PHASE I - ASR FEASIBILITY REPORT

June 2001

CITY OF TIGARD

MONTGOMERY WATSON

Golder Associates

City Of Tigard

PHASE I - ASR FEASIBILITY STUDY

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TABLE OF CONTENTS

EXECUTIVE SUMMARY

SECTION 1 INTRODUCTION

SECTION 2 SOURCES OF SUPPLY

SECTION 3 HYDROGEOLOGICAL EVALUATION

SECTION 7 CONCLUSIONS AND RECOMMENDATIONS

REFERENCES

APPENDICES

LIST OF FIGURES

Executive Summary

EXECUTIVE SUMMARY

OVERVIEW OF FEASIBILITY STUDY

The City of Tigard (City) is pursuing the development of an aquifer storage and recovery (ASR) system using it's existing wells and source supplies. The City currently utilizes surface water from: 1) the Bull Run system via the City of Portland and Tualatin Valley Water District (TVWD), 2) Lake Oswego from the Clackamas River source, and 3) City of Beaverton Joint Water Commission source. In addition, Tigard has four wells. ASR involves the injection of surplus water from other sources during periods of low demand into the aquifer with recovery of the water during the high demand period. This report, the Feasibility Study, is Phase I of a three Phase approach to ASR. Phase II includes the Pilot Test and Phase III is the Full Scale Implementation. Phase I determines the feasibility of the potential for ASR and identifies a potential well to be used in Phase II – Pilot Testing. Phase II uses the Pilot Test to confirm aquifer performance, and to confirm the feasibility of full-scale implementation.

Study Objectives

The purpose of the ASR Feasibility Study is to evaluate the feasibility of developing an ASR system for Tigard. The Feasibility Study involves an assessment of the potential storage capacity in the aquifer, recharge and recovery rates for wells, and potential impacts on groundwater conditions and water quality in the storage aquifer. The overall purpose of the feasibility study is to identify whether there are any potential fatal flaws for ASR and to determine the optimum strategy for implementing pilot testing to further evaluate ASR. There are several elements of the Phase I ASR Feasibility Study including:

- How ASR fit's into the City's overall water supply and identifying source water
- Determining which City well is best suited for ASR pilot testing
- Characterizing the hydrogeology in the area of the test well
- Evaluating water quality compatibility with the groundwater and source waters; and
- Identifying permitting issues to ensure regulatory success

Evaluation of these elements will reveal any fatal flaws for the feasibility of ASR in the City of Tigard. If no fatal flaws are found, then the Feasibility Study serves as the foundation for the development of the Pilot Test Plan – Phase II. One of the critical elements of the Feasibility Study is to determine which of the City's existing wells can be used to conduct the pilot test. In addition, the Feasibility Study will estimate storage volumes, predicte how the water quality may vary within the aquifer during storage, evaluate the source water and effects of mixing with groundwater and identify any permitting issues to ensure regulatory success.

ASR Applications

The City wishes to utilize ASR for both short-term and long-term needs. In the short-term, the City's current water supplies from the above mentioned sources do not provide additional water above the current peak day demands (13 mgd). For long-term planning, the City must consider population growth and the renewal of contracts with the City of Portland by 2007. If feasible, the City would like to use ASR to fill the gap in short-term water demands and potentially provide a consistent water supply in the long-term. ASR is a means of lowering the City's costs for peak day and peak season supply. Use of ASR would allow the City to make better use of its existing wells and reduce the need to obtain peak season supply. It may also allow for a more consistent water quality throughout the year. Ideally, the City would like to complete the Pilot Study by the middle of 2002 and begin delivering water to its customers by the summer of 2002. Initial production would be approximately 1-1.5 mgd. Ultimately, the City would like to utilize ASR with a production of 4-6 mgd within 10 years.

Hydrogeological Assessment

Hydrogeological investigations completed during the Feasibility Study indicate the following:

- The storage capacity within the unconfined basalt (that has been dewatered over the last 50 years) beneath Bull Mountain is estimated to be about 4 billion gallons. This is more than sufficient to enable development of an ASR scheme that is capable of producing up to 6 mgd for periods of up to 8 months;
- Injection rates of about 1,000 gpm in individual wells are feasible;
- Withdrawal capacities for new ASR wells are expected to range between 400 and 800 gpm and approximate 600 gpm;
- In order to achieve a 1.5 mgd ASR scheme pumping for 4 months, 240 million gallons of water would need to be recharged to the aquifer. This volume accounts for a 25% leakage loss. Two wells each injecting at an average daily rate of 2.0 mgd (1,390 gpm) could recharge the aquifer over a 4 month period. This quantity could be recovered over a 4 month period by two wells each pumping an average rate of 520 gpm.
- A 6 mgd ASR scheme pumping for 8 months would require recharging of about 1.92 billion gallons of water over a four month period. Accounting for the possibility of 25% losses during the recharge and storage period, about 1.44 billion gallons would be available for recovery. To recharge 1.92 billion gallons over 4 months would require 10 ASR wells each recharging approximately 1,100 gpm. During recovery, each well would operate at an average pumping rate of 400 gpm. Higher recovery rates may be possible for shorter time periods;
- There is expected to be no adverse water quality impacts associated with injection of treated surface waters into the basalt;

- Potential impacts associated with the development of an ASR scheme are likely to include a water level rise in other basalt wells on Bull Mountain. Other potential impacts may include an increase in spring discharge on the slopes of Bull Mountain.
- The effects of large-scale water level changes (increases and decreases) on individual well performance require additional monitoring of water levels.

Uncertainties

Assessment of ASR potential is subject to some uncertainty because of the limited data available for the Feasibility Study. At this time, the hydraulic behavior of the aquifer boundaries are unknown and require further study to determine how they will affect storage quantities and recovery efficiency of the stored water. Resolution of the uncertainty with regard to the aquifer conditions is recommended to confirm storage volumes, injection and recovery rates, groundwater level changes and effects on springs and streams.

Pilot Testing

The evaluation of the City's four wells indicate that Well No. 1 is best suited for ASR testing based on the hydrogeologic properties of the well and the location of nearby monitoring wells. However, geophysical logging of the well revealed a poor casing, thus requiring repairs for further production of groundwater or ASR development. Repairs to the well or a new well will be needed for the Pilot test in the fall of 2001. A schedule for the Pilot test is shown in Figure ES-1.

Cost Estimate for Pilot Phase II

Based on findings from the Feasibility Study, estimated costs were prepared for the Pilot Phase. Costs include the conversion of Well No. 1 to a monitoring well, drilling of a new well on the same site and associated piping, equipment and housing costs. These costs are estimated costs for planning purposes only and are based on previous ASR projects. Table ES-1 lists the costs included in Phase II – Pilot Test.

The following assumptions were made in developing the Phase II costs:

- A new well can be drilled on the Well No. 1 site and Well No. 1 can be converted to a monitoring well.
- The transmission line from the new well will be connected to the existing piping in the reservoir yard.
- The distance from the wellhead to the transmission line is 100 feet.
- The pump was sized for ASR injection and withdrawal rates at 1000 gpm
- No additional water treatment will be necessary beyond the chlorination system currently in place.

TABLE ES-1 PHASE II PLANING LEVEL COST ESTIMATE

Description	Costs
PERMITTING AND WATER RIGHTS*	**$ 19,500**
WELLHEAD MODIFICATIONS	
Conversion of Well No. 1 to monitoring well	**$ 18,000**
New Well Construction Costs	
Drill new well on Well No. 1 site (12 in.) 600 ft.	$ 80,000
Pump and installation (1000 gpm Vertical Turbine w/non-reverse ratchet)	$ 55,000
Pump House	$ 45,000
Electrical	$ 20,000
Infrastructure	
Flowmeter	$ 4,000
PRV/check valve	$ 3,300
Back Pressure valve	$ 2,600
Pump Control Valve	$ 3,000
Valves/Fittings	$ 8,000
SCADA	$ 8,000
Dip Tube	$ 500
Pressure Transducer	$ 3,000
Transfer existing chlorination system	$ 800
Subtotal	**$ 233,200**
Professional Services	
Hydrogeological oversite - includes pump test analysis	$ 20,000
Engineering Services	$ 42,000
Water quality testing	$ 3,000
Subtotal	**$ 65,000**
Contingency (20%)	**$ 63,240**
Subtotal	**$ 407,940**
ASR PILOT TEST	**$ 97,000**
GROUNDWATER MODEL & WELLHEAD MODIFICATIONS (If necessary)	**$ 50,000**
PILOT TEST REPORT	**$ 34,000**
TOTAL	***$ 579,940***

*$28,500 total costs for permitting. $9000 authorized in contingency from Phase I.

Full-Scale Implementation

To enable the development of a 6 mgd scheme capable of being used for up to 8 months, up to 10 wells would be required. Based on the City's desire to achieve full-scale production within 10 years an incremental approach is recommended. Specifically, the pilot test well would be converted to a full-scale ASR well followed by an additional well at that site. Subsequently, two wells could be drilled every 2-3 years until the system is fully developed. Assuming the ASR permit is obtained without delay, the first stage of the full-scale scheme could begin in the early part of 2003. Approximately two wells every two years would need to be developed. Figure ES-2 shows the recommended schedule for full-scale implementation. This approach is recommended for several reasons. First, the boundaries of the aquifer are uncertain at this time. Development of each well will help determine these boundaries with little risk to the City. Secondly, the flow characteristics of the aquifer can differ within short distances, thus producing different yields. An incremental approach allows the City to utilize ASR to their specific needs at that particular time. Should the City's contracts with the City of Portland change drastically, the City may decide to limit the need for ASR production. Finally, this approach will allow the City to implement the project without a large upfront investment.

ASR Well Locations and System Phasing

As indicated above, 10 ASR wells will be required to meet the overall performance objectives of ASR. These wells should be developed across the service area such that each well site is limited to a maximum of two ASR wells, unless indicated otherwise via pilot testing. Widespread spacing of ASR wells will reduce interference effects and will minimize the risk to the system in the event of potential groundwater contamination. Figure ES-3 shows the potential and possible ASR wells sites. We have identified sites that are located in close proximity to the City's existing distribution system and where possible are on City-owned property, or on property that is owned by other public agencies amenable to well siting. The number of sites listed provides for some redundancy in the event that the preferred sites are unavailable. Potential sites are those that have the greatest likelihood of success for ASR. Possible ASR sites may have reduced well yields and/or storage volumes may be lower because of less favorable hydrogeological conditions.

Cost Estimate for Full Scale System

Cost estimates for Full Scale ASR development and implementation are listed in Table ES-2. The costs are presented in increments with 5 stages to complete the ultimate 4-6 mgd ASR scheme. Cost estimates for full-scale implementation were calculated based on the following assumptions:

- Ultimate ASR production is 4-6 mgd – a total of 10 wells.
- The full scale system will involve the new well used for the pilot test, modifications to existing well 2, and eight new ASR wells;
- Purchase of land and extended pipeline cost beyond minimal distance from the existing distribution system is not included.
- Costs are based on 2001 numbers.

TABLE ES-2 PHASE III COST ESTIMATE

Description	Costs
PERMITTING	**$ 17,000**
STAGE 1 - DEVELOP SECOND WELL AT WELL NO. 1 SITE	
NEW WELL CONSTRUCTION COSTS (PER WELL)	
Drill new well (12 in.)	$ 80,000
Pump and installation (1000 gpm Vertical Turbine w/reverse ratchet)	$ 55,000
Pump House	$ 45,000
Electrical	$ 20,000
Infrastructure	
Flowmeter	$ 4,000
PRV/check valve	$ 3,300
Back Pressure valve	$ 2,600
Pump Control Valve	$ 3,000
Valves/Fittings	$ 8,000
SCADA	$ 8,000
Dip Tube	$ 500
Pressure Transducer	$ 3,000
Chlorination system	$ 3,500
Subtotal	**$ 235,900**
Professional Services	
Hydrogeological oversite - includes pump test analysis	$ 15,000
Water quality testing	$ 3,000
Engineering Services	$ 35,500
Subtotal	**$ 53,500**
Contingency (20%)	**$ 57,900**
TOTAL	**$ 347,300**
IMPLEMENTATION, OPERATION AND MONITORING	**$ 6,400**
STAGE 1 TOTAL	***$ 370,700***
STAGE 2 - DEVELOP SECOND WELL AT WELL NO. 2	
MODIFICATIONS TO WELL NO. 2	**$ 50,000**
NEW WELL CONSTRUCTION COSTS	**$ 347,300**
IMPLEMENTATION, OPERATION AND MONITORING	**$ 6,400**
STAGE 2 TOTAL	***$ 403,700***
STAGE 3 - DEVELOP TWO WELLS	
NEW WELL CONSTRUCTION COSTS ($347,300 PER WELL)	**$ 694,600**
IMPLEMENTATION, OPERATION AND MONITORING	**$ 6,400**
STAGE 3 TOTAL	***$ 701,000***
STAGE 4 - DEVELOP TWO WELLS	
NEW WELL CONSTRUCTION COSTS ($347,300 PER WELL)	**$ 694,600**
IMPLEMENTATION, OPERATION AND MONITORING	**$ 6,400**
STAGE 4 TOTAL	***$ 701,000***
STAGE 5 - DEVELOP TWO WELLS	
NEW WELL CONSTRUCTION COSTS ($347,300 PER WELL)	**$ 694,600**
IMPLEMENTATION, OPERATION AND MONITORING	**$ 6,400**
STAGE 5 TOTAL	***$ 701,000***
GRAND TOTAL	**$ 2,877,400**

Based on 2001 rates and other reasonable assumptions, the cost to purchase water for and operate ASR is approximately 45% less than costs to purchase water during peak season. Table ES-3 shows the cost comparison.

TABLE ES-3 FULL-SCALE COST COMPARISON

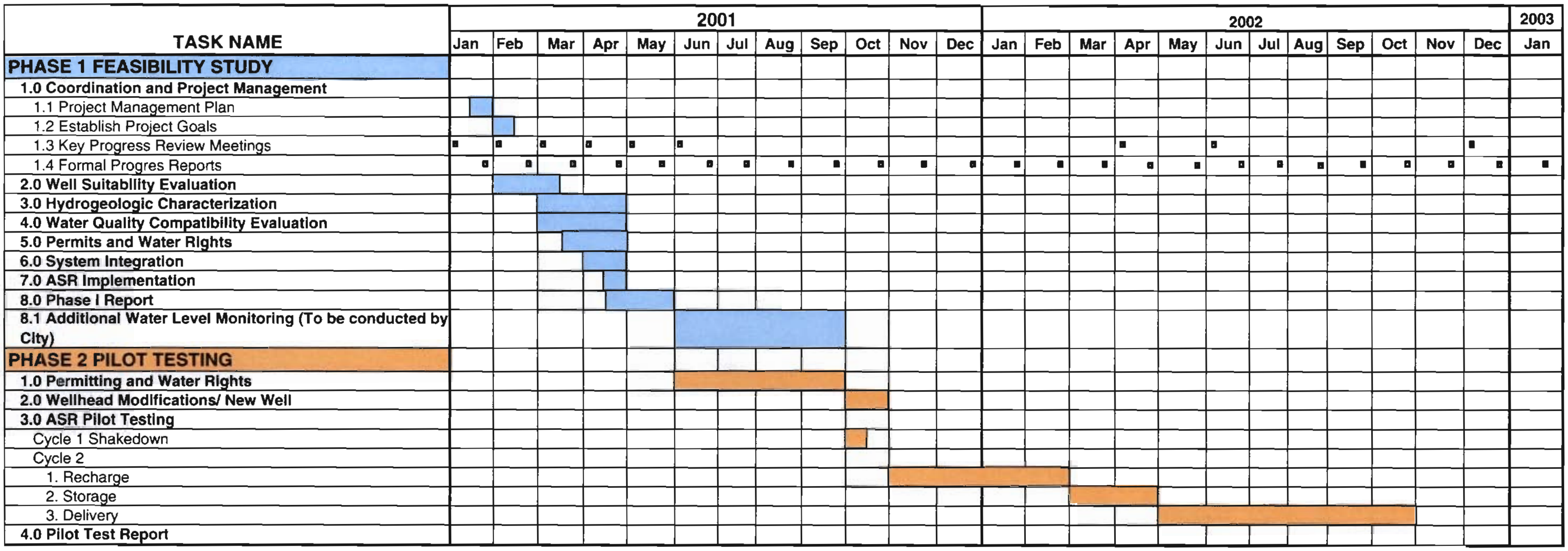
Costs to Purchase Water	
Peak Season Water Purchase Rate (per ccf)	$ 0.91
Demand (gpd)	6,000,000
Duration (days)	120
Total Costs	***$ 875,936***
ASR Costs	
ASR Injection	
OffSeason Water Purchase Rate (per ccf)	$ 0.30
Pump Costs (per ccf)	$ -
Storage Needed to Achieve 6 mgd Recovery	8,000,000
(Assumes 25% water loss) - gpd	
Duration (days)	120
Subtotal	***$ 385,027***
ASR Recovery	
Peak Season Purchase Rate (per ccf)	$ -
Pump Costs (per ccf)	$ 0.10
Demand (gpd)	6,000,000
Duration (days)	120
Subtotal	***$ 96,257***
Total Costs	***$ 481,283***
Annual Savings	***$ 394,652***
Cost Difference	45%

RECOMMENDATIONS

- At this stage it appears feasible to develop an ASR scheme using the Bull Mountain basalt, as such the City should proceed with the development and implementation of a pilot test plan;
- In view of the poor condition of Well No. 1 casing, a new production well should be constructed at the Canterbury Lane site that is capable of being used for the ASR Pilot test. The existing well should be converted to a multi-level monitoring well for pilot testing.
- Before Wells No. 1 and 2 are used this summer, the well-heads should be modified to enable a water level meter to be used to monitor the water levels in the two wells;

- In the period prior to the use of the wells, water levels in all of the City's wells should be monitored on a weekly basis;
- Arrangements to access the Tigard High School and James Templeton Elementary School wells for monitoring purposes should be put into place prior to the use of the wells;
- Consultant should be notified prior to the use of the wells so that consultant staff can be in attendance at the start up of the pumps to record (valuable) early time test data;
- During the subsequent period that the wells are used, water level measurements should be taken in both the City's wells and adjacent observation wells and the production totals should be noted. As far as possible, measurements should be taken daily throughout the summer;
- Once additional monitoring is complete, the City should confirm how ASR fits in its water supply strategy and identify its role in both short-term and long-term planning. At that time, the City should proceed with the level of ASR that is commensurate with its needs.
- Development and implementation of the full-scale scheme should occur incrementally over a 10 year period to allow better understanding of the aquifer performance and allow the City to develop the project with little risk.

FIGURE ES-1
ASR Pilot Project Schedule



TASK NAME	2001												2002												2003
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan
PHASE 1 FEASIBILITY STUDY																									
1.0 Coordination and Project Management																									
1.1 Project Management Plan	🟦																								
1.2 Establish Project Goals		🟦																							
1.3 Key Progress Review Meetings	■	■	■	■	■	■										■		■						■	
1.4 Formal Progres Reports	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
2.0 Well Suitability Evaluation		🟦	🟦																						
3.0 Hydrogeologic Characterization			🟦	🟦																					
4.0 Water Quality Compatibility Evaluation			🟦	🟦																					
5.0 Permits and Water Rights			🟦	🟦																					
6.0 System Integration				🟦																					
7.0 ASR Implementation				🟦																					
8.0 Phase I Report				🟦	🟦																				
8.1 Additional Water Level Monitoring (To be conducted by City)						🟦	🟦	🟦	🟦																
PHASE 2 PILOT TESTING																									
1.0 Permitting and Water Rights						🟧	🟧	🟧	🟧																
2.0 Wellhead Modifications/ New Well										🟧															
3.0 ASR Pilot Testing																									
Cycle 1 Shakedown										🟧															
Cycle 2																									
1. Recharge											🟧	🟧	🟧	🟧											
2. Storage															🟧	🟧									
3. Delivery																	🟧	🟧	🟧	🟧	🟧	🟧			
4.0 Pilot Test Report																									

FIGURE ES-2
Proposed ASR Development Schedule

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
TASK NAME													
PHASE II- PILOT TEST													
ESTIMATED COSTS	$ 579,940												
PHASE 3 FULL SCALE ASR IMPLEMENTATION													
PERMITTING													
STAGE 1 - Convert Pilot Well to ASR Well and develop second ASR well on Canterbury site			1-1.5 mgd										
ESTIMATED CIP COSTS			$ 370,000										
ESTIMATED COSTS TO PURCHASE WATER FOR ASR (1.5 mgd)			$ 120,321										
STAGE 2 - Modify Existing Well No. 2 and develop second ASR well at site					1.5-2.5 mgd								
ESTIAMTED COSTS					$ 404,000								
ESTIMATED COSTS TO PURCHASE WATER FOR ASR (2.5 mgd)					$ 200,535								
STAGE 3 - Install two wells at appropriate site							2.5-4 mgd						
ESTIMATED COSTS							$ 701,000						
ESTIMATED COSTS TO PURCHASE WATER FOR ASR (4 mgd)							$ 320,856						
STAGE 4 - Install two wells at appropriate site									4-5 mgd				
ESTIMATED COSTS									$ 701,000				
ESTIMATED COSTS TO PURCHASE WATER FOR ASR (5 mgd)									$ 401,070				
STAGE 5 - Install two wells at appropriate site											5-6 mgd		
ESTIMATED COSTS											$ 701,000		
ESTIMATED COSTS TO PURCHASE WATER FOR ASR (6 mgd)											$ 481,283		

All costs are based on 2001 numbers. Costs to purchase water are based on 0.91/cfs from JWC

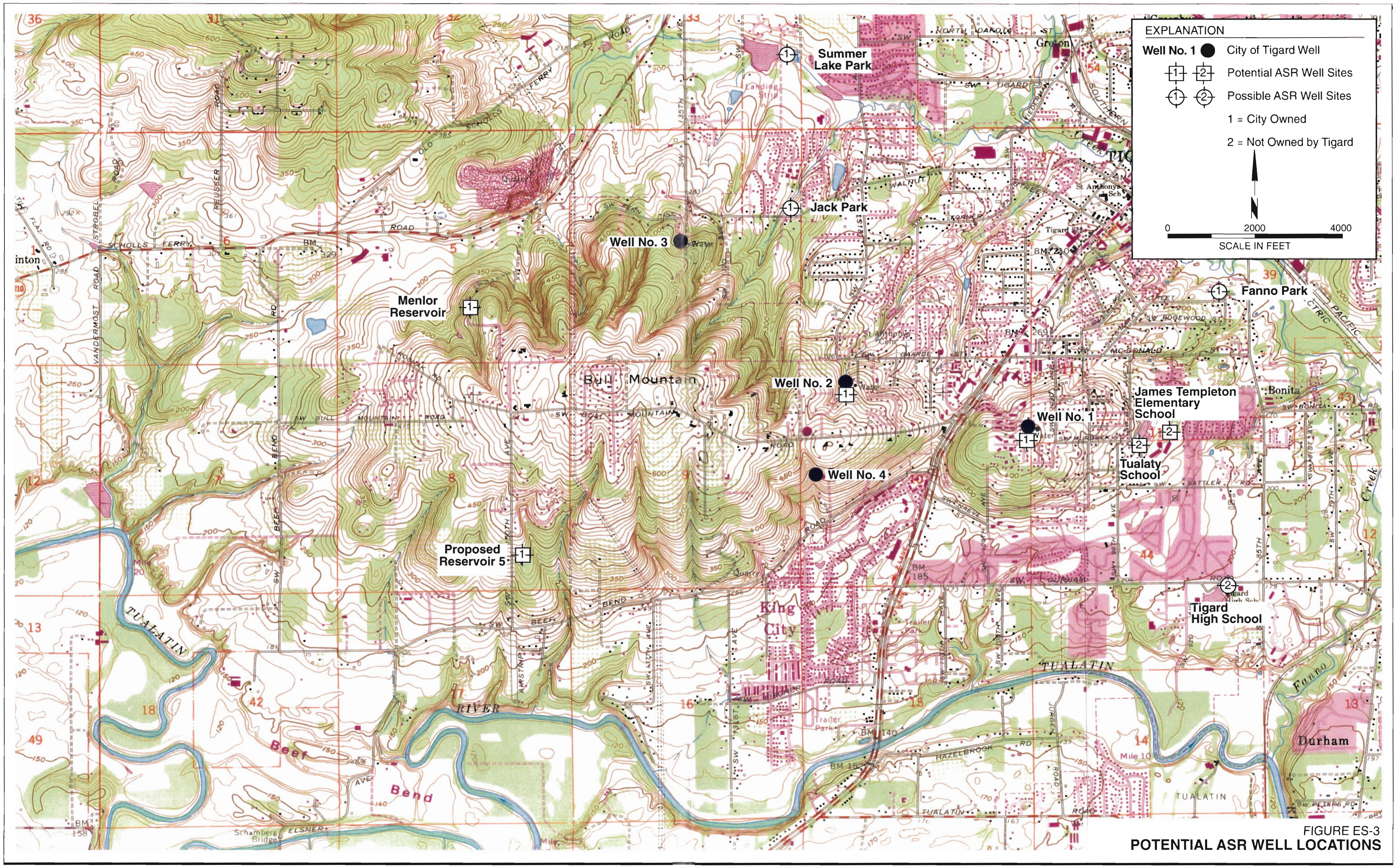


FIGURE ES-3
POTENTIAL ASR WELL LOCATIONS

PROJECT NO 013 1419 008 DRAWING NO 94657 DATE 05/24/01 DRAWN BY JSR

Golder Associates

Section 1

SECTION 1 INTRODUCTION

The City of Tigard (City) is pursuing the development of an aquifer storage and recovery (ASR) system using it's existing wells and source supplies. The City currently utilizes surface water from: 1) the City of Portland Bull Run system, 2) Lake Oswego from the Clackamas River source, and 3) City of Beaverton Joint Water Commission source. In addition, Tigard has four wells. ASR involves the injection of surplus water from other sources during periods of low demand into the aquifer with recovery of the water during the high demand period. This report, the Feasibility Study, is Phase I of a three Phase approach to ASR. Phase II includes the Pilot Test and Phase III is the Full Scale Implementation. Phase I determines the feasibility of the potential for ASR and identifies a well to be used in Phase II – Pilot Testing. Phase II uses the Pilot Test to confirm groundwater quality and availability, and to provide hydrogeologic parameters for the full-scale implementation.

STUDY OBJECTIVES

The purpose of the ASR Feasibility Study is to evaluate and demonstrate the feasibility of ASR using the City's existing wells and current source supplies. There are several elements of the Phase I ASR Feasibility Study:

- Determine how ASR fit's into the City's overall water supply and identifying source water
- Evaluate the City's wells to determine which well is best suited for ASR Pilot testing
- Characterize the hydrogeology in the area of the test well and estimate the quantity of water that could be stored and potential impacts on the groundwater system
- Evaluate water quality compatibility with the groundwater and source waters
- Identify permitting issues to ensure regulatory success

Evaluation of these elements will reveal any fatal flaws for the feasibility of ASR in the City of Tigard. If no fatal flaws are found, then the Feasibility Study serves as the foundation for the development of the Pilot Test Plan – Phase II. One of the critical elements of the Feasibility Study is to determine which of the City's existing wells can be used to conduct the pilot test. In addition, the Feasibility Study will predict how the water quality may vary within the aquifer, evaluate the source water and effects of mixing with groundwater and identify any permitting issues to ensure regulatory success.

PREVIOUS STUDIES

The hydrogeology of the Cooper-Bull Mountain basalt aquifers has previously been examined in connection with the following:

- Delineation and establishment of the Cooper-Bull Mountain critical groundwater area (Beach and Bartholomew, 1973), and;

- Assessment of the feasibility of using the Cooper Mountain basalt aquifers for ASR purposes (CH2M Hill, 1997).

These studies show that although the basalt beneath the Cooper-Bull Mountain is moderately transmissive, the ability of the formation to support large scale withdrawals is limited by the relatively small amount of water that is recharged to the system annually. In part, this is thought to reflect the presence of low permeability fault zones and the effect that these have in dividing the aquifer into a series of hydraulically separate sub-aquifers.

This proposition is supported by the results of the ASR cycle testing reported by CH2M Hill for both the Tualatin Valley Water District (TVWD) and the City of Beaverton (1999 and 2000). At the TVWD Schuepbach test site, aquifer boundary conditions are thought to have been responsible for the rapid build-up of groundwater heads in the recharged basalt, the loss of stored water from the system as seepage at the ground surface and a reduction in estimates of the available storage capacity. At the City of Beaverton Hanson Road test site, structural bounding of the basalt in the vicinity of the well was also confirmed by ASR cycle testing, although not to the extent apparent at the TVWD site.

Possible implications for the ASR program being pursued for the City of Tigard include:

- Faulting bounding may result in some limitation on the available storage capacities;
- For schemes that can be operated within such limitations, low permeability boundaries typically enable the injected water to be stored without significant loss;
- Demonstrating that the stored water can be retained tends to be easier in such systems, as the injection typically results in a water level rise that is both significant and stable;
- Moderately transmissive aquifers enable the injection and recovery of the stored water to be undertaken using relatively few wells.

Subject to constraints on the available storage capacity, the previous studies suggest that the basalts beneath Cooper-Bull Mountain are potentially suitable for ASR development.

REPORT ORGANIZATION

This report is organized into the following sections:

Section 2 provides a summary of the existing water supply system in the City of Tigard.

Section 3 describes the site setting in the Vicinity of Well No.1, the local and regional geology and groundwater conditions, the investigations completed as part of this study including the evaluation of the City's existing wells, identification of local monitoring wells, testing of Well No. 1 and water quality sampling.

Section 4 describes the feasibility of ASR using Well No. 1 and in the basalt aquifer in the vicinity of Well No. 1.

Section 5 describes the steps required for Phase II – Pilot Test Study.

Section 6 describes the steps involved with the Phase III – Full Scale Implementation.

Section 7 provides conclusions and recommendations.

Several Appendices are included with supplemental information. Appendix A contains Figures. Appendix B contains copies of the well permits and registrations for the City's wells. Appendix C contains well logs for wells in the Bull Mountain area. Appendix D contains the results of the well evaluation. Appendix E contains water quality data for Well No. 1 and recharge sources. Appendix F contains the results of the geophysical logging and pump test conducted in Well No. 1 and Appendix G contains a mixing analysis to evaluate the chemical interaction between native groundwater and recharge water.

Section 2

MONTGOMERY WATSON

SECTION 2 SOURCES OF SUPPLY

This section provides a brief summary of the City's current water supply and discusses the requirements for ASR in terms of their water supply strategy.

SOURCES OF SUPPLY

The City of Tigard (the City) currently serves over 46,000 people in the Cities of Tigard, Durham, and King City and unincorporated Washington County through approximately 14,900 residential, commercial and industrial service connections (Wegner, 2001). The City receives water from a number of surface and groundwater sources within the region.

SURFACE WATER

Currently, the City's primary water supply is from the City of Portland (COP), connecting with a transmission line from Portland and through the Metzger area of the Tualatin Valley Water District (TVWD). The City of Portland's primary source of water is the Bull Run watershed. Water from Bull Run is unfiltered, but is chloraminated prior to delivery into the distribution system. The City also has a supply connection to the Clackamas River source through the City of Lake Oswego (which once was the main supply) and a small connection to the Joint Water Commission source through the City of Beaverton. The Joint Water Commission treats water from the Trask and Tualatin Rivers. The City has other connections to the Lake Grove Water District and the City of Tualatin. Connections to Beaverton, Tualatin and Lake Grove District primarily allow the City to provide emergency supplies. Table 2.1 lists the current water supplies obtained from named sources (Wegner, 2001).

TABLE 2.1 SURFACE WATER SOURCES

Source	City of Portland	Lake Oswego	JWC
Supply	10.3 mgd*	1-2 mgd	2 mgd

*1.8 from TVWD

GROUNDWATER

The City owns four wells located in the Bull Mountain and Cooper Mountain area. Figure 1 shows the locations of these wells. The Cooper Mountain-Bull Mountain area was declared a Critical Groundwater Area by OWRD in 1974 in response to declining groundwater levels in the area. Table 2.2 lists the well depth, production capacity, pump type and operational status for each well. Wells. No. 1, 2 and 3 have a combined production capacity of approximately 1.3 mgd. Well No. 4 has not been operational since the 1970's due to equipment failure and water quality issues. The City primarily relies on Wells No. 1 and 2 during summer months to augment existing surface water supplies, producing approximately 1 mgd. Well No. 3 is used for emergency backup.

TABLE 2.2 TIGARD WELL SUMMARY

Well	Depth (ft)	Production Capacity (gpm)	Pump Type	Operational Status
1	612	300	Line-shaft turbine	Operational
2	453	500	Line-shaft turbine	Operational
3	494	125	Electric Submersible	Emergency Backup
4	925	500	Line-shaft turbine	Out of Service since 1974

The City has in the past also received groundwater from the City of Portland's Columbia Southshore Wellfield. During heavy rains, turbidity in the Bull Run supply can rise beyond acceptable limits and COP must rely on its groundwater supply near the south shore of the Columbia River. COP only uses its groundwater during emergencies and during peak season when Bull Run cannot meet the demands. During the winter of 1998 and 1999 the COP was forced to shut down Bull Run due to increased turbidity and resort to using its groundwater until turbidity reached acceptable levels.

Water Rights

The City does not hold any surface water rights to its current supply. All surface water is purchased from other sources. However, the City holds groundwater rights to its four wells. Table 2.3 lists the wells and their respective appropriation (WRD). Permits for groundwater were not issued until 1955. Those wells with priority dates before 1955 were given registration or certificate numbers. Registered water rights are non-transferrable. Copies of the well permits are located in Appendix B.

TABLE 2.3 GROUNDWATER RIGHTS

Well No.	Location (T/R/S)	Registration No.	Permit No.	Certificate No.	Permitted Diversion (cfs)	Date Drilled
1	2S/1W SW/NW 11	GR616	G3270	G588/46639	0.44/0.67	1947/1966
2	2S/1W NW/NW 10	GR615	-	G587	1.1	1949
3	2S/1W SW/NE 4	-	G655	28971	0.78	1958
4	2S/1W SW/NE 4	-	G2999	46638	0.63	1966/1967

WATER DEMAND AND FUTURE GROWTH

Over the last several years, the City has been investigating a number of potential water supply options in its efforts to secure a long-term water supply to meet the needs of the community. Table 2.4 presents those needs as recently determined in the City's Water Distribution System Hydraulic Study, completed in May 2000 (Murray, Smith & Associates). As can be seen, peak day demand is projected to grow about 40% and average demand is projected to grow about 25% over the next fifty years.

TABLE 2. 4 FORECAST WATER DEMANDS

Year	Average Day Demand (MGD)	Maximum Day Demand
2000	6.0	13.8
2010	6.8	17.2
2020	7.1	18.0
2030	7.4	18.7
2040	7.5	19.1
2050	7.6	19.4

Population is growing at a rate of approximately 3.5% to 4% annually (Wegner, 2001). This increase in population will continue to place demands on the City's water supply. Current supplies do not provide any surplus water in the short-term and this situation will turn into a deficit of several million gallons a day by 2010.

AQUIFER STORAGE AND RECOVERY REQUIREMENTS

The City wishes to utilize ASR for both short-term and long-term needs. In the short-term, the City's current water supplies from the above mentioned sources do not provide additional water above the current peak day demands (13 mgd). For long-term planning, the City must consider population growth and the renewal of contracts with the City of Portland by 2007. If feasible, the City would like to use ASR to fill the gap in short-term water demands and potentially provide a consistent water supply in the long-term. ASR is a means of lowering the City's costs for peak day and peak season supply. Use of ASR would allow the City to make better use of its existing wells and reduce the need to obtain peak season supply. It may also allow for a more consistent water quality throughout the year. Ideally, the City would like to complete the Pilot Study by the middle of 2002 and begin delivering water to its customers by the summer of 2002. Initial production would be approximately 1-1.5 mgd. Ultimately, the City would like to utilize ASR with a production of 4-6 mgd within 10 years.

Section 3

SECTION 3 HYDROGEOLOGICAL EVALUATION

BACKGROUND

Well-field Development

The original City wells were constructed in 1947 (Well No. 1) and 1949 (Well 2) to exploit groundwater in the basalt that underlies Bull Mountain. To increase the production from the basalt, additional wells were added to the system in 1958 (Well 3) and 1966 (Well 4) and in 1966 and 1967 Wells 1 and 4 were deepened. During the early 1970's, however, the Cooper-Bull Mountain area was declared a critical groundwater area and further withdrawal of groundwater from the basalt was restricted. Given that the yields available from other aquifer systems in the Tigard area were too small meet the needs of a large-scale municipal water supply, the establishment of the critical groundwater area prevented any further development or expansion of the City's well field.

The location of the four City wells is shown on Figure 1. Until comparatively recently, areas in the immediate vicinity of Wells 2, 3 and 4 were composed of homesteads, woodland and pasture. Recent development, however, means that all of the wells are now located in areas that are adjacent to residential housing.

Topography

Bull Mountain rises from the floodplain of the Tualatin River, forming a plateau at the eastern end of the Tualatin watershed with a maximum elevation in excess of 700 ft. The plateau surface is approximately 0.5 mile wide and 1 mile long and is elongated in an east-west direction. The southern and northern slopes of the plateau run-out onto the flood plains of the Tualatin River and Fanno Creek and terminate at elevations of 120 ft and 150 ft respectively. The eastern and western slopes terminate in a pair of dry valleys. The valley to the west has a maximum elevation of 280 ft and separates Bull Mountain from Cooper Mountain. The valley to the east has a maximum elevation of 310 ft and separates Bull Mountain from an adjacent, unnamed, area of elevated ground (Canterbury Lane).

To the north, east and south of Bull Mountain lie the Portland Hills, Petes Mountain, Parret Mountain and the Chehalem Mountains. These upland areas mark the northern, eastern and southern boundaries of the Tualatin watershed.

Climate

The climate of the Willamette Valley is characterized by cool, wet winters and warm, dry summers. Average monthly precipitation and temperature data for the NOAA climate gauging stations nearest to Bull Mountain are presented in Table 3.1 (Oregon Climate Service, 2001). The precipitation data is derived from measurements taken at the Rex 1S station, which is located at an elevation of 520 ft on western side of Parrett Mountain. As no reliable temperature data is available for this station, the temperature data in Table 3.1 is derived from measurements at the adjacent N. Willamette Experimental Station (elevation 150 ft).

TABLE 3.1 MONTHLY CLIMATE DATA (1961-1990)

Month	Mean Rainfall[1] (in.)	Monthly Mean	Mean Min.	Mean Max.
January	6.28	39.2	32.2	45.8
February	4.49	42.7	34.6	51.3
March	4.21	46.0	36.5	55.4
April	2.59	49.7	39.0	59.4
May	2.18	55.4	44.0	66.8
June	1.56	61.5	49.5	73.1
July	0.63	66.1	52.4	79.6
August	1.00	66.2	52.2	80.2
September	1.82	61.6	48.4	74.1
October	3.18	52.8	41.2	64.0
November	6.41	45.2	37.3	52.7
December	7.02	39.6	33.3	46.3

Table 3.1 shows that the average annual precipitation at the Rex 1S station was slightly in excess of 41 inches for the period 1961-1990. Over the same period, maximum and minimum monthly totals were recorded for December (7.02 inches) and July (0.63 inches) with the majority of the available rainfall (69%) falling between November and March. The equivalent temperature data shows an average annual temperature of 52.2 F°, with minimum and maximum mean monthly temperatures being recorded for January (39.2 F°) and August (66.2 F°).

Annual pan evaporation for the Tualatin valley is estimated from historical data to be approximately 30 inches (Hart and Newcomb, 1965). The majority of the evaporation occurs between the months of April and October, with mean monthly losses of approximately 6-inches being experienced in July and August. These values compare with a more recent pan evaporation estimate of 35 inches per year for the entire Willamette valley climate zone (Oregon Climate Service, 2001).

Surface Water Hydrology

The northern and southern slopes of Bull Mountain support numerous small streams that drain to Fanno Creek and the Tualatin River respectively.

The Tualatin River rises in the Coastal range and drains eastwards in the direction of Bull Mountain and the Willamette. The system receives drainage from a 700 square mile area that encompasses portions of the Coastal Range, the Portland Hills, the Chehalem Mountains, Cooper, Bull, Petes and Parrett Mountain as well as the valley floor. The available gauging data shows an annual pattern of variation in which flow in the river at the confluence with the Willamette varies between 50 cubic feet per second (cfs) in the summer and 10,000 cfs in the winter (USGS, 2001).

Fanno Creek drains the northern slopes of the Cooper-Bull Mountain area and the southeast slopes of the Portland Hills. The stream has a total watershed area of 31.5 square miles and the available gauging data shows that this supports flows that vary between 2 cfs in the summer and 800 cfs in the winter (USGS, 2001).

GEOLOGY

Litho-Stratigraphy

The geology of the Tualatin valley comprises the sequence of sedimentary and volcanic rocks described in Table 3.2 :

TABLE 3.2 GEOLOGICAL UNITS IN THE TUALATIN VALLEY

Division			Age	Strata
Cenozoic	Quaternary	Holocene	0 – 0.01 Million Years BP	Alluvium Undifferentiated sediments (Pliocene to Holocene including Portland Hills Silt, lacustrine deposits, Troutdale Formation and Helvetia Formation)
		Pleistocene	0.01 – 1.6 Million Years BP	Undifferentiated sediment (see above) Catastrophic Flood Deposits Unnamed conglomerate (early Pleistocene) Boring Lavas (early to middle Pleistocene)
	Tertiary	Pliocene	1.6 – 5.3 Million Years BP	Undifferentiated sediment (see above) Unnamed conglomerate (late Pliocene) Boring Lavas (late Pliocene)
		Miocene	5.3 – 23.7 Million Years BP	Columbia River Basalt Group (middle Miocene) Marine sedimentary deposits (early Miocene)
		Oligocene	23.7 to 36.6 Million Years BP	Marine sedimentary deposits
		Eocene	36.6 – 52 Million Years BP	Basalt of Waverly Heights (middle to late Eocene)

The geology in the vicinity of Bull Mountain is illustrated in Figures 2 and 3. These show Bull Mountain and the Canterbury Lane area to be composed of outcrops of the Columbia River Basalt Group. The adjacent low-lying areas are underlain by catastrophic flood deposits. These rest on an underlying sequence of undifferentiated sediments that are thought to contain elements of the Troutdale Formation, Sandy River

Mudstone equivalent and the Helvetia Formation. In areas close to the Tualatin River, the catastrophic flood deposits give way to deposits of more recent alluvium. Details of the lithology are described below:

Recent Alluvium
The alluvium consists of poorly consolidated silts, sands and organic material. The deposits typically vary in thickness between 20 ft to 40 ft but locally may attain thicknesses of 70 ft.

Catastrophic Flood Deposits
The Catastrophic Flood Deposits consist of poorly consolidated and poorly structured, medium sand and silt composed predominantly of quartz and feldspar with significant concentrations of mica. The sediments were deposited by one or more phases of catastrophic (glacial outburst) floods from late Pliestocene Lake Missoula. Typically, the unit is between 30 ft and 60 ft thick but locally thicknesses may approach 180 ft. The upper portions of the unit contain a significant clay fraction. This is thought to represent the effects of soil development.

Undifferentiated Sediments
These are commonly fine grained, massive to finely bedded sediments that are moderately to poorly lithified. In the study area these sediments include the Troutdale Formation and Sandy River Mudstone equivalent and, in the lower sections, the Helvetia Formation. Samples recovered during drilling are variously described as quartzo-micaeous siltstone, claystone and fine sandstone with rare gravel interbeds. The thickness of the unit is extremely variable and may vary between 15 ft and 200 ft.

Columbia River Basalt Group
This unit consists of Miocene flood basalts that were periodically erupted from linear fissure systems in eastern Washington, eastern Oregon and western Idaho. On the basis of geochemical, paleomagnetic and lithological variations, the flows that resulted may be divided into five formations. Within the study area, only two of these are represented, the Wanapum and Grand Ronde Basalts. Each of these is composed of a number of individual, mappable, flows, which vary in thickness between 25 ft and 400 ft. In total, up to 1,000 ft of basalt is present in the study area. Within the basalt of the Tualatin Valley, appreciable thicknesses of interflow sediments are absent and the exposed rock comprises a sequence of brown, red, black or dark gray, dense, blocky, jointed lavas that contains small amounts of breccia. The zones between individual flows are denoted by changes in the color of the basalt, typically from black and gray to red and brown or by an increasingly porous (vesicular or granular) texture.

Geological Structure

The area enclosed within the Tualatin watershed is underlain by a geological structure known as the Tualatin Basin. The basin is a broad, northwest trending syncline (bowl like structure) that is bounded by the Portland Hills, the Chehalem Mountains, Petes

Mountain, Parrett Mountain and the Coastal Range. The structural movements responsible for the basin post-date the deposition of the Columbia River Basalt Group and, as such, the basalt underlies the entire structure. In most areas, the dip of the basalt strata is towards the center of the basin and the Tualatin River.

Within the eastern portion of the basin, however, strata beneath Cooper Mountain and Bull Mountain are up-warped to form a subordinate, anticlinal, structure. This divides the main basin into two separate sub-basins. These lie beneath the present day course of Fanno Creek and the lower Tualatin River and extend north and south in the direction of the Portland Hills and the Chehalem Mountains respectively. The axis of the Bull Mountain anticline runs east to west across the center of the plateau and is assumed to pass further east beneath the Canterbury Lane area. Strata on either side of the axis dip at between 4 and 6 degrees to the north and south, in the direction of the two synclinal sub-basins.

The north, east, southeast and southwest edges of the Bull Mountain structure terminate at a series of intra-basin faults. The displacments on these suggest that the anticline takes the form of an up-faulted block in which strata is raised above the level of corresponding strata in the surrounding rocks. An east-west extension to the Bull Mountain faulting is thought to pass to the south of the Canterbury Lane area, dropping the basalt to the south. The structural effects associated with this are accentuated in areas beneath the lower Tualatin River by the presence of a buried channel. This greatly increases the depth to the basalt in areas to the south of the fault. A similar buried channel feature extends along the lower reaches of Fanno Creek, although this is not thought to be associated with any faulting.

HYDROGEOLOGY

Principal Aquifers

The two principal aquifers in the Tualatin Basin are the Columbia River Basalt Group (basalt) and the valley fill sediments. The permeability of the underlying Oligocene marine sedimentary deposits is relatively low and as such these sediments are usually considered to form the base of the overlying groundwater system. General hydraulic characteristics of the valley fill and the basalt are described below:

Valley Fill Aquifer

The valley fill aquifers are restricted in occurrence to areas close to the valley floor.

Groundwater within the fill is concentrated in relatively thin (< 10ft thick) sequences of bedded sands that, typically, are distributed at irregular intervals within a greater mass of silty or clayey sediment. The sands tend to be localized in occurrence and are difficult to correlate over large areas. The yield available from the sand varies between 2.5 gpm and 40 gpm, with an average of between 10 gpm and 15 gpm for the deeper wells. The associated specific capacity is typically less than 1 gpm/ft, implying a maximum transmissivity of 2,000 gpd/ft.

No information describing the storage properties or the vertical permeability of the valley fill is available.

Basalt Aquifer

Wells that produce groundwater from the basalt are distributed throughout the Tualatin valley, from areas on the valley floor to areas within the surrounding mountains. The associated yields vary from < 20 gpm for domestic supply to > 1,000 gpm for wells designed to meet large industrial or municipal demands.

The lower boundary of the basalt aquifer system comprises low-permeability marine sedimentary deposits. The basalt outcrops on Bull Mountain, therefore in this area the silts and clays derived from weathering of the underlying basalt represent the upper boundary of the basalt aquifer. However, over much of Bull Mountain, the groundwater level is below the top boundary of the basalt and hence the aquifer is unconfined in this area. Elsewhere, in confined portions of the basalt aquifer, the upper boundary comprises the overlying deposits of relatively low permeability valley fill sediments.

In areas to the east of Bull Mountain, it is likely that lateral boundaries are formed by the low permeability sediments that are found within the Fanno Creek and lower Tualatin River buried channels. In areas south of the Canterbury Lane area, this boundary may also coincide with the presence of an east-west trending fault. A similar combination of faulting and buried channels is also considered likely to bound the northern and southern limits of the system in the areas of Bull Mountain to the west of Canterbury Lane.

Groundwater flow in the basalt is typically concentrated in discrete zones of enhanced permeability. These zones develop at the interface between successive basalt flows and may be composed of weathered basalt, paleo-soils, granular sedimentary material or, where the younger basalt flowed into a pre-existing water feature, highly porous, vesicular material. Owing to the lower permeability of the intervening basalt, the interflow zones tend to be hydraulically isolated. As such, the basalt typically behaves as a multi-layered system in which the net aquifer transmissivity is a function of the number, permeability and lateral extent of the interflow zones that are present. Given that the thickness and extent of individual zones varies, yields from the basalt may also vary - sometimes significantly over relatively short distances. The intervening, un-weathered, basalt contributes little to the overall productivity of basalt aquifer systems.

The transmissivity of the basalt beneath Bull Mountain is estimated from the available well testing data to vary between 200 gpd/ft and 73,000 gpd/ft with an average of approximately 7,000 gpd/ft. In the absence of an obvious spatial correlation, this large range is considered to reflect a combination of the following:

- the effect of well design and construction on the number and permeability of the interflow zones that are exposed in each well and
- variations in the thickness and lateral extent of individual interflow zones.

Table 3.3 shows that estimates of the transmissivity of the basalt penetrated by the City wells vary from 7500 gpd/ft (Well 3) to 20,000 gpd/ft (Well No. 1). Equivalent estimates for Wells 2 and 4 were 9000 gpd/ft and 10,000 gpd/ft respectively. The broadly comparable performance of each well can be attributed to interception and penetration of a similar number of (potentially identical) interflow zones. The higher transmissivity of Well No. 1 is considered likely to reflect the effects of additional permeability development that may be associated with sub-vertical fracturing along the axis of the Bull Mountain anticline.

No site-specific estimates of the storage properties of the Bull Mountain basalt were available from the existing pumping test data. Estimates derived from other studies, however, suggest that the unconfined basalt is likely to have a specific yield of between 0.01 and 0.05 and that the confined basalt will have a storativity of between $1.0x10^{-5}$ and $1.0x10^{-3}$. Copies of the well logs are located in Appendix C.

TABLE 3.3 HYDRAULIC TEST AND RELATED DATA FOR THE CITY WELLS

Well	Estimated Transmissivity (gpd/ft)[1,2]	Number of Interflow Zones Penetrated Below Water Table and (Total thickness)[2] (ft)	Water Level Elevation at Time of Testing[2] (ft)
1	20,000	10 (130)	178
2	9,000	5 (47)	199
3	10,000	5 (126)	180
4	7,500	10 (187)	148

[1] Estimate based on draw down predicted for 300 gpm production rate
[2] Data obtained from available well logs (OWRD data base)

GROUNDWATER FLOW DYNAMICS

Recharge

Available estimates of the volume of water that is recharged to the aquifers of the Tualatin valley, expressed as effective rainfall in inches per year, are given below in Table 3.4

TABLE 3.4 RECHARGE OF TUALATIN VALLEY AQUIFER

Source of Estimate	Aquifer Systems	Recharge (inches per year)
Beach and Bartholomew (1973)	Cooper-Bull Mountain Basalts	2 - 3
Driscoll (1986)	Columbia River Basalt Group (entire formation)	0.2 - 10
Miller et al. (1994)	Parrett Mountain Basalt	0.72 - 2.86
Hart and Newcomb (1965)	Valley fill	11

In addition, since the 1940's, base flows in the Tualatin have been stable at levels of approximately 50 cfs. Assuming that flows of this magnitude are indicative of a basin-wide state of dynamic equilibrium, between groundwater recharge and surface water flows, the effective rainfall required to sustain this equilibrium would be equivalent to 0.97 inches. Conceptually, this would be distributed between the valley fill and basalt aquifers across the entire 700 square miles of the watershed. The calculation also assumes that minimal volumes of groundwater leave the basin as underflow that is not measured as streamflow.

In reality, net recharge is likely to be within the 0.72 to 3 inches range estimated by Beach and Bartholomew (1973) and Miller et al (1994) and to occur as a combination of (a) precipitation excess over evapotranspiration losses and run-off, (b) limited leakage losses from streams, and (c) leakage of treated water and effluent from the City's network of buried pipes. As such, it is also likely to be concentrated in the following areas:

- Outcrops of the basalt in areas where the surface soils are permeable, where the topography is flat and where the water table is well below ground surface;
- Outcrops of the basalt where surface or sub-surface drainage flows in contact with permeable strata in which the water table is below ground surface.

In addition, the basalt will also be recharged in areas where groundwater in the overlying valley fills drains vertically under the influence of downward hydraulic gradients. Recharge of this type is expected to be concentrated in areas where the valley fill sediments fringe the upland areas of outcropping basalt.

Under circumstances where groundwater withdrawal results in the development of a large cone of depression, it would normally be expected that lateral inflows from adjacent portions of the affected aquifer would also recharge the depleted area. The development and persistence of the cone of depression beneath Bull Mountain, however, suggests that recharge of this type may be restricted. Possible constraints include the presence of low permeability zones within the basalt that may be associated with either (a) the intra-basin faulting, or (b) the presence of the buried channels.

Groundwater Flow

Groundwater flow within the Tualatin basin will be from the recharge zones towards the regions where the groundwater is discharged.

Prior to the construction of wells, Bull Mountain is likely to have formed a groundwater divide, separating groundwater catchments that were associated with the lower Tualatin River and Fanno Creek synclinal sub-basins. As such, the pre-development directions of groundwater flow are likely to have been from the axis of the anticline towards the north and south. In areas beneath the two rivers, the hydraulic gradients are likely to have developed a strong vertical component, with the result that groundwater in the basalt would be driven upwards through the overlying valley fill surface water. A modified version of this pattern would also occur to the east of Bull Mountain, with recharge migrating from the Canterbury Lane area to the north, east and south in the direction of the Tualatin River, Fanno Creek and the confluence between the two.

Possible exceptions to this general pattern would occur under circumstances in which:

- Discharge of groundwater to springs rising on the flanks of Bull Mountain causes a local, lateral, diversion of flow and the premature discharge of groundwater from the system (from either perched water tables or the main, regional, water table);
- The permeability of the valley fill deposits is sufficiently low that groundwater in the confined basalt is "trapped" and the majority of the recharge to the system is discharged at the boundary between the confined and unconfined basalt;
- Faulting of the basalt introduces a significant degree of anisotropy with respect to large scale permeability (either by significantly increasing or decreasing permeability along the fault zone), with the result that groundwater is diverted laterally;

The depletion of the groundwater levels that has been experienced in the Bull Mountain area since the late 1940's can be expected to have produced the following effects on groundwater flow:

- A reduction in the volume of groundwater that was discharged from the regional water table as spring flow on the slopes of Bull Mountain;
- An increase in the volume of valley fill groundwater that recharges the basalt in areas on the margins of Bull Mountain;
- A reduction in the magnitude of the flows to the north and south of the Bull Mountain anticlinal axis;
- A reduction in the volume of groundwater flowing from the basalt to the valley fill in areas close to the Tualatin River and Fanno Creek.

Groundwater Discharge

Permitted withdrawals from the Bull Mountain basalt total 176,894,475 ft^3/yr (approximately 2,500 gpm). Of this, 114,775,470 ft^3/yr (1,632 gpm) is allocated to the City of Tigard for operation of the City's wells. The remainder is allocated for irrigation.

Assuming that residential development on Bull Mountain has eliminated the need for large scale irrigation and that the City withdrawals have been restricted to summer use of Well No. 1, actual withdrawals from the basalt are likely to be between 10,000,000 ft^3/yr to 20,000,000 ft^3/yr (150 to 300 gpm). Assuming an outcrop area of 6 square miles and effective rainfall of between 1 and 3 inches, this sum compares to values of recharge that vary between 14,000,000 ft^3/yr and 42,000,000 ft^3/yr (200 to 600 gpm). Given that withdrawal approximates recharge and that groundwater levels beneath Bull Mountain have stabilized in recent years, it is apparent that the volume of groundwater naturally discharged from the system is relatively small and likely to be less than 20,000,000 ft^3/yr (300 gpm).

HYDROGEOLOGICAL INVESTIGATIONS (MARCH - APRIL 2001)

As part of the City of Tigard aquifer storage and recovery (ASR) program a number of preliminary investigations have been completed. The purpose of these has been to confirm details of the geology and hydrogeology in the City's well field, to characterize the quality of the groundwater that is produced and to determine which of the City's wells is the most suitable for use as an ASR pilot test well. The investigations that have been completed include the following;

- Well suitability evaluation;
- Water quality investigation;
- Preliminary geophysical and hydraulic testing;
- ASR geochemical evaluation.

The results of each investigation are presented as a series of Technical Memorandum that are contained in Appendix D-G of this report. A summary is provided below.

Well Suitability Evaluation

The primary purpose of the well suitability evaluation was to identify which of the City's wells would be the most suitable for use as the ASR pilot test well. The criteria used in the selection process included compliance with current OWRD well construction standards, available recharge capacity, engineering considerations and the availability of nearby observation wells.

Of the four wells examined, Well No. 1 was considered to offer the greatest potential. The specific advantages of Well No. 1 included the largest recharge capacity, the ready availability of nearby observation wells and the likelihood of minimal modification of the existing well-head engineering. It was also originally thought that this well best complied with OWRD well construction standards, but a video inspection subsequently proved that the well had a leak in the casing.

Water Quality Investigation

The water quality evaluation comprised an assessment of the available groundwater quality data, sampling and analysis of the groundwater produced from Well No. 1 and a review of the quality of the treated water that is likely to be injected into the basalt during future ASR operations. The results are summarized below:

Basalt Groundwater Quality

The available water quality data indicated that the groundwater in the City's wells is moderately soft, with a low mineral content. The reviewed data also indicated that concentrations of trace metals have historically been detected at all four wells, including copper, zinc, lead, barium, iron and aluminum. None were present at levels in excess of the corresponding Maximum Contaminant Level (MCL) or Secondary Maximum Contaminant Level (SMCL). Similarly, no samples recovered from Well Nos. 1, 2 and 3 contained any detectable concentrations of regulated Volatile Organic Compounds (VOCs) and Synthetic Organic Compounds (SOCs). Water quality data was not available for Well No. 4.

Historically, samples from Well Nos. 1, 2 and 3 have also been analyzed for an additional 42 unregulated VOCs and 13 unregulated SOCs. The results of this testing confirmed the presence of low concentrations of chloroform in the groundwater. This is likely to have originated as a disinfection by-product present in treated water that is either:

- run into the well during periods when the pump is not operating (to lubricate the pump column bearings), or;
- leaks into the basalt from overlying storage reservoirs and associated pipe-work.

No other substances were detected.

The results of sampling and analysis of the groundwater produced from Well No. 1 during the Feasibility Study investigations confirmed the findings of previous sampling and analysis at the well.

Injected Water Quality

The three potential sources of injection water that were examined comprised the following:

- Lake Oswego WTP – Direct Filtration
- City of Portland Bull Run – Unfiltered
- Joint Water Commission – Conventional Filtration
-

Review of the available water quality data showed that none of the sources contained any constituent at levels above 50 % of the corresponding MCL or SMCL. Exceedance of this criteria would require the recharge water to be treated prior to injection into the wells.

Preliminary Geophysical and Hydraulic Testing of Well No. 1

Following identification of Well No. 1 as the prospective pilot test well, the well was geophysically logged and subjected to a series of short duration pumping tests. The purpose of the testing was to confirm details about the well engineering and basalt geology, to determine values for hydraulic properties and to identify any near-well aquifer boundary conditions that may influence ASR related testing or operations.

The geophysical logs that were produced included natural gamma, formation resistivity, fluid temperature and conductivity, caliper and flow. A Closed Circuit TV (CCTV) log of the wells was also produced. The pumping tests that were completed included a stepped rate test and 6 day constant rate test. The constant rate test was run approximately five days longer than anticipated owing to the development of a constant head boundary condition and the need to confirm this in the late time test data (see below). The results of the geophysical logging are summarized in Figure 4 and the results of the aquifer test are shown in Figure 5. Figure 5 shows that the drawdown observed in the production well is composed of three separate elements. These include;

- 1 min. to 1000 mins. Delayed yield and well-bore storage response (denoted by initial steep rate of drawdown and subsequent near stabilization)
- 1000 mins. to 3500 mins. Confined aquifer response (denoted by constant rate of drawdown)
- 3500 mins. to end of test. Constant head boundary response (denoted by stabilization)

Interpretation of Figure 4 and Figure 5 confirmed the following about the basalt in the vicinity of Well No. 1:

- The aquifer comprises a series of (interflow zone) sub-aquifers that in the near vicinity of the well, appear to be linked as a consequence of networks of sub-vertical fractures;
- In the vicinity of the well the basalt is unconfined, with a depth to water (unsaturated zone) of 250 ft and a specific yield that is likely to be equivalent to the effective porosity (of the order of 0.05);

- In areas distant from the well, the basalt is confined with a transmissivity of the order of 6,500 gpd/ft and a storativity which is likely to be of the order of 1.1×10^{-5} or greater;
- The region of the basalt penetrated by the well appears to be bounded by one or more high permeability features;
- To the south, these may reflect the effects of faulting or interception of permeable paleo-channel deposits;
- To the west, these may reflect water table conditions beneath Bull Mountain or the effects of faulting.

It is also noted that the current yield appears to be limited by the pumping capacity that is installed in the well. As such, it is considered likely that greater yields from the well may be possible, provided that the additional draw-down does not de-water any of the existing groundwater inflow zones that contribute water to the well.

Geochemical Evaluation

The purpose of the geochemical evaluation was to determine whether injection of any of the available source water was likely to result in adverse geochemical reactions that may either:

- Result in the clogging of the basalt aquifer in the near vicinity of the well; or
- Cause an unacceptable impact on the quality of the recovered water.

The results of the modeling demonstrated that mixing of the in-situ groundwater with either the Portland or JWC water is not likely to result in any adverse geochemical impacts. The dissolution amorphous silica from the basalt may result in an increase in the silica concentrations in the recovered water. However, maximum silica concentrations are not expected to exceed 40 mg/L and concentrations at these levels are less than those that are present in the in-situ groundwater.

As the available analysis for the Lake Oswego water was significantly incomplete, this was not used in any of the associated modeling.

Section 4

Section 4

MONTGOMERY WATSON

SECTION 4 ASR FEASIBILITY

This section describes the feasibility of ASR in terms of the hydrogeological conditions, development and implementation costs and the City' system potential.

ASR OBJECTIVES

The City wishes to develop an ASR system utilizing water purchased from either the City of Portland, Joint Water Commission or Lake Oswego that will be recharged into a basalt aquifer using the City's existing wells. The initial goal is a supply of 1 to 1.5 mgd for 120 days, however, the City is interested in evaluating the maximum ASR storage capacity of the basalt aquifer. In the short-term, the recharged water would typically be stored for 3 to 6 months, then recovered to meet summer peak demands or emergency needs. For long-term use, recharged water would be injected during winter (120 days) and utilized for the rest of the year. The recovered water will be required to have a composition similar to the recharge water, and have acceptable taste and odor. The overall objective is to design a system to maximize the recovery of recharge water while providing consistent water quality to the City.

It is currently understood that the City desires to implement ASR operations in two distinct phases: The objectives for the proposed Bull Mountain ASR scheme comprise the following:

- An initial, intermediate, phase in which ASR is used to generate a 1 mgd to 1.5 mgd peaking supply which would be available for a 4 month period each summer (180 million gallons);
- A subsequent, full development phase in which ASR is used to supply between 4 mgd and 6 mgd over a period provisionally estimated to be up to 8 months long.

During the intervening 4 to 8 month (non-recovery) period, the basalt system would be recharged using available resources of treated surface water.

ASR ISSUES

To determine whether or not it is feasible to achieve these objectives, a number of ASR feasibility issues require evaluation. These include the following:

- What is the total storage capacity available within the target aquifer? (including an assessment of the risk of significant leakage or off-site migration losses)
- At what rate can water be injected into the target aquifer?
- At what rate can the water be recovered?
- What are the impacts of recharge on local and regional groundwater and geotechnical conditions and on surface water features that are connected to the groundwater system.

- What reactions will take place in the aquifer between the recharge water, the native groundwater and minerals within the target aquifer matrix?
- Based on the conceptual hydrogeological model, is there sufficient confidence to proceed with a pilot test? If a pilot test is performed, what approach should be taken to collecting the information necessary to design a full-scale scheme?

Evaluation of these issues is usually performed using a phased approach in which the commitment of resources is commensurate with the level of confidence in a successful outcome.

EVALUATION OF ASR IN TIGARD

Conceptual Hydrogeological Model

Key features of the conceptual hydrogeological model of the Bull Mountain basalt are illustrated in Figure 6 and are summarized below:

Aquifer Units
The basalt is the main aquifer system in the study area. The unit comprises between 4 and 6 sub-aquifer units that are formed from the permeable material that occurs between individual basalt flows. These sub-units appear to be present over a wide area and to collectively possess a transmissivity that varies between 5,000 gpd/ft to 10,000 gpd/ft. Along the axis of the Bull Mountain anticline, the basalt permeability is likely to have been further enhanced by the presence of networks of sub-vertical fractures.

The aquifer is unconfined beneath Bull Mountain and confined beneath the adjacent valleys of Fanno Creek and the Lower Tualatin River.

The permeability of the overlying valley fill sediments appears to be significantly lower than that of the basalt. Despite this condition, the sediments support small amounts of groundwater withdrawal and as such are considered to form a leaky confining unit that is capable of transferring limited volumes of groundwater to or from the basalt.

Aquifer Boundaries
The lower boundary of the basalt aquifer system comprises low-permeability marine sedimentary deposits. The basalt outcrops on Bull Mountain, therefore, in this area the silts and clays derived from weathering of the underlying basalt represent the upper boundary of the basalt aquifer. However, over much of Bull Mountain, the groundwater level is below the top boundary of the basalt and hence the aquifer is unconfined in this area. Elsewhere, in confined portions of the basalt aquifer, the upper boundary comprises the overlying deposits of relatively low permeability valley fill sediments.

In areas to the east of Bull Mountain, it is likely that lateral boundaries are formed by the low permeability sediments that are found within the Fanno Creek and lower Tualatin River buried channels. In areas south of the Canterbury Lane area, this boundary may also coincide with the presence of an east-west trending fault. A similar combination of faulting and buried channels is also considered likely to bound the northern and southern limits of the system in the areas of Bull Mountain to the west of Canterbury Lane. It should be noted, however, that there is considerable uncertainty with respect to the effects of such boundaries on groundwater flow and aquifer storage and as such significant volumes of groundwater may be transferred across them. In areas to the extreme west, the Bull Mountain system appears to be directly connected to the basalt beneath Cooper Mountain.

Recharge

Recharge to the basalt occurs at a rate that is likely to be equivalent to between 1 and 3 inches of effective rainfall per year. This is most likely to be composed of precipitation excess that infiltrates through the soils of the basalt outcrop where the topography is flat, the outcrop soils are permeable and where the water table is below ground surface. The presence of a groundwater mound beneath Bull Mountain implies that this is an active groundwater recharge zone. Estimates of the total volume of water that is naturally recharged in the Bull Mountain area vary between 14 and 42 million cubic feet per annum (equivalent to between 200 gpm and 600 gpm).

Groundwater Flow

Groundwater in the unsaturated zone of both the basalt and the valley fill will migrate vertically to the regional water table, unless intercepted by a laterally extensive low permeability horizon. Where a low permeability horizon is intercepted, the migrating groundwater will be diverted laterally and may then either emerge at the surface or recharge the underlying basalt via some discontinuity (uncased well, fault or sub-vertical fracture). Similar vertical flow processes may be expected to operate beneath the water table, with lower sub-aquifer units being recharged by flows that are derived from the overlying sub-aquifer units.

Under natural (non-pumping) conditions, the subsequent direction of flow will be to the north and south, in the direction of the center of the Fanno Creek and lower Tualatin River synclinal sub-basins. Vertical components of the head gradients at the center of the basins are then expected to drive the basalt groundwater into the overlying valley fill and ultimately result in the discharge of groundwater to the overlying surface waters. This general pattern of groundwater flow may be locally modified as a consequence of the following:

- Large scale withdrawal of groundwater from the basalt;
- A lower than expected bulk permeability for the valley fill deposits;
- Faulting of the basalt and large scale anisotropy with respect to permeability.

Depending upon the hydraulic behavior of the faults and buried channels, two alternative conceptual hydrogeological models of the Bull Mountain area are proposed at this time. These correspond to low and high permeability conditions respectively and include:

- Bounded, hydraulically isolated block into which recharge is limited by a combination of minimal precipitation excess and limited leakage from surface waters;
- Fault connected, regionally extensive aquifer that extends beyond the centers of the synclinal sub-basins that lie beneath Fanno Creek and the lower Tualatin River.

Given the development and persistence of the cone of depression beneath Cooper-Bull Mountain, it is considered more likely that the groundwater system behaves as a permeable, fault and channel bounded block that extends eastwards from Bull Mountain to areas beneath Cooper Mountain.

Groundwater Discharge

The total volume of groundwater discharge from the Bull Mountain basalt is estimated to vary between 10 and 20 million cubic feet per annum (equivalent to between 150 gpm and 300 gpm). The majority of this is assumed to be withdrawn for municipal water supply.

Storage Capacity

Assuming that the Bull Mountain system performs hydraulically as a fault bounded block, water injected into the basalt will be stored by filling the unsaturated pore and fracture spaces. The available space is likely to occupy a volume that is defined laterally by the boundary between the confined and unconfined aquifer and vertically by the historical (pre-development) groundwater levels. Storage at levels in excess of the historical levels is considered unlikely as these are likely to represent levels at which groundwater naturally leaked from the system, feeding springs, baseflow to springs, or the natural groundwater leakage to the valley-fill sediments that surround Bull Mountain.

The area of the unconfined aquifer on Bull Mountain that could be developed for storage is estimated to be approximately 7.5 square miles. The associated thickness of the de-watered basalt is estimated to vary between 50 ft and 60 ft based on the following information listed in Table 4.1:

TABLE 4.1 HISTORICAL STATIC WATER LEVELS

Tigard Well No.	Historical Static Water Level Elevation (ft)	Date of Measurement	2001 Static Water Level Elevation (ft)	Difference (ft)
1	212	1946	145.55	66.45
2	200	1948	142.03	57.97
3	180	1958	137.02	42.98
Source of Data OWRD Water Level Records No comparable data available for Well 4 (only constructed and operated between 1966 and 1974)			Average	55.8

Assuming a specific capacity for the basalt of between 0.01 and 0.05, the available storage capacity could vary between 850 million gallons and 4,250 million gallons. However, owing to the presence and apparent influence of the sub-vertical fracturing along the axis of the Bull Mountain anticline, it is considered that the specific yield is likely to be closer to the 0.05 value than the 0.01 value. As such the available storage capacity is likely to be of the order of 4 billion gallons.

This, potentially available, storage capacity compares to a required capacity of 225 million gallons to achieve the intermediate phase objectives and 1.4 billion gallons to implement the full-scale scheme.

Number of Wells Required for ASR

Assuming an average transmissivity for deep production wells on Bull Mountain of 10,000 gpd/ft, the specific capacity of any new ASR wells can be expected to be approximately 5 gpm/ft. In areas close to the Bull Mountain anticline, transmissivity and specific capacity values may increase to 20,000 gpd/ft and 10 gpm/ft respectively. As injection capacities are usually marginally lower than production capacities (a ratio of 0.75 is assumed), associated injection capacities are likely to vary between of 3.75 gpm/ft and 7.5 gpm/ft.

The available (gravity) injection head on Bull Mountain is equivalent to the depth to static water level and, based on the elevation of the static water levels in the City's wells at the present time, is approximately 250 ft. Under circumstances in which the basalt is fully recharged and static water levels are at elevations of approximately 210 ft, the available injection head will reduce to 190 ft. As such, the injection capacity of the ASR wells is likely to vary between 712 gpm (1 mgd) and 1,425 gpm (2 mgd).

Assuming that the injection source water will only be available for 4 months per year and a leakage rate during storage of 25%, it will be necessary to inject at an average daily rate of 2.0 mgd for 120 days to acheive the 1.5 mgd objective. This will result in the recharge of 240 mg. Based on our previous experience, about 25% or (60 mg) of the recharge water could be "lost" as leakage during storage (i.e. increased spring discharge, baseflow, etc). Therefore, after storage, 180 mg would be available for recovery providing 1.5 mgd for 120 days.

The full scale system requires up to 6 mgd for 240 days. To implement the 1,440 million-gallon, full-scale scheme, as much as 1,920 million gallons may need to be injected into the basalt at an average daily rate of 16 mgd (11,100 gpm).

Table 4.2 shows the estimated average well recharge and pumping capacities to meet the above objectives. The initial phase will require either one or two wells depending on well performance. The full-scale system will require between 7 and 10 wells. Short term pumping and recharge rates may be greater than that shown on the table. The pilot test will be used to better estimate recharge and pumping rates of the ASR wells.

TABLE 4.2 ESTIMATED WELL CAPACITIES AND RECHARGE RATES

RECHARGE - INJECTION						
PHASE	**Recharge Rate**		**Wells**		**Recharge Duration**	**Total Volume Recharged****
	(mgd)	(gpm)	Number	Avg. Cap. (gpm)	(days)	(mg)
Iniital (min)	1.33	926	1	926	120	160
Initial(max)	2.00	1,389	2	694	120	240
Full-scale(min)	10.67	7,407	7	1,058	120	1,280
Full-scale (max)	16.00	11,111	10	1,111	120	1,920
RECOVERY - WITHDRAWAL						
PHASE	**ASR Supply**		**Wells**		**Pumping Duration**	**Total ASR Water Pumped**
	(mgd)	(gpm)	Number	Avg. Cap. (gpm)	(days)	(mg)
Initial (min)	1	694	1	694	120	120
Initial (max)	1.5	1,042	2	521	120	180
Full-scale (min)	4	2,778	7	397	240	960
Full-scale (max)	6	4,167	10	417	240	1,440

*All pumping rates are average - higher capacities are possible for shorter durations
**Assumes 25% Leakage Loss

As production rates are likely to be lower than the required injection rates and the corresponding production capacities will be greater, fewer wells could be required to recover the stored water.

ASR Well Locations and System Phasing

As indicated above, up to 10 ASR wells could be required to meet the overall performance objectives of ASR. These wells should be developed across the service area such that each well site is limited to a maximum of two ASR wells, unless indicated otherwise via pilot testing. Widespread spacing of ASR wells will reduce interference effects and will minimize the risk to the system in the event of potential groundwater contamination. Figure 7 shows the potential and possible ASR wells sites. Sites were identified based on their proximity to the City's existing distribution system and where possible on City-owned property, or on property that is owned by other public agencies amenable to well siting. The number of sites listed provides for some redundancy in the event that the preferred sites are unavailable. Potential sites are those that have the greatest likelihood of success for ASR. Possible ASR sites may have reduced well yields and/or storage volumes may be lower because of less favorable hydrogeological conditions.

It is the understanding that the City wishes to develop the overall system over a 10-year period. Therefore, an incremental approach to the development of the full-scale system is recommended. The first step involves the conversion of the pilot test well to a full-scale ASR well followed by an additional well at that site if ASR proves feasible. Subsequently, two wells could be drilled approximately every 2 years until the system is fully developed. Assuming a 2003 start date, the City can achieve the the 4-6 mgd by 2013. Figure 8 shows the stages involved with the full-scale development.

Potential Impacts of ASR

ASR operations will result in a cyclic increase in ground water levels in the basalt beneath Bull Mountain. Adverse environmental impacts that could potentially be associated with this include ASR related flooding and slope de-stabilization. Typically, ASR flooding impacts are associated with non-artesian wellhead completions or the stimulation of surface water flow (seeps, springs and streams).

Owing to the high storage capacity and moderate transmissivity of the basalt, it is considered likely that the increases in water level will be moderate (< 50 ft) and in all cases less than levels that historically occurred in the aquifer. As such, any flooding risk will be restricted to either newly constructed wells that have been drilled into the unsaturated basalt at relatively low elevations or springs that historically were active but subsequently dried-up owing to regional lowering of the water table. Based on a review of the available documentation, it is currently believed that the potential for any such impact is low. Similarly, as ground water levels are unlikely to be raised above historical levels, it is currently considered unlikely that ASR operations will have any adverse effects on slope stability.

Uncertainties

The assessment described above contains a number of significant assumptions that, at the present time, are subject to some uncertainty. These include the following:

- The vertical and lateral distribution of permeability across the Bull Mountain block and associated variations in well performance;
- The effects of large scale water level changes (increases and decreases) on individual well performance;
- Possible limits on the available head build-up capacity within the Bull Mountain as a consequence of losses to springs and streams that rise on the slopes of Bull Mountain;
- The effective permeability of the lateral boundaries to the system and the potential magnitude of any loss of stored water from the Bull Mountain basalt block to adjacent basalt blocks (i.e. Cooper Mountain and the basalt beyond the centers of the Fanno Creek and lower Tualatin River synclinal sub-basins).

Resolving the relative significance of these uncertainties is a priority is terms of confirming the feasibility of developing the full-scale scheme. Whilst the Phase II pilot testing will address this issue, data collected in the meantime may be used to make a preliminary evaluation and to guide the subsequent data collection effort. The key to any such (intermediate) effort is the systematic recording of daily production rates from the City's wells and weekly monitoring of the associated water level response. This includes measuring the water level in the production wells and at nearby observation wells.

Recharge Water

The City could use any of the following sources of water for the Pilot Test and long-term operation of ASR:

- City of Portland - Bull Run and/or Columbia Southshore Wellfield
- Joint Water Commission – Trask/Tualatin River
- Lake Oswego – Clackamas River
- TVWD – City of Portland water

Different sources could be used at different times during the project or a mixture of sources. Source water will depend on availability at the time of injection. Based on the City's current supply, it is likely that the City of Portland water will be used as a source water. A water quality compatibility model was completed as part of the Feasibility Study to evaluate the potential effect of reactions between the injected water and both the in-situ groundwater and the basalt aquifer matrix. Modeling results indicate that there is unlikely to be any adverse impacts. Appendix E contains the complete report of the modeling.

Quantity and Duration Available for Recharge

Currently, the City obtains water from the City of Portland (COP) throughout the year (8.5 mgd). As water demands are typically lower in the winter, the City could purchase surplus water from COP to use as recharge water. During the winter, the City's demand for water is lower than in the summer. The City's contract with the City of Portland does not expire until 2007. The City's renewal of their contract with COP will determine in part on the quantity and duration of water received for use in ASR.

Short-term needs for ASR will require an injection rate of 2.0 mgd for 120 days to achieve 1-1.5 mgd for peak demands during the summer. Long-term requirements for ASR include an injection rate of 16 mgd for 120 days in order to achieve a supply of 4-6 mgd for up to 240 days throughout the year. Both these injection requirements account for 25% leakage losses.

Permitting

Permitting requirements for ASR involves two major components: the Limited License and ASR permit. The Limited License is required to perform the Pilot Test. This permit enables the applicant to confirm the storage capacity of the aquifer and water quality of the withdrawn water. Submittal of this application requires the identification of a well for testing, monitoring wells and source water(s). The ASR permit allows continued use of ASR and cannot be applied for until the Pilot Test is complete. The Water Resources Department (WRD) is the agency responsible for issuing the permits and consults with the Oregon Health Department (OHD) and Department of Environmental Quality (DEQ).

It has been determined that Well No. 1 could be used for the Pilot Test and COP water would be the source or recharge water. One of the reasons that the permit process requires identifying the source of supply is that the recharge water from these surface water sources will have a different water quality than the native groundwater. Because the City may use different or a mix of source waters during ASR, water quality will be an important issue.

In addition, the conditions of the aquifer at Well No. 1 indicate that the well is affected by a boundary that may be related to one or more geological conditions. With the limited data currently available, it is uncertain how the boundary will affect the storage of water in the aquifer and how groundwater levels will behave during recharge and recovery. Typically, WRD accounts for groundwater storage by measuring the water level rise during recharge and the water level decline during pumping. In view of the uncertain behaviour of the aquifer during recharge and pumping, both groundwater elevations and water quality criteria could be required as part of the permit conditions to account for the stored water. These alternative methods could include additional water quality monitoring or monitoring surrounding wells. The details of the permit will be developed during the Pilot Phase to help determine the design of the Full Scale Implementation.

During the Pilot test, water initially withdrawn from the well will need to be wasted until it has been demonstrated that it meets all water quality standards. Water wasted from the well can be discharged into the existing sanitary or storm system. The existing detention pond on site could be used for discharge during the Pilot test. Depending on the volume and rate of discharge, a discharge permit (NPDES) from DEQ may be required.

Cost Comparison

To adequately evaluate the feasibility of ASR, a comparison of costs to purchase water versus that of ASR production is appropriate. Two scenarios were used for the analysis: Intermediate ASR – 1.5 mgd and Full-Scale ASR – 6 mgd. Both scenarios assume a demand of 120 days during peak season. The analysis includes the cost to purchase water and well operations costs. Well development costs are not included in this comparison but addressed in Sections 5 and 6. Costs to deliver water are the same. It is assumed that the City can purchase water from a current supplier with two applicable rates: peak season rates ($0.91/ccf) and winter rates ($0.30/ccf). Costs to operate the wells during ASR injection and withdrawal are assumed to be $0.10/ccf. All rates are based on 2001 costs. Table 4.3 illustrates the costs for the Intermediate scheme. Table 4.4 illustrates the costs of the Full-Scale scheme.

Annual operating cost savings both for the Intermediate operation of ASR and in the long-term, are 45%. This equates to $98,663 a year initially, and rising to $394,652 after full-scale implementation. Assuming a total full-scale implementation cost of approximately $3.5 million (see Sections 5 and 6), the operating cost savings will pay for the ASR system in less than 10 years.

TABLE 4.3 INTERMEDIATE ASR COST COMPARISON

Costs to Purchase Water	
Peak Season Rate (per ccf)	$0.91
Demand (gpd)	1,500,000
Duration (days)	120
Total Costs	***$ 218,984***
ASR Costs	
ASR Injection	
OffSeason Rate (per ccf)	$0.30
Pump Costs (per ccf)	$ -
Storage Needed to Achieve 1.5 mgd Recovery	
(Assumes 25% water loss) - gpd	2,000,000
Duration (days)	120
Subtotal	***$ 96,257***
ASR Recovery	
Peak Season Rate (per ccf)	$ -
Pump Costs (per ccf)	$0.10
Demand (gpd)	1,500,000
Duration (days)	120
Subtotal	***$ 24,064***
Total Costs	***$ 120,321***
Annual Savings	***$ 98,663***
Cost Difference	45%

TABLE 4.4 FULL-SCALE COST COMPARISON

Costs to Purchase Water	
Peak Season Water Purchase Rate (per ccf)	$ 0.91
Demand (gpd)	6,000,000
Duration (days)	120
Total Costs	***$ 875,936***
ASR Costs	
ASR Injection	
OffSeason Water Purchase Rate (per ccf)	$ 0.30
Pump Costs (per ccf)	$ -
Storage Needed to Achieve 6 mgd Recovery	8,000,000
(Assumes 25% water loss) - gpd	
Duration (days)	120
Subtotal	***$ 385,027***
ASR Recovery	
Peak Season Purchase Rate (per ccf)	$ -
Pump Costs (per ccf)	$ 0.10
Demand (gpd)	6,000,000
Duration (days)	120
Subtotal	***$ 96,257***
Total Costs	***$ 481,283***
Annual Savings	***$ 394,652***
Cost Difference	45%

SUMMARY OF ASR FEASIBILITY

In summary:

- The available data indicates that there is sufficient storage capacity within the unconfined basalt beneath Bull Mountain to enable development of an ASR scheme that is capable of producing up to 6 mgd for periods of up to 8 months;
- Based on the available well testing data, construction and operation of 1000 gpm (Bull Mountain basalt) injection wells is feasible;
- Assuming a 4 month injection period, 1 to 2 wells would be required to enable development of a 1 to 1.5 mgd scheme capable of being used to provide a peaking supply for periods of up to 4 months;
- To enable the development of a 4 to 6 mgd scheme capable of being used for up to 8 months, 7 to 10 wells would be required. The construction of these wells should be phased to develop the ultimate ASR capacity over a 10 year period;

- The costs to purchase water for and operate ASR are approximately 45% less than that to purchase water during peak season. This savings does not account for infrastructure costs.
- It is likely that the recovery of the injected water could be achieved using fewer wells than are required for the injection;
- There is expected to be no adverse water quality impacts associated with injection of treated surface waters into the basalt;
- Potential impacts associated with the development of an ASR scheme are likely to include a water level rise in other basalt wells on Bull Mountain. Other potential impacts may include an increase in spring discharge on the slopes of Bull Mountain.
- There is expected to be no adverse impacts on slope stability.

It should be recognized, however, that the assessment presented above is based on a number of significant assumptions. These are subject to some uncertainty and resolution of the significance of the uncertainty is recommended to confirm storage volumes, injection and recovery rates, groundwater level changes and effects on springs and streams.

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Section 5

Section 5

MONTGOMERY WATSON

TABLE 5.1 PHASE II COST ESTIMATE

Description	Costs
PERMITTING AND WATER RIGHTS*	**$ 19,500**
WELLHEAD MODIFICATIONS	
Conversion of Well No. 1 to monitoring well	**$ 18,000**
New Well Construction Costs	
Drill new well on Well No. 1 site (12 in.) 600 ft.	$ 80,000
Pump and installation (1000 gpm Vertical Turbine w/non-reverse ratchet)	$ 55,000
Pump House	$ 45,000
Electrical	$ 20,000
Infrastructure	
Flowmeter	$ 4,000
PRV/check valve	$ 3,300
Back Pressure valve	$ 2,600
Pump Control Valve	$ 3,000
Valves/Fittings	$ 8,000
SCADA	$ 8,000
Dip Tube	$ 500
Pressure Transducer	$ 3,000
Transfer existing chlorination system	$ 800
Subtotal	**$ 233,200**
Professional Services	
Hydrogeological oversite - includes pump test analysis	$ 20,000
Engineering Services	$ 42,000
Water quality testing	$ 3,000
Subtotal	**$ 65,000**
Contingency (20%)	**$ 63,240**
Subtotal	**$ 407,940**
ASR PILOT TEST	**$ 97,000**
GROUNDWATER MODEL & WELLHEAD MODIFICATIONS (If necessary)	**$ 50,000**
PILOT TEST REPORT	**$ 34,000**
TOTAL	***$ 579,940***

The following assumptions were made in developing the Phase II costs:

- The new well can be drilled on the Well No. 1 site;
- The transmission line from the new well will be connected to the existing piping in the reservoir yard;
- The distance from the wellhead to the transmission line is 50 feet;
- The pump was sized for ASR injection and withdrawal rates;
- No additional water treatment will be necessary beyond the chlorination system currently in place.

SECTION 5 PHASE II – PILOT TEST PLAN

PHASE II – PILOT TEST PLAN

Objectives

Pilot testing will be accomplished under the terms of a Limited License for ASR. The goals of the Pilot Test Plan are to determine the percent recovery of stored water, the potential of recovered water to meet water quality standards and the ultimate capacity of the aquifer.

Limited License Application

This section describes the requirements of the Oregon Water Resources Department (WRD) for obtaining a Limited License, which is required to conduct an ASR pilot test. These requirements are specified in OAR 690-350 Aquifer Storage and Recovery (ASR) and Artificial Groundwater Recharge, in Section 0020 "ASR Testing Under Limited License".

> Pilot testing under the terms of a limited license is addressed in Section (1):
>
> *(1) Testing Purposes. To store and use water injected into an aquifer for aquifer storage and recovery testing purposes requires a limited license. Only after completion of an ASR testing program under a limited license may an applicant apply for a permanent ASR permit. The testing approach shall be designed to provide information as needed to evaluate the ultimate capacity anticipated for the project. The limited license may allow for a beneficial use(s) of the recovered water.*
>
> A pre-application conference is required prior to application for a limited license:
>
> *(2) Pre-application Conference. The Department requires at least one pre-application conference with a prospective licensee prior to filing an application requesting the right to use water under a limited license for ASR testing. The purpose of the conference is to describe and discuss the processes and requirements which the Department associates with water storage and recovery in the ASR Program. The conference may serve as a point of review for the apparent adequacy of the applicant's hydrogeologic and other information. The Department shall invite personnel from both the DEQ and HD to the conference.*
>
> The proposed ASR testing program is addressed in Section (3) (b) (A) as follows:
>
> *Proposed ASR Test Program. The proposed testing program shall include injection rates and schedules, water storage volumes, the injected water storage*

durations, recovery rates and schedule, water quality sampling including a quality assurance and quality control plan, water level monitoring including location of observation wells, contingency plan for use of recovered water if the intended use not possible, information on the anticipated final project (scope and conceptual design), and testing report outline. (A licensed professional will be required to develop this information as required by Oregon Law)

The proposed system design is addressed in Section (3) (b) (B):

(B) Proposed System Design. The proposed system design package shall include well construction information for any injection, recovery, observation and source wells, the wellhead assembly, piping system for injection and recovery, and other conceptual design components of the system. (A licensed professional will be required to develop this information as required by Oregon Law).

Groundwater information requirements are addresses in Section (3) (b) (C):

(C) Groundwater Information. Preliminary hydrogeologic information shall include the local geology, a conceptual hydrogeologic model, a description of the aquifer targeted for storage, estimated flow direction and rate of movement, allocation of surface water, springs or wells within the area affected by ASR wells, rationale for estimating the affected area, anticipated changes to the groundwater system due to the proposed ASR testing, potential natural resource problems of testing, and other information on groundwater and surface water conditions antecedent to ASR for basing recovery estimations. (A licensed professional will be required to develop this information as required by Oregon law. (ORS 672.505-705))

The source water quality is addressed in Section (3) (b) (D) as follows*:*

(D) Quality of Source Water. The applicant shall provide information regarding the quality and treatment of the proposed injection source water relevant to the proposed injection time of year for:

(i) Regulated constituents with maximum contaminant levels under OAR 333-061-0030 (test results from a laboratory approved by the HD (OAR 333-061-0036));

(ii) Unregulated constituents under OAR 333-061-0036 (test results from a laboratory approved by the HD (OAR 333-061-0036));

(iii) Constituents with maximum measurable levels established under OAR 340-040 (ORS 468B.165) (test results from a laboratory approved by the HD (OAR 333-061-0036));

(iv) Compliance with treatment requirements and performance standards for source waters that fall in categories identified in OAR 333-061-0032;

(v) Common ion constituents and water quality parameters to include: alkalinity or bicarbonate, calcium, magnesium, iron, manganese, sodium, potassium, chloride, sulfate, silica, total dissolved solids, pH, redox potential and temperature;

(vi) Other constituents as required by the Department.

Additional information on the source water quality, including compliance with applicable water quality standards, is addressed in Section (3) (b) (E):

(E) Comments on Source Water/Standards. The applicant shall address the following situations as they apply:

(i) If a constituent that is regulated under OAR 333-061-0030 (ORS 448.131 and 448.273) or OAR 340-040 (ORS 468B.165) is detected in the source water, the applicant shall demonstrate that there are not other sources of water available to the applicant which would be satisfactory for injection and lower in the constituent of concern;

(ii) If a constituent is detected in the source water above 50% of the levels established under OAR 333-061-0030 (ORS 448.131 and 448.273) or OAR 340-040 (ORS 468B.165), the applicant shall install a treatment method, system or other alternative method to reduce the constituent to less than 50% of those levels, unless the applicant can show that there is not a treatment method, system or other alternative method that will reduce the level of a contaminant below the 50% level, or the lesser of:

(I) The applicant can show that it would be more costly to provide the treatment method, system or other alternative method necessary than to obtain the same amount of stored water from the next cheapest feasible water supply alternative; or

(II) In the case of a drinking water system the applicant can show the cost of adding the treatment method, system or other alternative method increases the cost per household of providing water (including operation, maintenance, and debt service for prior water projects) above 1.5% of the median household income of the community.

(iii) Notwithstanding paragraph (3)(b)(E)(ii) of this rule, in the event the applicant cannot reduce a constituent to less than the 50% level, the applicant shall minimize the constituent level by providing the level of treatment available or other alternative method which for the same amount of stored water is not as

costly as either the next cheapest water supply alternative or an amount equal to that necessary to increase the cost per household of providing water to 1.5% of the median household income of the community, whichever is less;

(iv) Notwithstanding the provisions of paragraphs (3)(b)(E)(i), (ii) and (iii) of this rule and after consulting with the DEQ and the HD, the Department may determine that the circumstances are such that an alternative source, treatment method, system, or other alternative method is acceptable or not necessary.

The quality of the receiving water (native groundwater quality) is addressed in Section (3) (b) (F) as follows:

(F) Quality of Receiving Aquifer Water. The applicant shall provide information regarding the quality of the receiving aquifer water for:

(i) Regulated constituents with maximum contaminant levels under OAR 333-061-0030 (test results from a laboratory approved by the HD (OAR 333-061-0036));
(ii) Unregulated constituents under OAR 333-061-0036 (test results from a laboratory approved by the HD (OAR 333-061-0036));

(iii) Constituents with maximum measurable levels established under OAR 340-040 (ORS 468B.165) (test results from a laboratory approved by the HD (OAR 333-061-0036));

(iv) Common ion constituents and water quality parameters to include: alkalinity or bicarbonate, calcium, magnesium, iron, manganese, sodium, potassium, chloride, sulfate, silica, total dissolved solids, pH, redox potential and temperature;

(v) Other constituents as required by the Department.

The compatibility of the recharge source water and receiving aquifer water is addressed in Section (3) (b) (G) as follows:

(G) Comments on Compatibility. The applicant shall evaluate the compatibility of the injection source water and receiving aquifer water for possible changes in aquifer characteristics due to hydrogeologic or hydrogeochemical changes.

Agency Review

Once a completed application for a Limited License is received by Oregon Water Resources Department (WRD) almost five months must be allowed for in the schedule. By rule, WRD has 45 days to consult with the Health Division and Department of

Environmental Quality about the completeness of the application. It then has 7 days to provide public notice of the request for the License. A 30 day public comment period follows posting of the public notice. WRD then has 60 days within which to prepare a final order with conditions on the License. The public notice period is expanded to 60 days, and upon issuance of the final order with the permit, there is a 45-day protest period within which anyone objecting to the permit may file. Even prior to issuing a final order, the application can be sent to the Water Resources Commission for review. While no protests or significant policy concerns requiring Commission attention are anticipated on the application, it is not possible to assume that none will materialize.

Modifications to Pump for Pilot Testing

In its current state, Well No. 1 cannot be used for the Pilot test without costly repairs. In order to meet the State standards for well construction, the well casing would need a sleeve to repair the leak, thus reducing the size of the columns and pump. In turn, the production of the well would be decreased significantly.

To conduct the Pilot Test, a new well should be drilled on the Well No. 1 site. A 12-inch well would allow a larger pump, thus allowing greater recharge and withdrawal rates. The new well would be equipped with a pump allowing recharge water to be introduced, monitor the progress of the testing, and dispose of the recovered water. Specifically, these features include : a pump designed to rotate in reverse as may occur during recharge; disabling of check valves; installation of a water level monitoring port and sounding tube; installation of 2-way flowmeters and other meters as needed; installation of a pump-to-waste connection or other means to dispose of the recovered water, and other considerations. The existing well will be converted to a monitoring well with minor modifications.

Modifications to Distribution System for Pilot Testing

The existing distribution system allows for the delivery of groundwater from the City's wells. With the construction of a new well at Well No. 1 site, new piping will be needed to connect to the distribution system and reservoirs for the Pilot Test and long-term operation of ASR. The new well will be located on the opposite end of the building where the existing well is located. Connection to the system can be readily accomplished with minor modifications.

Water Rights

Since the City does not hold any surface water rights to any of three potential sources, a water right holder agreement will be needed from the appropriate water provider(s) as part of the ASR permit application. The agreement must indicate permission for use of the water for ASR testing. Early contact with potential source water providers will be required to facilitate this permitting process.

Monitoring

Close coordination with the Oregon Health Department will be required to ensure that all water quality standards are being met. Additional or increased frequency of water quality monitoring may be required during the Pilot Test and initial ASR operation. Once the City has demonstrated that the withdrawn water meets all drinking water standards, the OHD may reduce these monitoring requirements.

Schedule

The anticipated schedule for the injection phases of cycle testing would occur during the winter of 2001/2002. This is ideal from the perspective of availability of source water for injection. Surplus water is available during these months and can be utilized for the Pilot Test. Figure 9 shows the schedule for the Pilot Test Plan.

Assuming there are no delays in the Pilot Test, initial delivery of ASR water to customers would occur in the summer of 2002. The period for the Limited License will be at least two years and is recommended to be the five year maximum to allow operation of the ASR system by the summer of 2002 regardless of the status of ongoing ASR permitting. While the ASR system is operating and serving water under the terms of the Limited License, the long-term ASR permit can be obtained.

Cost Estimate

Based on findings from the Feasibility Study, estimated costs were prepared for the Pilot Phase. Costs include the conversion of Well No. 1 to a monitoring well, drilling of a new well on the same site and associated piping, equipment and housing costs. Table 5.1 lists the costs included in Phase II – Pilot Test.

Section 6

Section 6

MONTGOMERY WATSON

SECTION 6 PHASE III – FULL-SCALE IMPLEMENTATION

Objectives

Full-scale implementation will be accomplished under the terms of an ASR permit. The goals of Phase III are to develop and implement a plan for full-scale implementation based upon hyrdogeologic requirements identified in the Feasibility Report and Pilot Test Plan and the water supply needs of the City. The findings of this report indicate that a total of 10 wells will be needed to achieve the 4-6 mgd scheme. The City has expressed a desire to complete the full-scale implementation within a 10 year period.

ASR Permit

Based on the results of Pilot testing, a permit application from WRD for full-scale operation will be prepared. It is assumed that this application will be submitted while the ASR system is operated under the terms of the Limited License. A formal preapplication conference will be held with WRD to review application requirements as required under WRD rules. The application will contain all information required under OAR 690-350-030. These requirements are similar to those for the Limited License Application.

Agency Review

Once received by WRD, the agency has 45 days to review the application for completeness. DEQ and the OHD are provided opportunity to review the application. Once deemed complete, WRD will notify the City that the application is complete. Within 7 days of this notification, a public notice is released by WRD commencing a 60-day comment period. After this 60 day comment period, the WRD will issue a proposed final order on the application. The City will be notified of the final order. Certain conditions may be placed on the ASR permit including the maximum allowable injection rate, storage volume and duration and the maximum allowable recovery rate.

Schedule for Implementation

Once the initial Pilot testing is complete and the Pilot Test Report is written, application for the ASR permit can be made. Assuming there are no delays in the Pilot Test, application could be made as early as the fall of 2002. Based on the City's desire to achieve full-scale production within 10 years an incremental approach is recommended. Specifially, the Pilot test well would be converted to a full-scale ASR well followed by an additional well at that site. Subsequently, two wells could be drilled every 2-3 years until the system is fully developed. Assuming the permit is obtained without delay, the first stage of the full-scale scheme could begin in the early part of 2003. Figure 8 shows the recommended schedule for full-scale implementation. This approach is recommended for several reasons. First, the boundaries of the aquifer are uncertain at this time.

Development of each well will help determine these boundaries with little risk to the City. Secondly, the flow characteristics of the aquifer can differ within short distances, thus producing different yields. This was evidenced in the Salem, Oregon ASR well field. An incremental approach allows the City to utilize ASR to their specific needs at that particular time. Should the City's contracts with the City of Portland change drastically, the City may decide to limit the need for ASR production. Finally, this approach will allow the City to implement the project without a large upfront investment.

Integration with Existing System

Based on the City's desire to utilize ASR as a constant source supply, ASR can be developed with minor modifications to its existing distribution system. Dedicated ASR wells will require connection to the system. Initial review of the City's current properties indicates that parcels close to major distribution pipelines are available for development of ASR wells.

Well Locations and Capacities

Feasibility Study investigations indicate that 7 to 10 wells could be needed in order to achieve the 4-6 mgd ASR production. Assuming Well No. 1 is converted to a monitoring well (as recommended), and a new well is drilled to replace it, only Well No. 2 could potentially be used for long-term ASR. Wells No. 3 and 4 were ruled out due to potentially poor ASR production capacity, inaccessibility to repair or replace the pump and uncertainties with regard to future property ownership. The existing Well No. 2 could be equipped with a larger pump, thus allowing greater injection and withdrawal rates.

In addition to the existing wells, it is recommended that new ASR wells be drilled at sites throughout the City. These wells should be developed across the service area such that each well site is limited to a maximum of two ASR wells, unless indicated otherwise via pilot testing. Widespread spacing of ASR wells will reduce interference effects and will minimize the risk to the system in the event of potential groundwater contamination. Figure 7 shows the potential and possible ASR well sites. Sites are located in close proximity to the City's existing distribution system and where possible are on City-owned property, or on property that is owned by other public agencies amenable to well siting. The number of sites listed provides for some redundancy in the event that the preferred sites are unavailable. Potential sites are those that have the greatest likelihood of success for ASR. Possible ASR sites may have reduced well yields and/or storage volumes may be lower because of less favorable hydrogeological conditions. ASR well capacities during pumping are expected to range from 400 to 800 gpm. Testing will be required at each well site to determine well yields.

Recharge Water

Similar to the Pilot Test, multiple source waters from the City's suppliers could be used for ASR. Because the City does not hold any water rights to these sources, a water right agreement will be required. Water used for ASR recharge may come from one or more of the following surface water sources available to the City:

- Clackamas River via Lake Oswego (or South Fork Water Board),
- Bull Run River via the City of Portland; or
- Trask-Tualatin River via the Joint Water Commission.

This situation could change in the future as long-term supply decisions are solidified.

Monitoring

Increased water quality monitoring or frequency of monitoring may be required to account for water injected and withdrawn from the aquifer. This will be determined once Phase II is complete. Monitoring of water levels in the ASR wells and other local wells will be required to demonstrate the effects of the system on local groundwater levels. Existing wells should primarily be used for this purpose such as the monitoring wells that would be installed in Wells No. 1, 3 and 4, and irrigation wells at local schools and golf courses.

Cost Estimate for Full Scale System

Cost estimates for Full Scale ASR development and implementation are listed in Table 6.1. Cost estimates were calculated based on the following assumptions:

- Ultimate ASR production is 4-6 mgd from 10 ASR wells.
- The 10 ASR wells consist of:
  - The Pilot Test well at Well site No.1;
  - Modifications to Well No. 2 and
  - Eight new ASR wells developed over a 10 year period.
- Land acquisition is not included.
- Full-scale implementation will occur in five stages over a 10 year period.

If fewer wells are needed to achieve system goals, the cost of the full program will be reduced.

TABLE 6.1 PHASE III COST ESTIMATE

Description	Costs
PERMITTING	**$ 17,000**
STAGE 1 - DEVELOP SECOND WELL AT WELL NO. 1 SITE	
NEW WELL CONSTRUCTION COSTS (PER WELL)	
Drill new well (12 in.)	$ 80,000
Pump and installation (1000 gpm Vertical Turbine w/reverse ratchet)	$ 55,000
Pump House	$ 45,000
Electrical	$ 20,000
Infrastructure	
Flowmeter	$ 4,000
PRV/check valve	$ 3,300
Back Pressure valve	$ 2,600
Pump Control Valve	$ 3,000
Valves/Fittings	$ 8,000
SCADA	$ 8,000
Dip Tube	$ 500
Pressure Transducer	$ 3,000
Chlorination system	$ 3,500
Subtotal	**$ 235,900**
Professional Services	
Hydrogeological oversite - includes pump test analysis	$ 15,000
Water quality testing	$ 3,000
Engineering Services	$ 35,500
Subtotal	**$ 53,500**
Contingency(20%)	**$ 57,900**
TOTAL	**$ 347,300**
IMPLEMENTATION, OPERATION AND MONITORING	**$ 6,400**
STAGE 1 TOTAL	***$ 370,700***
STAGE 2 - DEVELOP SECOND WELL AT WELL NO. 2	
MODIFICATIONS TO WELL NO. 2	**$ 50,000**
NEW WELL CONSTRUCTION COSTS	**$ 347,300**
IMPLEMENTATION, OPERATION AND MONITORING	**$ 6,400**
STAGE 2 TOTAL	***$ 403,700***
STAGE 3 - DEVELOP TWO WELLS	
NEW WELL CONSTRUCTION COSTS ($347,300 PER WELL)	**$ 694,600**
IMPLEMENTATION, OPERATION AND MONITORING	**$ 6,400**
STAGE 3 TOTAL	***$ 701,000***
STAGE 4 - DEVELOP TWO WELLS	
NEW WELL CONSTRUCTION COSTS ($347,300 PER WELL)	**$ 694,600**
IMPLEMENTATION, OPERATION AND MONITORING	**$ 6,400**
STAGE 4 TOTAL	***$ 701,000***
STAGE 5 - DEVELOP TWO WELLS	
NEW WELL CONSTRUCTION COSTS ($347,300 PER WELL)	**$ 694,600**
IMPLEMENTATION, OPERATION AND MONITORING	**$ 6,400**
STAGE 5 TOTAL	***$ 701,000***
GRAND TOTAL	**$ 2,877,400**

Section 7

Section 7

MONTGOMERY WATSON

SECTION 7 CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

The City wishes to utilize ASR for both short-term and long-term needs utilizing its existing wells and water supplies. The Feasibility Study investigated the potential of ASR to meet these requirements. An evaluation of the City's wells indicate that Well No. 1 is most suitable for use as an ASR pilot test well. Hydrogeological investigations were conducted at Well No.1 to characterize the aquifer and groundwater quality. These initial investigations revealed the following about the aquifer in the vicinity of Well No. 1:

- There is sufficient storage capacity within the unconfined basalt beneath Bull Mountain to enable development of an ASR scheme that is capable of producing up to 6 mgd for periods of up to 8 months;
- Construction and operation of 1,000 gpm (Bull Mountain basalt) injection wells is feasible;
- Assuming a 4 month injection period, 1 to 2 such wells would be required to enable development of a 1 mgd to 1.5 mgd scheme capable of being used to provide a peaking supply for periods of up to 4 months;
- To enable the development of a 4 to 6 mgd scheme capable of being used for up to 8 months, 7 to 10 wells would be required
- ASR wells should be developed incrementally over a 10 year period.
- It is likely that the recovery of the injected water could be achieved using fewer wells than are required for the injection;
- There is expected to be no adverse water quality impacts associated with injection of treated surface waters into the basalt;
- Potential impacts associated with the development of an ASR scheme are likely to include a water level rise in other basalt wells on Bull Mountain. Other potential impacts may include an increase in spring discharge on the slopes of Bull Mountain.
- The effects of large-scale water level changes (increases and decreases) on individual well performance require additional monitoring of water levels.
- If additional monitoring of water levels show little change in the draw-down, alternative methods may be imposed as part of the permit conditions required to account for the withdrawn water.

In summary, the results of the Feasibility Study indicate there are no fatal flaws for ASR development in the City of Tigard. It should be recognized, however, that the assessment is subject to some uncertainty. At this time, the boundaries of the aquifer are unknown and require further study to determine their influence on the storage of recharged water. Resolution of the uncertainty in the aquifer boundary conditions is recommended to confirm storage volumes, injection and recovery rates, groundwater level changes and effects on springs and streams.

RECOMMENDATIONS

The following is recommended:

- Before Wells No. 1 and 2 are used this summer, the well-heads should be modified to enable a water level meter to be used to monitor the water levels;
- In the period prior to the use of the wells, water levels in all of the City's wells should be monitored on a weekly basis;
- Arrangements to access the Tigard High School and James Templeton Elementary School wells for monitoring purposes should be put into place prior to the use of the Tigard wells;
- Consultant should be notified prior to the use of the Tigard wells so that consultant staff can be in attendance at the start up of the pumps to record (valuable) early time test data;
- During summer use of the Tigard wells, water level measurements should be taken in both the City's wells and adjacent observation wells. Pumping rates should be noted for all wells. Measurements should be taken daily throughout the summer;
- At this stage it appears feasible to develop an ASR scheme using the Bull Mountain basalt. As such the City should proceed with the development and implementation of a pilot test plan;
- In view of the poor condition of Well No. 1 casing, a new test well should be constructed at the Canterbury Lane site and the existing well should be converted to a multi-level monitoring well for pilot testing.
- Once additional monitoring is complete, the City should confirm how ASR fits in its water supply strategy and identify its role in both short-term and long-term planning. At this time, the City should proceed with the level of ASR that is commensurate with its needs.
- Develop and implement the proposed ASR scheme incrementally over 10 years to achieve the 4-6 mgd scheme by 2013.

References

References

MONTGOMERY WATSON

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Appendices

MONTGOMERY WATSON

Appendix A

MONTGOMERY WATSON

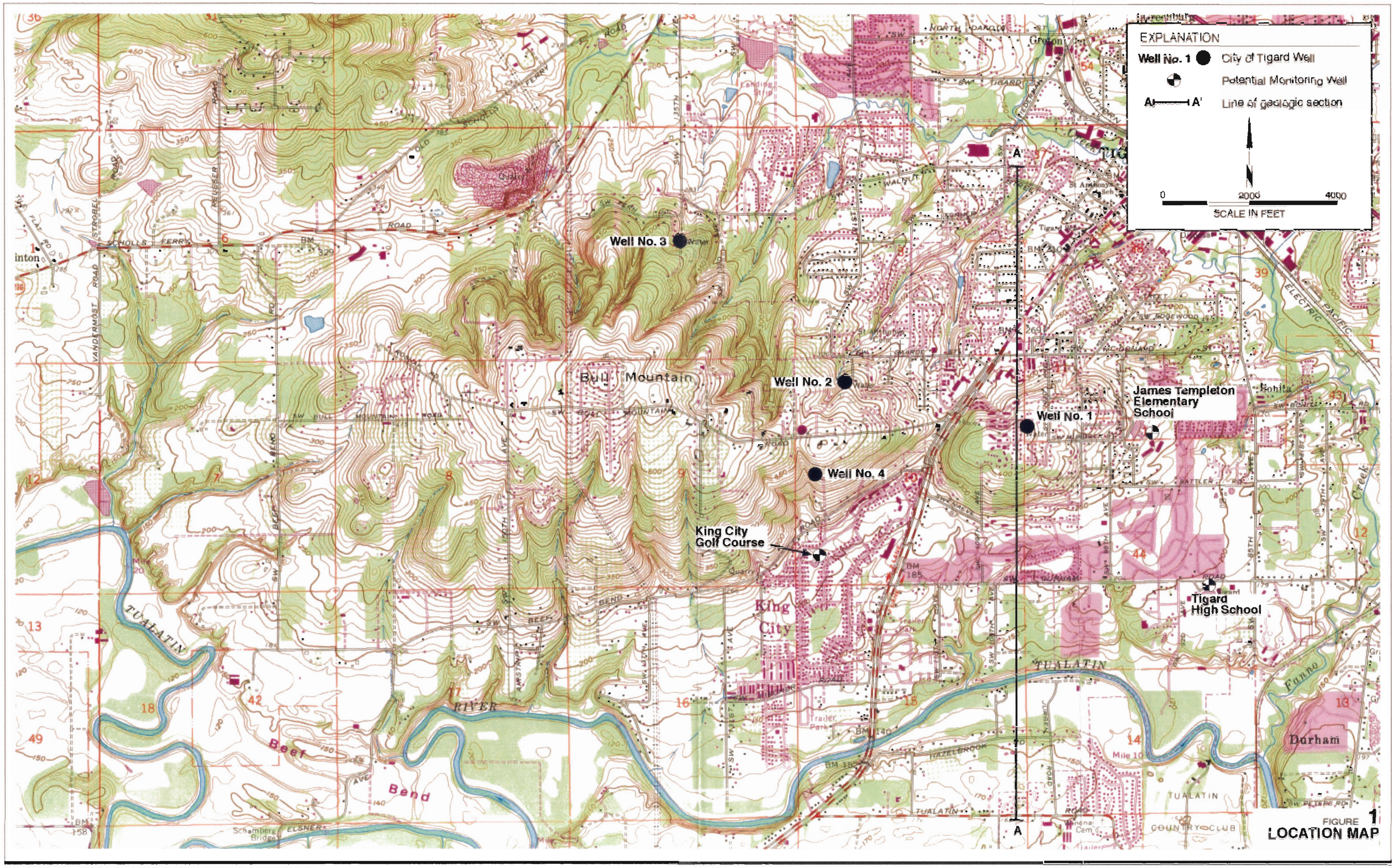


FIGURE 1
LOCATION MAP

PROJECT NO 013 1419.008 DRAWING NO 94621 DATE 04/28/01 DRAWN BY JSR

Golder Associates

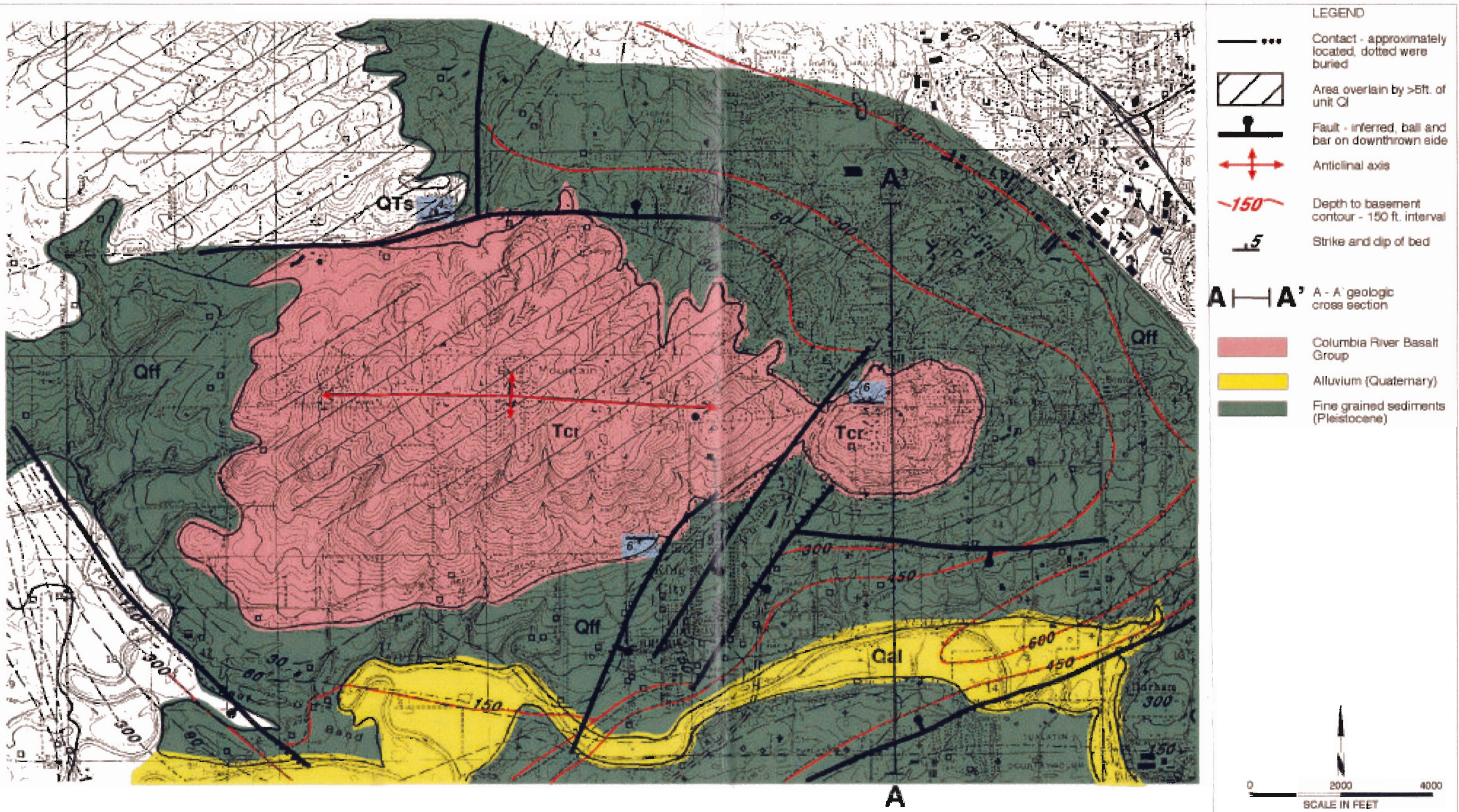


FIGURE **2**

GEOLOGIC PLAN

MW/TIGARD/OR

PROJECT NO 013 1418.008 DRAWING NO 94008 DATE 04/30/01 DRAWN BY JSR

Golder Associates

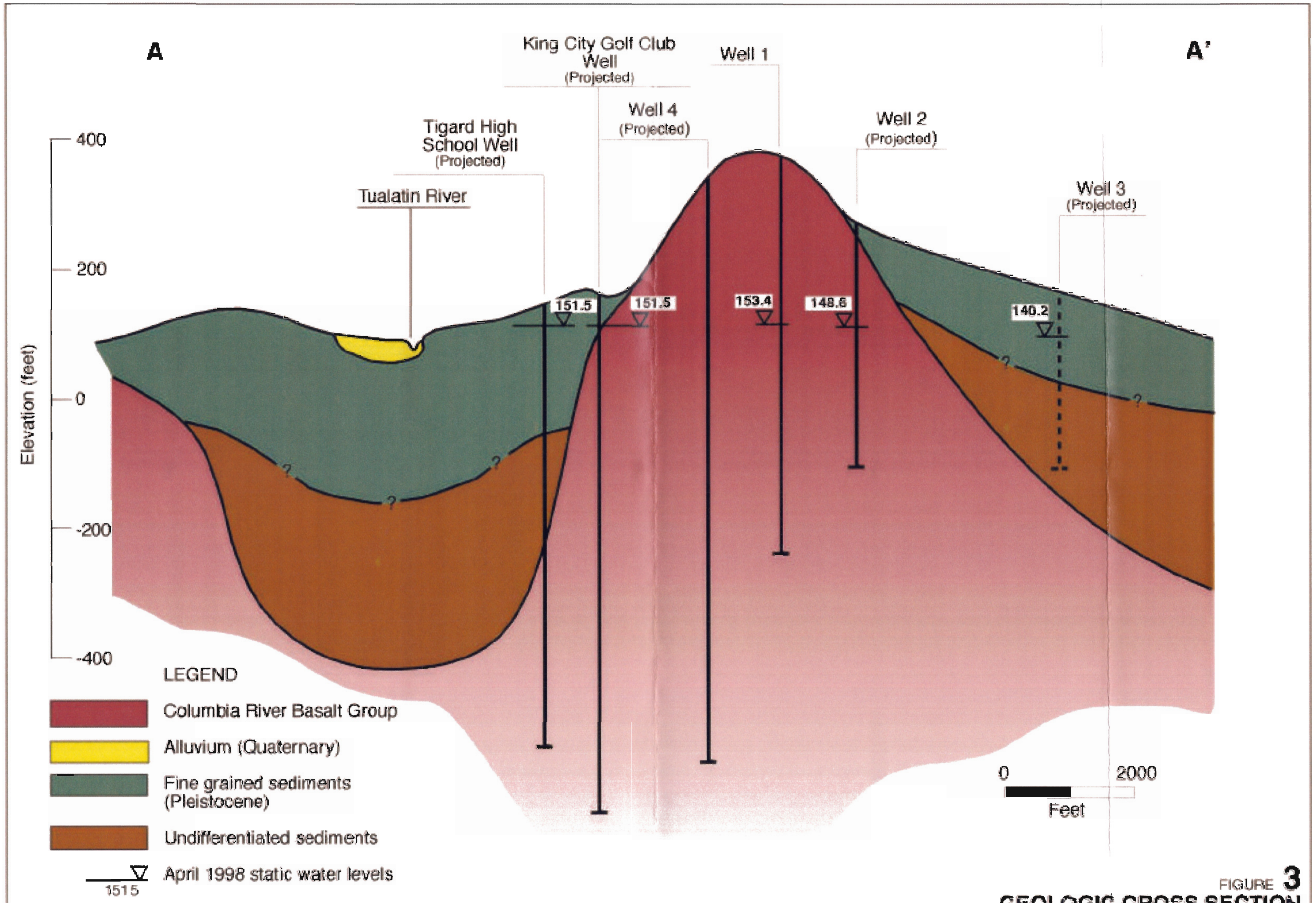


FIGURE **3**

GEOLOGIC CROSS SECTION

MW/TIGARD/OR

PROJECT NO.013 1419.008 DRAWING NO. 94605 DATE 04/30/01 DRAWN BY JSR

Golder Associates

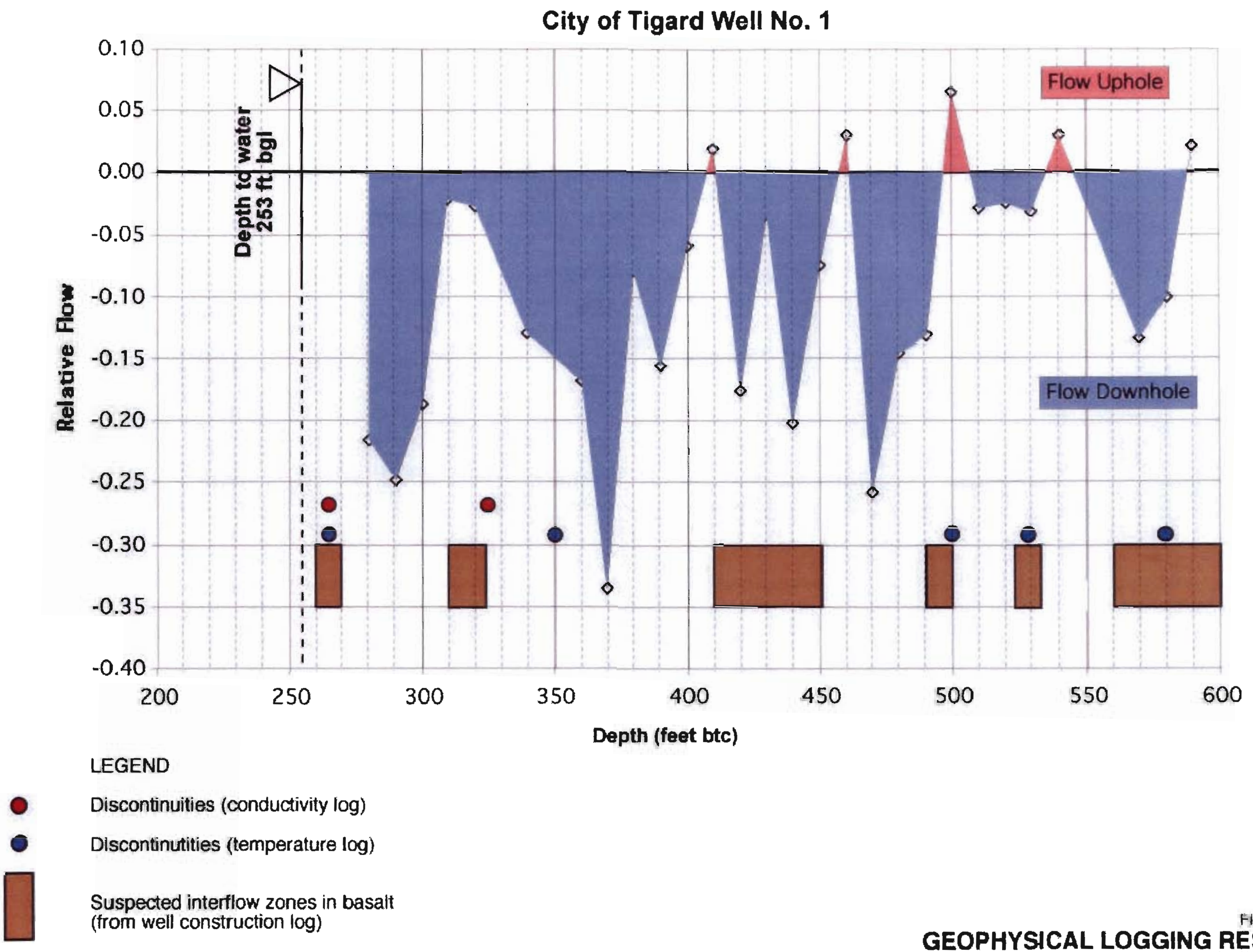


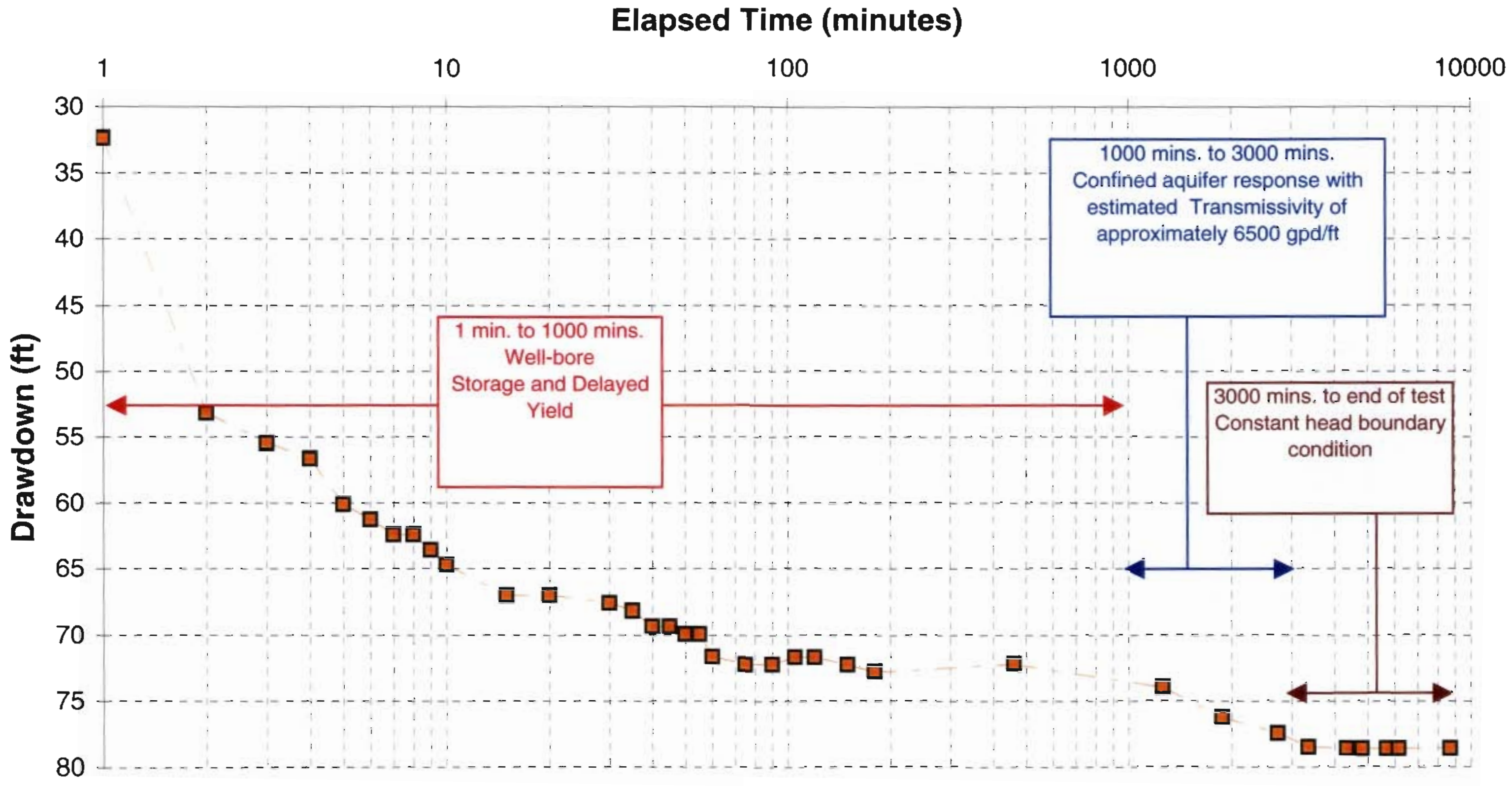
FIGURE **4**

GEOPHYSICAL LOGGING RESULTS

MW/TIGARD/OR

PROJECT NO 013 1419.008 DRAWING NO 94607 DATE 04/28/01 DRAWN BY JSR

Golder Associates



City of Tigard Well No. 1 Aquifer Test

Average Production Rate 310 gpm

Test conducted from 3/31/2001 to 4/6/2001

013-1419, 04/04/2001, Data Plot01.xls

Figure 5. Constant Rate Test Data Interpretation

Montgomery Watson
City of Tigard ASR

Golder Associates

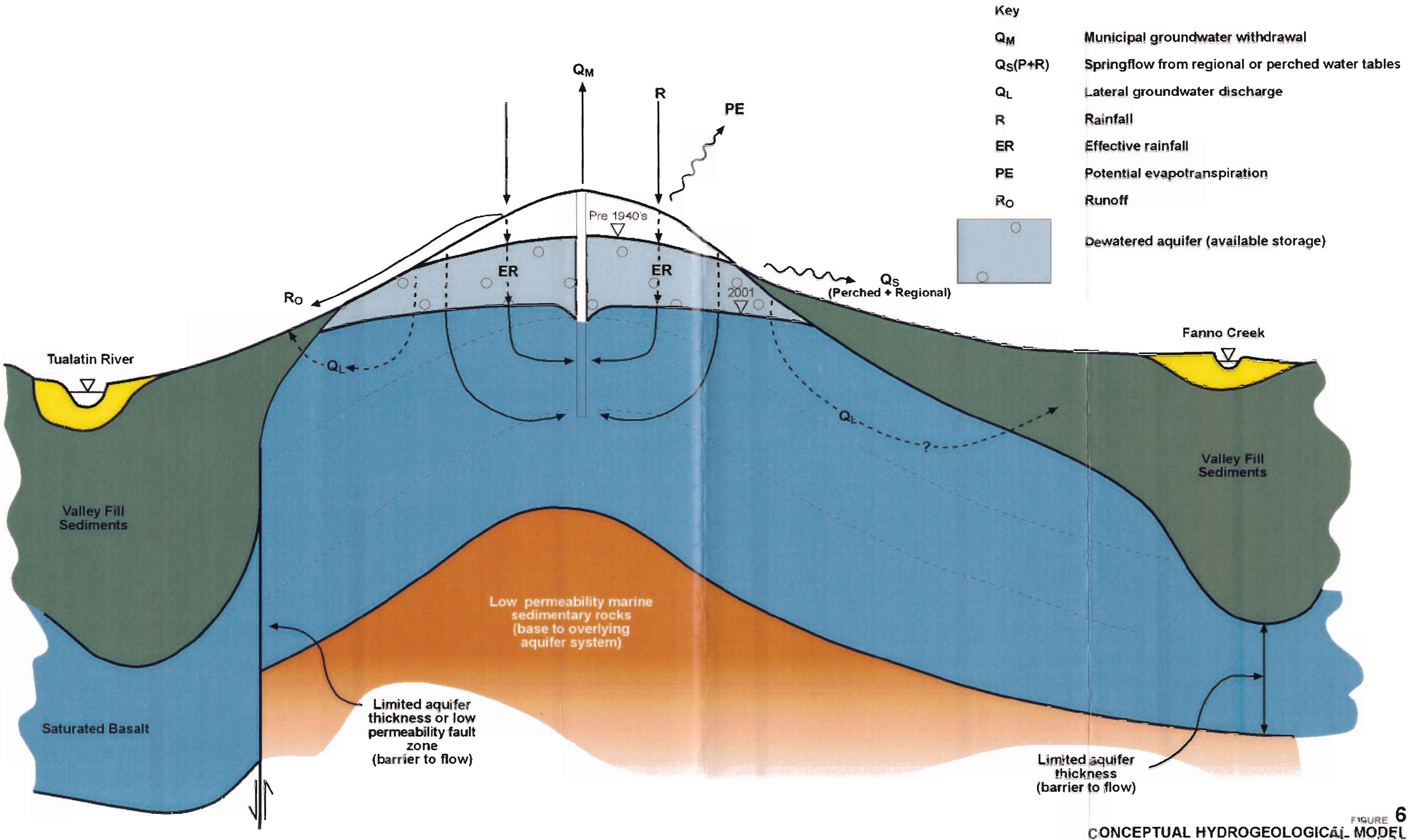


FIGURE 6

CONCEPTUAL HYDROGEOLOGICAL MODEL

MW/TIGARD/OR

PROJECT NO 013 1419 008 DRAWING NO 94622 DATE 04/29/01 DRAWN BY JSR

Golder Associates

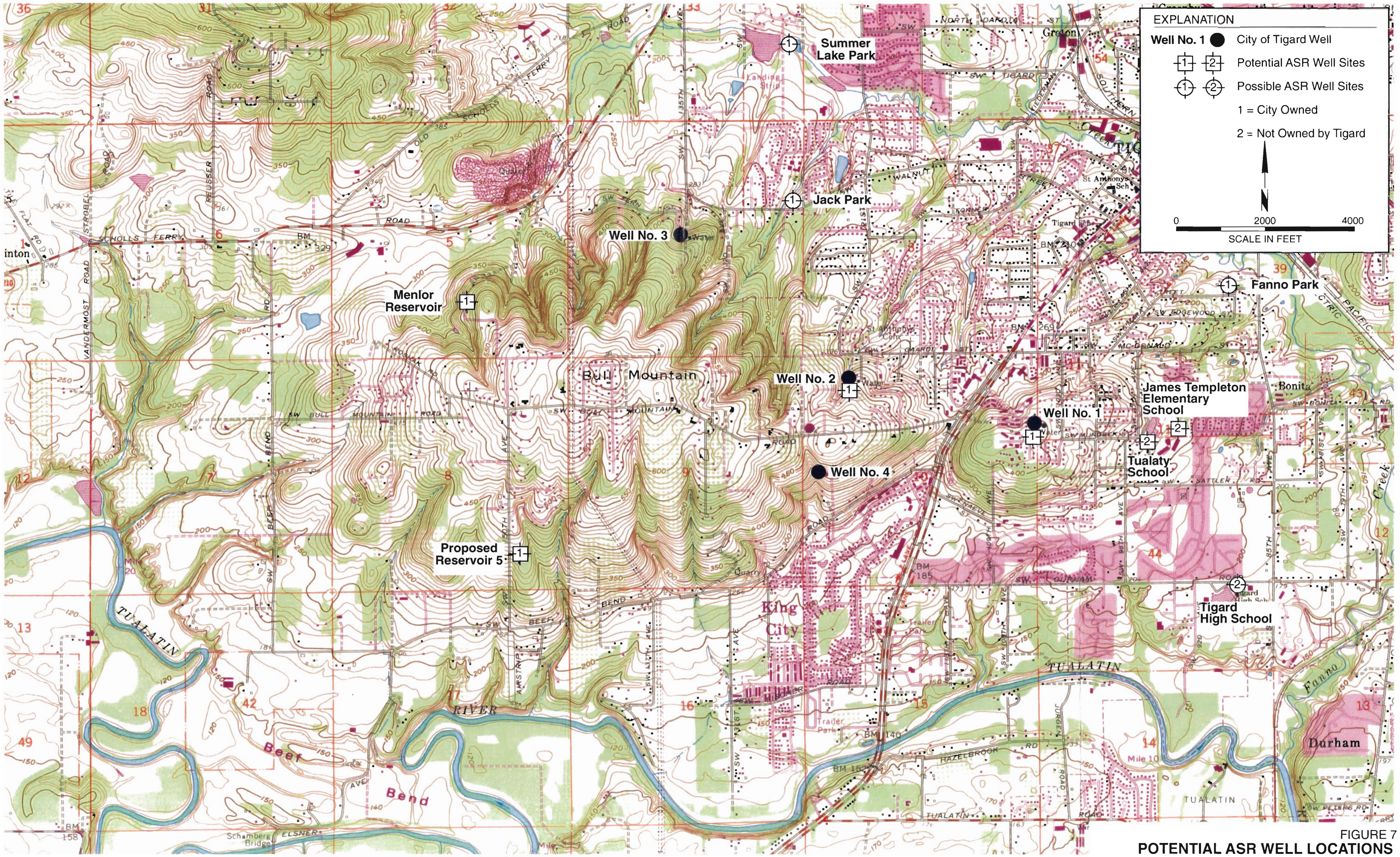


FIGURE 7
POTENTIAL ASR WELL LOCATIONS

PROJECT NO 013 1419 008 DRAWING NO 94657 DATE 05-24/01 DRAWN BY JSR

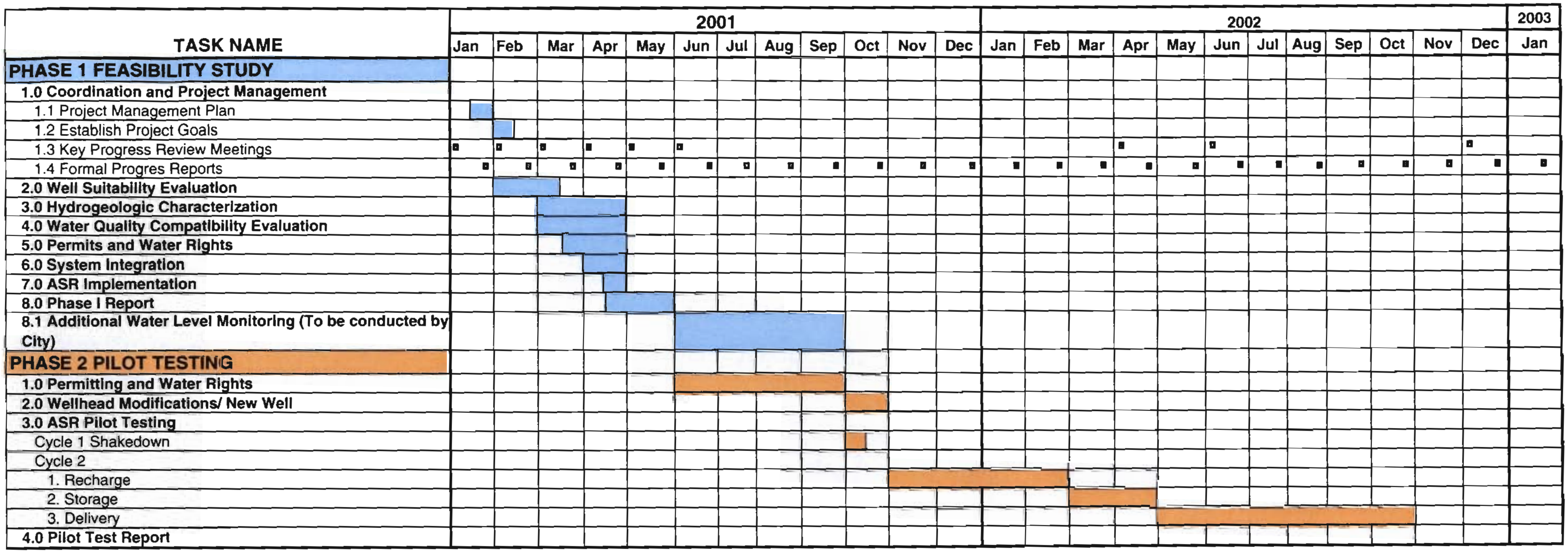
Golder Associates

FIGURE 8
Proposed ASR Development Schedule

TASK NAME	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
PHASE II- PILOT TEST	🟧	🟧											
ESTIMATED COSTS	$	579,940											
PHASE 3 FULL SCALE ASR IMPLEMENTATION													
PERMITTING		🟨	🟨										
STAGE 1 - Convert Pilot Well to ASR Well and develop second ASR well on Canterbury site			1-1.5 mgd										
ESTIMATED CIP COSTS			$370,000										
ESTIMATED COSTS TO PURCHASE WATER FOR ASR (1.5 mgd)			$120,321										
STAGE 2 - Modify Existing Well No. 2 and develop second ASR well at site					1.5-2.5 mgd								
ESTIAMTED COSTS					$ 404,000								
ESTIMATED COSTS TO PURCHASE WATER FOR ASR (2.5 mgd)					$ 200,535								
STAGE 3 - Install two wells at appropriate site							2.5-4 mgd						
ESTIMATED COSTS							$701,000						
ESTIMATED COSTS TO PURCHASE WATER FOR ASR (4 mgd)							$320,856						
STAGE 4 - Install two wells at appropriate site									4-5 mgd				
ESTIMATED COSTS									$701,000				
ESTIMATED COSTS TO PURCHASE WATER FOR ASR (5 mgd)									$401,070				
STAGE 5 - Install two wells at appropriate site												5-6 mgd	
ESTIMATED COSTS											$		701,000
ESTIMATED COSTS TO PURCHASE WATER FOR ASR (6 mgd)											$		481,283

All costs are based on 2001 numbers. Costs to purchase water are based on 0.91/cfs from JWC

FIGURE 9
ASR Pilot Project
Schedule



TASK NAME	2001												2002												2003
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan
PHASE 1 FEASIBILITY STUDY																									
1.0 Coordination and Project Management																									
1.1 Project Management Plan	🟦																								
1.2 Establish Project Goals		🟦																							
1.3 Key Progress Review Meetings	■	■	■	■	■	■										■		■						■	
1.4 Formal Progres Reports	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
2.0 Well Suitability Evaluation		🟦	🟦																						
3.0 Hydrogeologic Characterization			🟦	🟦																					
4.0 Water Quality Compatibility Evaluation			🟦	🟦																					
5.0 Permits and Water Rights			🟦	🟦																					
6.0 System Integration				🟦																					
7.0 ASR Implementation				🟦																					
8.0 Phase I Report				🟦	🟦																				
8.1 Additional Water Level Monitoring (To be conducted by City)						🟦	🟦	🟦	🟦																
PHASE 2 PILOT TESTING																									
1.0 Permitting and Water Rights						🟧	🟧	🟧	🟧																
2.0 Wellhead Modifications/ New Well										🟧															
3.0 ASR Pilot Testing																									
Cycle 1 Shakedown										🟧															
Cycle 2																									
1. Recharge											🟧	🟧	🟧	🟧											
2. Storage															🟧	🟧									
3. Delivery																	🟧	🟧	🟧	🟧	🟧	🟧			
4.0 Pilot Test Report																									

Appendix B

Appendix B

MONTGOMERY WATSON

Permit A-2—2M—5/77 SP*32957-890

STATE OF OREGON

COUNTY OF WASHINGTON

CERTIFICATE OF WATER RIGHT

This Is to Certify, *That* TIGARD WATER DISTRICT

of 8841 S.W. Commercial St., Tigard , *State of* Oregon, 97223 , *has made proof to the satisfaction of the Water Resources Director, of a right to the use of the waters of* a well

a tributary of Fanno Creek *for the purpose of* municipal

under Permit No. G-3270 *and that said right to the use of said waters has been perfected in accordance with the laws of Oregon; that the priority of the right hereby confirmed dates from* April 25, 1966 *that the amount of water to which such right is entitled and hereby confirmed, for the purposes aforesaid, is limited to an amount actually beneficially used for said purposes, and shall not exceed* 0.67 cubic foot per second

or its equivalent in case of rotation, measured at the point of diversion from the stream. The point of diversion is located in the Lot 2 (SW¼ NW¼), Section 11, T. 2 S., R. 1 W., W. M., 1625 feet South and 30 feet East from the NW Corner, Section 11

The amount of water used for irrigation, together with the amount secured under any other right existing for the same lands, shall be limited to ------------ *of one cubic foot per second per acre,*

and shall conform to such reasonable rotation system as may be ordered by the proper state officer.

A description of the place of use under the right hereby confirmed, and to which such right is appurtenant, is as follows:

SEE NEXT PAGE

STATE OF OREGON }
County of Washington } ss

I, Roger Thomssen, Director of Records and Elections and Ex-Officio Recorder of Conveyances for said county, do hereby certify that the within instrument of writing was received and recorded in book of records.

No. Book No. 5, Page No. 467 of said County.

Witness my hand and seal affixed.

ROGER THOMSSEN, Director of Records & Elections

Oct. 18, 1978 @ 3:20 PM

Deputy

Permit A-2—2M—3/77 SP*32957-690

STATE OF OREGON

COUNTY OF WASHINGTON

CERTIFICATE OF WATER RIGHT

This Is to Certify, *That* TIGARD WATER DISTRICT

of 8841 S.W. Commercial St., Tigard , *State of* Oregon, 97223 , *has made proof to the satisfaction of the Water Resources Director, of a right to the use of the waters of* a well

a tributary of Fanno Creek *for the purpose of* municipal

under Permit No. G-2999 *and that said right to the use of said waters has been perfected in accordance with the laws of Oregon; that the priority of the right hereby confirmed dates from* November 19, 1965
that the amount of water to which such right is entitled and hereby confirmed, for the purposes aforesaid, is limited to an amount actually beneficially used for said purposes, and shall not exceed 0.63 cubic foot per second

or its equivalent in case of rotation, measured at the point of diversion from the stream. The point of diversion is located in the NW¼ SW¼, Section 10, T. 2 S., R. 1 W., W. M., 25 feet South and 500 feet East from the W¼ Corner, Section 10

The amount of water used for irrigation, together with the amount secured under any other right existing for the same lands, shall be limited to ------------- *of one cubic foot per second per acre,*

and shall conform to such reasonable rotation system as may be ordered by the proper state officer.

A description of the place of use under the right hereby confirmed, and to which such right is appurtenant, is as follows:

SEE NEXT PAGE

STATE OF OREGON }
County of Washington } ss

I, Roger Thomssen, Director of Records and Elections and Ex-Officio Recorder of Conveyances for said county, do hereby certify that the within instrument of writing was received and recorded in book of records.

No. Book No. 5, Page No. 465
of said County.

Witness my hand and seal affixed.

ROGER THOMSSEN, Director
of Records & Elections

Oct. 18, 1978 @ 3:20 PM

Deputy

Abstract of Ground Water Registration

Registration No. GR-615 *Certificate No.* GR-587

Name Tigard Water District
By C. E. Janoe, Chairman, Board of Commissioners

Address 8900 S. W. Burnham Avenue
Tigard, Oregon

Source of water supply Pump well #2

Use Municipal

Point of diversion S. 610 ft. and E. 1270 ft. from NW corner of Sec. 10 being within NW¼ NW¼, Sec. 10, T. 2 S., R. 1 W., W.M. in the county of Washington. south of SW Gaarde St

Number of acres

DESCRIPTION OF LAND TO BE IRRIGATED OR PLACE OF USE

Twp	Range	Sec.	NE¼				NW¼				SW¼				SE¼			
			NE¼	NW¼	SW¼	SE¼	NE¼	NW¼	SW¼	SE¼	NE¼	NW¼	SW¼	SE¼	NE¼	NW¼	SW¼	SE¼
1 S	1 W	34									X	X	X	X	X	X	X	X
2 S	1 W	2	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
2 S	1 W	3	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
2 S	1 W	9	X	X	X	X	X	X	X	X								
2 S	1 W	10	X	X	X	X	X	X	X	X								
2 S	1 W	11	X	X	X	X	X	X	X	X								

Priority date 1949

Amount of water claimed 500 g.p.m.

Time limit to completely apply water completed *extended to* *extended to*

Remarks: Tigard Well No. 1 being registered.

Basin 2, Vol.

Registration No. GR-615

Certificate No. GR 587

Registration Statement

OF CLAIMANT OF RIGHT TO APPROPRIATE GROUND WATER

TO THE STATE ENGINEER OF OREGON:

Re: Tigard Well No. 2

TIGARD WATER DISTRICT
I, By C. E. JANOE, Chairman, Board of Commissioners

of 8900 S.W. Burnham Ave., Tigard (Mailing address) County of Washington

State of Oregon, do hereby make application for a certificate of registration as evidence of a right to appropriate ground water.

1. Source from which water is withdrawn is pump well #2 (Flowing well, pump well, infiltration trench, or tunnel)

2. Location is: 1½ miles southwest of Tigard, Oregon (Approximate distance and direction from nearest city or town)

and is more particularly described as follows:

(a) South 610 ft. and East 1270 ft. from NW corner of Section 10 (Give distance and bearing to corner of section or other legal subdivision)

being within NW¼ NW¼ (Smallest legal subdivision) of Sec. 10, Twp. 2 S. (N. or S.), Rge. 1 W. (E. or W.)

or (b) within limits of recorded platted property, town or city:

in Lot ______, Block ______ of ______ (Name of plat or addition)

______ (If within city or town, give name) County of ______

3. Construction Work was begun on 1949 (Date); was completed on July 30, ~~1957~~ 1949 Est. (Date)

and the ground water claimed was first used for the purposes set out below on September, 1949 (Date)

since which time the water has been used continuously (Continuously or intermittently)

from Sept., 1949 (Date) to Sept., 1957 (Date)

4. Quantity of water claimed and used is 600 gallons per minute; ______ acre feet per year.

5. Purpose or Purposes for which water is used municipal

(Domestic, irrigation, municipal, manufacturing, industrial, etc.)

6. Description of Well: Depth 453 feet. Type Drilled (Dug or drilled)

diameter 12 inches. Elevation of ground at well site ~~400~~ 375' (As near as known) feet, mean sea level.

Depth to water table 190 feet.

7. Capacity of Well: 325 g.p.m. with 72 feet drawdown.

400 g.p.m. with 90 feet drawdown.

Pumped 700 gpm for 24 hrs.

Date of test July, 1949

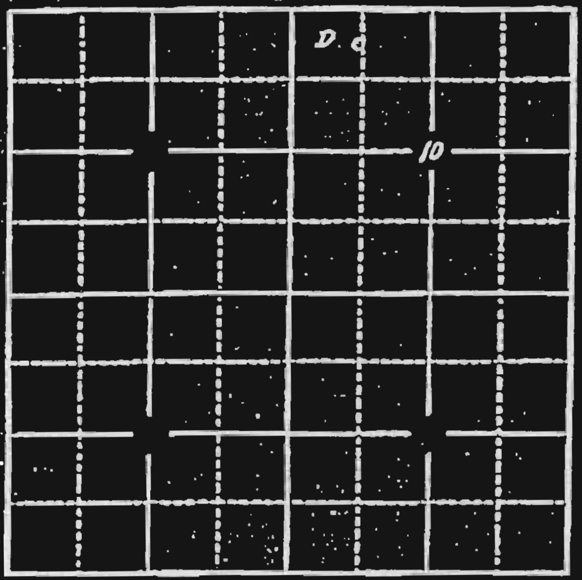
If Flowing Well: Measured discharge ______ g.p.m. on ______ (Date)

Shut-in pressure at ground surface ______ lbs. per sq. in. on ______ (Date)

Water is controlled by ______ (Cap, valves, etc.)

Township 2S Range 1W W.M.

North



Locate well and acreage of irrigated land on plat.

Scale: 2" — 1 Mile

STATE OF OREGON }
County of Washington } ss.

I, C. E. JANOE, being first duly sworn, do hereby certify that I have read the foregoing Registration Statement and that all of the items therein contained are true to the best of my knowledge and belief.

C. E. Jones
(Signature of Registrant)
Chairman
Board of Commissioners

Subscribed and sworn to before me this 9th day of September, 1957

My commission expires Feb 7, 1960 Lee L. Anderson
(Notary Public)

(SEAL)

CERTIFICATE OF REGISTRATION

STATE OF OREGON }
County of Marion } ss.

This is to certify that the foregoing Registration Statement was received in the office of the State Engineer on the 16th day of September, 19 57, at 8:00 o'clock A. M. and has been duly recorded in said office in Book No. 1 of Registration Statements on page GR-507 C

Witness my hand this 16th day of October, 19 57.

Lewis A. Stanley
(State Engineer)

By
(Deputy)

22^{00}

Map in File

Abstract of Permit No. G-655

Application No. G-760 *Certificate No.* 28971

Name Tigard Water District

Address 8841 S. W. Commercial
Tigard 23, Oregon

Source of water supply Tigard Well #3, a trib. of Fanno Creek (Tualatin River)

Use Municipal

Point of diversion Well No. 3: 25' N. and 50' E. from the center of Section 4, being within the SW¼ NE¼ Section 4, T. 2 S., R. 1 W., W.M., in the county of Washington.

Number of acres

East of 135th

DESCRIPTION OF LAND TO BE IRRIGATED OR PLACE OF USE

Twp.	Range	Sec.	NE¼				NW¼				SW¼				SE¼			
			NE¼	NW¼	SW¼	SE¼	NE¼	NW¼	SW¼	SE¼	NE¼	NW¼	SW¼	SE¼	NE¼	NW¼	SW¼	SE¼
1S	1W	34									x	x	x	x	x	x	x	x
		35									x	x	x	x	x	x	x	x
2S	1W	2	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
		3	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
		4	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
		5									x	x	x	x	x	x	x	x
		7	x			x									x			x
		8	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
		9	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
		10	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
		11	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x

Priority date September 16, 1957

Amount of water 0.78 c.f.s., measured at the point of diversion

Time limit to begin construction October 25, 1958

Time limit to complete construction 10/1/59 *extended to* *extended to*

Time limit to completely apply water 10/1/60 *extended to* *extended to*

Remarks:

Basin 2 Vol. 9

Abstract of Ground Water Registration

Registration No. GR-616 *Certificate No.* GR-588

Name TIGARD WATER DISTRICT by C. E. Janoe, Chairman, Board of Commissioners

Address 8900 S.W. Burnham Ave. Tigard, Oregon

Source of water supply Pump Well #1

Use Municipal

Point of diversion 1625' S. and 30' E. from NW cor. of Sec. 11; being within the SW¼ NW¼ of Sec. 11, T. 2 S., R. 1 W., W.M., in the county of Washington.

Number of acres

10430, SW [illegible]

Nj/cu

mgh

Fonne [illegible]

Basin 2, Vol. 16

DESCRIPTION OF LAND TO BE IRRIGATED OR PLACE OF USE

Twp.	Range	Sec.	NE¼				NW¼				SW¼				SE¼			
			NE¼	NW¼	SW¼	SE¼	NE¼	NW¼	SW¼	SE¼	NE¼	NW¼	SW¼	SE¼	NE¼	NW¼	SW¼	SE¼
1 S	1 W	34									X	X	X	X	X	X	X	X
2 S	1 W	2	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
		3	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
		9	X	X	X	X	X	X	X	X								
		10	X	X	X	X	X	X	X	X								
		11	X	X	X	X	X	X	X	X								

Priority date April 1947

Amount of water claimed 200 g.p.m.

Time limit to completely apply water Completed *extended to* *extended to*

Remarks: Tigard Well No. 2 being registered.

Registration No. GR- 616

Certificate No. GR 588

Registration Statement

OF CLAIMANT OF RIGHT TO APPROPRIATE GROUND WATER

TO THE STATE ENGINEER OF OREGON: Re: Tigard Well No. 1

I, TIGARD WATER DISTRICT By C. E. JANOE, Chairman, Board of Commissioners

of 8900 S.W. Burnham Ave., Tigard (Mailing address) County of Washington

State of Oregon do hereby make application for a certificate of registration as evidence of a right to appropriate ground water.

1. Source from which water is withdrawn is pump well #1 (Flowing well, pump well, infiltration trench, or tunnel)

2. Location is: One mile southwest of Tigard, Oregon (Approximate distance and direction from nearest city or town);

and is more particularly described as follows:

(a) South 1625 ft. and East 30 ft. from NW corner of Section 11 (Give distance and bearing to corner of section or other legal subdivision)

being within S.W.¼ NW¼ (Smallest legal subdivision) of Sec. 11, Twp. 2 S. (N. or S.), Rge. 1 W. (E. or W.)

or (b) within limits of recorded platted property, town or city:

in Lot ______, Block ______ of ______ (Name of plat or addition)

______ (If within city or town, give name) County of ______

3. Construction Work was begun on ______ (Date); was completed on April 25, 1947 (Date)

and the ground water claimed was first used for the purposes set out below on July 1, 1947 (Date),

since which time the water has been used continuously (Continuously or intermittently)

from July 1, 1947 (Date) to Sept., 1957 (Date)

4. Quantity of water claimed and used is 200 gallons per minute; ______ acre feet per year.

5. Purpose or Purposes for which water is used municipal

(Domestic, irrigation, municipal, manufacturing, industrial, etc.)

6. Description of Well: Depth 381 feet. Type Drilled (Dug or drilled)

diameter 12 inches. Elevation of ground at well site 400 403 (As near as known) feet, mean sea level.

Depth to water table 188 feet.

7. Capacity of Well: 170 g.p.m. with 46 feet drawdown.

210 g.p.m. with 97 feet drawdown.

Date of test April, 1947

If Flowing Well: Measured discharge ______ g.p.m. on ______ (Date)

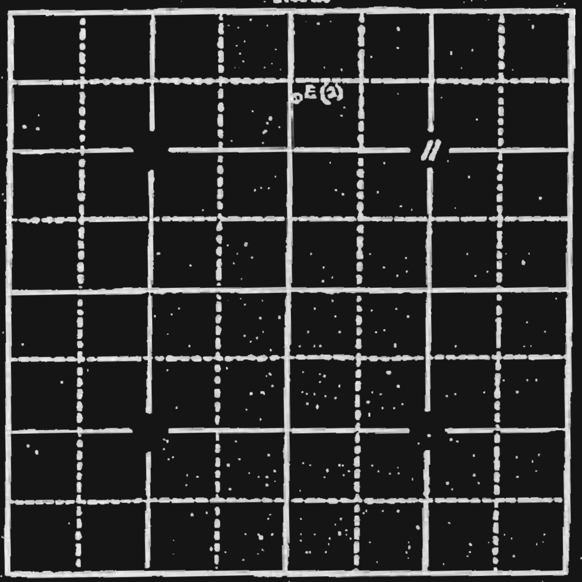
Shut-in pressure at ground surface ______ lbs. per sq. in. on ______ (Date)

Water is controlled by ______ (Cap, valve, etc.)

GW-4-37

Township 2S Range 1W W.M.

North



Locate well and acreage of irrigated land on plat.

Scale: 2" — 1 Mile

STATE OF OREGON
County of Washington } ss.

I, C. E. JANOE, being first duly sworn, do hereby certify that I have read the foregoing Registration Statement and that all of the items therein contained are true to the best of my knowledge and belief.

(Signature of Registrant)
Chairman
Board of Commissioners

Subscribed and sworn to before me this 9th day of September, 1957

My commission expires Feb 7 1960

(Notary Public)

(SEAL)

CERTIFICATE OF REGISTRATION

STATE OF OREGON
County of Marion } ss.

This is to certify that the foregoing Registration Statement was received in the office of the State Engineer on the 16th day of September, 1957, at 8:00 o'clock A. M. and has been duly recorded in said office in Book No. 4 of Registration Statements on page GR-588 C

Witness my hand this 16th day of October, 1957.

Lewis A. Stanley
(State Engineer)

$20.00

By
(Deputy)

Appendix C

Appendix C

MONTGOMERY WATSON

Map Number	Section[1]	Certificate	Permit	Priority Date	Quarter Section	Use[2]	Rate	Units	Status[3]	P_A_S[4]	Legal Description	Source Type[5]
1	3	29918	S 25054	8/13/57	SWSE	DO	0.01	cfs	V	P		SP
2	3	0	GR 567	3/3/53	SWSE	IR	60	gpm	V	P	522 FEET NORTH & 245 FEET EAST OF 1/4 SECTION CORNER, SOUTH LINE SECTION 3	WE
1	4	0	GR 548	12/31/53	NWNE	IR	250	gpm	V	P	1070 FEET SOUTH & 2200 FEET WEST FROM NE CORNER, SECTION 4	WE
2	4	0	GR 3997	12/31/49	SENW	DI	16	gpm	V	P	980 FEET NORTH & 1930 FEET EAST FROM W1/4 CORNER, SECTION 4	WE
3	4	28971	G 655	9/16/57	SWNE	MU	0.78	cfs	V	P	25 FEET NORTH & 50 FEET EAST FROM CENTER, SECTION 4	WE
4	4	35683	G 2367	2/28/63	NWNE	IR	0.18	cfs	C	P	1080 FEET SOUTH & 330 FEET EAST FROM N1/4 CORNER, SECTION 4	WE
5	4	72399	G 2367	2/28/63	NWNE	IR	0.106	cfs	V	P	1080 FEET SOUTH & 330 FEET EAST FROM N1/4 CORNER, SECTION 4	WE
1	5	40701	G 4167	5/29/68	SWNW	IR	0.2	cfs	V	P	1540 FT S & 1150 FT E FM NW COR, S5	WE
1	6	0	CG 488	2/7/57	SESE	IR	0.013	cfs	T	P	63 DEG 54 MIN WEST, 1200.8 FEET FROM SE CORNER, SECTION 6	WE
2	6	0	GR 352	10/31/52	SESE	IR	70	gpm	V	P	NO 63 DEG 54 MIN WEST 1200.81 FEET FROM SE CORNER, SECTION 6	WE
3	6	0	GR 1481	10/15/53	SWSW	IR	135	gpm	V	P	NORTH 38 DEG 27 MIN EAST 347 FEET FROM W1/4 CORNER, SECTION 6	WE
4	6	30332	G 488	2/7/57	SESE	IR	0.48	cfs	C	P	63 DEGREES 54 MINUTES WEST, 1200.8 FEET FROM SE CORNER, SECTION 6	WE
5	6	55550	G 1985	11/9/61	NWSE	DO	0.0007	cfs	V	P	158 FEET SOUTH & 1302 FEET EAST FROM CENTER 1/4 CORNER, SECTION 6	WE
6	6	73179	G 488	2/7/57	SESE	IR	0.467	cfs	V	P	NORTH 63 DEGREES 54 MINUTES WEST, 1200.8 FEET FROM SE CORNER, SECTION 6	WE
1	7	0	CG 488	2/7/57	NENE	DN	0.013	cfs	V	P	850 FEET SOUTH & 100 FEET WEST FROM NE CORNER, SECTION 7	WE
2	7	36444	G 3542	12/9/66	SWNE	IR	0.13	cfs	V	P	1280 FT E & 280 FT N FM CEN, S7	WE
1	10	0	GR 587	10/31/49	NWNW	MU	500	gpm	V	P	610 FEET SOUTH & 1270 FEET EAST FROM NW CORNER, SECTION 10	WE
2	10	0	GR 1545	8/27/51	NWSE	IR	28	gpm	V	P	1950 FEET NORTH & 1560 FEET WEST FROM SE CORNER, SECTION 10	WE
3	10	0	GR 2104	3/1/48	SWNE	IR	35	gpm	V	P	1700 FEET SOUTH & 2050 FEET EAST FROM NE CORNER, SECTION 10	WE
4	10	0	GR 2104	3/1/48	SWNE	IM	35	gpm	V	A	1700 FEET SOUTH & 2050 FEET EAST FROM NE CORNER, SECTION 10	WE
5	10	29661	G 612	6/24/57	SESE	IR	0.03	cfs	V	P	NORTH 27 DEGREES 55 MINUTES WEST 796.4 FEET FROM SE CORNER, SECTION 10	WE
6	10	32020	G 2170	4/30/62	NWSE	IR	0.03	cfs	V	P	30 CH N & 24 CH W FM SE COR, S10	WE
7	10	43690	G 3463	1/17/67	SWSW	IR	0.53	cfs	V	P	610 FT N & 570 FT E FM SW COR, S10	WE
8	10	46638	G 2999	11/19/65	NWSW	MU	0.63	cfs	V	P	25 FT S & 500 FT E FM W1/4 COR, S10	WE
1	11	69344	R 100555	1/1/93	NESE	WI	2.7	acre-feet	C	P		SP
2	11	73690	R 100555	1/1/93	SENE	WI	2.7	acre-feet	V	A		SP
3	11	73690	R 100555	1/1/93	SWNE	WI	2.7	acre-feet	V	P		SP
4	11	0	GR 122	2/15/53	NWSW	ID	35	gpm	V	P	392 FEET NORTH & 459 FEET EAST FROM CORNER, MARGUERITE ABSTRACT	WE
5	11	0	GR 123	12/31/52	NWSW	ID	10	gpm	V	P	50 FEET SOUTH & 900 FEET EAST FROM W1/4 CORNER, SECTION 11	WE
6	11	0	GR 588	4/25/47	SWNW	MU	200	gpm	V	P	1625 FEET SOUTH & 30 FEET EAST FROM NW CORNER, SECTION 11	WE
7	11	0	GR 1499	2/1/53	NWNE	IR	64	gpm	V	P	660 FEET NORTH & 2376 FEET EAST FROM NE CORNER, SECTION 11	WE
8	11	32496	G 1612	7/12/60	NWSW	IR	0.02	cfs	V	P	11.5 CHAINS SOUTH & 9.5 CHAINS EAST FROM NW CORNER, DLC 44	WE
9	11	46639	G 3270	4/25/66	SWNW	MU	0.67	cfs	V	P	1625 FT S & 30 FT E FM NW COR, S11	WE
1	12	0	S 48096	6/27/83	NWSE	DN	0.01	cfs	C	P	35 FEET NORTH & 25 FEET WEST FROM SE CORNER, LOT 11	SP
2	12	T 29260	D 29260	12/31/1867	SWNE	DO	0.01	cfs	V	P		SP
3	12	0	G 11155	5/22/90	SENE	IR	0.67	cfs	V	P	2630 FEET NORTH & 640 FEET WEST FROM SE CORNER, SECTION 12	WE
4	12	0	G 11155	5/22/90	SENE	RC	0.11	cfs	V	P	2630 FEET NORTH & 640 FEET WEST FROM SE CORNER, SECTION 12	WE
5	12	0	G 11340	5/14/91	SWSE	IR	0.04	cfs	V	P	440 FEET NORTH & 1090 FEET EAST FROM S1/4 CORNER, SECTION 12	WE
6	12	0	GR 3472	9/11/51	NWSE	IR	9	gpm	V	P	1470 FEET NORTH AND 1400 FEET WEST FROM SE CORNER, SECTION 12	WE
7	12	67910	G 11089	5/9/89	SWSE	IR	0.02	cfs	V	P	440 FEET NORTH & 1090 FEET EAST FROM S1/4 CORNER, SECTION 12	WE
1	13	8906	S 8061	7/5/27	NENE	IR	0.06	cfs	C	P		SP
2	13	S 11133	S 8061	7/5/27	NENE	IR	0.06	cfs	V	P		SP
3	13	T 0	S 37411	7/18/74	NENE	IM	0.05	cfs	C	P	SOUTH 11 DEGREES 35 MINUTES WEST 507.5 FEET FROM NE CORNER, SECTION 13	SP
4	13	T 32023	S 26285	7/20/59	NENE	DO	0.01	cfs	V	P		SP
5	13	0	GR 2156	6/30/41	NESW	ID	25	gpm	V	P	NORTH 49 DEGREES 40 MINUTES EAST, 347.6 FEET FROM CENTER, SECTION 13	WE
6	13	0	GR 2615	7/31/51	NWNW	SC	12	gpm	V	P	NORTH 45 DEGREES EAST 100 FEET FROM SW CORNER, LOT 4 DURHAM ACRES	WE
7	13	0	GR 3945	9/30/48	SWSE	IR	12	gpm	V	P	2230 FEET SOUTH & 400 FEET EAST FROM CENTER, SECTION 13	WE
8	13	47773	G 6547	8/15/75	SWNE	IR	0.02	cfs	V	P	1080 FT N & 170 FT E FM CEN, S13	WE
1	14	0	GR 1736	12/31/52	SWSW	IR	25	gpm	V	P	300 FEET NORTH & 50 FEET WEST FROM SE CORNER, LOT 1 HAZELBROOK FARM	WE
2	14	0	GR 2669	4/30/52	NWNE	IR	40	gpm	V	P	375 FEET SOUTH & 425 FEET EAST FROM N1/4 CORNER, SECTION 14	WE
3	14	48489	G 5823	8/14/75	NESE	IR	0.17	cfs	V	P	20 FT S & 280 FT W FM E1/4 COR, S14	WE
1	15	0	R 8480	5/18/82	NWSW	RC	1.7	acre-feet	C	P		SP
2	15	0	R 8480	5/18/82	NWSW	RC	0.78	acre-feet	C	P		SP
3	15	0	R 8480	5/18/82	NESW	RC	2.8	acre-feet	C	P		SP
4	15	23218	S 20055	12/28/50	NESW	DO	0.03	cfs	V	P		SP
5	15	23253	S 21683	8/6/52	NWSW	DO	0.01	cfs	V	P		SP
6	15	30540	S 25886	1/14/59	SWNE	DO	0.01	cfs	V	P		SP
7	15	40822	G 3304	5/26/66	SENW	IR	0.05	cfs	V	P	1750 FT S & 1700 FT E FM NW COR, S15	WE
8	16	41378	G 3116	9/23/65	NWSE	IR	0.01	cfs	V	P	2040 FT N & 1480 FT W FM SE COR, S16	WE
1	17	0	GR 1819	8/8/53	NWNE	IR	200	gpm	V	P	100 FEET SOUTH & 1800 FEET WEST FROM NE CORNER, SECTION 17	WE
1	18	0	GR 1818	12/31/51	NESE	IR	150	gpm	V	P	350 FEET SOUTH & 430 FEET WEST FROM NE CORNER, SECTION 19	WE
2	18	50548	G 5476	5/4/71	SENE	IR	0.34	cfs	C	P	1020 FT N & 480 FT W FM E1/4 COR, S18	WE
3	18	51171	G 5476	5/5/71	SENE	IR	0.34	cfs	V	P	1020 FT N & 480 FT W FM E1/4 COR, S18	WE
4	18	60569	G 6780	5/3/76	NENE	IR	0.03	cfs	C	P	1100 FEET SOUTH & 700 FEET WEST FROM THE NE CORNER,SECTION 18	WE

Notes
1. All Sections in Township 2 South, Range 1 East
2. DO-Domestic; IR-Irrigation; RC-Recreation; SC-School; IM-Industrial-Manufacturing; ID-Irrigation and Domestic; MU-Municpal; DN-Domestic, Including non-commerial; WI-Wildlife.
3. V-Non-Cancelled; C-Cancelled
4. P-Primary; A-Alternate
5. WE-Well; SP-Spring

OBSERVATION WELL

STATE ENGINEER
Salem, Oregon

WASH
011434

Well Record

STATE WELL NO. 2/1W-3Q(1)
COUNTY Wash.
APPLICATION NO. GR-597

OWNER: Leonard S. Davis

MAILING ADDRESS:

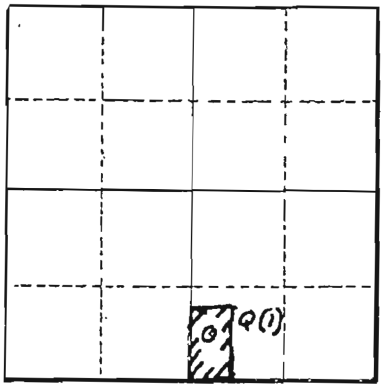
CITY AND STATE: Tigard, Ore.

LOCATION OF WELL: Owner's No.

SW ¼ SE ¼ Sec. 3 T. 2 S., R. 1 W., W.M.

Bearing and distance from section or subdivision corner 522 ft. N. & 245 ft. E. of S¼ cor. sec. 3

Altitude at well 270 feet



Section 3

TYPE OF WELL: Drilled Date Constructed March 10-54

Depth drilled 218 Depth cased 164

CASING RECORD:
6 inch

FINISH:

AQUIFERS:

WATER LEVEL:
-185 feet

PUMPING EQUIPMENT: Type Sumo Submersible H.P. 7½
Capacity 60 G.P.M.

WELL TESTS:
Drawdown .... ft. after .... hours .... G.P.M.
Drawdown .... ft. after .... hours .... G.P.M.

USE OF WATER irrigation-1A Temp. ...... °F. ...., 19......
SOURCE OF INFORMATION GR-597
DRILLER or DIGGER —
ADDITIONAL DATA:
Log ...... Water Level Measurements ...... Chemical Analysis ...... Aquifer Test ......

REMARKS:
Clay --- 98 ft.
Sand --- 66 ft.

State Printing 89316

STATE ENGINEER
Salem, Oregon

WASH
011447

Well Record

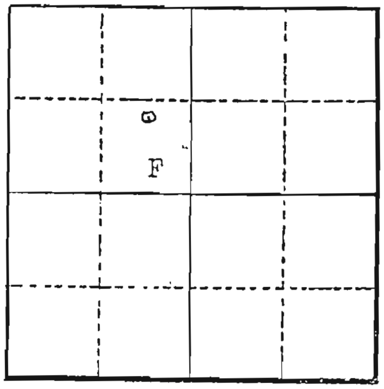
STATE WELL NO. 2/1W-4F
COUNTY Washington
~~APPLICATION NO.~~ GR-2636

OWNER: Reuben C. & Joyce V. Sandness
MAILING ADDRESS: 13725 S.W. Fern
LOCATION OF WELL: Owner's No.
CITY AND STATE: Tigard 23, Oregon

SE 1/4 NW 1/4 Sec. 4 T. 2 S., R. 1 W., W.M.

Bearing and distance from section or subdivision corner 1930' E & 980' N from W¼corner Sec 4

Altitude at well 300'



TYPE OF WELL: Drilled Date Constructed 1949
Depth drilled 178' Depth cased 63'
Section 4

CASING RECORD:

6-inch

FINISH:

AQUIFERS:

WATER LEVEL:

- 145'

PUMPING EQUIPMENT: Type Red Jacket submergible H.P. 1½
Capacity 16 G.P.M.

WELL TESTS:
Drawdown nil ft. after hours 16 G.P.M.
Drawdown ft. after hours G.P.M.

USE OF WATER Residence 1 acre garden Temp. °F. , 19
SOURCE OF INFORMATION GR-3997
DRILLER or DIGGER
ADDITIONAL DATA:
Log NA Water Level Measurements Chemical Analysis Aquifer Test

REMARKS:

JAN 17 1990

WATER RESOURCES DEPT
SALEM, OREGON

WASH
011435

2s/1w/4ac

STATE OF OREGON
WATER WELL REPORT
(as required by ORS 537.765)

(START CARD) # 14021

(1) OWNER:
Well Number:
Name City of Tigard
Address P. O. Box 23397
City Tigard State OR Zip 97223

(2) TYPE OF WORK:
☐ New Well ☐ Deepen ☐ Recondition ☒ Abandon

(3) DRILL METHOD
☐ Rotary Air ☐ Rotary Mud ☐ Cable
☐ Other

(4) PROPOSED USE:
☐ Domestic ☐ Community ☐ Industrial ☐ Irrigation
☐ Thermal ☐ Injection ☐ Other

(5) BORE HOLE CONSTRUCTION:
Special Construction approval Yes ☐ No ☐ Depth of Completed Well ____ ft.
Explosives used Yes ☐ No ☐ Type ____ Amount ____

HOLE			SEAL			
Diameter	From	To	Material	From	To	Amount sacks or pounds
			See #12			

How was seal placed: Method ☐ A ☐ B ☐ C ☐ D ☐ E
☐ Other
Backfill placed from ____ ft. to ____ ft. Material
Gravel placed from ____ ft. to ____ ft. Size of gravel

(6) CASING/LINER:

	Diameter	From	To	Gauge	Steel	Plastic	Welded	Threaded
Casing:	8"	+1	104	.250	☒	☐	☒	☐
					☐	☐	☐	☐
					☐	☐	☐	☐
					☐	☐	☐	☐
Liner:					☐	☐	☐	☐
					☐	☐	☐	☐

Final location of shoe(s)

(7) PERFORATIONS/SCREENS:
☒ Perforations Method Drive down
☐ Screens Type ____ Material

From	To	Slot size	Number	Diameter	Tele/pipe size	Casing	Liner
0	104	1/4 x3	1248			☒	☐
						☐	☐
						☐	☐
						☐	☐
						☐	☐
						☐	☐

(8) WELL TESTS: Minimum testing time is 1 hour
☐ Pump ☐ Bailer ☐ Air ☐ Flowing Artesian

Yield gal/min	Drawdown	Drill stem at	Time
			1 hr.

Temperature of water ____ Depth Artesian Flow Found
Was a water analysis done? ☐ Yes By whom
Did any strata contain water not suitable for intended use? ☐ Too little
☐ Salty ☐ Muddy ☐ Odor ☐ Colored ☐ Other
Depth of strata:

(9) LOCATION OF WELL by legal description:
County Washington Latitude ____ Longitude ____
Township 2 S N or S, Range 1 W E or W, WM.
Section 4 SW ¼ NE ¼
Tax Lot ____ Lot ____ Block ____ Subdivision
Street Address of Well (or nearest address)

(10) STATIC WATER LEVEL:
____ ft. below land surface. Date
Artesian pressure ____ lb. per square inch. Date

(11) WATER BEARING ZONES:
Depth at which water was first found

From	To	Estimated Flow Rate	SWL

(12) WELL LOG:
Ground elevation

Material	From	To	SWL
Casing perforated/well abandoned			
Cement/gel grout	0	130	34sac
Gravel backfill	130	190	
Cement grout	190	210	6 sac
Gravel fill	210	260	
Cement grout	260	275	5 sac
Gravel fill	275	325	
Cement grout	325	340	5 sac
Gravel fill	340	370	
Cement grout	370	385	5 sac

Date started 1/12/90 Completed 1/15/90

(unbonded) Water Well Constructor Certification:

I certify that the work I performed on the construction, alteration, or abandonment of this well is in compliance with Oregon well construction standards. Materials used and information reported above are true to my best knowledge and belief.

WWC Number
Signed ____ Date

(bonded) Water Well Constructor Certification:

I accept responsibility for the construction, alteration, or abandonment work performed on this well during the construction dates reported above. all work performed during this time is in compliance with Oregon well construction standards. This report is true to the best of my knowledge and belief.

WWC Number 1266
Signed ____ Date 1/15/90

ORIGINAL & FIRST COPY - WATER RESOURCES DEPARTMENT SECOND COPY - CONSTRUCTOR THIRD COPY - CUSTOMER 9809C 3/88

NOTICE TO WATER WELL CONTRACTOR
The original and first copy
of this report are to be
filed with the
STATE ENGINEER, SALEM, OREGON 97310
within 30 days from the date
of well completion.

WASH

WATER WELL REPORT
STATE OF OREGON
(Please type or print)
(Do not write above this line)

011478

RECEIVED
NOV 21 1967
STATE ENGINEER
OREGON

State Well No. 2/1w - 5E
State Permit No.
G-4422

(1) OWNER:
Name Harry Werner
Address Rt.1, Box 436
Beaverton, Oregon, 97005

(2) TYPE OF WORK (check):
New Well ☒ Deepening ☐ Reconditioning ☐ Abandon ☐
If abandonment, describe material and procedure in Item 12.

(3) TYPE OF WELL:
Rotary ☐ Driven ☐
Cable ☒ Jetted ☐
Dug ☐ Bored ☐

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

(5) CASING INSTALLED:
Threaded ☐ Welded ☒
8" Diam. from 0 ft. to 33 ft. Gage ½std.
" Diam. from ft. to ft. Gage
" Diam. from ft. to ft. Gage

(6) PERFORATIONS:
Perforated? ☐ 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.
perforations from ft. to ft.
perforations from ft. to ft.

(7) SCREENS:
Well screen installed? ☐ Yes ☒ No
Manufacturer's Name
Type Model No.
Diam. Slot size Set from ft. to ft.
Diam. Slot size Set from ft. to ft.

(8) WATER LEVEL: Completed well.
Static level 150 ft. below land surface Date Nov.7,67
Artesian pressure lbs. per square inch Date

(9) WELL TESTS:
Drawdown is amount water level is lowered below static level
Was a pump test made? ☐ Yes ☒ No If yes, by whom?
Yield: gal./min. with ft. drawdown after hrs.
" " " "
" " " "
Bailer test 30 gal./min. with 0 ft. drawdown after 2 hrs.
Artesian flow g.p.m. Date
Temperature of water Was a chemical analysis made? ☐ Yes ☐ No

(10) CONSTRUCTION:
Well seal—Material used Betonite
Depth of seal 20 ft.
Diameter of well bore to bottom of seal 11 in.
Were any loose strata cemented off? ☐ Yes ☒ No Depth
Was a drive shoe used? ☐ Yes ☒ No
Did any strata contain unusable water? ☐ Yes ☒ No
Type of water? depth of strata
Method of sealing strata off
Was well gravel packed? ☐ Yes ☐ No Size of gravel:
Gravel placed from ft. to ft.

(11) LOCATION OF WELL:
County Washington Driller's well number
¼ ¼ Section 5 T. 2 R. 1W W.M.
Bearing and distance from section or subdivision corner

(12) WELL LOG:
Diameter of well below casing 8
Depth drilled 229 ft. Depth of completed well 229 ft.

Formation: Describe color, texture, grain size and structure of materials; and show thickness and nature of each stratum and aquifer penetrated, with at least one entry for each change of formation. Report each change in position of Static Water Level as drilling proceeds. Note drilling rates.

MATERIAL	From	To	SWL
top soil	0	5	
clay - brown	5	22	
" "	22	33	
rock - brown	33	100	
" " hard	100	118	
" black	118	130	
" brown-not hard	130	155	
" little water, brown	155	160	
" brown	160	166	
" black- hard	166	181	
" " little water	181	201	
" black- little			
water in seams	201	229	

Work started Oct.26 1967 Completed Nov. 7 1967
Date well drilling machine moved off of well 19

Drilling Machine Operator's Certification:
This well was constructed under my direct supervision. Materials used and information reported above are true to my best knowledge and belief.
[Signed] Eugene V. Hood (Drilling Machine Operator) Date Nov 21. 1967
Drilling Machine Operator's License No. 217

Water Well Contractor's Certification:
This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.
NAME Barron & Strayer (Person, firm or corporation) (Type or print)
Address Rt.1, Box 254, Beaverton, Ore.
[Signed] R H Barron (Water Well Contractor)
Contractor's License No. 35 Date Nov. 21 1967

(USE ADDITIONAL SHEETS IF NECESSARY)

STATE ENGINEER
Salem, Oregon

WASH
011510

Well Record

GR-1481

STATE WELL NO. 2/1W-6E
COUNTY Washington
APPLICATION NO. GR-1538

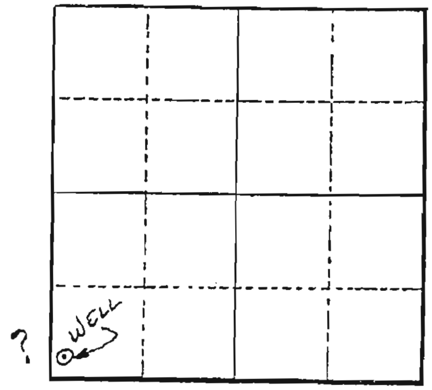
OWNER: E. J. & R. E. Lindquist
MAILING ADDRESS: Rt. 1, Box 832

LOCATION OF WELL: Owner's No.
CITY AND STATE: Beaverton, Oregon

SW ¼ NW ¼ Sec. 6 T. 2 XNX S., R. 1 XEX W., W.M.

Bearing and distance from section or subdivision corner N.38°27'E. 347' from SW cor. Sec. 6

Altitude at well



TYPE OF WELL: Drilled Date Constructed 1953
Depth drilled 544' Depth cased 29'
Section 6

CASING RECORD:
8"

FINISH:

AQUIFERS:

WATER LEVEL:
-88'

PUMPING EQUIPMENT: Type Johnson 4" turbine H.P. 10
Capacity 135 G.P.M.

WELL TESTS:
Drawdown 10 ft. after hours 300 G.P.M.
Drawdown ft. after hours G.P.M.

USE OF WATER Irrigation Temp. °F. , 19
SOURCE OF INFORMATION GR Record
DRILLER or DIGGER Bill Sennett
ADDITIONAL DATA:
Log N.A. Water Level Measurements Chemical Analysis Aquifer Test

REMARKS:
Irrigation of 7 acres.

STATE ENGINEER
Salem, Oregon

WASH
011513

Well Record

STATE WELL NO. 2/1W-6 R(
COUNTY Wash.
APPLICATION NO. GR-366

OWNER: Edward Roshak

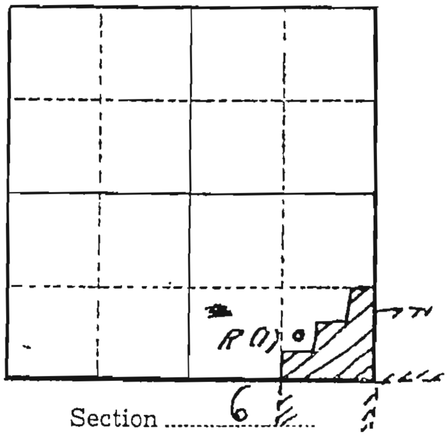
MAILING ADDRESS: Rt. 4 Box 392

LOCATION OF WELL: Owner's No. ....

CITY AND STATE: Sherwood, Ore

SE ¼ SE ¼ Sec. 6 T. 2 S., R. 1 W., W.M.

Bearing and distance from section or subdivision corner N. 63°54' W. 1200.81 ft. from S.E. cor. Sec. 6



Section 6

Altitude at well 265

TYPE OF WELL: Drilled Date Constructed Nov. '52

Depth drilled 232 Depth cased 92

CASING RECORD:

6 inch

FINISH:

AQUIFERS:

WATER LEVEL:

90

PUMPING EQUIPMENT: Type Peerless Certifical H.P. 5

Capacity 70 G.P.M.

WELL TESTS:

Drawdown .... ft. after .... hours .... G.P.M.

Drawdown .... ft. after .... hours .... G.P.M.

USE OF WATER irrigation Temp. .... °F. ...., 19....

SOURCE OF INFORMATION Ground Water Registration Record

DRILLER or DIGGER Wm. J. Stennat; Ore City, Ore.

ADDITIONAL DATA:

Log No Water Level Measurements .... Chemical Analysis .... Aquifer Test ....

REMARKS:

STATE ENGINEER
Salem, Oregon

WASH
011578

Well Record

GR- 1545

STATE WELL NO. 2/1W-10K
COUNTY Washington
APPLICATION NO. GR- 667

OWNER: William Bodman & Claire M. Sanders

MAILING ADDRESS:

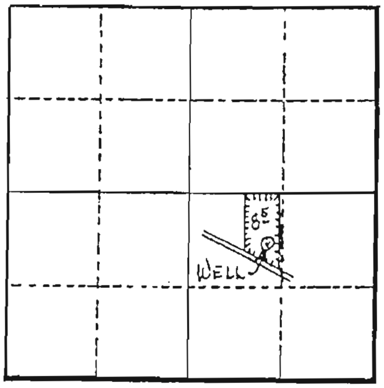
LOCATION OF WELL: Owner's No.

CITY AND STATE: Tigard, Oregon

NW ¼ SE ¼ Sec. 10 T. 2 ~~N~~ S., R. 1 ~~E~~ W., W.M.

Bearing and distance from section or subdivision corner 1950' N. & 1560' W. from SE cor. Sec. 10

Altitude at well 290'



Section 10

TYPE OF WELL: Drilled Date Constructed 1951

Depth drilled 125' Depth cased 20'

CASING RECORD:
8"

FINISH:

AQUIFERS:

WATER LEVEL:
70'

PUMPING EQUIPMENT: Type Dorward jet H.P. 2
Capacity 20 G.P.M.

WELL TESTS:
Drawdown 25 ft. after hours 28 G.P.M.
Drawdown ft. after hours G.P.M.

USE OF WATER Irrigation Temp. °F. , 19
SOURCE OF INFORMATION GR Record
DRILLER or DIGGER Klundt Bros.
ADDITIONAL DATA:
Log Water Level Measurements Chemical Analysis Aquifer Test

REMARKS:

Log:	Clay	0 to 10 ft.
	Soft rock	10 to 20 ft.
	Hard rock	20 to 125 ft.

Irrigation of 8.5 acres.

State Printing 89316

STATE ENGINEER
Salem, Oregon

WASH
011570

Well Record

STATE WELL NO. 2/1W - 10G
COUNTY WASHINGTON
~~APPLICATION NO.~~ GR-2199

OWNER: J. V. Chandler

MAILING ADDRESS: P. O. Box 6344

CITY AND STATE: Tigard, Oregon

LOCATION OF WELL: Owner's No.

SW ¼ NE ¼ Sec. 10 T. 2 N. S., R. 1 E. W., W.M.

Bearing and distance from section or subdivision corner 1700' S. and 2050' E.

Altitude at well

Section

TYPE OF WELL: Drilled Date Constructed 1948

Depth drilled 183 Depth cased 6 26

CASING RECORD:

8-Inch
6-Inch
6-Inch

FINISH:

AQUIFERS:

WATER LEVEL:

90-Feet

PUMPING EQUIPMENT: Type Pomona Turbine H.P. 3
Capacity 50 G.P.M.

WELL TESTS:
Drawdown 55 ft. after hours Pumping 35 G.P.M.
Drawdown ft. after hours G.P.M.

USE OF WATER Industrial & Irrigation Temp. °F. , 19
SOURCE OF INFORMATION GR-2104
DRILLER or DIGGER Harry Carsh, Tigard, Oregon
ADDITIONAL DATA:
Log Water Level Measurements Chemical Analysis Aquifer Test

REMARKS:

WASH
011573

NOTICE TO WATER WELL CONTRACTOR
The original and first copy
of this report are to be
filed with the
STATE ENGINEER, SALEM, OREGON 97310
within 30 days from the date
of well completion.

RECEIVED
JAN 17 19
STATE ENGINEER
SALEM, OREGON

WATER WELL REPORT
STATE OF OREGON
(Please type or print)

G-2309
G-2170

State Well No. 2/1W-10 E 8ba

State Permit No.

(1) OWNER:

Name William B. Sanders

Address R/ 11165 SW Naeve St.
Tigard, Oregon

(2) LOCATION OF WELL:

County Washington Driller's well number 2-67

NW ¼ SE ¼ Section 10 T. 2S R. 1W W.M.

Bearing and distance from section or subdivision corner

(3) TYPE OF WORK (check):

New Well ☐ Deepening ☒ Reconditioning ☐ Abandon ☐

If abandonment, describe material and procedure in Item 12.

(4) PROPOSED USE (check):

Domestic ☒ Industrial ☐ Municipal ☐

Irrigation ☒ Test Well ☐ Other ☐

(5) TYPE OF WELL:

Rotary ☐ Driven ☐

Cable ☒ Jetted ☐

Dug ☐ Bored ☐

(6) CASING INSTALLED:

Threaded ☒ Welded ☐

8" Diam. from 0 ft. to approx 22 ft. Gage 0.250

" Diam. from ft. to ft. Gage

" Diam. from ft. to ft. Gage

(7) PERFORATIONS:

Perforated? ☐ 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.

perforations from ft. to ft.

perforations from ft. to ft.

(8) SCREENS:

Well screen installed? ☐ Yes ☒ No

Manufacturer's Name

Type Model No.

Diam. Slot size Set from ft. to ft.

Diam. Slot size Set from ft. to ft.

(9) CONSTRUCTION:

Well seal—Material used in seal ?

Depth of seal ? ft. Was a packer used? ?

Diameter of well bore to bottom of seal ? in.

Were any loose strata cemented off? ☐ Yes ☒ No Depth

Was a drive shoe used? ☐ Yes ☒ No

Was well gravel packed? ☐ Yes ☒ No Size of gravel:

Gravel placed from ft. to ft.

Did any strata contain unusable water? ☐ Yes ☒ No

Type of water? depth of strata

Method of sealing strata off

(10) WATER LEVELS:

Static level 100 ft. below land surface Date 1/9/67

Artesian pressure lbs. per square inch Date

(11) WELL TESTS:

Drawdown is amount water level is lowered below static level

Was a pump test made? ☐ Yes ☒ No If yes, by whom?

Yield: gal./min. with ft. drawdown after hrs.

" " " "

" " " "

Bailer test 40 gal./min. with no ft. drawdown after 1 hrs.

Artesian flow g.p.m. Date

Temperature of water 53 Was a chemical analysis made? ☐ Yes ☒ No

(12) WELL LOG:

Diameter of well below casing 8"

Depth drilled 330 ft. Depth of completed well 330 ft.

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
This well originally drilled by J.E. Klundt in about 1953 to a depth of 125 feet. Eight inch hole was drilled to 100 feet and reduced to six inch hole to 125 feet. Columbia River Basalt from about 15 feet on.		
		125
Rock, dark grey, hard	125	165
Rock, grey, med. hard	165	168
Rock, Brown, med. soft	168	173
Rock, Brown, soft	173	186
Rock, Brown, white clay seams	186	193
Rock, Grey with brown seams (water)	193	220
Rock, Dark grey, hard	220	238
Rock, Brown	238	263
Rock, Grey with brown seams	263	295
Rock, Dark grey, med. hard	295	303
Rock, grey with brown seams	303	317
Rock, Brown honeycomb (water)	317	326
Rock, grey	326	330

Work started Dec. 13, 1966 Completed Jan. 9, 1967

Date well drilling machine moved off of well Jan. 9, 1967

(13) PUMP:

Manufacturer's Name Berkley—2 units

Type: Submersibles H.P. 1 and 1½

Water Well Contractor's Certification:

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

NAME Steinman Bros.
(Person, firm or corporation) (Type or print)

Address 15112 SE McLoughlin, Milwaukie, Ore.

Drilling Machine Operator's License No. 68

[Signed] Steinman Bros.
(Water Well Contractor)

Contractor's License No. 1 Date Jan. 16, 1967

(USE ADDITIONAL SHEETS IF NECESSARY)

WASH

NOTICE TO WATER WELL CONTRACTOR
The original and first copy
of this report are ~~to be~~
filed with the
STATE ENGINEER, SALEM, OREGON 97310
within 30 days from the date
of well completion.

011587

RECEIVED
APR 24 1967
STATE ENGINEER
SALEM OREGON

G-3777

~~WATER WELL~~ REPORT
STATE OF OREGON
(Please type or print)

State Well No. 2/1w-10 N
State Permit No.

(1) OWNER:

Name Tualatin Development Co.
Address 15475 SW Pacific Hwy.
Tigard, Ore.

(2) LOCATION OF WELL:

County Washington Driller's well number
¼ ¼ Section 10 T. 2S R. 1W W.M.
Bearing and distance from section or subdivision corner

(3) TYPE OF WORK (check):

[illegible] Well ☒ Deepening ☐ Reconditioning ☐ Abandon ☐
[illegible]andonment, describe material and procedure in Item 12.

(4) PROPOSED USE (check):

Domestic ☐ Industrial ☐ Municipal ☐
Irrigation ☒ Test Well ☐ Other ☐

(5) TYPE OF WELL:

Rotary ☒ Driven ☐
Cable ☒ Jetted ☐
Dug ☐ Bored ☐

(6) CASING INSTALLED:

Threaded ☐ Welded ☒
8" Diam. from 0 ft. to 248 ft. Gage .250
" Diam. from ft. to ft. Gage
" Diam. from ft. to ft. Gage

(7) PERFORATIONS:

Perforated? ☐ 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.
perforations from ft. to ft.
perforations from ft. to ft.

(8) SCREENS:

Well screen installed? ☐ Yes ☒ No
Manufacturer's Name
[illegible] Model No.
Diam. Slot size Set from ft. to ft.
Diam. Slot size Set from ft. to ft.

(9) CONSTRUCTION:

Well seal—Material used in seal Bentonite
Depth of seal 247 ft. Was a packer used? No
Diameter of well bore to bottom of seal 12 in.
Were any loose strata cemented off? ☐ Yes ☒ No Depth
Was a drive shoe used? ☐ Yes ☒ No
Was well gravel packed? ☐ Yes ☒ No Size of gravel:
Gravel placed from ft. to ft.
Did any strata contain unusable water? ☐ Yes ☒ No
Type of water? depth of strata
Method of sealing strata off

(10) WATER LEVELS:

Static level 47 ft. below land surface Date 1-19-67
Artesian pressure lbs. per square inch Date

(11) WELL TESTS:

Drawdown is amount water level is lowered below static level A.M.
Was a pump test made? ☒ Yes ☐ No If yes, by whom? Jannsen Drilling Co
Yield: 190 gal./min. with 23 ft. drawdown after 8 hrs.
" " " "
" " " "
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

(12) WELL LOG:

Diameter of well below casing 8" to 350' 6" to 805'
Depth drilled 805 ft. Depth of completed well 805 ft.

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
Brown clay	0	19
Sandy blue clay	19	67
Brown clay	67	145
Decomposed rock	145	237
Hard black rock	237	267
Clay & rock interbed	267	274
Brown & black rock - water bearing	274	291
Very hard gray rock	291	358
Soft black rock - 25 to 30 gpm	358	377
Hard gray rock with crevices	377	427
Hard black basalt	427	666
Gray hard basalt	666	702
Loose rock, lost cuttings	702	751
Hard black basalt	751	797
Lost cuttings	797	804
Hard black basalt	804	805

Work started 5-19 19 66 Completed 1-19 19 67
Date well drilling machine moved off of well 1-19 19 67

(13) PUMP:

Manufacturer's Name
Type: H.P.

Water Well Contractor's Certification:

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

NAME A. M. Jannsen Drilling Co.
(Person, firm or corporation) (Type or print)
Address 21075 SW Tual. Vlly. Hwy. Aloha, Ore.
Drilling Machine Operator's License No. 177
[Signed] Edward M. Jannsen
(Water Well Contractor)
Contractor's License No. 79 Date 4-18, 19 67

(USE ADDITIONAL SHEETS IF NECESSARY)

STATE ENGINEER
Salem, Oregon

WASH
011607

Well Record

STATE WELL NO. 2/1W-11 M(2)
COUNTY Washington
APPLICATION NO. GR-132

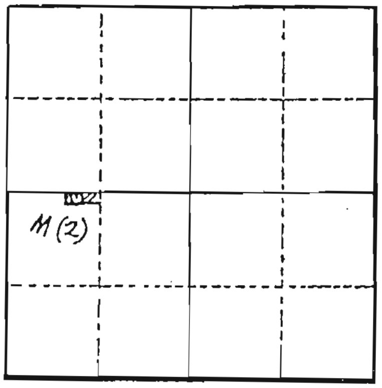
OWNER: Howard William & Marilyn K. Boyte
MAILING ADDRESS: Rt 2, Box 19

LOCATION OF WELL: Owner's No. 1
CITY AND STATE: Tigard, Oregon

NW ¼ SW ¼ Sec. 11 T. 2 ~~N.~~ S., R. 1 ~~E.~~ W., W.M.

Bearing and distance from section or subdivision corner East 566 feet of Lot #1 M. Ochords Tract.

Altitude at well ~~325~~ 275 feet Interpolated



TYPE OF WELL: Drilled Date Constructed Dec. 1952

Depth drilled 162 Depth cased 30

Section 11

CASING RECORD:

6 — inch steel casing set from 0 to 30 feet. [Rock 30 to 162 ft.]

FINISH:

none

AQUIFERS:

unknown

WATER LEVEL:

- 110 feet below land surface 2/28/53

PUMPING EQUIPMENT: Type Sumo 7CL 31S H.P. 2.
Capacity 10.44 G.P.M.

WELL TESTS:
Drawdown 0? ft. after hours 18 G.P.M.
Drawdown ft. after hours G.P.M.

USE OF WATER Irrigation 2.2 acres Temp. °F. , 19
SOURCE OF INFORMATION Registration Statement GR-132
DRILLER or DIGGER Lance W. Strayer Rt 1 Box 450 Beaverton, Oregon
ADDITIONAL DATA:
Log NO Water Level Measurements Chemical Analysis Aquifer Test

REMARKS:

State Printing 89316

STATE ENGINEER
Salem, Oregon

WASH
011599

Well Record

GR- 1499

STATE WELL NO. 2/1W-11B
COUNTY Washington
APPLICATION NO. GR- 1555

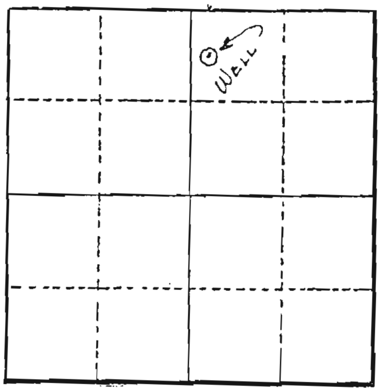
OWNER: George L. Penrose
MAILING ADDRESS: 9280 SW Mt. View Lane
CITY AND STATE: Tigard, Oregon

LOCATION OF WELL: Owner's No.

NW ¼ NE ¼ Sec. 11 T. 2 XX S., R. 1 XX W., W.M.

Bearing and distance from section or subdivision corner 660' N. & 2376' E. to NE cor. Sec. 11

Altitude at well 100'



Section 11

TYPE OF WELL: Drilled Date Constructed 1953
Depth drilled 200' Depth cased 37'

CASING RECORD:
8"

FINISH:

AQUIFERS:

WATER LEVEL:
165'

PUMPING EQUIPMENT: Type Deep well turbine H.P. 5
Capacity 64 G.P.M.

WELL TESTS:
Drawdown 10 ft. after hours 78 G.P.M.
Drawdown ft. after hours G.P.M.

USE OF WATER Irrigation Temp. °F. , 19
SOURCE OF INFORMATION GR Record
DRILLER or DIGGER Stienman Bros.
ADDITIONAL DATA:
Log N.A. Water Level Measurements Chemical Analysis Aquifer Test

REMARKS:
Irrigation of 10 acres.

STATE ENGINEER
Salem, Oregon

WASH
011606

OBSERVATION WELL
Well Record

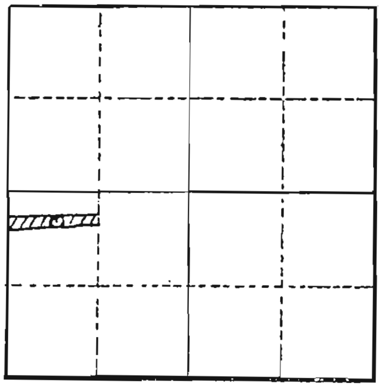
STATE WELL NO. 2/1W-11 M(1)
COUNTY Washington
APPLICATION NO. GR-131

OWNER: Walter H. & Hazel Pearl Engler
MAILING ADDRESS:
LOCATION OF WELL: Owner's No. 1
CITY AND STATE: Tigard, Oregon

NW ¼ SW ¼ Sec. 11 T. 2 ~~N.~~ S., R. 1 ~~E.~~ W., W.M.

Bearing and distance from section or subdivision corner 392 feet north and 459 feet east to corner of Marguerite Oaks Tract or 400 South and 700 feet from west'ly corner section 11.

Altitude at well ~~300~~ 275 feet Interpolated



TYPE OF WELL: Drilled Date Constructed 2/5/53
Depth drilled 262 Depth cased 108
Section 11

CASING RECORD:

6 — inch steel casing set from 0 to 108 feet. [Rock 108 to 262]

FINISH:

none

AQUIFERS:

unknown

WATER LEVEL:

- 100 feet below land surface Summer 1953

PUMPING EQUIPMENT: Type H.P.
Capacity G.P.M.

WELL TESTS:
Drawdown 0 ? ft. after hours 35 G.P.M.
Drawdown ft. after hours G.P.M.

USE OF WATER Irrigation 3.5 acres Temp. °F. , 19
SOURCE OF INFORMATION Registration Statement GR-131
DRILLER or DIGGER L.W. Strayer Rt.1 Box 450 Beaverton, Oregon
ADDITIONAL DATA:
Log NO Water Level Measurements Chemical Analysis Aquifer Test

REMARKS:

State Printing 89316

STATE ENGINEER
Salem, Oregon

WASH
011621

Well Record

STATE WELL NO. 2/1W-12K
COUNTY Washington
APPLICATION NO. GR-3810

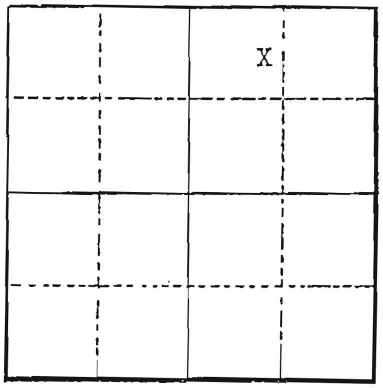
OWNER: William Clifford VanCott
MAILING ADDRESS: 15455 SW 72nd Ave.

LOCATION OF WELL: Owner's No.
CITY AND STATE: Tigard 23, Oregon

NW ¼ SE ¼ Sec. 12 T. 2 N. S., R. 1 E W., W.M.

Bearing and distance from section or subdivision corner 1400' W. & 1470' N. from SE Cor. Sec. 12

Altitude at well



Section 12

TYPE OF WELL: Dug Date Constructed 9/11/51
Depth drilled 29 feet Depth cased

CASING RECORD:

FINISH:

AQUIFERS:

WATER LEVEL:
12 feet below surface

PUMPING EQUIPMENT: Type Pacific Pump H.P. 1/2
Capacity 15 G.P.M.

WELL TESTS:
Drawdown 7.5 ft. after hours 8.5 G.P.M.
Drawdown 14. ft. after hours 14.2 G.P.M.

USE OF WATER Irrigation Temp. °F. , 19
SOURCE OF INFORMATION Well Registration Statement
DRILLER or DIGGER Charles Myers
ADDITIONAL DATA:
Log Water Level Measurements Chemical Analysis Aquifer Test

REMARKS:

State Printing 89316

3472

WASH
011662

File Original and
First Copy with the
STATE ENGINEER,
SALEM, OREGON

Copy from
GR 2259

WATER WELL REPORT
STATE OF OREGON

State Well No. 2/1W-13L(1)

State ~~Permit~~ cert. No. GR 2156

(1) OWNER:
Name Melville Eastham

Address 17015 S.W. Upper Boone Ferry Rd
Tigard

(2) LOCATION OF WELL:
Henry Mears, Agt.

County Wash. Owner's number, if any—

NE ¼ SW ¼ Section 13 T. 2S R. 1W W.M.

Bearing and distance from section or subdivision corner

N 49° 40′ E – 347.6 feet to the center of Section 13

(3) TYPE OF WORK (check):
New Well ☐ Deepening ☐ Reconditioning ☐ Abandon ☐

If abandonment, describe material and procedure in Item 11.

[illegible] PROPOSED USE (check):
Domestic ☐ Industrial ☐ Municipal ☐
Irrigation ☒ Test Well ☐ Other ☐

(5) TYPE OF WELL:
Rotary ☐ Driven ☐
Cable ☐ Jetted ☐
Dug ☐ Bored ☐

(6) CASING INSTALLED:
Threaded ☐ Welded ☐

8" Diam. from 0 ft. to 120 ft. Gage
" Diam. from ft. to ft. Gage
" Diam. from ft. to ft. Gage

(7) PERFORATIONS:
Perforated? ☒ Yes ☐ No

Type of perforator used Unknown

SIZE of perforations in. by in.

perforations from 80 ft. to 104 ft.
perforations from ft. to ft.
perforations from ft. to ft.
perforations from ft. to ft.
perforations from ft. to ft.

(8) SCREENS:
Well screen installed ☐ Yes ☐ No

Manufacturer's Name

Type Model No.

Diam. Slot size Set from ft. to ft.
[illegible] Slot size Set from ft. to ft.

(9) CONSTRUCTION:
Was well gravel packed? ☐ Yes ☐ No Size of gravel:

Gravel placed from ft. to ft.

Was a surface seal provided? ☐ Yes ☐ No To what depth? ft.

Material used in seal—

Did any strata contain unusable water? ☐ Yes ☐ No

Type of water? Depth of strata

Method of sealing strata off

(10) WATER LEVELS:
Static level 80 ft. below land surface Date June 1941

Artesian pressure lbs. per square inch Date

Log Accepted by:

[Signed] Date , 19
(Owner)

(11) WELL TESTS:
Drawdown is amount water level is lowered below static level

Was a pump test made? ☐ Yes ☐ No If yes, by whom?

Yield: 250 gal./min. with 6 ft. drawdown after hrs.
" " " "
" " " "

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

(12) WELL LOG:
Diameter of well 8 inches.

Depth drilled 120 ft. Depth of completed well 120 ft.

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
Soil	0	5
Boulders & Clay	5	20
Loose gravel, sand and clay	20	36
Gravel, clay, and boulders	36	80
Loose gravel	80	105
Gravel and clay	105	120

Work started 19 Completed 1941

(13) PUMP:
Manufacturer's Name Pomona

Type: H.P. 3

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 Steinman Bros.
(Person, firm, or corporation) (Type or print)

Address

Driller's well number

[Signed]
(Well Driller)

License No. Date , 19

(USE ADDITIONAL SHEETS IF NECESSARY)

STATE ENGINEER
Salem, Oregon

WASH
011680

Well Record

STATE WELL NO. 2/1W-13Q
COUNTY WASHINGTON
~~APPLICATION NO.~~ GR-3010

OWNER: Ben Brehm

MAILING ADDRESS: 18069 Lower Boones Ferrey Rd

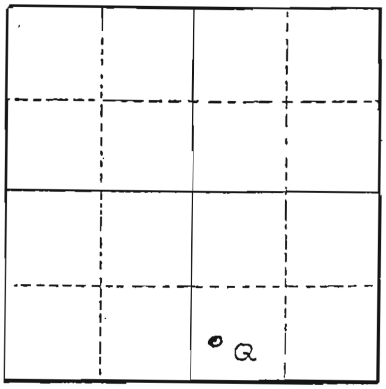
CITY AND STATE: Washington

LOCATION OF WELL: Owner's No.

SW ¼ SE ¼ Sec. 13 T. 2 ~~N.~~ S., R. 1 ~~E.~~ W., W.M.

Bearing and distance from section or subdivision corner 2230' S & 400' E from cor of sec 13

Altitude at well



Section 13

TYPE OF WELL: Drilled Date Constructed 1948

Depth drilled 91' Depth cased 91'

CASING RECORD:
6-inch

FINISH:

AQUIFERS:

WATER LEVEL:
56'

PUMPING EQUIPMENT: Type Montgomery Ward - Jet H.P. 1
Capacity 12½ G.P.M.

WELL TESTS:
Drawdown 5 ft. after hours 15 1/3 G.P.M.
Drawdown ft. after hours G.P.M.

USE OF WATER Irrigation Temp. °F. , 19
SOURCE OF INFORMATION GR-3945
DRILLER or DIGGER Sam Munson
ADDITIONAL DATA:
Log NA Water Level Measurements Chemical Analysis Aquifer Test

REMARKS:

ORIGINAL
File Original and Duplicate with the
STATE ENGINEER,
SALEM, OREGON

WASH
011690

WATER WELL DRILLERS REPORT
STATE OF OREGON

Do Not Fill In
State Well No. 2/1W-13D
State ~~Permit~~ No. ~~GR-2762~~ app. GR-2615 cat

Pg 1 of 3

(1) OWNER:
Name Washington Co. School Dist #82
Address 8040 SW Durham Road
Tigard #23, Ore.

(2) LOCATION OF WELL:
County Washington Owner's number, if any—
R. F. D. or Street No.
Bearing and distance from section or subdivision corner
N45°E 100' est to SW corner of Lot 4.
Durham Acres, NW¼ NE¼
1000' E & 300' S from NW cor. Sect. 13

(3) TYPE OF WORK (check): Reg. Statement
[illegible]w well ☐ Deepening ☐ Reconditioning ☐ Abandon ☐
[illegible]bandonment, describe material and procedure in Item 11.

(4) PROPOSED USE (check):
Domestic ☑ Industrial ☐ Municipal ☐
Irrigation ☐ Test Well ☐ Other ☐

(5) EQUIPMENT:
Rotary ☐
Cable ☑
Dug Well ☐

([illegible]) CASING INSTALLED:
Threaded ☐ Welded ☐

FROM	ft. to	ft.	Diam.	Gage or Wall
0	150		6	

If gravel packed

Diameter of Bore	from ft.	to ft.

Type and size of shoe or well ring
Size of gravel:
Describe joint

(7) PERFORATIONS:
Type of perforator used unk
SIZE of perforations in., length, by in.

FROM	ft. to	ft.	perf per foot	No. of rows
110	147	?		

SCREENS:
Give Manufacturer's Name, Model No. and Size

(8) CONSTRUCTION:
Was a surface sanitary seal provided? ☐ Yes ☐ No To what depth ft.
Were any strata sealed against pollution? ☐ Yes ☐ No
If yes, note depth of strata
FROM ft. to ft.
METHOD OF SEALING

(9) WATER LEVELS:
Depth at which water was first found ft.
Standing level before perforating ft.
Standing level after perforating ft.

Log Accepted by:
[Signed] Owner Dated , 19

(10) WELL TESTS:
Was a pump test made? ☐ Yes ☐ No If yes, by whom?
Yield: 17 gal./min. with ft. draw down after hrs.
Artesian flow g.p.m.
Shut-in pressure lbs. per square inch
Bailer test g.p.m. with ft. drawdown
Temperature of water Was a chemical analysis made? ☐ Yes ☐ No
Was electric log made of well? ☐ Yes ☐ No.

(11) WELL LOG:
Diameter of well 6 inches.
Total depth 200 ft. Depth of completed well 150 ft.

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.*

ft. to	ft.	
0	8	Brown Silt
8	64	" Sand
64	74	Clay blue, very sticky
74	95	Silt, brown & blue
95	105	Clay, blue sticky
105	120	Silt, brown & blue
120	125	Silt, brown
135	140	Silt, blue - Sand & water bearing - mica [illegible]
140	150	Shale, blue
150	200	Shale, blue, clay, [illegible] [illegible]

Ground elevation at well site feet above mean sea level.
Work started July 1957. Completed Aug 1957

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 unk. (Person, firm, or corporation) (Typed or printed)
Address
Driller's well number
[Signed] (Well Driller)
License No. Dated , 19

Pg 2 of 3

STATE ENGINEER
Salem, Oregon

WASH
011690

Well Record

STATE WELL NO. 2/1W-13
COUNTY WASHINGTON
~~APPLICATION NO.~~ GR-2764

OWNER: Washington Co. School Dist. #82 by Esther C. Belkington, clerk

MAILING ADDRESS: 8040 S.W. Durham Road

CITY AND STATE: Tigard 23, Oregon

LOCATION OF WELL: Owner's No. ______

NE¼ NW ¼ NW ¼ Sec. 13 T. 2 ~~N.~~ S., R. 1 ~~E.~~ W., W.M.

Bearing and distance from section or subdivision corner N. 45° E. 100' to SW corner Lot 4 Durham Acres

Altitude at well ______

TYPE OF WELL: drilled Date Constructed 1951

Depth drilled 150 Depth cased 150

Section ______

CASING RECORD:

6-inch

FINISH:

From 110 to 147

AQUIFERS:

Silt, sand, clay and shale

WATER LEVEL:

PUMPING EQUIPMENT: Type Dorwald Ejector H.P. 1½
Capacity 12 G.P.M.

WELL TESTS:
Drawdown ______ ft. after ______ hours Pumping 17 G.P.M.
Drawdown ______ ft. after ______ hours ______ G.P.M.

USE OF WATER Domestic & irrigation Temp. ______ °F. ______, 19____
SOURCE OF INFORMATION GR-2615
DRILLER or DIGGER ______
ADDITIONAL DATA:
Log X Water Level Measurements ______ Chemical Analysis ______ Aquifer Test ______

REMARKS:

State Printing 88816

wash
T16490

r3 3 of 3

STATE ENGINEER
Salem, Oregon

State Well No. 2/1W-13
County WASHINGTON
~~Application No.~~ GR-2764

Well Log

Owner: Washington Co. School Dist. #82 by Esther C. Pelkington clerk Owner's No.

Driller: Date Drilled 1951

CHARACTER OF MATERIAL	(Feet below land surface) From	To	Thickness (feet)
Brown silt	8 .		8
Brown sand	64		56
blue clay (very sticky)	74		10
blue and brown silt layers	95		21
blue clay (sticky)	105		10
blue silt mixed with brown	120		15
brown silt	135		15
blue silt (watercaving) sand and mika	140		5
blue shale	150		10
blue shald and clay some of the layers very cavey	200		50

STATE ENGINEER
Salem, Oregon

WASH
011708

Well Record

STATE WELL NO. 2/1W-14B
COUNTY WASHINGTON
~~APPLICATION NO.~~ GR-2832

OWNER: Union High School No. 2 Jt., Washington County, Oregon
MAILING ADDRESS: Tigard, Oregon
CITY AND STATE:

LOCATION OF WELL: Owner's No.

NW ¼ NE ¼ Sec. 14 T. 2 ~~N.~~ S., R. 1 ~~E.~~ W., W.M.

Bearing and distance from section or subdivision corner 375' S. and 425' E.

Altitude at well

TYPE OF WELL: drilled Date Constructed 1952

Depth drilled 680 Depth cased 664

Section

CASING RECORD:

10-inch

FINISH:

AQUIFERS:

WATER LEVEL:

PUMPING EQUIPMENT: Type Sump Sumo H.P. 10
Capacity 80 G.P.M.

WELL TESTS:
Drawdown 232 ft. after hours Pumping 40 G.P.M.
Drawdown ft. after hours G.P.M.

USE OF WATER school use, irrigation Temp. °F. , 19
SOURCE OF INFORMATION GR-2669
DRILLER or DIGGER
ADDITIONAL DATA:
Log Water Level Measurements Chemical Analysis Aquifer Test

REMARKS:

State Printing 89316

STATE ENGINEER
Salem, Oregon

WASH
011715

Well Record

GR-1735

STATE WELL NO. 2/1W-14N
COUNTY Washington
APPLICATION NO. GR-1736

OWNER: George L. Hansen

MAILING ADDRESS: Rt. 4, Box 146

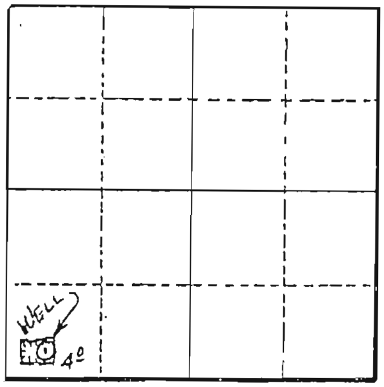
LOCATION OF WELL: Owner's No.

CITY AND STATE: Tualatin, Oregon

SW ¼ SW ¼ Sec. 14 T. 2 S., R. 1 W., W.M.

Bearing and distance from section or subdivision corner 300' N. & 50' W. from SE cor. of Lot 1 of Hazelbrook Farm

Altitude at well 150'



Section 14

TYPE OF WELL: Dug Date Constructed 1952

Depth drilled 46' Depth cased 46'

CASING RECORD:
36" circular brick walled

FINISH:

AQUIFERS:
Gravel

WATER LEVEL:
42'

PUMPING EQUIPMENT: Type Myers jet 2" x 1½" H.P. 1½
Capacity 20 G.P.M.

WELL TESTS:
Drawdown 0 ft. after hours 25 G.P.M.
Drawdown ft. after hours G.P.M.

USE OF WATER Irrigation Temp. °F. , 19
SOURCE OF INFORMATION GR Record
DRILLER or DIGGER
ADDITIONAL DATA:
Log N.A. Water Level Measurements Chemical Analysis Aquifer Test

REMARKS:
Irrigation of 4 acres.

NOTICE TO WATER WELL CONTRACTOR
The original and first copy
of this report are to be
filed with the

STATE ENGINEER, SALEM, OREGON 97310
within 30 days from the date
of well completion.

WASH NC

011717 **WATER WELL REPORT**
STATE OF OREGON
(Please type or print)
(Do not write above this line)

G-7070

G-6102

RECEIVED
APR 5 1973
STATE ENGINEER
SALEM, OREGON

State Well No. 25/1W-14da

State Permit No.

(1) OWNER:

Name John Thomas

Address 16575 S.W. 85th
Tigard, Ore. 97223

(2) TYPE OF WORK (check):

New Well ☒ Deepening ☐ Reconditioning ☐ Abandon ☐

If abandonment, describe material and procedure in Item 12.

(3) TYPE OF WELL:

Rotary ☐ Driven ☐
Cable ☒ Jetted ☐
Dug ☐ Bored ☐

(4) PROPOSED USE (check):

Domestic ☐ Industrial ☐ Municipal ☐
Irrigation ☐ Test Well ☐ Other ☐

CASING INSTALLED: Threaded ☐ Welded ☒

8" Diam. from +2' ft. to 168'6 ft. Gage .250

" Diam. from ft. to ft. Gage

" Diam. from ft. to ft. Gage

PERFORATIONS: Perforated? ☒ Yes ☐ No.

Type of perforator used Mills knifes

Size of perforations in. by in.

480 perforations from 117 ft. to 137 ft.

perforations from ft. to ft.

perforations from ft. to ft.

(7) SCREENS: Well screen installed? ☐ Yes ☒ No

Manufacturer's Name

Type Model No.

Diam. Slot size Set from ft. to ft.

Diam. Slot size Set from ft. to ft.

(8) WELL TESTS: Drawdown is amount water level is lowered below static level

Was a pump test made? ☒ Yes ☐ No If yes, by whom?

Yield: 125 gal./min. with 91 ft. drawdown after 6 hrs.

" 75 " 101 " 6½ "

" 60 " 79' " 7 "

Bailer test gal./min. with — ft. drawdown after — hrs.

Artesian flow g.p.m.

perature of water Depth artesian flow encountered ft.

(9) CONSTRUCTION:

Well seal—Material used pressure grouted cement & intrusion aid

Well sealed from land surface to 25 ft.

Diameter of well bore to bottom of seal 12 in.

Diameter of well bore below seal 12 in.

Number of sacks of cement used in well seal 16 sacks

Number of sacks of bentonite used in well seal 0 sacks

Brand name of bentonite —

Number of pounds of bentonite per 100 gallons of water — lbs./100 gals.

Was a drive shoe used? ☐ Yes ☒ No Plugs Size: location ft.

Did any strata contain unusable water? ☐ Yes ☒ No

Type of water? — depth of strata —

Method of sealing strata off —

Was well gravel packed? ☒ Yes ☐ No Size of gravel: 3/4-3/8

Gravel placed from 20 ft. to 160 ft.

(10) LOCATION OF WELL: John Thomas # 2-72

County Washington Driller's well number

¼ ¼ Section 14 T.2S R. 1W W.M.

Bearing and distance from section or subdivision corner

(11) WATER LEVEL: Completed well.

Depth at which water was first found 9' ft.

Static level 14' ft. below land surface. Date 2-22-73

Artesian pressure lbs. per square inch. Date

(12) WELL LOG: Diameter of well below casing —

Depth drilled 167 ft. Depth of completed well 167 ft.

Formation: Describe color, texture, grain size and structure of materials; and show thickness and nature of each stratum and aquifer penetrated, with at least one entry for each change of formation. *Report each change in position of Static Water Level and indicate principal water-bearing strata.*

MATERIAL	From	To	SWL
top soil	0	1	
blue clay	1	3	
gray clay	3	9	
brown sandy clay	9	25	
brown clay	25	51	
blue clay	51	128	
blue clay sand pea gravel & clam shells	128	135	
blue clay	135	167	

Work started 11-22 1972 Completed 1-26 1973

Date well drilling machine moved off of well 1-26 1973

Drilling Machine Operator's Certification:

This well was constructed under my direct supervision. Materials used and information reported above are true to my best knowledge and belief.

[Signed] Edgar J Mullen (Drilling Machine Operator) Date 2-25, 1973

Drilling Machine Operator's License No. 581

Water Well Contractor's Certification:

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

Name Milo Schneider Equipment Co (Person, firm or corporation) (Type or print)

Address Star Rt Box97 St. Paul, Ore

[Signed] Milo Schneider (Water Well Contractor)

Contractor's License No. 387 Date 2-25, 1973

(USE ADDITIONAL SHEETS IF NECESSARY)

SP*45656-119

Not on Map

NOTICE TO WATER WELL CONTRACTOR
The original and first copy
of this report are to be
filed with the
STATE ENGINEER, SALEM, OREGON 97310
within 30 days from the date
of well completion.

WASH
011806

WATER WELL REPORT
STATE OF OREGON
(Please type or print)

G-3240

State Well No. 2/1w-16 K
State Permit No.

(1) OWNER:
Name M. L. Terril
Address 17260 S. W. 131st
Tigard, Oregon

(2) LOCATION OF WELL:
County Washington Driller's well number 39-65
¼ SE ¼ Section 16 T. 2S R. 1W W.M.
Bearing and distance from section or subdivision corner

(3) TYPE OF WORK (check):
New Well ☒ Deepening ☐ Reconditioning ☐ Abandon ☐
If abandonment, describe material and procedure in Item 12.

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

(5) TYPE OF WELL:
Rotary ☐ Driven ☐
Cable ☒ Jetted ☐
Dug ☐ Bored ☐

(6) CASING INSTALLED: Threaded ☐ Welded ☒
6" Diam. from 0 ft. to 228 ft. Gage 0.250
" Diam. from ft. to ft. Gage
" Diam. from ft. to ft. Gage

(7) PERFORATIONS: Perforated? ☐ 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.
perforations from ft. to ft.
perforations from ft. to ft.

(8) SCREENS: Well screen installed? ☐ Yes ☒ No
Manufacturer's Name
Type Model No.
Diam. Slot size Set from ft. to ft.
Diam. Slot size Set from ft. to ft.

(9) CONSTRUCTION:
Well seal—Material used in seal Puddled clay.
Depth of seal 22 ft. Was a packer used? No
Diameter of well bore to bottom of seal 10 in.
Were any loose strata cemented off? ☐ Yes ☒ No Depth
Was a drive shoe used? ☒ Yes ☐ No
Was well gravel packed? ☐ Yes ☒ No Size of gravel:
Gravel placed from ft. to ft.
Did any strata contain unusable water? ☐ Yes ☒ No
Type of water? depth of strata
Method of sealing strata off

(10) WATER LEVELS:
Static level 35 ft. below land surface Date 8/9/65
Artesian pressure lbs. per square inch Date

(11) WELL TESTS:
Drawdown is amount water level is lowered below static level
Was a pump test made? ☐ Yes ☒ No If yes, by whom?
Yield: gal./min. with ft. drawdown after hrs.
" " " "
" " " "
Bailer test 30 gal./min. with 190 ft. drawdown after 1 hrs.
Artesian flow g.p.m. Date
Temperature of water 54° Was a chemical analysis made? ☐ Yes ☒ No

(12) WELL LOG:
Diameter of well below casing 6"
Depth drilled 285 ft. Depth of completed well 285 ft.

Formation: *Describe by color, character, size of material and structure, and show thickness of aquifiers 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
Clay, yellow sandy	0	22
Quicksand, brown	22	45
Silt, blue & grey packed	45 ~~125~~	58
Clay, blue sticky	58	70
Sand, blue	70	95
Clay, orange	95	112
Clay, grey	112	158
Clay, soft tan	158	187
Conglomerate, brown	187	218
Rock, decomposed brown	218	228
Rock, grey-yellow seams	228	255
Rock, brown	255	263
Rock, black	263	271
Rock, brown, seamy	271	275
Rock, black	275	285

RECEIVED
AUG 16 1965
STATE ENGINEER
SALEM, OREGON

Work started Aug. 2 1965 Completed Aug. 9 1965
Date well drilling machine moved off of well Aug. 11 1965

(13) PUMP:
Manufacturer's Name Myers
Type: Submersible H.P. 2

Water Well Contractor's Certification:

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

NAME Steinman Bros.
(Person, firm or corporation) (Type or print)
Address 15112 S. E. McLoughlin Blvd. Milwaukie, Ore.
Drilling Machine Operator's License No. 68
[Signed] Steinman Bros.
(Water Well Contractor)
Contractor's License No. I Date Aug. 12, 1965

(USE ADDITIONAL SHEETS IF NECESSARY)

NOTICE TO WATER WELL CONTRACTOR
The original and first copy
of this report are to be
filed with the
STATE ENGINEER, SALEM, OREGON 97310
within 30 days from the date
of well completion.

RECEIVED
JUN 24 1969
STATE ENGINEER
SALEM, OREGON

WATER WELL REPORT
STATE OF OREGON
(Please type or print)
(Do not write above this line)

WASH
011873

G-5501

State Well No. 2/1W-18 adb

State Permit No.

(1) OWNER:
Porter Walton Co. Inc. Nursery Pet. USB

Name ~~Yoshio & Sachiko Hasuike~~

Address 15685 S.W.150th.Ave.Tigard,Ore.97223

(2) TYPE OF WORK (check):
New Well ☒ Deepening ☐ Reconditioning ☐ Abandon ☐

If abandonment, describe material and procedure in Item 12.

(3) TYPE OF WELL:
Rotary ☐ Driven ☐
Cable ☒ Jetted ☐
Dug ☐ Bored ☐

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

[illegible] CASING INSTALLED:
Threaded ☐ Welded ☒

12" Diam. from 0 ft. to 52 ft. Gage .250
" Diam. from ft. to ft. Gage
" Diam. from ft. to ft. Gage

[illegible] PERFORATIONS:
Perforated? ☐ 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.
perforations from ft. to ft.
perforations from ft. to ft.

(7) SCREENS:
Well screen installed? ☐ Yes ☐ No

Manufacturer's Name

Type Model No.

Diam. Slot size Set from ft. to ft.
Diam. Slot size Set from ft. to ft.

(8) WATER LEVEL: Completed well.
Static level 60 ft. below land surface Date 6/18/69

[illegible]sian pressure lbs. per square inch Date

(9) WELL TESTS:
Drawdown is amount water level is lowered below static level

Was a pump test made? ☐ Yes ☒ No If yes, by whom? Haakon Bottner

Yield: 260 gal./min. with 50 ft. drawdown after 7 hrs.
414 " 79 " 2 "
" " " "

Bailer test gal./min. with ft. drawdown after hrs.

Artesian flow g.p.m. Date

Temperature of water 54° Was a chemical analysis made? ☐ Yes ☒ No

(10) CONSTRUCTION:
Well seal—Material used Cement & sand

Depth of seal 28 ft.

Diameter of well bore to bottom of seal 16 in.

Were any loose strata cemented off? ☐ Yes ☒ No Depth

Was a drive shoe used? ☐ Yes ☒ No

Did any strata contain unusable water? ☒ Yes ☐ No

Type of water? Sandy depth of strata 40' to 42'

Method of sealing strata off cased

Was well gravel packed? ☐ Yes ☒ No Size of gravel:

Gravel placed from ft. to ft.

(11) LOCATION OF WELL:
County Washington Driller's well number

¼ ¼ Section 18 T. 2S. R. 1W W.M.

Bearing and distance from section or subdivision corner

(12) WELL LOG:
Diameter of well below casing 12"

Depth drilled 392 ft. Depth of completed well 392 ft.

Formation: Describe color, texture, grain size and structure of materials; and show thickness and nature of each stratum and aquifer penetrated, with at least one entry for each change of formation. Report each change in position of Static Water Level as drilling proceeds. Note drilling rates.

MATERIAL	From	To	SWL
Top soil	0	3	
Clay, yellow	3	7	
Rock, broken	7	8	
Clay w/embeded rock	8	40	
Sand, yellow	40	42	27
Clay, yellow sandy	42	48	
Clay w/embeded rock	48	50	
Rock, brown solid	50	118	
Clay, brown	118	126	
Rock, red lava soft, water bearing	126	159	
Rock, black	159	197	
Clay, yellow	197	198	
Rock, black	198	358	
Rock, gray, mdm. hard	358	370	
Rock, brown, soft, w. brng.	370	389	60
Rock, black, hard	389	392	

Work started April 1 1969 Completed June 12 1969

Date well drilling machine moved off of well June 20 1969

Drilling Machine Operator's Certification:
This well was constructed under my direct supervision. Materials used and information reported above are true to my best knowledge and belief.

[Signed] Louis W. Brant Date 6/20, 1969
(Drilling Machine Operator)

Drilling Machine Operator's License No. 246-431

Water Well Contractor's Certification:
This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.

NAME HAAKON BOTTNER DRILLING COMPANY
(Person, firm or corporation) (Type or print)

Address 3424 S.E.174 th. AVE.PORTLAND,ORE.

[Signed] Haakon Bottner
(Water Well Contractor)

Contractor's License No. 109 Date 6/20/, 1969

(USE ADDITIONAL SHEETS IF NECESSARY)

Not on map

Appendix D

Appendix D

MONTGOMERY WATSON

MEMORANDUM

To: Jennifer Renninger, Montgomery Watson March 26, 2001

FR: Steve Moncaster, Golder Associates Inc.

Re: City of Tigard ASR Study Our ref: 013-1419.002

City of Tigard ASR Study – Task 2 Well Suitability Evaluation

1. Objective

The purpose of the work reported in this memorandum is to determine the feasibility of using the existing City of Tigard public water supply wells to inject and store treated water underground. This work forms part of an ASR pilot-testing program that is being performed for the City by Montgomery Watson and Golder Associates Inc..

2. Approach and Scope of Work

The approach used and related scope of work is summarized as follows;

- Collate and review the available well construction logs to determine whether or not each well complies with the current OWRD well construction standard;
- Determine the aquifer properties in the vicinity of each well and generate a preliminary estimate of the available recharge capacity;
- Identify the pump and pipeline engineering associated with each well and assess the ease with which treated water could be recharged to the underlying aquifers via use of the existing equipment;

In addition, an assessment has been made of the availability of monitoring wells in the vicinity of each production well.

Specific deliverables associated with this memorandum include the following;

- A summary of the issues described above;
- The available well construction and geological logs;
- A map identifying the location of suitable monitoring wells;

3 Compliance with OWRD Well Construction Standards

Current Oregon Water Resources Department (OWRD) regulations require compliance with the following well construction specifications:

- Casing – the well must be cased using steel or plastic casing in order to seal the upper portion of the borehole and prevent caving;
- Seal – the annular space between the casing and the borehole wall must be sealed using either a neat cement grout or bentonite. The seal must be a minimum of 18 ft deep;
- Co-mingling – under no circumstances should groundwater derived from more than one aquifer be permitted to mix within the well;
- Openings – each well should be constructed with an opening at the surface to enable the water level in the well to be measured;
- Top terminal height – the casing head shall be completed at a minimum of 12 inches above the local surface run-off level.

On the basis of the table below, it can be seen that Wells 1 and 3 fully comply with the OWRD regulations but that there is some uncertainty with respect to the surface seal construction and integrity in Wells 2 and 4. This means that there is also some uncertainty about the risks associated with co-mingling (between basalt groundwater and groundwater in the overburden) at these wells.

Compliance Issue	**Well**			
	1	**2**	**3**	**4**
Casing Type and Depth (depth to basalt aquifer)	12 inch steel to 71 ft bgl[1] (47 ft)	10 inch steel to 342 ft bgl (47 ft)	12 inch steel to 91.5 ft bgl (54 ft)	12 inch steel to 242 ft bgl (71 ft)
Seals (minimum 18 ft)	0 - 71 ft bgl cement grout	60 ft - 70 ft cement grout[2]	0 - 91.5 ft cement grout	0 - 242 ft bgl cement, sand and gravel
Risk of co-mingling	Minimal	In worst case[2] depends on the permeability distribution in top 30 ft of aquifer	Minimal	Depends on method of mixing and placement of concrete used for seal
Access for water level measurements	Available	Available	Available	Not available
Terminal Height	Complies with specification	Complies with specification	Complies with specification	Complies with specification

[1] bgl – below ground level

[2] Not clear from log whether the seal is from surface to between 60 ft and 70 ft bgl or the seal is between 60 ft and 70 ft (i.e. 10 ft thick)

In addition, it is noted that there is no apparent access at Well 4 for water level recording devices.

4 Recharge Capacities

For the purposes of comparison, the recharge capacity of each well has been estimated on the basis of the maximum amount of water that could be injected under the influence of gravity. The results are given below;

Well	Estimated Transmissivity[1] (gpd/ft)	Available Water Level Build-up (ft)[2]	Injection Capacity (gpm)[3]
1	23,000	222	2,418
2	21,600	190	1,943
3	5,000	215	509
4	2,400	257	292

[1] approximate estimate, empirically derived using the available drawdown data
[2] Based on static water level at time of construction
[3] Assumes steady-state conditions and that each well is 100 % hydraulically efficient.

The results suggest that significantly high rates of injection will be possible in Wells 1 and 2, principally as a consequence of the high transmissivity of the basalt at these sites and the significant depth to static water level.

By contrast, the injection capacities of Wells 3 and 4 are likely to be significantly lower than those of Wells 1 and 2. Given similar depths to static water levels, the large differences primarily reflect the lower transmissivity of the basalt in the vicinity of Wells 3 and 4.

5 Engineering Considerations

A summary of the available pump engineering data is given below;

Well	Pump Type	Capacity and Status	Nominal Pump Column Diameter (inches)	Nominal Annular Space (inches)
1	Peerless 75 hp Turbine line shaft (21 stages)	300 gpm Operational	8 reducing to 4 at 350 ft bgl	2 to 350 ft
2	Peerless 75 hp Turbine line Shaft (9 stages)	500 gpm Operational	6	2

Well	Pump Type	Capacity and Status	Nominal Pump Column Diameter (inches)	Nominal Annular Space (inches)
3	Crown Electric Submersible (25 hp 9 stage)	125 gpm Operational	4	4
4	150 hp Turbine line shaft	500 gpm Out of Service	Not known at present	Not known at present

In respect of the equipment present in Wells 1 and 2, the following is noted;

- The two Peerless turbine line shaft pumps are equipped with non-reverse ratchets on the pump motors (Mather and Sons, personal communication). These will enable water to be injected via the pump column without causing the pump motor to spin in reverse;
- The magnitude of the head losses likely to be experienced across the pump bowls is not known, with the result that there is some uncertainty with respect to the injection rates which can actually be achieved at each well;

In respect of the equipment present in Wells 3 and 4 the following is noted;

- The electric submersible pump in Well 3 contains a check valve that would prevent water being injected via the pump column (Mather and Sons, personal communication);
- To put the pump in Well 4 back into service would be difficult and expensive owing to a combination of
    1. limited access for lifting equipment;
    2. lack of level, stable ground in the immediate vicinity of the pump house for siting a crane or hoist;
    3. uncertainty with respect to the available electrical supply;
    4. limited space at the wellhead for the disassembly and assembly of the pump column;
    5. likely long length of the pump column;

Subject to further evaluation, therefore, it appears likely that the existing pumps and pump columns in Wells 1 and 2 could be used to inject treated water underground. By contrast, none of the equipment in Well 4 could be used in its current condition and use of the equipment present in Well 3 would require either insertion of an injection pipe into the well or recovery and modification of the existing submersible pump.

It is also noted that the future value of any additional engineering work at Wells 3 and 4 is likely to be constrained by the low specific capacity of these wells and the associated limits on recharge and recovery rates.

6 Observation Wells

Consultation with Marc Norton of the OWRD indicates that the following observation wells may be available for use in conjunction with any ASR pilot testing at Wells 1 and 2;

- Tigard High School (irrigation well)
- King City Golf Course (irrigation well)
- Wardin Well (domestic well)
- James Templeton Elementary School (irrigation well)

The location of these wells is shown on the attached figure, together with wells identified in the MW/Golder proposal document and two additional, domestic wells, identified by Mr. Norton. The domestic wells are located on Hoodview Drive and SW Kable Street, in an area that is immediately to the south east of Well 1. At the present time, the construction, status and accessibility of these are unknown.

It should be noted that there appears to be no grout seal between the casing and the adjacent geological formations in the Tigard High School well. Implications for future ASR operations include a potential flooding risk. A similar risk may be posed to the domestic wells on Hoodview Drive and SW Kable Street.

7 Summary

Subject to confirmation with respect to certain engineering issues, the injection capacities and equipment available at Wells 1 and 2 make both of these wells suitable for future ASR pilot testing and potentially suitable for full scale ASR operations. At the present time, however, uncertainty with respect to the integrity of the grout seal in Well 2 means that Well 1 offers the greater potential for immediate testing and development.

Other potential advantages inherent in the use of Well 1 include;

- Ready access to waste water disposal facilities (subject to any requirement to obtain a NPDES permit);
- Nearby location of observation wells;

By contrast, the feasibility of using Wells 3 and 4 is compromised by a combination of low injection capacities, failure to comply with current well construction standards (Well 4) and the lack of suitable existing equipment.

Addendum

CCTV logging of Well 1 on 03/02/01 revealed the presence of water cascading into the well via a perforation in the well casing. The location of the leak was estimated to be at approximately 50 ft bgl, the rate of inflow was subsequently estimated to be less than 1 gpm. In addition, it was also noted from the CCTV log that water appeared to be entering the well at the base of the casing.

The condition of the casing and the presence of the leak(s) mean that Well 1 fails to comply with the current OWRD well construction regulations. Subsequent discussion with OWRD confirmed that the leak would have to be repaired to prevent co-mingling of groundwater in the well. The two basic engineering options comprise the following;

- Insertion of narrower diameter casing into the well and grouting this into position in such a way that defections in the casing and seal are remedied;
- Construction of a new well at the site with either refurbishment or abandonment of the existing well.

During the discussions referred to above, OWRD indicated that any narrower diameter casing would likely have to be inserted to a depth of around 300 ft bgl. Whilst this is desirable from the point of view of a future ASR test (to prevent recharge of the unsaturated zone and problems associated with leakage loss or cascading), re-casing to this depth necessitates use of a casing smaller than 12 inches in diameter. It is likely that an 8-inch casing will be required to ensure a good grout seal between the casing and borehole wall.

However, casing of this diameter or less would restrict the pump column diameter that could be set and, as such, would significantly reduce the yield that could be developed from the well.

To avoid any yield restrictions, construction of a new well is recommended. The advantages inherent in this strategy for a future ASR test include the following;

- Reduced uncertainty with respect to the future performance of the production well seal during injection, storage and recovery;
- An option to design and construct the new well to enable the efficient collection of water level data (i.e. complete at a diameter sufficient to enable installation of an access tube for a pressure transducer);
- An option to re-furbish the existing production well so as to provide a dedicated on-site ASR monitoring well - without incurring the bulk of the associated construction costs;
- A related option to monitor ASR related water level responses in the basalt without having to gain access to or instrument off-site monitoring wells.

Finally, in view of the developing drought situation, it has been agreed with OWRD that remedial work on Well 1 can be deferred until after the (summer) period of peak demand, providing that;

(a) a sample of the inflow is obtained, analyzed and is shown to be free from contamination, and;
(b) a program of additional sampling and analysis of the production from the well is undertaken to demonstrate on-going compliance with water quality standards.

V:\PROJECTS_2001 PROJECTS\013-1419 - Tigard ASR\Task 2 - Well Suitability\Well Suitability A0-V1-DB edits.doc

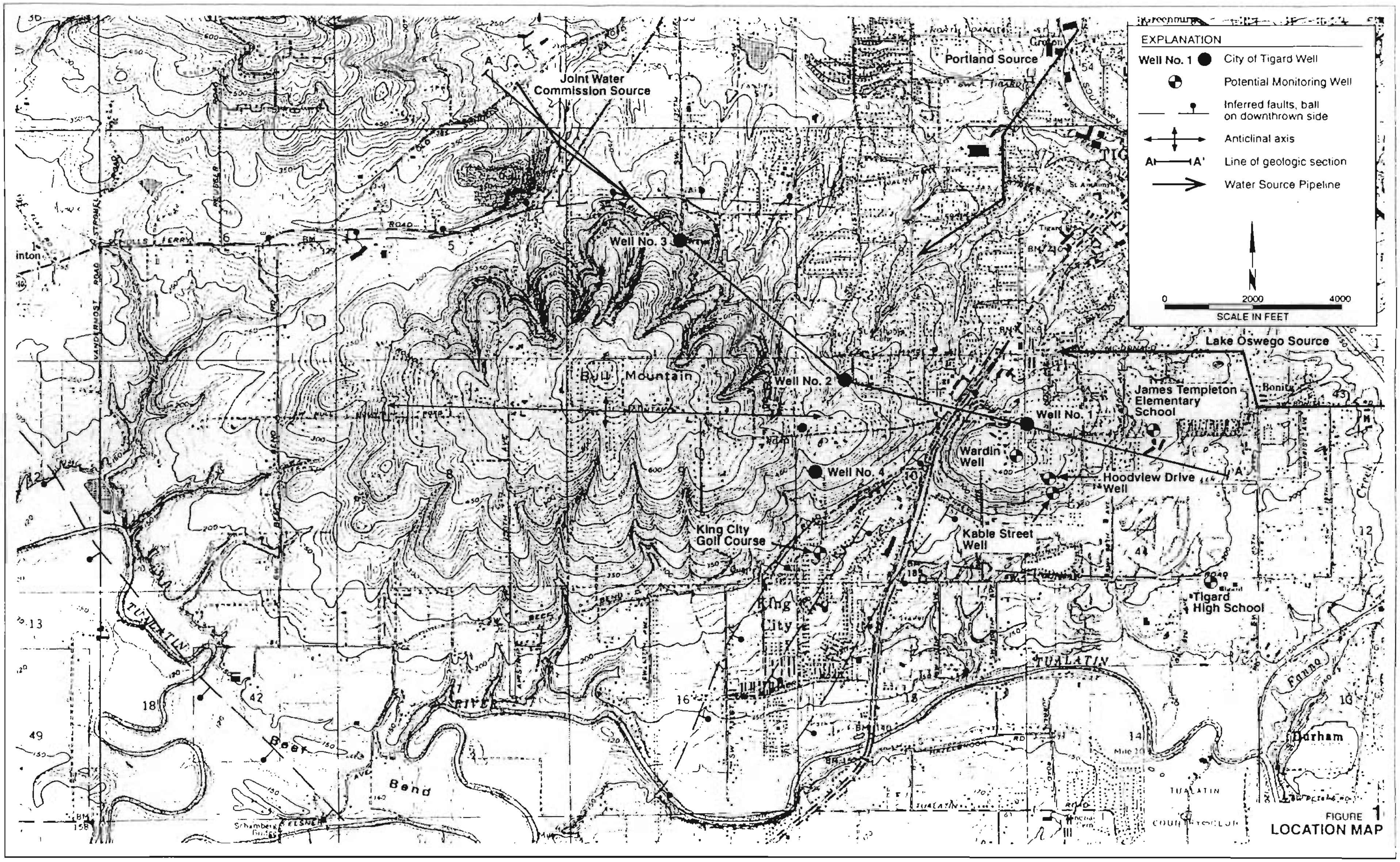


FIGURE 1
LOCATION MAP

PROJECT NO 013 1419 002 DRAWING NO 95277 DATE 03/30/01 DRAWN BY EL

Golder Associates

2/1W-11E(1)

WELL #1
November 18, 1947 Sounded

R. J. STRASSER DRILLING CO.

R 3, Box 594
Portland 6, Oregon

Log of 12" well drilled for Tigard Water District, Completed April 25, 1947 by R. J. Strasser Drilling Company.

Surface	to	2 ft.	Top soil
2 ft.	"	11 "	Yellow clay
11 "	"	22 "	Hard pan with some sand
22 "	"	47 "	Silt and yellow clay
47 "	"	64 "	Soft lava rock
64 "	"	84 "	Gray and green lava rock
84 "	"	168 "	Black, gray, red rock medium hard
168 "	"	192 "	Black and red rock medium hard
192 "	"	202 "	Black hard rock
202 "	"	212 "	Red and black soft porous rock with some water
212 "	"	220 "	Hard black rock
220 "	"	230 "	Hard black rock
230 "	"	260 "	Gray and black medium hard rock
260 "	"	272 "	Gray porous rock with water
272 "	"	309 "	Hard black rock some crevices
309 "	"	315 "	Red rock not so hard
315 "	"	325 "	Yellow and gray soft rock showing water
325 "	"	345 "	Gray hard rock
345 "	"	370 "	Medium hard gray rock
270 "	"	381 "	Hard gray rock

Well cased with 12" pipe to a depth of 71 feet and a cement grout placed to prevent surface water from entering the well.

Static water level 188feet from the surface.
Pump test showed 60 G.P.M. with 20 feet draw down.
" " " 120 " " 30 " " "
" " " 170 " " 46 " " "
" " " 210 " " 97 " " "

Would recommend pump setting of 250 feet column, bowls and 35 feet of suction capacity 176 G.P.M. Your pumping level would be 240 feet which would be the most practicable level to pump from as the next 40 feet of draw down only adds 40 G.P.M. of water and all of your water would need to be pumped that extra depth.

SEE DEEPENING 4-2-66

STATE ENGINEER
Salem, Oregon

WASH
011594

OBSERVATION WELL
Well-Record

STATE WELL NO. 2/1w-11 E
COUNTY Washington
APPLICATION NO. GR-616

OWNER: Tigard Water District

MAILING ADDRESS: c/o C.E. Janoe
8900 Burnham Ave. (S78)

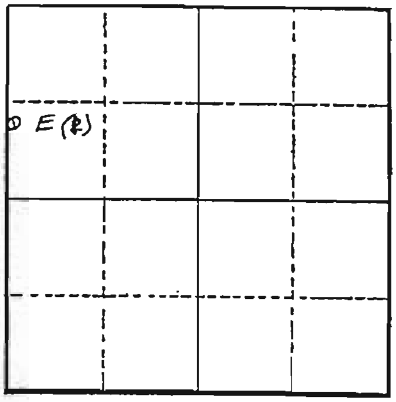
LOCATION OF WELL: Owner's No. #1

CITY AND STATE: Tigard, Oregon

SW ¼ NW ¼ Sec. 11 T. 2 S., R. 1 W., W.M.

Bearing and distance from section or subdivision corner S. 1625 ft. & E. 30 ft. from N.W. cor. sec. 11

Altitude at well 403



Section 11

TYPE OF WELL: drilled Date Constructed April 25, '47

Depth drilled 381 DEEPENED 4-2-66 Depth cased

CASING RECORD:
12 inch

FINISH:

AQUIFERS:

WATER LEVEL:
188

PUMPING EQUIPMENT: Type Peerless Turbine H.P. 15
Capacity 250 G.P.M.

WELL TESTS:
Drawdown 96 ft. after hours 170 G.
Drawdown 97 ft. after hours 210 G.

USE OF WATER municipal Temp. °F. , 19
SOURCE OF INFORMATION GR-616
DRILLER or DIGGER —
ADDITIONAL DATA:
Log — Water Level Measurements Chemical Analysis Aquifer Test

REMARKS:

SC = 3·69 - 2·16

State Printing 89316

SC = [illegible]/43 = 11.5 gpm/ft

[illegible] 10 gpm/ft

... 2, 1966

NOTICE TO WATER WELL CONTRACTOR
The original and first copy
of this report are to be
filed with the
STATE ENGINEER, SALEM, OREGON 97310
within 30 days from the date
of well completion.

WASH
011593

WATER WELL REPORT

STATE OF OREGON
(Please type or print)

Deepening

State Well No. 2/1W-11E

State Permit No.

(1) OWNER: ~~[illegible]~~

Name Tigard Water District

Address 8841 S.W.COMMERCIAL St.
Tigard Oregon

(2) LOCATION OF WELL: Near S.W.103rd.Ave. and Highway U.S. 99W

County Washington Driller's well number

S.W ¼ N.W. ¼ Section 11 T. 2S R. 1W W.M.

Bearing and distance from section or subdivision corner

Well #1

(3) TYPE OF WORK (check):

N[illegible] Well ☐ Deepening ☒ Reconditioning ☐ Abandon ☐

[illegible]ndonment, describe material and procedure in Item 12.

(4) PROPOSED USE (check):

Domestic ☐ Industrial ☐ Municipal ☒
Irrigation ☐ Test Well ☐ Other ☐

(5) TYPE OF WELL:

Rotary ☐ Driven ☐
Cable ☒ Jetted ☐
Dug ☐ Bored ☐

(6) CASING INSTALLED: Threaded ☐ Welded ☐

" Diam. from ft. to ft. Gage
" Diam. from ft. to ft. Gage
" Diam. from ft. to ft. Gage

(7) PERFORATIONS: Perforated? ☐ 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.
perforations from ft. to ft.
perforations from ft. to ft.

(8) SCREENS: Well screen installed? ☐ Yes ☒ No

Manufacturer's Name
T[illegible] Model No.
Diam. Slot size Set from ft. to ft.
Diam. Slot size Set from ft. to ft.

(9) CONSTRUCTION:

Well seal—Material used in seal
Depth of seal ft. Was a packer used?
Diameter of well bore to bottom of seal in.
Were any loose strata cemented off? ☐ Yes ☐ No Depth
Was a drive shoe used? ☐ Yes ☐ No
Was well gravel packed? ☐ Yes ☐ No Size of gravel:
Gravel placed from ft. to ft.
Did any strata contain unusable water? ☐ Yes ☐ No
Type of water? depth of strata
Method of sealing strata off

(10) WATER LEVELS:

Static level 222 ft. below land surface Date 4/1/66
Artesian pressure lbs. per square inch Date

(11) WELL TESTS:

Drawdown is amount water level is lowered below static level

Was a pump test made? ☒ Yes ☐ No If yes, by whom? Bottner Drilling

Yield: 165 gal./min. with 17 ft. drawdown after hr
" 374 " 40 "
" 452 " 46 combined 12"
~~XXXXX~~ test * 495 gal./min. with 43 ft. drawdown after 12 hr

Artesian flow g.p.m. Date

Temperature of water 53° Was a chemical analysis made? ☐ Yes ☐ N

(12) WELL LOG:

Diameter of well below casing 12"

Depth drilled ~~227~~ 229 ft. Depth of completed well 612

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

MATERIAL	FROM	TO
Rock, black	381	41
Rock, red	410	42
Clay, brown	426	44
Rock, black	449	49
Clay, w/ embeded rock	491	49
Rock, red	496	50
Rock, black	500	52
Cuttings washed away,		
water bearing	525	53
Rock, black hard	532	56
Rock, black (crevis)	560	56
Rock, brownish red, soft	562	57
Rock, red soft, coarse		
water bearing	579	59
Rock, black, mdm hard	597	61

Note :
To Straighten well, back filled with boulders & gravel from 383 ft. to 368 ft, redrilled and back filled the 2nd. time .
* After pumping 12 hrs. gained 3 ft.

Work started Jan. 27 1966 Completed April 2 19
Date well drilling machine moved off of well April 6 19

(13) PUMP:

Manufacturer's Name
Type: H.P.

Water Well Contractor's Certification:

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

NAME HAAKON BOTTNER DRILLING COMPANY
(Person, firm or corporation) (Type or print)

Address 3424 S.E. 174 Street Portland Or

Drilling Machine Operator's License No. 380 & 246

[Signed] H. Bottner
(Water Well Contractor)

Contractor's License No. 109 Date April 9, 196

WELL # 2

R. J. STRASSER DRILLING COMPANY
8110 S.E. Sunset Lane
Portland 6, Oregon

Log of well # 2 for the Tigard Water District 12 inch well cased with 10 inch to 342 feet deep. Comleted 7/30/49.

Surface		to	2	Ft	Top soil
2	ft	"	29	"	Yellow and red clay
29	"	"	47	"	Decomposed rock
47	"	"	83	"	Hard gray rock
83	"	"	97	"	Brownish red medium rock
97	"	"	192	"	Hard gray rock
192	"	"	201	"	Soft brownish red rock with around 100 G.P.M.
209	"	"	229	"	Hard gray rock
209	"	"	224	"	Porous brown rock with a little water
224	"	"	265	"	Gray and brown rock
265	"	"	274	"	Porous brown rock a little water
274	"	"	319	"	Hard gray rock Well was tested at 342 feet and furnished 220 G.P.M.a draw down of 140 feet.
335	"	"	362	"	Hard gray rock
362	"	"	368	"	Brown porous rock
368	"	"	395	"	Hard clay
395	"	"	400	"	Soft red rock should have some water
400	"	"	438	"	Gray rock
438	"	"	447	"	Very soft yellow rock with water
447	"	"	453	"	Gray rock

Static water levil 190 feet from the surface.

Pump test showed	325 G.P.M. with	72	feet draw down
	400 " "	90	" " "

A cement seal was made around the casing at a depth of 60 t0 70 feet to prevent any water from entering the well above the 70 ft. level.

SC = (4.44 - 4.51) gpm/ft

T ≈ 10,000 gpd/ft

STATE ENGINEER
Salem, Oregon

WASH
011592

OBSERVATION WELL

Well Record

STATE WELL NO. 2/1W-10
COUNTY Washington
APPLICATION NO. GR-6A

OWNER: Tigard Water District

MAILING ADDRESS: % C.E. Janoe Chairman — 8900 SW Burnham ave.

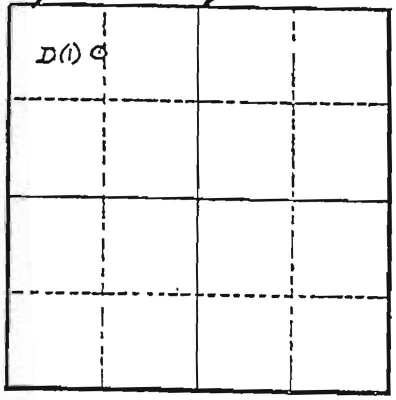
LOCATION OF WELL: Owner's No. #2

CITY AND STATE: Tigard, Oregon

NW ¼ NW ¼ Sec. 10 T. 2 S., R. 1 W., W.M.

Bearing and distance from section or subdivision corner S. 610 ft. & E. 1270 ft. from N.W. cor. sec. 10

Altitude at well 375 ft.



TYPE OF WELL: drilled Date Constructed July 30, '49

Depth drilled 453 Depth cased 342

Section 10

CASING RECORD:
12 inch

FINISH:

AQUIFERS:

WATER LEVEL:
190 Feet

PUMPING EQUIPMENT: Type Peerless Turbine H.P. 15
Capacity 500+ G.P.M.

WELL TESTS:
Drawdown 72 ft. after hours 325 G.
Drawdown 90 ft. after hours 400 G.

USE OF WATER municipal Temp. °F. , 19
SOURCE OF INFORMATION GR-615
DRILLER or DIGGER
ADDITIONAL DATA:
Log — Water Level Measurements Chemical Analysis Aquifer Test

REMARKS:

State Printing 89316

ORIGINAL
File Original and
Duplicate with the
STATE ENGINEER,
SALEM, OREGON

OBSERVATION WELL

WATER WELL REPORT
STATE OF OREGON

WASH

011449

G760

State Well No. 2/1W-46(1

State Permit No. G-655

(1) OWNER:
Name Tigard Water District
Address Tigard, Oregon
W&M 3

(2) LOCATION OF WELL:
County WASH. Owner's number, if any—
¼ ¼ Section T. R. W.M.
Bearing and distance from section or subdivision corner

(3) TYPE OF WORK (check):
New Well ☒ Deepening ☐ Reconditioning ☐ Abandon ☐
If abandonment, describe material and procedure in Item 11.

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

(5) TYPE OF WELL:
Rotary ☒ Driven ☐
Cable ☒ Jetted ☐
Dug ☐ Bored ☐

(6) CASING INSTALLED: Threaded ☐ Welded ☒
12" Diam. from Surface ft. to 91.5 ft. Gage 45 #/ft.
" Diam. from ft. to ft. Gage
" Diam. from ft. to ft. Gage

(7) PERFORATIONS: Perforated? ☐ 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.
perforations from ft. to ft.
perforations from ft. to ft.

(8) SCREENS: Well screen installed ☐ Yes ☒ No
Manufacturer's Name
Type Model No.
Diam. Slot size Set from ft. to ft.
Diam. Slot size Set from ft. to ft.

(9) CONSTRUCTION:
Was well gravel packed? ☐ Yes ☒ No Size of gravel:
Gravel placed from ft. to ft.
Was a surface seal provided? ☒ Yes ☐ No To what depth? 91.5 ft.
Material used in seal— neat cement grout
Did any strata contain unusable water? ☐ Yes ☒ No
Type of water? Depth of strata
Method of sealing strata off

(10) WATER LEVELS:
Static level 215 ft. below land surface Date at completion of pump test and after 218 ft depth in hole was reached
Artesian pressure lbs. per square inch Date

Log Accepted by:
[Signed] (Owner) Date , 19

(11) WELL TESTS:
Drawdown is amount water level is lowered below static level
Was a pump test made? ☒ Yes ☐ No If yes, by whom? Strasse Drillin
Yield: 380 gal./min. with 153 ft. drawdown after 24
" 350 " 128 " 24
" 300 " 80 " 24
Bailer test gal./min. with ft. drawdown after
Artesian flow g.p.m. Date
Temperature of water Was a chemical analysis made? ☒ Yes ☐

(12) WELL LOG:
Diameter of well 12 inc
Depth drilled 494 ft. Depth of completed well 494

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

MATERIAL	FROM	TO
Topsoil and brown clay	Surfa.	
Red shale	9	2
Grey and green conglomerate	26	5
Soft grey basalt	54	8
Red and brown rock	86	11
Grey basalt	114	13
Grey and brown rock - clay seams	136	15
Red rock	150	16
Grey basalt	168	21
Porous grey basalt (water)	218	26
Brown and grey basalt	263	28
Porous grey basalt	287	301
Hard grey basalt	301	31
Porous grey basalt	312	33
Porous brown and grey basalt	330	341
Hard grey basalt	341	35
Brown and grey porous basalt	357	37
Hard grey basalt	376	404
Porous grey basalt	404	42
Black basalt	422	434
Porous grey basalt	434	45
Hard grey basalt	450	456
Porous black basalt(muddy water dpeosits)	456	48
Grey basalt	483	494

Work started Dec. 11 1957 Completed Feb. 17 19

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

Well Driller's Statement:

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

NAME R. J. Strasser Drilling Col
(Person, firm, or corporation) (Type or print)
Address 8110 SE Sunset Lane, Portland 6, Orego

Driller's well number ~~10~~ 3094

[Signed] Robert L. Strasser - Partner
(Well Driller)

License No. 10 Date March 5 19

(USE ADDITIONAL SHEETS IF NECESSARY)

SC = 3.71 / 2.73 / 2.48 ✓ T = 4967 gpd/ft.

SC - 2.08 w 7.57

WASH
011590

RECEIVED
OCT 27 1966
ENGINEER
OREGON

1966

NOTICE TO WATER WELL CONTRACTOR
The original and first copy
of this report are to be
filed with the
STATE ENGINEER, SALEM, OREGON 97310
within 30 days from the date
of well completion.

WATER WELL REPORT
STATE OF OREGON
(Please type or print)

State Well No. ~~Well No. 4~~ 2/1w-10
State Permit No.

(1) OWNER:

Name Tigard Water District
Address 8841 S.E. COMMERCIAL ST.
TIGARD OREGON 97223

(2) LOCATION OF WELL:

County WASHINGTON Driller's well number #4
¼ NW ¼ Section 10 T. 2S R. 1W W.M.
Bearing and distance from section or subdivision corner
North of S.W. Bend West of S.W.Pacific Highway near the King City Development

~~Well #4~~

(3) TYPE OF WORK (check):

N[illegible] Well ☒ Deepening ☐ Reconditioning ☐ Abandon ☐
If abandonment, describe material and procedure in Item 12.

(4) PROPOSED USE (check):

Domestic ☐ Industrial ☒ Municipal ☐
Irrigation ☐ Test Well ☐ Other ☐

(5) TYPE OF WELL:

Rotary ☐ Driven ☐
Cable ☒ Jetted ☐
Dug ☐ Bored ☐

(6) CASING INSTALLED:

Threaded ☐ Welded ☒
242 " Diam. from ft. to ft. Gage
" Diam. from ft. to ft. Gage
12 " Diam. from 0 ft. to 242 ft. Gage .330

(7) PERFORATIONS:

Perforated? ☐ 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.
perforations from ft. to ft.
perforations from ft. to ft.

(8) SCREENS:

Well screen installed? ☐ Yes ☐ No
Manufacturer's Name
T[illegible] Model No.
Diam. Slot size Set from ft. to ft.
Diam. Slot size Set from ft. to ft.

(9) CONSTRUCTION:

Well seal—Material used in seal Cement, sand & gravel
Depth of seal 242 ft. Was a packer used? no
Diameter of well bore to bottom of seal 16 in.
Were any loose strata cemented off? ☐ Yes ☒ No Depth
Was a drive shoe used? ☐ Yes ☒ No
Was well gravel packed? ☐ Yes ☒ No Size of gravel:
Gravel placed from ft. to ft.
Did any strata contain unusable water? ☐ Yes ☐ No
Type of water? depth of strata
Method of sealing strata off

(10) WATER LEVELS:

Static level 257 ft. below land surface Date
Artesian pressure lbs. per square inch Date

(11) WELL TESTS:

Drawdown is amount water level is lowered below static level
Was a pump test made? ☒ Yes ☐ No If yes, by whom?
Yield: 250 gal./min. with 33 ft. drawdown after 8
" 303 " 60 " 8
" 360 " 173 " 8
Bailer test gal./min. with ft. drawdown after
Artesian flow g.p.m. Date
Temperature of water 56 Was a chemical analysis made? ☐ Yes ☒

(12) WELL LOG:

Diameter of well below casing 12 "
Depth drilled 725 ft. Depth of completed well 725

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
Clay, brown w/grey rock	0	25
Clay & broken rock	25	71
Rock , black	71	103
Rock , brown soft	103	111
Rock , ~~red~~ black ?	111	141
Clay , red	141	146
Rock , brown soft	146	161
Rock , black hard	161	210
Rock , blue	210	242
Rock , brown	242	320
Rock , red	320	360
Rock , brown	360	389
Rock , red	389	421
Rock , brown	421	429
Rock , blue	429	436
Clay , brown	436	438
Rock , brown	438	460
Rock , blue	460	488
Rock , black , softer	488	500
Rock , blue	500	585
Rock , blue, hard	585	688
Rock , black , coarse	688	695
Rock , brown , reddish (w.brg)	695	712
Basalt, grey, hard	712	725

Work started Feb. 1st. 1966 Completed Aug. 9 19
Date well drilling machine moved off of well Aug. 15 19

(13) PUMP:

1966

Manufacturer's Name
Type: H.P.

Water Well Contractor's Certification:

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

NAME HAAKON BOTTNER DRILLING COMPANY
(Person, firm or corporation) (Type or print)
Address 3424 S.E. 174th. AVENUE
PORTLAND , OREGON 97236
Drilling Machine Operator's License No. 246 & 380
[Signed] Haakon Bottner
(Water Well Contractor)
Contractor's License No. 109 Date 19

ORIGINAL
File Original and Duplicate with the STATE ENGINEER, SALEM, OREGON

OBSERVATION WELL

WATER WELL REPORT
STATE OF OREGON

WASH
011449

G760

State Well No. 2/1W-46(1

State Permit No. G-655

(1) OWNER:

Name Tigard Water District

Address Tigard, Oregon

(2) LOCATION OF WELL:

County WASH. Owner's number, if any—

¼ ¼ Section T. R. W.M.

Bearing and distance from section or subdivision corner

Well 3 ?

[illegible]) TYPE OF WORK (check):

New Well ☒ Deepening ☐ Reconditioning ☐ Abandon ☐

If abandonment, describe material and procedure in Item 11.

(4) PROPOSED USE (check):

[illegible]mestic ☐ Industrial ☐ Municipal ☒
Irrigation ☐ Test Well ☐ Other ☐

(5) TYPE OF WELL:

Rotary ☒ Driven ☐
Cable ☒ Jetted ☐
Dug ☐ Bored ☐

(6) CASING INSTALLED:

Threaded ☐ Welded ☒

12" Diam. from Surface ft. to 91.5 ft. Gage 45 #/ft.
" Diam. from ft. to ft. Gage
" Diam. from ft. to ft. Gage

(7) PERFORATIONS:

Perforated? ☐ 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.
perforations from ft. to ft.
perforations from ft. to ft.

[illegible] SCREENS:

Well screen installed ☐ Yes ☒ No

[illegible]ufacturer's Name

Type Model No.

Diam. Slot size Set from ft. to ft.
Diam. Slot size Set from ft. to ft.

[illegible] CONSTRUCTION:

Was well gravel packed? ☐ Yes ☒ No Size of gravel:

Gravel placed from ft. to ft.

Was a surface seal provided? ☒ Yes ☐ No To what depth? 91.5 ft.

Material used in seal— neat cement grout

Did any strata contain unusable water? ☐ Yes ☒ No

Type of water? Depth of strata

Method of sealing strata off

(10) WATER LEVELS:

Static level 215 ft. below land surface Date at completion of pump test and after 218 ft depth in hole was reached

Artesian pressure lbs. per square inch Date

Log Accepted by:

[Signed] Date , 19
(Owner)

(11) WELL TESTS:

Drawdown is amount water level is lowered below static level

Was a pump test made? ☒ Yes ☐ No If yes, by whom? Strasse Drillin

Yield: 380 gal./min. with 153 ft. drawdown after 24
" 350 " 128 " 24
" 300 " 80 " 24

Bailer test gal./min. with ft. drawdown after

Artesian flow g.p.m. Date

Temperature of water Was a chemical analysis made? ☒ Yes ☐

(12) WELL LOG:

Diameter of well 12 inc

Depth drilled 494 ft. Depth of completed well 494

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

MATERIAL	FROM	TO
Topsoil and brown clay	Surfa.	9
Red shale	9	26
Grey and green conglomerate	26	54
Soft grey basalt	54	86
Red and brown rock	86	114
Grey basalt	114	136
Grey and brown rock - clay seams	136	150
Red rock	150	168
Grey basalt	168	218
Porous grey basalt (water)	218	263
Brown and grey basalt	263	287
Porous grey basalt	287	301
Hard grey basalt	301	312
Porous grey basalt	312	330
Porous brown and grey basalt	330	341
Hard grey basalt	341	357
Brown and grey porous basalt	357	376
Hard grey basalt	376	404
Porous grey basalt	404	422
Black basalt	422	434
Porous grey basalt	434	450
Hard grey basalt	450	456
Porous black basalt (muddy water deposits)	456	483
Grey basalt	483	494

Work started Dec. 11 1957 Completed Feb. 17 195

(13) PUMP:

Manufacturer's Name

Type: H.P.

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 R. J. Strasser Drilling Col
(Person, firm, or corporation) (Type or print)

Address 8110 SE Sunset Lane, Portland 6, Oregon

Driller's well number ~~10~~ 3094

[Signed] Robert L. Strasser - Partner
(Well Driller)

License No. 10 Date March 5 1958

(USE ADDITIONAL SHEETS IF NECESSARY)

ICE TO WATER WELL CONTRACTOR
The original and first copy
of this report are to be
filed with the
STATE ENGINEER, SALEM, OREGON 97310
within 30 days from the date
of well completion.

G-330 (1961)
Well #4
WASH

WATER WELL REPORT
STATE OF OREGON
(Please type or print)
(Do not write above this line)

RECEIVED
JAN 5 1968
STATE ENGINEER
SALEM, OREGON

State Well No. 2/1w-10
State Permit No.
Deepening

011591

(1) OWNER:
Name TIGARD WATER DISTRICT
Address 8841 S.W. COMMERCIAL ST
TIGARD, OREGON 97223

(2) TYPE OF WORK (check):
New Well ☐ Deepening ☒ Reconditioning ☐ Abandon ☐
If abandonment, describe material and procedure in Item 12.

(3) TYPE OF WELL:
Rotary ☐ Driven ☐
Cable ☒ Jetted ☐
Dug ☐ Bored ☐

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

CASING INSTALLED:
Threaded ☐ Welded ☐
" Diam. from ft. to ft. Gage
" Diam. from ft. to ft. Gage
" Diam. from ft. to ft. Gage

PERFORATIONS:
Perforated? ☐ 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.
perforations from ft. to ft.
perforations from ft. to ft.

(7) SCREENS:
Well screen installed? ☐ Yes ☒ No
Manufacturer's Name
Type Model No.
Diam. Slot size Set from ft. to ft.
Diam. Slot size Set from ft. to ft.

(8) WATER LEVEL: Completed well.
Static level 268 ft. below land surface Date
sian pressure lbs. per square inch Date

(9) WELL TESTS:
Drawdown is amount water level is lowered below static level
Was a pump test made? ☒ Yes ☐ No If yes, by whom? Bottner Drilling
Yield: 230 gal./min. with 142 ft. drawdown after 4 hrs.
265 " 209 " 8 "
" 305 " 259 " 7 "
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) CONSTRUCTION:
Well seal—Material used
Depth of seal ft.
Diameter of well bore to bottom of seal in.
Were any loose strata cemented off? ☐ Yes ☒ No Depth
Was a drive shoe used? ☐ Yes ☐ No
Did any strata contain unusable water? ☐ Yes ☒ No
Type of water? depth of strata
Method of sealing strata off
Was well gravel packed? ☐ Yes ☒ No Size of gravel:
Gravel placed from ft. to ft.

(11) LOCATION OF WELL:
County Washington Driller's well number
¼ N.W. ¼ Section 10 T. 2S R. 1W
Bearing and distance from section or subdivision corner

(12) WELL LOG:
Diameter of well below casing 12" to 765' — 10" from to bot
Depth drilled 197 ft. Depth of completed well 928

Formation: Describe color, texture, grain size and structure of mater and show thickness and nature of each stratum and aquifer penetra with at least one entry for each change of formation. Report each cha in position of Static Water Level as drilling proceeds. Note drilling ra

MATERIAL	From	To	SW
Basalt, black hard	725	746	
" gray, softer	746	761	
" black, hard	761	798	
" brown, soft	798	802	
" black, hard	802	837	
Clay, white	837	839	
Rock, gray Mdm. hard	839	846	
Basalt, black, hard	846	895	
" , black, softer	895	906	
Rock, black w/ clay seams	906	914	
Rock, black broken caving	914	925	

Work started May 8 1967 Completed Sept. 26 19
Date well drilling machine moved off of well Sept. 29 19

Drilling Machine Operator's Certification:
This well was constructed under my direct supervision. Materials used and information reported above are true to my be knowledge and belief.
[Signed] H. Bottner Date , 19
(Drilling Machine Operator)
Drilling Machine Operator's License No. 246,463,431

Water Well Contractor's Certification:
This well was drilled under my jurisdiction and this report true to the best of my knowledge and belief.
NAME HAAKON BOTTNER DRILLING COMPANY
(Person, firm or corporation) (Type or print)
Address 3424 S.E. 174 th. AVENUE
PORTLAND, ORE
[Signed] Haakon Bottner
(Water Well Contractor)
Contractor's License No. 109 Date Oct. 31, 19

NOTICE TO WATER WELL CONTRACTOR
The original and first copy
of this report are to be
filed with the
STATE ENGINEER, SALEM, OREGON 97310
within 30 days from the date
of well completion.

RECEIVED
SEP - 2 1970
STATE ENGINEER
SALEM, OREGON

RECEIVED
SEP 18 1970
STATE ENGINEER
SALEM, OREGON

WASH 011598

WATER WELL REPORT
STATE OF OREGON
(Please type or print)
(Do not write above this line)

State Well No. 2/1W-11a
State Permit No.

(1) OWNER: JAMES TEMPLETON SCHOOL
Name TIGARD SCHOOL DIST 23J
Address 9500 SW MURDOCK
TIGARD, ORE. 97223

(2) TYPE OF WORK (check):
New Well ☒ Deepening ☐ Reconditioning ☐ Abandon ☐
If abandonment, describe material and procedure in Item 12.

(3) TYPE OF WELL:
Rotary ☒ Driven ☐
Cable ☒ Jetted ☐
Dug ☐ Bored ☐

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

[illegible] CASING INSTALLED: Threaded ☐ Welded ☒
8" Diam. from 0 ft. to 72 ft. Gage .277
" Diam. from ft. to ft. Gage
" Diam. from ft. to ft. Gage

[illegible] PERFORATIONS: Perforated? ☐ 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.

(7) SCREENS: Well screen installed? ☐ Yes ☒ No
Manufacturer's Name
Type Model No.
Diam. Slot size Set from ft. to ft.
Diam. Slot size Set from ft. to ft.

(8) WELL TESTS: Drawdown is amount water level is lowered below static level
Was a pump test made? ☒ Yes ☐ No If yes, by whom? STRASSER
Yield: 300 gal./min. with 38 ft. drawdown after 7 hrs.
250 " 27 " 7½ "
" 200 " 19 " 8 "
Bailer test gal./min. with ft. drawdown after hrs.
Artesian flow g.p.m.
Temperature of water 52° Depth artesian flow encountered ft.

(9) CONSTRUCTION:
Well seal—Material used CEMENT GROUT
Well sealed from land surface to 62-72 AND 0-18 ft.
Diameter of well bore to bottom of seal 12 in. BACKFILLED WITH CUTTINGS AND CLAY FROM 62-18 FT
Diameter of well bore below seal 8 in.
Number of sacks of cement used in well seal 18 sacks
Number of sacks of bentonite used in well seal sacks
Brand name of bentonite
Number of pounds of bentonite per 100 gallons of water lbs./100 gals.
Was a drive shoe used? ☐ Yes ☒ No Plugs Size: location ft.
Did any strata contain unusable water? ☐ Yes ☒ No
Type of water? depth of strata
Method of sealing strata off
Was well gravel packed? ☐ Yes ☒ No Size of gravel:

(10) LOCATION OF WELL:
County WASH. Driller's well number 5255
SW ¼ NE ¼ Section 11 T. 2S R. 1W W.M.
Bearing and distance from section or subdivision corner

(11) WATER LEVEL: Completed well.
Depth at which water was first found 190 ft.
Static level 139 ft. below land surface. Date 8/18/7
Artesian pressure lbs. per square inch. Date

(12) WELL LOG: Diameter of well below casing 8
Depth drilled 243 ft. Depth of completed well 243 ft.
Formation: Describe color, texture, grain size and structure of materials and show thickness and nature of each stratum and aquifer penetrated with at least one entry for each change of formation. *Report each change in position of Static Water Level and indicate principal water-bearing strata*

MATERIAL	From	To	SWL
BROWN AND RED CLAY	0	6	
SAND	6	27	
BROWN SAND AND CLAY	27	49	
BLUE SILT	49	58	
FRACUTURED LAVA	58	63	
BROWN ROCK	63	109	
FRACTURED BROWN AND			
GREY ROCK	109	125	
MED HARD GREY ROCK	125	142	
HARD GREY ROCK	142	147	
GREY AND BROWN POROUS	147	174	
BROWN AND GREY BROKEN	174	233	
HARD GREY ROCK	233	236	
SOFT BROKEN ROCK	236	243	

Work started AUG 5 1970 Completed AUG 19 197
Date well drilling machine moved off of well AUG 20 197

Drilling Machine Operator's Certification:
This well was constructed under my direct supervisio Materials used and information reported above are true to m best knowledge and belief.
[Signed] Date AUG 31 197
(Drilling Machine Operator)
Drilling Machine Operator's License No. 56

Water Well Contractor's Certification:
This well was drilled under my jurisdiction and this report i true to the best of my knowledge and belief.
Name RL STRASSER DRILLING Co
(Person, firm or corporation) (Type or print)
Address 8110 SE SUNSET LANE PORTLAND
[Signed] Robert L. Strasser
(Water Well Contractor)
70 Date AUG 31 197

RECEIVED
NOV - 7 1994
WATER RESOURCES DEPT.
SALEM, OREGON

WASH
4251

2S/1W/11

STATE OF OREGON 18
WATER WELL REPORT
(as required by ORS 537.765)

(START CARD) # 56075

(1) OWNER:
Well Number
Name John Wardin
Address 15082 SW 103rd
City Tigard State OR Zip 97224

(2) TYPE OF WORK:
☐ New Well ☐ Deepen ☒ Recondition ☐ Abandon

(3) DRILL METHOD:
☐ Rotary Air ☐ Rotary Mud ☐ Cable
☒ Other Boom Truck to Set Manhole Section

(4) PROPOSED USE:
☐ Domestic ☐ Community ☐ Industrial ☒ Irrigation/Landscape
☐ Thermal ☐ Injection ☐ Other

(5) BORE HOLE CONSTRUCTION:
Special Construction approval ☒ Yes ☐ No Depth of Completed Well 375 ft.
Explosives used ☐ Yes ☒ No Type Amount

HOLE			SEAL			Amount
Diameter	From	To	Material	From	To	sacks or pounds
UNCHANGED - SEE DESCRIPTION OF WORK						

How was seal placed: Method ☐ A ☐ B ☐ C ☐ D ☐ E
☐ Other
Backfill placed from ft. to ft. Material
Gravel placed from ft. to ft. Size of gravel

(6) CASING/LINER:

	Diameter	From	To	Gauge	Steel	Plastic	Welded	Threaded
Casing:	6"	*	*		☒	☐	☐	☐
	*UNCHANGED FROM				☐	☐	☐	☐
		EXISTING			☐	☐	☐	☐
					☐	☐	☐	☐
Liner:					☐	☐	☐	☐
					☐	☐	☐	☐

Final location of shoe(s)

(7) PERFORATIONS/SCREENS:
☐ Perforations Method
☐ Screens Type Material

From	To	Slot size	Number	Diameter	Tele/pipe size	Casing	Liner
						☐	☐
	UNCHANGED					☐	☐
						☐	☐
						☐	☐
						☐	☐

(8) WELL TESTS: Minimum testing time is 1 hour
☐ Pump ☐ Bailer ☐ Air ☐ Flowing Artesian

Yield gal/min	Drawdown	Drill stem at	Time
See Water	Right Pump Test Data		1 hr.
for Permit No. G-1612, Certificate No. 32496,			
Performed	6/26/90.		

Temperature of Water Depth Artesian Flow Found
Was a water analysis done? ☐ Yes By whom
Did any strata contain water not suitable for intended use? ☐ Too little
☐ Salty ☐ Muddy ☐ Odor ☐ Colored ☐ Other

(9) LOCATION OF WELL by legal description:
County Washington Latitude Longitude
Township 2S N or S. Range 1W E or W.
Section 11 NW ¼ SW ¼
Tax Lot Lot Block Subdivision
Street Address of Well (or nearest address) 15082 SW 103rd
Tigard, OR 971

(10) STATIC WATER LEVEL:
205 ft. below land surface. Date 6/26
Artesian pressure lb. per square inch. Date

(11) WATER BEARING ZONES:
Depth at which water was first found

From	To	Estimated Flow Rate

(12) WELL LOG:
Ground elevation approx. 360' above

Material	From	To
NO DRILLING.		
Description of Work:		
Excavated around existing well depth to		
depth of apprximately 2 feet. Set concr		
manhole section over well and poured pre-		
mixed concrete around base of manhole se		
and up inside cone section for 8" thick		
concrete base with 30 sacks of premix		
concrete. Grouted watertite frame and d		
in place and sealed pipe and conduit		
penetration opening into manhole section.		
Pump was never removed from the well.		
Backfilled around the manhole section af		
concrete was set. Cut off 2" PVC inside		
manhole section so any water seepage		
would discharge into drain.		
SEE ATTACHED.		

Date started 10/3/94 Completed 10/6/94

(unbonded) Water Well Constructor Certification:

I certify that the work I performed on the construction, alteration, or a ment of this well is in compliance with Oregon well construction standards. M used and information reported above are true to my best knowledge and bel

WWC Number
Signed Date 11/2/94

(bonded) Water Well Constructor Certification:

I accept responsibility for the construction, alteration, or abandonment w formed on this well during the construction dates reported above. All work pe during this time is in compliance with Oregon well construction standards. Thi is true to the best of my knowledge and belief.

WWC Number 67

WASH
011604

STATE ENGINEER
Salem, Oregon

Well Record

STATE WELL NO. 25/1W-1
COUNTY Washing
APPLICATION NO.

OWNER: N. C. Kahle
MAILING ADDRESS:

LOCATION OF WELL: Owner's No.
CITY AND STATE:

¼ ¼ Sec. T. N. S., R. E. W., W.M.

Bearing and distance from section or subdivision corner

Section

Altitude at well 265 ft.

TYPE OF WELL: drilled Date Constructed

Depth drilled 132 ft. Depth cased 68 ft.

CASING RECORD: 6-inch

FINISH:

AQUIFERS: Basalt from 76 to 132 ft.

WATER LEVEL: 50 ft. below land surface.

PUMPING EQUIPMENT: Type jet H.P.
Capacity G.P.M.

WELL TESTS:
Drawdown ft. after hours G.
Drawdown ft. after hours G.

USE OF WATER domestic & stock Temp. °F. , 19
SOURCE OF INFORMATION U.S.G.S.
DRILLER or DIGGER
ADDITIONAL DATA:
Log Water Level Measurements Chemical Analysis Aquifer Test

REMARKS: Reported 66 ft. of sandy clay and 10 ft. of basal above aquifer; bailed 25 gpm for 1 hour with 30 ft. of drawdown.

WASH

NOTICE TO WATER WELL CONTRACTOR
The original and first copy
of this report are to be
filed with the
STATE ENGINEER, SALEM, OREGON 97310
within 30 days from the date
of well completion.

011587

WATER WELL REPORT
STATE OF OREGON
(Please type or print)

RECEIVED
APR 24 1967
STATE ENGINEER
SALEM OREGON

G-3777

State Well No. 2/1w-10

State Permit No.

(1) OWNER:

Name Tualatin Development Co.

Address 15475 SW Pacific Hwy.

Tigard, Ore.

(2) LOCATION OF WELL:

County Washington Driller's well number

¼ ¼ Section 10 T. 2S R. 1W W.M.

Bearing and distance from section or subdivision corner

KING CITY GOLF COURSE

(3) TYPE OF WORK (check):

N[illegible] Well ☒ Deepening ☐ Reconditioning ☐ Abandon ☐

[illegible]andonment, describe material and procedure in Item 12.

(4) PROPOSED USE (check):

Domestic ☐ Industrial ☐ Municipal ☐

Irrigation ☒ Test Well ☐ Other ☐

(5) TYPE OF WELL:

Rotary ☒ Driven ☐

Cable ☒ Jetted ☐

Dug ☐ Bored ☐

(6) CASING INSTALLED:

Threaded ☐ Welded ☒

8" Diam. from 0 ft. to 248 ft. Gage .250

" Diam. from ft. to ft. Gage

" Diam. from ft. to ft. Gage

(7) PERFORATIONS:

Perforated? ☐ 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.

perforations from ft. to ft.

perforations from ft. to ft.

(8) SCREENS:

Well screen installed? ☐ Yes ☒ No

Manufacturer's Name

Type Model No.

Diam. Slot size Set from ft. to ft.

Diam. Slot size Set from ft. to ft.

(9) CONSTRUCTION:

Well seal—Material used in seal Bentonite

Depth of seal 247 ft. Was a packer used? No

Diameter of well bore to bottom of seal 12 in.

Were any loose strata cemented off? ☐ Yes ☒ No Depth

Was a drive shoe used? ☐ Yes ☒ No

Was well gravel packed? ☐ Yes ☒ No Size of gravel:

Gravel placed from ft. to ft.

Did any strata contain unusable water? ☐ Yes ☒ No

Type of water? depth of strata

Method of sealing strata off

(10) WATER LEVELS:

Static level 47 ft. below land surface Date 1-19-67

(11) WELL TESTS:

Drawdown is amount water level is lowered below static level

Was a pump test made? ☒ Yes ☐ No If yes, by whom? A.M. Jannsen

Yield: 190 gal./min. with 23 ft. drawdown after 8

Bailer test gal./min. with ft. drawdown after

Artesian flow g.p.m. Date

Temperature of water Was a chemical analysis made? ☐ Yes ☒

(12) WELL LOG:

Diameter of well below casing 8" to 3
8" to 8

Depth drilled 805 ft. Depth of completed well 805

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

MATERIAL	FROM	TO
Brown clay	0	19
Sandy blue clay	19	67
Brown clay	67	145
Decomposed rock	145	237
Hard black rock	237	267
Clay & rock interbed	267	274
Brown & black rock - water bearing	274	291
Very hard gray rock	291	358
Soft black rock - 25 to 30 gpm	358	377
Hard gray rock with crevices	377	427
Hard black basalt	427	666
Gray hard basalt	666	702
Loose rock, lost cuttings	702	751
Hard black basalt	751	797
Lost cuttings	797	804
Hard black basalt	804	805

Work started 5-19 19 66 Completed 1-19 19

Date well drilling machine moved off of well 1-19 19

(13) PUMP:

Manufacturer's Name

Type: H.P.

Water Well Contractor's Certification:

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

NAME A. M. Jannsen Drilling Co.
(Person, firm or corporation) (Type or print)

Address 21075 SW Tual. Vlly. Hwy. Aloha, Ore.

Drilling Machine Operator's License No. 177

[Signed]
(Water Well Contractor)

Appendix E

Appendix E

MONTGOMERY WATSON

MEMORANDUM

MONTGOMERY WATSON

April 13, 2001

FINDINGS OF WATER QUALITY INVESTIGATIONS

This memorandum presents results of water quality testing performed on waters pertinent to the City of Tigard (City) ASR system including water from the Columbia River Basalt Aquifer and waters from the potential sources of injection water. The object of the water quality sampling was to characterize ambient groundwater quality and evaluate compatibility between groundwater and recharge water. To evaluate ambient water quality conditions in the basalt aquifer, data was collected from the following sources:

- Historical data from City Well No. 1 (COT-1)
- Recent data collected as part of the initial ASR feasibility investigation from COT-1

Injection water for the ASR system could potentially come from one of three different water treatment plants in the region: Lake Oswego WTP, City of Portland or Joint Water Commission.. Historical finished water quality data from each of these three plants was reviewed to characterize the injection water.

HISTORICAL WATER QUALITY DATA IN THE COLUMBIA BASALT AQUIFER

Historical water quality data was obtained from the City of Tigard for all four wells. Since they have been in operation the longest, the majority of data is available for Wells No. 1 and 2. The period of record for Well No. 1 extends from 1949 to 2000 and 1983 to 2000 for Well No. 2; both wells were sampled intermittently throughout their respective record period. Tables 1 and 2 summarize the available historical water quality data for Wells No. 1 and 2. Little data is available for Wells No. 3 and 4 since they have not been used on a regular basis. Tables 3 and 4 list the available water quality for Wells No. 3 and 4 respectively. Water quality data for Well No. 4 is limited to general minerals and metals only. Analyses of organic compounds were not conducted at this well.

General Mineral Quality

In general, water at all four wells is moderately soft. Hardness at Well No. 1 ranged from 50 mg/L in 1949 to 118 mg/L as measured in 1966. Mineral content consisted mostly of calcium and magnesium. Low concentrations of minerals at each well indicate a consistent aquifer characteristic in the region.

Metals

Trace metals were detected at all four wells, including copper, zinc, lead, barium, iron and aluminum. None exceeded the MCL at any of the wells.

Organics (SOCs and VOCs)

Wells No. 1, 2 and 3 have been historically sampled for all regulated VOCs and SOCs. Total Trihalomethanes (TTHMs) were detected at low concentrations at all three wells, mostly in the form of chlorform and bromodichlormethane. None exceeded the current MCL of 0.08 mg/L. This detection is likely the effect of using chlorinated surface water to lubricate the pump. No other regulated compounds were detected at any of the wells over the period of record. An additional 42 unregulated VOCs and 13 SOCs were sampled for at each well. No SOCs were detected at any of the three wells over the period of record.

Radionuclides

No historical data for radon is available for any of the wells. Gross alpha at Well No. 1 ranged from -.79 to 0.4 pCi., 0.1 to 1.79 pCi at Well No. 2 and 0.3 to 1.63 pCi at Well No. 3.

RECENT WATER QUALITY RESULTS

An initial assessment of the City's four wells indicated that Well No. 1 might be a good candidate for the Pilot Test. Based on this assessment, a groundwater sample was collected from Well No. 1 on February 7, 2001 for general minerals and regulated VOCs. Montgomery Watson collected the sample after the pump test at the wellhead. Analyses were performed by Montgomery Watson Laboratories. Results of all sampling are shown in Table 1.

General Mineral Quality

In general, mineral content and physical parameters were consistent with historical data. Less than half the solids consisted of calcium, magnesium and sodium, thus indicating a low mineral content. Hardness was comparable to historical observations, remaining fairly moderate (108 mg/L).

Organics (VOCs)

The sample was analyzed for all regulated and additional unregulated VOCs. No regulated compounds were detected. Chloroform, a THM was detected at 0.0009 mg/L. This detection is likely a result of using chlorinated surface water to lubricate the pump.

INJECTION WATER QUALITY

Three major water suppliers are being considered for injection water for the City's ASR project: Lake Oswego (LO), City of Portland (COP) and the Joint Water Commission (JWC). Depending on the availability of water from these suppliers, the City could potentially use one or a combination of these sources for ASR testing and long-term operation. In addition, the location of the well may determine which source will be used. For example, Clackamas River water could be readily brought to Well No. 1, but not Well No. 3. Thus, each of these three local sources were considered as potential injection water for the City's ASR program:

- Lake Oswego WTP – Direct Filtration
- City of Portland – Unfiltered
- Joint Water Commission – Conventional Filtration

Each of the three water sources conduct water quality sampling for the complete list of constituents listed under the Safe Drinking Water Act. The following discussion focuses on minerals/metals and disinfection by-products (DBPs).

Lake Oswego

Lake Oswego treats Clackamas River water. The Clackamas River watershed is generally a sparsely populated and heavily forested with little agricultural activity. Thus, there are currently few sources of potential contaminants in the watershed. Table 5 lists historical water quality data from LO. In general, the water is fairly soft. The water is also low in naturally occurring organic material as reflected by the low levels of disinfection by-products in the distribution system. In spite of residual disinfection with free chlorine, maximum values for trihalomethanes (THMs) were 0.0179 mg/L. Under the current regulation, the running annual average must be below the maximum contaminant level of 0.08 parts per million.

City of Portland

The City of Portland's primary source of water is the Bull Run watershed. Water from Bull Run is unfiltered, but is chlorinated prior to delivery into the distribution system. Water quality data as submitted to OHD are listed in Table 6. Bull Run water is considered moderately soft water, with minimal contributions from calcium and manganese. Total dissolved solids were fairly low at 20 mg/L. Total THMs ranged from 0.001 mg/L to 0.0056 mg/L.

During heavy rains, turbidity can rise beyond acceptable limits and the City must rely on its groundwater supply near the south shore of the Columbia River. Use of this groundwater is limited to summer peaking or emergencies. However, with the current drought conditions, the City may decide to blend surface water from Bull Run with groundwater. Table 7 lists water quality for the wellfield. In general, groundwater from the wellfield is low in mineral content and fairly soft. Low levels of TCE have been detected. The source has been confirmed as a nearby commercial facility. Cleanup efforts are underway and water quality continues to meet the standards.

Joint Water Commission

The Joint Water Commission treats water from the Trask and Tualatin Rivers. Table 8 lists available data for treated water at the WTP. Water quality results as reported to the OHD indicate that the treated water is fairly soft with total hardness ranging from 26 mg/L to 40 mg/L. The majority is comprised of calcium and magnesium. Mineral content is fairly low as indicated by Total Dissolved Solids (54-91 mg/L).

Summary

Based on the water quality data from each of the three sources, no constituent has been detected at levels above 50% of the corresponding MCL. Thus all three of the proposed source waters for injection meet OAR standards and no additional treatment is required prior to injection. Mixing or blending of source waters will present new water quality issues. A water quality model of the source waters will be beneficial once these have been determined.

TABLE 1
CITY OF TIGARD WELL NO 1
HISTORICAL WATER QUALITY DATA

CITY WELL NO. 1			DATE																						
Analyte	MCL	Unit	2/7/01	6/28/00	2/18/00	6/8/99	6/28/99	6/24/98	7/8/98	2/12/96	11/10/95	7/14/94	7/14/93	8/26/92	6/2/92	6/6/91	7/3/91	7/9/90	8/26/89	7/12/89	7/20/88	6/1/83	6/12/79	4/5/66	4/30/48
Physical																									
pH			7 5		6 85																			7 2	6 8
Alkalinity		mg/L	104		120																				
Hardness	250	mg/L	108		110																			118	50
Iron		mg/L	ND		ND																	0 22		0 03	0 1
Bicarbonate		mg/L	127																					122	162
Calcium		mg/L	25		26 9																				
Carbonate as CO3		mg/L	0 261																					0	
Chloride		mg/L	3 67																					6 6	3 6
Conductivity		uS			200																				
Free CO2		mg/L	8 03																						
Gross Alpha	15	pCi/L				-0 79					-0 077					0 4									
Hydroxide as OH		mg/L	0 005																						
Silica		mg/L	66																						
Total Dissolved Solids		mg/L	180																						206
Inorganics																									
Antimony	0 006	mg/L				ND				ND		ND	ND												
Arsenic	0 05	mg/L				ND				ND		ND	ND	<0 002								0 036	ND		
Asbestos	7	MF/L								NA		NA	NA												
Barium	2	mg/L				ND				ND		ND	ND	<0 025								0 01	ND		
Beryllium	0 004	mg/L				ND				ND		ND	ND												
Cadmium	0 005	mg/L				ND				ND		ND	ND	<0 005								ND	ND		
Chromium	0 1	mg/L				ND				ND		ND	ND	<0 005								ND	ND		
Copper	1 3	mg/L				0 005				ND		ND	ND												
Cyanide	0 2	mg/L				ND				ND		ND	ND												
Fluoride	4	mg/L				ND				ND		ND	0 17	0 18								0 24	ND		
Lead	0 015	mg/L				ND				ND		0 002	ND	<0 002								0 005	ND		
Magnesium		mg/L	11																						
Manganese		mg/L	ND																						
Mercury	0 002	mg/L				ND				ND		ND	ND	<0 0002								ND	ND		
Nickel	0 1	mg/L				ND				ND		ND	ND												
Nitrate	10	mg/L		1 3		1 5	ND		0 5	1		1 6	1	1 2								1 01	ND		
Nitrite	1	mg/L				ND				ND		ND	ND												
Potassium		mg/L	3																						
Selenium	0 05	mg/L				ND				ND		ND	ND	0 003								ND	ND		
Silver	0 05	mg/L																				ND	ND		
Sodium		mg/L	8 5			9 13				8 7		8 8	8 7	10 3											
Sulfate	250	mg/L	3 24			ND				ND		ND	13 5											3	
Thallium	0 002	mg/L				ND				ND		ND	ND												
Disinfection By-Products																									
Total Haloacetic Acids	0 060	mg/L																							
Total Trihalomethanes	0 08	mg/L	0 0009			0 0013		0 0266							0 0351		0 0195	0 0002							
VOC's Regulated																									
1,1 Dichloroethylene	0 007	mg/L	ND			ND				ND		ND	ND		ND		ND	ND	ND	ND	ND				
1,1,1 Trichloroethane	0 2	mg/L	ND			ND				ND		ND	ND		ND		ND	ND		ND	ND				
1,1,2 Trichlorethane	0 005	mg/L	ND			ND				ND		ND	ND		ND		ND	ND							
1,2 Dichloroethane (EDC)	0 005	mg/L	ND			ND				ND		ND	ND		ND		ND	ND		ND	ND				
1,2 Dichlorpropane	0 005	mg/L	ND			ND				ND		ND	ND		ND		ND	ND							
1,2,4 Trichlorobenzene	0 07	mg/L	ND			ND				ND		ND	ND		ND		ND	ND							
Benzene	0 005	mg/L	ND			ND				ND		ND	ND		ND		ND	ND		ND	ND				
Carbon Tetrachloride	0 005	mg/L	ND			ND				ND		ND	ND		ND		ND	ND		ND	ND				
Chlorobenzene	0 1	mg/L	ND			ND				ND		ND	ND		ND		ND	ND							
cis 1,2 Dichloroethylene	0 07	mg/L	ND			ND				ND		ND	ND		ND		ND	ND							
Dichloromethane	0 005	mg/L	ND			ND				ND		ND	ND		ND		ND	ND							
Ethylbenzene	0 7	mg/L	ND			ND				ND		ND	ND		ND		ND	ND							
o Dichlorobenzene	0 6	mg/L	ND			ND				ND		ND	ND		ND		ND	ND							
p-Dichlorobenzene	0 075	mg/L	ND			ND				ND		ND	ND		ND		ND	ND		ND	ND				
Styrene	0 1	mg/L	ND			ND				ND		ND	ND		ND		ND	ND							
Tetrachloroethylene	0 005	mg/L	ND			ND				ND		ND	ND		ND		ND	ND							
Toluene	1	mg/L	ND			ND				ND		ND	ND		ND		ND	ND							
trans 1,2 Dichloroethylene	0 1	mg/L	ND			ND				ND		ND	ND		ND		ND	ND							
Trichloroethylene	0 005	mg/L	ND			ND				ND		ND	ND		ND		ND	ND		ND	ND				
Vinyl Chloride	0 002	mg/L	ND			ND				ND		ND	ND		ND		ND	ND		ND	ND				
Xylenes	10	mg/L	ND			ND				ND		ND	ND		ND		ND	ND							
VOC's Unregulated																									
1,1 Dichloroethane		mg/L	ND			ND				ND		ND	ND		ND		ND	ND							
1,1 Dichloropropene		mg/L	ND			ND				ND		ND	ND		ND		ND	ND							
1,1,1,2 Tetrachloroethane		mg/L	ND			ND				ND		ND	ND		ND		ND	ND							
1,1,2,2, Tetrachloroethane		mg/L	ND			ND				ND		ND	ND		ND		ND	ND							
1,2,3 Trichloropropane		mg/L	ND			ND				ND		ND	ND		ND		ND	ND							
1,3 Dichloropropene		mg/L	ND			ND				ND		ND	ND		ND		ND	ND							
2,2 Dichloropropane		mg/L	ND			ND				ND		ND	ND		ND		ND	ND							
2 Butanone (MEK)		mg/L	ND																						
4 - Methyl 2- Pentanone (MIBK)		mg/L	ND																						
Bromobenzene		mg/L	ND			ND				ND		ND	ND		ND		ND	ND							
Bromodichloromethane		mg/L	ND			ND		ND		ND		ND	ND		0 0025		0 0023	ND							
Bromoform		mg/L	ND			ND		ND		ND		ND	ND		ND		ND	ND							

TABLE 1
CITY OF TIGARD WELL NO. 1
HISTORICAL WATER QUALITY DATA

CITY WELL NO. 1			DATE																						
Analyte	**MCL**	**Unit**	**2/7/01**	**8/29/00**	**2/18/00**	**9/8/99**	**8/28/99**	**8/24/99**	**7/8/98**	**2/12/96**	**11/10/95**	**7/14/94**	**7/14/93**	**8/26/92**	**8/2/92**	**8/8/91**	**7/3/91**	**7/9/90**	**8/28/89**	**7/12/89**	**7/20/88**	**8/1/83**	**8/12/79**	**4/5/66**	**4/30/49**
Bromomethane		mg/L	ND			ND				ND		ND	ND		ND		ND	ND							
Chloroethane		mg/L	ND			ND				ND		ND	ND		ND		ND	ND							
Chloroform		mg/L	0.0009			0.0013		0.0266		ND		ND	ND		0.0323		0.017	0.0002							
Chloromethane		mg/L	ND			ND				ND		ND	ND		ND		ND	ND							
cis 1,23 Dichloropropene		mg/L	ND																						
Dibromomethane		mg/L	ND			ND				ND		ND	ND		ND		ND	ND							
Dibromochloromethane		mg/L	ND			ND		ND		ND		ND	ND		0.0003		0.0002	ND							
m-Dichlorobenzene		mg/L	ND			ND				ND		ND	ND		ND		ND	ND							
Di-isopropyl ether		mg/L	ND																						
o-Chlorotoluene		mg/L	ND			ND				ND		ND	ND		ND		ND	ND							
p-Chlorotoluene		mg/L	ND			ND				ND		ND	ND		ND		ND	ND							
Bromochloromethane		mg/L	ND			ND									ND		ND	ND							
n-Butylbenzene		mg/L	ND			ND									ND		ND	ND							
Dichlorodifluoromethane		mg/L	ND			ND									ND		ND	ND							
Fluorotrichloromethane		mg/L	ND			ND									ND		ND	ND							
Hexachlorobutadiene		mg/L	ND			ND									ND		ND	ND							
Isopropylbenzene		mg/L	ND			ND									ND		ND	ND							
p-Isopropyltoluene		mg/L	ND			ND									ND		ND	ND							
Methyl Tert-butyl ether (MTBE)		mg/L	ND																						
Napthalen		mg/L	ND			ND									ND		ND	ND							
n-Propylbenzene		mg/L	ND																						
sec-Butylbenzene		mg/L	ND			ND									ND		ND	ND							
tert-Butylbenzene		mg/L	ND			ND									ND		ND	ND							
tert-amyl Methyl Ether		mg/L	ND																						
tert-Butyl Ethyl Ether		mg/L	ND																						
Trichlorotrifluoroethane (Freon)		mg/L	ND																						
trans 1,3 Dichloropropene		mg/L	ND																						
1,2,3 Trichlorobenzene		mg/L	ND			ND									ND		ND	ND							
1,2,4 Trimethylbenzene		mg/L	ND			ND									ND		ND	ND							
1,3,5 Trimethylbenzene		mg/L	ND			ND									ND		ND	ND							
SOCs Regulated																									
2,4 D	0.07	mg/L				ND				ND		ND	ND												
2,4,5 TP	0.05	mg/L				ND				ND		ND	ND												
Alachlor	0.002	mg/L				ND				ND		ND	ND												
Atrazine	0.003	mg/L				ND				ND		ND	ND												
Benzo(a)pyrene	0.0002	mg/L				ND				ND		ND	ND												
Carbofuran	0.04	mg/L				ND				ND		ND	ND												
Chlordane	0.002	mg/L				ND				ND		ND	ND												
Dalapon	0.2	mg/L				ND				ND		ND	ND												
DBCP (Dibromochloropropane)	0.0002	mg/L				ND						ND	ND		ND		ND	ND							
Di(2-ethylhexyl)adipate	0.4	mg/L				ND				ND		ND	ND												
Di(2-ethylhexyl)phthalate	0.006	mg/L				ND				ND		ND	ND												
Dinoseb	0.007	mg/L				ND				ND		ND	ND												
Dioxin	3x10-8	mg/L										ND	ND												
Diquat	0.02	mg/L				ND				ND		ND	ND												
EDB (Ethylene Dibromide)	0.00005	mg/L				ND						ND	ND		ND		ND	ND							
Endothall	0.1	mg/L				ND				ND		ND	ND												
Endrin	0.002	mg/L				ND				ND		ND	ND												
Glyphosphate	0.7	mg/L				ND				ND		ND	ND												
Heptachlor	0.0004	mg/L				ND				ND		ND	ND												
Heptachlor Epoxide	0.0002	mg/L				ND				ND		ND	ND												
Hexachlorobenzene	0.001	mg/L				ND				ND		ND	ND												
Hexachlorocyclopentadiene	0.05	mg/L				ND				ND		ND	ND												
Lindane	0.0002	mg/L				ND				ND		ND	ND												
Methoxychlor	0.04	mg/L				ND				ND		ND	ND												
Oxamyl	0.2	mg/L				ND				ND		ND	ND												
PCBs	0.0005	mg/L				ND				ND		ND	ND												
Pentachlorophenol	0.001	mg/L				ND				ND		ND	ND												
Picloram	0.5	mg/L				ND				ND		ND	ND												
Simazine	0.004	mg/L				ND				ND		ND	ND												
Toxaphene	0.003	mg/L				ND				ND		ND	ND												
SOCs Unregulated																									
3 Hydroxycarbofuran		mg/L				ND				ND		ND	ND												
Aldicarb		mg/L				ND				ND		ND	ND												
Aldicarb Sulfone		mg/L				ND				ND		ND	ND												
Aldicarb Sulfoxide		mg/L				ND				ND		ND	ND												
Aldrin		mg/L				ND				ND		ND	ND												
Butachlor		mg/L				ND				ND		ND	ND												
Carbaryl		mg/L				ND				ND		ND	ND												
Dicamba		mg/L				ND				ND		ND	ND												
Dieldrin		mg/L				ND				ND		ND	ND												
Methomyl		mg/L				ND				ND		ND	ND												
Metolachlor		mg/L				ND				ND		ND	ND												
Metribuzin		mg/L				ND				ND		ND	ND												
Propachlor		mg/L				ND				ND		ND	ND												

TABLE 2
CITY OF TIGARD WELL NO. 2
HISTORICAL WATER QUALITY DATA

CITY WELL NO.2			Date																	
Analyte	MCL	Unit	6/25/00	2/14/00	9/8/99	5/19/99	7/1/98	2/12/96	6/28/95	6/30/94	7/14/93	6/2/92	7/3/91	7/9/90	9/26/89	7/12/89	7/20/88	8/5/87	7/9/87	8/1/83
Physical																				
pH				6.56																
Alkalinity		mg/L		120																
Hardness	250	mg/L		110																
Iron		mg/L		ND																0.15
Bicarbonate		mg/L																		
Calcium		mg/L		21.1																
Carbonate as CO3		mg/L																		
Chloride		mg/L																		
Conductivity		uS		190																
Free CO2		mg/L																		
Gross Alpha	15	pCi/L			1.12				1.79				0.1					0.225		
Hydroxide as OH		mg/L																		
Silica		mg/L																		
Total Dissolved Solids		mg/L																		
Inorganics																				
Antimony	0.006	mg/L			ND			ND		ND	ND									
Arsenic	0.05	mg/L			ND			ND		ND	ND								ND	0.019
Asbestos	7	MF/L						NA		NA	NA									
Barium	2	mg/L			ND			ND		ND	ND								ND	0.01
Beryllium	0.004	mg/L			ND			ND		ND	ND									
Cadmium	0.005	mg/L			ND			ND		ND	ND								ND	ND
Chromium	0.1	mg/L			ND			ND		ND	ND								ND	ND
Copper	1.3	mg/L			ND															
Cyanide	0.2	mg/L			ND			ND		ND	ND									
Fluoride	4	mg/L			ND			ND		ND	ND								ND	0.17
Lead	0.015	mg/L			ND			ND		ND	0.003								ND	0.001
Magnesium		mg/L																		
Manganese		mg/L																		
Mercury	0.002	mg/L			ND			ND		ND	ND								ND	ND
Nickel	0.1	mg/L			ND			ND		ND	ND									
Nitrate	10	mg/L	0.5		ND	0.5	ND	0.25		1.5	2.5								0.12	0.18
Nitrite	1	mg/L			ND			ND		ND	ND									
Potassium		mg/L																		
Selenium	0.05	mg/L			ND			ND		ND	ND								ND	0.001
Silver	0.05	mg/L																	ND	0.0004
Sodium		mg/L			ND			8.1		5.8	7.8								8.35	
Sulfate	250	mg/L			ND			ND		ND	ND									
Thallium	0.002	mg/L			ND			ND		ND	ND									
Disinfection By-Products																				
Total Haloacetic Acids	0.060	mg/L																		
Total Trihalomethanes	0.08	mg/L	0.0009			0.0142					0.0014	0.0152	0.001				0.002			
VOC's Regulated																				
1,1 Dichloroethylene	0.007	mg/L			ND			ND		ND	ND	ND	ND	ND	ND	ND	ND			
1,1,1 Trichloroethane	0.2	mg/L			ND			ND		ND	ND	ND	ND	ND	ND	ND	ND			
1,1,2 Trichlorethane	0.005	mg/L			ND			ND		ND	ND	ND	ND	ND	ND					
1,2 Dichloroethane (EDC)	0.005	mg/L			ND			ND		ND	ND	ND	ND	ND	ND	ND	ND			
1,2 Dichlorpropane	0.005	mg/L			ND			ND		ND	ND	ND	ND	ND	ND					
1,2,4 Trichlorobenzene	0.07	mg/L			ND			ND		ND	ND	ND	ND	ND	ND					
Benzene	0.005	mg/L			ND			ND		ND	ND	ND	ND	ND	ND	ND	ND			
Carbon Tetrachloride	0.005	mg/L			ND			ND		ND	ND	ND	ND	ND	ND	ND	ND			
cis 1,2 Dichloroethylene	0.07	mg/L			ND			ND		ND	ND	ND	ND	ND	ND					
Dichloromethane	0.005	mg/L			ND			ND		ND	ND	ND	ND	ND	ND					
Ethylbenzene	0.7	mg/L			ND			ND		ND	ND	ND	ND	ND	ND					
Chlorobenzene	0.1	mg/L			ND			ND		ND	ND	ND	ND	ND	ND					
o-Dichlorobenzene	0.6	mg/L			ND			ND		ND	ND	ND	ND	ND	ND					
p-Dichlorobenzene	0.075	mg/L			ND			ND		ND	ND	ND	ND	ND	ND	ND	ND			
Styrene	0.1	mg/L			ND			ND		ND	ND	ND	ND	ND	ND					
Tetrachloroethylene	0.005	mg/L			ND			ND		ND	ND	ND	ND	ND	ND					
Toluene	1	mg/L			ND			ND		ND	ND	ND	ND	ND	ND					
Xylenes	10	mg/L			ND			ND		ND	ND	ND	ND	ND	ND					
trans 1,2 Dichloroethylene	0.1	mg/L			ND			ND		ND	ND	ND	ND	ND	ND					
Trichloroethylene	0.005	mg/L			ND			ND		ND	ND	ND	ND	ND	ND	ND	ND			
Vinyl Chloride	0.002	mg/L			ND			ND		ND	ND	ND	ND	ND	ND	ND	ND			

TABLE 2
CITY OF TIGARD WELL NO. 2
HISTORICAL WATER QUALITY DATA

CITY WELL NO.2			Date																	
Analyte	MCL	Unit	6/29/00	2/18/00	8/8/99	5/19/99	7/1/98	2/12/96	6/28/95	8/30/94	7/14/93	4/2/92	7/2/91	7/9/90	9/26/89	7/12/89	7/20/88	8/5/87	7/9/87	6/1/83
VOC's Unregulated																				
1,1 Dichloroethane		mg/L			ND			ND		ND	ND	ND	ND	ND	ND					
1,1 Dichloropropene		mg/L			ND			ND		ND	ND	ND	ND	ND	ND					
1,1 1 2 Tetrachloroethane		mg/L			ND			ND		ND	ND	ND	ND	ND	ND					
1,1 2 2, Tetrachloroethane		mg/L			ND			ND		ND	ND	ND	ND	ND	ND					
1,2,3 Trichloropropane		mg/L			ND			ND		ND	ND	ND	ND	ND	ND					
1,3 Dichloropropane		mg/L			ND			ND		ND	ND	ND	ND	ND	ND					
2 2 Dichloropropane		mg/L			ND			ND		ND	ND	ND	ND	ND	ND					
2 Butanone (MEK)		mg/L																		
4 - Methyl 2- Pentanone (MIBK)		mg/L																		
Bromobenzene		mg/L			ND			ND		ND	ND	ND	ND	ND	ND					
Bromodichloromethane		mg/L			ND	0 0004		ND		ND	ND	0 0014	ND	ND	ND					
Bromoform		mg/L			ND	ND		ND		ND	ND	ND	ND	ND	ND					
Bromomethane		mg/L			ND			ND		ND	ND	ND	ND	ND	ND					
Chloroethane		mg/L			ND			ND		ND	ND	ND	ND	ND	ND					
Chloroform		mg/L	0 0009		ND	0 0134		ND		ND	0 0014	0 0138	0 001	ND	ND		0 002			
Chloromethane		mg/L			ND			ND		ND	ND	ND	ND	ND	ND					
cis 1 2 3 Dichloropropene		mg/L																		
Dibromomethane		mg/L			ND			ND		ND	ND	ND	ND	ND	ND					
Dibromochloromethane		mg/L			ND	ND		ND		ND	ND	ND	ND	ND	ND					
m Dichlorobenzene		mg/L			ND			ND		ND	ND	ND	ND	ND	ND					
Di isopropyl ether		mg/L																		
o-Chlorotoluene		mg/L			ND			ND		ND	ND	ND	ND	ND	ND					
p-Chlorotoluene		mg/L			ND			ND		ND	ND	ND	ND	ND	ND					
Bromochloromethane		mg/L			ND			ND		ND	ND	ND	ND	ND	ND					
n Butylbenzene		mg/L			ND			ND		ND	ND	ND	ND	ND	ND					
Dichlorodifluoromethane		mg/L			ND			ND		ND	ND	ND	ND	ND	ND					
Fluorotrichloromethane		mg/L			ND			ND		ND	ND	ND	ND	ND	ND					
Hexachlorobutadiene		mg/L			ND			ND		ND	ND	ND	ND	ND	ND					
Isopropylbenzene		mg/L			ND			ND		ND	ND	ND	ND	ND	ND					
p-Isopropyltoluene		mg/L			ND			ND		ND	ND	ND	ND	ND	ND					
Methyl Tert butyl ether (MTBE)		mg/L																		
Napthalen		mg/L			ND			ND		ND	ND	ND	ND	ND	ND					
n-Propylbenzene		mg/L			ND			ND		ND	ND	ND	ND	ND	ND					
sec Butylbenzene		mg/L			ND			ND		ND	ND	ND	ND	ND	ND					
tert Butylbenzene		mg/L			ND			ND		ND	ND	ND	ND	ND	ND					
tert amyl Methyl Ether		mg/L																		
tert Butyl Ethyl Ether		mg/L																		
Trichlorotrifluoroethane (Freon)		mg/L																		
trans 1 3 Dichloropropene		mg/L																		
1 2,3 Trichlorobenzene		mg/L			ND			ND		ND	ND	ND	ND	ND	ND					
1 2 4 Trimethylbenzene		mg/L			ND			ND		ND	ND	ND	ND	ND	ND					
1,3 5 Trimethylbenzene		mg/L			ND			ND		ND	ND	ND	ND	ND	ND					
SOCs Regulated																				
2 4 D	0 07	mg/L			ND			ND		ND	ND									
2 4 5 TP	0 05	mg/L			ND			ND		ND	ND									
Alachlor	0 002	mg/L			ND			ND		ND	ND									
Atrazine	0 003	mg/L			ND			ND		ND	ND									
Benzo(a)pyrene	0 0002	mg/L			ND			ND		ND	ND									
Carbofuran	0 04	mg/L			ND			ND		ND	ND									
Chlordane	0 002	mg/L			ND			ND		ND	ND									
Dalapon	0 2	mg/L			ND			ND		ND	ND									
DBCP (Dibromochloropropane)	0 0002	mg/L			ND			ND		ND	ND									
Di(2-ethylhexyl)adipate	0 4	mg/L			ND			ND		ND	ND									
Di(2-ethylhexyl)phthalate	0 006	mg/L			ND			ND		ND	ND									
Dinoseb	0 007	mg/L			ND			ND		ND	ND									
Dioxin	3x10 8	mg/L			ND			ND		ND	ND									
Diquat	0 02	mg/L			ND			ND		ND	ND									
EDB (Ethylene Dibromide)	0 00005	mg/L			ND			ND		ND	ND									
Endothall	0 1	mg/L			ND			ND		ND	ND									
Endrin	0 002	mg/L			ND			ND		ND	ND									
Glyphosphate	0 7	mg/L			ND			ND		ND	ND									
Heptachlor	0 0004	mg/L			ND			ND		ND	ND									
Heptachlor Epoxide	0 0002	mg/L			ND			ND		ND	ND									
Hexachlorobenzene	0 001	mg/L			ND			ND		ND	ND									
Hexachlorocyclopentadiene	0 05	mg/L			ND			ND		ND	ND									
Lindane	0 0002	mg/L			ND			ND		ND	ND									
Methoxychlor	0 04	mg/L			ND			ND		ND	ND									
Oxamyl	0 2	mg/L			ND			ND		ND	ND									
PCBs	0 0005	mg/L			ND			ND		ND	ND									
Pentachlorophenol	0 001	mg/L			ND			ND		ND	ND									
Picloram	0 5	mg/L			ND			ND		ND	ND									
Simazine	0 004	mg/L			ND			ND		ND	ND									
Toxaphene	0 003	mg/L			ND			ND		ND	ND									
SOCs Unregulated																				
3 Hydroxycarbofuran		mg/L			ND			ND		ND	ND									
Aldicarb		mg/L			ND			ND		ND	ND									
Aldicarb Sulfone		mg/L			ND			ND		ND	ND									
Aldicarb Sulfoxide		mg/L			ND			ND		ND	ND									
Aldrin		mg/L			ND			ND		ND	ND									
Butachlor		mg/L			ND			ND		ND	ND									
Carbaryl		mg/L			ND			ND		ND	ND									
Dicamba		mg/L			ND			ND		ND	ND									
Dieldrin		mg/L			ND			ND		ND	ND									
Methomyl		mg/L			ND			ND		ND	ND									
Metolachlor		mg/L			ND			ND		ND	ND									
Metribuzin		mg/L			ND			ND		ND	ND									
Propachlor		mg/L			ND			ND		ND	ND									

TABLE 3
CITY OF TIGARD WELL NO. 3
HISTORICAL WATER QUALITY DATA

			DATE				
CITY WELL NO.3	MCL	Unit	9/9/99	8/13/99	7/10/96	6/24/92	2/7/58
Analyte							
Physical							
pH					6.51		6.9
Alkalinity		mg/L					0
Hardness	250	mg/L			34		113.7
Iron		mg/L			0.15		0.76
Bicarbonate		mg/L					121
Calcium		mg/L					
Carbonate as CO3		mg/L					
Chloride		mg/L			4 3		9 6
Conductivity		uS					
Free CO2		mg/L					
Gross Alpha	15	pCi/L	1.63		0 3	0	
Hydroxide as OH		mg/L					
Silica		mg/L					
Total Solids		mg/L			88		
Total Dissolved Solids		mg/L					
Inorganics							
Antimony	0.006	mg/L			ND		
Arsenic	0.05	MF/L			ND	ND	
Asbestos	7	mg/L			NA		
Barium	2	mg/L			ND	ND	
Beryllium	0.004	mg/L			ND		
Cadmium	0.005	mg/L			ND	MD	
Chromium	0 1	mg/L			ND	ND	
Copper	1.3	mg/L			0.15		
Cyanide	0.2	mg/L			ND		
Fluoride	4	mg/L			ND	0 24	
Lead	0.015	mg/L			0 007	ND	
Magnesium		mg/L					
Manganese		mg/L			0.22		
Mercury	0.002	mg/L			ND	ND	
Nickel	0 1	mg/L			ND		
Nitrate	10	mg/L		ND	ND	0.32	
Nitrite	1	mg/L			ND		
Potassium		mg/L					
Selenium	0.05	mg/L			ND	ND	
Silver	0.05	mg/L				ND	
Sodium		mg/L			5	17.8	
Sulfate	250	mg/L			ND		5
Thallium	0.002	mg/L			ND		
Zinc		mg/L			0.02		
Disinfection By-Products							
Total Haloacetic Acids	0.060	mg/L					
Total Trihaolmethanes	0.08	mg/L			0.02		
VOC's Regulated							
1,1 Dicholoroethylene	0.007	mg/L			ND	ND	
1,1,1 Trichloroethane	0.2	mg/L			ND	ND	
1,1,2 Trichlorethane	0.005	mg/L			ND	ND	
1,2 Dichloroethane (EDC)	0.005	mg/L			ND	ND	
1,2 Dichlorpropane	0.005	mg/L			ND	ND	
1,2,4 Trichlorobenzene	0.07	mg/L			ND	ND	
Benzene	0.005	mg/L			ND	ND	
Carbon Tetrachloride	0.005	mg/L			ND	ND	
cis 1,2 Dichloroethylene	0.07	mg/L			ND	ND	
Dichloromethane	0.005	mg/L			ND	ND	
Ethylbenzene	0.7	mg/L			ND	ND	
Chlorobenzene	0.1	mg/L			ND	ND	
o-Dichlorobenzene	0.6	mg/L			ND	ND	
p-Dichlorobenzene	0.075	mg/L			ND	ND	
Styrene	0.1	mg/L			ND	ND	
Tetrachloroethylene	0.005	mg/L			ND	ND	
Toluene	1	mg/L			ND	ND	
Xylenes	10	mg/L			ND	ND	
trans 1,2 Dichloroethylene	0.1	mg/L			ND	ND	
Trichloroethylene	0.005	mg/L			ND	ND	
Vinyl Chloride	0.002	mg/L			ND	ND	
VOC's Unregulated							
1,1 Dichloroethane		mg/L			ND	ND	
1,1 Dichloropropene		mg/L			ND	ND	
1,1,1,2 Tetrachloroethane		mg/L			ND	ND	
1,1,2,2. Tetrachloroethane		mg/L			ND	ND	
1,2,3 Trichloropropane		mg/L			ND	ND	
1,3 Dichloropropene		mg/L			ND	ND	
2,2 Dichloropropane		mg/L			ND	ND	
2 Butanone (MEK)		ug/L					
4 - Methyl 2- Pentanone (MIBK)		mg/L					
Bromobenzene		mg/L			ND	ND	
Bromodichloromethane		mg/L			0.001	ND	

TABLE 3
CITY OF TIGARD WELL NO. 3
HISTORICAL WATER QUALITY DATA

			DATE				
CITY WELL NO.3	MCL	Unit	9/9/99	8/13/99	7/10/96	6/24/92	2/7/58
Bromoform		mg/L			ND	ND	
Bromomethane		mg/L			ND	ND	
Chloroethane		mg/L			ND	ND	
Chloroform		mg/L			0.019	ND	
Chloromethane		ug/L			ND	ND	
cis 1,2,3 Dichloropropene		mg/L					
Dibromomethane		mg/L			ND	ND	
Dibromochloromethane		mg/L			ND	ND	
m-Dichlorobenzene		ug/L			ND	ND	
Di-isopropyl ether		mg/L					
o-Chlorotoluene		mg/L			ND	ND	
p-Chlorotoluene		mg/L			ND	ND	
Bromochloromethane		mg/L			ND	ND	
n-Butylbenzene		mg/L			ND	ND	
Dichlorodifluoromethane		mg/L			ND	ND	
Fluorotrichloromethane		mg/L			ND	ND	
Hexachlorobutadiene		mg/L			ND	ND	
Isopropylbenzene		mg/L			ND	ND	
p-Isopropyltoluene		ug/L			ND	ND	
Methyl Tert-butyl ether (MTBE)		mg/L					
Napthalen		ug/L			ND	ND	
n-Propylbenzene		mg/L			ND	ND	
sec-Butylbenzene		mg/L			ND	ND	
tert-Butylbenzene		ug/L			ND	ND	
tert-amyl Methyl Ether		ug/L					
tert-Butyl Ethyl Ether		ug/L					
Trichlorotrifluoroethane (Freon)		ug/L					
trans 1,3 Dichloropropene		mg/L					
1,2,3 Trichlorobenzene		mg/L			ND	ND	
1,2,4 Trimethylbenzene		mg/L			ND	ND	
1,3,5 Trimethylbenzene		mg/L			ND	ND	
SOCs Regulated							
2,4 D	0.07	mg/L			ND		
2,4,5 TP	0.05	mg/L			ND		
Alachlor	0.002	mg/L			ND		
Atrazine	0.003	mg/L			ND		
Benzo(a)pyrene	0.0002	mg/L			ND		
Carbofuran	0.04	mg/L			ND		
Chlordane	0.002	mg/L			ND		
Dalapon	0.2	mg/L			ND		
DBCP (Dibromochloropropane)	0.0002	mg/L			ND		
Di(2-ethylhexyl)adipate	0.4	mg/L			ND		
Di(2-ethylhexyl)phthalate	0.006	mg/L			ND		
Dinoseb	0.007	mg/L			ND		
Dioxin	3x10-8	mg/L			ND		
Diquat	0.02	mg/L			ND		
EDB (Ethylene Dibromide)	0.00005	mg/L			ND		
Endothall	0.1	mg/L			ND		
Endrin	0.002	mg/L			ND		
Glyphosphate	0.7	mg/L			ND		
Heptachlor	0.0004	mg/L			ND		
Heptachlor Epoxide	0.0002	mg/L			ND		
Hexachlorobenzene	0.001	mg/L			ND		
Hexachlorocyclopentadiene	0.05	mg/L			ND		
Lindane	0.0002	mg/L			ND		
Methoxychlor	0.04	mg/L			ND		
Oxamyl	0.2	mg/L			ND		
PCBs	0.0005	mg/L			ND		
Pentachlorophenol	0.001	mg/L			ND		
Picloram	0.5	mg/L			ND		
Simazine	0.004	mg/L			ND		
Toxaphene	0.003	mg/L			ND		
SOCs Unregulated							
3 Hydroxycarbofuran		mg/L			ND		
Aldicarb		mg/L			ND		
Aldicarb Sulfone		mg/L			ND		
Aldicarb Sulfoxide		mg/L			ND		
Aldrin		mg/L			ND		
Butachlor		mg/L			ND		
Carbaryl		mg/L			ND		
Dicamba		mg/L			ND		
Dieldrin		mg/L			ND		
Methomyl		mg/L			ND		
Metolachlor		mg/L			ND		
Metribuzin		mg/L			ND		
Propachlor		mg/L			ND		

TABLE 4
CITY OF TIGARD WELL NO. 4
HISTORICAL WATER QUALITY DATA

COT WELL NO. 4	Drinking Water			Date
	MCL			
Analyte	Primary	Secondary	Unit	2/13/69
Color		15	ACU	2
Turbidity		TT	NTU	
Total Solids			mg/L	294
Volatile Solids			mg/L	89
Carbon Dioxide			mg/L	1
pH		6.5-8.5		7.4
Alkalinity, Total as CaCO3			mg/L	128
Hardness	250		mg/L	108.8
Calcium			mg/L	29.5
Magnesium			mg/L	8.6
Total Iron		0.3	mg/L	0.01
Manganese		0.005	mg/L	0.01
Arsenic	0.05		mg/L	ND
Conductance			uS	255
Chlorides		250	mg/L	9.5
Sodium			mg/L	10.8
Potassium			mg/L	3.3
Flouride	4	2.0	mg/L	0.27
Phosphates			mg/L	mg/L
Sulfates		250	mg/L	2.1
Silicon			mg/L	68.6
Aluminum		0.05-0.2	mg/L	0.09
Ammonia			mg/L	0.1
Nitrate	10		mg/L	0.01
Nitrite	1		mg/L	0.07

Table 5
Lake Oswego
Historical Water Quality

	Drinking Water Standards			Lake Oswego														
	MCL																	
Parameter	Primary	Secondary	Units	10/24/01	9/6/00	8/17/00	7/14/00	6/7/00	5/10/00	3/23/00	1/18/00	1/11/00	2/2/99	4/22/97	8/14/96	6/14/96	1/9/96	12/1/96
Conventional Parameters																		
Calcium			mg/L															
Chloride		250	mg/L											5				
Color		15																
Conductivity			umhos/cm															
Corrosivity			-															
Fluoride (free)	4	2	mg/L									ND	ND	ND	ND	ND	ND	
Magnesium			mg/L															
MBAS (Surfactants)			mg/L															
Nitrate	10		mg/L			ND						ND	0.6	ND	ND	ND	ND	0.6
Nitrite	1		mg/L									ND	ND	ND	ND	ND	0.42	
Total nitrate and nitrite	10		mg/L												ND	ND	0.42	
Orthophosphate			mg/L															
Odor		3	TON															
pH		6.5-8.5												6.44				
Total Phosphorus			mg/L															
Potassium			mg/L															
Silica (SiO2)	mg/L		mg/L															
Sodium			mg/L									3.8	3.6	1.8	17.5	3	2.2	
Sulfate		250	mg/L									ND	ND	11	ND	ND	ND	
Total Alkalinity			mg/L		30		31	26	20									
(TDS) Total Dissolved Solids		500	mg/L															
(TS) Total Solids			mg/L											43				
(TSS) Total Suspended Solids			mg/L															
Total Volatile Solids			mg/L															
Total Hardness		250	mg/L-CaCO2											18				
Total Kjeldahl Nitrogen			mg/L															
(TOC) Total Organic Carbon			mg/L		0.5		0.9	1.4	1.1	0.8								
Turbidity	0.3		NTU															
Inorganics																		
Aluminum		0.05-0.2	mg/L															
Antimony	0.006		mg/L									ND	ND	ND	ND	ND	ND	
Arsenic	0.05		mg/L	ND								ND	ND	ND	ND	ND	ND	
Asbestos	7		MFL															
Barium	2		mg/L									0.006	ND	ND	ND	ND	ND	
Beryllium	0.004		mg/L									ND	ND	ND	ND	ND	ND	
Cadmium	0.005		mg/L									ND	ND	ND	ND	ND	ND	
Chromium	0.1		mg/L									ND	ND	ND	ND	ND	ND	
Copper	TT	1.0	mg/L									ND	ND	ND				
Cyanide	0.2		mg/L									ND	ND	ND	ND	ND	ND	
Iron		0.3	mg/L											ND				
Lead	TT	0.0009	mg/L									ND	ND	ND	ND	ND	0.002	
Manganese		0.05	mg/L											ND				
Mercury	0.002		mg/L									ND	ND	ND	ND	ND	ND	
Nickel			mg/L									ND	ND	ND	ND	ND	ND	
Selenium	0.05		mg/L									ND	ND	ND	ND	ND	ND	
Silver		0.10																
Thallium	0.002		mg/L									ND	ND	ND	ND	ND	ND	
Zinc		5	mg/L											ND				
Radionuclides																		
Gross Alpha	15		pCi/L								0.15						0.05	
Gross Beta			pCi/L															
Radon (Rn 222)			pCi/L															
Iodine 131			pCi/L															
Strontium 90			pCi/L															
Tritium			pCi/L															
Disinfection By-Products																		
Total Haloacetic Acids	0.060		mg/L															
Total Trihalomethanes	0.08		mg/L														0.0179	
VOC's Regulated																		
1,1 Dichloroethylene	0.007		mg/L									ND	ND		ND		ND	
1,1,1 Trichloroethane	0.2		mg/L									ND	ND		ND		ND	
1,1,2 Trichloroethane	0.005		mg/L									ND	ND		ND		ND	
1,2 Dichloroethane (EDC)	0.005		mg/L									ND	ND		ND		ND	
1,2 Dichloropropane			mg/L									ND	ND		ND		ND	
1,2,4 Trichlorobenzene	0.07		mg/L									ND	ND		ND		ND	
Benzene	0.005		mg/L									ND	ND		ND		ND	
Carbon Tetrachloride	0.005		mg/L									ND	ND		ND		ND	
Chlorobenzene	0.1		mg/L									ND	ND		ND		ND	
cis 1,2 Dichloroethylene	0.07		mg/L									ND	ND		ND		ND	
Dichloromethane	0.005		mg/L									ND	ND		ND		ND	
Ethylbenzene	0.7		mg/L									ND	ND		ND		ND	
o-Dichlorobenzene	0.6		mg/L									ND	ND		ND		ND	
p-Dichlorobenzene	0.075		mg/L									ND	ND		ND		ND	
Styrene	0.1		mg/L									ND	ND		ND		ND	
Tetrachloroethylene	0.005		mg/L									ND	ND		ND		ND	
Toluene	1		mg/L									ND	ND		ND		ND	
trans 1,2 Dichloroethylene	0.1		mg/L									ND	ND		ND		ND	
Trichloroethylene	0.005		mg/L									ND	ND		ND		ND	
Vinyl Chloride	0.002		mg/L									ND	ND		ND		ND	
Xylenes	10		mg/L									ND	ND		ND		ND	
VOC's Unregulated																		
1,1 Dichloroethane			mg/L									ND	ND		ND		ND	
1,1 Dichloropropene			mg/L									ND	ND		ND		ND	
1,1,1,2 Tetrachloroethane			mg/L									ND	ND		ND		ND	
1,1,2,2 Tetrachloroethane			mg/L									ND	ND		ND		ND	
1,2,3 Trichloropropane			mg/L									ND	ND		ND		ND	
1,3 Dichloropropene			mg/L									ND	ND		ND		ND	
2,2 Dichloropropane			mg/L									ND	ND		ND		ND	
2 Butanone (MEK)			mg/L									ND	ND		ND		ND	

Table 5
Lake Oswego
Historical Water Quality

	Drinking Water Standards			Lake Oswego														
	MCL																	
Parameter	Primary	Secondary	Units	10/24/01	9/6/00	8/17/00	7/14/00	6/7/00	6/10/00	3/23/00	1/19/00	1/11/00	3/2/99	4/22/97	8/14/96	6/14/96	1/9/96	12/1/96
4 - Methyl 2- Pentanone (MIBK)			mg/L									ND	ND		ND		ND	
Bromobenzene			mg/L									ND	ND		ND		ND	
Bromodichloromethane			mg/L									ND	ND		ND		0.0009	
Bromoform			mg/L									ND	ND		ND		ND	
Bromomethane			mg/L									ND	ND		ND		ND	
Chloroethane			mg/L									ND	ND		ND		ND	
Chloroform			mg/L									ND	ND		ND		0.017	
Chloromethane			mg/L									ND	ND		ND		ND	
cis 1,2,3 Dichloropropene			mg/L									ND	ND		ND		ND	
Dibromomethane			mg/L									ND	ND		ND		ND	
Dibromochloromethane			mg/L									ND	ND		ND		ND	
m Dichlorobenzene			mg/L									ND	ND		ND		ND	
Di-isopropyl ether			mg/L									ND	ND		ND		ND	
o-Chlorotoluene			mg/L									ND	ND		ND		ND	
p-Chlorotoluene			mg/L									ND	ND		ND		ND	
Bromochloromethane			mg/L									ND	ND		ND		ND	
n Butylbenzene			mg/L									ND	ND		ND		ND	
Dichlorodifluoromethane			mg/L									ND	ND		ND		ND	
Fluorotrichloromethane			mg/L									ND	ND		ND		ND	
Hexachlorobutadiene			mg/L									ND	ND		ND		ND	
Isopropylbenzene			mg/L									ND	ND		ND		ND	
p-Isopropyltoluene			mg/L									ND	ND		ND		ND	
Methyl Tert butyl ether (MTBE)			mg/L									ND	ND		ND		ND	
Napthalen			mg/L									ND	ND		ND		ND	
n Propylbenzene			mg/L									ND	ND		ND		ND	
sec-Butylbenzene			mg/L									ND	ND		ND		ND	
tert Butylbenzene			mg/L									ND	ND		ND		ND	
tert amyl Methyl Ether			mg/L									ND	ND		ND		ND	
tert Butyl Ethyl Ether			mg/L									ND	ND		ND		ND	
Trichlorotrifluoroethane (Freon)			mg/L									ND	ND		ND		ND	
trans 1,3 Dichloropropene			mg/L									ND	ND		ND		ND	
1,2,3 Trichlorobenzene			mg/L									ND	ND		ND		ND	
1,2,4 Trimethylbenzene			mg/L									ND	ND		ND		ND	
1,3,5 Trimethylbenzene			mg/L									ND	ND		ND		ND	
SOCs Regulated																	ND	
2,4 D	0.07		mg/L									ND	ND		ND		ND	
2,4,5 TP	0.05		mg/L									ND	ND		ND		ND	
Alachlor	0.002		mg/L									ND	ND		ND		ND	
Atrazine	0.003		mg/L									ND	ND		ND		ND	
Benzo(a)pyrene	0.0002		mg/L									ND	ND		ND		ND	
Carbofuran	0.04		mg/L									ND	ND		ND		ND	
Chlordane	0.002		mg/L									ND	ND		ND		ND	
Dalapon	0.2		mg/L									ND	ND		ND		ND	
DBCP (Dibromochloropropane)	0.0002		mg/L									ND	ND		ND		ND	
Di(2 ethylhexyl)adipate	0.4		mg/L									ND	ND		ND		ND	
Di(2-ethylhexyl)phthalate	0.006		mg/L									ND	ND		ND		ND	
Dinoseb	0.007		mg/L									ND	ND		ND		ND	
Dioxin	3x10-8		mg/L									ND	ND		ND		ND	
Diquat	0.02		mg/L									ND	ND		ND		ND	
EDB (Ethylene Dibromide)	0.00005		mg/L									ND	ND		ND		ND	
Endothall	0.1		mg/L									ND	ND		ND		ND	
Endrin	0.002		mg/L									ND	ND		ND		ND	
Glyphosphate	0.7		mg/L									ND	ND		ND		ND	
Heptachlor	0.0004		mg/L									ND	ND		ND		ND	
Heptachlor Epoxide	0.0002		mg/L									ND	ND		ND		ND	
Hexachlorobenzene	0.001		mg/L									ND	ND		ND		ND	
Hexachlorocyclopentadiene	0.05		mg/L									ND	ND		ND		ND	
Lindane	0.0002		mg/L									ND	ND		ND		ND	
Methoxychlor	0.04		mg/L									ND	ND		ND		ND	
Oxamyl	0.2		mg/L									ND	ND		ND		ND	
PCBs	0.0005		mg/L									ND	ND		ND		ND	
Pentachlorophenol	0.001		mg/L									ND	ND		ND		ND	
Picloram	0.5		mg/L									ND	ND		ND		ND	
Simazine	0.004		mg/L									ND	ND		ND		ND	
Toxaphene	0.003		mg/L									ND	ND		ND		ND	
Vydate			mg/L									ND	ND		ND		ND	
SOCs Unregulated																		
3 Hydroxycarbofuran			mg/L									ND	ND		ND		ND	
Aldicarb			mg/L									ND	ND		ND		ND	
Aldicarb Sulfone			mg/L									ND	ND		ND		ND	
Aldicarb Sulfoxide			mg/L									ND	ND		ND		ND	
Aldrin			mg/L									ND	ND		ND		ND	
Butachlor			mg/L									ND	ND		ND		ND	
Carbaryl			mg/L									ND	ND		ND		ND	
Dicamba			mg/L									ND	ND		ND		ND	
Dieldrin			mg/L									ND	ND		ND		ND	
Methomyl			mg/L									ND	ND		ND		ND	
Metolachlor			mg/L									ND	ND		ND		ND	
Metribuzin			mg/L									ND	ND		ND		ND	
Propachlor			mg/L									ND	ND		ND		ND	
TT - Treatment Technique																		

Table 6
City of Portland - Bull Run
Historical Water Quality

	Drinking Water Standards			Bull Run				
	MCL					Conduit 3	Conduit 4	
Parameter	Primary	Secondary	Units	3/27/00	8/2/99	4/22/99	3/29/99	3/31/98
Conventional Parameters								
Calcium			mg/L	2.9	1.6			
Chloride		250	mg/L	1.5	1.9			
Color		15		ND	ND			
Conductivity			umhos/cm	24	29			
Corrosivity			-					
Fluoride (free)	4	2	mg/L	ND	ND	ND		
Magnesium			mg/L	0.80	0.66			
MBAS (Surfactants)			mg/L					
Nitrate	10		mg/L	0.02	0.02		0.03	
Nitrite	1		mg/L	ND	0.002		0.001	
Total nitrate and nitrite	10		mg/L				0.031	
Orthophosphate			mg/L					
Odor		3	TON					
pH		6.5-8.5		7.5	7.3			
Total Phosphorus			mg/L	0.007				
Potassium			mg/L	0.20				
Silica (SiO2)			mg/L	3.9	4			
Sodium			mg/L	2.6			1.9	
Sulfate		250	mg/L	ND	ND		<0.5	
Total Alkalinity			mg/L	7.9	9.9			
(TDS) Total Dissolved Solids		500	mg/L	20				
(TS) Total Solids			mg/L	21	28			
(TSS) Total Suspended Solids			mg/L	1	0.5			
Total Volatile Solids			mg/L					
Total Hardness		250	mg/L-CaCO2	10	6.8			
Total Kjeldahl Nitrogen			mg/L					
(TOC) Total Organic Carbon			mg/L	1.10	1.0			
Turbidity	5		NTU	0.31	0.29			
Inorganics								
Aluminum		0.05-0.2	mg/L	0.670		ND	ND	
Antimony	0.006		mg/L	ND		ND	ND	
Arsenic	0.05		mg/L	ND		ND	ND	
Asbestos	7		MFL					
Barium	2		mg/L	0.002		ND	ND	
Beryllium	0.004		mg/L			<0.001	ND	ND
Cadmium	0.005		mg/L	ND		ND	ND	
Chromium	0.1		mg/L	ND		ND	ND	
Copper	TT	1.0	mg/L	0.19				
Cyanide	0.2		mg/L			<0.025	ND	ND
Iron		0.3	mg/L	0.066	0.018			
Lead	TT	0.0009	mg/L	0.009		ND	ND	
Manganese		0.05	mg/L	ND	ND			
Mercury	0.002		mg/L	ND		ND	ND	
Nickel			mg/L	0.002		ND	ND	
Selenium	0.05		mg/L	ND		ND	0.002	
Silver		0.10		ND		ND	ND	
Thallium	0.002		mg/L	ND		ND	ND	ND
Zinc		5	mg/L	ND				
Radionuclides								
Gross Alpha	15		pCi/L					
Gross Beta			pCi/L					
Radon (Rn-222)			pCi/L					
Iodine-131			pCi/L					
Strontium-90			pCi/L					
Tritium			pCi/L					
Disinfection By-Products								
Total Haloacetic Acids	0.060		mg/L					
Total Trihaolmethanes	0.08		mg/L			0.0056		
VOC's Regulated								
1,1 Dicholoroethylene	0.007		mg/L			ND		
1,1,1 Trichloroethane	0.2		mg/L			ND		
1,1,2 Trichlorethane	0.005		mg/L			ND		
1,2 Dichloroethane (EDC)	0.005		mg/L			ND		
1,2 Dichlorpropane			mg/L			ND		
1,2,4 Trichlorobenzene	0.07		mg/L			ND		
Benzene	0.005		mg/L			ND		
Carbon Tetrachloride	0.005		mg/L			ND		
Chlorobenzene	0.1		mg/L			ND		
cis 1,2 Dichloroethylene	0.07		mg/L			ND		
Dichloromethane	0.005		mg/L			ND		
Ethylbenzene	0.7		mg/L			ND		
o-Dichlorobenzene	0.6		mg/L			ND		
p-Dichlorobenzene	0.075		mg/L			ND		
Styrene	0.1		mg/L			ND		
Tetrachloroethylene	0.005		mg/L			ND		
Toluene	1		mg/L			ND		
trans 1,2 Dichloroethylene	0.1		mg/L			ND		
Trichloroethylene	0.005		mg/L			ND		
Vinyl Chloride	0.002		mg/L			ND		
Xylenes	10		mg/L			ND		
VOC's Unregulated								
1,1 Dichloroethane			mg/L			ND		
1,1 Dichloropropene			mg/L			ND		
1,1,1,2 Tetrachloroethane			mg/L			ND		
1,1,2,2, Tetrachloroethane			mg/L			ND		
1,2,3 Trichloropropane			mg/L			ND		
1,3 Dichloropropene			mg/L			ND		
2,2 Dichloropropane			mg/L			ND		
2 Butanone (MEK)			mg/L			ND		

Table 6
City of Portland - Bull Run
Historical Water Quality

	Drinking Water Standards			Bull Run				
	MCL					Conduit 3	Conduit 4	
Parameter	Primary	Secondary	Units	3/27/00	8/2/99	4/22/99	3/29/99	3/31/98
4 - Methyl 2- Pentanone (MIBK)			mg/L			ND		
Bromobenzene			mg/L			ND		
Bromodichlromethane			mg/L			0.0006		
Bromoform			mg/L			ND		
Bromomethane			mg/L			ND		
Chloroethane			mg/L			ND		
Chloroform			mg/L			0.005		
Chloromethane			mg/L			ND		
cis 1,2,3 Dichloropropene			mg/L			ND		
Dibromomethane			mg/L			ND		
Dibromochloromethane			mg/L			ND		
m-Dichlorobenzene			mg/L			ND		
Di-isopropyl ether			mg/L			ND		
o-Chlorotoluene			mg/L			ND		
p-Chlorotoluene			mg/L			ND		
Bromochloromethane			mg/L			ND		
n-Butylbenzene			mg/L			ND		
Dichlorodifluoromethane			mg/L			ND		
Fluorotrichloromethane			mg/L			ND		
Hexachlorobutadiene			mg/L			ND		
Isopropylbenzene			mg/L			ND		
p-Isopropyltoluene			mg/L			ND		
Methyl Tert-butyl ether (MTBE)			mg/L			ND		
Napthalen			mg/L			ND		
n-Propylbenzene			mg/L			ND		
sec-Butylbenzene			mg/L			ND		
tert-Butylbenzene			mg/L			ND		
tert-amyl Methyl Ether			mg/L			ND		
tert-Butyl Ethyl Ether			mg/L			ND		
Trichlorotrifluoroethane (Freon)			mg/L			ND		
trans 1,3 Dichloropropene			mg/L			ND		
1,2,3 Trichlorobenzene			mg/L			ND		
1,2,4 Trimethylbenzene			mg/L			ND		
1,3,5 Trimethylbenzene			mg/L			ND		
SOCs Regulated								
2,4 D	0.07		mg/L			ND		ND
2,4,5 TP	0.05		mg/L			ND		ND
Alachlor	0.002		mg/L			ND		ND
Atrazine	0.003		mg/L			ND		ND
Benzo(a)pyrene	0.0002		mg/L			ND		ND
Carboturan	0.04		mg/L			ND		ND
Chlordane	0.002		mg/L			ND		
Dalapon	0.2		mg/L			ND		ND
DBCP (Dibromochloropropane)	0.0002		mg/L			ND		
Di(2-ethylhexyl)adipate	0.4		mg/L					ND
Di(2-ethylhexyl)phthalate	0.006		mg/L					ND
Dinoseb	0.007		mg/L			ND		ND
Dioxin	3x10-8		mg/L					
Diquat	0.02		mg/L			ND		ND
EDB (Ethylene Dibromide)	0.00005		mg/L			ND		
Endothall	0.1		mg/L			ND		ND
Endrin	0.002		mg/L			ND		ND
Glyphosphate	0.7		mg/L			ND		ND
Heptachlor	0.0004		mg/L			ND		ND
Heptachlor Epoxide	0.0002		mg/L			ND		ND
Hexachlorobenzene	0.001		mg/L			ND		ND
Hexachlorocyclopentadiene	0.05		mg/L			ND		ND
Lindane	0.0002		mg/L			ND		ND
Methoxychlor	0.04		mg/L			ND		ND
Oxamyl	0.2		mg/L					ND
PCBs	0.0005		mg/L			ND		ND
Pentachlorophenol	0.001		mg/L			ND		ND
Picloram	0.5		mg/L			ND		ND
Simazine	0.004		mg/L			ND		ND
Toxaphene	0.003		mg/L			ND		ND
Vydate			mg/L			ND		
SOCs Unregulated								
3 Hydroxycarbofuran			mg/L			ND		ND
Aldicarb			mg/L			ND		ND
Aldicarb Sulfone			mg/L			ND		ND
Aldicarb Sulfoxide			mg/L			ND		ND
Aldrin			mg/L			ND		ND
Butachlor			mg/L			ND		ND
Carbaryl			mg/L			ND		ND
Dicamba			mg/L			ND		ND
Dieldrin			mg/L			ND		ND
Methomyl			mg/L			ND		ND
Metolachlor			mg/L			ND		ND
Metribuzin			mg/L			ND		ND
Propachlor			mg/L			ND		ND
TT - Treatment Technique								

Table7
City of Portland - Columbia Southshore Wellfield
Historical Water Quality

	Drinking Water Standards			City of Portland - Well Field																				
	MCL																							
Parameter	Primary	Secondary	Units	Groundwater Pump Station 6/1/00	Well No. 1 3/27/00	Well No.2 3/27/00	Well No.3 3/27/00	Well No.4 3/27/00	Well No.5 3/27/00	Well No.6 3/27/00	Well No. 7 3/27/00	Well No. 8 3/27/00	Well No.9 3/27/00	Well No. 10 3/27/00	Well No.11 3/27/00	Well No.12 3/27/00	Well No.13 3/27/00	Well No.14 3/27/00	Well No.15 3/27/00	Well No.16 3/27/00	Well No. 18 3/27/00	Well No. 19 3/27/00	Park Rose 3/27/00	Groundwater Pump Station 12/2/98
Conventional Parameters																								
Calcium			mg/L																					20
Chloride		250	mg/L																					5.9
Color		15																						ND
Conductivity			umhos/cm																					206
Corrosivity			-																					
Fluoride (free)	4	2	mg/L																					0.12
Magnesium			mg/L																					9.1
MBAS (Surfactants)			mg/L																					
Nitrate	10		mgN/L																					0.5
Nitrite	1		mgN/L																					ND
Total nitrate and nitrite	10		mgN/L																					
Orthophosphate																								
Odor		3	TON																					
pH		6.5-8.5																						7.3
Total Phosphorus																								
Potassium			mg/L																					
Silica (SiO2)	mg/L		mg/L																					
Sodium			mg/L																					
Sulfate		250	mg/L																					5.1
Total Alkalinity			mg/L																					93
(TDS) Total Dissolved Solids		600	mg/L																					
(TS) Total Solids			mg/L																					162
(TSS) Total Suspended Solids																								0.5
Total Volatile Solids																								
Total Hardness		250	mg/L-CaCO2																					86
Total Kjeldahl Nitrogen																								
(TOC) Total Organic Carbon			mg/L																					0.55
Turbidity	5		NTU																					0.2
Inorganics																								
Aluminum		0.05-0.2	mg/L																					
Antimony	0.006		mg/L																					
Arsenic	0.05		mg/L																					
Asbestos	7		MFL																					
Barium	2		mg/L																					
Beryllium	0.004		mg/L																					
Cadmium	0.005		mg/L																					
Chromium	0.1		mg/L																					
Copper	TT	1.0	mg/L																					
Cyanide																								
Iron		0.3	mg/L																					0.032
Lead	TT	0.0009	mg/L																					
Manganese		0.05	mg/L																					0.058
Mercury	0.002		mg/L																					
Nickel			mg/L																					
Selenium	0.05		mg/L																					
Silver		0.10	mg/L																					
Thallium	0.002		mg/L																					
Zinc		5	mg/L																					
Radionuclides																								
Gross Alpha	15		pCi/L																					
Gross Beta			pCi/L																					
Radon (Rn-222)			pCi/L																					
Iodine-131			pCi/L																					
Strontium-90			pCi/L																					
Tritium			pCi/L																					
Disinfection By-Products																								
Total Haloacetic Acids	0.060		mg/L																					
Total Trihalomethanes	0.08		mg/L																				0.001	
VOC's Regulated																								
1,1 Dichloroethylene	0.007		mg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
1,1,1 Trichloroethane	0.2		mg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
1,1,2 Trichloroethane	0.005		mg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
1,2 Dichloroethane (EDC)	0.005		mg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
1,2 Dichlorpropane			mg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
1,2,4 Trichlorobenzene	0.07		mg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
Benzene	0.005		mg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
Carbon Tetrachloride	0.005		mg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
Chlorobenzene	0.1		mg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
cis 1,2 Dichloroethylene	0.07		mg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
Dichloromethane	0.005		mg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
Ethylbenzene	0.7		mg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
o-Dichlorobenzene	0.6		mg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
p-Dichlorobenzene	0.075		mg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
Styrene	0.1		mg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
Tetrachloroethylene	0.005		mg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0005	0.0015	
Toluene	1		mg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
trans 1,2 Dichloroethylene	0.1		mg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
Trichloroethylene	0.005		mg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
Vinyl Chloride	0.002		mg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
Xylenes	10		mg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	

Table7
City of Portland - Columbia Southshore Wellfield
Historical Water Quality

	Drinking Water Standards				City of Portland - Well Field																			
Parameter	MCL Primary	Secondary	Units	Groundwater Pump Station 8/1/00	Well No. 1 3/27/00	Well No.2 3/27/00	Well No.3 3/27/00	Well No.4 3/27/00	Well No.5 3/27/00	Well No.6 3/27/00	Well No. 7 3/27/00	Well No. 8 3/27/00	Well No.9 3/27/00	Well No. 10 3/27/00	Well No.11 3/27/00	Well No.12 3/27/00	Well No.13 3/27/00	Well No.14 3/27/00	Well No.15 3/27/00	Well No.16 3/27/00	Well No. 18 3/27/00	Well No. 19 3/27/00	Park Rose 3/27/00	Groundwater Pump Station 12/2/99
VOC's Unregulated																								
1,1 Dichloroethane			mg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
1,1 Dichloropropene			mg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
1,1,1,2 Tetrachloroethane			mg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
1,1 2 2, Tetrachloroethane			mg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
1 2 3 Trichloropropane			mg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
1 3 Dichloropropane			mg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
2 2 Dichloropropane			mg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
2 Butanone (MEK)			mg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
4 - Methyl 2- Pentanone (MIBK)			mg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
Bromobenzene			mg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
Bromodichloromethane			mg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
Bromoform			mg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
Bromomethane			mg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
Chloroethane			mg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
Chloroform			mg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.001	
Chloromethane			mg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
cis 1,2,3 Dichloropropene			mg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
Dibromomethane			mg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
Dibromochloromethane			mg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
m-Dichlorobenzene			mg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
Di isopropyl ether			mg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
o-Chlorotoluene			mg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
p-Chlorotoluene			mg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
Bromochloromethane			mg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
n Butylbenzene			mg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
Dichlorodifluoromethane			mg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
Fluorotrichloromethane			mg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND		
Hexachlorobutadiene			mg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND		
Isopropylbenzene			mg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND		
p-Isopropyltoluene			mg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND		
Methyl Tert butyl ether (MTBE)			mg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND		
Napthalen			mg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND		
n Propylbenzene			mg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND		
sec-Butylbenzene			mg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND		
tert Butylbenzene			mg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND		
tert-amyl Methyl Ether			mg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND		
tert Butyl Ethyl Ether			mg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND		
Trichlorotrifluoroethane (Freon)			mg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND		
trans 1,3 Dichloropropene			mg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND		
1 2 3 Trichlorobenzene			mg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND		
1 2 4 Trimethylbenzene			mg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND		
1 3 5 Trimethylbenzene			mg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND		
SOCs Regulated																								
2,4 D	0.07		mg/L	ND																				
2 4 5 TP	0.05		mg/L	ND																				
Alachlor	0.002		mg/L	ND																				
Atrazine	0.003		mg/L	ND																				
Benzo(a)pyrene	0.0002		mg/L	ND																				
Carbofuran	0.04		mg/L	ND																				
Chlordane	0.002		mg/L	ND																				
Dalapon	0.2		mg/L	ND																				
DBCP (Dibromochloropropane)	0.0002		mg/L	ND																				
Di(2-ethylhexyl)adipate	0.4		mg/L	ND																				
Di(2-ethylhexyl)phthalate	0.006		mg/L	ND																				
Dinoseb	0.007		mg/L	ND																				
Dioxin	3 x 10 8		mg/L	ND																				
Diquat	0.02		mg/L	ND																				
EDB (Ethylene Dibromide)	0.00005		mg/L	ND																				
Endothall	0.1		mg/L	ND																				
Endrin	0.002		mg/L	ND																				
Glyphosphate	0.7		mg/L	ND																				
Heptachlor	0.0004		mg/L	ND																				
Heptachlor Epoxide	0.0002		mg/L	ND																				
Hexachlorobenzene	0.001		mg/L	ND																				
Hexachlorocyclopentadiene	0.05		mg/L	ND																				
Lindane	0.0002		mg/L	ND																				
Methoxychlor	0.04		mg/L	ND																				
Oxamyl	0.2		mg/L	ND																				
PCBs	0.0005		mg/L	ND																				
Pentachlorophenol	0.001		mg/L	ND																				
Picloram	0.5		mg/L	ND																				
Simazine	0.004		mg/L	ND																				
Toxaphene	0.003		mg/L	ND																				
Vydate			mg/L	ND																				
SOCs Unregulated																								
3 Hydroxycarbofuran			mg/L																					
Aldicarb			mg/L																					
Aldicarb Sulfone			mg/L																					
Aldicarb Sulfoxide			mg/L																					
Aldrin			mg/L																					
Butachlor			mg/L																					
Carbaryl			mg/L																					
Dicamba			mg/L																					
Dieldrin			mg/L																					
Methomyl			mg/L																					
Metolachlor			mg/L																					
Metribuzin			mg/L																					
Propachlor			mg/L																					

TT - Treatment Technique

Table 8
Joint Water Commission
Historical Water Quality

	Drinking Water Standards			JWC							
	MCL										
Parameter	Primary	Secondary	Units	8/8/00	2/22/00	12/21/99	12/8/99	1/13/99	7/15/98	7/24/97	1/15/97
Conventional Parameters											
Calcium			mg/L	6.2	8.66	6.25			8.1	7.7	6.8
Chloride		250	mg/L	10	8	8			4.7	4.6	4.7
Color		15		ND	ND	ND			ND	ND	ND
Conductivity			umhos/cm	77	100	88			120	120	110
Corrosivity			-								
Fluoride (free)	4	2	mg/L	ND	ND	ND		ND	ND	ND	ND
Magnesium			mg/L	2	2.5	2.13			2.9	2.7	2.3
MBAS (Surfactants)			mg/L	ND	ND	ND			ND		0.01
Nitrate	10		mgN/L	ND	0.8	0.7		0.42	0.21	0.22	0.4
Nitrite	1		mgN/L	ND	ND	ND		ND	ND	ND	ND
Total nitrate and nitrite	8		mgN/L								
Orthophosphate			mgN/L	ND	ND	ND			ND		ND
Odor		3	TON								
pH		6.5-8.5		7.6	7.7	7.8			7.33	7.6	7.6
Total Phosphorus			mg/L	ND	ND	ND			ND	ND	ND
Potassium			mg/L	0.4	0.5	0.6			0.6	0.6	
Silica (SiO2)			mg/L	16	20	19			14	15	15
Sodium			mg/L	11.41	13.5	13.9		14	13	13	14
Sulfate		250	mg/L	8	12	10		10	9.4	10	10
Total Alkalinity			mg/L	41	42	39			39	38	41
(TDS) Total Dissolved Solids		500	mg/L	54	83	91			64	96	72
(TS) Total Solids			mg/L	80	82	98			67	92	120
(TSS) Total Suspended Solids			mg/L	ND	ND	ND			ND	ND	ND
Total Volatile Solids			mg/L	20	27	57			ND	33	25
Total Hardness		250	mg/L-CaCO2	27	40	28			32	30	26
Total Kjeldahl Nitrogen			mg/L	ND	ND	ND			ND		ND
(TOC) Total Organic Carbon			mg/L	ND	1.5	0.7			0.6	0.5	0.9
Turbidity			NTU	0.04	0.04	0.04			0.1	0.04	
Inorganics											
Aluminum		0.05-0.2	mg/L	0.08	ND	ND			0.013	0.007	0.007
Antimony	0.006		mg/L	ND	ND	ND		ND	ND	ND	ND
Arsenic	0.05		mg/L	ND	ND	ND		ND	ND	ND	ND
Asbestos	7		MFL								
Barium	2		mg/L	ND	0.02	ND		0.004	0.004	0.0037	0.005
Beryllium			mg/L	ND	ND	ND		ND	ND	ND	ND
Cadmium	0.005		mg/L	ND	ND	ND		ND	ND	ND	ND
Chromium	0.1		mg/L	ND	ND	ND		ND	ND	ND	ND
Copper	TT	1.0	mg/L	ND	0.011	ND			0.0011	ND	0.001
Cyanide	0.2		mg/L	ND	ND	ND		ND	ND	ND	ND
Iron		0.3	mg/L	ND	ND	ND			ND	ND	ND
Lead	TT		mg/L	ND	ND	ND			ND	ND	ND
Manganese		0.05	mg/L	ND	ND	ND			0.0006	ND	ND
Mercury	0.002		mg/L	ND	ND	ND		ND	ND	ND	ND
Nickel			mg/L	ND	ND	ND		ND	ND	ND	ND
Selenium	0.05		mg/L	ND	ND	ND		ND	ND	ND	ND
Silver		0.10	mg/L	ND	ND	ND			ND	ND	ND
Thallium	0.002		mg/L	ND	ND	ND		ND	ND	ND	ND
Zinc		5	mg/L	ND	ND	ND			ND	ND	0.008
Radionuclides											
Gross Alpha	15		pCi/L					ND			
Gross Beta			pCi/L								
Radon (Rn-222)			pCi/L								
Iodine-131			pCi/L								
Strontium-90			pCi/L								
Tritium			pCi/L								
Disinfection By-Products											
Total Haloacetic Acids	0.060		mg/L								
Total Trihaolmethanes	0.08		mg/L					0.013			
VOC's Regulated											
1,1 Dicholoroethylene			mg/L					ND			
1,1,1 Trichloroethane	0.2		mg/L					ND			
1,1,2 Trichlorethane	0.005		mg/L					ND			
1,2 Dichloroethane (EDC)	0.005		mg/L					ND			
1,2 Dichlorpropane	0.005		mg/L					ND			
1,2,4 Trichlorobenzene	0.07		mg/L					ND			
Benzene	0.005		mg/L					ND			
Carbon Tetrachloride	0.005		mg/L					ND			
Chlorobenzene	0.1		mg/L					ND			
cis 1,2 Dichloroethylene	0.07		mg/L					ND			
Dichloromethane	0.005		mg/L					ND			
Ethylbenzene	0.7		mg/L					ND			
o-Dichlorobenzene	0.6		mg/L					ND			
p-Dichlorobenzene	0.075		mg/L					ND			
Styrene	0.1		mg/L					ND			
Tetrachloroethylene	0.005		mg/L					ND			
Toluene	1		mg/L					ND			
trans 1,2 Dichloroethylene	0.1		mg/L					ND			
Trichloroethylene	0.005		mg/L					ND			
Vinyl Chloride	0.002		mg/L					ND			
Xylenes	10		mg/L					ND			

Table 8
Joint Water Commission
Historical Water Quality

	Drinking Water Standards			JWC							
	MCL										
Parameter	Primary	Secondary	Units	8/8/00	2/22/00	12/21/99	12/8/99	1/13/99	7/15/98	7/24/97	1/15/97
VOC's Unregulated											
1,1 Dichloroethane			mg/L					ND			
1,1 Dichloropropene			mg/L					ND			
1,1,1,2 Tetrachloroethane			mg/L					ND			
1,1,2,2, Tetrachloroethane			mg/L					ND			
1,2,3 Trichloropropane			mg/L					ND			
1,3 Dichloropropene			mg/L					ND			
2,2 Dichloropropane			mg/L					ND			
2 Butanone (MEK)			mg/L					ND			
4 - Methyl 2- Pentanone (MIBK)			mg/L					ND			
Bromobenzene			mg/L					ND			
Bromodichloromethane			mg/L					ND			
Bromoform			mg/L					ND			
Bromomethane			mg/L					ND			
Chloroethane			mg/L					ND			
Chloroform			mg/L					0.013			
Chloromethane			mg/L					ND			
cis 1,2,3 Dichloropropene			mg/L					ND			
Dibromomethane			mg/L					ND			
Dibromochloromethane			mg/L					ND			
m-Dichlorobenzene			mg/L					ND			
Di-isopropyl ether			mg/L					ND			
o-Chlorotoluene			mg/L					ND			
p-Chlorotoluene			mg/L					ND			
Bromochloromethane			mg/L					ND			
n-Butylbenzene			mg/L					ND			
Dichlorodifluoromethane			mg/L					ND			
Fluorotrichloromethane			mg/L					ND			
Hexachlorobutadiene			mg/L					ND			
Isopropylbenzene			mg/L					ND			
p-Isopropyltoluene			mg/L					ND			
Methyl Tert-butyl ether (MTBE)			mg/L					ND			
Napthalen			mg/L					ND			
n-Propylbenzene			mg/L					ND			
sec-Butylbenzene			mg/L					ND			
tert-Butylbenzene			mg/L					ND			
tert-amyl Methyl Ether			mg/L					ND			
tert-Butyl Ethyl Ether			mg/L					ND			
Trichlorotrifluoroethane (Freon)			mg/L					ND			
trans 1,3 Dichloropropene			mg/L					ND			
1,2,3 Trichlorobenzene			mg/L					ND			
1,2,4 Trimethylbenzene			mg/L					ND			
1,3,5 Trimethylbenzene			mg/L					ND			
SOCs Regulated											
2,4 D	0.07		mg/L					ND			
2,4,5 TP	0.05		mg/L					ND			
Alachlor	0.002		mg/L				ND	ND			
Atrazine	0.003		mg/L				ND	ND			
Benzo(a)pyrene	0.0002		mg/L					ND			
Carbofuran	0.04		mg/L					ND			
Chlordane	0.002		mg/L					ND			
Dalapon	0.2		mg/L					ND			
DBCP (Dibromochloropropane)	0.0002		mg/L					ND			
Di(2-ethylhexyl)adipate	0.4		mg/L					ND			
Di(2-ethylhexyl)phthalate	0.006		mg/L					ND			
Dinoseb	0.007		mg/L					ND			
Dioxin	0.00000003		mg/L					ND			
Diquat	0.02		mg/L					ND			
EDB (Ethylene Dibromide)	0.00005		mg/L					ND			
Endothall	0.1		mg/L					ND			
Endrin	0.002		mg/L					ND			
Glyphosphate	0.7		mg/L					ND			
Heptachlor	0.0004		mg/L					ND			
Heptachlor Epoxide	0.0002		mg/L					ND			
Hexachlorobenzene	0.001		mg/L					ND			
Hexachlorocyclopentadiene	0.05		mg/L					ND			
Lindane	0.0002		mg/L					ND			
Methoxychlor	0.04		mg/L					ND			
Oxamyl	0.2		mg/L					ND			
PCBs	0.0005		mg/L					ND			
Pentachlorophenol	0.001		mg/L					ND			
Picloram	0.5		mg/L					ND			
Simazine	0.004		mg/L				ND	ND			
Toxaphene	0.003		mg/L					ND			
Vydate			mg/L					ND			
SOCs Unregulated											
3 Hydroxycarbofuran			mg/L					ND			
Aldicarb			mg/L					ND			
Aldicarb Sulfone			mg/L					ND			
Aldicarb Sulfoxide			mg/L					ND			
Aldrin			mg/L					ND			
Butachlor			mg/L				ND	ND			
Carbaryl			mg/L					ND			
Dicamba			mg/L					ND			
Dieldrin			mg/L					ND			
Methomyl			mg/L					ND			
Metolachlor			mg/L				ND	ND			
Metribuzin			mg/L				ND	ND			
Propachlor			mg/L					ND			
TT - Treatment Technique											

Appendix F

Appendix F

MONTGOMERY WATSON

MEMORANDUM

TO: Jennifer Renninger, Montgomery Watson Inc. Friday April 13th 2001

FR: Steve Moncaster

RE: FINAL VERSION Our ref: 013-1419.003

City of Tigard ASR Study – Hydrogeologic
Evaluation Technical Memorandum

Purpose and Scope

This memorandum presents results and interpretation arising from the geophysical logging and preliminary hydraulic testing of the City of (City) Tigard Well 1. The reported activities have been undertaken as part of an ASR feasibility investigation. This is being completed for the City by Montgomery Watson Inc. (MW) and Golder Associates Inc (Golder).

The purpose of the geophysical logging was to determine the following;

- The condition of the well casing;
- The geology penetrated by the well;
- Any (apparent) vertical variation in the hydraulic properties of the aquifer;
- Any related variation in water quality.

The hydraulic testing was performed in order to determine values for aquifer parameters and to identify near-well aquifer boundary conditions that may influence ASR related testing or operational activities.

Geophysical Logging

Following removal of the pump, pump column and bowls from Well 1, the Well was geophysically logged using the following suite of tools;

- CCTV;
- Caliper;
- Natural gamma;
- Formation resistivity;
- Temperature and conductivity;
- Flow logging.

With the exception of the CCTV log, the results are presented in Figures 1 to 5. A record of the CCTV log has been made using a VHS video. Golder currently retains this.

CCTV Logging

The results of the CCTV logging and a visual inspection of the recovered pump and column, indicate the following in respect of the down-hole engineering at Well 1;

1. The pump column comprises 35 no. 10 ft lengths of nominal 8 inch diameter tubing which reduces to 20 no. 10 ft lengths of nominal 4 inch diameter tubing immediately above the pump bowls;
2. At the top of the well, the column joins to a 10 ft length of nominal 8 inch diameter tubing, which is attached to the pump motor anchor plate. The base the column joins to the pump bowls and intake. A coarse wire mesh screens the intake.
3. The condition of the pump column was noted to be poor, with corrosion and encrustation evident;
4. The existing airline used to measure depth to water appeared to be damaged at the base and was noted to be in a poor condition, with corrosion and encrustation evident;
5. The 12 inch diameter permanent steel casing was perforated at approximately 50 ft below ground level, with water entering the well via the perforation at a rate estimated to be less than 1 gpm;
6. Water also appeared to be entering the well from the behind the base of the casing at a depth of approximately 71 ft below ground level.

The results therefore confirm that although serviceable, the down-hole engineering is in a generally poor condition.

Formation Logging

The results of the natural gamma, SP and formation resistivity logs indicate the presence of discontinuities in the underlying basalt (aquifer) at the following depths;

- 71 ft to 140 ft
- 170 ft to 200 ft
- 260 ft to 280 ft
- 300 ft to 330 ft
- 420 ft to 450 ft
- 490 ft to 510 ft
- 560 ft to 590 ft

A comparison between the distribution of these features and features noted on both the drillers logs and the caliper log is given in Table 1 below.

Table 1 indicates that the discontinuities are associated with a combination of water bearing features, weathered basalt and well diameter enlargement(s). As such, the discontinuities probably represent basalt interflow zones. These form at the contact between successive basalt flows and may be composed of either weathered basalt, paleo-soils, proto-sedimentary features and, where the younger basalt flowed into water, overlying deposits of highly vesicular or scoriated material. Basalt interflow zones within the Columbia River Basalt Group (CRBG) are typically associated with high permeability.

Examination of the natural gamma log shows that the bulk of the intervening strata is composed of rock which is variously described as black, gray and hard. With the exception of the inflows noted between 500 ft bgl and 525 ft bgl, the drillers logs show that none of this strata yielded significant inflows of water. Given the distribution and apparent low permeability of these zones, they are considered to represent basalt flow interiors.

Depth of natural gamma, SP or formation resistivity discontinuity (ft bgl)	Well Diameter[1] (inches)	Notes from Drillers Log (ft bgl)
60 - 140	13 – 17	Grey and green lava rock (64-84) Black, gray, red rock medium hard (84-168)
170 - 200	13 - 19	Black and red rock medium hard (168-192)
260 -280	14 - 23	Gray porous rock with water (260-272)
300 - 330	13 - 23	Red rock not so hard (309-315) Yellow and gray soft rock showing water (315-325)
420 - 450	13 - 23	Rock, red (410-426) Clay, brown (426-449)
490 - 510	12 - 23	Rock, red (496-500) Rock, black Cuttings washed away, water bearing (500-525)
560 - 590	12 - 14	Rock, brownish red, soft (562-579) Rock, red soft, coarse water bearing (579-597)
[1] Nominal diameter of Well 13 inches ft bgl – feet below ground level		

Table 1. Formation Log Data

The CCTV log shows that strata within both the interflow zones and flow interiors are heavily fractured. The fractures are both vertically and horizontally orientated.

Fluid Logging

The temperature-conductivity log shows evidence of minor changes in water quality at the following depths below ground level;

- 270 ft – 280 ft (temperature and conductivity)
- 330 ft (conductivity)
- 350 ft to 370 ft (temperature)
- 500 ft (temperature)
- 520 ft to 540 ft (temperature)
- 580 ft (temperature and conductivity)

Typically such changes are associated with the location of flow zones in the formation penetrated by the well.

A comparison of the temperature-conductivity log with interpretation of the heat pulse log shows that the location of these features corresponds to depths in the well where the flows were accentuated. This confirms that flow in the basalt occurs within a series of discrete zones. Comparison to Table 1 indicates that these are primarily associated with the interflow zones.

Further examination of the heat pulse log shows that downward flows predominate between 250 ft bgl and 400 ft bgl while a mixture of upward and downward flows occur between 400 ft bgl and the base of the well. This distribution suggests that the lower flow zones within the basalt are recharged by downward flow from the overlying upper flow zones.

Well Testing

Well Performance Test

To determine the baseline hydraulic performance of the Well, a stepped rate pumping test was performed. The test was conducted on 4/3/01 and involved pumping the well at a series of successively greater rates while monitoring the associated water level response. The test data was interpreted using the methodology described in Kruseman and de Ridder (1991).

The pump used for the testing was the existing turbine line shaft production pump. The flow from this was controlled by making adjustments to a control valve located on the distribution pipe-work at the wellhead (CLA-valve). The range of flows permitted by adjustment of the valve varied from 280 gpm to 360 gpm. The water levels were measured using a newly installed water level measurement airline and the existing pressure gauge. This was considered to be accurate to within +/- 1 psi. The water produced during the testing was discharged to Fanno Creek, via an on-site retention basin and associated below ground pipe-work.

The results of the test are presented in Figure 6, the interpretation in Figure 7. Figure 6 shows that the well was pumped at rates of 282 gpm, 309 gpm and 359 gpm. The figure also shows that the duration of each step was 60 minutes and that the resulting drawdowns stabilized at 58 ft bgl, 69 ft bgl and 75 ft bgl respectively. Interpretation of the results gives the following;

$s = (0.17)Q + (0.0001)Q^2$

From:

$s = BQ + CQ^2$

Where:

s = drawdown for production rate Q (ft)
Q = production rate (gpm)
B = Linear well loss coefficient
C = Non linear well loss coefficient

It should be noted that the reported performance is specific to the time-scale over which the measurements were taken and that long term performance may be different, both as a consequence of the extra drawdown which results from pumping over extended periods and the influence of any local boundary conditions. Despite this, it appears that the current yield is limited by the pumping capacity installed in the well and that greater yields are likely to be available from the basalt beneath the site.

Aquifer Performance Test

Following the stepped rate test, the water level in the well was allowed to recover overnight. An extended (6 day) constant rate test was then performed. This began Saturday 31st March and was completed Friday 6th April.

The test equipment and arrangements used for the constant rate test were the same as those described above for the stepped rate test. In addition, the water level response in two adjacent observation wells were also monitored (Tigard High School and City of Tigard Well 2). The pumping rate used for the test averaged 310 gpm.

The water level responses in the production and Tigard High School observation well are given in Figures 8 and 9. The City Well No. 2 did not respond to the testing and as such no data is presented.

From Figure 7 it can be seen that there are three components to the drawdown response curve for the production well. These include the following;

1. 1 min. to 1000 mins. – well bore storage and delayed yield response (denoted by initial steep rate of drawdown and subsequent near stabilization*)
2. 1000 mins. to 3500 mins. - confined aquifer response (denoted by constant rate of drawdown)
3. 3500 mins. to end of test - constant head boundary response (denoted by stabilization)

* stabilization – horizontal trend line

The well bore storage effects are evident as the initial rapid rate of water level decline. This type of behavior reflects the removal of water from the well under circumstances in which there is little or no yield from the adjacent aquifer. Well bore storage effects are not a significant influence on the operation of the well and, as such, are not considered further.

Delayed yield is typically produced under conditions in which the pumped water derives from a combination of horizontal flow to the well and vertical flow through overlying leaky confining units. At the site, this response could be accounted for by the locally unconfined nature of the basalt and the resulting interaction between flow from the deep interflow zones and vertical drainage from either overlying sub-aquifer units or the water table. Sub-vertical flow could occur either via the well or through networks of sub-vertical fractures in the adjacent basalt. It is noted that the presence of such fractures was identified on the CCTV log.

The following period of confined aquifer response reflects conditions in which the effects of vertical drainage diminish and the hydraulic properties of the deep interflow zones predominate. Interpretation of the data from this portion of the curve, using the modified Cooper-Jacob approximation, indicates that the transmissivity of the confined basalt is approximately 6500 gpd/ft.

The constant head boundary that is evident in the late time test data is representative of conditions in which water is being supplied to the aquifer at the same rate as it is being withdrawn. In the vicinity of the test site, this condition may reflect some combination of the following

- zones of high transmissivity, associated with the faulting evident to the south and west of the site, that may connect the basalt in the vicinity of the well to a much larger region of the surrounding basalt aquifer;
- the production of water from sands and other permeable sediments that occupy the fault-bounded paleochannel that lies beneath the present day course of the Tualatin River;
- Interception of water table conditions beneath Bull Mountain, to the west of the site;
- A second period of delayed yield, reflecting additional drainage of the upper basalt flow zones during the latter stages of the test.

Further testing is required to determine the relative significance of these potential sources of recharge.

Although no estimate of the aquifer storage properties is possible from the production well test data, the delayed yield response indicates that storage in the near vicinity of the well is likely to be a function of the effective porosity of the basalt. As such, the specific yield of the basalt in this region may be as much as 0.05.

In theory, the storage characteristics of the deep confined basalt can be estimated from the Tigard High School data. However, the limited draw down response seen at this well indicates that the aquifer in this area is likely to have been influenced by the same constant head boundary condition that produced the late time stabilization in the production well data. As such, there is some uncertainty with respect to the validity of the 1.1E-05 storativity value estimated from the High School test data.

Summary

The geophysical logging and well testing that have been performed at the site confirm the following in respect of the underlying basalt aquifer;

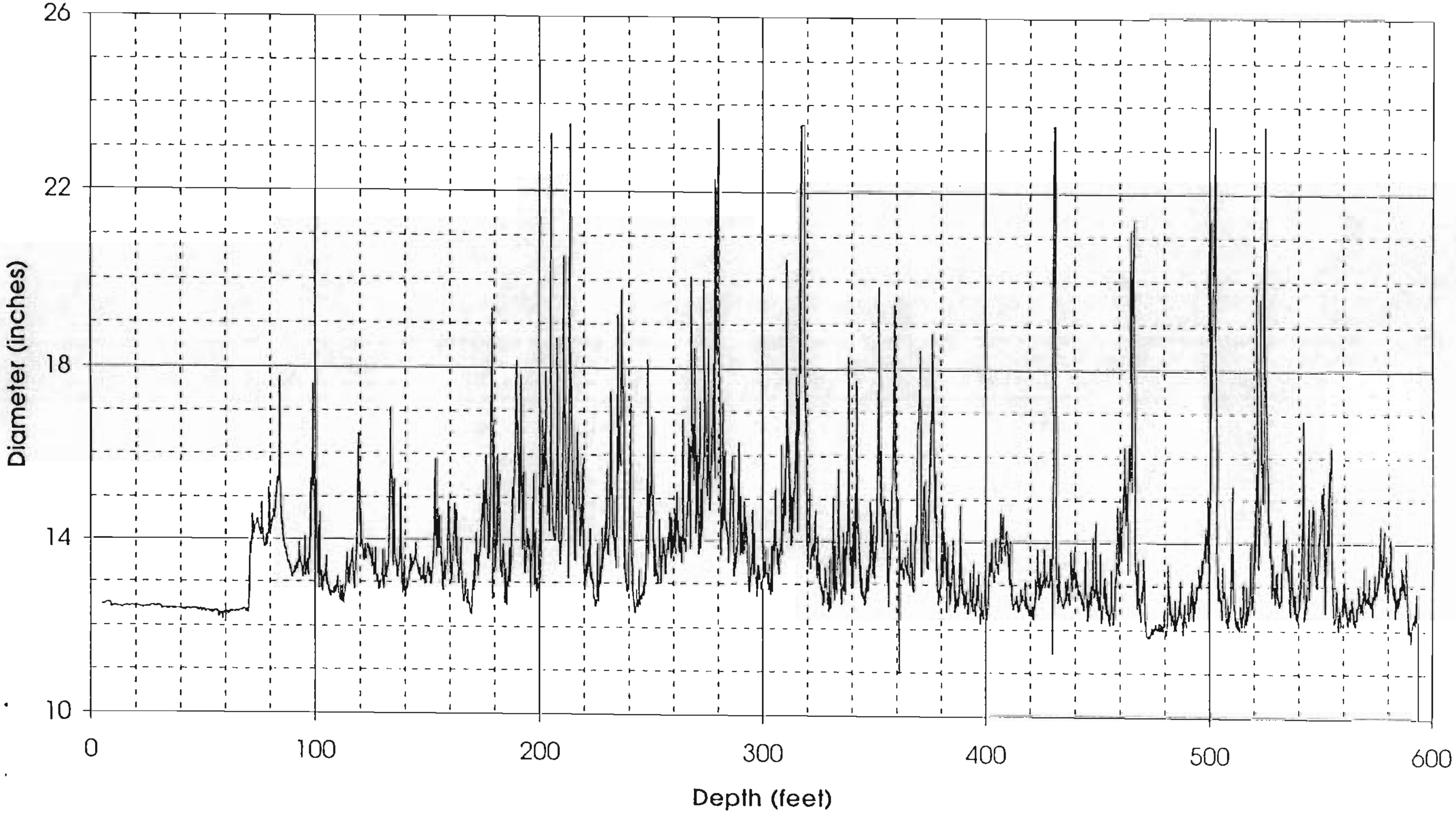
1. The aquifer comprises a series of sub-units that, in the near vicinity of the well, appear to be linked as a consequence of networks of sub-vertical fractures;
2. In the vicinity of the well the basalt is unconfined, with a depth to water (unsaturated zone) of 250 ft and a specific yield that is likely to be equivalent to the effective porosity (of the order of 0.05);
3. In areas distant from the well, the basalt is confined with a transmissivity of the order of 6500 gpd/ft and a storativity which is likely to be of the order of 1.1E-05 or greater;
4. The region of the basalt penetrated by the well is bounded by high permeability features;
5. To the south, these may reflect the effects of faulting or permeable paleo-channel deposits;
6. To the west, these may reflect water table conditions beneath Bull Mountain or the effects of faulting.

It is also noted that the current yield appears to be limited by the pumping capacity installed in the well. As such, it is considered likely that greater yields can be sustained from the basalt beneath the site.

References

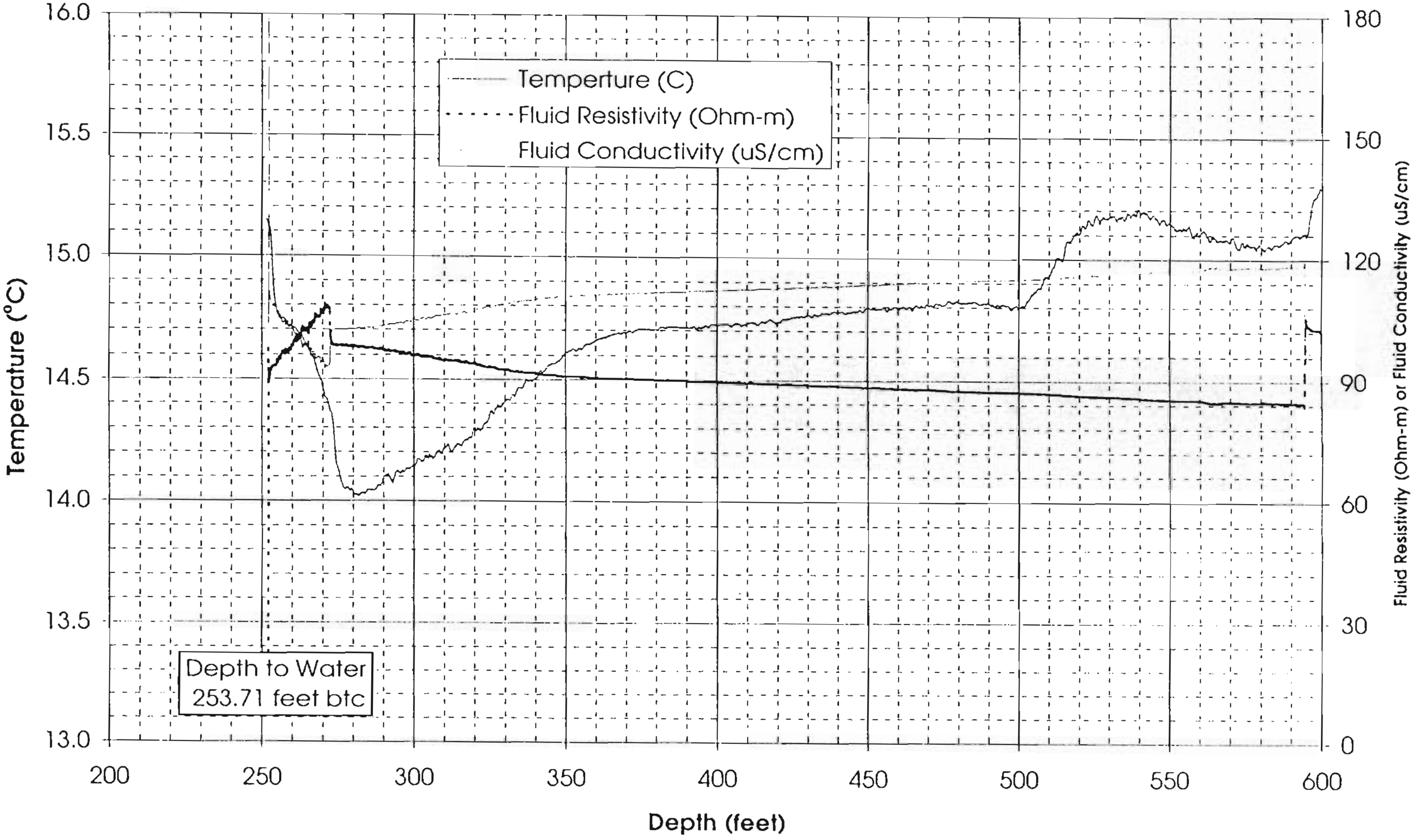
Kruseman, G.P. and de Ridder, N.A. (1991) “Analysis and Evaluation of Pumping Test Data” International Institute for Land Reclamation and Improvement Publication 47, The Netherlands.

Figure 1. City of Tigard Well No. 1
Caliper Log



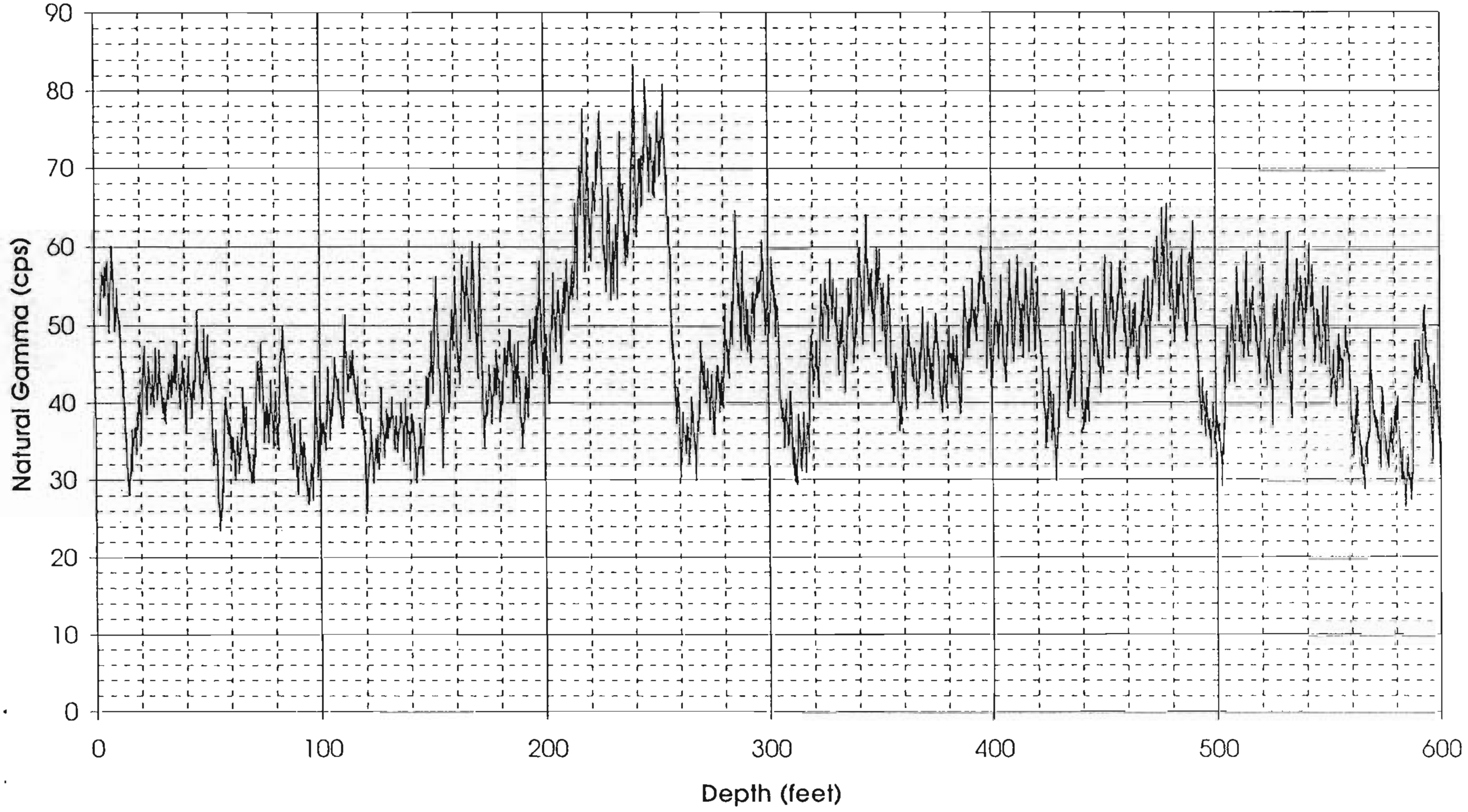
well 1 caliper.xls

Figure 2. City of Tigard Well No. 1
Fluid Logs



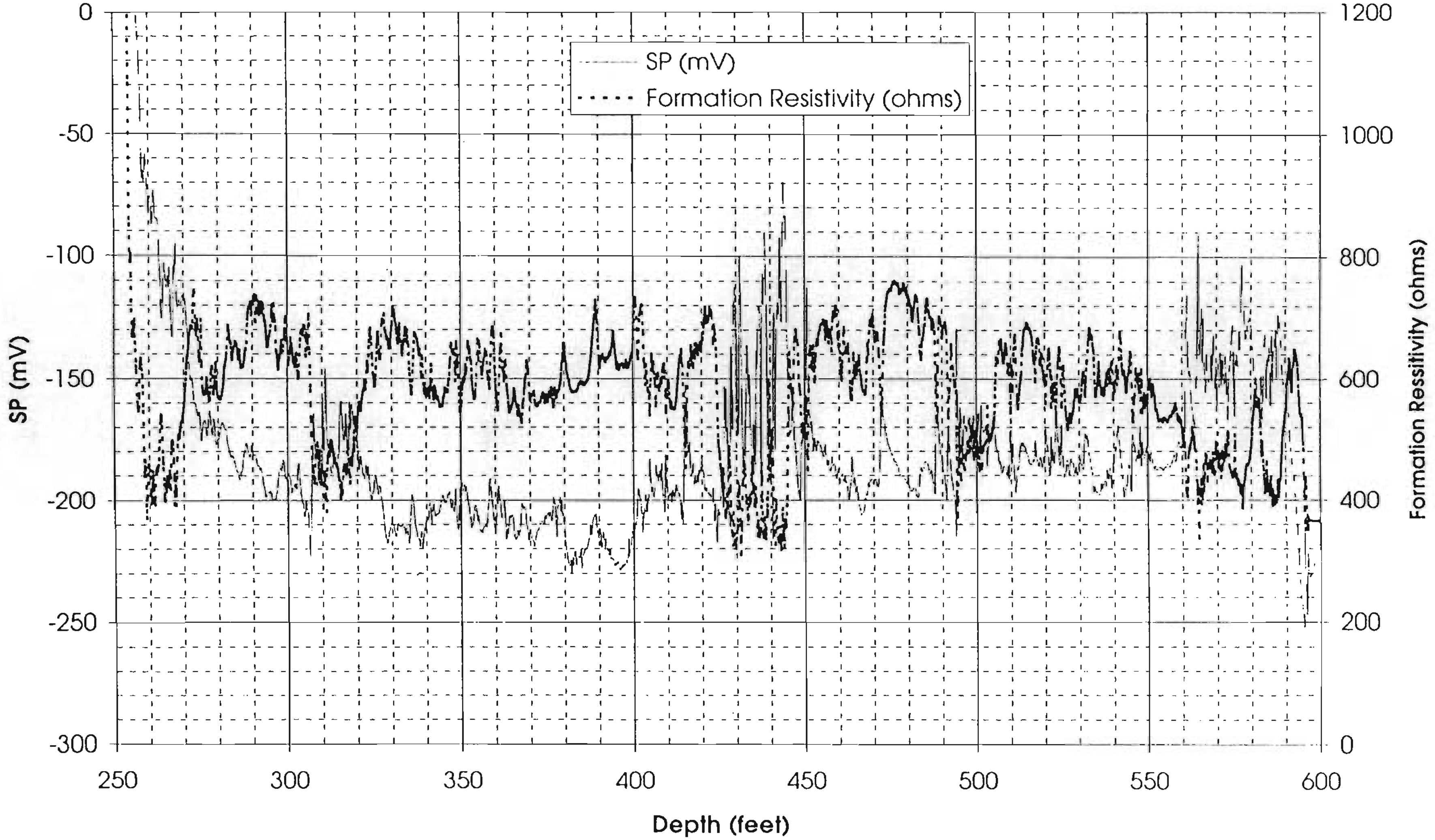
well 1 fluid logs.xls

Figure 3 City of Tigard Well No. 1
Natural Gamma Log (Moving Average of 20 Readings)



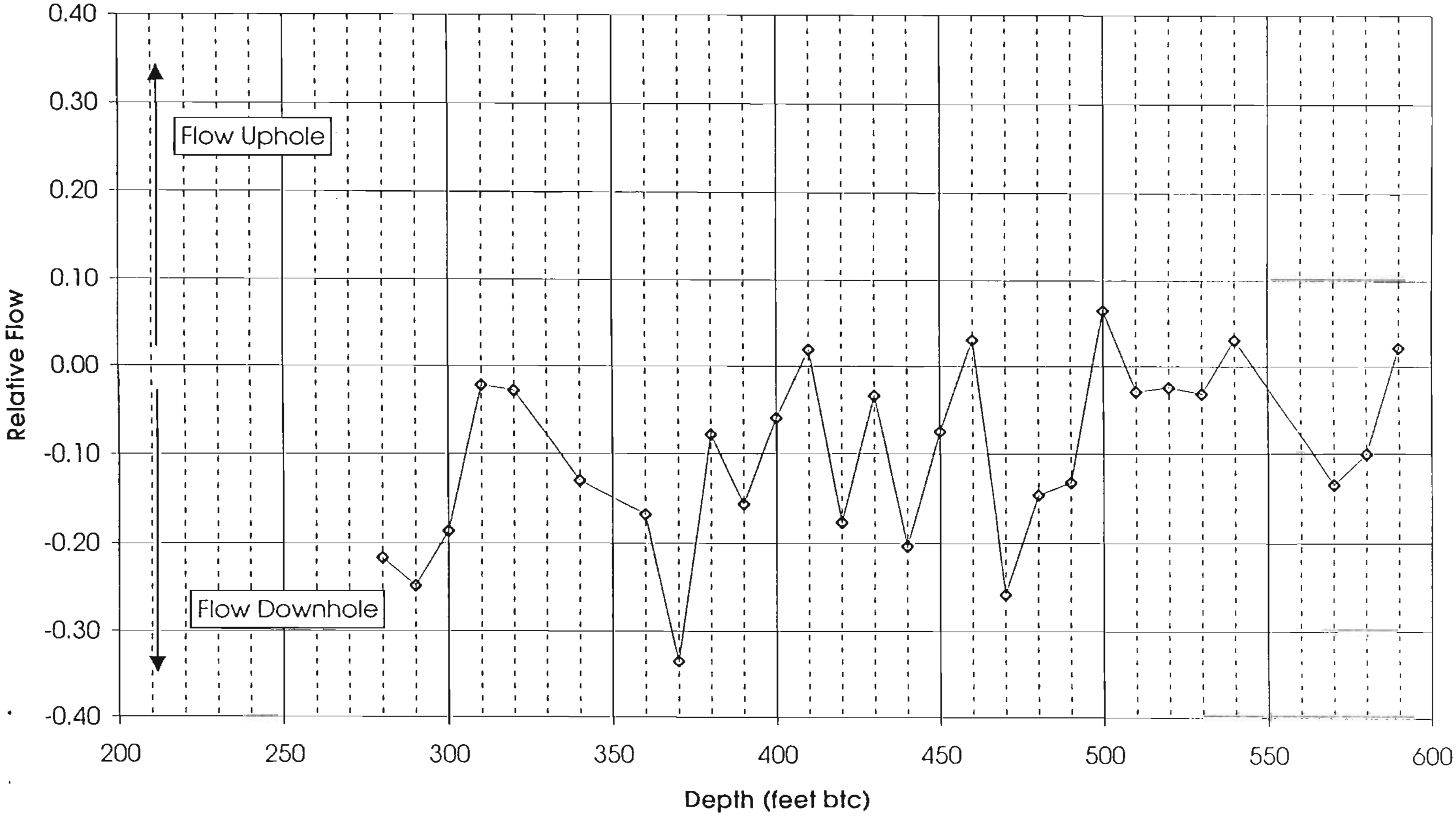
well 1 gamma log.xls

Figure 4. City of Tigard Well No. 1
SP and Formation Resistivity Logs

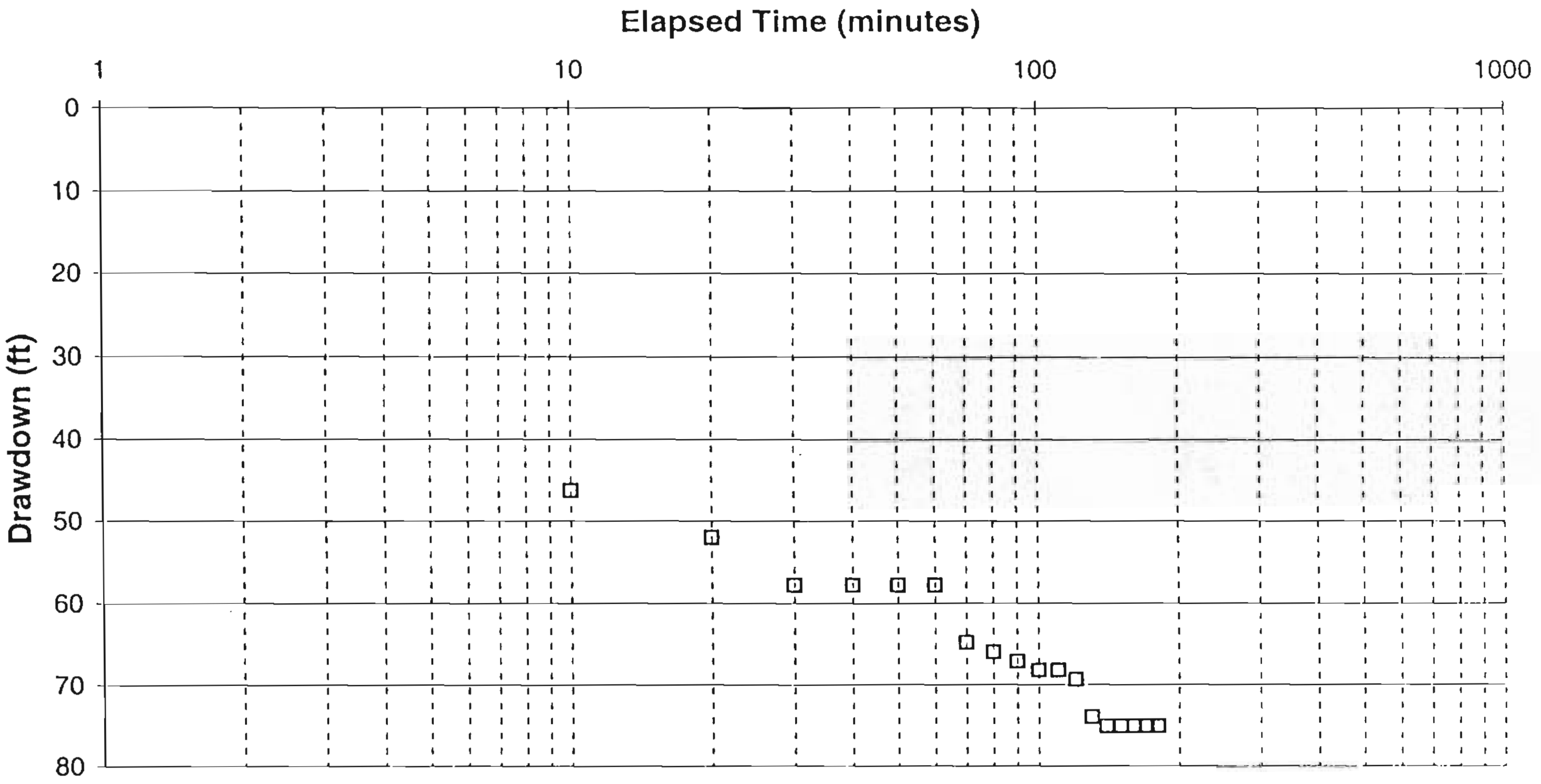


well 1 res-sp.xls

Figure 5. City of Tigard Well No. 1
Heat Pulse Interpretation Log



well 1 heat pulse log01.xls



City of Tigard Well No. 1 Well Test

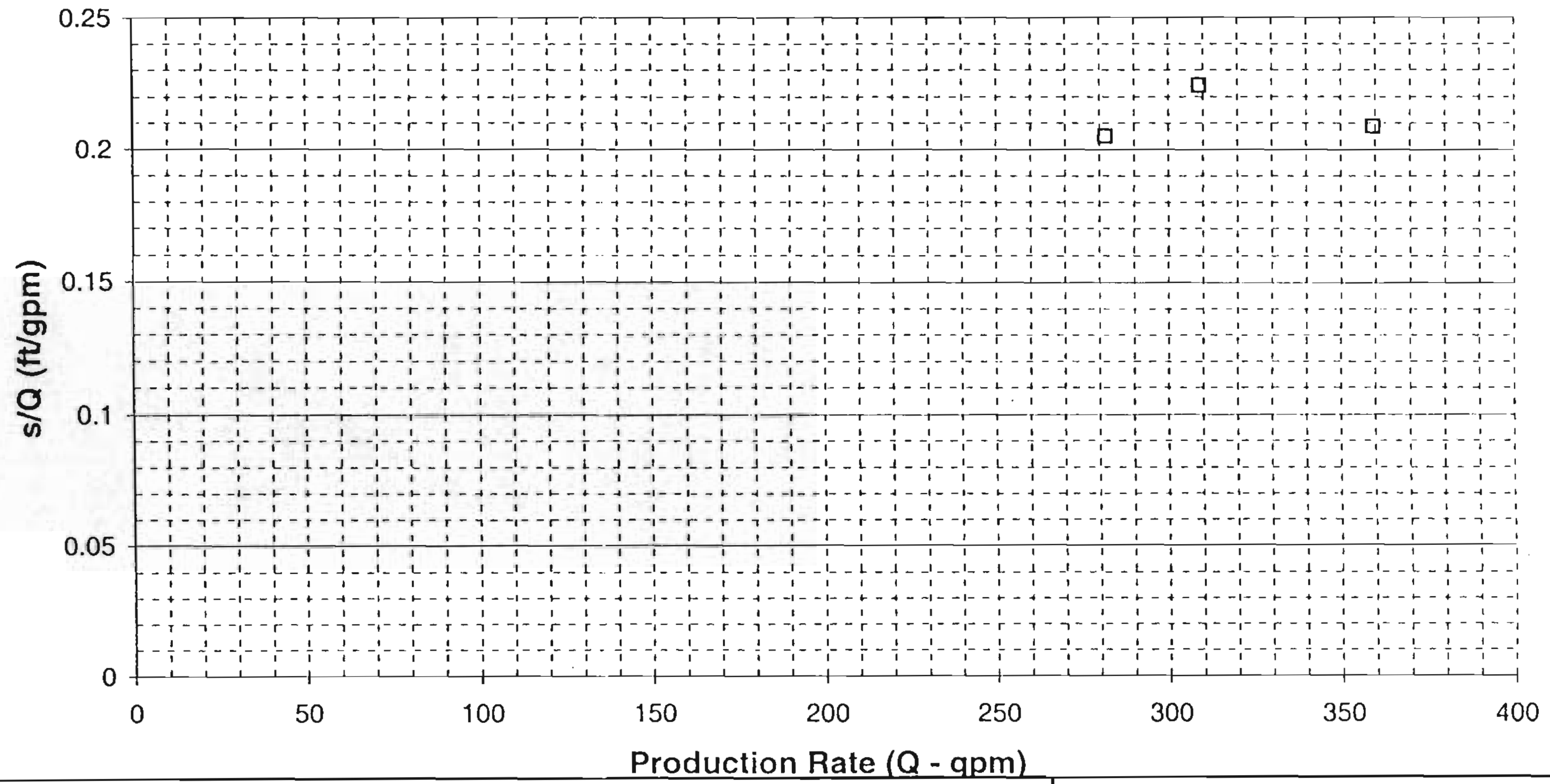
Production Rates 282 gpm, 309 gpm and 359 gpm
Test conducted 3/30/2001

013-1419,04/04/2001, Data Plot02.xls

FIGURE 6: Stepped Rate Test Data

Montgomery Watson
City of Tigard ASR

Golder Associates



City of Tigard Well No. 1 Well Test

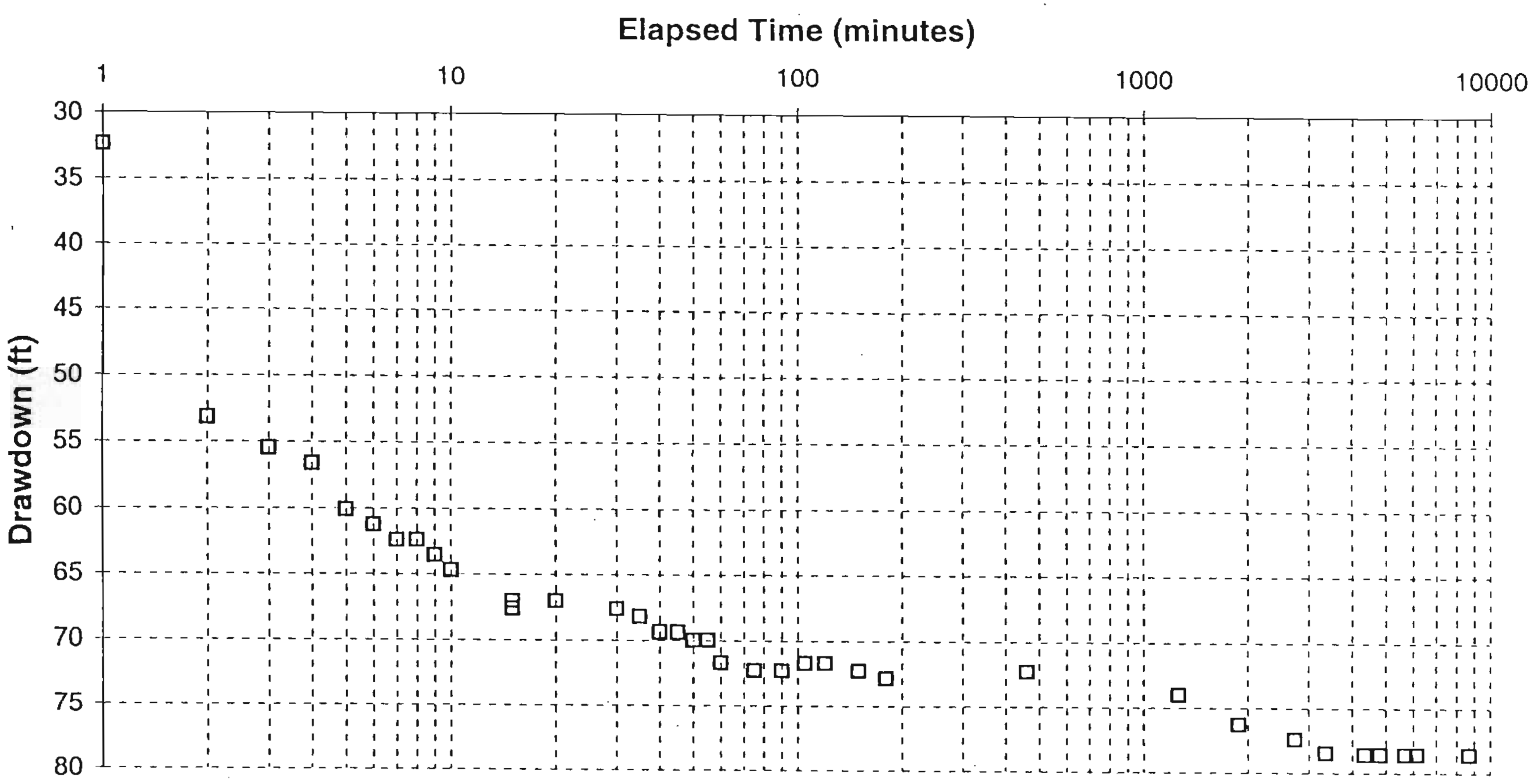
Production Rates 282 gpm, 309 gpm and 359 gpm
Test conducted 3/30/2001

013-1419, 04/04/2001, Data Plot04.xls

FIGURE 7: Test Data Interpretation

Montgomery Watsor
City of Tigard ASR

Golder Associates



City of Tigard Well No. 1 Aquifer Test

Average Production Rate 310 gpm

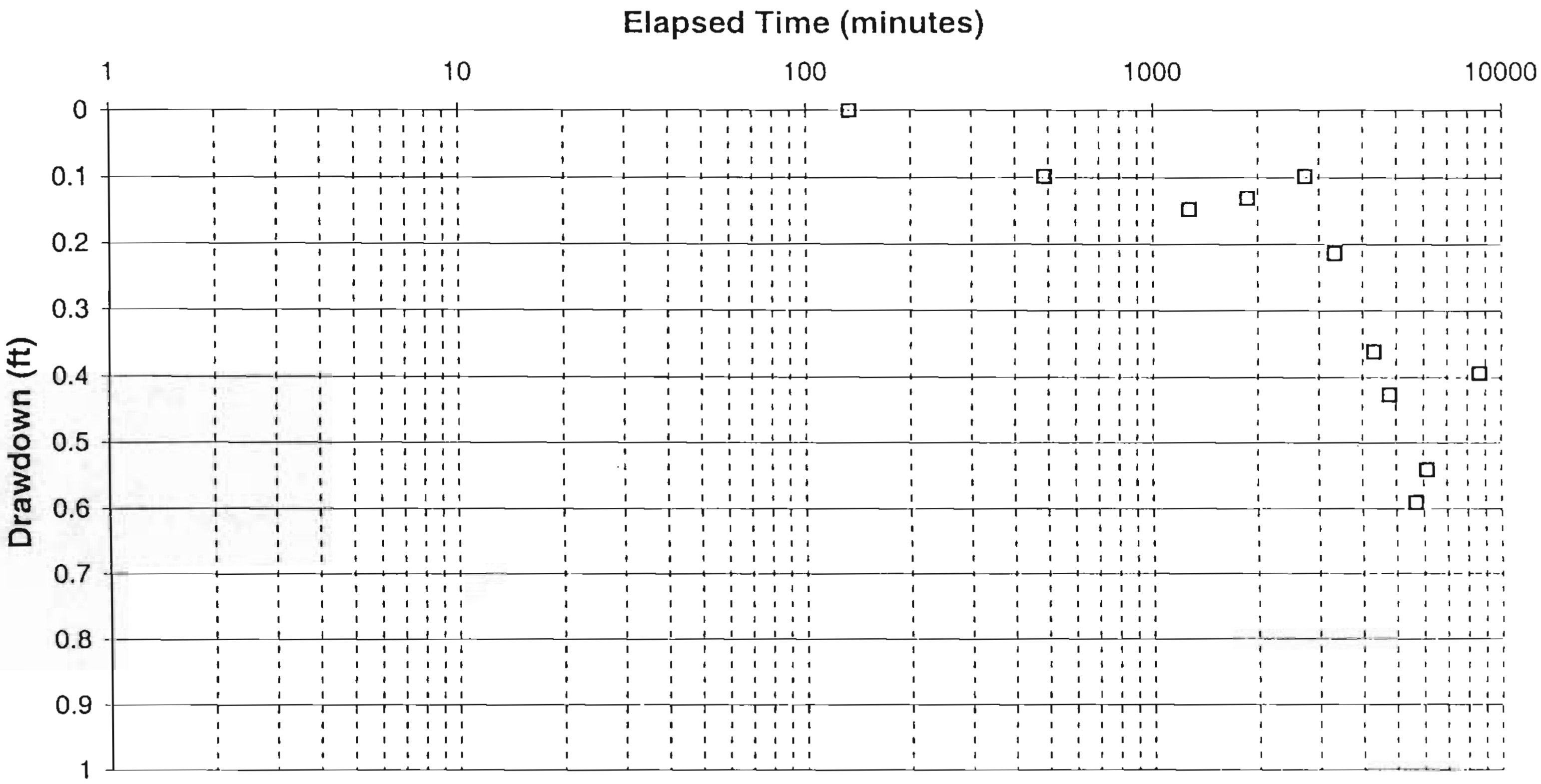
Test conducted from 3/31/2001 to 4/6/2001

013-1419, 04/04/2001, Data Plot01.xls

FIGURE 8: Constant Rate Test Data

Montgomery Watson
City of Tigard ASR

Golder Associates



City of Tigard Well No. 1 Aquifer Test

Average Production Rate 310 gpm

Test conducted from 3/31/2001 to 4/6/2001

013-1419,04/04/2001, Data Plot03.xls

FIGURE 9: Tigard High School Data

Montgomery Watson
City of Tigard ASR

Golder Associates

Appendix G

Appendix G

MONTGOMERY WATSON

MEMORANDUM

TO: Joe Glicker And Jennifer Renninger - Montgomery Watson April 13, 2001

FR: Cheryl Ross, Steve Moncaster And David Banton - Golder Associates

RE: FINAL MEMORANDUM 013-1419.004

TIGARD ASR GEOCHEMICAL EVALUATION

INTRODUCTION

The Tigard Aquifer Storage and Recovery (ASR) program proposes to store treated surface water in the ground during periods of low demand. Currently, the proposed recharge well is the City Well No. 1 (COT-1). The three potential suppliers of recharge water are: Lake Oswego (LO), the City of Portland (COP) and the Joint Water Commission (JWC).

This memorandum presents the results of geochemical modeling conducted to evaluate geochemical reactions that may occur during recharge of surface water to the COT-1 Well. Mixing of recharge water and groundwater may result in mineral precipitation reactions. Minerals that typically precipitate during mixing of well oxygenated surface water with less oxidized groundwater include carbonates and iron, aluminum and manganese oxides and hydroxides. Mineral precipitation is generally regarded as a problem during ASR projects due to the potential for clogging of the well screen and formation. Because the COT-1 Well is an open hole well completed in fractured basalt, the potential for clogging due to mineral precipitation is expected to be low. Mineral precipitation reactions are however still of interest due to their effects on water quality. Changes in water quality may also result from mineral dissolution following interaction of the injected water and the basalt.

Historical recharge and groundwater quality was previously presented by Montgomery Watson (2001). This document provides a brief characterization of both recharge water and groundwater and presents the results of geochemical modeling.

GROUNDWATER WATER QUALITY

The COT-1 Well is a 610-foot basalt well cased to a depth of 71 feet. Historical water quality data are presented in Table 1. The most recent sampling of COT-1 was conducted by Montgomery Watson on February 7, 2001 during a pumping test.

The February 7, 2001 sampling indicates that COT-1 water is near neutral in pH and has a total dissolved solids concentration (TDS) of 180 mg/L. The redox potential (Eh) of COT-1 groundwater was 183 mV, indicating mildly oxidizing conditions. Mildly oxidizing conditions are supported by the absence of iron and manganese (both Fe and Mn were below detectable limits) and the presence of dissolved oxygen (7 mg/L).

Although nitrate analysis was not conducted on the February 7, 2001 sample, historical nitrate concentrations are typically on the order of 1 mg/L. The presence of nitrate is consistent with oxidizing conditions.

Over the period of record, iron concentrations in COT-1 have declined. Iron concentrations for the three sampling events between 1949 and 1983 ranged from 0.03 mg/L (4/5/66) to 0.22 mg/L (6/1/83). During the two sampling events in 2000 and 2001, iron was below detectable limits. On the last sampling event, the detection limit for iron was 0.1 mg/L. A possible decline in iron concentrations may be the result of a decline in water levels. Between 1947 and 2001, the static water level in the COT-1 Well declined 65 feet (from 188 feet to 253 feet). It is possible that the source of iron in groundwater samples collected prior to 1983 was the shallow sediments, which are now part of the unsaturated zone. Because recharge to the COT-1 well may result in a rise in groundwater levels in the area immediately surrounding the well, a potential shallow source of iron is relevant. Geophysical logging of the COT-1 Well by a Golder Hydrogeologist in 2001 identified regions of high groundwater flow in both the shallow (280 feet) and deep (>500 feet) sections of the well.

INJECTION WATER QUALITY

Three water suppliers are being considered as source water for the Tigard ASR Project: Lake Oswego (LO), the City of Portland (COP) and the Joint Water Commission (JWC). Lake Oswego and the Joint Water Commission have river water sources, the Clackamas River (LO) and the Trask and Tualatin Rivers (JWC), respectively. Both LO and the COP filter their river water prior to distribution. The City of Portland's primary source of water is the Bull Run Watershed.

Historical water quality data (1996 to 2001) for the three potential recharge waters are presented in Table 2. Complete inorganic analyses are available for both the JWC and COP waters. Complete major ion chemistry is not available for Lake Oswego. Both calcium and magnesium are missing from historical analysis. Lake Oswego water was therefore not included in geochemical mixing modeling.

All three source waters exhibit near neutral pH. Major ion concentrations in JWC water are generally higher than those in COP. This difference is illustrated by comparison of the most recent total dissolved solids concentrations (TDS) for JWC and COP, 54 mg/L (8/8/00) and 20 mg/L (3/27/00), respectively. Stiff Diagrams for the two source waters (Figure 1) also clearly illustrate this difference. A Stiff Diagram for COT-1 groundwater is included for comparison. The relative concentrations of major ions in COP, COT-1 and JWC are illustrated in Figure 2. This diagram shows that groundwater is more calcium and bicarbonate rich than the surface water. Relative cation concentrations for the two surface waters are similar. It is notable that for both the Piper and Stiff diagram, a sulfate concentration of 10 mg/L for COP was assumed. The reason for this assumption is explained in the geochemical modeling section of this document.

Dissolved oxygen data is not available for the three recharge waters. However, because these waters are in contact with atmospheric oxygen they should contain oxygen. Both manganese and iron are presently below detectable limits in JWC. The most recent sampling of COP water indicated manganese below detectable limits and iron at a concentration of 0.066 mg/L. Nitrate is typically present in both waters. Average nitrate concentrations for COP and JWC waters are 0.02 mg/L and 0.5 mg/L, respectively.

GEOCHEMICAL MODELING

During recharge, treated drinking water injected into the basalt aquifer will displace native groundwater in the area surrounding the COT-1 well. Advection and dispersion will result in some mixing of recharge water and groundwater as the recharge water flows through the aquifer. To evaluate the geochemical effects of this interaction between surface water and groundwater, mixing modeling was conducted using PHREEQC Version 2.3.1 (Parkhurst and Appelo, 1999) and the Minteqa2 database. The potential for both secondary mineral precipitation and mineral dissolution were evaluated.

PHREEQC is an equilibrium mass transfer code developed by the United States Geological Survey (USGS). It is widely accepted by the regulatory and scientific community. PHREEQC was used to calculate the aqueous speciation and stability of minerals with respect to dissolved constituents following mixing. The potential for mineral precipitation was assessed using the saturation index (SI) calculated according to Equation 1.

$$SI = \log \frac{IAP}{K_{sp}} \tag{1}$$

The saturation index is the ratio of the ion activity product (IAP) of a mineral and the solubility product (K_{sp}). An SI greater than zero indicates that the water is supersaturated with respect to a particular mineral phase and therefore mineral precipitation may occur. An evaluation of precipitation kinetics is then required to evaluate the likelihood that a supersaturated mineral will indeed form. An SI less than zero denotes undersaturation, and that the mineral in question will have a general propensity to dissolve. Mineral stability was evaluated for a limited number of geochemically-credible phases that are known to precipitate/dissolve relatively easily under surficial conditions.

Model simulations were conducted in which recharge water was mixed with native groundwater (COT-1) in 10% increments. Simulations were conducted using both COP and JWC recharge water. Mixing simulation conditions ranged from a groundwater dominated system (90% groundwater : 10% recharge water) to a recharge water dominated system (10% groundwater : 90% recharge water). The simulation of a range of mixing ratios was intended to bracket conditions that may occur throughout the aquifer. The greatest mixing of recharge water and groundwater is expected to occur during the early stages of injection when recharge water displaces groundwater. As injected water occupies a greater aquifer volume around the well, interaction of recharge and groundwater will likely be limited to the periphery of the recharge water under quasi steady state conditions.

Speciation Modeling

The first step in geochemical modeling was to speciate and charge balance each water chemistry. For each water type (COT-1, COP and JWC) the most recent complete chemical analysis was used in model simulations. A summary of the chemistry data used in model simulations is provided in Table 3. As shown in Table 3, only constituents with detectable concentrations were included.

Charge balance errors for the three water chemistries were 46% (COP), 13% (JWC) and 7% (COT-1). A charge balance error less than 5% is generally accepted as indicative of a good analysis (Hounslow, 1995). The charge balance error for COP is particularly poor. Although organic constituents may account for some of this error (total organic carbon = 1.1 mg/L), they likely cannot account for such a large discrepancy. Consideration was given to using the results from the August 2, 1999 sampling date in model simulations; however, incomplete major ion data for this date (Na and K) prevented its use. Both the COP and JWC waters were anion deficient. Sulfate was therefore added to these waters to achieve electroneutrality. For the COP water, 10 mg/L of sulfate was added. Sulfate was below detectable limits in COP water at a detection limit of 0.5 mg/L. Addition of 10-mg/L sulfate therefore represents a significant input; however, sulfate addition did not effect the model results with respect to predictions regarding mineral precipitation and dissolution. Potassium was added to JWC to achieve electroneutrality.

Injection Water (COP and JWC)

For recharge water (COP and JWC), an initial Eh of 900 mV was assumed. This Eh is representative of near neutral pH waters in contact with the atmosphere (Appelo and Postma, 1994). COP and JWC were equilibrated with atmospheric oxygen at a partial pressure of 0.2 atmospheres resulting in dissolved oxygen concentrations of approximately 6 mg/L.

Saturation indices for select minerals are presented in Table 4. For carbon dioxide, the partial pressure of the gas is provided. The COP water is at equilibrium with respect to gibbsite (amorphous) and supersaturated with respect to ferrihydrite. Both waters are near equilibrium with carbon dioxide at atmospheric pressure ($10^{-3.5}$ atm), as would be expected.

Groundwater (COT-1)

The redox condition of the groundwater was initially assumed to be equal to the measured value (183 mV). Based on the oxygen concentration in the groundwater, an Eh of 850 mV was calculated by PHREEQC. This Eh is considered high for a groundwater system (Appelo and Postma, 1994). Because inclusion of dissolved oxygen resulted in Eh adjustments by PHREEQC to values above what typical groundwaters exhibit, dissolved oxygen was omitted from the initial groundwater chemistry. It is possible that field measured dissolved oxygen values may overestimate groundwater dissolved oxygen concentrations due to atmospheric contact during sampling. It is likely that the groundwater does contain dissolved oxygen, although perhaps at lower concentrations. Omission of oxygen from the groundwater chemistry did not result in any significant changes to the final mixture chemistry with respect to potential mineral precipitation and dissolution reactions.

Saturation indices for COT-1 are provided in Table 4. Groundwater is at equilibrium with respect to amorphous silica (SI = -0.12). Silica [SiO2] accounts for greater than 50% of the total oxide composition of the basalt. Although quartz has extremely sluggish reaction kinetics, amorphous silica is less stable and may control groundwater silicon concentrations (Appelo and Postma, 1994). Amorphous silica was therefore included as an equilibrium phase during mixing modeling scenarios. As such, amorphous silica was present and allowed to dissolve to maintain equilibrium (SI=0).

Both iron (<0.1 mg/L) and manganese (<2 µg/L) were below detectable limits in COT-1 on February 7, 2001. The iron detection limit is considered high with respect to evaluation of mineral precipitation reactions. Because oxidation of iron and manganese resulting in mineral precipitation is common during recharge of oxygenated surface water into less oxygenated groundwater, a simulation was conducted in which both iron and manganese were present at a concentration equal to the detection limit. At an Eh of 183 mV, ferrihydrite [$Fe(OH)_3$] and manganite [MnOOH] were both undersaturated with SIs of −0.7 and −9.5, respectively.

Mixing Modeling

As outlined earlier, to simulate the range of geochemical conditions expected to occur throughout the aquifer, recharge water was mixed with groundwater in 10% increments. Due to the similarities in pH and redox conditions of the groundwater and recharge (both COP and JWC) waters, mixing of these waters did not result in significant mineral precipitation. The minerals listed in Table 4 that were initially undersaturated, remained undersaturated following mixing. Ferrihydrite, which was initially supersaturated in the COP water, remained supersaturated following mixing. Ferrihydrite precipitation may therefore occur in the aquifer if it does not occur prior to injection.

Mixing of COP and JWC with COT-1 water containing iron and manganese at the their respective detection limits was conducted to evaluate the potential for ferrihydrite and manganite precipitation. These simulations predicted supersaturation with respect to both minerals. Due to the low manganese concentrations (<0.0002 mg/L), if manganese precipitation should occur, it not be significant. To better evaluate the potential for iron mineral precipitation, groundwater sampling at a lower detection limit is required. Because mineral precipitation is not anticipated to be a problem in the fractured aquifer, this sampling is not warranted at this time.

For all mixing simulations, oxidizing conditions persisted. Because the groundwater does not contain significant concentrations of any reduced species (e.g. Fe^{2+}, HS^-, and $Mn2^+$), oxygen introduced into the aquifer in recharge water is not consumed by redox reactions. Without detailed mineralogic information for the aquifer, consumption of oxygen by mineral oxidation cannot be fully addressed. Iron carbonate (siderite) and iron sulfides (pyrite, marcasite) are typically the most susceptible minerals to oxidation by recharge water (Pyne, 1995). On the basis of groundwater quality for COT-1, it can be speculated that if these minerals were present in significant concentrations in the basalt and their oxidation rate was not limited by kinetic impediments, these minerals would consume the oxygen present in the groundwater.

Equilibrium with respect to amorphous silica resulted in silica dissolution during mixing. Figure 3 plots predicted silica concentrations for mixing of COP and COT-1 water. Both the concentration following pure mixing (open circles) and equilibration with amorphous silica (closed circles) are shown. Dissolution of silica results in a final silicon concentration of between 34 mg/L and 40 mg/L over the range of mixing ratios. This silicon concentration is representative of an upper limit due to the fact that the kinetics of silica dissolution may prevent complete attainment of equilibrium during the period of storage in the aquifer. Silicon is not a regulated drinking water parameter and therefore the observed range in predicted concentrations is not a concern. Mixing of JWC and COT-1 water yielded similar results.

SUMMARY

Due to the similarities in pH and redox conditions of the groundwater and recharge waters (both COP and JWC), mixing of these waters is not predicted to result in significant mineral precipitation. Throughout injection, oxidizing conditions are expected to persist in the aquifer. Dissolution of amorphous silica [SiO2] may result in an increase in silicon concentrations. Maximum silicon concentrations are not expected to exceed 40 mg/L.

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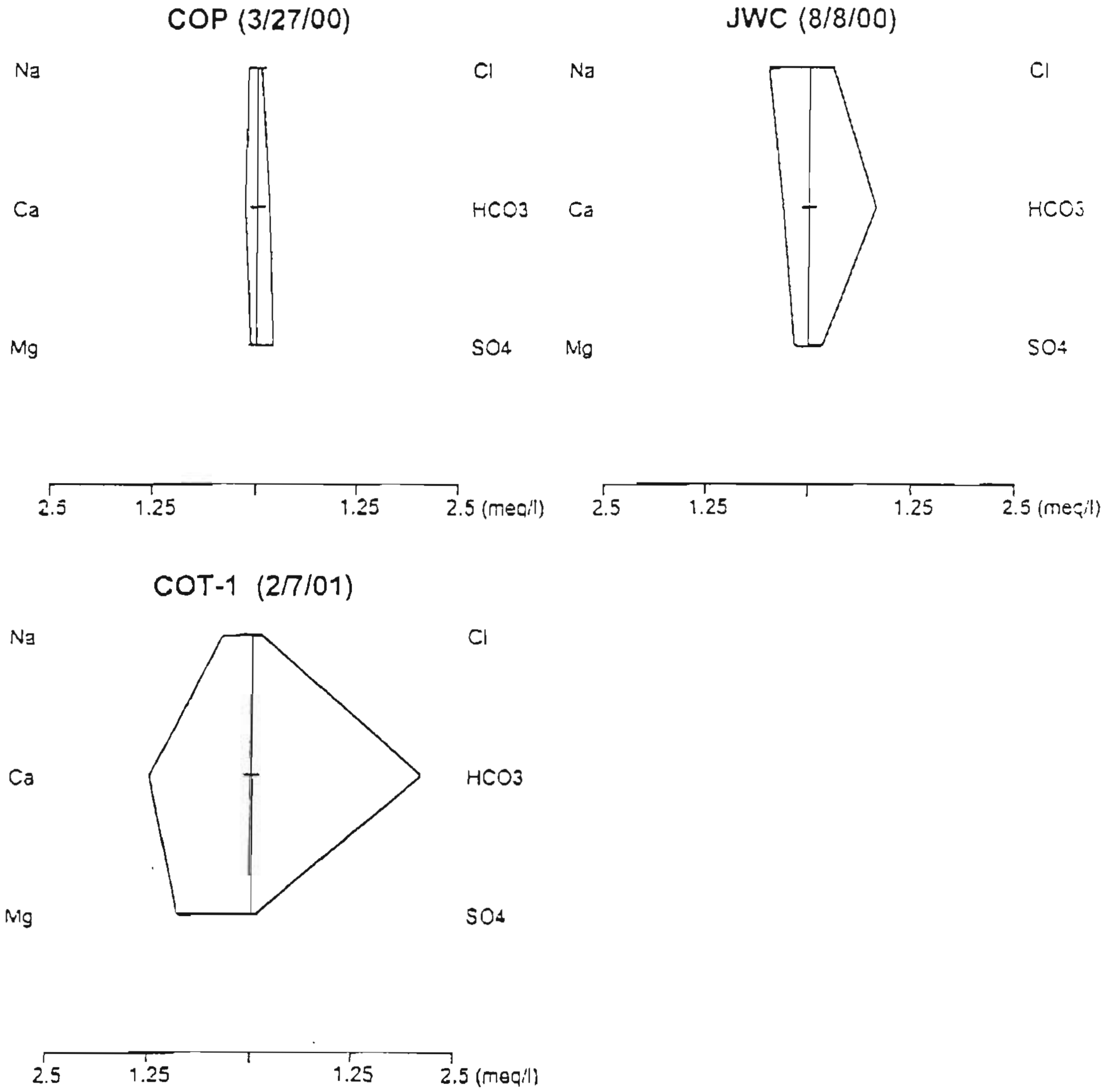

Sulfate concentration of 10 mg/L assumed for COP.

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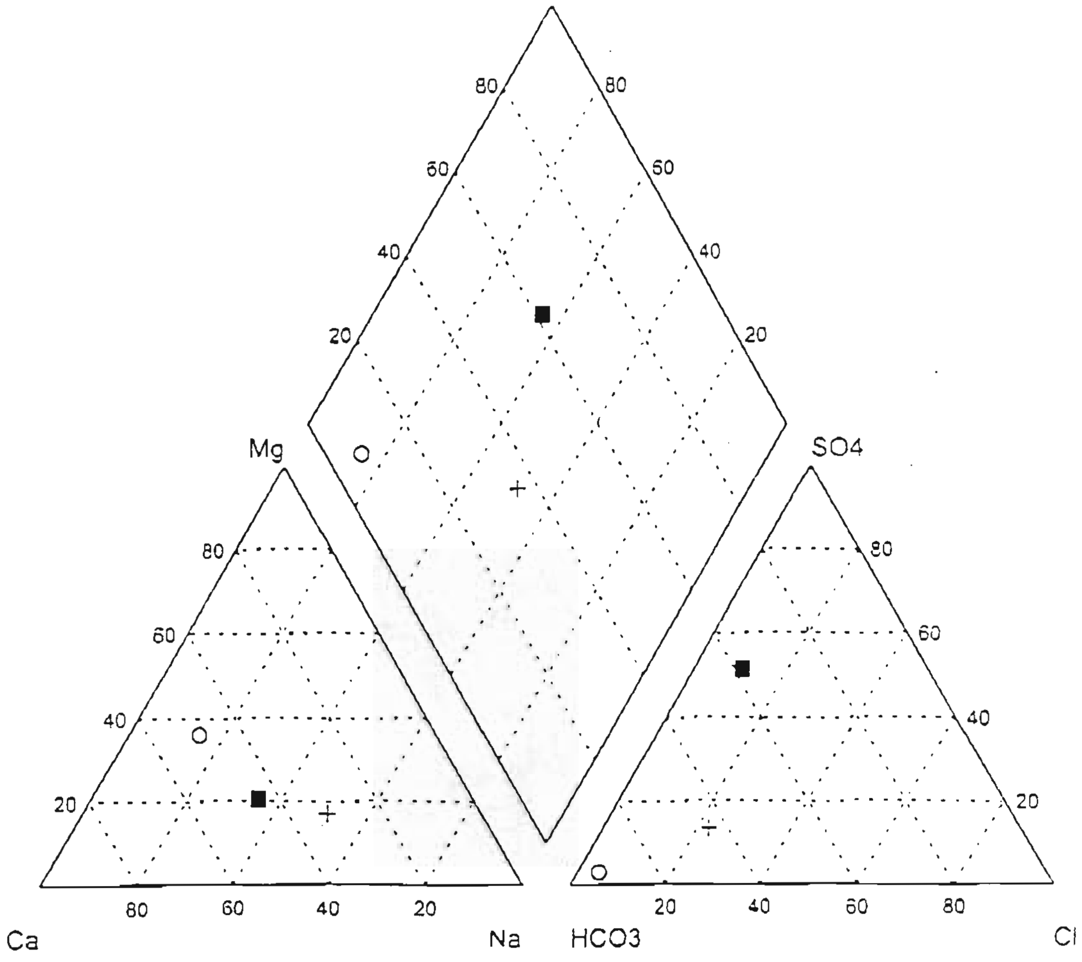
FIGURE 1 Groundwater and Injection Water Stiff Diagams

PROJECT NO.: 013-1409.004

DATE: April 6, 2001



Sulfate concentration of 10 mg/L assumed for COP.

Golder Associates

FIGURE 2 Groundwater and Injection Water Piper Diagram

PROJECT NO.: 013-1409.004

DATE: April 6, 2001

FIGURE 3

Silicon Concentrations
COP - COT-1 Mixing

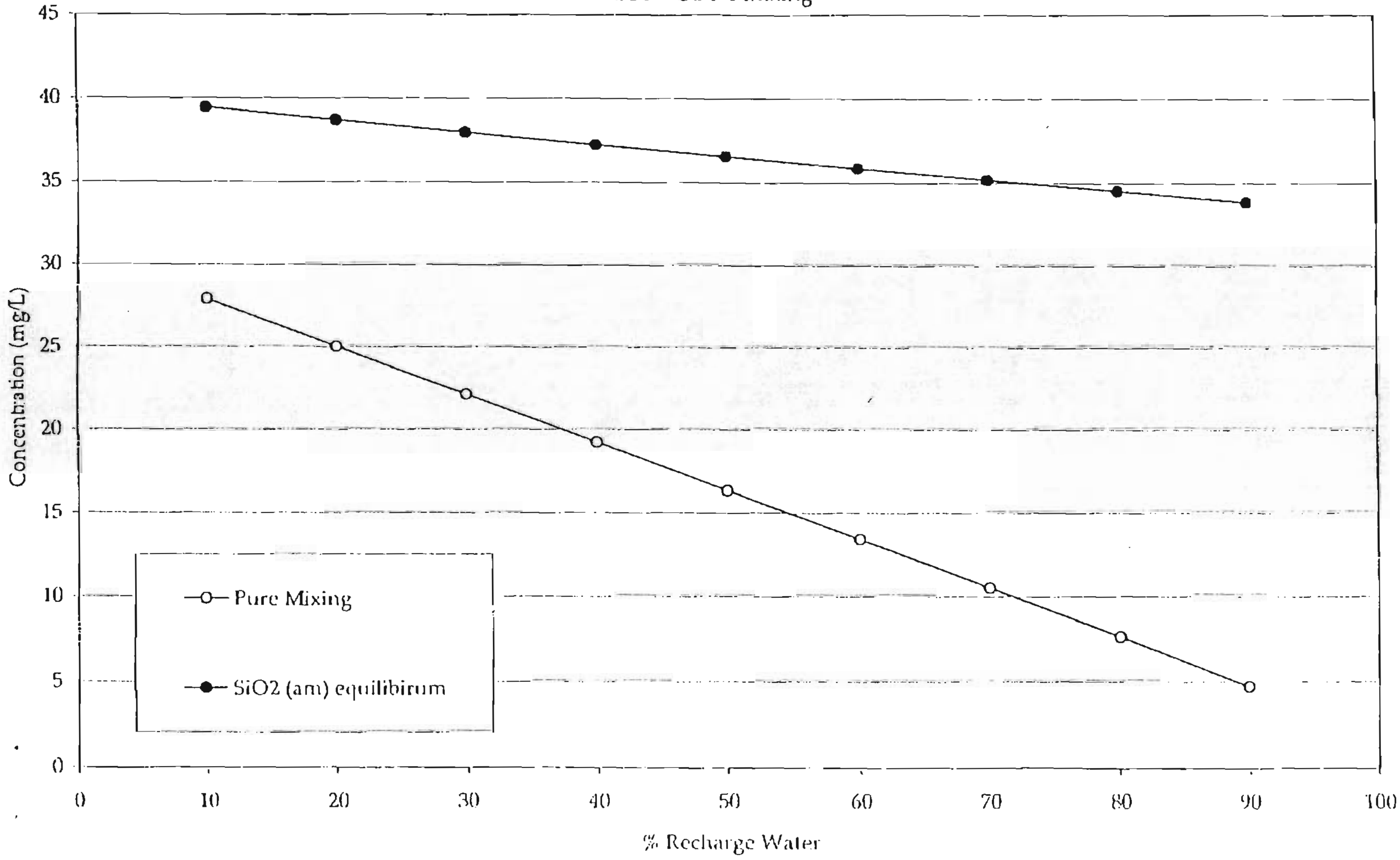


TABLE 1

Well No. 1 (COT-1) Historical Water Quality Data

Parameter	MCL	Unit	2/7/01	6/29/00	2/18/00	9/8/99	6/28/99	7/8/98	2/12/96	7/14/94	7/14/93	8/26/92	6/1/83	6/12/79	4/5/66	4/30/49
Alkalinity		mg/L	104	-	120	-	-	-	-	-	-	-	-	-	-	-
Antimony	0.006	mg/L	-	-	-	ND	-	-	ND	ND	ND	-	-	-	-	-
Arsenic	0.05	mg/L	-	-	-	ND	-	-	ND	ND	ND	<0.002	0.036	ND	-	-
Barium	2	mg/L	-	-	-	ND	-	-	ND	ND	ND	<0.025	0.01	ND	-	-
Beryllium	0.004	mg/L	-	-	-	ND	-	-	ND	ND	ND	-	-	-	-	-
Bicarbonate		mg/L	127	-	-	-	-	-	-	-	-	-	-	-	122	162
Cadmium	0.005	mg/L	-	-	-	ND	-	-	ND	ND	ND	<0.005	ND	ND	-	-
Calcium		mg/L	25	-	26.9	-	-	-	-	-	-	-	-	-	-	-
Carbonate as CO3		mg/L	0.261	-	-	-	-	-	-	-	-	-	-	-	0	-
Chloride		mg/L	3.67	-	-	-	-	-	-	-	-	-	-	-	6.6	3.6
Chromium	0.1	mg/L	-	-	-	ND	-	-	ND	ND	ND	<0.005	ND	ND	-	-
Conductivity		µS/cm	145	-	200	-	-	-	-	-	-	-	-	-	-	-
Copper	1.3	mg/L	-	-	-	0.005	-	-	ND	ND	ND	-	-	-	-	-
Cyanide	0.2	mg/L	-	-	-	ND	-	-	ND	ND	ND	-	-	-	-	-
Dissolved Oxygen		mg/L	6.98	-	-	-	-	-	-	-	-	-	-	-	-	-
Eh		mV	183	-	-	-	-	-	-	-	-	-	-	-	-	-
Fluoride	4	mg/L	-	-	-	ND	-	-	ND	ND	0.17	0.16	0.24	ND	-	-
Free CO2		mg/L	8.03	-	-	-	-	-	-	-	-	-	-	-	-	-
Hardness	250	mg/L	108	-	110	-	-	-	-	-	-	-	-	-	118	50
Hydroxide as OH		mg/L	0.005	-	-	-	-	-	-	-	-	-	-	-	-	-
Iron	0.3	mg/L	ND	-	ND	-	-	-	-	-	-	-	0.22	-	0.03	0.1
Lead	0.015	mg/L	-	-	-	ND	-	-	ND	0.002	ND	<0.002	0.005	ND	-	-
Magnesium		mg/L	11	-	-	-	-	-	-	-	-	-	-	-	-	-
Manganese		mg/L	ND	-	-	-	-	-	-	-	-	-	-	-	-	-
Mercury	0.002	mg/L	-	-	-	ND	-	-	ND	ND	ND	<0.0002	ND	ND	-	-
Nickel	0.1	mg/L	-	-	-	ND	-	-	ND	ND	ND	-	-	-	-	-
Nitrate	10	mg/L	-	1.3	-	1.5	ND	0.5	1	1.6	1	1.2	1.01	ND	-	-
Nitrite	1	mg/L	-	-	-	ND	-	-	ND	ND	ND	-	-	-	-	-
pH (field)			6.78	-	-	-	-	-	-	-	-	-	-	-	-	-
pH			7.5	-	6.85	-	-	-	-	-	-	-	-	-	7.2	6.8
Potassium		mg/L	3	-	-	-	-	-	-	-	-	-	-	-	-	-
Selenium	0.05	mg/L	-	-	-	ND	-	-	ND	ND	ND	0.003	ND	ND	-	-
Silica		mg/L	66	-	-	-	-	-	-	-	-	-	-	-	-	-
Silver	0.05	mg/L	-	-	-	-	-	-	-	-	-	-	ND	ND	-	-
Sodium		mg/L	8.5	-	-	9.13	-	-	8.7	8.6	8.7	10.3	-	-	-	-
Sulfate	250	mg/L	3.24	-	-	ND	-	-	ND	ND	13.5	-	-	-	3	-
Temperature		°C	11.7	-	-	-	-	-	-	-	-	-	-	-	-	-
Thallium	0.002	mg/L	-	-	-	ND	-	-	ND	ND	ND	-	-	-	-	-
Total Dissolved Solids		mg/L	180	-	-	-	-	-	-	-	-	-	-	-	-	206

ND = non-detect

'-' indicates constituent not measured.

TABLE 2

Injection Water Historical Water Quality Data

		Lake Oswego (continued)							Joint Water Commission (JWC)						
Parameter	**Units**	**1/11/00**	**2/2/99**	**4/22/97**	**8/14/96**	**5/14/96**	**1/9/96**	**12/1/95**	**8/8/00**	**2/22/00**	**12/21/99**	**1/13/99**	**7/15/98**	**7/24/97**	**1/15/97**
Aluminum	mg/L	-	-	-	-	-	-	-	0.08	ND	ND	-	0.013	0.007	0.007
Antimony	mg/L	ND	ND	ND	ND	ND	ND	-	ND	ND	ND	ND	ND	ND	ND
Arsenic	mg/L	ND	ND	ND	ND	ND	ND	-	ND	ND	ND	ND	ND	ND	ND
Barium	mg/L	0.006	ND	ND	ND	ND	ND	-	ND	0.02	ND	0.004	0.004	0.0037	0.005
Beryllium	mg/L	ND	ND	ND	ND	ND	ND	-	ND	ND	ND	ND	ND	ND	ND
Cadmium	mg/L	ND	ND	ND	ND	ND	ND	-	ND	ND	ND	ND	ND	ND	ND
Calcium	mg/L	-	-	-	-	-	-	-	6.2	8.66	6.25	-	8.1	7.7	6.8
Chloride	mg/L	-	-	8	-	-	-	-	10	8	8	-	4.7	4.6	4.7
Chromium	mg/L	ND	ND	ND	ND	ND	ND	-	ND	ND	ND	ND	ND	ND	ND
Conductivity	µmhos/cm	-	-	-	-	-	-	-	77	100	88	-	120	120	110
Copper	mg/L	ND	ND	ND	-	-	-	-	ND	0.011	ND	-	0.0011	ND	0.001
Cyanide	mg/L	ND	ND	ND	ND	ND	ND	-	ND	ND	ND	ND	ND	ND	ND
Fluoride (free)	mg/L	ND	ND	ND	ND	ND	ND	-	ND	ND	ND	ND	ND	ND	ND
Iron	mg/L	-	-	ND	-	-	-	-	ND	ND	ND	-	ND	ND	ND
Lead	mg/L	ND	ND	ND	ND	ND	0.002	-	ND	ND	ND	-	ND	ND	ND
Magnesium	mg/L	-	-	-	-	-	-	-	2	2.5	2.13	-	2.9	2.7	2.3
Manganese	mg/L	-	-	ND	-	-	-	-	ND	ND	ND	-	0.0006	ND	ND
Mercury	mg/L	ND	ND	ND	ND	ND	ND	-	ND	ND	ND	ND	ND	ND	ND
Nickel	mg/L	ND	ND	ND	ND	ND	ND	-	ND	ND	ND	ND	ND	ND	ND
Nitrate	mgN/L	ND	0.6	ND	ND	ND	ND	0.6	ND	0.8	0.7	0.42	0.21	0.22	0.4
Nitrite	mgN/L	ND	ND	ND	ND	ND	0.42	-	ND	ND	ND	ND	ND	ND	ND
Orthophosphate		-	-	-	-	-	-	-	ND	ND	ND	-	ND	-	ND
pH		-	-	6.44	-	-	-	-	7.6	7.7	7.8	-	7.33	7.6	7.6
Potassium	mg/L	-	-	-	-	-	-	-	0.4	0.5	0.6	-	0.6	0.6	-
Selenium	mg/L	ND	ND	ND	ND	ND	ND	-	ND	ND	ND	ND	ND	ND	ND
Silica (SiO2)	mg/L	-	-	-	-	-	-	-	16	20	19	-	14	15	15
Silver	mg/L	-	-	-	-	-	-	-	ND	ND	ND	-	ND	ND	ND
Sodium	mg/L	3.8	3.6	1.9	17.5	3	2.2	-	11.41	13.5	13.9	14	13	13	14
Sulfate	mg/L	ND	ND	11	ND	ND	ND	-	8	12	10	10	9.4	10	10
Thallium	mg/L	ND	ND	ND	ND	ND	ND	-	ND	ND	ND	ND	ND	ND	ND
Total Alkalinity	mg/L	-	-	-	-	-	-	-	41	42	39	-	39	38	41
Total Hardness	mg/L-CaCO2	-	-	16	-	-	-	-	27	40	28	-	32	30	26
Total Kjeldahl Nitrogen		-	-	-	-	-	-	-	ND	ND	ND	-	ND	-	ND
Total nitrate and nitrite	mgN/L	-	-	-	ND	ND	0.42	-	-	-	-	-	-	-	-
Total Phosphorus		-	-	-	-	-	-	-	ND	ND	ND	-	ND	ND	ND
Total Volatile Solids		-	-	-	-	-	-	-	20	27	57	-	ND	33	25
(TDS) Total Dissolved Solids	mg/L	-	-	-	-	-	-	-	54	83	91	-	61	96	72
(TOC) Total Organic Carbon	mg/L	-	-	-	-	-	-	-	ND	1.5	0.7	-	0.6	0.5	0.9
(TS) Total Solids	mg/L	-	-	43	-	-	-	-	80	82	98	-	67	92	120
(TSS) Total Suspended Solids		-	-	-	-	-	-	-	ND	ND	ND	-	ND	ND	ND
Turbidity	NTU	-	-	-	-	-	-	-	0.04	0.04	0.04	-	0.1	0.04	-
Zinc	mg/L	-	-	ND	-	-	-	-	ND	ND	ND	-	ND	ND	0.008

ND = non-detect
'-' indicates constituent not measured.

TABLE 3

Model Simulation Input Data

Parameter	Units	COT-1	COP	JWC
Alkalinity	mg/L	104	7.9	41
Aluminum	mg/L	-	0.67	0.08
Barium	mg/L	-	0.002	-
Calcium	mg/L	25	2.9	6.2
Chloride	mg/L	3.67	1.5	10
Copper	mg/L	-	0.19	-
Eh	mV	183	885	885
Iron	mg/L	-	0.066	-
Lead	mg/L	-	0.009	-
Magnesium	mg/L	11	0.8	2
Manganese	mg/L	-	-	-
Nickel	mg/L	-	0.002	-
Nitrate	mg/L N	-	0.02	-
pH	s.u.	6.78	7.5	7.6
Phosphorus	mg/L	-	0.007	-
Potassium	mg/L	3	0.2	0.4
Silicon	mg/L	30.9	1.82	7.5
Sodium	mg/L	8.5	2.6	11.41
Sulfate	mg/L	3.24	-	8
Temperature	°C	11.7	4	4

TABLE 4

Saturation Indices

Mineral		**Saturation Index**		
		COP	**JWC**	**COT-1**
Gibbsite - amorphous	$Al(OH)_3$	-0.50	-1.43	NA
Calcite	$CaCO_3$	-2.99	-1.57	-1.31
Gypsum	$CaSO_4$-$2H_2O$	-3.36	-3.19	-3.09
Dolomite	$CaMg(CO_3)_2$	-6.57	-3.67	-2.86
Silica - amorphous	SiO_2	-1.26	-0.65	-0.12
Ferrihydrite	$Fe(OH)_3$	2.17	NA	NA
Carbon dioxide	CO2(g)	$10^{-4.0}$	$10^{-3.1}$	$10^{-1.8}$

[1] Partial pressure shown.