Quality Assurance Project Plan

Boss Well Testing

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WRYBIP-2325-Moxeec-00048

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Each study conducted or funded by the Washington State Department of Ecology (Ecology) must have an approved Quality Assurance Project Plan (QAPP). The QAPP describes the objectives of the study and the procedures to be followed to achieve those objectives.

This QAPP was prepared by a licensed hydrogeologist. A signed and stamped copy of the report is available upon request. This QAPP is available via Ecology's publication database and upon request. The Ecology publication number for this QAPP is 24-12-016. This QAPP is valid through October 2029.

Field data collected for this project will be uploaded to Ecology's Environmental Information Management (EIM) database under Study ID: WRYBIP-2325-00048.

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COVER PHOTO: The Boss Wellhead. *Photo by Aspect Consulting.*

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WRYBIP-2325-Moxeec-00048

by Ian Lauer, Derek Holom, and Tyson Carlson

Published October 2024

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1.0 Table of Contents

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2.0 Abstract

This Quality Assurance Project Plan (QAPP) was prepared by Aspect Consulting (Aspect) for the City of Moxee (City) to address data collection procedures for well testing and water level data in support of the City's Aquifer Storage and Recovery (ASR) program evaluation. The City is currently completing an ASR Feasibility Study (FS) (Ecology Agreement ID WRYBIP-2123-Moxeec-00036). As part of the FS, a Data Gaps Technical Memo was produced which detailed the need for additional well performance, aquifer parameter, and water level data collection to support the feasibility analysis. The Boss Well is an irrigation supply well completed in the Ellensburg Aquifer and is located east of The City of Moxee; this well was identified during the planning stages of the ASR FS as a good candidate for the proposed testing because it is completed at a similar depths to the City's wells in the Ellensburg Formation, has existing infrastructure for source water supplies, and is available to the City to test under an agreement.

The objective of this work is to conduct pumping tests on the Boss Well to evaluate aquifer properties and well performance. Additionally, groundwater level data will be collected from the City's well network to evaluate groundwater elevation trends. This QAPP covers pumping test procedures and analytical methods to determine if the Boss Well is a good candidate for ASR pilot testing. These data and analyses will be combined with water quality results and other hydrogeologic analysis performed under the existing FS (Aspect, 2023). The results will be compared to the existing FS hydrogeologic conceptual model and ASR system design to determine if the Boss Well can meet the needs of the ASR system and permitting requirements in Washington Administrative Code (WAC) 173-157.

3.0 Background

3.1 Introduction and problem statement

The City of Moxee is currently completing a Phase 1 ASR FS funded by the Department of Ecology (Agreement ID: WRYBIP-2123-Moxeec-00036; Aspect, 2023). The goal of the FS is to evaluate whether ASR can be implemented as a component of the City's long-term water supply strategy to mitigate declining groundwater levels and improve water availability in summer months. The ASR program would accomplish this by re-timing availability of water on the Yakima River by diverting water during spring freshet flows and injecting it into the Ellensburg Formation Aquifer via one of the City's wells. Water recharged into the Ellensburg Aquifer would then be potentially available for later withdrawal by the City.

As part of the ongoing Phase 1 ASR FS, the City identified the need for completion of additional data review and testing to satisfy data gaps outlined in the Data Gaps Technical Memo (Aspect, 2022). The initial FS findings have identified a lack of locally derived hydraulic parameters, along with missing multiple key constituents within water quality records in order to complete geochemical equilibrium modelling for the target aquifer. In addition, the City has a Supervisory Control and Data Acquisition (SCADA) system that contains historical pumping and groundwater level data, but the City does not have the required expertise to retrieve or analyze the data.

To obtain the missing site-specific hydrogeologic data, the City proposed testing the Boss Well. The Boss Well is located approximately one mile east of the City of Moxee and is completed in a deep portion of the Ellensburg Aquifer; this aquifer is the primary groundwater source pumped by the City's existing wells and is identified for ASR in the FS. The City has secured an access agreement with the landowner of the Boss Well to test the well as part of a pre-purchase due diligence through a 2022 Letter of Intent with Lenseigne Farms. The primary goals of the pumping test and monitoring work is to estimate hydraulic parameters in the deep Ellensburg Aquifer, including storativity, hydraulic conductivity, and groundwater elevations to better estimate the storage potential and range of injection rates for the site. Water chemistry data collected during the test will also be used for geochemical modeling as part of the ASR FS. The geochemical modelling will evaluate compatibility potential for adverse chemical reactions in the Ellensburg Aquifer and wells used for ASR (i.e., mineral precipitation) or dissolution of minerals that could adversely affect stored water quality.

This QAPP covers the task of performing pumping tests on the Boss Well; collection of field parameters during testing; and collection and processing of water level data from the City's SCADA database. Collection of water quality samples are included in a separate QAPP (Aspect, 2023) that was approved by Ecology for this ASR FS.

3.2 Study area and surroundings

The City of Moxee is located in the Moxee Valley, the eastern half of the Yakima Basin which is bisected by the Yakima River (Figures 1 and 2). The Yakima Basin was formed during the development of the Yakima Fold and Thrust Belt (YFTB), which produced the east-west trending valleys and ridges along the eastern flank of the Cascades in central Washington. The Valley is structurally bound to the west by the uplift of units along the Cascades and to the east by the uplift along the Hog Ranch-Naneum Anticline, which runs north-south between the Yakima Ridge and Rattlesnake Hills (Figure 2). The Moxee Valley is bound by the Yakima Ridge anticline to the north and the Rattlesnake Hills anticline to the south (Jones et al., 2006). Additionally, the Bird Canyon Fault, Firewater Canyon Fault, and Myers Anticline present structural boundaries in the eastern margin of the Moxee Valley.

The primary geologic units in the area include (from youngest to oldest): surficial stream deposits (alluvium), the Ellensburg Formation, and members of the Columbia River Basalt Group (CRBG).

- **Alluvium and Unconsolidated Sediments** forms the uppermost surface across most of the valley and is composed of unconsolidated sedimentary deposits that range from 0 to 200 feet thick. The alluvial formation hosts a shallow aquifer, which is in continuity with the Yakima River and underlying upper Ellensburg Aquifer.
- **The Upper Ellensburg Formation**, the focus of this study, is a package of interbedded, semi-consolidated to consolidated sedimentary units that were deposited in the valley bottoms overlying the CRGB. It is distinguished from the lower Ellensburg Formation, which forms interbeds within the CRBG. The upper Ellensburg Formation is thickest in the western and central portions of the Yakima Basin and thins towards the margins of the valley and to the east. (Vaccaro, 2009). In the study area, the upper Ellensburg Formation is greater than 1,000 feet thick as illustrated in Figures 2 and 3 (Jones and Vaccaro, 2008; Sinclair, 2007). The upper Ellensburg Formation hosts a productive aquifer which is highly anisotropic and exhibits significant vertical gradient in hydraulic head due to the heterogenous and spatially discontinuous water bearing zones. For the purposes of this study, it is important to distinguish that the upper Ellensburg Formation Aquifer is split into two distinct zones based on hydrogeologic regimes, both of which overlie the CRBG formations:
    - **Shallow Ellensburg Aquifer:** The shallow portions of the upper Ellensburg Aquifer are generally composed of unconsolidated to semi-consolidated layers and exhibit semi-confined to unconfined conditions.
    - **Deep Ellensburg Aquifer:** The deep portions of the upper Ellensburg Aquifer are generally semi-consolidated to consolidated and exhibit confined aquifer conditions.
- **The CRBG** forms the bedrock stratigraphy in the area and is composed of several geologic formations including the Saddle Mountains Basalt, Wanapum Basalt, and Grand Ronde Basalt. These formations are subdivided into members which are composed of individual basalt flow packages and sedimentary interbeds. Sedimentary interbeds are generally confining and composed of silt, sand, and gravel. These interbeds are identified as members of the lower Ellensburg Formation and are considered separate units from those that house the Ellensburg Aquifer discussed herein. The CRBG basalt formations each contain aquifers which are frequently used for groundwater supply in the Moxee Valley, usually for irrigation use.

Groundwater is the primary source of drinking water in the area and is primarily withdrawn from the Ellensburg Aquifer. Domestic wells are primarily completed in the shallow Ellensburg Aquifer, at depths ranging from 100 to 300 feet. The City's drinking water supply consists of four groundwater wells completed in the deep portion of the upper Ellensburg Aquifer at depths ranging from 700 to 1,400 feet below ground surface (bgs). Due to the laterally extensive confining layers in the deeper portions of the upper Ellensburg Formation, City Well Nos. 1 and 3 once exhibited artesian conditions. All City wells have exhibited groundwater declines, which range from 0.6 to 2.5 feet per year (Table 1).

Table 1. City of Moxee Well Water Levels

	First Measurement[1]		Recent Measurement[2]			
	Water Level (ft, bgs)	Date	Water Level (ft, bgs)	Date	Total Decline (feet)	Rate of Decline (feet/yr)
Well 1	-85.5	Jan-1943	-34.7	Jan-2022	50.8	0.6
Well 2	22	Mar-1983	54.3	Mar-2022	32.3	0.8
Well 3	-10	Jan-2015	7.6	Jan-2022	17.6	2.5
Well 4	77.9	Jan-2021	79.2	Jan-2022	1.3	1.3

1. Water level at time of drilling from the driller's well log
2. Obtained from the City of Moxee during evaluation of Data Gaps for the ASR FS.

Surface waters of the Yakima River are the primary source of irrigation water supply in the area and are distributed through multiple canal systems including the Selah-Moxee Irrigation Canal system and the Roza Irrigation Canal system.

The Boss Well is an irrigation supply well located approximately 1 mile east of the City (Figure 1) and is completed in the deep Ellensburg Aquifer with a 6-inch diameter casing set at a depth of 950 feet bgs (Appendix A). The well log reports a post-construction pumping test performed in April of 1948 that was completed with a static wellhead shut-in pressure of 31 pounds per square inch (psi), equivalent to a potentiometric water level of 71 feet above ground surface (ags). The pumping test was performed at a discharge of 300 gallons per minute (gpm) and resulted in 22 feet of drawdown. The City is currently under agreement to consider acquiring the well. The well makes an ideal candidate for ASR testing due to sharing similar completions with the existing City wells and its proximity to nearby surficial water supplies of both the Selah-Moxee Irrigation District (SMID) ditch and the Roza Irrigation District (Roza) ditch.

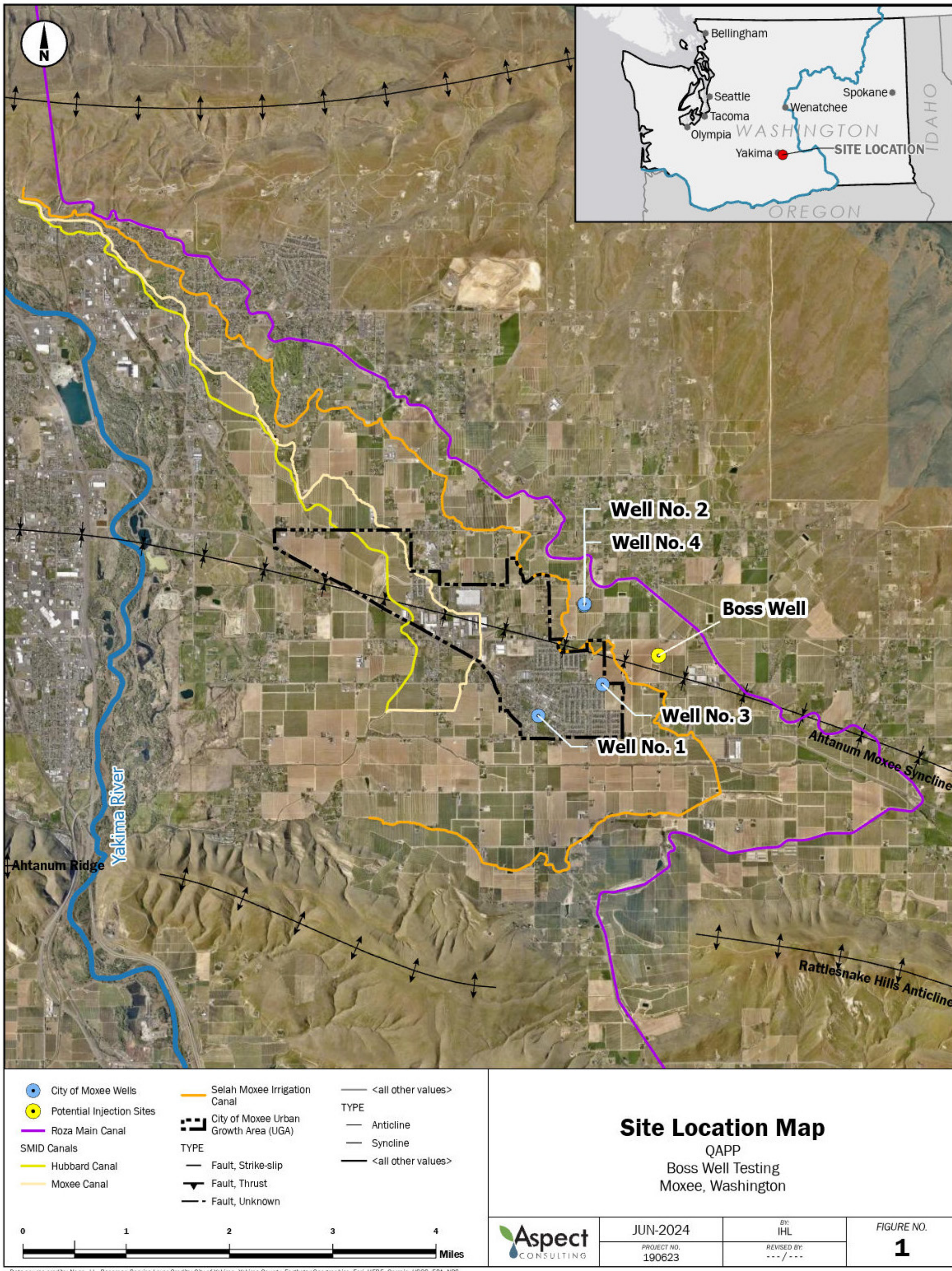


Figure 1. Site Location Map.

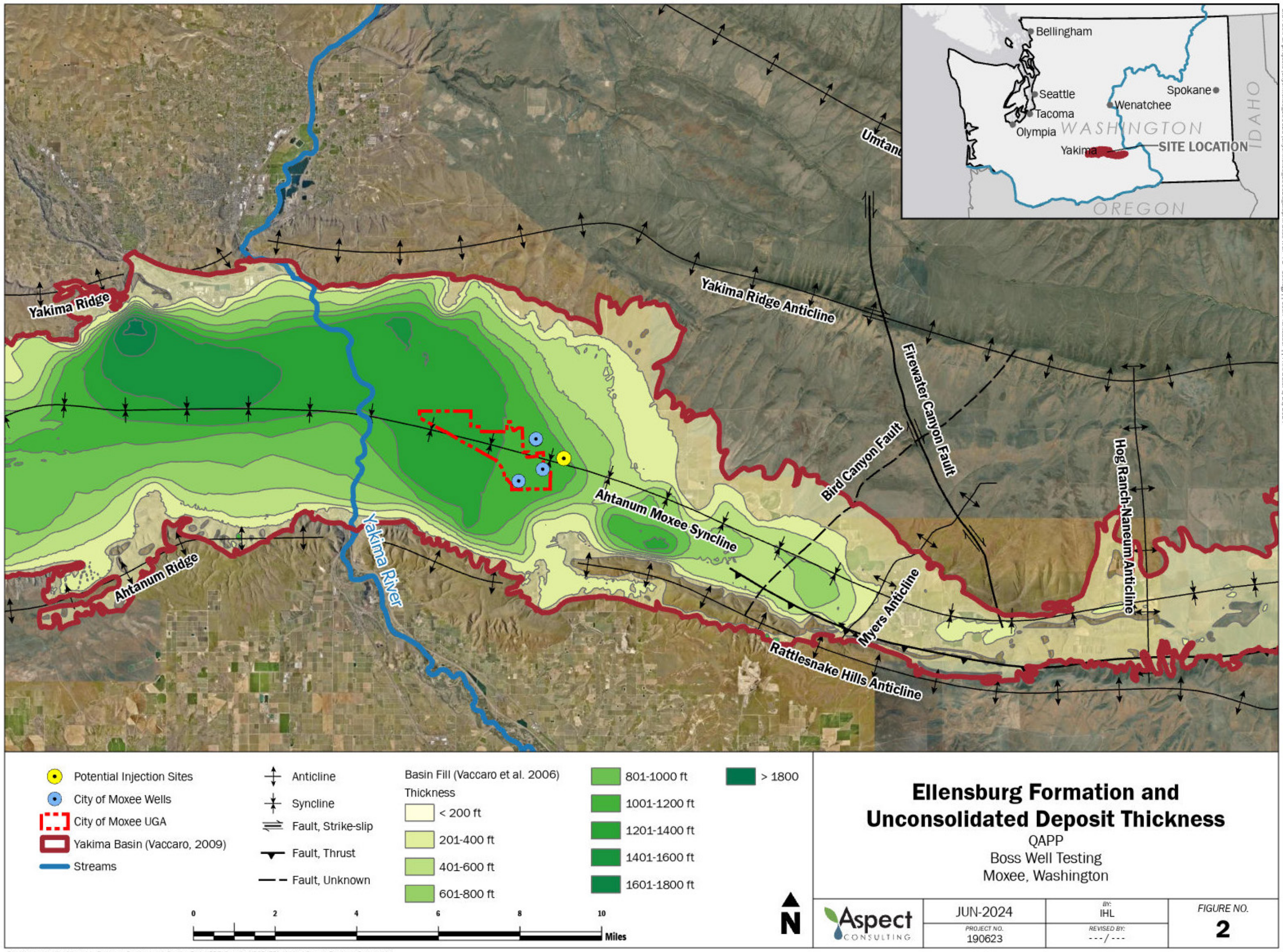
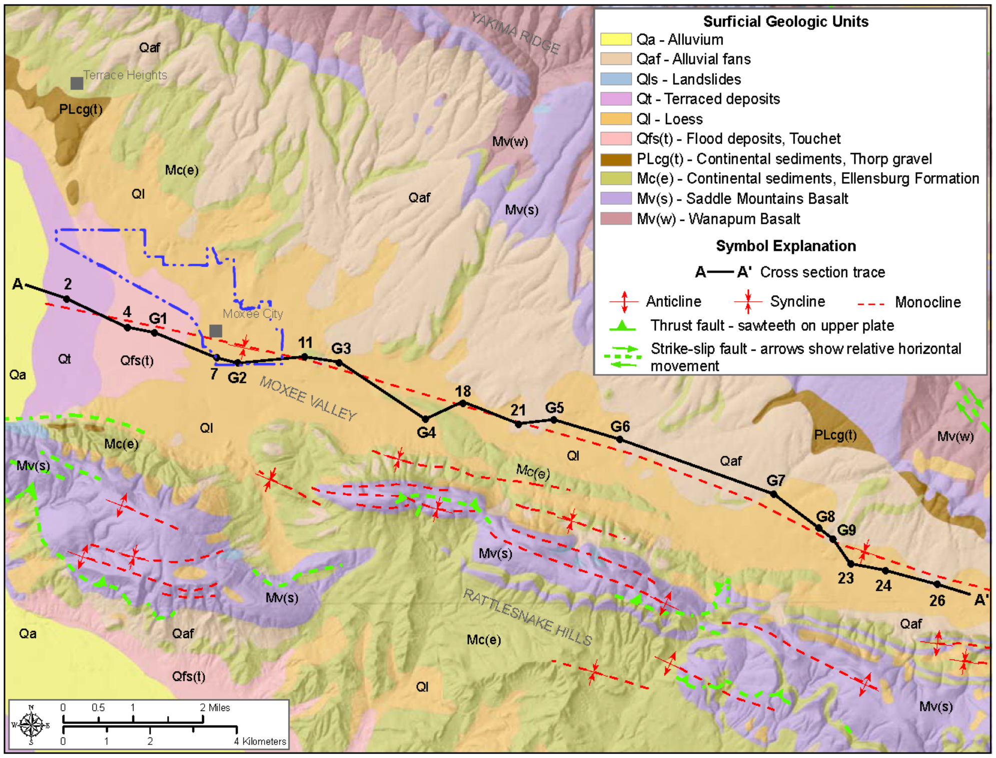


Figure 2. Ellensburg Formation and Geologic Structures Map



Data source: Washington division of Geology and Earth Resources, digital data, 2005, 1:100,000

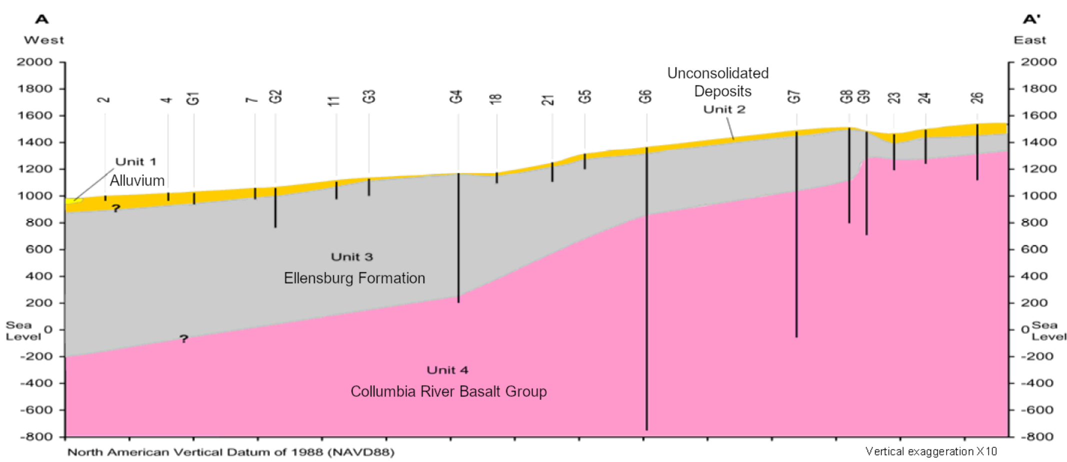


Figure 3. Surficial Geology and Cross-section of the Moxee Valley, modified from Sinclair, 2007

3.2.1 History of study area

The City relies fully on the groundwater supply from the deep Ellensburg Aquifer to supply a population between 4,000 and 5,000 people. However, groundwater levels have been observed to diminish significantly in recent history. G.O. Smith (1901) first described the local hydrogeologic conditions (folds and confining units) and water bearing units of the Ellensburg Formation that resulted in artesian conditions in the Moxee Valley. Smith documented several Ellensburg Aquifer wells completed from 525 to 1,026 feet bgs that produce water from single to multiple water bearing units. For example, some historical wells (e.g., Clark Well Nos 2 and 3) had a potentiometric surface of 30 to 115 feet of water above ground surface and flowed at 0.5 to 2.0 cubic feet per second (cfs). Some City wells (e.g., Well No. 2) have experienced water level declines of approximately 70 feet since time of construction in the 1980s. Based on historical well data from nearby wells completed in the deep Ellensburg Aquifer, such as Clark Well Nos. 2 and 3, groundwater levels in the area may have declined as much as 185 feet since their completion in 1892. These declines are leading to a decrease in pumping water level and specific capacity of the wells, resulting in an overall diminished water supply.

3.2.2 Summary of previous studies and existing data

The ASR program being evaluated by the City consists of diverting water from the Yakima River using existing infrastructure (e.g., conveyance via Selah-Moxee Irrigation District or Roza Irrigation District, and the City's existing distribution system) and recharging a deep aquifer tapped by existing City wells and other users. Stored water would be recovered through pumping by the City and passive return flow to the Yakima River (Anderson, et al. 2009; Vaccaro, et al. 2009). Aspect conducted a review of available data and hydrogeologic reports relevant to the City's proposed ASR program to assess suitability of the data for use in the FS and to identify remaining data gaps. Key findings include:

- The existing hydrogeologic data and reports provide a solid foundational knowledge for assessing the hydrogeologic setting and viability of the local Ellensburg Formation Aquifer near the City for ASR once synthesis of additional existing and new data is completed for the FS.
- Conditions of the City's wells are documented, and completion information is sufficient to support analysis required for the FS. Additionally, many neighboring well logs exist with sufficient completion information to inform additional hydrologic interpretation. Opportunistically, additional exploration and/or testing of existing wells should be incorporated into the conceptual model supporting the FS.
- A survey of City wellhead conditions and approximate elevations is needed to determine absolute groundwater elevations across the aquifer near the City.
- Manual water level data collection is needed for all City production wells, as allowed by wellhead access, to validate past automated measurements and correct data to groundwater elevations.

- Site-specific data provided from the City's SCADA system and recent pumping tests at Well No. 4 provide local validation (and support future updates) of the numerical model and aquifer parameters. Additional processing of SCADA data is required to use higher frequency measurements and to better document groundwater conditions in the target aquifer. This includes refinement of groundwater elevation trends across multiple (shallow and deep) water bearing zones. This will allow for greater estimation of aquifer performance in support of ASR as part of the FS.
- Water quality data exists for all sources and for the City wells but has a variable analyte list and temporal coverage. A complete set of water quality samples will need to be collected for the proposed source waters and storage aquifer in order to assess chemical compatibility, treatment needs, and regulatory compliance. Sampling will be performed for all potential water sources consistent with WAC 246-290-310 under the FS scope.
- Groundwater data is available from multiple water bearing zones (i.e., shallow and deep) within the Ellensburg Aquifer. These include the following:
    - The City's wells are equipped with a SCADA system that continuously monitor and record water levels and pumping rates at each of its water supply wells. Periodic water level data from 2015 to 2022 has been retrieved from the wells, which report depth of water above the sensor. Data has been corrected for elevations reported in well logs and pump set depth. However, field verification of SCADA water level readings, and extraction of additional data will need to be performed to improve accuracy to the level required for the FS. The City's wells are completed in the center of the valley in the deep Ellensburg Aquifer at depths of 783 to 1,376 feet. Inspection of available data suggests groundwater levels in the City's wells have all experienced declines of 1.6 to 2.5 feet/year since 2015.
    - The USGS National Water Information System (NWIS) and Ecology's EIM database provide publicly available groundwater monitoring within the Yakima Basin. The EIM systems identified seven wells near the City that are completed into the Ellensburg Formation and have groundwater level measurements spanning a discontinuous period from 1977 through 2021. These data were entered into the EIM database as part of data compilation efforts completed for the Ecology's Central Regional Office Groundwater Database (CRGWDB) study. The wells are completed into the Ellensburg Formation at depths of 212 to 645 feet, shallower than the completion of the City's wells. Groundwater levels within these wells range from stable to declining conditions. Three wells illustrated stable water levels, two showed groundwater declines of 0.2 to 0.7 ft/yr, and one well was too variable to determine an accurate trend.
    - Well water level data were also queried from the USGS NWIS database. The NWIS database contained over 300 groundwater wells within an approximate 48-square-mile area surrounding the City, with periods of record spanning discontinuous

periods from 1890 to 2008. Twenty-two of these wells are listed as completed within the Ellensburg Formation, of which five have two or more recorded water levels. Several of these are mapped directly with hydrographs via a USGS monitoring website (Keys, 2008). Well depths range from 131 to 605 feet. Groundwater levels in the wells range from stable to declines up to 0.5 feet/year.

Extraction and synthesis of these data will provide a more complete understanding of groundwater behavior across the Ellensburg Aquifer (i.e., shallow and deep) which will be incorporated in the hydrogeologic conceptual model included in the FS.

3.2.3 Parameters of interest and potential sources

No potential sources of contamination are being considered within this scope of work. Water quality testing and analysis is covered under the QAPP approved by Ecology for the City's ASR FS study (Aspect, 2023). Field parameters will be taken during pumping tests for evaluation of well conditions only.

3.2.4 Regulatory criteria or standards

This study will comply with the data requirements required to meet aquifer parameter characterization as outlined in WAC 173-157-120 and -130. Water Quality standards of that code will be met through sampling in the ASR FS (WRYBIP-2123-Moxeec-00036).

3.3 Water quality impairment studies

Not applicable.

3.4 Effectiveness monitoring studies

Not applicable.

4.0 Project Description

4.1 Project goals

The primary goals of the Boss Well Evaluation for the City of Moxee are to develop aquifer parameters for the deep Ellensburg Aquifer and to determine if the Boss Well can be used for ASR injection. The Boss Well is known to exist within the target aquifer for ASR and is proximal to both the City's extraction wells and available source water conveyance. However, limited data exists on aquifer parameters for the deep Ellensburg Aquifer and the current condition and performance of the Boss Well is not known. Performance testing of the Boss Well is required to determine the feasibility of using the well for ASR and identify potential well construction issues that would preclude the well's use for ASR. Analysis of testing results will produce aquifer parameters that will determine potential injection rates and available aquifer storage volumes. Based on the results of our evaluation, we will make a recommendation to either move forward with a plan to acquire and outfit the well for further testing or make a recommendation on other alternatives for ASR implementation.

A secondary goal of this scope is to fill data gaps within the City's SCADA water level records for the purpose of determining groundwater levels in the deep Ellensburg Aquifer. The City's wellfield is the only publicly available long-term record of groundwater levels within the deep Ellensburg Aquifer in the Moxee Valley. However, gaps in the data limit our analysis of groundwater level trends, both seasonal and historical, and therefore are required to evaluate aquifer conditions related to water availability and storage volume potentials that are important for implementing the City's proposed ASR program.

4.2 Project objectives

The objectives to meet the project goals are summarized below:

- Determine if the Boss Well can be equipped for ASR use.
- Evaluate Boss Well performance and aquifer parameters.
- Evaluate long-term groundwater elevation trends in the City's Wells.
- Evaluate if the Boss Well is a good candidate for pilot ASR testing.

4.3 Information needed and sources

New data that will be collected and assembled under this QAPP includes:

- Groundwater level measurements from the Boss Well, including background, pumping, and recovery periods.
- Groundwater level data from the City's SCADA system and manual verification of depth to groundwater in each City well.

4.4 Tasks required

Project tasks included in this QAPPs scope include:

Task 1: Pumping Tests

Work under this task will be completed to evaluate the storage aquifer conditions (transmissivity, storage coefficient, boundary conditions, etc.) and to assess the performance of the Boss Well. Results collected during this task will provide information required in WAC 173-157-120 and -130.

Task 1.1: Well Inspection and Test Preparation

A detailed assessment of the Boss wellhead, well appurtenances, conveyance infrastructure, and design constraints will be completed. A well contractor will be hired to pull the existing pump and equipment, perform a video scan of the well, and install a temporary test pump if the original pump is not sufficient. Sounding tubes will be installed to perform manual water level measurements and install temporary equipment (pressure transducers or dataloggers) in the Boss Well. The City's Well No. 3 will be equipped with a paired datalogger and barometer for observational data at least one week prior to the pumping testing and for one week following test completion. We will also collect manual water level measurements and measuring point information from the City well's for SCADA data evaluation. Dataloggers will be installed and maintained at least one day prior to the pumping tests in the Boss Well and at least one week prior to the pumping test in the observation well. Dataloggers will be installed and maintained for at least 10 days after test completion to monitor background groundwater levels.

Task 1.2: Conduct step-rate pumping test

A step-rate pumping test will be conducted using best practices at the Boss Well to evaluate well capacity and performance. The results of the step-rate test will be analyzed to determine the sustainable yield of the constant-rate pumping test.

Task 1.3: Conduct constant-rate pumping test

A constant-rate pumping test will be conducted for a minimum of 24 hours at the City's Boss Well. The pumping rate will be the maximum rate that is anticipated to be practically maintained within the constraints of the well and existing conveyance infrastructure. Infrastructural constraints include the discharge location for test water, which is expected to include discharging to ground or to one of the canals adjacent to the Boss Well (SMID or Roza).

Task 2: Reporting and Analysis

Work under this task will be completed to analyze and document the methods and results of the study.

Task 2.1: Pumping Test Analysis

The pumping test data will be analyzed using industry standard methods as appropriate for the well completion, data retrieved, and the anticipated aquifer parameters required for reporting, including specific capacity, transmissivity, and hydraulic conductivity. If drawdown is observed at the observation well the study will also allow analysis of aquifer storativity.

Task 2.2: Reporting

The methods, findings, conclusions, and recommendations of the tasks described above will be documented in a technical memorandum. Recommendations regarding design, permitting, and testing of the proposed ASR pilot program will be presented. Water level data will be plotted and analyzed using conventional pumping test analytical methods and the performance of the Boss Well and target storage aquifer will be evaluated. A draft memo will be prepared and submitted to Ecology, then a final memo will be prepared that addresses Ecology's comments.

The final technical memorandum will be included as an appendix to the ongoing ASR FS report, and the findings will be incorporated into the overall assessment of anticipated ASR performance presented in the ASR FS.

4.5 Systematic planning process

This QAPP has been prepared to satisfy the systematic planning needs for this project.

5.0 Organization and Schedule

5.1 Key individuals and their responsibilities

Table 2. Organization of project staff and responsibilities.

Staff	Title	Responsibilities
Jeff Dermond Department of Ecology, Office of the Columbia River Phone: 509-268-1784	Project Manager, OCR	Provides oversight of the Study and Ecology Grant. Clarifies scope of the project. Provides internal review of the QAPP and approves the final QAPP.
Scott Tarbutton Department of Ecology, Office of the Columbia River Phone: 509-329-3539	Quality Assurance Coordinator	Provides review of all copies of the QAPP and approves the final QAPP.
Jeff Burkett City of Moxee Phone: 509-575-8851	Project Manager	Reviews the draft and final QAPP and project deliverables, manages the project budget, and submits deliverables for the Ecology grant.
Tyson Carlson Aspect Consulting Phone: 509-895-5923	Principal Investigator, Project Manager	Co-author of QAPP and Aspect Project Manager. Oversees approach development, data analysis, and QA/QC. Reviews final report.
Derek Holom Aspect Consulting Phone: 206-941-4973	Project Hydrogeologist	Co-author of QAPP. Conducts oversight of field program development and execution. Performs review of data, analyzes, and hydrogeologic interpretations. Co-authors the draft and final reports.
Ian Lauer Aspect Consulting Phone: 208-540-1964	Project Hydrogeologist, Field Lead	Co-author of QAPP. Develops and oversees field program. Schedules field work and logistics. Collects field data. Performs review, analysis and interpretation of data. Co-authors the draft and final reports.
Stephen Bartlett Aspect Consulting Phone: 509-834-7040	Data Scientist	Reviews and Uploads EIM data.
Lea Beard Aspect Consulting Phone: 206-780-7749	Data Scientist	Reviews and Uploads EIM data.

QAPP: Quality Assurance Project Plan
EIM: Environmental Information Management System

5.2 Special training and certifications

A hydrogeologist licensed in the State of Washington will perform all analyses and interpretation of field data and provide oversight of hydrogeologic data collection. All field staff involved in this project will have either the relevant experience in the required standard operating procedures (SOPs) or be trained by more senior field staff or the project manager who has the required experience. The experienced staff will then lead the field data collection and oversee/mentor less-experienced staff.

5.3 Organization chart

Not applicable – See Table 2.

5.4 Proposed project schedule

Tables 3 – 5 list key activities, due dates, and lead staff for this project. Field work scheduling and subsequent deliverables are dependent on contractor availability.

Table 3. Schedule for completing field and laboratory work

Task	Anticipated Due date	Duration (weeks)	Lead staff
Field work	October 2024	2	Ian Lauer
Data analyses	November 2024	4	Ian Lauer

Table 4. Schedule for data entry

Task	Anticipated Due date	Duration (weeks)	Lead staff
EIM data loaded	March 2025	-	Lea Beard

EIM: Environmental Information Management System

Table 5. Schedule for final report

Task	Anticipated Due date	Duration (weeks)	Lead staff
Draft to supervisor	December 2024	2	Ian Lauer
Draft to client/ peer reviewer	January 2025	2	Derek Holom
Draft to external reviewers	January 2025	2	Tyson Carlson
Final draft to external reviewers	February 2025	4	Tyson Carlson
Final report due on web	March 2025	4	Tyson Carlson

5.5 Budget and funding

The City has received a grant from Ecology OCR (WRYBIP-2325-Moxeec-00048) to complete all tasks, as described in Section 4.4. This work is completed to fulfill data gaps within the active ASR FS that the City is completing under Ecology OCR funding (WRYBIP-2123-Moxeec-00036).

6.0 Quality Objectives

6.1 Data quality objectives [1]

The main data quality objective (DQO) for this study is to collect sufficient pumping test data to analyze aquifer parameters and evaluate if the well is a good candidate for pilot ASR testing. Groundwater level measurements and barometric pressure data will be collected from the Boss Well and observation wells, covering at minimum pre-test static conditions, pumping test drawdown and recovery, and return to static groundwater condition. Pumping test analysis will use appropriate methodologies to evaluate well performance and aquifer parameters based on the observed groundwater level response to pumping. Groundwater elevation hydrographs of the City's wells will be prepared using the City's SCADA data.

6.2 Measurement quality objectives

Measurement Quality Objectives (MQOs) are statements of the precision, bias, and lower measurement limits necessary to meet the Study objectives. Precision and bias together express data accuracy, whereas other considerations include the representativeness, completeness, and comparability of the data.

The investigation will be conducted to measure water levels in the test well and observation wells. The MQOs for the field investigation are chosen based on the data requirements for the analytical methods, the accuracy and precision of the field equipment used to collect measurements, and the standard operating procedures employed to make decisions in the field. The data collection instrumentation listed in Table 6 will meet the MQOs listed below.

Groundwater Level Monitoring

The MQOs for the groundwater level monitoring of the Boss Well and City wells are as follows:

- Obtain horizontal well locations within 2-meter (6.5 feet) accuracy in the North American Datum of 1983 (NAD83).
- Obtain the elevation (if not already obtained) of the wellhead or water level reference point relative to ground surface within 1-foot accuracy in the North American Vertical Datum of 1988 (NAVD88).

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[1] 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.

- Obtain ground surface elevations within a 1-foot accuracy (using GPS measurements, with elevations cross-referenced with a 10-meter digital elevation model available from the Department of Natural Resources).
- Obtain ground water level measurements relative to the established measuring point or ground surface within a 0.1-foot accuracy.
- Record discharge rate measurements using an operable flowmeter with a calibrated range appropriate to the pumping rate, as stated in Table 6 and based on performance of the well at time of drilling.
- Obtain historical water level records from the City's SCADA system within 1-foot accuracy.

A description of the water level monitoring techniques that will be used to obtain the MQOs for the water level measurements and well locations is provided in the Field Procedures section (Section 8.2). Water level monitoring during well and aquifer testing (discharge and recovery testing) will be conducted per Ecology's Aquifer Test Procedures and Depth to Water Measurement SOP (Ecology, 2023a; Ecology, 2023b).

Table 6. Field Equipment Specifications

Parameter	Equipment /Method	Bias (median)	Precision of Field Duplicates (median)	Equipment Information			Expected Range
				Accuracy	Resolution	Range	
Air Monitoring							
Temperature	Van Essen Baro-Diver	--	--	0.1°C	0.01°C	-10 to 50°C	-7 to 31°C
Barometric Pressure	Van Essen Baro-Diver	--	--	0.016 ft-H_2O	0.001 ft-H_2O	--	50 to 300 ft- H_2O
Groundwater Level Measurements							
Temperature	Seametrics PT2X – 300 PSI Vented	--	--	0.5°C	0.1°C	-15 to 55°C	0 to 25°C
Pressure	Seametrics PT2X – 300 PSI Vented	--	--	±0.05% FSO	±0.0034% FSO	Max 692 ft-H_2O	10 to 300 ft-H_2O
Temperature	Van Essen TD-Diver D1801	--	--	0.1°C	0.01°C	0 to 50°C	1 to 25°C
Pressure	Van Essen TD-Diver D1801	--	--	0.016 ft-H_2O	0.007 ft-H_2O	Max 330 ft-H_2O	10 to 300 ft-H_2O

Parameter	Equipment /Method	Bias (median)	Precision of Field Duplicates (median)	Equipment Information			Expected Range
				Accuracy	Resolution	Range	
Depth to Water	Waterline Envirotech 800-ft Water Level Meter Tape	--	--	0.05 ft	0.01 ft	0.5 to 800 ft	50 to 300 ft
Wellhead Position (GPS)	EOS Arrow 100+ GNSS Receiver (RTK)	--	--	0.1 ft	0.01 ft	--	--
Aquifer Testing Measurements							
Discharge Rate	Soundwater Orcas T31-C7 Ultrasonic Flowmeter	--	--	± 2.0%	0.01 gpm	0 to 60 ft/s (0 to >5000 gpm in 6-inch diameter pipe)	50 to 500 gpm
Field Water Quality Parameters							
pH	In-Situ AquaTroll 500 (with flow-through cell)	--	--	±0.1 SU	0.01 SU	0 to 14 SU	6.5 to 8.5 SU
Specific Conductivity		--	--	±0.5% + 1 µS/cm	0.1 µS/cm	0 to 350,000 µS/cm	150 to 500 µS/cm
Dissolved Oxygen		--	--	± 0.1 mg/L	0.01 mg/L	0 to 20 mg/L	0 to 10 mg/L
Oxidation-Reduction Potential		--	--	±5 mV	0.1 mV	-1400 to +1400 mV	-300 to +300 mV
Temperature		--	--	±0.1°C	0.01°C	-5 to 50°C	1 to 25°C

*Pumping equipment supplied by contractors will follow specify standards and be properly calibrated. All equipment supplied by the contractor will be recorded and reported within the final report.

6.2.1 Targets for precision, bias, and sensitivity

Pumping test procedures are covered in the referenced SOPs and anticipated pumping rates, etc., are provided in Section 8.2.5. The reporting limits of the methods listed in the table are appropriate for the expected range of results and the required level of sensitivity to meet project objectives.

The quality and usability of data collected will be determined based on the outcomes of data verification and validation and will be expressed as the measurement quality objectives

(MQOs): precision, accuracy (bias), representativeness, comparability, completeness, and sensitivity.

6.2.1.1 Precision

Precision is defined as the degree of agreement between or among independent, similar, or repeated measurements. Precision is a measure of variability in the results of replicate measurements due to random error. Precision is usually assessed by analyzing duplicate field measurements and random error is imparted by the variation in field procedures. Therefore, field sampling precision is addressed by collection of replicate measurements. Replicate measurements will be taken for manual water levels during installation and retrieval of dataloggers. Additionally, manual water level observations will be taken at the Boss Well during pumping and recovery stages of the test to provide replicate measurements for the automated pressure transducer readings of drawdown and recovery. Discharge rates measurements will be replicated using two flow meters, an Orcas ultrasonic flowmeter and a contractor supplied totalizing flow meter. The two readings will be compared and evaluated along with totalized discharge.

6.2.1.2 Bias

Bias is the difference between the sample mean and the true value. The most likely source of bias in the proposed project tasks are sensor drift (accuracy loss) over time in automated monitoring equipment, including both pressure transducer and SCADA data, and lack of sufficient sampling rate to accurately resolve changes in measurement. All measurements will be performed at or greater than the frequency outlined in the SOP. Automated equipment will be calibrated and checked for accuracy by performing contemporaneous manual field measurements and comparing time-plots of both data sets based on the SOP. Groundwater level measurements for the pressure transducer are barometrically corrected through the use of a vented tube and collection of atmospheric data in an independent barometric pressure transducer. Transducer submergence depths are plotted with manual measurements to assess if a bias is present. If sensor drift is observed, it will be corrected using appropriate method as outlined in EAP074 (Ecology, 2019a).

6.2.1.3 Sensitivity

Sensitivity is a measure of the capability of a method to detect a substance. It is commonly described as a detection limit. The minimum measurable limits of equipment are addressed in in Table 6 as the equipment’s resolution and detectable range.

6.2.2 Targets for comparability, representativeness, and completeness

6.2.2.1 Comparability

Comparability is the degree to which the data can be compared to historical data, reference values (such as background), and reference materials. This will be achieved through the use of standard techniques to collect samples and consistent units to report analytical results. The standard operating procedures that will be followed for this project are listed in Section 8.2. Data comparability depends on data quality. Data of unknown quality cannot be compared and will be identified.

6.2.2.2 Representativeness

Representativeness is the degree to which sample results represent the system under study. This component is generally considered during the design phase of a program. This program will use the results of all analyses to evaluate the data in terms of its intended use.

6.2.2.3 Completeness

Valid and invalid data (i.e., data qualified with the R flag [rejected]) will be identified during data validation. The completeness target for the study is 95 percent of water level measurements.

6.3 Acceptance criteria for quality of existing data

The City's existing historical water level data collected from the SCADA system will be used to analyze historic aquifer conditions, available storage volumes, and hydraulic connectivity of the City's well field. SCADA data retrieved from the City's wells will be manually checked for errors and inconsistencies in historical data and erroneous data will be flagged, as described in Section 14. Measuring points, depth to water, and groundwater elevations will be manually collected from the wells as described in Section 8.2 and compared to the automated data. Any differences in measuring points and or resulting depth to water measurements will be documented. The overall accuracy of the historical water level readings will be 1-foot as described in Section 6.2.

6.4 Model quality objectives

Not applicable.

7.0 Study Design

A narrative of the overall study design is provided in Section 4. This section provides the details of the data collection and analysis.

7.1 Study boundaries

The study area is defined as the extent of the City of Moxee's wellfield and including the Boss Well to the east, shown in Figure 1. All data collected for this study will be at well sites shown.

7.2 Field data collection

7.2.1 Sampling locations and frequency

Manual depth-to-water measurements will be collected during the aquifer testing program at the Boss Well according to Ecology's Aquifer Test Procedures (Ecology, 2023a) using an electronic water level indicator as discussed in Section 8 and in accordance with EAP052 standard operating procedures. (Ecology, 2023b). Manual water levels will be measured both during deployment and retrieval of dataloggers to provide depth-to-water, groundwater elevation, and sensor drift corrections to the pressure transducer data.

Dataloggers will be installed at least one day prior to testing to collect background water levels and will remain in the well for at least 10 days following test completion. A dedicated pressure transducer will be installed at the Boss Well to collect continuous groundwater level measurements prior to and after testing and will record at minimum rate of one observation per minute. During testing, a vented PT2X pressure transducer will be used to collect drawdown and recovery data in the Boss Well and will record at a minimum interval of every 30 seconds. A barometric pressure transducer will be installed at the Boss Well to collect continuous atmospheric pressure measurements prior to and after testing at a rate of one observation every ten minutes.

Dataloggers will installed in the observation well, Well No. 3, one week prior to testing and will remain in the well for at least 10 days following test completion. Dataloggers will consist of a dedicated pressure transducer and barometer to measure observation water level data and atmospheric pressure. Water levels will be measured at a rate of one observation per minute, and atmospheric pressure

Manual depth-to-water measurements will be collected at each the City wells using an electronic water level indicator. Measurements will be performed twice at each well to verify depth to water and will be scheduled to avoid pumping intervals and be contemporaneous with SCADA logging intervals if possible.

Additional details on groundwater monitoring are provided in Section 8.2.2.

7.2.2 Field parameters and laboratory analytes

Field water quality parameters will be measured at the Boss Well during the constant-rate pumping test to evaluate changes in well or aquifer conditions only. Parameters will be measured using an In-Situ AquaTroll 500 multimeter, as described in Section 8.2; these include:

- Specific Conductance
- Dissolved Oxygen
- Oxidation-Reduction Potential (ORP)
- pH
- Temperature
- Turbidity

7.3 Modeling and analysis design

Aquifer and well performance will be estimated using conventional analytical methods for the observed hydrogeologic conditions and available data as follows:

- Aquifer transmissivity and storativity will be determined using conventional analytical methods for time-drawdown and distance-drawdown data collected during the constant-rate pumping test (e.g., Theis curve fitting or Cooper-Jacob methods).
- Well efficiency testing will be conducted using analytical methods for step-rate pumping (e.g., the Hantush-Bierschenk method).

The published underlying assumptions for the analytical methods used will be verified as being met prior to selecting a specific analytical method.

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 assumes that groundwater level data are of sufficient quality to compare with data collected under this QAPP and sufficient budget to complete tasks. There are also several assumptions around designing a pumping test and analyzing the results. These assumptions include:

- The equipment used in the pumping test (flow meters, pressure transducers, water level data loggers, water level indicators, etc.,) give accurate readings when they are installed, used, and calibrated properly.

- Discharge from the pumping test will not recharge the aquifer.
- A constant discharge is maintained during the entirety of the pumping test.
- An appropriate method will be used to analyze aquifer test data. Analytical methods have several built-in assumptions that are incorporated into this study, including:
    - The aquifer has infinite areal extent;
    - The aquifer is homogeneous, isotropic and of uniform thickness;
    - Flow to the pumping well is horizontal;
    - The aquifer is nonleaky, confined or semi-confined;
    - Water is released instantaneously from storage with decline in hydraulic head;
    - Diameter of the pumping well is very small so that storage in the well can be neglected.
- Opportunistic collection of observation well data:
    - The observation wellhead is accessible for water level collection.
    - The observation well is completed within a unit that is hydraulically connected with the Ellensburg Formation.
    - The observation well is located so that they exhibit sufficient drawdown to produce usable data.

7.5 Possible challenges and contingencies

7.5.1 Logistical problems

Logistical problems that interfere with measurement collection may occur during fieldwork. These problems may include, but are not limited to:

1. Inability to access groundwater measurement locations (observation wells);
2. Inability to install pressure transducers in observation wells;
3. The condition of the Boss Well or any appurtenances cannot be made operable, and the project is delayed due to additional effort being required.

7.5.2 Practical constraints

Practical constraints that can interfere with a project include scheduling problems with personnel, equipment failure, or availability of adequate resources. Funding opportunities are typically the greatest limitation to collection of baseline data.

7.5.3 Schedule limitations

Scheduling is limited by ability to contract and execute fieldwork in coordination with project partners and landowners. Current scheduling issues are likely to arise from conflicts with deliverable reviewer schedules, contractor availability and scheduling, and unforeseen circumstances.

8.0 Field Procedures

8.1 Invasive species evaluation

No immediate issues with invasive species are identified in this study. Field staff will follow Ecology's SOP EAP070 (publicly available in digital format on Ecology's website), located in Appendix B, on minimizing the spread of invasive species (Ecology, 2023c). At the end of each field visit, field staff will clean field gear in accordance with the SOP for minimizing the spread of invasive species for areas of moderate concern.

Field staff will minimize the spread of invasive species after conducting field work by:

- Inspecting and cleaning all equipment by removing any visible soil, vegetation, vertebrates, invertebrates, plants, algae, or sediment. If necessary, a scrub brush will be used and then rinsed with clear water either from the site or brought for that purpose. The process will be continued until all equipment is clean.

- Draining all water in samplers or other equipment that may harbor water from the site. This step will take place before leaving the sampling site or at an interim site. If cleaning after leaving the sampling site, field staff will ensure that no debris will leave the equipment and potentially spread invasive species during transit or cleaning.

Established Ecology procedures will be followed if an unexpected contamination incident occurs.

8.2 Measurement and sampling procedures

The procedures used in this study are typical for any hydrogeologic investigations. SOPs to be followed are publicly available in digital format online and include the following:

- Ecology's Aquifer Test Procedures (Ecology, 2023a),
- SOP EAP052, Version 1.4 – Manual Well-Depth and Depth-to-Water Measurements (Ecology, 2023b),
- SOP EAP074, Version 1.2 – Use of Submersible Pressure Transducers During Groundwater Studies (Ecology, 2019a), and
- Standard Operating Procedure EAP070, Version 2.3 – Minimize the Spread of Invasive Species (Ecology, 2023c)

8.2.1 Well Location Survey

The horizontal location and ground surface elevation of the Boss Well and any observation wells will be determined using an EOS Arrow 100+ GPS. Care will be taken to collect a GPS location within a horizontal and vertical accuracy of better than 1 foot, as discussed in the *Quality Objectives* section (Section 6).

8.2.2 Field Parameters

Field water quality parameters (temperature, pH, specific conductance, dissolved oxygen, ORP, and turbidity) will be monitored using a closed flow through cell during the constant rate pumping test. Parameters will be used for observation of well and aquifer conditions over the duration of the test only.

8.2.3 Groundwater Level Monitoring

Groundwater levels will be measured at the Boss Well and observation wells with both manual electronic water level indicator and with automated pressure transducers installed in each well. Long term monitoring data will be collected with a pressure transduces installed below the anticipated minimum water level of the well. Barometric pressure loggers will collect paired atmospheric observations, which will be used to correct pressure transducer data into gaged submergence pressure (feet of water above the sensor). During the pumping test and recovery, a vented PT2X pressure transducer will be deployed in the Boss Well to take direct submergence pressure readings. During testing, manual measurements will be performed in the test well at a frequency equal to or more frequent than outlined in Ecology's Aquifer Test Procedures (Ecology, 2023a). Manual measurements in the test and observation well will be made during deployment and recovery of pressure transducers to provide manual verification and calibration of automated transducer data.

Water levels will be collected using an electrical water level meter with a precision of 0.01-ft and estimated accuracy of 0.05-ft. Water levels will be measured from the existing measurement point (MP) at each well to ensure data comparability. If an MP does not exist, then we will establish one based on the following procedure:

1. MPs are normally established on the north side of the top rim of the actual well casing; this position is commonly referred to as "top of casing" (TOC). Locate the MP at a convenient place from which to measure the water level. If the TOC is level, collect the measurement from the north edge.
2. Clearly mark the MP. The MP must be as permanent as possible and be clearly visible and easily located. The MP may be marked using a permanent black marker, bright colored paint stick, or with a notch filed into the TOC.
3. Describe the position of the MP clearly in the field-data sheets.
4. The MP height is established in reference to a land surface datum (LSD). The LSD is generally chosen to be approximately equivalent to the average altitude of ground surface around the well.
5. Measure the height of the MP in feet relative to the LSD. Generally, MPs are established to the nearest 0.1-ft using a pocket tape to measure the distance from the MP to the LSD. Note that values for measuring points that lie below land surface should be preceded by a minus sign (-). Record the height of the MP and the date it was established.
6. MPs and the LSD may change over time, the distance between the two should be checked whenever there have been activities, such as land development that could have affected

either the MP or LSD at the site. Such changes must be measured as accurately as possible, documented and dated in field-data sheets, and in any database(s) into which the water-level data are entered.

All subsequent water level measurements should be referenced to the established MP. The MP value will be used to convert measurements into values that are relative to land surface.

After a permanent MP is stablished for each well, continue sampling using the following process:

1. Open the top of the well and note any “popping” sounds that would indicate pressure buildup, any odors, and the condition of the well head.
2. If there is a pressure transducer attached to the well cap carefully note the initial position of the cap (mark cap position on casing with permanent marker). If the well was airtight, wait a few minutes for the water level to return to equilibrium with atmospheric pressure.
3. Turn the water level meter on and slowly lower the probe into the well until it makes a tone indicated contact with the water level. To confirm contact, slowly raise and lower the electric-tape probe in and out of the water column. If necessary, adjust the sensitivity setting of the meter to provide a “crisp” indication of the water surface. Measure the depth of water against the MP and mark the date and time the reading was made.
4. At the precise location the indicator shows contact with the water surface, pinch the tape between your fingernails at the MP. Read the depth-to-water.
5. Repeat the measurement to ensure that the water level is stable (not rising or falling over time).
6. When the probe is pulled back up, make a note of any mud, staining, or anything else on the tip. Before moving on to the next well, decontaminate the probe with a brush or paper towel, then rinse with distilled water and 10 percent bleach.

On occasion, condensation on the interior casing of the well can prematurely trigger the electric-tape indicator giving a false positive reading. In this situation, it can help to center the tape in the well casing above the water level and lightly shake the tape to remove the excess water on the probe.

8.2.4 Atmospheric Pressure Monitoring

A barometric pressure transducer and datalogger will be deployed within the project limits. Data from this transducer will be used to correct measured well water levels for barometric effects at the Boss Well and the observation wells. Barometric efficiency can affect the representativeness of water level measurements from vented and unvented transducers (Spane, 2002). Corrections for barometric efficiency of wells will be made, as appropriate.

8.2.5 Aquifer and Well Testing

Well and aquifer testing will be performed in accordance with Ecology’s *Aquifer Test Procedures* (Ecology, 2023a). A licensed hydrogeologist will oversee all testing activities by staff listed in Table 2 and ensure data collection is conducted in accordance with professional standards.

Step-Rate Pumping Tests

A step-rate pumping test will be conducted at the Boss Well using best practices to evaluate well capacity and performance. The results of the step-rate test will be analyzed to determine the sustainable yield of the constant rate pumping test as described in Section 4.4.

The anticipated duration and rates for the step-rate pumping test are summarized in Table 7.

Table 7. Anticipated Step-rate Pumping Test Rates, 1-hour per step

Step No.	Pumping Rate (% sustainable production)	Anticipated Pumping Rate (gpm)
1	50	150
2	75	225
3	100	300
4	125	375

Based on the original well log and existing pump configuration, the sustainable production capacity of the Boss Well is anticipated to be approximately 300 gpm. Pending available equipment and measured well production, the maximum pumping rate capability may be as much as 500 gpm. Actual pumping rates will be determined while conducting the test to ensure that four evenly spaced steps can be accommodated with the existing capabilities of the well and equipment as shown in Table 7. The first step will be performed at the minimum pumping rate of the installed test pump. The final (maximum) pumping rate will be the maximum rate that is sustainable for approximately 1 hour (note that this duration differs from Ecology's Aquifer Test Procedures [Ecology, 2023a]). Based on the observed specific capacity of 3 gpm/foot (Appendix A), the aquifer is expected to be highly transmissive, and testing will likely be limited by the casing diameter.

The duration of each step will be a minimum of 1-hour, which is typically the minimum time required to reach a stable rate of drawdown and for conventional analysis of the test data to determine turbulent and laminar flow losses. The stability of the rate of drawdown (derivative of the drawdown) will be confirmed on the first step and prior to advancing to the 2nd step. If stable drawdown has not been reached within the 1st hour, the step will be extended until stable drawdown is observed. Each subsequent step will be equivalent in duration to the first step.

Discharge rates will be observed throughout testing to ensure constant discharge throughout each step. Discharge rates will be recorded at the same interval as manual depth to water readings and during any manual correction to discharge rate. Totalizer readings will be recorded prior to initializing the test and at the conclusion of each step.

Constant Rate Pumping Tests

A constant-rate pumping test will be conducted for a minimum of 24 hours at the Boss Well. The pumping rate will be the maximum rate that is anticipated to be practically maintained within the constraints of the well and existing conveyance infrastructure (i.e., the sustainable yield), as determined by the step-rate test.

Discharge rates will be observed throughout testing to ensure constant discharge throughout each step. Discharge rates will be recorded at the same interval as manual depth to water readings and during any manual correction to discharge rate. Totalizer readings will be recorded prior to initializing the test and at the conclusion of each step.

8.3 Containers, preservation methods, holding times

Not applicable.

8.4 Equipment decontamination

Equipment will be decontaminated and washed on site as listed in Section 8.1. No contamination is expected.

8.5 Sample ID

Not applicable.

8.6 Chain of custody

Not applicable.

8.7 Field log requirements

During the collection of any field samples accompanying field documentation must be made clearly stating:

- Name and location of project
- Field personnel
- Sequence of events
- Any changes or deviations from the QAPP or SOPs
- Environmental conditions
- Date, time, location, ID, and description of measurements
- Field instrument calibration procedures
- Field measurement results
- Unusual circumstances that might affect interpretation of results

For this Study, data collected in the field will be contained in a field log (a binder backed by electronic scans of documents) that will consist of field notes (freehand notes) and Aspect field data sheets (Appendix C).

Field notes should be bound, waterproof notebooks with prenumbered pages (e.g., Rite in the Rain®). Permanent, waterproof ink should be used for all entries. Corrections should be made with single-line strikethroughs, initials, and date of correction. Use of white-out or correction fluid is not permitted.

While conducting field work, the field hydrogeologist or technician (Table 2) will document general pertinent observations and events in waterproof field notes and, when warranted, provide photographic documentation of specific sampling efforts. Data collected during the sample collection procedures will be recorded on standard Aspect field data sheets (Appendix C). Field notes will include a description of each field activity, sample descriptions, and associated details, such as the date, time, and field conditions. Upon completion of a field task, the field personnel will then scan field notes and Aspect field data sheets into computer files and provide the original versions to the Aspect Project Manager. Copies of Aspect field data sheet and laboratory chain of custody are provided in Appendix C.

8.8 Other activities

Not applicable.

9.0 Laboratory Procedures

Not applicable. No laboratory analysis is performed under this scope. All sampling is covered by the QAPP approved by Ecology for the City of Moxee ASR FS (Aspect, 2023).

9.1 Lab procedures table

Not applicable.

9.2 Sample preparation method(s)

Not applicable.

9.3 Special method requirements

Not applicable.

9.4 Laboratories accredited for methods

Not applicable.

10.0 Quality Control Procedures

Implementing QC procedures provides the information needed to assess the quality of the data that is collected. These procedures also help identify problems or issues associated with data collection or data analysis while the project is underway.

10.1 Table of field and laboratory quality control

Manual measurements will be taken before, during, and after automated collection of groundwater and flow measurements. All measurements will be field checked prior to leaving the field site as further detailed in Section 13.1. Deviation of automated and manual measurements will be assessed by the residual difference between measurements. Deviations will be assessed to determine whether they are the result of sensor drift in the dataset, erroneous measurement, or other errors and will be marked with a data flag as detailed in Section 13. Data that is flagged will not be used in subsequent analysis.

10.2 Corrective action processes

Drifts in transducer measurements will be checked with manual readings. Any linear trends identified in the datasets will be removed prior to use in our analysis. The drift corrections will be documented and provided in an appendix showing the uncorrected versus corrected data.

In the event of a transducer failure, we will endeavor to replace it as soon as practical. In the case of transducer failure during the pumping test, we may have to rely on the manual water level readings as back-up.

11.0 Data Management Procedures

11.1 Data recording and reporting requirements

Field technicians will record all field data in a water-resistant field notebook, electronic data forms, or Aspect standard field data sheet. Before leaving each site, staff will check field notebooks, data sheets, or electronic data forms for missing or improbable measurements. Field technicians will enter field-generated data into spreadsheets or a project database as soon as practical after they return from the field. For data collected electronically, data will be backed up on servers when staff return from the field. Raw data files will be stored separate from processed data files.

The Aspect field hydrogeologist and field technician will check data entry against the field notebook data for errors and omissions. The hydrogeologist will notify the Aspect Project Manager of missing or unusual data.

Data will be uploaded to Ecology's EIM database as described in Section 11.4.

11.2 Laboratory data package requirements

Not applicable.

11.3 Electronic transfer requirements

Not applicable.

11.4 Data upload procedures

Manual and automated groundwater level and flow measurements will be tabulated in the format of a csv or xls file (comma-separated value and Excel workbook). The data package will include the following sections: Case narrative; Summary of QA/QC results; and Raw data. Final Study data will be uploaded to Ecology's Environmental Information Management (EIM) database under Study ID: WRYBIP-2325-00048.

11.5 Model information management

Not applicable.

12.0 Audits and Reports

12.1 Audits

Field technicians will be required to review this QAPP prior to each monitoring event and to maintain a copy of the QAPP and its appendices in the field. Field technicians may be audited at any time by the project manager or the Aspect data manager (Table 2) to ensure that field work is being completed and documented according to this QAPP, work plan, and published SOPs.

12.2 Responsible personnel

Personnel responsible for the audits are as follows:

- Field audit: Aspect Project Manager
- Field consistency review: experienced (at least 3 years) staff (senior hydrogeologist or project manager)
- Data analysis: Aspect hydrogeologists (field, senior, and principal, as required for specific analysis)

Personnel assigned to these roles are listed in Table 2.

12.3 Frequency and distribution of reports

Results of the field data collection, data quality assessment, and any data analysis will be documented in a published report. The final report will be distributed to all other stakeholders involved or interested in the study as determined by the City and Ecology.

Field and Laboratory Data will be entered into EIM when data collection is complete.

12.4 Responsibility for reports

The Aspect Project Manager is responsible for verifying data completeness and usability before the data are used in the technical report and entered into the Environmental Information Management (EIM) database. The Aspect Project Manager is also responsible for writing the final technical report or memo, unless an alternate author is agreed upon and documented at the start of the project.

The Aspect Project Manager is responsible for assigning a peer reviewer with the appropriate expertise for the technical report. A draft report will be prepared and submitted to Ecology, then a final report will be prepared that addresses Ecology’s comments. The peer reviewer is responsible for working with the report author to resolve or clarify any issues with the report.

13.0 Data Verification

Data verification is the process of evaluating the completeness, correctness, and conformance/compliance of a specific data set against the method, procedural, or contractual requirements.

13.1 Field data verification, requirements, and responsibilities

Field notebooks, data sheets, and electronic information storage will be checked for missing or improbable measurements, and initial data will be verified before leaving each site. This process involves checking the data sheet (written or electronic) for omissions or outliers. If measurement data are missing or a measurement is determined to be an outlier, the measurement will be flagged in the data sheet and repeated if possible. The field hydrogeologist or field technician is responsible for in-field data verification.

Upon returning from the field, data are either manually entered (data recorded on paper) or downloaded from instruments and then uploaded into the appropriate database or project folder (see Data Management Section). Manually entered data will be verified/checked by a staff member who did not enter the data. Downloaded electronic data files will also be checked for completeness and appropriate metadata (such as file name, time code).

Following data entry verification, raw field measurement data will undergo a quality analysis verification process to evaluate the performance of the sensors. Field measurement data may be adjusted for bias or drift (increasing bias over time) based on the results of fouling, field, or standards checks following general USGS guidelines (Wagner, 2007) and this process:

Review Discrete Field QC Checks

The field check of instrumentation will consist of a manual measurement for water levels, and measurement of water quality parameters in the field (checks with water quality parameters will be completed separate from calibration events). The post check data for field QC instrument check (water quality and water level) will be reviewed, and the result will be qualified, rejected, or accepted as appropriate.

Review/Adjust Time Series (Continuous) Data

1. Plot raw time series with field checks.
2. Reject data based on deployment/retrieval times, site visit disruption, blatant fouling events, and sensor/equipment failure.
3. Review sensor offsets for both recalibration and post-deployment buffer/standard checks. Flag any potential chronic drift or bias issues specific to the instrument.
4. If applicable, review fouling check and make drift adjustment, if necessary. In some situations, an event fouling adjustment may be warranted based on abrupt changes in flow, stage, sediment loading, etc.

5. Review residuals from both field checks and post-checks, together referred to as QC checks. Adjust data, as appropriate, using a weight-of-evidence approach. Give the most weight to post-checks with National Institute of Standards and Technology standards (for pH, specific conductance, and ORP), then field checks are accepted, rejected, or qualified. Do not use field checks rated poor. Potential data adjustments include:
    a. **Bias** – Data are adjusted by the average difference between the QC checks and deployed instrument. Majority of QC checks must show bias to use this method.
    b. **Regression** – Data adjusted using regression, typically linear, between QC checks and deployed instrument. This accounts for both a slope and bias adjustment. The regression must have at least five data points and an R^2 value of >0.95 to use for adjustment. Do not extrapolate regressions beyond the range of the QC checks.
    c. **Calibration/Sensor Drift** – Data adjusted using linear regression with time from calibration or deployment to post-check or retrieval. Majority of QC checks, particularly post-checks, must confirm pattern of drift.
6. Typically, choose the adjustment that results in the smallest residuals and bias between the adjusted values and QC checks. Best professional judgement and visual review are necessary to confirm adjustment.
7. If the evidence is weak, or inconclusive, do not adjust the data.

Aspect will note in the final report if any data are adjusted. Data adjustment must be performed or reviewed by an Aspect Project Manager, or personnel with the appropriate training and experience in processing raw sensor data.

13.2 Laboratory data verification

Not applicable.

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 Aspect Project Manager will assess all data (qualified and unqualified), results or verification, compliance with MQOs, and the overall quality of the data set to provide a final determination regarding usability in the context of the project-specific goals and objectives. The final report will document whether the final, acceptable-quality data set meets the needs of the project (allows desired conclusion/decisions to be made with the desired level of certainty).

14.2 Treatment of non-detects

Not applicable.

14.3 Data analysis and presentation methods

Data found to be of acceptable quality for project objectives will be analyzed before being summarized. Any relevant and interesting data analysis will be presented in the final report using a combination of tables and plots of various kinds, such as time-series plots, histograms, and box plots.

The report will contain a summary table of field parameters; figures of continuous data (water level hydrographs, potentiometric maps, etc.); discussion of results pertaining to each sample location (well); and a map of the study area. Aquifer response to pumping will be analyzed spatially and temporally. Aquifer conditions (transmissivity, storage coefficient, boundary conditions, etc.,) will be evaluated.

14.4 Sampling design evaluation

Not applicable.

14.5 Documentation of assessment

In the final report, the Aspect Project Manager will include a summary and detailed description of the data quality assessment and evaluation of findings. This summary is usually included in the Data Quality section of reports. The final report will also provide results of the data analysis, uncertainty analysis, and margin of safety.

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16.0 Appendices

Appendix A. Well Logs

Flowing & pump

STATE OF WASHINGTON
DEPARTMENT OF CONSERVATION AND DEVELOPMENT

WELL LOG No. Decla #754
Cert. #779-D

Date 1896, 19

Record by Reuben A. Boss

Source G. W. Decla. Claim

Location: State of WASHINGTON

County Yakima

Area

Lot 2

¼ ¼ sec. 6 T. 12 N., R. 20 E.

DIAGRAM OF SECTION

Drilling Co.

Address

Method of Drilling drilled Date May 10 1946

Owner Reuben A. Boss

Address Moxee City, Wash.

Land surface datum ft. above below

CORRELATION	MATERIAL	THICKNESS (feet)	DEPTH (feet)
	(Transcribe driller's terminology literally but paraphrase as necessary, in parentheses. If material water-bearing, so state and record static level if reported. Give depths in feet below land-surface datum unless otherwise indicated. Correlate with stratigraphic column, if feasible. Following log of materials, list all casings, perforations, screens, etc.)		
	no record		
Pump Test:			
	Dim: 950' x 6"		
	SWL: flowing and pump, 20		
	Dd: 22'		
	Yield: 300 g.p.m.		
	Discharge: 60 g.p.m. Apr. 10, 1948		
	Shut-in pressure: 31lbs. per sq. in.		
	Control: valve		
	Casing: 10" dia. from 0' to 25', 6" dia. from 25' to 950'		

Turn up Sheet of sheets

Cert. #
779D

Appli. #10341
Per. # 9449
Cert. #6882-A

STATE OF WASHINGTON
DEPARTMENT OF CONSERVATION
DIVISION OF WATER RESOURCES

WELL LOG

Record by Owner
Source Owner's record

Location: State of WASHINGTON
County Yakima
Area
Map
SE ¼ NW ¼ sec. 6 T. 12 N., R. 20 E.

Diagram of Section

Drilling Co. UNKNOWN
Address "
Method of Drilling cable Date -- , 19
Owner EDGAR & ALPHONSINE CHARRON
Address Route 1, Box 174; Moxee City, Wash.
Land surface, datum ---- ft. above/below --
SWL: -- Date -- , 19 Dims.: 5" x 900'

CORRELATION	MATERIAL	From (feet)	To (feet)
	(Transcribe driller's terminology literally but paraphrase as necessary, in parentheses. If material water-bearing, so state and record static level if reported. Give depths in feet below land-surface datum unless otherwise indicated. Correlate with stratigraphic column, if feasible. Following log of materials, list all casings, perforations, screens, etc.)		
	DOMESTIC AND IRRIGATION		
	Well drilled in 1915 -- no log avialable.		
	Casing: threaded.		
	Artesian Pressure: 14 lbs. per sq. inch.		
	controlled by valve.		
	Well test: 240 gpm with 18' DD - on 7/10/69		
	Artesian flow-- 120 gpm; temp. 72°.		
	Pump: Sears, Roebuck & Co., centrifugal 5 hp		

Turn up Sheet of sheets

Map No.

Town. Moxee, Wash X
Company.
Farm. E. S. Wiseman
Authority. N. C. Jannsen
Elevation. 1150'
Collector. W. Warren
Confidential. No
Date 1908

No.

R. 20 E. W.
T. 12 N.
Sec. 6
NE¼, NW¼

No.	Strata	Thickness Feet	Thickness In.	Depth Feet	Depth In.
	Alluvium				
1.	Soil and gravel	18		18	
	Ringold and/or Ellensburg formation				
2.	Sandstone	20		38	
3.	Sandstone and shale	60		98	
4.	Sandstone	120		218	
5.	Shale	40		258	
6.	Sandstone	229		487	
7.	Shale	190		677	
8.	Gravel	2		679	
9.	Shale	31		710	
10.	Sandstone	53		763	
11.	Shale, flow	65		828	
12.	Sandstone	100		928	
	5" well				

JBR

County. YAKIMA

Index No. Y.4706.36

Appendix B. Aspect Field Data Sheets

DAILY REPORT

350 Madison Avenue North
Bainbridge Island, Washington 98110
(206) 780-9370

710 Second Avenue, Suite 550
Seattle, Washington 98104
(206) 328-7443

DATE: Field - Enter Date Mo/Day/Year	**PROJECT NO.** Field - Enter Project No.	**WEATHER:**
PROJECT NAME: Enter - Project Name	**CLIENT:**	
EQUIPMENT USED:	**PROJECT LOCATION:**	

THE FOLLOWING WAS NOTED:

COPIES TO: File, Client	**Aspect Consulting PROJECT MANAGER:** Name, Designation
Document1	**Page 1 of 1** **FIELD REP.:** Name, Designation

Aspect CONSULTING

350 Madison Avenue North
Bainbridge Island, Washington 98110
(206) 780-9370

401 Second Avenue S, Suite 201
Seattle, Washington 98104
(206) 328-7443

PUMPING TEST DATA

Page ____ of ____

Project: ______________________________ Project No. __________
Date: ______________________________
Pumping well: ______________________________
Water level measuring point: ______________________________
MP to ground surface (ft): ______________________________
Depth to initial static water level (ft):

Date & Clock Time	Elapsed Time (minutes)	Depth to Water (feet)	Drawdown Below Initial SWL (feet)	Flow Totalizer (gallons)	Discharge Rate (gpm)	

Aspect Consulting

C:\Users\ian.lauer\OneDrive - Geosyntec\Documents\Pumping Test Data1

Appendix C. Glossaries, Acronyms, and Abbreviations

Glossary of General Terms

Ambient: Background or away from point sources of contamination. Surrounding environmental condition.

Baseflow: The component of total streamflow that originates from direct groundwater discharges to a stream.

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.

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.

Dissolved oxygen (DO): A measure of the amount of oxygen dissolved in water.

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.

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.

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.

Sediment: Soil and organic matter that is covered with water (for example, river or lake bottom).

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.

Acronyms and Abbreviations

DO	Dissolved oxygen
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
GIS	Geographic Information System software
GPS	Global Positioning System
i.e.	In other words
MQO	Measurement quality objective
QA	Quality assurance
QC	Quality control
RPD	Relative percent difference
RSD	Relative standard deviation
SOP	Standard operating procedures
SRM	Standard reference materials
TSS	Total suspended solids
USGS	United States Geological Survey
WAC	Washington Administrative Code
WQA	Water Quality Assessment
WRIA	Water Resource Inventory Area

Units of Measurement

°C	degrees centigrade
cfs	cubic feet per second
cms	cubic meters per second, a unit of flow
ft	feet
g	gram, a unit of mass
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
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
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

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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