WRIA 13 ASSESSMENT
CHAPTER 4 – GEOLOGY & GROUNDWATER

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CHAPTER 4 - GEOLOGY AND GROUNDWATER

4.1 WHY IS GEOLOGY AND GROUNDWATER IMPORTANT TO WRIA 13 WATERSHED PLANNING?

Water quantity is central to planning under the Watershed Planning Act RCW 90.82. And in WRIA 13 groundwater is the source of virtually all domestic use and nearly all industrial and irrigation uses. Contents of this chapter and their significance for watershed planning:

- ***Glacial history***: The glacial history of our region is reflected in the complex underground "landscape" of water-rich aquifers and water-impeding aquitards underlying our area. Our surface watersheds do not always reflect groundwater recharge areas and direction of flow.

- ***Aquifer location and depth***: Not all areas are the same regarding groundwater resources. The southern portion of WRIA 13 – where the glaciers ended their advances – has less deep glacial sediment and fewer distinct aquifers, compared to the north area with over 1,000 feet of glacial sediment and multiple aquifers. Upper aquifers may directly support streamflow while deeper aquifers largely discharge to Puget Sound. The groundwater/surface water continuity issue is at the heart of water resource management – and very complex.

- ***Groundwater budget***: The 1999 USGS report provided an overall groundwater budget for the region. This describes in broad terms the groundwater picture of our region, including "secondary recharge" provided by irrigation, septic drainfields and other water uses.

- ***Current groundwater withdrawal and trends in groundwater level***: Groundwater withdrawal is estimated for various uses. Groundwater trends in North Thurston County have been monitored for several years. To date, no significant decline in aquifer level has been detected.

- ***Impacts of potential future groundwater withdrawal***: USGS modeled the impact of meeting projected long-term population growth. Long-term population estimate used for the model was 288,000 – a doubling of current population[1]. In the model, demand was met by continued pumping of existing municipal wells. The model calculated reduced flows in various rivers and reductions in lake levels if this course were pursued. In reality, new proposed water rights must address instream flow impacts to gain approval from DOE.

[1] USGS used the 50-year population forecast in the 1986 Reservation of Future Public Water Supply for Thurston County, WAC 173-591.

4.2 GLACIAL HISTORY AND AQUIFERS

Repeated glacial advance and retreat formed the geology underlying most of WRIA 13. The area's prairies, rolling terrain and lakes reflect the advance and retreat of the Vashon Glaciation, the most recent of several glaciers that extended to the area. Beginning with a cooling period about 15,000 years ago, a continental ice mass extended from British Columbia to its terminus in south Thurston County. The Yelm Lobe of the Vashon Glacier extended beyond present-day Lake Lawrence, to the edge of the Bald Hills in the upper Deschutes basin. Extent of glacier advance is shown on Figure 4-1.

As the climate warmed about 13,500 years ago, the glacier retreated northward. With surface water drainage to the north blocked, several temporary drainage routes were created across present-day Thurston County to the Chehalis River, conveying the Deschutes and Nisqually Rivers and glacial melt waters. As shown on Figure 1, westerly-flowing drainage routes as the glacier retreated north included:

- Johnson Creek flowing southwest to the Skookumchuck River;
- McIntosh Lake/Scatter Creek;
- Offutt Lake/Beaver Creek;
- Spurgeon Creek and Salmon Creek west to the Black River;
- Lakes area in the upper Woodland Creek watershed and flowing westerly to the upper Black River.

Tremendous volumes of glacial sediment were deposited in the study area, ranging from very fine silt (compressed to form impermeable "hardpan") to large boulders called "glacial erratics". (A good example is the house-sized rock near the Lake Lawrence fire hall on 153rd Avenue. The flat sides of the boulder reflect long distances being scrapped along at the head of an advancing glacial lobe.) The glacial sediment forms one or more *aquifers* underlying the area north of the Bald Hills – aquifers that supply virtually all water serving our current and future communities.

Depth of glacial sediment increases dramatically from south to north in the study area, as illustrated on Figure 4-2. Total depth of glacial sediments above bedrock increases from less than 300 feet at Lake Lawrence to over 1,800 feet at Johnson Point. In contrast, the surface elevation at Lake Lawrence is only about 300 feet above sea level. Variation in the sub-surface "topography" (sediment above bedrock) is five times the variation in surface elevation from Lake Lawrence to Puget Sound.

The Vashon Drift deposited during the most recent glaciation is composed of large quantities of stratified sand and gravel deposited by glacial advance and retreat. The upper aquifers generally have a high degree of "continuity" between groundwater and surface water in streams and lakes. This is a very significant factor is obtaining water rights for new wells. Deeper aquifers have less continuity due to depth and presence of one or more “aquitards” – glacial sediment layers with fine, hard-packed materials restricting downward movement of groundwater.

The upper formation is the Vashon recessional outwash (Qvr), which creates the hummocky terrain and the numerous lakes of the region. In some locations, springs and seeps flow from this upper aquifer into area streams. Large springs in WRIA 13 include Silver Spring on the Deschutes and the springs at the Nisqually trout hatchery on Woodland Creek near Martin Way (Beatty Springs). The USGS estimated Silver Springs flow at over 1 cfs and Beatty Springs in excess of 6 cfs (about ¼ the flow at McAllister Springs).[2]

Below the Qvr is a generally confining layer called the Vashon glacial till (Qvt). This “hardpan” is composed of sand and gravel encased in a matrix of silt and clay. The depth and degree of compaction varies with the period the till was laid down, with more compact till developing beneath the heavy mass of glacial ice and less compact till forming during the glacial melting period.

At the bottom of the Vashon Drift are materials laid down during the Vashon glacial advance (Qva), which serves as a significant potable aquifer for the region. Some municipal wells and many smaller wells are located in this aquifer, which is estimated to provide about ½ of the total source for wells in the glacial deposit region of Thurston County.[3]

Below the Vashon materials lay the clay and silts of the earlier Kitsap formation, which is generally a confining layer for groundwater. Deeper still are the deposits of “penultimate” glaciation (Qc), which is beginning to be used as a municipal water source. About ½ of the totals well withdrawal in the USGS study was identified as utilizing the Qc. Deeper yet lie the “unconsolidated and undifferentiated” Tqu deposits, which are deep deposits of mixed glacial and non-glacial origin, thought to include areas of both aquifers and confining layers.

[2] Conceptual Model and Numerical Simulation of the Groundwater Flow System in the Unconsolidated Sediments of Thurston County, Washington, USGS, 1999. Table 4 lists major springs and the associated geohydrologic units.
[3] USGS study cited above. See Table 5 for estimated groundwater use by aquifer based on the detailed study conducted in 1988.

Table 1 - Hydrogeologic Units in WRIA 13 Planning Area

Geologic Unit	Map Unit	% of Supply	Characteristics
Vashon Recessional Outwash Aquifer	Qvr	9%	Mostly unconfined aquifer. Qvr is at the surface except in peninsulas and uplands, where it is not present. Supports lakes and stream flow. Source for many smaller wells, some Olympia wells and Ward Farms wells along Yelm Highway. Not present in peninsulas.
Vashon Till	Qvt	1%	Confining bed of sand and gravel in silt and clay matrix, deposited by glacial ice. Qvt is at surface over most of peninsulas. Some thin lenses of clean sand and gravel.
Vashon Advance Aquifer	Qva	45%	Mostly confined aquifer. Very important source for small and large wells from Rainier north to peninsulas. Source for Chambers Prairie/Shana Park and some Tumwater Valley wells.
Kitsap Till	Qf	1%	Clay and silt confining bed, 20 – 70 feet in depth.
Deposits of Penultimate Glaciation (“Sea-Level Aquifer”)	Qc	35%	Confined aquifer. Important source for large wells in Tumwater area. Supplies many smaller wells in peninsulas and McLane Creek basin.
Unconsolidated and Undifferentiated Deposits	Tqu	8%	Both glacial and nonglacial origin aquifers and confining beds. Supplies deeper wells in Cooper Point and other areas. Formation is not well understood. Deposits exceed 1,000 feet deep in north end of WRIA.

Groundwater contours and direction of groundwater flow for the two principal aquifers was calculated by the USGS (USGS, 1999). Flow direction in the Vashon advance aquifer (Qva) is generally consistent with surface topography in the Henderson Inlet watershed. See Qva groundwater contours at Figure ___ from the USGS groundwater study for Thurston County.

In the southern part of the Henderson Inlet basin (Lakes/Chambers Prairie area), the pre-Vashon Qc aquifer is understood to flow easterly toward the McAllister Springs vicinity, contradictory to the existing surface topography. See Figure 6. Much of this aquifer is believed to discharge to Puget Sound.[4] A significant portion of the precipitation falling in the Lakes/Chambers Prairie area does not route to surface streams in the Henderson Inlet watershed. Due to the very porous soils and flat topography, 80-90% of the precipitation falling on the upper Woodland Creek basin flows to McAllister Creek or Puget Sound without entering Woodland Creek.[5]

. Conceptual Model and Numerical Simulation of the Groundwater Flow System in the Unconsolidated Sediments of Thurston County, Washington, USGS, 1999. See Figure 23e.[4]

[5] Woodland and Woodard Future Conditions, Thurston County, Washington, Final Results, Aqua-Terra, 1994.

Figure 1 - Maximum Extent and Drainage Routes of The Vashon Glacier

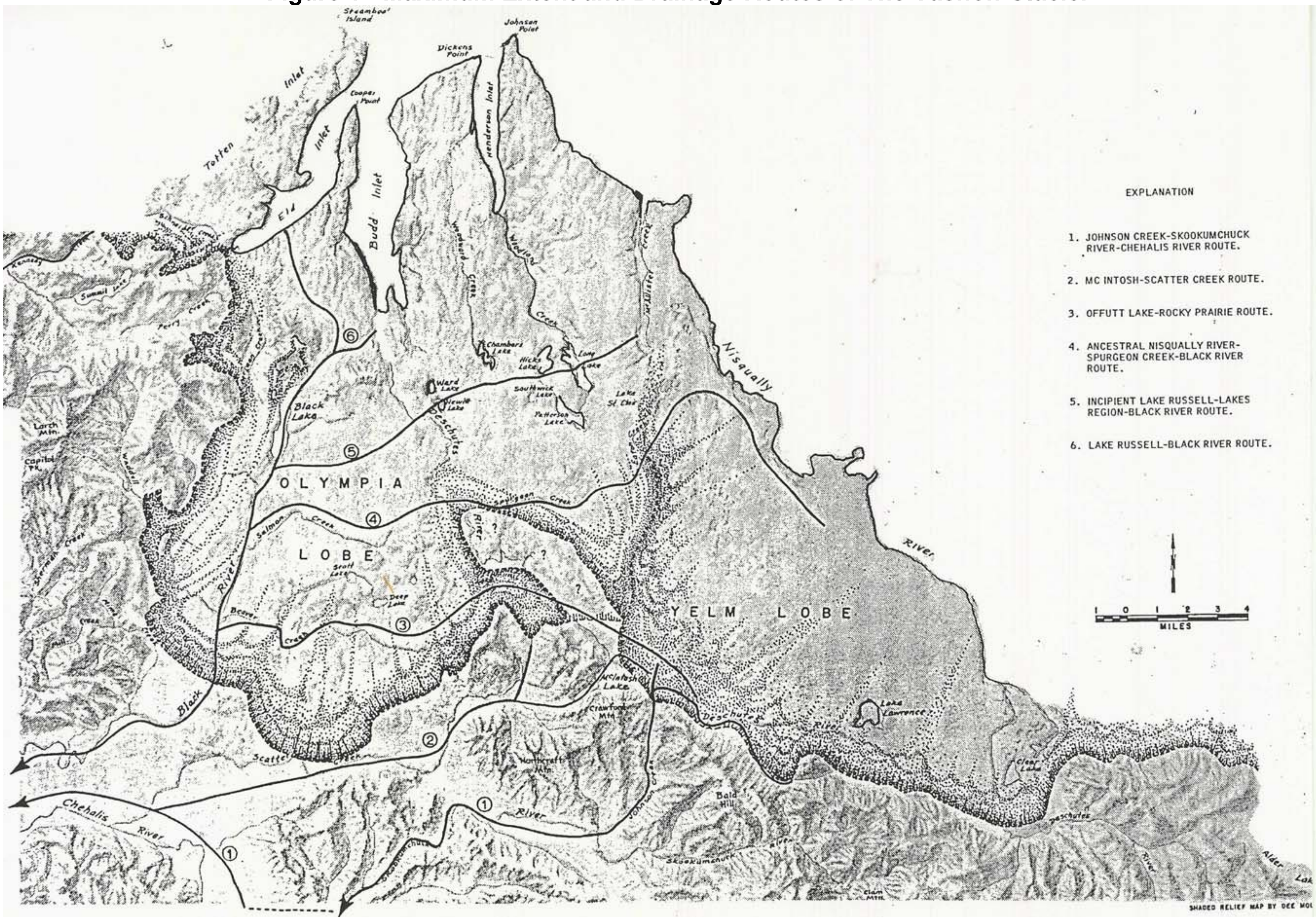


Figure 2 - Depth to Bedrock in Northern Thurston County

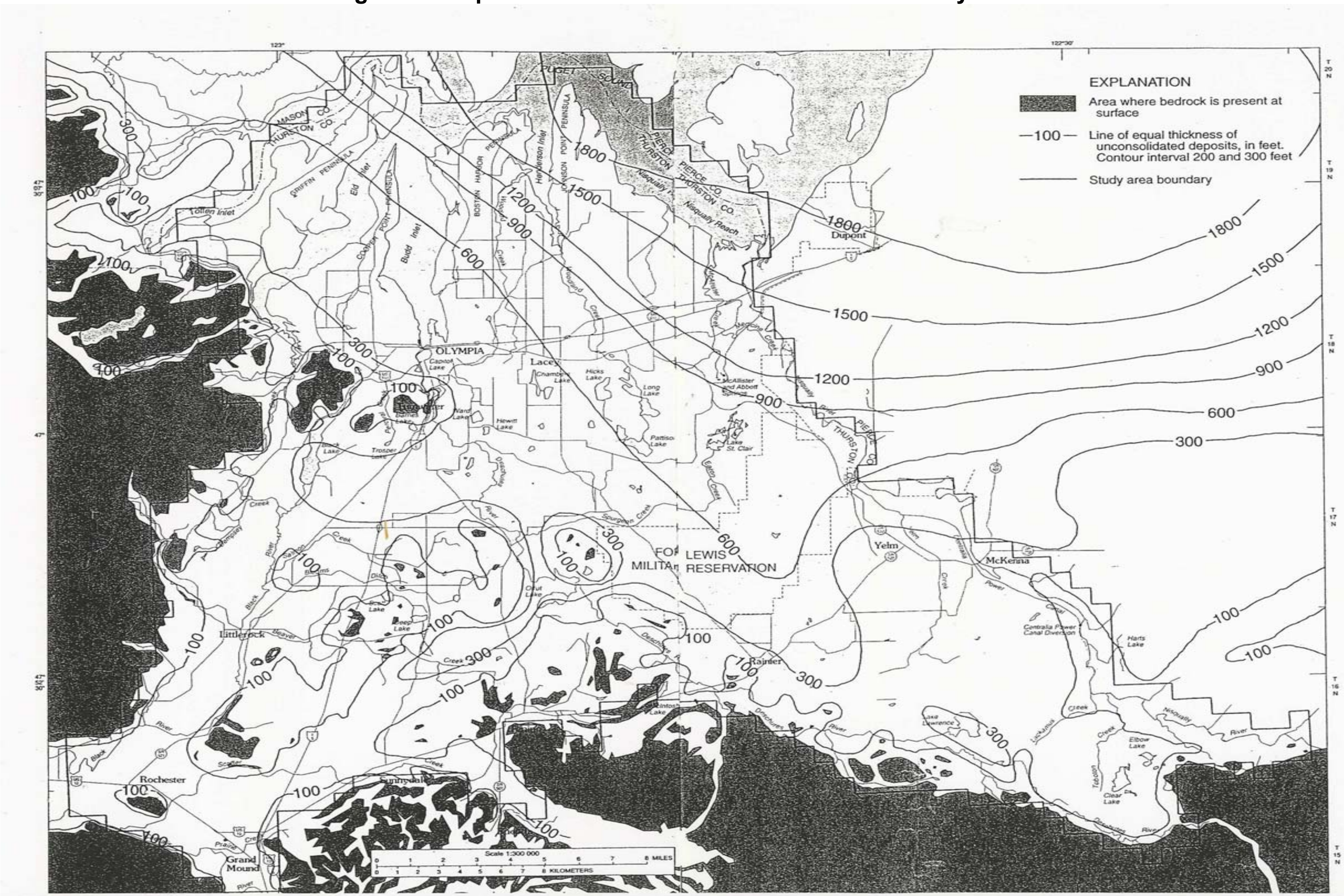
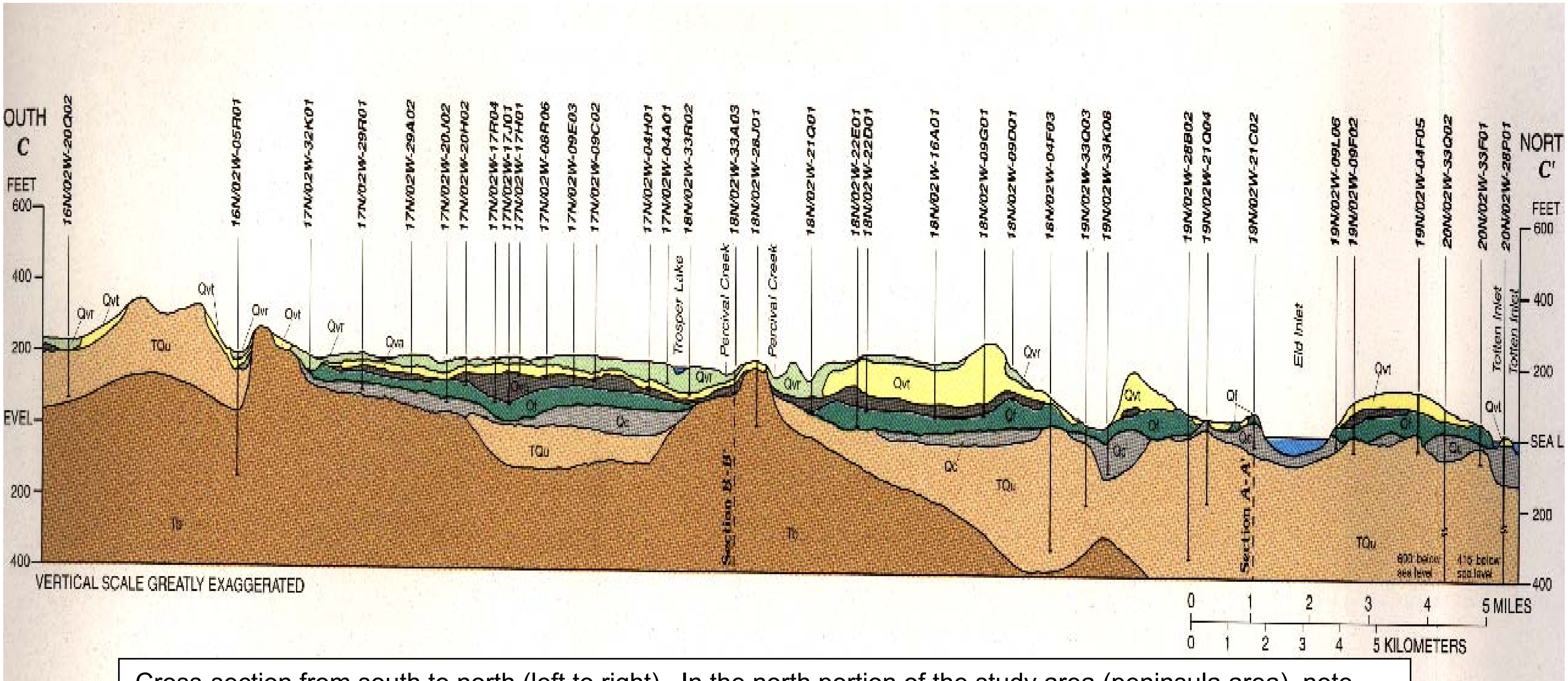


Figure 3 - Geohydrologic Cross-Section: Maytown to Steamboat Island
(From 1999 USGS Groundwater Model report)



Cross-section from south to north (left to right). In the north portion of the study area (peninsula area), note absence of upper aquifer (Qr), increasing presence of the Vashon Till layer (Qvt) and dramatically increasing depth of the deepest “unconsolidated deposits” aquifer.

Figure 4 – Qva (Vashon Glacier Advance Aquifer) Contours and Direction of Flow

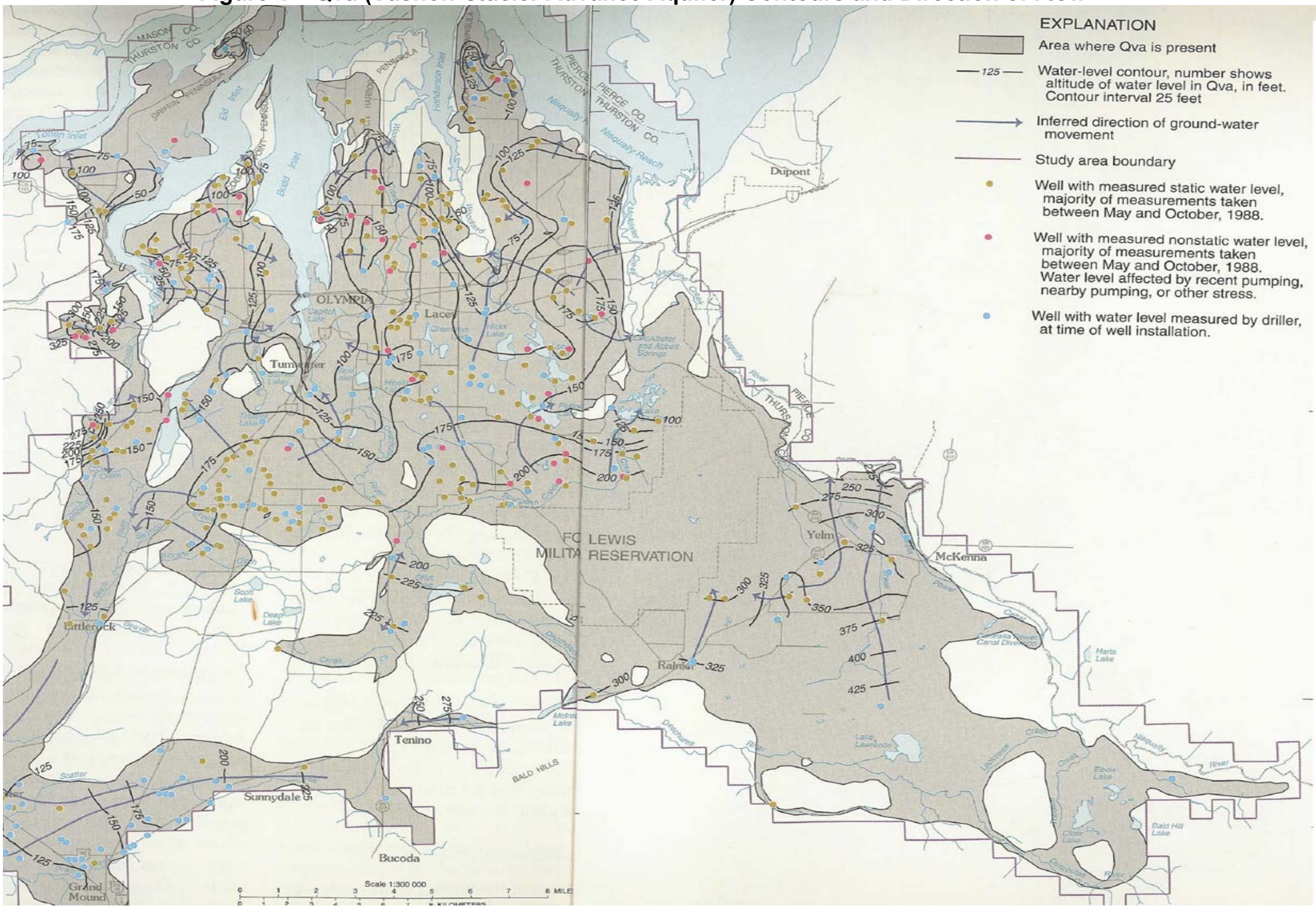
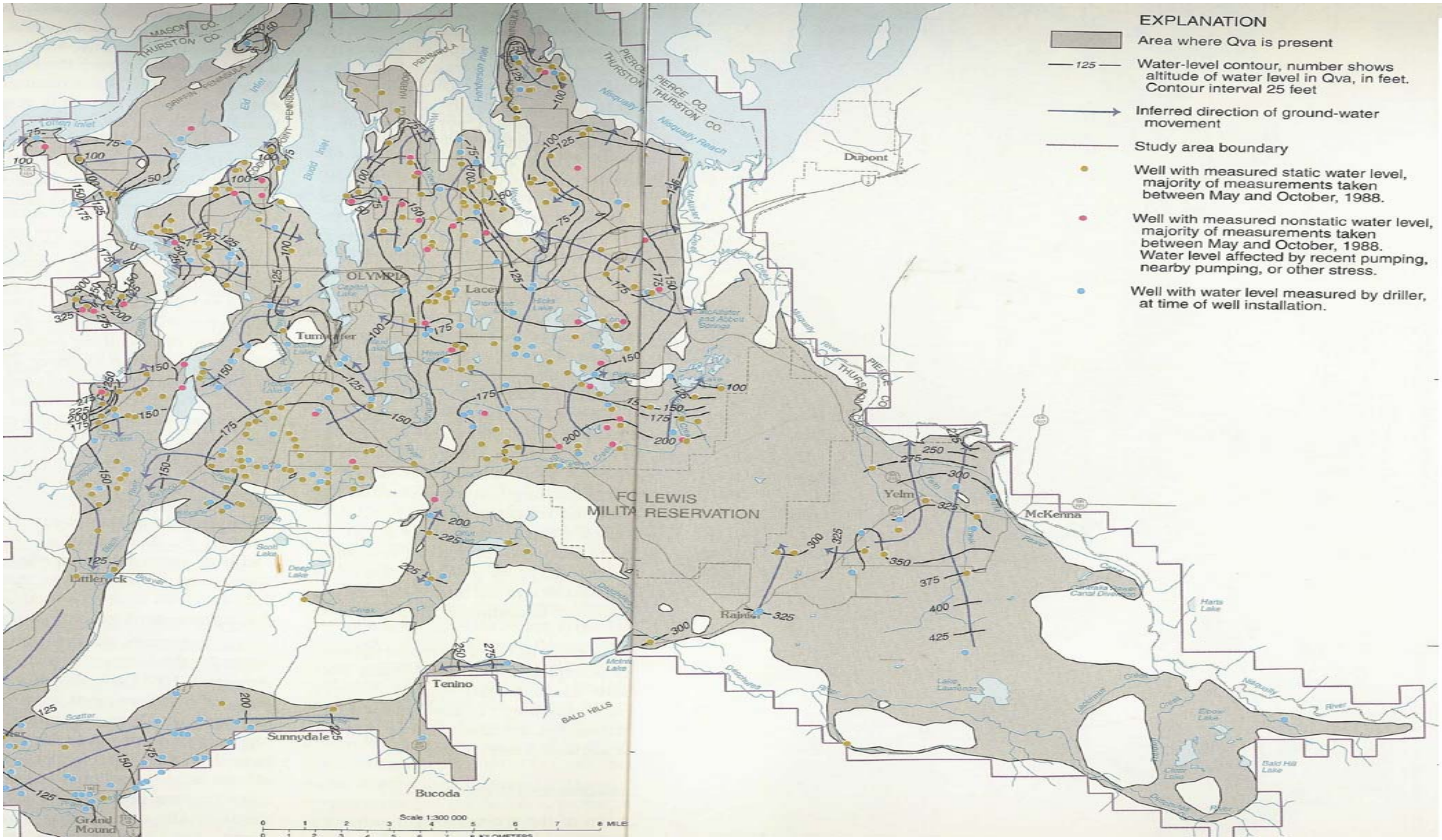


Figure 5 – Qc ("Sea-Level Aquifer") Contours and Direction of Flow

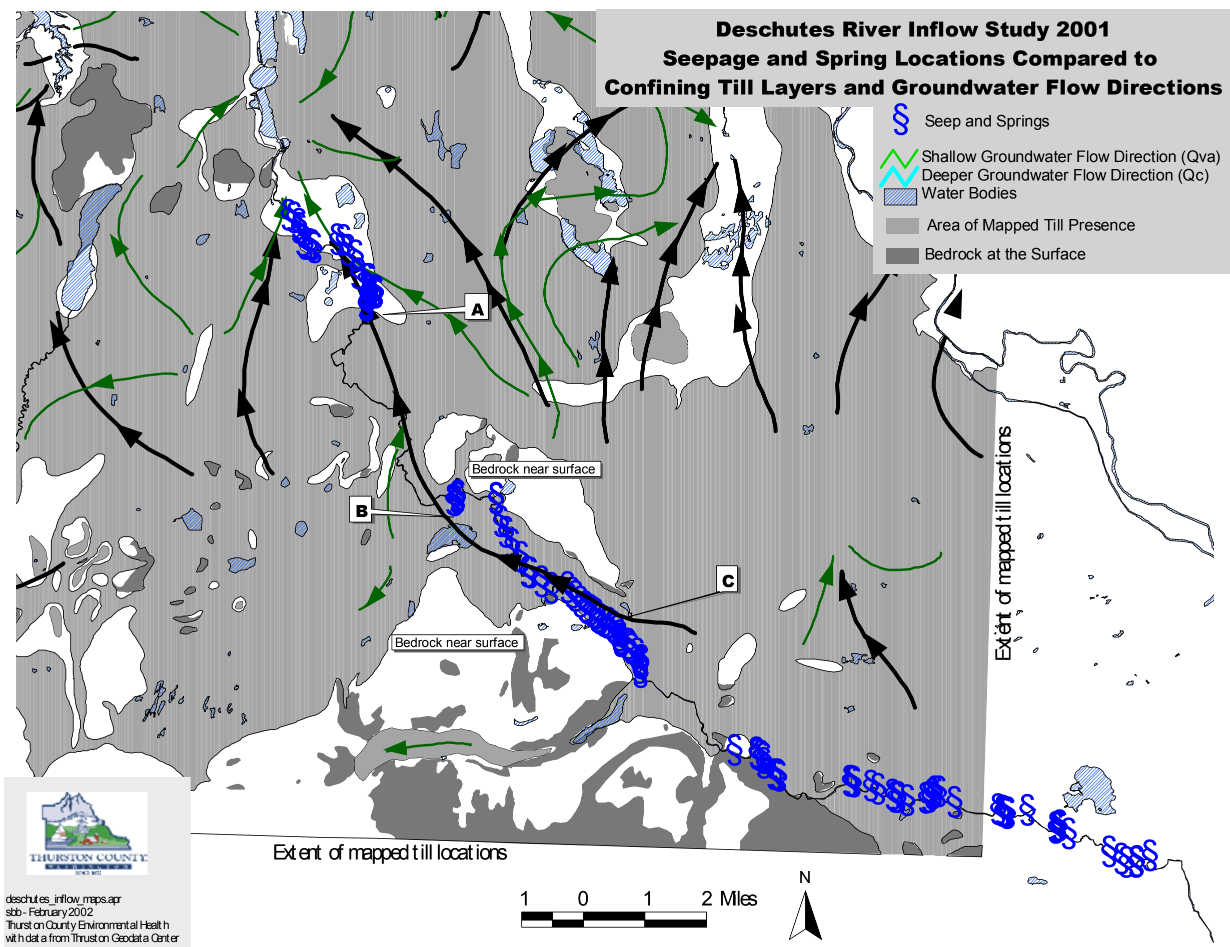


4.3 GROUNDWATER INTERACTION WITH SURFACE WATER

For the Deschutes River, a Watershed Plan-sponsored study investigated groundwater/surface water interaction during low flow conditions. Sections of the river gaining and losing from groundwater were identified through measurement water temperature and other field data collection methods.[6]

Outcome of the study and linkage to geology of the watershed are illustrated below. Spring locations and the area underlain by till or bedrock are identified. Note the presence of a large number of springs at "A" (near Henderson Blvd) where the till layer stops and water from the Vashon Advance aquifer drains into the river. This reach gains over 18 cfs (a 48% gain). "B" and "C" are at either end of a channel created by bedrock hills near Offut Lake. Large amounts of groundwater are funneled from prairie to the east through this channel and appear as springs along the Deschutes River.

Figure 6 – Deschutes Inflow Study 2001



[6] 2001 Deschutes Groundwater Inflow Survey Deschutes River, Thurston County, Washington February 2002

4.4 REGIONAL GROUNDWATER BUDGET

One perspective on overall groundwater resources is provided by the estimated groundwater budget. For the North Thurston County Ground Water Management Area (basically all of north county including McAllister Springs) basic components of a groundwater budget were estimated by the USGS in a 1998 report. The estimated recharge from precipitation was 310,000 acre-feet; estimated withdrawal from wells (in 1988) was 21,000 acre-feet or about 7% of recharge from precipitation. The result of the USGS study indicated that most ground-water flow through the study area discharges to surface water bodies and as underflow to marine waters. [7]

A more thorough groundwater budget was subsequently developed by the USGS in a follow-up report covering for the entire glacial outwash portion of Thurston County - which includes most of the county outside the Black Hills, Bald Hills and Maytown Upland. As shown below, this water budget included assessment of secondary recharge through irrigation and septic systems. Water supplied to the Olympia water system by diversion from McAllister Springs in WRIA 11 (estimated at 24,000 acre feet or about 27% of total water use) is included in the spring discharge element. [8]

Table 2: USGS Model-Derived Groundwater Budget: Unconsolidated Sediments Area of Thurston County

Recharge: Acre-Feet per Year		
560,000	85%	Recharge from precipitation
38,000	6%	Recharge from streams and lakes
63,000	10%	Secondary recharge
5,800	1%	Groundwater inflow to study area along Chehalis
	100%	
Discharge: Acre-Feet per Year		
310,000	48%	Discharge to streams and lakes
190,000	29%	Discharge to springs and seepage faces
88,000	14%	Discharge as submarine seepage
62,000	10%	Pumping from wells
12,000	2%	Discharge to groundwater along the Chehalis River
	100%	

[7] Hydrology and Quality of Ground Water in Northern Thurston County, Washington, USGS Water-Resources Investigations Report 92-4109 (Revised), 1998

[8] Conceptual Model and Numerical Simulation of the Groundwater Flow System in the Unconsolidated Sediments of Thurston County, Washington, USGS, 1999. See budget at page 89 and use estimate summary at page 50.

The USGS water budget included assessment of "secondary recharge" – water infiltrating back into aquifers after various uses. Factors employed by the USGS to reflect the percent of water returning to groundwater:

Septic Systems	87% secondary recharge
Irrigation	57%
Stock watering	13%
Aquaculture	80%
Commercial/Ind.	84%

4.4 GROUNDWATER WITHDRAWAL AND TRENDS IN GROUNDWATER LEVELS

Current Groundwater Withdrawal

Current withdrawal by wells was estimated through updating a comprehensive well survey conducted by USGS in 1988. Over ½ of groundwater withdrawal supplied Residential and Commercial/Industrial uses through the municipal water utilities. About 12% was utilized by non-municipal community water systems. Exempt wells were estimated to withdraw about 1,400 acre feet/year or 7% of the total.

TABLE 3: ESTIMATED WRIA 13 1998 GROUNDWATER WITHDRAWAL

Groundwater Use			Types of Use
Ac Ft/Yr	%	Systems	
			RESIDENTIAL
7,300	34%	4	**Municipal System Residential Service**
1,100	5%	3	**Large Non-Municipal Utilities**
1,600	7%	125	**Smaller Non-Muni public Water Systems**
1,400	7%	4,000	**Exempt Wells** (Single family to 6-party wells)
11,400	53%	4,128	**Sub-Total Residential Use**
			COMMERCIAL/INDUSTRIAL/GOVERNMENT
4,000	19%	4	**Municipal Comm/Ind/Govt Service**
2,100	10%	1	**Major Industrial Independent Wells**
1,400	7%	23	**Other Comm/Ind/Gov't Wells**
7,500	35%	28	**Sub-Total Comm/Ind/Gov't:**
			IRRIGATION NOT INCLUDED IN OTHER CATEGORIES
2,500	12%	65	
21,400	100%	4,221	**TOTAL ESTIMATED GROUNDWATER W/D**

The estimates range widely in level of accuracy. Information sources used for the estimate:

- Cities and large private systems: Pumping records.
- Other Group A water systems: DOH data on population served multiplied by standard use factor.
- Exempt wells: Developed parcels not within a Group A water service area.
- Non-municipal commercial and irrigation uses: Update of USGS estimates (mainly acreage times use factor.)

Groundwater Level Trends Monitoring

As the Thurston County Groundwater Monitoring Report for 1999-2001 Water Year indicates,

> "It is important to monitor water levels over time in order to assess the rate of water withdraws compared to recharge (rainfall). A steady decrease of water levels over a few years would suggest that water withdraws are occurring at a greater rate than recharge. This could be the result of increasing development pressure, or long-term changes in rainfall patterns, or a combination of the two. Such information will be crucial in assessing the aquifers' ability to provide an adequate supply of high quality water for a growing population while maintaining necessary base flows to surface water bodies."[9]

The North Thurston County Ambient Monitoring Network includes well water level monitoring on a quarterly basis. About 25 wells have been monitored since 1995.

In general, there have been no observed trends in water levels beyond the impacts of high and low rainfall years. In 1999, most of the monitored wells had average static water levels 2 – 6 feet higher than the 1995-96 baseline. Only four of the monitored wells had water levels lower than the 1995-96 baseline during 1997-1999. [10]

The water year running from October 2000 to September 2001 was the driest on record. Rainfall at the Olympia Airport NOAA weather station was only 33 inches, compared to average annual rainfall of 50 inches. Over ½ the 39 wells monitored during the period showed a marked decrease in water level in the summer of 2001; nearly all showed some reduction in water levels.

Several years of monthly record is available for one of the monitored wells located in the Vashon Advance aquifer. Water levels typically lag behind rainfall by about four to five months at this well. As illustrated on Figures 6-A and 6-B this well recorded a marked decrease in the yearly low level between 1992 and

[9] Ground Water Monitoring Report 1999-2001 Water Year, May 2002, Thurston County Environmental Health, included in Thurston County Water Resources Monitoring Report 1999-2001 Water Year.
[10] Same citation.

1995. This three-year low water level period was preceded by a three-year period of below-average rainfall. This delay is also apparent in well level response to above-average rainfall in the 1994-1998 period and low rainfall in 1999. [11]

Water level monitoring continues through the Ambient Monitoring Network program. An enhancement recommended in the May 2002 report is addition of continuous recording devices to a few wells each year, to provide a more dynamic picture of groundwater level fluctuations and improve data accuracy.

4.5 LONG-TERM IMPLICATIONS OF GROUNDWATER WITHDRAWAL

The central importance of understanding the region's aquifers in meeting future water needs was underscored by the USGS report Hydrology and Quality of Ground Water In Northern Thurston County, Washington in the discussion of the water budget of the North Thurston County Groundwater Management Area:

> "Not all water that discharges naturally is available for further ground-water development. As pointed out by Bredehoeft and others (1982), new discharge (withdrawals) superimposed on a previously stable system must be balanced by an increase in recharge, a decrease in the original discharge, a loss of storage within the aquifer, or by a combination of these factors.
>
> Considering the ground water of northern Thurston County in particular, the possibility of increased natural recharge on a long-term basis appears remote. In fact, the trend of increased residential development and central storm sewers may result in decreased recharge. Additional withdrawals, therefore, would result in a loss of storage (with an attendant decline in water levels) and a decrease in natural discharge.
>
> As discussed previously, not all natural discharge in the study area is to the sea; a large but undetermined quantity of ground water discharges to streams and springs. In those places, it is used both directly and indirectly for streamflow maintenance, fish propagation, waste dilution, recreation, and public supply. The magnitude of potential ground-water development, therefore, depends on the hydrologic effects on discharge that can be tolerated.
>
> Because it may take many years for a new equilibrium to become established, the full effects of additional ground-water development will most likely not be immediately apparent."

[11] Same cite. See Figure 4 on page 419.

The USGS provided a model of long-term withdrawal to meet projected water demands – and the resulting impact on our region's water resources.[12] For long-range water demand, USGS utilized the "Thurston County Reservation of Public Water Supply" adopted as WAC 173-591. The 1986 Reservation was intended as planning tool to ensure adequate supply to meet municipal and other domestic water needs in a 50-year time period within northern Thurston County. (Area of the Reservation was similar to WRIA 13 excluding the middle and upper Deschutes.) 50-year population projection in the 1986 Reservation was 285,000 (remarkably similar to the 300,000 "developable lands" total capacity projection by TRPC in 2002.) The 50-year Reservation projects an additional 23,000 acre-feet/year to serve 2030 population.

USGS modeled the surface water impacts of meeting year 2030 population through increased withdrawal from the existing municipal wells. Modeled impact on WRIA 13 waterbodies included loss of flow to Deschutes River (6.4 cfs equaling about 6% of mean September streamflow) and Woodland Creek (1.2 cfs or nearly 10% of mean September flow.) Results of the model:

TABLE 4 – USGS MODEL LONG-TERM GROWTH IMPACTS ON STREAM AND SPRING FLOW
USGS GROUNDWATER MODEL OUTPUT (1999 REPORT)
BASED ON 1988 "RESERVATION" POPULATION PROJECTION TO 2030

Major Streams & Springs:	Acre Feet/Yr Added Loss	Cubic Feet/ Second Loss	Mean September Streamflow
Deschutes River	4,600 acre ft	6.4 Cfs	103 cfs (1
Woodland Creek	870 acre ft	1.2 Cfs	13 cfs (1
Woodard Creek	140 acre ft	0.2 Cfs	4 cfs (2
Nisqually River	1,400 acre ft	1.9 Cfs	432 cfs (1
McAllister Springs	1,200 acre ft	1.7 Cfs	25 cfs (3
Eaton Creek	140 acre ft	0.2 Cfs	2 to 7 cfs (2
Lakes:		**Lake Level Impact**	
Pattison/Long/St.Clair Lakes	1,600 acre ft	0.5 feet annual loss	
Black Lake	720 acre ft	0.8 feet annual loss	
Marine Seeps	3,600 acre ft		

Mean September streamflow data sources:
1.) Estimated Baseflow Characteristics of Selected WA Rivers and Streams, DOE Water Supply Bulletin No. 60, 1999
2.) Thurston County Dept of Water and Waste Management
3.) USGS groundwater modeling report

[12] Conceptual Model and Numerical Simulation of the Groundwater Flow System in the Unconsolidated Sediments of Thurston County, Washington, USGS, 1999. See section beginning page 90.

While only a rough “snapshot” of potential impacts from future withdrawals, the USGS model provides an important regional quantification of surface water losses if we continue utilizing existing wells to meet our long-term anticipated population. Avoiding or mitigating such impacts will be at the heart of achieving “water for fish and water for people”.