

Geology of the Luckiamute River Watershed, Upper Willamette Basin, Polk and Benton Counties, Oregon

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INTRODUCTION

This report is compiled as part of the Luckiamute Watershed assessment, conducted under the auspices of the Luckiamute Watershed Council. This work forms part of long-term research on the Luckiamute by faculty and students at Western Oregon University. The project was derived from a 6-week Environmental Science Institute course convened in Summer 2001 at Western Oregon University. The institute course targeted undergraduate science majors, preservice education majors, practicing education professionals, and masters-level education students. The course was designed with four integrated science modules in geomorphology, field botany, paleoclimatology, and environmental chemistry. The geomorphology module focused on landscape analysis, geographic information systems, surficial mapping methodology, and field hydrology. The botany module emphasized characterization of riparian habitats, floristic changes over time, impacts of invasive plant species, and field monitoring methodologies. The paleoclimatology module included derivation of climate variables from modern and ancient flora, and examination of the Tertiary fossil record of the mid-Willamette Valley. The environmental chemistry module examined land use and water quality issues in the Willamette Basin, with a focus on aqueous chemistry, field measurement techniques, and pesticide contamination.

A significant portion of this report is excerpted from a published field guide by Taylor and others (2001). A new addition is the hydrogeology section which reflects recent advances in characterizing the geologic framework of the Luckiamute Basin. Figures and tables are presented at the end of the appendix.

PHYSIOGRAPHY

The Luckiamute River comprises a portion of the Willamette Basin in west-central Oregon (Figure 1). This seventh-order watershed (Strahler, 1957) drains eastward from the Coast Range into the Willamette River and occupies a total drainage area of 815 km². The Luckiamute Basin is bounded by the Willamette River to the east, the crest of the Coast Range to the west, Green Mountain and Marys River to the south, and the Rickreall Creek Watershed to the north (Figure 1). Land surface elevations range from 46 m (150 ft) at the confluence with the Willamette

River to 1016 m (3333 ft) at Fanno Peak. The Luckiamute has an average gradient of 3 m/km, a total stream length of 90.7 km, and an average basin elevation of 277 m (910 ft) (Rhea, 1993; Slack and others, 1993). Fanno Ridge separates the watershed into two tributary subbasins, with the Little Luckiamute to the north and the main stem of the Luckiamute proper to the south (Kings Valley) (Figure 1). Lower-order tributaries include Boughey Creek, Waymire Creek, Vincent Creek, Plunkett Creek, Woods Creek, Maxfield Creek, and Soap Creek.

The greater Willamette Valley extends northward 190 km from Eugene to Portland, Oregon. This lowland is up to 60 km wide, separating the Coast Range to the west from the Cascade Range to the east. Valley floor elevations range from 150 m (500 ft) to 3 m (10 ft), with an average gradient of 2 m/km (Slack and others, 1993).

TECTONIC SETTING

The Luckiamute Watershed is situated on a convergent tectonic margin with the Juan de Fuca Plate subducting eastward beneath North America (Figure 2). This subduction zone is associated with a long history of oblique convergence, tectonic accretion, arc volcanism, dextral shear, and clockwise rotation (Wells and others, 1984). Paleomagnetic studies indicate that the Coast Range experienced greater than 50° clockwise rotation during the Eocene (58 to 38 m.y. ago) (Simpson and Cox, 1977). Long-term rates of plate convergence average 3.5 to 4.0 cm/yr (Adams 1984). Paleoseismic studies along coastal Oregon suggest that the region experiences large magnitude, subduction-style earthquakes with a recurrence interval of approximately 300 to 500 years (Darienzo and Peterson, 1990).

The western two-thirds of the Luckiamute River drains the central Oregon Coast Range (Figure 1). This mountain system began to uplift between 15 and 10 Ma (Snively and others, 1993). The Coast Range continues to be neotectonically active with variable rates of uplift along its length (Adams, 1984). Thus present-day relief in is a combination of net uplift due to plate convergence and vertical incision by surface processes (Kelsey and others, 1994).

Tectonic convergence, accretion, and mountain building in the Coast Range resulted in extensive faulting, folding, and fracturing of bedrock. Notable structures in the vicinity of the Luckiamute

include the Kings Valley and Corvallis faults, in addition to numerous smaller-scale fractures throughout the region (Figure 3). The Corvallis fault zone trends northeast, dips approximately 10° NW, and is associated with 11 to 13 km of crustal shortening (Yeats and others, 1996). The net result is westward juxtaposition of older lower Eocene Siletz River Volcanics next to younger Tertiary sedimentary strata (to the east). Snively and others (1993) extended the Corvallis Fault offshore to the southwest, where it intersects a north-trending dextral strike-slip fracture referred to as the Fulmar Fault. Their offshore mapping suggests that the Corvallis Fault is a major geologic feature associated with convergent-margin tectonics.

Historic re-leveling surveys of western Oregon suggest that the western boundary of the Luckiamute is presently tilting eastward at a rate of approximately 1×10^{-8} rad/yr with crustal shortening of 10^{-7} yr⁻¹ (Adams, 1984). Although tilt data suggest that portions of the Luckiamute are neotectonically active, Mitchell and others (1994) reported no evidence for historic uplift in this part of the Coast Range. By comparing topographic relationships in this region to the southern Coast Range and Olympics, Kelsey and others (1994) hypothesized that the subducting Juan de Fuca slab is likely segmented at the latitude of the Luckiamute.

The Willamette Valley proper represents a forearc basin situated between the accretionary Coast Range and Cascade Volcanic arc (Figure 2). The valley has formed a lowland depocenter for fluvial and lacustrine sediments since the Pliocene (McDowell, 1991). The northern Coast Range forms a broad, north-plunging anticlinorium, with pre-Miocene strata dipping eastward across the Willamette Valley (Yeats and others, 1996). The Cascades are associated with a long history of intermediate to mafic volcanism dating from late Eocene (40-35 Ma) to present. Arc volcanism has been narrowing and migrating eastward over time, with the geometry of High Cascade volcanoes controlled by the present-day subduction-zone configuration (Priest, 1990)

BEDROCK GEOLOGY

Lithostratigraphy

Yeats and others (1996) and Snively and Wells (1996) provided comprehensive summaries of the bedrock geology in the Luckiamute region. Bedrock is comprised of an Eocene to Oligocene sequence of basaltic volcanic rocks, marine sedimentary rocks, and mafic intrusives of varying composition (Figure 3). In ascending order, lithostratigraphic units include the Siletz River Volcanics (upper Paleocene to middle Eocene; 58-46 Ma), Tyee Formation (middle Eocene; 53-48 Ma),

Yamhill Formation (middle and upper Eocene; 48-44 Ma), Spencer Formation (upper Eocene; 44-41 Ma), and undifferentiated mafic intrusions (middle Oligocene; 34-30 Ma) (Figure 4).

The Siletz River Volcanics are composed primarily of submarine basalt lava flows interbedded with breccia, sandstone, and siltstone (Figure 4). Snively and others (1968) suggested that this unit is approximately 10,000 feet thick, thus forming the basement rocks of the Coast Range. Siletz River basalts and related sedimentary rocks are interpreted to be the result of *in situ* eruption in an extensional rift basin associated with northeast oblique convergence of the ancestral Kula and Farallon plates (Snively and Wells, 1996).

The Tyee Formation is characterized by thickly-bedded arkosic sandstone and siltstone lithofacies (Figure 4). The Tyee outcrops extensively in the central to southern Coast Range, with the northernmost occurrence located in the southwest portion of the Luckiamute Basin (Figure 3). The Tyee is interpreted as deltaic and submarine fan deposits that were derived from an uplifted Klamath terrane and Jurassic-Cretaceous arc complexes in Idaho (Heller and others, 1985).

The Yamhill Formation is comprised of interbedded siltstone and shale of marine origin; marking the onset of rapid subsidence in the Cascadia forearc basin and deposition in a deep marine trough (Snively, 1987). This unit is overlain by shallow marine deposits of the Spencer Formation (Figure 4). The Spencer is composed of over 1000 ft of tuffaceous sandstone, siltstone, and mudstone, with volcanoclastics derived from the early Tertiary Cascade volcanic arc to the east.

The Eocene volcanic-sedimentary sequence in the Luckiamute was subsequently intruded by renewed rift-related magmas during the Oligocene (30-34 m.y. ago) (Figures 3 and 4). These Oligocene intrusives are composed of sheets, sills, and dikes of iron-rich gabbros. The Oligocene intrusives represent a final phase of rift-related extension and magmatism (Snively and Wells, 1996).

Lithospacial Distribution

Bedrock map units are grouped into four lithospacial domains in the Luckiamute, as recognized on the basis of outcrop pattern (Figure 3). These include the Siletz River Volcanics Domain (south), the Tyee Domain (west-southwest), the Yamhill-Intrusive Domain (north-northwest), and the Spencer-Valley Fill Domain (east). The Siletz River Volcanics Domain comprises 19% of the watershed and is mainly seafloor basalt. The Tyee Domain (29% of total area) is underlain primarily by Tyee Formation with local mafic intrusives supporting ridge tops. The Yamhill-Intrusive Domain occupies 23% of the

watershed and is characterized by outcrop of equal portions of the Yamhill Formation and mafic intrusives. The Spencer-Valley Fill Domain (29%) is underlain by a patchwork of Spencer Formation and Quaternary alluvium. Each of these bedrock spatial domains is associated with unique landform assemblages and surficial processes.

SURFICIAL GEOLOGY AND GEOMORPHOLOGY

Geomorphic systems of the Luckiamute Watershed can be divided into a valley-floor regime to the east and a hillslope-colluvial regime to the west (Figure 5). Style of surficial process and landform associations are controlled by topographic position, underlying bedrock geology, and resistance to erosion. Hillslope landforms and colluvial processes dominate the Siletz River, Tyee, and Yamhill-Intrusive domains, whereas fluvial landforms and alluvial processes are characteristic of the Spencer-Valley Fill Domain.

Valley floor-fluvial regime

The lower Luckiamute is characterized by a mix of alluvial stratigraphic units and geomorphic surfaces. Landforms include active channels, floodplains, fill terraces, and strath-pediment surfaces (McDowell, 1991). In addition to these fluvial landforms, the lower Luckiamute is also associated with swaths of low-relief colluvial hillslopes supported by the Spencer Formation (Figure 5). Present-day geomorphic conditions extend back to at least the Pliocene, the time at which the Willamette River eroded through intrabasinal divides, permitting open drainage to the Columbia River (McDowell, 1991). Pleistocene through Holocene terrace development records a complex history of base level fluctuation, internal erosion-deposition cycles, and glacial-outburst floods (Missoula Floods) from the Columbia River system.

Maximum thickness of Pliocene-to-Holocene sedimentary fill in the mid-Willamette Valley is up to 150 m (490 ft) (Yeats and others, 1996). Lower basin fill is comprised predominantly of fluvial and glacio-fluvial fan gravels shed from the Cascades, with lesser volumes of sediment derived from smaller Coast Range watersheds (Figure 6) (McDowell, 1991; O'Connor and others, 2001). These early to middle Pleistocene gravels are overlain by rhythmically-bedded, silty slack-water deposits of the Willamette Formation (Figure 6) (the "Willamette Silt" of Allison 1953). These late Pleistocene fine-grained deposits cover the valley floor to an elevation of 120 m (400 ft) and are associated with multiple floods from Glacial Lake Missoula (from 13.5 to 12 t.y. ago) (Waite, 1985; Minervini and others, 2003). Lake Missoula in

western Montana was associated with catastrophic outburst floods that eroded the channeled scablands of Washington and traveled the length of the Columbia River Gorge, backflooding south into the Willamette Valley. The resulting flood deposits of the Willamette Formation are characterized by subparallel sheets of silt, clay, and sand, punctuated by the conspicuous occurrence of exotic boulders with lithologies that are foreign to the Willamette Basin (Allison, 1953).

In the Luckiamute Watershed proper, the lower drainage is characterized by terrace and floodplain surfaces underlain by late Pleistocene and Holocene deposits (Figure 5) (Balster and Parson, 1966; Bela, 1981). The active channel of the lower Luckiamute is incised 8 to 9 m below the floodplain, with higher level terrace surfaces at 12 to 15 m above mean annual stage (Reckendorf, 1993). The higher-level terrace surfaces are covered with rhythmically-bedded, silty slack-water deposits of the Willamette Formation (Missoula Flood deposits; 13.5-12 ka). The Willamette Formation has maximum thickness of 40 m (130 ft) in northern Willamette Valley, thinning to less than 3 m (10 ft) in the southern valley. This deposit is 6 to 9 m (20-30 ft) thick in the vicinity of the Luckiamute River (Gannett and Caldwell, 1998). These late Pleistocene surfaces are inset with lower terrace and floodplain deposits that are predominantly Holocene in age (post-Missoula Flood; <12 ka) (Figure 5; O'Connor and others, 2001).

Hillslope-colluvial regime

Parsons (1978) presented a geomorphic overview of the Coast Range portion of the Luckiamute. Small-scale intrusions and volcanic rocks support ridge tops and provide the resisting media for steep terrain. On average, hillslope gradients range from 25 to 30% with maxima up to 90%. Local relief is on the order of 300 to 500 m (980 to 1640 ft). This portion of the Luckiamute Watershed is dominated by colluvial hillslope processes including slide, debris flow, creep, tree throw, and faunal turbation. Fluvial transport and erosion occur in narrow, low-order tributary valleys. Upland landforms include ridge tops, side slopes, hollows, landslide scars, and dissected pediments. Narrow valley bottoms are geomorphically active with channels, floodplains, low terraces, and small-scale debris fans (Balster and Parsons, 1968).

The Oregon Coast Range is noted for hazards associated with landslides, flooding, and debris flow activity (Gresswell and others, 1979; Robinson and others, 1999). The Oregon Department of Forestry (2000) released a set of debris-flow hazard maps for portions of the Luckiamute Watershed. These maps were derived from slope analysis of 30-meter digital elevation models. Preliminary evaluation of the ODF hazard maps indicate that hillslopes underlain by the

Tyee Formation are most prone to debris flow (Table 1). Data suggest that bedrock lithology exerts a strong control on the style of hillslope process, soil development, and related landforms in the upland portion of the Luckiamute.

Soil Associations

Geographic Information System (GIS) analyses of County Soil Surveys (Knezevich, 1975, 1982) yield distribution data for soil series, orders, and subgroups in the Luckiamute Basin. Inceptisols, Ultisols, and Mollisols are the most abundant soil orders in the watershed, representing 38%, 31%, and 24% of the total area, respectively. Inceptisols are typically comprised of up to 50% lithic clasts and are associated with active hillslopes (>45% gradient). More deeply weathered Ultisols are common on metastable, lower-gradient hillslopes and pediment surfaces (Parsons, 1978). Representative subgroups include Haplohumults (31%), Xerochrepts (14%), Haplumbrepts (14%), Argixerolls (8%), and Haplaquolls (8%). Colluvial soil associations in the Coast Range portion include: (1) Jory, Peavine, Bellpine, Apt, and Honeygrove (Haplohumults); and (2) Price, Ritner, Klickitat, Valsetz, Luckiamute, and Cruiser (Haplumbrepts and Cryochrepts). Down basin, alluvial soil associations include: (1) Woodburn, Coburg, Willamette, Malabon (Argixerolls); (2) Veneta, Willakenzie (Haploxeralfs); and (3) Waldo, Wapato (Haplaquolls). The spatial distribution of soil assemblages is ultimately controlled by geomorphic process. As such, Reckendorf (1973, 1993) emphasized their use as a primary criteria for floodplain mapping in the mid-Willamette Valley.

HYDROGEOLOGIC FRAMEWORK

Ground water in the Luckiamute Watershed forms part of the Willamette Lowland aquifer system of western Oregon and southwestern Washington. Approximately 70% of the population of Oregon resides in the Willamette Valley. Rapid population growth in the past several decades has led to increasing demand on ground water resources for domestic, industrial, and agricultural use (Woodward and others, 1998). As surface-water rights are largely allocated according to the Doctrine of Prior Appropriation, ground-water resources are increasingly utilized to satisfy the growing demand. Since 1955, the number of water wells drilled in the Willamette Basin increased from 500 per year to over 4000 (Orzol and others, 2000). These water useage trends are also applicable to the Luckiamute Basin where the populations of Polk and Benton counties have increased 26% and 10%, respectively, in the past decade (U.S. Census Bureau, 2004). Thus a thorough

understanding of the hydrogeologic framework is critical for sustainable water resource planning.

The Luckiamute represents a basin-margin watershed in the Willamette Valley, over 70% of which is underlain by Tertiary sedimentary and volcanic rocks. Most groundwater is used for domestic and agricultural purposes, with municipal supplies serving the communities of Monmouth and Independence. Little detailed information is known about local aquifer conditions in the Luckiamute Watershed (Karl Wozniak, Oregon Water Resources Dept., Personal Communication). Recent regional ground-water studies focused on high-capacity aquifer units elsewhere in the Willamette Valley, although included portions of the lower Luckiamute and Ash Creek subbasins (Woodward and others, 1998; Gannett and Caldwell, 1998). More detailed work on the hydrogeology and ground-water quality of the Dallas-Monmouth area was conducted by Gonthier (1983) and Caldwell (1993); however their work has not been extended south into the Luckiamute. It should be emphasized that while the general hydrogeologic conditions of the Luckiamute study area are known, detailed quantitative analyses are lacking. The Gonthier (1983) and Caldwell (1993) studies provide an excellent platform from which to extend hydrogeologic research to the south, into the Luckiamute proper. The sections that follow provide a summary of existing published information, and represent a starting point for future detailed investigations.

Regional Aquifer System

The Willamette Valley is divided into four structural basins, as defined on the basis of fault and fold patterns (Woodward and others, 1998). From north to south these include the Portland Basin, Tualatin Basin, Central Willamette Valley, and Southern Willamette Valley (Figure 7). The latter two basins are physiographically separated by the Eola and Salem Hills, both underlain by Miocene Columbia River Basalts. Each of the four structural basins in the Willamette Valley possesses distinctive hydrogeologic characteristics. High production aquifer systems are comprised of either coarse-grained valley-fill sediments (Willamette alluvium and glacio-fluvial fans) or fractured Columbia River Basalts (Gannett and Caldwell, 1998). The Central and Southern Willamette Basins are dominated by the former aquifer type. The Spencer-Valley Fill domain in the lower Luckiamute, downstream from Falls City and Pedee, forms part of the western margin of the southern Willamette aquifer system (Figure 7).

General Hydrology

Taylor and Hannan (1999) summarized historic climate data for western Oregon. The Luckiamute straddles Oregon Climate Zones 1 (Coastal Area) and 2 (Willamette Valley), with westerly Pacific marine air serving as the primary moisture source. Precipitation patterns are strongly seasonal with 75% of the annual total occurring from October to March. Hydrometeorologic events are driven primarily by cyclonic and frontal storm systems. Rain-on-snow events are common at higher elevations.

Annual precipitation varies greatly from west to east across the Luckiamute Watershed, as governed by westerly airflow and a lee-side rain-shadow effect in the Coast Range. Annual precipitation in the watershed ranges from 3600 mm along the northwestern boundary to 1140 mm in the center of the Willamette Valley, a west-to-east precipitation gradient of 95 mm/km (Figure 2). The Luckiamute is associated with one of the highest intra-basinal precipitation gradients in the continental United States.

The U.S. Geological Survey maintains a gauging station on the Luckiamute River at Helmick State Park (USGS Suver Station 14190500; Location 6 on Figure 1). The station is 18 km upstream from the basin outlet, with 650 km² of drainage area positioned above the monitoring point (approximately 80% of total). Analysis of stream-flow record reveals that flooding and high discharges directly correspond to seasonal precipitation patterns. During the winter season, average discharge is on the order of 50 m³/sec, whereas summer months are typified by less than 3 m³/sec. The two peak discharges of record were observed at 700 and 620 m³/sec during December 1964 and February 1996, respectively. The 100-yr flood event at the Suver Station is marked by a discharge of 760 m³/sec (Waichler and others, 1997). The combined annual discharge of the Luckiamute and related Coast Range tributaries (Tualatin, North Yamhill, South Yamhill, Marys, and Long Tom Rivers) accounts for approximately 17% of the total annual discharge of the Willamette River Basin (Woodward and others, 1998).

Waichler and others (1997) derived a rainfall-runoff model for the Luckiamute Watershed. They estimated an average annual precipitation of 1894 mm for the entire watershed, with a total input volume of 1.23×10^9 m³. Water budget analysis indicates that 61% of the total annual rainfall is accounted for as runoff, whereas 39% is consumed in the form of evapotranspiration and groundwater flow. Based on numerical modeling, estimated mean annual ground-water recharge in the Luckiamute and Ash Creek subbasins ranges from 51 to 76 cm/year (20 to

30 inches/year) and 25 to 51 cm/year (10 to 20 inches/year), respectively (Woodward and others, 1998).

Hydrostratigraphy

Gannett and Caldwell (1998) and Woodward et al. (1998) delineated the principle hydrostratigraphic units in the Southern Willamette Basin. In ascending order these include: (1) basement confining unit (BCU), (2) Willamette confining unit (WCU), (3) Willamette aquifer (WAq), and (4) Willamette Silt (WS). The lowermost unit is represented by indurated bedrock, while the latter three are comprised of unconsolidated alluvium and valley-fill sediments. Alluvial-fill thickness in the lower Luckiamute and Ash Creek sub-basins ranges up to 30 m (100 ft) with most localities in the 12 to 24 m (40 to 80 ft) range. Luckiamute alluvial-fill thickens to the east towards the center of the Willamette Valley, and thins upstream to a minimum near the communities of Falls City and Pedee (Figure 8) (Caldwell, 1993; Gannett and Caldwell, 1998).

The basement confining unit is composed predominantly of Tertiary marine sedimentary rocks and related submarine basalts. This unit is characterized by relatively low permeability lithofacies with intermixed low-yield aquifer horizons and aquitards. In the lower Luckiamute and Ash Creek subbasins, BCU is composed largely of Spencer Formation strata. The Siletz River Volcanics form the basement unit in the southern portion of the watershed, along Soap Creek (Figure 8).

The Willamette confining unit is composed of unconsolidated fine-grained fluvial facies deposited by low-gradient streams during the Pleistocene. Drilling logs commonly refer to this unit as "blue clay", "silty clay" or "shale", containing laterally discontinuous sandy and gravelly interbeds. WCU is characterized by limited ground water production, however coarse-grained interbeds locally serve as aquifers. Regional yields from wells set in this unit range from 2 to 10 gallons per minute. WCU thickness in the study area ranges from a maximum of 18 m (60 ft) at Luckiamute Landing, to less than 6 m (20 ft) upstream of Helmick State Park. The Willamette confining unit is less than 18 m (60 ft) thick in the Ash Creek subbasin.

The Willamette aquifer is composed of coarse-grained facies associated with Pleistocene alluvial fans and deposits of smaller side tributaries. This unit was referred to as the "Linn Gravel" by Allison (1953). It is characterized by thick-bedded sand and gravel facies with thin interbeds of fine-grained sand, silt and clay. WAq is locally cemented and partially indurated. Regionally, the Willamette aquifer is formed by fluvio-glacial outwash from large drainage systems in the Cascades that debouch westward onto the valley floor. Given lower summit

elevations, the Coast Range was not glaciated during the Pleistocene. Thus eastward-draining tributaries to the Willamette, including the Luckiamute, tend to be smaller in area compared to those of the western Cascades, and are not associated with high-volume fluvio-glacial aquifer systems. The lower end of the Luckiamute lies approximately 30 km (18 mi) west of the Stayton and Lebanon fans, deposits of the North and South Santiam Rivers, respectively. Given the distal position of the Luckiamute in relation to large fan deposits, WAq gravels in the watershed are generally less than 6 m (20 ft) thick and are likely composed of sediments derived locally from Coast Range sources.

The Willamette Silt is the uppermost valley-fill unit and is comprised of late Pleistocene Missoula Flood deposits (map unit Qff2 of O'Connor and others, 2001). Fine-grained clay, silty clay, and silt occurs up to an elevation of 120 m (400 ft) in Luckiamute Basin and is less than 6 to 9 m (20 to 30 ft) thick. This unit serves as a semi-confining aquitard for the Willamette aquifer, however it is partly saturated and is commonly associated with water table conditions throughout much of the Willamette Basin.

In addition to the valley ground-water system, a significant portion of the Luckiamute is served by upland bedrock aquifer horizons set in strata of the Siletz River Volcanics, Tyee Formation, Yamhill Formation, and Oligocene Intrusives. Crystalline volcanic and intrusive rocks have inherently low porosity and permeability, but secondary fracture porosity can be significant (Freeze and Cherry, 1979). In the case of the Siletz River basalts, low-grade alteration and secondary zeolitization has likely resulted in significant reduction of hydraulic conductivity. Similarly, the fine-grained nature of the Tyee and Yamhill formations makes them of limited value as aquifer material.

Aquifer Properties

Table 2 provides a preliminary summary of hydrogeologic data from well inventories in the Luckiamute Watershed. These data were collected from field-located wells as part of the Willamette Regional Aquifer Systems Analysis (RASA) conducted by the U.S. Geological Survey (Woodward and others, 1998; Gannett and Caldwell, 1998). Approximately 40% of well heads are located in unconsolidated valley-fill alluvium, with 60% situated in basement-confining or upland bedrock units (Figure 8). Given that maximum alluvial fill in the Luckiamute-Ash Creek basins is generally less than 30 m (100 ft), all of the wells in the inventory have bottom depths situated in the basement-confining or upland bedrock aquifers. Average depth relations reveal that the bedrock wells have greater total depths

and lower static water level elevations compared to wells situated on valley fill. Although quantitative hydraulic analyses are lacking in the Luckiamute, Gonthier (1983) documented hydraulic conductivities in the range of 0.2 to 0.3 ft/day for the Dallas-Monmouth Area. Accordingly, the average specific capacity for wells ranges from <1 to 7 gallons per minute per foot of drawdown (Table 2) (Woodward and others, 1998).

The Spencer-Valley Fill domain in the Luckiamute forms part of the regional Willamette aquifer system which is generally associated with unconfined potentiometric conditions. Valley-fill aquifers in the Ash Creek subbasin are hydrogeologically separated from the Luckiamute by a hydraulic divide comprised of low-permeability lithofacies in the Spencer Formation (basement confining unit of Gannett and Caldwell, 1998). The lower Luckiamute valley-fill aquifer system is characterized by eastward ground water flow and hydraulic gradients on the order of 5 ft/mi (Woodward and others, 1998). Unconsolidated valley fill is more prevalent in the Ash Creek subbasin with eastward-directed hydraulic gradients of 20 ft/mi (Caldwell, 1993). Regionally, seepage velocity in the Willamette aquifer ranges from 3 to 30 ft/day, comparable to other coarse-grained aquifers. Iverson and Haggerty (2002) are conducting ongoing research in the Willamette Silt to determine hydraulic and geochemical properties. The results of their preliminary work along the Pudding River suggests that WS serves as a confining unit to the underlying Waq. Horizontal hydraulic conductivities are on the order of 0.004 to 5.53 ft/day, with vertical permeabilities of 0.008 ft/day and porosity of 40%.

Natural ground water quality ranges from good to poor in the Luckiamute-Ash Creek subbasins. Caldwell (1993) documented localized high salinity concentrations in the Monmouth-Independence area. His study utilized trace element analyses to relate bedrock mineralogy to ground water residence times and salinity contamination risk. The results indicate that ground water in the region is associated with chloride-dominant ionic species (CaCl_2 and NaCl) and poses a potential water quality hazard. It is interpreted that increased salinity levels are derived from connate brine waters trapped in Tertiary marine sedimentary rocks. This saline water mixes with shallow ground water via upward migration along folds and faults in the basement confining units. Preliminary analyses of water quality data to the south indicate that similar salinity conditions may also be present in Luckiamute aquifers. Detailed quantitative analyses of Luckiamute aquifer systems are needed to delineate the physical and chemical nature of hydrogeologic processes in the basin.

CONCLUSION

The Luckiamute Watershed provides a platform from which to study integrated environmental systems in western Oregon. Active tectonics, extreme precipitation patterns, variable bedrock geology, dynamic geomorphic systems, and intensive land use result in complex interactions between physical and biological components. The geologic framework has a direct influence on land use and ecologic viability. This report represents a starting point from which to design advanced research projects and restoration plans. The pursuit of such endeavors will be necessary to enhance and sustain local watersheds in the 21st century and beyond.

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Table 1. Debris flow hazard potential ranked by lithospacial domain, Luckiamute Watershed (data derived from Robinson and others, 1999)

| Lithospacial Domain (km ²) | Domain Area Hazard Zone | Percent of Domain Area in Rank | Hazard |
|----------------------------------------|-------------------------|--------------------------------|--------|
| Tyee | 241 | 38.1 | 1 |
| Yamhill-Ti | 193 | 24.6 | 2 |
| Siletz River | 151 | 30.2 | 3 |
| Spencer-Valley Fill | 229 | 0.7 | 4 |

Table 2. Preliminary Results of Luckiamute Well Survey (from U.S. Geological Survey Located Wells Inventory).

| Surface Geology | Aquifer Unit | No. Wells | Min Depth (ft) | Max Depth (ft) | Avg Depth (ft) | Avg Deep (ft) | Avg DTW (ft) | Avg.# Specific Capacity (gpm/ft) |
|------------------------------|-----------------------------------------|-----------|----------------|----------------|----------------|---------------|--------------|----------------------------------|
| Qal – Holocene Alluvium | Basement Confining (Spencer Formation) | 17 | 182 | 485 | 276 | 100 | 18 | 59.9 |
| Qs – Willamette Silt | Basement Confining (Spencer Formation) | 62 | 183 | 420 | 249 | 128 | 20 | 59.9 |
| Ti – Oligocene Intrusives | Upland Bedrock (Tertiary Intrusives) | 2 | 665 | 680 | 673 | 189 | 44 | N/D |
| Tsr – Siletz River Volcanics | Upland Bedrock (Siletz River Volcanics) | 42 | 235 | 1160 | 453 | 169 | 36 | 1.1 |
| Tss – Spencer Formation | Upland Bedrock (Spencer Formation) | 27 | 185 | 602 | 326 | 120 | 49 | 59.9 |
| Tt – Tyee Formation | Upland Bedrock (Tyee Formation) | 30 | 283 | 750 | 364 | 104 | 25 | N/D |
| Ty – Yamhill Formation | Upland Bedrock (Yamhill Formation) | 16 | 265 | 750 | 476 | 149 | 45 | 0.3 |
| Luckiamute Watershed Summary | | 196 | 182 | 1160 | 402 | 137 | 34 | |

* Min Depth = minimum total well depth (feet), Max Depth = maximum total well depth (feet), Avg Depth = average total well depth (feet), Avg Deep = average well deepening (feet), Avg DTW = average depth to water from surface (feet)

#Specific capacity = well pumping rate (gallons per minute) divided by feet of drawdown (data from Caldwell, 1993 for Ash Creek subbasin)

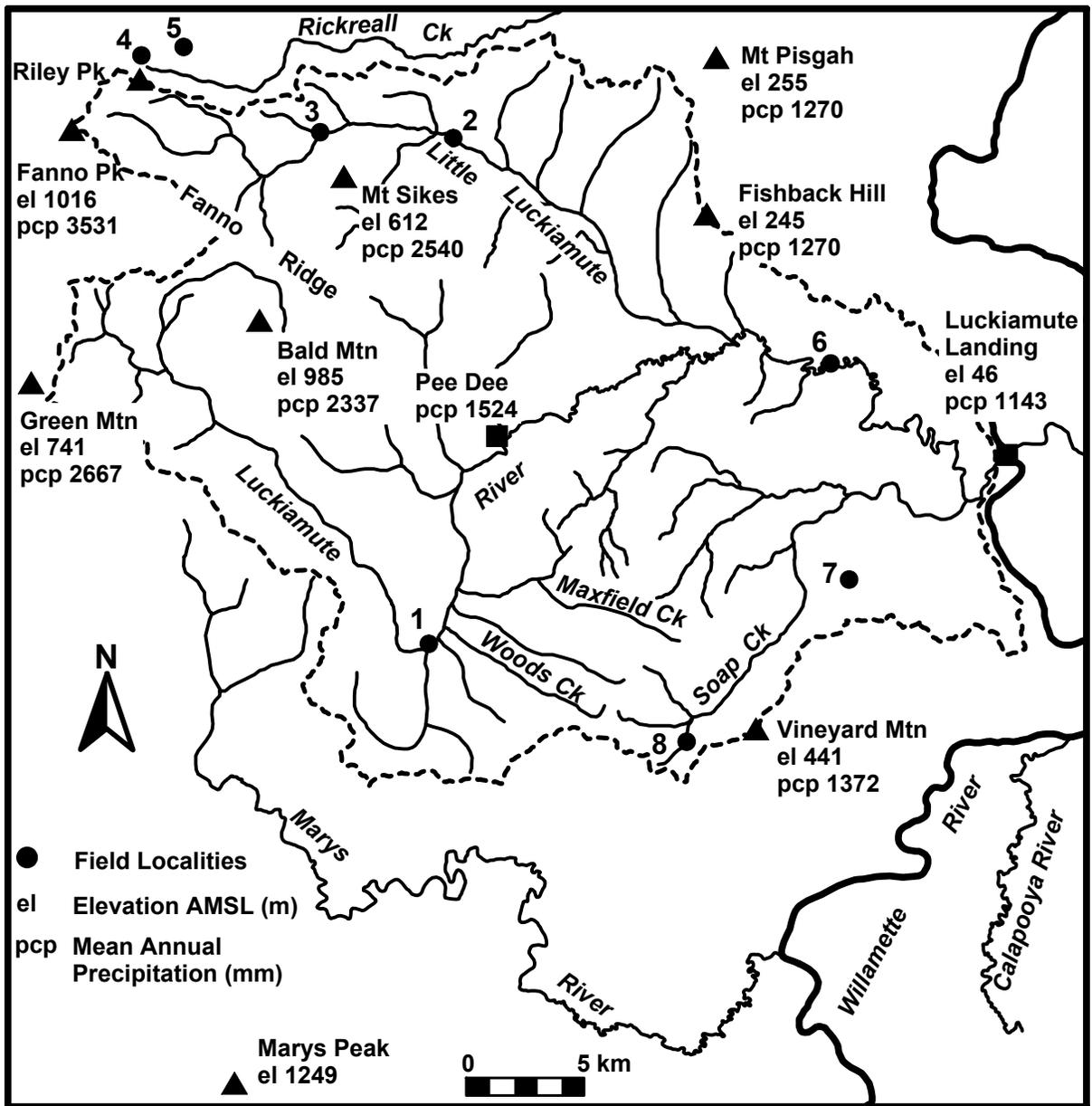


Figure 1. Physiographic map and spot annual precipitation for the Luckiamute Watershed.

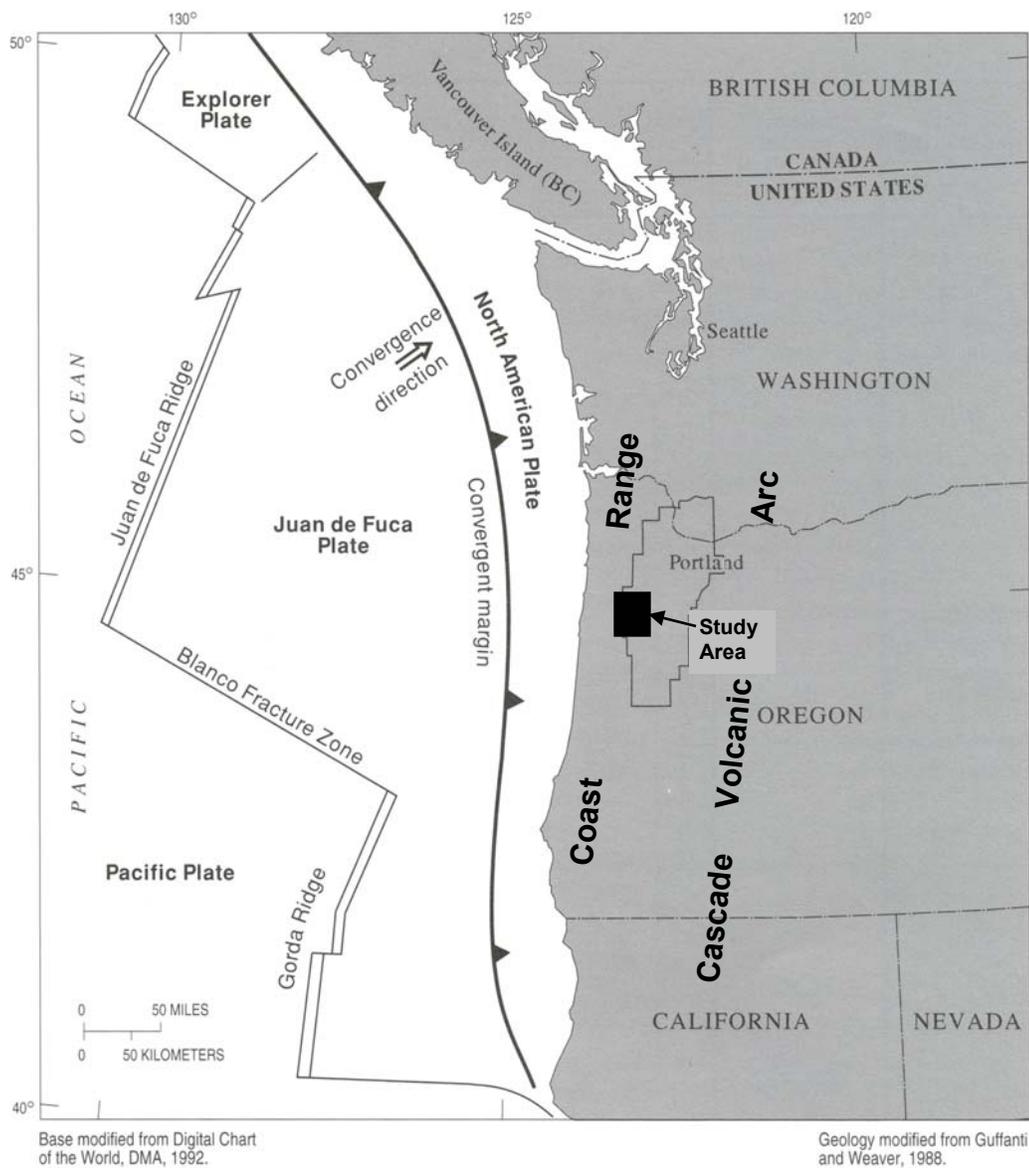


Figure 2. Plate tectonic setting of the Pacific Northwest (modified from Gannett and Caldwell, 1998)

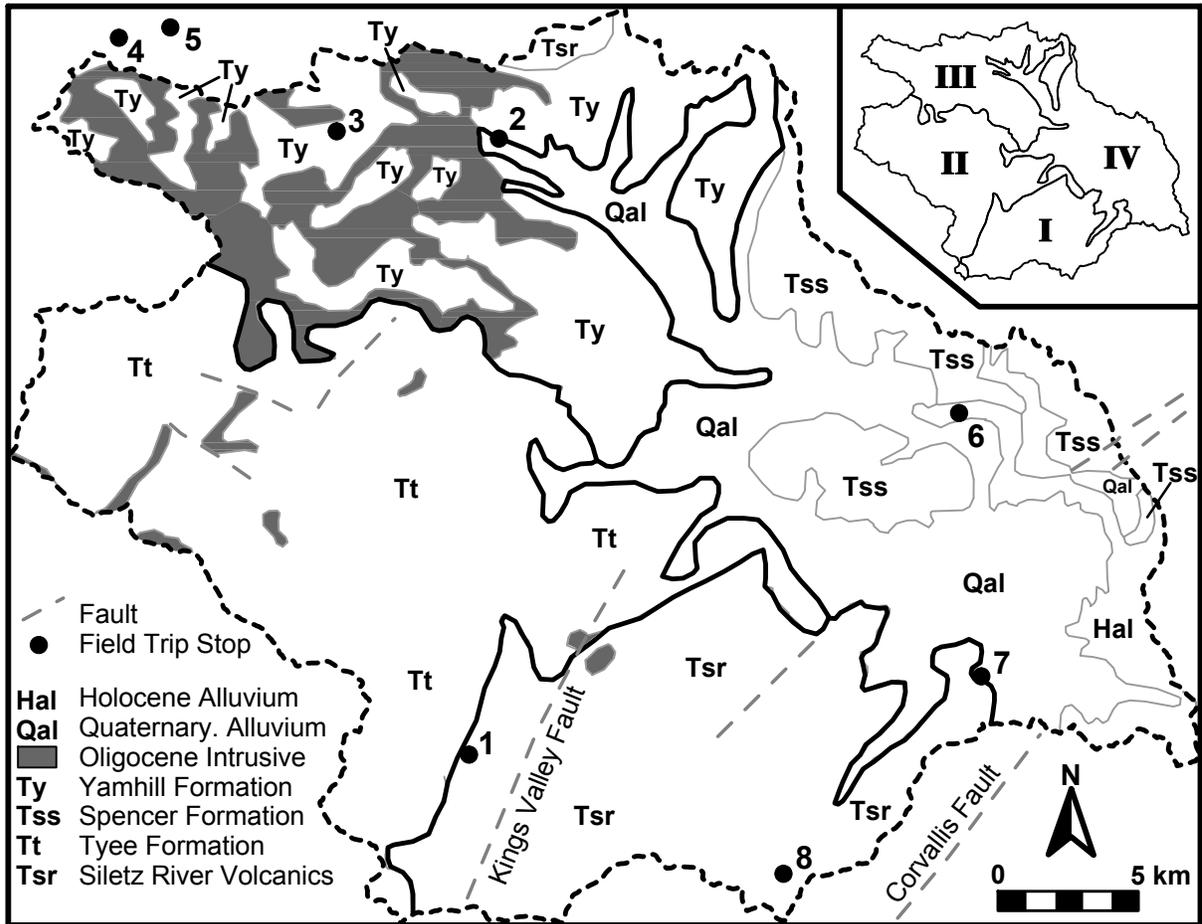


Figure 3. Bedrock geology of the Luckiamute Watershed (after Walker and MacLeod, 1991). Inset map shows grouping of recognized lithospatial domains: I = Siletz River Domain, II = Tye Domain, III = Yamhill-Ti (Tertiary Intrusive) Domain, IV = Spencer-Valley Fill Domain.

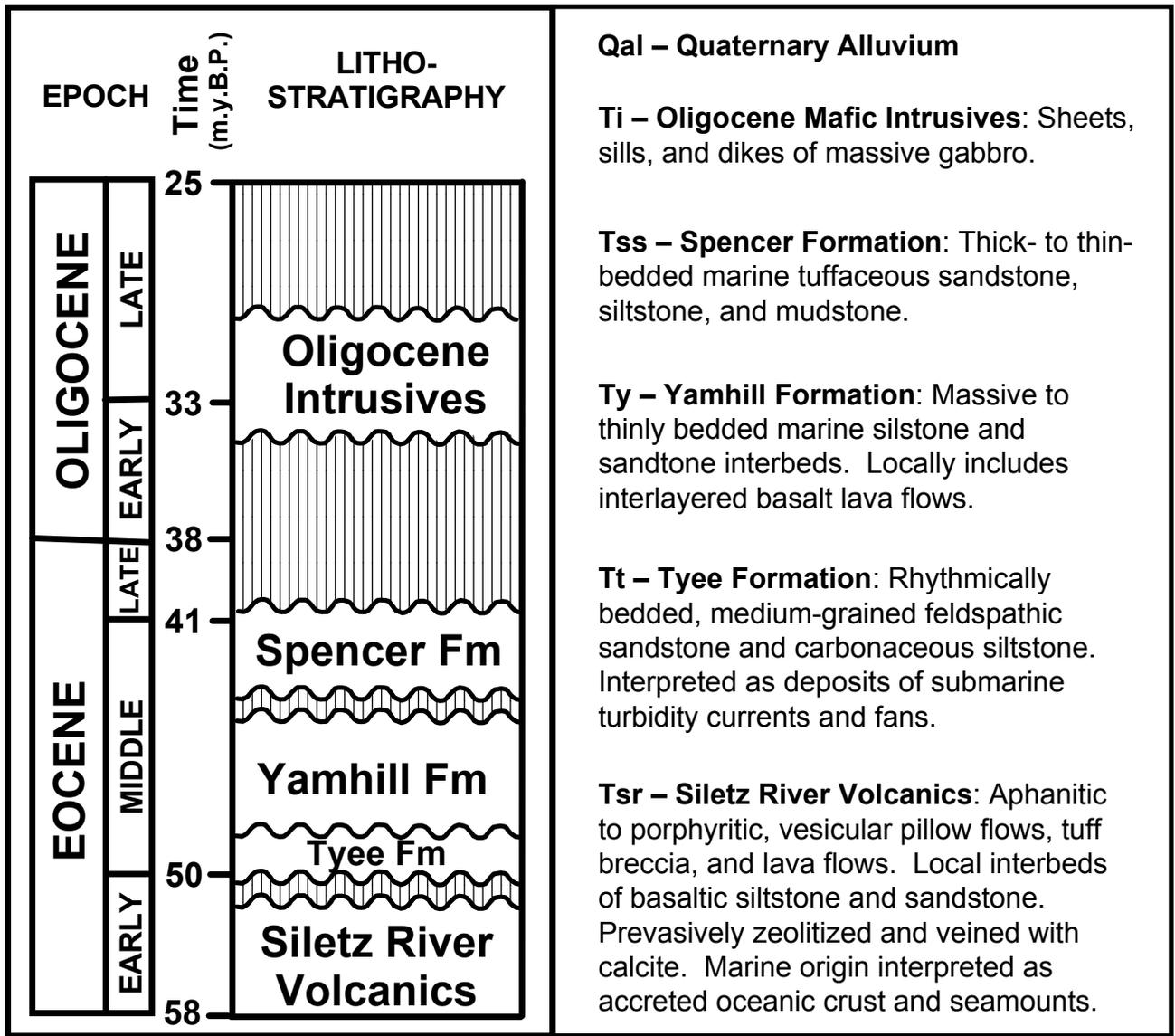


Figure 4. Bedrock stratigraphy of the Luckiamute Watershed

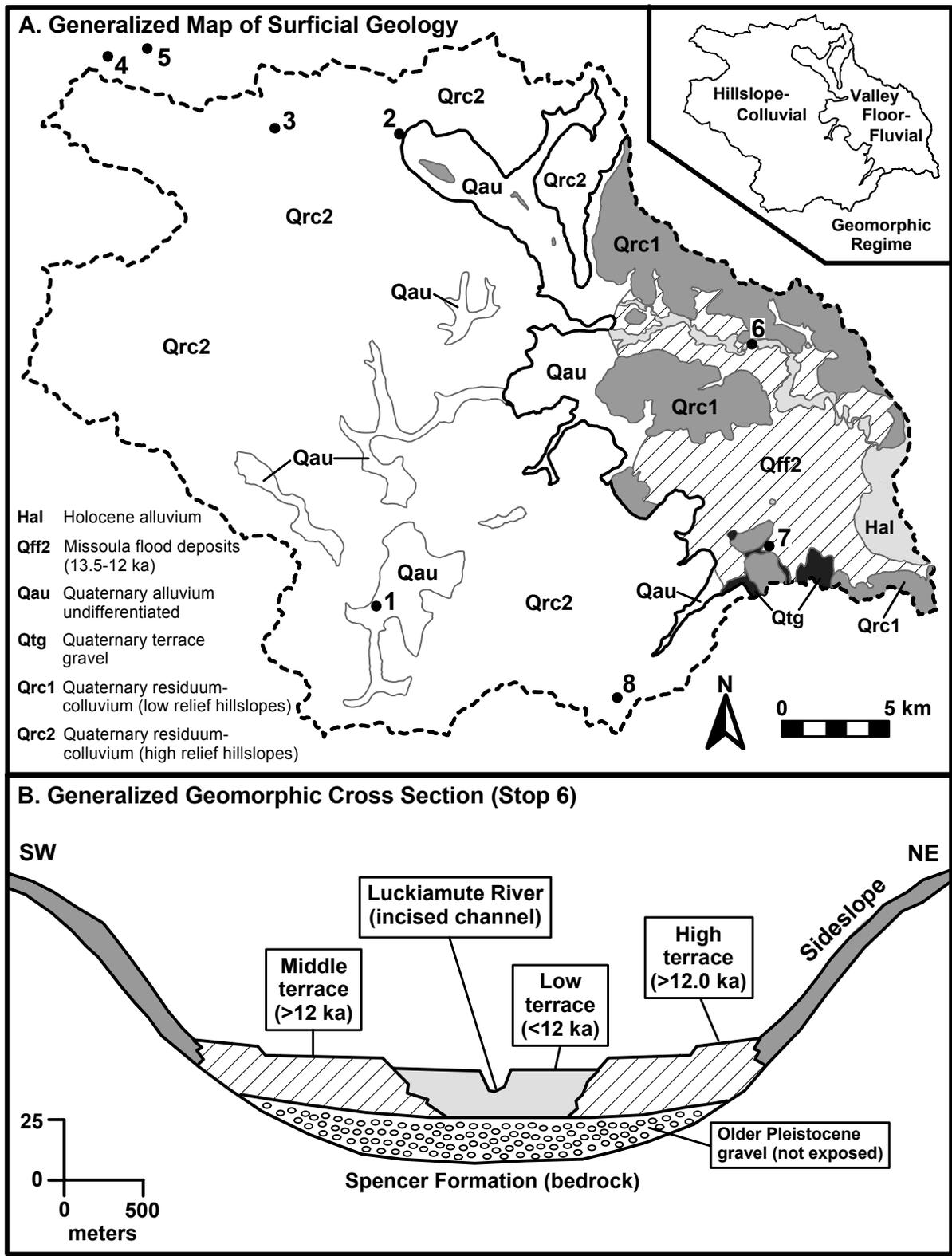


Figure 5. Surficial geology and geomorphology of the Luckiamute River Basin. □ Surficial map units are modified from O'Connor and others (2001), after Taylor and others (1996). Cross section shown in frame B represents generalized landform elements at Helmick State Park (Locality 6).

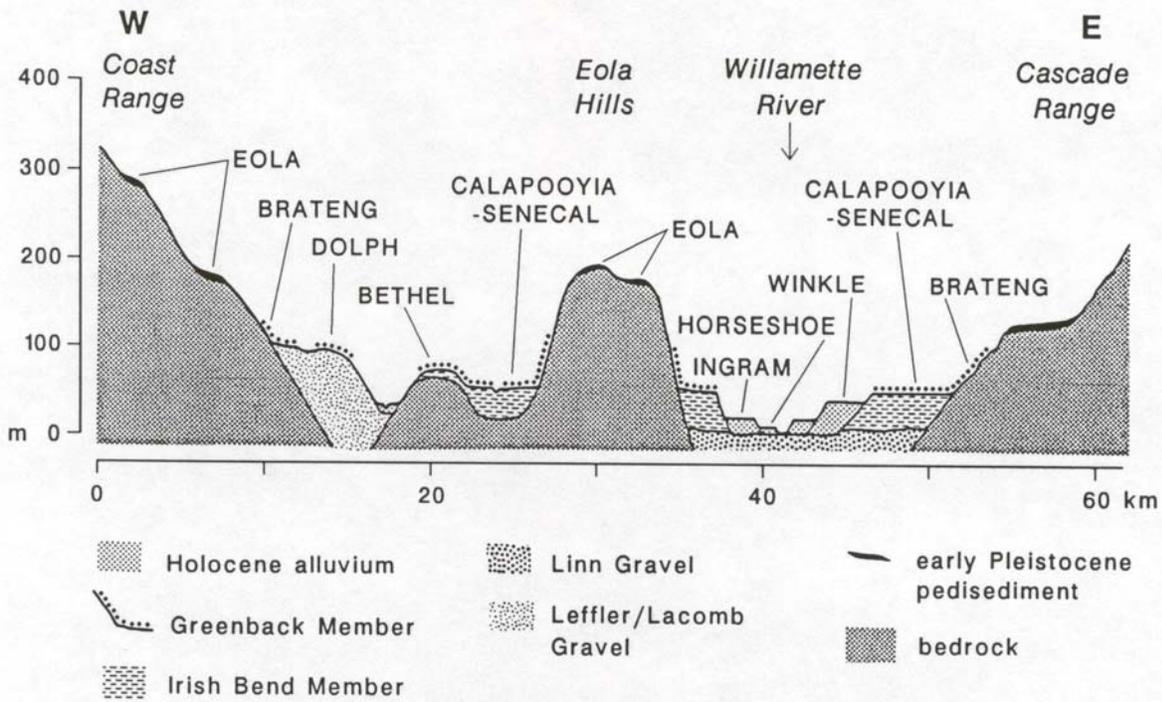
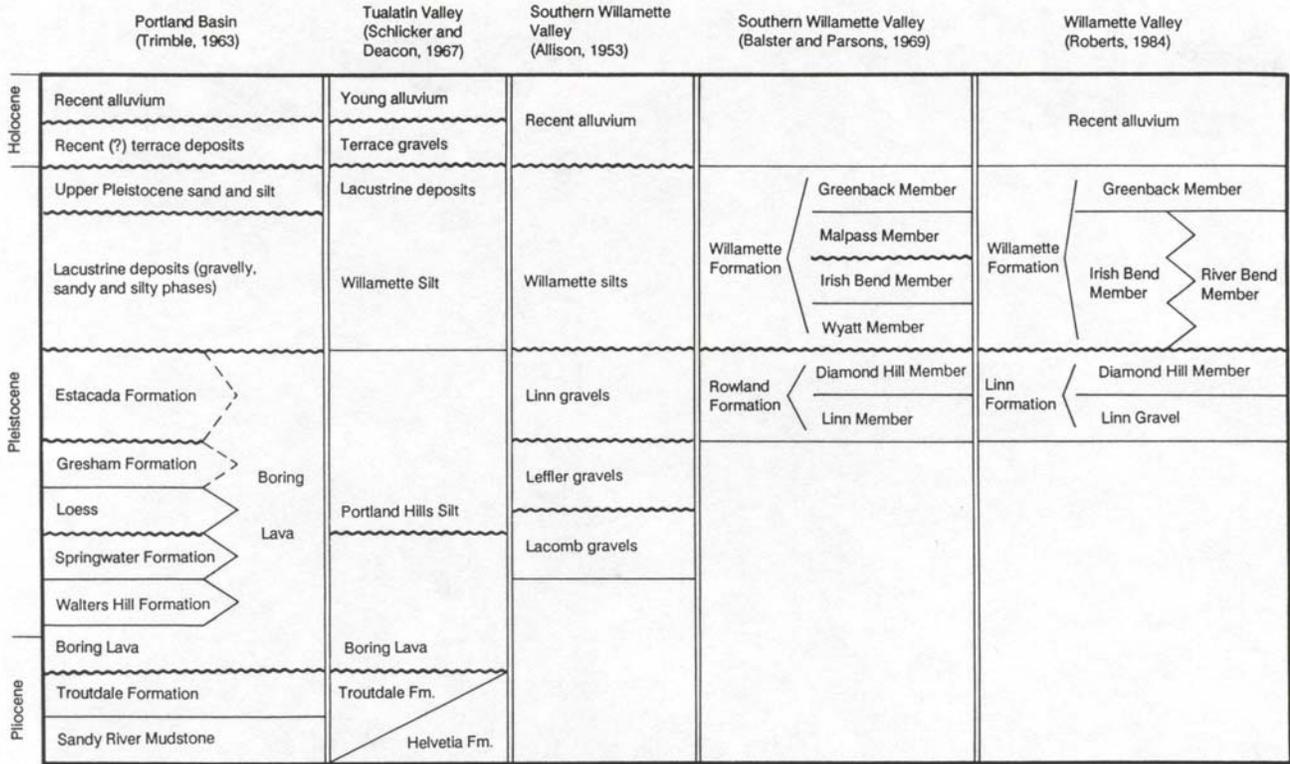


Figure 6. Quaternary stratigraphy and geomorphic surfaces of the Willamette Basin (from McDowell, 1991).

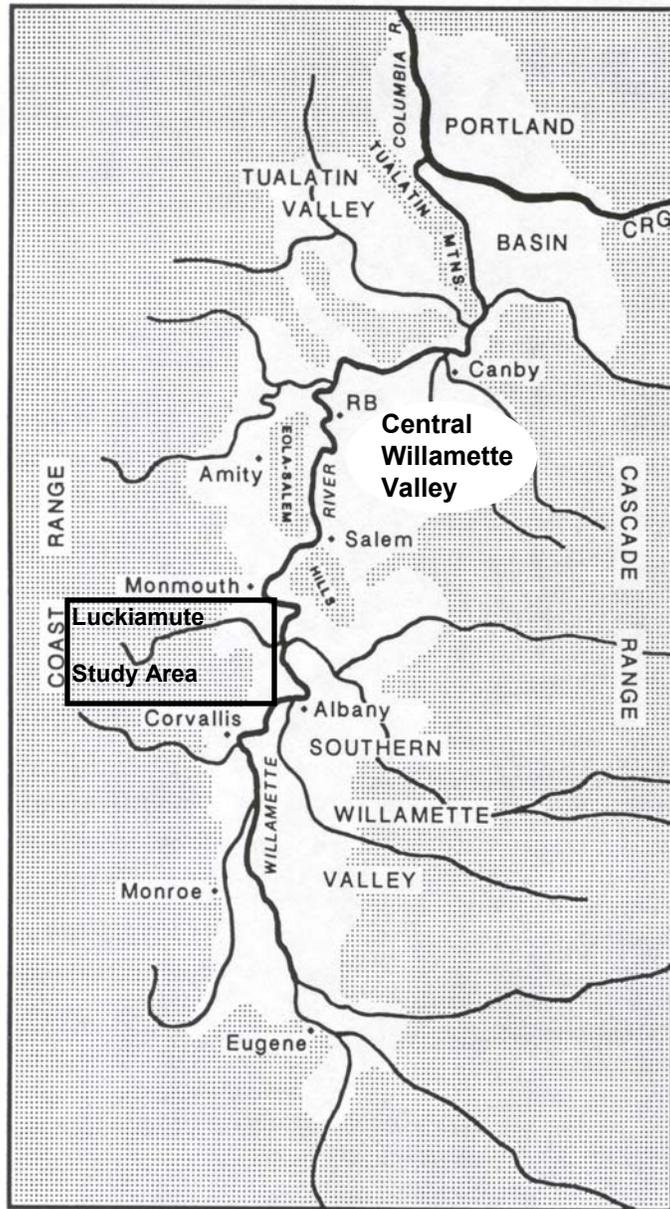


Figure 7. Map showing structural subbasins in the Willamette Valley (modified from McDowell, 1991).

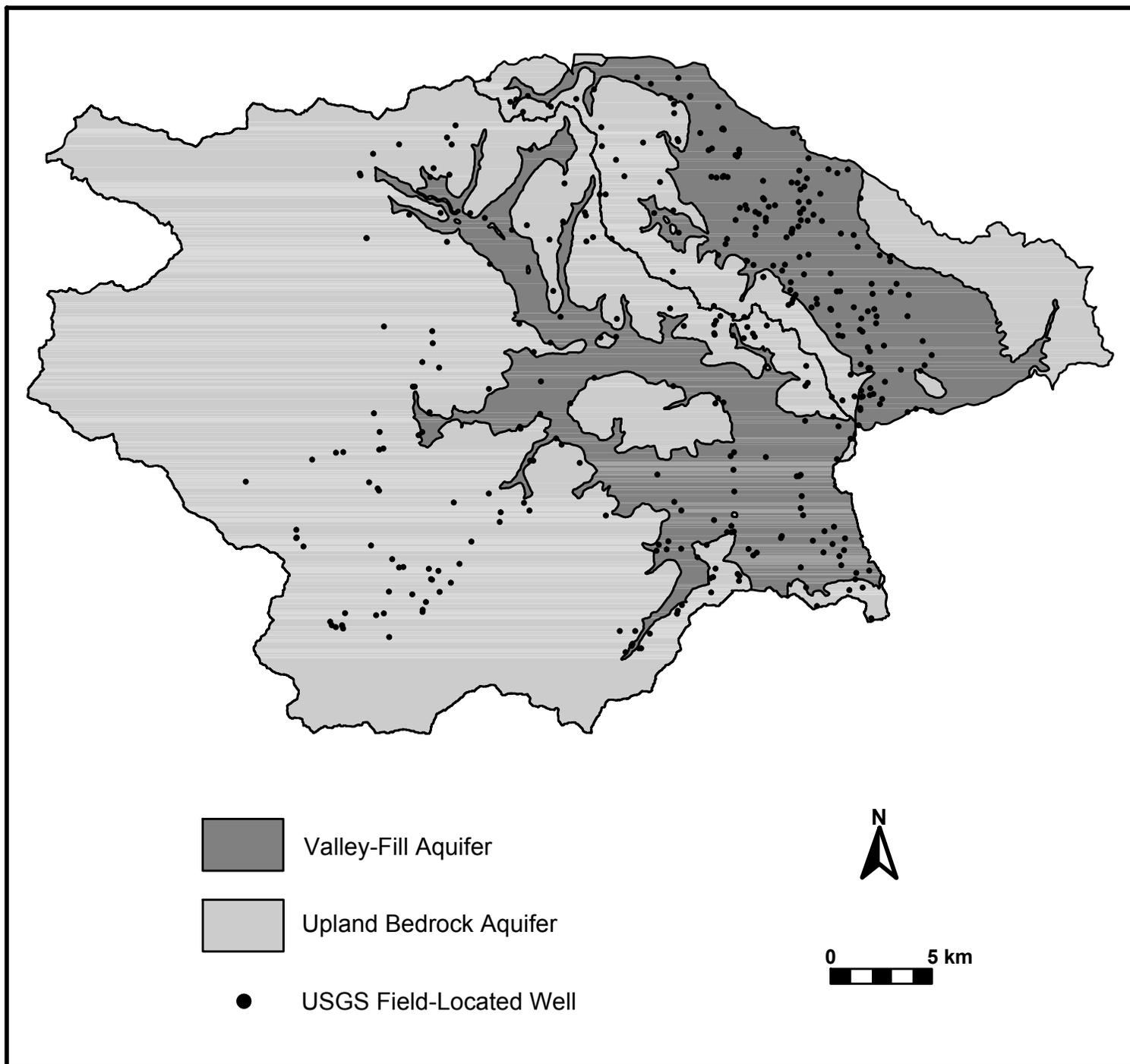


Figure 8. Aquifer type distribution in the Luckiamute-Ash Creek subbasins (from Gannett and Caldwell, 1998).