# CITY OF WHITE SALMON AQUIFER STORAGE AND RECOVERY FEASIBILITY ASSESSMENT

## Prepared for: City of White Salmon

Project No. 090094-001-03 • April 22, 2011
Project funded through Ecology Grant No. G0900235

earth + water

Aspect
CONSULTING

Ecology Publication Number: 11-12-027

# CITY OF WHITE SALMON AQUIFER STORAGE AND RECOVERY FEASIBILITY ASSESSMENT

## Prepared for: City of White Salmon

Project No. 090094-001-03 • April 22, 2011

***Aspect Consulting, LLC***

State of Washington
Hydrogeologist
795
Licensed Geologist
Joe Morrice

4-22-11

Timothy J. Flynn

**Joseph N. Morrice, LHG**
Senior Hydrogeologist
jmorrice@aspectconsulting.com

**Timothy J. Flynn, LHG, CGWP**
Principal Hydrogeologist
tflynn@aspectconsulting.com

W:\090094 2009 Water System Imprvmts-ASR Project\Deliverables\ASR FS\White Salmon ASR FS (Final 4-22-11).doc

# Contents

## List of Tables

## List of Figures

## List of Appendices

# 1 Introduction

This report presents an assessment of the potential for using aquifer storage and recovery (ASR) to augment existing water supplies and meet future water demands within the City of White Salmon's (City) water service area, located within the White Salmon subbasin of Water Resource Inventory Area (WRIA) 29. This water storage project was funded under Columbia River Program Grant Number G0900235, between the City of White Salmon and the Washington State Department of Ecology (Ecology).

The term ASR refers to temporarily storing water in an aquifer for later recovery and use. In the 2000 session, the Washington State Legislature expanded the definition of "reservoir" in Revised Code of Washington (RCW) 90.03.370 to include "any naturally occurring underground geological formation where water is collected and stored for subsequent use as part of an underground artificial storage and recovery project." In March 2003, Ecology adopted a rule (Chapter 173-157 Washington Administration Code [WAC]) pertaining to ASR projects. This rule defines water rights/permitting requirements for an ASR project, the process and information requirements for obtaining an ASR permit, and Ecology's process for reviewing ASR permit applications. This feasibility study report is intended to provide the information requirement to support the ASR permitting process as defined in Chapter 173-157 WAC.

The City faces water supply shortages in annual quantities (Qa) authorized under its existing water rights and, due to decreased well source production, in the instantaneous capacity of its groundwater sources. The City's current water rights authorize annual withdrawals of up to 688 acre-feet per year (afy), compared to past average annual use for the 2003 to 2008 period of approximately 900 afy. Based on the annual water supply deficit, the Washington State Department of Health required the City to institute a moratorium on new connections to the City's water system until sufficient additional annual supply is obtained. Through implementation of severe conservation measures, reduction in unaccounted for water (leak repair), and rate adjustment, the City has significantly reduced annual use but still faces a deficit in meeting both short-term and long-term growth demands.

The City also anticipates problems in meeting peak seasonal demand using its two groundwater sources (Well No. 1 and Well No. 2). Water levels in these wells, especially Well No. 2, have consistently decreased since they were brought online in 2002, reducing well production to the point where it may no longer reliably meet peak demand.

The City has pursued several options to address these shortages, including:

- Applying for new surface water and groundwater rights requesting additional annual and instantaneous quantities;
- Pursuing a long-term lease agreement with the Klickitat County Public Utility District (PUD) to provide additional instantaneous and annual water supply under the PUD's existing upstream Columbia River surface water rights;

- Installing a slow sand filtration system and chlorination station at its originally authorized surface water source from Buck Creek (a tributary to the White Salmon River) to provide additional instantaneous source capacity; and
- Pursuit of this ASR project to increase well source capacity and total annual volume of water supply.

Figure 1.1 presents a project location map for the ASR project area. Figure 1.2 shows the location of the City's existing water supply wells (Well No. 1 and Well No. 2), the Buck Creek diversion and slow sand filter, and the City's existing water supply infrastructure, including reservoirs and distribution system piping.

Under the proposed ASR project, the City would divert and treat surface water on a seasonal basis (anticipated diversion between November and April) from the existing Buck Creek diversion and inject and store the water in the Grande Ronde Basalt aquifer using Well No. 2. Stored water would then be recovered to meet peak summer water demands. The proposed ASR project would address shortages in the authorized annual quantity and help increase the instantaneous capacity of Well No. 2 during peak demand.

The primary objective of this feasibility study is to identify a target ASR aquifer zone and location, and provide a detailed assessment of the feasibility of applying ASR as a water supply strategy. The ASR feasibility study addresses technical, operational, environmental, legal, and economic considerations associated with applying ASR. This study is structured to provide information required in an application to Ecology for an ASR permit, as specified in Chapter 173-157 WAC.

While this assessment addresses required elements to be included with an ASR application, it is based on available information. Additional site-specific data – resulting from a phased ASR pilot testing program as defined in the Phase II component of the current grant agreement – is needed to verify assumptions and demonstrate the effectiveness of ASR as a viable future water supply strategy. In addition, a demonstration of how implementation of an ASR project will comply with all applicable regulations, including the antidegradation provisions under Washington's Groundwater Quality Standards, is necessary before an ASR permit is issued by Ecology.

Following this introductory section, the remainder of the report is organized as follows:

- **Section 2, Source Evaluation:** An evaluation of quantity and quality of source water potentially available for storage.
- **Section 3, ASR Target Aquifer:** A description of the locations initially considered for ASR, and selection of a target area for the feasibility study.
- **Section 4, Legal Assessment:** A description of an ASR project's prospective water rights for diversion of source water, its storage in a subsurface reservoir, and its beneficial use when recovered from the reservoir.
- **Section 5, Hydrogeologic System Description:** A description (conceptual model) of the hydrogeologic system pertinent to the project, including evaluation of potential changes in groundwater elevations, changes to groundwater quality, and recoverability of stored water.

- **Section 6, Environmental Assessment:** An assessment of potential adverse environmental impacts to the surrounding area resulting from ASR.
- **Section 7, Project Monitoring Plan:** Scoping of a project monitoring plan to verify the assumptions of the project conceptual model should the City and Ecology choose to proceed with ASR pilot testing.
- **Section 8, Conceptual Project Operation Plan:** A conceptual plan generally describing how the City could apply ASR within its overall water supply system, based on the current level of understanding.
- **Section 9, Limitations.**
- **Section 10, References:** List of references cited in this document.

The sections of the report are generally organized consistent with the requirements for that element as per Chapter 173-157 WAC.

# 2 Source Evaluation

To assess the feasibility for the City of White Salmon to use ASR to increase available water supply, it is necessary to first evaluate the quantity and quality of source water potentially available for storage. For this assessment, water from the City's Buck Creek source is evaluated as the water to be stored and subsequently recovered to help meet the City's water supply needs.

The City's surface water diversion on Buck Creek is located about 6 miles northwest of the City and about 4 miles northwest of Well No. 1 and Well No. 2 (Figure 1.2). Buck Creek historically served as the primary source of the City's water supply. In 1999, based on water quality issues and limited surface water treatment capabilities, the City began developing new groundwater sources. Construction of Well No. 1 and Well No. 2 were completed in 1999 and 2001, respectively. The well field provided the City's primary supply with Buck Creek serving as an untreated emergency source.

Water levels and production capacity from the wells, especially Well No. 2, have exhibited a continued decreasing trend since coming online. In response to declining production, the City is currently redeveloping the Buck Creek diversion, both as a continuous treated source of water supply for municipal use and as a potential seasonal source for ASR use. Construction of a slow sand filter for treatment of Buck Creek water was completed in December 2009 and is awaiting final approval from the Washington State Department of Health (DOH) before being brought online. The design capacity of the sand filter is 2.2 cubic feet per second (cfs), or 1,000 gallon per minute (gpm). Additional improvements include upgrading the conveyance system between Buck Creek and the City's existing storage and distribution system, construction of a chlorination station at the Buck Creek source, and installation of controls and valving to allow testing and use of Well No. 2 for ASR.

This section evaluates the City's existing water rights and pending water right applications and the Buck Creek source capacity relative to projected water demands, with the objective of determining the quantity and timing of surplus Buck Creek water that could be made available for ASR. The water quality of the Buck Creek source is also briefly described.

## 2.1 Existing Water Rights

The City's current water rights and pending water right applications are summarized in Table 2.1. The City holds two surface water rights for diversions from Buck Creek (Certificate Nos. 3474 and 7109) and one surface water right for diversion from an unnamed spring tributary to Jewett Creek (Certificate No. 10252). In 1999, the City applied for and received approval to add two groundwater wells (Well No. 1 and Well No. 2) as points of withdrawal to the Buck Creek water right certificates.

Certificate Nos. 3474 and 7109 each authorize an instantaneous diversion from Buck Creek of up to 2 cfs (4 cfs combined) for municipal supply. Certificate No. 7109 authorizes an annual quantity of 688 afy, while Certificate No. 3474 does not list an annual maximum quantity. The change applications for these certificates as approved by Ecology authorized the addition of groundwater wells as points of withdrawal, and limited the combined diversion from Buck Creek and withdrawals from the wells to an instantaneous rate of 4 cfs or 1,795 gpm and an annual volume of 688 afy.

The City also holds four pending applications for new water rights. One application for a new surface water right (S4-35068), filed August 31, 2005, requests a diversion of 3,000 gpm (6.7 cfs) and 1,500 afy from the White Salmon River. The City submitted a letter to Ecology, dated May 27, 2009, requesting that application S4-35068 be amended to specify Buck Creek as the point of diversion, rather than the White Salmon River. On May 24, 2010, Ecology accepted a second amendment to the application, reducing the requested Qa to 780 afy, additive to existing rights, and reducing the requested Qi to 2.2 cfs, of which 1.2 cfs is additive and 1.0 cfs is non-additive to existing Certificate Nos. 3474 and 7109. Ecology is currently processing this surface water right application as a water budget neutral appropriation. The City proposes to offset the consumptive use of this appropriation with consumptive use mitigation credits available from placement of existing Klickitat County PUD water rights into the state’s Trust Water Rights Program.

The three other applications (G4-32539, G4-32540, and G4-32541) were filed in 1997, each requesting new groundwater rights of 1,500 gpm and 1,600 afy from up to three wells. These applications are not related to the ASR project, but are included here for completeness.

The City does not have excess Qa under its existing water rights to support the proposed ASR project. Assuming the City’s pending water right application (S4-35068) is approved, the City may be able to implement a limited ASR program. However, this would not address the City’s long-term instantaneous or annual water supply needs. The City’s objective is to operate an ASR program using a new seasonal surface water right authorizing additional diversion from Buck Creek. This would enable full use of the City’s combined wellfield capacity of approximately 3 cfs as well as the full 2.2 cfs treatment capacity at its Buck Creek source.

New water right permits from Ecology that will be required for the project include a new surface water right to divert seasonal flows from Buck Creek, a reservoir permit authorizing aquifer storage of diverted water, and secondary use permits authorizing subsequent recovery of stored water for municipal and instream flow uses. Applications for a surface water diversion permit, reservoir permit, and secondary use permits will be filed as part of Phase II, if the City and Ecology determine that the ASR project is feasible. Additional discussion of the required permits, including permit processing options, is provided in Section 4.

## 2.2 Buck Creek Flows

Daily flow measurements at the Buck Creek diversion dam are available for the period from November 2001 through April 2004. Stage measurements were collected using a pressure transducer at the Buck Creek diversion and converted to flows based on a rating curve developed by Bell Design Company (2002b). The diversion dam was constructed with a bypass controlled by a sluice gate. The rating curve was developed with the sluice gate partially open, and is only valid for this configuration.

Flow data are not available after April 2004. In October 2009, the City installed a new pressure transducer at the diversion to collect stage data. The sluice gate is maintained in a closed position and the previously developed rating curve is not valid for converting the recent stage data to flows. The City is currently pursuing modifications to the diversion dam structure, including addition of a weir. Once the weir is completed, flow measurements will resume.

Figure 2.1 presents daily flows at the Buck Creek point of diversion available over the period of November 2001 through April 2004. Table 2.2 summarizes monthly average flows over the same period. Based on these data, minimum monthly average flows of about 18 to 20 cfs occur from July through November, when snowmelt runoff and precipitation are typically low. From December through May, average monthly flows range from about 30 to 70 cfs. The minimum measured daily flows were about 6 cfs for 12 days in November 2001, but otherwise have remained above about 18 cfs (Figure 2.1). As discussed below, November 2001 was the end of an extremely dry water year and the data from this period likely represent extreme drought year low-flows for November.

Figure 2.2 presents the annual precipitation and the cumulative departure from the mean annual precipitation for Hood River (NOAA Station No. 354003), which is the active station closest to the project area. Annual precipitation data are shown for water years ending on September 30, over the period of 1924 through 2009. Data from this station extend back to 1893; however, based on numerous missing data points, the earlier data were not included in this evaluation. Annual precipitation averages 30.2 inches, and ranges from 13.6 inches in water year 1977 to about 47 inches in water year 1997.

Data from water years corresponding to the period when Buck Creek flow measurements were made are shown in red on Figure 2.2. Precipitation for water years 2002 through 2004 (i.e., October 2001 through September 2004) was at or slightly below the long-term average. Precipitation for water year 2001 (October 2000 through September 2001) was 11.4 inches below the long-term average, and was the fourth lowest total over the period of record. This very dry water year immediately preceded the minimum measured flows in Buck Creek in November 2001. Based on these data, the flow measurements from Buck Creek are representative of both average and late-season drought year flows.

## 2.3 Source Water Available for Storage

The amount of source water available for storage depends on the following factors:

- Physical and legal availability of water at the Buck Creek diversion;
- Water quality treatment capacity of the slow sand filter; and
- Storage capacity and yield of the ASR target aquifer.

Availability of water includes physical availability (flows at the diversion) and legal availability (water right authorization). Physical availability of water (flows) at the Buck Creek diversion and excess treatment capacity are discussed in the remainder of this section. Legal availability of water, including a summary of potentially affected senior water rights and instream flow requirements that would be evaluated in the water right permitting process, is addressed in Section 4.3. Aquifer yield and storage capacity are addressed in Sections 5.3.1 and 5.3.5, respectively.

For the period November 2001 through April 2004 average monthly flows at the Buck Creek diversion were at least 18 cfs, with minimum daily flows of 6 cfs measured following a drought year. Without further expansion of the recently completed slow sand filtration treatment system, the maximum possible flow that would be diverted from Buck Creek for City supply and ASR purposes is currently constrained to the 2.2 cfs treatment capacity. Given that the minimum daily flows exceed the treatment capacity, physical availability of water at the diversion from November through April is not expected to be a limiting factor for ASR feasibility.

A second constraint is the sand filter treatment capacity available between November and April for ASR use while still meeting the City’s water supply demands. For the years 2003 through 2008, the City’s annual water use averaged about 890 acre-ft/year (Table 2.2). Peak total use of about 1,030 acre-feet occurred in 2005, but has since declined considerably as the City implemented severe conservation measures, reduced unaccounted for water (leak repairs), and adjusted rates. In the past two years (2008 and 2009) total use had decreased to approximately the maximum annual use of 688 acre-feet authorized under the City’s water rights.

On a monthly basis, peak use occurs during the months of June, July, and August, with moderate use in May and September (Table 2.2). From November through April use is fairly consistent at about 50 acre-feet per month, or an average daily demand of about 400 gpm (0.9 cfs). Assuming for the purposes of ASR feasibility that use from November through April is supplied entirely by the Buck Creek diversion, the average excess treatment capacity would be about 600 gpm. Over a six-month period this equates to about 480 acre-feet of excess treatment capacity available for ASR use. Additional excess source capacity could be realized if the City were to use Well No. 1 to meet part of the demand from November through April; however, modification of the conveyance system between the wellfield and the City’s distribution system is necessary, since currently the distribution system does not allow simultaneous delivery of water to Well No. 2 for aquifer storage and pumping from Well No. 1 for City use.

## 2.4 Source Water Quality

Buck Creek water is a very high quality source, meeting all groundwater and surface water quality standards. Notably, sand-filtered source water exhibits low alkalinity, low total dissolved and total suspended solids, and low total organic carbon. Historical water quality problems with the Buck Creek source water were the result of high turbidity and the presence of pathogens (*Giardia* and *Cryptosporidium*) in the raw source water. Treatment with sand filtration and chlorination is expected to address these issues. Section 5.3.6 further details the quality of the proposed ASR source water, relative to ambient groundwater quality in the proposed basalt storage aquifer.

# 3 ASR Target Aquifer

An initial task in this feasibility study was to identify potential ASR target aquifers. Well No. 1 and Well No. 2 were identified as potential target sites, based on the City's existing water supply well locations and infrastructure (Figure 1.2). The following sections describe these wells and the aquifers they tap, followed by the rationale for selecting Well No.2 as the preferred ASR target site for evaluation in the remainder of this feasibility study.

## 3.1 Potential ASR Target Aquifers

Well No. 1 was drilled to a depth of 755 feet below ground surface (bgs) in October 1998. The Grande Ronde Basalt was encountered at a depth of 200 feet bgs. An interbed, consisting of silt and sand, was encountered at approximately 360 ft bgs, and the yield steadily increased from about 300 to 1,100 gpm at a depth of 755 ft bgs. The Grande Ronde Basalt encountered while drilling Well No. 1 was highly fractured, likely related to movement along the nearby Hood River Fault (see Section 5.2 for a detailed description of geologic structure and stratigraphy). The axis of a nearby unnamed syncline may also have been the source of additional fracturing in the vicinity of Well No. 1.

A 48-hour constant rate aquifer test was conducted in Well No. 1 in November 1998 (Mark Yinger Associates, 1999). The groundwater level drawdown data from Well No. 1 indicate it is completed in a semi-confined aquifer. The aquifer test also indicates the presence of both a no-flow boundary and a leakage or a recharge boundary. The recharge boundary was interpreted to reflect hydraulic continuity with nearby Northwestern Lake (Figure 1.1) through the highly fractured Grande Ronde Basalt in the vicinity of Well No. 1. The no-flow boundary was interpreted to be the nearby Hood River Fault.

Well No. 2 was drilled to a depth of 1,242 feet bgs in March 2001. The Grande Ronde Basalt was encountered at a depth of 180 feet bgs and between depths of 845 and 870 feet bgs the formation became brecciated, which is likely indicative of a shear zone. As the boring was advanced from 818 to 890 feet bgs, there was an approximately 328-foot increase in head, resulting in free-flowing (artesian) water above ground surface. The shut-in pressure was 98 pounds per square inch (psi), which equates to a static water level of 226 feet above ground surface. The presence of brecciated basalt and the significant increase in head is interpreted to be associated with the fault zone between 845 and 870 feet bgs acting as a vertical/downgradient boundary to groundwater flow.

A 24-hour constant rate aquifer test was conducted in Well No. 2 in April 2001 (Mark Yinger Associates, 2001). The groundwater level drawdown data from Well No. 2 indicate it is completed in a confined aquifer. Confined conditions likely result from the low-permeability flow interiors of the Grande Ronde Basalt overlying the zone tapped by Well No. 2 and the presence of the shear zone. The aquifer test also indicates the presence of a no-flow boundary interpreted to be the nearby Hood River fault. Several observation wells completed in the Grande Ronde Basalt at shallower depths than Well

No. 2 were monitored during the aquifer test. There was no discernible effect on groundwater levels in any of these wells during the aquifer test.

Since coming on-line, Well No. 2 has shown a continued decrease in pumping water level and shut-in pressure, with a current shut-in pressure of approximately 65 to 70 psi.

## 3.2 Selection of ASR Target Aquifer

Given the available infrastructure, either Well No. 1 or Well No. 2 is suitable for ASR use. However, based on the following operational considerations, physical attributes, and regional use, the aquifer tapped by Well No. 2 is recommended as the preferred ASR target zone for evaluation in the feasibility study:

- Well No. 2 is completed in an aquifer that is vertically confined, and laterally bounded by faults, isolating it from surface water and other aquifers. This contrasts with Well No. 1, which appears to be in hydraulic continuity with surface water of Northwestern Lake.
- The deeper aquifer tapped by Well No. 2 is not tapped by other wells, and ASR using this well would not affect other groundwater users.
- The aquifer tapped by Well No. 2 is artesian, which provides better operational conditions for ASR, minimizing the potential for air entrainment and well screen fouling.
- The decreased shut-in pressure at Well No. 2 indicates that pumping of this well has depressurized the aquifer, making storage available for ASR.
- Although production has declined, Well No. 1 remains a viable source for continued supply, while the viability of Well No. 2 as a continued source is marginal. Increasing potential production from Well No. 2 through ASR would provide a greater benefit to the City’s water supply than increasing production from Well No. 1.

Additional information on geologic structure and stratigraphy of the Grande Ronde Basalt in the project area is summarized below and detailed in Section 5.2.

Both Well No. 1 and Well No. 2 are completed in the Grande Ronde Basalt. The aquifer test at Well No. 1 indicated the presence of a no-flow boundary that is likely related to the nearby Hood River fault. This no-flow boundary would prevent the flow of groundwater to the southwest, bounding the aquifer in that direction. However, the constant rate aquifer test also indicated the presence of leakage and/or a recharge boundary, interpreted to result from hydraulic continuity with the overlying Quaternary deposits and Northwestern Lake. The leakage or recharge likely occurs through the intense fracturing in the Grande Ronde Basalt in the vicinity of Well No. 1. If Well No. 1 is in hydraulic continuity with the overlying Quaternary deposits and Northwestern Lake, water stored through ASR could be lost to the lake or nearby domestic wells completed in the Quaternary deposits, reducing the recoverability of stored water. Because this aquifer is not “well-bounded,” Well No. 1 is not considered further as a prospective site for ASR in this assessment.

The aquifer tapped by Well No. 2 appears to be well-bounded, with no hydraulic continuity with surface water or aquifers tapped by nearby wells. Well No. 2 is completed beneath relatively massive, unfractured flow interiors of the Grande Ronde Basalt, which act to vertically confine the aquifer. The well is also completed beneath a fault zone that acts as a vertical/downgradient boundary to groundwater flow. Based on the aquifer test, the Hood River fault located to the southwest of Well No. 2 acts as another barrier to groundwater flow. Although not detected during the pumping test, a third fault (Buck Creek fault) located about one mile northeast of Well No. 2 likely also acts as a barrier to groundwater flow.

The geologic structures define a fault block within which the aquifer tapped by Well No. 2 is laterally and vertically isolated from the rest of the Grande Ronde Basalt, overlying Quaternary deposits, and Northwestern Lake. The conclusion that groundwater within the fault block is isolated is supported by the large observed change in head across the shear zone and the strong artesian conditions in Well No. 2; the lack of a significant leakage or a recharge boundary during the aquifer test; and the lack of any detectable drawdown during the aquifer test in nearby wells completed at shallower depths in the Grande Ronde Basalt. The lack of continuity with surface water or other aquifers would minimize potential losses and increase the potential recoverability of water stored in this aquifer through ASR. Based on these considerations, the aquifer tapped by Well No. 2 has been selected as the ASR target aquifer for further evaluation.

# 4 Legal Assessment (Water Rights)

This section provides an overview of water right permits required under Chapter 173-157 WAC for a prospective ASR project, permit processing options, and an overview of other water rights in the area.

## 4.1 Water Right Permits for ASR

Water right permits from Ecology that will be required for the ASR project include a new surface water right to divert seasonal flows from Buck Creek, a reservoir permit authorizing aquifer storage of diverted water, and secondary use permits authorizing recovery of stored water for municipal and instream flow uses. Applications for a surface water diversion permit, reservoir permit, and secondary use permit will be submitted as part of Phase II, if the City and Ecology determine that the ASR project is feasible.

### 4.1.1 Water Rights for Source Water

ASR provides an opportunity for the City to augment its existing water supplies, both in terms of annual quantity of supply and water right authorization. One of the key benefits of ASR is the ability to divert seasonally available surface water (i.e., outside the high demand irrigation season) for placement into storage. In the short term, the City may be able to implement a limited ASR program using existing water rights, assuming successful processing of its pending water right application (S4-35068). However, the City’s objective is to operate an ASR program using a new seasonal surface water right authorizing additional diversion from Buck Creek. This would enable full use of the City’s combined wellfield capacity of approximately 3 cfs as well as the full 2.2 cfs treatment capacity at its Buck Creek source.

Given the good water quality and reliable flows of Buck Creek and the existing surface water diversion, treatment, and conveyance infrastructure (Section 2), the Buck Creek diversion is a logical source of water for seasonal storage. As discussed in Section 2.3, based on the estimated winter surplus treatment capacity of the slow sand filter, the seasonal water right diversion from Buck Creek for ASR could be on the order of 600 gpm (1.3 cfs) and 480 acre-feet. The final duration and instantaneous and annual quantities of diversion under the requested water right will be refined during the permitting process, based in part on ASR pilot testing to assess storage capacity of the target aquifer. Pilot testing would be performed under the Phase II portion of this project, if funded.

### 4.1.2 Reservoir Permit for Storage

Under the Washington State water code, a reservoir permit is required to store water above ground or below ground (RCW 90.03.370). Chapter 173-157 WAC outlines the requirements for an application for a right to store water in an ASR program; in this case the reservoir permit is referred to as an ASR permit. This feasibility study is structured to provide information to support an application for an ASR permit.

Prior to submitting an application for an ASR permit, the City should have a pre-application meeting with Ecology water resources staff to discuss the overall proposed ASR program, including plans for pilot testing and monitoring and evaluating potential impacts associated with the program.

In addition, a well used for ASR will need to be registered with the state underground injection control (UIC) program, in accordance with Chapter 90.48 RCW.

### *4.1.3 Secondary Permit for Use of Stored Water*

A new secondary use permit is required to authorize recovery of stored water for municipal and instream flow uses (RCW 90.03.370). The secondary use permit can be applied for and processed as a single application with the reservoir permit.

## 4.2 Permit Processing Options

Currently, there is a significant backlog of water right applications waiting processing by Ecology under the standard water right permitting procedure. There are other options to the standard processing procedure for Ecology to process an application for a seasonal diversionary right to support ASR. These include the criteria for out-of-priority (i.e., expedited) processing of water rights in proposed amendments to Chapter 173-152 WAC (also known as the Hillis Rule), and the Cost Reimbursement Program authorized under Revised Code of Washington (RCW) 43.21A.690 and RCW 90.03.265. Additionally, under RCW 90.03.370 permits for storage proposals may qualify for expedited processing under certain conditions. An overview of the process for each of these options is presented below.

### *4.2.1 Priority Processing Under the Hillis Rule and RCW 90.03.370*

The current Hillis Rule allows for out-of-priority processing of new water rights only for a public health or safety emergency, or if the proposed use is water budget neutral and would substantially enhance or protect the quality of the natural environment. Inadequate water rights for a public water system to serve existing hook-ups or to accommodate future growth do not constitute a public health or safety emergency under the rule and do not allow for out-of-priority processing.

Ecology has proposed amendments to the Hillis Rule and recently completed the public comment period of the draft Rule amendment. The proposed amendment to the Hillis Rule (draft version dated June 7, 2010) would revise the criteria for out-of-priority processing of water rights. Proposed rule changes potentially applicable to the city of White Salmon's ASR project include allowing out-of-priority (expedited) processing of new diversionary rights into reservoirs that do not conflict with adopted state instream flow rules, federal flow target, or federal biological opinions, and is funded or supported pursuant to RCW 90.90 (Columbia River Basin - Water Supply).

RCW 90.03.370(1)(b) authorizes expedited processing of storage proposals that: do not require a new water right for diversion or withdrawal of the water to be stored; add or change the purpose of use of stored water; increase capacity of existing storage; or are for secondary permits to secure use from existing storage facilities.

Based on the proposed revisions to the Hillis Rule, if adopted, and the criteria for expedited processing in RCW 90.03.370(1)(b), the City could request priority processing of a seasonal diversionary surface water right as a Columbia River Water Supply funded project and, once that right is secured, request priority processing of the reservoir permit and secondary use permits. Adoption of the amendments to the Hillis Rule (Chapter 173-152 WAC) is anticipated for December 2010. The viability of this permitting strategy will need to revisited once Rule amendments are adopted.

### 4.2.2 Cost Reimbursement Processing

A second option for processing the water rights needed for ASR is to enter Ecology's Cost Reimbursement program, established under RCW 43.21A.690. Under this option, the City would enter into an agreement with Ecology to pay for the cost of hiring a private consultant to evaluate its water right application plus any senior and competing applications for the same source of water. In this case, competing applications would be limited to those requesting diversions or withdrawals during the same period of use (i.e., November through April) as the City. Although Cost Reimbursement can greatly expedite processing of water rights, the cost (if there are a large number of senior applicants requiring processing) can be prohibitively high.

An initial review of Ecology's Water Rights Tracking System (WRTS) indicates there are about 14 pending applications for surface water and groundwater rights in the White Salmon watershed. There are approximately 85 additional applications for surface water diversions from the mainstem Columbia River, two of which appear to be located downstream of the White Salmon River. Additional review of the individual applications would be required to determine whether they propose to use the same source of water during the same period of use as the City's Buck Creek diversion and would thus require processing ahead of the City's application.

Amendments to the Cost Reimbursement process were recently passed by the Washington State legislature under Engrossed Second Substitute Senate Bill 6267 and became effective June 10, 2010. Section 1(b) of amendments to RCW 90.03.265 waive the requirement to pay for the cost of all senior applications from the same source of supply if the application for a new appropriation or amendment of a water right would not diminish the water available to earlier pending applications from the same source of supply. Section 3 of amendments to RCW 90.03.265 allows Ecology, upon request of an applicant, to initiate a coordinated Cost Reimbursement process, in which each applicant would pay for processing of its application at a cost proportionate to the quantity of water requested. Depending on the number of applications ultimately determined to be requesting use of the same source of water as the City, pursuit of the coordinated Cost Reimbursement process would significantly reduce processing costs under this option.

## 4.3 Senior Water Rights in Project Vicinity

This section provides a summary of the existing water rights in the ASR project area and provides an evaluation of the potential impairment of the senior water rights. Final determination of the potential for impairment would be made as part of the permitting process. A brief discussion of the instream flow rule for the Columbia River and Bureau of Reclamation operations as they relate to a new surface water appropriation from Buck Creek is also provided.

Figures 4.1 and 4.2 illustrate the distribution of senior surface water rights and groundwater rights, respectively, based on information retrieved from the WRTS. A detailed listing of the surrounding water rights is presented in Tables 4.1 and 4.2. Listed water rights are limited to certificates and permits with source locations within Township 4N, Range 10E and Township 3N, Range 10E, which include the City's Buck Creek surface water diversion and the City's Well No. 1 and Well No. 2. These areas encompass the surface water bodies (i.e., below the Buck Creek diversion and downstream portions of the White Salmon River) and groundwater sources that could be affected by the City's request for additional withdrawals from the Buck Creek diversion and by ASR using Well No. 2.

The water right information is presented by public land survey location (i.e., township, range, and section). The cumulative authorized instantaneous diversion in cfs associated with the surface water rights in each section is posted on Figure 4.1. The cumulative authorized annual withdrawal in afy associated with the groundwater rights in each section is shown on Figure 4.2.

There are 92 surface water certificates and permits and 21 groundwater certificates and permits within the area defined above. The surface water rights authorize a cumulative instantaneous diversion of 102.7 cfs and an annual quantity of about 5,740 afy. The majority of the surface water rights are primarily seasonal irrigation, stock watering, and single and multiple domestic. The groundwater rights authorize a cumulative instantaneous withdrawal of about 2,240 gpm and an annual quantity of about 5,740 afy. The authorized purposes of use for the groundwater rights are primarily seasonal irrigation and single and multiple domestic.

In addition to the water right permits and certificates, there are about 105 surface claims and 43 groundwater claims registered in the area defined above. However, the extent and validity of the existing certificates and claims has not been established. With the exception of one claim (Claim No. 200115) held by Pacific Power and Light for power generation at Condit Dam, the claims are for seasonal irrigation, stock watering, and domestic uses.

### 4.3.1 Potential for Impairment

Well No. 2 is completed in an aquifer that is vertically confined and laterally bounded by faults, isolating it from surface water and other aquifers. A review of Ecology's well log database and files for nearby groundwater rights did not identify any wells that tap the same aquifer as Well No. 2. Based on the confined and laterally bounded conditions and the lack of other wells tapping the same aquifer as Well No. 2, use of this well for ASR would not impair existing groundwater rights, including water right permit-exempt wells.

The White Salmon Irrigation District holds two water rights (Certificate Nos. 3475 and 8821A) authorizing a combined Qi of 4.5 cfs from Buck Creek for seasonal irrigation and year-round multiple domestic use (Table 4.1 and Figure 4.1). The City of White Salmon's and the White Salmon Irrigation District's are the only water rights diverting from Buck Creek. The Irrigation District's water rights limit the Qi for year-round domestic use to

0.11 cfs, with the remaining 4.39 cfs available for seasonal irrigation. The duration of the irrigation season is not explicitly defined in these water rights; however, the Washington Irrigation Guide (USDA, 2007) indicates the typical irrigation season in nearby Dallesport extends from early May to early October, depending on crop type. Based on this, it is assumed that the maximum use by the White Salmon Irrigation District from mid-October through April is limited to the 0.11 cfs for domestic use.

It is anticipated that the new water right for ASR would request a seasonal diversion from Buck Creek from November through April. Diversion over this period would not compete with the irrigation portion the White Salmon Irrigation District water rights. As discussed in Section 2.2, the minimum daily flows in Buck Creek were 6 cfs and average monthly flows from November through April range from about 18 to 70 cfs. Based on these data, diverting 2.2 cfs (the maximum treatment capacity of the sand filter) from Buck Creek diversion would not impair the domestic portion of the White Salmon Irrigation District water rights.

Two water rights are listed as authorizing diversions from the White Salmon River or Northwestern Lake, downstream of the confluence with Buck Creek. Mount Adams Orchard Corporation holds a water right (Certificate No. S4-25155C) to divert 0.7 cfs from Northwestern Lake for seasonal irrigation. A seasonal diversion from Buck Creek for ASR from November through April is not expected to impair exercise of this existing water right.

The U.S. Department of Fish and Wildlife holds a water right (Certificate No. 6483) to divert 30 cfs from the White Salmon River for fish propagation. The period of use for this water right is not listed. Data from the U.S. Geological Survey (USGS) stream gaging station located downstream of Condit Dam at Underwood (Station No. 14123500) were reviewed to assess whether a new seasonal diversion for ASR from Buck Creek could impair this right. Over the period of record (1915 to 2009), average monthly flows ranged from a low of 625 cfs in August to about 1,500 cfs from February through May. Based on these data, a new seasonal diversion from Buck Creek would not impair the U.S. Department of Fish and Wildlife water right.

### *4.3.2 Instream Flows and Agency Consultation*

There are currently no promulgated minimum instream flows for surface waters of the White Salmon River or Buck Creek that would affect processing of a new water right application for Buck Creek. However, as standard procedure Ecology provides copies of water right applications to relevant state and federal agencies and Indian tribes for their review and comment.

It is expected that agency review will consider potential impacts of a new diversion on Bull Trout, which is listed by the United States Fish and Wildlife Service (USFWS) as a threatened species under the federal Endangered Species Act and is a candidate species for listing by the Washington State Department of Wildlife (WDFW). The White Salmon River below Condit Dam is designated as critical habitat for Bull Trout by the USFWS. Proposed rules under consideration would expand the area designated as critical habitat to the mainstem of the White Salmon River and tributary streams, including Buck Creek (Federal Register, 2010). The WDFW also considers Buck Creek as priority habitat for Bull Trout.

Under Chapter 173-563 WAC (Instream Resources Protection Program for the Mainstem Columbia River) applications for new water rights affecting the Columbia River are evaluated for possible impacts on fish and existing water rights. This evaluation includes, in part, a consultation process with local, state, and federal agencies and Indian tribes. Provisions regarding mitigation or protection of instream flows are determined on a case-by-case basis through the consultation process. At this time it is uncertain what mitigation or instream flow requirements, if any, a new seasonal new water right would be subject to, although it is expected that any new surface water right appropriation will need to be consistent with the Bureau of Reclamation's operations at Bonneville Dam. In addition to flow requirements for power generation, the Bureau of Reclamation operations are subject to Biological Opinions (BiOps) for the USFWS and the National Oceanographic and Atmospheric Administration (NOAA) regarding fisheries resources.

# 5 Hydrogeologic System Description

## 5.1 Physical Geography

On a regional scale, the project area includes the southern portion of the White Salmon River subbasin, extending west to Whistling Ridge and east to Bald Mountain (Figure 1.1). From its headwaters on the southwest flanks of Mount Adams, the White Salmon River flows south through the project area past Husum and the west side of the City of White Salmon, before discharging to the Columbia River. The White Salmon River is currently dammed by Condit Dam, forming the Northwestern Lake Reservoir from approximately River Mile 3.5 upstream to approximately River Mile 5. Several tributaries discharge into Northwestern Lake, including Buck Creek, Mill Creek, and Little Buck Creek.

USGS stream gaging stations located upstream of Condit Dam at BZ Corner (Station No. 14122900) and Husum (Station No. 14123000) indicate mean monthly flows in the White Salmon River range from 382 cfs (September) to 1,130 cfs (April) and from 565 cfs (October) to 1,440 cfs (May), respectively. The only tributary between the two stream gaging stations is Gilmer Creek, which generally has relatively low mean monthly flows, ranging from 2 cfs (August) to 91 cfs (December). Based on the gaging data, the White Salmon River likely gains more than 200 cfs in groundwater contributions between BZ Corner and Husum (Aspect, 2009). In addition, numerous springs and seeps have been observed on the slopes east of the White Salmon River, likely discharging from the base of the fine-grained Glacial Lake Missoula – Channeled Scabland flood deposits, formerly referred to as the Bretz Flood deposits (Mark Yinger Associates, 2002a). The USGS stream gaging station located downstream of Condit Dam at Underwood (Station No. 14123500) indicates that the White Salmon River has mean monthly flows downstream of the dam ranging between 597 cfs (October) and 1,490 cfs (May).

Regionally, the mean annual precipitation in the White Salmon River subbasin is estimated to be 59 inches per year, but can range between 35 and 125 inches per year (WPN and Mark Yinger Associates, 2002). The majority of the precipitation occurs between November and March in the form of rain and snow. The nearest NOAA weather observation station in the project area is located at Hood River, Oregon (NOAA Station No. 354003); where the mean annual precipitation is 31.57 inches for the period of record (1924 to 2009). Figure 2.2 provides a summary of the historical precipitation data at the Hood River station. Precipitation in the hills surrounding the City of White Salmon and upriver of Northwestern Lake is expected to be significantly higher due to orographic effects.

## 5.2 Geologic Setting

To limit potential loss of water injected into the selected aquifer for storage, a preferred ASR location should be sited in an area where the selected aquifer is both horizontally and vertically confined to create a subsurface reservoir. To assist in evaluating the geologic stratigraphy and structure, detailed geologic cross sections of the project area were developed based on published geologic maps and reports and well log data from the Ecology well log database. The cross sections are geologic interpretations of the data used to construct them and are part of the conceptual model of the presence and thickness of the various basalt flows and sedimentary interbeds, as well as the location of faults and folds, which define the structure within the project area.

The following sections present the methodology used to locate and select well logs for developing the cross sections, interpret stratigraphic conditions and geologic structure of the project area, and describe the conceptual model of the proposed ASR target area.

### *5.2.1 Well Locations and Development of Cross Sections*

Well logs and relevant well completion information (depth, diameter, screen interval, static water level, and unit of completion) for 417 wells completed within the project area were obtained from Ecology's well log database. Well depths and approximate locations of wells described in the logs are shown on Figure 5.1. Table 5.1 provides a summary of relevant well completion information. Wells were initially located at the center of the quarter-quarter section listed in the Ecology well log database (green well locations on Figure 5.1). If a valid Klickitat County tax parcel number was provided for a specific well in the Ecology well log database, the well was located at the center of the respective parcel (purple well locations on Figure 5.1). The locations of several key wells were field verified and located (yellow well locations on Figure 5.1) using a Trimble GeoXT Global Positioning System (GPS) during site visits by Aspect personnel. The mapped GPS locations have a horizontal accuracy of about 3 feet and a vertical accuracy of about 10 feet.

The cross sections used well logs for 23 of the 417 wells within the project area. The relevance of each well log for use in developing the cross sections was assessed based on the completeness and reliability of the materials description on the log and the location of the well within the study area. Based on the geologic map (Figure 5.1) and lithologic descriptions from the well logs, two cross sections were created in the vicinity of City's existing water supply wells (Figures 5.2 and 5.3). The various geologic members of the Wanapum Basalt and Grande Ronde Basalt, including associated interbeds, were interpreted based on composition, color, and thickness, and were correlated on the cross sections to determine both lateral and vertical extent of the various units.

### *5.2.2 Stratigraphy*

Figure 5.1 presents a surficial geologic map of the project area, based on Washington State Department of Natural Resources mapping (Korosec, 1987). The primary geologic units present within the City of White Salmon ASR project area include (from youngest to oldest): Quaternary flood deposits (Glacial Lake Missoula – Channeled Scabland floods), Quaternary volcanic deposits, ancestral White Salmon River alluvial deposits, and Columbia River Basalt Group (CRBG) deposits.

The CRBG was deposited between 17 and 6 million years before present (ybp), during the Miocene epoch, and consisted of a widespread extrusion of numerous basalt flows originating from vents located in the Pasco area (Bauer and Hansen, 2000). The CRBG in the project area includes the geologic formations of the Wanapum Basalt (map unit

Mv[w]) and the older Grande Ronde Basalt (Mv[g]). The Wanapum Basalt can be further subdivided into members, which in the project area primarily consist of the Frenchman Springs member (Mv[wfs]). The Grande Ronde Basalt can also further be subdivided into members based on the magnetic polarity at the time of deposition. Within the project area, the $N_2$ (Mv[g$N_2$]; normal magnetic polarity) and $R_2$ (Mv[g$R_2$]; reversed magnetic polarity) members of the Grande Ronde Basalt are present (Tolan et al., 1989).

Each member is generally composed of numerous flows of variable lateral extent that range from several feet to hundreds of feet thick. The thicker flows generally include a sequence (from bottom to top) of basal colonnade, a thicker flow interior consisting of generally massive basalt, and a flow top. The flow top usually consists of vesicular basalt (Bauer et al., 1985), which generally represents the primary water-bearing zone within the flow. Where two stacked flows are in contact, the combined flow top and basal colonnade together are termed the interflow zone. The massive flow interiors of relatively thick flows generally act as an impediment to groundwater flow (except via fracture flow). Thinner flows generally consist of weathered, altered, rubbly, or vesicular flow tops and bottoms with a fractured interior.

Sediments interbedded within the various members of the CRBG (deposited during times between basalt flows) are collectively considered part of the Ellensburg Formation (Mc[e]), and generally consist of terrestrial sediments (silt, sand, and gravel). Within the project area, both the Squaw Creek member (Mc[es]), which overlies the Frenchman Springs member of the Wanapum Basalt, and the Vantage member (Mc[ev]), which occurs between the Wanapum Basalt and the underlying Grande Ronde Basalt are present. The thickness and lateral extent of the interbeds can vary considerably. Sedimentary interbeds within the Grande Ronde Basalt are rare, generally only a few feet thick and of limited lateral extent (Whiteman et al., 1994). Where present, these interbeds vary in grain size from clay to gravel. Depending on the composition, thickness, and lateral extent of the interbeds, they can act as either a barrier or conduit to groundwater flow.

Following the deposition of the CRBG, the ancestral White Salmon River eroded a valley into the CRBG, depositing unconsolidated alluvial sediments consisting primarily of sand and gravel (Qfg). Later, a series of Quaternary volcanic flows flooded the valley bottom, burying the unconsolidated alluvial sediments (Mark Yinger Associates, 2002a). The Quaternary volcanic deposits within the project area include undifferentiated basalts (Qvb and QPLvb); the Ice Cave (Qvb[ic]), North White Salmon (Qvb[wn]), White Salmon (Qvb[ws]), and Underwood (Qvb[uw]) basalts; and the Rattlesnake Creek (Qva[rs]) and McCoy Flat (Qva[mc]) andesites. The Quaternary volcanic deposits generally consist of a mixture of cinder and broken basalt (Korosec, 1987). Finally, unconsolidated fine-grained sediments were deposited during the Pleistocene epoch by the Glacial Lake Missoula – Channeled Scabland outburst floods (Qfs).

Of primary hydrogeologic interest in the project area is the Grande Ronde Basalt. This formation is one of the primary water-bearing units within the ASR target area and the formation in which a majority of the municipal water supply wells are completed. Both of the City’s existing water supply wells (Well No. 1 and Well No. 2) are completed within the Grande Ronde Basalt. As previously discussed (Section 1), the aquifers tapped by these wells have shown considerable decline in groundwater levels.

## 5.2.3 Geologic Structure

### 5.2.3.1 Geologic Structure of the Project Area

The area being evaluated for ASR feasibility is located within the fault-blocked western margin of the CRBG. Evidence indicates that regional compression began during the deposition of the Grand Ronde Basalt, starting 16 million ybp and continuing to today (Reidel et al., 1989). This compression resulted in the formation of the southwest-northeast trending folds (synclines and anticlines), and northwest-southeast and southwest-northeast trending faults (reverse and thrust faults) present in the region. The structural features formed during this period are generally referred to as the Yakima Fold Belt, and include non-cylindrical, asymmetrical, anticlinal ridges separated by synclinal valleys. The folds also generally tend to have emergent high angle reverse faults that transition into low angle thrust faults at depth, with detachment surfaces occurring within the various flows of the CRBG or in the sediments below the CRBG (Reidel et al., 1989). Within the area being evaluated for ASR feasibility, these structures include the concealed syncline beneath Northwestern Lake and Husum and the associated anticline to the southeast, and the high-angle fault (Columbia River fault) associated with the Horse Heaven Hills anticline (Korosec, 1987). Figure 5.1 provides a geologic map illustrating the location of these structures.

The Columbia River fault may predate the formation of the Yakima Fold Belt (Mark Yinger Associates, 2002). However, the geologic map by Korosec (1987) indicates that the Columbia River fault postdates the deposition of the Frenchman Springs member of the Wanapum Basalt, based on the offset observed across the fault, and likely formed as part of the Yakima Fold Belt. Mark Yinger Associates (2002a) also indicates the presence of an unnamed and unmapped reverse fault in the vicinity of the Columbia River fault and the Horse Heaven Hills anticline, which dips to the southeast and transitions into a low angle thrust fault with the shear zone extending through Well No. 2.

The geologic map (Korosec, 1987), also indicates the presence of an unnamed and unmapped shear zone (reverse fault) in the vicinity of Northwestern Lake. This fault accounts for the offset of the Frenchman Springs member of the Wanapum Basalt and the Grande Ronde Basalt that is observed in the vicinity of Northwestern Lake. The presence of this fault is supported by the descriptions of brecciation and cementation in the Well No. 2 well log and the 328-foot difference in head observed across the shear zone. The presence of this structure was noted and shown schematically on cross sections by Mark Yinger Associates (2001 and 2002a). This structure likely dips to the south-southeast and trends parallel to the syncline identified by Bela (1980 on Figure 5.1) in the vicinity of Northwestern Lake (Figure 5.1).

Studies by Reidel et al. (1984) indicate that in addition to the northwest-southeast compression, there was also a component of clockwise rotation along a northwest trending dextral shear system that developed in the anticlines of the Yakima Fold Belt during periods of compression. This clockwise rotation is attributed to right-lateral shear between the westward moving North American continental plate and the northward moving Juan de Fuca oceanic plate. The right-lateral shear led to the creation of several northwest-southeast trending high-angle faults in the project area, including the Hood River and Buck Creek faults (Korosec, 1987). These faults are mapped with the southwestern side downthrown, as illustrated on Figure 5.1.

Significant fracturing was observed during drilling of Well No. 1 (Mark Yinger Associates, 1999). The fracturing is likely associated with the nearby Hood River fault and possibly the axis of the concealed syncline located in the vicinity of Northwestern Lake. Drawdown response during a long-term (48-hour) pumping test of Well No. 1 indicated the presence of a recharge boundary, which was interpreted to indicate continuity of the aquifer zone with Northwestern Lake. Significant fracturing was not observed while drilling Well No. 2, nor did the pumping test of this well indicate the presence of a recharge boundary as was observed with Well No. 1. Based on the significant displacement of the CRBG formations in the project area (Figures 5.2 and 5.3), it is assumed that the faults generally act as barriers to groundwater flow within the CRBG.

### 5.2.3.2 Geologic Structure of the ASR Target Area

In the ASR target area, the most important structural features are the Hood River and Buck Creek faults, the unnamed/unmapped reverse fault in the vicinity of Northwestern Lake, and the Columbia River fault (Figure 5.1). As discussed below, Well No. 2 is completed in a fault block that is laterally bounded to the southwest by the Hood River fault, to the northeast by the Buck Creek fault, and to the southeast by an apparent unnamed/unmapped reverse fault located in the vicinity of Northwestern Lake. The fault block boundaries act as hydraulic barriers to groundwater flow, isolating groundwater within the fault block. Figure 5.4 presents a schematic block diagram of the City’s water supply wells and the interpreted faults and folds bounding the fault block.

The water-bearing zone tapped by Well No. 2 is vertically bounded by the massive flow interiors of the Grande Ronde Basalt. Upgradient recharge to the target aquifer is thought to primarily occur where the water-bearing interflows tapped by Well No. 2 outcrop to the northwest of the well. Based on a rough estimate of the regional dip of the Frenchman Springs member of the Wanapum Basalt and the underlying Grande Ronde Basalt (see conceptual model discussion below), the water-bearing interflows are expected to daylight at a minimum of 8,500 feet upgradient of Well No. 2, although the actual location is uncertain. Based on the relatively rapid decline in water levels and source capacity at Well No. 2, upgradient recharge is likely limited and/or migrates through the formation slowly.

The following section presents the hydrogeologic conceptual model of the ASR target area. Based on the complexity of the geologic conditions and uncertainties in the available data, an alternative interpretation of the geologic structure based on prior work was also considered. Based on evaluation of this alternative hypothesis, as discussed below, it was determined to be unlikely and, therefore, was not considered further in this ASR Feasibility Study.

#### *Conceptual Model of ASR Target Area*

The available data indicate that the four fault boundaries forming the fault block of the ASR target area act as barriers to groundwater flow. Based on a 24-hour constant rate aquifer test conducted in Well No. 2, a no-flow boundary was detected at approximately 330 minutes into the test. This hydraulic boundary likely represents the nearby Hood River fault. The Buck Creek fault, which is similar in origin and structure to the Hood River fault, is also expected to act as a no-flow boundary. Based on the geologic map

(Korosec, 1987), it is assumed that the Columbia River fault extends to the surface and acts as an upgradient barrier to groundwater flow within the Grande Ronde Basalt.

Well No. 2 is completed beneath a shear zone, which likely acts as a vertical/ downgradient barrier to groundwater flow. This assumption is supported by the observed 328-foot head difference across the shear zone. Based on previous work by Mark Yinger Associates (1999, 2001, and 2002a), this shear zone is interpreted to represent an unnamed/unmapped reverse fault in the vicinity of Northwestern Lake. The unmapped fault is suspected to run sub-parallel to the trace of the synclinal axis approximately coincident with the White Salmon River valley near Northwestern Lake. This fault is likely associated with the inferred concealed compressional structure mapped in the same location.

Recharge of the target aquifer occurs in the fault block between the Columbia River fault and the unnamed/unmapped reverse fault in the vicinity of Northwestern Lake. A dip of approximately 17 degrees to the southeast (Figure 5.1) was calculated for the overlying Frenchman Springs member of the Wanapum Basalt (Mv[wfs]) and Ellensburg Formation (Mc[es]). Assuming this dip is also representative of the underlying Grande Ronde Basalt and does not vary significantly, the water-bearing zones encountered below a depth of 845 feet bgs in Well No. 2 would daylight at least 8,500 feet to the northwest of the well. Although the single calculated dip only provides a rough estimate of the regional dip, it indicates that the water-bearing zones, occurring below a depth of 845 feet bgs in Well No. 2, would likely surface to the south of the Columbia River fault, which is located about 20,000 feet to the northwest. The significantly higher elevation of the recharge zone in addition to Well No. 2 being bound downgradient by the unnamed/unmapped fault in the vicinity of Northwestern Lake, accounts for the artesian conditions in Well No. 2.

The massive basalt flow interiors of the Grande Ronde Basalt act as a vertical hydraulic barrier, limiting areal recharge and vertical leakage of groundwater. If the massive basalt flow interiors within the fault block did not act as a barrier to groundwater flow, groundwater levels in the nearby domestic wells completed at shallower depths in the Grande Ronde Basalt would be impacted by the pumping of Well No. 2. During the 24-hour constant rate aquifer test conducted in Well No. 2 (Mark Yinger Associates, 2001), several observation wells were monitored, including the City of White Salmon's Observation Well No. 2, the Ottman well, and the Spring Creek Hatchery well. Flow from the Spring Creek Hatchery spring was also monitored. There was no discernible impact on groundwater levels in any of these wells or flows at the spring during the aquifer test, indicating that Well No. 2 is isolated from these wells and the spring.

#### *Evaluation of Alternative Interpretation of ASR Target Area*

An alternative hypothesis is that the Columbia River fault may extend through Well No. 2. This is a variant on a hypothesis presented in the City of White Salmon Wellhead Protection Plan (Yinger, 2002a). Due to the limited subsurface geologic data (i.e., well logs) available to the north of Northwestern Lake, it is not possible to directly assess the geologic structure in this area and confirm this hypothesis. However, this hypothesis is inconsistent with the anticipated characteristics of shallow faulting within the Grande Ronde Basalt and with observed water level response in nearby wells to pumping of Well No. 2.

In this alternative hypothesis, the Columbia River fault would act as a vertical barrier to groundwater flow, with recharge to the target aquifer occurring in the fault block to the northwest of the Columbia River fault. However, for this to occur, the Columbia River fault would have to transition from a high angle reverse fault in the vicinity of its surface exposure to a relatively low angle (approximately 1.5 degree) thrust fault. It has been suggested that frontal faults associated with the Yakima Fold Belt may be low angle thrust faults at depth, with detachment surfaces within either the CRBG or the sediments underlying the CRBG (Reidel et al., 1989). However, it is unlikely that detachment surfaces and low angle thrust faults formed at such shallow depths (less than 1,000 feet) within the Grande Ronde Basalt. This scenario is considered unlikely and not considered further for this feasibility study.

## 5.3 Target Aquifer for Storage

A candidate aquifer for water storage and recovery should ideally be both laterally and vertically confined. Leakage of stored water from an inadequately confined reservoir, into either another aquifer or nearby surface waters, would make it unavailable for future recovery from the ASR well.

Based on the available data, the water-bearing zone tapped by Well No. 2 in the Grande Ronde Basalt is a suitable aquifer for water storage and recovery within the ASR target area. Characteristics of the Grande Ronde Basalt aquifer are discussed below. Both of the City’s existing water supply wells (Well No. 1 and Well No. 2) are completed in water-bearing zones within the Grande Ronde Basalt. Based on the cross sections (Figures 5.2 and 5.3), Well No. 2 is likely the only well, municipal or domestic, completed in the target aquifer of the fault block discussed above (Section 5.2.3).

### *5.3.1 Overview of the Grande Ronde Basalt Formation*

Within the project area, both the $N_2$ and $R_2$ members of the Grande Ronde Basalt are present. The $N_2$ member consists of the Sentinel Bluffs, Slack Canyon, Field Springs, Winter Water, Umtanum, Ortley, and Armstrong Canyon units. The $R_2$ member consists of the Meyer Ridge, Grouse Creek, Wapshilla, and Mount Horrible units (Tolan et al., 1989). Due to the variable extent and thickness of the individual units, it can be relatively difficult to distinguish between the $N_2$ and $R_2$ members of the Grande Ronde Basalt, especially without detailed physical, chemical, and paleomagnetic data.

Based on the conceptual model discussed in Section 5.2.3, it is likely that the target aquifer is located within the $N_2$ member of the Grande Ronde Basalt. Recharge of the target aquifer would occur where the water-bearing interflows of the $N_2$ member are expected to daylight south of the Columbia River fault. Detailed studies in the Pasco Basin (Department of Energy, 1988; Myers and Price, 1981) indicate that the thickness of the $N_2$ member of the Grande Ronde Basalt ranges between 1,500 and 1,750 feet in that area. The maximum thickness of the CRBG occurs in the Pasco Basin, and it is expected that the thickness of the individual flows of the $N_2$ member are thinner in the ASR project area. It is also likely that the unnamed/unmapped reverse fault in the vicinity of Northwestern Lake resulted in the uplift and erosion of several hundred feet of the Grande Ronde Basalt sequence in this area. These factors imply the maximum thickness of the $N_2$ member could be on the order of 1,300 to 1,500 feet. Given the 1,242 feet bgs depth of completion and 1,060 feet of Grand Ronde Basalt encountered during drilling of Well No. 2, it is likely that Well No. 2 is completed near the bottom of the $N_2$ member.

#### 5.3.1.1 Lateral and Vertical Confinement

Except where extensive fractures are present or where a basalt flow is exposed at the surface, the relatively massive basalt flow interiors of the Grande Ronde Basalt are expected to provide significant vertical confinement of the water-bearing interflow zones. As discussed in Section 3, the intense fracturing observed in the Grande Ronde Basalt in the vicinity of Well No. 1 likely provides semi-confined aquifer conditions, limiting the vertical confinement provided by the massive basalt flow interiors. The same intense fracturing, likely related to the nearby Hood River fault and possibly the concealed syncline in the vicinity of Northwestern Lake, does not appear to be present at Well No. 2. Therefore, the relatively unfractured, massive basalt flow interiors of the Grande Ronde Basalt are expected to provide the necessary vertical confinement for ASR activities at Well No. 2. The presence of a shear zone, likely related to the unnamed/unmapped reverse fault in the vicinity of Northwestern Lake, also provides additional vertical/downgradient confinement, as demonstrated by the greater than 300-foot head difference across the shear zone.

Based on the geologic map (Figure 5.1), both the $N_2$ and $R_2$ members of the Grande Ronde Basalt are exposed at the surface within the project area. The $N_2$ member is primarily exposed at the surface in the area surrounding the City’s water supply wells, while the $R_2$ member is exposed at the surface in the vicinity of the Columbia River fault. As discussed in Section 5.2.3 and illustrated on Figure 5.4, upgradient recharge to the bounded $N_2$ aquifer in which Well No. 2 is completed likely occurs where the water-bearing interflows are expected to daylight at the surface, south of the Columbia River fault.

Faults typically act as partial or complete barriers to groundwater flow, providing lateral confinement. Within the ASR target area, both the $N_2$ and $R_2$ members of the Grande Ronde Basalt are likely laterally confined to the southwest by the Hood River fault and to the northeast by the Buck Creek fault. The unnamed/unmapped reverse fault in the vicinity of Northwestern Lake also is interpreted to provide lateral confinement to the southeast of the ASR target area.

#### 5.3.1.2 Effect of Condit Dam Removal

Since the target aquifer in the vicinity of Well No. 2 (ASR target area) is vertically confined by the relatively massive flow interiors of the Grande Ronde Basalt and the unnamed/unmapped reverse fault in the vicinity of Northwestern Lake, the aquifer is not believed to be in hydraulic continuity with Northwestern Lake. This is supported by the lack of significant leakage or the observation of a recharge boundary during the 24-hour constant rate aquifer test conducted in Well No 2. The removal of Condit Dam and draining of Northwestern Lake is not expected to significantly affect groundwater levels within the ASR target aquifer and the associated aquifer yield.

Removal of the Condit Dam may potentially affect the City’s Well No. 1, based on pumping test results and observed recharge boundary influence, previously described in Section 5.2.3.1.

### 5.3.1.3 Aquifer Yield

Within the project area, a majority of the water supply wells completed within the Grande Ronde Basalt aquifer are either irrigation or municipal wells (Aspect, 2009). Estimated well yields and specific capacity values (pumping rate divided by drawdown) based on driller's well logs when available, are provided on the cross sections (Figures 5.2 and 5.3). Based on these limited data, the well logs indicate that the Grande Ronde Basalt in general is relatively productive, although highly variable. Reported well yields range between 1 and 1,380 gpm, with specific capacities ranging between 0.29 and 8.22 gallons per minute per foot of drawdown (gpm/ft). It is uncertain whether the reported well yields are limited by quality of well construction, pump capacity, and/or water rights, rather than aquifer yield characteristics.

The City's existing water supply wells completed within the Grande Ronde Basalt aquifer include Well No. 1 and Well No. 2. Well No. 1 had a yield of approximately 650 gpm and a specific capacity of 8.22 gpm/ft based on a 48-hour constant rate aquifer test conducted on November 18, 1998. Well No. 2, completed in the ASR target aquifer, had a yield of approximately 1,380 gpm and a specific capacity of 1.45 gpm/ft during a 24-hour constant rate aquifer test conducted on April 19, 2001. Since starting production in 2001, the sustainable yield from Well No. 2 has decreased to about 600 gpm, as a result of declining available drawdown (water levels) and resulting decrease in specific capacity of the well.

### 5.3.1.4 Target Aquifer

The water-bearing zones tapped by Well No. 2 was selected as the ASR target aquifer for this feasibility study, based on the hydrogeologic conditions discussed in the preceding sections. The selected ASR target area would allow the City to take advantage of existing water system infrastructure, including conveyance and treatment facilities, and to use Well No. 2 for injection and recovery purposes.

In terms of hydrogeology, this target zone was chosen for the following reasons:

- The presence of relatively massive, unfractured flow interiors of the Grande Ronde Basalt, which provide vertical confinement.
- The presence of the unnamed/unmapped reverse fault in the vicinity of Northwestern Lake which provides additional vertical confinement of the Grande Ronde Basalt aquifer from the overlying Quaternary deposits and Northwestern Lake, as evidenced by a greater than 300-foot head difference across the shear zone. The fault also laterally confines the target aquifer downgradient (southeast) of the ASR target area.
- The presence of the Columbia River fault, which provides lateral confinement of the target aquifer upgradient of the recharge zone.
- The presence of the Hood River and Buck Creek faults, which provide lateral confinement of the target aquifer to the southwest and northeast of the ASR target area, respectively. An ASR well should not be located any closer to the Hood River fault than Well No. 2, due to the expectation of greater no-flow boundary effects.

- The absence of domestic wells completed in the same water-bearing interflows of the N2 member of the Grande Ronde Basalt. Both the injection to and extraction from the target aquifer would be unlikely to affect water levels in surrounding domestic wells, as confirmed by the previous aquifer test conducted in Well No. 2.
- The primary water-bearing zones (870 to 955 feet bgs and 1,050 to 1,100 feet bgs) are moderately productive. The target aquifer within the ASR target area was initially expected to provide a yield of about 1,400 gpm, with a specific capacity of approximately 1.5 gpm/ft, based on the yield and drawdown measured at Well No. 2 (Mark Yinger Associates, 2001). Since starting production in 2001, sustainable yield from Well No. 2 has declined to about 600 gpm.
- The target aquifer is artesian, which provides better operational conditions for ASR, minimizing potential for air entrainment and well screen fouling.
- The water quality of the target aquifer meets drinking water standards.

As required by WAC 173-157-120 for a hydrogeologic conceptual model, the following report subsections describe our current understanding of several parameters pertaining to the target aquifer. These include estimates of lateral and vertical aquifer extent, evaluation of whether the aquifer is confined or unconfined, permeability and transmissivity, total storage volume available, and the potential for physio-chemical changes in the aquifer as a consequence of recharge. Because an ASR pilot test has not been conducted, the following evaluation is based on available data and would be refined under the Phase II portion of this project, if funded.

### 5.3.2 Lateral and Vertical Extent

On a regional scale, the Grande Ronde Basalt is laterally extensive over the entire White Salmon River subbasin, with a thickness of at least 1,060 feet in the vicinity of the ASR target area (based on depth of Well No. 2). The Grande Ronde Basalt in the vicinity of Well No. 2 consists of both the $N_2$ and $R_2$ members, which are each laterally extensive. Based on estimates from the Pasco Basin (Department of Energy, 1988; Myers and Price, 1981) and accounting for regional variation and uplift and erosion of the Grande Ronde Basalt, the $N_2$ member in the ASR project area is estimated to have a maximum thickness of between 1,300 and 1,500 feet. The water-bearing interflows between the individual basalt flows also appear to be relatively continuous and generally range in thickness between 30 and 60 feet.

In the vicinity of the ASR target area and Well No. 2, the top of the Grande Ronde Basalt is encountered at a depth of 180 feet bgs, equating to an elevation of about 300 feet (MSL). While drilling Well No. 2 artesian (free-flowing) conditions were encountered starting between depths of 845 and 870 feet bgs (elevations of between -365 and -390 feet MSL), with the primary water-bearing interflow zones occurring between 870 and 955 feet bgs (elevation of between -390 and -475 feet MSL) and between 1050 and 1100 feet bgs (elevation of between -570 and -620 feet MSL). Based on the limited data, these water-bearing interflow zones appear to be laterally continuous within the fault block; although, as discussed in Section 5.3.1.1, the water-bearing zones of the target aquifer are likely laterally and vertically confined.

### 5.3.3 Confined or Unconfined

As discussed in Section 5.2.3, Well No. 2 is completed in a fault block. The target aquifer within the Grande Ronde Basalt is vertically confined by the massive flow interiors of the Grande Ronde Basalt. The presence of a shear zone, associated with the unnamed/unmapped reverse fault in the vicinity of Northwestern Lake, also likely provides additional vertical/downgradient confinement, as evidenced by the greater than 300-foot head difference across the shear zone. This conclusion that the ASR target aquifer is confined is further supported by the fact that Well No. 2 is artesian (free-flowing), while all other nearby domestic wells completed at shallower depths in the Grande Ronde Basalt have depths to groundwater of between 90 and 250 feet bgs (Figures 5.2 and 5.3).

### 5.3.4 Hydraulic Properties

Table 5.2 presents a compilation of reported values for the hydraulic conductivity (ft/day), transmissivity ($ft^2$/day), and storativity (dimensionless) of the Grande Ronde Basalt aquifer regionally and in the vicinity of the ASR target area. Hydraulic conductivity is a quantitative measure of an aquifer's ability to transmit water; the term is often used interchangeably with permeability. Transmissivity (hydraulic conductivity multiplied by aquifer thickness) is a measure of how much water can move through the aquifer and is a more direct indicator of the aquifer's productivity. Storativity is the product of specific storage and aquifer thickness, where specific storage is defined as the volume of water (cubic feet) that a 1 cubic foot volume of aquifer releases from storage when the hydraulic head drops by 1 foot.

The hydraulic parameters presented in Table 5.2 were compiled from published literature, analysis of local aquifer test data, and estimates derived from available domestic well specific capacity data. Regional data, based primarily on model calibrations and specific capacity data, indicate the transmissivity of the Grande Ronde Basalt aquifer is expected to range between 40 and 16,000 $ft^2$/day, with a hydraulic conductivity between 0.1 and 8.6 ft/day (Hansen et al., 1994). The storativity is expected to range between $1 \times 10^{-5}$ and $1 \times 10^{-3}$. These regional data provide the general range of expected hydraulic parameters in the Grande Ronde Basalt.

The City's Well No. 2 is the only well completed in the ASR target aquifer. An aquifer test conducted in this well indicated a transmissivity of between 145 and 169 $ft^2$/day, and a hydraulic conductivity of between 1.1 and 1.3 ft/day (Mark Yinger Associates, 2001). Because there are no other wells completed in this aquifer, observation well data required to estimate storativity were not collected.

The transmissivity at Well No. 2 is at least an order of magnitude lower than the transmissivity estimated from pumping tests at two other nearby water supply wells completed in the Grande Ronde Basalt. An aquifer test conducted in the City's Well No. 1, located near Well No. 2 but on the opposite side of the unnamed/unmapped fault, indicates a transmissivity of between 2,090 and 2,350 $ft^2$/day, and a hydraulic conductivity of between 4.0 and 4.5 ft/day (Mark Yinger Associates, 1999). Measurements of water level response in an observation well completed in the same aquifer (Observation Well No. 1) were used to estimate a storativity of between $5.6 \times 10^{-4}$ and $7.0 \times 10^{-4}$. An aquifer test conducted in the Underwood Water District well (WPN and Mark Yinger Associates, 2002), located to the south of the ASR target area, indicates a transmissivity of approximately 51,400 $ft^2$/day and a hydraulic conductivity of 553 ft/day.

Specific capacity data from domestic wells within the project area were also used to estimate transmissivity and hydraulic conductivity. Four domestic wells completed in the Grande Ronde Basalt aquifer with available specific capacity data were identified in the project area. Transmissivity for a confined aquifer can be estimated from specific capacity data based on the following empirical equation (Driscoll, 1986):

$$T = 2000\frac{Q}{s}$$

where: T = Transmissivity (gpd/ft)

Q = Yield of well (gpm)

s = Drawdown in well (ft)

Based on the above equation and the thickness of the water-bearing zones listed on the domestic well logs, the transmissivity and hydraulic conductivity of the Grande Ronde Basalt aquifer tapped by the four domestic wells ranges between 22 and 251 $ft^2$/day, and 0.4 and 5.0 ft/day, respectively.

Based on the available data, the transmissivity of the ASR target aquifer tapped by Well No. 2 is estimated to be about 145 to 169 $ft^2$/day. Storativity data for this aquifer are not available. Rather the storativity is assumed to be similar to the values estimated for Well No. 1 (between $5.6 \times 10^{-4}$ and $7.0 \times 10^{-4}$).

### 5.3.5 Total Storage Volume Available

WAC 173-157-120 requires an estimation of the total storage volume available in the target aquifer. While it is possible to estimate the total storage volume, such an estimate would depend on the number of ASR wells used for storage and the area of coverage. For the current conceptual evaluation of ASR feasibility, the more pertinent question to address is whether the target aquifer has sufficient storage capacity around the ASR well to accommodate the storage volume desired for an ASR program to meet the City of White Salmon’s needs

Well No. 2 is completed in a laterally and vertically confined fault block of the Grande Ronde Basalt, with artesian conditions in the target aquifer. Upon completion in March 2001, the well exhibited a shut-in pressure of 98 pounds per square inch (psi) (about 226 feet of head) and had an estimated specific capacity of 1.45 gpm/ft. However, based on communication with City personnel, Well No. 2 currently requires approximately 65 to 70 psi of shut-in pressure to maintain static, no-flow conditions. At a shut-in pressure of 10 psi, the well produces approximately 120 gpm (Wellman, 2009), indicating a current specific capacity of 0.94 gpm/ft. The capacity of the target aquifer to accommodate additional pressurization, as would occur during artificial recharge via an ASR well, is directly related to available storage capacity in the aquifer. The expected change in head due to potential ASR activities is calculated in the following section to assess the target aquifer storage capacity.

### 5.3.5.1 Change in Head and Estimated Radius of Influence

Parameters of interest when evaluating a prospective ASR program are the anticipated changes in head with distance, and the radius of influence about an ASR well during recharge (mounding) and recovery (drawdown) cycles. The amount of drawdown or mounding with respect to distance from the ASR well can be calculated from the equation (Driscoll, 1986):

$$dh = \frac{264Q}{T}\log\frac{0.3Tt}{r^2S}$$

where: dh = the amount of drawdown or mounding (feet)

Q = the pumping/injection rate (gpm)

T = the aquifer transmissivity (gpd/ft)

t = the time of continuous pumping/injection (days)

r = the distance from the well (feet)

S = the aquifer storativity (dimensionless)

Theoretically, the mounding or drawdown in the aquifer will be of the same magnitude for recharge or discharge (pumping), respectively, at a set flow rate, but only different in direction (mounding vs. drawdown).

Using the above equation, the injection rate achievable at a given injection pressure and the radius of influence can be estimated for hypothetical ASR operational scenarios. As previously discussed in the Source Evaluation section (Section 2), it is assumed that Buck Creek water would be available for as much as a 6-month period of time (180 days) between November and April.

For the purposes of analysis in this feasibility study, two scenarios were evaluated. In the first scenario, the injection rate is limited by the injection pressure of about 225 psi that can be delivered to the wellhead by the City’s existing infrastructure. As discussed below, under this scenario, water would be continuously injected at a rate of 220 gpm to achieve storage of approximately 175 acre-feet during a given 6-month period.

The second scenario assumes addition of a booster pump and modification of the wellhead at Well No. 2 to allow injection and recovery at higher pressure. Under this scenario, an injection pressure of 375 psi was assumed, allowing continuous injection at a rate of 425 gpm and storage of 340 acre-feet. Water to supply either scenario is expected to be available, based on the available instantaneous flows and treatment capacity in Buck Creek.

A more detailed water system evaluation would be required to assess whether ASR operations at pressures higher than 375 psi is feasible. Higher operating pressure would accommodate increased annual storage volume. For example, using the approach discussed above, it is estimated that annual storage of 500 acre-feet would require an operating pressure of about 525 psi. Actual achievable injection rates and storage and recovery volumes would be determined during ASR pilot testing under the Phase II portion of this project, if funded.

### *Injection at 225 psi*

For the first scenario, the head change (mounding) after 6 months of injection at Well No. 2 is set equal to 160 psi (about 370 feet), the difference between the maximum pressure of 225 psi that can be delivered with the City's existing infrastructure and the shut-in pressure of 65 psi. Assuming a transmissivity of 169 $ft^2$/day and a storativity of $5.6 \times 10^{-4}$ (Table 5.2), an injection rate of 220 gpm would result in 370 feet of mounding immediately adjacent to the well after 6 months (lower graph on Figure 5.5). This rate and injection period equates to about 175 acre-feet of storage.

### *Injection at 375 psi*

For the second scenario, the head change (mounding) after 6 months of injection at Well No. 2 is set equal to 310 psi (about 720 feet), the difference between the maximum pressure of 375 psi assumed at the wellhead with system upgrades and the shut-in pressure of 65 psi. Assuming the same aquifer parameters as under the first scenario, an injection rate of 425 gpm would result in about 720 feet of mounding immediately adjacent to the well after 6 months (lower graph on Figure 5.5). This rate and injection period equates to about 340 acre-feet of storage.

### *Estimated Radius of Influence*

The above equation can also be used to estimate the radius of influence, which is the distance from the well (initially assumed to be the same in all directions radially from the well, i.e., no anisotropy) at which groundwater mounding or drawdown will affect the heads. Using the parameters discussed above and setting *dh* to zero, the radius of influence is estimated to be approximately 2.1 miles after 6 months of injection. This equates to a radial area of roughly 13.8 square miles, although it is important to note that the presence of any structures that inhibit groundwater flow (i.e., the Hood River fault, the Buck Creek fault, and the unnamed/unmapped reverse fault in the vicinity of Northwestern Lake) would limit the lateral propagation of the radius of influence across these features. Rather, the radius of influence and greater head changes would likely be extended to the northwest where there are no apparent structural boundaries. Figure 5.5 depicts the relationship between the estimated drawdown or mounding in the aquifer and the radial distance from Well No. 2 for the two scenarios. Note that the radius of influence is independent of the injection rate, but the slope of the line and predicted mounding within the radius is directly proportional to the injection rate.

Although not apparently tapping the same aquifer, the closest well (3N/10E-3K01 on Figure 5.3 and Table 5.1) completed in the same fault block as Well No. 2 is about 1,000 feet to the northwest. This well is completed in basalt, with the bottom of the well completed about 500 feet above the water-bearing zone tapped by Well No. 2. The next closest wells are about 2,000 feet to the northwest, with the deepest (3N/10E-3X01 on Figure 5.3 and Table 5.1) completed in basalt about 300 feet above the interpreted top of the water-bearing zone tapped by Well No. 2.

As shown on Figure 5.5, at an injection rate of 220 gpm for 6 months, mounding could be on the order of 70 feet at a distance of 1,000 feet from Well No. 2 and 50 feet at a distance of 2,000 feet from Well No. 2. At an injection rate of 425 gpm for 6 months, mounding could be on the order of 185 feet at a distance of 1,000 feet from Well No. 2 and 130 feet at a distance of 2,000 feet from Well No. 2.

Since Well No. 2 is vertically confined (Sections 5.3.1.1 and 5.3.3) from nearby domestic wells by the relatively massive flow interiors of the Grande Ronde Basalt, the injection and extraction of water associated with ASR activities at Well No. 2 is not expected to impact the head (static groundwater levels) in any of the nearby domestic wells. Well No. 2 produced about 500 afy for several years after starting production in 2002 with no report of water level impacts in nearby wells. This suggests that the basalt flow interiors do not exhibit significant vertical leakage, even with long-term pumping. Additionally, water proposed for storage would be recovered over the 6 months following injection before a new injection cycle begins, reducing the potential for mounding effects to accrue over time.

### *5.3.6 Controls on Groundwater Quality and Potential for Physio-Chemical Changes*

This section provides the basis for understanding the major controls on water quality within the Grande Ronde Basalt, the target aquifer for ASR. Data and concepts presented in this section are discussed further in Section 5.10, where the compatibility of source water and ambient groundwater is evaluated. In general, basalt mineralogy and residence time of groundwater in the aquifer are the primary controls on ambient groundwater quality. The basic findings are summarized below.

- Grande Ronde Basalt is composed primarily of a volcanic glass matrix and crystalline minerals including plagioclase feldspar, pyroxene, and crystalline titanium-iron oxides. Dissolution of these primary minerals controls the major elemental chemistry of the groundwater.
- In interflow zones, where groundwater flow occurs, a variety of secondary minerals can form from reaction of groundwater and the aquifer matrix. Equilibration with secondary minerals can impact groundwater pH, oxidation-reduction (redox) potential, and the presence of trace metals.
- Across the region, Grande Ronde Basalt groundwater chemistry types include calcium-magnesium bicarbonate, and, less commonly, magnesium bicarbonate, sodium bicarbonate, and calcium-magnesium sulfate-chloride. Calcium-magnesium bicarbonate waters are typically fresher (lower total dissolved solids [TDS]) and found closer to recharge zones and at shallower depths.
- Overall, ambient groundwater quality in the target aquifer meets drinking water standards.

These findings are described in greater detail below. An overview of regional geochemical information on the Grande Ronde Basalt is presented first, followed by the site-specific water quality collected for the ASR target aquifer area as part of this feasibility study. Water quality data collected from the proposed Buck Creek source are also presented.

#### 5.3.6.1 Regional Geochemical Information for the Grande Ronde Basalt

***Grande Ronde Basalt Mineralogy***

The mineralogy of the Grande Ronde Basalt predominantly controls the ambient water quality in the aquifer. Groundwater moves through the basalt flows primarily along vesicular and fractured zones, and the groundwater composition is chemically altered by the dissolution and precipitation of minerals in these interflow zones. Therefore, it is important to identify the mineralogy of the Grande Ronde Basalt and associated sedimentary interbeds to determine the range of potential physiochemical changes in water quality that may occur with implementation of an ASR program.

Each of the major CRBG units is compositionally distinct; however, the bulk mineralogy of the units is generally similar. The unaltered rocks of the CRBG are classified as tholeiitic basalts. Fresh basalt samples consist primarily of volcanic glass, composed primarily of silicon, aluminum, and iron, with trace amounts (less than 10% by weight in the oxide form) of magnesium, calcium, sodium, and potassium. Other important mineral components include plagioclase feldspar, pyroxene (augite to sub-calcic augite, diopside), and crystalline titanium-iron oxides of the ilmenite-magnetite solid solutions series (Ames, 1980). Accessory minerals may include apatite, olivine (fayalite), and metallic sulfides (Steinkampf and Hearn, 1996).

Secondary minerals form coatings and skins within fractures. Secondary mineral surfaces generally contain nontronitic smectites (clay mineral byproducts of feldspar weathering), clinoptilolite (zeolite minerals important in ion-exchange processes), amorphous iron oxyhydroxides, and silica. Minor secondary minerals include illite (clay), pyrite (iron sulfide), and calcite (Steinkampf and Hearn, 1996). These minerals may control trace metal concentrations resulting from sorption and ion exchange. Well No. 2 is completed in a fracture zone where secondary sedimentary minerals are thought to be limited. The limited secondary mineral phases expected in the fracture zones are favorable for maintaining high quality water during ASR operations.

***Grande Ronde Basalt Groundwater Geochemistry***

Regionally, the chemical composition of the Grande Ronde Basalt groundwater depends on the composition and solubility of aquifer minerals, chemical characteristics of the native recharge water, and the amount of time the water is in the aquifer system (residence time). Solutes potentially contributed to groundwater by basalt dissolution include calcium, magnesium, iron, sodium, potassium, silica, sulfates, chloride, fluoride, and bicarbonate. Sulfate may also be derived naturally from the dissolution of metal sulfides (pyrite) or sedimentary interbeds (i.e., gypsum and caliche).

Table 5.3 presents a summary of regional groundwater quality data from the Grande Ronde Basalt. Groundwater can be grouped into different types based on the proportions of the predominant cations and anions present in the water. Groundwater types can be indicative of groundwater residence time and thus location within a regional flow system (e.g., near recharge area or further downgradient). They also serve as an indicator of overall water quality. In general, bicarbonate water types provide the best drinking water quality, whereas sulfate and chloride water types are less desirable.

- On a regional scale, calcium-magnesium bicarbonate is the dominant groundwater type in the Grande Ronde Basalt. Sodium bicarbonate is the next most prevalent type, and calcium-magnesium sulfate-chloride is the least prevalent groundwater type. The sodium bicarbonate and calcium-magnesium sulfate-chloride waters typically occur in deeper wells and locations with long groundwater residence times (distant from recharge sources). Calcium-magnesium bicarbonate waters are typically fresher and are found closer to recharge zones and at shallower depths (Steinkampf, 1989).

Based on the regional groundwater quality data set, the following information is apparent for Grande Ronde Basalt groundwater quality:

- Total Dissolved Solids (TDS) range from 94 to 510 milligrams per liter (mg/L) in the Grande Ronde. TDS values are generally higher in deeper locations. An increase in TDS, usually followed by an increase in sodium, is present in downgradient areas and discharge areas as a result of a longer residence time for rock-water interaction (Whitemann et al., 1994).
- pH ranges from 6.7 to 9.4, with a mean pH of 7.9. The pH of slightly acidic waters (pH less than 7 or the low end of the observed range) is influenced by the production of carbonic acid, which enters the groundwater as dissolved carbon dioxide derived from microbial oxidation of organic matter in soil-rich interflow zones. Low pH waters have a tendency to both increase concentrations of solutes and increase pH by dissolving some minerals. When pH increases above calcite stability (approximately 8.2 pH units), calcite precipitation occurs. Calcite, in this case, can buffer the pH, as well as the dissolved concentrations of calcium, magnesium, iron, and manganese.
- Silica concentrations ranging from 29 to 110 mg/L result from the dissolution of glassy minerals. The solubility of amorphous silica limits these concentrations, and in general buffers pH to about 9.5 (Whiteman et al., 1994). A maximum pH of 9.4 in the more basic Grande Ronde Basalt groundwater is probably controlled by amorphous silica solubility.
- Dissolved oxygen concentrations vary significantly, ranging from anoxic to almost full oxygen saturation (10.2 to 0.1 mg/L). Dissolved oxygen concentrations strongly influence the groundwater’s redox potential and affect mineral dissolution and precipitation, in particular for redox-reactive metals such as iron, manganese, and arsenic. Redox conditions in an aquifer are typically highly variable and difficult to determine.

### 5.3.6.2 Target Aquifer and Buck Creek Source Water Quality

***Existing Water Quality Data***

Existing water quality data for Well No. 2 and Buck Creek sources were provided by the City. The data set included historical data for all three of the City’s water sources, including Well No. 1, augmented by more recent water quality data. Site-specific water quality samples were collected from the City’s Well No. 2, completed in the Grande Ronde Basalt target storage aquifer, and the Buck Creek surface water source. The more recent data were based on samples collected on February 17, 2010, by City personnel and transported to AddyLab analytical laboratory of Vancouver, Washington, using standard chain-of-custody and sample shipping procedures. Laboratory certificates of analysis are provided in Appendix A.

Well No. 2 was sampled following generally accepted groundwater sampling procedures for production wells. The well was purged by pumping for 10 to 20 minutes prior to sampling. Sampling methods involved collecting water from an external spigot/discharge line located at the wellhead, prior to (upstream of) any treatment. The water sample from the Buck Creek source was collected after treatment by the recently completed slow sand filtration system, but prior to any chlorination, as the planned chlorination station for this source is not currently on-line.

Field parameters were measured using hand-held probes. Field parameters include pH, oxidation-reduction potential (ORP), dissolved oxygen, specific conductance, and temperature. All field instruments were calibrated prior to use in accordance with manufacturer’s instructions.

Water sample analyses performed by AddyLab include:

- Dissolved target analyte list metals, 23 metals that include common cations (calcium, magnesium, sodium, potassium);
- Major and minor anions (sulfate, chloride, sulfide);
- Total alkalinity;
- Ammonia;
- Orthophosphate and total phosphorus;
- Silica;
- Total organic carbon (TOC);
- Total suspended solids (TSS); and
- Total dissolved solids (TDS).

#### ***Water Quality Results***

Table 5.4 presents results for the samples collected from Well No. 2 and the Buck Creek source on February 17, 2010, as well as historical water quality data from Well No. 1, Well No. 2, and the Buck Creek source. The historical data include analyses for volatile organics, metals, trihalomethanes (THMs), total hardness, cyanide, fluoride, sulfate, nitrogen species (nitrate and nitrite), TDS, color, radionuclides, turbidity, and specific conductance. Potentially applicable groundwater quality standards, drinking water standards, and surface water criteria are also presented in Table 5.4.

The target aquifer groundwater and the Buck Creek source water are of very good quality. Low TDS, neutral pH, and generally low dissolved metals and sulfide concentrations are all indications of good water quality. The constituents meet groundwater quality standards, drinking water standards, and surface water criteria, with the exception of manganese in the most recent sample from Well No. 2, which exceeded the federal Secondary Maximum Contaminant Level (MCL) of 50 micrograms per liter (μg/L). Historical data from Well No. 2 indicate manganese concentrations are typically below the Secondary MCL. Secondary MCLs are non-mandatory standards established as guidelines to address potential aesthetic concerns for drinking water, such as odor, taste, or color, but are not considered to present a human health risk.

Chloroform, a disinfection byproduct and THM, was detected in a sample from the Buck Creek source collected in 1998. No other THMs were detected. The chloroform concentration of 2.7 μg/L was less than the groundwater quality standard of 7 μg/L and the drinking water standard for total THMs of 80 μg/L. The presence of THMs is typically due to reaction of chlorine or bromine with organic carbon present in water during treatment. In 1998, Buck Creek source water was chlorinated, but the slow sand filtration system was not in operation. It is expected that the slow sand filter will reduce turbidity and organic carbon content of the source water, in turn reducing the potential for generation of THMs during chlorination.

A piper diagram (Figure 5.6), based on data collected from the City's existing water supply wells (Well No. 1 and Well No. 2) and the Buck Creek source, allows for quick visual comparison of water-types for each source based on the relative concentrations of the major cations (calcium, magnesium, and sodium) and major anions (bicarbonate, sulfate, and chloride). In comparison to Well No. 2, Well No. 1 water contains higher TDS, mostly as calcium-magnesium bicarbonate, suggesting a greater degree of water-rock interaction with carbonate and other evaporate minerals. Higher TDS can indicate older water, but that does not appear to be the explanation for higher TDS observed in Well No. 1 relative to Well No. 2. The major composition of Well No. 1 is generally in equilibrium with calcite (as determined by calcium and alkalinity), while Well No. 2 water-type suggests ion exchange and silicate mineral equilibria that require longer residence times (i.e., higher Na:Ca, higher Mg:Ca, and modeled equilibrium with silicate mineral phases).

## 5.4 Groundwater Flow Directions and Rates of Movement

Based on Vaccaro (1999), regional groundwater flow within the Grande Ronde Basalt is inferred to be in a southerly direction, toward the Columbia River. In general, local groundwater flow within the CRBG is expected to be toward major surface water bodies, away from anticlinal axes and in the direction of regional geologic dip (Steinkampf, 1989). During the formation of an anticline, the compression of the various basalt flows leads to both the folding and uplift of the respective flows. Erosion of the upper flows will later expose the lower flows at the surface, thus allowing for the areal recharge of the respective flow. For this reason, groundwater generally flows away from these relatively high points of recharge and down the geologic dip.

A groundwater elevation contour map of the Grande Ronde Basalt aquifer for the ASR project area was created based on the well locations provided in the Ecology well log database. These data are as reported by the well drillers at the time of drilling and can span decades in time and be from different seasons. As previously discussed (Section 5.2), wells were initially located at the center of their respective quarter-quarter section; select wells were also located by parcel number or by a Trimble GPS (Well No. 1 and

Well No. 2), to provide more accurate well locations. Ground surface elevations used to convert depth to groundwater measurements to groundwater elevations were determined at the individual well locations using a 10-meter Digital Elevation Model (DEM). Ground surface elevations at Well No. 1 and Well No.2 were measured by GPS. Based on the relatively significant topographic relief, ground surface elevations can vary by about 100 feet within a 40-acre quarter-quarter section for the ASR project area. For this reason, the groundwater elevation contour map provides only a general idea of local groundwater flow directions (100-foot contour interval).

Table 5.5 provides a summary of the groundwater elevation data and Figure 5.7 presents a groundwater elevation contour map (100-foot contour interval) for the upper portion of the Grande Ronde Basalt aquifer. The water level contours do not include the measured water level at Well No. 2, as it appears to tap an aquifer that is distinct from the aquifer(s) tapped by other wells in the area, as discussed below.

Well No. 2 is completed in a bounded fault block (Section 5.2.2) and the target aquifer is vertically confined by the massive flow interiors of the Grande Ronde Basalt and the Columbia River fault (Section 5.3.1.1). One nearby domestic well (Ottman well) completed in the same fault block, but at a shallower depth, did not show any water level response during a 24-hour constant rate aquifer test conducted in Well No. 2. Review of the well logs indicates that the other domestic wells completed in the same fault block as Well No. 2 are either completed at much shallower depths and/or exhibit water levels that are inconsistent with the strong artesian conditions at Well No. 2. It is unlikely that any of these wells are completed in the same target aquifer as Well No. 2.

A more refined determination of groundwater flow directions and gradients in the basalt tapped by Well No. 2 will need to be determined following the installation of a monitoring well under the Phase II portion of this project, if funded.

### *5.4.1 Groundwater Flow Direction and Hydraulic Gradient*

As discussed above, there do not appear to be any other wells tapping the same aquifer as Well No. 2. It is expected that groundwater within the ASR target aquifer generally flows south-southeast from the likely recharge area toward Well No. 2. Flow is expected to generally parallel the Buck Creek and Hood River faults, although some leakage across these faults and the unnamed/unmapped fault may occur. Limited leakage may also occur vertically through the massive flow interiors of the Grande Ronde Basalt.

Based on the limited data (Well No. 2 is the only well identified in this zone), it is not possible to develop an accurate estimate of the hydraulic gradient in the ASR target aquifer. The remainder of this section discusses hydraulic gradients and flow direction in the ASR project vicinity, results of which are used as a rough approximation of potential gradients in the ASR target aquifer.

Based on the interpretation of Figure 5.7, local groundwater flow within the upper portions of the Grande Ronde Basalt is generally toward the White Salmon River, indicating that the upper portion of the Grande Ronde Basalt may be in hydraulic continuity with the overlying Quaternary deposits and the White Salmon River.

To the northeast of the Buck Creek fault, groundwater within the Grande Ronde Basalt generally flows toward the White Salmon River and the concealed syncline in the vicinity of Husum (down-dip), and away from the anticline located to the southeast. Gradients in this area range from about 0.06 to 0.16 feet per feet (ft/ft ) and potentially reflect the influence of both surface topography and geologic structure (dip). As discussed in Section 5.1, the White Salmon River gains approximately 200 cfs in groundwater contributions between BZ Corner and Husum. Although a large portion of these groundwater gains are likely from the Quaternary deposits, a portion of the gains may be from the underlying Grande Ronde Basalt.

Between the Hood River and Buck Creek faults, in the same fault block as Well No.2, groundwater flow within the upper Grande Ronde Basalt appears to converge on Northwestern Lake. To the north of Northwestern Lake, groundwater flows in a southeast direction toward the concealed syncline (down-dip) located in the vicinity of Northwestern Lake with a gradient of approximately 0.08 ft/ft. This is a moderately high groundwater gradient is likely reflective of the steep surface topography to the north of Northwestern Lake. To the south of Northwestern Lake, it is anticipated that groundwater flows toward the Columbia River in a southeasterly direction, although there is limited well data in this area.

### 5.4.2 Groundwater Velocity

The hydraulic gradient can be used to determine an average groundwater flow velocity by applying Darcy's Law of the form (Fetter, 2001):

$$V_x = -\frac{Kdh}{n_e dl}$$

where:

$v_x$ is the average linear groundwater velocity (ft/day), K is the hydraulic conductivity (ft/day), dh/dl is the hydraulic gradient, and $n_e$ is the effective porosity. An average effective porosity of 0.04 was estimated for individual basalt flows of the CRBG, based on grain density (Hansen et al., 1994). However, the flow-tops and vesicular water-bearing zones were estimated to have a slightly higher range of effective porosities, with an average effective porosity of 0.15 (Whiteman et al., 1994). Therefore, an effective porosity of 0.15 was used to calculate the average groundwater velocity.

As discussed in Section 5.3.4, the hydraulic conductivity of the ASR target aquifer is about 1.3 ft/day. Applying the porosity of 0.15 and the range of hydraulic gradients estimated for the Grande Ronde Basalt in the study area (0.06 to 0.16 ft/ft), the average groundwater velocity in the vicinity of Well No. 2 could range from approximately 0.5 to 1.4 feet/day or about 190 to 510 feet/year. These values likely overestimate groundwater velocities in the target aquifer near Well No. 2, as the nearby Hood River fault and the unnamed/unmapped fault are expected to greatly limit downgradient groundwater flow.

### 5.4.3 Interaction with Possible Flow Barriers

The ASR target aquifer tapped by Well No. 2 is laterally bounded by the Buck Creek fault, the Hood River fault, and an unnamed/unmapped fault near Northwestern Lake.

The fault block boundaries act as hydraulic barriers to groundwater flow, isolating groundwater within the fault block and limiting flow. The water-bearing zone tapped by Well No. 2 is also vertically bounded by the massive flow interiors of the Grande Ronde Basalt. The conclusion that these features act as hydraulic barriers is further supported by the significantly higher head and strong artesian conditions at Well No. 2 compared to other nearby wells.

Upgradient recharge to the target aquifer is thought to primarily occur where the water-bearing interflows tapped by Well No. 2 outcrop to the northwest of the well. Based on the estimated regional dip of the Frenchman Springs member of the Wanapum Basalt and the underlying Grande Ronde Basalt, the water-bearing interflows are expected to daylight at a minimum of 8,500 feet upgradient of Well No. 2, although the actual location is uncertain.

## 5.5 Recoverability of Stored Water

A relatively simple numerical groundwater flow model was created using the USGS MODFLOW code to: (1) illustrate schematically the recharge and recovery of a hypothetical ASR system, and estimate the recoverability of the stored water, and (2) anticipate changes to the groundwater system from ASR activities while accounting for boundary effects from the low permeability faults. The numerical groundwater model was created based on the hydrogeologic conceptual model discussed above. A transmissivity of 169 $ft^2$/day was estimated based on results of the pumping test at Well No. 2 and storativity of $5.6 \times 10^{-4}$ was estimated based on average literature values for the CRBG (Table 5.2). Low permeability boundaries were simulated along the Buck Creek fault, the Hood River fault, and the unnamed/unmapped fault near Northwestern Lake. Constant head boundary conditions were applied at the upgradient (northwest) and downgradient (southeast) ends of the model to produce a gradient across the fault block in which Well No. 2 is completed.

Groundwater flow direction and velocity are important considerations in how an ASR system is operated to maximize recovery of the stored water. Recoverability (expressed as the percent of the water volume stored that can subsequently be recovered) will typically decrease in aquifers with a higher ambient (natural) groundwater velocity. This occurs because the volume of recharge water stored (the “recharge bulb”) flows with the natural groundwater velocity away from the ASR well, potentially to a point that pumping of the ASR well can no longer capture it (draw it back against the ambient flow velocity).

Although there is some uncertainty in the regulatory interpretation of recoverability of stored water through ASR, it is assumed that the full quantity of water stored in a body of public groundwater can be recovered as long as it remains in that body of groundwater.

The main operational components to be examined by the modeling are recharge (injection) and recovery (extraction) rates and durations. It is important to stress that this preliminary modeling is essentially conceptual, to schematically illustrate operational concepts that can improve recoverability of the recharge bulb. Major sources of uncertainty include the ambient hydraulic gradient in the ASR target aquifer tapped by Well No. 2 and the potential degree of leakage across the fault boundaries. Pilot testing would be needed to better quantify aquifer parameters and water quality in a specific location, as well as recharge and recovery rates. This information would refine the degree of recoverability relative to that indicated by this preliminary modeling. This modeling also assumes no mixing between recharge water and the ambient groundwater. Such mixing would occur along the fringe of the recharge bulb, reducing the volume of “pure” recharge water that could be recovered relative to these modeling simulations. However based on the water quality analysis of the source water (Buck Creek) and groundwater (ASR target zone), water quality issues from mixing is not anticipated (see Section 5.10).

Two operational scenarios were modeled. As previously discussed in Section 5.3.5, one scenario assumes recharge of Buck Creek water for a 6-month period of time (180 days) between November and April at a rate of approximately 225 gpm to achieve storage of 175 acre-feet. Following the recharge period, groundwater would be recovered over a 6-month period of time (180 days) between May and October. A second operational scenario assumed system upgrades to increase the injection rate to 425 gpm over 6 months with storage of 340 acre-feet, followed by 6 months of recovery. Modeling of these two operational scenarios was performed assuming an ambient groundwater velocity in the fault block of about 190 ft/year, which assumes a horizontal hydraulic gradient of 0.06 ft/ft in the ASR target area (Section 5.4).

Results of the modeling for these conceptual operational scenarios are summarized in Table 5.6. The degree of recovery (i.e., capture of the recharge water) is directly dependent on the ambient groundwater velocity, with a higher ambient groundwater velocity resulting in lower recovery. The degree of recovery is also dependent on the amount of leakage across the faults that bound the ASR target aquifer. Less leakage results in higher recovery, as less groundwater is able to exit the fault block before being recovered. The groundwater velocity (hydraulic gradient) and potential leakage across the fault boundaries are not well defined for the ASR target aquifer. As such, results of this modeling should be considered rough approximations of potential recovery of stored water.

In Scenario 1 (recharge at 225 gpm for 6 months; recovery at 225 gpm for 6 months), an estimated 72 percent of the recharge water (130 acre-feet) is recovered based on the modeling. Under this scenario, 50 acre-feet of the recharge water is unrecovered; rather 50 acre-feet of ambient groundwater is recovered (Table 5.6).

In Scenario 2 (recharge at 425 gpm for 6 months; recovery at 425 gpm for 6 months), an estimated 81 percent of the recharge water (275 acre-feet) is recovered based on the modeling. Under this scenario, 65 acre-feet of the recharge water is unrecovered; rather 65 acre-feet of ambient groundwater is recovered (Table 5.6).

The modeling is only a rough approximation of recoverability based on limited data. Because the ASR target aquifer is in a well-bounded fault block that greatly limits downgradient migration of groundwater, the hydraulic gradients and groundwater velocities are expected to be lower than assumed for the modeling. Assuming this is the case, then actual percent recoverability will be higher.

To improve recoverability, one option would be to withdraw at rates in excess of the injection rates. This would result in greater capture downgradient of the well and increase the amount of injected water that could be recovered. Well No. 2 has a sustainable yield of about 600 gpm, exceeding the modeled injection rates. The increased head following ASR injection would further increase the available drawdown and the capacity of Well No. 2, allowing higher sustained recovery rates than this well can currently achieve. Ultimately, optimization of injection and recovery rates and durations would need to be determined through pilot testing.

In general, the following are observations with respect to recoverability of stored water:

- Recoverability increases with an increase in injection rate;
- Recoverability decreases with an increase in ambient groundwater velocity;
- Recoverability decreases with an increase in leakage across the fault boundaries; and
- Recoverability increases if the withdrawal rate exceeds the injection rate.

## 5.6 Anticipated Changes to Groundwater System from ASR Project

The largest anticipated changes to the groundwater system from an ASR project would be changes in head (drawdown/mounding) and changes in local groundwater flow direction and velocity around the ASR well. Figures 5.8 and 5.9 show the modeled water level change (mounding/drawdown) at the end of a 180-day aquifer recharge period for Scenario 1 and Scenario 2, respectively.

During the 180-day aquifer recharge period for Scenario 1, the maximum mounding near Well No. 2 is estimated to be approximately 400 feet. A modeled 400-foot change in head near the well location is similar to the 370-foot change in head calculated using an analytical solution in Section 5.3.5.The equation applied in Section 5.3.5 assumes an aquifer of infinite areal extent with no boundaries, whereas the numerical model assumes the aquifer system is bound by a low permeability fault boundaries. The modeled change in head in the aquifer north of the well is higher than predicted in Section 5.3.5, with mounding of about 230 and 180 feet at distances of 1,000 and 2,000 feet, respectively.

The maximum modeled mounding near the well for Scenario 2 is about 750 feet. This is similar to the mounding immediately outside the well of 720 feet calculated in Section 5.3.5. The modeled change in head in the aquifer north of the well is higher than predicted in Section 5.3.5, with mounding of about 440 and 340 feet at distances of 1,000 and 2,000 feet, respectively.

## 5.7 Estimated Area Potentially Affected by ASR Activities

The conceptual model assumes the target aquifer is bound laterally by the Buck Creek fault, the Hood River fault, and an unnamed/unmapped fault near Northwestern Lake. The numerical modeling described above, with aquifer boundary conditions simulating this geologic structure, should provide a more reasonable estimate of the area potentially affected by ASR activities than the radius of influence calculations described in Section 5.3.5.

Based on the modeling of recharge and recovery for operational Scenario 1 and Scenario 2, the estimated area affected by ASR activities is presented on Figures 5.8 and 5.9, respectively. These areas are based on the 50-foot mounding contour from the 180-day recharge period. The model predicts mounding on the order of 50 feet could occur throughout the ASR target aquifer under both scenarios.

## 5.8 Location of Wells or Other Sources of Groundwater within the Area Affected by ASR Activities

Figures 5.8 and 5.9 show the location of wells completed within the project area, and those within the area potentially affected by ASR activities, according to the Ecology well log database. The figures also distinguish between ranges of well completion depths. As discussed in Section 5.4, there do not appear to be any other wells completed within the target ASR aquifer. Since Well No. 2 is confined (Sections 5.3.1.1 and 5.3.3) from nearby wells by the massive flow interiors of the Grande Ronde Basalt and the fault boundaries, the injection and extraction of water associated with ASR activities at Well No. 2 are not expected to have a significant impact on the head (static groundwater levels) in any of the nearby domestic wells. Well No. 2 has historically produced about 500 acre-feet per year, for several years after starting production in 2002 with no report of water level impacts in nearby wells. This suggests that the basalt flow interiors and fault boundaries do not exhibit significant leakage, even with long-term pumping. Additionally, water proposed for storage would be recovered over the 6 months following injection before a new injection cycle begins, reducing the potential for mounding effects to accrue over time.

## 5.9 Location of Natural Hazards, Surface Waters, and Springs Potentially Affected by ASR Project

WAC 173-157-120 specifies identification of natural hazards, surface waters, and springs potentially affected by the ASR project as part of the Hydrogeologic Conceptual Model. These same items are also required to be identified and evaluated as part of the Environmental Assessment (WAC 173-157-150), and, therefore, is presented in Section 6.

## 5.10 Chemical/Physical Composition of Source Water and Compatibility with Ambient Groundwater

This section presents a preliminary water quality analysis of prospective Buck Creek source water and ambient groundwater in the ASR target aquifer at Well No. 2 to identify potential “fatal flaws” in their compatibility if mixed during potential future ASR operations. In particular, compatibility is evaluated with regards to potential for adverse chemical reactions (e.g., mineral precipitation) clogging the ASR aquifer and production well, as well as compliance with the antidegradation policy under the state groundwater quality standards (WAC 173-200-030).

The analysis includes preliminary modeling of the geochemical interactions from mixing the waters within the assumed basalt ASR target aquifer and interaction with the aquifer rock matrix. The modeling makes use of the site-specific water quality data collected for this study and information on regional Grande Ronde Basalt mineralogy (Section 5.3.6), and serves as an initial “fatal flaw” analysis as one component in evaluating ASR feasibility for the City.

Samples of prospective source water for storage were collected from the Buck Creek source, as described in Section 5.6.3. At the time of sample collection (February 2010), construction of a slow sand filter treatment system for the source water had been completed, but a planned chlorination station was not. As a result, this initial analysis does not account for potential effects on source water chemistry resulting from planned chlorination of source water, including the potential generation of THM disinfection byproducts.

### 5.10.1 Comparison of Source Water and Groundwater Quality

The prospective Buck Creek source water and ambient groundwater are of very good quality, generally meeting drinking water standards (Table 5.4). The source water contains higher dissolved oxygen and lower TDS than ambient groundwater. Since the quality of the recharge water is generally better than the ambient groundwater quality, mixing due to successive ASR cycles may gradually improve groundwater quality in the target aquifer over the long term.

In terms of redox conditions, groundwater at Well No. 2 is a mixed (oxic-anoxic) system with predominantly oxygen ($O_2$) and manganese ($Mn^{4+}$) redox processes, based on the moderately high dissolved oxygen saturation (5 mg/L) and elevated manganese concentration without the presence of sulfide. Buck Creek is a mixed (oxic-anoxic) system with $O_2$ redox processes dominating, based on elevated dissolved oxygen, depressed sulfate, scarce dissolved metals, and no sulfide detected.

The well and source water samples each have relatively low concentrations of dissolved metals. However, other wells in the Grande Ronde Basalt (regionally) have shown relatively high concentrations of dissolved iron, typical of more reducing (suboxic to anoxic) zones than those at Well No. 2.

### 5.10.2 Modeling of Water Mixing

Geochemical reactions between ambient groundwater, treated source water, and aquifer mineralogy can potentially have unwanted effects on the host aquifer and the quality and quantity of recovered water in an ASR program. Listed below are some of the more common geochemical issues that may arise in association with ASR:

- Mixing of native water and storage water may cause mineral precipitation that can clog the ASR well’s open area and decrease well efficiency during storage and recovery.
- Aquifer mineral dissolution can occur, causing a decrease in water quality.

- Reactions between chlorinated drinking water and organic matter in native groundwater can temporarily generate disinfection byproducts (DBPs) including THMs and/or haloacetic acids (HAAs).

The likelihood of these issues occurring, based on data made available for this study, are addressed in the following sections.

#### 5.10.2.1 Potential for Groundwater Quality Changes with ASR

A PHREEQC thermodynamic equilibrium model (Parkhurst et al., 1980) was developed to evaluate the geochemical effects of mixing native groundwater and source water to be stored in the ASR target aquifer. Table 5.7 presents modeled groundwater compositions under different assumptions for the degree of Buck Creek (source) water-groundwater mixing and interaction with the aquifer matrix, including simple mixing with no interaction with the mineral phase, mixing with basalt mineral dissolution, and mixing with complete water-rock interaction (dissolution and precipitation). Model methods and analysis are discussed below.

A simple mixing model assuming 50 percent source water and 50 percent native groundwater suggests that simple mixing of waters will not negatively affect water quality (results presented under “No Mineral Phases” heading in Table 5.7). Temperature, pH, and redox conditions, as well as dissolved ion concentrations, do not vary greatly between the source and ambient groundwater, and the mixed water quality generally improves as the slightly fresher source water dilutes the native groundwater.

A second level of analysis was performed by modeling the mixing of waters in combination with equilibrium basalt mineral dissolution, but not accounting for re-precipitation of metal-oxide minerals. By ignoring the potential for metal-oxide precipitation and assuming equilibrium dissolution, this provides a very conservative assessment of the effects of mineral dissolution on water quality. Results are summarized in Table 5.7 under the heading “Dissolution of Basalt Mineral Phases.” This analysis indicates that some metals may be released into solution, primarily iron and to a lesser extent magnesium, calcium, aluminum, and manganese. However, as discussed in the following paragraphs, exposing dissolved iron, aluminum, and manganese to dissolved oxygen leads to the rapid precipitation of relatively insoluble metal oxides, such that precipitation reactions are predicted to quickly generate metal-oxide minerals, removing the freshly dissolved metals from solution and depositing them as coatings on mineral grains.

A third level of analysis was performed by modeling the mixing of waters in combination with potential basalt mineral dissolution and accounting for re-precipitation of metal-oxide minerals. In this analysis, the dissolution of basalt minerals assuming native groundwater-to-source-water mix ratios of 20:80, 50:50, and 80:20 were modeled, followed by modeling of precipitation of iron-, manganese-, and aluminum-oxide minerals. Results of these analyses are presented on Table 5.7 under the heading “Complete Mineral Interaction.” Redox conditions in the mixed groundwater are predicted to be more oxidizing than in native groundwater. The more oxidizing conditions are expected to cause precipitation of dissolved iron and manganese as oxide phases, thus removing them from the water. The model suggests that after mineral reactions have occurred, the ASR storage/native groundwater mix will remain of excellent quality.

#### 5.10.2.2 Potential for Mineral Precipitation

The PHREEQC model was used to evaluate the potential degree of metal-oxide mineral precipitation. Table 5.8 presents model estimated metal-oxide precipitation mass for the three groundwater-to-source-water mix ratios previously discussed. The modeled mixed groundwater oxide composition is predominantly iron-oxide (goethite), with minor amounts of manganese- and aluminum-oxides (birnessite and gibbsite). Of the three modeled mixes, the greatest amount of mineral precipitation is predicted in the 20:80 (Well No. 2:Buck Creek) mix ratio, where approximately 6.5 milligrams of metal-oxide precipitate are conservatively predicted to form per liter of mixed water. Assuming a metal-oxide density of 1.25 grams per cubic centimeter, this precipitated oxide mass would represent about 0.05 percent of the total volume of water injected per ASR cycle.

While the model suggests some mineral precipitation may occur, it is important to note that the metal-oxide precipitation predicted by the model first requires dissolution of metals from basalt minerals under equilibrium conditions. Dissolved iron and manganese were not detected in the Buck Creek source water and ambient groundwater contains relatively low concentrations of dissolved metals, suggesting that the precipitation would be limited. Actual concentrations are likely to vary from the modeled concentrations based on aquifer mineralogy, which was assumed for these simulations based on regional mineralogy data for the Grande Ronde Basalt (see Section 5.3.6). Geochemical testing during potential future ASR pilot testing would be recommended to confirm these model results.

### *5.10.3 Disinfection Byproducts and the Antidegradation Policy*

The Phase I Scope of Work under which this feasibility study was prepared includes a preliminary evaluation of strategies to address compliance with state Groundwater Quality Standards and AKART requirements. Water from the Buck Creek source currently meets these standards; however, because the chlorination station was not on-line at the time the source water was sampled it is not certain if chlorination will affect water quality. The primary concern is the potential for formation of DBPs. Since source water currently meets applicable standards and it is unknown whether DBPs will be present once the source water is chlorinated, it is premature to evaluate strategies to address compliance with state Groundwater Quality Standards.

Once the chlorination station is on-line, a sample of chlorinated Buck Creek water will be analyzed for water quality parameters, including DBPs. If Buck Creek source water fails to meet state Groundwater Quality Standards, an AKART analysis of source water treatment options would be completed as a component of the Phase II of this project. If DBPs are detected we expect that the antidegradation policy will be a regulatory issue of importance in permitting an ASR program for the City. The remainder of this section discusses the antidegradation policy and the potential for formation of DBPs by chlorination of Buck Creek water.

If the water to be stored during ASR has chemical constituents present at concentrations above that in the ambient groundwater in the storage aquifer, injection into storage could be interpreted to violate the antidegradation provision of the state's Ground Water Quality Standards. The state's groundwater antidegradation policy is stated as follows (WAC 173-200-030):

A. Existing and future beneficial uses shall be maintained and protected and degradation of groundwater quality that would interfere with or become injurious to beneficial uses shall not be allowed.

B. Degradation shall not be allowed of high quality groundwaters constituting an outstanding national or state resource, such as waters of national and state parks and wildlife refuges, and waters of exceptional recreational or ecological significance.

C. Whenever groundwaters are of a higher quality than the criteria assigned for said waters, the existing water quality shall be protected, and contaminants that will reduce the existing quality thereof shall not be allowed to enter such waters, except in those instances where it can be demonstrated to the department's satisfaction that:

    i. An overriding consideration of the public interest will be served; and

    ii. All contaminants proposed for entry into said groundwaters shall be provided with all known, available, and reasonable methods of prevention, control, and treatment ("AKART") prior to entry.

For an ASR program, compliance with the antidegradation policy under the state's Groundwater Quality Standards (Chapter 173-200 WAC) requires an analysis of the potential for production and fate of disinfection byproducts (DBPs). Byproducts from chlorine disinfection are THMs including chloroform, bromodichloromethane, dibromochloromethane, and bromoform, as well as HAAs including monochloroacetic acid, dichloroacetic acid, trichloroacetic acid, bromoacetic acid, and dibromoacetic acid. DBPs form from reaction of chlorine or bromine with organic matter in the water.

Drinking water disinfection byproducts are potentially carcinogenic and the EPA has established primary drinking water standards (MCLs) for total THMs and total HAAs of 80 and 60 µg/L, respectively. DBPs in groundwater are of particular interest with respect to the quality of treated source water to be stored, since they are generally not expected in ambient groundwater.

Historical water quality data from the Buck Creek source indicate the general absence of THMs in the prospective source water for an ASR project, with the exception of a low-level detection of chloroform (2.7 µg/L, below the state Groundwater Quality Standard of 7 µg/L). Total THMs in the Buck Creek sample collected in 1998 are 2.7 µg/L, well below the 80 µg/L criteria. This sample was of chlorinated source water before construction of the slow sand filter. Source water treated by the slow sand filter is expected to have lower turbidity and TOC concentrations, reducing the potential for generation of DBPs.

THM formation requires only a chlorine oxidant and humic substances (the latter represented here as TOC). Maintaining residual chlorine in the source water is required by state DOH regulation for public water systems. Concentrations of TOC, the other reactant needed for producing DBPs, is low in the Buck Creek source water after slow sand filtration (0.54 mg/L in February 2010). The low TOC content of the slow sand filter-treated source water suggests that there is limited likelihood of formation of DBP products in the source water prior to ASR injection. Additionally, because the TOC is low it is expected that the City will be able to maintain low residual chlorine concentrations in the treated source water while still meeting water treatment requirements.

Case study data (Pyne, 2005) indicate that DPBs may also form from the reaction of residual chlorine in the treated source water and dissolved organic carbon in the ambient groundwater. The TOC concentration in ambient groundwater at Well No. 2 is very low (less than the 0.5 mg/L reporting limit) and it is expected that residual chlorine in the treated source water will also be low, suggesting that formation of DBPs in the aquifer would be limited. The case study data generally suggest that THMs are degraded biologically in a matter of weeks under anoxic groundwater conditions, but persist under the more oxic conditions expected in the mixture of ambient groundwater and source water. In summary, although the potential for formation of DPBs in treated source water or from reaction of residual chlorine with TOC in ambient groundwater appears to be minimal; furthermore, if DBPs form they are unlikely to significantly attenuate in the aquifer.

If the water to be stored has constituents present at concentrations above that of the ambient groundwater (e.g., disinfection byproducts), the storage could be interpreted to violate the antidegradation provision of the state’s Groundwater Quality Standards (WAC 173-200-30). Since the prospective source water meets drinking water standards, beneficial use of the groundwater would not be degraded, thus meeting the intent of the Groundwater Quality Standards. Further, implementation of an ASR program could be interpreted to be in the overriding public interest, providing greater flexibility and reliability for meeting future peak municipal demand without diverting additional Buck Creek flows during the peak summer months. The state ASR rule states “The department shall give strong consideration to the overriding public interest in its evaluation of compliance with groundwater quality protection standards.” (WAC 173-157-200[2]).

# 6 Environmental Assessment

This section provides an assessment of potential impacts to the surrounding environment from implementing an ASR program. The environmental assessment can be used to establish whether a determination of nonsignificance or an environmental impact statement is required for an ASR project, per State Environmental Policy Assessment (SEPA) regulations (Chapter 197-11 WAC).

As discussed in Sections 3 and 5, the aquifer tapped by Well No. 2 is recommended as the preferred target aquifer for ASR. Therefore, this Environmental Assessment focuses on a discussion of potential impacts to the surrounding environment in the vicinity of Well No. 2 (ASR target area). The following information addresses requirements for an environmental assessment as per WAC 173-157-150.

## 6.1 Description of Environment within ASR Project Area

### *6.1.1 Proximity to Contaminated Areas*

The Ecology Toxics Cleanup Program's on-line databases (Cleanup Site Information) were reviewed to identify nearby areas of known soil or groundwater contamination. Five sites listed in the confirmed and suspected contaminated sites (CSCSs) database were identified within about 5 miles of the ASR target area (Table 6.1 and Figure 6.1). Each of these sites is confirmed as having soil contaminated by petroleum products and, in one case, non-halogenated solvents. Three of the sites are also confirmed as having contaminated groundwater. The identified sites are located at least 2.5 miles to the southeast (downgradient) of the ASR target area.

As discussed in previous sections (Section 5.2.2), the ASR target aquifer is in a well-bound fault block that is bound to the southeast by the unnamed/unmapped reverse fault in the vicinity of Northwestern Lake, which extends through Well No. 2. The ASR target aquifer is also vertically confined by the overlying massive, flow interiors of the Grande Ronde Basalt (Section 5.3.3). Therefore, for any contaminants to reach the target aquifer, groundwater would have to pass through the relatively impermeable unnamed/unmapped reverse fault in the vicinity of Northwestern Lake or the overlying massive basalt flow interiors. Furthermore, as discussed in Section 5.4, regional groundwater flow within the ASR project area is toward the Columbia River, such that any contaminants associated with the CSCSs are located downgradient of the target aquifer. For these reasons, the target aquifer would have very low susceptibility to both existing and potential future surface contamination sources.

### *6.1.2 Land Use*

Figure 6.1 identifies current land use in the ASR project area. A majority of the land use in the ASR project area consists of forest (deciduous, evergreen, and mixed), grasslands/ herbaceous, shrub/scrub, hay/pasture, or cultivated crops (primarily orchards). In the vicinity of the Well No. 2 and the target aquifer, the land use consists primarily of grasslands/herbaceous; however, there is also some developed land, ranging between low and high intensity, located approximately 1,000 feet east of Well No. 2. As discussed above, there are currently no contaminated sites in this area of developed land, with the closest contaminated site located approximately 2.5 miles to the southeast.

### 6.1.3 Surface Waters, Wetlands, and Floodplains

The ASR project area is located within the White Salmon River subbasin of WRIA 29, which is a major tributary to the Columbia River. The headwaters of the White Salmon River originate from snowmelt runoff and groundwater discharge along the flanks of Mount Adams (WPN and Mark Yinger Associates, 2002). The major tributaries to the White Salmon River in the ASR project area include, from upbasin (north) to downbasin (south): Hangman Creek, Gilmer Creek, Rattlesnake Creek, Indian Creek, Buck Creek, Mill Creek, and Little Buck Creek. The White Salmon River also receives runoff from numerous minor tributaries; however, these flows are considered insignificant relative to the major tributaries. As previously discussed in Section 5.1, additional groundwater contributions to the base flow of the White Salmon River in the ASR project area occur from the Quaternary deposits and possibly the CRBG, as observed between BZ Corner and Husum.

Figure 6.2 presents discharge data for the White Salmon River, measured downstream of Condit Dam, near Underwood (USGS Station No. 14123500), between January 2005 and December 2009. Table 6.2 presents average monthly discharge for three gaging stations on the White Salmon River and for two tributaries (Gilmer Creek and Rattlesnake Creek) for the existing periods of record. Based on Table 6.2, summer low flow periods generally occur in September and October before increasing from November through May.

In addition to the tributaries discussed above, the White Salmon River also receives runoff from numerous springs and seeps in the area. Approximately 22 springs were identified by Hennelly et al. (1994) upstream of the confluence of Gilmer Creek with the White Salmon River. Mark Yinger Associates (2002) indicated that springs and seeps along the slopes to the east of the White Salmon River in the vicinity of the City’s existing water supply wells (Well No. 1 and Well No. 2) generally occurred at the base of the Quaternary flood deposits (discussed in Section 5.2.2). Springs may also occur along the slopes of the White Salmon River where the water-bearing interflow zones of the Columbia River Basalt Group (CRBG) outcrop. Additional springs have been reported as discharging to the upper reaches of Buck Creek, north of the Columbia River fault and about 4 to 5 miles northwest of Well No. 2 (Futrell, Redford, Saxton, 1973).

Figure 6.3 illustrates the location of the Federal Emergency Management Agency (FEMA) 100-year floodplain defined within the ASR project area. The 100-year floodplain is limited to areas adjacent to the White Salmon River upstream of BZ Corner, and the White Salmon River at Northwestern Lake and downstream of Condit Dam. Well No. 2 is located approximately 200 feet above the 100-year floodplain near Northwestern Lake.

The USFWS National Wetlands Inventory (NWI) online database was searched to identify wetlands in the ASR project area. Mapped wetlands adjacent to the White

Salmon River are limited an approximately 1.1-acre riverine wetland located about 1/2 mile downstream of Northwestern Lake, a 1.5-acre forested wetland adjacent to Northwestern Lake, and to several small (less than 2 acre) riverine wetlands upstream of Northwestern Lake in the Husum area. Two freshwater emergent wetlands are also mapped on the uplands northeast of Northwestern Lake. No wetlands are mapped within the Buck Creek drainage.

## 6.2 Potential for Adverse Environmental Impacts within ASR Project Area

### *6.2.1 Natural Hazards Potentially Affected by ASR Project*

Natural hazards within the ASR project area that could potentially result from or be exacerbated by ASR operations include slope stability and erosion, the presence of floodplains, the ground deformation/subsidence, and faults. Based on the well-confined conditions of the target aquifer, ASR operations are not expected to result in significant changes in hydrogeologic conditions (e.g., increased water levels) outside of the target aquifer, and the potential risk of increased natural hazards is considered minimal.

Within the ASR project area, the Soil Conservation Service (SCS) categorizes soils as slight, moderate, severe, or very severe soil erosion hazards based on soil type and the presence of steep slopes. Mapped soil erosion hazards for the ASR project area are shown on Figure 6.3. Generally, soils with a slope of more than 65 percent are classified as very severe soil erosion hazards. Soils with a slope of between 30 and 65 percent are generally classified as severe soil erosion hazards. Soil with a slope of less than 30 percent are classified as moderate or slight soil erosion hazards. The closest area of severe or very severe soil erosion hazards is approximately 1,500 feet to the southwest of Well No. 2, along the White Salmon River south of Northwestern Lake.

Soil erosion hazards may be exacerbated during ASR operation if groundwater levels rise near ground surface during the recharge period. The ASR target aquifer is located at a depth of more than 845 feet bgs (Section 3), and vertically confined by the relatively massive flow interiors of the Grande Ronde Basalt (Section 5.3.3). The effectiveness of the confining unit is demonstrated by the artesian (free-flowing well) conditions at Well No. 2, where the initial shut-in pressure is equivalent to a water level of 226 feet above ground surface (Section 3.1). Based on the confined conditions, increasing the head in the target aquifer during storage is not expected to result in increased head or water levels in overlying aquifers. Therefore, the areas of geologically hazardous soils should not experience increased water levels and would not be affected by ASR operations.

As discussed in Section 6.1.3, Well No. 2 is located approximately 600 to 800 feet south and east of the 100-year floodplain that encompasses the White Salmon River in the vicinity of Northwestern Lake (Figure 6.3). Although the 100-year floodplain is located within the estimated area potentially affected by ASR activities (Section 5.7), no adverse impacts are expected based on the confined nature of the target aquifer.

Ground deformation is not expected to be a problem within the ASR project area. The target aquifer is composed of indurated basalt that should not be susceptible to deformation from increased hydraulic head during the storage period of ASR operations.

Although of limited occurrence and extent, sedimentary interbeds are present within the Grande Ronde Basalt. The interbeds are also indurated, and have limited potential for deformation.

As described in Section 5.2.2, the Buck Creek fault is located approximately 1,000 feet to the southwest of Well No. 2, and the unnamed/unmapped reverse fault in the vicinity of Northwestern Lake extends through Well No. 2. We are unaware of any evidence that either fault is an active seismic hazard. Even if it were, an ASR project is at no greater risk, nor are there are any greater implications if a seismic event does occur, than for a conventional production well. During ASR activities, large water level fluctuations would occur near the ASR well, and decrease in magnitude substantially with distance from the well. Based on groundwater modeling, we predict a head change on the order of 300 to 500 feet at the Buck Creek fault in response to hypothetical ASR recharge scenarios (Figures 5.8 and 5.9). Although this is a significant change in head, the target aquifer already has relatively high heads and is artesian (free-flowing) at Well No. 2. Therefore, the potential pressure change from ASR activities is not expected to pose additional risk for inducing movement along the fault.

### 6.2.2 Surface Waters Potentially Affected by ASR Project

Figure 6.3 presents the location of the White Salmon River and tributary streams within the ASR project area. The USGS has stream gaging stations on the White Salmon River at BZ Corner (Station No. 14122900), Husum (Station No. 14123000), and Underwood (Station No. 14123500). In addition, the City monitored flows at the Buck Creek diversion from November 2001 through April 2004. Figure 6.2 shows White Salmon River flows at Underwood between 2005 and 2010, while Figure 2.1 illustrates historical Buck Creek flows. There are no minimum instream flows for the White Salmon River and its tributaries defined in Washington State administrative rules. As previously discussed (Section 6.1.3), wetlands within the ASR project area are limited riverine and forested wetland areas adjacent to the White Salmon River and Northwestern Lake, and wetlands located in the uplands northeast of Northwestern Lake.

As summarized in Table 6.4, Ecology has listed several water body segments within the ASR project area as having impaired water quality (Categories 4 or 5). Water bodies listed as impaired and the basis for the listings include:

Impaired by a Non-Pollutant, Not Requiring a TMDL (Category 4C)

- White Salmon River below Condit Dam – Instream Flow

Impaired and Require a TMDL (Category 5)

- Gilmer Creek – Temperature and Fecal Coliform
- Indian Creek – Temperature
- Northwestern Lake – PCB in Fish Tissue
- Rattlesnake Creek – Temperature and Fecal Coliform
- White Salmon River near Gilmer Creek – Fecal Coliform

The remaining listed water body segments in the subbasin (Table 6.3) are listed as Waters of Concern (Category 2) for specific parameters. Of the six listings for impaired waters, four (Gilmer Creek, Indian Creek, Rattlesnake Creek, and White Salmon River near Gilmer Creek) are water bodies located at least 3 miles northeast of the ASR target aquifer and at least 2 miles upstream of the confluence of Buck Creek and the White Salmon River. The listing for the White Salmon River below Condit Dam was based on concerns about inadequate flows from Condit Dam raised by resource agencies during relicensing of the dam in 1993.

The most likely surface water features potentially affected by ASR activities are Northwestern Lake, the White Salmon River, and Buck Creek. Potential effects would be most likely to occur from increased seasonal surface water diversions at the Buck Creek source for ASR storage. The increased diversions would be limited to the period of November through April when flows in Buck Creek and the White Salmon River are generally higher, and would be less likely to adversely affect instream flows or habitat. The potential impacts to instream flows and habitat would be addressed during consultation with Indian tribes and applicable state agencies as part of processing a water right for the seasonal diversion from Buck Creek.

Storing water in the target aquifer during ASR operations is not expected to affect nearby surface water features. As previously discussed (Section 5.3.1.2), the target aquifer does not appear to be in hydraulic continuity with Northwestern Lake and the confined conditions of the aquifer are expected to isolate stored water from surface water bodies.

To satisfy the Columbia Basin Water supply grant funding requirements, a portion of the water made available by the ASR project would be conveyed permanently to Ecology for instream flow purposes and possible future appropriation (see Section 8). The method by which water will be conveyed to Ecology has not been finalized, but the City’s preferred option will likely include direct discharge of water from the ASR well (Well No. 2) to the White Salmon River. Ambient groundwater quality and the expected quality of water recovered via ASR from Well No. 2 meet applicable surface water quality criteria, and would not be expected to adversely affect surface water of the White Salmon River.

## 6.3 Conclusion

Based on the discussions above, the potential for adverse environmental impacts within the ASR project area are expected to be minimal as a result of the target aquifer being confined by the overlying massive, flow interiors of the Grande Ronde Basalt. The confined conditions and the presence of faults acting as vertical hydraulic barriers will isolate the ASR target aquifer from nearby surface waters, wetlands, and springs. Potential adverse impacts are likely limited to reduced surface water flows in Buck Creek and the White Salmon River from November through April from increased diversion of water from Buck Creek. Surface water flows in Buck Creek and the White Salmon River are generally higher over this period. Processing of the water rights to authorize ASR, including the new appropriation from the Buck Creek diversion, will require consultation with Indian tribes and state agencies to evaluate the effects on aquatic resources.

Based on this assessment, a determination of nonsignificance under SEPA appears reasonable for operation of an ASR system in the target area. Depending on the scope of construction for any additional infrastructure required to support an ASR system, additional SEPA review may be appropriate. The need for SEPA review can be considered if and when the City chooses to proceed with ASR pilot testing.

# 7 Project Monitoring Plan (Pilot Test Plan)

This section summarizes general elements of an ASR pilot test to further evaluate the feasibility of applying ASR as a water supply alternative to help meet City of White Salmon's water demands. A Quality Assurance Project Plan (QAPP) would be developed prior to pilot testing or collection of any new data. The QAPP will include a Sampling and Analysis Plan (SAP) that will describe the objectives, sampling and collection procedures, handling, testing methods, and reporting requirements for any additional physical or chemical data collection planned for the project.

## 7.1 Pilot Test Overview

An ASR pilot test involves testing the expected ASR program including water recharge, storage, and recovery. The testing includes baseline hydraulic testing to document baseline well performance for both recharge and recovery; water quality sampling and analysis of the recharge water, stored water in the aquifer, and recovered water; water level monitoring of the ASR well and storage aquifer; pressure monitoring of the pump and piping systems to ensure efficient operation; followed by successive cycles of operation under a range of conditions converging on an expected full-scale operational condition. The testing program would start simply, and gradually be adapted and lengthened in duration as testing information is collected and performance evaluated. This plan outlines an initial test program, which would then be refined for additional testing if the initial results are promising.

## 7.2 ASR Well and Piping

This section provides general recommendations for the wellhead, piping, and appurtenances. More detailed review and design would be warranted as part of the initial Phase II effort if the City chooses to proceed with ASR pilot testing.

Well No. 2 is the recommended target location for conducting ASR pilot testing. In 2009 to support potential use of Well No. 2 for ASR the City completed several improvements to Well No. 2 wellhead piping, the well field piping, and the intertie of the Buck Creek conveyance line with Childs Reservoir and the well field. As-built drawings of the current infrastructure are provided in Appendix B.

The Buck Creek conveyance line runs from the Buck Creek source diversion to the City of White Salmon distribution system (Figure 1.2), with interties to the wellfield and Childs Reservoir. Under normal operation, water from Buck Creek will be treated (slow sand filtration and chlorination) and conveyed by a 14-inch line to the intertie, where it is diverted to Childs Reservoir via a 20-inch line for storage. Water from the wellfield pump station can be simultaneously conveyed to the reservoir via a line that is tied-in to the same 20-inch line. Water from the reservoir is then conveyed back to the 14-inch line below the intertie for distribution in the City's system.

The existing intertie allows water from Buck Creek to be conveyed to the wellfield for injection at Well No. 2, while still providing supply to the City from Childs Reservoir. The system piping is such that water from Buck Creek could be conveyed simultaneously to the reservoir for storage/distribution and to the wellfield for injection at Well No. 2; however, additional pressure control valves may be required to control the proportion of flow conveyed to the reservoir and the wellfield. Evaluation, design, and installation of the necessary valves are recommended prior to performing the ASR pilot test.

Under normal well field operation, water from Well No. 1 and/or Well No. 2 is chlorinated and conveyed to a surge tank reservoir. Water from Well No. 2 can be collected either as natural artesian flow (without pump operation) or actively pumped. Water from the surge tank flows to the pump station and is then conveyed to Childs Reservoir via a single 20-inch line. During ASR injection, treated source water would be conveyed from the Buck Creek intertie to the wellfield by gravity flow, where a second intertie prior to the pump station allows water to be conveyed to the wellhead of Well No. 2. Because there is a single 20-inch line leading from the wellfield to the intertie with Childs Reservoir, Well No. 1 could not be used for water supply during ASR injection under the current configuration.

The Well No. 2 wellhead piping and valves were also improved to allow both injection and extraction of water. A pressure gauge and flow meter were installed to measure operating pressures and instantaneous recharge/withdrawal rates and cumulative flow volumes. The wellhead is plumbed to waste discharge to allow flushing of the piping (to remove pipe scale and sediment) prior to the start of each recharge cycle.

For ASR storage, water could be injected down the discharge piping of a line-shaft turbine pump and/or down the annulus between the well casing/borehole and the pump discharge pipe. Because the well is under artesian conditions potential problems with air entrainment due to cascading water and well screen fouling should be minimal. Recovery of water would occur as either artesian flow or under pumped conditions, as under current operation of Well No. 2.

The current conveyance system is capable of delivering water to Well No. 2 at a pressure of about 225 psi. As discussed in Section 5.3, injection at this pressure would result in estimated annual storage of about 175 acre-feet. Higher injection rates and storage volumes could be achieved if booster pumps were installed near the wellhead to increase the injection pressures. We recommend proceeding with the pilot test using the current system configuration without installing booster pumps; however, if pilot testing is favorable the benefit of installing booster pumps to increase storage should be evaluated.

## 7.3 Source Water

As described above, the source water for an ASR pilot test would be the same as that planned for full-scale ASR operation using chlorinated water from the Buck Creek diversion. This source water meets drinking water standards and would thus not degrade beneficial use of the target storage aquifer. As mentioned above, the distribution system next to the ASR well must always be flushed prior to beginning recharge to limit introduction of suspended solids into the well.

## 7.4 Baseline Well Testing

The first step of the ASR pilot test program would be baseline testing of the ASR well. The objective of the baseline testing is to verify the recharge and pumping capacities of the ASR well/pump/piping combination, both of which are used to define the subsequent pilot testing program. It also documents the well’s initial hydraulic performance as measured by specific capacity – flow rate in gpm divided by drawdown/mounding in feet – for both recharge and recovery; this baseline measurement allows evaluation of changes in well performance throughout operation.

The baseline testing would start with a one-day step-rate pumping test, involving pumping at progressively higher rates for relatively short durations to document initial specific capacity and well efficiency of the ASR well under varying pumping conditions. Following the step-rate pumping test, a one-day step-rate recharge test would be conducted. It would follow the same general process as the step-rate pumping test, but would involve injecting water into the ASR well at progressively higher rates. From this baseline testing, recharge and recovery rates would be chosen for the balance of the ASR pilot test.

A constant-rate pumping test would not be needed in this baseline testing since aquifer parameters and presence of aquifer boundaries would be determined from data collected during the subsequent long-term recharge and recovery testing cycles.

## 7.5 Recharge, Storage, and Recovery Cycles

We recommend the following recharge, storage, and recovery cycle for the initial pilot test:

- Recharge at a constant rate (to be determined from baseline testing) for 21 days (3 weeks);
- 28-day (4-week) storage period in which no recharge or recovery occurs, other than periodic minimal pumping for water quality sampling; and
- Recover at a constant rate (to be determined) for 28 days (4 weeks). The recovery rate and duration would be determined such that a substantially greater volume of water is recovered than recharged (e.g., 150 percent of recharge volume). This would allow a more complete assessment of mixing in the aquifer by evaluating water quality changes in the recovery water as recovery proceeds.

The above recharge, storage, and recovery time periods would serve as a reasonable starting point for the ASR pilot test. Results from this initial test could then lead to several additional cycles of testing under a range of conditions, with the expectation that the testing would eventually be equivalent to the expected full-scale operational condition. For example, Cities of Seattle and Walla Walla have conducted ASR pilot testing for many years, refining and optimizing operations over that period while putting the recovered water to beneficial use.

## 7.6 Hydraulic Monitoring

The purpose of an ASR pilot test is to collect sufficient information to predict the long-term performance of an ASR program. To that end, extensive hydraulic and water quality monitoring is necessary throughout the testing program. We recommend installing one monitoring well within a few hundred feet of the ASR well - within the expected extent of the recharge bulb - and completed across the same portion of the target aquifer as the ASR well (Well No. 2).

Although no nearby wells appear to be completed in the ASR target aquifer, monitoring of nearby wells completed in overlying aquifers is also important. Based on the confined nature of the target aquifer, there appears to be a very low probability of adverse impact to other wells, surface water, wetlands, slope stability etc. associated with ASR in the target aquifer. Monitoring of existing wells provides the empirical data needed to confirm that ASR poses no potential adverse impacts to neighboring wells and the environment, and thus determine the need for a project mitigation plan (WAC 173-157-160).

The following hydraulic monitoring elements would be conducted throughout the initial pilot test:

- Monitor water levels continuously (data logger) in the ASR well;
- Monitor barometric pressure continuously (data logger) at the ASR well to allow assessment and correction of water level change due to barometric change;
- Monitor water levels continuously in the target aquifer monitoring well (data logger);
- Monitor water levels in accessible neighboring wells completed in aquifers overlying the target aquifer. Potential wells include the City’s Well No. 1 and Observation Well Nos. 1 and 2.
- Recharge and recovery flow rates, both instantaneous (gpm) and cumulative volume (gallons).
- Monitor injection pressure at the ASR wellhead throughout recharge.
- Monitor pressure throughout the City’s distribution system in the vicinity of the ASR well.

Evaluation of the hydraulic monitoring data would include the following:

- Aquifer parameters (transmissivity, storativity) and identification of hydraulic boundaries to the aquifer.
- Magnitude and extent of recharge mounding and its dissipation with time during the storage period.
- Magnitude and extent of drawdown cone during pumping and its dissipation with time and distance.
- Water level changes at nearby well(s) in shallower water-bearing zones.
- Identification of affected area from ASR.

- Influences of external effects (barometric pressure, pumping of neighboring wells) on aquifer water levels.
- Capture zone extent during recovery. This likely cannot be determined without use of analytical or numerical groundwater modeling tools.
- Baseline well performance (as measured by specific capacity) in both recharge and recovery modes, and changes in that performance following completion of the full ASR cycle conducted in the initial test.
- Distribution system pressure response in the vicinity of the ASR well.

## 7.7 Water Quality Monitoring

Water quality monitoring will be performed in the ASR well throughout the pilot test for the purposes of:

- Documenting that water being recharged to the target aquifer meets drinking water standards and thus will not degrade beneficial use of the groundwater resource;
- Document the quality of recovered water to meet the City’s requirements for returning it to the distribution system;
- Evaluate how mixing of recharge water with ambient groundwater affects recoverability of water meeting drinking water standards and other City requirements, and use this information to adjust duration/rate of recharge and recovery, and duration of storage, to optimize recovery;
- Document fate of disinfection byproducts (THMs/HAAs), if present, and residual chlorine in the storage aquifer; and
- Evaluate water quality changes that can affect hydraulic performance of the ASR well.

Table 7.1 provides a preliminary water quality monitoring schedule (frequency and analytes) for the ASR well during baseline well testing (document ambient groundwater quality), and then during the recharge, storage, and recovery cycles during the initial pilot test. Water quality monitoring for each cycle of the pilot test is further discussed in the following sections. All water quality analyses will be performed at a laboratory certified by the Washington State Department of Ecology and Department of Health. Because ASR is being considered as an alternate municipal water source for the City, Table 7.1 includes a comprehensive analyte list to assess compliance with drinking water standards and the antidegradation policy in the initial test. We recommend that the monitoring schedule in Table 7.1 be adjusted, particularly constituents serving as prospective tracers of the recharge water (i.e., major anions and cations), following completion of the baseline well testing. Likewise, we recommend that the monitoring frequency and analytes be refined in subsequent testing cycles, based on results from the initial test, so as to collect those data of greatest value for documenting ASR performance.

### 7.7.1 Ambient Groundwater in Storage Aquifer

Analyses of ambient groundwater quality in the storage aquifer will be performed during the baseline step-rate recovery test. The baseline water quality analyses will document background groundwater conditions in the target aquifer preceding the initial recharge cycle. During the baseline step-rate recovery test, the field parameters (temperature, pH, dissolved oxygen, redox potential, specific conductivity) would be monitored at approximately 15-minute intervals (expected pumping duration of up to 8 hours). In addition to the collection of field parameters, a one-time sampling event will be performed near the end of the baseline step-rate recovery test. This sample will be analyzed for a comprehensive suite of general chemistry constituents and disinfection byproducts (Table 7.1).

### 7.7.2 Recharge Source Water

Water quality analyses of the recharge source water will be performed during the 21-day recharge cycle of the initial pilot test. Field parameters will be measured daily to evaluate general water quality changes in the source water over the recharge duration. Total suspended solids (TSS) will also be analyzed daily to closely track the mass of suspended solids entering the ASR well during recharge. The other constituents in the monitoring program will be analyzed both at the start of the recharge cycle and at an approximate 7-day interval thereafter during the recharge cycle (total of four sample events). Disinfection byproducts will be monitored to document the range of concentrations in the recharge water, and ensure compliance with drinking water standards and the antidegradation policy. Prospective tracers will be monitored during the recharge cycle to document their ranges of concentrations for comparison during the storage and recovery cycles. The comprehensive list of general water quality and drinking water parameters will document the range of concentrations in the source water and confirm that the source water meets drinking water standards.

### 7.7.3 Stored Water

Water quality monitoring of water stored in the aquifer will occur during the 28-day storage cycle of the pilot test. Field parameters, prospective tracers, and disinfection byproducts will be sampled at an approximately 7-day interval during the storage cycle. Water quality analyses performed during the storage cycle of the pilot test are primarily meant to monitor changes in constituent concentrations from physical mixing and/or chemical reactions between the source water and ambient groundwater. Disinfection byproducts are monitored to ensure they remain below drinking water standards, and to evaluate potential concentration changes caused by their creation (reaction of residual chlorine with natural organic matter) and/or degradation and dispersion in the storage aquifer. The full list of general water quality and drinking water parameters will be analyzed at an approximately 14-day interval to document potential concentration changes relative to the recharge water that may occur during storage (Table 7.1).

### 7.7.4 Recovered Water

Water quality monitoring of recovered water will occur during the 28-day recovery cycle of the initial pilot test. Field parameters will be measured daily throughout recovery to document general water quality changes. Disinfection byproducts will be sampled and analyzed at an approximately 3-day interval during the recovery cycle to document compliance with drinking water standards. Tracer constituents will also be analyzed at an approximately 3-day interval, to estimate the proportion of recharge water and ambient groundwater being recovered over time. The full list of general water quality/drinking water parameters will be analyzed at an approximately 7-day interval to document water quality changes throughout recovery and how potentially changing water quality compares with drinking water standards (Table 7.1).

### *7.7.5 Water Quality Monitoring Data Evaluation*

Reported laboratory analytical results will be qualified by the laboratory to identify quality control (QC) concerns in accordance with the specifications of the analytical methods. An independent data quality review summary can also be completed.

The water quality data would be evaluated to evaluate concentrations in the recharge, stored, and recovered waters relative to drinking water standards and the antidegradation policy. In addition, data from the complete program should be evaluated thoroughly to document water quality mixing and help assess recoverability of the recharge water. The fate of disinfection byproducts in the aquifer can be illustrated by plotting concentrations with concentrations of residual chlorine over time throughout the full initial test program.

## 7.8 Threshold Values

Threshold values for operation of the initial ASR pilot test include:

- Recharge water will meet drinking water standards.
- Recovery pumping rates will be maintained so as to not dewater the pump in the ASR well.
- Recovery water returned to the City’s water distribution system will meet state drinking water standards for Group A public water systems and other requirements that the City may have.

## 7.9 Reporting of Initial Pilot Test

Following completion of the initial pilot test outlined above, a report of test findings would be prepared for review and discussion prior to proceeding with subsequent testing cycles. The report would include the results and evaluation of the hydraulic and water quality monitoring from the initial test as outlined above. The report should make preliminary conclusions regarding feasible recharge and recovery rates for the ASR well, water quality relative to drinking water standards throughout the duration of the ASR cycle, recoverability of the water recharged, and available storage volume using Well No. 2. If warranted based on water quality differences between source and aquifer ambient water qualities and observed changes in the recovered water, geochemical modeling could also be conducted to evaluate geochemical reactions (e.g., mineral precipitation) that could reduce hydraulic performance of the ASR well. The report should also make recommendations for subsequent testing, including revisions to hydraulic and/or water quality monitoring.

# 8 Conceptual Project Operation Plan

Although it is premature within a feasibility study to present a plan for operation of an ASR system (as per WAC 173-157-130), this section provides a general concept to illustrate how the City of White Salmon might apply ASR as an additional water source to help meet its future water demands. A more detailed and accurate operation plan would need to be developed following pilot testing of an actual ASR system, should the City choose to proceed with ASR based on demonstrated success of pilot testing.

In concept, application of ASR by the City of White Salmon would involve the following general steps:

- Convey treated water from the Buck Creek diversion in excess of water supply needs during the months of November through April to the wellfield. Based on the information in Section 2.4, it is anticipated that about 600 gpm or 480 acre-feet of treated Buck Creek water might be available for storage during the months of November through April under current system demands. The City would need to secure a seasonal water right to divert water from Buck Creek in excess of its current authorization;
- Recharge the water into the aquifer tapped by Well No. 2; and
- Subsequently pump the full quantity of stored water from the ASR well during the peak demand months (e.g., June through September).

The quantity of water that can be stored would depend ultimately on achievable injection pressures, the efficiency of Well No. 2, and the surrounding aquifer conditions. Based on existing well performance data and the range of expected injection pressures, annual storage volumes on the order of 175 to 340 acre-feet were estimated for this feasibility study. Actual storage volumes would be determined through pilot testing.

Assuming the upper end of the range of storage volumes is achievable and a new seasonal water right for diversion from Buck Creek of 340 acre-feet is issued for the ASR project, the City would continuously divert water at the Buck Creek diversion. During the months of November through April, the City would use about 320 acre-feet (average of about 400 gpm) to meet demand (or supplement with Well No. 1 supply) while 340 acre-feet of water (425 gpm) is stored via the ASR well. The combined quantity of 825 gpm is well below the 1,000 gpm treatment capacity of the Buck Creek diversion.

Stored water could be withdrawn from Well No. 2 as early as May after the storage period ends. However, it is likely that most of the recovery of stored water would occur from June through September, when system demands are highest. Assuming all of the stored water is recovered over this period, the average pumping rate would be about 630 gpm to remove 340 acre-feet. Well No. 2 is currently capable of yielding about 600 gpm and, with the increase pressures produced during the storage period, should be able to produce higher yields during the recovery period.

Throughout the non-storage months of May through October, demand will be met from a combination of Buck Creek and Well No. 1 and Well No. 2. Buck Creek will likely be used to the full treatment capacity, since it is the City's lowest cost source (gravity-supplied, no pumping costs).

Under the Columbia Basin Water supply grant funding requirements, a portion of the net water savings or "water supplies" resulting from implementation of the ASR project (i.e., water stored and recovered via ASR) shall be permanently conveyed to Ecology. The quantity of water to be conveyed to Ecology is proportionate to Ecology's contribution to the total cost of the project. It is our understanding that 1/3 of the water conveyed to Ecology will be dedicated to instream flows while the remaining 2/3 of the water conveyed to Ecology will be available for appropriation for out-of-stream uses.

The method by which Ecology's portion of the net water savings will be provided has not been finalized, but will be formalized as part of a memorandum of agreement (MOA) to be developed between Ecology and the City. The MOA will also define the timing when Ecology's portion of water will be provided (e.g., a fixed schedule or a variable schedule determined each year). The City's preferred option will likely be to provide Ecology's portion of water as discharge from the ASR well (Well No. 2) directly to the White Salmon River. There is currently a settling pond and waste discharge pipe extending from Well No. 2 to the river; it is expected that this existing infrastructure would be sufficient to convey Ecology's portion of water to the river. One advantage of this approach is that Well No. 2 is under artesian conditions, such that the City could provide water from the well as passive flow without incurring pumping expenses, assuming the passive flow rates are high enough.

# 9 Limitations

Work for this project was performed and this report prepared in accordance with generally accepted professional practices for the nature and conditions of work completed in the same or similar localities, at the time the work was performed. It is intended for the exclusive use of City of White Salmon for specific application to the referenced property. This report does not represent a legal opinion. No other warranty, expressed or implied, is made.

# 10 References

Ames, L.L., 1980, Hanford Basalt Flow Mineralogy: Richland, Washington, Pacific Northwest, Laboratory Report No. PNL-2847, 447 p.

Aspect Consulting, 2009, Hydrologic Report, Husum/BZ Corner Subarea, Prepared for Klickitat County Planning Department, November 4, 2009.

Bauer, H.H., J.J. Vaccaro and R.C. Lane, 1985, Maps showing ground-water levels in the Columbia River Basalt and overlying material, spring 1983, southeastern Washington, U.S. Geological Survey Water-Resources Investigations Report 84-4360.

Bauer, H.H., and Hansen, A.J., Jr., 2000, Hydrology of the Columbia Plateau Regional Aquifer System, Washington, Oregon, and Idaho: U.S. Geological Survey Water-Resources Investigations Report 96-4106.

Bela, J. L., 1982, Geologic and Neotectonic Evaluation of North-Central Oregon: The Dalles 1º x 2º Quadrangle. Oregon Department of Geology and Mineral Industries, GMS-27.

Bell Design Company, 2002, Buck Creek Flow Measurements, Prepared for City of White Salmon, June 25, 2002.

Department of Energy, 1988, Site Characterization Plan Consultation Draft, Reference, Repository Locations, Hanford Site, Washington, U.S. Department of Energy Office of Civilian Radioactive Waste Management, DOE/RW-1064.

Driscoll, F.G. 1986, Groundwater and Wells (2nd Edition), Johnson Screens, St. Paul, Minnesota.

Federal Register, 2010, Volume 75, Number 9, January 14, 2010.

Fetter, C.W., 2001, Applied Hydrogeology (4th Edition), Prentice-Hall Inc., Upper Saddle River, New Jersey.

Futrell, Redford, Saxton, 1973, Town of White Salmon, Washington, A Report on an Engineering Design Study and preliminary Design of Water System Facilities, December 17, 1973.

Hansen, Jr. A.J., J.J. Vaccaro, and H.H. Bauer, 1994, Ground-Water Flow Simulation of the Columbia Plateau Regional Aquifer System, Washington, Oregon, and Idaho, U.S. Geological Survey Water-Resources Investigations Report 91-4187.

Korosec, M.A., compiler, 1987, Geologic map of the Hood River quadrangle, Washington and Oregon: Washington Division of Geology and Earth Resources Open File Reports 87-6.

Mark Yinger Associates, 1999, Aquifer Test Report - Power House Road Test Well - City of White Salmon, prepared for Bell Design Company, January 22, 1999.

Mark Yinger Associates, 2001, Aquifer Test Report - Production Well #2 - City of White Salmon, prepared for Bell Design Company, May 21, 2001.

Mark Yinger Associates, 2002, City of White Salmon Wellhead Protection Plan, prepared for City of White Salmon Director of Public Works, May 6, 2002.

Myers, C.W. and S.M. Price 1981, Subsurface Geology of the Cold Creek Syncline. Prepared for U.S. Department of Energy by Rockwell Hanford Operations, Richland, Washington, RHO-BWI-ST-14.

Parkhurst, D.L., Thorstenson, D.C., and Plummer, L.N., 1980, PHREEQE--a computer program for geochemical calculations: U.S. Geological Survey Water-Resources Investigations Report 80-96, 195 p. (Revised and reprinted, 1990.)

Pyne, R.D.G., 2005, Aquifer Storage Recovery: A Guide to Groundwater Recharge through Wells, ASR Press, 608 p.

Reidel, S.P., G.R. Scott, D.R. Bazard, R.W. Cross, and B. Dick, 1989, Post-12 Million Year Clockwise Rotation in the Central Columbia Plateau, Washington, Tectonics, Vol. 3, No. 2, Pages 251-273, April 1984.

Steinkampf, W.C., 1989, Water-Quality Characteristics of the Columbia River Regional Aquifer System in Parts of Washington, Oregon, and Idaho, USGS Water-Resources Investigation report 87-4242.

Steinkampf, W.C., Hearn, P.P., Jr., 1996, Ground-Water Geochemistry of the Columbia Plateau Aquifer System, Washington, Oregon, and Idaho, USGS Open-File Report 95-467.

Tolan, T.L., Reidel, S.P., Beeson, M.H., Anderson, J.L., Fecht, K.R., and Swanson, D.A., 1989, Revisions to the Estimates of the Areal Extent and Volume of the Columbia River Basalt Group, in Reidel, S.P., and Hooper, P.R., eds, Volcanism and Tectonism in the Columbia River Flood-Basalt Province. Geological Society of America, Special Paper 239.

Vaccaro, J.J., 1999, Summary of the Columbia Plateau Regional Aquifer-System Analysis, Washington, Oregon, and Idaho, U.S. Geological Survey Professional Paper 1413-A.

WPN and Mark Yinger Associates, 2002, Wind/White Salmon Watershed (WRIA 29) - Level 1 Technical Assessment, Prepared by Envirovision Corporation for WRIA 29 Planning Unit, January 2003.

Wellman, Mike, 2009, personal communication.

Whiteman, K.J., J.J. Vaccaro, J.B. Gonthier and H.H. Bauer, 1994, The Hydrogeologic Framework and Geochemistry of the Columbia Plateau Aquifer System, Washington, Oregon, and Idaho. U.S. Geological Survey Professional Paper 1413-B.

# Table 2.1 - Water Right Summary

City of White Salmon ASR, White Salmon, Washington

**Existing Water Rights**

| Water Right Document Number | Document Type | Source Name | Priority Date | Qi | Qa (acre-feet) |
|---|---|---|---|---|---|
| SWC3474 | Certificate | Buck Creek | 5/18/1923 | 2 cfs | not listed |
| CS4-SWC3474 | Change ROE | Well Field | 4/9/1999 | 1,795 gpm | 688 |
| SWC7109 | Certificate | Buck Creek | 2/13/1957 | 2 cfs | 688 |
| CS4-SWC7109 | Change ROE | Well Field | 4/9/1999 | 1,795 gpm | 688 |
| SWC10252 | Certificate | Jewett Springs | 2/27/1963 | 1 cfs | 688 (non-additive) |

**Pending Applications**

| Water Right Document Number | Document Type | Source Name | Priority Date | Qi | Qa (acre-feet) |
|---|---|---|---|---|---|
| G4-32539 | Application | Up to 3 wells | 4/28/1997 | 1,500 gpm | 1,600 |
| G4-32540 | Application | Up to 3 wells | 4/28/1997 | 1,500 gpm | 1,600 |
| G4-32541 | Application | Up to 3 wells | 4/28/1997 | 1,500 gpm | 1,600 |
| S4-35068 | Application | Buck Creek | 9/20/2005 | 3,000 gpm | 1,500 |

Notes:

Qi - Maximum authorized instantaneous diversion or withdrawal

Qa - Maximum authorized annual diversion or withdrawal

gpm - gallons per minute

cfs - cubic feet per second

The Change ROEs for Certificate Nos. 7109 and 3474 limited the combined instantaneous rate and annual use under these certificates to 4 cfs (1,795 gpm) and 688 acre-feet per year, respectively.

The Change ROEs for Certificate Nos. 7109 and 3474 added Well No. 1 and Well No. 2 as additional points of withdrawal. The Buck Creek source originally authorized under these rights was maintained as a point of diversion.

The annual quantity authorized under Certificate No. 10252 is non-additive to the quantities authorized under Certificate Nos. 7109 and 3474 and associated Change ROEs.

Application S4-35068 originally requested the White Salmon River as the source of appropriation. The application was amended to specify the Buck Creek diversion as the proposed source.

# Table 2.2 - Buck Creek Flows and City of White Salmon Water Use

Aquifer Storage and Recovery Feasibility Assessment
White Salmon Washington

| Month | Buck Creek Flows (2001 - 2004) | | | City's Usage (2003 - 2008) | | |
|---|---|---|---|---|---|---|
| | Years of Data | Monthly Average (cfs) | Average Monthly Total (acre-ft) | Monthly Average (cfs) | Monthly Average (gpm) | Average Monthly Total (acre-ft) |
| **January** | **3** | 61.0 | 3,749 | 0.9 | 412 | 56.5 |
| **February** | **3** | 42.7 | 2,392 | 0.8 | 379 | 47.4 |
| **March** | **3** | 71.0 | 4,368 | 0.8 | 369 | 50.5 |
| **April** | **3** | 61.0 | 3,630 | 0.9 | 404 | 53.6 |
| **May** | **2** | 51.8 | 3,187 | 1.3 | 564 | 77.3 |
| **June** | **2** | 26.1 | 1,553 | 1.7 | 771 | 102.2 |
| **July** | **1** | 20.4 | 1,252 | 2.1 | 950 | 130.2 |
| **August** | **2** | 20.5 | 1,264 | 2.0 | 884 | 121.1 |
| **September** | **2** | 20.5 | 1,258 | 1.4 | 644 | 85.3 |
| **October** | **2** | 20.6 | 1,269 | 1.0 | 455 | 62.3 |
| **November** | **3** | 18.2 | 1,081 | 0.9 | 389 | 51.6 |
| **December** | **3** | 30.7 | 1,885 | 0.8 | 362 | 49.5 |
| **Yearly Total** | | **-** | **26,888** | **-** | **-** | **888** |

## Table 4.1 - Summary of Existing Surface Water Rights

Aquifer Storage and Recovery Feasibility Assessment
White Salmon, Washington

| File # | Cert # | Name | Doc | Priority Date | Purpose | Qi | UOM | Qa | Ir Acres | TRS | QQ/Q | Src's | 1stSrc |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| S4-*15790CWRIS | 7846 | DAVISON G E | Cert | 12/4/1959 | DS | 0.01 | CFS | | | 03.0N 10.0E 01 | | 1 | UNNAMED STREAM |
| S4-30120CWRIS | | CORBEILLE R & B | Cert | 11/30/1989 | IR,DS | 0.02 | CFS | 1 | 0.5 | 03.0N 10.0E 01 | SW/NW | 1 | UNNAMED SPRING |
| S4-*02336CWRIS | 1545 | READ T E | Cert | 6/19/1928 | IR,DS | 0.05 | CFS | | 7 | 03.0N 10.0E 02 | | 1 | UNNAMED SPRING |
| S4-25827GWRIS | | HALLETT BRIAN | Cert | 4/3/1978 | IR | 0.04 | CFS | 8 | 2.5 | 03.0N 10.0E 02 | SE/NW | 1 | UNNAMED STREAM |
| S4-28887CWRIS | | HALLETT BRIAN | Cert | 3/12/1986 | ST,DS | 0.13 | CFS | 1 | | 03.0N 10.0E 02 | SE/NW | 2 | UNNAMED SPRING |
| S4-29171CWRIS | | HALLETT BRIAN | Cert | 12/26/1986 | IR | 0.09 | CFS | | 2.5 | 03.0N 10.0E 02 | SE/NW | 1 | UNNAMED STREAM |
| S4-23463CWRIS | | Mt Adams Orchard Corporation | Cert | 7/1/1974 | IR | 0.7 | CFS | 196 | 70 | 03.0N 10.0E 10 | NE/NW | 1 | UNNAMED SPRING |
| S4-25155CWRIS | | Mt Adams Orchard Corporation | Cert | 4/21/1977 | IR | 0.7 | CFS | 196 | 70 | 03.0N 10.0E 10 | NW/NE | 1 | NORTHWESTERN LAKE |
| S4-*18921CWRIS | 9719 | CONNOLLY M J | Cert | 3/24/1965 | IR | 0.1 | CFS | 36 | 9 | 03.0N 10.0E 11 | NW/SW | 1 | UNNAMED SPRING |
| S4-26815CWRIS | | YOUNGBLOOD AMOS D | Cert | 5/16/1980 | DS | 0.02 | CFS | 1 | | 03.0N 10.0E 11 | NW/SE | 1 | UNNAMED SPRING |
| S4-01272CWRIS | | HENDERSON C V | Cert | 7/12/1962 | IR,DS | 0.33 | CFS | 81 | 40 | 03.0N 10.0E 12 | NW/NE | 2 | UNNAMED SPRING |
| S3-+21178CWRIS | | ASTON W W SR | Cert | 5/18/1973 | IR | 0.01 | CFS | 4.6 | 10 | 03.0N 10.0E 14 | SW/SE | 1 | UNNAMED SPRING |
| S3-+21883CWRIS | | CONNOLLY ERSULA | Cert | 9/18/1973 | ST,DS | 0.01 | CFS | 2 | | 03.0N 10.0E 14 | SW/SE | 1 | UNNAMED SPRING |
| S4-*12157CWRIS | 6483 | US Dept Fish & Wildlife | Cert | 2/26/1953 | FS | 30 | CFS | | | 03.0N 10.0E 14 | SW/NW | 1 | WHITE SALMON RIVE |
| S4-*01692CWRIS | 174 | CLARK H C | Cert | 4/20/1926 | IR,DS | 0.25 | CFS | | 15 | 03.0N 10.0E 24 | | 1 | UNNAMED SPRING |
| S3-+00900CWRIS | | Mt Adams Orchard Corporation | Cert | 7/16/1968 | IR,DM | 0.09 | CFS | 44.6 | 15 | 04.0N 10.0E 01 | NW/SE | 1 | UNNAMED SPRING |
| S3-+00901CWRIS | | Mt Adams Orchard Corporation | Cert | 7/16/1968 | IR,DM | 0.1 | CFS | 44.8 | 15 | 04.0N 10.0E 01 | SE/SE | 1 | UNNAMED SPRING |
| S3-+00903CWRIS | | Mt Adams Orchard Corporation | Cert | 7/16/1968 | DM | 0.04 | CFS | 5.6 | | 04.0N 10.0E 01 | SE/SE | 1 | UNNAMED SPRING |
| S3-+00905CWRIS | | Mt Adams Orchard Corporation | Cert | 7/16/1968 | IR,DM | 0.2 | CFS | 70.6 | 25 | 04.0N 10.0E 01 | | 1 | UNNAMED SPRING |
| S3-+00907CWRIS | | Mt Adams Orchard Corporation | Cert | 7/16/1968 | IR,DM | 0.2 | CFS | 84.1 | 30 | 04.0N 10.0E 01 | S2/NE | 1 | UNNAMED SPRING |
| S3-+00909CWRIS | | Mt Adams Orchard Corporation | Cert | 7/16/1968 | IR,DM | 0.13 | CFS | 58.1 | 20 | 04.0N 10.0E 01 | SE/SW | 1 | UNNAMED SPRING |
| S3-+00910CWRIS | | Mt Adams Orchard Corporation | Cert | 7/31/1968 | IR,DM | 0.2 | CFS | 70.6 | 25 | 04.0N 10.0E 01 | | 1 | HANGMAN CREEK |
| S4-*00781CWRIS | 1128 | MAY G H | Cert | 7/31/1922 | IR | 0.5 | CFS | | 20 | 04.0N 10.0E 01 | SW/SW | 1 | GILMER CREEK |
| S4-*04507CWRIS | 1575 | RAYBURN U W ET AL | Cert | 3/4/1938 | DM | 0.1 | CFS | | | 04.0N 10.0E 01 | SE/SW | 1 | UNNAMED SPRING |
| S4-*05904CWRIS | 2705 | STRODE B A / C F | Cert | 9/24/1943 | IR | 0.2 | CFS | | 12 | 04.0N 10.0E 01 | SW/SW | 1 | GILMER CREEK |
| S4-*19515CWRIS | 9792 | GROSS W A | Cert | 3/11/1966 | DS | 0.01 | CFS | 1 | | 04.0N 10.0E 01 | SW/NW | 1 | UNNAMED SPRING |
| S4-*00628CWRIS | 1188 | MCFARLAND J M | Cert | 5/25/1921 | IR,DS | 0.3 | CFS | | 15 | 04.0N 10.0E 02 | | 1 | PECK CR * |
| S4-*06006CWRIS | 2122 | HARRISON C R | Cert | 4/20/1944 | IR,DS | 0.02 | CFS | | 1 | 04.0N 10.0E 02 | NW/SE | 1 | SPRING CREEK |
| S4-*15736CWRIS | 8168 | KYTE A D ET UX | Cert | 10/26/1959 | IR,DM | 0.06 | CFS | 9 | 3 | 04.0N 10.0E 02 | SW/NE | 1 | PECK CR * |
| S4-*15737CWRIS | 8218 | GROSS G E ET UX | Cert | 10/26/1959 | DM | 0.03 | CFS | | | 04.0N 10.0E 02 | SE/NW | 1 | PECK CR * |
| S4-*16281CWRIS | 9135 | KELLY C / M | Cert | 8/18/1960 | IR,DS | 0.06 | CFS | 10 | 5 | 04.0N 10.0E 02 | | 2 | UNNAMED SPRING |
| S4-01162CWRIS | | MEYERS LAWRENCE B | Cert | 7/28/1964 | DM | 0.03 | CFS | 3 | | 04.0N 10.0E 02 | SW/SE | 1 | UNNAMED SPRING |
| S4-30135 | | Mt Adams Orchard Corporation | Cert | 1/2/1990 | IR | 2.5 | CFS | 970 | 805 | 04.0N 10.0E 02 | SE/SE | 1 | WHITE SALMON RIVE |
| S4-*03971CWRIS | 5272 | B Z Corners Water Co | Cert | 5/1/1934 | DM | 0.05 | CFS | | | 04.0N 10.0E 03 | | 1 | B Z CR * |
| S3-+21570CWRIS | | HAYS VETA | Cert | 8/1/1973 | DS | 0.01 | CFS | 1 | | 04.0N 10.0E 11 | E2/NW | 2 | UNNAMED SPRING |
| S4-*00812CWRIS | 645 | COLBURN C L | Cert | 8/29/1922 | IR,DS | 0.5 | CFS | | 20 | 04.0N 10.0E 11 | N2/SW | 1 | OLD LOGGING CAMP |
| S4-*02573CWRIS | 1512 | MAY G H | Cert | 5/3/1929 | IR,DS | 0.1 | CFS | | 5 | 04.0N 10.0E 11 | SE/NW | 1 | CEDAR CREEK |
| S4-*04579CWRIS | 2357 | MCILROY M S | Cert | 8/2/1938 | IR,DS | 0.1 | CFS | | 12 | 04.0N 10.0E 11 | SE/SW | 1 | EAST SPRING CR * |
| S4-*13303CWRIS | 7197 | DE LAY A O | Cert | 2/23/1955 | IR,DS | 0.01 | CFS | | 1 | 04.0N 10.0E 11 | NW/SE | 1 | UNNAMED SPRING |
| S4-*13304CWRIS | 6881 | BAUGHER E J | Cert | 2/28/1955 | IR,DS | 0.01 | CFS | | 1 | 04.0N 10.0E 11 | NW/SE | 1 | UNNAMED SPRING |
| S4-*14543CWRIS | 7348 | CHAPMAN T A | Cert | 10/14/1957 | DS | 0.01 | CFS | | | 04.0N 10.0E 11 | NW/SE | 1 | UNNAMED SPRING |
| S4-*15669CWRIS | 7708 | JOHNSON M L ET AL | Cert | 8/28/1959 | DM | 0.04 | CFS | | | 04.0N 10.0E 11 | NW/SE | 1 | UNNAMED SPRING |
| S4-*15676CWRIS | 9003 | ARNETT W H / M H | Cert | 9/1/1959 | IR,DS | 0.03 | CFS | 3 | 1 | 04.0N 10.0E 11 | NE/NE | 1 | UNNAMED SPRING |
| S4-*15738CWRIS | 8160 | BEASLEY O M | Cert | 10/27/1959 | IR,DS | 0.01 | CFS | 3 | 1 | 04.0N 10.0E 11 | NE/NE | 1 | UNNAMED SPRING |
| S4-*15740CWRIS | 8161 | BEASLEY I G ET UX | Cert | 10/27/1959 | IR,DS | 0.01 | CFS | 3 | 1 | 04.0N 10.0E 11 | NE/NE | 1 | UNNAMED SPRING |
| S4-*15741CWRIS | 8177 | SKIDMORE J | Cert | 10/27/1959 | DS | 0.01 | CFS | | | 04.0N 10.0E 11 | NE/NE | 1 | UNNAMED SPRING |
| S4-*15742CWRIS | 8162 | GROSS H | Cert | 10/27/1959 | IR,DS | 0.01 | CFS | 3 | 1 | 04.0N 10.0E 11 | NE/NE | 1 | UNNAMED SPRING |
| S4-28939CWRIS | | MCCLAIN C & G | Cert | 5/16/1986 | DS | 0.01 | CFS | 1 | | 04.0N 10.0E 11 | W2/NE | 1 | MCFARLAND CREEK |
| S4-29139CWRIS | | NEWTON LORIETA | Cert | 10/20/1986 | DS | 0.01 | CFS | 1 | | 04.0N 10.0E 11 | W2/NE | 1 | MCFARLAND CREEK |
| S4-*03234CWRIS | 1459 | BIESANZ W A | Cert | 11/19/1930 | IR,DS | 0.05 | CFS | | 2 | 04.0N 10.0E 12 | SW/NW | 1 | CARSTENS CR * |
| S4-*03767CWRIS | 1074 | WALLACE F D | Cert | 12/24/1932 | IR,DS | 0.07 | CFS | | 5 | 04.0N 10.0E 12 | SW/NW | 1 | CARSTENS CR * |
| S4-*20025CWRIS | 10518 | WEBER DON E | Cert | 12/27/1966 | IR | 0.8 | CFS | 120 | 40 | 04.0N 10.0E 12 | | 1 | WHITE SALMON RIVE |
| S4-*21184CWRIS | 11188 | MOON L E | Cert | 8/23/1968 | IR,DS | 0.04 | CFS | 5 | 1.5 | 04.0N 10.0E 12 | NW/SW | 1 | WHITE SALMON RIVE |
| S4-22908CWRIS | | BENJAMIN/ENSIMINGER | Cert | 4/29/1974 | DS | 0.01 | CFS | 2 | | 04.0N 10.0E 12 | SW/NW | 1 | UNNAMED SPRING |
| S4-26523GWRIS | | Mt Adams Orchard Corporation | Cert | 1/8/1980 | IR,FP | 4 | CFS | 1431 | 880 | 04.0N 10.0E 12 | SE/SE | 1 | WHITE SALMON RIVE |
| S4-30248GWRIS | | HENNING-DRIVER K | Cert | 4/20/1990 | IR,DS | 0.09 | CFS | 6.9 | 2.95 | 04.0N 10.0E 12 | SW/NW | 1 | UNNAMED SPRING |
| S3-+00336CWRIS | | GRIBNER W O | Cert | 8/12/1970 | ST,IR | 0.05 | CFS | 7.5 | 2 | 04.0N 10.0E 13 | NE/SW | 1 | UNNAMED SPRING |
| S4-*03123CWRIS | 2360 | JONES F T M ET AL | Cert | 9/3/1930 | PO,IR | 33 | CFS | | 60 | 04.0N 10.0E 13 | SE/SE | 1 | WHITE SALMON RIVE |
| S4-*07298CWRIS | 2917 | MOORE A F | Cert | 7/1/1946 | DS | 0.01 | CFS | | | 04.0N 10.0E 13 | SE/SE | 1 | UNNAMED SPRING |
| S4-*14905CWRIS | 8052 | MURPHY A D | Cert | 7/11/1958 | DS | 0.01 | CFS | | | 04.0N 10.0E 13 | SW/NW | 1 | UNNAMED SPRING |
| S4-23564CWRIS | | TOLBERT J M & J M | Cert | 6/17/1974 | IR | 0.33 | CFS | 49 | 17 | 04.0N 10.0E 13 | NW/NE | 1 | WHITE SALMON RIVE |
| S4-*08781CWRIS | 3371 | GROSS A J | Cert | 5/9/1949 | IR,DS | 0.15 | CFS | | 20 | 04.0N 10.0E 14 | SE/NE | 1 | UNNAMED SPRING |
| S4-*09743CWRIS | 4726 | THOMPSON W R | Cert | 7/6/1950 | IR,DS | 0.04 | CFS | | 3 | 04.0N 10.0E 14 | SE/NE | 1 | UNNAMED SPRING |
| S4-*20206CWRIS | 11208 | MURPHY L A / B R | Cert | 4/19/1967 | DS | 1 | CFS | 2 | | 04.0N 10.0E 14 | SE/NE | 1 | UNNAMED SPRING |
| S4-*00935ABKCWRIS | 3474 | White Salmon City | Cert | 5/18/1923 | MU | 2 | CFS | | | 04.0N 10.0E 16 | SE/SE | 1 | BUCK CREEK |
| S4-*14229CWRIS | 7109 | White Salmon City | Cert | 2/13/1957 | MU | 2 | CFS | 688 | | 04.0N 10.0E 16 | SE/SE | 1 | BUCK CREEK |
| S3-+20297CWRIS | | CASAD ALICE SILVERTO | Cert | 6/14/1972 | DS | 0.01 | CFS | 1 | | 04.0N 10.0E 23 | SW/SE | 1 | UNNAMED SPRING |
| S3-+20298CWRIS | | CASAD ALICE SILVERTO | Cert | 6/14/1972 | DS | 0.01 | CFS | 1 | | 04.0N 10.0E 23 | SW/SE | 1 | UNNAMED SPRING |
| S4-*15769CWRIS | 8054 | CLARIDGE A J ET | Cert | 11/17/1959 | IR,DS | 0.09 | CFS | 24 | 8 | 04.0N 10.0E 23 | NW/SE | 1 | UNNAMED SPRING |
| S3-+20631CWRIS | | SMITH LANE | Cert | 11/27/1972 | ST,IR | 0.55 | CFS | 182 | 60 | 04.0N 10.0E 24 | SW/SE | 1 | SPRING CREEK |
| S3-+21483CWRIS | | SCHAMBRON DUANE ETUX | Cert | 8/8/1973 | ST,IR | 1.5 | CFS | 529 | 175 | 04.0N 10.0E 24 | NE/NE | 1 | WHITE SALMON RIVE |
| S4-22820CWRIS | | OLSON KENT C | Cert | 4/5/1974 | DS | 0.01 | CFS | 2 | | 04.0N 10.0E 24 | SW/NW | 1 | UNNAMED SPRING |
| S4-24349CWRIS | | SMITH L W ET UX | Cert | 7/14/1976 | IR,DS | 0.12 | CFS | 19 | 5 | 04.0N 10.0E 24 | SE/SW | 1 | UNNAMED SPRING |
| S4-27922CWRIS | | SMITH LANE | Cert | 5/6/1982 | WL,PO | 10 | CFS | | | 04.0N 10.0E 24 | SW/SE | 1 | SPRING CREEK |
| S3-+20661CWRIS | | ARMSTRONG LEIGHTON | Cert | 12/11/1972 | DS | 0.02 | CFS | 2 | | 04.0N 10.0E 25 | NE/SW | 1 | SPRING CREEK |
| S4-*22051CWRIS | 11339 | MITCHELL L C ET UX | Cert | 3/2/1970 | IR,DS | 0.09 | CFS | 12.5 | 4 | 04.0N 10.0E 25 | SE/NE | 1 | WHITE SALMON RIVE |
| S4-22940CWRIS | | LOCKE WILLIAM RALPH | Cert | 5/7/1974 | IR,DS | 0.13 | CFS | 9 | 2.5 | 04.0N 10.0E 25 | SE/NE | 1 | WHITE SALMON RIVE |
| S4-26368C | | CARMICHAEL H E | Cert | 9/4/1979 | ST,DS | 0.02 | CFS | 0.5 | 0 | 04.0N 10.0E 25 | NW/NW | 1 | UNNAMED SPRING |
| S4-23371CWRIS | | FRANK LEO B | Cert | 9/4/1974 | DS | 0.02 | CFS | 1 | | 04.0N 10.0E 26 | SE/SE | 1 | WHITE SALMON RIVE |
| S4-31663CWRIS | | Sky Farm Center Inc | Cert | 3/25/1993 | WL,RE | 0.06 | CFS | | | 04.0N 10.0E 26 | NW/NE | 3 | UNNAMED SPRING |
| S4-*15868AWCWRIS | 08821A | White Salmon Irrigation District | Cert | 1/20/1960 | IR,DM | 2 | CFS | 472 | 189 | 04.0N 10.0E 27 | | 2 | UNNAMED SPRING |
| S4-03475C | 3475 | White Salmon Irrigation District | Cert | 5/18/1923 | IR | 4.5 | CFS | | 405.79 | 04.0N 10.0E 27 | NW/SE | 1 | BUCK CREEK |
| S4-31292 | | Bell Richard | Cert | 6/11/1992 | IR | 0.02 | CFS | 1 | 0.5 | 04.0N 10.0E 35 | S2/NW | 1 | UNNAMED SPRING |
| S4-31293 | | Bell Richard | Cert | 6/11/1992 | DS | 0.02 | CFS | 1 | 0.5 | 04.0N 10.0E 35 | NW/SW | 1 | UNNAMED SPRING |
| S4-*12982CWRIS | 7207 | MOON H L | Cert | 6/14/1954 | ST,IR | 0.48 | CFS | 72 | 24 | 04.0N 10.0E 36 | SE/NW | 1 | CATHY CR * |
| S4-*13522CWRIS | 7797 | Fordyce Spring Inc | Cert | 7/13/1955 | DM | 0.23 | CFS | | | 04.0N 10.0E 36 | SE/SE | 1 | LOST CREEK |
| S4-*16648CWRIS | 8197 | APLIN S R | Cert | 4/25/1961 | DS | 0.01 | CFS | | | 04.0N 10.0E 36 | SW/SW | 1 | UNNAMED SPRING |
| S4-*20746CWRIS | 10539 | TALBERT H W | Cert | 2/14/1968 | DS | 0.01 | CFS | 2 | | 04.0N 10.0E 36 | NW/NE | 1 | WHITE SALMON RIVE |
| S4-*21893CWRIS | 11665 | COSTANZO F & L H | Cert | 11/5/1969 | IR | 0.9 | CFS | 166 | 45 | 04.0N 10.0E 36 | NE/NE | 1 | WHITE SALMON RIVE |
| S4-01133CWRIS | | SCHMID LOREN L | Cert | 2/21/1968 | DS | 0.01 | CFS | 1 | | 04.0N 10.0E 36 | NW/NE | 1 | UNNAMED SPRING |
| S4-23072CWRIS | | WALL MELVILLE F JR | Cert | 5/14/1974 | DM | 0.02 | CFS | 4 | | 04.0N 10.0E 36 | NW/SE | 1 | UNNAMED SPRING |
| S4-29830 | | Kempton Henry | Pmt | 9/28/1988 | IR,DS | 0.07 | CFS | 15 | 7 | 04.0N 10.0E 12 | | 1 | CARSTEN'S CREEK |

Notes:
Qi - instantaneous rate of diversion
UOM - unit of measure
TRS - Township, Range, Section
QQ/Q - quarter-quarter section
Src - source(s)
CFS - cubic feet per second

Purpose of Use Codes:
DM - multiple domestic
DS - single domestic
FS - fish propagation
IR - irrigation
PO - power
ST - stockwater
WL - wildlife propagation

## Table 4.2 - Summary of Existing Groundwater Rights

Aquifer Storage and Recovery Feasibility Assessment
White Salmon, Washington

| File # | Cert # | Name | Doc | Priority Date | Purpose | Qi | UOM | Qa | Ir Acres | TRS | QQ/Q | Src's | 1stSrc |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CG3-22699C | | Husum Water Association | Chng/ROE | 2/16/2005 | MU | 20 | GPM | 11 | | 03.0N 10.0E 02 | NE/NE | 1 | Well 2 |
| G4-27964GWRIS | | GIBNEY D R | Cert | 6/28/1982 | IR,DS | 60 | GPM | 15.2 | 4.31 | 03.0N 10.0E 02 | NE/SW | 1 | WELL |
| G4-31472 | | Fordyce Spring Inc | Pmt | 9/14/1992 | DM | 80 | GPM | 56 | | 03.0N 10.0E 02 | | 1 | WELL |
| CS4-SWC7109 | 7109 | White Salmon City | Chng/ROE | 4/9/1999 | MU | 2 | CFS | | | 03.0N 10.0E 03 | SE/SE | 2 | WELL |
| CS4-SWC3474 | 3474 | White Salmon City | Chng/ROE | 4/9/1999 | MU | 2 | CFS | | | 03.0N 10.0E 10 | NE/NE | 2 | WELL |
| G3-+21592CWRIS | | WEDRICK LAURENCE | Cert | 8/22/1973 | DS | 8 | GPM | 2 | | 03.0N 10.0E 13 | NE/SE | 1 | WELL |
| G4-*06062CWRIS | 4117 | WEDRICK M S | Cert | 9/22/1961 | IR,DS | 30 | GPM | 9.6 | 2 | 03.0N 10.0E 13 | NE/SE | 1 | WELL |
| G4-*09545CWRIS | 6574 | MOORE A F | Cert | 6/26/1968 | IR,DS | 20 | GPM | 6 | 2 | 03.0N 10.0E 13 | SW/SW | 1 | WELL |
| G4-*08950CWRIS | 6384 | KRALL N E & M | Cert | 9/11/1967 | IR,DS | 20 | GPM | 5 | 1 | 04.0N 10.0E 11 | SE/NE | 1 | WELL |
| G4-*09643CWRIS | 6418 | HALE O G | Cert | 8/8/1968 | IR,DM | 18 | GPM | 6 | 1 | 04.0N 10.0E 11 | NE/NE | 1 | WELL |
| G4-*09648CWRIS | 6707 | BAUGHER F L | Cert | 8/9/1968 | IR,DS | 15 | GPM | 3 | 1 | 04.0N 10.0E 11 | NE/SE | 1 | WELL |
| G4-*10960ALCWRIS | 07328A | BELDING C F | Cert | 6/12/1970 | IR,DS | 24 | GPM | 2.5 | 0.5 | 04.0N 10.0E 11 | NE/SE | 2 | WELL |
| G4-01145CWRIS | | RANSIER F ET AL | Cert | 7/12/1971 | IR,DM | 20 | GPM | 4.8 | 1 | 04.0N 10.0E 11 | SE/NE | 1 | WELL |
| G4-29176CWRIS | | PARSONS WILLIAM R | Cert | 12/19/1986 | IR,DM | 13 | GPM | 5 | 1 | 04.0N 10.0E 11 | N2/NE | 1 | WELL |
| G3-+21687CWRIS | | MORRIS EUGENE C & G E | Cert | 9/4/1973 | DS | 10 | GPM | 2 | | 04.0N 10.0E 13 | SE/NW | 1 | WELL |
| G4-*01010CWRIS | 315 | MOORE A F | Cert | 10/8/1948 | IR | 17 | GPM | 8 | 2 | 04.0N 10.0E 13 | SW/SE | 1 | WELL |
| G4-*04373CWRIS | 3774 | MOORE A F | Cert | 7/3/1956 | IR | 50 | GPM | 28 | 7 | 04.0N 10.0E 13 | | 1 | WELL |
| G4-*10133CWRIS | 6973 | ROBBINS J E & D G | Cert | 4/15/1969 | DS | 10 | GPM | 2 | | 04.0N 10.0E 13 | SE/NW | 1 | WELL |
| G3-+22699CWRIS | | HUSUM WATER SERVICE | Cert | 2/19/1974 | DM | 20 | GPM | 25 | | 04.0N 10.0E 25 | | 1 | WELL |
| G3-+20529CWRIS | | BAKER GEORGE | Cert | 9/25/1972 | DS | 5 | GPM | 2 | | 04.0N 10.0E 36 | SE/NW | 1 | WELL |
| G4-25078CWRIS | | KITCH ROBERT I | Cert | 3/18/1977 | DS | 9 | GPM | 2 | | 04.0N 10.0E 36 | NE/NW | 1 | WELL |

# Table 5.1 - Summary of Well Completion Details in the Project Area

Aquifer Storage and Recovery Feasibility Assessment
White Salmon, Washington

| | | | | | | | | | Water Level Data | | | Well Yield Data | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Depth (ft bgs) | Dia. (in.) | Well Owner (well log) | Label | TRS Identifier | Date | Water System ID | DEM Elevation | Source | Date | SWL (ft bgs) | SWE (ft MSL) | Yield (gpm) | Drawdown (ft) | Specific Capacity (gpm/ft) |
| 240 | 6 | CLAUDE CORBEILLE (578) | E01 | 3N/10E-1E01 | 8/26/1992 | | 941 | Qtr-Qtr Section | 8/26/1992 | 110 | 831 | | | |
| 600 | 6 | SCOTT M LOZIER | J01 | 3N/10E-1J01 | 5/4/2000 | | 1711 | Qtr-Qtr Section | 5/4/2000 | 495 | 1216 | | | |
| 65 | 6 | AL PILAND | X01 | 3N/10E-2X01 | 5/18/1987 | | 522 | Qtr-Qtr Section | | | | | | |
| 340 | 6 | ABEL NEWTON-VAN | X02 | 3N/10E-2X02 | 5/15/1993 | | 522 | Qtr-Qtr Section | | | | | | |
| 145 | 6 | DENNIS CHISHOLM | A01 | 3N/10E-2A01 | | | 485 | Qtr-Qtr Section | | | | | | |
| 7.5 | 2 | NORMAN & MYRNA NORTHROP \| SOIL SOLUTIONS | A02 | 3N/10E-2A02 | 4/3/2009 | | 485 | Qtr-Qtr Section | | | | | | |
| 120 | 6 | VICTOR BLANDINE | B01 | 3N/10E-2B01 | 8/14/1985 | | 311 | Qtr-Qtr Section | 8/14/1985 | 10 | 301 | | | |
| 145 | 6 | ED & DIANE SWICK | B02 | 3N/10E-2B02 | 4/30/1996 | | 311 | Qtr-Qtr Section | 4/30/1996 | 59 | 252 | | | |
| 160 | 6 | DAROLD E WARD | B03 | 3N/10E-2B03 | 7/30/1999 | | 311 | Qtr-Qtr Section | | | | | | |
| 40 | 6 | PACIFIC POWER & LIGHT CO. | B04 | 3N/10E-2B04 | | | 311 | Qtr-Qtr Section | 11/24/1973 | 5 | 306 | 40 | 11 | 3.64 |
| 100 | 6 | DES VERLEY | B05 | 3N/10E-2B05 | 3/17/2005 | | 311 | Qtr-Qtr Section | | | | | | |
| 265 | 6 | D. K. DICKSON | H01 | 3N/10E-2H01 | 9/11/1989 | | 584 | Qtr-Qtr Section | | | | | | |
| 203 | 6 | JAMES SPRING | H02 | 3N/10E-2H02 | 8/27/1992 | | 584 | Qtr-Qtr Section | 8/27/1992 | 51 | 533 | | | |
| 220 | 6 | CHARLES MC GRAW | G01 | 3N/10E-2G01 | 7/15/1978 | | 472 | Qtr-Qtr Section | 7/15/1978 | 104 | 368 | 40 | 92 | 0.43 |
| 85 | 6 | CHRISTOPHER HOULT | G02 | 3N/10E-2G02 | 4/16/1996 | | 472 | Qtr-Qtr Section | 4/16/1996 | 15 | 457 | | | |
| 85 | 6 | DES VERLEY | C01 | 3N/10E-2C01 | 5/15/1990 | | 436 | Qtr-Qtr Section | | | | | | |
| 140 | 6 | TOM HUMBERG | C02 | 3N/10E-2C02 | 8/11/1986 | | 436 | Qtr-Qtr Section | | | | | | |
| 145 | 8 | FORDYCE SPRINGS INC | C03 | 3N/10E-2C03 | 6/28/1994 | | 436 | Qtr-Qtr Section | 6/28/1994 | 47 | 389 | | | |
| 105 | 6 | TRACY ZOLLER | C04 | 3N/10E-2C04 | 8/6/1986 | | 436 | Qtr-Qtr Section | | | | | | |
| 127 | 6 | PACICORP REAL ESTATE MGMT | C05 | 3N/10E-2C05 | 6/13/2003 | | 436 | Qtr-Qtr Section | | | | | | |
| 280 | 8 | FORDYCE SPRINGS | C06 | 3N/10E-2C06 | 10/26/1994 | 05182 J | 448 | GPS | 10/26/1994 | 54 | 394 | | | |
| 260 | 6 | MICHAEL MCCASLIN | D01 | 3N/10E-2D01 | 7/9/1980 | | 420 | Qtr-Qtr Section | | | | | | |
| 65 | 6 | JACK T SIMMS | D02 | 3N/10E-2D02 | 10/24/1997 | | 420 | Qtr-Qtr Section | 10/24/1997 | 13 | 407 | | | |
| 100 | 8 | KIRK SHARP | F01 | 3N/10E-2F01 | 9/1/1992 | | 369 | Qtr-Qtr Section | 9/1/1992 | 12 | 357 | | | |
| 36.6 | 6 | Pacificorp | J01 | 3N/10E-2J01 | 1/14/2009 | | 821 | Qtr-Qtr Section | | | | | | |
| 200 | 6 | D. R. GIBNEY | L01 | 3N/10E-2L01 | 5/11/1982 | | 555 | Qtr-Qtr Section | 5/11/1982 | 101 | 454 | | | |
| 145 | 6 | P JAMES WANNER | M01 | 3N/10E-2M01 | 9/16/2003 | | 452 | Qtr-Qtr Section | 9/16/2003 | 50 | 402 | | | |
| 125 | 6 | DICK WALTON | M02 | 3N/10E-2M02 | 9/25/1995 | | 452 | Qtr-Qtr Section | | | | | | |
| 320 | 6 | JAMES WANNER | M03 | 3N/10E-2M03 | 5/5/2005 | | 452 | Qtr-Qtr Section | 5/5/2005 | 211 | 241 | | | |
| 520 | 6 | ERIC PLIMMER | X01 | 3N/10E-3X01 | 5/19/1993 | | 544 | Qtr-Qtr Section | | | | | | |
| 290 | 6 | GARY OTTMAN | X02 | 3N/10E-3X02 | 5/13/1993 | | 544 | Qtr-Qtr Section | | | | | | |
| 310 | 6 | WALTER HOWARD | X03 | 3N/10E-3X03 | | | 544 | Qtr-Qtr Section | | | | | | |
| 187 | 6 | SCOTT MAYTUBBY | X04 | 3N/10E-3X04 | 10/13/2005 | | 544 | Qtr-Qtr Section | | | | | | |
| 92.2 | 6 | Pacificorp | H01 | 3N/10E-3H01 | 1/13/2009 | | 319 | Qtr-Qtr Section | | | | | | |
| 80 | 6 | Pacificorp | H02 | 3N/10E-3H02 | 1/6/2009 | | 319 | Qtr-Qtr Section | | | | | | |
| 80 | 6 | Pacificorp | H03 | 3N/10E-3H03 | 1/6/2009 | | 319 | Qtr-Qtr Section | | | | | | |
| 375 | 6 | WILLIAM FULTON | G01 | 3N/10E-3G01 | 8/6/1996 | | 534 | Qtr-Qtr Section | 8/6/1996 | 225 | 309 | | | |
| 245 | 6 | JOHN SHIGO | NW01 | 3N/10E-3NW01 | 4/22/1998 | | 738 | Qtr-Qtr Section | | | | | | |
| 390 | 6 | MARK KING | NW02 | 3N/10E-3NW02 | 5/23/1994 | | 738 | Qtr-Qtr Section | | | | | | |
| 425 | 6 | BOYD FITZGERALD | C01 | 3N/10E-3C01 | 7/15/1995 | | 709 | Qtr-Qtr Section | 7/15/1995 | 290 | 419 | | | |
| 300 | 6 | DES VERLEY | C02 | 3N/10E-3C02 | 5/20/1993 | | 709 | Qtr-Qtr Section | 5/20/1993 | 220 | 489 | | | |
| 615 | 6 | ROBERT HUNTINGTON | C03 | 3N/10E-3C03 | 6/26/1995 | | 709 | Qtr-Qtr Section | 6/26/1995 | 259 | 450 | | | |
| 250 | 6 | BURSETT ATSUKO | C04 | 3N/10E-3C04 | 3/16/2000 | | 709 | Qtr-Qtr Section | | | | | | |
| 385 | 6 | BURSETT ATSUKO | C05 | 3N/10E-3C05 | 3/21/2000 | | 709 | Qtr-Qtr Section | 3/21/2000 | 300 | 409 | | | |
| 270 | 6 | RICHARD D RYDER | D01 | 3N/10E-3D01 | 6/19/2006 | | 901 | Qtr-Qtr Section | 6/19/2006 | 145 | 756 | | | |
| 115 | 6 | EDWARD SWICK | D02 | 3N/10E-3D02 | 3/14/2007 | | 901 | Qtr-Qtr Section | | | | | | |
| 456 | 6 | CURTIS STEELE | F01 | 3N/10E-3F01 | 11/3/1995 | | 625 | Qtr-Qtr Section | 11/3/1995 | 275 | 350 | | | |
| 485 | 6 | NORL PROCTOR | F02 | 3N/10E-3F02 | 7/4/1995 | | 625 | Qtr-Qtr Section | | | | | | |
| 400 | 6 | WAYNE WOOSTER | F03 | 3N/10E-3F03 | 10/17/1994 | | 625 | Qtr-Qtr Section | 10/17/1994 | 275 | 350 | | | |
| 340 | 6 | MICHAEL GUNDLACH | F04 | 3N/10E-3F04 | 11/7/2003 | | 625 | Qtr-Qtr Section | 11/7/2003 | 265 | 360 | | | |
| 140 | 6 | WAYNE LEASE | K01 | 3N/10E-3K01 | 6/7/1983 | | 294 | Qtr-Qtr Section | | | | | | |
| 1242 | 14 | CITY OF WHITE SALMON | Q01 | 3N/10E-3Q01 | 4/23/2001 | 96350 B | 477 | GPS | 11/18/1998 | -226 | 703 | | | |
| 180 | 6 | DONALD OMAN | L01 | 3N/10E-3L01 | 3/12/1992 | | 486 | Qtr-Qtr Section | | | | | | |
| 145 | 6 | LEN LERITZ | L02 | 3N/10E-3L02 | 7/14/1993 | | 486 | Qtr-Qtr Section | | | | | | |
| 265 | 6 | WILLIAM PROTHERO JR | L03 | 3N/10E-3L03 | 8/14/1998 | | 486 | Qtr-Qtr Section | | | | | | |
| 100 | 6 | MOSS - STEWARD 430 | L04 | 3N/10E-3L04 | 6/15/1992 | | 486 | Qtr-Qtr Section | 6/15/1992 | 50 | 436 | | | |
| 345 | 6 | BRIAN UTHMANN | M01 | 3N/10E-3M01 | 7/10/2001 | | 562 | Qtr-Qtr Section | 7/10/2001 | 270 | 292 | | | |
| 570 | 6 | JERRY AND BRENDA POWERS | M02 | 3N/10E-3M02 | 8/4/2005 | | 562 | Qtr-Qtr Section | 8/4/2005 | 410 | 152 | | | |
| 60 | 6 | RAYMOND DOUGDALE | X01 | 3N/10E-9X01 | 6/26/1969 | | 1391 | Qtr-Qtr Section | 6/26/1969 | 47 | 1344 | 20 | 13 | 1.54 |
| 120 | 6 | HARRY ELLIOT | B01 | 3N/10E-9B01 | 3/17/1978 | | 1301 | Qtr-Qtr Section | 3/17/1978 | 55 | 1246 | | | |
| 110 | 6 | DAVID KAPP | H01 | 3N/10E-9H01 | 4/9/2004 | | 1240 | Qtr-Qtr Section | 4/6/2004 | 65 | 1175 | | | |
| 143 | 6 | DAVID KAPP | G01 | 3N/10E-9G01 | 11/3/2006 | | 1309 | Qtr-Qtr Section | 11/3/2006 | 80 | 1229 | | | |
| 100 | 6 | JIM HOWARD | Q01 | 3N/10E-9Q01 | 11/28/1977 | | 1312 | Qtr-Qtr Section | 11/28/1973 | 60 | 1252 | | | |
| 356 | 8 | CITY OF WHITE SALMON | A01 | 3N/10E-10A01 | 11/13/1998 | | 460 | GPS | 11/13/1998 | 111 | 349 | | | |
| 755 | 12 | CITY OF WHITE SALMON | A02 | 3N/10E-10A02 | 11/24/1998 | 96350 B | 438 | GPS | 11/24/1998 | 125 | 313 | | | |
| 739 | 12 | CITY OF WHITE SALMON | A03 | 3N/10E-10A03 | 9/2/1999 | 96350 B | 438 | GPS | | | | | | |
| 500 | 8 | CITY OF WHITE SALMON | A04 | 3N/10E-10A04 | 4/20/1999 | | 484 | GPS | 4/20/1999 | 140 | 344 | | | |
| 180 | 6 | JASON SPADARO | A05 | 3N/10E-10A05 | 8/19/2003 | | 489 | Qtr-Qtr Section | | | | | | |
| 155 | 6 | ROBERT ODELL | A06 | 3N/10E-10A06 | 6/21/2006 | | 489 | Qtr-Qtr Section | 6/21/2006 | 77 | 412 | | | |
| 125 | 6 | TOM BECKER | H01 | 3N/10E-10H01 | 9/15/1999 | | 480 | Qtr-Qtr Section | 9/15/1999 | 60 | 420 | | | |
| 185 | 12 | RON RIGGLEMAN (RIGGLEMAN ORCHARDS) | J01 | 3N/10E-10J01 | 3/15/1999 | | 386 | Qtr-Qtr Section | 3/15/1999 | 147 | 239 | | | |
| 370 | 6 | RON RIGGLEMAN \| RIGGLEMAN ORCHARD | J02 | 3N/10E-10J02 | 4/24/2000 | | 386 | Qtr-Qtr Section | | | | | | |
| 545 | 8 | RON RIGGLEMAN \| RIGGLEMAN ORCHARDS | J03 | 3N/10E-10J03 | 4/18/2000 | | 386 | Qtr-Qtr Section | 4/18/2000 | 162 | 224 | 105 | 364 | 0.29 |
| 620 | 8 | RIGGLEMAN ORCHARDS | J04 | 3N/10E-10J04 | 5/29/2001 | | 386 | Qtr-Qtr Section | 5/29/2001 | 162 | 224 | | | |
| 845 | 6 | ROBERT MARQUEZ | Q01 | 3N/10E-10Q01 | 9/5/2001 | | 761 | Qtr-Qtr Section | 9/5/2001 | 745 | 16 | | | |
| 445 | 6 | DUDLEY CHELTON | M01 | 3N/10E-10M01 | 8/31/1988 | | 1189 | Qtr-Qtr Section | | | | | | |
| 860 | 6 | WAYNE TENNANT | N01 | 3N/10E-10N01 | 7/9/1981 | | 1254 | Qtr-Qtr Section | 7/9/1981 | 760 | 494 | | | |
| 141 | 60 | LAWRENCE M WEDRICK | J01 | 3N/10E-13J01 | 9/1/1962 | | 1003 | Qtr-Qtr Section | | 0 | 1003 | 5 | 4 | 1.25 |
| 475 | 6 | DIANA SHEPLER | J02 | 3N/10E-13J02 | 2/13/2004 | | 1003 | Qtr-Qtr Section | 2/13/2004 | 378 | 625 | 15 | 13 | 1.15 |
| 469 | 6 | DIANA SHEPLER | K01 | 3N/10E-13K01 | 1/26/1993 | | 903 | Qtr-Qtr Section | 1/26/1991 | 380 | 523 | 15 | 16 | 0.94 |
| 401 | 6 | ANDY MILLER | R01 | 3N/10E-13R01 | 7/24/2008 | | 775 | Parcel | 7/24/2008 | 325 | 450 | | | |
| 160 | 6 | DUSTY MOSS | Q01 | 3N/10E-13Q01 | 4/20/1995 | | 788 | Qtr-Qtr Section | 4/30/1995 | 0 | 788 | | | |
| 660 | 6 | DUSTY MOSS | Q02 | 3N/10E-13Q02 | 5/3/1995 | | 788 | Qtr-Qtr Section | 5/3/1995 | 460 | 328 | | | |
| 170 | 6 | MICHAEL MCVEIGH | P01 | 3N/10E-13P01 | 2/22/2005 | | 841 | Parcel | 2/22/2005 | 0 | 841 | | | |
| 610 | 6 | MICHAEL MCVEIGH | P02 | 3N/10E-13P02 | 7/5/2005 | | 842 | Qtr-Qtr Section | 7/5/2005 | 455 | 387 | | | |
| 385 | 6 | DAN DARLING | N01 | 3N/10E-13N01 | 3/30/1987 | | 816 | Qtr-Qtr Section | | | | | | |
| 640 | 6 | DAN DARLING | N02 | 3N/10E-13N02 | 10/23/2006 | | 816 | Qtr-Qtr Section | 10/23/2006 | 520 | 296 | | | |
| 420 | 8 | RAY MEADOWS 579 | C01 | 3N/10E-14C01 | 12/2/1988 | | 328 | Qtr-Qtr Section | 12/2/1988 | 200 | 128 | | | |
| - | 6 | RAY MEADOWS 875 | C02 | 3N/10E-14C02 | 4/23/1993 | | 328 | Qtr-Qtr Section | | | | | | |
| 420 | 8 | RAY MEADOWS | C03 | 3N/10E-14C03 | | | 328 | Qtr-Qtr Section | 12/2/1988 | 200 | 128 | | | |
| 420 | 8 | RAY MEADOWS | C04 | 3N/10E-14C04 | | | 328 | Qtr-Qtr Section | 12/2/1988 | 200 | 128 | | | |
| 400 | 6 | RON RIGGLEMAN (RIGGLEMAN ORCHARDS) | C05 | 3N/10E-14C05 | 3/30/2006 | | 412 | Parcel | 3/30/2006 | 267 | 145 | | | |
| 440 | 6 | GEORGE MERSEREAU | K01 | 3N/10E-14K01 | 7/19/2007 | | 610 | Parcel | 7/19/2007 | 325 | 285 | | | |
| 573 | 6 | JOHN E DEAN | R01 | 3N/10E-14R01 | 11/3/2005 | | 736 | Parcel | 11/2/2005 | 469 | 267 | 8 | 0 | - |
| 493 | 6 | KARL SCHUEMANN | R02 | 3N/10E-14R02 | 12/28/2006 | AB800 J | 767 | Qtr-Qtr Section | 12/28/2006 | 326 | 441 | | | |
| 400 | 6 | ERSULA HOWARD | R03 | 3N/10E-14R03 | 9/4/2007 | | 767 | Qtr-Qtr Section | 9/4/2007 | 300 | 467 | | | |
| 456 | 6 | HOWARD KREPS | R04 | 3N/10E-14R04 | 6/26/2007 | | 672 | Parcel | 6/26/2007 | 365 | 307 | | | |
| 29 | 6 | PHILIP JONES | X01 | 3N/10E-15X01 | 1/29/1975 | | 600 | Qtr-Qtr Section | 1/29/1975 | 0 | 600 | 25 | 10 | 2.50 |
| 320 | 6 | PAUL HOLMAN | X02 | 3N/10E-15X02 | 7/23/1998 | | 600 | Qtr-Qtr Section | 7/23/1998 | 276 | 324 | 19 | 2 | 9.50 |
| 160 | 6 | B. VANHORN | NE01 | 3N/10E-15NE01 | 4/22/1991 | | 560 | Qtr-Qtr Section | | | | | | |
| 230 | 6 | SAM DAVIS | H01 | 3N/10E-15H01 | 8/20/2006 | | 540 | Qtr-Qtr Section | | | | | | |
| 570 | 6 | JOHN WENDT | G01 | 3N/10E-15G01 | 12/7/1990 | | 591 | Qtr-Qtr Section | 12/7/1990 | 298 | 293 | | | |
| 800 | 6 | VERNON ELLSON | C01 | 3N/10E-15C01 | 7/17/2001 | | 935 | Qtr-Qtr Section | 7/17/2001 | 725 | 210 | | | |
| 545 | 6 | CHARLES SCWARTZ | F01 | 3N/10E-15F01 | 9/26/1996 | | 827 | Qtr-Qtr Section | 9/26/1996 | 450 | 377 | | | |
| 70 | 6 | CARL RODGERS | P01 | 3N/10E-15P01 | 7/16/1970 | | 615 | Qtr-Qtr Section | 7/16/1970 | 18 | 597 | 10 | 50 | 0.20 |

# Table 5.1 - Summary of Well Completion Details in the Project Area

Aquifer Storage and Recovery Feasibility Assessment
White Salmon, Washington

| | | | | | | | | | Water Level Data | | | Well Yield Data | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Depth (ft bgs) | Dia. (in.) | Well Owner (well log) | Label | TRS Identifier | Date | Water System ID | DEM Elevation | Source | Date | SWL (ft bgs) | SWE (ft MSL) | Yield (gpm) | Drawdown (ft) | Specific Capacity (gpm/ft) |
| 95 | 5 | PAUL NEWELL | P02 | 3N/10E-15P02 | | | 615 | Qtr-Qtr Section | 9/15/1970 | 23 | 592 | | | |
| 63 | 6 | WILLIAM KOENEMANN | P03 | 3N/10E-15P03 | 5/30/2003 | | 615 | Qtr-Qtr Section | 5/30/2003 | 25 | 590 | | | |
| 170 | 6 | CARL RODGERS JR | P04 | 3N/10E-15P04 | 9/2/2008 | | 615 | Qtr-Qtr Section | 9/2/2008 | 100 | 515 | | | |
| 345 | 6 | BLAIR SIMPSON | N01 | 3N/10E-15N01 | 6/8/1998 | | 720 | Qtr-Qtr Section | 6/8/1998 | 235 | 485 | | | |
| 75 | 6 | FRANK BULTER | N02 | 3N/10E-15N02 | 6/8/1979 | | 720 | Qtr-Qtr Section | 6/8/1979 | 35 | 685 | | | |
| 165 | 6 | NORMAN DEO | N03 | 3N/10E-15N03 | 6/12/1979 | | 720 | Qtr-Qtr Section | 6/12/1979 | 40 | 680 | | | |
| 125 | 6 | JEROME HOLTMANN | H01 | 3N/10E-16H01 | 5/12/1987 | | 1110 | Qtr-Qtr Section | 5/12/1987 | 95 | 1015 | | | |
| 280 | 6 | ROBERT SNYDER | G01 | 3N/10E-16G01 | 7/21/1982 | | 1246 | Qtr-Qtr Section | | | | | | |
| 160 | 6 | ROBERT SNYDER | G02 | 3N/10E-16G02 | 7/21/1982 | | 1246 | Qtr-Qtr Section | 7/21/1982 | 75 | 1171 | | | |
| 70 | 6 | FRANK BUTLER | R01 | 3N/10E-16R01 | 8/28/1972 | | 892 | Qtr-Qtr Section | 8/28/1972 | 43 | 849 | 7.5 | 20 | 0.38 |
| 105 | 6 | LEE SHISSLER | R02 | 3N/10E-16R02 | 7/7/1997 | | 892 | Qtr-Qtr Section | 7/7/1997 | 55 | 837 | | | |
| 38 | | BZ CORNER | A01 | 4N/10E-1A01 | 11/6/2006 | | 1207 | Qtr-Qtr Section | | | | | | |
| 41 | | BZ CORNER | A02 | 4N/10E-1A02 | 11/6/2006 | | 1207 | Qtr-Qtr Section | | | | | | |
| 20 | | BZ CORNER | A03 | 4N/10E-1A03 | 11/6/2006 | | 1207 | Qtr-Qtr Section | | | | | | |
| 55 | | BZ CORNER | A04 | 4N/10E-1A04 | 11/6/2006 | | 1207 | Qtr-Qtr Section | | | | | | |
| 176 | 6 | TODD M COLLINS | E01 | 4N/10E-1E01 | 2/7/2006 | AB566 K | 752 | Qtr-Qtr Section | 2/7/2006 | 85 | 667 | | | |
| 154 | 6 | MATT COLLOTON | A01 | 4N/10E-2A01 | 6/8/2006 | | 785 | Qtr-Qtr Section | 6/8/2006 | 97 | 688 | | | |
| 140 | 6 | CHAD AND EMILY AMAN | A02 | 4N/10E-2A02 | 6/20/2006 | | 785 | Qtr-Qtr Section | 6/20/2006 | 90 | 695 | | | |
| 310 | 6 | CURTIS MCCLAIN | B01 | 4N/10E-2B01 | 8/14/1987 | | 950 | Qtr-Qtr Section | | | | | | |
| 220 | 6 | SCOTT EVANS | B02 | 4N/10E-2B02 | 6/19/2002 | | 950 | Qtr-Qtr Section | | | | | | |
| 210 | 6 | MIKE CLARK | B03 | 4N/10E-2B03 | 11/11/2003 | | 950 | Qtr-Qtr Section | | | | | | |
| 210 | 6 | TODD BIERNACKI | B04 | 4N/10E-2B04 | 11/27/2006 | | 950 | Qtr-Qtr Section | | | | | | |
| 191 | 6 | ALEX C MCCLAIN | B05 | 4N/10E-2B05 | 9/14/2006 | | 950 | Qtr-Qtr Section | | | | | | |
| 85 | 6 | TODD BIERNACKI | B06 | 4N/10E-2B06 | 12/12/2007 | | 950 | Qtr-Qtr Section | | | | | | |
| 145 | 6 | BILL GROSS | H01 | 4N/10E-2H01 | 3/13/1982 | | 834 | Qtr-Qtr Section | 3/13/1992 | 95 | 739 | | | |
| 141 | 6 | WILLIAM GROSS | H02 | 4N/10E-2H02 | 12/24/1977 | | 834 | Qtr-Qtr Section | 12/24/1977 | 75 | 759 | | | |
| 160 | 6 | GARY WILLIAMS | H03 | 4N/10E-2H03 | 8/9/2005 | | 834 | Qtr-Qtr Section | | | | | | |
| 160 | 6 | GLEN BUNSELMEYER | H04 | 4N/10E-2H04 | 7/24/2008 | | 827 | Parcel | | | | | | |
| 200 | 6 | PATRICIA KREPS | G01 | 4N/10E-2G01 | 7/31/1996 | | 1049 | Qtr-Qtr Section | 7/31/1996 | 105 | 944 | | | |
| 255 | 6 | NATHAN GROSS | D01 | 4N/10E-2D01 | 2/21/2005 | | 1624 | Qtr-Qtr Section | 2/21/2005 | 135 | 1489 | | | |
| 140 | 6 | EUGENE BURCH | R01 | 4N/10E-2R01 | 6/28/1978 | | 716 | Qtr-Qtr Section | 6/28/1978 | 75 | 641 | | | |
| 165 | 6 | FRED MCDAVID | R02 | 4N/10E-2R02 | 8/16/1990 | | 716 | Qtr-Qtr Section | 8/16/1990 | 85 | 631 | | | |
| 130 | 6 | RAY SWETWOOD | R03 | 4N/10E-2R03 | 1/12/1977 | | 716 | Qtr-Qtr Section | 1/12/1977 | 81 | 635 | 25 | 45 | 0.56 |
| 140 | 6 | RAYMOND DUHEKOP | R04 | 4N/10E-2R04 | 6/30/1978 | | 716 | Qtr-Qtr Section | 6/30/1978 | 80 | 636 | | | |
| 220 | 6 | BILL & JUDY GROSS | Q01 | 4N/10E-2Q01 | 3/23/1999 | | 837 | Qtr-Qtr Section | 3/23/1999 | 120 | 717 | | | |
| 120 | 6 | KEVIN GROSS | Q02 | 4N/10E-2Q02 | 3/17/1999 | | 837 | Qtr-Qtr Section | 3/17/1999 | 30 | 807 | | | |
| 150 | 6 | RHONDA CHAPMAN | Q03 | 4N/10E-2Q03 | 7/19/2001 | | 837 | Qtr-Qtr Section | 7/19/2001 | 100 | 737 | | | |
| 185 | 6 | BILL W GROSS | N01 | 4N/10E-2N01 | 9/3/1998 | | 1530 | Qtr-Qtr Section | 9/3/1998 | 100 | 1430 | | | |
| 140 | 6 | WILLIAM PARSONS | NE01 | 4N/10E-11NE01 | 5/18/1995 | | 753 | Qtr-Qtr Section | | | | | | |
| 260 | 6 | RONNIE BRUCE | NE02 | 4N/10E-11NE02 | 5/29/2001 | | 753 | Qtr-Qtr Section | | | | | | |
| 120 | 6 | CLARA GROSS | A01 | 4N/10E-11A01 | 7/21/1977 | | 660 | Qtr-Qtr Section | 7/21/1977 | 80 | 580 | 15 | 35 | 0.43 |
| 150 | 6 | JACK GROSS | A02 | 4N/10E-11A02 | 4/30/1979 | | 660 | Qtr-Qtr Section | 4/30/1979 | 88 | 572 | 20 | 60 | 0.33 |
| 180 | 8 | NORMAN KROLL | A03 | 4N/10E-11A03 | 7/20/1977 | | 660 | Qtr-Qtr Section | 7/20/1977 | 93 | 567 | 20 | 80 | 0.25 |
| 137 | 6 | ORLIS HALE | A04 | 4N/10E-11A04 | | | 660 | Qtr-Qtr Section | | | | | | |
| 130 | 6 | J WIGHT & S HARMON | A05 | 4N/10E-11A05 | 8/25/1995 | | 660 | Qtr-Qtr Section | | | | | | |
| 145 | 6 | LOREN D MEYERS | B01 | 4N/10E-11B01 | 10/2/1997 | | 885 | Qtr-Qtr Section | | | | | | |
| 160 | 6 | LOREN D MEYERS | B02 | 4N/10E-11B02 | 10/6/1997 | | 885 | Qtr-Qtr Section | | | | | | |
| 145 | 6 | AUBREY M BRUCE | B03 | 4N/10E-11B03 | 3/18/2009 | | 885 | Qtr-Qtr Section | | | | | | |
| - | - | | H01 | 4N/10E-11H01 | | | 693 | Qtr-Qtr Section | | | | | | |
| 165 | 6 | BILL GROSS | H02 | 4N/10E-11H02 | 7/25/1997 | FS144 G | 687 | GPS | 7/25/1997 | 96 | 591 | | | |
| 155 | 6 | DENNIS L VOIGT | H03 | 4N/10E-11H03 | 9/2/1998 | | 693 | Qtr-Qtr Section | 9/2/1998 | 100 | 593 | | | |
| 72 | 6 | E. W. KRALL | H04 | 4N/10E-11H04 | 5/20/1947 | | 693 | Qtr-Qtr Section | | | | | | |
| 140 | 6 | HOBERT NEWMAN | H05 | 4N/10E-11H05 | 1/11/1977 | | 693 | Qtr-Qtr Section | 12/11/1977 | 87 | 606 | 30 | 48 | 0.63 |
| 130 | 6 | J. R. VERLEY | H06 | 4N/10E-11H06 | 10/3/1973 | | 693 | Qtr-Qtr Section | 10/3/1973 | 94 | 599 | | | |
| 140 | 6 | JOHN COOK | H07 | 4N/10E-11H07 | 8/23/1990 | | 693 | Qtr-Qtr Section | 8/23/1990 | 75 | 618 | | | |
| 120 | 6 | L. M. VOIGT | H08 | 4N/10E-11H08 | 1/25/1982 | | 693 | Qtr-Qtr Section | 1/25/1982 | 75 | 618 | | | |
| 150 | 6 | SUE & GARY RUDE | H09 | 4N/10E-11H09 | 1/20/1981 | | 693 | Qtr-Qtr Section | 1/20/1981 | 75 | 618 | | | |
| 130 | 6 | GENE VERLEY | H010 | 4N/10E-11H010 | 10/4/1997 | | 693 | Qtr-Qtr Section | 10/4/1997 | 89.5 | 604 | 15 | 10 | 1.50 |
| 140 | 6 | PHILLIP T ZOLLER | H011 | 4N/10E-11H011 | 8/2/1999 | AA049 D | 674 | GPS | 8/2/1999 | 91 | 583 | | | |
| 122 | 6 | WILHELM SCHEURNER | H012 | 4N/10E-11H012 | 6/15/2000 | | 693 | Qtr-Qtr Section | 6/16/2000 | 82 | 611 | | | |
| 180 | 6 | LYNN & MOLLIE KRALL | H013 | 4N/10E-11H013 | 11/3/2004 | | 693 | Qtr-Qtr Section | 11/3/2004 | 80 | 613 | | | |
| 130 | - | THE LOGS RESTAURANT | H014 | 4N/10E-11H014 | - | 47760 1 | 692 | GPS | | | | | | |
| 135 | 6 | BILL RIATT | G01 | 4N/10E-11G01 | 3/15/1973 | | 842 | Qtr-Qtr Section | 3/15/1973 | 89 | 753 | 18 | 12 | 1.50 |
| 220 | 6 | BONNIE BAEMAN | G02 | 4N/10E-11G02 | 9/30/1994 | | 842 | Qtr-Qtr Section | | | | | | |
| 108 | 6 | CHARLES WAMSLEY | G03 | 4N/10E-11G03 | 4/11/1987 | | 842 | Qtr-Qtr Section | | | | | | |
| 130 | 6 | DARREL GILDERHUS | G04 | 4N/10E-11G04 | 7/30/1992 | | 842 | Qtr-Qtr Section | 7/30/1992 | 78 | 764 | | | |
| 240 | 6 | KENNETH GROSS | G05 | 4N/10E-11G05 | 9/19/1980 | | 842 | Qtr-Qtr Section | 9/19/1980 | 95 | 747 | | | |
| 150 | 6 | RAY ROGERS | G06 | 4N/10E-11G06 | 8/13/1979 | | 842 | Qtr-Qtr Section | 8/13/1979 | 100 | 742 | 20 | 30 | 0.67 |
| 158 | 6 | RICK GRAVES | G07 | 4N/10E-11G07 | 7/13/2004 | | 759 | GPS | 7/13/2004 | 102 | 657 | 22 | 4 | 5.50 |
| 225 | 6 | RICK GRAVES | G08 | 4N/10E-11G08 | 7/9/2004 | | 770 | GPS | 7/9/2004 | 122 | 648 | | | |
| 130 | 6 | ALLAN BUCHITE | C01 | 4N/10E-11C01 | 3/21/1996 | | 960 | Qtr-Qtr Section | 3/21/1996 | 80 | 880 | | | |
| 170 | 6 | LYLE FREMOUW | C02 | 4N/10E-11C02 | 7/27/1984 | | 960 | Qtr-Qtr Section | 7/27/1984 | 99 | 861 | | | |
| 125 | 6 | ROBERT RUS | C03 | 4N/10E-11C03 | 7/25/1984 | | 960 | Qtr-Qtr Section | 7/25/1984 | 70 | 890 | | | |
| 160 | 6 | WILLIAM PARSONS | C04 | 4N/10E-11C04 | 7/24/1984 | 04005 U | 960 | Qtr-Qtr Section | 7/24/1984 | 105 | 855 | | | |
| 205 | 6 | GAYLE PARSONS | C05 | 4N/10E-11C05 | 12/24/2002 | | 960 | Qtr-Qtr Section | 12/24/2002 | 115 | 845 | | | |
| 165 | 6 | GAYLE PARSONS | C06 | 4N/10E-11C06 | 4/12/2005 | | 960 | Qtr-Qtr Section | 4/12/2005 | 105 | 855 | | | |
| 80 | 6 | DES VERLEY | D01 | 4N/10E-11D01 | 8/16/1977 | | 1352 | Qtr-Qtr Section | 8/16/1977 | 41 | 1311 | | | |
| 125 | 6 | F. L. BAUGHER | J01 | 4N/10E-11J01 | 8/1/1968 | | 697 | Qtr-Qtr Section | | | | | | |
| 180 | 6 | RICK GRAVES | J02 | 4N/10E-11J02 | 9/8/1998 | | 697 | Qtr-Qtr Section | 9/8/1998 | 85 | 612 | | | |
| 130 | 6 | RICK GRAVES | J03 | 4N/10E-11J03 | 9/13/2001 | | 697 | Qtr-Qtr Section | 9/13/2001 | 72 | 625 | | | |
| 117 | 6 | RICK GRAVES | J04 | 4N/10E-11J04 | 9/13/2001 | | 697 | Qtr-Qtr Section | 9/13/2001 | 82 | 615 | | | |
| 148 | 6 | RICK GRAVES | J05 | 4N/10E-11J05 | 9/27/2002 | AA267 C | 697 | Qtr-Qtr Section | 9/27/2002 | 70 | 627 | | | |
| 220 | 6 | KEITH ROBISON | J06 | 4N/10E-11J06 | 10/18/2007 | | 697 | Qtr-Qtr Section | 10/18/2007 | 115 | 582 | | | |
| 130 | 6 | THOMAS T ARNOLD | K01 | 4N/10E-11K01 | 8/25/1998 | | 771 | Qtr-Qtr Section | 8/25/1998 | 55 | 716 | | | |
| 105 | 6 | CARL BELDING | M01 | 4N/10E-11M01 | | | 1370 | Qtr-Qtr Section | | | | | | |
| 100 | 6 | MARK VANCE | P01 | 4N/10E-11P01 | 4/21/1978 | | 922 | Qtr-Qtr Section | 4/21/1978 | 55 | 867 | | | |
| 125 | 6 | FRED HEANY | D01 | 4N/10E-12D01 | 4/22/1996 | | 834 | Qtr-Qtr Section | 4/22/1996 | 90 | 744 | | | |
| 125 | 6 | DICK HILL | E01 | 4N/10E-12E01 | 7/9/1990 | | 784 | Qtr-Qtr Section | 7/9/1990 | 75 | 709 | | | |
| 185 | 6 | HANK KEMPTON | E02 | 4N/10E-12E02 | 7/10/1990 | | 784 | Qtr-Qtr Section | 7/10/1990 | 100 | 684 | | | |
| 145 | 6 | GOSMAN ROB (01480) | E03 | 4N/10E-12E03 | 11/8/1999 | | 784 | Qtr-Qtr Section | 11/8/1999 | 85 | 699 | | | |
| 165 | 6 | TERRY BENJAMIN | SE01 | 4N/10E-12SE01 | 8/19/1990 | | 960 | Qtr-Qtr Section | | | | | | |
| 179 | 6 | ROY MOULTON | J01 | 4N/10E-12J01 | 9/12/2007 | | 934 | Parcel | 9/12/2007 | 100 | 834 | | | |
| 168 | 6 | ARLIN ULRICH | R01 | 4N/10E-12R01 | 8/13/1990 | | 928 | Qtr-Qtr Section | 8/13/1990 | 95 | 833 | | | |
| 100 | 6 | MARK VOEGELE | SW01 | 4N/10E-12SW01 | 12/16/1999 | | 646 | Qtr-Qtr Section | | | | | | |
| 140 | 6 | MARK VOEGLE | SW02 | 4N/10E-12SW02 | 12/12/1999 | | 646 | Qtr-Qtr Section | | | | | | |
| 118 | 6 | DALE BLANKESHIP | M01 | 4N/10E-12M01 | 9/13/1983 | | 647 | Qtr-Qtr Section | 9/13/1983 | 82 | 565 | | | |
| 125 | 6 | ROBERT POMRENIE | M02 | 4N/10E-12M02 | 3/10/1994 | | 647 | Qtr-Qtr Section | 3/10/1994 | 10 | 637 | | | |
| 140 | 6 | TOM WEBER | M03 | 4N/10E-12M03 | 6/11/2003 | | 647 | Qtr-Qtr Section | 6/11/2003 | 90 | 557 | | | |
| 137 | 6 | NOAH HUBBARD | M04 | 4N/10E-12M04 | 9/20/2005 | | 664 | Parcel | | | | | | |
| 120 | 6 | CLINT VOEYELE | P01 | 4N/10E-12P01 | 11/9/1999 | | 584 | Qtr-Qtr Section | 11/9/1999 | 43 | 541 | | | |
| 137 | 6 | CLINT VOEGELE | P02 | 4N/10E-12P02 | 11/13/1999 | | 584 | Qtr-Qtr Section | 11/14/1999 | 52 | 532 | | | |
| 62 | 6 | MARK VOEGELE | P03 | 4N/10E-12P03 | 12/20/1999 | | 584 | Qtr-Qtr Section | 12/20/1999 | 43 | 541 | | | |
| 120 | 6 | CLINT VOEGELE | P04 | 4N/10E-12P04 | 10/25/1999 | | 584 | Qtr-Qtr Section | 10/22/1999 | 41 | 543 | | | |
| 98 | 6 | ROD & SHARON EICHNER | N01 | 4N/10E-12N01 | 4/6/2006 | | 560 | Parcel | | | | | | |
| 85 | 6 | EUGENE MORRIS | NE01 | 4N/10E-13NE01 | | | 548 | Qtr-Qtr Section | | | | | | |

# Table 5.1 - Summary of Well Completion Details in the Project Area

Aquifer Storage and Recovery Feasibility Assessment
White Salmon, Washington

| | | | | | | | | | Water Level Data | | | Well Yield Data | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Depth (ft bgs) | Dia. (in.) | Well Owner (well log) | Label | TRS Identifier | Date | Water System ID | DEM Elevation | Source | Date | SWL (ft bgs) | SWE (ft MSL) | Yield (gpm) | Drawdown (ft) | Specific Capacity (gpm/ft) |
| 20 | 6 | RON BECKWITH | B01 | 4N/10E-13B01 | 7/15/1986 | | 539 | Qtr-Qtr Section | 7/15/1986 | 55 | 484 | | | |
| 103 | - | GEORGE ZENT SONS | H01 | 4N/10E-13H01 | 8/21/1964 | | 512 | Qtr-Qtr Section | | | | | | |
| 103 | 6 | MRS. CORA RAYBURN | H02 | 4N/10E-13H02 | 8/21/1964 | | 512 | Qtr-Qtr Section | | | | | | |
| 135 | 6 | THOMAS ARNOLD | NW01 | 4N/10E-13NW01 | 11/17/2003 | | 641 | Qtr-Qtr Section | 11/17/2003 | 70 | 571 | | | |
| 160 | 6 | TAYLOR GROSS & S JOHNSON | C01 | 4N/10E-13C01 | 3/26/2002 | | 639 | Qtr-Qtr Section | 3/26/2002 | 50 | 589 | | | |
| 100 | 6 | FRED A MCDAVID | D01 | 4N/10E-13D01 | 10/27/2004 | | 678 | Qtr-Qtr Section | 10/27/2004 | 50 | 628 | | | |
| 105 | 6 | ARTHUR KIESLING | F01 | 4N/10E-13F01 | 7/22/1977 | | 621 | Qtr-Qtr Section | 7/22/1977 | 60 | 561 | 12 | 40 | 0.30 |
| 105 | 6 | DOUG YARNELL | F02 | 4N/10E-13F02 | 9/21/1988 | | 621 | Qtr-Qtr Section | | | | | | |
| 103 | 6 | HARRY MERRITT | F03 | 4N/10E-13F03 | 5/22/1989 | | 621 | Qtr-Qtr Section | 5/22/1989 | 30 | 591 | | | |
| 100 | 6 | LEONARD BURRIS | F04 | 4N/10E-13F04 | 4/21/1995 | | 621 | Qtr-Qtr Section | 4/21/1995 | 50 | 571 | | | |
| 118 | 6 | FRANCISCO CORTEZ | E01 | 4N/10E-13E01 | 10/2/2002 | | 686 | Qtr-Qtr Section | 10/8/2002 | 56 | 630 | | | |
| 84 | 6 | LAWRENCE ASHLEY | K01 | 4N/10E-13K01 | 7/20/1972 | | 588 | Qtr-Qtr Section | 7/20/1972 | 44 | 544 | 10 | 10 | 1.00 |
| 110 | 6 | LEE GRIBNER | K02 | 4N/10E-13K02 | 11/5/1992 | | 588 | Qtr-Qtr Section | 11/5/1992 | 70 | 518 | | | |
| 135 | 6 | CRUZ AVILA | K03 | 4N/10E-13K03 | 6/22/2000 | | 588 | Qtr-Qtr Section | 6/22/2000 | 34 | 554 | | | |
| 81 | 6 | R A KNAPP | K04 | 4N/10E-13K04 | | | 588 | Qtr-Qtr Section | 7/13/1972 | 44 | 544 | 30 | 10 | 3.00 |
| 120 | 6 | DANIEL W GORDON | K05 | 4N/10E-13K05 | 8/23/2004 | | 588 | Qtr-Qtr Section | 8/23/2004 | 60 | 528 | | | |
| 77 | 8 | JOHN WENDT | K06 | 4N/10E-13K06 | 9/21/2007 | | 591 | Parcel | 9/21/2007 | 23.5 | 567 | 19 | 8 | 2.38 |
| 85 | 6 | JAY E. & DELIA ROBBINS | R01 | 4N/10E-13R01 | 6/16/1970 | 34856 R | 535 | Qtr-Qtr Section | | | | | | |
| 300 | 6 | C HOOPER & D ZDUNIAK | R02 | 4N/10E-13R02 | 9/25/1995 | | 535 | Qtr-Qtr Section | 9/25/1995 | 210 | 325 | | | |
| 160 | 6 | GEORGE L YARNELL | R03 | 4N/10E-13R03 | 10/25/2006 | | 535 | Qtr-Qtr Section | 10/25/2006 | 40 | 495 | | | |
| 81 | 6 | B A KNAPP | Q01 | 4N/10E-13Q01 | 7/13/1972 | | 576 | Qtr-Qtr Section | 7/13/1972 | 44 | 532 | 30 | 10 | 3.00 |
| 81 | 6 | GEO ZENT | Q02 | 4N/10E-13Q02 | 4/24/1948 | | 576 | Qtr-Qtr Section | | | | | | |
| 104 | 6 | L. M. ASHLEY | Q03 | 4N/10E-13Q03 | 5/15/1974 | | 576 | Qtr-Qtr Section | | 53 | 523 | 20 | 12 | 1.67 |
| 80 | 6 | W. O. GRIBNER | Q04 | 4N/10E-13Q04 | 9/12/1975 | | 576 | Qtr-Qtr Section | 9/12/1975 | 39 | 537 | 40 | 35 | 1.14 |
| 255 | 6 | GEORGE ZENT | Q05 | 4N/10E-13Q05 | | | 576 | Qtr-Qtr Section | | | | | | |
| 140 | 6 | DON WEBER | SW01 | 4N/10E-13SW01 | 6/6/1989 | | 881 | Qtr-Qtr Section | | | | | | |
| 100 | 6 | LOWELL MURPHY | L01 | 4N/10E-13L01 | 8/29/1981 | | 639 | Qtr-Qtr Section | 8/28/1981 | 51 | 588 | | | |
| 100 | 6 | LUTHER ADAMS | L02 | 4N/10E-13L02 | 8/26/1981 | | 639 | Qtr-Qtr Section | | | | | | |
| 110 | 6 | LEE GRIBNER | L03 | 4N/10E-13L03 | 10/30/2001 | | 639 | Qtr-Qtr Section | 10/29/2001 | 35 | 604 | | | |
| 130 | 6 | JOHN C WENDT | L04 | 4N/10E-13L04 | 6/27/2002 | | 639 | Qtr-Qtr Section | | | | | | |
| 100 | 6 | JOHN DOYLE | L05 | 4N/10E-13L05 | 10/24/1995 | | 639 | Qtr-Qtr Section | | | | | | |
| 110 | 6 | GARY MEIRHOFER | P01 | 4N/10E-13P01 | 3/31/1982 | | 670 | Qtr-Qtr Section | 3/31/1982 | 45 | 625 | | | |
| 185 | 6 | RODGER GROSS | N01 | 4N/10E-13N01 | 8/10/1990 | | 802 | Qtr-Qtr Section | 8/10/1990 | 98 | 704 | | | |
| 385 | 6 | CHARLES HOOPER | R01 | 4N/10E-23R01 | 9/8/1994 | | 923 | Qtr-Qtr Section | 9/8/1994 | 300 | 623 | | | |
| 146 | 6 | HARRIET WILSON | Q01 | 4N/10E-23Q01 | 4/20/2005 | | 1139 | Qtr-Qtr Section | | 33 | 1106 | 12 | 62 | 0.19 |
| 93 | 6 | BOB JARVIS | SE01 | 4N/10E-24SE01 | 8/27/1974 | | 520 | Qtr-Qtr Section | | 35 | 485 | 30 | 35 | 0.86 |
| 58 | 6 | BRUCE BULICK | J01 | 4N/10E-24J01 | 7/27/2007 | | 520 | Parcel | | | | | | |
| 93 | 6 | BRUCE BULICK | J02 | 4N/10E-24J02 | 7/27/2007 | | 526 | Qtr-Qtr Section | | | | | | |
| 135 | 6 | JIM WEBSTER | R01 | 4N/10E-24R01 | 9/23/1986 | | 515 | Qtr-Qtr Section | 9/23/1986 | 25 | 490 | | | |
| 140 | 6 | MIKE FINLEY | Q01 | 4N/10E-24Q01 | 7/23/1977 | | 494 | Qtr-Qtr Section | 7/23/1977 | 54 | 440 | 15 | 80 | 0.19 |
| 95 | 6 | A. W. FREDRICK | H01 | 4N/10E-25H01 | | | 494 | Qtr-Qtr Section | | | | | | |
| 95 | 6 | A. W. FREDRICK | H02 | 4N/10E-25H02 | 7/27/1972 | | 494 | Qtr-Qtr Section | | | | | | |
| 80 | 6 | CLAUDE BLACK | H03 | 4N/10E-25H03 | 10/5/1973 | | 494 | Qtr-Qtr Section | | | | | | |
| 105 | 6 | STEVE MORGAN | H04 | 4N/10E-25H04 | 3/29/1996 | | 494 | Qtr-Qtr Section | | | | | | |
| 145 | 6 | STEVE G MORGAN | H05 | 4N/10E-25H05 | 8/3/1999 | | 494 | Qtr-Qtr Section | | | | | | |
| 290 | 6 | HOWARD CARMACHAEL | C01 | 4N/10E-25C01 | 10/3/1989 | | 503 | Qtr-Qtr Section | | | | | | |
| 120 | 6 | RICK KNOWLES | C02 | 4N/10E-25C02 | 3/28/1991 | | 503 | Qtr-Qtr Section | 3/28/1991 | 47 | 456 | | | |
| 142 | 6 | ROBERT KITCH | C03 | 4N/10E-25C03 | 2/16/1977 | | 503 | Qtr-Qtr Section | 2/16/1977 | 67 | 436 | 9 | 65 | 0.14 |
| 145 | 6 | TERRY MITCHELL | F01 | 4N/10E-25F01 | 10/1/2001 | | 456 | Qtr-Qtr Section | | | | | | |
| 110 | 6 | BILL LOCKE | F02 | 4N/10E-25F02 | 10/25/1995 | | 456 | Qtr-Qtr Section | 10/25/1995 | 25 | 431 | | | |
| 188 | 6 | ERIC TUNICK | E01 | 4N/10E-25E01 | 7/7/1993 | | 530 | Qtr-Qtr Section | 7/7/1993 | 42 | 488 | | | |
| 260 | 6 | MELVA LOCKE | E02 | 4N/10E-25E02 | 5/22/1981 | | 530 | Qtr-Qtr Section | 5/22/1981 | 52 | 478 | | | |
| 180 | 6 | STUART SNEIDER | E03 | 4N/10E-25E03 | 10/6/1977 | | 530 | Qtr-Qtr Section | | | | | | |
| 121 | 6 | MERLE REEVES | SE01 | 4N/10E-25SE01 | 7/10/1996 | | 489 | Qtr-Qtr Section | | | | | | |
| 60 | 6 | ART HOISINGTON | J01 | 4N/10E-25J01 | 6/20/1985 | | 492 | Qtr-Qtr Section | 6/20/1985 | 4 | 488 | | | |
| 110 | 6 | DICK KELLY | J02 | 4N/10E-25J02 | 8/22/1990 | | 492 | Qtr-Qtr Section | 8/22/1990 | 72 | 420 | | | |
| 180 | 6 | DICK KELLY | J03 | 4N/10E-25J03 | 5/7/1991 | | 492 | Qtr-Qtr Section | 5/7/1991 | 70 | 422 | | | |
| 97.5 | 6 | LOUIS VADAY | J04 | 4N/10E-25J04 | 4/4/2007 | | 421 | Parcel | | | | | | |
| 150 | - | HUSUM WATER SYSTEM | J05 | 4N/10E-25J05 | | 63440 X | 429 | GPS | | | | | | |
| 57 | 6 | JOHN BARRESSE | R01 | 4N/10E-25R01 | 3/30/2002 | | 461 | Qtr-Qtr Section | 3/30/2002 | 9 | 452 | | | |
| 78 | 6 | WAYNE BARTON | R02 | 4N/10E-25R02 | 4/16/2002 | | 461 | Qtr-Qtr Section | 4/26/2002 | 9 | 452 | | | |
| 240 | 6 | MERLE REEVES | Q01 | 4N/10E-25Q01 | 7/29/2002 | | 461 | Qtr-Qtr Section | 7/29/2002 | 50 | 411 | | | |
| 152 | 6 | MERLE REEVES | Q02 | 4N/10E-25Q02 | 6/4/2008 | | 476 | Parcel | 5/4/2008 | 45 | 431 | | | |
| 220 | 6 | JERRY LEWIS | M01 | 4N/10E-25M01 | 9/12/2003 | | 477 | Qtr-Qtr Section | 9/9/2003 | 90 | 387 | | | |
| 288 | 6 | AMBER YEZEK | A01 | 4N/10E-26A01 | | | 802 | Qtr-Qtr Section | 6/23/1983 | 193 | 609 | 25 | 70 | 0.36 |
| 285 | 6 | THOMAS MASSART | A02 | 4N/10E-26A02 | 5/15/2001 | | 802 | Qtr-Qtr Section | 5/15/2001 | 210 | 592 | | | |
| 360 | 6 | RONALD AND MARY CONNINE | A03 | 4N/10E-26A03 | 9/7/2000 | | 802 | Qtr-Qtr Section | 9/7/2000 | 245 | 557 | | | |
| 225 | 6 | BOB KUNZER | B01 | 4N/10E-26B01 | 3/23/1979 | | 963 | Qtr-Qtr Section | 3/23/1979 | 175 | 788 | | | |
| 320 | 6 | MICHAEL BEUG | B02 | 4N/10E-26B02 | 5/6/1980 | | 963 | Qtr-Qtr Section | 5/6/1980 | 220 | 743 | | | |
| 255 | 6 | CHUCK BRYAN | J01 | 4N/10E-26J01 | 10/20/1988 | | 563 | Qtr-Qtr Section | 10/20/1988 | 192 | 371 | | | |
| 250 | 6 | CHARLES BRYAN | J01 | 4N/10E-26J01 | 12/6/2005 | | 563 | Qtr-Qtr Section | 12/6/2005 | 80 | 483 | | | |
| 260 | 6 | CASSANDRA CASS | J02 | 4N/10E-26J02 | 6/14/2006 | | 899 | Parcel | | | | | | |
| 298 | 8 | RICK & BETTY HOWARD | Q01 | 4N/10E-26Q01 | 10/27/1988 | | 584 | Qtr-Qtr Section | | | | | | |
| 225 | 8 | JAMES NIELSEN | L01 | 4N/10E-26L01 | 8/20/1984 | | 941 | Qtr-Qtr Section | | | | | | |
| 310 | 6 | VAN G KELLEMS | B01 | 4N/10E-34P01 | 6/17/2002 | | 1355 | Parcel | 6/17/2002 | 195 | 1160 | | | |
| 230 | 6 | AUSTIN BELL | C01 | 4N/10E-35C01 | 7/17/1998 | | 764 | Qtr-Qtr Section | 7/17/1998 | 75 | 689 | | | |
| 200 | 6 | ROBERT NIPPOLT | D01 | 4N/10E-35D01 | | | 613 | Qtr-Qtr Section | | | | | | |
| 205 | 6 | JONN ANDERSON | K01 | 4N/10E-35K01 | 9/7/1988 | | 433 | Qtr-Qtr Section | 9/7/1988 | 160 | 273 | | | |
| 105 | 6 | JOHN JESSUP | R01 | 4N/10E-35R01 | 11/25/2008 | | 741 | Parcel | 11/25/2008 | 40 | 701 | | | |
| 70 | 6 | THOMAS W RESER | Q01 | 4N/10E-35Q01 | 4/15/1999 | | 329 | Qtr-Qtr Section | 4/15/1999 | 15 | 314 | | | |
| 160 | 6 | THOMAS RESER | Q02 | 4N/10E-35Q02 | 11/4/2003 | | 329 | Qtr-Qtr Section | 11/4/2003 | 10 | 319 | | | |
| 105 | 6 | STEVE HOSKINS | SW01 | 4N/10E-35SW01 | 8/5/1998 | | 522 | Qtr-Qtr Section | | | | | | |
| 465 | 6 | SANDRA ANDERSON | N01 | 4N/10E-35N01 | 5/1/2008 | | 398 | Parcel | 5/1/2008 | 160 | 238 | | | |
| 130 | 6 | GEORGE BAKER | X01 | 4N/10E-36X01 | 7/31/1972 | | 486 | Qtr-Qtr Section | | 49 | 437 | 30 | 60 | 0.50 |
| 130 | 6 | SIX S CO | A01 | 4N/10E-36A01 | 6/25/2002 | | 362 | Qtr-Qtr Section | 6/25/2002 | 70 | 292 | | | |
| 100 | 6 | SIX S CO | A02 | 4N/10E-36A02 | 6/24/2002 | | 362 | Qtr-Qtr Section | 6/24/2002 | 50 | 312 | | | |
| 160 | 10 | HUSUM HILLS GOLF COURSE | A03 | 4N/10E-36A03 | 6/19/1997 | 34859 A | 362 | Qtr-Qtr Section | 6/19/1997 | 91 | 271 | | | |
| 135 | 6 | DAVID BARNETTE | G01 | 4N/10E-36G01 | 9/19/1988 | | 483 | Qtr-Qtr Section | 9/19/1988 | 40 | 443 | | | |
| 120 | 6 | DAVID GIBNOY | G02 | 4N/10E-36G02 | 5/28/1973 | | 483 | Qtr-Qtr Section | 5/28/1973 | 58 | 425 | | | |
| 140 | 6 | LOREN SCHMID | C01 | 4N/10E-36C01 | 8/15/1977 | | 472 | Qtr-Qtr Section | 8/15/1977 | 52 | 420 | | | |
| 130 | 10 | BOYD YOUNG | F01 | 4N/10E-36F01 | | | 472 | Qtr-Qtr Section | | | | | | |
| 60 | 6 | MC COY HOLLISTON INS CO. | F02 | 4N/10E-36F02 | 10/7/1973 | | 472 | Qtr-Qtr Section | 10/7/1973 | 16 | 456 | | | |
| 120 | 6 | STUART FRASER | E01 | 4N/10E-36E01 | 10/4/1973 | | 431 | Qtr-Qtr Section | 10/4/1973 | 61 | 370 | | | |
| 140 | 6 | LEO GARVIN | J01 | 4N/10E-36J01 | 11/24/1973 | | 722 | Qtr-Qtr Section | | | | | | |
| 85 | 8 | DON STRUCK | J02 | 4N/10E-36J02 | 5/4/2004 | | 722 | Qtr-Qtr Section | 5/6/2004 | 22 | 700 | | | |
| 145 | 6 | ELLEN HENDRYX | K01 | 4N/10E-36K01 | 3/15/1988 | | 658 | Qtr-Qtr Section | 3/15/1988 | 75 | 583 | | | |
| 149 | - | QS - 2 - 59 | R01 | 4N/10E-36R01 | | | 1102 | Qtr-Qtr Section | | | | | | |
| 200 | 6 | DALE LOFTHUS | Q01 | 4N/10E-36Q01 | 10/8/1977 | | 691 | Qtr-Qtr Section | 10/8/1977 | 100 | 591 | | | |
| 200 | 6 | ROSEVE APLIN | Q02 | 4N/10E-36Q02 | 9/23/1981 | | 691 | Qtr-Qtr Section | 9/23/1981 | 91 | 600 | | | |
| 125 | 6 | SVERRE BAKKE | L01 | 4N/10E-36L01 | 5/9/1991 | | 499 | Qtr-Qtr Section | | | | | | |
| 100 | 6 | THOMAS MOORE | L02 | 4N/10E-36L02 | 5/7/1992 | | 499 | Qtr-Qtr Section | 5/7/1982 | 42 | 457 | | | |
| 130 | 6 | TOM STEVENSON | L03 | 4N/10E-36L03 | 9/13/1999 | | 499 | Qtr-Qtr Section | 9/13/1999 | 30 | 469 | | | |
| 1701 | 6 | KENDRA DUBY | L04 | 4N/10E-36L04 | 11/6/2000 | | 499 | Qtr-Qtr Section | 11/6/2000 | 55 | 444 | | | |
| 175 | 6 | CHAD BRUNTON | L05 | 4N/10E-36L05 | 9/29/2003 | | 499 | Qtr-Qtr Section | 9/29/2003 | 75 | 424 | | | |
| 150 | 6 | TALMAGE ALBERTS | M01 | 4N/10E-36M01 | 3/18/1988 | | 471 | Qtr-Qtr Section | 3/18/1988 | 50 | 421 | | | |

# Table 5.1 - Summary of Well Completion Details in the Project Area

Aquifer Storage and Recovery Feasibility Assessment
White Salmon, Washington

| | | | | | | | | | Water Level Data | | | Well Yield Data | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Depth (ft bgs) | Dia. (in.) | Well Owner (well log) | Label | TRS Identifier | Date | Water System ID | DEM Elevation | Source | Date | SWL (ft bgs) | SWE (ft MSL) | Yield (gpm) | Drawdown (ft) | Specific Capacity (gpm/ft) |
| 30 | - | QUARRY SITE 7-59 | P01 | 4N/10E-36P01 | | | 793 | Qtr-Qtr Section | | | | | | |
| 75 | 6 | CLEM CLARK | N01 | 4N/10E-36N01 | 10/3/1973 | | 526 | Qtr-Qtr Section | | | | | | |
| 320 | 6 | RUSSELL CRIPE | N02 | 4N/10E-36N02 | 3/20/1996 | | 526 | Qtr-Qtr Section | 3/20/1996 | 70 | 456 | | | |
| 1020 | 6 | MELVIN WALKER | G01 | 4N/11E-4G01 | 11/21/2006 | | 2059 | Qtr-Qtr Section | 12/4/2006 | 865 | 1194 | 12 | 100 | 0.12 |
| 185 | 8 | K. W. RIGGLEMAN | E01 | 4N/11E-5E01 | 8/13/1962 | 20540 Q | 1633 | Qtr-Qtr Section | 8/13/1962 | 80 | 1553 | | | |
| 915 | 8 | RIGGLEMAN ORCHARDS | E02 | 4N/11E-5E02 | 6/19/1983 | 20540 Q | 1633 | Qtr-Qtr Section | 6/20/1983 | 740 | 893 | 195 | 0 | - |
| 780 | 8 | RIGGLEMAN ORCHARDS | H01 | 4N/11E-6H01 | 9/6/1979 | | 1580 | Qtr-Qtr Section | 8/29/1979 | 540 | 1040 | 10 | 0 | - |
| 825 | 8 | RON RIGGLEMAN | H02 | 4N/11E-6H02 | 1/2/1993 | | 1580 | Qtr-Qtr Section | | | | | | |
| 786 | 8 | MT ADAMS ORCHARDS CORP | N01 | 4N/11E-6N01 | 5/10/2001 | 56397 V | 1245 | Qtr-Qtr Section | 5/10/2001 | 525 | 720 | | | |
| 500 | 6 | GERALD STOCKWELL | SE01 | 4N/11E-7SE01 | 8/11/1995 | | 1417 | Qtr-Qtr Section | | | | | | |
| 620 | 6 | GERALD STOCKWELL | J01 | 4N/11E-7J01 | 8/11/1995 | | 1531 | Qtr-Qtr Section | | | | | | |
| 280 | 6 | JB RANCH | J02 | 4N/11E-8J02 | 12/8/1973 | | 1970 | Qtr-Qtr Section | 12/8/1993 | 260 | 1710 | | | |
| 180 | 6 | E. L. JONES | P01 | 4N/11E-8P01 | 11/8/1965 | | 1632 | Qtr-Qtr Section | | | | | | |
| 300 | 6 | SOPHIE THOMAS | K01 | 4N/11E-10K01 | | | 910 | Qtr-Qtr Section | | | | | | |
| 125 | 6 | HUGH SHIELDS | K02 | 4N/11E-10K02 | 7/24/2001 | | 910 | Qtr-Qtr Section | | | | | | |
| 150 | 4 | DONALD & LISA FAGEN | R01 | 4N/11E-10R01 | 10/10/1992 | | 1360 | Qtr-Qtr Section | | 41 | 1319 | 1 | 80 | 0.01 |
| 375 | 6 | DAVID DOROCKE | M01 | 4N/11E-17M01 | 10/2/1995 | | 933 | Qtr-Qtr Section | | | | | | |
| 118 | 6 | PAUL AND MARY CARLOSS | N01 | 4N/11E-17N01 | 6/10/2005 | | 716 | Parcel | | 32 | 684 | 12 | 33 | 0.36 |
| 176 | 8 | DON STRUCK | N02 | 4N/11E-17N02 | 7/15/2007 | | 1227 | Parcel | 7/8/2007 | 117 | 1110 | | | |
| 455 | 6 | CHARLES G MONKMAN | A01 | 4N/11E-18A01 | 2/1/2007 | | 1179 | Qtr-Qtr Section | 2/1/2007 | 345 | 834 | | | |
| 570 | 6 | TERRY W BRADLEY | A02 | 4N/11E-18A02 | 6/23/2008 | | 1042 | Parcel | 6/23/2008 | 365 | 677 | | | |
| 410 | 6 | DES VERLEY | B01 | 4N/11E-18B01 | 3/15/2005 | | 1123 | Qtr-Qtr Section | 3/15/2004 | 320 | 803 | | | |
| 470 | 6 | DAVID BENSON | C01 | 4N/11E-18C01 | 10/10/1977 | | 1044 | Qtr-Qtr Section | 10/10/1977 | 263 | 781 | 30 | 190 | 0.16 |
| 135 | 6 | SHELDON WEINBERG | Q01 | 4N/11E-18Q01 | 9/8/1990 | | 647 | Qtr-Qtr Section | 9/8/1990 | 78 | 569 | | | |
| 285 | 6 | CHARLES SMITH | A01 | 4N/11E-19A01 | 10/10/1991 | | 646 | Qtr-Qtr Section | | | | | | |
| 245 | 6 | THOMAS STOELTING | A02 | 4N/11E-19A02 | 6/3/1999 | | 646 | Qtr-Qtr Section | 6/3/1999 | 60 | 586 | | | |
| 290 | 6 | THOMAS PROVENZANO | A03 | 4N/11E-19A03 | 11/5/2002 | | 646 | Qtr-Qtr Section | 11/5/2002 | 100 | 546 | | | |
| 190 | 6 | JIM BLACK BURN | H01 | 4N/11E-19H01 | 6/24/1994 | | 722 | Qtr-Qtr Section | 6/24/1994 | 99 | 623 | | | |
| 203 | 6 | BILL PARKS | F01 | 4N/11E-19F01 | 7/7/1978 | | 540 | Qtr-Qtr Section | 7/7/1978 | 96 | 444 | 20 | 98 | 0.20 |
| 85 | 6 | FRANK HUNSAKER | F02 | 4N/11E-19F02 | 9/7/1989 | | 540 | Qtr-Qtr Section | 9/7/1989 | 21 | 519 | | | |
| 138 | 8 | TOM COPE | F03 | 4N/11E-19F03 | 9/20/2007 | | 508 | Parcel | 9/20/2007 | 66 | 442 | | | |
| 120 | 6 | SK ORCHARDS | E01 | 4N/11E-19E01 | 5/30/2007 | | 439 | Parcel | 5/30/2007 | 10 | 429 | | | |
| 435 | 6 | JHON S. PARADIS & GENE MAREOTTE | J01 | 4N/11E-19J01 | 5/26/1974 | | 828 | Qtr-Qtr Section | 5/26/1974 | 225 | 603 | | | |
| 390 | 8 | JERRY LEWIS | K01 | 4N/11E-19K01 | 9/1/1992 | | 809 | Qtr-Qtr Section | 9/1/1992 | 345 | 464 | | | |
| 505 | 6 | MARK HARRIE | K02 | 4N/11E-19K02 | 10/30/1991 | | 809 | Qtr-Qtr Section | 10/30/1991 | 345 | 464 | | | |
| 220 | 6 | TOM CULP | NW01 | 4N/11E-20NW01 | 9/13/1999 | | 857 | Qtr-Qtr Section | | | | | | |
| 201 | 10 | DON GENSLER | C01 | 4N/11E-20C01 | 9/18/1993 | | 977 | Qtr-Qtr Section | 9/18/1992 | 92 | 885 | | | |
| 428 | 6 | JOHN ROSS | D01 | 4N/11E-20D01 | 6/17/1983 | | 714 | Qtr-Qtr Section | 6/7/1983 | 140 | 574 | 15 | 260 | 0.06 |
| 480 | 6 | TJ LUTZ | R01 | 4N/11E-20R01 | 10/23/2006 | | 733 | Qtr-Qtr Section | 10/23/2006 | 275 | 458 | | | |
| 320 | 6 | TOM LUTZ | P01 | 4N/11E-20P01 | 5/17/1982 | | 820 | Qtr-Qtr Section | 5/17/1982 | 250 | 570 | | | |
| 425 | 6 | TOM LUTZ | P02 | 4N/11E-20P02 | 8/6/1997 | | 820 | Qtr-Qtr Section | 8/6/1997 | 250 | 570 | | | |
| 300 | 6 | KIRK WALSTON | J01 | 4N/11E-28J01 | 5/10/2006 | | 2254 | Qtr-Qtr Section | 5/10/2006 | 195 | 2059 | | | |
| 304 | 6 | JOHN KOHEN | R01 | 4N/11E-28R01 | 6/23/1999 | | 2240 | Qtr-Qtr Section | | | | | | |
| 445 | 6 | TED & GRACE LUTZ | D01 | 4N/11E-29D01 | 4/9/1990 | | 612 | Qtr-Qtr Section | 4/4/1990 | 255 | 357 | | | |
| 370 | 6 | MIKE NYSTROM | A01 | 4N/11E-30A01 | 8/13/1997 | | 807 | Qtr-Qtr Section | 8/13/1997 | 303 | 504 | | | |
| 405 | 6 | CARL & JAMES TEEL | B01 | 4N/11E-30B01 | 11/11/1993 | | 674 | Qtr-Qtr Section | 11/11/1993 | 355 | 319 | | | |
| 365 | 6 | JAMES TEEL | B02 | 4N/11E-30B02 | 9/27/2000 | | 674 | Qtr-Qtr Section | 9/27/2000 | 300 | 374 | | | |
| 302 | 6 | MARGARET KANTOLA | G01 | 4N/11E-30G01 | 8/5/1999 | | 527 | Qtr-Qtr Section | 8/5/1999 | 175 | 352 | | | |
| 370 | 6 | JAY JOHNSTON | D01 | 4N/11E-30D01 | 3/11/2005 | | 521 | Qtr-Qtr Section | 3/11/2005 | 295 | 226 | | | |
| 215 | 8 | BERNIE ELSNER | F01 | 4N/11E-30F01 | 7/17/1980 | | 623 | Qtr-Qtr Section | 7/17/1980 | 170 | 453 | | | |
| 205 | 6 | BERNARD M ELSNER | E01 | 4N/11E-30E01 | 8/31/2004 | | 513 | Qtr-Qtr Section | 8/31/2004 | 160 | 353 | | | |
| 183 | 6 | DAVIE WELCH | K01 | 4N/11E-30K01 | 9/4/1981 | | 521 | Qtr-Qtr Section | | | | | | |
| 290 | 6 | DANIEL JONES | R01 | 4N/11E-30R01 | 8/6/1993 | 05870 5 | 567 | Qtr-Qtr Section | 8/6/1993 | 162 | 405 | 20 | 290 | 0.07 |
| 80 | 6 | JOHN D WEST | M01 | 4N/11E-30M01 | 7/28/1999 | | 522 | Qtr-Qtr Section | 7/28/1999 | 26 | 496 | | | |
| 110 | 6 | HUNSAKER OIL CO. C/O FRANK HUNSAKER | N01 | 4N/11E-30N01 | 9/5/1989 | | 414 | Qtr-Qtr Section | 9/5/1989 | 28 | 386 | | | |
| 98 | 6 | RICHARD SMITH | N02 | 4N/11E-30N02 | 5/23/1983 | | 414 | Qtr-Qtr Section | 5/23/1983 | 10 | 404 | | | |
| 65 | 6 | STEPHEN STAMPFLI | N03 | 4N/11E-30N03 | 10/11/1996 | | 414 | Qtr-Qtr Section | 10/11/1996 | 14 | 400 | | | |
| 80 | 6 | W. M. DAVIS | N04 | 4N/11E-30N04 | 5/31/1985 | | 414 | Qtr-Qtr Section | | | | | | |
| 80 | 6 | JAY JOHNSTON | N05 | 4N/11E-30N05 | 3/30/2000 | | 414 | Qtr-Qtr Section | 3/30/2000 | 23 | 391 | | | |
| 41 | 8 | HERMAN DONLEY | N06 | 4N/11E-30N06 | 4/6/2002 | | 414 | Qtr-Qtr Section | 4/3/2002 | 11 | 403 | | | |
| 80 | 6 | STEVEN CROW | N07 | 4N/11E-30N07 | 9/26/2006 | | 414 | Qtr-Qtr Section | 6/26/2006 | 25 | 389 | | | |
| 112 | 6 | MICHAEL CLEMENTS | N08 | 4N/11E-30N08 | 9/1/2006 | | 414 | Qtr-Qtr Section | 9/1/2006 | 5 | 409 | | | |
| - | - | HUSUM DEPT OF NATURAL RESOURCES | N09 | 4N/11E-30N09 | - | NR395 U | 405 | GPS | | | | | | |
| 160 | 6 | DEREK GOODWIN | B01 | 4N/11E-31B01 | 4/12/1995 | | 633 | Qtr-Qtr Section | 4/12/1995 | 10 | 623 | | | |
| 110 | 6 | DUHRKOP, JOHN (01340) | NW01 | 4N/11E-31NW01 | 8/28/1998 | | 484 | Qtr-Qtr Section | | | | | | |
| 180 | 6 | SCOTT NIELSON | NW02 | 4N/11E-31NW02 | 6/12/2006 | | 484 | Qtr-Qtr Section | | | | | | |
| 200 | 6 | KEN DICKEN | C01 | 4N/11E-31C01 | 8/21/1990 | | 470 | Qtr-Qtr Section | 8/21/1990 | 65 | 405 | | | |
| 65 | 6 | FRED JORGISON | C02 | 4N/11E-31C02 | 10/2/2001 | | 470 | Qtr-Qtr Section | 10/2/2001 | 25 | 445 | | | |
| 67 | 6 | FRED JORGENSEN | C03 | 4N/11E-31C03 | 9/28/2005 | | 470 | Qtr-Qtr Section | 9/28/2005 | 20 | 450 | | | |
| 114 | 8 | JERRY SMITH | C04 | 4N/11E-31C04 | 10/3/2006 | | 470 | Qtr-Qtr Section | | | | | | |
| 240 | 8 | CAM THOMAS | C05 | 4N/11E-31C05 | 9/28/2006 | | 470 | Qtr-Qtr Section | | | | | | |
| 80 | 6 | GLENN TAYLOR | C06 | 4N/11E-31C06 | 12/27/2007 | | 429 | Parcel | 12/27/2007 | 30 | 399 | | | |
| 75 | 6 | CLINT COLBERT | D01 | 4N/11E-31D01 | 8/12/1993 | | 430 | Qtr-Qtr Section | | | | | | |
| 65 | 6 | JERRY SMITH | D02 | 4N/11E-31D02 | 7/24/1996 | | 430 | Qtr-Qtr Section | 7/24/1996 | 28 | 402 | | | |
| 130 | 6 | MERLIN GRANBERG | D03 | 4N/11E-31D03 | 11/7/1988 | | 430 | Qtr-Qtr Section | | | | | | |
| 80 | 6 | JIM AND LORRAINE BRADSHAW | D04 | 4N/11E-31D04 | 10/10/2002 | | 430 | Qtr-Qtr Section | 10/10/2002 | 45 | 385 | | | |
| 100 | 6 | SCOTT NIELSON | D05 | 4N/11E-31D05 | 4/18/2005 | | 430 | Qtr-Qtr Section | 4/18/2005 | 20 | 410 | | | |
| 162 | 6 | HUSUM HILLS GOLF CLUB | D06 | 4N/11E-31D06 | 4/15/1969 | | 430 | Qtr-Qtr Section | 4/15/1965 | 76 | 354 | 40 | 28 | 1.43 |
| 220 | 8 | JERRY SMITH | F01 | 4N/11E-31F01 | 5/31/2005 | AB373 E | 531 | GPS | 5/31/2005 | 68 | 463 | | | |
| 180 | 8 | DON STRUCK | K01 | 4N/11E-31K01 | 5/10/2004 | AB174 E | 846 | Qtr-Qtr Section | 5/10/2004 | 70 | 776 | | | |
| 490 | 8 | MT. ADAMS ORCHARD COMPANY | R01 | 4N/11E-31R01 | 6/11/1965 | AA988 E | 1499 | Qtr-Qtr Section | | | | | | |
| 148 | 6 | ALAN SHIPP | L01 | 4N/11E-31L01 | 5/18/1979 | | 897 | Qtr-Qtr Section | 5/28/1979 | 15 | 882 | 10 | 120 | 0.08 |
| 190 | 6 | RICK QUIGLEY | A01 | 4N/11E-32A01 | 6/30/1994 | | 1617 | Qtr-Qtr Section | | | | | | |
| 160 | 6 | DAVID TURNER | B01 | 4N/11E-32B01 | 8/9/1996 | | 1003 | Qtr-Qtr Section | 8/9/1996 | 30 | 973 | | | |
| 60 | 6 | GARY BALDOZIER | C01 | 4N/11E-32C01 | 4/18/1995 | | 730 | Qtr-Qtr Section | 4/18/1995 | 10 | 720 | | | |
| 260 | 6 | TEX R JACOBS | SW01 | 5N/10E-26SW01 | 6/29/2001 | | 1324 | Qtr-Qtr Section | | | | | | |
| 220 | 6 | CHARLES BAUGUESS | P01 | 5N/10E-26P01 | 6/26/2001 | | 1067 | Qtr-Qtr Section | 6/26/2001 | 160 | 907 | | | |
| 150 | 6 | ORLIS HALE | X01 | 5N/10E-35X01 | 3/22/1973 | | 922 | Qtr-Qtr Section | | 104 | 818 | 20 | 12 | 1.67 |
| 225 | 6 | JOHN E CHANEY | R01 | 5N/10E-35R01 | 2/14/2006 | | 886 | Qtr-Qtr Section | 2/14/2006 | 100 | 786 | | | |
| 167 | 8 | LARRY VAUGHAN | Q01 | 5N/10E-35Q01 | 9/18/2007 | | 885 | Parcel | 9/18/2007 | 115 | 770 | | | |
| 215 | 6 | ANNIE PIPER-BURNS | L01 | 5N/10E-35L01 | 10/6/2005 | | 927 | Parcel | 10/6/2005 | 120 | 807 | | | |
| 460 | 6 | PATRICIA KREPS | B01 | 5N/11E-32B01 | 11/28/1990 | | 1445 | Qtr-Qtr Section | | | | | | |
| 75 | 8 | HOPP - DEWILDE MILL CO. | N01 | 5N/11E-32N01 | 9/10/1947 | | 1359 | Qtr-Qtr Section | | | | | | |
| 130 | 6 | MRS. ALLEN | X01 | 5N/11E-33X01 | 10/14/1973 | | 1695 | Qtr-Qtr Section | | | | | | |
| 424 | 6 | HEATH JACOBS | R01 | 5N/11E-34R01 | 9/15/2004 | | 1962 | Qtr-Qtr Section | | | | | | |
| 360 | 6 | EDWARD AND BRENDA LEXA | L01 | 5N/11E-34L01 | 11/8/2001 | | 2239 | Qtr-Qtr Section | | | | | | |

# Table 5.2 - Aquifer Hydraulic Parameters
# Grande Ronde Basalt

Aquifer Storage and Recovery Feasibility Assessment
White Salmon, Washington

| Location | Method | Number of Wells | Specific Capacity (gpm/ft) | | | Transmissivity ($ft^2$/day) | | | Hydraulic Conductivity (ft/day) | | | Storativity (Dimensionless) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Minimum | Maximum | Geometric Mean | Minimum | Maximum | Mean or Accepted Value | Minimum | Maximum | Mean or Accepted Value | Minimum | Maximum |
| Columbia Plateau Aquifer System[1] | Model | - | - | - | - | 40 | 16,000 | 3,700 | 0.1 | 8.6 | 2.3 | 0.00001 | 0.00110 |
| City of White Salmon Power House Road Test Well[2] | Aquifer Test | 1 | - | - | - | 2,090 | 2,350 | 2,350 | 4.0 | 4.5 | 4.5 | 0.00056 | 0.00070 |
| City of White Salmon Production Well No. 2[3] | Aquifer Test | 1 | - | - | - | 145 | 169 | 169 | 1.1 | 1.3 | 1.3 | - | - |
| Underwood Water District Well[4] | Aquifer Test | 1 | - | - | - | - | - | 51,400 | - | - | 553 | - | - |
| Ecology Well Logs[5] | Specific Capacity Data | 4 | 0.08 | 0.94 | 0.23 | 22 | 251 | 61 | 0.4 | 5.0 | 1.2 | - | - |

**Notes:**

[1] Ground-Water Flow Simulation of the Columbia Plateau Regional Aquifer System, Washington, Oregon, and Idaho (Hansen, Vacarro, and Bauer, 1994).

[2] Aquifer Test Report - Power House Road Test Well (Mark Yinger Associates, 1999).

[3] Aquifer Test Report - Production Well #2 (Mark Yinger Associates, 2001).

[4] WRIA 29 Hydrology and Geology Assessment (WPN & Mark Yinger Associates, 2002).

[5] Washington State Department of Ecology Well Log Database.

Transmissivity (in gpd/ft) was calculated for wells without pumping test reports using the following equation:
Confined Aquifer (Grande Ronde Basalt):

$$\frac{Q}{s} = \frac{T}{2000}$$

where:
Q is the pumping rate in gallons per minute
$\Delta s$ is the drawdown in feet over a log cycle of time

The hydraulic conductivity for wells without aquifer test reports is based on an assumed saturated thickness of the water-bearing zone of 50 feet.

# Table 5.3 - Regional and Local Grande Ronde Basalt Groundwater Quality

Aquifer Storage and Recovery Feasibility Assessment
White Salmon, Washington

| | Regional Data | | | | Site-Specific Data | | |
|---|---|---|---|---|---|---|---|
| Constituent | Number of Analyses | Maximum Concentration | Mean Concentration | Minimum Concentration | Well No. 1 (11/23/05) | Well No. 2 (2/17/10) | Source Water (2/17/10) |
| Temperature ($^{o}$C) | 202 | 36.7 | 18.3 | 7.6 | - | 12.2 | 5.5 |
| pH (standard units) | 202 | 9.4 | 7.89 | 6.7 | - | 8.16 | 8.05 |
| Dissolved oxygen (DO) | 160 | 10.2 | 2.6 | 0.1 | - | 5.00 | 10.85 |
| Specific conductance (uS/cm) | 203 | 830 | 311.7 | 119 | - | 100 | 50 |
| Calcium (Ca) | 203 | 88 | 22.9 | 0.95 | 21.0 | 8.87 | 5.73 |
| Magnesium (Mg) | 203 | 33 | 10.3 | 0.01 | 9.3 | 3.17 | 1.87 |
| Sodium (Na) | 203 | 90 | 27.7 | 4.1 | 8.00 | 7.81 | 2.39 |
| Potassium (K) | 203 | 13 | 4.9 | 1.1 | - | 2.55 | 1.13 |
| Chloride (Cl) | 203 | 45 | 6.9 | 0.8 | 1.30 | 1.20 | 1.16 |
| Sulfate ($SO_4$) | 203 | 96 | 14 | 0.2 | 2.5 | 2.87 | 0.53 |
| Alkalinity ($CaCO_3$) | - | - | - | - | 90.0 | 52.5 | 29.0 |
| Bicarbonate (HCO3) | 203 | 339 | 169.9 | 42 | - | - | - |
| Carbonate ($CO_3$) | 20 | 56 | 18.7 | 2 | - | - | - |
| Silica (SiO2) | 203 | 110 | 57.2 | 29 | - | 37.7 | 24.9 |
| Iron (Fe) (ug/L) | 203 | 760 | 51 | 3 | 100 U | 80 | 50 U |
| Manganese (Mn) (ug/L) | 203 | 810 | 15 | 1 | 0.2 U | 93 | 5 U |
| Total Dissolved Solids (TDS) | 183 | 510 | 235 | 94 | 150 | 96 | 46 |

**Notes:**

U - Not detected at associated detection limit. "-" Not analyzed.

Values in milligrams per liter (mg/L) unless otherwise indicated.

Regional water quality data from Water-Quality Characteristics of the Columbia Plateau Regional Aquifer System in Parts of Washington, Oregon, and Idaho (Steinkampf, 1989).

Total hardness was used as a substitute for alkalinity for Well No. 1.

Source water is sand filtered, unchlorinated surface water from Buck Creek, provided as a comparison.

# Table 5.4 - Site-Specific Groundwater Quality Data

Aquifer Storage and Recovery Feasibility Assessment
White Salmon, Washington

| | Groundwater | | | | Source Water | | | | Washington Regulatory Standards | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | Surface Water Criteria | |
| Chemical Name | Well No. 1 (11/23/05) | Well No. 2 (9/21/05) | Well No. 2 (9/29/09) | Well No. 2 (2/17/10) | Buck Creek (5/7/97) | Buck Creek (8/31/98) | Buck Creek (11/4/08) | Buck Creek (2/17/10) | Primary or Secondary MCLs (WAC 246-290) | Groundwater Quality Standards (WAC 173-200) | Acute Surface Water Quality Criteria (WAC 173-201A) | Chronic Surface Water Quality Criteria (WAC 173-201A) |
| **Metals (EPA 6000 series Methods)** | | | | | | | | | | | | |
| Dissolved Aluminum in ug/L | | | | 10 U | | | | 28 | | | | |
| Dissolved Antimony in ug/L | 0.5 U | 0.5 U | 1 U | 1 U | 0.5 U | | | 1 U | 6 | | | |
| Dissolved Arsenic in ug/L | 0.5 U | 0.5 U | 1 U | 1 U | 0.5 U | | | 1 U | 10 | 0.05 | 360 | 190 |
| Dissolved Barium in ug/L | 1.7 | 1.2 | 1 | 3 | 3 | | | 3 | 2000 | 1000 | | |
| Dissolved Berylium in ug/L | 0.5 U | 0.5 U | 1 U | 2 U | 0.5 U | | | 2 U | 4 | | | |
| Dissolved Cadmium in ug/L | 0.2 U | 0.2 U | 1 U | 1 U | 0.2 U | | | 1 U | 5 | 10 | 3.7** | 1.0** |
| Dissolved Calcium in ug/L | 21000 | 9500 | | 8870 | 5000 | | | 5730 | | | | |
| Dissolved Chromium in ug/L | 1 | 1 U | 10 U | 5 U | 1 U | | | 5 U | 100 | 50 | 549** | 178** |
| Dissolved Cobalt in ug/L | | | | 1 U | | | | 1 U | | | | |
| Dissolved Copper in ug/L | 1 U | 1 U | 5 U | 5 U | 20 U | | | 5 U | 1300 | *1000* | 17** | 11** |
| Dissolved Iron in ug/L | 100 U | 100 U | 110 | 80 | 50 U | | | 50 U | *300* | *300* | | |
| Dissolved Lead in ug/L | 2 U | 0.3 | 1 U | 1 U | 0.9 | | | 1 U | 15 | 50 | 65** | 3** |
| Dissolved Magnesium in ug/L | 9300 | 3800 | | 3170 | 2000 | | | 1870 | | | | |
| Dissolved Manganese in ug/L | 0.2 U | 7.6 | 8 | **93** | 5 U | | | 5 U | *50* | *50* | | |
| Dissolved Mercury in ug/L | 0.4 U | 0.4 U | 0.2 U | 0.2 U | 0.5 U | | | 0.2 U | 2 | 2 | 2.1 | 0.012 |
| Dissolved Nickel in ug/L | 0.5 U | 0.5 U | 5 U | 1 U | 10 U | | | 1 U | 100 | | 1415** | 157** |
| Dissolved Potassium in ug/L | | | | 2550 | | | | 1130 | | | | |
| Dissolved Selenium in ug/L | 5 U | 5 U | 5 U | 5 U | 1 U | | | 5 U | 50 | 10 | 20 | 5 |
| Dissolved Silver in ug/L | 0.5 U | 0.5 U | 10 U | 1 U | 1.1 | | | 1 U | *100* | 50 | 3.4** | |
| Dissolved Sodium in ug/L | 8000 | 7000 | 7500 | 7810 | 2900 | | | 2390 | 20000 | | | |
| Dissolved Thallium in ug/L | 0.2 U | 0.2 U | 1 U | 1 U | 0.2 U | | | 1 U | 2 | | | |
| Dissolved Vanadium in ug/L | | | | 1 U | | | | 2 U | | | | |
| Dissolved Zinc in ug/L | 6 | 25 | 34 | 5 U | 20 U | | | 5 U | *5000* | *5000* | 114** | 105** |
| **Volatile Organics (EPA Method 524.2)** | | | | | | | | | | | | |
| 1,1,1,2-Tetrachloroethane in ug/L | 0.5 U | 0.5 U | 0.5 U | | | 0.5 U | | | | | | |
| 1,1,1-Trichloroethane in ug/L | 0.5 U | 0.5 U | 0.5 U | | | 0.5 U | | | 200 | 200 | | |
| 1,1,2,2-Tetrachloroethane in ug/L | 0.5 U | 0.5 U | 0.5 U | | | 0.5 U | | | | | | |
| 1,1,2-Trichloroethane in ug/L | 0.5 U | 0.5 U | 0.5 U | | | 0.5 U | | | 5 | | | |
| 1,1-Dichloroethane in ug/L | 0.5 U | 0.5 U | 0.5 U | | | 0.5 U | | | | 1 | | |
| 1,1-Dichloroethene in ug/L | 0.5 U | 0.5 U | 0.5 U | | | 0.5 U | | | 7 | | | |
| 1,1-Dichloropropene in ug/L | 0.5 U | 0.5 U | 0.5 U | | | 0.5 U | | | | | | |
| 1,2,3-Trichlorobenzene in ug/L | 0.5 U | 0.5 U | 0.5 U | | | 0.5 U | | | | | | |
| 1,2,3-Trichloropropane in ug/L | 0.5 U | 0.5 U | 0.5 U | | | 0.5 U | | | | | | |
| 1,2,4-Trichlorobenzene in ug/L | 0.5 U | 0.5 U | 0.5 U | | | 0.5 U | | | 70 | | | |
| 1,2,4-Trimethylbenzene in ug/L | 0.5 U | 0.5 U | 0.5 U | | | 0.5 U | | | | | | |
| 1,2-Dibromo-3-chloropropane in ug/L | 0.5 U | 0.5 U | 0.5 U | | | 0.5 U | | | | | | |
| 1,2-Dibromomethane ug/L | 0.5 U | 0.5 U | 0.5 U | | | 0.5 U | | | | 0.001 | | |
| 1,2-Dichlorobenzene in ug/L | 0.5 U | 0.5 U | 0.5 U | | | 0.5 U | | | 600 | | | |
| 1,2-Dichloroethane (EDC) in ug/L | 0.5 U | 0.5 U | 0.5 U | | | 0.5 U | | | 5 | 0.5 | | |
| 1,2-Dichloropropane in ug/L | 0.5 U | 0.5 U | 0.5 U | | | 0.5 U | | | 5 | 0.6 | | |
| 1,3,5-Trimethylbenzene in ug/L | 0.5 U | 0.5 U | 0.5 U | | | 0.5 U | | | | | | |
| 1,3-Dichlorobenzene in ug/L | 0.5 U | 0.5 U | 0.5 U | | | 0.5 U | | | | | | |
| 1,3-Dichloropropane in ug/L | 0.5 U | 0.5 U | 0.5 U | | | 0.5 U | | | | 0.2 | | |
| 1,4-Dichlorobenzene in ug/L | 0.5 U | 0.5 U | 0.5 U | | | 0.5 U | | | 75 | 4 | | |
| 2,2-Dichloropropane in ug/L | 0.5 U | 0.5 U | 0.5 U | | | 0.5 U | | | | | | |
| 2-Chlorotoluene in ug/L | 0.5 U | 0.5 U | 0.5 U | | | 0.5 U | | | | | | |
| 4-Chlorotoluene in ug/L | 0.5 U | 0.5 U | 0.5 U | | | 0.5 U | | | | | | |
| p-Isopropyltoluene in ug/L | 0.5 U | 0.5 U | 0.5 U | | | 0.5 U | | | | | | |
| Benzene in ug/L | 0.5 U | 0.5 U | 0.5 U | | | 0.5 U | | | 5 | 1 | | |
| Bromobenzene in ug/L | 0.5 U | 0.5 U | 0.5 U | | | 0.5 U | | | | | | |
| Bromomethane in ug/L | 0.5 U | 0.5 U | 0.5 U | | | 0.5 U | | | | | | |
| Carbon tetrachloride in ug/L | 0.5 U | 0.5 U | 0.5 U | | | 0.5 U | | | 5 | 0.3 | | |
| Chlorobenzene in ug/L | 0.5 U | 0.5 U | 0.5 U | | | 0.5 U | | | 100 | | | |
| Bromochloromethane in ug/L | 0.5 U | 0.5 U | 0.5 U | | | 0.5 U | | | | | | |
| Chloroethane in ug/L | 0.5 U | 0.5 U | 0.5 U | | | 0.5 U | | | | | | |
| Chloromethane in ug/L | 0.5 U | 0.5 U | 0.5 U | | | 0.5 U | | | | | | |
| cis-1,2-Dichloroethene in ug/L | 0.5 U | 0.5 U | 0.5 U | | | 0.5 U | | | 70 | | | |
| cis-1,3-Dichloropropene in ug/L | 0.5 U | 0.5 U | 0.5 U | | | 0.5 U | | | | | | |
| Dibromomethane in ug/L | 0.5 U | 0.5 U | 0.5 U | | | 0.5 U | | | | | | |
| Dichlorodifluoromethane in ug/L | 0.5 U | 0.5 U | 0.5 U | | | 0.5 U | | | | | | |
| Ethylbenzene in ug/L | 0.5 U | 0.5 U | 0.5 U | | | 0.5 U | | | 700 | | | |
| Hexachlorobutadiene in ug/L | 0.5 U | 0.5 U | 0.5 U | | | 0.5 U | | | | | | |
| Isopropylbenzene in ug/L | 0.5 U | 0.5 U | 0.5 U | | | 0.5 U | | | | | | |
| Methylene chloride in ug/L | 0.5 U | 0.5 U | 0.5 U | | | 0.5 U | | | 5 | | | |
| Methyl tert-butyl ether | | | 1 U | | | | | | | | | |
| Naphthalene in ug/L | 0.5 U | 0.5 U | 0.5 U | | | 0.5 U | | | | | | |
| n-Butylbenzene in ug/L | 0.5 U | 0.5 U | 0.5 U | | | 0.5 U | | | | | | |
| n-Propylbenzene in ug/L | 0.5 U | 0.5 U | 0.5 U | | | 0.5 U | | | | | | |
| sec-Butylbenzene in ug/L | 0.5 U | 0.5 U | 0.5 U | | | 0.5 U | | | | | | |
| Styrene in ug/L | 0.5 U | 0.5 U | 0.5 U | | | 0.5 U | | | 100 | | | |
| tert-Butylbenzene in ug/L | 0.5 U | 0.5 U | 0.5 U | | | 0.5 U | | | | | | |
| Tetrachloroethene (PCE) in ug/L | 0.5 U | 0.5 U | 0.5 U | | | 0.5 U | | | 5 | 0.8 | | |
| Toluene in ug/L | 0.5 U | 0.5 U | 0.5 U | | | 0.8 | | | 1000 | | | |
| trans-1,2-Dichloroethene in ug/L | 0.5 U | 0.5 U | 0.5 U | | | 0.5 U | | | 100 | | | |
| trans-1,3-Dichloropropene in ug/L | 0.5 U | 0.5 U | 0.5 U | | | 0.5 U | | | | | | |
| Trichloroethene (TCE) in ug/L | 0.5 U | 0.5 U | 0.5 U | | | 0.5 U | | | 5 | 3 | | |
| Trichlorofluoromethane in ug/L | 0.5 U | 0.5 U | 0.5 U | | | 0.5 U | | | | | | |
| Vinyl chloride in ug/L | 0.5 U | 0.5 U | 0.5 U | | | 0.5 U | | | 2 | 0.02 | | |
| Xylenes (total) in ug/L | 0.5 U | 0.5 U | 0.5 U | | | 0.5 U | | | 10000 | | | |
| **Trihalomethanes (EPA Method 524.2)** | | | | | | | | | | | | |
| Bromodichloromethane in ug/L | 0.5 U | 0.5 U | | | | 0.5 U | | | | 0.3 | | |
| Bromoform in ug/L | 0.5 U | 0.5 U | | | | 0.5 U | | | | 5 | | |
| Chloroform in ug/L | 0.5 U | 0.5 U | | | | 2.7 | | | | 7 | | |
| Dibromochloromethane in ug/L | 0.5 U | 0.5 U | | | | 0.5 U | | | | 0.5 | | |
| Total Trihalomethanes in ug/L * | 0.5 U | 0.5 U | | | | 2.7 | | | 80 | | | |
| **Conventionals (APHA/EPA Methods)** | | | | | | | | | | | | |
| Alkalinity in mg/L as $CaCO_3$ | | | | 52.5 | | | | 29 | | | | |
| Total Hardness in mg/L | 90 | 39 | 46 | | 21 | | | | | | | |
| Chloride in mg/L | 1.3 | 1.2 | | 1.2 | 1.7 | | | 1.16 | *25* | *250* | 860 | 230 |
| Cyanide in mg/L | 0.005 U | 0.005 U | 0.04 U | | 0.005 U | | | | 0.2 | | | |
| Fluoride in mg/L | 0.2 U | 0.2 U | 0.08 J | | 0.2 U | | | | *2* | 4 | | |
| Sulfate in mg/L | 2.5 | 2.6 | 2.5 | 2.87 | 0.4 | | | 0.53 J | *250* | *250* | | |
| Sulfide in mg/L | | | | 0.1 U | | | | 0.1 U | | | | |
| Silica as $SiO_2$ in mg/L | | | | 37.7 | | | | 24.9 | | | | |
| Nitrate as Nitrogen in mg/L | 0.1 | 0.1 U | 0.02 J | | 0.01 U | | 0.1 U | | 10 | 10 | | |
| Nitrite as Nitrogen in mg/L | 0.1 U | 0.1 U | 0.1 U | | 0.01 U | | | | 1 | | | |
| Ammonia as Nitrogen in mg/L | | | | 0.02 J | | | | 0.01 J | | | ** | ** |
| Orthophosphate as Phosphorous in mg/L | | | | 0.1 U | | | | 0.1 U | | | | |
| Total Phosphorous in mg/L | | | | 0.048 | | | | 0.019 | | | | |
| Total Organic Carbon (TOC) in mg/L | | | | 0.5 U | | | 1.5 | 0.54 | | | | |
| Total Dissolved Solids (TDS) in mg/L | 150 | 80 | | 96 | 40 | | | 46 | 500 | *500* | | |
| Total Suspended Solids (TSS) in mg/L | | | | 5 U | | | | 5 U | | | | |
| Color (in Color Units) | 5 U | 5 U | 5 U | | 5 U | | | | 15 | *15* | | |

# Table 5.4 - Site-Specific Groundwater Quality Data

Aquifer Storage and Recovery Feasibility Assessment
White Salmon, Washington

| | Groundwater | | | | Source Water | | | | Washington Regulatory Standards | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | Surface Water Criteria | |
| Chemical Name | Well No. 1 (11/23/05) | Well No. 2 (9/21/05) | Well No. 2 (9/29/09) | Well No. 2 (2/17/10) | Buck Creek (5/7/97) | Buck Creek (8/31/98) | Buck Creek (11/4/08) | Buck Creek (2/17/10) | Primary or Secondary MCLs (WAC 246-290) | Groundwater Quality Standards (WAC 173-200) | Acute Surface Water Quality Criteria (WAC 173-201A) | Chronic Surface Water Quality Criteria (WAC 173-201A) |
| **Radionuclides ***** | | | | | | | | | | | | |
| Gross Alpha in pCi/L | 2.9 +/- 0.9 | | 1.9 +/- 0.8 | | | | | | | 15 | | |
| Radium 228 in pCi/L | 0.7 +/- 0.7 U | | 0.9 +/- 0.8 | | | | | | | 5 | | |
| **Field Parameters** | | | | | | | | | | | | |
| Temperature Celsius | | | | 12.2 | | | | 5.5 | | | | |
| Turbidity in NTU | 0.37 | 0.32 | 1.03 | | 0.24 | | | | | | | |
| Specific Conductance in uS/cm | 210 | 120 | 113 | 100 | 45 | | | 50 | 700 | | | |
| pH | | | | 8.16 | | | | 8.05 | | *6.5 - 8.5* | | |
| Dissolved Oxygen in mg/L | | | | 5.00 | | | | 10.85 | | | | |
| Eh (ORP) in mvolts | | | | -47 | | | | -24 | | | | |

**Notes:**

U - Not detected at associated detection limit. J: Estimated concentration. Blank: Not analyzed.

MCL - Federal Drinking Water Maximum Contaminant Level

Secondary MCLs are in italics.

* Totals calculated as sum of detected values only.

** Metals criteria are calculated values at hardness of 100 mg/L. Ammonia value is pH dependent. refer to formulas provided in WAC 173-201A-240.

*** Sampled on June 30, 2009.

# Table 5.5 - Summary of Groundwater Level Data Grande Ronde Basalt

Aquifer Storage and Recovery Feasibility Assessment
White Salmon, Washington

| | | | | | | | Well Location (SPS83) | | | | Water Level Data | | | Well Yield Data | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Depth (ft bgs) | Dia. (in.) | Well Owner (well log) | Label | TRS Identifier | Date | Water System ID | X Coord | Y Coord | DEM Elevation | Source | Date | SWL (ft bgs) | SWE (ft MSL) | Yield (gpm) | Drawdown (ft) | Specific Capacity (gpm/ft) |
| 240 | 6 | CLAUDE CORBEILLE (578) | E01 | 3N/10E-1E01 | 8/26/1992 | | 1384073 | 163402 | 941 | Qtr-Qtr Section | 8/26/1992 | 110 | 831 | | | |
| 600 | 6 | SCOTT M LOZIER | J01 | 3N/10E-1J01 | 5/4/2000 | | 1387995 | 162113 | 1711 | Qtr-Qtr Section | 5/4/2000 | 495 | 1216 | | | |
| 280 | 8 | FORDYCE SPRINGS | C06 | 3N/10E-2C06 | 10/26/1994 | 05182 J | 1382347 | 164359 | 448 | GPS | 10/26/1994 | 54 | 394 | | | |
| 320 | 6 | JAMES WANNER | M03 | 3N/10E-2M03 | 5/5/2005 | | 1378861 | 162081 | 452 | Qtr-Qtr Section | 5/5/2005 | 211 | 241 | | | |
| 425 | 6 | BOYD FITZGERALD | C01 | 3N/10E-3C01 | 7/15/1995 | | 1374925 | 164786 | 709 | Qtr-Qtr Section | 7/15/1995 | 290 | 419 | | | |
| 300 | 6 | DES VERLEY | C02 | 3N/10E-3C02 | 5/20/1993 | | 1374925 | 164786 | 709 | Qtr-Qtr Section | 5/20/1993 | 220 | 489 | | | |
| 615 | 6 | ROBERT HUNTINGTON | C03 | 3N/10E-3C03 | 6/26/1995 | | 1374925 | 164786 | 709 | Qtr-Qtr Section | 6/26/1995 | 259 | 450 | | | |
| 385 | 6 | BURSETT ATSUKO | C05 | 3N/10E-3C05 | 3/21/2000 | | 1374925 | 164786 | 709 | Qtr-Qtr Section | 3/21/2000 | 300 | 409 | | | |
| 270 | 6 | RICHARD D RYDER | D01 | 3N/10E-3D01 | 6/19/2006 | | 1373617 | 164818 | 901 | Qtr-Qtr Section | 6/19/2006 | 145 | 756 | | | |
| 456 | 6 | CURTIS STEELE | F01 | 3N/10E-3F01 | 11/3/1995 | | 1374927 | 163489 | 625 | Qtr-Qtr Section | 11/3/1995 | 275 | 350 | | | |
| 400 | 6 | WAYNE WOOSTER | F03 | 3N/10E-3F03 | 10/17/1994 | | 1374927 | 163489 | 625 | Qtr-Qtr Section | 10/17/1994 | 275 | 350 | | | |
| 340 | 6 | MICHAEL GUNDLACH | F04 | 3N/10E-3F04 | 11/7/2003 | | 1374927 | 163489 | 625 | Qtr-Qtr Section | 11/7/2003 | 265 | 360 | | | |
| 375 | 6 | WILLIAM FULTON | G01 | 3N/10E-3G01 | 8/6/1996 | | 1376237 | 163451 | 534 | Qtr-Qtr Section | 8/6/1996 | 225 | 309 | | | |
| 345 | 6 | BRIAN UTHMANN | M01 | 3N/10E-3M01 | 7/10/2001 | | 1373620 | 162233 | 562 | Qtr-Qtr Section | 7/10/2001 | 270 | 292 | | | |
| 570 | 6 | JERRY AND BRENDA POWERS | M02 | 3N/10E-3M02 | 8/4/2005 | | 1373620 | 162233 | 562 | Qtr-Qtr Section | 8/4/2005 | 410 | 152 | | | |
| 1242 | 14 | CITY OF WHITE SALMON | Q01 | 3N/10E-3Q01 | 4/23/2001 | 96350 B | 1376870 | 161114 | 477 | GPS | 11/18/1998 | -226 | 703 | | | |
| 356 | 8 | CITY OF WHITE SALMON | A01 | 3N/10E-10A01 | 11/13/1998 | | 1376704 | 160228 | 460 | GPS | 11/13/1998 | 111 | 349 | | | |
| 755 | 12 | CITY OF WHITE SALMON | A02 | 3N/10E-10A02 | 11/24/1998 | 96350 B | 1376733 | 160097 | 438 | GPS | 11/24/1998 | 125 | 313 | | | |
| 500 | 8 | CITY OF WHITE SALMON | A04 | 3N/10E-10A04 | 4/20/1999 | | 1376927 | 160879 | 484 | GPS | 4/20/1999 | 140 | 344 | | | |
| 545 | 8 | RON RIGGLEMAN \| RIGGLEMAN ORCHARDS | J03 | 3N/10E-10J03 | 4/18/2000 | | 1377541 | 156849 | 386 | Qtr-Qtr Section | 4/18/2000 | 162 | 224 | 105 | 364 | 0.29 |
| 860 | 6 | WAYNE TENNANT | N01 | 3N/10E-10N01 | 7/9/1981 | | 1373607 | 155662 | 1254 | Qtr-Qtr Section | 7/9/1981 | 760 | 494 | | | |
| 845 | 6 | ROBERT MARQUEZ | Q01 | 3N/10E-10Q01 | 9/5/2001 | | 1376223 | 155576 | 761 | Qtr-Qtr Section | 9/5/2001 | 745 | 16 | | | |
| 469 | 6 | DIANA SHEPLER | K01 | 3N/10E-13K01 | 1/26/1993 | | 1386532 | 151532 | 903 | Qtr-Qtr Section | 1/26/1991 | 380 | 523 | 15 | 16 | 0.94 |
| 420 | 8 | RAY MEADOWS 579 | C01 | 3N/10E-14C01 | 12/2/1988 | | 1380101 | 154217 | 328 | Qtr-Qtr Section | 12/2/1988 | 200 | 128 | | | |
| 800 | 6 | VERNON ELLSON | C01 | 3N/10E-15C01 | 7/17/2001 | | 1374888 | 154298 | 935 | Qtr-Qtr Section | 7/17/2001 | 725 | 210 | | | |
| 545 | 6 | CHARLES SCWARTZ | F01 | 3N/10E-15F01 | 9/26/1996 | | 1374841 | 152987 | 827 | Qtr-Qtr Section | 9/26/1996 | 450 | 377 | | | |
| 110 | 6 | LEE GRIBNER | L03 | 4N/10E-13L03 | 10/30/2001 | | 1385624 | 183353 | 639 | Qtr-Qtr Section | 10/29/2001 | 35 | 604 | | | |
| 300 | 6 | C HOOPER & D ZDUNIAK | R02 | 4N/10E-13R02 | 9/25/1995 | | 1388198 | 181978 | 535 | Qtr-Qtr Section | 9/25/1995 | 210 | 325 | | | |
| 385 | 6 | CHARLES HOOPER | R01 | 4N/10E-23R01 | 9/8/1994 | | 1382864 | 176645 | 923 | Qtr-Qtr Section | 9/8/1994 | 300 | 623 | | | |
| 220 | 6 | JERRY LEWIS | M01 | 4N/10E-25M01 | 9/12/2003 | | 1384163 | 172639 | 477 | Qtr-Qtr Section | 9/9/2003 | 90 | 387 | | | |
| 360 | 6 | RONALD AND MARY CONNINE | A03 | 4N/10E-26A03 | 9/7/2000 | | 1382847 | 175296 | 802 | Qtr-Qtr Section | 9/7/2000 | 245 | 557 | | | |
| 310 | 6 | VAN G KELLEMS | B01 | 4N/10E-34B01 | 6/17/2002 | | 1376116 | 170062 | 1355 | Qtr-Qtr Section | 6/17/2002 | 195 | 1160 | | | |
| 465 | 6 | SANDRA ANDERSON | N01 | 4N/10E-35N01 | 5/1/2008 | | 1380488 | 166055 | 398 | Parcel | 5/1/2008 | 160 | 238 | | | |
| 160 | 10 | HUSUM HILLS GOLF COURSE | A03 | 4N/10E-36A03 | 6/19/1997 | 34859 A | 1388036 | 170009 | 362 | Qtr-Qtr Section | 6/19/1997 | 91 | 271 | | | |
| 120 | 6 | STUART FRASER | E01 | 4N/10E-36E01 | 10/4/1973 | | 1384118 | 168674 | 431 | Qtr-Qtr Section | 10/4/1973 | 61 | 370 | | | |
| 1020 | 6 | MELVIN WALKER | G01 | 4N/11E-4G01 | 11/21/2006 | | 1402709 | 195103 | 2059 | Qtr-Qtr Section | 12/4/2006 | 865 | 1194 | 12 | 100 | 0.12 |
| 915 | 8 | RIGGLEMAN ORCHARDS | E02 | 4N/11E-5E02 | 6/19/1983 | 20540 Q | 1394970 | 195191 | 1633 | Qtr-Qtr Section | 6/20/1983 | 740 | 893 | 195 | 0 | - |
| 786 | 8 | MT ADAMS ORCHARDS CORP | N01 | 4N/11E-6N01 | 5/10/2001 | 56397 V | 1389657 | 192622 | 1245 | Qtr-Qtr Section | 5/10/2001 | 525 | 720 | | | |
| 320 | 6 | TOM LUTZ | P01 | 4N/11E-20P01 | 5/17/1982 | | 1396052 | 176553 | 820 | Qtr-Qtr Section | 5/17/1982 | 250 | 570 | | | |
| 425 | 6 | TOM LUTZ | P02 | 4N/11E-20P02 | 8/6/1997 | | 1396052 | 176553 | 820 | Qtr-Qtr Section | 8/6/1997 | 250 | 570 | | | |
| 480 | 6 | TJ LUTZ | R01 | 4N/11E-20R01 | 10/23/2006 | | 1398537 | 176432 | 733 | Qtr-Qtr Section | 10/23/2006 | 275 | 458 | | | |
| 300 | 6 | KIRK WALSTON | J01 | 4N/11E-28J01 | 5/10/2006 | | 1403804 | 172646 | 2254 | Qtr-Qtr Section | 5/10/2006 | 195 | 2059 | | | |
| 445 | 6 | TED & GRACE LUTZ | D01 | 4N/11E-29D01 | 4/9/1990 | | 1394770 | 175285 | 612 | Qtr-Qtr Section | 4/4/1990 | 255 | 357 | | | |
| 370 | 6 | JAY JOHNSTON | D01 | 4N/11E-30D01 | 3/11/2005 | | 1389434 | 175395 | 521 | Qtr-Qtr Section | 3/11/2005 | 295 | 226 | | | |
| 160 | 6 | DEREK GOODWIN | B01 | 4N/11E-31B01 | 4/12/1995 | | 1391936 | 170044 | 633 | Qtr-Qtr Section | 4/12/1995 | 10 | 623 | | | |
| 200 | 6 | KEN DICKEN | C01 | 4N/11E-31C01 | 8/21/1990 | | 1390638 | 170034 | 470 | Qtr-Qtr Section | 8/21/1990 | 65 | 405 | | | |
| 148 | 6 | ALAN SHIPP | L01 | 4N/11E-31L01 | 5/18/1979 | | 1390569 | 167440 | 897 | Qtr-Qtr Section | 5/28/1979 | 15 | 882 | 10 | 120 | 0.08 |

**Notes:**

Well data compiled from the Washington State Department of Ecology Well Log Database (May 2009).

White Salmon Well No. 2 water level data (highlighted) not included in the Groundwater Elevation Contour Map, due to the well being completed in a different aquifer.

# Table 5.6 - Model Results for Different ASR Operational Scenarios

Aquifer Storage and Recovery Feasibility Assessment
White Salmon, Washington

| | Recharge | | | Recovery | | | Estimated Recovery of Stored Water | | |
|---|---|---|---|---|---|---|---|---|---|
| Operational Scenario | Time (Days) | Rate (gpm) | Volume (acre-ft) | Time (Days) | Rate (gpm) | Volume (acre-ft) | Recovery % | Volume Recovered (acre-ft) | Volume Unrecovered (acre-ft) |
| 1 | 180 | 225 | 180 | 180 | 225 | 180 | 72 | 130 | 50 |
| 2 | 180 | 425 | 340 | 180 | 425 | 340 | 81 | 275 | 65 |

# Table 5.7 - Geochemical Model Results for Mixing

Aquifer Storage and Recovery Feasibility Assessment
White Salmon, Washington

**Mixing Ratios Well No.2:Buck Creek**

| Water Quality Constituent | Well No. 2 Groundwater | No Mineral Phase Interaction[1] 50:50 Mix | Basalt Mineral Phases Interaction Only[2] 50:50 Mix | Complete Mineral-Interaction[3] |  |  | Buck Creek Source Water |
|---|---|---|---|---|---|---|---|
|  |  |  |  | 80:20 Mix | 50:50 Mix | 20:80 Mix |  |
| Temperature( °C) | 12.20 | 8.85 | 8.85 | 10.86 | 8.85 | 6.84 | 5.50 |
| pH (standard units) | 8.16 | 8.13 | 8.23 | 8.18 | 8.24 | 8.31 | 8.05 |
| pe (standard units) | 2.90 | 13.68 | 13.52 | 13.38 | 13.52 | 13.64 | 14.06 |
| Dissolved Oxygen (DO) | 5.00 | 7.93 | 5.20 | 3.43 | 5 | 6.93 | 10.85 |
| Calcium (Ca) | 8.87 | 7.30 | 9.14 | 9.30 | 9.14 | 9.00 | 5.73 |
| Magnesium (Mg) | 3.17 | 2.52 | 3.66 | 3.58 | 3.66 | 3.76 | 1.87 |
| Sodium (Na) | 7.81 | 5.10 | 5.10 | 6.73 | 5.10 | 3.48 | 2.39 |
| Potassium (K) | 2.55 | 1.84 | 1.85 | 2.27 | 1.85 | 1.42 | 1.13 |
| Aluminum (Al) | 0.009 | 0.02 | 0.05 | 0.0006 | 0.0006 | 0.0005 | 0.03 |
| Iron (Fe) | 0.08 | 0.07 | 3.46 | 0.00 | 0.00 | 0.00 | 0.05 |
| Manganese (Mn) | 0.09 | 0.05 | 0.10 | 0.00 | 0.00 | 0.00 | 0.01 |
| Chloride (Cl) | 1.20 | 1.18 | 1.18 | 1.19 | 1.18 | 1.17 | 1.16 |
| Alkalinity (as $CaCO_3$) | 52.20 | 40.62 | 49.24 | 48.70 | 45.68 | 42.76 | 29.01 |
| Sulfate ($SO_4$) | 2.87 | 1.70 | 5.54 | 6.24 | 5.54 | 4.84 | 0.53 |
| Barium (Ba) | 0.003 | 0.003 | 0.001 | 0.001 | 0.001 | 0.001 | 0.003 |
| Phosphate ($HPO_4$) | 0.05 | 0.03 | 0.03 | 0.04 | 0.03 | 0.02 | 0.02 |
| Silica ($SiO_2$) | 37.71 | 31.31 | 33.89 | 36.34 | 33.89 | 31.55 | 24.91 |

[1] Mix generated using PHREEQC. Waters were mixed at 1:1 ratio with no rock-interations.

[2] Mix generated using PHREEQC. Waters were mixed at 1:1 ratio and allowed to dissolve basalt mineral phases. No metal-oxide precipitation allowed.

[3] Mix generated using PHREEQC. Waters were mixed and allowed to equilibrate with basalt mineral phases, followed by metal oxide precipitation.

Values in milligrams per liter (mg/L) unless otherwise indicated.

# Table 5.8 - Geochemical Model Results for Mineral Precipitation

Aquifer Storage and Recovery Feasibility Assessment
White Salmon, Washington

| | Mix Ratios of Well No. 2:Buck Creek | | |
|---|---|---|---|
| **Mineral Phases** | **20:80 Mix** | **50:50 Mix** | **80:20 Mix** |
| **mg oxide per liter water** | | | |
| Birnessite | 0.02 | 0.02 | 0.02 |
| Goethite | 1.70 | 1.45 | 1.25 |
| Gibbsite | 4.82 | 4.83 | 4.84 |
| Total | 6.54 | 6.30 | 6.10 |
| **percent oxide by volume (assume 1.25 g/cm$^3$ bulk density of hydrated metal-oxides)** | | | |
| Birnessite | 0.0002% | 0.0002% | 0.0002% |
| Goethite | 0.01% | 0.01% | 0.01% |
| Gibbsite | 0.04% | 0.04% | 0.04% |
| Total | 0.05% | 0.05% | 0.05% |

# Table 6.1 - Confirmed and Suspected Contaminated Sites

Aquifer Storage and Recovery Feasibility Assessment
White Salmon, Washington

| FS ID | City | Site Name | Address | Zip | Ecology Status | Site Type | Rank Status | Affected Media | Affected Media Status | Petroleum Products | Non Halogenated Solvents |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 403 | WHITE SALMON | Town Pump Gas Station | 521 E JEWETT BLVD | 98672 | RA conducted, residual contam. left, instit contrl | Program Plan | 1 | Groundwater | Confirmed | Confirmed | |
| 403 | WHITE SALMON | Town Pump Gas Station | 521 E JEWETT BLVD | 98672 | RA conducted, residual contam. left, instit contrl | Program Plan | 1 | Surface Water | Confirmed | Confirmed | |
| 403 | WHITE SALMON | Town Pump Gas Station | 521 E JEWETT BLVD | 98672 | RA conducted, residual contam. left, instit contrl | Program Plan | 1 | Soil | Confirmed | Confirmed | |
| 13233349 | BINGEN | WILSON OIL II | 117 E STEUBEN | 98605 | Awaiting SHA | | | Soil | Confirmed | Confirmed | |
| 28537434 | BINGEN | HUNSAKER OIL COMPANY INC BINGEN | 102 E STEUBEN | 98605 | Ranked, Awaiting RA | Independent | 5 | Groundwater | Confirmed | Confirmed | Confirmed |
| 28537434 | BINGEN | HUNSAKER OIL COMPANY INC BINGEN | 102 E STEUBEN | 98605 | Ranked, Awaiting RA | Independent | 5 | Soil | Confirmed | Confirmed | Confirmed |
| 61834259 | BINGEN | Unocal Bulk Plant 0046 | 217 E STEUBEN | 98605 | Ranked, Awaiting RA | | 3 | Soil | Confirmed | Confirmed | |
| 61834259 | BINGEN | Unocal Bulk Plant 0046 | 217 E STEUBEN | 98605 | Ranked, Awaiting RA | | 3 | Groundwater | Confirmed | Confirmed | |
| 76225533 | WHITE SALMON | KLICKITAT COUNTY SHOP WHITE SALMON | CHILDS RD | 98672 | Awaiting SHA | Independent | | Soil | Confirmed | Confirmed | |

Notes:
SHA - site hazard assessment
RA - remedial action
Rank status - 1 represents highest risk, 5 represents lowest risk

# Table 6.2 - Average Historical Monthly Streamflows for the White Salmon River and Tributaries

Aquifer Storage and Recovery Feasibility Assessment
White Salmon, Washington

**White Salmon River near Underwood USGS # 14123500 (period of record 1912 - 2009)**

| Month | | Jan. | Feb. | Mar. | Apr. | May | Jun. | Jul. | Aug. | Sep. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Exeedance Flows | 90% | 574 | 705 | 857 | 1010 | 918 | 708 | 563 | 482 | 458 | 452 | 482 | 534 |
| | 50% | 1080 | 1310 | 1380 | 1440 | 1490 | 1170 | 826 | 670 | 608 | 597 | 667 | 892 |
| | 10% | 2400 | 2520 | 2300 | 2040 | 2100 | 1910 | 1290 | 927 | 817 | 818 | 1280 | 1920 |

**White Salmon River at Husum USGS # 14123000 (period of record 1909 - 1962)**

| Month | | Jan. | Feb. | Mar. | Apr. | May | Jun. | Jul. | Aug. | Sep. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Exeedance Flows | 90% | 489 | 550 | 738 | 994 | 919 | 720 | 552 | 469 | 458 | 443 | 430 | 472 |
| | 50% | 879 | 980 | 1080 | 1300 | 1440 | 1200 | 829 | 670 | 609 | 565 | 640 | 700 |
| | 10% | 1824 | 1820 | 1784 | 1780 | 1860 | 1751 | 1235 | 870 | 775 | 720 | 1182 | 1440 |

**White Salmon River at BZ Corner USGS # 14122900 (period of record 1958 - 1965)**

| Month | | Jan. | Feb. | Mar. | Apr. | May | Jun. | Jul. | Aug. | Sep. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Exeedance Flows | 90% | 735 | 703 | 634 | 722 | 860 | 643 | 465 | 357 | 315 | 335 | 344 | 458 |
| | 50% | 735 | 950 | 835 | 1130 | 1140 | 935 | 603 | 462 | 382 | 405 | 521 | 668 |
| | 10% | 1500 | 1713 | 1432 | 1542 | 1530 | 1361 | 750 | 540 | 493 | 576 | 1280 | 1160 |

**Gilmer Creek (period of record 1995 - 1997)**

| Month | Jan. | Feb. | Mar. | Apr. | May | Jun. | Jul. | Aug. | Sep. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Average Flow | 38 | 68 | 74 | 14 | 10 | 8 | 3 | 2 | 4 | 1 | 3 | 91 |

**Rattlesnake Creek (period of record 1995 - 1997)**

| Month | Jan. | Feb. | Mar. | Apr. | May | Jun. | Jul. | Aug. | Sep. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Average Flow | 196 | 380 | 284 | 32 | 13 | 4 | 3 | 2 | 3 | 3 | 6 | 491 |

# Table 6.3 - 2008 Water Quality Assessment Listings for White Salmon River Subbasin

Aquifer Storage and Recovery Feasibility Assessment
White Salmon, Washington

| Listing Detail | Category | WRIA | Water Body Name | Parameter | Medium |
|---|---|---|---|---|---|
| 21582 | 2 | 29 | Buck Creek | Fecal Coliform | Water |
| 16775 | 5 | 29 | Gilmer Creek | Fecal Coliform | Water |
| 5882 | 5 | 29 | Indian Creek | Temperature | Water |
| 51618 | 2 | 29 | Northwestern Lake | 2,3,7,8-TCDD TEQ | Tissue |
| 52675 | 5 | 29 | Northwestern Lake | PCB | Tissue |
| 5884 | 5 | 29 | Rattlesnake Creek | Temperature | Water |
| 5885 | 5 | 29 | Rattlesnake Creek | Temperature | Water |
| 5886 | 5 | 29 | Rattlesnake Creek | Fecal Coliform | Water |
| 21617 | 2 | 29 | Rattlesnake Creek | pH | Water |
| 6222 | 4C | 29 | White Salmon River below Condit Dam | Instream Flow | Habitat |
| 21580 | 2 | 29 | White Salmon River below Condit Dam | Fecal Coliform | Water |
| 51055 | 2 | 29 | White Salmon River below Condit Dam | pH | Water |
| 5889 | 5 | 29 | White Salmon River near Gilmer Creek | Fecal Coliform | Water |

Water quality categories:

**2) Waters of Concern**: available data are not sufficient to show impairment but do raise a concern.

**4) Impaired but Does Not Require a TMDL** (3 subcategories):

4A) Has a TMDL: water is impaired by a pollutant and a TMDL has already been prepared.

4B) Has a Pollution Control Project in place: water is impaired by a pollutant and another agency has prepared a plan that Ecology expects will improve water quality in a manner comparable to a TMDL and has active implementation ongoing.

4C) Impaired by a Non-Pollutant: impaired by aquatic habitat degradation that is not the result of a pollutant (such as loss of spawning gravel or channel incision).

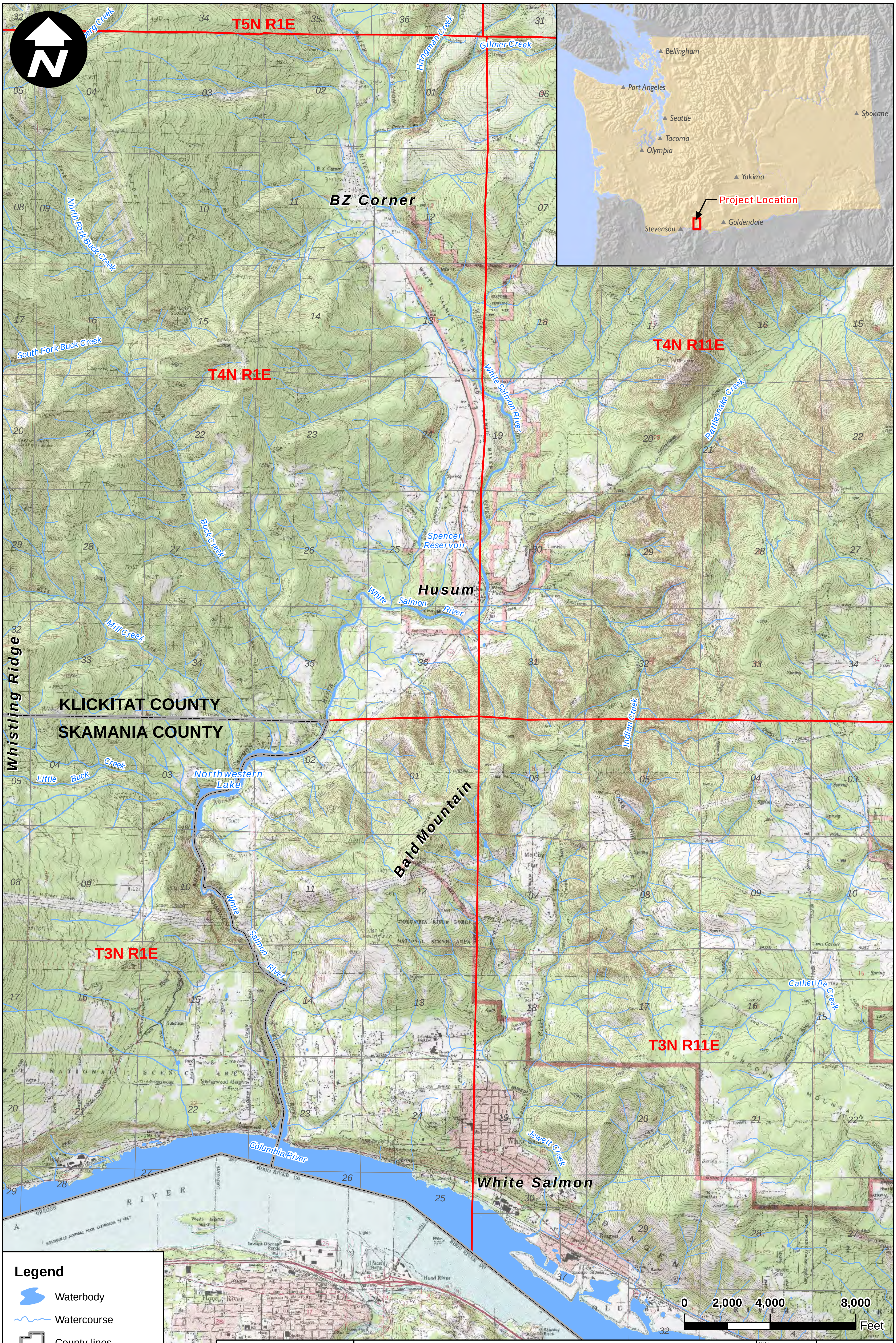
**5) Impaired [the 303(d) list]**: waters that do not meet an applicable water quality standard for one or more pollutants. A TMDL is required for each waterbody segment on the 303(d) list.

# Table 7.1. Preliminary Water Quality Monitoring Schedule for Initial ASR Pilot Test

Aquifer Storage and Recovery Feasibility Assessment
White Salmon, Washington

| | **Frequency of Analysis** | | | |
|---|---|---|---|---|
| **Stage of Initial Pilot Test** | **Field Parameters** | **General Chemistry/Drinking Water Parameters** | **Prospective Tracers** | **Disinfection Byproducts** |
| **Baseline Testing** | | | | |
| Step Recovery Test | 15-minute interval | 1 time event | 1 time event | 1 time event |
| Step Recharge Test | - | - | - | - |
| **ASR Testing** | | | | |
| Recharge (21 days) | Daily | 7-day interval | 7-day interval | 7-day interval |
| Storage (42 days) | 7-day interval | 14-day interval | 7-day interval | 7-day interval |
| Recovery (28 days) | Daily | 7-day interval | 3-day interval | 3-day interval |
| **Post-ASR Testing** | | | | |
| Step Recovery Test | 15-minute interval | - | - | - |
| Step Recharge Test | - | - | - | - |
| **Constituents** | Temperature<br>pH<br>Dissolved Oxygen<br>Redox Potential<br>Specific Conductivity<br>Turbidity<br>Methane<br>Hydrogen Sulfide | General Chemistry<br>Alkalinity<br>TDS<br>TSS**<br>Silica<br>Total Organic Carbon<br><br>Additional Anions<br>Bromide<br>Fluoride<br>Nitrate-N<br>Nitrite-N<br><br>Metals<br>Arsenic<br>Antimony<br>Aluminum<br>Barium<br>Beryllium<br>Cadmium<br>Chromium<br>Copper<br>Iron<br>Lead<br>Manganese<br>Mercury<br>Nickel<br>Selenium<br>Silica<br>Silver<br>Thallium<br>Zinc | Major Cations<br>Calcium<br>Magnesium<br>Potassium<br>Sodium<br><br>Major Anions<br>Bicarbonate<br>Chloride<br>Sulfate | Trihalomethanes (THMs)<br>Chloroform<br>Bromoform<br>Bromodichloromethane<br>Dibromochloromethane<br><br>Haloacetic Acids (HAAs)<br>Monochloroacetic Acid<br>Dichloroacetic Acid<br>Trichloroacetic Acid<br>Monobromoacetic Acid<br>Dibromoacetic Acid<br>Bromochloroacetic Acid<br><br>Residual Chlorine |

**: TSS will be analyzed daily throughout the recharge period.



## Legend

Waterbody

Watercourse

County lines

Township and Range

☐ Section

Aspect CONSULTING

# Site Location Map

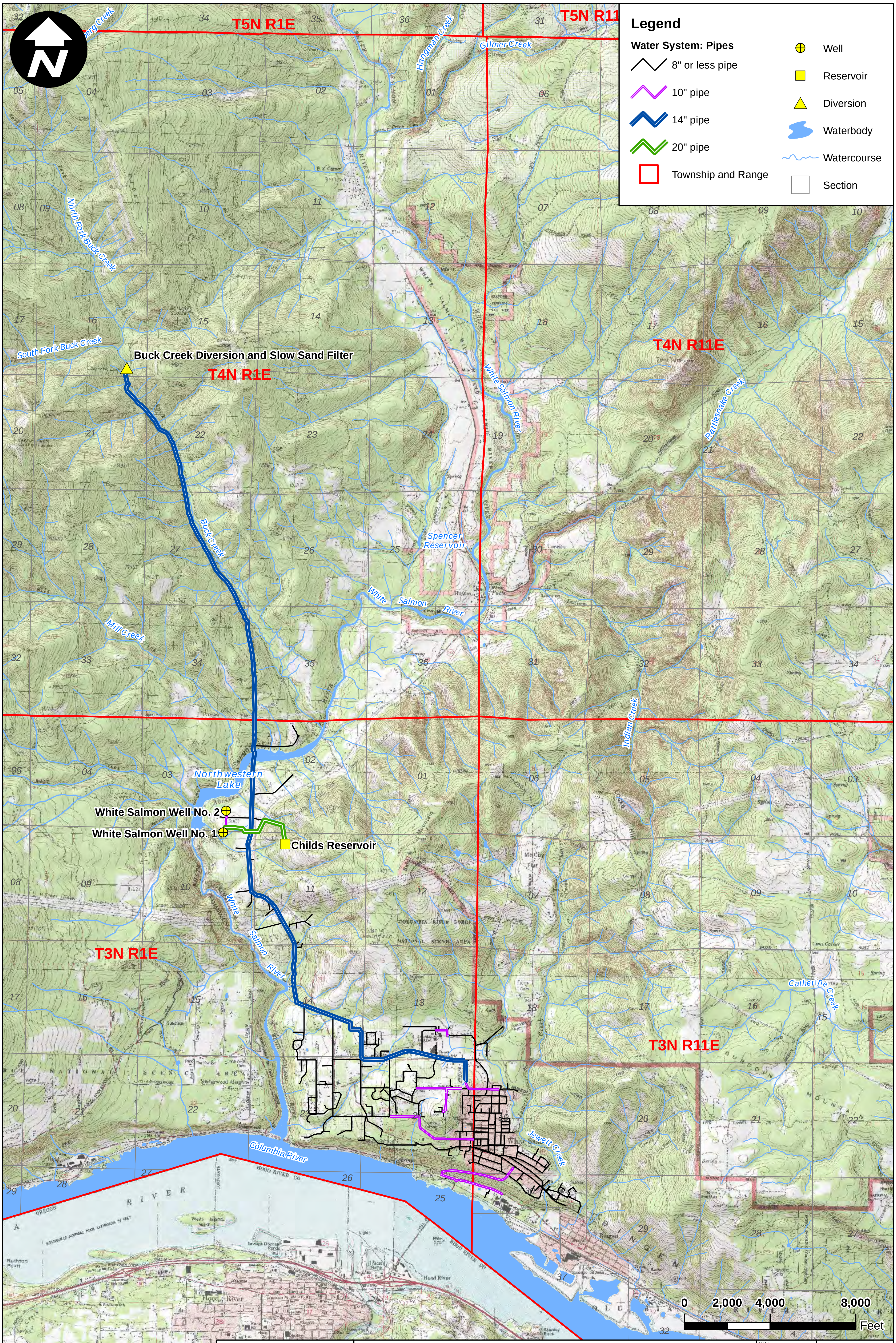
City of White Salmon ASR
White Salmon, Washington

| | |
|---|---|
| DATE: | Sep 2010 |
| DESIGNED BY: | PPW |
| DRAWN BY: | PPW |
| REVISED BY: | PPW |

PROJECT NO.
090094

FIGURE NO.
1.1

Path: T:\projects_8\white_salmon\2010\Delivered\1_1 Site_Loc_Map.mxd



**City of White Salmon**
**Water System Infrastructure**
City of White Salmon ASR - White Salmon, Washington

Aspect CONSULTING

| | |
|---|---|
| DATE: Sep 2010 | PROJECT NO. 090094 |
| DESIGNED BY: PPW | |
| DRAWN BY: PPW | FIGURE NO. 1.2 |
| REVISED BY: PPW | |

Path: T:\projects_8\white_salmon\2010\Delivered\1_2 Water_System_Infrastructure.mxd

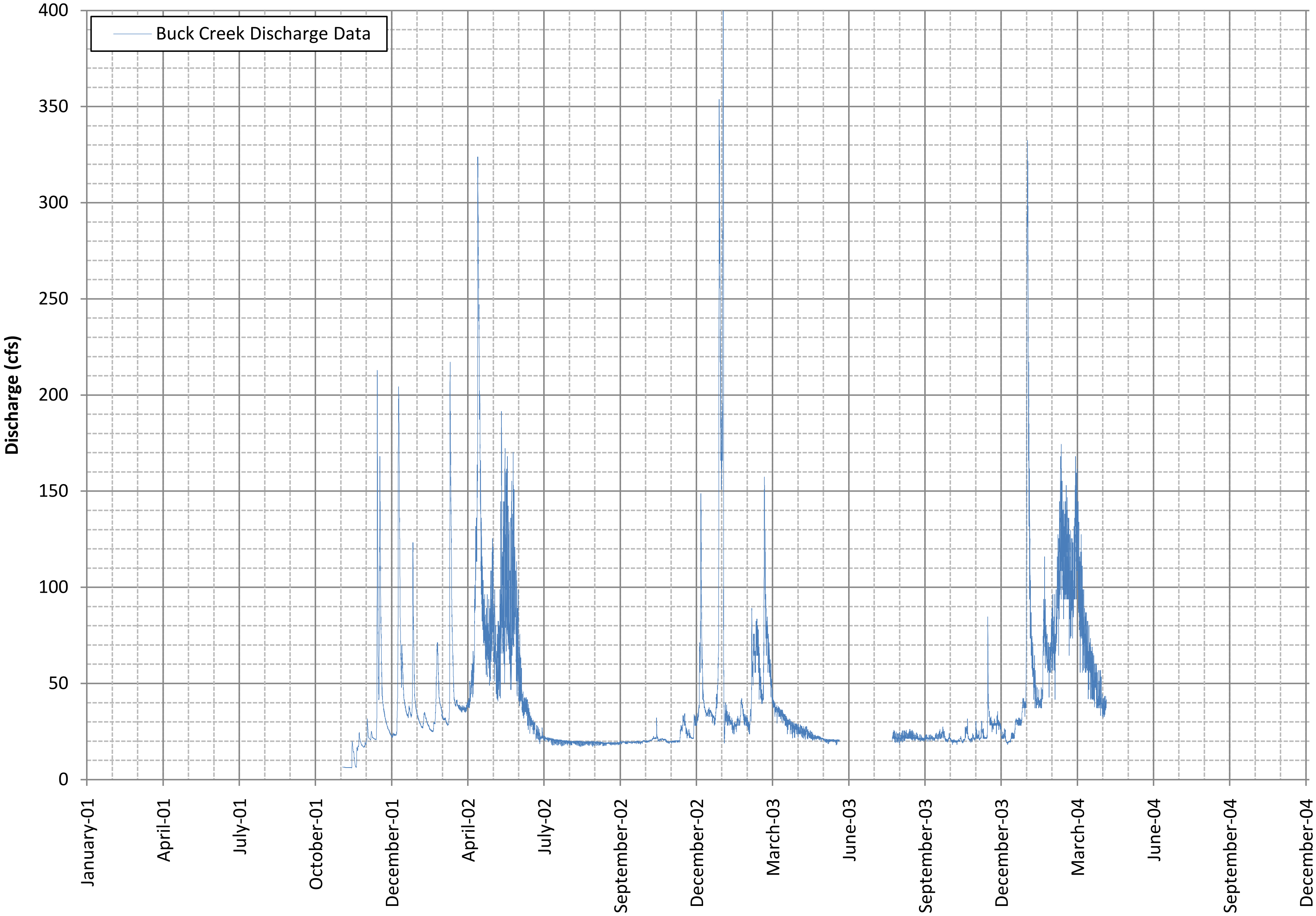


**Figure 2.1 - Historical Buck Creek Flows**

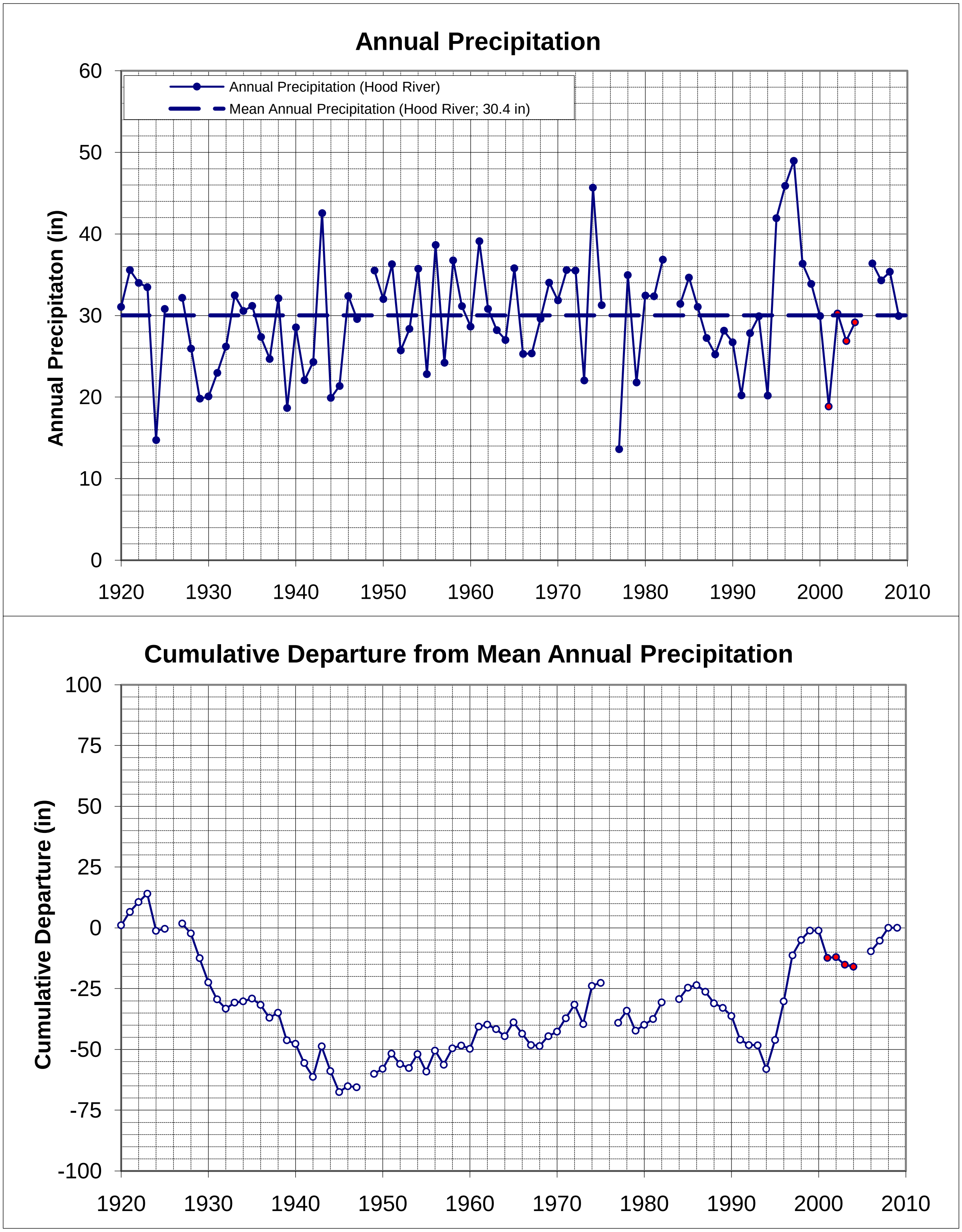
Aquifer Storage and Recovery Feasibility Assessment

White Salmon, Washington

**Aspect Consulting**

4/22/2011

W:\090094 2009 Water System Imprvmts-ASR Project\Deliverables\ASR FS\figures\Figure 2.1 - Historical Buck Creek Flows



**Notes**:

Annual precipitation data from Hood River (NOAA Station No. 354003).

Annual data are the water year ending September 30.

Individual months with more than 5 days of missing data were not used for either monthly or annual statistics.

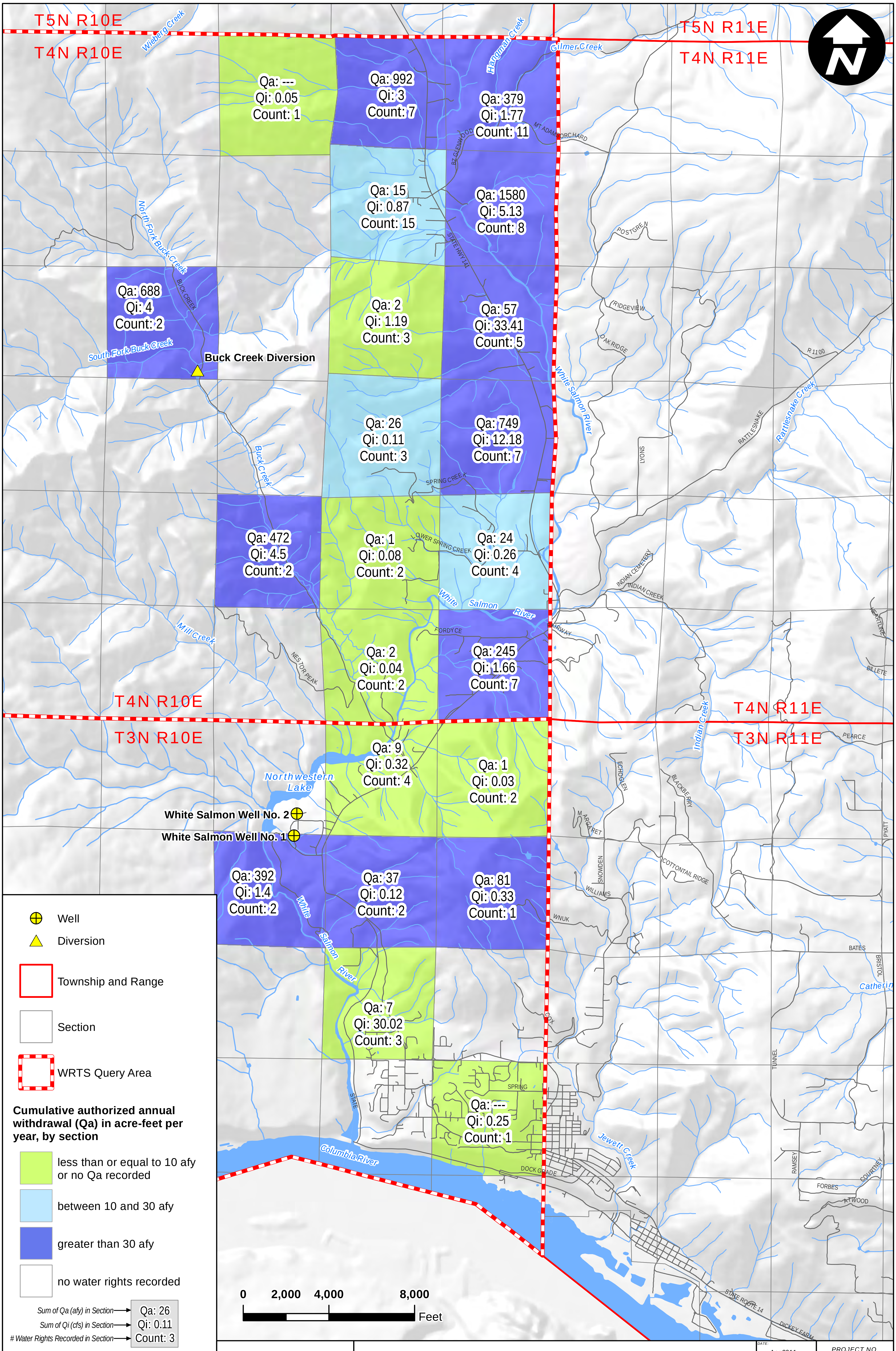
Precipitation data points corresponding to years with Buck Creek flow measurements are shown in red.

**Figure 2.2**

**Long-Term Precipitation Analysis**

Aquifer Storage and Recovery Feasibility Assessment
White Salmon, Washington

**Aspect Consulting**
4/22/2011
*W:\090094 2009 Water System Imprvmts-ASR Project\Deliverables\ASR FS\figures\Figure 2.2 - Long-Term Precipitation Analysis*



Data obtained from Ecology WRTS Database (April, 2010).

Water right location plotted based on first source location listed in WRTS. Water rights may exist with multiple sources in multiple sections that are not shown on this map.

**Aspect CONSULTING**

# Distribution of Existing Surface Water Rights

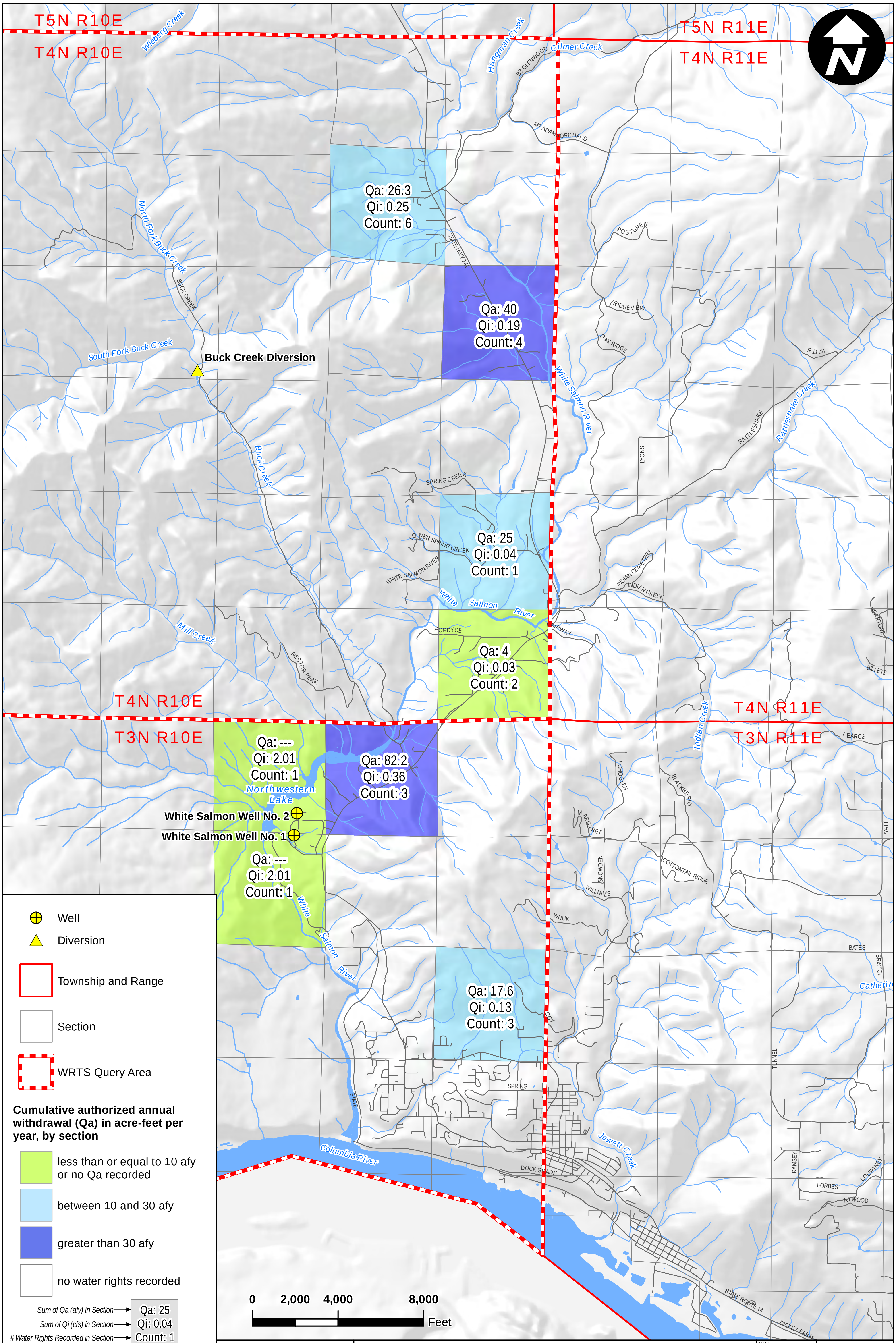
City of White Salmon ASR - White Salmon, Washington

DATE: Apr 2011
DESIGNED BY: PPW
DRAWN BY: PPW
REVISED BY: PPW

PROJECT NO. **090094**

FIGURE NO. **4.1**

Path: T:\projects_8\white_salmon\2010\Delivered\4_1 Surface_Water_Rights_Distro.mxd



Data obtained from Ecology WRTS Database (April, 2010).

Water right location plotted based on first source location listed in WRTS. Water rights may exist with multiple sources in multiple sections that are not shown on this map.

Aspect
CONSULTING

## Distribution of Existing Groundwater Rights

City of White Salmon ASR - White Salmon, Washington

| | |
|---|---|
| DATE: | Apr 2011 |
| DESIGNED BY: | PPW |
| DRAWN BY: | PPW |
| REVISED BY: | PPW |
| PROJECT NO. | 090094 |
| FIGURE NO. | 4.2 |

Path: T:\projects_8\white_salmon\2010\Delivered\4_2 Groundwater_Rights_Distro.mxd

**Geology Data Sources: WA DNR 1:100K; Bela, 1980; Newcomb, 1969**

**Surficial Geologic Units**

| | |
|---|---|
| ▭ | Qa - alluvium |
| ▭ | Qfg - outburst flood deposits (gravels) |
| ▭ | Qfs - outburst flood deposits (silts and sands) |
| ▭ | Qls - landslide |
| ▭ | Qva(mf) - McCoy Flat andesite |
| ▭ | Qva(rs) - Rattle Snake Creek andesite |
| ▭ | Qvb - basalt flows (unnamed) |
| ▭ | Qvb(ic) - Ice Cave basalt |
| ▭ | Qvb(uw) - Underwood basalt |
| ▭ | Qvb(wn) - North of White Salmon basalt |
| ▭ | Qvb(ws) - White Salmon basalt |
| ▭ | QPLvb - basalt flows |
| ▭ | Mc(e) - Ellensburg formation |
| ▭ | Mv(wfs) - Wanapum basalt, Frenchman Springs |
| ▭ | Mv(gN1) - Grande Ronde basalt, N1 |
| ▭ | Mv(gN2) - Grande Ronde basalt, N2 |
| ▭ | Mv(gR2) - Grande Ronde basalt, R2 |

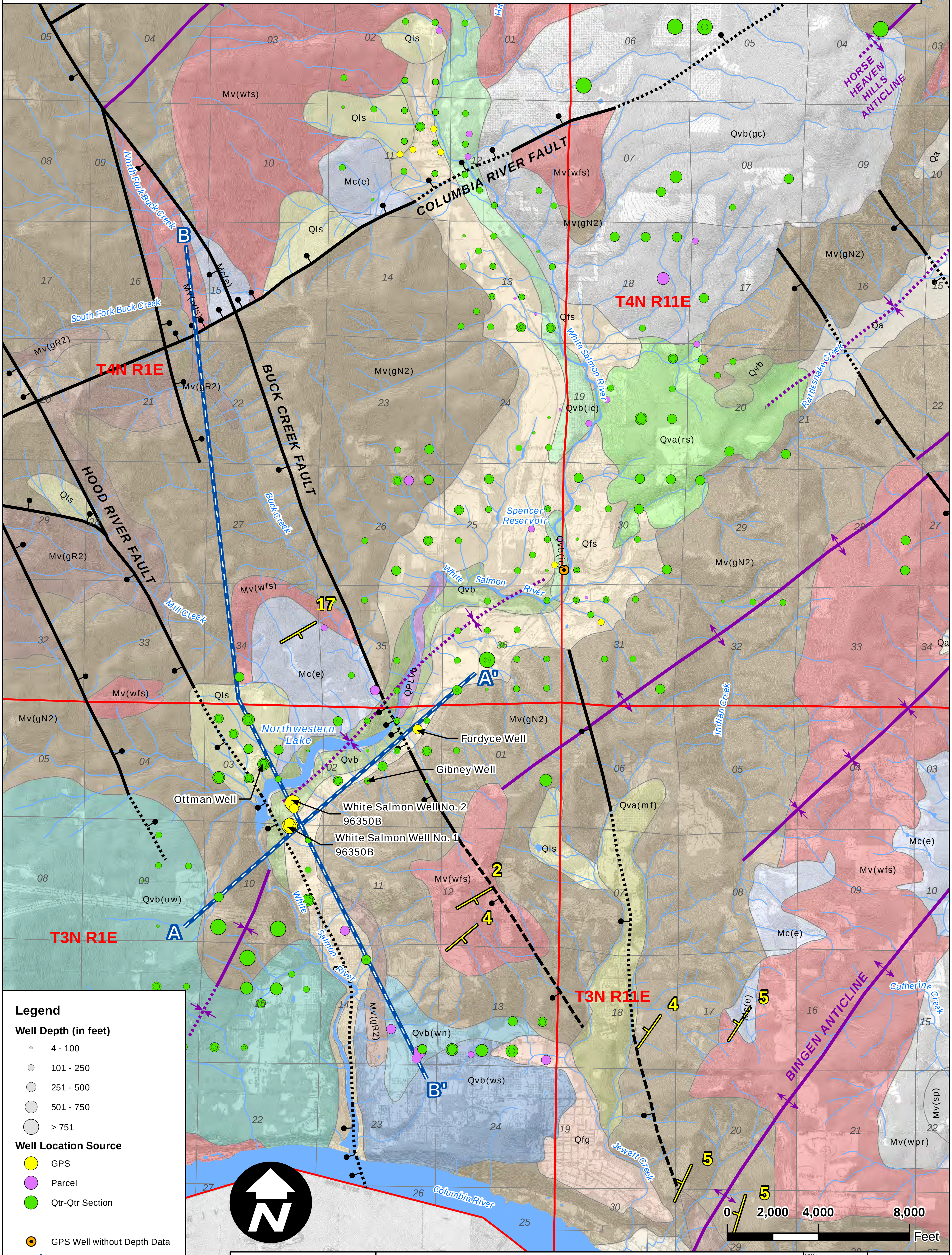
**Faults**

- Fault, unknown offset, concealed
- High-angle fault, bar and ball on downthrown side
- High-angle fault, concealed, bar and ball on downthrown side
- High-angle fault, inferred, bar and ball on downthrown side

**Folds**

- Anticline
- Anticline, concealed
- Syncline
- Syncline, concealed

5 Strike and Dip



**Legend**

**Well Depth (in feet)**

- 4 - 100
- 101 - 250
- 251 - 500
- 501 - 750
- \> 751

**Well Location Source**

- 🟡 GPS
- 🟣 Parcel
- 🟢 Qtr-Qtr Section

- GPS Well without Depth Data
- Cross Section
- 🟥 Township and Range
- ▭ Section

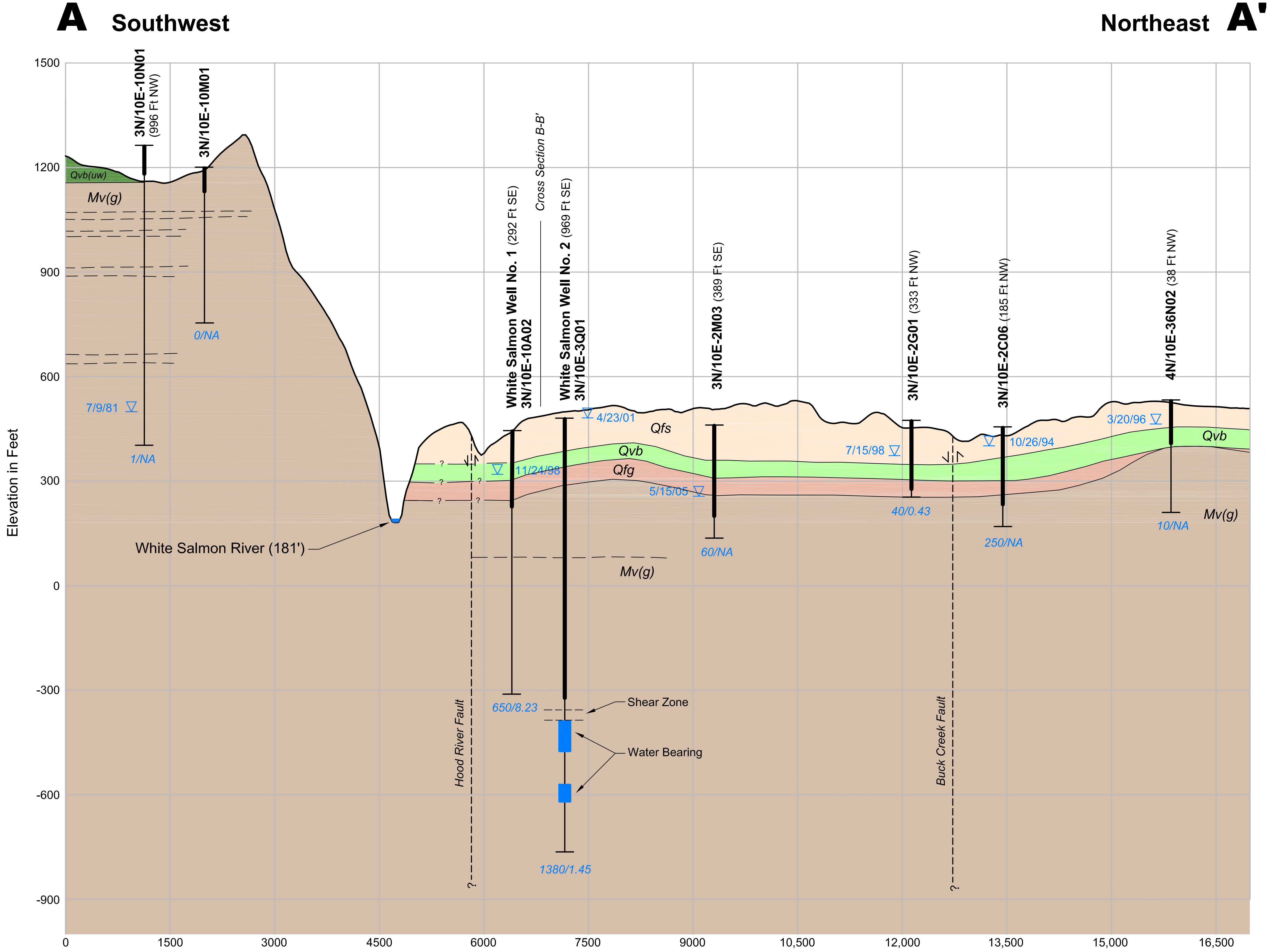
Aspect CONSULTING

# Well Location and Geologic Map

City of White Salmon ASR
White Salmon, Washington

| | |
|---|---|
| DATE: | Sep 2010 |
| DESIGNED BY: | JMS |
| DRAWN BY: | PPW |
| REVISED BY: | SCC |
| PROJECT NO. | 090094 |
| FIGURE NO. | 5.1 |

Path: T:\projects_8\white_salmon\2010\Delivered\5_1 Well_Location_And_Geology.mxd



## LEGEND

| | |
|---|---|
| **3N/10E-2M03**<br>(389 Ft SE) | Well Name (Projected Distance) |
| ▬ | DEM Ground Surface |
| — | Geologic Unit Contact |
| — ? — | Inferred Geologic Unit Contact |
| — — | Fractured Interflow |
| ▽ | Static Water Level Reported on Well Log |
| Qa | Interpreted Hydrostratigraphic Unit |
| 🟦 | Water Bearing Unit |
| ▮ | Cased/Grouted Interval |
| *650/823* | Pumping Rate (gpm)/Specific Capacity (gpm/ft) |

Qa - Alluvium
Qls - Landslide
Qfs - Bretz Flood
Qvb - Undifferentiated Basalt
Qfg - Ancestral White Salmon River Sand and Gravel
Qvb (wn) - North of White Salmon Basalt
Qvb (uw) - Underwood Basalt
Mc (es) - Ellensburg Formation, Squaw Creek
Mv (wfs) - Wanapum Basalt, Frenchman Springs
Mc (ev) - Ellensburg Formation, Vantage
Mv (g) - Grande Ronde Basalt

Horizontal Scale: 1" = 1500'
Vertical Scale: 1" = 300'
(5x Exaggeration)

0 1500 3000
*Feet*

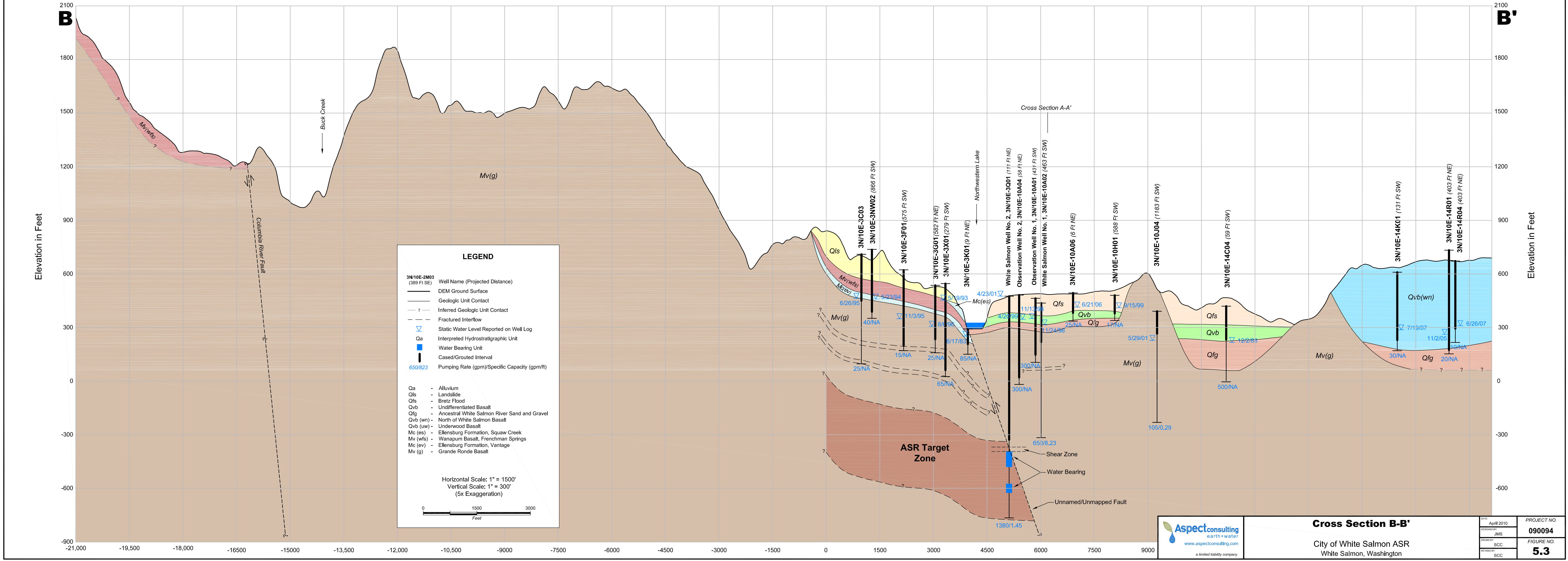
Aspect consulting
earth+water
www.aspectconsulting.com
*a limited liability company*

# Cross Section A-A'

City of White Salmon ASR
White Salmon, Washington

| | |
|---|---|
| DATE: April 2010 | PROJECT NO. 090094 |
| DESIGNED BY: JMS | |
| DRAWN BY: SCC | FIGURE NO. **5.2** |
| REVISED BY: SCC | |

Q:\City of White Salmon\090094\2010-04 ASR\090094-AA.dwg



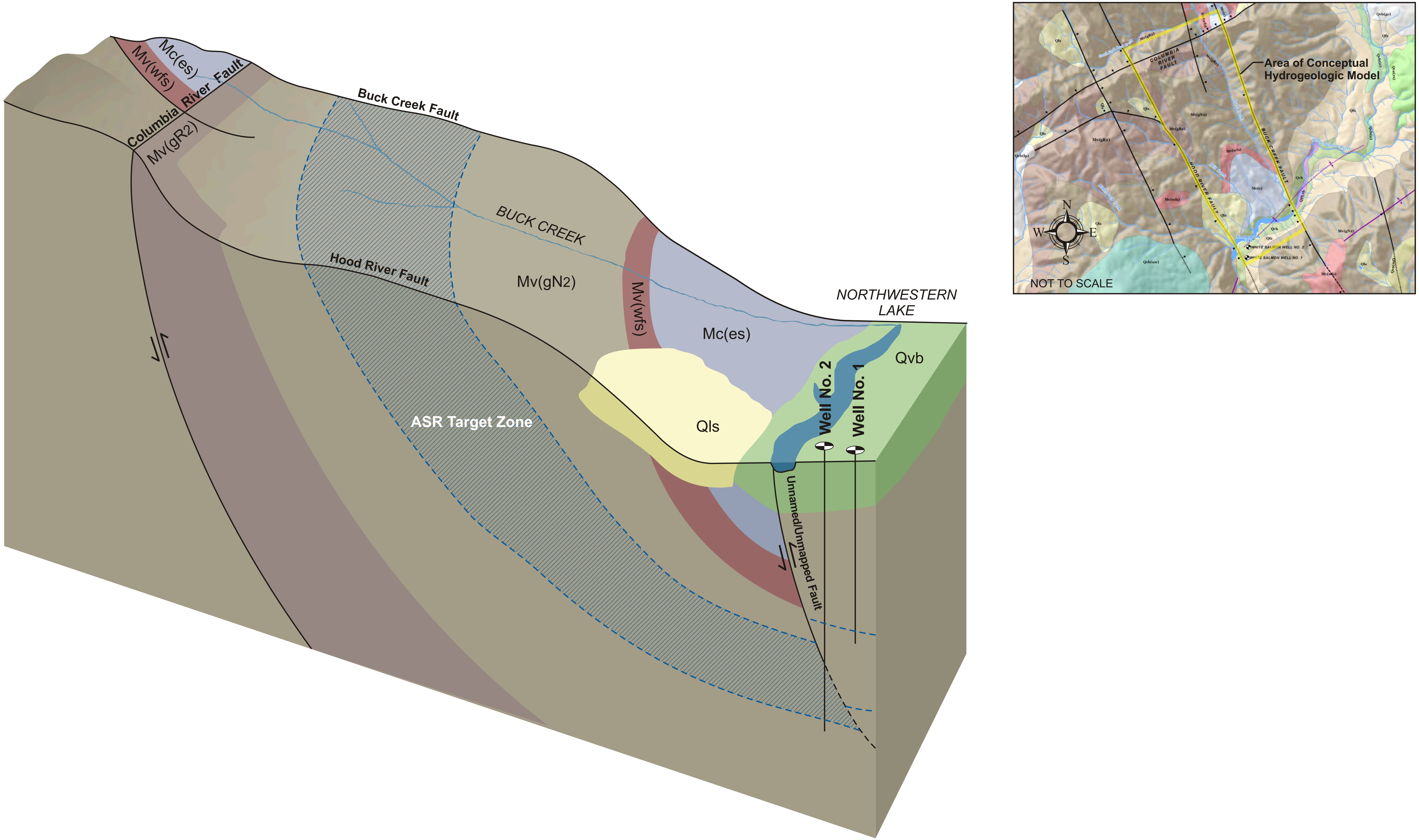
Aspect consulting
earth+water
www.aspectconsulting.com
a limited liability company

## Cross Section B-B'

City of White Salmon ASR
White Salmon, Washington

| | |
|---|---|
| DATE: | April 2010 |
| DESIGNED BY: | JMS |
| DRAWN BY: | SCC |
| REVISED BY: | SCC |
| PROJECT NO. | 090094 |
| FIGURE NO. | 5.3 |

Q:\City of White Salmon\090094\2010-04 ASR\090094-BB.dwg



Aspect consulting
earth + water
www.aspectconsulting.com
a limited liability company

# Conceptual Hydrogeologic Model

City of White Salmon ASR
White Salmon, Washington

| | |
|---|---|
| DATE: April 2010 | PROJECT NO. 090094 |
| DESIGNED BY: JMS | |
| DRAWN BY: EG | FIGURE NO. 5.4 |
| REVISED BY: - | |

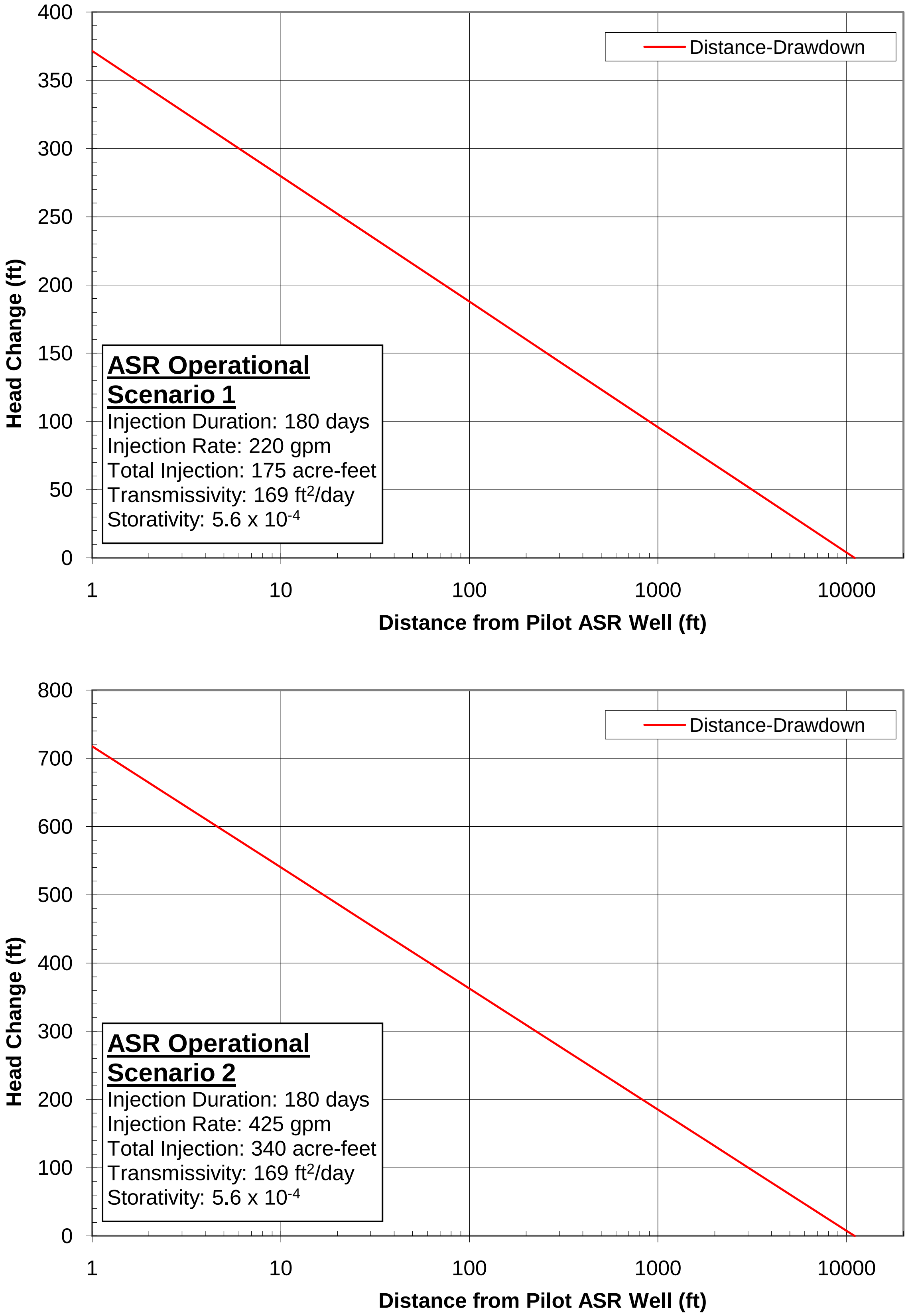
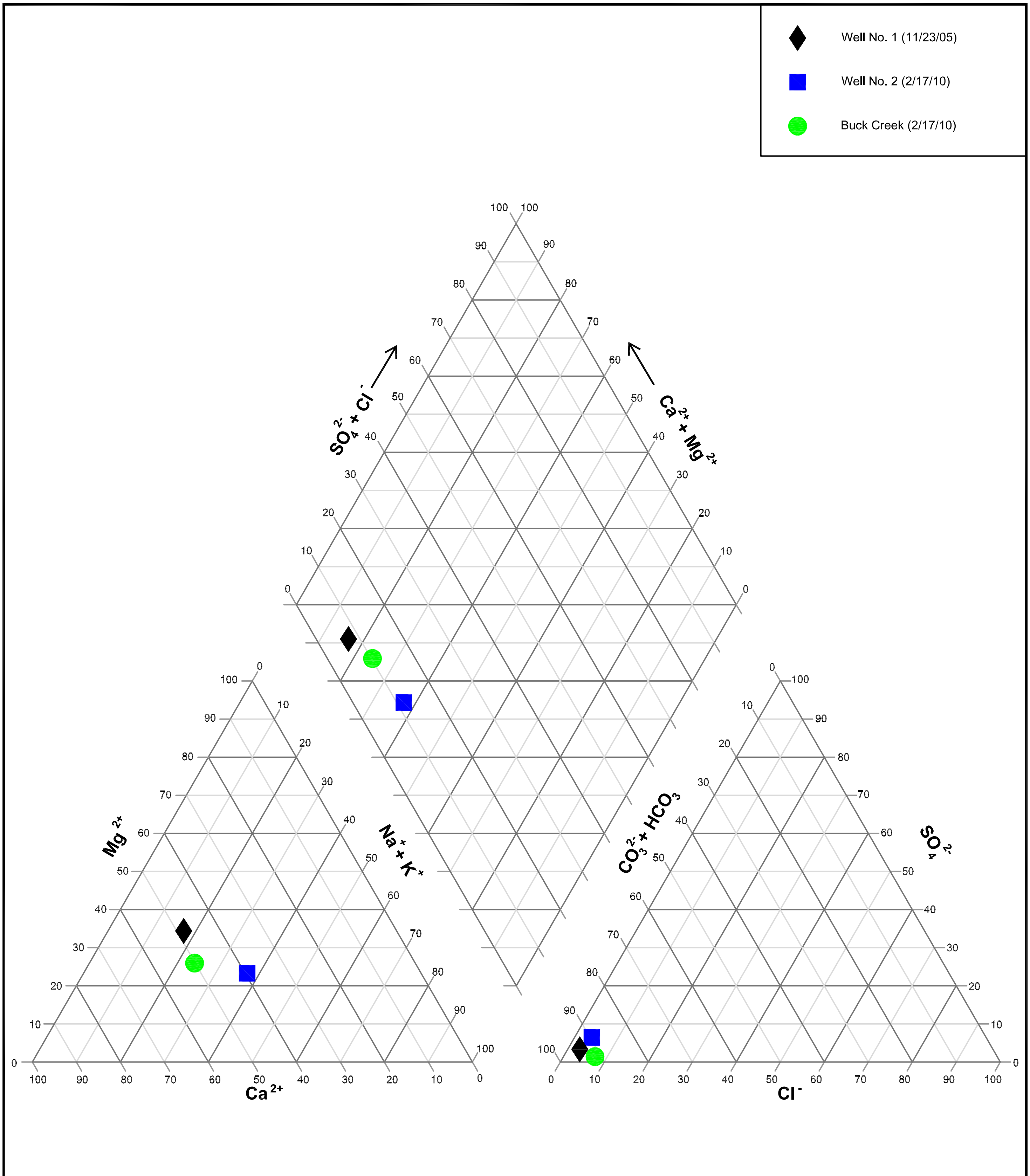


**Figure 5.5**

**Distance-Drawdown Curves for Hypothetical ASR Scenarios**

City of White Salmon ASR,
White Salmon, WA

**Aspect Consulting**
4/22/2011
*W:\090094 2009 Water System Imprvmts-ASR Project\Deliverables\ASR FS\figures\Figure 5.5 distance drawdown*



Aspect consulting
earth+water
www.aspectconsulting.com
*a limited liability company*

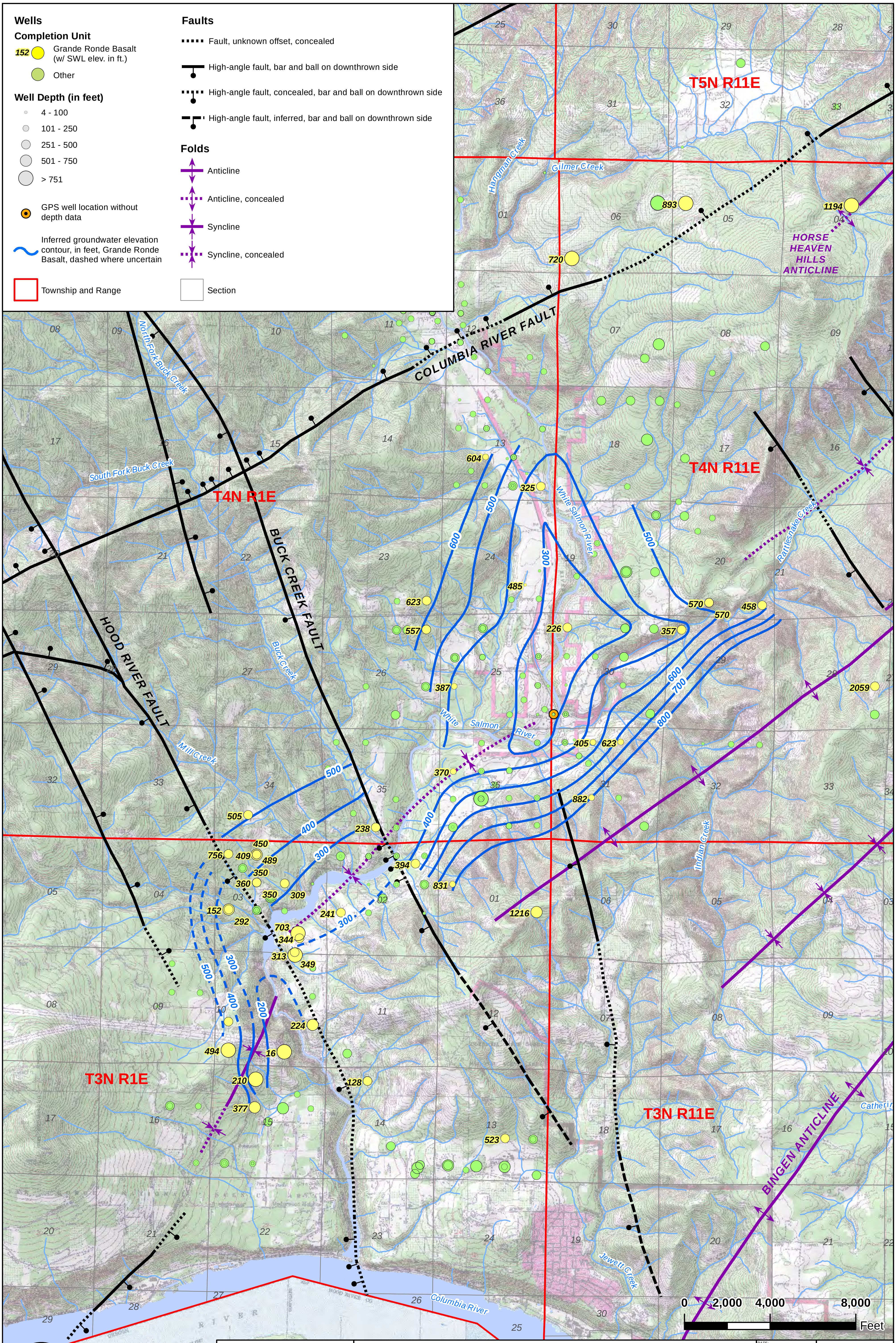
# Piper Diagram of Groundwater and Surface Water Quality Data

City of White Salmon ASR

White Salmon, Washington

| | |
|---|---|
| DATE: April 2010 | PROJECT NO. 090094 |
| DESIGNED BY: JMS | |
| DRAWN BY: MS | FIGURE NO. 5.6 |
| REVISED BY: | |

Q:\City of White Salmon\090094\2010-04 ASR\090094-Piper.dwg



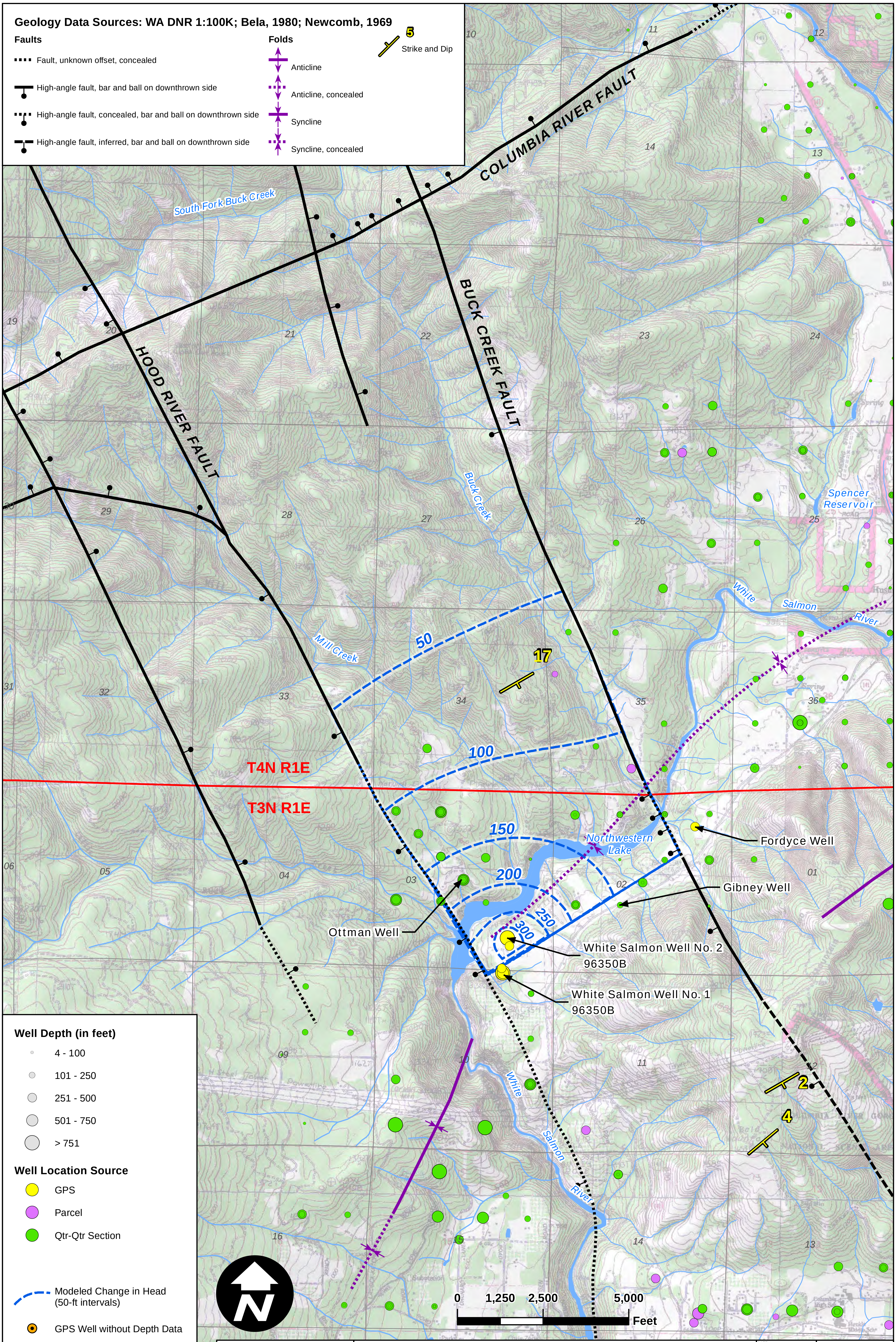
Aspect CONSULTING

# Groundwater Elevation Contour Map
# Grande Ronde Basalt

City of White Salmon ASR - White Salmon, Washington

| | |
|---|---|
| DATE: Sep 2010 | PROJECT NO. 090094 |
| DESIGNED BY: JMS | |
| DRAWN BY: PPW | FIGURE NO. 5.7 |
| REVISED BY: PPW | |

Path: T:\projects_8\white_salmon\2010\Delivered\5_7 GR_Basalt_GW_Elevation_Map.mxd



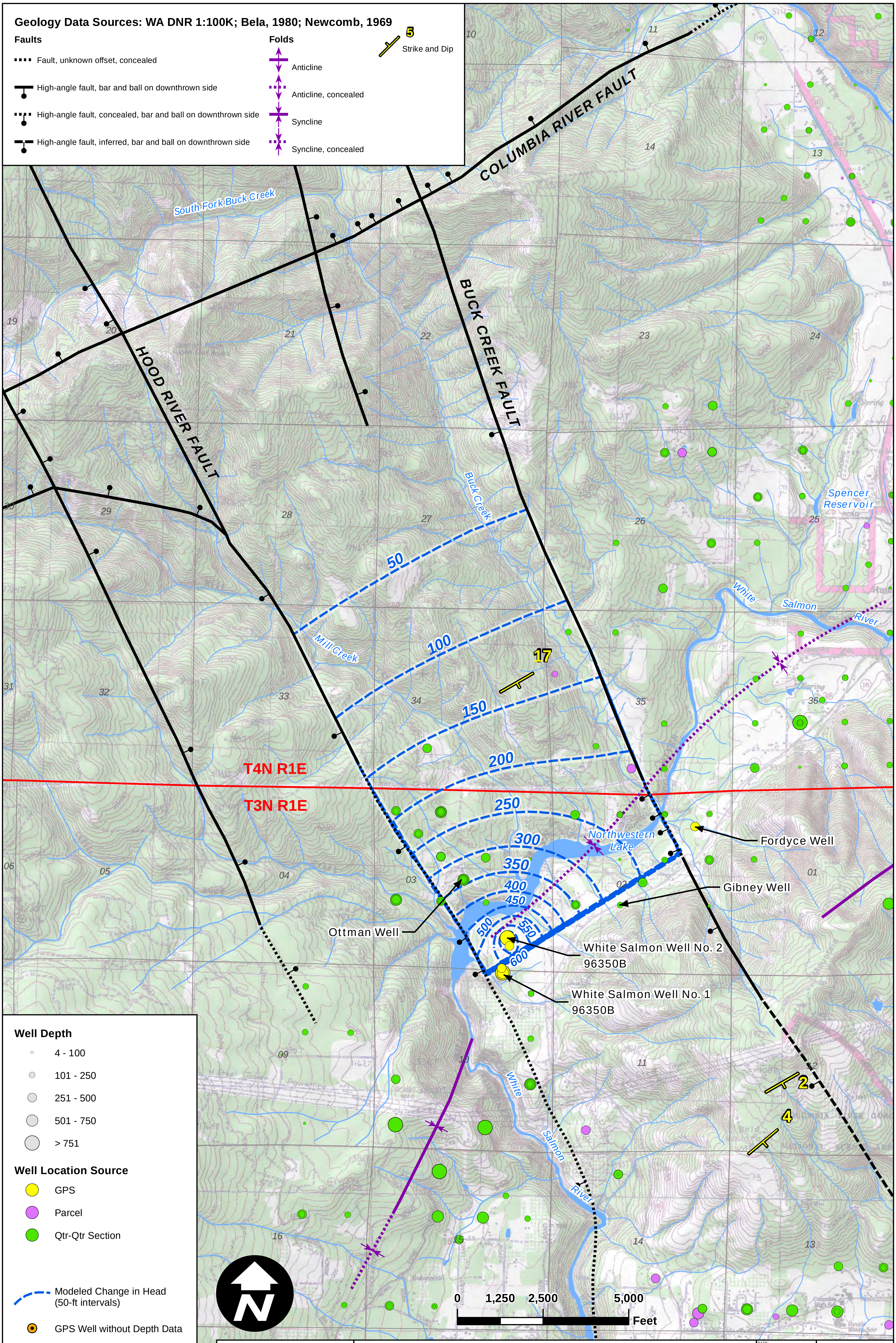
Aspect CONSULTING

# Modeled Changes in Head for Scenario 1

City of White Salmon ASR
White Salmon, Washington

| | |
|---|---|
| DATE: Sep 2010 | PROJECT NO. 090094 |
| DESIGNED BY: JM | |
| DRAWN BY: PPW | FIGURE NO. 5.8 |
| REVISED BY: PPW | |

Path: T:\projects_8\white_salmon\2010\Delivered\5_8 ModeledHeadChange_Scenario1.mxd



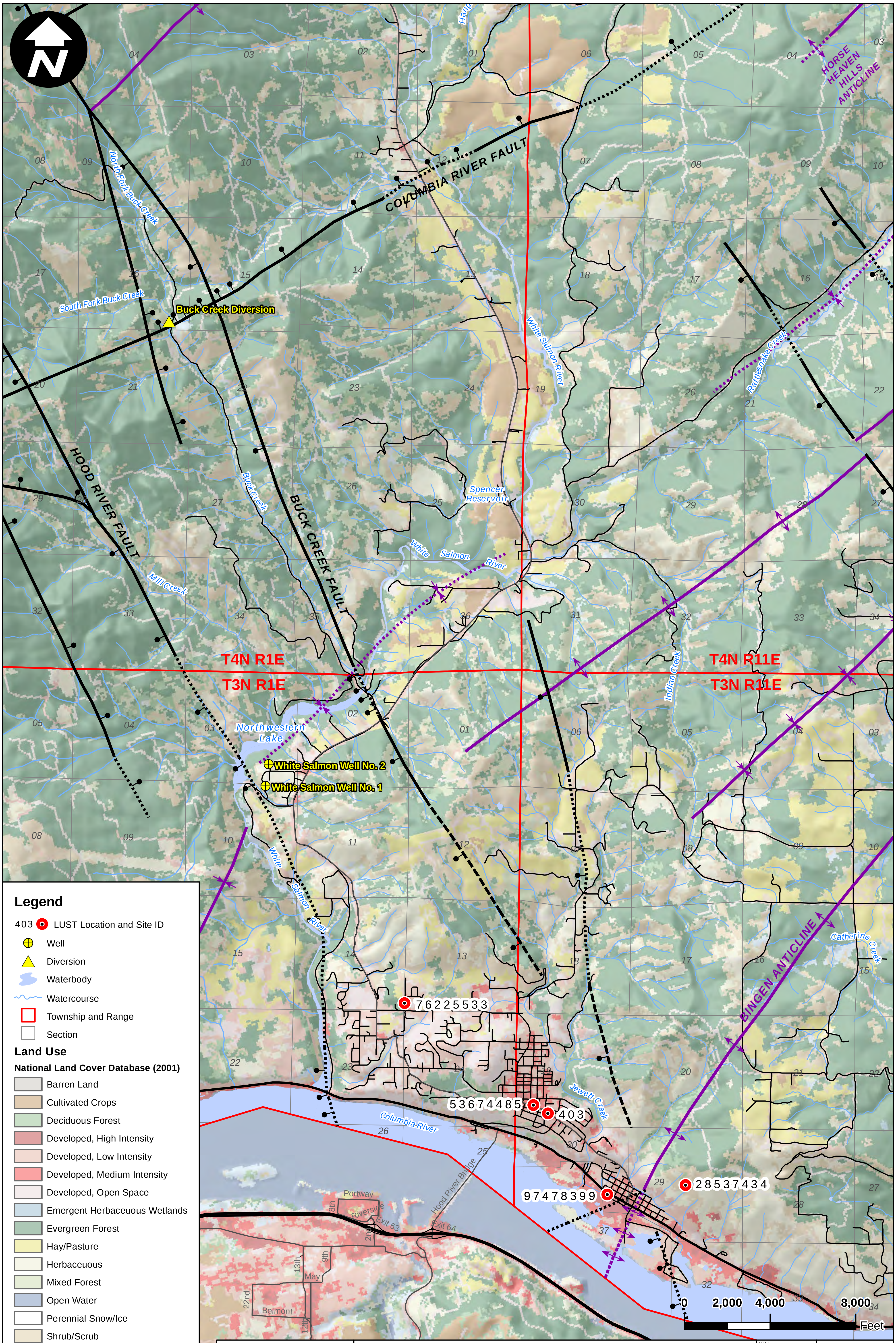
**Aspect** CONSULTING

## Modeled Changes in Head for Scenario 2

City of White Salmon ASR
White Salmon, Washington

| | |
|---|---|
| DATE: | Sep 2010 |
| DESIGNED BY: | JM |
| DRAWN BY: | PPW |
| REVISED BY: | PPW |
| PROJECT NO. | 090094 |
| FIGURE NO. | 5.9 |

Path: T:\projects_8\white_salmon\2010\Delivered\5_9 ModeledHeadChange_Scenario2.mxd



## Legend

403 ● LUST Location and Site ID

⊕ Well

▲ Diversion

Waterbody

Watercourse

☐ Township and Range

☐ Section

**Land Use**

**National Land Cover Database (2001)**

- Barren Land
- Cultivated Crops
- Deciduous Forest
- Developed, High Intensity
- Developed, Low Intensity
- Developed, Medium Intensity
- Developed, Open Space
- Emergent Herbaceuous Wetlands
- Evergreen Forest
- Hay/Pasture
- Herbaceuous
- Mixed Forest
- Open Water
- Perennial Snow/Ice
- Shrub/Scrub
- Woody Wetlands

***Note:*** *No locations on CSCS list appear in map extent.*

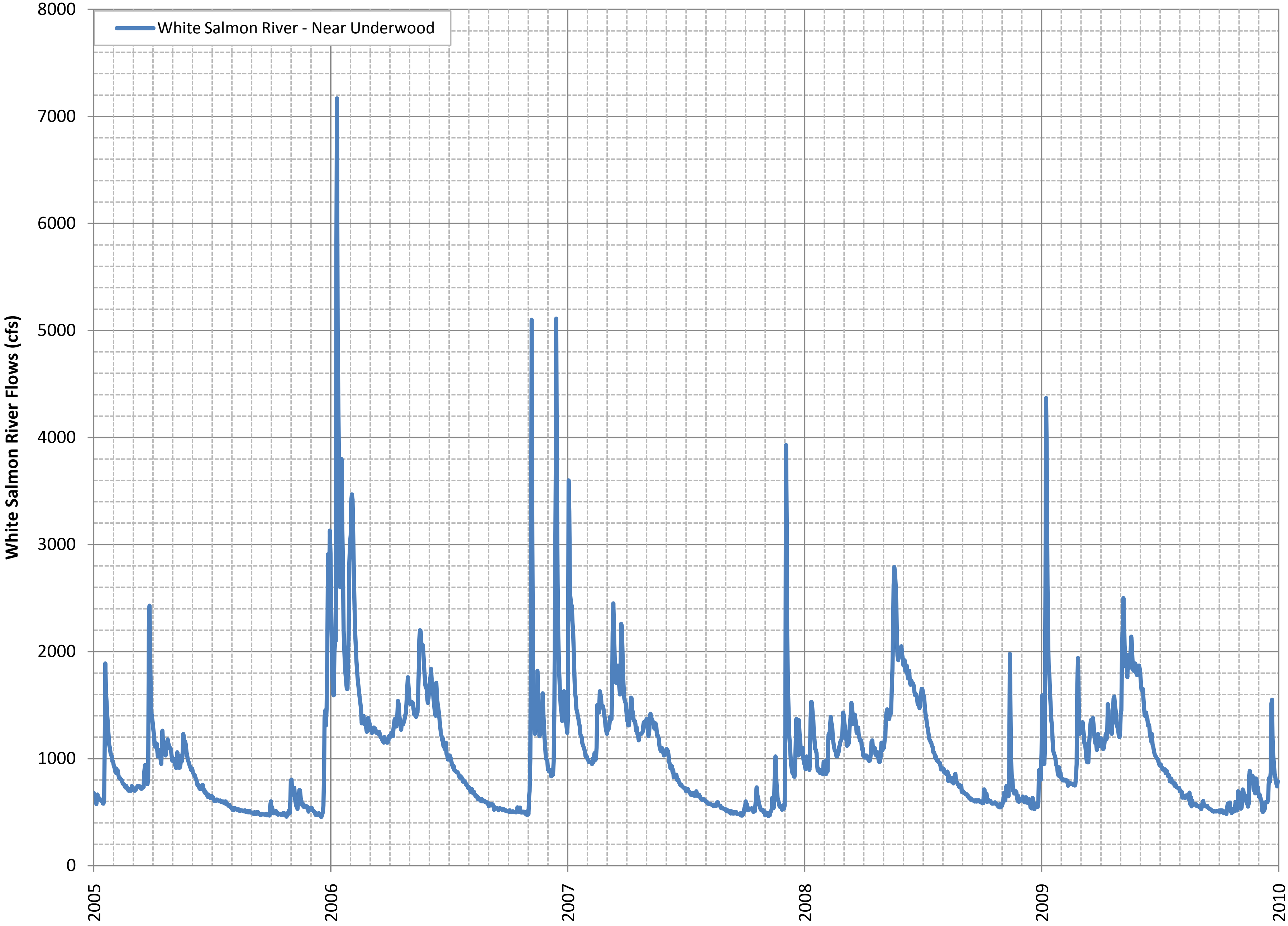
Aspect CONSULTING

# Land Use and Contaminated Sites

City of White Salmon ASR
White Salmon, Washington

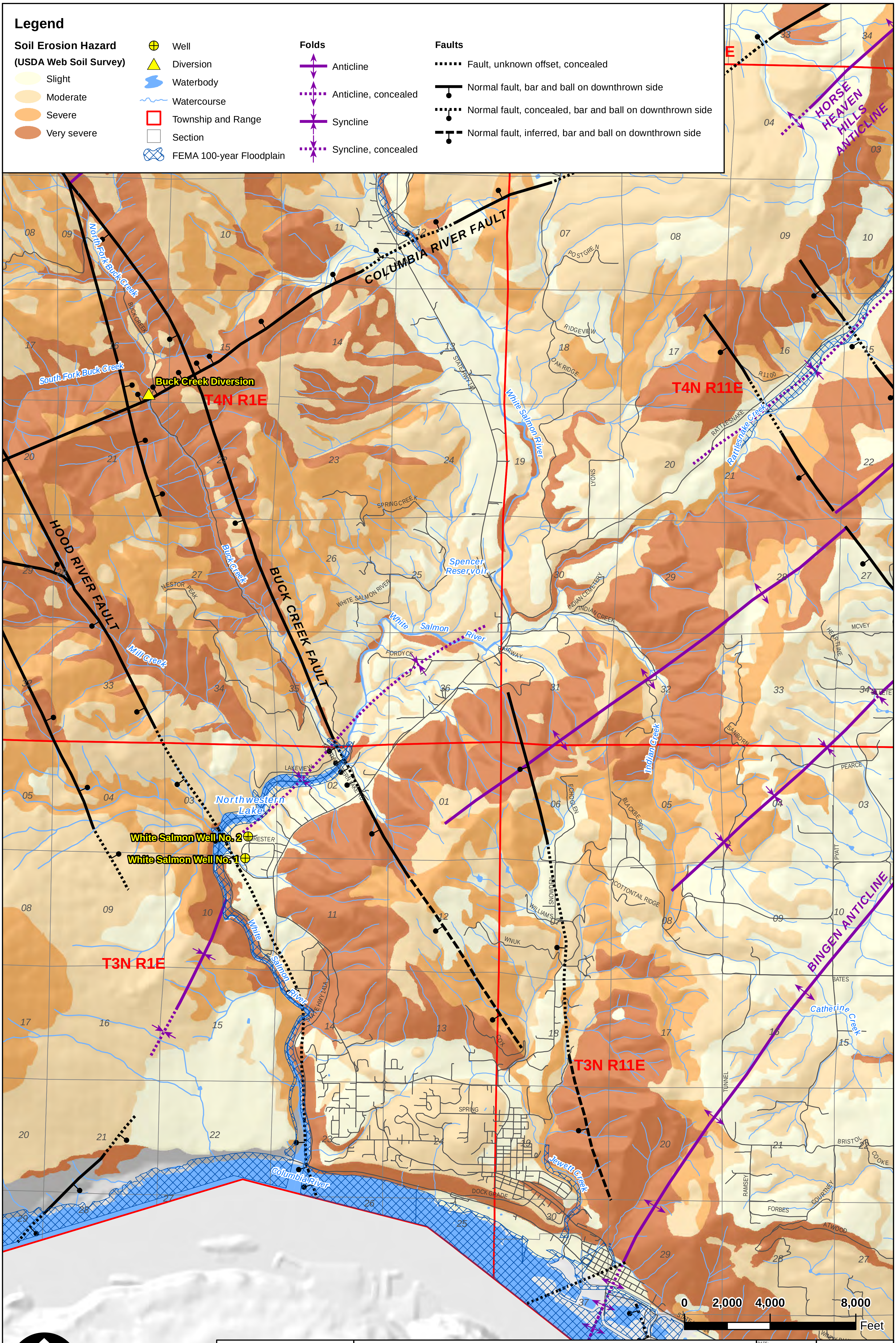
| | |
|---|---|
| DATE: Sep 2010 | PROJECT NO. 090094 |
| DESIGNED BY: PPW | |
| DRAWN BY: PPW | FIGURE NO. 6.1 |
| REVISED BY: PPW | |

Path: T:\projects_8\white_salmon\2010\Delivered\6_1 LandUse_and_Contam_Sites.mxd



**Aspect Consulting**
4/22/2011

**Figure 6.2 - White Salmon River Discharge, 2005 through 2009**
Aquifer Storage and Recovery Feasibility Assessment
White Salmon, Washington



**Soil Erosion Hazard and Floodplains**
City of White Salmon ASR
White Salmon, Washington

Aspect CONSULTING

DATE: Sep 2010
DESIGNED BY: PPW
DRAWN BY: PPW
REVISED BY: PPW

PROJECT NO. 090094
FIGURE NO. 6.3

Path: T:\projects_8\white_salmon\2010\Delivered\6_3 Soil_Hazards_And_Floodplains.mxd

# APPENDIX A

## Laboratory Reports for February 2010 Water Quality Data

2517 E. Evergreen Blvd.
Vancouver, WA 98629

AddyLab

**Phone: 360 750-0055**
Fax: 360 750-0057
Email: addylab@wa-net.

| | | | |
|---|---|---|---|
| **Client:** | City of White Salmon | **Reference #:** | 10AL0178 |
| **Sample Matrix:** | Drinking Water—S01 | **Date Received:** | 2/17/10 |
| **Date Collected:** | 2/17/10 | **Collected By:** | Troy |
| **Lab #:** | 14470127/14490127 | **Report Date:** | 3/2/10 |

| Analyte | Result | Units | MRL | Method | Date Analyzed | Batch | Analyst |
|---|---|---|---|---|---|---|---|
| TSS | **ND** | mg/L | 5.0 | SM 2540 D | 2/19/10 | 5A-113 | SV |
| Ammonia-N | **0.01 J** | mg/L | 0.05 | EPA 350.3 | 3/1/10 | 4B-038 | SV |
| Alkalinity | **29** | mg/L | 10.0 | SM 2320 B | 2/22/10 | 5A-114 | SV |
| TDS | **46** | mg/L | 15 | SM 2540 C | 2/22/10 | 5A-116 | SV |
| Chloride | **1.16** | mg/L | 1.00 | EPA 300.0 | 2/18/10 | 7-123 | SV |
| Sulfate | **0.53 J** | mg/L | 1.00 | EPA 300.0 | 2/18/10 | 7-123 | SV |
| Orthophosphate | **ND** | mg/L | 0.10 | EPA 300.0 | 2/18/10 0254 | 7-123 | SV |

| Definitions: | | |
|---|---|---|
| | TSS | Total Suspended Solids |
| | TDS | Total Dissolved Solids |
| | BOD | Biochemical Oxygen Demand |
| | mg/L | milligram per Liter |
| | ug/L | microgram per Liter |
| | MRL | Method Reporting Limit |
| | ND | Analyte Not Detected at or above the Method Detection Level (MDL). |
| | J | An estimate that is less than the MRL but greater than or equal to the MDL. |
| | * | Metals analyzed by ESC Lab. |

Test results for pH, color, anions except o-phosphorus, E. coli, coliform bacteria and turbidity conducted by AddyLab meet all the requirements of NELAC, unless otherwise stated in writing, and relate only to these samples.

Reviewed TM Date 3/2/10

[✓ Client] File

EDGE ANALYTICAL LABORATORIES

Burlington WA | 1620 S Walnut St - 98233
Corporate Office | 800.755.9295 • 360.757.1400 • 360.757.1402fax
Bellingham WA | 805 Orchard Dr Suite 4 - 98225
Microbiology | 360.671.0688 • 360.671.1577fax

ACCREDITED IN ACCORDANCE WITH nelac
Florida Dept of Health Lab E871040

# INORGANIC COMPOUNDS (IOC) REPORT

Client Name: Addy Lab
2517 East Evergreen Blvd
Vancouver, WA 98661

Reference Number: 10-02246
Project: 10AL0178

System Name: CITY OF WHITE SALMON
System ID Number: 96350B
DOH Source Number: 01
Multiple Sources:
Sample Type: B - Before treatment
Sample Purpose: Investigative or Other
Sample Location: (S01) Buck Creek
County: Klickitat

Sample Number: 10AL0178
Lab Number: 046-05007
Collect Date: 2/17/10 07:11
Date Received: 2/18/10
Report Date: 3/1/10
Sampled By: Troy Rosenburg
Sampler Phone: 509-493-1137
Released by:

| DOH# | ANALYTES | RESULTS | UNITS | SRL | Trigger | MCL | Analyst | METHOD | Analyzed | COMMENT |
|---|---|---|---|---|---|---|---|---|---|---|
| | **EPA Regulated** | | | | | | | | | |
| 4 | ARSENIC | **ND** | mg/L | 0.001 | 0.010 | | mvp | 200.8 | 02/22/10 | |
| 5 | BARIUM | **0.003** | mg/L | 0.001 | 2 | | mvp | 200.8 | 02/22/10 | |
| 6 | CADMIUM | **ND** | mg/L | 0.001 | 0.005 | | mvp | 200.8 | 02/22/10 | |
| 7 | CHROMIUM | **ND** | mg/L | 0.005 | 0.1 | | mvp | 200.8 | 02/22/10 | |
| 11 | MERCURY | **ND** | mg/L | 0.0002 | 0.002 | 0.002 | ccn | 245.1 | 02/19/10 | |
| 12 | SELENIUM | **ND** | mg/L | 0.005 | 0.05 | | mvp | 200.8 | 02/22/10 | |
| 110 | BERYLLIUM | **ND** | mg/L | 0.002 | 0.004 | | mvp | 200.8 | 02/22/10 | |
| 111 | NICKEL | **ND** | mg/L | 0.001 | 0.1 | | mvp | 200.8 | 02/22/10 | |
| 112 | ANTIMONY | **ND** | mg/L | 0.001 | 0.006 | | mvp | 200.8 | 02/22/10 | |
| 113 | THALLIUM | **ND** | mg/L | 0.001 | 0.002 | | mvp | 200.8 | 02/22/10 | |
| | **EPA Regulated (Secondary)** | | | | | | | | | |
| 8 | IRON | **ND** | mg/L | 0.050 | 0.3 | | bj | 200.7 | 02/23/10 | |
| 10 | MANGANESE | **ND** | mg/L | 0.005 | 0.05 | | mvp | 200.8 | 02/22/10 | |
| 13 | SILVER | **ND** | mg/L | 0.001 | 0.05 | | mvp | 200.8 | 02/22/10 | |
| 24 | ZINC | **ND** | mg/L | 0.005 | 5 | | mvp | 200.8 | 02/22/10 | |
| | **State Regulated** | | | | | | | | | |
| 14 | SODIUM | **2.39** | mg/L | 5.0 | | | bj | 200.7 | 02/23/10 | |
| | CALCIUM | **5.73** | mg/L | 0.500 | | | bj | 200.7 | 02/23/10 | |
| | MAGNESIUM | **1.87** | mg/L | 0.500 | | | bj | 200.7 | 02/23/10 | |
| | POTASSIUM | **1.13** | mg/L | 0.500 | | | bj | 200.7 | 02/23/10 | |
| | **State Unregulated** | | | | | | | | | |
| 9 | LEAD | **ND** | mg/L | 0.001 | | | mvp | 200.8 | 02/22/10 | |
| 23 | COPPER | **ND** | mg/L | 0.005 | | | mvp | 200.8 | 02/22/10 | |

NOTES:

SRL (State Reporting Level): indicates the minimum reporting level required by the Washington Department of Health (DOH).
MCL (Maximum Contaminant Level) maximum permissible level of a contaminant in water established by EPA; Federal Action Levels are 0.015 mg/L for Lead and 1.3 mg/L for Copper. Sodium has a recommended limit of 20 mg/L. A blank MCL value indicates a level is not currently established.
Trigger Level: DOH Drinking Water Response level. Systems with compounds detected in excess of this level are required to take additional samples. Contact your regional DOH office.
ND (Not Detected): indicates that the parameter was not detected above the Specified Reporting Limit (SRL).
An * in front of the parameter name indicates it is not NELAP accredited but it is accredited through WSDOH or USEPA Region 10.

These test results meet all the requirements of NELAC, unless otherwise stated in writing, and relate only to these samples.

If you have any questions concerning this report contact us at the above phone number.

FORM: IOC_ST

EDGE ANALYTICAL LABORATORIES

Burlington WA | 1620 S Walnut St - 98233
Corporate Office | 800.755.9295 • 360.757.1400 • 360.757.1402fax
Bellingham WA | 805 Orchard Dr Suite 4 - 98225
Microbiology | 360.671.0688 • 360.671.1577fax

ACCREDITED IN ACCORDANCE WITH nelac
Florida Dept of Health Lab E871040

# INORGANIC COMPOUNDS (IOC) REPORT

Client Name: Addy Lab
2517 East Evergreen Blvd
Vancouver, WA 98661

Reference Number: **10-02246**

Project: 10AL0178
Field ID: 10AL0178
Sample Description: (S01) Buck Creek
Sampled By: Troy Rosenburg
Sample Date: 2/17/10 7:11

Lab Number: -05007
Report Date: 3/1/10
Date Received: 2/18/10
Sampler Phone: 509-493-1137

Released By:

| CAS | Compound | RESULT | UNITS | PQL | MDL | MCL | Analyst | METHOD | Analyze | COMMENT |
|---|---|---|---|---|---|---|---|---|---|---|
| 7631-86-9 | *SILICA | **24.9** | mg/L | 0.05 | 0.007 | | bj | 200.7 | 02/23/10 | |
| 7429-90-5 | ALUMINUM | **0.028** | mg/L | 0.010 | 0.10 | | bj | 200.7 | 02/23/10 | |
| 7440-48-4 | *COBALT | **ND** | mg/L | 0.001 | 0.001 | | bj | 200.7 | 02/23/10 | |
| 7440-62-2 | VANADIUM | **ND** | mg/L | 0.002 | 0.004 | | bj | 200.7 | 02/23/10 | |
| 7723-14-0 | *TOTAL PHOSPHORUS | **0.019** | mg/L | 0.010 | 0.0026 | | spl | SM4500-P F | 02/24/10 | |
| 18496-25-8 | *HYDROGEN SULFIDE | **ND** | mg/L | 0.100 | | | ccn | SM4500-S2 E | 02/24/10 | |
| E-10195 | TOTAL ORGANIC CARBON | **0.54** | mg/L | 0.50 | 0.085 | | bj | SM5310 B | 02/23/10 | |

NOTES:

PQL Practical Quantitation Limit indicates the lower level of quantitation at which an analyte can be determined with a confidence of plus or minus 20%.

MCL (Maximum Contaminant Level) maximum permissible level of a contaminant in water established by EPA; Federal Action Levels are 0.015 mg/L for Lead and 1.3 mg/L for Copper. Sodium has a recommended limit of 20 mg/L. A blank MCL value indicates a level is not currently established.

MDL Method Detection Limit is a theoretical detection limit at which there is a 99% certainty that the analyte concentration is greater than zero.

ND = Not detected above the listed practical quantitation limit (PQL) or not above the Method Detection Limit (MDL), if requested.

An * in front of the parameter name indicates it is not NELAP accredited but it is accredited through WSDOH or USEPA Region 10.

These test results meet all the requirements of NELAC, unless otherwise stated in writing, and relate only to these samples.
If you have any questions concerning this report contact us at the above phone number.

2517 E. Evergreen Blvd.
Vancouver, WA 98629

AddyLab

**Phone: 360 750-0055**
Fax: 360 750-0057
Email: addylab@wa-net.

| | | | |
|---|---|---|---|
| **Client:** | City of White Salmon | **Reference #:** | 10AL0179 |
| **Sample Matrix:** | Drinking Water—S04 | **Date Received:** | 2/17/10 |
| **Date Collected:** | 2/17/10 | **Collected By:** | Troy |
| **Lab #:** | 14470128/14490128 | **Report Date:** | 3/2/10 |

| Analyte | Result | Units | MRL | Method | Date Analyzed | Batch | Analyst |
|---|---|---|---|---|---|---|---|
| TSS | **ND** | mg/L | 5.0 | SM 2540 D | 2/19/10 | 5A-113 | SV |
| Ammonia-N | **0.02 J** | mg/L | 0.05 | EPA 350.3 | 3/1/10 | 4B-038 | SV |
| Alkalinity | **52.5** | mg/L | 10.0 | SM 2320 B | 2/22/10 | 5A-114 | SV |
| TDS | **96** | mg/L | 15 | SM 2540 C | 2/22/10 | 5A-116 | SV |
| Chloride | **1.20** | mg/L | 1.00 | EPA 300.0 | 2/18/10 | 7-123 | SV |
| Sulfate | **2.87** | mg/L | 1.00 | EPA 300.0 | 2/18/10 | 7-123 | SV |
| Orthophosphate | **ND** | mg/L | 0.10 | EPA 300.0 | 2/18/10 0312 | 7-123 | SV |

| | | |
|---|---|---|
| Definitions: | TSS | Total Suspended Solids |
| | TDS | Total Dissolved Solids |
| | BOD | Biochemical Oxygen Demand |
| | mg/L | milligram per Liter |
| | ug/L | microgram per Liter |
| | MRL | Method Reporting Limit |
| | ND | Analyte Not Detected at or above the Method Detection Level (MDL). |
| | J | An estimate that is less than the MRL but greater than or equal to the MDL. |
| | * | Metals analyzed by ESC Lab. |

Test results for pH, color, anions except o-phosphorus, E. coli, coliform bacteria and turbidity conducted by AddyLab meet all the requirements of NELAC, unless otherwise stated in writing, and relate only to these samples.

Reviewed TAN Date 3/2/10

[✓ Client] File

EDGE ANALYTICAL LABORATORIES

Burlington WA | 1620 S Walnut St - 98233
Corporate Office | 800.755.9295 • 360.757.1400 • 360.757.1402fax
Bellingham WA | 805 Orchard Dr Suite 4 - 98225
Microbiology | 360.671.0688 • 360.671.1577fax

ACCREDITED IN ACCORDANCE WITH nelac
Florida Dept of Health Lab E871040

# INORGANIC COMPOUNDS (IOC) REPORT

Client Name: Addy Lab
2517 East Evergreen Blvd
Vancouver, WA 98661

Reference Number: 10-02233
Project: 10AL0179

System Name: CITY OF WHITE SALMON
System ID Number: 96350B
DOH Source Number: 04
Multiple Sources:
Sample Type: B - Before treatment
Sample Purpose: Investigative or Other
Sample Location: SO4 Well #2
County: Klickitat

Sample Number: 10AL0179
Lab Number: 046-04988
Collect Date: 2/17/10 07:38
Date Received: 2/18/10
Report Date: 3/1/10
Sampled By: Troy
Sampler Phone: 509-493-1137
Released by:

| DOH# | ANALYTES | RESULTS | UNITS | SRL | Trigger | MCL | Analyst | METHOD | Analyzed | COMMENT |
|---|---|---|---|---|---|---|---|---|---|---|
| | **EPA Regulated** | | | | | | | | | |
| 4 | ARSENIC | **ND** | mg/L | 0.001 | 0.010 | | mvp | 200.8 | 02/22/10 | |
| 5 | BARIUM | **0.003** | mg/L | 0.001 | 2 | | mvp | 200.8 | 02/22/10 | |
| 6 | CADMIUM | **ND** | mg/L | 0.001 | 0.005 | | mvp | 200.8 | 02/22/10 | |
| 7 | CHROMIUM | **ND** | mg/L | 0.005 | 0.1 | | mvp | 200.8 | 02/22/10 | |
| 11 | MERCURY | **ND** | mg/L | 0.0002 | 0.002 | 0.002 | ccn | 245.1 | 02/19/10 | |
| 12 | SELENIUM | **ND** | mg/L | 0.005 | 0.05 | | mvp | 200.8 | 02/22/10 | |
| 110 | BERYLLIUM | **ND** | mg/L | 0.002 | 0.004 | | mvp | 200.8 | 02/22/10 | |
| 111 | NICKEL | **ND** | mg/L | 0.001 | 0.1 | | mvp | 200.8 | 02/22/10 | |
| 112 | ANTIMONY | **ND** | mg/L | 0.001 | 0.006 | | mvp | 200.8 | 02/22/10 | |
| 113 | THALLIUM | **ND** | mg/L | 0.001 | 0.002 | | mvp | 200.8 | 02/22/10 | |
| | **EPA Regulated (Secondary)** | | | | | | | | | |
| 8 | IRON | **0.08** | mg/L | 0.050 | 0.3 | | bj | 200.7 | 02/23/10 | |
| 10 | MANGANESE | **0.093** | mg/L | 0.005 | 0.05 | | mvp | 200.8 | 02/22/10 | |
| 13 | SILVER | **ND** | mg/L | 0.001 | 0.05 | | mvp | 200.8 | 02/22/10 | |
| 24 | ZINC | **ND** | mg/L | 0.005 | 5 | | mvp | 200.8 | 02/22/10 | |
| | **State Regulated** | | | | | | | | | |
| 14 | SODIUM | **7.81** | mg/L | 5.0 | | | bj | 200.7 | 02/23/10 | |
| | CALCIUM | **8.87** | mg/L | 0.500 | | | bj | 200.7 | 02/23/10 | |
| | MAGNESIUM | **3.17** | mg/L | 0.500 | | | bj | 200.7 | 02/23/10 | |
| | POTASSIUM | **2.55** | mg/L | 0.500 | | | bj | 200.7 | 02/23/10 | |
| | **State Unregulated** | | | | | | | | | |
| 9 | LEAD | **ND** | mg/L | 0.001 | | | mvp | 200.8 | 02/22/10 | |
| 23 | COPPER | **ND** | mg/L | 0.005 | | | mvp | 200.8 | 02/22/10 | |

NOTES:

SRL (State Reporting Level): indicates the minimum reporting level required by the Washington Department of Health (DOH).
MCL (Maximum Contaminant Level) maximum permissible level of a contaminant in water established by EPA; Federal Action Levels are 0.015 mg/L for Lead and 1.3 mg/L for Copper. Sodium has a recommended limit of 20 mg/L. A blank MCL value indicates a level is not currently established.
Trigger Level: DOH Drinking Water Response level. Systems with compounds detected in excess of this level are required to take additional samples. Contact your regional DOH office.
ND (Not Detected): indicates that the parameter was not detected above the Specified Reporting Limit (SRL).
An * in front of the parameter name indicates it is not NELAP accredited but it is accredited through WSDOH or USEPA Region 10.

These test results meet all the requirements of NELAC, unless otherwise stated in writing, and relate only to these samples.

If you have any questions concerning this report contact us at the above phone number.

EDGE ANALYTICAL LABORATORIES

Burlington WA | 1620 S Walnut St - 98233
Corporate Office | 800.755.9295 • 360.757.1400 • 360.757.1402fax
Bellingham WA | 805 Orchard Dr Suite 4 - 98225
Microbiology | 360.671.0688 • 360.671.1577fax

ACCREDITED IN ACCORDANCE WITH nelac
Florida Dept of Health Lab E871040

# INORGANIC COMPOUNDS (IOC) REPORT

Client Name: Addy Lab
2517 East Evergreen Blvd
Vancouver, WA 98661

Reference Number: **10-02233**

Project: 10AL0179
Field ID: 10AL0179
Sample Description: SO4 Well #2
Sampled By: Troy
Sample Date: 2/17/10 7:38

Lab Number: -04988
Report Date: 3/1/10
Date Received: 2/18/10
Sampler Phone: 509-493-1137

Released By:

| CAS | Compound | RESULT | UNITS | PQL | MDL | MCL | Analyst | METHOD | Analyze | COMMENT |
|---|---|---|---|---|---|---|---|---|---|---|
| 7631-86-9 | *SILICA | **37.7** | mg/L | 0.05 | 0.007 | | bj | 200.7 | 02/23/10 | |
| 7429-90-5 | ALUMINUM | **ND** | mg/L | 0.010 | 0.10 | | bj | 200.7 | 02/23/10 | |
| 7440-48-4 | *COBALT | **ND** | mg/L | 0.001 | 0.001 | | bj | 200.7 | 02/23/10 | |
| 7440-62-2 | *VANADIUM | **ND** | mg/L | 0.001 | 0.004 | | bj | 6010B | 02/23/10 | |
| 7723-14-0 | *TOTAL PHOSPHORUS | **0.048** | mg/L | 0.010 | 0.0026 | | spl | SM4500-P F | 02/24/10 | |
| 18496-25-8 | *HYDROGEN SULFIDE | **ND** | mg/L | 0.100 | | | ccn | SM4500-S2 E | 02/24/10 | |
| E-10195 | TOTAL ORGANIC CARBON | **ND** | mg/L | 0.50 | 0.085 | | bj | SM5310 B | 02/23/10 | |

NOTES:

PQL Practical Quantitation Limit indicates the lower level of quantitation at which an analyte can be determined with a confidence of plus or minus 20%.

MCL (Maximum Contaminant Level) maximum permissible level of a contaminant in water established by EPA; Federal Action Levels are 0.015 mg/L for Lead and 1.3 mg/L for Copper. Sodium has a recommended limit of 20 mg/L. A blank MCL value indicates a level is not currently established.

MDL Method Detection Limit is a theoretical detection limit at which there is a 99% certainty that the analyte concentration is greater than zero.

ND = Not detected above the listed practical quantitation limit (PQL) or not above the Method Detection Limit (MDL), if requested.

An * in front of the parameter name indicates it is not NELAP accredited but it is accredited through WSDOH or USEPA Region 10.

These test results meet all the requirements of NELAC, unless otherwise stated in writing, and relate only to these samples.
If you have any questions concerning this report contact us at the above phone number.

2517 E. Evergreen Blvd.
Vancouver, WA. 98661

AddyLab

Phone: 360-750-0055
Fax: 360-750-0057
Email: info@addylab.com

# CHAIN OF CUSTODY REPORT

10AL0179

CLIENT: City of White Salmon
REPORT TO: tom Smith
ADDRESS: 220 NE tohomish
PHONE: (504) 509 493 1137
FAX: 509-493-1147

INVOICE TO: City of White Salmon
P.O Box 2139
White Salmon WA 98672

P.O. NUMBER:

PROJECT NAME:
PROJECT NUMBER: (504) 963508
SAMPLED BY: TROY

TURNAROUND REQUEST in Business Days*
Organic & Inorganic Analyses: 10 [✓ STD.] ☐ 7 ☐ 5 ☐ 4 ☐ 3 ☐ 2 ☐ 1 ☐ <1
Petroleum Hydrocarbon Analyses: ☐ 5 STD. ☐ 4 ☐ 3 ☐ 2 ☐ 1 ☐ <1
☐ OTHER Please Specify ____
*Turnaround Requests less than standard may incur Rush Charges.

REQUESTED ANALYSES

| | CLIENT SAMPLE IDENTIFICATION | SAMPLING DATE/TIME | EA | MATRIX (W, S, O) | # OF CONT. | COMPLIANCE ☐ COMMENTS |
|---|---|---|---|---|---|---|
| 1. | toc | 2-17-10/7:46AM | 1 | | | |
| 2. | total Pos | 2-17-10/7:42AM | 1 | | | |
| 3. | [redacted] | [redacted] | 1 | | | |
| 4. | [redacted] | [redacted] | 1 | | | |
| 5. | [redacted] | [redacted] | 1 | | | |
| 6. | Silica | 2-17-10/7:39AM | 1 | | | |
| * 7. | See Comments | 2-17-10/7:41AM | Metals → | | | 10-02233 |
| 8. | [redacted] | [redacted] | 1 | | | |
| 9. | Sulfide | 2-17-10/7:38AM | 1 | | | |
| 10. | | | | | | |
| 11. | | | | | | |
| 12. | | | | | | |
| 13. | | | | | | |

10-02233
4988

Metals [illegible]* Al, Sb, As, Ba, Be, Cd, Ca, Cr, Co, Cu, Fe, Pb, Mg, Mn, Hg, Ni, K, Se, Ag, Na, Tl, V, Zn

RELINQUISHED BY:
DATE: 2-17-10
PRINT NAME: Troy Rosenburg FIRM: City of White Salmon TIME: 8:37 AM

RECEIVED BY: Carl L Sely
DATE: 2/17/10
PRINT NAME: FIRM: TIME: 1045

TEMP: 3°C at [illegible]

RELINQUISHED BY:
DATE: 2-17-10
PRINT NAME: Jeff Buckley FIRM: Same Day [illegible] TIME: 09:23

RECEIVED BY: HH
3°
DATE: 2-18-10
PRINT NAME: FIRM: UPS TIME: 0840

PAGE OF

COC REV 07/08

**AddyLab**

2517 E. Evergreen Blvd.
Vancouver, WA 98661
Phone: (360) 750-0055 Fax: (360) 750-0057
Email: reports@addylab.com

# Drinking Water Sample Information (WSI) for Inorganic & Organic Chemical Analysis

## CLIENT & BILLING INFORMATION

Report To: tom Smith
Address: 220 NE tohomish
City: White Salmon State: WA Zip: 98672
Phone: 509 493 1137 Fax:
Email: TomS@ci.white-Salmon.WA.uS
Contact: troy
Project Name:

Bill To: City of White Salmon Same As Report To
Address: 100 N Main
City: White Salmon State: WA Zip: 98672
Phone: 509 493 1133
P.O.#: 2139

## SAMPLING INFORMATION

1. Date Collected: 2.17.10 Time Collected: [✓ AM] PM
2. Collected By: TROY Telephone: 509 493 1137
3. Specific Location where sample taken 504 Well #2
4. If taken from Distribution, indicate address:

## PUBLIC WATER SYSTEM (ONLY)

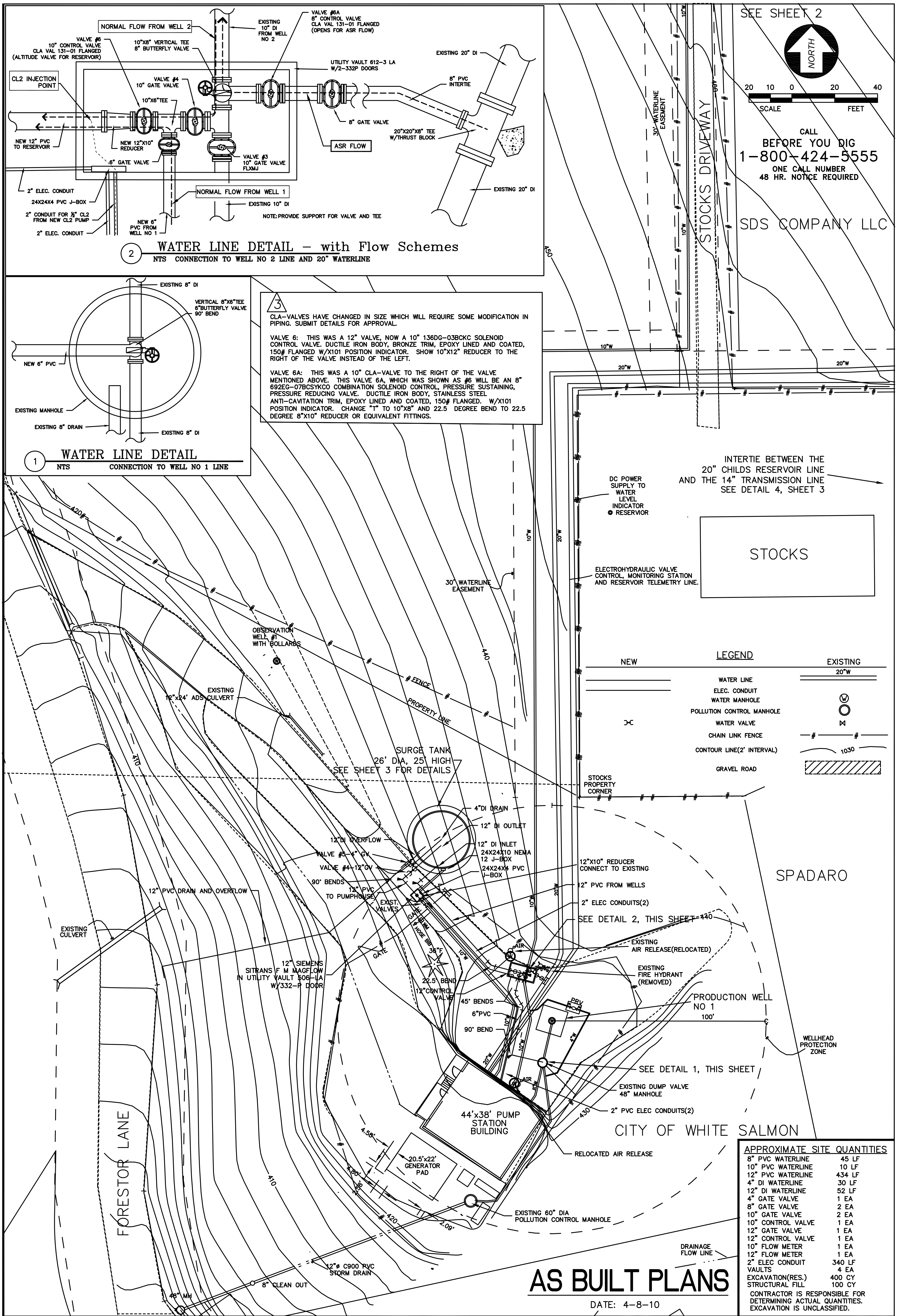
4. System ID Number: 96350B
5. DOH Source Number: 504
(If Sample blended from more than one source, list all) Check here if this is a New Source.
6. Group: [✓ A] B
7. System Name: City of White Salmon
8. Source Type: Surface Well/Ground Water [✓ Well Field] Spring Purchased
9. County Klickitat
10. Check here if this analysis is for compliance with State regulations for Public Water Systems. (Results will be sent to you and State)
11. Sample taken [✓ Before Treatment] After Treatment No Treatment
12. Treatment Type: None Aeration Filtration Chlorination Fluoridation Softener Other
13. Utilities Name for this source: 504
14. Remarks:

## For Laboratory Use only

| | | |
|---|---|---|
| Time & Date received | Reference #: | Date Analyzed: |

# APPENDIX B

## As-Built Plans, City of White Salmon Water System Improvements, 2009



② WATER LINE DETAIL – with Flow Schemes
NTS CONNECTION TO WELL NO 2 LINE AND 20" WATERLINE

① WATER LINE DETAIL
NTS CONNECTION TO WELL NO 1 LINE

CALL
BEFORE YOU DIG
1-800-424-5555
ONE CALL NUMBER
48 HR. NOTICE REQUIRED

△3

CLA-VALVES HAVE CHANGED IN SIZE WHICH WILL REQUIRE SOME MODIFICATION IN PIPING. SUBMIT DETAILS FOR APPROVAL.

VALVE 6: THIS WAS A 12" VALVE, NOW A 10" 136DG-03BCKC SOLENOID CONTROL VALVE. DUCTILE IRON BODY, BRONZE TRIM, EPOXY LINED AND COATED, 150# FLANGED W/X101 POSITION INDICATOR. SHOW 10"X12" REDUCER TO THE RIGHT OF THE VALVE INSTEAD OF THE LEFT.

VALVE 6A: THIS WAS A 10" CLA-VALVE TO THE RIGHT OF THE VALVE MENTIONED ABOVE. THIS VALVE 6A, WHICH WAS SHOWN AS #6 WILL BE AN 8" 692EG-07BCSYKCO COMBINATION SOLENOID CONTROL, PRESSURE SUSTAINING, PRESSURE REDUCING VALVE. DUCTILE IRON BODY, STAINLESS STEEL ANTI-CAVITATION TRIM, EPOXY LINED AND COATED, 150# FLANGED. W/X101 POSITION INDICATOR. CHANGE "T" TO 10"X8" AND 22.5 DEGREE BEND TO 22.5 DEGREE 8"X10" REDUCER OR EQUIVALENT FITTINGS.

## LEGEND

| NEW | | EXISTING |
|---|---|---|
| | | 20"W |
| — | WATER LINE | ═ |
| — | ELEC. CONDUIT | |
| | WATER MANHOLE | Ⓦ |
| | POLLUTION CONTROL MANHOLE | ◎ |
| ⋈ | WATER VALVE | ⋈ |
| | CHAIN LINK FENCE | —#—#— |
| | CONTOUR LINE(2' INTERVAL) | 1030 |
| | GRAVEL ROAD | ▨ |

# AS BUILT PLANS

DATE: 4-8-10

## APPROXIMATE SITE QUANTITIES

| | |
|---|---|
| 8" PVC WATERLINE | 45 LF |
| 10" PVC WATERLINE | 10 LF |
| 12" PVC WATERLINE | 434 LF |
| 4" DI WATERLINE | 30 LF |
| 12" DI WATERLINE | 52 LF |
| 4" GATE VALVE | 1 EA |
| 8" GATE VALVE | 2 EA |
| 10" GATE VALVE | 2 EA |
| 10" CONTROL VALVE | 1 EA |
| 12" GATE VALVE | 1 EA |
| 12" CONTROL VALVE | 1 EA |
| 10" FLOW METER | 1 EA |
| 12" FLOW METER | 1 EA |
| 2" ELEC CONDUIT | 340 LF |
| VAULTS | 4 EA |
| EXCAVATION(RES.) | 400 CY |
| STRUCTURAL FILL | 100 CY |

CONTRACTOR IS RESPONSIBLE FOR DETERMINING ACTUAL QUANTITIES. EXCAVATION IS UNCLASSIFIED.

| No. | Date | Revisions |
|---|---|---|
| 4 | 7-14-09 | Revised Reservoir Location |
| △3 | 4-27-09 | ADDENDUM 03 |
| 2 | 4-1-09 | Bid Set |
| 1 | 3-1-09 | Submitted for Review |

FRANK E. CHILDS JR. 18028

**Pioneer Surveying & Engineering, Inc.**
Civil Engineering and Land Planning
228 South Columbus Avenue, Suite 104
Goldendale, Washington 98620
Phone (509) 773-4945, Fax (509) 773-5888,
E-Mail pse@gorge.net

CADD FILE NAME: 09-014\C1.1

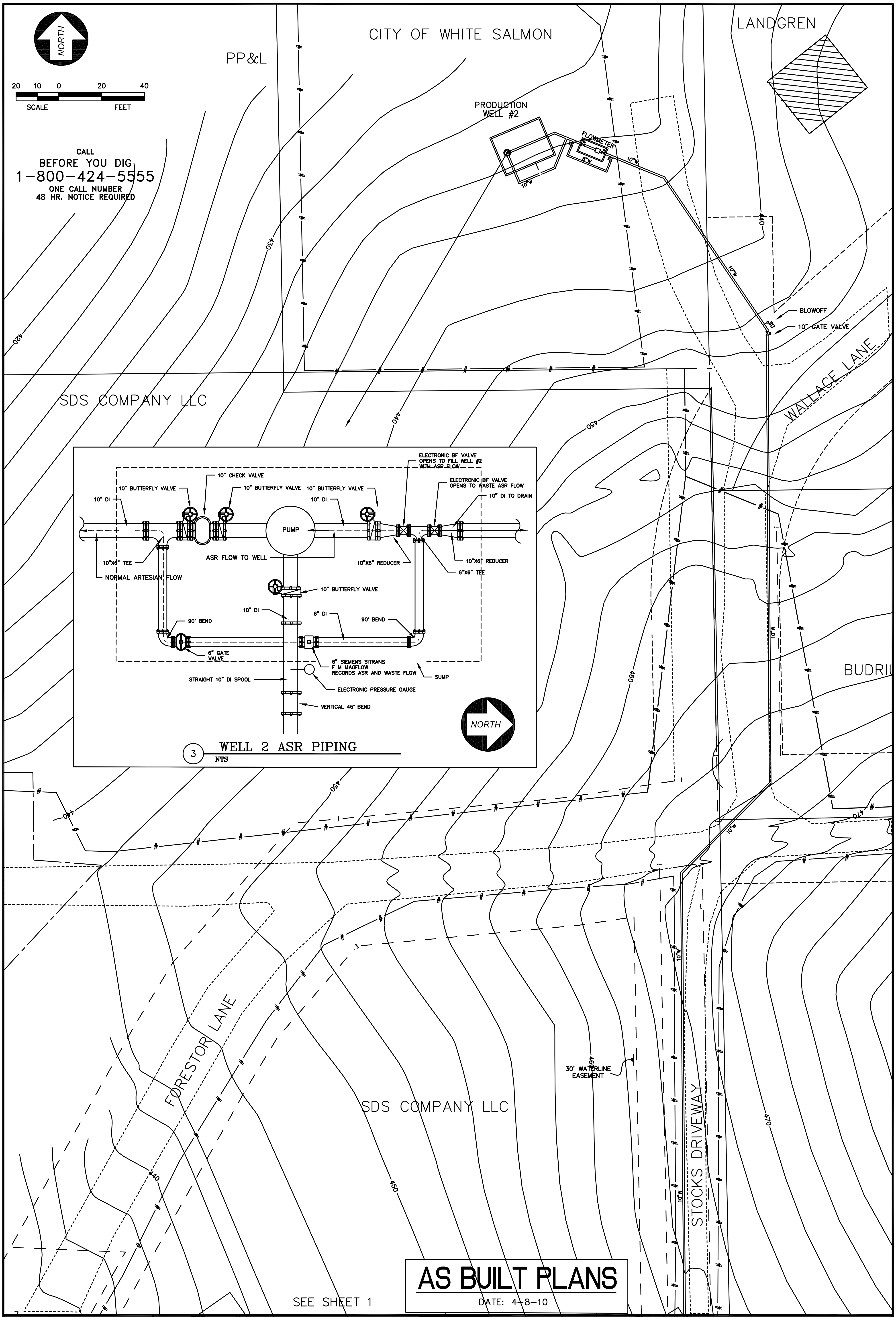
**City of White Salmon**
**Public Works Department**
PO BOX 2139
100 N. Main Ave.
White Salmon, Wa. 98620
509-493-1133

MICHAEL S. WELLMAN 16470

*WELL FIELD PIPING PLAN*

*CITY OF WHITE SALMON*
*2009 WATER SYSTEM*
*IMPROVEMENTS–PHASE 2*
*KLICKITAT COUNTY, WASHINGTON*

1 / 3



**AS BUILT PLANS**

DATE: 4-8-10

| No. | Date | Revisions |
|---|---|---|
| | | |
| | | |
| 2 | 4-1-09 | Bid Set |
| 1 | 3-1-09 | Submitted for Review |

FRANK E. CHILDS JR. 18028

Pioneer Surveying & Engineering, Inc.
Civil Engineering and Land Planning
228 South Columbus Avenue, Suite 104
Goldendale, Washington 98620
Phone (509) 773-4945, Fax (509) 773-5888,
E-Mail pse@gorge.net

CADD FILE NAME: 09-014\C1.1

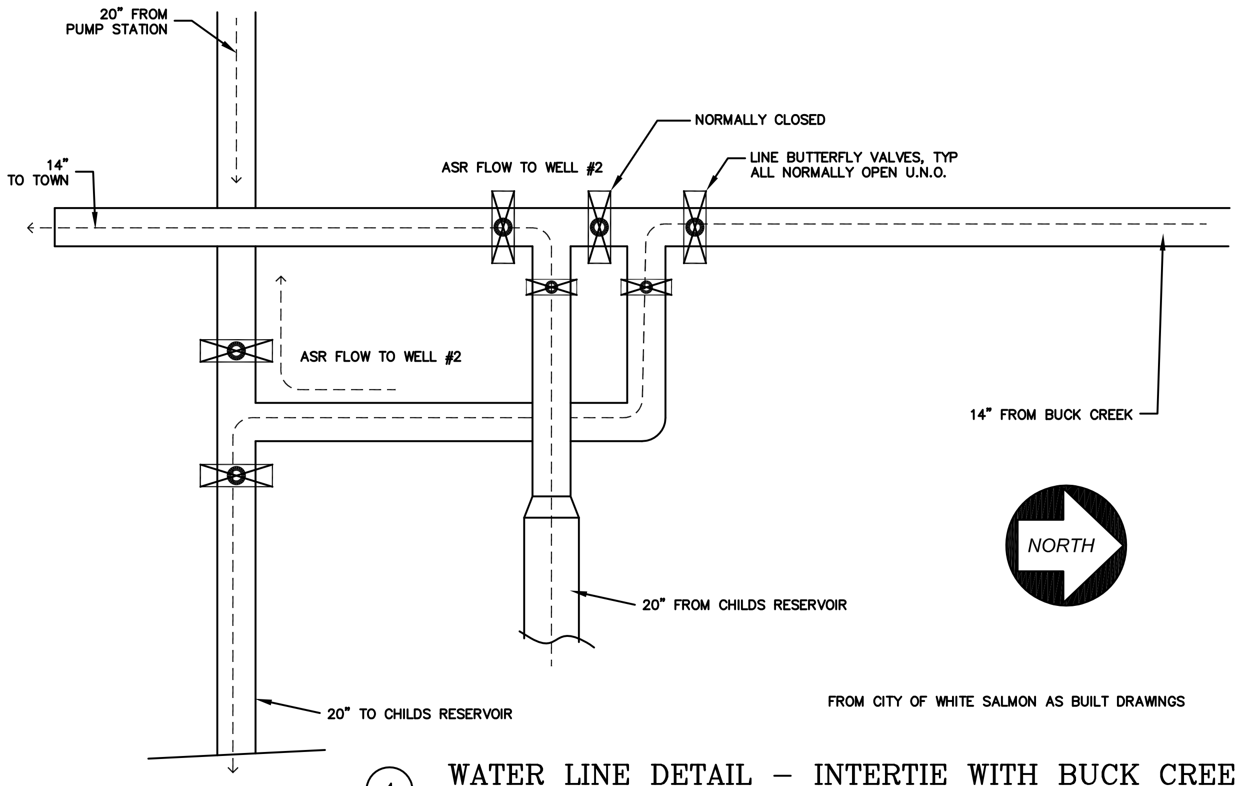
City of White Salmon
Public Works Department
PO BOX 2139
100 N. Main Ave.
White Salmon, Wa. 98620
509-493-1133

MICHAEL S. WELLMAN 16470

## WELL NO 2 PIPING PLAN

CITY OF WHITE SALMON
2009 WATER SYSTEM
IMPROVEMENTS–PHASE 2
KLICKITAT COUNTY, WASHINGTON

2 / 3

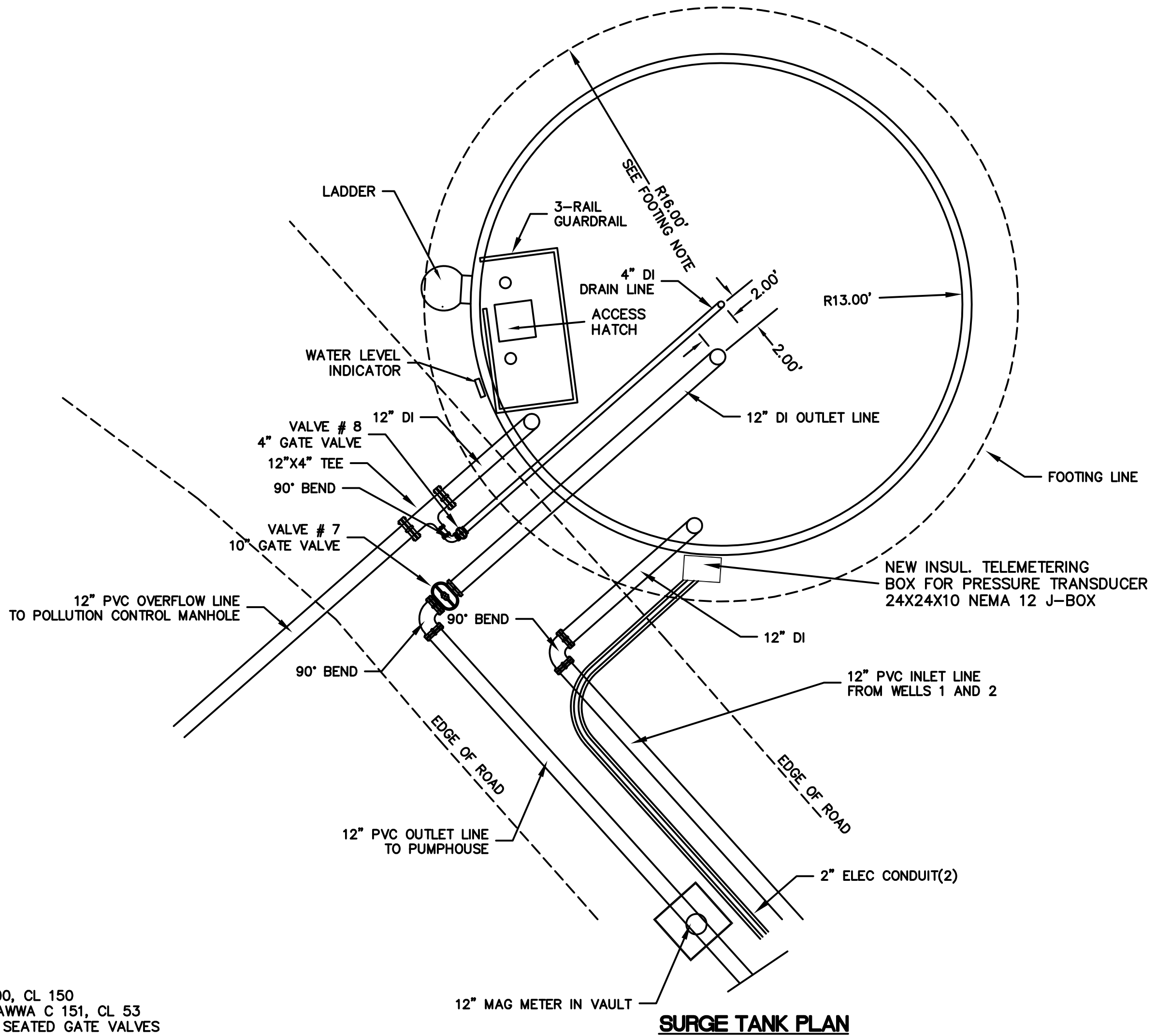


FROM CITY OF WHITE SALMON AS BUILT DRAWINGS

△2 FOR INFORMATION ONLY

④ WATER LINE DETAIL – INTERTIE WITH BUCK CREEK LINE
NTS INTERTIE 20" TO 14"

CALL
BEFORE YOU DIG
1–800–424–5555
ONE CALL NUMBER
48 HR. NOTICE REQUIRED



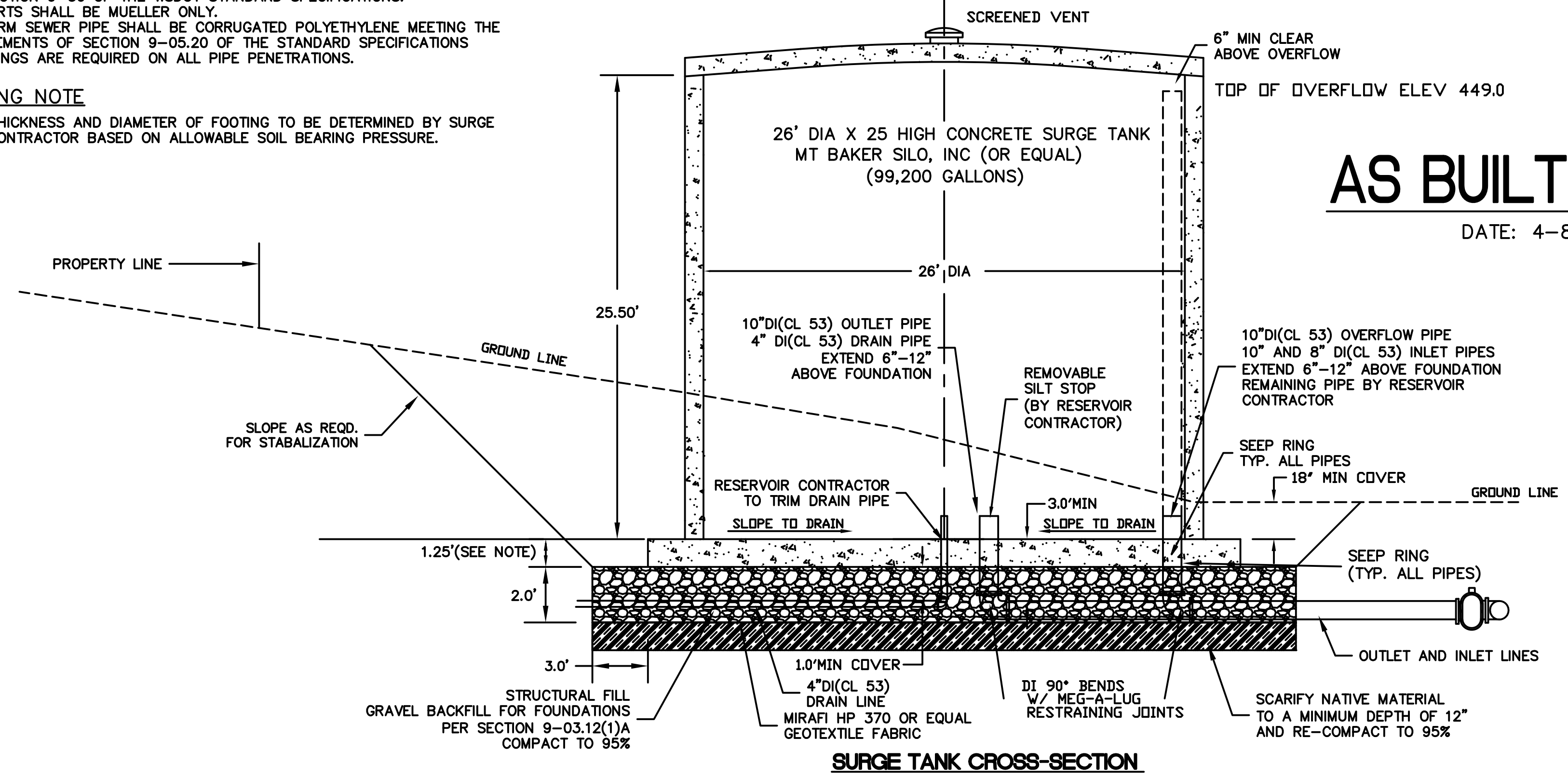
**SURGE TANK PLAN**
NOT TO SCALE

PIPING NOTE
PVC WATER PIPE SHALL BE AWWA C900, CL 150
DUCTILE IRON WATER PIPE SHALL BE AWWA C 151, CL 53
VALVES SHALL BE MUELLER RESILIENT SEATED GATE VALVES
FITTINGS SHALL BE DUCTILE IRON CONFORMING TO AWWA C110 OR C153
INSTALLATION SHALL BE IN ACCORDANCE WITH SECTIONS 7–08 THROUGH 7–15 AND SECTION 9–30 OF THE WSDOT STANDARD SPECIFICATIONS.
ALL PARTS SHALL BE MUELLER ONLY.
PE STORM SEWER PIPE SHALL BE CORRUGATED POLYETHYLENE MEETING THE REQUIREMENTS OF SECTION 9–05.20 OF THE STANDARD SPECIFICATIONS
SEEP RINGS ARE REQUIRED ON ALL PIPE PENETRATIONS.

FOOTING NOTE
FINAL THICKNESS AND DIAMETER OF FOOTING TO BE DETERMINED BY SURGE TANK CONTRACTOR BASED ON ALLOWABLE SOIL BEARING PRESSURE.

# AS BUILT PLANS

DATE: 4–8–10



**SURGE TANK CROSS-SECTION**
NOT TO SCALE

| No. | Date | Revisions |
|---|---|---|
| | | |
| | | |
| △2 | 4–23–09 | ADDENDUM 02 |
| 2 | 4–1–09 | Bid Set |
| 1 | 3–1–09 | Submitted for Review |

FRANK E. CHILDS JR. 18028

**Pioneer Surveying & Engineering, Inc.**
Civil Engineering and Land Planning
228 South Columbus Avenue, Suite 104
Goldendale, Washington 98620
Phone (509) 773–4945, Fax (509) 773–5888,
E-Mail pse@gorge.net

CADD FILE NAME: 09–014\C1.1

**City of White Salmon**
**Public Works Department**
PO BOX 2139
100 N. Main Ave.
White Salmon, Wa. 98620
509–493–1133

MICHAEL S. WELLMAN 16470

*WELL FIELD SURGE TANK DETAILS*

*CITY OF WHITE SALMON*
*2009 WATER SYSTEM*
*IMPROVEMENTS–PHASE 2*
*KLICKITAT COUNTY, WASHINGTON*

3 / 3

# APPENDIX C

# Response to Ecology Comments on Draft City of White Salmon Aquifer Storage and Recovery Feasibility Assessment

Aspect CONSULTING

# MEMORANDUM

Project No.: 090094-001-03

April 19, 2011

**To:** Tom Mackie – Washington State Department of Ecology

**cc:** Pat Munyan – City of White Salmon
Dan Haller – Washington State Department of Ecology

**From:** Tim Flynn, LHG

Joe Morrice, LHG

**Re:** **Response to Ecology Comments on Draft City of White Salmon Aquifer Storage and Recovery Feasibility Assessment**

---

The following presents our response to Washington State Department of Ecology's (Ecology) letter dated January 11, 2011 (attached), providing comments on the draft City of White Salmon Aquifer Storage and Recovery Feasibility Assessment dated September 9, 2010. The numbered responses below correspond to those in the Ecology letter. Replacement text, tables, and figures noted below have been incorporated into the final report.

1. The existing infrastructure will allow water from Buck Creek to be conveyed to the wellfield for injection at Well No. 2, while still providing supply to the City from Childs Reservoir. The system piping is such that water from Buck Creek could be conveyed simultaneously to the reservoir for storage/distribution and to the wellfield for injection at Well No. 2; however, additional pressure control valves as well as other infrastructure improvements may be required to control the proportion of flow conveyed to the reservoir and the wellfield. Evaluation, design, and installation of the necessary valves are recommended prior to performing the ASR pilot test.

2. Yes, the existing conveyance system (with modifications identified above) and existing Well No. 2 are planned for the ASR pilot testing and, if the project advances to implementation, are planned for use for full scale operation.

3. Agreed. A meeting with the City of White Salmon and Ecology to discuss first steps to developing a memorandum of agreement (MOA) between the City and Ecology was held March 24, 2011. In addition, the response to comments on the draft FS and the scope of the Phase II effort were also discussed.

4. The well casing terminates about 40 feet above the brecciated zone in fractured basalt. The fractures are described in the well log as being cemented with hard, greenish-white cement. As noted in the comment, potential leakage to shallower aquifers through the uncased borehole above the brecciated zone is not evaluated in the FS. Monitoring of Observation Well No. 2 and the Ottman well during initial testing of Well No. 2, and continued monitoring of the Ottman well after Well No. 2 was put into production (see response to comment number 11 below) do not indicated hydraulic continuity between the deeper ASR target zone and upper zones of the basalt. Based on these observations we do not believe leakage from the borehole above the brecciated zone is significant, but will plan to monitor water levels in the City's observation

wells and the Ottman well prior to and during the ASR pilot test to further evaluate potential leakage.

5. Although there are differences in the water quality between the upper and lower zones of the Grande Ronde (e.g., Well No. 1, completed in the upper Grande Ronde has higher TDS and higher proportion of calcium and magnesium than Well No. 2), we do not believe these differences are distinct enough that monitoring water quality from the upper Grande Ronde will prove useful for evaluating potential leakage. Evaluation of water quality data would be further complicated by the similar cation/anion signatures of Buck Creek water (planned for injection at Well No. 2) and water from Well No. 1 (see piper diagram, Figure 5.6 of the FS). Instead, we propose to rely on the hydraulic monitoring discussed in response to comment number 4 to evaluate leakage.

6. The units of Buck Creek flows and City water usage on Table 2 are consistent with each other; however the table headings may have been confusing. A replacement Table 2.2 is provided in the final report.

7. Agreed. Replacement Figures 4.1 and 4.2 are provided in the final report.

8. The White Salmon Irrigation District (WSID) water rights authorize year-round use of water (0.11 cfs) for domestic purposes, and seasonal use of water (4.39 cfs) for irrigation purposes. The period of use for irrigation is not specified, but based on the Washington Irrigation Guide should generally be from early May through early October. A new seasonal diversion from Buck Creek to serve the ASR project is proposed from November through April. This new diversion would be in addition to the domestic portion of the WSID water rights, but is not expected to compete with the larger irrigation portion.

9. We feel the pilot test and monitoring activities are closely linked, and that it is appropriate for the FS to outline the water quality and hydraulic monitoring in the pilot test program description. Please note that as part of Phase II a QAPP and SAP will be prepared, incorporating and expanding on the monitoring plans in Section 7. The QAPP will specify the type and quality of data required to evaluate pilot test effectiveness and the SAP will describe objectives, sampling procedures, testing and analysis methods, and reporting requirements for data collected during the pilot test. Monitoring activities proposed in the FS will be updated and incorporated into the QAPP and SAP.

10. Comment noted. Necessary permit applications, including a temporary water right permit to allow use of Buck Creek water for the pilot test, will be completed under the initial task of Phase 2.

11. The potential for springs to form where interflows of the CRBG outcrop at the White Salmon River are hypothetical; we are not aware that springs in this area have been observed or mapped. Review of water level monitoring data collected from the Ottman well, located about ½ mile northwest of Well No. 2, support the conclusion that ASR activities at Well No. 2 will not significantly affect groundwater elevations in shallower aquifers or, by extension, springs and seeps fed by the shallower aquifers.

The Ottman well is completed in the Grande Ronde Basalt with a screened interval between elevations of approximately 210 and 250 feet. This screened interval is about the same elevation as where springs, if present, would form at CRBG outcrops along the White Salmon River. With the exception of short-term drawdown apparently due to pumping of the Ottman well itself, water level elevations measured at this well on a weekly to monthly interval have remained within a very narrow range of about 290 to 292 feet, with no apparent long-term trends. Based on these observations, the more than 500 feet of basalt overlying the aquifer tapped by Well No. 2 effectively isolates this deeper aquifer from shallower aquifers, and ASR activities are not expected to affect shallower groundwater elevations or associated springs. Consequently we do not think it is necessary to monitor individual springs and instead propose to continue monitoring the Ottman well during the pilot test to evaluate potential impacts of ASR activities to shallower groundwater and springs.

In response to the second comment, yes, details of the hydraulic (and water quality) monitoring will be provided in the QAPP.

12. Comment noted. The amount of stored water that is recoverable for subsequent use will be evaluated further in the pilot test program, and would ultimately be quantified in either the ASR reservoir or secondary use permits.

13. The springs contributing to Buck Creek are located north of the Columbia River Fault, about 4 to 5 miles northwest of Well No. 2. As discussed in the FS, the ASR target aquifer likely outcrops to the south of the fault. In this case, the target aquifer would not be hydraulically connected to the spring system farther north and ASR activities would not affect the springs contributing to Buck Creek. Alternatively, if the ASR target aquifer does not outcrop but continues to the north, it would be truncated by the Columbia River Fault. The fault is expected to act as a hydraulic barrier, limiting the connection between groundwater north and south of the fault, such that ASR activities would not be expected to affect the springs. Regardless, monitoring of water levels in a monitoring well completed in the ASR target aquifer near Well No. 2 will allow for more accurate evaluation of potential groundwater mounding from ASR activities to evaluate whether impacts to springs are likely.

14. Comment noted. Replacement text for Section 6 is provided in the final report.

15. It is anticipated that the “net water savings” will be provided by a discharge to the White Salmon River. Replacement text for Section 6 includes a discussion of surface waters potentially affected by this discharge.

16. Comment noted. Requested additional details will be provided in the QAPP/SAP.

17. Comment noted. Replacement text for Section 8 is provided in the final report.

## Limitations

Work for this project was performed and this memorandum prepared in accordance with generally accepted professional practices for the nature and conditions of work completed in the same or similar localities, at the time the work was performed. It is intended for the exclusive use of the City of White Salmon for specific application to the referenced property. This memorandum does not represent a legal opinion. No other warranty, expressed or implied, is made.

## Attachments

Ecology comment letter, dated January 11, 2011

Document2

1889

STATE OF WASHINGTON
DEPARTMENT OF ECOLOGY
*15 W Yakima Ave, Ste 200 • Yakima, WA 98902-3452 • (509) 575-2490*

January 11, 2011

Timothy J. Flynn
Aspect Consulting, LLC
179 Madrone Lane N
Bainbridge Island, WA 98110

RE: Comments on draft City of White Salmon Aquifer Storage and Recovery Feasibility Assessment dated September 9, 2010. White Salmon, Washington.
Columbia River Program Grant # G0900235

Dear Tim:

The Washington State Department of Ecology (Ecology) Water Resources Program has completed its review of the draft City of White Salmon Aquifer Storage and Recovery Feasibility Assessment dated September 9, 2010 and submitted on September 15, 2011 on behalf of the City of White Salmon, Washington. Based on our review, Ecology offers the following comments:

1. It looks, from the report, that no capital investment is needed to proceed to pilot. Is this correct?

2. Will the ASR project rely on existing conveyance and existing well?

3. We would like to meet with the City to discuss more specifically how the State's 1/3 for in stream flow will work before the pilot phase of the project. For example, where, when do we get it and who pays if there are O&M costs, etc. (This will be the subject of an MOA between the City and the State.)

4. It should be noted that the well casing does not extend to the brecciated zone interpreted to be the upper boundary of the artesian aquifer. Leakage to shallower aquifers through this uncased portion of the well into Grand Ronde Basalt above the brecciated zone is not addressed in the Feasibility Assessment and should be one focus for later investigation and monitoring as the project moves forward.

5. The Feasibility Assessment includes a good water quality monitoring plan. Monitoring of the Grande Ronde above the brecciated zone should be included to detect leakage from the uncased portion of Well No 2 above the brecciated zone aquifer boundary.

6. Table 2.2 – Buck Creek Flows and City of White Salmon Water Use. Comment - the instantaneous rates (cfs) would be more comparable if they were reported for the same time period; as it is now the average flows for Buck Creek are monthly and the average use by the City is daily.

7. Page 4-4, 2nd Paragraph – "The cumulative authorized instantaneous diversion in cfs associated with the surface water rights in each section is posted on Figure 4.1. The cumulative authorized annual withdrawal in afy associated with the groundwater rights in each section is shown on Figure 4.2." Comment – cumulative quantities are reported in two different units; surface water authorizations are reported as an instantaneous rate and groundwater authorizations are reported as an annual volume; suggest the cumulative quantities be reported as both an instantaneous rate (cfs) and an annual volume (afy) for both surface water and groundwater authorizations. Figures should be changed accordingly.

8. Page 4-5, 1st and 2nd Paragraphs - "Based on this, it is assumed that the maximum use by the White Salmon Irrigation District from mid-October through April is limited to the 0.11 cfs for domestic use." "It is anticipated that the new water right for ASR would request a seasonal diversion from Buck Creek from November through April. Diversion over this period would not compete with the irrigation portion the White Salmon Irrigation District water rights." Comment – If the Irrigation District has water use through April, a diversion for the ASR project in April would be in competition.

9. Page 7-1, Section 7 – Project Monitoring Plan (Pilot Test Plan) Comment – most of Section 7 appears to discuss the operational details of the "Pilot Test Plan" rather than the "Monitoring Plan." It might be useful to break out the actual "Monitoring Plan" (Section 7.6) from Section 7 and create a new section specific to the "Monitoring Plan".

10. Page 7-3, Section 7.5 – Recharge, Storage, and Recovery Cycles - Comment – Any beneficial use of water during testing would require a Temporary Permit.

11. Page 7-4, Section 7.6 – Hydraulic Monitoring - Comment – Section 6.1.3 states that "Additional springs may also occur along the slopes of the White Salmon River where the water-bearing interflow zones of the Columbia River Basalt Group (CRBG) outcrop." If the locations of any of these springs are known they should be monitored before, during, and after testing as well in order to determine if there is any change that can be attributed to ASR operations. As an alternative another monitoring well west of the Hood River Fault and east of the White Salmon River could prove useful in determining the hydraulic nature of the fault at depth (i.e., isolation of spring source water from ASR reservoir). Comment – It is assumed that hydraulic monitoring details (frequency, length of time, methods, etc.) will be documented in the QAPP.

12. Page 8-1, Section 8 – Conceptual Project Operation Plan Several statements are made in this section with regard to pumping the full quantity of stored water from the ASR well.

    - "Subsequently pump the full quantity of stored water from the ASR well during the peak demand months (e.g., June through September)."

    - "Assuming all of the stored water is recovered over this period, the average pumping rate would be about 630 gpm to remove 340 acre-feet."

    - ➢ Comment – Since 100% recovery of the stored water is not likely possible, the volume extracted for secondary use is likely to be less than the volume pumped into aquifer storage.

13. Section 5. Much of the flow in Buck Creek, especially late season flow, is reported to be from springs located in Township 4 North, Range 10 East, Sections 8, 9, 16, 17, 19, and 20 [1]. Please discuss the significance of these springs with respect to the surface water flows in Buck Creek, their occurrence (geologic, structural, and hydrogeologic setting), and relationship to the target aquifer. As with Comment No. 11, if the locations of these springs are known, they may need to be monitored before, during, and after testing as well in order to determine if there is any change that can be attributed to ASR operations.

14. Section 6.1.3. Please include a discussion of the springs listed in Comment No. 13 in this section.

15. Section 6.2.2. If the "net water savings" per Ecology grant # 0900235, Special Terms and Conditions, Paragraph C includes a discharge to surface water, that discharge should be discussed here.

16. Section 7. In addition to those things that are listed, please also include the following in the SAP: sampling schedule, description of QA/QC samples, procedures for analysis of samples (detection or quantification limits, analytical methods, and lab QA/QC).

17. Section 8. Please include how "net water savings" per Ecology Grant # 0900235, Special Terms and Conditions, Paragraph C, will be satisfied operationally.

Ecology would like to thank Aspect Consulting for the considerable effort that has gone into this draft feasibility assessment. Final approval will be issued after the resolution of the comments listed above.

---

[1] Futrell, Redford, and Saxton, 1973, "Town of White Salmon Washington - A Report on an Engineering Study and Preliminary Design of Water System Facilities" Engineering Report submitted to the Town of White Salmon.

Please call me at (509) 249-6298 and we will set up a meeting or telephone call to work through the comments.

Sincerely,

Thomas L. Mackie

Thomas L. Mackie, LHG
Technical Unit Supervisor
Water Resources Program

TLM:gh
110128

Ecopy: Dan Haller, OCR