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Pacific Groundwater Group

Preliminary Data Assessment and Proposed Work Plan Lacey Wellhead Protection Program

October 28, 1992

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I. INTRODUCTION

A. Background Information

The City of Lacey (the City) depends almost exclusively on local groundwater resources to meet the water demands of approximately 10,000 customers in Lacey and adjacent communities. The City has met these demands by withdrawing groundwater at a rate of about 4.3 million gallons per day (mgd) from 14 active production water wells. In addition, the City uses water from the intertie that has conveyed about 0.4 mgd from the City of Olympia's water source at McAllister Springs (City Production Records for 1990).

A water source inventory list is presented in Table I-1. The City's "main" water system includes all wells except the "satellite" systems of Beachcrest and Nisqually.

Based on locations of City production wells, groundwater flow directions, and land use activities, a Wellhead Protection (WHP) study area encompassing 84 square miles was selected for this investigation. The project data collection area is shown on Figure I-1. Location of the WHP study area and City production wells are shown on Figure I-2. Approximately 90% of the City's total groundwater production in 1991 was from Wells 1, 2, 3, 4, 7, 9, 10, and CC01 located in the southwest part of the study area. City wells located outside this area include Beachcrest Wells 1 and 2 (BC1 and BC2), Meridian Acres Wells 1 and 2 (MA1 and MA2), and Nisqually Wells 19A and 19C (19A and 19C).

In addition to the City's active production wells, the City owns or leases other wells in the WHP study area, and is planning production from other wells. City Well 8R is currently not used and future use is not expected. City Well 18B is presently on loan to South Sound Utilities and provides water for the Evergreen Estates development. The Capital City Golf Course Well (CC01) is leased from the Capital City Golf Course and used by the City. Production will begin at Well 6C, after permit approval by the Department of Ecology (DOE). Production is scheduled to start at the Hawks Prairie (HP) and Glacier Park (GP) wells in 1993. Additional production wells are proposed for construction in the Hawks Prairie/Glacier Park area and at the Pleasant Glade School site.

Long-term water quality issues related to the McAllister Springs source were investigated by Golder Associates (1990) as part of the McAllister Springs Geologically Sensitive Area (GSA) study. Long-term monitoring of groundwater that flows toward the McAllister Springs has been addressed as part of the City of Olympia Wellhead Protection program

(Pacific Groundwater Group, in prep.). The City of Olympia's program is separate and distinct from the City of Lacey Wellhead Protection program (WHPP) recommended in this report. However, a coordinated monitoring and data collection program for protection of groundwater quality in the general study area should be implemented by the City of Lacey, the City of Olympia, and the Thurston County Health Department.

B. Potential Degradation of Groundwater Quality

Potential degradation of water quality in aquifers that yield water to City production wells exists because of past, current, and future land use activities in the WHP study area. A groundwater quality issue of substantial importance is occurrence of elevated concentrations of pesticides in groundwater along the south side of Pattison Lake and extending west toward the area of Wells 4, 9, 10, and CC01. Water quality issues of moderate importance include the occurrence of volatile organic compounds (VOCs) in groundwater at Thurston County Landfill (Pacific Groundwater Group, 1992), elevated concentrations of pesticides in groundwater at Ostrom Mushroom, elevated concentrations of organic chemicals in Well 1 of the Thurston County Water District Well No. 2, past chemical spills/leaks near City Well 7 and near the I-5 interchange northwest of City Wells MA1 and MA2, and elevated nitrate concentrations south of Pattison Lake and northeast of Long Lake.

Potential sources of contamination exist in areas of any industrial development and along major transportation corridors. In addition, groundwater quality can be affected by septic wastes particularly unsewered residential areas. Farm practices can impact groundwater quality through land surface application of fertilizers, herbicides, and pesticides. A groundwater quality issue of potentially moderate importance is an underground fuel oil distribution system that occurs throughout much of Section 28, T18N, R1W. This distribution system is currently being investigated by the City. City Wells 1, 2, 3, and 6C are located in this area.

Potential degradation of groundwater quality can be assessed in relation to aquifer *susceptibility* and *vulnerability*. In the context of wellhead protection, an aquifer is considered to be susceptible to contamination if its natural hydrogeologic characteristics would facilitate movement of contaminants. An aquifer is considered to be vulnerable if it is susceptible, and if land use activities have caused or potentially could cause a release of contaminants to the groundwater system. Varying degrees of aquifer susceptibility and vulnerability result from variation in hydrogeologic properties and land use within the WHP study area.

C. Objectives of Investigation

only on basis of existing data

The chief objectives of this investigation are to assess the vulnerability of aquifers that are the principal water source for the City, and to design a long-term management and monitoring program which will protect groundwater quality. The approach used to satisfy these objectives was as follows:

- o Hydrogeologic and groundwater quality conditions in the WHP study area were characterized based on review and analysis of existing data for City production wells and for other wells; available published literature; and available information from the Thurston County Geographic Information Facility (TGIF), Thurston County Health Department (TCHD), Washington Department of Ecology (WDOE), and the U. S. Geological Survey (USGS).

- o Aquifer vulnerability was assessed in the vicinity of each production well site and ranked on the basis of several parameters which included average (projected) pumping rate, occurrence of fine-grained or confining units which may impede the movement of contaminants to the principal aquifer, depth of the well (i.e. top of the well screen), and distance to confirmed and/or potential upgradient contaminant sources. Result of the aquifer vulnerability assessment are summarized in an Aquifer Vulnerability Matrix.

- o Capture zones and travel time contours for each production well were delineated using the U.S. Environmental Protection Agency (USEPA) Wellhead Protection Analysis (WHPA) program.

- o Confirmed and potential sites of contaminant sources and general land use activities in the study area were indentified.

- o Water supply sources that are at the greatest risk for water quality impacts were identified using results from the Aquifer Vulnerability Matrix and application of the EPA WHPA program.

- o Based on the results of these investigations, a Work Plan was developed to monitor groundwater quality and water level in high-risk areas. The Work Plan includes a proposed area and specification for groundwater monitoring wells, and subsequent field data collection, analysis, management, and quality assurance / quality control (QA/QC) procedures.

D. Findings and Recommendations

The following provides a brief summary of the major findings and recommendations of this study. The reader is referred to the remainder of the report for more details.

- o The City of Lacey (the City) uses 14 active production wells to withdraw groundwater from shallow, intermediate, and deep aquifers. The shallow aquifer comprises deposits of Quaternary Vashon Advance outwash (Qva). The intermediate aquifer comprises deposits of the Penultimate Glaciation (Qc). The deep aquifer system comprises deposits of the Tertiary/Quaternary Undifferentiated unit (TQu). Eight of the 14 active wells supply approximately 90% of the City's total groundwater production; these wells are located in the southwest part of the study area.

- The Qva aquifer consists of outwash sand and gravel that occurs throughout the study area. This aquifer is highly susceptible to land use impacts because of its relatively shallow occurrence. However, Vashon till (Qvt) typically overlies the Qva aquifer and in areas where the till has low permeability and is laterally continuous, water quality in the Qva aquifer is moderately well protected from land use activities. Wells 1, 4, BC1, BC2, and CC01 withdraw water from the Qva aquifer.

- The Qc aquifer consists of outwash sand and gravel that occurs throughout most of the study area. This aquifer is moderately susceptible to land use impacts in areas where both the till (Qvt) and the Kitsap Formation (Qf) occur and are laterally continuous. However, in areas where the Qvt and Qf are absent or are moderately permeable, the Qc aquifer is poorly protected from land use impacts. City Wells 2, 3, 10, and 18B withdraw water from this aquifer.

- The TQu unit consists of sand and gravel aquifers with interbedded clay and silt, and minor peat, wood, and volcanic ash. Aquifer zones within the TQu are in many areas separated from one another by fine-grained, low permeability units. These aquifers are relatively unsusceptible to land use impacts particularly in areas where the Qvt and Qf occur and a silt and or clay layer occurs between the Qc aquifer and a TQu aquifer. Within the TQu, wells screened in the lower part of the TQu deposits would be better protected from land use impacts than wells screened in the upper part of the TQu unit. Wells 9, MA1, MA2, 19A, and 19C are screened in upper part of the TQu unit, and Wells 7, HP, GP are screened in the lower part of the TQu unit. Lacey Well 6C (Judd Hill) is completed within both the QTu and Qc aquifers.

- The vulnerability of aquifers to potential water quality impacts was assessed using an Aquifer Vulnerability Matrix. The analysis was based on parameters such as well pumping rate, well screen/perforation depth, occurrence and character of overlying confining units, and distance to confirmed or potential sources of contamination. Confirmed contamination sources included those sites where groundwater contamination has been documented by previous studies. Potential contamination sources include those sites where historical land use activity could possibly pose a threat to groundwater quality of the area. Results of this analysis indicate that City wells completed in aquifers with highest vulnerability are 4, 6C, 10, 19A, and 19C; wells completed in aquifers with moderate vulnerability are 1, 2, 3, 7, 9, CC01, MA1, MA2, and GP; and wells completed in aquifers with low vulnerability are 18B, HP, and the proposed north Hawks Prairie well (NHP).

- Time of travel capture zones were estimated for each of the production wells completed in the Qva, Qc, or TQu aquifers. The results of the modeling analysis indicate four general areas that yield groundwater to City wells. These areas include the southwest Lacey wells, the Hawks Prairie/Glacier Park/Beachcrest wells, the Meridian Acres wells, and the Nisqually wells. Long-term land use management should be implemented to reduce the risk of groundwater quality degradation in these important production well source areas.

- o The one- and five-year capture zones and the associated management buffer areas can be used to establish areas around wellheads where use of potential contaminants should be properly inventoried and managed. The long-term management areas that include the 10-year capture zones can be used for planning appropriate future land use.

- o As new water level and water quality data are obtained during long-term monitoring for the Lacey WHPP, results from the capture zone and aquifer vulnerability analyses contained in this report should be re-evalutated so that aquifer vulnerability and capture zone areas accurately reflect current information.

- o Historic water quality from the City's active production wells is generally good. Volatile organic compounds have not been detected in samples obtained from the City's currently active production wells since monitoring began in 1988, except trihalomethanes were detected in Well MA1 in June 1989. The City has been in compliance with the total coliform rule and has no history of waterborne disease. All primary and secondary maximum contaminant levels (MCLs) were met at City wells that have been sampled, except for elevated manganese at Well 7 and turbidity at Well 8.

- o The most substantial groundwater quality concern with potential for future impact to City wells is pesticide contamination that extends from the south side of Pattison Lake west along Yelm highway in the vicinity of Wells 4, 9, 10, and CC01. Other groundwater quality concerns with potential for future impacts to City wells include: 1) VOC contamination in groundwater at the Thurston County landfill located northwest of City Wells MA1 and MA2, 2) pesticide contamination in groundwater at the Ostrom Mushroom farm located west of Wells MA1 and MA2, 3) VOC contamination in Well #1 of the Thurston County Water District No. 2 located about 500 feet from City Well 7, 4) nitrate in groundwater northeast of Long Lake and west of Wells MA1 and MA2, 5) nitrate in groundwater south of Pattison Lake and west of Wells 4, 9, 10, and CC01, and 6) the Section 28, T18N, R1W underground fuel distribution system located in the vicinity of City Wells 1, 2, 3, and 6C.

- o A well construction and data collection program was formulated for the study area based on the results of this study and the budget for field activities. The data collection program will consist of installation monitoring wells, and long-term water level and water quality monitoring.

- o Six new monitoring wells are proposed in the southwest part of study area. Proposed well locations are in or near the model capture zones for City wells completed in aquifers most vulnerable to contamination. In addition to the new wells, a network of about 12 existing wells will be used to obtain information on water levels and water quality in the southwest study area.

- o Additional wells in the southwest and north parts of the study area will be selected to augment the existing set of wells used by TCHD and the City of Olympia for monitoring water levels. Water level data from these additional wells will provide information for estimating groundwater flow directions near City production wells.

- o Data obtained through field studies will provide improved definition of hydrostratigraphy, water levels, groundwater flow directions, and groundwater quality in the vicinity of Wells 1, 2, 3, 4, 6C, 7, 9, 10, and CC01. These efforts will result in the implementation of a monitoring network for long-term analysis of groundwater quality and level trends.

- o City of Lacey should consider future WHP efforts focused on the intermediate and deep aquifers in the southwest part of the study area, and in the vicinity of City wells located in Hawks Prairie/Glacier Park/Beachcrest, Meridian Acres, Nisqually, and Evergreen Estates areas.

- o City of Lacey should conduct WHP studies for any future well sites as part of planning and developing new groundwater sources. Groundwater modeling and land-use surveys for assessing potential groundwater contamination problems should precede any well drilling efforts. During drilling of future wells, sufficiently detailed geologic logs should be obtained to accurately assess local site hydrostratigraphy.

- o The City of Lacey has implemented a survey and inventory program to identify potential contaminants used or generated within the one- and five-year capture zones given in this report. The City should also identify land use activities in areas between the five- and ten-year capture zones, and implement management strategies that protect groundwater quality.

This report is divided into seven sections. Sections I and II summarize the results of background hydrogeologic investigations. Section III presents the proposed Work Plan. Section IV outlines a Quality Assurance/Quality Control (QA/QC) plan for the project. Section V describes the data reduction and analysis. Section VI give procedures for data management and mapping techniques which will be used in the study. Section VII contains references cited in this report.

This work was performed and this report was prepared in accordance with generally accepted hydrogeologic practices at this time and in this area for the exclusive use of the City of Lacey and their consultants to this project. No other warranty, expressed or implied, is made.

August 11, 1992

TABLE I-1
CITY OF LACEY WELL SUMMARY *

Well No.	Location	Status	Date of Installation	Elevation Well Head (ft)	Static Water (ft)	Draw-Down (ft)	Depth (ft)	Diameter (inches)	Installed Horsepower	Maximum Operating Capacity (gpm) (1)
Lacey Main System										
1	College & 32nd Avenue	Production	10/65	232	65.9	72.4	122	10	50	700
2	College & 32nd Avenue	Production	10/69	231	85.6	124.1	218	16	75	674
3	College & 32nd Avenue	Production	10/69	233	82.5	143.8	226	16	30	286
4	Capitol City Golf Course	Production	8/73	215	37.3	50.8	110	16	100	1,485
6A	Judd Hill	Abandoned	7/59	–	–	–	123	8	–	0
6B	Judd Hill	Monitoring	–	–	–	–	–	–	–	0
6C	Judd Hill (2)	Begin Prod. 1992	–	–	–	–	–	–	–	800
7	Behind Fire Station	Production	4/69, 10/76	181	34	–	550	16 – 12	200	1,767
8 and 8R	Tanglewide East	Failed	12/63	214	180	–	385	12		0
9	E. of Yelm Hwy Safeway	Production	9/81	194	36.2	123.3	284	16	100	892
10	Mnt. Green (Yelm Hwy) (3)	Production	6/81	197	24	76.3	208	16	200	1,582
18A	Evergreen Estates (4)	Production	6/66	259	214	–	239	10	–	0
MA1	Dutterrow, S. of Judy Ln. (5)	Production	–	227	196.9	199.0	–	–	20	0
MA2	Dutterrow, S. of Judy Ln. (6)	Production	–	227	199.3	245.4	–	–	25	180
CC1	Capitol City Golf Course (7)	Production	–	–	–	–	–	–	–	489
	Hawks Prairie (8)	Begin Prod. 1993	–	–	–	–	–	–	–	800
Subtotal Lacey Main										
	Existing Wells									8,055
	Post-1992 Wells									9,655
Olympia Intertie										1,389
Beachcrest Water System										
BC1	48th and Carole Dr.	Production	–	–	78.4	118.3	–	–	15	222
BC2	48th and Carole Dr.	Production	–	–	81.6	107.3	–	–	20	292
Subtotal Beachcrest System										514
Nisqually Water System										
19A	6th Ave & Hayko Lane	Production	–	19	13	28.4	–	–	7.5	64
19C	6th Ave & Hayko Lane	Production	–	19	13.6	17.8	–	–	25	316
Subtotal Nisqually System										380

(1) Based on 1990 maximum average monthly operation data.

(2) Will come on line in October, 1992.

(3) Restricted capacity to prevent sand pumpage.

(4) Restricted by throttling to maintain local pressure. On loan to South Sound Utilities. Not included in totals. 40 gpm capacity.

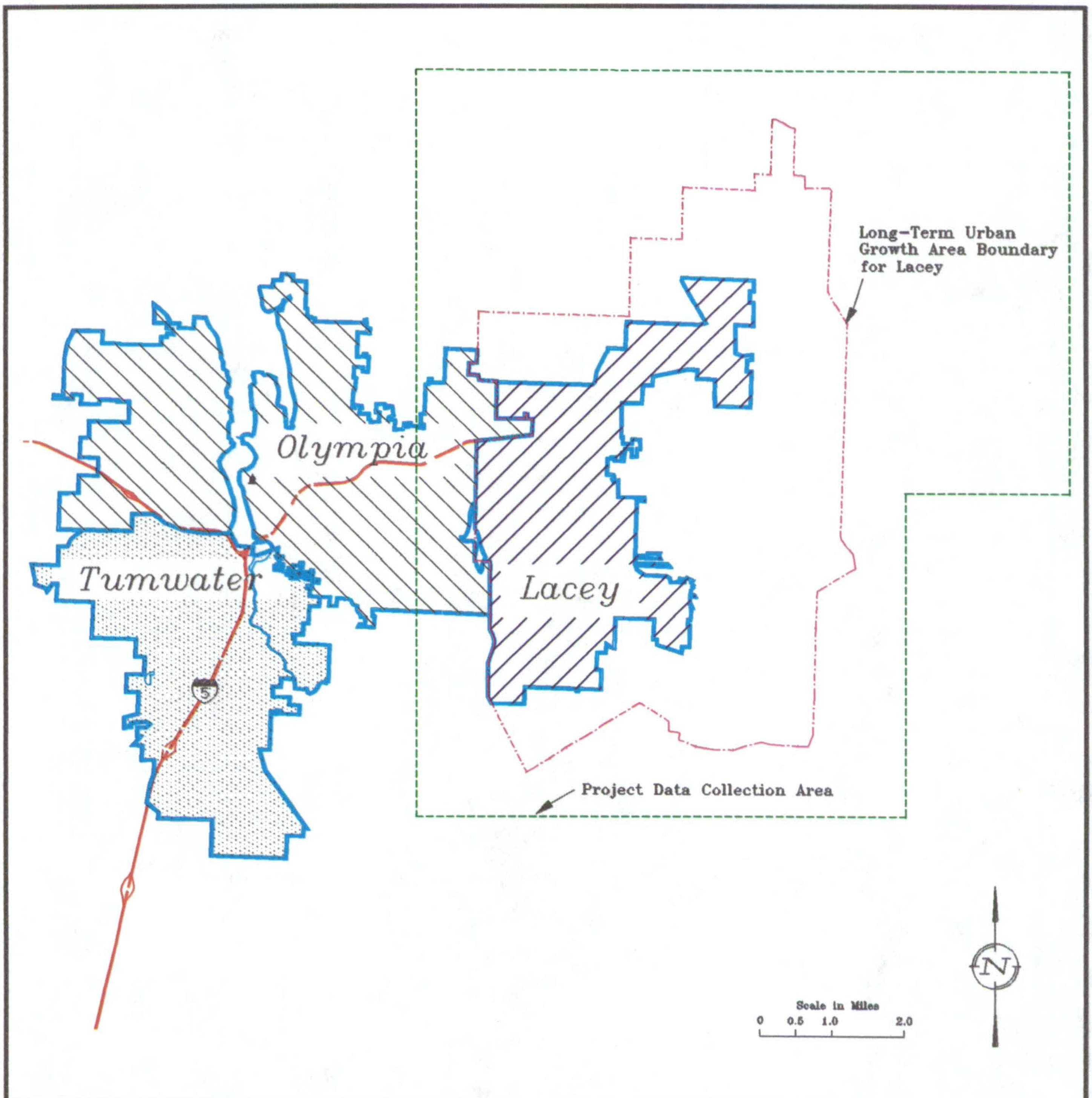
(5) Well off-line. Well not cost effective to use. May be used as a monitoring well.

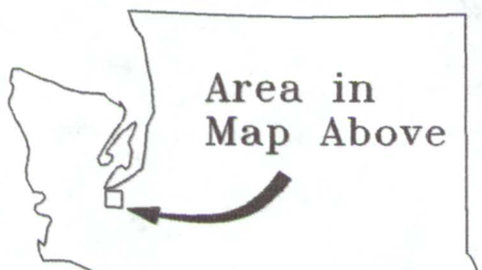
(6) Capacity estimated by hydrogeologist.

(7) Not owned by City of Lacey but used under contractual arrangement with Capital City Golf Course.

(8) Will come on line in 1993.

(*) Modified from Draft Water Supply Plan document, EES, 1992.





Lacey Wellhead Protection Program

Figure I-1
Project Location

Pacific Groundwater Group

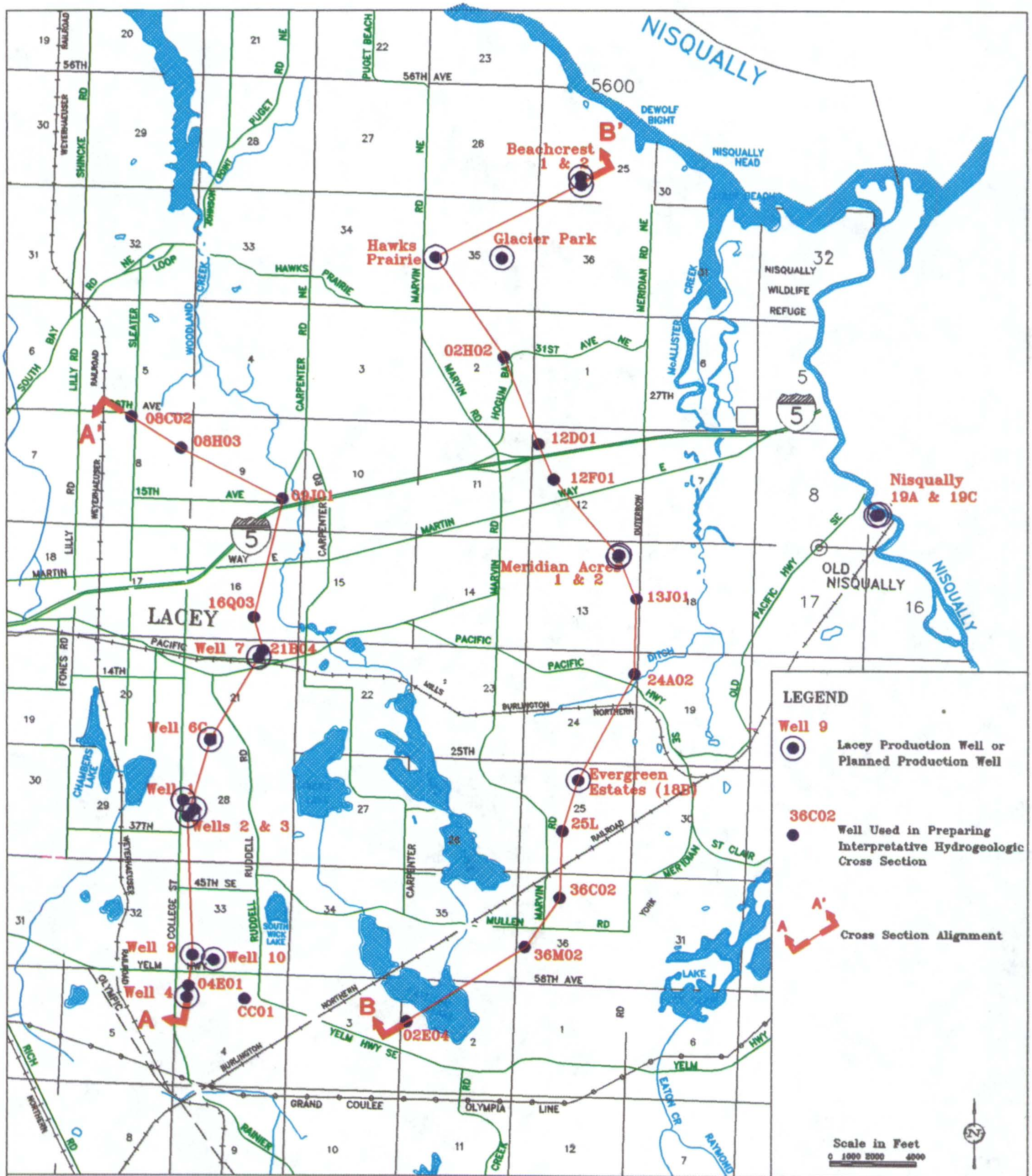


Figure I-2 City of Lacey Production Wells and Cross Section Alignments

Lacey Wellhead Protection Program

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II. BACKGROUND ANALYSIS

A. Existing Data Sources

Existing information for wells, hydrogeology, water quality, and land use in the WHP study area were compiled and reviewed. The data sources included regional and local technical reports, and hydrogeologic, well, and water quality data.

The regional hydrogeology was characterized by Noble and Wallace (1966) in *Geology and Groundwater Resources of Thurston County, Washington*. A hydrogeologic characterization in the northern Thurston County Ground Water Management Area (GWMA) was a three year study conducted by the U.S. Geological Survey (USGS) in cooperation with Thurston County Health Department (TCHD) beginning in May 1988. A report on this GWMA study is currently in review. Selected data from this study have been used in this Preliminary Data Assessment report and these data are cited as *"N.P. Dion, pers. comm. to City of Lacey, 1992"*. The stratigraphic nomenclature used by the USGS for the northern Thurston County area is used in this report.

Technical reports addressing the local-scale hydrogeology are available mostly in the form of well construction reports submitted by consultants to the City. Well construction reports generally include geologic logs, aquifer test results, well as-builts, and water quality data for inorganic constituents. Hydrogeologic investigations conducted for the City to address groundwater utilization and management include reports, letters, and memos by Hart Crowser (1981a&b, 1988a&b, 1989a&b, 1991) and Robinson, Roberts & Associates, Inc. 1969).

Selected water quality data were reviewed from the City well files. In addition, data in the form of maps and tables were compiled from the GWMA study and the Draft Northern Thurston County Ground Water Management Plan (TCHD, 1992).

A database of well information was assembled by the USGS for the GWMA study. These data have been reformatted into a PC database management system. The system includes ownership, location, construction, water level, and water quality data. Other well and hydrogeologic information for the WHP study area has been compiled into a digital spreadsheet that will be incorporated into the database management system (DMS) used for the Lacey WHPP.

B. Location

The WHP study area is at the southern edge of the Puget Sound lowland between the Cascade and Coast Ranges in west-central Washington. The study area is located in northeast Thurston County and encompasses 84 square miles in the Chambers Creek, Woodland Creek, and McAllister Creek/Nisqually River drainage basins. Prominent surface water features include Chambers Lake; Hicks, Pattison, and Long Lakes; Woodland Creek; Lake St. Clair; McAllister Creek and Nisqually River (Figures I-1 and I-2). All City wells are located within the long-term urban growth management area, except Wells 19A and 19C which are located on the west bank of the Nisqually River. The major population center in the WHP study area is the City of Lacey and the adjacent residential developments.

C. Hydrogeologic Characterization

1. Surface Soils and Aquifer Susceptibility

The characteristics of the surface and near-surface soils have a substantial effect on potential downward movement of contaminants from sources at or near land surface. In general, groundwater is less vulnerable to degradation in areas where fine-grained, low permeable soils such as organic-rich silt and clay occur at land surface, and is more vulnerable to degradation in areas where coarse-grained soils such as sand and gravel occur at land surface. Organic-rich fine-grained soils also have a greater capacity to adsorb certain chemical constituents and thereby retard contaminant movement.

A soil based characterization of aquifer susceptibility in the WHP study areas was conducted by TCHD (Northern Thurston County Ground Water Management Plan, 1992). TCHD used the 1990 U.S. Department of Agriculture Soil Conservation Service soil map to delineate areas of extreme, high, moderate, and low susceptibility. All City production wells are located in, or are surrounded by areas classified as having extreme or high susceptibility. Areas of extreme susceptibility (Category I) contain highly permeable soils that allow rapid inflow of water with minimal removal of contaminants (TCHD, 1992). Areas of high susceptibility (Category II) are similar to Category I, but contain less permeable soils that have poor drainage properties.

2. Hydrogeologic Units

Six principal hydrogeologic units occur in the Lacey WHP study area from land surface to a depth of about 750 feet. These units have been described by the USGS in the northern Thurston County GWMA study and they range from Miocene to Pleistocene in age. The units include: 1) Quaternary Vashon recessional outwash (Qvr), 2) Quaternary Vashon till (Qvt), 3) Quaternary Vashon advance outwash (Qva), 4) Kitsap Formation fine-grained deposits (Qf), 5) Penultimate Glacial outwash deposits (Qc), and 6) Tertiary and/or Quaternary undifferentiated deposits (TQu). Figure I-2 is a map that shows locations of cross section alignments. Subsurface relationships for the units are shown on Figures II-1 and II-2. Of these units, the Qva, Qc, and TQu are the principal water supply sources in the Lacey WHP study area. The Qvt and Qf unit are generally considered to be aquitards that impede water movement, but locally they contain zones of coarser grain materials that may transmit water.

a. Quaternary Vashon Recessional Aquifer

The Vashon recessional (Qvr) outwash occurs at land surface over most of the study area. This unit consists of sand and gravel, and was deposited by streams emanating from the melting and receding Vashon glacier. Thickness of Qvr ranges from 5 to 130 feet. City wells are not completed in this unit. The Qvr aquifer primarily yields groundwater to domestic wells in the study area. This aquifer is very susceptible to contamination because downward movement of contaminants is not impeded by an overlying fine-grained unit, and local water levels are near land surface.

b. Quaternary Vashon Till

The Vashon till (Qvt) occurs at or near land surface in much of the study area. The till typically separates the Qvr and the underlying advance outwash sand and gravel. This unit consists of variably compact sand and gravel in a matrix of silt and clay. The compact character of the till resulted from the overburden pressure of the Vashon glacier. Well drillers commonly describe the till as "hardpan" or "cemented gravel". Thickness of the till is variable and ranges from 0 to 110 feet. Comparison of the till thickness in hydrogeologic section A-A' and B-B' indicates that the till is thicker in the north and east part of the study area and thinner in the south and west part (Figures II-1 and II-2)

Because the till is generally compact and has low permeability, it impedes the vertical movement of groundwater. Where the till is relatively thick, very compact, and laterally continuous, it protects underlying aquifers from downward contaminant movement. However, the Qvt is not laterally continuous throughout the study area. Although the till is shown on section A-A' at Wells 6C and 7, the character of the till at these locations is not certain (Figure II-1). The till is interpreted to be absent is at the Thurston County landfill (Figure II-2).

c. Quaternary Vashon Advance Aquifer

The Vashon advance (Qva) aquifer occurs below the till, or below Qvr where the till is absent, and generally is between 150 and 50 feet mean sea level. The Qva aquifer consists of sand and gravel that was deposited from meltwaters along the perimeter of the Vashon ice sheet. Thickness of the Qva in the study area ranges from 10 to 100 feet.

The Qva is an important aquifer where the unit occurs in substantial thickness and areal extent. Wells completed in Qva include Wells 1, 4, BC1, BC2, and CC01 (Figures II-1 and II-2). The Qva aquifer is locally very transmissive and can yield moderate to large amounts of water to wells. For example, City Well 4 has a capacity of 1,485 gpm. The aquifer is apparently confined in the area of Well 4, but becomes unconfined to the north or east of Well 4. The degree to which the Qvt impedes downward movement of groundwater at

Wells 1, 4, and CC01 is not certain.

For this study Well CC01 is interpreted to be perforated in Qva aquifer. However, a thin layer of clay and gravel underlain by gravel and coarse sand occurs in the lower portion of the perforated interval (see Appendix A). These strata could be interpreted to be the Qf and Qc units described in the following sections. Review of additional borehole data in vicinity of the CC01 well would provide better definition of the hydrostratigraphy in this area.

The susceptibility of the Qva aquifer is very substantial because: 1) City wells in this unit are shallow, 2) the overlying Qvt is locally thin or is absent in the south and west parts of the study area, and 3) the Qva aquifer is locally highly permeable which would facilitate the horizontal movement of contaminants.

d. Kitsap Formation Fine-grained Deposits

The Kitsap Formation fine-grained deposits (Qf) is stratigraphicly below the Qva aquifer, and generally occurs between 100 and 0 feet mean sea level in the study area. The deposits of the unit separate the Qva aquifer and the underlying Penultimate glacial aquifer. The Qf predominately consists of clay and silt with minor sand, gravel, peat, and wood. Some borehole logs also indicate a "hardpan" or "cemented gravel" overlying the clay and silt of the Kitsap formation. This till may be part of a pre-Vashon glacial event. Because this till would have similar hydraulic characteristics to the Kitsap formation, it is grouped in the Qf unit. Thickness of the Qf unit ranges from 30 to 130 feet. Comparison of the Qf unit thickness in hydrogeologic sections A-A' and B-B' indicates that the Qf unit is thicker in the north and east part of the study area and thinner in the south and west part (Figures II-1 and II-2).

Where Qf unit is relatively thick and laterally continuous, and is composed of clay and silt, it is an aquitard that protects underlying aquifers from downward contaminant movement. However, near City Wells 4 and 6C, the Qf unit is considered to be moderately permeable, and therefore would not sufficiently protect underlying aquifers from downward contaminant movement. In addition the Qf unit may be locally absent. The character of the till at Well 7 is not certain (Figure II-1).

e. Penultimate Glacial Aquifer

The Penultimate glacial (Qc) aquifer is stratigraphicly below the Qf unit, or the Qva aquifer in areas where the Qf unit is absent. The Qc aquifer is also known as the "sea level" aquifer, and typically occurs between 50 and -50 feet mean sea level. This unit consists of coarse sand and gravel. Noble and Wallace (1966) refer to this unit as the Salmon Springs Drift. The USGS refer to this unit as the penultimate drift based on nomenclature and descriptions of Lea (1984). Similar to the USGS unit classification, the Qc aquifer shown on Figure II-1 and II-2 represents only the coarse-grained deposits of the penultimate drift (N. Dion, USGS, pers. comm. to Lacey, 1992). Any underlying finer-grained deposits that may be associated with the penultimate drift are grouped in the underlying undifferentiated deposits unit.

The Qc aquifer is an important aquifer where it occurs in substantial thickness and areal extent. City wells completed in this aquifer include Wells 2, 3, 6C, 10, and 18B. Well 6C also yields water from the lower undifferentiated deposits aquifer. The Qc aquifer is locally very transmissive and can yield moderate to large amounts of water to wells including 1,450 gpm at Well 10. Transmissivity of the Qc ranges from 19,000 gallons per day per foot (gpd/ft) at Wells 2 and 3, to 49,000 gpd/ft at Well 10 (Robinson, Roberts & Associates, 1969; and Hart Crowser, 1981b). Thickness of the Qc aquifer in the study area ranges from 20 to 70 feet, and is generally larger in the north and east parts of the study area and smaller in the south and west parts of the study area.

The Qc aquifer is generally confined where the overlying Qf unit consists of clay and silt, and is laterally continuous. However, in the vicinity of Wells 2, 3, 6C, and 10 the coarse-grained facies of the Qf unit occurs above the Qc aquifer, and therefore, the Qc is not confined by the Qf. Evidence that the Qc aquifer is hydraulically connected to the overlying Qva aquifer in the vicinity of the Well 6C is indicated from the observation of one foot of drawdown at Qva Well 6A during a 24 hour test at Well 6C. Water level difference of about 10 feet between Well 1 (completed in Qva) and Well 2 (completed in Qc) suggests that the Qc aquifer is at least semi-confined near these wells. This water level difference is based on 1988 data. The character of the Qf unit near Well 10 is uncertain.

The susceptibility of the Qc aquifer in the vicinity of Wells 2, 3, 6C, and 10 is moderate to high because: 1) the character of Qf unit is relatively coarse-grained in the vicinity of Wells 6C and 10, and 2) the Qc aquifer is locally very permeable and would facilitate the horizontal movement of contaminants.

f. Tertiary-Quaternary Undifferentiated Deposits

The undifferentiated deposits (TQu) comprise all glacial and non-glacial sediments below the Qc aquifer from a depth of about -50 feet to locally deeper than -550 feet mean sea level. This unit consists of sand and gravel aquifers with interbedded clay and silt and minor peat, wood, and volcanic ash. In general, a fine-grained unit separates the Qc from the underlying TQu sand and gravel aquifer zones. City wells completed in TQu aquifers include Wells 6C, 7, 9, 19A, 19C, MA1, MA2, HP, and GP. The proposed NHP well would likely be completed in a TQu aquifer.

The TQu unit contains important aquifer zones particularly in the area from Well 7 south to Well 6C, and in the Hawks Prairie/Glacier Park area. The areal extent of aquifer zones in the TQu deposits has not been previously investigated, but geologic logs and pumping test results for the Hawks Prairie Test Well indicate that a laterally continuous and hydraulically connected aquifer occurs between the Hawks Prairie and Glacier Park wells (Hart Crowser, 1989b).

TQu aquifers are locally very transmissive and can yield moderate to large amounts of water to wells including 900 gpm at Well 9. Transmissivity of TQu aquifers ranges from approximately 30,000 gpd/ft at Well 9 and MA2 to 53,000 gpd/ft in the Hawk Prairie/Glacier Park area (Hart Crowser, 1981b; Hart Crowser, 1991; and Hart Crowser, 1989b). An estimate of storage coefficient for a TQu aquifer in the vicinity of Hawks Prairie area is 0.0002, based on a 24-hour aquifer test (Hart Crowser, 1989b).

Geologic logs for wells completed in the TQu unit indicate that the aquifer zones are commonly separated by fined-grained units that range from 5 to 25 feet in thickness. The areal extent of these fine-grained units in not certain. Protection of TQu water quality from land use activities would be substantial in areas where TQu fine-grained units are areally extensive, and where Qf and Qvt occur.

The vulnerability of water quality in TQu aquifers to land use activities is moderate to low. Areas of moderate susceptibility include Wells 7, 9, 19A, 19C. This is based on the absence of overlying fine-grained units, large well capacity, or well screen relatively near land surface. Areas of low susceptibility include the Hawks Prairie and Glacier Park Wells. This is based on the deep location of the well screens and the occurrence of fine-grained units.

D. Hydrologic Characterization

The hydrologic cycle of the WHP study area comprises three general components that include the region's climate, surface water, and groundwater. All three components are physically interdependent and can be characterized in terms of a regional *water budget*. At the scale of the study area, the water budget includes hydrologic factors such as precipitation, runoff, evapotranspiration, recharge, natural and controlled discharge. Other factors include changes in water storage in lakes or aquifers which may only be substantial on a long-term basis. Although the climate, surface water, and groundwater are equally important to the hydrologic cycle of the WHP study area, this report focuses on the regional and local groundwater system. A brief description of climate and surface water features is presented in the following two sections.

1. Climate

Northern Thurston County has a marine warm-temperate climate, with relatively warm dry summers and typically mild, rainy winters. Annual average precipitation in the study area is likely to be slightly less than precipitation at the Olympia Airport which averaged 51 inches per year (in/yr) between 1951 and 1980 (Golder Associtates, 1990). Precipitation is greatest between the beginning of October and the end of March, when monthly totals exceed 4 inches. Variability of total annual precipitation can be substantial. Annual precipitation at the Olympia airport between 1950 and 1961 averaged 53.5 inches, and varied between 38 and 67 in/yr. Based on a water budget calculation the USGS estimated evapotranspiration to be approximately 17 in/yr in the northern Thurston County GWMA.

2. Surface Water Features

The principal surface water feature in the WHP study area is the Hicks, Pattison, and Long Lakes system that drains into Woodland Creek. Golder Associates suggest that these lakes may be underlain by till (1990). However, the occurrence of till beneath the south part of Pattison Lake is uncertain (Figure II-2). Flow in Woodland Creek from Long Lake is northward into the Puget Sound. Golder Associates (1990) report annual average outflow from Long Lake was 12 cubic feet per second in 1984. Other surface water features include the Chambers Lake/Creek system that drains southwestward to the Deschutes River, the Eaton Creek-Lake St. Clair-McAllister Creek system that drains northward into the Puget Sound, and the Nisqually River that drains northward in the Puget Sound.

3. Groundwater Occurrence and Flow

Groundwater in the WHP study area occurs under unconfined, semiconfined, and confined conditions. Unconfined conditions occur in the Qvr, Qva, or Qc aquifers in areas where water levels are below a fine-grained unit or where permeable formation extends from land surface to the water table. Semi-confined conditions likely occur in areas where the Qvt or Qf units are slightly permeable to vertical movement of groundwater. Confined conditions likely occur for the Qc or TQu aquifers where the overlying fine-grained units have low permeability and areally extensive.

Water level data for wells in the study area were obtained in July/August 1988 for wells that were not pumping, and these data were compiled into regional groundwater level contour maps as part of the GWMA study (N. Dion, USGS, pers. comm. to Lacey, 1992). The water level contour maps shown on Figures II-3, II-4, and II-5 provide an indication of the direction of horizontal groundwater flow in the Qva, Qc, and TQu aquifers. In addition, these contour maps may indicate the potential for vertical flow between aquifers where water level elevations differ for separate aquifers at the same map location. For pumping conditions in the near vicinity of active City production wells, local water level contours would indicate radial flow toward the well.

Groundwater level contours for the Qva aquifer are shown on Figure II-3. Water level elevations range from 175 feet msl near the south part of the study area boundary to 100 feet msl near the east and north study area boundaries. Regional flow directions in this aquifer are northward from the south part of the study area, and west, north, and east from an apparent groundwater recharge area that extends from north of Chamber Lake to South Wick Lake to northeast of Long Lake. Except for City Well 1, horizontal gradients near City wells completed in the Qva range from about 0.002 to 0.004.

Groundwater level contours for the Qc aquifer are shown on Figure II-4. Water level elevations range from 175 ft msl near the southern study area boundary to 25 ft msl in the northern and eastern study area boundary. Regional flow directions in the Qc aquifer are northward from the southern study area boundary; eastward and westward from a groundwater ridge that occurs along the eastern study area boundary; and west, north, and east from an area in the vicinity of the Hawks Prairie well. Horizontal gradients near City wells completed in the Qva range from about 0.002 to 0.003.

Groundwater level contours for the TQu aquifer system are shown on Figure II-5. Water level data used for constructing these contours included only wells that are screened below -50 ft msl. Water level elevations range from 175 ft msl near the southern study area boundary to 25 ft msl along the north and east study area boundary. Regional flow directions in the TQu aquifer system are to the northwest, north and northeast from the southern study area boundary. Horizontal gradients near City wells completed in the TQu range from about 0.002 to 0.004.

Vertical groundwater flow likely occurs between aquifers where hydraulic head differences exist across fine-grained units that are permeable. In general, the potential for downward flow from the Qva aquifer to the Qc aquifer exists in the central an north parts of the study area based on vertical hydraulic gradients indicated from the water level contour maps for the Qva and Qc aquifers (Figure II-3 and II-4). Furthermore, downward flow from land surface to the Qc aquifer is indicated based on the occurrence of elevated nitrogen concentrations in the Qvr, Qva, and Qc aquifers in the south Pattison Lake area and northeast of Long Lake (Golder Associates, 1990). Locally, City well sites where downward vertical gradients exist for non-pumping conditions include Wells 1 and 2, and Wells 9 and 10. The vertical gradient at Wells 1 and 2 was 0.12 downward in 1988; vertical gradient at Wells 9 and 10 was 0.10 downward in 1981.

4. Groundwater Recharge

Groundwater recharge predominately occurs as infiltration of precipitation to unconfined aquifers in the study area. Recharge water moves downward from land surface to the Qvr aquifer and in areas where the Qva and Qc aquifers are unconfined. Recharge to areas where the Qva, Qc, and TQu are overlain by the Qvt and Qf units likely occurs where these fine-grained units are locally permeable. On a regional scale, substantial quantities of recharge may be transmitted through the Qvt and Qf units.

Amount of recharge is controlled by factors such as soil permeability, precipitation rate, surface topography and evapotranspiration. Recharge estimates based results of models used by USGS indicate that recharge varies spatially from 15 to 35 in/yr within the study area. These recharge rates were computed by applying the precipitation/recharge relations observed in King County, to the distribution of surficial geologic units in northern Thurston County (N. Dion, USGS, pers. comm. to Lacey, 1992).

5. Groundwater Discharge

Groundwater discharges locally into springs, creeks and streams. Golder Associates (1990) suggest that the Lakes region is an area of discharge for the shallow Qvr aquifer. McAllister Springs is believed to be a discharge point for groundwater that flows through the southeast part of the study area.

E. Aquifer Vulnerability Analysis

The vulnerability of local aquifers to potential water quality impacts was evaluated for individual City production well sites using an Aquifer Vulnerability Matrix. The vulnerability of an aquifer in the vicinity of a production well characterizes the "risk" of groundwater contamination based on location of contaminant sources, and the natural susceptibility of an aquifer. Natural susceptibility of an aquifer characterizes the surface and/or subsurface hydrogeologic system as having the capacity to impede or facilitate the movement of contaminants.

The Vulnerability Matrix provides a basis for ranking production well sites that are at risk of contamination. Identification of highly vulnerable aquifers can then be used to select areas for groundwater monitoring or other management strategies.

The Aquifer Vulnerability Matrix is given in Table II-1. The following four parameters were considered for this evaluation: 1) annual average pumping rate; 2) depth to top of well screen or perforations; 3) occurrence and thickness of overlying fine-grained or confining unit(s); and 4) distance from the well to confirmed and/or potential sources of contamination.

- *Pumping rate* was considered in the analysis because the extent of the capture zone for each well, and contaminant transport velocity to the well both increase as pumping rate increases. Larger pumping rates also have a greater influence on groundwater flow directions, and locally may change natural groundwater flow patterns.

- *Depth to top of well screen* was considered because wells that produce water from shallow zones will be more susceptible to water quality degradation from overlying contaminant sources than wells that withdraw water from deeper zones. Contaminants would have a longer vertical migration path before reaching deeper production zones.

- o *Occurrence and thickness of an overlying fine-grained or confining unit* was considered because these units limit the amount of hydraulic communication between overlying sources of contamination and the well's production zone. Contaminant transport through fine-grained media (such as hard till in the Qvt, and silt or clay in the Qf) would be impeded because: 1) groundwater flow velocities may be several orders of magnitude slower through these media than through coarse-grained media, and 2) fine-grained units have the capacity to adsorb certain chemical constituents.

- o *Distance to confirmed/potential sources of contamination* was considered because the potential for water quality degradation is substantially greater for wells located near sources of contamination. Distances to confirmed contaminant sources were measured from wellhead locations to contaminant source locations identified in the Draft Northern Thurston County Ground Water Management Plan (1992) and shown on capture zone Figures II-6, II-7, and II-8. Only contaminant sites within the hydraulic influence of a well (within the 10-year capture zone or upgradient) were include as confirmed or potential sources. No consideration was given to the status of the contaminant problem, i.e. whether or not the contaminant site is partially or fully remediated. Potential contamination sources include those sites where historical land use activity could possibly pose a threat to groundwater quality of the area. The only potential source of contamination considered for this analysis is an underground fuel storage and delivery system that exists in Section 28 T18N, R1W (see Section II.G.f).

Other factors that may influence aquifer vulnerability include the contaminant source area, rate of contaminant source release, duration of contaminant source, occurrence of fractures in fine-grained units, occurrence of highly permeable zones in an aquifer, and the actual capture zone configurations for each well.

For each City production well, a ranking from 1 to 10 was assigned for four of the five parameters, where a score of 10 indicates highest potential to affect aquifer vulnerability and a score of 1 indicates lowest potential to affect aquifer vulnerability. Maximum ranking for distance to potential sources of contamination was assigned a value of 4. Ranking criteria for each parameter are given in Table II-1. A weighting factor of 1 was assigned to all the parameters except for depth to top of the screened or perforated interval, which was assigned a weighting factor of 2. A total "score" of 54 points was possible for each well. The well rankings were normalized by dividing the score for each well by the possible total score for each well.

Results of the analysis indicate that the normalized scores range from 0.19 to 0.63. The wells have been divided into three groups based on relative vulnerability, as follows:

Low Vulnerability Wells	Moderate Vulnerability Wells	High Vulnerability Wells
HP, NHP,18B	MA1, MA2, BC1, BC2, GP, 1, 2, 3, 7, 9, CC01	4, 6C, 10, 19A, 19C

An average pumping rate of 500 gpm per well was assumed for Wells 6C, HP, GP, and NHP. Capacity for each of these wells, except the proposed well (NHP), is approximately 800; a rate of 500 gpm was selected based on anticipated non-pumping periods during a calendar year (pers. comm., Lacey, 1992). The annual average pumping rate for the NHP well was assumed to 0 be 500 gpm.

F. Well Capture Zone and Travel Time Analysis

Time of travel capture zones were estimated for each production well source. A time of travel capture zone is the area surrounding the pumping well that will supply groundwater to the well within a specific period of time. The location of the time of travel capture zones together with the aquifer vulnerability assessment provides a basis for identifying areas to direct future monitoring and data collection.

1. Modeling Approach

The Wellhead Protection Analysis (WHPA) computer program developed by the U.S. Environmental Protection Agency (USEPA) was used to estimate capture zones for 1-, 5-, and 10-year travel times for each well used by the City. The WHPA program is described in the document titled *A Modular Semi-Analytical Model for the Delineation of Wellhead Protection Areas* (1991). Use of the program with input parameters constitutes a model that provides capture zone solutions for a horizontal homogeneous aquifer of uniform thickness that has two-dimensional, steady-state groundwater flow. Multiple pumping wells can be included in a single model for capture zone analysis. The WHPA program includes four separate modules for capture zone and travel time analysis. The RESSC module was used for the analysis of capture zones for City wells.

Input to the model consists of the following parameters:

- o Well locations
- o Pumping rates
- o Aquifer transmissivity
- o Aquifer thickness
- o Hydraulic gradient and direction for ambient flow
- o Aquifer porosity

A summary of input parameters used in the modeling analysis are given in Table II-2.

Pumping rates for the wells were estimated from production data for years 1989, 1990, and 1991. The model pumping rate for each well is the arithmetic average of the annual pumping rates for each of the three years. The annual pumping rate, in gpm, for a given year is a well's total production in gallons divided by the total minutes per year. The annual pumping rates for Wells 6C, HP, GP, and NHP were assumed to be 500 gpm. The model pumping rate used for Well 7 is 75 gpm, base on an average rate from 1990 and 1991. Use of this well has decreased since start of 1989, and is the last well to be activated in the City water system.

The aquifer transmissivities used in the model were estimated from pumping test data for Wells 2, 3, 6C, 9, 10, MA2, HP, and GP. Transmissivity values were calculated for Wells 4, 7, 18B, BC1 and BC2. Calculated transmissivity is the product of the average hydraulic conductivity for nearby wells and the thickness of the aquifer in the vicinity of the City production well. The source of the hydraulic conductivity values for wells is contained the in summary table of hydrologic parameters for wells used in the GWMA study area (N. Dion, pers. comm. to Lacey, 1992).

Aquifer thickness values were obtained from the hydrogeologic cross sections (Figures II-1 and II-2). Thickness used for model inputs were selected as production zone interval located between upper and lower fine-grained unit. For wells completed in the TQu zone, fine-grained units were considered to be the top or bottom of aquifer if they are greater than five feet thick. For TQu wells where a lower fine-grained unit was not indicated, the bottom of the aquifer was selected at the total depth of the borehole.

The magnitude of hydraulic gradient and groundwater flow direction were estimated from the water level contour maps shown on Figures II-3, II-4, and II-5. Two well sites were assigned a gradient of zero. These wells include Well 1 which is located in the vicinity of a groundwater "saddle point" point where gradients would be small, and Wells 19A and 19C which are in an area of insufficient water level data to estimate hydraulic gradient and direction.

A constant aquifer porosity of 0.20 was used for the entire modeling analysis.

Separate model runs were conducted for Wells 2, 3, 7, 6C, 9, and 10 because for the one- and five-year time of travel they are at sufficient distances from other wells so that well interference effects could ignored. The remaining wells were combined into five other model runs. Wells that were grouped together include Wells 4 and CC01; Wells BC1 and BC2; Wells MA1 and MA2; and the Hawks Prairie/Glacier Park wells. Model input parameters for these grouped model runs were average values for transmissivity and thickness.

The modeling approach used for Wells 1, 19A, and 19C is known as the calculated fixed-radius method. This method results in an estimate of the radius of a cylindrical volume of aquifer that contains the volume of water pumped in one, five, and ten years. This method is based on the assumed hydraulic gradient of zero at these three well sites. Parameters used for these calculations include total annual volume pumped based on the annual average pumping rate, aquifer thickness, and aquifer porosity. Geologic logs for Wells 19A and 19C indicate the wells withdraw groundwater from different zones but vertically adjacent zones in the TQu unit, and therefore, they are modeled as one aquifer zone (see Appendix A).

2. Results of Capture Zone Analysis

The modeled capture zones for the one-, five-, and ten-year travel time analyses are shown on Figures II-6, II-7, and II-8. Locations of known contaminant sites are also shown on these figures. The capture zones areas shown on each map represent the estimated zone of groundwater contribution to a well or to wells. Water particles within a time of travel capture zone will move to a well or wells during the specified time of travel. Most of a well's capture area extends in the upgradient direction from the well. The downgradient limit of the capture area is defined by the location of a stagnation point. Water particles between the stagnation point and the well move toward the well.

In addition to the one- and five-year capture zones shown on Figures II-6 and II-7, areas identified as "management buffer areas for wells that have large capture zone aspect ratio" are constructed for Wells 7, CC01, MA1, MA2, BC1, and BC2. For this report, capture zone with large aspect ratios are those that have relatively large length to width ratios. The management buffer area include an approximately 45 degree area upgradient from the well. These areas incorporate some of the uncertainty in capture zone locations that results from uncertainty in model input parameters.

The ten-year capture zones shown on Figure II-8 indicate two large and two small sources areas for City production wells. The two large areas include the southwest part of the study area and the Hawks Prairie-Glacier Park-Beachrest area. The two small areas include Meridian Acres and Nisqually. The same method used for constructing the one- and five-year management buffer areas, used with the 10-year capture zones to construct the limits for the recommended long-term management areas shown on Figure II-8.

A capture zone was computed for Well 18B. The resulting capture zone for this well was extremely elongated because of the small pumping rate relative to the hydraulic gradient and calculated transmissivity. Definition of capture zones and a management buffer area for this well is problematic because the calculated transmissivity may not accurately represent aquifer properties far upgradient from the well, and therefore, a Well 18B capture zone is not presented. However, the actual capture zone for this well likely occurs very near the wellhead and in the direction south-southwest from the well.

3. Sensitivity Assessment for Capture Zone Areas

Because of the simplifying assumptions used in application of the WHPA program, and the uncertainty in the model input parameters, the actual capture zones resulting from pumping City wells will differ to some degree from the capture zones presented in this report. A qualitative sensitivity assessment is given below that describes the effect of model input parameters on capture zone results. The "magnitude comparison" refers to the factor by which the parameter was changed relative to the model parameters given in Table II-2. Length and width dimensions of a capture zone refer to the long and short axes defined by the capture zone limit.

Parameter	Magnitude Comparison	Approximate Effect on Capture Zone
Pumping Rate	Increase by 2	Twice the width, similar length
Pumping Rate	Decrease by 2	Half the width, similar length
Transmissivity	Increase by 2	Half the width, twice the length
Transmissivity	Decrease by 2	Twice the width, half the length
Hydraulic Gradient	Increase by 2	Half the width, twice the length
Hydraulic Gradient	Decrease by 2	Twice the width, half the length
Aquifer Thickness or Porosity	Increase by 2	Similar width, half the length
Aquifer Thickness or Porosity	Decrease by 2	Similar width, twice the length

The orientation of the capture zones shown on Figures II-6, II-7, and II-8 depends on the gradient directions obtained from the water level contours shown on Figures II-3, II-4, and II-5. Gradient directions that differ from those estimated from the contours maps would result in capture zones for wells that would be similar in shape to those shown of Figures II-6, II-7, and II-8 but would be rotated about the well location.

Wells that pump water from aquifers that have hydraulic communication with overlying or underlying permeable zones will commonly derive water from strata that is stratigraphicly above or below the principal water production zone. The effect of this "vertical leakage" on capture zone dimensions would be to decrease the horizontal extent for the time of travel capture zones. Vertical leakage likely occurs at City Well 6C and possibly other City well sites in the southwest part of the study area.

4. Use of the Capture Zones and Management Areas

Because the one-, five-, and ten-year capture zones shown on Figures II-6, II-7, and II-8 were computed based on parameters that have uncertain value, and because simplifying assumptions are required for application of the WHPA program, the actual capture zones for City wells may differ from those shown. However, based on the available hydrogeologic data for the WHP study area, these capture zones provide a reasonable estimate of the source areas within the Qva, Qc, and TQu aquifers that contribute groundwater to City production wells.

The one- and five-year capture zones and the associated management buffer areas can be used to establish areas around wellheads where use of potential contaminants should be properly inventoried and managed. The long-term management areas that include the 10-year capture zones can be used for planning appropriate future land use.
The groundwater source areas together confirmed occurrences or potential sources of contamination have been used in this report to identify areas for additional field investigations, land use surveys, and long-term monitoring.

G. Historical Water Quality

The City of Lacey's historical water quality data gathered from its production wells and storage reservoirs were reviewed. The data were analyzed and summarized in accordance with existing Safe Drinking Water Act (SDWA) regulations. Additional data gathered by the Thurston County Health Department (TCHD), the United States Geological Survey (USGS), and other sources were also reviewed. These data represent conditions throughout the Lacey distribution system and in the WHP study area.

1. Production Well Water Quality

Historical volatile organic chemical (VOC) data, bacteriological data, and inorganic and physical water quality data gathered for regulatory purposes (Table II-3) were reviewed to evaluate the City's status for potential compliance with the City's wellhead protection program.

a. VOCs

The City of Lacey began monitoring for VOCs in the main system in 1988. Monitoring in the two satellite systems began in 1990. Samples were analyzed for 8 compounds with maximum contaminant levels (MCLs) and for the additional 34 discretionary compounds as determined by the Department of Health (DOH). Although the City may not have sampled according to standardized frequencies, VOCs have not been detected in any of the samples collected from the City's production wells since monitoring began in 1988, except trihalomethanes (THMs) were detected in Well MA1 in June 1989. Detected concentration of THMs were less than 3 micrograms per liter (ug/L). There is currently no state or federal MCL for THM compounds in a groundwater supply.

The 1986 amendments to the SDWA include a standardized monitoring framework that is scheduled to take effect in January of 1993. At this time, systems which have met all previous MCL and monitoring requirements will be eligible to monitor on a yearly basis. Systems that have not met all requirements will begin monitoring on a quarterly basis. It is likely that Lacey will be required to monitor quarterly for VOCs under the new framework, and the additional data collected will be reviewed in relation to the goals of the City's WHP.

b. Bacteria

Coliform data collected from 1991 to the present were reviewed for the Main system and Lacey's two satellite systems in accordance with DOH requirements. Based on system populations, 30 samples per month were required from the main system and 1 sample per month was required from each of the satellite systems. The City meets or exceeds the regulatory requirements for bacteriological monitoring in both the main and satellite systems.

The City of Lacey has been in compliance with the total coliform rule and has no history of waterborne disease or illness. The City is currently in the process of developing other requirements of the rule such as sample siting plans for its main and satellite systems.

c. Inorganic Chemical and Physical Parameters

Data collected between 1988 through 1990 from the main and satellite systems were reviewed in order to determine compliance with DOH regulations for primary and secondary chemical and physical parameters. According to the DOH, primary and secondary parameters must be measured from each source every thirty-six months. Although each of Lacey's wells have been tested for the required parameters since 1988, each unique source has not been resampled according to DOH protocol for inorganics.

All primary and secondary MCLs (with the exception of manganese levels at Well 7 and turbidity at Well 8) were met on the days and at the locations sampled. Typical concentration ranges for selected primary and secondary inorganic and physical parameters are listed below.

Parameter	Concentration Range
Nitrate	>0.2 - 2.4 mg/L (as N)
Hardness	30 - 100 mg/L (as $CaCO_3$)
Conductivity	100 - 210 umhos/cm
Turbidity	0.1 - 1.8 NTU

2. Monitoring and Private Well Water Quality

Historical water quality data gathered from monitoring wells and private wells throughout Lacey and the McAllister Springs basin was also reviewed. The GWMA study (1990) resulted in data from 356 wells and 3 springs in Thurston County between April and June of 1989 (N.P. Dion, pers. comm., to the City of Lacey, 1992). Seventy-one percent of the residences sampled received water supplied by public water systems and twenty-nine percent of the sites consisted of private wells. Approximately one-third of the total number of wells sampled were within Lacey service area boundaries.

Additional hydrogeologic studies conducted by Hart Crowser (1988a) for the City of Lacey provided water quality data for two production wells and two test wells. Samples were analyzed for primary and secondary inorganic parameters and VOCs.

A report to the TCHD prepared by Golder Associates Inc. (1990) provided a hydrogeologic evaluation of the geologically sensitive areas around McAllister Springs. Many of the 156 wells previously monitored by the USGS (1988) were also evaluated in the Golder study (1990) and were within the Lacey service area.

a. Pesticides/VOCs:

Ethylene dibromide (EDB) and 1,2-Dibromo-3-chloropropane (DBCP) have historically been used in the area near the Yelm Highway, south of Lake St. Clair, on the southeast boundary of the Lacey water supply system. The pesticide compounds were detected in 26 domestic water wells along the south side of Pattison Lake (see Figure II-9) at concentrations ranging from 0.1 to 1.4 ug/L and 0.1 to 0.3 ug/L for EDB and DBCP, respectively (N.P. Dion, USGS, pers. comm. to the City of Lacey, 1992). Although the pesticides were applied by a licensed pesticide applicator using label-recommended quantities and methods, these compounds have now been designated by the EPA as compounds which may readily leach from soil and enter groundwater. Additionally, 1,2-Dichloropropane (DCP) levels at concentrations of 0.7 to 5.8 ug/L were also detected in 8 domestic wells south of Lake Pattison and along the Yelm Highway (N.P. Dion, personal communication to the City of Lacey, 1992).

Several other VOCs were detected in private wells within the Lacey service boundary. Six wells with detectable levels of the following contaminants were also identified:

Well No.	Organic Parameter	Conc. ug/L	Depth (Feet)	Current MCL (ug/L)
17N/01W-02E03	1,2-Dibromomethane	0.9	49.0	
	Dichloroethylene	0.5		7.0
	Trichloroethylene	0.4		5.0
	1,3-Dichloropropane	0.8		
	Chlorobenzene	0.5		
	Toluene	0.4		1,000
18N/01W-02G02	Chloroform	0.3	241.0	
	Bromodichloromethane	0.2		
18N/01W-17H05	Chloroform	0.2	101.0	
18N/01W-11P05	Trichloroethane	0.2	73.0	
17N/01W-02L02	1,3-Dichloropropane	1.5	78.0	
18N/01W-06A03	Benzene	0.5	118.0	5.0
	Xylene	0.2		10,000
	Ethylbenzene	0.3		

Many of the compounds detected above do not have MCLs, however, their presence suggests that wells throughout the Lacey area are susceptible to contamination from VOCs.

Two organic compounds, methylene chloride and trichlorofluoromethane, were detected at 5.6 and 1 ug/L, respectively, during a complete Class 1 water quality analysis conducted by Hart Crowser (1988) in the City Well 6C. Presence of the compounds was attributed to either: 1) their actual presence in the groundwater system, 2) contamination from pumping test equipment, or, 3) contamination from laboratory glassware. This well was not scheduled for production until 1992, and a resampling program was recommended. During the same study, toluene was detected at 3 ug/L in a sample collected from the Hawks Prairie production well which is scheduled for production in 1993. The source of the toluene was attributed to either pumping equipment or laboratory contamination.

b. Bacteria:

The GWMA study measured coliform levels in conjunction with VOCs and inorganics from 359 monitoring wells and private wells. Bacteria were present in 20 of the 359 wells sampled, and 4 of those twenty were within the Lacey service boundary. The sites that tested positive for bacteria are listed below.

Well Number	Fecal Coliform (CFU/100 mL)	Fecal Streptococci (CFU/100 mL)	Depth (feet)
18N/01W-03H02	<1	1	233
18N/01W-09J01	<1	1	195
18N/01W-33F01	<1	2	62
18N/01W-35L02	<1	19	56

Both fecal coliform (FC) and fecal streptococci (FS) are used as indicator organisms since they are more numerous and more easily tested for than truly pathogenic organisms. The presence of coliform bacteria is taken as an indication that pathogenic organisms may be present in the sample.

The ratio of FC to FS discharged by humans is significantly different from the ratio discharged by animals. The ratio FC to FS for humans is typically greater than 4, while the ratio for animals is less than 1. However, ratios obtained in the range of 1 to 2 cannot be interpreted with certainty (Metcalf and Eddy, Inc., 1979). Only the results from 18N/01W-35L02 suggest that the bacteria may have originated from human waste.

c. Inorganic Chemical and Physical Parameters:

A study conducted by the Department of Ecology (DOE) and the USEPA on nitrate values in the Chambers Prairie area south of Lake Pattison found the highest nitrate levels in an area of commerical agricultural activity (Leaf, 1988). The average nitrate levels observed in this area were 12 mg/L, above the current regulatory level of 10 mg/L.

For the GWMA study (N. Dion, USGS, pers. comm. to City of Lacey, 1992), wells in the WHP study area were analyzed for the following parameters:

Temperature	Fluoride
Conductivity	Silica
pH	Dissolved Solids
Hardness	Nitrate
Calcium	Iron
Magnesium	Manganese
Sodium	Total and Fecal Coliform
Potassium	Alkalinity

Sulfate	Chloride
Dissolved Oxygen	Phosphorous

The following ranges for selected parameters were observed:

Conductivity	81 - 825 umhos/cm
Temperature	9 - 14°C
pH	6.2 - 8.3
Dissolved Oxygen	0 - 11.0 mg/L
Hardness	27 - 270 mg/L as $CaCO_3$
Alkalinity	22 - 464 mg/L as Ca CO_3
Nitrate/Nitrite	<0.1 - 9.3 mg/L as N

The distribution of nitrate values derived from the GWMA study are shown in Figure II-10.

The study prepared by Golder Associates (1990) identified high nitrate levels in the area south of Pattison Lake. This area is an agricultural area with reported heavy fertilizer application. A second area of elevated nitrogen concentrations was identified in the >150 foot elevation zone north of Long Lake. It is believed that the nitrate source may be a result of the high density of unsewered residential development in the area or run-off from the mushroom farm located in the vicinity (Golder, 1990). Elevated nitrate levels (3-4 mg/L) were detected all three well completion elevation zones (<50, 50-150, and >150 feet).

H. Land Use and Sources of Potential Contamination

The quality of groundwater can be impacted by the type and intensity of land use activities that occur in the recharge or capture area of a particular aquifer. Corresponding land use activities within aquifer recharge zones have been reviewed and more than 60 documented cases of groundwater contamination have arisen from land use activities in Thurston County. Land use activities within the 1, 5, and 10 year time of travel zones of production wells in the City of Lacey have been reviewed.

1. Land Use

a. Zoning

A study prepared for the Thurston County Department of Public Works (Brown and Caldwell, 1990) described much of the study area as residential, agricultural or undeveloped, with small, isolated industrial and commercial utilizations. The largest concentration of commercial land use is along Martin Way and Pacific Highway. Additional land use data will be available from the City of Lacy after October 13, 1992 (S. Messagee, pers. comm., 1992)

2. Potential Sources of Contamination

a. Storm Drainage

Much of the storm water runoff is discharged to the subsurface through dry wells, infiltration basins, and generalized infiltration through ditches, lawns, and other vegetated areas. Surface drainage generated in areas immediately adjacent to Long Lake, Pattison Lake, and Lake St. Clair is directed into these surface water bodies, however, a larger fraction of all runoff ultimately enters the groundwater system (Brown and Caldwell, 1990). Contaminants such as heavy metals, organics, bacteria, and viruses can also enter the groundwater through stormwater systems.

b. Septic Systems

Septic systems can be a source of several groundwater contaminants including nitrate, bacteria, sulfate, phosphate, and sodium. Although septic systems can be very effective at removing microbial organisms and pathogens, they are considered to be the largest contributors of nitrogen to the groundwater systems of Thurston County (Golder, 1990). Large areas of nitrate contamination in excess of 2 mg/L have been located in highly populated areas with septic systems. Approximately 4,500 of the 7,700 residences are currently billed for sewerage, resulting in approximately 10,000 residents utilizing some sort of septic system (pers. comm., Lacey Public Works, 1992). Septic systems can also be a source of household hazardous waste contamination of groundwater.

c. Agriculture

Agricultural activity can provide a source of nitrogen, in the form of fertilizers, as well as pesticides and herbicides (such as EDB and DBCP) to the groundwater. Agricultural activity occurs throughout the Lacey service area. The transport of pesticides to the groundwater system is complex since these compounds can undergo numerous chemical, physical, and biological changes.

An evaluation of the best management practices in the McAllister Springs area was completed in 1989. This evaluation indicated that pesticide and fertilizer practices appear to be of greater potential significance to the quality of groundwater than manure handling and disposal practices. Agricultural activity in the area south of the Yelm Highway may have the greatest impact on groundwater quality in the Lacey service area.

d. Transportation Spills

Vehicles transporting hazardous materials can be a source of groundwater contamination through accidents and resultant spills of material. Hazardous materials are transported through the Lacey service area on a daily basis. The major arterials in the area are Highway 510 (Marvin Rd. and Pacific Highway), Meridian Road, Yelm Highway, and Highway I-5 (Brown and Caldwell, 1990). Accidents resulting in spills of hazardous materials may contaminate both surface and groundwater systems.

The major Burlington Northern rail line between Portland and Seattle passes directly through the center and through the southern part of the Lacey service area. According to Burlington Northern officials, (J. Miller, pers. comm. to Brown and Caldwell, 1990) trains run on this line 24 hours per day. Approximately fifteen percent of the 40 trains that travel on the line each day are passenger trains, while the remaining 85 percent are Burlington Northern or Union Pacific freight trains.

e. Potential Hazardous Waste Sites

There are currently no superfund (CERCLA) sites in Thurston County. Potential state and federal hazardous waste sites located in or near the Lacey service boundary include (TCPD, 1990):

Site	Address
EDB 1 Thurston County	Yelm Highway
J.R. Setina Manufacturing	2926 Yelm Highway S.E.
Ostrum Mushroom Farms	8323 Steilacoom Road
Pacific Sand and Gravel	1831 Carpenter Road
Puget Power and Light	2703 Pacific Road
Spooners Strawberry Farm	3323 Yelm Highway
Weyerhaeuser County - Box Plant	7727 Union Mill Road S.E.

f. Underground Fuel Lines

Gasoline and other petroleum products can cause widespread water quality deterioration from either direct contact with the groundwater, uptake by the soil, or groundwater contact with vapors. Typically, presence of compounds such as benzene, toluene, ethylbenzene, and xylenes in groundwater indicate that a fuel leak or spill has occurred.

The City is currently investigating the underground fuel oil distribution system that occurs throughout much of Section 28 T18N, R1W. City wells located in this area include Wells

1, 2, 3, and 6C. Fuel oils may contain volatile organic compounds such as of benzene, toluene, ethylbenzene, and xylenes, and semi-volatile compounds such as naphthalene and polynuclear aromatic hydrocarbons.

H. Confirmed Contamination Sites

To date, there have been 11 confirmed soil and/or water contamination events in Lacey (TCHD, 1992). The locations of the contamination events are shown in Figure II-8. Contamination has resulted from either improper handling or discharge of chemicals, leaking underground storage tanks (LUST), chemical spills, or leaching of contaminant from the soil to the groundwater. Of these 11 contamination events, two have involved pesticides, four have involved organic chemicals such as volatiles or solvents, two have been a result of petroleum spills or leaks, and three have involved inorganic chemicals. A review of the contamination data discussed in the Draft Northern Thurston County Ground Water Management Plan (1992) is provided below.

1. Pesticide Contamination

The pesticides EDB, DBCP, and DCP have historically been applied to control pests that would damage or ruin the crop of berry plants (Leaf, 1988). These chemicals were first applied in 1984 near the Yelm Highway along Fairoaks and Kelly Beach roads, resulting in the contamination of the drinking water for approximately 200 homes in the Lake Pattison region.

Other pesticides were identified in the groundwater from wells located along Steilacoom Rd, within the long-term management area around the Meridian Acres production wells. These pesticides were applied in conjunction with mushroom farming activities.

2. Organic Chemical Contamination

Solvents which were discharged from a valve grinding operation were measured in the groundwater on Bowker Street. The site of contamination was adjacent to the City of City Well 7. Tetrachloroethylene was also detected in groundwater on Bowker Street, and resulting in contamination of public well water.

Two organic chemical spills occurred on Martin Way, also within the long-term management area around the Meridian Acres production wells. One of the spills occurred at the Auto Mall and resulted in contamination of the soil in the area.

3. Petroleum Spills/Leaks

Two LUSTS were identified in Lacey, one on Lacey Boulevard and the other on Marvin Road. Although the leaking tanks have been removed on Marvin Road, contamination due to petroleum is still a problem on Lacey Boulevard. Compounds associated with LUSTs include benzene, toluene, ethylbenzene, and xylenes.

4. Inorganic Contaminants

Heavy metals were discharged on Union Mill Road along with septic effluent. The metals eventually migrated to the water table, causing contamination of the groundwater in the vicinity. High levels of chlorides were measured in the groundwater along Hogum Bay Rd. The chlorides were discharged during spraying of whey at the Olympia Cheese Factory. Additionally, excessive conductivity levels were measured in the groundwater near Hogum Bay Road. It is believed that the high levels may have been caused by leachate from the Thurston County Landfill (TCHD, 1992).

Table II–1. Aquifer Vulnerability Matrix for Lacey Production Wells

PARAMETER	WEIGHT FACTOR	ACTIVE CITY OF LACEY PRODUCTIO…															FUTURE OR PROPOSED WELLS……			
		1	2	3	4	7	9	10	CC01	18B	19A	19C	BC1	BC2	MA1	MA2	6C	HP	GP	NHP
Average Pumping Rate (gpm)		78	354	105	524	75	357	900	96	17	25	69	32	31	31	73	500	500	500	500
Ranking	1	2	6	3	10	2	6	10	2	2	2	2	2	2	2	2	8	8	8	8
Deph to Top of Screen (feet)		100	188	197	65	430	223	178	100	229	98	58	116	113	240	272	190	585	539	550 *
Ranking	2	7	6	6	8	3	5	6	7	5	8	8	7	7	5	5	6	1	1	1
Overlying Fine–Grained Unit (feet)		66	128	135	10	78	20	15	37	108	31	25	77	87	139	185	0	231	282	250 *
Ranking	1	4	0	0	8	2	8	8	6	0	6	6	2	2	0	0	10	0	0	0
Distance to Confirmed Upgradient Contaminant Source (feet)		>10000	>10000	>10000	>10000	600 2500	>10000	>10000	>10000	>10000	4700	4700	>10000	>10000	7700 9300	7700 9300	>10000	>10000	7400	>10000
Ranking	1	0	0	0	0	10	0	0	0	0	10	10	0	0	7	7	0	0	7	0
Distance to Potential Upgradient Contaminant Source (feet)		1300	1100	1500	>10000	>10000	>10000	>10000	>10000	>10000	>10000	>10000	>10000	>10000	>10000	>10000	4100	>10000	>10000	>10000
Ranking	1	4	4	4	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0
Overall Ranking For Well		24	22	19	34	20	24	30	22	12	34	34	18	18	19	19	34	10	17	10
Normalized Well Ranking		0.44	0.41	0.35	0.63	0.37	0.44	0.56	0.41	0.22	0.63	0.63	0.33	0.33	0.35	0.35	0.63	0.19	0.31	0.19

Ranking Criteria for Parameters

Average Pumping Rate:

- less than 100 gpm = 2
- 100 to 200 gpm = 3
- 200 to 300 gpm = 4
- 300 to 400 gpm = 6
- 400 to 500 gpm = 8
- more than 500 gpm = 10

Depth to Top of Screen:

- less than 50 feet = 10
- 50 to 100 feet = 8
- 100 to 150 feet = 7
- 150 to 200 feet = 6
- 200 to 300 feet = 5
- 300 to 400 feet = 4
- 400 to 500 feet = 3
- more than 500 feet = 1

Overlying Fine–Grained Unit:

- less than 10 feet = 10
- 10 to 25 feet = 8
- 25 to 50 feet = 6
- 50 to 75 feet = 4
- 75 to 100 feet = 2
- more than 100 feet = 0

Distance to Confirmed Contaminant Source:

- less than 5,000 feet = 10
- 5,000 to 10,000 feet = 7
- more than 10,000 feet = 0

Distance to Potential Contaminant Source:

- less than 5,000 feet = 4
- 5,000 to 10,000 feet = 2
- more than 10,000 feet = 0

* Indicates assumed depth or thickness

\+ Indicates thickness may be larger

Table II–2 – Wellhead Protection Program Model Parameter Summary
City of Lacey Wellhead Protection Program

Well Number	Aquifer	Hydraulic Gradient [1]	Gradient Angle [2]	Transmiss. (gpd/ft) [3]	Transmiss. Source [4]	Modeled Transmiss. (gpd/ft) [5]	Aquifer Thickness (ft) [6]	Modeled Aquifer Thickness (ft)	Annualized Average Well Yield (gpm) [7]	Remarks
1	Qva	0.0000	0				57	55	78	Calculated fixed radius capture zone
2	Qc	0.0032	99	19000	P	19000	29	35	354	Wells 2 and 3 modeled together with an
3	Qc	0.0032	99	19000	P	19000	36	35	105	aquifer thickness of 350 feet.
4	Qva	0.0026	99		C	68000	48	50	524	Well 4 and CC01 modeled together
CC01	Qva	0.0026	99		P	68000	83	85	96	
6C	Qc+TQu	0.0055	73	50000	P	50000	215		500	Gradient is average of Qc & TQu;
7	TQu	0.0042	57		C	45000	121		75	
9	TQu	0.0029	143	29700	P	30000	89?	90	357	
10	Qc	0.0022	99	48600	P	49000	42	40	900	
18B	Qc	0.0028	70		C	110000				
19A	TQu	0.0000	0				14+	30	25	19A and 19C completed in different zones but
19C	TQu	0.0000	0				18	30	69	modeled as single source. Calc. fixed radius capture zone.
BC1	Qva	0.0038	57		C		56	50	32	
BC2	Qva	0.0038	57		C		45	50	31	
MA1	Qc/TQu	0.0032	356		A	30000	?	40	31	
MA2	TQu	0.0032	356	30000	P	30000	42	40	73	
HP	TQu	0.0016	33	53000, 38000	P	53000	104	125	500	High T = GP obs; Low T = rec data. Wells HP, NHP, and
NHP	TQu	0.0016	33		A	53000		125	500	GP modeled together. Well NHP is proposed.
GP	TQu	0.0016	33	53000	P	53000	147	125	500	

Notes:

[1] Hydraulic gradient in vicinity of well source.

[2] Gradient angle measured counter clockwise from x–axis.

[3] Estimate of aquifer transmissivity.

[4] Source of transmissivity estimates; pumping test data (P) or calculated from aquifer parameter data (C), or assumed based nearby aquifer parameter data (A).

[5] Transmissivity value used in EPA WHP modeling analysis.

[6] Estimated aquifer thickness in vicinity of the well.

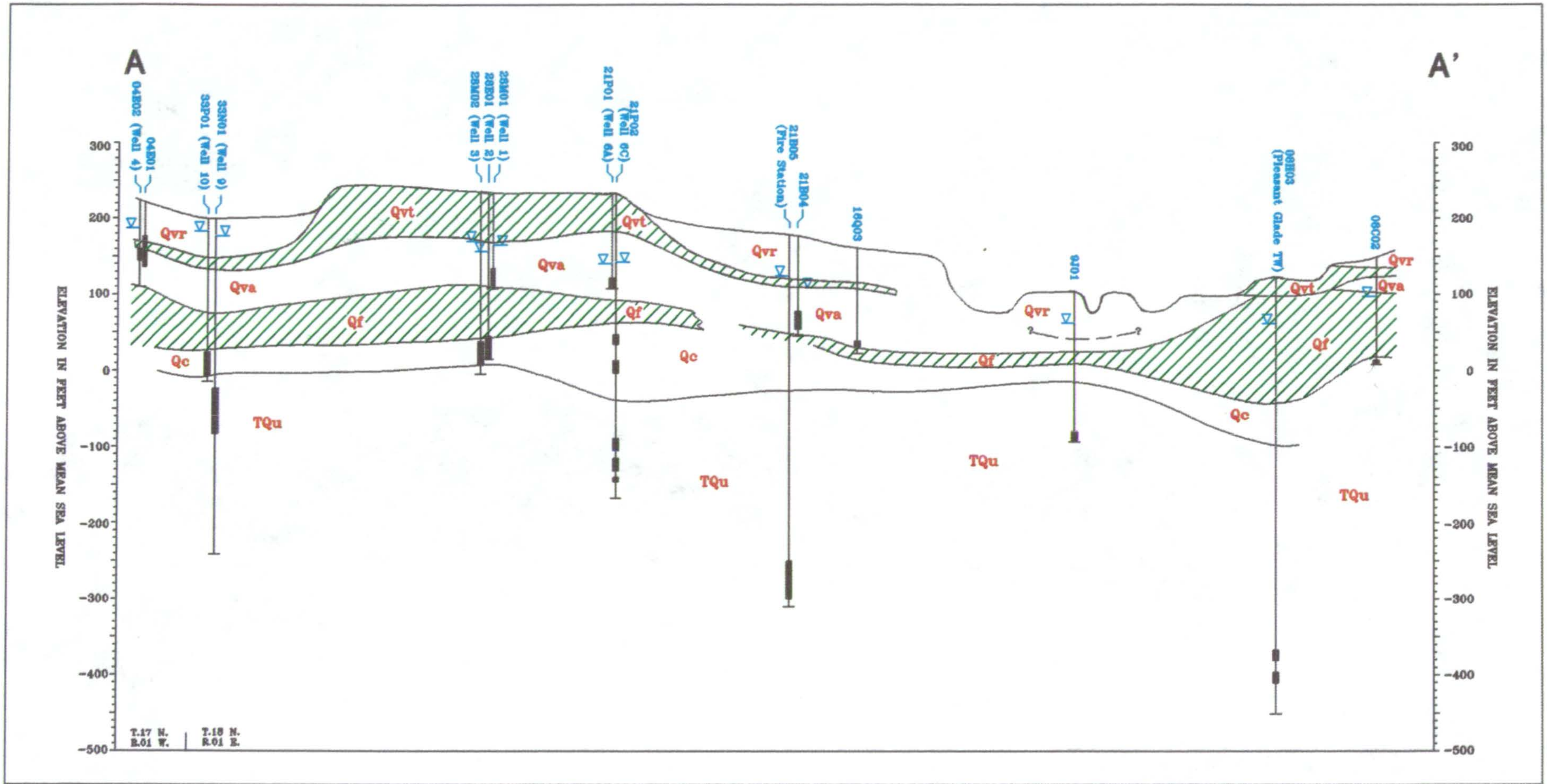
[8] Average pumping rate for well based bsed on production years 1989–1991 and projected well use.

Table II–3
City of Lacey
Production Well Water Quality Summary

Parameter	Wells Monitored (Well Number)	Date	Compliance Status
VOCs (1)	1,2,3,4,6,8,9,10,MA1,MA2 1,10,MA1,MA2 BC2 19c,19a 1,2,3,4,7,9,10,MA2 BC1, BC2 7	2/22/88 6/26/89 12/3/90 12/17/90 7/8/91 7/23/91 4/21/92	Yes*
Bacteriological	Distribution System	1991–1992	Yes
Inorganics (2)	1,2,3,4,7,8,9,10 19c 7 7 Steilacoom Tank Beachcrest Res. Nisqually Res.	8/23/88 5/23/89 7/23/90 8/15/90 10/2/90 10/2/90 10/2/90	Yes*

Legend

(1) VOC = Volatile Organic Chemicals
(2) Inorganics includes all primary and secondary chemical and physical parameters.
* MCL compliance is based on monitoring frequency as well as contaminant concentration. Although contaminant concentrations did not exceed their respective MCLs, sampling frequency was not conducted according to standardized DOH protocol.



LEGEND

Qvr	Quaternary Vashon Recessional Outwash
Qvt	Quaternary Vashon Till
Qva	Quaternary Advance Outwash
Qf	Kitsap Formation/Fine-Grained Deposits
Qc	Penultimate Glaciation Deposits
TQu	Tertiary-Quaternary Undifferentiated Deposits
	Low Permeability Deposits Consisting of Vashon Till and the Kitsap Formation

33P01 (Well 10) — Well Number

Water Level

Completion Interval

Horizontal Scale in Feet: 0, 1000, 2000, 4000

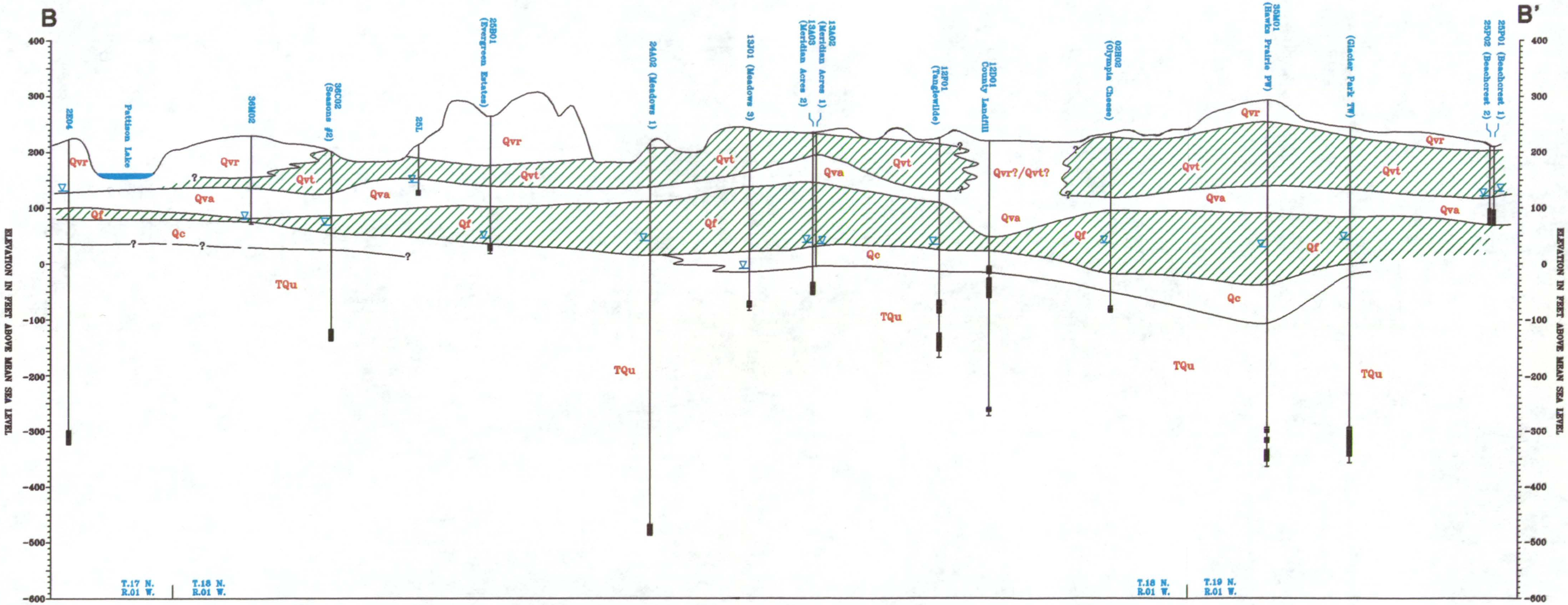
Vertical Scale in Feet: 0, 50, 100, 200

Pacific Groundwater Group

Lacey Wellhead Protection Program

Figure II-1

Hydrogeologic Cross Section A - A'



LEGEND

Qvr	Quaternary Vashon Recessional Outwash
Qvt	Quaternary Vashon Till
Qva	Quaternary Advance Outwash
Qf	Kitsap Formation/Fine-Grained Deposits
Qc	Penultimate Glaciation Deposits
TQu	Tertiary-Quaternary Undifferentiated Deposits
(hatched)	Low Permeability Deposits Consisting of Vashon Till and the Kitsap Formation

33P01 (Well 10) — Well Number

Water Level

Completion Interval

Horizontal Scale in Feet: 0, 1000, 2000, 4000
Vertical Scale in Feet: 0, 50, 100, 200

Pacific Groundwater Group

Lacey Wellhead Protection Program

Figure II-2

Hydrogeologic Cross Section B - B'

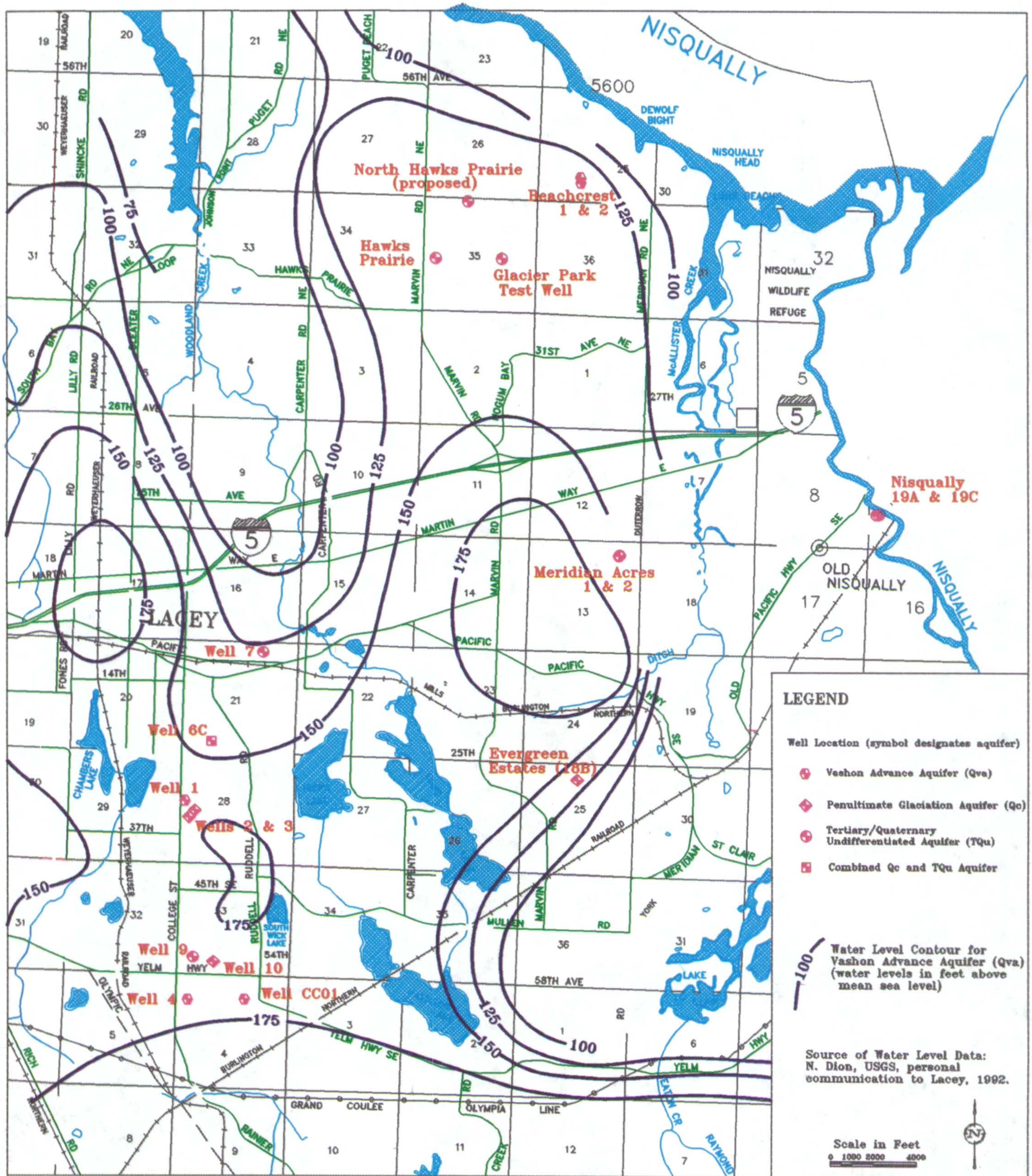


Figure II-3 Water Level Contours for Vashon Advance Outwash Aquifer (Qva)

Lacey Wellhead Protection Program

Pacific Groundwater Group

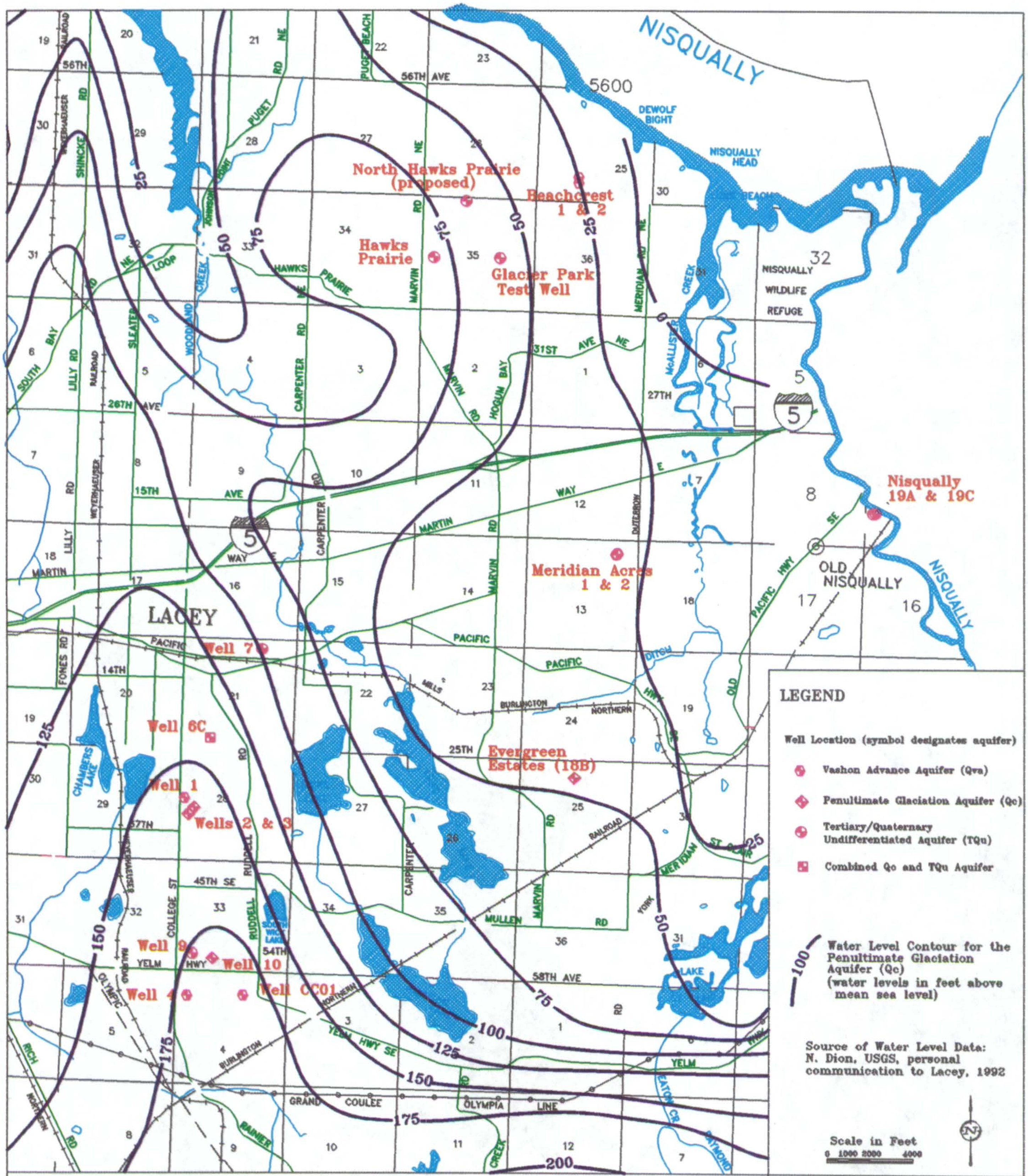


Figure II-4 Water Level Contours for Penultimate Glaciation Aquifer (Qc)

Lacey Wellhead Protection Program

Pacific Groundwater Group

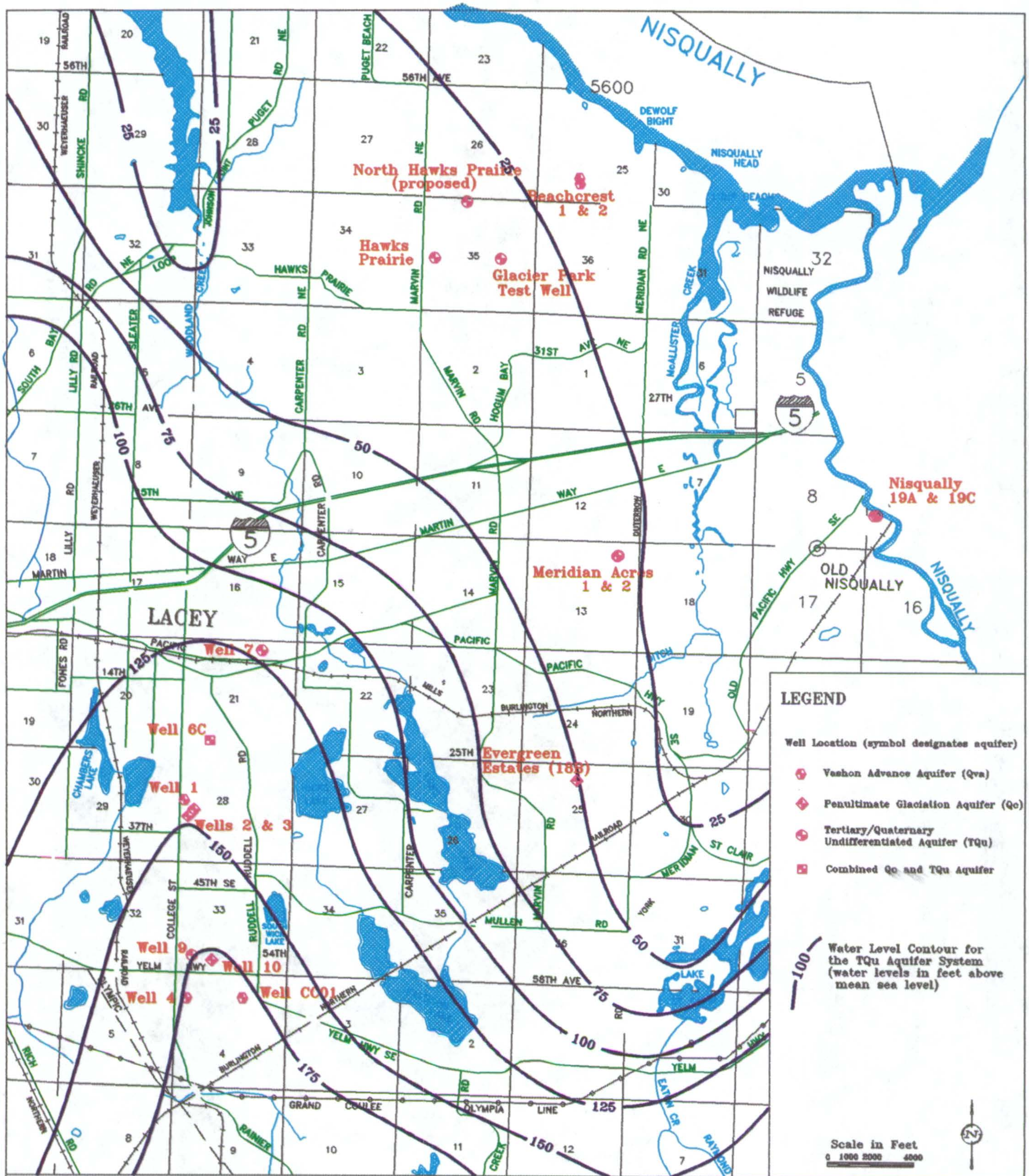


Figure II-5 Water Level Contours for TQu Aquifer System

Lacey Wellhead Protection Program

Pacific Groundwater Group

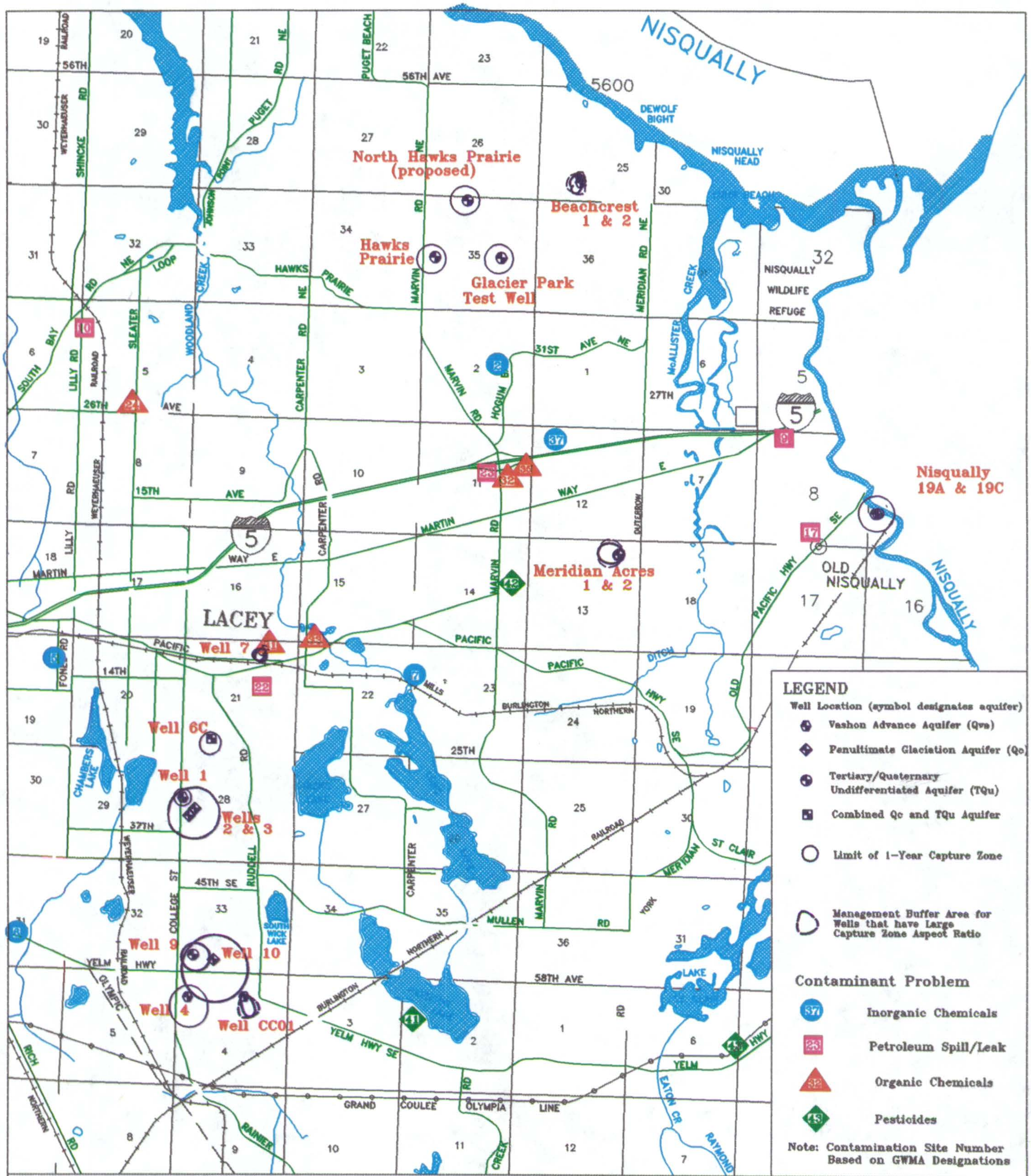


Figure II-6 One-Year Travel-Time Capture Zones for Lacey Supply Wells

Scale in Feet
0 1000 2000 4000

Lacey Wellhead Protection Program

Pacific Groundwater Group

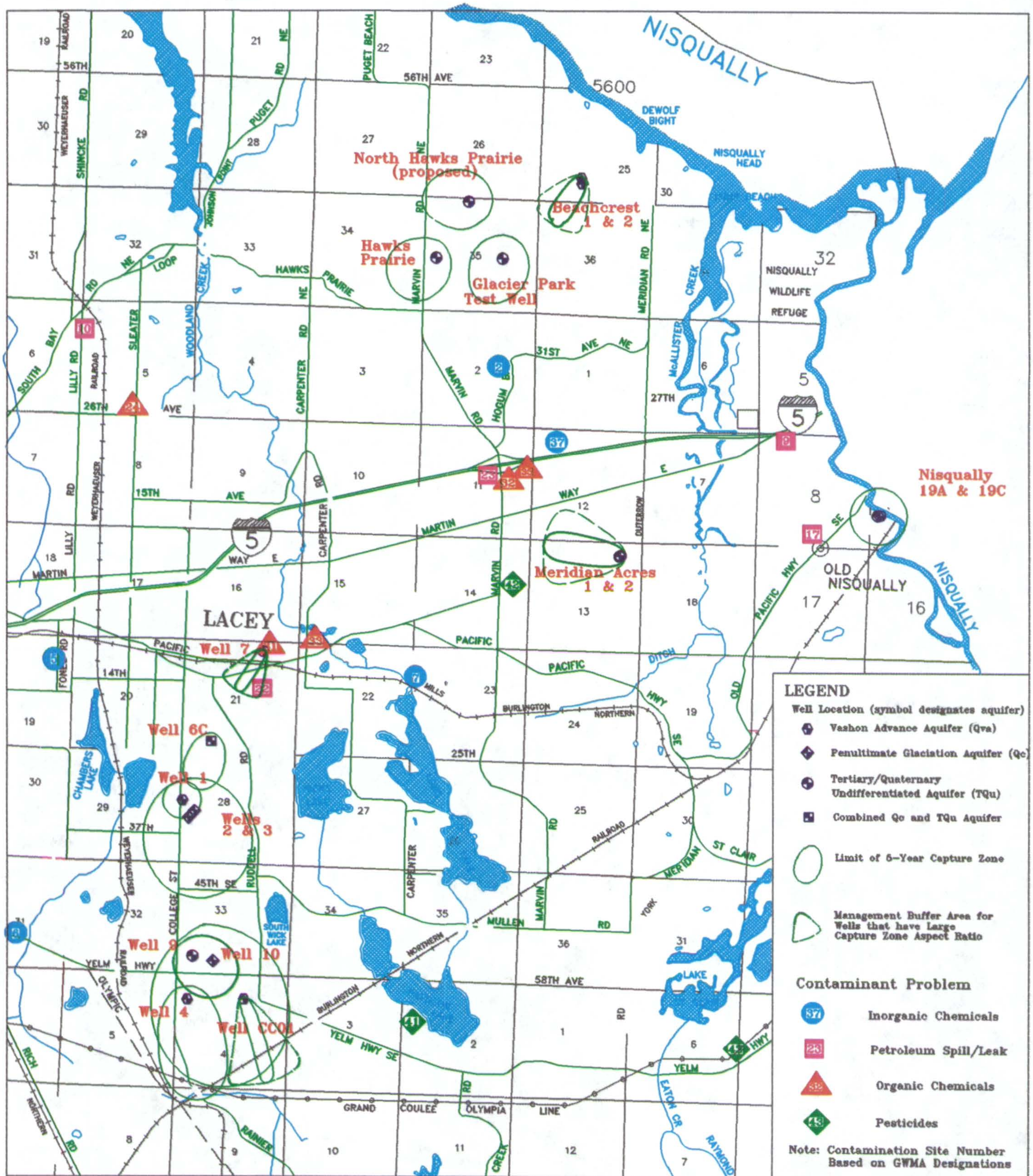


Figure II-7 Five-Year Travel-Time Capture Zones for Lacey Supply Wells

Scale in Feet
0 1000 2000 4000

N

Lacey Wellhead Protection Program

Pacific Groundwater Group

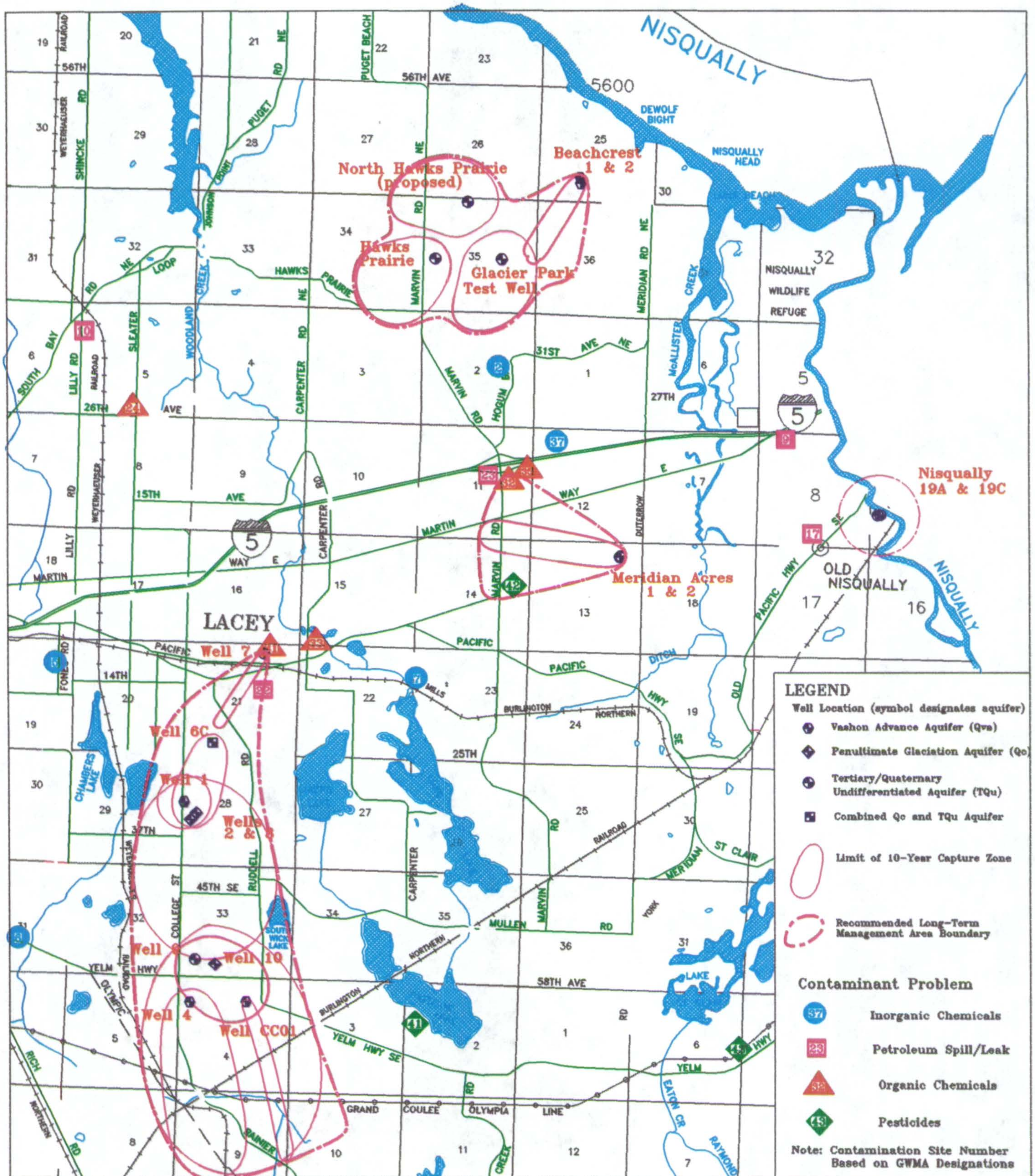
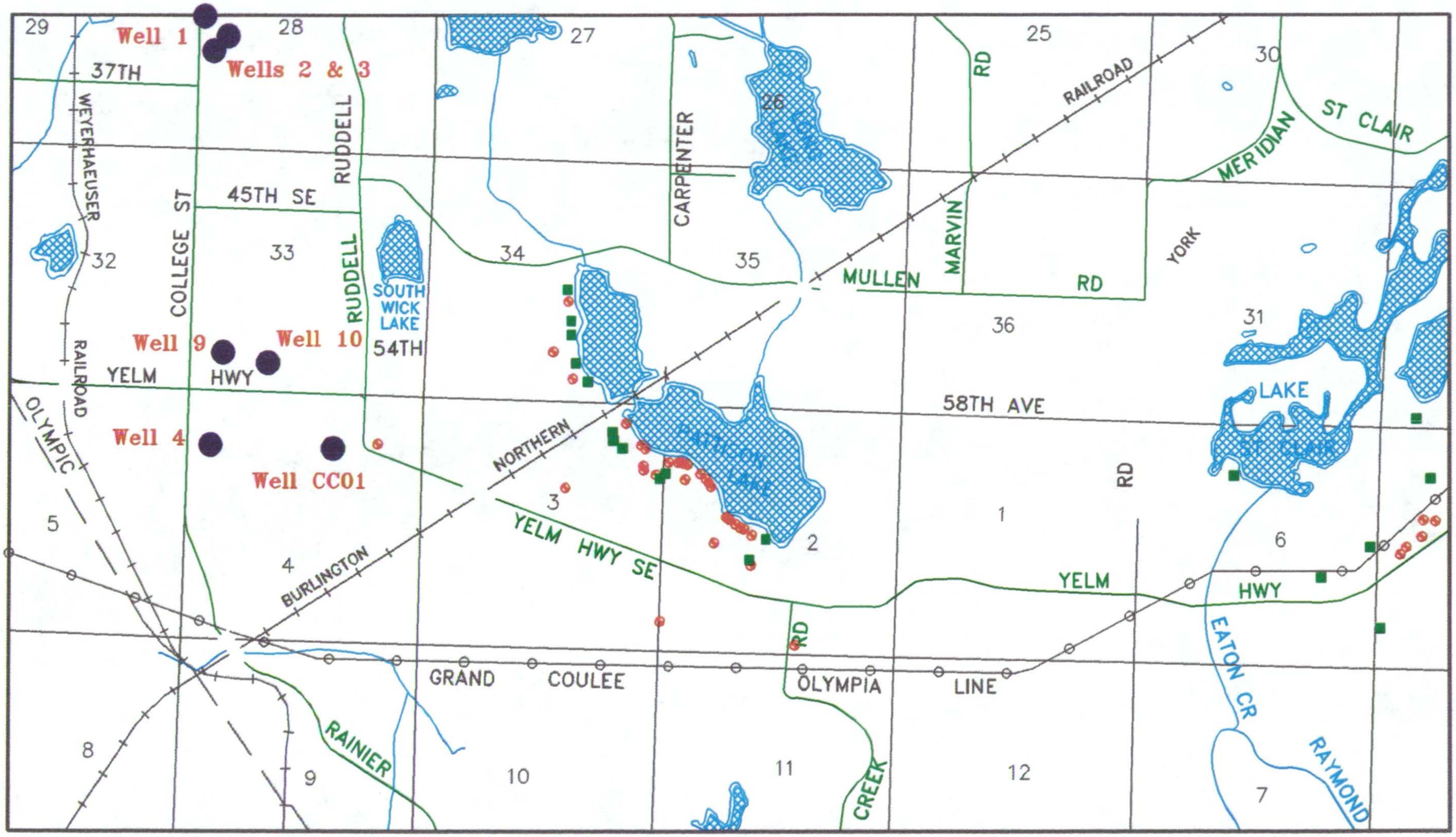


Figure II-8 Ten-Year Travel-Time Capture Zones for Lacey Supply Wells and Preliminary Long-Term Management Areas

Scale in Feet
0 1000 2000 4000

Lacey Wellhead Protection Program

Pacific Groundwater Group



LEGEND

- Lacey supply well
- Well with detectable level of a pesticide compound (EDB, DCP, DBCP)
- Well tested with no detectable level of a pesticide compound

Scale in Feet

0 1000 2000 4000

N

Pacific Groundwater Group

Lacey Wellhead Protection Program

Figure II-9
Location of Wells with Detectable Pesticide Compounds

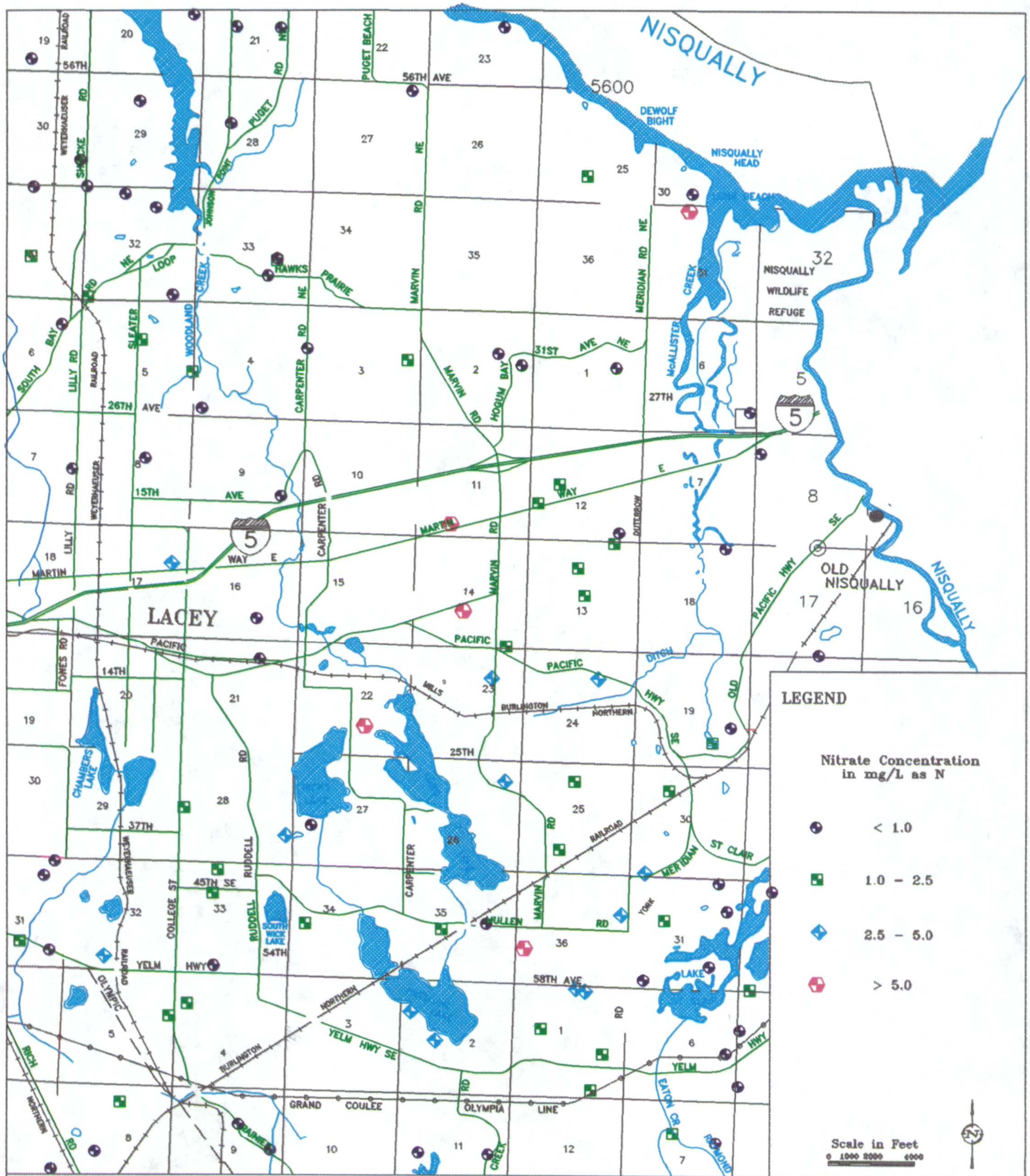


Figure II-10 Concentration of Nitrate in Groundwater

Lacey Wellhead Protection Program

Pacific Groundwater Group

III. DATA COLLECTION

Results of the preliminary data assessment used to characterize the subsurface geology and hydrologic flow system in the WHP study area indicate that additional monitoring of groundwater quality and water levels is necessary in the southwest part of the study area (see hatched area on Figure III-1). This monitoring would provide long-term data that could be used to protect groundwater quality in the area of the City's principal groundwater sources. Data collected in this area would be obtained from approximately six new monitoring wells and approximately 12 existing wells selected from the well database (see Appendix B for well list). The construction and installation of new monitoring wells would specifically improve definition of hydrostratigraphy and aquifer properties. Implementation of sampling and water level monitoring of new and existing wells would provide information on groundwater flow directions and groundwater quality trends that could be used as an "early warning" of contaminants moving toward City wells.

In addition to the monitoring effort described above, an expanded area of water level monitoring program is recommended for the area extending from the southwest to north part of the study area (see stipled area on Figure III-1). Long-term water level data from wells in this area would provide improved definition of hydraulic gradients and groundwater flow directions.

Groundwater quality and water level data in the south and southeast part of the study area (the Lakes area) and McAllister Springs are obtained by the City of Olympia for its Wellhead Protection Program and by Thurston County for the County's regional groundwater monitoring program (Figure III-1). Because groundwater quality issues are a regional concern in the study area, future groundwater monitoring for the Lacey Wellhead Protection Program should be coordinated with Thurston County and Olympia monitoring activities. This coordination would provide a more complete and consistent set of data, and therefore, would facilitate an accurate assessment of groundwater flow and quality conditions in the Lacey WHP study area. Also, a coordinated effort in which each party would have access to field equipment would reduce costs for Lacey. A scenario for future monitoring activities might be that Thurston County Department of Health assumes the organizational role in a cooperative effort between Lacey, Olympia, and the County.

A. Monitoring Wells

Installation of six monitoring wells is recommended in the hatched area shown on Figure III-1. This was selected because of relatively high aquifer vulnerability based on the results of the aquifer vulnerability matrix and the capture zone analysis, and because this area contains the City's principal water supply sources. The target zone for these recommended wells is the relatively shallow Qva aquifer. These wells would provide water level and water quality data from the same aquifer that yields groundwater to City Wells 1 and 4, and Well CC01. Monitoring water quality in the Qva using the recommended wells would also provide some degree of "early warning" for contaminants that could move from the Qva to the underlying Qc aquifer. City Wells 2, 3, 6C, and 10 are completed in the Qc aquifer.

All wells will be installed and constructed in accordance with Washington Department of Ecology (WDOE) standards set forth in Chapter 173-160. A schematic diagram that shows the monitoring well design is presented in Figure III-2. The wells will be drilled using an auger method to anticipated depths ranging from 75 to 125 feet. Borehole diameter will be 8-inches to accommodate a 2-inch PVC well and the annular material. The 2-inch PVC monitoring wells will be exposed to the adjacent aquifer through a 5-foot slotted interval set within an appropriate filter pack. Centering guides will be used to center the monitoring wells within the borehole. Three-quarter (3/4) inch PVC sounding tubes will be strapped to the 2-inch monitoring wells and will provide access for water level measurements.

A Pacific Groundwater Group hydrogeogolgist will be on site during drilling operations. A summary of well construction costs for six monitoring wells is given in Table III-1. These estimates are based on an assumed depth of 100 feet per well. Actual well depths and costs may vary from those presented.

B. Water Level Monitoring

Depth to water will be measured in the newly constructed monitoring wells, City wells, and selected wells from the well database. Some of the selected wells will include those used to monitor water levels as part of the northern Thurston County GWMA study. Collection of water level data will be conducted by qualified City personnel with assistance from a Pacific Groundwater Group representative. Calibrated electronic sounders will be used to measure depth to water to an accuracy of 0.01 foot.

It is recommended that City survey the newly constructed monitoring wells for elevation control. The current budget for well construction and installation does not include costs for surveys. Most wellhead elevation for private wells are estimated from topographic maps, and may be accurate to plus or minus 10 feet. If accurate definition of local groundwater flow patterns is necessary in certain areas, the City should consider private wellhead elevation surveys. Pacific Groundwater Group will provide specific recommendations on survey requirements at a later date.

A water level monitoring program should be implemented whereby depth to water during a single monitoring event (e.g. March 1993) would be measured by the City of Lacey for its WHP program, by Thurston County Health Department for its 60 wells in the McAllister Springs GSA, and by the City of Olympia for its WHP program. This would provide data that could be used to construct water level contour maps and evaluate "wet" season groundwater flow directions within the Lacey WHP study area.

C. Water Quality Monitoring

The objectives of the water quality monitoring program are to :

- o Assess the present groundwater quality conditions in the southwest part to the Lacey WHP study area and establish a water quality database for evaluating long-term trends.

- o Implement a monitoring network that will provide an "early warning" of potential contaminant movement toward City of Lacey production wells.

A proposed water quality data collection plan and cost estimate is given in Table III-2. This plan would be conducted in accordance with state and federal regulations and includes the 1986 amendments of the SDWA that will take effect in January 1993. In addition to monitoring for bacteria, nitrate, inorganics, and VOCs, analyses for pesticides compounds EDB, DBCP, and DCP is recommended for selected wells.

In addition to the analyses recommended in Table III-2, other analyses may be recommended at a later date. For example, if the City's investigation of the underground fuel distribution system located in the vicinity of Wells 1, 2, and 3 provides information on the release of fuel oil in this area, then analytical methods such as Washington Total Petroleum Hydrocarbons or Acid Base/Neutral Extractables may be recommended.

These water quality data will provide a year of baseline data that can be used to characterize water quality near City wellheads and make recommendation for monitoring efforts in the southwest part of the Lacey WHP study area.

D. Suggested Future Areas for Groundwater Monitoring

City of Lacey should consider future WHP efforts focused on the Qc and TQu aquifers in the southwest part of the study area, and in the vicinity of City wells located in Hawks Prairie/Glacier Park/Beachcrest, Meriadian Acres, Nisqually, and Evergreen Estates areas. The current well database may contain information on existing wells completed in Qc and TQu aquifers near City production wells that could be used for monitoring water levels and water quality. Construction of monitoring wells in the Qc and TQu aquifers is outside the scope of this Work Plan.

Table III–1. Subcontractor Cost Estimate for Monitoring Wells
Lacey Wellhead Protection Program
(Hollow–Stem Auger Monitoring Wells to 100 feet)

Description	Quanity	Unit Costs	Total Costs
Drilling:			
Hard 0–50 ft	50 L.F.	$13.00	$650.00
Hard 50–100 ft	50 L.F.	$16.00	$800.00
Extra Samples	4 each	$15.00	$60.00
2–inch PVC Riser	90 L.F.	$5.50	$495.00
2–inch PVC Screen	10 L.F.	$7.50	$75.00
Sand Pack	4 sack	$15.00	$60.00
Bentonite Granules	12 sack	$7.00	$84.00
Monument	1 each	$250.00	$250.00
Hourly	8 hrs.	$125.00	$1,000.00
Unit Cost Per Well			$3,474.00
Total Drilling Cost Summary			
Total Costs for Six Wells			$20,844.00
Mobiliation Costs (L.S.)			$1,500.00
Subtotal			$22,344.00
WSST (@ 7.9 %)			$1,765.18
Total Costs for Monitoring Wells			$24,109.18

TABLE III–2
Proposed Water Quality Data Collection Plan
Lacey Wellhead Protection Program

Well Number	Bacteriologi (#/year)	Nitrate* (#/year)	Regulated Physical & Inorganic (#/year)	Additional Physical & Inorganic (#/year)	VOCs (#/year)	Pesticides** (#/year)
MW–1	4	2	2	2	2	2
MW–2	4	2	2	2	2	2
MW–3	4	2	2	2	2	2
MW–4	4	2	2	2	2	2
MW–5	4	2	2	2	2	0
MW–6	4	2	2	2	2	0
^PW 1–12	4	2	2	0	0	2
Trip Blanks	4	2	2	2	2	2
Field Dups	4	2	2	2	2	2
Cost ($)	1200	600	9000	1008	3920	4320
Total Cost~ ($)	17040.8					

Note: Prices listed in this table are estimates. Actual costs may vary.

* Nitrate monitoring is in addition to that included in Regulated Physical and Inorganic parameters.
** Pesticide monitoring for EDB, DBCP, and DCP is in addition to that included in VOC monitoring.
^ Approximately 12 private wells in the vicinity of College St. and the Yelm Hwy. will be sampled.
~ Total cost includes 15% discount through analytical laboratory.

Bacteriological

- Total coliform
- Fecal coliform

Regulated Physical & Inorganic

Turbidity	Nitrate
Color	Selenium
Hardness	Sodium
Conductivity	Chloride
Total Dissolved Solids	Fluoride
Arsenic	Sulfate
Barium	Copper
Cadmium	Iron
Chromium	Manganese
Lead	Silver
Mercury	Zinc

Additional Physical & Inorganic

- pH
- Temperature
- Alkalinity
- Calcium
- Magnesium
- Potassium
- Silica

VOCs

REGULATED
- Trichloroethylene
- 1,2–Dichloroethane
- 1,1–Dichloroethylene
- Carbon Tetrachloride
- Benzene
- 1,1,1–Trichloroethane
- Vinyl Chloride
- para–Dichlorobenzene

UNREGULATED
- Bromobenzene
- Bromomethane
- Chlorobenzene
- Chloroethane
- Chloromethane
- o–Chlorotoluene
- p–Chlorotoluene
- Dibromomethane
- m–Dichlorobenzene
- o–Dichlorobenzene*
- trans–1,2–Dichoroethylene*
- cis–1,2–Dichoroethylene*
- Dichloromethane
- 1,1–Dichloroethane
- 1,1–Dichloropropene
- 1,2–Dichloropropane*
- 1,3–Dichloropropene
- 2,2–Dichloropropane
- 1,3–Dichloropropane
- Ethylbenzene*
- Styrene*
- 1,1,2–Trichloroethane
- 1,1,1,2–Tetrachloroethane
- 1,1,2,2–Tetrachloroethane
- Tetrachloroethylene*
- p–Xylene
- o–Xylene
- m–Xylene
- Bromochloromethane
- n–Butylbenzene
- Dichlorodifluoromethane
- Fluorotrichloromethane
- Hexachlorobutadiene
- Isopropylbenzene
- p–Isopropyltoluene
- Napthalene
- n–Propylbenzene
- Sec–butylbenzene
- Tert–butylbenzene
- 1,2,3–Trichlorobenzene
- 1,2,4–Trichlorobenzene
- 1,2,4–Trimethylbenzene
- 1,3,5–Trimethylbenzene
- Trihalomethanes:
  - Bromodichloromethane
  - Dibromochloromethane
  - Tribromomethane
  - Trichloromethane
- 1,2,3–Trichloropropane
- Toluene*

DISCRETIONARY
- Ethylene dibromide
- 1,2–Dibromo–3–Chloropropane

Note: *Will be regulated as of January, 1993

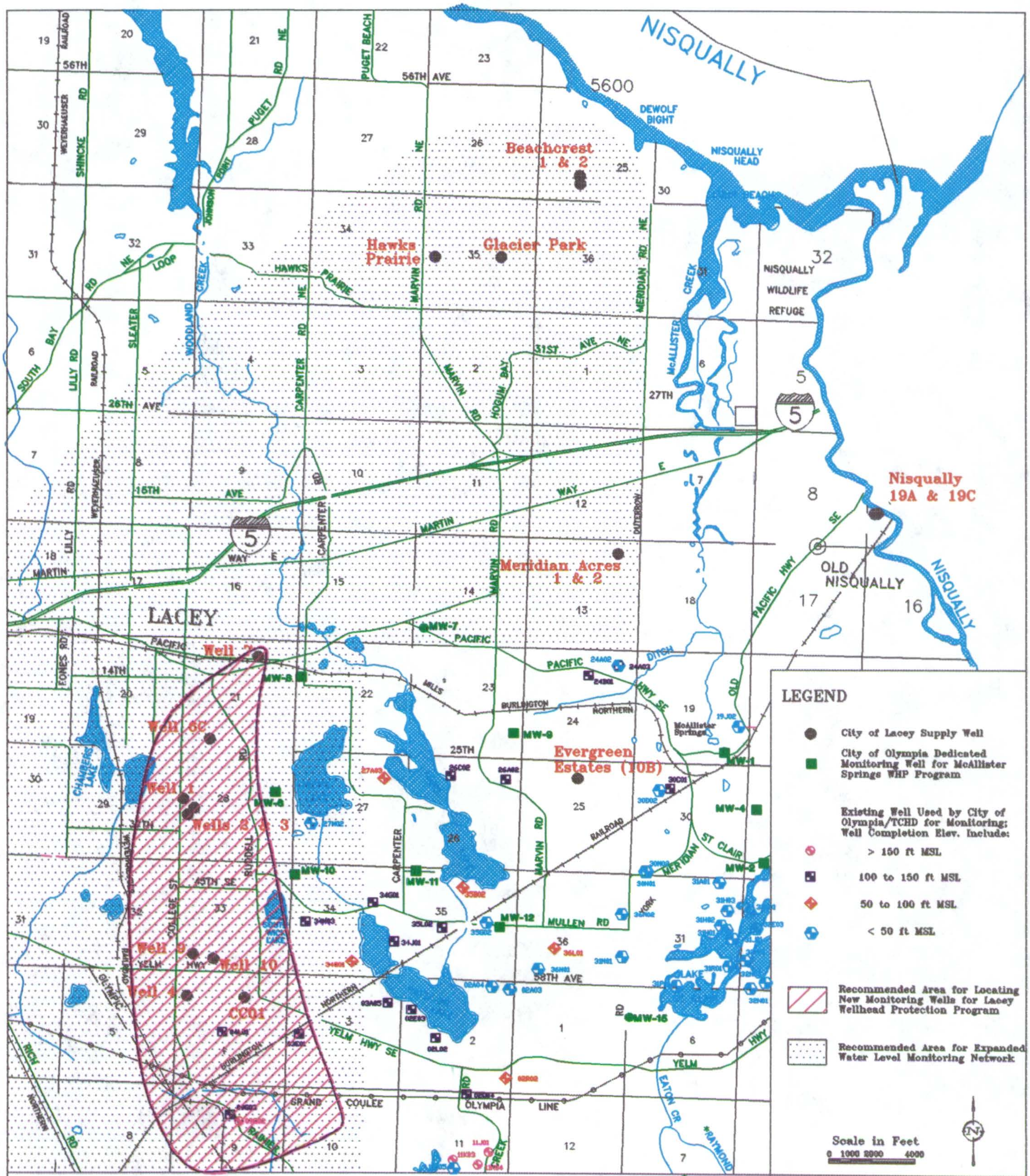
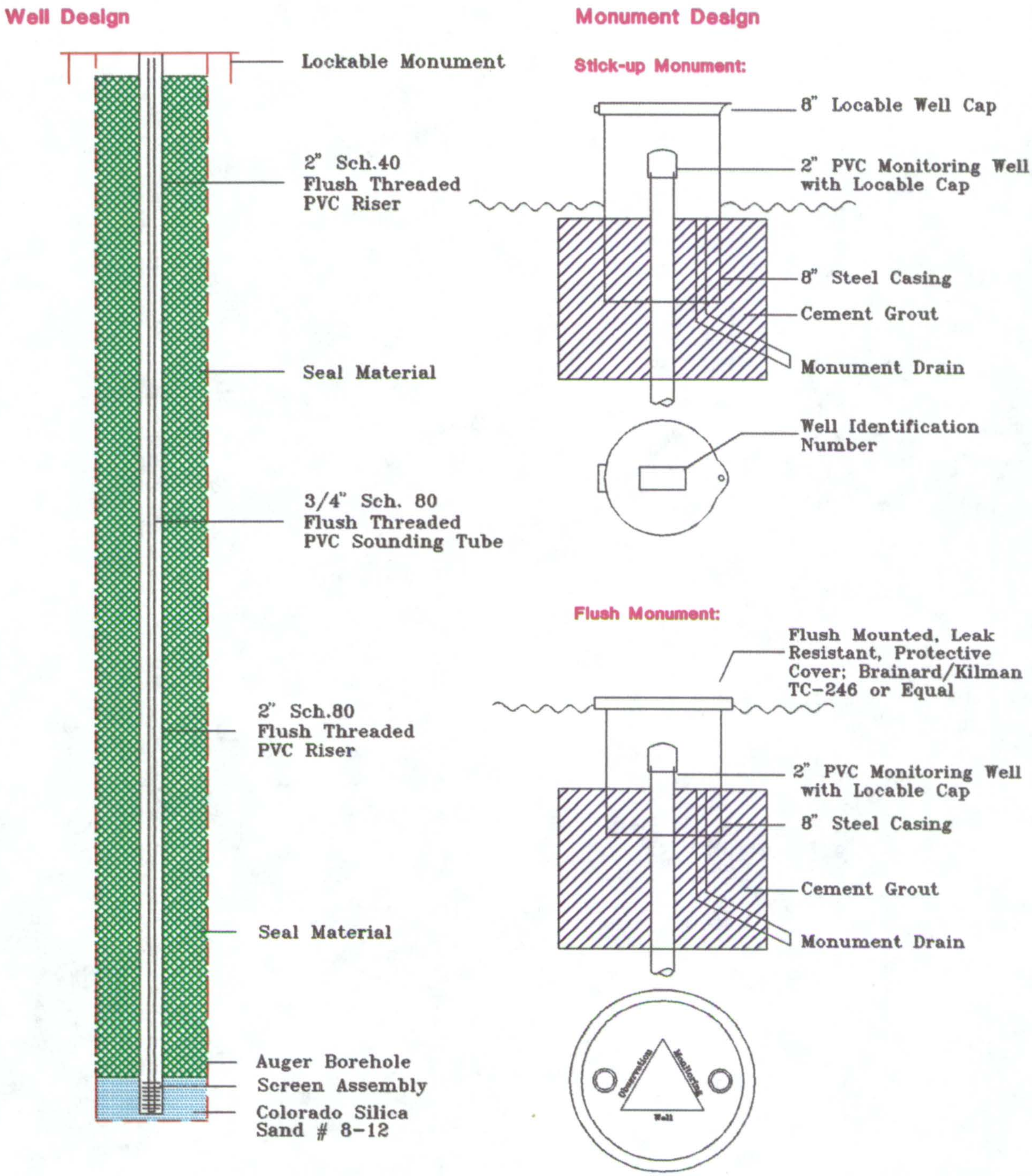


Figure III-1 Location of Existing Monitoring Well Sites and Proposed Areas for Additional Monitoring

Lacey Wellhead Protection Program

Pacific Groundwater Group



Lacey Wellhead Protection Program

Figure III-2
Auger Monitoring Well Design

IV. DATA REDUCTION AND ANALYSIS

The data collected through the activities described above will require reduction, analysis, and interpretation. Drilling of monitoring wells will provide hydrostratigraphic information to be incorporated into geologic logs and cross sections. Water level data will provide additional information regarding groundwater flow directions and gradients. Groundwater sampling will supply more detailed characterization of the distribution of water quality parameters.

The following sections describe the data reduction and analyses to be performed in order to make meaningful interpretations of the data.

A. Data Reduction

Raw data collected during drilling, well installation and testing, water quality and water level monitoring, and stream gaging need to be compiled and reduced. Drilling and well installation data will be incorporated into well as-builts to illustrate both completed well constructions and geologic descriptions of the materials encountered. Water level and water quality data from well sampling will be tabulated and incorporated into the database management system (see Section VI).

B. Hydrostratigraphic Cross Sections

The subsurface hydrogeologic interpretations presented on Figures II-1, and II-2 will be refined based on the results of monitoring well installation. Additional well logs obtained from USGS and WDOE may also be analyzed. Hydrogeologic cross sections will be generated and/or modified to incorporate the additional data, and will include pertinent well completion and water level information.

C. Water Level Contour Maps

Data obtained during water level monitoring will be used to construct refined water level contour maps. Water level maps will be prepared for the "wet" season conditions. The maps will be used to evaluate groundwater flow directions, hydraulic gradients, and the location of groundwater divides. In addition, the maps will allow evaluation of the seasonal changes in the groundwater system that are associated with variations in recharge conditions and pumpage patterns.

D. Capture Zone and Travel Time Assessment

Water level contour maps and additional aquifer property data (transmissivity, aquifer thickness, hydraulic gradient, groundwater flow direction) will be used to refine the capture zone and travel time analysis discussed in Section II-F. The new data will be used to modify the 1-yr, 5-yr, and 10-yr travel-time capture zones for the City production wells (as required). The degree of confidence associated with capture zone estimations will be evaluated, and strategies for further modeling of the flow system to improve definition of travel times and contaminant flowpaths will be recommended.

E. Water Quality Analysis

Water quality data collected will be used to evaluate the impact of various land use activities on the future water quality of City production wells. This data will be evaluated in conjunction with other data obtained as part of the proposed Work Plan, and will be used to further refine the capture zone and travel-time analyses and as well as other technical work products.

V. QUALITY ASSURANCE/QUALITY CONTROL (QA/QC)

This section identifies the quality assurance and quality control procedures to maintain consistent quality of project data. Quality assurance (QA) objectives for data are expressed as the accuracy, precision, completeness, representativeness, and comparability that bear on its ability to satisfy the purposes of this study. The quality assurance objectives, assessment procedures, and tolerance limits for this work plan are similar to those stated in the WDOE's "Quality Assurance Interim Guidelines for Water Quality Sampling Analysis: Ground Water Management Areas" (WDOE, 1986) and the USEPA's "Quality Assurance Manual for Drinking Water Programs Branch Investigations (USEPA Region 10, 1987). The following section contains QA/QC recommendations for:

- Sampling and Field Measurement Procedures
- Laboratory Procedures
- Data Reduction, Validation, and Reporting

A. Sampling and Field Measurement Procedures

This section describes routine procedures to be followed by field personnel. The procedures are designed to ensure that all samples collected are consistent with the following project objectives:

- samples are identified, preserved, and transported so that data are representative of the actual site conditions;
- information is not lost in sample transferral; and
- laboratory data can be used for wellhead protection assessment and evaluation.

The analytical laboratory will provide sample containers composed of appropriate materials and prepared by appropriate methods to preserve the integrity of the sample.

The documents to control and validate sample custody include sample identification numbers, chain-of-custody records, and custody seals. The following sections describe procedures to use these documents.

1. Sample Identification Numbers

Samples should be identified using a sequential numbering system so that data can be entered into the data base. Also, because two aquifer zones may be sampled from the same well, samples should be identified by aquifer as well.

2. Chain-of-Custody

The possession of samples must be traceable from the time the samples are collected until the results are reported by the laboratory. To maintain and document sample custody, the chain-of-custody procedures described here are followed. A sample is under custody if:

- It is in your actual possession, or
- It is in your view, after being in your physical possession, or
- It was in your possession and then you locked or sealed it up to prevent tampering, or
- It is in a secure area

a. Transfer of Custody and Samples.

As few people as possible should handle samples. The field sampler is personally responsible for the care and custody of the samples collected until they are transferred or dispatched properly. When transferring samples, the individuals relinquishing and receiving will sign, date, and note the time on the Chain-of-Custody record. This record documents sample custody transfer.

Samples should be packaged properly for shipment and dispatched to the appropriate laboratory for analysis, with a separate Chain-of-Custody Record accompanying each shipment (one for each laboratory). Shipping containers (i.e. coolers) are sealed with custody seals if shipment to the laboratory is by any other means than project personnel. In this event, two seals will be placed on each shipping container (cooler), one at the front and one at the back to allow the recipient of the container to determine whether or not the container has been opened. Clear tape may be placed over the seals to ensure that seals are not accidentally broken during shipment. The method of shipment, courier name(s), and other pertinent information are entered in the "Remarks" section of the Chain-of-Custody Record.

All shipments are accompanied by the Chain-of-Custody Record, which identifies its contents. The original record accompanies the shipment and the CPU representative retains a copy.

b. Laboratory Custody

The laboratory personnel are required to adhere to these custody procedures. A designated laboratory sample custodian accepts custody of the shipped samples and verifies that the information on the Sample Identification number matches that on the Chain-of-Custody Records. Pertinent information such as the shipment, pickup, and courier is entered in the"Remarks" section.

The laboratory custodian uses the Sample Identification number or assigns a unique laboratory number to each sample and ensures that all samples are transferred to the proper analyst or stored in the appropriate secure area. Laboratory personnel are responsible for the care and custody of samples from the time they are received until the sample is exhausted or stored for future analysis.

3. Field Quality Control

This section presents routine procedures to conduct field measurements and collect samples. The methods presented in this section are intended to ensure that field measurements and sample collection are conducted in a similar and consistent manner by all individuals involved.

The following types of QC samples will be collected in the field and shipped to the laboratories along with the other samples:

a. Trip/Travel Blank

Trip blanks measure potential sample contamination due to the presence of contaminants in the reagent water source, preservative chemicals, and the sample bottles; as well as due to the contamination of the blank itself during the blank preparation, shipment of the prepared blank to the field and/or shipment from the field to the laboratory. The trip blank will be prepared using High Performance Liquid Chromatography (HPLC) grade organic free water with the addition of all appropriate preservative chemicals. Trip blanks will accompany the sample shipping container to the field and will remain unopened until after receipt by the laboratory for analysis. Trip blanks will be analyzed for all of the parameters of interest.

Trip blanks will be collected at a minimum frequency of one per shipment or 1/20 samples (whichever is greater) and will be shipped "blind" to the laboratory along with the other samples.

b. Field Duplicates

Field duplicates are two samples collected identically and consecutively from the same location over a minimum period of time. Field duplicates provide a measure of the total analytical bias (field and laboratory variance) including bias resulting from the heterogeneity of the duplicate sample set itself.

Field duplicates will be collected at a minimum frequency of 1/20 samples, or at least one per sampling day if fewer samples are collected.

4. Documentation of Activities - Field Log Books

Field personnel will maintain a field notebook to provide a daily record of significant events, observations, and measurements during field investigations. The field notebook will contain information such as: personnel present, site conditions, sampling procedures, measurement procedures, calibration records, etc. All entries in the field notebooks and on logs will be signed and dated. The field notebooks will be kept as a permanent record.

These notebooks are intended to provide sufficient data and observations to enable participants to reconstruct events that occurred during the project.

5. Equipment Calibration and Decontamination

All instruments and equipment purchased or used in this study will be inspected to ensure that the item meets and performs to project specifications.

Specific conductivity, pH and temperature will be measured in the field. Proper calibration of these instruments is imperative to ensure quality of all data collected. All instruments used in data collection will be calibrated daily. The calibration event and readings before and after calibration will be recorded in the field log book.

All sampling equipment will be placed in a soapy water wash (Alconox or equivalent laboratory grade detergent) and thoroughly scrubbed with stiff brushes. Equipment will then be rinsed with tap water three times and final deionized (DI) water rinse twice.

B. Analytical Procedures

The primary objective of the analytical quality control activities is to ensure the integrity of analytical results. Therefore, the quality control procedures proposed to be mandatory for drinking water/groundwater samples are required.

The analytical laboratory will analyze samples according to the methods and quality control quidelines specified. The laboratory will follow the USEPA Contract Laboratory Program (CLP) setup and continuing calibration protocols. Laboratory deliverables will include analytical and QA/QC results, raw data, chromatograms, and calculations. The deliverables will not be complete CLP deliverables; however, the laboratory will have complete CLP data available, should it be required.

In addition, surrogate spikes will be run on all samples. The lab will do immediate rerun for any K values outside the calibration range or for surrogate spikes/matrix spikes outside tolerance limits. The lab will also rerun those samples with matrix spike/matrix spike duplicates with relative percent differences outside tolerance limits.

1. Specific Quality Assurance Objectives

Quality assurance objectives for measurement data are usually expressed in terms of accuracy, precision, completeness, representativeness, and comparability. Definitions of these characteristics are as follows:

a. Accuracy

A sample spike is prepared by adding a known amount of a pure compound to the sample (before extraction for extractables), and the compound is the same or similar (as in isotopically labeled compounds) as that being assayed for in the environmental sample. These spikes simulate the background and interferences found in the actual samples and calculated percent recovery of the spike is taken as a measure of the accuracy of the total analytical method. When there is no change in volume due to the spike, it is calculated as follows:

$$\% \text{ Recovery} = (dC/Cs) \times 100$$

where:

dC = the concentration increase measured due to spiking (relative to the unspiked portion)

Cs = the known concentration increase in the spike

Tolerance limits for acceptable percent recovery have been established and will be followed for this project. Sample spike recoveries that fall outside the tolerance limits must be assessed and the problem identified and corrected. The result for that analyte in the unspiked sample is suspect and may not be reported for regulatory compliance purposes.

Surrogate spikes are also a measure of accuracy. When surrogate recoveries are outside the control limits established in the SW-846 methods of the CLP, the corrective action procedures specified in the methods must be followed by the laboratory.

b. Precision

Aliquots are made in the laboratory of the same sample and each aliquot is treated exactly the same throughout the analytical method. The relative percent difference between the values of the duplicates, as calculated below, is taken as a measure of the precision of the analytical method.

$$RPD = \frac{C1 - C2}{C} \times 100\%$$

where:

C1 = the resulting concentration for replicate #1

C2 = the resulting concentration for replicate #2

C = the mean of a series of replicate measurements

The tolerance limit for percent differences between laboratory duplicates has been established as +/- 20%. If the precision values are outside the tolerance limits, the laboratory should recheck the calculations and/or identify the problem. Reanalysis may be required. Sample results associated with the out-of-control precision results may be qualified at the time of validation.

c. Completeness

Completeness will be measured as:

Completeness of analytical effort, (in percent) = Number of sample analyses that have been validated / Total number of samples that have been submitted for validation.

The target for completeness is 90 percent. If the 90 percent target for completeness is not met, the appropriate corrective action will be determined at the time of validation.

d. Representativeness

Representativeness is the degree to which data accurately and precisely represent the true value of a characteristic of a population, parameter variations at a sampling point, or an environmental condition. Representativeness is maximized by following standard procedures for sampling and analysis.

e. Comparability

Comparability is maximized through the use of standard analytical methods or methods with demonstrable equivalency in terms of method performance criteria and equivalent reported units.

2. Detection Limits

The detection limits required are those specified in the applicable method. Matrix effects may prevent attainment of the detection levels. If this is the case, QC justification will be provided.

C. Data Reduction, Validation, and Reporting

1. Field Measurement Data

Reduction and validation of data obtained from field measurements will be performed. Validity of all data will be determined by checking calibration procedures utilized in the field, and by comparing the data to previous measurements obtained at the specific location. Large variations (greater than 10%) will be examined in association with changes in local conditions and general trends. Variations in data which can not be explained by local changes will be assigned a lower level of validity and will be used for limited purposes. Relevant field measurement data will be summarized and included in the report of findings.

Analytical data generated during the work will be evaluated to ensure that the data meet the requirements of the project. The laboratory will be required to follow the protocols established in the Clean Water Act standards (Federal Register, 1984), Contract Laboratory Program (CLP) (USEPA, 1985) limits or guidelines, EPA Region X Quality Assurance Manual for Drinking Water Programs Branch Investigations (1985), or project-acceptable requirements. The quality assurance coordinator will evaluate the data based on:

- Holding Times
- Method blanks
- Detection limits
- Chromatograms
- Matrix spikes
- Matrix spike duplicates
- Surrogates
- Sample custody
- Field duplicate samples
- Field blank samples

VI. DATA MANAGEMENT

A computerized database management system (DMS) will be developed for this project for data storage and manipulation. The system will have two components: a relational database (i.e. dBase IV) for sorting and manipulating tabular data and a graphical database (AutoCAD) for storing diagrams, maps, and geographic reference points. These two databases will be linked with software that will allow easy transfer of data between them. The DMS will include menu driven procedures that allow convenient input, editing, retrieval, transfer and backup of data. The DMS will be designed to perform the following functions:

The relational database system structure will compatible with the WDOE Data Reporting Manual for the Ground Water Management Program (1988). The database system will accommodate a wide variety of water resource information including:

- Site information for wells and other monitoring points
- Well construction data
- Geologic data from well drillers logs
- Water level data
- Water quality data
- Well owner data
- Miscellaneous data such as water use, water rights, precipitation, and testing information (i.e. specific capacity, aquifer properties, etc.)

All database information will be organized and indexed using a site identification number based on the USGS protocol. Water quality and other time series data are organized and stored according to the EPA STORET protocol.

A. Existing Data

Existing sources of data that can be used to develop the database for this project are outlined below. Following each data source are the type of data available.

1. USGS Well Data

An extensive database of well information was assembled by the USGS as part of the north Thurston County Ground Water Management Program. The database includes well location, construction, water level, lithologic, and water quality data for approximately 1300 wells within the north County area. Approximately 400 of these wells occur within the Lacey WHP project data collection area (Figure I-1). All of these data have been downloaded from the USGS national computer archives to a PC based data management system. The DMS and associated data reside at the project consultant offices as well as the Thurston County Health Department.

2. Lacey Well Data

Information available from the City files include well construction reports, water quality data collected as part of regulatory monitoring efforts, water use data, and other miscellaneous information such as water level data, pumping test data, etc. Pertinent data from the City's files has been incorporated into the PC based relation DMS.

3. Water Quality Data

Existing water quality data are stored and maintained by federal, state, and local agencies including USEPA, DOH, and Thurston County Environmental Health.

4. Parcel Data from TGIF

TGIF GIS system includes parcel data which will serve as a basis for land use surveys that will be performed by the City of Lacey.

5. Potential Contaminant Sources Data

Data and reports regarding potential contaminant sources within the project vicinity are available through several sources including:

a. Department of Ecology Files for Hazardous waste generators, NPDES permit holders, etc.
b. Thurston County Stormwater Plan
c. Olympia Yelm Stormwater Plan
d. Hawks Prairie Landfill Studies

B. New Data

New sources of data that will be developed for this project are outlined below.

1. Monitoring Well Data

Water levels and water quality data will be generated on an on-going basis from a network of new and existing monitoring wells. Monthly water level measurement will likely be collected at a number of wells to evaluate trends. Quarterly or semiannual water quality sampling will be performed at a number of monitoring wells to document water quality conditions, trends, and potential threats to supply wells. Construction data for new wells and water level data will be entered into the DMS. Water quality data collected from the monitoring wells will be maintained in computerized spreadsheets.

2. Land Use Surveys/Data

Land use information will be developed by City personnel as part of field surveys within the one-year capture zone. Land use audits will also be performed on a periodic basis to track waste handing activity in these areas. Existing land use data will be compiled from the TGIF GIS system for areas that lie within the 5 and 10 year capture zones. A data management module will be developed to allow the City to track land use information and waste handling. All data that are developed by the City through surveys and inventories will include parcel numbers to insure compatibility with the TGIF database system.

C. Data Maintenance Responsibilities

Data maintenance agreements may need to be developed and/or expanded between the City and County agencies to provide data for the DMS. The majority of the data, including all new data generated from the monitoring wells and the land use surveys, will be maintained by the City. Water quality and water level data from the GWMA/USGS files will be maintained by Thurston County Health District. Digital land use/parcel data will be maintained by TGIF.

D. Data Collection and Transfer Protocols and Procedures

The database system will be comprised of data from various databases and will require the development of data exchange protocols and procedures to ensure easy data transfer. Data collections protocols and procedures will be needed to ensure that new data is compatible with existing databases. The following are key elements needed to develop data collection and transfer protocols and procedures.

1. Data Format

The DMS format will be designed to maintain compatibility with existing data systems including Department of Ecology Groundwater Management Program, USGS protocol, and USEPA STORET protocol. All geographic data will be compatible will TGIF protocol.

2. Unique ID's

A unique identification number is a key element of a standardized data collection form and facilitates the transfer and merging of data that is collected for different programs. Unique ID's include source/well site ID's and assessor parcel numbers. A fifteen digit USGS Siteid numbering system provides the current standard for tracking well information. A new system for tagging wells with six digit unique source identification numbers has recently been developed by Ecology. This system could be adopted in Thurston County through a coordinated agreement with the TCHD and the Cities. Assessor parcel numbers will be used to track the land use survey information.

3. Standardized Data Dictionary

A universal data dictionary should be developed for the DMS. This dictionary would contain descriptions of each data item in the DMS. This will help facilitate data transfer between databases and to provide a record of the information that is maintained in the DMS. A standard data collection format should be adopted in conjunction with the data dictionary. The standard data collection format would insure that all data is collected in a mutually compatible fashion.

E. Software and Hardware Compatibility

The DMS will be designed to operate on any standard PC based computer system that includes a 40 Mbyte fixed disk. System performance will be substantially improved through the use of a 80386 of a 80486 based system configured with high speed fixed disk (100 Mbytes or more) and at least 8 Mbytes of RAM. The DMS will be designed to maintain compatibility with software packages in use by City and County agencies that will be providing data for this system. The City Public Works Department uses AutoCAD to maintain geographic data. The City Planning Department maintains it's building permit system using Tidemark Software, which can export data in a dBase compatible format. Thurston County Health District uses AutoCAD and Dbase software packages for it's water resource database. TGIF uses Arc/Info and Oracle software packages.

F. AutoCAD Mapping

AutoCAD Computer-Aided Design/Drafting Software will be used to prepare maps and other related work projects during the study. A Quad level base map which includes section lines, hydrography, principal roads, and other pertinent reference features has been developed, and will be used to present findings in technical reports and for presentations. In addition, parcel base maps developed by TGIF will be used to present land use data and other reduced scale information.

The AutoCAD maps use coordinates based on the Washington State Plane Coordinate System (Lambert Projection), South Zone. All tabular database information will also be stored by State Plane Coordinates allowing retrieval and display of water resource information on the AutoCAD base maps.

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APPENDIX A

SELECTED BOREHOLE LOGS

WELL CC01

STATE OF WASHINGTON
DEPARTMENT OF CONSERVATION
AND DEVELOPMENT

WELL LOG #2

No. Appl. 371
Cert. 55-A

Date Aug., 1946

Record by N.C.Jannsen Drilling Co.

Source Driller Record

Location: State of WASHINGTON

County Thurston

Area

Map

W½ ¼NE ¼ sec. 4 T. 17 N., R. 1 W.

DIAGRAM OF SECTION

Drilling Co. N.C.Jannsen Drilling & Mfg. Co.

Address 9407 E. Marginal Way, Seattle, Wn.

Method of Drilling Date August 1946

Owner W. R. Rowe

Address Naches, Washington

Land surface, datum ft. above / below

CORRELATION	MATERIAL	THICKNESS (feet)	DEPTH (feet)
	(Transcribe driller's terminology literally but paraphrase as necessary, in parentheses. If material water-bearing, so state and record static level if reported. Give depths in feet below land-surface datum unless otherwise indicated. Correlate with stratigraphic column, if feasible. Following log of materials, list all casings, perforations, screens, etc.)		
	Black sandy soil	5	5
	Sand	5	10
	Hard clay with sand	6	16
	Clay with gravel	13	29
	Water gravel	3	32
	Sand	4	36
	Large gravel	4	40
	Clay with gravel	2	42
	Large gravel	15	57
	Hard packed gravel	19	76
	Gravel sand	25	101
	Sand	9	110
	Gravel sand with water	3	113
	Clay and gravel	8	121
	Gravel	9	130
	(over)		

Turn up Sheet ____ of ____ sheets

CONTINUED ON NEXT PAGE

WELL CC01

WELL LOG.—Continued

No. Appl. 371

Correlation	Material	Thickness (feet)	Depth (feet)
	Depth forward	——	130
	Sand Coarse	29	159
	Hard pan with large rocks	4	163
	Cement gravel	7	170
	Cement gravel with large rocks	8	178
	Hard pan	17	195
	Brown clay with gravel	30	225
	Blue clay with gravel	18	243

Pump test:

Dim: 22" to 76'
10" to 243'

Swl: 25'

Dd: 25'

Casing: 24" from 0 to 30'
14" " 0 to 76'
10" " 57 to 185'
10" open hole from 185' to 243'

Perforations:

Mill knife perforations from 100' to 160'

Yield: 800 g.p.m.

EHH.

S.F. 7449-46 REMINGTON INC-20 20 745-2

File Original and First Copy with Department of Ecology
Second Copy — Owner's Copy
Third Copy — Driller's Copy

WATER WELL REPORT
STATE OF WASHINGTON

Application No. ....
Permit No. ....

(1) OWNER: Name CITY OF LACEY Address 6TH AVE SE - NISQUALLY

(2) LOCATION OF WELL: County THURSTON — W½ SW¼ Sec. 9 T. 18N N., R. 1E W.M.

Bearing and distance from section or subdivision corner

(3) PROPOSED USE: Domestic ☒ Industrial ☐ Municipal ☒ Irrigation ☐ Test Well ☐ Other ☐

(4) TYPE OF WORK: Owner's number of well (if more than one) 2 (19A)
New well ☐ Deepened ☒ Reconditioned ☐
Method: Dug ☐ Bored ☐ Cable ☐ Driven ☐ Rotary ☐ Jetted ☐

(5) DIMENSIONS: Diameter of well 6 inches.
Drilled 108 ft. Depth of completed well 107 ft.

(6) CONSTRUCTION DETAILS:
Casing installed: 6" Diam. from +1 ft. to 98 ft.
Threaded ☐ ...... " Diam. from ...... ft. to ...... ft.
Welded ☒ ...... " Diam. from ...... ft. to ...... ft.

Perforations: Yes ☐ No ☒
Type of perforator used ......
SIZE of perforations ...... in. by ...... in.
...... perforations from ...... ft. to ...... ft.
...... perforations from ...... ft. to ...... ft.
...... perforations from ...... ft. to ...... ft.

Screens: Yes ☒ No ☐
Manufacturer's Name JOHNSON
Type ...... Model No. ......
Diam. 6 Slot size 18 from 107 ft. to 98 ft.
Diam. ...... Slot size ...... from ...... ft. to ...... ft.

Gravel packed: Yes ☐ No ☒ Size of gravel: ......
Gravel placed from ...... ft. to ...... ft.

Surface seal: Yes ☐ No ☐ To what depth? ...... ft.
Material used in seal NO
Did any strata contain unusable water? Yes ☐ No ☐
Type of water? ...... Depth of strata ......
Method of sealing strata off ......

(7) PUMP: Manufacturer's Name BERKLEY
Type: SUB H.P. 7½

(8) WATER LEVELS: Land-surface elevation above mean sea level.... +20 ft.
Static level 13'-6 ft. below top of well Date 5/20
Artesian pressure ...... lbs. per square inch Date ......
Artesian water is controlled by ...... (Cap, valve, etc.)

(9) WELL TESTS: Drawdown is amount water level is lowered below static level
Was a pump test made? Yes ☒ No ☐ If yes, by whom? TIM
Yield: 110 gal./min. with 20'+ ft. drawdown after 4 hrs.

Recovery data (time taken as zero when pump turned off) (water level measured from well top to water level)

Time	Water Level	Time	Water Level	Time	Water Level
0	33'-7"				
30 sec	17-9"	— TOO FAST FOR GOOD			
60 sec	14-1"	MEASUREMENTS			

Date of test ......
Bailer test ...... gal./min. with ...... ft. drawdown after ...... hrs.
Artesian flow ...... g.p.m. Date ......
Temperature of water ...... Was a chemical analysis made? Yes ☒ No ☐

(10) WELL LOG:

Formation: Describe by color, character, size of material and structure, and show thickness of aquifers and the kind and nature of the material in each stratum penetrated, with at least one entry for each change of formation.

MATERIAL	FROM	TO
UNKNOWN	0	63
WB SAND-GRAVEL	63	68
SAND-GRAVEL-CLAY	68	88
CEMENTED SAND-GRAVEL	88	94
WB Sand	94	96
WB Sand-gravel	96	107
Purple Sand - WB	107	108

Work started 5, 1986 Completed 5, 1986

WELL DRILLER'S STATEMENT:

This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.

NAME TIMS WELL DRILLING (Person, firm, or corporation) (Type or print)
Address 6246 LIBBY RD NE
[Signed] [signature] (Well Driller)
License No. 0832 Date 5/29, 1986

(USE ADDITIONAL SHEETS IF NECESSARY)

ECY 050-1-20

Well #14C

File Original and First Copy with the Division of Water Resources
Second Copy — Owner's Copy
Third Copy — Driller's Copy

WATER WELL REPORT
STATE OF WASHINGTON

Application No. G2-20104
Permit No. G2-20104P

(1) OWNER: Name CITY OF LACEY — Address P.O. Drawer B, Lacey, Wn. 98503

(2) LOCATION OF WELL: County THURSTON — SW ¼ SW ¼ Sec. 9 T. 18 N., R. 1 E W.M.

Bearing and distance from section or subdivision corner N45°E, 300 FT FROM S.W. 1/16 COR

(3) PROPOSED USE: Domestic ☐ Industrial ☐ Municipal ☒ Irrigation ☐ Test Well ☐ Other ☐

(4) TYPE OF WORK: Owner's number of well (if more than one) ....

New well ■ Deepened ☐ Reconditioned ☐ — Method: Dug ☐ Cable ■ Rotary ☐ Bored ☐ Driven ☐ Jetted ☐

(5) DIMENSIONS: Diameter of well 10 inches. Drilled 79 ft. Depth of completed well 73 ft.

(6) CONSTRUCTION DETAILS:

Casing installed: 10 " Diam. from 0 ft. to 58 ft.
Threaded ☐ ____ " Diam. from ____ ft. to ____ ft.
Welded ■ ____ " Diam. from ____ ft. to ____ ft.

Perforations: Yes ☐ No ■
Type of perforator used ____
SIZE of perforations ____ in. by ____ in.
____ perforations from ____ ft. to ____ ft.
____ perforations from ____ ft. to ____ ft.
____ perforations from ____ ft. to ____ ft.

Screens: Yes ■ No ☐
Manufacturer's Name JOHNSON
Type ST. STEEL Telescope Model No. ____
Diam. 10" Slot size .100 from 58 ft. to 73 ft.
Diam. ____ Slot size ____ from ____ ft. to ____ ft.

Gravel packed: Yes ☐ No ■ Size of gravel: ____
Gravel placed from ____ ft. to ____ ft.

Surface seal: Yes ■ No ☐ To what depth? 30 ft.
Material used in seal CONCRETE
Did any strata contain unusable water? Yes ☐ No ■
Type of water? ____ Depth of strata ____
Method of sealing strata off ____

(7) PUMP: Manufacturer's Name ____
Type: ____ H.P. ____

(8) WATER LEVELS: Land-surface elevation above mean sea level .... 20 ft.
Static level 15 ft. below top of well Date 7-12-72
Artesian pressure ____ lbs. per square inch Date ____
Artesian water is controlled by ____ (Cap, valve, etc.)

(9) WELL TESTS: Drawdown is amount water level is lowered below static level
Was a pump test made? Yes ■ No ☐ If yes, by whom? DRILLER
Yield: 450 gal./min. with 11.5 ft. drawdown after 4 hrs.

Recovery data (time taken as zero when pump turned off) (water level measured from well top to water level)

Time	Water Level	Time	Water Level	Time	Water Level
1600	26.5				
1601	20.8				
1602	15.0				

Date of test 7-12-72
Bailer test ____ gal./min. with ____ ft. drawdown after ____ hrs.
Artesian flow ____ g.p.m. Date ____
Temperature of water ____ Was a chemical analysis made? Yes ■ No ☐

(10) WELL LOG:

Formation: Describe by color, character, size of material and structure, and show thickness of aquifers and the kind and nature of the material in each stratum penetrated, with at least one entry for each change of formation.

MATERIAL	FROM	TO
SAND, SOME SILTY CLAY BINDER	0	19
SAND & GRAVEL	19	32
SAND & GRAVEL (TIGHT)	32	43
SAND & GRAVEL, (CEMENTED IN CLAY TILL)	43	49
SAND & GRAVEL (TIGHT & DIRTY)	49	55
SAND & GRAVEL LOOSE (WATER DRIVE & BAIL)	55	58
SAND & GRAVEL (WATER DRIVE & BAIL)	58	73
SAND & GRAVEL (TIGHT VERY DIRTY NO WATER)	73	75
SAND & GRAVEL (CEMENTED)	75	79

RECEIVED
OCT 4 1973
DEPARTMENT OF ECOLOGY
SOUTHWEST REGIONAL OFFICE

Work started 6-29 1972 Completed 7-1 1972

WELL DRILLER'S STATEMENT:

This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.

NAME Stoner-Armstrong Drilling Inc. (Person, firm, or corporation) (Type or print)
Address 514½ River Road
[Signed] John E. Armstrong (Well Driller)
License No. ____ Date 9-10- 1972

OK/WHT 10-12-73

(USE ADDITIONAL SHEETS IF NECESSARY)

APPENDIX B

SELECTED DATABASE WELL INFORMATION

Summary of Data

SITEID NUMBER -	Fifteen digit unique well identification number assigned during data compilation and entry into computer database. When initially assigned, the number is generated by concatenating the latitude and longitude and adding a sequence number (i.e. 01, 02, ..., etc). Once assigned the number does not change even if the well location is changed.
LOCAL NUMBER -	Local well number represents the well's location based on the rectangular system for subdivision of public land, which indicates township, range, section and 40-acre tract within the section. For example, in the well number 18N/01W-24Q01, the part preceding the hyphen indicates successively the township and range (T. 18 N., R. 1 E.) north and east of the Willamette baseline and meridian. The first number following the hyphen indicates the section. In the example cited above, the well is in section 24. Each section is divided into 40-acre tracts and each of these is assigned a letter beginning within A in the northeast corner, and ending with R in the southeast corner. The 40-acre tracts are lettered serially in the same sequence used in the numbering of sections within a township. The letters "I" and "O" are omitted because of the likelihood of mistaking them for "one" or "zero". The last number "01" is a serial number of the well in the particular 40-acre tract.
ALTITUDE -	The altitude of the well in feet above mean sea level.
WELL DEPTH -	Depth of well below ground surface in feet.
W.L. DEPTH -	Depth of the static water level in feet below ground surface.
W.L. ELEV. -	Elevation of the static water level in feet above mean sea level.
W.L. DATE -	Date of the water level measurement in YYYYMMDD format.
W.L. SOURCE -	Source of water level data; U refers to USGS water level data file, D refers to water level reported on the drillers log. In some cases, the sources are the same.
COMP. GEOL. -	Indicates whether a computerized lithologic log exists within the database management system (i.e. .T.).
WELL DIA. -	Primary diameter of the well in inches.
TOP SCR DEPTH -	Depth to the top of the uppermost screen section in feet below ground surface.
BOT SCR DEPTH -	Depth to the bottom of the lowermost screen section in feet below ground surface.
OWNER NAME -	Name of well owner.

SITEID	LOCAL NO.	ALTITUDE	WELL DEPTH	W.L. DEPTH	W.L. ELEV.	W.L. DATE	W.L. SOU.	LOG?	WELL DIA.	TOP SCR DEPTH	BOT SCR DEPTH	WELL DISCHARGE	SPEC. CAP.	OWNER, WELL NO.
465938122424701	17N/01E-05D01	222.00	219.00	183.00	39.00	198308	D	.F.	6.00	215.00	219.00	1.50		SAARINEN
465945122424101	17N/01E-05D02	240.00	220.00	183.85	56.15	19900725	U	.F.	6.00	210.00	220.00	15.00		TROCHE MARIO
465939122425401	17N/01E-05D03	165.00	149.00	111.90	53.10	19880623	D	.F.	6.00	145.00	149.00	12.00		WARE JAMES
465928122425601	17N/01E-05E01	221.00	218.00	170.65	50.35	19900725	U	.T.	6.00			30.00		WALNER WARREN
465931122422901	17N/01E-05F01	245.00	180.00	146.63	98.37	19900724	U	.F.	6.00	176.00	180.00	20.00		LACEY FIRE DEPARTMENT
465904122425601	17N/01E-05N01	225.00	305.00	88.99	136.01	19880623	U	.T.	12.00	268.00	305.00	1020.00	8.79	
465940122430701	17N/01E-06A01	115.00	120.00	87.00	28.00	19870930	D	.T.	6.00	116.00	118.00	30.00		MCBURNEY ROBERT
465937122434501	17N/01E-06C01	100.00	52.00	41.70	58.30	19880518	U	.T.	6.00	47.00	52.00	42.00	16.80	
465917122430502	17N/01E-06J03D1	205.00	425.00	64.33	140.67	19900726	U	.T.	8.00	395.00	425.00	170.00		SUMMER SHORES WATER CO
465809122441301	17N/01E-06J04	175.00	75.00	52.12	122.88	19880516	U	.F.	6.00	70.00	75.00	30.00	5.00	TOBINSKI FRANK
465912122441101	17N/01E-06M02	210.00	172.00	85.06	124.94	19900725	U	.T.	6.00			19.00		METZ DOUGLAS
465844122431701	17N/01E-07A01	210.00	154.00	55.00	155.00	19880701	D	.F.	6.00	149.00	154.00	25.00	1.25	
465852122433101	17N/01E-07B04	215.00	42.00	29.00	186.00	19880623	D	.F.	6.00	37.00	42.00	8.00	1.78	
465849122433301	17N/01E-07B05	213.00	190.00	45.00	168.00	19870104	D	.F.	6.00	185.00	190.00	20.00		COOPER RICHARD
465845122434901	17N/01E-07C01	215.00	131.00	71.00	144.00	19781006	D	.F.	6.00	126.00	131.00	30.00		DUFF RICHARD
465844122435801	17N/01E-07D01	208.00	138.00	70.00	138.00	19790912	D	.F.	6.00	133.00	138.00	20.00		ANDERSEN JIM
465839122433901	17N/01E-07F01	208.00	104.00	30.60	177.40	19880628	U	.T.	6.00	100.00	104.00	30.00	3.00	
465835122431001	17N/01E-07H01	204.00	40.00	24.57	179.43	19880628	U	.T.	6.00	35.00	40.00			WALTERS VIC
465816122435401	17N/01E-07L01	215.00	72.00	30.00	185.00	19780115	D	.F.	6.00	68.00	72.00	30.00		TIMM MELVIN W
465806122435001	17N/01E-07P02	226.00	74.00	16.86	209.14	19880627	U	.F.	6.00	71.00	74.00	4.50	0.11	
465809122434401	17N/01E-07P03	267.00	260.00	10.14	256.86	19880627	U	.F.	6.00	250.00	260.00	60.00		CARSON LARRY
465804122433601	17N/01E-07Q02	210.00	35.00	12.68	197.32	19900724	U	.F.	6.00					PARSHALL STEVE
465802122432901	17N/01E-07Q03	211.00	35.00	7.48	203.52	19880629	U	.F.	6.00	31.00	35.00	8.50	1.06	
465819122423101	17N/01E-08L02	218.00	258.00	28.00	190.00	19700410	D	.F.	8.00	247.00	258.00	45.00	0.38	SCHOEPFER JACK
465735122430801	17N/01E-08L03	250.00	171.00	67.89	182.11	19880628	U	.T.	8.00	166.00	171.00	50.00		SCHOEPFER JACK
465943122443501	17N/01W-01B01	230.00	205.00	148.80	81.20	19880726	D	.F.	8.00	200.00	205.00	30.00	1.50	COLONIAL WATER SYSTEM
465944122444101	17N/01W-01B03	222.00	182.00	149.30	72.70	19880727	D	.F.	6.00					GRABHORN LYNN
465945122444701	17N/01W-01B04	222.00	191.00	143.01	78.99	19900726	U	.T.	6.00	187.00	191.00	30.00	1.36	
465926122451001	17N/01W-01F01	230.00	160.00	139.81	90.19	19900723	U	.T.	6.00			20.00		MACDONALD WILLIAM H
465927122444001	17N/01W-01G01	226.00	232.00	159.60	66.40	19880727	D	.T.	12.00	209.00	229.00	500.00	167.00	
465920122443801	17N/01W-01G02	215.00	212.00	140.60	74.40	19880727	U	.F.	12.00	187.00	212.00	500.00	27.80	
465926122442101	17N/01W-01H01	213.00	236.00	122.39	90.61	19880727	U	.T.	10.00	142.00	232.00	160.00	5.33	DNR, CENTRAL WELL
465927122442801	17N/01W-01H02	218.00	225.00	153.96	64.04	19880727	U	.T.	12.00	202.00	222.00	557.00	186.00	
465921122443001	17N/01W-01H03	214.00	220.00	126.50	87.50	19880727	U	.F.	12.00	190.00	220.00	46.00	1.35	
465912122442301	17N/01W-01J03	190.00	180.00	67.47	122.53	19880518	U	.F.	8.00	170.00	180.00	50.00	1.25	SUMMERSET WATER ASSOC.
465917122450301	17N/01W-01L01	210.00	157.00	87.69	122.31	19880802	U	.F.	6.00	152.00	157.00	20.00	0.32	SWENSON PHIL
465857122443701	17N/01W-01Q01	205.00	97.00	70.68	134.32	19880523	U	.F.	8.00			50.00	6.25	GLACIER VIEW MOBILE HOME PARK
465858122444701	17N/01W-01Q03	200.00	58.00	41.00	159.00	19900723	U	.F.	6.00			20.00		FRENCH DONALD
465858122443601	17N/01W-01Q04	205.00	108.00	71.00	134.00	19880523	D	.F.	8.00	98.00	108.00	60.00		GLACIER VIEW MOBILE HOME PARK
465915122442801	17N/01W-01R01	217.00	122.00	67.10	149.90	19900723	U	.F.	6.00			18.00		HIRCOCK JERRY
465943122453201	17N/01W-02A03	216.00	231.00	140.80	75.20	19880516	D	.T.	8.00	221.00	231.00	40.00		SO SOUND UTIL CO, WINWOOD WELL
465944122454401	17N/01W-02A04	202.00	166.00	140.80		19880516		.F.	6.00			75.00		PATTISON WATER CO.
465932122463801	17N/01W-02E03	178.00	49.00	25.30	152.70	19880801	D	.F.	6.00			20.00		DEEGAN W E
465925122463801	17N/01W-02E04	215.00	542.00	79.44	135.56	19900727	U	.T.	8.00	516.00	542.00	500.00	3.85	
465915122455801	17N/01W-02K01	222.00	146.00	85.00	137.00	197710	D	.F.	6.00			35.00		THOMAS STEVE
465919122462101	17N/01W-02L02	216.00	78.00	54.14	161.86	19900724	U	.F.	6.00			15.00		ZIMMERMAN BILL
465917122461401	17N/01W-02L03	211.00	67.00	32.00	179.00	19800709	D	.F.	6.00	57.00	62.00	25.00		ORR DAVID S
465901122460501	17N/01W-02Q03	210.00	154.00	33.00	177.00	19880419	D	.F.	12.00	119.00	154.00	500.00	8.45	
465853122455901	17N/01W-02Q04	208.00	79.00	31.01	176.99	19900724	U	.F.	6.00	74.00	79.00	50.00		BURKE, BRIAN
465903122453301	17N/01W-02R02	209.00	158.00	41.40	167.60	19880719	D	.T.	10.00	43.00	47.00	165.00		MAHURIN HOWARD
465935122465401	17N/01W-03A05	206.00	80.00	46.48	159.52	19900724	U	.T.	6.00			20.00		MONTOYA ERNIE
465933122475801	17N/01W-03D01	188.00	46.00	13.29	174.71	19900723	U	.T.	6.00	42.00	46.00	36.00		LWIN MYINT
465922122473601	17N/01W-03E01	197.00	68.00	32.00	165.00	194708	D	.F.	24.00	25.00	60.00	1000.00	28.57	
465919122475001	17N/01W-03E02	199.00	81.00	18.00	181.00	19670615	D	.F.	16.00	60.00	80.00	508.00	63.50	
465905122471301	17N/01W-03Q01	201.00	127.00	28.00	173.00	19550516	D	.F.	10.00	32.00	81.00	400.00	8.51	WARD, MERVIN
465933122490902	17N/01W-04E01	216.00	84.00	28.00		19550516		.F.	24.00	44.00	84.00	900.00		CITY OF LACEY
465933122491001	17N/01W-04E02	210.00	111.00	37.00	173.00	19730912	D	.F.	16.00			1500.00		CITY OF LACEY, WELL NO 4
465933122485002	17N/01W-04F01	214.00	72.00	25.00	189.00	19460419	D	.T.	24.00	32.00	72.00	600.00	24.00	

SITEID	LOCAL NO.	ALTITUDE	WELL DEPTH	W.L. DEPTH	W.L. ELEV.	W.L. DATE	W.L. SOU.	LOG?	WELL DIA.	TOP SCR DEPTH	BOT SCR DEPTH	WELL DISCHARGE	SPEC. CAP.	OWNER, WELL NO.
465932122483301	17N/01W-04G01	207.00	243.00	21.00	186.00	19480504	D	.T.	24.00	100.00	243.00	800.00	32.00	CAPITOL CITY GOLF CLUB
465919122485201	17N/01W-04L01	198.00	87.00	22.00	176.00	19571113	D	.F.	24.00	30.00	87.00	300.00	10.71	ROWE, W.R.
465927122492101	17N/01W-05H02	210.00	68.00	38.70	171.30	19900725	U	.T.	6.00	62.00	64.00	30.00		PUST WES
465939122511001	17N/01W-06B02	185.00	80.00	38.70		19900725		.T.	8.00	70.00	80.00	90.00		CITY OF OLYMPIA, SHANA PARK
465911122511101	17N/01W-06K05	190.00	81.00	31.68	158.32	19900725	U	.F.	6.00	79.00	81.00	12.00		SPAHR JIM
465821122510301	17N/01W-07G02	209.00	104.00	54.00	155.00	19880804	D	.F.	6.00			8.00		BAUER
465813122503701	17N/01W-07R03	210.00	120.00	47.06	162.94	19900725	U	.F.	6.00					CARLSON WILLIAM R
465845122494801	17N/01W-08B01	216.00	59.00	35.30	180.70	19900725	U	.F.	6.00			17.00		MCGRAW MIKE
465846122500901	17N/01W-08B02	211.00	54.00	29.00	182.00	19750326	D	.F.	8.00	49.00	54.00	40.00	36.40	
465846122501401	17N/01W-08C02	210.00	52.00	22.00	188.00	19870824	D	.F.	6.00			15.00		TOPPS LES
465846122503101	17N/01W-08D03	209.00	48.00	29.20	179.80	19900725	U	.F.	6.00	43.00	48.00			HOLCOMB & CEDERSTROHM
465842122502501	17N/01W-08D04	210.00	62.00	32.00	178.00	198204	D	.F.	6.00	59.00	62.00	15.00		HAMSIK RANDALL
465818122492701	17N/01W-08J01	220.00	84.00	36.00	184.00	19900726	U	.F.	6.00	79.00	82.00			REESE DAVE
465822122500901	17N/01W-08L02	200.00	85.00	32.00	168.00	19790612	D	.F.	6.00	82.00	85.00	7.00		HOLLADAY, JIM
465815122501801	17N/01W-08N01	210.00	90.00	40.87	169.13	19900725	U	.F.	6.00			8.00		NESBIT JERRY
465805122495901	17N/01W-08P03	215.00	94.00	45.49	169.51	19900725	U	.F.	6.00			10.00		BROWN, D.
465804122495301	17N/01W-08Q02	220.00	180.00	40.00	180.00	19750730	D	.F.	8.00	150.00	166.00	50.00		VANDERVORT JUDY
465842122483601	17N/01W-09B01	210.00	38.00	18.20	191.80	19880802	D	.F.	6.00			30.00		HARPER MIKE
465853122490701	17N/01W-09D01	190.00	41.00	9.00	181.00	19860809	D	.T.	6.00			20.00		LEWIS E M
465837122483201	17N/01W-09G02	216.00	55.00	18.95	197.05	19900726	U	.F.	6.00			16.00		IVERSON GARY
465840122483801	17N/01W-09G03	206.00	90.00	20.30	185.70	19880720	D	.T.	6.00			45.00		BUSCHE RON
465825122481001	17N/01W-09J02	200.00	100.00	15.00	185.00	19760628	D	.F.	6.00			20.00		JOHNSON BILL
465808122475201	17N/01W-10N02	236.00	78.00	38.88	197.12	19900724	U	.F.	6.00			20.00		SENN HARRY
465826122454301	17N/01W-11J01	218.00	34.00	10.97	207.03	19900724	U	.T.	6.00	29.00	34.00	15.00		OBERT WILLIAM
465822122460701	17N/01W-11K03	264.00	96.00	68.88	195.12	19900724	U	.T.	6.00			20.00		DENZLER GUS
465820122455001	17N/01W-11K04	217.00	28.00	9.33	207.67	19900724	U	.F.	6.00			35.00		DUSSAULT
465818122460601	17N/01W-11K05	224.00	301.00	32.95	191.05	19900727	U	.F.	12.00	291.00	301.00	200.00		
465826122463001	17N/01W-11M01	270.00	334.00	84.94	185.06	19900727	U	.F.	6.00			20.00		SUNWOOD LAKES, WELL NO. 3
465846122444001	17N/01W-12B02	232.00	146.00	60.80	171.20	19880520	D	.F.	12.00	60.00	146.00	264.00		LAWYER NURSERY, WELL NO. 2
465847122450301	17N/01W-12C01	214.00	92.00	38.30	175.70	19880520	U	.F.	16.00	70.00	90.00	530.00	13.25	
465847122452101	17N/01W-12D01	209.00	139.00	32.18	176.82	19900724	U	.F.	16.00	42.00	129.00	200.00		IND FORESTRY ASSOC, WELL NO. 3
465847122451101	17N/01W-12D02	206.00	174.00	29.00	177.00	19880520	D	.F.	16.00	55.00	125.00	350.00		LAWYER NURSERY, WELL NO. 4
465827122442601	17N/01W-12J02	270.00	186.00	76.83	193.17	19900725	U	.F.	6.00					PATTISON WATER CO.
465754122455701	17N/01W-14B01	270.00	85.00	64.18	205.82	19900724	U	.T.	6.00			30.00		BENLINE LORI
465751122465901	17N/01W-15A01	264.00	91.00	55.44	208.56	19900724	U	.F.	6.00			20.00		SIGMAN KIM
465752122491301	17N/01W-16D01	220.00	110.00	33.23	186.77	19900725	U	.T.	6.00			14.00		HALL LESLIE L
465757122490801	17N/01W-16D02	220.00	71.00	24.68	195.32	19900725	U	.F.	6.00	68.00	71.00	18.00	0.86	
465753122492101	17N/01W-17A01	215.00	78.00	25.30	189.70	19900725	U	.F.	6.00			8.00		KLEIN WALTER
465753122495301	17N/01W-17B03	215.00	39.00	28.00	187.00	19900725	U	.F.	6.00			30.00		VANSYCKLE RON
465801122505601	17N/01W-18B02	210.00	103.00	59.59	150.41	19900725	U	.F.	6.00	93.00	103.00	20.00	2.00	
465750122510501	17N/01W-18B03	200.00	300.00	52.67	147.33	19900725	U	.F.	6.00	290.00	300.00	20.00		ELWANGER, JOHN
470425122424101	18N/01E-05M01	10.00	900.00	52.67		19900725		.F.	12.00					U.S. FISH AND WILDLIFE SERVICE
470413122441101	18N/01E-06N01	230.00	253.00	185.00	45.00	19780518	U	.T.	8.00			40.00	3.33	PARKS HAROLD
470417122430101	18N/01E-06R01	18.00	250.00	0.00	18.00	19880622	U	.T.	12.00	191.00	226.00	2360.00		U.S. FISH AND WILDLIFE SERVICE
470344122440201	18N/01E-07A01	15.00	130.00	0.00	15.00	19880803	U	.F.	10.00	124.00	130.00	200.00	133.00	BALCOM BILL
470355122430201	18N/01E-07A02	10.00	120.00	1.00	9.00	19540401	D	.F.				500.00	166.67	ELWESS GENE
470356122441201	18N/01E-07D01	238.00	260.00	205.00	33.00	19760629	D	.F.	6.00			30.00		WEBB PAUL
470351122441101	18N/01E-07E01	230.00	223.00	204.00	26.00	1960	D	.F.	6.00					BUCK, VIRGINIA
470341122435001	18N/01E-07F01S	100.00		204.00		1960		.F.						NIS. TROUT FARM (G. STROKER)
470347122434801	18N/01E-07F02S	100.00		204.00		1960		.F.						NIS. TROUT FARM (G. STROKER)
470331122433801	18N/01E-07L01	15.00	100.00	0.00	15.00	19880622	U	.T.	12.00	80.00	100.00	300.00	3.75	
470358122425301	18N/01E-08D03	10.00	112.00	0.00		19880622		.F.	8.00	101.00	110.00	810.00	119.00	
470315122423901	18N/01E-17D02	15.00	110.00	0.00		19880622		.T.	2.00					LACHANCE TED
470313122431501	18N/01E-18A01	15.00	120.00	0.00		19880622		.F.	8.00	112.00	117.00	250.00		SCHOLS, HERMAN
470309122431301	18N/01E-18A02	10.00	123.00	2.17	7.83	19880715	U	.F.	12.00			271.00		SCHOLS HERMAN
470306122433301	18N/01E-18B01	15.00	84.00	2.17		19880715		.F.	6.00	72.00	80.00	50.00		
470259122432501	18N/01E-18G01	20.00	135.00	2.17		19880715		.F.	18.00					WASH DEPT OF FISHERIES
470251122425901	18N/01E-18H01	10.00	130.00	1.90	8.10	19880623	U	.T.	10.00	120.00	130.00			JESS THOMSEN INC

SITEID	LOCAL NO.	ALTITUDE	WELL DEPTH	W.L. DEPTH	W.L. ELEV.	W.L. DATE	W.L. SOU.	LOG?	WELL DIA.	TOP SCR DEPTH	BOT SCR DEPTH	WELL DISCHARGE	SPEC. CAP.	OWNER, WELL NO.
470231122434001	18N/01E-18P01S	15.00		1.90		19880623		.F.						UNKNOWN
470154122430001	18N/01E-19J01	70.00	68.00	60.44	9.56	19900725	U	.F.	6.00					LOFTIN , FRED
470149122430801	18N/01E-19J01S	7.00		60.44		19900725		.F.						
470149122430301	18N/01E-19J02	39.00	112.00	27.12	11.88	19881115	U	.F.	2.00	72.00	92.00			CITY OF OLYMPIA, ABBOTT TW
470140122432401	18N/01E-19Q01	60.00	134.00	60.99	-0.99	19900713	D	.F.	6.00	124.00	134.00	145.00		CITY OF OLYMPIA
470142122432001	18N/01E-19Q01S	5.00		60.99		19900713		.F.						
473916122423901	18N/01E-20M01	120.00	130.00	109.85	10.15	19880822	U	.F.	6.00					THOMPSEN JOHN
470119122434801	18N/01E-30C01	160.00	26.00	1.80	158.20	19880525	D	.F.	8.00	16.00	26.00	200.00	50.00	
470128122440801	18N/01E-30D02	160.00	153.00	114.52	45.48	19880525	U	.T.	8.00	143.00	153.00			THOMSEN HANS
470058122440701	18N/01E-30M01	175.00	170.00	124.40	50.60	19880510	D	.F.	6.00					NISQ HOG RANCH
470048122514701	18N/01E-30N01	212.00	194.00	154.50	57.50	19880510	U	.F.	8.00	183.00	194.00	290.00	74.40	SOUTH SOUND UTIL, HOLIDAY 1
470040122440301	18N/01E-30N02	212.00	190.00	155.07	56.93	19880510	U	.T.	8.00	181.00	190.00	91.00	91.00	
470047122434701	18N/01E-30P01	212.00	220.00	170.00	42.00	19751218	D	.T.	8.00	150.00	213.00	20.00		ADAMS VIRGIL
470036122431301	18N/01E-31A01	83.00	92.00	60.72	22.28	19880511	U	.T.	6.00			30.00		OBRIEN C F
470017122441201	18N/01E-31E02	221.00	167.00	60.72		19880511		.F.	6.00					LUBITZ JAMES
470018122434901	18N/01E-31F01	210.00	214.00	183.74	26.26	19880627	U	.T.	6.00	114.00	120.00	40.00	10.00	
470019122435901	18N/01E-31F02	216.00	213.00	164.57	51.43	19880512	U	.F.	6.00	208.00	213.00	25.00		AKEHURST CAROL
470016122432601	18N/01E-31G01	103.00	76.00	66.20	36.80	19580117	D	.F.	6.00					WILLIAMS , E V
470017122430601	18N/01E-31H01	108.00	101.00	70.33	37.67	19880511	U	.F.	6.00			40.00		PETERSON WILLIAM
470018122430701	18N/01E-31H02	111.00	119.00	75.48	35.52	19880630	U	.F.	6.00	109.00	119.00	25.00		ZURFLUHS
470023122430701	18N/01E-31H03	160.00	193.00	135.84	24.16	19880624	U	.T.	6.00	189.00	193.00	70.00	70.00	
470008122430401	18N/01E-31J01	94.00	80.00	54.97	39.03	19900725	U	.F.	6.00					CALVERT , R D
470006122434001	18N/01E-31M01	215.00	190.00	147.14	67.86	19880512	U	.F.	8.00	180.00	190.00	150.00	23.10	SOUTH SOUND UTIL, TRIPLE G 1
470000122441801	18N/01E-31M02	220.00	192.00	147.14		19880512		.T.	6.00	181.00	192.00	180.00	12.90	
465950122440201	18N/01E-31N01	212.00	139.00	84.00	128.00	19790130	D	.F.	6.00	134.00	139.00	45.00		ACTON GLEN
465947122434001	18N/01E-31P01	138.00	106.00	92.40	45.60	19880513	D	.F.	6.00					KAGY ROBERT
465957122431802	18N/01E-31Q01D1	156.00	373.00	117.11	38.89	19880513	U	.T.	6.00	368.00	373.00	25.00	0.58	
465957122430501	18N/01E-31R01	82.00	91.00	46.40	35.60	19880705	U	.F.	6.00			18.00		SEAUNIER PHIL
465957122430101	18N/01E-31R02	78.00	85.00	39.47	38.53	19880513	U	.T.	6.00			15.00		DOYLE RICHARD
470033122423701	18N/01E-32C02	160.00	128.00	115.20	44.80	19880627	U	.T.	6.00			20.00		FRANKLIN MICHAEL G
470028122424402	18N/01E-32D04D1	80.00	76.00	48.64	31.36	19900724	U	.F.	6.00			18.00		WELLS V
470023122424801	18N/01E-32D05	100.00	98.00	77.27	22.73	19880630	U	.F.	6.00			20.00		CUDNEY ROBERT
470023122425201	18N/01E-32E01	73.00	93.00	57.91	15.09	19880607	U	.F.	6.00	88.00	93.00	18.00		ROMPA WILLIAM
470020122424501	18N/01E-32E02	100.00	83.00	73.89	26.11	19880516	U	.F.	6.00			15.00		KRUEGER JEFF
470015122424701	18N/01E-32E03	97.00	98.00	69.70	27.30	19880516	U	.F.	6.00	92.00	95.00	30.00		MCKECHNIE DON
470012122424301	18N/01E-32E04	80.00	67.00	41.00	39.00	19750612	D	.F.	6.00	63.00	65.00	15.00		RUIZ, J. R.
470009122425001	18N/01E-32M01	121.00	112.00	88.85	32.15	19900725	U	.F.	6.00			15.00		ERNST
470020122421401	18N/01E-32N01	115.00	92.00	81.30	33.70	19880706	U	.T.	6.00	87.00	92.00	38.00	18.80	
465953122425001	18N/01E-32N02	76.00	81.00	42.69	33.31	19880628	U	.F.	6.00	76.00	81.00	15.00		HALL JACK
465950122424001	18N/01E-32N03	162.00	158.00	131.76	30.24	19880517	U	.F.	8.00	152.00	158.00	30.00	30.00	
465958122423701	18N/01E-32P02	70.00	81.00	44.52	25.48	19880706	U	.T.	6.00	78.00	81.00	24.00		PETERSON LEE
470442122441801	18N/01W-01H01	225.00	120.00	91.24	133.76	19880607	U	.T.	6.00			20.00		CHRISTOPHERSON CURTIS
470436122443201	18N/01W-01H02	225.00	255.00	222.00	3.00	19781028	D	.F.	10.00	250.00	255.00	50.00		SOUTH SOUND UTIL, WHITE FIRS
470412122442601	18N/01W-01R01	238.00	236.00	212.00	26.00	19730630	D	.F.	6.00	231.00	236.00	10.00	1.43	
470442122455201	18N/01W-02G01	235.00	131.00	93.00	142.00	19640529	D	.F.	8.00	105.00	131.00	46.00	3.83	OLYMPIA CHEESE CO.
470440122455201	18N/01W-02G02	237.00	241.00	176.00	61.00	19741005	D	.T.	8.00	231.00	241.00	30.00		OLYMPIA CHEESE CO
470436122453601	18N/01W-02H01	245.00	139.00	107.88	137.12	19880607	U	.F.	6.00			30.00		MCCARTHY, J. JR.
470438122454801	18N/01W-02H02	235.00	319.00	200.00	35.00	19770226	D	.F.	8.00	309.00	319.00	430.00	134.00	
470421122462401	18N/01W-02L01	235.00	212.00	168.97	66.03	19880607	U	.F.	8.00	206.00	212.00			BETTI BRUNO
470423122463201	18N/01W-02M01	240.00	218.00	148.00	92.00	19721019	D	.F.	8.00	212.00	218.00	38.00		BETTI BRUNO
470414122454701	18N/01W-02R01	220.00	256.00	165.95	54.05	19880607	U	.T.	12.00	231.00	256.00	300.00		TOM MARTIN CONSTRUCTION CO
470452122473001	18N/01W-03B01	234.00	204.00	155.94	78.06	19880823	U	.F.	6.00	200.00	204.00	20.00	0.82	
470458122471301	18N/01W-03B02	238.00	280.00	210.00	28.00	19790421	D	.F.	8.00	275.00	280.00	80.00	2.29	
470441122480101	18N/01W-03E01	95.00	67.00	37.89	57.11	19880608	U	.F.	6.00	60.00	63.00	35.00		POND RANDY
470439122470701	18N/01W-03G01	195.00	151.00	123.00	72.00	19840627	D	.F.	6.00	146.00	151.00	30.00	15.00	
470437122465301	18N/01W-03H02	205.00	233.00	145.95	59.05	19880608	U	.T.	12.00	224.00	233.00	200.00	3.57	
470429122491801	18N/01W-04M01	65.00	77.00	43.60	21.40	19880608	U	.F.	6.00	67.00	77.00	30.00		GALLAGER THOMAS
470428122490501	18N/01W-04M02	65.00	158.00	14.64	50.36	19880613	U	.T.	6.00	149.00	151.00	30.00		HALL DON

SITEID	LOCAL NO.	ALTITUDE	WELL DEPTH	W.L. DEPTH	W.L. ELEV.	W.L. DATE	W.L. SOU.	LOG?	WELL DIA.	TOP SCR DEPTH	BOT SCR DEPTH	WELL DISCHARGE	SPEC. CAP.	OWNER, WELL NO.
470412122491101	18N/01W-04N01	80.00	326.00	34.27	45.73	19880608	U	.T.	6.00			40.00		KELLEHER JOHN
470418122485401	18N/01W-04P01	50.00	75.00	3.24	46.76	19880714	U	.F.	6.00	70.00	75.00	20.00		MIDDAGH NANCY
470434122502701	18N/01W-05E02	165.00	50.00	30.72	134.28	19880613	U	.F.	6.00			20.00		ESTES ROBERT
470440122503001	18N/01W-05E03	165.00	46.00	31.55	133.45	19880615	U	.F.	6.00			22.00		LOVIEN MARK
470437122493701	18N/01W-05G01	90.00	75.00	44.82	45.18	19880714	U	.F.	6.00	69.00	75.00	15.00		JACKSON
470443122495301	18N/01W-05G02	110.00	56.00	23.41	86.59	19880620	U	.F.	6.00	51.00	56.00	40.00		SCOTT J W
470433122500601	18N/01W-05L02	160.00	40.00	25.74	134.26	19880713	U	.F.	6.00			15.00		RUGGIERO LEN
470428122500401	18N/01W-05L03	158.00	40.00	11.00	147.00	19860906	D	.F.	6.00	34.00	40.00	30.00		SCHMITKE LARRY
470433122500602	18N/01W-05L04	160.00		24.95	135.05	19900723	U	.F.						RUGGIERO LEN
470431122495601	18N/01W-05L05	136.00	153.00	50.00	86.00	19780804	D	.T.	6.00			30.00		BROWN GARY
470449122504701	18N/01W-06A03	160.00	118.00	51.05	108.95	19880614	U	.F.	6.00	113.00	118.00	30.00		SPURR MAHLON
470435122505501	18N/01W-06G02	160.00	50.00	28.75	131.25	19880613	U	.F.	6.00			20.00		FULTON FRANK
470435122505203	18N/01W-06H03D1	160.00	157.00	114.10	45.90	19880615	U	.F.	6.00			20.00		MILLS RAY
470412122510901	18N/01W-06Q04	160.00	65.00	35.51	124.49	19880616	U	.F.	6.00	60.00	65.00	20.00		MORRIS JUANITA
470410122503601	18N/01W-06R03	165.00	72.00	19.16	145.84	19880616	U	.F.	6.00			15.00		HANNA LAWRENCE J
470359122504801	18N/01W-07A06	175.00	67.00	25.00	150.00	19880616	U	.F.	6.00			10.00		COHN JACK
470342122503701	18N/01W-07H04	195.00	141.00	66.46	128.54	19880620	U	.T.	6.00	135.00	141.00	45.00		CROSLEY LARRY
470406122495601	18N/01W-08C02	150.00	140.00	45.80	104.20	19880714	D	.T.	6.00	136.00	140.00	20.00	0.29	
470343122502701	18N/01W-08E01	190.00	77.00	33.69	156.31	19880620	U	.T.	6.00			15.00		ROBINSON JOHN
470348122494801	18N/01W-08G02	150.00	67.00	9.80	140.20	19880622	U	.T.	6.00	62.00	67.00	40.00	2.67	
470353122492502	18N/01W-08H03	124.00	570.00	55.00	69.00	19880922	D	.T.	12.00	488.00	530.00	350.00	2.00	
470332122495701	18N/01W-08L01	202.00	97.00	41.88	160.12	19880713	U	.F.	8.00	92.00	97.00	30.00	30.00	CHRISTIANSON HARRY
470332122500501	18N/01W-08L03	202.00	100.00	50.00	152.00	19670710	D	.F.	8.00	90.00	100.00	35.00	1.52	
470332122500401	18N/01W-08L04	202.00	101.00	40.70	161.30	19880713	D	.F.	8.00					CHRISTIANSON HARRY
470406122490301	18N/01W-09D01	85.00	71.00	39.88	45.12	19880615	U	.F.	6.00	66.00	71.00	20.00		FISHER DON
470353122482901	18N/01W-09G01	82.00	345.00	15.51	66.49	19880720	U	.T.	8.00	341.00	345.00			PARKS HAROLD
470332122481601	18N/01W-09J01	105.00	195.00	36.76	68.24	19880622	U	.T.	6.00	185.00	195.00	30.00		SELNESS DARRELL
470336122481501	18N/01W-09K03	93.00	83.00	7.11	85.89	19880707	U	.F.	8.00	73.00	83.00	36.00		MECONI R F
470337122483801	18N/01W-09K04	92.00	88.00	6.90	85.10	19900723	U	.T.	8.00	79.00	88.00	71.00	1.97	
470337122483701	18N/01W-09K05	95.00		8.12	86.88	19900723	U	.F.						MECONI R F
470346122474501	18N/01W-10F01	150.00	195.00	70.70	79.30	19880714	D	.F.	8.00	155.00	195.00	150.00	1.72	OLYMPIA SAND & GRAVEL, WELL 1
470316122465401	18N/01W-10R02	208.00	171.00	136.00	72.00	19581020	D	.F.	8.00	161.00	171.00	140.00	35.00	
470324122465601	18N/01W-10R03	210.00	178.00	120.00	90.00	19510906	D	.T.	6.00	166.00	178.00	140.00	35.00	MOON J K
470357122451901	18N/01W-11A01	217.00	481.00	190.00	27.00	19700828	D	.T.	8.00	225.00	481.00	200.00		LAKESIDE INDUSTRIES INC
470338122453101	18N/01W-11J01	215.00	165.00	125.00	90.00	1938	D	.F.	6.00					WA DEPT NAT RESOURCES
470321122462101	18N/01W-11P05	205.00	73.00	36.36	168.64	19880623	U	.T.	6.00			10.00		MILLS GARY.
470355122452101	18N/01W-12C01	220.00	200.00	168.00	52.00	19890105	D	.F.	6.00					THURSTON CO. PUBLIC WORKS DEPT
470341122450801	18N/01W-12F01	225.00	380.00	187.00	38.00	19870828	D	.T.	12.00	291.00	380.00	375.00	5.03	
470332122441401	18N/01W-12J02	240.00	230.00	209.07	30.93	19880707	U	.F.	6.00			12.00		RICHARDSON PAUL
465833122443902	18N/01W-12L04	218.00	112.00	108.16	109.84	19880819	U	.F.	6.00			15.00		LANDRAM DREW
470332122452302	18N/01W-12M01D1	218.00	239.00	190.00	28.00	19641105	D	.F.	6.00	234.00	239.00	60.00		NORTH END MANOR & RENTALS
470320122442101	18N/01W-12R02	237.00	231.00	205.00	32.00	19780424	D	.T.	6.00			20.00		DUTERROW JAMES
470319122442701	18N/01W-12R03	235.00	145.00	54.11	180.89	19880623	U	.F.	6.00			25.00		SMITH SYLVIA
470312122442501	18N/01W-13A01	225.00	228.00	165.00	60.00	19800216	D	.F.	6.00			20.00		BONTEMPS JEFF
470314122443001	18N/01W-13A02	235.00	240.00	195.95	39.05	19900727	U	.F.	8.00			20.00		CITY OF LACEY, WELL MA 1
470313122443101	18N/01W-13A03	235.00	292.00	197.96	37.04	19900727	U	.F.	10.00			250.00		CITY OF LACEY, WELL MA 2
470308122443301	18N/01W-13B01	230.00	259.00	206.64	23.36	19880623	U	.F.	6.00			35.00		BROWN HAROLD
470301122445501	18N/01W-13C01	200.00	16.00	10.00	190.00	19580128	D	.F.	30.00					BOONE & BOONE PROP MANAGERS
470256122450301	18N/01W-13F01	200.00	16.00	8.20	191.80	19580306	D	.F.	48.00					OWEN , BOYD
470249122444901	18N/01W-13G02	210.00	259.00	176.01	33.99	19880623	U	.F.	8.00	248.00	259.00	126.00	1.87	
470253122450001	18N/01W-13G03	223.00	275.00	207.17	15.83	19880822	U	.F.	8.00	264.00	275.00	50.00	50.00	WASHINGTON LAND YACHT HARBOR
470247122442701	18N/01W-13J01D1	240.00	321.00	238.66	1.34	19880526	U	.F.	8.00	303.00	307.00	144.00	2.53	MEADOWS WATER CO, WELL 3
470447122442401	18N/01W-13J02	245.00	336.00	223.79	21.21	19880601	U	.F.	6.00	327.00	336.00	17.00	0.41	MEADOWS WATER CO, WELL 5
470246122443401	18N/01W-13J03	240.00	292.00	217.35	22.65	19880526	U	.F.	8.00	276.00	292.00	86.00	57.30	MEADOWS WATER CO, WELL 4
470248122441801	18N/01W-13J04	240.00	324.00	220.00	20.00	19890330	D	.F.	8.00	309.00	324.00	300.00	66.70	SO SOUND UTILITY, MEADOWS NO.6
470233122452401	18N/01W-13N01	265.00	284.00	236.96	28.04	19880627	U	.T.	8.00	274.00	284.00	72.00	72.00	
470311122462101	18N/01W-14D04	203.00	226.00	162.00	41.00	19620512	D	.F.	12.00	211.00	223.00	118.00	2.62	
470251122454701	18N/01W-14H02	235.00	64.00	46.27	188.73	19900723	U	.F.	8.00			35.00	3.50	OSTROM MUSHROOM FARM

SITEID	LOCAL NO.	ALTITUDE	WELL DEPTH	W.L. DEPTH	W.L. ELEV.	W.L. DATE	W.L. SOU.	LOG?	WELL DIA.	TOP SCR DEPTH	BOT SCR DEPTH	WELL DISCHARGE	SPEC. CAP.	OWNER, WELL NO.
470252122454401	18N/01W-14H04	232.00	260.00	199.00	33.00	19560112	D	.T.	8.00	240.00	260.00	210.00	210.00	OSTROM MUSHROOM FARM
470240122461101	18N/01W-14L02	218.00	52.00	37.00	181.00	19880706	U	.F.	6.00			40.00		HOPKINS BRAD
470224122454101	18N/01W-14R01	225.00	254.00	191.00	34.00	19690208	D	.T.	8.00	232.00	254.00	175.00	64.80	
470304122471801	18N/01W-15B04	180.00	149.00	108.00	72.00	19620630	D	.F.	6.00	139.00	149.00	30.00	1.88	MINELGA ANTANAS
470308122480001	18N/01W-15D01S	75.00		108.00		19620630		.F.						NIS. TROUT FARM (G. STROKER)
470259122465901	18N/01W-15H01	175.00	186.00	135.00	40.00	195707	D	.F.	12.00	167.00	177.00	100.00	10.00	
470304122482001	18N/01W-16A01S	75.00		135.00		195707		.F.	.					ST. MARTINS COLLEGE
470234122483001	18N/01W-16Q03	160.00	137.00	135.00		195707		.F.	8.00	122.00	137.00	75.00		REINHARDT HERMAN
470256122500601	18N/01W-17C01	199.00	187.00	85.00	114.00	19630326	D	.F.	8.00	177.00	187.00	250.00	8.33	
470256122500602	18N/01W-17C02	199.00	190.00	84.00	115.00	19670101	D	.F.	8.00	180.00	190.00	80.00	2.00	
470254122495501	18N/01W-17G02	200.00	62.00	18.00	182.00	19670429	D	.F.	6.00	55.00	62.00	25.00	0.83	
470259122492801	18N/01W-17H05	202.00	101.00	51.00	151.00	19660611	D	.T.	8.00	76.00	101.00	213.00	17.80	
470211122504501	18N/01W-19A01	195.00	92.00	21.00	174.00	19620902	D	.F.	6.00	88.00	92.00	25.00	1.25	
470204122511402	18N/01W-19F02	182.00	42.00	20.57	161.43	19900727	U	.F.	6.00			30.00	3.00	CRAIG, LAURA
470158122505801	18N/01W-19G02	202.00	60.00	42.35	159.65	19900727	U	.F.	6.00			30.00		WEISS, OSKAR
470205122514101	18N/01W-19H02	198.00	82.00	35.00	163.00	19880907	D	.F.	6.00	64.00	78.00	50.00	16.67	DETRAY, PAUL
470221122482401	18N/01W-21B04	175.00	120.00	64.00	111.00	19590427	D	.F.	10.00	98.00	120.00	575.00	47.92	
470214122482901	18N/01W-21B05	182.00	107.00	60.00	122.00	19541029	D	.F.	8.00	97.00	107.00	50.00	2.50	CITY OF LACEY FIRE DEPT
470216122481901	18N/01W-21B06	178.00	481.00	52.00	126.00	19760814	D	.T.	12.00	430.00	481.00	2000.00	24.41	
470212122491501	18N/01W-21D03	194.00	153.00	60.00	134.00	19530414	D	.F.	10.00	139.00	153.00	300.00		HUNTAMER, TOM
470216122480301	18N/01W-21H02	150.00	340.00	15.00	135.00	19770613	D	.F.	8.00	324.00	340.00	300.00	12.00	LACEY PARKS & REC DEPT
470137122485701	18N/01W-21P01	228.00	119.00	85.00	143.00	19591119	D	.T.	8.00	109.00	119.00	300.00	60.00	CITY OF LACEY, WELL 6B
470135122485802	18N/01W-21P02	235.00	385.00	94.00	141.00	19880825	D	.F.	16.00	190.00	340.00	630.00	11.10	CITY OF LACEY, WELL 6C
470145122471501	18N/01W-22K01	199.00	56.00	47.00	152.00	19640430	D	.F.	6.00	51.00	56.00	20.00		DOTSON
470208122455701	18N/01W-23B02	167.00	32.00	15.87	151.13	19880817	U	.F.	36.00	19.00	20.00	85.00	21.25	SMITH WESLEY M
470140122455001	18N/01W-23Q01	181.00	161.00	142.65	38.35	19880729	U	.T.	6.00			10.00		ERIKSON RICHARD L
470216122442501	18N/01W-24A02	213.00	797.00	162.38	50.62	19880526	U	.F.	8.00	781.00	796.00	200.00	3.12	MEADOWS WATER CO, WELL NO. 1
470216122442502	18N/01W-24A03	214.00	103.00	44.18	169.82	19880526	U	.T.	8.00	93.00	103.00	20.00	1.00	MEADOWS WATER CO, WELL NO. 2
470211122444501	18N/01W-24B01	222.00	85.00	50.00	172.00	19580115	D	.F.	8.00					EVERGREEN BALLROOM
470210122443801	18N/01W-24B02	242.00	103.00	53.44	188.56	19880728	U	.T.	6.00	98.00	103.00	25.00	1.14	
470219122452001	18N/01W-24D02	226.00	96.00	48.66	177.34	19880802	U	.F.	6.00			30.00		CONELY DONNA
470202122452001	18N/01W-24E01	230.00	82.00	48.66		19880802		.F.	5.00					TRAVIS, DAVID
470122122445201	18N/01W-25B01	260.00	239.00	216.00	44.00	19660714	D	.F.	10.00	229.00	239.00	150.00		SO SOUND UTIL, EVERGREEN EST
470051122450301	18N/01W-25P02	181.00	57.00	23.00	158.00	19880729	D	.T.	10.00	31.00	57.00	600.00		DRAPER T W
470121122453901	18N/01W-26A02	230.00	118.00	80.97	149.03	19880729	U	.T.	6.00			20.00		MAY ROBERT
470122122461601	18N/01W-26C02	189.00	65.00	38.93	150.07	19880802	U	.T.	6.00	60.00	65.00	20.00		EVERETT JOEL
470110122455701	18N/01W-26G01	187.00	73.00	38.72	148.28	19880817	U	.F.	6.00	68.00	73.00	50.00	50.00	LAKERIDGE WATER CO
470039122462801	18N/01W-26N01	182.00	85.00	34.00	148.00	19570311	D	.T.	8.00	75.00	85.00			HUNTAMER WATER SERVICE
470039122462901	18N/01W-26N02	185.00	386.00	103.00	82.00	19881213	D	.F.	8.00	321.00	337.00	195.00	1.17	
470120122470101	18N/01W-27A03	166.00	78.00	24.05	141.95	19880729	U	.T.	6.00	73.00	78.00	10.00		GLASS RAY
470104122472401	18N/01W-27K01	205.00	84.00	50.80	154.20	19881003	D	.F.	8.00	57.00	80.00	75.00	75.00	CITY OF LACEY, WELL NO. 5
470058122474901	18N/01W-27M02	190.00	386.00	43.30	146.70	19880824	U	.F.	8.00	378.00	386.00	38.00	1.06	
470102122491501	18N/01W-28E01	232.00	217.00	65.60	166.40	19880708	D	.F.	16.00	188.00	217.00	776.00	7.76	
470053122480601	18N/01W-28J01	185.00	127.00	26.93	158.07	19880817	U	.F.	6.00			30.00		HANSON BOB
470059122491501	18N/01W-28M01	232.00	227.00	99.70	132.30	19900727	U	.F.	16.00	197.00	227.00	350.00	3.72	
470103122491601	18N/01W-28M02	232.00	225.00	61.00	171.00	19691020	D	.F.	16.00			300.00		CITY OF LACEY, WELL NO 3
470050122485001	18N/01W-28P01	235.00	121.00	54.00	181.00	19531127	D	.T.	10.00	60.00	89.00	160.00	22.86	JACKSON E A
470112122503301	18N/01W-29E01	212.00	100.00	50.00	162.00	19670520	D	.F.	6.00			15.00		NICKERSON, CARL
470042122493201	18N/01W-29Q02	238.00	137.00	72.93	165.07	19880725	U	.T.	10.00	90.00	137.00	107.00		ROSS DEWEY
470422122504501	18N/01W-30A01	278.00	362.00	145.00	133.00	19840827	D	.F.	16.00	324.00	358.00			CITY OF OLYMPIA, WELL NO. 3
470031122504801	18N/01W-31A02	210.00	140.00	67.40	142.60	19880727	U	.T.	6.00			20.00		WARNER JOHN
470038122504101	18N/01W-31A03	209.00	139.00	64.89	144.11	19880805	U	.F.	8.00			18.00		DIXON BETTY
470018122510101	18N/01W-31G01	205.00	84.00	22.00	183.00	19720208	D	.F.	6.00	74.00	84.00	60.00		
470017122510201	18N/01W-31G02	204.00	102.00	38.50	165.50	19880907	D	.F.	6.00			60.00		JACOBSEN, HAROLD
470016122510101	18N/01W-31G03	205.00	80.00	25.00	180.00	19710401	D	.F.	6.00	70.00	80.00	50.00		JACOBSEN, HAROLD
470000122510301	18N/01W-31K03	212.00	64.00	31.78	180.22	19880805	U	.F.	6.00	59.00	64.00	8.00	0.80	
465956122504301	18N/01W-31R02	200.00	154.00	40.00	160.00	19750326	D	.F.	8.00	149.00	154.00			CITY OF OLYMPIA, WELL NO. 14
470034122502801	18N/01W-32D02	203.00	91.00	54.91	148.09	19880808	U	.T.	8.00	81.00	91.00	50.00		BENNETT JAMES

SITEID	LOCAL NO.	ALTITUDE	WELL DEPTH	W.L. DEPTH	W.L. ELEV.	W.L. DATE	W.L. SOU.	LOG?	WELL DIA.	TOP SCR DEPTH	BOT SCR DEPTH	WELL DISCHARGE	SPEC. CAP.	OWNER, WELL NO.
470002122501501	18N/01W-32L01	215.00	79.00	43.70	171.30	19880805	D	.F.	6.00			10.00	2.00	HUTSON , JERRY
465958122503101	18N/01W-32N02	212.00	98.00	41.27	170.73	19880805	U	.F.	6.00			20.00		SKAIFE LARRY
465951122500701	18N/01W-32P01	202.00	56.00	25.00	177.00	19580502	D	.F.	10.00	38.00	44.00	50.00		CITY OF OLYMPIA, WELL NO. 4
465951122500901	18N/01W-32P02	200.00	194.00	24.74	175.26	19900725	U	.F.	16.00	173.00	194.00	450.00	4.11	
465950122501001	18N/01W-32P03	200.00	88.00	29.00	171.00	19881213	D	.F.	16.00	38.00	88.00	970.00		OLYMPIA, SHANA PARK WELL 11
465952122500601	18N/01W-32P04	200.00	47.00	21.00	179.00	19750215	D	.F.	8.00	42.00	47.00	200.00		CITY OF OLYMPIA, WELL NO. 5
465952122500602	18N/01W-32P05	200.00	168.00	21.00		19750215		.F.	8.00	38.00	170.00	150.00		OLYMPIA, NO. 6/ABANDONED
470037122482301	18N/01W-33B01	212.00	118.00	40.00	172.00	19590402	D	.F.	8.00	97.00	118.00	115.00	3.48	
470036122485101	18N/01W-33C01	208.00	73.00	40.31	167.69	19880805	U	.T.	6.00	63.00	68.00	40.00	1.90	
470015122485301	18N/01W-33F01	208.00	62.00	34.00	174.00	19621017	D	.T.	6.00	50.00	60.00			PARKER REBECCA
470020122483601	18N/01W-33G02	212.00	102.00	33.00	179.00	19590430	D	.T.	8.00	85.00	102.00	120.00		JACKSON, ERVIN
465951122481901	18N/01W-33J02	201.00	61.00	32.65	168.35	19900723	U	.F.	8.00	61.00				ROSENTHAL, ROSS
465953122490501	18N/01W-33N01	197.00	283.00	22.00	175.00	19811019	D	.T.	16.00	223.00	283.00	1100.00	8.09	
465951122485201	18N/01W-33P01	198.00	208.00	33.35	164.65	19880708	U	.F.	16.00	178.00	208.00	1400.00	29.20	
470018122470801	18N/01W-34G01	175.00	59.00	19.29	155.71	19900723	U	.F.	8.00	49.00	59.00	150.00	5.00	
470020122471601	18N/01W-34G01S	165.00		19.29		19900723		.F.						UNKNOWN
470004122465101	18N/01W-34J01	172.00	55.00	20.30	151.70	19900723	U	.F.	6.00			15.00		GRONKA, WALTER
470032122465401	18N/01W-34J02	200.00	461.00	58.00	142.00	19650925	D	.F.	8.00	456.00	461.00	95.00	0.40	
470012122475101	18N/01W-34M03	202.00	80.00	45.12	156.88	19880804	U	.F.	8.00	75.00	80.00	40.00		COX WALT
465950122471701	18N/01W-34Q01	194.00	109.00	39.02	154.98	19880824	U	.F.	6.00	104.00	109.00	50.00		RUMAC FUND WATER ASSOC
470035122453302	18N/01W-35A04	161.00	32.00	10.42	150.58	19880802	U	.T.	6.00			10.00		STEFFENS JIM
470030122460601	18N/01W-35B02	176.00	82.00	25.78	150.22	19880818	U	.T.	8.00	77.00	82.00	120.00		SOUTH SHORE WATER CO
470014122454901	18N/01W-35G02	181.00	139.00	101.22	79.78	19880728	U	.F.	6.00			35.00		ROBERTS JAMES L
470011122461901	18N/01W-35L02	193.00	56.00	41.40	151.60	19900723	U	.F.	6.00			30.00		WARICK SKIP
465952122464201	18N/01W-35N01	185.00	76.00	36.00	149.00	19630102	D	.F.	6.00	71.00	76.00	23.00	4.60	BIENICH JOE
470026122450301	18N/01W-36C01	195.00	230.00	130.42	64.58	19880708	U	.T.	8.00	219.00	230.00	125.00	1.72	
470027122450301	18N/01W-36C02	195.00	336.00	126.87	68.13	19880708	U	.F.	8.00	317.00	336.00	150.00	0.87	
470013122451601	18N/01W-36E01	210.00	150.00	126.87		19880708		.F.	6.00					BAYNE , SID
470020122441801	18N/01W-36H02	221.00	188.00	166.48	54.52	19880802	U	.T.	6.00			30.00		SWANSON KENNETH
470006122442001	18N/01W-36J01	228.00	260.00	155.00	73.00	19790518	D	.F.	8.00	240.00	260.00	40.00		RICHARDSON WATER CO
470003122450301	18N/01W-36L01	222.00	163.00	154.38	67.62	19880728	U	.F.	8.00			37.00		CHAPMAN WILLIAM K
470004122450201	18N/01W-36L02	223.00	90.00	154.38		19880728		.F.	6.00					BAUGHN, EARL
470003122452301	18N/01W-36M02	225.00	160.00	149.29	75.71	19880802	U	.T.	6.00			900.00		TOWER & MCCULLOCK
465953122450101	18N/01W-36N01	218.00	217.00	149.14	68.86	19880817	U	.T.	10.00	150.00	180.00	200.00		PATTISON WATER COMPANY
465950122452801	18N/01W-36N02	210.00	217.00	149.14		19880817		.F.	10.00					PATTISON WATER CO
470618122440901	19N/01E-30E01	10.00	34.00	149.14		19880817		.F.	6.00					NATIONAL FISH AND OYSTER CO.
470557122424401	19N/01E-30P06	150.00	186.00	154.91	-4.91	19880713	U	.F.	6.00			10.00		CONNER ANN
470555122434301	19N/01E-30P07	150.00	60.00	7.25	142.75	19880708	U	.F.	6.00	55.00	60.00	40.00		JOHNSON ROBERT
470559122433501	19N/01E-30Q01	62.00	107.00	71.00	-9.00	19860420	D	.F.	6.00			15.00		KREIDER C D
470600122433501	19N/01E-30Q02	80.00	104.00	80.17	-0.17	19880708	U	.F.	6.00			15.00		IVEY CURTIS
470547122434401	19N/01E-31C03	200.00	238.00	80.17		19880708		.F.						RAMEZ MARIA
470549122434601	19N/01E-31C04	190.00	38.00	18.00	172.00	19850919	D	.F.	6.00			15.00		SMITH DICK
470545122434402	19N/01E-31C05	208.00		39.90	168.10	19880708	D	.F.	6.00					JOHANSEN NORVAL
470708122512301	19N/01W-19L02	70.00	98.00	25.00	45.00	198306	D	.F.	6.00	95.00	98.00	12.00		SEIBOLD BILL
470651122511301	19N/01W-19P03	120.00	105.00	68.32	51.68	19880914	U	.F.	6.00	100.00	105.00	20.00		LEDGERWOOD KELLY
470713122494001	19N/01W-20G01	115.00	158.00	113.00	2.00	19640601	D	.F.	6.00	149.00		110.00	2.75	GLEN ALDER CO
470714122492501	19N/01W-20H01	142.00	180.00	147.00	-5.00	19640108	D	.F.	8.00	151.00	175.00	50.00	50.00	HUSK RICHARD
470710122500601	19N/01W-20L01	15.00	377.00	0.00	15.00	19790612	U	.F.	6.00			150.00		SNUG HARBOR OWNERS CLUB
470645122495801	19N/01W-20Q01	95.00	116.00	96.00	-1.00	195403	D	.F.	6.00			25.00		WRIGHT J M
470654122493101	19N/01W-20R03	15.00	68.00	11.00	4.00	19580923	D	.F.	6.00					LONG R R
470708122482501	19N/01W-21K01	130.00	128.00	72.00	58.00	19750716	D	.F.	6.00	121.00	128.00	11.00		BRUNS DAVID W
470708122485501	19N/01W-21L02	115.00	78.00	26.19	88.81	19880728	U	.F.	6.00	73.00	78.00	20.00		WILMOUTH WILLIAM J
470704122485901	19N/01W-21M01	90.00	116.00	19.52	70.48	19880719	U	.F.	6.00	111.00	116.00	20.00		GREEN BILL
470704122490001	19N/01W-21M02	89.00	123.00	85.74	3.26	19880818	U	.F.	6.00	119.00	123.00	20.00		SMITH CHARLES
470646122490401	19N/01W-21N01	125.00	218.00	50.00	75.00	1960	D	.F.	6.00					FLAHAUT FLORENCE
470716122471001	19N/01W-22G01	120.00	128.00	92.00	28.00	19780306	D	.F.	6.00	124.00	128.00	20.00		JOACHIM JEFF
470712122461401	19N/01W-23F02	40.00	388.00	92.00		19780306		.F.	6.00					ASHLEY K R
470711122455401	19N/01W-23G02	84.00	108.00	60.00	24.00	19810929	D	.F.	6.00	97.00	108.00	20.00	1.83	

SITEID	LOCAL NO.	ALTITUDE	WELL DEPTH	W.L. DEPTH	W.L. ELEV.	W.L. DATE	W.L. SOU.	LOG?	WELL DIA.	TOP SCR DEPTH	BOT SCR DEPTH	WELL DISCHARGE	SPEC. CAP.	OWNER, WELL NO.
460649122464301	19N/01W-23N01	181.00	111.00	72.70	108.30	19880817	U	.F.	6.00	101.00	103.00	28.00	1.65	
470621122445801	19N/01W-25F01S	125.00		72.70		19880817		.F.						UNKNOWN
470604122445501	19N/01W-25P01	215.00	140.00	77.00	138.00	19760628	D	.F.	12.00			250.00		CITY OF LACEY, WELL BC 1
470603122445601	19N/01W-25P02	215.00	138.00	84.60	130.40	19880708	D	.F.	10.00			250.00		CITY OF LACEY, WELL BC 2
470641122465501	19N/01W-27A01	200.00	118.00	77.62	122.38	19880712	U	.F.	8.00	107.00	118.00	76.00	4.28	
470602122475301	19N/01W-27N01	225.00	259.00	0.00	225.00	1902	U	.F.	8.00	248.00	259.00	100.00		SOUTH SOUND UTIL, FOXHALL 3
470602122475302	19N/01W-27N02	225.00	148.00	96.04	128.96	19880617	U	.F.	8.00	135.00	148.00	114.00	4.22	
470634122480901	19N/01W-28A02	116.00	117.00	40.15	75.85	19880906	U	.F.	6.00	113.00	117.00	18.00		ALLEN ROGER
470635122484801	19N/01W-28C02	170.00	146.00	101.96	68.04	19880819	U	.F.	6.00	141.00	146.00	20.00		GILSON JOHN
470643122490001	19N/01W-28D04	150.00	250.00	110.00	40.00	19790105	D	.F.	6.00	218.00	228.00	10.00	0.12	
460724122485701	19N/01W-28F02	120.00	99.00	64.18	55.82	19880728	U	.F.	6.00	94.00	99.00	15.00		SAYLOR JOHN
470629122485601	19N/01W-28F04	140.00	110.00	72.60	67.40	19881027	D	.F.	6.00	105.00	110.00	10.00		LAUR, N.
460616122485301	19N/01W-28L02	72.00	78.00	31.17	40.83	19880728	U	.F.	6.00	73.00	78.00	30.00		KANEEN
470607122490001	19N/01W-28M01	65.00	84.00	12.00	53.00	19760716	D	.F.	6.00	69.00	84.00	35.00	1.89	
470614122491501	19N/01W-28M02	30.00	393.00	12.00		19760716		.F.	6.00					STILLMAN, CHARLES
470605122490601	19N/01W-28N02	60.00	112.00	12.00		19760716		.F.	6.00					SADLER RONALD
470639122493801	19N/01W-29A01	12.00	225.00	12.00		19760716		.F.	2.00					MAYNARD
470633122495901	19N/01W-29C02	145.00	152.00	137.17	7.83	19880906	U	.F.	8.00	144.00	152.00	20.00	20.00	
470553122503301	19N/01W-29N01	135.00	120.00	37.63	97.37	19880907	U	.F.	6.00	115.00	120.00	20.00		SPRINGER BILL
470629122503801	19N/01W-30H02	120.00	88.00	48.00	72.00	198311	D	.F.	6.00	84.00	88.00	18.00		VANNOY RANDY
470607122503601	19N/01W-30J01	115.00	74.00	35.00	80.00	19800226	D	.F.	6.00	70.00	74.00	25.00	0.78	
470615122440401	19N/01W-30M01	55.00	73.00	56.71	-1.71	9780508S	D	.F.	6.00					FOREMAN ZETTA M
470605122503801	19N/01W-30R02	115.00	67.00	23.38	91.62	19880908	U	.F.	6.00			150.00		GALIVAN HARRY
470552122510901	19N/01W-31B03	126.00	78.00	26.96	99.04	19880913	U	.F.	6.00	73.00	78.00	20.00		COLLINS MIKE
470537122511401	19N/01W-31F01	140.00	130.00	115.00	25.00	19880203	D	.F.	6.00			15.00		CARPENTER, DENNY
470520122510901	19N/01W-31K04	155.00	77.00	39.36	115.64	19880621	U	.F.	8.00	71.00	77.00	38.00	1.33	
470502122511201	19N/01W-31Q01	145.00	46.00	17.00	128.00	19840406	D	.F.	6.00	42.00	46.00	7.00		CRIST BRIAN
470508122504201	19N/01W-31R01	139.00	164.00	126.94	12.06	19880720	U	.F.	6.00			30.00		HAZEL JOHN
470544122494601	19N/01W-32B01	50.00	211.00	39.16	10.84	19880906	U	.F.	6.00	206.00	211.00	40.00		WESTON MIKE
470550122500701	19N/01W-32C04	145.00	94.00	46.00	99.00	19870326	D	.F.	8.00	90.00	94.00	50.00	2.17	
470546122503401	19N/01W-32D03	157.00	70.00	52.18	104.82	19880915	U	.F.	6.00	65.00	70.00	30.00		KIRKLAND KENNETH
470523122493701	19N/01W-32K03	100.00	38.00	16.04	83.96	19880908	U	.F.	6.00	33.00	38.00	20.00		SODDEN ED
470518122495301	19N/01W-32K04	128.00	62.00	54.86	73.14	19880711	U	.F.	6.00	57.00	62.00	15.00		HOCHGRAEF RON
470502122503001	19N/01W-32N03	157.00	70.00	52.22	104.78	19880831	U	.F.	6.00			18.00		ROSE CLYDE
470507122502201	19N/01W-32P03	142.00	75.00	50.08	91.92	19880913	U	.F.	6.00	69.00	75.00			TOPPER
470506122494201	19N/01W-32Q03	100.00		29.40	70.60	19880620	D	.F.	6.00					TABER RON
470504122493301	19N/01W-32R01	80.00	86.00	0.60	79.40	19881101	D	.F.	6.00			10.00		ROBB, STEVE
470545122491701	19N/01W-33D03	25.00	70.00				D	.F.						GRETCHMAN A G
470531122491901	19N/01W-33E01	5.00	150.00	161.00				.F.	3.00					LOHRER , E M
470521122482301	19N/01W-33K03	160.00	110.00	80.00	80.00	19880617	D	.F.	6.00					SOUTH SOUND UTILITY, FOXHALL 1
470522122482301	19N/01W-33K04	160.00	163.00	79.40	80.60	19880617	D	.F.	6.00	154.00	163.00	40.00		SOUTH SOUND UTILITY, FOXHALL 2
470514122482901	19N/01W-33K05	154.00	122.00	52.55	101.45	19880908	U	.F.	6.00	117.00	122.00	14.00	1.40	
470541122470401	19N/01W-34B01	298.00	174.00	157.40	140.60	19880720	D	.F.	8.00	164.00	174.00			DROHMAN, ROBERT
470513122475301	19N/01W-34M02	151.00	111.00	85.00	66.00	19880831	D	.F.	6.00					WILLIS, MIKE
470503122474701	19N/01W-34N03	151.00	112.00	77.90	73.10	19880906	D	.F.	6.00	106.00	112.00	10.00	0.36	
470501122473901	19N/01W-34P01	190.00	148.00	88.80	101.20	19880831	D	.F.	6.00			15.00		BEAIRD, PAT
470501122472101	19N/01W-34Q02	232.00	116.00	94.00	138.00	196807	D	.F.	6.00			17.00		KUHNAU, DAVE
470526122464401	19N/01W-35M01	290.00	653.00	259.00	31.00	19881215	D	.F.	16.00	585.00	642.00	860.00	6.02	
470758122573901	19N/02W-17G01	105.00	210.00	701.00	-596.00	9700601	D	.F.	6.00			20.00	10.00	CLARK KEITH