Project Report: Southern Thurston County Aquifer Characterization Study

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Acknowledgements

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Table of Contents

Executive Summary

Ground water is the only source of drinking water for nearly all residents in southern Thurston County. It is also susceptible to contamination from activities on the land surface. This study was brought about by desires of elected officials, county and Department of Ecology staff, and residents in southern Thurston County to better understand this resource and to protect it from contamination. In addition this study provided an opportunity to analyze water quality and quantity data from other studies and research projects that have occurred over the past few years. These studies, referred to in the report and the bibliography, have added much to our understanding of the aquifers in south Thurston County.

Southern Thurston County is blessed with relatively large aquifers containing large quantities of ground water. Ground water supplies almost all drinking water in south Thurston County and also provides water for irrigation, industrial processing, and aquaculture. Much of the water flowing to streams, rivers, lakes, wetlands, Puget Sound, and other surface water bodies comes from ground water. This natural ground water discharge is particularly important during the summer, when it may supply up to 100 percent of the total or base flow in a stream.

This report divides southern Thurston County into six main aquifer areas based on either bedrock boundaries or by the predominant direction of flow in the uppermost aquifer. These aquifer areas are: 1) Scatter Creek, 2) the Black River, 3) the Maytown Uplands, 4) the Deschutes River corridor, 5) Rainier, 6) Yelm. The boundaries separating the aquifers are important to understanding ground water flow and water quality data.

Key findings of this study are:

- The southern boundary of the northern Thurston County Ground Water Management Area (GWMA) does not mark the actual ground water boundary between northern and southern Thurston County.. The actual boundary is farther south than the GWMA boundary south of Fort Lewis and farther north in the Black River basin. The ground water management boundary between northern and southern Thurston County should be adjusted to better reflect the actual flow of ground water.

- McAllister Springs, one of the most significant ground water features in Northern Thurston County, gets some of its water from aquifers in south county near Rainier. Head elevation data from the area around the town of Rainier suggests that the southern boundary of the McAllister Springs capture zone lies 1-1.5 miles to the west of Rainier and 2-3 miles east and southeast of Rainier.

- Analysis of U.S. Geological Survey computer records on 3,405 wells in the study area indicates that the most common range of well depths is 51-100 feet, with the median depth being 77 feet. These records represent only a fraction of the wells in the study area and do not account for wells that were drilled and later abandoned. This is best viewed as a cumulative measure of the depths of wells drilled in the study area in the last 25 years.

- The major aquifers in south county consist largely of sands and gravels, from depths of several hundred feet to the surface. Rainfall easily permeates these sands and gravels and, not surprisingly, rainfall is the primary source of water for these aquifers.

- The highly permeable nature of the soils that overlay the aquifers makes them susceptible to contamination. As rainfall infiltrates into the ground, it may carry with it contaminants deposited within or on the ground. In south county the areas with the most significant aquifers and water supplies are also the areas most susceptible to contamination.

- Water quality in south county aquifers is relatively good. However contamination has been found in some specific areas.

- In the Yelm and Violet Prairie areas over twenty wells had nitrate levels over 5 ppm. Six wells were found with nitrate levels above the drinking water standard of 10 ppm, one well was found with a nitrate level of 30 ppm. A normal background level of nitrate in ground water would be in the 1-2 parts per million range. The number of wells found with nitrates over 5 ppm indicates that these aquifers are susceptible to contamination and that actions are needed to reduce the sources of the nitrate loading. The highest levels of contamination are strongly associated with over application and improper storage of livestock wastes.

- The nitrate data from Violet Prairie tended to be highly variable in time and space. Rather than comprising a single contaminant plume, the nitrate contamination is believed to occur in numerous smaller plumes coming from numerous sources.

- On-site sewage disposal systems contribute to the slightly elevated but widespread nitrate levels.

- The incidence of elevated iron levels in wells in southern Thurston County sampled in this study does not differ significantly from that in northern Thurston County. The incidence of elevated manganese levels found in this study is less than half the frequency of high-manganese wells noted by the USGS in northern Thurston County. The elevated iron and manganese levels are believed to be caused by changes in the oxidation/reduction state of ground water caused by bacterial metabolism of organic matter from a variety of natural and human-related sources.

Ground Water Resources of Southern Thurston County

I. Introduction

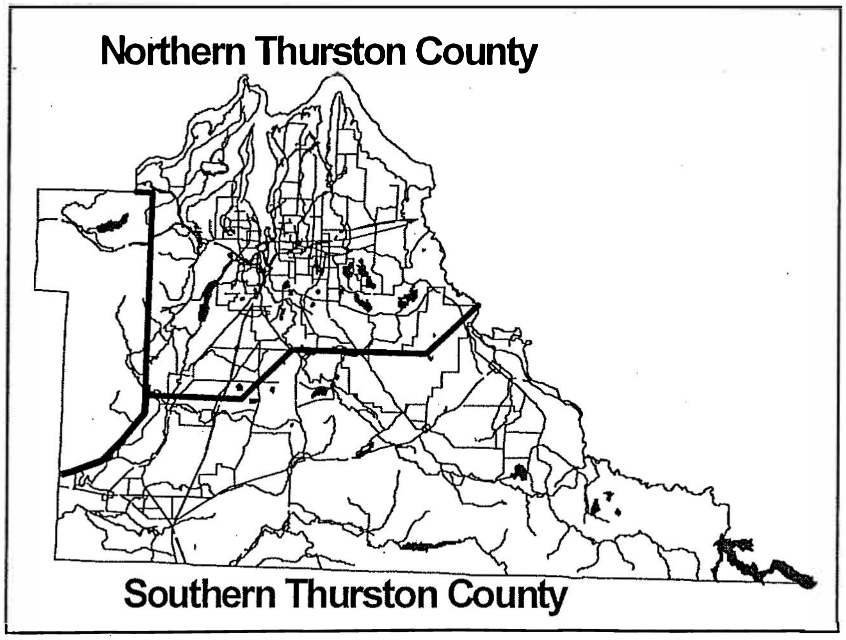

Figure 1 - The southern Thurston County ground water study area lies south of the boundary lines shown on the map.

There have been numerous studies of the geology and ground water of Thurston County. The most recent and detailed study was of northern Thurston County by Dion and others (1995). The approximate boundary of their study is shown in Figure 1. This boundary also forms the southern boundary of the Northern Thurston County Ground Water Management Area. The boundary was estimated early in the design of their study and was intended to represent an approximate hydrological boundary between northern and southern Thurston County. This study is intended to complete the aquifer characterization of Thurston County's aquifers began in that study.

II. Geology of Southern Thurston County

The oldest rocks in Thurston County were deposited in the Eocene Epoch (about 38-55 million years ago) and are found mainly in southern Thurston County. At that time, Thurston County was part of a warm, shallow sea near a gently-sloping continental plain that lay to the east (McIntosh Formation). In late middle Eocene time, andesitic and basaltic flows and pyroclastic deposits of the Northcraft Formation were deposited from the Northcraft volcanic center west of Morton (Buckovic, 1979). In the late Eocene, the near-shore marine and continental delta deposits of the Skookumchuck Formation were deposited, including some coal deposits.

A similar near-shore marine environment continued through the deposition of the Oligocene Lincoln Formation and into the mid-Miocene Epoch, about 15 million years ago . At this time, uplift of the ancestral Cascades caused the shallow sea to become largely filled in by sediments eroded from the mountains to the east (Astoria Formation).

During the last part of the Miocene Epoch and the start of the Pliocene Epoch (2-5 million years ago), the mountains were substantially eroded, with the debris being deposited as the sands and gravels of the late Miocene Mashel Formation. During the Pliocene, the Cascade Mountains were uplifted into approximately their present form (Noble and Wallace, 1966).

The present land forms of Thurston County are largely the result of glacial action during the last part of the ice age that lasted from 2,500,000 years ago to 10,000 years ago (the Pleistocene Epoch). This ice age was a period in which the earth's climate was cooler than it is now, causing glaciers now found only in high mountainous areas to grow and move downward and southward. These valley glaciers joined into huge continental glaciers that were thousands of feet thick.

At their maximum advance, the glaciers extended to Scatter Creek south of Olympia, and to the Deschutes River in eastern Thurston County. The glaciers advanced and retreated four times during the ice age, with the last advance named the Vashon stade (substage) of the Fraser glaciation.

As the glaciers moved southward from British Columbia they gouged and scoured the land beneath them and picked up large amounts of sediment ranging from boulders to silt. The friction of movement caused melting of the ice at the glaciers' base, resulting in some of the sediment load being deposited as a compressed layer directly below the glacier. This formed the dense, generally impermeable material known as glacial till (also hardpan or boulder clay). As the glacier melted, the waters that flowed off it carried large amounts of silt, sand, and gravel. Coarser materials were deposited close to the glacier's edge, while sands were carried farther and deposited on the flood plains. Silt and clay were deposited mainly in lakes and marine waters.

After the glacier melted, large remnant ice blocks were left on the outwash plains. These blocks were covered by younger sediments that later subsided into the voids left by the melted ice blocks, forming the numerous "kettle" lakes of the county.

The sediments deposited by these events are grouped in this report into seven major geologic units representing the older bedrock and deposits from two glacial advances. Some of these units are aquifers, meaning they can provide water to wells or springs in usable quantities. Other finer-grained silt, clay, or hardpan layers are aquitards (restrictive layers), which means they slow or restrict the passage of water.

The most recent aquifer, the Vashon Recessional Outwash, consists of sand and gravel layers deposited by streams during the melting (receding) of the most recent glacial period. This unit is a source of water for some shallow wells, particularly older wells. Newer wells tend to be drilled deeper than the Vashon Recessional Outwash to get better protection against contamination. Twenty-five feet is a typical thickness for this unit (Dion and others, 1995).

The Vashon Till lies below the Vashon Recessional Outwash. Vashon Till was deposited directly under the glacier under high pressure, and is an unsorted mixture of sand, gravel, and boulders in a compacted matrix of silt and clay. Vashon Till generally has a low permeability, which makes it unsuitable as an aquifer in most cases. Many wells that do produce water from sandy layers within the till have low yields, particularly during the late summer and fall months. Till can also retard the downward percolation of water or act as a confining layer for underlying artesian ground water. A typical thickness for this unit is 40 feet (Dion and others, 1995), but it can range from several feet to 175 feet in thickness.

Vashon Advance Outwash is the third major geologic unit. It consists of layers of stratified sand and gravel deposited by glacial meltwaters at the front and sides of the advancing glacier. The Advance Outwash is typically 30 feet thick, but can be as much as 135 feet thick in northern Thurston County (Dion and others, 1991). This unit occurs mainly in the eastern part of the study area.

The Kitsap Formation underlies the Vashon Advance Outwash. This unit contains layers of clay and silt, with scattered thinner layers of sand, gravel, and peat. It is generally about 55 feet thick, but locally is up to 150 feet thick. It is unimportant as an aquifer in Thurston County, since it is relatively impermeable. In many places the Kitsap Formation effectively retards the downward percolation of water, thereby causing storage of water in the overlying deposits of the Vashon Advance. This unit also occurs mainly in the eastern part of the study area.

The fifth major geologic unit was described in older reports as the Salmon Springs Drift. More recent geologic research has shown that this a different unit from the true Salmon Springs Drift found in other parts of western Washington. More recent studies refer to this unit as the Penultimate Drift (deposits of the penultimate, second-most recent glaciation). This penultimate drift is a significant aquifer that averages 30 feet in thickness, and can range up to 220 feet thick (Dion and others, 1995).

In the eastern part of the study area, some wells are completed in aquifer materials below the Penultimate Drift. The well driller's reports of the few wells finished in this unit show a sequence of unconsolidated clays, silts, sand, and gravel. In general, these materials appear to belong to several different geologic units, which are heterogenous in nature. Because of their heterogeneity and the relatively limited number of deep wells, it is difficult to reliably distinguish these units based solely on well logs. Therefore, in this report, all material below the Penultimate Drift and above consolidated bedrock will be called the Undifferentiated Deposits. The lower boundary of the Penultimate Deposits may be difficult to discern. The Undifferentiated Deposits include the Kitsap Formation, the Logan Hill Formation (Pleistocene), the Mashel Formation (Middle-late Miocene), and possibly other units. The Mashel Formation has been described as bedrock in some previous reports, but its generally unconsolidated nature makes it difficult to conclusively identify as bedrock based on well logs.

The stratigraphically lowest and oldest geologic unit found under Thurston County consists of sandstones with interbedded siltstone layers deposited during the Tertiary Period (2-63 million years ago). This includes the McIntosh Formation (Eocene), the Skookumchuck Formation

(Late Eocene), the Lincoln Formation (Oligocene), the Astoria Formation (Middle Miocene), . Dark, fine-grained volcanic rocks (basalt and andesite) are also common. This includes the Northcraft Formation (Late Eocene), the Columbia River Group (?) (Miocene), and part of the McIntosh Formation (Eocene). Together these rocks form the Tertiary bedrock unit.

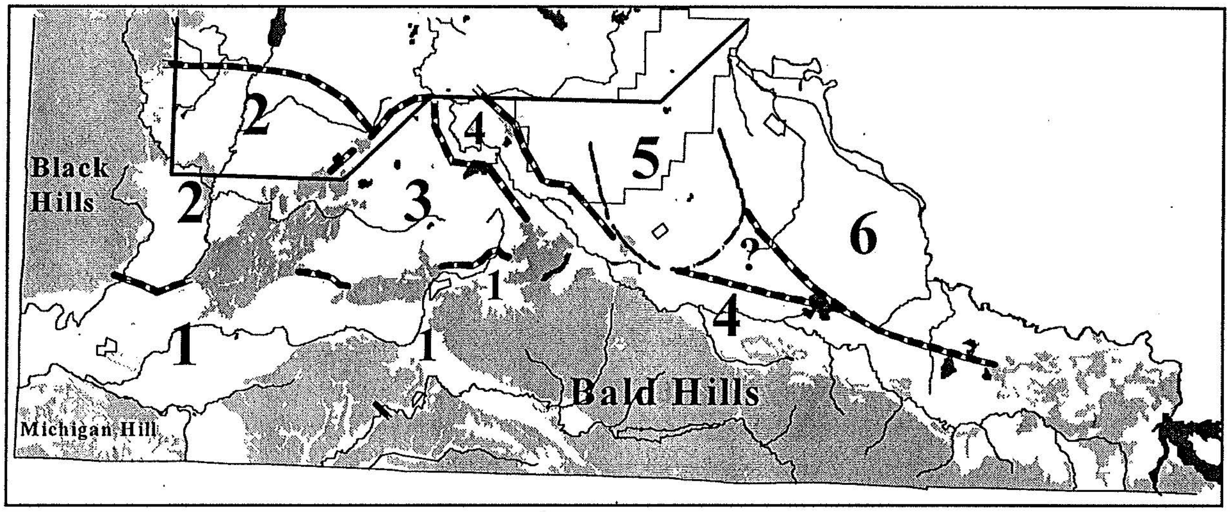

Figure 2 *- Aquifer areas: 1) Scatter Creek, 2) Black River, 3) Maytown Uplands, 4) Deschutes River, 5) Rainier, 6) Yelm*

III. Aquifer Areas

This report divides southern Thurston County into six main aquifer areas (Figure 2). Because there may be more than one aquifer underlying a given area, where possible, the aquifer area were based on bedrock boundaries that separate all aquifers. In the remaining cases, the areas were separated based on the predominant direction of flow in the uppermost aquifer.

The boundaries separating the aquifers are important to understanding ground water flow and water quality data. These boundaries are approximately located in some cases based on the best available data. More accurately mapping these aquifer boundaries should be a priority for future ground water studies in this area.

The Scatter Creek Aquifer (1)

The Scatter Creek Aquifer is generally the same as the Southern Prairie Subarea and the Southwestern Prairie Subarea of Noble and Wallace (1966). Ground water in the Scatter Creek aquifer flows to the west-southwest (Figure 3), as described in Sinclair and Hirschey (1992). The lines shown in Figure 3 are contoured elevations of the hydraulic head measured in wells. The direction of ground water flow is perpendicular to the contours in the direction of lower head. Flow directions change slightly throughout the year due to seasonal changes in recharge and discharge to streams.

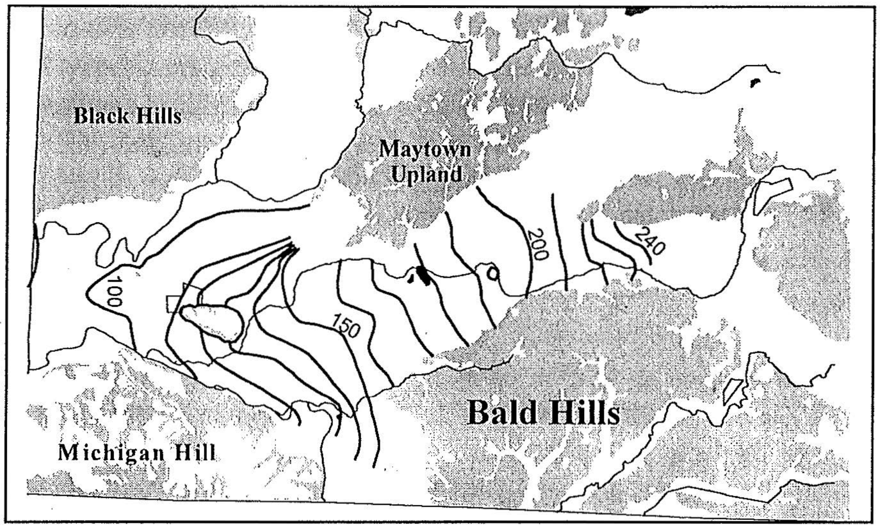

Figure 3 - *March 1990 head elevation contours in the western part of the Scatter Creek aquifer (Sinclair and Hirschey, 1992).*

The upgradient end of the Scatter Creek aquifer extends as far northeast as two miles east of Tenino, where it receives recharge from north and south of the main valley (Noble and Wallace, 1966). On the southeast side, the Scatter Creek aquifer receives some ground water flow from the lower Skookumchuck River valley, although a significant part of the flow from the Skookumchuck valley exits through the alluvial gravels southwestward along the Skookumchuck River at Bucoda.

Tenino and Bucoda are both situated above narrow, shallow aquifers surrounded by Tertiary bedrock of the McIntosh, Skookumchuck, and Northcraft formations. Wells in the valley bottom generally draw water from this shallow glacial aquifer and any wells in the surrounding hills draw water from the bedrock. The maximum thickness of the alluvial aquifer penetrated by wells in both the Bucoda and Tenino vicinities is approximately 100 feet. The width of the aquifer is generally 1/4 to 1/3 mile.

The upper part of the aquifer consists of gravel and sand of the Vashon Recessional Outwash (Qvr) and Quaternary Alluvium (Qal), otherwise known as recent river deposits. These deposits overlie outwash of the Penultimate Deposits. The U.S. Geological Survey (Noble and Wallace, 1966) reported the widespread presence of hardpan layers in both the Tenino area and the lower Skookumchuck River valley. Because the Vashon glacier did not enter these areas (Lea, 1984), the till deposits must be interpreted as belonging to the Penultimate Deposits. As in the lower Scatter Creek aquifer, these till deposits are discontinuous, indicating that the aquifer is not well protected from the downward migration of contaminants by an aquitard.

Flow from the Maytown Uplands aquifer north of Violet Prairie in T16N R2W sections 20-21 contributes to the Scatter Creek aquifer, as shown by head elevation maps in Noble and Wallace (1966)and Sinclair and Hirschey (1992). The flow boundary between the Scatter Creek and Maytown Uplands aquifers lies some distance south of Beaver Creek. The boundary probably roughly parallels Beaver Creek and passes through the north or central part of section 15, T16 N, R 2W.

According to head elevation maps in Noble and Wallace (1966)and Sinclair and Hirschey (1992), ground water flows in the Black River and Scatter Creek aquifers converge in the area of the Black River in sections 20-22, T16N, R3W. This convergence in the head maps suggests that a significant part of the flow in the Black River and Scatter Creek aquifers in that area is discharging into the Black River. Pickett (1994) found lower temperatures and higher levels of some chemical constituents in the Black River in this area that suggested ground water input. Pickett also found clear, low conductivity water in the Clearwater Lagoon, which connects to the Black River in this area. He interpreted this as suggesting a source other than Black River water for the water in the lagoon. The southern (downgradient) end of the Black River aquifer is constricted by shallow bedrock on its west side in section 20, T16N, R3W. This leaves an aquifer width of only approximately 1.5 miles for the passage of ground water. This constriction may be partly responsible for the ground water discharge to surface water.

The amount of water of recharge water that enters the Scatter Creek aquifer system far exceeds the discharge into the Black and Chehalis Rivers. The most likely explanation is that the shallower part of the aquifer discharges into the Black and Chehalis Rivers, with the deeper aquifer flow eventually discharging into Greys' Harbor.

A number of wells in the Grand Mound area have intersected bedrock at depths from 45-140 feet. A depth range of 90-120 feet is typical in the central part of the aquifer channel. Static water levels between 20-30 feet below ground surface are common, although in some areas water levels are greater than 40 feet or less than 10 feet below the surface. This means that typical saturated thicknesses for the aquifer usually range from 60-100 feet. Sinclair and Hirschey (1992) found saturated aquifer thicknesses that ranged from 41-115 feet.

The surficial deposits in the Scatter Creek aquifer area are either Quaternary alluvium (recent river deposits) or Vashon Recessional Outwash. Older bedrock crops out in the valley walls, the "Grand Mound" itself, and the low hill just southeast of Rochester. The Vashon glacier only advanced as far as Scatter Creek in the Mound Prairie area and as far as Mima Creek, several miles north of the Scatter Creek aquifer (Noble and Wallace, 1966). Outwash from the melting glacier spread out over the entire Grand Mound area south into Lewis County and west into Gray's Harbor County.

The previous glacial advance, which was associated with the Penultimate Deposits, advanced significantly farther (Lea, 1984). It extended nearly to Centralia and reached about 2.5 km. up the Skookumchuck River valley. In most of the Scatter Creek aquifer area, well logs record a discontinuous layer of "hardpan", "cemented gravel", or "clay, sand, and gravel" that marks the upper boundary of the Penultimate Deposits. The top of this till layer is commonly found from 10-30 feet below the surface, but in places may be deeper than 50 feet. The thickness rarely exceeds 40 feet, and in most cases is less than 20 feet. The ambiguity of the terms used in well logs often make it difficult to interpret the true thickness of this till layer.

The top of the till layer is generally 30 feet or less below the surface and the total thickness of unconsolidated deposits in the aquifer is usually a little over 100 feet. In other words, the Vashon deposits above the Penultimate till layer comprise less than one-third of the material in the Scatter Creek aquifer. The majority of the Scatter Creek aquifer consists of the Penultimate Deposits.

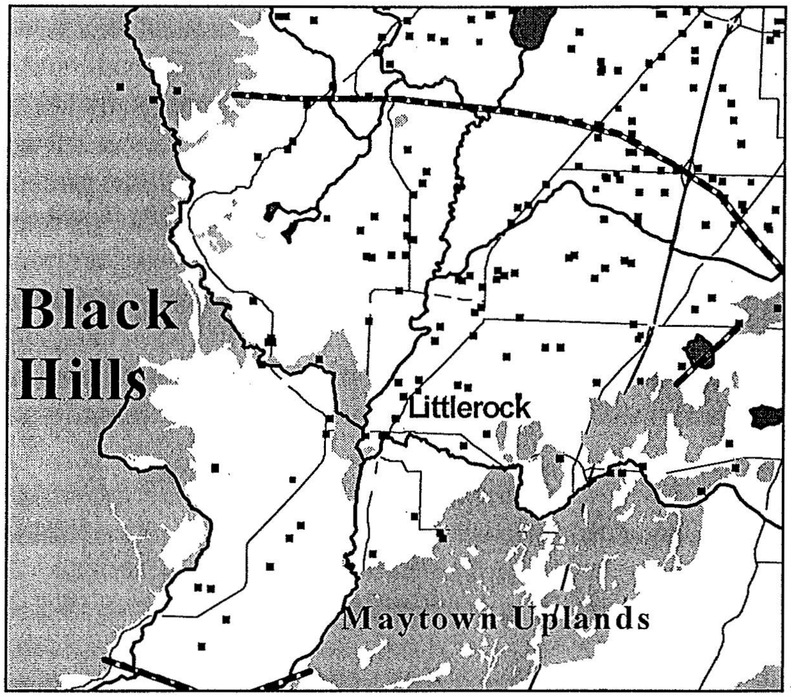

Figure 4 *- Distribution of wells within the Black River aquifer area. Not all wells in the area are shown Bedrock is shaded.*

The Black River Aquifer (2)

The Black River aquifer is bounded by the Black Hills on the west, by the bedrock deposits of the Maytown upland on the east, and by ground water divides on the north and south. Ground water flows from north to south down the Black River valley, generally paralleling the slope of the ground surface. At its southern end, it contributes water to the Scatter Creek aquifer and to the Black River.

The surficial deposits are primarily Vashon Recessional Outwash, with a large body of Vashon morainal deposits in the central and exposures of Vashon Till occurring in several locations. Parts of this area are sparsely populated, especially in the extensive wetland areas along the Black River. So in some places there is little ground water information available. This shortage of data adjacent to the river will make it hard to characterize surface water/ground water interaction in the future.

The Maytown Uplands Aquifer (3)

This triangular-shaped aquifer lies within the Maytown uplands, a gentle topographic high underlain by bedrock of Tertiary age. The geology is more complex than in the other aquifer areas. The aquifer is generally thin and is strongly affected by local topography and by the flow patterns of surface water.

Ground water in the Maytown Uplands aquifer flows in several directions. Water to the south of Beaver Creek generally flows southwestward toward the Scatter Creek aquifer. Ground water in the northeastern part of the aquifer drains toward the Deschutes River. Much of the surface water above this aquifer drains to the west, and ground water probably follows a similar path.

Offut Lake is a small kettle lake surrounded by morainal deposits (Noble and Wallace, 1966). Directly to the north of Offut Lake, the lake water level is approximately 30 feet above the level of the water in the Deschutes River and an associated wetland. Ground water from the vicinity of Offut Lake is undoubtedly seeping through the moraine to the north and discharging into the Deschutes River System.

The Deschutes River Corridor (4)

Throughout much of its length in southern Thurston County, the Deschutes River flows adjacent to or very close to volcanic or sedimentary bedrock of Tertiary age. This bedrock has much lower permeability than the overlying Pleistocene outwash material. In some places, such as the area between Vail and Rainier, the Deschutes River lies within a narrow valley incised into bedrock that contains a relatively thin alluvial valley fill and alluvial terraces. The zone of ground water interaction around the Deschutes is considerably smaller than the surface water watershed.

Within the area of the Deschutes River, interchange with the River is expected to be the dominant hydrologic condition. The USGS conducted a seepage run (mass balance) study along the Deschutes River in 1988. They concluded that the lower part of the river, north of the Rich Road bridge, was generally gaining flow from ground water (Dion and others, 1995). The Deschutes River north and east of Offut Lake appears to be a zone of high discharge of ground water to the river.

It is clear from the presence of springs in several location near the upper Deschutes River that ground water is discharging to the river near those locations. Examples of these springs are Silver Spring (SW 1/4 T16N, R1W) and springs along the river in T16N, R1E sections 20 and 21. Figure 5 shows the location of some of the known springs within the Deschutes River corridor.

The Rainier Aquifer (5)

The surface soils in the Rainier area are derived from the Quaternary Vashon Till (Qvt) and Vashon Recessional Outwash (Qvr) aquifers. The Qvt may be more than 100 feet thick north of Rainier. The Qvt is underlain by either Vashon Advance Outwash (Qva) or Deposits of the Penultimate Glaciation (Qc), formerly called the Salmon Springs Formation. Tertiary Bedrock is at least 240 below the surface in the Town of Rainier.

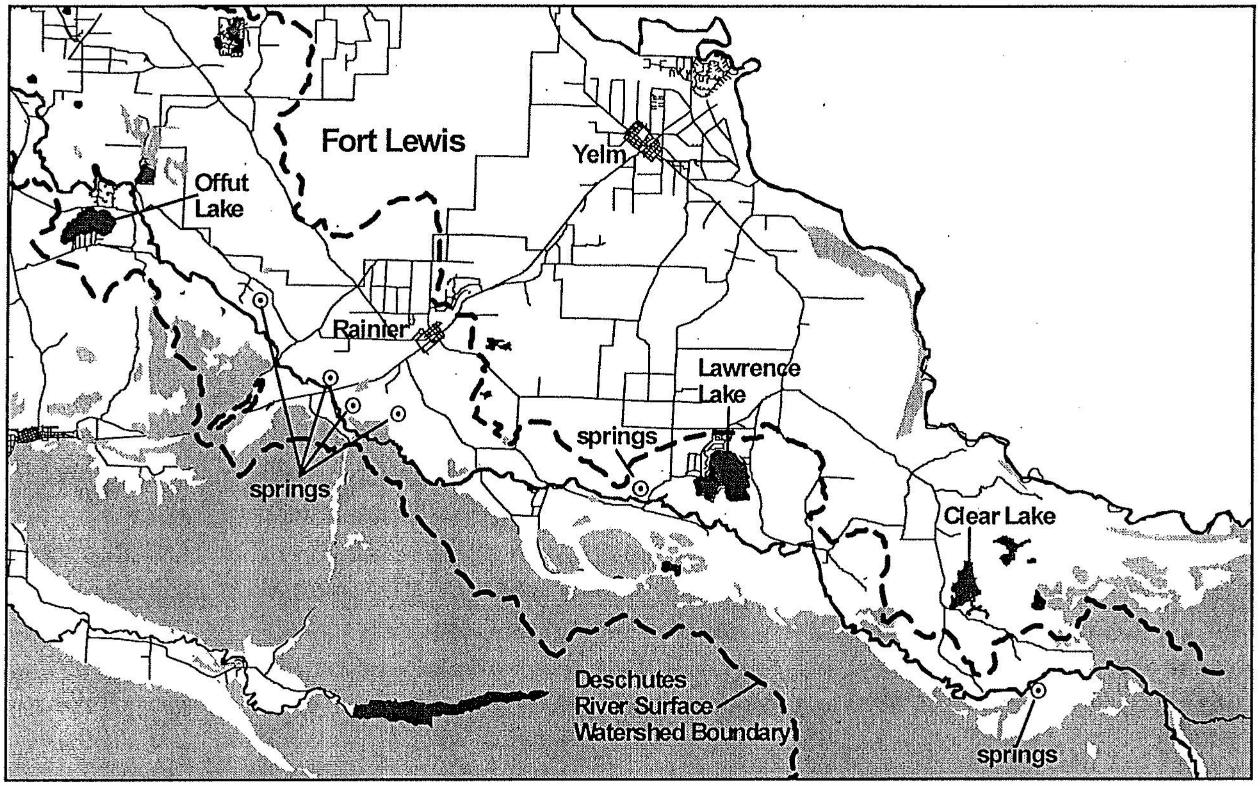

***Figure 5** - The Deschutes River Corridor.*

There are at least two, and probably three ground water flow systems in the Rainier area. The shallow (Vashon Recessional Outwash) ground water system is tapped by wells completed above the Vashon Till, which is very thick in the area north of Rainier. Flow directions in this aquifer are not well characterized due to the small number of wells completed in this aquifer. This aquifer is also the most influenced by interaction with surface water, so ground water flow directions would be expected to be the most variable.

An intermediate aquifer system appears to flow through the Vashon Advance outwash, the Penultimate Deposits, and the upper part of the Undifferentiated Deposits flows northward. There appears to be a deeper ground water system entirely within the Undifferentiated Deposits, also developed by few wells, that probably flows northward as well.

McAllister Springs, in northern Thurston County is one of the most significant ground water features in Thurston County. Extensive hydrologic studies have been carried out in northern Thurston County to delineate the extent of its capture zone. Determining the southern extent of its capture zone has been hindered by the lack of wells on the Fort Lewis military reservation.