydroxlapatite	gypsum	MnCl2,1w
magnetite	magnesite	halite	MnCl2,4w
siderite	MnHPO4	huntite	MnCl2,4w
talc	quartz	hydromagnesite	MnOH3
tremolite	rhodochrosite	mirabilite	MnSO4
	sepiolite	nahcolite	pyrolusite
	Si gel	thenardite	trona
	Si glass	MnOH2	
	vivianite	manganite	
		tephroite	
		rhodonite	

Bruer Pool	Na-Cl Mist Gas Field Well	Spec. Cond. 45,000 μmhos/cm	
supersaturated	near equilibrium	undersaturated	greatly undersaturated
log IAP/KT > +1	-1 < log IAP/KT < +1	-10 < log IAP/KT < -1	log IAP/KT < -10
annite	adularia	alunite	clinoptilolite
boehmite	albite	analcime	erionite
diaspore	AlOH3A	anhydrite	forsterite
goethite	aragonite	anorthite	hausmannite
hematite	calcite	barite	hydromagnesite
illite	chalcedony	brucite	manganite
kaolinite	flourite	chlorite	Mn2SO4,3
K-mica	halloysite	chryosotile	MnCl2
laumonite	quartz	clinoenstatite	MnCl2,1W
magnetite	Si glass	diopside	MnCl2,2W
montmoril-AB	Si gel	dolomite	MnOH3
montmoril-BF		FeOH3A	MnSO4
montmoril-CA		greenalite	mordenite
phillipsite		gypsum	pyrolustite
pyrophyllite		halite	rhodonite
		huntite	tephroite
		maghemite	trona
		magnesite	
		mirabilite	
		MnCl2,4W	
		MnOH2	
		nahcolite	
		phlogopite	
		prehnite	
		rhodochrosite	
		sepiolite	
		siderite	
		talc	
		thenardite	
		thremolite	
		wairakite	
		witherite	

Longview Fibre Na-Cl Mist Gas Field Well Spec. Cond. 45,000 µmhos/cm			
supersaturated log IAP/KT > +1	near equilibrium -1 < log IAP/KT < +1	undersaturated -10 < log IAP/KT < -1	greatly undersaturated log IAP/KT < -10
adularia	AlOH3A	alunite	clinoptilolite
albite	analcime	anhydrite	erionite
annite	anorthite	brucite	hausmannite
boehmite	aragonite	crysotile	hydromagnesite
diaspore	barite	clinoenstatite	Mn2SO4,3
goethite	calcite	diopside	MnCl2
greenalite	chalcedony	dolomite	MnCl2, 1W
halloysite	chlorite	FeOH3A	MnCl2,2W
hematite	flourite	forsterite	MnOH2
illite	maghemite	gypsum	MnSO4
kaolinite	prehnite	halite	mordenite
K-mica	quartz	huntite	pyrolusite
laumonite	siderite	magnesite	rhondonite
magnetite	Si glass	manganite	trona
montmoril-AB	Si gel	mirabilite	
montmoril-BF	wairakite	MnCl2,4W	
montmoril-Ca		MnOH2	
phillipsite		Nahcolite	
		phlogopite	
		pyrophyllite	
		rhodochrosite	
		sepiolite	
		talc	
		tephrite	
		thenardite	
		tremolite	
		witherite	