Department of Ecology
Publication No. 15-03-015

Groundwater Level Gauging Project
Lower Lake Roosevelt Watershed (WRIA 53), Northern Lincoln County, Washington

Prepared for:
WRIA 53 Planning Unit

JUNE 20th, 2011

Under Ecology Watershed Planning
Grant No. G-0800258

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WNR GROUP

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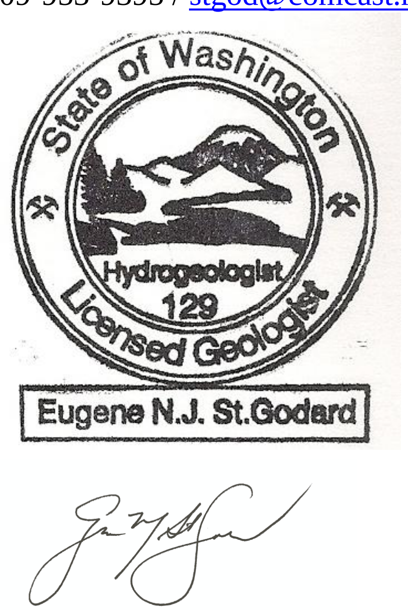

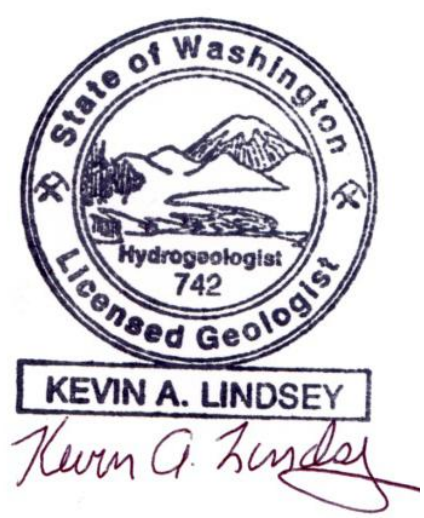

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1.0 INTRODUCTION

The WRIA 53 – Lower Lake Roosevelt Watershed initiated a groundwater level measuring and surface water gauging program during its Phase 2 Level 2 watershed planning process. This program was initiated in order to better understand the groundwater elevations and fluctuations in the three major aquifers within the WRIA 53 watershed (Figure 1), primarily located in northern Lincoln County as shown in Figure 2. Surface water gauging was focused in Hawk Creek, the largest stream in the WRIA (Figure 3). The watershed encompasses approximately 326,164 acres, or approximately 509.63 square miles. The Columbia River bisects the watershed with 118,730 acres (185.52 square-miles) located north of the Columbia River, primarily within the boundaries of the Colville Indian Reservation, and 207,432 acres (324.11 square miles) located south of the Columbia River, that area which is the primary focus of this assessment. In general, the watershed encompasses that portion of the Columbia River and it is tributaries between the confluence of the Spokane River to the east and the location of Grand Coulee Dam to the west.

The Groundwater Level Gauging Program was initiated in July 2009. The project consisted of:

1) Developing an informational flyer that was sent out to all property owners in the watershed to request participation of landowners in the groundwater gauging program;
2) Preparing a Quality Assurance Project Plan for the groundwater gauging program;
3) Conducting additional personal outreach to landowners to solicit their participation in the project;
4) Researching well logs and well construction attributes to determine if a well which was volunteered for gauging would be suitable for the project;
5) Performing an on-site inspection of each well to determine if access to the wells would not be restricted;
6) Preparing and signing an access agreement with each of the participating landowners;
7) Gauging the wells on a six to eight week frequency; and
8) Preparing periodic updates to the WRIA 53 Planning Unit.

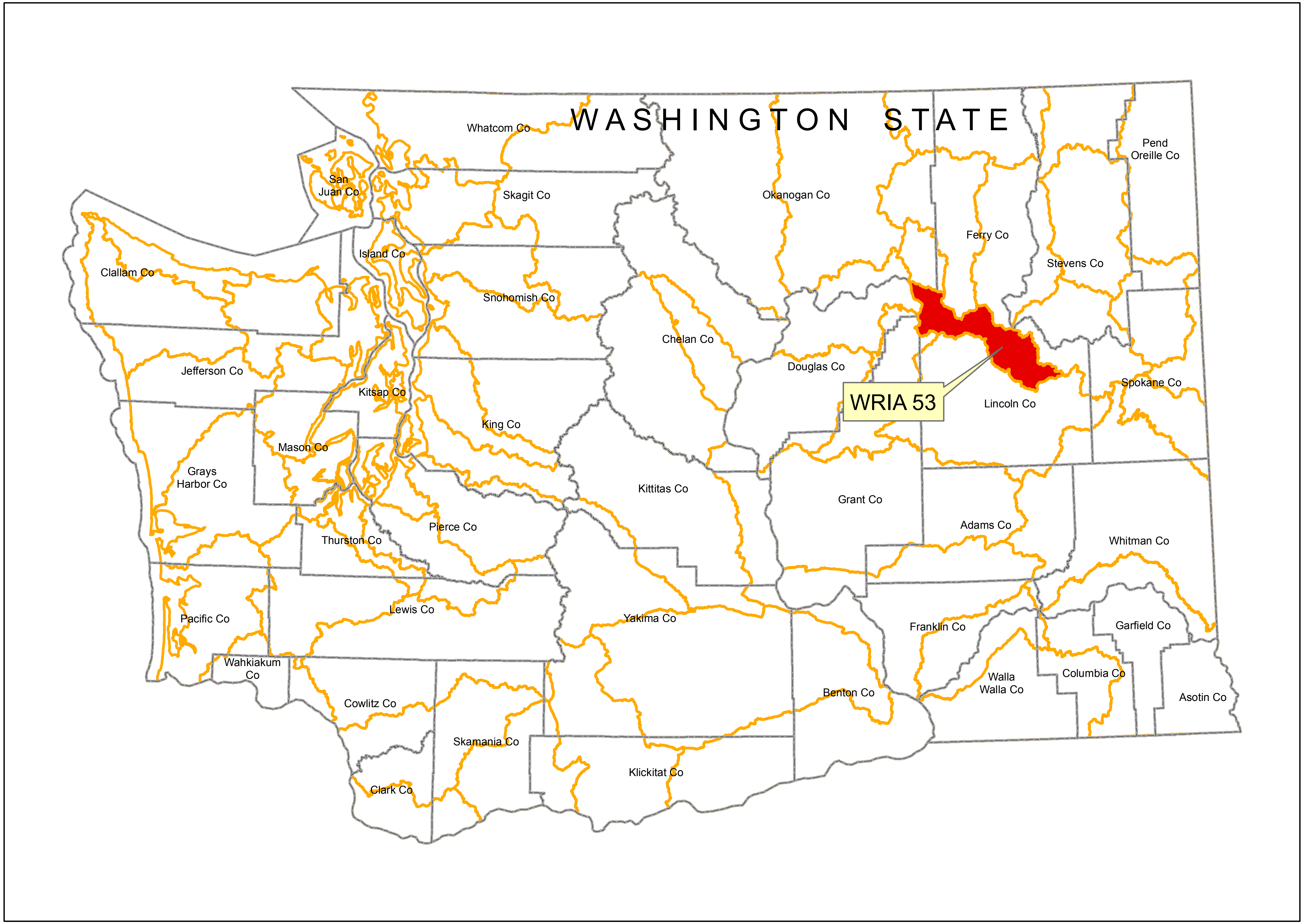
Tasks 1 through 6 were completed from July through December 2009. Gauging of some wells began in late December 2009 and early January 2010. It should be noted that throughout the project, additional outreach to potential landowners was ongoing, and additional wells were added as the project progressed. Some wells were also dropped from the gauging program due to access problems. Gauging of wells continued throughout the project and data through April 2011 are presented in this report. Additional data may be collected in May and June 2011, and will be recorded in the project data bases.

Surface water gauging was initiated in October 2009 by Ecology until June 2010. The LCCD conducted gauging at the three stations on Hawk Creek from August 2010 through June 2011.

Figure 1

Location of WRIA 53

Lower Lake Roosevelt Watershed



Legend

- County Boundary
- WRIA Boundary

0 12.5 25 50 75 100 125 150 175

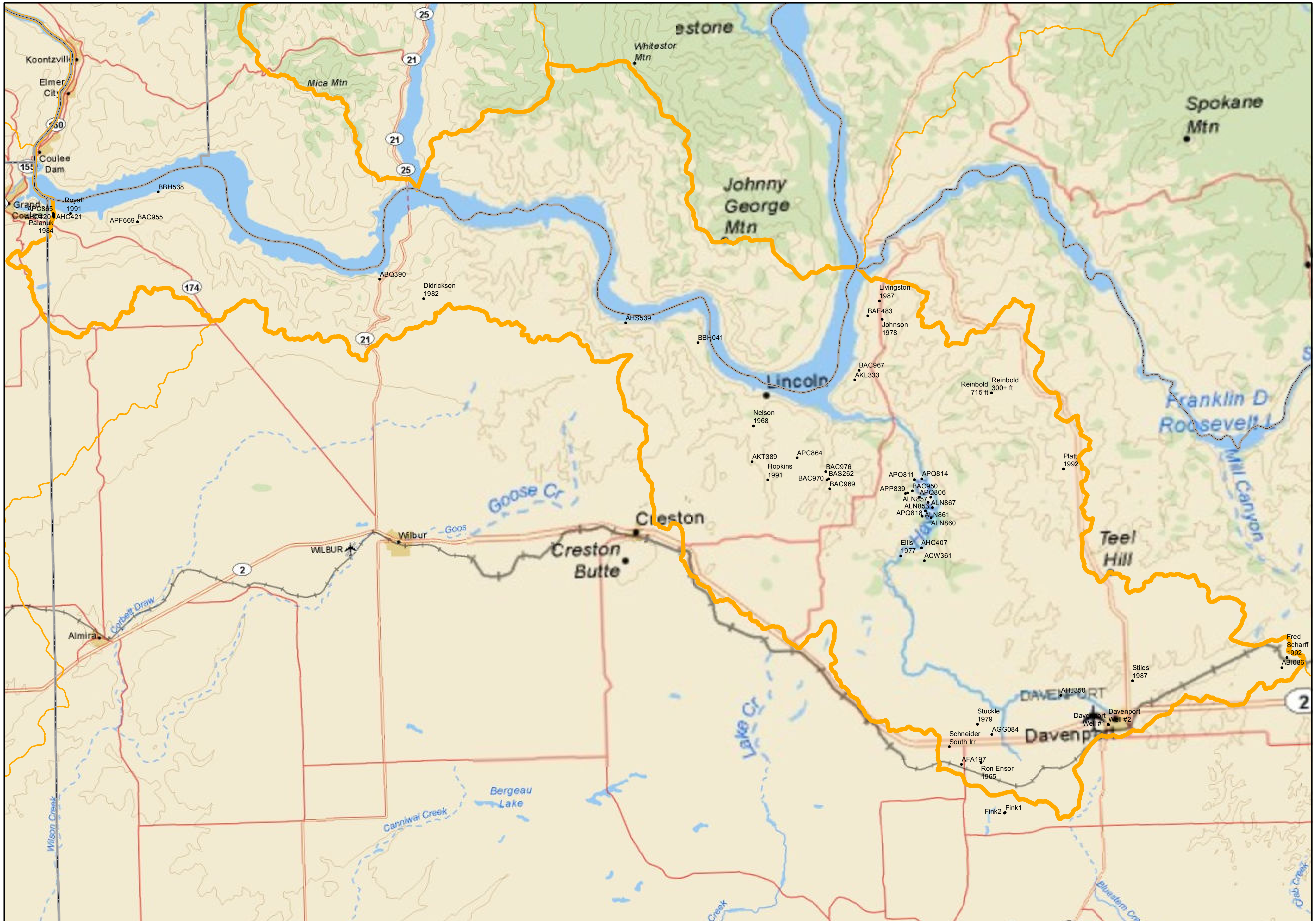
Miles

Land Services
Planning - Building - GIS
Lincoln County Washington, USA

This is not a survey. Actual relationships and distances between features may be different from those depicted on this map. Accurate measurements are required in order to verify these relationships and distances.

Figure 2

Groundwater Monitoring Wells WRIA 53



Legend

- GW Monitoring Wells
- County Boundary

WRIA Boundary

- WRIA 53
- Other WRIA Bnd

0 2.5 5 10 15 20

Miles

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This is not a survey. Actual relationships and distances between features may be different from those depicted on this map. Accurate measurements are required in order to verify these relationships and distances.

Figure 3

Stream Flow Monitoring
Sites - WRIA 53

Legend

- Stream Flow Sites
- County Boundary

WRIA Boundary

- WRIA 53
- Other WRIA Bnd

N W E S

0 2.5 5 10 15 20

Miles

This is not a survey. Actual relationships and distances between features may be different from those depicted on this map. Accurate measurements are required in order to verify these relationships and distances.

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1.1 GOALS AND OBJECTIVES

The Groundwater Level Gauging and Surface Water Gauging Project are funded by a watershed grant from the Washington State Department of Ecology (Ecology) under grant number G0800258. The overall general objective of the Gauging Project is to develop a database of Hawk Creek surface water flows and groundwater levels in the three distinctive aquifers in WRIA 53 which can be used on a long-term basis for scientifically-based water resource management and planning activities. Specific objectives include refining hydrogeologic conceptual models, identifying local groundwater flow systems, and quantitatively evaluating regional-scale and local-scale groundwater occurrence, movement, recharge, and discharge. Data can subsequently be used for future land use management decisions based on availability of groundwater resources.

The Goals for the project was to gauge 50 to 75 wells throughout the watershed for a minimum of one year. Distribution of wells throughout the three distinct aquifers was attempted, with the majority of wells within the basalt aquifer, which is the most regional aquifer and the primary water source for most water users in the watershed. Surface monitoring goals for Hawk Creek were to determine the seasonal variation of flows and potential impacts from out of stream uses.

1.2 PROCEDURES AND RESPONSIBILITIES

The WNR Group, supported by its primary subcontractor GSI, is acting as the lead investigators for the Groundwater Level Gauging Project under the direction of the WRIA 53 Planning Unit and contracted through Lincoln County. The Lincoln County Conservation District (LCCD) conducted the field activities under their MOU with Lincoln County and the supervision of Gene St.Godard, L.Hg., and Dr. Kevin Lindsey, L.Hg. Gene St.Godard is acting as the project manager and principal investigator for the consultant team. Mr. St.Godard is responsible for seeing that quality assurance goals on the Project are met and as project manager reports to Mr. Jim DeGraffenreid, Director of Lincoln County Planning and subsequently to the WRIA 53 Planning Unit. Mr. Jim DeGraffenreid of Lincoln County Planning has overall fiscal oversight and contract management responsibility under the WRIA 53 grant contract with Ecology. For LCCD, the district manager, Mr. David Lundgren coordinates the field technicians for the field gauging program. LCCD staff under the direction of Mr. David Lundgren are conducting data collection activities described in the QAPP prepared for this project.

Key overall project responsibilities of each of the project participants are defined below:

1. <u>WRIA 53 Management: Mr. Jim DeGraffenreid, Director of Lincoln County Planning, Lincoln County Board of County Commissioners</u>
    a. Responsible for oversight of all WRIA 53 projects.
    b. Responsible for the decision and policy making process which guides project activities and day-to-day operations of the WRIA 53 Groundwater Level Gauging and Surface Water Gauging Project.
    c. Responsible for overall project budget tracking and periodic reporting to Ecology.
    d. Responsible for data storage and project documentation.

2. WNR Group & GSI
    a. Lead investigator in charge of project organization
    b. Prepare sampling plans, including the QAPP.
    c. Assist in development of spreadsheet databases in which data collected for the project are stored, perform data entry.
    d. Plan and conduct oversight activities of the hydrogeologic data collection.
    e. Conduct evaluation, and data validation activities as determined by the project scientific team.
    f. Oversee the progress of data collection, evaluation, and database compilation; provide project oversight; and check data validity.
    g. Prepare Technical Memorandum's and presentations updating the Planning Unit on the data collected, and prepare this report.
3. LCCD
    a. Conduct field data collection for surface and groundwater.
    b. Notify WRIA 53 Management regarding unplanned activities or unforeseen circumstances affecting project data collection.
    c. LCCD field staff were trained by WNR Group and GSI and will work under sampling plans prepared by the project hydrogeologists (St.Godard and Lindsey).

In addition to these formal roles and responsibilities, the WRIA 53 project team is in regular communication with Ecology staff to share data and insights into the hydrogeology of WRIA 53 and surrounding area. While Ecology staff members are not a formal part of the WRIA 53 water gauging team, we anticipate continued discussions with them, to include but not be limited to, data sharing and peer review.

1.2.1 Surface Water Gauging Procedures

Three sites were selected to conduct stream gauging activities (Figure 3). Stream gauging by Ecology occurred from October 2009 through March 2010 using a FlowTracker Handheld ADV (Acoustic Doppler Velocimeter) flow meter produced by SonTek/YSI Inc. Data is analyzed using Firmware Version 3.7 and the Smart QC Software Version 2.30. Beginning in June 2010, the LCCD collected stream measurements using a Marsh-McBirney Model 2000 electro/hydrodynamic sensor and display unit along with the accompanying wading rod to take Hawk Creek flow measurements.

1.2.2 Groundwater Gauging Procedures

Well levels were measured approximately once a month starting with the first wells in December 2009 and continuing through April 2011. During May, November and December 2010, measurements were not collected for all the wells. During January 2011, no measurements were taken due to winter snow, cold and bad road conditions.

Where feasible, both the sonic meter and the Etape where used to take measurements in as many wells as possible. The sonic meter was used first in order to take remote sensing well level depth measurements that would identify the water depth to within about 0.1 to 1.5 feet of the following measurement that would be taken directly by the Etape. Knowing the approximate depth to expect water made it faster and more efficient to take measurements with the Etape.

Some well casings are so full of pipe, power cable wires, and pressure tanks in the upper part that it was impossible to try to pass the Etape past these obstructions, and so only the sonic meter was used in these wells. Some wells have 4" PVC liners with not much space between the liner wall and pipe and cable, and with depth to water 50 feet or greater. In these wells, there is a significant risk of getting the Etape hung up in the well, and so only the sonic meter was used in these wells.

For those wells in which valid measurements could not be obtained by both the sonic meter and the Etape, these wells were dropped from the study and no further attempts were made to measure them, except for two wells in which a borrowed Bureau of Reclamation style Etape with a flexible tip composed of brass washers was used to obtain well levels in March and April 2011.

An older model sonic meter, Ravensgate Model 200 Sonic Water Level Meter with measurements down to 0.1 foot, was borrowed and used from February through June 2010. A new sonic meter, Ravensgate Model 200U / Global Water Model WL650 Sonic Water Level Meter with measurements down to 0.1 foot, was subsequently purchased and used from July 2010 up through April 2011. A round disk of cardboard that was covered in duct tape to increase the durability and sonic reflectivity of the disk was used to seal off the top of the well casing in order to take measurements with the sonic meter. With the new sonic meter, extensive use of the ignore top X feet option in normal mode (for water depths less than 200 feet) and in deep mode (in general for water depths between 200 and 750 feet) was made in order to get past any well features above the water level and obtain the most accurate measurement of well water depth as possible with the meter.

A Solinst Water Level Meter Model 101 Etape with P6 probe and M2 tape with markings every 0.01 foot was used to take direct Etape measurements of well water depth from the top of the well casing. A felt pen was used to mark the location where the Etape was lowered down the casing, for measurement consistency, and also to mark a safe location where the Etape could be reliably lowered and retrieved back out of the well. A large 3-D cell Maglite flashlight with a very bright white and focused beam was used to shine down the casing to avoid any potential obstructions and to confirm that the Etape was inside the white PVC liner for those wells with a PVC liner.

A handheld Garmin Etrex Vista HCx GPS unit was used to obtain coordinates for each well out in the field. The averaging mode was used, and the GPS unit was allowed to run at least 3 minutes at each well site in order to obtain accurate horizontal coordinates that in most cases had an EPE (expected position error) of 5 feet or less. The 1:24,000 Garmin topo map for Washington and Oregon was installed in the GPS unit. The elevation from the internal Garmin topo map was used for the elevation of the ground surface at the well location site, and in many cases, was 10 to 30 feet more accurate than the GPS measurement of elevation taken from the top of the well casing. The Garmin topo map elevations are also in the desired NAVD 88 vertical datum, which was required by Ecology under the grant agreement.

1.3 SCHEDULE

The project schedule for the Groundwater Level Gauging Project began in July 2009 with the public outreach portion to locate potential landowners for gauging of their groundwater wells. This activity continued through December 2010. Field data collection began in December 2009 and is scheduled through June of 2011. The actual project schedule will be dictated by data collection needs associated with watershed planning efforts, actual conditions encountered in the field, and new information and insights into the WRIA 53 groundwater conditions as the work proceeds. Data for this report, as presented in the text, tables and graphs is through the April 2011 monitoring event.

2.0 SURFACE WATER GAUGING

During the Phase 2 watershed planning effort, Ecology and the LCCD have conducted stream flow monitoring in Hawk Creek on behalf of the Planning Unit. The planning unit identified six potential stream monitoring locations on Hawk Creek during the initial Phase 2 planning effort. Due to land access and stream morphology, Ecology was able to collect flow measurements at three of these locations (HC-1, HC-3, and HC-5). Locations of the monitoring stations are shown on Figure 3.

2.1 PRECIPITATION AND TEMPERATURE

The purpose of the climate analysis is to compile information on seasonal changes in precipitation and temperature and to evaluate the distribution of precipitation and temperature across the watershed. Variations in precipitation and climate are a dominating influence on groundwater recharge and streamflows and largely determine the availability of groundwater and surface water resources (Smith, 1993). Temperature and precipitation are significantly impacted by elevation in the WRIA 53 watershed with temperature generally decreasing with increasing elevations and precipitation increasing with increasing elevation.

The climate in WRIA 53 is typical of northeast Washington, combining characteristics typical of mountain climates with those more typical of a semi-arid climate. Precipitation amounts and patterns as well as temperature regimes are strongly influenced by air masses and storms from the Pacific Ocean that migrate from the west coast. The north-south trending mountain ranges and deep valleys are the dominant influence on local climate. Prevailing weather is from the west, bringing air masses from the Pacific with high moisture content and moderate temperatures. Since the mountain ranges are more or less perpendicular to the prevailing weather, the air masses are forced to rise and cool, dumping their moisture as rain or snow on the mountains and rendering the adjacent valleys relatively drier (Daley et al. 1994). Summers are generally warm or hot in most valleys and much cooler in the mountains. Summers are also relatively dry, as the majority of the moister air from the Pacific Ocean does not cross the Cascades. Arctic air from the north and continental influences from the east cause winters to be cold and relatively long.
Climatic data were reviewed from the Western Regional Climate Center (WRCC) database (WRCC, 2011) and data reviewed at http://www.wrcc.dri.edu/. The WRCC compiles and

maintains climatic data from the National Oceanographic and Atmospheric Administration (NOAA), the Natural Resource Conservation Service Snowpack Telemetry System (SNOTEL), and regional cooperators that operate individual recording stations (WRCC, 2011). Climatic data was collected for the Davenport, Washington recording station within the WRIA 53 watershed. This climate station is designated by the WRCC as Davenport Station No. 452007.

Table 1 presents a summary of the monthly precipitation and temperature data from October 2009 through April 2011. Figure 4 presents a graphical presentation of this data.

TABLE 1: Temperature & Precipitation Data at Davenport Station No. 452007

Month-Year	Precip (in)	Avg. Temp (F)
Oct-09	1.79	41.05
Nov-09	1.34	35.32
Dec-09	1.03	22.37
Jan-10	4.18	33.13
Feb-10	1.51	36.29
Mar-10	1.23	39.92
Apr-10	1.17	45.20
May-10	1.81	49.66
Jun-10	2.37	56.52
Jul-10	0.15	65.03
Aug-10	0.04	63.89
Sep-10	0.8	55.45
Oct-10	2.48	47.27
Nov-10	2.31	30.10
Dec-10	2.32	26.02
Jan-11	1.39	24.69
Feb-11	0.29	26.00
Mar-11	0.36	32.39

The average monthly and annual air temperatures were obtained from PRISM (Daly and Taylor, 1998). The temperature was imported into a GIS layer to generate an area-weighted average annual air temperature for the WRIA 53 watershed, and is presented in Figure 5. Average annual air temperature for the WRIA 53 ranges from approximately 41 degrees Fahrenheit located in the northeastern highlands of the Coulee Dam North Subbasin to 51 degrees Fahrenheit along the main stem of the Columbia River.

An isohyetal precipitation distribution map was developed for the entire WRIA 53 watershed based on PRISM (Daly and Taylor), a statistical topographic model developed by Daly and others (1994) for mapping precipitation in mountainous terrain. The isohyetal precipitation distribution was imported into a GIS layer, and is presented in Figure 6 as the average for the years 1910 through 2009. As shown on Figure 6, the average annual precipitation ranges from approximately 9-inches along the Columbia River to approximately 21–inches in the highlands in the northern part of the watershed on the

Colville Indian Reservation. In the southern half of the watershed, precipitation is typically lowest along the Columbia River and increases as you move south in the watershed to an average annual precipitation of approximately 15-inches per year near Davenport, Washington.

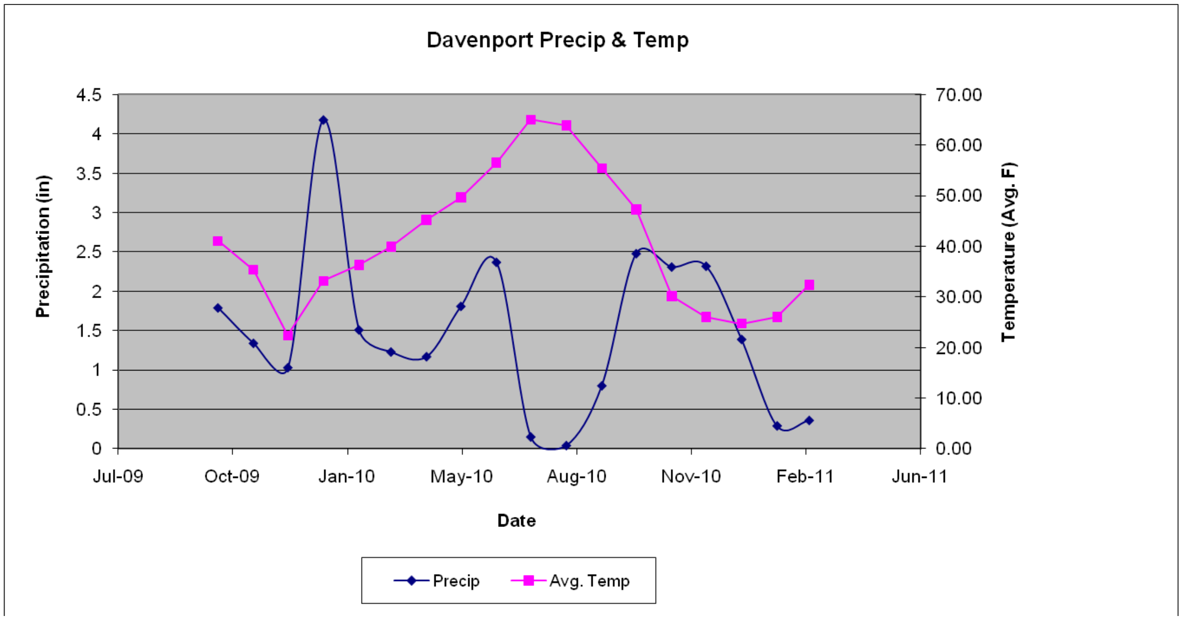

FIGURE 4: GRAPHICAL PRESESNTATION OF TEMPERATURE AND PRECIPITATION DATA AT DAVENPORT STATION No. 452007. FROM WRCC CLIMATE DATA SITE: http://www.wrcc.dri.edu/

2.2 LAKE ROOSEVELT LAKE LEVEL

Data was also compiled on Lake Roosevelt lake levels for the duration of the project. This data was collected in order to compare lake levels to groundwater levels to determine which wells were in hydraulic continuity with the lake. Table 2 presents a summary of lake levels, as presented during the days in which groundwater data was collected. Figure 7 presents a graphical presentation of the Lake Roosevelt levels. Data is collected from http://www.cbr.washington.edu/dart/river.html.

2.3 RESULTS OF SURFACE WATER GAUGING

Ecology monitored the three stream stations on Hawk Creek from October 2009 through June 2010. The LCCD then began monitoring at the three stations in August 2010 through June 2011. Locations of stream monitoring locations are shown in Figure 3. Table 3 presents a summary of the flow monitoring results collected through April 2011. Data summery sheets are presented in Attachment B.

The locations of the monitoring stations were modified slightly by the LCCD slightly to accommodate access and equipment utilized by the LCCD. However, the new locations by the LCCD are within a few hundred feet of the Ecology monitoring locations, and are within the same stream reach and not influenced by any tributary contributions. Therefore, the data sets are presented as the same representation of flows for the respective reaches.

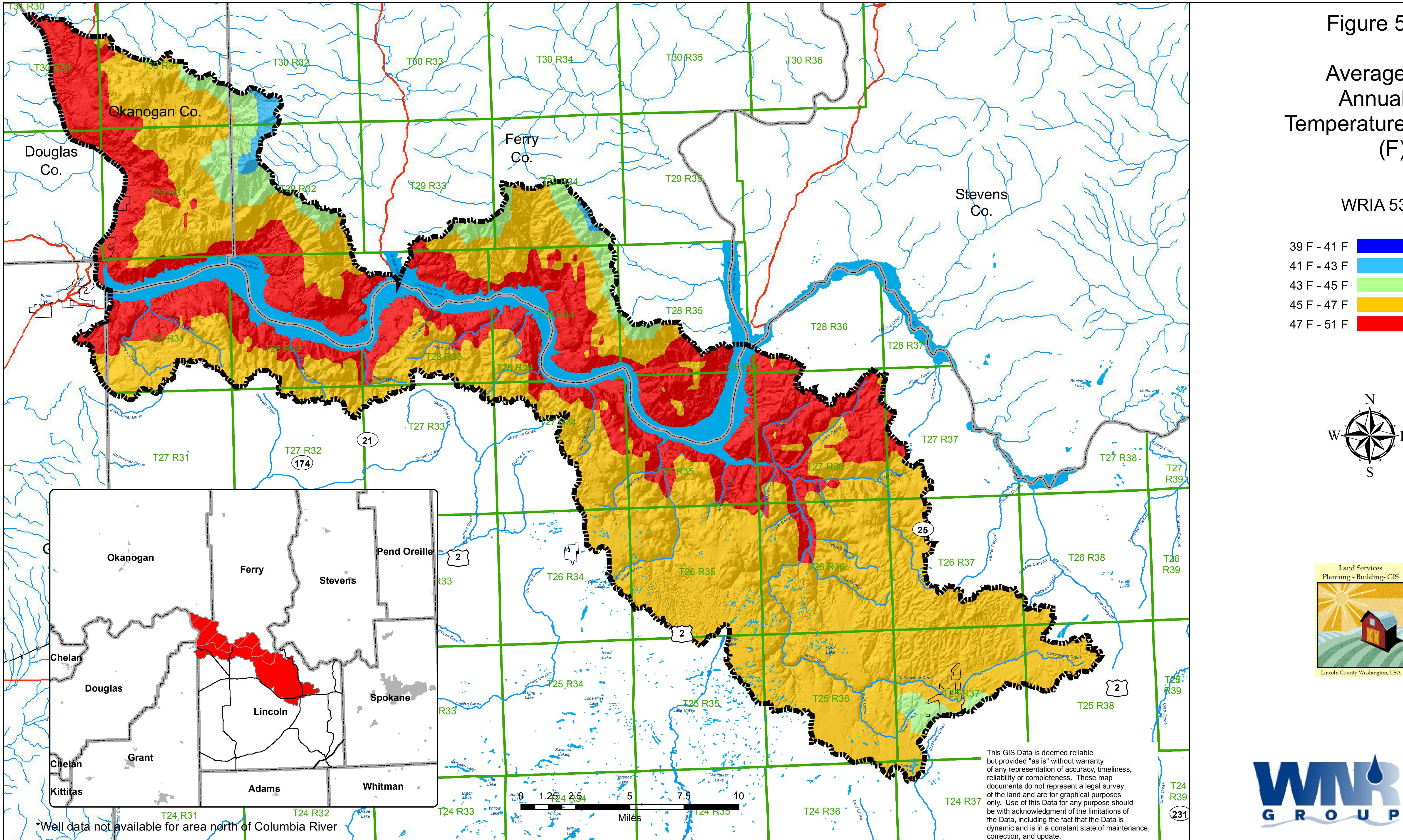

Figure 5

Average Annual Temperature (F)

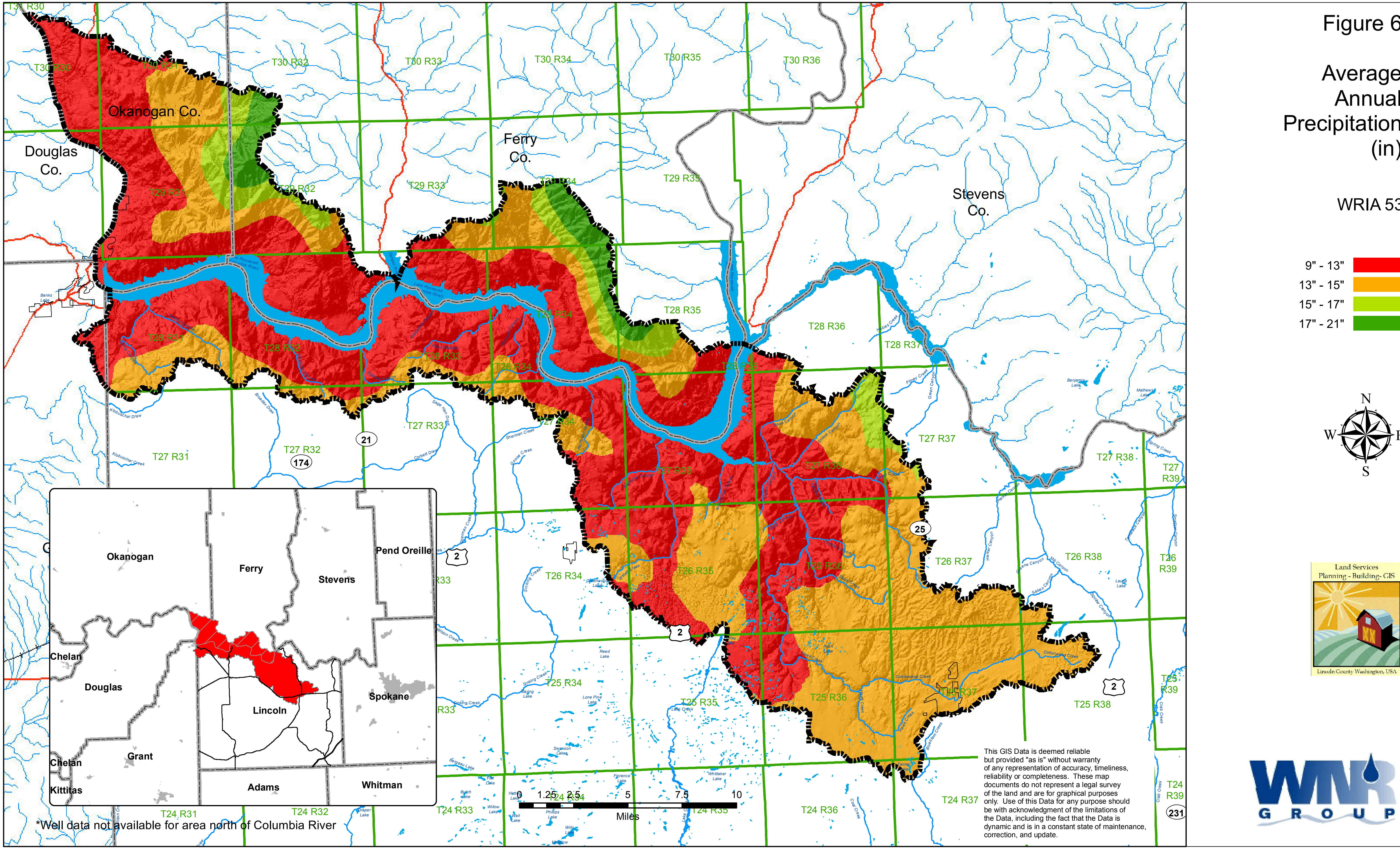

Figure 6

Average Annual Precipitation (in)

TABLE 2: LAKE ROOSEVELT LEVELS

Date	Lk Roos (ft amsl)
12/29/2009	1284.08
1/8/2010	1285.00
1/19/2010	1287.24
2/4/2010	1285.05
2/12/2010	1283.83
2/19/2010	1281.74
3/8/2010	1278.58
3/16/2010	1276.18
4/20/2010	1276.19
4/22/2010	1276.74
4/27/2010	1277.08
6/3/2010	1271.81
6/4/2010	1274.45
6/8/2010	1283.53
7/26/2010	1288.16
8/18/2010	1282.21
9/22/2010	1283.14
10/22/2010	1288.39
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3/22/2011	1253.67
4/19/2011	1230.61

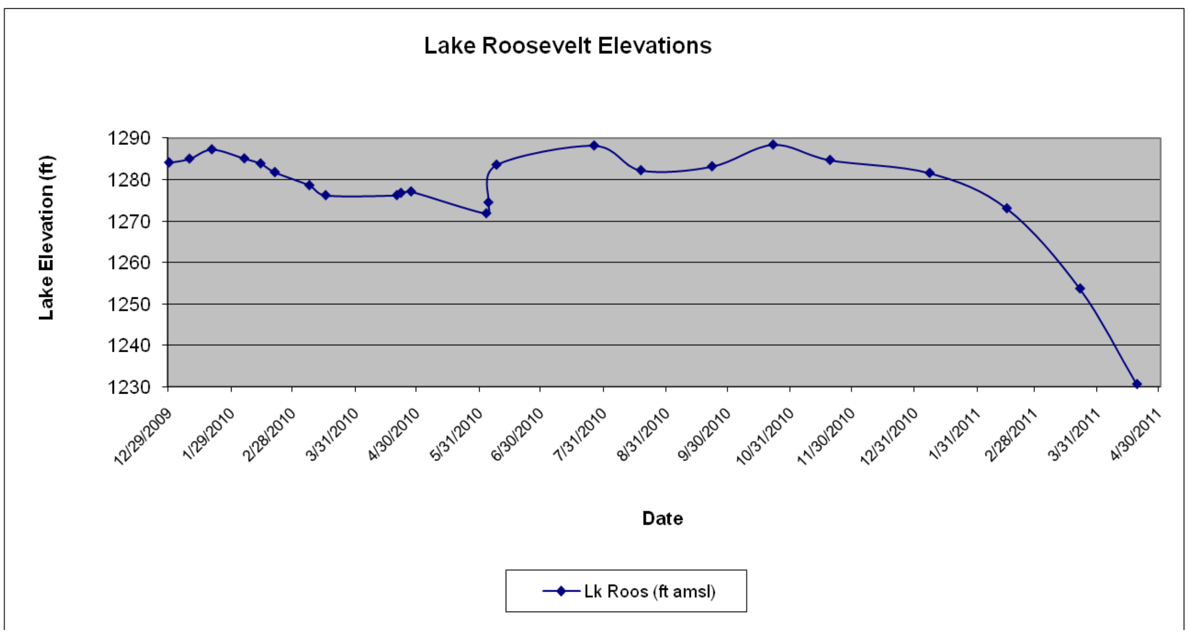

FIGURE 7: HYDROGRAPH OF LAKE ROOSEVELT LAKE LEVELS

TABLE 3: HAWK CREEK FLOW DATA (cfs)

Date	HC-1	HC-3	HC-5
4/20/2011	7.53	21.46	36.78
3/17/2011	14.35	26.23	48.51
2/23/2011	7.91	11.92	23.71
1/24/2011	5.51	7.71	21.54
12/27/2010	2.06	3.80	11.23
11/15/2010	1.10	2.67	8.40
10/19/2010	1.23	2.54	8.75
9/20/2010	0.15	2.28	7.58
8/13/2010	0.62	3.20	7.31
6/2/2010	3.32	7.55	16.29
3/30/2010	5.22	10.52	19.10
1/11/2010	3.26	7.60	13.19
10/14/2009	1.91	5.25	10.37

As shown in Table 3 and in Figure 8, Hawk Creek appears to be a gaining stream from near the headwaters (station HC-1) to station HC-5 which is at the bridge on Miles Creston Road. During all monitoring dates, the stream appears to proportionally gain from each station to the next. Flows in the late winter and early spring of 2011 are almost three times the flows recorded in 2010. This is interpreted to be a result of the numerous rain on snow and wet spring observed during early 2011.

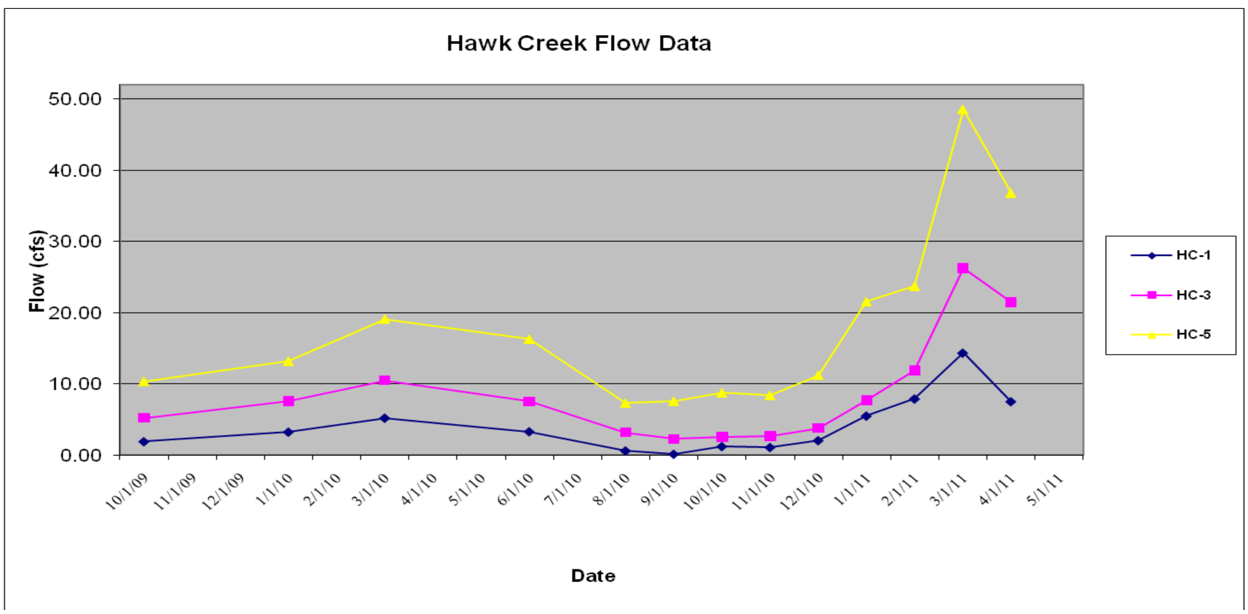

FIGURE 8: GRAPHICAL PRESESNTATION OF HAWK CREEK FLOW DATA

3.0 LOCATION OF AQUIFERS IN LOWER LAKE ROOSEVELT WATERSHED

The surficial geology of WRIA 53 is summarized in Stoffel et al. (1991), Waggoner (1990), Hansen et al. (1994), Whiteman (1994) and St.Godard (2009). The WRIA 53 watershed lies within the northern extent of the Columbia Basin. This section presents a brief review of the geologic framework of the aquifers found within the WRIA 53 area. Potable groundwater in WRIA 53 is found predominantly in: 1) Pleistocene Cataclysmic Flood deposits and younger alluvial sediments (unconsolidated alluvial valley fill aquifers), 2) Miocene continental flood basalt and intercalated sedimentary units of the Columbia River Basalt Group (CRBG), and 3) pre-basalt basement rocks (predominantly crystalline intrusive granitic rocks and metamorphic rocks).

Generally from youngest to oldest, the main geologic units found within WRIA 53 include the following:

- Holocene loess, alluvial and colluvial deposits less than 10,000 years old.
- Pleistocene Missoula Flood deposits ranging in age from approximately 12,000 years to more than 800,000 years.
- Pleistocene loess (the Palouse Formation) ranging in age from approximately 12,000 years to possibly over 1,000,000 years.
- Columbia River Basalt Group, which in WRIA 53 includes units ranging in age from approximately 14.5 million years to 16.5 million years.
- Pre-basalt basement rocks that probably include intrusive rocks over 40 million years old, and may include metasedimentary rocks greater than 600 million years old.

The CRBG is the most widespread and common of the rock types hosting potable groundwater currently being used in WRIA 53. Basalt flows of the CRBG underlie most of the WRIA except the northern and eastern edges where pre-basalt basement rocks crop out at the earth's surface. The following sections summarize the basic geologic setting of these rocks, and the folding and faulting that influences their distribution. Much of this discussion is based on regional characterization efforts on-going within the Columbia Basin Ground Water Management Area (GWMA) (GWMA, 2004, 2007a, 2007b, 2009a, 2009b, 2009c, 2009d).

3.1 UNCONSOLIDATED ALLUVIAL AQUIFERS

Within WRIA 53 the suprabasalt sediment, or alluvial, aquifer system comprises all saturated sediments that overlie the CRBG and pre-basalt basement. The base of the alluvial aquifer system is defined as the top of these underlying rocks, and it is hosted predominantly by Pleistocene Cataclysmic Flood deposits. The alluvial aquifer system is unconfined, although local semi-confined conditions may be encountered. The alluvial aquifer system water table can lie as shallow as 1 ft (0.3 m) near surface water bodies, including Lake Roosevelt to over 100 feet (30 m) on the high alluvial benches found along the shores of Lake Roosevelt. Where the CRBG and pre-basalt basement is exposed at the

Earth's surface and present above the unconfined water table, the alluvial aquifer system is absent.

The presence of bedrock highs acts to localize occurrences of the alluvial aquifer system. Consequently, the alluvial aquifer system generally consists of a number of small, isolated sub-systems that have no direct connection with each other. Existing geologic mapping for the WRIA (Waggoner, 1990) allows one to generally predict where these sub-systems may occur. However, a detailed evaluation of surface geology and well pumping records would be required to delineate the location, extent, and water resources associated with these local alluvial aquifer sub-systems.

Generally, the Pleistocene Cataclysmic Flood deposits that host the most productive portions of the alluvial aquifer system consist of high permeability and high effective porosity sand facies and gravel facies. These strata typically are unconfined, and measured hydraulic conductivity for this unit ranges between 2,000 to 25,000 feet/day, with effective porosity greater than 10 percent (U.S. DOE, 1988). In many cases, water wells in these strata may sustain pumping rates in excess of 2000 gpm, especially where there is a significant degree of hydraulic continuity with surface water or the physical extent of the system great enough to store enough water. However, in areas where high permeability suprabasalt aquifer materials do not have a significant connection with surface water, or the surface water body is small, or the local sediment accumulations are small, it can be relatively easy to dewater the alluvial aquifer system.

3.2 CRBG AQUIFERS

Numerous studies of CRBG aquifers have been conducted within the Columbia Basin to better understand their hydraulic characteristics and to develop a model of how various factors (e.g., physical characteristic/properties of CRBG flow, tectonic features/properties, erosional features, climate, etc.) interact to create and govern the CRBG groundwater system (e.g., Hogenson, 1964; Newcomb, 1961, 1969; Brown, 1978, 1979; Gephart et al., 1979; Oberlander and Miller, 1981; Livesay, 1986; Drost and Whiteman, 1986; Davies-Smith et al., 1988; USDOE, 1988; Burt, 1989; Johnson et al., 1993; Hansen et al., 1994; Spane and Webber, 1995; Wozniak, 1995; Steinkampf and Hearn, 1996; Packard et al., 1996; Sabol and Downey, 1997). One of the most significant findings of these studies is the similarity of the hydrogeologic characteristics, properties, and behavior of the CRBG aquifers across the region. This similarity allows for the application of the knowledge of the general hydraulic characteristics and behavior of the CRBG aquifers to be applied to CRBG aquifers in other areas.

Groundwater in the CRBG generally occurs in a series of aquifers hosted by the interflow zones between the flow units comprising the upper three CRBG formations (Grande Ronde, Wanapum, and Saddle Mountains) and the interstratified Ellensburg Formation. CRBG aquifers have been characterized as generally semi-confined to confined. The major water-bearing and transmitting zones (aquifers) within the CRBG are variously identified as occurring in sedimentary interbeds of the Ellensburg Formation, between adjacent basalt flows (in the interflow zones), and in basalt flow tops (Gephart et al., 1979; Hansen et al., 1994; Packard et al., 1996; Sabol and Downey, 1997; USDOE, 1988). For the region it is generally accepted that lateral hydraulic gradients and groundwater flow directions in the CRBG aquifers are predominantly down structural dip (Drost and Whiteman, 1986; USDOE, 1988).

The physical characteristics and properties of individual CRBG flows affect their intrinsic hydraulic properties and influence potential distribution of groundwater within the CRBG. Interflow zones, in comparison to dense flow interiors, form the predominant water-transmitting zones (aquifers) within the CRBG (Newcomb, 1969; Oberlander and Miller, 1981; Lite and Grondin, 1988; USDOE, 1988; Davies-Smith et al., 1988; Wozniak, 1995; Bauer and Hansen, 2000; Tolan and Lindsey, 2000). Individual interflow zones are as laterally extensive as the sheet flows between which they occur. Given the extent and thickness (geometry) of individual interflow zones, this creates a series of relatively planar-tabular, stratiform layers that have the potential to host aquifers within the CRBG. Given the typical distribution and physical characteristics of CRBG intraflow structures, groundwater primarily resides within the interflow zones. The physical properties of undisturbed, laterally extensive, dense interiors of CRBG flows result in this portion of the flow having very low permeability (Newcomb, 1969; Oberlander and Miller, 1981; Lite and Grondin, 1988; USDOE, 1988; Davies-Smith et al., 1988; Lindberg, 1989; Wozniak, 1995). While the dense interior portion of a CRBG flow is replete with cooling joints, in their undisturbed state these joints have been found to be typically 77 to +99 percent filled with secondary minerals (clay, silica, zeolite). Void spaces that do occur are typically not interconnected (USDOE, 1988; Lindberg, 1989). The fact that CRBG dense flow interiors typically act as aquitards accounts for the confined behavior exhibited by most CRBG aquifers. In many areas around the Columbia Plateau artesian (flowing) conditions and low pressure zones within the CRBG aquifer system have been encountered.

Field data and inferences based on modeling studies suggest that the hydraulic properties of CRBG aquifers are laterally and vertically complex (e.g., Drost and Whiteman 1986; USDOE, 1988; Whiteman et al., 1994; Hansen et al., 1994). Vertically averaged lateral hydraulic conductivities were estimated in Whiteman et al. (1994) to range from 7×10^{-3} to 1,892 feet/day for the Saddle Mountains, 7×10^{-3} to 5,244 feet/day for the Wanapum, and 5×10^{-3} to 2,522 feet/day for the Grande Ronde aquifers. Hydraulic conductivity of dense basalt flow interiors, where they can even be measured, have been estimated to be 5 orders of magnitude, or less, than flow tops (USDOE, 1988). The available data on hydraulic properties of the various CRBG aquifers, including permeability, porosity, and storativity, indicate that a large variability in local flow characteristics is expected.

Aquifers within the CRBG are typically found at depths of greater than 100-feet below grade. Recharge to the shallow basalt aquifers is most likely a result of direct precipitation and recharge from the unconsolidated valley fill aquifers. Recharge to the deeper CRBG aquifers, deeper than 200 feet, is not defined at this time, but is most likely recharged from distant recharge areas, and/or ancestral Glacial Lake Missoula flood waters, as defined from the age dating completed by the GWMA study showing many CRBG aquifers have water dated at greater than 10,000 years old.

3.3 GRANITIC BEDROCK AQUIFERS

The granitic bedrock aquifers are primarily located in the northwestern part of the Lower Lake Roosevelt Watershed (west of Lincoln) and in several smaller areas in the east central portion of the watershed. Well logs reviewed determined that water supply wells withdraw water primarily from fractures within granites at depths greater than 100 feet. However, yields are generally low.

4.0 RESULTS OF GROUNDWATER GAUGING

Lincoln County Planning Department mailed out over 300 solicitation letters to landowners throughout the watershed. Approximately 50 responses were received by Lincoln County from landowners who were interested in participating in the Groundwater Gauging Project. In addition, approximately 15 other landowners volunteered to participate whom were contacted through the public outreach program. From these, 61 wells were selected for participation in the project. Nine were eventually dropped out of the project due to downhole access problems with gauging the wells, resulting in 52 wells monitored for the project.

Water level measurements are collected using a Solinist e-tape and a WL650/200U sonic meter. The Solinist e-tape provides a more accurate reading to the depth of groundwater and is preferred over the sonic meter readings. However, where an e-tape could not be used, the sonic meter provided the most representative data. Prior to collecting any groundwater measurements, the well was measured for latitude and longitude using a handheld field GPS unit. Measurements were entered into the County's GIS system and elevations of the wellheads were determined and recorded in NAVD88 format. Measurements are recorded and maintained at the Lincoln County Planning GIS Department.

A total of 52 wells are currently being gauged in the WRIA 53 Groundwater Gauging Project. Figure 2 shows the location of the wells being gauged for the project. Hydrographs of all the wells monitored for the project are presented in Attachment 1. Field sheets for the groundwater monitoring are presented in Attachment 3. Hydrographs presented in Attachment 1 include all data collected on each well site. However, within the field sheets presented in Attachment 3, some notations are made on specific data measurements which may not be truly representative of actual conditions. Where noted in Attachment C, these data collections should be interpreted with the noted limitations.

4.1 Sand & Gravel Wells

Six (6) wells which withdraw groundwater from the sand & gravel aquifers in WRIA 53 are currently being gauged for the project. Two sand & gravel wells are gauged in Hawk Creek drainage, two in the Welch Creek drainage, and two in the area of Grand Coulee which are in direct hydraulic continuity with Lake Roosevelt. Table 4 presents a summary of the gauging measurements collected in the sand & gravel wells located in Hawk and Welch Creek. These sand and gravel wells are in the valley gravels and appear to be in hydraulic connection with Hawk and Welch Creek in their respective drainages. Figure 9 is a graphical presentation of the sand and gravel wells located in the Hawk and Welch

Creek drainages. Seasonal fluctuations in groundwater have been observed to date in the sand & gravel wells and are inferred to be directly related to precipitation and stream flow.

TABLE 4: SUMMARY OF WATER LEVEL ELEVATIONS IN SAND & GRAVEL WELLS

Date	APQ814-HC	ELL1977-HC	NEL1968-WC	HOP1991-WC
12/29/09	1479.37			
1/8/10		1726.38		
2/4/10	1479.72			
2/19/10		1726.93	1509.48	
3/8/10	1480.06			
3/16/10		1726.92	1509.83	
4/20/10	1482.22			
4/27/10		1726.81	1510.87	1722.72
6/4/10		1726.41	1510.09	1721.12
6/8/10	1482.25			
7/26/10	1481.61	1725.39	1510.36	1719.32
8/18/10	1481.42	1725.01	1510.18	1718.12
9/22/10	1481.12	1724.95	1509.94	1716.32
10/22/10	1480.69	1724.99	1509.53	1715.72
11/19/10		1725.13	1509.31	1715.02
1/7/11	1479.76	1726.35	1508.89	1718.92
2/14/11	1480.09	1727.22	1509.89	1723.12
3/22/11	1482.57	1727.61	1511.16	1730.12
4/18/11	1485.57	1727.46	1513.64	1734.22

Note: HC = Located in Hawk Creek, WC = Located in Welch Creek

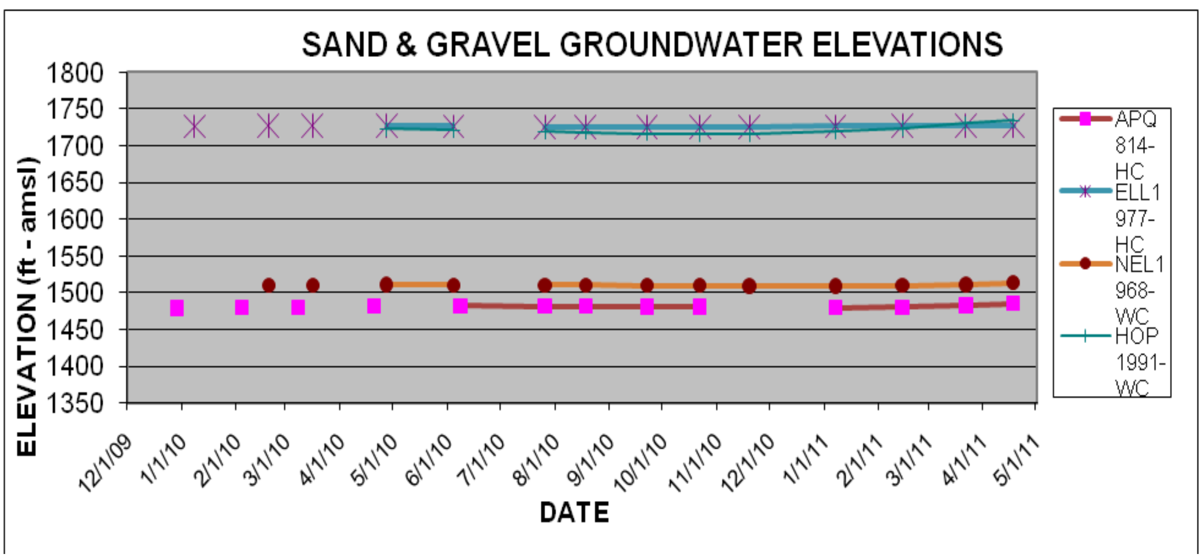

FIGURE 9: GRAPHICAL PRESENTATION OF GROUNDWATER ELEVATIONS IN SAND & GRAVEL WELLS IN THE HAWK AND WELCH CREEK DRAINAGES

Table 5 presents the results of monitoring within the two sand and gravel wells near Grand Coulee. Lake levels of Lake Roosevelt are also presented in the table. As shown on Figure 10, these wells are in direct hydraulic continuity with the lake, and fluctuate with the raising and lowering of the reservoir. During the early spring (Feb-Apr) 2011, maintenance occurring on Grand Coulee Dam lowered the lake to approximately 1230 feet amsl.

TABLE 5: SUMMARY OF WATER LEVEL ELEVATIONS IN SAND & GRAVEL WELLS in CONNECTION WITH LAKE ROOSEVELT near GRAND COULEE

Date	Lk Roos	BBH538	ABQ390
1/19/2010	1287.24	1292.42	
2/12/2010	1283.83	1288.35	1287.01
3/8/2010	1278.58	1283.30	1281.41
4/22/2010	1276.74	1275.36	1273.71
6/3/2010	1271.81	1276.84	1270.61
7/26/2010	1288.16	1293.01	1289.61
8/18/2010	1282.21	1288.24	1285.61
9/22/2010	1283.14	1287.85	1283.41
10/22/2010	1288.39	1293.21	1289.41
11/19/2010	1284.68	1289.97	1285.81
1/7/2011	1281.56	1285.98	1283.61
2/14/2011	1273.02	1282.50	1281.41
3/22/2011	1253.67	1258.47	1256.61
4/19/2011	1230.61	1234.28	1237.41

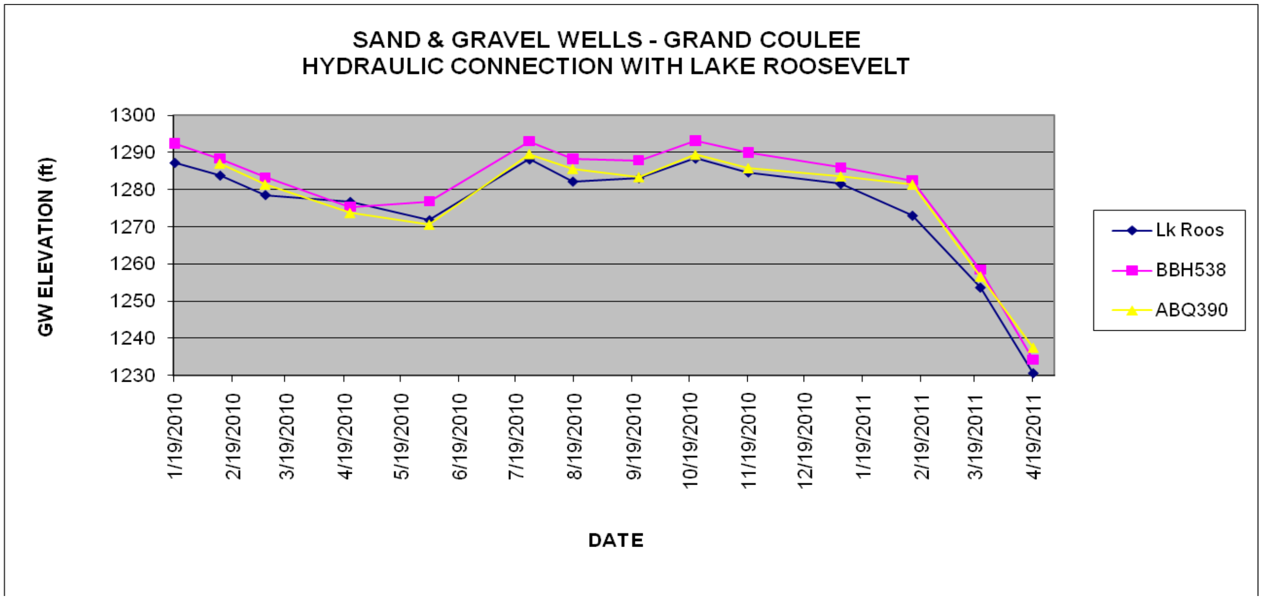

FIGURE 10: GRAPHICAL PRESENTATION OF GROUNDWATER ELEVATIONS IN SAND AND GRAVEL WELLS IN THE GRAND COULEE AREA WHICH ARE IN DIRECT HYDRAULIC CONTINUITY WITH LAKE ROOSEVELT.

4.2 Basalt Wells

Forty-one (41) wells which withdraw groundwater from the basalt aquifers are currently being gauged for the WRIA 53 project. CRBG wells are inferred to be in the following units:

- 14 wells in the Wanapum Basalt
  - 10 in the Davenport area
  - 4 in other areas of the WRIA
- 27 wells in the Grande Ronde Basalt
  - 9 in the Hawk Creek area
  - 4 in the Grand Coulee area
  - 7 in the Welch Creek area
  - 3 in the Davenport area
  - 4 in the Grand Coulee and 7-Bays area which are in direct hydraulic continuity with Lake Roosevelt.

4.2.1 Wanapum Basalt Wells

Fourteen wells inferred to be in the Wanapum Basalt are currently being monitored for the project. Table 6 presents the groundwater elevations of the 10 groundwater wells being monitored in the Davenport area. Figure 11 presents the hydrographs of these 10 wells. As shown on the hydrograph in the figure, and within the individual graphs presented in Attachment 1, Wanapum wells in the Davenport area remained fairly stable until the winter of 2011, at which time, many of the groundwater elevations rose. This is interpreted to be a result of some surficial recharge to the shallow aquifer from precipitation and a potential reduction in pumping in the area.

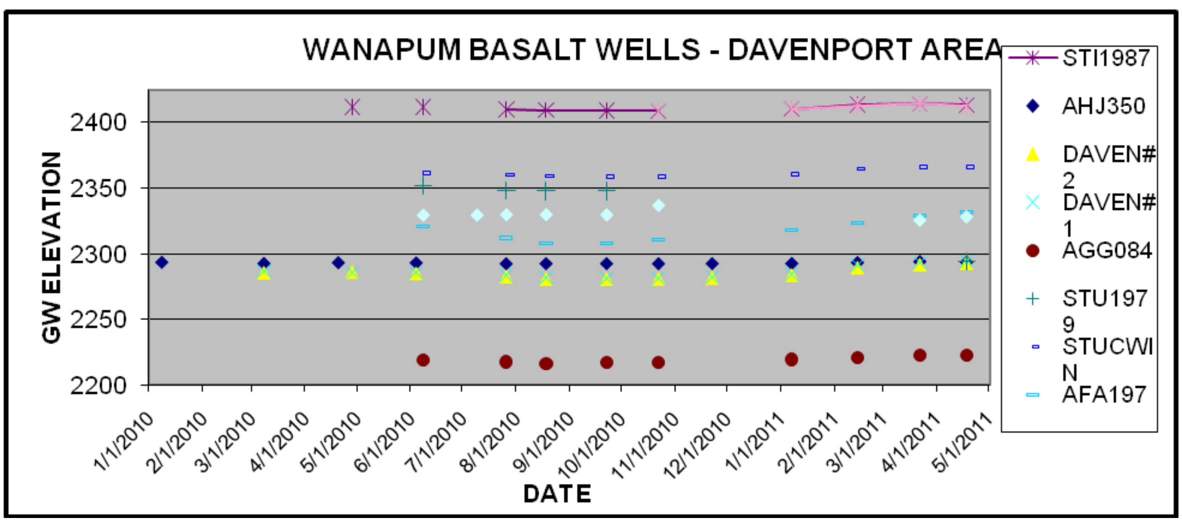

FIGURE 11: GRAPHICAL PRESENTATION OF GROUNDWATER ELEVATIONS IN WANAPUM WELLS LOCATED IN THE DAVENPORT, WASHINGTON AREA.

TABLE 6: SUMMARY OF GROUNDWATER LEVEL MEASUREMENTS IN WANAPUM BASALT WELLS IN THE DAVENPORT, WA AREA

Date	AHJ350	DAVEN #2	DAVEN #1	STI1987	AGG084	STU1979	STUCWIN	AFA197	ENS1965	ACW 391
1/8/2010	2293.54									
2/12/2010										
3/8/2010	2292.64	2285.42	2286.65							
4/20/2010	2293.22									
4/28/2010		2285.79	2286.00	2411.73						
6/4/2010	2293.10	2284.84	2285.98							
6/8/2010				2411.84	2219.15	2352.08	2361.65	2321.10	2329.65	
7/9/2010									2329.65	
7/26/2010	2292.40	2282.40	2283.45	2410.07	2217.55	2348.10	2360.11	2312.00	2329.95	
8/18/2010	2292.50	2280.65	2281.62	2409.47	2216.55	2348.00	2359.26	2307.70	2330.05	
9/22/2010	2292.52	2280.46	2281.25	2409.21	2217.15	2348.00	2358.73	2307.50	2329.85	
10/22/2010	2292.42	2280.69	2281.44	2408.85	2217.35		2358.55	2311.00	2336.85	2408.15
11/22/2010	2292.54	2281.29	2282.09							
1/7/2011	2292.63	2283.53	2284.53	2410.46	2219.35		2360.52	2317.60		2409.85
2/14/2011	2293.33	2289.11	2291.63	2413.64	2221.15		2364.46	2323.80		2412.95
3/22/2011	2294.05	2291.51	2293.15	2414.32	2222.55		2366.01	2328.60	2325.92	2414.18
4/18/2011	2293.57	2292.69	2294.34	2413.29	2222.85	2294.00	2365.95	2331.90	2328.37	2412.35

TABLE 7: SUMMARY OF GROUNDWATER LEVEL MEASUREMENTS IN WANAPUM BASALT WELLS OUTSIDE DVENPORT, WA AREA

Date	DID1982-EGC	APC864-WC	Platt1992-EHC	Scharf1992
2/12/2010	2428.22			
3/8/2010	2427.82			
4/22/2010	2427.62			
6/8/2010				2498.75
7/26/2010	2403.22	2322.77	2377.15	2496.95
8/18/2010	2403.02	2333.17	2377.35	2496.55
9/22/2010	2402.82	2334.77	2377.35	2496.55
10/22/2010	2403.02	2335.17	2377.35	2495.95
11/22/2010	2403.62	2335.87		
1/7/2011	2403.22	2336.37	2377.95	2495.75
2/14/2011	2402.82	2337.17	2377.65	2495.95
3/22/2011	2402.42	2338.57	2377.65	2496.25
4/19/2011	2402.02	2340.37	2377.28	2496.35

Note: EGC=East of Grand Coulee, WC=Welch Creek, EHC=East of Hawk Creek

Table 7 presents a summary of the gauging measurements collected in the Wanapum basalt wells located in other areas throughout the watershed. As shown on the Table, and within Figure 12, no major fluctuations in groundwater have been observed to date in these wells, except for APC864, which is located in Welch Creek. The groundwater table in this well rose approximately 18 feet from July 2010 through April 2011. The other wells have remained at a fairly stable static level.

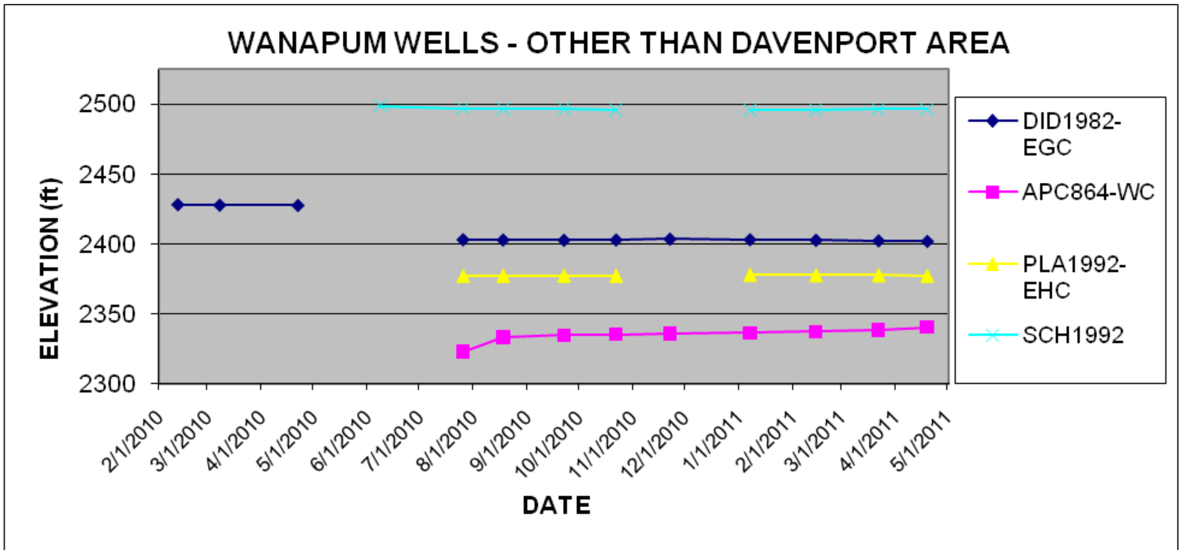

FIGURE 12: GRAPHICAL PRESENTATION OF GROUNDWATER ELEVATIONS IN WANAPUM WELLS LOCATED OUTSIDE THE DAVENPORT, WASHINGTON AREA.

4.2.2 Grande Ronde Basalt Wells

Twenty-seven groundwater wells withdrawing from the Grande Ronde Basalt are being monitored throughout the watershed. These wells are monitored in four diferent areas of the watershed: the Hawk Creek area, the Grande Coulee area, the Welch Creek area, and other areas in the watershed. Table 8 presents the groundwater elevations in nine Grande Ronde wells measured in the Hawk Creek area, primarily in those areas around the Hawk Creek development. A hydrograph of the nine Hawk Creek Grande Ronde wells is presented in Figure 13. As shown on the table and figure, there is a large variation in groundwater elevations in the Hawk Creek area. This is interpretted to be a result of the wells being screened in various Grande Ronde interflows, and/or being influenced by structural controls in the Hawk Creek drainage.

Table 9 presents a table of groundwater elevations in Grande Ronde wells which were being monitored in the Welch Creek drainage. Figure 14 presets a hydrograph of the Welch Creek Grande Ronde wells. As shown on the table and figure, there is a large variance in groundwater elevations in these wells. It is inferred that structural controls, as described in Hawk Creek drainage may be influencing the hydrostatic heads in this drainage also. Although there is a large variance in the groundwater elevations, no major groundwater table fluctuations were observed in the Grande Ronde wells in Welch and Hawk Creek.

TABLE 8: SUMMARY OF WATER LEVEL ELEVATIONS IN GRANDE RONDE BASALT WELLS-HAWK CREEK

Date	APQ811	APQ806	BAC950	APB762	APP839	ALN867	ALN853	AHC407	ACW361
12/29/2009		1966.74			2214.00	1493.35			
1/19/2010								1632.22	
1/22/2010	1475.15								
1/29/2010							1519.08		
2/4/2010	1474.85	1964.03	1703.94	1939.59	2214.10	1494.98	1519.30		
2/12/2010								1638.42	
3/8/2010	1475.49	1965.23	1703.64	1938.99	2214.26	1495.80	1520.06		
3/16/2010								1640.31	1833.28
4/20/2010	1475.99	1966.39	1703.74	1938.59	2214.28	1496.48	1521.15		
4/22/2010								1637.27	1834.38
6/3/2010									1831.78
6/8/2010	1475.47	1966.23	1702.24	1937.17	2214.13	1496.17	1520.93		
7/26/2010	1475.68	1966.21	1702.54	1937.19	2214.02	1495.81	1519.53	1610.92	
8/18/2010	1475.58	1965.34	1703.14	1937.39	2213.97	1495.65	1520.53	1590.12	
9/22/2010	1475.54	1962.27	1703.14	1938.09	2213.89	1495.45	1519.63	1624.72	
10/22/2010	1475.43	1959.15	1703.44	1938.39	2213.82	1495.21	1519.73	1632.02	
11/22/2010								1632.21	
1/7/2011	1476.20	1956.29	1704.44	1940.09	2213.95	1494.70	1518.13		
2/14/2011	1476.80	1965.77	1704.54	1939.49	2214.87	1496.33	1519.93	1641.82	
3/22/2011	1477.40	1968.52	1703.74	1938.79	2215.90	1499.08	1522.33	1651.38	
4/19/2011	1478.80	1972.27	1703.74	1938.39	2216.16	1500.72	1525.42	1644.11	

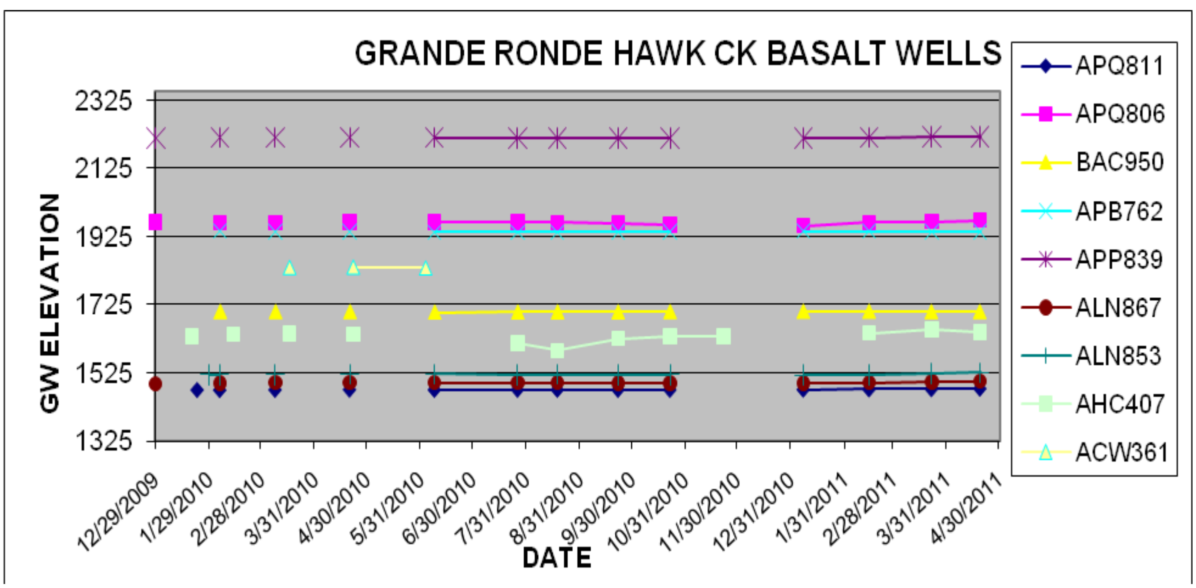

FIGURE 13: GRAPHICAL PRESENTATION OF GROUNDWATER ELEVATIONS IN GRANDE RONDE WELLS LOCATED IN THE HAWK CREEK DRAINAGE.

TABLE 9: SUMMARY OF WATER LEVEL ELEVATIONS IN WELCH CREEK GRANDE RONDE BASALT WELLS

Date	AHS539	BBH041	BAC976	BAS262	BAC970	BAC969	AKT389
1/8/10				2198.29	2370.00	2282.94	
1/22/10		1548.11					
2/19/10		1548.18	2129.77	2160.69	2327.99	2282.90	
3/16/10	1462.95	1548.26	2129.75	2161.00	2328.10	2282.71	
4/22/10	1461.64						
4/28/10		1548.33	2129.56	2161.99	2328.15	2283.03	
6/3/10	1462.61						
6/4/10		1548.26	2129.36	2161.09	2327.81	2282.42	
7/27/10	1456.11	1548.18	2129.36	2161.09	2326.92	2282.00	1750.28
8/17/10	1460.30	1548.04	2129.24	2160.59	2326.60	2281.72	1750.38
9/21/10	1457.23	1547.94	2129.37		2326.33	2282.08	1750.28
10/21/10	1458.95	1547.92	2129.23		2326.00	2282.14	1750.48
11/19/10	1460.59	1547.93	2129.20		2325.84	2282.44	1750.48
1/14/11		1548.02					1750.48
2/10/11	1462.42	1548.15	2128.48		2325.45	2282.54	1750.48
3/23/11	1463.25	1548.34	2127.67		2325.72	2283.18	1750.28
4/19/2011	1463.57	1548.61	2127.55		2326.07	2284.05	1750.38

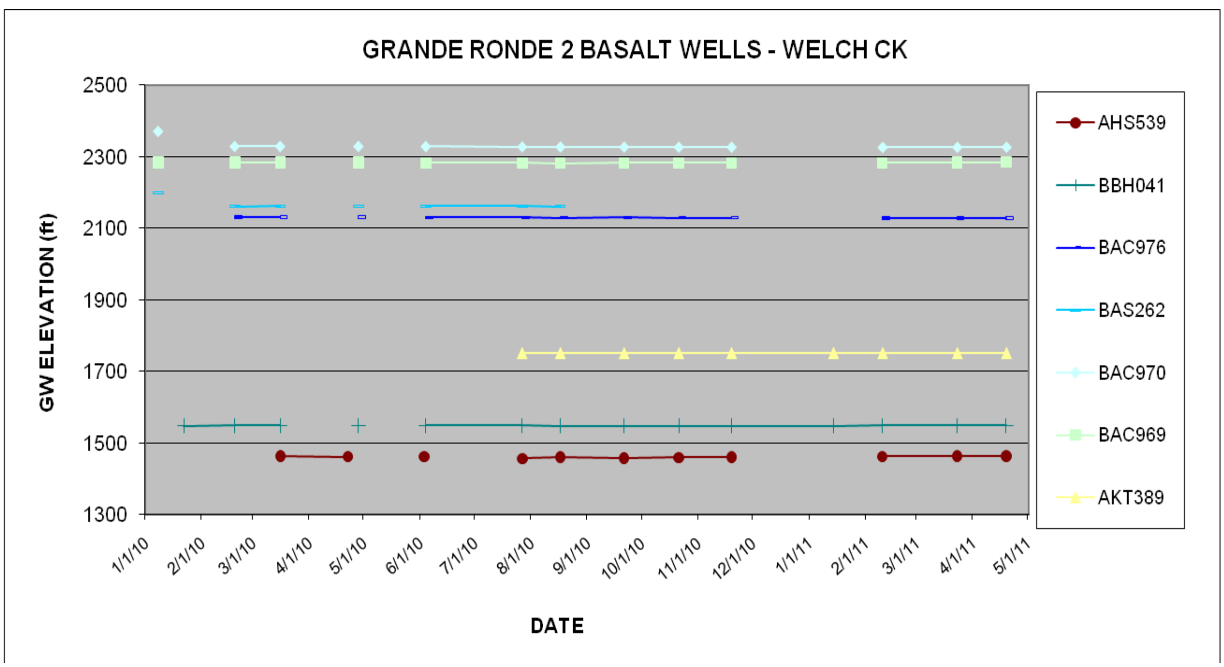

FIGURE 14: GRAPHICAL PRESENTATION OF GROUNDWATER ELEVATIONS IN GRANDE RONDE WELLS LOCATED IN THE WELCH CREEK DRAINAGE.

Table 10 presents the Grande Ronde well data for the Grand Coulee (4 wells), Lincoln (1 well), and Davenport (2 wells), Washington areas. As shown in the table and in Figure 15, groundwater levels have remained fairly constant throughout the monitoring period. Wells in the Grande Ronde in the Davenport area are approximately 500 to 1000 feet higher in elevation than the other wells in the Lincoln and Grand Coulee areas.

Table 11 presents the monitoring results of four wells which withdraw water from the Grande Ronde basalt, but are in direct hydraulic continuity with Lake Roosevelt. As shown on the table and on Figure 16, the groundwater elevations fluctuate with the lake and have dropped significantly with the lowering of the lake in the spring of 2011.

Although these wells are in direct hydraulic continuity with Lake Roosevelt, it does not appear that this water table is hydraulically connected to the Grand Ronde aquifers to the south. The GWMA studies have identified a basement ridge/barrier between these basalts and the main WRIA 53 Grande Ronde basalts underlying the watershed to the south. This discontinuity is also evident from the differences in groundwater elevations, where these wells have static elevations of 1230-1300 feet amsl, the other basalts to the south of the basement ridge have groundwater static elevations of 1500 – 2200 feet amsl.

TABLE 10: SUMMARY OF WATER LEVEL ELEVATIONS IN GRANDE RONDE BASALT WELLS IN GRAND COULEE, LINCOLN AND DAVENPORT AREAS

Date	BAC955-GC	APF669-GC	ACS240-GC	AHC421-GC	LIV1987-LINC	REIN300-NDAV	ABI086-EDAV
1/19/10	1698.13	1700.18		1350.46			
2/12/10	1697.61	1700.48	1366.20	1352.88			
3/8/10	1697.53	1700.43	1364.70	1353.03	1585.94		
4/22/10	1697.68	1700.50	1365.30	1353.03	1585.74		
4/28/10						2322.90	2476.19
6/3/10	1697.62	1700.48	1366.30	1354.22			2475.08
6/4/10					1584.94	2321.90	
7/27/10	1697.60	1700.41	1360.83	1354.44	1584.74	2344.50	2474.68
8/17/10	1697.54	1700.39		1354.36	1584.94	2345.00	2474.18
9/21/10	1697.56	1700.41	1350.25	1354.07	1585.44	2344.90	2474.18
10/21/10	1697.54	1700.37	1358.70	1353.95	1585.34	2345.10	2473.48
11/19/10	1697.58	1700.42		1353.99			
1/14/11	1697.45	1700.29	1374.30	1354.28	1586.34		2473.28
2/10/11	1697.28	1700.18	1377.75	1354.90	1586.34		2474.28
3/23/11	1697.40	1700.33	1383.58	1356.62	1585.54		2474.88
4/19/2011	1697.36	1700.23	1385.00	1357.40	1585.74		2475.28

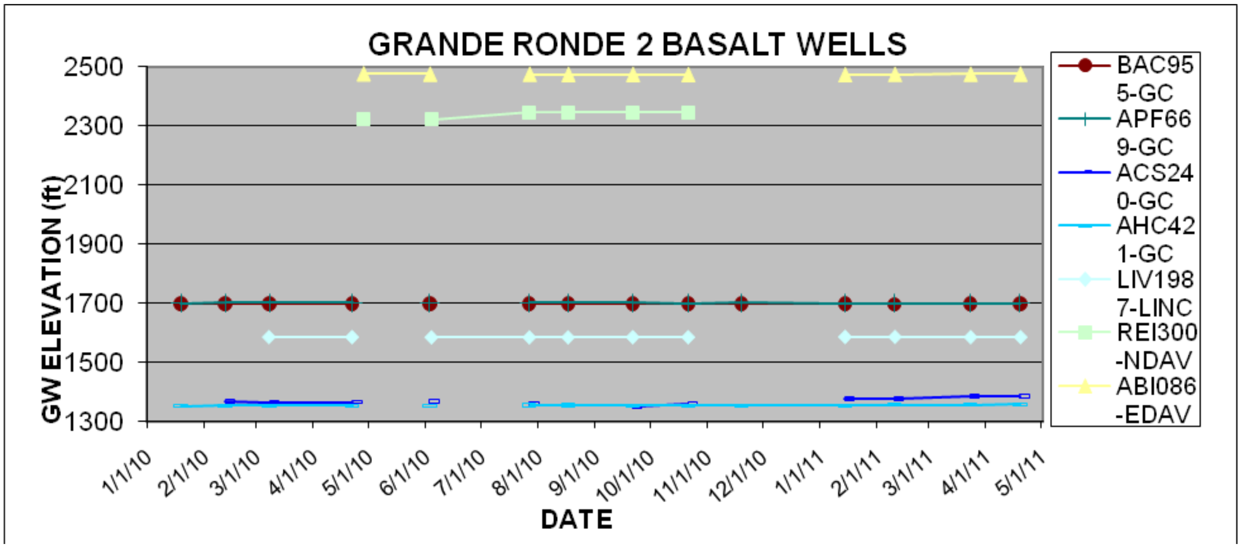

FIGURE 15: GRAPHICAL PRESENTATION OF GROUNDWATER ELEVATIONS IN GRANDE RONDE WELLS LOCATED IN THE GRAND COULEE, LINCOLN AND DAVENPORT AREAS.

TABLE 11: SUMMARY OF WATER LEVEL ELEVATIONS IN GRANDE RONDE BASALT WELLS IN CONTINUITY WITH LAKE ROOSEVELT

Date	LKRoos	ROY1991-GC	BAC967-7B	AKL333-7B	BAF483-7B
2/12/2010	1283.83	1300.44	1285.99		1282.50
3/8/2010	1278.58	1295.05	1279.39		1276.60
4/22/2010	1276.74	1288.78	1272.39	1274.43	1271.20
6/3/2010	1271.81	1282.43			
6/8/2010	1283.53		1279.89	1279.73	1266.80
7/27/2010	1287.66	1303.29	1288.19	1289.53	1283.80
8/17/2010	1282.79	1299.77	1282.79	1284.43	1280.70
9/21/2010	1282.61	1295.64	1282.49	1284.03	1276.60
10/21/2010	1288.13	1302.86	1288.29	1289.83	1283.40
11/19/2010	1284.68	1301.68			
1/14/2011	1280.80	1297.64	1282.89		1280.80
2/10/2011	1277.14	1296.17	1275.59	1277.43	1276.40
3/23/2011	1253.20	1272.51	1254.59	1256.43	1255.40
4/18/2011	1231.41	1255.96	1233.79	1236.93	1243.20

Note: GC = Grand Coulee, 7B = Seven Bays Area

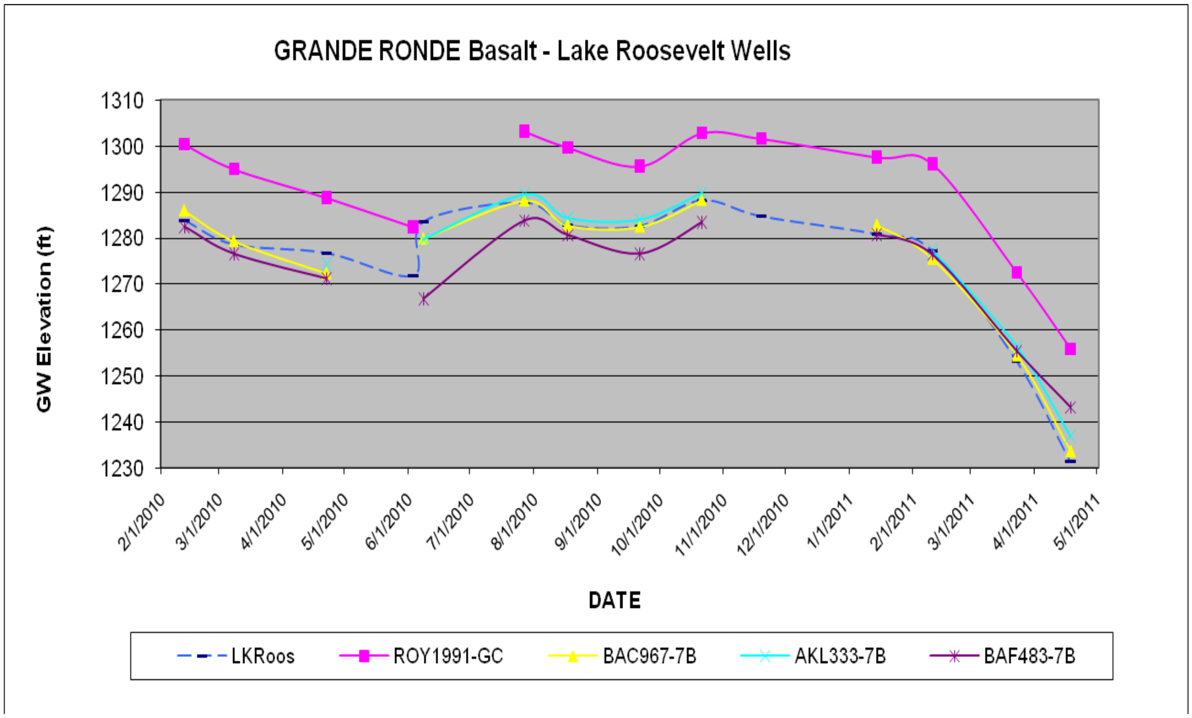

FIGURE 16: GRAPHICAL PRESENTATION OF GROUNDWATER ELEVATIONS IN GRANDE RONDE WELLS IN THE GRAND COULEE AND 7-BAYS AREAS WHICH ARE IN HYDRULIC CONTINUITY WITH LAKE ROOSEVELT.

4.3 Granite Wells

Five (5) wells which withdraw groundwater from the basement (granite) aquifers were gauged for the project. Table 12 presents a summary of the gauging measurements collected in the granite wells. As shown on the table, and within Figure 17, no major sustained drawdown in groundwater elevations have been observed in the bedrock wells. However, the granite wells in the area do have water tables that fluctuate, interpreted to be a result of delayed recharge and potential impacts from other granite wells in the same fractures.

TABLE 12: SUMMARY OF WATER LEVEL ELEVATIONS IN GRANITE WELLS

Date	ALN861-HC	ALN860-HC	REI715-NDAV	AHC420-GC	APC865-GC
12/29/09	2063.84				
1/19/10				1369.71	1272.53
2/4/10	2064.74	1783.14			
2/12/10				1372.96	1284.83
3/8/10	2064.88	1785.75		1375.50	1300.61
4/20/10	2064.39	1786.39			
4/22/10				1379.25	1285.63
4/28/10			1972.49		
6/3/10				1370.41	1245.63
6/8/10	2065.45	1785.47	1969.19		
7/26/10	2063.83	1785.51	1964.40	1368.29	1227.23
8/18/10	2063.45	1785.10	1965.60	1374.05	1254.43
9/22/10	2062.77	1784.46	1966.40	1371.24	1240.13
10/22/10	2060.47	1783.89	1964.80	1370.14	1240.23
11/19/10				1372.71	1260.63
1/7/11	2065.35	1783.88	1968.60	1382.82	1284.63
2/14/11	2064.92	1787.66	1966.60	1382.19	1281.43
3/22/11	2065.66	1793.89	1969.20	1383.76	1261.43
4/18/11	2064.70	1794.57	1966.80	1388.34	1290.23

Note: GC = Grand Coulee Area, NDAV = North of Davenport, HC = Hawk Creek Area

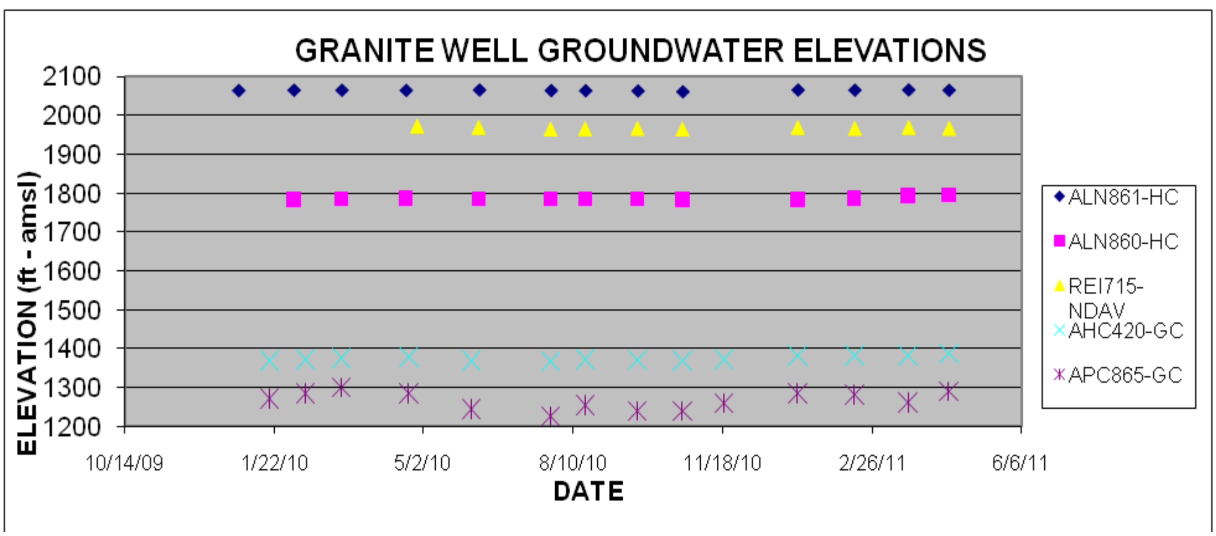

FIGURE 17: GRAPHICAL PRESENTATION OF GROUNDWATER ELEVATIONS IN GRANITE (BASEMENT) WELLS.

5.0 CONCLUSIONS

5.1 SURFACE WATER

Surface water flow monitoring was conducted in Hawk Creek from December 2009 through April 2011. Flows in the creek consistently show a gaining reach of creek down the Hawk Creek drainage. This is interpreted to be a result of tributary flow contributions, and some interchange of water with the groundwater table. Water tables in the sand and gravel aquifers in Hawk and Welch Creek drainages do not fluctuate immediately with the increased stream flows in the creek, and appear to only have delayed rise slightly as the flows increase in the creeks. This may be a result of groundwater contributing flows to the creek, and a direct relationship of the distance of the wells monitored for the study to the creeks.

Wells in sand and gravel deposits in the Grand Coulee area are founded in the sediments of the Columbia River Valley. These wells fluctuate directly with the lake level. Water supply from these wells are directly related to the management of the Columbia River, and need to be completed to a depth below the lowest level of the lake observed during maintenance of the dam.

5.2 GROUNDWATER

This section summarizes our basic interpretations of groundwater conditions and trends as suggested by the water level data collected to date. Most of the water level data collected for this project is grouped into five geographic areas for analysis. Plate 1 shows the locations of these wells, and is color-coded to delineate these 5 areas. These areas were largely dictated by the location and clustering of wells from which water level data were collected. These areas, and the wells used in deriving the groundwater conclusions included in each area are as follows:

- Davenport: STU1979, AFA197, ENS1965, AGG084, AHJ350, STI1987, DAVEN#2, DAVEN#1.
- Grand Coulee: APC865, AHC420, AHC421, PAL1984, BBH538, BAC955, APF669, ROY1991.
- Seven Bays: BAF483, BAC967, AKL333, LIV1987.
- Welch Creek: NEL1968, HOP1991, APC864, BAC976, BAC970, BAC969, AKT389
- Hawk Creek: APQ811, APQ814, BAC950, ALN853, ALN860, APB762, APP839, ALN867, APQ806, ALN861, AHC407, ELLIS1997.

These areas are not evaluated together because of the distance separating them, ranging from 2 to 20 miles.

Wells for which data were collected, but which were not assigned to a geographic area for this evaluation include:

- ABQ390, AHS539, PLA1992, and ABI086 because they are deemed to be too far from the well groups noted above to be considered with them.

- BBH041, ACW362, and BAS262 because of small data sets, relative to the other wells.

5.2.1 Davenport Area

Wells measured in the Davenport area are all interpreted to be open to the Wanapum Basalt. However, based on GWMA's subsurface maps, several of these wells (AGG084, DAVEN#1, and DAVEN #2) may also be open to the uppermost Grande Ronde Basalt. Based on the water level data collected to-date (Figure 18), and contoured water levels illustrated on Plates 2 through 3, it appears that groundwater in the Davenport area generally is moving to the south. However, the general movement direction appears to change to the west of town. Around the cluster of wells west of town (STU1979, AGG084, ENS1965, AFA197) this southerly flow appears to change to one directed more to the east, towards Davenport. There are several possible explanations for this apparent change in groundwater flow direction.

It is possible that the apparent change in groundwater flow direction suggested by the interpreted water table contours reflect a persistent depression on the aquifer associated with the pumping of Davenport wells and well AGG084. Another possible explanation is that the data for AGG084 is somehow incorrect as water level on this well is significantly lower than in nearby wells. If this well was removed from the data set for this area, groundwater flow suggested by the remaining data would be generally to the south-southeast. A third possible explanation is that the wells measured in the Davenport area are open to different combinations of water-bearing zones.

Using GWMA's subsurface maps of this area it is possible that several of these wells (AGG084, DAVEN#1, and DAVEN#2) are open to the Grande Ronde Basalt, in addition to the Wanapum Basalt. These, and other wells open to multiple water-bearing zones have the potential to display a composite water level, one reflective of the interaction of all water-bearing zones, and not just one. The depression observed on the maps may therefore also reflect a depressed water level caused by one, or more, low pressure water-bearing zones in these three wells which would yield a lower composite water level. At this time we do not have a preferred explanation for the apparent change in water levels near Davenport, and the apparent associated change in groundwater flow direction suggested by the mapped water levels.

5.2.2 Coulee Dam Area

Wells in the Coulee Dam area display a wide range of water levels that likely reflect different hydrologic regimes (Figure 19). Wells APF669 and BAC955, both suspected Grande Ronde Basalt wells, display water levels of approximately 1700 feet above mean sea level (amsl). Conversely, the water level in nearby Lake Roosevelt was well below this elevation, being 1300 to 1260 feet amsl. Giving that the lake sits on a canyon carved into the basement rock underlying the Grande Ronde Basalt, we would interpret these water levels to reflect little to essentially no hydraulic connection between the Grande Ronde Basalt portion of the aquifer system being measured on these two wells and the lake.

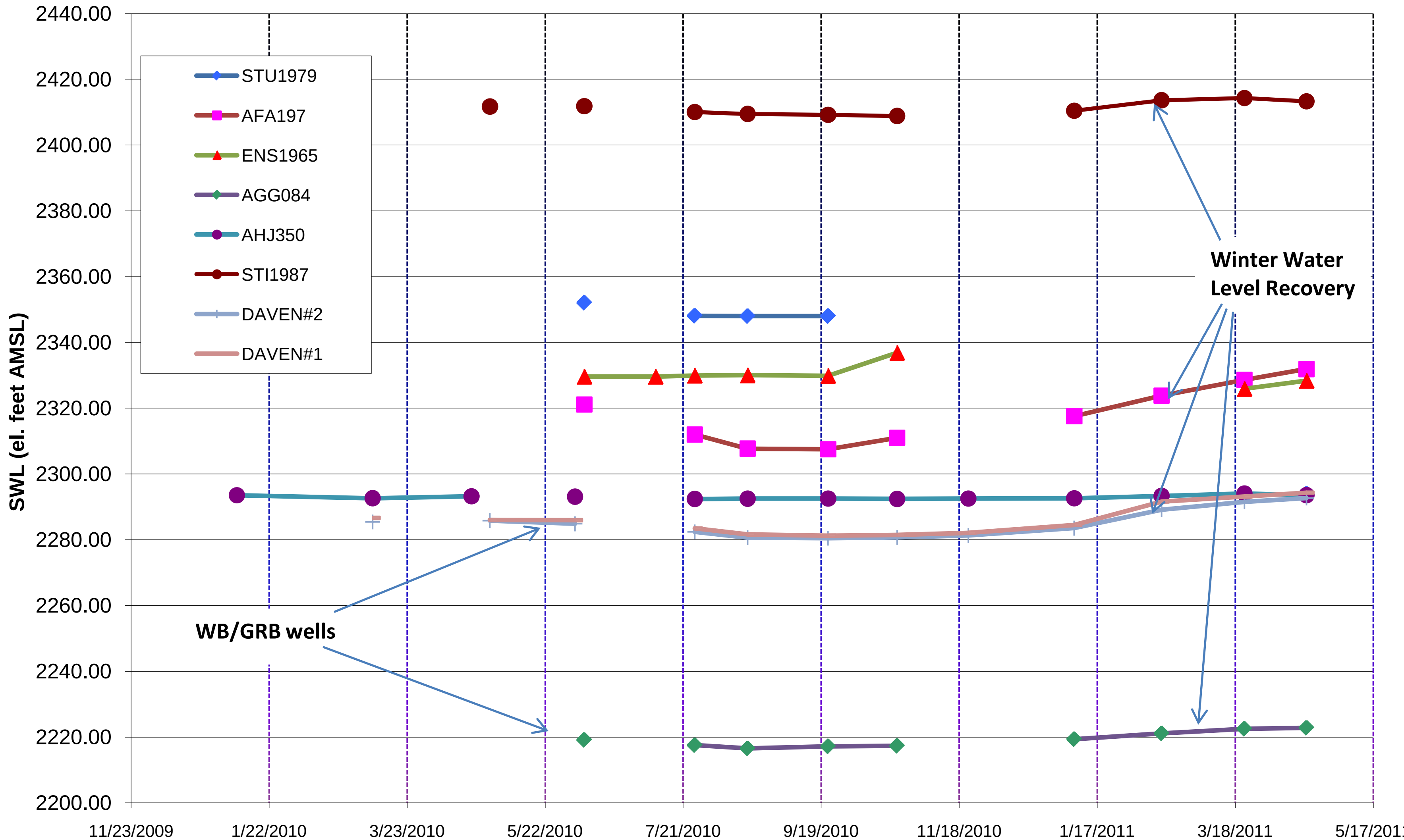

Figure 18. Hydrographs for wells in the Davenport Area. Grande Ronde influenced water levels appear to be lower than Wanapum only levels.

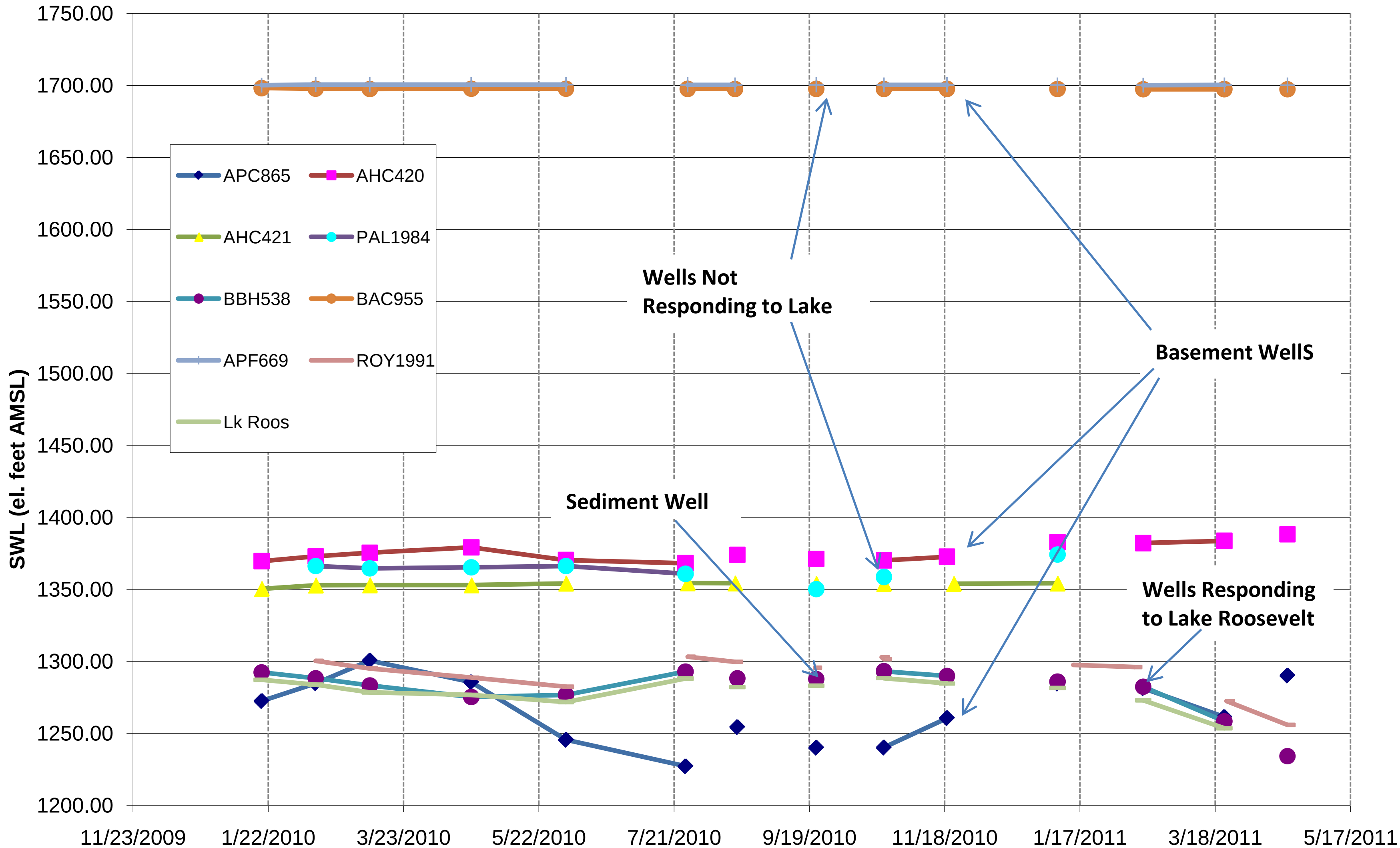

Figure 19. Hydrographs for wells in the Grand Coulee Dam area. Several groupings of water levels present.

Two wells that are interpreted to show strong hydraulic continuity with Lake Roosevelt are ROY1991 and BBH538. The latter of these two is a sediment or alluvial well and likely is pumping groundwater in hydraulic connection with the lake. ROY1991 is however thought to be a Grand Ronde Basalt well based on information provided by the well owner. However, based on mapped bedrock geology in the Coulee Dam area this is highly unlikely and we suspect this is in fact a sediment well.

Two basement wells (APC865 and AHC420) measured in the Coulee Dam area display water levels that differ more or less from trends seen in the lake. However, with these differences, well APC865 does occasionally display water level trends that appear to track with the lake. It appears to track with the lake in winter and spring, but does not in the summer. This may suggest a limited connection with the lake. It may be drawn-down significantly by summer pumping, then recharge slowly in the winter and spring until it comes into equilibrium with the lake. Such a response would suggest a limited, physically restricted hydraulic connection between the portion of the basement aquifer system monitored by this well and the Lake.

The other two wells monitored in the area, PAL1984 and AHC421 are basalt wells, likely open to the Grande Ronde. These wells have water levels 50-75 feet above the lake, but over 300 feet less than basalt wells APF669 and BAC955. These two sets of basalt wells likely are monitoring water levels in different parts of the basalt aquifer system displaying little to essentially no hydraulic continuity.

5.2.3 Seven Bays Area

Water levels were compiled for 4 Grande Ronde Basalt wells in the Seven Bays area (Figure 20). All but one of these wells (LIV1987) displayed water levels very similar to Lake Roosevelt. The portion of the Grande Ronde Basalt these three wells (BAF483, BAC967, and AKL333) are extracting water from is interpreted to be in direct hydraulic connection with the lake. Based on water levels discussed in the Hawk Creek Area discussion in section 5.2.4, this Grande Ronde/Lake Roosevelt hydraulic continuity is interpreted to be relatively local.

5.2.4 Welch Creek

Water levels in and near the Welch Creek area were compiled from 7 wells (Figure 21), three at or near the bottom of the Welch Creek canyon (NEL1968, HOP1991, AKT389) and four (APC864, BAC976, BAC970, BAC969) on the upland plateau into which the canyon is incised. Given the water levels measured in the three wells in the canyon, approximately 1500 to 1750 feet amsl (Plates 2 through 4), we interpret these wells to not have a direct hydraulic connection with nearby Lake Roosevelt which has water levels less than 1300 feet amsl. Instead, the two sediment wells (NEL1968, HOP1991) likely are measuring water levels in alluvial deposits that probably are hydraulically connected to Welch Creek. Well AKT389, which is a Wapshila Ridge Member well deep in the Grande Ronde, also has water levels similar to the two alluvial wells. This well also may be hydraulically connected to the creek. As drawn, our water table maps (Plates 2 through 4) suggest this connection, if present, has this portion of the basalt aquifer system discharging into Welch Creek.

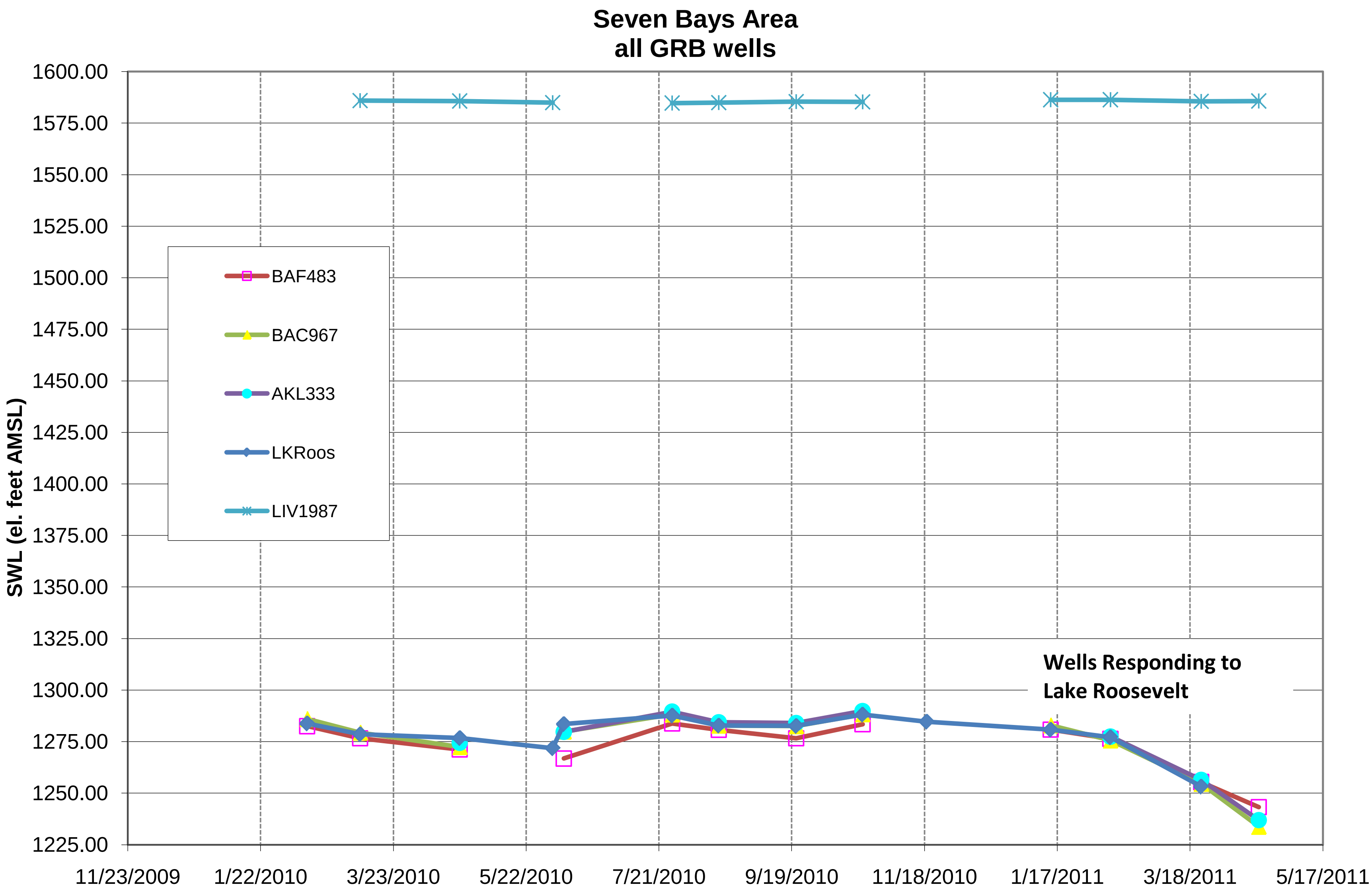

Figure 20. Hydrographs for wells in the Seven Bays area.

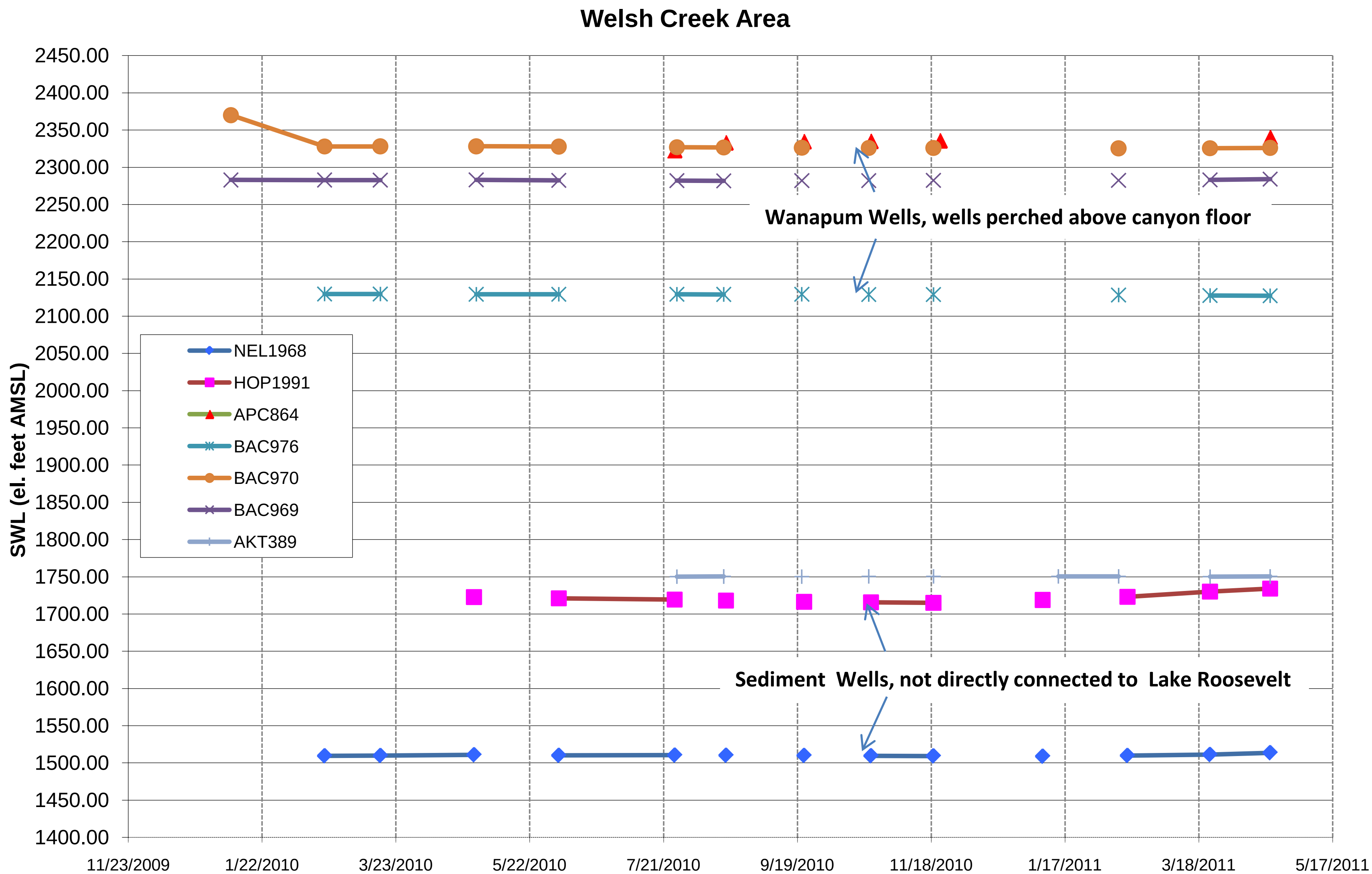

Figure 21. Hydrographs for wells in the Welsh Creek area.

The other four wells in the area are all measuring water levels high above the canyon floor (Plates 2 through 4). These water levels are interpreted to be for a groundwater system within the uppermost 2 or 3 interflow zones high on the upland, and incised into and through by the canyons which dissect this upland area. This basalt-hosted upland groundwater system likely is found within a thin Priest Rapids Member of the Wanapum Basalt and underlying interflow zones in the uppermost Sentinel Bluffs Member of the Grande Ronde Basalt. Any hydraulic connection this upland groundwater system might have with nearby surface water (Lake Roosevelt and Welch Creek) would be indirect, via springs high on the canyon walls feeding small streams that then flow down the canyon walls into these larger water bodies.

5.2.5 Hawk Creek

The conditions that are interpreted from Hawk Creek area water levels are similar to those seen in the Welch Creek area. There are wells in and near the canyon bottom monitoring alluvial sediments and basalts (Figure 22). These wells have very similar water levels and are interpreted to have a high degree of hydraulic connection. The canyon bottom water levels were measured in wells ALN853 (Grande Ronde), ALN867 (Grande Ronde), APQ814 (sediment), APQ811 (Grande Ronde), and ELL1977 (sediment).

There appear to be several possible water-bearing zones in the basalt aquifer system above the canyon floor. These systems are at intermediate to higher elevations on the canyon walls (wells AHC407, BAC950, APQ806, and APB762) and immediately beneath the dissected upland surface well (APP839) (Figure 22). The variety of basalt aquifer system water levels suggested by these different water levels may reflect multiple, stacked water-bearing intervals and/or structural influences. The Hawk Creek area is crossed by several faults. These faults may have offset water-bearing intervals resulting in the multiple water levels suggested by the data collected to-date. These portions of the basalt aquifer system are only hydraulically connected to Hawk Creek indirectly via springs on the canyon wall.

In addition to the water levels from the basalt aquifer system and the canyon bottom sediments, several wells in this area are measuring water levels in the granite basement underlying the entire area. These wells, ALN860 and ALN861, display water levels well above the valley bottom (Figure 22). As with the water levels seen high in the basalt system, these seen in the basement suggest hydraulic connection to surface water on the canyon floor would likely be indirect via springs.

While we do contour possible groundwater elevations (Plates 2 through 4) we do not contour all of the data portrayed on each map. This is because we interpreted the data compiled to date to represent several hydraulic systems with varying degrees of hydraulic connection, from essentially none to significant. A single water level map for these data at any time step would misrepresent the presence of several water-bearing systems by placing all of that data on a single map.

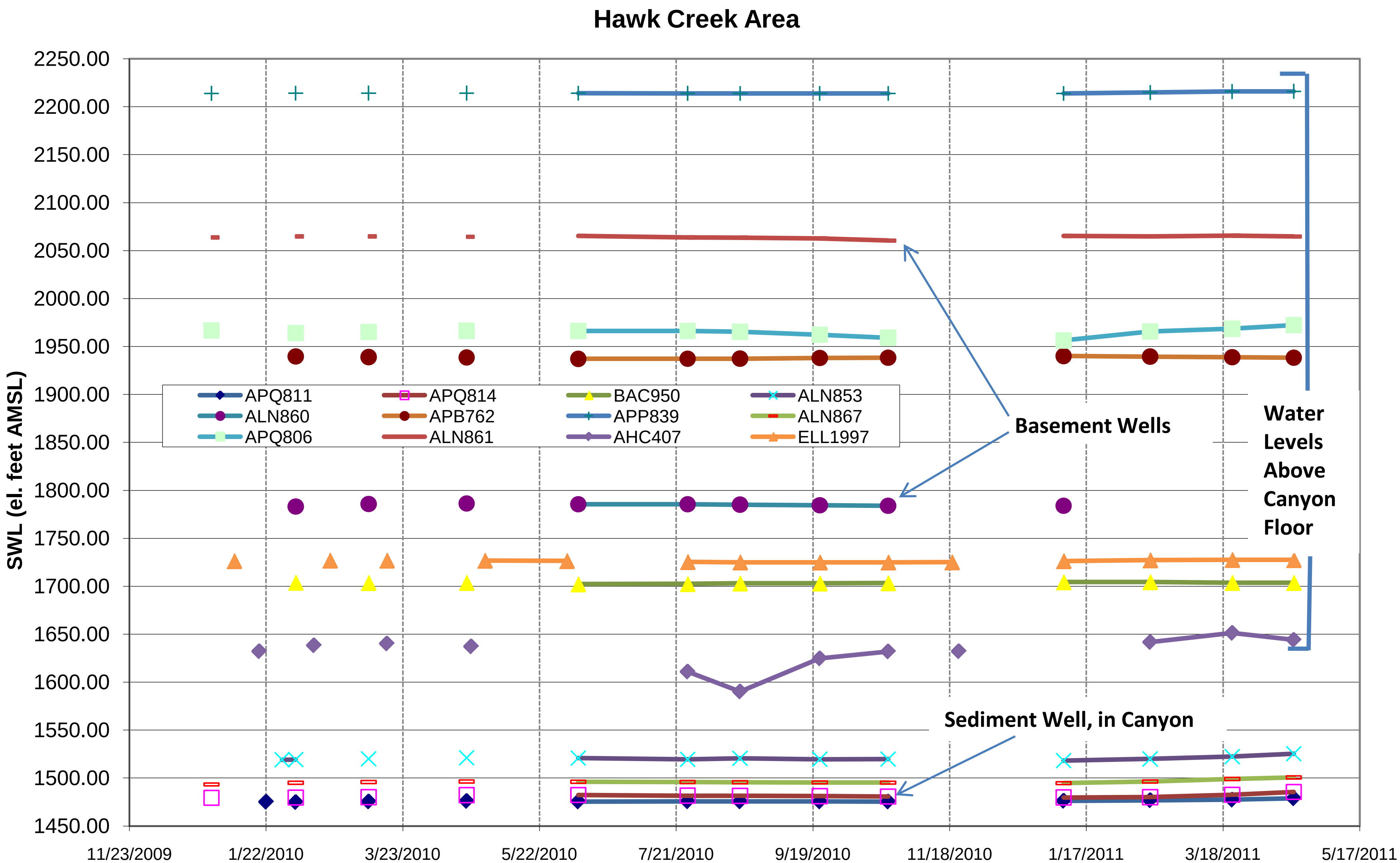

Figure 22. Hydrographs for wells in the Hawk Creek area. A variety of potential water-bearing zones present.

6.0 RECOMMENDATIONS AND PATH FORWARD

Currently, 41 basalt groundwater wells, six sand & gravel wells, and five granite wells are being gauged under the WRIA 53 Groundwater Gauging Project. The Gauging program has been occurring for a period of 16 months (12/29/09 through 4/19/11). No major sustained dropping in groundwater elevations have been observed to date. However, gauging has only occurred through one water year, and long time trends cannot be projected. In addition, a wet winter and spring has also occurred. In order to fully observe the influences of several seasonal fluctuations and longer range sustainability, several years of data collection must occur.

The WRIA 53 Planning Unit will continue to gauge the wells through June 2011. The Planning Unit has submitted grant applications for the next biennium to request funds to continue the stream and groundwater monitoring program in the watershed.

7.0 DATA STORAGE

Project documents are maintained at the Lincoln County Planning Department GIS office and the LCCD offices in Davenport, Washington. Specific Documents include:

1) Quality Assurance Project Plan for WRIA 53 – Lower Lake Roosevelt Watershed Groundwater Level Gauging Program: Northern Lincoln County, Washington, dated December 28th, 2009, completed by the WNR Group and GSI Water Solutions. This document is located within all project team members' offices, and kept on the WRIA 53 web-site and the Lincoln County Planning Department offices. A copy is also with each field technician measuring the wells.
2) Landowners access agreements. These documents are maintained at the LCCD offices in Davenport, Washington. Each field technician also has a copy of the access agreements while in the field.
3) Logs of wells being monitored. These logs were retrieved from the Ecology Water Well Log Database, and are kept within the LCCD office and the Lincoln County Planning Department offices in Davenport, Washington. Field copies are also with the field technicians sampling the wells.
4) Groundwater level databases. Draft databases and maps are compiled by the LCCD staff and sent to the Lincoln County Planning Department and WNR Group. Interpretation of field data is conducted by the WNR Group and final databases maintained at their office and the Lincoln County Planning Department office.
5) Surface water gauging databases. Draft databases and maps are compiled by the LCCD staff and sent to the Lincoln County Planning Department and WNR Group. Interpretation of field data is conducted by the WNR Group and final databases maintained at their office and the Lincoln County Planning Department office.

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