Quality Assurance Project Plan

Managed Aquifer Recharge (MAR) in Basalts of the Rattlesnake Ridge Area

February 2023

WA State Department of Ecology, Office of Columbia River Contract No. C2200178

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Publication Information

Studies funded by the Washington State Department of Ecology (Ecology) must have an approved Quality Assurance Project Plan (QAPP). This plan describes the objectives of the study and the procedures to be followed to achieve those objectives. After completing the study, Ecology will post the final report of the study to the Internet.

This Quality Assurance Project Plan is available via Ecology's publications database and upon request. The Ecology publication number for this Quality Assurance Project Plan is 23-12-004

Field data collected for this project will be uploaded to Ecology's Environmental Information Management (EIM) database. This QAPP is valid through February 28, 2028.

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COVER PHOTO: View of lower Yakima Valley looking south from Rattlesnake Ridge, taken in August 2022. PHOTO BY CAREY GAZIS

Quality Assurance Project Plan

Managed Aquifer Recharge (MAR) in Basalts of the Konnowac Pass/Rattlesnake Ridge Area

Contract No. 2200178

by Carey Gazis

Published February 2023

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2.0 Abstract

In order to meet long-term water needs in the Yakima River basin, this project evaluates the potential for water storage in Columbia River Basalt aquifers in the Rattlesnake Ridge area, west of Yakima, WA. Water levels in basalt aquifers have declined significantly over the past few decades and there is ample room for storage of tens of thousands of acre-ft of water, likely supplied through the Roza Irrigation District canal. To assess groundwater storage potential, pumping tests will be conducted on nine wells in February-March, 2023. Wells will be fitted with transducers and monitored during two types of pump tests: 4-hour stepped pumping tests to determine well efficiency and aquifer properties close to the well; and 24-hour aquifer tests to determine larger scale transmissivity and storativity and to monitor for nearby boundaries that limit flow. The 4-hour stepped pumping test will be conducted on each of the nine wells and 24-hour aquifer test will be performed on two of the wells, using the remaining seven wells as observation wells. In addition to pump tests, water quality will be analyzed to determine compatibility of groundwater and source water and to identify any potential water quality concerns. Samples will be collected from the nine pump-test wells as well as six additional wells that represent hydrogeologic units not sampled by the pumping test wells or from locations where surface water may be entering the basalt aquifers through fractures. Surface water samples will be collected from the Yakima River above the Roza diversion and from four locations along the Roza canal. All water samples will be analyzed for major ion and trace element concentrations, as well as stable isotope ratios. Surface waters will also be analyzed for basic water quality parameters, (nutrients, suspended solids, etc.).

3.0 Background

3.1 Introduction and problem statement

This project supports the Groundwater Storage element of the Yakima Basin Integrated Plan by evaluating groundwater storage capacity and potential for artificial recharge to Columbia River Basalt Group (CRBG) formations east of the Yakima River in the Konnowac Pass/Rattlesnake Ridge region. The CRBG on and around Rattlesnake Ridge east of the Yakima River forms productive aquifers used for drinking water, irrigation, and municipal supplies. The CRBG aquifers are also used to provide drought relief for agricultural irrigation when deliveries of surface water are reduced during state-declared droughts.

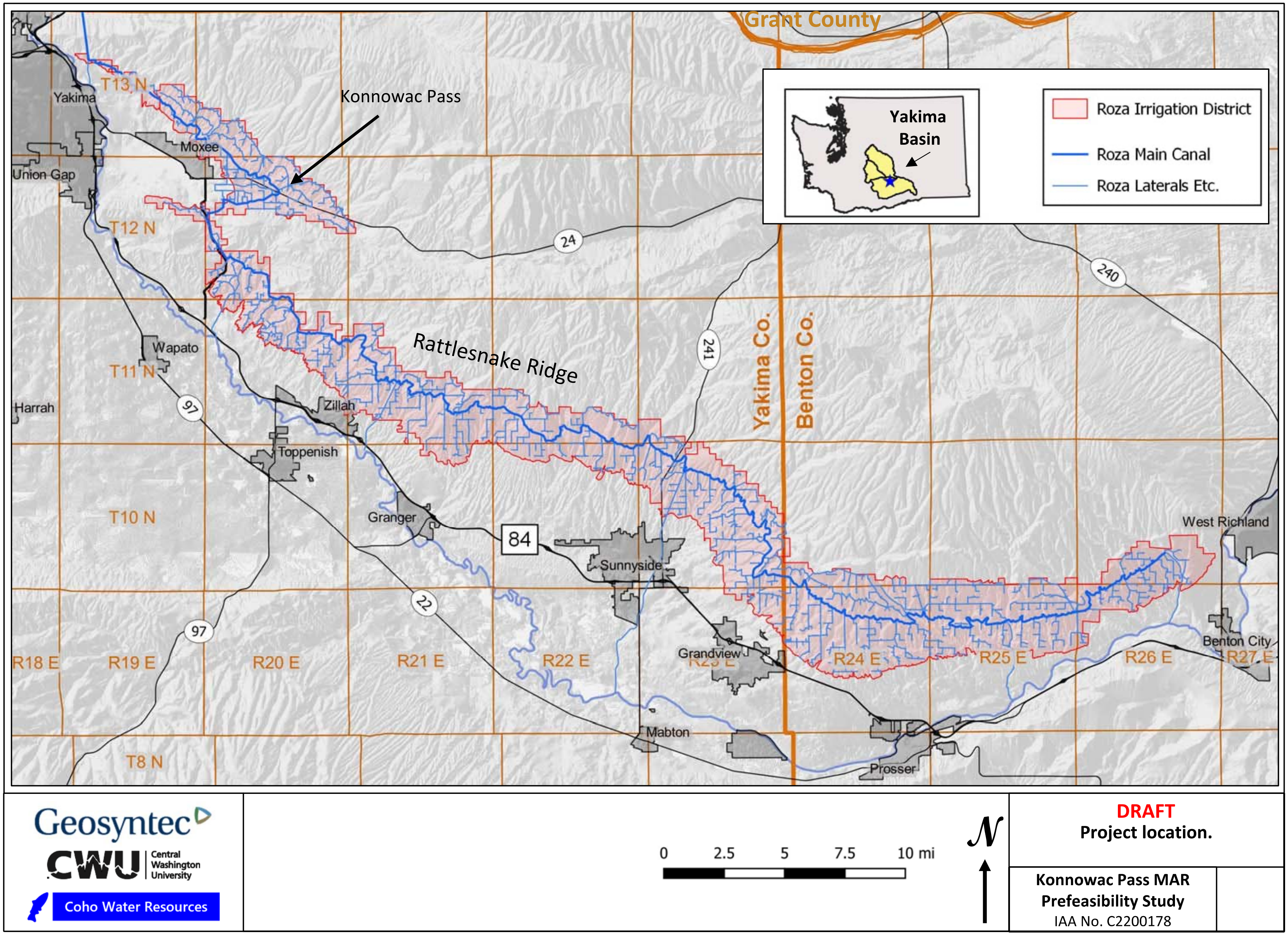
The entire project, funded under Ecology Office of Columbia River contract C2200178, consists of four tasks: Task 1, Project Management; Task 2, Data Compilation and Field Reconnaissance; Task 3, Injection Testing and Assessment; Task 4, Project Coordination and Reporting. A detailed description of the study area and summary of existing data is provided in the Task 2 report (Geosyntec, 2022) and is summarized here. This QAPP pertains to activities in Task 3 of the contract.

The existing conditions are of declining groundwater levels in portions of the CRBG aquifer system. In some locations levels have dropped by more than 100 feet in basalt wells over the last century (Vaccaro and others, 2009). Thus, this is a major underground water storage reservoir that has been depleted and groundwater storage capacity is available in some portions of the CRBG aquifer system. Past studies (Anderson and others, 2009) suggest up to 1000 AF of potential storage in the Rattlesnake Ridge area. This available storage can be accessed and used with Managed Aquifer Recharge (MAR) techniques to store surface water when it is available and to withdraw it when needed, particularly during dry years when surface water availability is limited. This restored storage, managed in a sustainable way, would be a major improvement to existing conditions.

This study will evaluate MAR in basalt aquifers through injection. The study area (Figure 1) encompasses the Roza Irrigation District in the area around Konnowac Pass and south of Rattlesnake Ridge. Groundwater levels in several wells in the study area have dropped by more than 100 ft in the period from 1970 to 2000 alone (Keys and others, 2008). The Department of Ecology has continued to monitor water levels in the region. Analysis of this data indicates that water levels have continued to fall up until the present, with an average decline of 3.0 ft/year for the Wanapum wells (Geosyntec, 2022). This suggests that there is ample volume for aquifer storage. Sites that can be served water through the Roza Irrigation District are considered potential recharge sites. The source of water for this evaluation of MAR (both infiltration and injection) is the Roza Irrigation Canal. The availability of this water for recharge is subject to physical constraints related to the operation of the canal. After storage in the basalt aquifers, the water would be recovered via pumping from existing wells.

The proposed project will address the following knowledge gaps that were identified by the Groundwater Subcommittee of YRBWEP:

- The volume of available storage in the CRBG formations within the study area.
- The best method for artificially recharging the CRBG formations and associated recharge rates.



Rattle LetLand (2022-08-31).ppt (2022-09-29)

Figure 1. Map of study area. Shaded pink indicates area served by Roza Irrigation District.

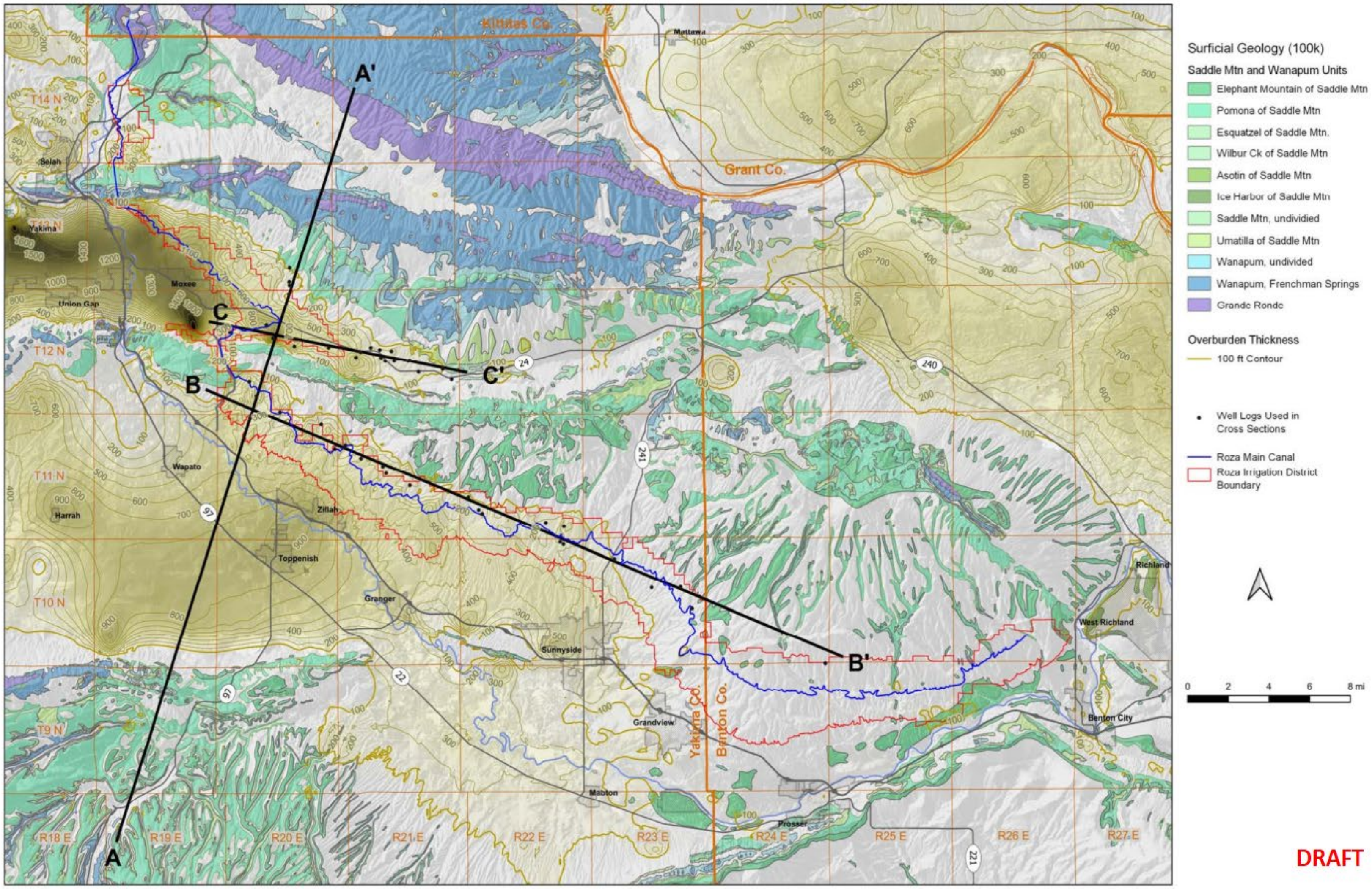
This project has the support of the Roza Irrigation District. The District is willing to provide both a source of recharge water and access to potential wells within the project area.

3.2 Study area and surroundings

The study area is focused on the Roza Irrigation District on the east side of the Yakima River (Figure 1). It straddles Rattlesnake Ridge in the Konnowac Pass area, and extends southeast through the Lower Yakima Valley. Elevation ranges from approximately 3,800 feet above sea level (asl) on Yakima Ridge to less than 700 feet asl near the county line. Annual precipitation in the project area is approximately eight inches (Washington Climate Summaries, 2023).

Geologically, the study area lies within the Yakima Fold Belt, a regional structural feature that has resulted from the interplay of Columbia Basin flood basalts originating from the east, erosion of the Cascade volcanic arc to the west, and compression from the south. The dominant bedrock within this study area is the Columbia River Basalt Group (CRBG), which is folded and faulted to form a series of large synclinal basins. The CRBG is comprised of thick sequences of basalt flows with sporadic sedimentary interbeds. In the interflow zones, the basalt is fractured and permeable, forming aquifers that are hydrogeologically significant because of their volume and storage potential.

A geologic map and cross sections of the study area (from Geosyntec, 2023) are provided in Figures 2-4. The geologic map is modified from Washington Department of Natural Resources (2016). The three cross sections were constructed from well logs and surface geology (Figure 3-4). The north-south cross section (A-A') uses data from 8 wells on the north end of the cross section and is based largely on surface geology in the south. The west-east cross section (B-B') was constructed using 20 wells within 3,300 feet of the cross-section line. The third cross section (C-C') runs along the Moxee Valley and includes information from 20 wells.

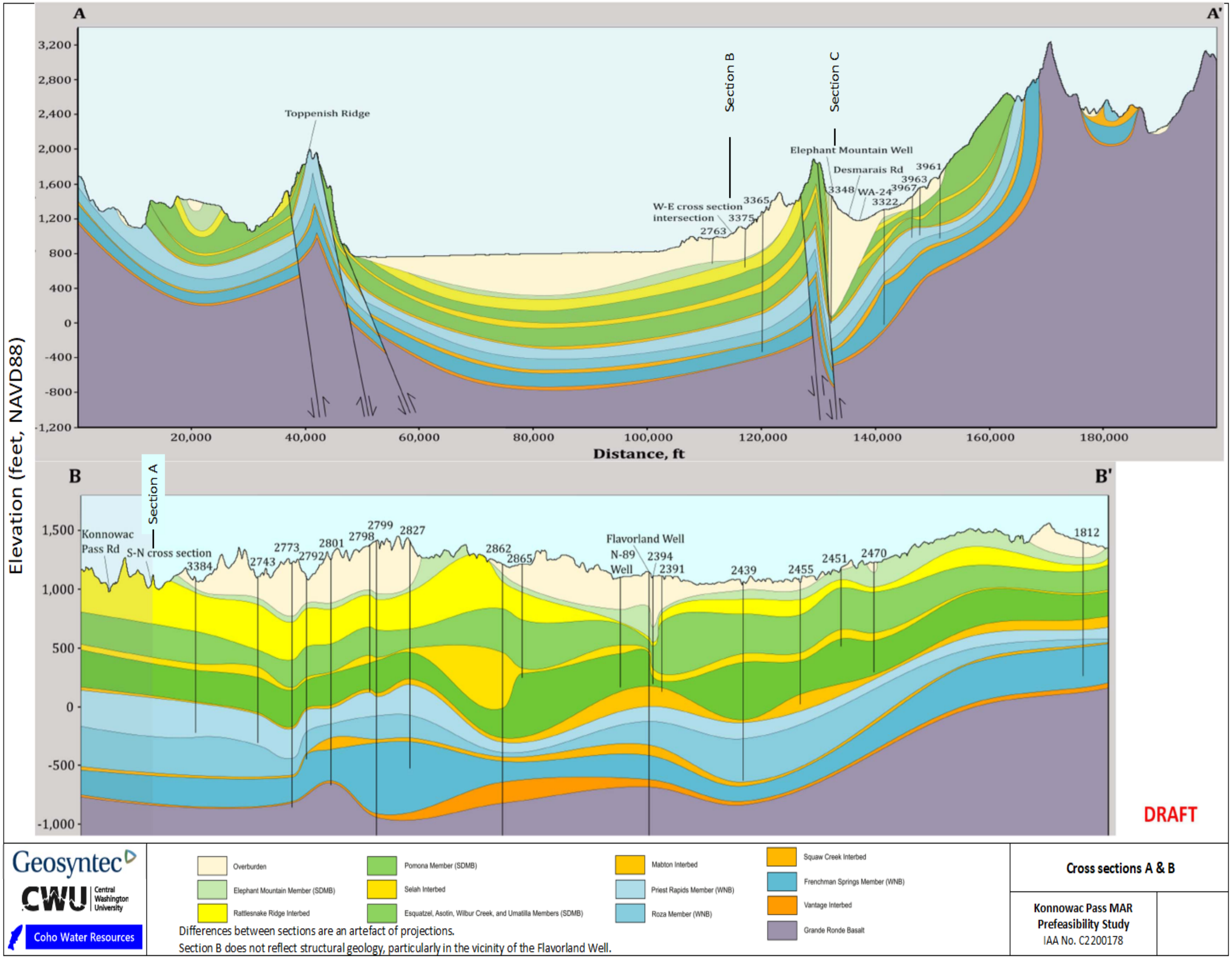


Geosyntec
CWU Central Washington University
Coho Water Resources

Selected surficial geology.

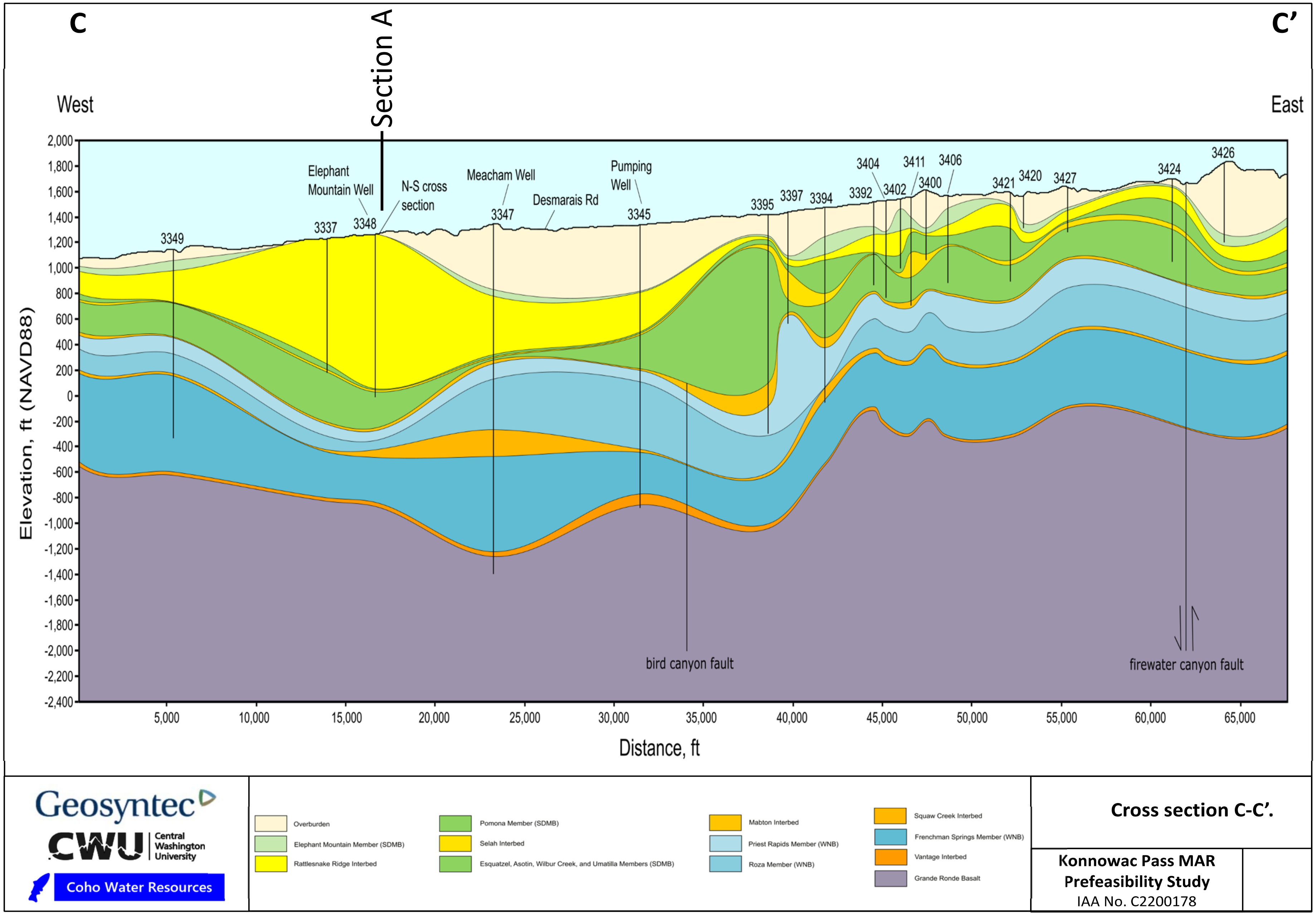
Konnowac Pass MAR
Prefeasibility Study
IAA No. C2200178

Figure 2. Geologic map of study area.



Differences between sections are an artefact of projections.
Section B does not reflect structural geology, particularly in the vicinity of the Flavorland Well.

Figure 3. Cross sections A-A’ and B’ B’ (see Figure 2).



Rattle LetLand (2022-08-31).ppt

Figure 4. Cross section C-C (see Figure 2).

3.2.1 History of study area

The study area is part of the ceded area of the Yakama Nation, land that was used by the Yakama tribe for winter settlements and subsistence by hunting, fishing, and gathering. Between 1917 and 1950, the Roza Irrigation District (RID) was planned and engineered to convert most of the study area to irrigated farmland, accomplished through a diversion at Roza Dam and distribution through a series of canals, laterals, pumps, and drains. It is currently used to produce a wide range of crops including orchards, grapes, hops, mint, as well as dairy farms. Approximately 72,000 acres of land are irrigated through a water right granted to the district. Within the framework of Yakima River basin water rights, the RID water right is considered junior under the Washington State Water code, meaning that they must defer to senior water rights that were obtained prior to 1905. Because of this junior right, the district is often given prorations in drought years as described below.

The United States Bureau of Reclamation (BOR) delivers water to the Roza Irrigation District (RID) and other entities. When the full amount of expected water cannot be delivered, the BOR implements storage control in which less than the full amount of water contracted is delivered. The percent reduction of water supply for RID under storage control conditions is variable and has been as low as 37%. Storage control has occurred approximately every three years over the last 20 years. The time at which storage control starts ranges from the beginning of the irrigation season (March-April) to late in the irrigation season (e.g., July). Based on climate projections, future incidents of storage control are expected to occur more frequently and be more extreme (e.g., Vano et al. 2010; Mote, 2014).

Groundwater from the CRBG aquifers has been used extensively, particularly to meet agricultural and municipal needs. Groundwater levels have been monitored in numerous wells within the study area since the 1970s; many wells have records of more than 30 years. These records indicate that water levels have declined throughout the region within all three basalt aquifers (Grande Ronde, Wanapum, and Saddle Mountain). Based on available EIM data for the study area, the median drawdown rate in the Wanapum Formation is 3.0 ft/year (Geosyntec, 2022). Although this drawdown rate does not account for pumping effects within individual well, it averages a large number of measurements in both pumped and unpumped wells. As such, it represents a regional pattern. The overall objective of this project is to address data gaps and further determine the feasibility of artificial groundwater recharge within the study area basalt aquifers, particularly the Wanapum unit.

3.2.2 Summary of previous studies and existing data

A major study of the hydrogeology of the Yakima River basin was conducted by the USGS over a number of years, resulting in a series of publications (Vaccaro and others, 2009 and references therein). This study and a larger-scale study of the CRBG aquifer system (Vaccaro and others, 2015) describe the framework of the basalt aquifers including their spatial distribution and their aquifer properties. These USGS efforts mapped the extent and thicknesses of the overburden, basalt units (Saddle Mountain, Wanapum and Grande Ronde), and selected interbed formations (Mabton and Vantage) using well log data, contour maps, and geologic maps (Jones and Vaccaro, 2008).

The possibility of groundwater storage in basalt aquifers has been discussed over the years among the water management community. Anderson and others (2009) analyzed short-term specific capacity information from 36 CRBG well logs throughout the Yakima Basin identified in Ecology's online well log database. The wells were completed in basalts, but were not distinguished by basalt formation (i.e., Saddle Mountain, Wanapum, Grande Ronde). The specific capacity of the wells reviewed ranged from less than 1 gpm/ft to 423 gpm/ft of drawdown. Estimated transmissivities ranged from approximately 100 to 110,000 ft^2/day, based on the use of a standard transmissivity approximation (Driscoll, 1986).

The OCR contract C2200178 Task 2 report for this project (Geosyntec, 2022) presents a summary of the above studies and other existing data for the study area and an analysis of that data in terms of groundwater storage. Based on RID transmission capacity, there is potential to deliver up to an additional 560 cfs during the "shoulders" of the irrigation season. This season can provide up to 123,000 acre-ft/yr. Based on analysis of water level declines and their spatial extent, long-term storage loss from the Wanapum aquifer is estimated to be 50,000-100,000 acre-ft/yr. In addition, 90% of the wells within the Wanapum aquifer are used for agricultural purposes and have high capacities (e.g., 1000-3000 gpm). The production capacity of a well is a good indicator of its recharge capacity.

3.2.3 Parameters of interest and potential sources

The parameters of interest in this study are the geologic stratigraphy and structure, aquifer characteristics, and flow regimes for the basalt aquifers of the study area, particularly the Wanapum basalt, as well as the ability of existing wells to transmit water. These characteristics will be assessed using measurements of the following parameters:

- Atmospheric pressure
- Atmospheric temperature
- Groundwater level elevation
- Groundwater temperature
- Pumping rate

In addition, basic water quality and chemistry measures in surface water and groundwater are parameters of interest for two purposes: 1) to determine the chemical compatibility of the surface source water with native groundwater, and 2) the physio-chemical impact of addition of the surface source water to the basalt aquifer. The water quality and chemistry analysis will also provide a preliminary assessment of treatment needs for future ASR projects. A complete AKART assessment of water treatment needs is beyond the scope of this project and should be accomplished in a future phase of the project. To accomplish the water chemistry/quality part of this study, the following parameters will be measured:

Field Parameters

pH
Temperature
Electrical conductivity
Oxidation-Reduction Potential (ORP)
Dissolved Oxygen (DO)

Laboratory - General Chemistry

Ammonium
Alkalinity
Aluminum
Arsenic
Barium
Calcium
Dissolved Organic Carbon (DOC)
Total Organic Carbon (TOC)
Chloride
Chromium
Copper
Deuterium
Fluoride
Iron
Lead
Magnesium
Molybdenum
Nickel
Nitrate-N
Nitrite-N
Total Kjelstad Nitrogen (TKN)
Oxygen-18
Phosphate-P
Total Phosphorus
Potassium
Silica
Sodium
Sulfate
Uranium
Vanadium

Laboratory - Sediment Load and Size

Total Suspended Solids (TSS)
Turbidity
Sediment Size Distribution

Laboratory - Bacteriological

E. coli
Fecal Coliform

Laboratory - Pesticides/Herbicides

Endothall
General Pesticides/PCB screening
Acrolein

3.2.4 Regulatory criteria or standards

Not applicable.

3.3 Water quality impairment studies

Not applicable.

3.4 Effectiveness monitoring studies

Not applicable.

4.0 Project Description

This project evaluates the potential for MAR to basalts in the Rattlesnake Ridge region, which includes the Konnowac Pass area and the southern flank of Rattlesnake Ridge. This area possesses key components for a successful MAR program:

- The need for water to maintain reliable supply, particularly to the RID whose supply is pro-ratable during drought years.
- Available water during years of surplus that can be delivered via the RID distribution system for MAR applications.
- Potential target aquifers for groundwater storage.

The CRBG in this area are productive aquifers used for agricultural irrigation, municipal water and other uses. Groundwater levels in many CRBG-completed wells in the study area have dropped by more than 100’ in the period from 1970 to 2000 (Keys and others, 2008), indicating groundwater storage capacity is available. MAR can access this available storage to store surface water when available. If well-compartmentalized aquifers are identified, this stored water can be retained for a specified time and withdrawn for use when needed.

Storage in the basalt aquifers in the vicinity of Rattlesnake Ridge has been discussed in the past by Anderson and others (2009). Their study suggested total storage capacity of up to 100,000 AF for this area but lacked sufficient information to derive firm estimates of both total capacity and the capacity of individual MAR sites. This study will refine these estimates.

4.1 Project goals

The overall goal of this project is to assess opportunities for storing water in basalt aquifers in the Konnowac Pass/Rattlesnake Ridge area. To achieve that end, more specific goals of the project are:

1. Determine storage capacity of CRBG aquifers in the Konnowac Pass/Rattlesnake Ridge area.

2. Characterize hydraulic properties of flow units and structures in the CRBG formations based on well log analysis and testing.
3. Evaluate hydrogeologic conditions and opportunities for managed aquifer recharge through direct injection into existing or new wells.
4. Investigate possible water quality interactions between the source water, the CRBG groundwaters and the CRBG rock matrix.

This project is not intended to be a feasibility study for ASR using a single well in the study area, but rather an assessment of the overall potential for groundwater storage in CRBG aquifers at a more regional scale. As such, the aquifer testing and surface water sampling strategy are designed to provide a picture of well efficiencies, hydraulic conductivities and water chemistries across the study area.

4.2 Project objectives

In order to achieve the above goals, the following activities will be undertaken:

- Install pressure transducers in 8 wells
- Perform 4-hour stepped pump tests on 6 wells
- Perform 24-hour pump tests on two wells, monitoring water levels in 3-4 nearby wells for each pump test
- Analyze pump test results to determine well efficiencies and aquifer properties
- Collect 8 groundwater samples and 20 surface water samples
- Analyze groundwater and surface water samples for major ion, trace element, stable isotope and water quality parameters
- Use standard software to analyze chemical interactions between source water and the aquifer to assess water quality impacts and potential for deposition/clogging.

4.3 Information needed and sources

There is a wealth of relevant existing data related to hydrogeology of the study area. Much of it has already been reviewed and analyzed as part of Task 2 of this overall project and OCR contract (Geosyntec, 2022). The data was used to identify the target areas for new data collection. The sources of existing data are:

1. Surficial Geology Map: DNR (2022) 1:100,000 surficial geology map and the unpublished data used to construct this coverage.
2. CRBG studies (e.g., Reidel and others, 2013; Tolan and others, 2009).
3. USGS framework and modeling of the hydrogeology of the basalts in the Yakima River Basin (Vaccaro and others, 2009, and supporting documents).
4. Well logs from the Washington Department of Ecology’s Well Report Viewer.
5. The USGS stratigraphic well compilation (Burns and others, 2011)
6. Examination of the hydrogeology of the Moxee Valley (Kirk and Mackie, 1993).

7. Unpublished DNR and Ecology cross-sections of the geology of south flank of Rattlesnake Ridge.
8. Water level data from Ecology’s EIM database.
9. Results from two pump tests (Repasky, 1993; Lindsey, 2012)
10. Water quality data from Ecology’s EIM database, USGS Water Data website and Zuroske (2009).
11. Water quality data and herbicide treatment histories from Roza Irrigation District.

The new data that will be collected to supplement the existing data are:

1. Water levels before, during, and after pump tests in nine wells. A four-hour stepped pump test will be performed in all of the wells. A 24-hour pump test will be performed in two of the wells, with the other wells used as monitoring wells.
2. Water chemistry/quality data for eight groundwater samples from the pump-test wells. Parameters include pH, conductivity, DO, ORP, major ions, trace elements, and stable isotopes.
3. Water chemistry/quality data from 20 surface water samples (Yakima River and four sites along the Roza Canal, sampled five times). This sampling strategy was chosen to get an overall picture of water quality within the Roza Canal system and how water quality changes moving down the system, an area where there is currently a data gap. Parameters include pH, conductivity, DO, major ions, trace elements, stable isotopes, grain size distribution, standard measures of water quality (E. coli, fecal coliform, total suspended solids, turbidity, nutrients, etc.).

4.4 Tasks required

In order to accomplish the new data collection and analysis, the following tasks are required:

1. Obtained well owner permissions and access to wells and ensure that wells have been modified as needed for project (have flowmeter and access port and column for pressure transducer).
2. Install pressure transducers in nine wells.
3. Conduct six pump tests, four 4-hour tests and two 24-hour tests and monitor water levels in wells throughout these tests.
4. Analyze pump test results using standard methods that examine time-drawdown curves and their derivatives and compare to theoretical curves under different conditions (e.g., confined versus leaky confined aquifers).
5. Collect eight groundwater samples and 20 surface water samples. Groundwater samples will be collected at the end of pumping tests or at the time of water level measurements. Surface water samples will be collected at five times in the irrigation season.

6. Conduct analysis of water samples at CWU (major ion, trace element, stable isotope, grain size distribution, see Tables 7 and 9).
7. Send surface water samples for additional analyses to AmTest Laboratories (water quality parameters in Table 8).
8. Analyze water chemistry interactions between surface water and aquifer material and surface water and groundwater using Geochemist's Workbench and PHREEQ.

4.5 Systematic planning process

The preparation of this QAPP constitutes the systematic planning for this data collection effort.

5.0 Organization and Schedule

5.1 Key individuals and their responsibilities

This QAPP was prepared by Carey Gazis from Central Washington University (CWU). Dr. Gazis, a professor in the Department of Geological Sciences at CWU, is the Project Manager and Principal Investigator. Two CWU M.S. students, Bethany Kharrazi and Bailey Hillard, are assisting with this project as part of their thesis research. In addition, CWU is teaming up with two consultants, Bob Anderson from Geosyntec Consulting and Chris Pitre from Coho Water Resources. They are assisted by Brian Webb (Geosyntec) and Sherry Wilhem (Coho Water Resources). Subcontracts have been issued to these two consultants to assist in all aspects of the project. Geosyntec will take the lead in aquifer testing and report preparation. The Principal Investigator and her collaborators will communicate regularly with Scott Tarbutton, grant project manager, at the Department of Ecology and other members of the Groundwater Storage Subcommittee of the Yakima Basin Integrated Plan. Table 1 shows the responsibilities of those who will be involved in this project.

Table 1. Organization of project staff and responsibilities.

Staff	Title	Responsibilities
Carey Gazis Central Washington University Phone: 509-963-2820	Project Manager/Principal Investigator	Oversees the budget. Writes the QAPP[1]. Oversees water sampling, water analyses, and transportation of samples to laboratory. Conducts QA review of data, analyzes and interprets data. Oversees entry of data into EIM[2]. Helps write the draft and final reports.
Bob Anderson Geosyntec Consulting, Inc. Phone: 206-496-1454	Consultant, subcontract to CWU	Provides internal review of the QAPP. Interfaces with well owners. Oversees the pump testing. Conducts QA[3] review of pump-test data, analyzes and interprets data. Leads writing the draft report and final report.
Chris Pitre Coho Water Resources, Inc. Phone: 206-406-9596	Consultant, subcontract to CWU	Provides internal review of the QAPP. Oversees pressure transducer installation, helps with water level monitoring during pump tests and analysis of results. Coho will help prepare figures for the final report.
Bailey Hillard Central Washington University Phone: 509-963-2701	Graduate Student/ Field Assistant for Water Quality	Collects water samples and records field information, helps with laboratory analyses, sends samples to the external laboratory. Assists with data entry into EIM.
Bethany Kharrazi Central Washington University Phone: 509-963-2701	Graduate Student/ Field Assistant for Pump Tests	Oversees on-the-ground logistics during pump tests including water level and flow monitoring, troubleshooting, interactions with well owners. Assists with data entry into EIM.
Scott Tarbutton Office of Columbia River, Department of Ecology Phone: 509-867-6534	Grant Project Manager	Manages the project grant and provides oversight of the project, and approves the budget. Provides review of the QAPP, and approves the final QAPP.
Aaron Young Amtest Laboratories Phone: 425-885-1664	Lab Director	Oversees water quality measurement of surface water samples including QA/QC[4] procedures and documentation.
Scott Tarbutton Office of Columbia River, Department of Ecology Phone: 509-867-6534	Quality Assurance Coordinator	Reviews and approves the draft QAPP and the final QAPP.

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[1] Quality Assurance Project Plan
[2] Environmental Information Management
[3] Quality Assurance
[4] Quality Assurance/Quality Control

5.2 Special training and certifications

The three leads on the project, Carey Gazis, Bob Anderson, and Chris Pitre, have extensive experience conducting the tasks outlined above (water sampling and analysis, water level monitoring, and pump tests). Central Washington students will assist with the data collection and will be trained as follows.

Bethany Kharrazi, a graduate student who will provide on-the-ground support for the pump tests, will be trained in data logger management (launching, downloading, atmospheric pressure correction, etc.), manual water level measurement, and pump flow monitoring and control. She will be assisted by undergraduate students, who will help with field logistics and record keeping.

Bailey Hillard, a graduate student who will oversee the water quality measurements, will be trained in field meter calibration, and water sampling. She will also receive training in laboratory safety, sample preparation, and use of the Picarro water isotope analyzer, ion chromatograph, and inductively coupled plasma mass spectrometer, including all QA/QC protocols. These trainings will be given by Dr. Gazis and Marie Tanach, an engineering technician at Central Washington University.

5.3 Organization chart

Not applicable – See Table 1.

5.4 Proposed project schedule

Tables 2 – 4 list key activities, due dates, and lead staff for this project.

Table 2. Schedule for completing field and laboratory work

Task	Due date	Lead staff
Field work, pump tests	March, 2023	Bob Anderson
Field work, water sampling	September, 2023	Carey Gazis
Laboratory analyses	September, 2023	Carey Gazis
Contract lab data validation	September, 2023	Carey Gazis

Table 3. Schedule for data entry

Task	Due date	Lead staff
EIM data loaded	October, 2023	Carey Gazis
EIM QA	October, 2023	Carey Gazis
EIM complete	October, 2023	Carey Gazis

Table 4. Schedule for final report

Task	Due date	Lead staff
Final report draft to Ecology	November, 30 2023	Bob Anderson, Carey Gazis
Final report to Ecology	December 31, 2023	Bob Anderson, Carey Gazis

5.5 Budget and funding

This project is funded by the Department of Ecology Office of Columbia River contract C2200178, as recommended by Groundwater Storage Subcommittee under the Yakima Basin Integrated Plan. Tables 5 and 6 show the total budget for the project including all review of existing data, new data collection and analysis (the subject of this QAPP), and report writing. Some of the instrument expenses for the pump testing (e.g., rental of pressure transducers and water level meters) are included in the consultant subcontracts.

Table 5. Project budget and funding

Cost Category	Cost ($)
Salary, benefits, and indirect/overhead	$46,436
Equipment	$0
Travel and other (software, supplies, graduate student tuition)	$16,863
Contracts (Geosyntec, Coho Water Resources)	$252,113
Laboratory (See Table 6 for details.)	$9,435
Total	$324,847

Table 6. Laboratory budget details

Parameter	Number of Samples	Number of QA Samples	Total Number of Samples	Cost Per Sample ($)	Lab Subtotal ($)
Dissolved major ion (Ca, Mg, Na, K, Cl, NO3, SO4, P2O5)	32	12	44	$20	$880
Trace Element (Al, V, Cr, Mn, Fe, Ni, Cu, Zn, As, Mo, Ba, Pb, U)	32	12	44	$30	$1320
Stable Isotope (d18O, dD)	32	12	44	$15	$660
Sediment size distribution	20	NA	20	$20	$400
E. Coli, Fecal Coliform	20	NA	20	$60	$1200
TSS, Turbidity	20	NA	20	$25	$500
Nutrients (NOx, TKN, TP, NH3)	20	Lab provided	20	$100	$2000
TOC, DOC	20	Lab provided	20	$35	$875

Parameter	Number of Samples	Number of QA Samples	Total Number of Samples	Cost Per Sample ($)	Lab Subtotal ($)
Pesticides/PCBs	4	Lab provided	4	$400	$1600

6.0 Quality Objectives

6.1 Data quality objectives [5]

The data collection will have two parts: 1) measurement of water levels associated with pump tests in nine wells, and 2) water quality analysis of surface water and groundwater. For water level measurements, the data quality objective is to make continuous groundwater level and temperature measurements throughout a four-hour pump test for each well and then during and after a 24-hour pump test in two wells. Pressure transducers and electric tape will be used to collect data to meet the groundwater level measurement quality objectives (MQOs) described below.

For water quality measurements, the main data quality objective (DQO) for this project is to collect 8 groundwater samples and 20 surface water samples for the purpose of predicting any water quality concerns (e.g., mixing reactions, treatment needs) associated with managed aquifer recharge. The analyses will use standard methods to obtain pH, conductivity, dissolved oxygen (DO), alkalinity, major ion, trace element, stable isotope, and water quality data that meet measurement quality objectives (MQOs) that are described below and are comparable to previous study results.

6.2 Measurement quality objectives

The MQOs for project results, expressed in terms of acceptable precision, bias, and sensitivity, are described in this section and equipment specifications are summarized in Tables 7, through 11 below.

Data quality objectives (DQOs) for geochemistry/water quality data in this project are based on precision, bias, and sensitivity and are used to establish measurement quality objectives (MQOs) which will be used to assess data quality. Laboratory MQOs for the individual parameters are summarized in Tables 7 and 8. Grain size distribution will be measured using a Mastersizer

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[5] DQO can also refer to ***Decision*** Quality Objectives. The need to identify Decision Quality Objectives during the planning phase of a project is less common. For projects that do lead to important decisions, DQOs are often expressed as tolerable limits on the probability or chance (risk) of the collected data leading to an erroneous decision. And for projects that intend to estimate present or future conditions, DQOs are often expressed in terms of acceptable uncertainty (e.g., width of an uncertainty band or interval) associated with a point estimate at a desired level of statistical confidence.

3000, which employs a laser diffraction method to determine the distribution and relative abundances by volume of different grain sizes for dispersed particles (suspended sediment) in water. The specifications of the Mastersizer 3000 are given in Table 9.

Acceptable data quality for field parameter measurements will be ensured by calibration of instruments according to manufacturer's specifications. The following meters or an equivalent model from another brand will be used: Hanna Instruments HI98196 multimeter, Orion Star A221 portable pH meter, Orion Star A122 portable conductivity meter, YSI 550A dissolved oxygen meter. Meter calibration is accomplished by purchase of appropriate calibration standards when needed and a meter-specific calibration procedure that is described in the meter user's manual. Repeat analyses of these standards as samples are performed periodically after calibration to assure reproducibility, accuracy, and precision. Each meter has a calibration certificate, and a user's manual that addresses calibration procedures, maintenance, and trouble shooting.

Water level data loggers will be installed in nine wells to determine variations in water levels before, during, and after pumping tests. Specifications for these data loggers are given in Table 10 and MQOs for the water level and temperature measurements are given in Table 11. Absolute elevation of groundwater will be calculated based on the ground surface elevation at the well head. That elevation will be obtained using GPS measurements cross referenced with a digital elevation model with 10-meter accuracy. This method will provide a <3-foot uncertainty on the ground surface elevation.

6.2.1 Targets for precision, bias, and sensitivity

The MQOs for project results, expressed in terms of acceptable precision, bias, and sensitivity, are described in this section and summarized in Tables 7, 8, and 11 below. Equipment specification for grain size analysis and groundwater level measurements are given in Tables 9 and 10.

Table 7. Measurement quality objectives CWU laboratory analyses

Parameter	Laboratory Duplicate (RPD)	Field Duplicate (RPD)	Matrix Spike Duplicate (RPD)	Lab Control Standard (%Recovery)	Matrix Spike (% Recovery)	Internal Standard Recovery (% Recovery)	Lowest Concentration of Interest (Detection Limit*)
Alkalinity	<10%	<10%	<10%	75-125%	75-125%	NA	10 mg/L
Chloride	<10%	<10%	<10%	75-125%	75-125%	NA	0.1 mg/L
Fluoride	<10%	<10%	<10%	75-125%	75-125%	NA	0.1 mg/L
Sulfate	<10%	<10%	<10%	75-125%	75-125%	NA	0.5 mg/L
Nitrate-N	<10%	<10%	<10%	75-125%	75-125%	NA	0.1 mg/L
Nitrite-N	<10%	<10%	<10%	75-125%	75-125%	NA	0.1 mg/L
Phosphate-P	<10%	<10%	<10%	75-125%	75-125%	NA	0.05 mg/L
Calcium	<10%	<10%	<10%	75-125%	75-125%	NA	0.05 mg/L
Magnesium	<10%	<10%	<10%	75-125%	75-125%	NA	0.05 mg/L
Potassium	<10%	<10%	<10%	75-125%	75-125%	NA	0.05 mg/L
Sodium	<10%	<10%	<10%	75-125%	75-125%	NA	0.05 mg/L
Silica	<10%	<10%	<10%	75-125%	75-125%	NA	0.5 mg/L
Aluminum	<10%	<10%	<10%	75-125%	75-125%	80-120%	0.34 ppb
Vanadium	<10%	<10%	<10%	75-125%	75-125%	80-120%	0.02 ppb
Chromium	<10%	<10%	<10%	75-125%	75-125%	80-120%	0.21 ppb
Manganese	<10%	<10%	<10%	75-125%	75-125%	80-120%	0.11 ppb
Iron	<10%	<10%	<10%	75-125%	75-125%	80-120%	1.0 ppb
Nickel	<10%	<10%	<10%	75-125%	75-125%	80-120%	0.33 ppb
Copper	<10%	<10%	<10%	75-125%	75-125%	80-120%	0.27 ppb
Zinc	<10%	<10%	<10%	75-125%	75-125%	80-120%	0.50 ppb
Arsenic	<10%	<10%	<10%	75-125%	75-125%	80-120%	0.31 ppb
Molybdenum	<10%	<10%	<10%	75-125%	75-125%	80-120%	0.10 ppb
Barium	<10%	<10%	<10%	75-125%	75-125%	80-120%	0.38 ppb
Lead	<10%	<10%	<10%	75-125%	75-125%	80-120%	0.15 ppb
Uranium	<10%	<10%	<10%	75-125%	75-125%	80-120%	0.08 ppb
Oxygen-18	0.1 per mil	0.1 per mil	NA	NA	NA	NA	NA
Deuterium	0.6 per mil	0.6 per mil	NA	NA	NA	NA	NA

NA Not Applicable

* Although statistically derived, these values represent a realistic estimate of the detection limit rather than a statistical measure of instrument detection; Treatment of measurements below detection limits is discussed in section 14.2 (Treatment of Non-Detects)

Table 8. Measurement quality objectives AmTest Laboratory

Parameter	Laboratory Duplicate (RPD)	Field Duplicate (RPD)	Matrix Spike Duplicate (RPD)	Lab Control Standard (%Recovery)	Matrix Spike (% Recovery)	Lowest Conc. of Interest (Detection Limit*)	Method
E. coli	<50%	<50%	N/A	N/A	75-125%	1 CFU/100 mL	SM9222D9 222G
Fecal coliform	<50%	<50%	N/A	N/A	75-125%	1 CFU/100 mL	SM9222D
TSS	<67%	<67%	N/A	78.6-121%	75-125%	1.0 mg/L	SM2540D
Turbidity	<10%	<10%	N/A	90-110%	75-125%	0.5 NTU	EPA 180.1
Nitrate/Nitrite	<15%	<15%	<15%	90-110%	75-125%	0.02 mg/L	EPA 353.2
TKN	<21%	<21%	<21%	90-110%	75-125%	0.25 mg/L	EPA 351.2
Total P	<20%	<20%	<20%	90-110%	75-125%	0.005 mg/L	SM 4500PF
Ammonia	<12%	<12%	<12%	84.2-116%	75-125%	0.02 mg/L	EPA 350.1
DOC	<28%	<28%	<28%	85.4-115%	80.2-120%	0.5 mg/L	SM 5310B
TOC	<35%	<35%	<35%	86.6-113%	75-125%	0.5 mg/L	SM 5310B
Pesticides/PCBs*	<30%	<30%	<30%	80-120%	50-150%	0.1 ug/L	EPA 608
Endothall	<20%	<20%	<20%	90-110%	75-125%	0.0003 mg/L	EPA 548.1
Acrolein	<11%	<11%	<11%	73.5-127%	75-125%	0.0005 mg/L	EPA 624.1

*values vary depending on pesticide measured. Typical values are given.

Table 9. Specifications of Mastersizer 3000, used for grain size distribution measurement.

Size Measurement	Range
Particle size	0.01 – 3500 mm*
Number of size classes	100 (user adjustable)
Accuracy	<0.6%**
Precision/Repeatability	<0.5% variation*
Reproducibility	<1% variation*

* sample and sample preparation dependent
** accuracy based on measurement of monomodal latex standards

Table 10. Specifications of Van Essen water level data loggers.

Measurement	Range	Accuracy	Resolution	Response Time (90%)	Stability (Drift)
Pressure Baro-Diver (water column height)	0 to 1.5 m H_2O	± 0.5 cm (typical) ± 2.0 cm (max)	<0.1 cm H_2O	< 1 sec	2 cm H2O

Measurement	**Range**	**Accuracy**	**Resolution**	**Response Time (90%)**	**Stability (Drift)**
Pressure TD-Diver DI810 (water column height)	0 to 100 m H_2O	± 5.0 cm (typical) ± 20.0 cm (max)	<2.0 cm	< 1 sec	20 cmH_2O
Temperature	-20°C to 80°C	± 0.1°C	0.01°C	3 min	–

Table 11. Measurement quality objectives for water levels and temperature.

MQO Parameter	**Precision Duplicate Measurement or Sensor Resolution**		**Bias Based on reported accuracies**	**Sensitivity Minimum Measurement**
Groundwater Level (transducers)	3 %RPD*	10 cm water	20 cm water	10 cm water above sensor
Groundwater Level (manual measurement)	3 %RPD	2 cm	4 cm	2 cm
Temperature	5 %RPD	0.10°C	0.44°C	0.1°C

*Relative Percent Difference

6.2.1.1 Precision

Precision will be determined based on duplicate field measurements and laboratory measurements of duplicate samples. For alkalinity, major ion, and trace element concentrations the MQOs require that duplicate samples are within 10% of each other. For stable isotope analyses, measurements are of ratios that are expressed in delta notation[*] (per mil units). For these analyses, in addition to measuring duplicate samples, the laboratory method includes multiple injections and measurements of each sample (typically ten). The first three injections are discarded because of memory effects. The reproducibility of the remaining analyses provides another determination of the precision of the method. Both the duplicate sample measurements and the multiple analyses of the same sample should meet the MQOs for stable isotopes, 0.1 per mil for oxygen-18 and 0.6 per mil for deuterium.

For transducer water level and temperature measurements, precision is the sensor resolution. For manual water level measurements using a water level meter, estimated precision is based on duplicate measurements.

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[*] *$\delta = (\frac{R_{sam}-R_{std}}{R_{std}}) * 1000$, where R_{sam} and R_{std} are the isotope ratios ($\frac{^{18}O}{^{16}O}$) for $\delta^{18}O$, $\frac{D}{H}$ for δD) of the sample and the standard, respectively.*

6.2.1.2 Bias

Bias will be determined based on measurement of quality control (QC) standards of known ion concentration or isotopic composition. These QC samples are independent from the calibration standards for each measurement. For major ions, the recovery limits for these QC standards should be 90-110%. For stable isotope analyses, these QC standards should measure within 0.1 per mil (oxygen-18) and 0.6 per mil (deuterium) from their known value. For chemical constituents, particularly trace elements, field and laboratory blanks will be used to ensure that there is no bias introduced by contamination. If bias is recognized in blank samples early in the project, additional steps will be taken to isolate the source of error, and field procedures or equipment will be modified to eliminate the problem.

For transducer water level and temperature measurements, bias targets are based on the reported accuracies (maximum error) of the sensors. For manual depth-to-water measurements, bias is introduced by any curvature in the measuring tape.

6.2.1.3 Sensitivity

Sensitivity is a measure of the capability of a method to detect a substance. Sensitivity is usually not an issue for major constituents of water and it is not relevant for stable isotope analyses, which are measured as ratios. For trace elements, detection limits are critical and have been calculated based on recent operating conditions for the ICP-MS at CWU. Instrumental detection limits for the major ion analyses and for trace element analyses are given as the lowest concentration of interest in Table 7. For water quality parameters to be measured by outside laboratories, AmTest laboratories have provided detection limits for all measurements (Table 8).

6.2.2 Targets for comparability, representativeness, and completeness

6.2.2.1 Comparability

Comparability is the degree to which data can be compared directly to similar studies. The use of standardized sampling procedures, analytical methods with comparable sensitivity, and units of reporting, and quality control procedures and standards ensure comparability of data. For comparability with existing data, particularly for stable isotope analyses, standards of known concentration will be analyzed and those analyses will either serve as the basis for the measurement calibration or as a check (quality control) standard for the calibration.

The same model of water-level pressure transducer and data logger will be installed in all wells to ensure comparability. Comparison of datalogger depth-to-water measurements with manual measurements will ensure that the absolute measurements between wells are comparable and that each data logger is well calibrated within the range of water levels measured.

Standardized sampling procedures will be used as described in this document and informed by the following Ecology standard operating procedures (SOPs):

- Aquifer Test Procedures
  https://apps.ecology.wa.gov/publications/documents/2011093.pdf
- Purging and Sampling Monitoring Wells for General Chemistry Parameters
  https://apps.ecology.wa.gov/publications/SummaryPages/1903205.html
- Use of Submersible Pressure Transducers During Groundwater Studies
  https://apps.ecology.wa.gov/publications/SummaryPages/1803215.html
- Manual Well-Depth and Depth-to-Water Measurements
  https://fortress.wa.gov/ecy/publications/documents/1803214.pdf
- Collecting Groundwater Samples for Metal Analysis from Water Supply Wells
  https://fortress.wa.gov/ecy/publications/documents/1903204.pdf
- Collection, Processing, and Analysis of Stream Samples
  https://fortress.wa.gov/ecy/publications/documents/1703207.pdf
- Collection of Fecal Coliform Bacteria Samples in Surface Water
  https://apps.ecology.wa.gov/publications/documents/1803239.pdf
- Collection and Field Processing of Metals Samples
  https://apps.ecology.wa.gov/publications/documents/1803204.pdf

The following Ecology SOPs will be used for pH and conductivity measurements:

- Collection and Analysis of pH Samples
  https://fortress.wa.gov/ecy/publications/documents/1803240.pdf
- Collection and Analysis of Conductivity Samples
  https://fortress.wa.gov/ecy/publications/documents/1703206.pdf

The following methods will be used for major ion analyses:

- U.S. EPA. 1997. Method 300.1: Determination of Inorganic Anions in Drinking Water by Ion Chromatography, Revision 1.0.
  http://quimica.udea.edu.co/~carlopez/cromatoion/ionchro_envir_anal.pdf
- Jackson P.E., 2006 Ion Chromatography in Environmental Analysis. Encyclopedia of Analytical Chemistry: Applications, Theory and Instrumentation.
  http://quimica.udea.edu.co/~carlopez/cromatoion/ionchro_envir_anal.pdf

The following method will be used for trace element analyses:

U.S. EPA, 1994. Method 200.8: Determination of Trace Elements in Waters and Wastes by Inductively Coupled Plasma-Mass Spectrometry, Revision 5.4. Cincinnati, OH

https://www.epa.gov/esam/epa-method-2008-determination-trace-elements-waters-and-wastes-inductively-coupled-plasma-mass

6.2.2.2 Representativeness

Representativeness is the degree to which sample data from the project accurately represent a particular characteristic of the environmental matrix which is being sampled. Representativeness of the samples collected is ensured by adherence to the field sampling protocols and standard laboratory protocols. Sampling locations are selected to represent the groundwater geochemistry and aquifer characteristics in the vicinity of each well.

Groundwater levels will be monitored throughout pump tests. In some cases, comparison of nearby wells during 24-hour pump tests will allow for direct comparison of nearby wells and assessment of representativeness. More broadly, water level data for a given well can be compared to existing water level data in the Ecology EIM or well log databases to assess whether a given well has a representative water level.

6.2.2.3 Completeness

Completeness is the percentage of valid results obtained compared to the total number of samples collected for a particular analysis. To ensure data completeness, only properly calibrated and maintained equipment will be used. Data logger measurements will be corrected and compared to manual measurements and any data logger that is not collecting high quality complete data will be replaced. Problems occasionally arise during sample collection that cannot be controlled. Example problems are site access problems, measurement drift, or equipment failure. For the laboratory analyses, a complete or valid result will include sample documentation and a laboratory analysis report. Greater than 95% completeness is expected for samples collected as part of this project.

6.3 Acceptance criteria for quality of existing data

Existing geochemical data will be used as a comparison to data collected in this project. It will only be included in overall analysis if it has been collected through an accredited laboratory. Any QAPP, internal laboratory quality assurance plan, and SOPs will also be reviewed to ensure that existing data meets our measurement quality outcomes. For example, existing water quality data that is collected by the Roza-Sunnyside Board of Joint Control (RSBOJC) is obtained from certified laboratories, which provide measures of data quality and use standard methods. The quality of existing data from Central Washington University is known and the data will not be used unless it has met the same measurement quality outcomes outlined here. The quality of existing USGS data is well documented in their reports and will be assessed by the same criteria.

There is a data gap in regular measurements of water quality for the Roza Canal water. RSBOJC does regularly measure E. coli in the canal water, but most other data quality measurements are made at drainage points that represent effluent from the combined Roza and Sunnyside Irrigation districts. Additionally, groundwater chemistry data from basalt aquifers in the region is available from previous studies. However, the geochemistry of groundwater for the specific wells that have been identified for this study is not known. This study will fill these data gaps by collecting water quality/chemistry data for the target wells and along the Roza Canal.

6.4 Model quality objectives

Not applicable.

7.0 Study Design

7.1 Study boundaries

The study area is within the Roza Irrigation District extending from the Konnowac Pass area in the northwest along the southern side of Rattlesnake Ridge to near the county line (Figure 2). The area was chosen because it contains basalt aquifers that have been overdrafted and recharge water can be supplied by the Roza Irrigation District distribution network. The Wanapum basalt aquifer is targeted because it is primarily used for agricultural purposes. Cross sections based on well logs and surficial geology (Figures 3 and 4) reveal that the Wanapum is present throughout the region with thicknesses ranging between 500 and 1000 feet. The Wanapum units and the major interbeds appear to be continuous in the east-west direction. In the north-south direction, they are cut, by the major ridge-forming faults. Water level jumps across these faults suggest that they serve as barriers to flow and thus serve to compartmentalize the aquifers on either side.

Specific sampling and pump test locations for this project are shown in Figure 2. All wells are in the Wanapum formation. One cluster of wells is in the Konnowac Pass area, just north of the ridge and faults, near cross section C-C’ (Figure 4); and a second cluster is located on the southern flank of Rattlesnake Ridge towards the middle of cross section B-B’ (Figure 3).

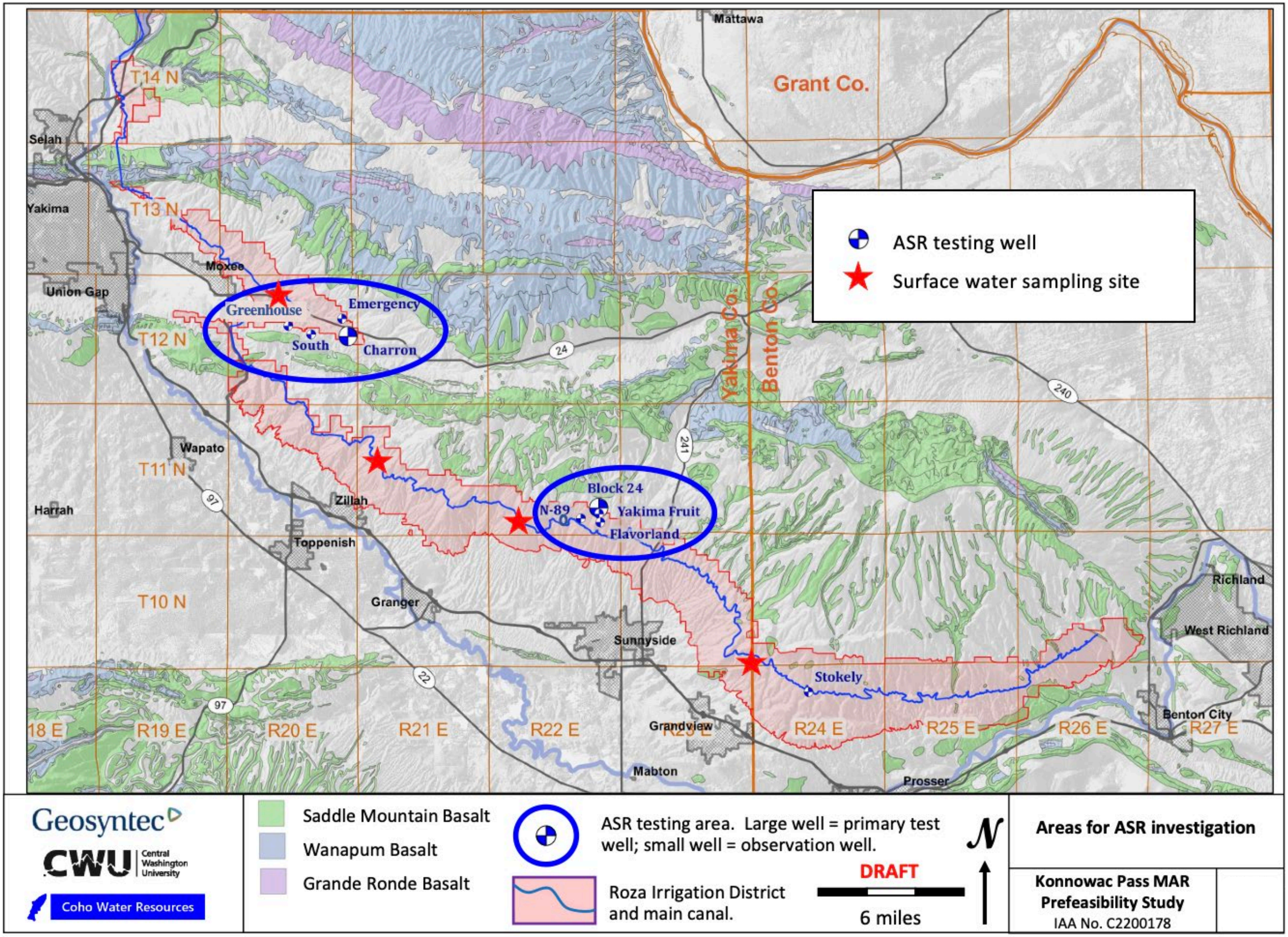

Figure 5. Map showing study area and sampling locations

7.2 Field data collection

Field data collection locations consist of: 1) wells for pump tests and water quality sampling; 2) additional wells for water quality sampling; 3) surface water sampling sites on the Yakima River and in the Roza Irrigation Canal. Figure 2 shows the sample locations. The rational for these locations is described below in 7.2.1

7.2.1 Sampling locations and frequency

Proposed aquifer test sites were selected after consideration of a number of factors. Following a review of well logs, wells were prioritized in terms of suitability for pump tests. Priority in this process was given to large, productive wells that are finished in the Wanapum Formation. With the help of the Roza Irrigation District, well owners were contacted to request a visit to their wells. Thirteen wells were visited in August 2022 to evaluate and discuss the well modifications and discharge locations necessary for future possible pumping tests. These wells were narrowed down to eight wells belonging to four owners that are most suitable for pumping tests (Figure 2 and Table 12). All wells are completed in the Wanapum formation and are well suited as monitoring wells during extended aquifer tests. Additional information about these wells, including well logs and schematic cross sections at each test site, are provided in Appendix A.

Table 12. Summary of pump test wells

Wells	Surface Elevation in ft.	Well Depth in ft.	Pumping Tests		Transducer Interval	
			Well Efficiency 4-hour step-test to determine well efficiency	**Aquifer** 24-hour aquifer test to determine transmissivity and storage coefficient	Continuous Monitoring (prior to pump test)	Pumping Test Monitoring
Roy Greenhouse Well	1225	1270	Yes	Pumping Well	15-minute	5-min* 30-sec**
Roy South/Meacham Well	1406	2802	Yes	Monitor for Greenhouse test	15-minute	5-min* 30-sec**
Charron Primary Well	1337	2105	No	Monitor for Greenhouse test	15-minute	5-min
Charron Emergency Well	1360	1105	No	Monitor for Greenhouse test	15-minute	5-min
Evans Block 24 Well	1283	1568	Yes	Pumping Well	15-minute	5-min* 30-sec**
Evans Yakima Fruit Well	1264	1105	Yes	Monitor for Block 24 test	15-minute	5-min* 30-sec**
Evans North 80 Well	1159	1000	No	Monitor for Block 24 test	15-minute	5-min
AHP-776	1079	1718	No	Monitor for Block 24 test	15-minute	5-min

*24-hour pump test, **4-hour step test

The water quality sampling plan is designed as a preliminary assessment of source water and aquifer water to identify potential water quality concerns in future basalt ASR projects. The sampling plan has three purposes:

1. To determine water chemistry/quality of potential source water from Roza Canal in order to identify constituents of concern. This will be useful in the future when treatment options are assessed. Existing water quality data for the Yakima River and Roza Irrigation District data will also be examined in this analysis. The Yakima River is included in this analysis because it is the source of the Roza irrigation water and it is useful to understand where water quality is changing in the overall system. RID and Sunnyside Irrigation District combined are mandated to monitor water quality at several exit points from their

network, but there is no systematic monitoring of basic water quality along the canal. This analysis of the Yakima River and sites along the Roza canal will fill a current data gap and provide baseline data that will be useful for ASR assessment across the study area.

2. To obtain groundwater chemistry information from target aquifers for a first order compatibility assessment of source water. In particular, it is necessary to determine whether any adverse chemical reaction (e.g., precipitation of minerals) will occur when the source water is introduced. In an ideal ASR system, source water spreads into the aquifer in a bubble around the infiltration well. In this region, the source water mixes with the ambient groundwater and also interacts with the basalt aquifer. The chemistry of Columbia River Basalts is well documented (e.g., McDougall, 1976). Groundwater and source water chemistry obtained in this study will be used to fill out the geochemical information needed to determine the direction of chemical equilibrium for the combined aqueous solution.

To achieve these ends, groundwater samples will be collected from the eight pump test wells (Table 13). Five alternative wells that were identified as potential pump test wells and have regularly been monitored for groundwater level by Ecology are also identified in Table 13.

Table 13. Summary of groundwater chemistry wells

#	Well	Surface Elevation (ft)	Well Depth (ft)	Unit	Other
	Target Wells				
1	Charron Primary	1337	2213	Wanapum	24-hr test, Konnowac Pass
2	Charron Emergency	1360	2177	Wanapum	monitoring, Konnowac Pass test
3	Roy South/Meacham	1406	2610	Wanapum	monitoring, Konnowac Pass test
4	Roy Greenhouse	1225	1270	Wanapum	monitoring, Konnowac Pass test
5	Evans Block 24	1283	1568	Wanapum	24-hr test, Rattlesnake Ridge
6	Evans Yakima Fruit	1264	1105	Wanapum	monitoring, Rattlesnake Ridge test
7	AHP-776	1079	1718	Wanapum	monitoring, Rattlesnake Ridge test
8	Evans North 80	1159	1000	Wanapum	monitoring, Rattlesnake Ridge test
	Alternate Wells				
1	Roy/DNR Elephant Mtn	1491	1369	Wanapum	backup pump test well
2	W Stokely Well	1092	1135	Wanapum	backup pump test well
3	CRGWDB-200013	1332	2205	Wanapum	backup pump test well
4	CRGWDB-201712	1158	923	Wanapum	backup pump test well
5	Evans Flavorland	1228	3500	Grande Ronde	backup pump test well

The surface water sampling plan has been designed to provide a preliminary picture of how surface water quality varies spatially and with time, particularly during the potential aquifer recharge periods. This new data combined with existing water quality data will be used to identify any potential constituents of concern. Surface waters will be sampled from five locations: the Yakima River at Roza Recreation area, immediately upstream of the Roza dam diversion; and four locations along the main Roza Irrigation canal across the region of interest in this study (Figure 2). Each of the four sampling locations has a bridge over the Roza canal that will allow consistent sampling access. Samples will be collected from the five locations at two times, once during each of the shoulder seasons (Figure 3).

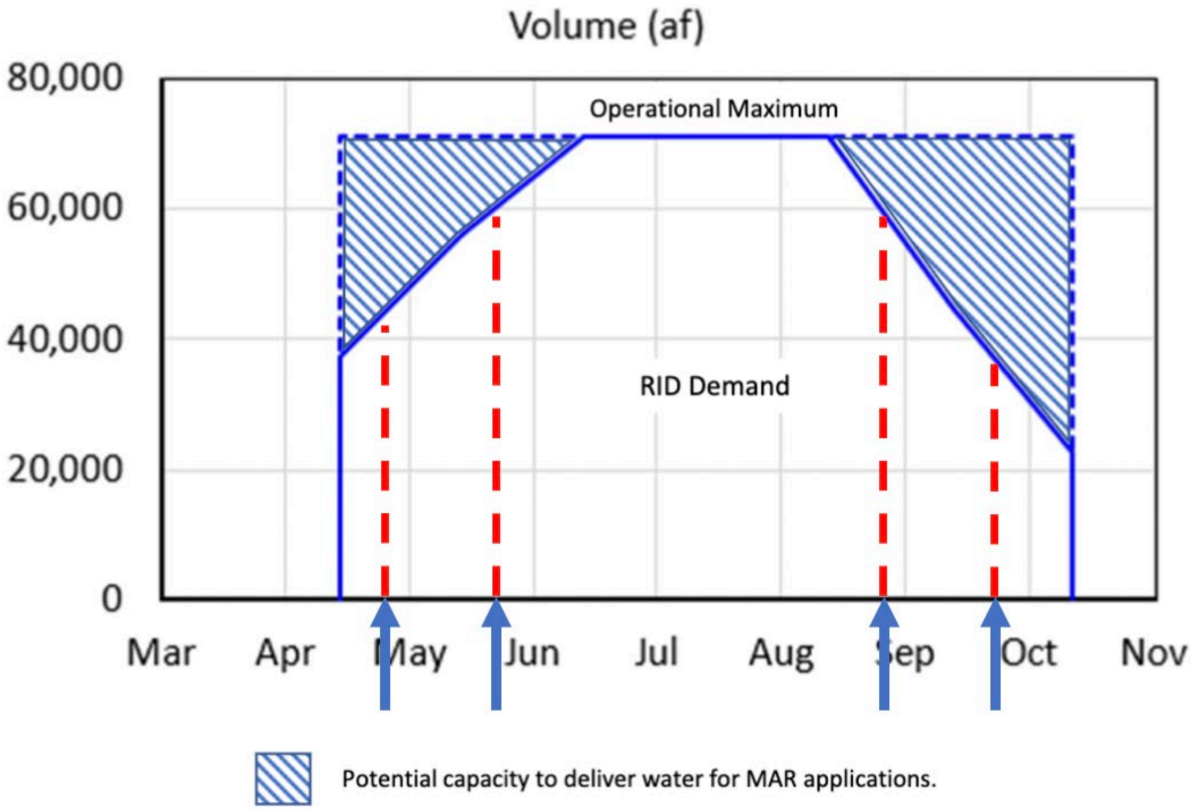

Figure 6. Plan for surface water sample collection. Shaded blue shows potential source water volume and time of availability (shoulder seasons).

7.2.2 Field parameters and laboratory analytes to be measured

During the pump tests, the following parameters will be measured in each well:

1. Flow rate, measured via flow meter in well.
2. Manual water levels measured with electrical water-level tape before, during, and after pump test and as needed when water level is in question. Manual measurement will be taken at least four times prior to the pump test, at the time of transducer installation and three other times, and hourly during the pump test.

3. Atmospheric pressure and temperature measured using pressure transducer at 30-second intervals throughout 4-hour pump tests and at 5-minute intervals during 24-hour pump test. Pressure transducers will be equipped with a communication cable so that data can be downloaded without removing the transducer from the well.
4. Absolute pressure (to be corrected for barometric pressure and barometric efficiency to determine water level) and temperature, measured using a non-vented pressure transducer, to be measured at 30-second intervals throughout 4-hour pump tests for each well individually and 5-minute intervals during 24-hour pump tests, measured in pumping well and associated monitoring wells.

Groundwater samples will be collected at the end of each pump test and the following field measurements will be recorded during the pump test to ensure stabilization criteria (Table 14) from the EAP099 SOP (Ecology, 2018) is met prior to the final measurement reading and sample collection: pH, conductivity, dissolved oxygen (DO), ORP. Alkalinity will be measured by titration in the laboratory at CWU within 24 hours of sampling.

Surface water samples will be collected from one site on the Yakima River (representing the source water to the canal) and the main Roza Irrigation District canal at four times during the summer. The following field measurements will be made on all samples: pH, conductivity, DO, ORP. Alkalinity will be measured by titration in the laboratory at CWU within 24 hours of sampling.

For all water samples (surface water and groundwater), four instruments will be used to measure the following constituents:

1. Ion chromatograph: Ca, Mg, K, Na, NH_4, NO_3, SO_4, Cl, F
2. Inductively coupled plasma mass spectrometer (ICP-MS): Al, V, Cr, Mn, Fe, Ni, Cu, Zn, As, Mo, Ba, Pb, U
3. Inductively coupled plasma optical emission spectrometer (ICP-OES): Si
4. Cavity Ring-down Spectrometer (Picarro): $^{18}O/^{16}O$ ratio, D/H ratio

Surface water samples will be sent to Amtest Laboratories or an equivalent certified laboratory where the following water quality measurements will be made on all samples: E. coli, Fecal coliform, Total Suspended Solids (TSS), Turbidity, Nitrate/Nitrite, Total Kjelstad Nitrogen (TKN), Total Phosphorus, Ammonia, Total Organic Carbon (TOC), Dissolved Organic Carbon (DOC).

A subset of the surface water samples (two locations closest to pumping test wells, two sampling dates) will be screened for Pesticides/PCBs through AmTest. These analyses will include a general screening using EPA Method 608 and targeted analyses of Endothal (EPA 548.1) and Acrolein (EPA 624.1), the two organic herbicides commonly used in the Roza Canal. EPA Method 608 includes a number of legacy and current-use pesticides that have been detected in the Yakima River: α-BHC, chlordane, DDT, DDE, DDD, Dieldrin, Endosufan (Johnson and others, 2010).

7.3 Modeling and analysis design

Not applicable.

7.3.1 Analytical framework

Not applicable.

7.3.2 Model setup and data needs

Not applicable.

7.4 Assumptions of study design

This study design is based on the assumption that the Wanapum aquifer is relatively continuous and isolated from the overlying Saddle Mountain Formation by the Mabton clay interbed. Large capacity agricultural wells (1000 to 3000 gpm) are assumed to have good recharge capacities (injection rates of 500 to 1000 gpm). The wells that have been chosen for pump testing and water quality sampling are assumed to be representative of the target aquifer and to be potential future injection wells.

7.5 Possible challenges and contingencies

One potential challenge of this project is access to wells and ensuring that wells are properly configured for the pump tests. To address this challenge, we have had multiple conversations with well owners and their farm managers and have visited potential wells multiple times. The well owners have agreed to install flow meters and access ports for transducers if they do not already have them. Back-up wells have also been identified.

7.5.1 Logistical problems

A number of logistical steps are necessary for this project to be completed in a timely manner. Pump tests are planned for late-February to early-March, hopefully after any winter snow and before the beginning of the irrigation season. Prior to pump testing, access agreements with well owners must be established and this QAPP must be approved. We are in the process of finalizing both of these documents so that the pump tests are not delayed by these contracts and approvals. In addition, as described above, some wells need to be modified prior to the pump tests. These modifications are either complete or underway. Even if all of these logistics are handled smoothly, it is possible that snow or other inclement weather will delay the pump tests. We do have a cushion of about a month between our planned pump tests and the beginning of irrigation.

Another possible schedule complication is related to our surface water sampling plan. If there is curtailment of the Roza water supply due to storage control, the fall sampling times will need to be adjusted. In this case, there will be ample warning that will allow for this adjustment.

7.5.2 Practical constraints

Practical constraints may occur during pump tests including difficulty controlling pumping rates and drawdown below the level of the transducer. We are trying to minimize the impact of these problems by visiting wells ahead of time and measuring water levels and assessing well configurations and flow meters. In general, we will follow the guidelines provided by Ecology (https://apps.ecology.wa.gov/publications/documents/2011093.pdf), which outline planning procedures that will minimize practical constraints. For example, we will use forward modeling to predict drawdown and will use the stepped drawdown test to determine pumping rates and flow rates for the 24-hour test.

7.5.3 Schedule limitations

Our schedule is constrained by the following:

QAPP approval – the QAPP was submitted in early December 2022 and we will need approval by February 2023 in order to meet our planned schedule.

Well owner access agreements – these have been negotiated. Two are in place and two will be finalized by February 28, 2023.

Well modifications – most well modifications have been made or should be complete by February 28, 2023.

The schedules of participants – CWU students and faculty are constrained by the academic calendar and must work around class schedules until June. Consultants have other contracts that constrain their availability.

Irrigation season – well owners have requested that we do not conduct tests or collect water samples during the irrigation season. This timing will also minimize any well interference. Surface water sampling must begin shortly after the irrigation season begins in order to capture the chemistry during the target ASR season.

8.0 Field Procedures

8.1 Invasive species evaluation

The majority of samples will be collected from wells in or near a farm or built environment that does not present significant risk of invasive species contamination. In situations where invasive species are present, SOP EAP070, Version 2.2 (Parsons and others, 2018) will be followed to minimize any chance of spreading of invasive species.

8.2 Measurement and sampling procedures

Eight wells have been selected for pumping tests, to be conducted in February-March, 2023. Wells will be retrofitted as needed so that they each have a flow meter and an access port and PVC pipe to protect a pressure transducer. Flow meters will be checked and calibrated as needed prior to the pump tests. A pressure transducer will be installed in each well one week prior to testing and will remain in the wells until the water level has recovered to within 95% or pre-pumping conditions. The transducers will be monitored via a communication cable during two types of pump tests: 4-hour stepped pumping tests to determine well efficiency and aquifer properties close to the well; and 24-hour aquifer tests to determine larger scale transmissivity and storativity and to monitor for nearby boundaries that limit flow. The 4-hour stepped pumping test will be conducted on four of the eight wells. A water quality sample will be collected at the end of each test. A 24-hour aquifer test will be performed on two of the wells, using the remaining six wells as observation wells. Additional water quality samples will be collected from the pumping wells at the conclusion of the 24-hour test. ASR testing areas are shown on Figure 2 and the pumping test plan is outlined in Table 12.

Pump tests will follow the procedure outlined in the Department of Ecology's Water Resource Program Guidance on Aquifer Test Procedures:

https://apps.ecology.wa.gov/publications/documents/2011093.pdf

A general plan for the test follows:

Step drawdown test – A 4-hour step drawdown test will be conducted on four of the wells. A pressure transducer will be installed within the pumping well and observation wells via the access port and monitored throughout the test. Manual water level measurements will be made before, during, and after the pumping test. The well will be pumped at four successively higher pumping rates for one hour per step. The target rates will be 50, 75, 100 and 125 percent of the maximum design rate. Flow will be controlled using the flow control valve and flow rates will be monitored manually via the flow meter. Discharge water from the pumping test will flow to the owner's distribution system. A total discharge volume of 0.5 AF is expected for each test. A water quality sample will be collected at the end of the test via the sampling spigot or at the discharge location. The pressure transducers will remain in all monitoring wells during the 24-hour pump tests.

24-hour pumping test – A 24-hour constant rate test will be conducted on two wells (Table 12). The time may be extended to 36 hours as needed. The final duration of the test will be determined in the field based on the water level response in the well. The well will be pumped at a single continuous pumping rate determined by the step drawdown test. Flow rates will be monitored manually via the flow meter. If necessary, flow will be adjusted using the flow control valve to maintain a constant flow rate. A total discharge volume of 4.5 to 6.5 AF is expected for this test. Water rights are in place to remove this water. Discharge water from the pumping test will flow to the owner's distribution system. A water sample will be collected at the end of the test via the sampling spigot or at the discharge location. A pressure transducer will be installed via the access port throughout the test. Pressure transducer measurements will be set at 5-minute intervals in both pumping wells and monitoring wells for the 24-hour test. Manual measurements will be taken at 1-hour intervals in wells and compared to pressure transducer data. If the two measurements are in agreement, the manual measurement interval will be reduced to minimize the need to remove the pressure transducer in order to make the manual measurements and the potential for shifting slightly the depth of the transducer.

Collection of samples and associated field QC samples will follow accepted procedures and the SOPs referenced in section 6.2.2. Sampling for stable isotope, major ion, and trace element analysis will be done in accordance with protocols developed by the CWU laboratories that have been conducting these analyses. The principal investigator will ensure that Bailey Hillard and any other field sampling personnel will be appropriately trained and thoroughly familiar with these procedures.

Groundwater samples will be collected using the general procedures for sampling described in the SOP Purging and Sampling Monitoring Wells for General Chemistry Parameters

(https://fortress.wa.gov/ecy/publications/documents/1803214.pdf).

Groundwater samples from the pump test wells will be collected following the pump test, when the wells have been thoroughly purged. All other wells will be purged prior to sampling using existing pumps and plumbing. Samples will be obtained from a tap as close to the wellhead as possible, and prior to holding or pressure tanks whenever possible. No samples will be collected downstream of filters, water treatment units, hot water tanks, etc. that could modify the water chemistry of the sample. Temperature, specific conductance, pH, and dissolved oxygen will be recorded at intervals during well purging through the use of a metered, closed-atmosphere flow cell. During purging, water from the selected tap will be routed by a clean "Y" fitting directly to the flow cell using a short section of tubing. Discharge from the flow cell will be routed to a suitable location identified by the well owner. Wells that are not routinely pumped will be purged for a minimum of three casing volumes and/or until all field parameters have stabilized for three consecutive readings. Wells that are routinely in use will be purged for a minimum of 5 minutes and until all field parameters stabilize for three consecutive readings. Table 14 presents the criteria for purge stabilization.

Table 14. Stabilization criteria for well purging

Parameter	Stabilization Criteria (maximum change for 3 successive readings)
Temperature	0.1ºC
pH	0.1 standard units
Specific conductance	+ 10.0 umhos/cm for values < 1000 umhos/com + 20.0 umhos/cm for values > 1000 umhos/cm
Dissolved oxygen	+ 0.05 mg/L for values < 1 mg/L + 0.2 mg/L for values > 1 mg/L

Once the stabilized parameter values have been recorded, water will be re-directed to the second outlet of the "Y" fitting for sample collection. Water samples designated for laboratory analysis will be collected directly into the appropriate containers. Samples requiring filtration will be collected into a clean 60-ml polypropylene syringe connected to a 0.45-micron filter. Samples will then be filtered on site into the appropriate containers. The number and types of containers to be filled for each analysis, as well as holding times and any special sample handling or preservation requirements are listed in Table 15.

Clean latex or nitrile (powder-free) gloves will be worn by sampling personnel during sampling and replaced between wells. The sampler will record the location of the sampling point relative to any treatment units or other in-line hydraulic components such as surge/pressure tanks or cisterns. Upon collection, samples will be labeled and immediately placed on ice in a cooler or otherwise stored as specified in Table 15 until delivery to the laboratory. When necessary, field equipment will be decontaminated using a liquinox solution and rinsed with deionized water.

The surface water sampling sites are either ramps or bridges. Roza water quality samples will be collected from bridges using an alpha sampler. This sample collection will be used to fill all bottles except the trace element sample bottles. A telescoping water sampler with a Teflon bottle will be used to collect trace element samples.

As needed, sampling procedures will be adapted based on the following SOPs:

Collection and Analysis of pH Samples
https://fortress.wa.gov/ecy/publications/documents/1803240.pdf

Collection of Fecal Coliform Bacteria Samples in Surface Water

https://apps.ecology.wa.gov/publications/documents/1803239.pdf

Purging and Sampling Monitoring Wells for General Chemistry Parameters

https://fortress.wa.gov/ecy/publications/documents/1803214.pdf

Collecting Groundwater Samples for Metal Analysis from Water Supply Wells https://fortress.wa.gov/ecy/publications/documents/1903204.pdf

Collection, Processing, and Analysis of Stream Samples

https://fortress.wa.gov/ecy/publications/documents/1703207.pdf

Collection and Analysis of Conductivity Samples

https://fortress.wa.gov/ecy/publications/documents/1703206.pdf

Groundwater Manual Depth to Water Measurements

https://apps.ecology.wa.gov/publications/SummaryPages/1803215.html

8.3 Containers, preservation methods, holding times

Table 15 presents containers, preservation techniques, and holding times for all laboratory geochemical analyses.

Table 15. Sample containers, preservation, and holding times.

Parameter	Minimum Quantity Required	Container	Sample Handling and Preservative	Holding Time
Alkalinity, sediment size distribution	50 ml	250 mL high density polyethylene (HPDE) bottle	No headspace, store at 4°C	3 days
E. coli, fecal coliform	100 mL	250 mL	EDTA/< 6°C	24 hours
TSS	100 mL	500 mL	Non-preserved/< 6°C	7 days
Turbidity	50 mL		Non-preserved/< 6°C	48 hours
Nutrients: NOx, TKN, TP, NH3	20-50mL	250 mL	H2SO4	28 days
DOC, TOC	40 mL	40 mL	Zero headspace vial with H2SO4	28 days
Major Anion: Chloride, Fluoride, Sulfate, Nitrate, Phosphate	5 ml	60 mL HDPE bottle	Filtered (0.45 micron), store at 4°C	28 days
Pesticides/PCBs	1000 mL	1 L amber glass	EPA 3510/3520	7 day to extraction
Major Dissolved Cation: Calcium, Magnesium, Potassium, Sodium, Ammonium	5 ml	Acid-washed 60 mL HDPE bottle	Filtered (0.45 microns), store at 4°C, nitric acid to pH < 2	6 months
Trace Element: Aluminum, Vanadium, Chromium, Manganese, Iron, Copper, Nickel, Zinc, Arsenic, Molybdenum, Barium, Lead, Uranium	10 ml	Acid-washed 60 mL HDPE bottle	Filtered (0.45 microns), store at °4C, ultrapure nitric acid to pH < 2	6 months
Stable Isotopes (O and H)	2 ml	30 mL HDPE bottle sealed with tape	Tightly sealed to prevent evaporation	6 months

8.4 Equipment decontamination

It is unlikely that any sample will contain high levels of contaminants or organic materials. In addition, dedicated sampling equipment will be used for this study so there is not a chance of cross-contamination from another project. In some cases, samples will be collected directly into bottles, which then function as single-use sampling devices. In the event that there is a possibility of contamination, the following SOP will be used to decontaminate equipment:

SOP EAP090, *Decontamination of Field Equipment for Sampling Toxics in the Environment.* https://apps.ecology.wa.gov/publications/documents/2103202.pdf

All non-dedicated, non-disposable field equipment coming into contact with sample water will be cleaned between uses at subsequent sampling locations to prevent cross-contamination of samples. Prior to collection of samples, a thorough rinsing with deionized water followed by rinsing three times with sample water shall be considered sufficient.

8.5 Sample ID

Sample identification will be based on a format that includes the overall project and year, the site, the type of water, and a sample number. The format will be as follows: YRB23-RR-sample#, where YRB23 is this project designation and year, RR designates this project, the sample# is G-1 to G-xx for the groundwaters, YR for Yakima River sample and RC-1A to RC-4D for the Roza Canal sample sites; A to D are the different sampling times. For each sampling location/date, the following information will be recorded in a field log:

- Sample number
- Sample location
- Sampling date and time
- Sampler's name and names of other field personnel present
- Well purging information (flow rate, duration, total volume purged)
- Field parameter readings during purging
- Final (stabilized) field parameter readings
- Analytes sampled for and number of bottles collected for each analysis
- QA samples collected
- Any other relevant information (field conditions, details of how sample was collected).

Sample bottles will be labeled using self-adhesive labels, which will be completed in indelible ink and include:

- Sample identification number
- Analysis type (cation, anion, isotope)
- If acid is added
- Sample date and time

Following completion of each sampling trip, the principal investigator will review the field logs recorded by the samplers for completeness, accuracy, and clarity. The principal investigator will retain a copy of all documentation.

8.6 Chain of custody

A subset of the samples will remain within the custody of Bailey Hillard at Central Washington University throughout the project. They will be stored on project-designated shelves in a refrigerator in the Stable Isotope Laboratory in the Geological Sciences Department.

Another subset of the samples will be sent to AmTest Laboratories or an equivalent certified laboratory for water quality analyses. For these samples, we will use the laboratory's chain of custody form, which includes the following information:

A unique sample location/field ID combination.

The date and time of sample collection.

The sample collector's name.

Customer/Project information for billing and report mailing.

The sample matrix.

Sample preservation.

The analyses requested.

8.7 Field log requirements

Field data will be recorded by field personnel at the time of measurement or sampling in a field notebook (log). Data to be entered into field notebooks includes

- Names of field personnel
- Sequence of events
- Site identification and description
- Environmental conditions
- Dates and times of measurement or sampling
- History of recent well usage, if groundwater
- Estimated flow (based on visual inspection and nearby measurements when available), of surface water
- Appropriate field measurement values and units of measure
- Sample numbers
- And detailed notes on any deviations from prescribed procedures

8.8 Other activities

In addition to the standardized procedures described above, the following additional steps will be taken to ensure an adequate level of quality control during sampling:

- Field instruments will be calibrated and/or checked in accordance with the manufacturer's instructions on a daily basis at the beginning of each sampling day, and as needed during the day.
- All non-dedicated, non-disposable field equipment coming into contact with sample water will be cleaned between uses at subsequent sampling locations to prevent cross-contamination of samples. Prior to collection of samples, a thorough rinsing with deionized water followed by rinsing three times with sample water shall be considered sufficient.
- Sources of extraneous contamination (generator fumes, gasoline, sunscreen, wearing of luminescent watches, etc.) will be minimized during sampling. Sampling personnel will employ a "clean hands/dirty hands" approach to sample collection.
- Equipment/filter field blanks will be collected during each sampling round to determine if sampling equipment or filters are introducing bias into the sampling results. Blanks will be used to determine whether the sample tubing, filters, sample containers, preservatives, or transport methods represent a source of bias. If bias is recognized in blank samples early in the project, additional steps will be taken to isolate the source of error, and field procedures or equipment will be modified to eliminate the problem.

9.0 Laboratory Procedures

9.1 Lab procedures table

The standard laboratory quality control procedures in place at CWU are adequate to estimate laboratory precision and accuracy. As described in Appendix B, the CWU laboratory is accredited for a subset of these analyses and audited regularly. Laboratory quality control samples will include blanks, duplicates, matrix spikes, and check standards (QC standards). Duplicates, matrix spikes, and matrix spike duplicates will be used to estimate overall bias due to the combination of the analytical procedure and matrix interferences. Check standards will be used to verify analytical precision, to test for instrument drift, and to provide an estimate of bias due to calibration. On the inductively coupled plasma mass spectrometer (ICP-MS) an internal standard is routinely used to correct for any instrument drift due to variations in nebulization and pumping. Laboratory method blanks will be used to measure the response of the analytical system at a theoretical concentration of zero.

Table 13 presents a summary of the types and minimum frequency of field and laboratory quality control samples for this project. If QC results regularly fall outside of the acceptable limits defined in Table 7, the investigators will review the sampling and/or analytical methods to determine an appropriate course of action to obtain the desired data quality and rerun samples as needed. Any changes in procedure will be submitted for approval to Ecology. Table 16 summarizes the laboratory analytical methods for the study.

Table 16. Measurement methods (laboratory).

Analyte	Sample Matrix	Samples (Number/ Arrival Date)	Expected Range of Results*	Detection Limit	Sample Prep Method	Analytical (Instrumental) Method**
Alkalinity	water	16/Mar 2023 10/April 2023 10/Sept 2023	30 - 500mg/L	10 mg/L	unfiltered	titration
Chloride	water	Same as alkalinity	0 - 50 mg/L	0.1 mg/L	filtered	IC, EPA 300.1
Fluoride	water	Same as alkalinity	0 - 10 mg/L	0.1 mg/L	filtered	IC, EPA 300.1
Sulfate	water	Same as alkalinity	0 - 50 mg/L	0.5 mg/L	filtered	IC, EPA 300.1
Nitrate-N	water	Same as alkalinity	0 - 20 mg/L	0.1 mg/L	filtered	IC, EPA 300.1
Phosphate-P	water	Same as alkalinity	0 - 5 mg/L	0.05 mg/L	filtered	IC, EPA 300.1
Calcium	water	Same as alkalinity	0 - 100 mg/L	0.05 mg/L	filtered	IC, EPA 300.1
Magnesium	water	Same as alkalinity	0 - 50 mg/L	0.05 mg/L	filtered	IC, EPA 300.1
Potassium	water	Same as alkalinity	0 - 50 mg/L	0.05 mg/L	filtered	IC, EPA 300.1
Sodium	water	Same as alkalinity	0 - 100 mg/L	0.05 mg/L	filtered	IC, EPA 300.1

Analyte	Sample Matrix	Samples (Number/ Arrival Date)	Expected Range of Results*	Detection Limit	Sample Prep Method	Analytical (Instrumental) Method**
Aluminum	water	Same as alkalinity	0 - 50 ppb	0.34 ppb	filtered, acidified	ICP-MS, EPA 200.8
Vanadium	water	Same as alkalinity	0 - 50 ppb	0.02 ppb	filtered, acidified	ICP-MS, EPA 200.8
Chromium	water	Same as alkalinity	0 - 10 ppb	0.21 ppb	filtered, acidified	ICP-MS, EPA 200.8
Manganese	water	Same as alkalinity	0 - 50 ppb	0.11 ppb	filtered, acidified	ICP-MS, EPA 200.8
Iron	water	Same as alkalinity	0 - 100 ppb	1.0 ppb	filtered, acidified	ICP-MS, EPA 200.8
Nickel	water	Same as alkalinity	0 - 50 ppb	0.33 ppb	filtered, acidified	ICP-MS, EPA 200.8
Copper	water	Same as alkalinity	0 - 50 ppb	0.27 ppb	filtered, acidified	ICP-MS, EPA 200.8
Zinc	water	Same as alkalinity	0 - 1000 ppb	0.50 ppb	filtered, acidified	ICP-MS, EPA 200.8
Arsenic	water	Same as alkalinity	0 - 10 ppb	0.31 ppb	filtered, acidified	ICP-MS, EPA 200.8
Molybdenum	water	Same as alkalinity	0 - 10 ppb	0.10 ppb	filtered, acidified	ICP-MS, EPA 200.8
Barium	water	Same as alkalinity	0 - 500 ppb	0.38 ppb	filtered, acidified	ICP-MS, EPA 200.8
Lead	water	Same as alkalinity	0 - 10 ppb	0.15 ppb	filtered, acidified	ICP-MS, EPA 200.8
Uranium	water	Same as alkalinity	0 - 10 ppb	0.08 ppb	filtered, acidified	ICP-MS, EPA 200.8
Oxygen-18	water	Same as alkalinity	–5 to–25‰	NA	filtered	CRS
Deuterium	water	Same as alkalinity	–30 to –170‰	NA	filtered	CRS
E. coli	water	10/April 2023 10/Sept 2023	10-1000 CFU/ 100 mL	1 CFU/ 100mL	EDTA	SM9222D9222G
Sediment size distribution	water	10/April 2023 10/Sept 2023	NA	NA	none	PSA

Analyte	Sample Matrix	Samples (Number/ Arrival Date)	Expected Range of Results*	Detection Limit	Sample Prep Method	Analytical (Instrumental) Method**
Fecal coliform	water	Same as E. coli	10-1000 CFU/ 100 mL	1 CFU/ 100mL	EDTA	SM9222D
TSS	water	Same as E. coli	0-500 mg/L	1.0 mg/L	none	SM2540D
Turbidity	water	Same as E. coli	0-60 NTU	0.05 NTU	none	EPA 180.1
Nitrate/Nitrite	water	Same as E. coli	0-30 mg/L	0.02 mg/L	H2SO4	EPA 353.2
TKN	water	Same as E. coli	0-30 mg/L	0.25 mg/L	H2SO4	EPA 351.2
Total P	water	Same as E. coli	0-2 mg/L	0.005 mg/L	H2SO4	SM4500PF
Ammonia	water	Same as E. coli	0-2 mg/L	0.02 mg/L	H2SO4	EPA 350.1
DOC	water	Same as E. coli	0-30 mg/L	0.5 mg/L	Zero headspace vial, H2SO4	SM5310B
TOC	water	Same as E. coli	0-50 mg/L	0.5 mg/L	Zero headspace vial, H2SO4	SM5310B
Endothall	water	2/ April 2023 2/Sept 2023	0-20 mg/L	3 mg/L	EPA 3510/3520	EPA 548.1
Acrolein	water	Same as Endothall	0-20 mg/L	5 mg/L	EPA 3510/3520	EPA 624.2
Pesticides/PCBs	water	Same as Endothall	0-2.0 mg/L	0.1 mg/L	EPA 3510/3520	EPA 608

* Treatment of measurements below detection limits is discussed in section 14.2 (Treatment of Non-Detects)

** IC= ion chromatography; ICP-MS = inductively coupled plasma mass spectrometry; CRS = cavity ring-down spectroscopy; PSA = particle size analysis

The laboratory equipment and instrumentation that will be used in these analyses are:

Ion chromatograph – Thermo Scientific Dionex ICS-5000+ IC
Inductively-coupled plasma mass spectrometer – Agilent 8900 Triple Quad (QQQ) ICP-MS
Inductively-coupled plasma optical emission spectrometer – Agilent 8100 ICP-OES
Cavity ring down spectroscope – Picarro L2130-I Isotopic H2O Analyser
Mastersizer 3000 particle size analyzer

In most cases, there is alternative instrumentation to perform each type of analyses in cases where equipment or instrumentation are malfunctioning.

9.2 Sample preparation method(s)

For major ion and trace element analyses, two samples are collected, one for cations plus trace elements and one for anions. Both samples are filtered in the field using a clean 60-ml polypropylene syringe connected to a 0.45-micron polypropylene filter. The cation sample is placed in a 60 ml acid-washed high-density polyethylene (HDPE) bottle. The anion sample is placed in a clean 60 ml HDPE bottle that has not been acid washed.

For stable isotope analysis water sample is collected directly into a clean, dry 30 mL HDPE bottle, filling it almost to the top, and capping it tightly. The main objective is to protect the sample from evaporation and exchange with atmospheric water vapor. Samples need not be filtered unless they contain abundant particulate matter. Samples are stored at ambient temperature in the Stable Isotope Laboratory at CWU.

For surface water samples, four additional samples will be collected for water quality measurements made at AmTest Laboratory: 1) 250 mL autoclaved polypropylene bottle with added EDTA for bacterial sampling; 2) 500 mL polypropylene bottle with no preservation for TSS and Turbidity analysis; 3) 250 mL polypropylene bottle for nutrient analyses, acidified with H_2SO_4; 4) 40 mL bottle, acidified with H_2SO_4 and with zero head space for TOC, DOC analyses. 5) 1 L amber bottles will be used to collect four samples for pesticide analysis with no filtration or preservative added. For all surface water samples, a 250 mL bottle will be filled with unfiltered sample for sediment size analysis.

In the laboratory at CWU, SOPs in accordance with the methods in Table 16 are used for sample preparation and analysis. Cation/trace element samples are acidified with 2% ultrapure nitric acid prior to analysis. Prior to sediment size analysis, Calgon, a dispersing agent, is added to the surface water sample, to deflocculate sediment samples.

9.3 Special method requirements

Not applicable.

9.4 Laboratories accredited for methods

The Central Washington University Chemistry Department, through Dr. Anne Johansen, is accredited for major ion analyses. Documentation for that certification is provided in Appendix B. Stable isotope analyses is a specialized type of geochemical analysis that does not have EPA accreditation criteria. Dr. Gazis's laboratory in the Geological Sciences Department has been performing this type of analyses for over twenty years, including over 350 analyses for an Ecology-funded project in the Columbia Basin Groundwater Management Area (Vlassopoulos, 2008). Trace element analysis will be performed on a 5-year-old state-of-the-art inductively coupled plasma mass spectrometer (ICP-MS), which has a triple quadrupole (QQQ) detection system. Central Washington University is in the process of seeking accreditation for trace element analyses. We will use standard EPA methods (EPA method 200.8) on these analyses and include similar QA/QC procedures to those used in our accredited major ion analyses. If possible, a subset of the samples will be sent to an accredited laboratory for trace element analysis. If not, trace element analyses will be used qualitatively and will not be entered into the EIM database.

Other water quality analyses will be performed at AmTest Laboratory in Kirkland, WA or an equivalent accredited laboratory. For coliform analysis, which has a short holding time, we will hand deliver the samples immediately to an accredited laboratory, preferably one in the Yakima area.

10.0 Quality Control Procedures

The quality control procedures for field and laboratory measurements are outlined in the sections above. Field notebooks and field data will be reviewed after each sampling trip. During pump testing, Bob Anderson will meet daily with Bethany Kharrazi to review well testing procedures and results. Laboratory results will be reviewed immediately to ensure that quality control standards are within accepted range and that there are no problems with the blanks, duplicates, or matrix spikes. For water chemistry/quality data, the principal investigator will meet weekly with Bailey Hillard to review quality control results and discuss any problems that have arisen. For quality control of field data, pumping test results and procedures will be reviewed daily with Bethany Kharrazi and any field assistants.

10.1 Table of field and laboratory quality control

Table 17 shows a plan for frequency and types of quality control samples. Each parameter also has MQOs associated with it that will be used to evaluate the quality and usability of the results.

Table 17. Quality control samples, types, and frequency.

Parameter	Field Blanks	Field Replicates	Laboratory Check Standards	Laboratory Method Blanks	Analytical Duplicates	Laboratory Matrix Spikes
pH	NA	1/15	1/12	NA	1/6	NA
conductivity	NA	1/15	1/12	NA	1/6	NA
DO	NA	1/15	1/12	NA	1/6	NA
Alkalinity	NA	1/15	1/12	NA	1/6	NA
Chloride	1/15	1/15	1/6	1/12	1/6	1/20
Fluoride	1/15	1/15	1/6	1/12	1/6	1/20

Parameter	Field Blanks	Field Replicates	Laboratory Check Standards	Laboratory Method Blanks	Analytical Duplicates	Laboratory Matrix Spikes
Sulfate	1/15	1/15	1/6	1/12	1/6	1/20
Nitrate-N	1/15	1/15	1/6	1/12	1/6	1/20
Phosphate-P	1/15	1/15	1/6	1/12	1/6	1/20
Calcium	1/15	1/15	1/6	1/12	1/6	1/20
Magnesium	1/15	1/15	1/6	1/12	1/6	1/20
Potassium	1/15	1/15	1/6	1/12	1/6	1/20
Sodium	1/15	1/15	1/6	1/12	1/6	1/20
Aluminum	1/15	1/15	1/6	1/12	1/6	1/20
Vanadium	1/15	1/15	1/6	1/12	1/6	1/20
Chromium	1/15	1/15	1/6	1/12	1/6	1/20
Manganese	1/15	1/15	1/6	1/12	1/6	1/20
Iron	1/15	1/15	1/6	1/12	1/6	1/20
Nickel	1/15	1/15	1/6	1/12	1/6	1/20
Copper	1/15	1/15	1/6	1/12	1/6	1/20
Zinc	1/15	1/15	1/6	1/12	1/6	1/20
Arsenic	1/15	1/15	1/6	1/12	1/6	1/20
Molybdenum	1/15	1/15	1/6	1/12	1/6	1/20
Barium	1/15	1/15	1/6	1/12	1/6	1/20
Lead	1/15	1/15	1/6	1/12	1/6	1/20
Uranium	1/15	1/15	1/6	1/12	1/6	1/20
Oxygen-18	NA	1/15	1/6	NA	1/6	NA
Deuterium	NA	1/15	1/6	NA	1/6	NA
E. coli	1/15	1/15	NA	NA	NA	NA
Fecal coliform	1/15	1/15	NA	NA	NA	NA

Parameter	Field Blanks	Field Replicates	Laboratory Check Standards	Laboratory Method Blanks	Analytical Duplicates	Laboratory Matrix Spikes
TSS	1/15	1/15	NA	NA	1/15	NA
Turbidity	1/15	1/15	NA	NA	1/15	NA
Nitrate/Nitrite	1/15	1/15	>1/batch	>1/batch	1/15	1/20
TKN	1/15	1/15	>1/batch	>1/batch	1/15	1/20
Total P	1/15	1/15	>1/batch	>1/batch	1/15	1/20
Ammonia	1/15	1/15	>1/batch	>1/batch	1/15	1/20
DOC	1/15	1/15	>1/batch	>1/batch	1/15	1/20
TOC	1/15	1/15	>1/batch	>1/batch	1/15	1/20
Sediment size distribution	NA	1/15	NA	NA	1/5	NA
Endothall	NA	NA	>1/batch	>1/batch	NA	NA
Acrolein	NA	NA	>1/batch	>1/batch	NA	NA
Pesticides/PCBs	NA	NA	>1/batch	>1/batch	NA	NA

10.2 Corrective action processes

For water level measurements, manual measurements will be compared to pressure transducer measurements whenever possible, ideally four times prior to pump tests as well as during and after the pump test. The pressure transducers will be equipped with a communication cable so that water levels can be continuously monitored. This check will ensure that the pressure transducer is properly calibrated and doesn't experience any drift. During the pump tests, water level measurements will not be made frequently because of the need to remove the pressure transducer to make a manual measurement. Data will be downloaded periodically and compared to predicted values as well as the most recent manual measurement. If the water level data is at all suspect, the transducer will be removed and a manual water level measurement will be made. If the manual water level does not agree with the pressure transducer data, a replacement pressure transducer will be installed if possible. If this is not possible, water levels will be measured manually throughout the remainder of the pump test. For the 24-hour pump test, this might involve moving pressure transducers between wells to ensure that the most important wells are outfitted with a working transducer.

If there is a problem with a single sample or a set of samples, a series of steps will be taken to correct any faulty data:

- A series of standards and blanks will be run through the instrument to ensure that it is operating and calibrated properly.
- If there is a problem with the instrument, the instrument technicians at CWU will help with any troubleshooting to solve the problem.
- Once the instrument is operating properly, the samples will be rerun and checked again for quality of analysis.
- If necessary, samples will be recollected in the method described in this QAPP.

11.0 Data Management Procedures

11.1 Data recording and reporting requirements

All field data will be recorded in a field notebook. Field notebooks will be checked for missing or improbable measurements before leaving each site. Field-generated data will be entered into Excel spreadsheets as soon as practical after returning from the field. Data entry will be checked by the field assistant against the field notebook data for errors and omissions. Missing or unusual data will be brought to the attention of the project manager for consultation.

Laboratory generated data will be managed by the Laboratory Information Management Systems (LIMS) at CWU and backed up on the Geological Sciences department's server. In addition to sample results, the laboratory data package will include all relevant QC results needed for data validation. Following evaluation of the analytical data against the project data quality objectives, the investigators will incorporate the results into a master Excel spreadsheet database. For each sample, the spreadsheet database will record station identification, coordinates, sampling date, and associated field and laboratory analytical data. The documentation for each sampling location will include the completed field notebook (log) entry, a copy of the analytical results, as well as analytical results for associated field and laboratory QC samples. Full documentation for all samples will be compiled and stored at the investigator's office at CWU. At the end of the project, the data will be uploaded to the Department of Ecology's EIM database using Study ID: CWURRASR_001.

Results of quality control checks and calibrations will be recorded on electronic forms to allow for quality assurance review. Quality assurance records will be saved on CWU computers until Ecology's final approval of the project report so they may be accessed for post-project analysis and audits.

11.2 Laboratory data package requirements

The laboratory data generated at CWU will initially be transferred into an Excel workbook and sorted into the following worksheets:

1. Raw data
2. Results for calibration standards and calibrations
3. Results for QC standards with graph of results with time and comparison to quality control thresholds
4. Results of other QC samples (duplicates, matrix spikes, etc.) and comparison with expected values
5. Results for unknowns (samples)

For externally run samples, the laboratory will provide a cover narrative along with the detailed results in an electronic data deliverable (EDD). They will also be required to provide all relevant quality control data.

11.3 Electronic transfer requirements

The laboratory EDD transferred from an external laboratory will be requested in a readily usable format (e.g., Microsoft Excel) to minimize data entry problems when transferring data.

11.4 Data upload procedures

Data will be transferred to Ecology’s EIM system, using Study ID: CWURRASR_001, annually per online submittal guidelines. The EIM data coordinator will be consulted if data submittal problems arise. Bailey Hillard or another CWU student will complete EIM training offered by Ecology and follow all existing Ecology business rules and the EIM User’s Manual for loading, data quality checks, and editing.

11.5 Model information management

Not applicable.

12.0 Audits and Reports

12.1 Audits

Not applicable.

12.2 Responsible personnel

Not applicable.

12.3 Frequency and distribution of reports

The data collected under this project will be summarized in a formal report that includes results, methods, data quality assessment, and data analysis. This final report will be submitted by October 2023. It will be an extension of an existing technical report that was previously submitted for a prior phase (Task 2) of this project (Geosyntec, 2022). That report describes the hydrogeologic framework of the project area and existing information regarding groundwater in the study area. The final report will also include the presentation of the new data described in this QAPP and an overall analysis of the potential for MAR in the study area.

12.4 Responsibility for reports

Bob Anderson (Geosyntec) will be the lead author of the final report with assistance from Brian Webb at Geosyntec, Carey Gazis at CWU, and Chris Pitre and Sherry Wilhelm from Coho Water Resources. CWU graduate students Bethany Kharrazi and Bailey Hillard will each contribute to sections of the report.

13.0 Data Verification

All data collected is subject to review by the principal investigator and lead collaborators to determine if the data meets QAPP objectives. Decisions to reject or qualify data are made by the principal investigator in conjunction with the other investigators. Data may be rejected because of inadequate or deficient documentation or because the QC sample results fail to meet the MQOs identified in Section 4.

13.1 Field data verification, requirements, and responsibilities

Field personnel will review data recorded in field notebooks for correctness, clarity and completeness at the end of each sampling day. Field data will also be verified to ensure MQOs described within this QAPP have been met.

13.2 Laboratory data verification

Prior to delivery to the principal investigator, all laboratory data will undergo a quality assurance review by Bailey Hillard to verify that laboratory quality control samples met acceptance criteria as specified in the laboratory's standard operating procedure for that method. Appropriate qualifiers will be attached to results that do not meet requirements. An explanation for the data qualification will be attached with the data package.

13.3 Validation requirements, if necessary

Not applicable.

13.4 Model quality assessment

Not applicable.

13.4.1 Calibration and validation

Not applicable.

13.4.1.1 Precision

Not applicable.

13.4.1.2 Bias

Not applicable.

13.4.1.3 Representativeness

Not applicable.

13.4.1.4 Qualitative assessment

Not applicable.

13.4.2 Analysis of sensitivity and uncertainty

Not applicable.

14.0 Data Quality (Usability) Assessment

14.1 Process for determining project objectives were met

The first means of evaluating the quality of pump test water level data is the comparison between manual measurements and pressure transducer measurements. If multiple measurements are in disagreement and no explanation is found, the transducer data will be discarded. Thus, transducer data that does not meet MQOs will not be used. Ideally, any such transducer data problem will be identified in the field and the transducer can be restarted or replaced. In the 24-hour pump tests, there are several monitoring wells associated with each pumping well. With this design, if one pressure transducer fails, there will still be water level data from multiple observation wells.

Upon receipt of the verified laboratory data, the principal investigator will determine if the results meet the MQOs for bias, precision, and accuracy for that sampling episode. Precision will be estimated by calculating the relative percent difference (RPD) between results for duplicate pairs. These values provide an indication of the degree of random variability introduced by sampling and analytical procedures. These values will be compared to the mean duplicate concentration (over the entire concentration range reported during the project) to assess the ability of the data to meet the project measurement quality objectives. The RPD for duplicate pairs at or near the reporting limit is typically higher than the allowed error described by the MQOs but small in absolute terms and will therefore not automatically result in rejection of the data. Analytical bias is assumed to be within acceptable limits if laboratory quality control limits are met for blanks, matrix spikes, and check standards. Sampling bias will be checked by verifying that the correct sampling and handling procedures were used, and review of analytical results for field blank samples.

14.2 Treatment of non-detects

When a chemical constituent is not detected, it will be entered as “ND” on the data table. This value will be converted to half of the detection limit for purposes of graphing and statistical analyses when necessary.

14.3 Data analysis and presentation methods

Pump test data analysis will follow guidelines provided in Ecology (2020). Pressure transducer data will be corrected for atmospheric pressure contribution and plotted as hydrographs showing water level versus time for each of the pump tests. Flow rate and temperature will also be plotted versus time. Stepped pump tests will be used to determine the specific capacity of the well, calculated by dividing the pumping rate by the change in head for each step (Fetter, 2001). The well efficiency, 60 to 80% of the specific capacity, will also be determined (Heath, 1983).

For the 24-hour pump tests, pumping well and monitoring hydrographs will be made as separate plots and as a single plot for each well field. Drawdown data will be compared to analytical pump-test models using open-source spreadsheets available from the USGS (Halford and Kuniansky, 2016). If the flow regime is complex, a commercial software (e.g., AQTESOLV) with a library of analytical models will be used to interpret the drawdown curves. In this analysis, multiple possible flow regimes will be assessed (e.g., confined versus leaky confined aquifer, different boundary conditions). Derivative analysis will also be used to support flow regime identification.

Geochemical data will be analyzed by a variety of means. To obtain a first-order view of geochemical variations, major ion data will be plotted on Piper diagrams and Stiff plots; stable isotope data will be displayed on a plot of delta-18O versus delta-D. A matrix scatter plot will be examined to find first order correlations between variables. Based on that result, simple x-y plots of data pairs will be examined to quantify correlations between variables and any clustering among samples. In this way, distinct hydrochemical facies can be identified as well as any evidence for surface water infiltration into basalt aquifers. This analysis will also provide a measure of the range of groundwater and surface water chemistries that might be encountered in future ASR projects in this region.

Interactions between source water (canal water) and groundwater/aquifer system will be assessed by calculating the thermodynamic equilibrium for the water mixture and the water-rock system, using the range of observed values. This will be done using Geochemist's Workbench, a commercially available software with this capability, and with PHREEQ, a free software provided by the USGS. The analysis is used to determine the thermodynamically stable phase. It does not determine the rates of reactions, which are dependent on kinetic factors. This analysis will be used to assess whether any adverse reactions (e.g., precipitation of minerals, dissolution of matrix material) might be expected in an ASR system.

General water quality data (bacteria, nutrients, sediment load, pesticides) will be analyzed along with existing water quality data that is available from the Sunnyside-Roza Board of Joint Control (SRBOJC), which oversees water quality measurement and compliance for both Roza and Sunnyside Irrigation Districts. Data available from SRBOJC includes measurements of E. coli in the Roza Canal at five locations every three weeks during the irrigation season, measurements of turbidity near the canal intake every three weeks, and a range of basic water quality measurements towards the end of effluent channels into the Yakima River. These represent composite waters from both Roza and Sunnyside Irrigation Districts. SRBOJC also has records of herbicide application amounts and timing. Our new water quality data will be combined with all available data for the past five years in order to create a picture of the overall quality of Roza Canal water, how it varies spatially and with time. Any pollutants of concern will be identified.

14.4 Sampling design evaluation

The sampling design targets nine wells for pump testing and 15 groundwater wells and five surface water sampling sites. The project manager, with assistance from her collaborators, will decide whether the data package meets MQOs including criteria for completeness and representativeness. The goal is to assess the potential for aquifer storage throughout the study region by testing multiple wells within the same unit (Wanapum) to obtain a measure of the variability within the region. The sample size was chosen to fit within the project budget and to provide enough measurements that any outliers, either in aquifer properties or in water chemistry, would be distinguishable.

14.5 Documentation of assessment

The final technical report will include a section summarizing the findings of the data quality assessment.

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16.0 Appendices

Appendix A. Well Details

Appendix B. Laboratory Certification Documentation

Appendix C. Glossaries, Acronyms, and Abbreviations

Appendix A. Well Details

This appendix gives additional details and well logs for the wells that have been identified for pump tests and water quality analysis. The 24-hour pump tests will be clustered in two areas, the Konnowac Pass area and an area on the south side of Rattlesnake Ridge (see Figure 2).

There are four well owners, referred to here as Well Owners A, B, C, and D, involved in the planned pump tests. Well owner access agreements have been arranged.

Well Owner A: Two wells belonging to Well Owner A are targeted as pump-test wells (Nilsson and Greenhouse) and an additional well (Meacham) is designated as an alternate well. These wells are in the Konnowac Pass area cluster. Well completion information is summarized below and logs are provided at the end of this Appendix.

	Roy/Charron Area		
	Roy G4-29893 (Meacham)	**Roy G4-31681 (Nilsson/South)**	**Roy G4-29667P (Greenhouse)**
Latitude	46.52342	46.5244	46.53207
Longitude	-120.29553	-120.27513	-120.29372
Surface elevation (CHECK THESE)	1403	1339	1224
Total depth	2802	2100	2802
Casing/seal depth	1811	1460	942
Completion top (elevation)	-408	-121	282
Bottom Elevation	-1399	-761	-1578
Open inteval (feet)	991	640	1860
Completion formation	Wanapum	Wanapum	Wanapum
WL Depth at completion	215	87	201
WL Elev at completion	1188	1252	1023
11/17/2022 WL Depth	329	235	No Access
WL Change	-114	-148	
11/17/2022 WL Elev	1074	1104	
Pump depth setting	TBD	TBD	TBD
Access port notes	Access via angle port on wellhead footing. High risk of transducer hang up with airline at 50 ft. Fouling of water-level tape	Access via angle port on wellhead footing. WL access was smooth.	Existing port cannot accept transducer or WL probe
Flow meter notes	No Flow meter. Complex piping. Clamp-on meter likely not feasible.	Flow meter in place	No flow meter. Conventional or clamp on meter possible.
Well Appurtenance Requirements	Remove from Test Plan	Access port modifications recommended but not mandatory.	Install new access port. Install new flow meter.
Testing Plan		Step test + 24 Hr Test	Step Test Only. Monitor during Nillson Test

Well Owner B: Two wells from Well Owner B are targeted for pump tests: Charron #1 and Charron #2. These wells are in the Konnowac Pass area cluster. Well completion information is summarized below and logs are provided at the end of this Appendix.

	Roy/Charron Area	
	Charron #1	**Charron #2**
Latitude	46.52224	46.53388
Longitude	-120.2604	-120.2658
Surface elevation (CHECK THESE)	1280	1280
Total depth	2105	1105
Casing/seal depth	1248	570
Completion top (elevation)	32	710
Bottom Elevation	-825	175
Open inteval (feet)	857	535
Completion formation	Wanapum	Wanapum
WL Depth at completion	280	210
WL Elev at completion	1000	1070
11/17/2022 WL Depth	No Access	284
WL Change		-74
11/17/2022 WL Elev		996
Pump depth setting	TBD	TBD
Access port notes	Access via angle port on wellhead footing. Access blocked at 22 ft	Access via angle port on wellhead footing. WL access was smooth.
Flow meter notes	No flow meter. Conventional or clamp on meter possible.	No Flow meter. Piping goes underground right at wellhead. Clamp-on meter likely not feasible. Consider flow monitoring at discharge area.
Well Appurtenance Requirements	Install new access port. Install rental sonic meter. Conduct step test. Monitor 24 Hr test.	Access port modifications recommended but not mandatory.
Testing Plan	Step Test Only. Monitor during other tests. Consider 24-hour test if feasible.	Step Test Only. Monitor during other testing.

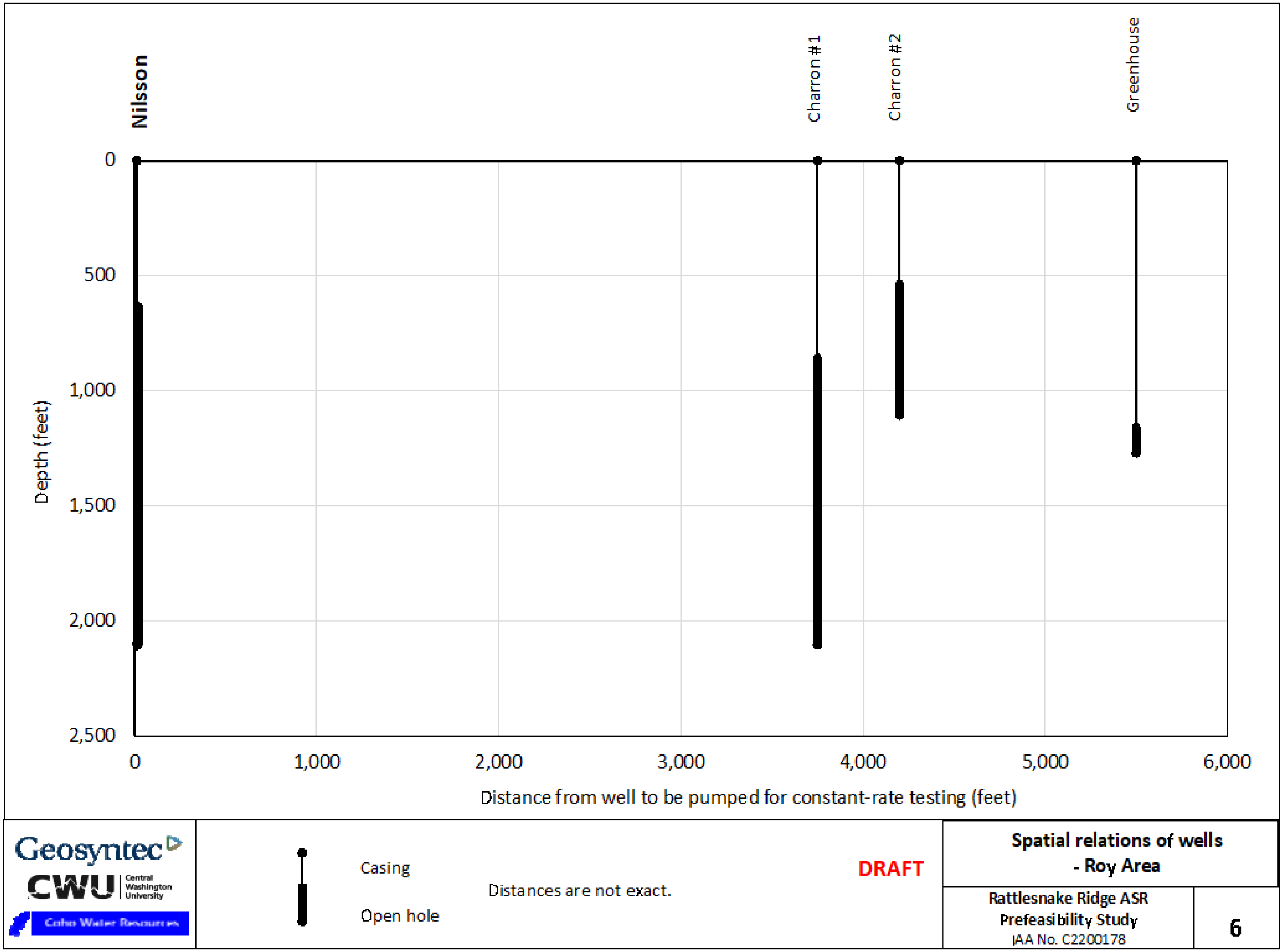
Well Owner C: Four wells from Well Owner C are targeted for a pump tests: Flavorland, Block 24, Yakima Fruit, and North 89. These wells are in the Rattlesnake Ridge cluster. Well completion information is summarized below and logs are provided at the end of this Appendix.

	Evans Wellfield			
	Flavorland	**Yakima**	**Block 24**	**North 80**
Latitude	46.39685	46.403333	46.407586	46.400703
Longitude	-120.01965	-120.020786	-120.021331	-120.037272
Surface elevation (CHECK THESE)	1160	1265	1205	1160
Total depth	3500	1105	1568	1000
Casing/seal depth	1900	712	620	740
Completion top (elevation)	-740	553	585	420
Bottom Elevation	-2340	160	-363	160
Open inteval (feet)	1600	393	948	260
Completion formation	Grand Ronde	Wanapum	Wanapum	Wanapum
WL Depth at completion	380	587	520	388
WL Elev at completion	780	678	685	772
7/2022 WL Depth (751 means >750)	732	751	NA	751
WL Change	-352	-164		-363
11/17/2022 WL Elev	428	514		409
Pump depth setting	TBD	TBD	TBD	TBD
Date of Original pumping test	1993	1981		1981
Rate (gpm)	Unknown	2420	Unknown	2400
Drawdown (feet)		13		181
Access port notes	Access via angle port on wellhead footing. WL access was smooth.	Access via thread port on wellhead. WL access was smooth to 750	Access via threded port on wellhead. Existing port cannot accept transducer or WL probe	Access via thread port on wellhead. High risk of transducer hang up a 300 ft
Flow meter notes	Flow meter in place	No flow meter. Adequate straight run for inline or clamp-on meter	No Flow meter. Short pipe run from wellhead to underground. Clamp-on meter likely not feasible. Consider flow monitoring at discharge area or excavation.	No Flow meter. Short pipe run to filters, then underground. Clamp-on meter likely not feasible. Consider flow monitoring at discharge area or excavation downstream of filters.
Well Appurtenance Requirements	Access port modifications recommended but not mandatory.	Access port modifications recommended but not mandatory. Flow meter required.	Access port modifications required. Flow meter required.	Access port modifications required. Flow meter required.
Testing Plan	Conduct step-test. Monitor 24 Hr test.	Conduct step-test. Monitor 24 Hr test.	Conduct step-test. Conduct 24 hour test.	Conduct step-test. Monitor 24 Hr test.

Well Owner D: Well Owner D has one well, AHP-776, that will be tested and monitored in this study. That well is located approximately three miles east of the Rattlesnake Ridge cluster. Well completion information is summarized in Table 18 and a log is provided at the end of this Appendix.

Table 18 Well AHP 776 information.

	AHP776
Latitude	46.3053
Longitude	-119.8142
Elevation (feet)	1277
Total depth (feet)	1718
Casing/seal depth (feet)	725
Completion top (elevation in feet)	552
Bottom Elevation (feet)	-441
Open interval (feet)	993
Completion formation	Wanapum
WL Depth at completion (feet)	531
WL Elev at completion (feet)	746
Pump depth setting (feet)	TBD
Date of Original pumping test	NA
Rate (gpm)	NA
Drawdown (feet)	NA
Access port notes	Access via threaded port on wellhead. Owner will modify to accept transducer
Flow meter notes	Existing flow meter, cannot adjust rate
Well Appurtenance Requirements	Modify access port. Flow meter is fine
Testing Plan	Monitor during testing, backup well for 24-hour pump test
distances in feet	



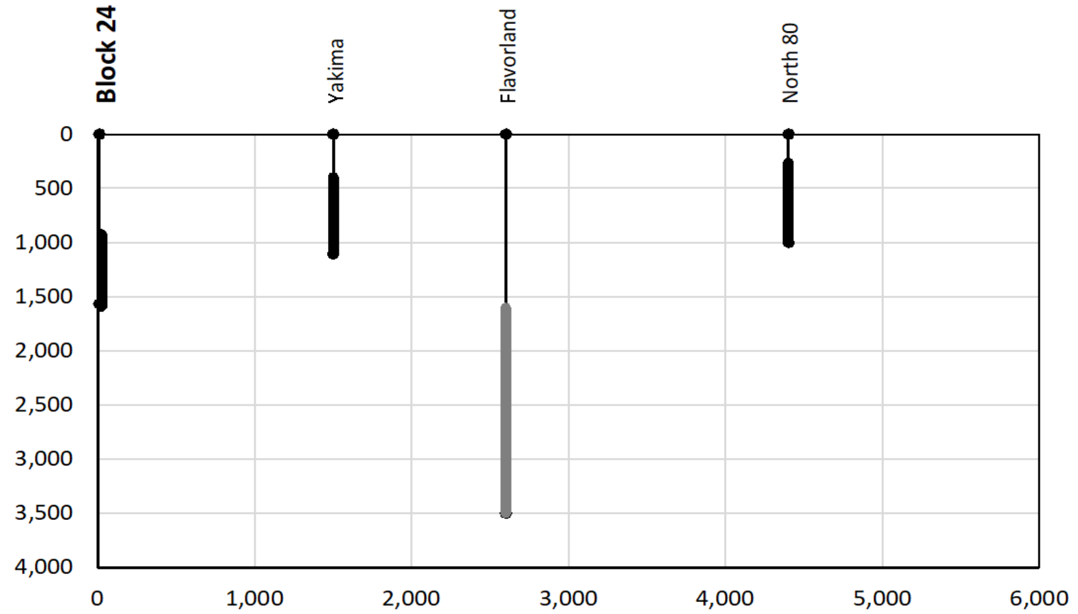
Updated Well Table with Field Notes (2022-11-22 cvp).xlsx (2022-12-05)

Coho Water Resources

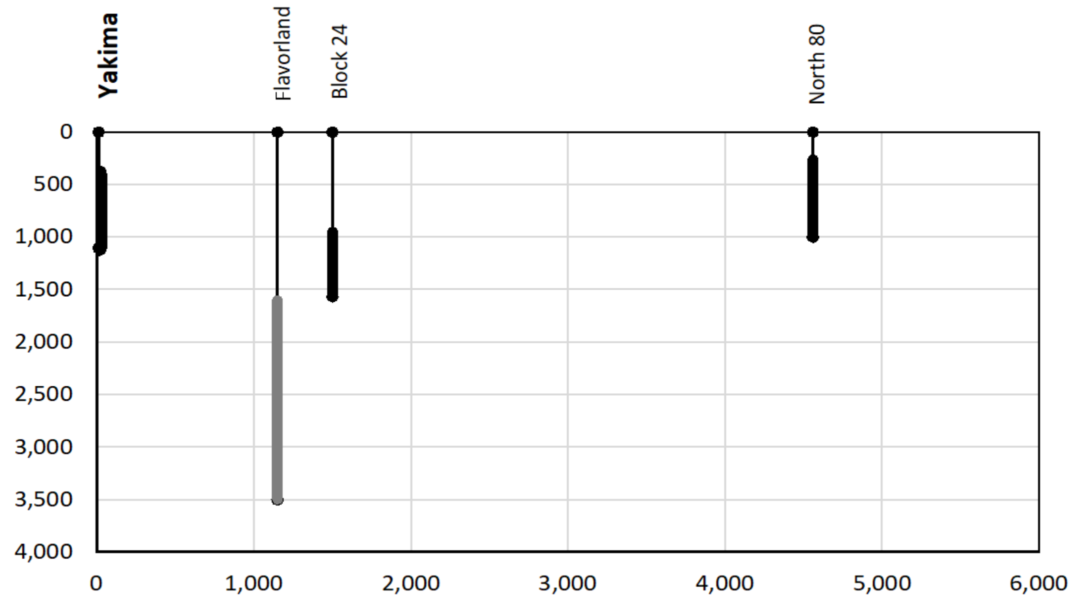
Figure 7 Schematic cross sections showing distances between pumping and monitoring wells, and well depths.

Screened intervals are shown in the following figures

a) BLOCK 24 focus



b) YAKIMA focus



Geosyntec CWU Central Washington University Coho Water Resources

Casing

Distances are not exact.

DRAFT

Spatial relations of wells - Evans Area.

Rattlesnake Ridge ASR Prefeasibility Study

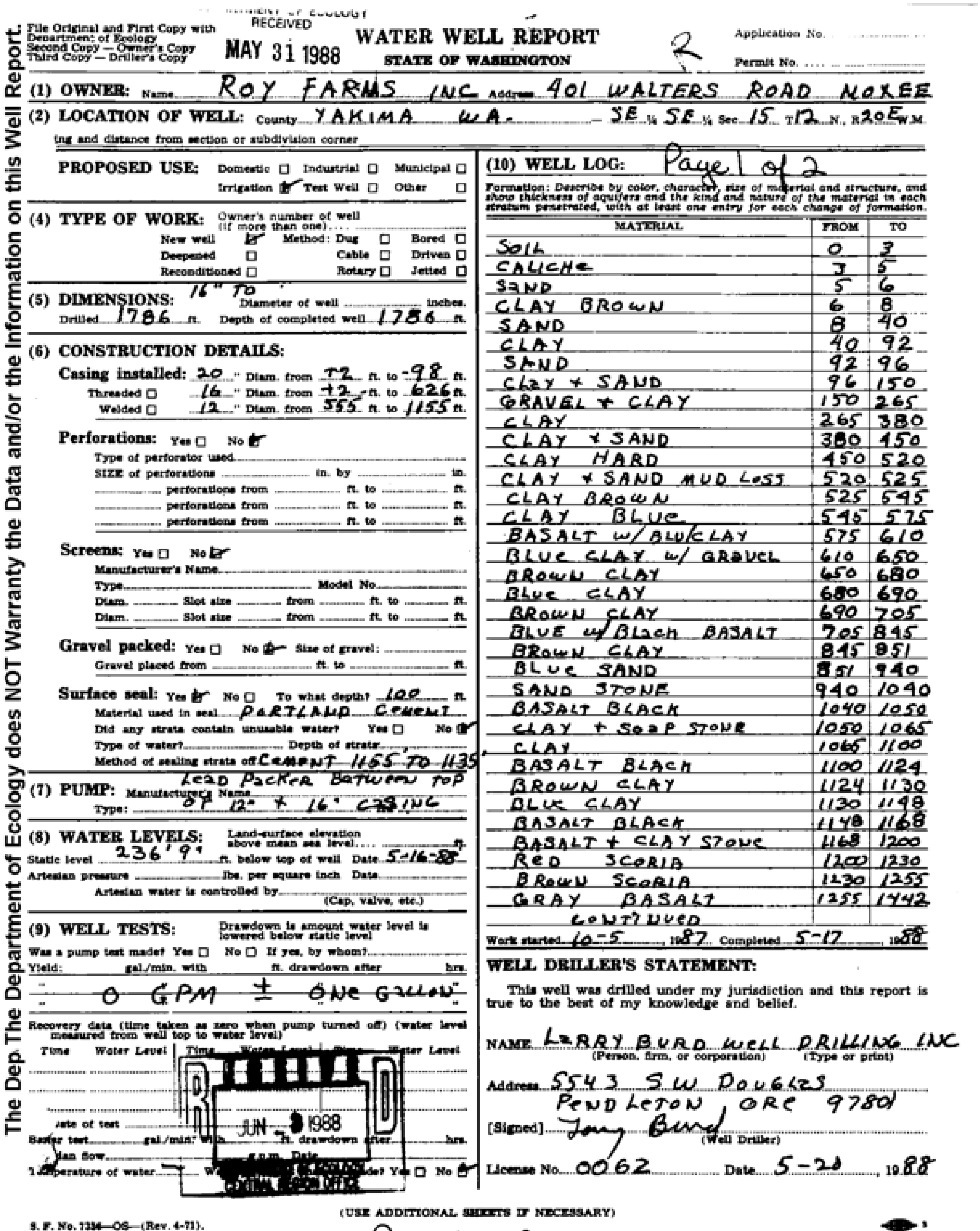
IAA No. C2200178

7

Updated Well Table with Field Notes (2022-11-22 cvp).xlsx (2022-12-05)

Coho Water Resources

Meacham Well (pg 1)



The Dep. The Department of Ecology does NOT Warranty the Data and/or the Information on this Well Report.

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

DEPARTMENT OF ECOLOGY
RECEIVED
MAY 31 1988

WATER WELL REPORT
STATE OF WASHINGTON

2

Application No.
Permit No.

(1) OWNER: Name ROY FARMS INC Address 401 WALTERS ROAD MOXEE

(2) LOCATION OF WELL: County YAKIMA WA. — SE ¼ SE ¼ Sec. 15 T 12 N., R 20E W.M.
ing and distance from section or subdivision corner

PROPOSED USE: Domestic ☐ Industrial ☐ Municipal ☐ Irrigation ☑ Test Well ☐ Other ☐

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

(5) DIMENSIONS: Diameter of well 16" TO inches.
Drilled 1786 ft. Depth of completed well 1786 ft.

(6) CONSTRUCTION DETAILS:
Casing installed: 20" Diam. from +2 ft. to -98 ft.
Threaded ☐ 16" Diam. from +2 ft. to 626 ft.
Welded ☐ 12" Diam. from 555 ft. to 1155 ft.

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

Screens: Yes ☐ No ☑
Manufacturer's Name
Type Model No.
Diam. Slot size from ft. to ft.
Diam. Slot size from ft. to ft.

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

Surface seal: Yes ☑ No ☐ To what depth? 100 ft.
Material used in seal PARTLAND CEMENT
Did any strata contain unusable water? Yes ☐ No ☑
Type of water? Depth of strata
Method of sealing strata off CEMENT 1155 TO 1135 LEAD PACKER BETWEEN TOP OF 12" + 16" CASING

(7) PUMP: Manufacturer's Name
Type:

(8) WATER LEVELS: Land-surface elevation above mean sea level ft.
Static level 236' 9" ft. below top of well Date 5-16-88
Artesian pressure lbs. per square inch Date
Artesian water is controlled by (Cap, valve, etc.)

(9) WELL TESTS: Drawdown is amount water level is lowered below static level
Was a pump test made? Yes ☐ No ☐ If yes, by whom?
Yield: gal./min. with ft. drawdown after hrs.
" 0 GPM ± ONE GALLON "

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

Time	Water Level	Time	Water Level	Time	Water Level

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JUN 3 1988
DEPARTMENT OF ECOLOGY
CENTRAL REGION OFFICE

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

(10) WELL LOG: Page 1 of 2

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	3
CALICHE	3	5
SAND	5	6
CLAY BROWN	6	8
SAND	8	40
CLAY	40	92
SAND	92	96
CLAY + SAND	96	150
GRAVEL + CLAY	150	265
CLAY	265	380
CLAY + SAND	380	450
CLAY HARD	450	520
CLAY + SAND MUD LOSS	520	525
CLAY BROWN	525	545
CLAY BLUE	545	575
BASALT W/BLU/CLAY	575	610
BLUE CLAY W/ GRAVEL	610	650
BROWN CLAY	650	680
BLUE CLAY	680	690
BROWN CLAY	690	705
BLUE W/BLACK BASALT	705	845
BROWN CLAY	845	851
BLUE SAND	851	940
SAND STONE	940	1040
BASALT BLACK	1040	1050
CLAY + SOAP STONE	1050	1065
CLAY	1065	1100
BASALT BLACK	1100	1124
BROWN CLAY	1124	1130
BLUE CLAY	1130	1148
BASALT BLACK	1148	1168
BASALT + CLAY STONE	1168	1200
RED SCORIA	1200	1230
BROWN SCORIA	1230	1255
GRAY BASALT	1255	1442
CONTINUED		

Work started 10-5, 1987. Completed 5-17, 1988

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 LARRY BURD WELL DRILLING INC (Person, firm, or corporation) (Type or print)

Address 5543 S.W. DOUGLAS
PENDLETON, ORE 97801

[Signed] Tony Burd (Well Driller)

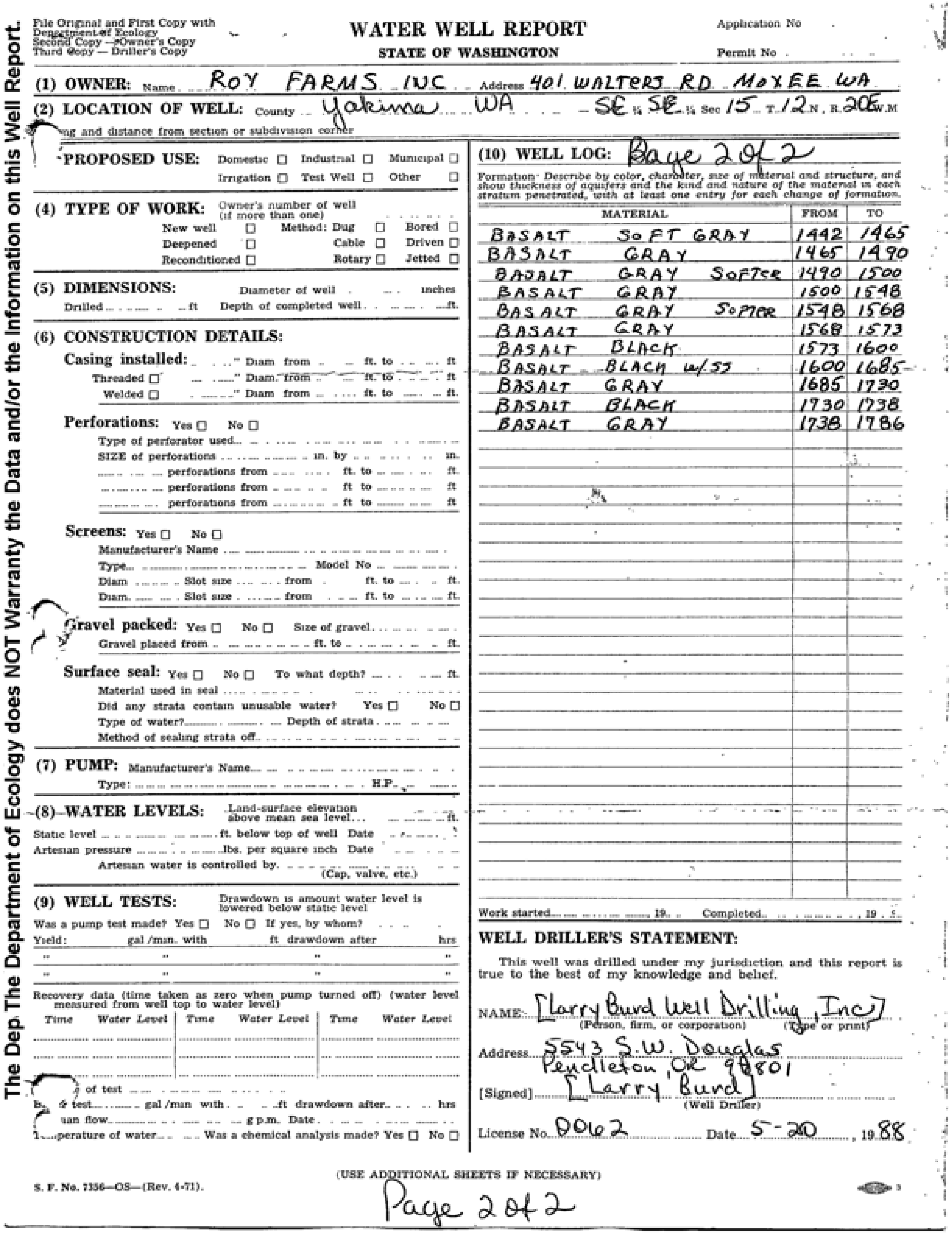
License No. 0062 Date 5-20, 1988

S. F. No. 7356—OS—(Rev. 4-71).

(USE ADDITIONAL SHEETS IF NECESSARY)

Page 1 of 2

Meacham Well (pg 2)



The Dep. The Department of Ecology does NOT Warranty the Data and/or the Information on this Well Report.

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

WATER WELL REPORT
STATE OF WASHINGTON

Application No
Permit No

(1) **OWNER:** Name ROY FARMS INC Address 401 WALTERS RD MOXEE WA

(2) **LOCATION OF WELL:** County Yakima WA SE ¼ SE ¼ Sec 15 T. 12 N., R. 20E W.M.

ng and distance from section or subdivision corner

PROPOSED USE: Domestic ☐ Industrial ☐ Municipal ☐ Irrigation ☐ Test Well ☐ Other ☐

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

(5) **DIMENSIONS:** Diameter of well inches
Drilled ft. Depth of completed well ft.

(6) **CONSTRUCTION DETAILS:**

Casing installed: " Diam. from ft. to ft.
Threaded ☐ " Diam. from ft. to ft.
Welded ☐ " Diam. from ft. to ft.

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

Screens: Yes ☐ No ☐
Manufacturer's Name
Type Model No
Diam. Slot size from ft. to ft.
Diam. Slot size from ft. to ft.

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

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

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

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

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

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

Time	Water Level	Time	Water Level	Time	Water Level

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

(10) **WELL LOG:** Page 2 of 2

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
BASALT SOFT GRAY	1442	1465
BASALT GRAY	1465	1490
BASALT GRAY SOFTER	1490	1500
BASALT GRAY	1500	1548
BASALT GRAY SOFTER	1548	1568
BASALT GRAY	1568	1573
BASALT BLACK	1573	1600
BASALT BLACK w/ SS	1600	1685
BASALT GRAY	1685	1730
BASALT BLACK	1730	1738
BASALT GRAY	1738	1786

Work started 19 Completed 19

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 [Larry Burd Well Drilling, Inc] (Person, firm, or corporation) (Type or print)

Address 5543 S.W. Douglas
Pendleton, OR 97801

[Signed] [Larry Burd] (Well Driller)

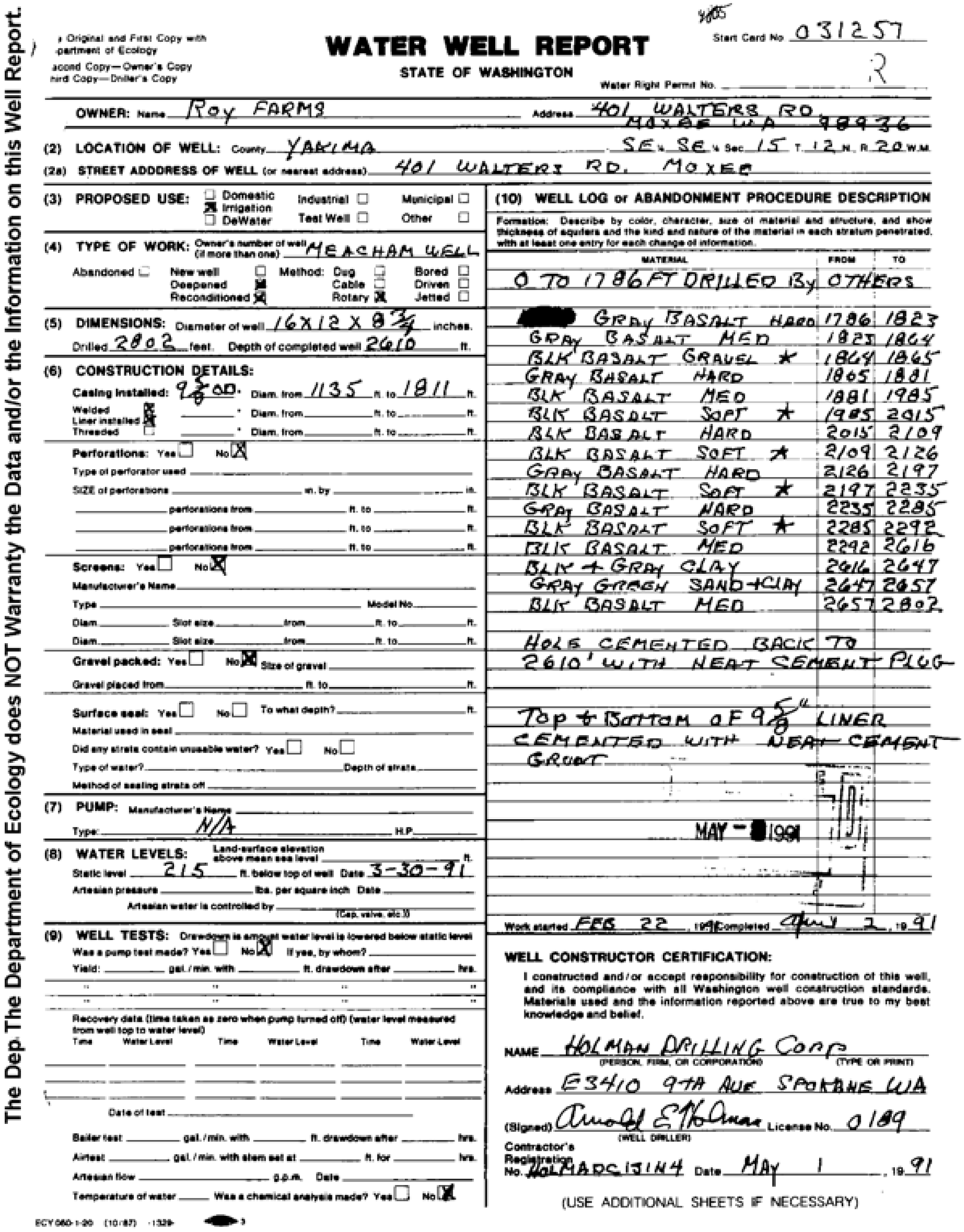
License No. 0062 Date 5-20, 1988

(USE ADDITIONAL SHEETS IF NECESSARY)

S. F. No. 7356—OS—(Rev. 4-71).

Page 2 of 2

Meacham Well (pg 3)



The Dep. The Department of Ecology does NOT Warranty the Data and/or the Information on this Well Report.

WATER WELL REPORT

STATE OF WASHINGTON

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

4805

Start Card No. 031257

Water Right Permit No. R

(1) OWNER: Name Roy FARMS Address 401 WALTERS RD, MOXEE WA 98936

(2) LOCATION OF WELL: County YAKIMA SE ¼ SE ¼ Sec. 15 T. 12 N., R. 20 W.M.

(2a) STREET ADDRESS OF WELL (or nearest address) 401 WALTERS RD. MOXEE

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

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

Abandoned ☐ New well ☐ Deepened ☒ Reconditioned ☒ Method: Dug ☐ Cable ☐ Rotary ☒ Bored ☐ Driven ☐ Jetted ☐

(5) DIMENSIONS: Diameter of well 16 X 12 X 8 3/4 inches.
Drilled 2802 feet. Depth of completed well 2610 ft.

(6) CONSTRUCTION DETAILS:
Casing installed: 9 5/8 OD. Diam. from 1135 ft. to 1811 ft.
Welded ☒ ______" Diam. from ______ ft. to ______ ft.
Liner installed ☒
Threaded ☐ ______" Diam. from ______ ft. to ______ ft.

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

Screens: Yes ☐ No ☒
Manufacturer's Name ______
Type ______ Model No. ______
Diam. ______ Slot size ______ from ______ ft. to ______ ft.
Diam. ______ Slot size ______ from ______ ft. to ______ ft.

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

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

(7) PUMP: Manufacturer's Name ______
Type: N/A H.P. ______

(8) WATER LEVELS: Land-surface elevation above mean sea level ______ ft.
Static level 215 ft. below top of well Date 3-30-91
Artesian pressure ______ lbs. per square inch Date ______
Artesian water is controlled by ______ (Cap, valve, etc.)

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

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

Time	Water Level	Time	Water Level	Time	Water Level

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

(10) WELL LOG or ABANDONMENT PROCEDURE DESCRIPTION

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 information.

MATERIAL	FROM	TO
0 TO 1786 FT DRILLED By OTHERS		
[redacted] GRAY BASALT HARD	1786	1823
GRAY BASALT MED	1823	1864
BLK BASALT GRAVEL ★	1864	1865
GRAY BASALT HARD	1865	1881
BLK BASALT MED	1881	1985
BLK BASALT SOFT ★	1985	2015
BLK BASALT HARD	2015	2109
BLK BASALT SOFT ★	2109	2126
GRAY BASALT HARD	2126	2197
BLK BASALT SOFT ★	2197	2235
GRAY BASALT HARD	2235	2285
BLK BASALT SOFT ★	2285	2292
BLK BASALT MED	2292	2616
BLK + GRAY CLAY	2616	2647
GRAY GREEN SAND + CLAY	2647	2657
BLK BASALT MED	2657	2802

HOLE CEMENTED BACK TO 2610' WITH NEAT CEMENT PLUG

TOP + BOTTOM OF 9 5/8" LINER CEMENTED WITH NEAT CEMENT GROUT

MAY - [redacted] 1991

Work started FEB 22, 1991 Completed April 2, 1991

WELL CONSTRUCTOR CERTIFICATION:

I constructed and/or accept responsibility for construction of this well, and its compliance with all Washington well construction standards. Materials used and the information reported above are true to my best knowledge and belief.

NAME HOLMAN DRILLING CORP (PERSON, FIRM, OR CORPORATION) (TYPE OR PRINT)

Address E3410 9TH AVE SPOKANE WA

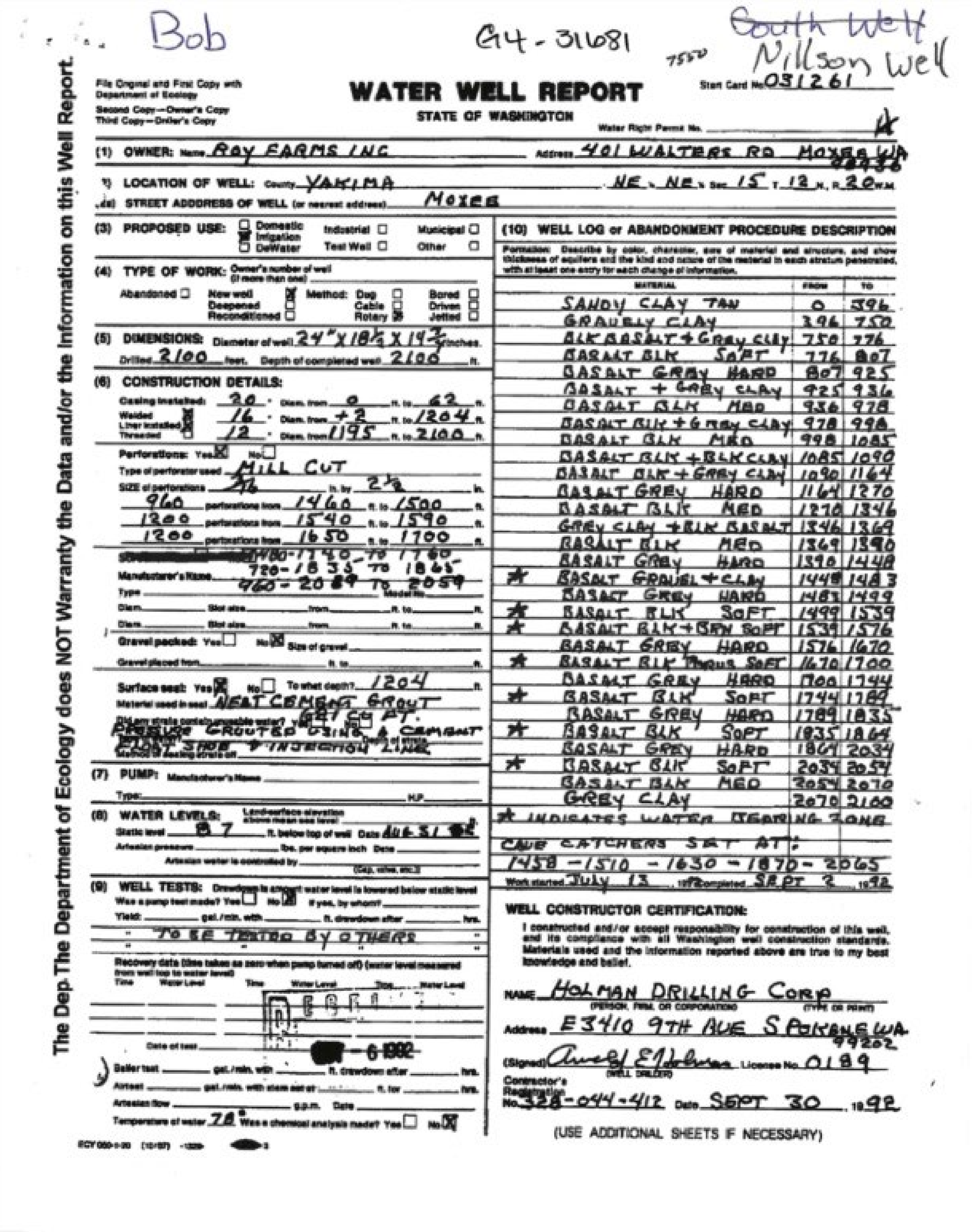
(Signed) Arnold E Holman (WELL DRILLER) License No. 0189

Contractor's Registration No. HOLMADC131N4 Date MAY 1, 1991

(USE ADDITIONAL SHEETS IF NECESSARY)

ECY 050-1-20 (10/87) -1329- [redacted] 3

Nilsson Well



Bob

G4-31681

~~South Well~~
7550 Nilsson Well

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

WATER WELL REPORT

STATE OF WASHINGTON

Start Card No. 031261

Water Right Permit No.

(1) OWNER: Name ROY FARMS INC Address 401 WALTERS RD MOXEE WA 98936

(2) LOCATION OF WELL: County YAKIMA NE ¼ NE ¼ Sec. 15 T. 12 N., R. 20 W.M.

(2a) STREET ADDRESS OF WELL (or nearest address) MOXEE

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

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

Abandoned ☐ New well ☒ Deepened ☐ Reconditioned ☐ Method: Dug ☐ Cable ☐ Rotary ☒ Bored ☐ Driven ☐ Jetted ☐

(5) DIMENSIONS: Diameter of well 24" X 18½ X 14¾ inches.

Drilled 2100 feet. Depth of completed well 2100 ft.

(6) CONSTRUCTION DETAILS:

Casing installed: 20" Diam. from 0 ft. to 62 ft.

Welded ☒ 16" Diam. from +2 ft. to 1204 ft.

Liner installed ☒ 12" Diam. from 1195 ft. to 2100 ft.

Threaded ☐

Perforations: Yes ☒ No ☐

Type of perforator used MILL CUT

SIZE of perforations 3/16 in. by 2½ in.

960 perforations from 1460 ft. to 1500 ft.

1200 perforations from 1540 ft. to 1590 ft.

1200 perforations from 1650 ft. to 1700 ft.

[redacted] 480-1740 TO 1760

720-1835 TO 1865

Manufacturer's Name 960-2019 TO 2059

Type Model No.

Diam. Slot size from ft. to ft.

Diam. Slot size from ft. to ft.

Gravel packed: Yes ☐ No ☒ Size of gravel

Gravel placed from ft. to ft.

Surface seal: Yes ☒ No ☐ To what depth? 1204 ft.

Material used in seal NEAT CEMENT GROUT 687 CU FT.

Did any strata contain unusable water? Yes ☐ No ☐

PRESSURE GROUTED USING A CEMENT FLOAT SHOE + INJECTION LINE

Method of sealing strata off

(7) PUMP: Manufacturer's Name

Type: H.P.

(8) WATER LEVELS: Land-surface elevation above mean sea level

Static level 87 ft. below top of well Date AUG 31 '92

Artesian pressure lbs. per square inch Date

Artesian water is controlled by (Cap, valve, etc.)

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

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

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

" TO BE TESTED BY OTHERS "

" " " "

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

Time Water Level Time Water Level Time Water Level

Date of test [illegible]-6 1992

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

Airtest gal./min. with stem set at ft. for hrs.

Artesian flow g.p.m. Date

Temperature of water 78° Was a chemical analysis made? Yes ☐ No ☒

ECY 050-1-20 (10/87) -1329-

(10) WELL LOG or ABANDONMENT PROCEDURE DESCRIPTION

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 information.

	MATERIAL	FROM	TO
	SANDY CLAY TAN	0	396
	GRAVELLY CLAY	396	750
	BLK BASALT + GREY CLAY	750	776
	BASALT BLK SOFT	776	807
	BASALT GREY HARD	807	925
	BASALT + GREY CLAY	925	936
	BASALT BLK MED	936	978
	BASALT BLK + GREY CLAY	978	998
	BASALT BLK MED	998	1085
	BASALT BLK + BLK CLAY	1085	1090
	BASALT BLK + GREY CLAY	1090	1164
	BASALT GREY HARD	1164	1270
	BASALT BLK MED	1270	1346
	GREY CLAY + BLK BASALT	1346	1369
	BASALT BLK MED	1369	1390
	BASALT GREY HARD	1390	1448
★	BASALT GRAVEL + CLAY	1448	1483
	BASALT GREY HARD	1483	1499
★	BASALT BLK SOFT	1499	1539
★	BASALT BLK + BRN SOFT	1539	1576
	BASALT GREY HARD	1576	1670
★	BASALT BLK POROUS SOFT	1670	1700
	BASALT GREY HARD	1700	1744
★	BASALT BLK SOFT	1744	1789
	BASALT GREY HARD	1789	1835
★	BASALT BLK SOFT	1835	1864
	BASALT GREY HARD	1864	2034
★	BASALT BLK SOFT	2034	2054
	BASALT BLK MED	2054	2070
	GREY CLAY	2070	2100

★ INDICATES WATER BEARING ZONE

CAVE CATCHERS SET AT:

1458 - 1510 - 1630 - 1870 - 2065

Work started July 13, 1992 Completed SEPT 2, 1992

WELL CONSTRUCTOR CERTIFICATION:

I constructed and/or accept responsibility for construction of this well, and its compliance with all Washington well construction standards. Materials used and the information reported above are true to my best knowledge and belief.

NAME HOLMAN DRILLING CORP
(PERSON, FIRM, OR CORPORATION) (TYPE OR PRINT)

Address E3410 9TH AVE SPOKANE WA 99202

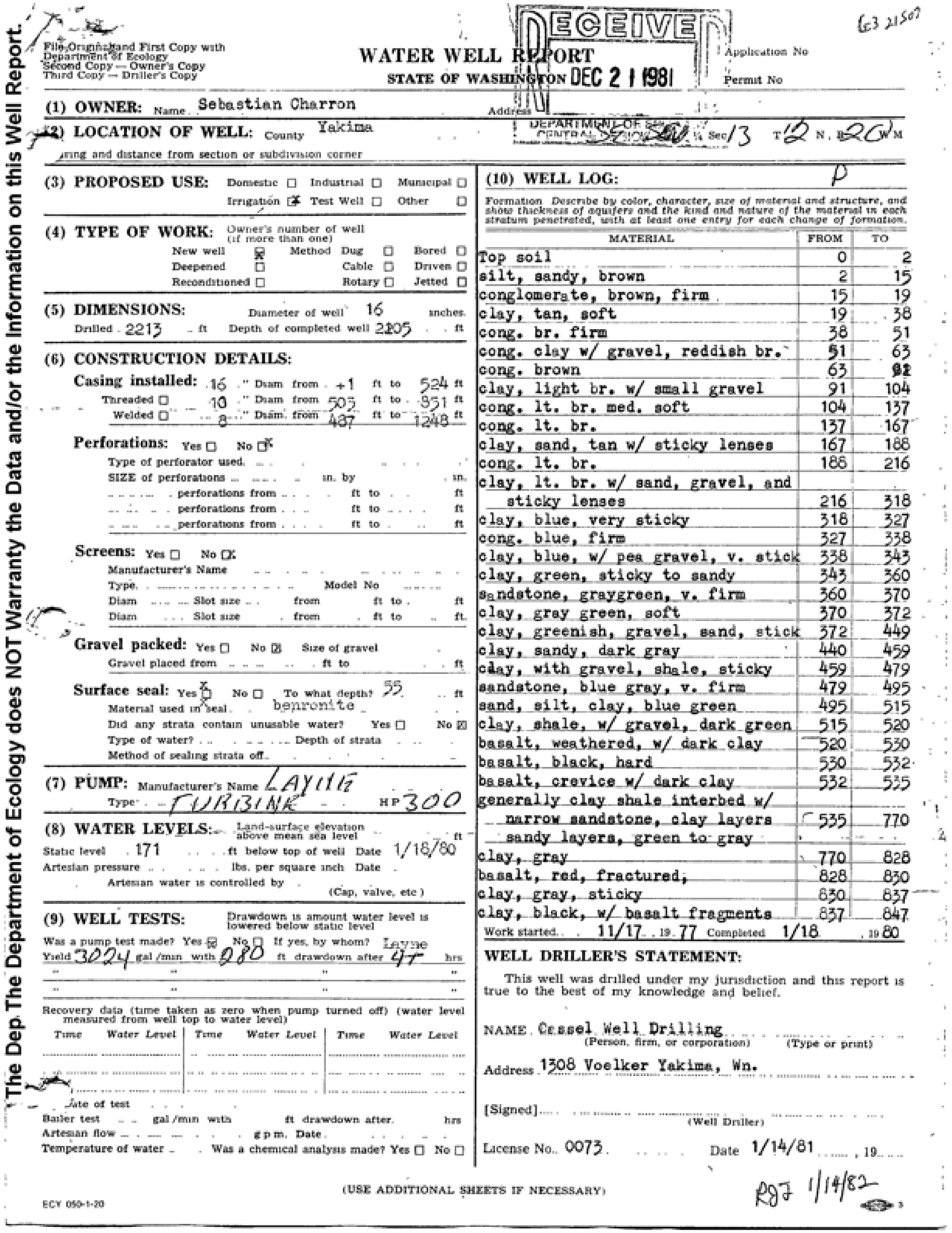
(Signed) License No. 0189
(WELL DRILLER)

Contractor's Registration No. 328-044-412 Date SEPT 30, 1992

(USE ADDITIONAL SHEETS IF NECESSARY)

The Dep. The Department of Ecology does NOT Warranty the Data and/or the Information on this Well Report.

Charron #1 Well (pg 1)



The Dep. The Department of Ecology does NOT Warranty the Data and/or the Information on this Well Report.

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Department of Ecology
Second Copy — Owner's Copy
Third Copy — Driller's Copy

63 21507

WATER WELL REPORT
STATE OF WASHINGTON

RECEIVED DEC 2 1 1981
DEPARTMENT OF
CENTRAL

Application No
Permit No

(1) OWNER: Name Sebastian Charron Address

(2) LOCATION OF WELL: County Yakima SE ¼ SW ¼ Sec 13 T 12 N., R 20 W.M.
Bearing and distance from section or subdivision corner

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

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

(5) DIMENSIONS: Diameter of well 16 inches.
Drilled 2213 ft. Depth of completed well 2205 ft.

(6) CONSTRUCTION DETAILS:

Casing installed: 16 " Diam. from +1 ft. to 524 ft.
Threaded ☐ 10 " Diam. from 505 ft. to 851 ft.
Welded ☐ 8 " Diam. from 487 ft. to 1248 ft.

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

Screens: Yes ☐ No ☒
Manufacturer's Name
Type Model No.
Diam. Slot size from ft. to ft.
Diam. Slot size from ft. to ft.

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

Surface seal: Yes ☒ No ☐ To what depth? 55 ft.
Material used in seal bentonite
Did any strata contain unusable water? Yes ☐ No ☒
Type of water? Depth of strata
Method of sealing strata off

(7) PUMP: Manufacturer's Name LAYNE
Type TURBINE HP 300

(8) WATER LEVELS: Land-surface elevation above mean sea level ft.
Static level 171 ft. below top of well Date 1/18/80
Artesian pressure lbs. per square inch Date
Artesian water is controlled by (Cap, valve, etc.)

(9) WELL TESTS: Drawdown is amount water level is lowered below static level
Was a pump test made? Yes ☒ No ☐ If yes, by whom? Layne
Yield 3024 gal./min. with 280 ft. drawdown after 47 hrs.

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

Time	Water Level	Time	Water Level	Time	Water Level

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

(10) WELL LOG: P

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
Top soil	0	2
silt, sandy, brown	2	15
conglomerate, brown, firm	15	19
clay, tan, soft	19	38
cong. br. firm	38	51
cong. clay w/ gravel, reddish br.	51	63
cong. brown	63	91
clay, light br. w/ small gravel	91	104
cong. lt. br. med. soft	104	137
cong. lt. br.	137	167
clay, sand, tan w/ sticky lenses	167	188
cong. lt. br.	188	216
clay, lt. br. w/ sand, gravel, and sticky lenses	216	318
clay, blue, very sticky	318	327
cong. blue, firm	327	338
clay, blue, w/ pea gravel, v. stick	338	343
clay, green, sticky to sandy	343	360
sandstone, graygreen, v. firm	360	370
clay, gray green, soft	370	372
clay, greenish, gravel, sand, stick	372	449
clay, sandy, dark gray	440	459
clay, with gravel, shale, sticky	459	479
sandstone, blue gray, v. firm	479	495
sand, silt, clay, blue green	495	515
clay, shale, w/ gravel, dark green	515	520
basalt, weathered, w/ dark clay	520	530
basalt, black, hard	530	532
basalt, crevice w/ dark clay	532	535
generally clay shale interbed w/ narrow sandstone, clay layers sandy layers, green to gray	535	770
clay, gray	770	828
basalt, red, fractured,	828	830
clay, gray, sticky	830	837
clay, black, w/ basalt fragments	837	847

Work started 11/17, 1977 Completed 1/18, 1980

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 Cassel Well Drilling (Person, firm, or corporation) (Type or print)

Address 1308 Voelker Yakima, Wn.

[Signed] (Well Driller)

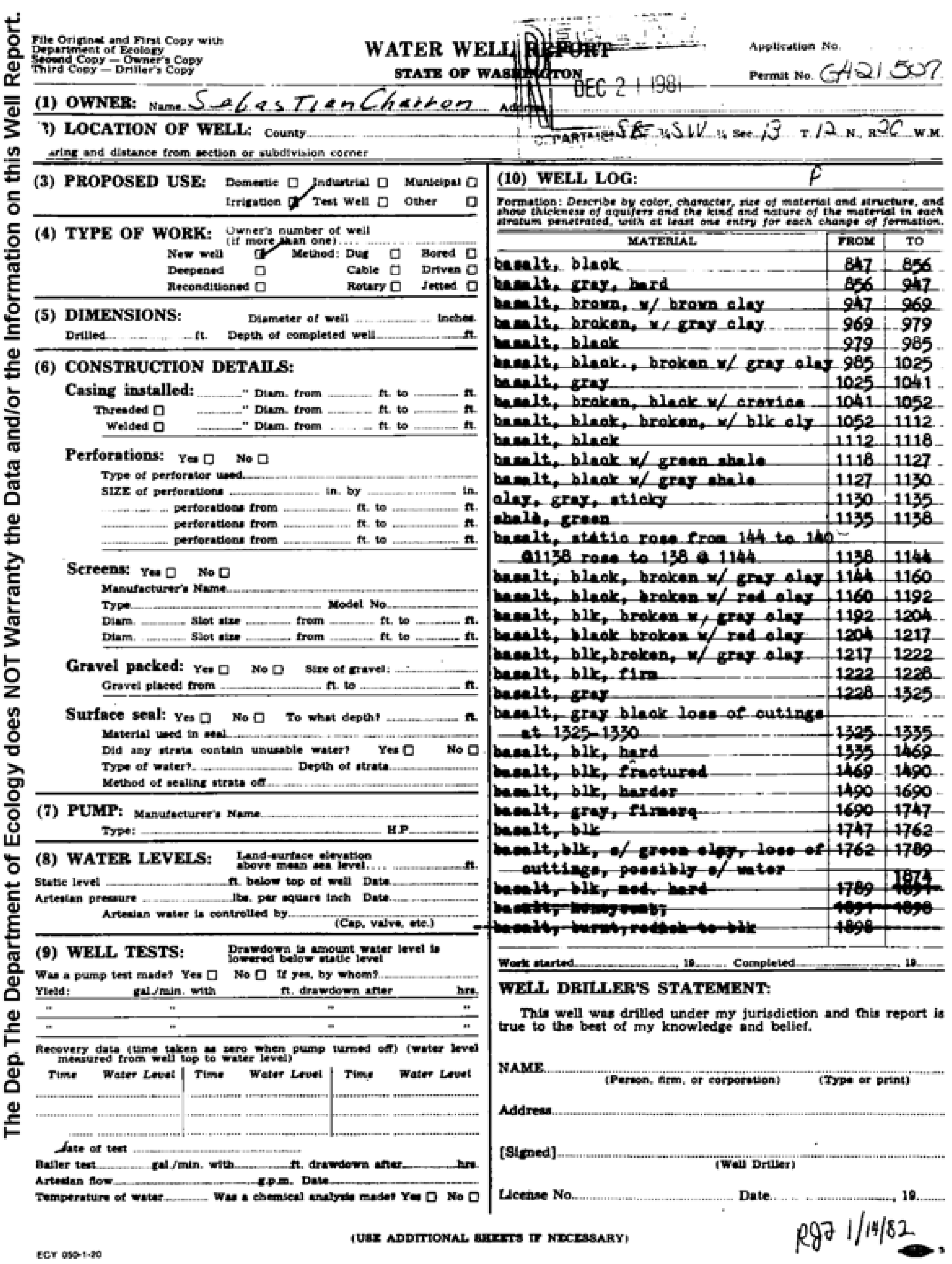
License No. 0073 Date 1/14/81, 19

(USE ADDITIONAL SHEETS IF NECESSARY)

RGJ 1/14/82

ECY 050-1-20

Charron #1 Well (pg 2)



The Dep. The Department of Ecology does NOT Warranty the Data and/or the Information on this Well Report.

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

WATER WELL REPORT
STATE OF WASHINGTON

DEC 2 1 1981

Application No.
Permit No. G4 21 507

(1) OWNER: Name Sebastian Charron Address

(2) LOCATION OF WELL: County .... SE ¼ SW ¼ Sec. 13 T. 12 N., R. 26 W.M.

Bearing and distance from section or subdivision corner

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

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

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

(6) CONSTRUCTION DETAILS:

Casing installed: ...." Diam. from .... ft. to .... ft.
Threaded ☐ ...." Diam. from .... ft. to .... ft.
Welded ☐ ...." Diam. from .... ft. to .... ft.

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

Screens: Yes ☐ No ☐
Manufacturer's Name........
Type........ Model No........
Diam. .... Slot size .... from .... ft. to .... ft.
Diam. .... Slot size .... from .... ft. to .... ft.

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

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

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

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

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

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

Time	Water Level	Time	Water Level	Time	Water Level

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

(10) WELL LOG: F

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
basalt, black	847	856
basalt, gray, hard	856	947
basalt, brown, w/ brown clay	947	969
basalt, broken, w/ gray clay	969	979
basalt, black	979	985
basalt, black., broken w/ gray clay	985	1025
basalt, gray	1025	1041
basalt, broken, black w/ crevice	1041	1052
basalt, black, broken, w/ blk cly	1052	1112
basalt, black	1112	1118
basalt, black w/ green shale	1118	1127
basalt, black w/ gray shale	1127	1130
clay, gray, sticky	1130	1135
shale, green	1135	1138
basalt, static rose from 144 to 140		
@1138 rose to 138 @ 1144	1138	1144
basalt, black, broken w/ gray clay	1144	1160
basalt, black, broken w/ red clay	1160	1192
basalt, blk, broken w/ gray clay	1192	1204
basalt, black broken w/ red clay	1204	1217
basalt, blk,broken, w/ gray clay	1217	1222
basalt, blk, firm	1222	1228
basalt, gray	1228	1325
basalt, gray black loss of cutings		
at 1325-1330	1325	1335
basalt, blk, hard	1335	1469
basalt, blk, fractured	1469	1490
basalt, blk, harder	1490	1690
basalt, gray, firmerq	1690	1747
basalt, blk	1747	1762
basalt,blk, w/ green clay, loss of	1762	1789
cuttings, possibly w/ water		
basalt, blk, med. hard	1789	1874 ~~1891~~
~~basalt, honeycomb;~~	~~1891~~	~~1898~~
~~basalt, burnt, reddish to blk~~	~~1898~~	~~------~~

Work started........, 19.... Completed........, 19....

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

Address........

[Signed]........ (Well Driller)

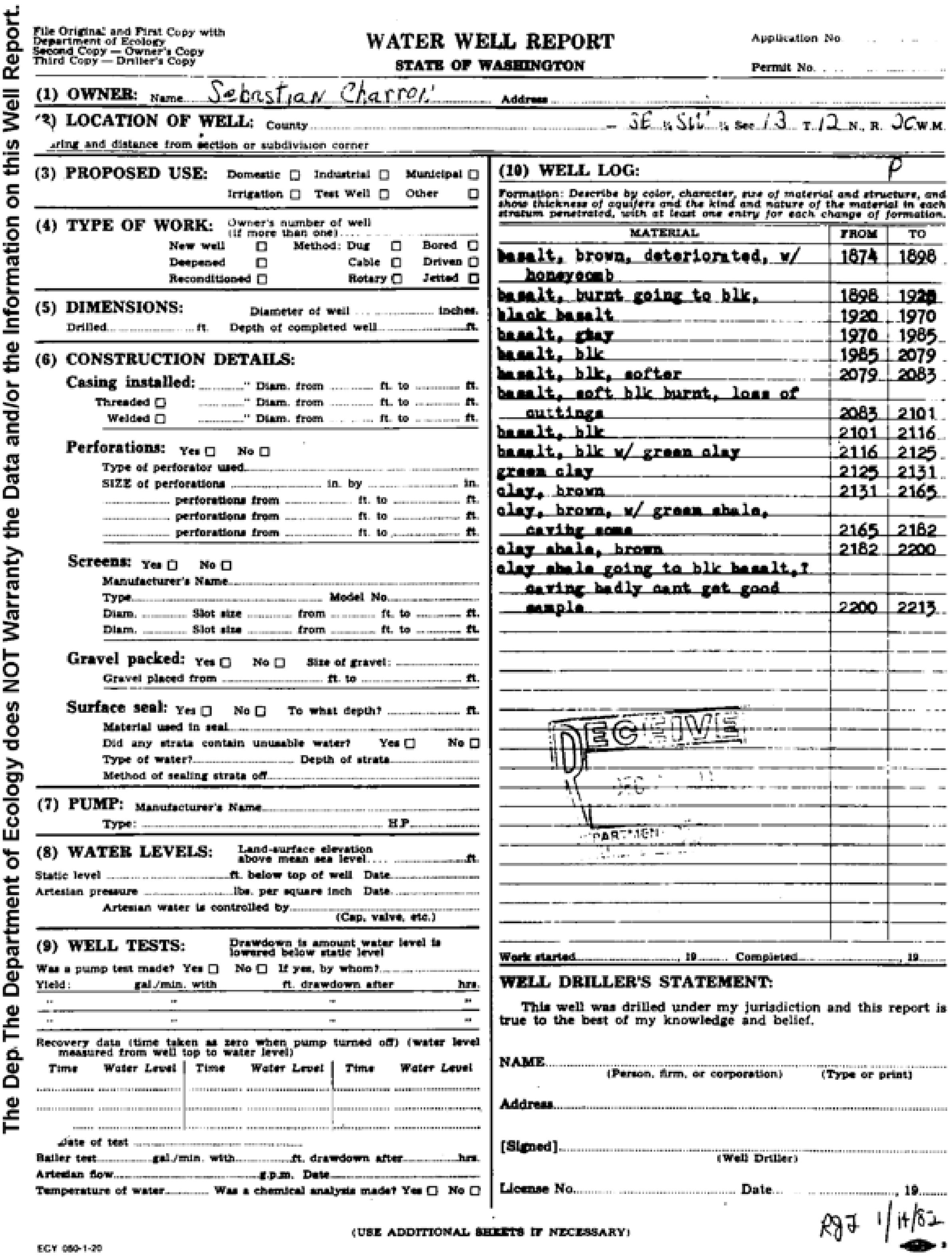
License No........ Date........, 19....

(USE ADDITIONAL SHEETS IF NECESSARY)

ECY 050-1-20

RGJ 1/14/82

Charron #1 Well (pg 3)



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

WATER WELL REPORT
STATE OF WASHINGTON

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

(1) OWNER: Name Sebastian Charron Address ....

(2) LOCATION OF WELL: County .... — SE ¼ SW ¼ Sec. 13 T. 12 N., R. 26 W.M.

Bearing and distance from section or subdivision corner

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

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

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

(6) CONSTRUCTION DETAILS:

Casing installed: ....” Diam. from .... ft. to .... ft.
Threaded ☐ ....” Diam. from .... ft. to .... ft.
Welded ☐ ....” Diam. from .... ft. to .... ft.

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

Screens: Yes ☐ No ☐
Manufacturer's Name ....
Type .... Model No. ....
Diam. .... Slot size .... from .... ft. to .... ft.
Diam. .... Slot size .... from .... ft. to .... ft.

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

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

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

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

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

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

Time	Water Level	Time	Water Level	Time	Water Level

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

(10) WELL LOG: P

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
basalt, brown, deteriorated, w/ honeycomb	1874	1898
basalt, burnt going to blk,	1898	1920
black basalt	1920	1970
basalt, gray	1970	1985
basalt, blk	1985	2079
basalt, blk, softer	2079	2083
basalt, soft blk burnt, loss of cuttings	2083	2101
basalt, blk	2101	2116
basalt, blk w/ green clay	2116	2125
green clay	2125	2131
clay, brown	2131	2165
clay, brown, w/ green shale, caving some	2165	2182
clay shale, brown	2182	2200
clay shale going to blk basalt,? caving badly cant get good sample	2200	2213

RECEIVED
DEPARTMENT

Work started ...., 19...... Completed ...., 19......

WELL DRILLER'S STATEMENT:

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

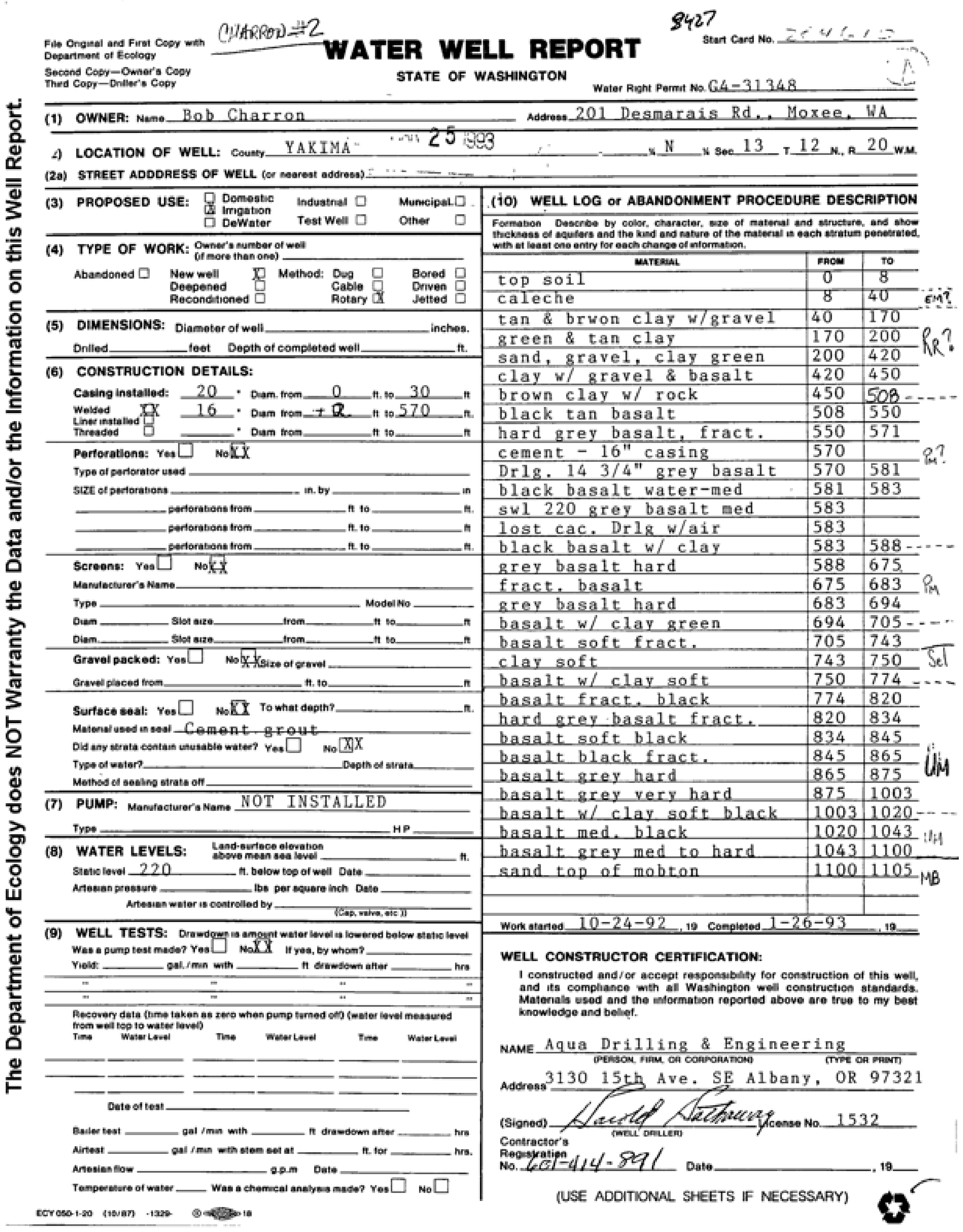
NAME .... (Person, firm, or corporation) (Type or print)
Address ....
[Signed] .... (Well Driller)
License No. .... Date ...., 19......

RGJ 1/14/82

(USE ADDITIONAL SHEETS IF NECESSARY)

ECY 050-1-20

Charron #2 Well (pg 1)



The Department of Ecology does NOT Warranty the Data and/or the Information on this Well Report.

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

CHARRON #2

8427

WATER WELL REPORT

STATE OF WASHINGTON

Start Card No. [illegible]

Water Right Permit No. G4-31348

(1) **OWNER:** Name Bob Charron Address 201 Desmarais Rd., Moxee, WA

(2) **LOCATION OF WELL:** County YAKIMA 25 1993 ¼ N ¼ Sec. 13 T. 12 N., R. 20 W.M.

(2a) **STREET ADDDRESS OF WELL** (or nearest address)

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

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

(5) **DIMENSIONS:** Diameter of well inches.
Drilled feet Depth of completed well ft.

(6) **CONSTRUCTION DETAILS:**
Casing installed: 20" Diam. from 0 ft. to 30 ft.
Welded ☒X 16" Diam from +2 ft. to 570 ft.
Liner installed ☐
Threaded ☐ " Diam from ft. to ft.

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

Screens: Yes ☐ No ☒X
Manufacturer's Name
Type Model No.
Diam. Slot size from ft. to ft.
Diam. Slot size from ft. to ft.

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

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

(7) **PUMP:** Manufacturer's Name NOT INSTALLED
Type H.P.

(8) **WATER LEVELS:** Land-surface elevation above mean sea level ft.
Static level 220 ft. below top of well Date
Artesian pressure lbs. per square inch Date
Artesian water is controlled by (Cap, valve, etc.)

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

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

Time	Water Level	Time	Water Level	Time	Water Level

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

ECY 050-1-20 (10/87) -1329- 18

(10) **WELL LOG or ABANDONMENT PROCEDURE DESCRIPTION**

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 information.

MATERIAL	FROM	TO	
top soil	0	8	
caleche	8	40	EM?
tan & brwon clay w/gravel	40	170	
green & tan clay	170	200	RR?
sand, gravel, clay green	200	420	
clay w/ gravel & basalt	420	450	
brown clay w/ rock	450	508	
black tan basalt	508	550	
hard grey basalt, fract.	550	571	
cement - 16" casing	570		RM?
Drlg. 14 3/4" grey basalt	570	581	
black basalt water-med	581	583	
swl 220 grey basalt med	583		
lost cac. Drlg w/air	583		
black basalt w/ clay	583	588	
grey basalt hard	588	675	
fract. basalt	675	683	RM
grey basalt hard	683	694	
basalt w/ clay green	694	705	
basalt soft fract.	705	743	
clay soft	743	750	Sel
basalt w/ clay soft	750	774	
basalt fract. black	774	820	
hard grey basalt fract.	820	834	
basalt soft black	834	845	
basalt black fract.	845	865	UM
basalt grey hard	865	875	
basalt grey very hard	875	1003	
basalt w/ clay soft black	1003	1020	
basalt med. black	1020	1043	UM
basalt grey med to hard	1043	1100	
sand top of mobton	1100	1105	MB

Work started 10-24-92, 19 Completed 1-26-93, 19

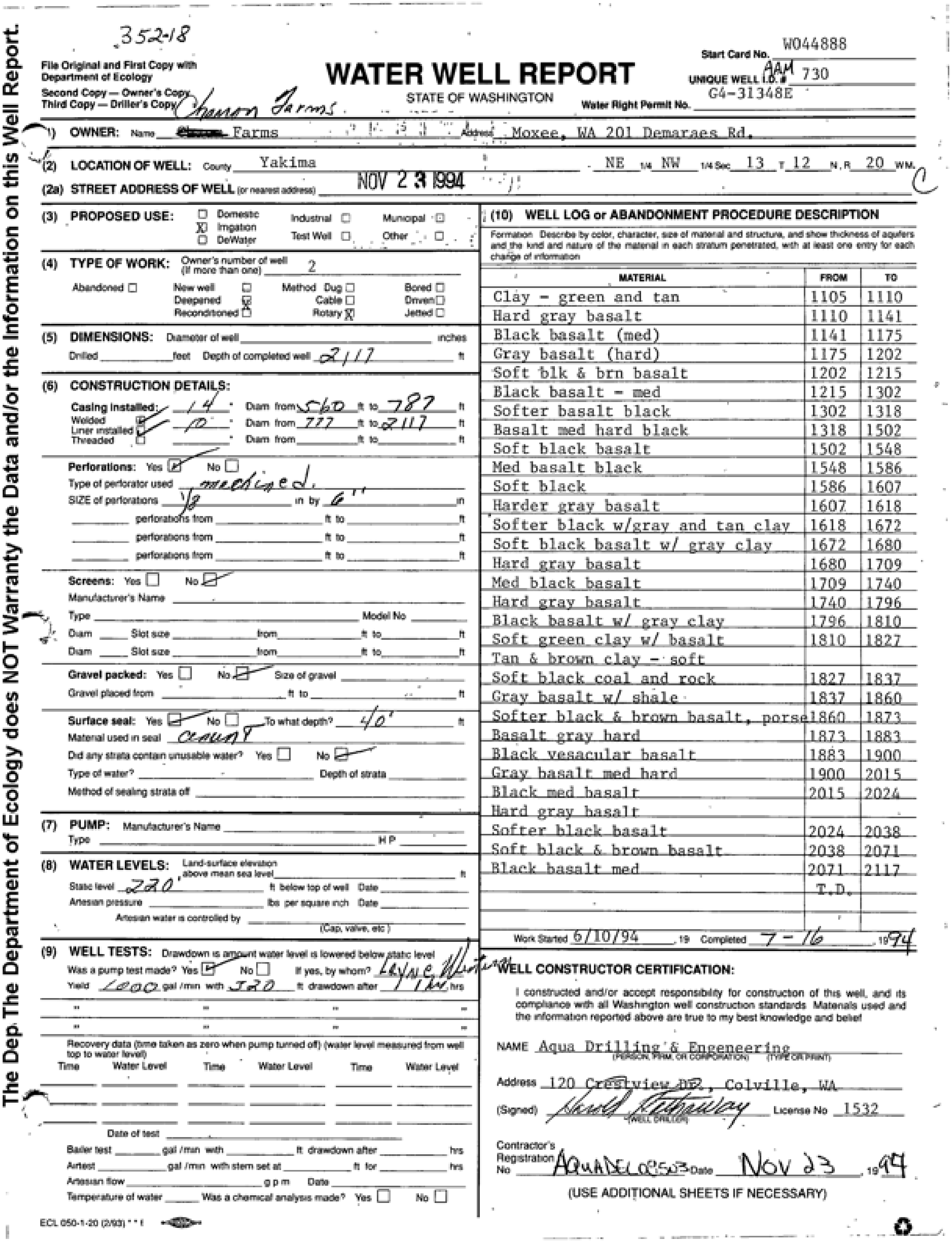
WELL CONSTRUCTOR CERTIFICATION:

I constructed and/or accept responsibility for construction of this well, and its compliance with all Washington well construction standards. Materials used and the information reported above are true to my best knowledge and belief.

NAME Aqua Drilling & Engineering (PERSON, FIRM, OR CORPORATION) (TYPE OR PRINT)
Address 3130 15th Ave. SE Albany, OR 97321
(Signed) (WELL DRILLER) License No. 1532
Contractor's Registration No. ACI-414-891 Date, 19

(USE ADDITIONAL SHEETS IF NECESSARY)

Charron #2 Well (pg 2)



The Dep. The Department of Ecology does NOT Warranty the Data and/or the Information on this Well Report.

352-18

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

Charron Farms

WATER WELL REPORT

STATE OF WASHINGTON

Start Card No. W044888
UNIQUE WELL I.D. # AAM 730
Water Right Permit No. G4-31348E

(1) OWNER: Name ~~[illegible]~~ Farms Address Moxee, WA 201 Demaraes Rd.

(2) LOCATION OF WELL: County Yakima — NE 1/4 NW 1/4 Sec 13 T 12 N., R 20 WM.

(2a) STREET ADDRESS OF WELL (or nearest address) NOV 23 1994

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

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

(5) DIMENSIONS: Diameter of well ______ inches
Drilled ______ feet Depth of completed well 2117 ft.

(6) CONSTRUCTION DETAILS:
Casing Installed: 14" Diam. from 560 ft. to 787 ft.
Welded ☑ 10" Diam. from 777 ft. to 2117 ft.
Liner installed ☑ ______" Diam. from ______ ft. to ______ ft.
Threaded ☐

Perforations: Yes ☑ No ☐
Type of perforator used machined.
SIZE of perforations 1/8 in. by 6" in.
______ perforations from ______ ft. to ______ ft.
______ perforations from ______ ft. to ______ ft.
______ perforations from ______ ft. to ______ ft.

Screens: Yes ☐ No ☑
Manufacturer's Name ______
Type ______ Model No. ______
Diam. ______ Slot size ______ from ______ ft. to ______ ft.
Diam. ______ Slot size ______ from ______ ft. to ______ ft.

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

Surface seal: Yes ☑ No ☐ To what depth? 40' ft.
Material used in seal cement
Did any strata contain unusable water? Yes ☐ No ☑
Type of water? ______ Depth of strata ______
Method of sealing strata off ______

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

(8) WATER LEVELS: Land-surface elevation above mean sea level ______ ft.
Static level 220' ft. below top of well Date ______
Artesian pressure ______ lbs. per square inch Date ______
Artesian water is controlled by ______ (Cap, valve, etc.)

(9) WELL TESTS: Drawdown is amount water level is lowered below static level
Was a pump test made? Yes ☑ No ☐ If yes, by whom? Layne Western
Yield 1000 gal./min. with 320 ft. drawdown after 1 1/4 hrs.
" " " "
" " " "
Recovery data (time taken as zero when pump turned off) (water level measured from well top to water level)

Time	Water Level	Time	Water Level	Time	Water Level

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

ECL 050-1-20 (2/93)

(10) WELL LOG or ABANDONMENT PROCEDURE DESCRIPTION

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 information.

MATERIAL	FROM	TO
Clay - green and tan	1105	1110
Hard gray basalt	1110	1141
Black basalt (med)	1141	1175
Gray basalt (hard)	1175	1202
Soft blk & brn basalt	1202	1215
Black basalt - med	1215	1302
Softer basalt black	1302	1318
Basalt med hard black	1318	1502
Soft black basalt	1502	1548
Med basalt black	1548	1586
Soft black	1586	1607
Harder gray basalt	1607	1618
Softer black w/gray and tan clay	1618	1672
Soft black basalt w/ gray clay	1672	1680
Hard gray basalt	1680	1709
Med black basalt	1709	1740
Hard gray basalt	1740	1796
Black basalt w/ gray clay	1796	1810
Soft green clay w/ basalt	1810	1827
Tan & brown clay - soft		
Soft black coal and rock	1827	1837
Gray basalt w/ shale	1837	1860
Softer black & brown basalt, porse	1860	1873
Basalt gray hard	1873	1883
Black vesacular basalt	1883	1900
Gray basalt med hard	1900	2015
Black med basalt	2015	2024
Hard gray basalt		
Softer black basalt	2024	2038
Soft black & brown basalt	2038	2071
Black basalt med	2071	2117
	T.D.	

Work Started 6/10/94, 19 Completed 7-16, 1994

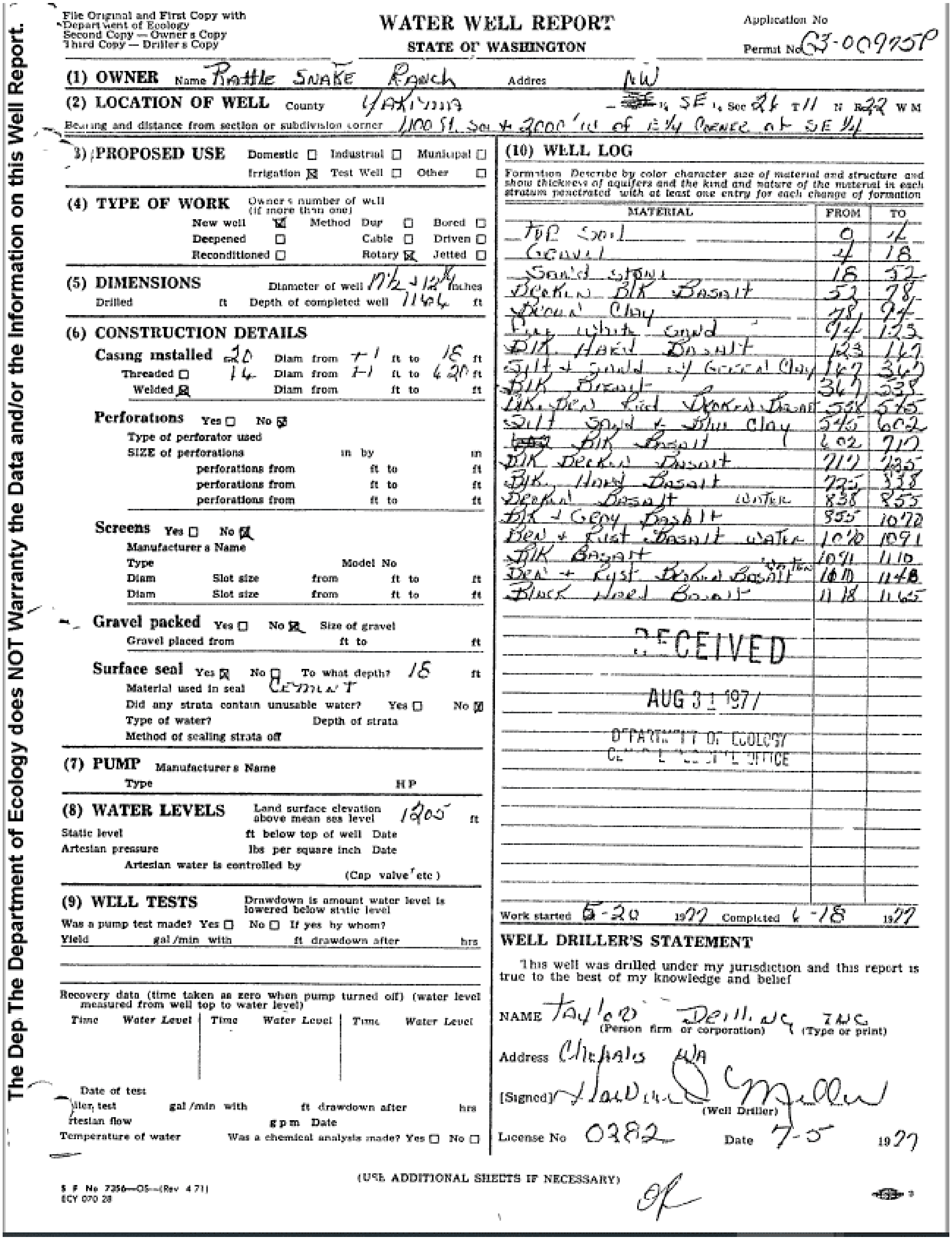
WELL CONSTRUCTOR CERTIFICATION:

I constructed and/or accept responsibility for construction of this well, and its compliance with all Washington well construction standards. Materials used and the information reported above are true to my best knowledge and belief.

NAME Aqua Drilling & Engeneering (PERSON, FIRM, OR CORPORATION) (TYPE OR PRINT)
Address 120 Crestview DR., Colville, WA
(Signed) (WELL DRILLER) License No. 1532
Contractor's Registration No. AQUADEL085Q3 Date Nov 23, 1994

(USE ADDITIONAL SHEETS IF NECESSARY)

Block 24 Well (pg 1)



The Dep. The Department of Ecology does NOT Warranty the Data and/or the Information on this Well Report.

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

WATER WELL REPORT
STATE OF WASHINGTON

Application No
Permit No G3-00975P

(1) OWNER Name Rattle Snake Ranch Address NW

(2) LOCATION OF WELL County Yakima — ~~SE~~ ¼ SE ¼ Sec 26 T 11 N R 22 W M

Bearing and distance from section or subdivision corner 1100 ft. So + 2000' W of E ¼ Corner of SE ¼

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

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

(5) DIMENSIONS Diameter of well 17½ + 12¼ inches
Drilled ft Depth of completed well 1164 ft

(6) CONSTRUCTION DETAILS
Casing installed 20 Diam from +1 ft to 15 ft
Threaded ☐ 14 Diam from +1 ft to 420 ft
Welded ☒ Diam from ft to ft

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

Screens Yes ☐ No ☒
Manufacturer's Name
Type Model No
Diam Slot size from ft to ft
Diam Slot size from ft to ft

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

Surface seal Yes ☒ No ☐ To what depth? 15 ft
Material used in seal Cement
Did any strata contain unusable water? Yes ☐ No ☒
Type of water? Depth of strata
Method of sealing strata off

(7) PUMP Manufacturer's Name
Type H P

(8) WATER LEVELS Land surface elevation above mean sea level 1205 ft
Static level ft below top of well Date
Artesian pressure lbs per square inch Date
Artesian water is controlled by (Cap valve etc)

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

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

Time	Water Level	Time	Water Level	Time	Water Level

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

(10) WELL LOG

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

MATERIAL	FROM	TO
Top Soil	0	4
Gravel	4	18
Sand stone	18	52
Broken Blk Basalt	52	78
Brown Clay	78	94
Fine white sand	94	123
Blk. Hard Basalt	123	147
Silt + sand w/ Green Clay	147	367
Blk Basalt	367	538
Blk. Brn Red Broken Basalt	538	545
Silt Sand + Blue Clay	545	602
Blk Basalt	602	717
Blk Broken Basalt	717	735
Blk. Hard Basalt	735	838
Broken Basalt water	838	855
Blk + Gray Basalt	855	1070
Brn + Rust Basalt water	1070	1091
Blk Basalt	1091	1110
Brn + Rust Broken Basalt water	1110	1148
Black Hard Basalt	1118	1165

RECEIVED
AUG 31 1977
DEPARTMENT OF ECOLOGY
CENTRAL REGIONAL OFFICE

Work started 5-20 1977 Completed 6-18 1977

WELL DRILLER'S STATEMENT

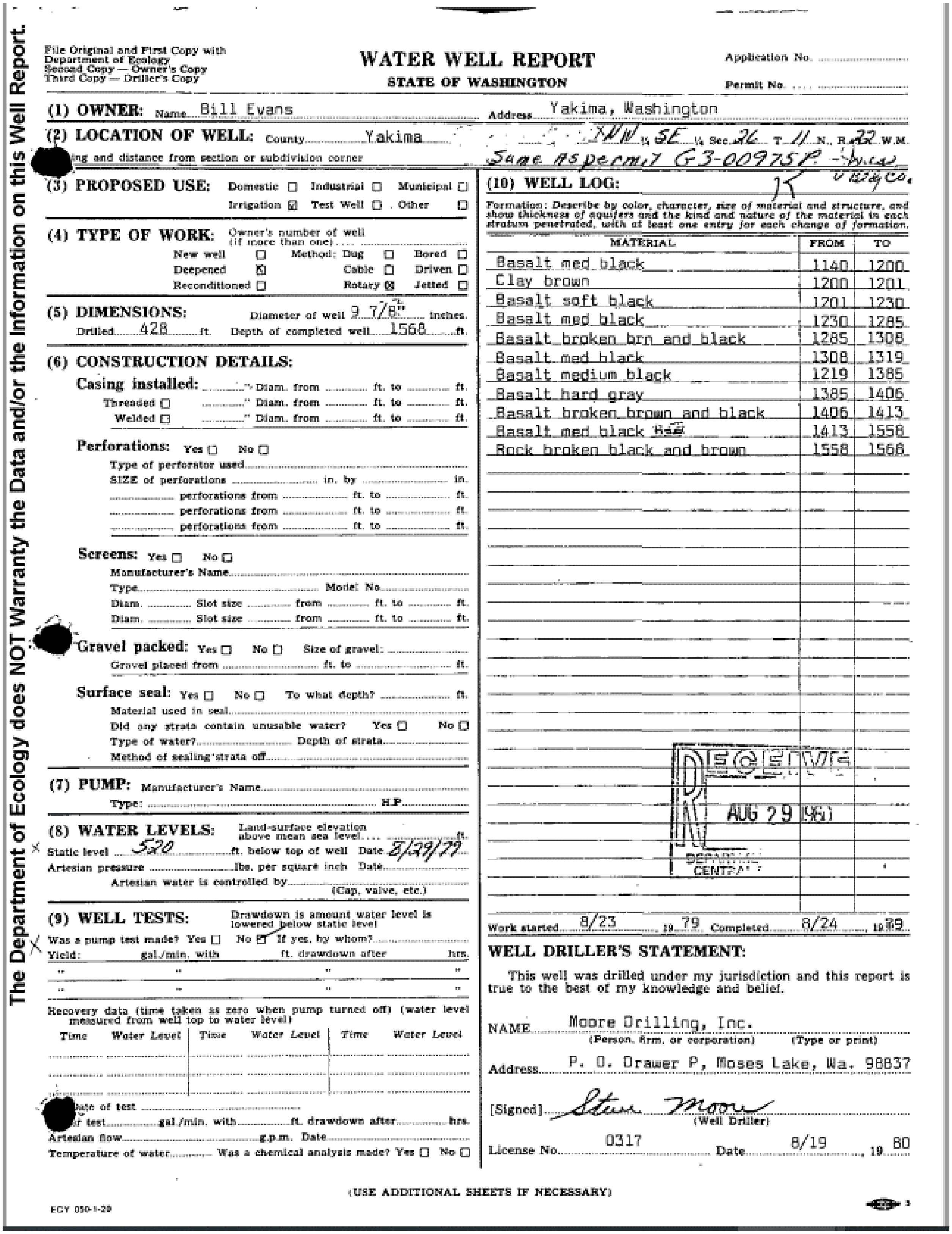
This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief

NAME Taylor Drilling Inc (Person firm or corporation) (Type or print)
Address Chehalis WA
[Signed] (Well Driller)
License No 0282 Date 7-5 1977

(USE ADDITIONAL SHEETS IF NECESSARY)

S F No 7356—OS—(Rev 4 71)
ECY 070 28

Block 24 Well (pg 2)



The Department of Ecology does NOT Warranty the Data and/or the Information on this Well Report.

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

WATER WELL REPORT
STATE OF WASHINGTON

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

(1) OWNER: Name Bill Evans Address Yakima, Washington

(2) LOCATION OF WELL: County Yakima ¼ NW ¼ SE ¼ Sec. 26 T. 11 N., R. 22 W.M.

ing and distance from section or subdivision corner Same as permit G3-00975P.

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

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

(5) DIMENSIONS: Diameter of well 9 7/8" inches.
Drilled 428 ft. Depth of completed well 1568 ft.

(6) CONSTRUCTION DETAILS:

Casing installed: ....." Diam. from ..... ft. to ..... ft.
Threaded ☐ ....." Diam. from ..... ft. to ..... ft.
Welded ☐ ....." Diam. from ..... ft. to ..... ft.

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

Screens: Yes ☐ No ☐
Manufacturer's Name ....
Type .... Model No. ....
Diam. ..... Slot size ..... from ..... ft. to ..... ft.
Diam. ..... Slot size ..... from ..... ft. to ..... ft.

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

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

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

(8) WATER LEVELS: Land-surface elevation above mean sea level ..... ft.
Static level 520 ft. below top of well Date 8/29/79
Artesian pressure ..... lbs. per square inch Date ....
Artesian water is controlled by .... (Cap, valve, etc.)

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

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

Time	Water Level	Time	Water Level	Time	Water Level

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

(10) WELL LOG:

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

MATERIAL	FROM	TO
Basalt med black	1140	1200
Clay brown	1200	1201
Basalt soft black	1201	1230
Basalt med black	1230	1285
Basalt broken brn and black	1285	1308
Basalt med black	1308	1319
Basalt medium black	1219	1385
Basalt hard gray	1385	1406
Basalt broken brown and black	1406	1413
Basalt med black	1413	1558
Rock broken black and brown	1558	1568

RECEIVED
AUG 29 1980
DEPARTMENT
CENTRAL

Work started 8/23 19 79 Completed 8/24 19 79

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 Moore Drilling, Inc. (Person, firm, or corporation) (Type or print)
Address P. O. Drawer P, Moses Lake, Wa. 98837

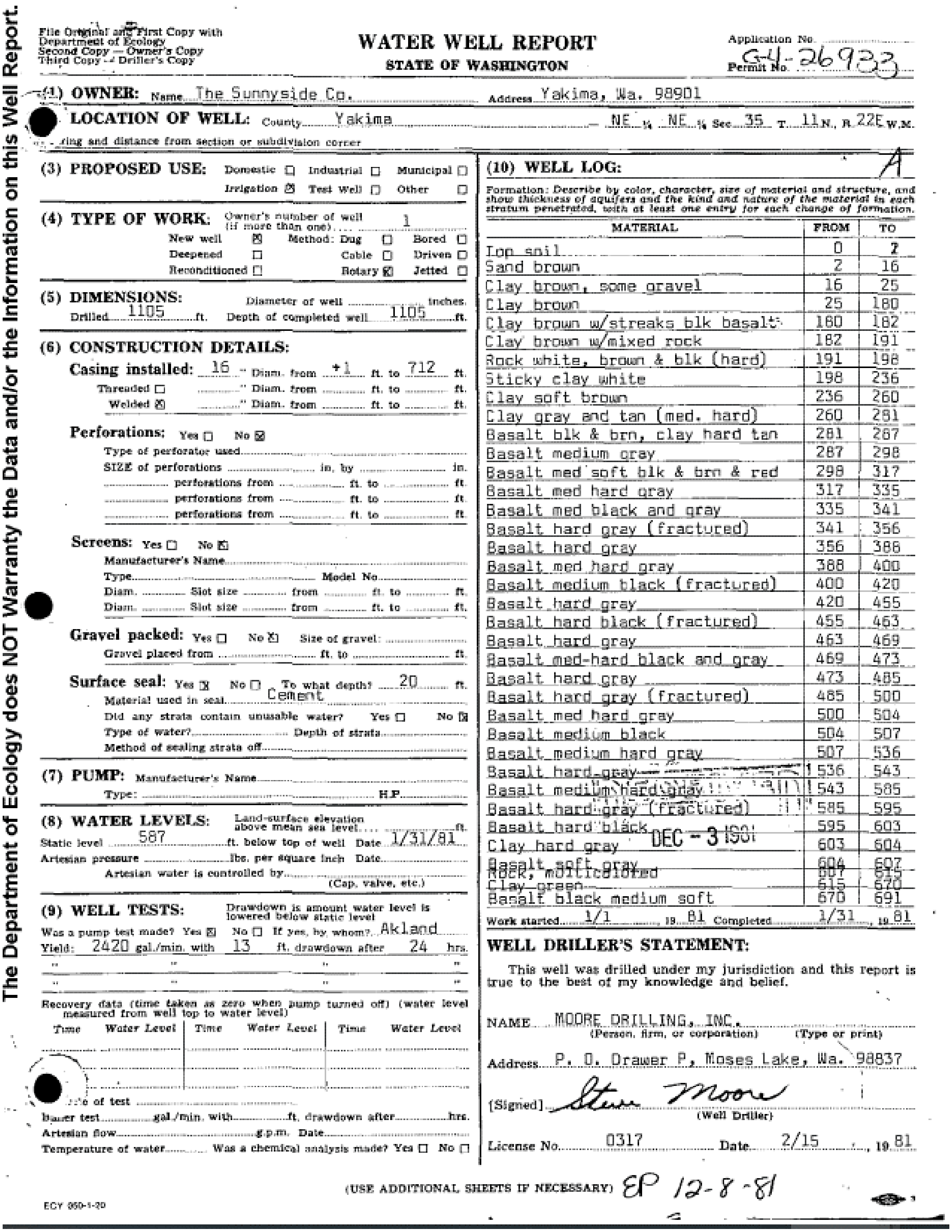
[Signed] Steve Moore (Well Driller)

License No. 0317 Date 8/19 19 80

(USE ADDITIONAL SHEETS IF NECESSARY)

ECY 050-1-20

Yakima Ranch Well (pg 1)



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

WATER WELL REPORT
STATE OF WASHINGTON

Application No. ....
Permit No. G4-26933

(1) OWNER: Name The Sunnyside Co. Address Yakima, Wa. 98901

LOCATION OF WELL: County Yakima — NE ¼ NE ¼ Sec. 35 T. 11 N., R. 22E W.M.

ring and distance from section or subdivision corner

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

(4) TYPE OF WORK: Owner's number of well (if more than one) 1

New well ☒ Deepened ☐ Reconditioned ☐

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

(5) DIMENSIONS: Diameter of well .... inches.

Drilled 1105 ft. Depth of completed well 1105 ft.

(6) CONSTRUCTION DETAILS:

Casing installed: 16 " Diam. from +1 ft. to 712 ft.

Threaded ☐ ......" Diam. from ...... ft. to ...... ft.

Welded ☒ ......" Diam. from ...... ft. to ...... ft.

Perforations: Yes ☐ No ☒

Type of perforator used..........

SIZE of perforations .... in. by .... in.

.... perforations from .... ft. to .... ft.

.... perforations from .... ft. to .... ft.

.... perforations from .... ft. to .... ft.

Screens: Yes ☐ No ☒

Manufacturer's Name..........

Type.......... Model No..........

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

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

Gravel packed: Yes ☐ No ☒ Size of gravel: ....

Gravel placed from .... ft. to .... ft.

Surface seal: Yes ☒ No ☐ To what depth? 20 ft.

Material used in seal Cement

Did any strata contain unusable water? Yes ☐ No ☒

Type of water?.......... Depth of strata..........

Method of sealing strata off..........

(7) PUMP: Manufacturer's Name..........

Type: .... H.P. ....

(8) WATER LEVELS: Land-surface elevation above mean sea level.......... ft.

Static level 587 ft. below top of well Date 1/31/81

Artesian pressure .... lbs. per square inch Date..........

Artesian water is controlled by.......... (Cap, valve, etc.)

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

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

Yield: 2420 gal./min. with 13 ft. drawdown after 24 hrs.

" " " "

" " " "

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

Time	Water Level	Time	Water Level	Time	Water Level

of test ....

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

Artesian flow .... g.p.m. Date..........

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

(10) WELL LOG: A

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
Top soil	0	2
Sand brown	2	16
Clay brown, some gravel	16	25
Clay brown	25	180
Clay brown w/streaks blk basalt	180	182
Clay brown w/mixed rock	182	191
Rock white, brown & blk (hard)	191	198
Sticky clay white	198	236
Clay soft brown	236	260
Clay gray and tan (med. hard)	260	281
Basalt blk & brn, clay hard tan	281	287
Basalt medium gray	287	298
Basalt med soft blk & brn & red	298	317
Basalt med hard gray	317	335
Basalt med black and gray	335	341
Basalt hard gray (fractured)	341	356
Basalt hard gray	356	388
Basalt med hard gray	388	400
Basalt medium black (fractured)	400	420
Basalt hard gray	420	455
Basalt hard black (fractured)	455	463
Basalt hard gray	463	469
Basalt med-hard black and gray	469	473
Basalt hard gray	473	485
Basalt hard gray (fractured)	485	500
Basalt med hard gray	500	504
Basalt medium black	504	507
Basalt medium hard gray	507	536
Basalt hard gray	536	543
Basalt medium hard gray	543	585
Basalt hard gray (fractured)	585	595
Basalt hard black	595	603
Clay hard gray	603	604
Basalt soft gray	604	607
Rock, multicolored	607	615
Clay green	615	670
Basalt black medium soft	670	691

DEC - 3 1981

Work started 1/1, 19 81 Completed 1/31, 19 81

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 MOORE DRILLING, INC. (Person, firm, or corporation) (Type or print)

Address P. O. Drawer P, Moses Lake, Wa. 98837

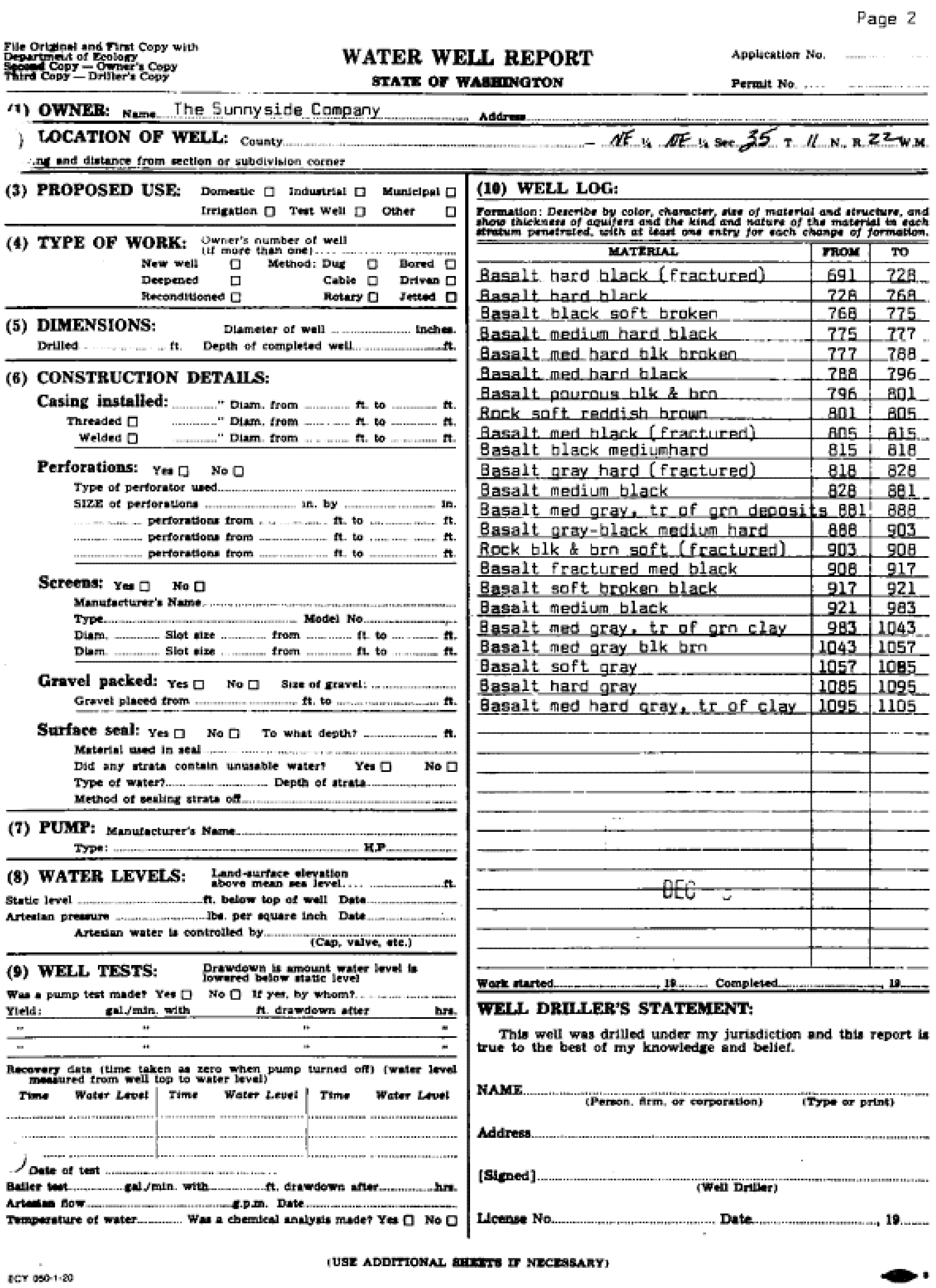
[Signed] Steve Moore (Well Driller)

License No. 0317 Date 2/15, 19 81

(USE ADDITIONAL SHEETS IF NECESSARY) EP 12-8-81

ECY 050-1-20

Yakima Ranch Well (pg 2)



Page 2

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

WATER WELL REPORT
STATE OF WASHINGTON

Application No.
Permit No.

(1) **OWNER:** Name The Sunnyside Company Address

(2) **LOCATION OF WELL:** County — NE ¼ NE ¼ Sec. 35 T. 11 N., R. 22 W.M.

Bearing and distance from section or subdivision corner

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

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

(5) **DIMENSIONS:** Diameter of well inches.
Drilled ft. Depth of completed well ft.

(6) **CONSTRUCTION DETAILS:**

Casing installed: " Diam. from ft. to ft.
Threaded ☐ " Diam. from ft. to ft.
Welded ☐ " Diam. from ft. to ft.

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

Screens: Yes ☐ No ☐
Manufacturer's Name
Type Model No.
Diam. Slot size from ft. to ft.
Diam. Slot size from ft. to ft.

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

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

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

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

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

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

Time	Water Level	Time	Water Level	Time	Water Level

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

(10) **WELL LOG:**

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

MATERIAL	FROM	TO
Basalt hard black (fractured)	691	728
Basalt hard black	728	768
Basalt black soft broken	768	775
Basalt medium hard black	775	777
Basalt med hard blk broken	777	788
Basalt med hard black	788	796
Basalt pourous blk & brn	796	801
Rock soft reddish brown	801	805
Basalt med black (fractured)	805	815
Basalt black mediumhard	815	818
Basalt gray hard (fractured)	818	828
Basalt medium black	828	881
Basalt med gray, tr of grn deposits	881	888
Basalt gray-black medium hard	888	903
Rock blk & brn soft (fractured)	903	908
Basalt fractured med black	908	917
Basalt soft broken black	917	921
Basalt medium black	921	983
Basalt med gray, tr of grn clay	983	1043
Basalt med gray blk brn	1043	1057
Basalt soft gray	1057	1085
Basalt hard gray	1085	1095
Basalt med hard gray, tr of clay	1095	1105

DEC

Work started 19 Completed 19

WELL DRILLER'S STATEMENT:

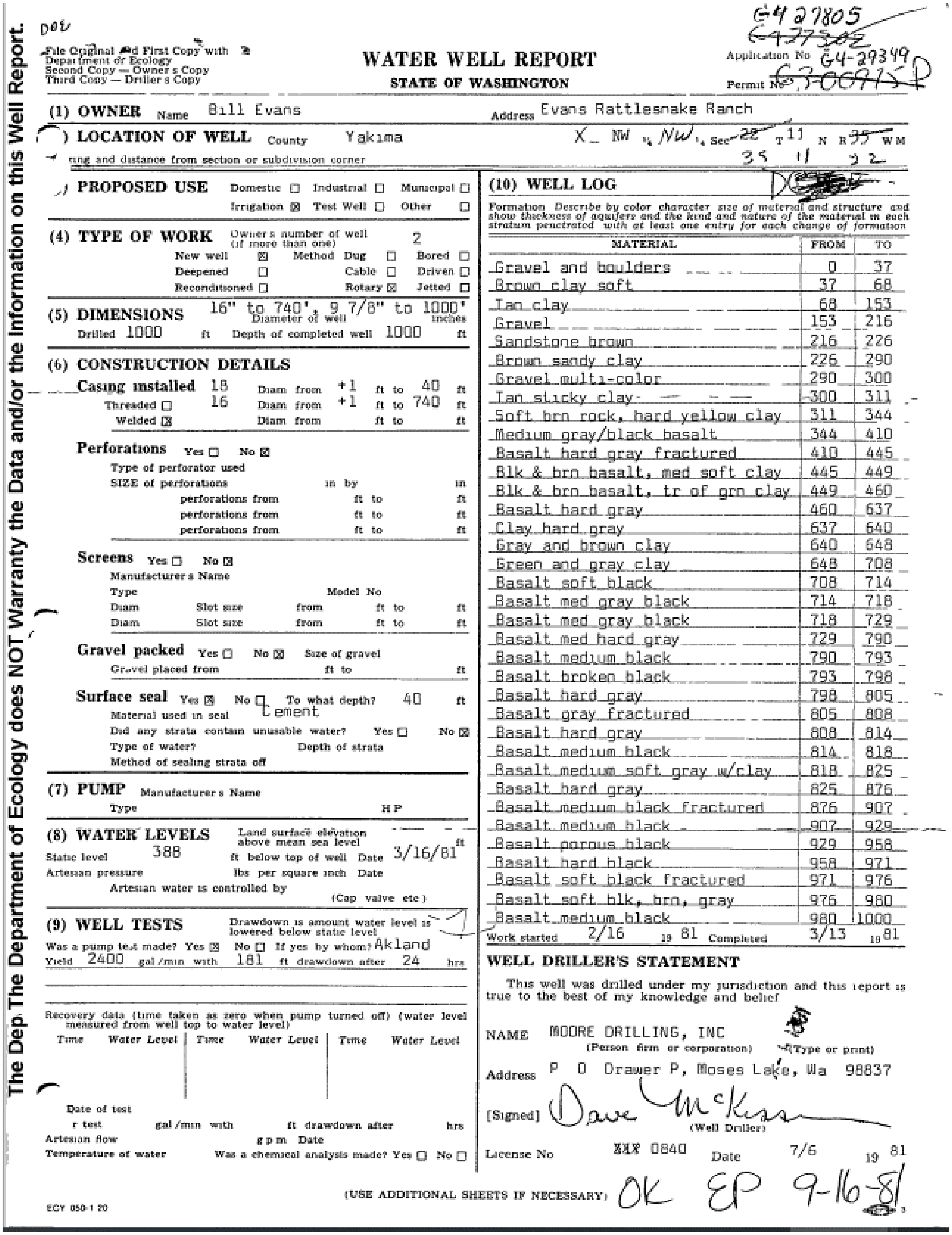
This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.

NAME (Person, firm, or corporation) (Type or print)
Address
[Signed] (Well Driller)
License No. Date , 19

(USE ADDITIONAL SHEETS IF NECESSARY)

ECY 050-1-20

North 80 Well



The Dep. The Department of Ecology does NOT Warranty the Data and/or the Information on this Well Report.

DOE

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

WATER WELL REPORT
STATE OF WASHINGTON

G4 27805
~~G427502~~
Application No G4-29349
Permit No G3-00975P

(1) OWNER Name Bill Evans Address Evans Rattlesnake Ranch

) LOCATION OF WELL County Yakima X NW ¼ NW ¼ Sec ~~22~~ 35 T 11 N R ~~35~~ 22 WM
ring and distance from section or subdivision corner

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

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

(5) DIMENSIONS Diameter of well 16" to 740', 9 7/8" to 1000' inches
Drilled 1000 ft Depth of completed well 1000 ft

(6) CONSTRUCTION DETAILS

Casing installed 18 Diam from +1 ft to 40 ft
Threaded ☐ 16 Diam from +1 ft to 740 ft
Welded ☒ Diam from ft to ft

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

Screens Yes ☐ No ☒
Manufacturer's Name
Type Model No
Diam Slot size from ft to ft
Diam Slot size from ft to ft

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

Surface seal Yes ☒ No ☐ To what depth? 40 ft
Material used in seal Cement
Did any strata contain unusable water? Yes ☐ No ☒
Type of water? Depth of strata
Method of sealing strata off

(7) PUMP Manufacturer's Name
Type H P

(8) WATER LEVELS Land surface elevation above mean sea level ft
Static level 388 ft below top of well Date 3/16/81
Artesian pressure lbs per square inch Date
Artesian water is controlled by (Cap valve etc)

(9) WELL TESTS Drawdown is amount water level is lowered below static level
Was a pump test made? Yes ☒ No ☐ If yes by whom? Akland
Yield 2400 gal/min with 181 ft drawdown after 24 hrs

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

Time	Water Level	Time	Water Level	Time	Water Level

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

(10) WELL LOG

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

MATERIAL	FROM	TO
Gravel and boulders	0	37
Brown clay soft	37	68
Tan clay	68	153
Gravel	153	216
Sandstone brown	216	226
Brown sandy clay	226	290
Gravel multi-color	290	300
Tan sticky clay	300	311
Soft brn rock, hard yellow clay	311	344
Medium gray/black basalt	344	410
Basalt hard gray fractured	410	445
Blk & brn basalt, med soft clay	445	449
Blk & brn basalt, tr of grn clay	449	460
Basalt hard gray	460	637
Clay hard gray	637	640
Gray and brown clay	640	648
Green and gray clay	648	708
Basalt soft black	708	714
Basalt med gray black	714	718
Basalt med gray black	718	729
Basalt med hard gray	729	790
Basalt medium black	790	793
Basalt broken black	793	798
Basalt hard gray	798	805
Basalt gray fractured	805	808
Basalt hard gray	808	814
Basalt medium black	814	818
Basalt medium soft gray w/clay	818	825
Basalt hard gray	825	876
Basalt medium black fractured	876	907
Basalt medium black	907	929
Basalt porous black	929	958
Basalt hard black	958	971
Basalt soft black fractured	971	976
Basalt soft blk, brn, gray	976	980
Basalt medium black	980	1000

Work started 2/16 19 81 Completed 3/13 19 81

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 MOORE DRILLING, INC (Person firm or corporation) (Type or print)

Address P O Drawer P, Moses Lake, Wa 98837

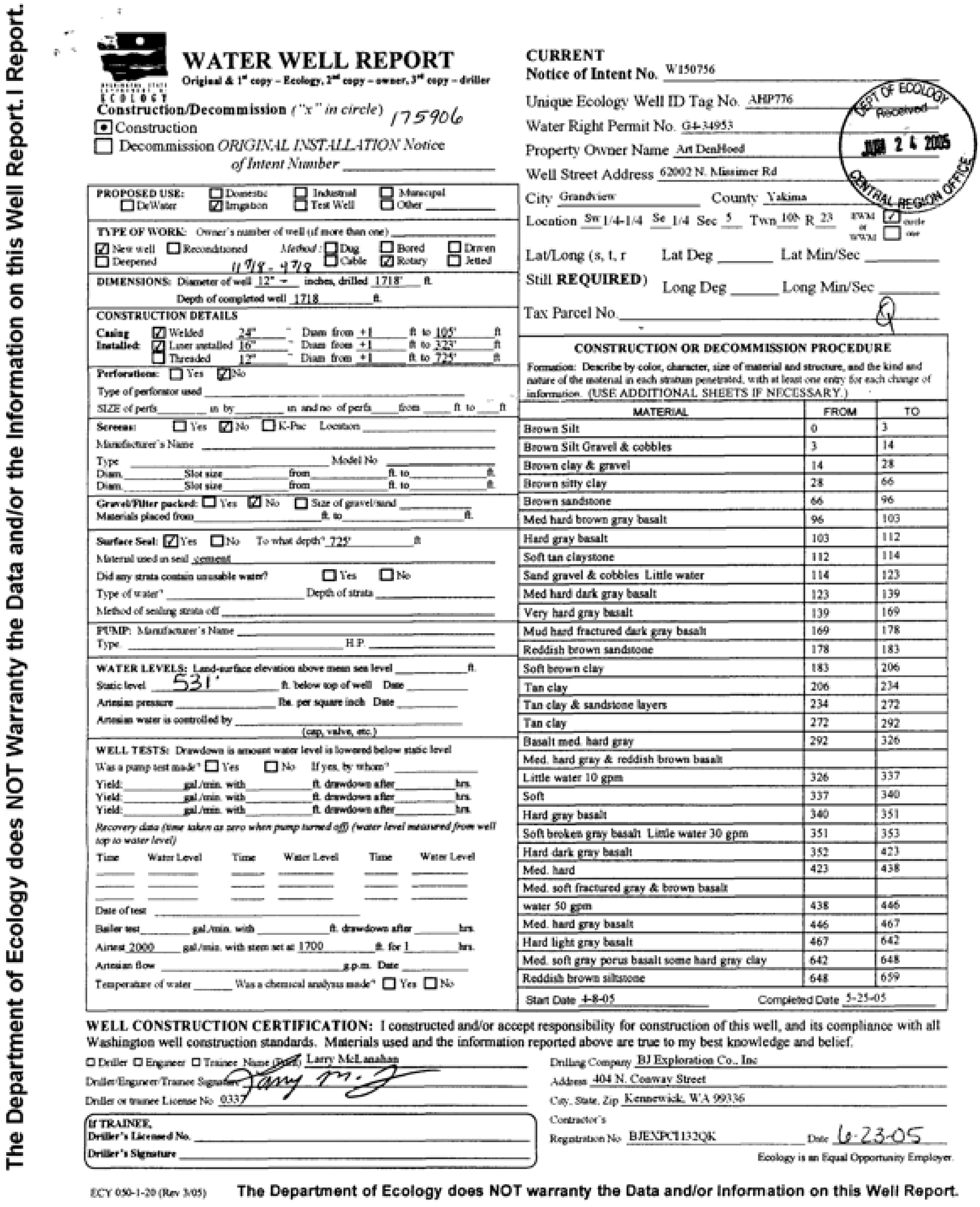
[Signed] Dave McKiss (Well Driller)

License No XXX 0840 Date 7/6 19 81

(USE ADDITIONAL SHEETS IF NECESSARY) OK EP 9-16-81

ECY 050-1 20

AHP-776 (pg 1)



The Department of Ecology does NOT Warranty the Data and/or the Information on this Well Report.

WATER WELL REPORT

Original & 1st copy – Ecology, 2nd copy – owner, 3rd copy – driller

Construction/Decommission *("x" in circle)* 175906
● Construction
☐ Decommission *ORIGINAL INSTALLATION Notice of Intent Number* ____________

CURRENT
Notice of Intent No. W150756
Unique Ecology Well ID Tag No. AHP776
Water Right Permit No. G4-34953
Property Owner Name Art DenHoed
Well Street Address 62002 N. Missimer Rd
City Grandview County Yakima
Location Sw 1/4-1/4 Se 1/4 Sec 5 Twn 10N R 23 EWM ☑ or WWM ☐ circle one
Lat/Long (s, t, r Still **REQUIRED**) Lat Deg ______ Lat Min/Sec ______ Long Deg ______ Long Min/Sec ______
Tax Parcel No. ____________

DEPT OF ECOLOGY
Received
JUN 2 4 2005
CENTRAL REGION OFFICE

PROPOSED USE: ☐ Domestic ☐ Industrial ☐ Municipal ☐ DeWater ☑ Irrigation ☐ Test Well ☐ Other ______

TYPE OF WORK: Owner's number of well (if more than one) ______
☑ New well ☐ Reconditioned *Method:* ☐ Dug ☐ Bored ☐ Driven
☐ Deepened ☐ Cable ☑ Rotary ☐ Jetted
11 9/8 - 47/8

DIMENSIONS: Diameter of well 12" → inches, drilled 1718' ft.
Depth of completed well 1718 ft.

CONSTRUCTION DETAILS
Casing Installed:
☑ Welded 24" Diam from +1 ft to 105' ft
☑ Liner installed 16" Diam from +1 ft to 323' ft
☐ Threaded 12" Diam from +1 ft to 725' ft

Perforations: ☐ Yes ☑ No
Type of perforator used ______
SIZE of perfs ______ in by ______ in and no of perfs ______ from ______ ft to ______ ft

Screens: ☐ Yes ☑ No ☐ K-Pac Location ______
Manufacturer's Name ______
Type ______ Model No ______
Diam. ______ Slot size ______ from ______ ft. to ______ ft.
Diam. ______ Slot size ______ from ______ ft. to ______ ft.

Gravel/Filter packed: ☐ Yes ☑ No ☐ Size of gravel/sand ______
Materials placed from ______ ft. to ______ ft.

Surface Seal: ☑ Yes ☐ No To what depth? 725' ft
Material used in seal cement
Did any strata contain unusable water? ☐ Yes ☐ No
Type of water? ______ Depth of strata ______
Method of sealing strata off ______

PUMP: Manufacturer's Name ______
Type ______ H.P. ______

WATER LEVELS: Land-surface elevation above mean sea level ______ ft.
Static level 531' ft. below top of well Date ______
Artesian pressure ______ lbs. per square inch Date ______
Artesian water is controlled by ______ (cap, valve, etc.)

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.
Yield: ______ gal./min. with ______ ft. drawdown after ______ hrs.
Yield: ______ gal./min. with ______ ft. drawdown after ______ hrs.
Recovery data (time taken as zero when pump turned off) (water level measured from well top to water level)

Time	Water Level	Time	Water Level	Time	Water Level

Date of test ______
Bailer test ______ gal./min. with ______ ft. drawdown after ______ hrs.
Airtest 2000 gal./min. with stem set at 1700 ft. for 1 hrs.
Artesian flow ______ g.p.m. Date ______
Temperature of water ______ Was a chemical analysis made? ☐ Yes ☐ No

CONSTRUCTION OR DECOMMISSION PROCEDURE

Formation: Describe by color, character, size of material and structure, and the kind and nature of the material in each stratum penetrated, with at least one entry for each change of information. (USE ADDITIONAL SHEETS IF NECESSARY.)

MATERIAL	FROM	TO
Brown Silt	0	3
Brown Silt Gravel & cobbles	3	14
Brown clay & gravel	14	28
Brown silty clay	28	66
Brown sandstone	66	96
Med hard brown gray basalt	96	103
Hard gray basalt	103	112
Soft tan claystone	112	114
Sand gravel & cobbles Little water	114	123
Med hard dark gray basalt	123	139
Very hard gray basalt	139	169
Mud hard fractured dark gray basalt	169	178
Reddish brown sandstone	178	183
Soft brown clay	183	206
Tan clay	206	234
Tan clay & sandstone layers	234	272
Tan clay	272	292
Basalt med. hard gray	292	326
Med. hard gray & reddish brown basalt		
Little water 10 gpm	326	337
Soft	337	340
Hard gray basalt	340	351
Soft broken gray basalt Little water 30 gpm	351	353
Hard dark gray basalt	352	423
Med. hard	423	438
Med. soft fractured gray & brown basalt		
water 50 gpm	438	446
Med. hard gray basalt	446	467
Hard light gray basalt	467	642
Med. soft gray porus basalt some hard gray clay	642	648
Reddish brown siltstone	648	659

Start Date 4-8-05 Completed Date 5-25-05

WELL CONSTRUCTION CERTIFICATION: I constructed and/or accept responsibility for construction of this well, and its compliance with all Washington well construction standards. Materials used and the information reported above are true to my best knowledge and belief.

☐ Driller ☐ Engineer ☐ Trainee Name (Print) Larry McLanahan
Driller/Engineer/Trainee Signature Larry M.
Driller or trainee License No 0337

If TRAINEE,
Driller's Licensed No. ______
Driller's Signature ______

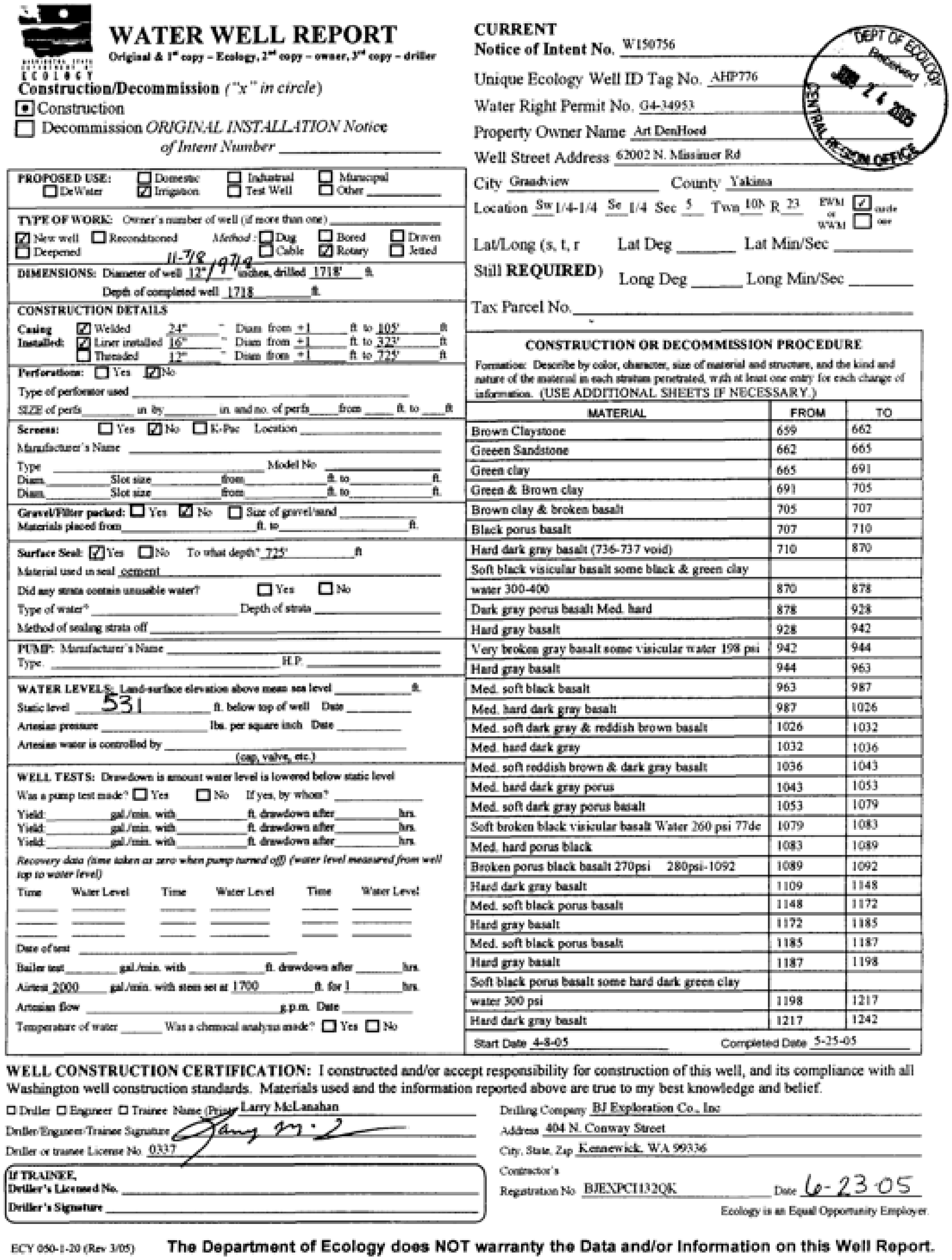
Drilling Company BJ Exploration Co., Inc
Address 404 N. Conway Street
City, State, Zip Kennewick, WA 99336
Contractor's Registration No BJEXPCI132QK Date 6-23-05

Ecology is an Equal Opportunity Employer.

ECY 050-1-20 (Rev 3/05) **The Department of Ecology does NOT warranty the Data and/or Information on this Well Report.**

AHP-776 (pg 2)

The Department of Ecology does NOT Warranty the Data and/or the Information on this Well Report.I Report.



WATER WELL REPORT

Original & 1st copy – Ecology, 2nd copy – owner, 3rd copy – driller

Construction/Decommission *("x" in circle)*
☒ Construction
☐ Decommission *ORIGINAL INSTALLATION Notice of Intent Number* ____________

CURRENT
Notice of Intent No. W150756
Unique Ecology Well ID Tag No. AHP776
Water Right Permit No. G4-34953
Property Owner Name Art DenHoed
Well Street Address 62002 N. Missimer Rd
City Grandview County Yakima
Location Sw 1/4-1/4 Se 1/4 Sec 5 Twn 10N R 23 EWM ☑ or WWM ☐ circle one
Lat/Long (s, t, r Still **REQUIRED**) Lat Deg ______ Lat Min/Sec ________ Long Deg ______ Long Min/Sec ________
Tax Parcel No. ____________

DEPT OF ECOLOGY
Received
[illegible] 2 4 2005
CENTRAL REGION OFFICE

PROPOSED USE: ☐ Domestic ☐ Industrial ☐ Municipal ☐ DeWater ☑ Irrigation ☐ Test Well ☐ Other ________

TYPE OF WORK: Owner's number of well (if more than one) ________
☑ New well ☐ Reconditioned *Method:* ☐ Dug ☐ Bored ☐ Driven
☐ Deepened ☐ Cable ☑ Rotary ☐ Jetted

DIMENSIONS: Diameter of well 12"/ 9" inches, drilled 1718' ft.
11-7/8 /9 7/8
Depth of completed well 1718 ft.

CONSTRUCTION DETAILS
Casing Installed:
☑ Welded 24" Diam. from +1 ft. to 105' ft.
☑ Liner installed 16" Diam. from +1 ft. to 323' ft.
☐ Threaded 12" Diam. from +1 ft. to 725' ft.

Perforations: ☐ Yes ☑ No
Type of perforator used ____________
SIZE of perfs ______ in. by ______ in. and no. of perfs ____ from ____ ft. to ____ ft.

Screens: ☐ Yes ☑ No ☐ K-Pac Location ____________
Manufacturer's Name ____________
Type ____________ Model No. ____________
Diam. ______ Slot size ______ from ______ ft. to ______ ft.
Diam. ______ Slot size ______ from ______ ft. to ______ ft.

Gravel/Filter packed: ☐ Yes ☑ No ☐ Size of gravel/sand ________
Materials placed from ______ ft. to ______ ft.

Surface Seal: ☑ Yes ☐ No To what depth? 725' ft.
Material used in seal cement
Did any strata contain unusable water? ☐ Yes ☐ No
Type of water? ________ Depth of strata ________
Method of sealing strata off ____________

PUMP: Manufacturer's Name ____________
Type: ____________ H.P. ________

WATER LEVELS: Land-surface elevation above mean sea level ______ ft.
Static level 531 ft. below top of well Date ________
Artesian pressure ________ lbs. per square inch Date ________
Artesian water is controlled by ____________ (cap, valve, etc.)

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.
Yield: ______ gal./min. with ______ ft. drawdown after ______ hrs.
Yield: ______ gal./min. with ______ ft. drawdown after ______ hrs.
Recovery data (time taken as zero when pump turned off) (water level measured from well top to water level)

Time	Water Level	Time	Water Level	Time	Water Level

Date of test ____________
Bailer test ______ gal./min. with ______ ft. drawdown after ______ hrs.
Airtest 2000 gal./min. with stem set at 1700 ft. for 1 hrs.
Artesian flow ________ g.p.m. Date ________
Temperature of water ______ Was a chemical analysis made? ☐ Yes ☐ No

CONSTRUCTION OR DECOMMISSION PROCEDURE

Formation: Describe by color, character, size of material and structure, and the kind and nature of the material in each stratum penetrated, with at least one entry for each change of information. (USE ADDITIONAL SHEETS IF NECESSARY.)

MATERIAL	FROM	TO
Brown Claystone	659	662
Greeen Sandstone	662	665
Green clay	665	691
Green & Brown clay	691	705
Brown clay & broken basalt	705	707
Black porus basalt	707	710
Hard dark gray basalt (736-737 void)	710	870
Soft black visicular basalt some black & green clay		
water 300-400	870	878
Dark gray porus basalt Med. hard	878	928
Hard gray basalt	928	942
Very broken gray basalt some visicular water 198 psi	942	944
Hard gray basalt	944	963
Med. soft black basalt	963	987
Med. hard dark gray basalt	987	1026
Med. soft dark gray & reddish brown basalt	1026	1032
Med. hard dark gray	1032	1036
Med. soft reddish brown & dark gray basalt	1036	1043
Med. hard dark gray porus	1043	1053
Med. soft dark gray porus basalt	1053	1079
Soft broken black visicular basalt Water 260 psi 77de	1079	1083
Med. hard porus black	1083	1089
Broken porus black basalt 270psi 280psi-1092	1089	1092
Hard dark gray basalt	1109	1148
Med. soft black porus basalt	1148	1172
Hard gray basalt	1172	1185
Med. soft black porus basalt	1185	1187
Hard gray basalt	1187	1198
Soft black porus basalt some hard dark green clay		
water 300 psi	1198	1217
Hard dark gray basalt	1217	1242

Start Date 4-8-05 Completed Date 5-25-05

WELL CONSTRUCTION CERTIFICATION: I constructed and/or accept responsibility for construction of this well, and its compliance with all Washington well construction standards. Materials used and the information reported above are true to my best knowledge and belief.

☐ Driller ☐ Engineer ☐ Trainee Name (Print) Larry McLanahan
Driller/Engineer/Trainee Signature Larry M
Driller or trainee License No. 0337

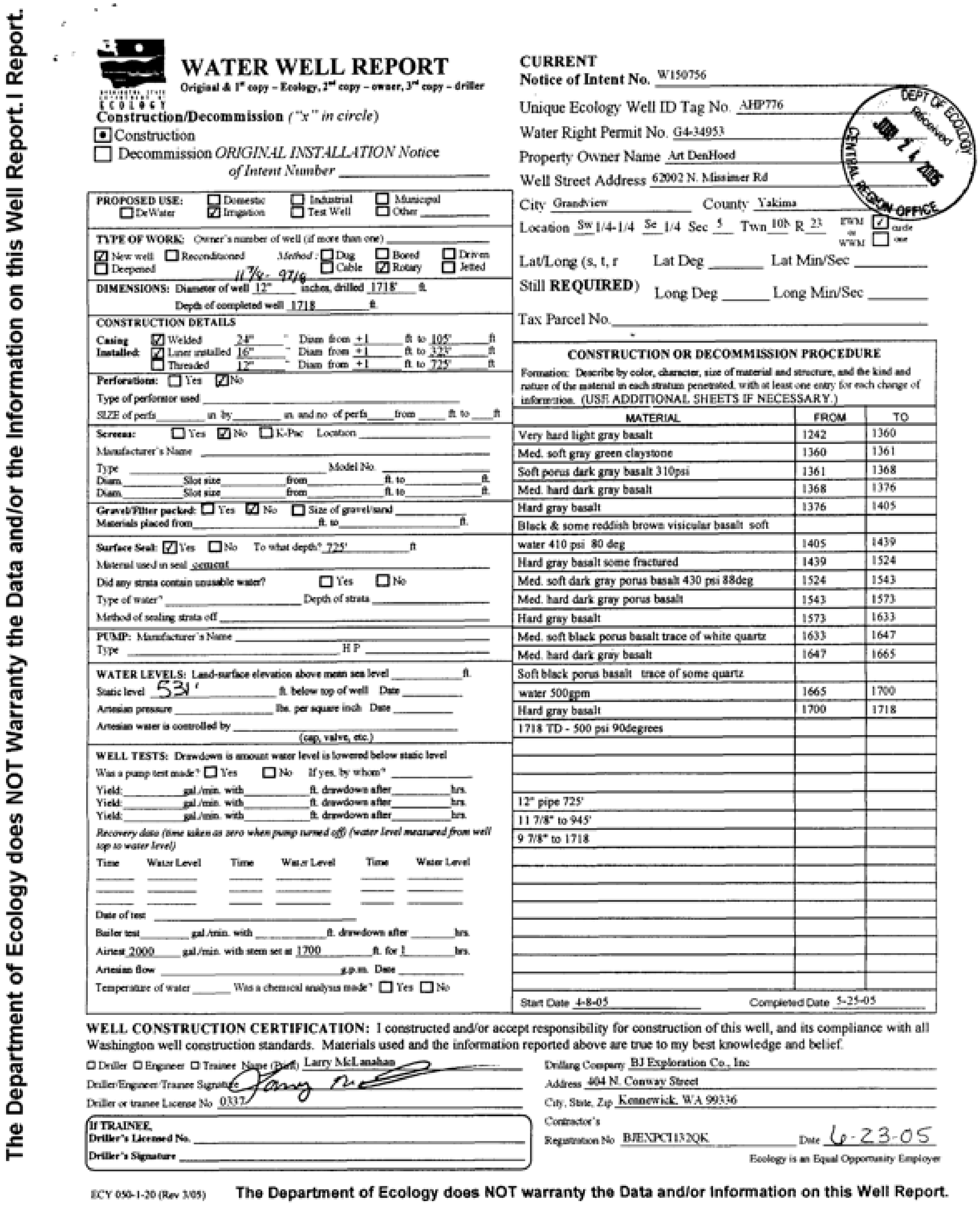
If TRAINEE,
Driller's Licensed No. ____________
Driller's Signature ____________

Drilling Company BJ Exploration Co., Inc
Address 404 N. Conway Street
City, State, Zip Kennewick, WA 99336
Contractor's Registration No. BJEXPCI132QK Date 6-23-05

Ecology is an Equal Opportunity Employer.

ECY 050-1-20 (Rev 3/05) **The Department of Ecology does NOT warranty the Data and/or Information on this Well Report.**

AHP-776 (pg 3)



The Department of Ecology does NOT Warranty the Data and/or the Information on this Well Report.

WATER WELL REPORT

Original & 1st copy – Ecology, 2nd copy – owner, 3rd copy – driller

Construction/Decommission *("x" in circle)*

☒ Construction
☐ Decommission *ORIGINAL INSTALLATION Notice of Intent Number* ______

CURRENT
Notice of Intent No. W150756

Unique Ecology Well ID Tag No. AHP776
Water Right Permit No. G4-34953
Property Owner Name Art DenHoed
Well Street Address 62002 N. Missimer Rd
City Grandview County Yakima
Location Sw 1/4-1/4 Se 1/4 Sec 5 Twn 10N R 23 EWM ☑ or WWM ☐ (circle one)
Lat/Long (s, t, r Still **REQUIRED**) Lat Deg ______ Lat Min/Sec ______ Long Deg ______ Long Min/Sec ______
Tax Parcel No. ______

DEPT OF ECOLOGY
Received
JUN 24 2005
CENTRAL REGION OFFICE

PROPOSED USE: ☐ Domestic ☐ Industrial ☐ Municipal ☐ DeWater ☑ Irrigation ☐ Test Well ☐ Other ______

TYPE OF WORK: Owner's number of well (if more than one) ______
☑ New well ☐ Reconditioned *Method:* ☐ Dug ☐ Bored ☐ Driven
☐ Deepened ☐ Cable ☑ Rotary ☐ Jetted

11 7/8 - 9 7/8

DIMENSIONS: Diameter of well 12" inches, drilled 1718' ft.
Depth of completed well 1718 ft.

CONSTRUCTION DETAILS

Casing Installed:	☑ Welded	24"	Diam from +1	ft to 105' ft
	☑ Liner installed	16"	Diam from +1	ft to 325' ft
	☐ Threaded	12"	Diam from +1	ft to 725' ft

Perforations: ☐ Yes ☑ No
Type of perforator used ______
SIZE of perfs ______ in by ______ in and no of perfs ______ from ______ ft to ______ ft

Screens: ☐ Yes ☑ No ☐ K-Pac Location ______
Manufacturer's Name ______
Type ______ Model No. ______
Diam. ______ Slot size ______ from ______ ft. to ______ ft.
Diam. ______ Slot size ______ from ______ ft. to ______ ft.

Gravel/Filter packed: ☐ Yes ☑ No ☐ Size of gravel/sand ______
Materials placed from ______ ft. to ______ ft.

Surface Seal: ☑ Yes ☐ No To what depth? 725' ft
Material used in seal cement
Did any strata contain unusable water? ☐ Yes ☐ No
Type of water? ______ Depth of strata ______
Method of sealing strata off ______

PUMP: Manufacturer's Name ______
Type ______ H P ______

WATER LEVELS: Land-surface elevation above mean sea level ______ ft.
Static level 531' ft. below top of well Date ______
Artesian pressure ______ lbs. per square inch Date ______
Artesian water is controlled by ______ (cap, valve, etc.)

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.
Yield: ______ gal./min. with ______ ft. drawdown after ______ hrs.
Yield: ______ gal./min. with ______ ft. drawdown after ______ hrs.
Recovery data (time taken as zero when pump turned off) (water level measured from well top to water level)

Time	Water Level	Time	Water Level	Time	Water Level

Date of test ______
Bailer test ______ gal./min. with ______ ft. drawdown after ______ hrs.
Airtest 2000 gal./min. with stem set at 1700 ft. for 1 hrs.
Artesian flow ______ g.p.m. Date ______
Temperature of water ______ Was a chemical analysis made? ☐ Yes ☐ No

CONSTRUCTION OR DECOMMISSION PROCEDURE

Formation: Describe by color, character, size of material and structure, and the kind and nature of the material in each stratum penetrated, with at least one entry for each change of information. (USE ADDITIONAL SHEETS IF NECESSARY.)

MATERIAL	FROM	TO
Very hard light gray basalt	1242	1360
Med. soft gray green claystone	1360	1361
Soft porus dark gray basalt 310psi	1361	1368
Med. hard dark gray basalt	1368	1376
Hard gray basalt	1376	1405
Black & some reddish brown visicular basalt soft		
water 410 psi 80 deg	1405	1439
Hard gray basalt some fractured	1439	1524
Med. soft dark gray porus basalt 430 psi 88deg	1524	1543
Med. hard dark gray porus basalt	1543	1573
Hard gray basalt	1573	1633
Med. soft black porus basalt trace of white quartz	1633	1647
Med. hard dark gray basalt	1647	1665
Soft black porus basalt trace of some quartz		
water 500gpm	1665	1700
Hard gray basalt	1700	1718
1718 TD - 500 psi 90degrees		
12" pipe 725'		
11 7/8" to 945'		
9 7/8" to 1718		

Start Date 4-8-05 Completed Date 5-25-05

WELL CONSTRUCTION CERTIFICATION: I constructed and/or accept responsibility for construction of this well, and its compliance with all Washington well construction standards. Materials used and the information reported above are true to my best knowledge and belief.

☐ Driller ☐ Engineer ☐ Trainee Name (Print) Larry McLanahan
Driller/Engineer/Trainee Signature
Driller or trainee License No 0337

If TRAINEE,
Driller's Licensed No. ______
Driller's Signature ______

Drilling Company BJ Exploration Co., Inc
Address 404 N. Conway Street
City, State, Zip Kennewick, WA 99336
Contractor's Registration No BJEXPCI132QK Date 6-23-05

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ECY 050-1-20 (Rev 3/05) **The Department of Ecology does NOT warranty the Data and/or Information on this Well Report.**

Appendix B. Laboratory Certification Documentation

The following pages contain the relevant parts of the Quality Assurance/Quality Control Manual for the Environmental Testing Laboratory in the Chemistry Department at Central Washington University. It includes procedures for processing samples from Mount Rainer Park. The Geological Sciences and Chemistry Departments share instruments and QA/QC methods.

QUALITY ASSURANCE/QUALITY CONTROL MANUAL

CENTRAL WASHINGTON UNIVERSITY CHEMISTRY DEPARTMENT ENVIRONMENTAL TESTING

Table of Contents

Organization/QA Policy

Laboratory Purpose:

The laboratory is a teaching and service laboratory which accepts samples from local, federal, and state agencies for analysis. We are concerned with environmental monitoring and the implications of the laboratory findings.

Laboratory Organization:

The laboratory is housed in the chemistry department at Central Washington University, and it is managed by Anne Johansen. The manager is responsible for the Quality Assurance and Quality Control.

Sample receiving, storage, and analytical work is performed by the manager as well as staff. The manager and staff may participate in QC work and data logging. The manager reviews all data and reports before release.

Staff:

The laboratory staff primarily consists of CWU students. Students who perform analytical work are required to meet a minimum course work qualification of junior status with one-year general chemistry, one quarter quantitative analysis, and one quarter instrumental analysis. Students involved in analyses have been given training on analytical QA/QC as part of their analytical chemistry curriculum and qualified students are then trained to accomplish the particular analyses assigned to them. Students will be required to satisfactorily analyze check standards before they are given the responsibility of working on environmental samples. This manual serves as a procedure manual.

QA/QC Policy Statement:

It is our goal that the analytical results from this laboratory will be reported with defined accuracy limits and with stated estimates of uncertainty and minimum detection limits. Sample handling, sample analysis, data manipulation, and data storage procedures are documented in this QA/QC manual.

The actual laboratory work is documented in laboratory notebooks. The analytical results of precipitation chemistry studies are archived in the computer file S:\Chemistry Research\Johansen Research\Mt Rainier.

Sample Management:

Procedures for requesting analysis: Samples are usually accepted as part of a defined study. For instance: Weekly bulk precipitation samples which have been collected at Mt. Rainier Paradise Station as a result of a working agreement with the National Park Service are analyzed for pH, conductivity, and major cations and anions. Filtered lake water samples which have been collected at lakes around Mt. Rainier and North Cascade National Park are also sent into our lab annually for cation and anion analyses.

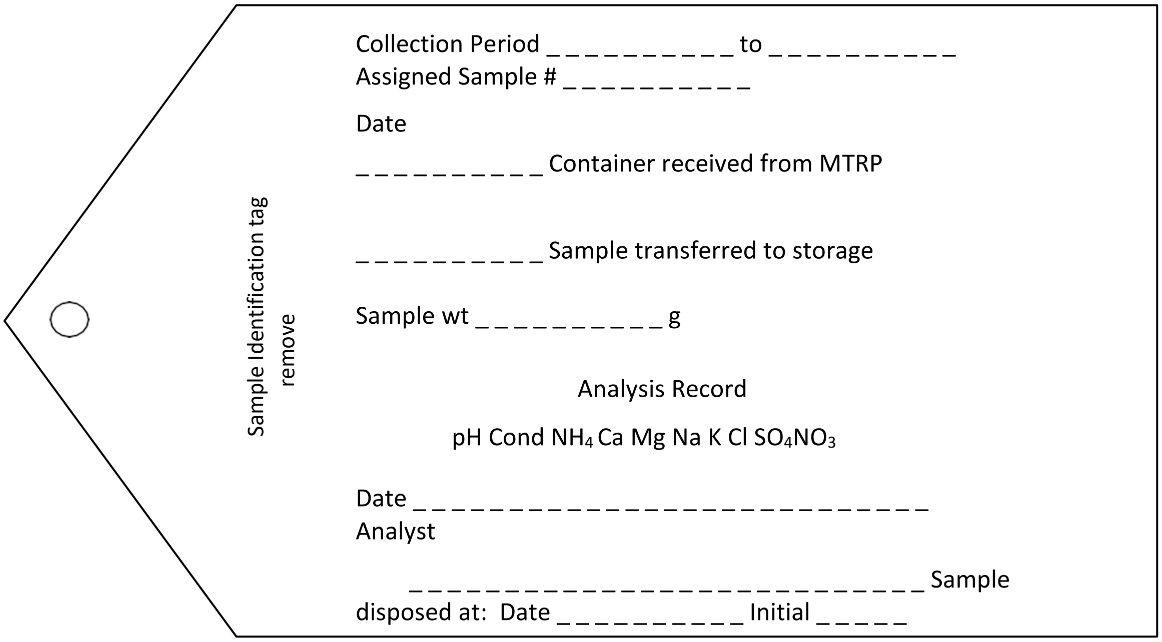
Procedure for receipt: Individual staff is assigned responsibility for receipt of samples for particular studies. On receipt, samples are to be inspected for container breakage, container integrity, and sample condition. The sample log sheet should be marked to show the observation of each parameter. If sample integrity has been compromised the sample will be rejected or a notation will be attached to the reported results for that sample.

Procedure for logging: The samples are logged in a notebook or binder dedicated to the particular study. Sample identity, size, condition, and processing date are logged. Sample containers are labeled with a sequential number to assure identification of those samples during all steps in the analysis. The identification number is also to be recorded on the sample log sheet.

Procedure for storage: If it is necessary to transfer samples from shipping containers to storage containers, the final containers and transfer equipment should be treated to avoid introduction of outside contaminants. The treatment procedure is described in the section of this manual titled: “Requirements: A; Container Requirements”. Samples should be well mixed before transfer.

Aliquots for analysis are poured from the sample storage containers. Containers are then returned to the storage site.

<u>Procedure for chain-of custody:</u> Procedures should be practiced to ensure that samples are traceable from time of collection through data collection to sample disposal. A designated person is responsible for receiving and logging-in all samples. In addition to assigning a sample number and recording the data concerning each sample into a logbook, the receiving person will affix a sample identification tag to each sample container. The tag will serve as chain of custody record. See the sample tag for the Mt. Rainier Precipitation Study. Figure 1.



Sample Identification tag
remove

Collection Period _ _ _ _ _ _ _ _ _ _ _ to _ _ _ _ _ _ _ _ _ _ _
Assigned Sample # _ _ _ _ _ _ _ _ _ _ _

Date

_ _ _ _ _ _ _ _ _ _ _ Container received from MTRP

_ _ _ _ _ _ _ _ _ _ _ Sample transferred to storage

Sample wt _ _ _ _ _ _ _ _ _ _ _ g

Analysis Record

pH Cond NH_4 Ca Mg Na K Cl $SO_4$$NO_3$

Date _
Analyst

_ Sample disposed at: Date _ _ _ _ _ _ _ _ _ _ _ Initial _ _ _ _ _

Figure 1 Sample ID Tag

<u>Criteria for sample acceptance/rejection:</u> Sample is not accepted for analysis if: (in all cases tag the samples and notify the lab manager)

a) Field log sheets indicate vandalism or accidental contamination.
b) Samples have been retained beyond “maximum holding times for parameters of interest” (see section on holding times).
c) Samples have not been cooled as prescribed.
d) Samples have not been preserved as prescribed*.

* Precipitation samples may be handled differently. Changes will be defined with the user.

Requirements:

A. Container requirements: Plastic collection buckets are scrubbed and rinsed with deionized water until the conductivity of the rinse is less than 1μS/cm. The conductivity of the collection buckets are logged before they are sent back to the collection site.

TraceClean™ High-density polyethylene bottles are used for sample storage container to ensure to meet U.S. EPA Specifications and Guideline for Contamination-Free Sample Container.

B. Holding times: Samples are held in a refrigerator at approximately 4°C until analysis to retard biological activity which might change analyte concentrations. Unless otherwise noted, the maximum holding times are:

Parameter	Maximum Holding Time
pH*	Analyze immediately
Nitrate + Nitrite**	28 days
Conductivity	28 days
Ammonia	28 days
Sulfate	28 days
Chloride	28 days
Calcium	6 months
Magnesium	6 months
Sodium	6 months
Potassium	6 months

*In the case of precipitated sample that have been collected over extended period, the holding time for the pH sample is irrelevant and pH is usually measured alongside with conductivity.

**If Nitrite is present in samples, it is assumed to be oxidized to Nitrate within the holding time.

C. Preservation requirements: Unless otherwise noted, metal samples (Ca, Mg, Na, K) should be preserved to pH < 2 with nitric acid, and ammonia samples should be preserved to pH < 2 with sulfuric acid.

Analytical Methods:

Analytical methods used are listed below:

Analyte	Technique	Method #
pH	Electrochemical	EPA 150.1
Conductivity	Electrochemical	EPA 120.1
Cation (Na, NH_4, K, Mg, Ca)	Ion Chromatography with Electrochemical Detector	EPA 300.7
Anion (Cl, NO_3, SO_4)	Ion Chromatography with Electrochemical Detector	EPA 300.1

Mt. Rainier Bucket Processing SOPs

Sample Receiving Procedure

A bucket should be arriving at the Chemistry main office at approximately the same time of day on the same day of the week each week (usually every Thursday by noon). When the bucket arrives, the sample water either needs to be transferred to storage containers or the whole bucket needs to be placed in the lab refrigerator at below 4 °C immediately.

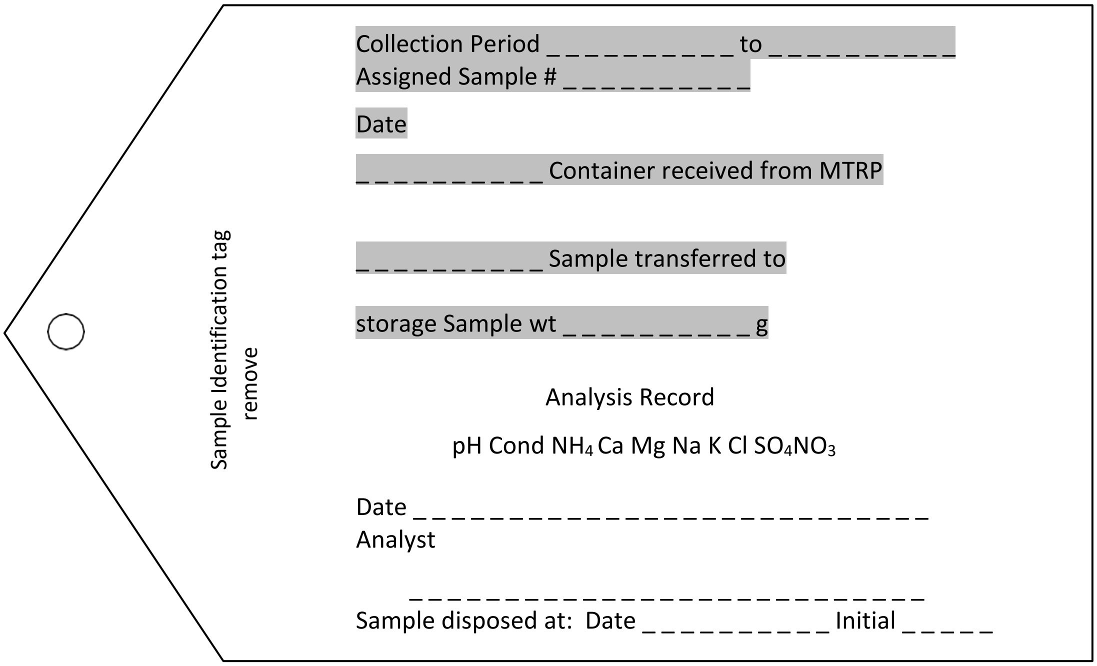
Failure to do so may cause unwanted evaporation and/or change the chemical content of the sample, i.e., biological, thermal decomposition, and to minimize evaporation.

Check the log sheet to make sure name on the bucket matches with the "Bucket ID" on the log sheet. Fill out the "Bucket Record Sheet", which is in the front of Mt. Rainier three-ring binder, with the date of bucket arrival to the Chemistry main office, and date of the water sample transfer to the storage bottles.

Sample Transferring Procedure

1. Wear plastic gloves to handle a bucket. Open the box and take the bucket out. Set the box aside until the next batch of buckets are shipped out. Reuse the plastic bag for as long as possible. If the plastic bag is torn, full of debris, or is wet, throw it away, and get new one from a waste can in the lab.
2. Use the aluminum bucket opener to get the lid off of the bucket. Take extra caution not to spill the contents, because the lid might be difficult to open.
3. If the bucket is empty, skip to the **Bucket Cleaning Procedure**. If there is water in the bucket, proceed to the Step 4.
4. Using the large Mettler balance, weigh the bucket and its contents. Write it down on the log sheet (See **Log Sheet**).
5. Get three unused 120 mL "Pre-Clean" HDPE bottles. Using a permanent marker, label each bottle with the sample name (See **Sample Name**) with analyses methods (one for "pH, Conductivity, and Anions", one for "Cations", and one for "Ammonia"). Rinse bottles with small amount of sample water from the bucket. It is ideal to rinse each bottle three times in this manner. If there is not enough sample to spare, they can be rinsed less than three times (or no rinsing); on the log sheet, make sure to note the reason for not rinsing three times.
6. Fill bottles with the sample water. If the water sample is large enough that you can let some of the water go down the drain, make an effort to dump out any debris in the water sample. At least 15-20 mL sample water must be present to be considered a useful amount for "pH, Conductivity, and Anions" analyses, and at least 2-3 mL sample water is needed for "Cations" and "Ammonia" analyses.
7. Once all three bottles are filled, the rest of water sample in the bucket can go down in the drain. Drain as much water as possible, and then place the empty bucket on the Mettler balance. Record it on the log sheet.

8. Subtract the mass of the empty bucket from the mass of the full bucket with rainwater to get the sample weight and record this on the log sheet. Initial the log sheet, write down any comments that you may have. (When in doubt, write it down.) Also be sure to write down the sample's identification name/number on the log sheet.
9. Now, "Cations" and "Ammonia" samples need to be treated with acid for preservation. Concentrated nitric acid and sulfuric acid dropper bottles are stored in the cabinet under the fume hood. Add the concentrated nitric acid drop by drop to the "Cation" sample until pH < 2. Check the pH with pH papers. Repeat this procedure for the "Ammonia" sample with the concentrated sulfuric acid.
10. Before these bottles are stored in the refrigerator, a sample tag is filled out and attached to one of the bottles. Blank tags are stored in the drawer by the Mettler balance along with the Mt. Rainier Sample stamp and an ink pad. Make a tag, and transfer information of first half of the tag (Collection Period to Sample wt.; highlighted with grey) from the bucket log sheet (Figure 1).



Sample Identification tag
remove

Collection Period _ _ _ _ _ _ _ _ _ _ _ to _ _ _ _ _ _ _ _ _ _ _
Assigned Sample # _ _ _ _ _ _ _ _ _ _ _

Date

_ _ _ _ _ _ _ _ _ _ _ Container received from MTRP

_ _ _ _ _ _ _ _ _ _ _ Sample transferred to

storage Sample wt _ _ _ _ _ _ _ _ _ _ _ g

Analysis Record

pH Cond NH_4 Ca Mg Na K Cl SO_4NO_3

Date _
Analyst

_ _
Sample disposed at: Date _ _ _ _ _ _ _ _ _ _ _ Initial _ _ _ _ _

Figure 1: Sample Tag

Bucket Cleaning Procedure

1. Turn on the deionized water faucet 5 to 10 minutes (if the deionized water has not been used for a while, wait a little bit longer) before starting the cleaning procedure. Take out the cleaning brush from the drawer (right side of the sink) and rinse it well with deionized water.
2. Rinse the lid of the bucket with deionized water for at least 2 minutes. Try to hold the lid by the edge or on the outside of the lid. Shake it well and set aside.
3. Rinse the inside and outside of the bucket with deionized water 3 times to remove any debris and dirt. Next using the cleaning brush, scrub the inside bottom of the bucket and rinse. Repeat this procedure 3 times. Then scrub the inner bucket wall and rinse 3 times. Finally rinse the bucket for 3 times. Each rinsing is carried out with about 1 to 1.5 L. Always hold outside of bucket while cleaning, and try not to touch inside of the bucket as much as possible.
4. The bucket has to be clean until the **conductivity** of the rinse water is below 1µs/cm. The Solomat MPM 1000 conductivity meter (usually kept by the sink) is used to measure the rinse conductivity, and the setting for our measurement is 0.1Cell, 160µS. The probe is kept in the test tube with deionized water. A plastic cup, such as a nalgene bottle with the top cut off, is used for sample container. Do not use the sample container for anything else. The hole on the probe must be submerged completely in the water, and to remove any air trapped within the hole swish the probe in the water. The probe should not touch the bottom or the wall of the container to obtain accurate measurements.
5. To measure the rinse water conductivity, first measure conductivity of deionized water. The reading should be below 0.5µS. Then place the bucket on the edge of the sink and use the hose coming from the deionized water faucet to rinse all surfaces of the inside of the bucket. Rotate the bucket to make sure all surfaces are equally rinsed. Rinse the plastic cup, described in Step 4, with the bucket rinse water three times, then, fill the cup with the rinse water. Take a conductivity measurement. The reading should be less than 1 µS (more like 0.5 to 0.8 µS). If the reading is higher, rinse the bucket with deionized water until the reading is in the acceptable range. Record the conductivity reading on the new log sheet and the bucket record sheet.
6. Empty the bucket and dry outside of bucket with paper towel. Place the lid on the bucket, but DO NOT SEAL.

Bucket Shipping Procedure

Put the clean bucket and lid in the clean plastic bag. Fill out the "DEPARTURE" section of a new log sheet, and put it in an envelope. Place the bucket and envelope in the box and tape the box. If a new box is used, make sure the address label with budget number (the current address label is *S:\Chemistry Research\Johansen Research\Mt Rainier\Mt. Rainier SOP's\Mt Rainier Address Label*) is pasted on the box, and "This way is up" sign is drawn on each side of the box. Take the box to the Facility Management building (across from the science building) for shipment.

Sample Names

A sample name for Mt. Rainier precipitation water has been **M-Last two digits of year-Sample number for the year**. M stands for Mt. Rainier. For example, the 22nd sample collected in the year 2007 is named **M-07-22**.

Log Sheet

Log sheets are used to exchange valuable information between the lab personnel and the person in charge of collecting buckets at Mt. Rainier. This information is useful for annual reports, so it is very important to fill them out correctly. The log sheet should be stored in the designated three-ring binder.

Before a bucket is processed, review the log sheet carefully. Make sure that the name of the bucket and the name on the log sheet matches, and the person who collected the bucket filled out all the necessary information. If some information is missing and/or it is not making sense, contact the responsible Mt. Rainier sample collector immediately (currently Rebecca Lofgren is in charge of collecting buckets. Her contact information can be found in *S:\Chemistry Research\Johansen Research\Mt Rainier\Mt. Rainier SOP's\Mt Rainier Contact Information*).

If there was no sample, check the box on the log sheet for "No Sample" and put it in the binder. If there was water in the bucket, fill out the Sample ID and DATA section of the log sheet. Write down any comments on the log sheet if unusual conditions are noted, i.e., some water leaked in the plastic bags, the bucket sat at room temperature overnight.

Ship the bucket with new log sheet with DEPARTURE section filled out.

Blank log sheets can be printed out from *S:\Chemistry Research\Johansen Research\Mt Rainier\Mt. Rainier SOP's\bucketlog*.

pH SOP

Instrument

Instrument:

pH Meter: Orion Model 420A

Electrode: Ross Electrode Model 81-02, combination pH Electrode Storage Solution: 1.0g KCl/200mL pH7.00 buffer solution

Analytical Procedure

Calibration:

1. Pour approximately 12mL of pH 4.00 buffer solution and pH 7.00* buffer solution to clean and labeled plastic containers.
2. Turn on the instrument main switch. Remove the electrode from the storage solution, and rinse it with Milli-Q water and gently tap with paper towel (do not over dry). Remove the filling hole cover during measurement to ensure uniform flow of filling solution.
3. Insert the probe into pH 4.00 buffer solution. Swirl the solution gently and wait until the reading stabilizes. Adjust the meter to read pH 4.00. Rinse and wipe the electrode. Insert the probe into pH 7.00 buffer solution. Adjust the meter to read pH 7.00.

Instrument Check:

1. Turn on the instrument's main power switch.
2. Rinse a small sample container twice with pH 5.00** buffer check standard (CS) solution and pour CS solution to the container.
3. Rinse the pH probe with Milli-Q water and gently remove water with Chem wipe (avoid rubbing or wiping electrode bulb, to reduce chance of error due to polarization) before placing it into the solution. Insert the electrode to the pH 5.00 CS solution and stir. The ceramic reference junction of the electrode must be submerged. Wait until the display is stable (a beep should go off). The pH reading should stabilize within few minutes to 5.00 ± 0.1.

* If the pH of sample(s) is (are) known to be larger than pH 7.00, use pH 4.00 and pH 10.00 buffer solution to calibrate the electrode.

** The pH 7.00 buffer solution or other known pH solutions could be used as the CS when pH 10.00 buffer was used for calibration.

Sample Analysis:

1. Allow samples to come to room temperature. Rinse the electrode with Milli-Q water between data collection of samples. If the same sample container is used for all measurements or containers are not dry, rinse the sample container twice with sample before filling again for analysis.

2. Place the electrode into the sample and observe pH.

3. Run CS solution, blank, and samples in the following order. After every 6th sample measure conductivity of the CS solution and a duplicate of the sample.
   1. CS 1
   2. Blank
   3. Sample 1
   4. Sample 2
   5. Sample 3
   6. Sample 4
   7. CS 2
   8. Duplicate of Sample 4
   9. Sample 5

Data Recording:

All pH data should be recorded in the designated notebook in the following form: Date of Measurement: Initial or name of personal: ______

pH of Buffer used for the calibration: ______

pH of Buffer used for the Check Standard: ______

Samples:_____

Run #	Sample ID	pH	Temperature (C^{o})
1	CS1		
2	Blank		
3	Sample 1		
4	Sample 2		
5	Sample 3		
6	Sample 4		
7	CS2		
8	Sample 4-2		
9	Sample 5		
…	…		

Conductivity SOP

Instrument

YSI 3200 with a model 3252 conductivity cell Cell constant (K): 0.964

Temperature correction: 2.00%/°C (Converted to 25°C)

Analytical Procedure

Check Standard Solution:

1. Dry ~2g of potassium chloride at 105°C for 2 hours, and cool it in a desiccator to room temperature (at least 20 min).
2.
3. The 0.01000M KCl stock solution is prepared by placing 0.7456g of KCl in a 1.000L volumetric flask and diluting to the mark with Milli-Q water.
4.
5. To prepare the 1.000X10-4M KCl working check standard solution, dilute 10.00mL of the KCl stock solution in a 1.000L volumetric flask.

Instrument Check:

1. Turn on the instrument's main power switch and make sure temperature compensation is on.

2. Rinse a small sample container twice with $1.000X10^{-4}$M KCl working check standard (CS) solution and pour CS solution to the container.

3. Rinse the conductivity cell with Milli-Q water and gently remove water with Kimwipes™ before placing it into the solution. Insert the cell to the CS solution and gently tap it to remove any air bubbles. The cell electrode must be submerged completely (the solution line must be above the holes). Wait until the temperature stabilizes. Gently move the cell side to side or up and down in the solution. Be careful that the cell does not touch the bottom or side of the solution container. The conductivity reading should stabilize within few minutes to 14.90µS/cm ±10%.

Sample Analysis:

1. Allow samples to equilibrate to room temperature. It is advisable to perform pH and Conductivity analysis on the same day to prevent samples from going through the temperature change twice. Rinse the conductivity cell with Milli-Q water between data collection of samples. If one sample container is used for all measurements or containers are not dry, rinse the sample container twice with analyte before filling again for analysis.
2. Place the conductivity cell into the analyte and observe the conductivity. Record temperature of the analyte after reading has stabilized. The conductivity reading should stabilize to < 0.2 µS/cm change over 1 minute.
3. Run CS solution, blank, and samples in the following order. After every 6th sample measure conductivity of the CS solution and a duplicate of the sample.
    1. CS 1
    2. Blank
    3. Sample 1
    4. Sample 2
    5. Sample 3
    6. Sample 4
    7. Sample 5
    8. CS 2
    9. Duplicate of Sample 5
    10. Sample 6
    11. Sample 7
    12. Sample 8
    13. Sample 9
    14. Sample 10
    15. CS 3

Data Recording:

All conductivity data should be recorded in the designated notebook in the following form:

Date of Measurement: ______

Initial or name of personal: ______

Cell Constant (K): ______

Temperature Correction: ______

Samples:

Run #	**Sample ID**	**Conductivity (µS/cm)**	**Temperature (Cº)**
1	CS1		
2	Blank		
3	Sample 1		
4	Sample 2		
5	Sample 3		

Ion Chromatograph Anions SOP

SO_4^{2-}, NO_3^-, Cl^-

Instrument

Instrument and Parts:

Chromatography System: DX500

Electrochemical Detector ED40 Gradient Pump GP50 Automated Sampler AS40

Column: Ion Pac AS14 4mm Analytical Column with AG14 4mm Guard Column

Suppressor: ASRS-ULTRA 4mm, run in Auto-suppression Mode

Injection Loop: 50µL

Program Software: Chromeleon® Version 6.80

Operation Procedure:

1. Check the reservoir for the sodium carbonate-sodium bicarbonate eluent. To prevent introducing air bubbles into the system, do not let eluent drop below 200mL. The eluent is prepared by following these procedures:

Stock Solutions:

Prepare the 0.25M stock solutions by placing 26.4903g Na_2CO_3 in a 500.0mL volumetric flask and diluting to the mark with Milli-Q water. Also place 21.0001g $NaHCO_3$ in a separate 500.0mL volumetric flask and dilute to the mark with Milli-Q water.

Working Eluent:

Prepare the 1.75mM Na_2CO_3 / 0.50mM $NaHCO_3$ working eluent by pipetting 7.00mL of the Na_2CO_3 stock solution and 2.00mL of the $NaHCO_3$ stock solution into the same 1.000L volumetric flak. Dilute to the mark with Milli-Q water.

Open the needle valve by the HCO_3^-/CO_3^{2-} eluent bottle and make sure that all the other needle valves are closed.

2. Turn on the ED40 and GP50 power switches.

3. Open the He gas main valve, and check that the He pressure to the system is at least 90psi.

4. Open the eluent flow valve, and adjust it to 80psi.

5. Load an anion method (usually saved as “as12_size of vial_date of calibration”, e.g., “as12_small_06December05”). Let the instrument equilibrate to about 1400psi, and conductivity 17.6µs/cm (takes 30 minutes to 2 hours).

Method parameters:

Pump Rate: 1.2mL/min

Eluent: 100% 1.75mM Na_2CO_3 / 0.50mM $NaHCO_3$

Suppressor Current: 50mA Sample Loop: 50µL

6. Turn on the AS40, and place sample trays into the slot. Press “Hold/Run” on the AS40 to position the first sample for the injection. Load the schedule and start run.

7. After completion of the full schedule, turn off the switches on ED40, GP50, and AS40, then close the eluent flow valve and He gas valve.

Analytical Procedure

Instrument: See Instrument. Reagents:

1. Reagents must be ACS reagent grade or better.

2. Milli-Q water is used as the deionized water. It must have a conductance of less than 1 µS/cm.

Stock Standard Solution (Prepare monthly):

1. Dry ~2 g of sodium chloride, potassium sulfate, and sodium nitrate at 105°C for 30 minutes, and let them cool for at least 20 minutes in a desiccator to room temperature.

2. To make the $1.000X10^4$ µeq/L (= 10.00mg/L) stock solution, weigh 0.5844 g NaCl, 0.8713g K_2SO_4, and 0.8499 g $NaNO_3$ in a 1.000 L volumetric flask and dilute to the mark with deionized water.

Store stock standard solution in a labeled and rinsed (with deionized water and subsequently the stock standard solution) 500 mL HDPE bottle in the refrigerator.

Calibration Standards (Prepare weekly):

1. Since there is a small amount of chloride ion present in the Milli-Q water, 100% Milli-Q water (Blank) is used for the first calibration point. All other calibration standards are prepared by diluting the stock standard solution in 500.0 mL or 100.0 mL volumetric flasks. If stock standard solution was stored in the refrigerator, let it warm up to room temperature before use (preferably overnight). Use automatic pipetter to measure accurate volumes of the stock solution and follow the table below.

Volume of Stock Solution (mL)	Diluted to	Concentration of calibration standards (µeq/L)
0.000	Use Blank	0.000
0.100	500mL	2.000
0.250	500mL	5.000
0.750	500mL	15.00
1.500	500mL	30.00
3.000	500mL	60.00
6.000	500mL	120.0
2.400	100mL	240.0
3.600	100mL	360.0

Quality Control Solution: (Prepare weekly)

1. Dionex Five Anion Standard (at room temperature) is used as the QC stock solution. To prepare the working QC solution, 10.00 mL of the QC stock solution is diluted to

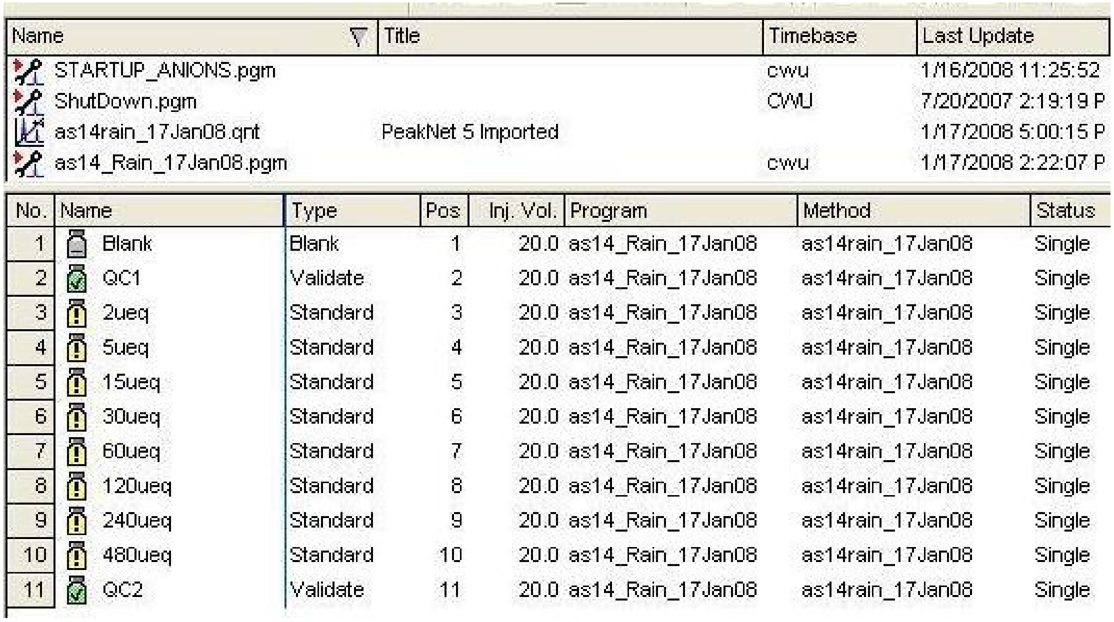
1.000L with deionized water. The target value (µeq/L) of each anion is calculated from the manufacturer’s data sheet.

Cleaning Automated Sampler Vials and Caps (as recommended by manufacturer):

1. During sample preparation and collection, or when handling clean vials and caps, always wear poly gloves (not latex gloves) to prevent contamination.
2. Rinse the filter caps with deionized water using a small syringe. Place vials and caps in a large pre-cleaned plastic container and rinse them for 3 to 5 times. Soak them for 4 hours in deionized water.
3. Drain the container and refill with deionized water. Soak the vials and caps for an additional 24 hours before use.
4. Plunge deionized water through each filter cap with the syringe before drying.

Solution Analysis:

1. Pour room temperature samples, calibration standards, and working QC solution in clean labeled 0.5mL automated sample vials. Fill the vial with analysis solution until it overflows, and insert the clean filter caps. If the vials are not dry, rinse the vial twice with the analysis solution before filling.
2. To obtain the calibration curve for each anion, run blank, calibration standards, and the QC standard in the following order.

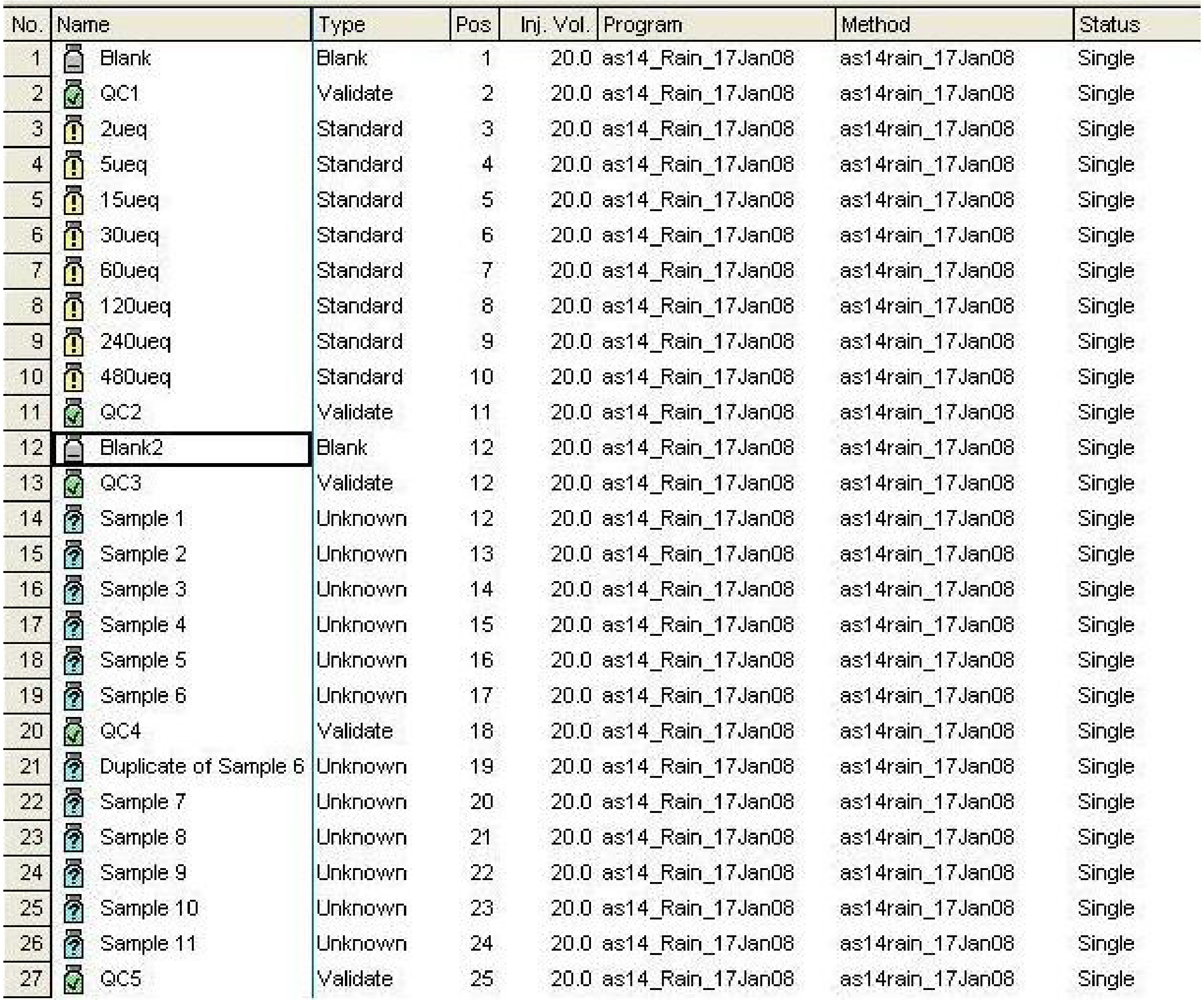


Name	Title	Timebase	Last Update
STARTUP_ANIONS.pgm		cwu	1/16/2008 11:25:52
ShutDown.pgm		CWU	7/20/2007 2:19:19 P
as14rain_17Jan08.qnt	PeakNet 5 Imported		1/17/2008 5:00:15 P
as14_Rain_17Jan08.pgm		cwu	1/17/2008 2:22:07 P

No.	Name	Type	Pos	Inj. Vol.	Program	Method	Status
1	Blank	Blank	1	20.0	as14_Rain_17Jan08	as14rain_17Jan08	Single
2	QC1	Validate	2	20.0	as14_Rain_17Jan08	as14rain_17Jan08	Single
3	2ueq	Standard	3	20.0	as14_Rain_17Jan08	as14rain_17Jan08	Single
4	5ueq	Standard	4	20.0	as14_Rain_17Jan08	as14rain_17Jan08	Single
5	15ueq	Standard	5	20.0	as14_Rain_17Jan08	as14rain_17Jan08	Single
6	30ueq	Standard	6	20.0	as14_Rain_17Jan08	as14rain_17Jan08	Single
7	60ueq	Standard	7	20.0	as14_Rain_17Jan08	as14rain_17Jan08	Single
8	120ueq	Standard	8	20.0	as14_Rain_17Jan08	as14rain_17Jan08	Single
9	240ueq	Standard	9	20.0	as14_Rain_17Jan08	as14rain_17Jan08	Single
10	480ueq	Standard	10	20.0	as14_Rain_17Jan08	as14rain_17Jan08	Single
11	QC2	Validate	11	20.0	as14_Rain_17Jan08	as14rain_17Jan08	Single

3. Within the instrument software plot concentration (µeq/L) vs. peak area using the data from the calibration standards. Choose linear curve fit type; force origin through zero, and record the equation and R^2 value. Print out each calibration graph. Update the method file.

4. Proceed with sample analysis. Run blank, QC standards, and samples in the following order. After every 6th sample determine a QC standard and a duplicate of the sample.



No.	Name	Type	Pos	Inj. Vol.	Program	Method	Status
1	Blank	Blank	1	20.0	as14_Rain_17Jan08	as14rain_17Jan08	Single
2	QC1	Validate	2	20.0	as14_Rain_17Jan08	as14rain_17Jan08	Single
3	2ueq	Standard	3	20.0	as14_Rain_17Jan08	as14rain_17Jan08	Single
4	5ueq	Standard	4	20.0	as14_Rain_17Jan08	as14rain_17Jan08	Single
5	15ueq	Standard	5	20.0	as14_Rain_17Jan08	as14rain_17Jan08	Single
6	30ueq	Standard	6	20.0	as14_Rain_17Jan08	as14rain_17Jan08	Single
7	60ueq	Standard	7	20.0	as14_Rain_17Jan08	as14rain_17Jan08	Single
8	120ueq	Standard	8	20.0	as14_Rain_17Jan08	as14rain_17Jan08	Single
9	240ueq	Standard	9	20.0	as14_Rain_17Jan08	as14rain_17Jan08	Single
10	480ueq	Standard	10	20.0	as14_Rain_17Jan08	as14rain_17Jan08	Single
11	QC2	Validate	11	20.0	as14_Rain_17Jan08	as14rain_17Jan08	Single
12	Blank2	Blank	12	20.0	as14_Rain_17Jan08	as14rain_17Jan08	Single
13	QC3	Validate	12	20.0	as14_Rain_17Jan08	as14rain_17Jan08	Single
14	Sample 1	Unknown	12	20.0	as14_Rain_17Jan08	as14rain_17Jan08	Single
15	Sample 2	Unknown	13	20.0	as14_Rain_17Jan08	as14rain_17Jan08	Single
16	Sample 3	Unknown	14	20.0	as14_Rain_17Jan08	as14rain_17Jan08	Single
17	Sample 4	Unknown	15	20.0	as14_Rain_17Jan08	as14rain_17Jan08	Single
18	Sample 5	Unknown	16	20.0	as14_Rain_17Jan08	as14rain_17Jan08	Single
19	Sample 6	Unknown	17	20.0	as14_Rain_17Jan08	as14rain_17Jan08	Single
20	QC4	Validate	18	20.0	as14_Rain_17Jan08	as14rain_17Jan08	Single
21	Duplicate of Sample 6	Unknown	19	20.0	as14_Rain_17Jan08	as14rain_17Jan08	Single
22	Sample 7	Unknown	20	20.0	as14_Rain_17Jan08	as14rain_17Jan08	Single
23	Sample 8	Unknown	21	20.0	as14_Rain_17Jan08	as14rain_17Jan08	Single
24	Sample 9	Unknown	22	20.0	as14_Rain_17Jan08	as14rain_17Jan08	Single
25	Sample 10	Unknown	23	20.0	as14_Rain_17Jan08	as14rain_17Jan08	Single
26	Sample 11	Unknown	24	20.0	as14_Rain_17Jan08	as14rain_17Jan08	Single
27	QC5	Validate	25	20.0	as14_Rain_17Jan08	as14rain_17Jan08	Single

Performance Report

Method Detection Limits (MDL) and Linear Range:

Analyte	Retention Time (min)	MDL		Linear Range	
		(µeq/L)	(mg/L)	(µeq/L)	(mg/L)
Chloride	3.1	1.42	0.0502	1.4 – 360	0.050 – 12.8
Nitrate	4.6	1.07	0.0665	1.0 – 360	0.067 – 22.3
Sulfate	6.1	1.35	0.0650	1.4 – 360	0.065 – 17.3

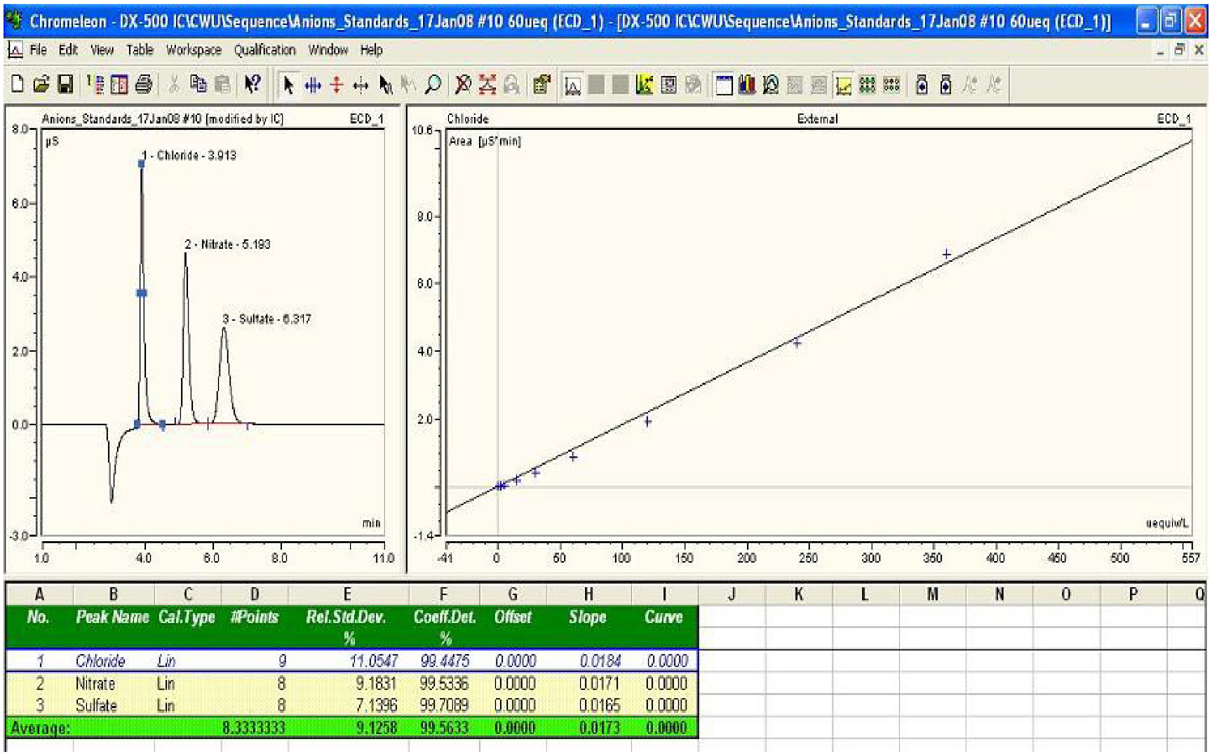
Standard Conditions:

Refer to Instrument section.

MDL calculated from 41 replicates of QC run from different days. MDL = t·std (t = 2.42 for 41 replicates with 98% confidence level). See attached spreadsheet in Appendix.

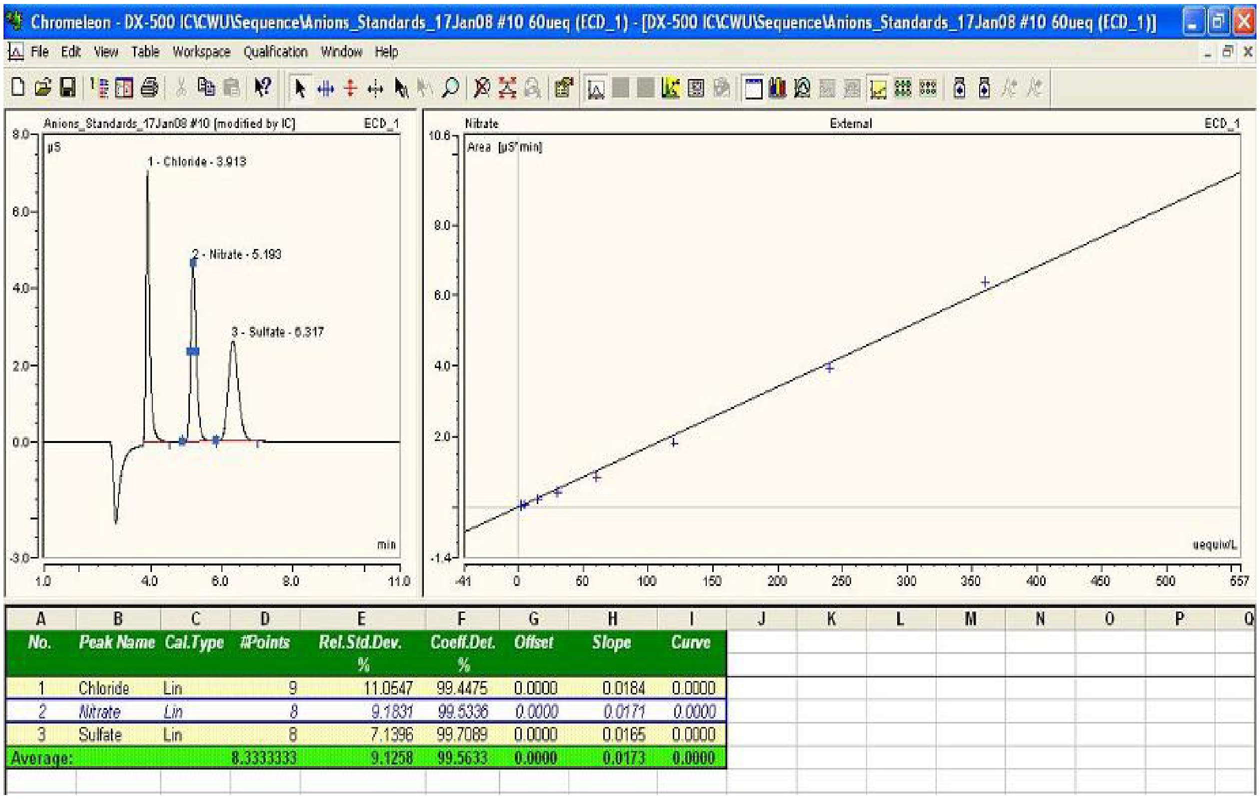
Calibration Curves:

1. Chloride standards 0.00 to 360µeq/L



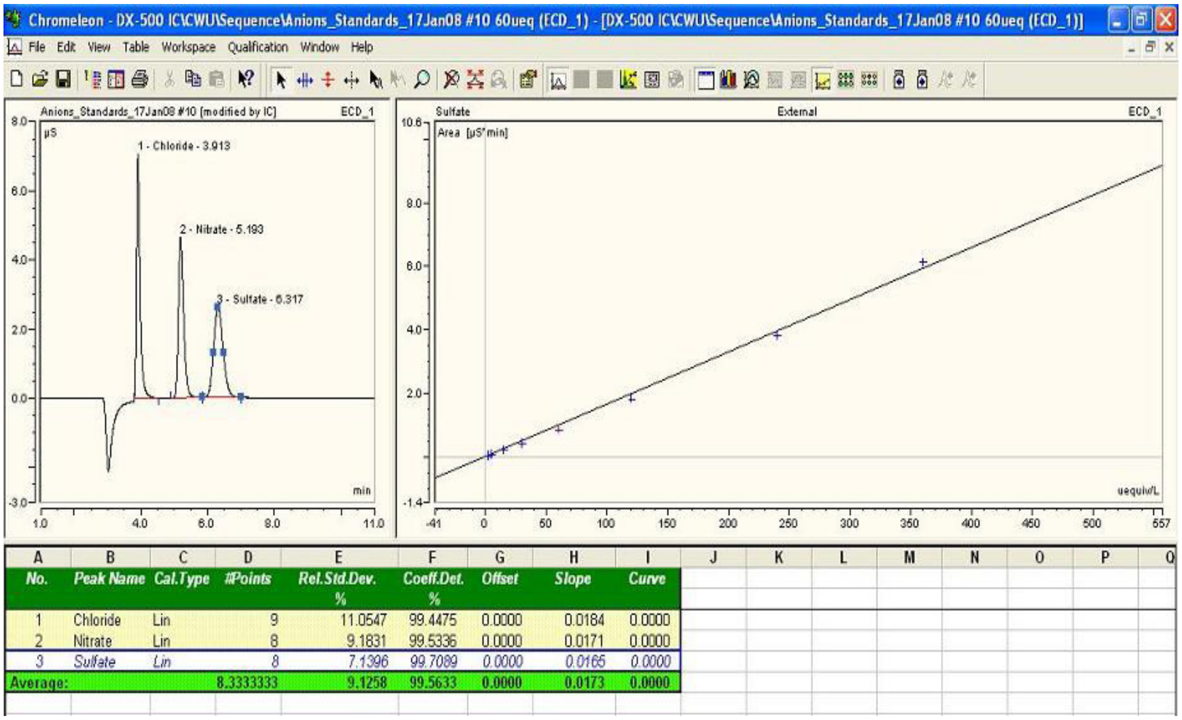
No.	Peak Name	Cal.Type	#Points	Rel.Std.Dev. %	Coeff.Det. %	Offset	Slope	Curve
1	Chloride	Lin	9	11.0547	99.4475	0.0000	0.0184	0.0000
2	Nitrate	Lin	8	9.1831	99.5336	0.0000	0.0171	0.0000
3	Sulfate	Lin	8	7.1396	99.7089	0.0000	0.0165	0.0000
Average:			8.3333333	9.1258	99.5633	0.0000	0.0173	0.0000

2. Nitrate standards 2.00 to 360µeq/L



A	B	C	D	E	F	G	H	I
No.	Peak Name	Cal.Type	#Points	Rel.Std.Dev. %	Coeff.Det. %	Offset	Slope	Curve
1	Chloride	Lin	9	11.0547	99.4475	0.0000	0.0184	0.0000
2	*Nitrate*	*Lin*	*8*	*9.1831*	*99.5336*	*0.0000*	*0.0171*	*0.0000*
3	Sulfate	Lin	8	7.1396	99.7089	0.0000	0.0165	0.0000
Average:			**8.3333333**	**9.1258**	**99.5633**	**0.0000**	**0.0173**	**0.0000**

3. Sulfate standards 2.00 to 360µeq/L



A	B	C	D	E	F	G	H	I
No.	Peak Name	Cal.Type	#Points	Rel.Std.Dev. %	Coeff.Det. %	Offset	Slope	Curve
1	Chloride	Lin	9	11.0547	99.4475	0.0000	0.0184	0.0000
2	Nitrate	Lin	8	9.1831	99.5336	0.0000	0.0171	0.0000
3	*Sulfate*	*Lin*	*8*	*7.1396*	*99.7089*	*0.0000*	*0.0165*	*0.0000*
Average:			**8.3333333**	**9.1258**	**99.5633**	**0.0000**	**0.0173**	**0.0000**

Appendix to IC Anion SOP:

1. Spreadsheet used to calculate MDLs QC deom 06-Dec-05 to 28-Feb-06

	QCD	Cl	NO3	SO4
6-Dec-05	1	8.39	15.37	31.30
	2	8.07	15.29	31.67
	3	8.11	15.48	31.71
	4	8.44	15.85	31.81
	5	7.93	15.80	32.00
	6	8.78	15.79	31.61
	7	8.01	15.65	31.90
	8	7.22	15.59	31.93
	9	7.70	16.18	32.19
	10	7.36	15.73	32.45
	11	10.26	16.57	33.07
	12	8.71	15.86	32.55
	13	8.38	15.70	32.54
8-Dec-05	14	8.39	15.86	32.25
	15	8.33	15.74	32.15
	16	8.47	15.73	32.16
	17	8.37	15.70	31.51
	18	8.50	15.74	32.11
	19	8.62	15.86	31.74
	20	7.76	15.70	32.04
	21	9.07	16.27	33.25
	22	7.46	15.13	31.43
	23	8.62	15.94	32.22
	24	7.70	15.89	32.15
	25	7.88	16.30	33.57
	26	7.53	15.95	32.24
9-Dec-05	27	8.16	15.82	32.17
	28	7.96	15.95	32.61
	29	7.70	16.06	32.96
	30	7.76	16.02	31.99
	31	7.75	16.30	31.65
	32	7.70	16.29	31.85
	33	7.55	16.19	32.99
	34	7.84	16.27	32.57
	35	7.73	16.48	32.41
	36	7.62	16.47	31.99

	QCD	Cl	NO3	SO4
6-Dec-05	1	8.39	15.37	31.30
	2	8.07	15.29	31.67
	3	8.11	15.48	31.71
	4	8.44	15.85	31.81
	5	7.93	15.80	32.00
	6	8.78	15.79	31.61
	7	8.01	15.65	31.90
	8	7.22	15.59	31.93
	9	7.70	16.18	32.19
	10	7.36	15.73	32.45
	11	10.26	16.57	33.07
	12	8.71	15.86	32.55
	13	8.38	15.70	32.54
8-Dec-05	14	8.39	15.86	32.25
	37	8.93	16.84	32.49
	38	7.72	17.27	32.46
	39	7.46	16.46	32.72
28-Feb-06	40	7.29	16.68	30.72
	41	7.71	15.19	31.51
Std Dev		0.58	0.44	0.56
MLD(ueq/L)		1.42	1.07	1.35
MLD(mg/L)		0.0502	0.0665	0.0650
Mean (ueq/L)		8.07	15.97	32.16
Actual Value (ueq/L)		8.55	16.00	31.00
M.W.		35.45	62.00	96.06
Charge		1	1	2

Ion Chromatograph Cations SOP

Na^+, NH_4^+, K^+, Mg^{2+}, Ca^{2+}

Instrument

Instrument and Parts:

Chromatography System: DX500

Electrochemical Detector ED40 Gradient Pump GP50 Automated Sampler AS40

Column: Ion Pac CS12A 4x250mm Analytical Column with CG 12A 4mm Guard Column

Suppressor: CSRS-ULTRA 4mm, run in Auto-suppression Mode

Injection Loop: 50µL

Program Software: Chromeleon® Version 6.80

Operation Procedure:

1. Check the reservoir for the 20.0mM Methanesulfonic acid (MSA) eluent. To prevent introducing air bubbles into the system, do not let eluent drop below 200mL. The 20.0 mM MSA is prepared by pipetting 2.590 mL MSA into a 2.000 L volumetric flask and diluting with deionized water to the mark. Open the needle valve by the MSA eluent bottle and make sure that all the other needle valves are closed.
2. Turn on the ED40 and GP50 power switches.
3. Open the He gas main valve, and check that the He pressure to the system is at least 90 psi.
4. Open the eluent flow valve, and adjust it to 80 psi.
5. Load a cation method (usually saved as “cs12_size of vial date of calibration”, e.g., “cs12_small_24Jan06”). Let the instrument equilibrate to about 1150 psi, and conductivity 1.0 to 1.3 µs/cm (takes 30 minutes to 2 hours).

Method parameters:

Pump Rate: 1.0 mL/min

Eluent: 100% 20 mM MSA Suppressor Current: 50 mA

Sample Loop: 50 µL

6. Turn on the AS40, and place sample trays into the slot. Press “Hold/Run” on the AS40 to position the first sample for the injection. Load the schedule and start run.
7. After completion of the full schedule, turn off the switches on ED40, GP50, and AS40, then close the eluent flow valve and He gas valve.

Analytical Procedure

Instrument: See Instrument. Reagents:

1. Reagents must be ACS reagent grade or better.
2. Milli-Q water is used as the deionized water. It must have a conductance of less than 1 µs/cm.

Stock Standard Solution (Prepare monthly):

1. Dry ~2 g of sodium chloride, ammonium chloride, potassium chloride, and calcium carbonate at appropriate temperatures (NaCl, NH_4Cl, and KCl at 105°C, $CaCO_3$ at 180°C) for 1 hour, and let them cool for at least 20 minutes in a desiccator to room temperature.
2. To make the $1.000X10^4$ μeq/L (= 10.00 mg/L) stock solution, weigh 0.5844 g NaCl, 0.5349 g NH_4Cl, 0.7455 g KCl, and 0.5005 g $CaCO_3$. For magnesium, sand the magnesium ribbon to remove any oxide and dissolve 0.1216 g of it in a minimal volume of 6N HCl (approximately less than 2 mL).
3. Add all reagents in a 1.000 L volumetric flask, and dissolve them in approximately 600 mL of deionized water. Add a minimal amount of concentrated HCl to the solution until all the $CaCO_3$ has dissolved (approximately less than 1 mL). Dilute to the 1.000 L mark with deionized water and mix well.
4. Store stock standard solution in a labeled and rinsed (with deionized water and subsequently the stock standard solution) 500 mL HDPE bottle in the refrigerator.

Calibration Standards (Prepare weekly):

1. All calibration standards are prepared by diluting the stock standard solution in 500.0 mL or 100.0 mL volumetric flasks. If stock standard solution was stored in the refrigerator, let it warm up to room temperature before use (preferably over night). Use automatic pipetter to measure accurate volumes of the stock solution and follow the table below.

Volume of Stock Solution (mL)	Diluted to	Concentration of calibration standards
0.100	500mL	2.000
0.250	500mL	5.000
0.750	500mL	15.00
1.500	500mL	30.00
3.000	500mL	60.00
6.000	500mL	120.0
2.400	100mL	240.0
4.800	100mL	480.0

Quality Control Solution: (Prepare weekly)

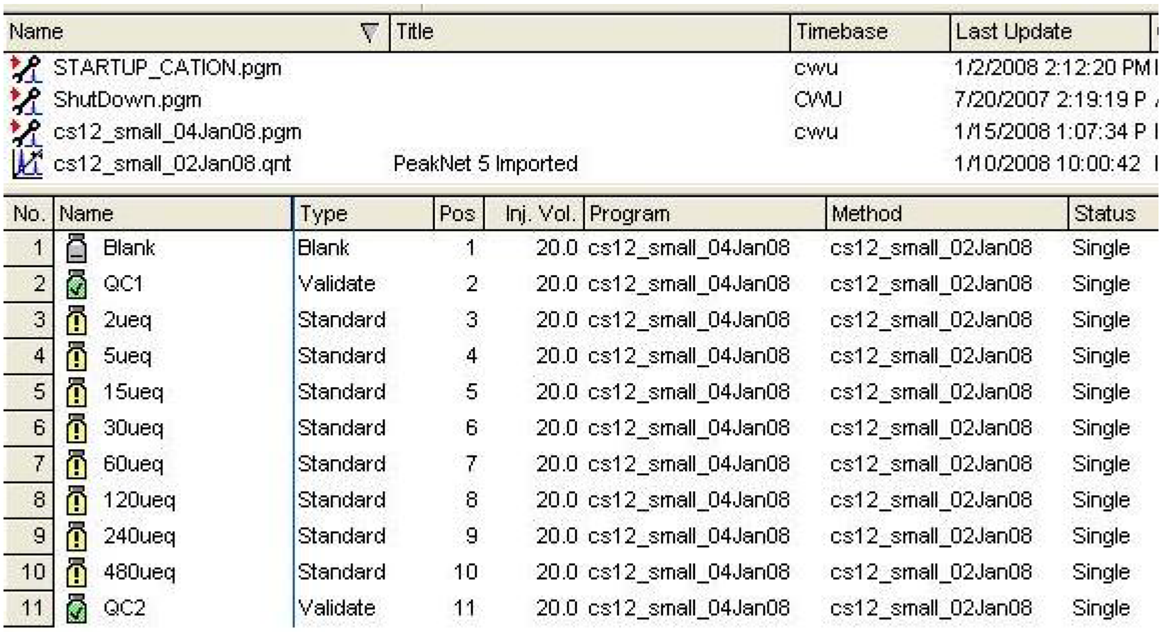
1. Dionex Six Cation-II Standard (at room temperature) is used as the QC stock solution. To prepare the working QC solution, 1.000 mL of the QC stock solution is diluted to 1.000L with deionized water. The target value (μeq/L) of each cation is calculated from the manufacturer's data sheet.

Cleaning Automated Sampler Vials and Caps (as recommended by manufacturer):

1. During sample preparation and collection, or when handling clean vials and caps, always wear poly gloves (not latex gloves) to prevent contamination.
2. Rinse the filter caps with deionized water using a small syringe. Place vials and caps in a large pre-cleaned plastic container and rinse them for 3 to 5 times. Soak them for 4 hours in deionized water.
3. Drain the container and refill with deionized water. Soak the vials and caps for an additional 24 hours before use.
4. Plunge deionized water through each filter cap with the syringe before drying.

<u>Solution Analysis:</u>

1. Pour room temperature samples, calibration standards, and working QC solution in clean labeled 0.5mL automated sample vials. Fill the vial with analysis solution until it overflows, and insert the clean filter caps. If the vials are not dry, rinse the vial twice with the analysis solution before filling.
2. To obtain the calibration curve for each cation, run blank, calibration standards, and the QC standard in the following order.

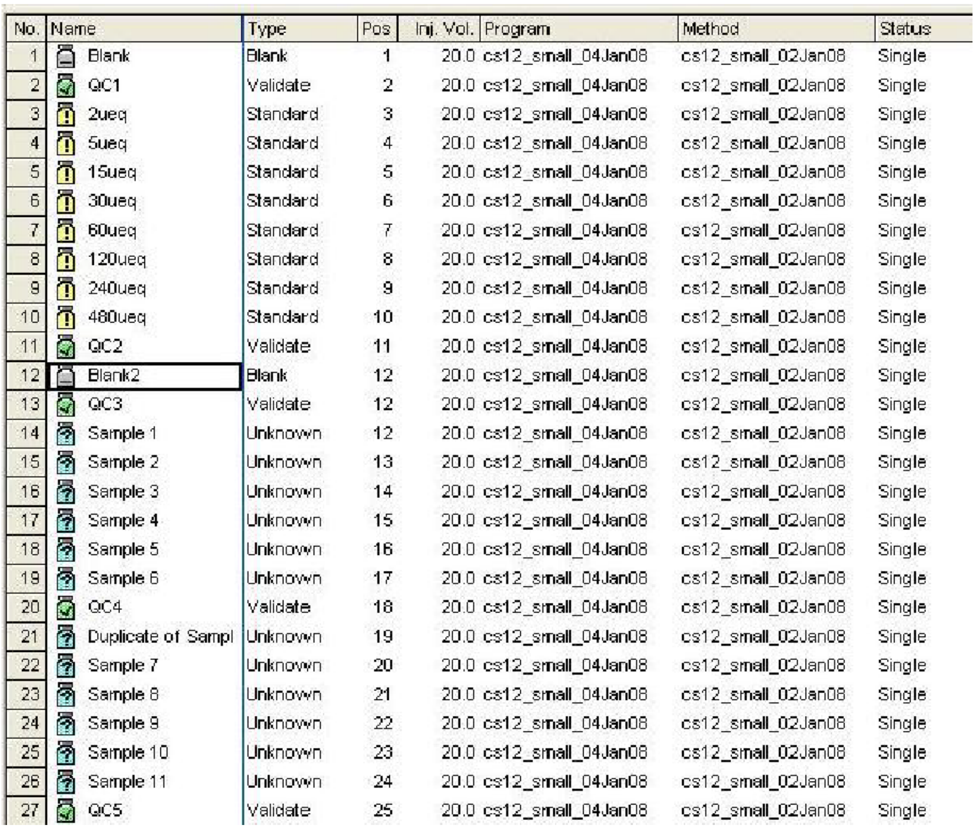


Name	Title	Timebase	Last Update
STARTUP_CATION.pgm		cwu	1/2/2008 2:12:20 PM
ShutDown.pgm		CWU	7/20/2007 2:19:19 P
cs12_small_04Jan08.pgm		cwu	1/15/2008 1:07:34 P
cs12_small_02Jan08.qnt	PeakNet 5 Imported		1/10/2008 10:00:42

No.	Name	Type	Pos	Inj. Vol.	Program	Method	Status
1	Blank	Blank	1	20.0	cs12_small_04Jan08	cs12_small_02Jan08	Single
2	QC1	Validate	2	20.0	cs12_small_04Jan08	cs12_small_02Jan08	Single
3	2ueq	Standard	3	20.0	cs12_small_04Jan08	cs12_small_02Jan08	Single
4	5ueq	Standard	4	20.0	cs12_small_04Jan08	cs12_small_02Jan08	Single
5	15ueq	Standard	5	20.0	cs12_small_04Jan08	cs12_small_02Jan08	Single
6	30ueq	Standard	6	20.0	cs12_small_04Jan08	cs12_small_02Jan08	Single
7	60ueq	Standard	7	20.0	cs12_small_04Jan08	cs12_small_02Jan08	Single
8	120ueq	Standard	8	20.0	cs12_small_04Jan08	cs12_small_02Jan08	Single
9	240ueq	Standard	9	20.0	cs12_small_04Jan08	cs12_small_02Jan08	Single
10	480ueq	Standard	10	20.0	cs12_small_04Jan08	cs12_small_02Jan08	Single
11	QC2	Validate	11	20.0	cs12_small_04Jan08	cs12_small_02Jan08	Single

3. Within instrument software plot concentration (μeq/L) vs. peak area using the data from the calibration standards. Choose linear curve fit type; force origin through zero, and record the equation and R^2 value. Print out each calibration graph. Update the method file.

4. Proceed with sample analysis. Run blank, QC standards, and samples in the following order. After every 6th sample determine a QC standard and a duplicate of the sample.



No.	Name	Type	Pos	Inj. Vol.	Program	Method	Status
1	Blank	Blank	1	20.0	cs12_small_04Jan08	cs12_small_02Jan08	Single
2	QC1	Validate	2	20.0	cs12_small_04Jan08	cs12_small_02Jan08	Single
3	2ueq	Standard	3	20.0	cs12_small_04Jan08	cs12_small_02Jan08	Single
4	5ueq	Standard	4	20.0	cs12_small_04Jan08	cs12_small_02Jan08	Single
5	15ueq	Standard	5	20.0	cs12_small_04Jan08	cs12_small_02Jan08	Single
6	30ueq	Standard	6	20.0	cs12_small_04Jan08	cs12_small_02Jan08	Single
7	60ueq	Standard	7	20.0	cs12_small_04Jan08	cs12_small_02Jan08	Single
8	120ueq	Standard	8	20.0	cs12_small_04Jan08	cs12_small_02Jan08	Single
9	240ueq	Standard	9	20.0	cs12_small_04Jan08	cs12_small_02Jan08	Single
10	480ueq	Standard	10	20.0	cs12_small_04Jan08	cs12_small_02Jan08	Single
11	QC2	Validate	11	20.0	cs12_small_04Jan08	cs12_small_02Jan08	Single
12	Blank2	Blank	12	20.0	cs12_small_04Jan08	cs12_small_02Jan08	Single
13	QC3	Validate	12	20.0	cs12_small_04Jan08	cs12_small_02Jan08	Single
14	Sample 1	Unknown	12	20.0	cs12_small_04Jan08	cs12_small_02Jan08	Single
15	Sample 2	Unknown	13	20.0	cs12_small_04Jan08	cs12_small_02Jan08	Single
16	Sample 3	Unknown	14	20.0	cs12_small_04Jan08	cs12_small_02Jan08	Single
17	Sample 4	Unknown	15	20.0	cs12_small_04Jan08	cs12_small_02Jan08	Single
18	Sample 5	Unknown	16	20.0	cs12_small_04Jan08	cs12_small_02Jan08	Single
19	Sample 6	Unknown	17	20.0	cs12_small_04Jan08	cs12_small_02Jan08	Single
20	QC4	Validate	18	20.0	cs12_small_04Jan08	cs12_small_02Jan08	Single
21	Duplicate of Sampl	Unknown	19	20.0	cs12_small_04Jan08	cs12_small_02Jan08	Single
22	Sample 7	Unknown	20	20.0	cs12_small_04Jan08	cs12_small_02Jan08	Single
23	Sample 8	Unknown	21	20.0	cs12_small_04Jan08	cs12_small_02Jan08	Single
24	Sample 9	Unknown	22	20.0	cs12_small_04Jan08	cs12_small_02Jan08	Single
25	Sample 10	Unknown	23	20.0	cs12_small_04Jan08	cs12_small_02Jan08	Single
26	Sample 11	Unknown	24	20.0	cs12_small_04Jan08	cs12_small_02Jan08	Single
27	QC5	Validate	25	20.0	cs12_small_04Jan08	cs12_small_02Jan08	Single

Performance Report

Method Detection Limits (MDL) and Linear Range:

Analyte	Retention Time (min)	MDL (µeq/L)	MDL (mg/L)	Linear Range (µeq/L)	Linear Range (mg/L)
Sodium	3.2	4.73	0.109	4.7 – 480	0.109 - 11.0
Ammonium	3.7	3.23	0.0583	3.2 – 120	0.0583 - 2.16
Potassium	4.9	2.47	0.0967	2.5 – 480	0.0967 – 18.8
Magnesium	8.1	3.11	0.0378	3.1 – 480	0.0378 – 5.83
Calcium	10.3	3.87	0.0775	3.9 - 480	0.0775 – 9.62

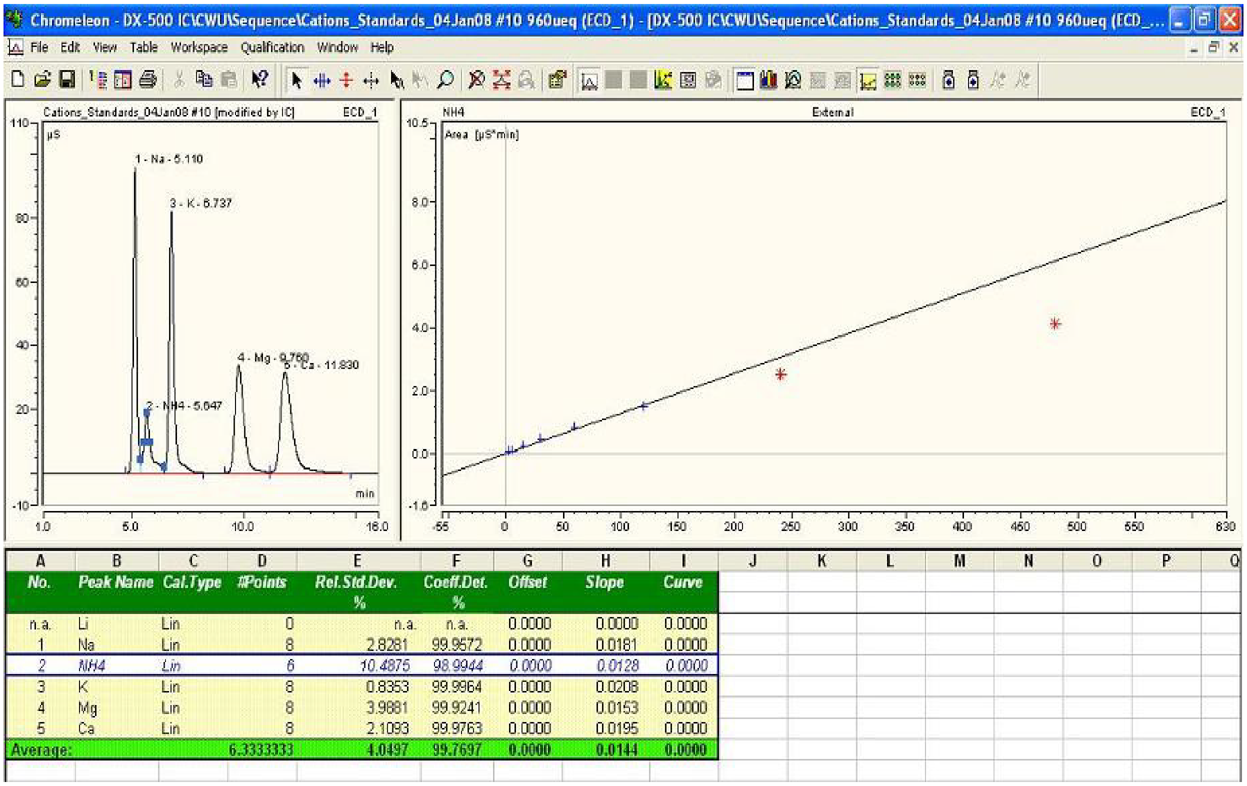
Standard Conditions:

Refer to Instrument section.

MDL calculated from 41 replicates of QC run from different days. MDL = t·std (t = 2.42 for 41 replicates with 98% confidence level). See attached spreadsheet in Appendix.

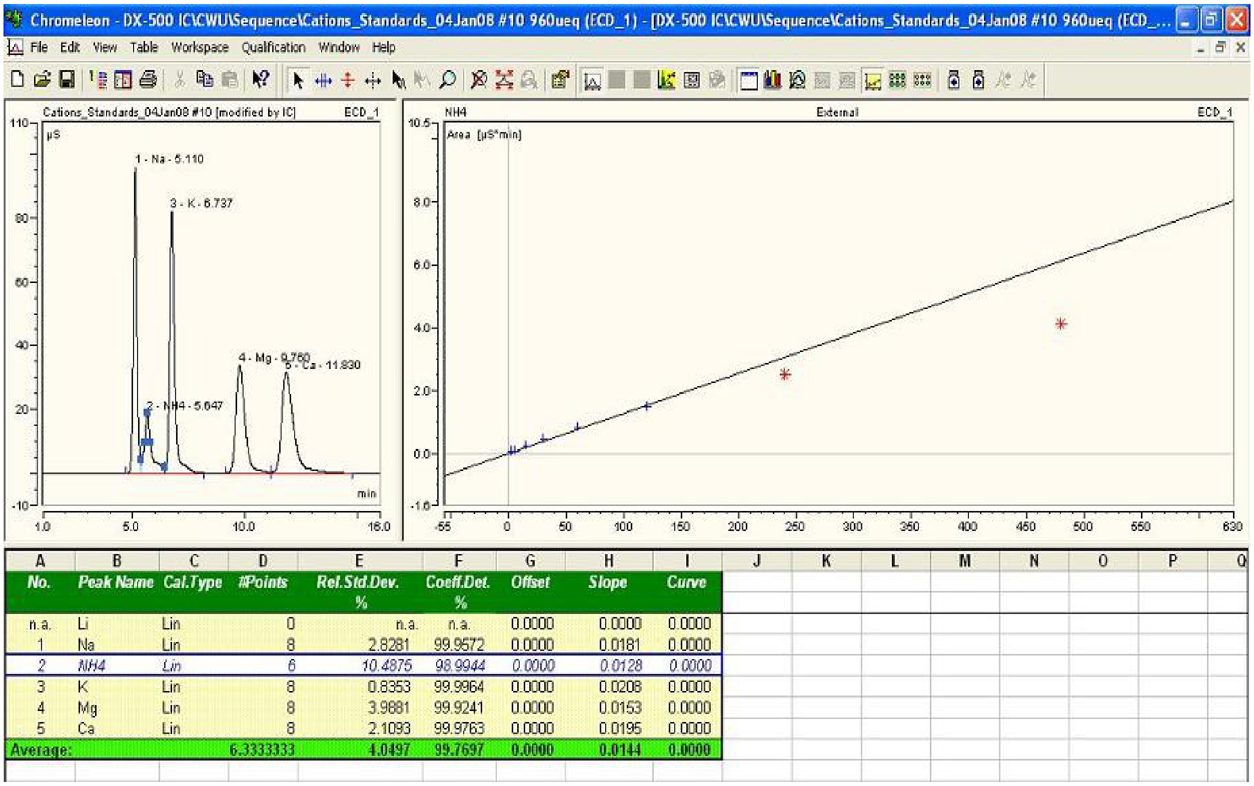
Calibration Curves:

1. Sodium standards 2.00 to 480µeq/L



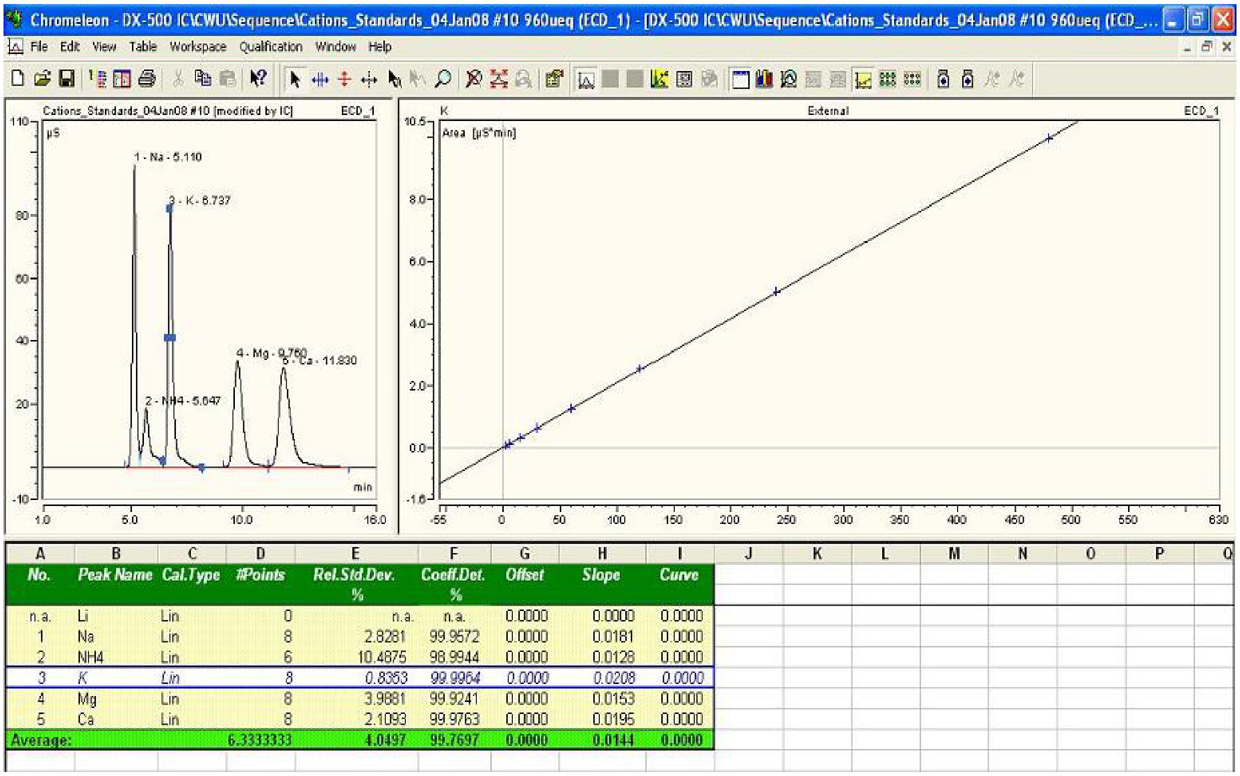
No.	Peak Name	Cal.Type	#Points	Rel.Std.Dev. %	Coeff.Det. %	Offset	Slope	Curve
n.a.	Li	Lin	0	n.a.	n.a.	0.0000	0.0000	0.0000
1	Na	Lin	8	2.8281	99.9572	0.0000	0.0181	0.0000
2	NH4	Lin	6	10.4875	98.9944	0.0000	0.0128	0.0000
3	K	Lin	8	0.8353	99.9964	0.0000	0.0208	0.0000
4	Mg	Lin	8	3.9881	99.9241	0.0000	0.0153	0.0000
5	Ca	Lin	8	2.1093	99.9763	0.0000	0.0195	0.0000
Average:			6.3333333	4.0497	99.7697	0.0000	0.0144	0.0000

2. Ammonium standards 2.00 to 120µeq/L



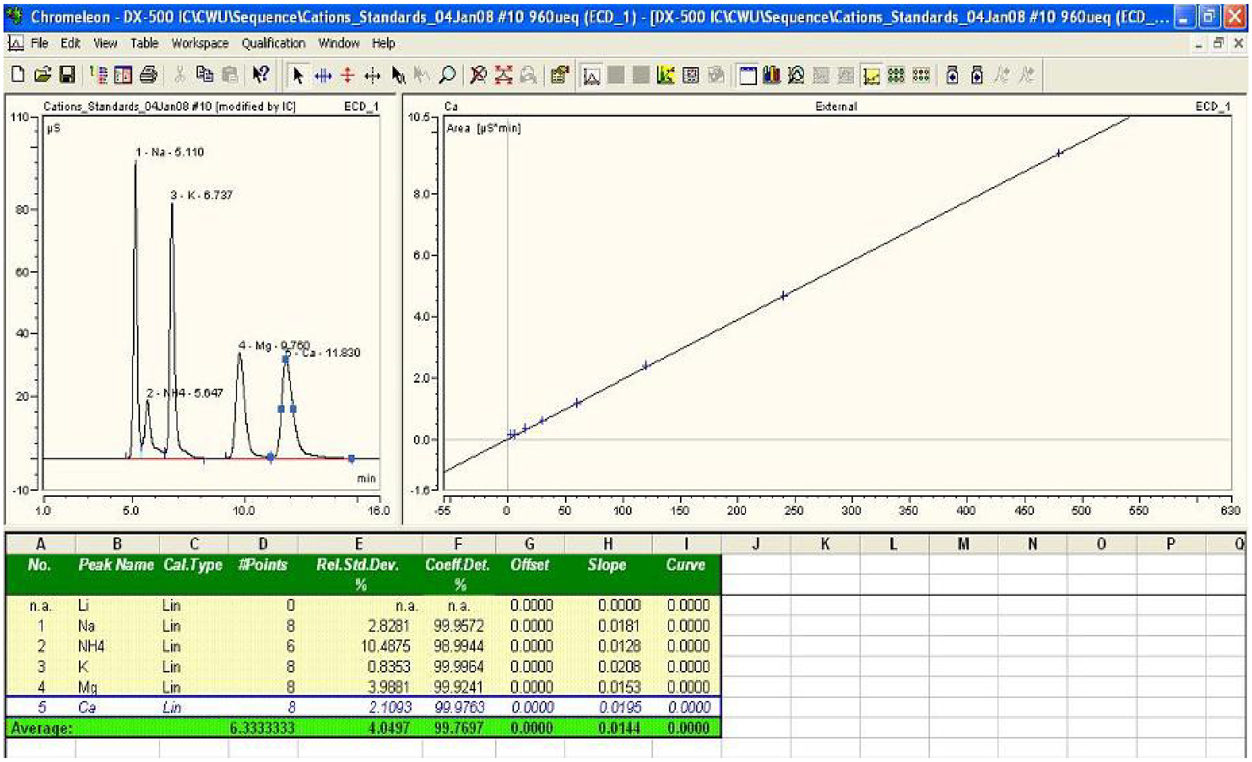
No.	Peak Name	Cal.Type	#Points	Rel.Std.Dev. %	Coeff.Det. %	Offset	Slope	Curve
n.a.	Li	Lin	0	n.a.	n.a.	0.0000	0.0000	0.0000
1	Na	Lin	8	2.8281	99.9572	0.0000	0.0181	0.0000
2	NH4	Lin	6	10.4875	98.9944	0.0000	0.0128	0.0000
3	K	Lin	8	0.8353	99.9964	0.0000	0.0208	0.0000
4	Mg	Lin	8	3.9881	99.9241	0.0000	0.0153	0.0000
5	Ca	Lin	8	2.1093	99.9763	0.0000	0.0195	0.0000
Average:			6.3333333	4.0497	99.7697	0.0000	0.0144	0.0000

3. Potassium standards 2.00 to 480µeq/L



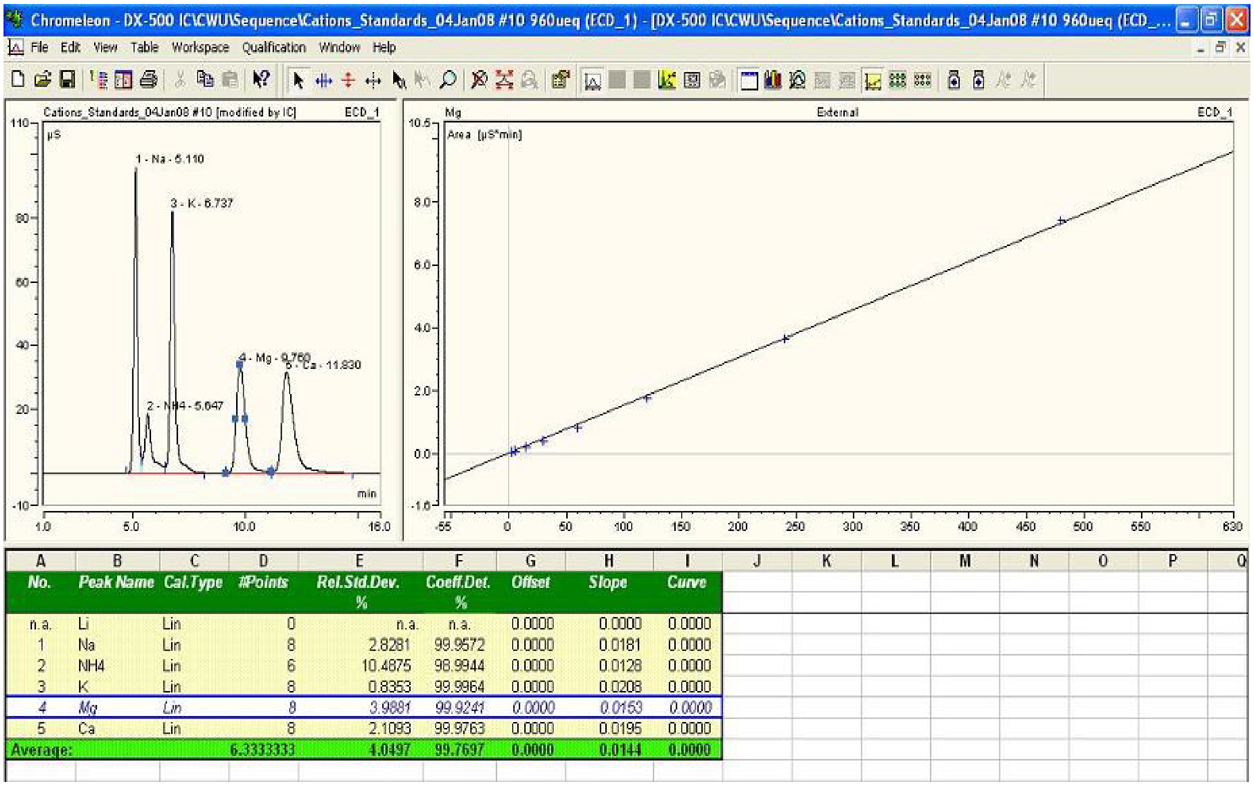
No.	Peak Name	Cal.Type	#Points	Rel.Std.Dev. %	Coeff.Det. %	Offset	Slope	Curve
n.a.	Li	Lin	0	n.a.	n.a.	0.0000	0.0000	0.0000
1	Na	Lin	8	2.8281	99.9572	0.0000	0.0181	0.0000
2	NH4	Lin	6	10.4875	98.9944	0.0000	0.0128	0.0000
3	K	Lin	8	0.8353	99.9964	0.0000	0.0208	0.0000
4	Mg	Lin	8	3.9881	99.9241	0.0000	0.0153	0.0000
5	Ca	Lin	8	2.1093	99.9763	0.0000	0.0195	0.0000
Average:			6.3333333	4.0497	99.7697	0.0000	0.0144	0.0000

4. Magnesium standards 2.00 to 480µeq/L



A	B	C	D	E	F	G	H	I
No.	**Peak Name**	**Cal.Type**	**#Points**	**Rel.Std.Dev. %**	**Coeff.Det. %**	**Offset**	**Slope**	**Curve**
n.a.	Li	Lin	0	n.a.	n.a.	0.0000	0.0000	0.0000
1	Na	Lin	8	2.8281	99.9572	0.0000	0.0181	0.0000
2	NH4	Lin	6	10.4875	98.9944	0.0000	0.0128	0.0000
3	K	Lin	8	0.8353	99.9964	0.0000	0.0208	0.0000
4	Mg	Lin	8	3.9881	99.9241	0.0000	0.0153	0.0000
5	*Ca*	*Lin*	*8*	*2.1093*	*99.9763*	*0.0000*	*0.0195*	*0.0000*
Average:			**6.3333333**	**4.0497**	**99.7697**	**0.0000**	**0.0144**	**0.0000**

5. Calcium standards 2.00 to 4



A	B	C	D	E	F	G	H	I
No.	**Peak Name**	**Cal.Type**	**#Points**	**Rel.Std.Dev. %**	**Coeff.Det. %**	**Offset**	**Slope**	**Curve**
n.a.	Li	Lin	0	n.a.	n.a.	0.0000	0.0000	0.0000
1	Na	Lin	8	2.8281	99.9572	0.0000	0.0181	0.0000
2	NH4	Lin	6	10.4875	98.9944	0.0000	0.0128	0.0000
3	K	Lin	8	0.8353	99.9964	0.0000	0.0208	0.0000
4	*Mg*	*Lin*	*8*	*3.9881*	*99.9241*	*0.0000*	*0.0153*	*0.0000*
5	Ca	Lin	8	2.1093	99.9763	0.0000	0.0195	0.0000
Average:			**6.3333333**	**4.0497**	**99.7697**	**0.0000**	**0.0144**	**0.0000**

Appendix to IC Cation SOP:

1. Spreadsheet used to calculate MDLs QC from 24, 25, 27, 31-Jan-06 (next page).

		Na	NH4	K	Mg	Ca
24-Jan-06	1	8.38	15.05	9.94	21.67	23.94
	2	9.63	14.07	10.62	19.76	25.30
25-Jan-06	3	15.66	14.62	13.21	20.20	28.61
	4	15.51	14.69	15.60	20.04	28.04
	5	11.05	12.35	10.97	21.62	26.77
	6	15.13	14.19	10.27	18.05	24.50
	7	11.62	14.37	11.38	20.16	27.56
	8	13.50	14.54	11.66	20.07	26.47
	9	9.97	13.60	11.27	20.38	25.84
	10	12.76	14.90	10.95	20.19	23.32
	11	13.66	13.17	10.96	19.52	24.72
	12	13.65	13.69	11.19	21.44	26.34
	13	12.56	15.85	11.24	21.13	28.16
	14	11.16	13.00	11.80	23.99	26.86
	15	10.87	14.74	11.21	21.21	25.58
	16	12.54	14.93	9.96	21.70	26.48
	17	13.10	13.44	10.67	19.74	23.42
	18	13.84	15.16	10.38	20.29	25.14
	19	12.79	14.26	10.74	19.01	24.19
	20	11.72	14.24	10.52	19.07	25.84
	21	10.03	14.55	10.91	20.06	26.64
	22	10.68	14.05	10.42	20.42	24.28
	23	9.07	15.13	10.42	20.60	26.20
	24	9.98	14.40	10.60	20.35	27.84
	25	12.35	14.24	10.77	17.68	24.60
	26	9.11	14.03	10.34	21.67	25.93
	27	11.57	15.20	9.80	18.45	24.26
27-Jan-06	28	9.47	12.58	10.79	20.49	24.27
	29	11.41	14.60	9.93	20.91	28.32

		Na	**NH4**	**K**	**Mg**	**Ca**
	30	11.53	14.23	11.40	19.94	25.89
	31	11.95	16.30	9.73	21.87	28.98
	32	8.01	14.03	10.20	20.60	25.04
	33	9.40	16.15	9.86	20.19	24.44
	34	15.18	14.84	10.66	19.34	24.78
	35	11.96	14.73	10.23	20.32	24.86
	36	12.76	14.64	10.74	20.24	24.31
	37	9.80	14.36	10.06	19.61	23.68
	38	11.50	16.30	11.27	20.01	23.01
	39	12.39	15.55	10.38	20.63	24.23
31-Jan-06 Redo	40	9.88	8.21	10.44	16.84	24.71
	41	9.55	12.75	9.55	17.83	23.26
Std Dev		1.96	1.34	1.02	1.29	1.60
MLD(ueq/L)		4.73	3.23	2.47	3.11	3.87
MLD(mg/L)		0.1088	0.0583	0.0967	0.0378	0.0775
Mean (ueq/L)		11.63	14.29	10.81	20.18	25.53
Actual Value (ueq/L)		8.79	14.03	12.76	20.98	25.45
M.W.		22.99	18.03	39.1	24.31	40.08
Charge		1	1	1	2	2

Quality Control Procedures

The following Quality Control (QC) Procedures are employed to assess and ensure that the error associated with the reported analytical results is known.

a) **Determination of Blanks**: A blank determination is intended to estimate the analytical response attributable to all factors other than the analyte in the sample. Blanks are analyzed identically to samples but do not contain the analyte (e.g., in water analyses, 18 MΩ Milli-Q water would be analyzed to determine the blank). Blank determinations will be carried out for each analyte, except pH, each time those specific determinations are carried out. A sample of deionized water will be treated in the same manner as analyte for each determination. An out-of-control blank could suggest laboratory contamination or instrumental malfunction, and appropriate action will be taken to eliminate problems before sample analyses.

b) **Check Standards (i.e., Quality Control (QC) Standards)**: Check standard solutions of known concentration are analyzed with each batch of analyte. These standards have to be from a different source than the calibration standards as results are used to monitor the precision of any bias of analysis. The results of the check standard determinations will be followed and documented using the technique of control charting. Actions will be taken as described in the section on Control Procedures: Control Charts. Check standards are to be determined at a frequency of one check sample determination before analyses, then one after every sixth sample. Check standard concentrations are listed in the SOP procedure for each analyte.

c) **Duplicates**: Duplicate determinations of analytes are determined to track precision of analysis on real samples, and are performed every sixth sample (before and after the check standard). The two results will be compared during the analysis, and if they differ more than 5% from each other, the sample will be reanalyzed.

d) **Performance Evaluation (Proficiency Testing)**: Performance evaluation samples will be analyzed semiannually as part of the EPA certification program. The sources and procedures for PE sample acquisition and result submission are described in the Procedural Manual For The Environmental Laboratory Accreditation Program, Washington State Department of Ecology, 98353-0488, Manchester, Washington, November 2002. The results of the PE (PT) determination will be documented for laboratory users.

e) **Procedure for the use of Control Charts**: Control charts will be used to document the results of repetitive analyses and to signal the need for corrective action as a result of analyses of check standards. “Control Charts” document the relationship of particular analytical results with respect to the mean and standard deviation of a statistically valid set of previous determinations of a reproducible sample (see Appendix III for example). The control chart presentation documents the mean and standard deviation of previous determination of sample as well as the value of the determination in question. Actions are taken if the values under consideration differ from the mean by specified amounts. If the determination under consideration differs from the mean by $\pm 2\sigma$ it is likely, at the 5% level, that the method analytical precision has changed or a determinant error has been introduced into the result.

This level is defined as the Warning Limit. If the determination differs from the mean by more than ±3σ it is likely, at the .3% level, that the method analytical precision has changed or a determinant error has been introduced into the results. This level is defined as the Action Limit.

A procedure is considered "out of control" (EPA) if:

1) Any result is beyond the action limit.
2) Any three consecutive results fall beyond the warning limit.
3) Any seven consecutive results are either above or below the mean of previous determinations.

The control chart technique will be used to document the running average of determinations of check standards (which can be compared to the expected value to determine bias).

f) **Guidelines for corrective action when data is "out of control":**
   1) Analytical results acquired after the procedure is discovered to be "out of control" will not be considered valid.
   2) New samples of blank, check standard, or duplicate sample (whichever was "out of control") will be re-determined. If the results do not fall within the acceptable ranges, instrumentation and method will be examined to determine and correct the cause of result error.

g) **Procedures for preparation and storage of standards**: See SOP for particular analyses.

h) **Definitions**: See the Glossary of Quality Assurance/Quality Control terms. Appendix IV.

i) **QA/QC Reports**: The laboratory will compile, review, and prepare a summary report describing the QA performance once a year. The report will describe laboratory activity including; number of determinations, staffing, performance on CRM samples, control chart results with respect to blanks, check standards, and duplicates. The corrective actions that were taken will be documented.

j) **Quantitation**: Calibration equations will be derived for those methods where a physical signal is recorded that is proportional in magnitude to the analyte concentration. If the relationship between concentration and physical signal is linear with $R^2 > 99\%$ the equation will be used to calculate subsequent analyte sample concentrations. The standard deviation of slope and intercept will be recorded.

Data Management:

a) **Recording**: All laboratory data is entered in laboratory notebooks as acquired. Integrator printouts are reduced and affixed to the notebooks.

b) **Calculations**: Calculations are performed using computer software (e.g., in the case of anions and cations it is instrument specific). The calculation method is entered in the lab notebook with summary copies of the computer printout.

c) **Archived data**: Analytical results of precipitation and lake studies are retained on a shared server, e.g., S:\Chemistry Research\Johansen Research\Mt Rainier.

d) Laboratory notebooks and records will be maintained for at least three years from the date of last entry. Records will be maintained for longer periods if the requirement is defined with a particular user.

References

Duncan, L.C., Quality Assurance/Quality Control Manual, Central Washington University, Ellensburg, WA, 1992

Kirchmer, C.J., Analytical Control Charting, Department of Ecology, Quality Assurance Section, Manchester, WA

Standard Practice for Sampling Chain of Custody Procedures, ASTM International, West Conshohocken, PA, 1988

Procedure Manual for the Environmental Laboratory Accreditation Program, Publication No. 02-03-055, Washington State Department of Ecology, Manchester

Appendix C. Glossaries, Acronyms, and Abbreviations

Glossary of General Terms

Ambient: Background or away from point sources of contamination. Surrounding environmental condition.

Anthropogenic: Human-caused.

Bankfull stage: Formally defined as the stream level that "corresponds to the discharge at which channel maintenance is most effective, that is, the discharge at which moving sediment, forming or removing bars, forming or changing bends and meanders, and generally doing work that results in the average morphologic characteristics of channels (Dunne and Leopold, 1978).

Baseflow: The component of total streamflow that originates from direct groundwater discharges to a stream.

Clean Water Act: A federal act passed in 1972 that contains provisions to restore and maintain the quality of the nation's waters. Section 303(d) of the Clean Water Act establishes the TMDL program.

Conductivity: A measure of water's ability to conduct an electrical current. Conductivity is related to the concentration and charge of dissolved ions in water.

Critical condition: When the physical, chemical, and biological characteristics of the receiving water environment interact with the effluent to produce the greatest potential adverse impact on aquatic biota and existing or designated water uses. For steady-state discharges to riverine systems, the critical condition may be assumed to be equal to the 7Q10 flow event unless determined otherwise by the department.

Designated uses: Those uses specified in Chapter 173-201A WAC (Water Quality Standards for Surface Waters of the State of Washington) for each water body or segment, regardless of whether or not the uses are currently attained.

Diel: Of, or pertaining to, a 24-hour period.

Dissolved oxygen (DO): A measure of the amount of oxygen dissolved in water.

Dilution factor: The relative proportion of effluent to stream (receiving water) flows occurring at the edge of a mixing zone during critical discharge conditions as authorized in accordance with the state's mixing zone regulations at WAC 173-201A-100.
http://apps.leg.wa.gov/WAC/default.aspx?cite=173-201A-020

Diurnal: Of, or pertaining to, a day or each day; daily. (1) Occurring during the daytime only, as different from nocturnal or crepuscular, or (2) Daily; related to actions which are completed in the course of a calendar day, and which typically recur every calendar day (e.g., diurnal temperature rises during the day, and falls during the night).

Effluent: An outflowing of water from a natural body of water or from a human-made structure. For example, the treated outflow from a wastewater treatment plant.

Eutrophic: Nutrient rich and high in productivity resulting from human activities such as fertilizer runoff and leaky septic systems.

Existing uses: Those uses actually attained in fresh and marine waters on or after November 28, 1975, whether or not they are designated uses. Introduced species that are not native to Washington, and put-and-take fisheries comprised of non-self-replicating introduced native species, do not need to receive full support as an existing use.

Fecal coliform (FC): That portion of the coliform group of bacteria which is present in intestinal tracts and feces of warm-blooded animals as detected by the product of acid or gas from lactose in a suitable culture medium within 24 hours at 44.5 plus or minus 0.2 degrees Celsius. Fecal coliform bacteria are "indicator" organisms that suggest the possible presence of disease-causing organisms. Concentrations are measured in colony forming units per 100 milliliters of water (cfu/100 mL).

Geometric mean: A mathematical expression of the central tendency (an average) of multiple sample values. A geometric mean, unlike an arithmetic mean, tends to dampen the effect of very high or low values, which might bias the mean if a straight average (arithmetic mean) were calculated. This is helpful when analyzing bacteria concentrations, because levels may vary anywhere from 10 to 10,000-fold over a given period. The calculation is performed by either: (1) taking the nth root of a product of n factors, or (2) taking the antilogarithm of the arithmetic mean of the logarithms of the individual values.

Hyporheic: The area beneath and adjacent to a stream where surface water and groundwater intermix.

Load allocation: The portion of a receiving water's loading capacity attributed to one or more of its existing or future sources of nonpoint pollution or to natural background sources.

Loading capacity: The greatest amount of a substance that a water body can receive and still meet water quality standards.

Margin of safety: Required component of TMDLs that accounts for uncertainty about the relationship between pollutant loads and quality of the receiving water body.

Near-stream disturbance zone (NSDZ): The active channel area without riparian vegetation that includes features such as gravel bars.

Nonpoint source: Pollution that enters any waters of the state from any dispersed land-based or water-based activities, including but not limited to atmospheric deposition, surface-water runoff from agricultural lands, urban areas, or forest lands, subsurface or underground sources, or discharges from boats or marine vessels not otherwise regulated under the NPDES program. Generally, any unconfined and diffuse source of contamination. Legally, any source of water pollution that does not meet the legal definition of "point source" in section 502(14) of the Clean Water Act.

Nutrient: Substance such as carbon, nitrogen, and phosphorus used by organisms to live and grow. Too many nutrients in the water can promote algal blooms and rob the water of oxygen vital to aquatic organisms.

Pathogen: Disease-causing microorganisms such as bacteria, protozoa, viruses.

pH: A measure of the acidity or alkalinity of water. A low pH value (0 to 7) indicates that an acidic condition is present, while a high pH (7 to 14) indicates a basic or alkaline condition. A pH of 7 is considered to be neutral. Since the pH scale is logarithmic, a water sample with a pH of 8 is ten times more basic than one with a pH of 7.

Point source: Source of pollution that discharges at a specific location from pipes, outfalls, and conveyance channels to a surface water. Examples of point source discharges include municipal wastewater treatment plants, municipal stormwater systems, industrial waste treatment facilities, and construction sites where more than 5 acres of land have been cleared.

Pollution: Contamination or other alteration of the physical, chemical, or biological properties of any waters of the state. This includes change in temperature, taste, color, turbidity, or odor of the waters. It also includes discharge of any liquid, gaseous, solid, radioactive, or other substance into any waters of the state. This definition assumes that these changes will, or are likely to, create a nuisance or render such waters harmful, detrimental, or injurious to (1) public health, safety, or welfare, or (2) domestic, commercial, industrial, agricultural, recreational, or other legitimate beneficial uses, or (3) livestock, wild animals, birds, fish, or other aquatic life.

Reach: A specific portion or segment of a stream.

Riparian: Relating to the banks along a natural course of water.

Salmonid: Fish that belong to the family *Salmonidae*. Species of salmon, trout, or char.

Sediment: Soil and organic matter that is covered with water (for example, river or lake bottom).

Stormwater: The portion of precipitation that does not naturally percolate into the ground or evaporate but instead runs off roads, pavement, and roofs during rainfall or snow melt. Stormwater can also come from hard or saturated grass surfaces such as lawns, pastures, playfields, and from gravel roads and parking lots.

Streamflow: Discharge of water in a surface stream (river or creek).

Surface waters of the state: Lakes, rivers, ponds, streams, inland waters, salt waters, wetlands and all other surface waters and water courses within the jurisdiction of Washington State.

Synoptic survey: Data collected simultaneously or over a short period of time.

System potential: The design condition used for TMDL analysis.

System-potential temperature: An approximation of the temperatures that would occur under natural conditions. System potential is our best understanding of natural conditions that can be supported by available analytical methods. The simulation of the system-potential condition uses best estimates of *mature riparian vegetation, system-potential channel morphology, and system-potential riparian microclimate* that would occur absent any human alteration.

Thalweg: The deepest and fastest moving portion of a stream.

Total Maximum Daily Load (TMDL): A distribution of a substance in a water body designed to protect it from not meeting (exceeding) water quality standards. A TMDL is equal to the sum of all of the following: (1) individual wasteload allocations for point sources, (2) the load allocations for nonpoint sources, (3) the contribution of natural sources, and (4) a margin of safety to allow for uncertainty in the wasteload determination. A reserve for future growth is also generally provided.

Total suspended solids (TSS): Portion of solids retained by a filter.

Turbidity: A measure of water clarity. High levels of turbidity can have a negative impact on aquatic life.

Watershed: A drainage area or basin in which all land and water areas drain or flow toward a central collector such as a stream, river, or lake at a lower elevation.

1-DMax or 1-day maximum temperature: The highest water temperature reached on any given day. This measure can be obtained using calibrated maximum/minimum thermometers or continuous monitoring probes having sampling intervals of thirty minutes or less.

303(d) list: Section 303(d) of the federal Clean Water Act, requiring Washington State to periodically prepare a list of all surface waters in the state for which beneficial uses of the water – such as for drinking, recreation, aquatic habitat, and industrial use – are impaired by pollutants. These are water quality-limited estuaries, lakes, and streams that fall short of state surface water quality standards and are not expected to improve within the next two years.

90th percentile: An estimated portion of a sample population based on a statistical determination of distribution characteristics. The 90th percentile value is a statistically derived estimate of the division between 90% of samples, which should be less than the value, and 10% of samples, which are expected to exceed the value.

Acronyms and Abbreviations

CRBG	Columbia River Basalt Group
DO	Dissolved oxygen
DOC	Dissolved organic carbon
e.g.	For example
Ecology	Washington State Department of Ecology
EIM	Environmental Information Management database
EPA	U.S. Environmental Protection Agency
et al.	And others
FC	Fecal coliform
GIS	Geographic Information System software
GPS	Global Positioning System
i.e.	In other words
MAR	Managed Aquifer Recharge
MQO	Measurement quality objective
ORP	Oxidation reduction potential
PBT	Persistent, bioaccumulative, and toxic substance
PCB	Polychlorinated biphenyls
QA	Quality assurance
QC	Quality control
RM	River mile
RID	Roza Irrigation District
RPD	Relative percent difference
RSD	Relative standard deviation
SOP	Standard operating procedures
SRBOJC	Sunnyside-Roza Joint Board of Control
SRM	Standard reference materials
TMDL	Total Maximum Daily Load
TOC	Total organic carbon
TSS	Total suspended solids
USFS	United States Forest Service

USGS	United States Geological Survey
WAC	Washington Administrative Code
WDFW	Washington Department of Fish and Wildlife
WQA	Water Quality Assessment
WRIA	Water Resource Inventory Area
WSTMP	Washington State Toxics Monitoring Program
WWTP	Wastewater treatment plant
YBIP	Yakima Basin Integrated Plan

Units of Measurement

°C	degrees centigrade
cfs	cubic feet per second
cfu	colony forming units
cms	cubic meters per second, a unit of flow
dw	dry weight
ft	feet
g	gram, a unit of mass
kcfs	1000 cubic feet per second
kg	kilograms, a unit of mass equal to 1,000 grams
kg/d	kilograms per day
km	kilometer, a unit of length equal to 1,000 meters
L/s	liters per second (0.03531 cubic foot per second)
m	meter
mm	millimeter
mg	milligram
mgd	million gallons per day
mg/d	milligrams per day
mg/kg	milligrams per kilogram (parts per million)
mg/L	milligrams per liter (parts per million)
mg/L/hr	milligrams per liter per hour
mL	milliliter
mmol	millimole or one-thousandth of a mole
mole	an International System of Units (IS) unit of matter
ng/g	nanograms per gram (parts per billion)
ng/kg	nanograms per kilogram (parts per trillion)
ng/L	nanograms per liter (parts per trillion)
NTU	nephelometric turbidity units
pg/g	picograms per gram (parts per trillion)
pg/L	picograms per liter (parts per quadrillion)
psu	practical salinity units

s.u.	standard units
µg/g	micrograms per gram (parts per million)
µg/kg	micrograms per kilogram (parts per billion)
µg/L	micrograms per liter (parts per billion)
µm	micrometer
µM	micromolar (a chemistry unit)
µmhos/cm	micromhos per centimeter
µS/cm	microsiemens per centimeter, a unit of conductivity
ww	wet weight

Quality Assurance Glossary

Accreditation: A certification process for laboratories, designed to evaluate and document a lab's ability to perform analytical methods and produce acceptable data (Kammin, 2010). For Ecology, it is defined according to WAC 173-50-040: "Formal recognition by [Ecology] that an environmental laboratory is capable of producing accurate and defensible analytical data."

Accuracy: The degree to which a measured value agrees with the true value of the measured property. USEPA recommends that this term not be used, and that the terms *precision* and *bias* be used to convey the information associated with the term *accuracy* (USEPA, 2014).

Analyte: An element, ion, compound, or chemical moiety (pH, alkalinity) which is to be determined. The definition can be expanded to include organisms, e.g., fecal coliform, Klebsiella (Kammin, 2010).

Bias: Discrepancy between the expected value of an estimator and the population parameter being estimated (Gilbert, 1987; USEPA, 2014).

Blank: A synthetic sample, free of the analyte(s) of interest. For example, in water analysis, pure water is used for the blank. In chemical analysis, a blank is used to estimate the analytical response to all factors other than the analyte in the sample. In general, blanks are used to assess possible contamination or inadvertent introduction of analyte during various stages of the sampling and analytical process (USGS, 1998).

Calibration: The process of establishing the relationship between the response of a measurement system and the concentration of the parameter being measured (Ecology, 2004).

Check standard: A substance or reference material obtained from a source independent from the source of the calibration standard; used to assess bias for an analytical method. This is an obsolete term, and its use is highly discouraged. See Calibration Verification Standards, Lab Control Samples (LCS), Certified Reference Materials (CRM), and/or spiked blanks. These are all check standards but should be referred to by their actual designator, e.g., CRM, LCS (Kammin, 2010; Ecology, 2004).

Comparability: The degree to which different methods, data sets and/or decisions agree or can be represented as similar; a data quality indicator (USEPA, 2014; USEPA, 2020).

Completeness: The amount of valid data obtained from a project compared to the planned amount. Usually expressed as a percentage. A data quality indicator (USEPA, 2014; USEPA 2020).

Continuing Calibration Verification Standard (CCV): A quality control (QC) sample analyzed with samples to check for acceptable bias in the measurement system. The CCV is usually a midpoint calibration standard that is re-run at an established frequency during the course of an analytical run (Kammin, 2010).

Control chart: A graphical representation of quality control results demonstrating the performance of an aspect of a measurement system (Kammin, 2010; Ecology 2004).

Control limits: Statistical warning and action limits calculated based on control charts. Warning limits are generally set at +/- 2 standard deviations from the mean, action limits at +/- 3 standard deviations from the mean (Kammin, 2010).

Data integrity: A qualitative DQI that evaluates the extent to which a data set contains data that is misrepresented, falsified, or deliberately misleading (Kammin, 2010).

Data quality indicators (DQI): Commonly used measures of acceptability for environmental data. The principal DQIs are precision, bias, representativeness, comparability, completeness, sensitivity, and integrity (USEPA, 2006).

Data quality objectives (DQO): Qualitative and quantitative statements derived from systematic planning processes that clarify study objectives, define the appropriate type of data, and specify tolerable levels of potential decision errors that will be used as the basis for establishing the quality and quantity of data needed to support decisions (USEPA, 2006).

Data set: A grouping of samples organized by date, time, analyte, etc. (Kammin, 2010).

Data validation: The process of determining that the data satisfy the requirements as defined by the data user (USEPA, 2020). There are various levels of data validation (USEPA, 2009).

Data verification: Examination of a data set for errors or omissions, and assessment of the Data Quality Indicators related to that data set for compliance with acceptance criteria (MQOs). Verification is a detailed quality review of a data set (Ecology, 2004).

Detection limit (limit of detection)**:** The concentration or amount of an analyte which can be determined to a specified level of certainty to be greater than zero (Ecology, 2004).

Duplicate samples: Two samples taken from and representative of the same population, and carried through and steps of the sampling and analytical procedures in an identical manner. Duplicate samples are used to assess variability of all method activities including sampling and analysis (USEPA, 2014).

Field blank: A blank used to obtain information on contamination introduced during sample collection, storage, and transport (Ecology, 2004).

Initial Calibration Verification Standard (ICV): A QC sample prepared independently of calibration standards and analyzed along with the samples to check for acceptable bias in the measurement system. The ICV is analyzed prior to the analysis of any samples (Kammin, 2010).

Laboratory Control Sample (LCS)/LCS duplicate: A sample of known composition prepared using contaminant-free water or an inert solid that is spiked with analytes of interest at the midpoint of the calibration curve or at the level of concern. It is prepared and analyzed in the same batch of regular samples using the same sample preparation method, reagents, and analytical methods employed for regular samples. Monitors a lab’s performance for bias and precision (USEPA, 2014).

Matrix spike/Matrix spike duplicate: A QC sample prepared by adding a known amount of the target analyte(s) to an aliquot of a sample to check for bias and precision errors due to interference or matrix effects (Ecology, 2004).

Measurement Quality Objectives (MQOs)**:** Performance or acceptance criteria for individual data quality indicators, usually including precision, bias, sensitivity, completeness, comparability, and representativeness (USEPA, 2006).

Measurement result: A value obtained by performing the procedure described in a method (Ecology, 2004).

Method: A formalized group of procedures and techniques for performing an activity (e.g., sampling, chemical analysis, data analysis), systematically presented in the order in which they are to be executed (USEPA, 2001).

Method blank: A blank prepared to represent the sample matrix, prepared and analyzed with a batch of samples. A method blank will contain all reagents used in the preparation of a sample, and the same preparation process is used for the method blank and samples (Ecology, 2004; Kammin, 2010).

Method Detection Limit (MDL): The minimum measured concentration of a substance that can be reported with 99% confidence that the measured concentration is distinguishable from method blank results (USEPA, 2016). MDL is a measure of the capability of an analytical method of distinguished samples that do not contain a specific analyte from a sample that contains a low concentration of the analyte (USEPA, 2020).

Minimum level: Either the sample concentration equivalent to the lowest calibration point in a method or a multiple of the method detection limit (MDL), whichever is higher. For the purposes of NPDES compliance monitoring, EPA considers the following terms to be synonymous: “quantitation limit,” “reporting limit,” and “minimum level” (40 CFR 136).

Parameter: A specified characteristic of a population or sample. Also, an analyte or grouping of analytes. Benzene and nitrate + nitrite are all parameters (Kammin, 2010; Ecology, 2004).

Population: The hypothetical set of all possible observations of the type being investigated (Ecology, 2004).

Precision: The extent of random variability among replicate measurements of the same property; a data quality indicator (USGS, 1998).

Quality assurance (QA): A set of activities designed to establish and document the reliability and usability of measurement data (Kammin, 2010).

Quality Assurance Project Plan (QAPP): A document that describes the objectives of a project, and the processes and activities necessary to develop data that will support those objectives (Kammin, 2010; Ecology, 2004).

Quality control (QC): The routine application of measurement and statistical procedures to assess the accuracy of measurement data (Ecology, 2004).

Relative Percent Difference (RPD): RPD is commonly used to evaluate precision. The following formula is used:

$$RPD = [Abs(a-b)/((a + b)/2)] * 100\%$$

where "Abs()" is absolute value and a and b are results for the two replicate samples. RPD can be used only with 2 values. Percent Relative Standard Deviation is (%RSD) is used if there are results for more than 2 replicate samples (Ecology, 2004).

Relative Standard Deviation (RSD): A statistic used to evaluate precision in environmental analysis. It is determined in the following manner:

$$RSD = (100\% * s)/x$$

where s is the sample standard deviation and x is the mean of results from more than two replicate samples (Kammin, 2010).

Replicate samples: Two or more samples taken from the environment at the same time and place, using the same protocols. Replicates are used to estimate the random variability of the material sampled (USGS, 1998).

Reporting level: Unless specified otherwise by a regulatory authority or in a discharge permit, results for analytes that meet the identification criteria (i.e., rules for determining qualitative presence/absence of an analyte) are reported down to the concentration of the minimum level established by the laboratory through calibration of the instrument. EPA considers the terms "reporting limit," "quantitation limit," and "minimum level" to be synonymous (40 CFR 136).

Representativeness: The degree to which a sample reflects the population from which it is taken; a data quality indicator (USGS, 1998).

Sample (field): A portion of a population (environmental entity) that is measured and assumed to represent the entire population (USGS, 1998).

Sample (statistical): A finite part or subset of a statistical population (USEPA, 1992).

Sensitivity: In general, denotes the rate at which the analytical response (e.g., absorbance, volume, meter reading) varies with the concentration of the parameter being determined. In a specialized sense, it has the same meaning as the detection limit (Ecology, 2004).

Spiked blank: A specified amount of reagent blank fortified with a known mass of the target analyte(s); usually used to assess the recovery efficiency of the method (USEPA, 2014).

Spiked sample: A sample prepared by adding a known mass of target analyte(s) to a specified amount of matrix sample for which an independent estimate of target analyte(s) concentration is available. Spiked samples can be used to determine the effect of the matrix on a method's recovery efficiency (USEPA, 2014).

Split sample: A discrete sample subdivided into portions, usually duplicates (Kammin, 2010).

Standard Operating Procedure (SOP): A document which describes in detail a reproducible and repeatable organized activity (Kammin, 2010).

Surrogate: For environmental chemistry, a surrogate is a substance with properties similar to those of the target analyte(s). Surrogates are unlikely to be native to environmental samples. They are added to environmental samples for quality control purposes, to track extraction efficiency and/or measure analyte recovery. Deuterated organic compounds are examples of surrogates commonly used in organic compound analysis (Kammin, 2010).

Systematic planning: A step-wise process which develops a clear description of the goals and objectives of a project, and produces decisions on the type, quantity, and quality of data that will be needed to meet those goals and objectives. The DQO process is a specialized type of systematic planning (USEPA, 2006).

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