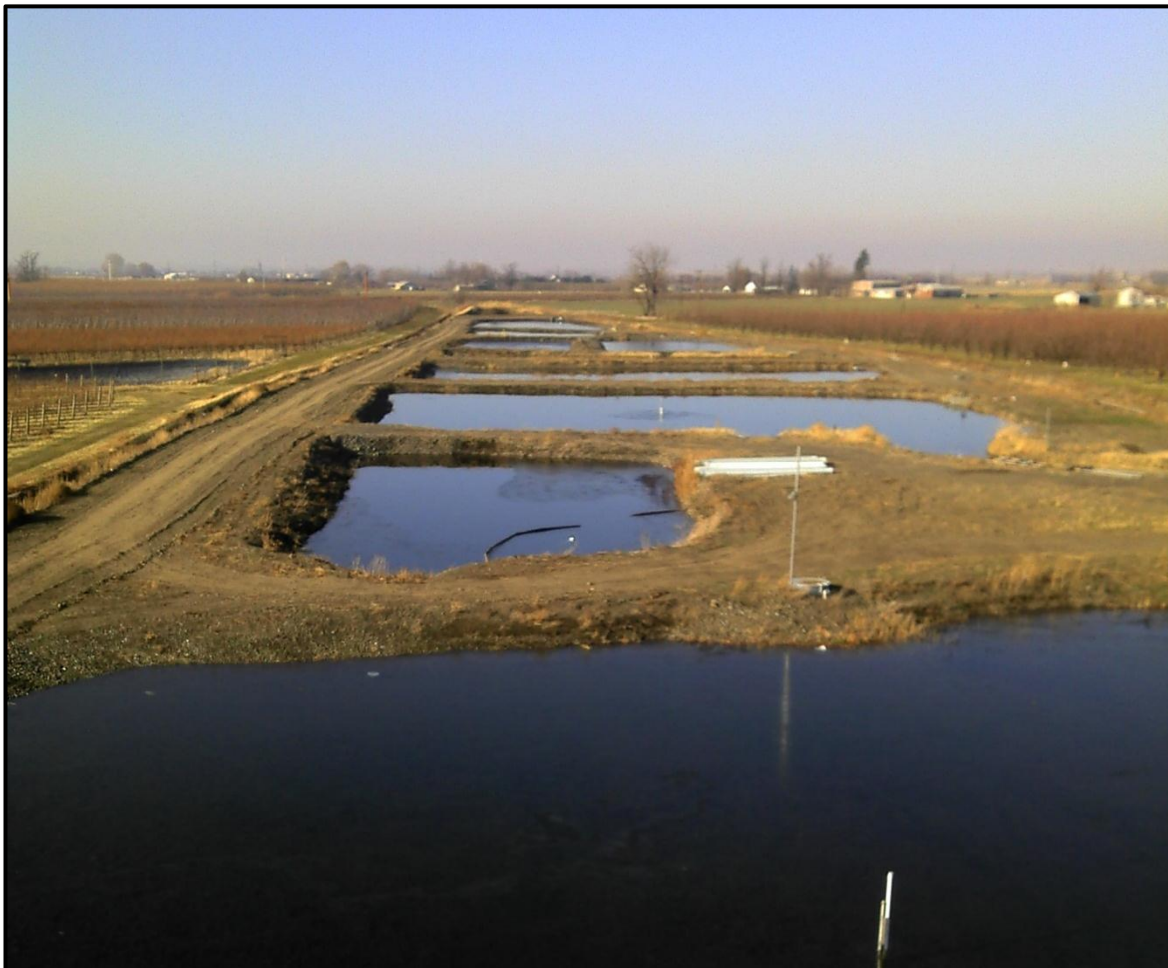
Hydrogeologic Setting and Source Water and Groundwater Monitoring and Reporting Plan for the Hudson Bay District Improvement Company Multi-Site Alluvial Aquifer Limited License Application LL1433, Umatilla County, Oregon



Prepared for:

Walla Walla Basin Watershed Council and Hudson Bay District Improvement Company

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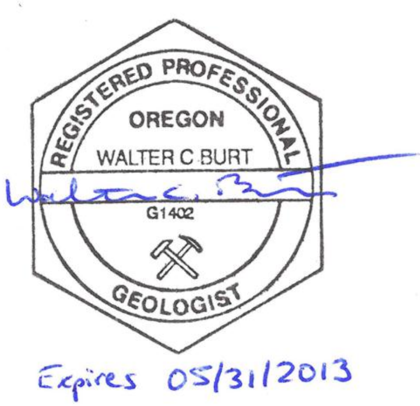

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INTRODUCTION

This document was prepared to fulfill certain requirements in Oregon Administrative Rules (OAR) 690-350-0110 through 0130 in support of the application for artificial recharge (AR) Limited License LL1433. The Hudson Bay District Improvement Company (HBDIC) is the owner of the project, which will be jointly managed with the Walla Walla Basin Watershed Council (WWBWC). The application for Limited License LL1433 was submitted to the Oregon Water Resources Department (OWRD) in September 2012. The HBDIC project includes up to seven recharge facilities located at different sites. Because of the unique nature of this project with distributed recharge facilities, as well as the availability of a body of information from other related or nearby recharge projects, OWRD staff requested that the applicant provide a summary compilation of the hydrogeologic information relevant to the overall project area and specific recharge sites, as well as a monitoring plan for the AR project. This document has been prepared in response to OWRD's request.

The objectives of the document are three-fold: (1) summarize the hydrogeologic setting of the recharge sites listed in the application for LL1433,(2) present a proposed source water and groundwater monitoring plan and (3) present a proposed water level monitoring plan (groundwater and surface water). All of these document elements were prepared in support of the Limited License application. The project described in this document and to be permitted under LL1433 is a multi-site aquifer recharge (AR) project. The recharge sites included in this project are referred to as Anspach, Trumbull, Hulette Johnson, NW Umapine, Dugger, Barrett, and ODOT (Figure 1). At this time only one of these sites, Hulette Johnson, is active. Pilot testing at the other sites will be initiated as the HBDIC and WWBWC are able to complete infrastructure improvements necessary to operate the sites. Current information regarding each of the seven sites, including recharge facilities, local hydrogeologic conditions and proposed monitoring, are summarized in this report.

Water quality data collected from three active sites (Hewlett-Johnson, Stiller Pond and Locher Road) and one inactive site (Hall-Wentland) in the greater Walla Walla Basin have shown that AR activities conducted to-date in the Walla Walla Basin have not lead to degradation of the alluvial groundwater system (GSI, 2009a, 2009b; WWBWC, 2010). Given this, the dispersed nature of the individual AR sites, and the common source water for this proposed program, the monitoring approach described herein focused on evaluating the effects of each recharge season on water quality using a dispersed, but integrated, monitoring network.

The balance of this document includes the following:

1. A summary of AR sites to be covered under LL1433 and project goals.
2. A description of alluvial aquifer hydrogeology in the project area and immediate vicinity of each site.
3. The scope of the proposed monitoring effort, including:
    a. Proposed number, locations, and physical characteristics of monitoring points.
    b. Constituents to be monitored for.
    c. Sample collection frequency.
4. Quality assurance and quality control (QA/QC) elements.
5. Reporting.

AQUIFER RECHARGE SITES AND PROJECT GOALS

Project Goals

The overarching goal of the proposed aquifer recharge projects is to restore and maintain the shallow alluvial aquifer for the benefit of people, the environment and wildlife. Specific goals of the projects include: (1) stopping and reversing the declines seen in the shallow alluvial aquifer system throughout the Walla Walla Valley, (2) reducing the hydraulic gradient away from streams and creeks in the valley to reduce surface water seepage, especially during dry summer months, and (3) restoring flows to springs that have either dried up or have reduced flow. .

Recharge planned to be conducted under Limited License LL1433 will occur at seven separate sites shown in Figure 1. Of the seven sites listed under LL1433, one is currently active. The active site, Hulette Johnson (also commonly referred to in the past as the Hudson Bay site) has been actively monitored for several years while operating under limited license LL1189, which is still in effect. This section summarizes the basic physical layout and planned sequencing of construction and operation of each of the seven sites.

Hulette Johnson

The Hulette Johnson site is an operational recharge site consisting of a combination of infiltration basins and infiltration galleries. The recharge capacity of the site ranges between 15 to 18 cubic feet per second (cfs). The site is located between County Road 650 and Hogden Road in SE ¼, SW ¼, Sec. 33, T6N, R35E, northwest of Milton-Freewater, OR (Figures 1, 2 and 3). There are 7 wells on or very near the site, including: 3 up-gradient wells (GW40, GW39 and GW41), one mid-site well (GW45), and 5 down-gradient wells (GW35, GW46, GW47, GW48, and GW118). Wells GW45, GW46, GW47, and GW48 are purpose-built monitoring wells which were drilled and constructed as a part of the original operation of the site several years ago. These wells have been used at various times for water quality monitoring and as part of the basin-wide WWBWC water level monitoring network. The other wells noted here also have been used in the basin-wide water level monitoring network. The Hulette Johnson site will be operated during the 2012/2013 recharge season under the existing limited license LL1189 until issuance of LL1433.

Recharge source water is delivered to the site from the White Ditch. Water delivery and infiltration basin operation is managed by HBDIC. The infiltration galleries are managed by the WWBWC.

Anspach

The Anspach site is currently under construction and will be brought into use in late 2012, pending issuance of the new limited license. The Anspach site is planned to consist of an approximately 5 cfs infiltration gallery located east of Winesap Road in NW ¼, NW ¼, Sec. 30, T6N, R35E, just outside of Milton-Freewater, OR (Figures 1, 2, and 4). There is an existing well (GW135) located at the up-gradient, southeastern corner of the proposed site. A second existing well (GW23) is located generally down gradient of, and west southwest of, the proposed site. These are water wells that have been adapted for use in the basin-wide water level monitoring network. A purpose-built monitoring well, designated PMW2, is currently proposed for the east side of the proposed site.

Recharge source water will be delivered by diverting from the HBDIC canal just west of where it crosses Old Milton Highway/Lamb Street. Water will flow through a pipeline either along the north or south edge of the property to the south of the canal and then turn south to deliver water to the project property.   HBDIC will be in charge of diverting recharge water to the site from the canal.

Trumbull

The Trumbull site will consist of a 3 to 5 cfs infiltration gallery, which will be located between the Umapine Highway and Trumbull Road in NW ¼, SW ¼, Sec. 27, T6N, R34E northwest of Milton-Freewater, OR (Figures 1, 2, and 5).   The Trumbull site will be brought into use in late 2012, pending issuance of the limited license. There are no existing monitoring wells located at the site. However, an existing purpose-built monitoring well (GW117) used in the basin-wide water level monitoring program is located approximately 0.3 to 0.4 miles east and up-gradient of the site. Two proposed purpose built wells, PMW3 and PMW4, currently are planned for locations generally 0.3 to 0.4 miles to the west and northwest of the Trumbull site (Figure 5). These locations are generally down gradient of the proposed site, and tentatively planned for installation in the autumn of 2012.

Recharge source water would be delivered to the site from the North Lateral into an infiltration gallery. HBDIC will be responsible for diverting water to the site.

NW Umapine

The NW Umapine site is planned to consist of a 5 cfs infiltration basin located north of the Umapine-Stateline Road and west of State Road 332 in SW ¼, SE ¼, T6N, R34E just northwest of Umapine, OR (Figures 1, 2 and 6). The NW Umapine facility is anticipated to be brought on line in late 2012/early 2013, pending issuance of the limited license. The infiltration basin will be built in a previously excavated pit that exists on the site. Only a portion of the pit will be used as an infiltration basin. There are no monitoring wells or observation wells present on the site. Existing wells in the general area of the site include GW34, GW36, GW63, and GW119, all of which are part of the basin-wide water level monitoring network. GW119 is a purpose built monitoring well which the others are water wells which have been adapted for use in the water level monitoring network. Two new purpose built wells are proposed for the area of this site, PMW1 located to the south-southeast and PMW5 located just to the west.

Recharge source water would be diverted from the Richartz pipeline to the basin. HBDIC will manage water to the site by a turn out from the Richartz pipeline.

Barrett

The proposed Barrett recharge facility will be located at a site between County Road 517 and Chuckhole Lane in SW ¼, SE ¼, Sec. 34, T6N, R35E, between the Anspach and Hewlett-Johnson sites (Figures 1, 2, and 7). The recharge facility is currently planned to consist of an infiltration gallery capable of 3 cfs of recharge, and is planned to be brought online in late 2012/early 2013. Only one well is in the immediate vicinity of this site, well GW62, which is located up gradient of the facility. This well is a water well adapted for use in the basin-wide water level monitoring program.

Recharge source water will be delivered from the Barrett pipeline into the currently proposed infiltration gallery. HBDIC will be responsible for operating the diversion into the site.

Dugger

This proposed recharge facility will be located at a site between Phillips Road and Ringer Road in NW ¼, SE ¼, Sec. 30, T6N, R35E (Figures 1, 2, and 8). The site is planned to be brought into operation in late 2013/early 2014, and the final design of the site has not yet been determined. There are two existing monitoring wells near the site, both part of the basin-wide water level monitoring network. Well GW36 (a water well) is located just north of the proposed site, and likely transverse to the groundwater flow direction in the area. This well, and a more distal, existing, purpose-built monitoring well, GW119, also located transverse to the anticipated groundwater flow direction, would at a minimum have utility in tracking water level changes in the area of the proposed site. On new purpose built monitoring well is proposed for the site. It (PMW1) would be located just west of the proposed recharge facility.

Water will be diverted off the White Ditch to feed the project. HBDIC will manage water to the site by a turn out from the ditch.

ODOT

The ODOT site is located SW ¼, NW ¼, Sec. 34, T6N, R35E (Figures 1, 2, and 9). The site is planned to be brought into operation in late 2013/early 2014. The facility is tentatively planned to consist of an infiltration basin. Water will be delivered to the site from the White Ditch, upstream of the Hulette Johnson site. Once the design for the site is finalized and planned monitoring points have been established, this monitoring plan will be amended to incorporate the updated information for the site.

WALLA WALLA BASIN HYDROGEOLOGIC SETTING

The goal of this section is to present a summary of alluvial aquifer hydrogeologic conditions regionally and within area of the HBDIC multi-site AR project. This summary is intended to provide the physical framework, or context, for the planned monitoring. It is not intended to provide detailed information about the groundwater system of the Walla Walla Valley. In addition, it does not include a discussion or summary of the deeper basalt aquifer systems underlying the area. For more details of area hydrogeology, the reader is referred to Newcomb (1965), Barker and McNish (1976), GSI (2007, 2009a, 2009b) and WWBWC (2010) and other citations as presented herein.

Hydrostratigraphy

Five alluvial sediment hydrostratigraphic units are mapped in the project area, including: (1) Quaternary fine unit, (2) Quaternary coarse unit, (3) Mio-Pliocene upper coarse unit, (4) Mio-Pliocene fine unit, and (5) Mio-Pliocene lower coarse unit. Figure 10 illustrates the stratigraphic relationships between the 5 mapped units and top of basalt. The following sections describe the basic physical characteristics of each suprabasalt sediment unit and top of basalt.

Quaternary Units

Quaternary Fine Unit

Newcomb (1965) and several subsequent investigators (Fecht and others, 1987; Busacca and MacDonald, 1994; Waitt and others, 1994) described a variety of Quaternary aged fine (clay/silt/fine sand dominated) units in the area of the Walla Walla Basin. Above elevations of approximately 1150 to 1200 feet above mean sea level (msl), these strata consist predominantly of loess. Isolated hills found on the valley floor and much of the upland area north of the Walla Walla River consist predominantly of Missoula flood deposited silt and sand referred to as the Touchet Beds. Reworked flood deposits and loess form local accumulations of fine strata across the valley floor near major streams. These strata are grouped into a single unit referred to as the Quaternary fine unit. The thickness of this unit varies greatly, depending on local topography, depth of stream incision, and original depositional patterns.

Variation in unit thickness and its absence locally, especially along modern stream courses, likely reflects both depositional factors and post-deposition erosion. For example, the wide distribution of the Quaternary fine unit around the northern edge of the Basin primarily reflects widespread deposition followed by localized deep erosion along relatively, ephemeral stream courses. Conversely, the fact that the unit is thin to absent along major stream courses (notably the Touchet River, Walla Walla River, and Mill Creek) likely reflects, at least in large part, the erosive effects of these major streams incising into and removing Pleistocene Cataclysmic Flood deposits and eolian deposited fines.

Quaternary Coarse Unit

Uncemented and nonindurated sandy to gravelly strata is found in the shallow subsurface beneath much of the Basin. These gravely deposits are basaltic, moderately to well bedded, have a silty to sandy matrix, and contain thin, local silt interbeds. These uncemented and nonindurated basaltic gravels generally are equivalent to Newcomb's (1965) younger alluvial sand and gravel and are referred to currently as the Quaternary coarse unit. This sequence of uncemented gravel is interpreted to record stream deposition in the Walla Walla Basin by streams draining off the adjacent Blue Mountains. These streams are inferred to include the ancestral courses of the modern stream drainage. Based on stratigraphic relationships the Quaternary coarse unit predates, is contemporaneous with, and post-dates Missoula flood deposits. Given this, the Quaternary coarse unit probably ranges in age from a few years old to as old as 1 million years or more.

Both depositional and erosional mechanisms can explain Quaternary coarse unit distribution. Its planar-tabular distribution in the Milton-Freewater area and the area beneath and east of Walla Walla probably reflects deposition in shallow, braided channel complexes on an active (or recently active) braid plain. To the west, elongate patterns may reflect gravel deposition down the topographically low axis of the Basin as it has existed in the recent geologic past (last 1 to 2 million years). The elongate areas where the unit is absent potentially reflect areas of non-deposition because of the absence of channels and/or post-depositional erosion. The highs and lows apparent in the top of this unit along the base of the Horse Heaven Hills are interpreted to be related to the deformation and uplift of these hills. During that uplift, the surface of the unit has been deformed, in some areas uplifted, in other areas, down-dropped.

Mio-Pliocene Strata

The primary basin-filling alluvial strata in the Basin include a sequence of indurated sand, gravel, siltstone, and claystone generally equivalent to Newcomb's (1965) old gravel and clay. Based on lithologic and stratigraphic relationships these indurated suprabasalt sediments are inferred to have a Miocene to late Pliocene age (10+ to ~3 million years old). These strata are subdivided into three mappable units – Mio-Pliocene upper coarse unit, Mio-Pliocene fine unit, and Mio-Pliocene basalt coarse unit.

Mio-Pliocene Upper Coarse Unit

The Mio-Pliocene upper coarse unit consists of a sequence of variably cemented sandy gravel, with a muddy to sandy, silicic to calcic matrix. This unit underlies much of the Walla Walla Basin. Field reconnaissance reveals thin, localized, discontinuous caliche at the top of these strata at some locations. Based on physical characteristics displayed by analogous strata in rare outcrops, field reconnaissance, and a small number of borehole log descriptions these strata are predominantly basaltic in composition and typically have a slightly too well developed red, red brown, and yellow brown color. The Mio-

Pliocene upper coarse unit generally is continuous beneath the entire Basin, being absent only in a few, relatively small areas.

Isopach data for this unit shows that it varies greatly in thickness, ranging from just a few feet thick to over 500 feet thick. The thickest accumulations of the unit tend to be along the southern edge of the Basin adjacent to the base of the Horse Heaven Hills where it generally ranges from 200 to more than 500 feet thick, and along the eastern edge of the Basin. The unit is interpreted to have been deposited predominantly in a braided stream system by the ancestral Walla Walla River, Mill Creek, and larger tributaries. These streams delivered large volumes of coarse detritus onto the basin floor as it subsided and the bounding uplands were uplifted. Generally, these streams merged into a single, main Walla Walla River ancestral stream that generally flowed to the west, much like the modern stream. In addition, faulting may also have played a role in unit distribution.

Mio-Pliocene Fine Unit

The Mio-Pliocene upper coarse unit generally is underlain by fine deposits variously described as silt, clay, sandy clay, and sandy mud having blue, green, gray, brown, and yellow colors. These strata are designated the Mio-Pliocene fine unit. This unit is thickest in the northeastern, north, central, and western Basin where it can range between 300 and 500 feet thick. These areas generally are located north and west of areas of thickest accumulation of the overlying Mio-Pliocene upper coarse unit. Depositional, erosional, and structural factors similar to those that are interpreted to affect the overlying unit also are interpreted to have had a role in controlling Mio-Pliocene fine unit distribution.

Mio-Pliocene Basal Coarse Unit

The basal coarse unit consists of arkosic-micaceous sand and silt in the basal portion of the Mio-Pliocene section directly overlying basalt. These strata form an interval several tens of feet to over 100 feet thick. This unit, with its distinctive arkosic mineralogy, is very different petrographically from other strata comprising the Mio-Pliocene sequence in the Basin. Because of this distinctive mineralogy, this unit is inferred to have been deposited by the ancestral Salmon-Clearwater River, which entered the Basin from the north.

Top of Basalt

The alluvial sequence overlies the Columbia River Basalt Group (CRBG) beneath the entire basin area. The top of the CRBG, while irregular, forms the base of the alluvial sequence, and it generally appears to dip downwards off the highlands surrounding the Basin, in to the center of the Basin. Given this, the top of basalt in the Basin ranges from the ground surface around the basin margins, to a depth of over 800 feet near the center of the basin.

Alluvial Aquifer Hydrogeology

Groundwater in the Walla Walla Basin region occurs in two principal aquifer systems: (1) the unconfined to confined suprabasalt sediment (“alluvial”) aquifer system which is primarily hosted by Mio-Pliocene conglomerate and Quaternary Coarse Unit, and (2) the underlying confined CRBG aquifer system (Newcomb, 1965).

The majority of the alluvial aquifer is hosted by Mio-Pliocene strata, although the uppermost part of the aquifer is found, at least locally, in the overlying Quaternary coarse unit. The alluvial aquifer is generally characterized as unconfined, but it does, at least locally, display evidence of confined conditions. Variation between confined and unconfined conditions within the aquifer system is probably controlled by sediment lithology (e.g., facies – coarse versus fine) and induration (e.g., cementation, compaction). Groundwater movement into, and through, the suprabasalt aquifer also is inferred to be controlled by sediment lithology and induration. Generally, the deeper portions of the alluvial aquifer unit are more likely to exhibit confined conditions relative to the shallower portions of the aquifer.

Aquifer Properties

Given the physical properties of the Quaternary course unit (non-indurated sand and gravel) versus those of the Mio-Pliocene upper coarse unit (e.g., finer matrix and the presence of naturally occurring cement), the Mio-Pliocene upper coarse unit probably has generally lower permeability and porosity than the Quaternary coarse unit. Consequently, suprabasalt aquifer groundwater flow velocities are inferred to be less where the water table lies within the Mio-Pliocene strata and/or the gradients are higher than where it lies within the younger, more permeable Quaternary strata. In addition, where the Quaternary coarse unit is saturated, this uncemented, high permeability gravel and sand may form preferred pathways for groundwater movement and areas of increased infiltration capacity in the shallow parts of the suprabasalt aquifer system.

Very little hydraulic property information is available for the alluvial aquifer system. Newcomb (1965) reports average effective porosity of 5 percent in his old gravel (i.e., the Mio-Pliocene upper coarse unit). Given the physical characteristics of the overlying Quaternary coarse unit, we suspect its average effective porosity is higher.

Basin-wide estimates of the hydraulic properties of alluvial aquifer system were made by Barker and Mac Nish (1976) as part of their effort to produce a digital model of this aquifer system. This modeling work used estimated hydraulic conductivity of $1.5x10^{-4}$ feet/second to $7.6x10^{-3}$ feet/second and transmissivity of 10,000 $feet^2$/day to 60,000 $feet^2$/day for the entire alluvial aquifer system. As with Newcomb's (1965) effective porosity estimate, we suspect hydraulic conductivity and transmissivity would be higher in saturated Quaternary coarse unit strata than in the saturated Mio-Pliocene upper coarse unit.

Groundwater Level and Flow Direction

Recent efforts by the WWBWC have begun to build a picture of alluvial aquifer water level conditions in the eastern and southern Walla Walla Basin. This data is compiled and available online at WWBWC website at http://www.wwbwc.org. Figure 11 is a water table map for the basin built from these data. Based on these data, and earlier investigations the following basic observations relative to alluvial aquifer water level and flow direction can be made:

- Groundwater flow in the alluvial aquifer system generally is from east to west. Locally this flow may converge towards the Walla Walla River and other streams where the alluvial aquifer water table is higher than the stream. Where this occurs, streams are, in part, fed by groundwater discharge. However, along many reaches of the Walla Walla River and other streams in the Basin, the alluvial water table may at least locally be below the bed of the stream during some or all of the year. When and where this occurs, such stream reaches probably lose water to the alluvial aquifer, thus acting as a recharge source for groundwater.
- Water level within the alluvial aquifer varies seasonally. Barker and MacNish (1976, p. 25) determined that the month of January was the time of year when this aquifer is under the smallest amount of pumping stress and that water table most reflect unmodified conditions. In some portions of the Basin, seasonal changes in the water table elevation can be as great as 50 feet (Newcomb, 1965; Pacific Groundwater Group, 1995).

- Groundwater level declines have been ongoing for a number of years, although recent AR efforts have reversed these trends at least locally near existing sites, in particular the Hulette Johnson site (WWBWC, 2010 – attached as Appendix E).

Aquifer Recharge and Discharge

Recharge to the alluvial aquifer is derived from infiltration of surface waters (e.g., where streams enter the basin), leakage from irrigation ditches, applied irrigation water, direct precipitation, and to a lesser extent leakage from the CRBG aquifer system (Newcomb, 1965; Barker and MacNish, 1976; Pacific Groundwater Group, 1995). The majority of this recharge probably occurs in the spring when streams flowing into the Basin reach peak discharges. Precipitation on parts of the Basin floor where the Quaternary coarse unit and older the Miocene-Pliocene upper coarse unit lie at, or near, the surface may also provide some natural recharge. Evaluation of these various sources of recharge to the alluvial aquifer suggests that direct precipitation and applied irrigation water are the dominant sources of recharge (Bauer and Vaccaro, 1990; Pacific Groundwater Group, 1995; WWBWC, 2010). With flood control and channelization of the Walla Walla River and smaller streams, natural recharge via infiltration from surface waters has probably decreased with continued development.

Artificial recharge of the alluvial aquifer from agricultural practices and water conveyance systems has become an important component of the Basin's hydrologic system since the 1920's and 1930's. This recharge is thought to have historically contributed water to at least some shallow water wells and springs (Newcomb, 1965; WWBWC, 2010). Artificial recharge probably occurs through irrigation ditch leakage and infiltration past the root zone in irrigated fields. With the advent of ditch/channel lining and reduction in the practice of flood irrigation, this type of recharge has probably decreased. Reduced natural and artificial recharge and pumping account for decreased alluvial aquifer water table levels. Decline in water table levels in-turn probably account for reduced spring flows and base level discharge to the Walla Walla River.

Discharge from the alluvial aquifer occurs in a number of ways, including direct discharge to streams, springs and seeps, pumped water wells, evapotranspiration, and localized leakage to the CRBG aquifer system (Newcomb, 1965; Barker and Mac Nish, 1976; Pacific Groundwater Group, 1995).

Alluvial Aquifer Water Quality

Historical water quality data available include a groundwater quality report prepared by Richerson and Cole (2000) and source water and groundwater quality reporting done for several AR sites, including the Hulette Johnson site. Based on Richerson and Cole (2000), the Hulette Johnson site data (WWBWC, 2010), and groundwater quality data collected from other AR sites in the Walla Walla Basin (GSI, 2009a, 2009b) some basic observations with respect to alluvial aquifer water quality can be made, including the following:

- With respect to nutrient type constituents, including nitrate-N, TKN, phosphate, and ortho-phosphate water quality in the area generally has not been significantly degraded. In addition, the groundwater down gradient of AR sites generally show declines in constituent concentrations, which are interpreted to reflect dilution of ambient groundwater concentrations by lower concentration AR water.
- Other parameters, such as TDS, chloride, and electrical conductivity also commonly show evidence of down gradient reductions attributed to AR activities. These trends are interpreted as evidence of dilution of these parameters in groundwater by AR water.

- The synthetic organic compound (SOC) data indicate that AR operations have essentially no influence on SOC's present in groundwater.
- In addition to these observations, the Hall-Wentland data are instructive as they show the importance of natural leakage from surface waters (which typically are the same waters these AR sites use for source water) in influencing local groundwater chemistry.

RECHARGE SITE HYDROGEOLOGY

Building on the preceding summary of basin wide hydrogeologic conditions, the following sections provide basic highlights of specific hydrogeologic conditions at each HBDIC project AR site. Geologic cross-sections for each site are built from the WWBWC's basin wide geologic and hydrogeologic model.

Hulette Johnson

Figure 12 provides a geologic cross-section of the Hulette Johnson site. Geologic units present in the vicinity of the site are as follows:

- Quaternary fines unit: This unit is interpreted to be essentially absent from this site, although thin surface occurrences are present offsite to the west and east. In addition, excavation work during infiltration gallery construction revealed a thin, local surface silty-sand that could be assigned to this unit. Nevertheless, where present in the immediate area, the unit is generally less than 10 feet thick.
- Quaternary coarse unit: This unit forms the uppermost geologic unit across the site area (except for the localized fines noted in the preceding bullet). Beneath the site the unit generally is interpreted to be 20 to 30 feet thick.
- Mio-Pliocene upper coarse unit: This unit underlies the entire site area and is interpreted to range from approximately 120 to 200 feet thick.
- Mio-Pliocene fine unit: This unit also underlies the entire site area where it is interpreted to be approximately 250 to 350 feet thick, increasing to the west-northwest.
- Mio-Pliocene basal coarse unit: This unit is not present beneath the site
- Top of Basalt: Beneath the site the top of basalt generally deepens to the west-northwest, ranging from approximately 425 feet bgs to 600 feet bgs.

The hydrogeology of the Hewlett-Johnson site is better understood than the other sites because of its active status, and has been previously reported on in WWBWC (2010). The alluvial aquifer water table generally varies between the basal part of the Quaternary coarse unit and the upper part of the Mio-Pliocene upper coarse unit, rising and falling seasonally and in response to AR and canal operations. Depth to water varies seasonally from 10 to 50 feet bgs according to on-site monitoring wells. Groundwater flow at the site generally is towards the northwest. The table below shows water volumes delivered to the Hulette Johnson site for each recharge season (Nov-May).

Recharge Season								
Spring 2004	2004-2005	2005-2006	2006-2007	2007-2008	2008-2009	2009-2010	2010-2011	2011-2012
~410 Acre Feet	~1870 Acre Feet	~ 2810 Acre Feet	~3230 Acre Feet	~2740 Acre Feet	~2840 Acre Feet	~3750 Acre Feet	~ 3700 Acre Feet *	~3970 Acre Feet

* Data collected for the first two months of the 2010-2011 recharge season was erroneous and/or missing. Water volumes for the first two months have been estimated based upon the 2009-2010 & 2011-2012 seasons

Anspach

Figure 13 provides a geologic cross-section of the Anspach site. Geologic units present at the Anspach site are as follows:

- Quaternary fines unit: This unit is interpreted to not be present at the site, but it is mapped in the area just to the west where it is less than 1 foot to approximately 20-30 feet thick.
- Quaternary coarse unit: At the site this unit is interpreted to extend from the ground surface downwards approximately 60 to 70 feet.
- Mio-Pliocene upper coarse unit: This unit is approximately 70 feet thick in the immediate vicinity of the site. To the east it is interpreted to directly overlie basalt. To the west it overlies the Mio-Pliocene fine unit.
- Mio-Pliocene fine unit: This unit is mapped as pinching out directly beneath the site. Just to the west and northwest of the site it is interpreted to thicken, as the top of basalt gets deeper.
- Mio-Pliocene basal coarse unit: This unit is not present beneath the site
- Top of Basalt: The site is interpreted to overlie an area where the top of basalt gets deeper just a short distance to the west. At and beneath the eastern part of the site top of basalt may be as little as 100 feet below ground surface (bgs). To the west it is interpreted to be over 250 feet bgs.

The alluvial aquifer water table generally lies at or near the top of the Mio-Pliocene upper coarse unit. Depth to water varies from about 15-35 feet depending on season (irrigation/non-irrigation). Groundwater flow direction in the alluvial aquifer at this site is interpreted to generally be to the west-northwest.

Trumbull

Figure 14 provides a geologic cross-section of the Trumbull site. Note, the specific location of the infiltration gallery currently envisioned for this site has yet to be determined. Geologic units present in the vicinity of the Trumbull site are as follows:

- Quaternary fines unit: This unit is only present in the area west of County Road 332. In that area it is less than 1 foot to approximately 15 feet thick.
- Quaternary coarse unit: This unit forms the uppermost geologic unit across the proposed site area where it is interpreted to range from 30 to 50 feet thick, thinning and pinching out to the west.
- Mio-Pliocene upper coarse unit: This unit underlies the entire site area and is interpreted to range from approximately 220 to 250 feet thick, thickening to the west.
- Mio-Pliocene fine unit: This unit also underlies the entire site area where it is interpreted to be approximately 300 feet thick.
- Mio-Pliocene basal coarse unit: This unit is not present beneath the site
- Top of Basalt: Beneath the site the top of basalt generally deepens to the west-northwest, ranging from approximately 550 feet bgs to 650 feet bgs.

The alluvial aquifer water table generally lies in the Quaternary coarse unit, resulting in the entire Mio-Pliocene upper coarse unit being saturated. In the immediate vicinity of the site depth to groundwater generally is 20 feet or less. However, a series of seasonal springs north of the site suggest groundwater in this area can be much shallower, at least seasonally. To the west, the depth to water is 45 feet bgs or greater just to the east of this site in well GW117. The groundwater flow direction is interpreted to be to the west-northwest.

NW Umapine

Figure 15 provides a geologic cross-section of the NW Umapine. Geologic units present in the vicinity of the site are as follows:

- Quaternary fines unit: This unit is interpreted to be present in the site area where it may be as much as 20 feet thick. However, at the site itself it is absent because it was removed during the excavation of the pit that will be used as the AR facility.
- Quaternary coarse unit: This unit is mapped to be present in the site area, but it is interpreted to be very thin, possibly less than 10 feet thick. As with the Quaternary fine unit, it is interpreted to be absent (as it was removed during digging) in the excavated pit which is planned as the AR facility.
- Mio-Pliocene upper coarse unit: This unit underlies the entire site area and is interpreted to range from approximately 200 to 250 feet thick. The existing pit identified as the candidate location for the infiltration basin is excavated into the top of the Mio-Pliocene upper coarse unit.
- Mio-Pliocene fine unit: This unit also underlies the entire site area where it is interpreted to be approximately 200 feet thick.
- Mio-Pliocene basal coarse unit: This unit is not present beneath the site
- Top of Basalt: Beneath the site the top of basalt generally lies at a depth of 500 feet bgs.

The depth to the alluvial aquifer water table is approximately 25 to 30 feet bgs (based on well GW34), which places the water table in the uppermost part of the Mio-Pliocene upper coarse unit.

Barrett

Figure 16 provides a geologic cross-section of the Barrett site. Geologic units present in the vicinity of the site are as follows:

- Quaternary fines unit: This unit is interpreted to be absent beneath the site.
- Quaternary coarse unit: This unit is interpreted to underlie the entire site area, ranging from approximately 30 to 50 feet thick.
- Mio-Pliocene upper coarse unit: This unit also underlies the entire site area and is interpreted to range from approximately 110 to 130 feet thick.
- Mio-Pliocene fine unit: This unit also underlies the entire site area where it is interpreted to be approximately 100 to 120 feet thick.
- Mio-Pliocene basal coarse unit: This unit is not present beneath the site
- Top of Basalt: Beneath the site the top of basalt appears to dip to the west-northwest and it lies at depths of 240 to 260 feet.

Beneath the Barrett site, the alluvial aquifer water table appears to generally lie at, or near, the bottom of the Quaternary coarse unit, at a depth of approximately 30 to 35 feet bgs. The groundwater flow direction at the site is generally to the northwest.

Dugger

Figure 17 provides a geologic cross-section of the Dugger site. Geologic units present in the vicinity of the site are as follows:

- Quaternary fines unit: This unit is interpreted to be present across most of the site area where it is interpreted to range from approximately 10 to 20 feet thick. Just to the south of the site the unit appears to pinch out.
- Quaternary coarse unit: This unit is interpreted to underlie the entire site area, ranging from approximately 20 to 30 feet thick.
- Mio-Pliocene upper coarse unit: This unit also underlies the entire site area and is interpreted to range from approximately 110 to 130 feet thick.
- Mio-Pliocene fine unit: This unit also underlies the entire site area where it is interpreted to be 300, or more, feet thick.
- Mio-Pliocene basal coarse unit: This unit is not present beneath the site
- Top of Basalt: Beneath the site the top of basalt appears to dip to the south, towards the Horse Heaven Hills. The top of basalt is interpreted to be approximately 475 to 525 feet bgs.

Beneath the Dugger site, the alluvial aquifer water table appears to generally lie at, or near, the bottom of the Quaternary coarse unit, at a depth of approximately 20 feet bgs. Although regional water level (Figure 11) shows groundwater flow to the west-northwest, Figure 17 suggests local water level may differ from this, at least at some times during the year. This will be evaluated further during site preparation work. If this flow direction proves to be correct, it is interpreted to be a local phenomenon.

ODOT

Figure 18 provides a geologic cross-section of the ODOT site. Geologic units present in the vicinity of the site are as follows:

- Quaternary fines unit: The Quaternary fine unit is interpreted to be absent this site.
- Quaternary coarse unit: This unit is interpreted to be approximately 20 to 30 feet thick at the site.
- Mio-Pliocene upper coarse unit: This unit is interpreted to be as much as 200 feet thick at the site.
- Mio-Pliocene fine unit: This unit underlies the entire site area and is interpreted to be approximately 200 feet thick.
- Mio-Pliocene basal coarse unit: This unit is not present beneath the site
- Top of Basalt: Beneath the site the top of basalt is interpreted to the northwest, ranging from depths of approximately 400 to 475 feet.

Beneath the ODOT site the alluvial aquifer water table appears to generally occur within the upper part of the Mio-Pliocene upper coarse unit, at a depth of approximately 30 to 40 feet bgs. The direction of groundwater flow at the site is generally towards the northwest.

PROPOSED MONITORING PLAN

This section presents the monitoring plan for the proposed multi-site AR limited license. This plan includes the following elements: source water and groundwater quality sampling and analysis, water level monitoring, and recharge water flow rate measurements. The proposed plan focuses on the objective of assessing the impacts to alluvial aquifer groundwater of the entire multi-site AR program. The following sections explain how this monitoring approach would be implemented, locations and constituents proposed for monitoring, and other supporting information relative to the monitoring program.

Water Quality Monitoring

Water quality monitoring for this multi-site AR project will integrate source water quality data from several locations in the canal delivery system with groundwater quality data collected from multiple locations to assess the impacts on area groundwater of the entire AR program. Under this programmatic approach individual AR facilities will be monitored to a greater or lesser extent in support of the entire program. This proposed programmatic approach was developed from evaluation of data from recharge projects in the region using similar source waters (Appendix A). Water quality sampling will be done for field parameters, cations, anions, metals, and synthetic organic compounds (SOC). Specifics regarding these are described in the following sections.

Water Sample Collection and Analysis for Field Parameters, Cation/Anions, and Metals

Recharge source water and alluvial groundwater will be sampled twice during each recharge cycle for analysis of a select list of indicator constituents considered to be most representative of the potential for AR degradation of alluvial aquifer groundwater quality, based on recharge water sources, adjacent land uses, and a review of AR data collected to-date at several sites in the Walla Walla Basin. The list of proposed analytes for is assembled using data from previous and on-going AR operations in the region using similar source water. Basic elements of the water quality sampling and analysis include the following:

- Samples will be collected at monitoring points listed in the following sections twice each recharge cycle: (1) within one week of the start of recharge operations, and (2) within one week after termination of each recharge season, commonly in May.
- Each sample will be analyzed for the following constituents: pH, temperature, electrical conductivity, dissolved oxygen, nitrate-N, TKN, sulfate, chloride, calcium, alkalinity, ortho-phosphate, sodium, total organic carbon, potassium, aluminum, magnesium, iron (dissolved), and manganese (dissolved). Table 1 lists these analytes and recommended analytical methods and method reporting limits.
- Turbidity, total dissolved solids, and total suspended solids data also will be collected to support operational goals, but not reported as a part of this monitoring plan.

Table 1. Proposed analyte list, analytical methods, and method reporting limits.

Analyte	Analytical method	Method reporting limit (mg/L)
pH	-	-
Temperature (^oC)	-	-
Electrical conductivity (mS/cm)	-	-
Dissolved oxygen (mg/L)	-	-
Total organic carbon	SM 5310B	0.5
Nitrate-N (mg/L)	EPA 300.0	0.1
TKN (mg/L)	SM 4500 N B	0.1
Sulfate (mg/L)	EPA 300.0	0.1

Analyte	Analytical method	Method reporting limit (mg/L)
Chloride (mg/L)	EPA 300.0	0.1
Alkalinity (mg/L)	SM232OB	5
Calcium (mg/L)	EPA 200.7	0.1
Ortho-phosphate (mg/L)	EPA 300.0	0.1
Sodium (mg/L)	SPA 200.7	0.1
Potassium (mg/L)	EPA 200.7	0.1
Magnesium (mg/L)	EPA 200.7	0.1
Aluminum (mg/L)	EPA 200.7	0.01
Iron (dissolved) (mg/L)	EPA 200.7	0.01
Manganese (dissolved) (mg/L)	EPA 200.7	0.05

SOC Sample Collection and Analysis

A single SOC alluvial groundwater sample will be collected each season. This sample will be collected within one week after termination of each recharge season, commonly in May. The same analyte list currently sampled for at the Hulette Johnson site is proposed for this monitoring plan. These are as follows:

- Rubigan (Fenarimol)
- Ridomil (Metalxyl)
- Systhane/Rally (Myclobutanil)
- Devrinol (Napropamide)
- DDD-DDE-DDT
- Elgetol (DNOC sodium salt)
- Alar/B-Nine (Daminozide)
- Lindane (Lindane)

Source Water Quality Monitoring Locations

Source water quality sampling will be conducted at several locations in the canal and pipeline recharge water conveyance system. Source water monitoring sites will be in the distribution system at select locations up-stream of AR facilities. Specific source water monitoring locations, both existing and potential future locations, are shown on Figure 19 and are as follows:

- Source water monitoring location S-1 will be established in the White Ditch canal up-stream of the proposed diversion to the Anspach site. Samples from this location represent source water diverted to the Anspach site and the Barrett site. Also, this location is up-stream of all recharge sites and this is considered representative of overall source water conditions.
- Source water monitoring location S-2 will be established on the White Ditch canal immediately upstream of the proposed diversion for the ODOT and Trumball site. This site is representative of source water quality diverted to the Hulette-Johnson site, ODOT site, and the Trumball site.
- Source water monitoring point S-3 will be established at the up-stream end of the Richartz Pipeline to represent source water delivered to the NW Umapine site.

Groundwater Quality Monitoring Locations

Groundwater quality monitoring will be conducted at monitoring points located to evaluate overall AR program impacts on up-gradient and down-gradient water quality for the multi-site AR project and also provide site-specific water quality data for specific AR locations to be operated under the proposed limited license.

Planned 2012/2013 recharge season groundwater monitoring locations (all in wells built to the monitoring well standard) and the general rationale for each are listed below and shown on Figure 2.

- PNW2: provides up gradient monitoring for the entire project and specifically for the Anspach and Barrett sites.
- GW46: provides down gradient monitoring for the Hulette Johnson site.
- GW117: provides water quality information for the central region of the AR program, and up gradient monitoring for the Trumball site.
- PNW3: provides down gradient coverage for the Trumbull site.
- GW119: provides up gradient coverage for both the NW Umapine site and it would provide a programmatic monitoring location further down gradient than the aforementioned wells do.
- PMW5: provides down gradient monitoring for the NW Umapine site and it provides the furthest down gradient monitoring point in the entire program.
    - This well will be the sampling location for the proposed SOC sampling event at the conclusion of each recharge season.

Data from these 6 wells, when combined with the source water data collected at the three locations named in the preceding section will be used to interpret water quality impacts of the entire proposed AR program. As this program develops it is anticipated that these monitoring locations will be periodically re-evaluated and potentially modified. One modification would be the addition of proposed well PMW-1 to the area immediately down gradient of the Dugger site. This monitoring system could expand or contract as the number of individual AR sites covered by it changes, such as when new sites are added or old sites are decommissioned.

Flow and Water Level Monitoring

Surface Flow Monitoring

Flow monitoring will be done in the canals or pipes feeding each individual AR site. The objective of flow monitoring is to document the volumes of water delivered to each AR site during its operations. A flow monitoring point has already been established for the Hulette Johnson site, and it will continue to be used for this project. For the other sites these monitoring points will be established as each facility becomes operational.

Each aquifer recharge site will have either a rated intake structure (Hulette Johnson) or have a flow meter installed at the diversion from the irrigation canal (Anspach, Barrett, NW Umapine, ODOT, Trumbull). Water volume delivered to each site will be collected and stored by the WWBWC and reported to OWRD in a written annual report which will include digital data. See Figure 20 for surface water monitoring locations. See Appendix B for details on surface measurement protocols and data management.

Groundwater Level Monitoring

The WWBWC currently maintains a water level monitoring program in the area of this project. Figure 2 shows the locations of wells in the WWBWC program in the project area and Figure 20 shows the WWBWC Oregon monitoring network. With the addition of 5 new wells shown on Figure 2, this project proposes to use the WWBWC water level monitoring program to track water level changes related to the proposed AR efforts. See Appendix C for groundwater level data and details on groundwater level monitoring protocols and data management.

Groundwater level monitoring locations provide useful information on aquifer recharge influences to the shallow aquifer. Wells were located to try to capture up-gradient to down-gradient influences from individual recharge projects. However, based upon limited funding and the spatial nature of the aquifer, it is not possible to have wells at every desired location. Wells in the water level network provide year round data for analysis of groundwater changes during recharge activities and also for longer term analysis of groundwater recovery (i.e. increased groundwater storage). Many of the wells used for monitoring have secondary hydraulic influences other than aquifer recharge. Wells located near the White Ditch show responses to ditch activity. A few wells may show draw down caused by pumping from other wells. See Appendix D for details on well locations (GPS coordinates) and UMAT numbers. Groundwater level data will be included in digital format with the written annual report.

SAMPLING AND ANALYSIS PROCEDURES

The equipment needs and sampling procedures proposed for this investigation are provided in the following sections.

Water Level Measurements

A static water level measurement will be obtained from each well prior to initiating water quality sampling. An electronic water level meter will be used to measure the depth to groundwater in each well to the nearest 0.01 foot. Static water levels must be measured prior to introducing any purging or sampling equipment in the well. Each measurement will be taken against the reference point located on top of the well casing. The static water levels in all wells should be measured on the same day for each site. Coordination with periodic sampling of other wells in the vicinity should be attempted.

Water Sampling Equipment

Sampling will be conducted using the following specific equipment, as follows:

- Submersible pump (Grundfos or similar) or dedicated bailers/sampling line.
- Temperature measuring instrument.
- pH and specific conductivity meter(s) with calibration reagent.
- Water level meter (0.01 ft resolution).
- Shipping cooler(s) with ice packs or ice.
- Five gallon pail marked at the 5 gallon level, stopwatch.
- Laboratory supplied sample containers with appropriate preservatives.
- Tap water, deionized water, phosphate-free soap, cleaning brushes, log sheets or field notebook.
- Chain of custody forms.

Additional information relative to periodic and contingent sampling is described below.

Decontamination

All non-disposable field equipment that may potentially come in contact with any soil or water sample shall be decontaminated in order to minimize the potential for cross-contamination between sampling locations. Thorough decontamination of all sampling equipment shall be conducted prior to each sampling event. In addition, the sampling technician shall decontaminate all equipment in the field as required to prevent cross-contamination of samples collected in the field. The procedures described in this section are specifically for field decontamination of sampling equipment.

At a minimum, field-sampling equipment should be decontaminated following these procedures:

- Wash the equipment in a solution of non-phosphate detergent (Liquinox® or equivalent) and distilled or deionized water. All surfaces that may come in direct contact with the samples shall be washed. Use a clean Nalgene and/or plastic tub to contain the wash solution and a scrub brush to mechanically remove loose particles. Wear clean latex, plastic, or equivalent gloves during all washing and rinsing operations.
- Rinse twice with distilled or deionized water.
- Dry the equipment before use, to the extent practicable.

Water Quality Sampling Procedures

Low Flow Sampling Protocol

The purpose of using low flow rates during low-flow purging is to avoid mobilization of formation solids and reduce purge volumes required to achieve collection of a sample representative of aquifer water quality. This technique is premised on minimizing drawdown of the aquifer and stabilization of field parameters prior to and during sample collection. Pump flow rates should be less than or equal to the yield of the well, so that a stabilized pumping water level is achieved as quickly as practical, in order to then expedite the stabilization of the indicator parameters.

Minimal-drawdown procedures should consist of evacuating the total volume of groundwater present in the sampling system to clear the well pump, tubing, and flow cell, if used, of any stagnant water left from prior sampling events. In general, a minimum of one (1) volume of the sampling system (i.e. pump, associated tubing, flow cell, etc.), must be purged. The maximum flow rate is determined by pumping at a rate, which allows for stabilization of the water level surface within the well. Field measurements should be initiated at the start of purging and continued at evenly spaced intervals until stabilization. Measurements of the indicator parameters must be taken at a frequency based on the time it takes to purge one (1) volume of the pump, associated tubing, and flow cell. For example, if the volume of the pump, associated tubing, and flow cell is 500 mL and the well is being purged at 250 mL/minute, the pump, associated tubing, and flow cell will be purged in two (2) minutes. Therefore, measurements must be taken at least two (2) minutes apart.

Purging will be continued until the final three consecutive measurements for each parameter agree to within 10% of each other prior to sample collection. Measurements should be taken at appropriate intervals during the purging process to determine stabilization. Once stabilization has been achieved, sampling can be conducted at the same rate.

Bailers may be used to collect samples from select wells if a suitable pump is not available or other circumstances require (e.g. if there is inadequate volume to use a pump). Bailers should be made of suitable inert materials (such as stainless steel, PVC, or Teflon), when monitoring for organic compounds. PVC bailers with non-glued joints may also be used. When bailers are used, the bailer cord shall be fastened securely to the bailer and shall be constructed of nylon, stainless steel, or polypropylene, and be specifically manufactured for use in the collection of environmental samples. This cord must be new, clean, and in good condition. Care should be taken not to excessively disturb the column of water in the well casing. Gently lower the bailer into the well with each cycle. The sampler's knowledge of the depth to water will help in this regard. Attempt to lower the bailer into the water only to the extent necessary to fill or nearly fill the chamber. Avoid submerging the top of the bailer. Calibration records should be recorded on the sample collection forms and/or field notebook.

Sample Collection

Samples are collected once water quality parameters have stabilized sufficiently to vary less than 10% between three consecutive readings.   Groundwater samples should be collected in the shortest possible time subsequent to purging the well. Discharge from a bailer will be controlled to minimize agitation and aeration. Sample containers should be sealed with tape, labeled, and immediately placed in a cooler with ice. Sample containers should be filled completely to eliminate head space. Sample containers are provided by the analytical laboratory and should be requested at least one week in advance of the sampling. The containers should meet specifications for size, type, and preservatives for parameters analyzed and all shipping coolers should have chain-of-custody seals placed on them prior to shipping. Well identification will be omitted from all sample identifications numbers and laboratory paperwork so that all samples can be analyzed in the laboratory without reference to well identification.

Sample Preservation and Holding Time

Samples should be stored immediately after collection in an ice chest containing sufficient ice to cool the samples to 4 degrees Celsius (°C). Use "blue ice" if possible. If water ice must be used, seal each bottle in a plastic bag. Make sure the ice is sealed in plastic bags too. Samples should remain cooled at 4°C and delivered to the laboratory within 24 hours of collection. Sample receipt at the laboratory must be sooner if analysis includes parameters with a shorter holding time. Care should be taken to prevent excessive agitation of samples or breakage/leakage of containers. Samples should be analyzed within the specified holding time for each constituent. One additional sample should be collected from one of the wells for quality control purposes. The well identification should be omitted from laboratory paperwork so the sample can be evaluated as a "blind duplicate."

Resampling

If monitoring results indicates a significant increase in the concentration of a monitored parameter for a well, the well will be resampled within one week of the receipt of analytical results that show the significant change. An increase or decrease is significant when the change can be considered statistically significant. Determination of a significant change in groundwater concentration is customarily done either by assessing concentrations in relation to established concentration limits or by using a statistical analysis.

Chain of Custody and Sample Handling

A chain-of-custody form will be completed and signed by the sampler on the day of sample collection. The chain-of-custody form must be signed by laboratory personnel upon receipt and any other individuals that maintain custody of the samples in the interim. An example chain-of-custody form is attached.

Coolers should be sealed and shipped or driven to the lab as soon as possible. The method of shipping (bus, next day air, etc.) is usually determined by the parameter having the shortest holding time. In any case, shipping times of more than 24 hours should not be used as the cooler(s) may warm and compromise sample quality.

Quality Assurance and Quality Control (QA/QC)

Field Records: All field notes, analytical results, and other pertinent data associated with the site should be maintained in a secure location and be archived for at least a five year period. Maintaining records will also facilitate tracking of environmental trends at the site.

Data Validation: Data validation for both field and lab QA/QC can be performed using a checklist. All pertinent information with respect to QA/QC will be checked. The following items are included:

- Completeness of field data sheets and observation (observations are used to check for potentially erroneous data)
- Completeness of chain-of-custody
- Holding times for all constituents
- Field blind duplicate results
- Laboratory method blanks, matrix spike, and matrix spike duplicates
- Surrogate percent recovery
- Completeness of laboratory quality control (duplicates, standards, QC samples)
- Comparisons between duplicates

Specific QA/QC guidance with respect to field blanks, field duplicates, and background data are summarized in the following bullets.

- Field blanks: Once per sampling event a blank sample with known concentrations of the monitored constituents will be included in the samples sent to the analytical laboratory. The field blank will be purchased from a scientific supply vender such as Hach.
- Field duplicates: Once per sampling event one additional sample will be collected from one of the wells for quality control purposes.

REPORTING

Primary reporting for this monitoring plan will focus on annual reports completed following the end of each recharge season, per OWRD requirements for the limited license and AR projects. The basic goals of the annual reports will be to: (1) analyze the data to evaluate how trends related to AR operations are influencing groundwater quality and (2) based on the results of that analysis provide recommendations (if any) for adjustments to the monitoring program and AR operations. In addition to annual reporting the monitoring data collected as described herein will be provided to OWRD and ODEQ on a periodic basis to facilitate data transfer and project communications.

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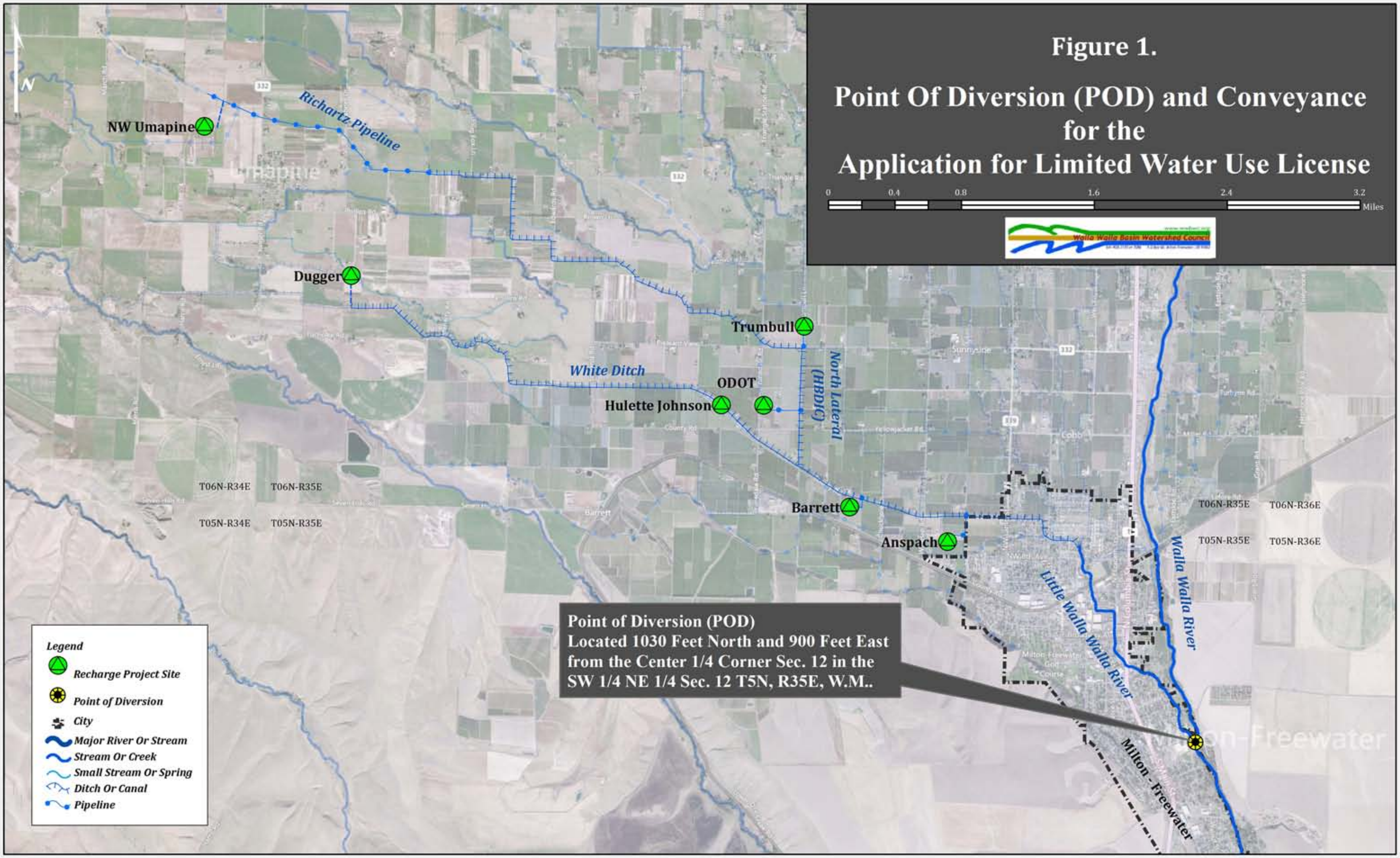


Figure 1.
Point Of Diversion (POD) and Conveyance for the Application for Limited Water Use License
0
0.4
0.8
1.6
2.4
3.2
Miles
N
NW Umapine
Richartz Pipeline
Dugger
Trumbull
White Ditch
ODOT
Hulette Johnson
North Lateral (HBDIC)
Barrett
Anspach
T06N-R34E
T06N-R35E
T05N-R34E
T05N-R35E
T06N-R35E
T06N-R36E
T05N-R35E
T05N-R36E
Walla Walla River
Little Walla Walla River
Milton - Freewater
Point of Diversion (POD)
Located 1030 Feet North and 900 Feet East from the Center 1/4 Corner Sec. 12 in the SW 1/4 NE 1/4 Sec. 12 T5N, R35E, W.M..
Legend
Recharge Project Site
Point of Diversion
City
Major River Or Stream
Stream Or Creek
Small Stream Or Spring
Ditch Or Canal
Pipeline

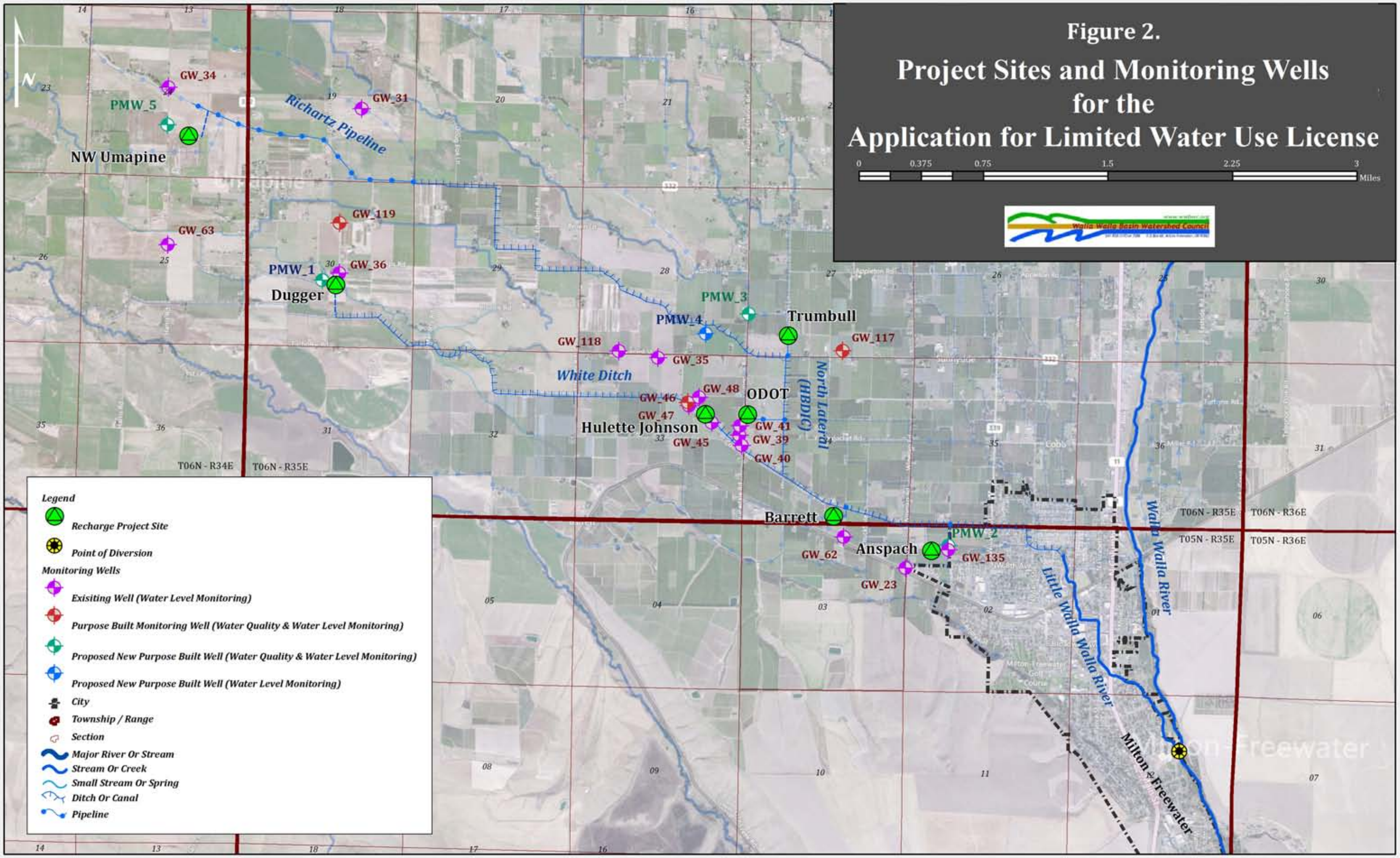


Figure 2.
Project Sites and Monitoring Wells
for the
Application for Limited Water Use License
0
0.375
0.75
1.5
2.25
3
Miles
Legend
Recharge Project Site
Point of Diversion
Monitoring Wells
Exisiting Well (Water Level Monitoring)
Purpose Built Monitoring Well (Water Quality & Water Level Monitoring)
Proposed New Purpose Built Well (Water Quality & Water Level Monitoring)
Proposed New Purpose Built Well (Water Level Monitoring)
City
Township / Range
Section
Major River Or Stream
Stream Or Creek
Small Stream Or Spring
Ditch Or Canal
Pipeline
NW Umapine
Dugger
Trumbull
ODOT
Hulette Johnson
Barrett
Anspach
PMW_1
PMW_2
PMW_3
PMW_4
PMW_5
GW_34
GW_31
GW_119
GW_63
GW_36
GW_118
GW_35
GW_117
GW_48
GW_46
GW_47
GW_45
GW_41
GW_39
GW_40
GW_62
GW_135
GW_23
Richartz Pipeline
White Ditch
North Lateral (HBDIC)
Little Walla Walla River
Walla Walla River
Milton-Freewater
T06N - R34E
T06N - R35E
T06N - R36E
T05N - R35E
T05N - R36E

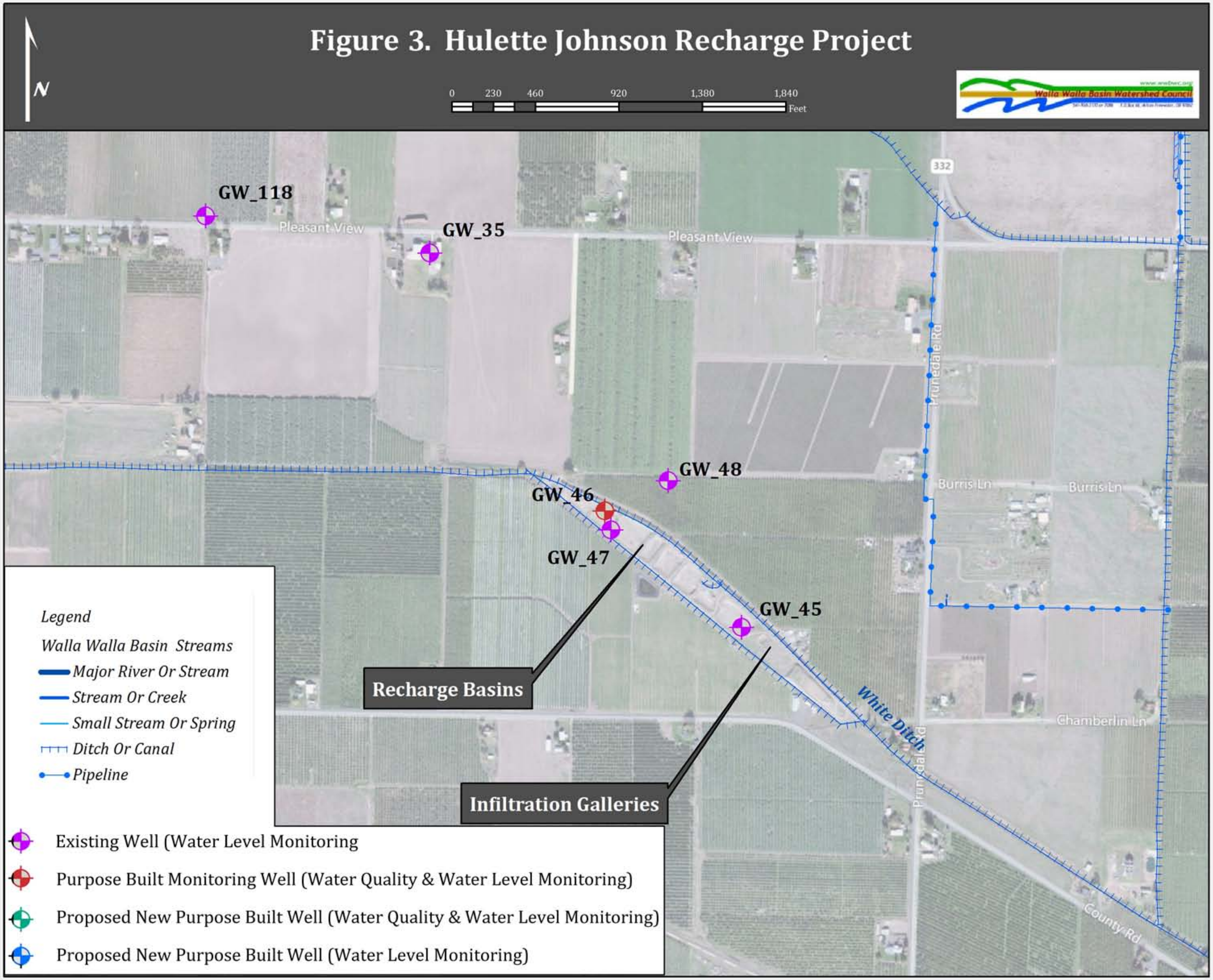


Figure 3. Hulette Johnson Recharge Project
N
0
230
460
920
1,380
1,840
Feet
Walla Walla Basin Watershed Council
GW_118
GW_35
Pleasant View
Pleasant View
332
GW_48
GW_46
GW_47
GW_45
Burris Ln
Burris Ln
Prunedale Rd
Recharge Basins
Infiltration Galleries
White Ditch
Chamberlin Ln
County Rd
Legend
Walla Walla Basin Streams
Major River Or Stream
Stream Or Creek
Small Stream Or Spring
Ditch Or Canal
Pipeline
Existing Well (Water Level Monitoring
Purpose Built Monitoring Well (Water Quality & Water Level Monitoring)
Proposed New Purpose Built Well (Water Quality & Water Level Monitoring)
Proposed New Purpose Built Well (Water Level Monitoring)

Figure 4. Anspach Project Monitoring Wells

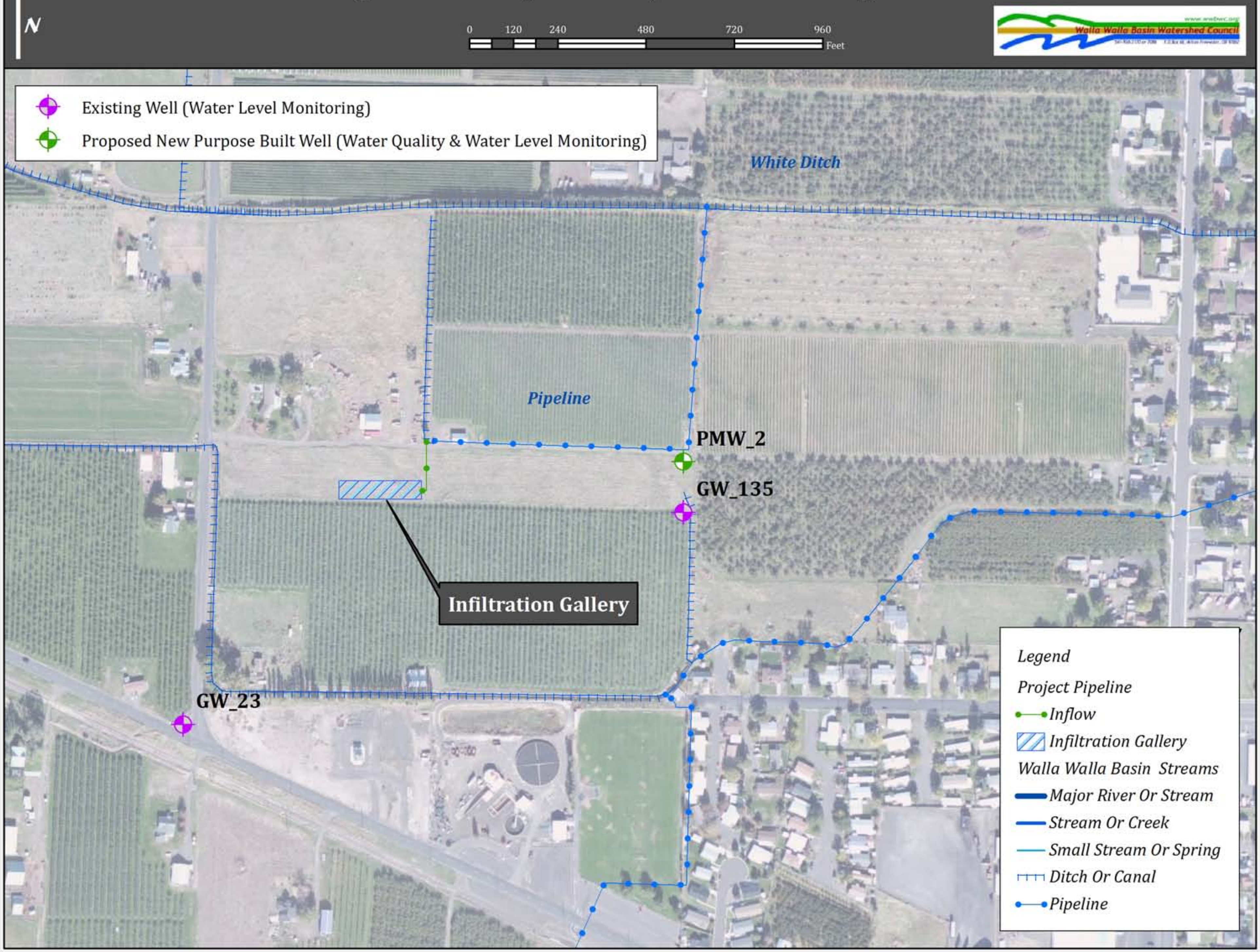
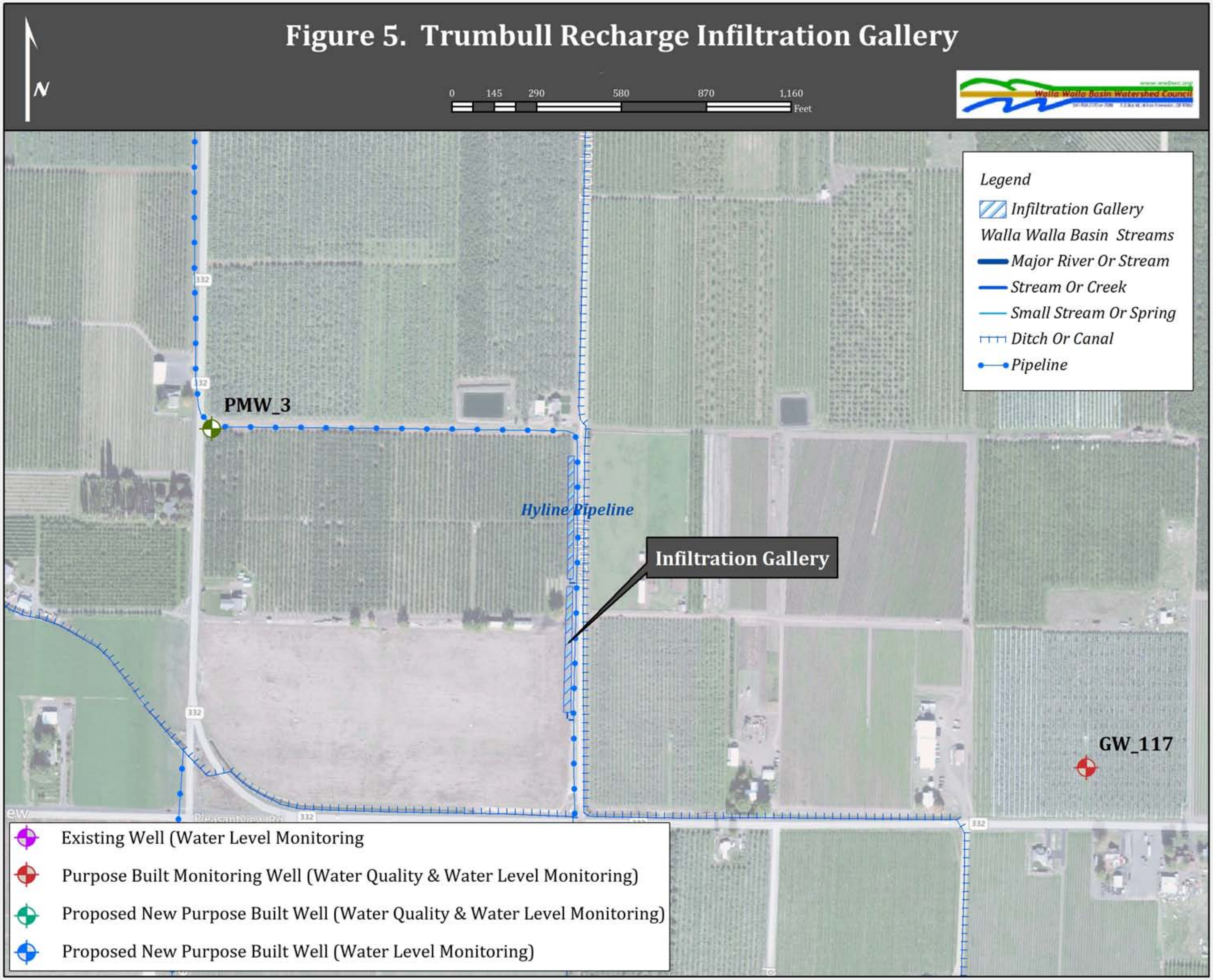


Figure 5. Trumbull Recharge Infiltration Gallery



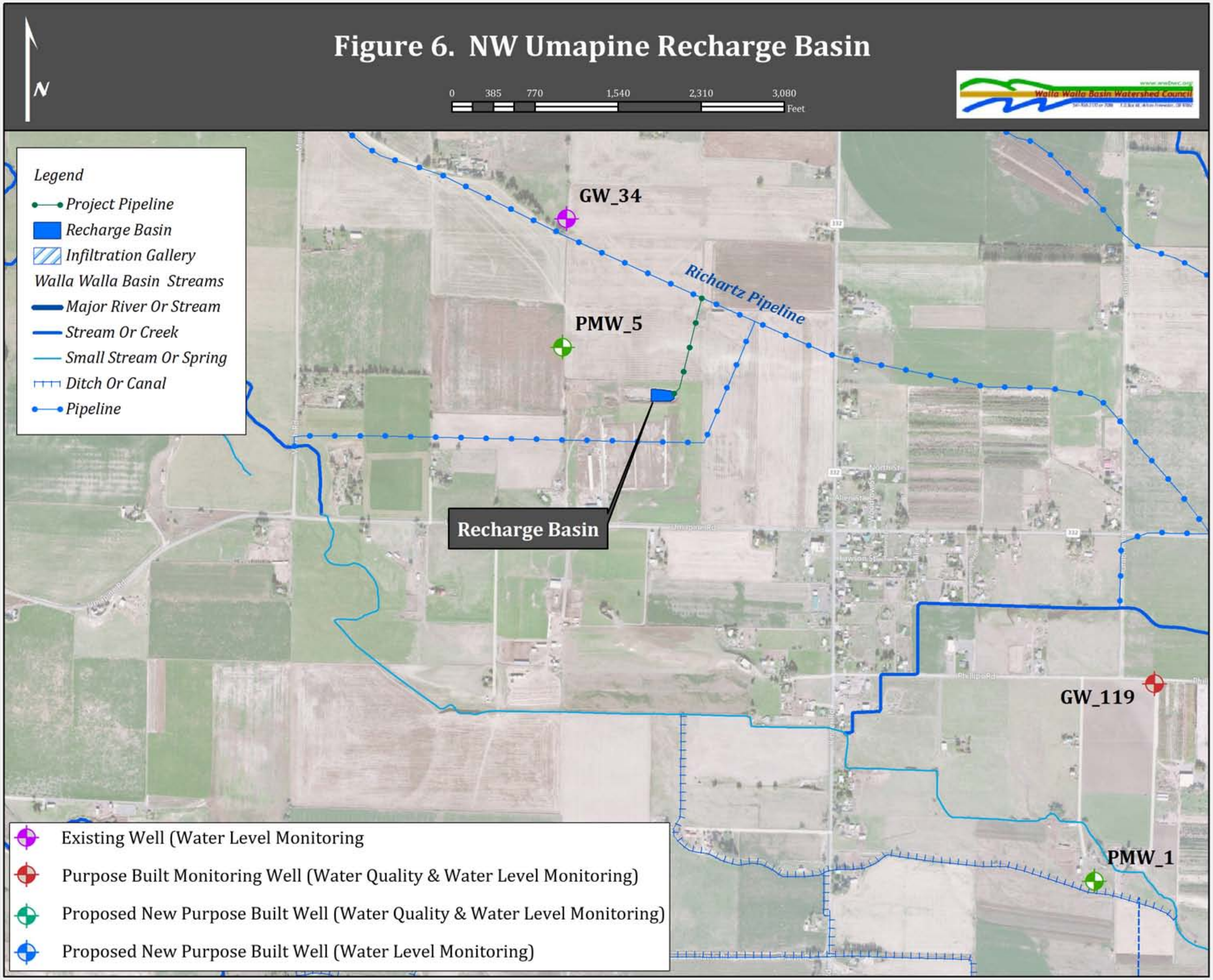


Figure 6. NW Umapine Recharge Basin

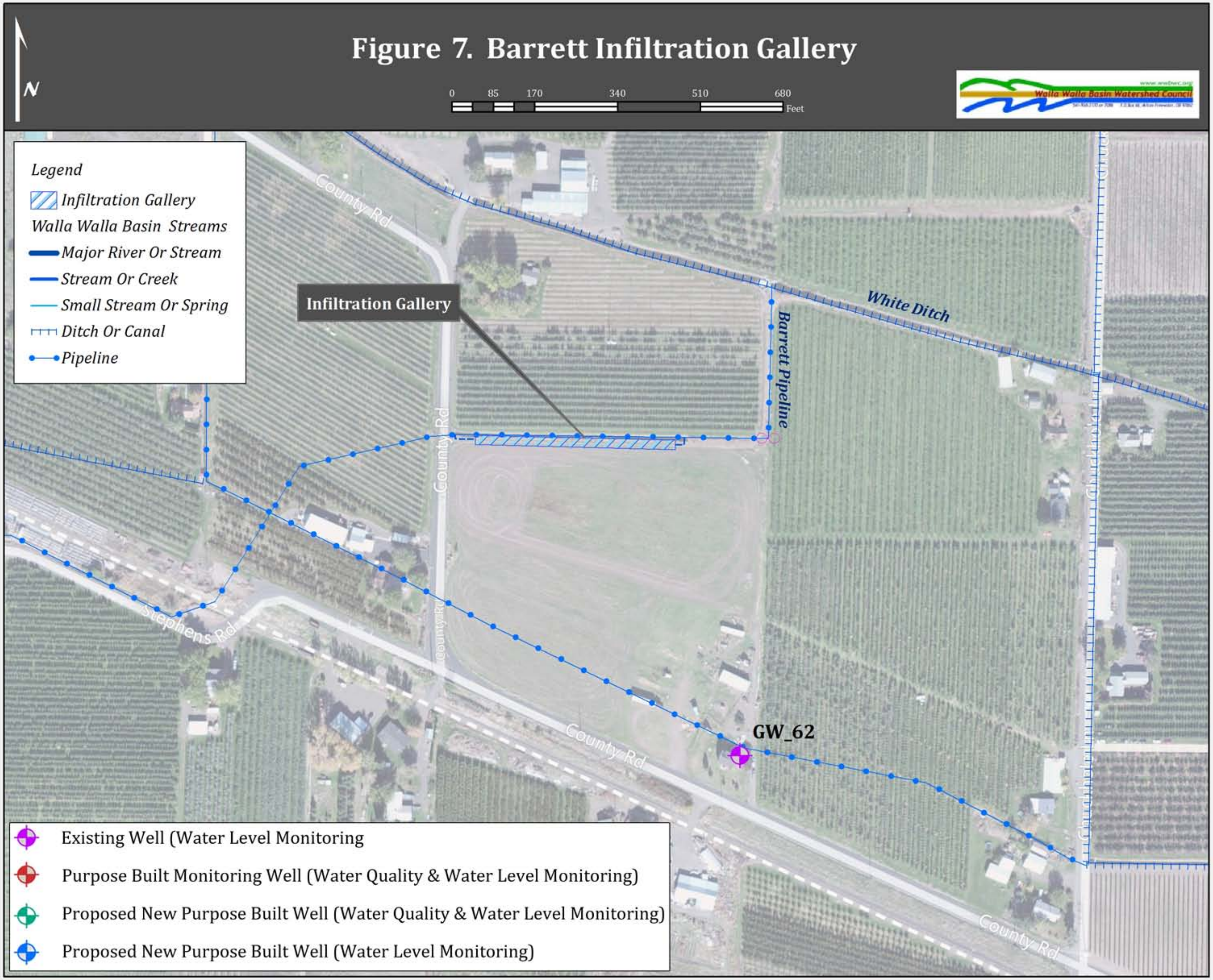


Figure 7. Barrett Infiltration Gallery
N
0
85
170
340
510
680
Feet
Walla Walla Basin Watershed Council
Legend
Infiltration Gallery
Walla Walla Basin Streams
Major River Or Stream
Stream Or Creek
Small Stream Or Spring
Ditch Or Canal
Pipeline
Infiltration Gallery
County Rd
White Ditch
Barrett Pipeline
County Rd
Stephens Rd
County Rd
GW_62
County Rd
Existing Well (Water Level Monitoring
Purpose Built Monitoring Well (Water Quality & Water Level Monitoring)
Proposed New Purpose Built Well (Water Quality & Water Level Monitoring)
Proposed New Purpose Built Well (Water Level Monitoring)

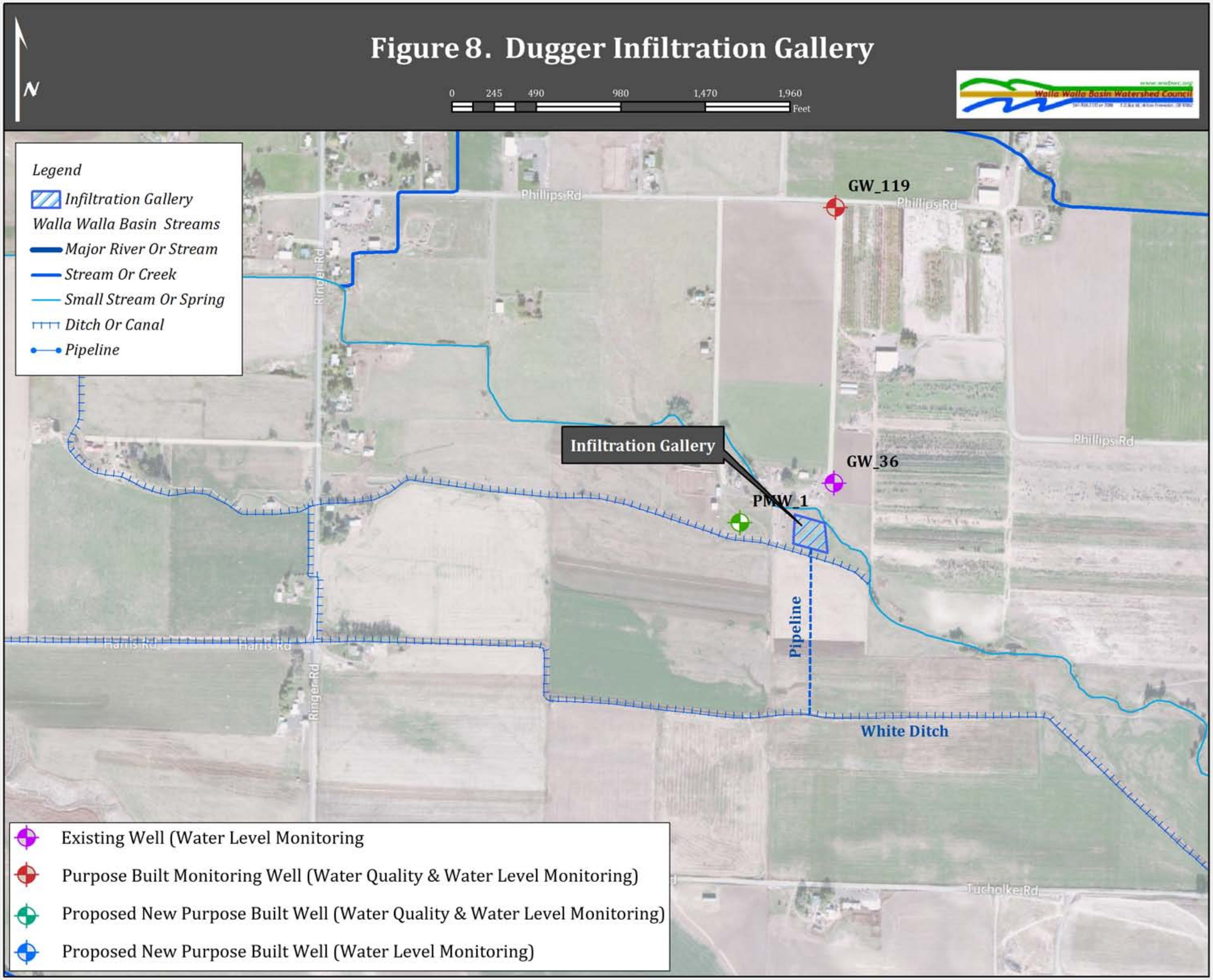
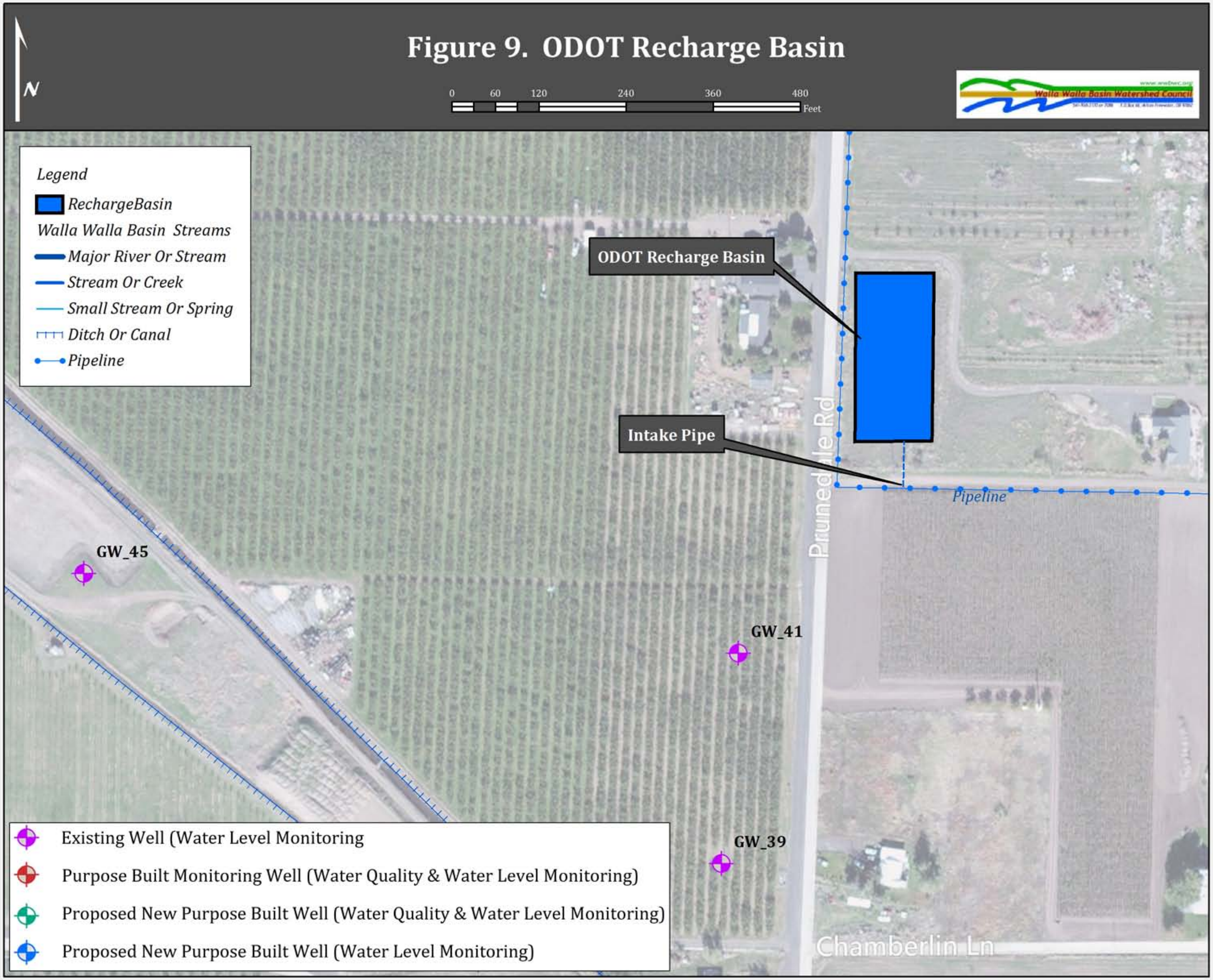


Figure 8. Dugger Infiltration Gallery
N
0
245
490
980
1,470
1,960
Feet
Walla Walla Basin Watershed Council
Legend
Infiltration Gallery
Walla Walla Basin Streams
Major River Or Stream
Stream Or Creek
Small Stream Or Spring
Ditch Or Canal
Pipeline
Phillips Rd
Ringer Rd
Harris Rd
Tucholke Rd
GW_119
GW_36
PMW_1
Infiltration Gallery
Pipeline
White Ditch
Existing Well (Water Level Monitoring
Purpose Built Monitoring Well (Water Quality & Water Level Monitoring)
Proposed New Purpose Built Well (Water Quality & Water Level Monitoring)
Proposed New Purpose Built Well (Water Level Monitoring)

Figure 9. ODOT Recharge Basin



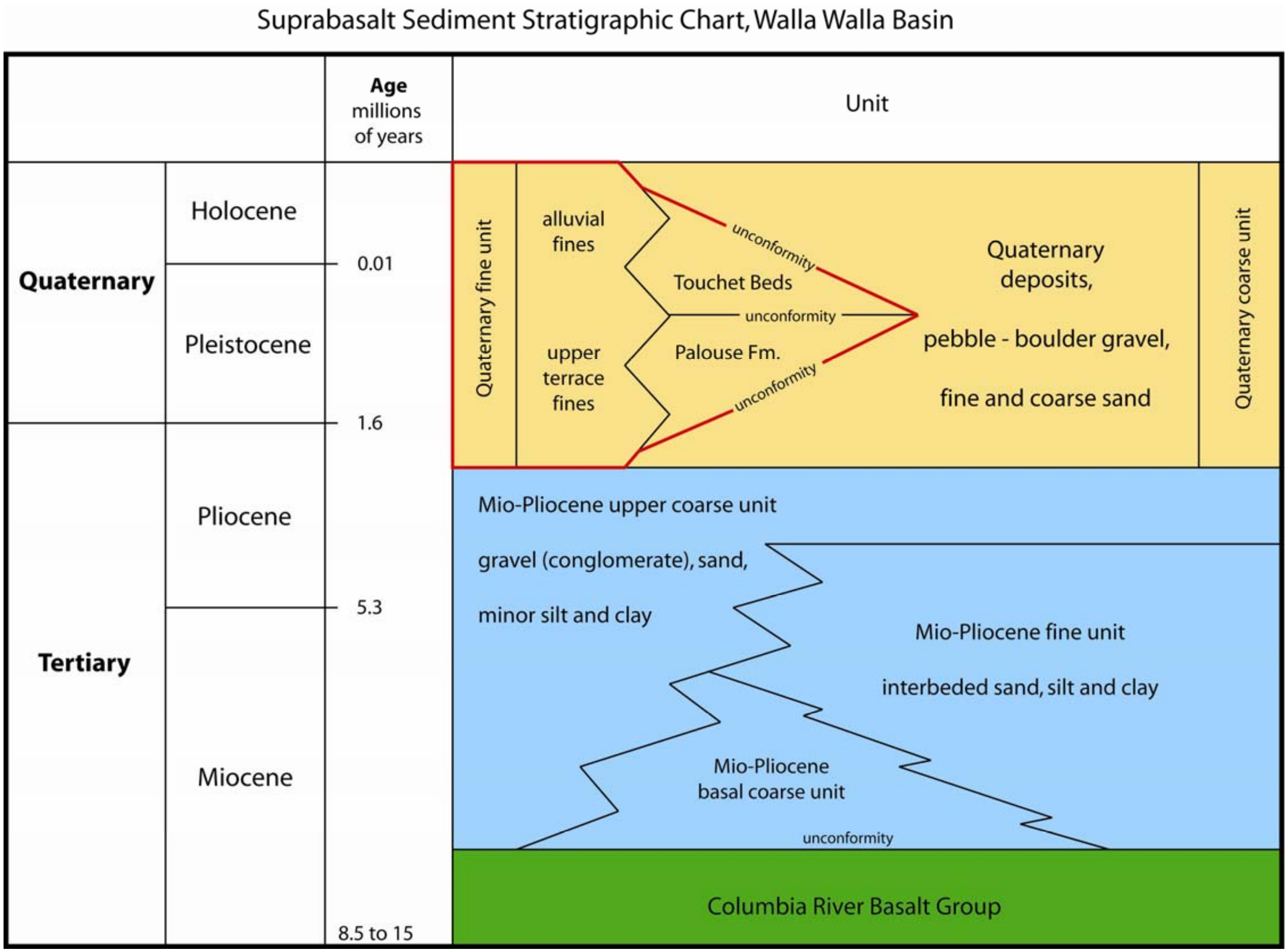


Figure 10. Suprabasalt sediment stratigraphy in the Walla Walla Basin as used in this report.

Figure 11. Walla Walla Valley - Water Table October, 2009

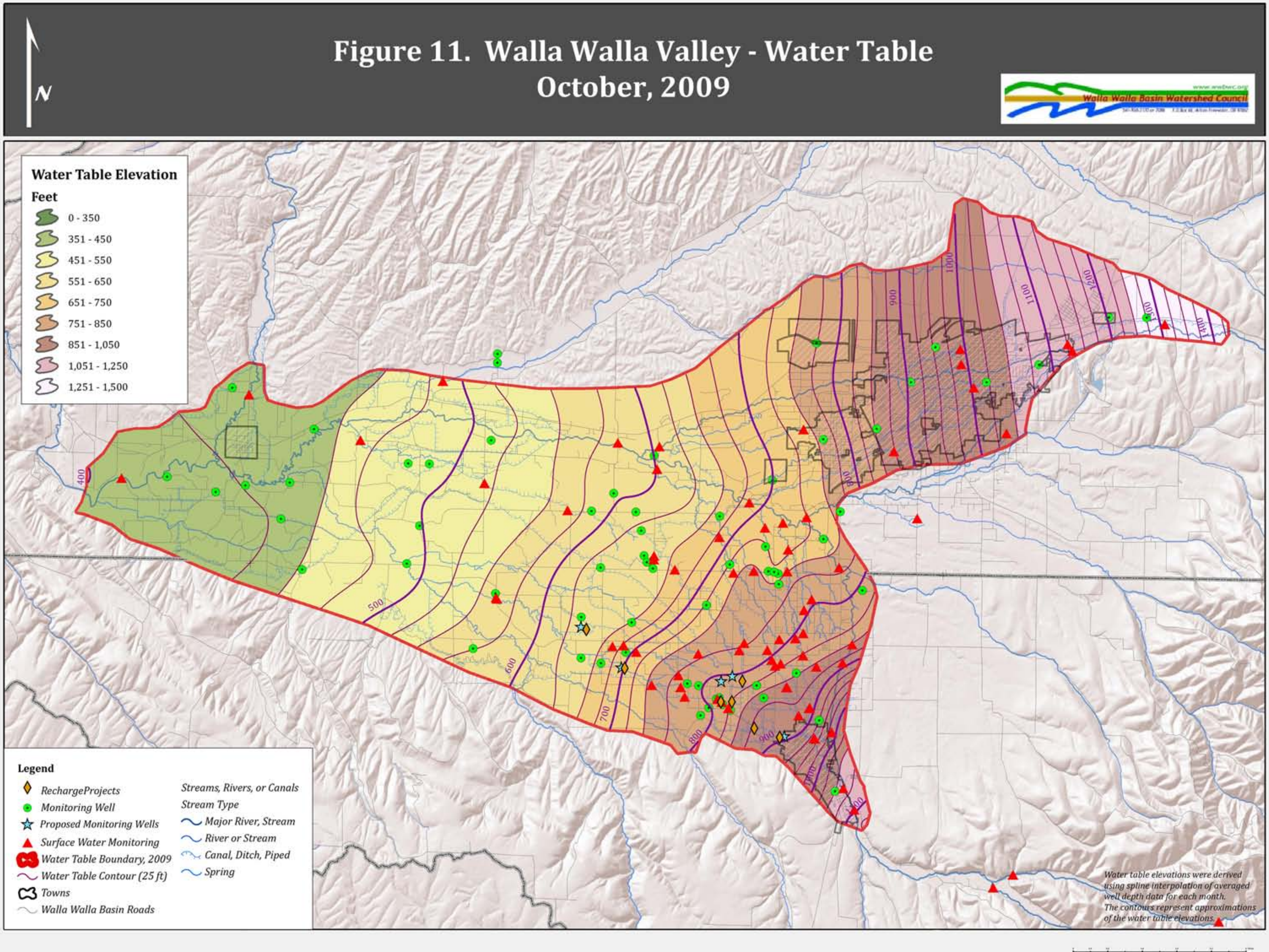
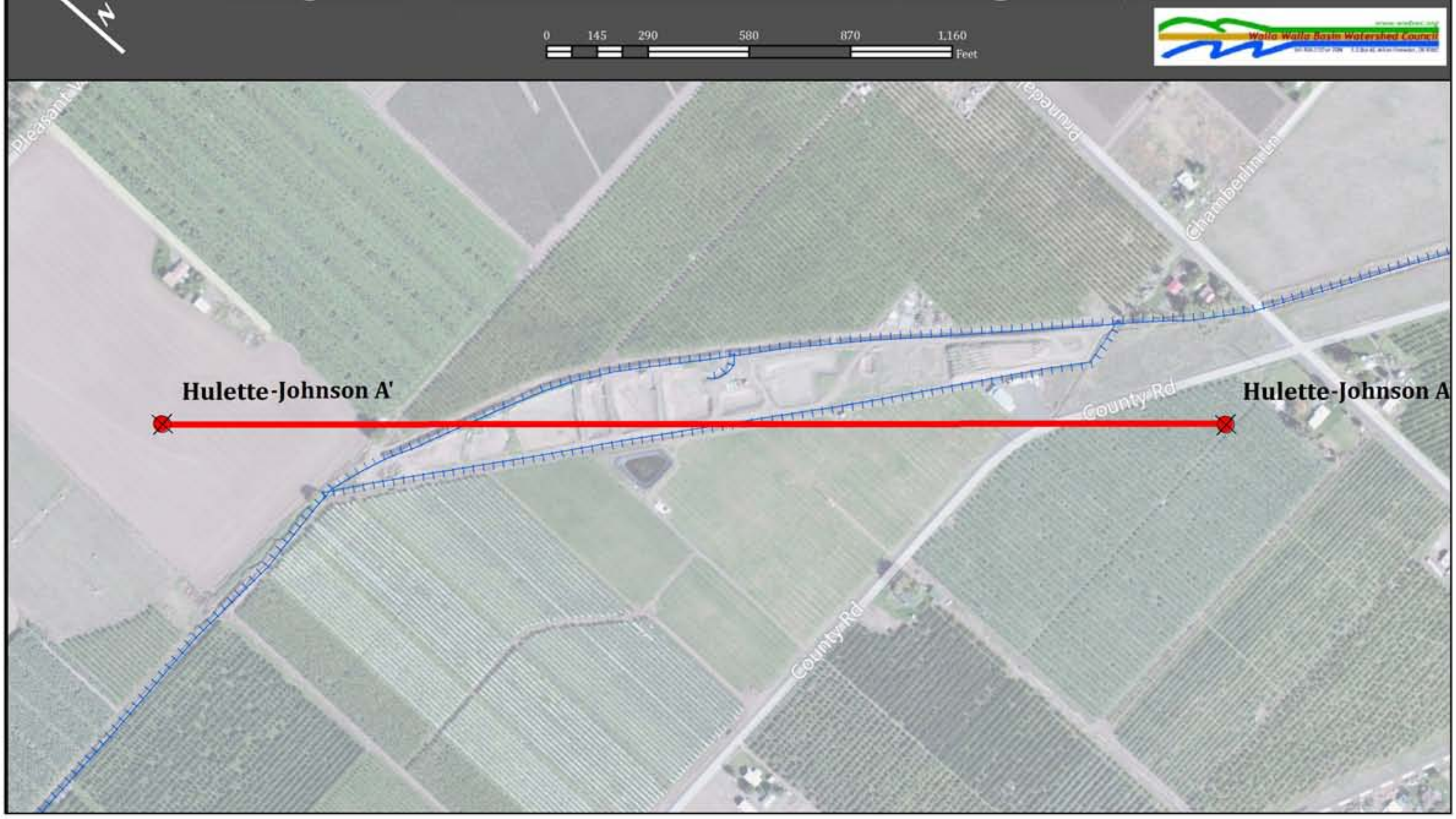


Figure 12. Hulette Johnson Recharge Project



Geologic Cross Section

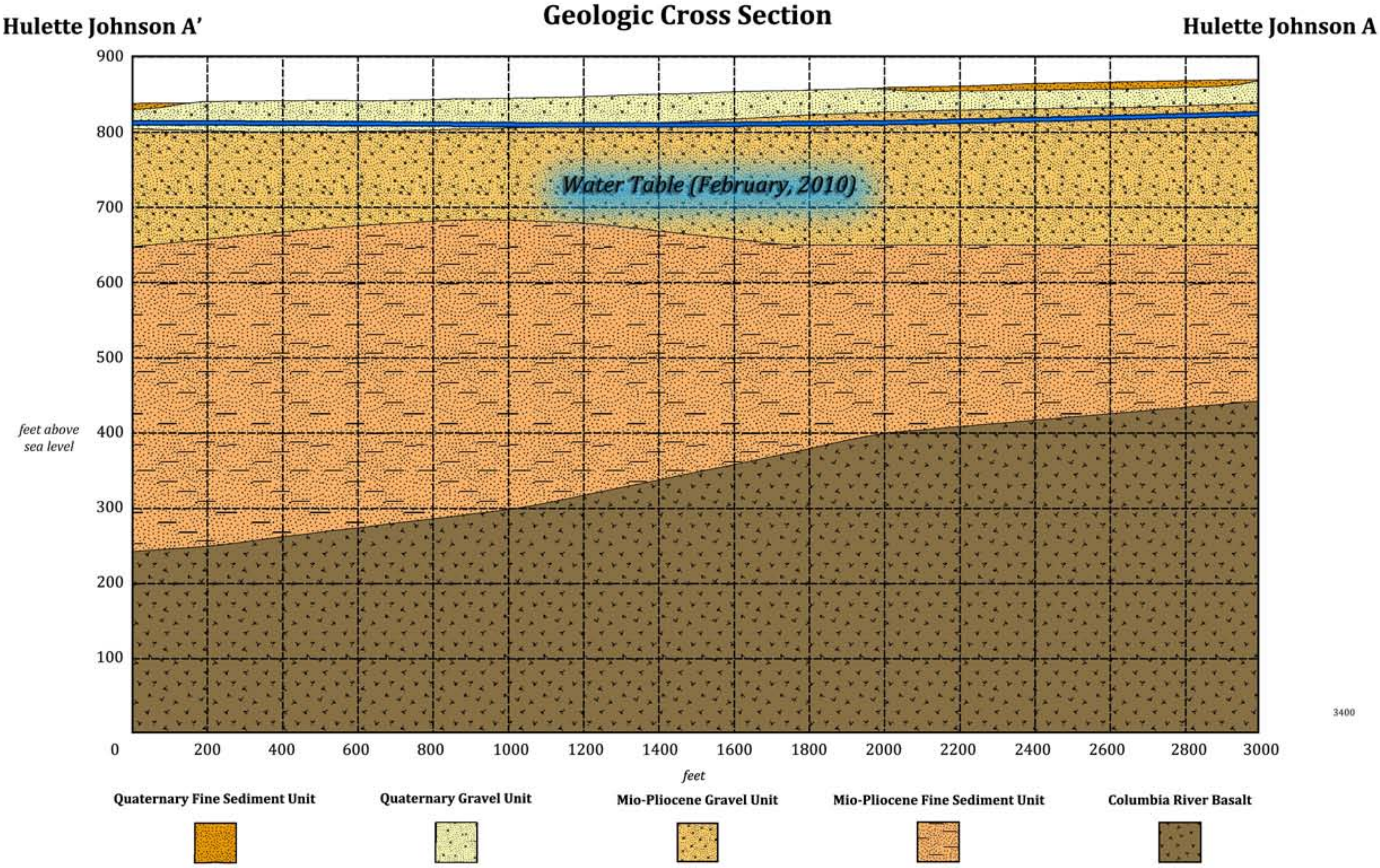


Figure 13. Anspach Recharge Project

Geologic Cross Section

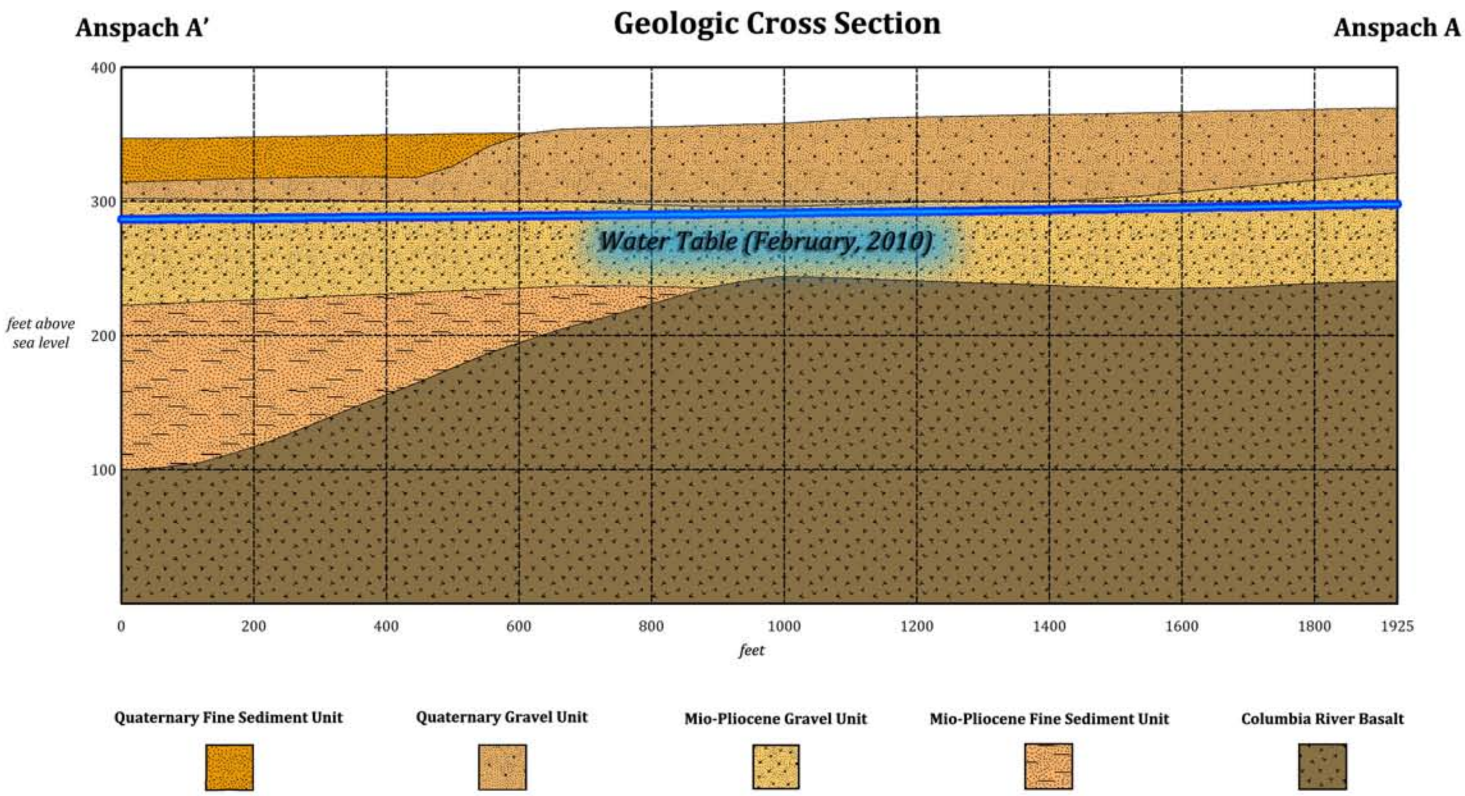
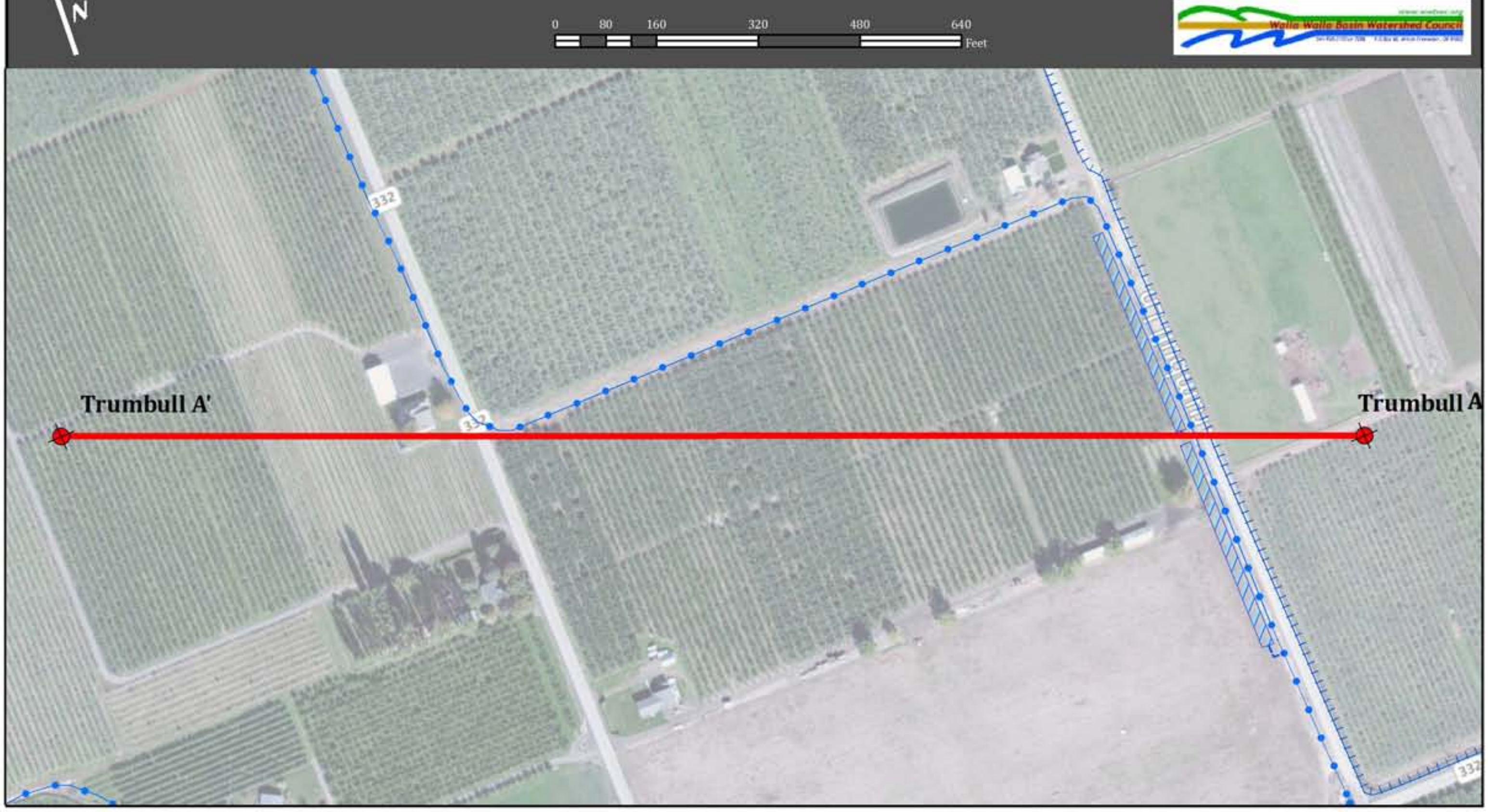


Figure 14. Trumbull Recharge Project



Geologic Cross Section

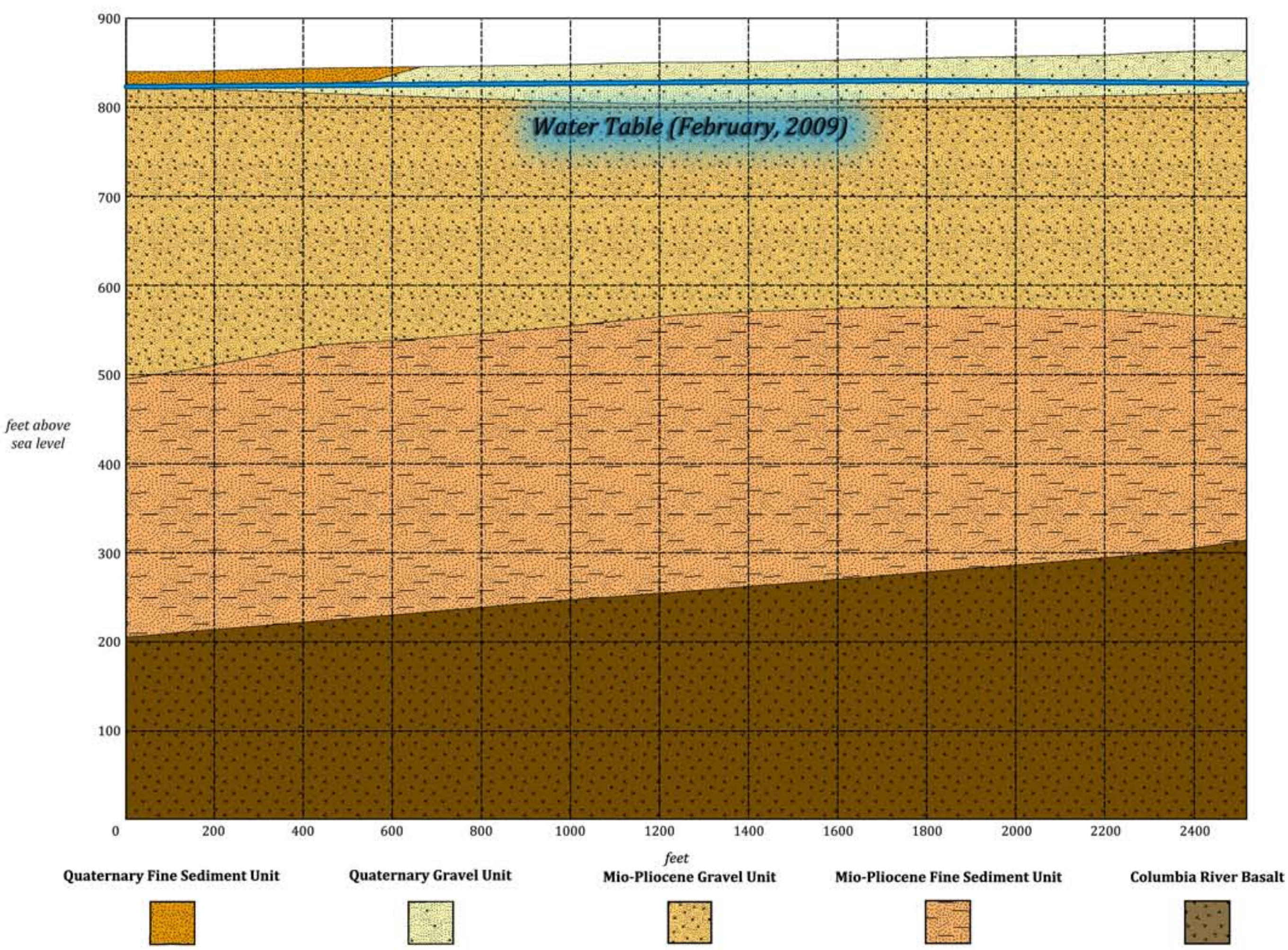
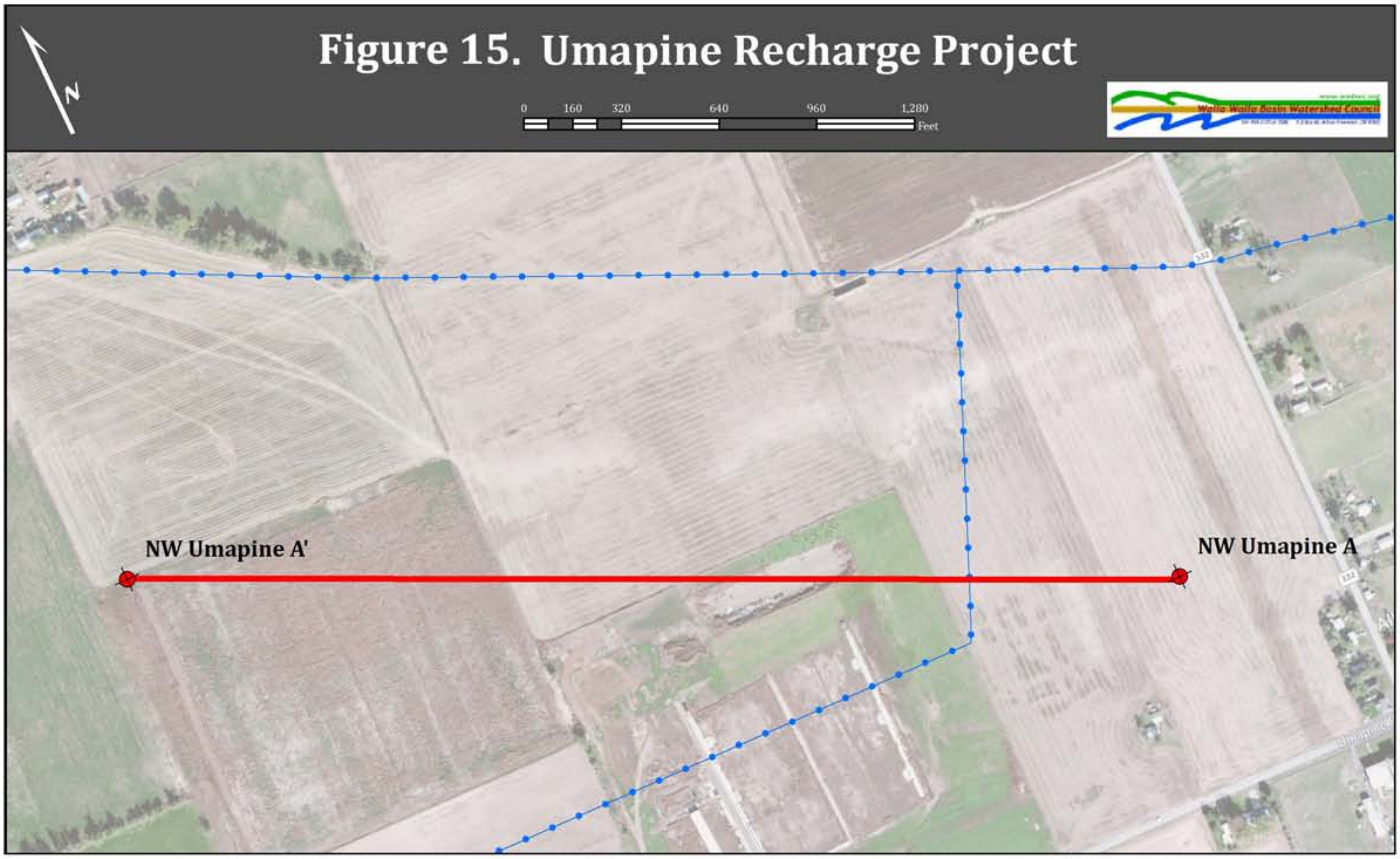


Figure 15. Umapine Recharge Project



Geologic Cross Section

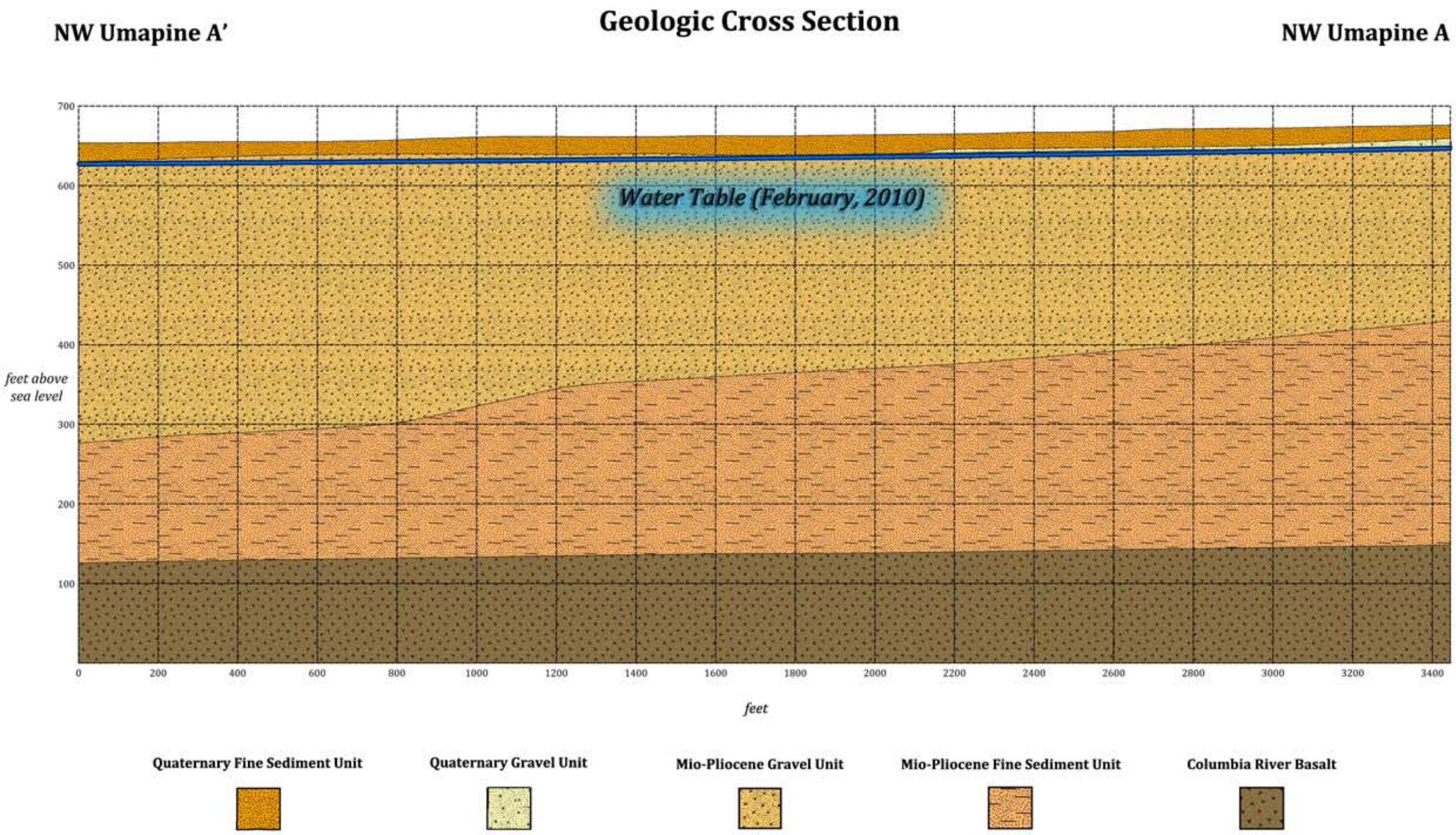
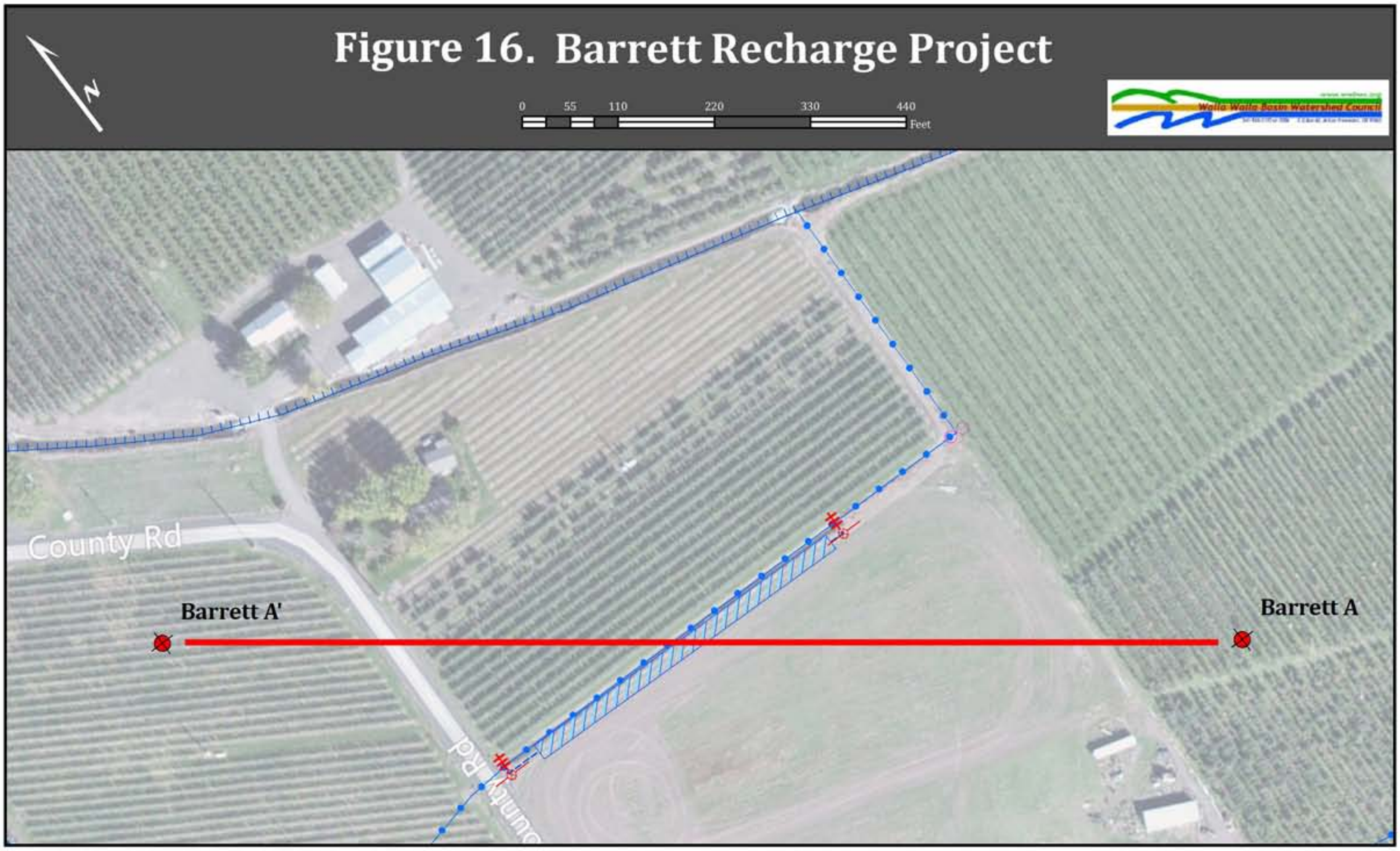


Figure 16. Barrett Recharge Project



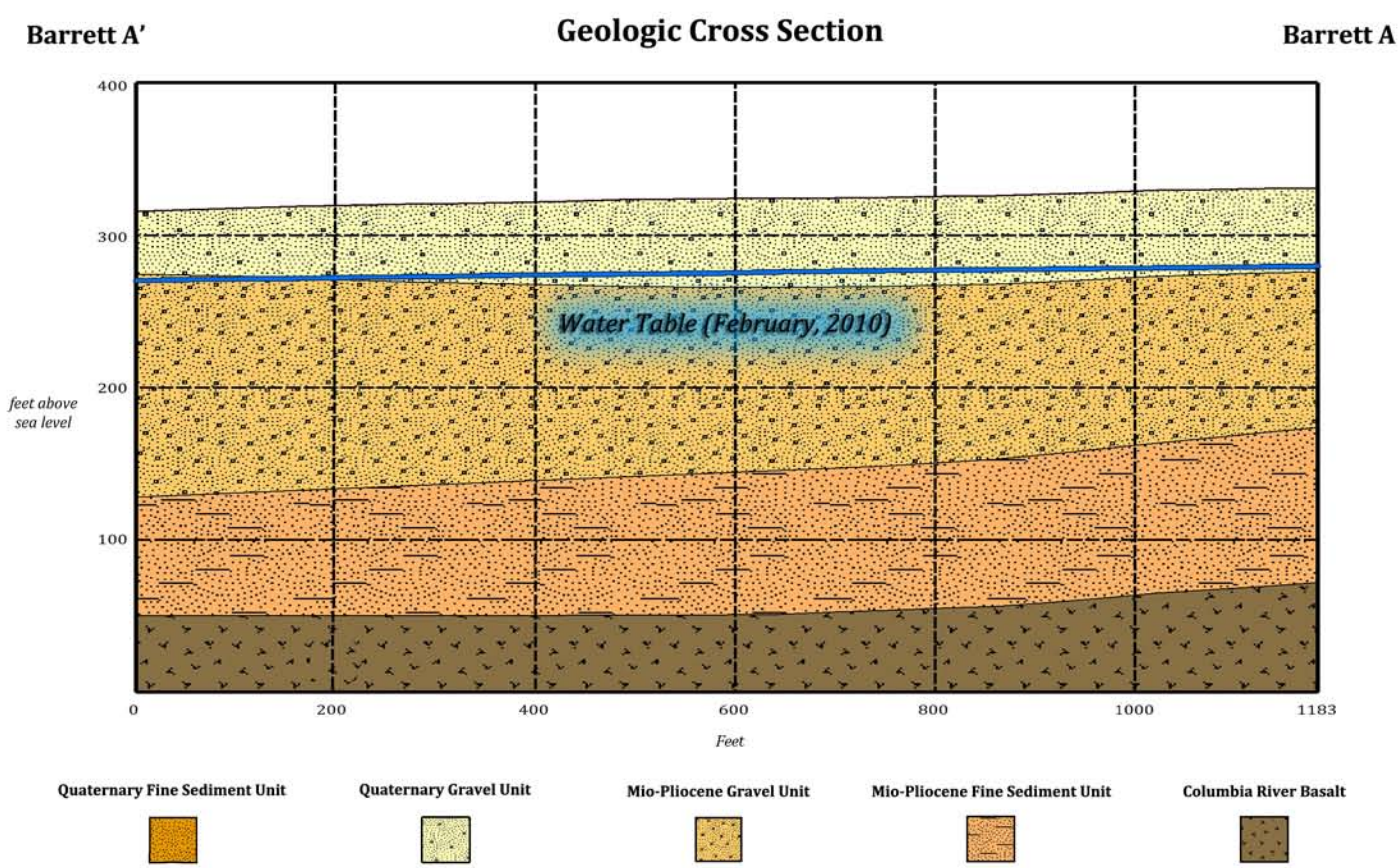
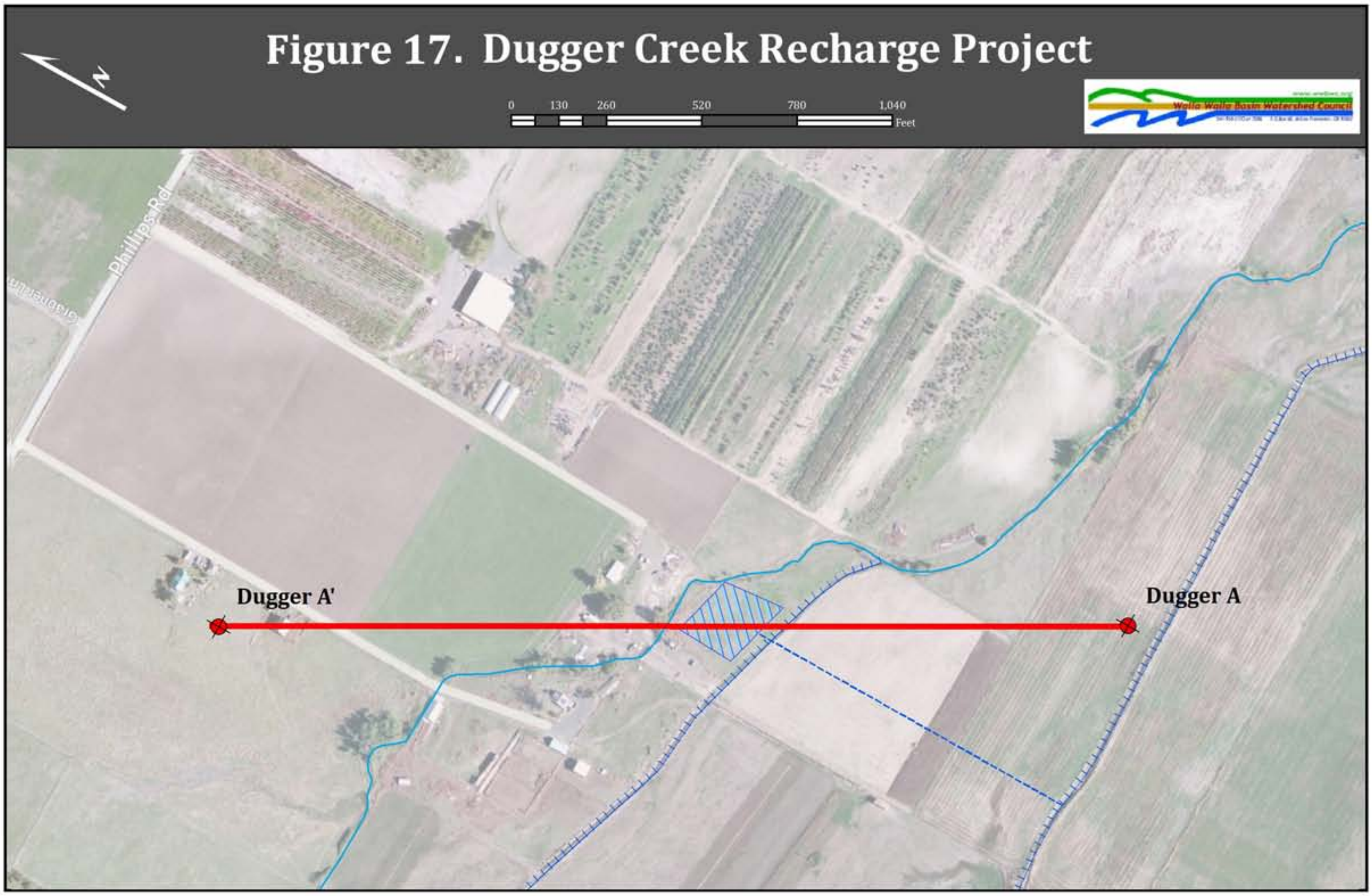


Figure 17. Dugger Creek Recharge Project



Geologic Cross Section

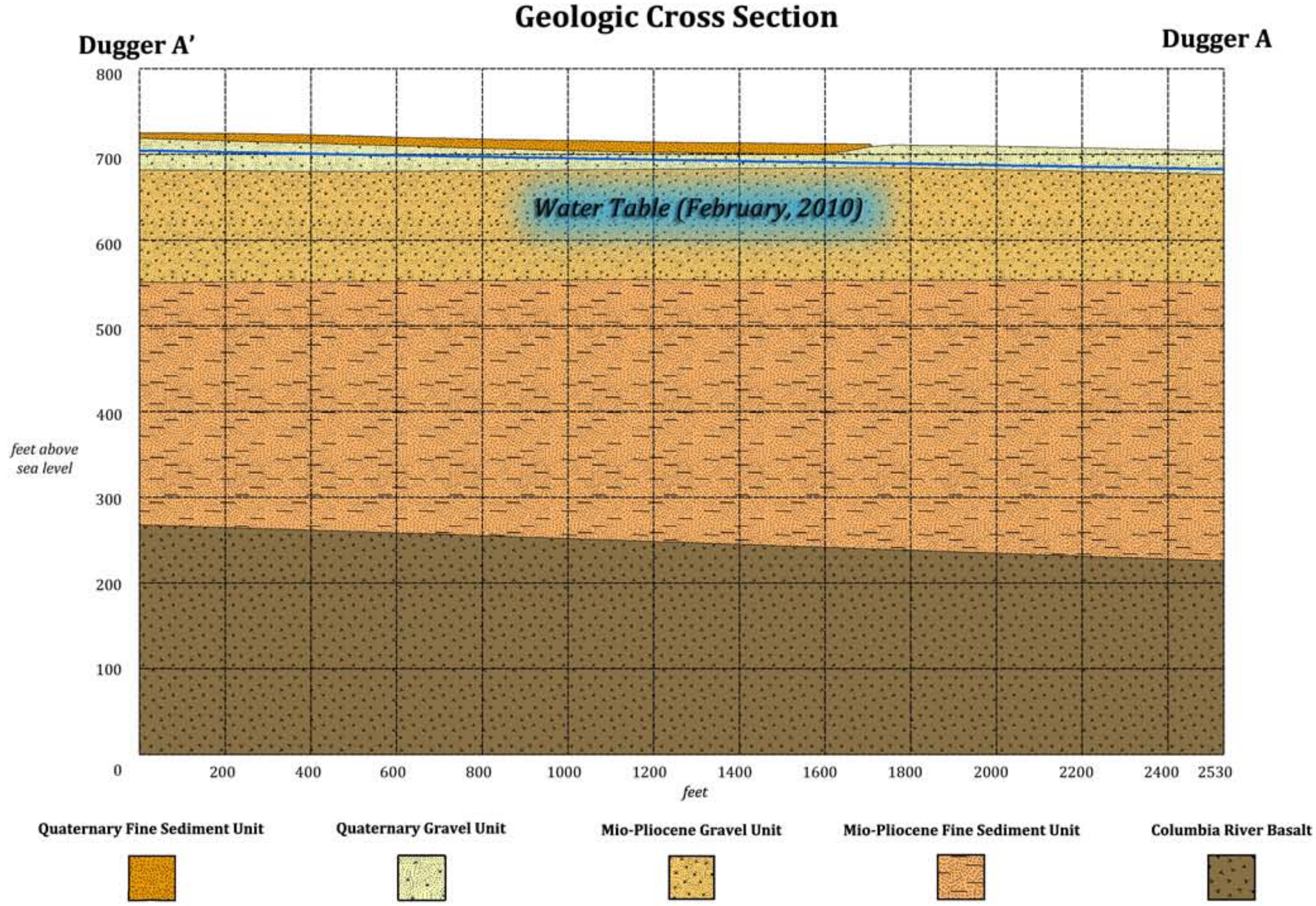
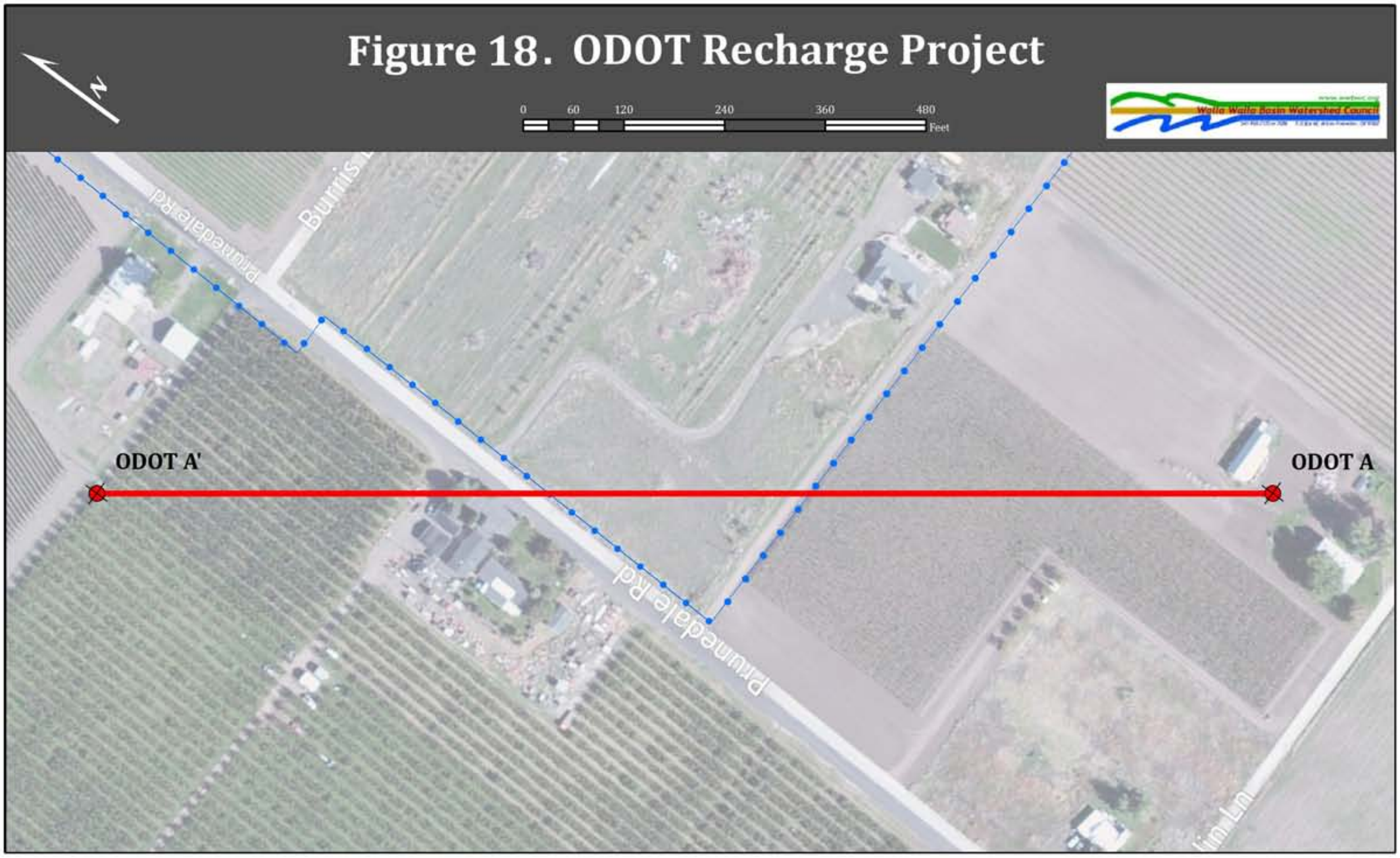
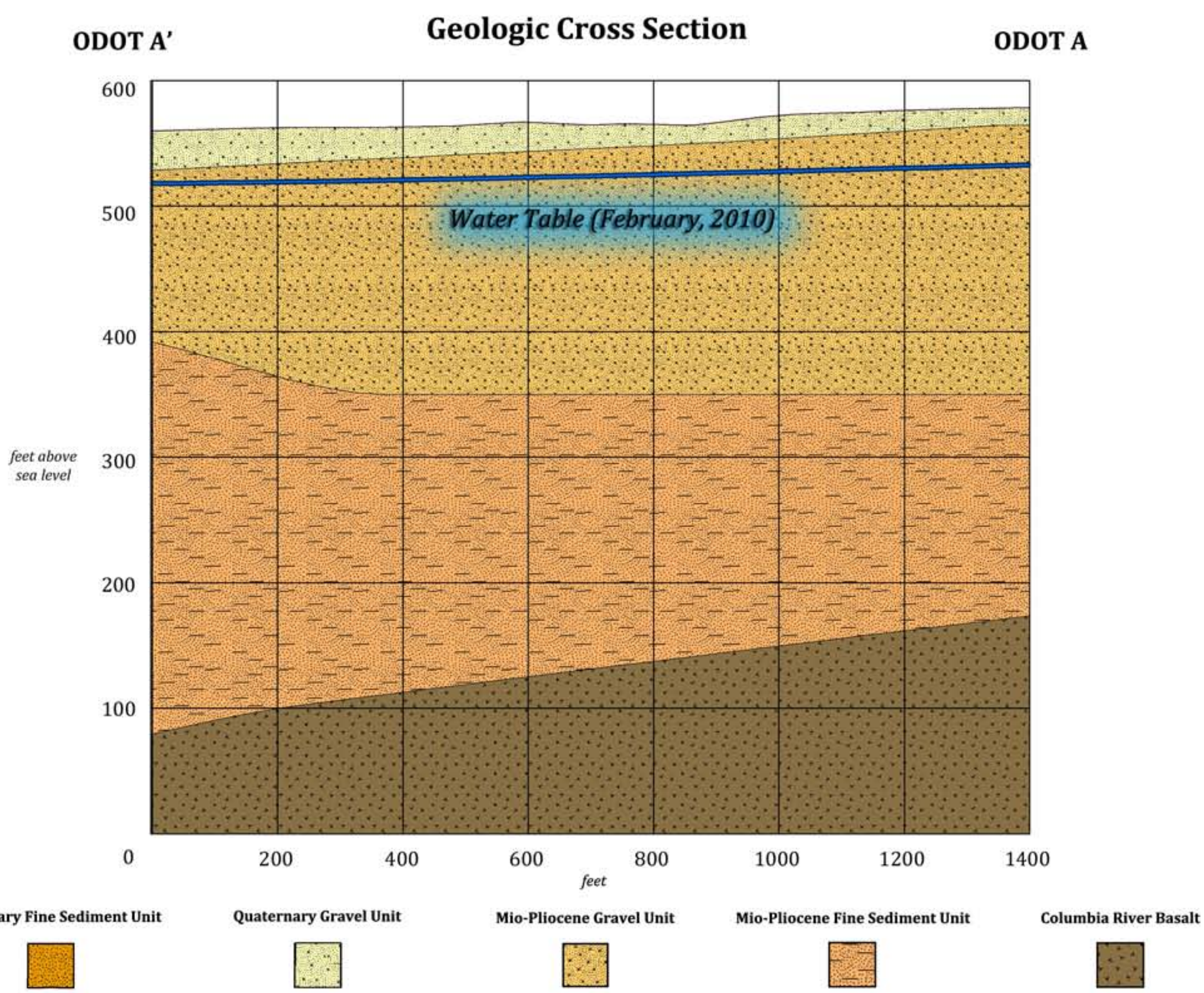


Figure 18. ODOT Recharge Project





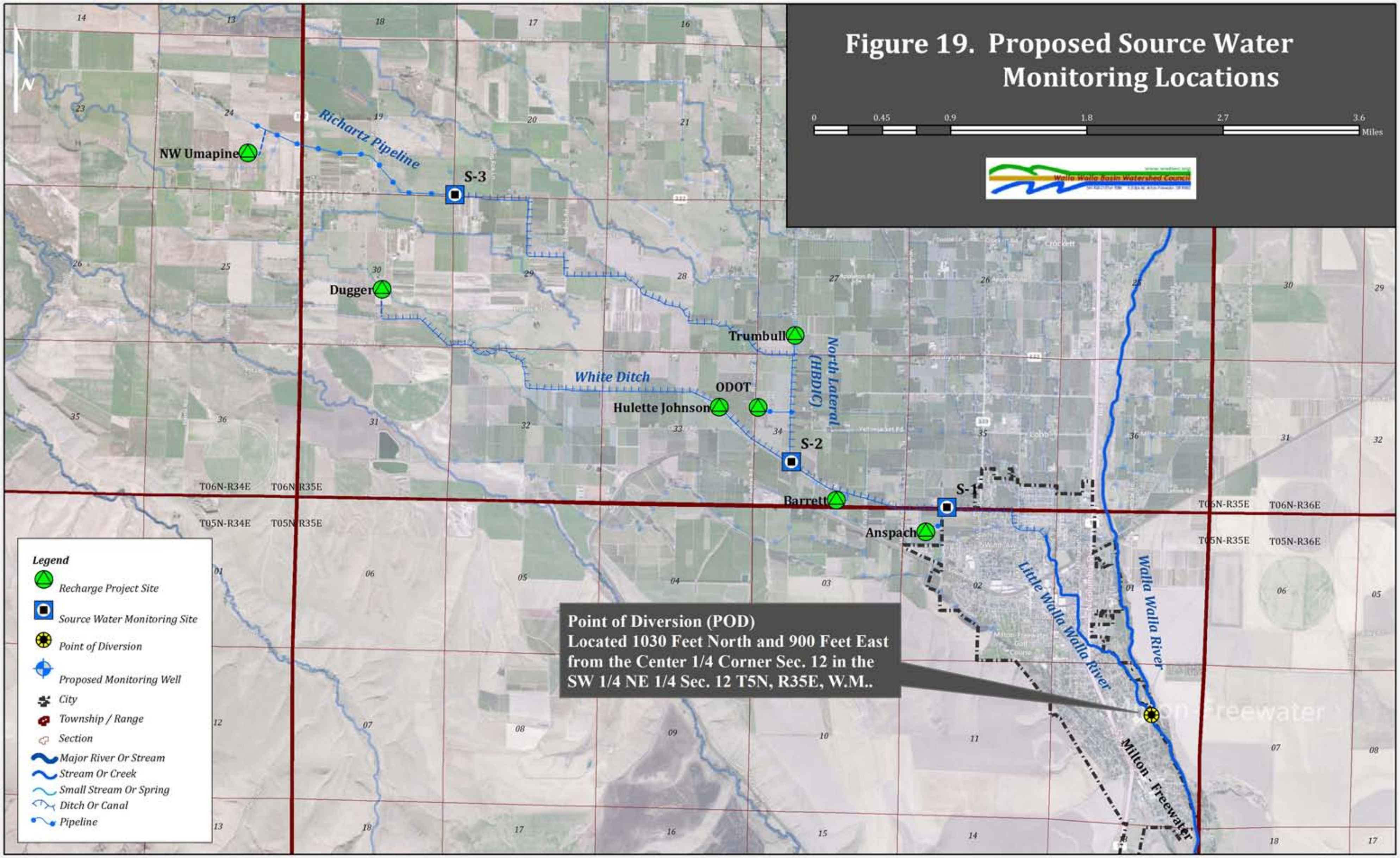
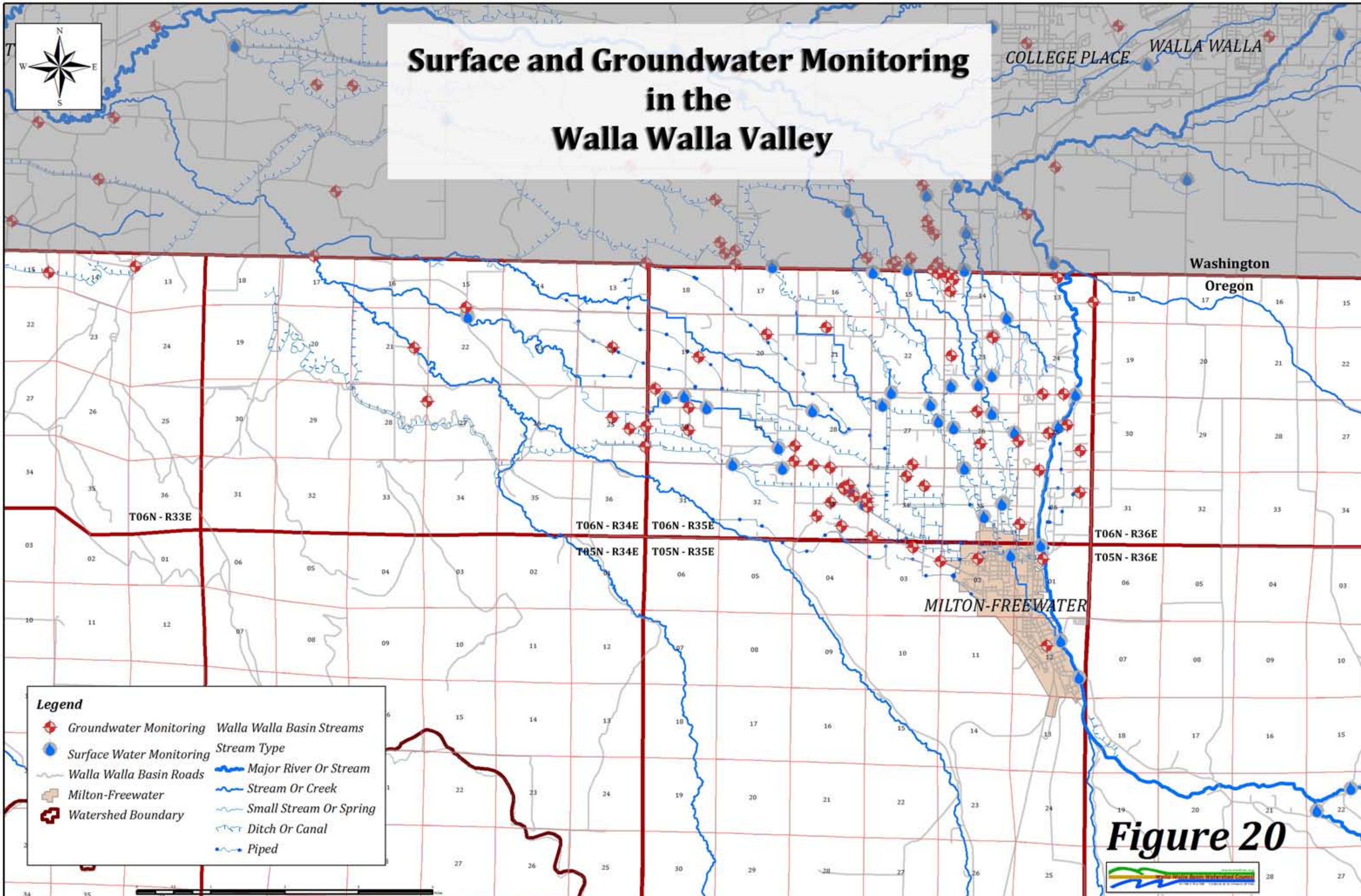


Figure 19. Proposed Source Water Monitoring Locations
0
0.45
0.9
1.8
2.7
3.6
Miles
Walla Walla Basin Watershed Council
NW Umapine
Richartz Pipeline
S-3
Dugger
Trumbull
North Lateral (HBDIC)
White Ditch
ODOT
Hulette Johnson
S-2
Barrett
S-1
Anspach
Little Walla Walla River
Walla Walla River
Milton - Freewater
T06N-R34E
T06N-R35E
T05N-R34E
T05N-R35E
T06N-R36E
T05N-R36E
Legend
Recharge Project Site
Source Water Monitoring Site
Point of Diversion
Proposed Monitoring Well
City
Township / Range
Section
Major River Or Stream
Stream Or Creek
Small Stream Or Spring
Ditch Or Canal
Pipeline
Point of Diversion (POD)
Located 1030 Feet North and 900 Feet East from the Center 1/4 Corner Sec. 12 in the SW 1/4 NE 1/4 Sec. 12 T5N, R35E, W.M..


Surface and Groundwater Monitoring
in the
Walla Walla Valley
COLLEGE PLACE
WALLA WALLA
Washington
Oregon
T06N - R33E
T06N - R34E
T06N - R35E
T06N - R36E
T05N - R34E
T05N - R35E
T05N - R36E
MILTON-FREEWATER
Legend
Groundwater Monitoring
Surface Water Monitoring
Walla Walla Basin Roads
Milton-Freewater
Watershed Boundary
Walla Walla Basin Streams
Stream Type
Major River Or Stream
Stream Or Creek
Small Stream Or Spring
Ditch Or Canal
Piped
Figure 20

Appendix A

Review of Previously Collected Source Water and Groundwater Quality Data from Alluvial Aquifer Recharge Projects in the Walla Walla Basin, Washington and Oregon

Contents

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Alluvial Aquifer Water Quality 3
AR Site Water Quality Findings 3
Hulette Johnson 3
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Introduction

Present and future alluvial aquifer recharge (AR) projects in the Walla Walla Basin (the Basin) must proceed with the assurance that these projects not only provide recharge to the alluvial aquifer but also that the additional recharge does not degrade native, or background, groundwater quality. Traditionally water quality monitoring focuses on project-by-project and/or site specific up-gradient and down-gradient sampling. For Walla Walla Basin AR projects this has resulted in each individual AR site having a water quality monitoring program specific to that site, and independent of other AR sites.

In reviewing water quality data collected at multiple AR sites in the Basin, Walla Walla Basin Watershed Council (WWBWC) staff and consultants have made a preliminary observation that AR in the Walla Walla Basin has not resulted in detectable degradation of native groundwater quality. Given this preliminary observation and the desire to streamline water quality monitoring associated with multiple, but inter-related AR sites, the WWBWC decided to do a more comprehensive review of the historical water quality monitoring data collected at the four AR sites it has worked on since AR began in the Walla Walla Basin in 2004. Two of these sites, Hall-Wentland and Hulette Johnson (formerly referred to as the Hudson Bay site) are located in Oregon. The other two, Locher Road and Stiller Pond, are located in Washington (Figure 1). Based on that effort the WWBWC, would like to eliminate synthetic organic compounds (SOC's) from the analyte list for the proposed multi-site AR monitoring program.

This report presents the results of this review of available AR water quality monitoring data, and WWBWC's recommendations for a single, multi-site water quality monitoring program to be used in lieu of a series of independent site-specific monitoring efforts, including the elimination of SOC sampling from normal AR monitoring for the proposed multi-site AR project.

To that end, the purpose of the analysis is twofold:

1. Evaluate water quality data collected before, during, and following various AR events at the four AR sites in an effort to identify analyte trends that may indicate any possible negative or positive effects with respect to water quality on the alluvial aquifer from AR operations.
2. Using that evaluation, propose removing synthetic organic compounds (SOC's) from the list of sampled parameters is plausible.

The remainder of this report focuses on a review of water quality data collected to-date at each of the four AR sites, the evaluation of the impacts of AR on groundwater quality, and recommendations for the scope of a potential future multi-site AR monitoring effort that eliminates expensive and time consuming SOC sampling. Details of AR operations at the four sites are found in Kennedy/Jenks (2006), GSI (2007a, 2007b, 2008a, 2008b, 2009, 2012), and WBWC and GSI (2010). Alluvial aquifer geology and hydrogeology are discussed in detail in Newcomb (1965), Barker and McNish (1976), and GSI (2007c).

Alluvial Aquifer Water Quality

Alluvial aquifer water quality data collected from the various AR sites and evaluated for this effort varies from site-to-site. However, they generally included field parameters, major ions, nutrients (nitrate-N, total Kjeldahl nitrogen (TKN) and ortho-phosphate), PCB's, bisphenol-A (BPA), and agricultural synthetic organic compounds (SOC's).

AR Site Water Quality Findings

Hulette Johnson

The Hulette Johnson site (Figures 1 and 2) is a fully developed AR site that has been in operations since 2004. Both recharge basins and infiltration galleries are used at this site. It is the most up-gradient of all the sites evaluated herein (WWBWC, 2012) and is located about 2 miles northwest of Milton-Freewater, Oregon. Water quality data used in this evaluation come from two monitoring wells (HJ-1 and HJ-2) and from the source water intake at the site. The source water is Walla Walla River water delivered to the site via the White Ditch operated by HBDIC. This site has been operated under a Limited License issued to the HBDIC.

The samples evaluated herein were collected periodically between 2006 and 2012. Water quality parameters evaluated from the Hulette Johnson site include nitrate-N, total Kjeldahl nitrogen (TKN), ortho-phosphate, chloride, total organic carbon (TOC), total suspended solids (TSS), total dissolved solids (TDS), hardness, and a suite of synthetic organic compounds (SOC's). Field parameter data, consisting of pH and electrical conductance (EC), where only collected at this site during its early years of operation. Plots for many of the parameters collected at this site are provided in Appendix A.

A range of source water and groundwater quality relationships are found in the Hulette Johnson site data. Some parameters display higher values in groundwater, while others display higher values in the source water. In other data sets groundwater quality parameter values are similar to those from source water samples. Specific observations are as follows.

Ortho-phosphate, nitrate-N (nutrient type parameters) and TDS generally are lower in source water during the same sampling events as compared to local groundwater. Slightly negative correlations (Table 1) between both source and alluvial groundwater ortho-phosphate data with sampling dates over time suggest that with respect to this parameter groundwater quality is not degraded but improved during AR operations. Groundwater nitrate-N concentrations have a slightly positive (0.02) correlation to sampling date but source water nitrate-N has a negative correlation (-0.45). The slightly increasing nitrate correlation in groundwater with sampling date over time, as compared to decreasing correlation in surface water, is interpreted to show that surface water introduced via AR is not degrading groundwater quality.

Chemical oxygen demand (COD) data exhibit no trends in groundwater and surface water, but do show generally values with the range of concentrations measured to-date in both systems overlapping (Appendix A Figure A-12). A slightly negative correlation between the data from each sampling location at this site and the sampling date suggests that groundwater quality at this site is not degraded but improved with respect to organic constituents.

TKN and TOC in groundwater and surface water generally show similar values with the range of concentrations measured to-date in both systems overlapping (Appendix A Figures A-17 and A-19). A slightly negative correlation (TKN = -0.31, TOC = -0.52) between the data from each sampling location at this site and the sampling date suggests that groundwater quality at this site is not degraded but improved with respect to TKN and TOC.

Chloride and TSS in source water generally is the same as, or higher than is seen in local groundwater (Appendix A Figures A-15 and A-13). The parameter concentrations measured to-date are low in general and suggest no contamination issues related to TSS and chloride. A positive correlation of chloride data to sampling date (0.54) suggests that chloride in groundwater may be increasing slightly over time. TSS source water data also has a positive correlation to sampling date (0.11), also suggesting that it could be slightly increasing over time. For both parameters though negative correlation in groundwater of -0.03 for chloride and -0.54 for TSS is interpreted to show that AR is not degrading local groundwater quality with respect to these two parameters.

Bisphenol-A (BPA) is the only ***SOC*** at this site with repeat detections, being detected intermittently in site groundwater between 2008 and 2012. BPA has not been detected at this site in source water. To-date, these measured BPA concentrations are two orders of magnitude lower than EPA toxic levels for aquatic organisms. EPA toxic levels for aquatics are between 1100 and 10,200 µg/L for aquatic organisms (EPA, 1988). Insufficient data is available for statistical and long term trend evaluation of BPA at this site.

In summary, these data are interpreted to show that to-date, AR operations at the Hulette Johnson site generally have not lead to degradation of local groundwater. Nutrients in source water are lower than seen in groundwater; therefore if they have any influence on groundwater, they decrease down gradient concentrations. Although Chloride and TSS are higher in source water, the relatively low concentrations seen in local groundwater are interpreted to reflect a minimal impact on local groundwater quality by AR operations. With respect to other parameters TDS, TKN, and TOC in both groundwater and surface water overlap to such a degree that they are interpreted to reflect a similar origin and AR operations has a minimal influence on them. SOC data collected to-date do not show any impact to groundwater by AR activities. BPA when found in groundwater is not detected in source water, suggesting its introduction to groundwater via other means than AR activity at this location.

Hall-Wentland

The Hall-Wentland site (Figures 1 and 3) hosted AR activity between 2006 and 2009. This site is located 4 miles southwest of Walla Walla, WA and about 6 miles northeast of the Hulette Johnson site. The Hall-Wentland site is on irrigated pasture and adjacent cropped ground which was flooded for AR operations. Water was delivered to the Hall-Wentland site via a small canal, the Wells ditch. Wells ditch is sourced from a weir structure on the East Branch of the Little Walla Walla River less than one mile south-southeast of the site. When operated, this AR project was operated under a Limited License issued to the WWRID, but operated by a local land owner.

WQ samples were collected in 2006, 2007, 2008, and 2009 from one up-gradient monitoring well (HW-2), two down-gradient monitoring wells (HW-1 and HW-3), and from source water before, during, and after AR operations. Parameters used in this evaluation of AR influences on groundwater at the Hall-Wentland site include pH, EC, turbidity, nitrate-N, hardness, TDS, chloride, and SOC's. Plots for these data are provided in Appendix B. As with the Hulette Johnson site, water quality data from the Hall-Wentland site shows that for some constituents source water and groundwater geochemistry are similar, while for others they differ, but without a significant change, or degradation, in groundwater conditions resulting from AR operations.

With respect to the ***field parameters (pH and EC)*** source water pH generally is higher than groundwater pH, and while there is a slight increase in down-gradient pH the differences between the two are small (Appendix B Figures B-13 and B-14), and up-gradient to down-gradient changes are not consistent. Source water EC generally is lower than groundwater EC, and groundwater EC does not show any clear up-gradient to down-gradient changes that are interpreted as indicative of AR influences on groundwater quality (Appendix B Figure B-14). These trends are exemplified with a positive correlation (0.23) between pH and sampling date over time in source water and slightly negative correlations between groundwater data sets (-0.05, -0.23 and -0.23 for HW-1, HW-2 and HW-3 respectively).

Turbidity also appears to be generally higher in source water when compared to groundwater. With that though, there is no readily apparent increase in groundwater turbidity from up-gradient to down-gradient at the Hall-Wentland site (Appendix B Figure B-15). This likely reflects the filtration of fines from the source water as it migrates through the vadose zone to the water table.

Source water generally displays lower values for ***hardness, TDS, and nitrate-N*** than groundwater (Appendix B Figures B-16 and B-19). Given that, if there were significant changes in groundwater quality caused by AR operations at the Hall-Wentland site one should expect to see up-gradient to down-gradient decreases in these parameters. Such trends are not readily apparent in the data collected to-date. Negative correlations (see Table 1) between source and groundwater samples at this site for all but one sampling location (HW-3, which is the furthest down-gradient) indicate that groundwater quality with respect to TDS could have improved due to AR at this site. All sampling locations at this site exhibited positive correlations between nitrate values and sampling dates over time (See Table 1). Being that groundwater values are higher than source water values (Appendix B Figure B-19), it is most likely that nitrate-N levels in groundwater are influenced by other activities than AR.

Ortho-phosphate in groundwater and surface water generally show similar values with the range of concentrations measured to-date in both systems overlapping (Appendix B Figure B-20). Positive correlations between ortho-phosphate values and sampling times (See Table 1) showed that values increased over the time of sampling at this site.

The ***chloride*** data collected during Hall-Wentland operations contains some anomalously high values which may mask a trend indicative of AR influences on groundwater quality (Appendix B Figure B-18). Although chloride concentrations generally are low in both groundwater and source water (<5 mg/L) high and low source water values do seem to generally be reflected in down-gradient increases and decreases. Given that though, negative correlations between chloride data and sampling dates over time for all sampling locations at this this site suggest that chloride over time could be decreasing.

Three ***SOC's, di(ethylhexyl)-phthalate, diethyl phthalate, and Malathion***, were detected in 4 different sampling events. However, in only one sampling event were SOC's (di(ethylhexyl)-phthalate and diethyl phthalate) detected in the source water. In all cases, the detected concentrations were below EPA drinking water standards, as follows:

- Di(ethylhexyl)-phthalate values ranged from 1.6 to 4.1 µg/L. The EPA drinking water standard is 6.0 µg/L.
- Diethyl phthalate values ranged from 0.5 to 2.2 µg/L. The EPA drinking water standard for diethyl phthalate is 5000 µg/L.
- Malathion was detected only for the 04/11/07 sampling event in the three wells and not in the source water. Malathion levels ranged 0.3 to 0.4 µg/L. This is far below the EPA drinking water standard of 500 µg/L.

Insufficient data is available for statistical and long term trend evaluation of SOC's at this site.

In summary data from the Hall-Wentland site are interpreted to show that AR operations generally had little or no significant influence on local groundwater quality. There are likely several reasons for this, including:

- The general similarity of the source water and the groundwater at the Hall-Wentland site may be related to the location and leaky nature of the Wells ditch with respect to the monitoring wells and the AR site. Wells ditch was shown during work on the AR project to be a leaking ditch, supplying recharge to local groundwater. The ditch is in-turn located up gradient of the up gradient well, HW-2. Given this relationship, water leaking from the canal to the aquifer has already influenced local groundwater up gradient of the AR site, masking any potential AR site influence on local groundwater. This relationship is one we have come to expect across much of the Basin, the surface water system contributes significant recharge to the alluvial aquifer, and as such, exerts a strong influence on local groundwater quality quite independently of any AR activity.
- For some constituents the soil column (vadose zone) acts as a filter and these constituents are held up, or filtered, by the soil column as water infiltrates from the surface to the underlying alluvial aquifer.
- In other cases, where constituents are present in groundwater but not in source water, such as is usually the case with SOC's, we infer that these entered the groundwater system at a location(s) other than the AR site.

Based on what was seen at the Hall-Wentland site when it was operated, AR activity may have influenced down-gradient water quality, but the changes from up to down-gradient are relatively small, with the total potential change caused by AR less than variation occurring independent of AR resulting from natural (or normal) canal and ditch operations. With that though, even normal operation generally appears to not cause degradation of the underlying alluvial aquifer.

Locher Road

The Locher Road site is an excavated basin specifically designed for AR located within a larger, inactive gravel pit. It is cross gradient of the Hall-Wentland site and down gradient from the Hulette Johnson site. It is located about 5 miles southwest of College Place, WA (Figures 1 and 4). AR operations occurred seasonally at the site in 2006, 2007, 2008, 2009, 2011, and 2012. The Locher Road site is operated by GFID#13 under an agreement with the owner of the site.

Water quality samples have been collected from one up gradient monitoring well (L-1), two down gradient monitoring wells (L-2 and L-3), and from the source water diversion on GFID's Burlingame Canal. Parameters used in this evaluation of potential AR influences on the alluvial aquifer include the field parameters pH and EC, turbidity, nitrate-N, hardness, TDS, chloride, and SOC's. Plots for these data are provided in Appendix C.

Locher Road groundwater monitoring data is interpreted to show that AR at this site does influence groundwater quality. In addition, some of the data may show the influence of local land uses.

TDS, hardness, and EC data are interpreted to show up gradient to down gradient decreases directly related to AR. Generally source water values are lower than down gradient groundwater, and down gradient groundwater values are lower than up gradient (Appendix C Figures C-15, C-16 and C-12). Scatter plot trends and positive correlations between TDS data and sampling dates over time for all site source and all groundwater datasets indicates a slight increasing trend over time. However, this trend appears to be slight enough as to not be indicative of any groundwater degradation by AR operations at the site (Appendix C Figures C-5, C-15 and Table 1). EC at this site exhibits slightly increasing trends on scatter plots and positive correlations between EC values and sampling dates over time in source water and all monitoring wells except the up-gradient well LR-1 which exhibits a slightly negative trend and negative correlation (Appendix C Figures C-2, C-12 and Table 1). However actual values of EC from LR-1 average higher than all other locations and source water at this site which is typical for up-gradient conditions. LR-1 is very close to the recharge basin and the decreasing trend and negative correlation with sampling date over time could be due to some groundwater dilution caused by possible groundwater mounding from AR.

Chemical oxygen demand (COD) show concentration ranges where both source water and groundwater overlap (Appendix C Figure C-14 and Table 1). These data are interpreted to show that there are no trends in groundwater and surface water.

Locher Road site ***nitrate- N*** data is interpreted to in part reflect groundwater impacts unrelated to AR operations. Source water nitrate-N is very low and prior to 2009 there was an up gradient to down gradient decrease in constituent concentration that is interpreted to result from source water dilution of groundwater nitrate -N. In the 2009, 2011, and 2012 there is elevated nitrate-N in the most down gradient well, L-2, while source nitrate-N is extremely low, less than 1 mg/L. Elevated nitrate-N in well L-2 is interpreted to be because the well is down gradient of an actively farmed field and results from fertilizer application on that field, and not AR operations. Box-plot analysis and positive correlation coefficient comparisons between sampling location datasets at this site indicate dilution of groundwater with respect to nitrate-N in a down gradient direction (Appendix C Figure C-18 and Table 1). This is interpreted to show no alluvial groundwater quality degradation, but possibly improvement, because of AR operations with respect nitrate-N.

Source water generally displays lower values for ***ortho-phosphate*** than groundwater. These values do trend together and are relatively close suggesting a common source of ortho-phosphate for both systems. These observations can be seen in box-plots comparing sampling location datasets for this site (Appendix C Figure C-19). Source water ortho-phosphate correlation with sampling date over time is slightly positive but moderately negative for all monitoring wells. This suggests that AR operation at Locher Road does not degrade alluvial groundwater quality with respect to ortho-phosphate.

Chloride, pH, and turbidity data are less clear, and at this time are interpreted to show that source water and local groundwater have many similarities. With that general interpretation groundwater chloride generally is higher than source water, groundwater pH generally is lower, and turbidity does not seem to show a clear trend because of intermittent elevated levels in L-1. On box-plots, source and groundwater chloride ranges overlap, further illustrating the similarity between them (Appendix C Figure C-17). Turbidity does exhibit slightly negative correlations with sampling dates over time suggesting some possible flushing of fine materials from the alluvial aquifer in the vicinity of Locher Road due to AR (Table 1).

With respect to ***SOC's***, the Locher Road SOC data collected in 2007 and 2008 is similar to the other SOC data sets, showing intermittent low concentration detections of just a few parameters ***(Bromacil, Malathion, Di-N-Butyl-Phthalate)***, although these parameters differ somewhat from the other sites. Bromacil is detected in some of the up gradient groundwater samples, but not in the down gradient samples, suggesting potential down gradient dilution from AR activities. The other low concentration SOC detections for Malathion (detected once in all three wells) and Di-N-Butyl-Phthalate (detected in 2 sampling events in 2007) are sporadic, low concentration in nature, and show down gradient reduction in concentrations when seen. These are interpreted to show that Locher Road AR activities are not causing degradation of local groundwater by introducing SOC's to the alluvial aquifer system. Insufficient data is available for statistical and long term trend evaluation of SOC's at this site.

Stiller Pond

The Stiller Pond AR site is an artificial pond that has been used historically as an irrigation water storage impoundment. Unlike the other three sites it is located north of the Walla Walla River and several miles west of Walla Walla (Figure 1 and 5). The source of water for the Stiller Pond site is Mill Creek, and water is delivered via a pipeline that extends from the creek to the site. The Stiller Pond site was operated by the WWCCD, under an agreement with the land owner.

AR operations first began at Stiller Pond in the spring of 2012 and lasted approximately 3 weeks. During this AR event water quality samples were collected at one down gradient well and from the source water. Parameters used in this evaluation of potential AR influences on the alluvial aquifer include the field parameters pH, EC, dissolved oxygen (DO), and oxidation-reduction potential (ORP) and hardness, chloride, magnesium, TDS, nitrate-N, phosphate, and TKN.

SOC's were not collected at the Stiller Pond site. Comparative histograms for the data collected are provided in Appendix D.

Like the other AR sites described herein, at Stiller Pond, the influence of AR operations on local groundwater is apparent but impacts are not major and do not appear to lead to degradation of local groundwater quality. Specifically:

- Pre- and post-test groundwater and source water ***pH*** remained relatively consistent.
- ***EC and ORP*** appear to have decreased as a result of AR activities, with the down gradient well dropping soon after the start of AR operations and infiltration of low EC and anion source water.
- ***Chloride, hardness, magnesium, and TDS*** were all lower following the AR event. This is again inferred to result from dilution of groundwater constituents as low concentration source water infiltrated to and recharge the local alluvial aquifer.
- Nutrient concentrations, which include ***nitrate-N, phosphate, and TKN*** are interpreted to show that AR at this site did not degrade groundwater quality. TKN was elevated slightly in the post-recharge sample, but this was expected due to the introduction of additional organic nitrogen, ammonia and ammonium to the groundwater via recharge through the biomass on the surface of the Pond in the form of decaying plant matter. This slight rise in TKN is not interpreted to reflect groundwater degradation because the slight increase in TKN did not correspond to a matching increase in nitrate-N. In fact, nitrate-N decreased in groundwater following the AR event.

Basic water quality parameters summarized above are interpreted to show that AR activities at the Site did not degrade groundwater quality during the 2012 AR season. This data, especially the fact that pre-test groundwater concentrations in most parameters are higher than post-test groundwater concentrations and source water, suggests AR operations at the Site may lead to reductions in parameter concentrations as recharge water is added to the alluvial aquifer underlying the Site.

Summary

Review of the groundwater quality monitoring data collected to-date at the three active AR sites, Hulette Johnson, Locher Road, and Stiller Pond and at the inactive Hall-Wentland site we conclude that while AR operations conducted in the Walla Walla Basin does influence local groundwater quality, this influence should not be construed as degradation. Based on the data reviewed here the basic changes seen include the following:

- With respect to nutrient type constituents, including nitrate-N, TKN, phosphate, and ortho-phosphate the groundwater changes we see generally show down gradient declines in constituent concentrations, which we interpret to reflect dilution of groundwater concentrations by AR water.
- Other parameters, such as TDS, chloride, and EC also commonly show evidence of down gradient reductions through AR sites that we again interpret as evidence of dilution of these parameters in groundwater by AR water.
- The SOC data available for these sites is interpreted to show that AR operations have essentially no influence on SOC's present in groundwater. Based on what we reviewed

SOC detections are sporadic, not systematic, and at very low concentrations. With that observation, we interpret the few detections to result from background conditions reflective of activities other than AR operations.

- In addition to these observations, the Hall-Wentland data is instructive as it shows the importance of natural leakage from surface waters (which typically are the same waters these AR sites use for source water) influencing local groundwater chemistry.

The water quality data collected over several AR seasons from four different sites are interpreted to have not resulted in alluvial aquifer water quality degradation. Field parameters and major ion hydrochemical trends seen in monitoring well data commonly show reduced concentrations, indicating dilution of groundwater concentrations by AR operations. A few anomalies did occur in these trends, but low source water concentrations versus high monitoring well concentrations strongly suggest that AR operations were not the cause of these anomalies. There were no significant SOC detections from any site. Of the SOC detections seen in the data sets, SOC concentrations are low enough to be considered background levels and/or these detections were instances of localized transient introduction to the water table from an unaltered ground surface AR site (specifically HW).

Recommendations

Based on our interpretation that AR has led to little to no degradation of groundwater quality in the Walla Walla Basin, we recommend that future monitoring of AR projects exclude extensive sampling and testing for SOC's. The data collected to-date is interpreted to show very low, and sporadic background SOC concentrations not related to AR activities. Rather SOC detections are likely related to transient events originating at sites other than the AR sites. Thus it is unlikely that SOC's have been or would be introduced to the alluvial groundwater by AR source water.

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WWBWC and GSI, 2010, Aquifer Recharge as a Water management Tool: Hudson Bay Recharge Testing Site Report (2004-9): Report written for Hudson Bay District Improvement Company.

Table 1. Correlation Coefficients between Water Quality Parameters and Sampling Dates over Time. EC =electrical conductivity, COD = chemical oxygen demand, TDS = total dissolved solids, TSS = total suspended solids, TKN = total Kjeldahl nitrogen and TOC = total organic carbon.

Site/ Well	**Correlation Coefficient**											
	pH	**EC**	**Turb.**	**COD**	**TDS**	**TSS**	**HCO3**	**Cl-**	**NO3-**	**TKN**	**Ortho-phos.**	**TOC**
Hall-Wentland												
Source	0.23	0.34	0.16	-0.33	-0.23	N/A	-0.15	-0.44	0.07	N/A	0.42	N/A
HW-1	-0.05	0.66	0.61	-0.28	-0.06	N/A	-0.08	-0.36	0.52	N/A	0.61	N/A
HW-2	-0.23	0.57	0.18	-0.28	-0.02	N/A	-0.36	-0.27	0.32	N/A	0.59	N/A
HW-3	-0.23	0.86	0.12	-0.25	0.21	N/A	0.05	-0.37	0.64	N/A	0.71	N/A
Hulette-Johnson												
Source	N/A	N/A	N/A	-0.89	0.33	0.11	N/A	-0.03	-0.45	-0.31	-0.15	-0.52
HJ-1	N/A	N/A	N/A	-0.57	0.30	-0.54	N/A	0.54	0.02	-0.25	-0.20	-0.35
Locher Road												
Source	-0.50	0.01	0.76	0.31	0.14	N/A	0.00	-0.57	-0.25	N/A	0.14	N/A
LR-1	-0.43	-0.16	-0.11	0.03	0.44	N/A	-0.37	0.40	0.28	N/A	-0.40	N/A
LR-2	-0.69	0.54	-0.03	-0.05	0.68	N/A	0.42	0.55	0.63	N/A	-0.42	N/A
LR-3	-0.65	0.12	-0.22	-0.09	0.33	N/A	0.07	-0.27	0.43	N/A	-0.39	N/A

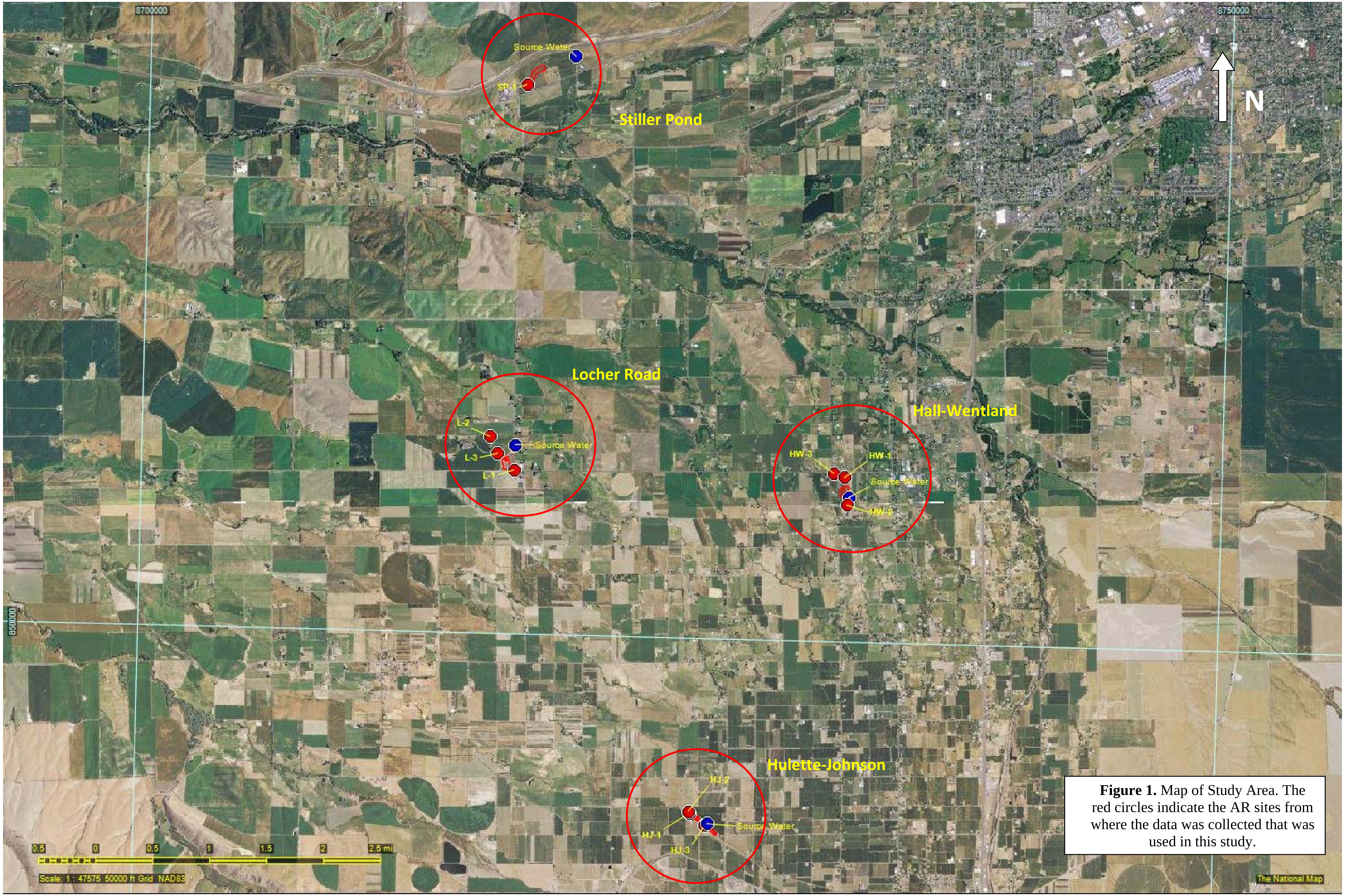

Figure 1. Map of Study Area. The red circles indicate the AR sites from where the data was collected that was used in this study.

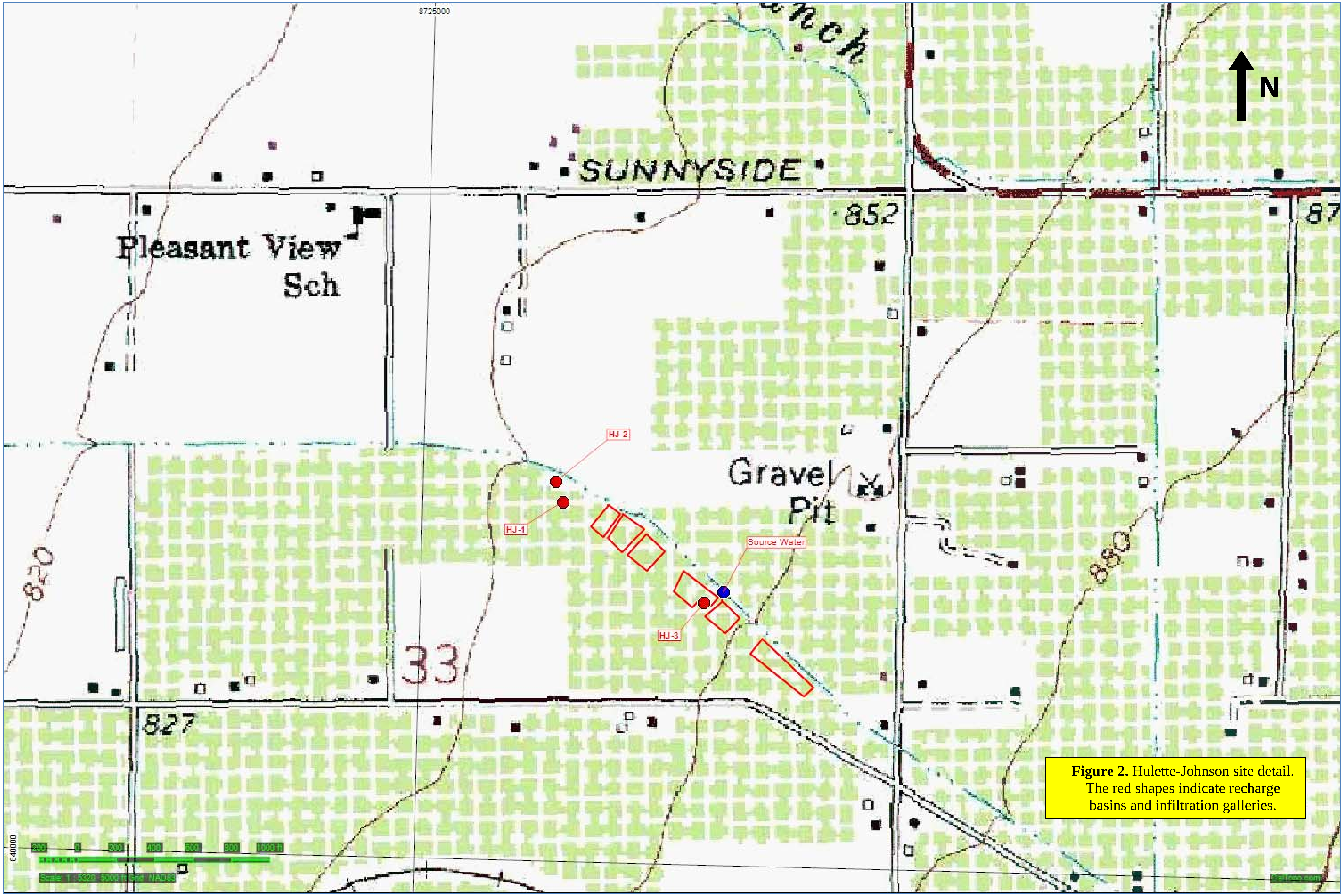

Figure 2. Hulette-Johnson site detail. The red shapes indicate recharge basins and infiltration galleries.

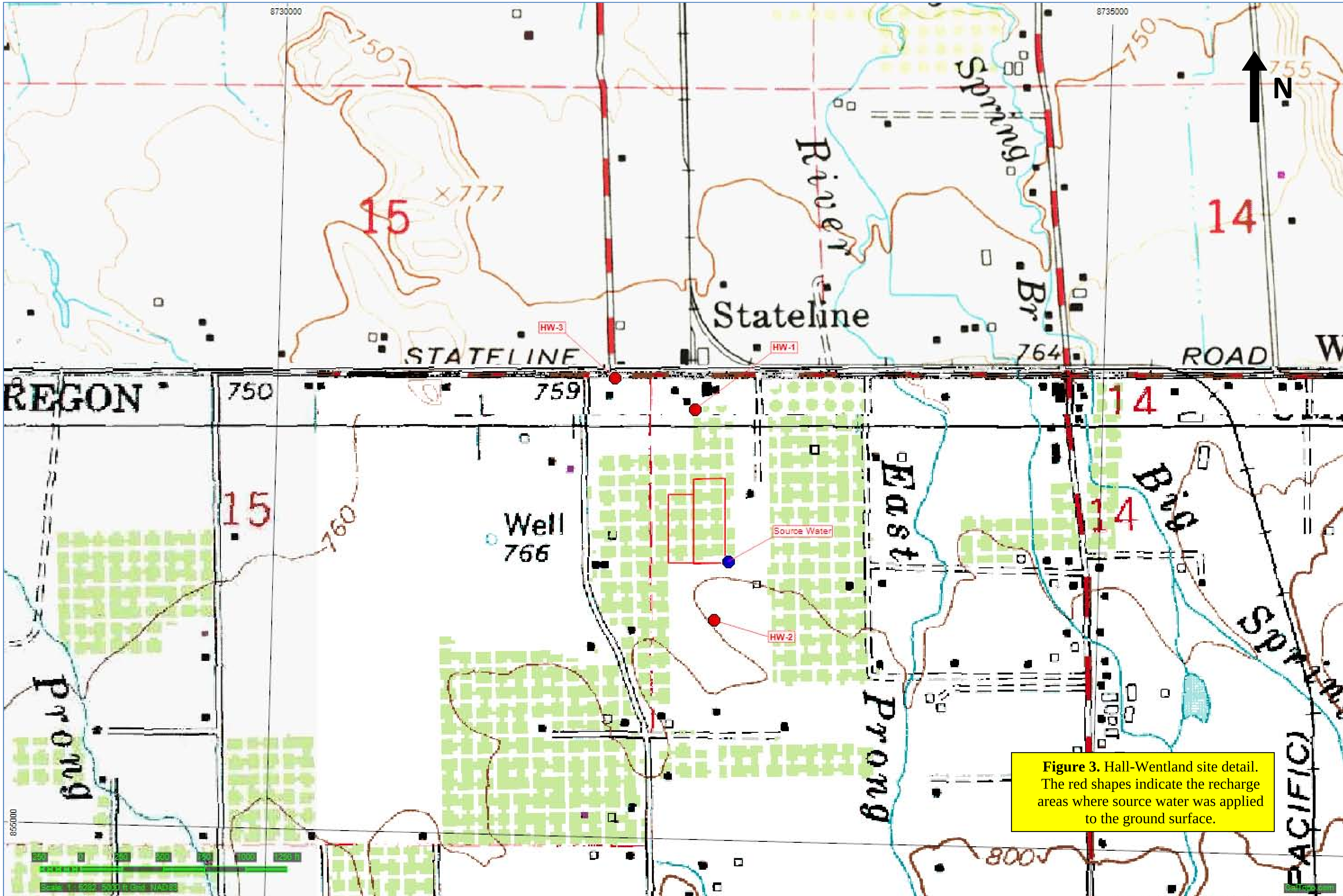

Figure 3. Hall-Wentland site detail. The red shapes indicate the recharge areas where source water was applied to the ground surface.

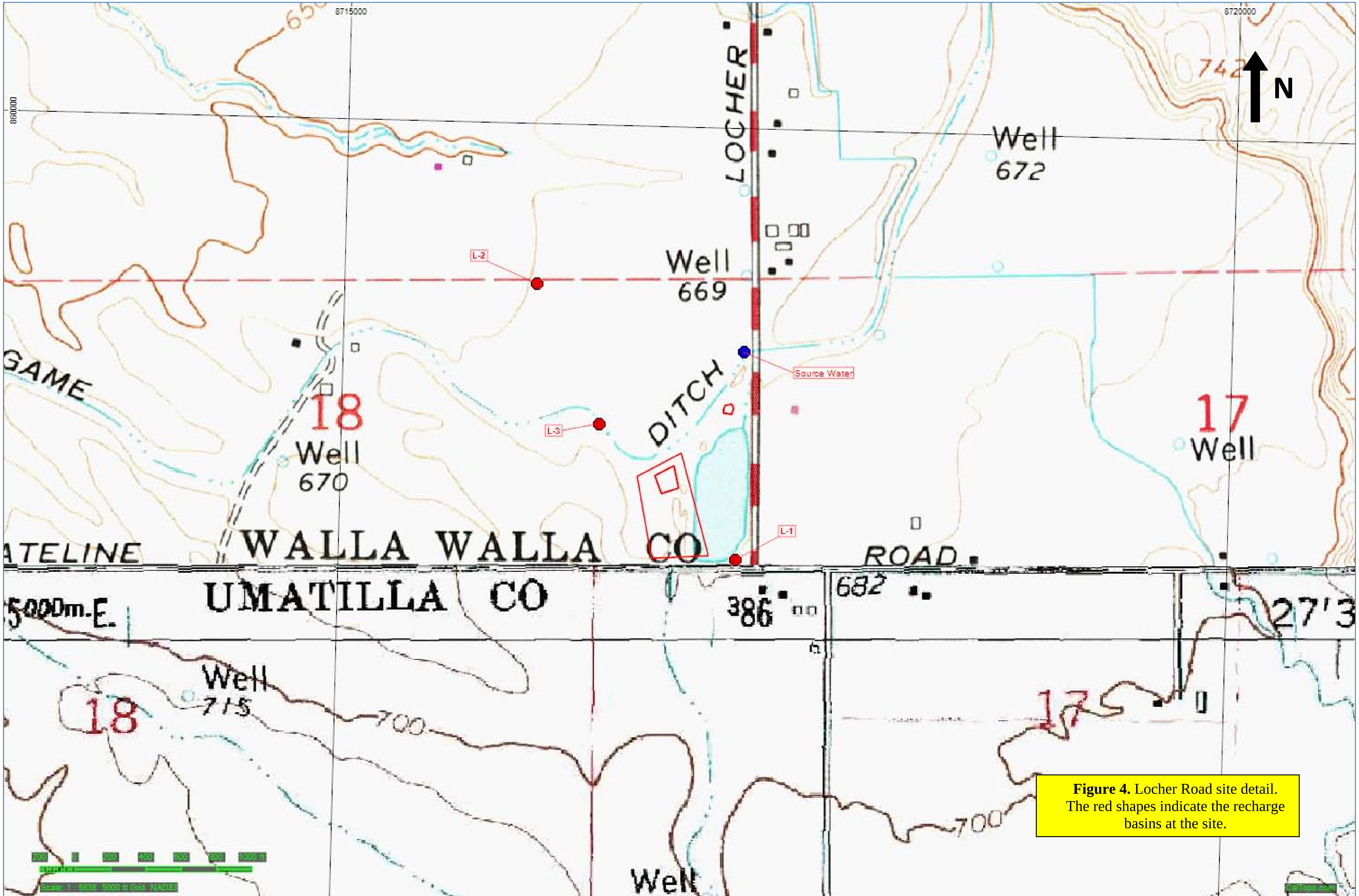

Figure 4. Locher Road site detail. The red shapes indicate the recharge basins at the site.

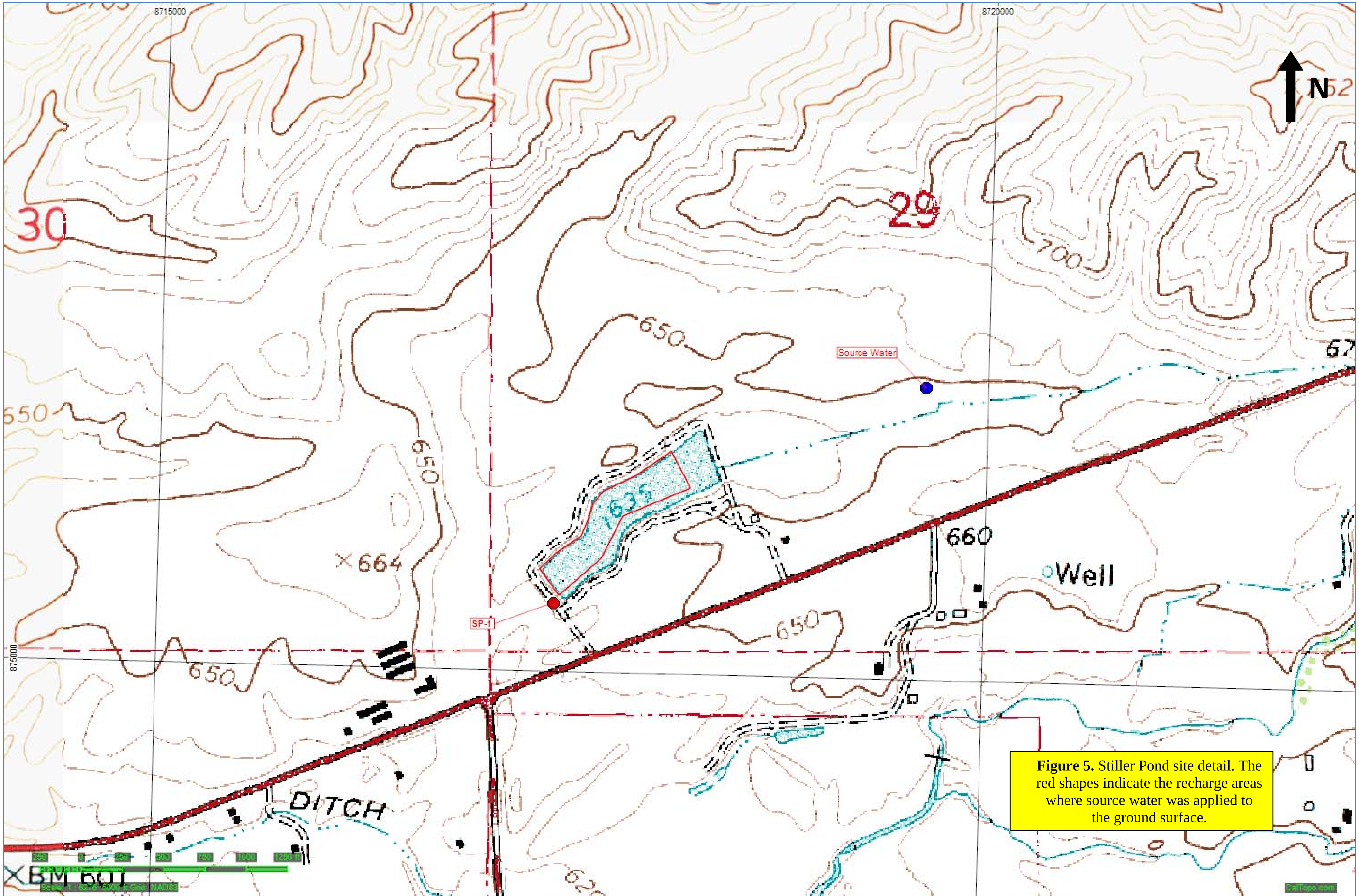

Figure 5. Stiller Pond site detail. The red shapes indicate the recharge areas where source water was applied to the ground surface.

Appendix A

Hewlett-Johnson Data Plots

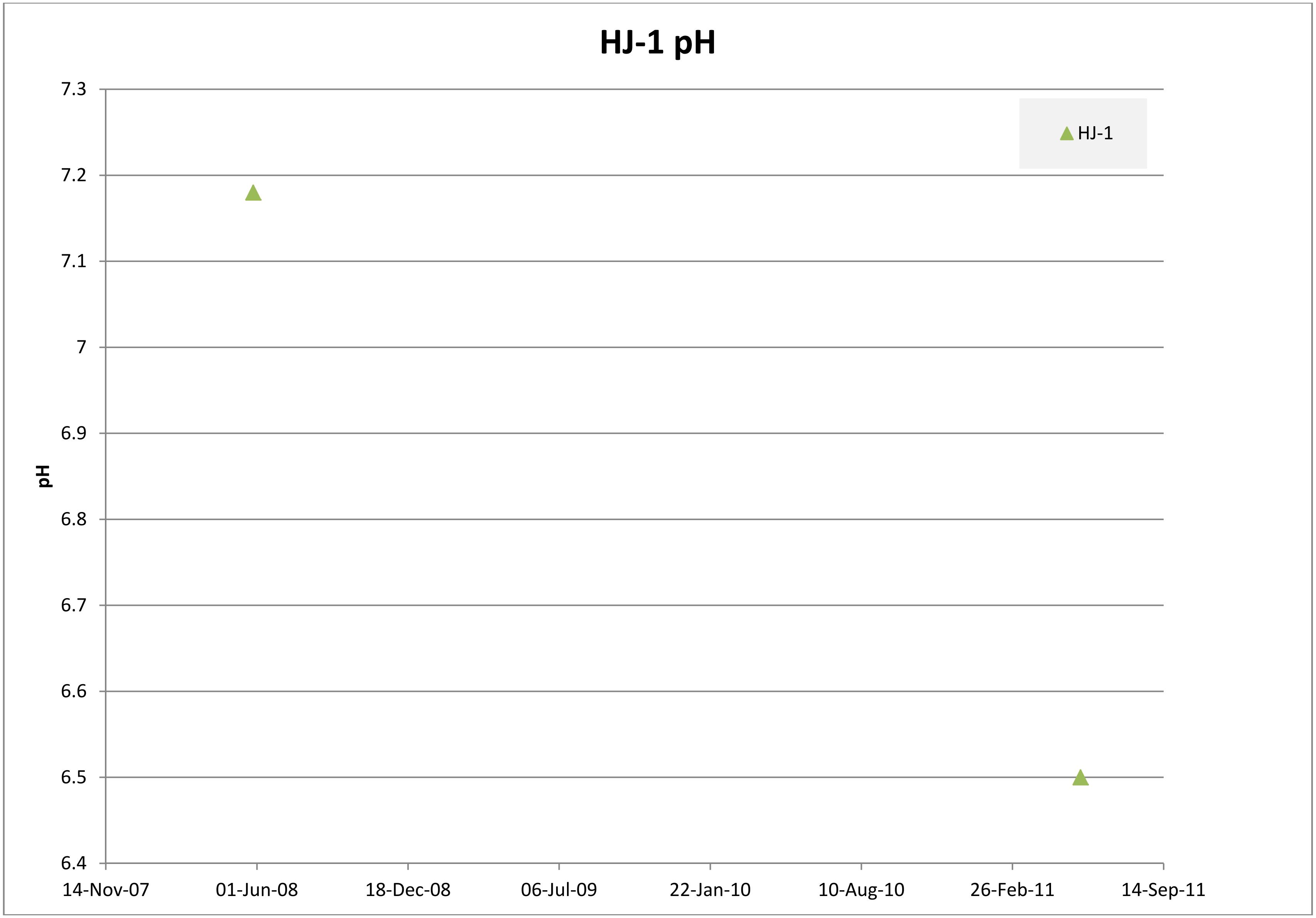

Figure A-1. Hewlett-Johnson pH. HJ-1 = Hewlett-Johnson monitoring well 1.

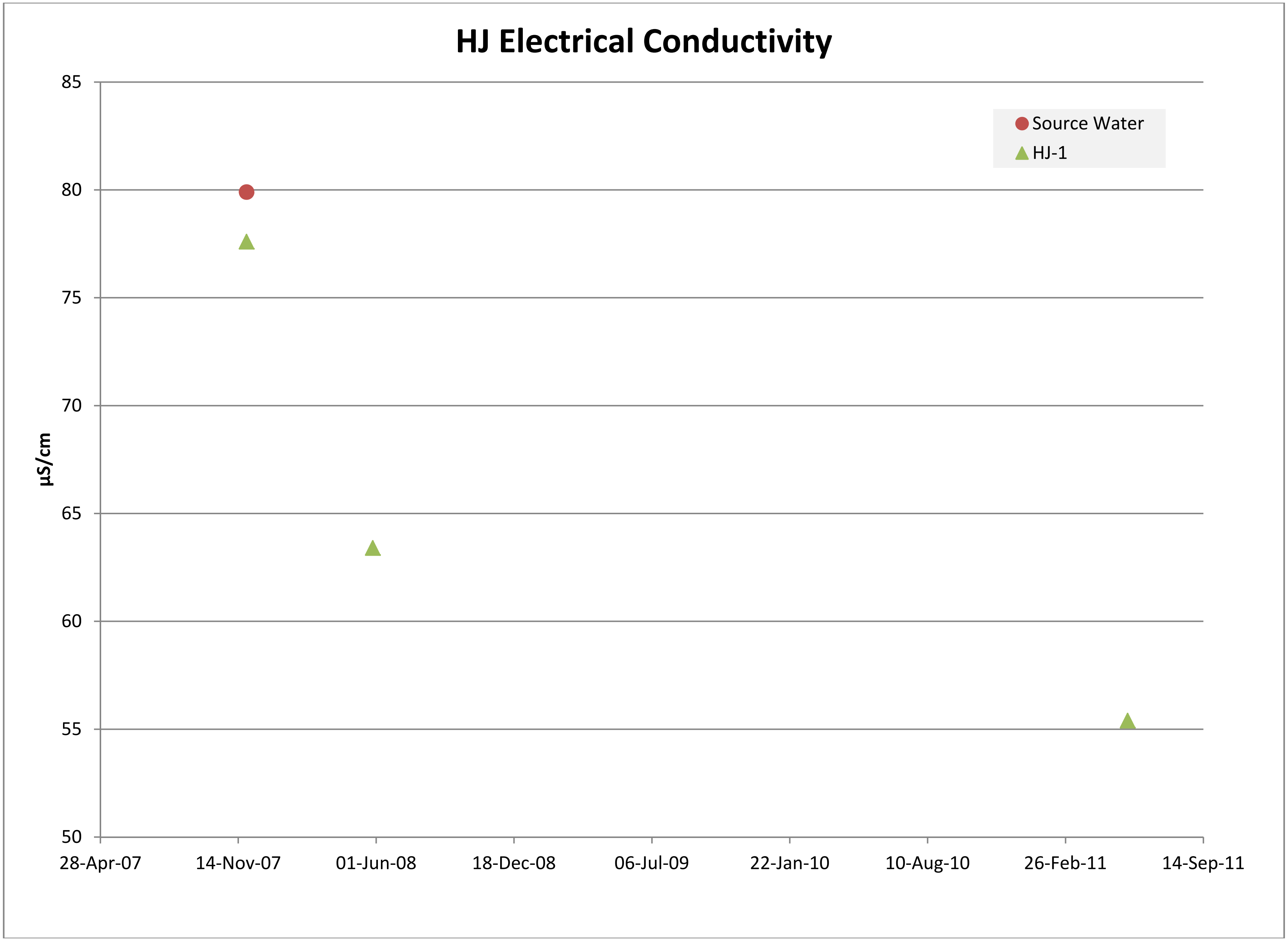

Figure A-2.Hewlett-Johnson electrical conductivity (EC). HJ-1 = Hewlett-Johnson monitoring well 1.

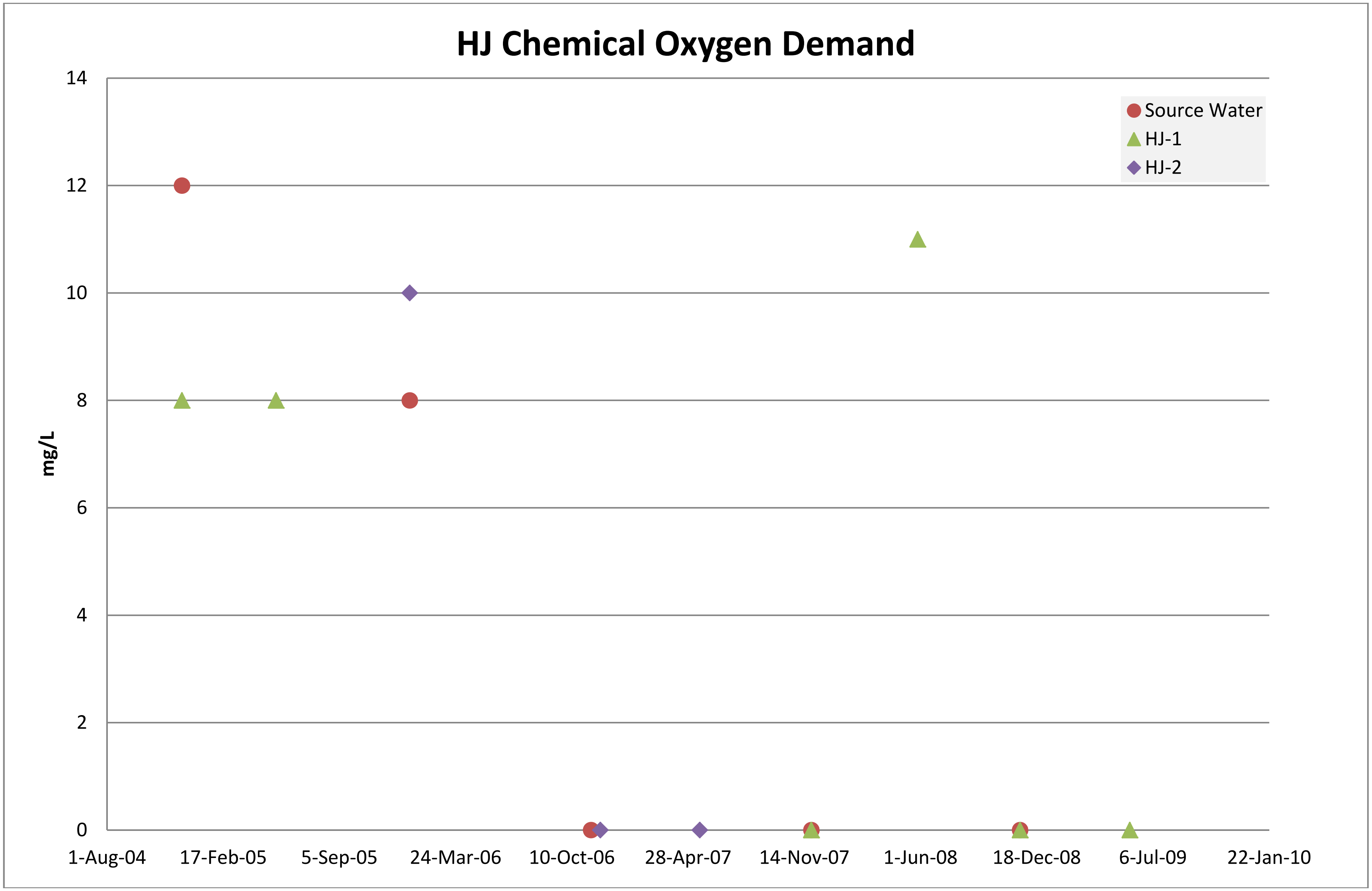

Figure A-3. Hewlett-Johnson chemical oxygen demand (COD). HJ-1 = Hewlett-Johnson monitoring well 1. HJ-2 = Hewlett-Johnson monitoring well 2.

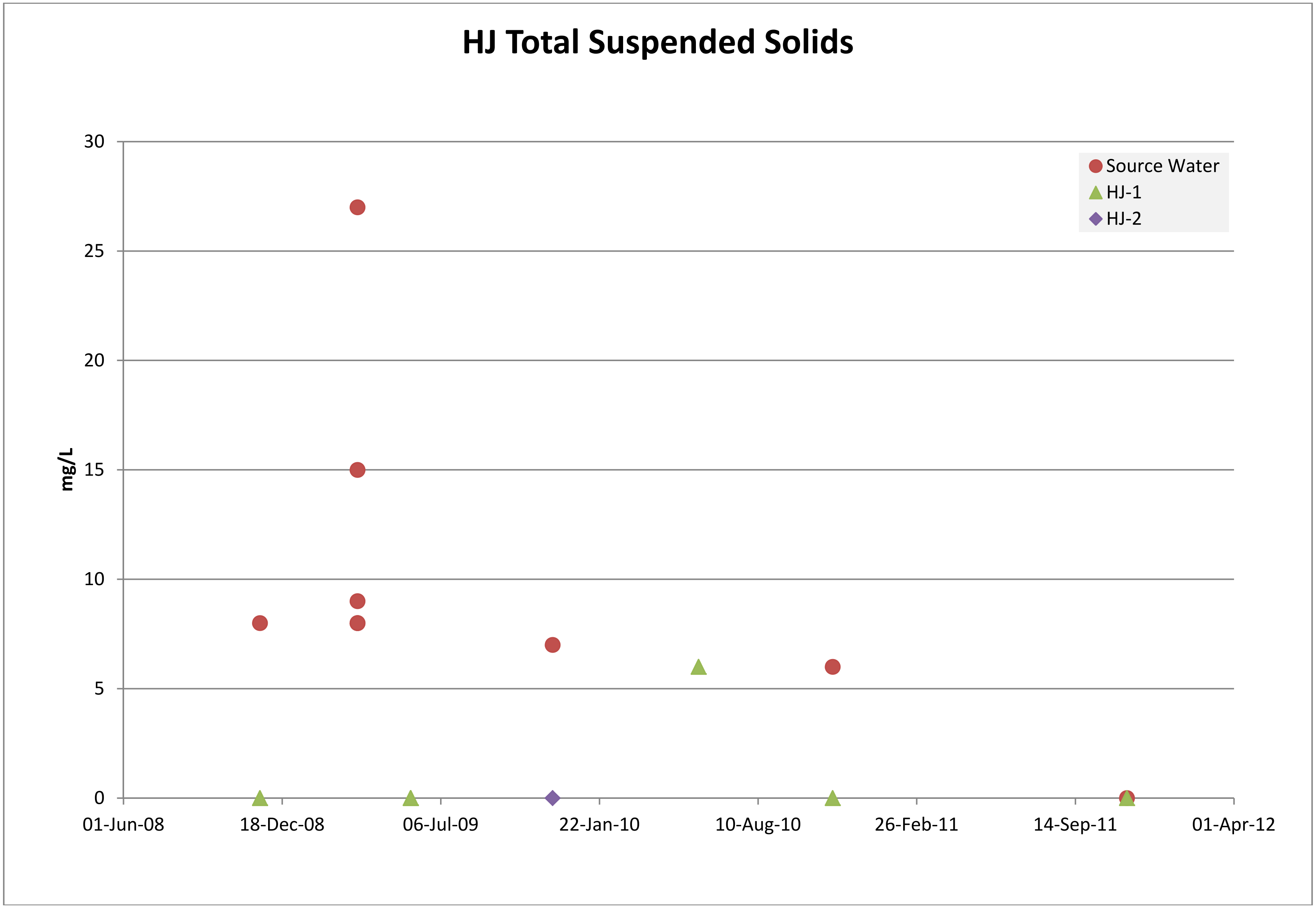

Figure A-4.Hewlett-Johnson total suspended solids (TSS). HJ-1 = Hewlett-Johnson monitoring well 1. HJ-2 = Hewlett-Johnson monitoring well 2.

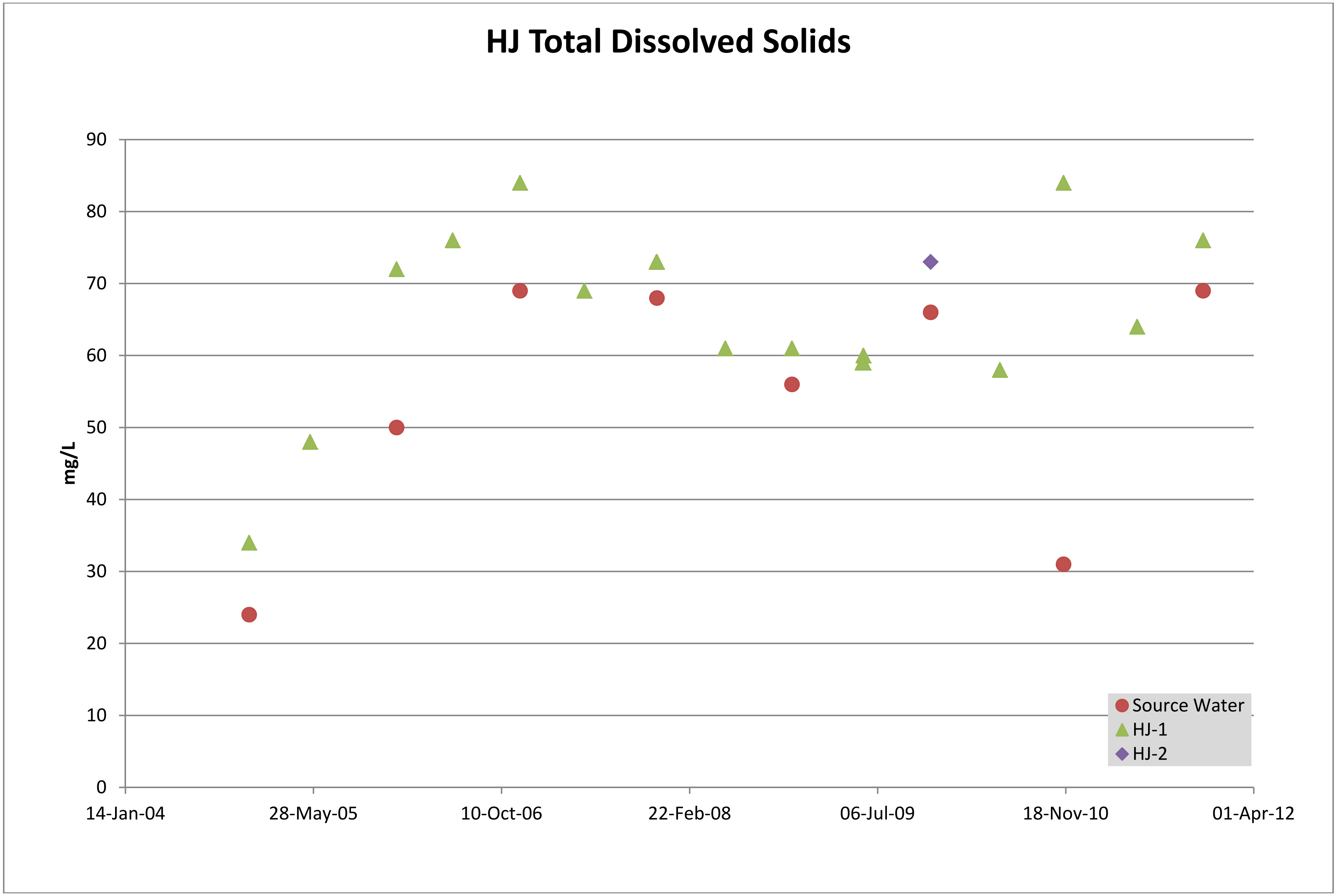

Figure A-5. Hewlett-Johnson total dissolved solids (TDS). HJ-1 = Hewlett-Johnson monitoring well 1. HJ-2 = Hewlett-Johnson monitoring well 2.

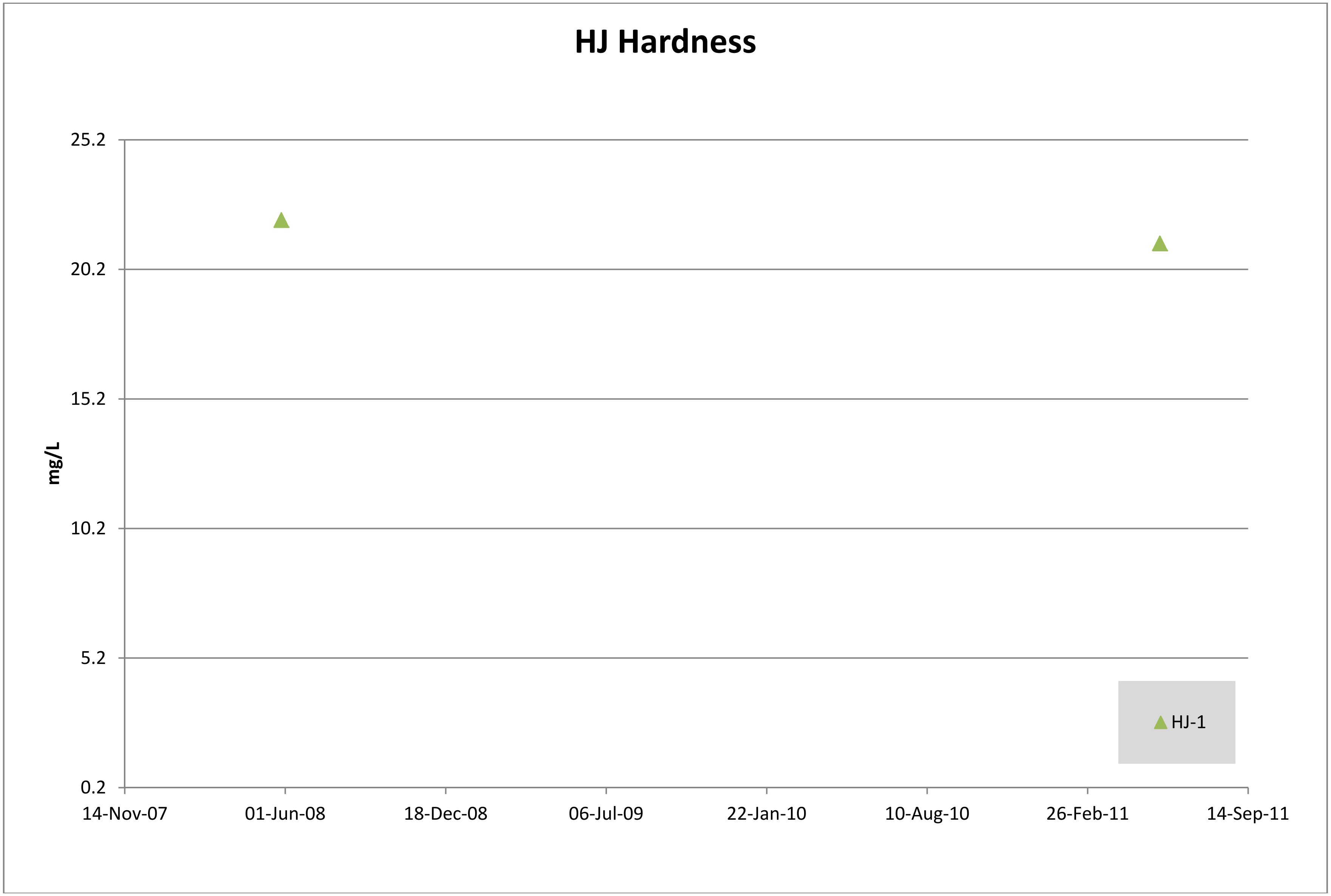

Figure A-6. Hewlett-Johnson hardness. HJ-1 = Hewlett-Johnson monitoring well 1. HJ-2 = Hewlett-Johnson monitoring well 2.

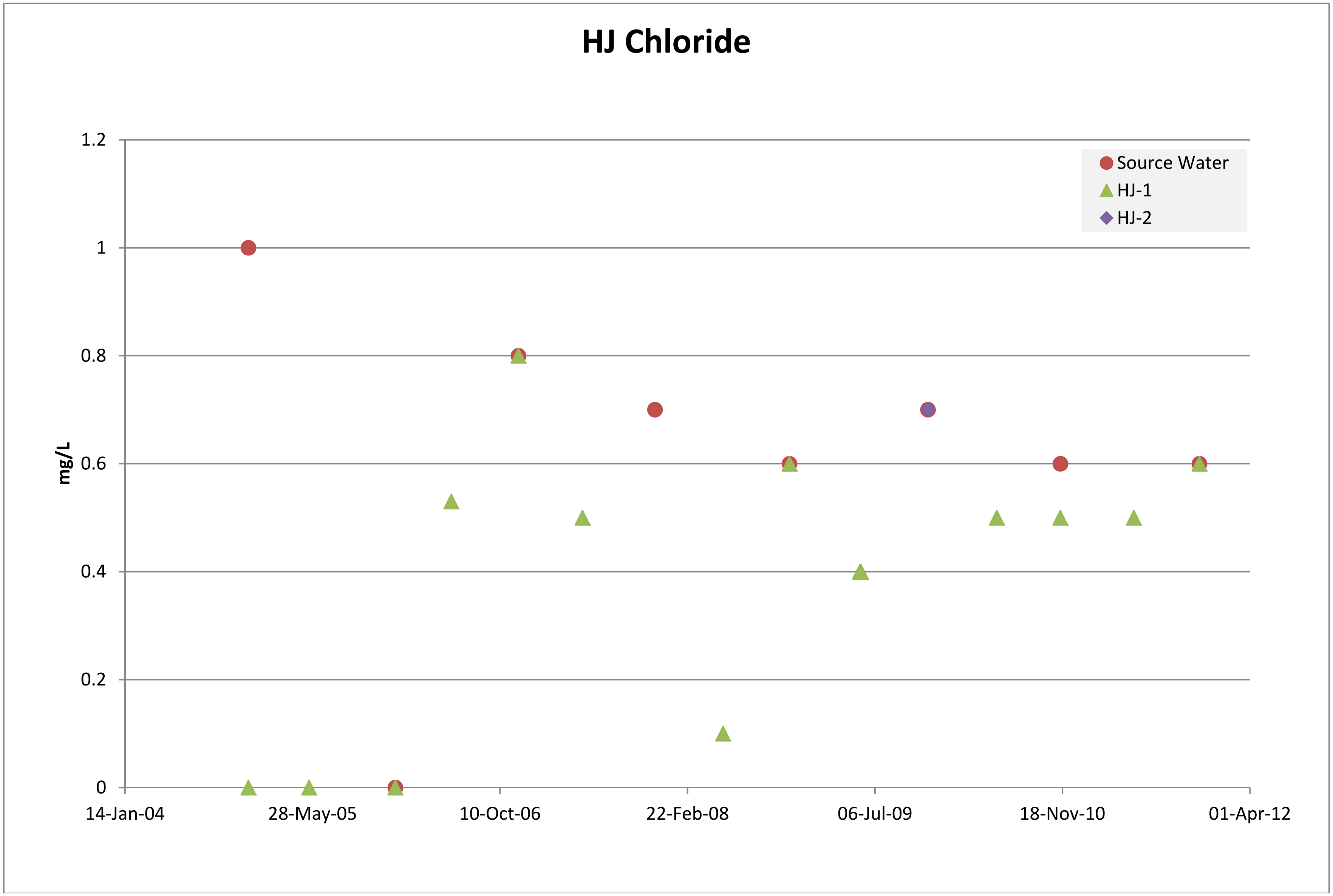

Figure A-7. Hewlett-Johnson chloride. HJ-1 = Hewlett-Johnson monitoring well 1. HJ-2 = Hewlett-Johnson monitoring well 2.

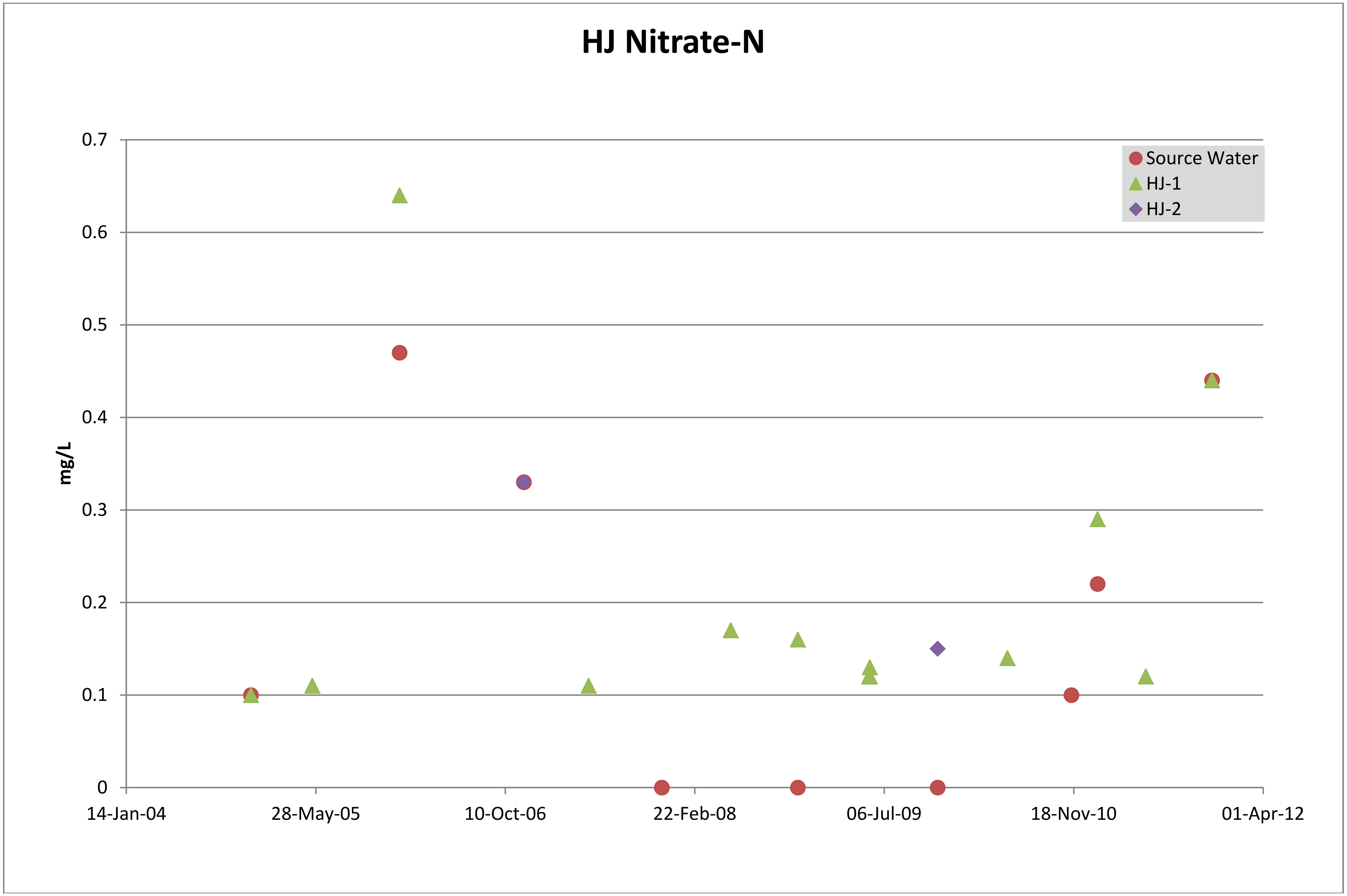

Figure A-8. Hewlett-Johnson nitrate. HJ-1 = Hewlett-Johnson monitoring well 1. HJ-2 = Hewlett-Johnson monitoring well 2.

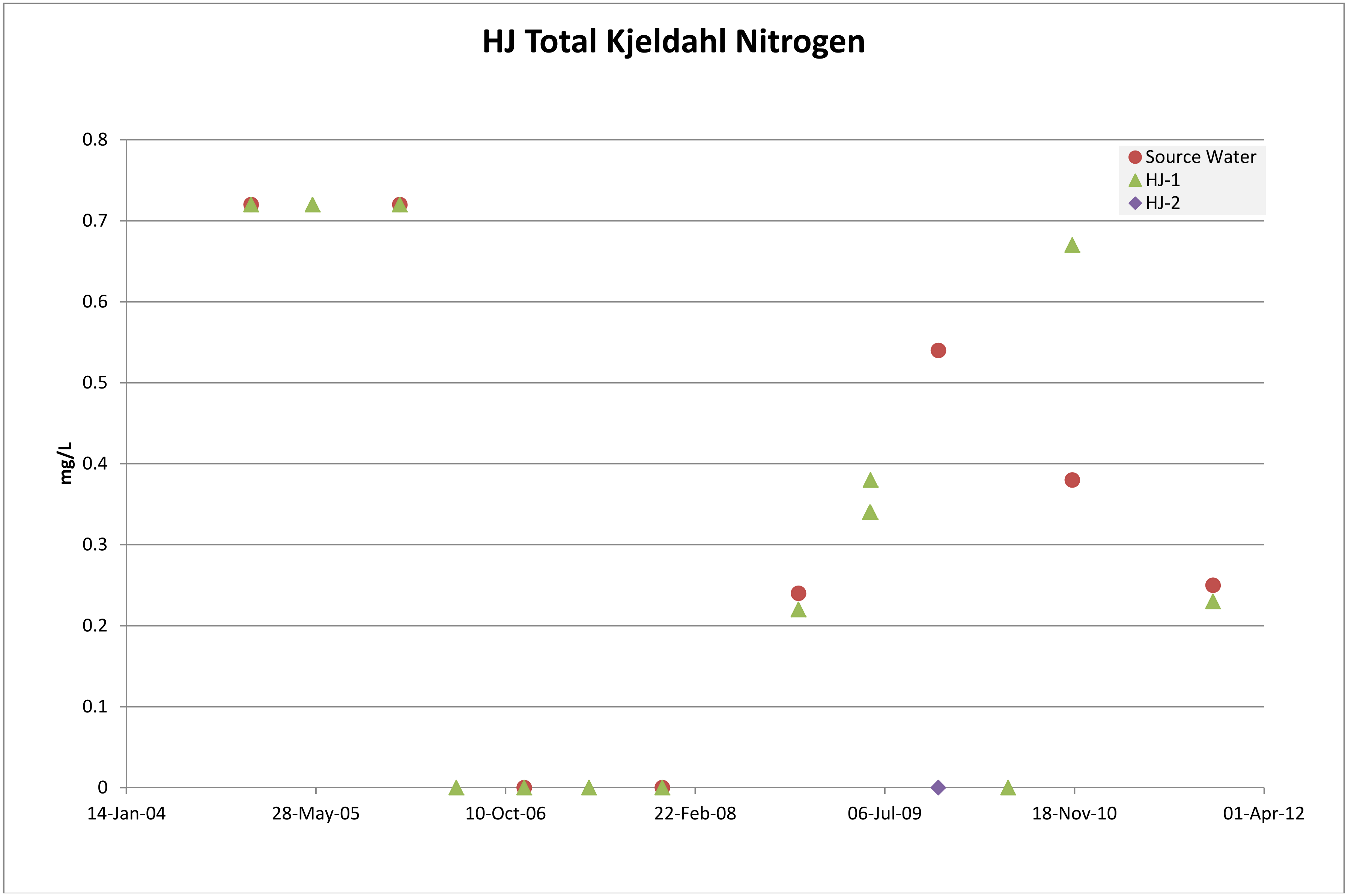

Figure A-9. Hewlett-Johnson total Kjeldahl nitrogen (TKN). HJ-1 = Hewlett-Johnson monitoring well 1. HJ-2 = Hewlett-Johnson monitoring well 2.

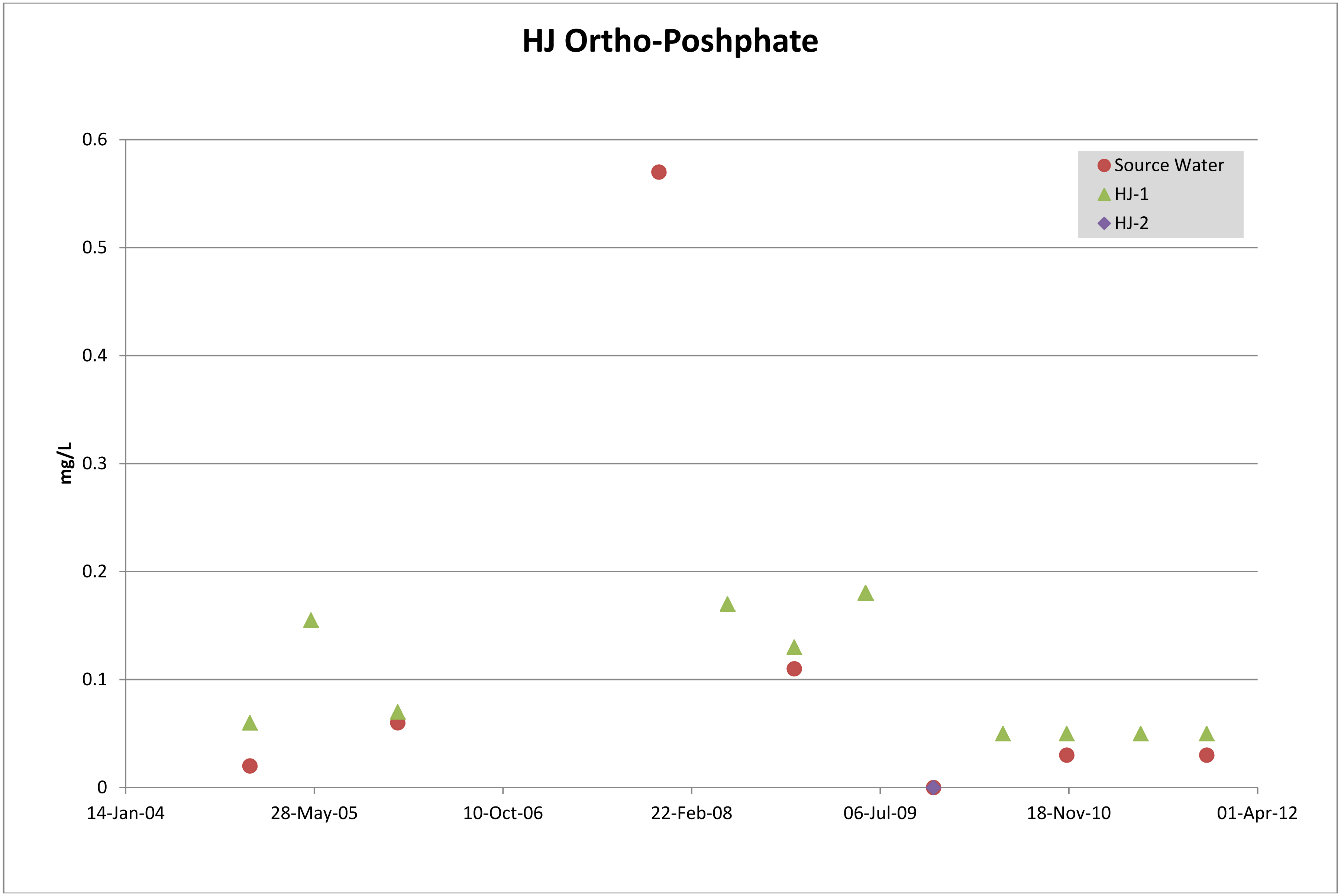

Figure A-10. Hewlett-Johnson ortho-phosphate. HJ-1 = Hewlett-Johnson monitoring well 1. HJ-2 = Hewlett-Johnson monitoring well 2.

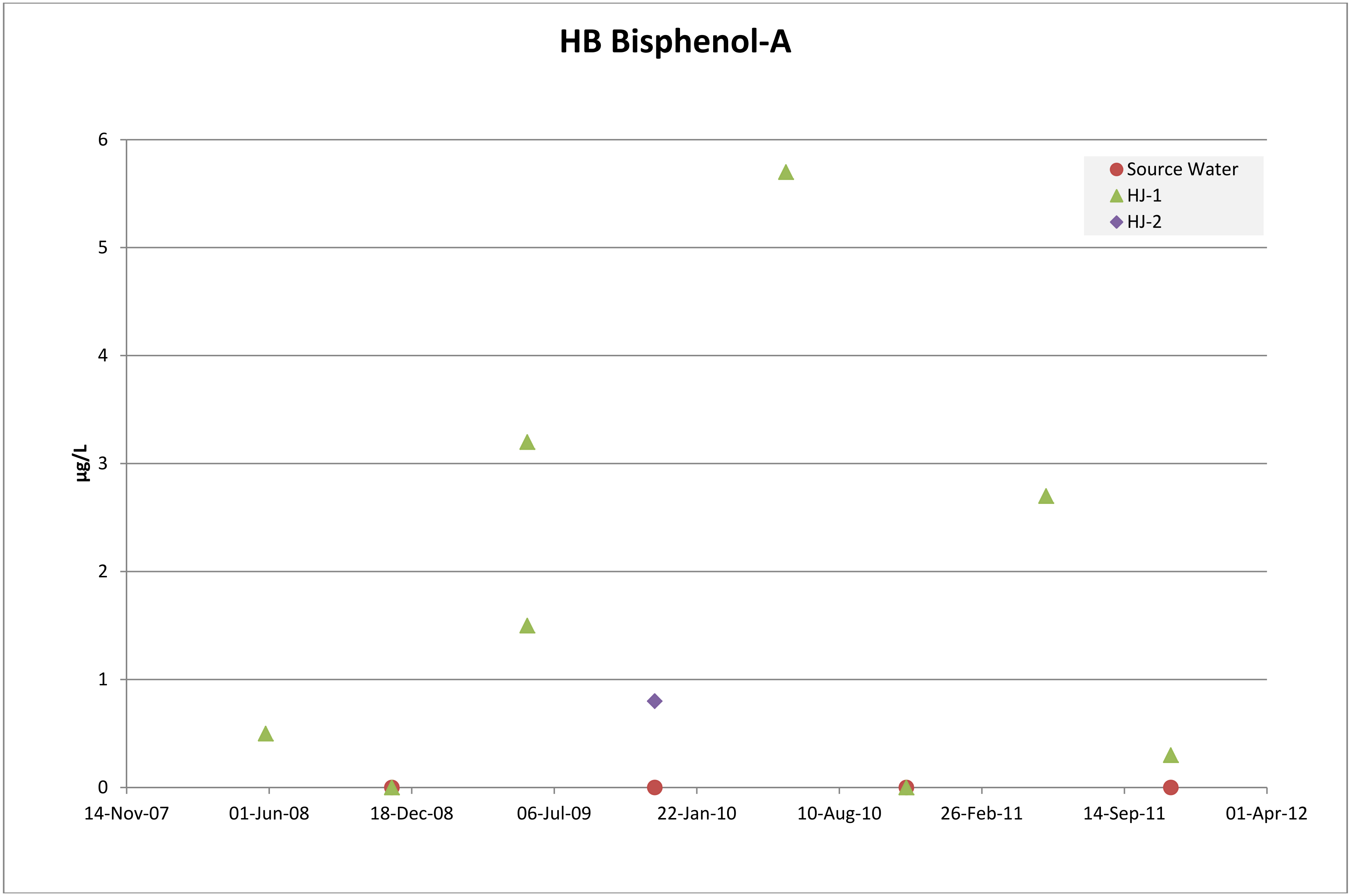

Figure A-11. Hewlett-Johnson bisphenol-A. HJ-1 = Hewlett-Johnson monitoring well 1. HJ-2 = Hewlett-Johnson monitoring well 2.

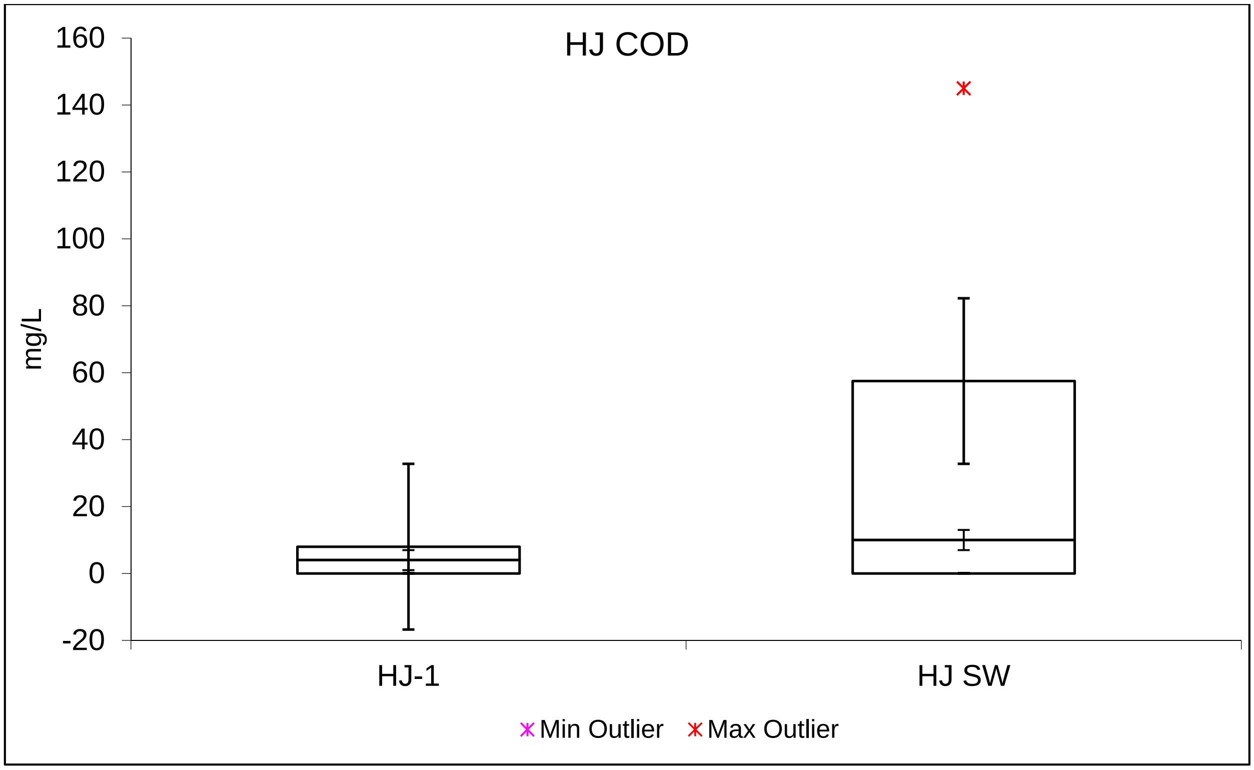

Figure A-12. Hewlett-Johnson pH box-plot comparison displaying standard error bars for the median, upper and lower interquartile ranges.

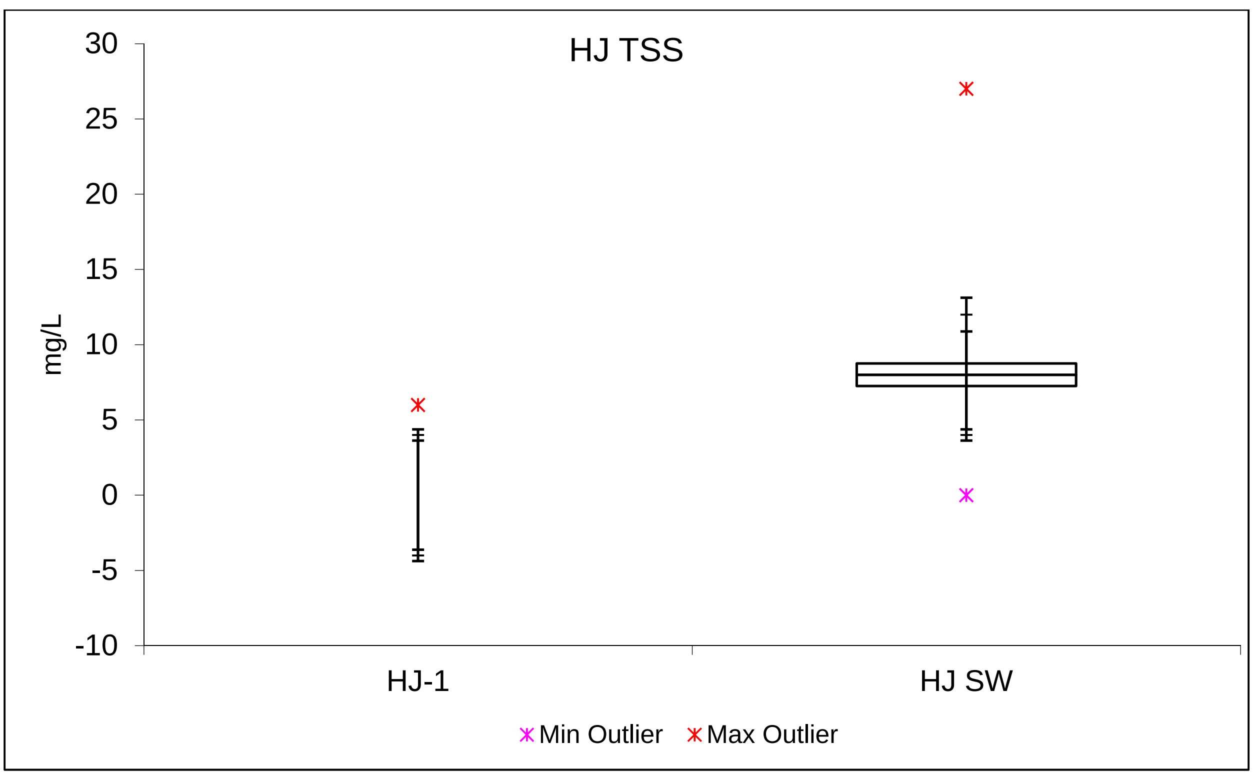

Figure A-13. Hewlett-Johnson TSS box-plot comparison displaying standard error bars for the median, upper and lower interquartile ranges.

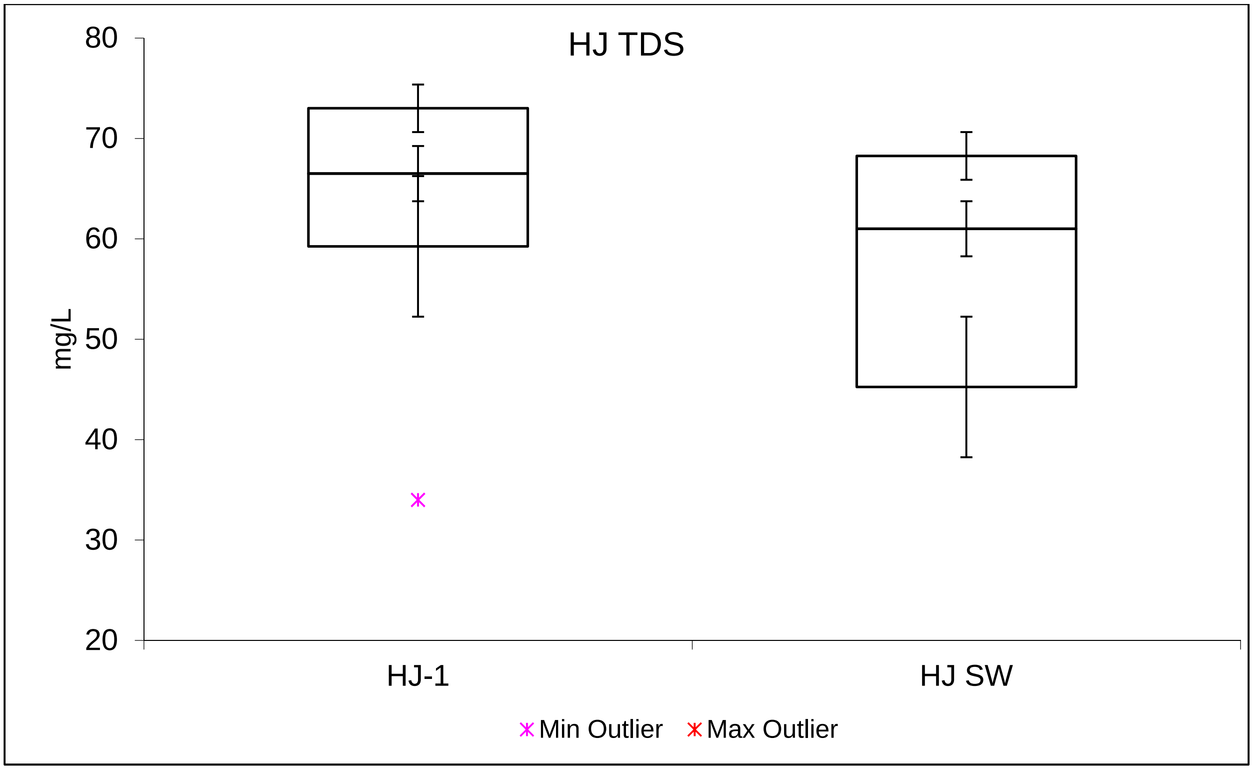

Figure A-14. Hewlett-Johnson TDS box-plot comparison displaying standard error bars for the median, upper and lower interquartile ranges.

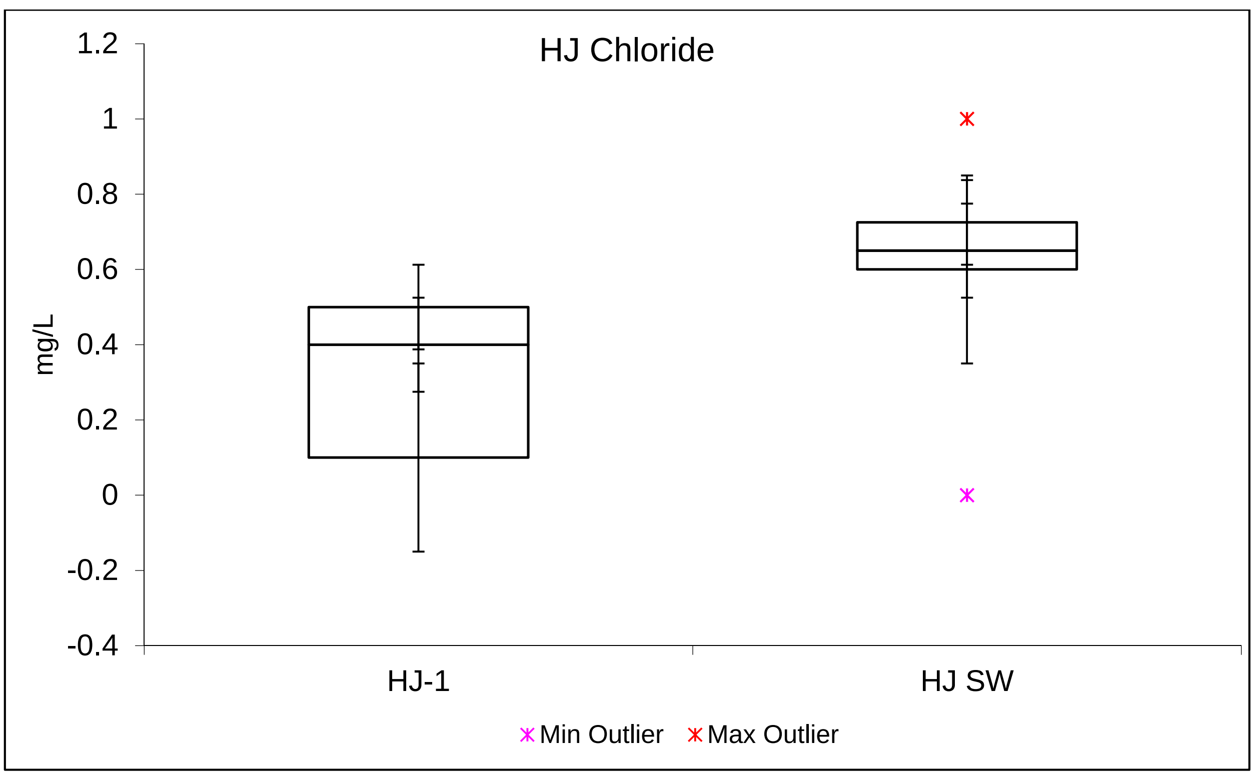

Figure A-15. Hewlett-Johnson chloride box-plot comparison displaying standard error bars for the median, upper and lower interquartile ranges.

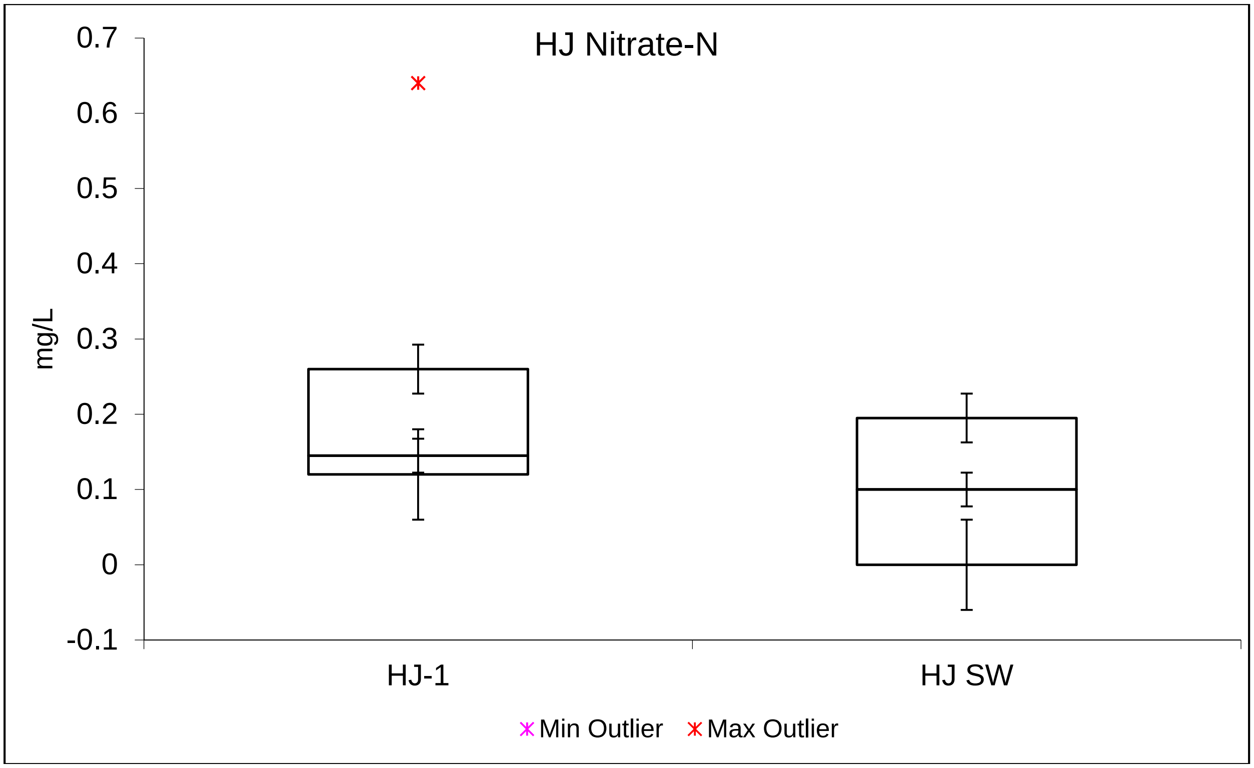

Figure A-16. Hewlett-Johnson nitrate-N box-plot comparison displaying standard error bars for the median, upper and lower interquartile ranges.

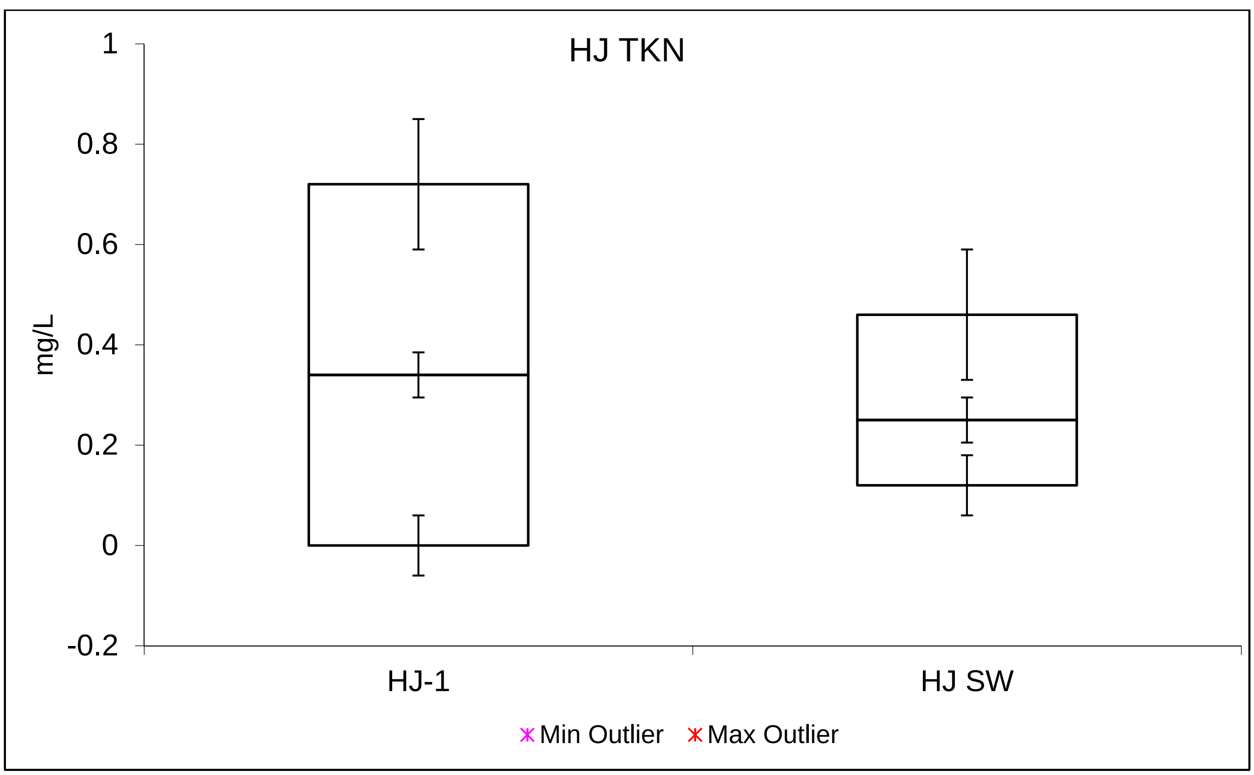

Figure A-17. Hewlett-Johnson TKN box-plot comparison displaying standard error bars for the median, upper and lower interquartile ranges.

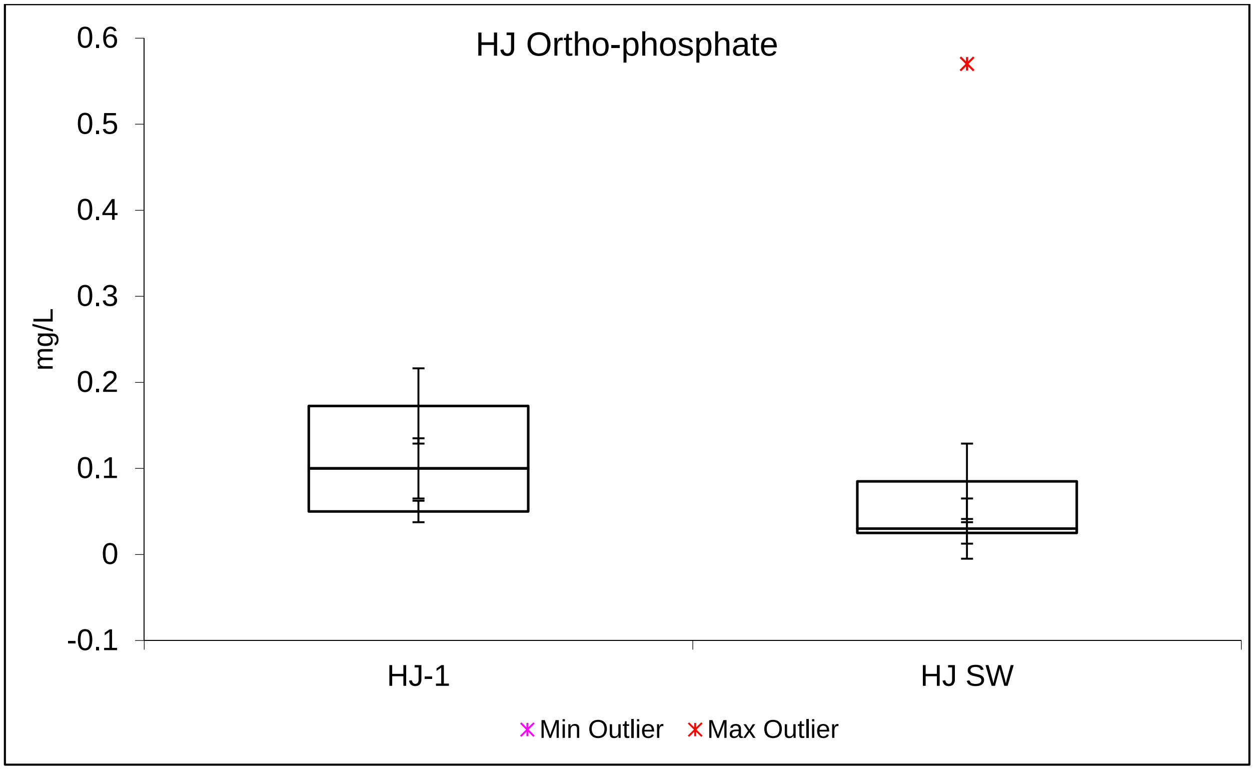

Figure A-18. Hewlett-Johnson ortho-phosphate box-plot comparison displaying standard error bars for the median, upper and lower interquartile ranges.

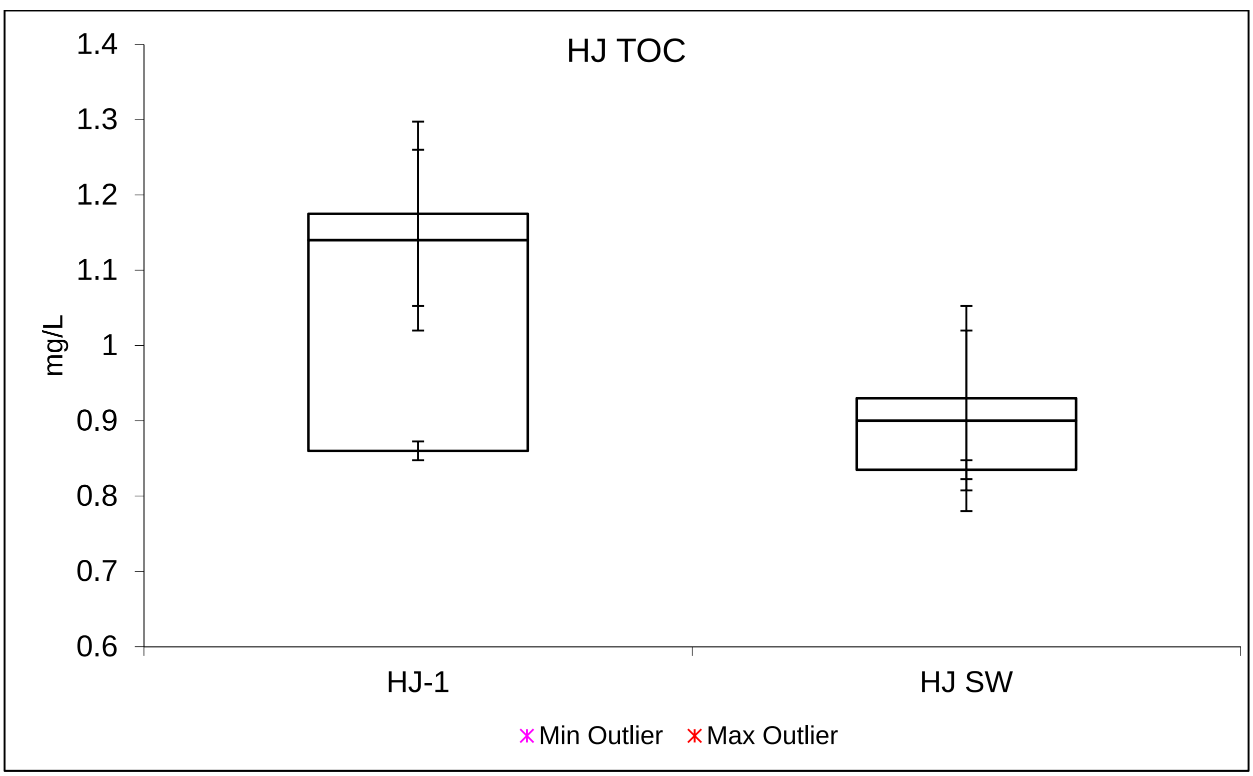

Figure A-19. Hewlett-Johnson TOC box-plot comparison displaying standard error bars for the median, upper and lower interquartile ranges.

Appendix B

Hall-Wentland Data Plots

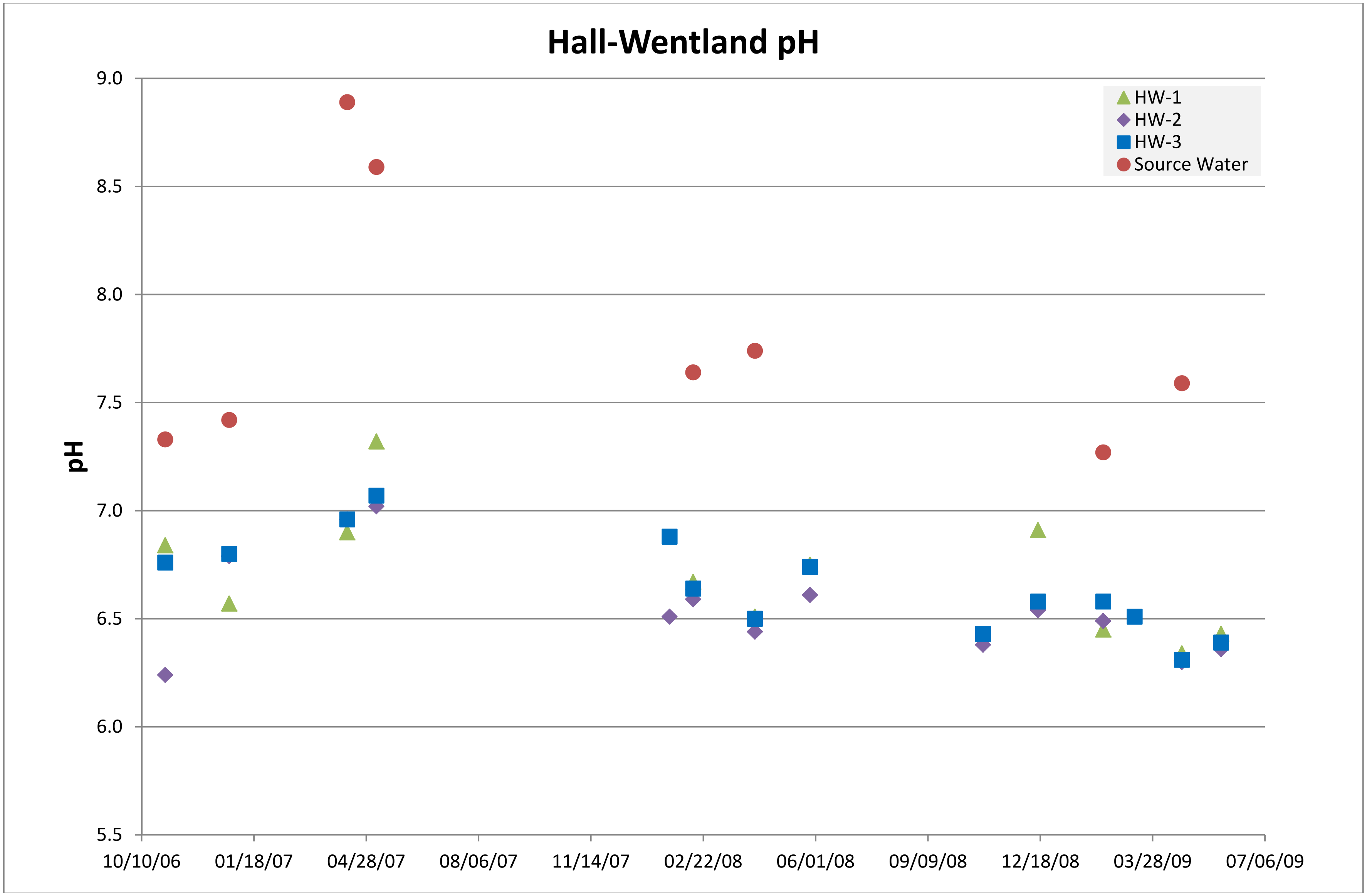

Figure B-1. Hall-Wentland pH. HW-1 = Hall-Wentland monitoring well 1. HW-2 = Hall-Wentland monitoring well 2. HW-3 = Hall-Wentland monitoring well 3.

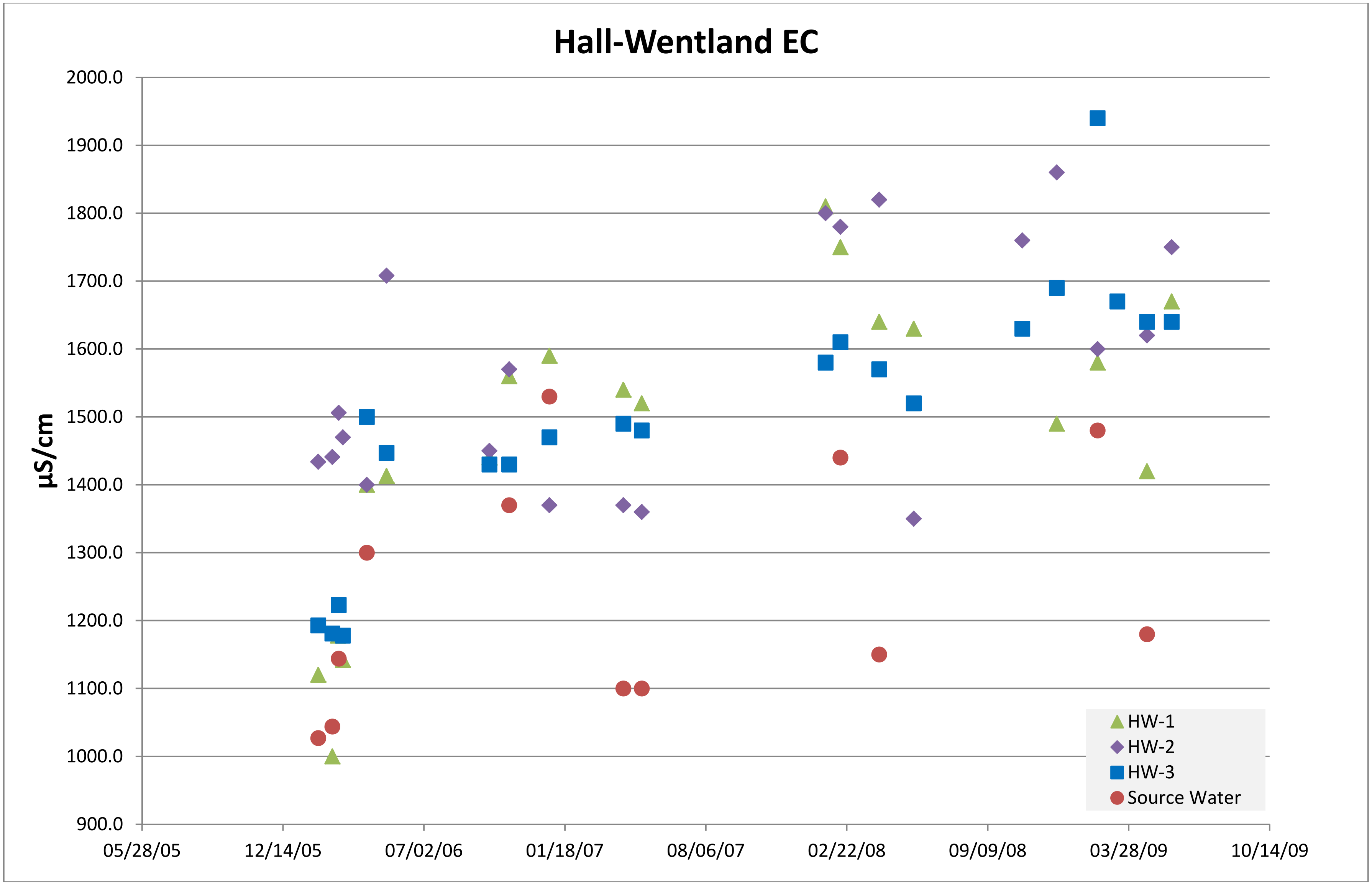

Figure B-2. Hall-Wentland electrical conductivity. HW-1 = Hall-Wentland monitoring well 1. HW-2 = Hall-Wentland monitoring well 2. HW-3 = Hall-Wentland monitoring well 3.

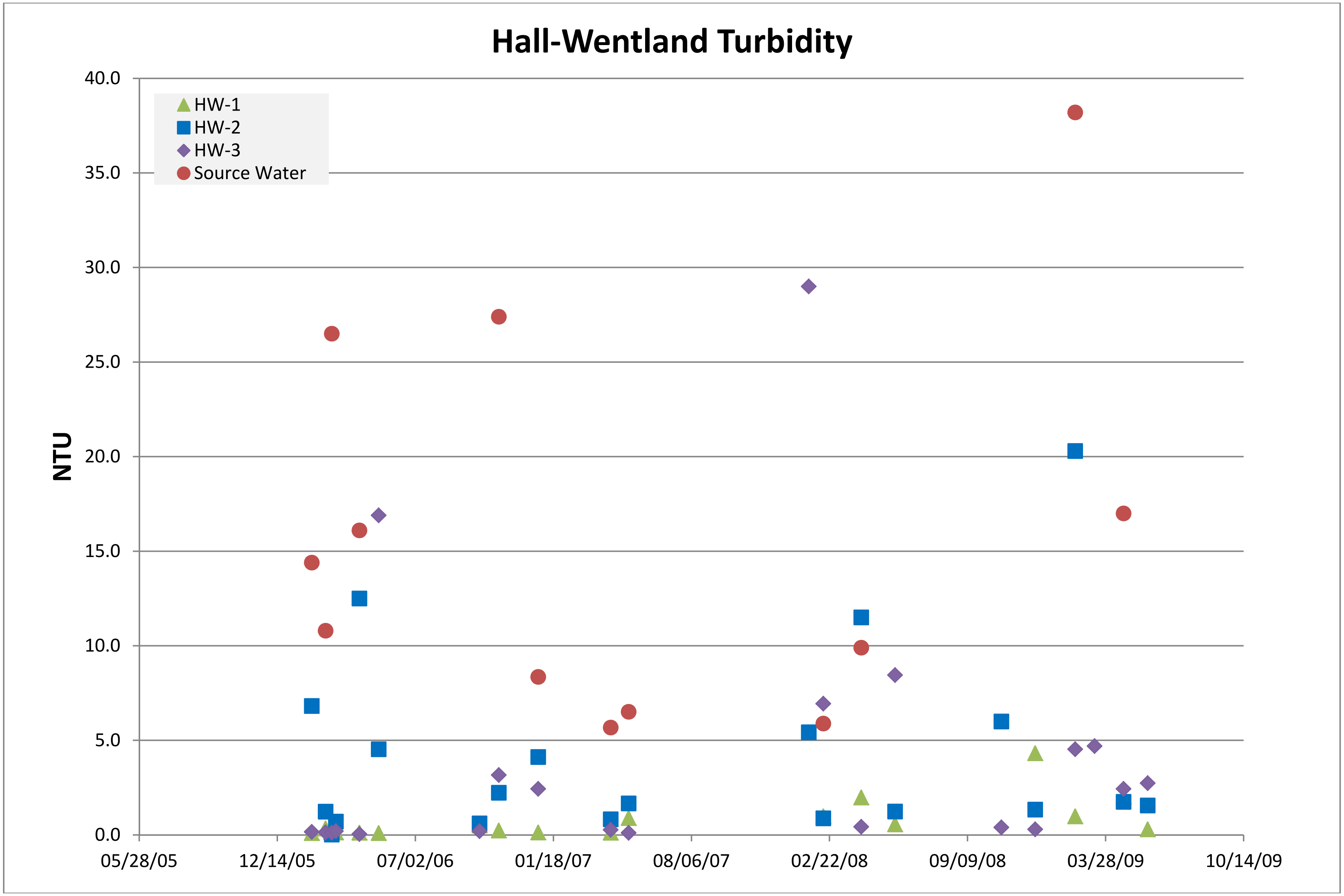

Figure B-3. Hall-Wentland turbidity. HW-1 = Hall-Wentland monitoring well 1. HW-2 = Hall-Wentland monitoring well 2. HW-3 = Hall-Wentland monitoring well 3.

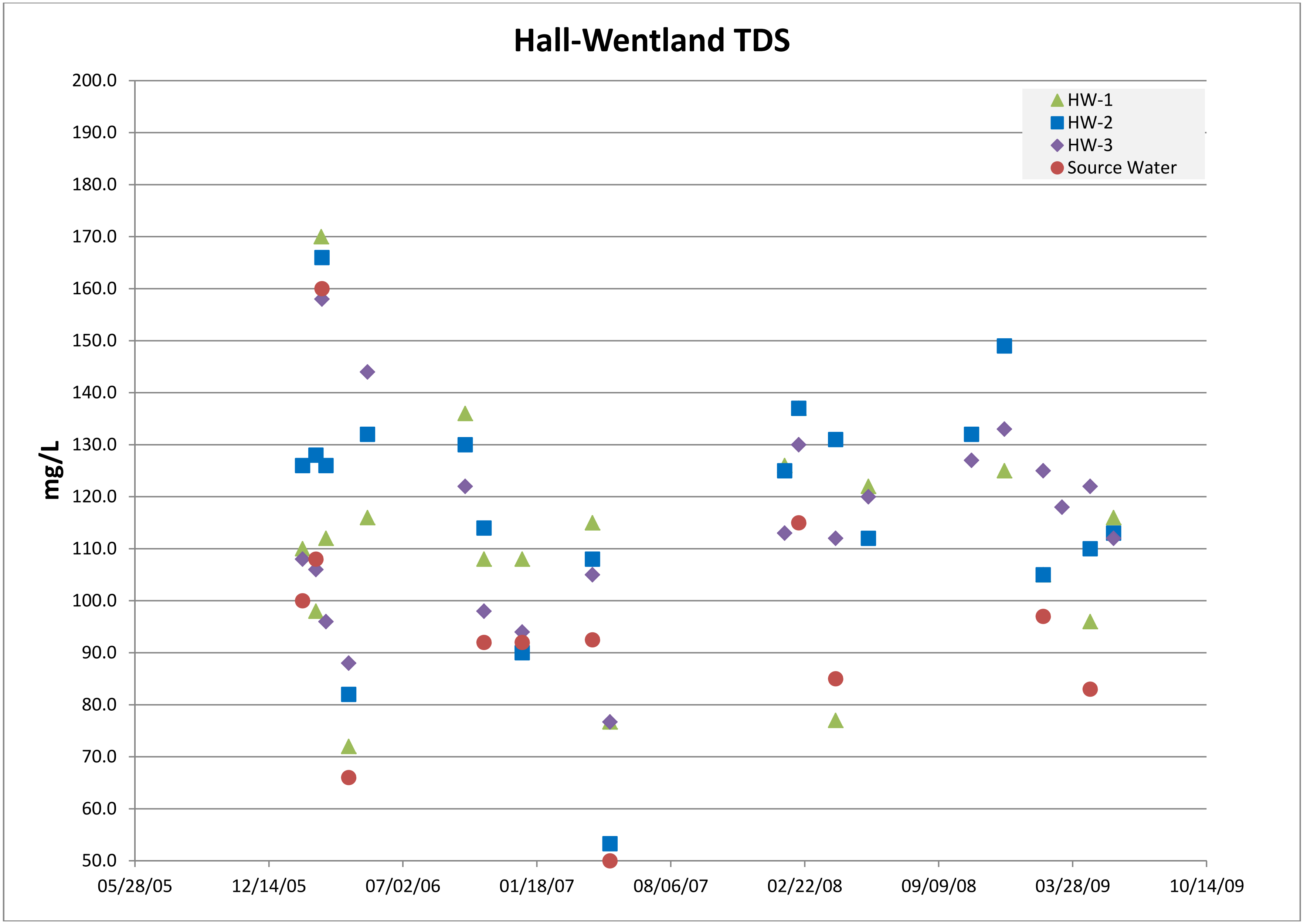

Figure B-4. Hall-Wentland total dissolved solids (TDS). HW-1 = Hall-Wentland monitoring well 1. HW-2 = Hall-Wentland monitoring well 2. HW-3 = Hall-Wentland monitoring well 3.

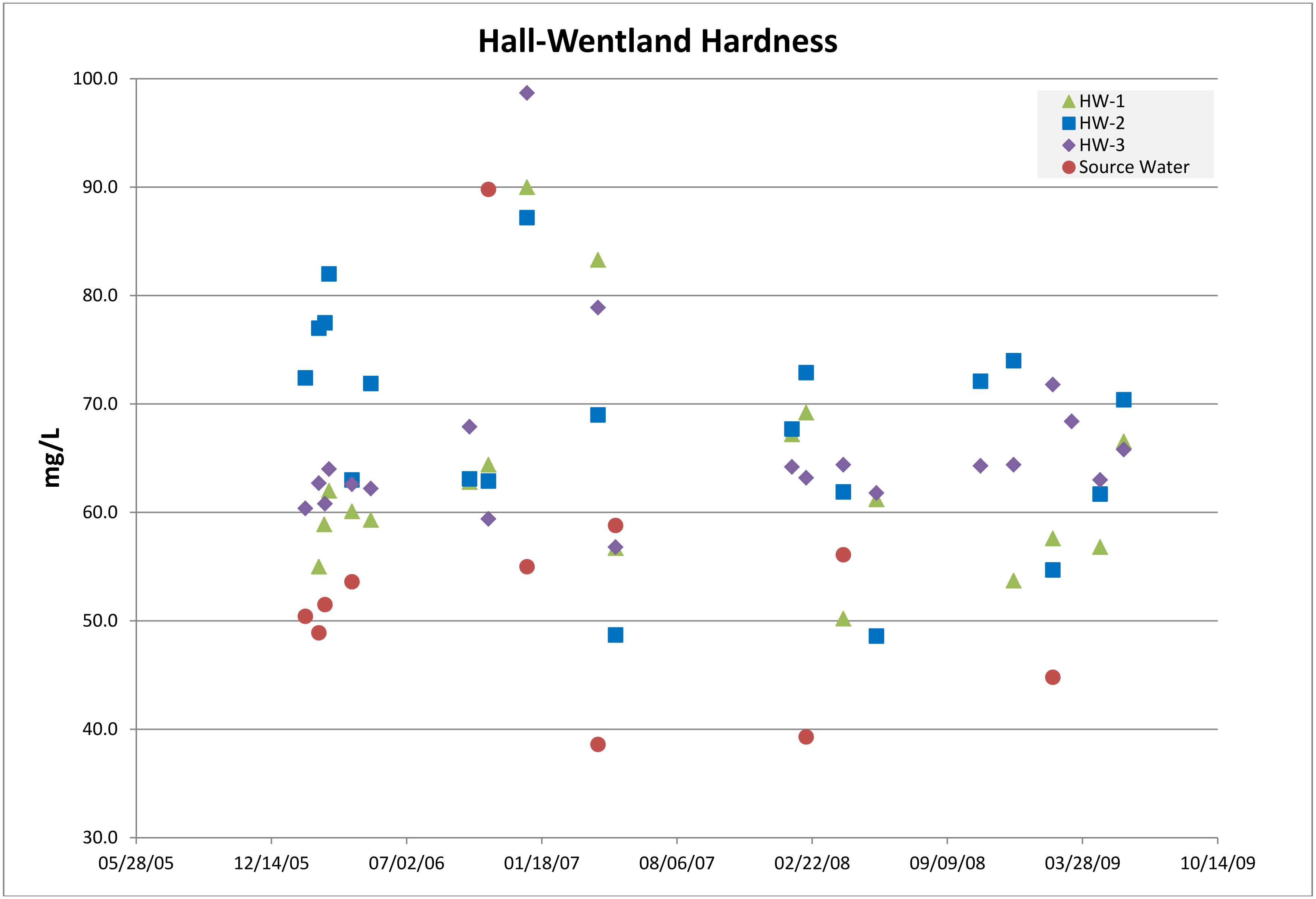

Figure B-5. Hall-Wentland Hardness. HW-1 = Hall-Wentland monitoring well 1. HW-2 = Hall-Wentland monitoring well 2. HW-3 = Hall-Wentland monitoring well 3.

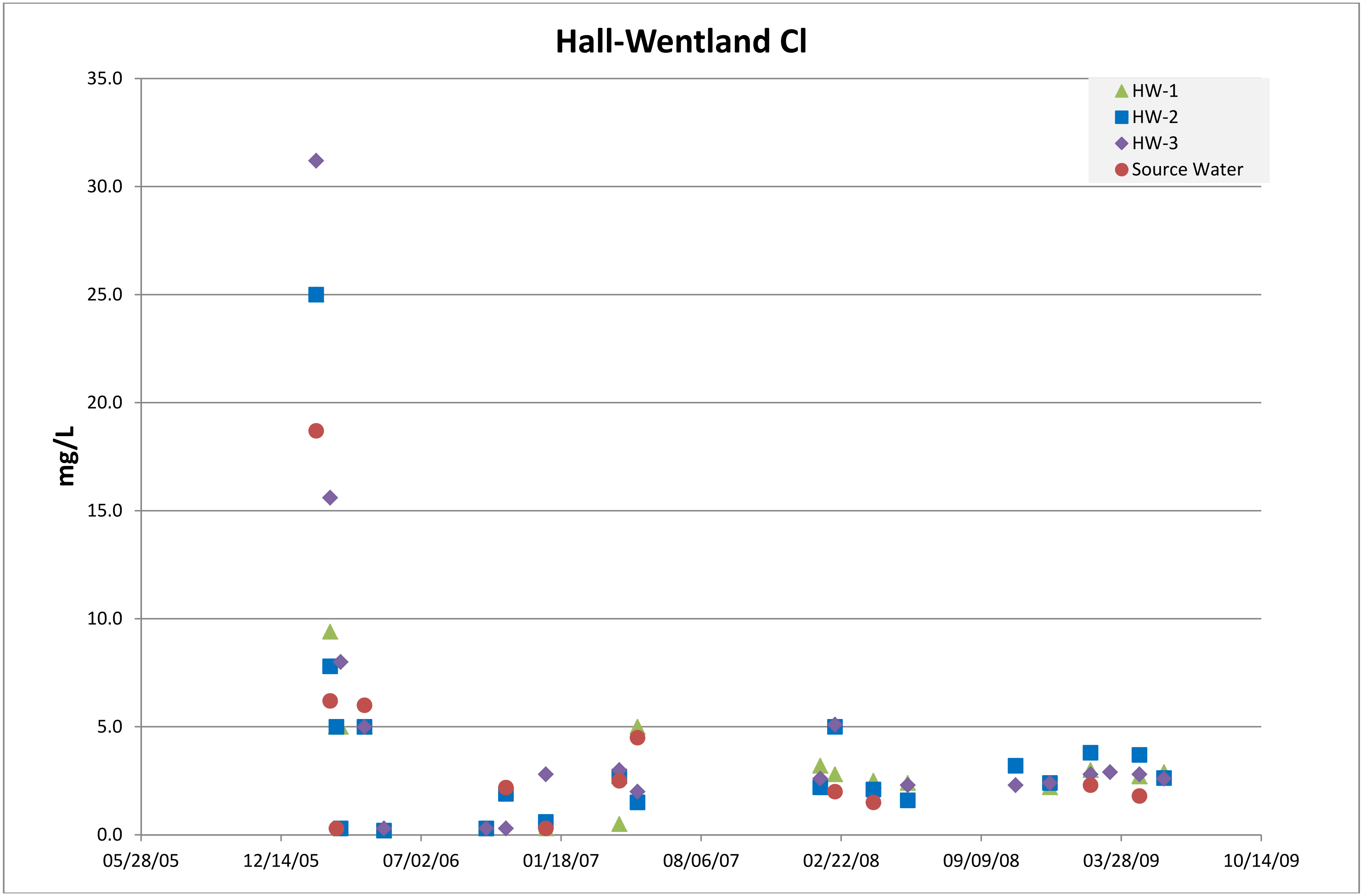

Figure B-6. Hall-Wentland chloride. HW-1 = Hall-Wentland monitoring well 1. HW-2 = Hall-Wentland monitoring well 2. HW-3 = Hall-Wentland monitoring well 3.

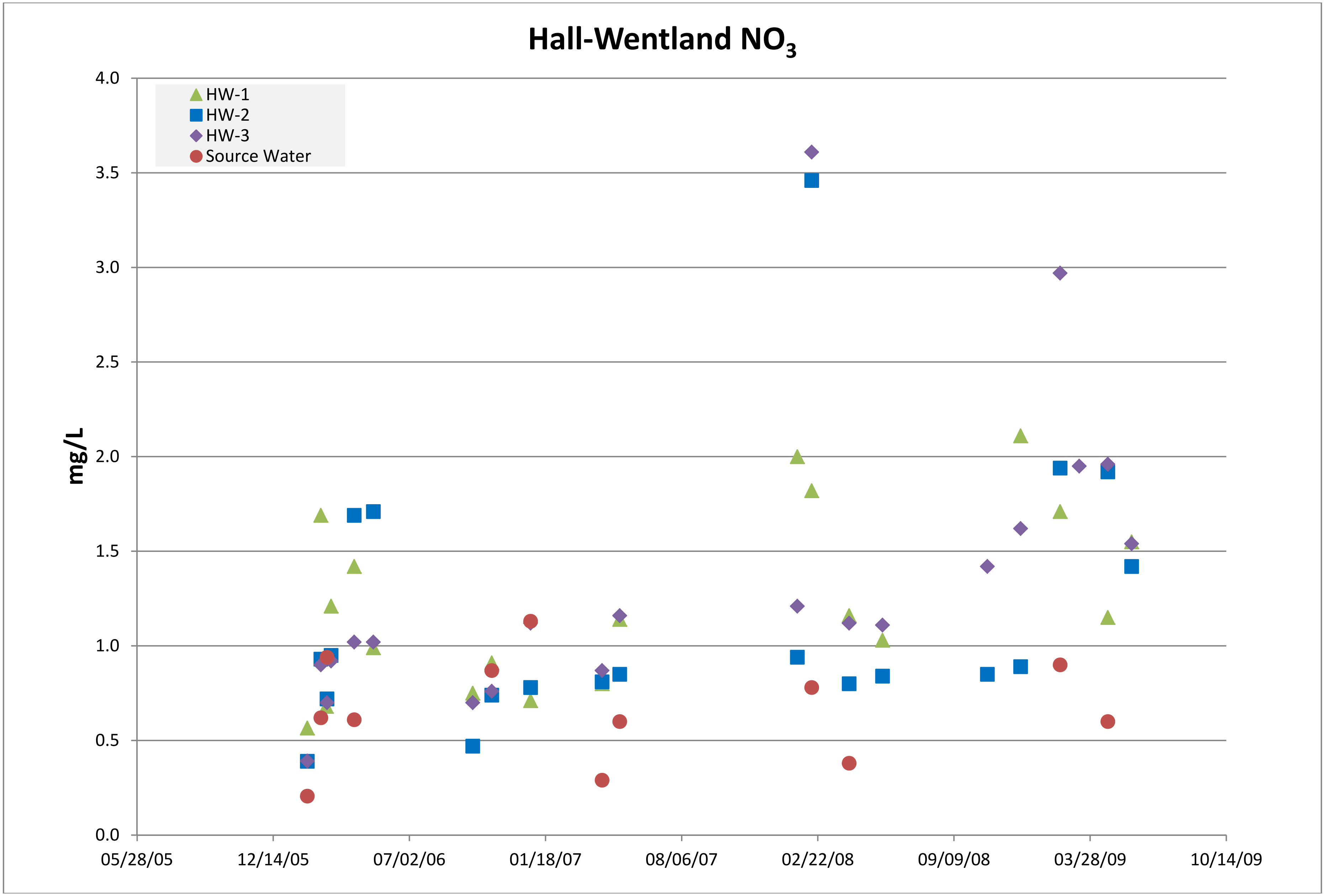

Figure B-7. Hall-Wentland nitrate-N. HW-1 = Hall-Wentland monitoring well 1. HW-2 = Hall-Wentland monitoring well 2. HW-3 = Hall-Wentland monitoring well 3.

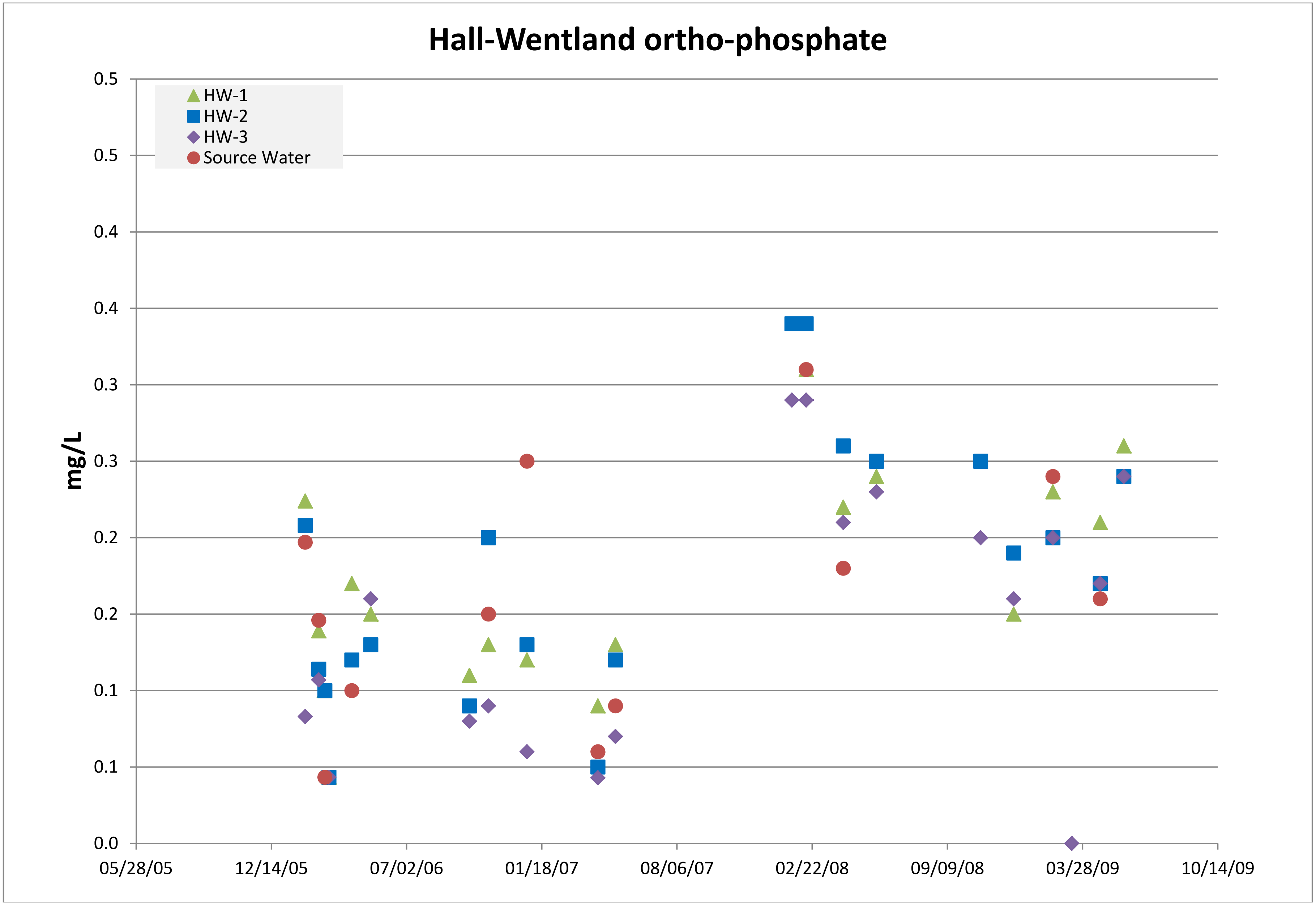

Figure B-8. Hall-Wentland ortho-phosphate. HW-1 = Hall-Wentland monitoring well 1. HW-2 = Hall-Wentland monitoring well 2. HW-3 = Hall-Wentland monitoring well 3.

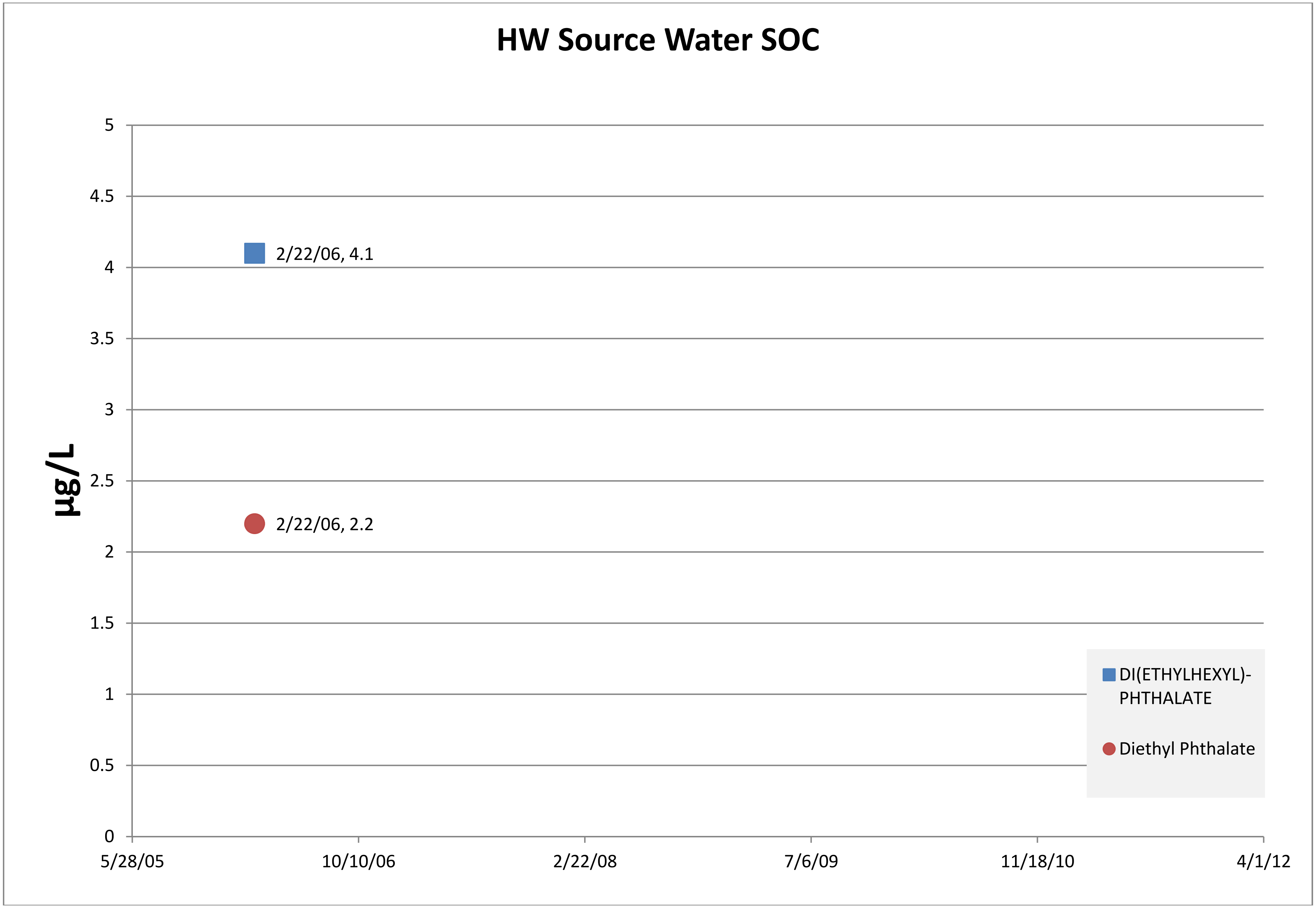

Figure B-9. Hall-Wentland source water SOC's.

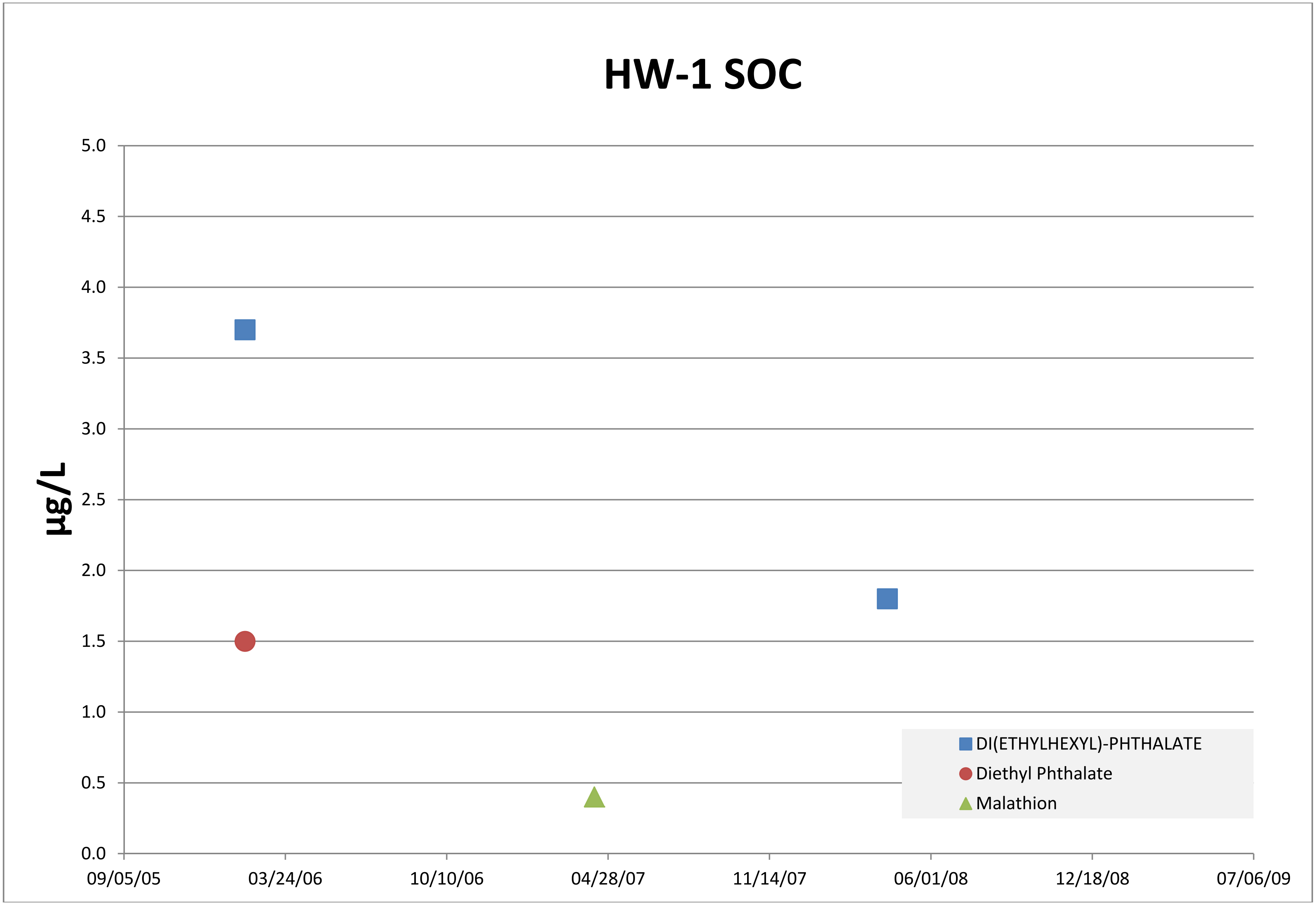

Figure B-10. Hall-Wentland monitoring well HW-1 water SOC's.

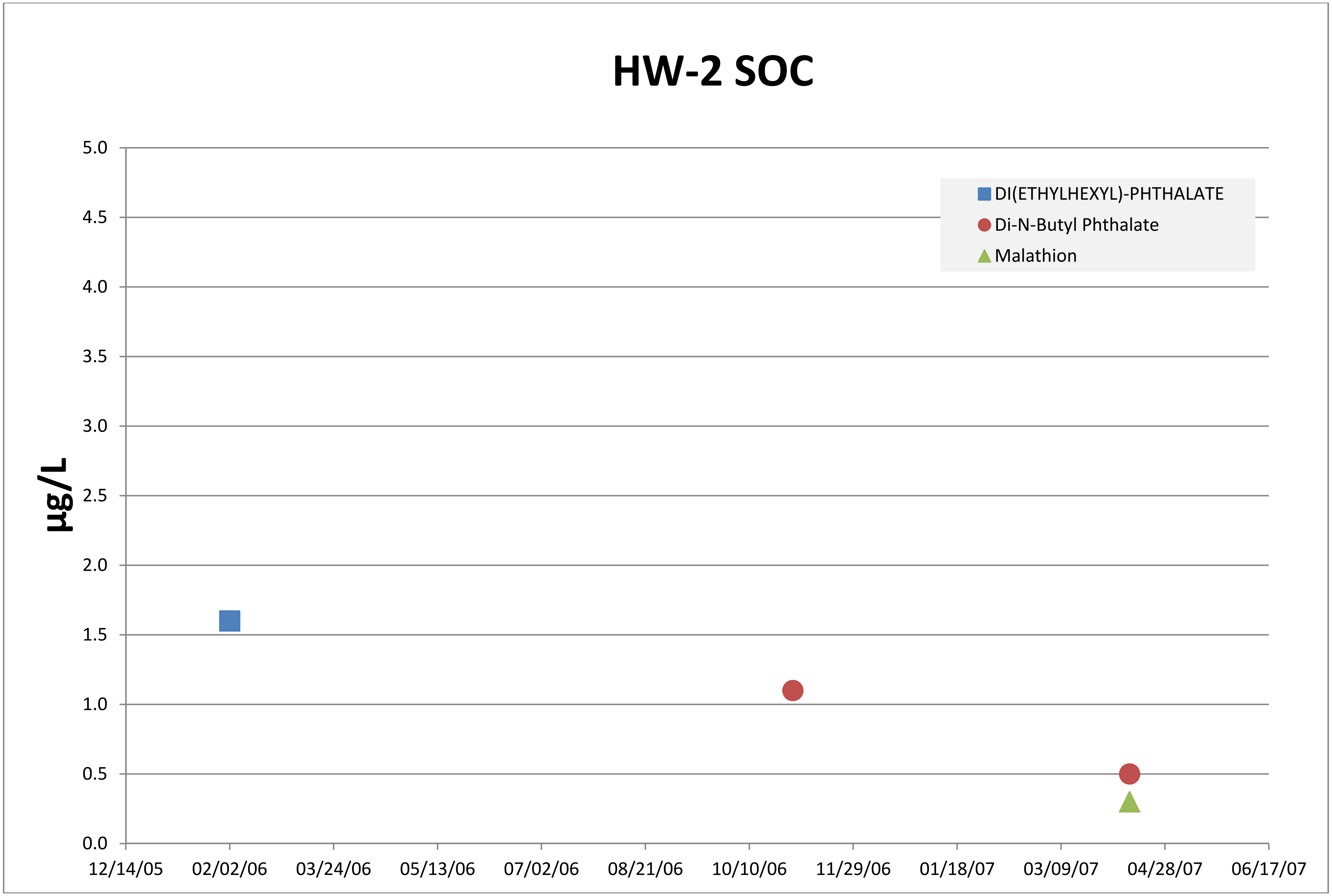

Figure B-11. Hall-Wentland monitoring well HW-2 water SOC’s.

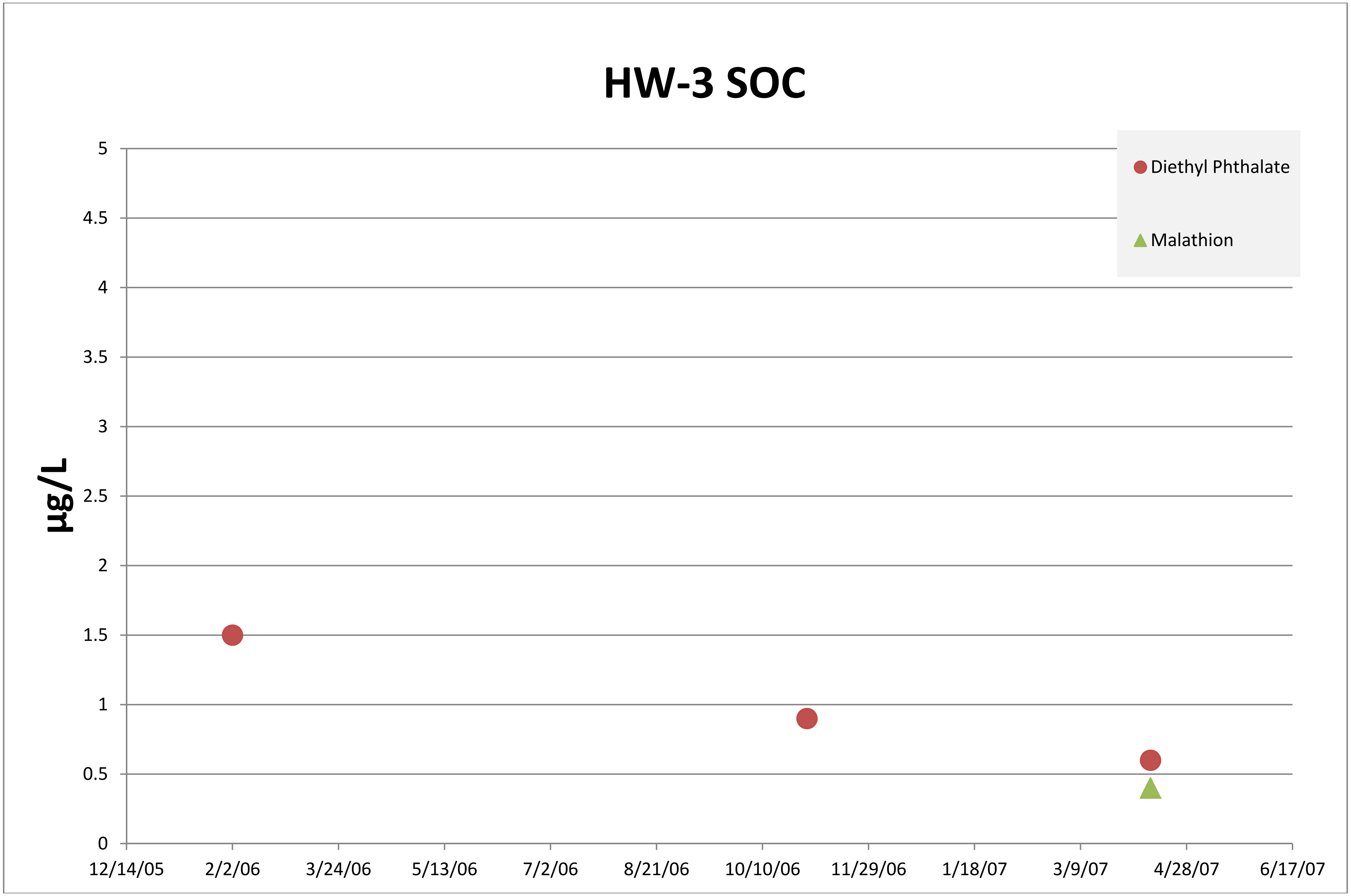

Figure B-12. Hall-Wentland monitoring well HW-3 water SOC's.

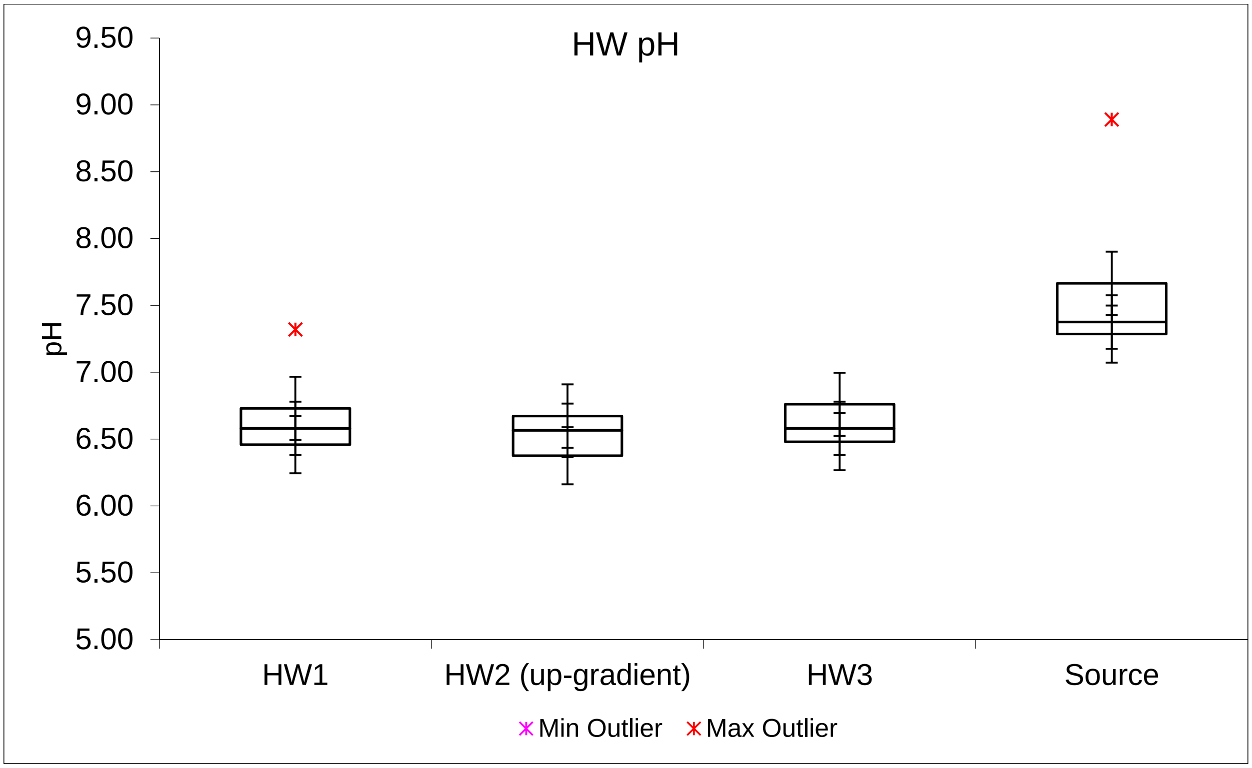

Figure B-13. Hall-Wentland pH box-plot comparison displaying standard error bars for the median, upper and lower interquartile ranges.

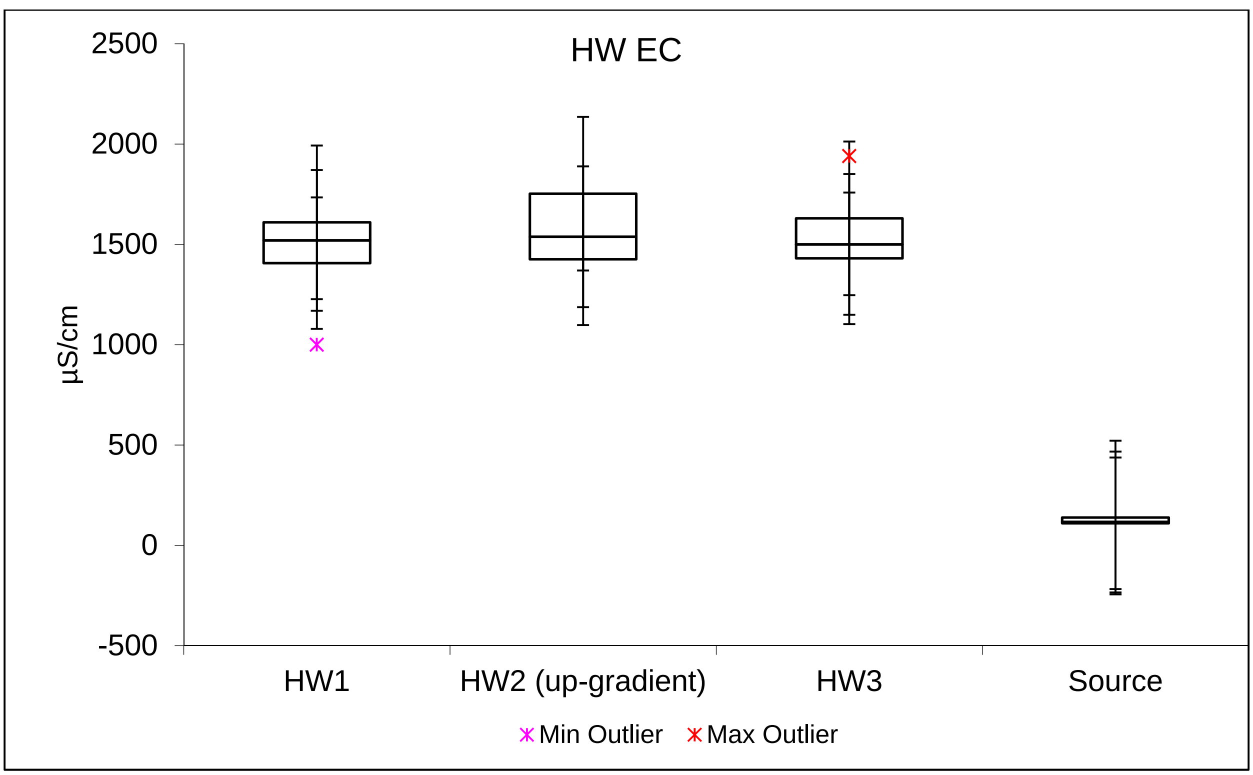

Figure B-14. Hall-Wentland EC box-plot comparison displaying standard error bars for the median, upper and lower interquartile ranges.

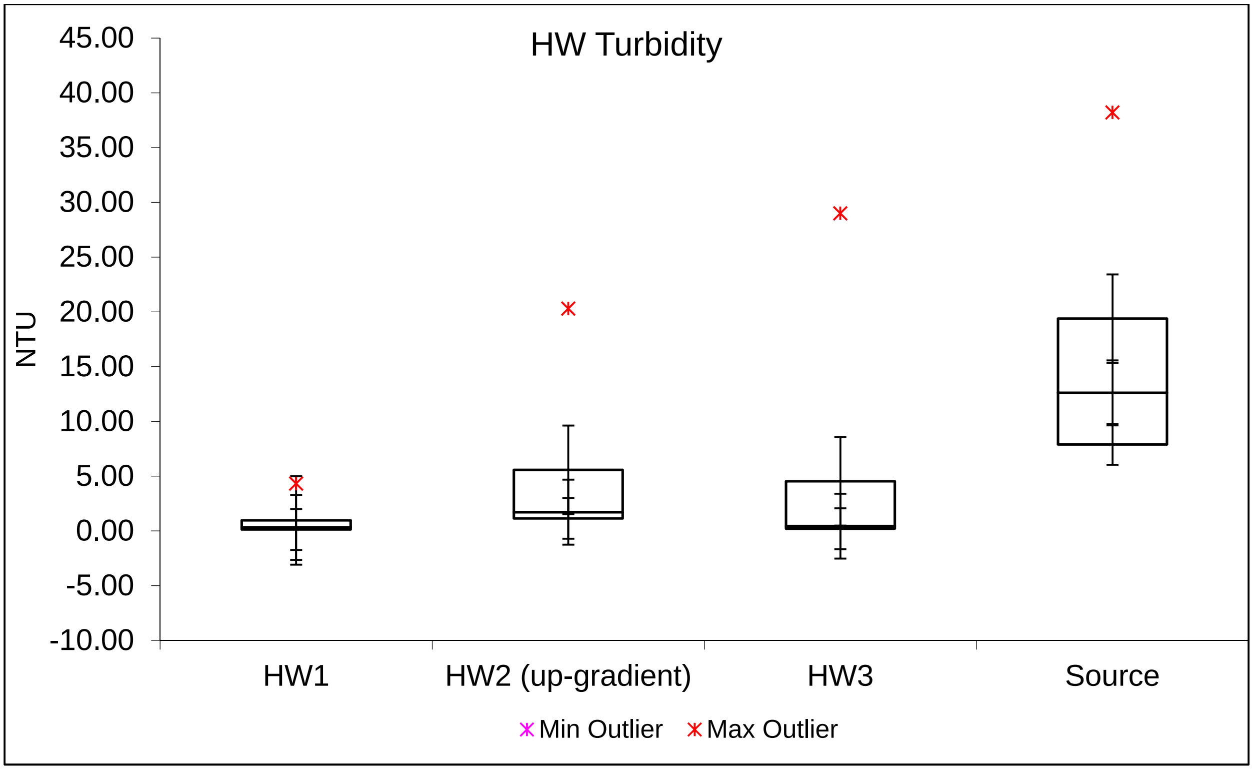

Figure B-15. Hall-Wentland turbidity box-plot comparison displaying standard error bars for the median, upper and lower interquartile ranges.

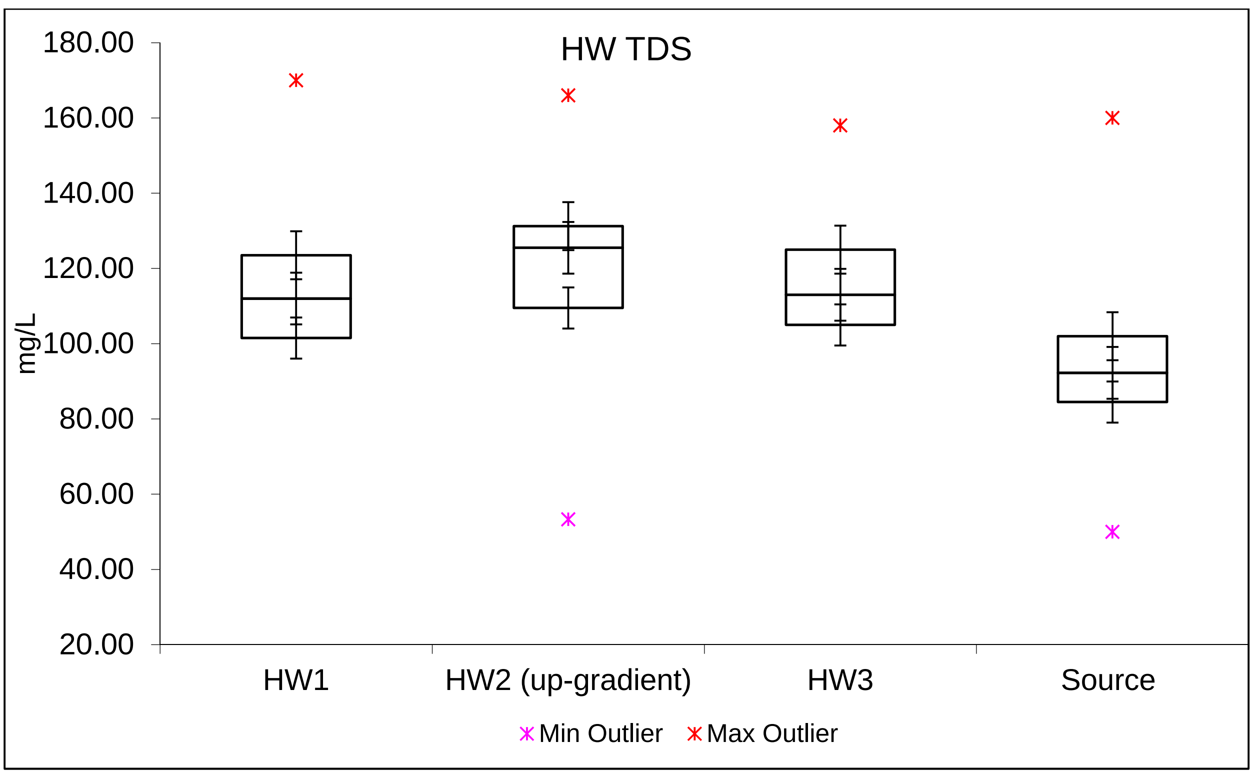

Figure B-16. Hall-Wentland TDS box-plot comparison displaying standard error bars for the median, upper and lower interquartile ranges.

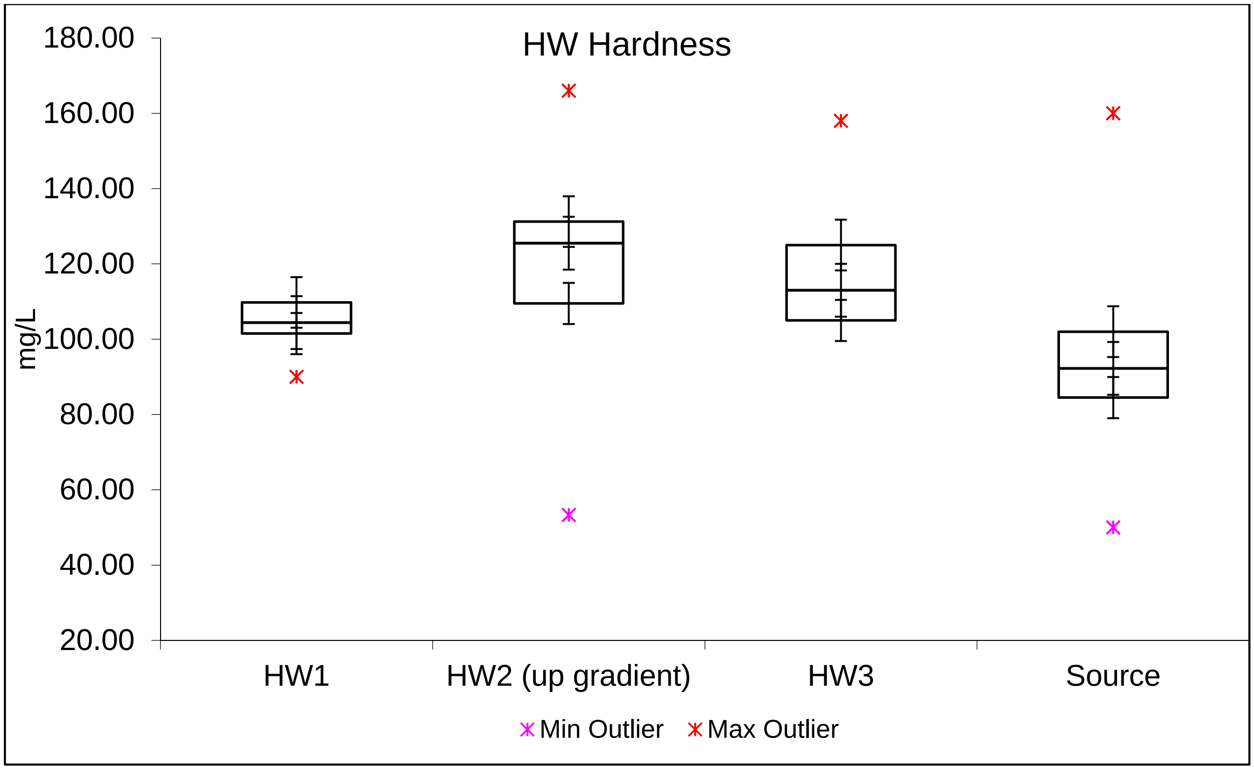

Figure B-17. Hall-Wentland hardness box-plot comparison displaying standard error bars for the median, upper and lower interquartile ranges.

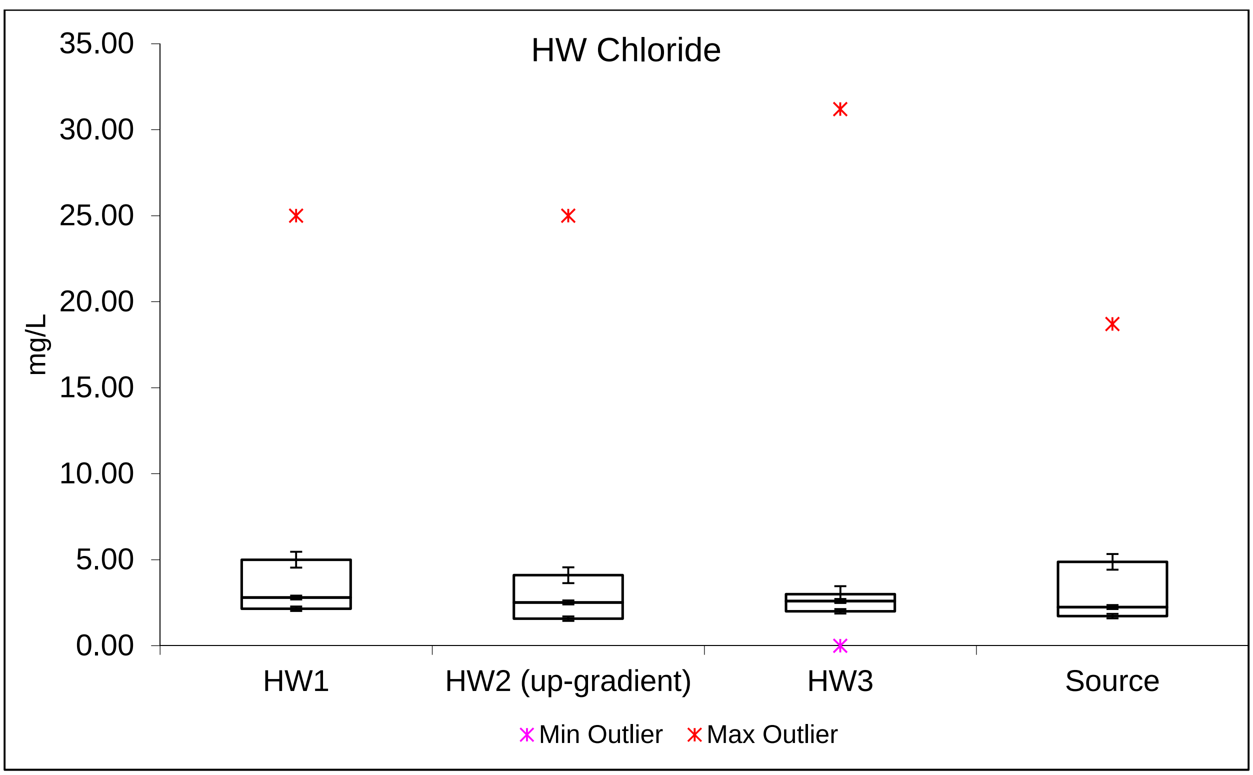

Figure B-18. Hall-Wentland chloride box-plot comparison displaying standard error bars for the median, upper and lower interquartile ranges.

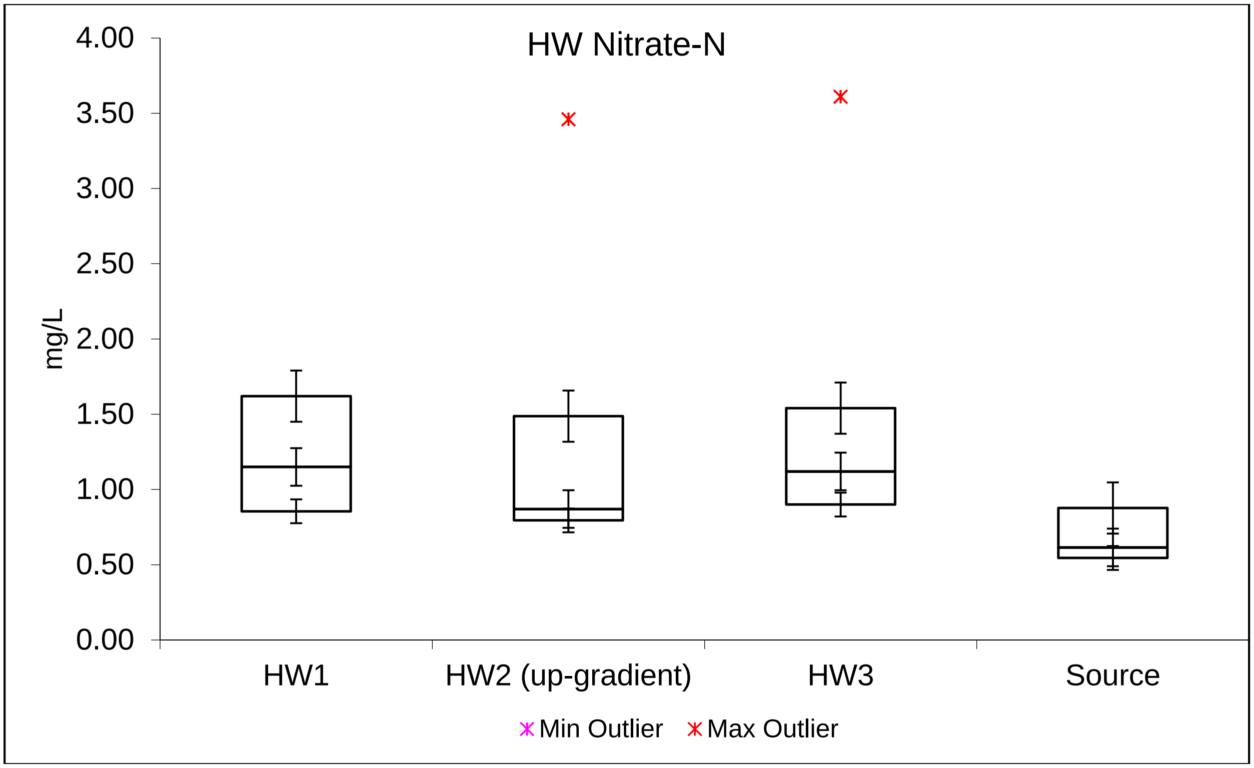

Figure B-19. Hall-Wentland nitrate-N box-plot comparison displaying standard error bars for the median, upper and lower interquartile ranges.

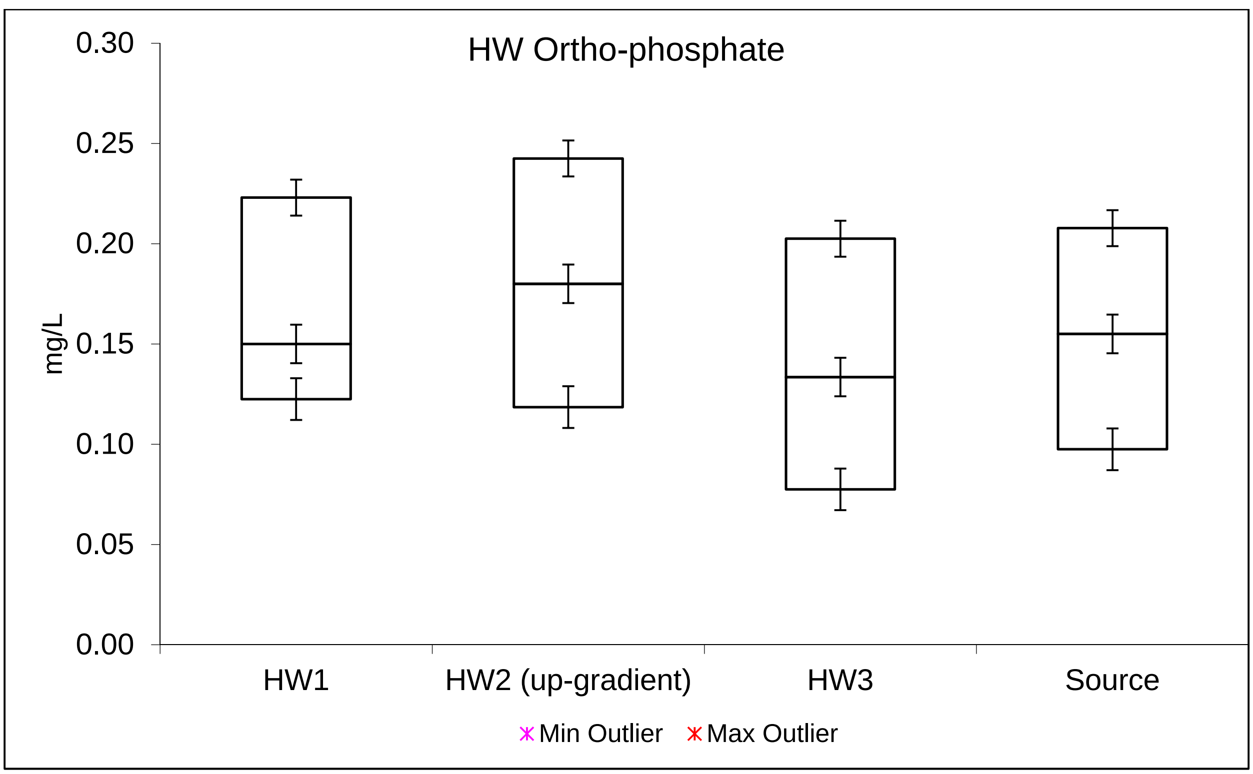

Figure B-20. Hall-Wentland ortho-phosphate box-plot comparison displaying standard error bars for the median, upper and lower interquartile ranges.

Appendix C

Locher Road Data Plots

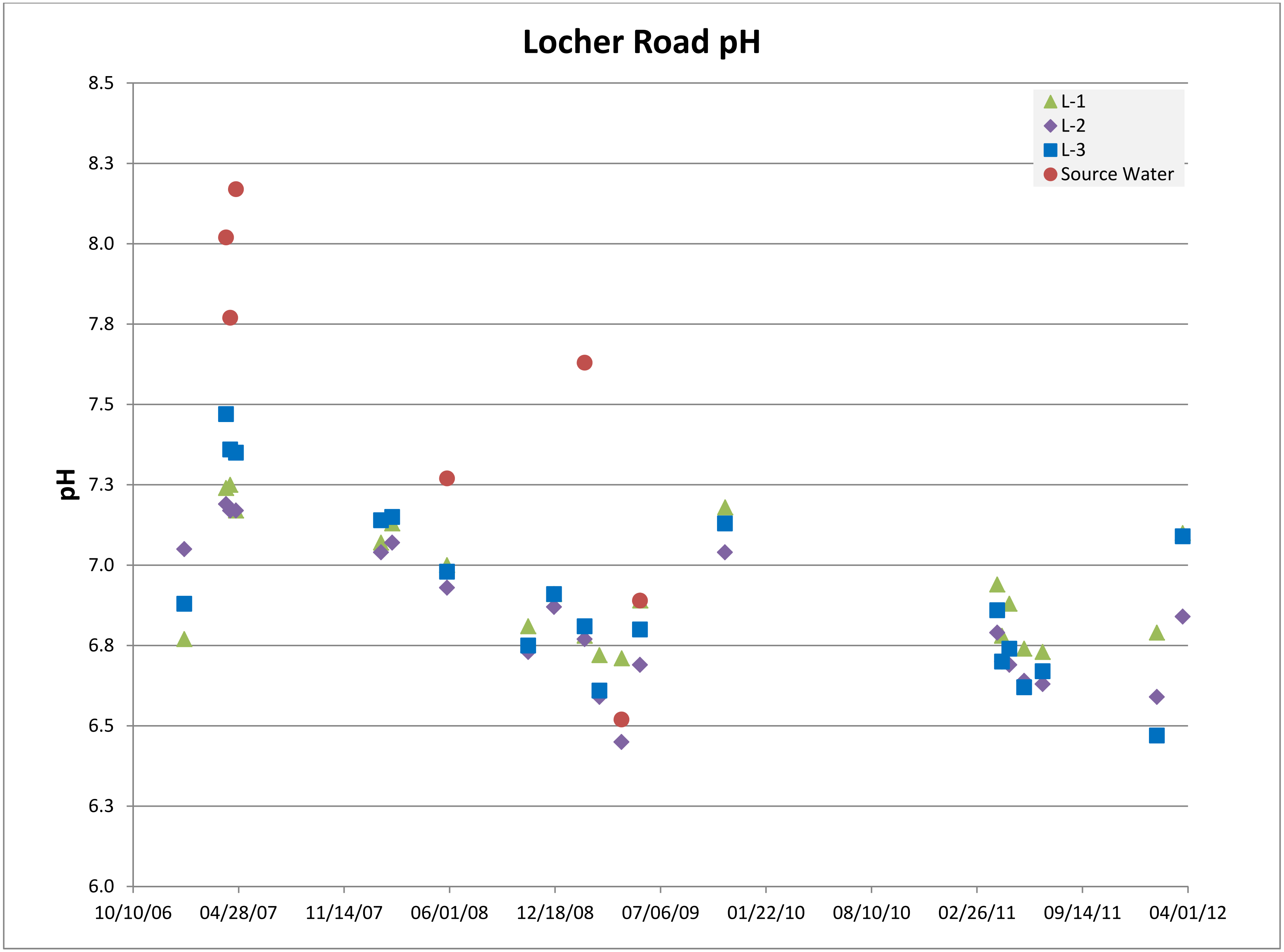

Figure C-1. Locher Road pH. L-1 = Locher Road monitoring well L-1. L-2 = Locher Road monitoring well L-2. L-3 = Locher Road monitoring well L-3.

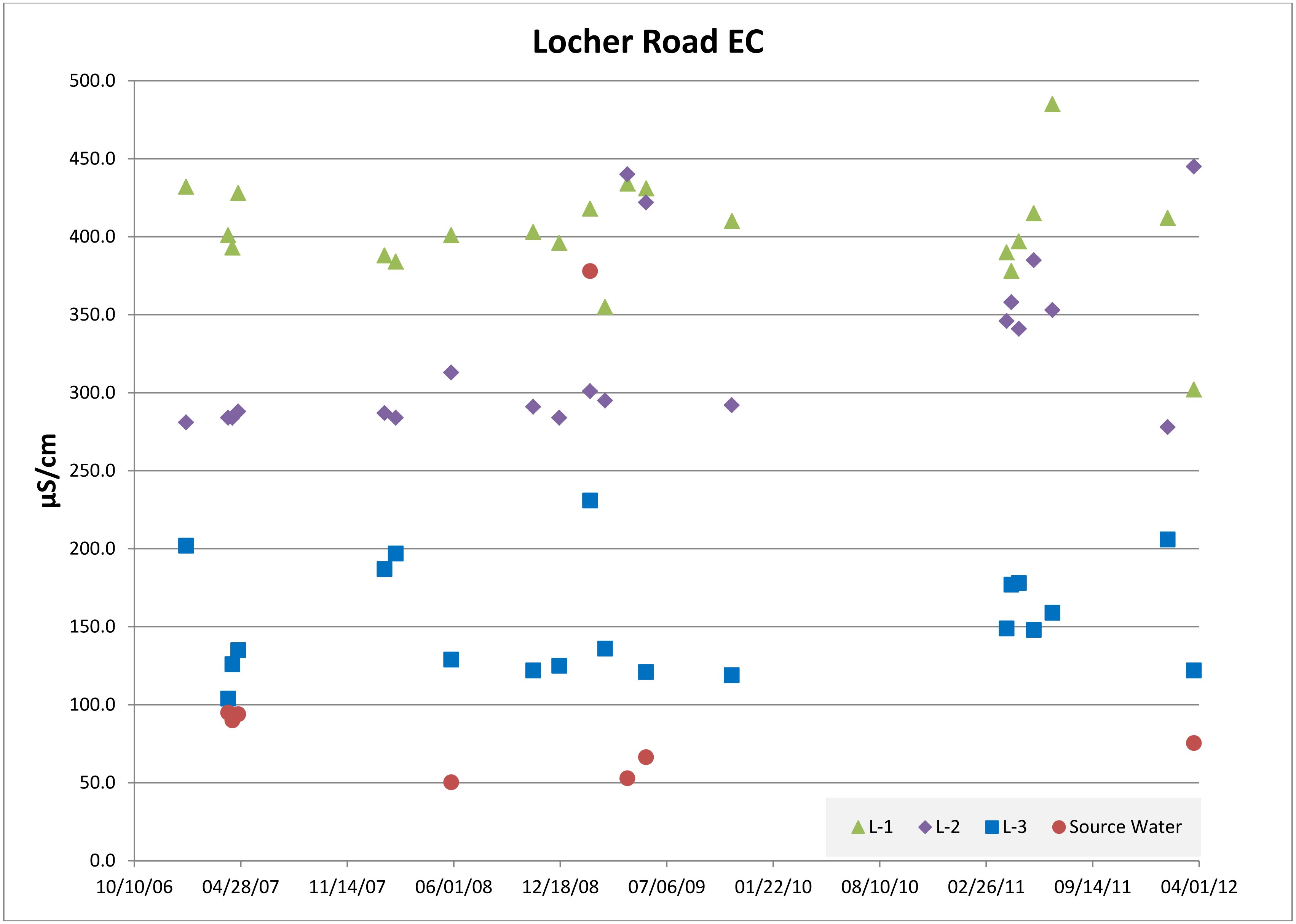

Figure C-2. Locher Road electrical conductivity (EC). L-1 = Locher Road monitoring well L-1. L-2 = Locher Road monitoring well L-2. L-3 = Locher Road monitoring well L-3.

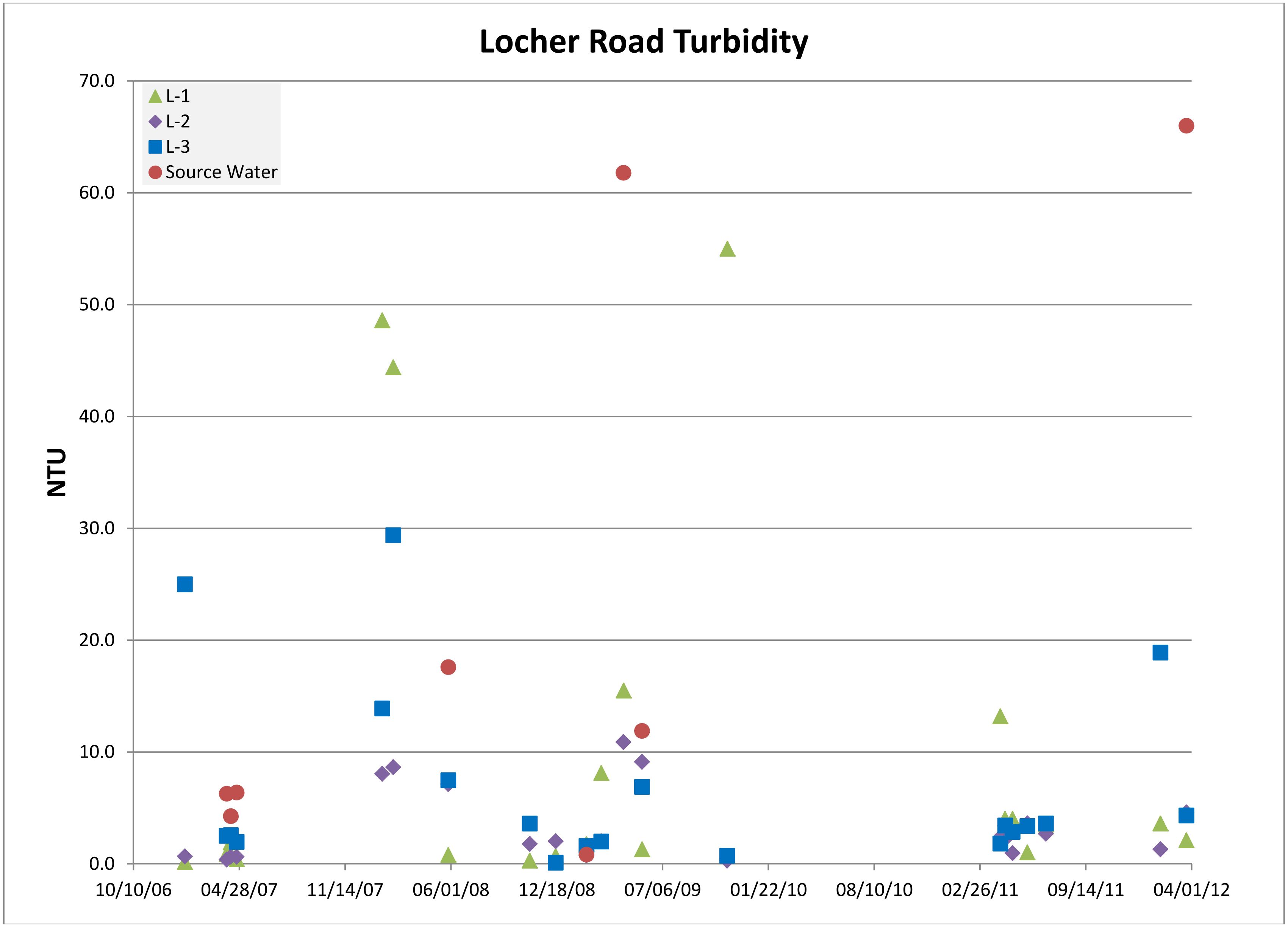

Figure C-3. Locher Road turbidity. L-1 = Locher Road monitoring well L-1. L-2 = Locher Road monitoring well L-2. L-3 = Locher Road monitoring well L-3.

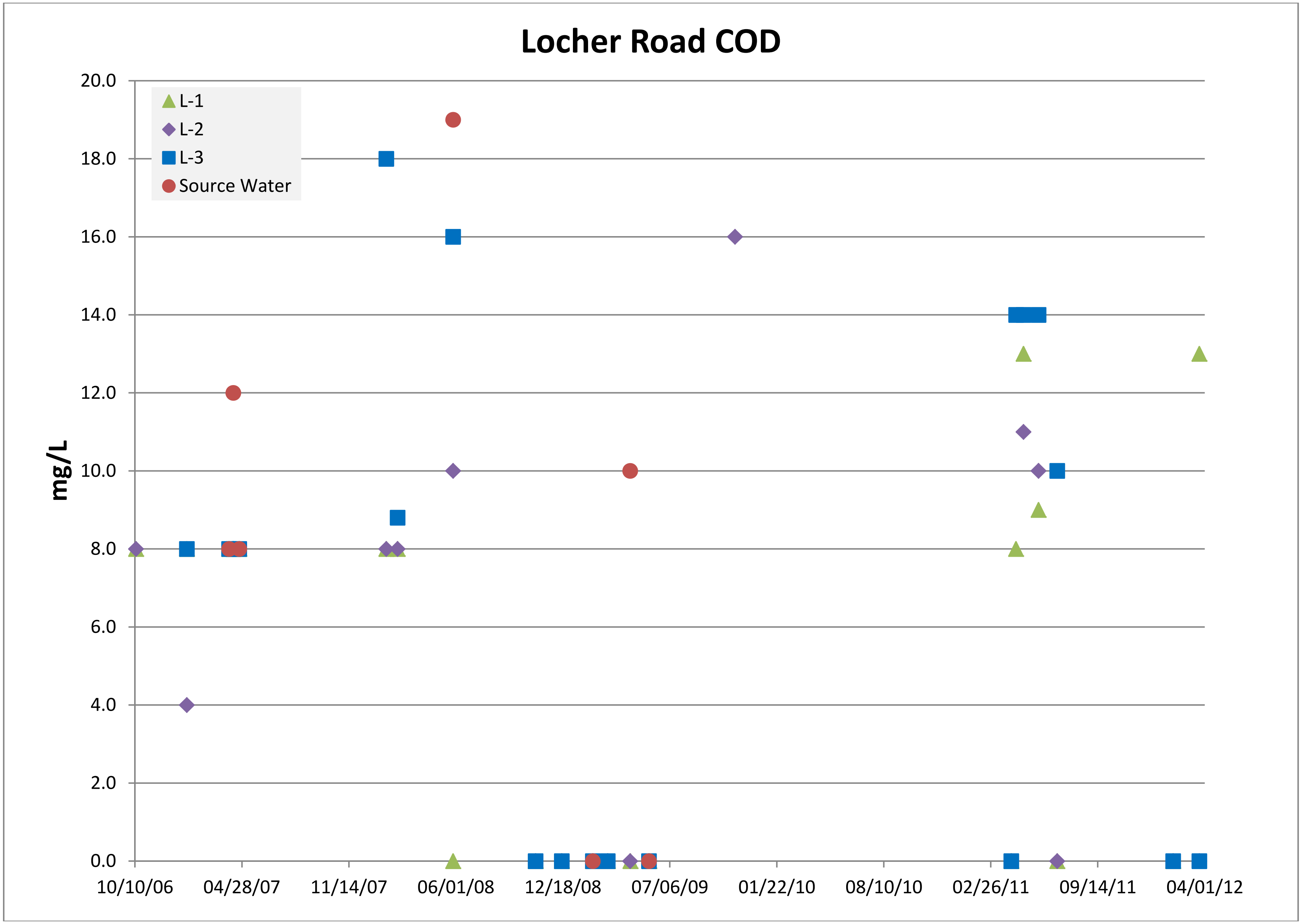

Figure C-4. Locher Road chemical oxygen demand (COD). L-1 = Locher Road monitoring well L-1. L-2 = Locher Road monitoring well L-2. L-3 = Locher Road monitoring well L-3.

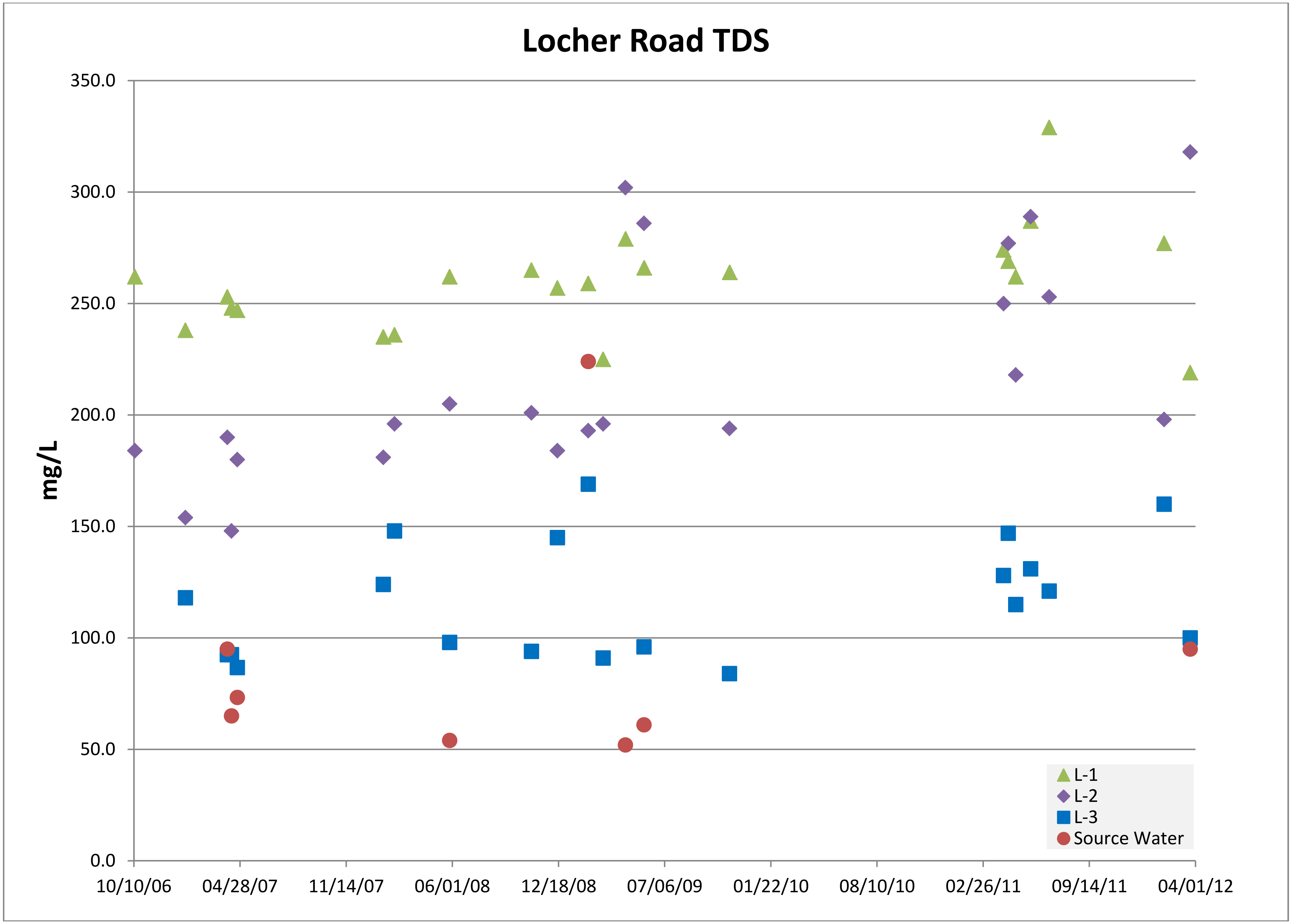

Figure C-5. Locher Road total dissolved solids (TDS). L-1 = Locher Road monitoring well L-1. L-2 = Locher Road monitoring well L-2. L-3 = Locher Road monitoring well L-3.

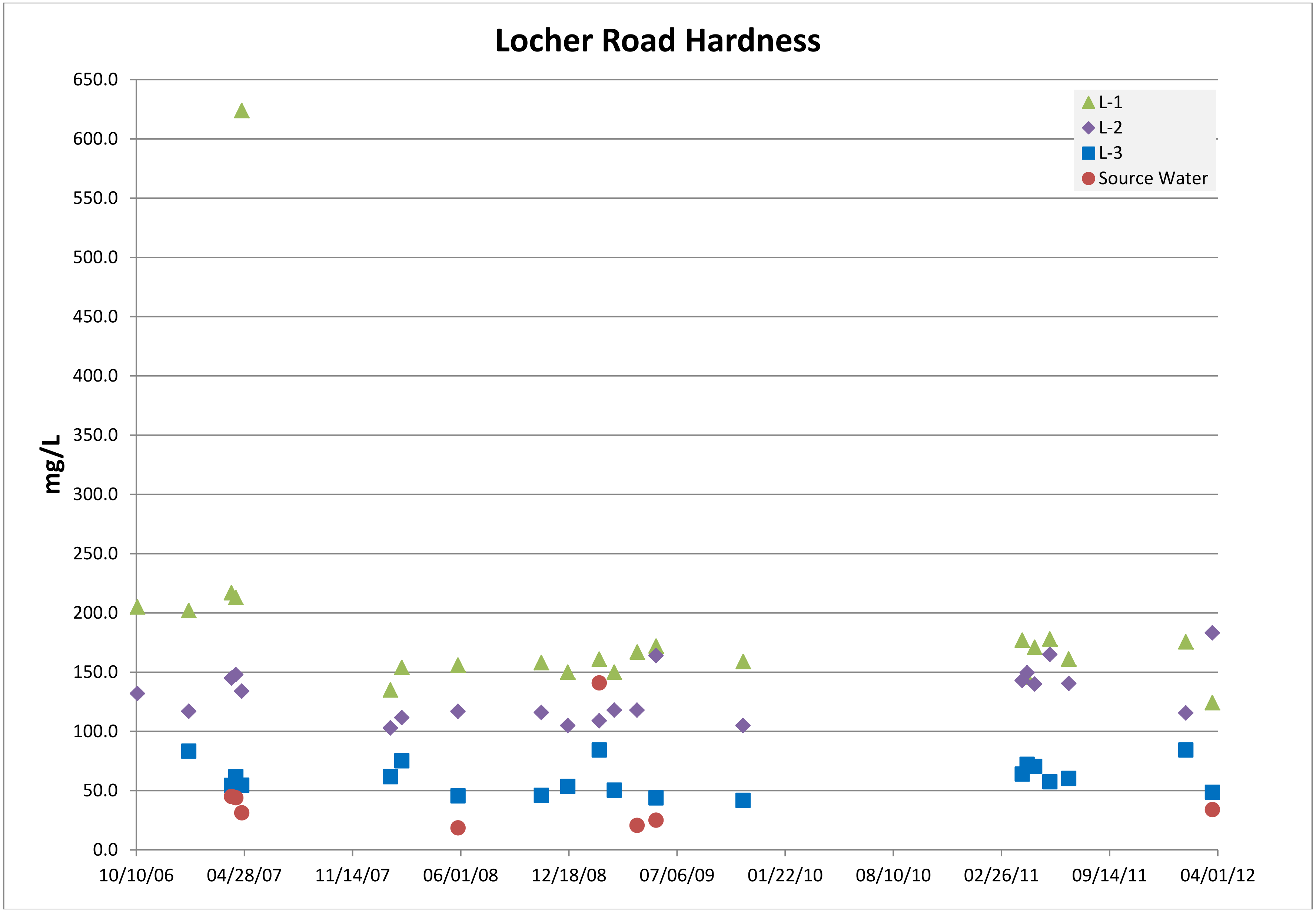

Figure C-6. Locher Road hardness. L-1 = Locher Road monitoring well L-1. L-2 = Locher Road monitoring well L-2. L-3 = Locher Road monitoring well L-3.

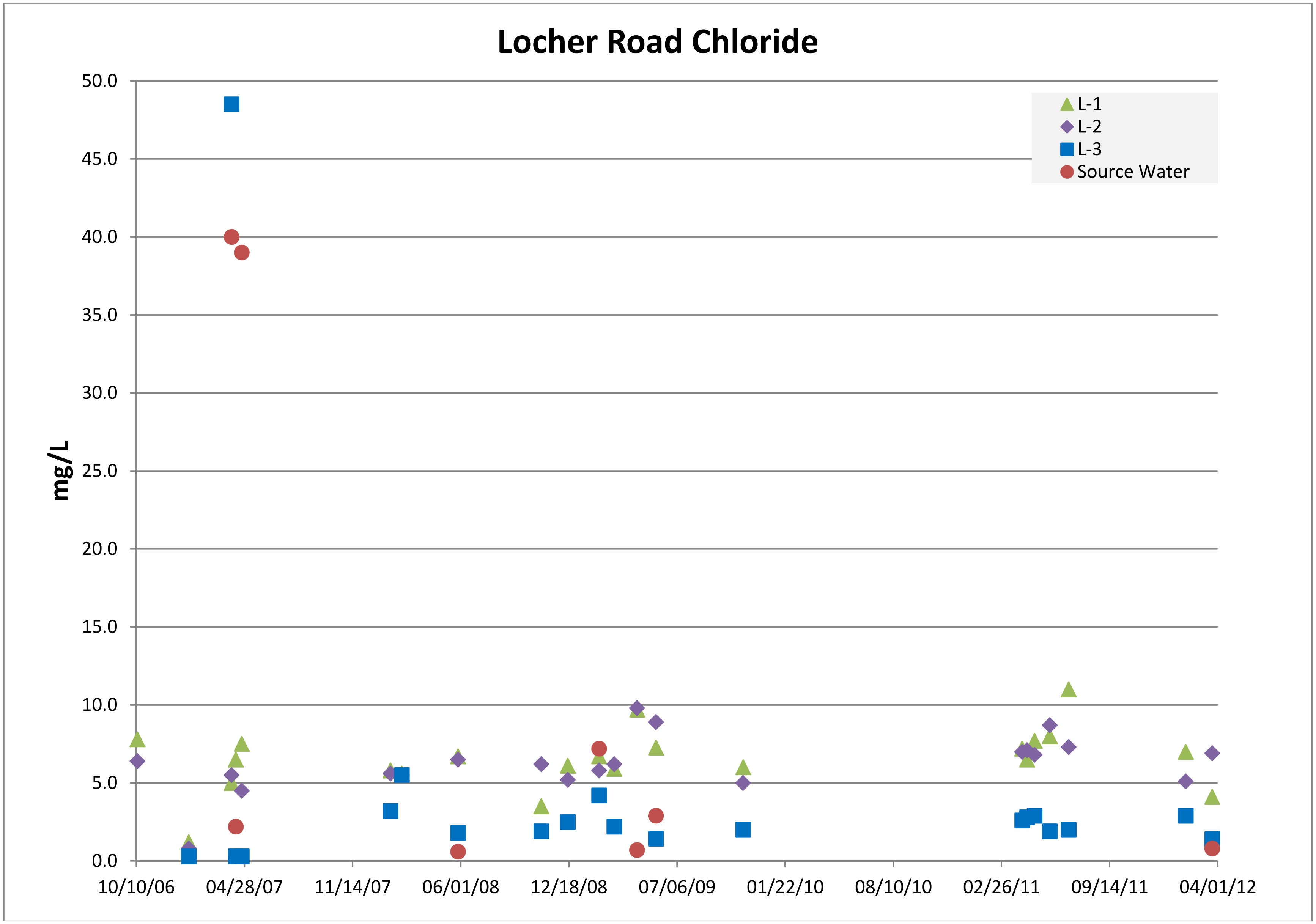

Figure C-7. Locher Road chloride. L-1 = Locher Road monitoring well L-1. L-2 = Locher Road monitoring well L-2. L-3 = Locher Road monitoring well L-3.

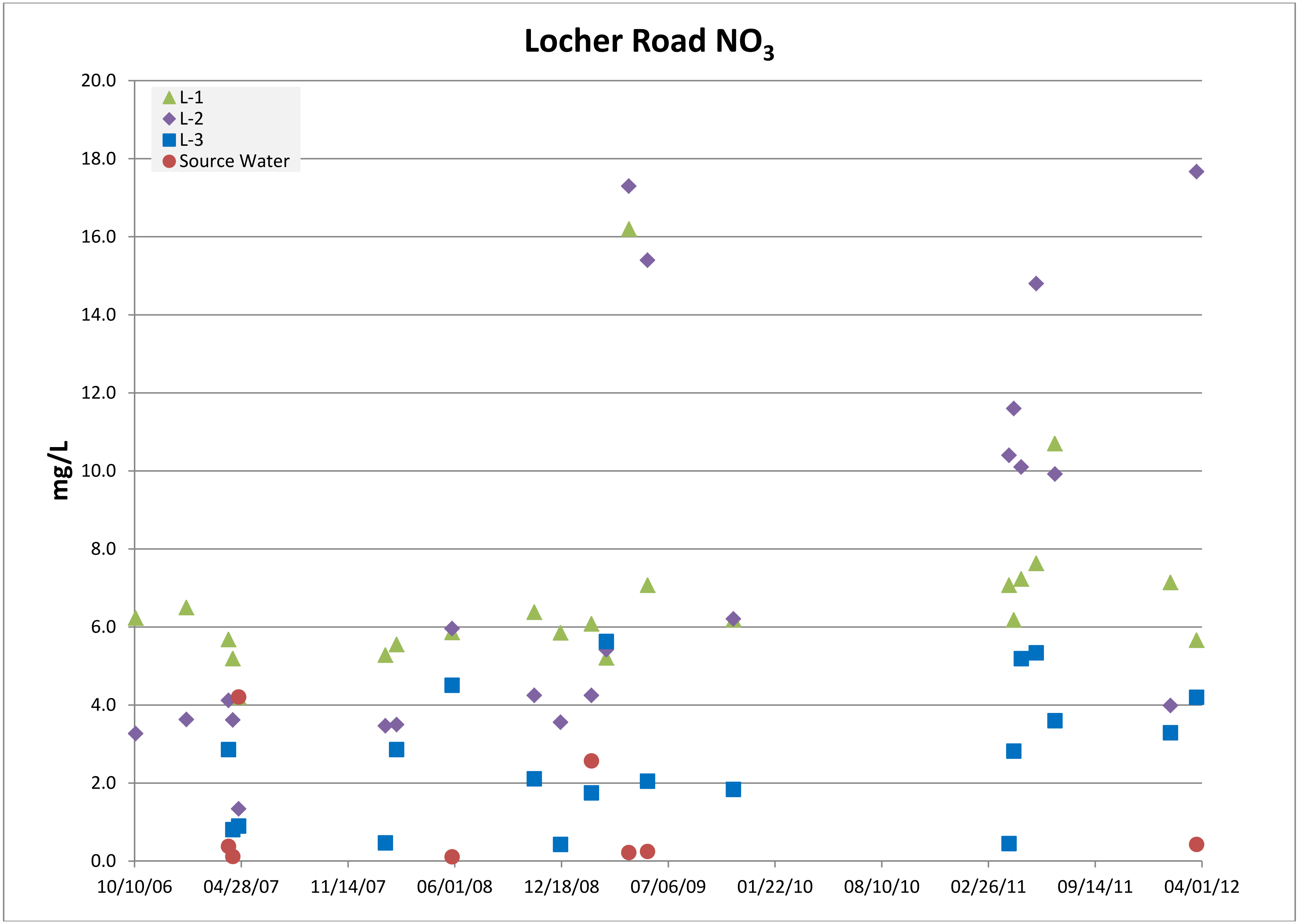

Figure C-8. Locher Road nitrate-N. L-1 = Locher Road monitoring well L-1. L-2 = Locher Road monitoring well L-2. L-3 = Locher Road monitoring well L-3.

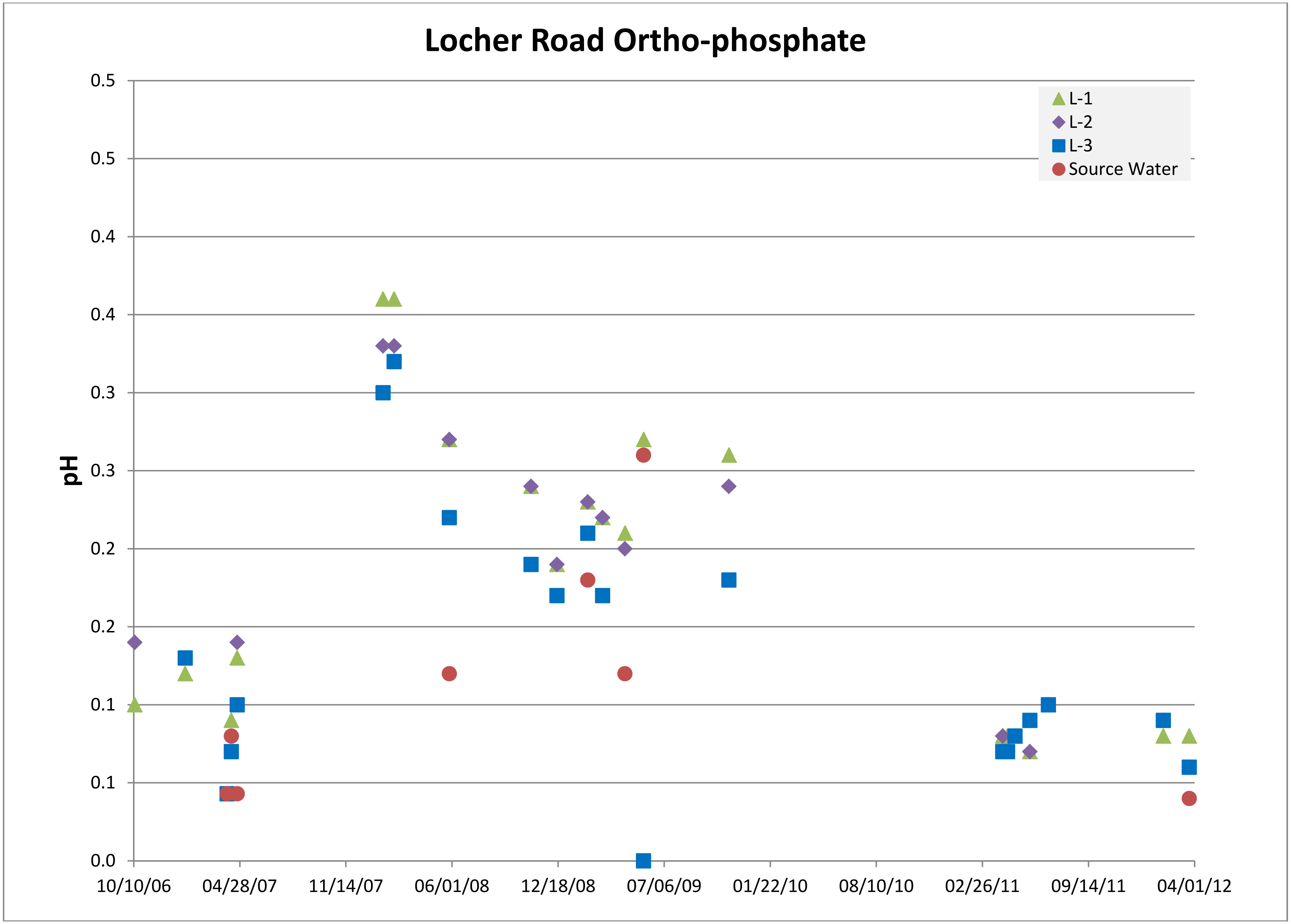

Figure C-9. Locher Road ortho-phosphate. L-1 = Locher Road monitoring well L-1. L-2 = Locher Road monitoring well L-2. L-3 = Locher Road monitoring well L-3.

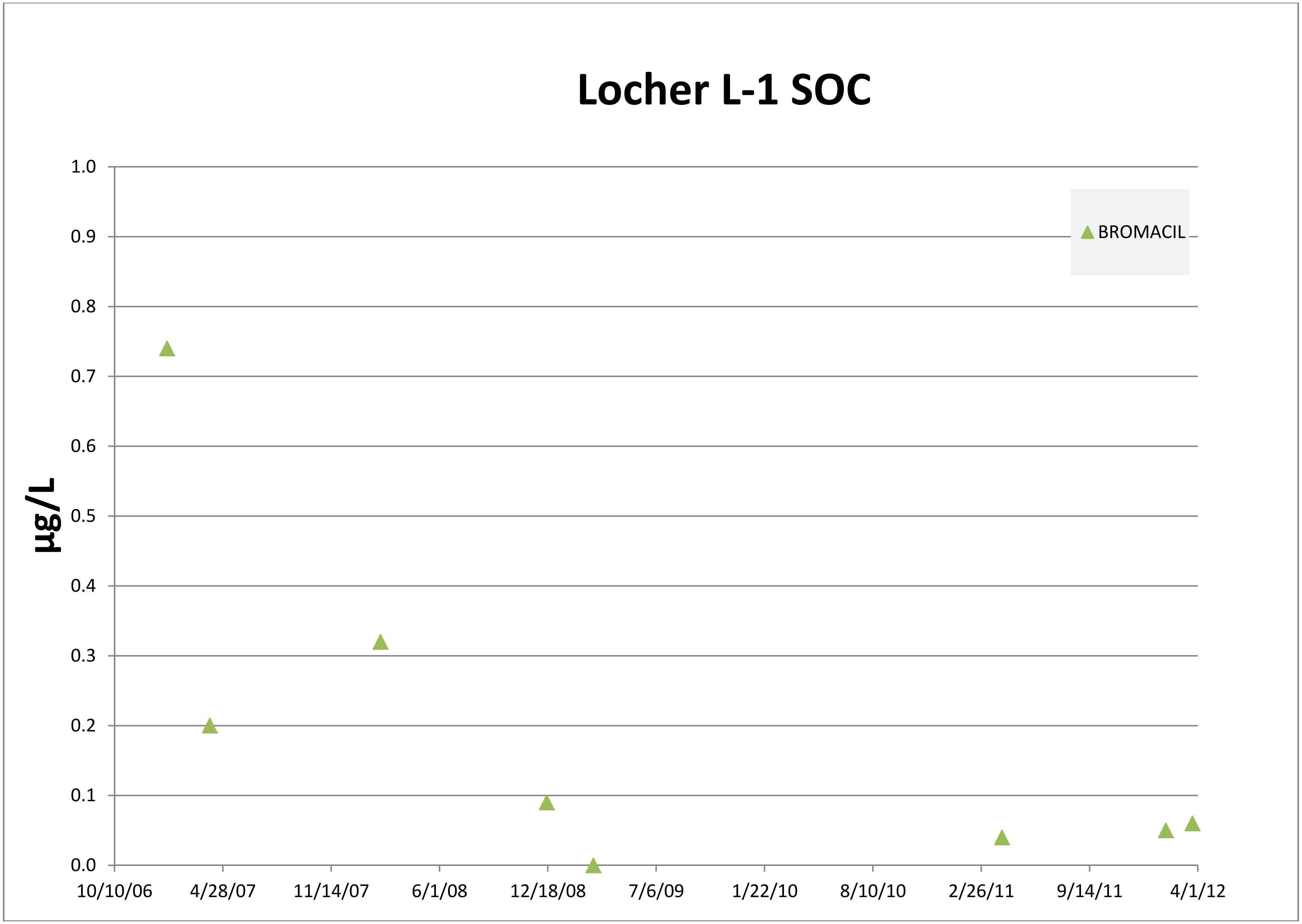

Figure C-10. Locher Road monitoring well L-1 SOC's.

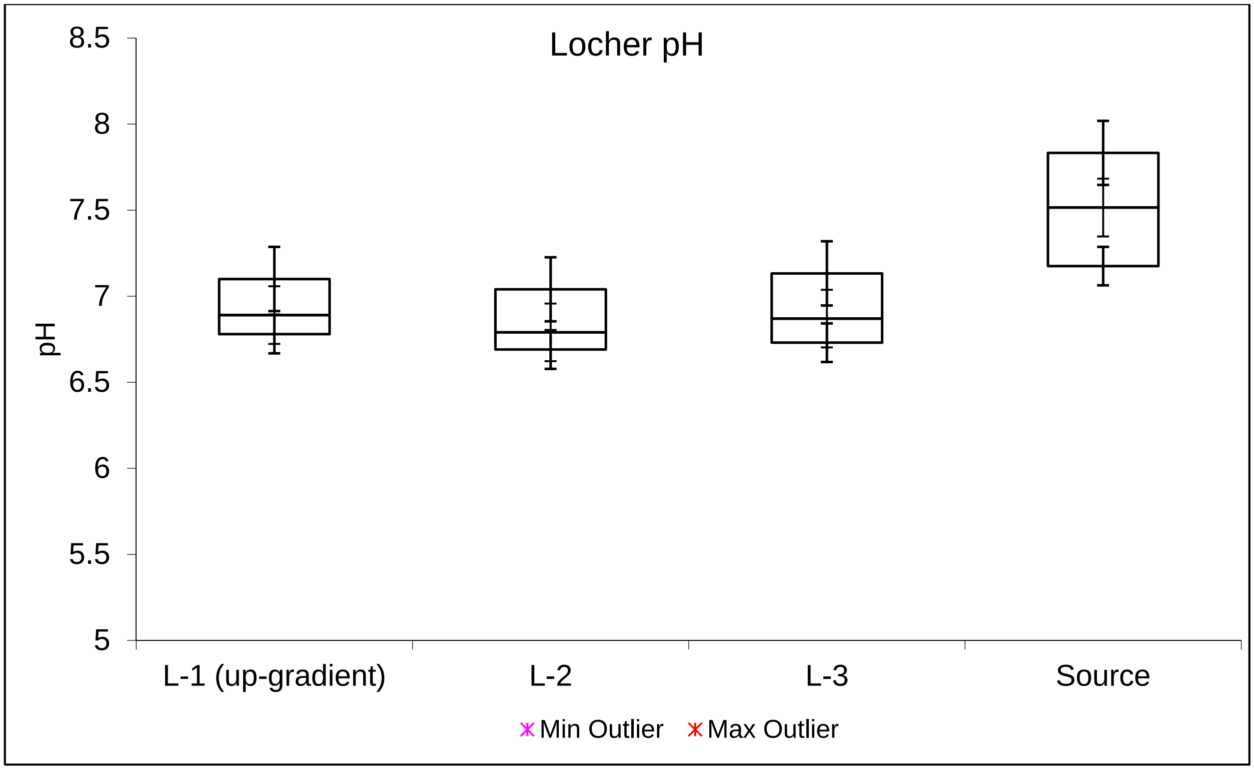

Figure C-11. Locher Road pH box-plot comparison displaying standard error bars for the median, upper and lower interquartile ranges.

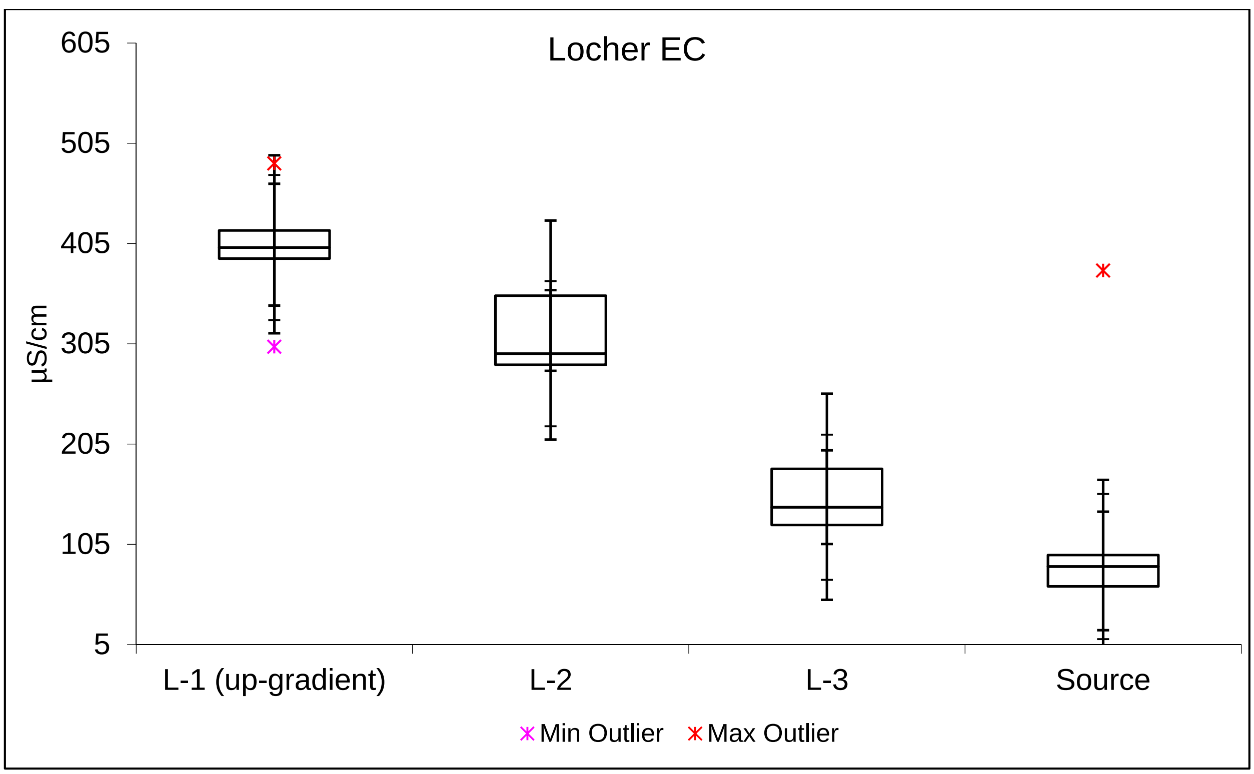

Figure C-12. Locher Road EC box-plot comparison displaying standard error bars for the median, upper and lower interquartile ranges.

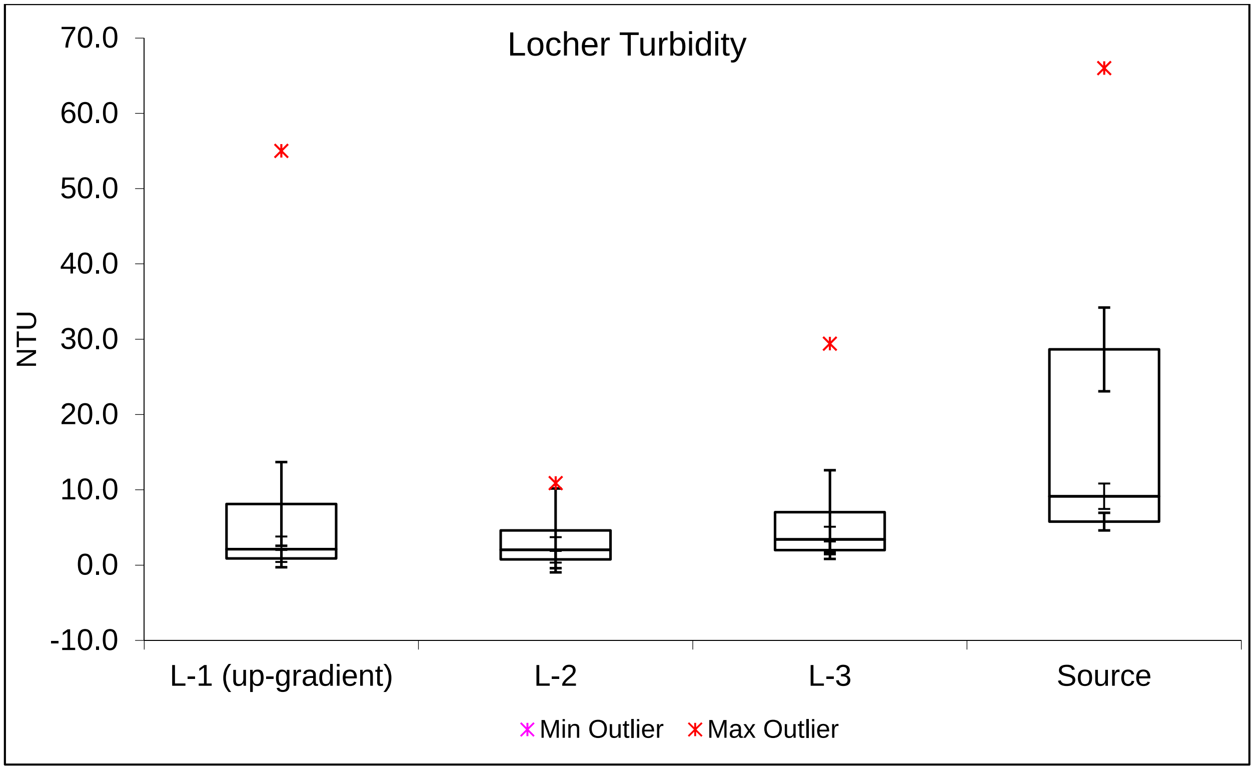

Figure C-13. Locher Road turbidity box-plot comparison displaying standard error bars for the median, upper and lower interquartile ranges.

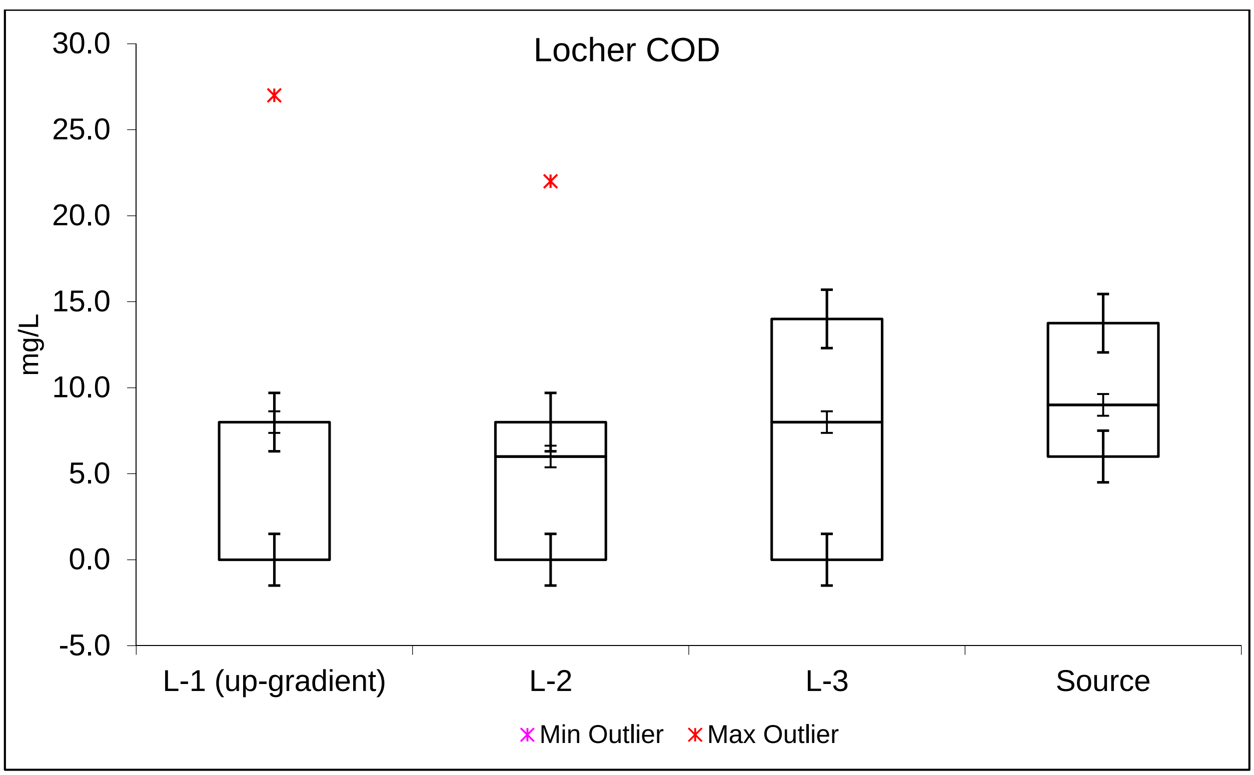

Figure C-14. Locher Road COD box-plot comparison displaying standard error bars for the median, upper and lower interquartile ranges.

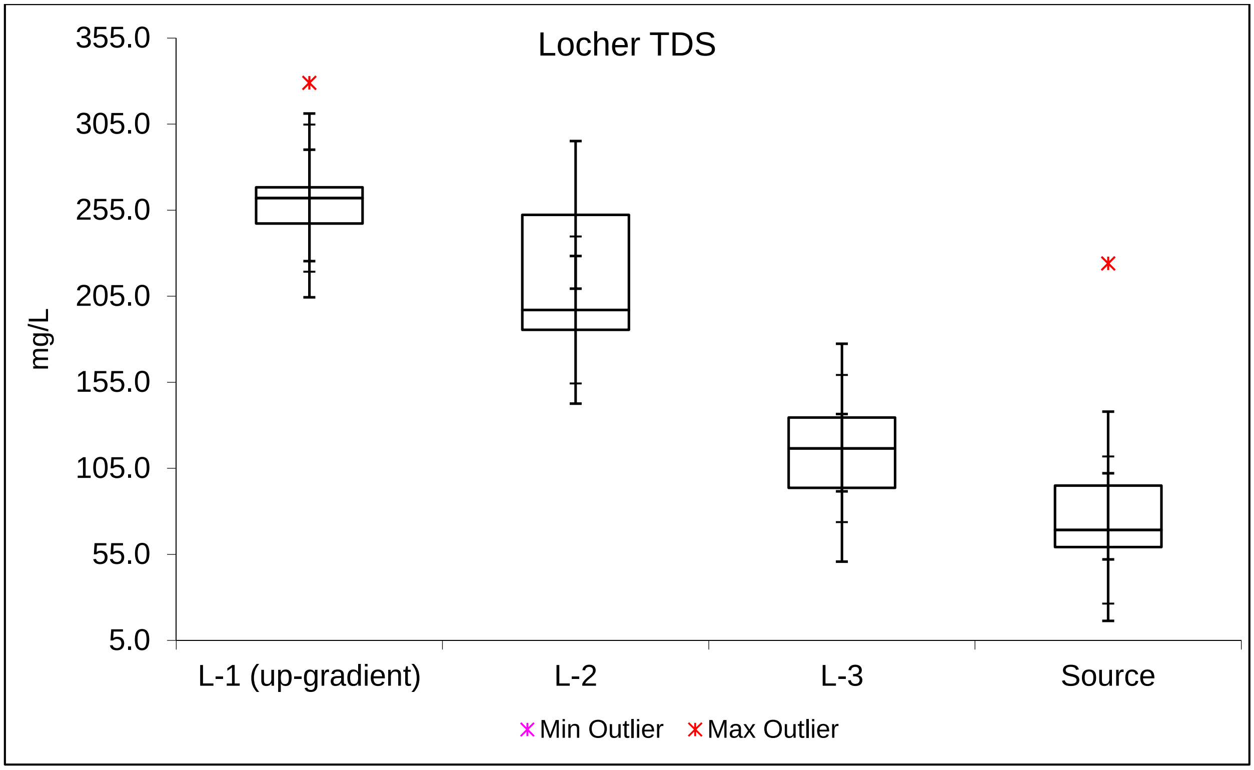

Figure C-15. Locher Road TDS box-plot comparison displaying standard error bars for the median, upper and lower interquartile ranges.

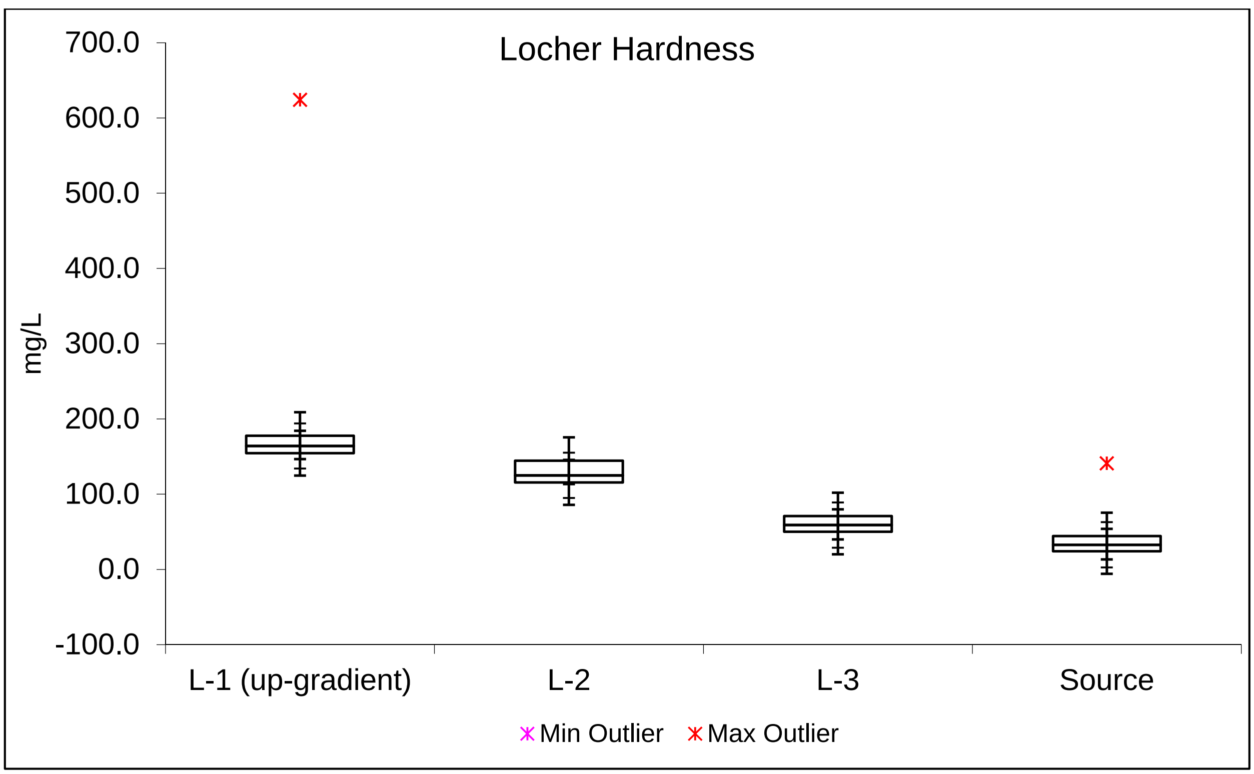

Figure C-16. Locher Road TDS box-plot comparison displaying standard error bars for the median, upper and lower interquartile ranges.

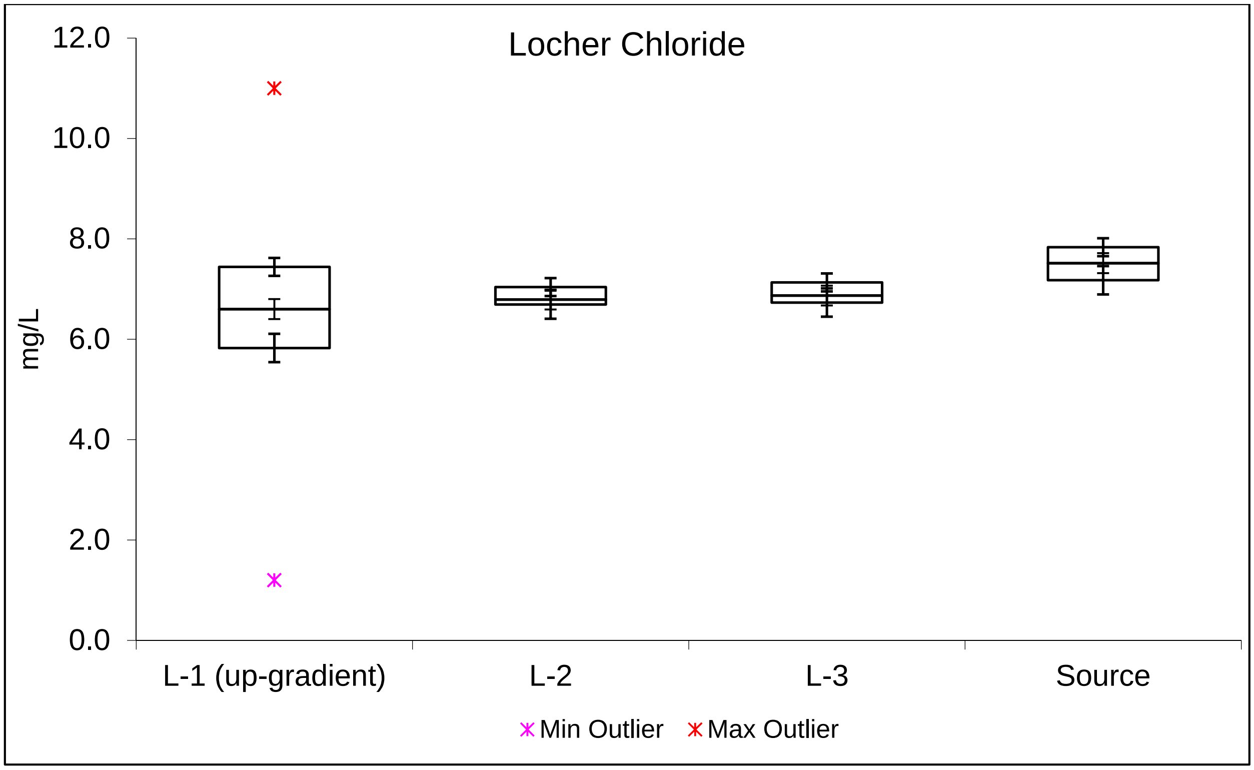

Figure C-17. Locher Road chloride box-plot comparison displaying standard error bars for the median, upper and lower interquartile ranges.

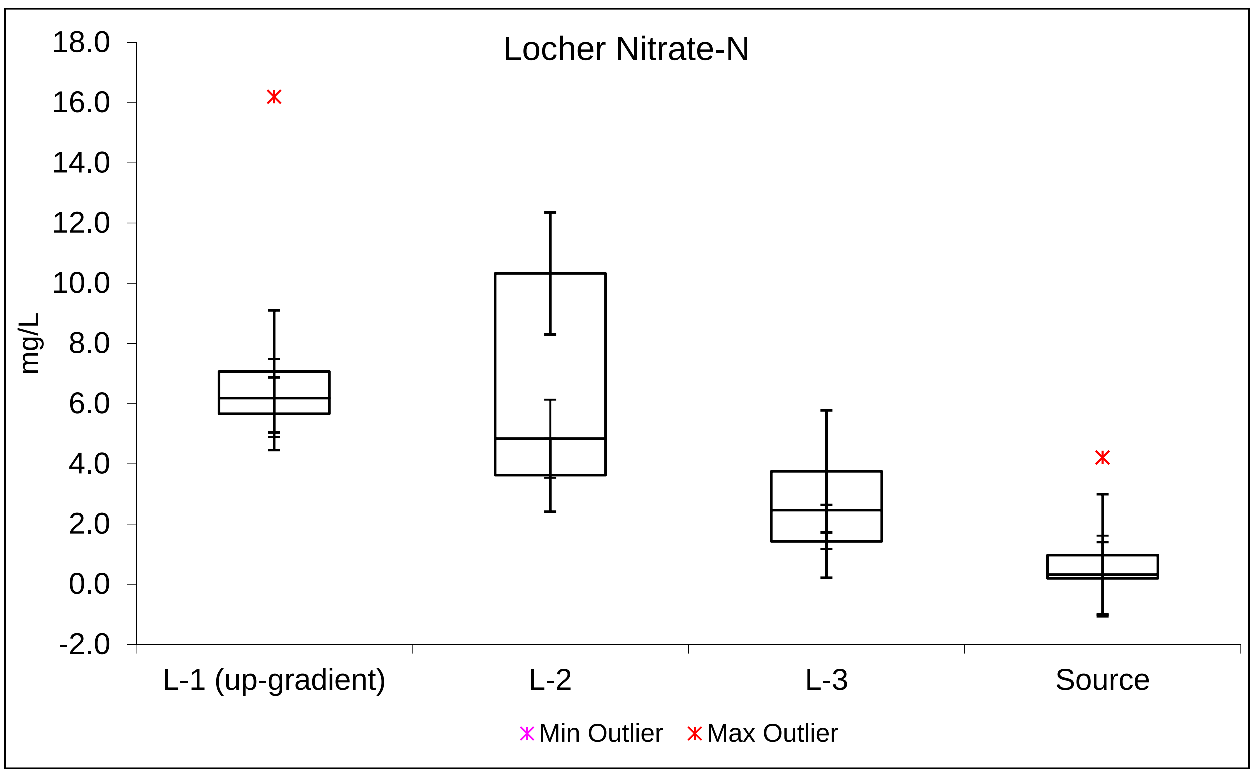

Figure C-18. Locher Road nitrate-N box-plot comparison displaying standard error bars for the median, upper and lower interquartile ranges.

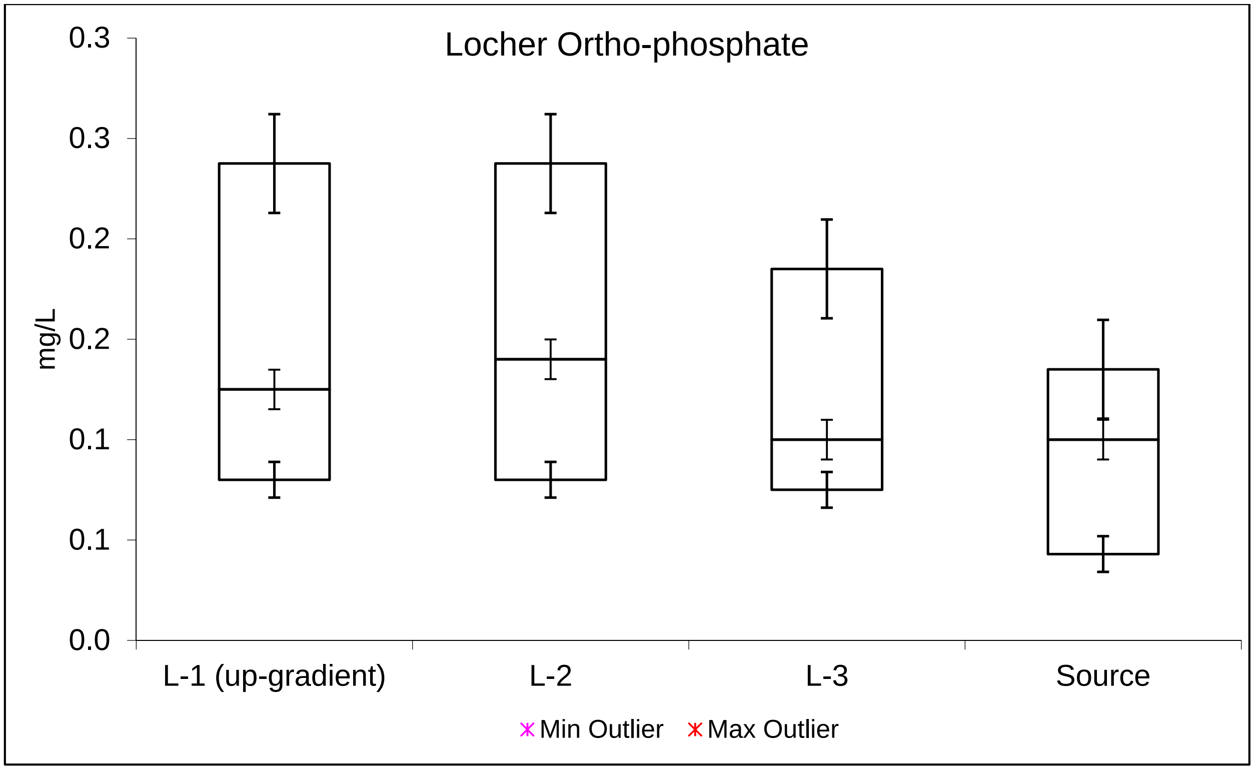

Figure C-19. Locher Road ortho-phosphate box-plot comparison displaying standard error bars for the median, upper and lower interquartile ranges.

Appendix D

Stiller Pond Data Comparison Histograms

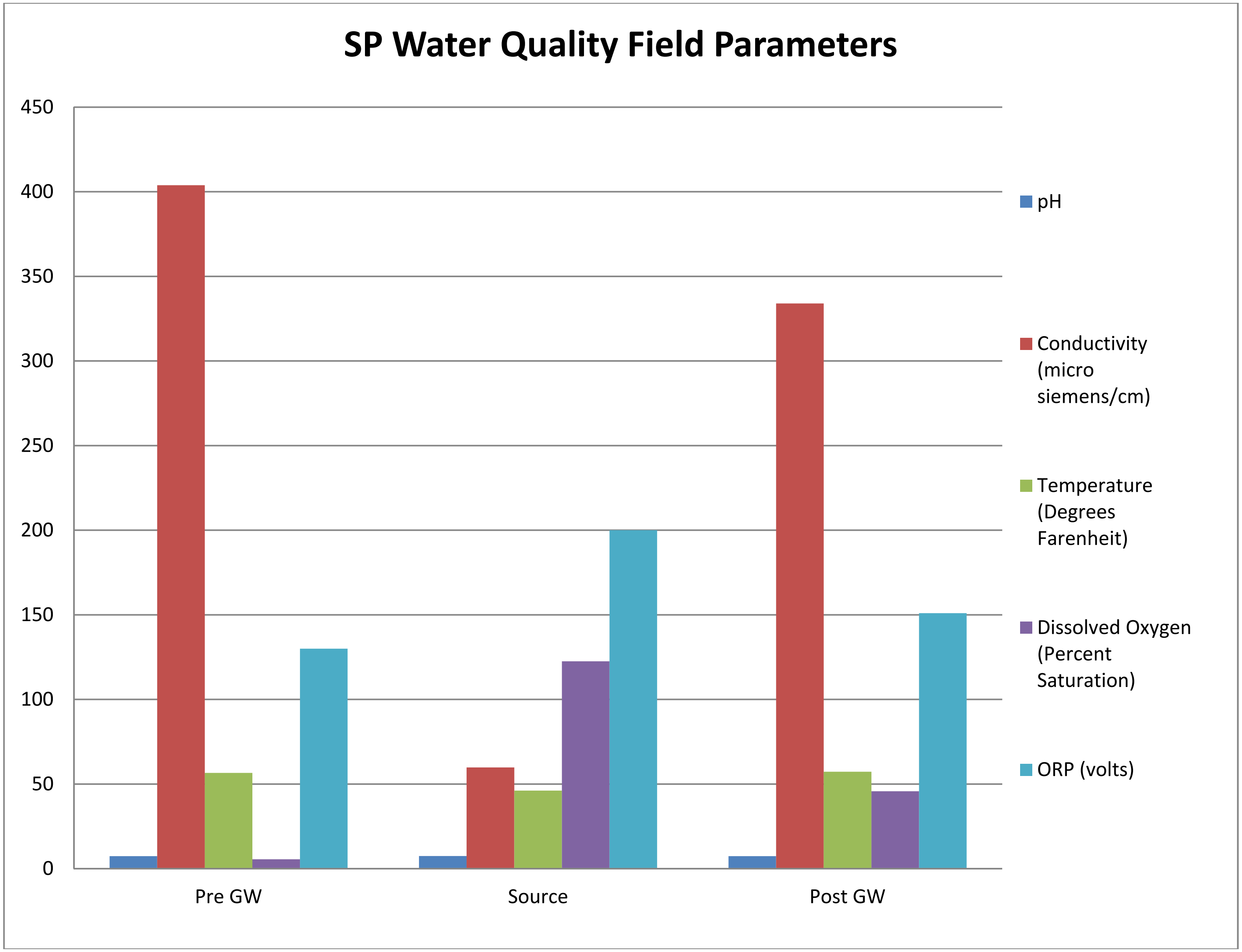

Figure D-1. Stiller Pond field parameters. Pre GW = pre-recharge groundwater sample; Source = recharge source water sample; Post GW = post-recharge groundwater sample. All groundwater samples were collected from monitoring well MWSP-1.

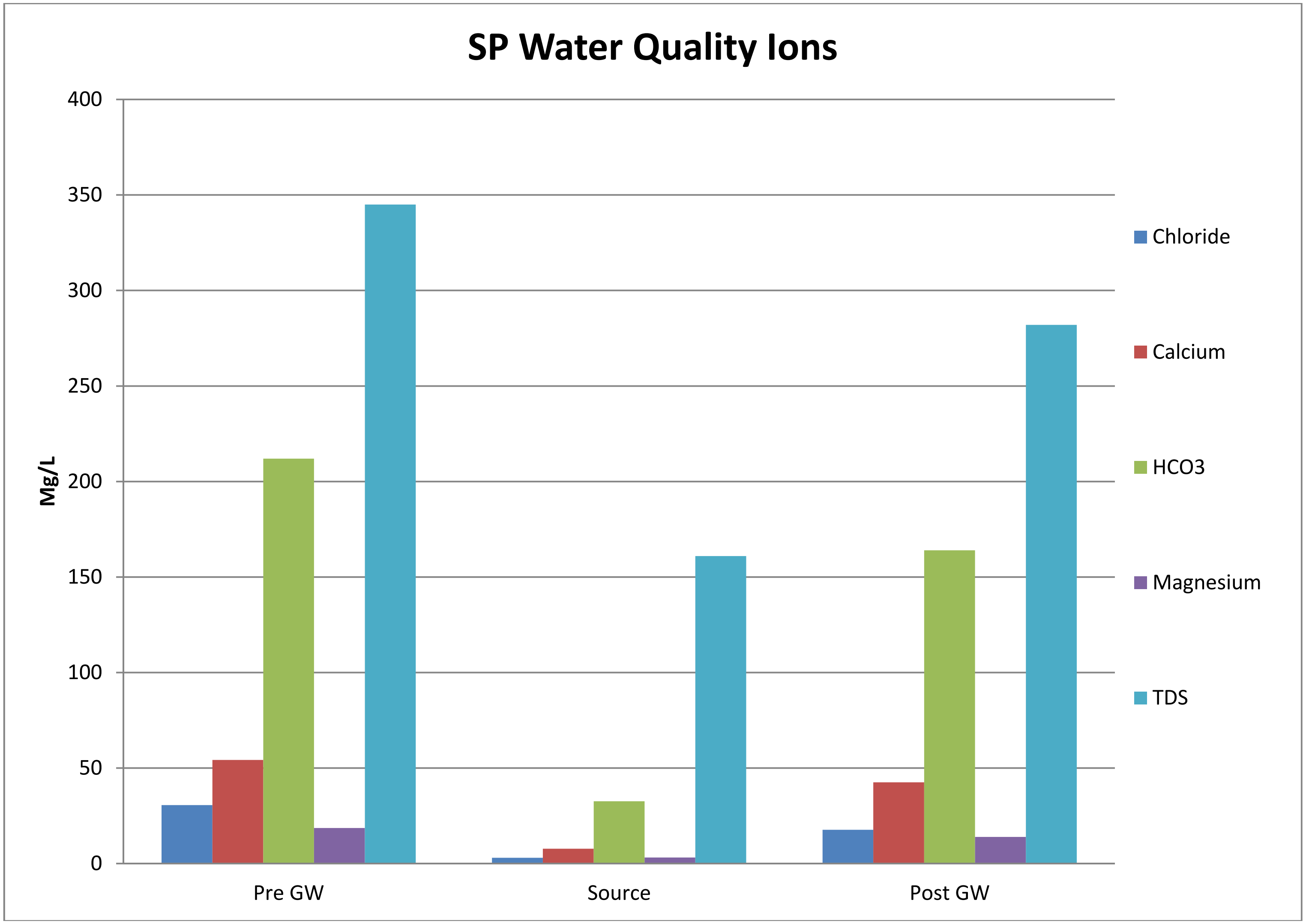

Figure D-2. Stiller Pond water quality ions. Pre GW = pre-recharge groundwater sample; Source = recharge source water sample; Post GW = post-recharge groundwater sample. All groundwater samples were collected from monitoring well MWSP-1. TDS = total dissolved solids.

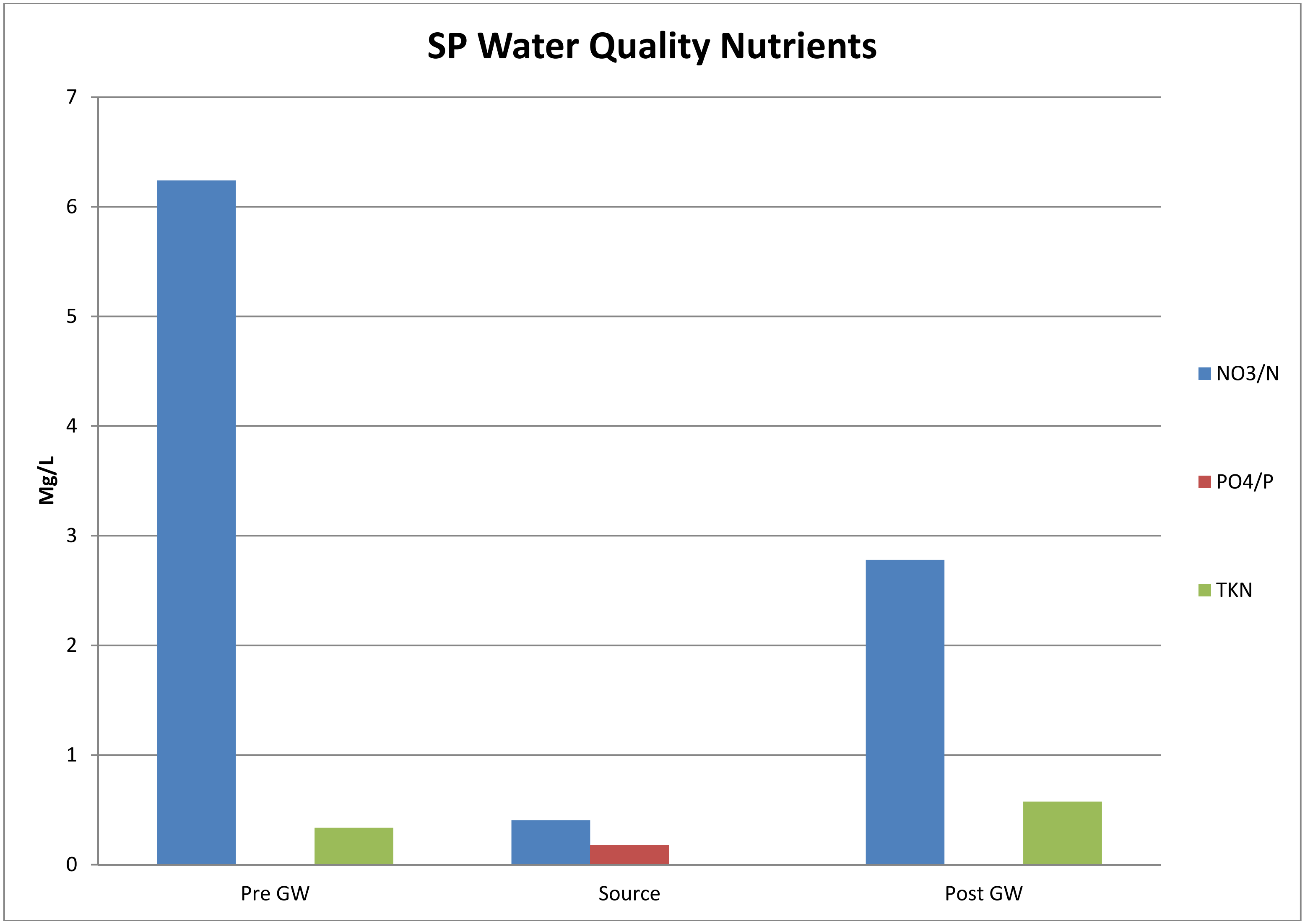

Figure D-3. Stiller Pond water nutrients. Pre GW = pre-recharge groundwater sample; Source = recharge source water sample; Post GW = post-recharge groundwater sample. All groundwater samples were collected from monitoring well MWSP-1. TKN = total Kjeldahl nitrogen.

Appendix B

Surface Water Monitoring in the Walla Walla Basin 2010-2011

www.wwbwc.org
Walla Walla Basin Watershed Council
541-938-2170 or 7086 P.O.Box 68, Milton-Freewater, OR 97862

Surface Water Monitoring in the Walla Walla Basin 2010 – 2011

The Walla Walla Basin Watershed Council's

Surface Water Monitoring Report

Will Lewis
Hydrologic Technician

In cooperation with

5 March 2012

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Introduction

Project Overview

The Walla Walla Basin covers an area of approximately 1760 square miles. It lies on the western side of the Blue Mountains, about 70 miles west of where the border between Oregon and Washington meets the Idaho border.

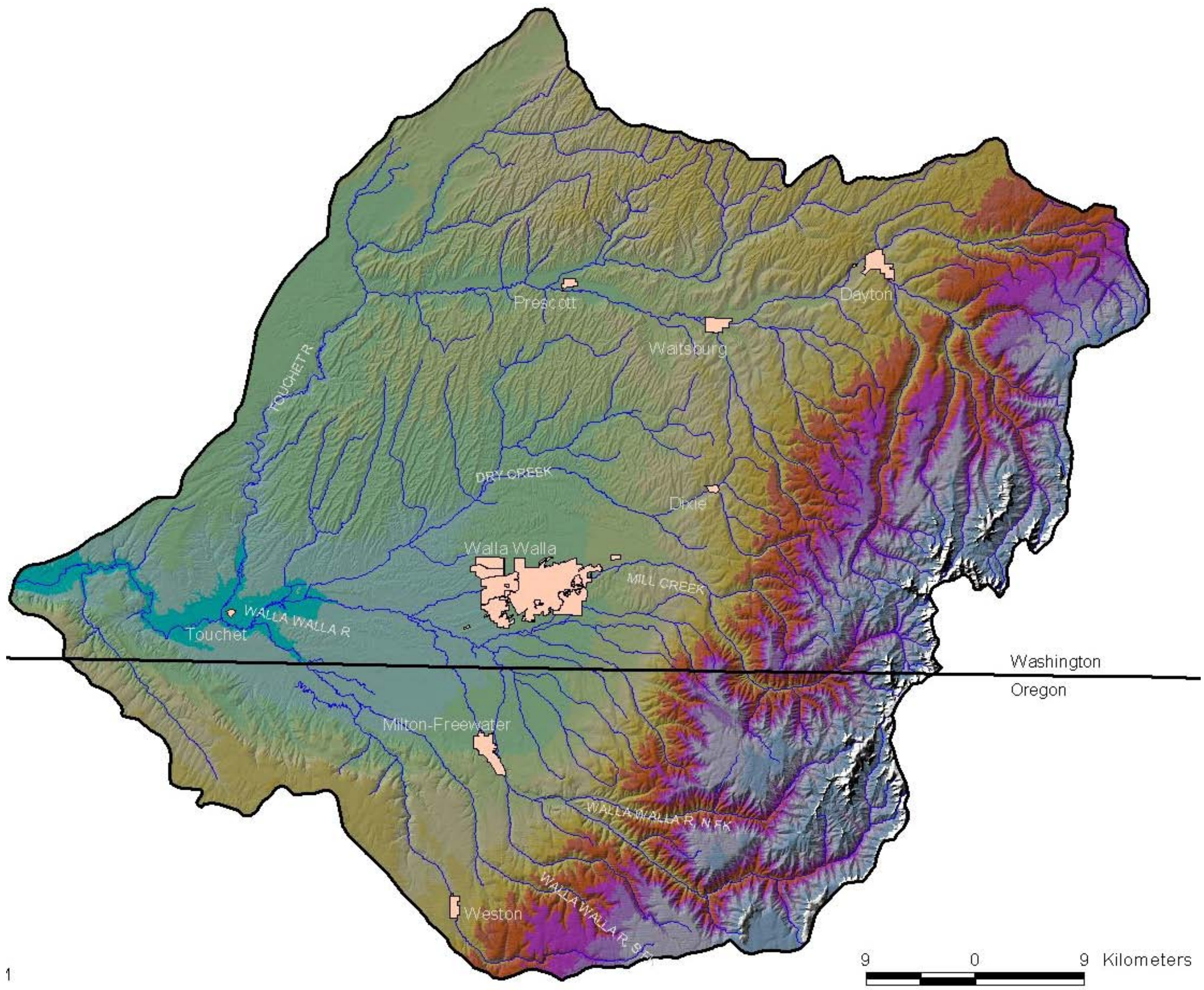

Figure 1. The Walla Walla Basin, a bi-state watershed.

Until recently, all of the water in the main stem of the Walla Walla River was seasonally diverted into the Little Walla Walla River[1]. In the spring of 2000 three major Walla Walla Basin irrigation districts, in conjunction with environmental groups and the US Fish and Wildlife Service, entered into a landmark agreement allowing approximately 30% of prior-appropriated irrigation-season water rights to be left in stream to aid salmon recovery efforts[2]. The agreement's intent was

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[1] The Little Walla Walla River is a system of irrigation canals and ditches that transport water throughout the Walla Walla River Valley.

[2] Bower, Bob. "Shallow Aquifer Recharge (SAR) as a water management tool for the Walla Walla Basin," Page 8. Walla Walla Basin Watershed Council. 30 August 2007.

to aid the recovery of anadromous fish species, but putting water back into the river has directly reduced the amount of water available to many residents of the valley. As a result of this reduced water availability and the desire of the irrigation districts and landowners for everyone's water requirements to be met, portions of the Little Walla Walla River and surrounding springs and streams seemed to be flowing less than in previous years and, by 2002, some feared their springs and streams were in danger of drying up[3].

The Walla Walla Basin Watershed Council (WWBWC) began its surface flow monitoring program in 2002 in order to provide the community with water flow data that could help manage the valley's water and support or assuage the fears of the concerned water users. Since that time, the network has gradually expanded and evolved to include 58 sites in the Walla Walla Valley, including The Walla Walla River, its tributaries, springs, small order streams, and irrigation ditches. The sites in the WWBWC's monitoring network were originally chosen to keep track of flow levels throughout the Little Walla Walla System so that water policy decisions in the future would be able to be informed by the gathered data. The WWBWC also chose several of the site locations in order to track the progress of the HBDIC Recharge Project and to gather data for the continued improvement of the WWBWC-OSU Walla Walla River Valley Groundwater Model. The sites on Johnson Creek in Umapine were installed, for example, because Johnson Creek started flowing seasonally after years of being dry when the HBDIC recharge project began to put water back into the ground.

[3] Although the agreement to leave a minimum flow in the Walla Walla River's main stem technically ended in 2007, the irrigation districts continue to bypass agreed-upon flows in an ongoing effort to aid the habitat conservation process, and efforts to ensure that these flows remain protected all the way to the Walla Walla River's mouth at the Columbia are ongoing.

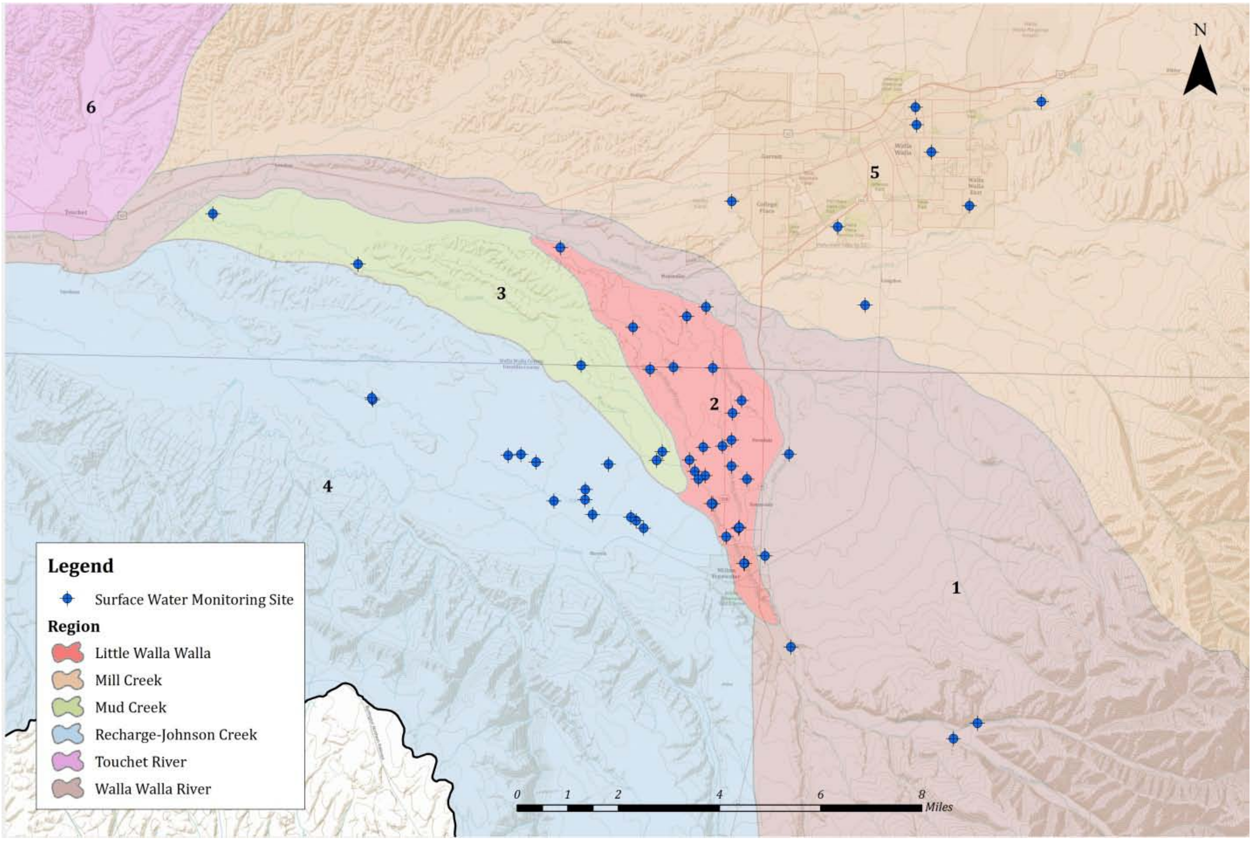

Figure 2. The WWBWC's surface flow monitoring network is bounded by Walla Walla Community College's Titus Creek on the northeast, the Frog in Milton-Freewater on the south and Mud Creek at Barney Road on the west, near the Walla Walla River.

By the time the WMI project began in 2006, the WWBWC had already begun a project dubbed Hydro North, which extended the monitoring network across the border into Washington. When the WMI project moved into Phase I it absorbed the Hydro North project, inheriting all of the WWBWC's surface water monitoring locations in Washington.

New Project Features

Because of the ongoing nature of this project and the way this report borrows from the previous iteration (especially in the introduction), I have included this section to discuss what's new with surface water monitoring in the Walla Walla Basin since the start of 2010.

New Organization System

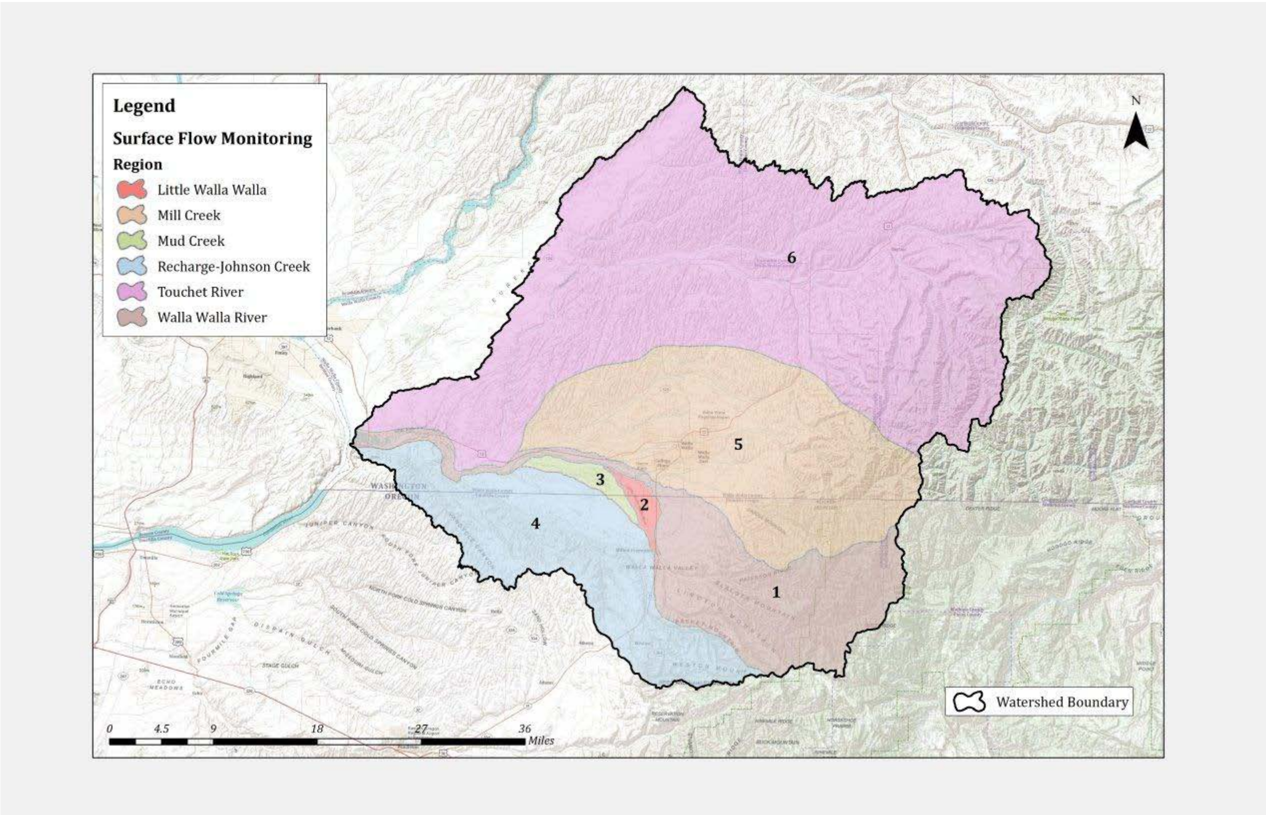

Figure 3. Sites in the WWBWC surface water monitoring network are now organized according to the regions depicted above.

Region	# of Sites[4]
1: Walla Walla River	5
2: Little Walla Walla River	26
3: Mud Creek System	5
4: HBDIC - Pine Creek	13
5: Mill Creek / Walla Walla Area	9
6: Touchet River	0
Total	58

[4] This only includes the number of sites operated by the WWBWC, and does not include new sites listed on the next page whose data is not included in this report.

New Naming System

WWBWC's new naming convention for surface water sites is to give each one a three-digit ID number where the first digit is determined by the region. For example, the Little Walla Walla Diversion from the Walla Walla River is given the name "S-201." S-202 is the Crockett Diversion at the Frog (the next site downstream from the Little Walla Walla Diversion), and so on. This isn't that important in the grand scheme of things, but it does make the site identifiers a lot less intimidating (since they used to have 3-5 letter mnemonic identifiers that usually only made sense to employees of the WWBWC).

New Monitoring Sites

The WWBWC's surface water monitoring network has grown since the end of 2009. The following list of new sites is a combination of those added in 2010, those added more recently, and those which will be added in 2012. Not all of them have data included with this report, but all will be updated on the website once they have enough data to make that action feasible.

- S513 Yellowhawk Creek
- S220 ELWW Stateline
- S413 White Ditch
- S414 Anspach Recharge
- S306 Middle Mud Creek Locher Rd
- S307 Middle Mud Creek Frog Hollow
- Eastside Recharge
- Walla Walla River @ Pepper (Former WDOE)
- Coppei Creek (Former WDOE)
- Walla Walla River @ Beet Rd (summer, WDOE)
- Birch Creek
- Dry Creek (WA)
- Stone Creek College Place
- Garrison Creek College Place
- Dry Creek (OR)
- Pine Creek

New Software

The WWBWC is in the process of adopting a new data management and analysis software suite. It was not used in the preparation of this report, but it will begin to be used immediately and all old data will be transferred to the new database system.

Data on Website

The WWBWC displays surface water flow data for our own surface water monitoring locations and also links to hydrographs and data of other surface flow gauges in the basin.

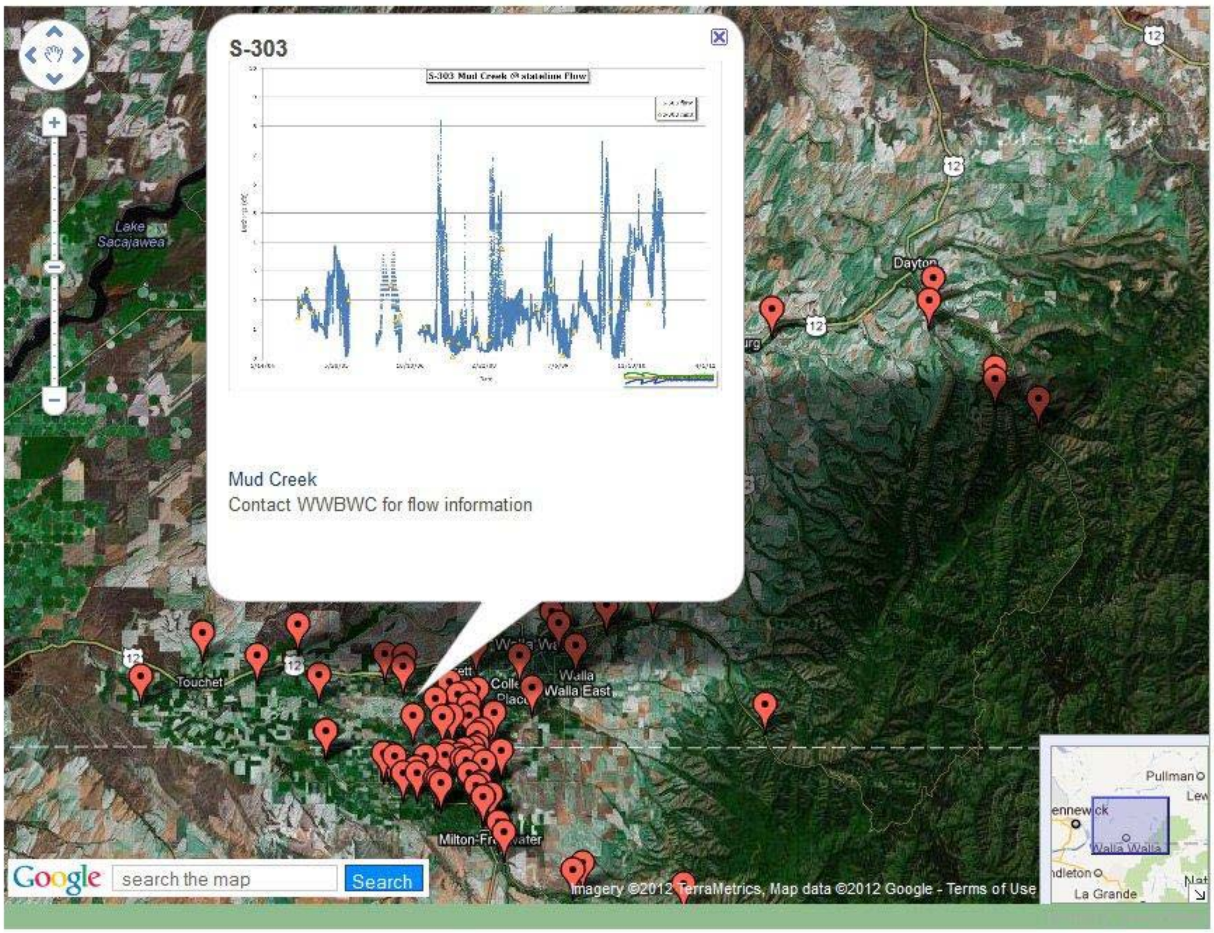

Figure 4. A screenshot of the Surface Water Monitoring Map on the WWBWC.org website.

Methods

The methods used to undertake this project will be covered in two sections, one on Data Collection and one on Data Analysis.

Data Collection Methods

The WWBWC uses electronic data loggers to record gauge height. The WWBWC uses loggers manufactured by TruTrack, Solinst, WaterLog, and In-Situ, Inc. Some of these loggers record the water level directly, and some are pressure transducers. Most sites record stage every 30 min.

Figure 5. This is the new location for the S226 gauge on the East Little Walla Walla River. Typical of many WWBWC gauges, a PVC stilling well and a staff gauge are lashed to a fence post imbedded in the channel.

In addition to continuous water height data, the WWBWC records instantaneous flow measurements at all applicable sites. These instantaneous flow measurements utilize a Marsh-McBirney Flo-Mate 2000 pressure sensor to estimate velocities of the flowing water in cells of varying width and depth along the cross section of the stream[5].

Figure 6. Instantaneous flow measurement of the Walla Walla River: A tape is hung across the river. At points along the tape, depth and velocity values are recorded. Discharge of a cell = Depth * velocity * cell width. This is how flow is estimated for instantaneous flow measurements.

Site visits are scheduled on a quarterly basis, and the following data is collected during a site visit:

- The data is downloaded and the logger is checked
- Site maintenance and ensuring the logger is monitoring flows properly
- A discharge measurement is taken (as described above, and in Figure 6)
- The staff gauge level is recorded
- Site is photographed
- Conductivity and temperature are measured with a portable electronic meter

[5] The WWBWC follows guidelines from the USGS Surface Water Training, as they apply to measuring small-order streams and springs. Training documents are found online at: http://wwwrcamnl.wr.usgs.gov/sws/SWTraining/Index.htm.

Each site has also had its GPS coordinates recorded, along with elevation, so the data may be easily implemented into Geographic Information Systems.

Data Analysis Methods

Water height recorded by a logger is checked against that site's staff gauge readings. If the staff gauge doesn't match up with a recorded water height, this can usually be fixed by applying a constant shift to each point in the data series. However, a more complex shift is sometimes needed to account for logger drift, or gradual site changes over time such as scour or silt buildup. In these situations water height data is corrected with a linear stepwise correction, where the total drift between staff gauge and recorded logger height is applied over period of time corresponding to the analyst's estimate of when the change occurred. This type of correction lowers that data's grade.

Once the continuous stage data for a site is corrected and compiled, the gauge site is rated. A rating curve is essentially a functional relationship between stage (water height) and discharge (flow). It is developed by plotting the discharge values of the instantaneous flow measurements with respect to the corresponding corrected stage values of the continuous stage data (in the example from Yellowhawk Creek below, this is the data series represented by blue diamonds).

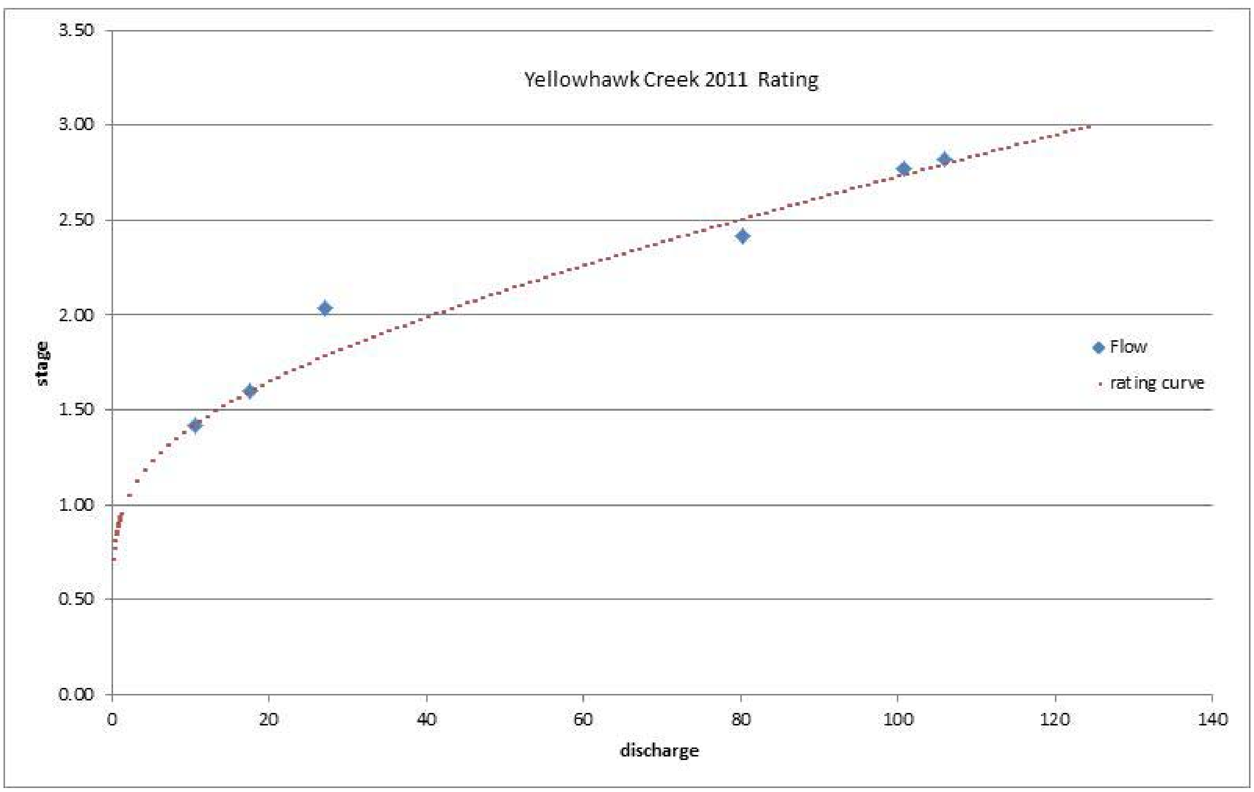

Figure 7. 2011 Rating Curve for S-513

Once the instantaneous flows are graphed in this way, a curve can be drawn (or calculated) along the data's trend which can then be used to interpolate flow values for each record in the logger's continuous stage file[6]. Rather than connecting the plotted points with a hand-drawn line, the WWBWC uses a method called least-squares regression (aided by a program called Table-Curve 2D[7]) to find the equation for a best-fit curve which models flow in the stream for each point of recorded water height data. The WWBWC's specific rating process is described in detail in Appendix A.

Some sites in the monitoring network equipped with flumes and weirs have the data analyzed using equations or tables provided by the engineer who designed the structure. Sites whose discharge may be calculated using these empirical methods generally produce more accurate data than sites whose discharge is based on a regression curve. Occasionally sites with engineered structures are also rated using the regression curve method described above (such as in the case of a damaged weir that no longer conforms to its once-engineered characteristics).

After the rating curve is generated the stage data is processed into flow data. Each point of the continuous (30 minute) water height data is input into the equation defining the rating curve, and the interpolated flow values are output. When the logger records water heights greater than the stage at the highest flow measurement the quality of the data drops off significantly because those points are only bounded by an actual measurement on one side. For example, if the logger in Yellowhawk Creek recorded heights of around 3.0 feet, the equation would output a flow of around 124 CFS. While we know flows at that water height would be greater than the 106 CFS of our highest measured flow, the rating curve cannot be relied upon to predict such outlier points with much accuracy. Figure 8 displays the flow data from the Yellowhawk Creek location whose rating curve is shown in Figure 7. High flows output by the rating equation are included in the graph but cannot be considered as accurate as those flows that lie within the boundaries of the points used to generate the curve. The instantaneous flow measurements are superimposed onto the flow data in the output graphs so that a viewer can see which flows are above those measurements.

---

[6] As long as the stage level being converted to flow lies within the bounds of the points (instantaneous flow measurements) used to create the curve.

[7] TableCurve2D is developed by Systat Software, Inc. More information is available at their website: http://www.sigmaplot.com/products/tablecurve2d/

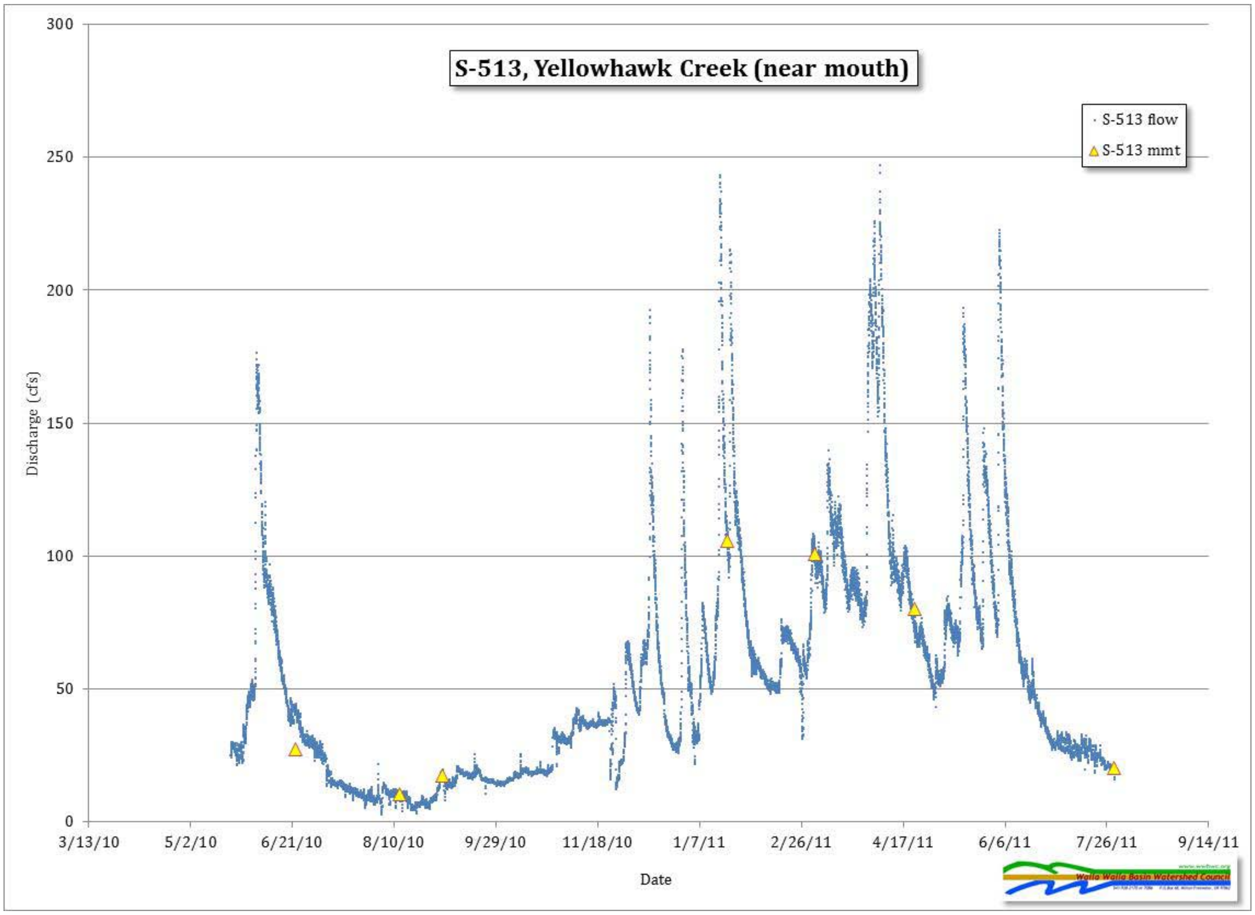

Figure 8. Data from Yellowhawk Creek where it crosses the Old Milton Highway near its outlet into Mill Creek. The yellow triangles represent the instantaneous flow measurements taken there. Data higher than 106 CFS is not reliable because it is only bounded on one side by a recorded value.

The flow data for the site is then graded. The WWBWC grades flow data from “1” to “4”, where grade 1 data is high quality data, as good as can be expected from a site rated with the linear regression “best-fit curve” method. Grades are lowered when significant chunks of data are missing, seasonal vegetation or other changes in the open channel disrupt the rating process, or when loggers malfunction or fail[8]. As an example, the data from the S-513 Yellowhawk Creek site in 2010-2011 (shown in Figure 8) is grade 2 data because a significant portion of the interpolated flow values are above the highest measured flow value.

And finally, for S-105(Grove School Bridge on the Walla Walla River), the flow data is reported in near-real time on the WWBWC.org website[9].

[8] For more information on rating grades, see Appendix A.
[9] The WWBWC will add more near-real time flow gauges to its website in the future.

Results and Discussion

For each site in the WWBWC's surface water monitoring network, the data recorded throughout the year is analyzed as follows:

- Instantaneous flow measurements and continuous water height data were combined into a single file.
- Recorded water height was corrected to the site's staff gauge and a file of continuous stage data was made ready.
- The rating curve was then produced (through "best fit" regression or by empirical means).
- The rating was then applied to the stage data file to generate continuous flow data.
- The analyzed data was graded.
- The current year's data was combined with previous data from the site and made available for sharing on the WWBWC.org website or by request.

Flow data for the WWBWC's surface water monitoring network is presented graphically in Appendix E.

Overall Trend

In general, 2010 was an average recent water year, and 2011 saw increased flows in most areas due to high precipitation in the winter and spring, and a high amount of snow pack in the mountains. Although many of the sites in the WWBWC's surface monitoring network are managed by the irrigation districts, the trend can often still be seen since they are able to take more if there is more water available. Some sites whose data exhibit this trend are shown below.

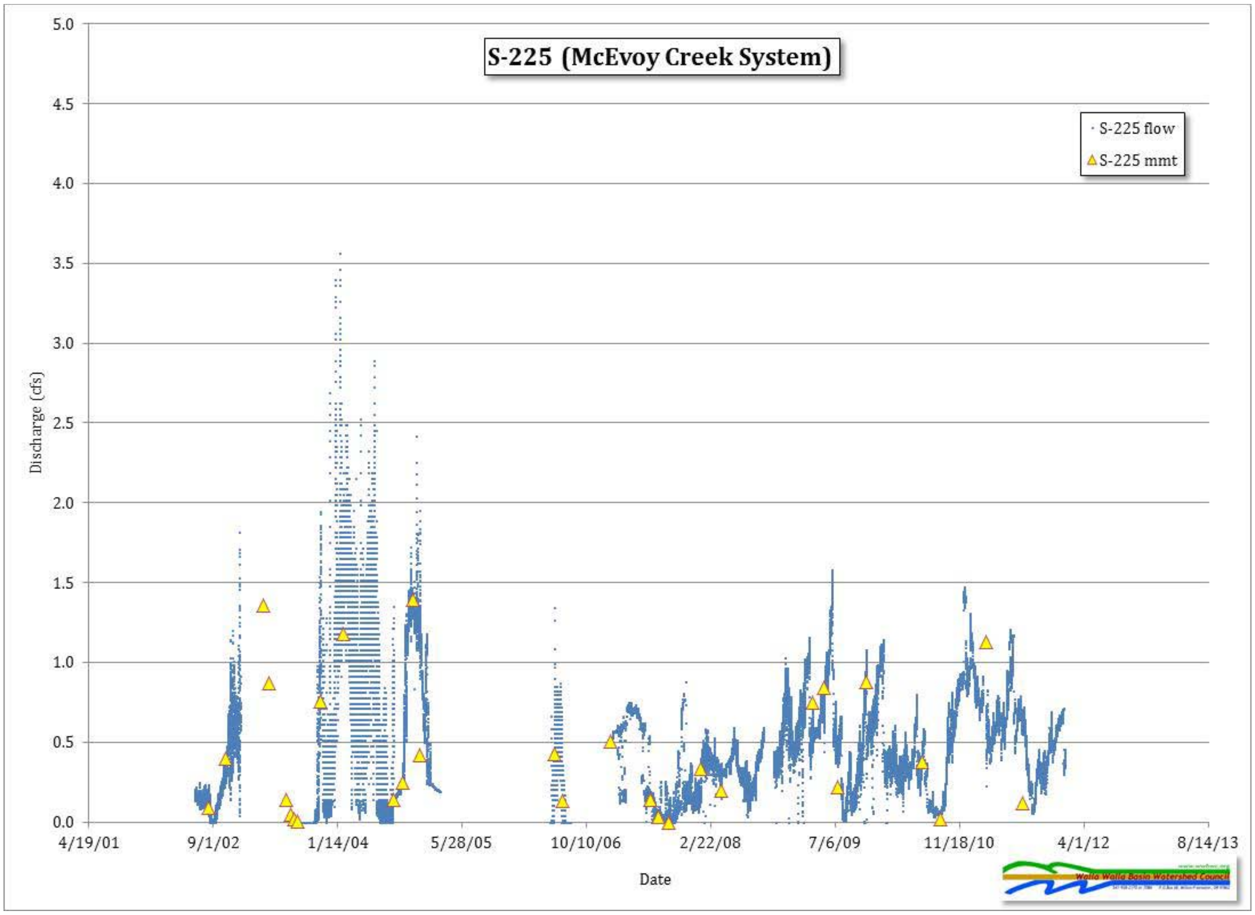

Figure 9. McEvoy Creek flowed higher in 2011 than it did in 2010

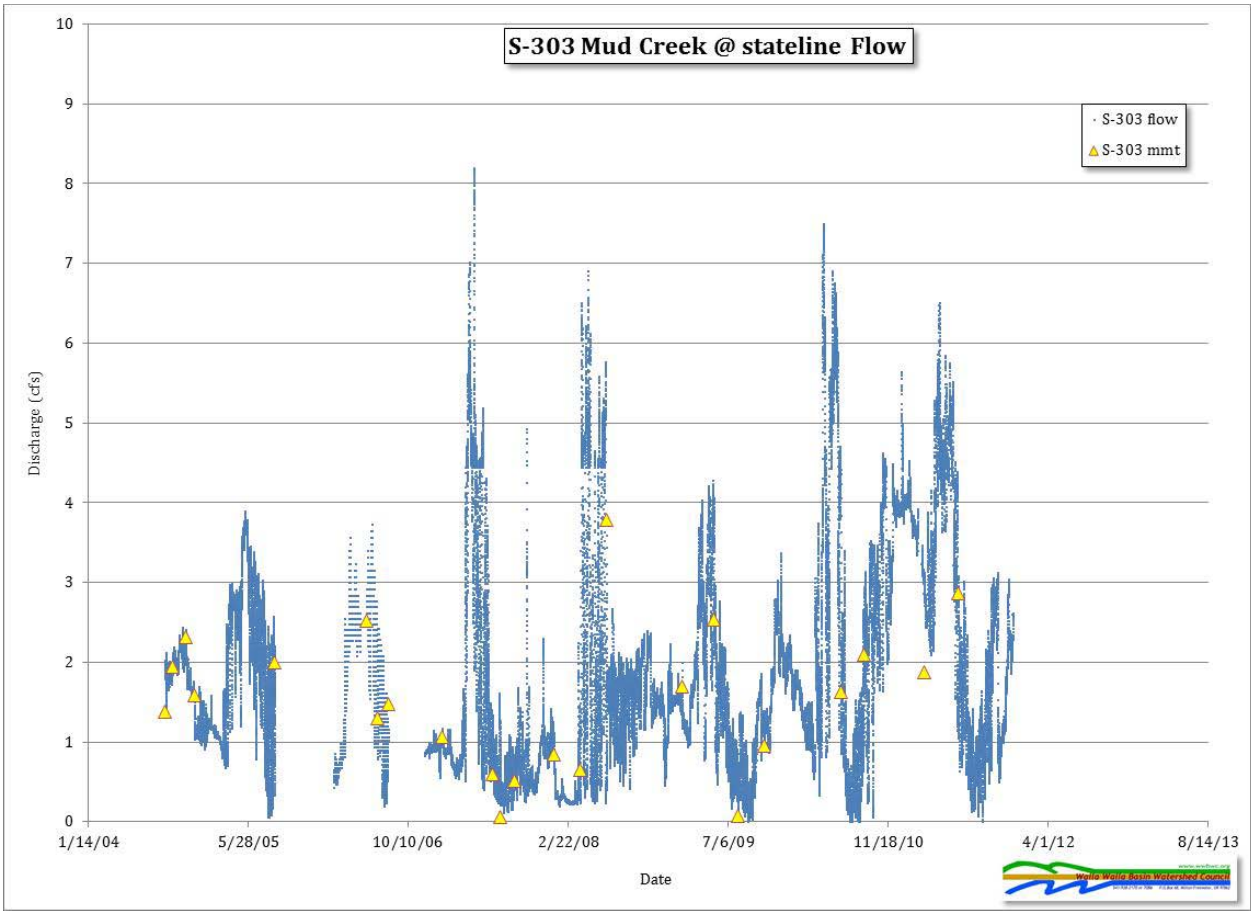

Figure 10. Mud Creek at Stateline Road didn't have flows drop in the summer of 2011 as much as usual.

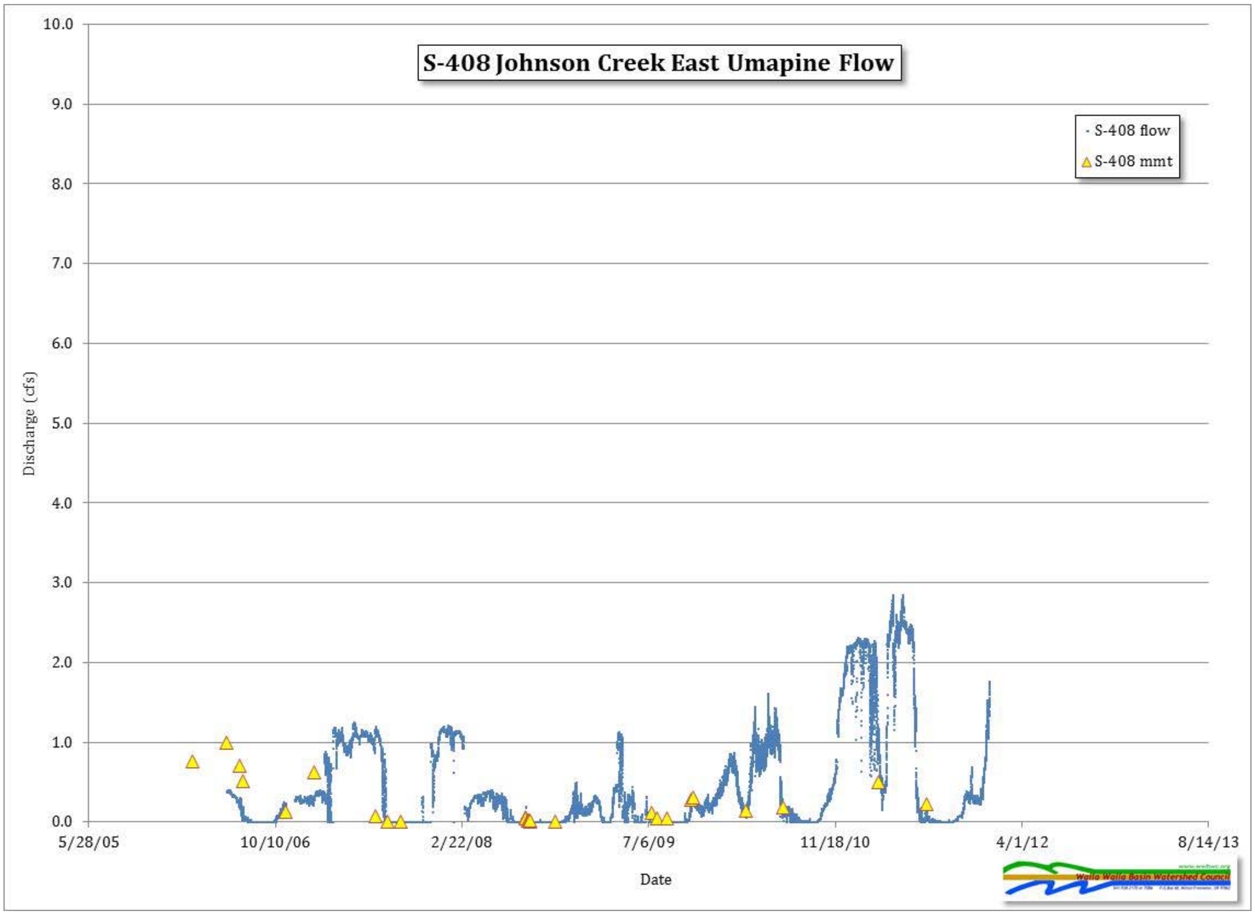

Figure 11. Johnson Creek East of Umapine flowed higher than usual, but went dry for about as long as in 2010

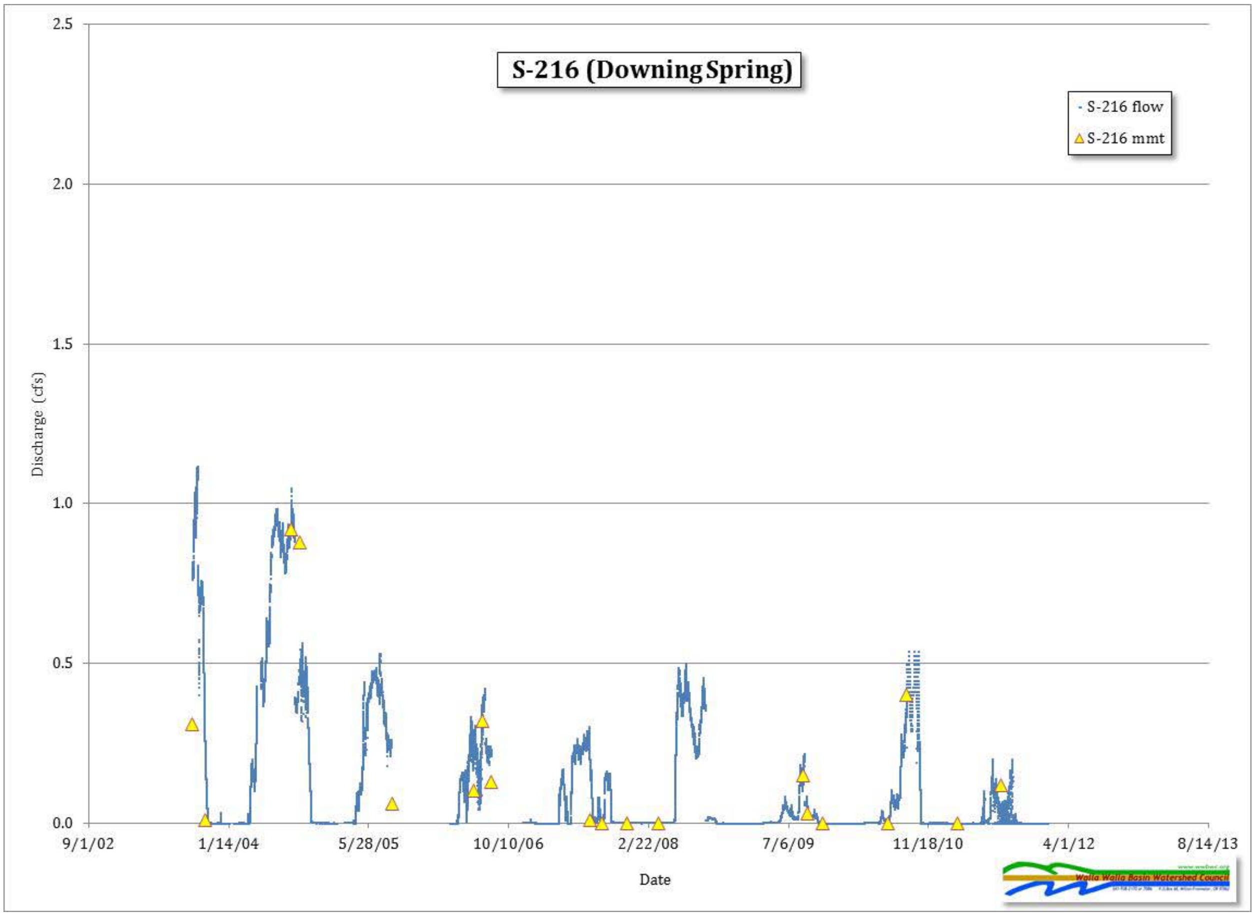

Figure 12. As this hydrograph of Downing Spring shows, though, 2011 flows were not higher than in 2010 for every site. Downing Spring has been on a sporadic decline for years, and did not flow more in 2011.

Missing or Omitted Data

When the hydrographs in Appendix E show no data for a period of time, this means one of two things: either there is no data, or the data has been purposefully omitted. Many TruTrack loggers the WWBWC had deployed came to the end of their life cycle during 2010 & 2011. In the majority of these cases, the loggers gave a low battery warning and were able to be swapped out without any significant data loss. Sometimes though, loggers fail in other ways. The data they are recording stops making sense and they begin to record unrealistic values. And sometimes sites undergo construction or some other change which makes them useless for a period of time until conditions are restored or the logger is re-deployed under the new conditions. Appendix D contains a list of missing data from 2010 & 2011 by site, along with a brief description of why the data is missing.

Problem Sites

There are many factors which may make data collected at a site unreliable or even unusable for a period of time. One of the main problems affecting the WWBWC's surface water monitoring network is seasonal vegetation growth. This is a problem because the vegetation grows in or near the water and impedes the free flow of the water at a site. The water level rises to go over or around the vegetation in the stream. This makes the rating model used to transform stage into flow report higher flow values than it should.

This seasonal vegetation growth was a problem at S-410 on Johnson Creek in Umapine.

Figure 13. S-410 in Johnson Creek. The creek flows into a pond in a pasture, under the fence shown here, over the sharp-crested weir, and into the metal grate where it flows into a pipe. Tumbleweeds like these seasonally clog up this weir and impede the water's flow.

In order to block the tumbleweeds from falling into the weir, I installed a plastic net in front of the cement pointed away from the weir to deflect the troublesome tumble weeds to the side and hopefully keep the weir free.

Figure 14. This close-up of the space between the deflector net and the weir at S-410 on Johnson Creek shows how the net kept most of the tumbleweeds out but did little to stop the algae.

While the net kept most of the large vegetation from clogging the weir, the free passage of water over it deposited more algae onto the grating behind.

Figure 15. S-410, Johnson Creek in Umapine, now has trouble with pond algae clogging the grating.

The algae built up until it was blocking so much of the grating the weir was completely flooded. Even though this weir gets cleaned out on every site visit, it isn't enough to keep the vegetation from affecting the site's data.

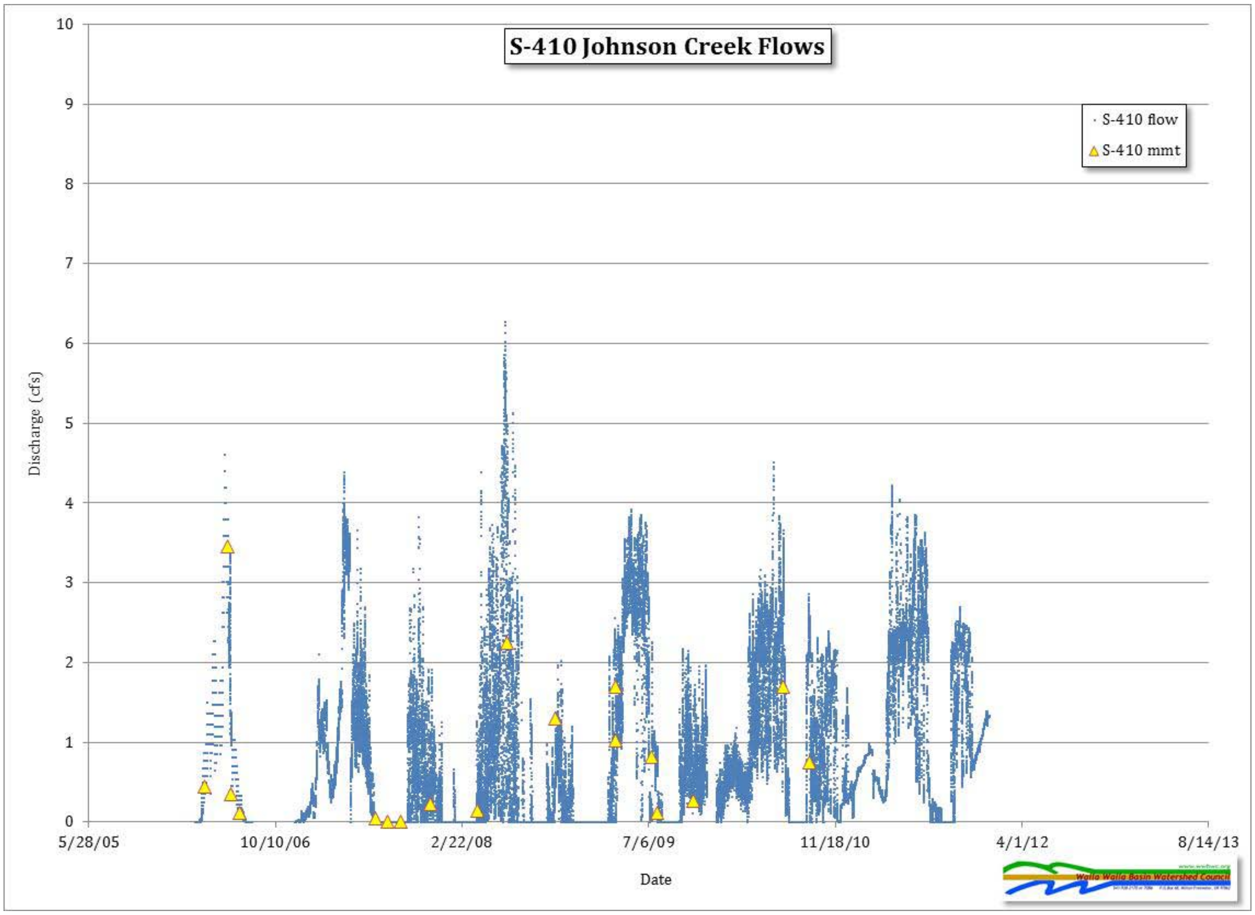

Figure 16. On this hydrograph of S-410, the data skips down about 0.4 CFS in February of 2011 as a result of the site being mucked out.

While S-410 was a somewhat difficult site to deal with because of the seasonal vegetation growth, it is not the only site that causes such problems. Reed Canary grass, silty buildup, and interference from people or animals can all cause similar problems for data accuracy. The data is corrected as much as possible and its grade lowered.

Summary

Maintaining the gauges in the WWBWC's surface water monitoring network provides many benefits for those who live and work in the Walla Walla Basin. In addition to the most obvious, that people can know how much water is flowing in streams, the data collected by this project is used for:

- Quantifying shallow aquifer recharge
- Quantifying the downstream effects of shallow aquifer recharge
- Modeling conditions for fish passage
- Analysis of positive test results for the Pesticide Sampling Partnership project
- High-flow event monitoring and analysis
- Study of channel loss and gain
- Model the basin-wide relationships between surface and ground water

This list is not exhaustive, but the data is available for viewing, download, and to be utilized for new and exciting purposes. It will continue to be updated multiple times per year.

In order to overcome problems such as those described in the "Problem Sites" section above, the WWBWC will be increasing the number of site visits in order to maintain flow conditions at some of the most unstable monitoring locations. This will help to ensure data from sites like S-410 on Johnson Creek, which have detrimental impacts from things like seasonal vegetation growth, is affected as little as possible.

As mentioned in the New Project Features section of the introduction, the WWBWC's surface water monitoring network will continue to grow and expand to support additional recharge efforts and to provide data at flow points of interest throughout the valley, with the data from all sites available for viewing and download at wwbwc.org.

Acknowledgements

Without the support of the Walla Walla Basin Watershed Council's partner agencies, this project would not be possible. Their involvement and support is appreciated.

Hudson Bay District Improvement Company
Oregon Water Resources Department
Oregon Watershed Enhancement Board
U.S. Fish & Wildlife Service
U.S. Forest Service
Walla Walla River Irrigation District
Washington Department of Ecology

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Appendix A: Rating Gauges

The WWBWC uses the following procedure for rating most of its sites[10]:

Steps for WWBWC *Simple, stable channel,* Low-medium flow range discharge ratings and data processing:

1. Create Database with site name, year, and "rate" in file name title
2. Input raw stage data from year(s) as workbooks inside the spreadsheet
3. Input field notes
4. Input Rating MMTS:
    a. Specifically: Date, Time, Q mmts, x-sectional area, average velocity and average depth, widths, who collected data,
    b. Input corresponding recorder stage for rating measurements in rating mmt table
    c. Check recorder stage versus staff stage
    d. Check for time shift (daylight savings)
    e. Graph MMTS: look for low-medium range flow best-fit regression(s)
5. Plot raw stage data, note shifts (positive or negative, value: using just before and after offset values)
6. Adjust stage with shifts
7. Plot adjusted stage (check graphically)
8. Determine regression and solution for low flow data (best least squares fit regression)
    a. Use equation and adjusted stage, check against measured Q values
9. Determine regression and solution for medium flow data (best least-squares fit regression)
    a. Use equation and adjusted stage, check against measured Q values
10. Determine adjustment between low-medium range regressions (adjust)
11. Determine regression and solution for flow data (extrapolated above highest mmt) (best least-squares fit regression)
12. Rank data quality (See Appendix B)
    a. Good (least squares and compared MMT Q shows strong correlation)
    b. Fair (shows correlation)
    c. Poor (shows weak correlation)
13. Insert Analysis notes worksheet, provide analysis synopsis and rank data
14. Create final data set and separate excel file. Include only data and contact information.

[10] ***DISCHARGE RATINGS AT GAGING STATIONS***. Chapter A10 of USGS Report: "Techniques of Water-Resources Investigations of the United States Geological Survey." By E. J. Kennedy, Book 3 (Applications of Hydraulics)

However, some sites in the WWBWC's network are rated differently. Weirs, for example, can be rated much more exactly using the equations listed below:

Weir equation
Q = 3.33Lh^1.5
Submerged weir correction eqation
Q/Qs = [1-(h2/h1)^n]^3.85
Q - free unsubmerged weir discharge
Qs - submerged discharge
h1 - upstream head
h2 - downstream head
n - coefficient (1.5 for suppressed rectangular) [11]

Flumes, used in many of the WWRID monitoring sites, can also use a different equation to derive flows from water heights, such as the following:

Q = K1*(H1+K2)^u

Where Q is the discharge, h1 is the upstream sill-referenced head, and K1, K2, and U are all constants defined by the flume.

[11] Although the equation for submerged weir correction is included, the WWBWC endeavors to keep all of its weirs from becoming submerged. None of the flow data for 2009 was generated using the submerged weir correction equation.

Appendix B: Rating Grades

The WWBWC began awarding grades to flow data in 2008. After starting out with a letter grade (A–D) grading system, we abandoned it in 2009 in favor of a grade 1–grade 4 system. Although the two systems are practically identical, it was felt that the numerical grading system does less to suggest a gauge station is not living up to its full potential. In a location where there is much seasonal vegetation growth, for example, the potential of the gauge station installed there might be to produce grade 3 data. Awarding a "C" grade to such a site implies that that site could have done better when, short of installing an engineered concrete structure and maintaining it for weeds and debris all year long, it could not do any better.

In 2008 there was also an attempt to apply mathematical constraints on the grades given to ratings based on how close the curve came to touching the actual measured points. This ended up not being very useful because sometimes a site would end up with a high grade even though conditions at the site were poor and something could have been wrong with the data (like a gap in the collected data, or outlying high flows that couldn't be substantiated) so this was abandoned as well. As much as it seems improper to base these grades on intuition and feelings, that is essentially what the WWBWC has done. The grade system is 1—4, with 1 being equal in quality to data from a USGS or WDFW gauge station, and grade 4 being a little bit better than data that only tells whether a site was flowing or dry. Grade 2 and grade 3 fall in between those. The grade is assigned at the end of the process, after the output flow has been graphed and is meant only as a guide to give the user of the data an idea of how much they can trust the data. Included with each site's data, though, are notes which state the reasons for the data's grade. If seasonal vegetation growth was problematic at the site, or if a logger malfunctioned, it is in the notes bundled with the data.

WWBWC Surface Flow Grade system (current):

1 – reliable flow data. Site likely equipped with a flume or weir or some other measuring device. No problems with logger or site's flow conditions.

2 – reliable flow data. Site may have experienced problems with logger or with flow conditions (changing channel, seasonal vegetation, etc.), but problems are minor.

3 – flow data less reliable. Site experienced more than one problem which could have affected the flow data. Better than wet/dry data, but not very accurate (usually due to canary grass, or other changing site conditions).

4 – flow data not very reliable. Data from a grade 4 site should not be relied on for too much more than wet/dry, or for relative flows over a short time period (usually canary grass and other plants are the cause of this).

5 – complete site failure. Data loss (logger malfunction or loss), or such drastic changes to the site that the logger ceases to even record wet/dry conditions.

Significant gaps in the data may also lower the grade of a site's data.

Appendix C: Surface Site Locations

Maps in Appendix G

Site Name	Stream/Spring Name	East	North	Elevation M
103	South Fork Bridge	398611.42	5083319.45	417.2712
104	North Fork Bridge	399370.9	5083810.12	429.4632
105	Grove School Br (M1a)	393438.004	5086234.287	334.202
106	Nursery Bridge (M4)	392614.098	5089124.466	295.684
107	Tum-A-Lum Bridge (M8)	393379.143	5092358.706	258.833
202	Frog Crockett	391966.541	5088893.205	301.327
203	Frog Ford	391964.518	5088893.761	301.581
205	Ford Ditch (C)	391951.326	5088894.137	301.265
206	Crockett Ditch (F)	391376.554	5089738.579	289.843
207	Crockett Ditch (A)	391768.775	5090011.766	288.282
208	Ford Ditch (H)	391791.236	5090036.505	288.008
209	Ford Ditch (MM)	390953.661	5090789.966	275.951
210	Crockett Ditch (B)	390917.692	5090787.295	276.007
211	Crockett End (I)	392039.328	5091564.326	271.057
212	Crockett Appleton (KK)	391547.979	5091982.015	264.104
213	Ford End (LW)	390709.601	5091673.508	265.299
214	West LWW (WP2)	390378.735	5091813.259	262.498
215	West LWW (WP)	390209.021	5092174.434	259.15
216	Downing Spring (DS)	390655.662	5092581.588	253.655
217	Ferndale Spring (SE)	391258.105	5092614.479	255.958
218	Big Spring @ Ballou (BS)	391550.822	5092807.999	255.024
219	Big Spring @ Yates (BSM1)	391581.087	5093667.729	244.931
220	East LWW @ stateline	391870.217	5094063.686	241.877
221	Walsh/Lewis Stateline (SLP)	390958.38	5095101.22	232.8672
222	West Prong Stateline (SWP)	389707.303	5095126.496	227.447
223	East LWW Big Spr Conf. (SBS)	388955.338	5095057.412	223.971
224	West LWW (WP3)	388416.901	5096389.529	211.044
225	McEvoy Spring (SMS)	390123.736	5096740.998	215.997
226	East LWW near mouth (SE2)	390740.26	5097038.44	214.5792
227	West LWW near mouth (WP4)	386102.18	5098925.316	184.757
228	Ford, Appleton&Winesap (FD)	390502.228	5091569.543	265.319
301	Fruitvale ditch (FV)	389167.605	5092165.968	253.689
302	Crystal Spring Pond (CP)	389351.455	5092436.239	249.408
303	Mud Creek Stateline (SMC2)	386764.8	5095185.27	212.1408
304	Mud Creek McDonald (MC3)	379670.65	5098398.568	158.871
305	Mud Creek Barney (MC4)	375056.723	5099997.266	140.835
401	White Ditch Bridge (WDB) SAR	388758.267	5090009.825	264.494

Site Name	Stream/Spring Name	East	North	Elevation M
402	HBDIC Recharge Inflow	388515.847	5090245.689	261.58
403	HBDIC Recharge Outflow	388347.557	5090354.229	259.248
404	Dugger Creek headw (DC1)	386889.25	5090918.98	241.4016
405	Little Mud Creek (MC)	387635.84	5092038.733	241.452
406	Johnson Spring (SJ)	386899.386	5091235.063	238.642
407	Dugger @ White split (DC2)	385903.342	5090873.007	229.578
408	Johnson Creek (JH)	385332.785	5092105.096	220.147
409	HBDIC Overflow on Grabner	384852.315	5092354.698	214.199
410	Johnson Pipe (JG)	384442.426	5092321.672	210.603
411	Swartz Creek (SC)	380132.786	5094092.534	170.421
412	White Ditch (WDDS)	380112.181	5094146.066	170.902
503	Titus Creek (TC1)	401403.771	5103565.739	355.738
505	Caldwell Creek Pond (SCD)	399121.785	5100252.294	303.998
506	Bryant Spring Creek (BS)	397399.428	5103389.687	304.246
507	College Creek (CC)	397431.91	5102826.123	303.311
508	Butcher Creek (BC)	397904.865	5101961.318	306.366
509	Lassiter Spring (LS)	395802.641	5097092.873	262.547
510	Stone Creek (SC)	394926.779	5099586.013	260.623
511	Doan Creek (SCK)	391558.34	5100401.54	230.116
513	Yellowhawk Creek (YHK)	391968.112	5088876.244	300.996

Appendix D: Missing Data

WWBWC Surface Flow Data Gaps 2010 - 2011

103 South Fork Bridge – seasonal gauge, removed during high flows

104 North Fork Bridge – seasonal gauge, removed during high flows

105 Grove School Bridge – n/a

106 Nursery Bridge – Solar panel vandalized in summer of 2010, battery went dead. Vandalized again in 2011, but data loss was much less significant (~2 weeks)

107 Tum-A-Lum Bridge – n/a

202 Frog Crockett – gauge installed in Feb 2011

203 Frog Ford – gauge installed in Feb 2011

205 Ford Ditch (C) – n/a

206 Crockett Ditch (F) – n/a

207 Crockett Ditch (A) – n/a

208 Ford Ditch (H) – n/a

209 Ford Ditch (MM) – n/a

210 Crockett Ditch (B) – n/a

211 Crockett End (I) – n/a

212 Crockett Appleton (KK) – Data loss from logger due to operator error (March – June 2010)

228 Ford, Appleton&Winesap (FD) – Flume dislodged during high flows, logger disturbed and data affected (March – June 2010)

213 Ford End (LW) – n/a

214 West LWW (WP2) – Logger failure (Sep 2010 – Feb 2011)

215 West LWW (WP) – Logger failed to start (Feb – Aug 2011)

216 Downing Spring (DS) – n/a

217 Ferndale Spring (SE) – n/a

218 Big Spring @ Ballou (BS) – n/a

219 Big Spring @ Yates (BSM1) – n/a

220 East LWW @ stateline – Logger needed replacing, missed one week in Feb 2011

221 Walsh/Lewis Stateline (SLP) – n/a

222 West Prong Stateline (SWP) – n/a

223 East LWW Big Spr Conf. (SBS) – n/a

224 West LWW (WP3) – n/a

225 McEvoy Spring (SMS) – n/a

226 East LWW near mouth (SE2) – n/a (Logger moved in late summer of 2011, installed in new location that has not been rated yet. No data loss, but data since the move is not reported).

227 West LWW near mouth (WP4) – n/a

301 Fruitvale ditch (FV) – Some data missing from summer of 2010 (logger dislodged by cow)

302 Crystal Spring Pond (CP) – two weeks in Feb 2011 missing (logger replaced)

303 Mud Creek Stateline (SMC2) – n/a

304 Mud Creek McDonald (MC3) – Much of 2010 data lost due to county road crew re-installing culvert. They said they threw the logger away. Re-installed once construction was finished

305 Mud Creek Barney (MC4) – n/a

401 White Ditch Bridge (WDB) SAR – Aug 10 – Feb 11 missing; logger failed to start (possible operator error)

402 HBDIC Recharge Inflow – n/a

403 HBDIC Recharge Outflow – n/a

404 Dugger Creek Spring (DC1) – Logger failure in early 2011. Logger replaced summer 2011, site has changed and needs more measurements to rate

405 Little Mud Creek (MC) – Summer of 2011 data no good because landowner dredged pond (and in the process, diverted flows away from the logger)

406 Johnson Spring (SJ) – n/a, pond stage only

407 Dugger @ White split (DC2) – n/a

408 Johnson Creek (JH) – n/a

409 HBDIC Overflow on Grabner – n/a

410 Johnson Pipe (JG) – n/a

411 Swartz Creek (SC) – n/a

413 White Ditch (WDDS) – n/a

503 Titus Creek (TC1) – n/a

505 Caldwell Creek Pond (SCD) – n/a

506 Bryant Spring Creek (BS) – Dec 2010 – Feb 2011, logger battery died

507 College Creek (CC) – Sep 2010 – Feb 2011, logger malfunction (data cannot be downloaded)

508 Butcher Creek (BC) – n/a

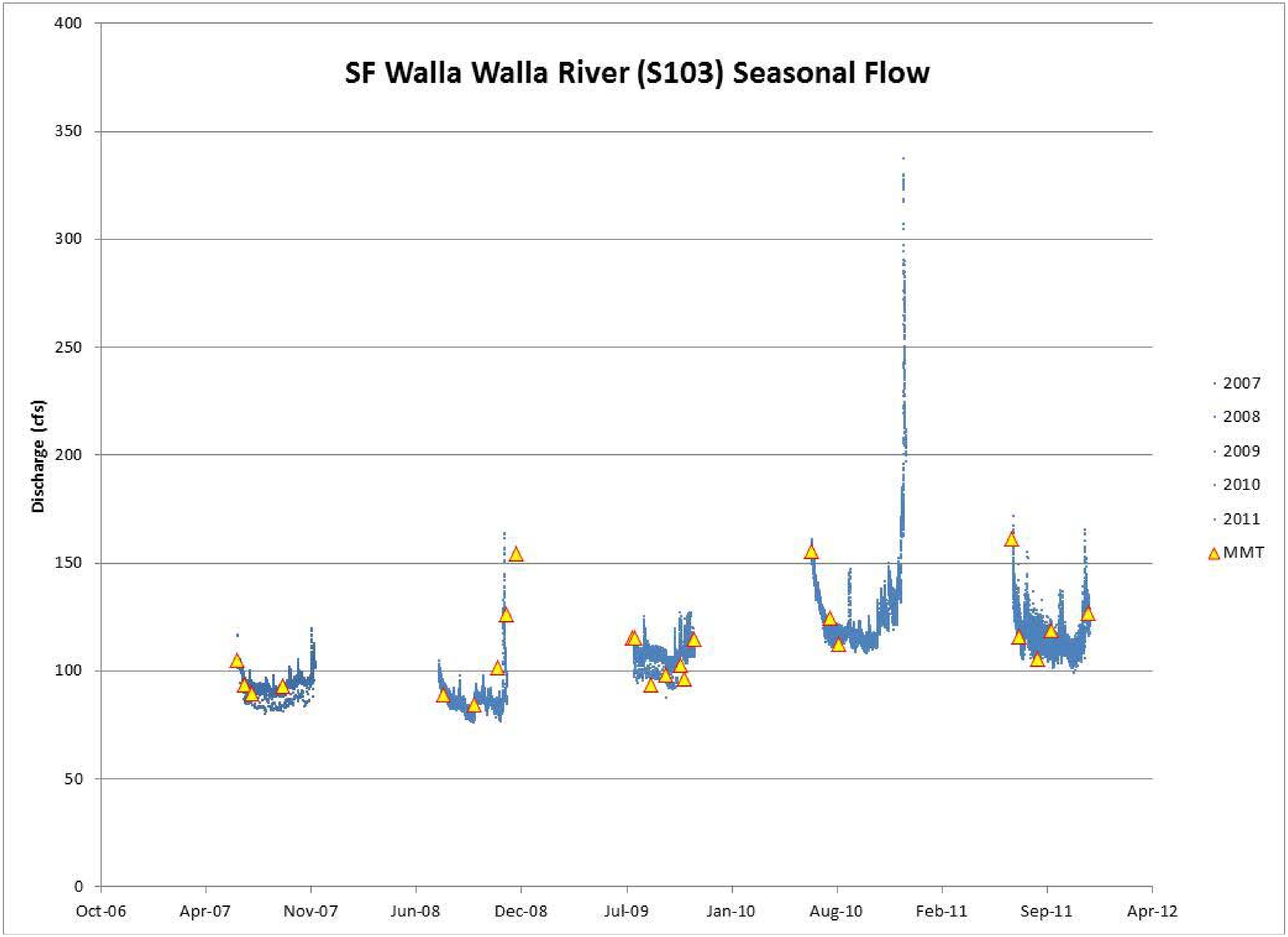
509 Lassiter Spring (LS) – Dec 2010 – Feb 2011, logger did not start.

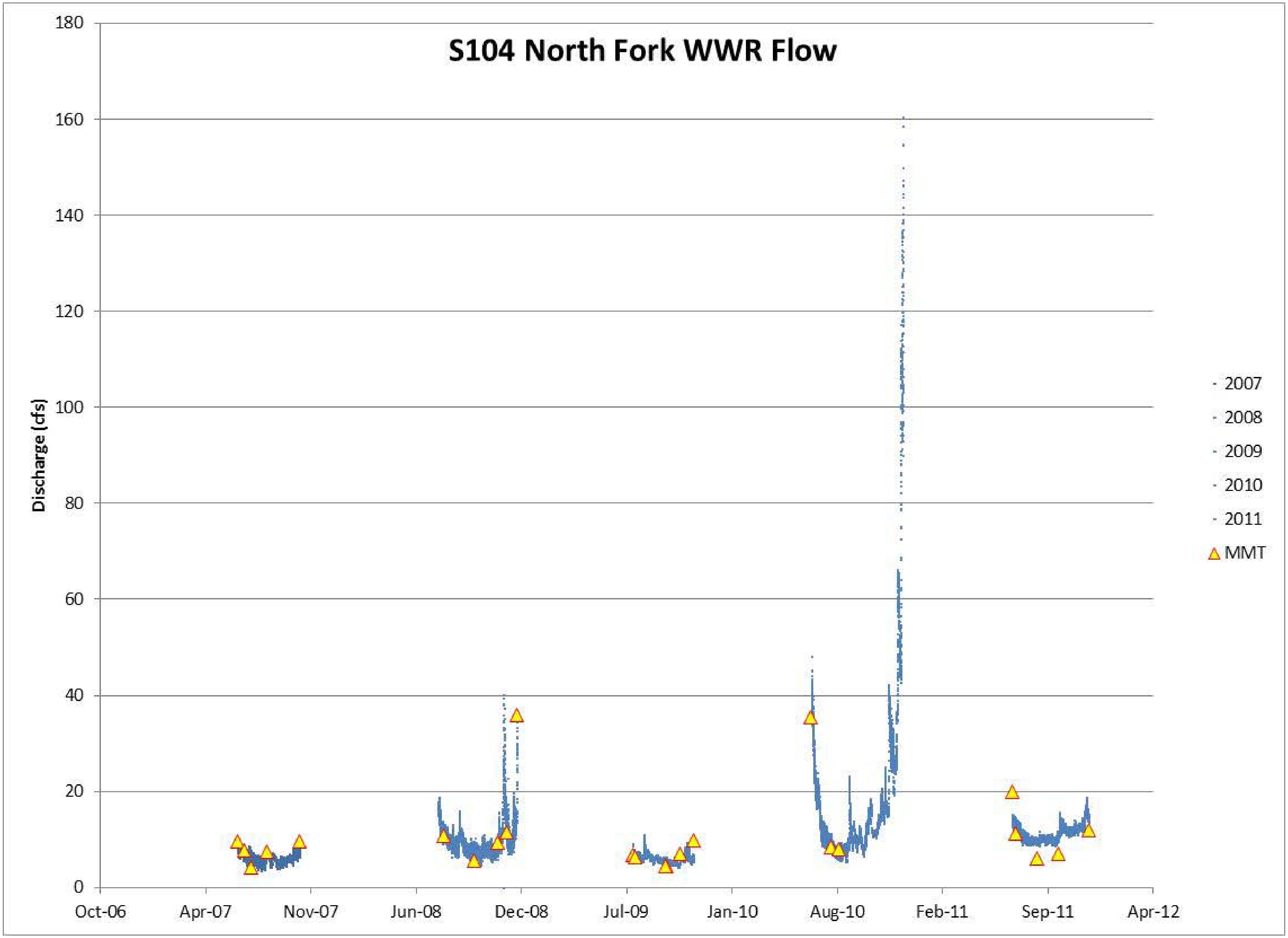
510 Stone Creek (SC) – Logger recorded bad data for much of 2011. Nonsensical data (damaged circuit)

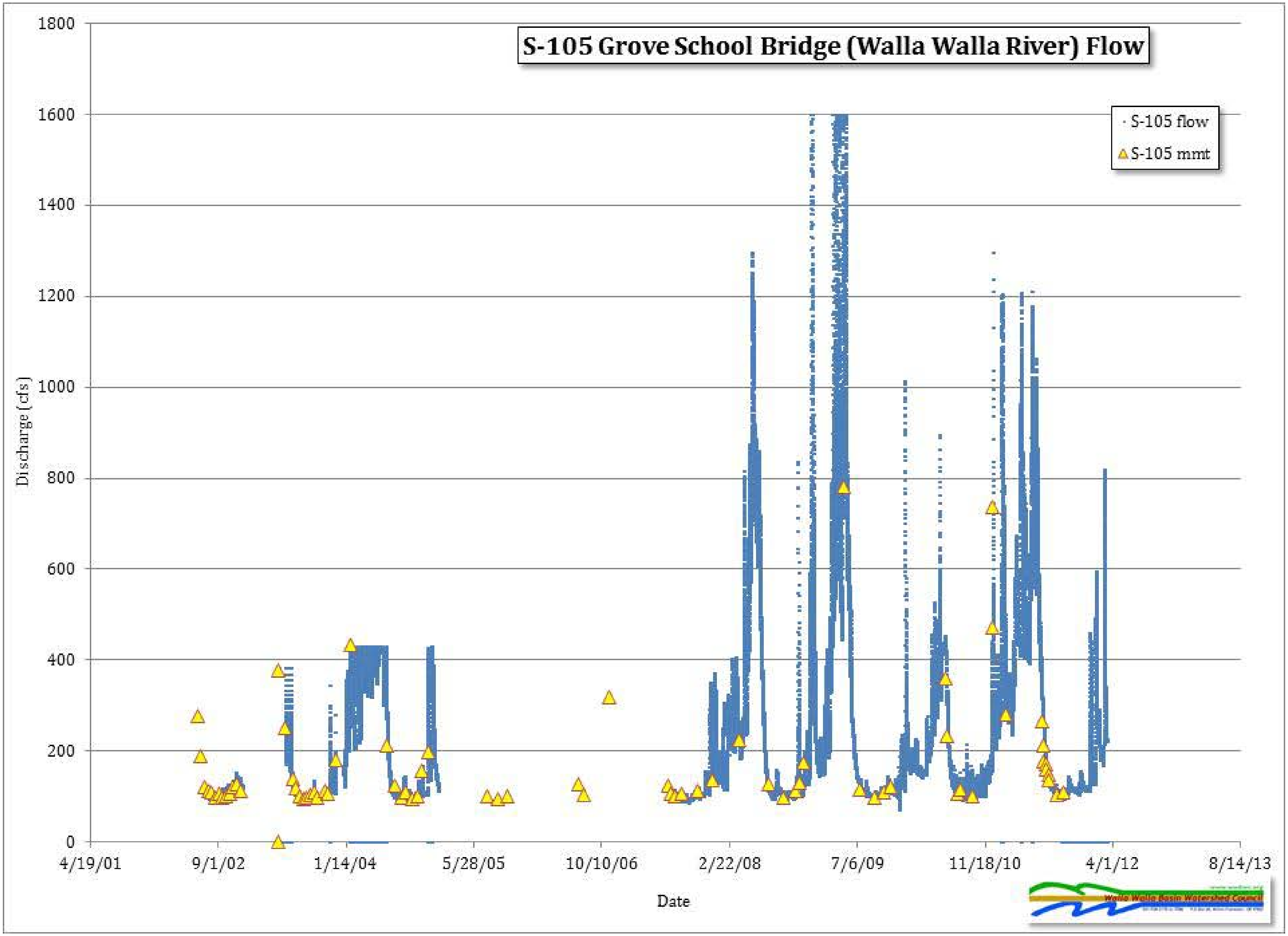
511 Doan Creek (SCK) – Logger died, Dec 2010 – Feb 2011

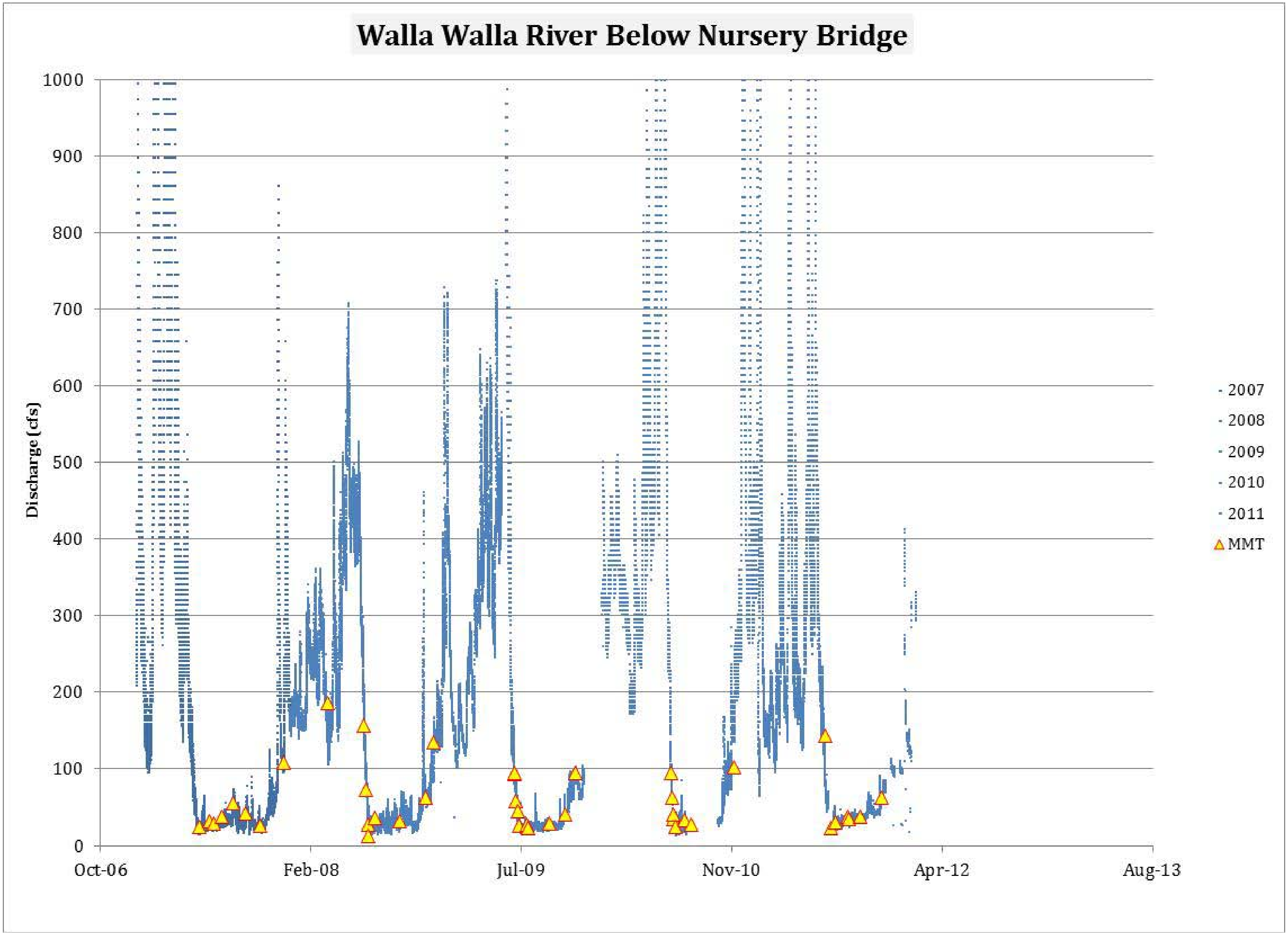
513 Yellowhawk Creek (YHK) – n/a (data from the latter part of 2011 withheld until more measurements can be taken)

Appendix E: Surface Flow Monitoring Hydrographs

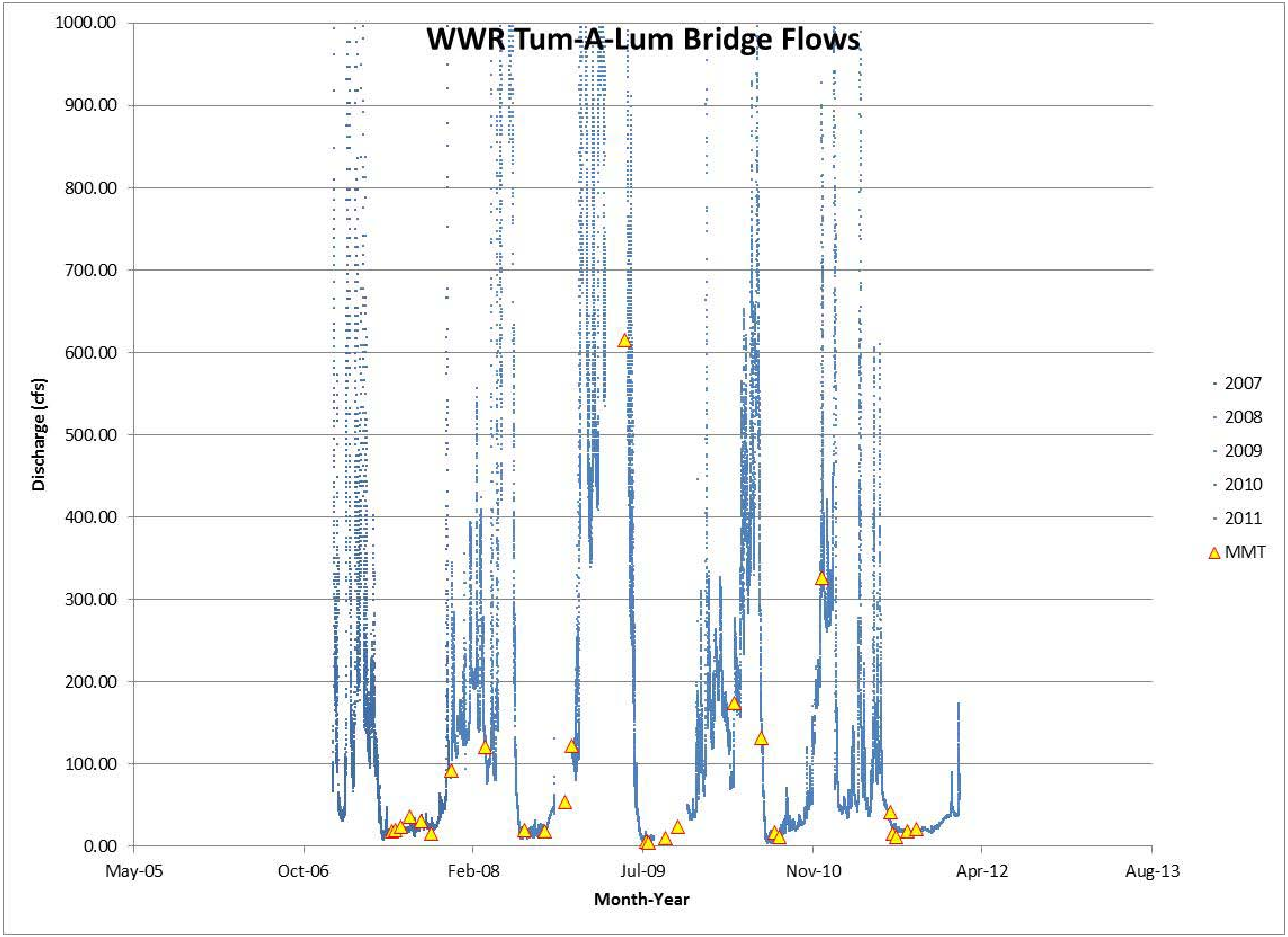


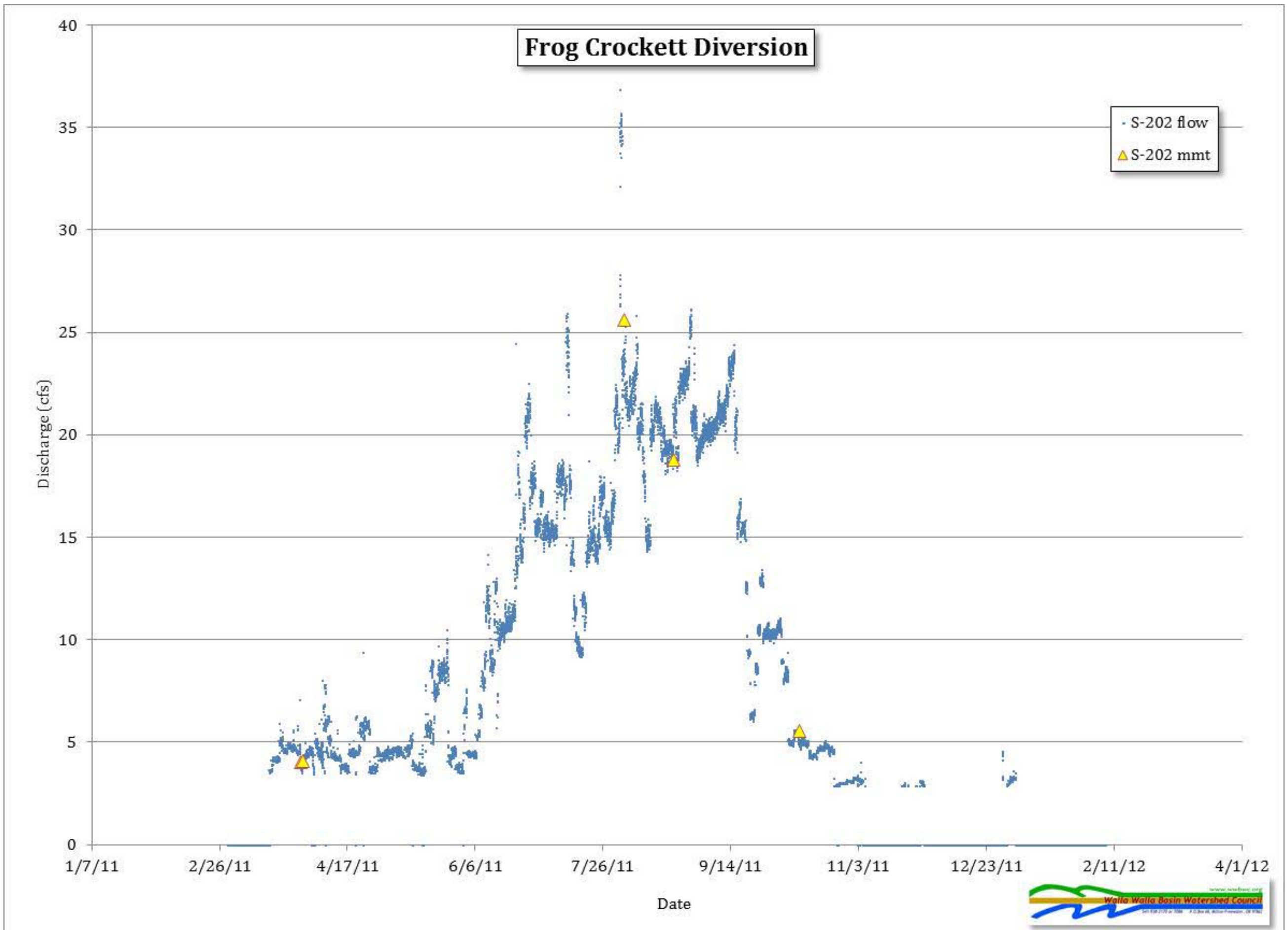

S104 North Fork WWR Flow
Discharge (cfs)
180
160
140
120
100
80
60
40
20
0
Oct-06
Apr-07
Nov-07
Jun-08
Dec-08
Jul-09
Jan-10
Aug-10
Feb-11
Sep-11
Apr-12
2007
2008
2009
2010
2011
MMT

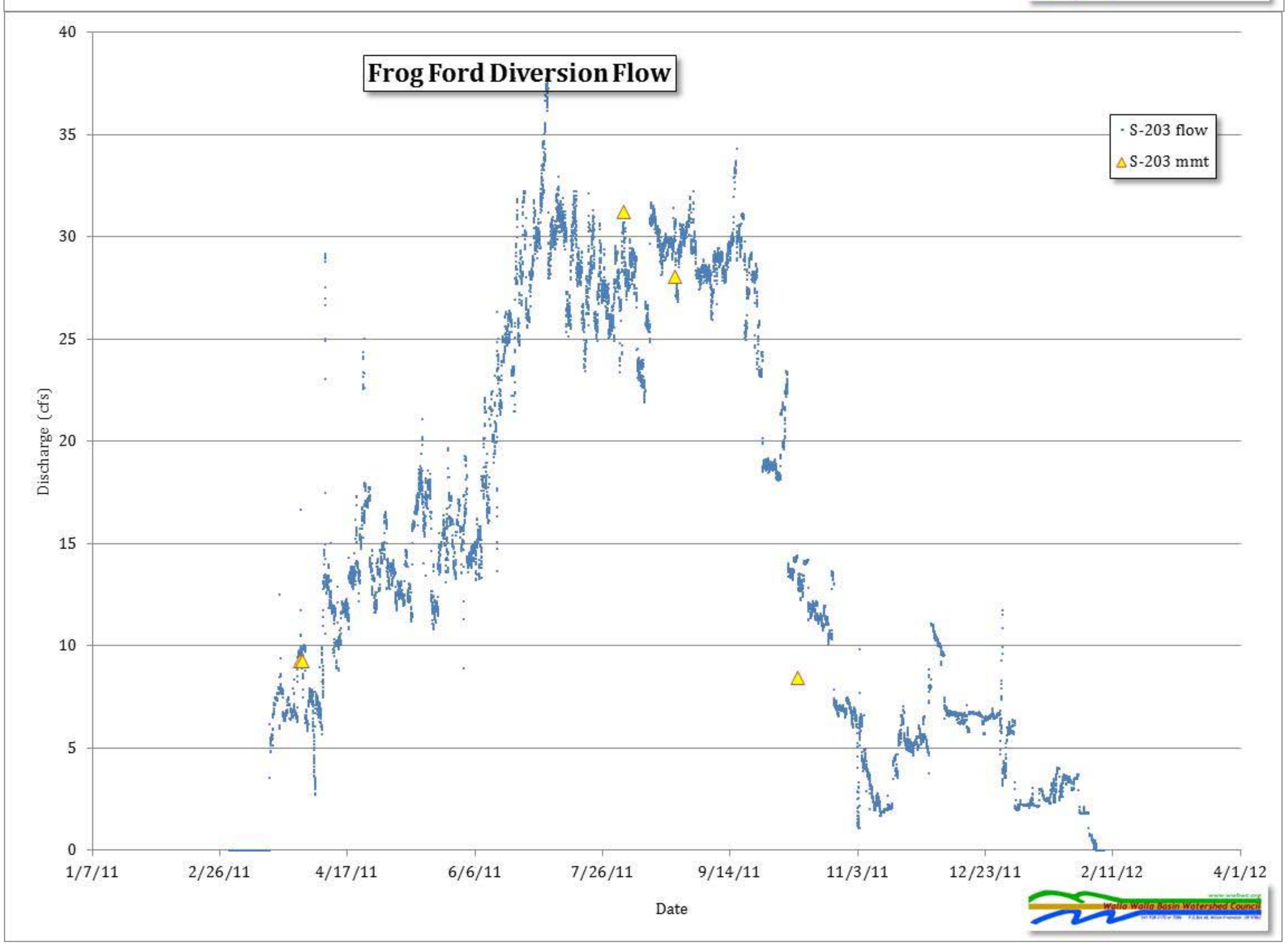

S-105 Grove School Bridge (Walla Walla River) Flow
S-105 flow
S-105 mmt
Discharge (cfs)
Date
1800
1600
1400
1200
1000
800
600
400
200
0
4/19/01
9/1/02
1/14/04
5/28/05
10/10/06
2/22/08
7/6/09
11/18/10
4/1/12
8/14/13
Walla Walla Basin Watershed Council

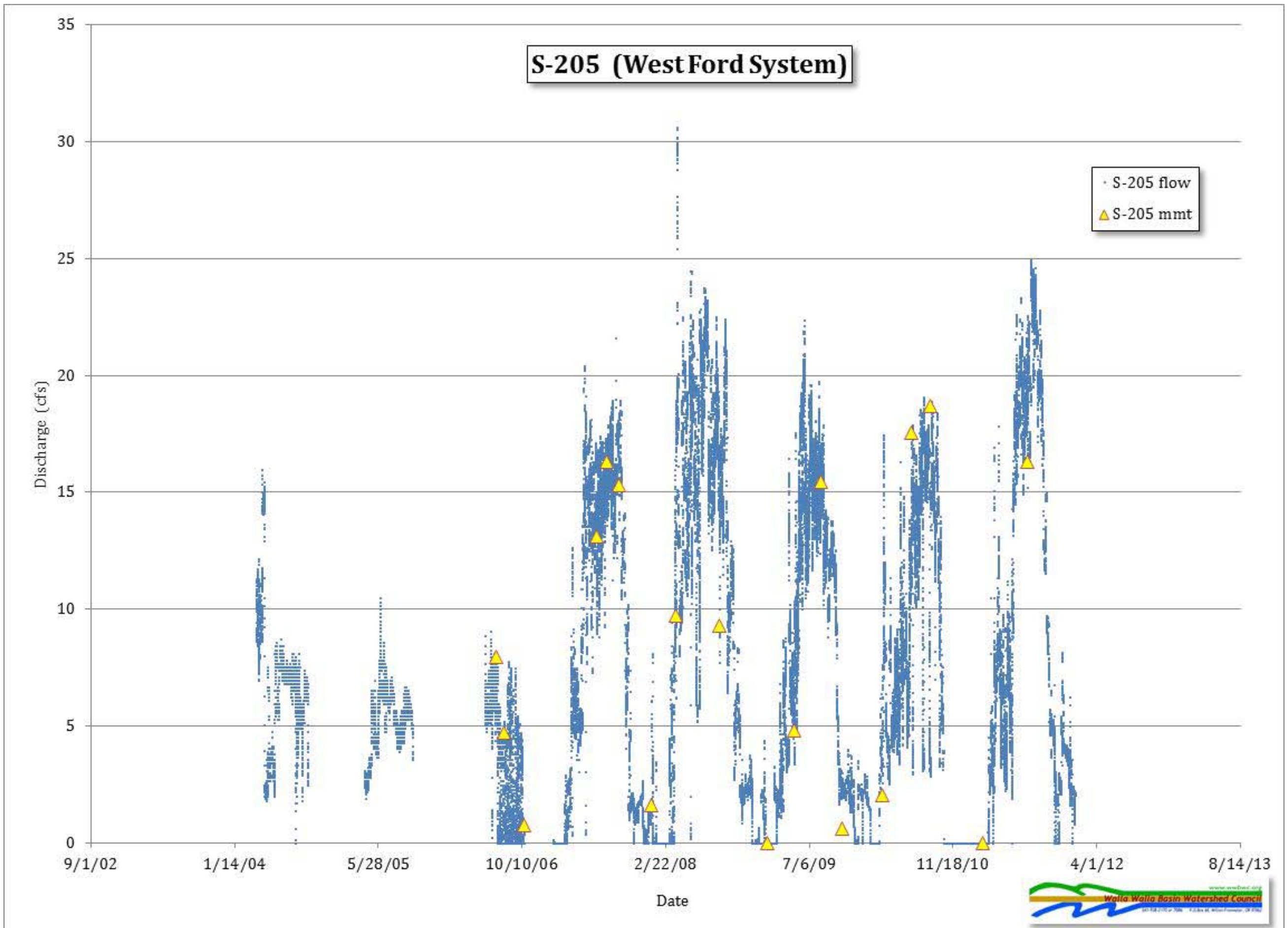


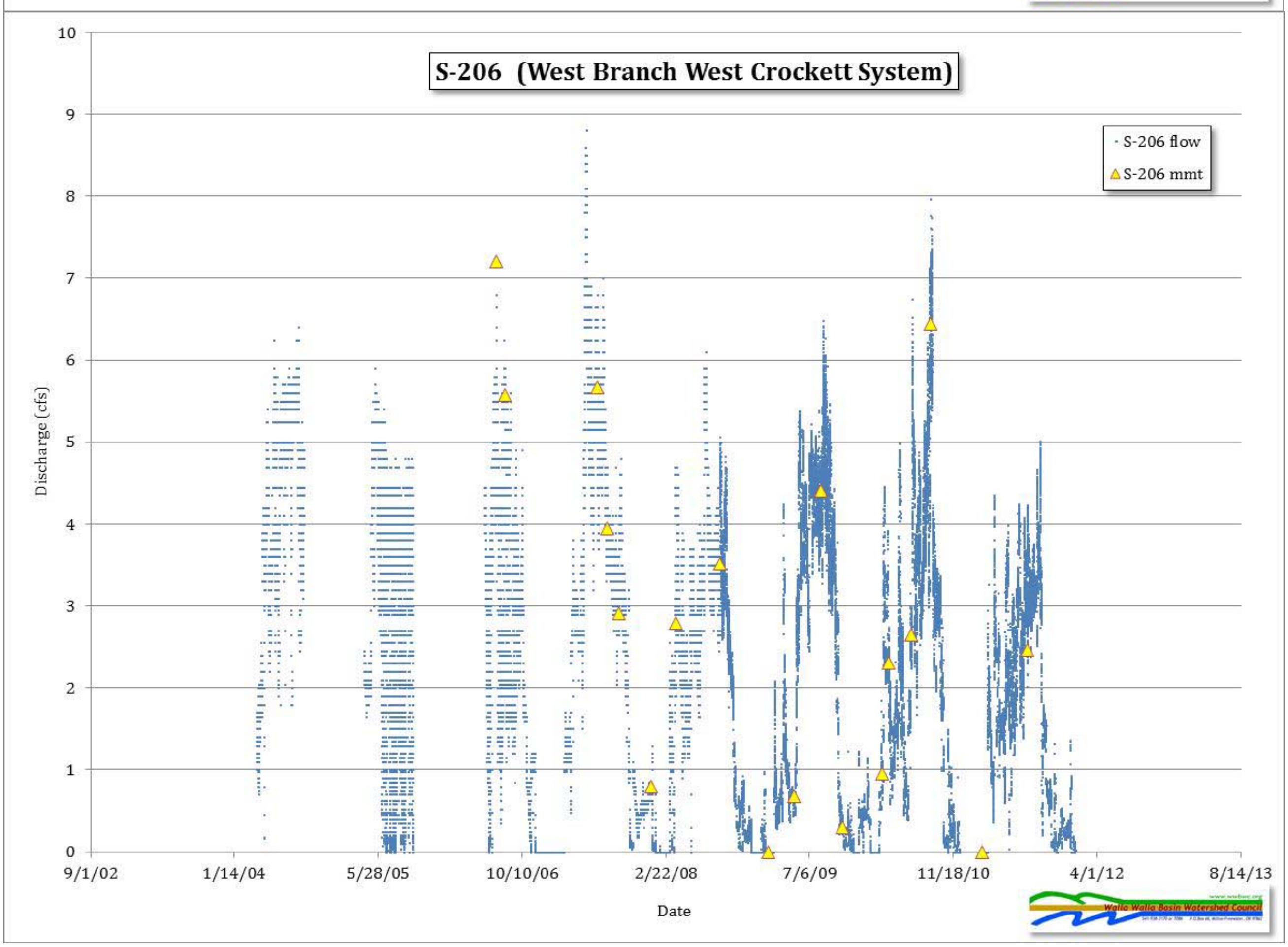
Walla Walla River Below Nursery Bridge
Discharge (cfs)
1000
900
800
700
600
500
400
300
200
100
0
Oct-06
Feb-08
Jul-09
Nov-10
Apr-12
Aug-13
2007
2008
2009
2010
2011
MMT

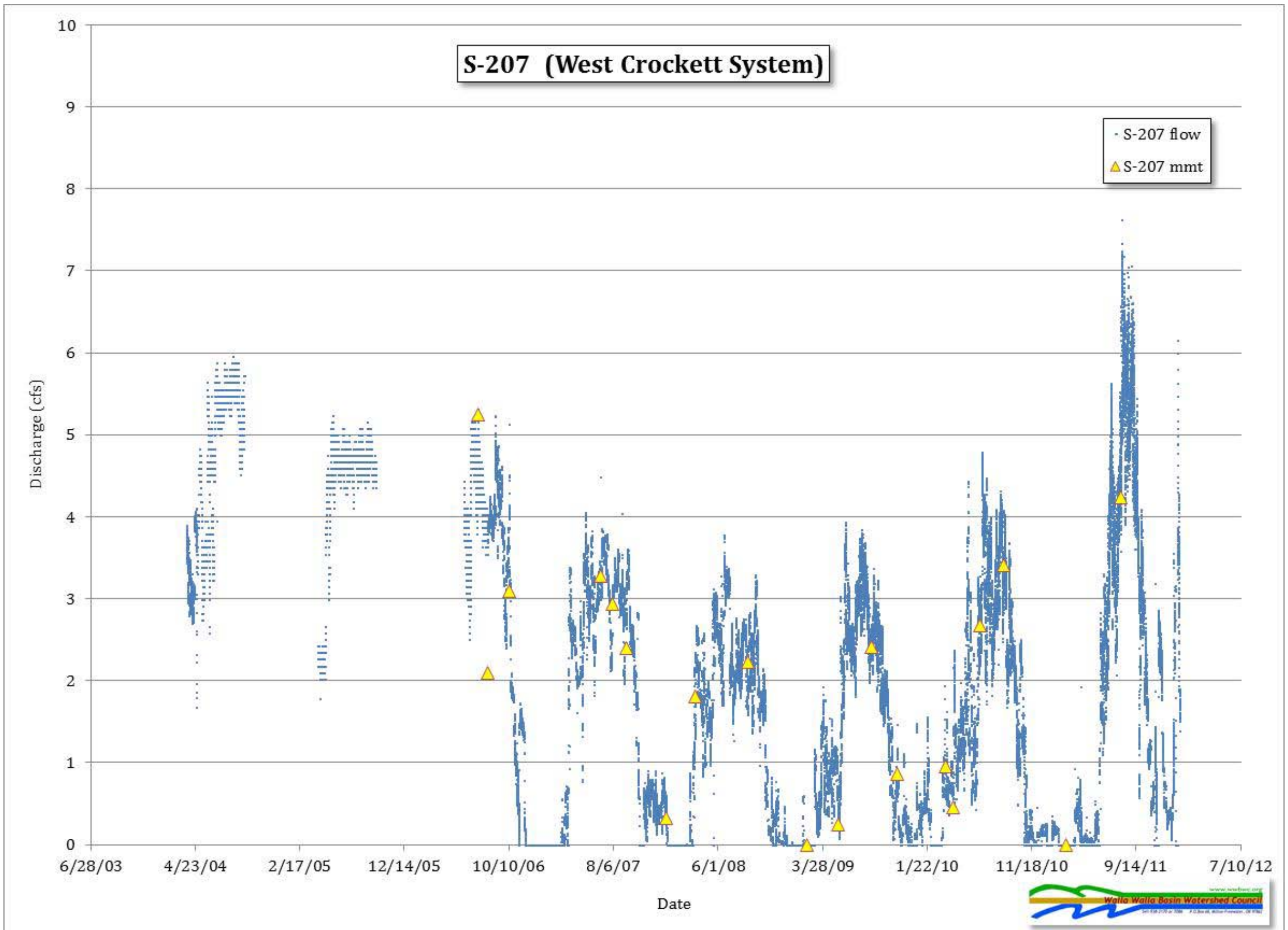

WWR Tum-A-Lum Bridge Flows
Discharge (cfs)
1000.00
900.00
800.00
700.00
600.00
500.00
400.00
300.00
200.00
100.00
0.00
May-05
Oct-06
Feb-08
Jul-09
Nov-10
Apr-12
Aug-13
Month-Year
2007
2008
2009
2010
2011
MMT

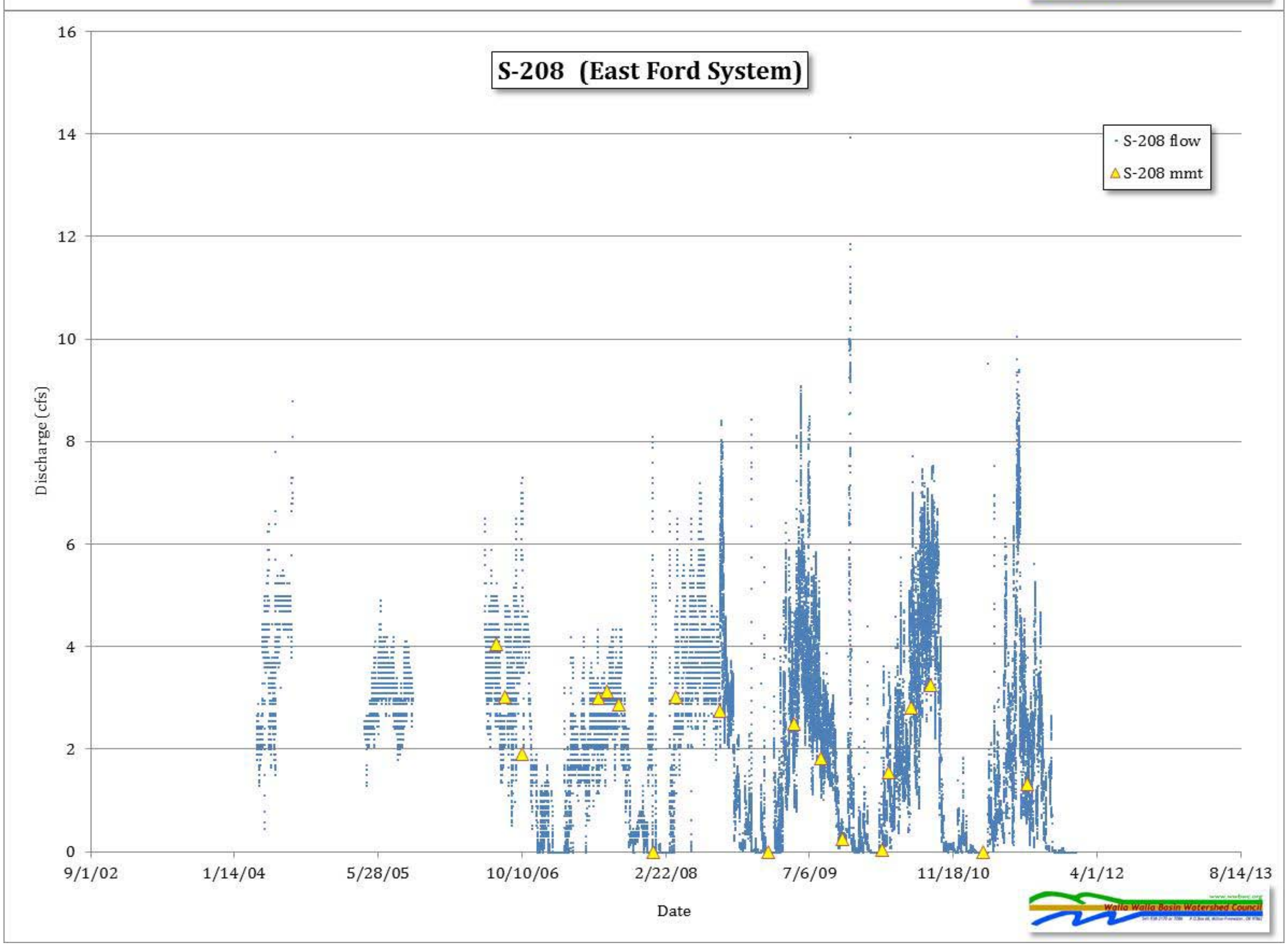

Frog Crockett Diversion
S-202 flow
S-202 mmt
Discharge (cfs)
Date
40
35
30
25
20
15
10
5
0
1/7/11
2/26/11
4/17/11
6/6/11
7/26/11
9/14/11
11/3/11
12/23/11
2/11/12
4/1/12
Walla Walla Basin Watershed Council

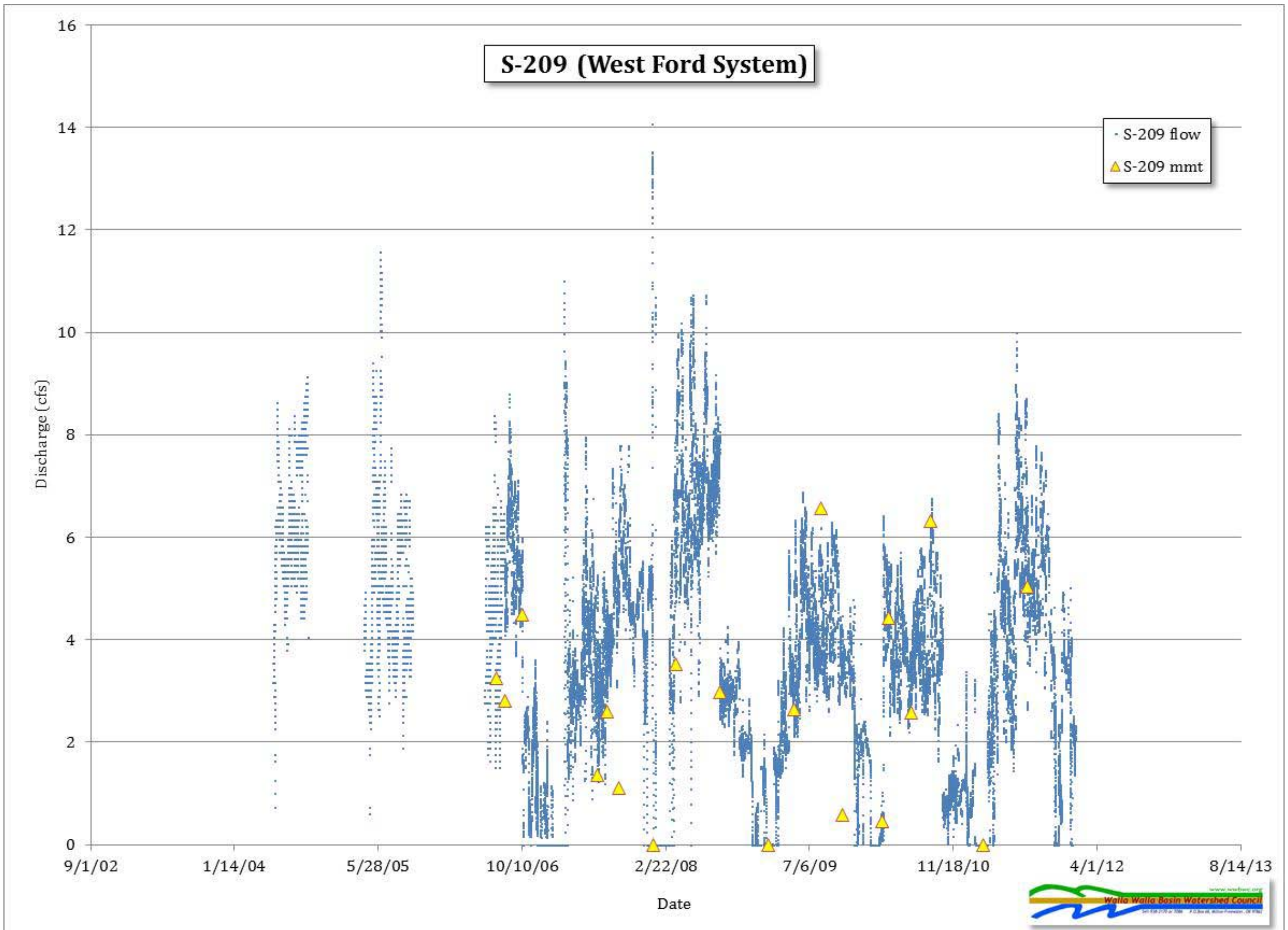

Frog Ford Diversion Flow
S-203 flow
S-203 mmt
Discharge (cfs)
Date
40
35
30
25
20
15
10
5
0
1/7/11
2/26/11
4/17/11
6/6/11
7/26/11
9/14/11
11/3/11
12/23/11
2/11/12
4/1/12
Walla Walla Basin Watershed Council

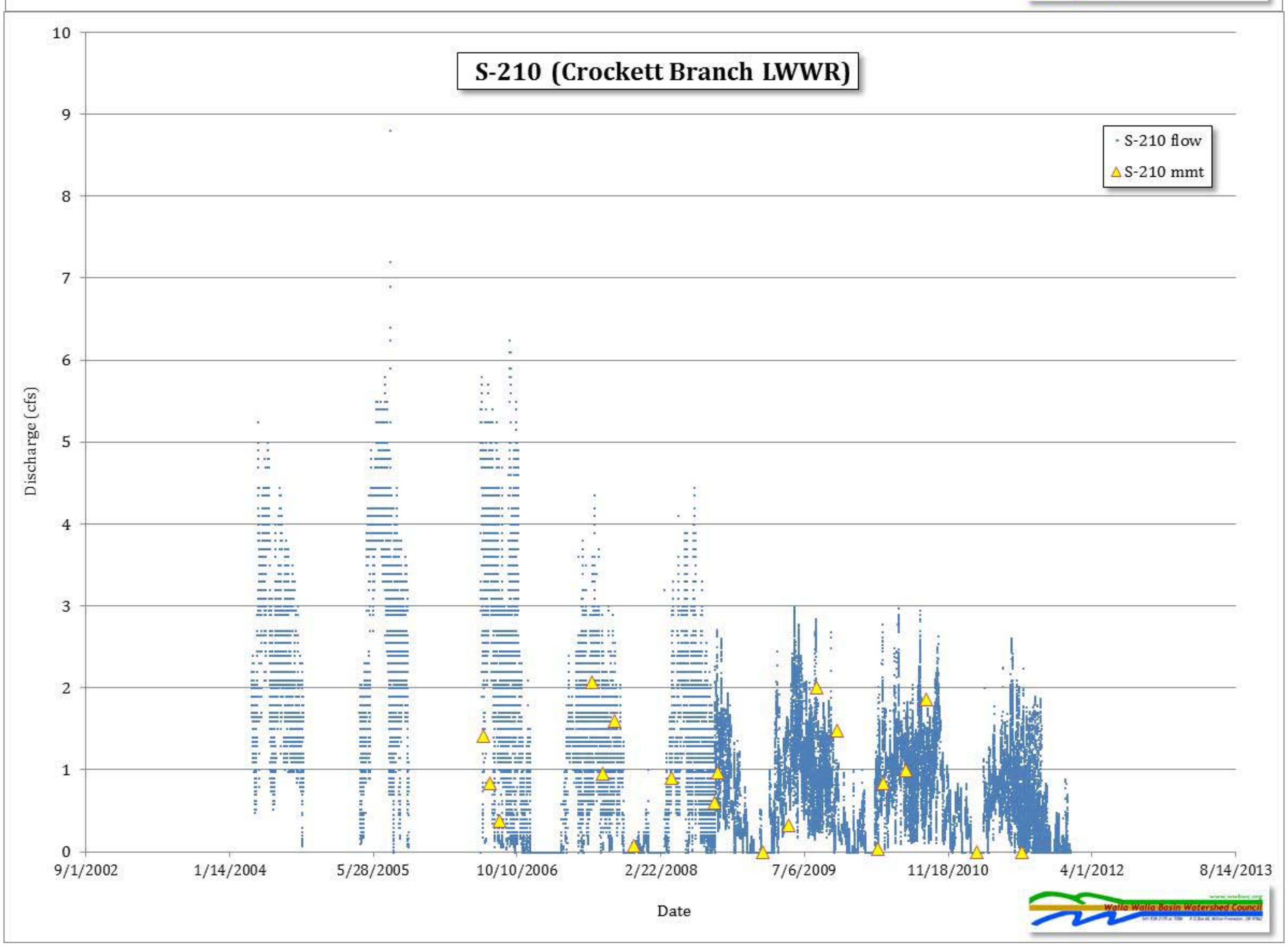

S-205 (West Ford System)
S-205 flow
S-205 mmt
Discharge (cfs)
Date
35
30
25
20
15
10
5
0
9/1/02
1/14/04
5/28/05
10/10/06
2/22/08
7/6/09
11/18/10
4/1/12
8/14/13
Walla Walla Basin Watershed Council

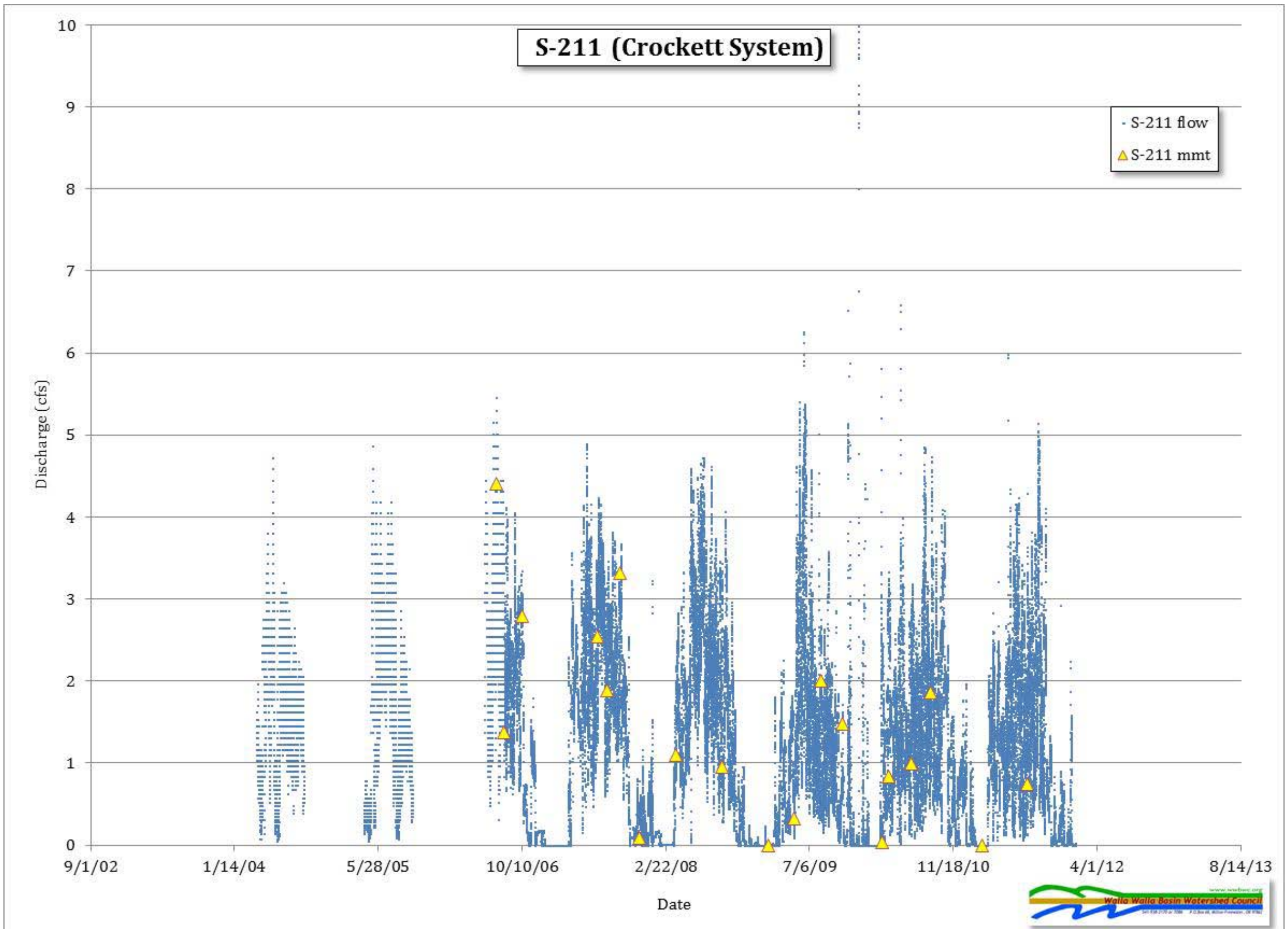

S-206 (West Branch West Crockett System)
S-206 flow
S-206 mmt
Discharge (cfs)
Date
10
9
8
7
6
5
4
3
2
1
0
9/1/02
1/14/04
5/28/05
10/10/06
2/22/08
7/6/09
11/18/10
4/1/12
8/14/13
Walla Walla Basin Watershed Council

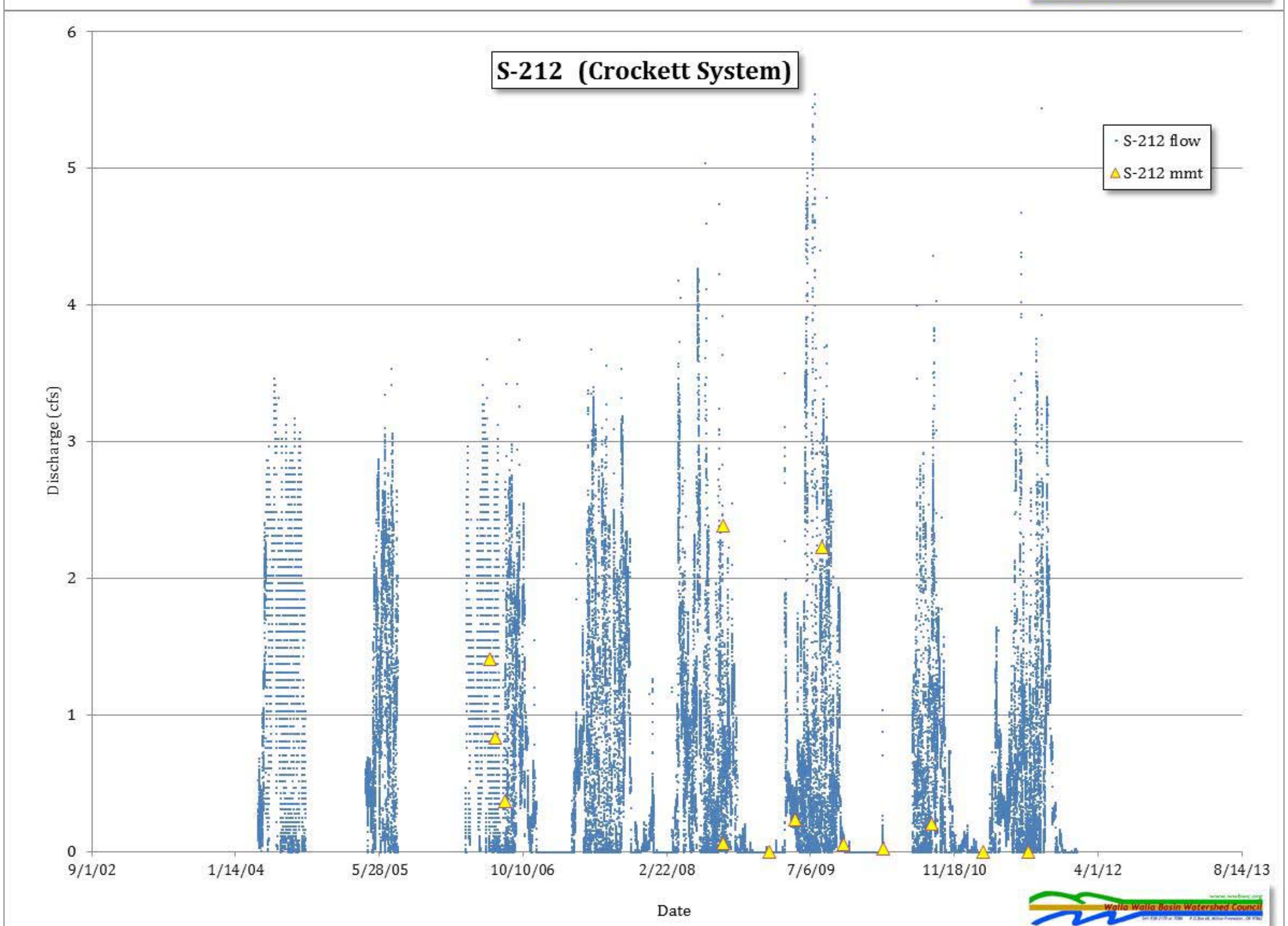

S-207 (West Crockett System)
S-207 flow
S-207 mmt
Discharge (cfs)
Date
0
1
2
3
4
5
6
7
8
9
10
6/28/03
4/23/04
2/17/05
12/14/05
10/10/06
8/6/07
6/1/08
3/28/09
1/22/10
11/18/10
9/14/11
7/10/12
Walla Walla Basin Watershed Council

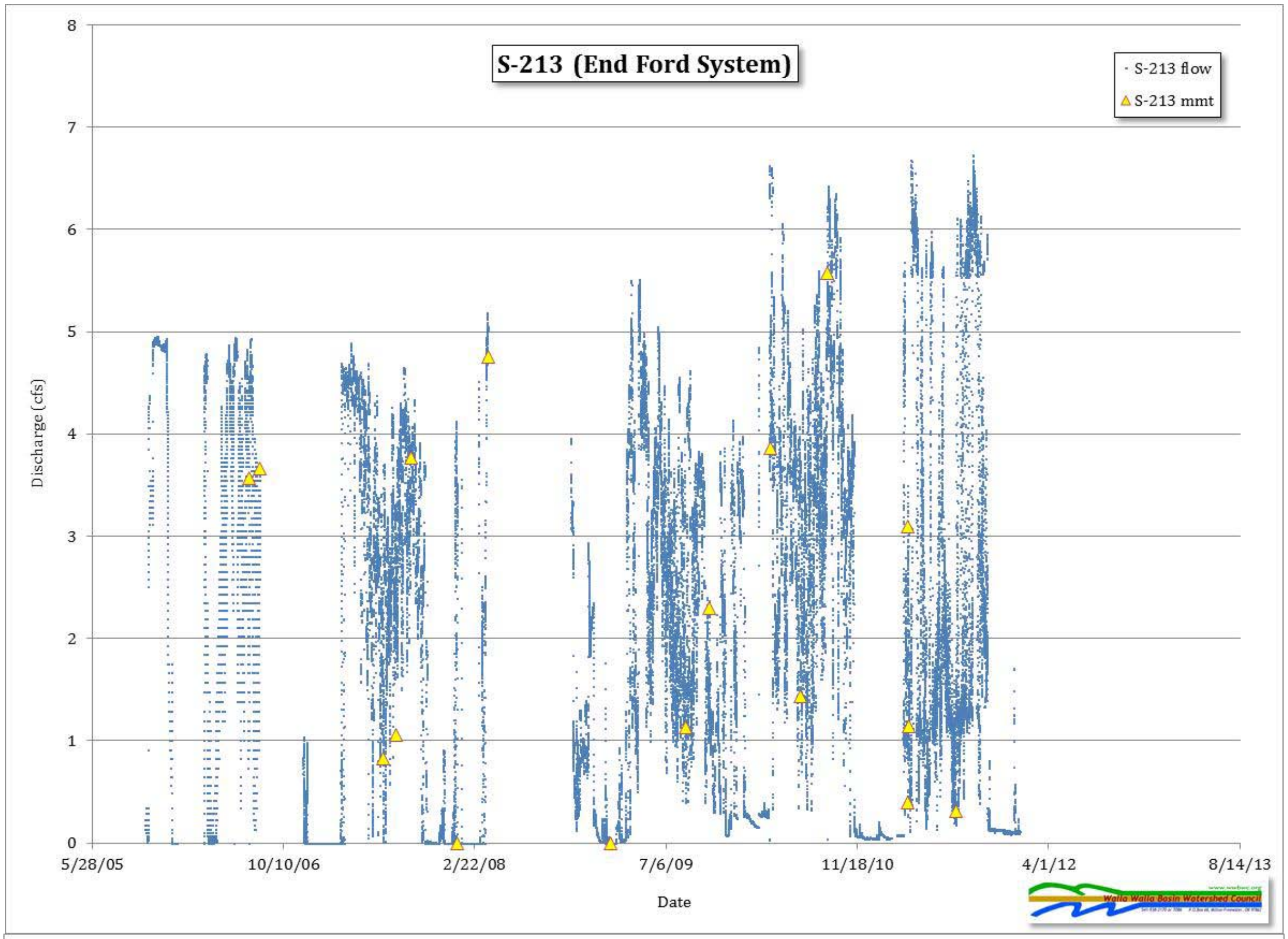

S-208 (East Ford System)
S-208 flow
S-208 mmt
Discharge (cfs)
Date
0
2
4
6
8
10
12
14
16
9/1/02
1/14/04
5/28/05
10/10/06
2/22/08
7/6/09
11/18/10
4/1/12
8/14/13
Walla Walla Basin Watershed Council

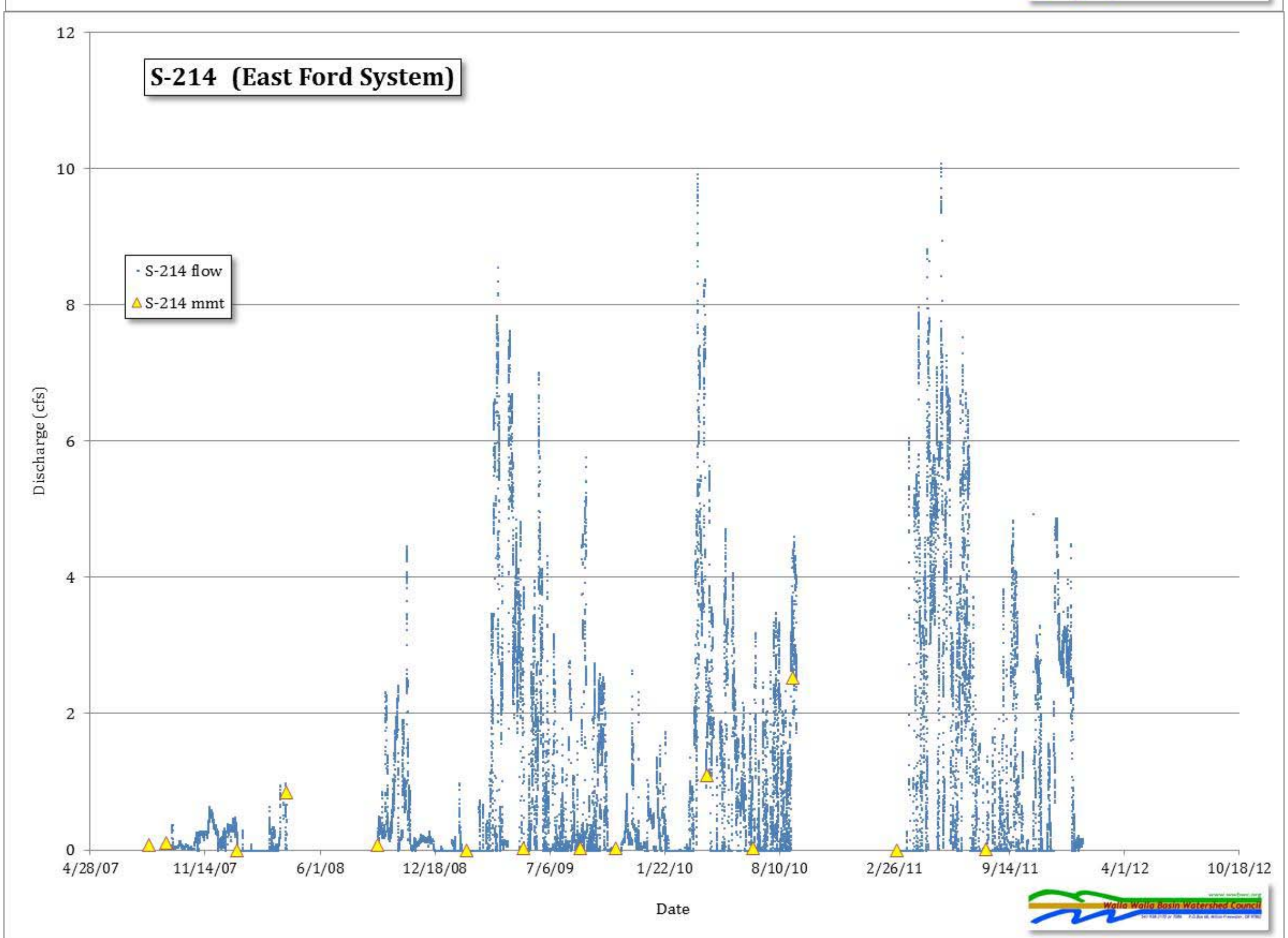

S-209 (West Ford System)
S-209 flow
S-209 mmt
Discharge (cfs)
Date
0
2
4
6
8
10
12
14
16
9/1/02
1/14/04
5/28/05
10/10/06
2/22/08
7/6/09
11/18/10
4/1/12
8/14/13
Walla Walla Basin Watershed Council

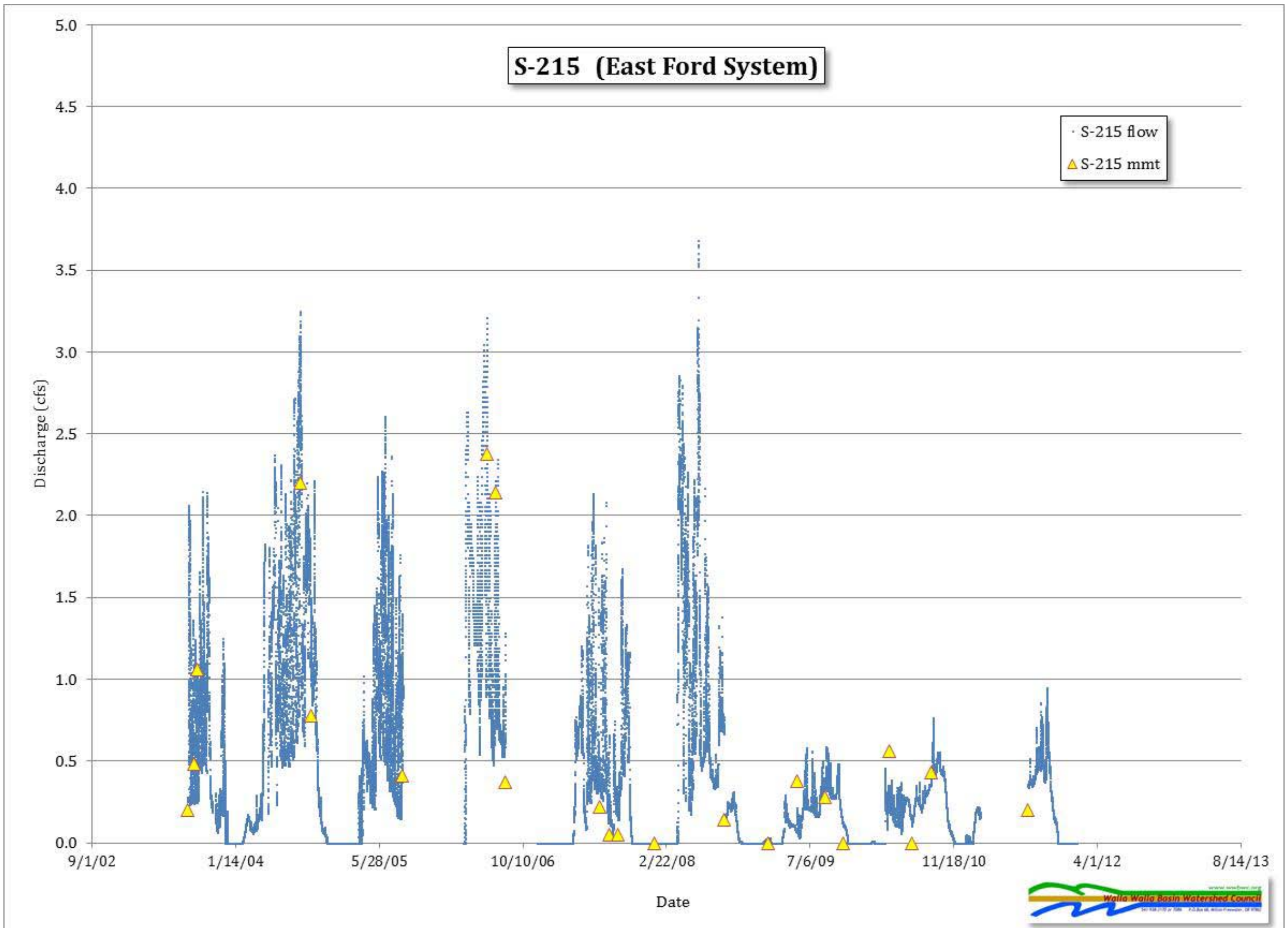

S-210 (Crockett Branch LWWR)
S-210 flow
S-210 mmt
Discharge (cfs)
Date
0
1
2
3
4
5
6
7
8
9
10
9/1/2002
1/14/2004
5/28/2005
10/10/2006
2/22/2008
7/6/2009
11/18/2010
4/1/2012
8/14/2013
Walla Walla Basin Watershed Council

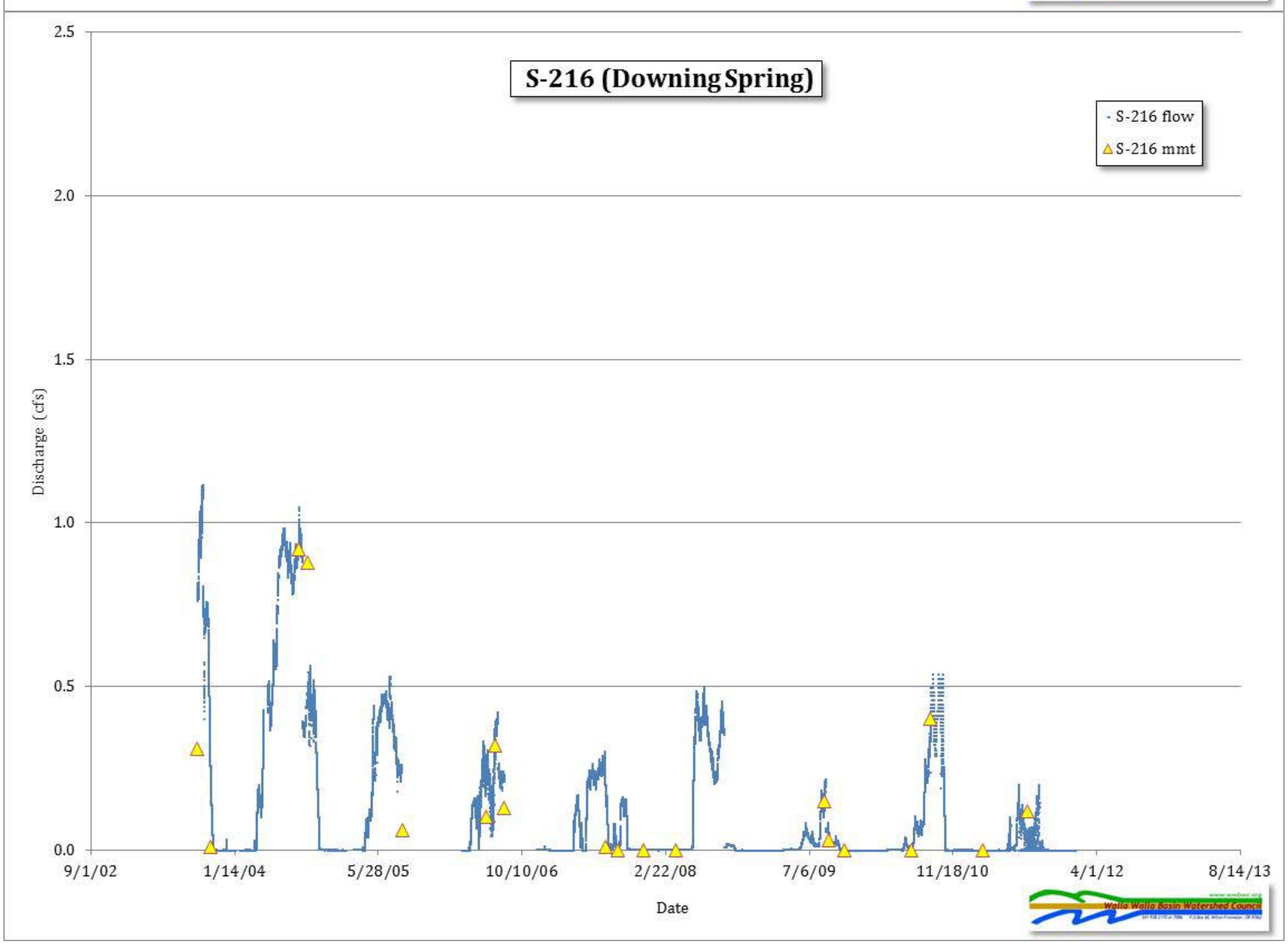

S-211 (Crockett System)
S-211 flow
S-211 mmt
Discharge (cfs)
Date
10
9
8
7
6
5
4
3
2
1
0
9/1/02
1/14/04
5/28/05
10/10/06
2/22/08
7/6/09
11/18/10
4/1/12
8/14/13
Walla Walla Basin Watershed Council

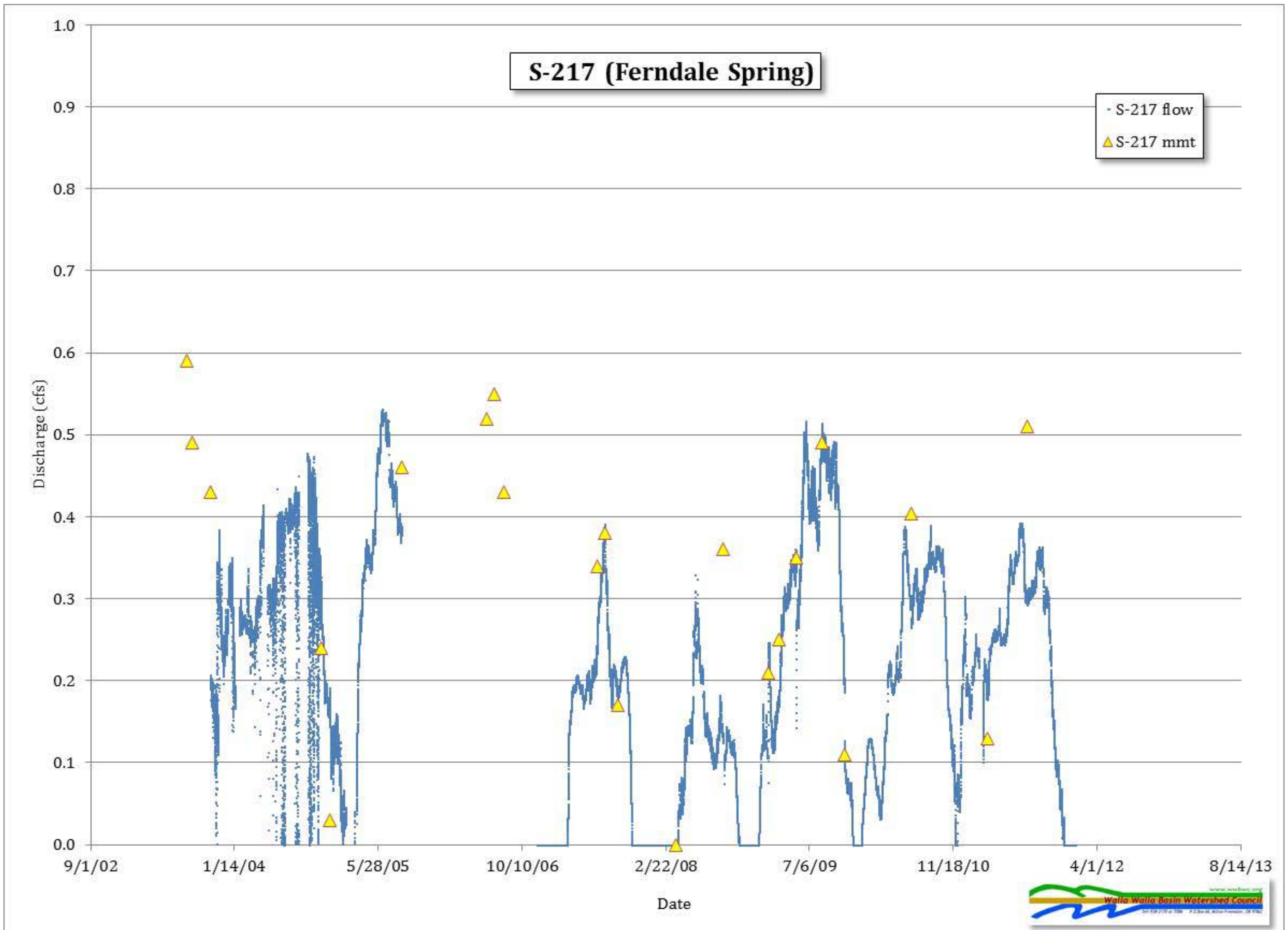

S-212 (Crockett System)
S-212 flow
S-212 mmt
Discharge (cfs)
Date
6
5
4
3
2
1
0
9/1/02
1/14/04
5/28/05
10/10/06
2/22/08
7/6/09
11/18/10
4/1/12
8/14/13
Walla Walla Basin Watershed Council

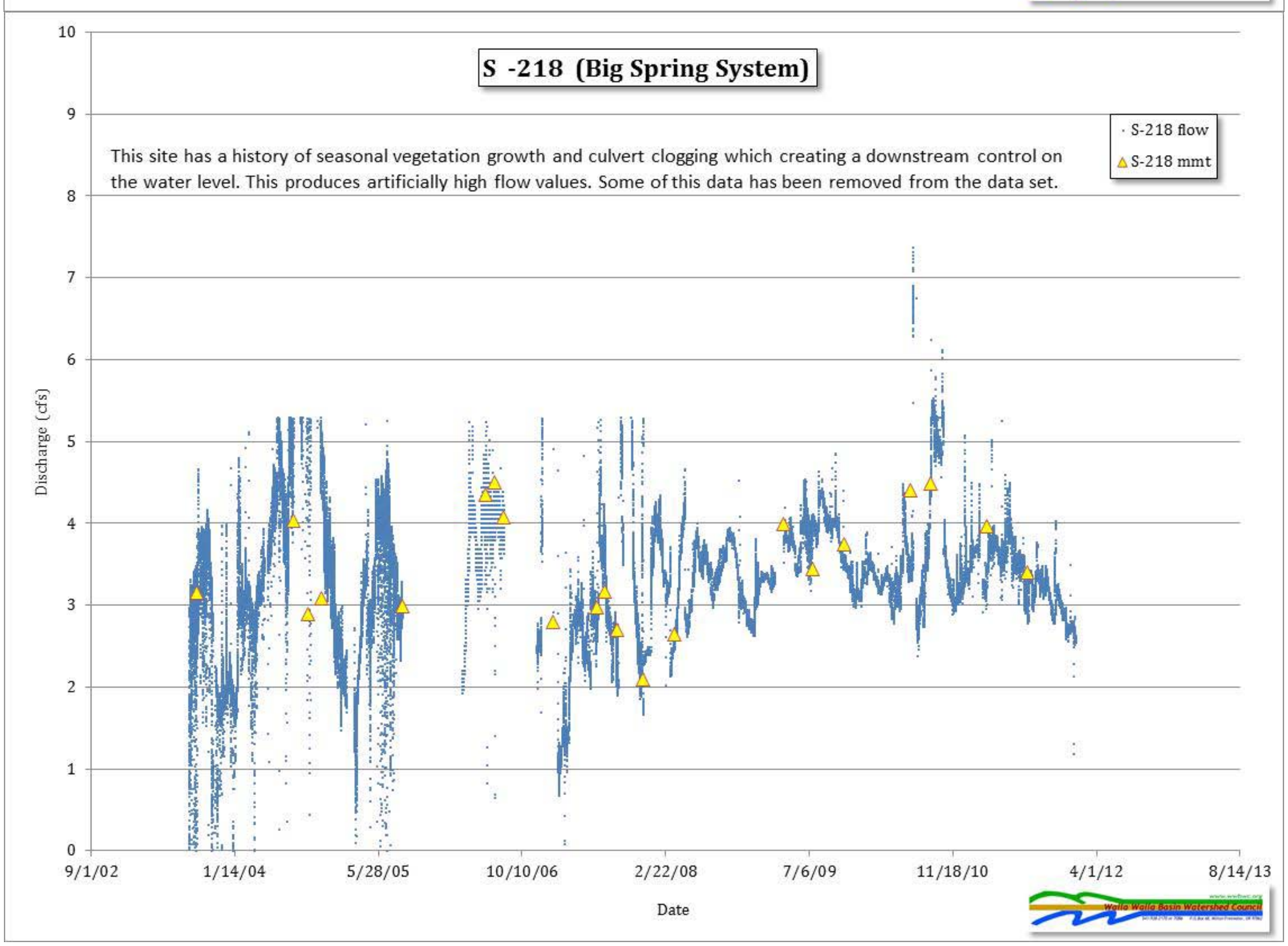

S-213 (End Ford System)
S-213 flow
S-213 mmt
Discharge (cfs)
Date
0
1
2
3
4
5
6
7
8
5/28/05
10/10/06
2/22/08
7/6/09
11/18/10
4/1/12
8/14/13
Walla Walla Basin Watershed Council

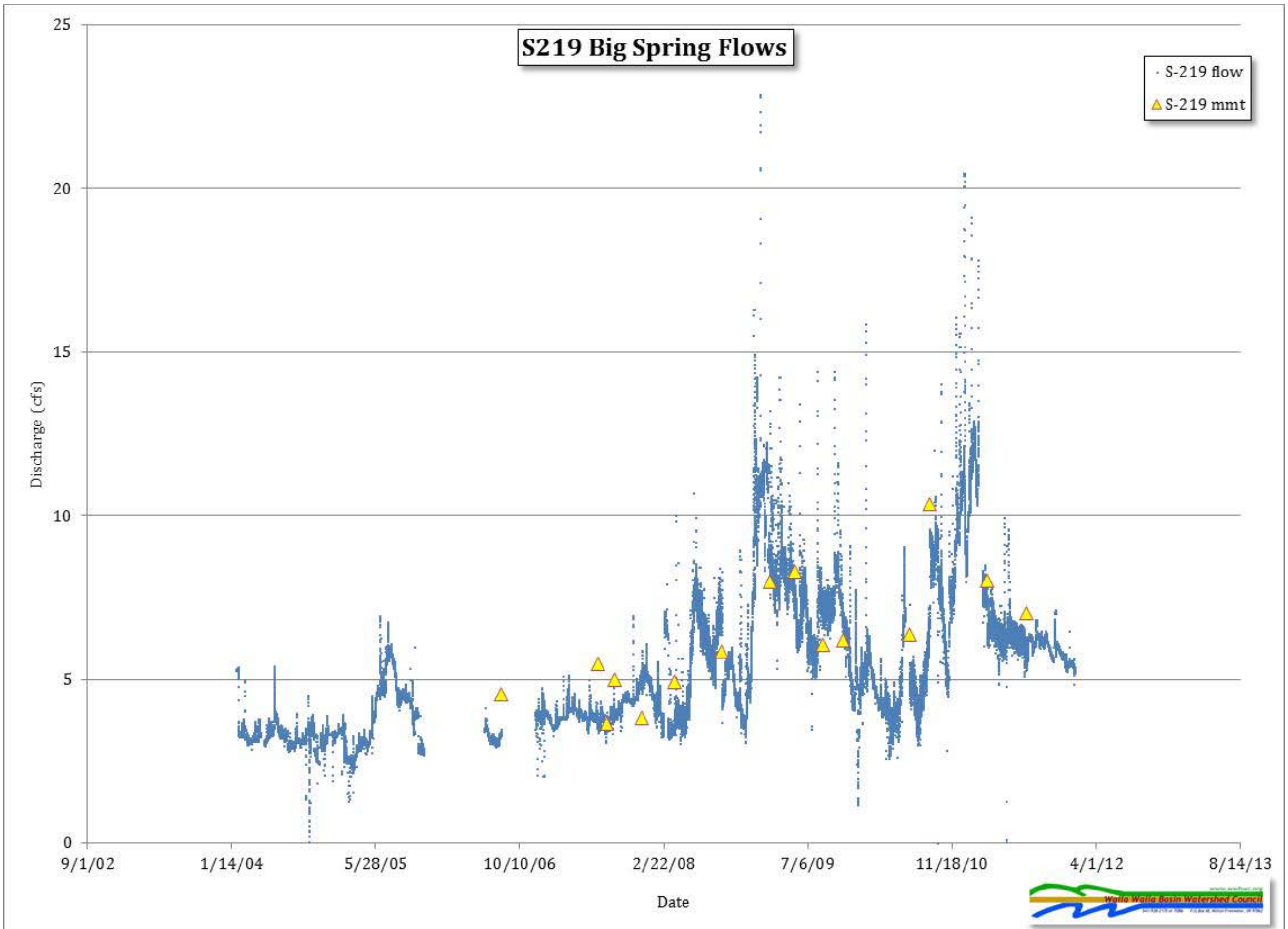

S-214 (East Ford System)
S-214 flow
S-214 mmt
Discharge (cfs)
Date
0
2
4
6
8
10
12
4/28/07
11/14/07
6/1/08
12/18/08
7/6/09
1/22/10
8/10/10
2/26/11
9/14/11
4/1/12
10/18/12
Walla Walla Basin Watershed Council

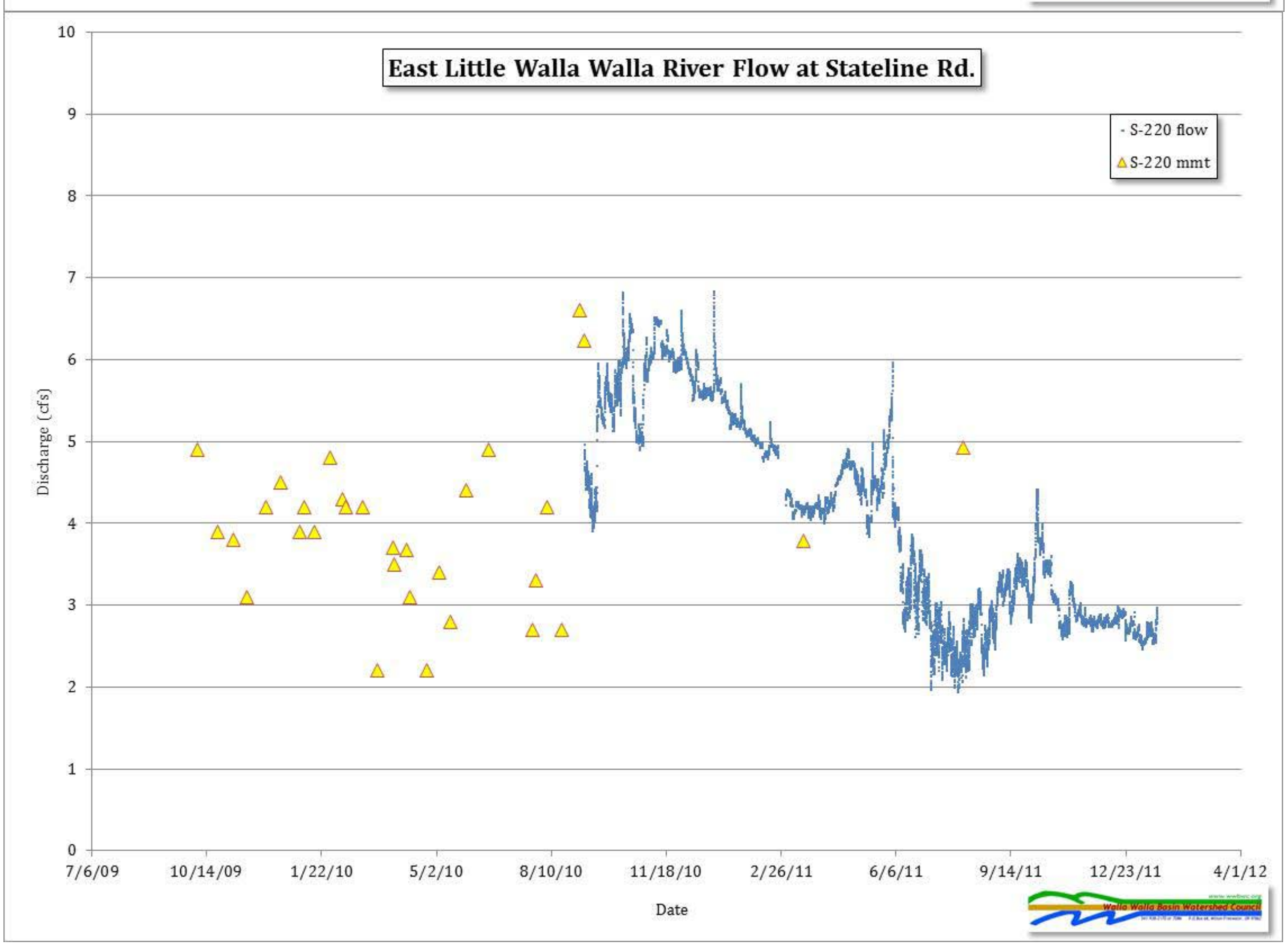

S-215 (East Ford System)
S-215 flow
S-215 mmt
Discharge (cfs)
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
9/1/02
1/14/04
5/28/05
10/10/06
2/22/08
7/6/09
11/18/10
4/1/12
8/14/13
Date
Walla Walla Basin Watershed Council

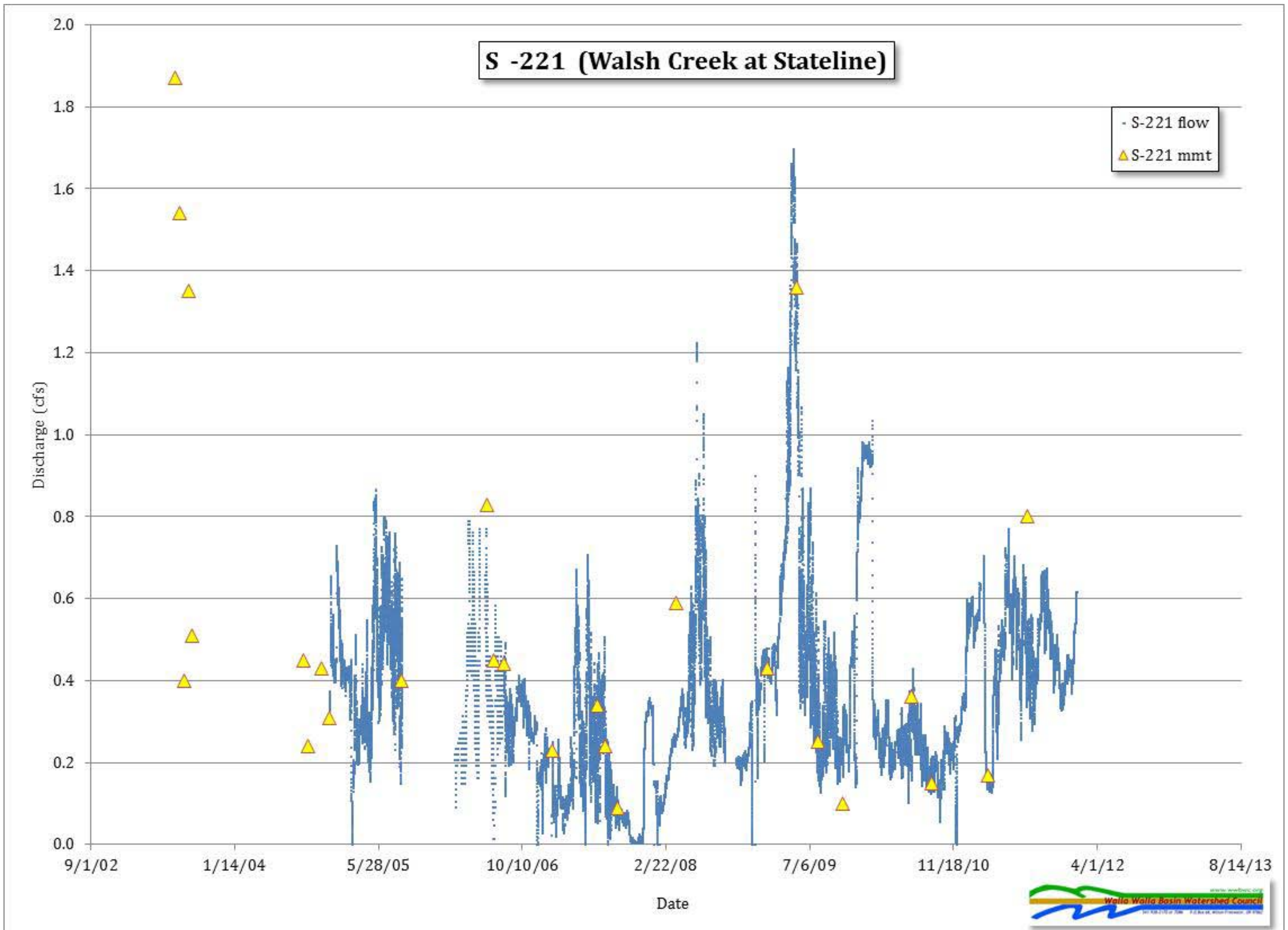

S-216 (Downing Spring)
S-216 flow
S-216 mmt
Discharge (cfs)
2.5
2.0
1.5
1.0
0.5
0.0
9/1/02
1/14/04
5/28/05
10/10/06
2/22/08
7/6/09
11/18/10
4/1/12
8/14/13
Date
Walla Walla Basin Watershed Council


S-217 (Ferndale Spring)
S-217 flow
S-217 mmt
Discharge (cfs)
Date
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
9/1/02
1/14/04
5/28/05
10/10/06
2/22/08
7/6/09
11/18/10
4/1/12
8/14/13
Walla Walla Basin Watershed Council

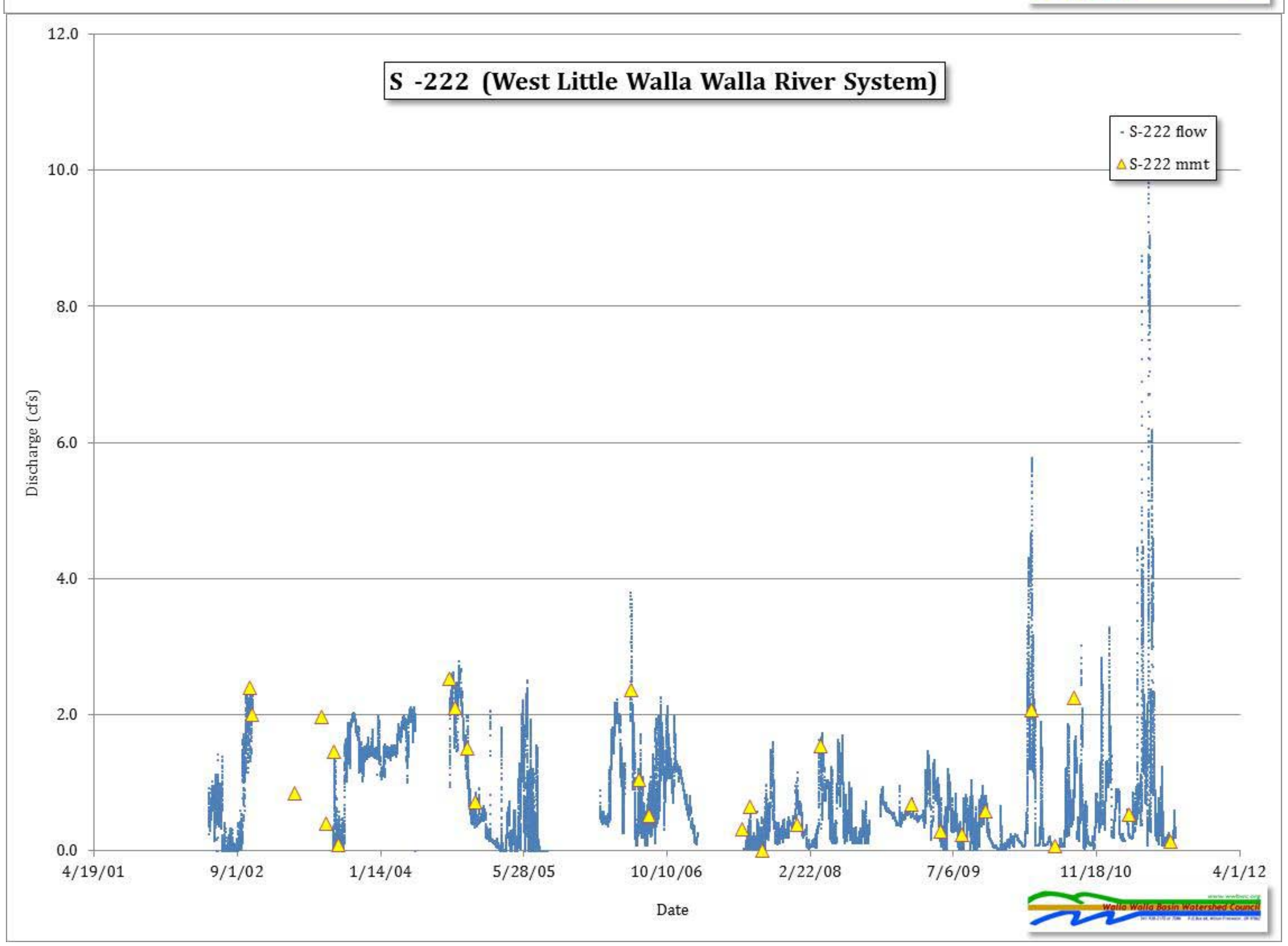

S -218 (Big Spring System)
S-218 flow
S-218 mmt
This site has a history of seasonal vegetation growth and culvert clogging which creating a downstream control on the water level. This produces artificially high flow values. Some of this data has been removed from the data set.
Discharge (cfs)
Date
10
9
8
7
6
5
4
3
2
1
0
9/1/02
1/14/04
5/28/05
10/10/06
2/22/08
7/6/09
11/18/10
4/1/12
8/14/13
Walla Walla Basin Watershed Council


S219 Big Spring Flows
S-219 flow
S-219 mmt
Discharge (cfs)
25
20
15
10
5
0
9/1/02
1/14/04
5/28/05
10/10/06
2/22/08
7/6/09
11/18/10
4/1/12
8/14/13
Date
Walla Walla Basin Watershed Council

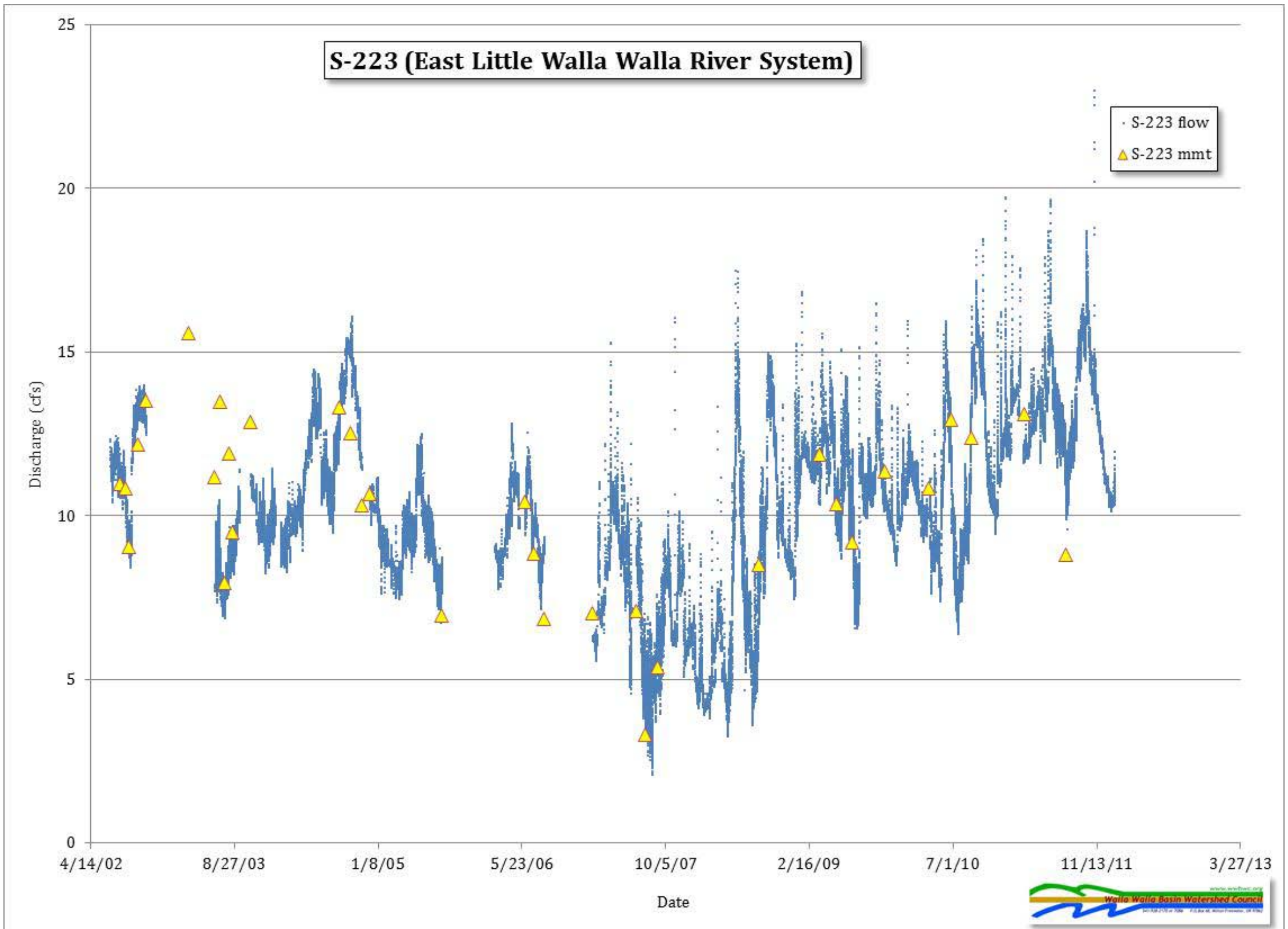

East Little Walla Walla River Flow at Stateline Rd.
S-220 flow
S-220 mmt
Discharge (cfs)
10
9
8
7
6
5
4
3
2
1
0
7/6/09
10/14/09
1/22/10
5/2/10
8/10/10
11/18/10
2/26/11
6/6/11
9/14/11
12/23/11
4/1/12
Date
Walla Walla Basin Watershed Council

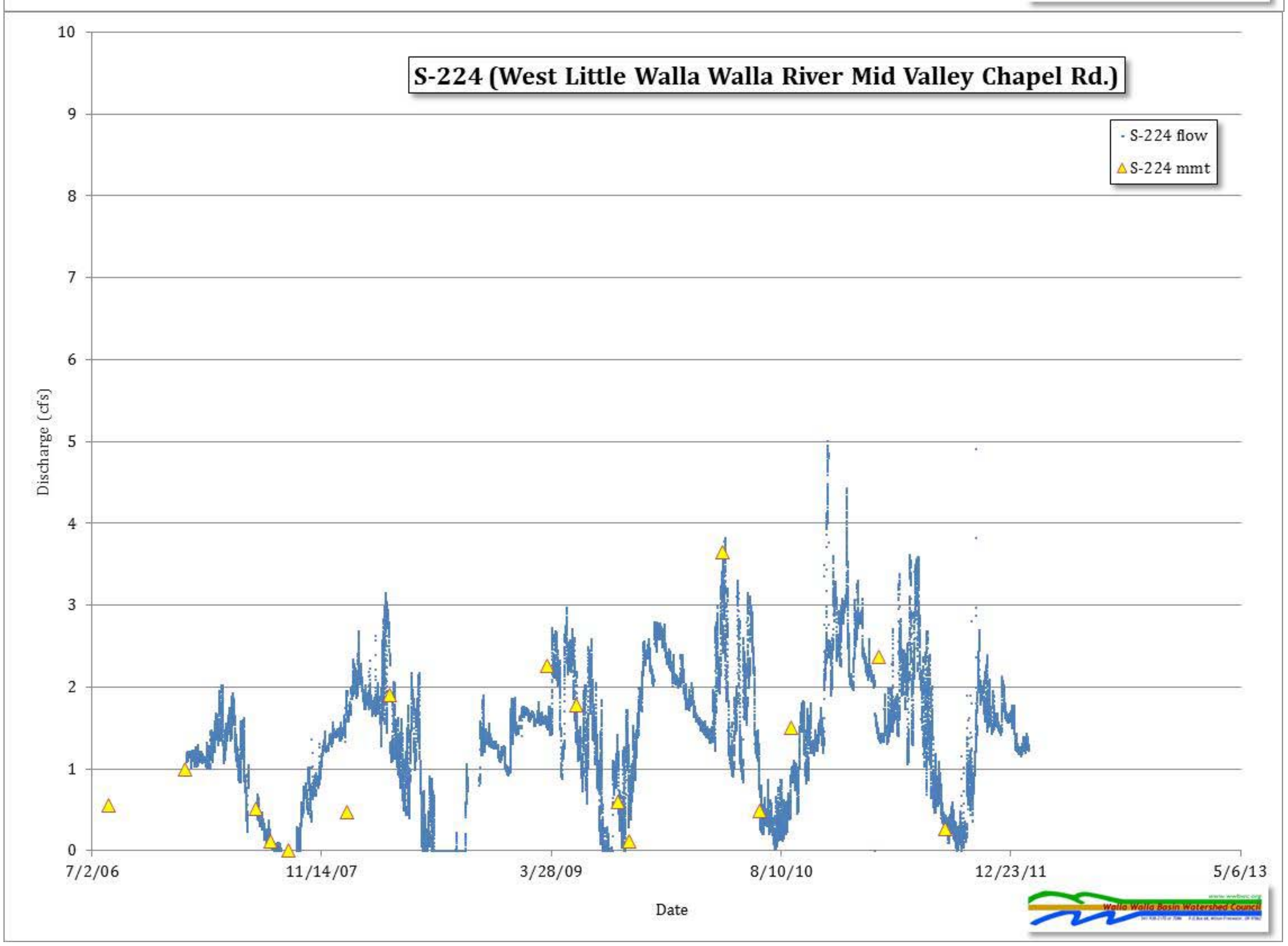


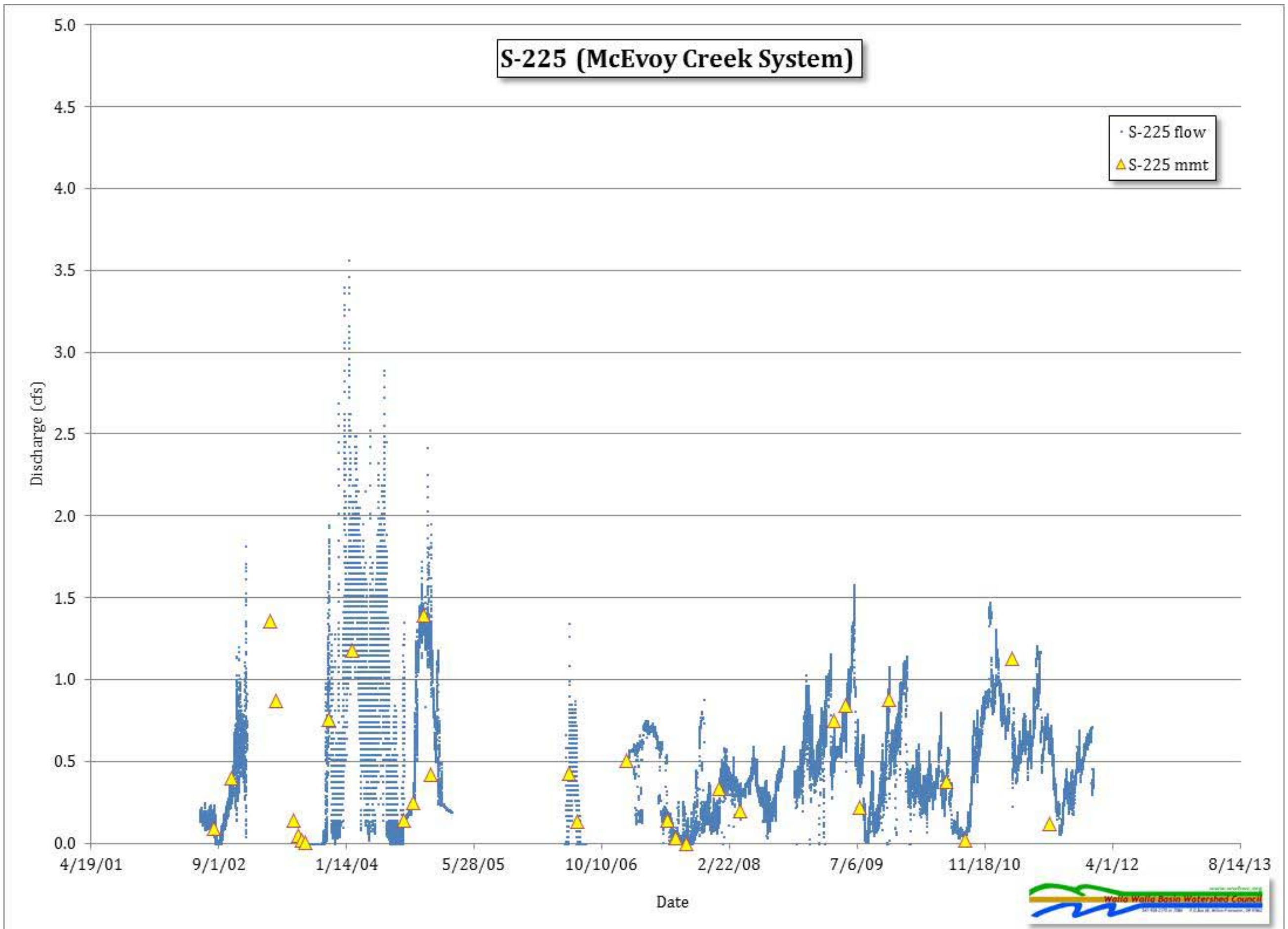
S -221 (Walsh Creek at Stateline)
S-221 flow
S-221 mmt
Discharge (cfs)
Date
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
9/1/02
1/14/04
5/28/05
10/10/06
2/22/08
7/6/09
11/18/10
4/1/12
8/14/13
Walla Walla Basin Watershed Council

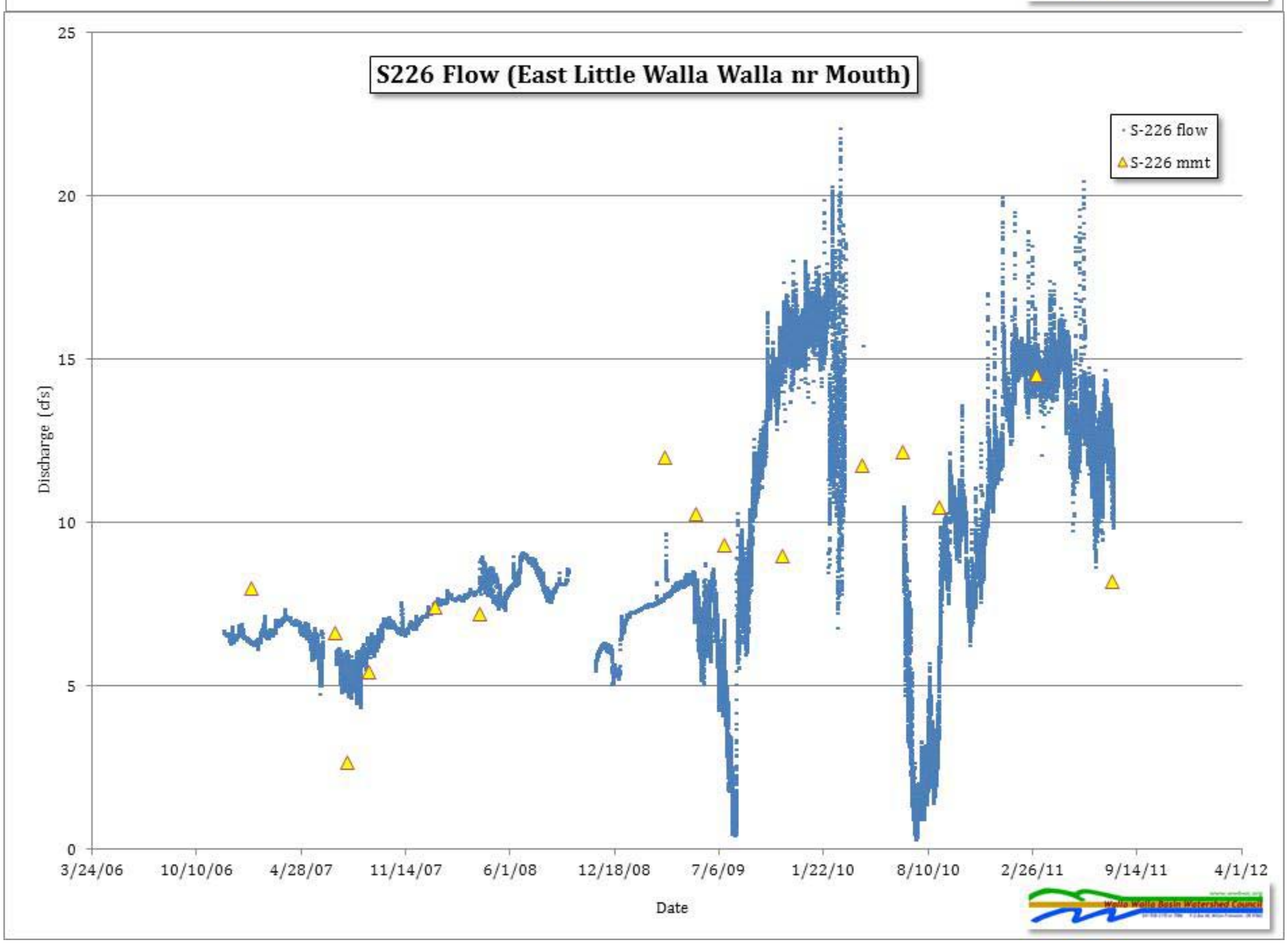


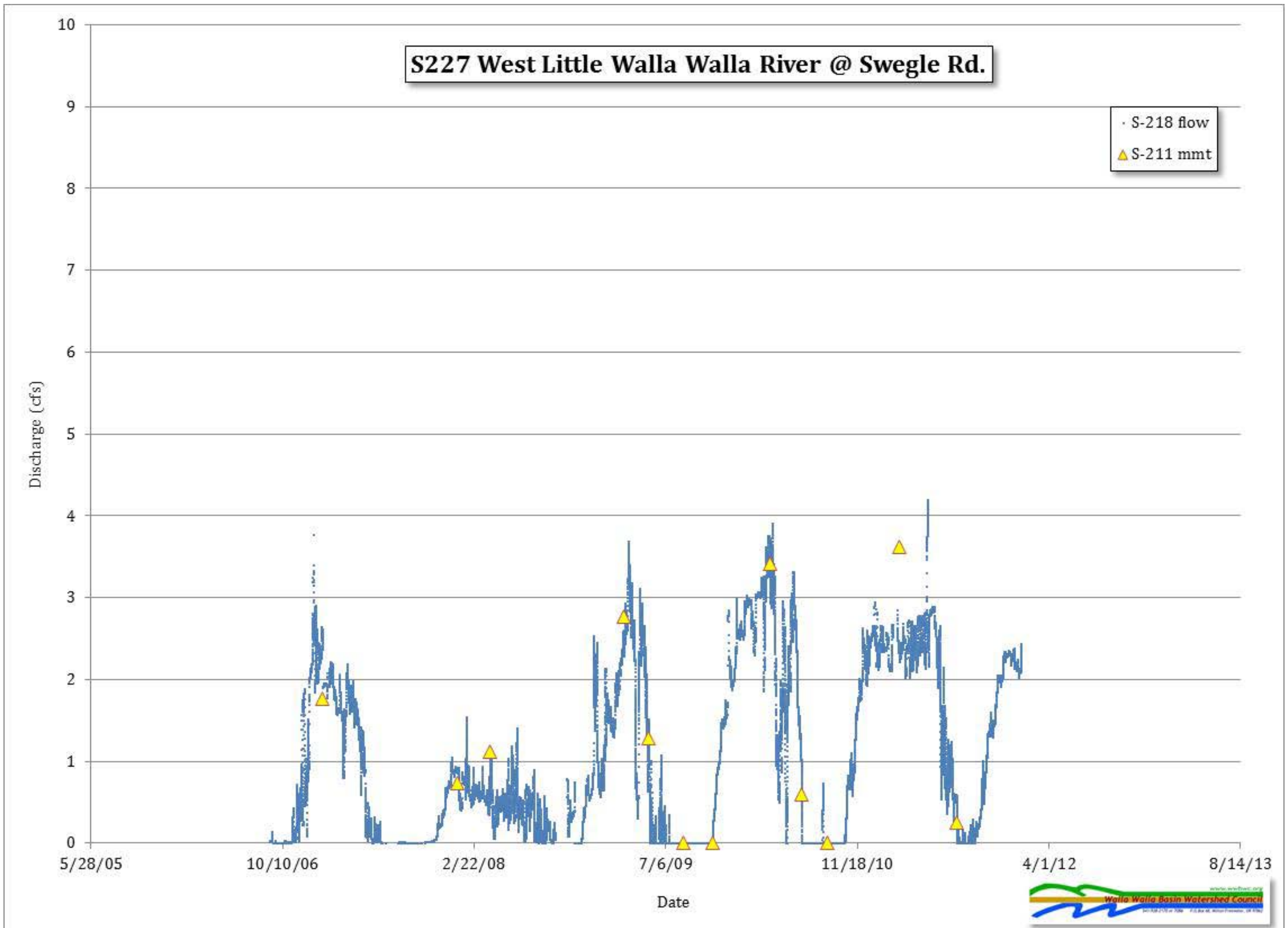
S -222 (West Little Walla Walla River System)
S-222 flow
S-222 mmt
Discharge (cfs)
Date
12.0
10.0
8.0
6.0
4.0
2.0
0.0
4/19/01
9/1/02
1/14/04
5/28/05
10/10/06
2/22/08
7/6/09
11/18/10
4/1/12
Walla Walla Basin Watershed Council

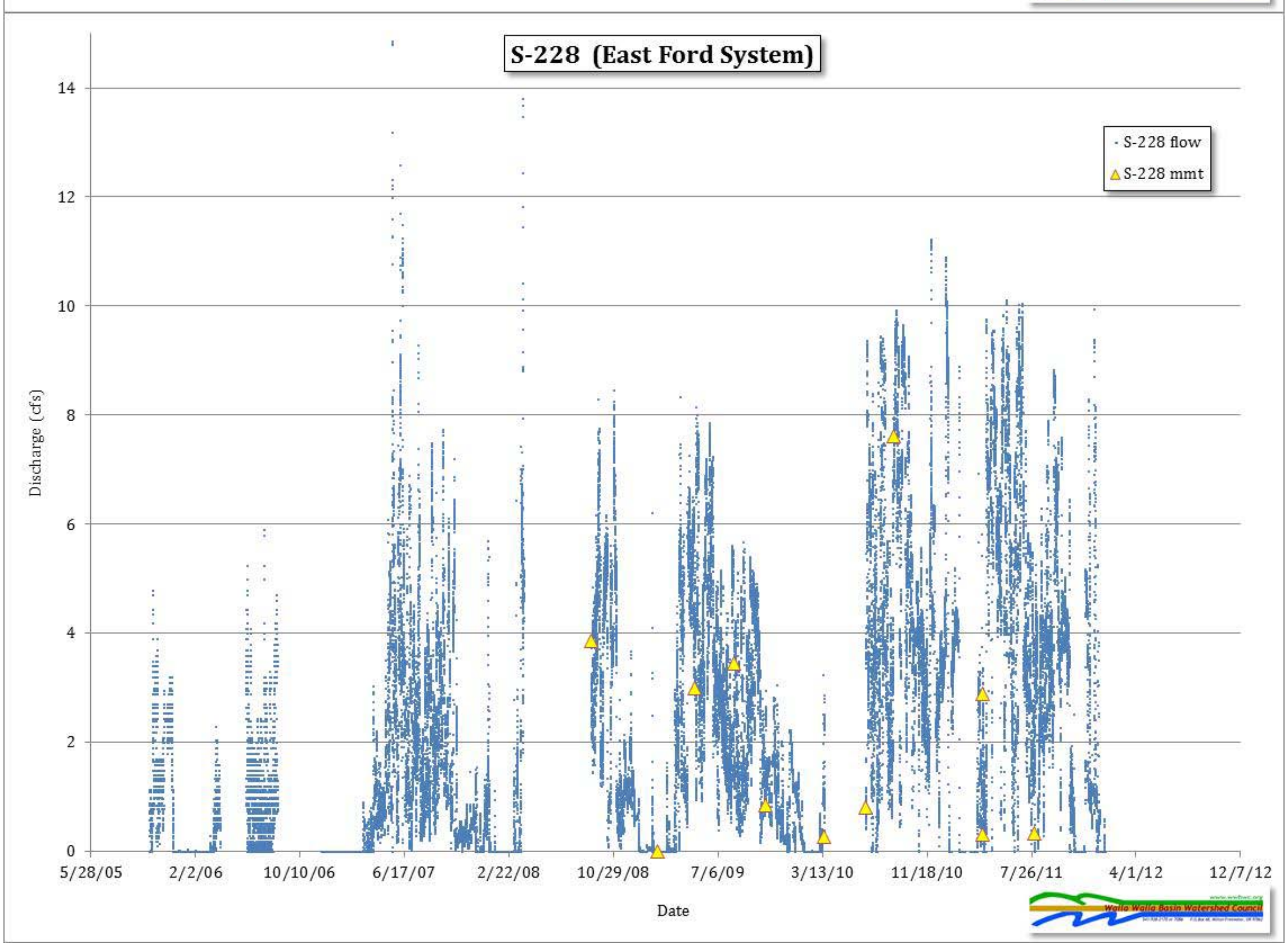

S-223 (East Little Walla Walla River System)
S-223 flow
S-223 mmt
Discharge (cfs)
Date
0
5
10
15
20
25
4/14/02
8/27/03
1/8/05
5/23/06
10/5/07
2/16/09
7/1/10
11/13/11
3/27/13
Walla Walla Basin Watershed Council

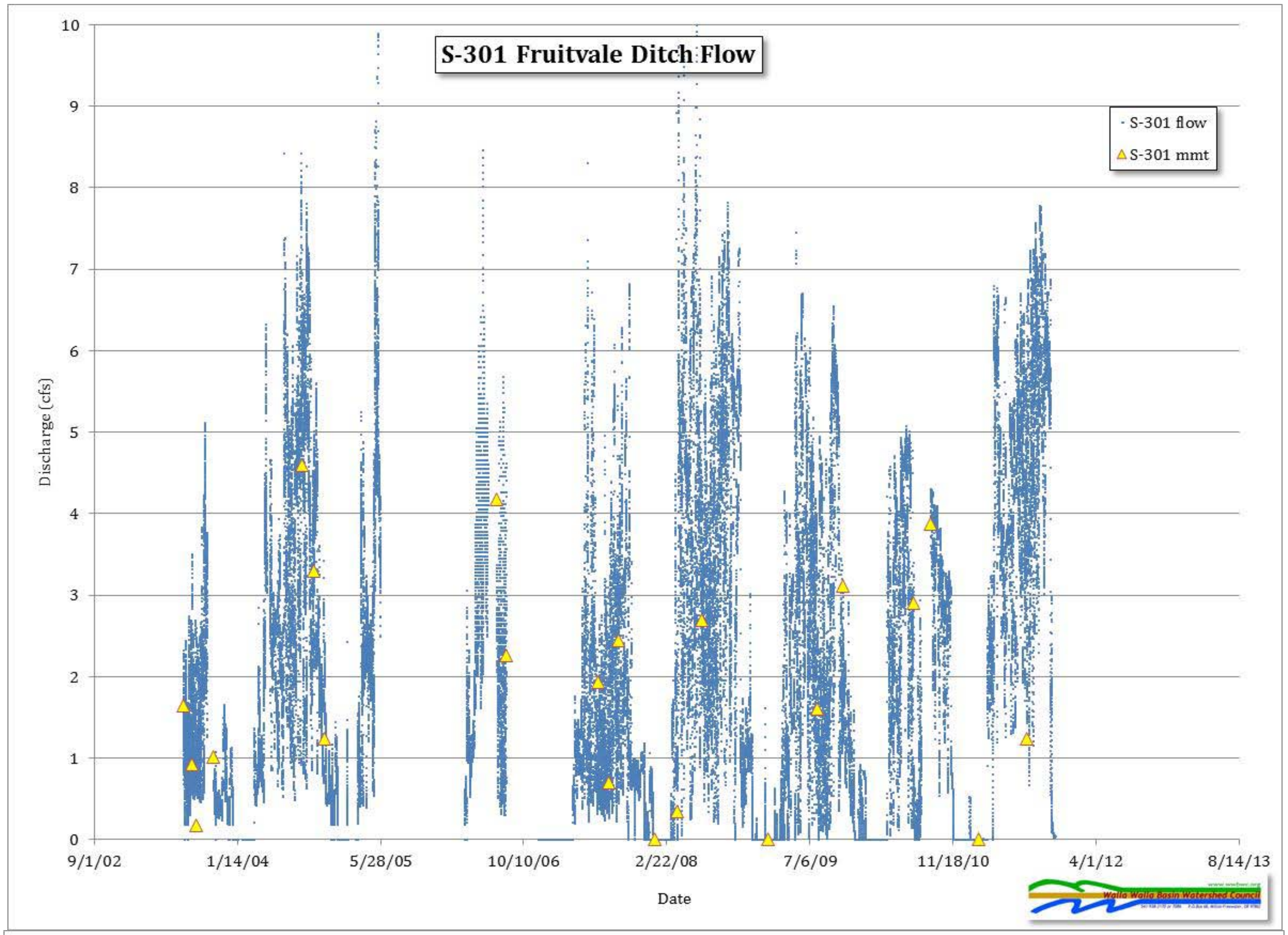

S-224 (West Little Walla Walla River Mid Valley Chapel Rd.)
S-224 flow
S-224 mmt
Discharge (cfs)
Date
0
1
2
3
4
5
6
7
8
9
10
7/2/06
11/14/07
3/28/09
8/10/10
12/23/11
5/6/13
Walla Walla Basin Watershed Council

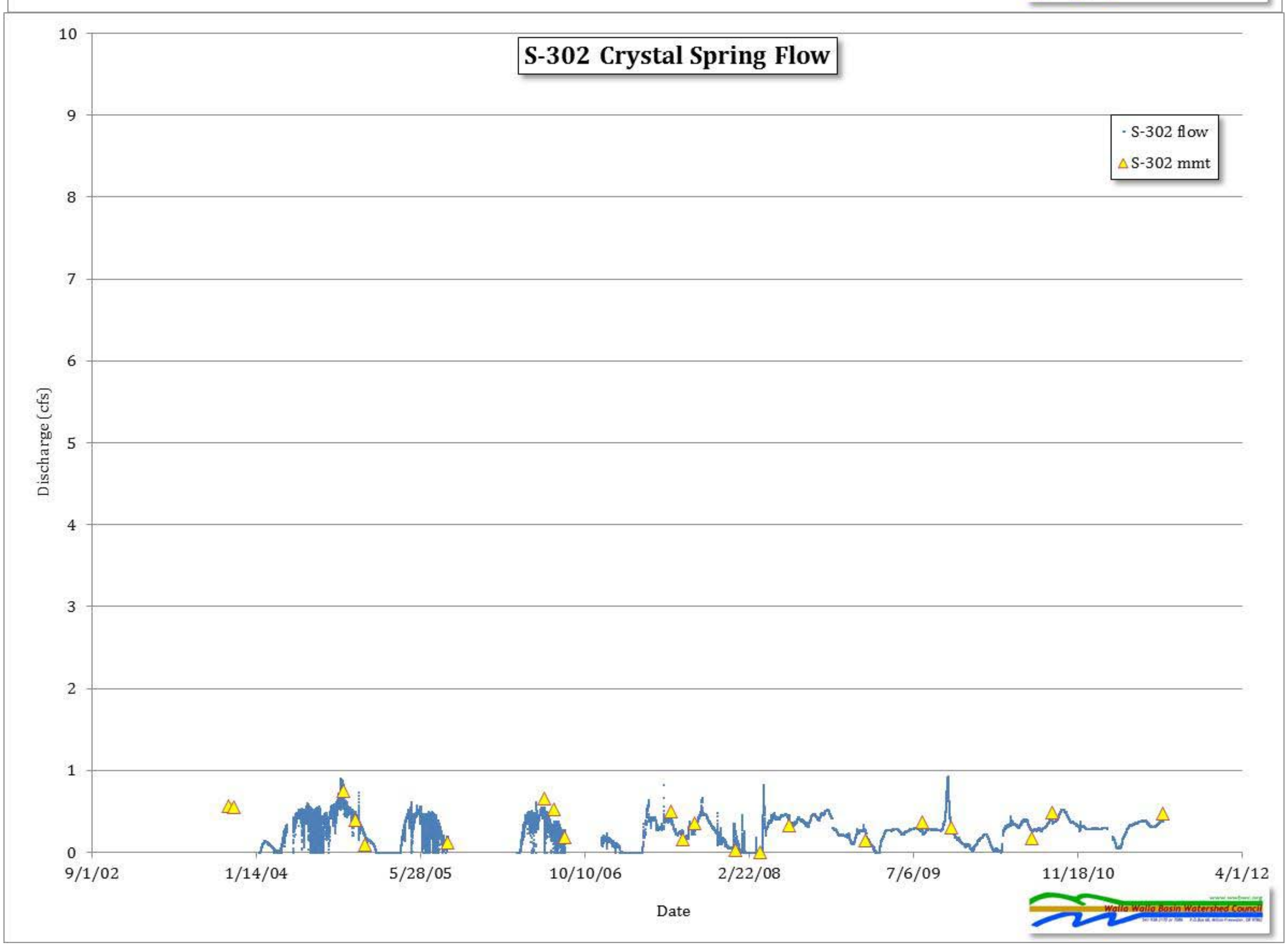

S-225 (McEvoy Creek System)
S-225 flow
S-225 mmt
Discharge (cfs)
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
4/19/01
9/1/02
1/14/04
5/28/05
10/10/06
2/22/08
7/6/09
11/18/10
4/1/12
8/14/13
Date
Walla Walla Basin Watershed Council

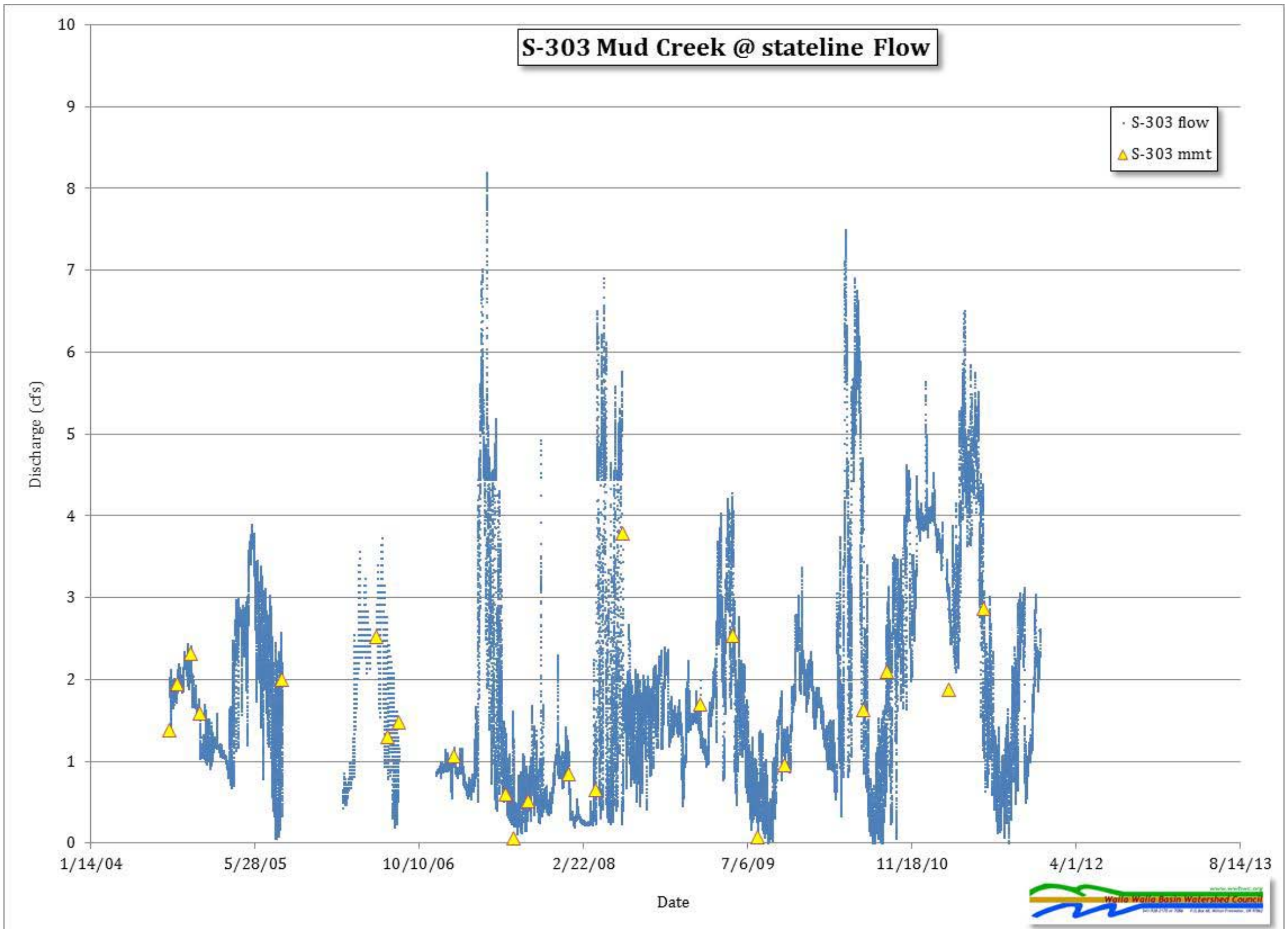

S226 Flow (East Little Walla Walla nr Mouth)
S-226 flow
S-226 mmt
Discharge (cfs)
25
20
15
10
5
0
3/24/06
10/10/06
4/28/07
11/14/07
6/1/08
12/18/08
7/6/09
1/22/10
8/10/10
2/26/11
9/14/11
4/1/12
Date
Walla Walla Basin Watershed Council


S227 West Little Walla Walla River @ Swegle Rd.
S-218 flow
S-211 mmt
Discharge (cfs)
Date
5/28/05
10/10/06
2/22/08
7/6/09
11/18/10
4/1/12
8/14/13
Walla Walla Basin Watershed Council

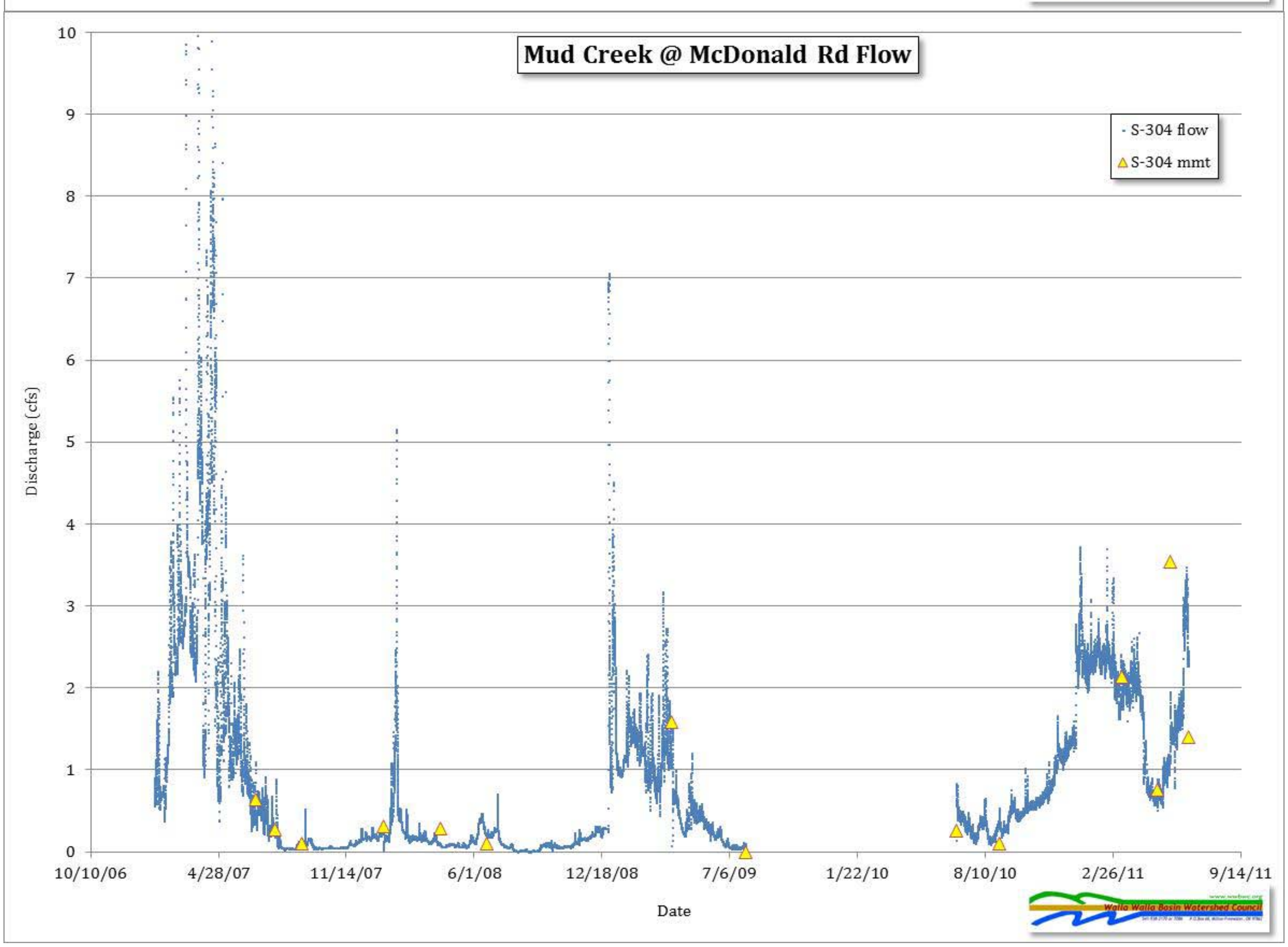

S-228 (East Ford System)
S-228 flow
S-228 mmt
Discharge (cfs)
Date
5/28/05
2/2/06
10/10/06
6/17/07
2/22/08
10/29/08
7/6/09
3/13/10
11/18/10
7/26/11
4/1/12
12/7/12
Walla Walla Basin Watershed Council


S-301 Fruitvale Ditch Flow
S-301 flow
S-301 mmt
Discharge (cfs)
10
9
8
7
6
5
4
3
2
1
0
9/1/02
1/14/04
5/28/05
10/10/06
2/22/08
7/6/09
11/18/10
4/1/12
8/14/13
Date
Walla Walla Basin Watershed Council

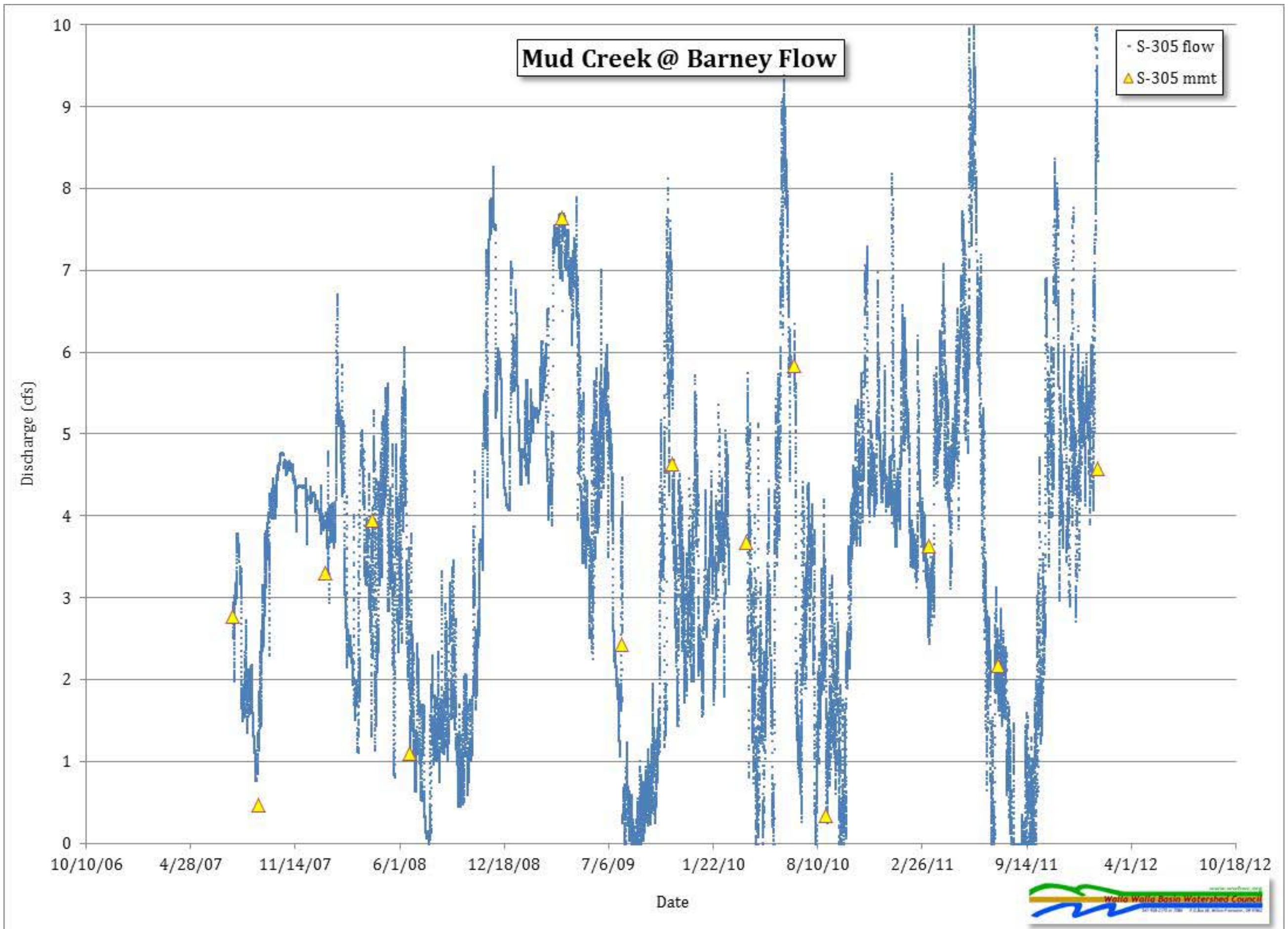

S-302 Crystal Spring Flow
S-302 flow
S-302 mmt
Discharge (cfs)
10
9
8
7
6
5
4
3
2
1
0
9/1/02
1/14/04
5/28/05
10/10/06
2/22/08
7/6/09
11/18/10
4/1/12
Date
Walla Walla Basin Watershed Council

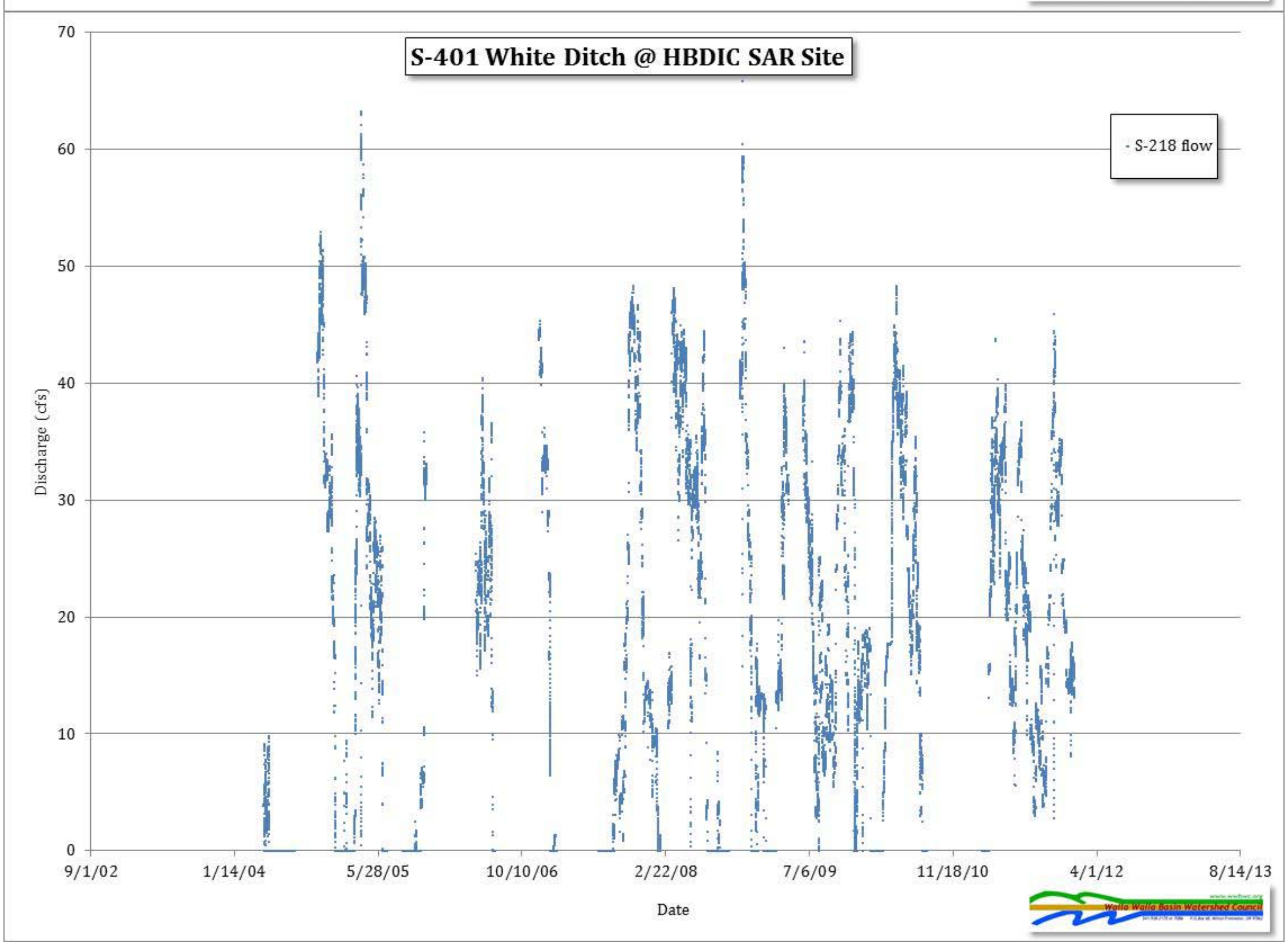


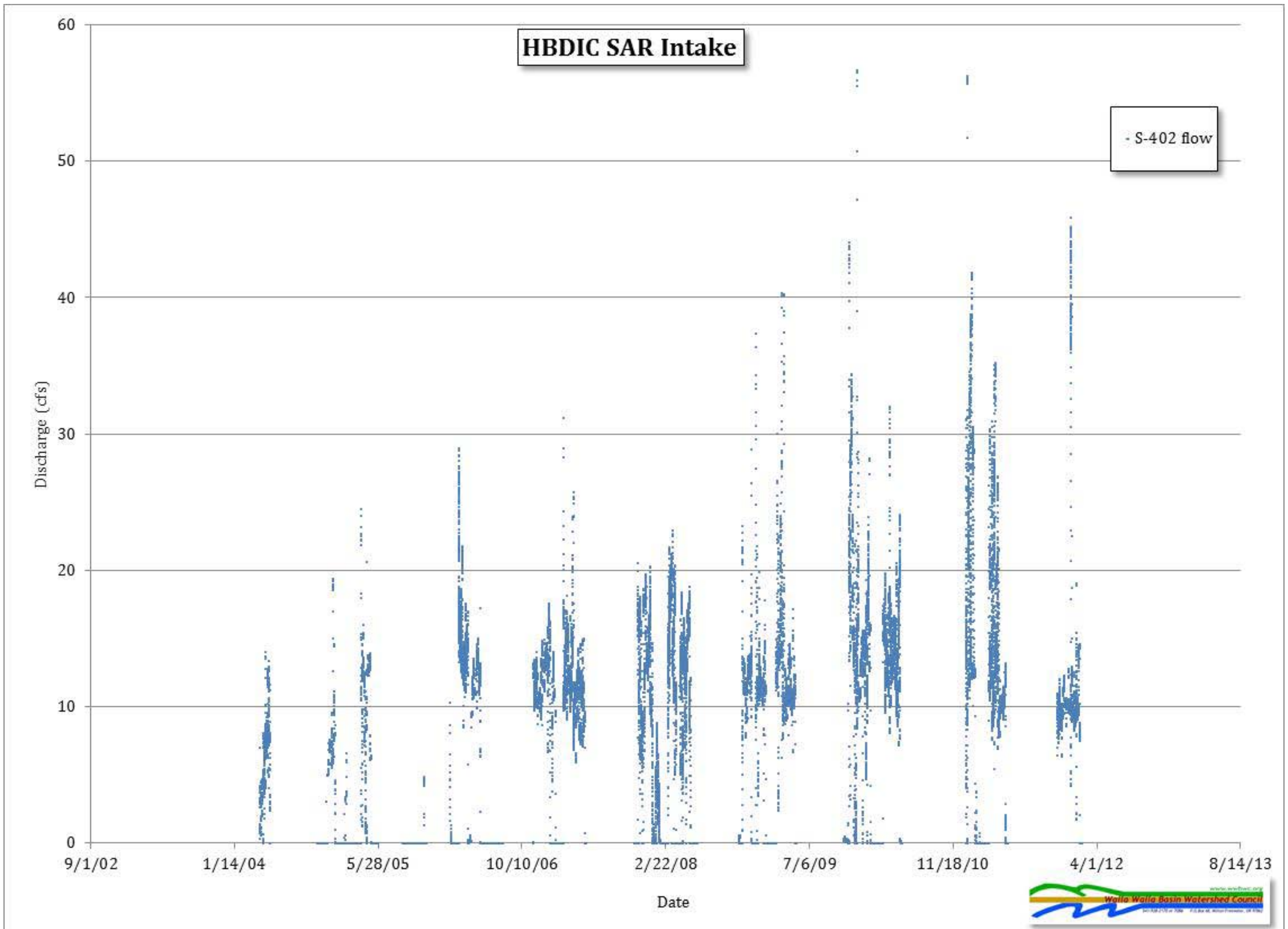
S-303 Mud Creek @ stateline Flow
S-303 flow
S-303 mmt
Discharge (cfs)
0
1
2
3
4
5
6
7
8
9
10
1/14/04
5/28/05
10/10/06
2/22/08
7/6/09
11/18/10
4/1/12
8/14/13
Date
Walla Walla Basin Watershed Council

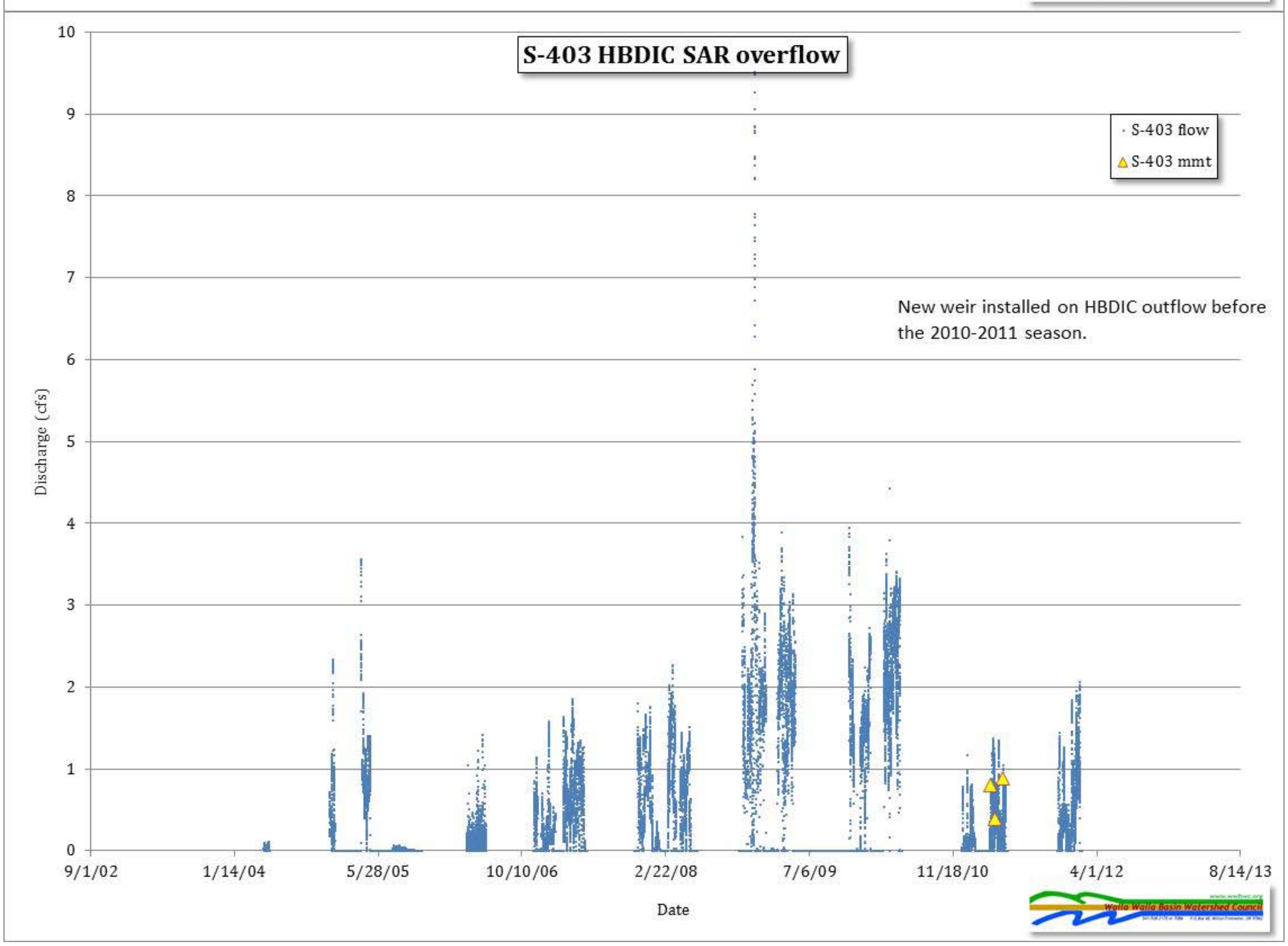


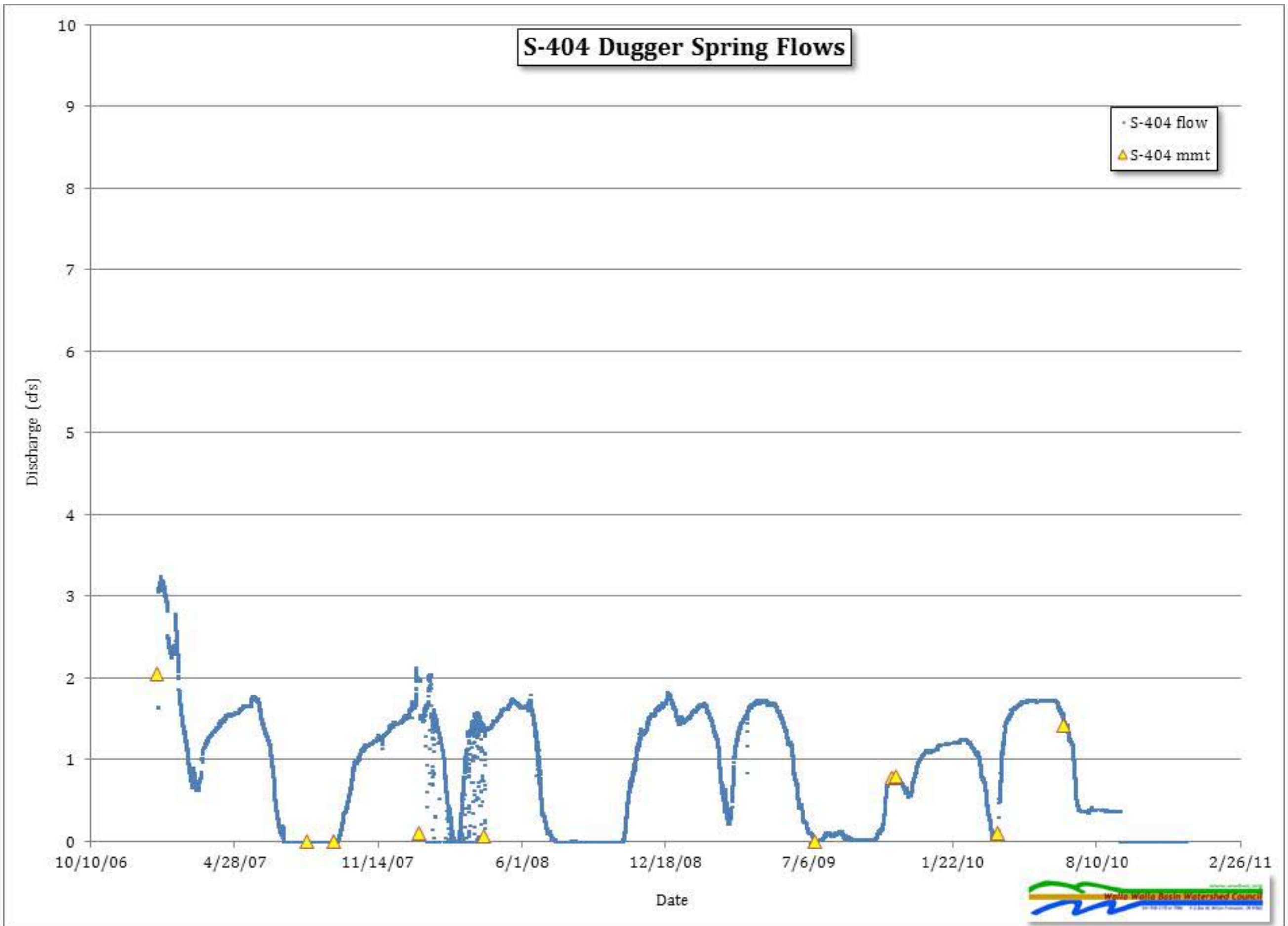
Mud Creek @ McDonald Rd Flow
S-304 flow
S-304 mmt
Discharge (cfs)
0
1
2
3
4
5
6
7
8
9
10
10/10/06
4/28/07
11/14/07
6/1/08
12/18/08
7/6/09
1/22/10
8/10/10
2/26/11
9/14/11
Date
Walla Walla Basin Watershed Council

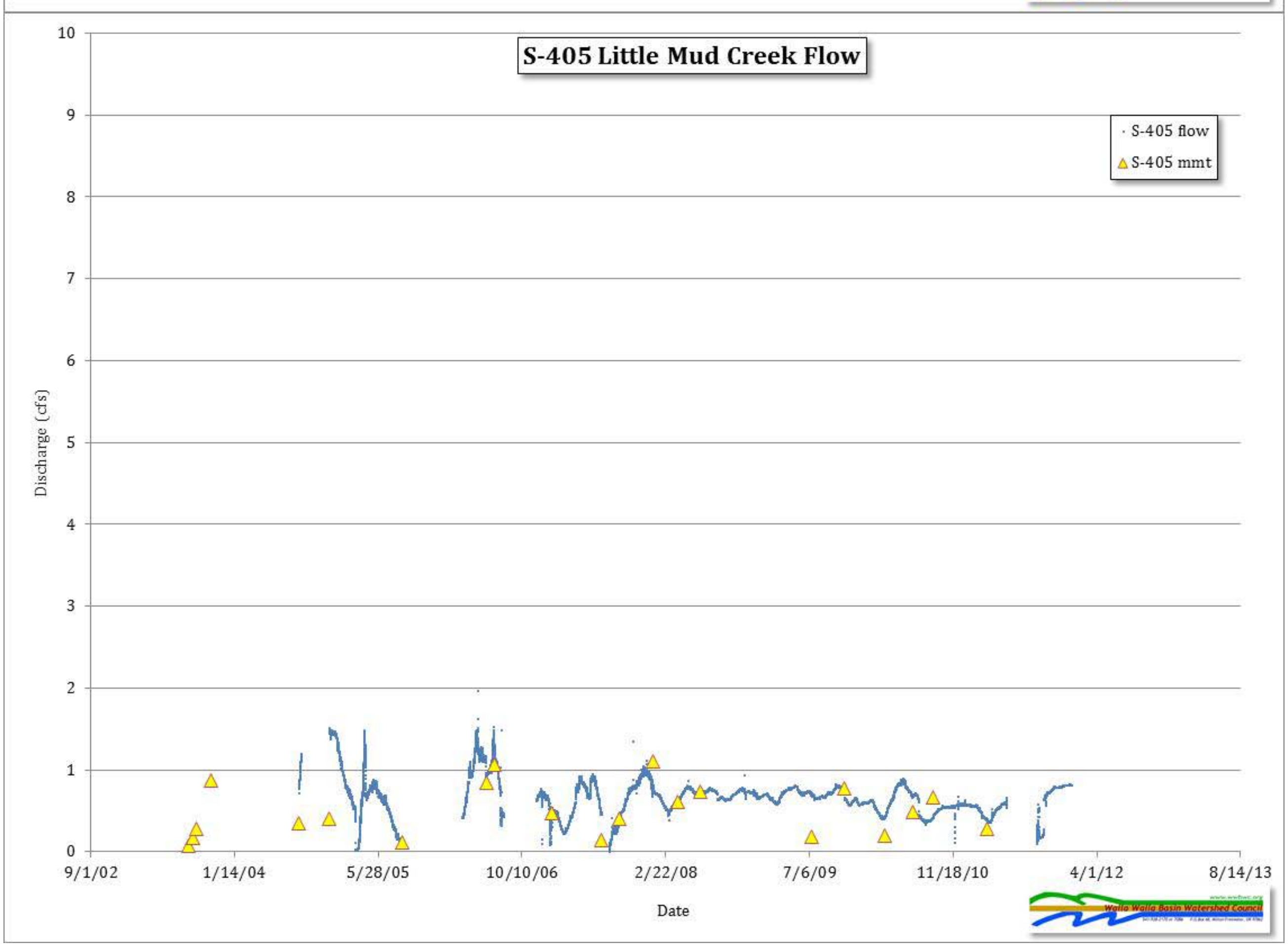

Mud Creek @ Barney Flow
S-305 flow
S-305 mmt
Discharge (cfs)
Date
10/10/06
4/28/07
11/14/07
6/1/08
12/18/08
7/6/09
1/22/10
8/10/10
2/26/11
9/14/11
4/1/12
10/18/12
Walla Walla Basin Watershed Council

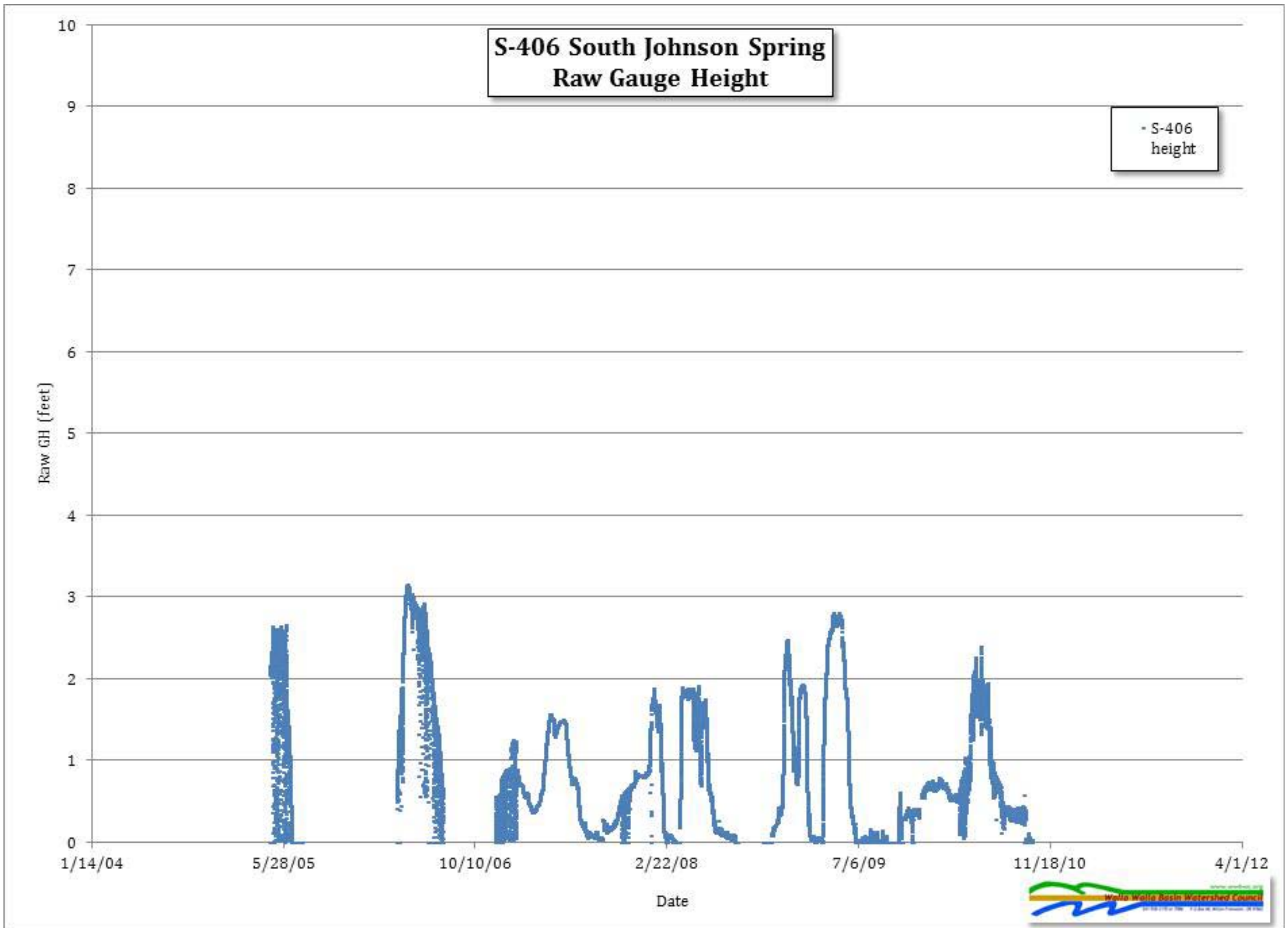

S-401 White Ditch @ HBDIC SAR Site
S-218 flow
Discharge (cfs)
Date
9/1/02
1/14/04
5/28/05
10/10/06
2/22/08
7/6/09
11/18/10
4/1/12
8/14/13
Walla Walla Basin Watershed Council

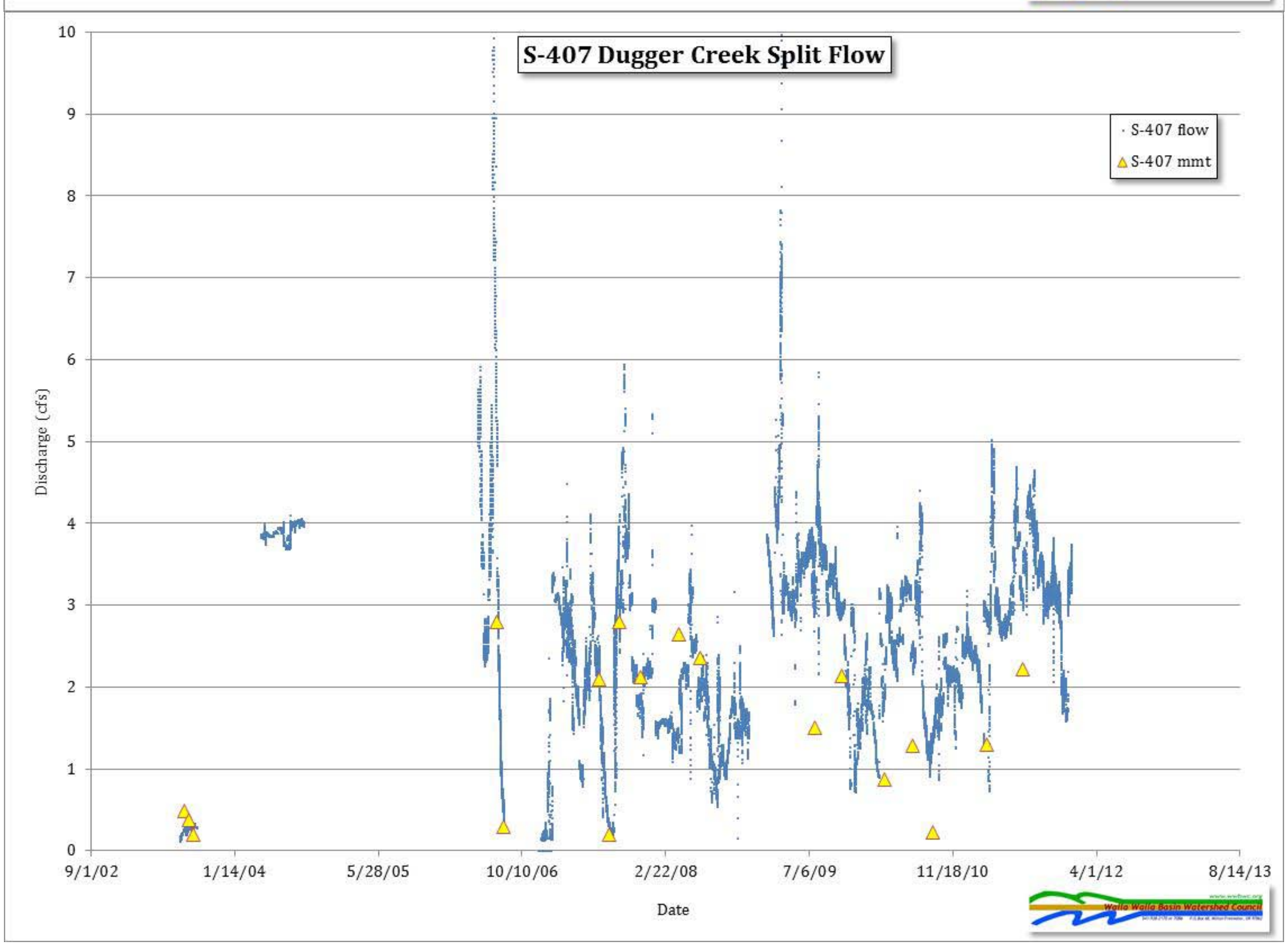

HBDIC SAR Intake
S-402 flow
Discharge (cfs)
60
50
40
30
20
10
0
9/1/02
1/14/04
5/28/05
10/10/06
2/22/08
7/6/09
11/18/10
4/1/12
8/14/13
Date
Walla Walla Basin Watershed Council

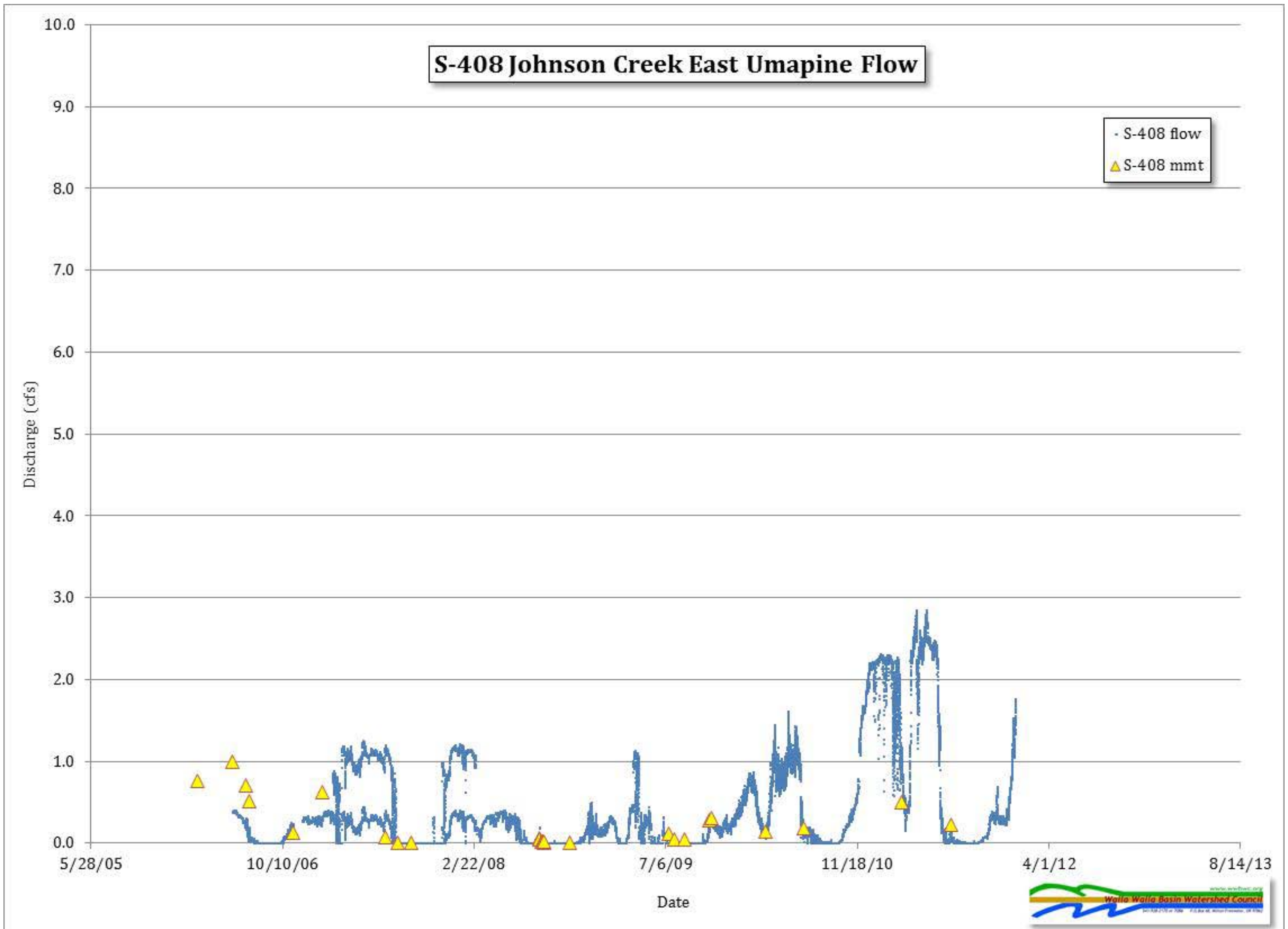

S-403 HBDIC SAR overflow
S-403 flow
S-403 mmt
New weir installed on HBDIC outflow before the 2010-2011 season.
Discharge (cfs)
10
9
8
7
6
5
4
3
2
1
0
9/1/02
1/14/04
5/28/05
10/10/06
2/22/08
7/6/09
11/18/10
4/1/12
8/14/13
Date
Walla Walla Basin Watershed Council

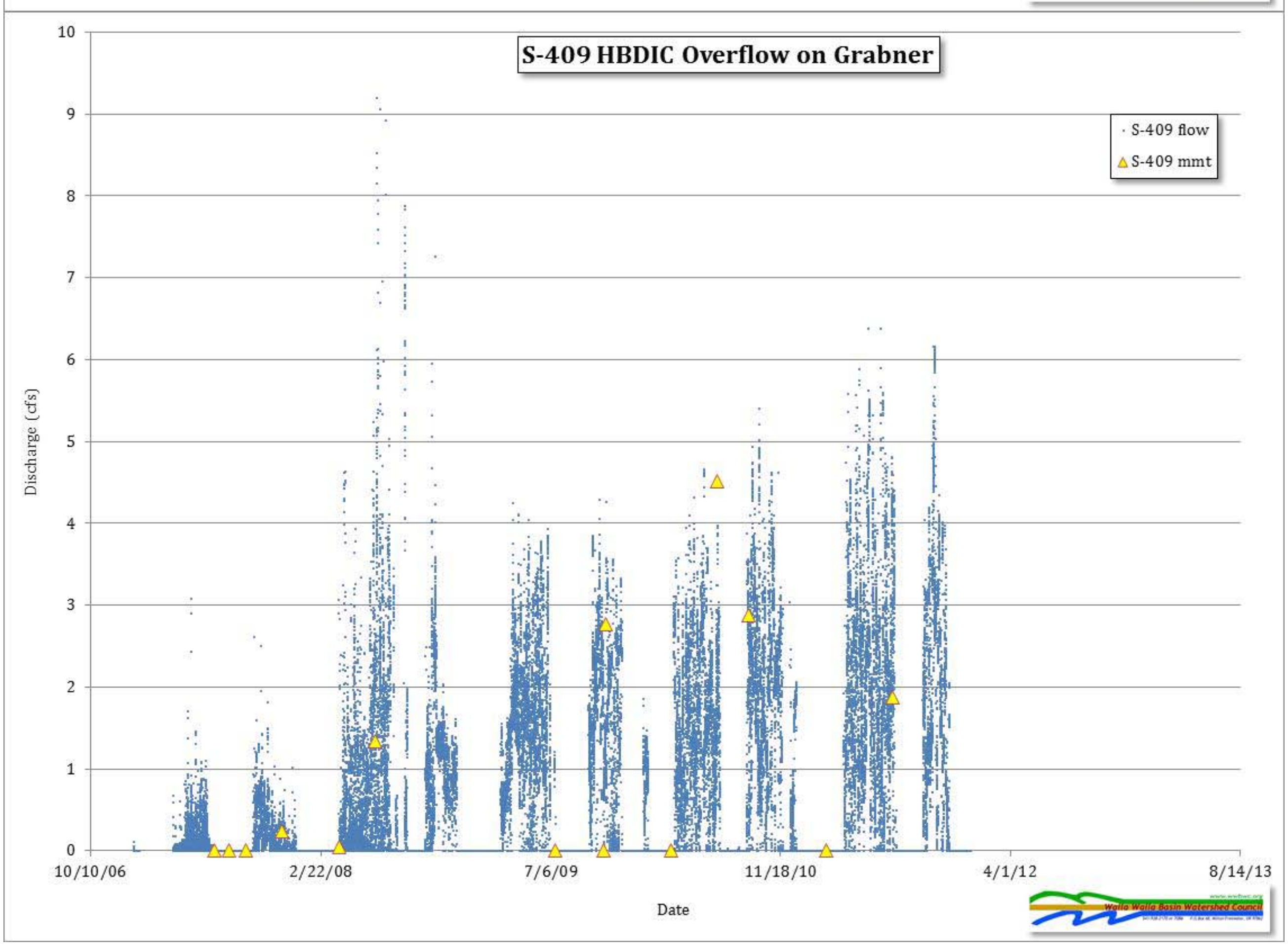

S-404 Dugger Spring Flows
S-404 flow
S-404 mmt
Discharge (cfs)
10
9
8
7
6
5
4
3
2
1
0
10/10/06
4/28/07
11/14/07
6/1/08
12/18/08
7/6/09
1/22/10
8/10/10
2/26/11
Date
Walla Walla Basin Watershed Council

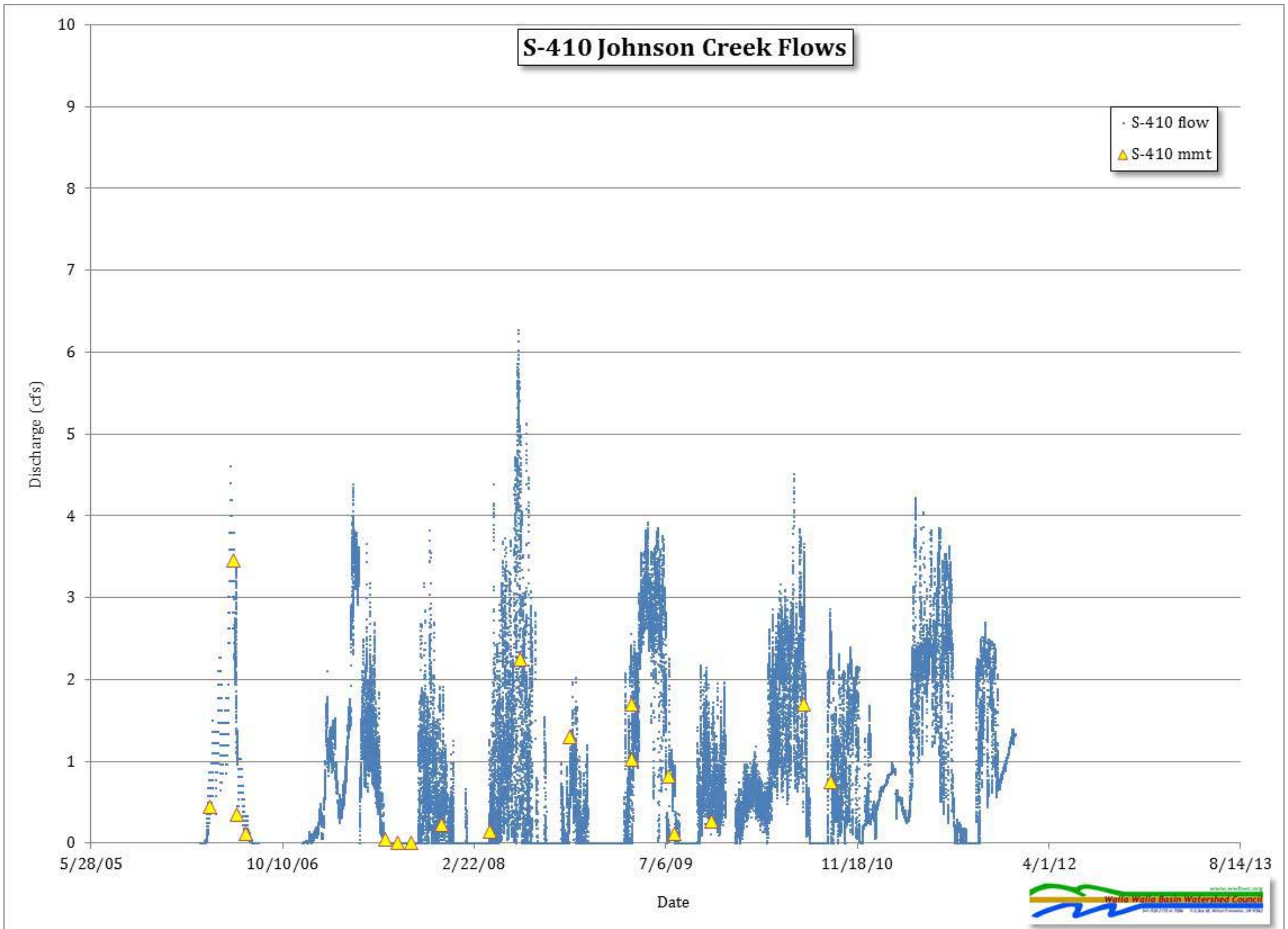

S-405 Little Mud Creek Flow
S-405 flow
S-405 mmt
Discharge (cfs)
10
9
8
7
6
5
4
3
2
1
0
9/1/02
1/14/04
5/28/05
10/10/06
2/22/08
7/6/09
11/18/10
4/1/12
8/14/13
Date
Walla Walla Basin Watershed Council

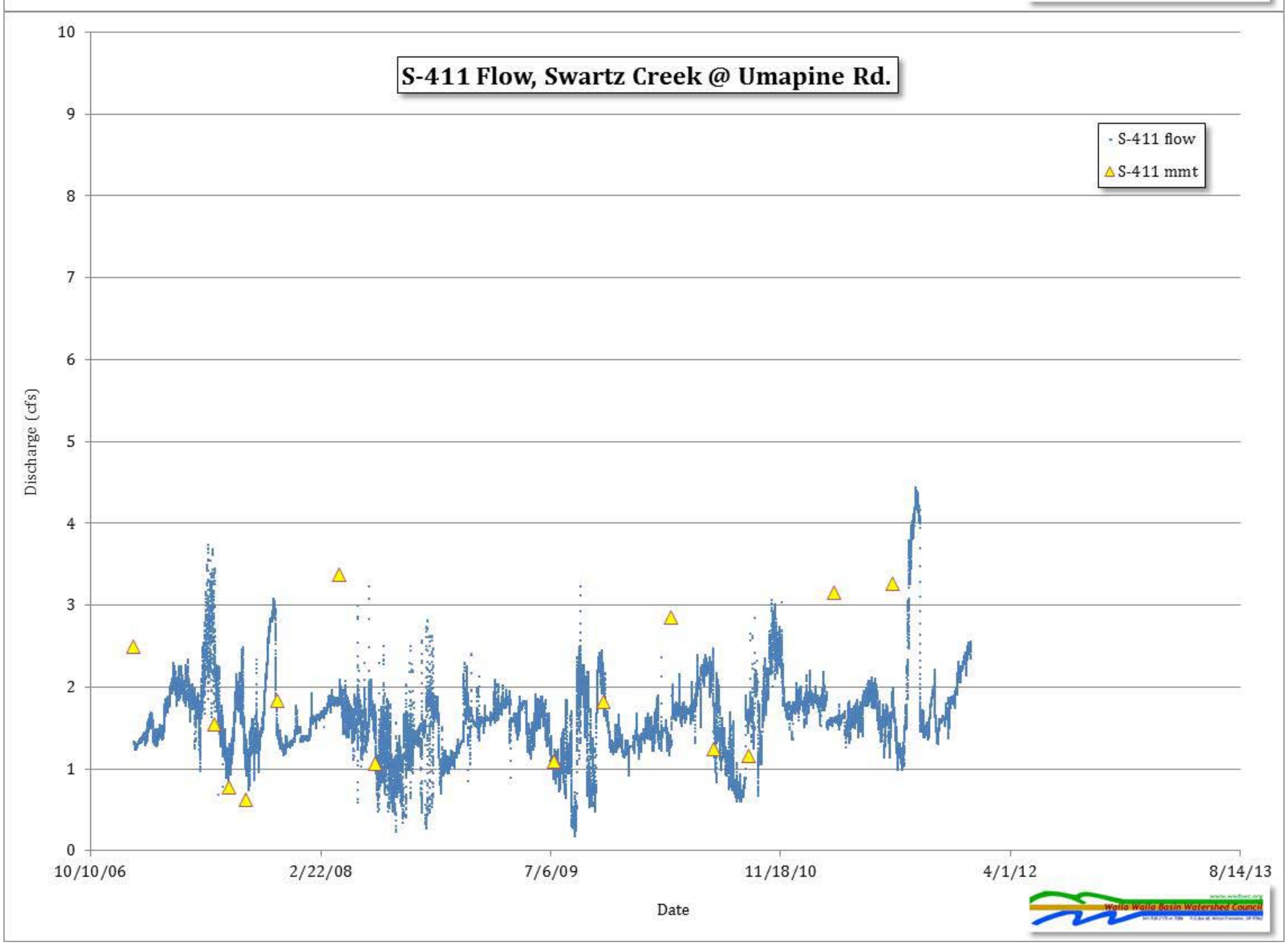

S-406 South Johnson Spring
Raw Gauge Height
S-406 height
Raw GH (feet)
Date
1/14/04
5/28/05
10/10/06
2/22/08
7/6/09
11/18/10
4/1/12
Walla Walla Basin Watershed Council

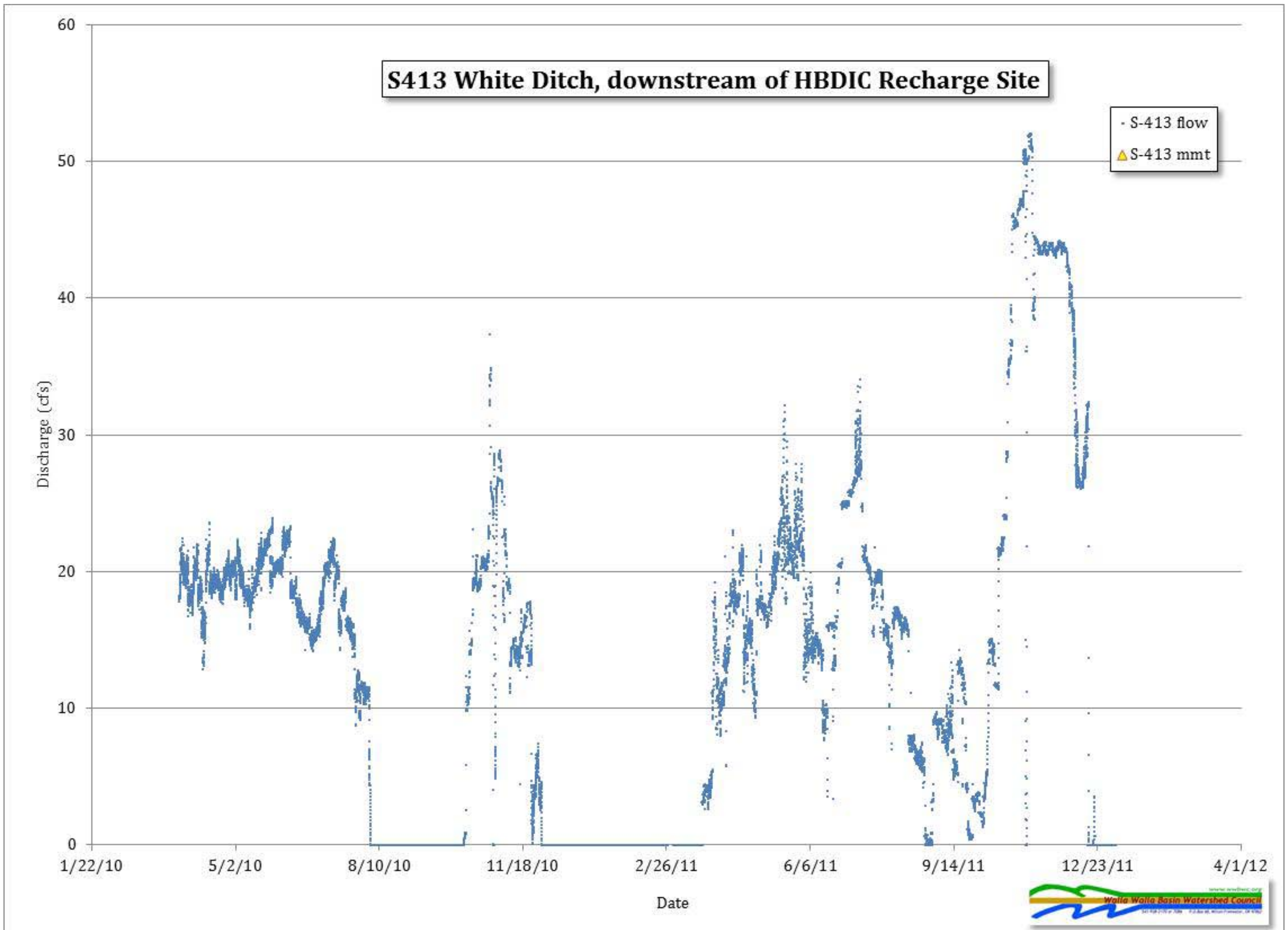

S-407 Dugger Creek Split Flow
S-407 flow
S-407 mmt
Discharge (cfs)
Date
9/1/02
1/14/04
5/28/05
10/10/06
2/22/08
7/6/09
11/18/10
4/1/12
8/14/13
Walla Walla Basin Watershed Council

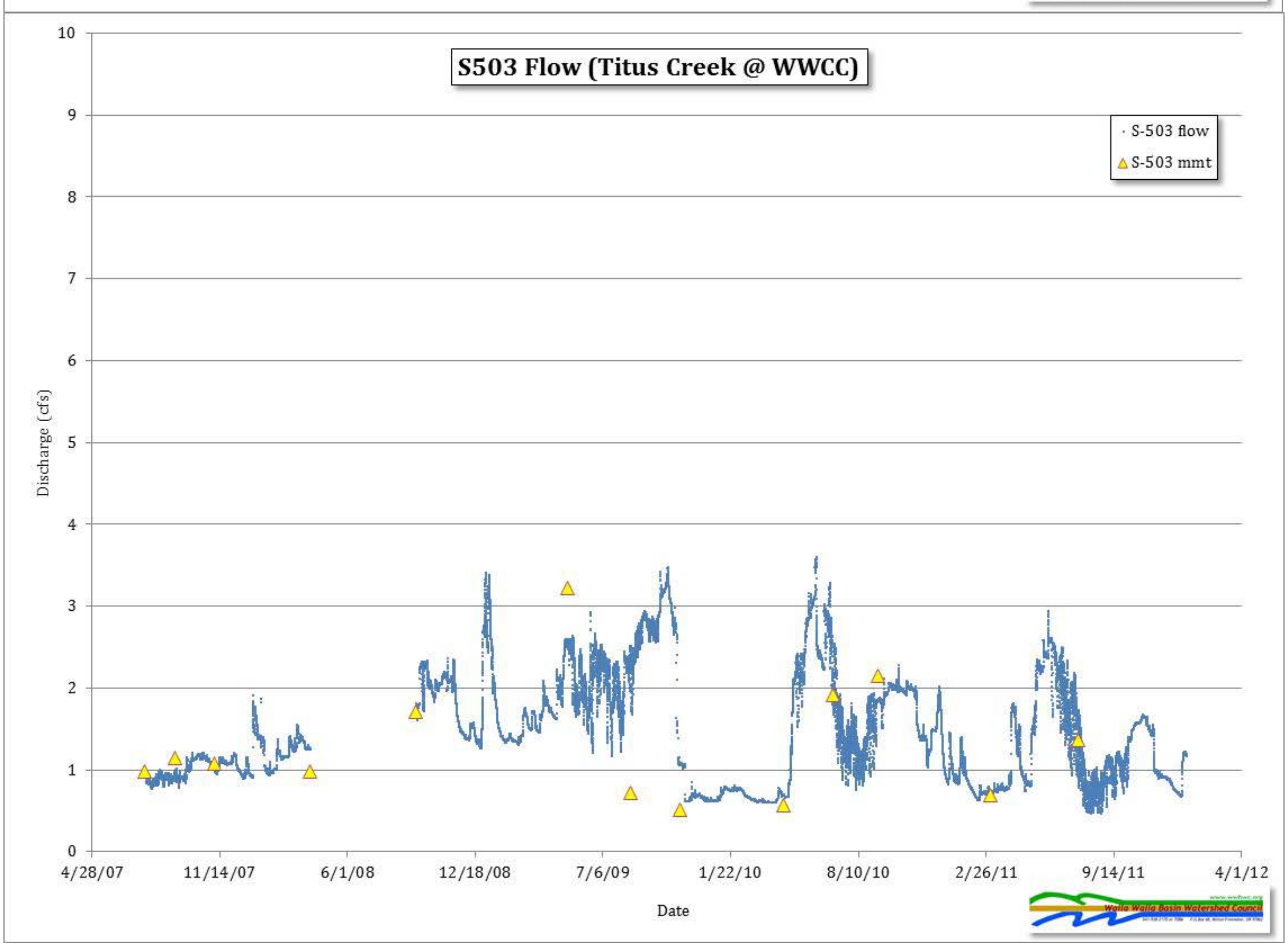

S-408 Johnson Creek East Umapine Flow
S-408 flow
S-408 mmt
Discharge (cfs)
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
5/28/05
10/10/06
2/22/08
7/6/09
11/18/10
4/1/12
8/14/13
Date
Walla Walla Basin Watershed Council

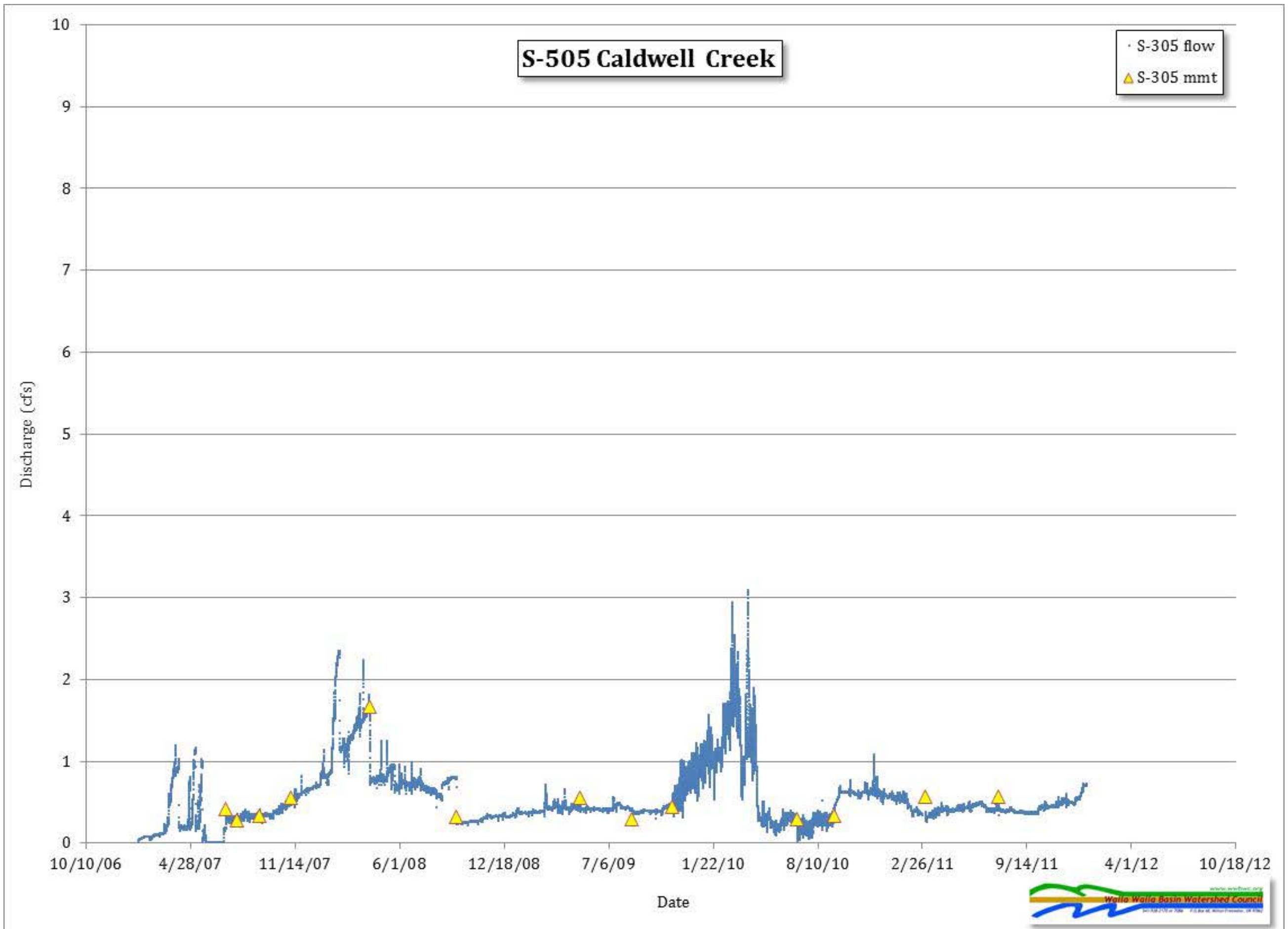

S-409 HBDIC Overflow on Grabner
S-409 flow
S-409 mmt
Discharge (cfs)
10
9
8
7
6
5
4
3
2
1
0
10/10/06
2/22/08
7/6/09
11/18/10
4/1/12
8/14/13
Date
Walla Walla Basin Watershed Council

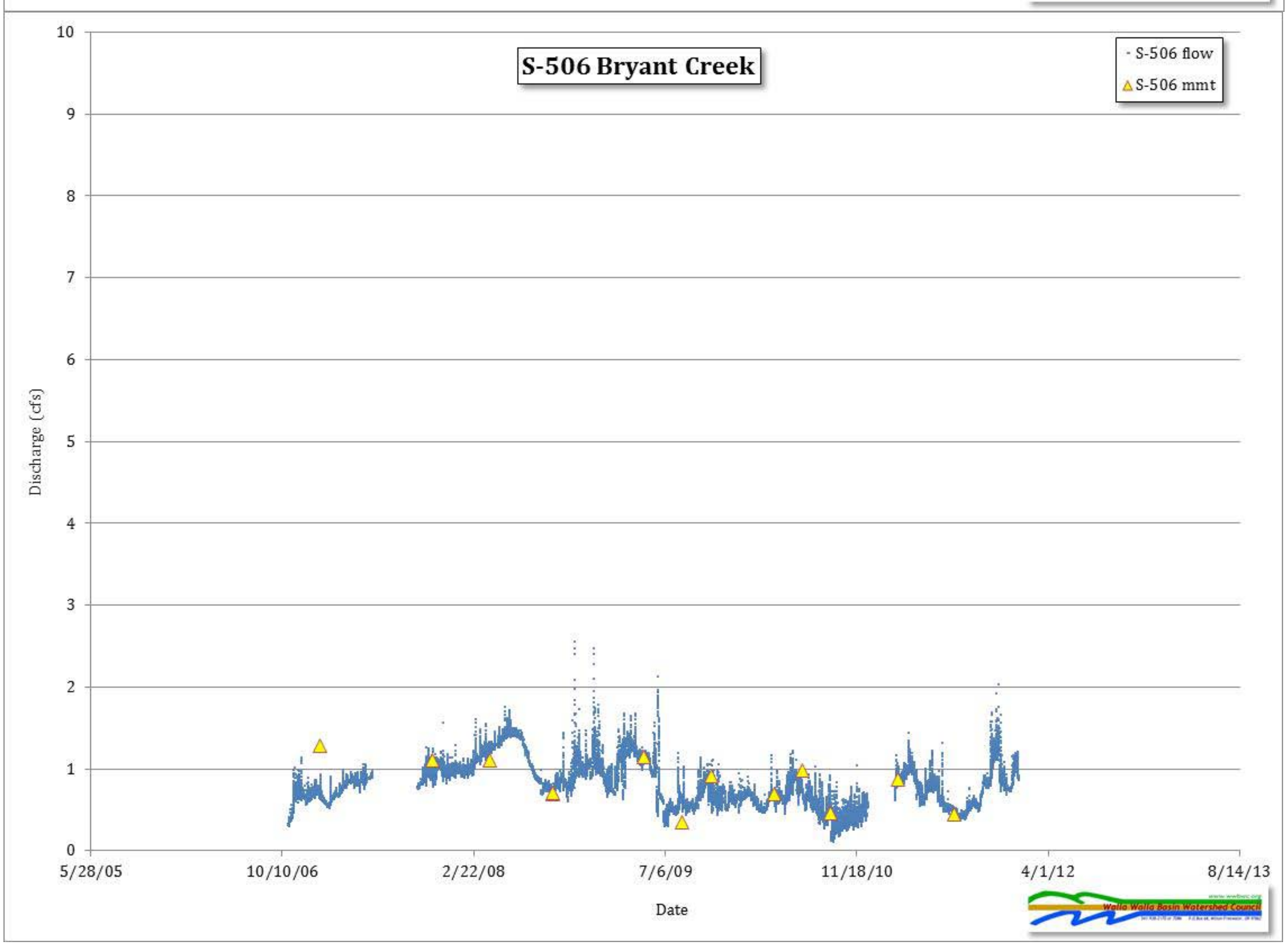

S-410 Johnson Creek Flows
S-410 flow
S-410 mmt
Discharge (cfs)
Date
10
9
8
7
6
5
4
3
2
1
0
5/28/05
10/10/06
2/22/08
7/6/09
11/18/10
4/1/12
8/14/13
Walla Walla Basin Watershed Council

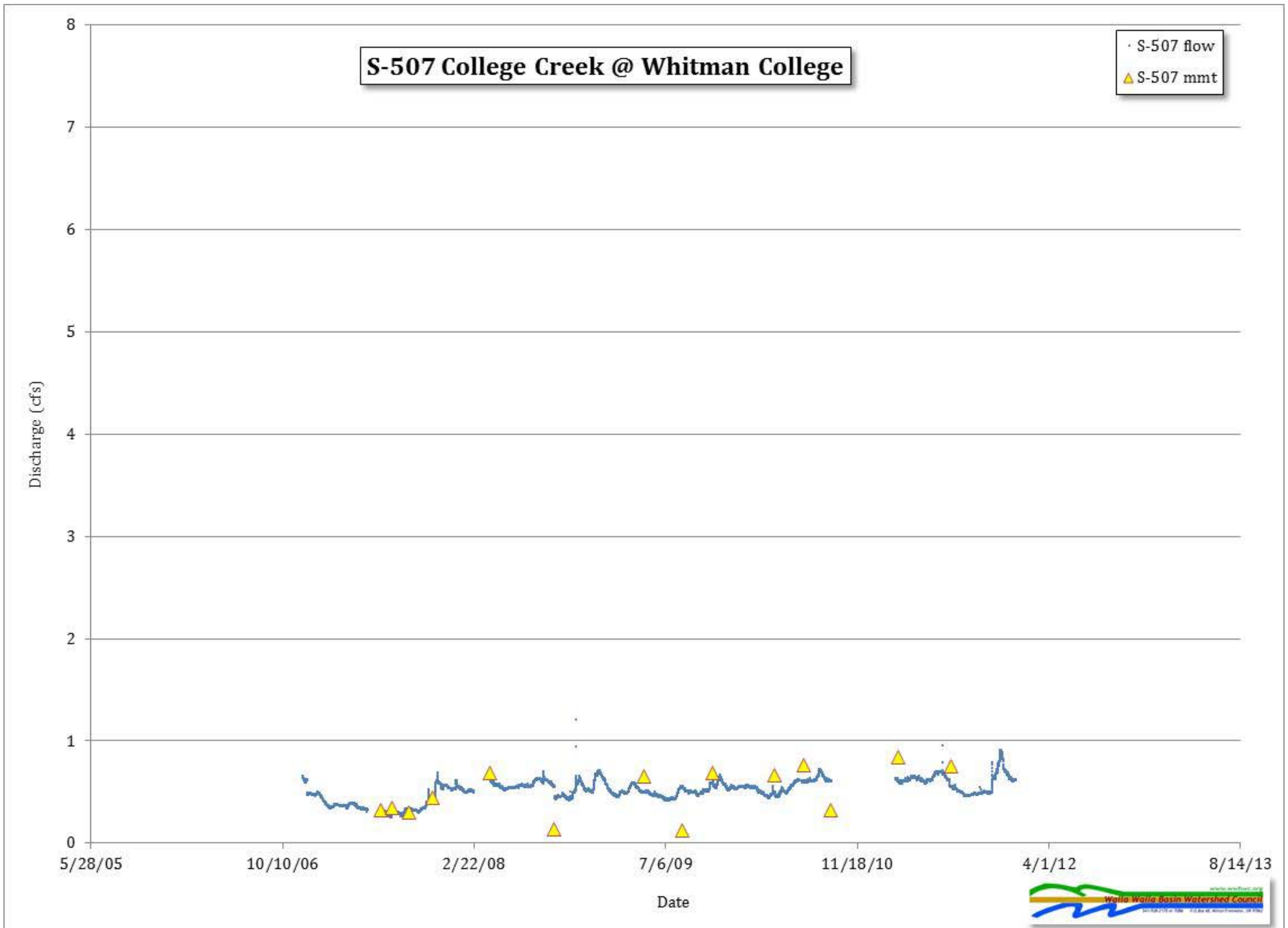

S-411 Flow, Swartz Creek @ Umapine Rd.
S-411 flow
S-411 mmt
Discharge (cfs)
Date
10
9
8
7
6
5
4
3
2
1
0
10/10/06
2/22/08
7/6/09
11/18/10
4/1/12
8/14/13
Walla Walla Basin Watershed Council


S413 White Ditch, downstream of HBDIC Recharge Site
S-413 flow
S-413 mmt
Discharge (cfs)
60
50
40
30
20
10
0
1/22/10
5/2/10
8/10/10
11/18/10
2/26/11
6/6/11
9/14/11
12/23/11
4/1/12
Date
Walla Walla Basin Watershed Council

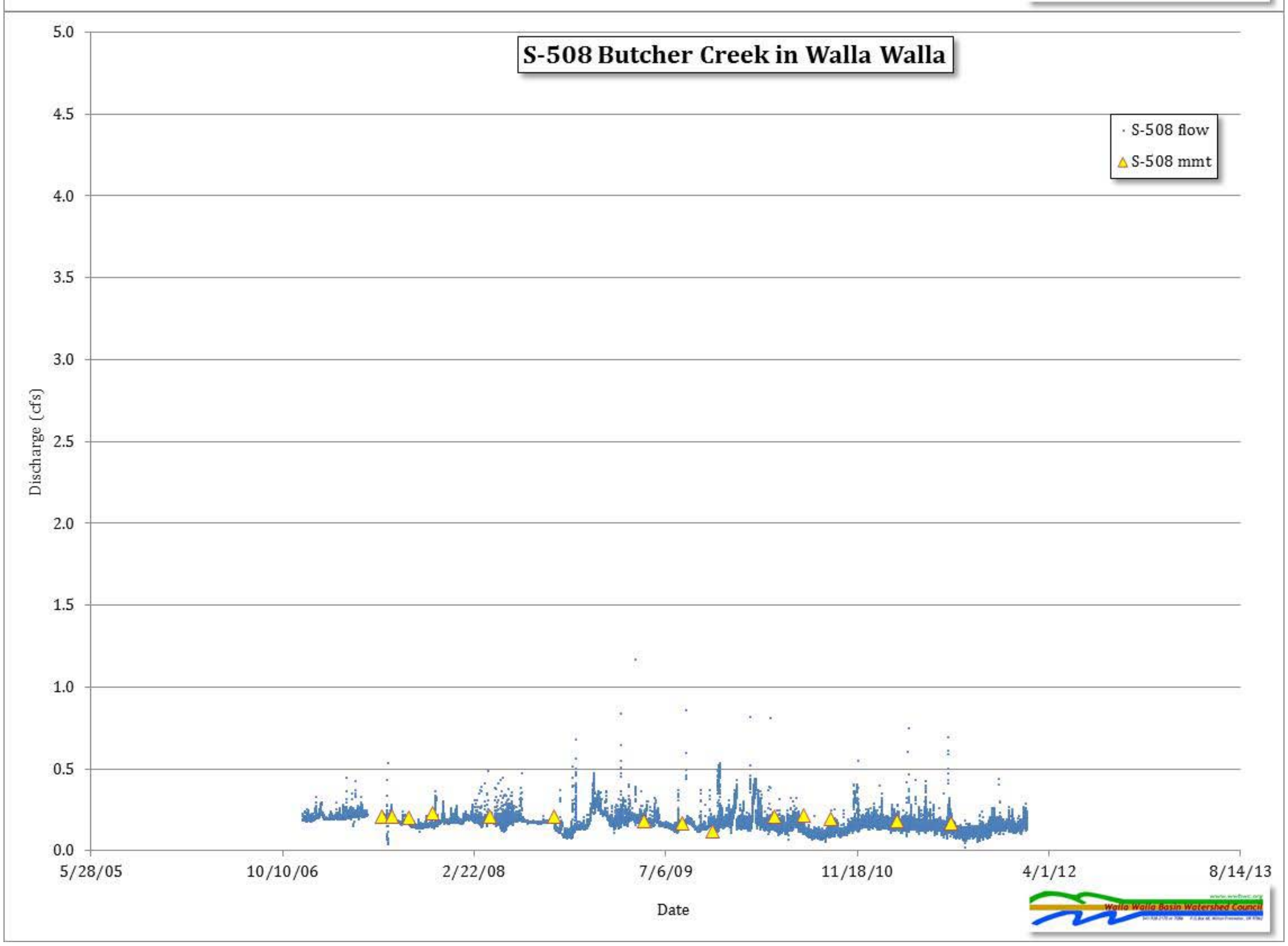

S503 Flow (Titus Creek @ WWCC)
S-503 flow
S-503 mmt
Discharge (cfs)
10
9
8
7
6
5
4
3
2
1
0
4/28/07
11/14/07
6/1/08
12/18/08
7/6/09
1/22/10
8/10/10
2/26/11
9/14/11
4/1/12
Date
Walla Walla Basin Watershed Council


S-505 Caldwell Creek
S-305 flow
S-305 mmt
Discharge (cfs)
Date
10
9
8
7
6
5
4
3
2
1
0
10/10/06
4/28/07
11/14/07
6/1/08
12/18/08
7/6/09
1/22/10
8/10/10
2/26/11
9/14/11
4/1/12
10/18/12
Walla Walla Basin Watershed Council

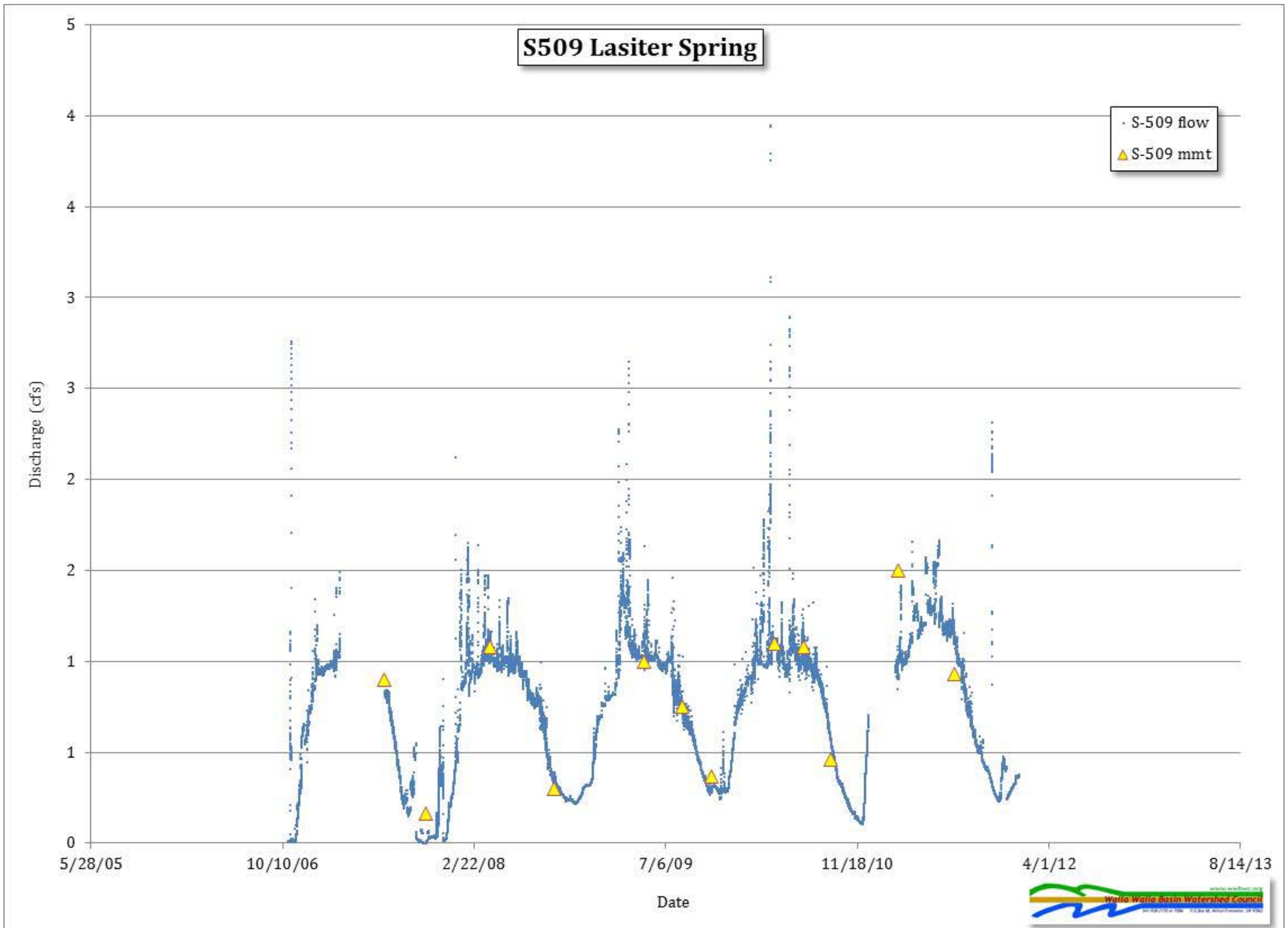

S-506 Bryant Creek
S-506 flow
S-506 mmt
Discharge (cfs)
Date
10
9
8
7
6
5
4
3
2
1
0
5/28/05
10/10/06
2/22/08
7/6/09
11/18/10
4/1/12
8/14/13
Walla Walla Basin Watershed Council

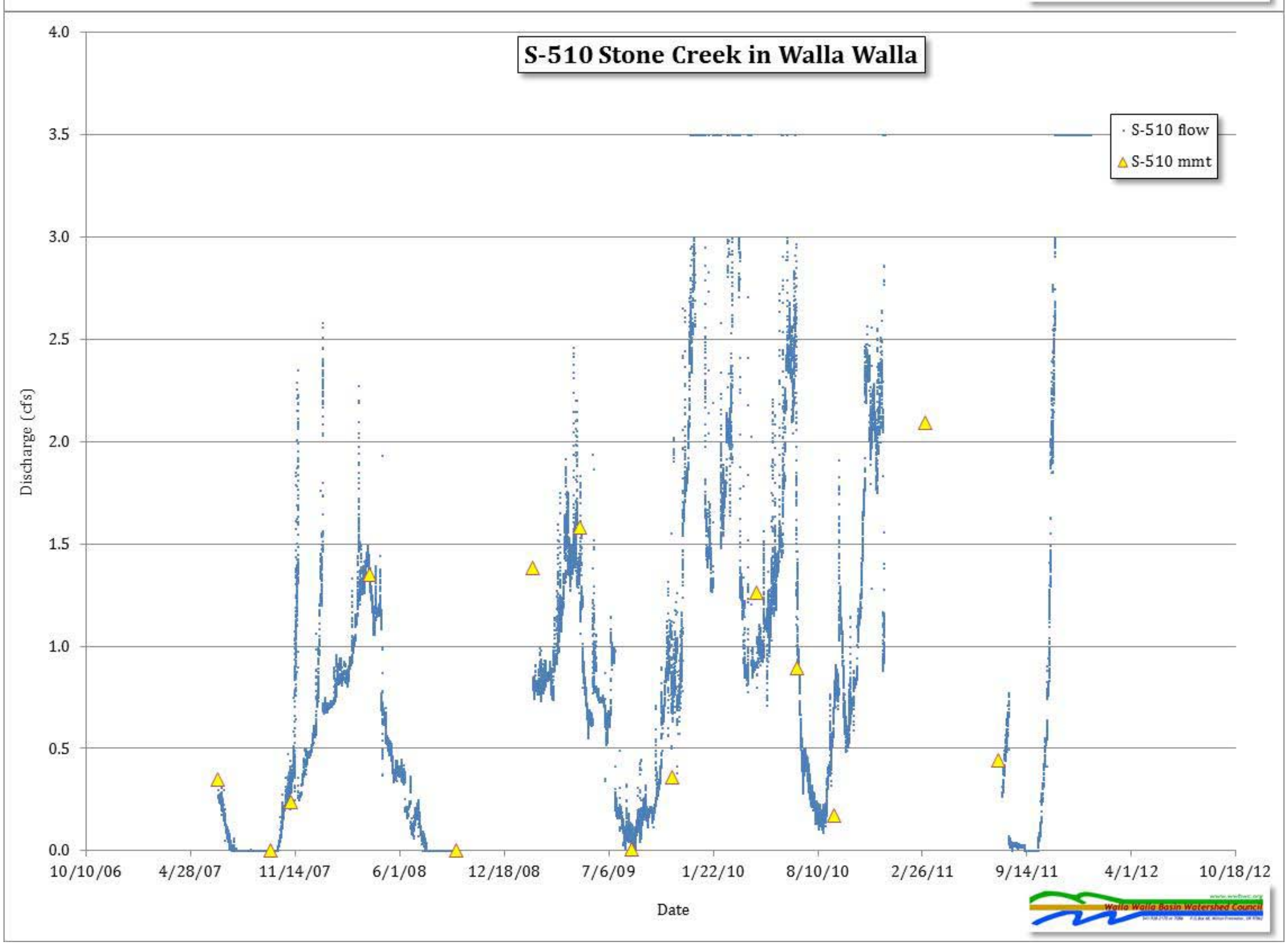


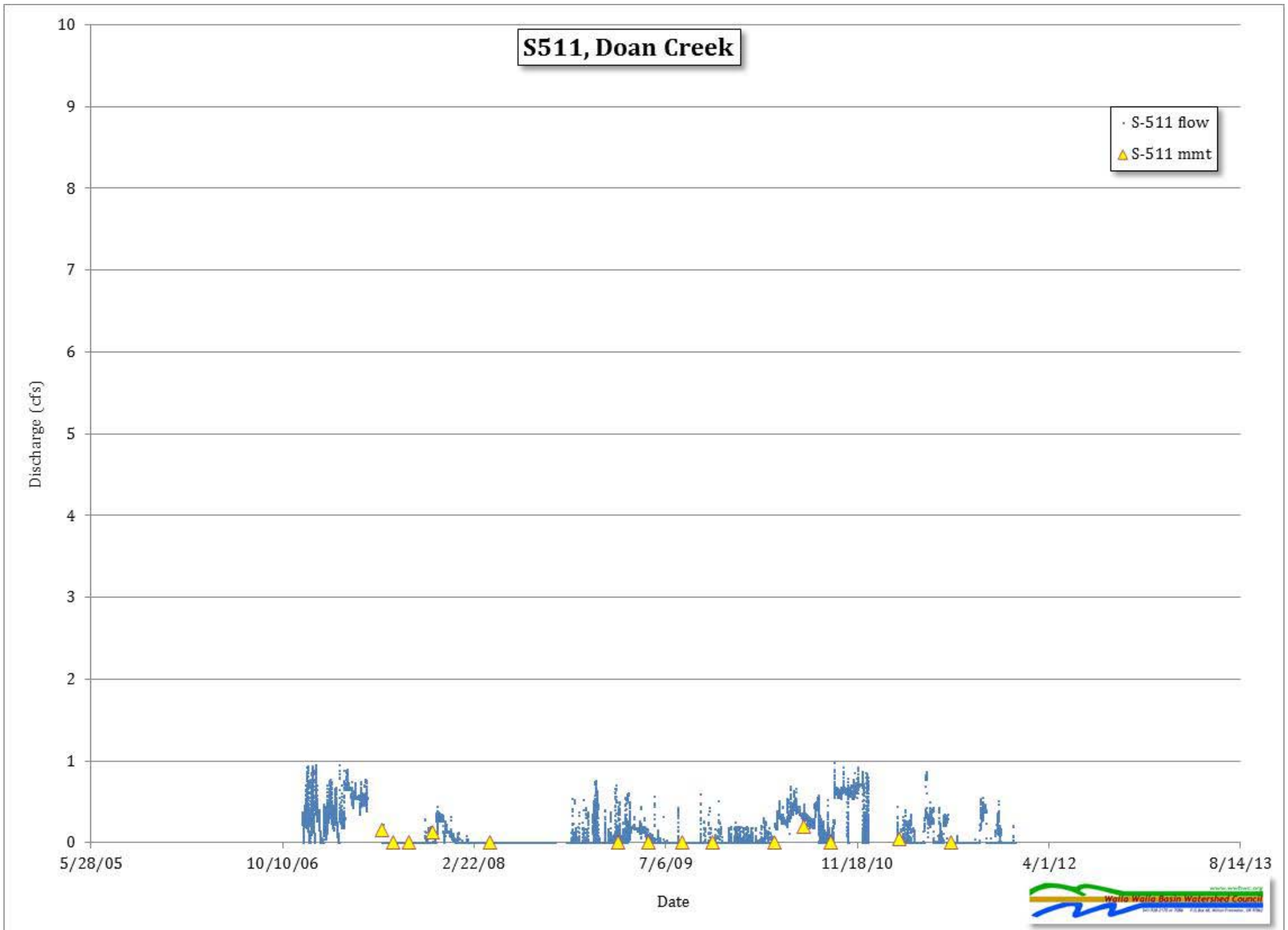
S-507 College Creek @ Whitman College
S-507 flow
S-507 mmt
Discharge (cfs)
0
1
2
3
4
5
6
7
8
5/28/05
10/10/06
2/22/08
7/6/09
11/18/10
4/1/12
8/14/13
Date
Walla Walla Basin Watershed Council

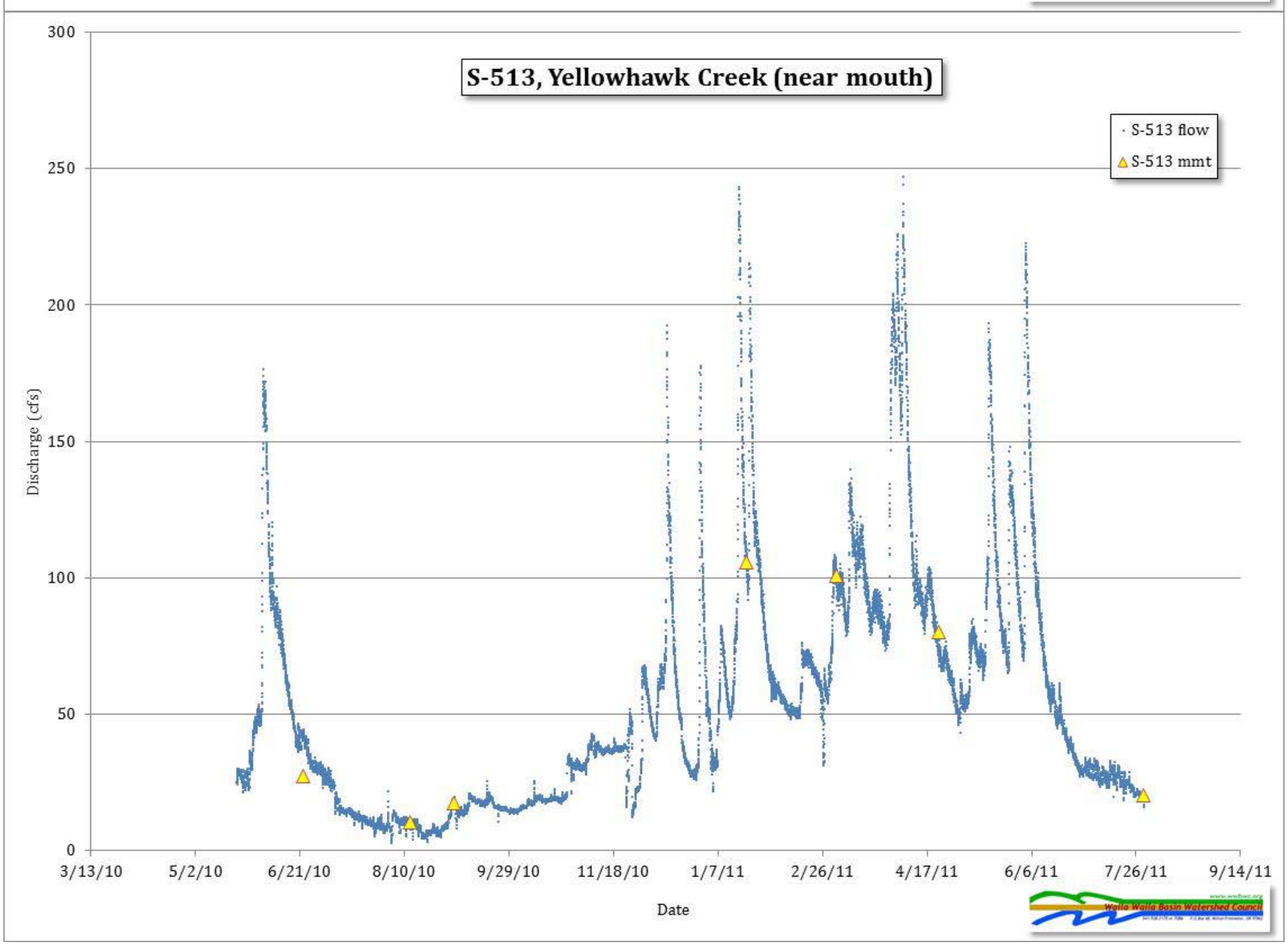


S-508 Butcher Creek in Walla Walla
S-508 flow
S-508 mmt
Discharge (cfs)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5/28/05
10/10/06
2/22/08
7/6/09
11/18/10
4/1/12
8/14/13
Date
Walla Walla Basin Watershed Council


S509 Lasiter Spring
S-509 flow
S-509 mmt
Discharge (cfs)
Date
5/28/05
10/10/06
2/22/08
7/6/09
11/18/10
4/1/12
8/14/13
Walla Walla Basin Watershed Council

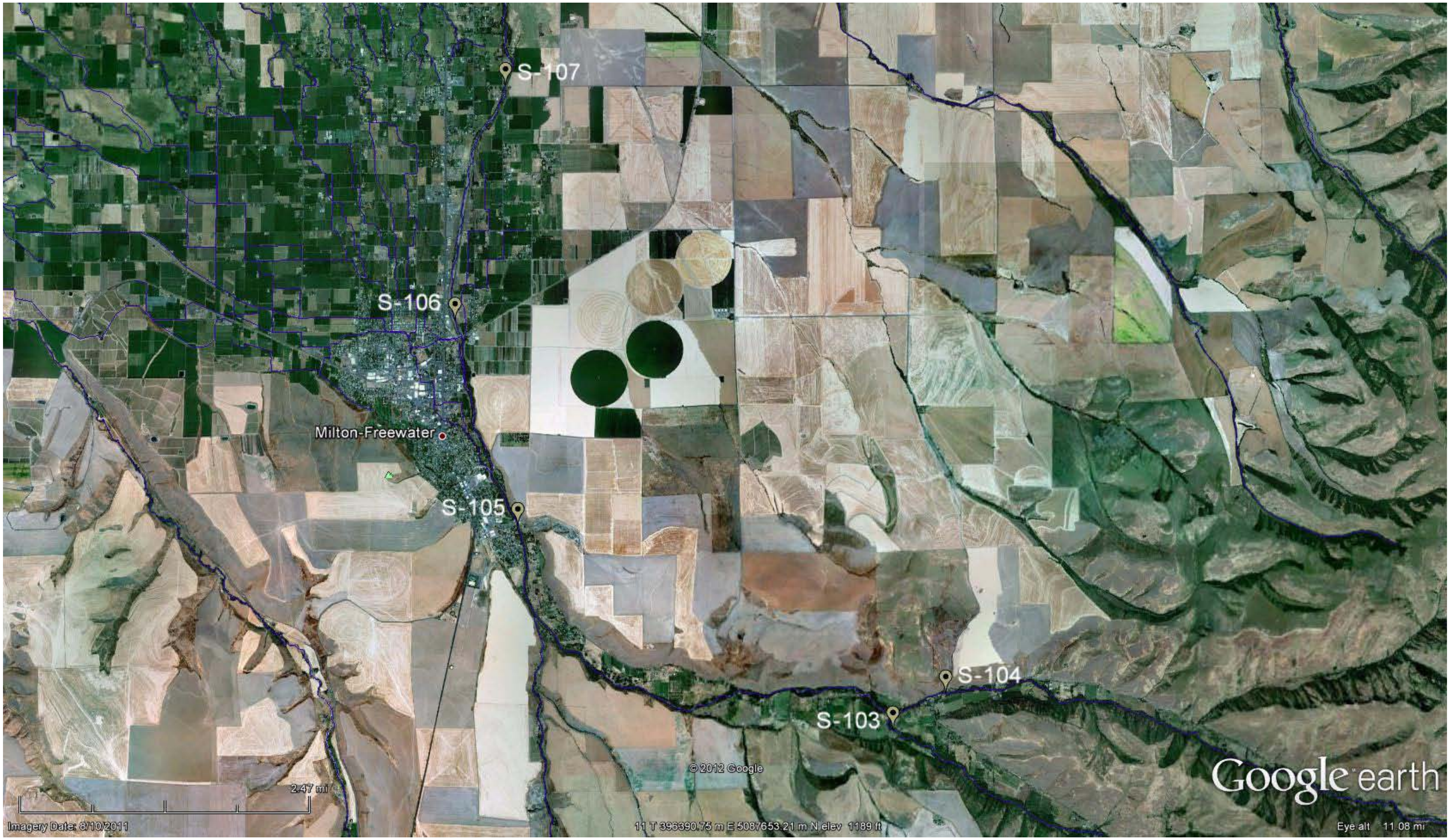

S-510 Stone Creek in Walla Walla
S-510 flow
S-510 mmt
Discharge (cfs)
Date
10/10/06
4/28/07
11/14/07
6/1/08
12/18/08
7/6/09
1/22/10
8/10/10
2/26/11
9/14/11
4/1/12
10/18/12
Walla Walla Basin Watershed Council


S511, Doan Creek
S-511 flow
S-511 mmt
Discharge (cfs)
10
9
8
7
6
5
4
3
2
1
0
5/28/05
10/10/06
2/22/08
7/6/09
11/18/10
4/1/12
8/14/13
Date
Walla Walla Basin Watershed Council

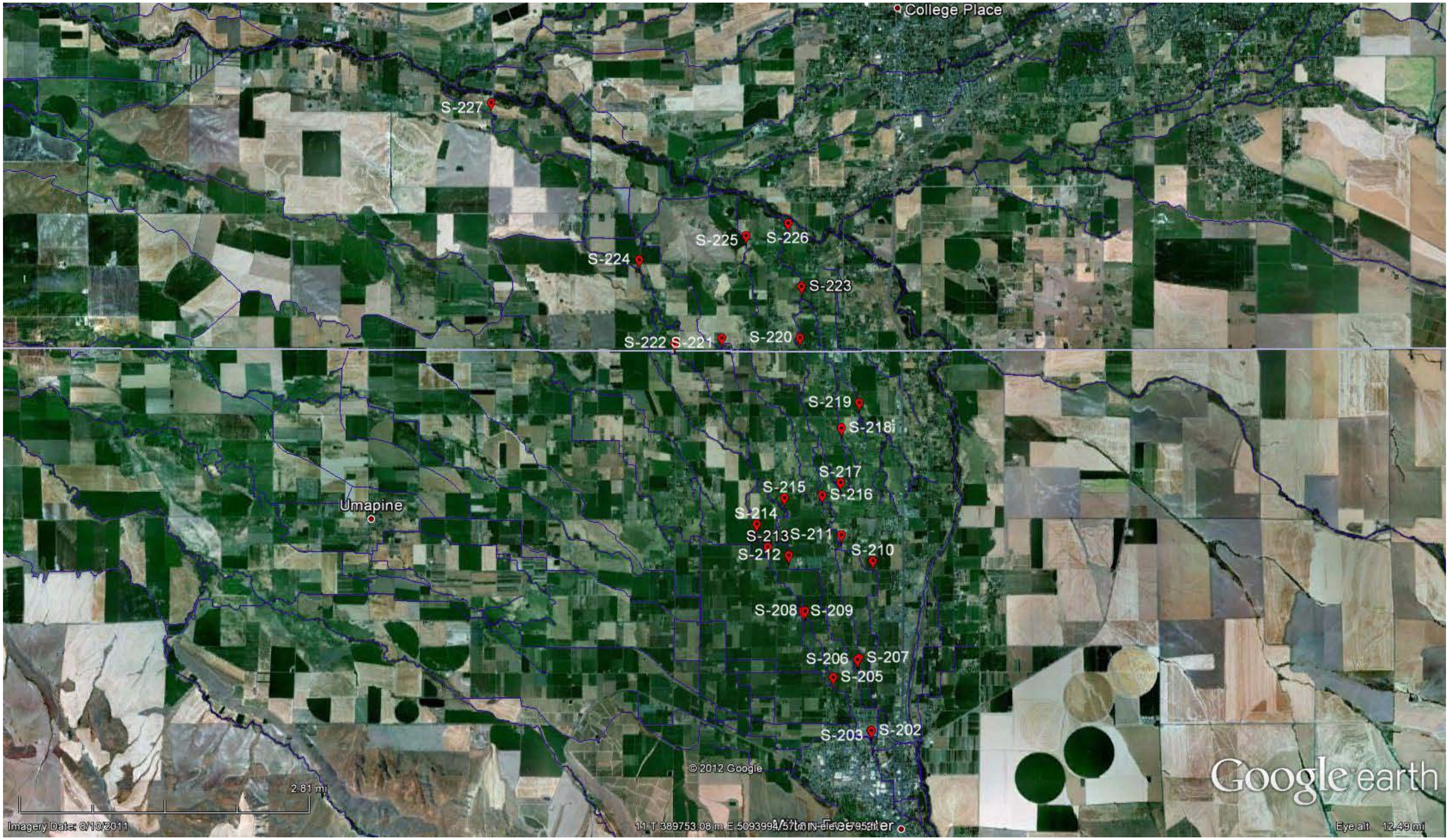

S-513, Yellowhawk Creek (near mouth)
S-513 flow
S-513 mmt
Discharge (cfs)
300
250
200
150
100
50
0
3/13/10
5/2/10
6/21/10
8/10/10
9/29/10
11/18/10
1/7/11
2/26/11
4/17/11
6/6/11
7/26/11
9/14/11
Date
Walla Walla Basin Watershed Council

Appendix F: Site Location Maps

1xx Sites

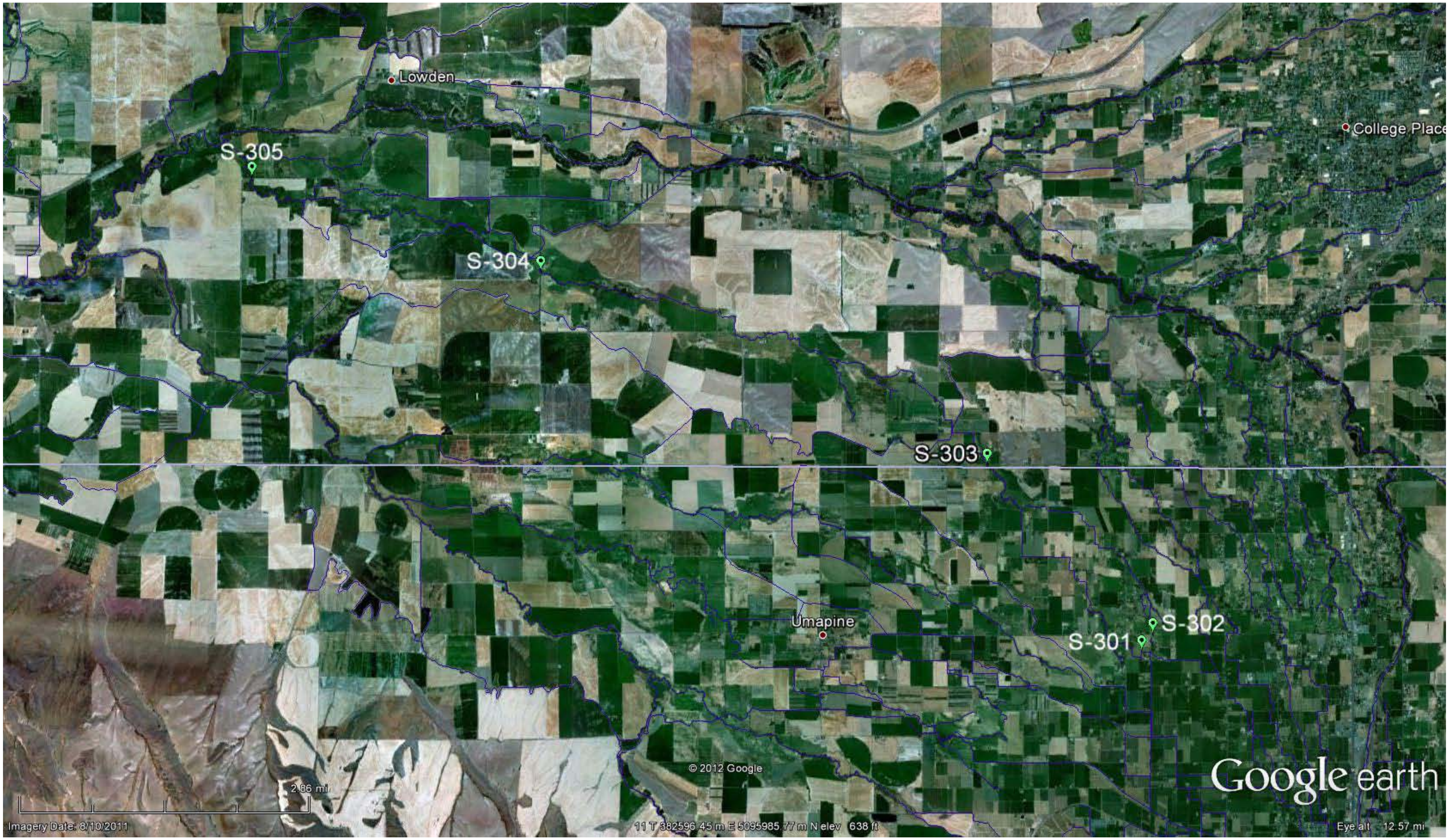


2xx Sites



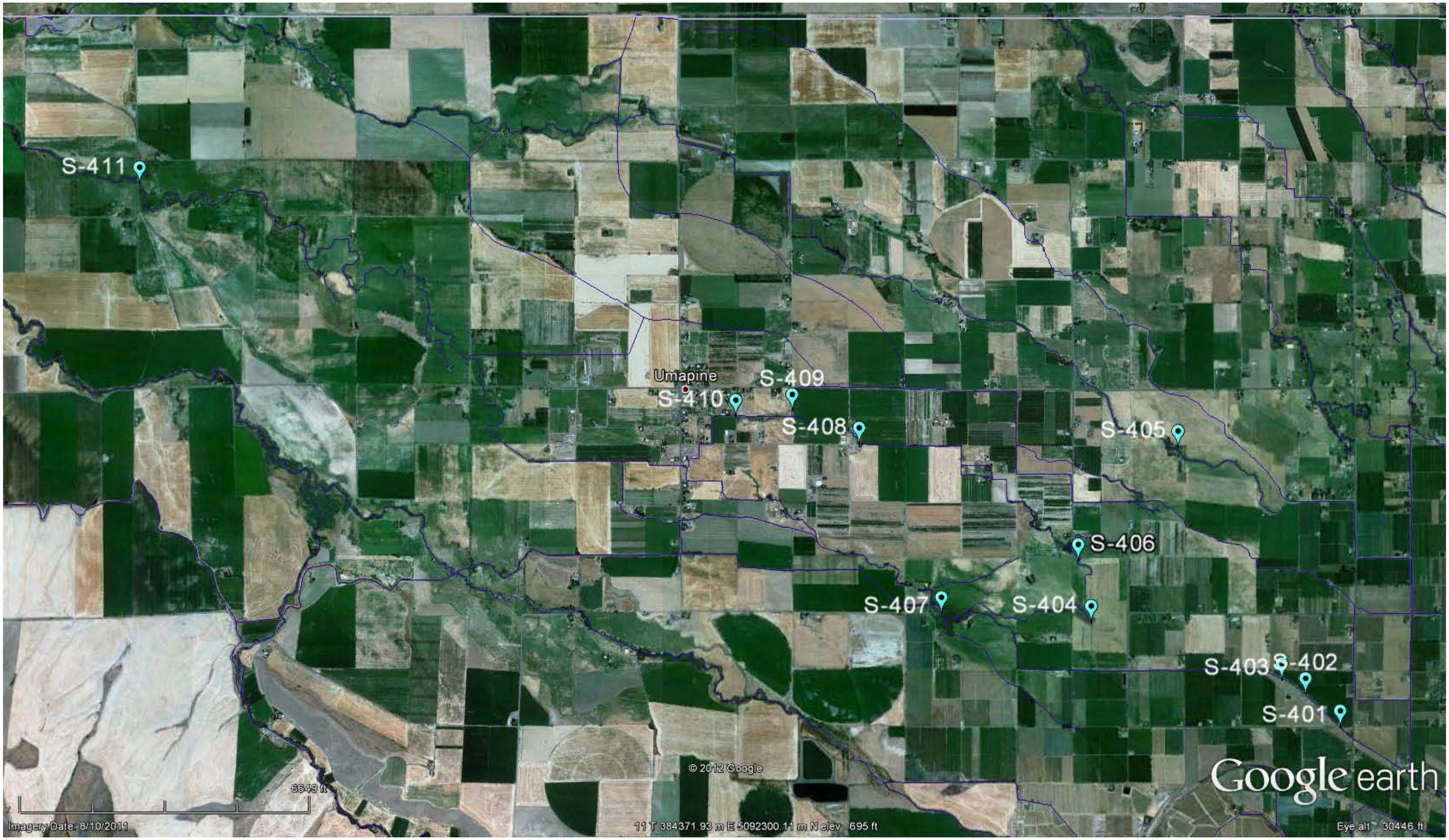
College Place
S-227
S-225
S-226
S-224
S-223
S-222
S-221
S-220
S-219
S-218
S-217
S-215
S-216
Umapine
S-214
S-213
S-211
S-210
S-212
S-208
S-209
S-206
S-207
S-205
S-203
S-202
© 2012 Google
2.81 mi
Imagery Date: 8/10/2011
Google earth
Eye alt 12.49 mi

3xx Sites



Lowden
College Place
S-305
S-304
S-303
Umapine
S-302
S-301
© 2012 Google
2.86 mi
Imagery Date: 8/10/2011
11 T 382596.45 m E 5095985.77 m N elev 638 ft
Google earth
Eye alt 12.57 mi

4xx sites


S-411
Umapine
S-409
S-410
S-408
S-405
S-406
S-407
S-404
S-403
S-402
S-401
© 2012 Google
Google earth
6649 ft
Imagery Date: 8/10/2011
11 T 384371.93 m E 5092300.11 m N elev 695 ft
Eye alt 30446 ft

5xx Sites

S-503
S-508
S-507
Walla Walla
S-506
Walla Walla East
S-511
College Place
S-505
S-510
S-513
S-509
© 2012 Google
Google earth
10486 ft
Imagery Date: 8/10/2011
11 T 395508.72 m E 5099956.52 m N elev 892 ft
Eye alt 46001 ft

Appendix C

Shallow Aquifer Monitoring in the Walla Walla Basin 2010-2011

www.wwbwc.org
Walla Walla Basin Watershed Council
541-938-2170 or 7086 P.O.Box 68, Milton-Freewater, OR 97862

Shallow Aquifer Monitoring in the Walla Walla Basin

2010-2011

Final Report

Steven Patten - Environmental Scientist

steven.patten@wwbwc.org

Submitted: March 7th, 2012

In Cooperation with:

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Locher Road Recharge Site 9
Eastside Wells 9
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Shallow Aquifer Monitoring in the Walla Walla Basin

Introduction

Overview

Since 2001 the Walla Walla Basin Watershed Council (WWBWC) has been building a network of monitoring wells in the Walla Walla River Valley as part of its long-term efforts to understand the shallow (unconfined) alluvial aquifer. The primary objectives of establishing this network is to provide needed data for informed water management in the bi-state basin and help water and fisheries managers in the basin better understand surface-groundwater interactions as they relate to salmon recovery and groundwater sustainability. The monitoring network is also used to track the implementation of artificial shallow aquifer recharge projects currently in operation and provide data for modeling projects.

The WWBWC worked with the Oregon Water Resource Department (OWRD) and Washington Department of Ecology (WDOE) to develop protocols for monitoring well location, measurement, and maintenance. Many of the original monitoring wells in the network were established or drilled by OWRD and WDOE. Other partners in the basin such as Hudson Bay District Improvement Company (HBDIC), Gardena Farms Irrigation District #13 (GFID#13), Walla Walla River Irrigation District (WWRID), The Native Creek Society, and the city of Walla Walla have contributed to expand the monitoring network through providing well access, historical information and landowner outreach. Some of the dedicated monitoring wells were established as part of the growing shallow aquifer recharge program throughout the valley. See Table 1 for a summary of the established monitoring wells.

Table 1. Well overview of the Shallow Aquifer Monitoring Network.

Monitoring Group	State	Number of Wells
OWRD	Oregon	9
WWBWC	Oregon	46
WDOE	Washington	22
City of Walla Walla	Washington	5
WWBWC	Washington	22

Well monitoring consists of measuring the water level, or the depth to water, water temperature and specific conductivity. The well monitoring network is comprised of two types of monitoring wells: continuous monitoring wells, instrumented with pressure transducers that measure water level every 15 minutes, and non-continuous wells which are measured manually approximately every three months. Temperature and conductivity measurements are taken quarterly at both types of monitoring wells if access permits.

In addition to well data collection, WWBWC also performed an extensive search for historical records and information about wells in the network. This historical and background information was compiled in 2008 and documented in the Monitoring Well Notebook, which includes water rights, well logs, USGS, WDOE and OWRD historical water level measurements, well GPS coordinates, elevation, maps, and photos of the wells. During the second phase of the Watershed Management Initiative all of the wells were surveyed, giving accurate longitude, latitude and elevation[1]. The Monitoring Well Notebook serves as institutional memory of the monitoring network and gives insight into historical uses and conditions of the wells and aquifer. It also allows WWBWC to easily share well information with the community and other agencies. As the well monitoring network continues to grow, new wells are incorporated into the Monitoring Well Notebook.

Shallow Aquifer Monitoring Area

The Walla Walla Valley River Basin is a bi-state system located in northeastern Oregon and southeastern Washington (Figure 1). The river basin is approximately 1,760 square miles, with an underlying shallow alluvial aquifer of 200 square miles (Figure 2). Shallow depth-to-water in certain locations in the valley and year round supply make the shallow aquifer a highly important source of water for irrigated agricultural lands as well as domestic and livestock uses.

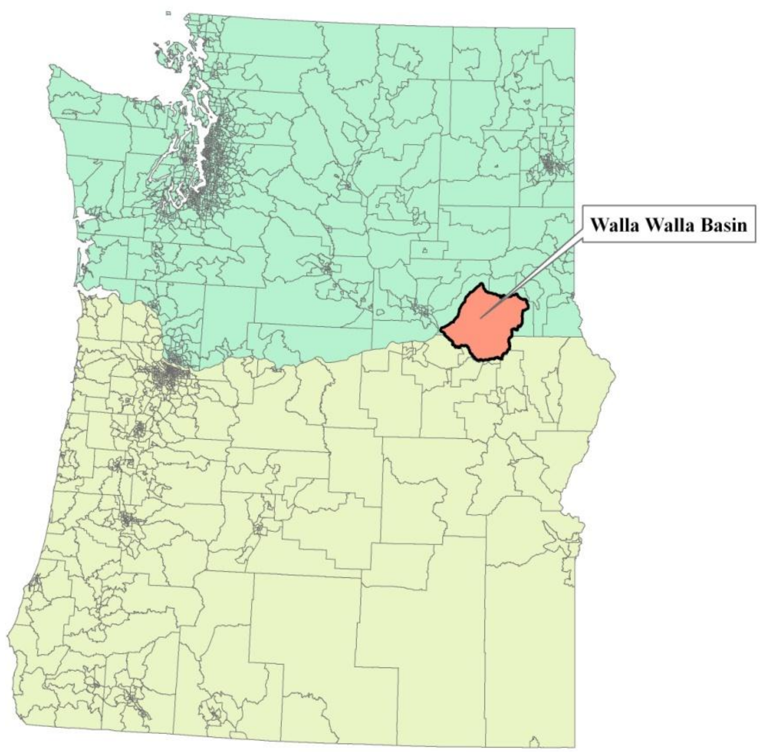

Figure 1. The bi-state Walla Walla River Basin in northeastern Oregon and southeastern Washington.

[1] Patten, S. 2010. *GPS Survey Report.* Walla Walla Basin Watershed Council, www.wwbwc.org.

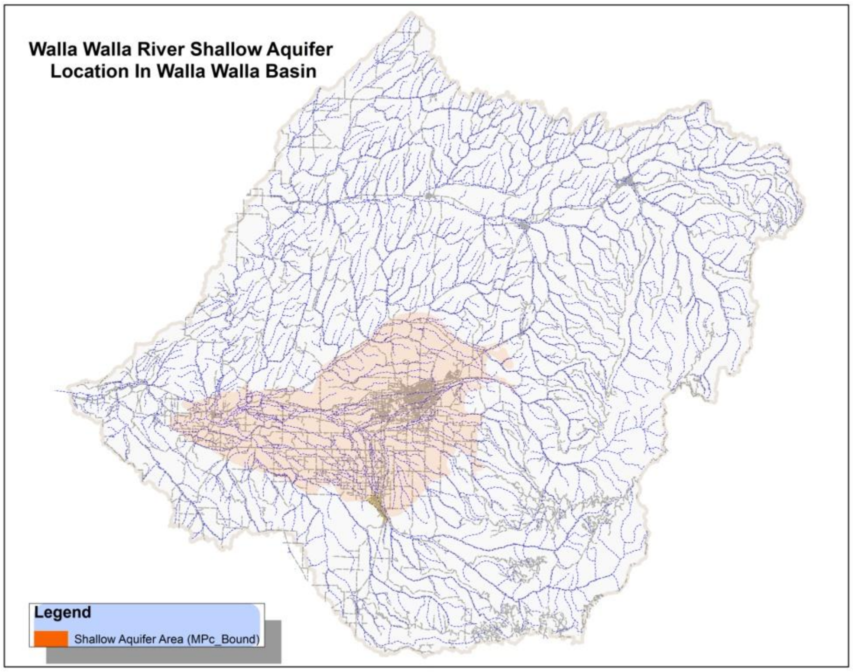

Figure 2. The Walla Walla River Basin with the underlying shallow alluvial aquifer.

In addition to supplying water for the wells, the shallow alluvial aquifer also feeds the numerous springs, streams, and rivers of the Walla Walla basin. The high connectivity between the shallow aquifer and surface water bodies is important for enhancing base flows and cooling water temperatures for reintroduced salmon and threatened steelhead and bull trout in the basin.[2]

Starting in 2001, the WWBWC and its partners have been building a community-based groundwater monitoring network. This network was developed to enhance knowledge about long-term water level trends and provide hydrogeologic information. In 2001, only a dozen shallow aquifer wells were monitored in Oregon and Washington. These wells were inadequate to effectively monitor and manage the vast aquifer which supplies hundreds of domestic and agricultural wells, provides water for the dozens of creeks and springs throughout the valley, and discharges cool water into the Walla Walla River during base flows. As of 2012, the WWBWC and its state and local partners monitor over 100 wells (Figure 3).

Wells included in the monitoring network include both urban and rural wells in and around Milton-Freewater, OR, Umapine, OR, Walla Walla, WA, College Place, WA, Lowden, WA, and Touchet, WA. The wells are owned by a variety of water users, including government agencies (state, county, and city), businesses, universities, and private landowners within the basin. Prior to drilling dedicated monitoring wells, most of the monitoring wells were irrigation (both active and abandoned) or old domestic wells owned by private land owners. All of the participating well owners do so voluntarily, aiding in the effort to understand and mitigate the decline of the aquifer: a critically important economic and ecological resource to the communities located within the Walla Walla Basin.

[2] Winter, T.C., *et al*. 1998. *Ground Water and Surface Water: A Single Resource.* U.S. Geological Survey Circular 1139.

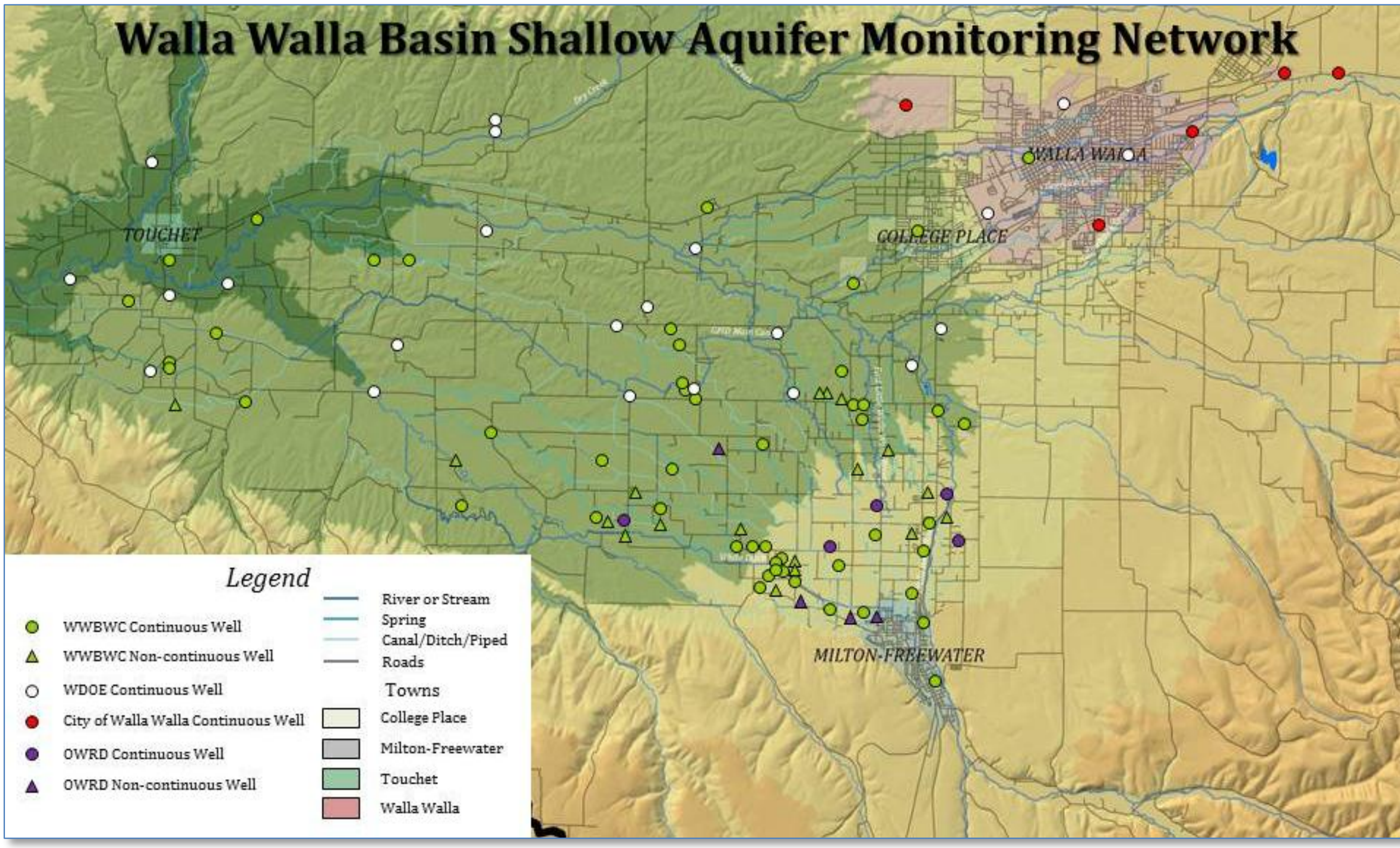

Figure 3. Map overview of wells in the Shallow Aquifer Monitoring Network as of the end of 2011.

Methodology

The WWBWC uses a modified USGS Quality Assurance (QA) document for its groundwater monitoring network (See Appendices). Almost all of the data collection procedures are identical, but there are differences in how the data are managed (e.g. different field data sheets and data analysis). Please see Appendix A for a copy of the Groundwater Monitoring QA document.

Non-continuous Wells

The shallow groundwater alluvial aquifer well network includes many non-continuous or quarterly monitored wells. Water level measurements for these wells are collected manually using an e-tape (Model 800, engineering tape, Waterline Envirotech Ltd, www.waterlineusa.com). All water level measurements are measured to an established measurement point and then adjusted for top of grade ("stickup height") so measurements are depth below ground surface.

Continuous Wells

Most of the monitoring network, more than three-fourths, consists of continuous monitoring wells which are instrumented with one of four different pressure transducers (Figure 4) that are suspended in the well below the water level, but not resting on the bottom of the well. Pressure transducers are suspended using 1/16th inch aviation cable, 14 gauge speaker wire, fishing line or a communication cable provided by the manufacture. The pressure transducers electronically determine and record the water pressure (pounds per square inch or feet of water) and water temperature (either °F or °C) once every 15 minutes. Transducer data are downloaded on a quarterly schedule. Manual water level measurements are made during the quarterly download to standardize the pressure transducers' data.

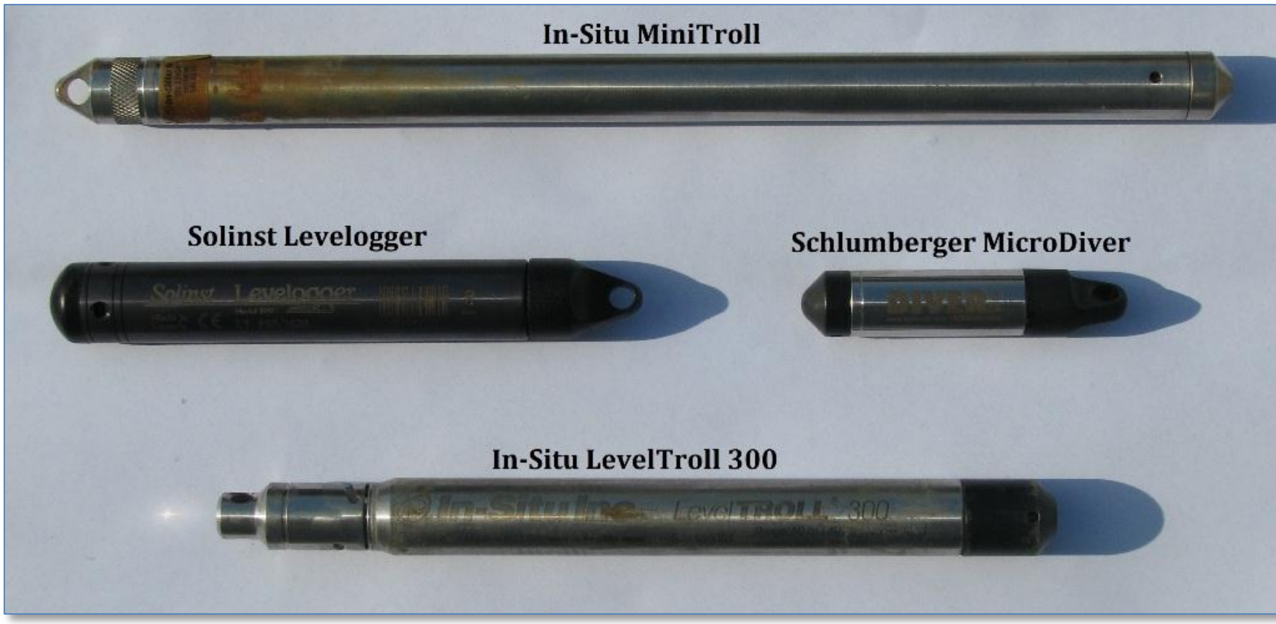

Figure 4. Pressure transducers used in the Shallow Aquifer Monitoring Network. Continuous wells have one of these pressure transducers deployed.

Manual Sampling (Water Level, Temperature and Conductivity)

Temperature and conductivity are measured at each well on a quarterly basis. Some wells did not have access points for collection of water for temperature and conductivity. Water samples are taken when the pressure transducer is downloaded or a water level measurement is taken. Water samples are collected using a bailer and transferred into a graduated cylinder.[3] Temperature and conductivity values are determined using a handheld conductivity meter (YSI 30, www.ysi.com). Pump condition (on or off) is also determined, if applicable, during each visit. A summary of continuous and non-continuous monitoring wells is shown in Table 2. Further details regarding transducer downloading, deployment, maintenance, and quarterly data collection can be found in Appendix A.

Data Processing and Analysis

Most of the loggers used by WWBWC are absolute (non-vented) loggers, therefore continuous pressure transducer data must be compensated for atmospheric pressure. Incorporated into the monitoring network are four (shortly moving to five) different barometric stations. Water level data are corrected using the data collected from dedicated barometric pressure transducers located throughout the valley (Figure 5). To prevent errors, the manufacturer's software is used for barometric compensation whenever possible. Water level data is converted from PSI to feet of water and subtracted from the estimated logger cable length (Estimated cable length is calculated by adding the manual water level measurement and the pressure reading from the transducer at the closest corresponding time to the manual measurement). This gives a depth to water value for each data point from the transducer data. The estimated logger cable length is determined for every manual water level measurement. Pressure transducer "drift" can be monitored by tracking the changes in the estimated cable length.

[3] Oregon Department of Environmental Quality. 1998. *DEQ Lab's Field Sampling Reference Guide.*

Table 2. Summary of well types in the Shallow Aquifer Monitoring Network.

Well Type	State	Number of Wells
Continuous with temperature and conductivity	Oregon	30
Continuous without temperature and conductivity	Oregon	6
Non-continuous with temperature and conductivity	Oregon	7
Non-continuous without temperature and conductivity	Oregon	12
Continuous with temperature and conductivity	Washington	40
Continuous without temperature and conductivity	Washington	6
Non-continuous with temperature and conductivity	Washington	0
Non-continuous without temperature and conductivity	Washington	3

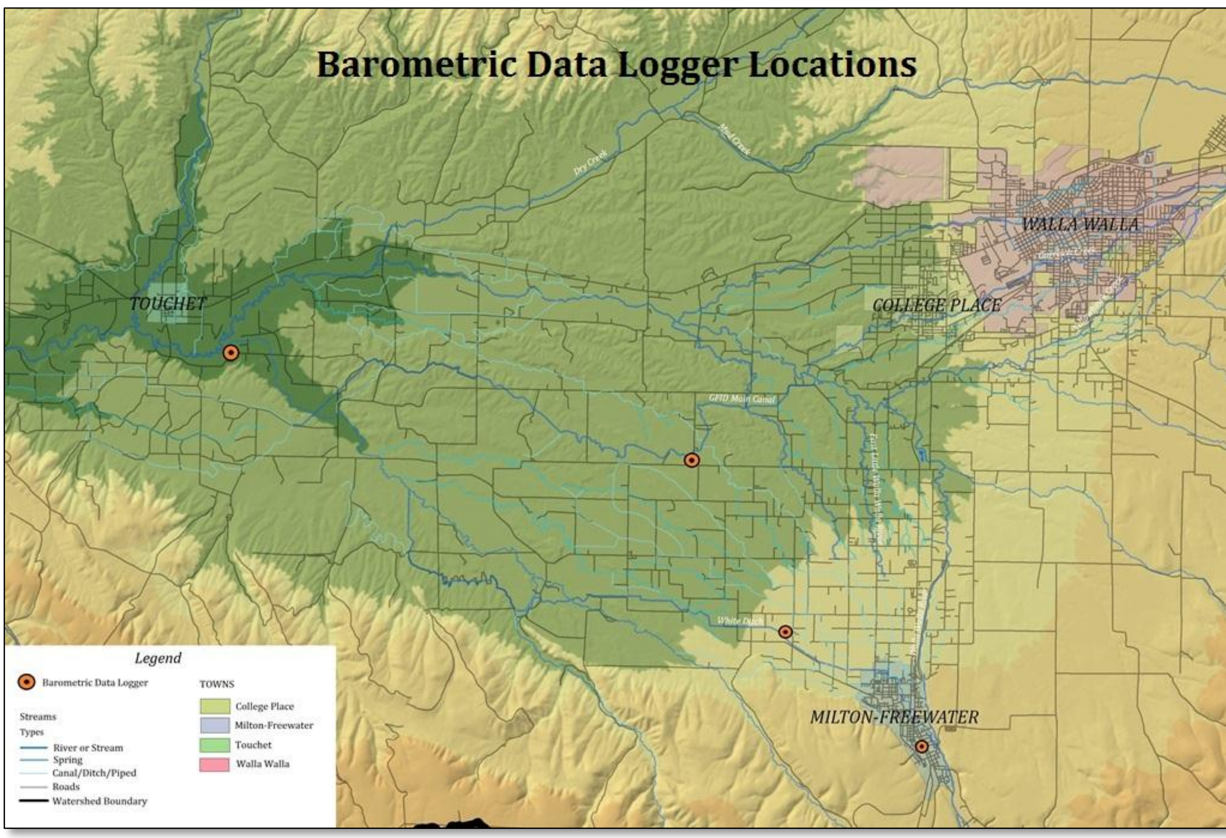

Figure 5. Barometric pressure transducer locations within the Shallow Aquifer Monitoring Network.

Pressure transducer data are graphed with manual water level measurements. Pressure transducer data are corrected to match manual water level measurements. This is normally done using the estimated cable length mentioned above, however occasionally this is done manually to account for logger hang-ups on pumps or other obstructions, well pumping during manual water measurement, and other irregularities. Graphed data allows for quick visual inspection to catch any mistakes in data entry, data analysis or in pressure transducer data.

Results

For all well data please visit the Watershed Council's website (www.wwbwc.org) and click on the groundwater monitoring button on the right side of the page. There you can view hydrographs, download data, and view metadata for the wells.

Historic Wells

Nine of the wells monitored in the shallow aquifer are historic wells with data going back to 1949 for most of them and 1933 for two of the wells (Figure 6). These wells are used to see long term trends in the Walla Walla basin's shallow alluvial aquifer. All but two of these wells have shown a declining water level (GW_22 and GW_57, Figures 7 & 8). One well, GW _17, was historically declining, but since the spring of 2005 has stabilized and possibly started to recover (Figure 9). Some of the historic wells are shallow hand-dug wells and have gone dry in the recent past, GW_25 has been dry since 2004 (Figure 10).

Recharge Monitoring Wells

Locher Road Recharge Site

This shallow aquifer recharge site has four monitoring wells associated with it and an array of down gradient wells that also provide groundwater level data (Figure 11). All of the monitoring wells at the recharge site show rising water levels (GW_57, 70-72, Figures 12-15). There are two up gradient wells to the southeast of the recharge site; one shows a declining water level and one shows a rising water level (GW_18 and GW_33, Figures 16 & 17). Wells down gradient, to the northwest, show recovering water levels (GW_110, 122, 103, 108, Figures 18-21).

Eastside Wells

Some wells east of the Tum-A-Lum reach of the Walla Walla River have shown dramatic declines or downward trends (Figures 22, 23, and 10).

Individual Wells

There are a number of wells that show a decline in water levels (Figure 24), for example, GW_28 has shown declining water levels over the last decade (Figures 25). GW_126, just north of Touchet, WA, is also showing a downward trend (Figure 26). Conversely, there are some wells that show a rising water level. The water levels in GW_106 and GW_113 have been trending upward over the last five years (Figures 27 & 28).

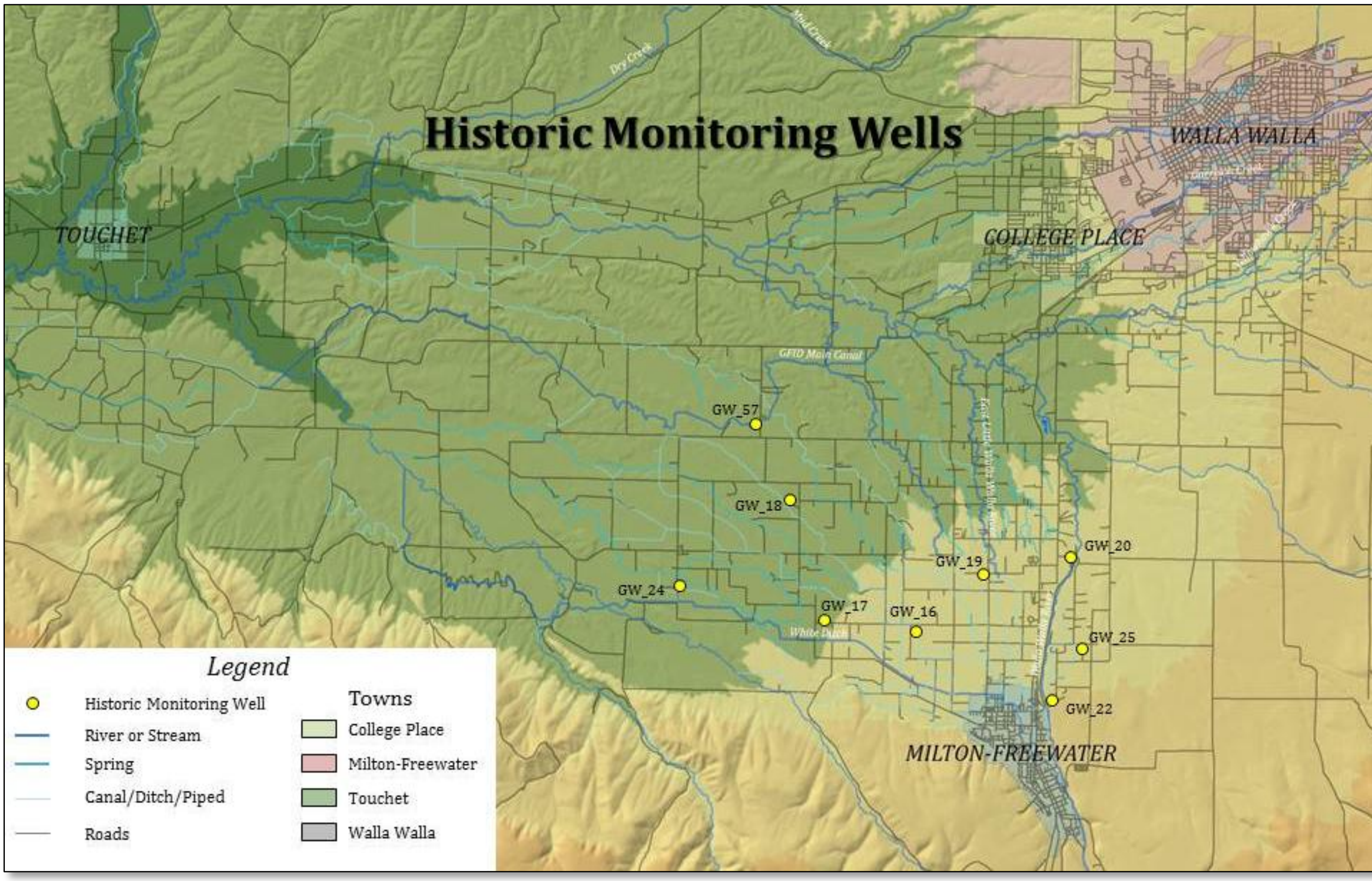

Figure 6. Historic wells included in the Shallow Aquifer Monitoring Network.

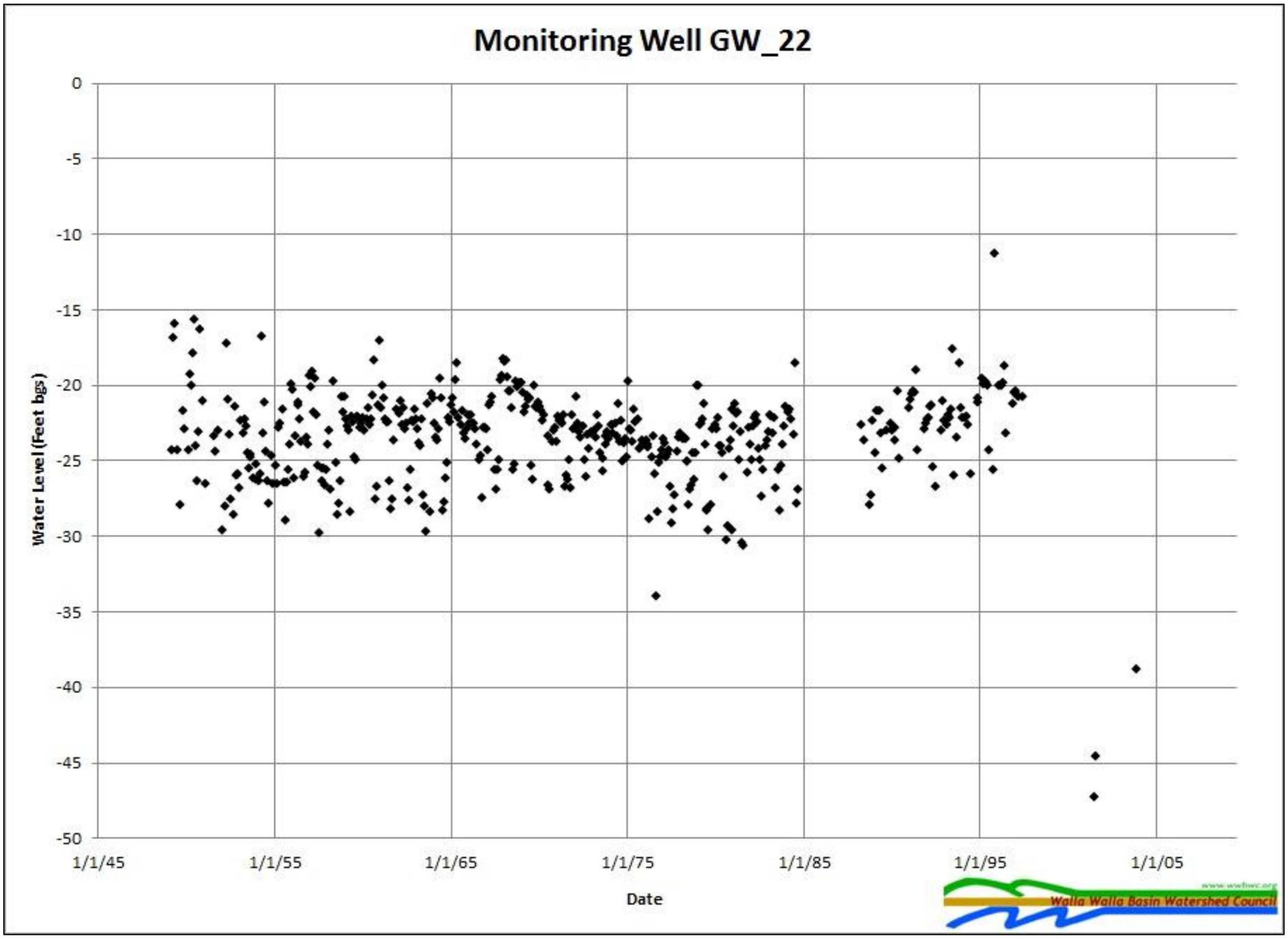

Figure 7. Manual water level measurements in feet below ground surface for the historic well GW_22 located in the WWBWC's Shallow Aquifer Monitoring Network.

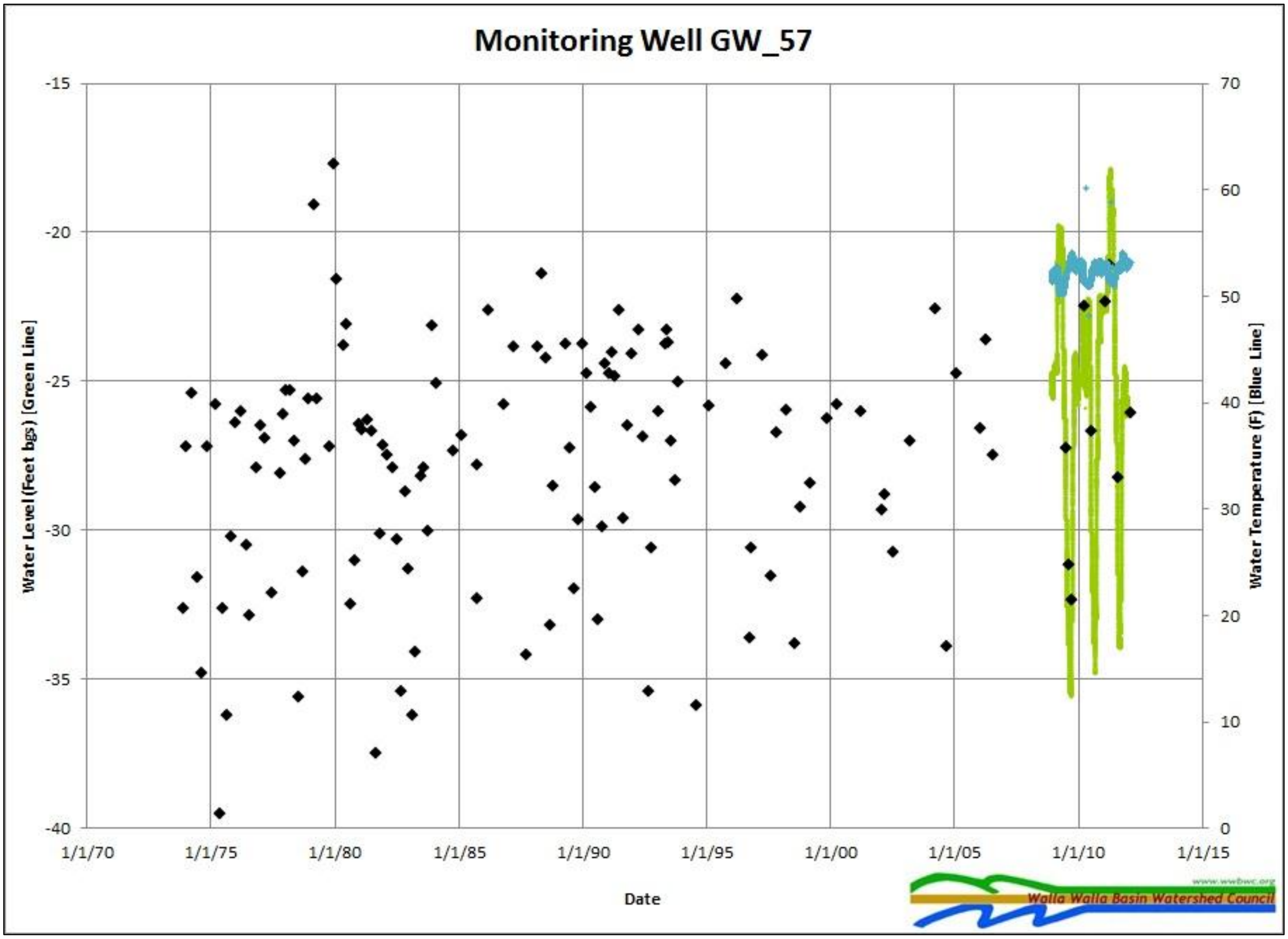

Figure 8. Manual water level measurements and pressure transducer data (green line) in feet below ground surface for the historic well GW_57 located in the WWBWC's Shallow Aquifer Monitoring Network.

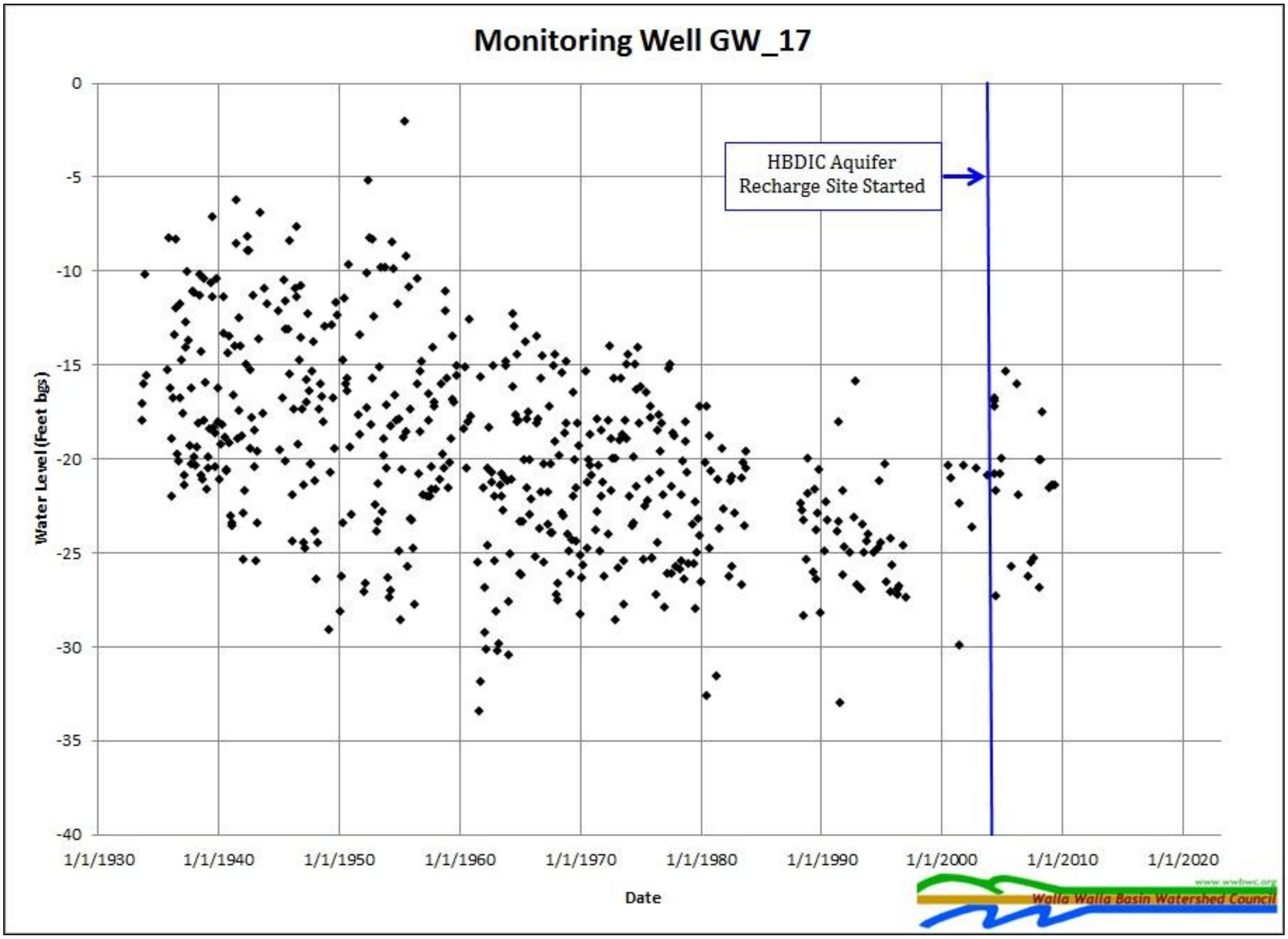

Figure 9. Manual water level measurements in feet below ground surface for the historic well GW_17 located in the WWBWC's Shallow Aquifer Monitoring Network.

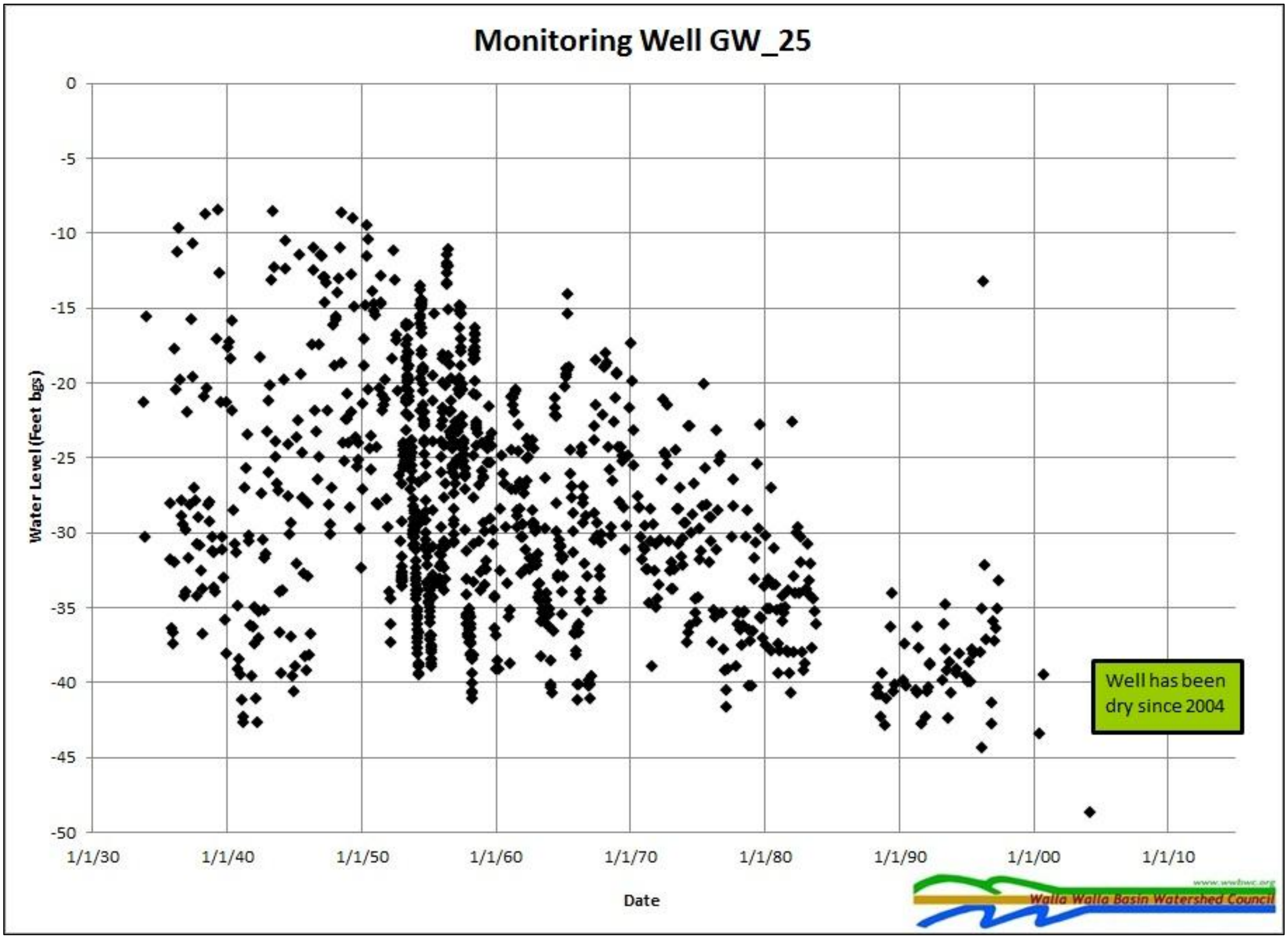

Figure 10. Manual water level measurements in feet below ground surface for the historic well GW_25 located in the WWBWC's Shallow Aquifer Monitoring Network.

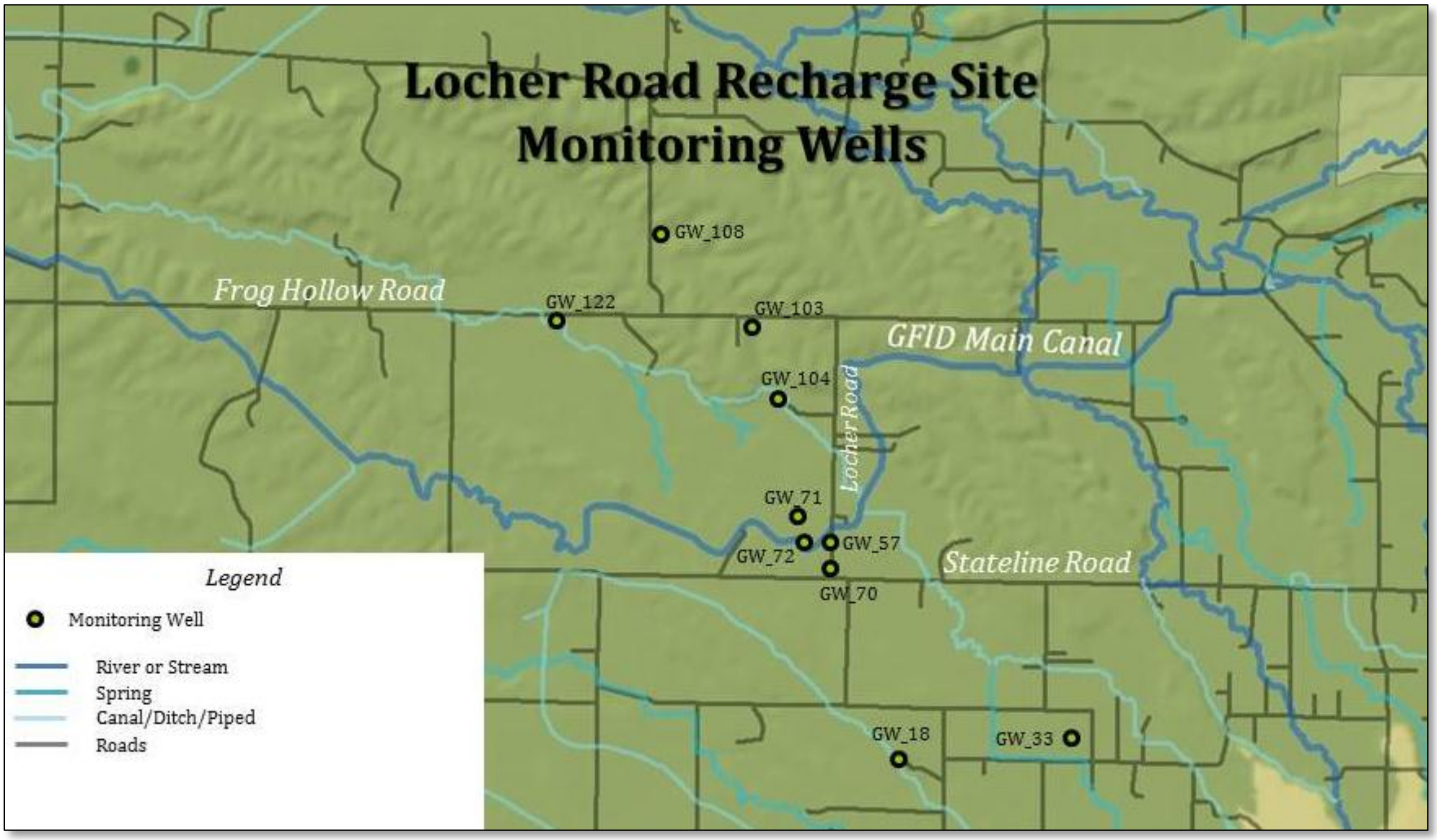

Figure 11. Monitoring well associated with the Locher Road Aquifer Recharge site.

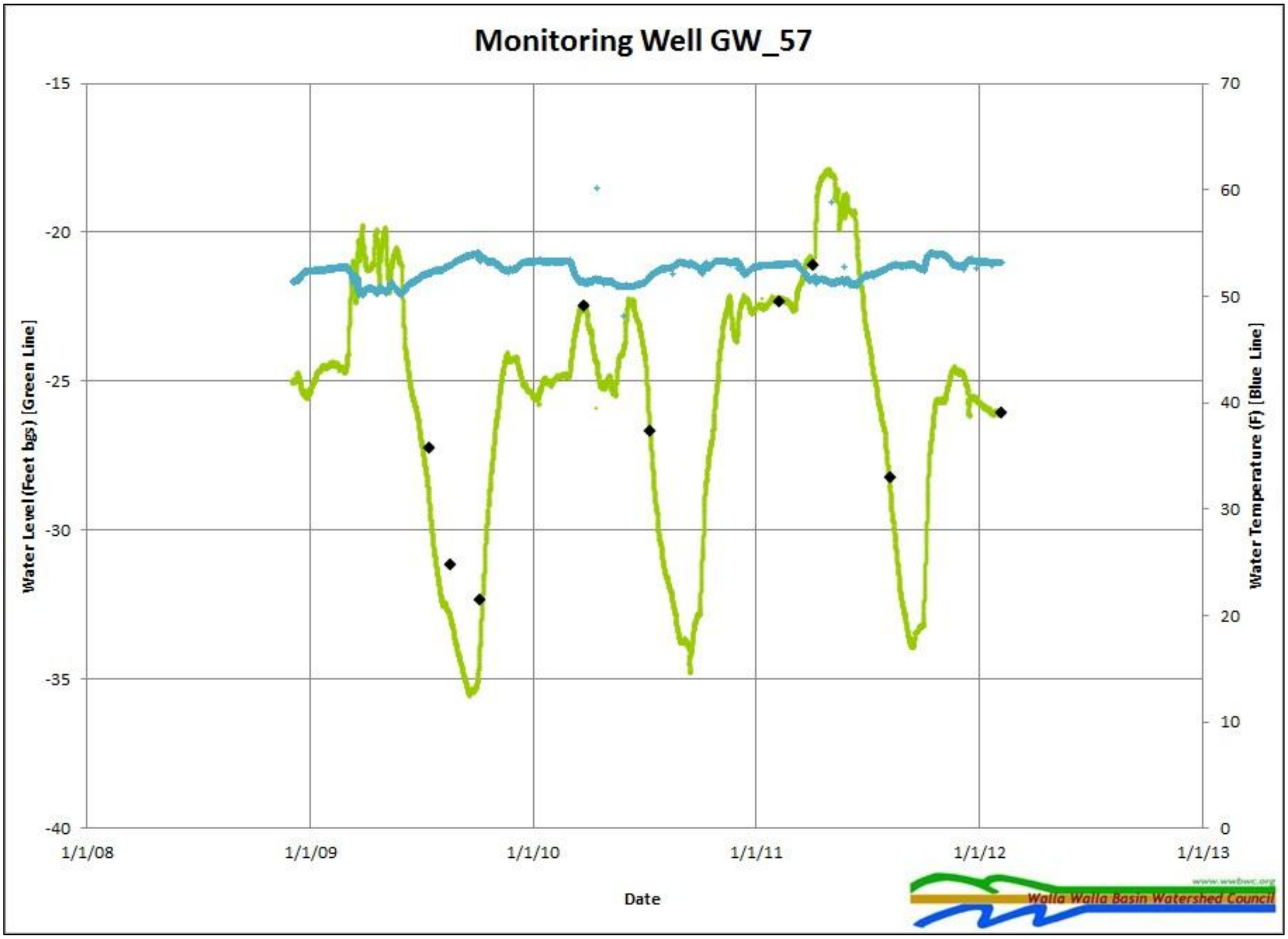

Figure 12. Manual water level measurements (black diamonds) and pressure transducer data (green line) in feet below ground surface for the well GW_57 located in the WWBWC's Shallow Aquifer Monitoring Network.

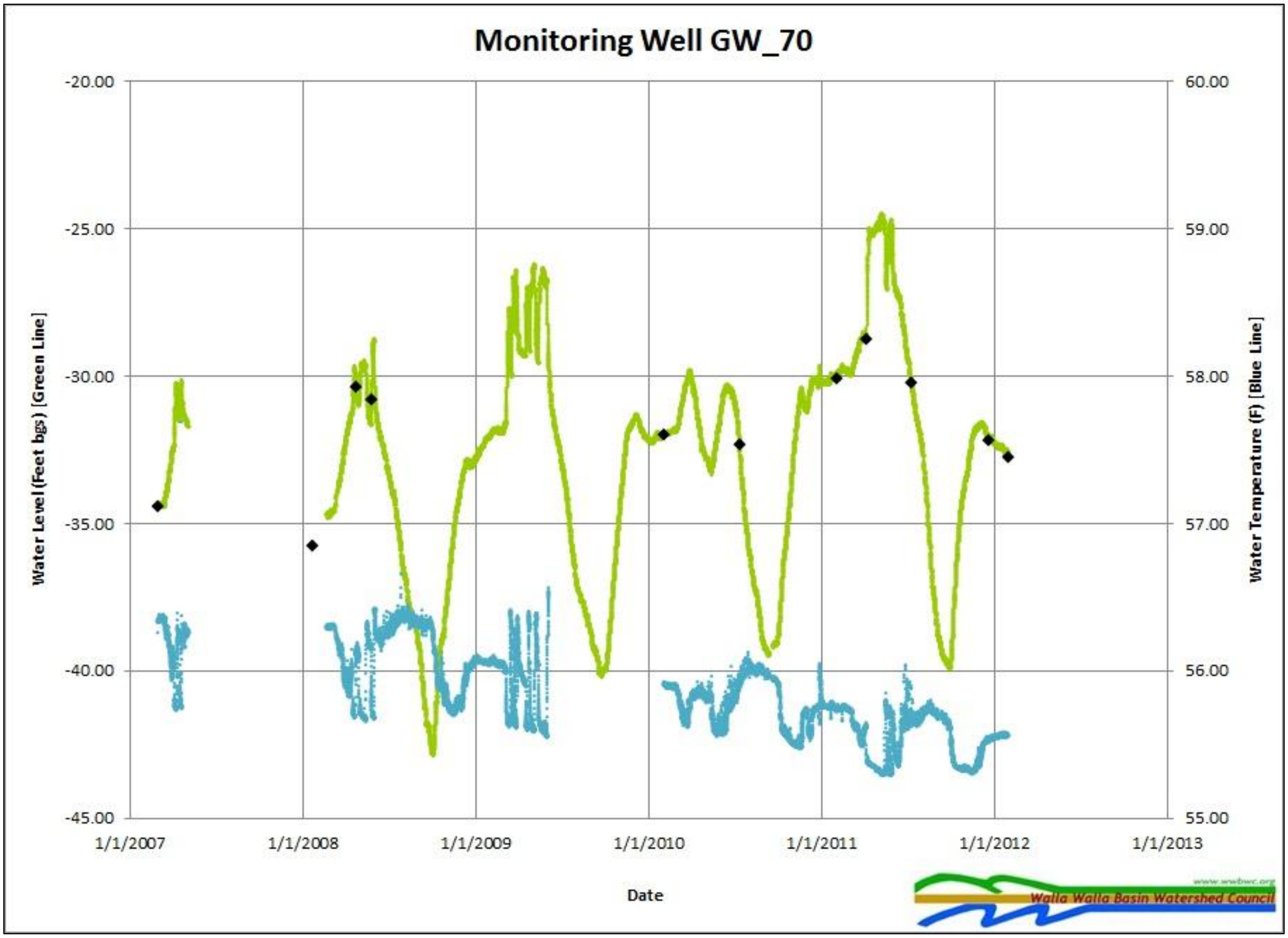

Figure 13. Manual water level measurements (black diamonds) and pressure transducer data (green line) in feet below ground surface for the well GW_70 located in the WWBWC's Shallow Aquifer Monitoring Network.

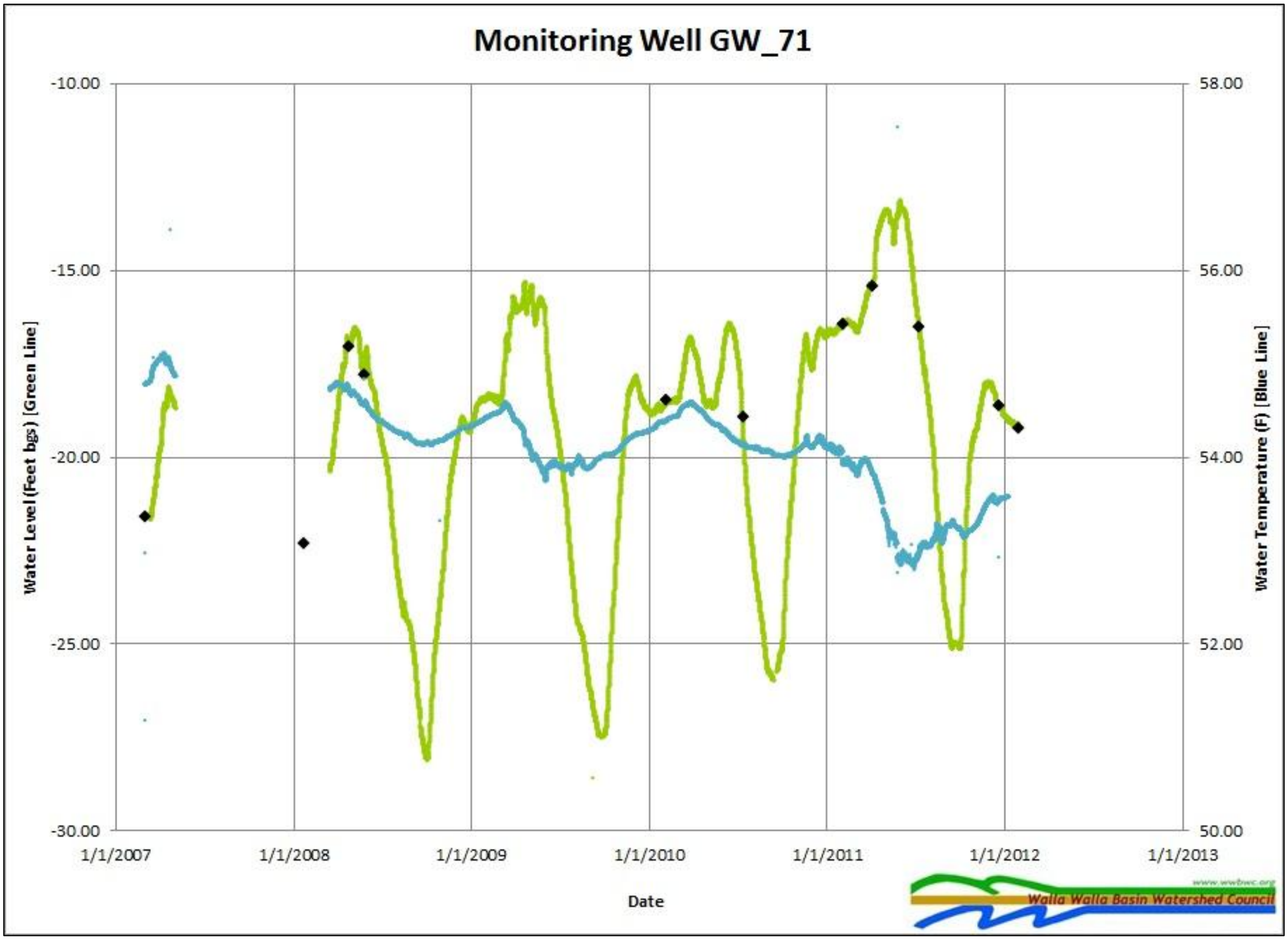

Figure 14. Manual water level measurements (black diamonds) and pressure transducer data (green line) in feet below ground surface for the well GW_71located in the WWBWC's Shallow Aquifer Monitoring Network.

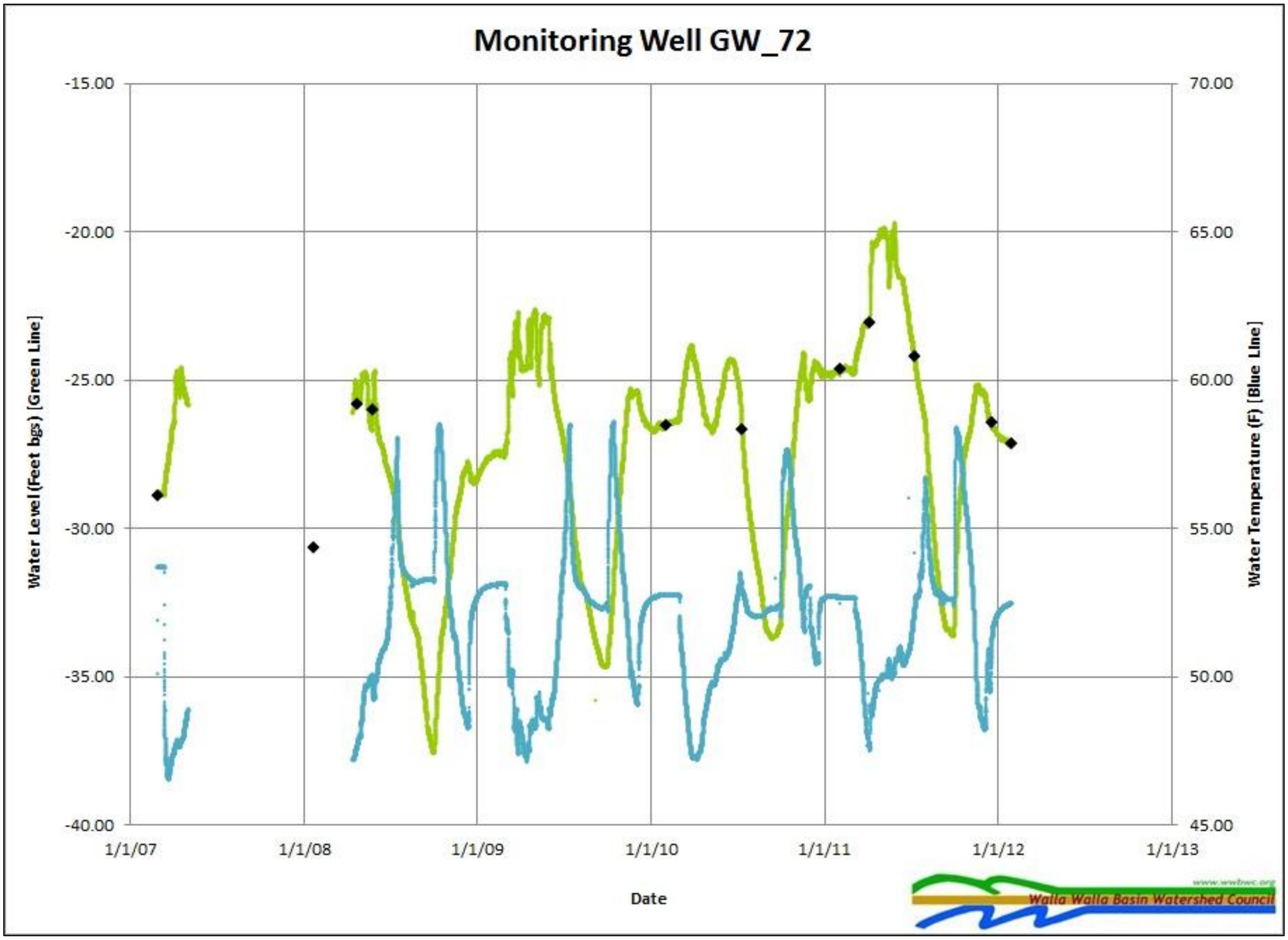

Figure 15. Manual water level measurements (black diamonds) and pressure transducer data (green line) in feet below ground surface for the well GW_72 located in the WWBWC's Shallow Aquifer Monitoring Network.

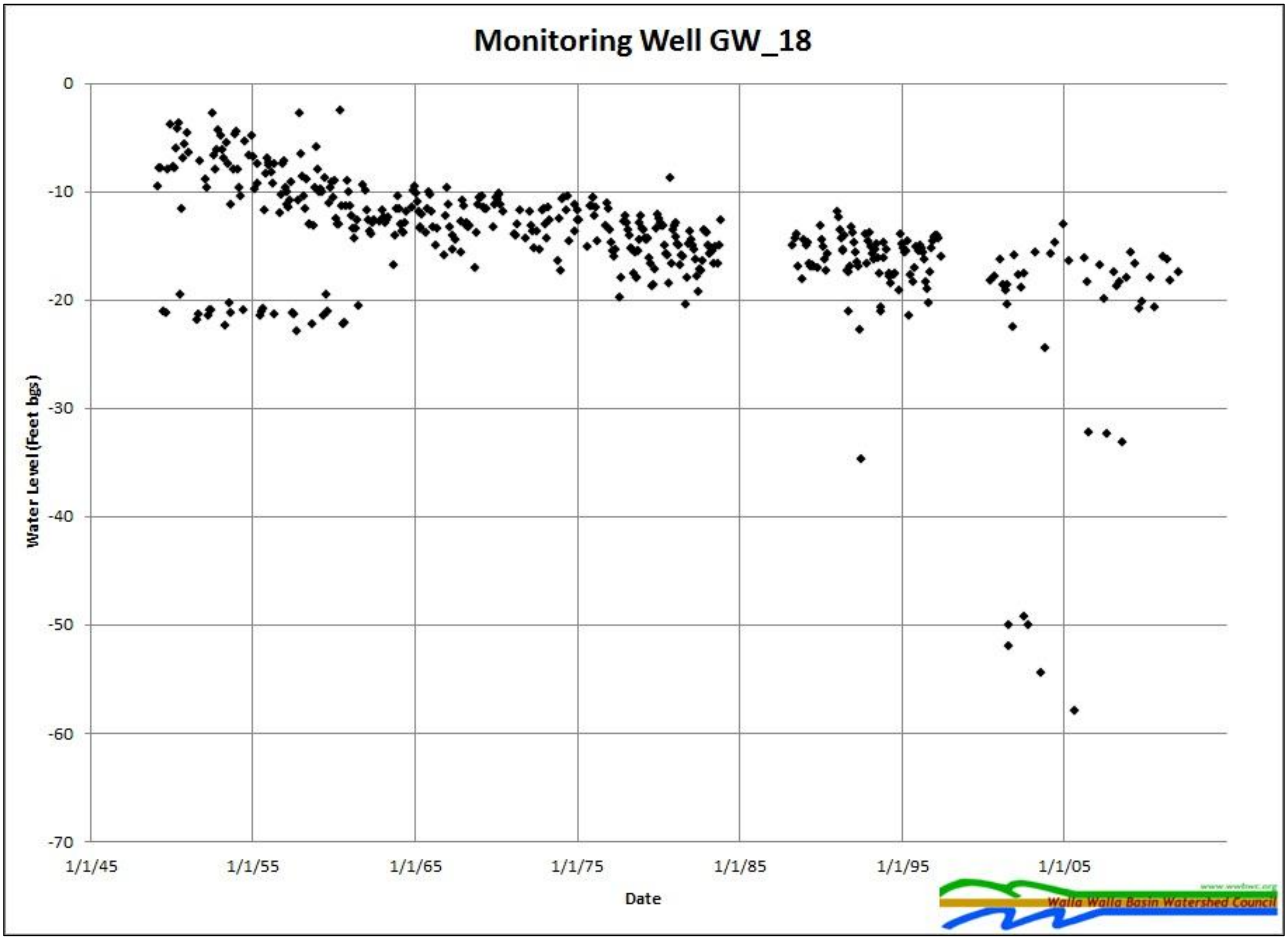

Figure 16. Manual water level measurements (black diamonds) and pressure transducer data (green line) in feet below ground surface for the well GW_18 located in the WWBWC's Shallow Aquifer Monitoring Network.

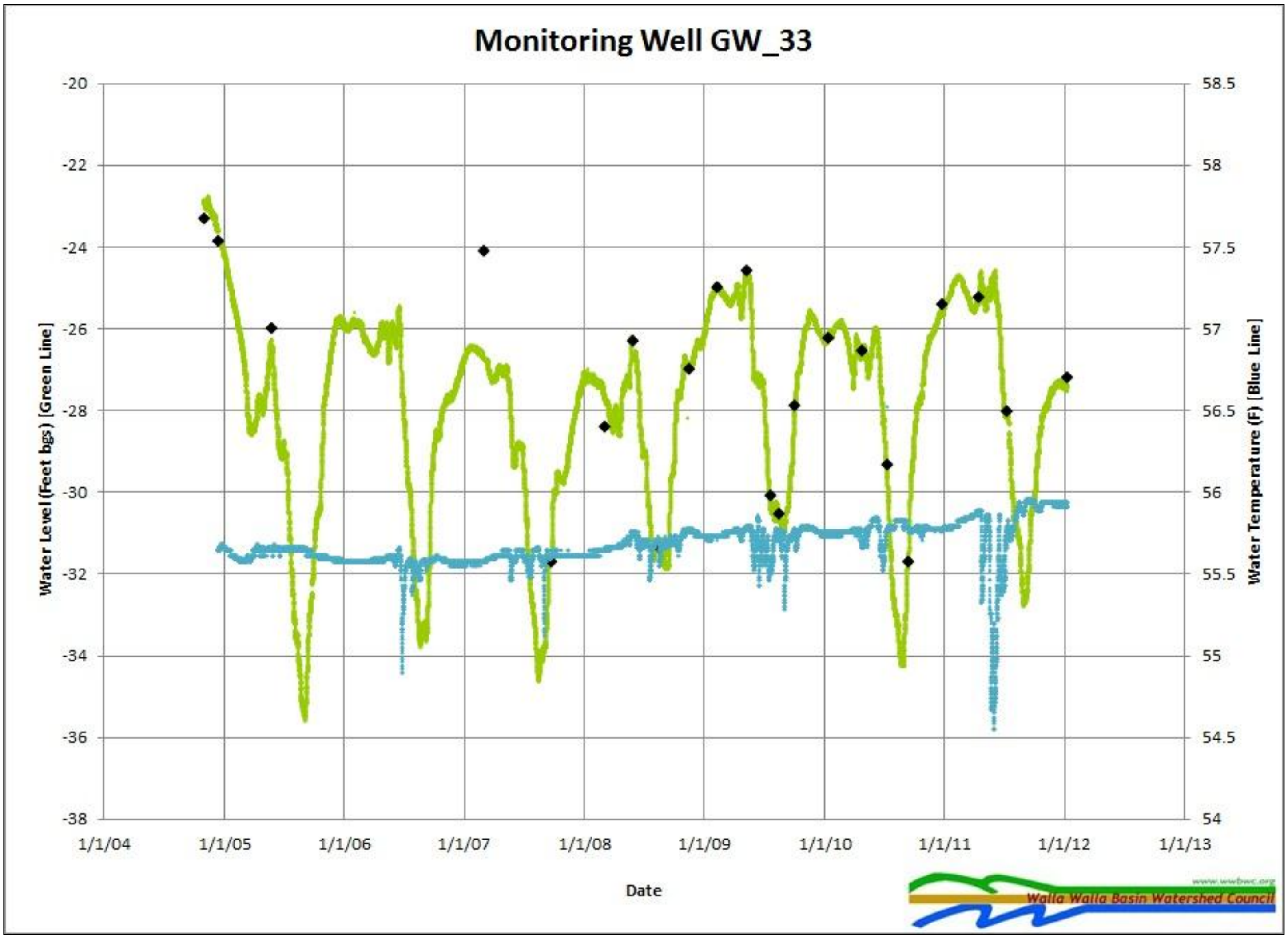

Figure 17. Manual water level measurements (black diamonds) and pressure transducer data (green line) in feet below ground surface for the well GW_33 located in the WWBWC's Shallow Aquifer Monitoring Network.

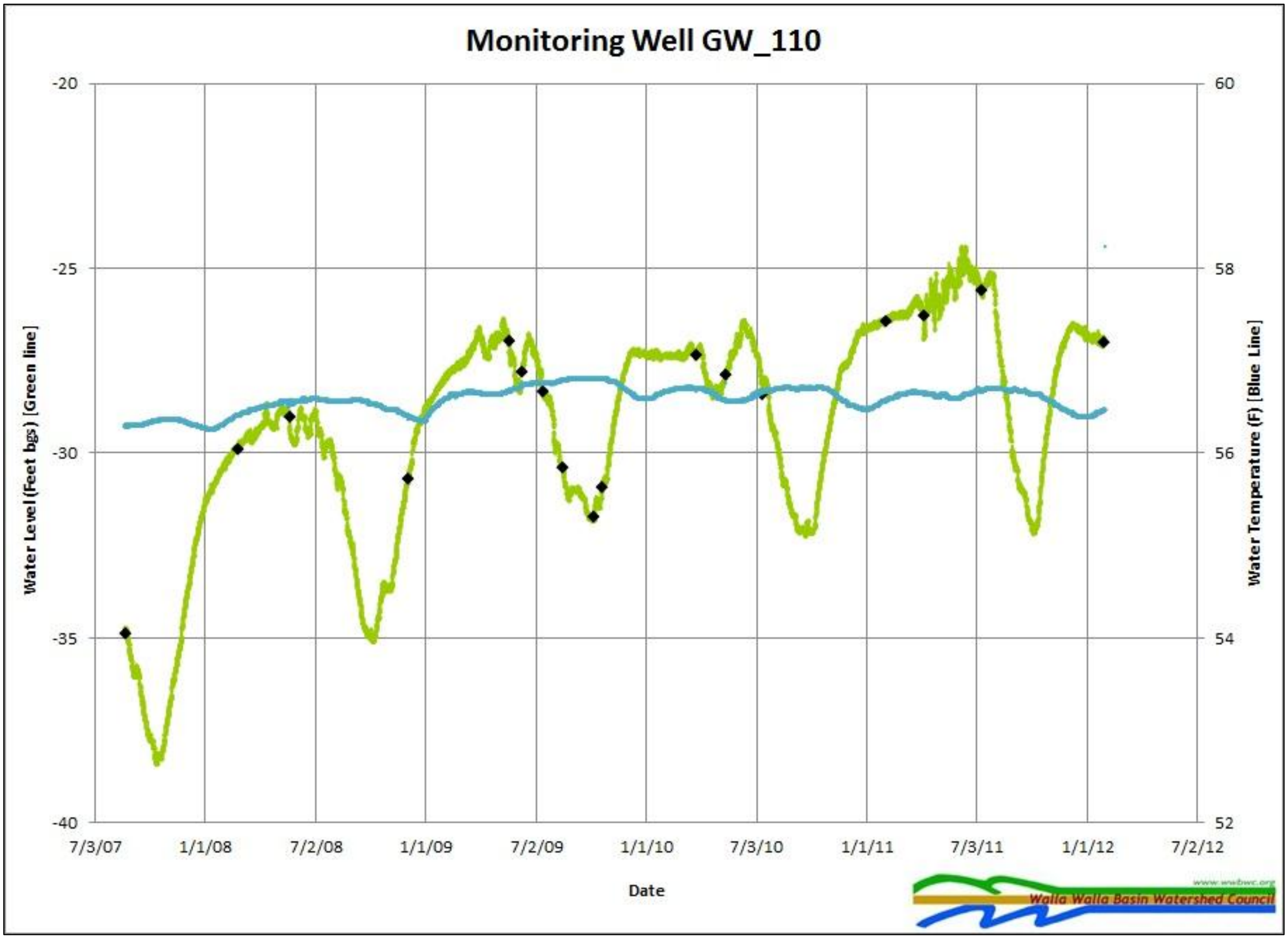

Figure 18. Manual water level measurements (black diamonds) and pressure transducer data (green line) in feet below ground surface for the well GW_110 located in the WWBWC's Shallow Aquifer Monitoring Network.

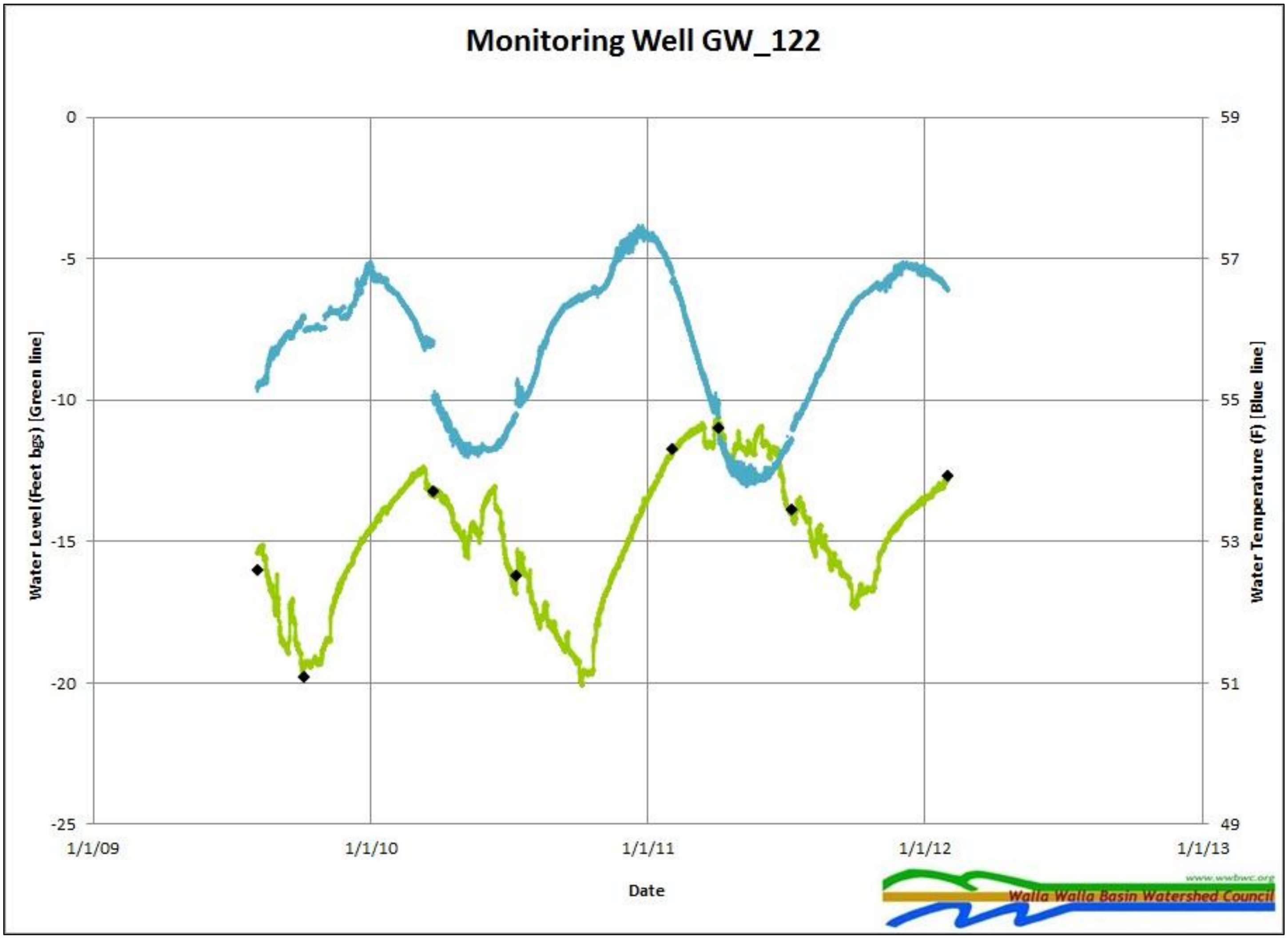

Figure 19. Manual water level measurements (black diamonds) and pressure transducer data (green line) in feet below ground surface for the well GW_122 located in the WWBWC's Shallow Aquifer Monitoring Network.

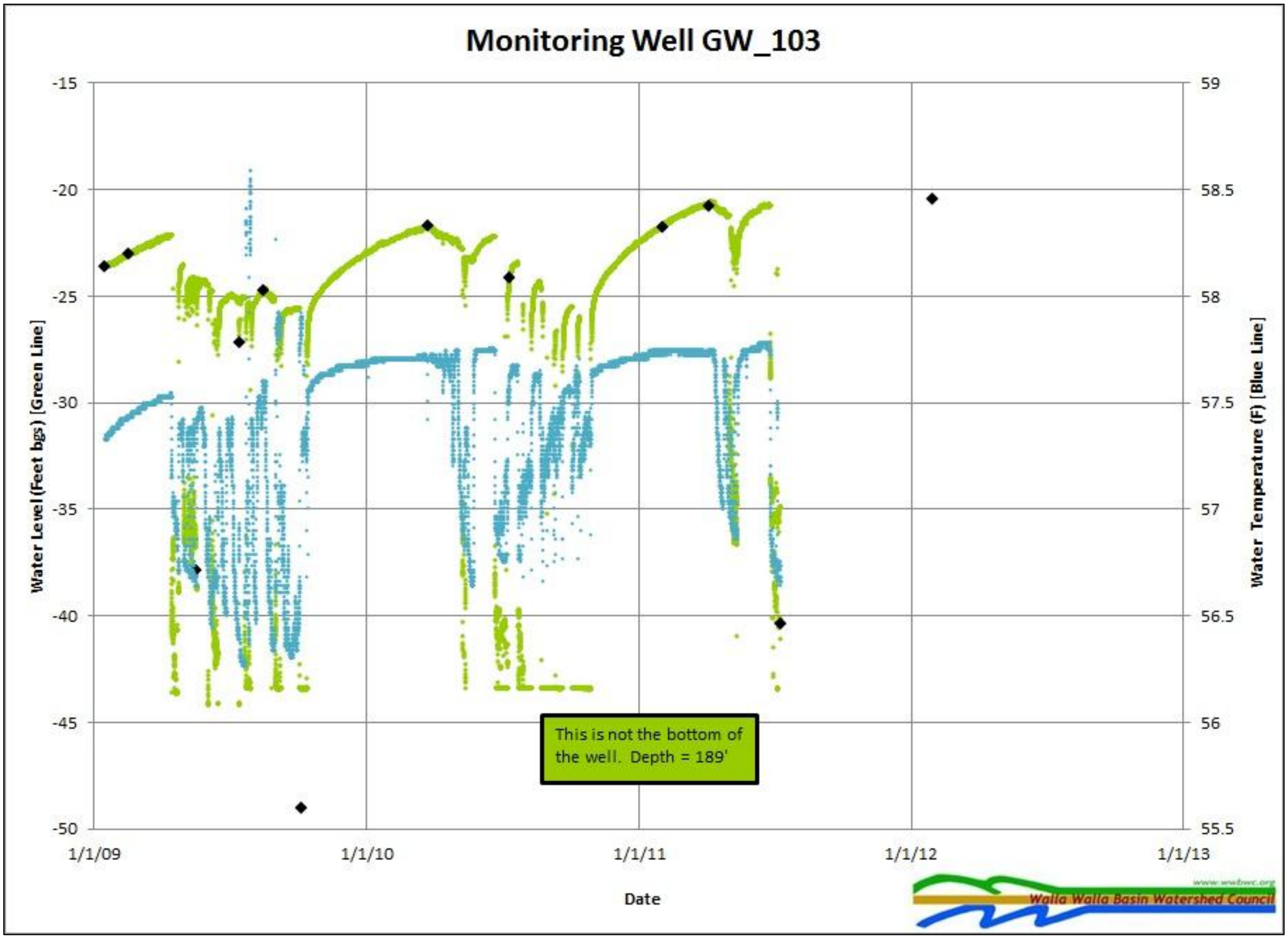

Figure 20. Manual water level measurements (black diamonds) and pressure transducer data (green line) in feet below ground surface for the well GW_103 located in the WWBWC's Shallow Aquifer Monitoring Network.

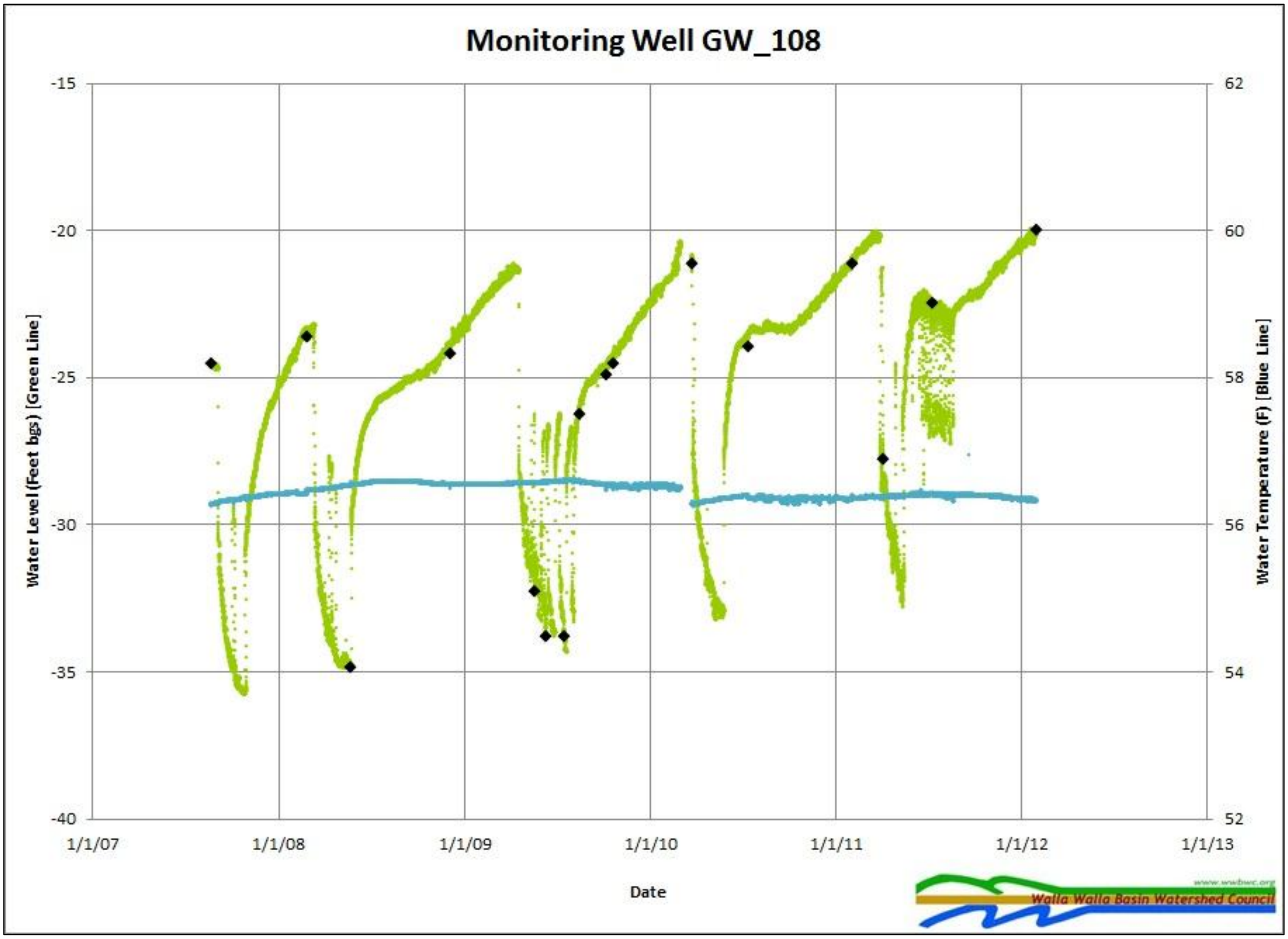

Figure 21. Manual water level measurements (black diamonds) and pressure transducer data (green line) in feet below ground surface for the well GW_108 located in the WWBWC's Shallow Aquifer Monitoring Network.

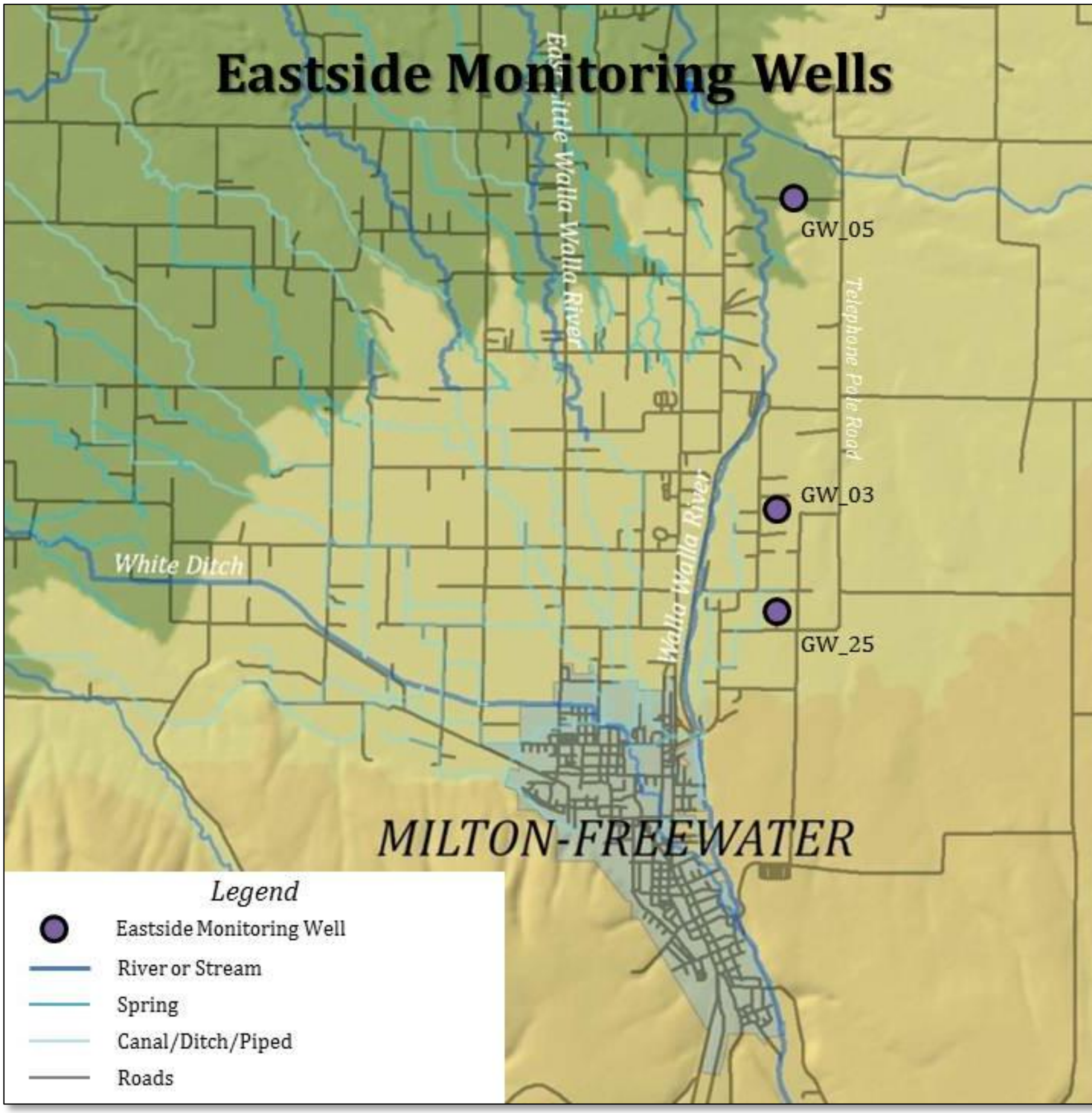

Figure 22. Eastside wells in the WWBWC's Shallow Aquifer Monitoring Network.

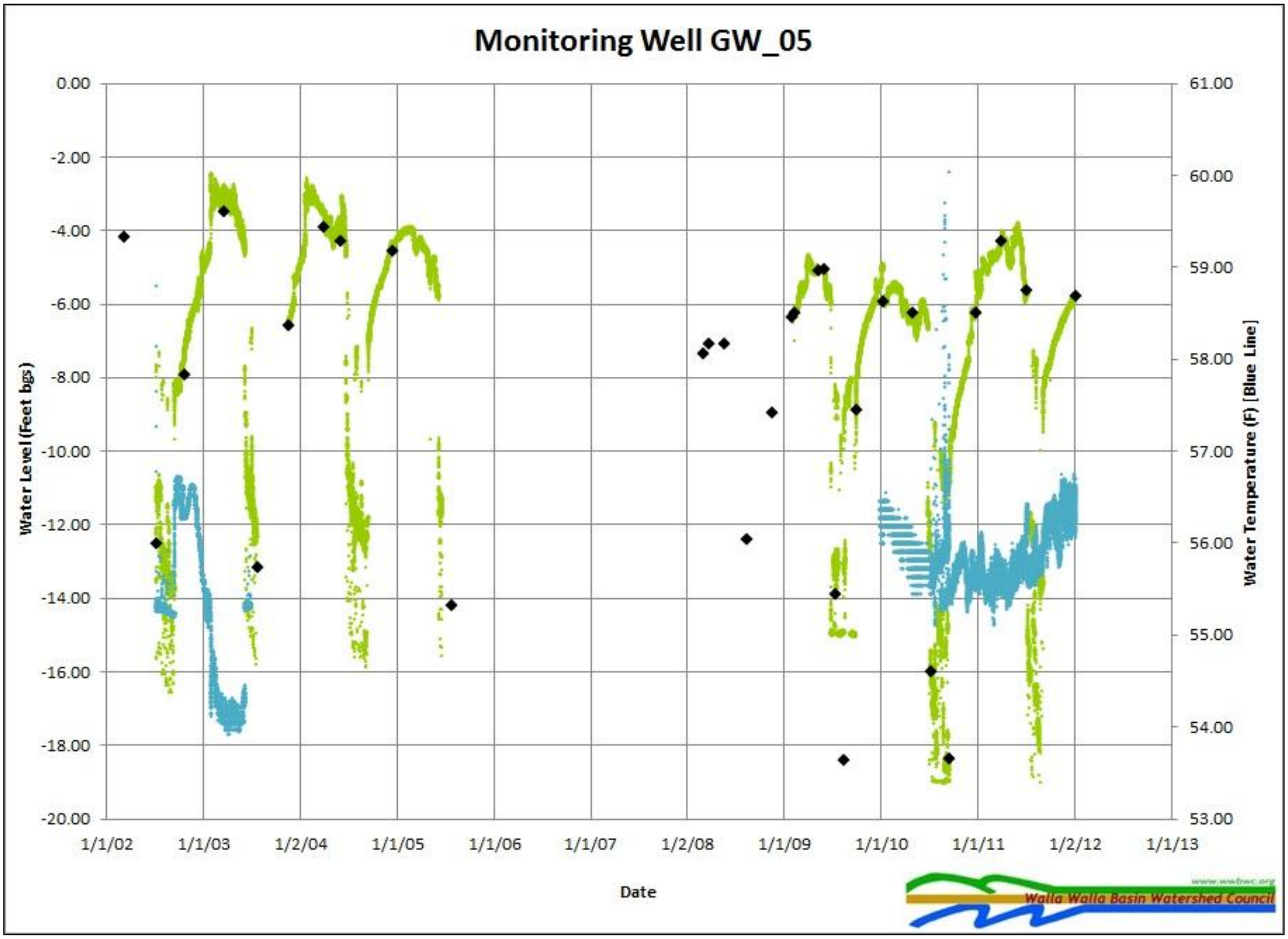

Figure 23. Manual water level measurements (black diamonds) and pressure transducer data (green line) in feet below ground surface for the well GW_05 located in the WWBWC's Shallow Aquifer Monitoring Network.

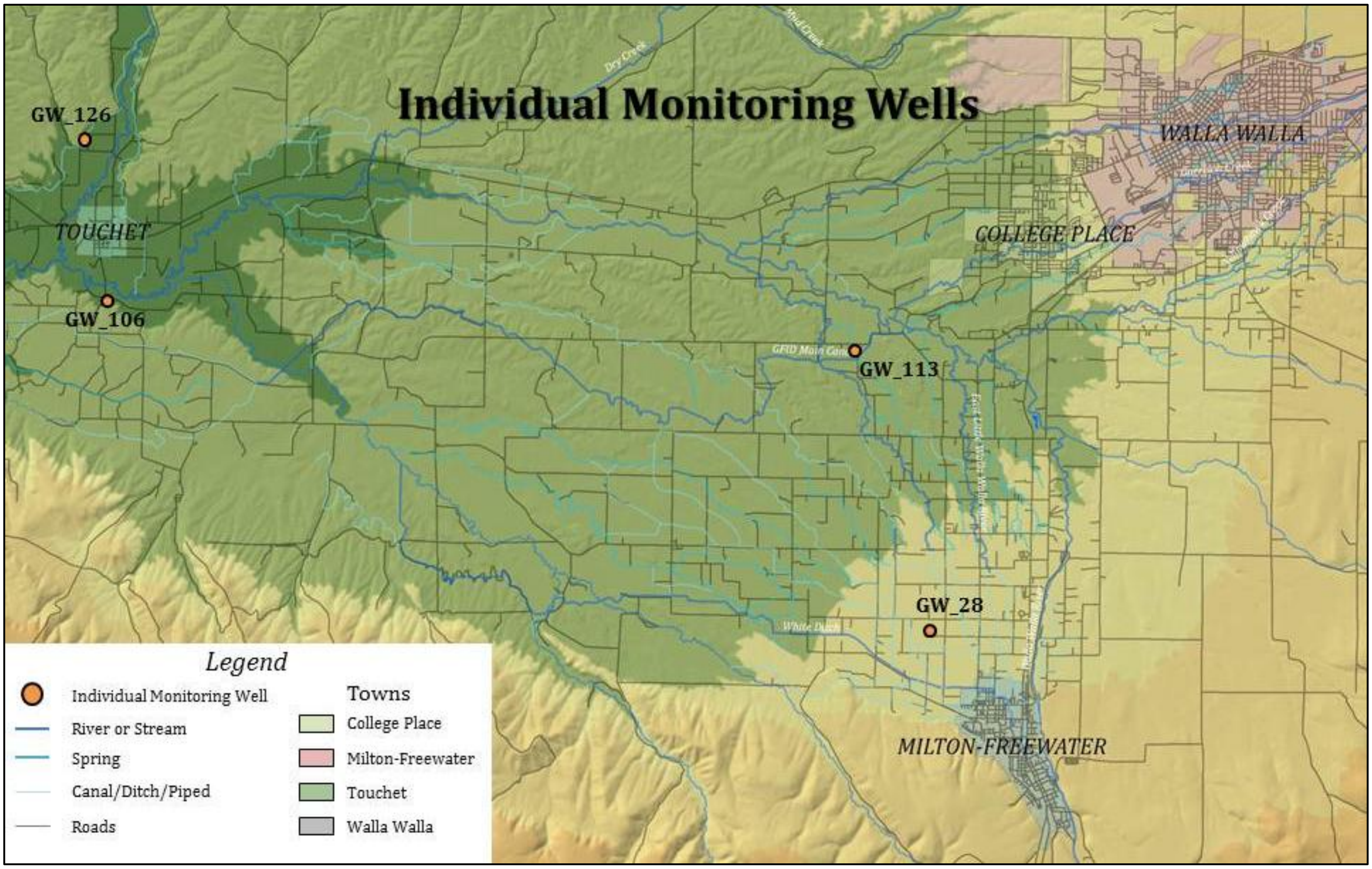

Figure 24. Some individual wells of the WWBWC's Shallow Aquifer Monitoring Network.

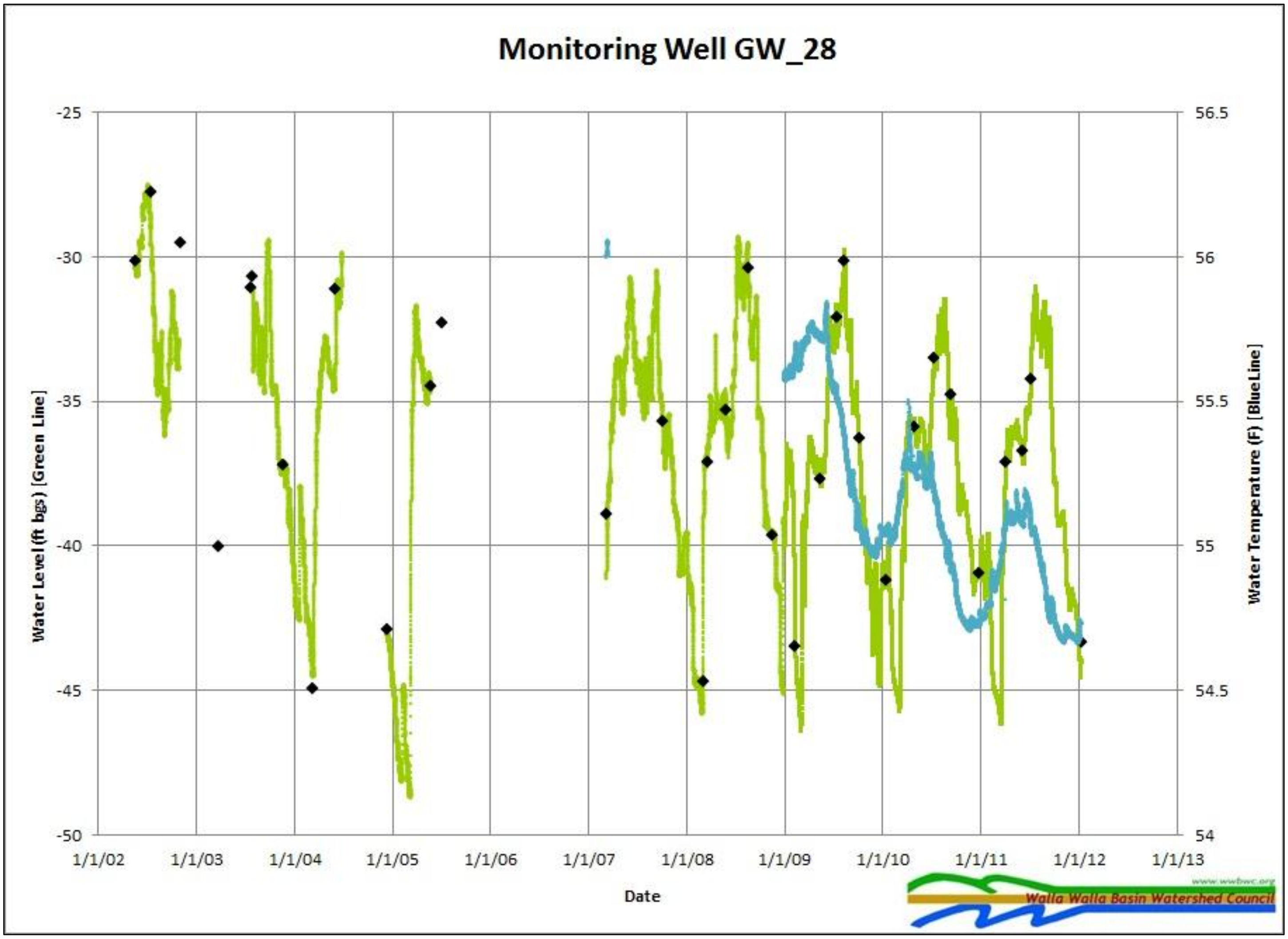

Figure 25. Manual water level measurements (black diamonds) and pressure transducer data (green line) in feet below ground surface for the well GW_28 located in the WWBWC's Shallow Aquifer Monitoring Network.

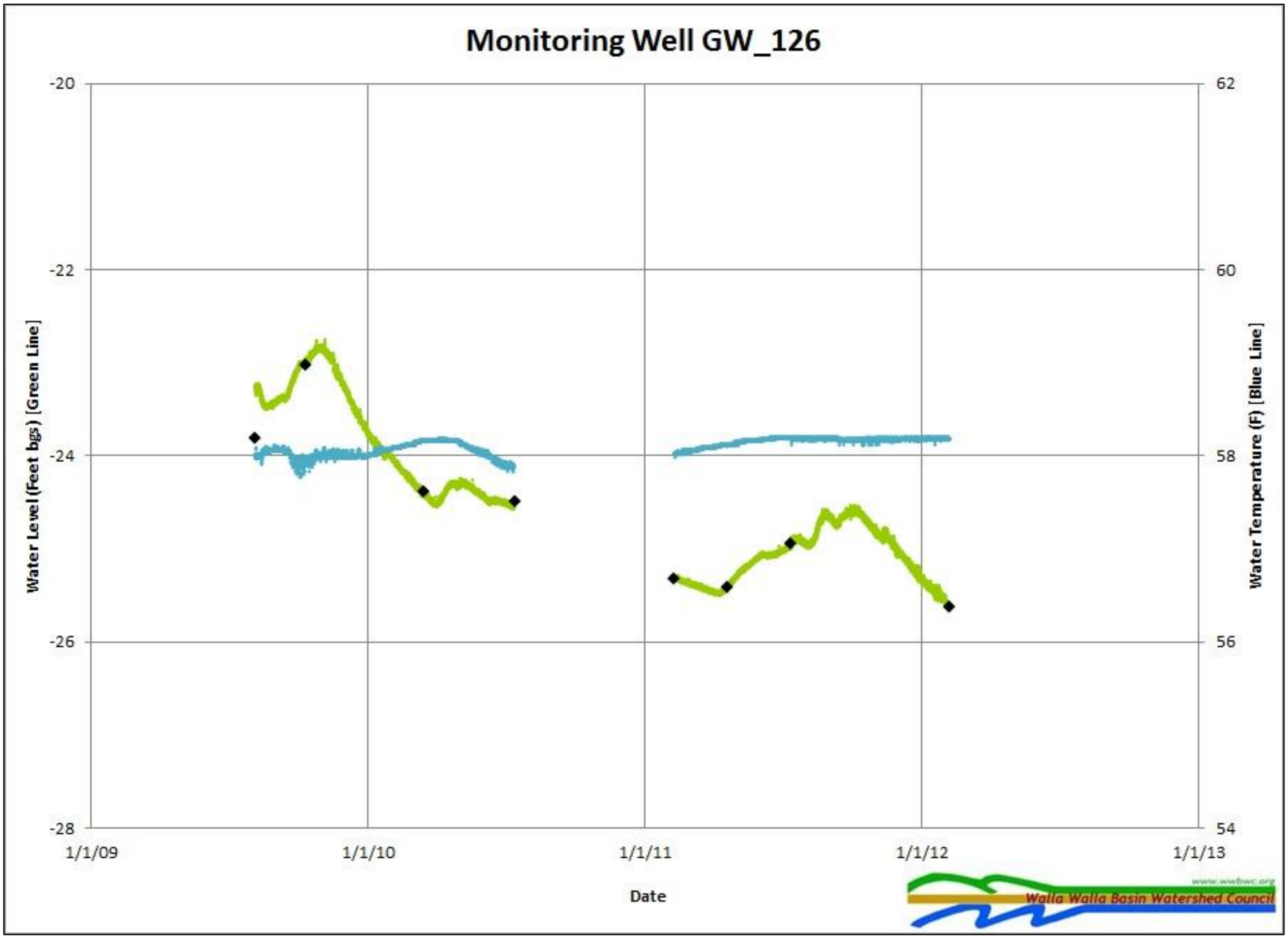

Figure 26. Manual water level measurements (black diamonds) and pressure transducer data (green line) in feet below ground surface for the well GW_126 located in the WWBWC's Shallow Aquifer Monitoring Network.

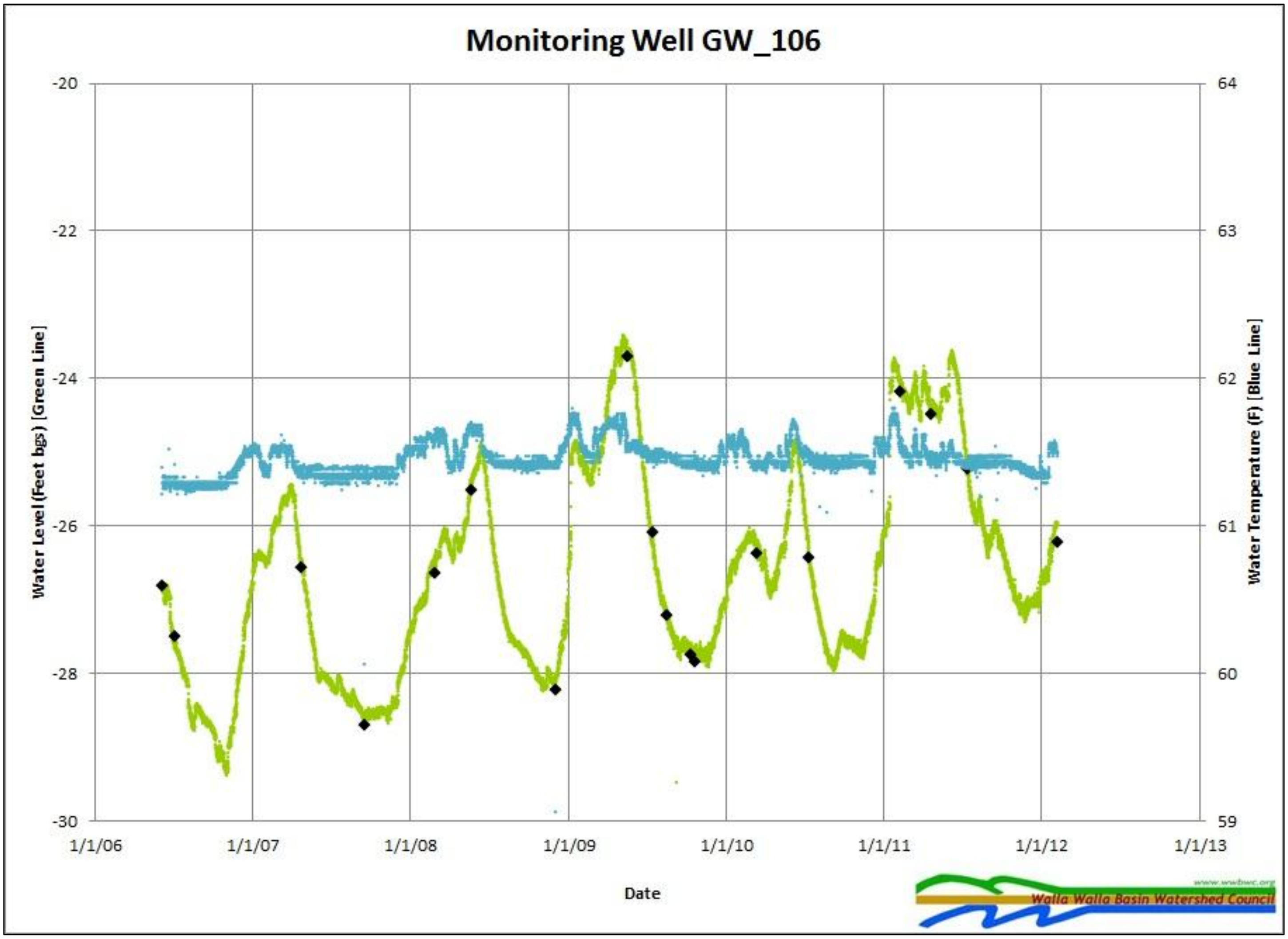

Figure 27. Manual water level measurements (black diamonds) and pressure transducer data (green line) in feet below ground surface for the well GW_106 located in the WWBWC's Shallow Aquifer Monitoring Network.

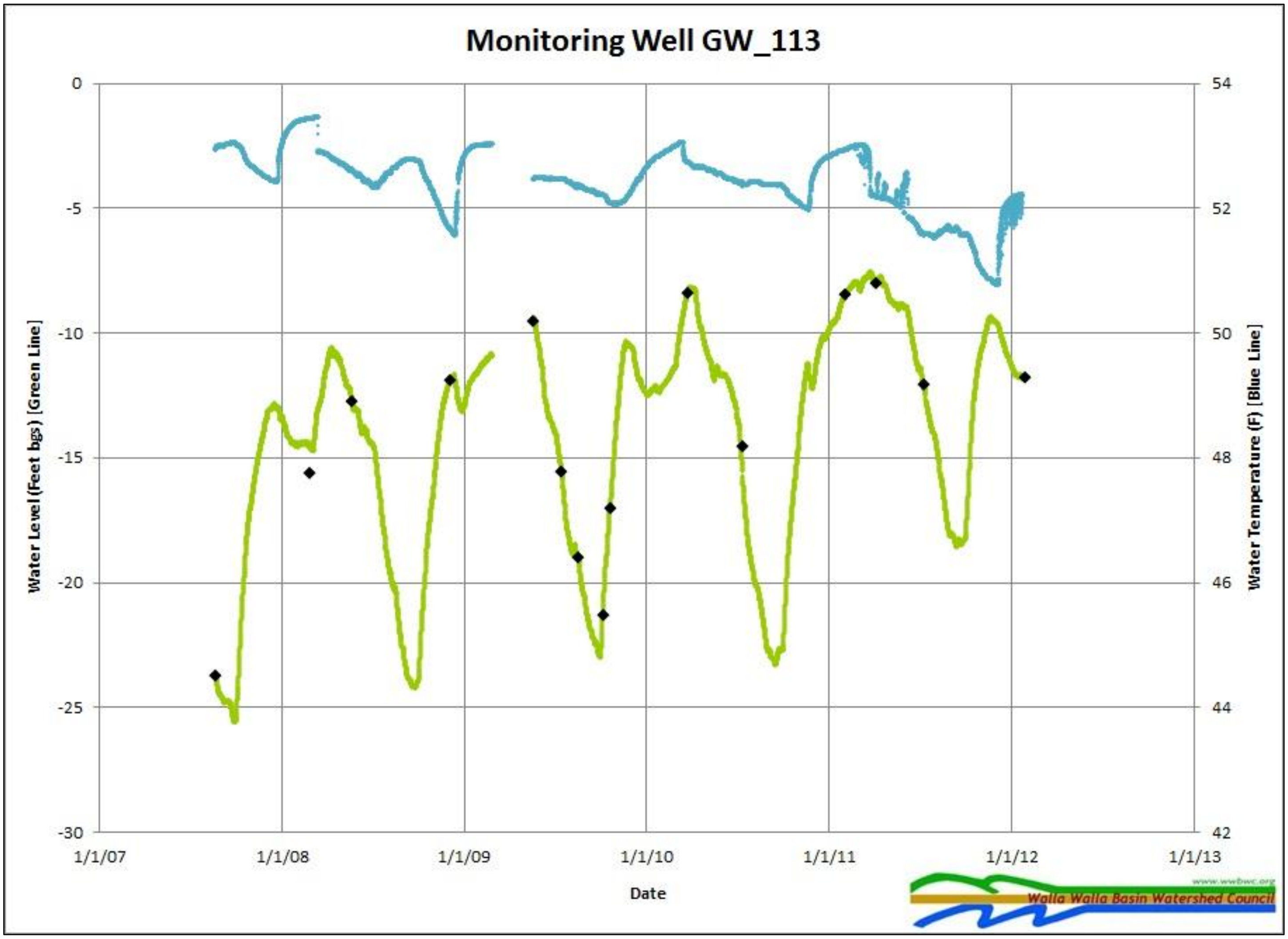

Figure 28. Manual water level measurements (black diamonds) and pressure transducer data (green line) in feet below ground surface for the well GW_113 located in the WWBWC's Shallow Aquifer Monitoring Network.

Discussion

The well monitoring network in the Walla Walla Basin's shallow alluvial aquifer is expanding every year, giving the WWBWC and other partners a better understanding of changing groundwater conditions throughout the valley. This network is providing valuable information for water issues including irrigation use and impacts, surface-ground water interactions, and what may be needed for long term groundwater stability in the Walla Walla Valley.

Continuous Data and Manual Water Level Measurements

More than three-fourths of the wells monitored by WWBWC are instrumented with pressure transducers (Table 2). Although it would be ideal to have all of the wells instrumented for continuous data collection, many abandoned and irrigation wells are not fitted with access ports that allow pressure transducers to be deployed in them or the pump is in the way. Static (non-continuous) wells provide an inexpensive way to expand the monitoring network throughout the valley. Static wells allow the WWBWC to collect "snap shot" information of the aquifer which is useful for tracking trends.

Temperature and Conductivity

Gathering temperature and conductivity data when monitoring wells allows the WWBWC to better understand the hydrologic/hydrogeologic connections between groundwater and surface water. By knowing the temperature and conductivity we are able to map where groundwater is increasing surface flows and where surface water is recharging the aquifer. Groundwater recharge via surface flows is very evident at a few locations in the basin, namely the HBDIC Aquifer Recharge Site and the ditches along the Little Walla Walla system. Groundwater-surface water interactions also help to stabilize flows in the river system, which is important for fish passage due to increased flow and lowered water temperature.

Historic Wells

Most of the historic wells that the WWBWC monitors have declining water levels. This could be caused by a number of factors. An increasing number of wells and increasing water usage for domestic and agricultural activities could be withdrawing more water than is sustainable for the basin's aquifer. A relatively new change in water management for the basin could also have had an effect on the basin's aquifer. Beginning with the 2001 Civil Penalty Settlement Agreement (Settlement Agreement) between U.S. Fish and Wildlife Service and the three irrigation districts in the Walla Walla basin (Walla Walla River Irrigation District, Hudson Bay Ditch Improvement Co, Gardena Farms Irrigation District #13), 18 cubic feet per second (cfs) has remained in the Walla Walla River during summer months, and then was incrementally raised to 25 cfs. During the previous ~100 years, the Walla Walla River ran dry during the summer because all of the water was diverted for irrigation uses. This water flowed through the vast array of irrigation ditches in the basin providing groundwater recharge as seepage occurred within the ditch systems. Since the Settlement Agreement in 2001, less water has been flowing through the Walla Walla/Gardena/Hudson Bay systems during the summer months leading to a reduced amount of groundwater recharge in the ditch system. However, since the decline in the aquifer seems to have started well before the 2001 Settlement Agreement, the reduced recharged from surface flows in the irrigation system does not explain everything. Also, increased efficiency for irrigation districts (piping projects, etc) has reduced the amount of groundwater recharge further from irrigation ditches and canals. Irrigation practices used to include flood irrigation which allowed for groundwater recharge, but newer drip and sprinkler systems only deliver as much water as is needed. Also, many irrigators have started using wells more than they had in the past: both supplemental wells, and newly drilled wells.

One of the historic wells, GW_17, has historically shown a decreasing water level; however, over the last 5 years it has started to recover (Figure 9). This recovery correlates with the start of the Hudson Bay Aquifer Recharge site about 0.6 miles (1 kilometer) to the southeast of the well. This, along with other effects, may demonstrate a possible strategy for aquifer stabilization and potentially recovery in the Walla Walla Basin. Creating an array of recharge sites throughout the basin may help to stop or even recover the declining shallow aquifer.

Recharge Monitoring Wells

Locher Road Recharge Site

The Locher Road Recharge Site started in 2007 and can recharge approximately 1.5 (cfs). As can be seen in the well hydrographs for the site (Figures 12-15), it did not run during the 2010 season because instream flows were not high enough. Down gradient wells have water level responses that correlate to recharge activities and show recovering water levels (Figures 18-21).

Eastside Wells

As indicated by GW_25 (Figure 10), groundwater levels on the eastside of the Walla Walla River (Tum-A-Lum Reach) have been declining for over half a century. According to this well, there have been almost 50 feet of groundwater decline in as many years. Other wells on the eastside of the river also show declining water levels. Farther to the north, the Yellowhawk drainage starts to impact groundwater levels on the eastside and stabilization can be seen in water levels. Also, recharge, both natural and artificial, in the eastern portion of the shallow aquifer is limited. The irrigation system has already been pipe and there are currently no recharge projects active on the eastside. There are significant groundwater withdrawals from this portion of the aquifer. With the combination of continued groundwater withdrawals and reduced recharge, the trend of declining water levels will probably continue.

Individual Wells

A well in the middle of the orchard district, GW_28 (Figure 25), shows distinct groundwater decline. This well shows what many people in the area talk about, a severe drop in groundwater levels. As less surface water is used for irrigation and orchardists turn to supplemental wells, the situation worsens. GW_16 (Appendix A) shows the same long term declining trend in the area. Again, changes in surface water management cannot be the only culprit because this problem started well before Settlement Agreement flows were being left in river.

Another area that is showing downward trends is the area north of Touchet, WA. GW_126 (Figure 26) has shown a downward trend over the last few years. Unfortunately the monitoring network is relatively new and not extensive in the area north of Touchet. The declining water level in this well may indicate groundwater impacts from the piping of the eastside and westside ditches upstream from Touchet, WA. High rates of seepage loss along the lower reaches of the Touchet River also seem to indicate declining groundwater levels in the area.[4]

Not all of the wells in the valley are showing groundwater declines. GW_113 (Figure 28) has shown rising water levels over the last five years. Along with other wells along Walsh Creek and West Little Walla Walla River, this well seems to represent a relatively stable area of groundwater. This could be impacted by future piping of the Burlingame Ditch, whose seepage may be helping the stability in groundwater levels.

GW_106 (Figure 27), a well south of Touchet WA, also shows rising water levels. Other wells in the area appear to be relatively stable; however most of them only have three years of data. Water levels in this area may also be heavily influenced by seepage from the North Lateral of the Gardena Farms system. Having background data before ditches are piped may provide an important insight into impacts of piping on groundwater levels and success of possible mitigation activities.

[4] Baker, T.W. 2011. *2011 Walla Walla Basin Seasonal Seepage Assessments Report*. Walla Walla Basin Watershed Council. www.wwbwc.org.

Moving Beyond Hydrology to Restoration

Groundwater recharge is typically associated with hydrology and hydrogeology. We often think of groundwater in relation to irrigation withdrawals and a source for domestic water in rural areas. But most people do not associate groundwater with salmon recovery and environmental restoration. Leaving water in-stream is used as a key function to restore salmon and steelhead fisheries. Because surface water has been the dominate focus of salmon restoration activities groundwater has been mostly excluded from salmon restoration activities. What if artificial groundwater recharge projects were viewed as importantly as leaving surface water in-stream.

An example from the Walla Walla River provides a practical look at this idea. The shallow aquifer on the eastside of the Tum-A-Lum reach of the Walla Walla River has been declining for 50 years or more (GW_25, Figure 10). The Tum-A-Lum reach shows the highest rates of seepage found in the Walla Walla River, with loses above 15 cfs per mile. With the declined shallow aquifer, leaving more surface water in-stream does not fix the problem. Instead you will typically see higher rates of seepage with increased flows. On the other hand, artificial recharge on the eastside of the river could potentially fix a portion of the seepage loss, help reduce water temperatures, and create better habitat for fish. If there was enough recharge on the eastside to bring the aquifer back to where it was in the 1940s, that could move the transition point of losing-to-gaining river water up to ½ mile upstream. This would encompass the worst section of the river and turn it from losing 15 cfs per mile to either a neutral or potentially a gaining reach. This has implications for flow, temperature, and vegetation. Flow would be enhanced through increased groundwater returns to the river and reduced seepage into the ground – meaning more surface water would stay surface water. Groundwater returns would also help reduce temperatures by adding cool water to one of the hottest portions of the Walla Walla River. Vegetation (fish habitat) would also be helped through increased flow, reduced temperatures and shallow groundwater for low flow times of the year.

This type of project would help people and fish – as almost all artificial recharge projects do. The change is not what we are doing, but what the goal is and how it is achieved. Fixing the seepage losses in the Tum-A-Lum reach will address multiple issues all in one stroke: reduced flows, high water temperatures, seepage losses and a declining aquifer. Framing artificial recharge as another tool for salmon restoration may provide the incentive to move forward with projects that will solve the problem.

Summary

Over 100 wells are currently monitored in the Walla Walla Basin shallow alluvial aquifer, up from only a dozen in 2001. In 2009, fifteen new dedicated monitoring wells were established in the Walla Walla Valley and three more were added in 2011. Six were drilled in Oregon and twelve were drilled in Washington (Figure 29). These new monitoring wells will help enhance the spatial coverage and the potential for understanding and mitigating aquifer decline and assist in general water management in the bi-state basin.

The importance and usefulness of the Shallow Aquifer Monitoring Project is clear; it is vital to the current and future understanding of groundwater resources, aquifer decline and recharge, surface-groundwater interactions, and groundwater returns to the Walla Walla River. Using the well network WWBWC and partners in the basin have quantitatively illuminated the decline of the shallow aquifer and shown the significant influence and response by the aquifer system to artificial recharge projects. Furthermore, the well monitoring network data are being used to inform decisions on current and future aquifer recharge projects. This data are also being used in the valley-wide WWBWC/OSU modeling projects which will provide insight for water management professionals and local communities to make water related decisions into the future.

Developing a widespread shallow aquifer monitoring system through dedicated and non-dedicated wells has been a major accomplishment of this project. Prior to 2001, the Walla Walla Basin only had about a dozen observation wells (Figure 6). As of December, 2011, there are more than 45 dedicated monitoring wells in the bi-state well network (Figure 29). We are continuing to expand the monitoring network through grass-roots based non-dedicated wells. More than 55 non-dedicated monitoring wells have been established with the cooperation of volunteer landowners throughout the basin's shallow aquifer.

Continuing to expand the Well Monitoring Network is important as we move into the future. Establishing more wells, especially to the east of the Walla Walla River and on the northern and western edges of the shallow aquifer, will be important to help complete the picture of how to properly manage the aquifer. There are also some "holes" in the current monitoring network that need to addressed including: the Little Walla Walla system (especially with continuous wells), in the middle of the Mud Creek system, and the upper Mud Creek system. Monitoring groundwater is critical to measure the impact of a variety of other projects including aquifer recharge and piping ditches/canals and to further understand the interactions between ground and surface water in the Walla Walla basin.

It would be helpful to expand the monitoring well network to include wells constructed into the basalt aquifer. Communication between the shallow alluvial aquifer and the basalt aquifers is thought to be minimal, mainly due to the presence of the Miocene-Pliocene Fine Unit that lies between the two aquifers. However, this relationship is not well understood and only through monitoring of both aquifers can this be learned.

Finally, the Shallow Aquifer Monitoring Project is successful not only in compiling aquifer data/analysis and expanding the well network, but also in community outreach because it depends on voluntary land owner participation and local support. Many citizens have contributed vital information to the project and also have become more aware of the declining aquifer and other water issues in the Walla Walla Basin.

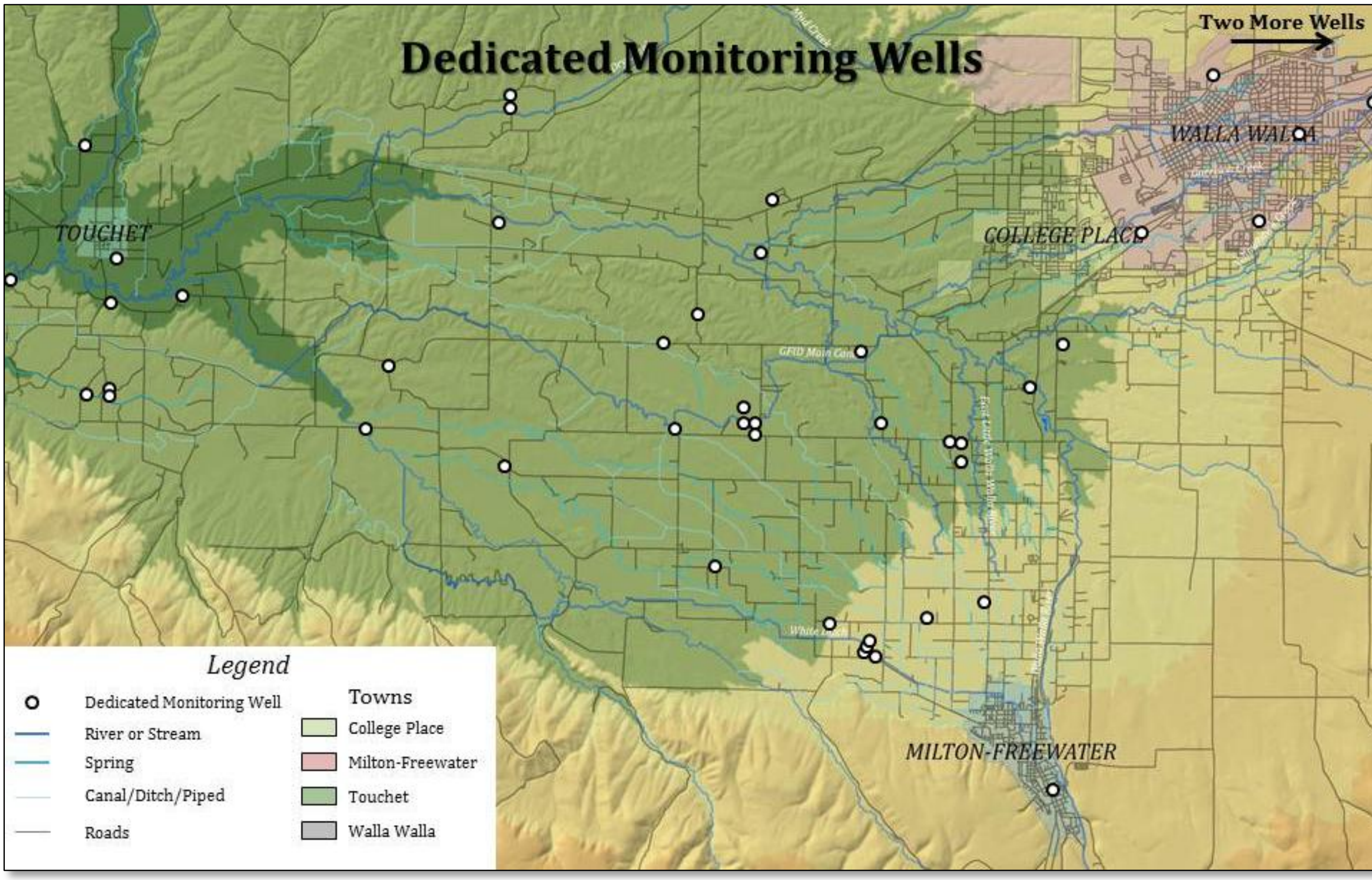

Figure 29. Dedicated monitoring wells incorporated into the WWBWC's Shallow Aquifer Monitoring Network.

www.wwbwc.org
Walla Walla Basin Watershed Council
541-938-2170 or 7086 P.O.Box 68, Milton-Freewater, OR 97862

APPENDIX A

WWBWC Well Monitoring Field Instructions

1.) Before you leave the office:
   a. Laptop should be charged
   b. Check battery replacement and logger download schedule
   c. Review "Equipment Needed" (see #2 below)
   d. Review WellNet notebook pages if needed
   e. Review "Procedures" (see #3 below)
   f. Sign out in main office
   g. Record your start miles, start time, and the project you will bill

2.) Equipment Needed:
   a. General:
      i. Well Keys (usually in backpack)
      ii. Cell phone, GPS, Camera and extra AA batteries
      iii. Flashlight, headlamp and extra batteries
      iv. Hammer, pipe wrench, flathead screwdriver, Phillips screwdriver, big crescent wrench, blue cable snips
      v. Socket set
   b. Information and Paperwork:
      i. Tatum/clipboard
      ii. Well Field Instructions and Procedures
         1. See: Groundwater Field Instructions and Procedures folder in WWBWC WellNet
      iii. Field data sheets and field notebook
         1. Field data sheets saved WWBWC server - Y:\WWBWC LIBRARY\MONITORING\WELLNET\Procedures, Manuals, Equipment\Templates\TEMPLATE_WellDataSheet_sp
         2. Record data onto hard copy of data sheet
      iv. Black WellNet notebook for reference. It contains the Well Info pages with maps, addresses, photos, coordinates, well owner names, etc. for each well.
      v. Business cards and pamphlets about WWBWC
   c. Downloading/Logger Equipment:
      i. Charged Field laptop
      ii. Cables for MiniTroll, LevelTroll 300, Solinst/MicroDiver, Solinst Direct Connect and MicroDiver Direct Connect
      iii. Battery removal tool for MiniTrolls

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WWBWC Well Monitoring Field Instructions (cont.)

- d. Logger Maintenance:
    - i. U-bolts, cable/speaker wire and wire crimps
    - ii. Extra AA lithium batteries
- e. Static and Grab Samples Equipment:
    - i. E-tape and extra 9V batteries
    - ii. Bailer
    - iii. Graduated cylinder
    - iv. Conductivity/EC meter (w/ thermometer)
- f. Other:
    - i. Sounding tape
    - ii. Measurement tape (meter tape)

3.) Procedures:

- a. Record Date and Time for given site.
- b. Manual Water Level Measurements:
    - i. Review well info page for the point at which you should take the manual measurement (Measurement Point - MP)
    - ii. Turn E-tape on to “Test” and make sure it sounds
        1. If it doesn’t buzz, adjust the “Sensitivity” knob
        2. If it still doesn’t buzz, change the batteries
    - iii. Turn E-tape to “Buzz”
    - iv. Lower E-tape into well slowly, making sure the tape doesn’t come off the sides of the reel
    - v. When the tape buzzes, pull the tape up and down until you can determine the exact level. Determine level to within 0.01 feet
    - vi. RECORD the static level and whether the pump is on or off. Pump on = 1, pump off = 0
    - vii. Double check manual measurement. If values differ by more than 0.01 feet determine why (well pumping, well recovering, etc) and document reason on data sheet
- c. Grab Samples:
    - i. Unlock the bailer and lower it into the well-you may hit bottom or hear it fill
        1. Lower bailer into well ONLY if there is ample space for it. Well Network Index sheet will indicate whether a grab sample should be done at a given well
        2. Do not lower it into wells with vent hole access only

WWBWC Well Monitoring Field Instructions (cont.)

ii. Reel the bailer back slowly, trying to keep it from banging against the sides of the well
iii. Empty the bailer contents into the graduated cylinder
iv. Put the EC/Cond probe into the graduated cylinder
    1. Push the on/off button
    2. Wait for reading to stabilize; Record temperature and conductivity values
    3. The YSI Meter should be reading in degrees C for temperature and µs for conductivity

d. Deploying Pressure Transducers (Data Loggers):
   i. Sound well and record or look up well log to find out what well depth is
   ii. Take a static depth and record manual measurement
   iii. Measure and cut aviation cable or speaker wire or use manufacturer's communication cable to hang data logger
       1. Order cable thru Widner Electric/Napa or obtain speaker wire from Home Depot
       2. Cable should be 2-3 feet from the bottom of the well (if the pressure range for the pressure transducer allows). If the pressure range doesn't allow for the logger to be near the bottom of the well place it so it has about 10-15 feet of pressure range still available (as determined by the manual measurement). Pressure transducers should not rest on the bottom of the well
       3. Remember to account for the length of the logger and the cable needed to attach the cable at the surface
       4. Record the length of the cable and the pressure transducer's serial number (and communication cable serial number if applicable)

   iv. Attach the cable to the logger using two wire crimps and a stainless steel u-bolt
       1. Aluminum crimps can be bought at PGG and Stainless Steel u-bolts can be bought at Home Depot (1/8th").
       2. Crimp the aluminum crimps with fencing tool or cable snips
       3. Tighten U-bolt with the socket or needle nose pliers

WWBWC Well Monitoring Field Instructions (cont.)

v. Attach the cable at the surface with crimps or u-bolts
vi. Once the logger is started and attached lower it slowly into the well
vii. Measure the top of ground adjustment (the distance between the measurement point and the ground). Record this in the TOG column
viii. Take photos of the well. Try to capture the area around the well, the well apparatus and the measurement point. Multiple photos may be required
ix. If well has not been surveyed, survey with Magellan ProMark 3 system as earliest opportunity (See GPS Survey Report for details)

e. Downloading Loggers:
i. Take a manual measurement before removing the pressure transducer
ii. Attach and connect to the data logger. Record the time you started the download (Download time column)
iii. Also record the any difference between the data logger time and computer time (Logger time column)
iv. Record battery condition (% battery left, New for Minitrolls with new batteries, or left blank for Minitrolls that did not get new batteries)
v. Record data logger serial number
vi. Record the status of the u-bolts and crimps (U-bolts column)
vii. Record if equipment (Cable, u-bolts, crimps, etc.) looks okay, if something needs to be added next time, or if you added any equipment
viii. Follow steps outlined in the procedures for particular brand of logger, saving all downloaded files on the laptop
ix. Visual check that the download raw data looks appropriate and there are not major issues that occur. The download software will graph the raw data. Look for any abrupt changes
x. Record when the data logger will restart if the data logger was stopped and restarted
xi. Record any comments or notes regarding the data logger or download in the comments section
xii. Put the field laptop into stand-by mode while traveling to the next well

WWBWC Well Monitoring Field Instructions (cont.)

f. Office transfer of data:
   i. Input all manual measurements, pump status, notes, TOG changes, temperature, and conductivity values into the Statics excel worksheet. Y:\WWBWC LIBRARY\MONITORING\WELLNET\Statics\Wellnet_Statics
   Highlight the site ID for each well after the data has been inputted into the excel file. This communicates to other staff that the data has been transferred to the excel file
   ii. Update the download schedule on the white board
   iii. Order needed equipment in advance of next field visit
   iv. Report any problems with wells, data, or safety to Supervisor

APPENDIX B

GPS coordinates for wells currently monitored in the Walla Walla Basin Shallow Aquifer. Note: GPS coordinates are in UTM (Datum = NAD83 and NAVD88 for Elevation).

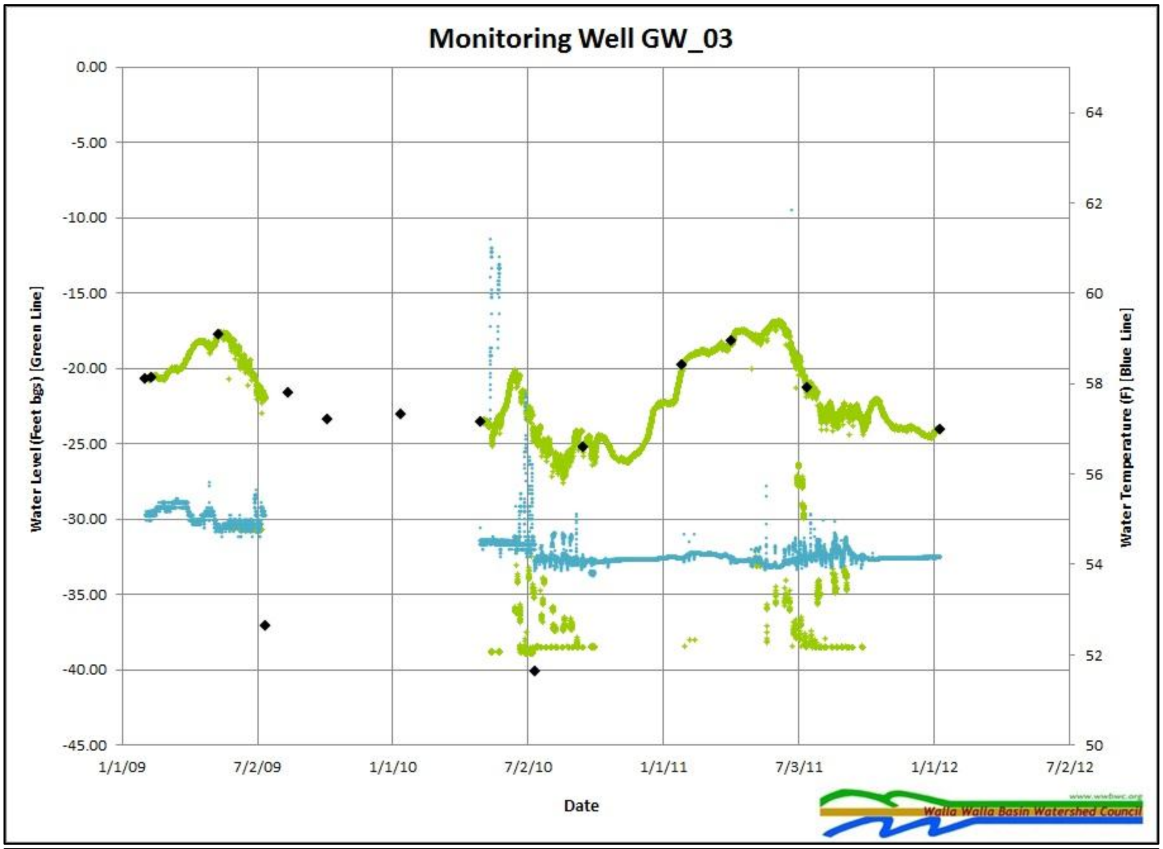
WELL_ID	Easting	Northing	Well Elevation in Meters	Well Elevation in Feet	Horizontal Confidence in Meters	Vertical Confidence in Meters	AGENCY
GW_03	393477.08	5091165.361	273.745	898.114	0.016	0.012	WWBWC
GW_04	393192.023	5091728.252	267.303	876.978	0.016	0.011	WWBWC
GW_05	393764.617	5094403.253	248.064	813.920	0.022	0.015	WWBWC
GW_06	392664.181	5092403.474	262.960	867.425	0.015	0.011	WWBWC
GW_07	392787.583	5091551.116	271.717	891.460	0.012	0.012	WWBWC
GW_08	392587.05	5090737.197	281.997	925.187	0.012	0.011	WWBWC
GW_09	392658.605	5088806.697	306.631	1006.007	0.014	0.01	WWBWC
GW_10	392132.402	5091372.824	273.696	897.950	0.022	0.019	WWBWC
GW_11	391570.533	5093637.708	247.687	812.621	0.015	0.017	WWBWC
GW_13	390667.86	5093232.622	250.852	823.004	0.013	0.015	WWBWC
GW_14	392157.683	5089568.006	295.488	969.449	0.012	0.009	WWBWC
GW_15	388945.465	5089304.752	272.057	892.575	0.003	0.003	OWRD
GW_18	386647.989	5093698.759	225.360	739.367	0.005	0.006	OWRD
GW_19	391225.116	5092022.761	265.289	870.369	0.014	0.018	OWRD
GW_20	393114.775	5092400.73	264.392	867.428	0.096	0.101	OWRD
GW_23	390432.546	5088757.822	292.342	959.125	0.006	0.007	OWRD
GW_25	393463.723	5090261.704	284.451	933.238	0.013	0.015	OWRD
GW_27	391245.146	5088811.531	298.777	980.239	0.008	0.009	OWRD
GW_28	390083.217	5090403.42	274.565	900.803	0.005	0.004	WWBWC
GW_31	385163.051	5093209.972	218.535	716.976	0.006	0.007	WWBWC
GW_33	387947.465	5093853.935	230.034	754.702	0.008	0.006	WWBWC
GW_34	383288.818	5093418.243	201.734	661.855	0.011	0.008	WWBWC
GW_35	388031.533	5090796.498	255.362	837.799	0.09	0.089	WWBWC
GW_36	384946.272	5091616.019	220.534	723.534	0.01	0.012	WWBWC
GW_37	384227.715	5092519.703	208.416	683.780	0.008	0.01	WWBWC
GW_38	392985.262	5094932.606	248.083	812.122	0.021	0.014	WWBWC
GW_39	388823.228	5090045.31	266.394	873.993	0.004	0.002	WWBWC
GW_40	388846.149	5089945.789	266.979	875.913	0.004	0.002	WWBWC
GW_41	388830.34	5090133.816	265.537	871.182	0.004	0.002	WWBWC
GW_45	388555.543	5090167.255	262.553	861.394	0.003	0.003	WWBWC
GW_46	388335.675	5090331.38	259.507	851.400	0.003	0.002	WWBWC
GW_47	388325.733	5090362.964	259.118	850.123	0.004	0.002	WWBWC
GW_48	388432.429	5090413.757	259.608	851.732	0.004	0.002	WWBWC
GW_54	390256.169	5095118.764	231.915	760.873	0.01	0.012	WWBWC
GW_57	385964.995	5095524.821	205.082	672.840	0.003	0.003	WDOE
GW_58	387261.534	5091269.173	245.655	805.953	0.005	0.004	WWBWC
GW_60	388039.791	5090041.577	257.473	844.726	0.003	0.003	WWBWC
GW_61	387730.609	5089747.583	255.862	839.440	0.003	0.003	WWBWC
GW_62	389834.806	5089059.234	283.305	929.478	0.006	0.004	WWBWC
GW_63	383280.245	5091893.17	203.980	669.226	0.014	0.01	WWBWC
GW_64	383657.595	5091641.274	208.550	684.218	0.011	0.013	WWBWC
GW_65	387239.855	5090936.276	246.133	807.520	0.005	0.003	WWBWC
GW_66	384016.598	5091700.048	209.851	688.485	0.014	0.01	WWBWC
GW_67	378968.413	5093403.081	175.056	574.330	0.019	0.02	WWBWC
GW_68	379255.547	5092242.311	181.305	594.831	0.022	0.018	WWBWC
GW_69	383991.427	5091254.854	212.394	696.829	0.013	0.013	WWBWC
GW_70	385959.296	5095225.597	206.799	678.472	0.003	0.003	WWBWC
GW_71	385628.631	5095705.396	202.314	663.757	0.003	0.003	WWBWC

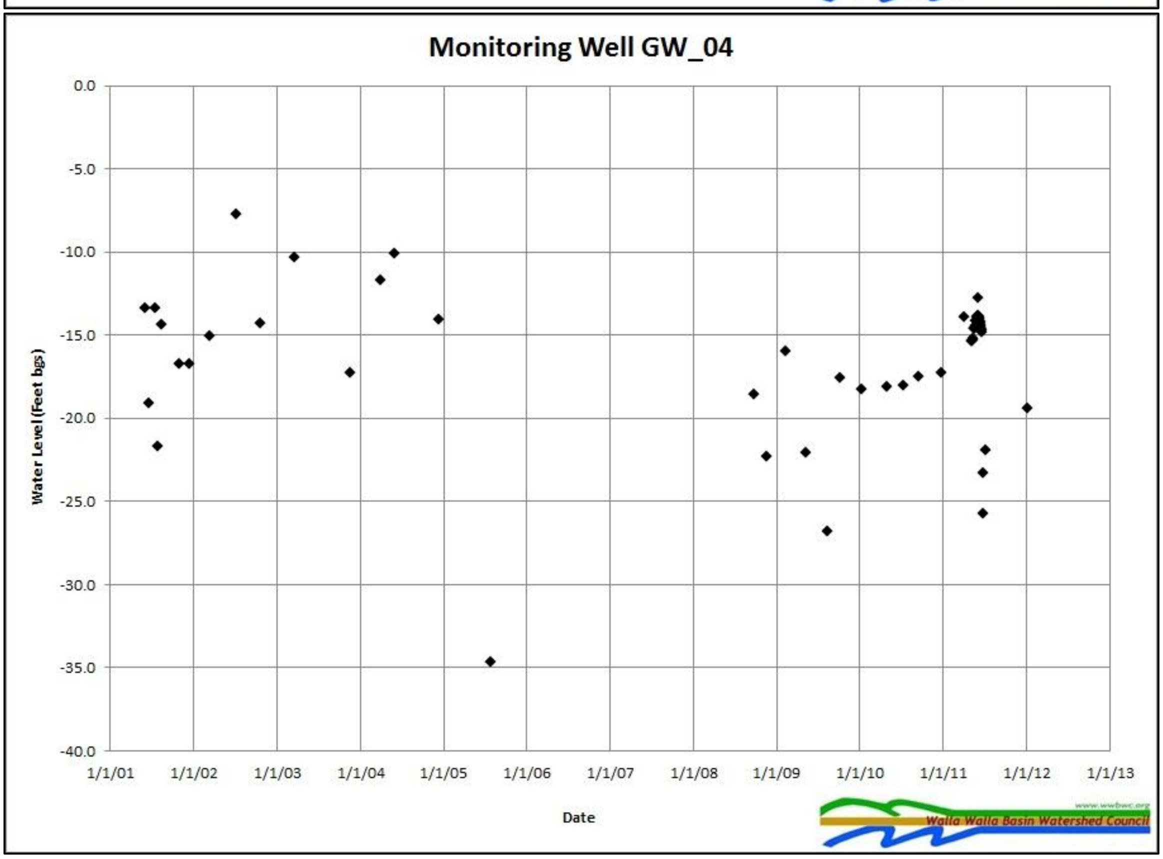
WELL_ID	Easting	Northing	Well Elevation in Meters	Well Elevation in Feet	Horizontal Confidence in Meters	Vertical Confidence in Meters	AGENCY
GW_72	385729.547	5095463.305	204.567	671.152	0.004	0.002	WWBWC
GW_73	390621.47	5095033.16	232.761	763.651			WWBWC
GW_74	390649.10	5094642.92	234.943	770.811			WWBWC
GW_75	390474.91	5095093.45	230.702	756.897			WWBWC
GW_82	369667.774	5098077.191	167.560	549.736	0.006	0.004	WWBWC
GW_83	395564.39	5102165.305	279.703	917.659	0.014	0.018	WWBWC
GW_85	390405.704	5098512.064	218.239	716.007	0.016	0.013	WWBWC
GW_86	370841.298	5099210.647	135.383	444.168	0.01	0.006	WWBWC
GW_87	402951.381	5104575.886	385.250	1263.942	0.006	0.004	CITY OF WALLA WALLA
GW_88	404352.529	5104571.294	402.095	1319.206	0.008	0.009	CITY OF WALLA WALLA
GW_89	400344.775	5102819.459	340.715	1117.829	0.004	0.004	CITY OF WALLA WALLA
GW_90	397598.227	5100192.121	295.908	970.825	0.012	0.014	CITY OF WALLA WALLA
GW_92	372892.083	5095185.179	170.620	559.775	0.017	0.016	WWBWC
GW_93	372093.92	5097078.055	177.130	581.135	0.014	0.01	WWBWC
GW_94	376840.306	5099135.812	151.368	496.613	0.032	0.021	WWBWC
GW_95	392050.438	5103625.036	257.941	846.261	0.022	0.027	WWBWC
GW_96	377627.97	5099120.23	151.895	498.342	0.03	0.02	WWBWC
GW_98	388276.158	5089528.166	263.425	864.255	0.021	0.014	WWBWC
GW_100	389461.838	5095285.116	226.025	741.552	0.011	0.008	WWBWC
GW_101	389376.906	5095242.378	227.345	745.881	0.009	0.01	WWBWC
GW_102	390157.378	5096042.65	222.966	731.513	0.013	0.01	WWBWC
GW_103	385326.833	5097329.298	195.595	641.715	0.005	0.006	WWBWC
GW_104	385521.562	5096636.159	198.959	652.752	0.004	0.003	WWBWC
GW_105	380175.563	5103218.696	169.084	554.736	0.027	0.025	WDOE
GW_106	370775.076	5098318.612	137.985	452.704	0.009	0.006	WDOE
GW_107	379927.288	5099999.592	159.637	523.741	0.024	0.017	WDOE
GW_108	384498.967	5098025.066	189.354	621.238	0.008	0.008	WDOE
GW_109	377261.415	5096816.914	157.012	515.130	0.026	0.021	WDOE
GW_110	384010.342	5095258.424	203.024	666.089	0.006	0.005	WDOE
GW_111	386005.353	5099434.302	185.580	608.857	0.011	0.01	WDOE
GW_112	388823.342	5095371.845	223.286	732.565	0.007	0.008	WDOE
GW_113	388445.622	5097173.405	207.196	679.776	0.01	0.006	WDOE
GW_114	392310.456	5096321.561	228.461	749.544	0.02	0.015	WDOE
GW_115	392743.234	5086919.977	326.984	1072.780	0.072	0.106	WWBWC
GW_116	391304.129	5091322.097	272.050	892.550	0.022	0.015	WWBWC
GW_117	389825.547	5090864.475	268.409	880.607	0.004	0.004	OWRD
GW_118	387655.395	5090858.899	250.210	820.898	0.004	0.003	OWRD
GW_119	384949.15	5092104.046	217.173	712.508	0.01	0.011	WWBWC
GW_120	380094.16	5094289.865	172.605	566.289	0.019	0.013	WWBWC
GW_121	376782.848	5095406.672	153.482	503.549	0.024	0.025	WDOE
GW_122	383671.11	5097361.742	183.508	602.059	0.01	0.007	WDOE
GW_123	372425.274	5098426.898	136.382	447.447	0.015	0.01	WDOE
GW_124	370208.59	5096168.176	154.515	506.938	0.011	0.007	WDOE
GW_125	367861.923	5098647.985	130.150	427.001	0.003	0.002	WDOE
GW_126	370288.485	5101958.994	141.772	465.132	0.014	0.009	WDOE
GW_127	396489.017	5103462.555	294.222	965.295	0.107	0.083	WDOE
GW_128	398388.076	5102166.693	315.769	1035.986	0.013	0.008	WDOE
GW_129	392937.709	5097342.666	235.127	771.414	0.023	0.016	WDOE
GW_130	371006.475	5095051.067	170.546	559.535	0.015	0.011	WWBWC

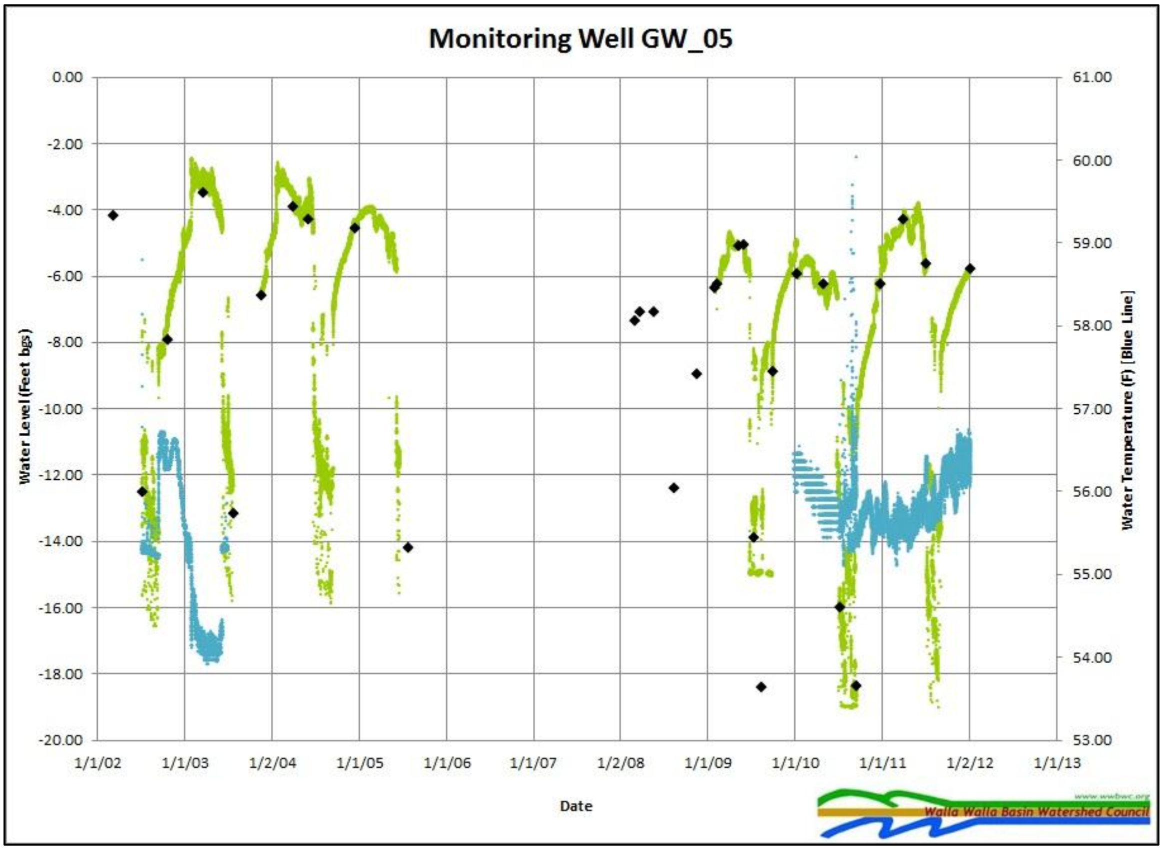
WELL_ID	Easting	Northing	Well Elevation in Meters	Well Elevation in Feet	Horizontal Confidence in Meters	Vertical Confidence in Meters	AGENCY
GW_131	373332.024	5100415.423	138.554	454.571	0.018	0.013	WWBWC
GW_132	394298.127	5100424.793	265.044	869.565	0.031	0.022	WDOE
GW_133	380163.278	5102894.259	167.725	550.277	0.024	0.026	WDOE
GW_134	392341.464	5100035.082	240.01	787.433	0.022	0.021	WWBWC
GW_135	390848.356	5088932.953	294.177	965.146	0.01	0.01	WWBWC

APPENDIX C

Well Hydrographs for wells in the WWBWC's Shallow Aquifer Monitoring Network.







Monitoring Well GW_05
Water Level (Feet bgs)
Water Temperature (F) [Blue Line]
Date
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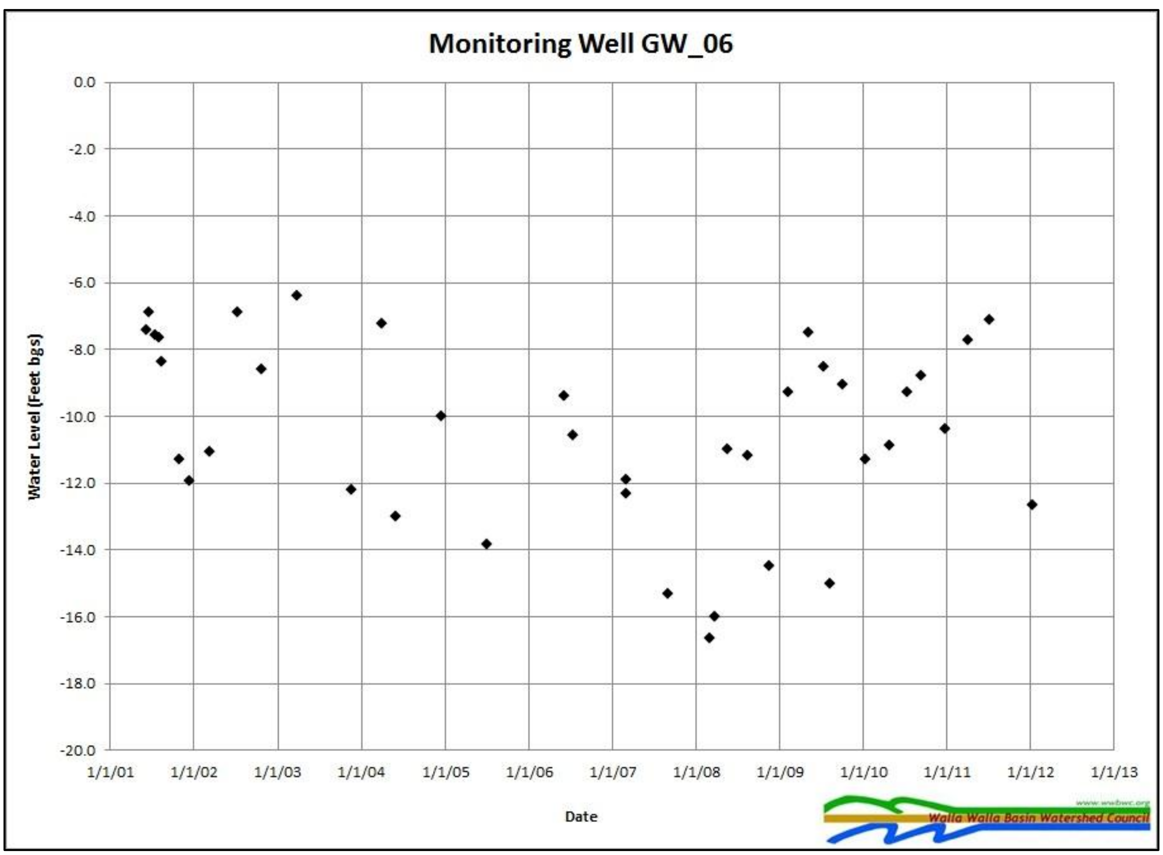
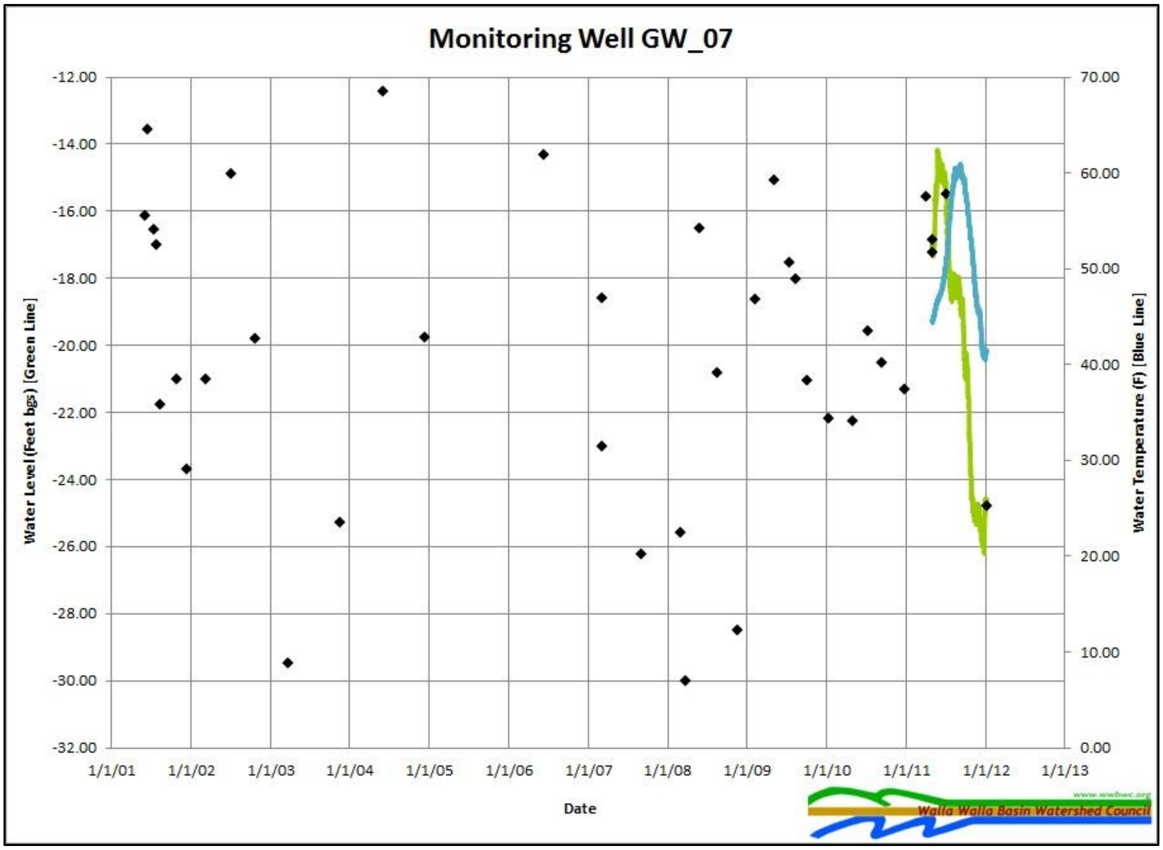
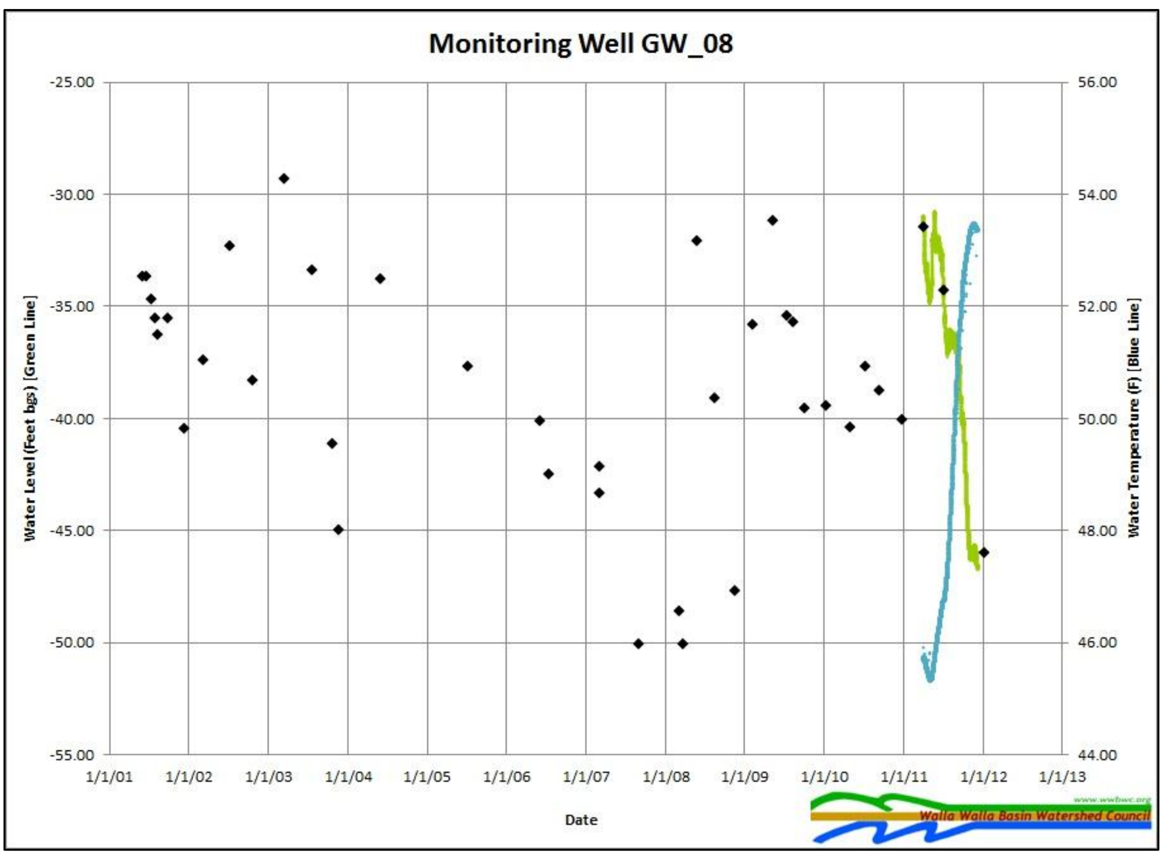
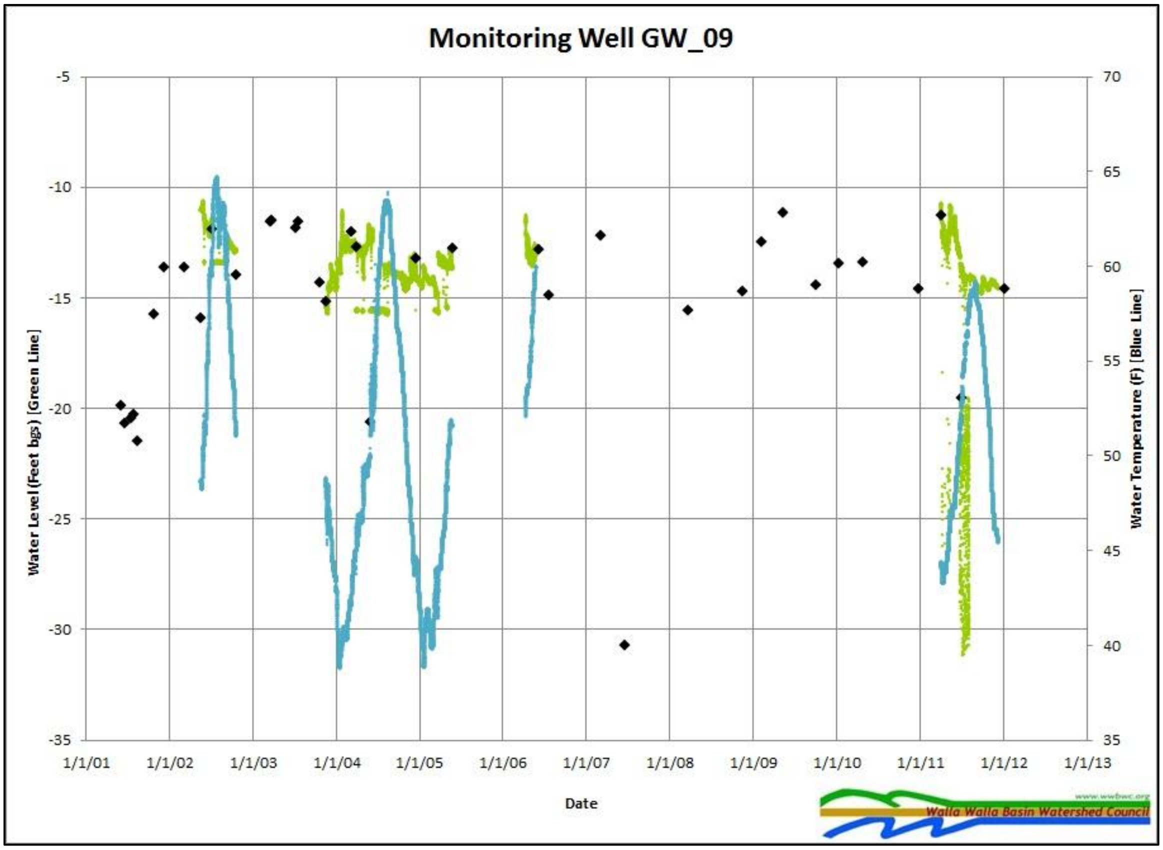
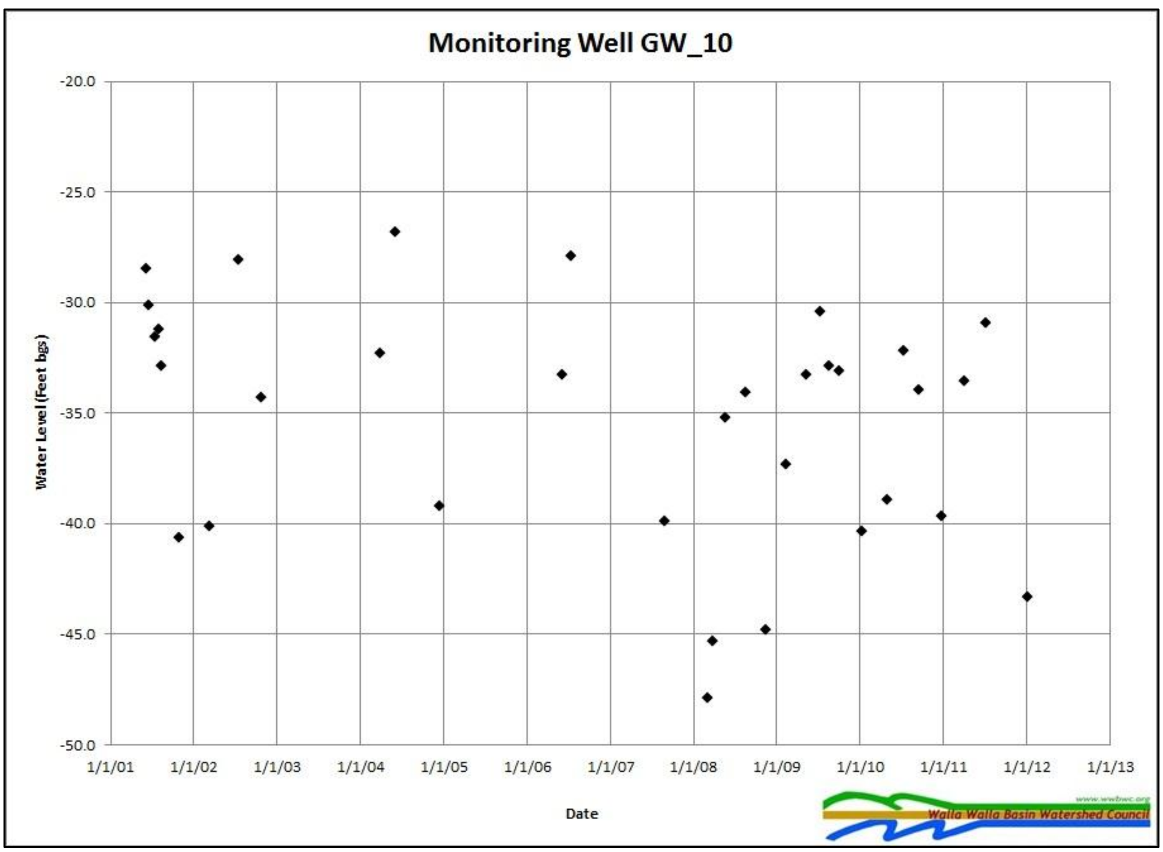


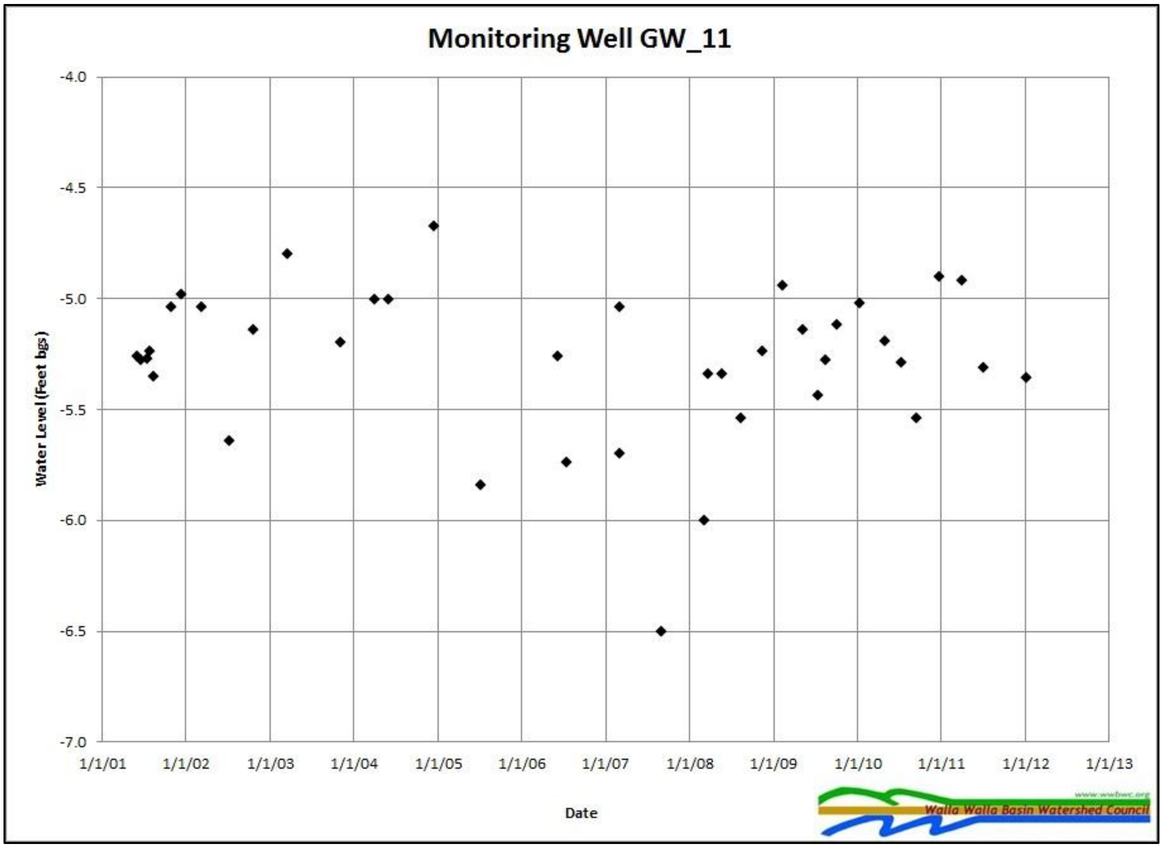
Monitoring Well GW_06
Water Level (Feet bgs)
Date
www.wwbwc.org
Walla Walla Basin Watershed Council

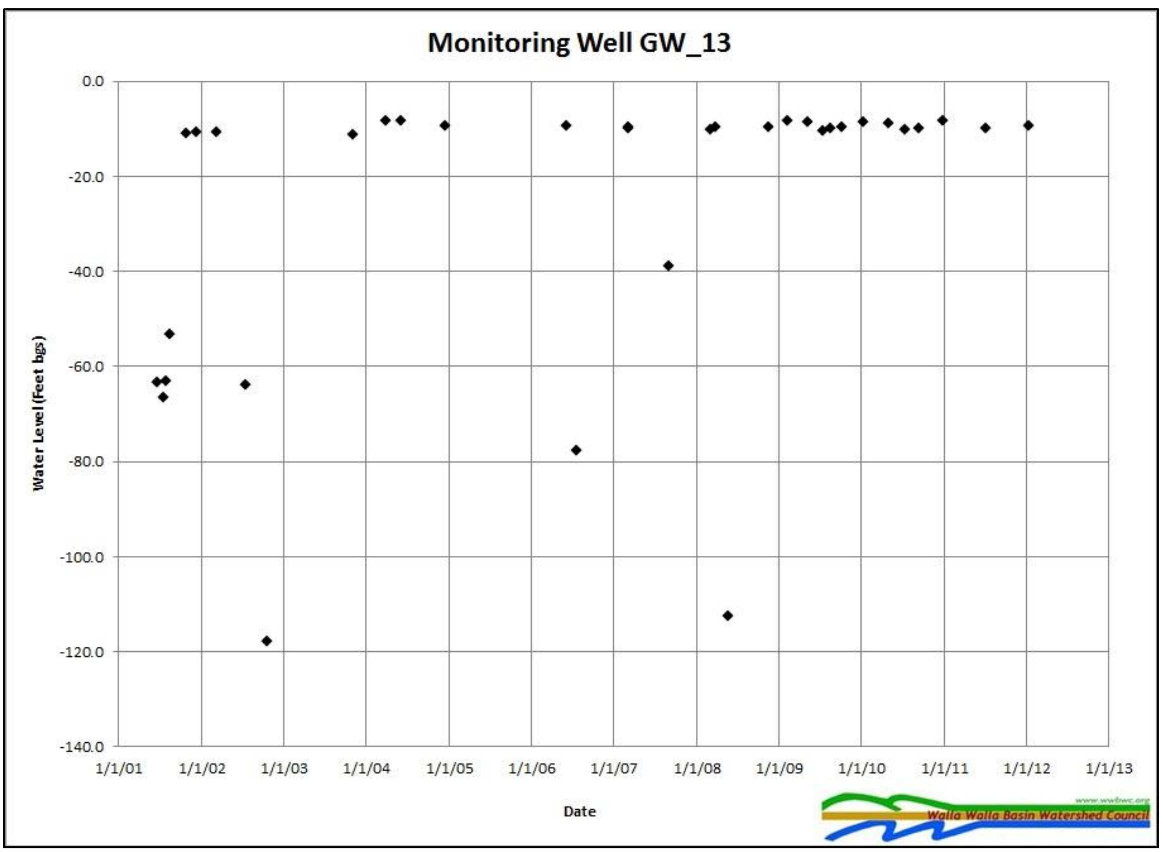

Monitoring Well GW_07
-12.00
-14.00
-16.00
-18.00
-20.00
-22.00
-24.00
-26.00
-28.00
-30.00
-32.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
1/1/01
1/1/02
1/1/03
1/1/04
1/1/05
1/1/06
1/1/07
1/1/08
1/1/09
1/1/10
1/1/11
1/1/12
1/1/13
Water Level (Feet bgs) [Green Line]
Water Temperature (F) [Blue Line]
Date
Walla Walla Basin Watershed Council

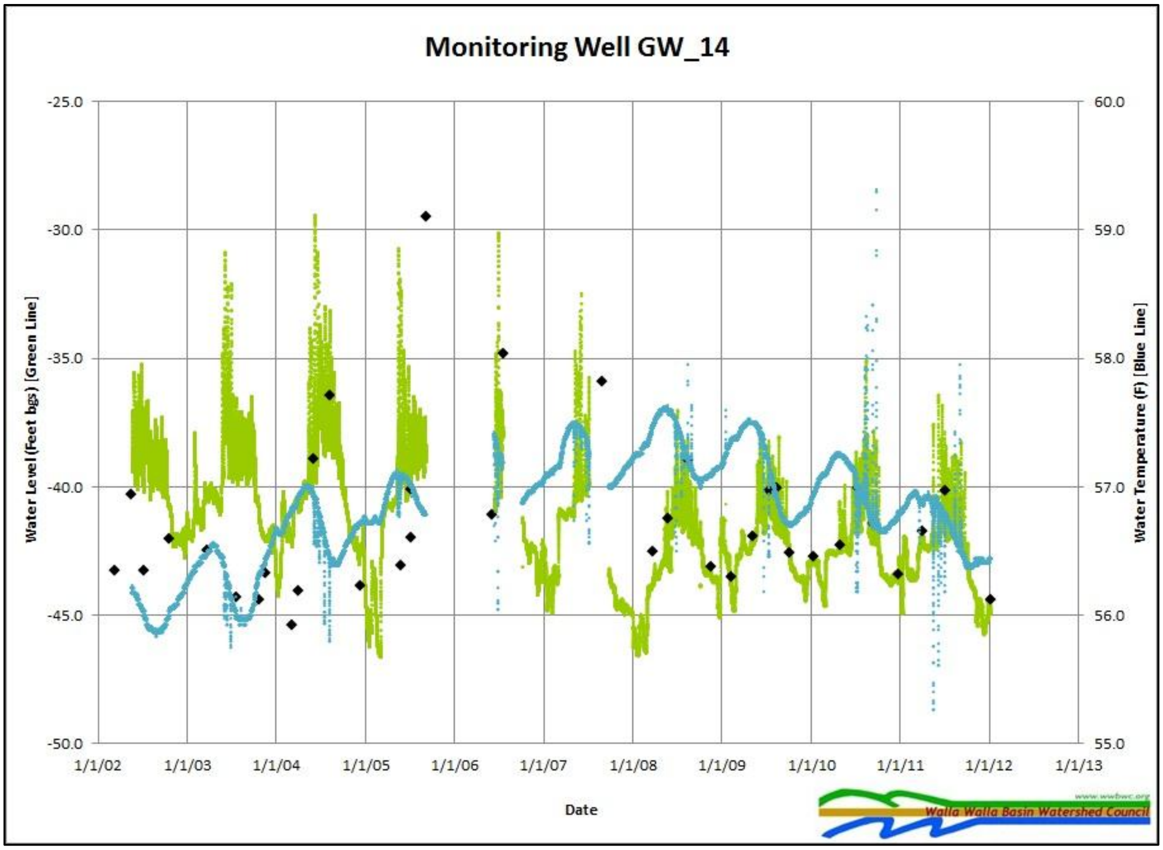

Monitoring Well GW_08
-25.00
-30.00
-35.00
-40.00
-45.00
-50.00
-55.00
56.00
54.00
52.00
50.00
48.00
46.00
44.00
1/1/01
1/1/02
1/1/03
1/1/04
1/1/05
1/1/06
1/1/07
1/1/08
1/1/09
1/1/10
1/1/11
1/1/12
1/1/13
Water Level (Feet bgs) [Green Line]
Water Temperature (F) [Blue Line]
Date
Walla Walla Basin Watershed Council


Monitoring Well GW_09
Water Level (Feet bgs) [Green Line]
Water Temperature (F) [Blue Line]
Date
-5
-10
-15
-20
-25
-30
-35
70
65
60
55
50
45
40
35
1/1/01
1/1/02
1/1/03
1/1/04
1/1/05
1/1/06
1/1/07
1/1/08
1/1/09
1/1/10
1/1/11
1/1/12
1/1/13
Walla Walla Basin Watershed Council

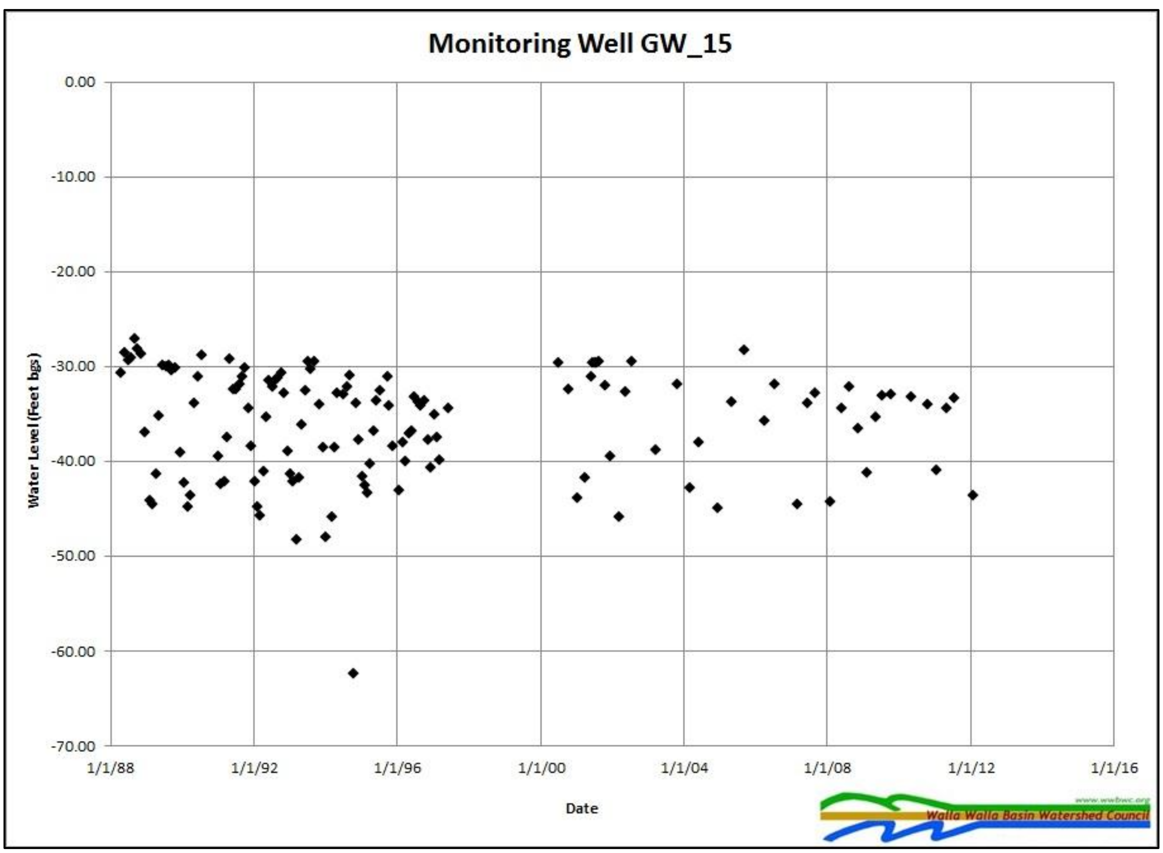

Monitoring Well GW_10
Water Level (Feet bgs)
Date
-20.0
-25.0
-30.0
-35.0
-40.0
-45.0
-50.0
1/1/01
1/1/02
1/1/03
1/1/04
1/1/05
1/1/06
1/1/07
1/1/08
1/1/09
1/1/10
1/1/11
1/1/12
1/1/13
Walla Walla Basin Watershed Council


Monitoring Well GW_11
Water Level (Feet bgs)
-4.0
-4.5
-5.0
-5.5
-6.0
-6.5
-7.0
1/1/01
1/1/02
1/1/03
1/1/04
1/1/05
1/1/06
1/1/07
1/1/08
1/1/09
1/1/10
1/1/11
1/1/12
1/1/13
Date
Walla Walla Basin Watershed Council

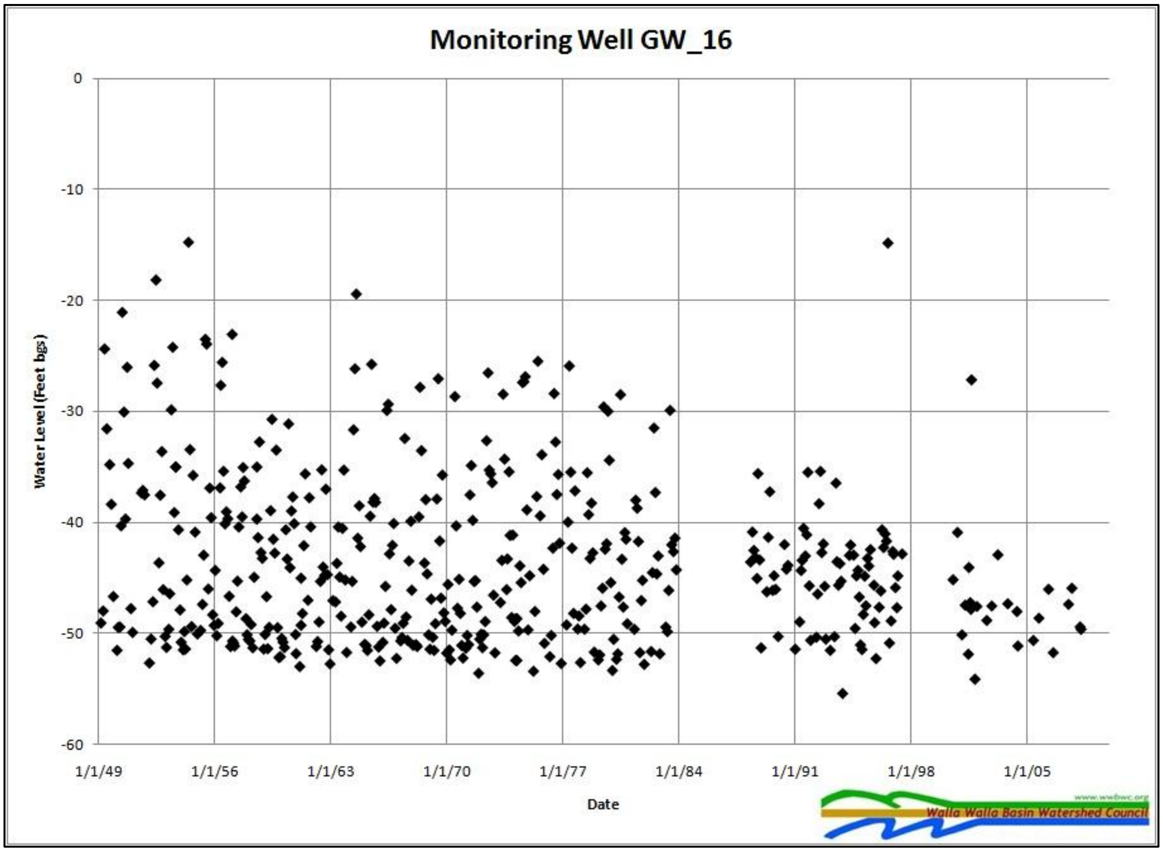

Monitoring Well GW_13
Water Level (Feet bgs)
0.0
-20.0
-40.0
-60.0
-80.0
-100.0
-120.0
-140.0
1/1/01
1/1/02
1/1/03
1/1/04
1/1/05
1/1/06
1/1/07
1/1/08
1/1/09
1/1/10
1/1/11
1/1/12
1/1/13
Date
Walla Walla Basin Watershed Council

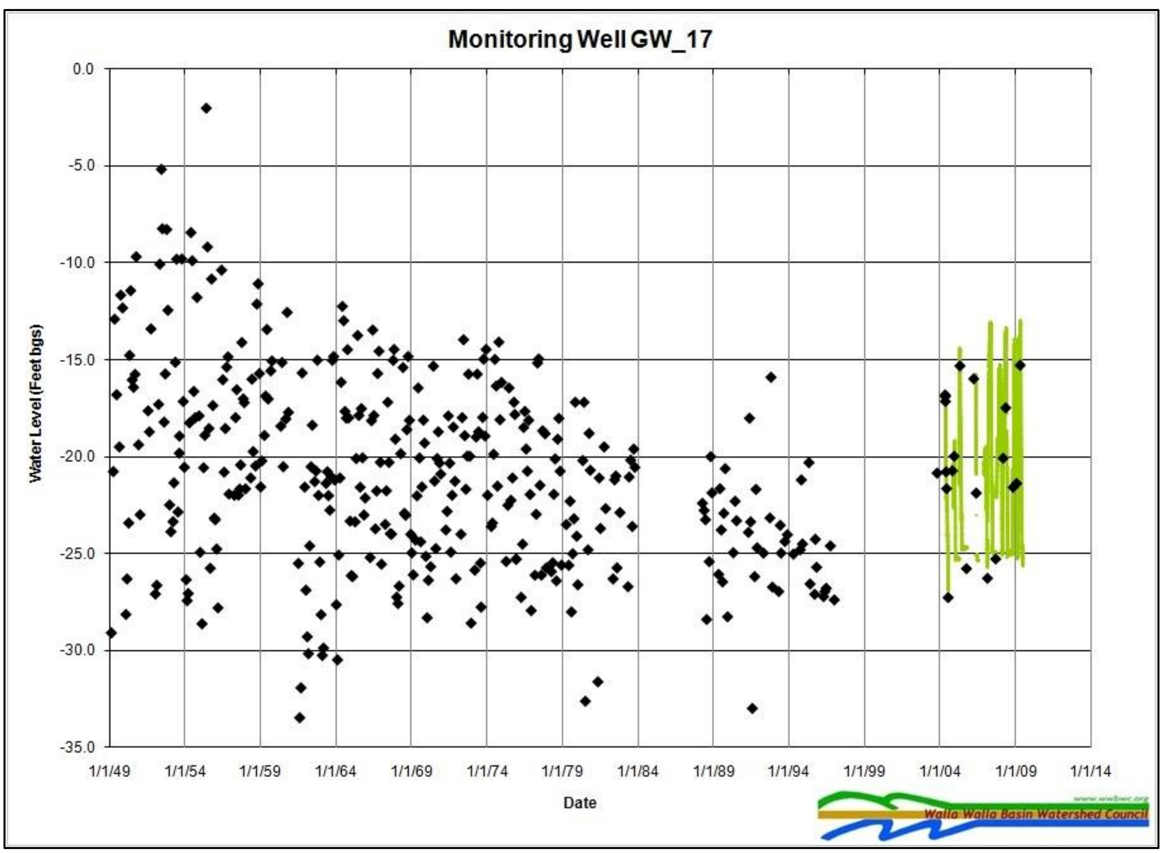


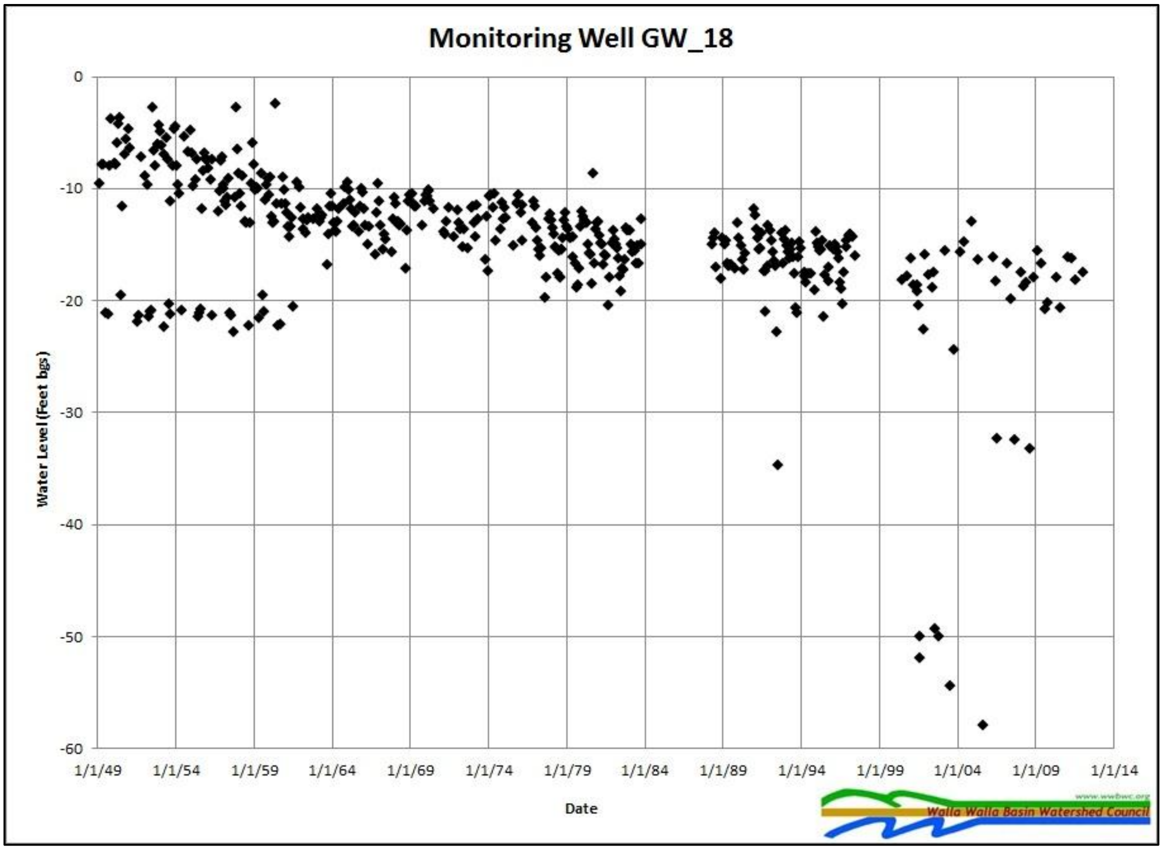
Monitoring Well GW_14
Water Level (Feet bgs) [Green Line]
Water Temperature (F) [Blue Line]
Date
-25.0
-30.0
-35.0
-40.0
-45.0
-50.0
60.0
59.0
58.0
57.0
56.0
55.0
1/1/02
1/1/03
1/1/04
1/1/05
1/1/06
1/1/07
1/1/08
1/1/09
1/1/10
1/1/11
1/1/12
1/1/13
Walla Walla Basin Watershed Council

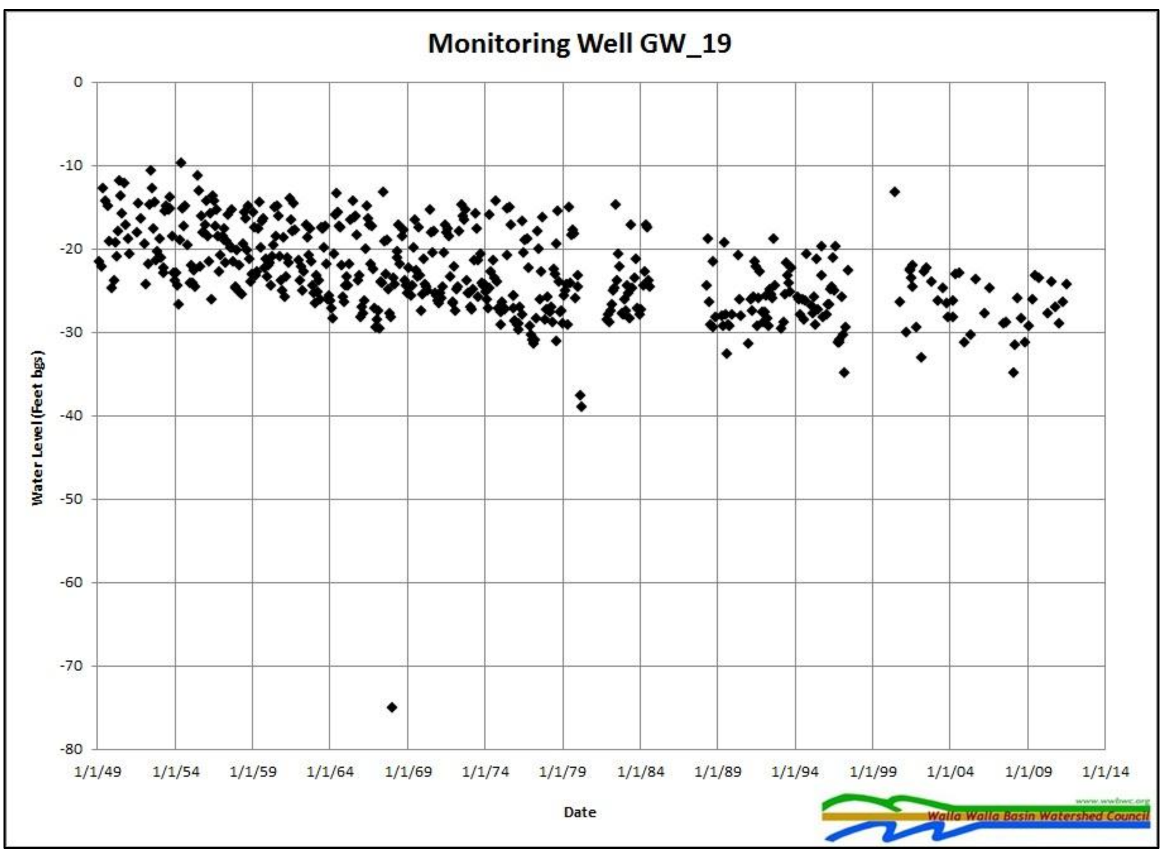


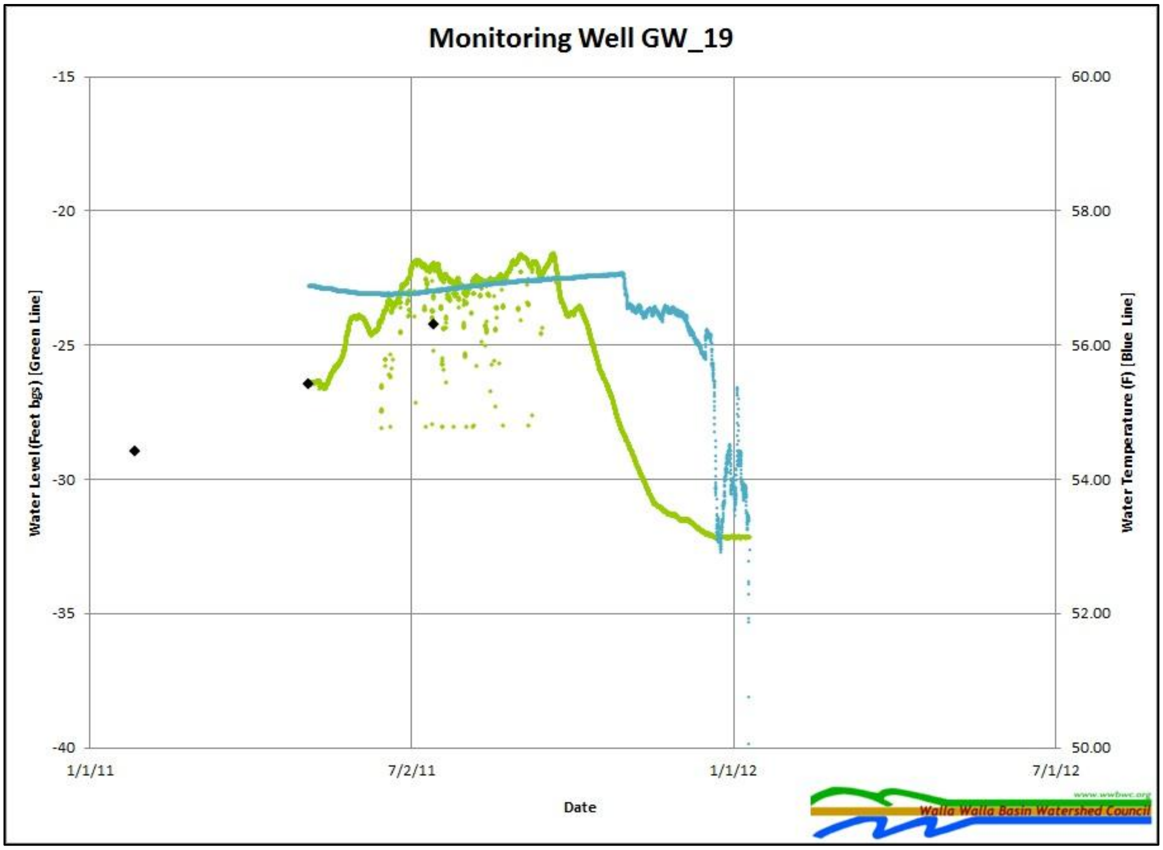
Monitoring Well GW_15
Water Level (Feet bgs)
Date
0.00
-10.00
-20.00
-30.00
-40.00
-50.00
-60.00
-70.00
1/1/88
1/1/92
1/1/96
1/1/00
1/1/04
1/1/08
1/1/12
1/1/16
Walla Walla Basin Watershed Council

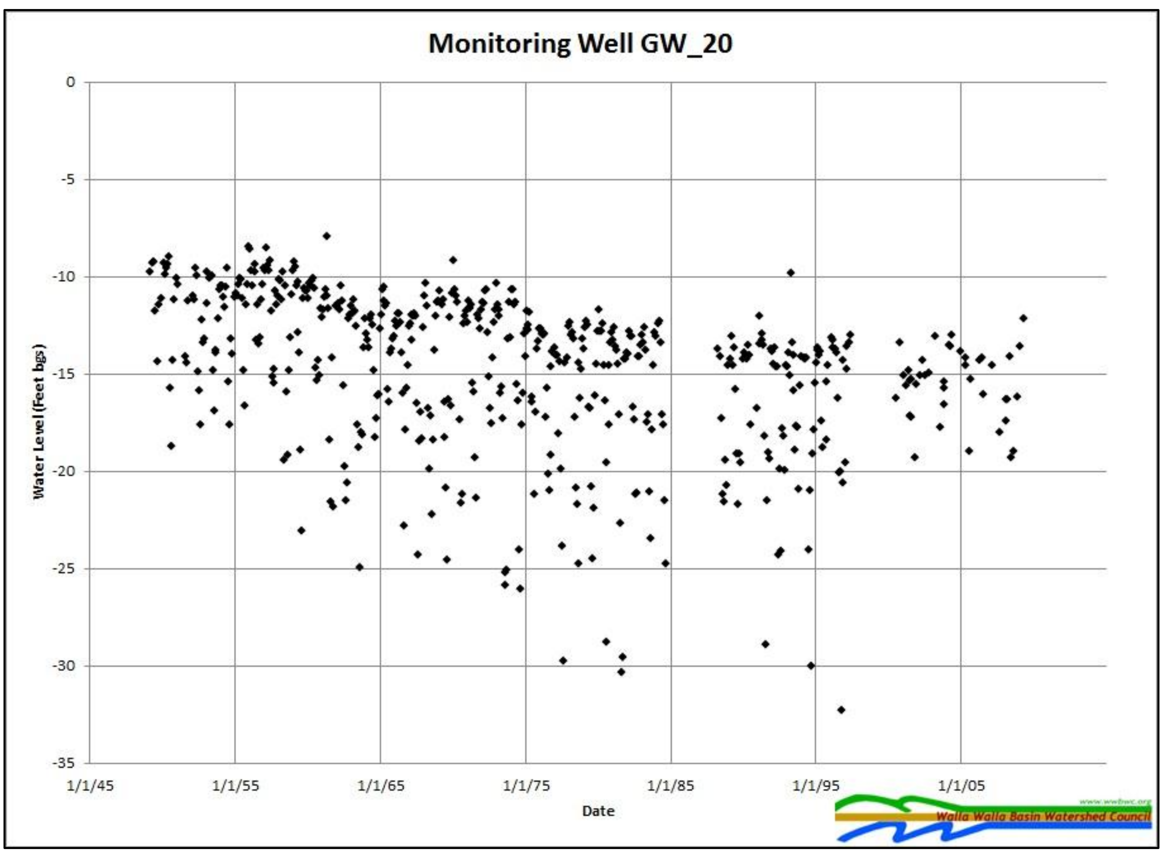

Monitoring Well GW_16
Water Level (Feet bgs)
0
-10
-20
-30
-40
-50
-60
1/1/49
1/1/56
1/1/63
1/1/70
1/1/77
1/1/84
1/1/91
1/1/98
1/1/05
Date
Walla Walla Basin Watershed Council

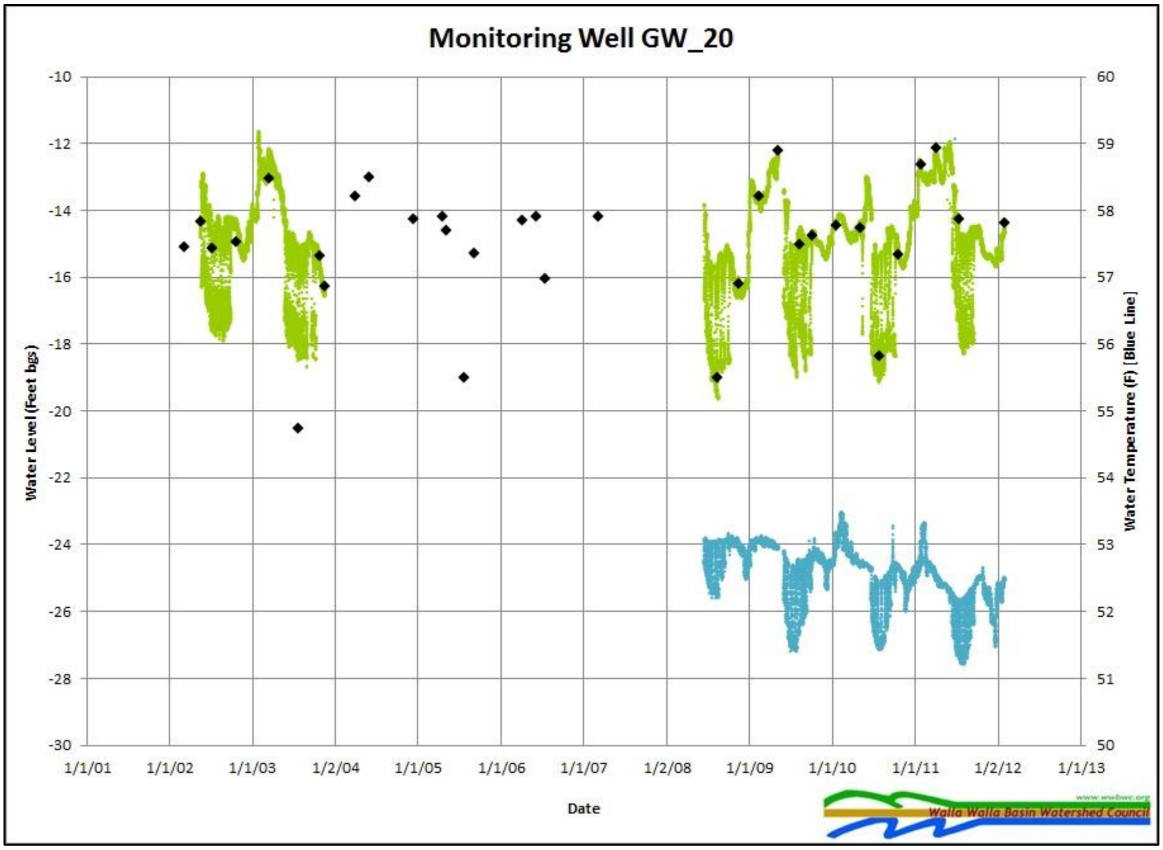

Monitoring Well GW_17
Water Level (Feet bgs)
0.0
-5.0
-10.0
-15.0
-20.0
-25.0
-30.0
-35.0
1/1/49
1/1/54
1/1/59
1/1/64
1/1/69
1/1/74
1/1/79
1/1/84
1/1/89
1/1/94
1/1/99
1/1/04
1/1/09
1/1/14
Date
Walla Walla Basin Watershed Council

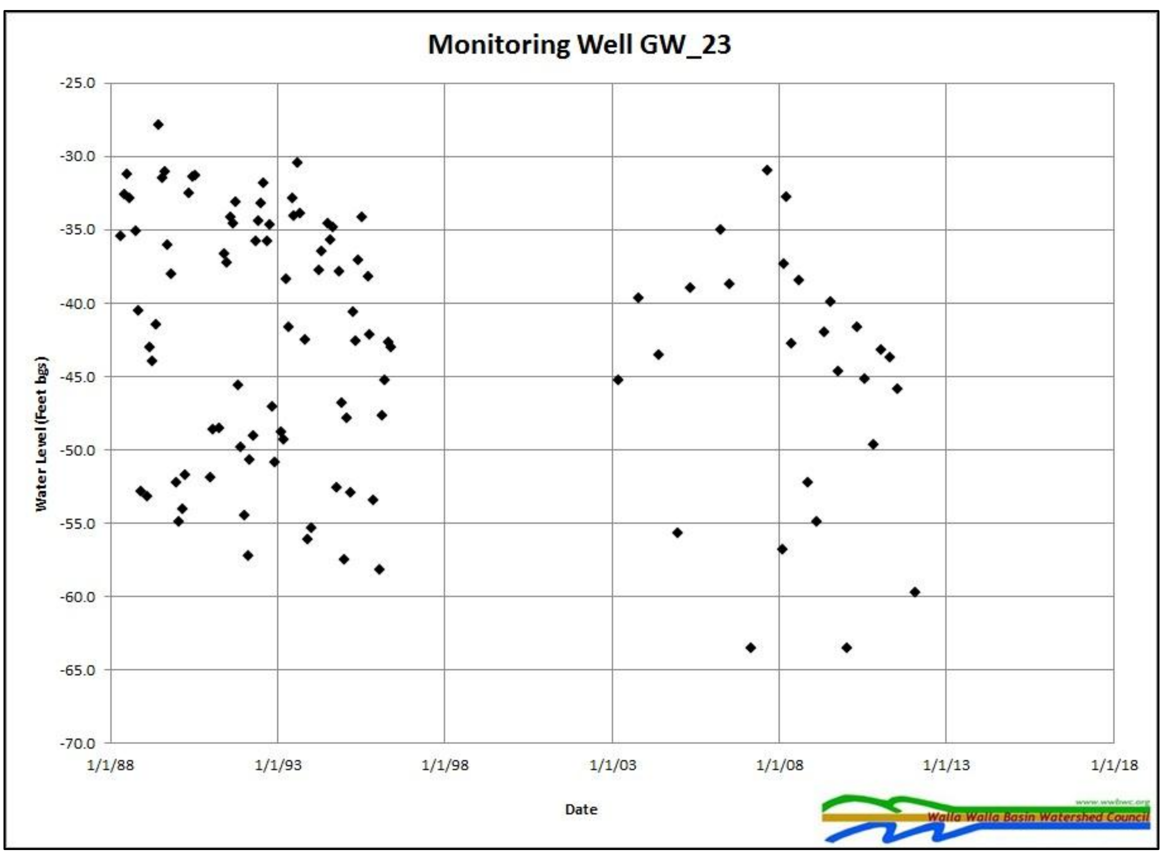

Monitoring Well GW_18
0
-10
-20
-30
-40
-50
-60
Water Level (Feet bgs)
1/1/49
1/1/54
1/1/59
1/1/64
1/1/69
1/1/74
1/1/79
1/1/84
1/1/89
1/1/94
1/1/99
1/1/04
1/1/09
1/1/14
Date
Walla Walla Basin Watershed Council

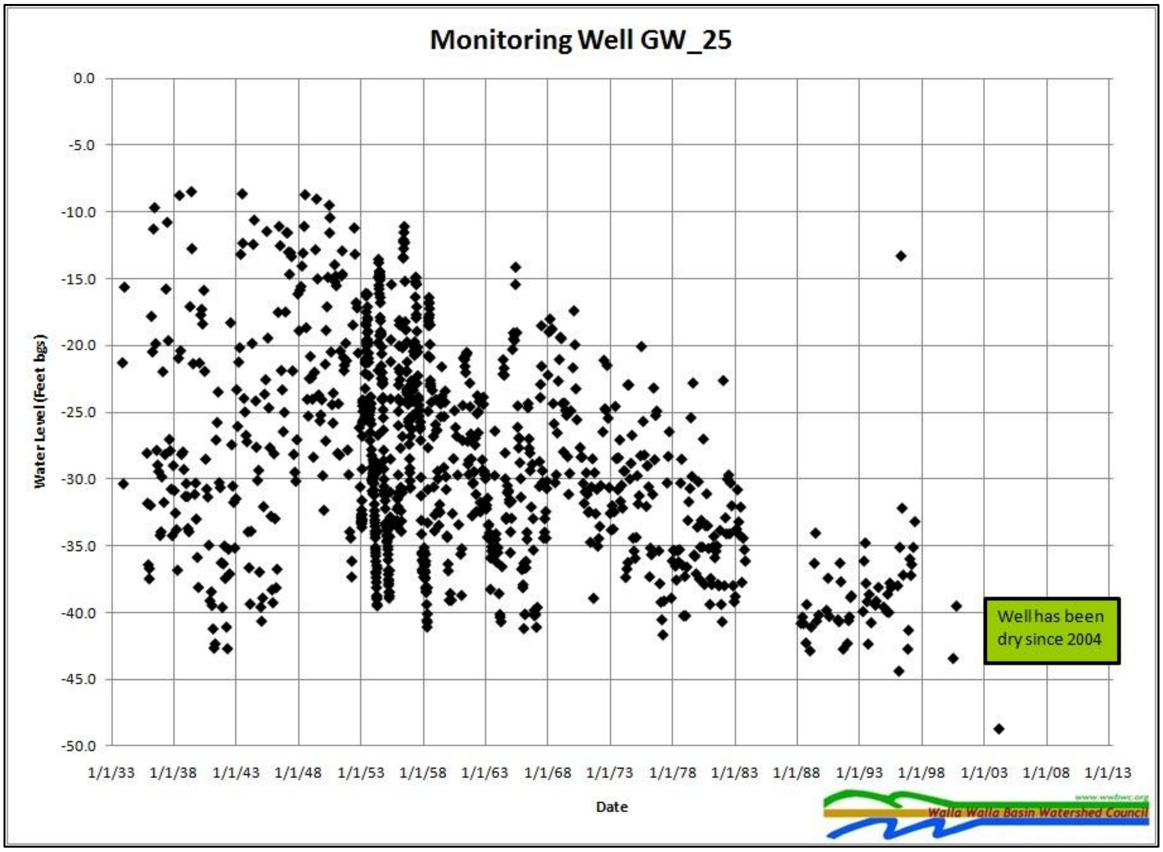

Monitoring Well GW_19
0
-10
-20
-30
-40
-50
-60
-70
-80
Water Level (Feet bgs)
1/1/49
1/1/54
1/1/59
1/1/64
1/1/69
1/1/74
1/1/79
1/1/84
1/1/89
1/1/94
1/1/99
1/1/04
1/1/09
1/1/14
Date
Walla Walla Basin Watershed Council

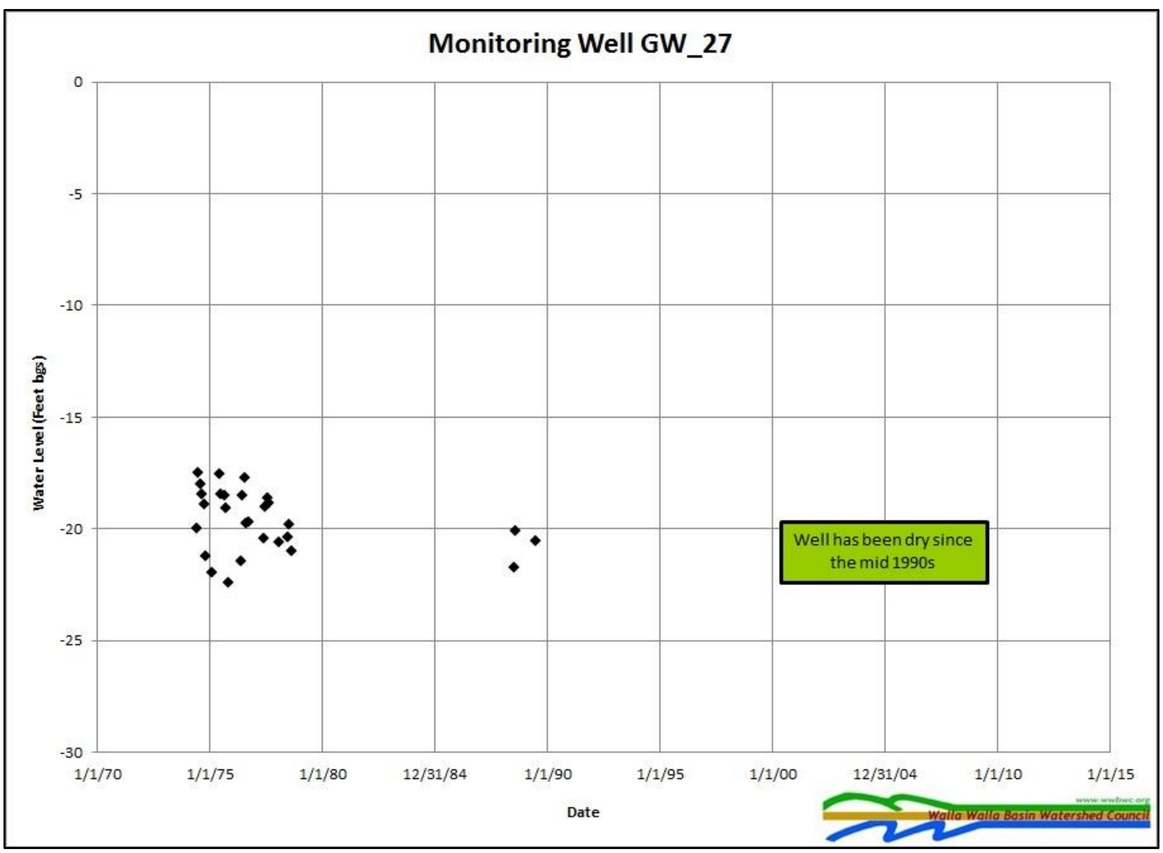

Monitoring Well GW_19
Water Level (Feet bgs) [Green Line]
Water Temperature (F) [Blue Line]
-15
-20
-25
-30
-35
-40
60.00
58.00
56.00
54.00
52.00
50.00
1/1/11
7/2/11
1/1/12
7/1/12
Date
Walla Walla Basin Watershed Council

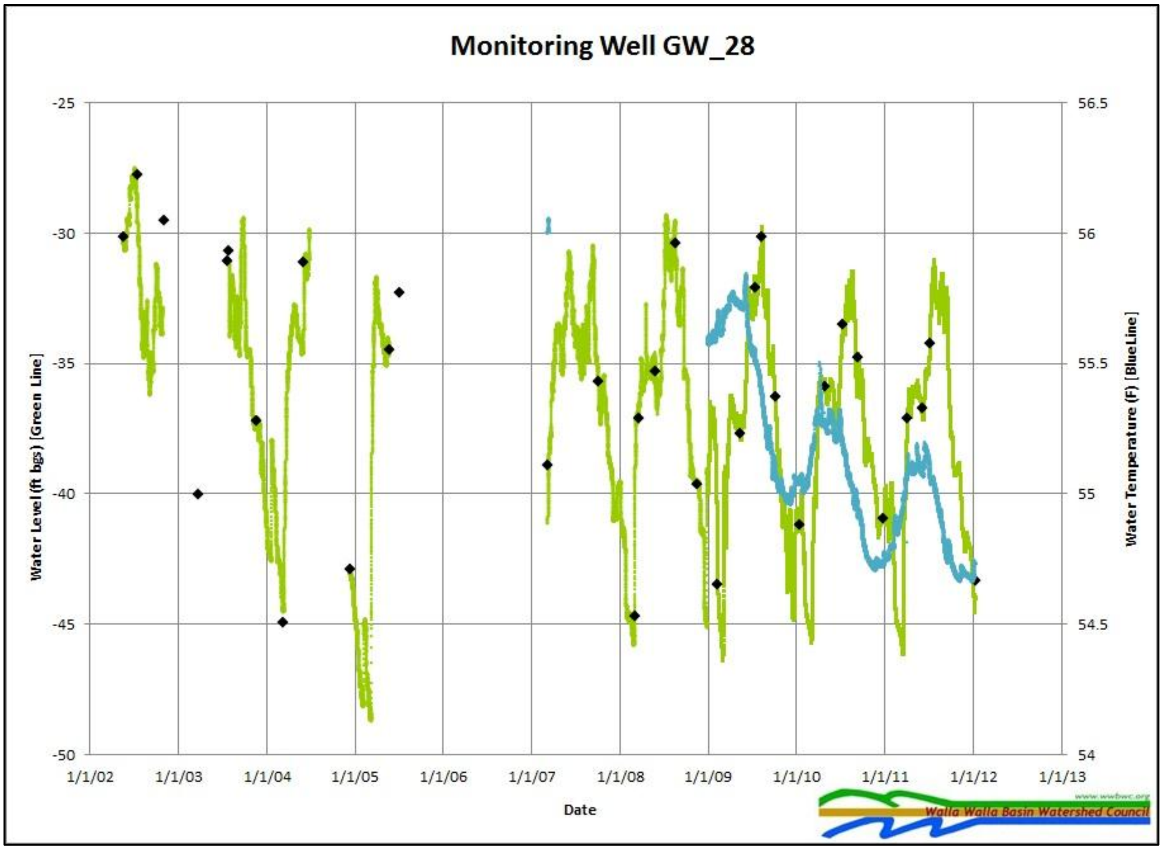

Monitoring Well GW_20
Water Level (Feet bgs)
0
-5
-10
-15
-20
-25
-30
-35
1/1/45
1/1/55
1/1/65
1/1/75
1/1/85
1/1/95
1/1/05
Date
Walla Walla Basin Watershed Council


Monitoring Well GW_20
Water Level (Feet bgs)
Water Temperature (F) [Blue Line]
-10
-12
-14
-16
-18
-20
-22
-24
-26
-28
-30
60
59
58
57
56
55
54
53
52
51
50
1/1/01
1/1/02
1/1/03
1/2/04
1/1/05
1/1/06
1/1/07
1/2/08
1/1/09
1/1/10
1/1/11
1/2/12
1/1/13
Date
Walla Walla Basin Watershed Council

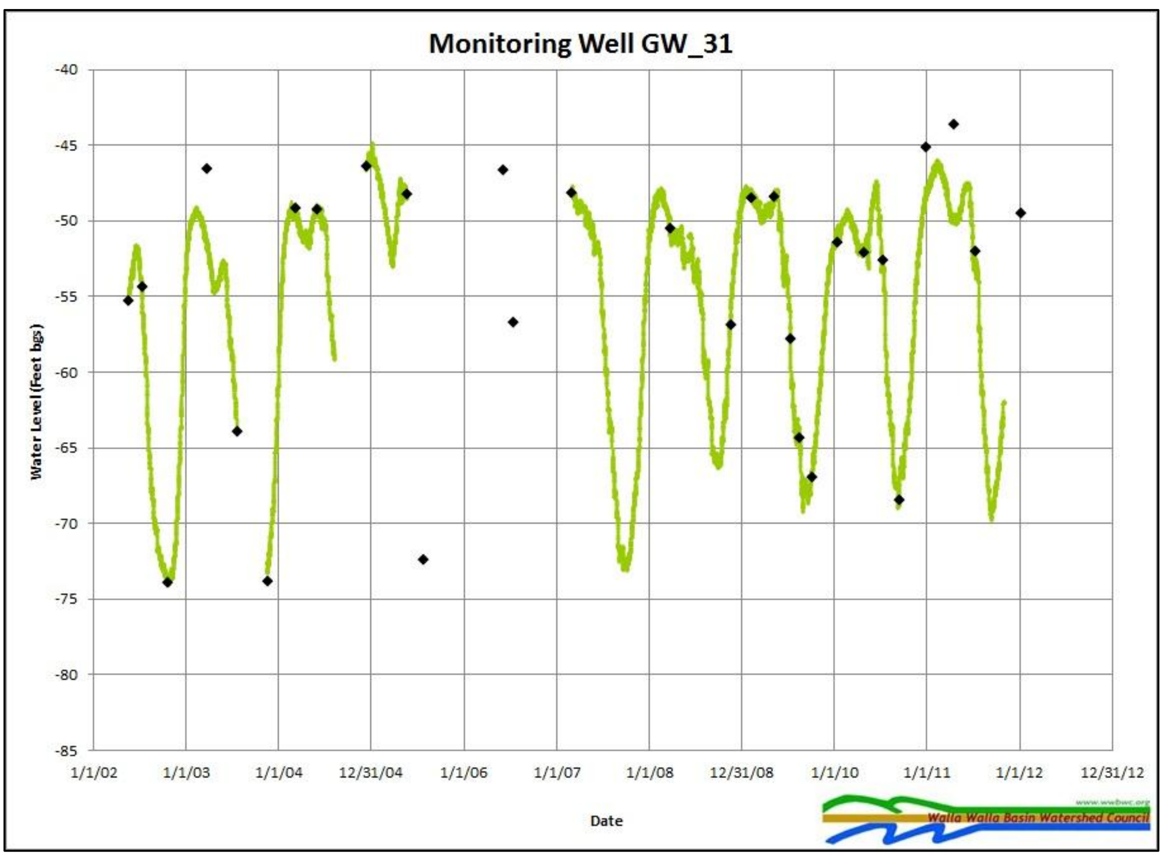

Monitoring Well GW_23
Water Level (Feet bgs)
-25.0
-30.0
-35.0
-40.0
-45.0
-50.0
-55.0
-60.0
-65.0
-70.0
1/1/88
1/1/93
1/1/98
1/1/03
1/1/08
1/1/13
1/1/18
Date
Walla Walla Basin Watershed Council


Monitoring Well GW_25
Water Level (Feet bgs)
Date
Well has been dry since 2004
Walla Walla Basin Watershed Council

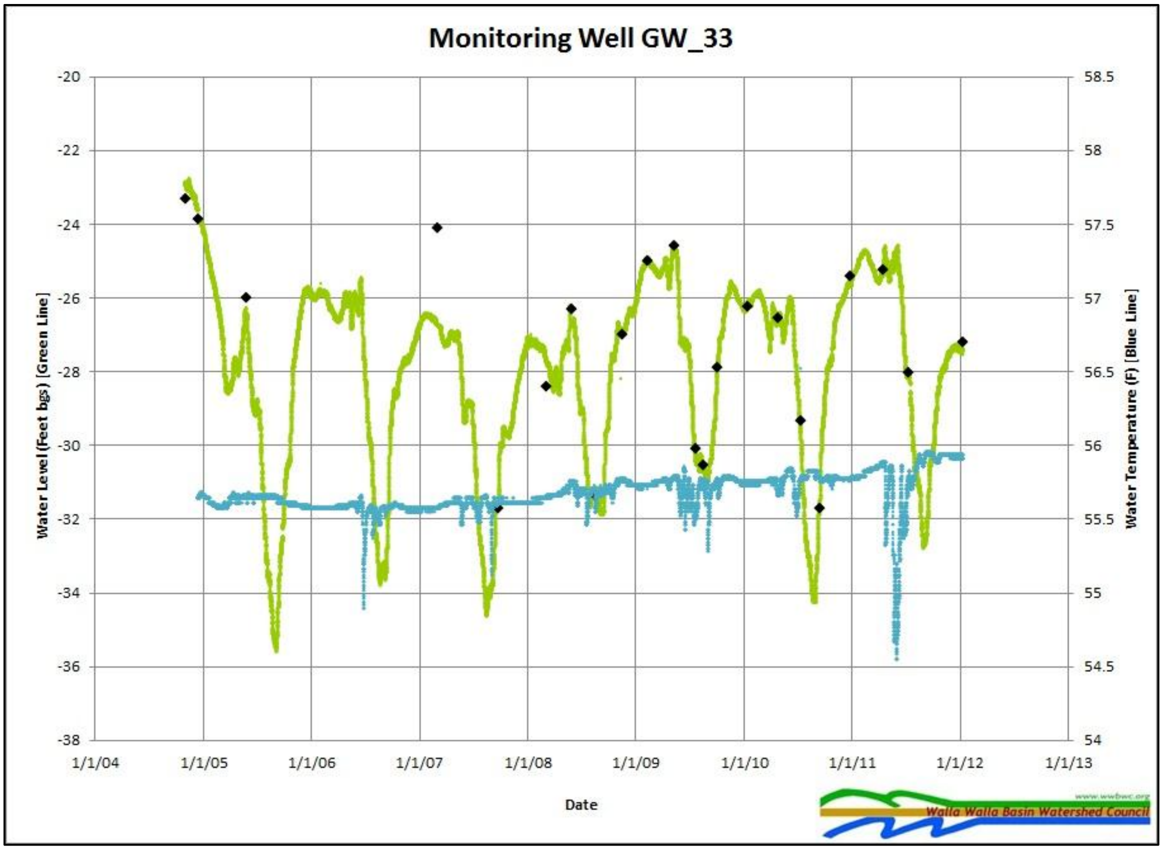

Monitoring Well GW_27
Water Level (Feet bgs)
Date
Well has been dry since the mid 1990s
Walla Walla Basin Watershed Council

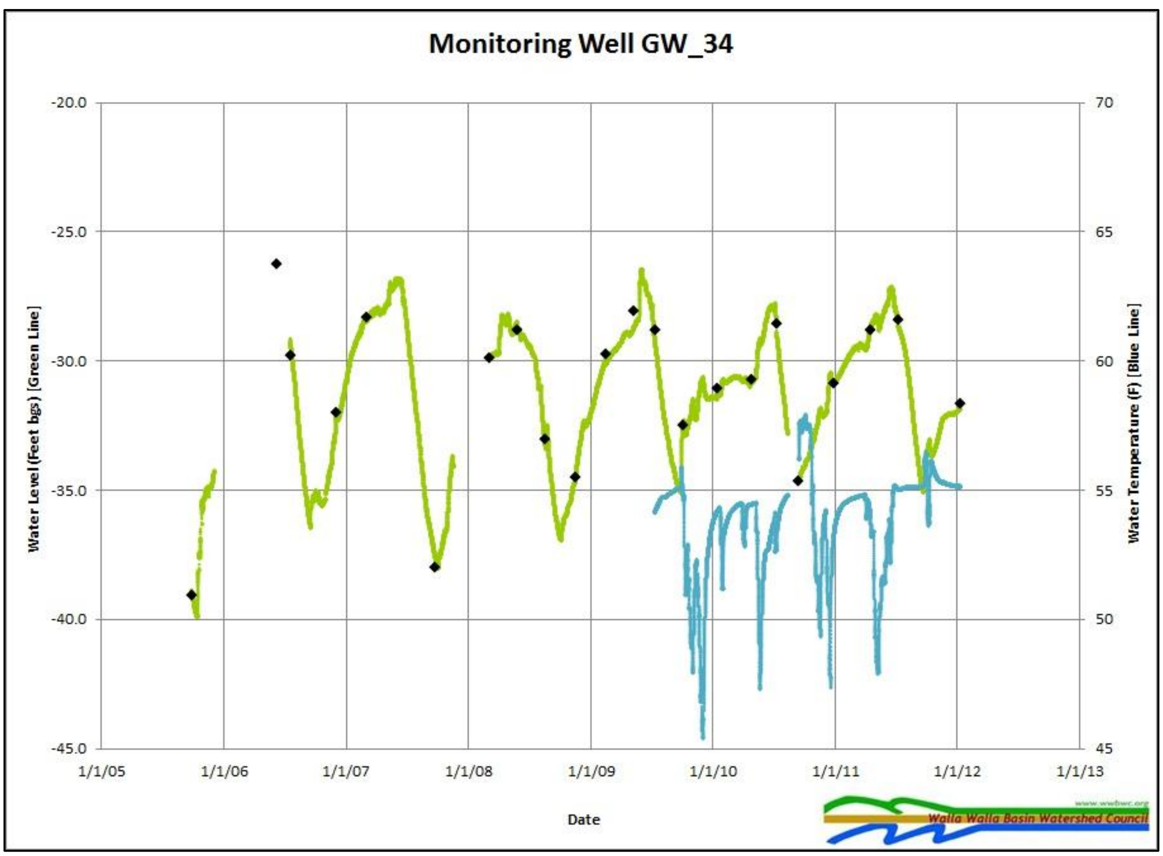


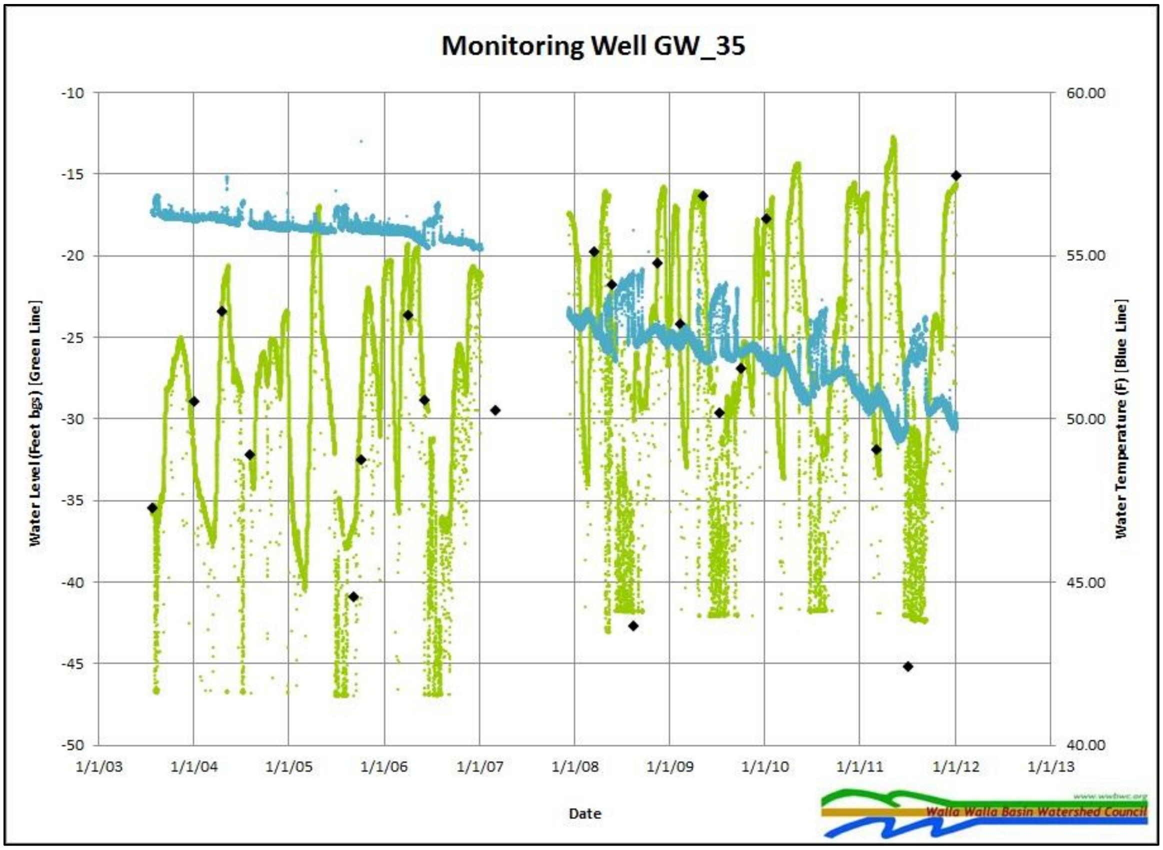
Monitoring Well GW_28
Water Level (ft bgs) [Green Line]
Water Temperature (F) [BlueLine]
-25
-30
-35
-40
-45
-50
56.5
56
55.5
55
54.5
54
1/1/02
1/1/03
1/1/04
1/1/05
1/1/06
1/1/07
1/1/08
1/1/09
1/1/10
1/1/11
1/1/12
1/1/13
Date
www.wwbwc.org
Walla Walla Basin Watershed Council

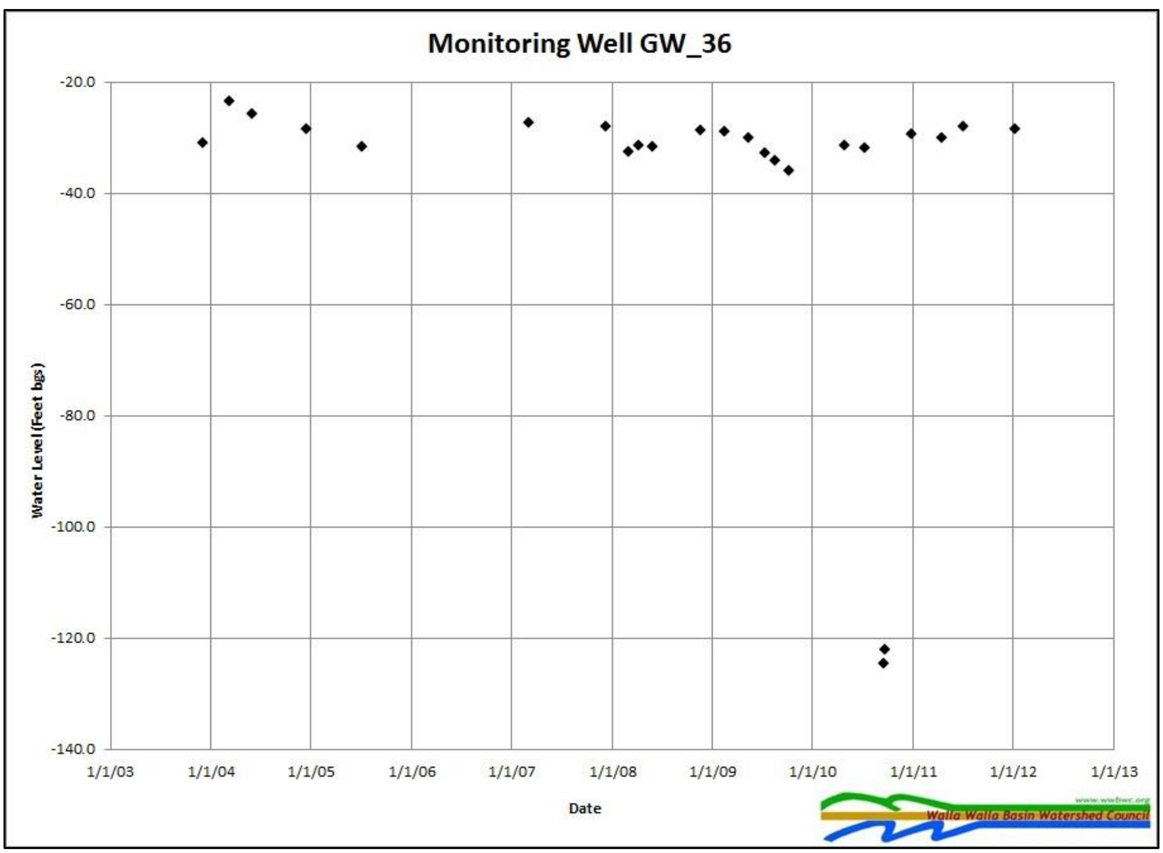


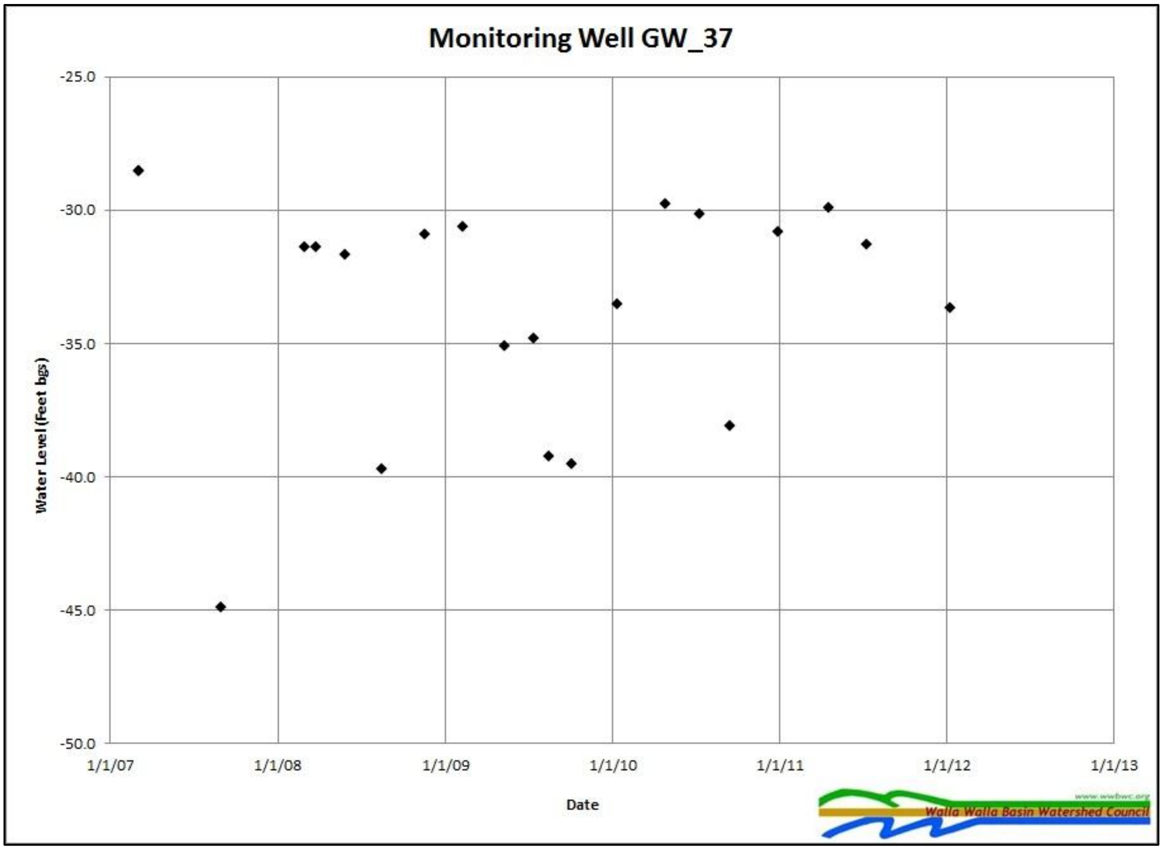
Monitoring Well GW_31
Water Level (Feet bgs)
-40
-45
-50
-55
-60
-65
-70
-75
-80
-85
1/1/02
1/1/03
1/1/04
12/31/04
1/1/06
1/1/07
1/1/08
12/31/08
1/1/10
1/1/11
1/1/12
12/31/12
Date
www.wwbwc.org
Walla Walla Basin Watershed Council

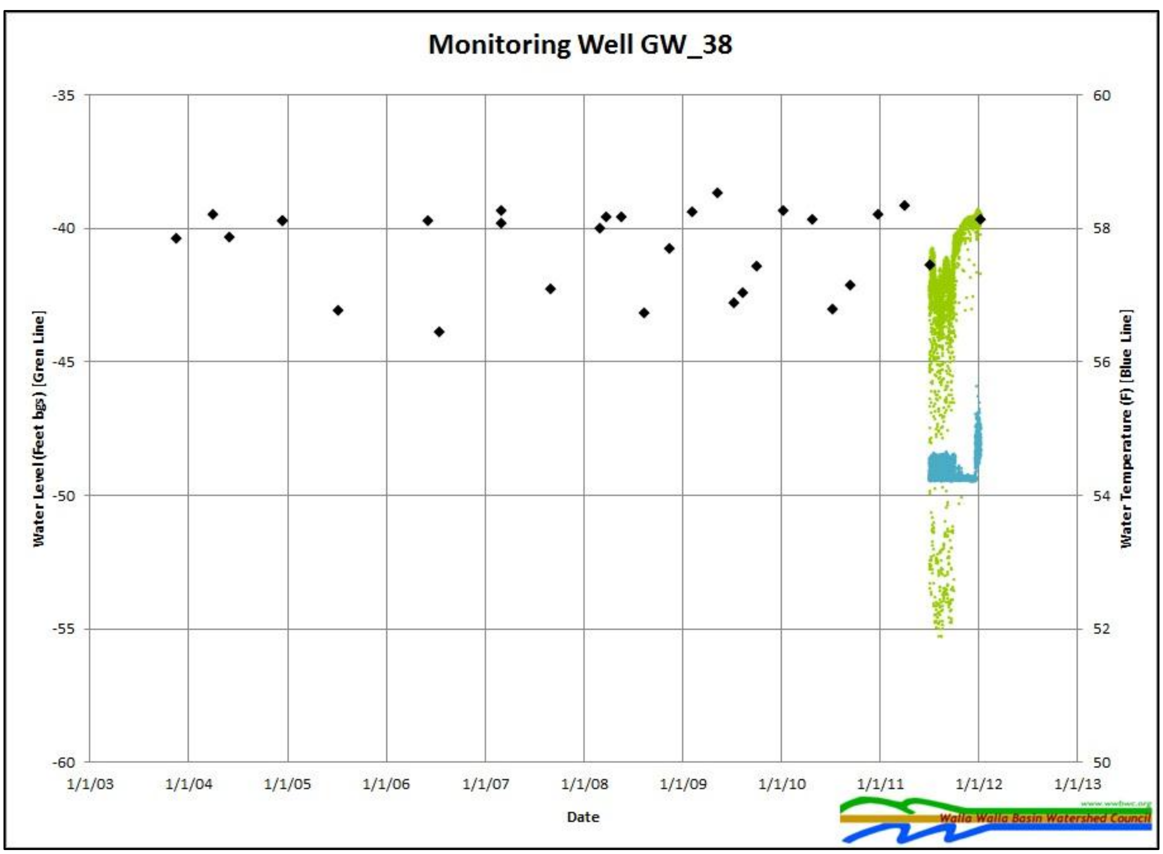

Monitoring Well GW_33
Water Level (Feet bgs) [Green Line]
Water Temperature (F) [Blue Line]
-20
-22
-24
-26
-28
-30
-32
-34
-36
-38
58.5
58
57.5
57
56.5
56
55.5
55
54.5
54
1/1/04
1/1/05
1/1/06
1/1/07
1/1/08
1/1/09
1/1/10
1/1/11
1/1/12
1/1/13
Date
Walla Walla Basin Watershed Council

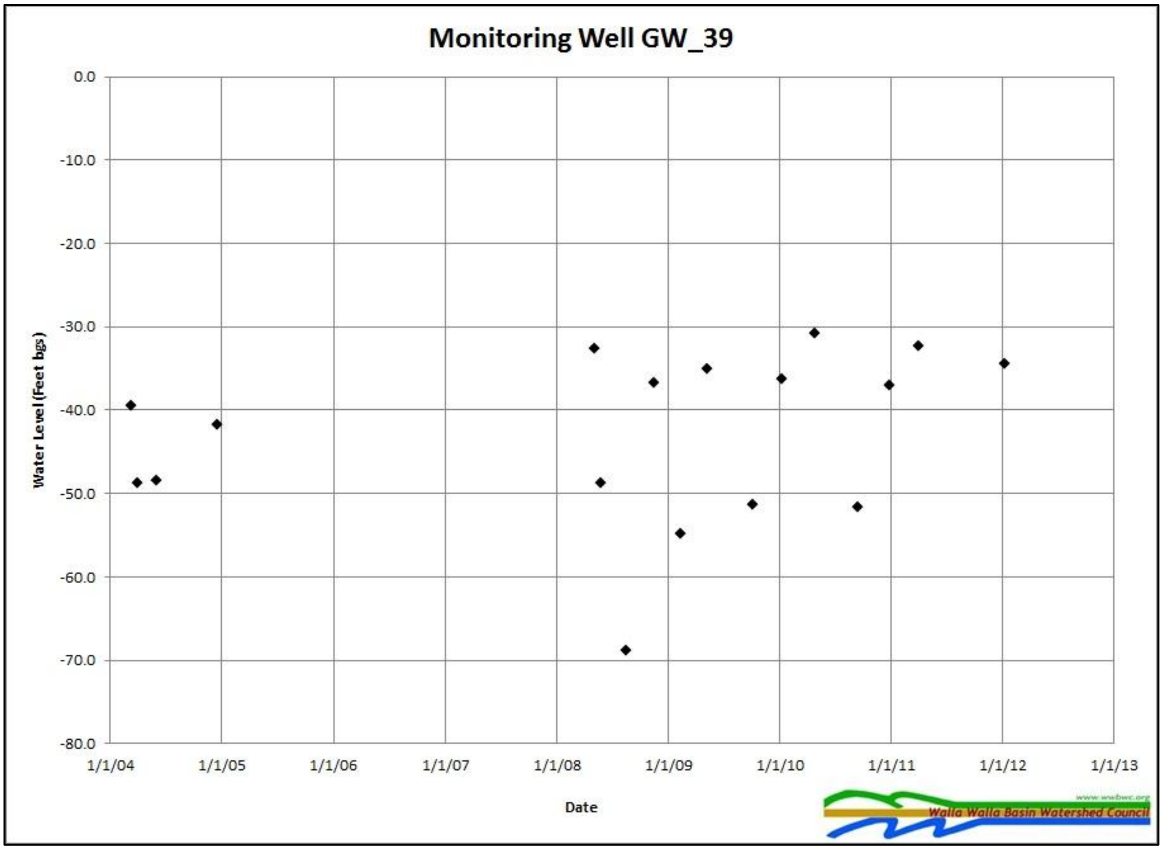

Monitoring Well GW_34
Water Level (Feet bgs) [Green Line]
Water Temperature (F) [Blue Line]
-20.0
-25.0
-30.0
-35.0
-40.0
-45.0
70
65
60
55
50
45
1/1/05
1/1/06
1/1/07
1/1/08
1/1/09
1/1/10
1/1/11
1/1/12
1/1/13
Date
Walla Walla Basin Watershed Council


Monitoring Well GW_35
Water Level (Feet bgs) [Green Line]
Water Temperature (F) [Blue Line]
-10
-15
-20
-25
-30
-35
-40
-45
-50
60.00
55.00
50.00
45.00
40.00
1/1/03
1/1/04
1/1/05
1/1/06
1/1/07
1/1/08
1/1/09
1/1/10
1/1/11
1/1/12
1/1/13
Date
www.wwbwc.org
Walla Walla Basin Watershed Council

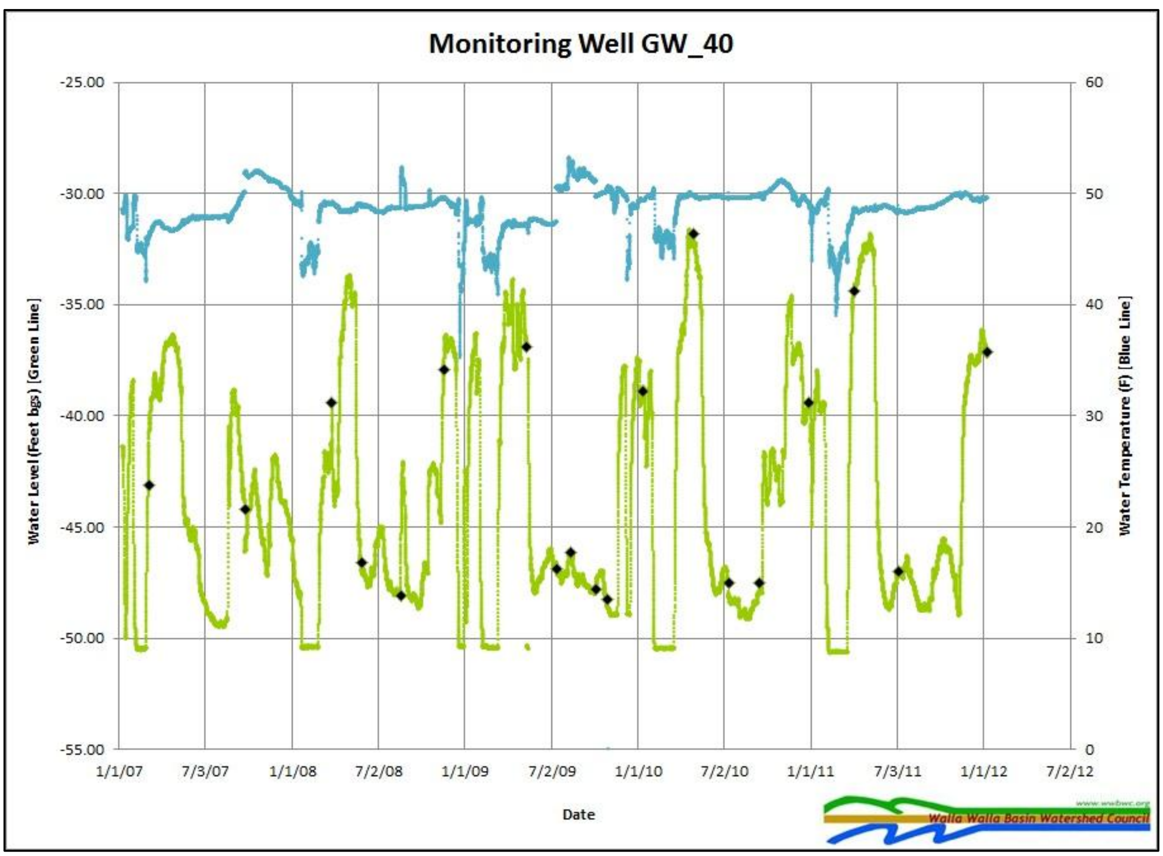

Monitoring Well GW_36
Water Level (Feet bgs)
-20.0
-40.0
-60.0
-80.0
-100.0
-120.0
-140.0
1/1/03
1/1/04
1/1/05
1/1/06
1/1/07
1/1/08
1/1/09
1/1/10
1/1/11
1/1/12
1/1/13
Date
www.wwbwc.org
Walla Walla Basin Watershed Council


Monitoring Well GW_37
-25.0
-30.0
-35.0
-40.0
-45.0
-50.0
Water Level (Feet bgs)
1/1/07
1/1/08
1/1/09
1/1/10
1/1/11
1/1/12
1/1/13
Date
Walla Walla Basin Watershed Council

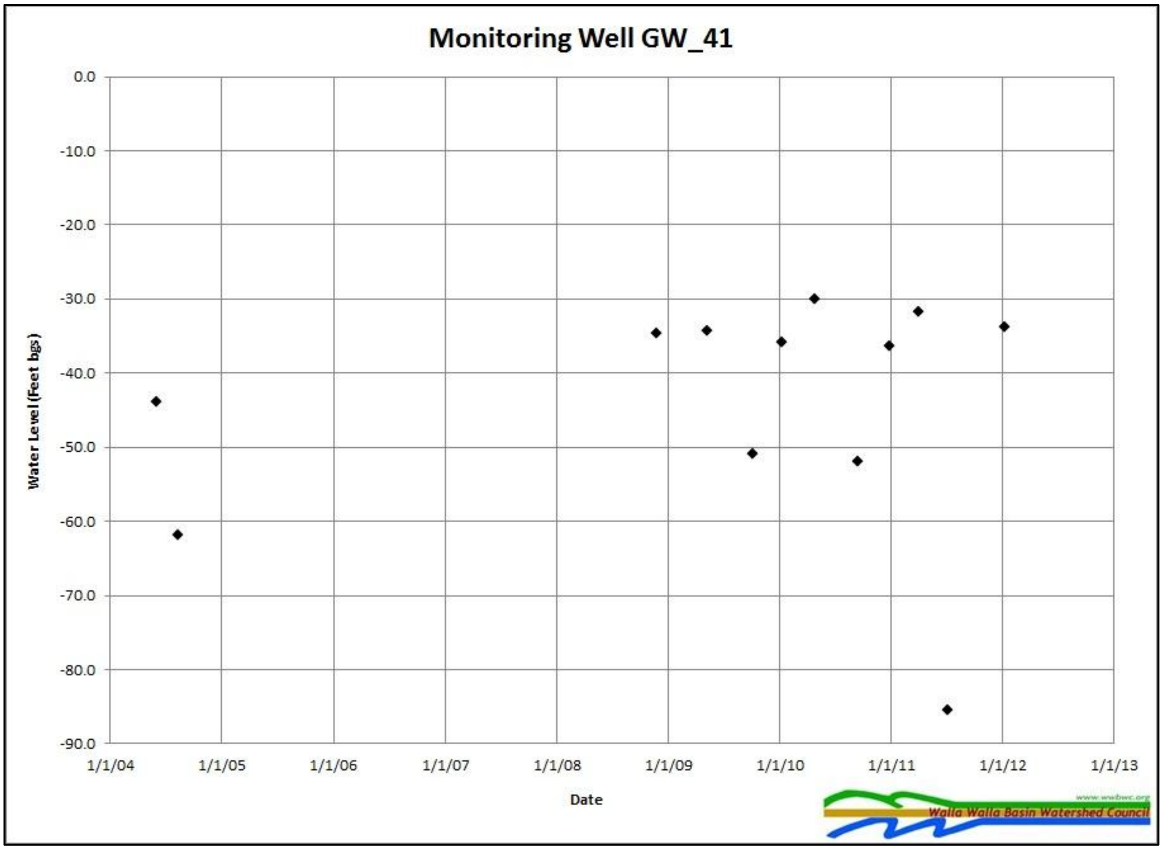

Monitoring Well GW_38
-35
-40
-45
-50
-55
-60
Water Level (Feet bgs) [Gren Line]
60
58
56
54
52
50
Water Temperature (F) [Blue Line]
1/1/03
1/1/04
1/1/05
1/1/06
1/1/07
1/1/08
1/1/09
1/1/10
1/1/11
1/1/12
1/1/13
Date
Walla Walla Basin Watershed Council

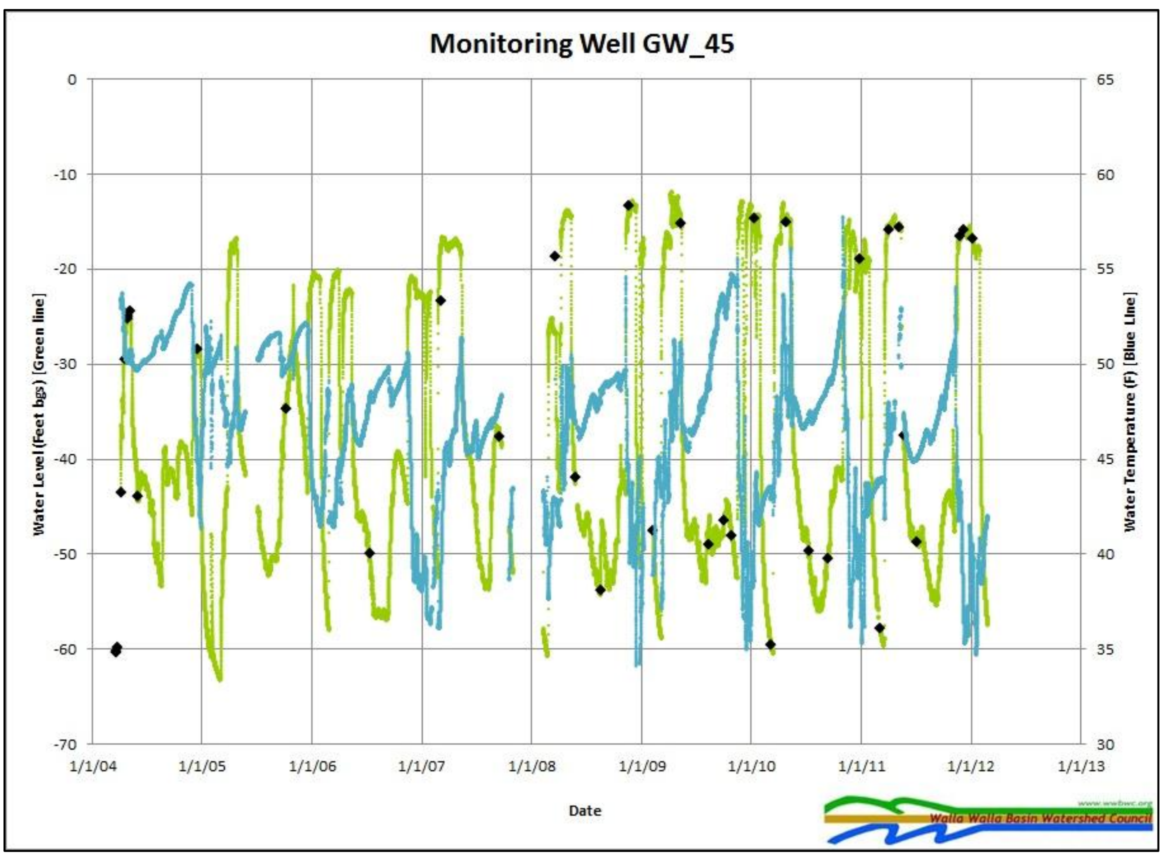


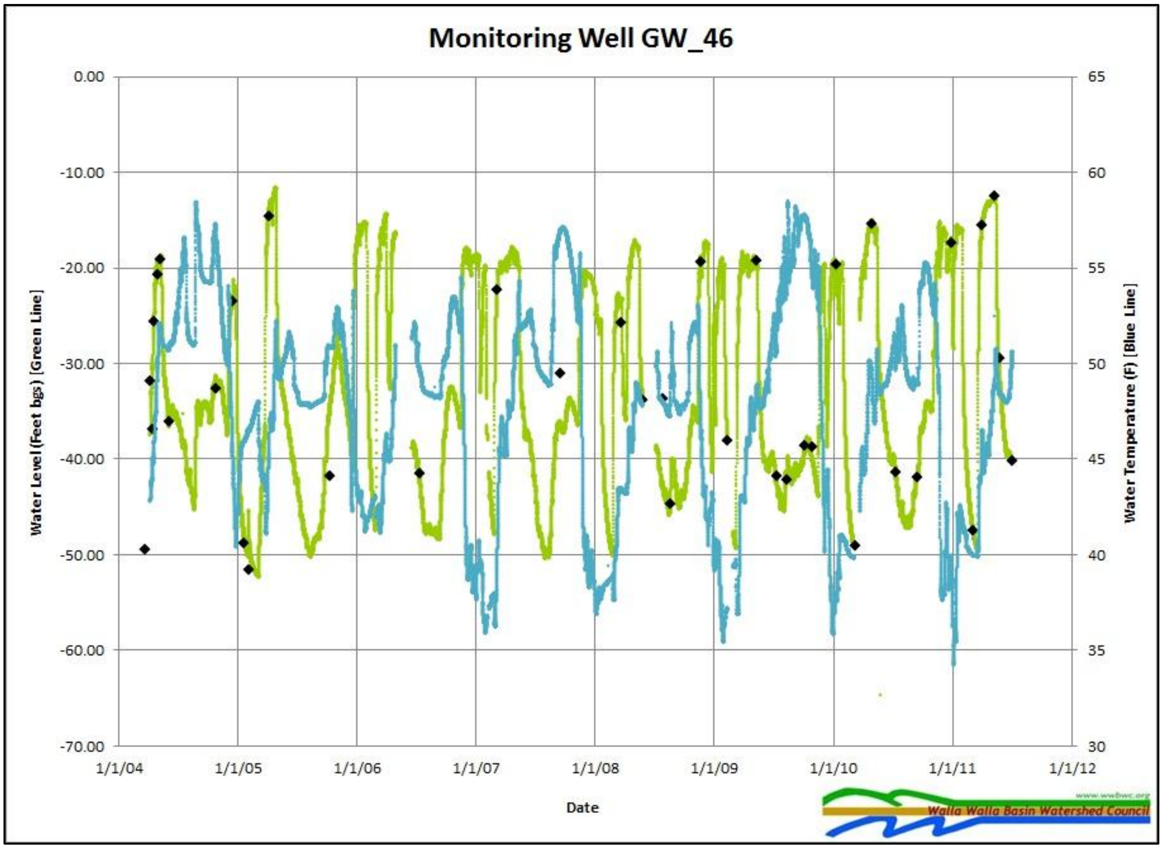
Monitoring Well GW_39
Water Level (Feet bgs)
0.0
-10.0
-20.0
-30.0
-40.0
-50.0
-60.0
-70.0
-80.0
1/1/04
1/1/05
1/1/06
1/1/07
1/1/08
1/1/09
1/1/10
1/1/11
1/1/12
1/1/13
Date
Walla Walla Basin Watershed Council



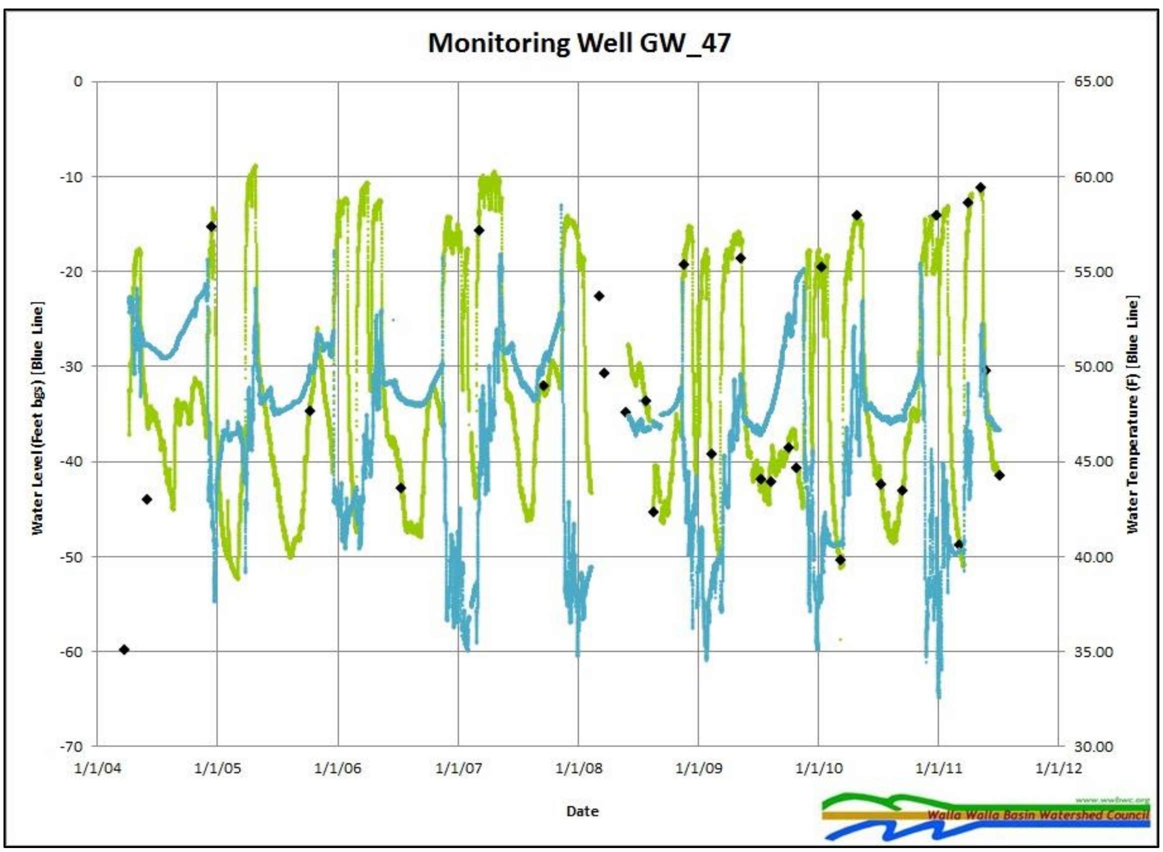
Monitoring Well GW_40
Water Level (Feet bgs) [Green Line]
Water Temperature (F) [Blue Line]
-25.00
-30.00
-35.00
-40.00
-45.00
-50.00
-55.00
60
50
40
30
20
10
0
1/1/07
7/3/07
1/1/08
7/2/08
1/1/09
7/2/09
1/1/10
7/2/10
1/1/11
7/3/11
1/1/12
7/2/12
Date
Walla Walla Basin Watershed Council


Monitoring Well GW_41
Water Level (Feet bgs)
0.0
-10.0
-20.0
-30.0
-40.0
-50.0
-60.0
-70.0
-80.0
-90.0
1/1/04
1/1/05
1/1/06
1/1/07
1/1/08
1/1/09
1/1/10
1/1/11
1/1/12
1/1/13
Date
Walla Walla Basin Watershed Council

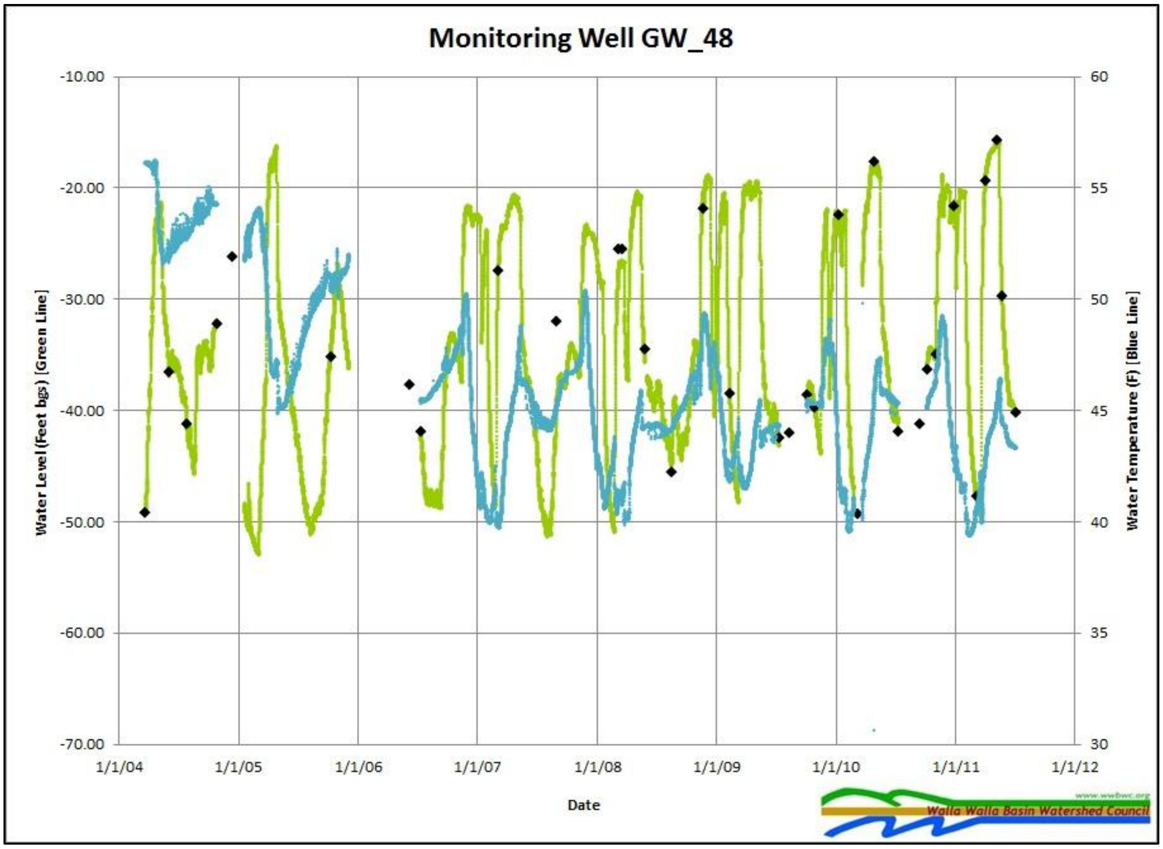

Monitoring Well GW_45
Water Level (Feet bgs) [Green line]
Water Temperature (F) [Blue Line]
0
-10
-20
-30
-40
-50
-60
-70
65
60
55
50
45
40
35
30
1/1/04
1/1/05
1/1/06
1/1/07
1/1/08
1/1/09
1/1/10
1/1/11
1/1/12
1/1/13
Date
Walla Walla Basin Watershed Council

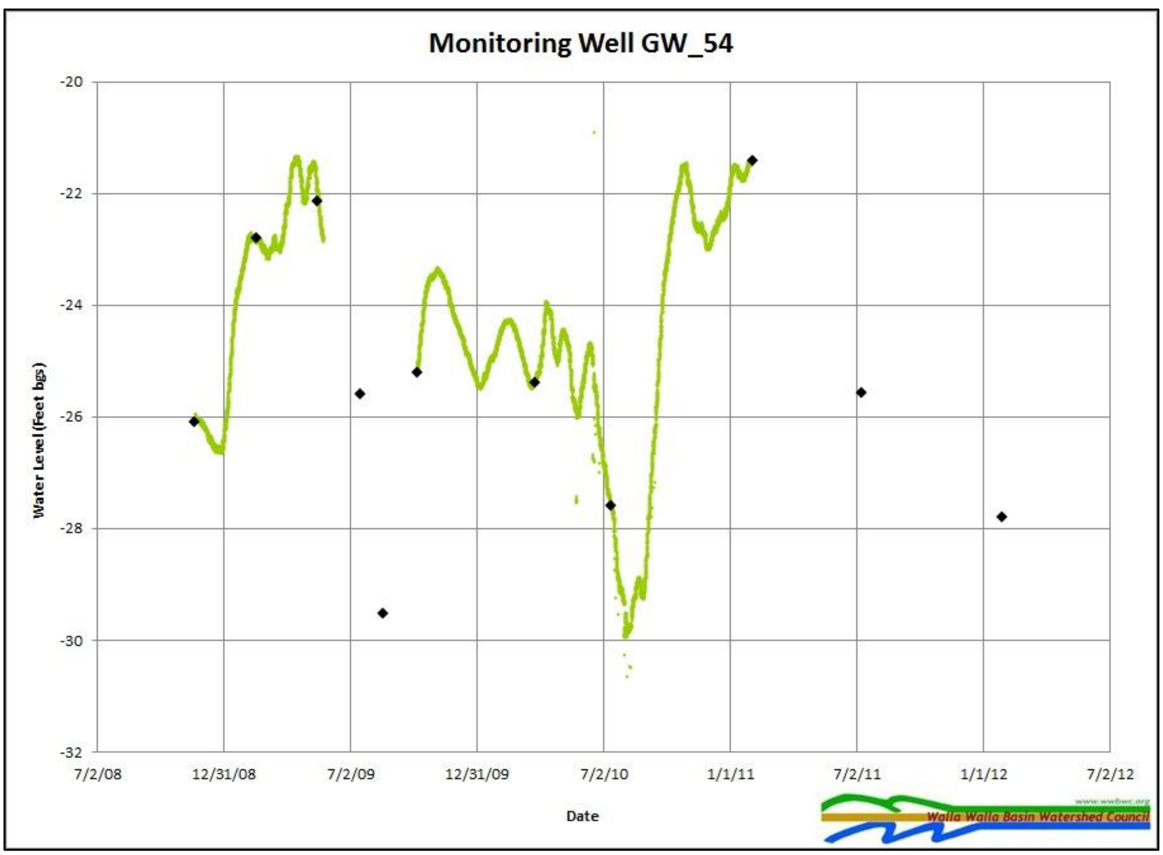


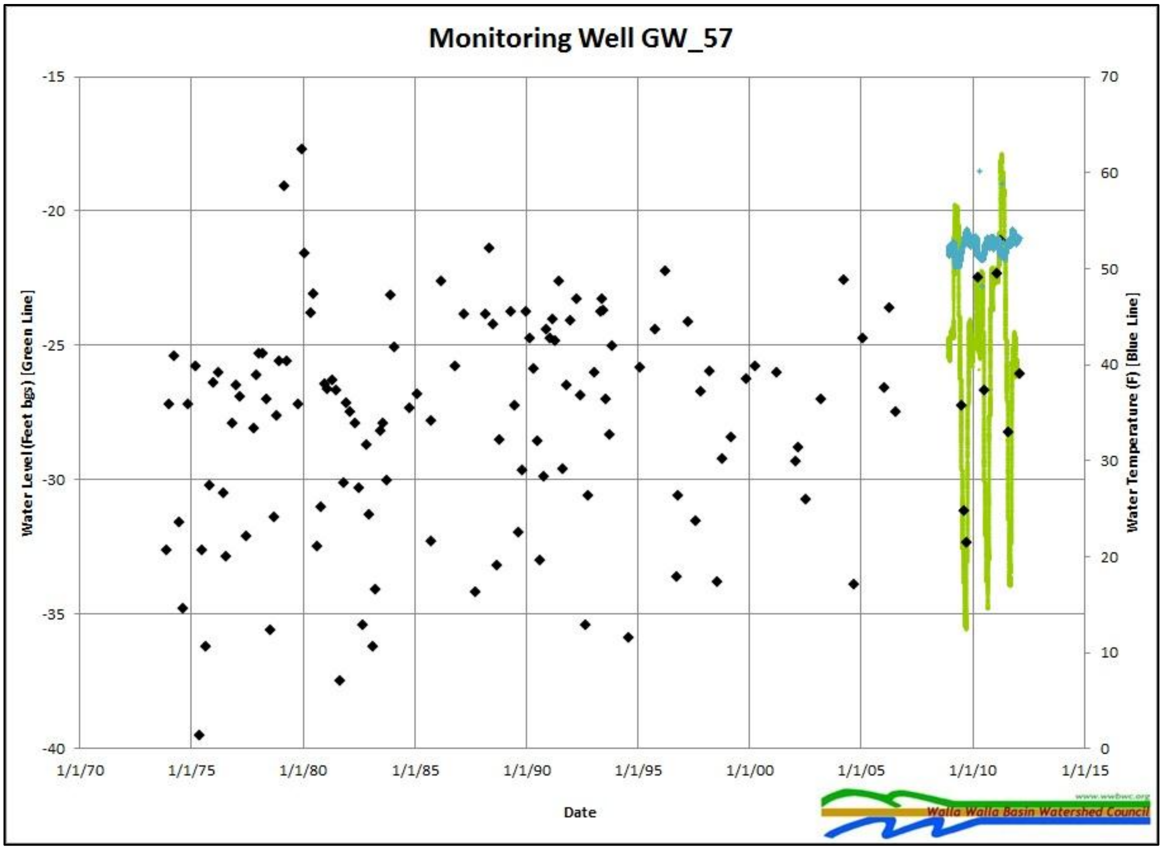
Monitoring Well GW_46
Water Level (Feet bgs) [Green Line]
Water Temperature (F) [Blue Line]
0.00
-10.00
-20.00
-30.00
-40.00
-50.00
-60.00
-70.00
65
60
55
50
45
40
35
30
1/1/04
1/1/05
1/1/06
1/1/07
1/1/08
1/1/09
1/1/10
1/1/11
1/1/12
Date
Walla Walla Basin Watershed Council

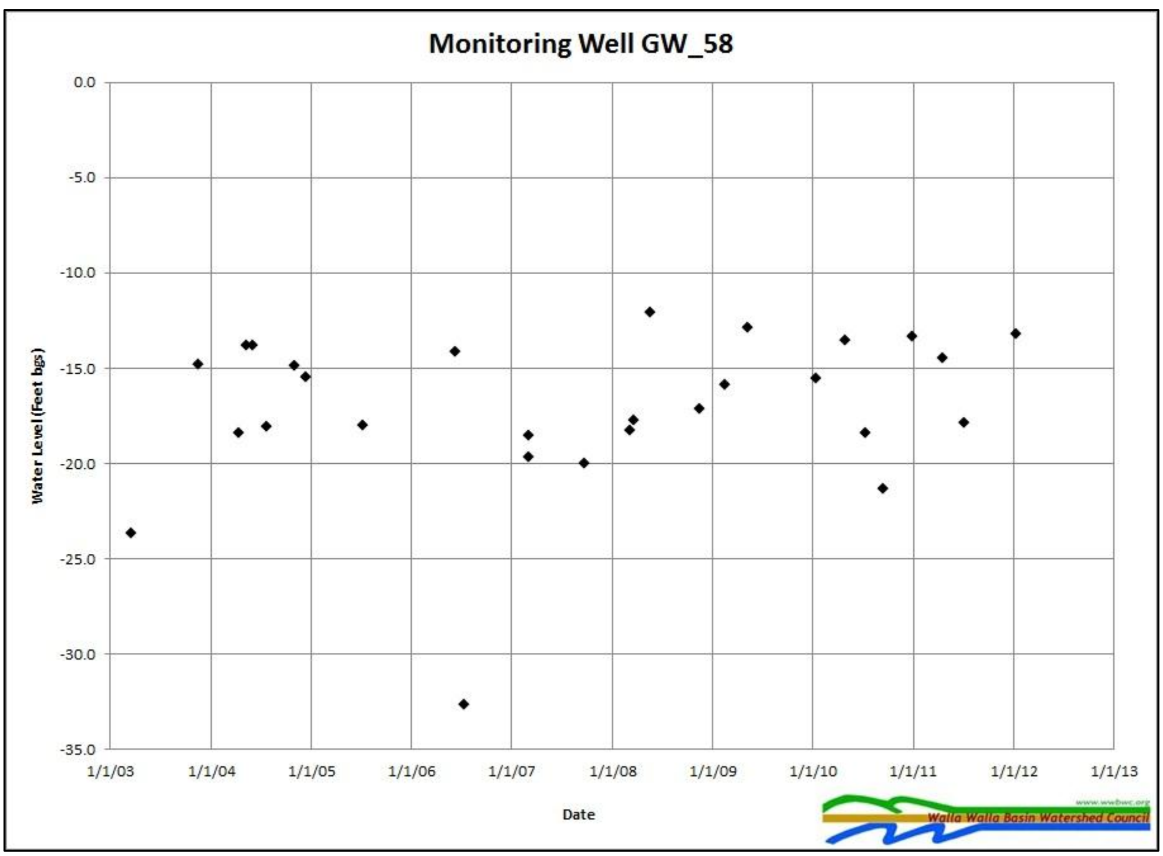


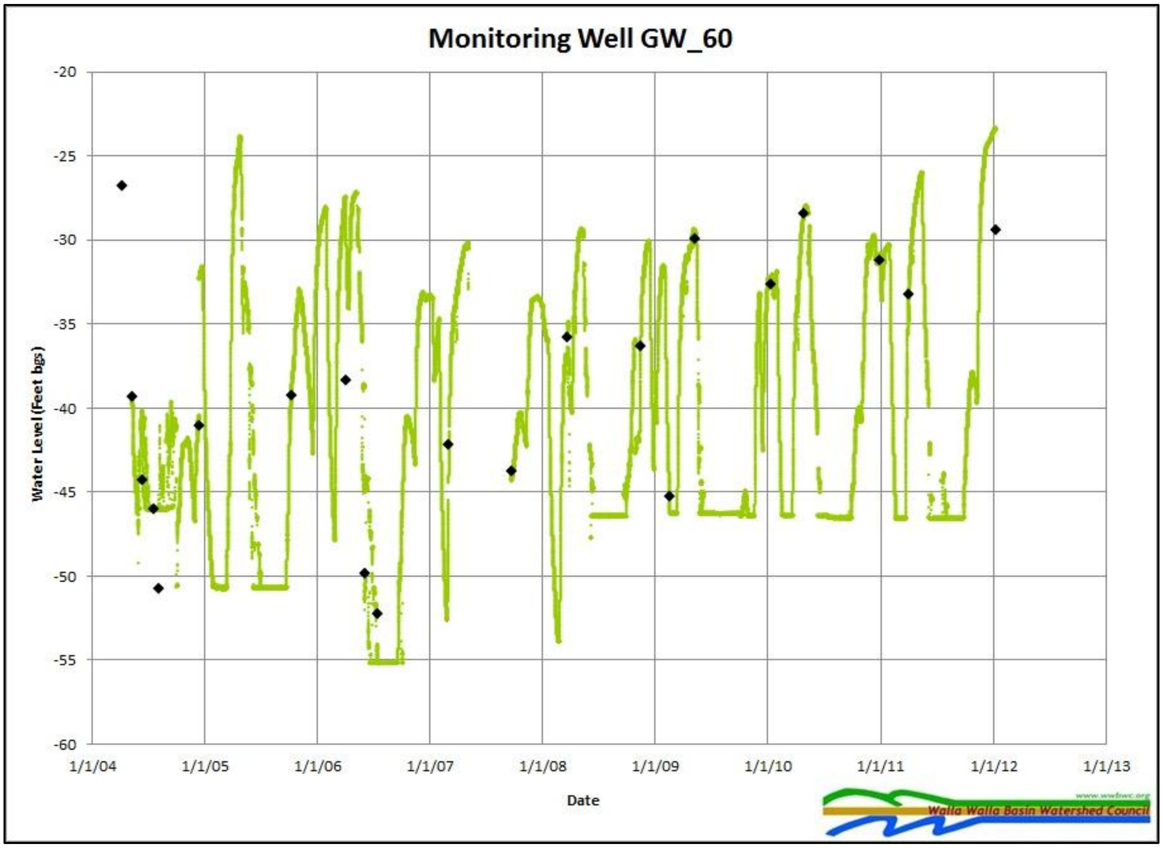
Monitoring Well GW_47
Water Level (Feet bgs) [Blue Line]
Water Temperature (F) [Blue Line]
0
-10
-20
-30
-40
-50
-60
-70
65.00
60.00
55.00
50.00
45.00
40.00
35.00
30.00
1/1/04
1/1/05
1/1/06
1/1/07
1/1/08
1/1/09
1/1/10
1/1/11
1/1/12
Date
Walla Walla Basin Watershed Council

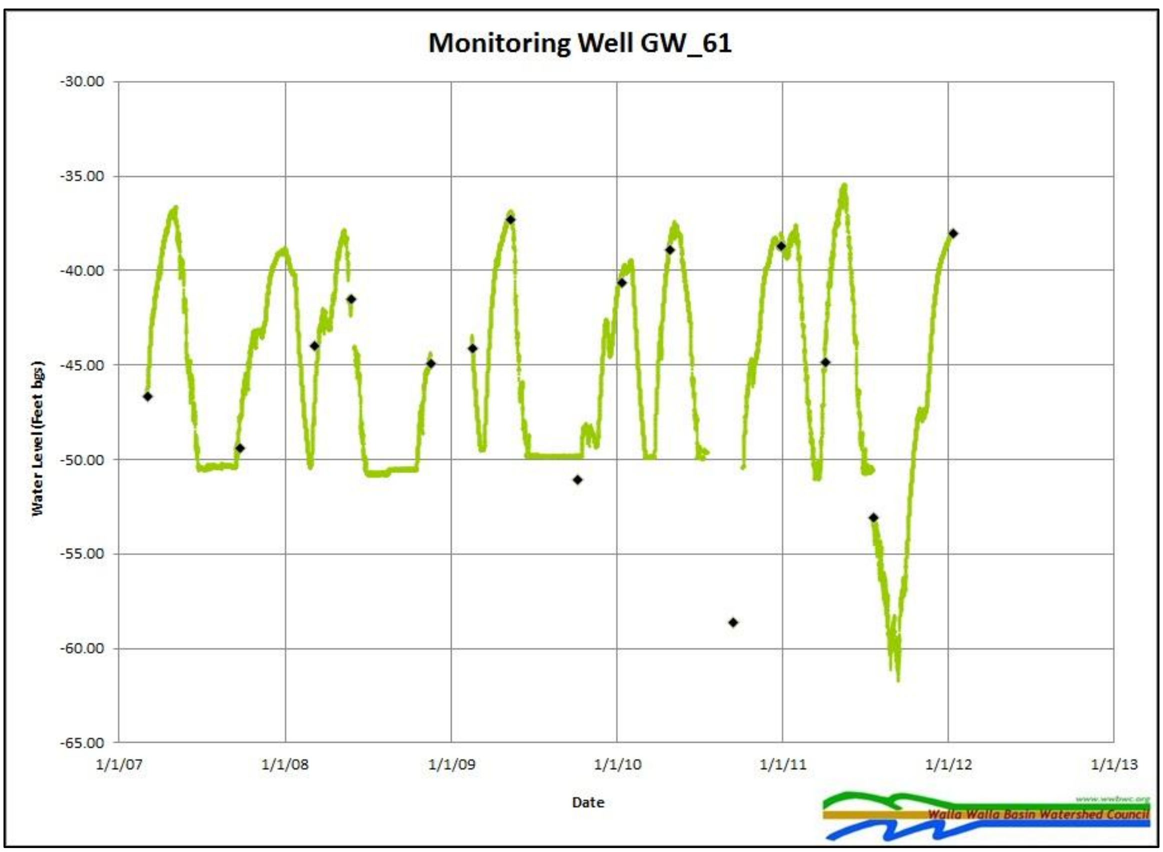

Monitoring Well GW_48
Water Level (Feet bgs) [Green Line]
Water Temperature (F) [Blue Line]
-10.00
-20.00
-30.00
-40.00
-50.00
-60.00
-70.00
60
55
50
45
40
35
30
1/1/04
1/1/05
1/1/06
1/1/07
1/1/08
1/1/09
1/1/10
1/1/11
1/1/12
Date
Walla Walla Basin Watershed Council

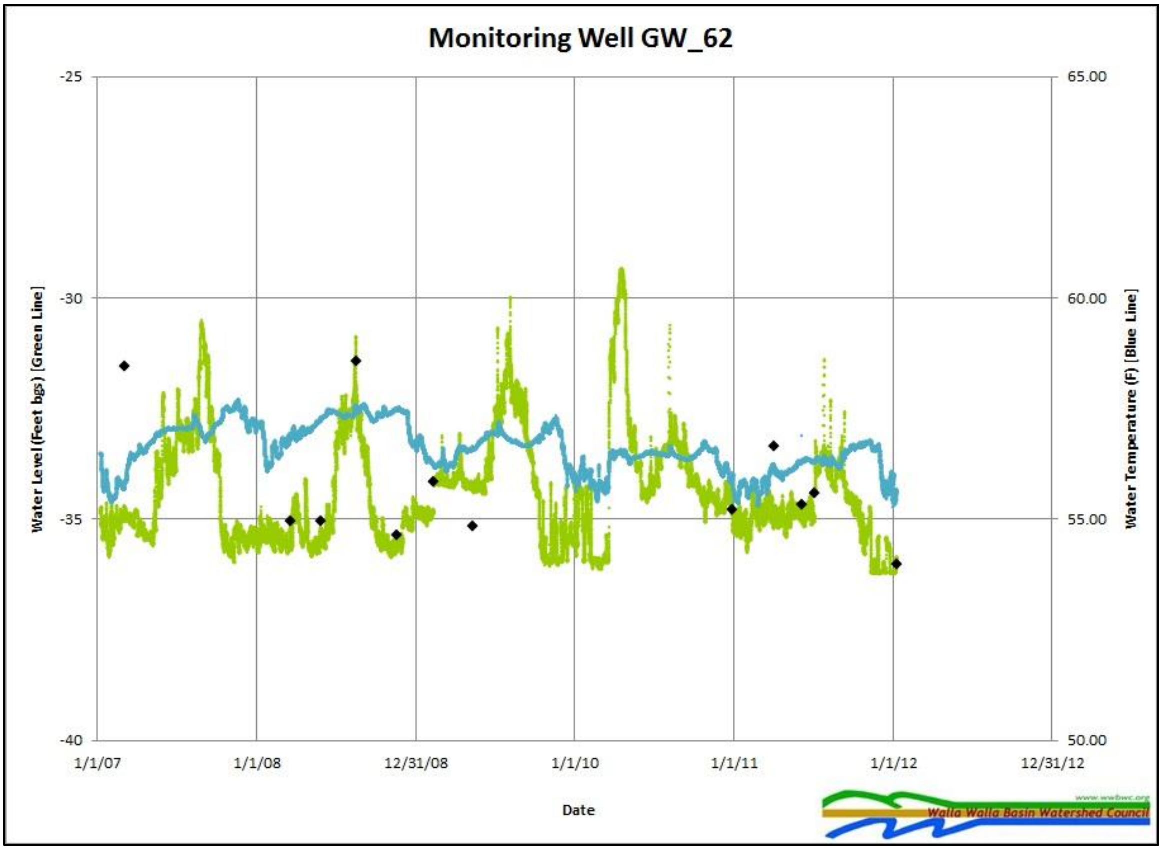

Monitoring Well GW_54
Water Level (Feet bgs)
-20
-22
-24
-26
-28
-30
-32
7/2/08
12/31/08
7/2/09
12/31/09
7/2/10
1/1/11
7/2/11
1/1/12
7/2/12
Date
Walla Walla Basin Watershed Council


Monitoring Well GW_57
Water Level (Feet bgs) [Green Line]
Water Temperature (F) [Blue Line]
-15
-20
-25
-30
-35
-40
70
60
50
40
30
20
10
0
1/1/70
1/1/75
1/1/80
1/1/85
1/1/90
1/1/95
1/1/00
1/1/05
1/1/10
1/1/15
Date
Walla Walla Basin Watershed Council


Monitoring Well GW_58
Water Level (Feet bgs)
0.0
-5.0
-10.0
-15.0
-20.0
-25.0
-30.0
-35.0
1/1/03
1/1/04
1/1/05
1/1/06
1/1/07
1/1/08
1/1/09
1/1/10
1/1/11
1/1/12
1/1/13
Date
Walla Walla Basin Watershed Council


Monitoring Well GW_60
-20
-25
-30
-35
-40
-45
-50
-55
-60
Water Level (Feet bgs)
1/1/04
1/1/05
1/1/06
1/1/07
1/1/08
1/1/09
1/1/10
1/1/11
1/1/12
1/1/13
Date
Walla Walla Basin Watershed Council


Monitoring Well GW_61
-30.00
-35.00
-40.00
-45.00
-50.00
-55.00
-60.00
-65.00
Water Level (Feet bgs)
1/1/07
1/1/08
1/1/09
1/1/10
1/1/11
1/1/12
1/1/13
Date
Walla Walla Basin Watershed Council


Monitoring Well GW_62
-25
-30
-35
-40
65.00
60.00
55.00
50.00
Water Level (Feet bgs) [Green Line]
Water Temperature (F) [Blue Line]
1/1/07
1/1/08
12/31/08
1/1/10
1/1/11
1/1/12
12/31/12
Date
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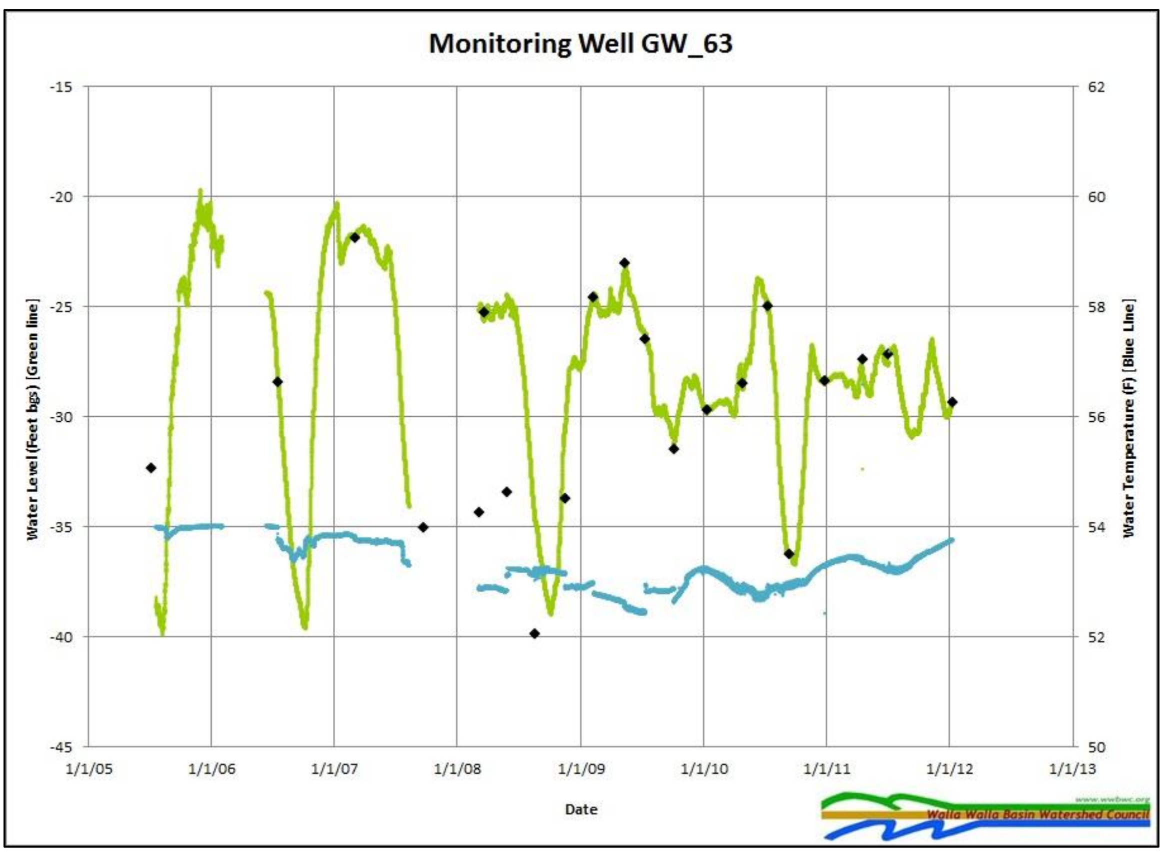
Walla Walla Basin Watershed Council


Monitoring Well GW_63
-15
-20
-25
-30
-35
-40
-45
62
60
58
56
54
52
50
Water Level (Feet bgs) [Green line]
Water Temperature (F) [Blue Line]
1/1/05
1/1/06
1/1/07
1/1/08
1/1/09
1/1/10
1/1/11
1/1/12
1/1/13
Date
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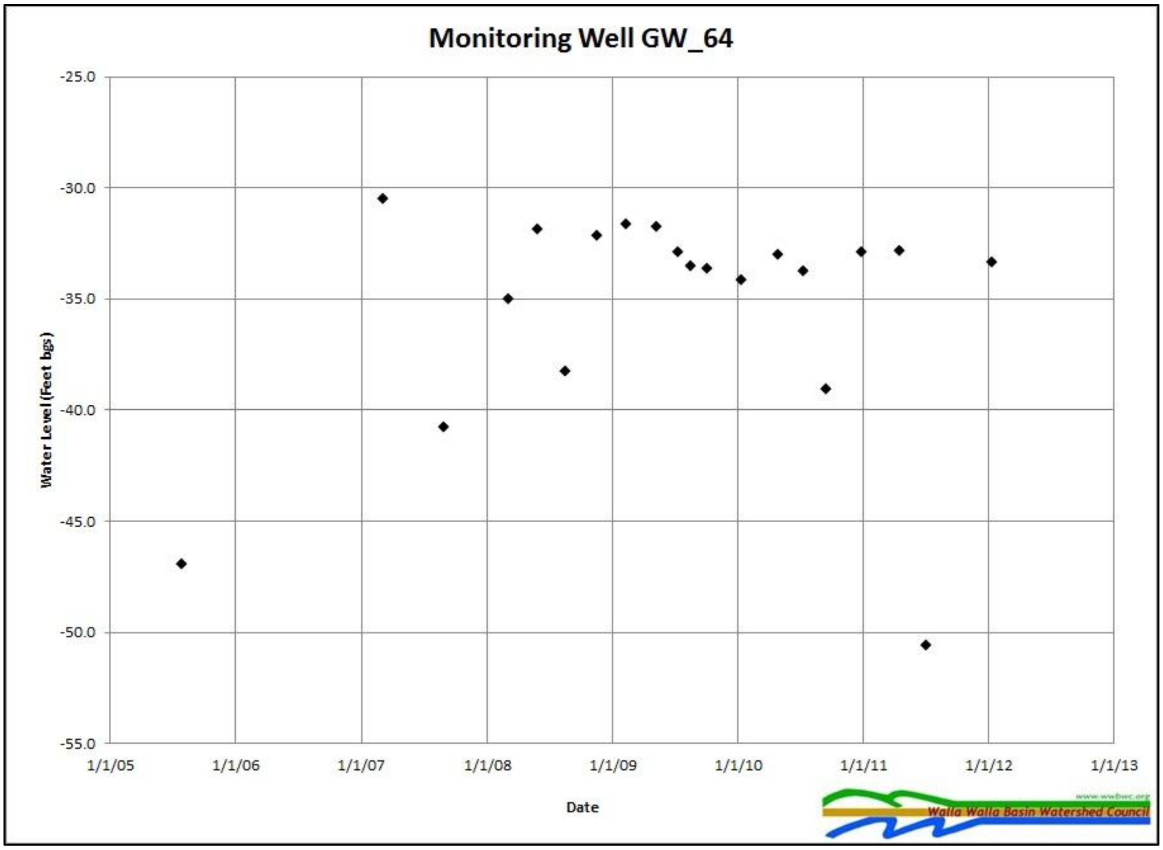
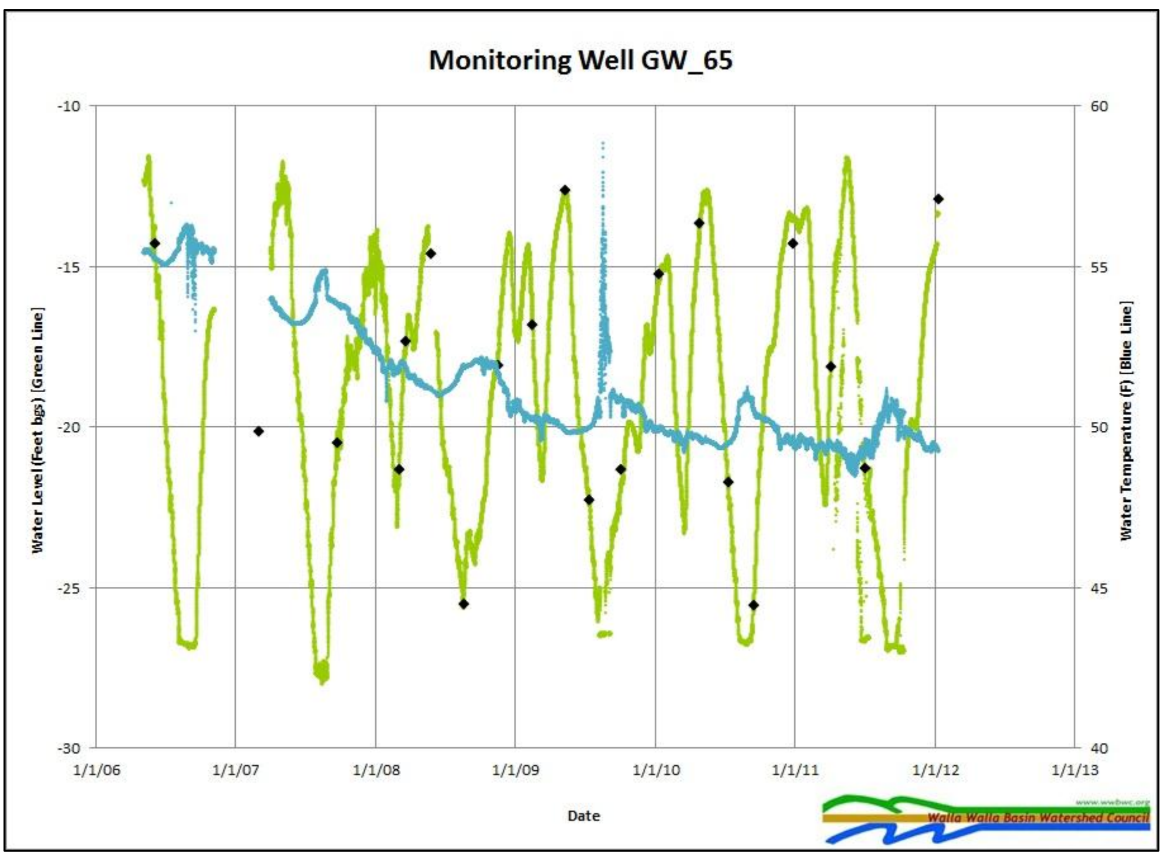
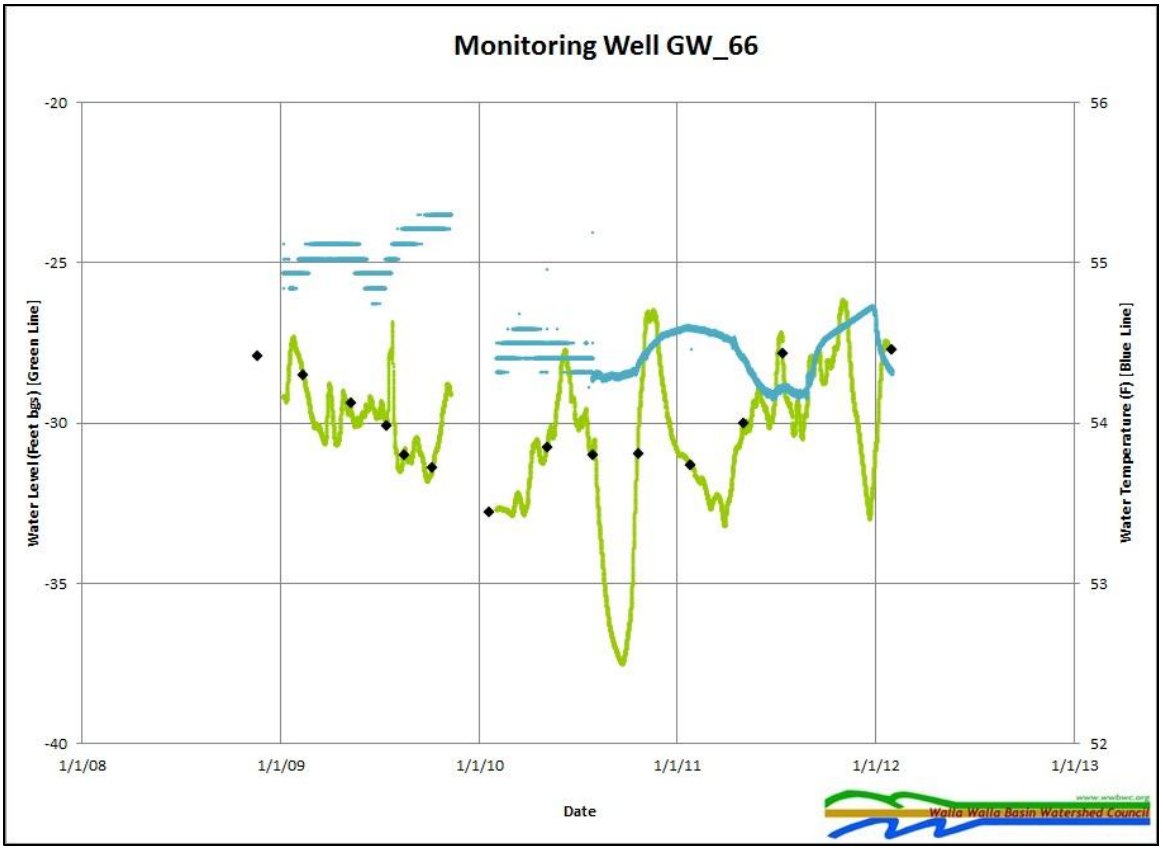
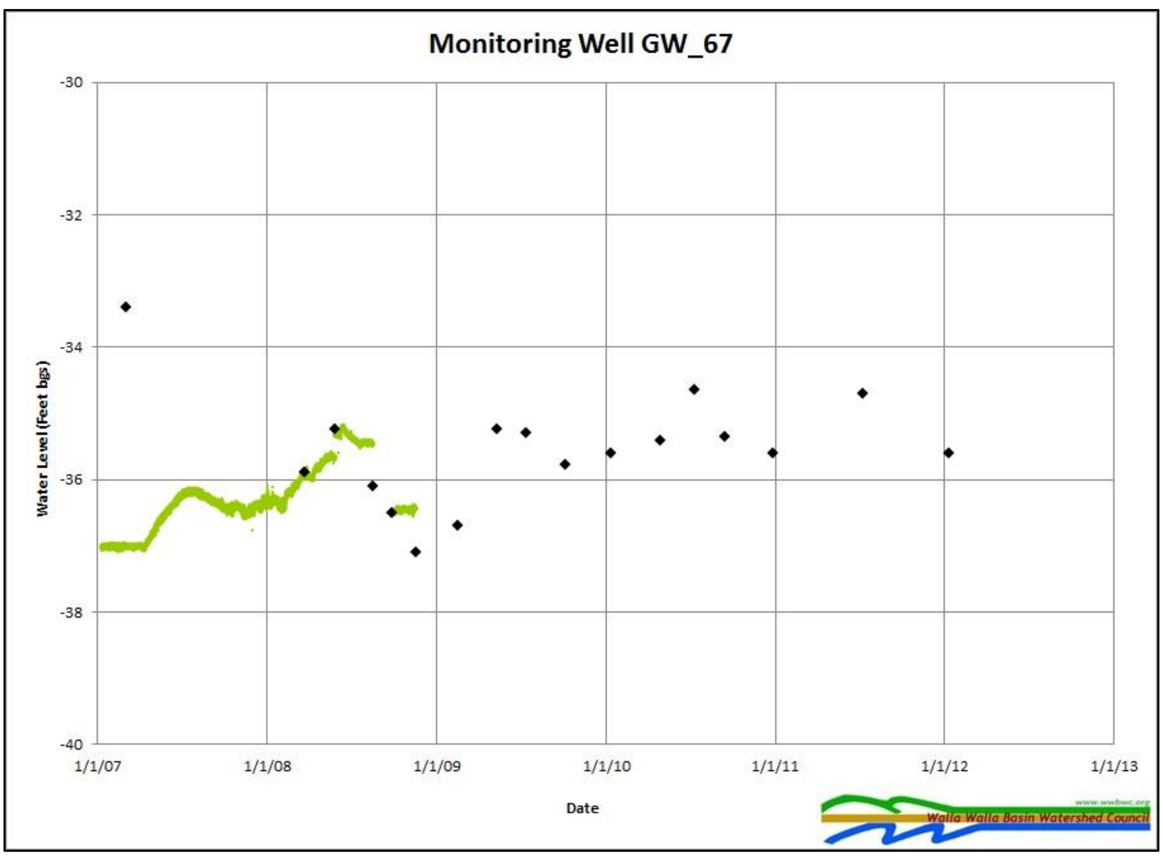
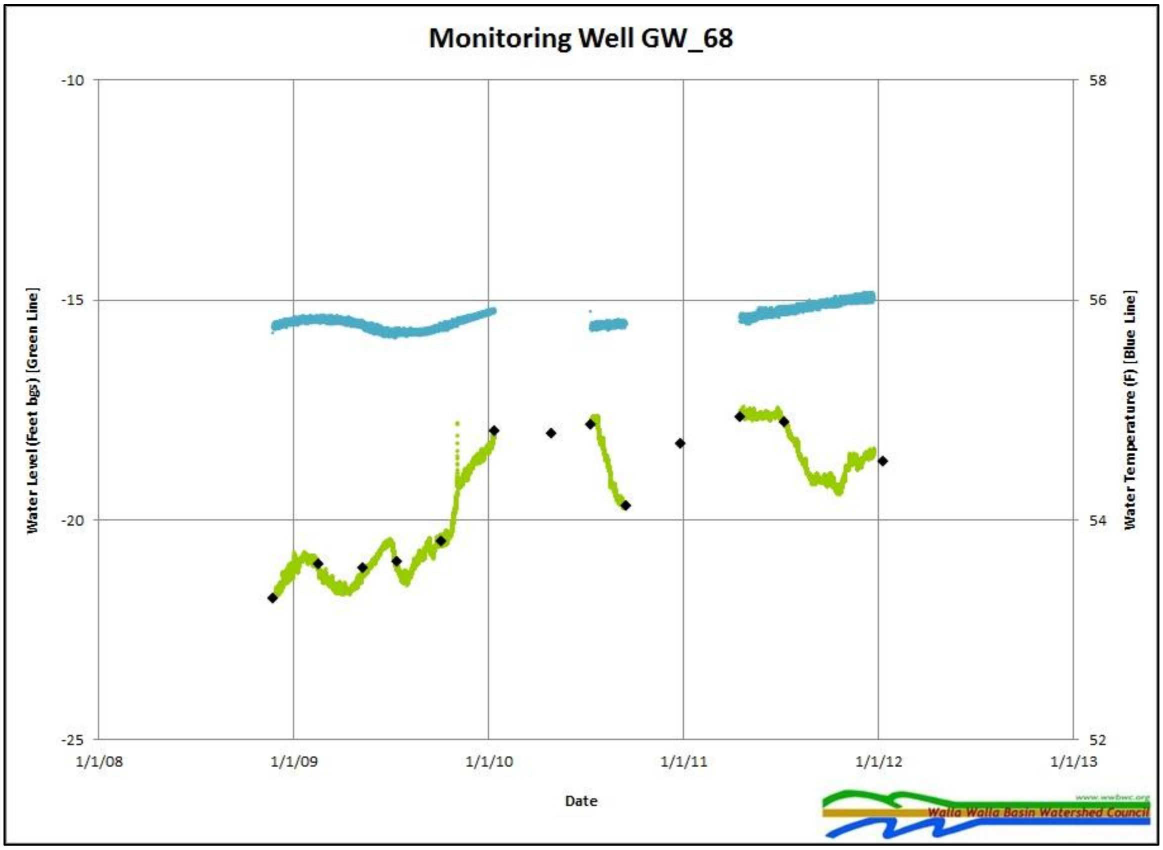

Monitoring Well GW_64
Water Level (Feet bgs)
-25.0
-30.0
-35.0
-40.0
-45.0
-50.0
-55.0
1/1/05
1/1/06
1/1/07
1/1/08
1/1/09
1/1/10
1/1/11
1/1/12
1/1/13
Date
Walla Walla Basin Watershed Council


Monitoring Well GW_65
Water Level (Feet bgs) [Green Line]
Water Temperature (F) [Blue Line]
-10
-15
-20
-25
-30
60
55
50
45
40
1/1/06
1/1/07
1/1/08
1/1/09
1/1/10
1/1/11
1/1/12
1/1/13
Date
Walla Walla Basin Watershed Council


Monitoring Well GW_66
Water Level (Feet bgs) [Green Line]
Water Temperature (F) [Blue Line]
-20
-25
-30
-35
-40
56
55
54
53
52
1/1/08
1/1/09
1/1/10
1/1/11
1/1/12
1/1/13
Date
Walla Walla Basin Watershed Council


Monitoring Well GW_67
Water Level (Feet bgs)
-30
-32
-34
-36
-38
-40
1/1/07
1/1/08
1/1/09
1/1/10
1/1/11
1/1/12
1/1/13
Date
Walla Walla Basin Watershed Council


Monitoring Well GW_68
Water Level (Feet bgs) [Green Line]
Water Temperature (F) [Blue Line]
-10
-15
-20
-25
58
56
54
52
1/1/08
1/1/09
1/1/10
1/1/11
1/1/12
1/1/13
Date
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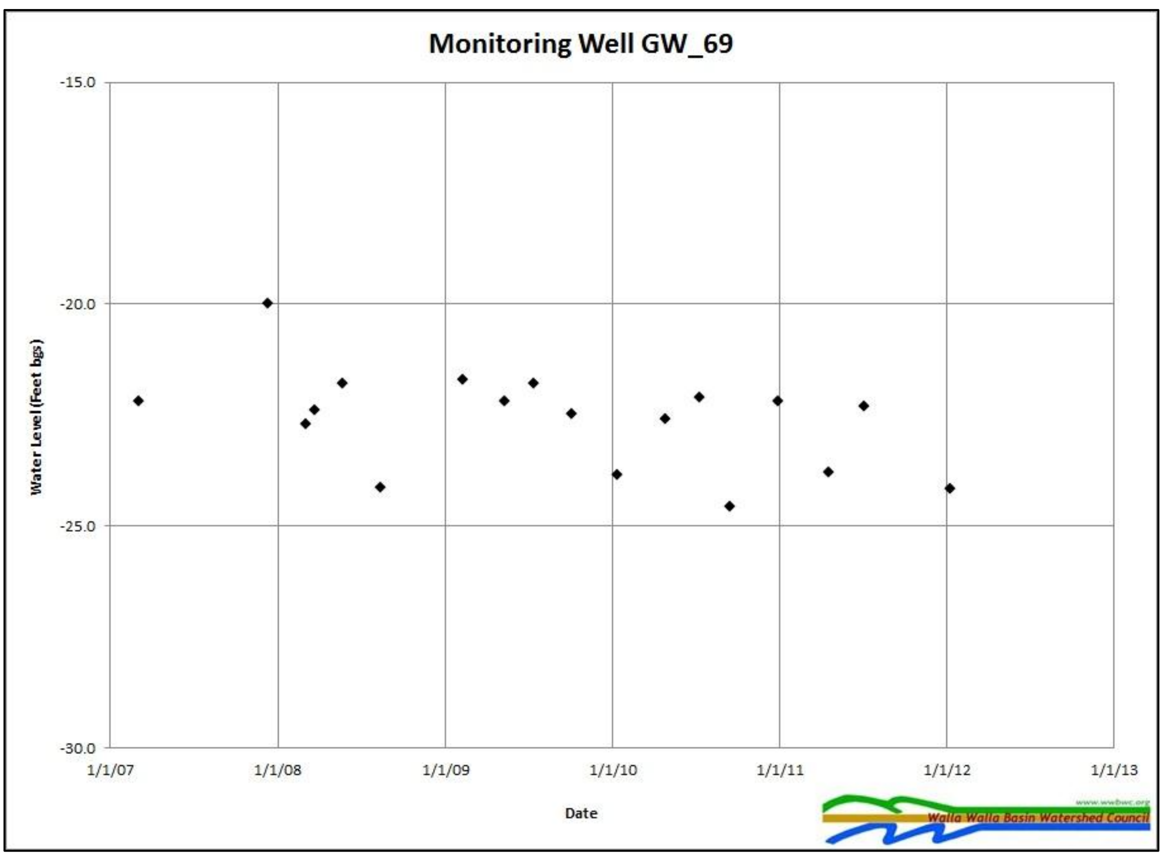
Monitoring Well GW_69
Water Level (Feet bgs)
-15.0
-20.0
-25.0
-30.0
1/1/07
1/1/08
1/1/09
1/1/10
1/1/11
1/1/12
1/1/13
Date
www.wwbwc.org
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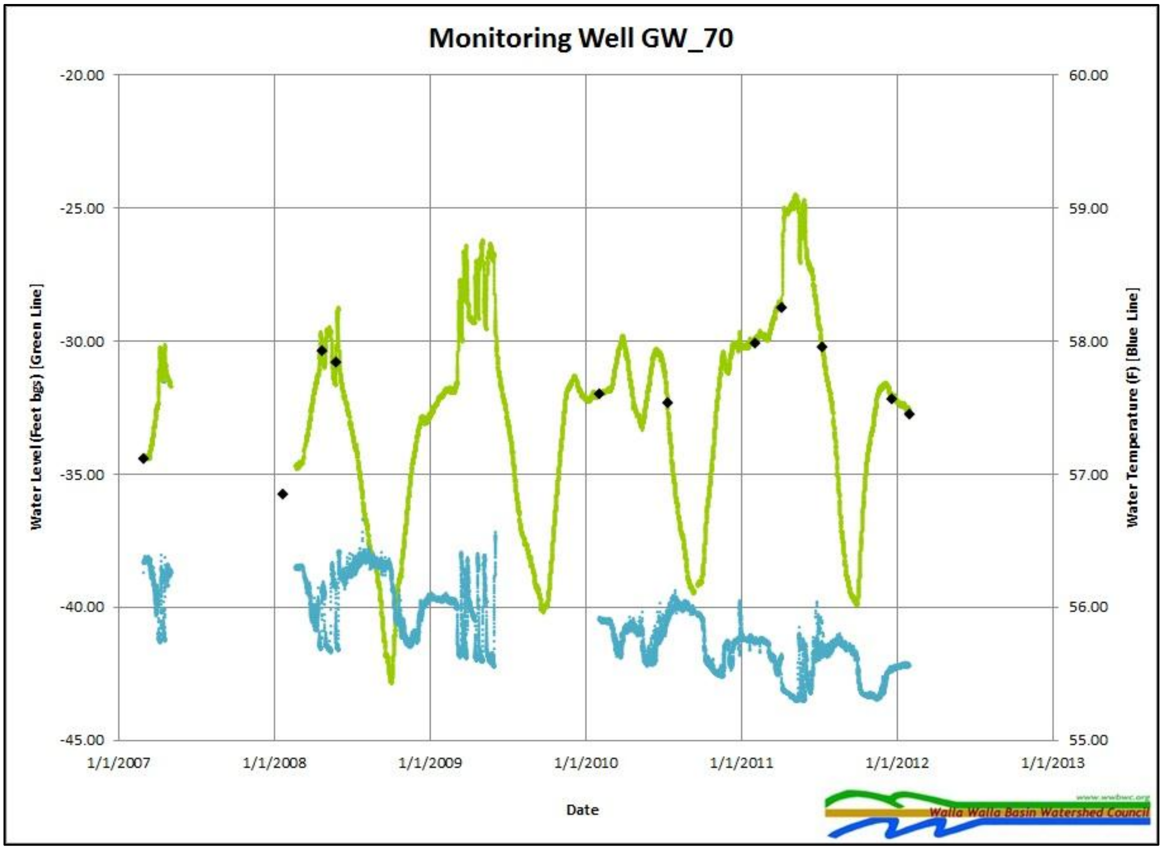
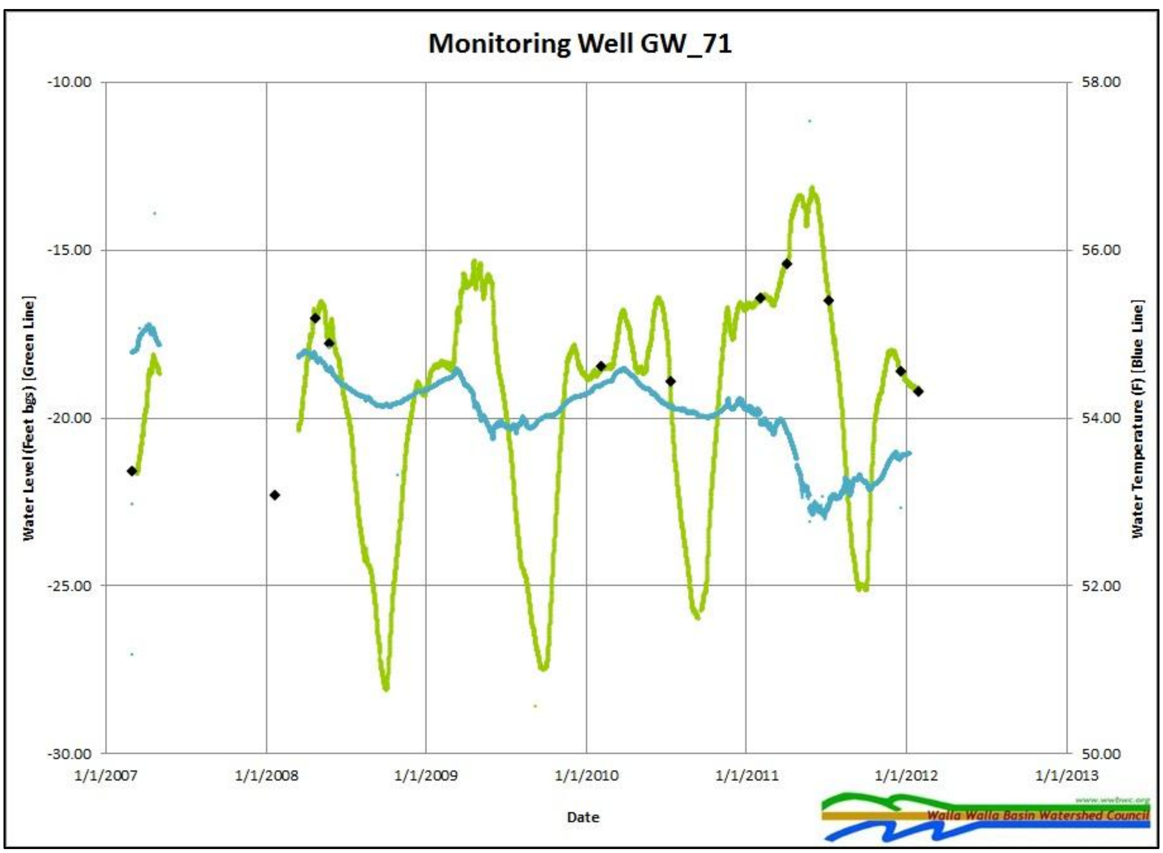
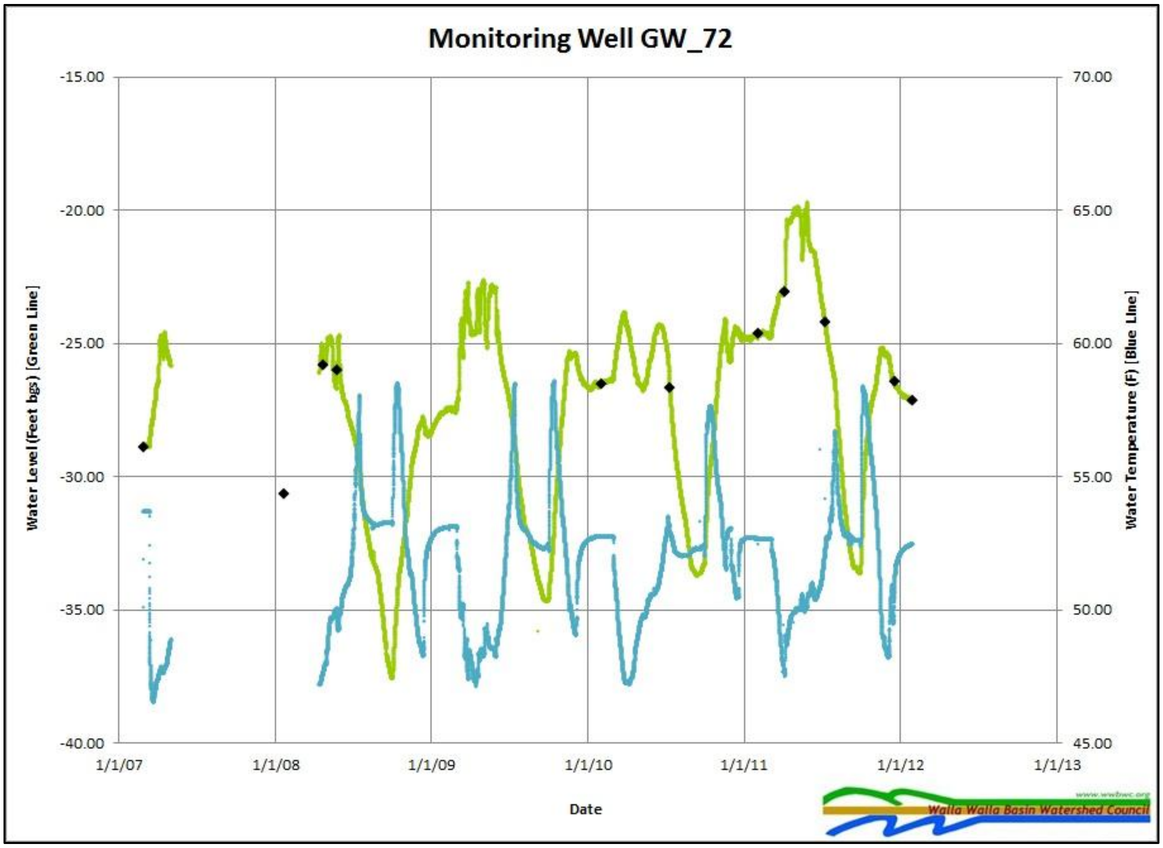
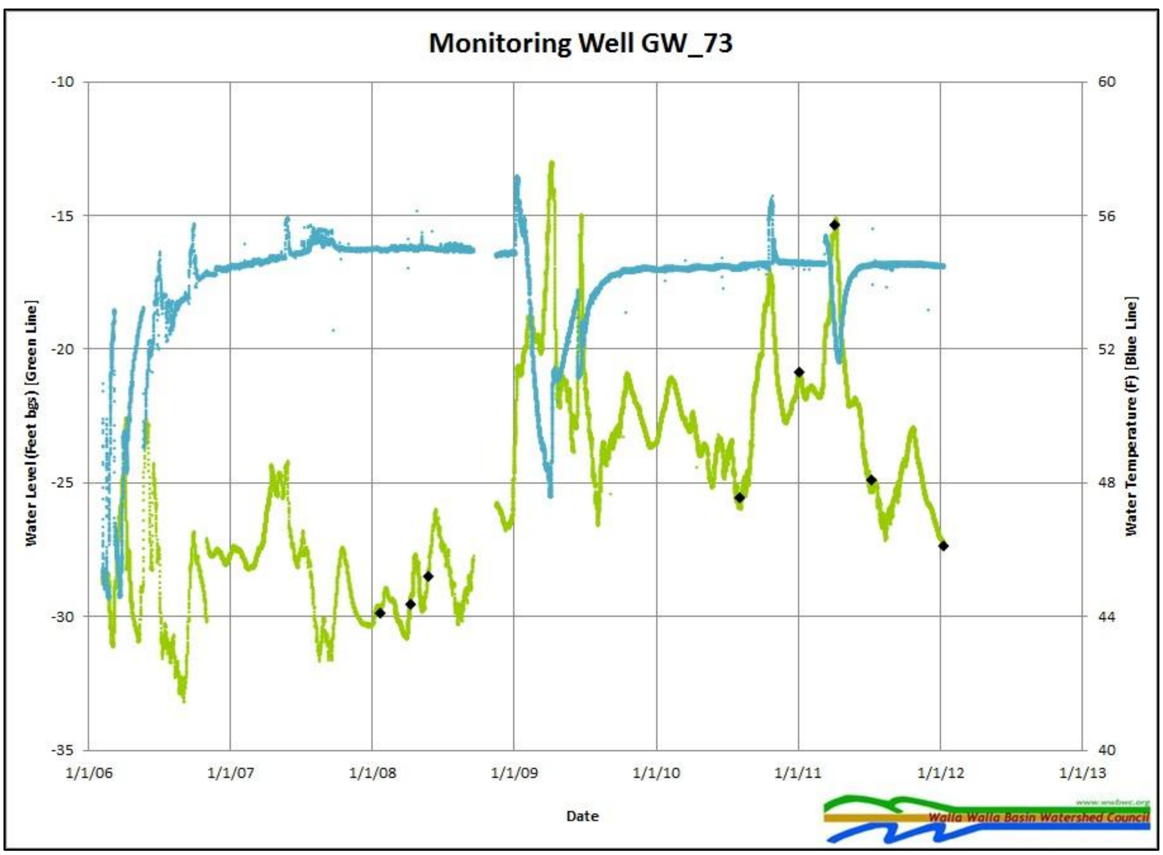


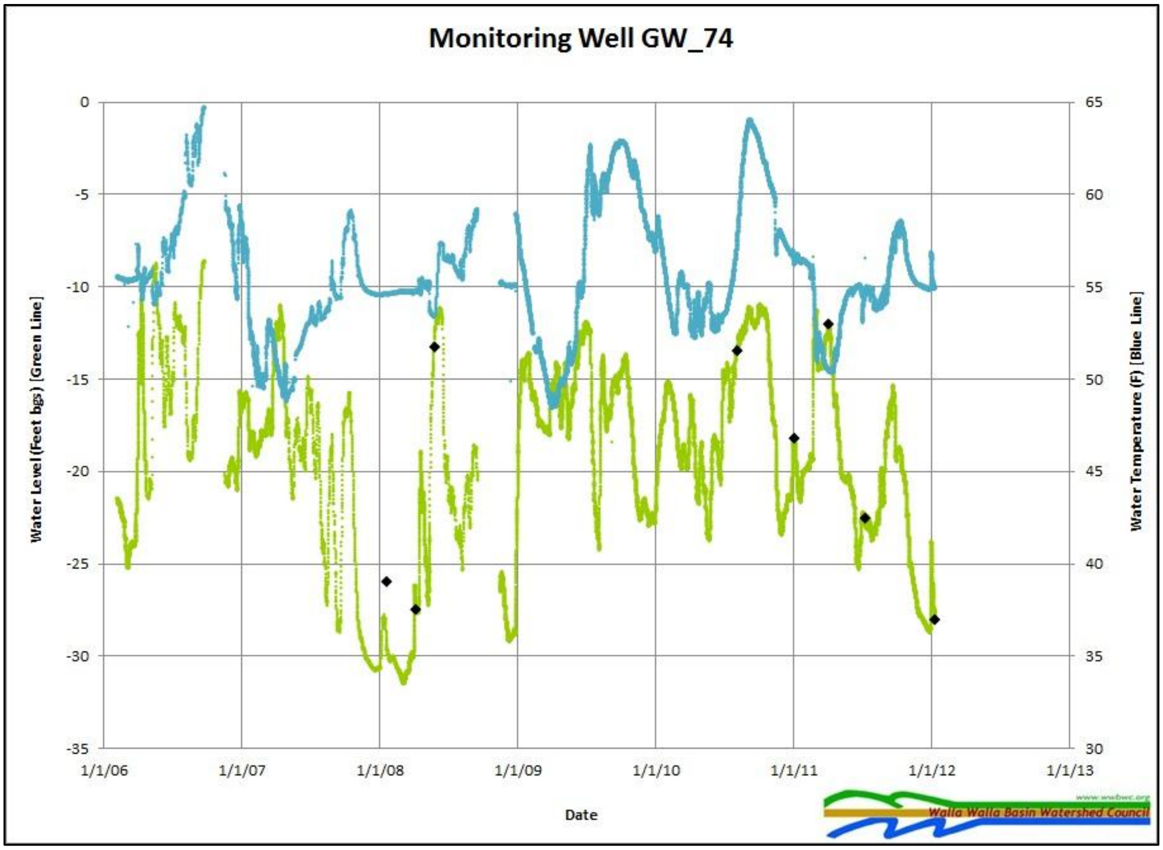
Monitoring Well GW_70
Water Level (Feet bgs) [Green Line]
Water Temperature (F) [Blue Line]
-20.00
-25.00
-30.00
-35.00
-40.00
-45.00
60.00
59.00
58.00
57.00
56.00
55.00
1/1/2007
1/1/2008
1/1/2009
1/1/2010
1/1/2011
1/1/2012
1/1/2013
Date
Walla Walla Basin Watershed Council

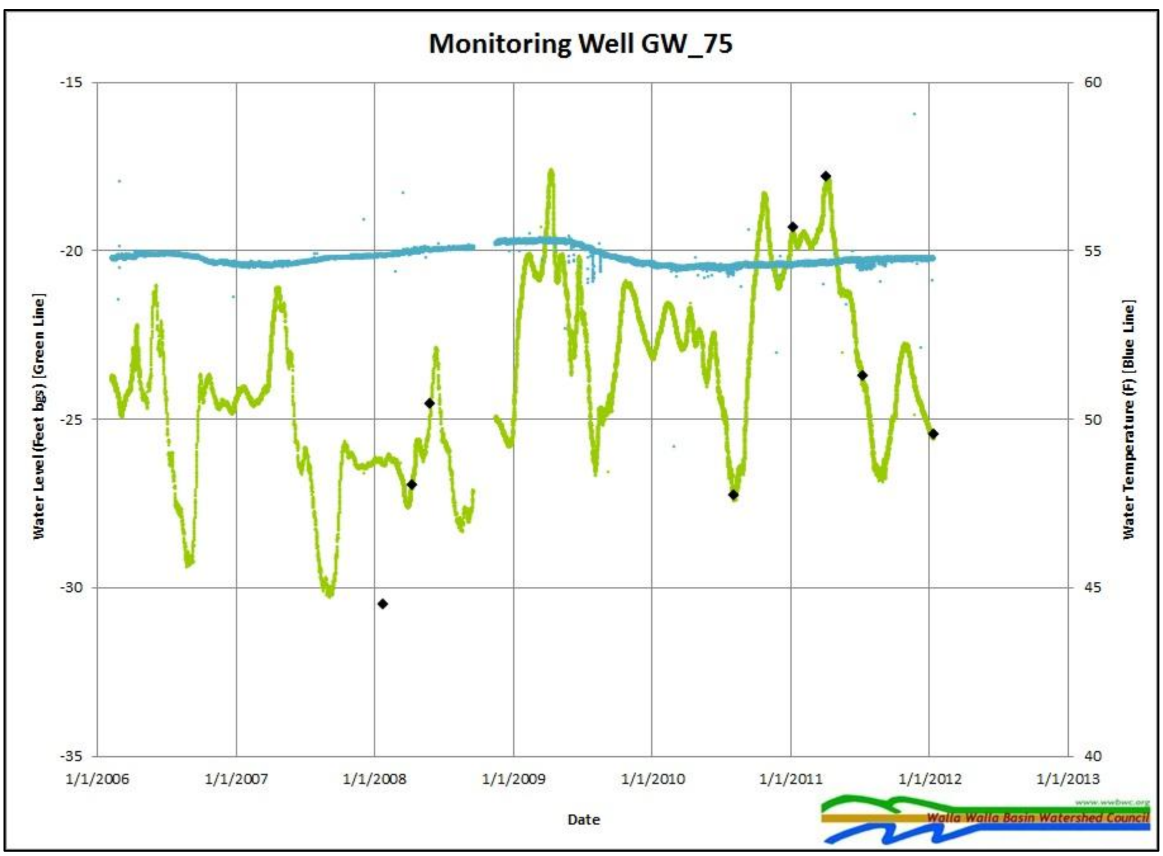


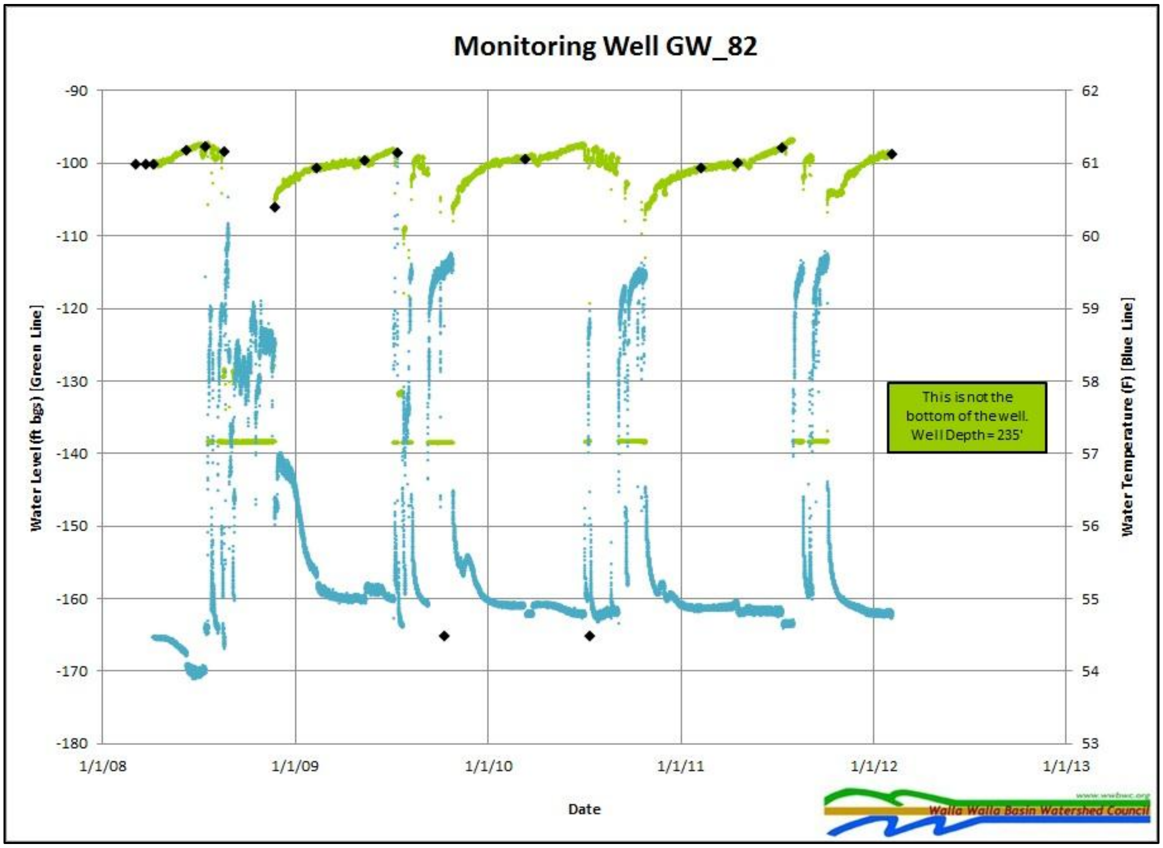
Monitoring Well GW_71
Water Level (Feet bgs) [Green Line]
Water Temperature (F) [Blue Line]
-10.00
-15.00
-20.00
-25.00
-30.00
58.00
56.00
54.00
52.00
50.00
1/1/2007
1/1/2008
1/1/2009
1/1/2010
1/1/2011
1/1/2012
1/1/2013
Date
Walla Walla Basin Watershed Council

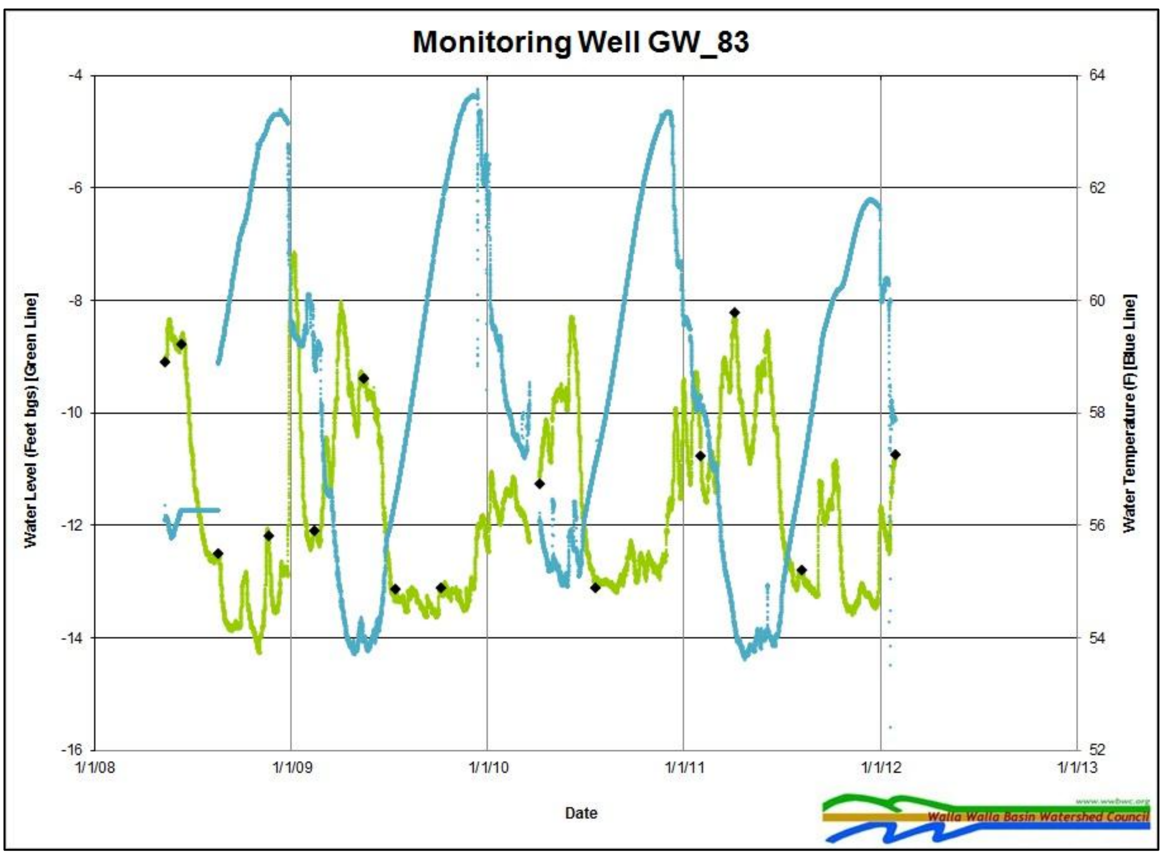

Monitoring Well GW_72
Water Level (Feet bgs) [Green Line]
Water Temperature (F) [Blue Line]
Date
-15.00
-20.00
-25.00
-30.00
-35.00
-40.00
70.00
65.00
60.00
55.00
50.00
45.00
1/1/07
1/1/08
1/1/09
1/1/10
1/1/11
1/1/12
1/1/13
Walla Walla Basin Watershed Council

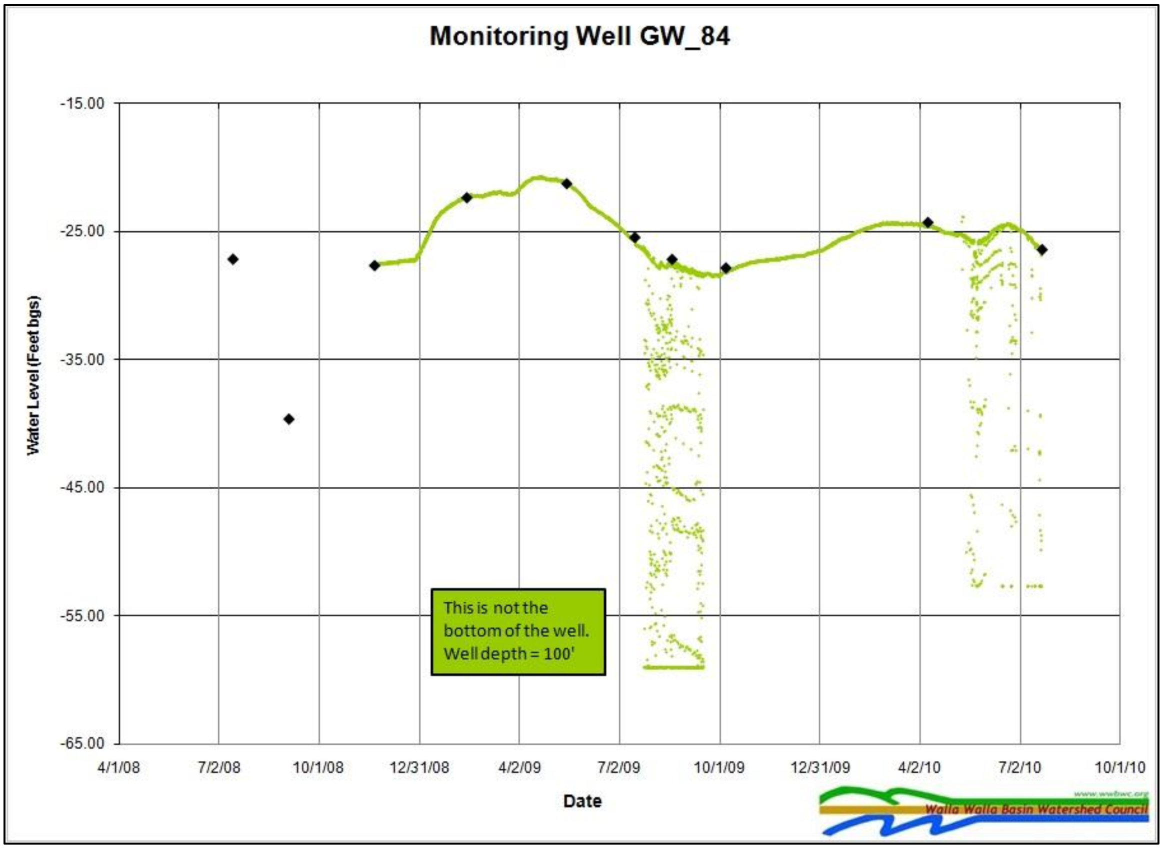

Monitoring Well GW_73
Water Level (Feet bgs) [Green Line]
Water Temperature (F) [Blue Line]
Date
-10
-15
-20
-25
-30
-35
60
56
52
48
44
40
1/1/06
1/1/07
1/1/08
1/1/09
1/1/10
1/1/11
1/1/12
1/1/13
Walla Walla Basin Watershed Council

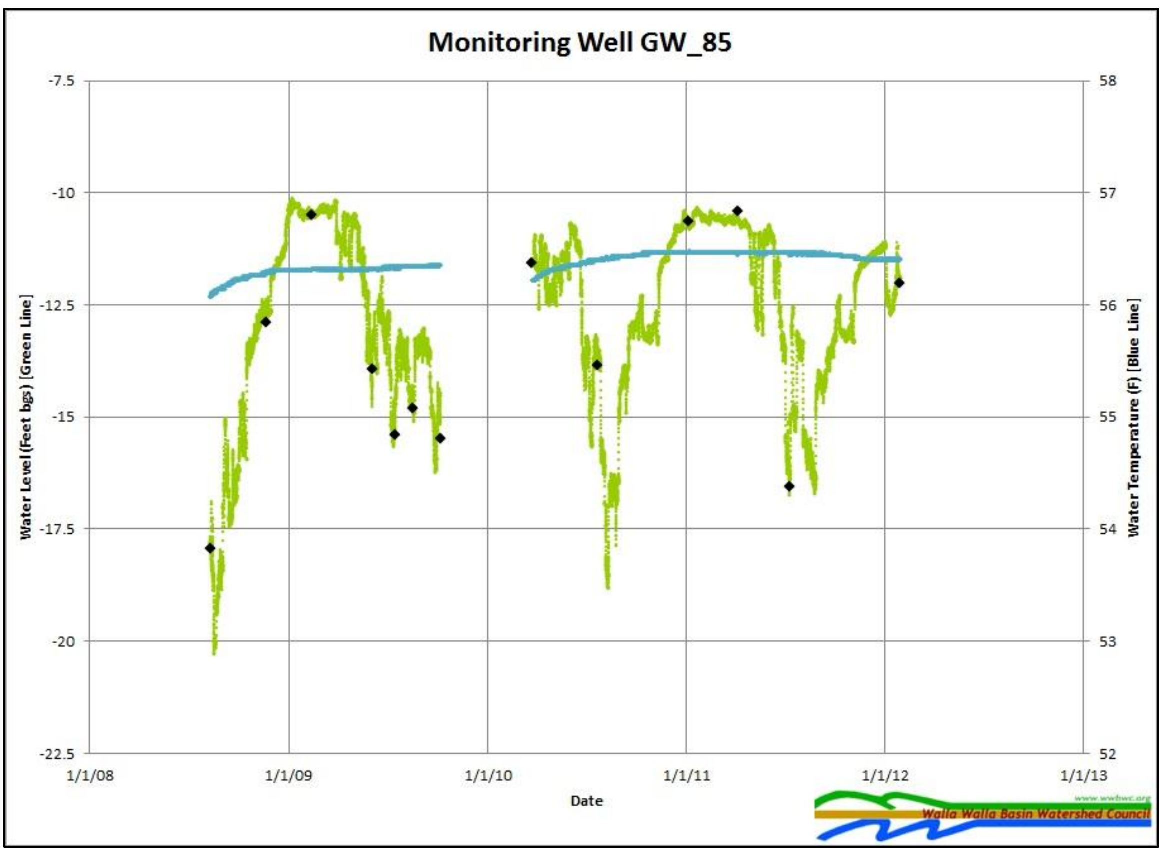

Monitoring Well GW_74
Water Level (Feet bgs) [Green Line]
Water Temperature (F) [Blue Line]
0
-5
-10
-15
-20
-25
-30
-35
65
60
55
50
45
40
35
30
1/1/06
1/1/07
1/1/08
1/1/09
1/1/10
1/1/11
1/1/12
1/1/13
Date
Walla Walla Basin Watershed Council

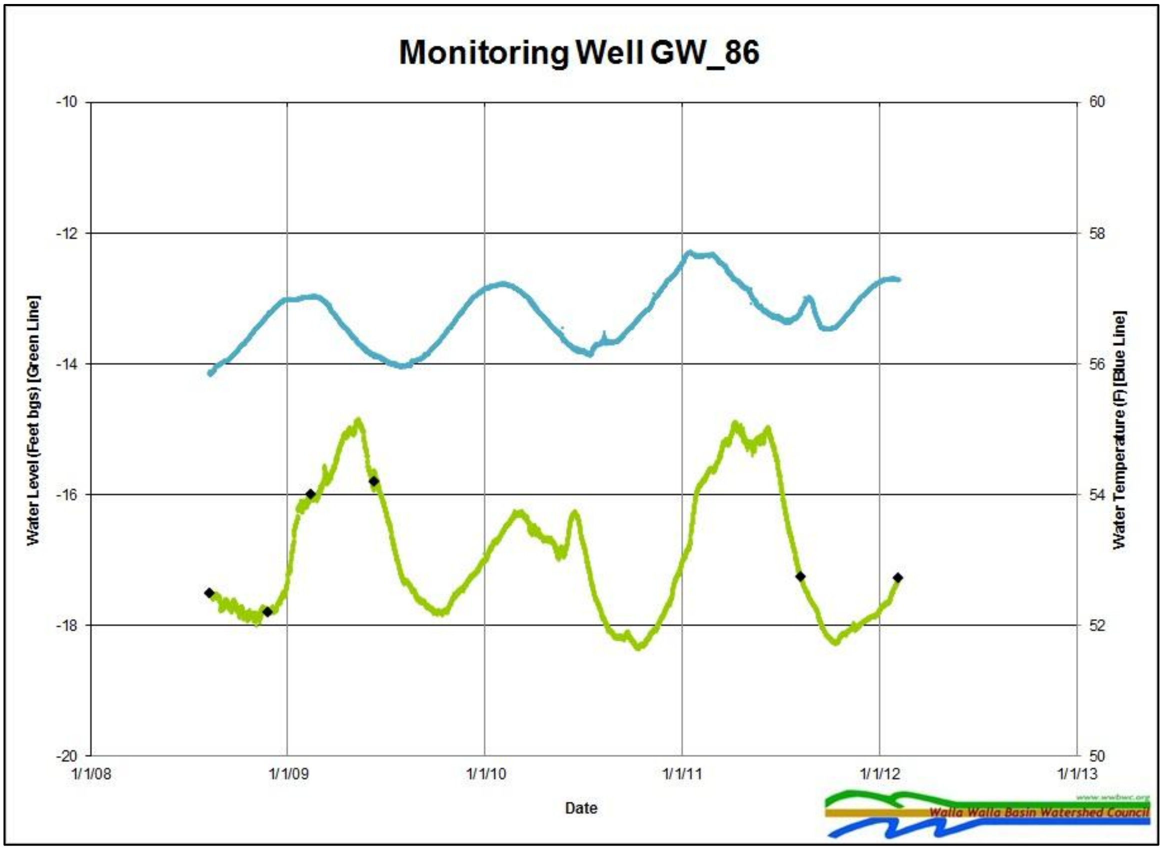

Monitoring Well GW_75
Water Level (Feet bgs) [Green Line]
Water Temperature (F) [Blue Line]
-15
-20
-25
-30
-35
60
55
50
45
40
1/1/2006
1/1/2007
1/1/2008
1/1/2009
1/1/2010
1/1/2011
1/1/2012
1/1/2013
Date
Walla Walla Basin Watershed Council

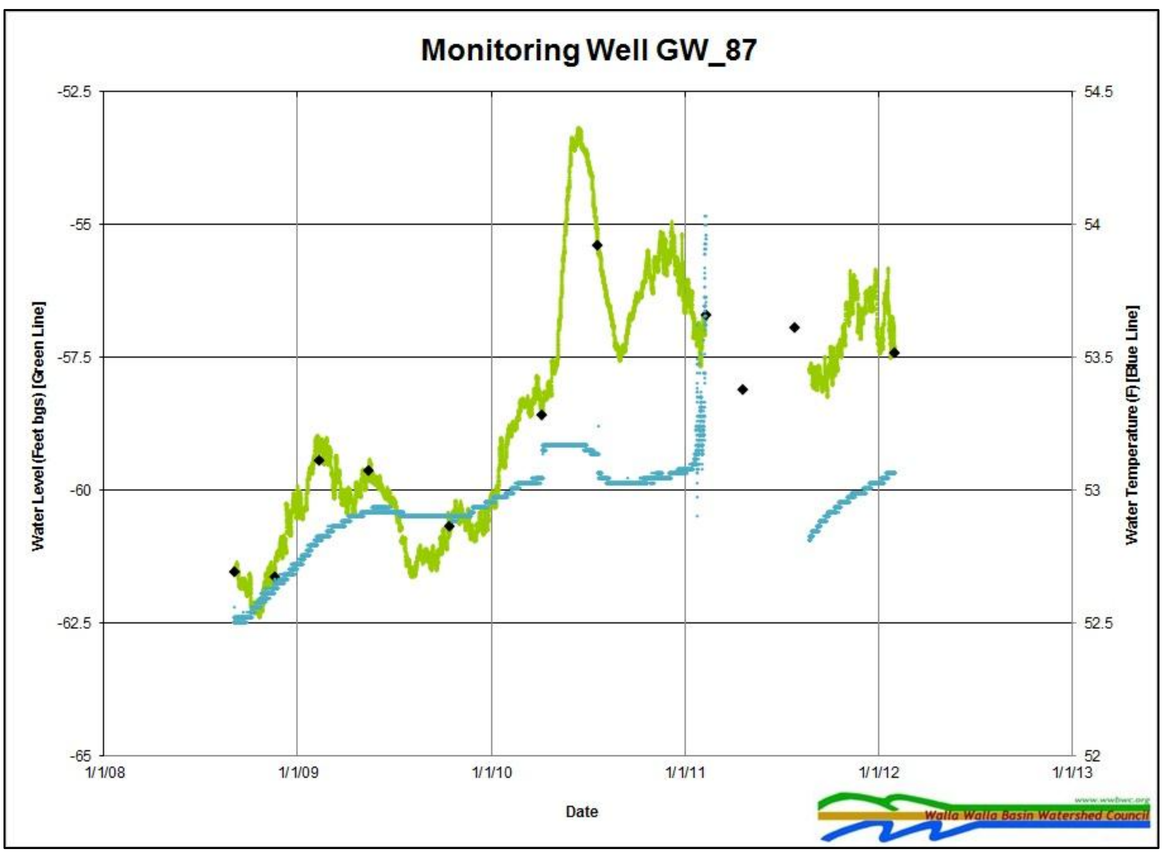

Monitoring Well GW_82
Water Level (ft bgs) [Green Line]
Water Temperature (F) [Blue Line]
This is not the bottom of the well. Well Depth = 235'
Date
1/1/08
1/1/09
1/1/10
1/1/11
1/1/12
1/1/13
Walla Walla Basin Watershed Council

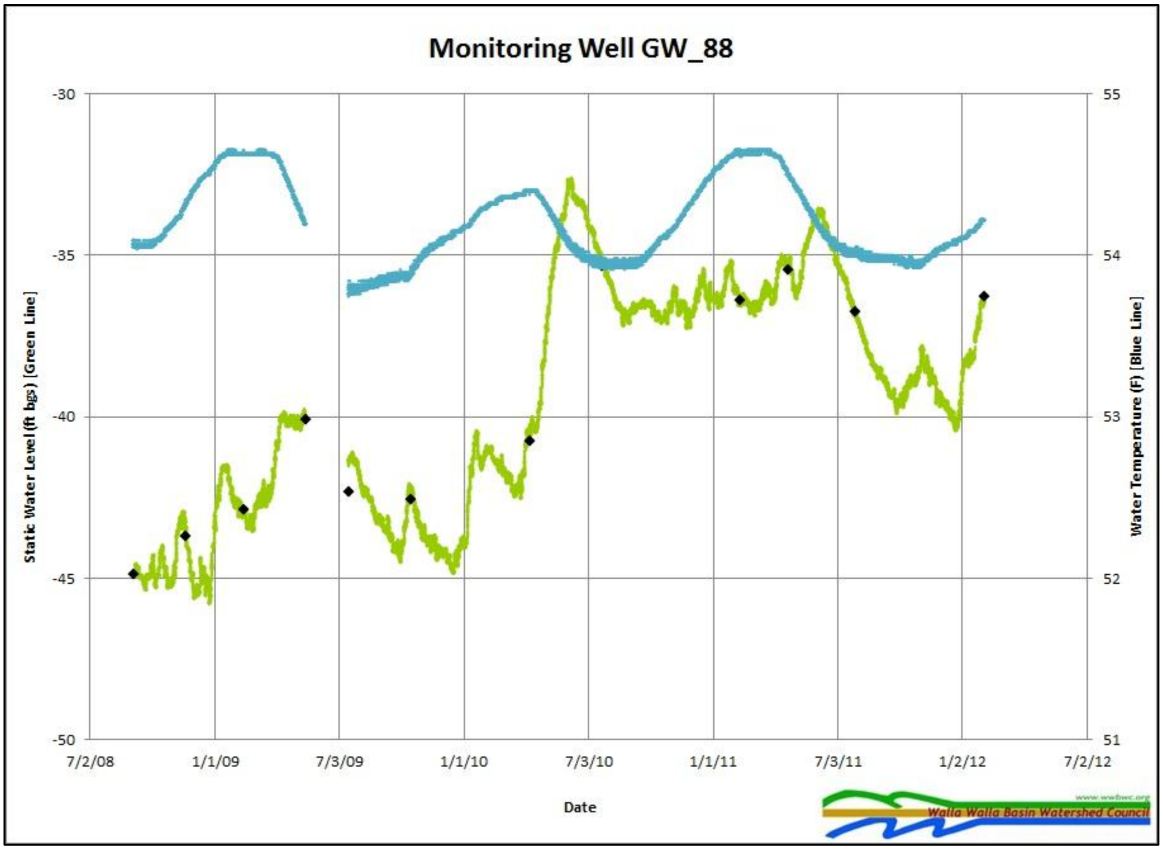

Monitoring Well GW_83
Water Level (Feet bgs) [Green Line]
Water Temperature (F) [Blue Line]
Date
1/1/08
1/1/09
1/1/10
1/1/11
1/1/12
1/1/13
Walla Walla Basin Watershed Council

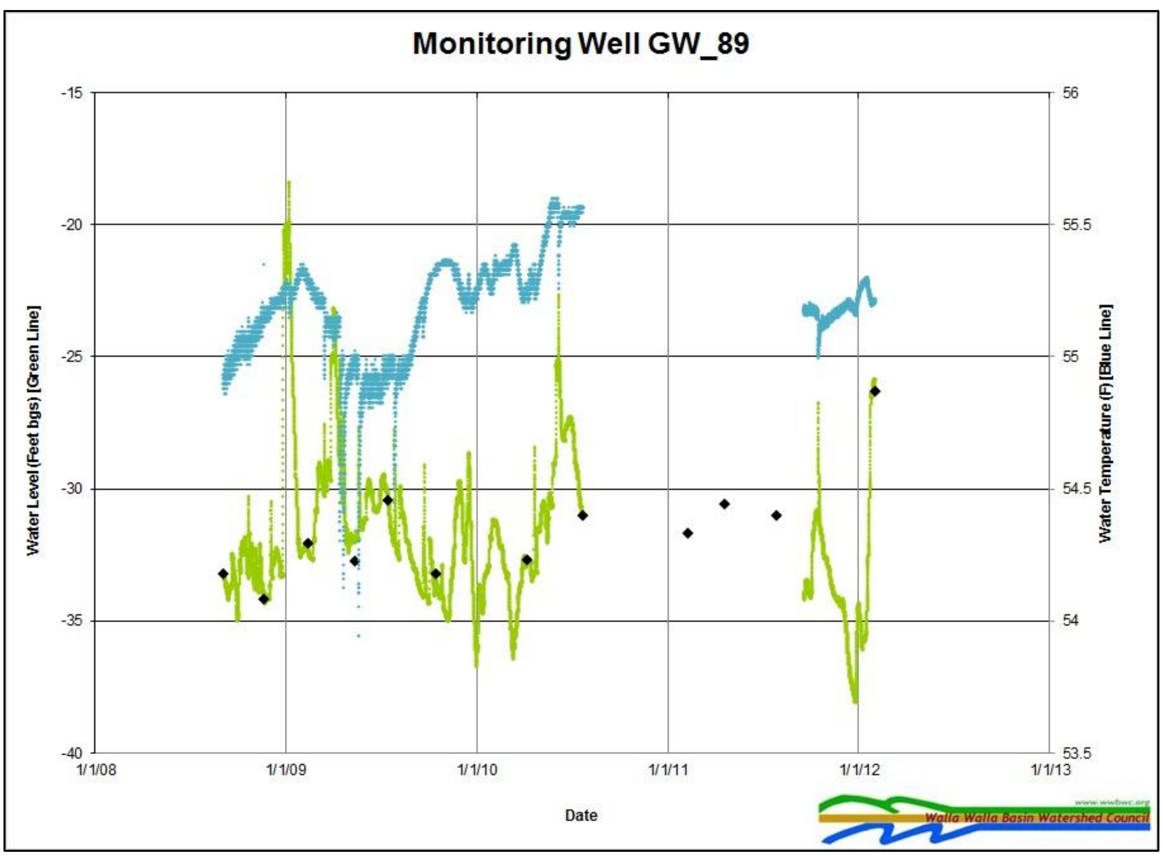

Monitoring Well GW_84
Water Level (Feet bgs)
-15.00
-25.00
-35.00
-45.00
-55.00
-65.00
4/1/08
7/2/08
10/1/08
12/31/08
4/2/09
7/2/09
10/1/09
12/31/09
4/2/10
7/2/10
10/1/10
Date
This is not the bottom of the well. Well depth = 100'
Walla Walla Basin Watershed Council

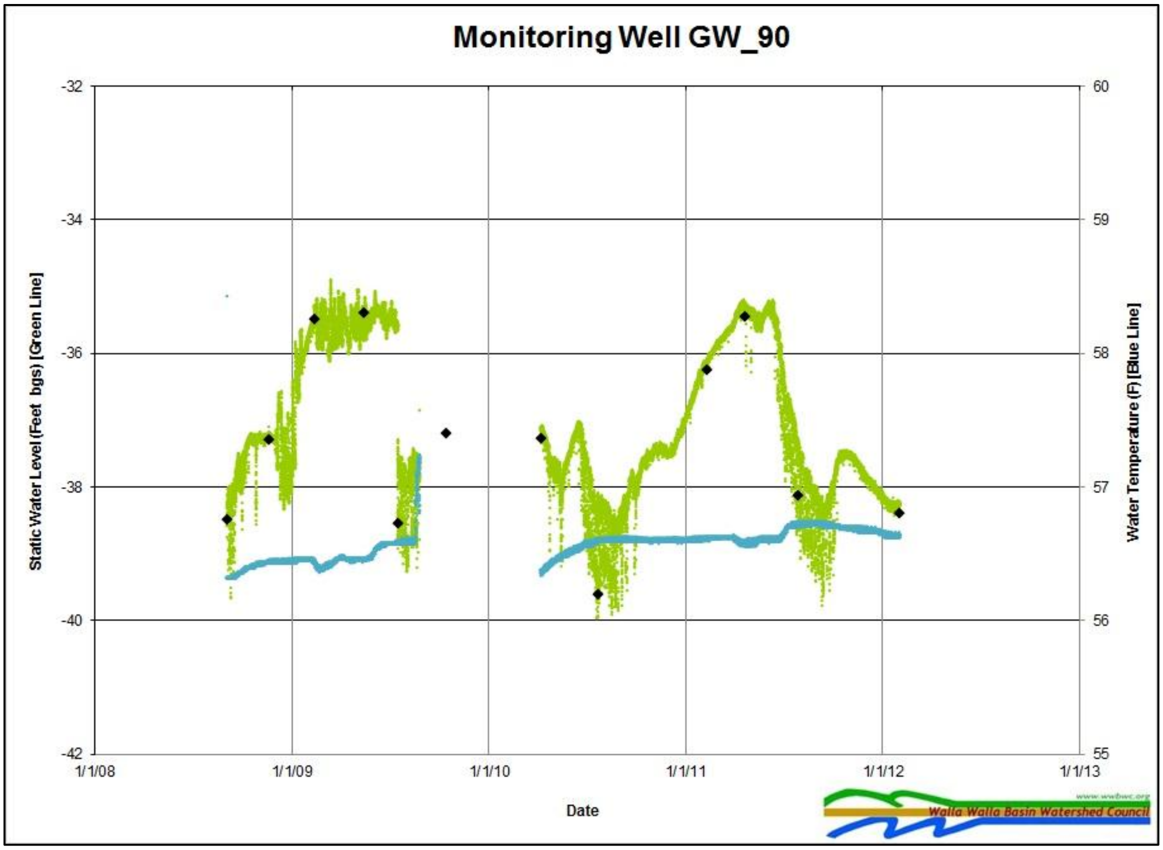

Monitoring Well GW_85
Water Level (Feet bgs) [Green Line]
Water Temperature (F) [Blue Line]
-7.5
-10
-12.5
-15
-17.5
-20
-22.5
58
57
56
55
54
53
52
1/1/08
1/1/09
1/1/10
1/1/11
1/1/12
1/1/13
Date
Walla Walla Basin Watershed Council


Monitoring Well GW_86
Water Level (Feet bgs) [Green Line]
Water Temperature (F) [Blue Line]
-10
-12
-14
-16
-18
-20
60
58
56
54
52
50
1/1/08
1/1/09
1/1/10
1/1/11
1/1/12
1/1/13
Date
Walla Walla Basin Watershed Council


Monitoring Well GW_87
Water Level (Feet bgs) [Green Line]
Water Temperature (F) [Blue Line]
-52.5
-55
-57.5
-60
-62.5
-65
54.5
54
53.5
53
52.5
52
1/1/08
1/1/09
1/1/10
1/1/11
1/1/12
1/1/13
Date
Walla Walla Basin Watershed Council


Monitoring Well GW_88
Static Water Level (ft bgs) [Green Line]
Water Temperature (F) [Blue Line]
-30
-35
-40
-45
-50
55
54
53
52
51
7/2/08
1/1/09
7/3/09
1/1/10
7/3/10
1/1/11
7/3/11
1/2/12
7/2/12
Date
Walla Walla Basin Watershed Council


Monitoring Well GW_89
Water Level (Feet bgs) [Green Line]
Water Temperature (F) [Blue Line]
-15
-20
-25
-30
-35
-40
56
55.5
55
54.5
54
53.5
1/1/08
1/1/09
1/1/10
1/1/11
1/1/12
1/1/13
Date
Walla Walla Basin Watershed Council



Monitoring Well GW_90
Static Water Level (Feet bgs) [Green Line]
Water Temperature (F) [Blue Line]
-32
-34
-36
-38
-40
-42
60
59
58
57
56
55
1/1/08
1/1/09
1/1/10
1/1/11
1/1/12
1/1/13
Date
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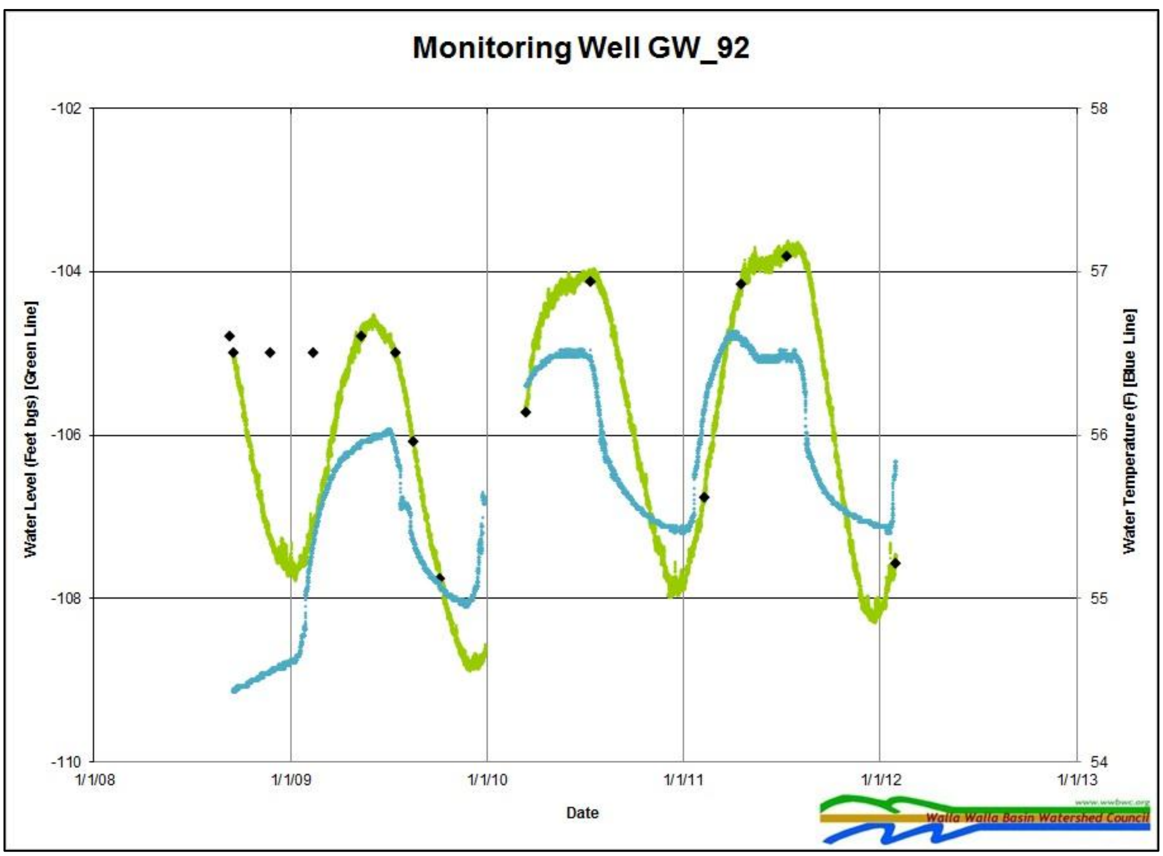
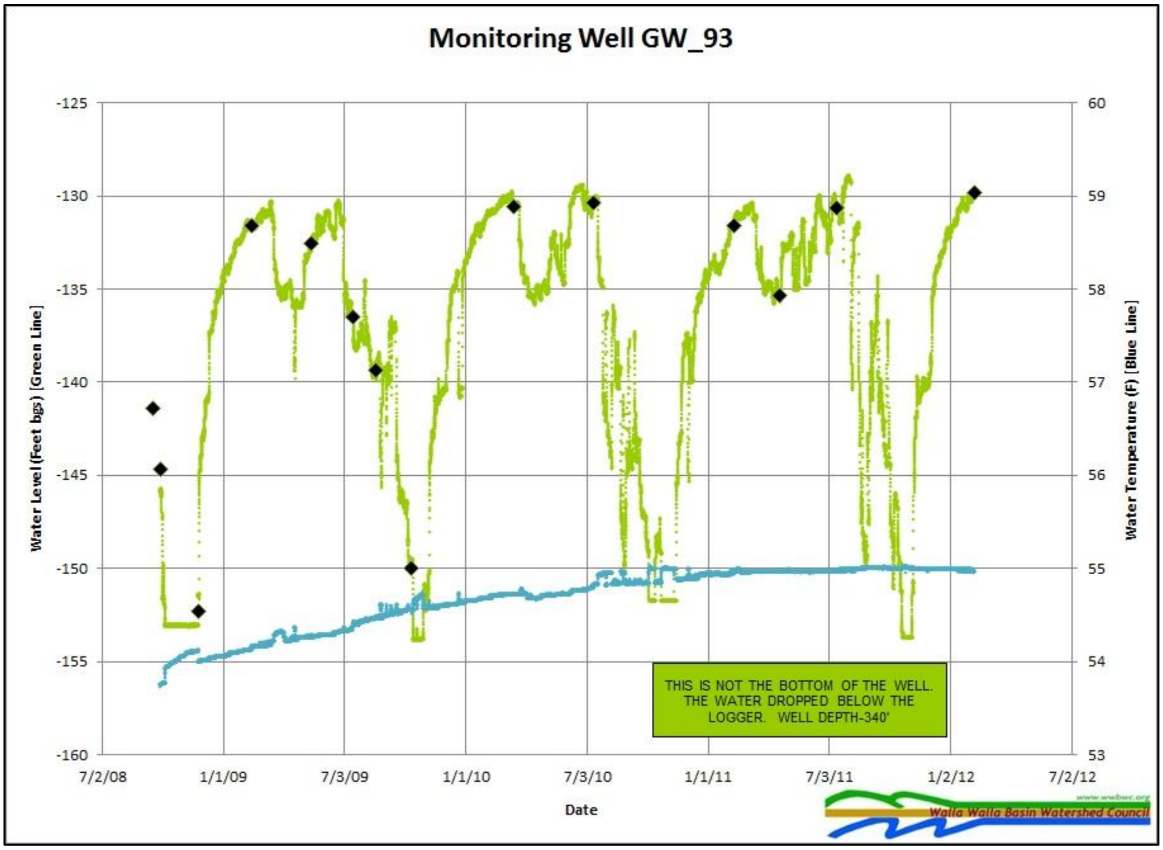
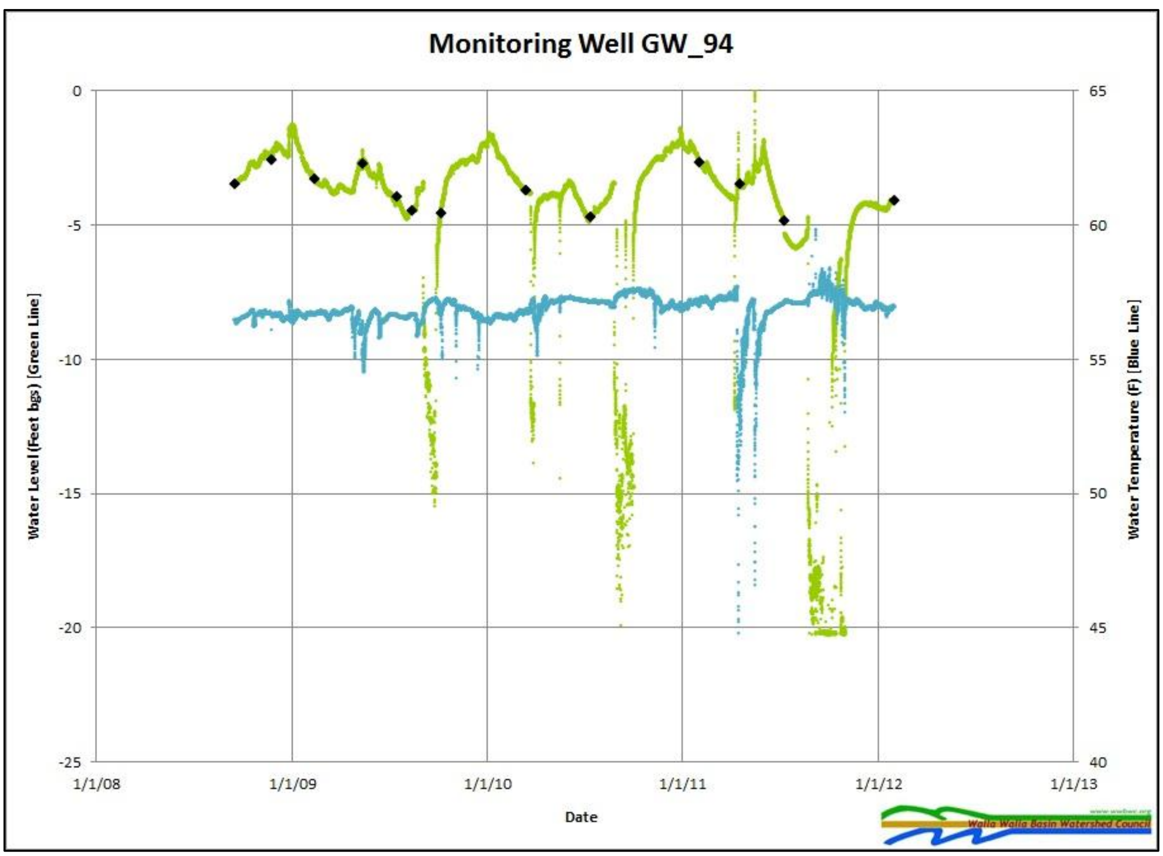
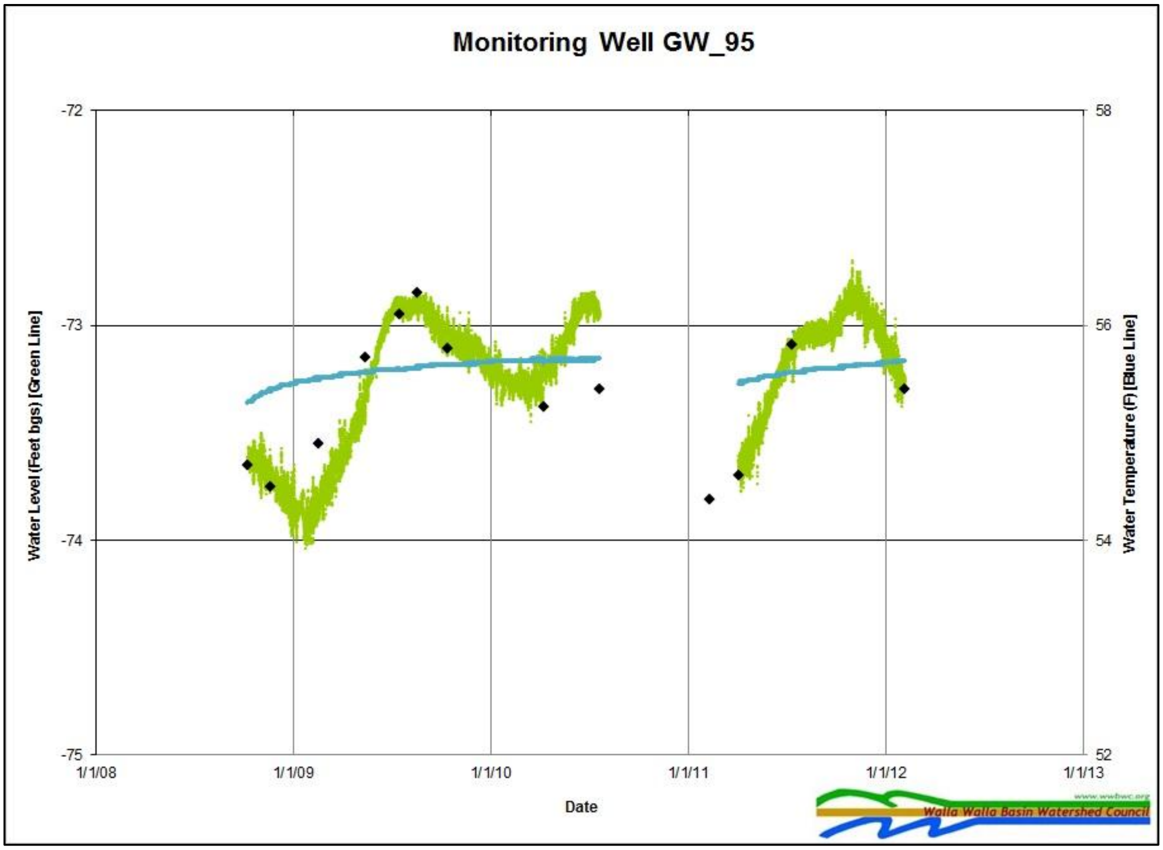
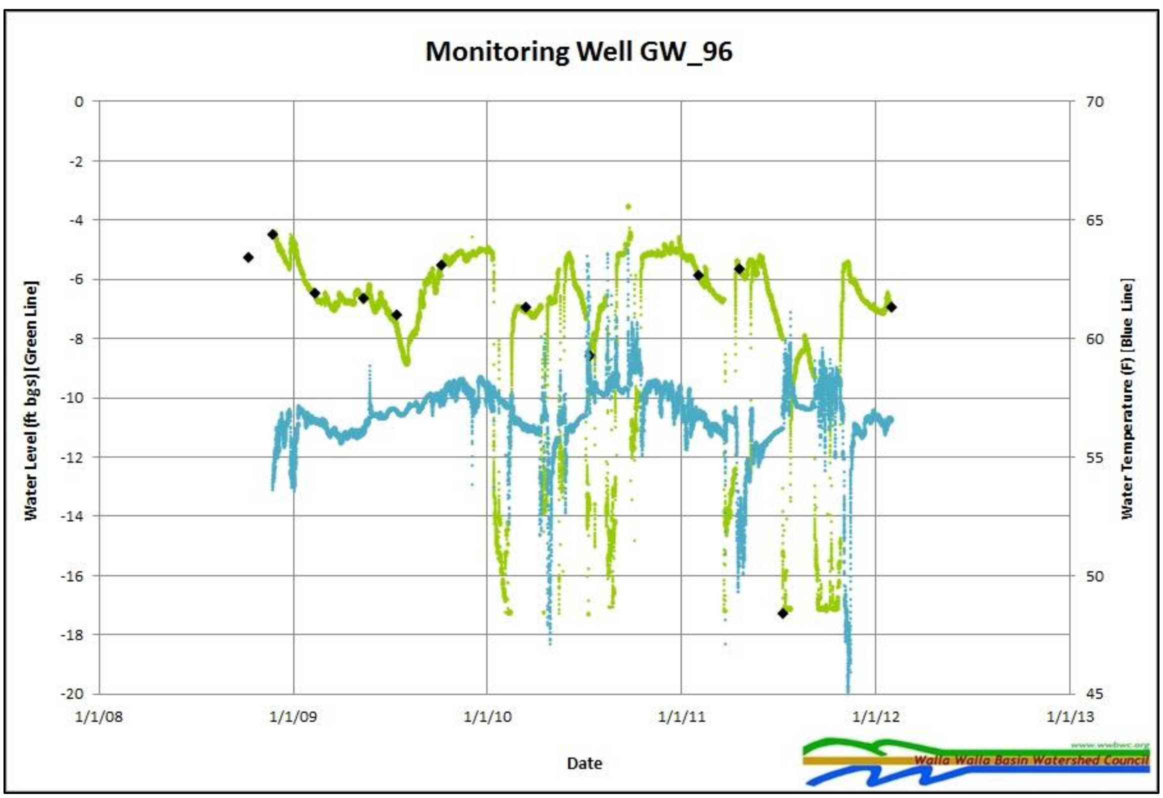


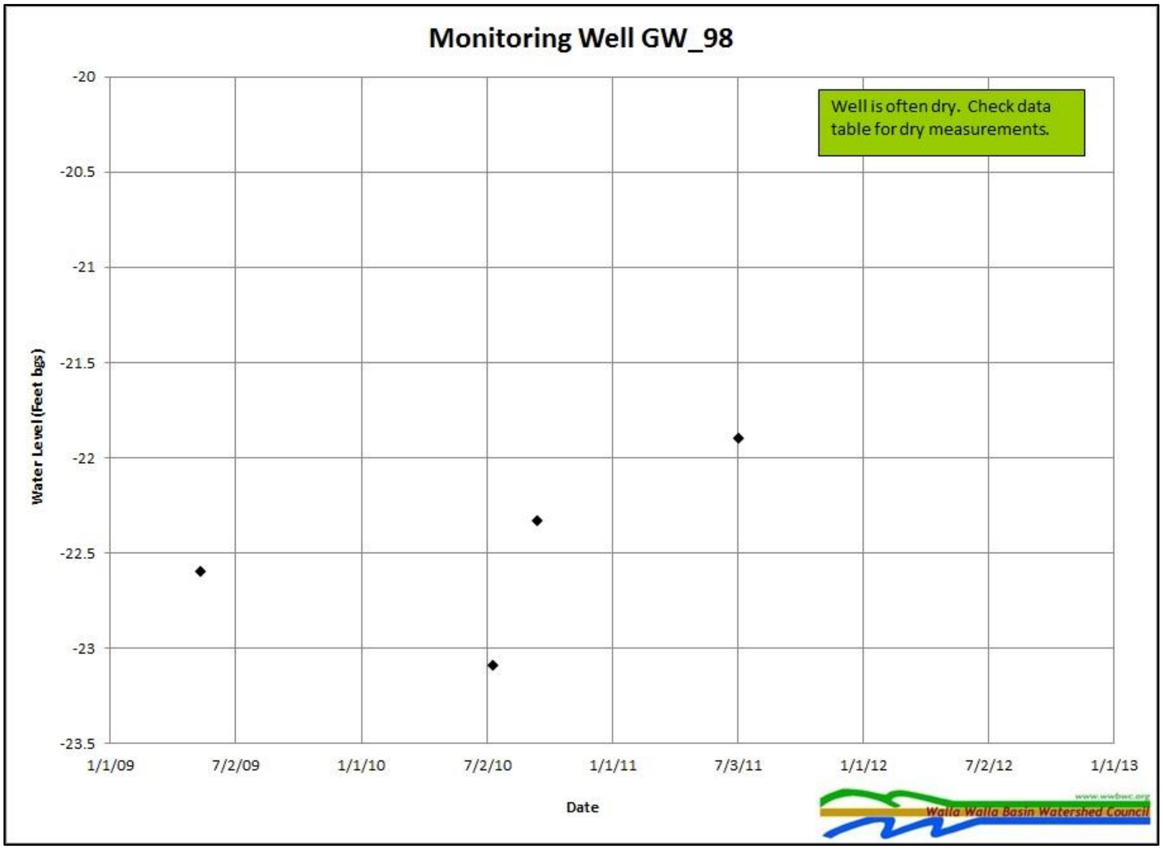
Monitoring Well GW_92
Water Level (Feet bgs) [Green Line]
Water Temperature (F) [Blue Line]
-102
-104
-106
-108
-110
58
57
56
55
54
1/1/08
1/1/09
1/1/10
1/1/11
1/1/12
1/1/13
Date
www.wwbwc.org
Walla Walla Basin Watershed Council


Monitoring Well GW_93
Water Level (Feet bgs) [Green Line]
Water Temperature (F) [Blue Line]
Date
THIS IS NOT THE BOTTOM OF THE WELL. THE WATER DROPPED BELOW THE LOGGER. WELL DEPTH-340'
Walla Walla Basin Watershed Council

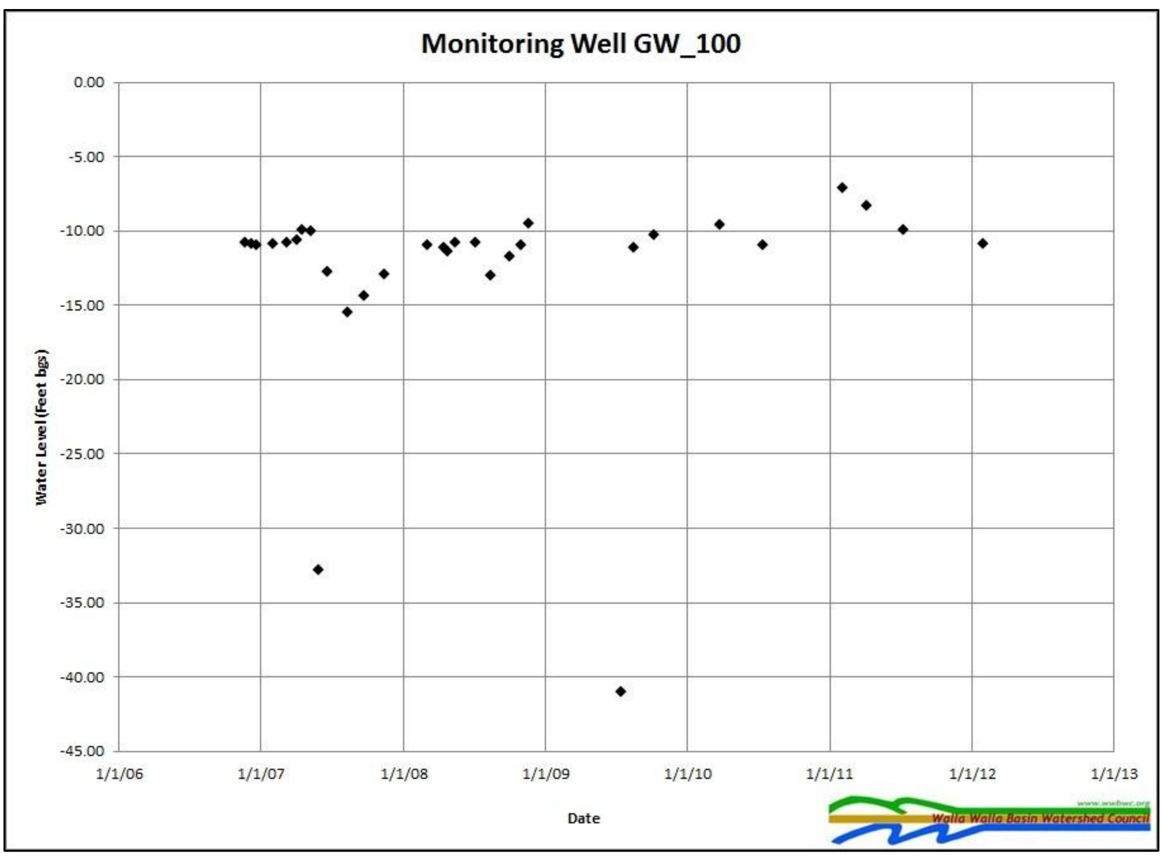

Monitoring Well GW_94
Water Level (Feet bgs) [Green Line]
Water Temperature (F) [Blue Line]
Date
Walla Walla Basin Watershed Council


Monitoring Well GW_95
Water Level (Feet bgs) [Green Line]
Water Temperature (F) [Blue Line]
-72
-73
-74
-75
58
56
54
52
1/1/08
1/1/09
1/1/10
1/1/11
1/1/12
1/1/13
Date
www.wwbwc.org
Walla Walla Basin Watershed Council

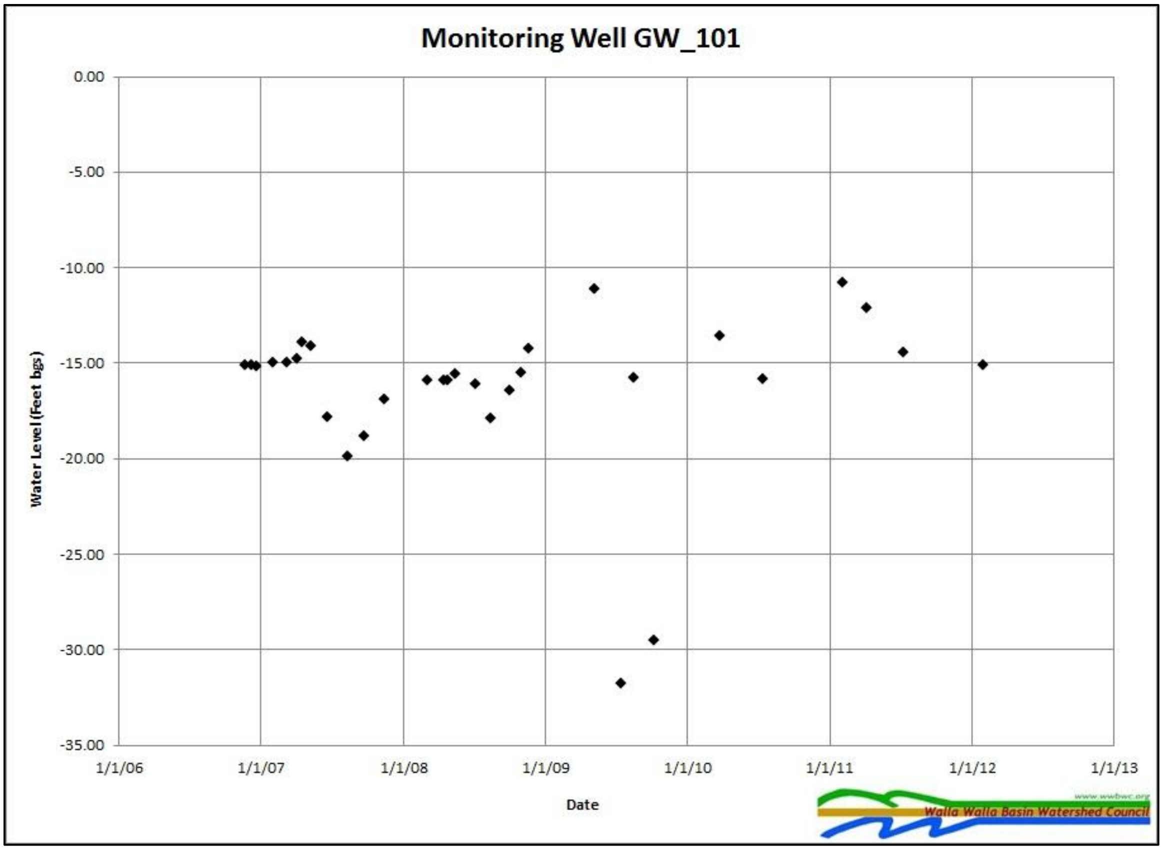

Monitoring Well GW_96
Water Level (ft bgs) [Green Line]
Water Temperature (F) [Blue Line]
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
70
65
60
55
50
45
1/1/08
1/1/09
1/1/10
1/1/11
1/1/12
1/1/13
Date
www.wwbwc.org
Walla Walla Basin Watershed Council

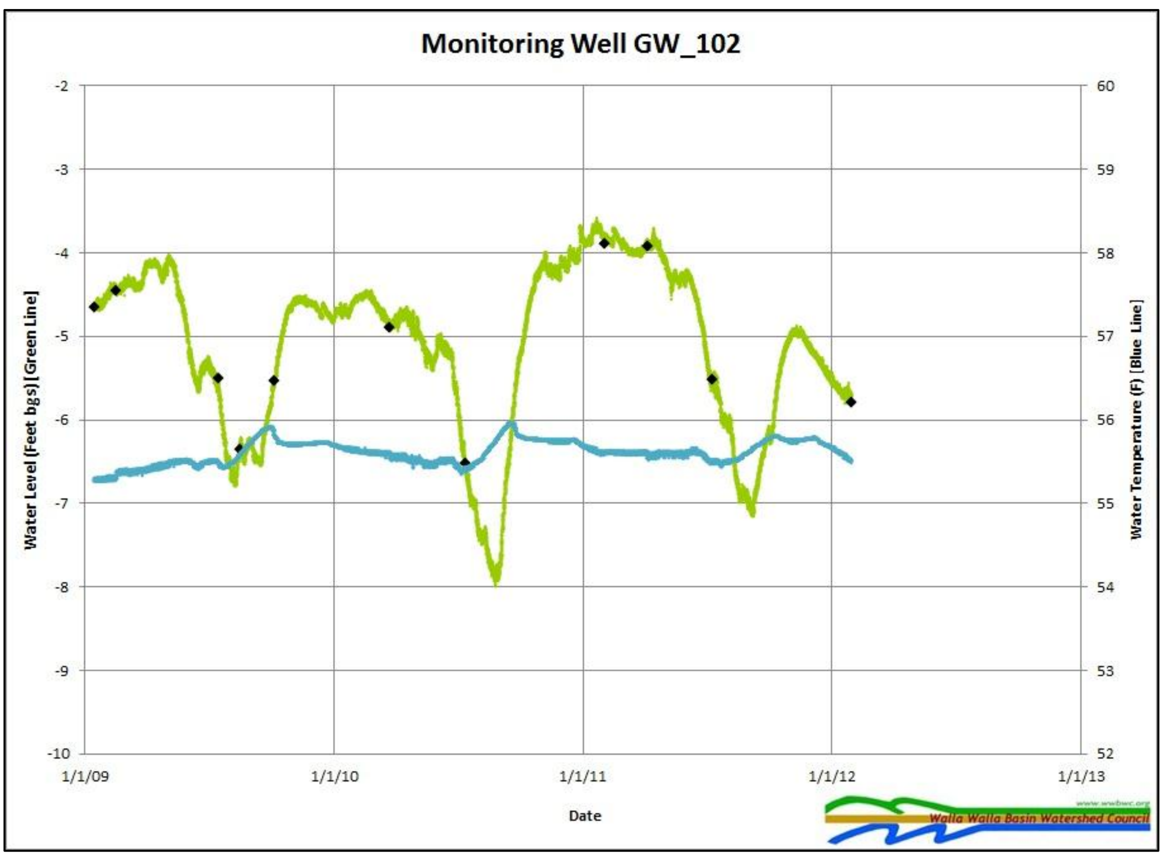


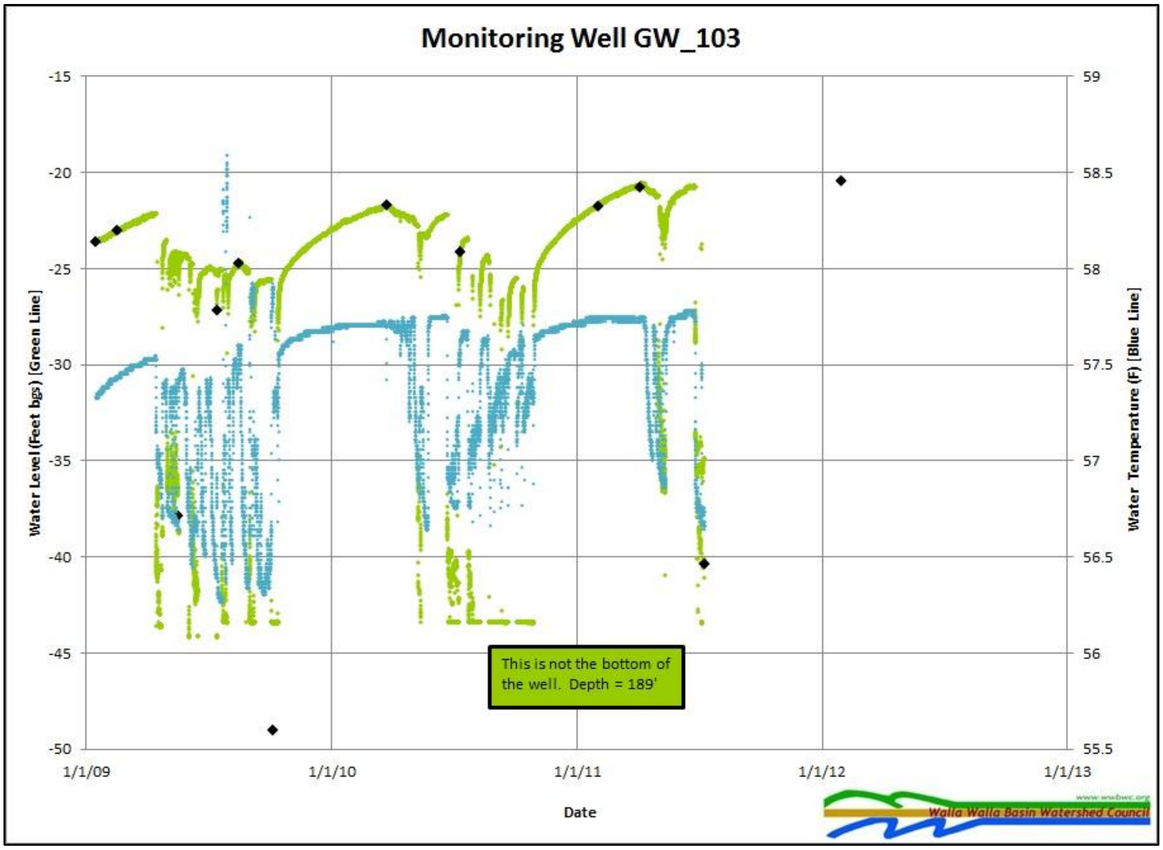
Monitoring Well GW_98
Well is often dry. Check data table for dry measurements.
Water Level (Feet bgs)
-20
-20.5
-21
-21.5
-22
-22.5
-23
-23.5
1/1/09
7/2/09
1/1/10
7/2/10
1/1/11
7/3/11
1/1/12
7/2/12
1/1/13
Date
Walla Walla Basin Watershed Council

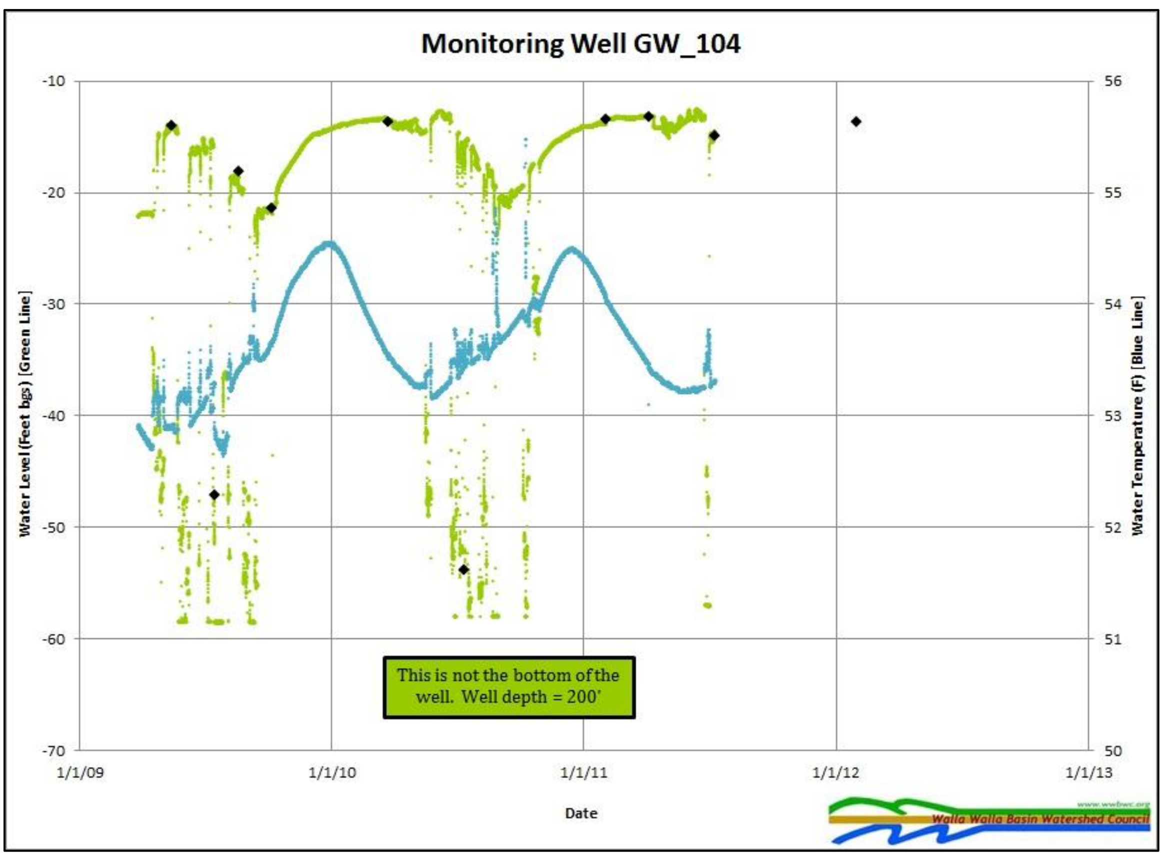


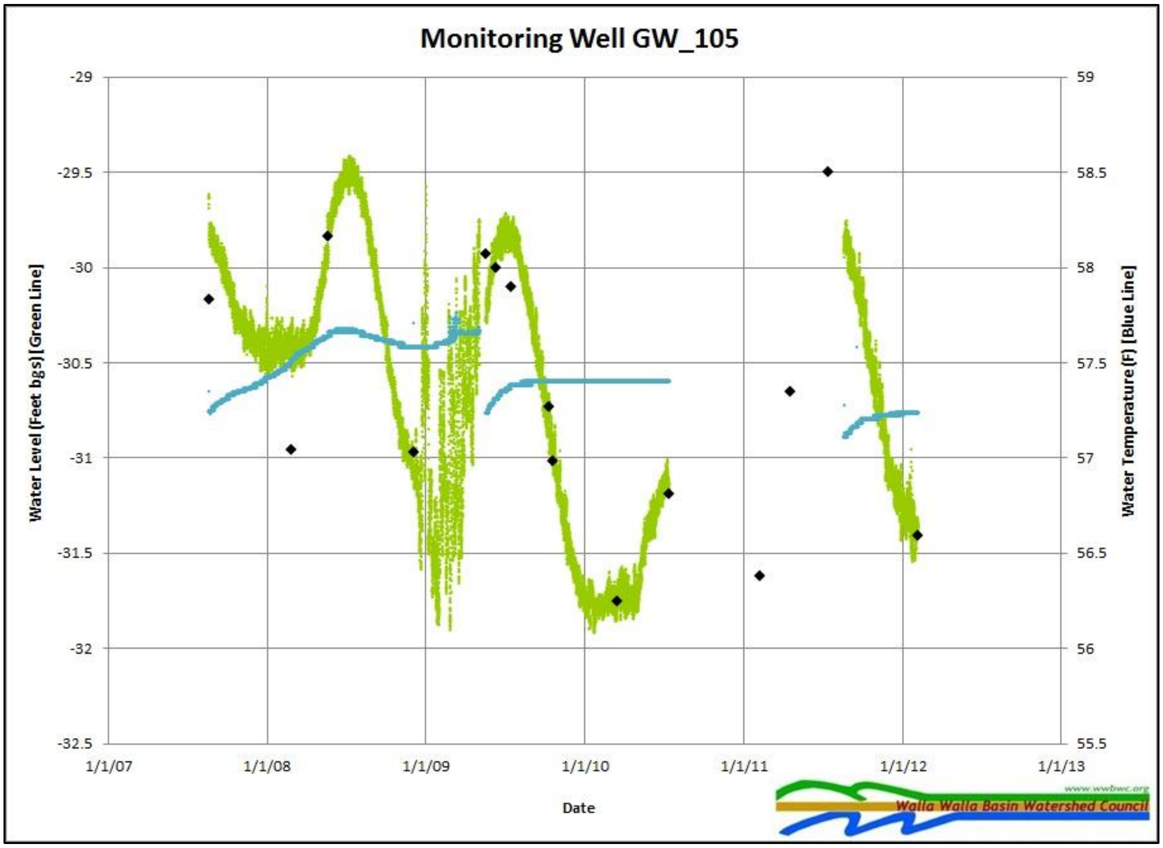
Monitoring Well GW_100
Water Level (Feet bgs)
0.00
-5.00
-10.00
-15.00
-20.00
-25.00
-30.00
-35.00
-40.00
-45.00
1/1/06
1/1/07
1/1/08
1/1/09
1/1/10
1/1/11
1/1/12
1/1/13
Date
Walla Walla Basin Watershed Council


Monitoring Well GW_101
Water Level (Feet bgs)
0.00
-5.00
-10.00
-15.00
-20.00
-25.00
-30.00
-35.00
1/1/06
1/1/07
1/1/08
1/1/09
1/1/10
1/1/11
1/1/12
1/1/13
Date
Walla Walla Basin Watershed Council


Monitoring Well GW_102
Water Level (Feet bgs) [Green Line]
Water Temperature (F) [Blue Line]
-2
-3
-4
-5
-6
-7
-8
-9
-10
60
59
58
57
56
55
54
53
52
1/1/09
1/1/10
1/1/11
1/1/12
1/1/13
Date
Walla Walla Basin Watershed Council


Monitoring Well GW_103
Water Level (Feet bgs) [Green Line]
Water Temperature (F) [Blue Line]
-15
-20
-25
-30
-35
-40
-45
-50
59
58.5
58
57.5
57
56.5
56
55.5
1/1/09
1/1/10
1/1/11
1/1/12
1/1/13
Date
This is not the bottom of the well. Depth = 189'
Walla Walla Basin Watershed Council


Monitoring Well GW_104
Water Level (Feet bgs) [Green Line]
Water Temperature (F) [Blue Line]
-10
-20
-30
-40
-50
-60
-70
56
55
54
53
52
51
50
1/1/09
1/1/10
1/1/11
1/1/12
1/1/13
Date
This is not the bottom of the well. Well depth = 200'
Walla Walla Basin Watershed Council



Monitoring Well GW_105
Water Level (Feet bgs) [Green Line]
Water Temperature (F) [Blue Line]
-29
-29.5
-30
-30.5
-31
-31.5
-32
-32.5
59
58.5
58
57.5
57
56.5
56
55.5
1/1/07
1/1/08
1/1/09
1/1/10
1/1/11
1/1/12
1/1/13
Date
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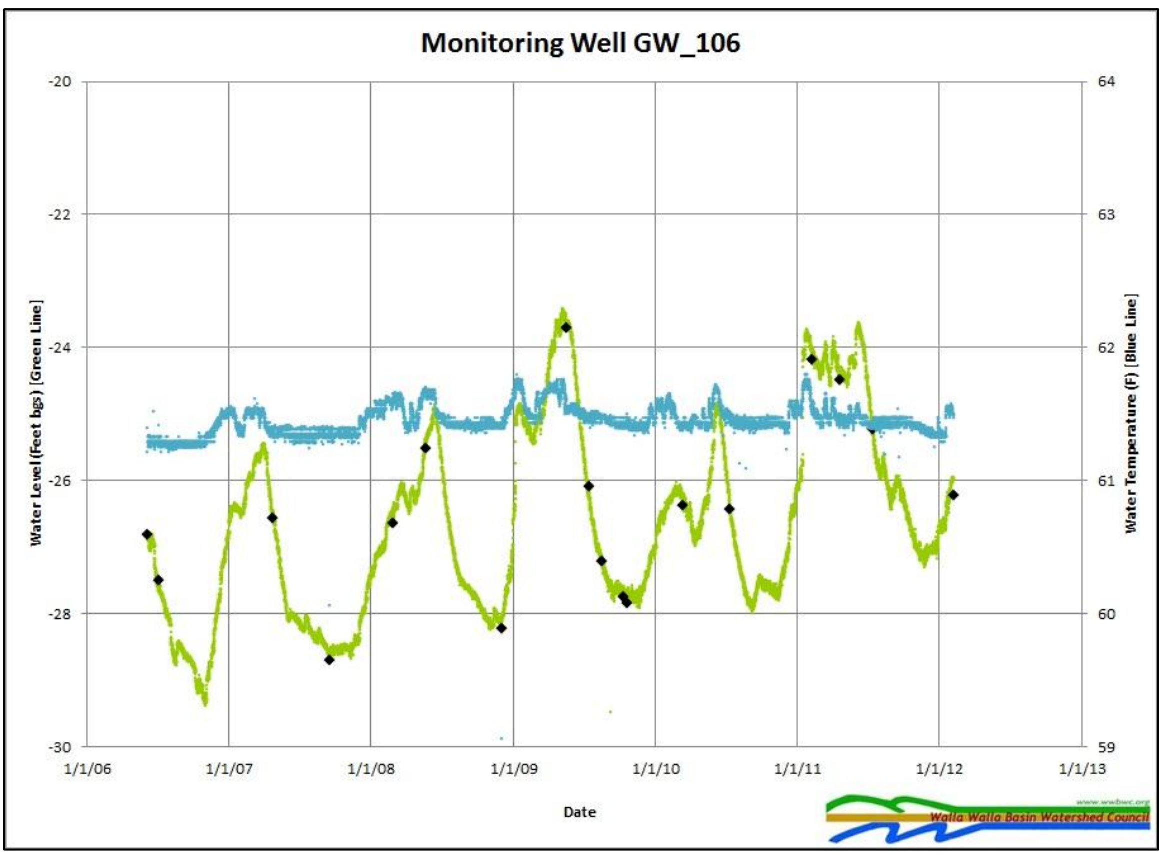

Monitoring Well GW_106
Water Level (Feet bgs) [Green Line]
Water Temperature (F) [Blue Line]
-20
-22
-24
-26
-28
-30
64
63
62
61
60
59
1/1/06
1/1/07
1/1/08
1/1/09
1/1/10
1/1/11
1/1/12
1/1/13
Date
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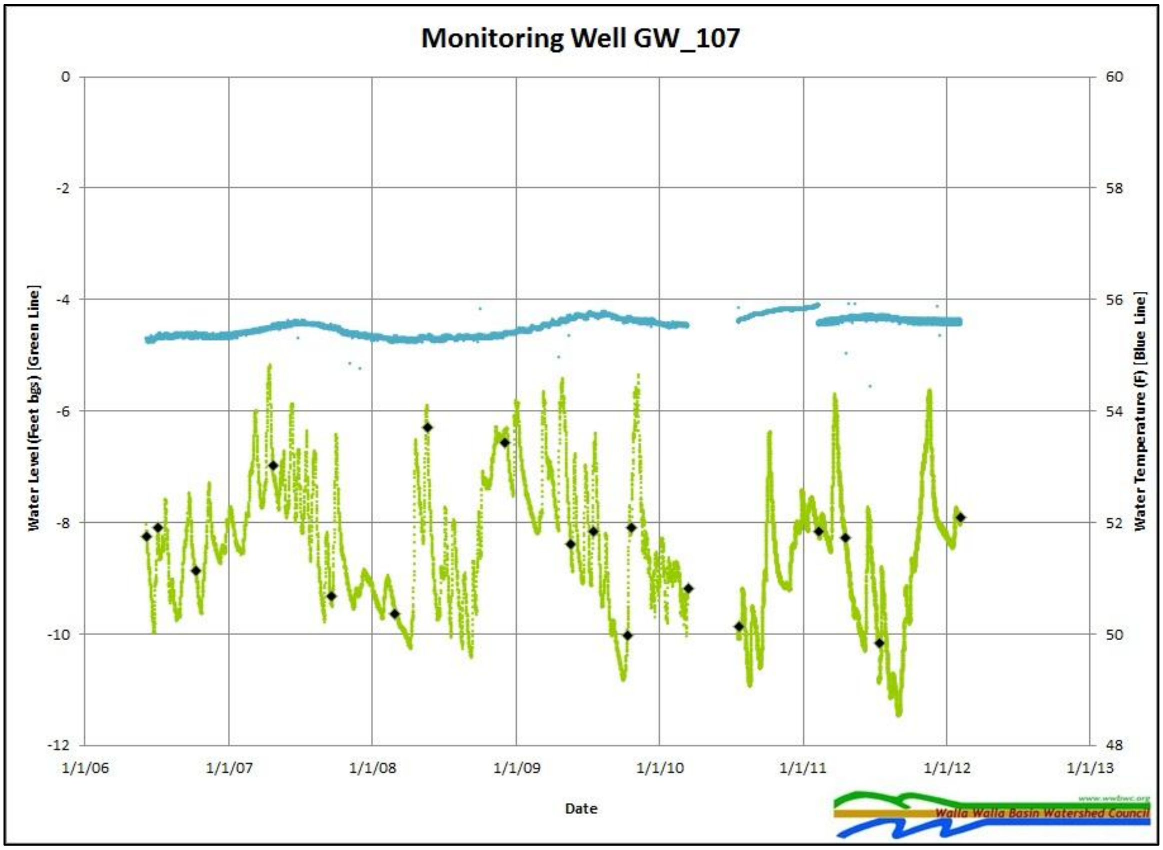
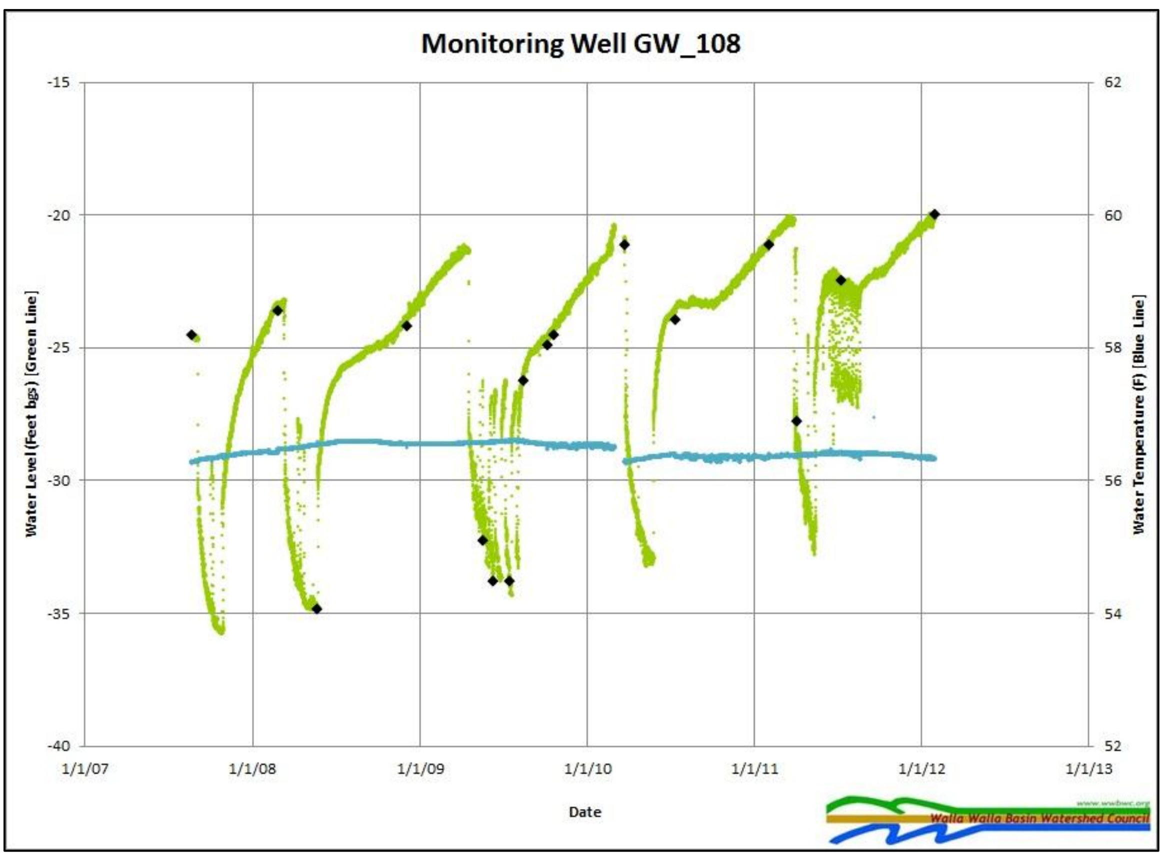
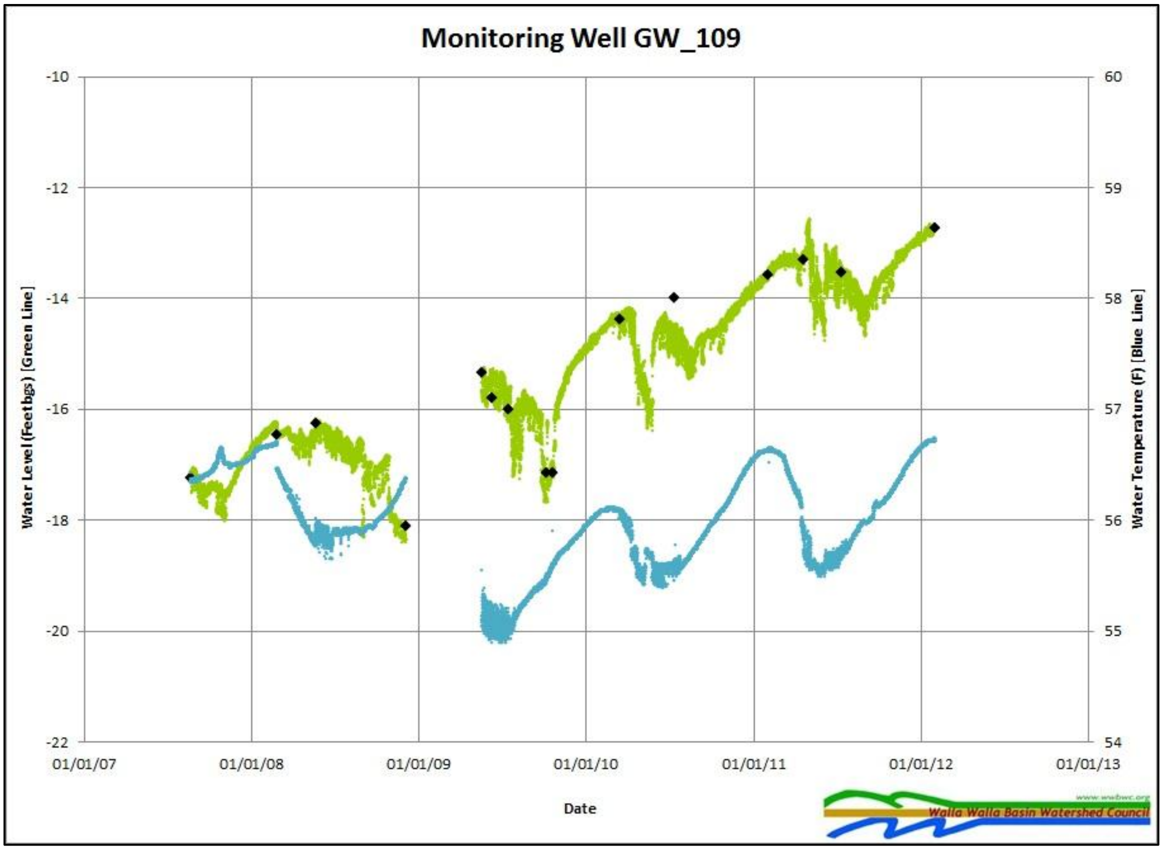
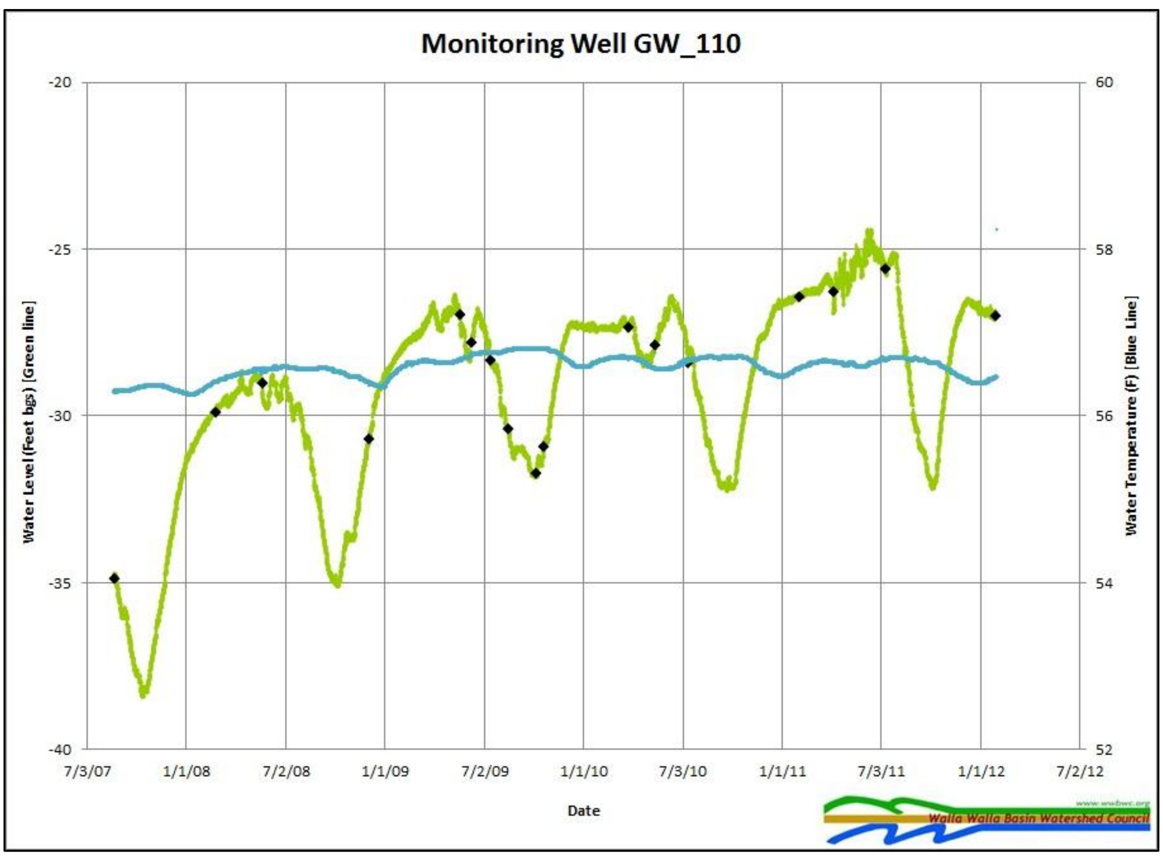
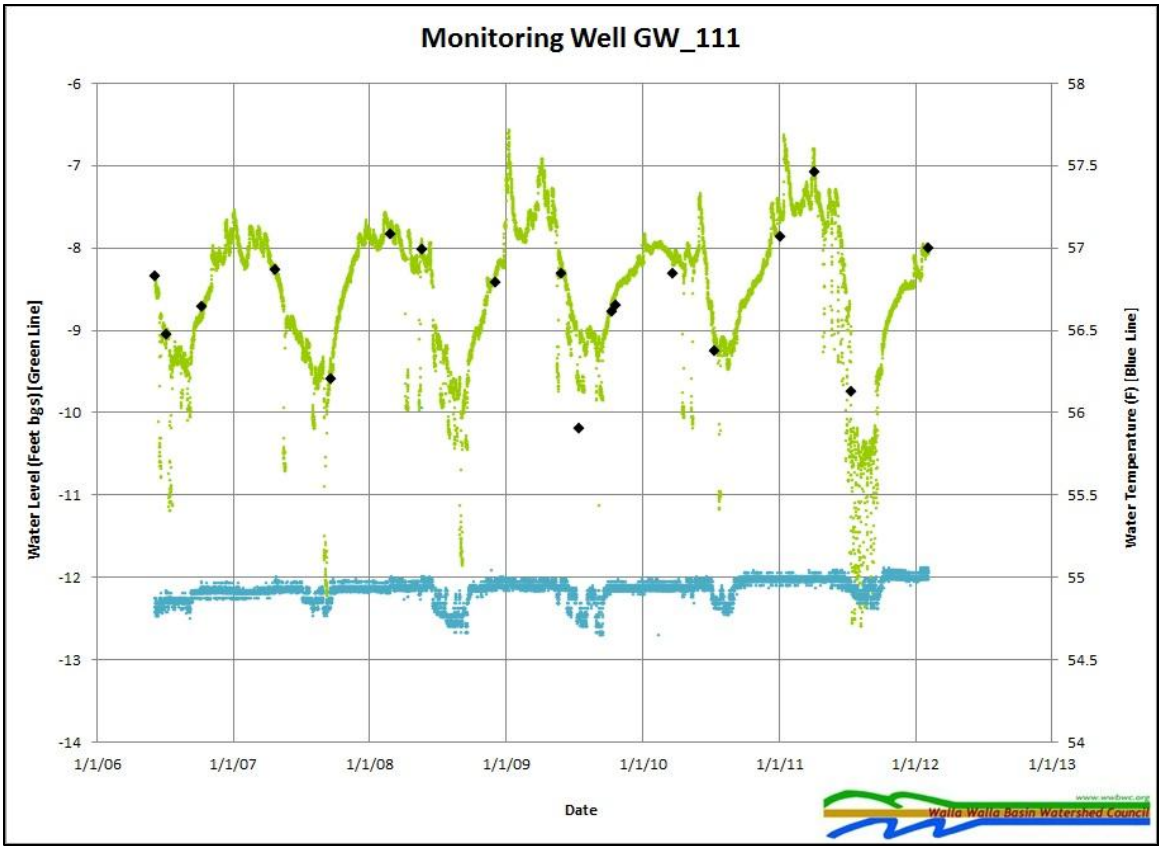

Monitoring Well GW_107
Water Level (Feet bgs) [Green Line]
Water Temperature (F) [Blue Line]
Date
0
-2
-4
-6
-8
-10
-12
60
58
56
54
52
50
48
1/1/06
1/1/07
1/1/08
1/1/09
1/1/10
1/1/11
1/1/12
1/1/13
Walla Walla Basin Watershed Council


Monitoring Well GW_108
Water Level (Feet bgs) [Green Line]
Water Temperature (F) [Blue Line]
Date
-15
-20
-25
-30
-35
-40
62
60
58
56
54
52
1/1/07
1/1/08
1/1/09
1/1/10
1/1/11
1/1/12
1/1/13
Walla Walla Basin Watershed Council


Monitoring Well GW_109
Water Level (Feetbgs) [Green Line]
Water Temperature (F) [Blue Line]
-10
-12
-14
-16
-18
-20
-22
60
59
58
57
56
55
54
01/01/07
01/01/08
01/01/09
01/01/10
01/01/11
01/01/12
01/01/13
Date
Walla Walla Basin Watershed Council


Monitoring Well GW_110
Water Level (Feet bgs) [Green line]
Water Temperature (F) [Blue Line]
-20
-25
-30
-35
-40
60
58
56
54
52
7/3/07
1/1/08
7/2/08
1/1/09
7/2/09
1/1/10
7/3/10
1/1/11
7/3/11
1/1/12
7/2/12
Date
Walla Walla Basin Watershed Council


Monitoring Well GW_111
Water Level (Feet bgs) [Green Line]
Water Temperature (F) [Blue Line]
-6
-7
-8
-9
-10
-11
-12
-13
-14
58
57.5
57
56.5
56
55.5
55
54.5
54
1/1/06
1/1/07
1/1/08
1/1/09
1/1/10
1/1/11
1/1/12
1/1/13
Date
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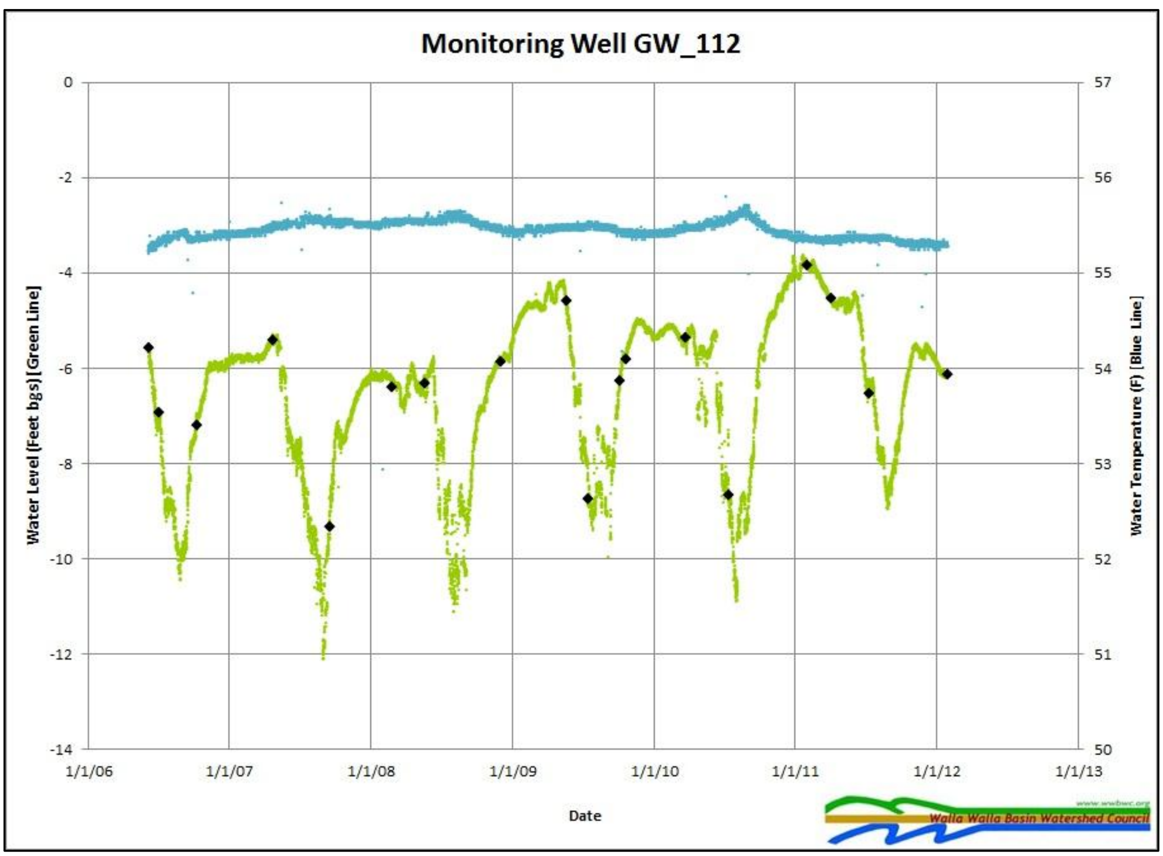
Monitoring Well GW_112
Water Level (Feet bgs) [Green Line]
Water Temperature (F) [Blue Line]
0
-2
-4
-6
-8
-10
-12
-14
57
56
55
54
53
52
51
50
1/1/06
1/1/07
1/1/08
1/1/09
1/1/10
1/1/11
1/1/12
1/1/13
Date
www.wwbwc.org
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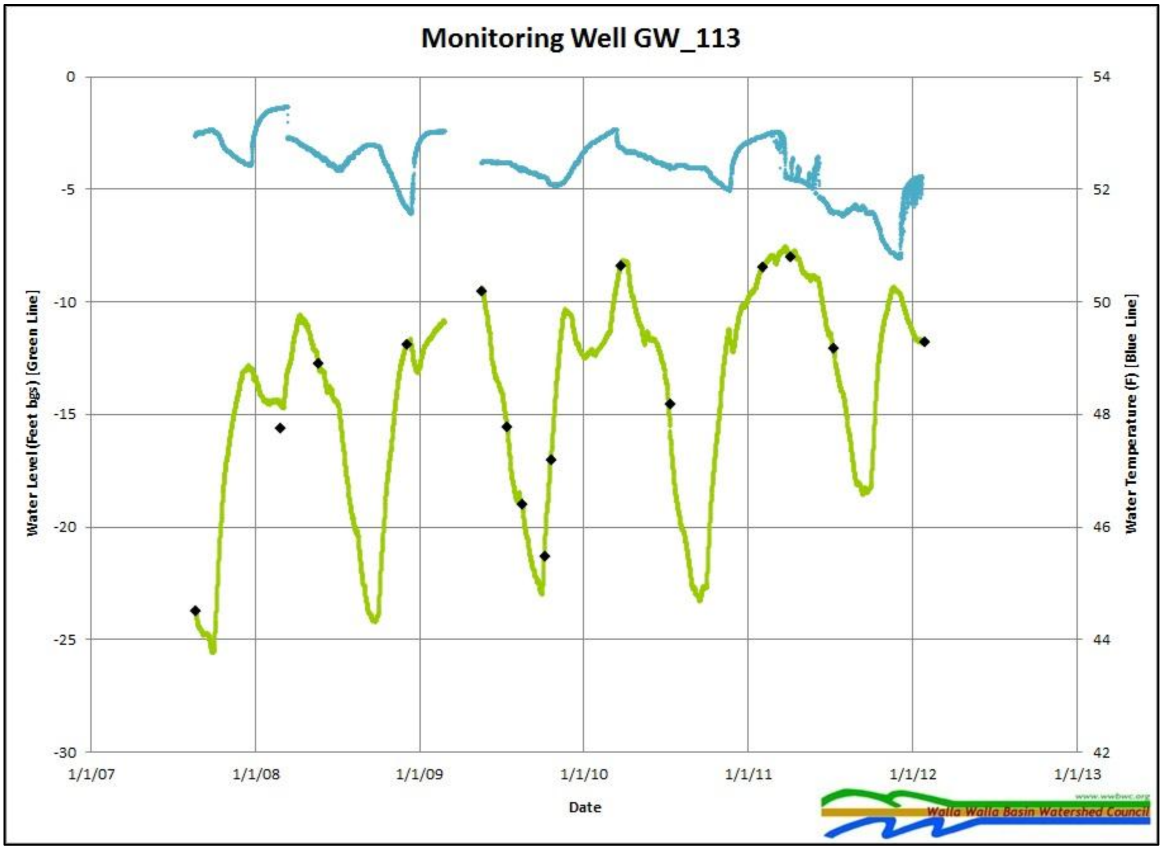
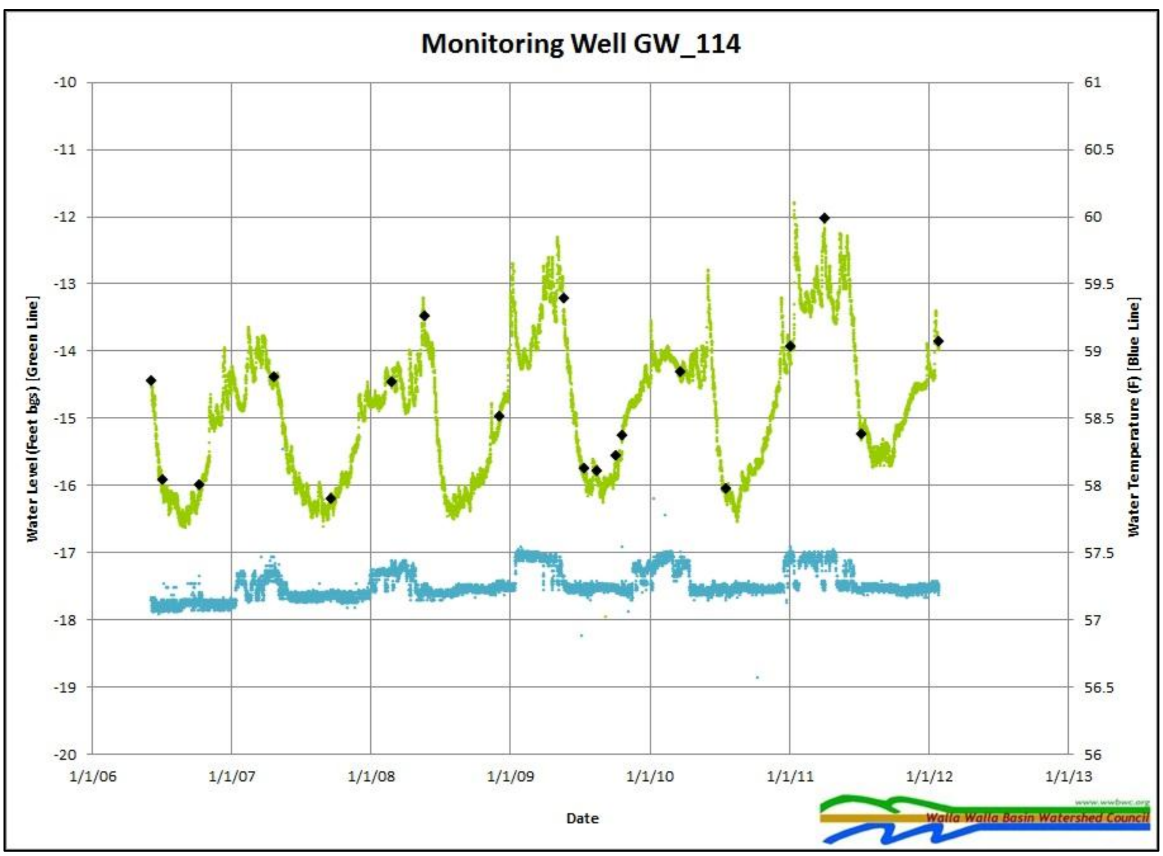


Monitoring Well GW_113
Water Level (Feet bgs) [Green Line]
Water Temperature (F) [Blue Line]
Date
0
-5
-10
-15
-20
-25
-30
54
52
50
48
46
44
42
1/1/07
1/1/08
1/1/09
1/1/10
1/1/11
1/1/12
1/1/13
Walla Walla Basin Watershed Council



Monitoring Well GW_114
Water Level (Feet bgs) [Green Line]
Water Temperature (F) [Blue Line]
Date
-10
-11
-12
-13
-14
-15
-16
-17
-18
-19
-20
61
60.5
60
59.5
59
58.5
58
57.5
57
56.5
56
1/1/06
1/1/07
1/1/08
1/1/09
1/1/10
1/1/11
1/1/12
1/1/13
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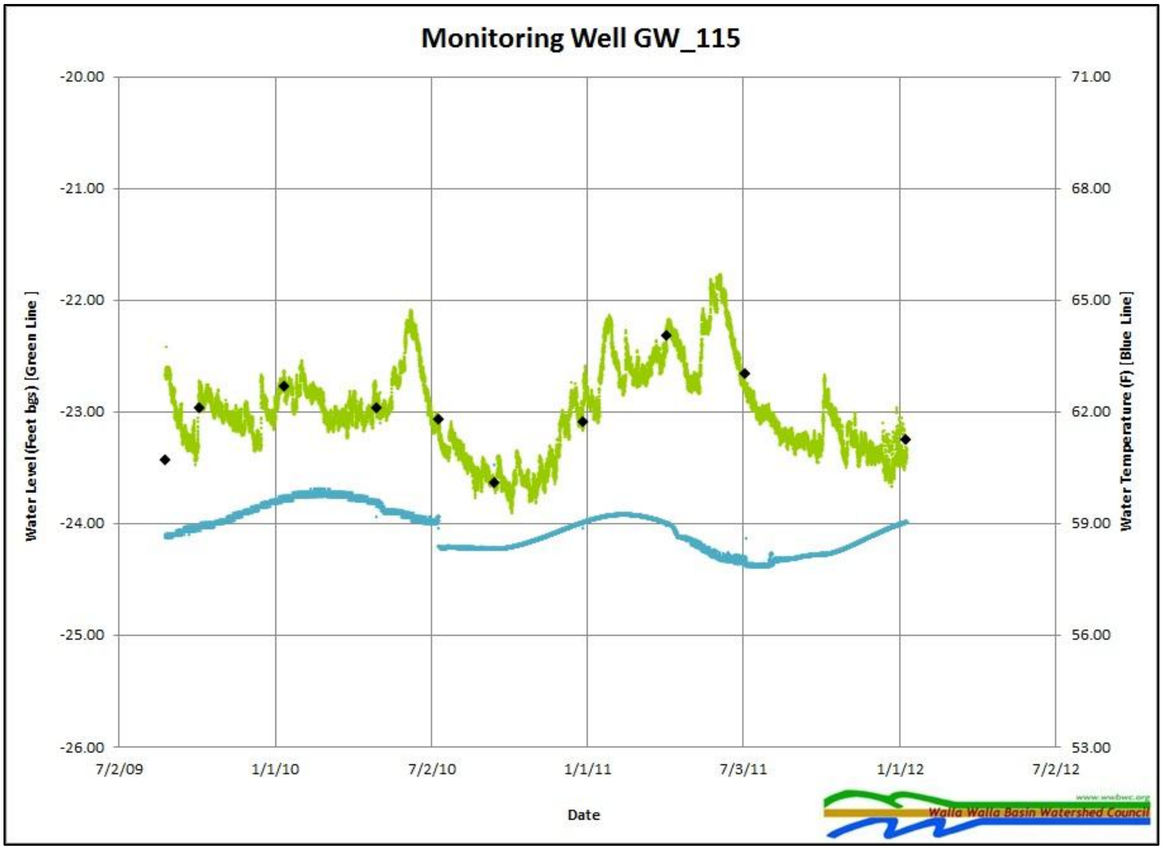
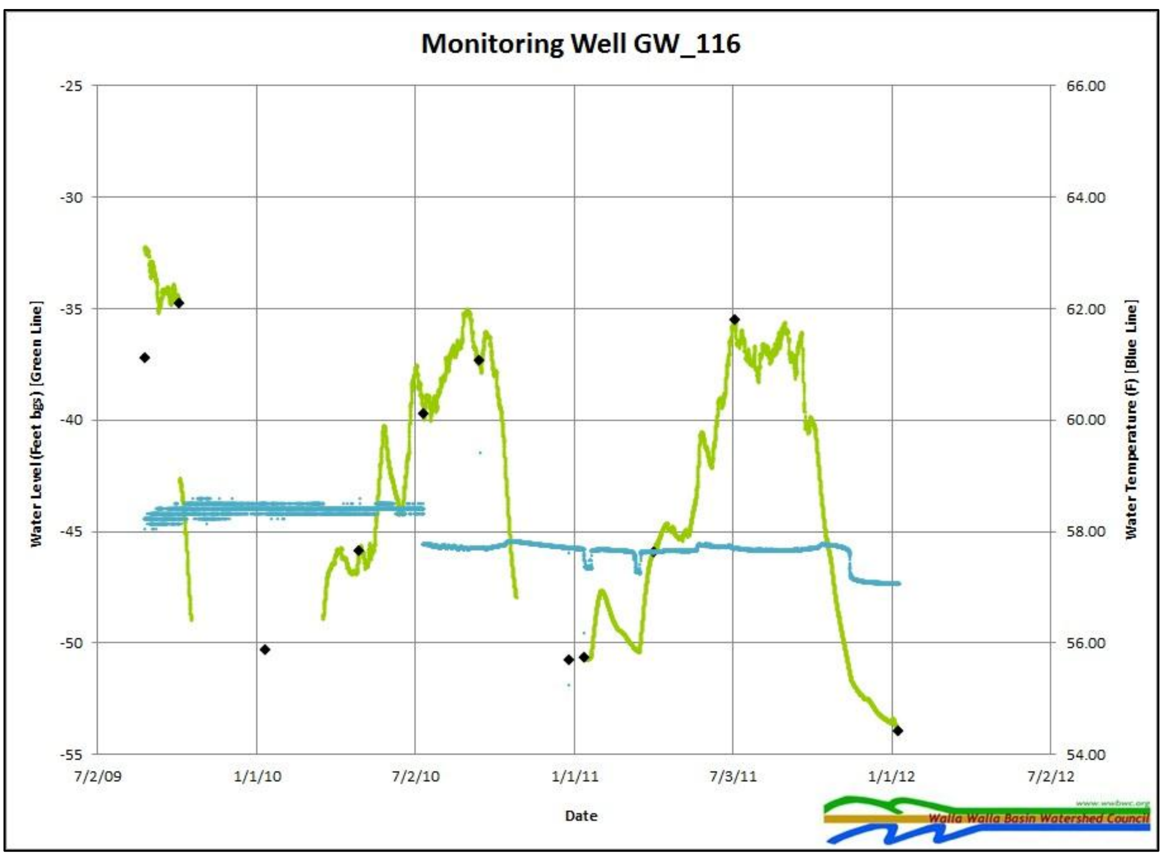
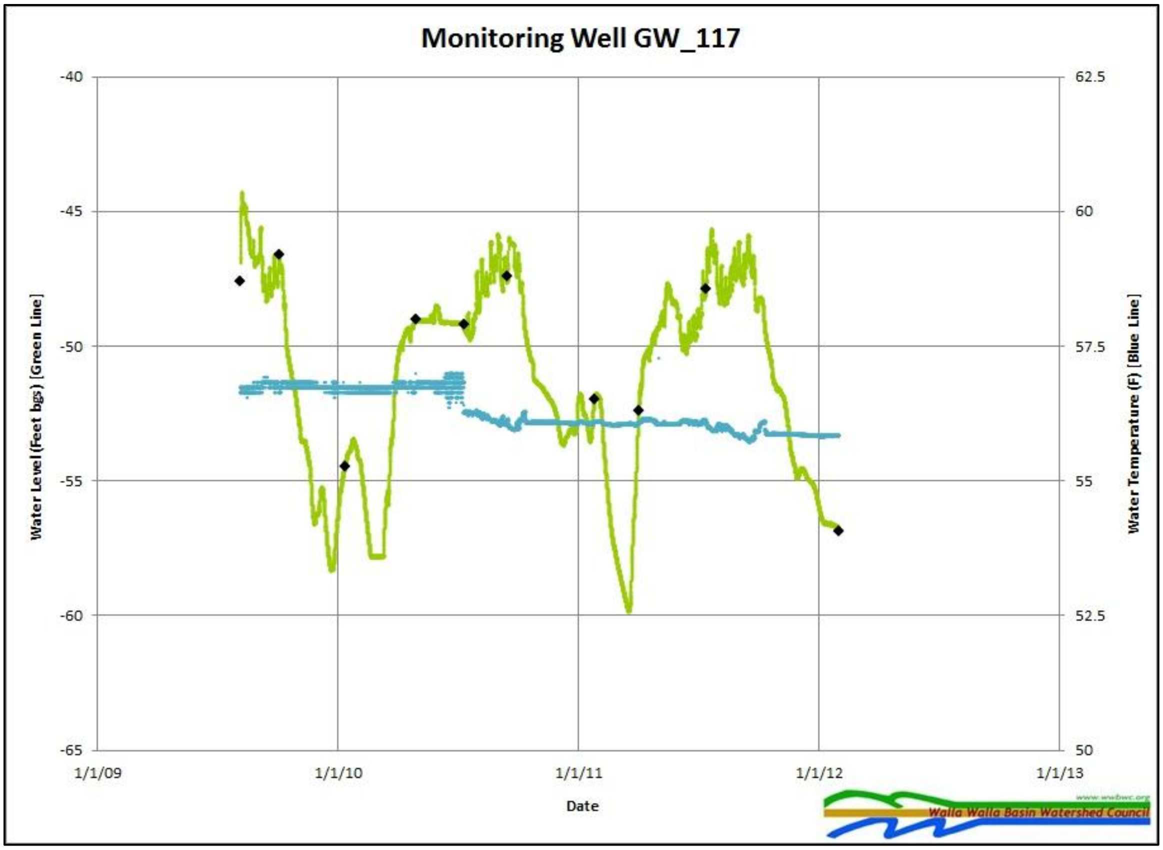

Monitoring Well GW_115
-20.00
-21.00
-22.00
-23.00
-24.00
-25.00
-26.00
71.00
68.00
65.00
62.00
59.00
56.00
53.00
7/2/09
1/1/10
7/2/10
1/1/11
7/3/11
1/1/12
7/2/12
Water Level (Feet bgs) [Green Line]
Water Temperature (F) [Blue Line]
Date
Walla Walla Basin Watershed Council


Monitoring Well GW_116
-25
-30
-35
-40
-45
-50
-55
66.00
64.00
62.00
60.00
58.00
56.00
54.00
7/2/09
1/1/10
7/2/10
1/1/11
7/3/11
1/1/12
7/2/12
Water Level (Feet bgs) [Green Line]
Water Temperature (F) [Blue Line]
Date
Walla Walla Basin Watershed Council


Monitoring Well GW_117
Water Level (Feet bgs) [Green Line]
Water Temperature (F) [Blue Line]
-40
-45
-50
-55
-60
-65
62.5
60
57.5
55
52.5
50
1/1/09
1/1/10
1/1/11
1/1/12
1/1/13
Date
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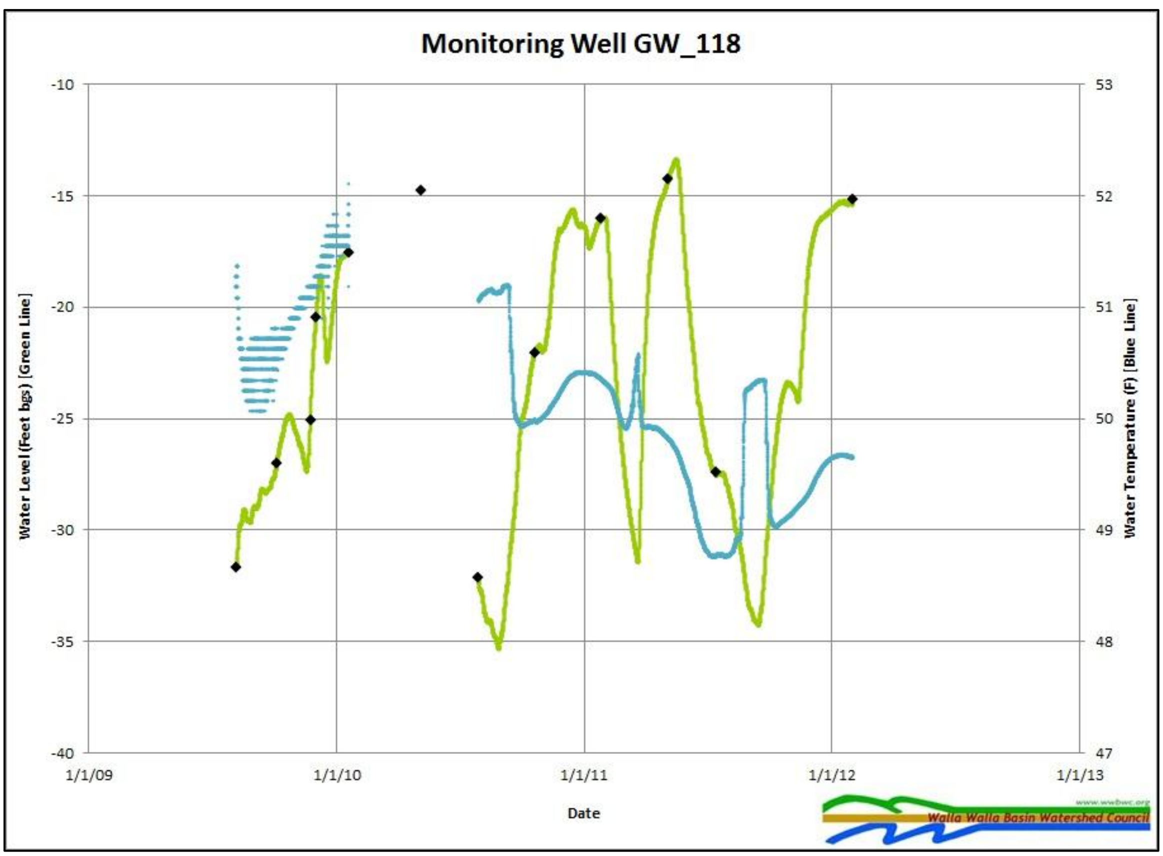
Monitoring Well GW_118
Water Level (Feet bgs) [Green Line]
Water Temperature (F) [Blue Line]
-10
-15
-20
-25
-30
-35
-40
53
52
51
50
49
48
47
1/1/09
1/1/10
1/1/11
1/1/12
1/1/13
Date
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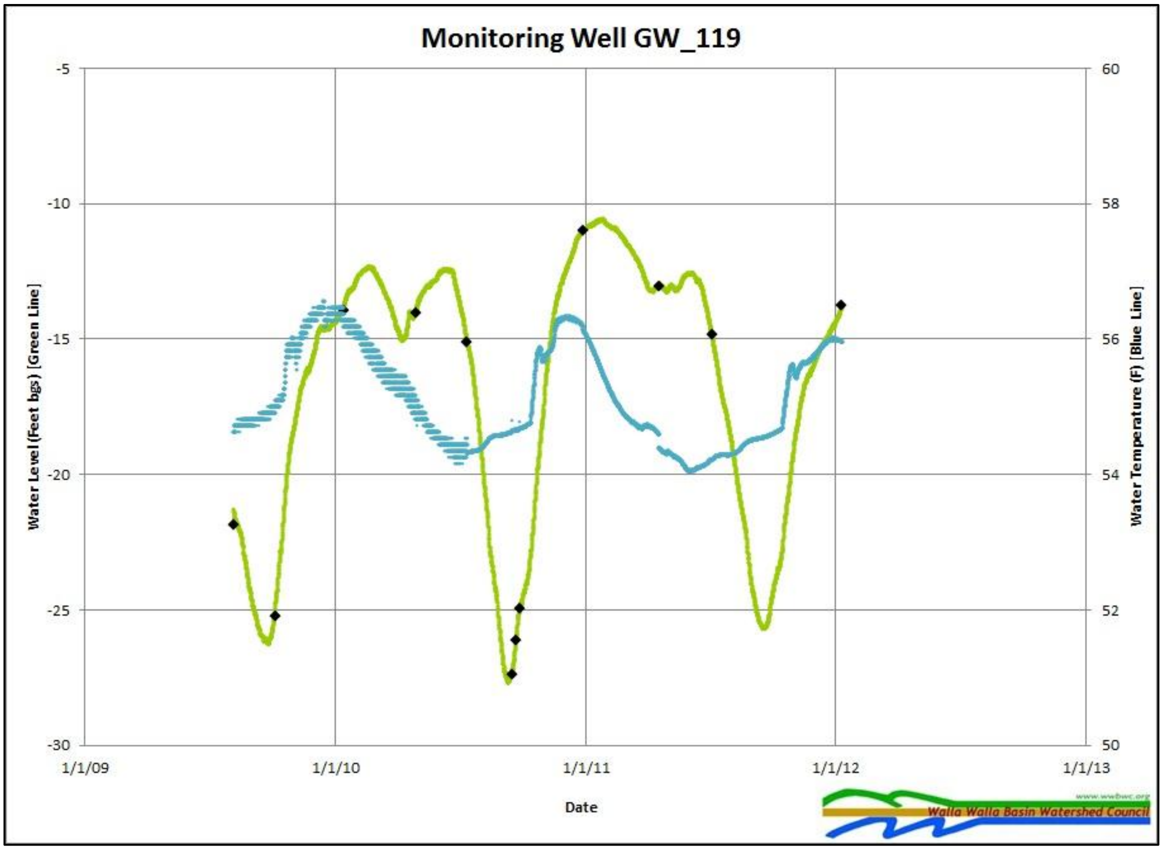
Monitoring Well GW_119
Water Level (Feet bgs) [Green Line]
Water Temperature (F) [Blue Line]
Date
-5
-10
-15
-20
-25
-30
60
58
56
54
52
50
1/1/09
1/1/10
1/1/11
1/1/12
1/1/13
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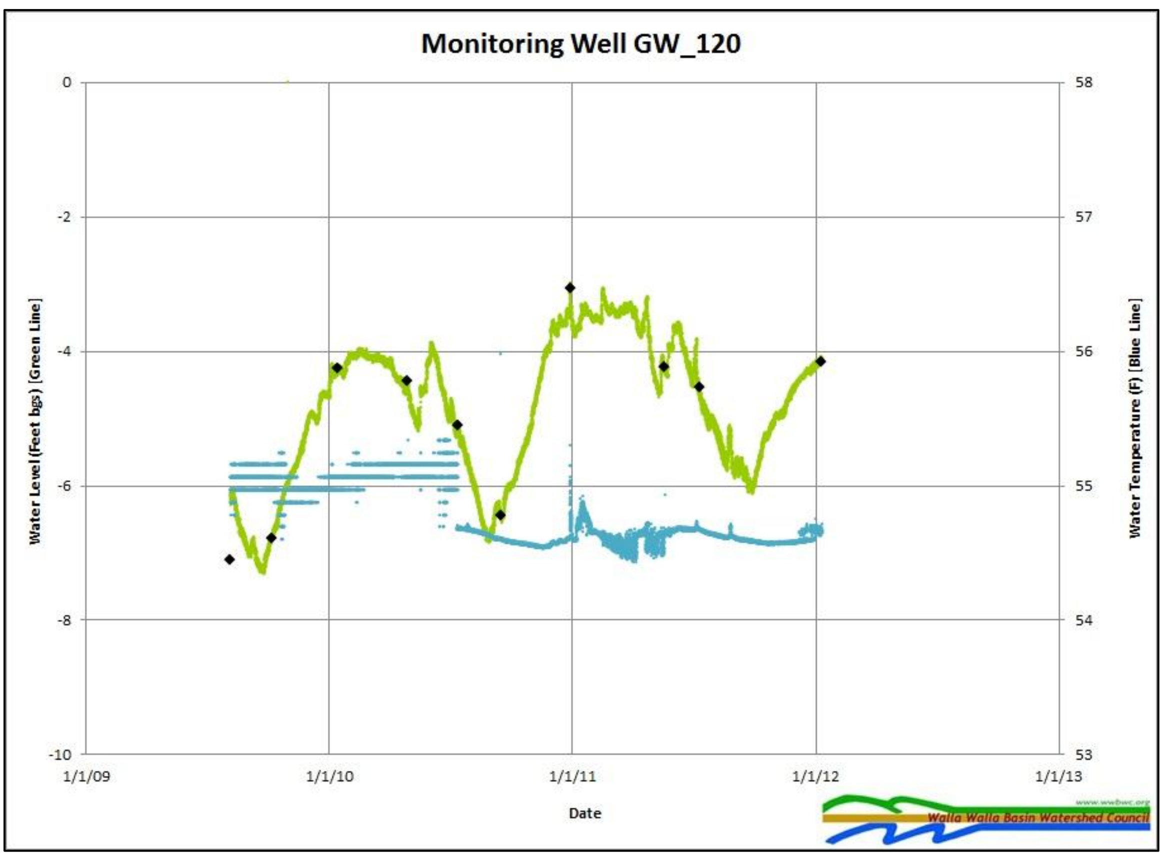
Monitoring Well GW_120
Water Level (Feet bgs) [Green Line]
Water Temperature (F) [Blue Line]
Date
0
-2
-4
-6
-8
-10
58
57
56
55
54
53
1/1/09
1/1/10
1/1/11
1/1/12
1/1/13
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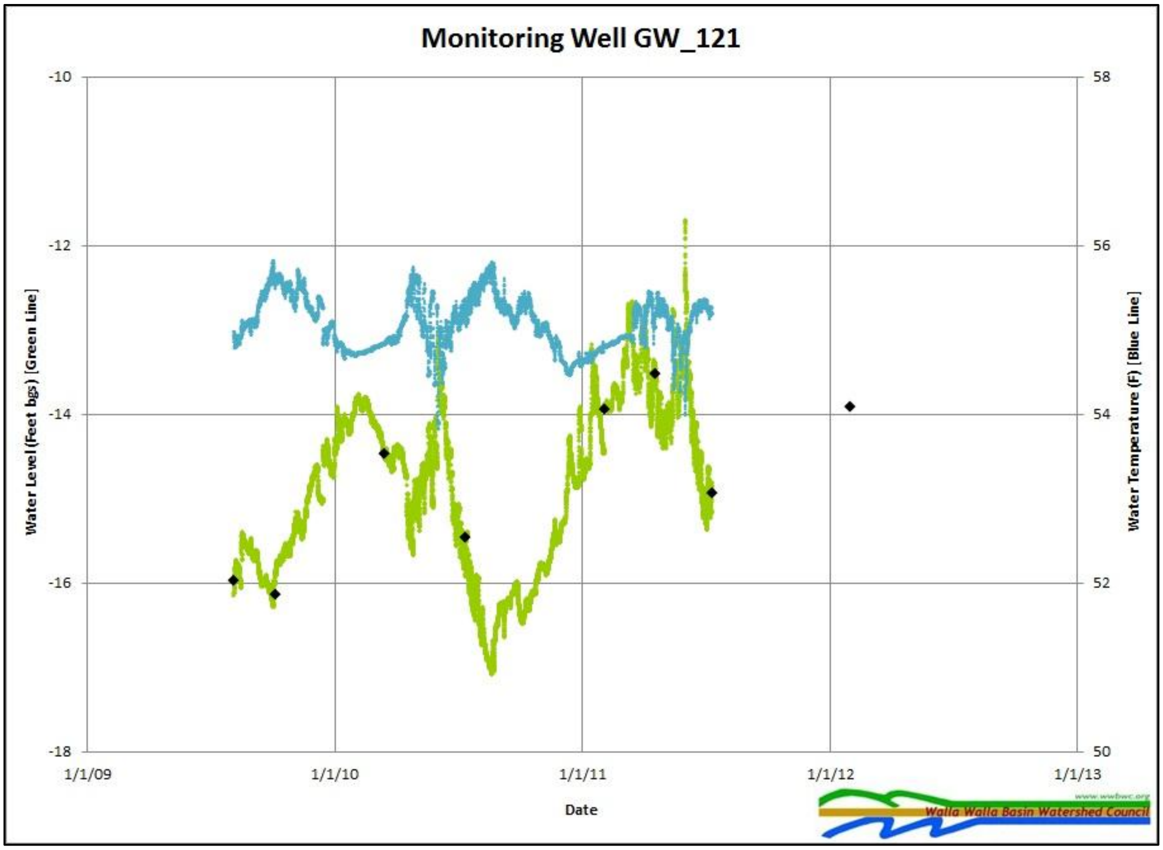
Monitoring Well GW_121
-10
-12
-14
-16
-18
58
56
54
52
50
1/1/09
1/1/10
1/1/11
1/1/12
1/1/13
Date
Water Level (Feet bgs) [Green Line]
Water Temperature (F) [Blue Line]
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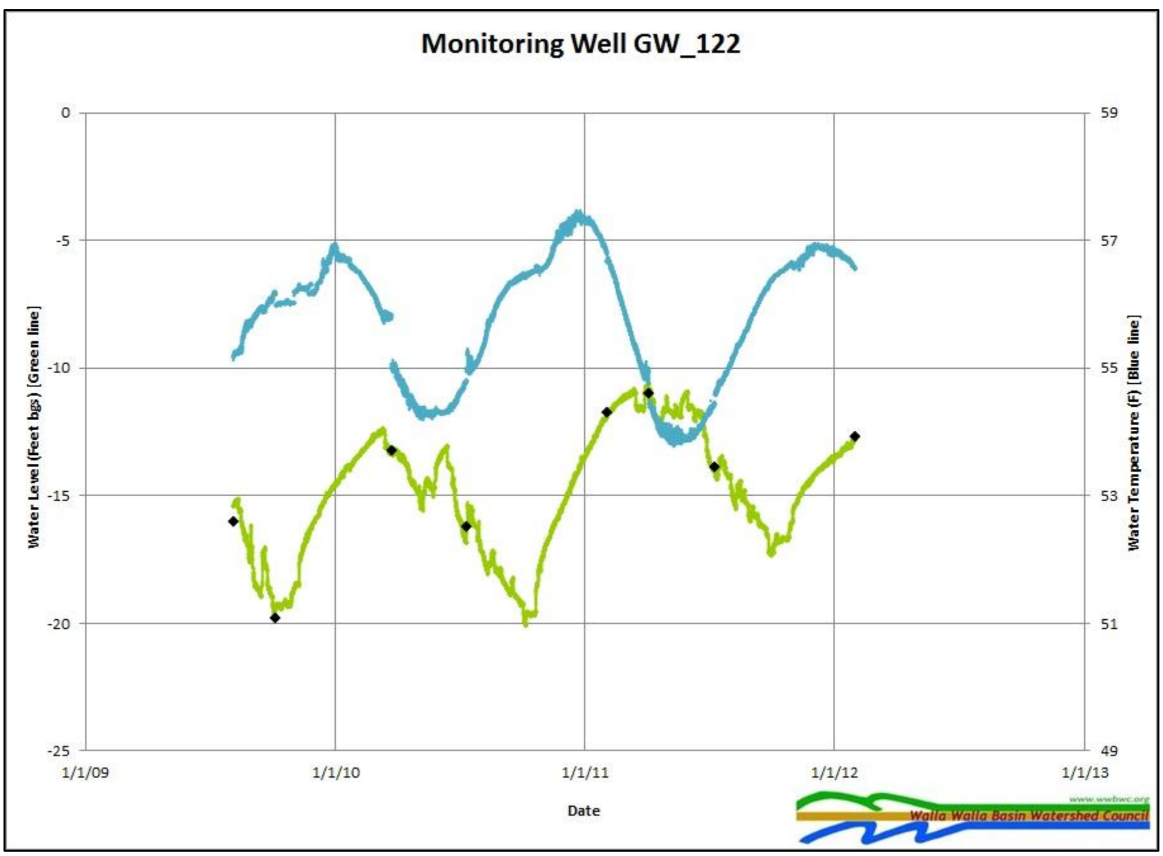
Monitoring Well GW_122
0
-5
-10
-15
-20
-25
59
57
55
53
51
49
1/1/09
1/1/10
1/1/11
1/1/12
1/1/13
Date
Water Level (Feet bgs) [Green line]
Water Temperature (F) [Blue line]
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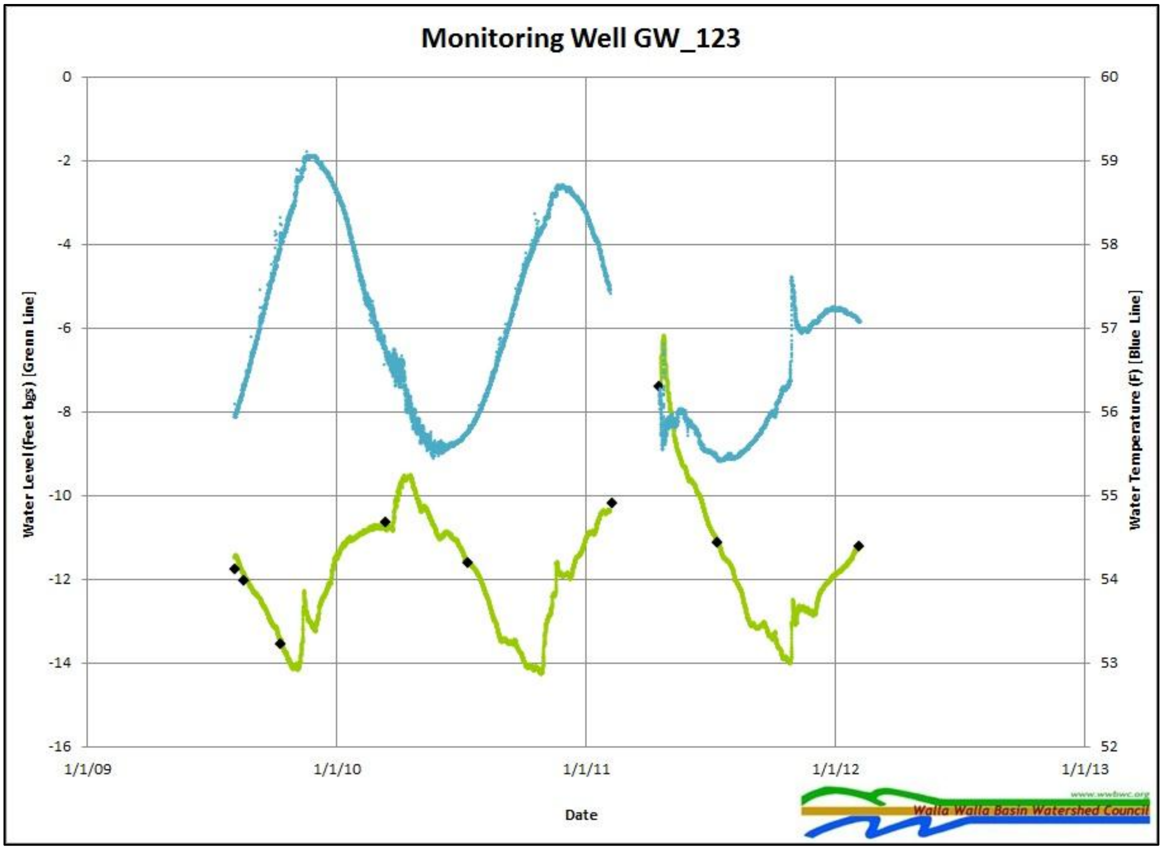
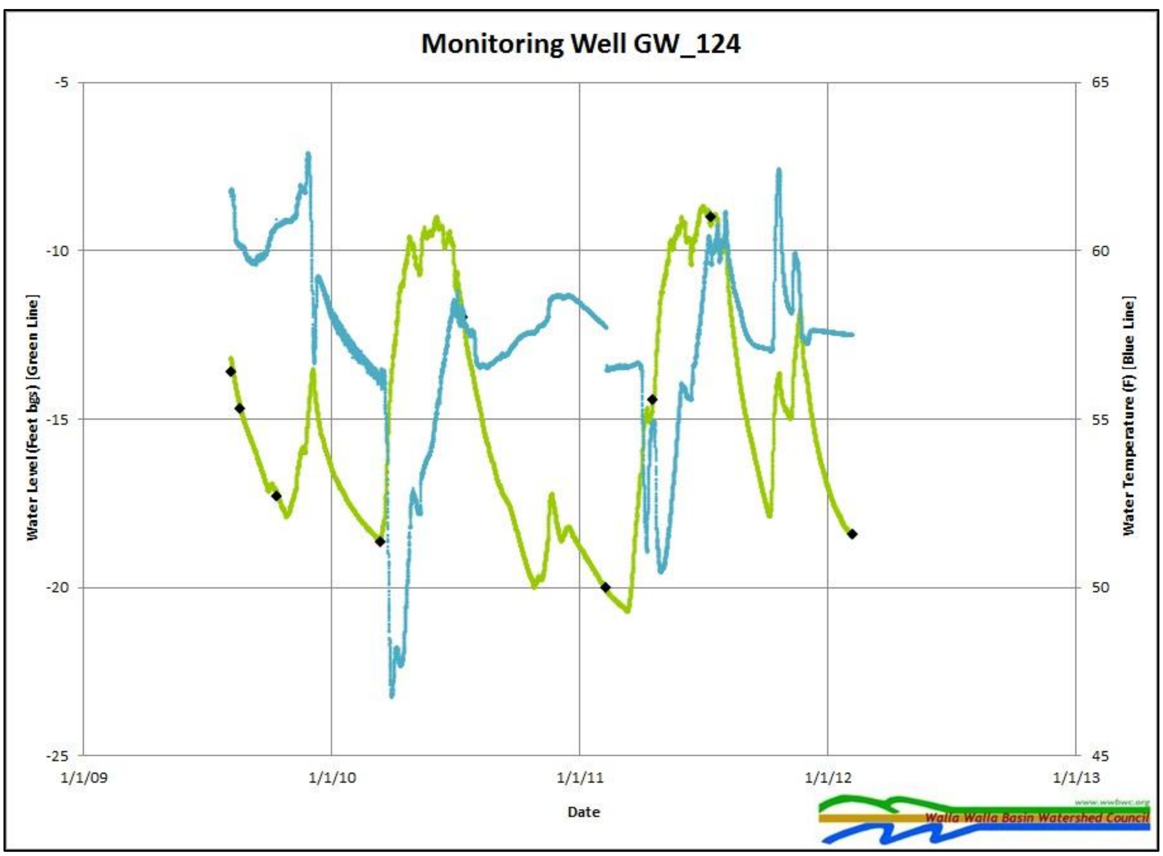

Monitoring Well GW_123
Water Level (Feet bgs) [Grenn Line]
Water Temperature (F) [Blue Line]
0
-2
-4
-6
-8
-10
-12
-14
-16
60
59
58
57
56
55
54
53
52
1/1/09
1/1/10
1/1/11
1/1/12
1/1/13
Date
www.wwbwc.org
Walla Walla Basin Watershed Council


Monitoring Well GW_124
Water Level (Feet bgs) [Green Line]
Water Temperature (F) [Blue Line]
-5
-10
-15
-20
-25
65
60
55
50
45
1/1/09
1/1/10
1/1/11
1/1/12
1/1/13
Date
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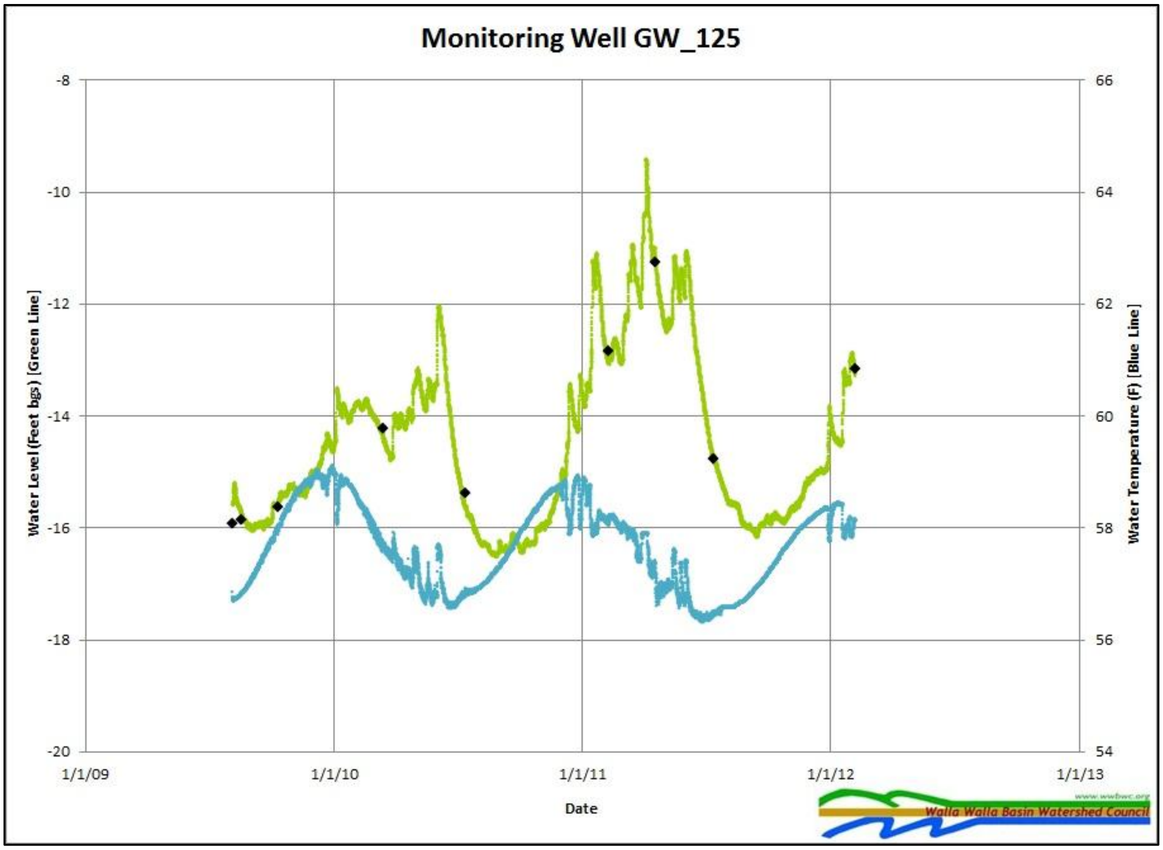
Monitoring Well GW_125
-8
-10
-12
-14
-16
-18
-20
66
64
62
60
58
56
54
1/1/09
1/1/10
1/1/11
1/1/12
1/1/13
Date
Water Level (Feet bgs) [Green Line]
Water Temperature (F) [Blue Line]
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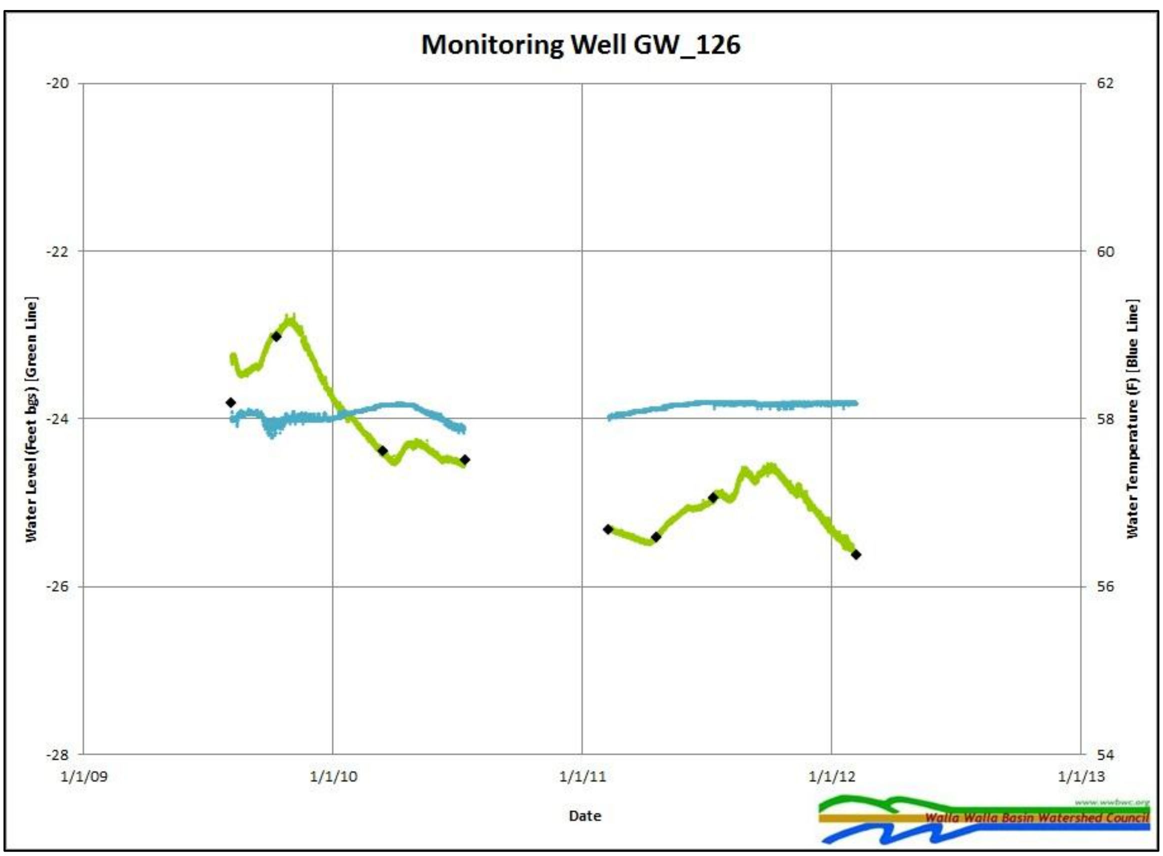
Monitoring Well GW_126
-20
-22
-24
-26
-28
62
60
58
56
54
1/1/09
1/1/10
1/1/11
1/1/12
1/1/13
Date
Water Level (Feet bgs) [Green Line]
Water Temperature (F) [Blue Line]
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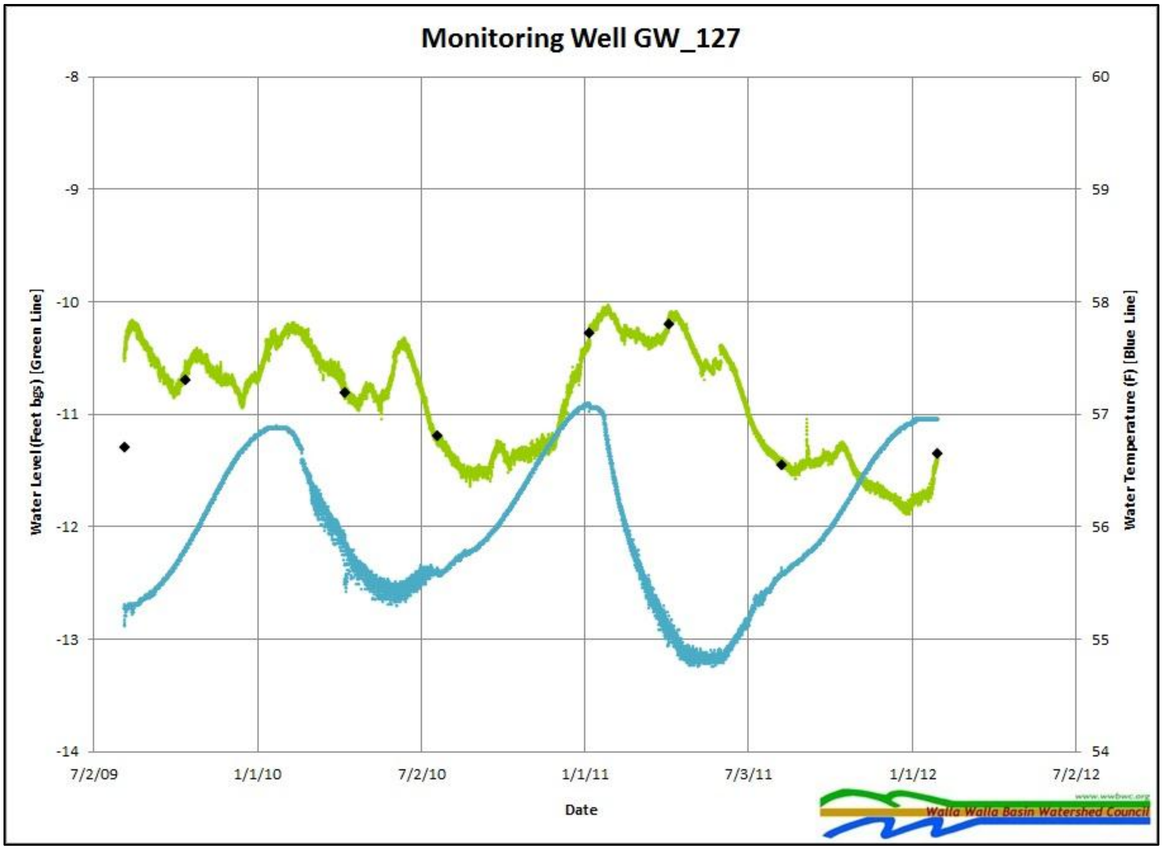
Monitoring Well GW_127
Water Level (Feet bgs) [Green Line]
Water Temperature (F) [Blue Line]
-8
-9
-10
-11
-12
-13
-14
60
59
58
57
56
55
54
7/2/09
1/1/10
7/2/10
1/1/11
7/3/11
1/1/12
7/2/12
Date
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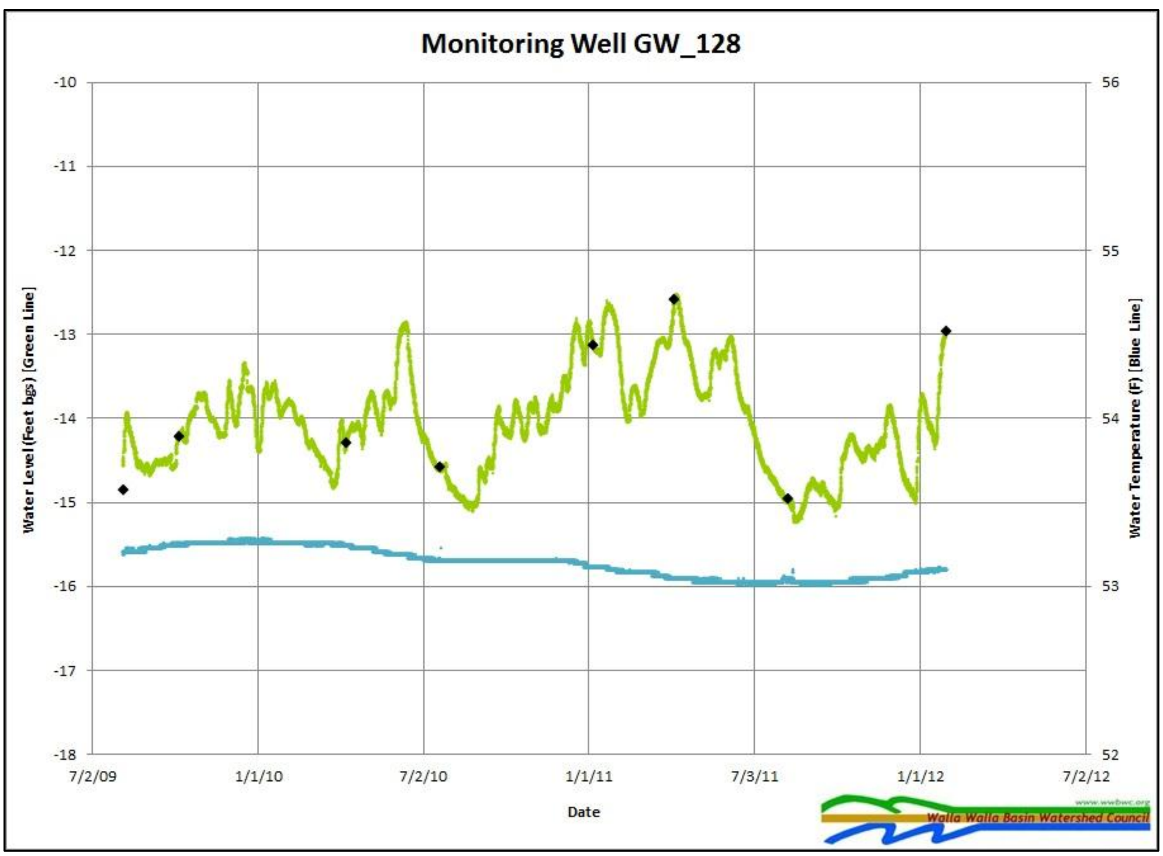
Monitoring Well GW_128
Water Level (Feet bgs) [Green Line]
Water Temperature (F) [Blue Line]
-10
-11
-12
-13
-14
-15
-16
-17
-18
56
55
54
53
52
7/2/09
1/1/10
7/2/10
1/1/11
7/3/11
1/1/12
7/2/12
Date
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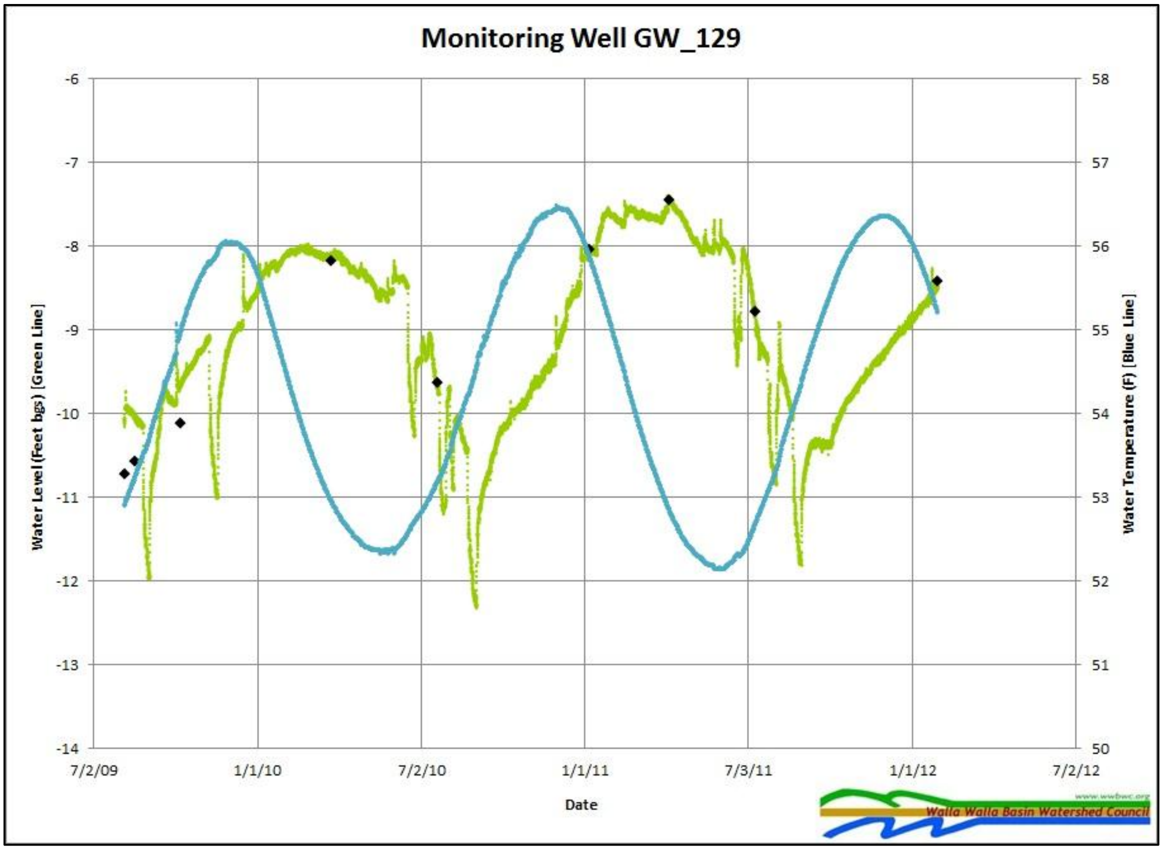
Monitoring Well GW_129
Water Level (Feet bgs) [Green Line]
Water Temperature (F) [Blue Line]
-6
-7
-8
-9
-10
-11
-12
-13
-14
58
57
56
55
54
53
52
51
50
7/2/09
1/1/10
7/2/10
1/1/11
7/3/11
1/1/12
7/2/12
Date
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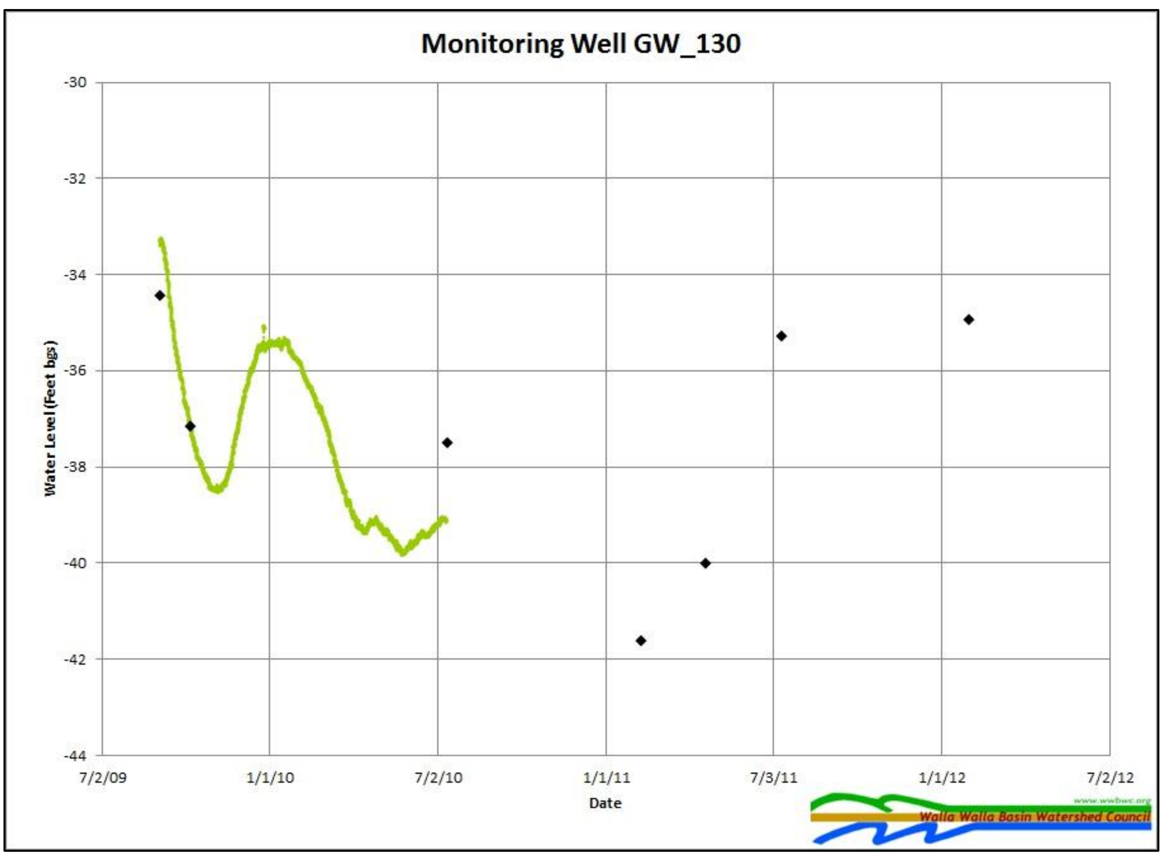
Monitoring Well GW_130
Water Level (Feet bgs)
-30
-32
-34
-36
-38
-40
-42
-44
7/2/09
1/1/10
7/2/10
1/1/11
7/3/11
1/1/12
7/2/12
Date
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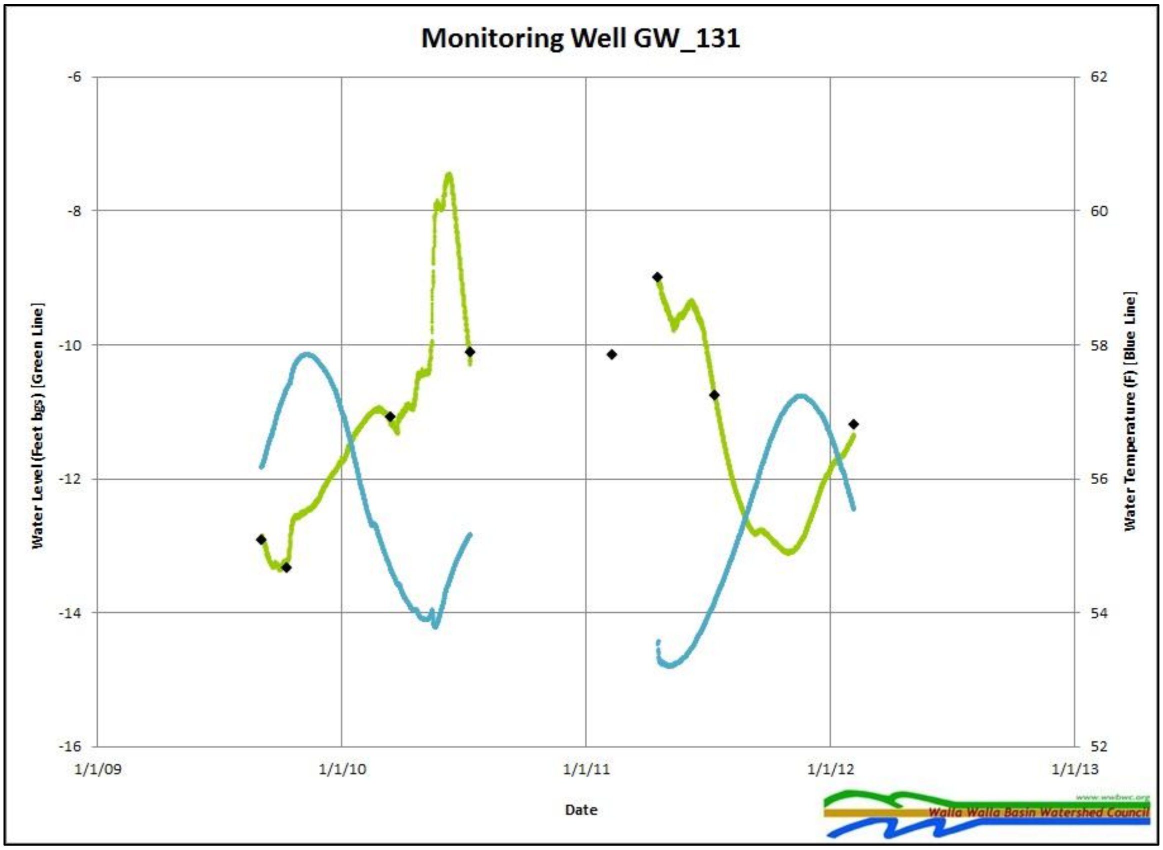
Walla Walla Basin Watershed Council


Monitoring Well GW_131
Water Level (Feet bgs) [Green Line]
Water Temperature (F) [Blue Line]
-6
-8
-10
-12
-14
-16
62
60
58
56
54
52
1/1/09
1/1/10
1/1/11
1/1/12
1/1/13
Date
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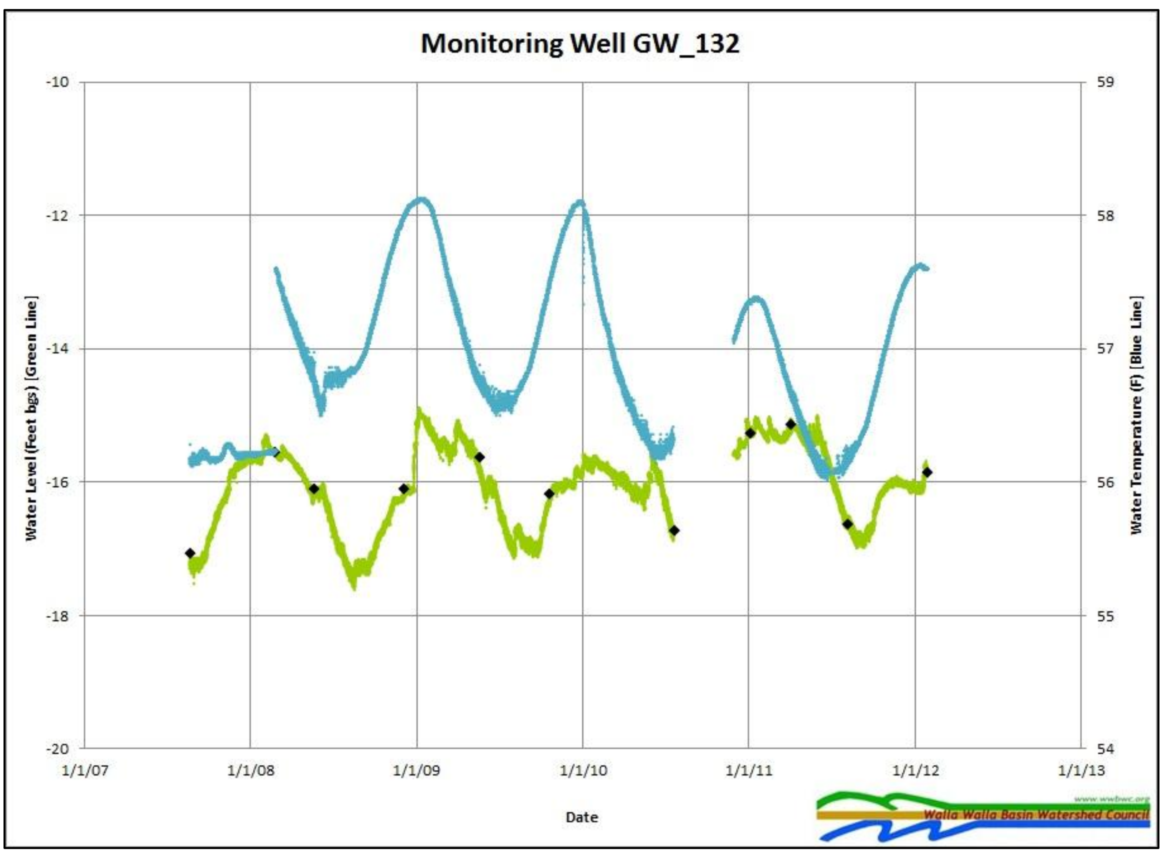
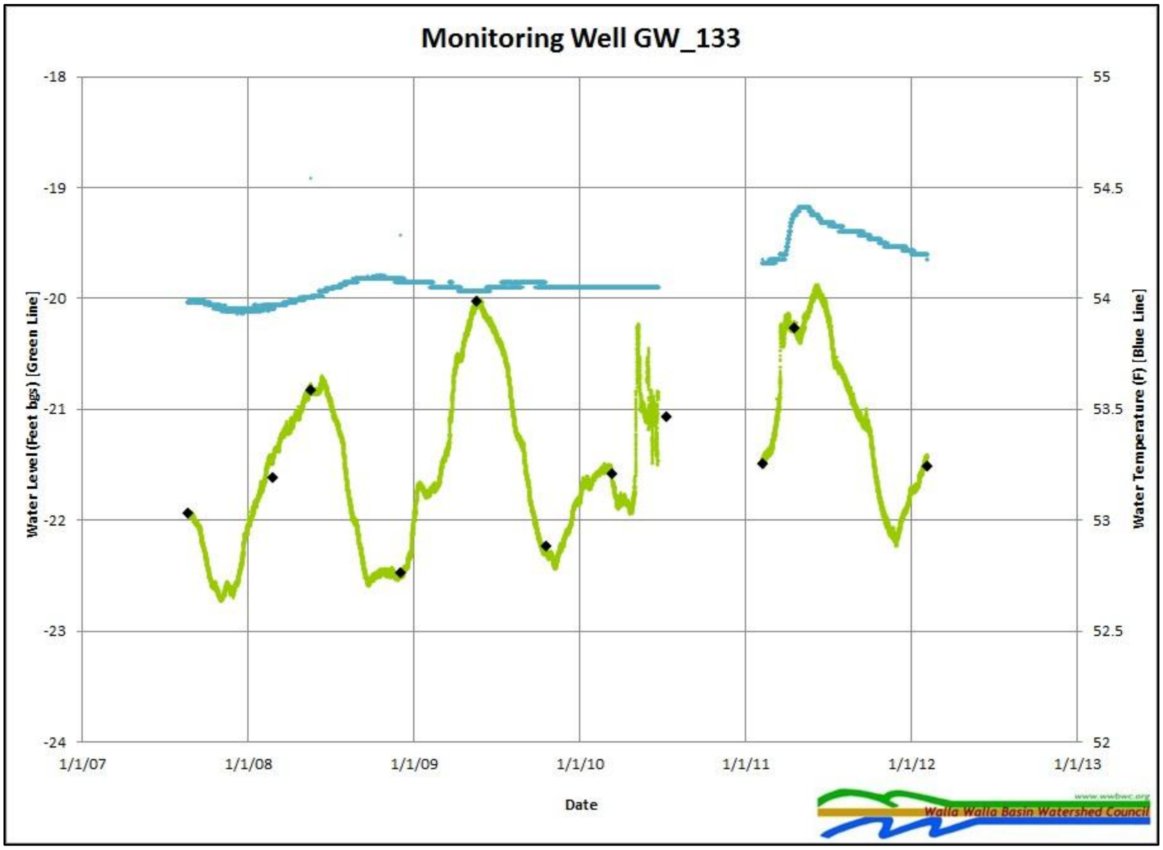

Monitoring Well GW_132
Water Level (Feet bgs) [Green Line]
Water Temperature (F) [Blue Line]
-10
-12
-14
-16
-18
-20
59
58
57
56
55
54
1/1/07
1/1/08
1/1/09
1/1/10
1/1/11
1/1/12
1/1/13
Date
www.wwbwc.org
Walla Walla Basin Watershed Council


Monitoring Well GW_133
Water Level (Feet bgs) [Green Line]
Water Temperature (F) [Blue Line]
Date
-18
-19
-20
-21
-22
-23
-24
55
54.5
54
53.5
53
52.5
52
1/1/07
1/1/08
1/1/09
1/1/10
1/1/11
1/1/12
1/1/13
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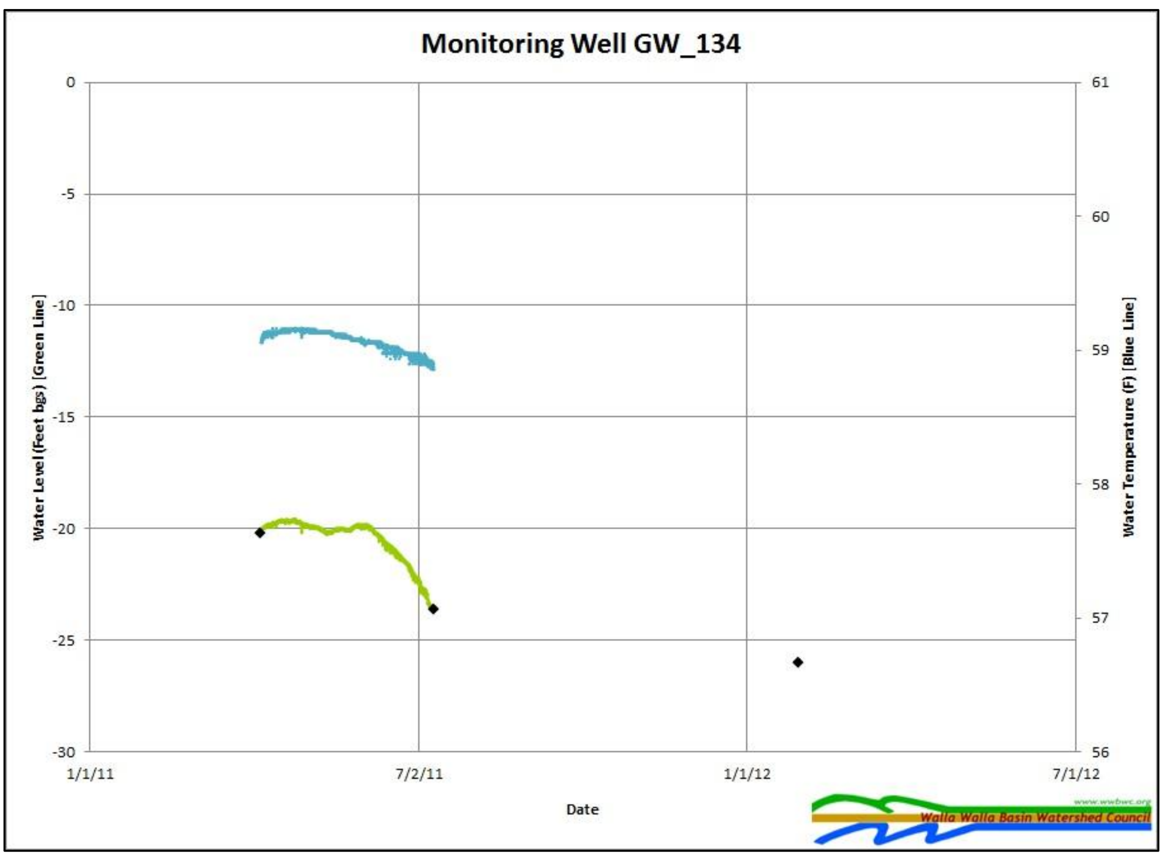
Monitoring Well GW_134
Water Level (Feet bgs) [Green Line]
Water Temperature (F) [Blue Line]
Date
0
-5
-10
-15
-20
-25
-30
61
60
59
58
57
56
1/1/11
7/2/11
1/1/12
7/1/12
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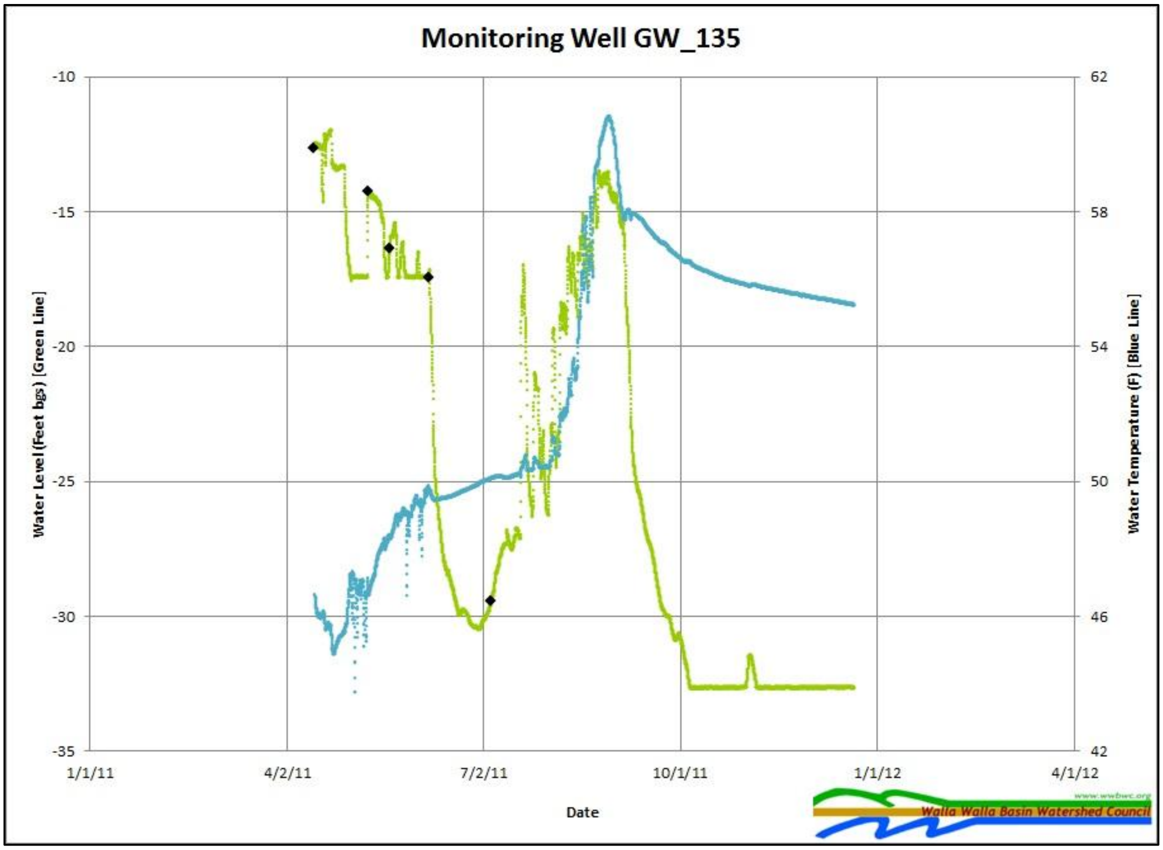
Monitoring Well GW_135
Water Level (Feet bgs) [Green Line]
Water Temperature (F) [Blue Line]
Date
-10
-15
-20
-25
-30
-35
62
58
54
50
46
42
1/1/11
4/2/11
7/2/11
10/1/11
1/1/12
4/1/12
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Appendix D

Data gap explanations – 2010-2012

GW_03 – July 2009-April 2010. Data logger malfunction.

GW_05 – July 2005-February 2009. Data logger removed from well.

GW_08 – December 10 2011-January 10 2012. Data logger ran out of memory, stopped recording new data.

GW_34 – August 2010-September 2010. Data logger malfunction.

GW_45 – May 10-May 25 2011. Data logger malfunction.

GW_46 – March 9-March 24 2010. Data logger malfunction.

GW_48 – July 2009-October 2009. Data logger malfunction.

February 2010-March 2010. Logger batteries died.

July 2010-October 2010. Data logger malfunction.

GW_54 – February 2011-Current. Data logger stuck in well, cable broke. Manual measurements only now.

GW_61 – July 2010-October 2010. Data logger malfunction.

GW_66 – November 2009-February 2010. Data logger malfunction.

GW_68 – January 2010-July 2010. Hardware failure, logger dropped into well.

September 2010-April 2011. Hardware failure, logger dropped into well.

GW_83 – March 2010-April 2010. Data logger malfunction.

GW_85 – October 2009- March 2010. Data logger malfunction

GW_87 – February 2011-August 2011. Data logger malfunction.

GW_89 – July 2010-September 2011. Data logger malfunctions.

GW_90 – August 2009-April 2010. Data logger malfunction.

GW_92 – December 2009-March 2010. Data logger malfunction.

GW_95 – July 2010-April 2011. Data logger malfunction.

GW_103 – July 2011-January 2012. Data logger malfunction.

GW_104 – July 2011-January 2012. Data logger malfunction.

GW_105 – July 2010-August 2011. Data logger malfunction.

GW_107 – March 2010-July2010. Data logger malfunction.

GW_108 – March 3 2010-March 25 2010. Data logger malfunction.

GW_116 – October 2009-March 2010. Data logger malfunction and deployment issues.

October 2010-December 2010. Deployment issues.

GW_118 – January 2010-July 2010. Data logger malfunction.

GW_121 – July 2011-January 2012. Data logger malfunction.

GW_123 – February 2011-April 2011. Data logger malfunction.

GW_126 – July 2010-January 2011. Data logger malfunction.

GW_131 – July 2010-April 2011. Data logger malfunction.

GW_132 – July 2010-December 2010. Data logger malfunction.

GW_133 – July 2010-January 2011. Data logger malfunction.

GW_134 – July 2011-January 2012. Data logger stolen.

GW_135 – December 2011-January 2012. Data logger ran out of memory, stopped recording new data.

Appendix D

Shallow Aquifer Well Information

WELL_ID	Well Log	East	North	ELIPS_HT_M	TwnRngSec	Pump	Water Right	Year Constructed	Well Depth
GW_03	UMAT 4599	393477.08	5091165.36	273.745	6N 35E S25 dac	Yes - Used for Rural Fire District	GR1268	1926	32
GW_04	UMAT 4619	393192.023	5091728.25	267.303	6N 35E S25 acd	Yes	GR3802	1915	78
GW_05	UMAT 4205	393764.617	5094403.25	248.064	6N 35E S13 dad	Yes - Used for Irrigation	U-397	1943	128
GW_06	UMAT 4474	392664.181	5092403.47	262.960	6N 35E S24 cdc	Yes - Used for yard operations	n/a	1979	85
GW_07	UMAT 4602	392787.583	5091551.12	271.717	6N 35E S25 caa	Yes - Irrigation	GR3218	1923	50
GW_08	n/a	392587.05	5090737.2	281.997	6N 35E S36 bab	Yes	n/a	n/a	102 (Sounded)
GW_09	UMAT 6471	392658.605	5088806.7	306.631	5N 35E S1 bac	Yes - Irrigation	n/a	1980	106
GW_10	UMAT 4589	392132.402	5091372.82	273.696	6N 35E S25 cbc	Yes	U-125	1943	70
GW_11	UMAT 4438	391570.533	5093637.71	247.687	6N 35E S25 abd	Yes	n/a	1961	64
GW_13	UMAT 4418	390667.86	5093232.62	250.852	6N 35E S23 bcc	Yes	n/a	1971	63
GW_14	UMAT 54050	392157.683	5089568.01	295.488	6N 35E S36 cbd	Yes	n/a	2000	201
GW_15	UMAT 6463	388945.465	5089304.75	272.057	6N 35E S34 ccc	Yes	16140	1976	76
GW_16	UMAT 5007	389690.237	5090610.17	269.610	6N 35E S34 baa	Yes	GR3169	1915	50
GW_18	UMAT 50354	386647.989	5093698.76	225.360	6N 35E S20 acb	Yes	n/a	1923	?
GW_19	UMAT 4691	391225.116	5092022.76	265.289	6N 35E S26 bad	Yes	GR-1295	1922	110
GW_20	UMAT 50356	393114.775	5092400.73	264.392	6N 35E S24 dcd	Yes	GR2098	1946	165
GW_23	UMAT 3941	390432.546	5088757.82	292.342	5N 35E S3 ada	Yes			
GW_25	UMAT 50359	393463.723	5090261.7	284.451	6N 35E S36 adb		12766	1933	44
GW_27	UMAT 3933	391245.146	5088811.53	298.777	5N 35E S2 bdd		U45	1932	23
GW_28	UMAT 4979/5009	390083.217	5090403.42	274.565	6N 35E S34 abd	Yes	GR2559	1910	111
GW_31	UMAT 4305	385163.051	5093209.97	218.535	6N 35E S19 dba	Yes	G685	1958	200

WELL_ID	Well Log	East	North	ELIPS_HT_M	TwnRngSec	Pump	Water Right	Year Constructed	Well Depth
GW_33	UMAT 5977	387947.465	5093853.94	230.034	6N 35E S21 bad	Yes	n/a	1994	105
GW_34	UMAT 4135	383288.818	5093418.24	201.734	6N 35E S24 bdd	No	GR1139	1918	50
GW_35	n/a	388031.533	5090796.5	255.362	6N 35E S33 baa	Yes	n/a		41 (Sounded)
GW_36	UMAT 4822	384946.272	5091616.02	220.534	6N 35E S30 dbb	Yes	n/a	1979	412
GW_37	UMAT 50725	384227.715	5092519.7	208.416	6N 35E S19 ccc	Yes	n/a		90
GW_38	n/a	392985.262	5094932.61	248.083	6N 35E S13 acc	Yes	n/a	n/a	40 (Sounded)
GW_39	UMAT 4919	388823.228	5090045.31	266.394	6N 35E S33 add	Yes	GR4228	1895	120
GW_40		388846.149	5089945.79	266.979	6N 35E 33 daa				
GW_41	n/a	388830.34	5090133.82	265.537	6N 35E 33 add	Yes	n/a	n/a	n/a
GW_45	UMAT 55115	388555.543	5090167.26	262.553	6N 35E 33 adc	No	n/a	2004	71
GW_46	UMAT 55114	388335.675	5090331.38	259.507	6N 35E 33 aca	No	n/a	2004	67
GW_47	UMAT 55116	388325.733	5090362.96	259.118	6N 35E 33 aca	No	n/a	2004	60
GW_48	UMAT 55117	388432.429	5090413.76	259.608	6N 35E 33 aca	No	n/a	2004	61
GW_54	170979	390256.169	5095118.76	231.915	6N 35E S15 dcc	Yes	n/a	1947	60
GW_57		385964.995	5095524.82	205.082	6N 35E S18 ada	No	n/a	1973	n/a
GW_58	n/a	387261.534	5091269.17	245.655	6N 35E S29 dad	No	n/a		19.4 (Sounded)
GW_60	UMAT 4917	388039.791	5090041.58	257.473	6N 35E S33 bdd	Yes	GR1724	1910	460
GW_61	UMAT 4909	387730.609	5089747.58	255.862	6N 35E S33 cac	Yes	GR1128	1919	125
GW_62	n/a	389834.806	5089059.23	283.305	6N 35E S3 abb	Yes			51.7 (Sounded)
GW_63	n/a	383280.245	5091893.17	203.980	6N 34E S25 acc	No	n/a		55 (Sounded)
GW_64	UMAT 53903/53982	383657.595	5091641.27	208.550	6N 34E S25 dab	Yes	n/a	1996	301
GW_65	n/a	387239.855	5090936.28	246.133	6N 35E S29 ddd	Yes	n/a		29.5 (Sounded)

WELL_ID	Well Log	East	North	ELIPS_HT_M	TwnRngSec	Pump	Water Right	Year Constructed	Well Depth
GW_66	n/a	384016.598	5091700.05	209.851	6N 35E S25 daa	No	n/a		68.2 (Sounded)
GW_67	n/a	378968.413	5093403.08	175.056	6N 34E S21 dab	No	n/a		42.7 (Sounded)
GW_68	n/a	379255.547	5092242.31	181.305	6N 34E S27 bbc	No	n/a		211 (Sounded)
GW_69	n/a	383991.427	5091254.85	212.394	6N 34E S25 dda	Yes	n/a		57.6 (Sounded)
GW_70	202412/336875	385959.296	5095225.6	206.799	6N 35E S18 ddd	No	n/a	2006	60
GW_71	202413/336876	385628.631	5095705.4	202.314	6N 35E S18 aab	No	n/a	2006	50
GW_72	256087	385729.547	5095463.31	204.567	6N 35E S18 adc	No	n/a	2006	68
GW_73	UMAT 55701	390621.47	5095033.16	232.761	6N 35E S14 bbb	No	n/a	2006	50
GW_74	UMAT 55700	390649.1	5094642.92	234.943	6N 35E S14 cbc	No	n/a	2006	50
GW_75	UMAT 55699	390474.91	5095093.45	230.702	6N 35E S15 aaa	No	n/a	2006	50
GW_82	AHE467	369667.774	5098077.19	167.560	6N 33E S4 ddb	Yes	3123	1996	235
GW_83	95802	395564.39	5102165.31	279.703	7N 36E S19 ddc	No	n/a	1987	20
GW_84	294336	392313.076	5100037.69	239.941	7N 35E S35 adb	Yes	n/a	1946	100
GW_85	164475	390405.704	5098512.06	218.239	6N 35E S3 aca	No	n/a	1981	160
GW_86	117842	370841.298	5099210.65	135.383	6N 33E S3 abb	No	n/a	2002	27
GW_87	417900	402951.381	5104575.89	385.250	7N 36E S13 cab	No	n/a	2005	75
GW_88	164616	404352.529	5104571.29	402.095	7N 36E S18 bcd	No	n/a	2005	87
GW_89	417897	400344.775	5102819.46	340.715	7N 36E S22 adc	No	n/a	2005	80
GW_90	417898	397598.227	5100192.12	295.908	7N 36E S33 bbc	No	n/a	2005	78
GW_92	UMAT 53833	372892.083	5095185.18	170.620	6N 33E S13 bbb	No	n/a	2000	210
GW_93	430256	372093.92	5097078.06	177.130	6N 33E S11 bdb	Yes	n/a	1992	340
GW_94	168365	376840.306	5099135.81	151.368	6N 34E S5 bba	Yes	n/a	1949	24
GW_95	432448	392050.438	5103625.04	257.941	7N 35E S23 aba	Yes	n/a	1991	84
GW_96	168365	377627.97	5099120.23	151.895	6N 34E S5 aba	Yes	n/a	1949	26

WELL_ID	Well Log	East	North	ELIPS_HT_M	TwnRngSec	Pump	Water Right	Year Constructed	Well Depth
GW_98	n/a	388276.158	5089528.17	263.425	6N 35E S33 dca	Yes	n/a	n/a	n/a
GW_100	n/a	389461.838	5095285.12	226.025	6N 35E S15 cba	Yes	n/a	n/a	n/a
GW_101	n/a	389376.906	5095242.38	227.345	6N 35E S15 cbc	Yes	n/a	n/a	n/a
GW_102	AFB274	390157.378	5096042.65	222.966	6N 35E S10 dba	No	n/a	2000	102 (Sounded)
GW_103	294307	385326.833	5097329.3	195.595	6N 35E S7 abb	Yes	n/a	1956	189
GW_104	155923	385521.562	5096636.16	198.959	6N 35E S7 acd	Yes	G33-517B-3089-A(B)	2007	200
GW_105	495880	380175.563	5103218.7	169.084	7N 34E S22 bdc	No	n/a	2007	65
GW_106	454317	370775.076	5098318.61	137.985	6N 33E S3 cad	No	n/a	2006	65
GW_107	454320	379927.288	5099999.59	159.637	7N 34E S34 bcd	No	n/a	2006	60
GW_108	495878	384498.967	5098025.07	189.354	6N 35E S6 cbb	No	n/a	2007	75
GW_109	495876	377261.415	5096816.91	157.012	6N 34E S8 acc	No	n/a	2007	85
GW_110	495877	384010.342	5095258.42	203.024	6N 34E S13 dcd	No	n/a	2007	85
GW_111	205983	386005.353	5099434.3	185.580	7N 35E S38 cad	No	n/a	2006	50
GW_112	454319	388823.342	5095371.85	223.286	6N 35E S16 dba	No	n/a	2006	45
GW_113	272908	388445.622	5097173.41	207.196	6N 35E S9 abb	No	n/a	2007	55
GW_114	515471	392310.456	5096321.56	228.461	6N 35E S11 add	No	n/a	2006	70
GW_115	UMAT 56443	392743.234	5086919.98	326.984	5N 35E S12 bda	No	n/a	2009	53
GW_116	UMAT 56442	391304.129	5091322.1	272.050	6N 35E S26 cad	No	n/a	2009	70
GW_117	UMAT 56444	389825.547	5090864.48	268.409	6N 35E S27 dcc	No	n/a	2009	70
GW_118	UMAT 56445	387655.395	5090858.9	250.210	6N 35E S28 ccd	No	n/a	2009	70
GW_119	UMAT 56447	384949.15	5092104.05	217.173	6N 35E S30 acb	No	n/a	2009	40
GW_120	UMAT 56446	380094.16	5094289.87	172.605	6N 34E S15 cdd	No	n/a	2009	31
GW_121	359743	376782.848	5095406.67	153.482	6N 34E S17 ccd	No	n/a	2009	40
GW_122	359749	383671.11	5097361.74	183.508	6N 34E S12 baa	No	n/a	2009	55
GW_123	359744	372425.274	5098426.9	136.382	6N 33E S2 dbb	No	n/a	2009	30
GW_124	359736	370208.59	5096168.18	154.515	6N 33E S10 ccd	No	n/a	2009	40
GW_125	359747	367861.923	5098647.99	130.150	6N 33E S5 acd	No	n/a	2009	30

WELL_ID	Well Log	East	North	ELIPS_HT_M	TwnRngSec	Pump	Water Right	Year Constructed	Well Depth
GW_126	359475	370288.485	5101958.99	141.772	7N 33E S27 bcc	No	n/a	2009	55
GW_127	359741	396489.017	5103462.56	294.222	7N 36E S20 bbd	No	n/a	2009	30
GW_128	359746	398388.076	5102166.69	315.769	7N 36E S21 dcc	No	n/a	2009	40
GW_129	359752	392937.709	5097342.67	235.127	6N 35E S1 cdc	No	n/a	2009	40
GW_130	n/a	371006.475	5095051.07	170.546	6N 33E S15 daa	No	n/a	n/a	n/a
GW_131	n/a	373332.024	5100415.42	138.554	7N 33E S36 bcb	No	n/a	n/a	n/a
GW_132	272911	394298.127	5100424.79	265.044	7N 36E S30 ccb	No	n/a	2007	60
GW_133	272909	380163.278	5102894.26	167.725	7N 34E S22 cba	No	n/a	2007	59
GW_134	107678	392341.464	5100035.08	240.010	7N 35E S35 adb	No	n/a	2001	40
GW_135	n/a	390848.356	5088932.95	294.177	5N 35E S2 bbd	Yes	n/a	n/a	n/a
GW_136	433419 / BCE307	386245.67	5100648.72	196.332	7N 35E S29 ccc	No	n/a	2011	41
GW_137	761560	370617.096	5096091.17	155.118	6N 33E S15 baa	No	n/a	2011	100
GW_138	761559	370615.025	5096090.09	155.146	6N 33E S15 baa	No	n/a	2011	47

Appendix E

Aquifer Recharge as a Water Management Tool:

Hudson Bay Recharge Testing Site Report (2004-2009)

Aquifer Recharge as a Water Management Tool: Hudson Bay Recharge Testing Site Report (2004-9)

HBDIC Recharge Project Expansion with Basin #1 (foreground), spring 2008

April 18th, 2010

Prepared by

Bob Bower, Hydrologist, WWBWC
Kevin Lindsey, LHG (WA), GSI

For

Hudson Bay District Improvement Company (HBDIC)

In Support of

OWRD Limited Testing License (Final Order #1059)
ODEQ Water Quality Reporting (Final Order #1059)
OWEB Grant Funding (#206-363)
BPA Grant Funding (#35684)

45 Years Ago…

"Some initial tests at artificially recharging the gravel aquifers by placing excess surface water into gravel pits and onto unused gravelly fields have reportedly helped raise temporarily the water level in wells of their vicinities. A comprehensive plan for the systematic management of the old gravel as a water reservoir is an obvious need that will surely come about ultimately. Such a comprehensive plan and systematic management will need to include all phases of natural and artificial recharge in order to obtain maximum benefits from this important natural water-storage facility."

Geology and Groundwater Resources of the Walla Walla River Basin, Washington-Oregon.

Robert Newcomb, USGS - 1965

"What you have to do and the way you have to do it is incredibly simple. Whether you are willing to do it is another matter." ***(Peter F. Drucker)***

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Dedicated to the citizens, water users and salmon recovery advocates of the Walla Walla Basin. Without the "can-do" spirit of the people of the Walla Walla River valley, none of this would have been possible.

Executive Summary

The Walla Walla Basin is a bi-state basin in northeastern Oregon and southeastern Washington, through which flows the Walla Walla River. The Walla Walla River, and its tributaries, originate in the Blue Mountains, and generally flow westward to a confluence with the Columbia River near Wallula Gap. The river system itself is a primary passage and rearing habitat for ESA-listed steelhead and bull trout, and a focus of tribal efforts at Chinook salmon and lamprey restoration. In addition, the portion of the Walla Walla River system which lies within the Walla Walla Basin and is the focus of this report overlies an alluvial aquifer system that displays a high degree of hydraulic continuity with the River. In the past 50 to 60 years a large number of wells (large and small) have been drilled into, and extract water from, this alluvial aquifer system.

This report:

1. Describes the basic hydrologic conditions that have developed in the Walla Walla Basin in response to development of basin water resources.
2. Looks more closely at alluvial aquifer system conditions that have developed – including a history of water level decline and the possible impacts these declines have had on streams and springs
3. Describes the results of six seasons of shallow aquifer recharge (SAR) activity at the Hudson Bay site.

The Setting: Alluvial sediments (clay, silt, sand, and gravel) largely derived from the adjacent Blue Mountains fills the Walla Walla Basin to a depth of 800 feet in some places. These strata filled a basin that formed as the basalt bedrock that underlies the region was down-dropped by a series of folds and faults that formed in response to regional tectonic stresses. As this bedrock dropped, sediments washed off the Blue Mountains by the ancestral Walla Walla River and other streams collected in the subsiding basin.

Prior to the advent of widespread diversion of surface water and groundwater for agricultural irrigation, industrial uses (primarily food processing), stock watering, and domestic and municipal water supply the Walla Walla Basin was crossed by a series of streams that drained off the Blue Mountains. Most of these streams flowed year round. In addition, as a result of seasonal snow melt and flooding these streams recharged an aquifer system hosted by the alluvial sediments filling the Basin. One of the manifestations of that recharge was the presence of numerous springs on the valley floor. These springs showed the locations where the aquifer system, once fed by seasonally flooding and recharge, discharged to surface waters providing base-flow for streams. In another sense, the abundant springs and streams demonstrated that the alluvial aquifer system was full, and had achieved an equilibrium that balanced recharge with discharge. With the advent of permanent settlement, irrigated farming, and the development of supporting industry, the hydrology of the basin was changed.

Changing Hydrologic Conditions: In the years following the establishment of the Whitman Mission, Fort Walla Walla, and the towns that now dot the Walla Walla Basin landscape, natural streams tributary to the Walla Walla River, and the Walla Walla River itself, have been straightened and channelized to facilitate the delivery of irrigation water and reduce the extent of seasonal flooding. Stream channel straightening, coupled with the draining of wetlands and boggy areas has increased cropped acreage, pasture availability, and rural residential home building sites. In recent years, un-lined ditches have been replaced by lined ditches and pipes to reduce water conveyance losses and withdrawals from the Wall Walla River. In addition, the primary irrigation districts active in the Basin have reduced the period of time during which they divert water from the Walla Walla River.

All of these actions resulted in the loss of alluvial aquifer recharge; as the residence time and spreading of surface water in the basin was reduced. These actions also likely facilitated a decline in alluvial aquifer water level as channel straightening led to channel deepening; this in turn led to declines in aquifer base level. With alluvial aquifer water level declines, stream flows were further impacted as base-flow and spring-flow was lost. Coupled with these changes to the surface hydrology has been a parallel increase in the number of wells extracting water from the alluvial aquifer system. The impact of these factors on Walla Walla Basin hydrology includes reduced river flow, a flashy river system, and declines in aquifer levels and corresponding base-flows, coupled with diminished aquifer storage.

Recognizing these trends, the Walla Walla Basin Watershed Council (WWBWC) in partnership with the Hudson Bay District Improvement Company (HBDIC) decided in 2003 and 2004 to build a pilot alluvial aquifer recharge project. The goals of this project are to test the feasibility of SAR, develop operational and monitoring plans that can be used to facilitate future SAR projects. Most importantly, the project aims to recharge the alluvial aquifer to the extent possible given the physical constraints of the recharge site and the surrounding aquifer system. Recharge operations have been conducted at the HBDIC SAR site in the winter and spring of each of the past 6 years, or seasons.

The HBDIC SAR Project: Construction and recharge operations at the Site began in the late winter and spring of 2004. At that time 3 infiltration basins, totaling 0.34 acres in size, were constructed adjacent to the HBDIC's White Ditch. The White Ditch delivers Walla Walla River water to the Site. Site recharge operations began in March 2004 after receiving Oregon Water Resources Department Limited License LL-758. This license permitted SAR at the site under OWRD's aquifer recharge rules, and includes:

1. Groundwater and source water monitoring requirements.
2. Stipulations on Site operation related to flows that can be delivered to the Site and minimum flows required in the Walla Walla River (the source of water for the project) to allow the project to operate.
3. The length of each recharge season, November 1st through the following May 15th.
4. Reporting criteria and requirements.

The license was granted following review and comment by other affected entities, including the Confederated Tribes of the Umatilla Indian Reservation and Oregon Department of Environmental Quality.

During the second season of operation, the 2004-2005 recharge season, the infiltration basins were increased in size, to a total area of 1.1 acres. A fourth basin was added during the 2007-2008 recharge season, increasing the total size of the infiltration basins to 1.4 acres. The original limited license expired in February 2009. In lieu of an application for a permanent water right to operate the HBDIC SAR project, a second limited license (LL#1059) was granted to the project that extended the operational schedule to the summer of 2013. During the 2008-2009 recharge season, all four infiltration basins plus a series of four infiltration galleries were operated.

Through the course of the six recharge seasons completed to-date, the site was operated for a total of 602 days. During this time, approximately 13,100 acre-feet of water was discharged to the underlying alluvial aquifer system. Recharge volumes ranged from a low of approximately 400 acre-feet during the first recharge season, 36 days in the spring of 2004, to a high of 3200 acre-feet in the 128 day long 2006-2007 recharge season. The HBDIC SAR project is interpreted to have had a beneficial impact on the surrounding area, including restoration of flow from the springs that feed Johnson Creek and increased water levels seen in wells in the vicinity of the Site. The fact that long-term water level declines appear to have been slowed, or even reversed in wells in the area of the project suggest that SAR has the potential to both increase water levels in the alluvial aquifer and replace water lost to pumping (increase storage). Groundwater quality also has been shown to have not been degraded as a result of the project.

Conclusions: Our basic conclusion is that the HBDIC SAR project shows that this type of activity is a viable option for water resource managers in the Walla Walla Basin. SAR recharges the aquifer in areas where natural recharge mechanisms have been lost. As long as good quality water is used, such as is naturally flowing into the Basin via the Walla Walla River, alluvial aquifer degradation is not expected to occur. Selectively locating SAR sites across the Basin has the potential to help water managers replenish depleted groundwater supplies and provide clean, cold base-flow to streams and springs at critical times. Some challenges for future SAR projects will be finding locations that allow water managers to meet such goals and acquiring a source of water to use for SAR.

PART I. BACKGROUND

Forward

Water remains at the center of nearly all the current natural resource restoration efforts in the bi-state Walla Walla Basin. The State of Oregon has designated beneficial uses[1] for water in the Walla Walla Basin's to include fish and aquatic life, wildlife, domestic supply, irrigation, livestock, industrial, boating, recreation and for its aesthetic qualities (**Figure** 1). The water needs have changed over the years and now the pressure has increased to find water to ensure all beneficial uses are supplied and maintained. Like many watersheds across the arid western United States, water managers and watershed planning groups struggle to find solutions to the water supply – demand balance. In the Walla Walla Basin, there has been increasing interest in the capture and storage of surplus wet season (winter/spring) water for use during the times when supply is at a deficit. Currently there are a number of groups working to design tools for aquifer management, including: building small and large scale surface-storage reservoirs, a Columbia River pumping exchange projects, a water banking system for surface and groundwater rights, and as this document details the use of managed aquifer recharge for subsurface-storage.

Figure 1. State of Oregon Beneficial Waters Uses for the Walla Walla Basin.

The main purposes of this report are to provide an introduction to managed aquifer recharge (MAR) as a water management tool, the water management needs it targets and provide a report on the design, operation, monitoring and analysis conducted at the basin's largest recharge site, the HBDIC Recharge Site from 2004-9.

[1] OAR 340-04-0330 Table 330A. Online at: http://www.deq.state.or.us/standards/WQstdsFinalGenBenUseTables.htm

Managed aquifer recharge and the use of natural landforms or features to store water are in concert with the WWBWC' community-based mission:

"Protect the resources of the Walla Walla Watershed, deal with issues in advance of resource degradation, and enhance the overall health of the watershed, while also protecting, as far as possible, the welfare, customs, and cultures of all citizens residing in the basin." (WWBWC, 2003)

The community's exploration of MAR demonstrates the emerging appreciation that real solutions to water resource challenges of the future are non-simplistic (e.g. pipe water here, save it there) and cannot be solved by trying to isolate interconnected parts into unilateral solutions. As water continues to be an issue of varying political views it is important to clearly state the perspective from which this report is written with assumptions being:

1. The Little Walla Walla River system was historically and is currently an important part of the management of the basin's surface and subsurface water resources; particularly as they relate to flow in the Walla Walla River mainstem.
2. The historic springs that rely on the shallow aquifer are worthy of protection and restoration, and they serve critical physical and biological roles in the health of the watershed system.
3. Solutions to our water management issues will only be achievable if surface and groundwater is managed conjunctively into the future.

To define the occurrence of water in the shallow aquifer, it is easiest first to discuss the aquifer as it relates to the watersheds overall water balance. For all practical purposes we can treat the water balance of the Walla Walla watershed as a closed system, meaning there are no significant external inflows or outflows of groundwater. However it should be clarified for the purposes of this discussion that an aquifer's storage is always changing due to time related events ranging in minutes to years. Storage can change due to rainfall, spring river freshets, irrigation season well pumping and a long list of other hydrologic events. But when you view this system on a longer timeline for the purpose of managing the resource for future use, this is when trends in storage can be effectively assessed. The general water balance is:

$$P = Q + E + \Delta S_S + \Delta S_G$$

Equation 1 Watershed Water Balance (budget) Equation (Freeze, 1979)

Where **P** represents all the precipitation that falls on the watershed, **Q** (discharge) represents all the flow that leaves the watershed via the surface, ***E*** as the total evapotranspiration, or the sum of all evaporation and plant transpiration, ΔS_S as the change in storage of the surface-water reservoir and ΔS_G representing the change in storage of the groundwater reservoir. The value for ΔS_G or change in groundwater storage is dictated by the balance between what is recharged to how much is discharged from the confined and unconfined aquifers of the basin. For the purposes of this discussion, we focus on only the changes that influence the balance of groundwater storage in the shallow aquifer system.

Conceptually the shallow aquifer ΔS_G can be seen as dependent on the net balance between inputs (recharge) and outputs (discharge). The physical mechanisms that induce infiltration or recharge to groundwater storage (S_G) come in a variety of forms including precipitation, channel bed losses from streams, rivers and ditches, and the application of irrigation water such as flood, rill or sprinklers. Mechanisms by which groundwater storage (S_G) is lost or discharged include well pumping, groundwater seepage directly to channel beds and springs and seeps, and the evapotranspiration of water though agricultural vegetation with roots that extract water directly from the aquifer's water table (**Figure** 2).

4.

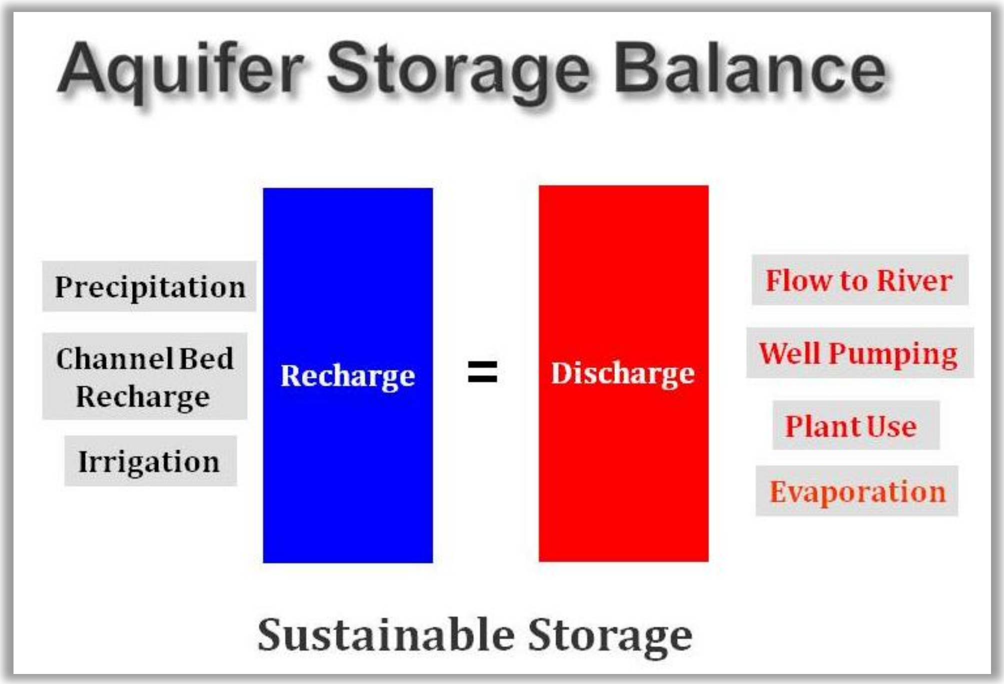


Figure 2. Mechanisms that influence balance of shallow aquifer storage (WWBWC, 2007)

We define an aquifer' storage as balanced or *sustainable* when the net quantity and timing[2] of recharged water is equal relative to net quantity and timing of discharge water (**Figure** 3). A system is out of balance when storage is either increasing or decreasing.

[2] For the purposes of this introductory to recharge, a steady-state water balance was assumed.

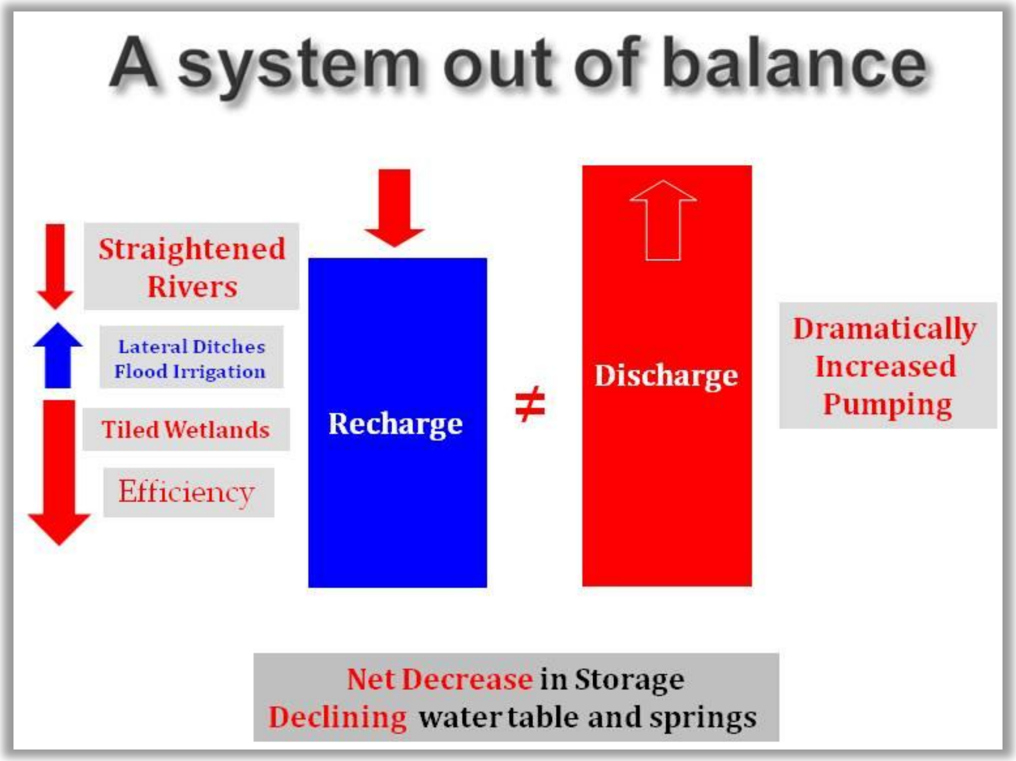


Figure 3. Historical changes propagating the status of shallow aquifer storage balance (ΔS_G)

Basin Overview and Development of Managed Aquifer Recharge

The Walla Walla basin is located in Northeastern Oregon and Southeastern Washington (**Figure** 4). This bi-state system's primary water supply comes from the Walla Walla River which originates in the Blue Mountains of Oregon and flows down through Washington to the Columbia River near Wallula Gap. This river system is the Walla Walla watershed's primary passage and rearing corridor for ESA-listed steelhead and bull trout, and species of tribal cultural significance including chinook salmon and lamprey. In addition, it also serves as the main recharge source for the underlying shallow aquifer system. The Walla Walla River also has had two EPA required Total Maximum Daily Load (TMDL) assessments for nonpoint source pollution which were completed in Oregon (ODEQ-WWBWC) for temperature and in Washington (WDOE) for soluble organic compounds, temperature and sediment.

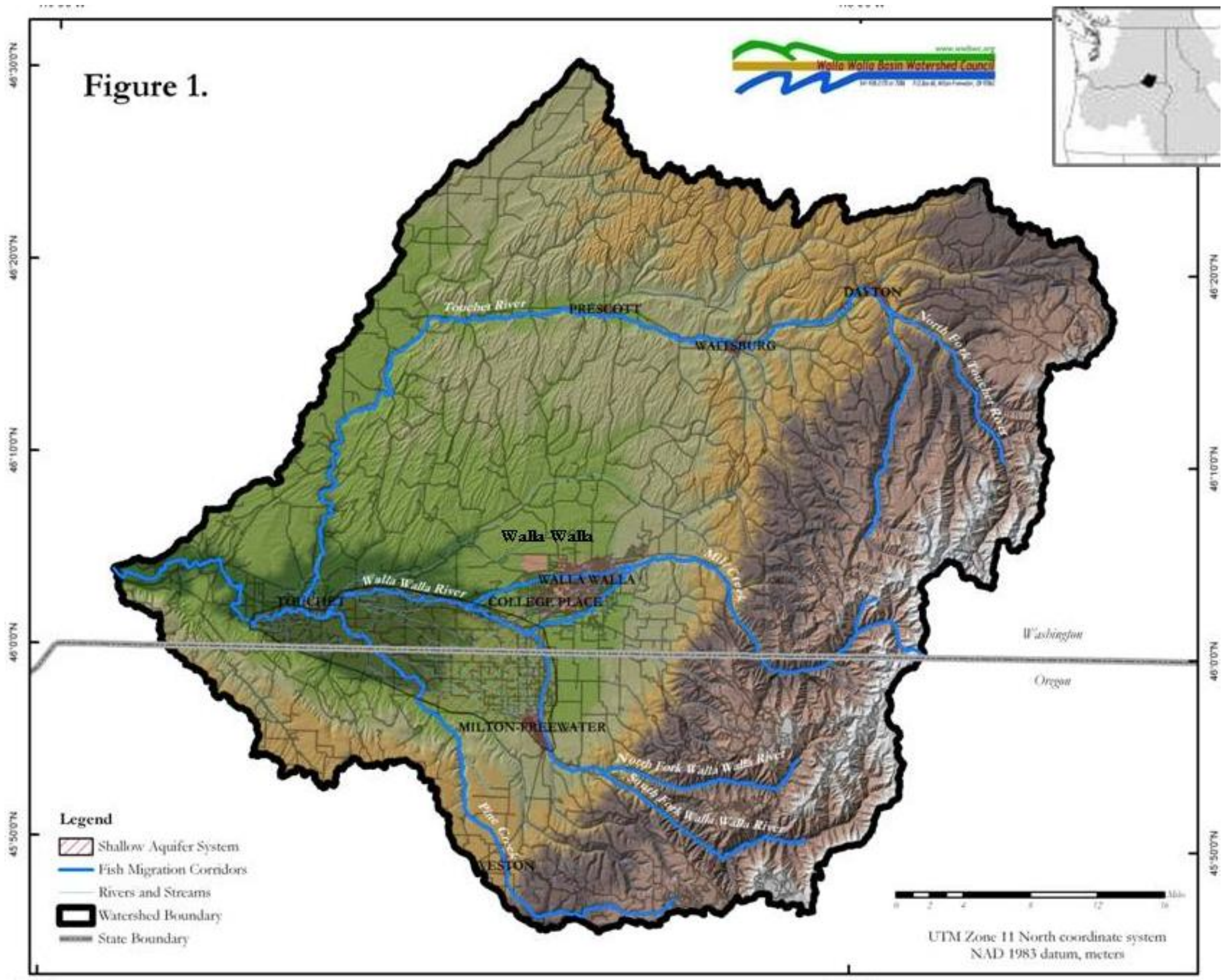


Figure 4 Map of the Walla Walla Basin Watershed (Baker T. , 2010)

The area this report focuses on is the Walla Walla River Valley subbasin.[3] In this subbasin the Walla Walla River historically exited the highlands bordering the basin, at which point it branched into a system of distributary channels that flowed out across the valley floor. These channels then recombined into a single main channel in the central portion of the valley (**Figure** 5). Within this branched distributary stream system groundwater fed spring-creeks were common. With agricultural development, many of these distributary branches were converted to and connected by, irrigation water delivery ditches and connecting lateral ditches.

Newcomb (1965), and even before him Piper (1933) provided a very compelling argument that showed the distributary and spring system was created and maintained over the top of an unconfined alluvial aquifer system. This aquifer supplies the baseflow for more than 50 valley spring-creeks in Oregon and Washington that historically provided year-round baseflow in the form of cool groundwater and off-channel habitat to the mainstem (**Figure** 6). The 240 square-mile

[3] 2006-2010 Development of a Surface-groundwater model to use as a flow restoration and aquifer replenishment planning and management tool.

aquifer also provides direct groundwater contributions in channel to the mainstem Walla Walla River which is particularly important during the summer irrigation and fisheries rearing and passage season. With historically braided and meandering channels and native beaver populations helping to pond and slow water down, the Walla Walla or as the Cayuse Tribe named this subbasin the "*land of many small waters*" historically supported a thriving salmon fisheries and miles of distributary habitat.

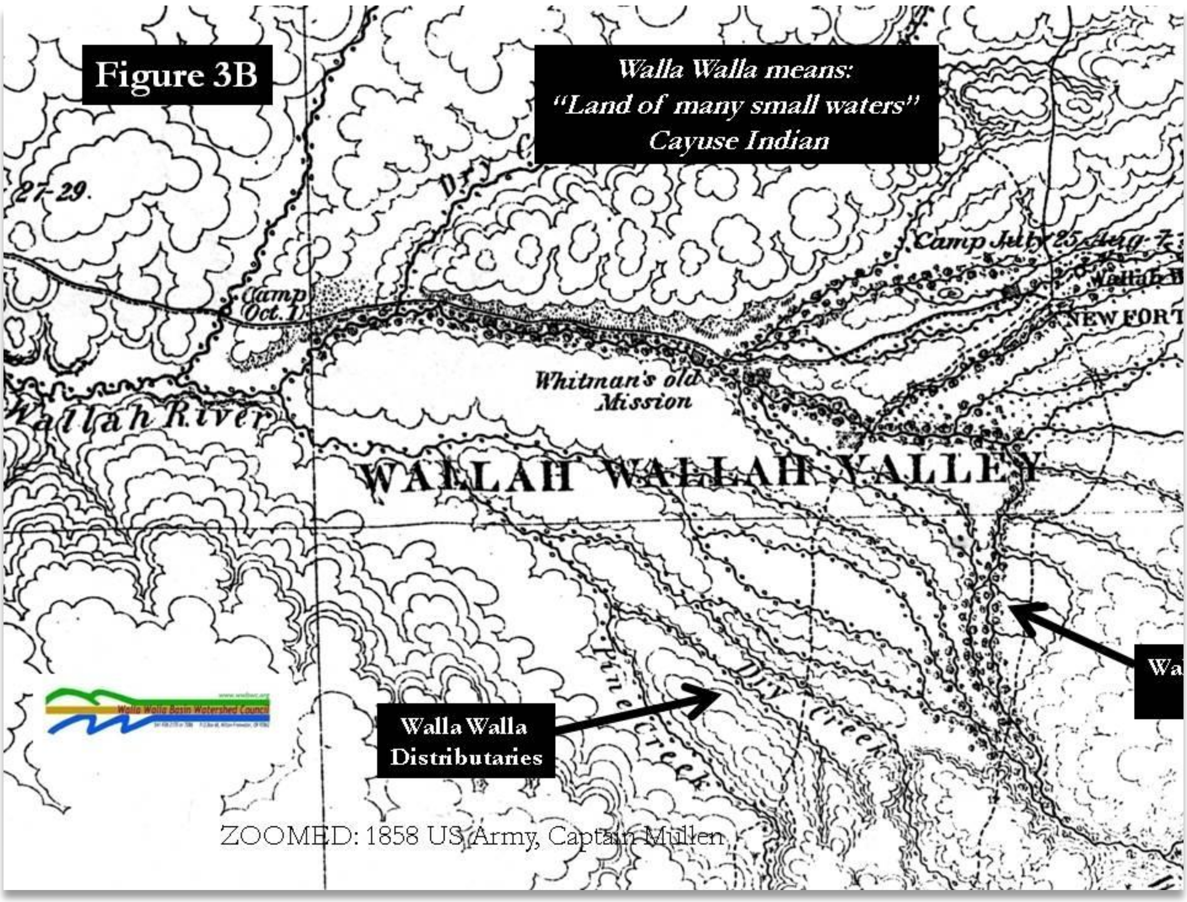


Figure 5. 1858 Mullen Map of Distributary Walla Walla and Little Walla Walla River System (Mullan, 1863)

With the onset of irrigated agriculture, the way in which water was redistributed and used began to change the hydrologic balance of this system. Naturally meandering rivers and creeks were straightened for flood control and irrigation water delivery, acting indirectly to speed up the flow of water through the system. This was offset to a degree by the valley's early flood and rill irrigation practices and the development of the lateral ditch system that acted to effectively 'slow' surface run-off. By redirecting surface waters away from the primary natural flow corridors, such activities were acting to unintentionally help recharge the underlying shallow aquifer system.

Coupled with these changes to the aquifer's ability to be replenished (recharged) there were subsequent dramatic increases in groundwater use**.** The dramatic increase in the number of wells for primary and supplemental irrigation rights acted to increase the amount of water coming out of groundwater storage. The net hydrologic impact of these changes was an aquifer-spring system that experienced reduced storage, as recharge was decreased and discharge was increased; creating an overall decline in storage that has manifested itself in a declining water table and the drying up of natural spring flows.

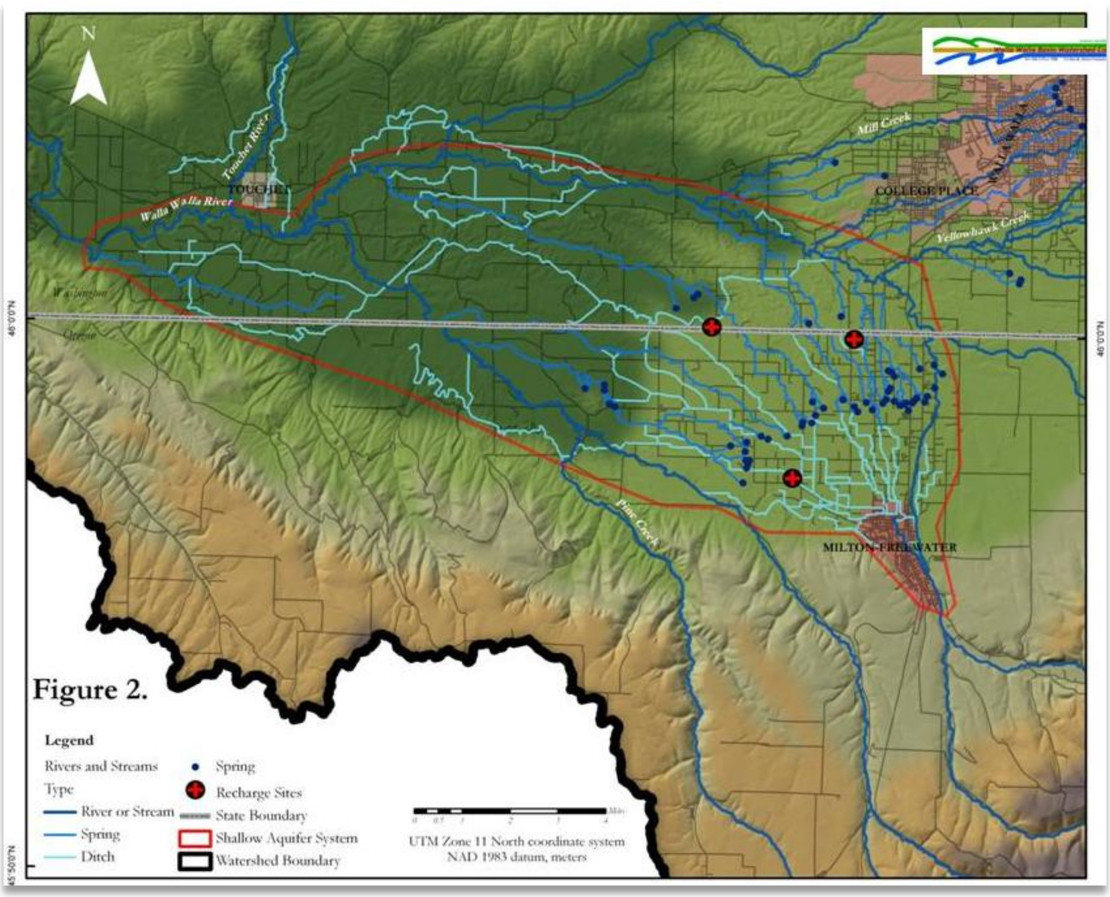


Figure 6. Bi-state Walla Walla and Little Walla Walla River System Area including Aquifer Recharge Testing (WWBWC)

While this surface to groundwater connection was first outlined by the USGS in 1933 (Piper, 1933) and again in 1965 (Newcomb, 1965) it was not revisited until the summer of 2000 that the community was forced to reexamine the situation. Starting with the ESA listing in 1998 and the *American Rivers* listing of the Walla Walla River on the top-10 most endangered rivers list in 2000, federal fish agencies worked out an agreement with the three larger irrigation districts to divert less water to these distributary branches and ditches and leave more in the 'mainstem' Walla Walla

River. This agreement re-watered an Oregon section of the river with 1/3 of the volume that had previously been diverted to irrigation during critically low summer-time base flows and was heralded nationally as a model of cooperation. However these dramatic changes in water management in the Little Walla Walla river system along with the piping of leaky ditches to stretch less water further had both immediate and longer term consequences. The springs that had been providing some baseflow (although not at historical potential) back to the Walla Walla River dramatically declined to the point that by 2009 many are nearly dry year round.

Through a series of public and WWBWC meetings, the WWBWC and its partners began to examine the historic conditions of these streams and their connection to the underlying alluvial aquifer; which they depend on for baseflow. Starting in 2001, the WWBWC and partners started developing a monitoring network and series of on-the-ground aquifer recharge projects designed to address these water management challenges. With the development of the Bi-state Watershed Management Initiative (WMI) Monitoring Program (2005 – present) a monitoring network currently comprising of over 110 wells and 50 stream flow gauges has been developed to monitor 'pre' and 'post' flow restoration conditions and provides the basis on which to build a programmatic solution**.** This program also funded a number of other technical activities from which to base the development of this program including: stratigraphy maps of the alluvial aquifer**,** a finite-element surface-groundwater numerical model (OSU) and various other field projects that help characterize the extent and properties of the shallow aquifer system.

Three main recharge projects have provided the basis upon which the WWBWC and its partners are now developing the Aquifer Replenishment and Spring Restoration (ARSR) Program (See Moving Forward Section)**.** The Hudson Bay District Improvement Company's (HBDIC) aquifer recharge project was the first of its kind in Oregon and Washington in both its physical design and its water quality monitoring plan (co-developed with ODEQ and OWRD staff). The HBDIC recharge project site, a 7-acre area Northwest of Milton-Freewater, is entering the final phase of its three part expansion under this program. The two other recharge testing projects funded by Washington's Department of Ecology include one testing field flooding[4] as a mechanism for aquifer recharge with the other using a historic gravel pit to recharge winter-spring water into groundwater storage. All of the sites have been providing detailed information on the designs, operations, monitoring and permitting-planning needs to implement aquifer recharge in the Walla Walla Basin.

Historical Trends in Walla Walla Basin Aquifer Hydrology and Hydrogeology Leading to Managed Aquifer Recharge

Generally the Walla Walla River, its tributaries, its distributaries and the shallow gravel aquifer they pass over are interpreted to be highly interconnected. Water moves relatively easily between ditches, streams, rivers and the shallow alluvial aquifer because of the highly permeable nature of gravel streambed channels so common across the Basin, and the gravelly character of the underlying alluvial aquifer system. Depending on the spatial variation in these streambed and aquifer conditions, the

[4] Hall-Wentland farm fields and the Locher Road historic gravel pit

degree of hydraulic connection between surface water and groundwater and the location of gaining and losing stream reaches generally can be defined by the depth to groundwater.

A survey of historical data shows changes in alluvial aquifer groundwater levels over time. WWBWC staff reviewed the existing data collected by Oregon Water Resources Department (OWRD) staff at historic observation wells originally set up by the United States Geological Survey (USGS). A total of 11 state observation wells (SOWs) that monitor the shallow, unconfined alluvial aquifer system were reviewed for trend information (**Figure** 7. Reviewing the data from the SOWs showed that all eleven wells display a downward trending water table with three (SOW # 844, 845, 857[5]) now having gone completely dry.

Taking a closer look at data from the OWRD SOW wells, SOW #850 shows approximately a 5 feet decline between 1940 and 2005 (**Figure** 8). The aquifer decline at this location is particularly

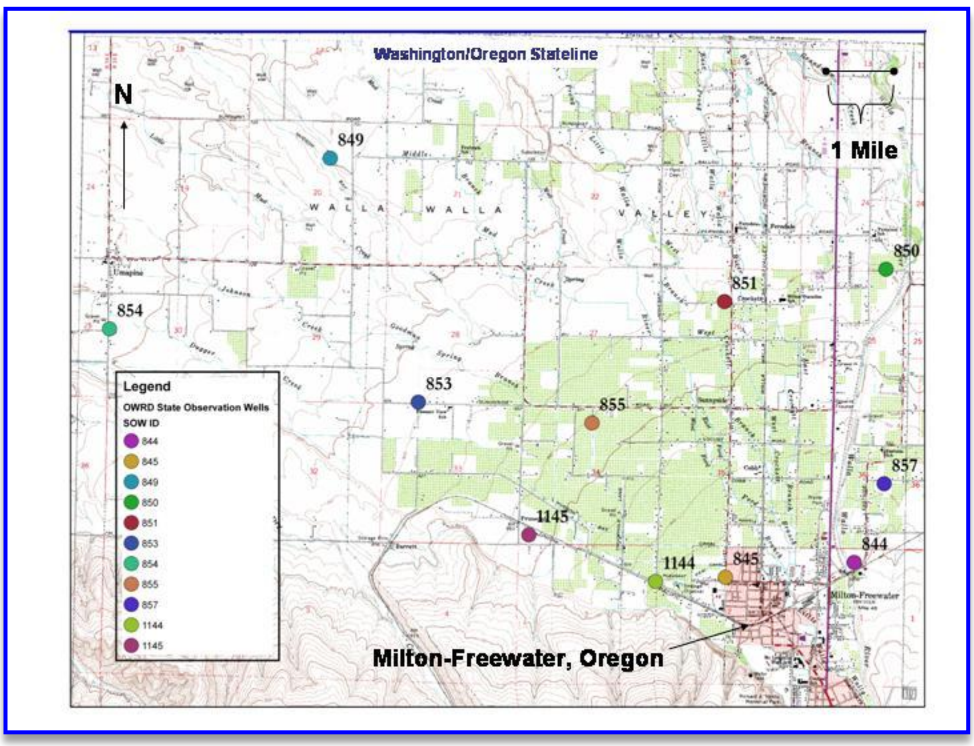


Figure 7. Site Map for Oregon Water Resources' State Observation Wells (1933 to present)

[5] SOWs 844 and 845 have since been abandoned and backfilled due to lack of water to measure and posed a safe hazard.

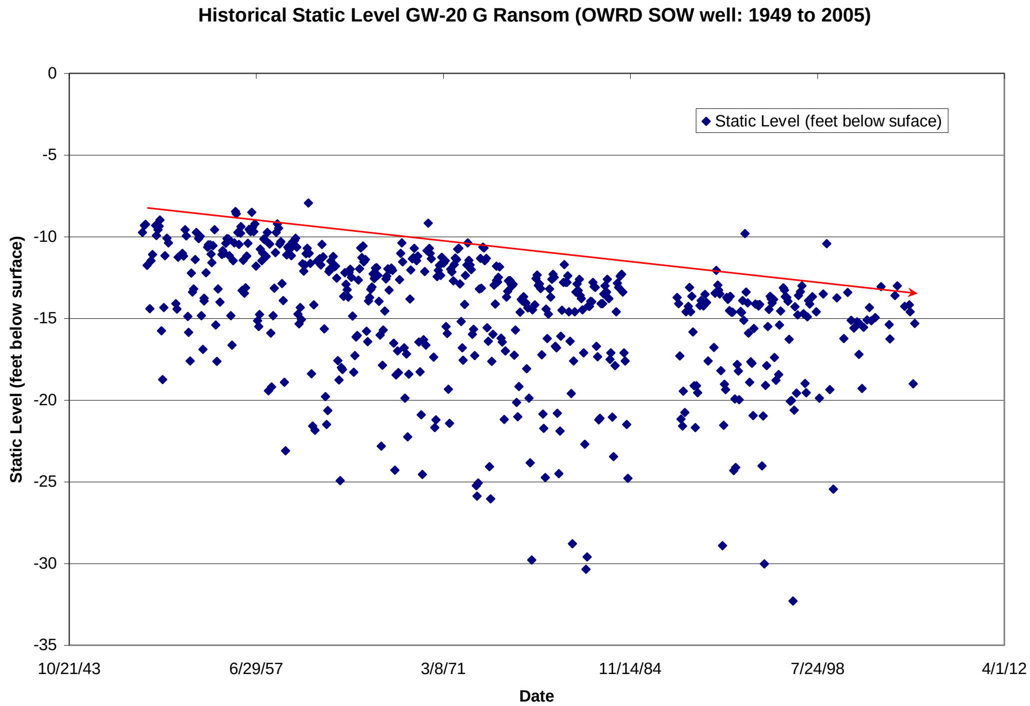


Figure 8. Depicting drop in aquifer at observation well next to Walla Walla River.

alarming because it is in an area near the Walla Walla River channel where considerable flow losses to the aquifer through the porous channel bottom is known to occur. Therefore, even with a steady source of recharge water available, aquifer level appears to be declining. This well location also sits on the geologic arc or contour of the 'inner zone springs'. Consequently, water level changes seen in it may provide insights into conditions expected within this zone of springs.

The well with one of the longer periods of record is SOW #853 (McKnight Well). It is located approximately 3 miles west, and down gradient from the Walla Walla River and Little Walla Walla River distributary system (**Figures** 7 and 9). The primary sources of recharge for this well generally are thought to include seepage from the Walla Walla River, the Little Walla Walla River, irrigation ditches and flood irrigation. This well demonstrates a characteristic found in nearly all of the historically hand-dug wells[6] in the Walla Walla River valley; alluvial aquifer water levels have dropped below the base of the well which was once productively producing water from the upper few feet of that aquifer. By 2001, this well was dry nearly year round with very little recovery during the winter-spring freshet period.

[6] Hand dug wells originally dug and utilized starting in the late 1800s. A typical design was a 6' x 6' hole, hand dug down to approximately 25-60 feet below ground surface. Water was originally extracted using a rope, pulley and bucket but later as combustion and electric water pumps became available, they were used to provide water for irrigation and domestic purposes. The WWBWC field staff, through working with numerous well owners around the valley, that a majority of these wells have been either outright abandoned, re-drilled deeper using casing and/or back filled all due to them having gone partially or completely dry.

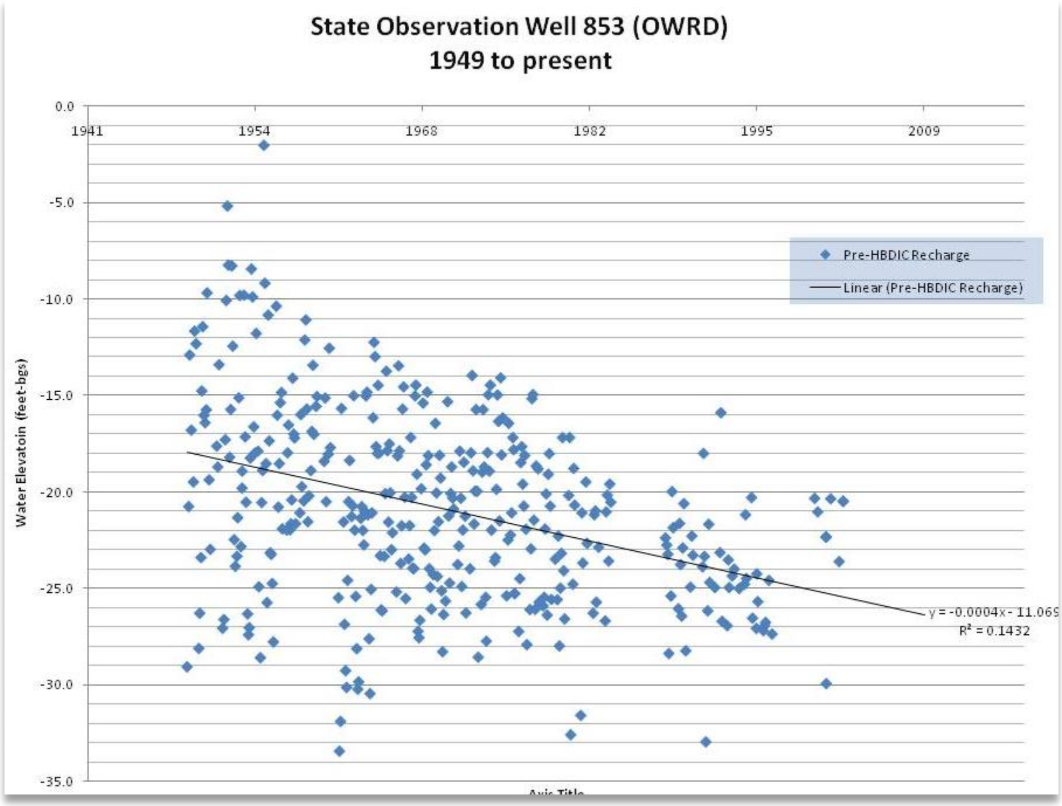


Figure 9. Oregon State Observation Well (SOW 853 – WWBWC #GW-17) showing historic declines of shallow aquifer water table.

Complementing the observation well data is the information provided by surface flow data collected at numerous springs across the Walla Walla River valley. Originally surveyed and measured by the USGS (Piper, 1933; Newcomb, 1965) these springs provide an excellent surficial indication of status of subsurface water supplies. In the early 1930s, Piper described these springs as a *"…integral part of the natural drainage system of the alluvial fan"* and likened them to *"the spillway of a reservoir, for they are supplied by overflow from the ground-water reservoir in the permeable alluvium… Consequently, the yield of the springs measures the decreased transmission capacity of the young alluvium."* (Piper, 1933)

He went on to note that well before his work in the 1930s, there were problem areas being identified with "*springs at the east end of the inner zone (Big Spring area) has decreased in the last 10-25 years.*[7]*"*, putting the start of the decline of the system somewhere around 1900. He also confronted the continuing debate that the springs were simply a product of up gradient water management practices such as flood irrigation by carefully noting: *"The regimen of the springs may well have been influenced in historic time by irrigation on the alluvial fans and flood plains but the springs were not created by that irrigation."* (Piper, 1933)

[7] The Big springs may have gone done due to more water being diverted to the East and West Prongs of the Little Walla Walla River, since the mainstem or Tum-a-lum Branch was used mainly in the winter for a flood control channel.

Walla Walla valley spring systems generally occur in two areas, the Little Walla Walla River and the Mill Creek– Yellowhawk Creek systems. The focus of this report is on the area Piper termed the "inner zone" where more than 30 springs occur on a contour-arc across the Walla Walla River alluvial fan near Milton-Freewater, Oregon (**Figure** 10). The hydrogeology created by a combination of geologic events, alluvial sedimentology and variation in hydraulic conductivity play significant roles in determining where and why these springs emerge.

Many of these *inner zone* springs are still flowing today, although their output has decreased significantly over the years. Piper measured these springs during his work in 1932-1934 which was continued until the early 1950s by the state of Oregon. Newcomb (USGS, 1965) contrasted Piper's measurements to that of his own and concluded:

"Under the natural and irrigation recharging of the 1930's and 1940s about 50,000 acre-feet of water passed through the gravel unit and flowed from the outlets during the average water year. Water diverted by pumping from wells has modified this formerly normal discharge as have changes in the recharge resulting from irrigation and other water regulation practices." (Newcomb, 1965)

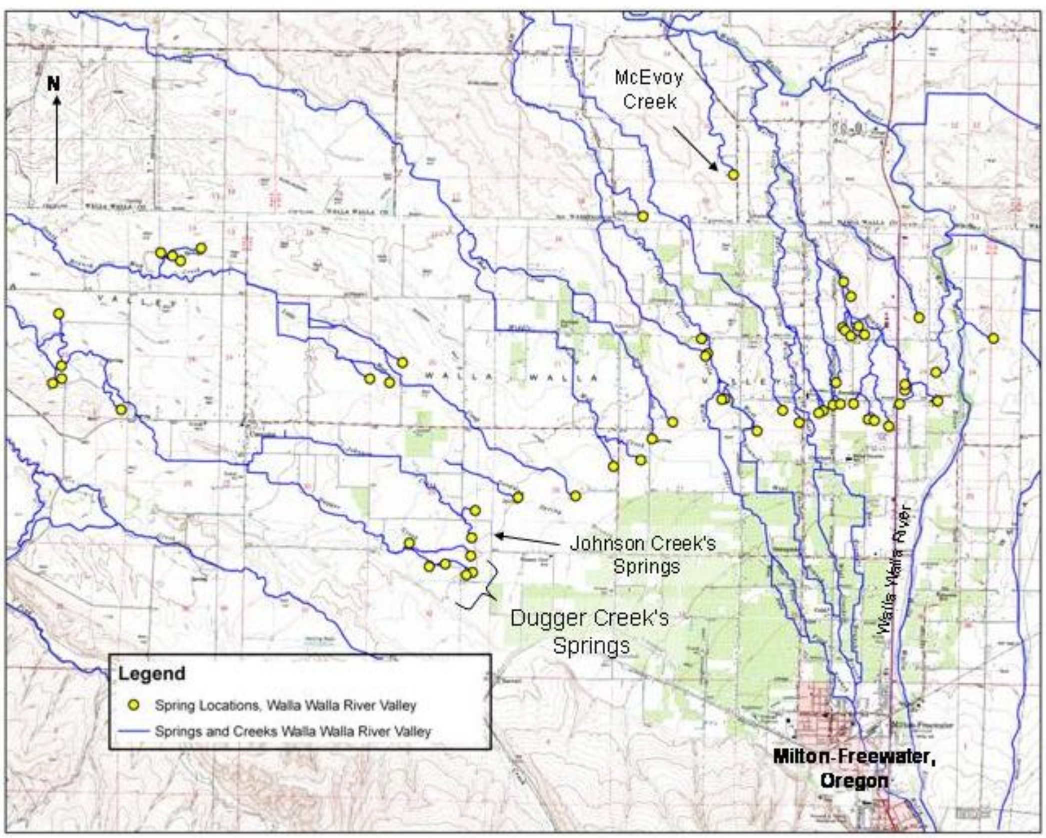


Figure 10. Map of Walla Walla River system spring-creeks (Oregon only), showing the basic distribution of the inner zone.

Starting in 2001, the WWBWC-Oregon State University Research team field surveyed these springs and set up flow monitoring stations at or as close as was feasible to where Piper had originally measured them. While the story tends to be the same across the inner zone spring system, the McEvoy Spring (just north of Washington/Oregon Stateline) is representative of their general degraded conditions. Measuring near the exact location measured in the 1930s, flows now represent a fraction of their historic averages (**Figure** 11). Also note the seasonal pattern of historical flows in McEvoy creek which are related to upgradient changes in irrigation water management and Little Walla Walla River flows.

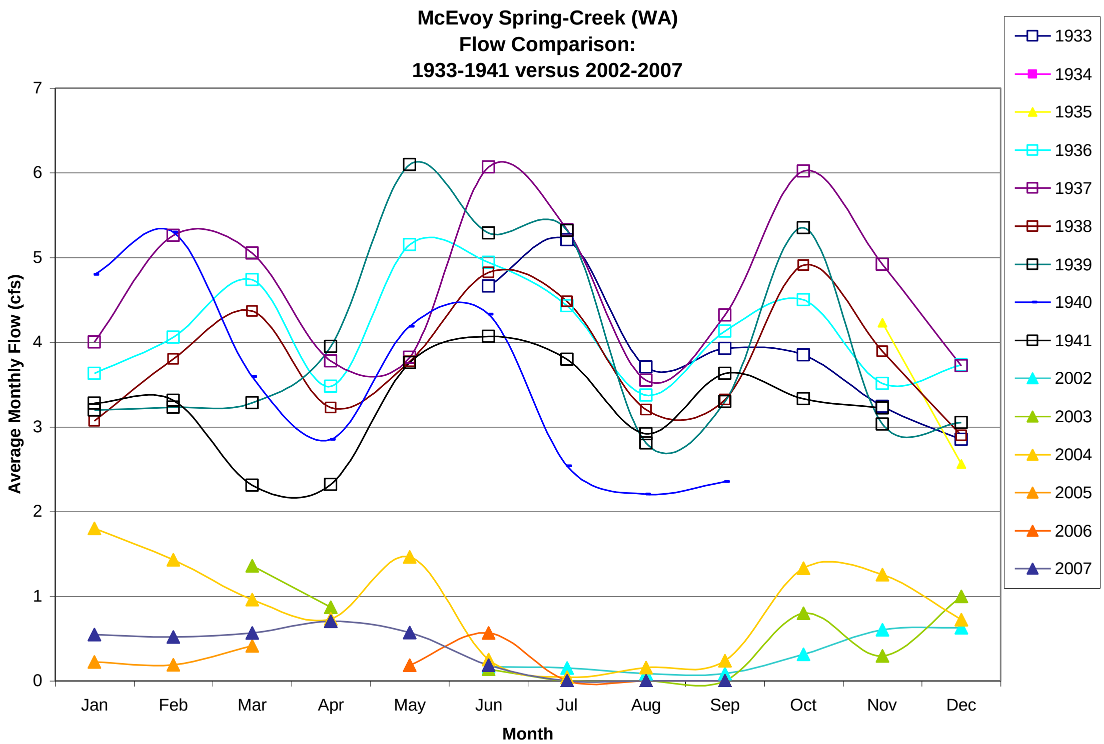


Figure 11. Historic versus Current Flow monitoring on McEvoy Spring Branch, tributary to the Walla Walla River

As of 2009, McEvoy Creek is often dry for a significant portion of the year. A local farmer and member of the Native Creek Society, Tom Page[8] was born, raised and still farms next to McEvoy Creek, and has publicly spoken many times about as his youth and being able to swim, fish for trout and irrigate out of the stream. Tom Page has worked to document the history of McEvoy Creek and many of the other valley spring-creeks providing some historical context to the loss of these natural resources.

"The namesake of McEvoy Spring Branch was John McEvoy. John McEvoy was married to Flora McBean, the daughter of William McBean. William McBean settled in the Walla Walla Valley in the 1840's when he worked for the Hudson's Bay Company. He was the Clerk in Charge at Fort Walla Walla at the time of

[8] Tom Page is the co-founder of the Native Creek Society, has led a riparian and stream morphology restoration project and is operations lead for the McEvoy Spring Creek Aquifer Recharge Testing project.

the Whitman Massacre in 1847. When he retired from Company service in 1851 he filed for a Donation Land Claim (#39), one of a handful in the Walla Walla Valley. It is interesting to note where he staked the boundaries of his claim, a mile square and 640 acres. His reasoning must have been to encompass the most possible water resources within its boundary." (Page, 2007)

Moving west on the contour-arc of the Walla Walla River springs and further from the major sources of recharged water; the flow volume situation gets significantly bleaker. Dugger Creek which is fed by springs that are the furthest west on the inner zone was measured in the early 1930s to be between 8-10 cfs through the summer season (USGS/OWRD data). The Dugger Creek drainage is now an area of high tension among water right holders due to what little irrigation season flows remain. Recently the WWBWC set up a gauge station directly at the site that Piper measured the 8-10 cfs, and in early July 2007 measured 2.1 cfs but by month's end the creek was completely dry.

Through the history of the Walla Walla basin there have been significant changes to the mechanisms that control both sides of this storage balance. Natural recharge has been altered in a number of ways, one of which is the historical manipulation of the streams and river's channel shapes and structures (**Figure** 12). Historically rivers were channelized for flood control structures, to increase agriculturally productive areas, and to allow for structures such as bridges and roads to be built. These actions while providing community benefits also resulted in rivers and streams that were shorter in length which in turn decreased the amount of resident-time that water was in the basin and available for recharge via channel bed infiltration. Additionally for decades the federal and states governments actively promoted the draining of wetland areas to increase agricultural production which also acted to reduce the recharge potential by decreasing the residence time water had in the basin.

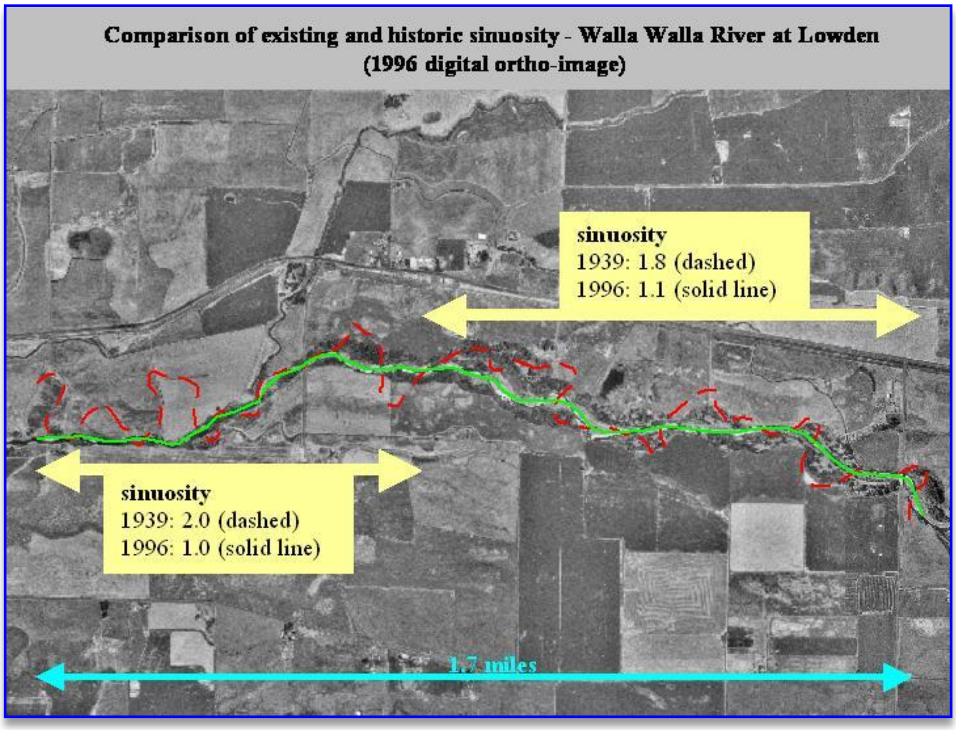
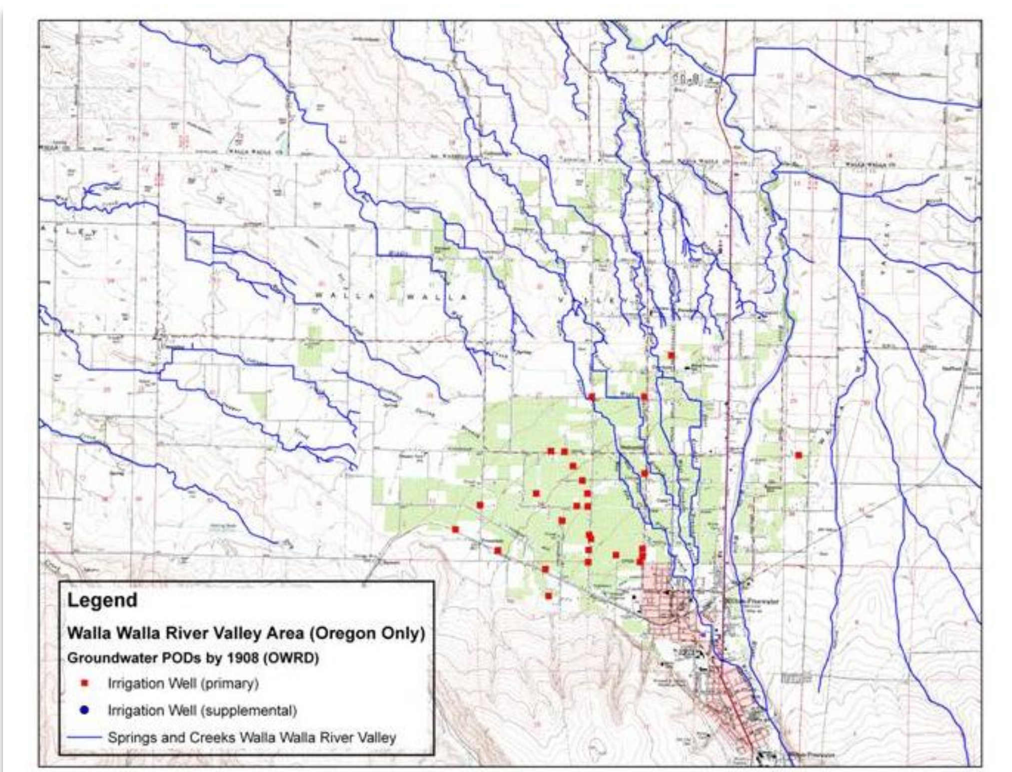


Figure 12. Comparison of the Walla Walla River meanders from 1939 to 2006 (ODEQ, 2006)

As irrigated agriculture became more prominent in the valley, the addition of lateral ditch systems and irrigation practices such as flood or rill irrigation acted to increase the recharge side of the balance. The USGS recently published a regionally relative report titled; *Estimates of ground-water recharge to the Yakima River Basin Aquifer System, Washington, for predevelopment and current land-use and land-cover conditions*.(USGS, 2006) In this report they quantified through modeling, the additional water contributed historically by irrigated agriculture to the groundwater storage balance. They estimated approximately a 38% (from 3.9 to 5.1 Million acre-feet) increase in recharged water entering the Yakima River aquifer from irrigation to that of pre-irrigation conditions. Therefore in the Walla Walla basin the expansion of irrigated agriculture has most likely added to the 'recharge' portion of the equation which has helped in part mediate for the dramatic increase in discharge or water use from the aquifer.

During the same period that irrigated agriculture was increasing the quantity of water being applied, the development of the aquifer's groundwater was taking place thus, increasing the discharge side of the storage balance (ΔS_G). Starting in the early 1900s, water wells were dug throughout the Walla Walla River valley for domestic, agricultural, municipal and industrial uses. Oregon Water Resource's Water Rights Information System (WRIS) database and Geological Information System (GIS) shows the numerous points of diversion (surface or groundwater) throughout the Oregon portion of the Walla Walla Basin, a significant majority of which are located in the Walla Walla River Valley.

Focusing specifically on Oregon's portion of the shallow aquifer, a WWBWC analysis of OWRD's WRIS GIS[9] database indicates that there are more than 650 permits[10] for irrigation wells with water rights totaling approximately 360 cfs, in the study area._Mapping this GIS information[11], **Figure** 13 (A, B, C, D) shows the historical progression of groundwater development in the Oregon portion of the shallow aquifer from 1908 to present. By 1908 primary irrigation wells were being permitted in the Walla Walla valley (**Figure** 13 A). About the time of the first hydrogeologic study of the basin (Piper, 1933), there was already a significant number of wells in the orchard area around Milton-Freewater (**Figure** 13B). When Newcomb was finishing his assessment, and Barker-McNish were starting their modeling project (USGS, 1976) permits for supplemental water rights, those used when the primary source (surface or groundwater) is no longer available due to lack of water, were becoming more prevalent for groundwater (**Figure** 13 C). And by December 31st, 2005, the permits for groundwater use had moved to all areas of the shallow aquifer system (**Figure** 13D).

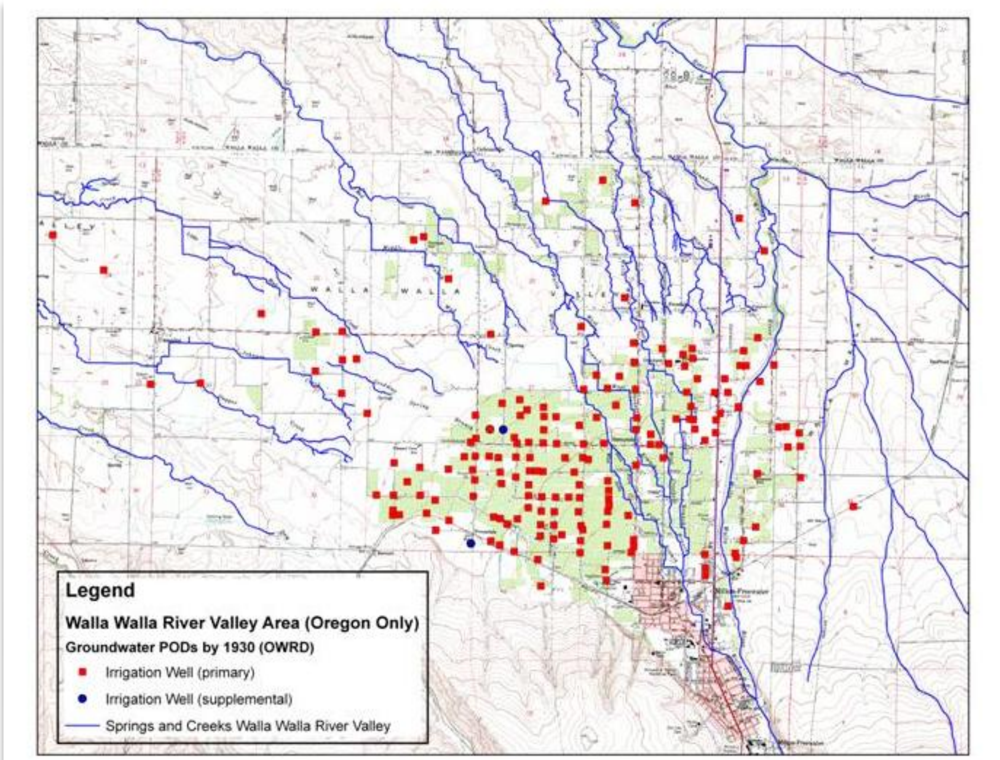


A. 1908

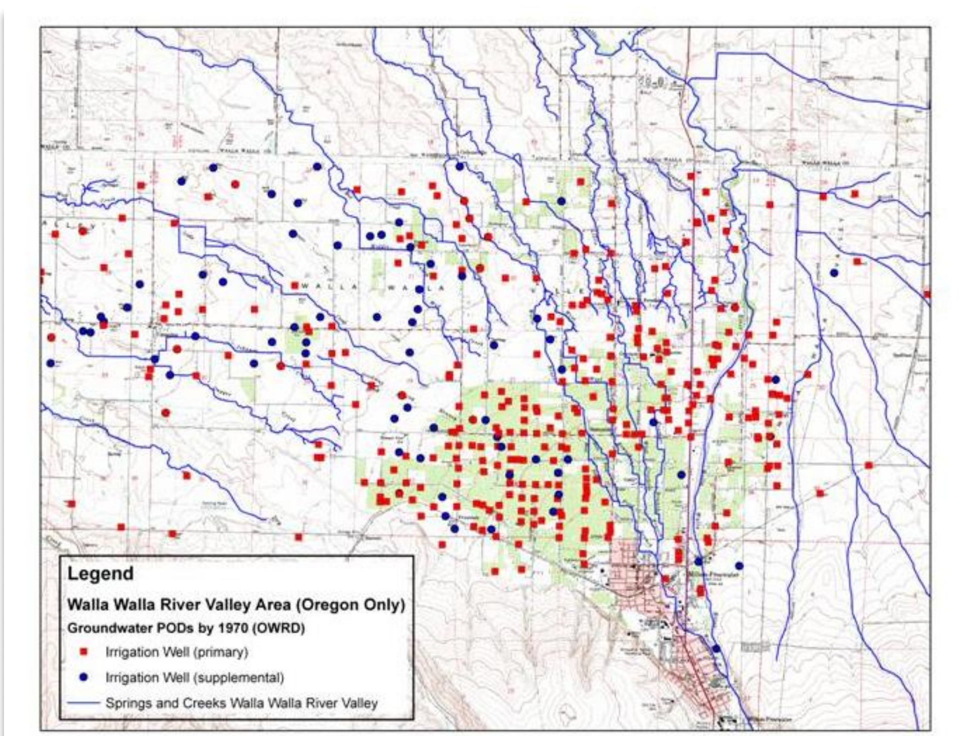
[9] http://www.wrd.state.or.us/OWRD/WR/wris.shtml

[10] Included in this data were wells cased into the confined, basalt aquifer system.

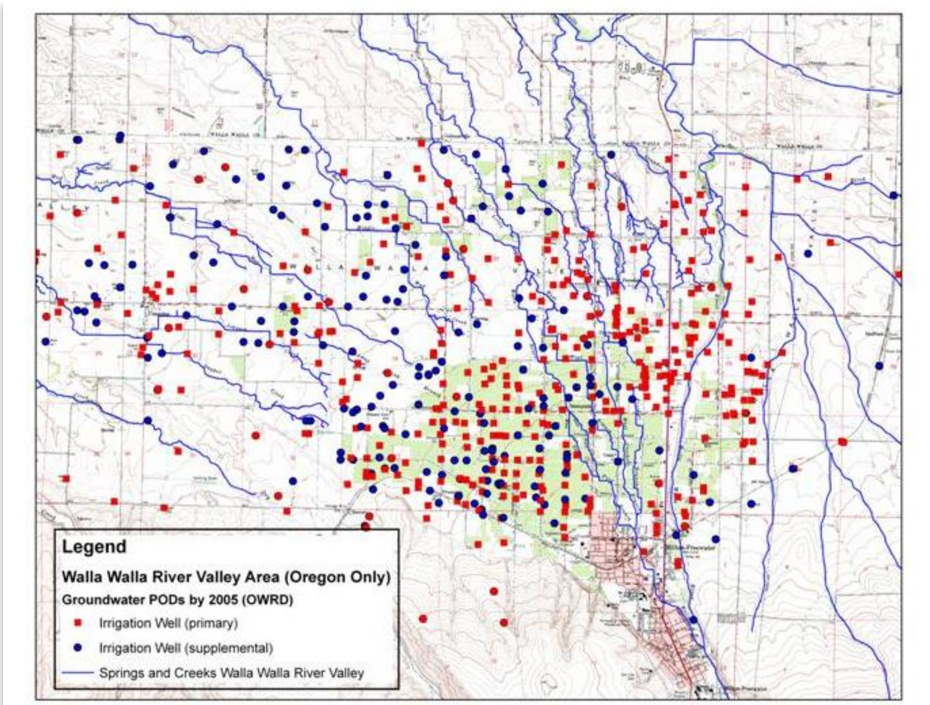
[11] Utilizing the GIS defined points of diversions and sorting them by priority date, a historical sequence of irrigation wells (water use codes IC, IS) was done by the WWBWC. Permits shown include those for wells drilled into the basalt, and do not include the exempt wells discussed by Wozniak.


Legend
Walla Walla River Valley Area (Oregon Only)
Groundwater PODs by 1930 (OWRD)
Irrigation Well (primary)
Irrigation Well (supplemental)
Springs and Creeks Walla Walla River Valley

B. 1930


Legend
Walla Walla River Valley Area (Oregon Only)
Groundwater PODs by 1970 (OWRD)
Irrigation Well (primary)
Irrigation Well (supplemental)
Springs and Creeks Walla Walla River Valley

C. 1970



D. 2005

Figure 13. (A, B, C, and D) Historical Progression of Groundwater Development - Oregon: 1903-2005 (WRIS Data, 2006)

Therefore the history of shallow aquifer development along with the surficial changes in water management has lead to dramatic changes to the shallow aquifer's water balance. The summation of these changes reflected in the historical groundwater levels and spring flows show a surface-groundwater system in decline.

What is Managed Aquifer Recharge?

In the western United States, managed aquifer recharge or MAR has been used for decades as a tool to help resolve water management issues. Three of the most common applications of recharge are for subsurface water storage and retrieval, offsetting salt water intrusion issues in impaired coastal aquifers, and mitigating for groundwater pollution issues. The objective of MAR is to capture and store available water into underlying aquifers and in the case of aquifer storage and recovery (ASR) retrieve that water for use when surface water is scarce. Some of the most common methods used to 'artificially' recharge groundwater are things such as engineered spreading basins, direct well injection and the use of streams and irrigation ditches as surficial water infiltration systems.

Water managers in many parts of the world have proven it to be cost effective way to capture and store water for these and many other water management needs. Significantly lower costs, land availability, and surface associated environmental concerns have made it an attractive alternative to more conventional water management tools such as dammed surface reservoirs and desalination plants. In response to this growing demand the American Society of Civil Engineers has established a standardized set of guidelines for aquifer recharge for use as a water management tool in its publication titled *Standard Guidelines for Artificial Recharge of Groundwater* (ASCE, 2001). This publication gives a good general overview of the specific engineering, societal, and watershed planning issues associated with aquifer recharge and is an excellent place to start for those new to the field.

In the western United States two of the most prominent recharge projects occur in Orange County, California and in the Phoenix, Arizona metropolitan area. In southern California, Orange County Water District (OCWD) supplies water to millions of patrons via aquifer recharge and their renowned 'Groundwater Replenishment System[12] (**Figure** 14 and 15). In the technical circles of aquifer recharge, OWCD is often referred to as leaders in the application of aquifer recharge in the US, and many municipalities and other interested parties have toured and even trained with the OCWD staff to learn how they apply and maintain this tool for water management applications.

Their recharge program plays a large and critical role in supplying water on a year-to-year basis for their ever growing population:

"*Groundwater reserves are maintained by a recharge system, which replaces water that is pumped from wells. OCWD's facilities have a recharge capacity of approximately 300,000 acre-feet per year. About two million people depend on this source for more than three-quarters of their water. Groundwater producers (city water departments and other local agencies) pump water from the groundwater basin and deliver it by pipeline to consumers.*[13] *(OWCD)*

While they have more than 9 separate recharge facilities, one of the largest are some former gravel pits that were converted into an aquifer recharge facility and "*currently recharge up to approximately 120 to 140 cubic feet per second (cfs) when full*."[14]

[12] http://www.gwrsystem.com/about/background.html
[13] http://www.ocwd.com/_html/recharge.htm
[14] http://www.ocwd.com/_assets/_pdfs/_rfp/SantiagoCreekInitialStudy.pdf

Figure 14. Anaheim Lake, one of OCWD's *recharge basins* (Courtesy of OCWD website)

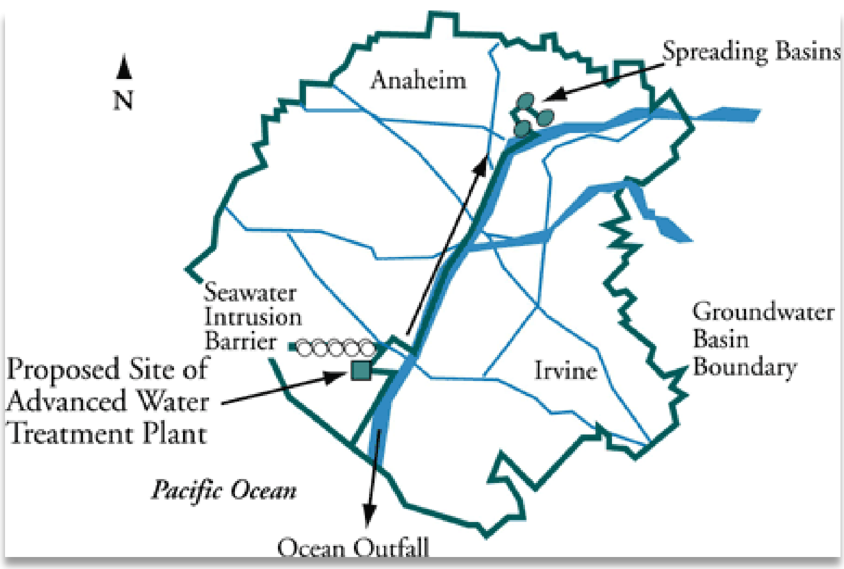


Figure 15. Map of OCWD's "Groundwater Replenishment System" (Courtesy OWCD website)

In the Phoenix Arizona metropolitan area aquifer recharge is also considered a critical component to its current and future water management planning needs. The Central Arizona Project or C.A.P.[15] project utilizes Arizona's allocation of Colorado River water (according to the multi-state, Colorado River Compact) to supply more than 1.5 million acre-feet annually to this region. Currently Arizona is not exercising its full allocation of Colorado River water rights. The unused portion which is in excess of 460,000 acre-feet annually is going to a multiple spreading basin aquifer recharge program, storing it for future use. The CAP program refers to aquifer recharge as playing:

[15] http://www.cap-az.com/index.cfm

"Recharge is a long-established and effective water management tool that allows renewable surface water supplies, such as Colorado River water, to be stored underground now for recovery later during periods of reduced water supply."[16]

During August 2006, the WWBWC staff hydrologist participated in a tour of two CAP recharge projects just outside of Phoenix (**Figure** 16). A CAP hydrogeologist and project manager provided informative demonstration of projects whose geologic and hydrologic settings were similar to those experienced in the Walla Walla basin. This information has proven useful in the continued refinement of our local design efforts of this tool and application for our current water management issues.

Figure 16. August, 2006, WWBWC staff toured the Aqua Fria Recharge Project outside Phoenix Arizona (Courtesy C.A.P. website)

Locally MAR was first explored in the 1970s by the City of Walla Walla who began testing and implementing a direct injection Aquifer Storage and Recovery (ASR) program. This program stores water in the basalt aquifer during the high flow portions of the water year and then reclaims the water during the high demand summer season.

The list of national and international water programs that feature aquifer recharge as one of their management tools is extensive and too numerous to cover in this report. Setting up a system that complements and enhances the other water management strategies for the Walla Walla basin is merely a matter of designing and collaborating to find better ways to store water. With a better understanding of MAR application elsewhere, we can begin to discuss the water issues facing the basin and its intended application in solving those problems.

[16] http://www.cap-az.com/static/index.cfm?contentID=81

Managed Aquifer Recharge – Not a New Idea

From these early assessments documenting the decline of the aquifer and associated springs artificial aquifer recharge was considered early in the assessment process as it was recommended by the USGS in 1965. R.C. Newcomb's' report titled *Geology and Ground-Water Resources of the Walla Walla River Basin Washington-Oregon* (USGS, 1965) is considered to be one of the most comprehensive assessment of the Walla Walla basin's water resources. R.C. Newcomb, who was highly respected in his time, had worked extensively in the arid American west assessing the geology and hydrology of many hydrologic systems. He was an early proponent for using our understandings of subsurface geologic features to store and manage water resources. Before coming to the Walla Walla basin, he had worked elsewhere in the Columbia basin and published a series of studies, one of which was titled: *Storage of ground water behind subsurface dams in the Columbia River basalt, Washington, Oregon, and Idaho, by R.C. Newcomb* (USGS, 1961), demonstrating his innovative approach to finding cost effective ways of better managing water. For the Walla Walla basin he observed:

"Some initial tests at artificially recharging the gravel aquifers by placing excess surface water into gravel pits and onto unused gravelly fields have reportedly helped raise temporarily the water level in wells of their vicinities. A comprehensive plan for the systematic management of the old gravel as a water reservoir is an obvious need that will surely come about ultimately. Such a comprehensive plan and systematic management will need to include all phases of natural and artificial recharge in order to obtain maximum benefits from this important natural water-storage facility."(USGS, 1965)

It was from Newcomb's early discussion of the potential of aquifer recharge that led the WWBWC and HBDIC to begin testing this tool. Additional interest was generated when further investigation revealed that there were other projects in the western United States (as discussed earlier) that had proven track records in recharge. Starting in 2003, a series of grants from the Oregon Watershed Enhancement Board (OWEB), the Walla Walla Watershed Alliance (WWWA) and in-kind contributions from the Hudson Bay District Improvement Company (HBDIC) allowed for the first successful limited testing license application, and subsequent installation and operation of the Hudson Bay Aquifer Recharge Project. The following sections will discuss the issues associated with aquifer recharge, the HBDIC project results to date, and aquifer recharge potential as a water management tool.

PART II. THE HBDIC ALLUVIAL AQUIFER RECHARGE PROJECT

Testing Managed Aquifer Recharge: HBDIC Site Operations and Monitoring (2004-9)

The Hudson Bay District Improvement Company (HBDIC) partnering with the Walla Walla Basin Watershed Council (WWBWC) sought and secured grant funding to test aquifer recharge starting in 2003. This project has been successfully operated for 6 recharge seasons and has been the main focus of the testing of MAR in the Walla Walla basin. This section reviews the results collected from the 2004-9 testing and helps provide the reader with a sense of how and what is monitored when testing MAR. There are two primary testing areas at the HBDIC Recharge Site; the spreading basins and the infiltration gallery testing areas. While the spreading basins have been operating since 2004, the infiltration galleries are relatively new being built during the 2008-9 recharge season.

To understand the application of aquifer recharge, hydrogeologic information about the aquifer-river system in the Walla Walla basin must be reviewed. For the purposes of simplification, this discussion focuses on the upper portion of the alluvial aquifer system, which is that portion of the alluvial system where groundwater is generally unconfined and hosted by gravelly strata. The basalt aquifer system will not be included in this discussion as its connection to surface water likely is minimal within the Walla Walla Basin (GSI, 2007). The deeper alluvial system also will not be discussed as it is at least semi-confined, hosted in and below extensive clayed strata, and probably has limited continuity to surface waters.

One of the first orders of business in defining the hydrogeology is to map the subsurface geologic features that influence the aquifer of interest. This subsurface mapping, sometimes referred to as hydrostratigraphic mapping, provides a three-dimensional, spatially-relevant description of the various layers (lenses, beds, formations) that comprise, or host, the aquifer system. Originally mapped by Newcomb in 1965, the alluvial aquifer system in the Walla Walla Basin generally is found within a mix of older river deposited (alluvial) clay, silt, sand, and gravel from the Blue Mountains, Missoula cataclysmic flood deposited silt and sand, and wind-blown loess.

The shallow or alluvial-aquifer system for our study area is present within a topographical depression, roughly triangular in shape bounded on the east by the Blue Mountains, the south and southwest by the Horse Heavens Hills, and the north and northwest by the Palouse slope. This alluvial aquifer system generally slopes from east to west, down the length of the Basin. The sloping aquifer receives most of its recharge from the Walla Walla River and Mill Creek drainages, although additional flow enters via the other smaller tributary drainages and through the subsurface. The water table gradient is generally east to west and its general movement is depicted in **Figure** 17. The basin has what we refer to as down gradient 'pinch point' through which surface water and groundwater eventually moves through. This point lies where the Walla Walla River crosses basalt outcrops at the base of Nine Mile Hill. The alluvial aquifer generally is considered to be *unconfined*, which means that it is open to receive water from the surface; and whose water table surface is free to fluctuate up and down, depending on the recharge/discharge rate. This condition is more prevalent in the upper portions of the valley and grows less so the further down gradient and west you move through the system due to increasing proportion of finer grained alluvium.

In 2007, utilizing funding from the Washington Department of Ecology and Oregon Watershed Enhancement Board, GSI Water Solutions Inc. completed a hydrostratigraphic mapping project of the Walla Walla River valley alluvial aquifer system (GSI, 2007). Five basic hydrostratigraphic units were defined and mapped in the alluvial aquifer system. All of these are sedimentary strata (e.g., clay, silt, sand, and gravel lithologies) overlying basalt bedrock, and sometimes referred to as the suprabasalt sediments. The five suprabasalt sediment units mapped for this project are the: (1) Quaternary fine unit, (2) Quaternary coarse unit, (3) Mio-Pliocene upper coarse unit, (4) Mio-Pliocene fine unit, and (5) Mio-Pliocene lower coarse unit. The terms Quaternary and Mio-Pliocene refer to geological time periods, Quaternary representing from 2 Million years ago till present, and the Mio-Pliocene referring to the late Pliocene through the Miocene periods (10.5 to 3.5 Million years ago). The younger Quaternary sedimentary units are on top of the older, Mio-Pliocene units (**Figure** 18 and 19).

An often used analogy for this alluvial aquifer system is to picture a large, multi-layered, silty, sandy, and gravel-to-cobble filled bath tub, with basalt bedrock acting as the walls and bottom of the tub. The structure contour map of the top of basalt clearly shows the shape of this basalt bath tub (**Figure** 20). This map also depicts the major folds and faults that influence the lateral continuity of the basalt bedrock and the overlying suprabasalt sediments. The degree of hydraulic continuity between the basalt (which hosts a variety of confined aquifers) and the suprabasalt (or alluvial) aquifer system is not well understood.

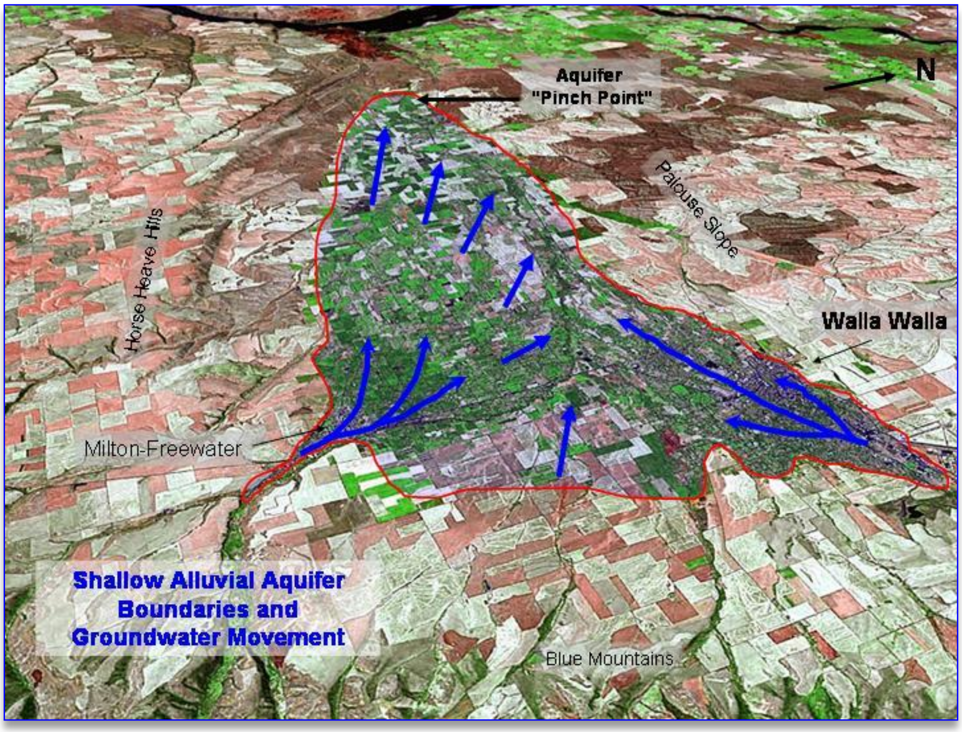


Figure 17. Walla Walla River valley shallow aquifer system.

Water is found in all of the sediment layers comprising the alluvial aquifer system, but it moves easiest through gravelly portions, which are most abundant near the surface. In addition to water moving through the gravel, water is also flowing in and out of it, moving between the gravel alluvial aquifer and water flowing over the surface in the form of rivers, streams and ditches. Because the system is pitched slightly toward the Columbia River, both the surface water and groundwater drain toward it. The thickest of the coarse alluvial hydrostratigraphic units is the Mio-Pliocene Upper Coarse Unit (**Figure** 19). These coarse strata form the primary unit in which alluvial groundwater is found in the Basin. For more information about the specific geologic information on the shallow aquifer please refer to Groundwater Solutions' report: *Geologic setting of the Miocene (?) to Recent Suprabasalt Sediments of the Walla Walla Basin, Southeastern Washington and Northeastern Oregon.* (GSI, 2007).

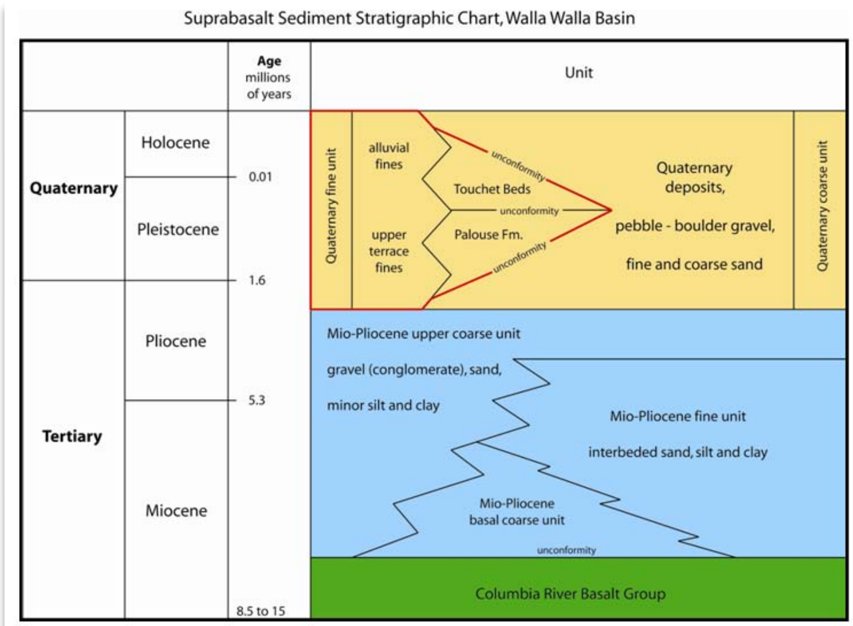


Figure 18 Sediment Stratigraphic Chart of the Walla Walla shallow aquifer units (GSI INC et. al., 2007)

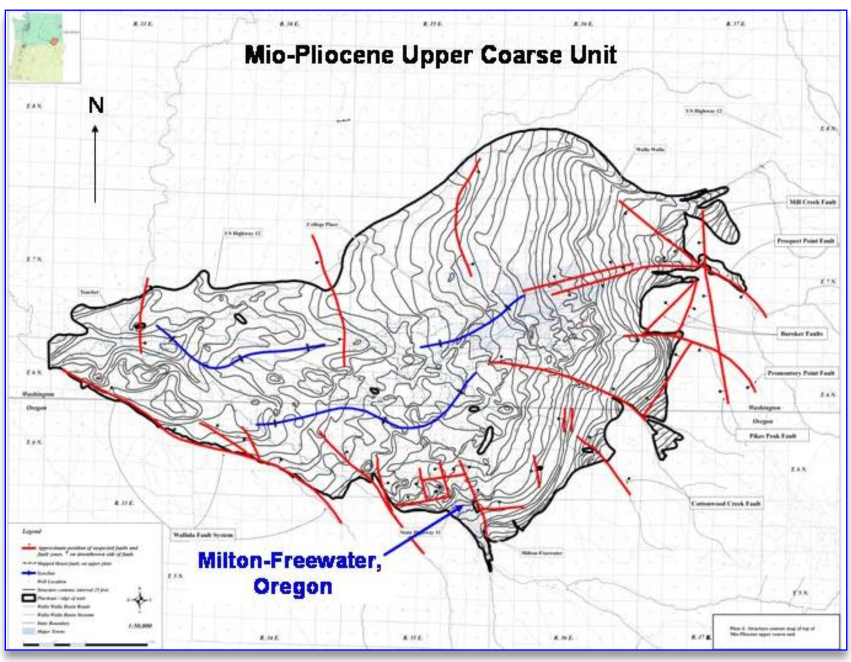


Figure 19. Major sedimentary layer of the Walla Walla River Valley Shallow Aquifer. (GSI, 2007)

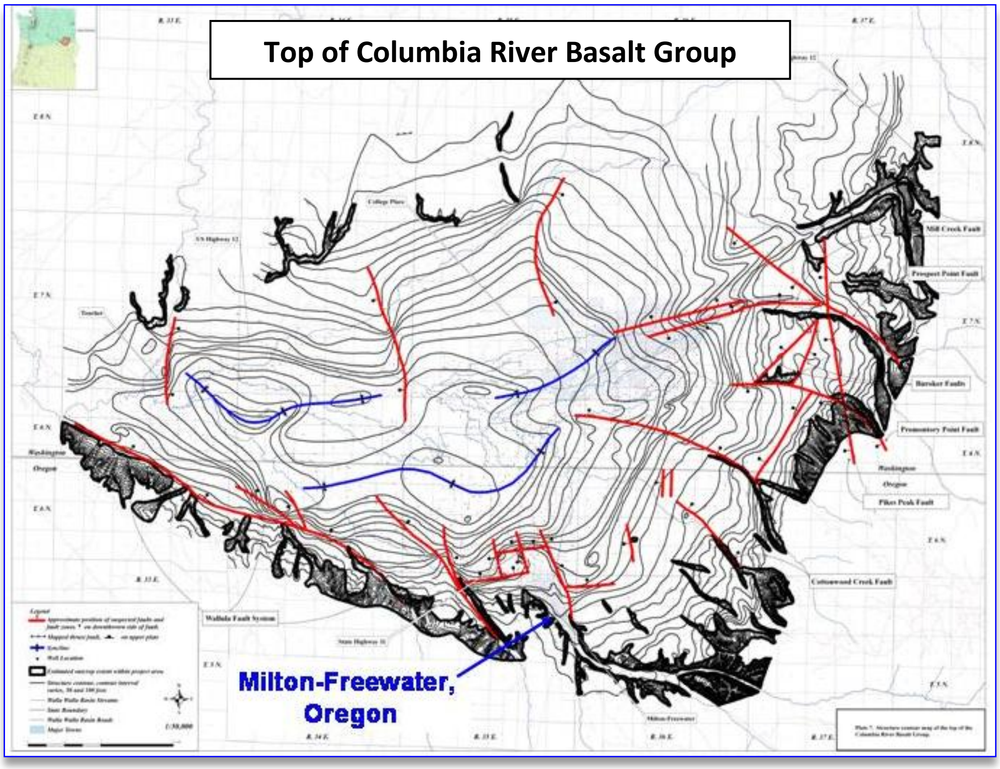


Figure 20. Top of Columbia River basalt, or bedrock boundary for shallow aquifer (GSI, 2007)

Site Specific Hydrogeology and Geology

This section summarizes site specific geologic and hydrogeologic conditions, and is based on fieldwork at the Site and the basin wide hydrostratigraphic mapping presented in GSI (2007). The geologic cross-section in **Figure** 21 was derived from this hydrostratigraphic mapping effort.

The uppermost geologic unit in the Test Site area is a sequence of interstratified silt and sand (Touchet Beds) comprising the Quaternary fine unit. However, at the site itself, these strata are absent and the uppermost unit is the coarse Quaternary unit. The coarse Quaternary unit at the Site consists of basaltic, sandy to clayey, uncemented gravel. Beneath the Test Site, geologic logging during site specific monitoring well drilling showed that these uncemented strata are approximately 20 feet-thick. The basin-wide mapping effort suggests these strata thicken to the west of the site.

Uncemented strata of the coarse Quaternary unit are underlain by the variably indurated (uncemented to cemented) Mio-Pliocene upper coarse unit. Site specific monitoring wells drilled for the project do not fully penetrate this unit. However, basin-wide hydrostratigraphic mapping (GSI, 2007) suggests this unit is approximately 150 to 160 feet thick in the immediate vicinity of the Site. Based on regional trends, interpretations of driller's logs, and our geologic logging of drill cuttings samples collected from recently drilled wells in the general area, the Mio-Pliocene upper coarse unit consists of variably indurated, weakly to moderately cemented, silty to sandy, indurated gravel (conglomerate). This unit is the primary host unit for the alluvial aquifer system in the general vicinity of the Site. The coarse Quaternary unit – Mio-Pliocene upper coarse unit contact was identified using the following combination of criteria:

- A notable change in cuttings color from gray dominated hues to brown and yellow-brown hues
- Presence of cemented sand clasts and sand cemented to pebble and cobble clasts in the cuttings samples
- Increased mud content in the fine fraction of the cuttings
- Generally better air circulation reported by the driller

The functional base of the upper portion of the alluvial aquifer system in the area of the Site is essentially the top of the Mio-Pliocene fine unit. The contact between this unit and the overlying Mio-Pliocene upper coarse unit is predicted to lie approximately 200 feet below ground surface at the Site. Although there will be a degree of hydraulic continuity between these two units, the prevalence of laterally extensive clay and silt lithologies in the fine unit limits this.

The deepest part of the alluvial aquifer system in the Site area is hosted within a locally occurring coarse interval referred to as the Mio-Pliocene basalt coarse unit. This unit differs from the upper coarse unit. It is generally felsic, displaying thin (<10 feet thick) quartz sand layers. It also is saturated and may indeed make a locally productive water-bearing interval. However, the thickness and wide lateral extent of the overlying fine unit is inferred to greatly limit the hydraulic connection of this unit to the upper coarse unit and surface waters.

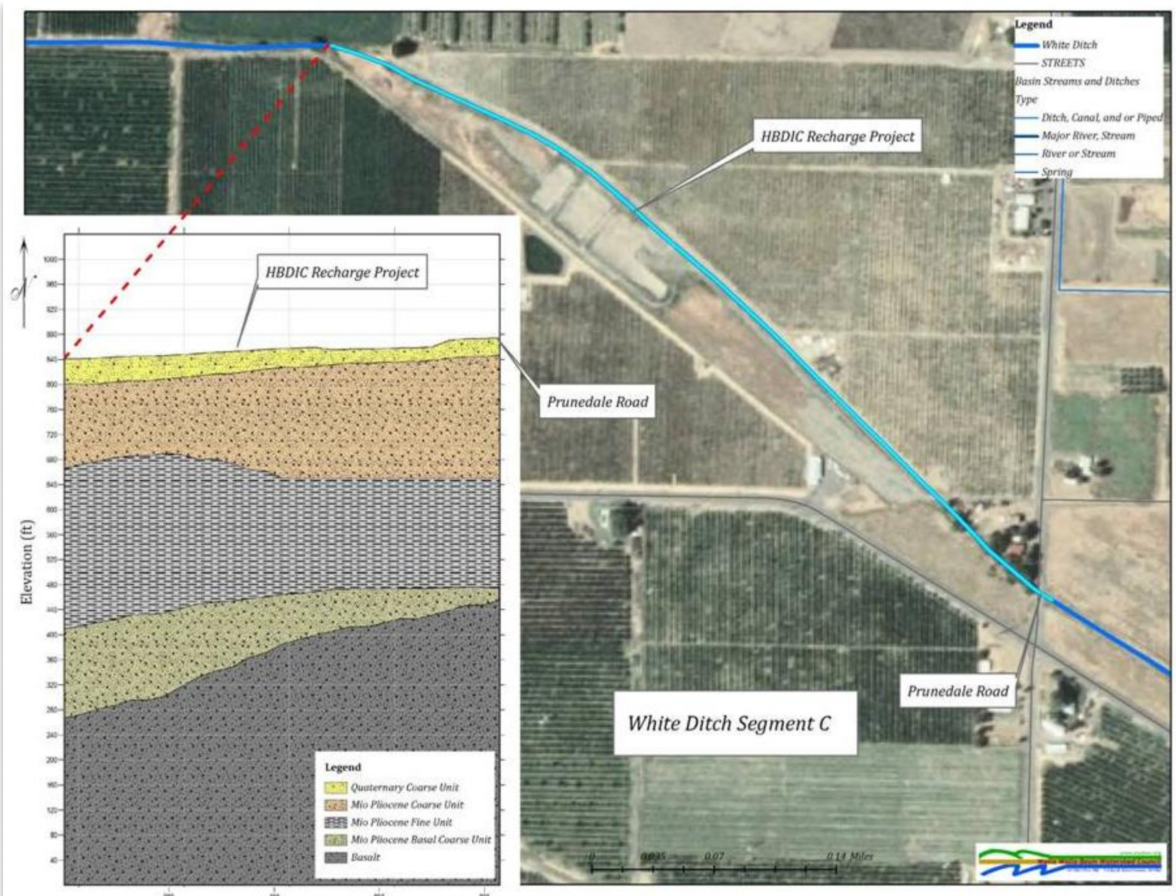


Figure 21. Geologic Transect of White Ditch at HBDIC Recharge Site (Baker T. , 2010)

A number of studies and reports have looked at the hydrologic conditions of the various geologic stratigraphy mentioned above. The most recent work was done by the WWBWC-OSU team as portion of the Integrated Surface Water-Groundwater Flow Model (IWFM) project in 2006-8 (Petrides, 2008). A series of aquifer tests were performed at various times of the year including a 72-hour constant-rate pumping test and a step-drawdown pumping test at observation well #1 (GW-46) on the HBDIC Recharge site. The hydraulic conductivity value from that testing of the upper two layers of the aquifer ranged from 22 – 34 meters/day with a groundwater velocity at approximately 1 meter day. Other estimates of hydraulic conductivity are based on modeling and literature reviews. The USGS estimated values from their modeling exercise (MacNish, 1976) gave ranges (depending on geologic unit) from 4 - 65.84 meters/day. The literature (Bear, 1972) provides values for unconsolidated sand and gravel in 10^1 meters/day with the EPA (EPA, 1986) estimating 27 - 30 meters/day (Petrides, 2008).

The HBDIC Alluvial Aquifer Recharge Site

Overview

Starting in 2004, the HBDIC Recharge site was operated over 6 consecutive seasons. The site began operations in March of 2004 after receiving the OWRD limited testing license (OWRD #LL-758) in

February 2004 and construction being completed as the project was first turned on in March 2004. This first season was unlike the subsequent seasons because the site was being operated even before it was completed. This was mainly due to the HBDIC-WWBWC team wanting to get some aquifer recharge testing completed before the shut off date of May 15th, 2004. From 2005-2009 site construction was done during the winter shutdown period (February 1st onward) or done parallel to the site being operated. The site was expanded twice during this period. The first (2004-5 season) from 0.34 acres to 1.1 acres when the three original 50’ x 100’ spreading basins (**Figure** 22) were expanded, with spreading basin #1 being more than tripled in size. During the 2005-6 seasons, a fourth basin was added bringing the total basin area to 1.4 acres with an average depth between 5’- 7’.

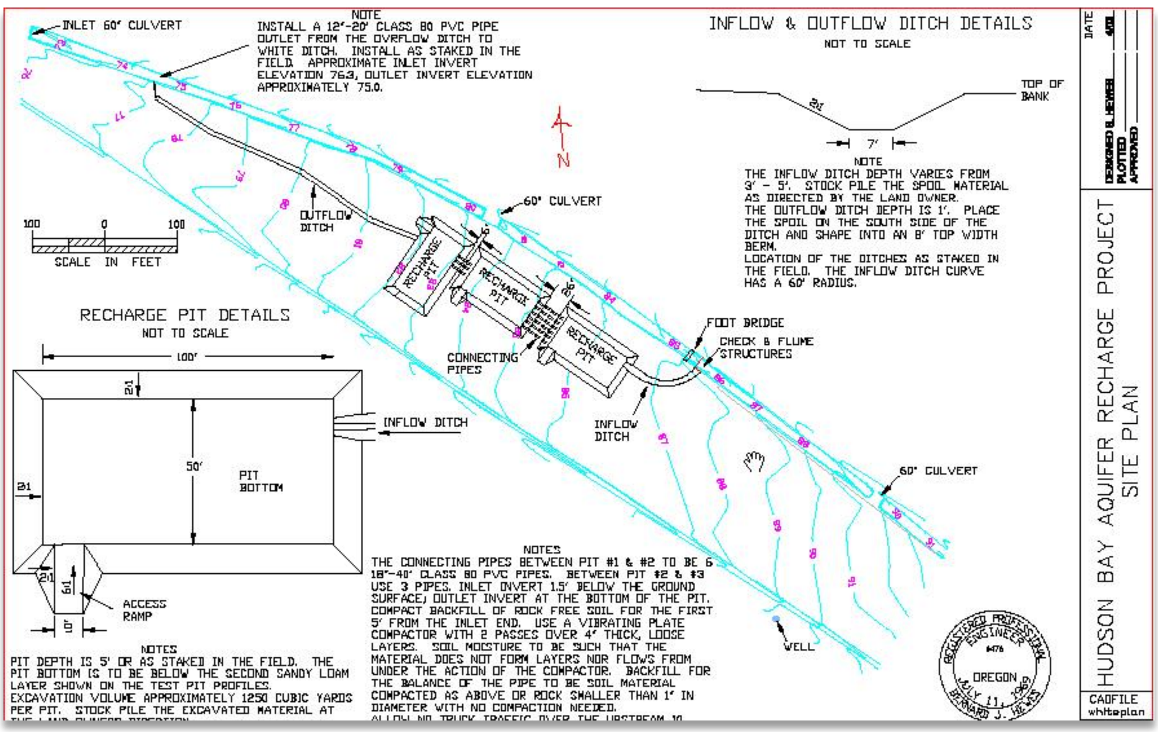


Figure 22. Original HBDIC Site Designs 2003 – Engineering by Bernie Hewes, PE Oregon

The spreading basins were operated successfully for 5 recharge seasons until the summer of 2008 just before the original OWRD limited testing license expired (February 2009). The HBDIC-WWBWC team informed OWRD resources that it intended to submit for a water right for the site through their department, the logical progression after successful limited license testing. Due to limitations in the OWRD Umatilla Basin Rules for the Walla Walla basin restricting aquifer recharge in this portion of the watershed, OWRD put together a Rules Advisory Committee (RAC) during the summer 2008. The Confederated Tribes of the Umatilla Indian reservation voiced concerns over aquifer recharge competing for non-irrigation season flows with a reservoir feasibility study they have been working on with the United States Army Corps of Engineers-Walla Walla (USACE). After several RAC meetings, it was decided that the HBDIC-WWBWC team would request another OWRD Limited testing License whilst awaiting the

CTUIR-USACE team to further work out their feasibility study details. This was applied for during the winter 2009 and received in time to operate the remaining of the 2008-9 recharge season. Since that decision, the CTUIR-USACE are advocating the Columbia River Pumping exchange project instead of the Pine Creek Reservoir, thus removing the potential for a water availability conflict between the two programs. Negotiations between the OWRD, HBDIC-WWBWC and CTUIR-USACE teams will now need to commence during this current limited license in order to allow the HBDIC project to apply for and receive a successful water right. Additionally through the collaboration of the groups mentioned above, aquifer recharge is now included in the CTUIR-USACE feasibility study to help protect and enhance Walla Walla River flows for salmon recovery. Currently no RAC meetings are scheduled but will need to be conducted before summer 2013 in order for the HBDIC site to receive a water right.

Starting in the fall of 2008, a portion of the HBDIC recharge site has been used as a test location for examining and comparing the performance of four different types of shallow aquifer recharge infiltration galleries. This test area is shown in **Figure** 23 below. Many of the local irrigators would like to implement shallow aquifer recharge on their farms, but do not have the space for spreading basins. Subsurface Infiltration galleries are being tested on the HBDIC site as a potential solution. A diagram in Appendix III shows the layout of the four galleries, water turnout, the location of meters, and piezometers to track groundwater responses.

Spreading Basins Operations

The HBDIC site consists of two operating areas, the first being the spreading basins the main focus of this document, with the second area designated for infiltration gallery testing, which will be covered in more detail in a later section. To conduct the recharge testing, the HBDIC project can divert a total of up to 50 cfs (OWRD LL#1059) from the Walla Walla River at the Little Walla Walla Diversion (OWRD # 14012100) during the November 1st through May 15th recharge period. OWRD, in the limited license, established minimum instream flows for the Walla Walla River that must be met at the Nursery Bridge (M-4) gauge (**Figure** 23) downstream of the HBDIC diversion. These minimum instream flows were determined through the OWRD limited testing license process in 2004 in consultation with Oregon Water Resources Department (OWRD), Oregon Department of Fish and Wildlife (ODFW), Oregon Department of Environmental Protection (ODEQ) and the Confederated Tribes of the Umatilla Indian Reservation (CTUIR). Minimum instream flows are only applicable to this project and any other OWRD water right currently diverting water from the Walla Walla River.

Other instream flow agreements such as the one completed under Civil Penalty agreement between the US Fish and Wildlife Service (USFWS) and the three main irrigation districts on the river do not apply to the HBDIC Recharge site Limited License requirements. The minimum instream flows and their applicable diversion periods for the HBDIC recharge site are listed in Table 1.

HBDIC Recharge Site Legal Diversion Periods	Minimum Walla Walla River Flow (cfs)
November 1st through November 30th	65 cfs
December 1st through January 31st	95 cfs
February 1st through May 15th	**150 cfs**

Table 1. HBDIC Minimum Instream Flow Requirements

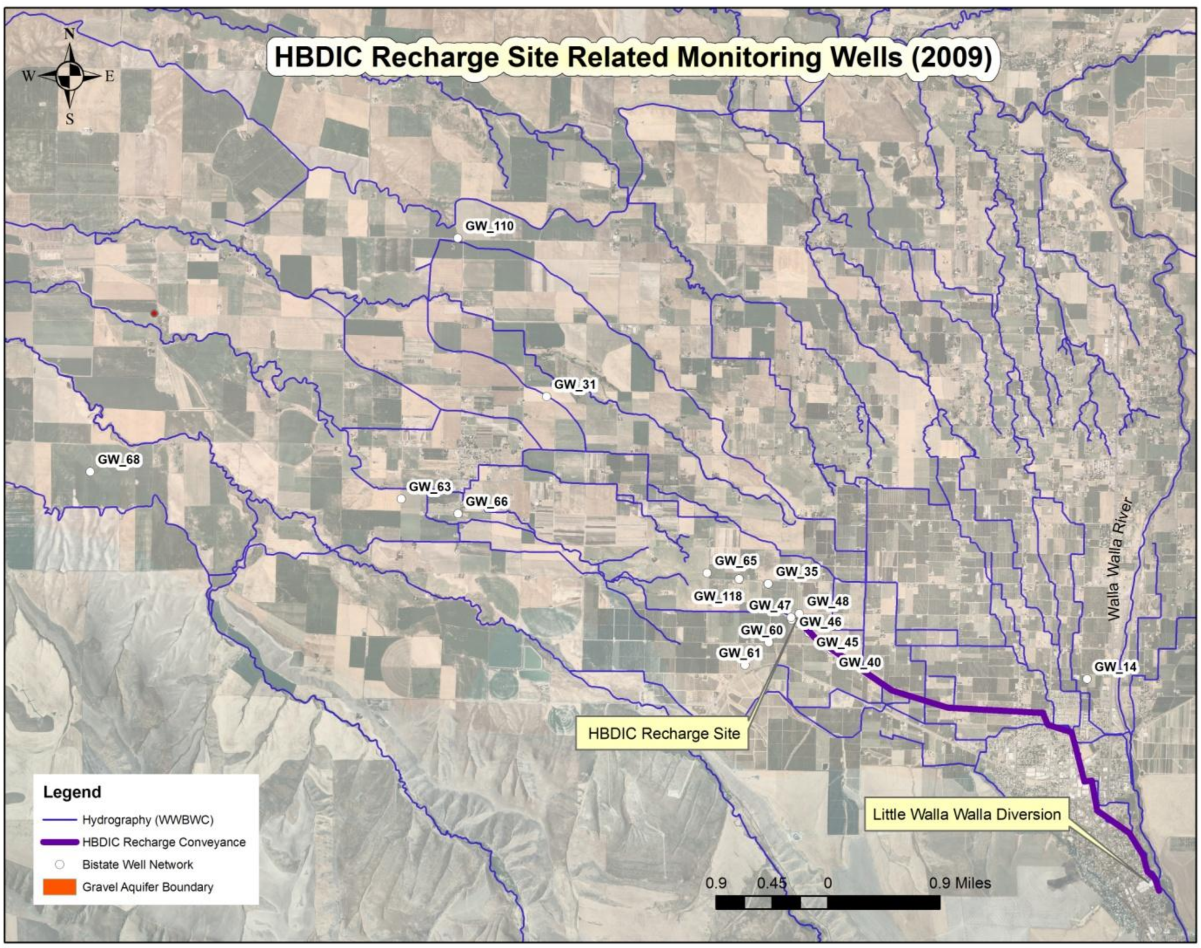


Figure 23. Map of HBDIC Recharge site and Source Water Delivery System

Figure 24 shows the average daily flow volumes for the Walla Walla River compared to those of the Little Walla Walla Diversion and the HBDIC recharge site flows for 2009 water year. Walla Walla

River Irrigation District and Hudson Bay District Improvement Company both divert a majority of their water rights at the Little Walla Walla River site at Cemetery Bridge (OWRD Gauge # 14012100). HBDIC White Ditch diverts water from the Little Walla Walla system at the OWRD HBDIC Gauge (OWRD Gauge # 14012300). The HBDIC recharge project diverts water from the White Ditch based on the instream flow values and other water user's priority as described earlier. HBDIC recharge flows represent only a small fraction of the total flow in the Walla Walla River during the November through May 15th operating period (**Figure** 24).

From the Little Walla Walla diversion, HBDIC recharge water flows to a split in the Little Walla Walla River system called the frog. At the frog HBDIC has an OWRD operated gauge station (OWRD # 14012300) to help monitor and manage their water use off the Little Walla Walla River system. The recharge water then flows into the White Ditch, HBDIC's main canal which flows for about 2.5 miles to the site's intake (**Figure** 25). The water then flows through the project filling the basins SP-1, SP-1B SP-2, SP-3, SP-4 with excessive water tailing back into the White Ditch. The intake and flow between each of the basins is maintained by HBDIC field staff and is controlled using a series of weir boards to control rates of flow in and through the project.

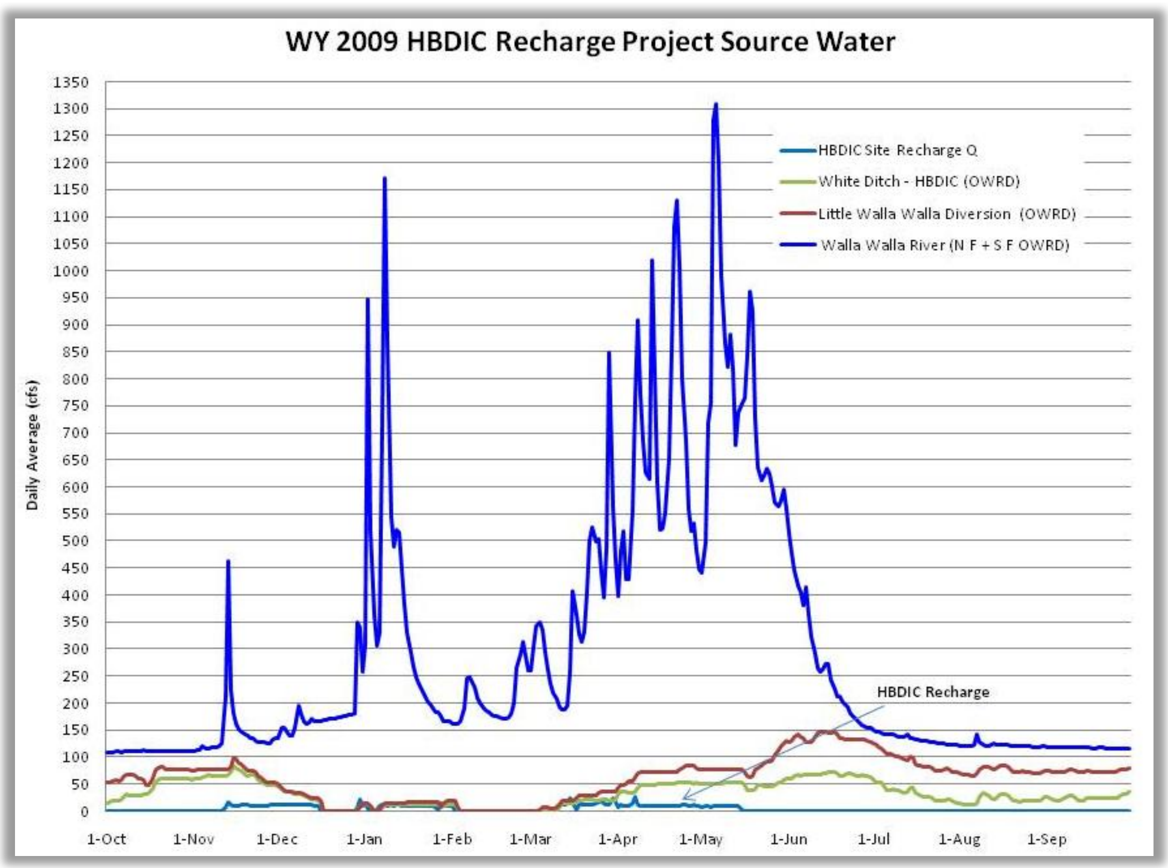


Figure 24. Comparison Walla Walla River source water to Diversions and Use (WY 2009).

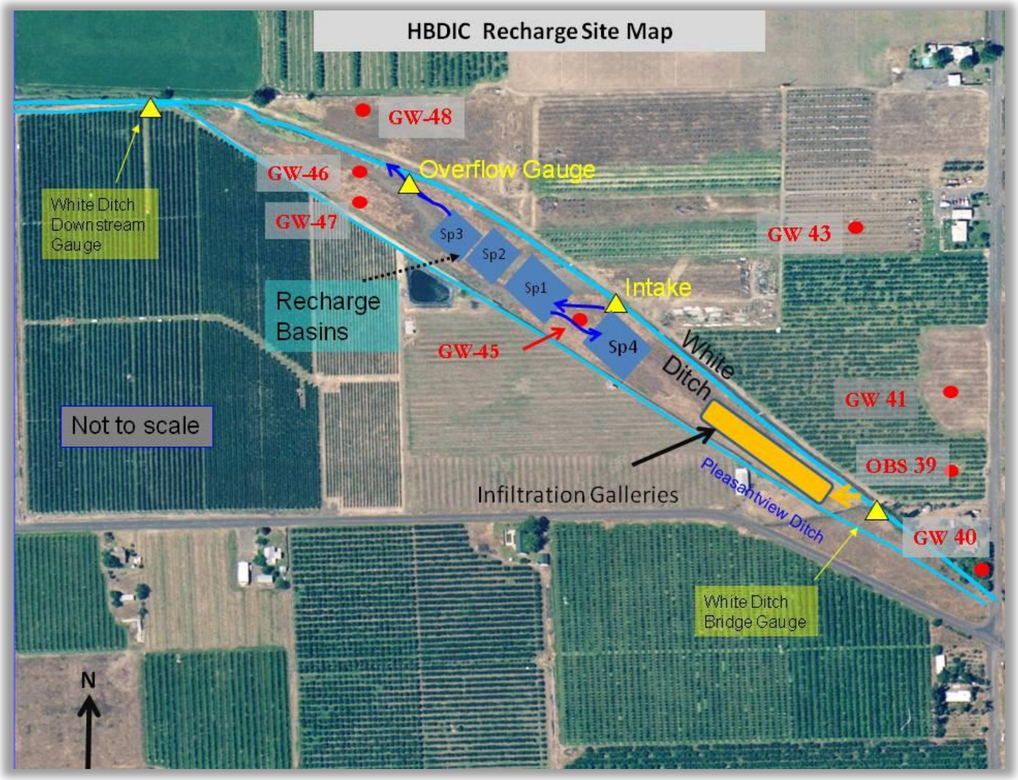


Figure 25. Aerial Map of HBDIC Recharge Site with Monitoring

Flow is measured into the project in the intake weir structure where an unvented *In-situ LT-100* level logger records water level in PSI. Atmospheric PSI data is also collected on site and at the WWBWC office to help correct for water levels in the weir. Using the engineered weir rating table, water level data is converted into 15-minute flow data and is compiled annually... Tail water leaving the site is measured in a portable ramp flume using the same equipment described above. Both the intake and overflow sites have physical staff gauges with which to check the electronic logger measurements against actual physical water levels. This provides calibration information for the logger data and ensures correction against drift and other recorder abnormalities. Data is plotted for a visual check by WWBWC hydrology staff and then used to calculate recharge rates and water usage at the site for testing and reporting purposes.

Spreading Basins Recharge Results

To calculate the total recharge volume and average recharge rate at the HBDIC site, instantaneous overflow data (cfs) is subtracted from the instantaneous intake data (cfs). The amount of water delivered to the Site in each season of operations has varied from a low of 409 acre-feet in 2004 to a high of 3234 acre-feet in 2006-2007 (Table 2). These amounts were calculated using stage data measured in the flume that delivers water into the Site. The stage data was measured using a digital data logger and pressure transducer programmed to measure depth of water through the flume hourly. Table 2 presents our calculated daily average recharge rate (in cfs) and total volume delivered (in acre-feet) for the site each recharge season, or portion of a recharge season. Table 2 also lists total infiltration basin area which has changed over time as the site has been periodically expanded. Comparing the area of the basins to the volume delivered shows us that recharge efficiency at the Site has varied over time.

The delivery of water to the site is influenced by a number of factors that are independent of site operation. Inflow to the site is susceptible to water elevation conditions in the White Ditch where upstream users can turn off, suddenly increasing the amount of water entering the project, making the overflow channel a necessity and the inflow data vary greatly. Alternatively, up gradient water users diverting water can cause the project to run below it optimal recharge potential. During the winter operational months, periods of low water temperatures can influence the rate at which water can infiltrate; decreasing water temperature equates to increasing water viscosity. All of these physical issues influence effective recharge rates, which are manifest in the variability in average daily Q seen in **Figure** 26.

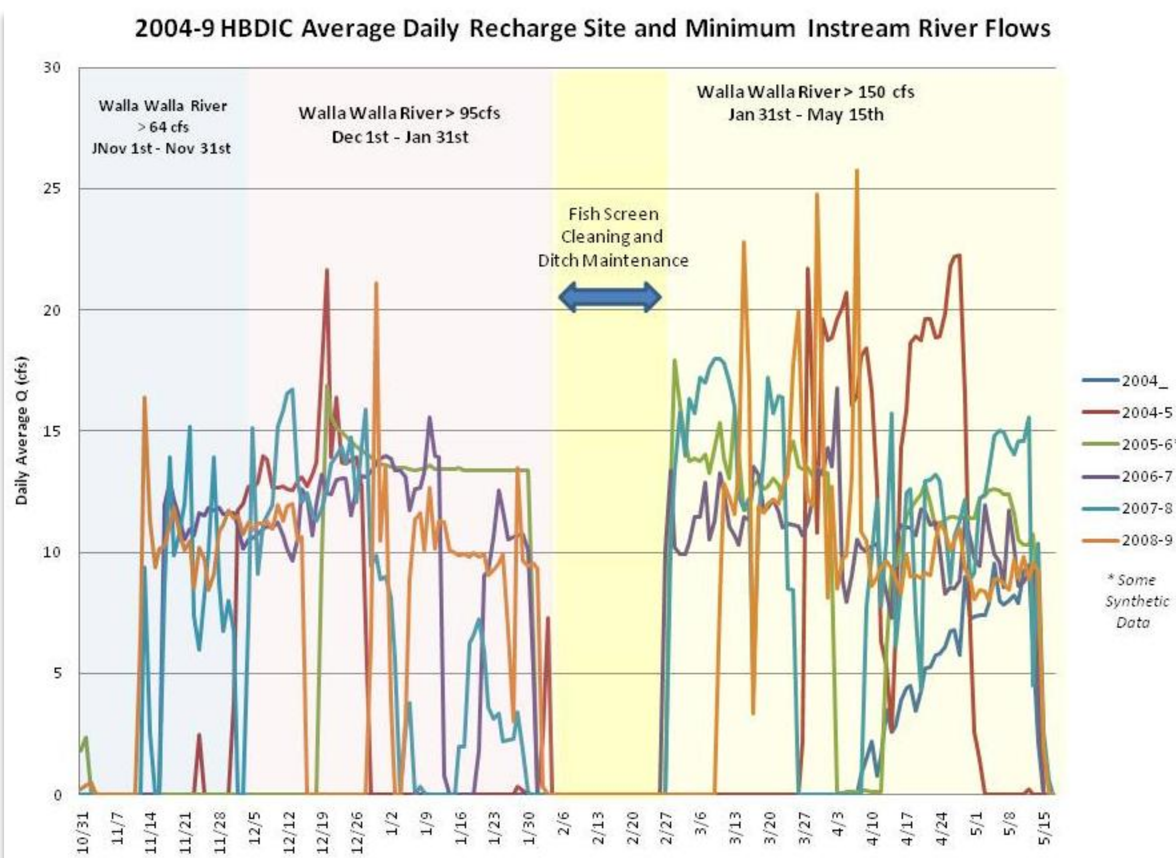


Figure 26. 2004-9 HBDIC Recharge Flows (daily average – cfs)

Reviewing the average daily flows, it generally appears that the period between November 1st through February 1st has a decreased recharge rate overall but is also less sporadic in the flow peaks than the February 21st through May 15th period. As shown above, the period starting on February 1st is the period for HBDIC and Little Walla Walla River system shutdown. This shutdown is due to two factors: 1) The fish screen structure located at the Little Walla Walla diversion needs to be cleaned every year in order to be effective and 2) the instream flow requirement for the HBDIC project goes from 95 cfs to 150 cfs on February 1st. This, coupled with the generally low flow seen in the river at this time due to cold temperature and headwaters snow packs, makes it a good time to service the fish ladders and turn off the system. Consequently both the WWRID and HBDIC irrigation districts now perform some of their ditch maintenance to correspond to this off period.

Recharge Seasons	Period of Operation	Days of Operation (actual)	Average Recharge Rate (cfs)	Site Expansion Phase	Infiltration Area (feet^2)	Infiltration Area (acres)	Basin Recharge Volume (acre-feet)	Basin Recharge Volume (Gallons x 1,000)	Total Basin Recharge (acre-feet)
Spring 2004	4/8/4 to 5/14/4	36.0	5.7	I	15,000	0.3	409	133,273	**409 (2004)**
2004-2005	12/1/4 to 2/3/5	28.7	13.2	I	15,000	0.3	388	126,398	**1871 (2004-5)**
2004-2005	3/27/5 to 4/30/5	35.7	15.8	II	47,420	1.1	650	211,803	
2005-2006	11/1/5 to 5/15/6	118.1	11.9	II	47,420	1.1	2,813	916,619	**2813 (2005-6)**
2006-2007	11/1/6 to 5/15/7	128.0	11.3	II	47,420	1.1	3,278	1,068,140	**3234 (2006-7)**
2007-2008	11/14/7 to 3/25/7	86.8	11.1	II	61,987	1.4	1,939	631,962	**2739 (2007-8)**
2007-2008	4/10/8 to 5/15/8	34.5	12.0	III	61,987	1.4	820	267,125	
2008-2009	11/1/8 to 5/15/9	134.5	10.7	III	61,987	1.4	2,840	925,417	**2840 (2008-9)**
	Total	602.3					13,137	4,280,736	

Table 2. 2004-9 HBDIC Spreading Basins Operations for Surface Flows

Clearly, actual water usage for the HBDIC site has been influenced by changes in foot-print and size. These included the "construct-as-you-run operations "of the spring 2004 season, to the HBDIC site upgrades during mid-recharge season (2004-5 and 2007-8). The periods and days of operations also varied depending on Walla Walla River flow conditions, water temperatures, and at times due to water users needs in the system. The site expansions were numbered I, II and III with the infiltration areas increasing from 0.3 acres (15,000 ft^2) to 1.4 acres (61,987 feet^2). The season for the highest total recharge rate was the second half of the 2004-5 season (15.8) cfs while the most effective year for total volume recharged was the 2006-7 season (3234 acre-feet). Over the six year period the site was operated for a total of 602 days for a total of 13,137 acre feet or over 4 billion gallons of water.

To better understand variations in recharge rates, volumes relative to changes in operation days and infiltration area were further calculated from the HBDIC site operations statistics (Table 3). With 194 potential operational days in a recharge season (as defined by the limited license) the 2006-7 year showed the highest number of operating days (144.1) and hours (3459). This was also the year having the highest *seasonal* average recharge rate (8.3 cfs) where average recharge is divided by the total number of potential recharge days. The 2004-5 recharge season showed the highest *operating* recharge rate (15 cfs) as well as the highest average deviation. The high average deviation suggests a higher variability in the recharge rate. For the purposes of clarity, the term *effective average recharge rate* used throughout the rest of this document refers to the highest *operating recharge rate.*

	HBDIC Recharge Results by Season					
Aquifer Recharge Operations Statistics	**2004**	**2004-5***	**2005-6**	**2006-7**	**2007-8**	**2008-9**
Recharge Season Potential (Days)	194	194	194	194	195	194
Recharge Operation (Days)	36.0	64.4	118.1	144.1	121.3	132.6
Recharge Operation (Hours)	867	1546	2835	3459	2910	3183
Seasonal Average Recharge Flow (cfs)	1.1	4.8	7.2	8.3	7.0	7.3
Operating Average Recharge Flow (cfs)	5.7	15.0	11.9	11.3	11.4	10.7
Operating Average Recharge Flow - Average Deviation (cfs)	2.3	4.1	2.5	1.4	3.5	2.3
Peak Recharge Flow Rate (cfs)	14.1	35.2	27.3	30.6	20.2	37.6

** Some Synthetic data*

	HBDIC Recharge Seasons					
	2004	**2004-5**	**2005-6**	**2006-7**	**2007-8**	**2008-9**
Average Flow Rate - Nov 1st through Jan 31st (Winter)	N/A	13.4	13.6	11.8	9.7	10.3
Average Deviation - Winter	N/A	1.5	0.8	1.3	3.9	2.0
Average Recharge Rate - Mar 1st through May 15th (Spring)	5.7	15.6	11.0	10.9	13.2	11.2
Average Deviation - Spring	2.3	5.1	3.1	1.5	2.6	2.8

Table 3. HBDIC Recharge Site Operational Statistics

Calculating the total *effective* recharge rate as well as the total recharge volumes for the HBDIC project also requires estimating the amount of water lost in conveyance in the White Ditch from Little Walla Walla Diversion to the site. This is required by the limited license. Various ditch loss studies have been conducted by the WWBWC, OSU and others with varied results and confidence levels. For the purposes of this report an estimated conveyance loss of 10 cfs was used to calculate the total values for the project. This value is based on the HBDIC manager's operational knowledge of this system (e.g. constantly supplying known volumes of water to his patrons) and is supported by reviewing the OWRD Gauge and HBDIC intake data during periods when only the HBDIC site is in operations. Like the spreading basins on site, this 10 cfs value likely varies with temperature, flow volumes and other factors.

To conclude, Table 4 shows that the total *effective* recharge rate for the site and ditch appears to average around 22 cfs with an average total volume of around 5,000 acre-feet (excluding the spring 2004 season). To provide perspective, 5,000 acre-feet is the equivalent of 7.8 miles^2 a foot-deep in water. The ~ 22 cfs *effective* recharge rate means that the spreading basins portion of the HBDIC site and the ditch supplying water to the site is currently utilizing 44% of its total allowed recharge rate from the Walla Walla River.

		Total Recharge Rates			Total Volumes		
Recharge Seasons	Days of Operation	Operating Average Recharge Rate (cfs)	Estimated Conveyance Recharge Rate (cfs)	Total Recharge Rate (cfs)	Total Basin Recharge (acre-feet)	Total Conveyance Recharge (acre-feet)	Total HBDIC Project (acre-feet)
Spring 2004	36	5.7	10.0	15.7	409.0	713.9	**1,122.9**
2004-2005	64.4	15.0	10.0	25.0	1,871.0	1,277.1	**3,148.1**
2005-2006	118.1	11.9	10.0	21.9	2,813.0	2,341.9	**5,154.9**
2006-2007	128.0	11.3	10.0	21.3	3,234.0	2,538.2	**5,772.2**
2007-2008	121.3	11.4	10.0	21.4	2,739.0	2,406.0	**5,145.0**
2008-2009	134.5	10.7	10.0	20.7	2,840.0	2,667.1	**5,507.1**
						Total Recharge	**25,850.2**

Table 4. Total Water Usage Values for the HBDIC Recharge Site (2004-9)

Deciphering the Variations in Recharge Volumes and Rates

As we review the water usage data provided in Tables 2 through 4 it becomes apparent that rates and volumes of recharge for the HBDIC site do not seem dependent solely on infiltration area or intake management. As discussed earlier there are many operational and physical factors that likely influence the effectiveness of the project to help replenish the shallow aquifer system. However there are other factors not mentioned in the previous section that also can influence the effectiveness of the spreading basins to replenish the shallow aquifer. For the purpose of this report we will review data relative to the following potential influences:

1. Seasonal Temperature Fluctuations
2. Seasonal and Long-term Infiltration Basin Clogging
3. Water Table Mounding

Seasonal Temperature Fluctuations

While the HBDIC-WWBWC team did not conduct an in-depth research project coupling the *effective* rates of recharge with the water and air temperatures at the site, it is a well established fact that water becomes more viscous with decreasing temperatures. This physical factor would have the effect of making it more difficult to recharge at maximum *effective* rates during the cooler portions of the recharge season typically from November 1st through February 28th. **Figure** 27 shows a basic comparison of average recharge rates for the first and second halves of each recharge season. While there does appear to be some variability in rates, it is not clear that temperature (e.g. first half (blue) dramatically influences the *overall effective* rate of recharge. A more in-depth site study where continuous water temperatures are measured against recharge rates would help to better define this potential operational consideration for the HBDIC site.

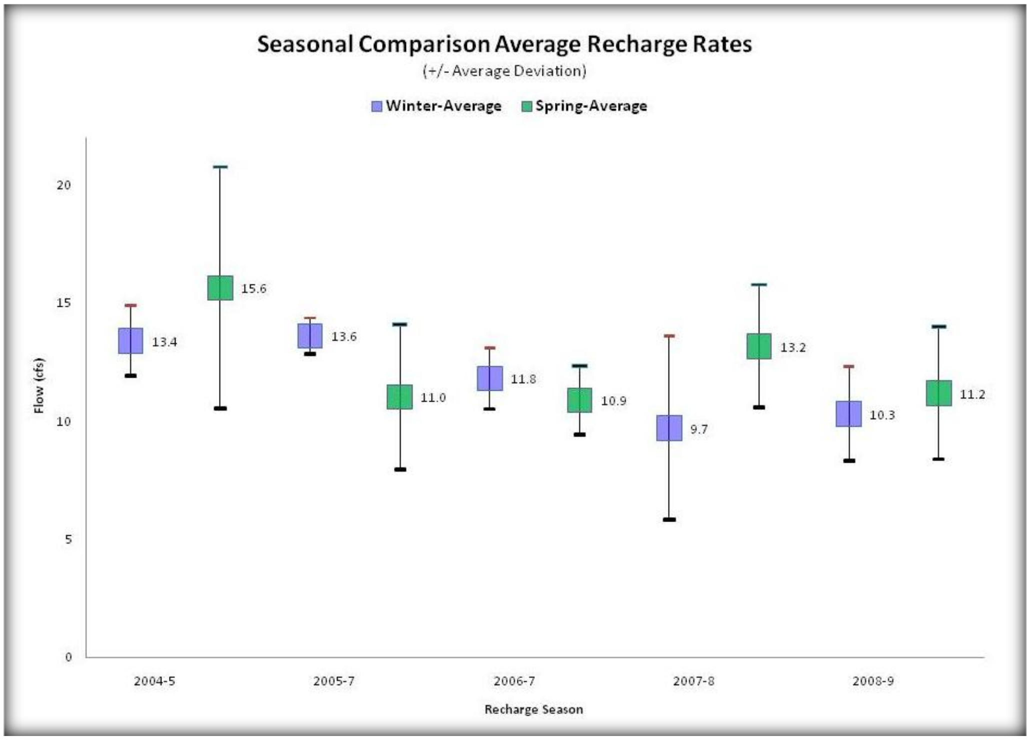


Figure 27. Comparison of fall vs. Winter *Effective Recharge Rates for Temperature*

Water Table Mounding and/or Basin Clogging

When we reviewed the overall rate information provided in Table 4 it became necessary to further partition the recharge rates and volumes based on infiltration areas. Therefore recharge rates were first grouped and graphed by infiltration areas (**Figure** 28). By doing this we could clearly see trends in the data. For the spring 2004 season and the first half of the 2004-5 seasons, rates varied a great deal. Some of this could likely be explained by the site construction operation limitations during the spring, but considering that the 13.4 cfs value in a 0.34 acre surface area is very high relative to the other seasons there may be other factors at work. Because this was the first portion of a season where all three original basins were operated it could be tied to the site being unclogged and ready for maximum infiltration. It should be noted that when engineering the design for the first 3’ x 50’ x 100’ foot ponds, a small-pit slug test was performed. That test showed an infiltration rate in this much smaller area to be high enough that the 3 original basins should have taken 50 cfs. This indicates the size of the pond footprint and its interactions with the underlying water table (mounding) likely has an influence on recharge rates.

The three recharge ponds (2004-5 through 2007-8) have a combined infiltration area of 1.1 acres. It does appear that during this period that the recharge rate is declining particularly from the first data point to the second. This may also be due to the accumulation of sediment through the operation at the site. A similar decreasing recharge rate trend also appears to be seen after the Phase III expansion, where recharge rate dropped from 12.0 cfs to 10.7 cfs. This is a lower average recharge than when the site was 1.1 acres in total size. However, as mentioned earlier in this section the staff operations of the intake relative to the white ditch, also may be playing a role influencing these values. Following this analysis, we weighted each of the recharge rates by total infiltration area (average recharge rate/infiltration area) and plotted the results in **Figure** 29. This helps to highlight that if surface area were the only thing to consider. It would appear that the benefits of increasing size to increase recharge rates likely plateaus somewhere between 0.34 acres and 1.1 acres, 38.3 cfs and 14.5 cfs respectfully. However the fact that infiltration rates do appear to drop when infiltration area is held constant indicates that surface area does not dictate infiltration rates alone.

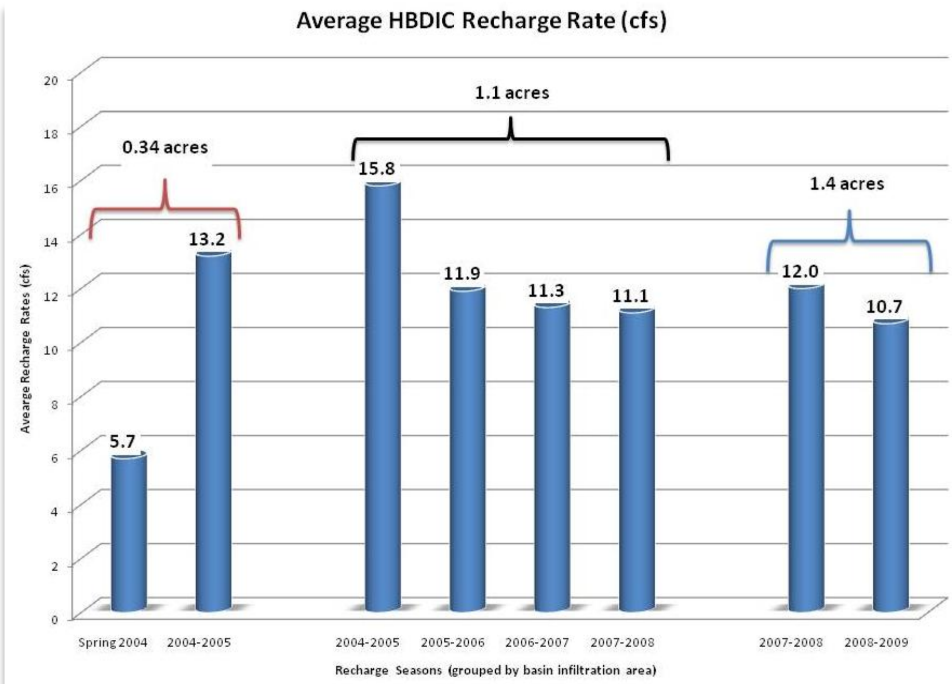


Figure 28. HBDIC *Effective* Recharge rates (cfs) – 2004-9

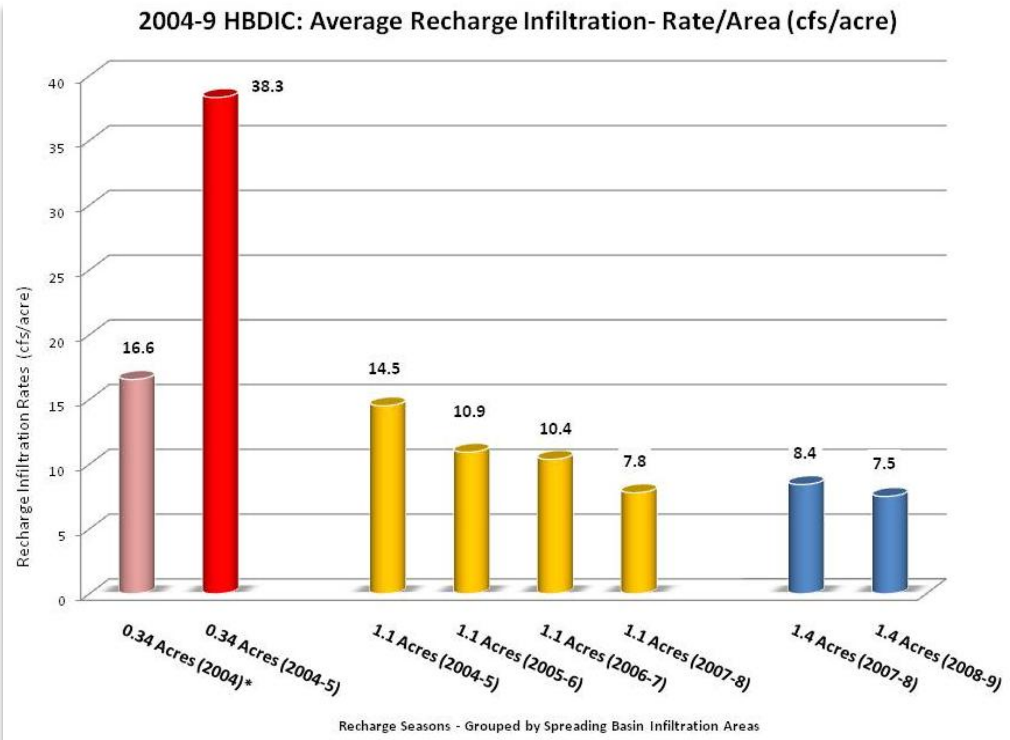


Figure 29. HBDIC Recharge Rates in Acre-feet/day

Mounding of the water table below the site could also be influencing these rates over time. The mounding below the recharge project happens due to the manner which water leaves the site and moves through the unsaturated (vadose zone) to the saturated (water table) subsurface zones. Water moving directly out of the bottom of the basin toward the water table moves quicker due to gravity and unsaturated conditions (**Figure** 30). Once that water mingles with the water table it slows down because then its only direction of movement is down gradient which is expressed by Darcy's law[17]; including permeability and pressure gradient (P) or more simply, slope of the unconfined water table. Because this rate of movement is slower than the vertical movement through the unsaturated zone, water tends to back up and "mound" upward toward the spreading basins. This water then begins to influence the rate at which water can infiltrate from the site. Relative to the data being presented here, this would likely manifest itself in reduced infiltration rates even with increased infiltration areas.

[17] In fluid dynamics and hydrology, Darcy's law is a phenomenologically derived constitutive equation that describes the flow of a fluid through a porous medium. Henry Darcy, *Les Fontaines Publiques de la Ville de Dijon* ("The Public Fountains of the Town of Dijon"), Dalmont, Paris (1856)

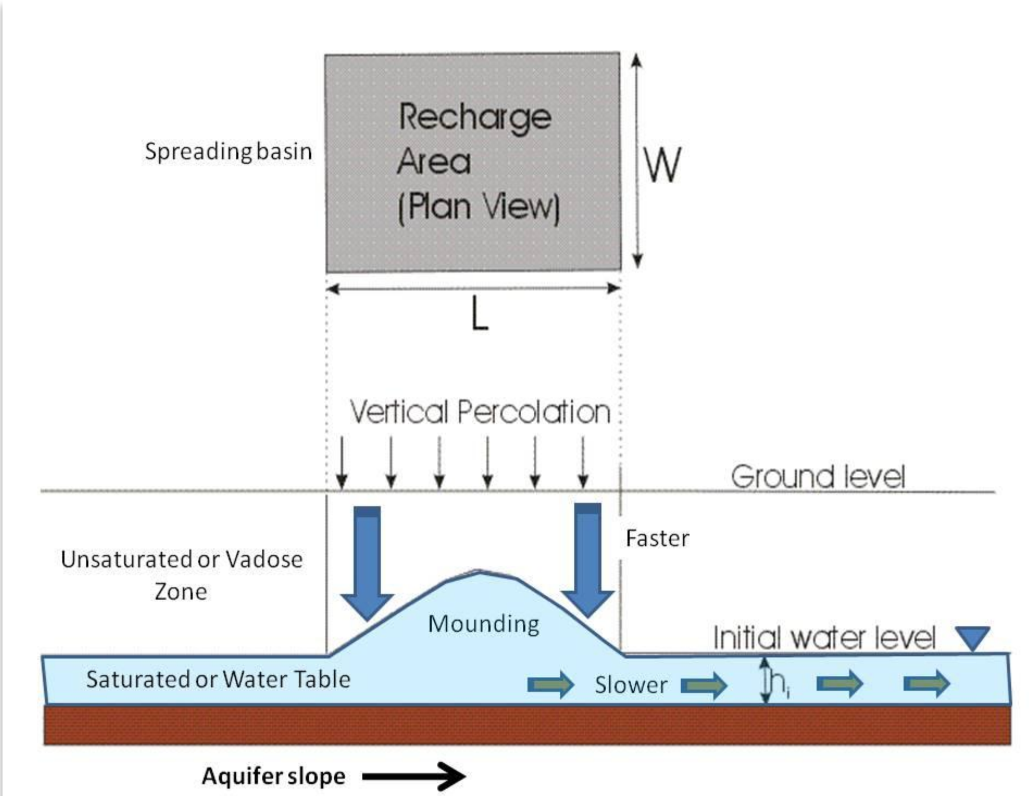


Figure 30. Conceptual Diagram of Aquifer Recharge Mounding and Saturated Groundwater Movement

Mounding could affect recharge rates over time if the HBDIC site was having the net effect of decreasing the distance between surface infiltration basins and the water table. In other words, if the HBDIC project through its six seasons of operations was having the net effect of localized aquifer recovery this could be expressed on the surface as decreasing *effective* recharge rates. **Figure** 31 shows one of the 4 on-site HBDIC monitoring wells (GW-45) and a seemingly increasing peak and trough recovery since recharge operations began. Due to localized aquifer pumping, the operations of the White Ditch and other potential up gradient influences on the water table, it is difficult to clearly use this graph to conclude a recovery. However, it does provide some insight into the possible reduction in overall average *effective* recharge rates at the site and as more years of operations occur, the trend may become even more conclusive.

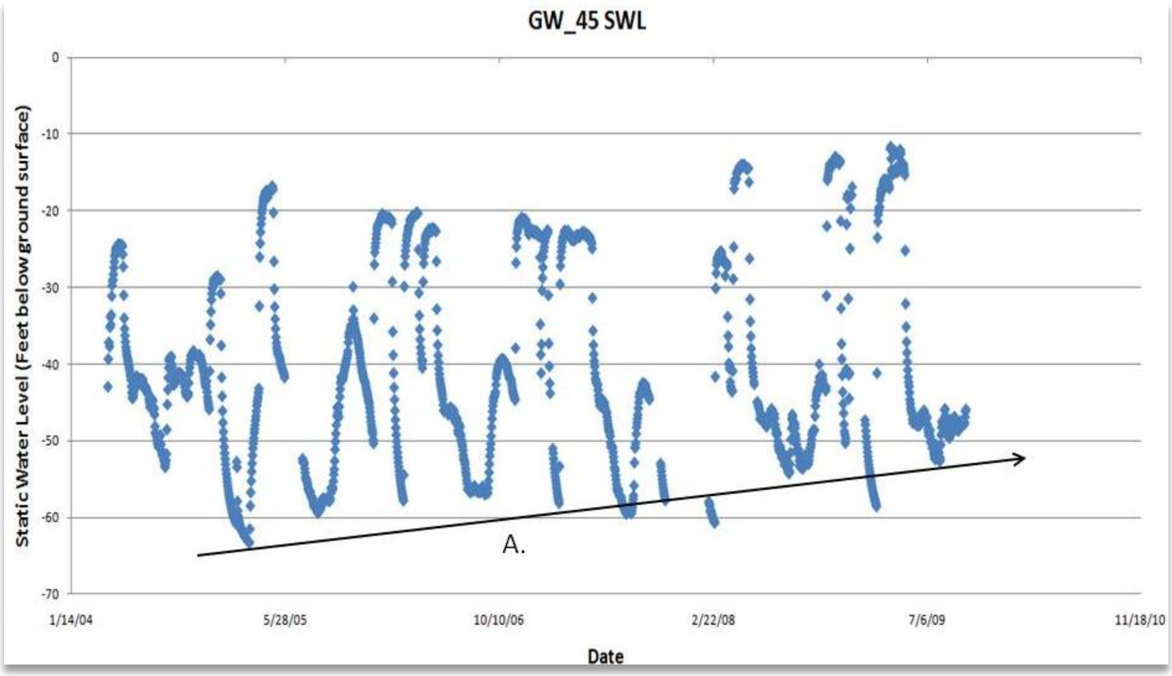


Figure 31. HBDIC On-site Observation Well Water Level Data (2004-9)

HBDIC Water Quality Monitoring Program and Procedures (2004-2009)

The HBDIC Recharge Project represented the first project to apply for a limited testing license for aquifer recharge in the State of Oregon. With this, a concise water-quality sampling plan was developed during the project. Monitoring and ensuring that water quality is adequate to operate an aquifer recharge project was and continues to be a top priority for the HBDIC-WWBWC project team. Starting in 2003 Phil Richardson at Oregon Department of Environmental Quality (Pendleton, Oregon) along with Thomas Darnell at Oregon State University Extension (Milton-Freewater, Oregon) worked with WWBWC staff to develop the water quality parameters and testing protocols for the HBDIC project. This was completed during the original Limited Testing License application process in 2003-4. For more information on how this site-specific water quality monitoring plan for aquifer recharge was compiled, details can be found in *Hudson Bay Aquifer Recharge Project: An application for ASR Testing Limited License to Oregon Water Resources Department (OWRD) (OAR 690-350-0020), and attachments* (Bower R. J., 2003).

Since the original conception of the water quality plan, there have been a variety of progressive changes to the original plan. Working with ODEQ, the HBDIC-WWBWC team has adaptively modified the water quality monitoring to prioritize the analytes based upon collected samples and subsequent results. This has allowed the project to move from a fairly high-intensity sampling plan to a reduced, but focused list of key parameters. In some cases the analytes that were of most interest (mainly due to historic or current basin use) were not available from the HBDIC site laboratory contractor. Cindy O'toole at Edge Analytical worked with the HBDIC-WWBWC team to create laboratory standards for those analytes. In 2006 the original EPA SOC list was downsized to focus on priority analytes. Some of the new standards that ODEQ was most interested in were added. As of the 2009-10 seasons, the list discussed below is the current water-quality parameter list. To summarize the program and the results from the past water quality monitoring, it is best to separate sampling into two categories of constituents.

Baseline Chemistry:

- nitrate
- total kjeldahl nitrogen (TKN)
- total dissolved solids (TDS)
- chemical oxygen demand (COD)
- chloride
- orthophosphate
- fecal coliform bacteria

Soluble Organic Compounds – Pesticides

(Common/Trade names, EPA Drinking Water Method)

- 2,4 D acid, Dacamine, 515.1
- Dimethoate, Cygon, 525.2
- Metalaxyl, Ridomil, 525.2
- Napropamide, Devrinol, 525.2
- Simazine, Princep, Aquazine, 525.2
- 1-Naphthaleneacetamide, Amid-thin 525.2
- Diazinon, Diazinon, 525.2
- Fenarimol, Rubigan, 525.2
- Lindane, Lindane, 525.2
- Methidathinon, Supracide, 525.2
- Mevinphos, Phosdrin, 525.2
- Myclobutanil, Systhane, Rally 525.2
- Triflumizole, Procure, 525.2
- Azinphos-methyl, Guthion, 525.2
- Carbaryl, Sevin, 531.1
- Chlorpyrifos, Dursban, Lorsban, 525.2
- DDD (TDE) Rhotane, DDD, 525.2
- DDE degradation product, 525.2
- DDT Anofex, Gesarol, 525.2
- Dicofol , Kelthane, 525.2
- Malathion, Cythion, 525.2
- Methyl Parathion, Penncap, 525.2
- Phosmet, Imidan, 525.2
- Propargite, Omite, Comit, 525.2
- Triadimefon Dimethoate, Bayleton, 525.2

- Oxamyl, Vydate, 531.1
- Hexazinone DPX 3674, Pronone, and Velpar, 525.2
- Parathion-Ethyl, Niran, Phoskil (56), 525.2

The WWBWC has a ODEQ approved Quality Assurance and Quality Control plan that requires at least 10% repeatability on all water quality and temperature sampling. Therefore, for all of the sampling completed at the HBDIC site, additional samples are collected for QA/QC. Edge Analytical Laboratory Inc. a certified laboratory in Burlingame, Washington, performed the basic chemistry and soluble organic compound analysis under their laboratory QA/QC plan. Their results are shared along with 2004-9 sampling results in Appendix **I**. Fecal coliform and total coliform testing is done by the City of Walla Walla's Water and Waste Water Treatment facility in Walla Walla, Washington. They also have an internal QA/QC plan that controls the quality and repeatability of their procedures.

In the first several years of site operations Kuo Testing Laboratories staff collected water quality samples. WWBWC staff took over the field sampling effort in 2008. Source water samples are collected from the weir-channel on the intake structure, typically in the weir's small backwater eddy. Groundwater samples were originally collected using sterile eco-bailers from Observation Well #1 (GW-46). In 2006 the HBDIC-WWBWC team purchased a submersible pump specifically designed for evacuating several total volumes of the observation well before collecting the water quality sample. This was to ensure that samples represented ambient groundwater conditions and not those inside the well casing.

Upon collection, samples are immediately placed in ice filled coolers that are transported to either the City of Walla Walla's laboratory (fecal coliform samples) or a local over-night shipping company to be sent to Edge Analytical. Typically, the samples arrived at Edge Analytical in adequate time for them to be processed in the required holding time. Turnaround time for the results from either lab is dependent upon the parameter being analyzed. Fecal coliform and general chemistry are often fairly quickly completed, while SOC analyses typically takes the longest to process. All results are sent as paper and electronic copies to the HBDIC-WWBWC and the information is kept in our project database. In the event there is any detection that appears to be of concern, ODEQ staff in Pendleton is immediately notified via email and/or phone. Instructions on how to proceed are acted upon by HBDIC-WWBWC staff in a timely manner. More information on the annual sampling can be requested from the WWBWC staff through the website or by phone.

WWBWC staff also conducted additional water quality sampling for the infiltration gallery testing portion of the site. Samples are collected and analyzed for Total Suspended Solids (TSS) and Total Organic Carbon (TOC). These samples were collected to evaluate the rates of clogging that can influence the design and operations of these infiltration galleries.

2004-2009 HBDIC Recharge Water Quality Results

All of the original laboratory reports for HBDIC water quality sampling from 2004 through 2009 recharge seasons can be found in Appendix I of this document. Results include laboratory QA/QC, field notes and other pertinent information on the collection of this information over the six recharge seasons. For the 2004-9 recharge seasons the baseline chemistry for both the source and groundwater sites is summarized in Table 4. All values appear to be well within the maximum contaminant levels (MCL) for the state of Oregon. Surface water samples typically have slightly higher Chloride, Phosphate (ortho), Total Dissolved Solids (TDS), Total Suspended Solids (TSS) and Total Organic Carbon (TOC). The recharged groundwater samples tend to have slightly higher Chemical Oxygen Demand (COD) and TKN as Nitrogen; with Nitrates being about the same for both surface and groundwater samples.

Water Sample Sites: Ground/Surface	Analyte	Samples (n)	Minimum	Maximum	Average	Units
Groundwater	Chloride	16	ND	0.8	0.3	mg/L
Groundwater	Chemical Oxygen Demand	18	ND	55	12.9	mg/L
Groundwater	Nitrate as Nitrogen	13	0.1	0.6	0.2	mg/L
Groundwater	Orthophosphate as P	14	ND	0.5	0.2	mg/L
Groundwater	TKN as Nitrogen	15	ND	1.6	0.2	mg/L
Groundwater	Total Dissolved Solids	15	ND	84	48.7	mg/L
Groundwater	Total Suspended Solids	3	ND	ND	ND	mg/L
Groundwater	Total Organic Carbon	3	0.9	1.2	1.1	mg/L
Surface	Chloride	8	ND	1	0.8	mg/L
Surface	Chemical Oxygen Demand	7	ND	21	ND	mg/L
Surface	Nitrate as Nitrogen	5	ND	0.5	0.2	mg/L
Surface	Orthophosphate as P	4	0.1	0.6	0.3	mg/L
Surface	TKN as Nitrogen	7	ND	ND	ND	mg/L
Surface	Total Dissolved Solids	7	ND	76	57.4	mg/L
Surface	Total Suspended Solids	1	N/A	8	N/A	mg/L
Surface	Total Organic Carbon	1	N/A	8	N/A	mg/L

ND - No Detection

Table 4. Summary of Baseline Chemistry Sampling Results (2004-9)

During the 2004-9 sampling period there were only two Soluble Organic Compounds (SOC) detections at the HBDIC recharge site... Di (ethylhexyl)-phthalate was detected in observation well #1 at 2.2 ug/L on April 13, 2004. The 2004 EPA Maximum Contaminant Level (MCL) value for this compound is 6.0 ug/L. HBDIC-WWBWC monitoring staff working with ODEQ concluded that this was possibly a low-level detection arising from the newly installed PVC observation-well casing or possibly the well sampling equipment. The substance was never detected again at the site; however the HBDIC WQ monitoring strategy continues to include this analyte in the sampling routine. The only other detection was 3.2 ug/L of Bisphenol-A at HBDIC Observation well #1 on May 27, 2009. Bisphenol-A is not listed by EPA as having a MCL value but has recently been in the national media associated with concerns over the chemicals widespread use in water bottles and other plastic containers. The HBDIC-WWBWC team continues to monitor for this analyte but are unclear as to its source, whether from the site or in the laboratory equipment.

Table 5 provides a statistical summary of the results of the fecal coliform analyses taken at both the surface and groundwater sites from 2004-9. Surface water samples averaged between 0 to 39 MPN/100 ml from 2004-9 while groundwater showed much lower averages of 0.8 to 3.8 MPN/100 ml. During the first two recharge seasons additional fecal coliform and total coliform samples were collected in order to clarify the extent to which the HBDIC sample results were controlled by ambient conditions. Those results and discussion were shared in the 2004 (Bower R. , 2004) and 2004-5 (Bower R. , 2005) reports which can be found by contacting the WWBWC. In summary, due to the widely distributed extent of low level fecal contamination, it was determined that the detected fecal coliform was considered an ambient background condition; and was not a result of HBDIC recharge site operations.

	Surface			Groundwater			
Sampling Year	Minimum	Maximum	Average	Minimum	Maximum	Average	Units
2004	1	130	39.8	0	14.8	3.8	MPN/100 ML
2004-5	0	62	9.4	0	12	2	MPN/100 ML
2005-6	14	20	17	0	3	1	MPN/100 ML
2006-7	7	23	15.3	0	3	1	MPN/100 ML
2007-8	11	14	12.5	0	1	0.5	MPN/100 ML
2008-9	N/A	19	N/A	0	2	0.8	MPN/100 ML

Table 5. 2004-9 Fecal Coliform Bacteria Sampling Statistical Summary of Results

Indicators of Soil-aquifer Treatment (SAT) at the HBDIC Recharge Site

Through the work of Dr. Herman Bouwer and others in the field of infiltration-basin aquifer recharge, the concept of natural attenuation of source water entering the groundwater through unsaturated soil has been formulated. Bouwer summarized the surface to subsurface process as:

"Where soil and groundwater conditions are favorable for artificial recharge of groundwater through infiltration basins, a high degree of upgrading can be achieved by allowing partially-treated sewage effluent to infiltrate into the soil and move down to the groundwater. The unsaturated or "vadose" zone then acts as a natural filter and can remove essentially all suspended solids, biodegradable materials, bacteria, viruses, and other microorganisms. Significant reductions in nitrogen, phosphorus, and heavy metals concentrations can also be achieved." (Bouwer, 1987)

While the source water entering the HBDIC site is not "sewage effluent" the process of bacteria and other pollutants being stripped from the water as it moves through the unsaturated zone is worthy of further review. When reviewing the data collected at the HBDIC recharge site, the parameter that is most likely to benefit from this process is ambient (but prevalent) fecal coliform contamination. During the initial start-up sampling of each recharge season, source and recharged water samples were collected. The results, when compared statistically, seem to indicate that natural attenuation is occurring at the site. **Figures** 32 and 33 show an order of magnitude lower fecal coliform concentration (average 2.7 MPN/100 ml) in the recharged groundwater than in the recharge source water (28.3 MPN/100 ml).

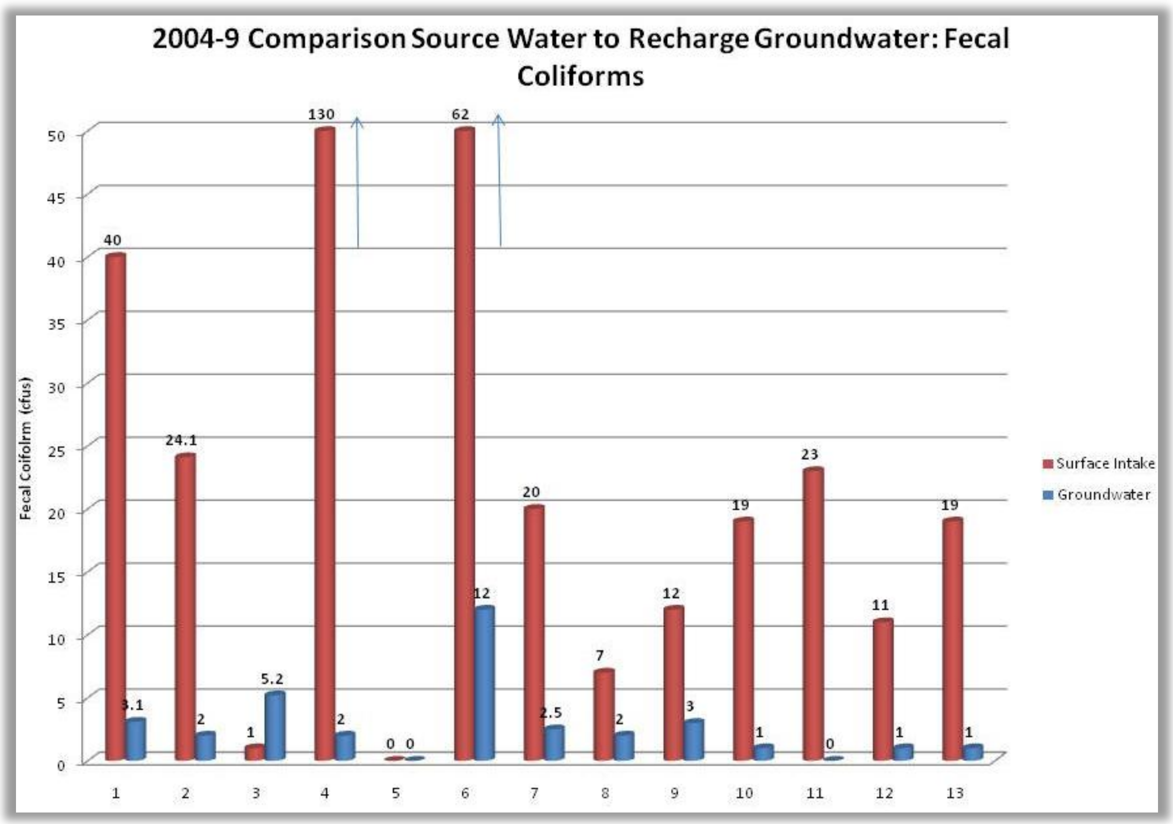


Figure 32. Surface versus Groundwater Fecal Coliform Results (2004-9)

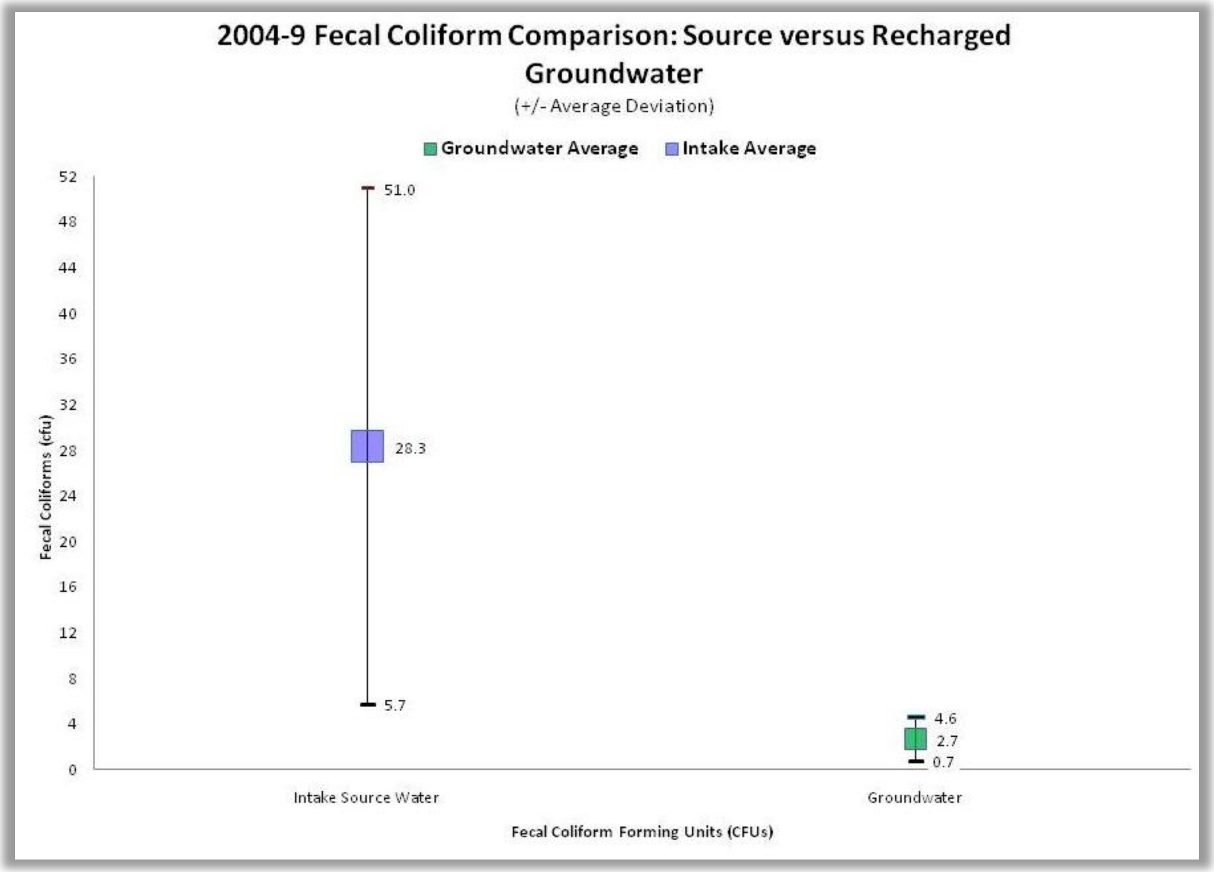


Figure 33. Comparison of Source vs. Groundwater fecal coliform statistics (2004-9)

Enteric bacteria like fecal coliform arise from the intestines of animals and are an indicator of more harmful pathogens in our water supplies. They have a limited range of temperature at which they can survive, usually corresponding to their host organism's body temperature (e.g. humans 37^0 C). While more sampling would be required to determine a more statistically robust conclusion, this does seem to correspond to literature supporting the process of source water quality improving through natural attenuation during aquifer recharge. This may help water quality regulators in the permitting future aquifer recharge projects.

Aquifer Response to Recharge

The purpose of aquifer recharge for the Walla Walla basin is to help stabilize and recover the shallow aquifer's groundwater storage supplies. Increased groundwater storage means historic springs that have experienced diminished flow could recover and flow again to the Walla Walla River- providing enhanced flow and off-channel habitat for recovering salmonids. In addition, increased groundwater storage would result in increased potential returns from the shallow aquifer to the Walla Walla River, helping to support and protect base flow - particularly during the low-flow months. Monitoring an aquifer recharge project, in order to document its contributions toward this overall aquifer recovery purpose, can be broken down into two main scientific questions:

1. Did the aquifer respond to aquifer recharge operations?
2. Did the springs respond to changes in aquifer conditions from recharge operations?

This section focuses on tracking the process of aquifer recharge from the site out through the groundwater system; then intends to document the connection between those responses seen in the groundwater to those expressed in the springs. As the shallow aquifer system is large and complex, the focus of this section is limited to an area where recharge response is visually and graphically apparent. To demonstrate the overall benefits to aquifer storage, system wide recovery of springs and contributions to the Walla Walla River, the HBDIC-WWBWC team is relying on the IWFM modeling work[18] that Oregon State University will complete in mid-2010. Since the HBDIC likely represents only a small portion of the recharge 'need' in the alluvial aquifer system, it is not intended to show complete recovery of the aquifer. Understanding how much recharge and where to place it for maximum benefit, will be based on the scenarios generated by the IWFM model as well through the WWBWC's Bi-state Aquifer Storage and Spring Restoration program (ARSRP)[19].

Site-Specific Groundwater Response

In order to track the aquifer response to HBDIC recharge operations, responses in on-site monitoring wells were reviewed. **Figure**s 34 and 35 illustrate the response of the four on-site monitoring wells (GW-45, GW-46, GW-47, and GW-48) to recharge operations during the 2008-2009 recharge seasons. These hydrographs are very typical of what was observed in previous recharge seasons.

[18] IWFM modeling project funded by WDOE and OWEB in collaboration with the WMI Monitoring Program. Contact the WWBWC for more information.

[19] ARSRP is a bi-state recovery strategy that was the logical outcome from the aquifer recharge and WMI monitoring program lead by the WWBWC. For more information contact the WWBWC.

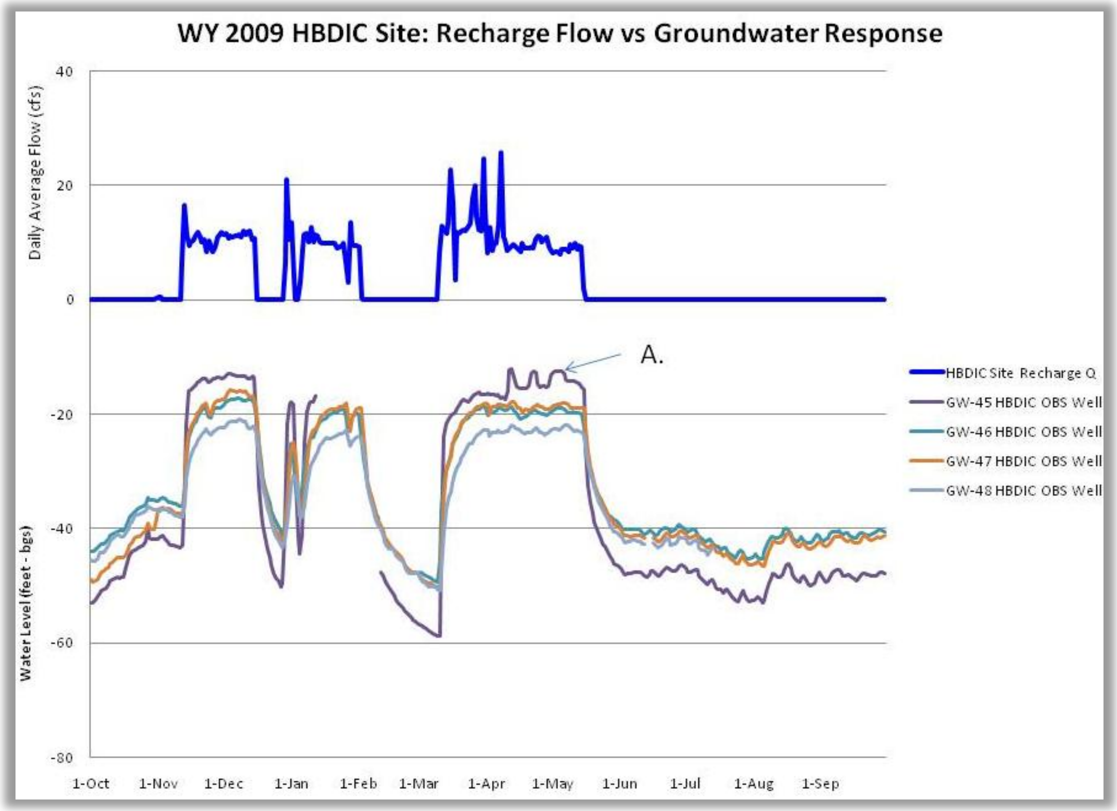


Figure 34. On-site Surface to Groundwater Response to Recharge Operations (2009)

Figure 34 shows the recharge flow rate (cfs) into the basins and the groundwater response to the recharge at the four on-site monitoring wells. It is clear that operations of the HBDIC recharge site have a direct mounding effect on the local water table. The staggered nature of the water levels in each of the wells is due to both their proximity to the mounding and their placement relative to the direction of groundwater flow. GW-45 now resides between the infiltration gallery and the down gradient spreading basins, which explain its higher overall water level. Also GW-45 shows the groundwater response (A.) to the 2008-9 infiltration galleries testing, which was done in 1-2 week blocks of operations.

Figure 35 shows GW-45 has the greatest response to operations. The up gradient well GW-40, which is ~10-15 feet from the White Ditch, also shows the influences of canal infiltration on the water table.

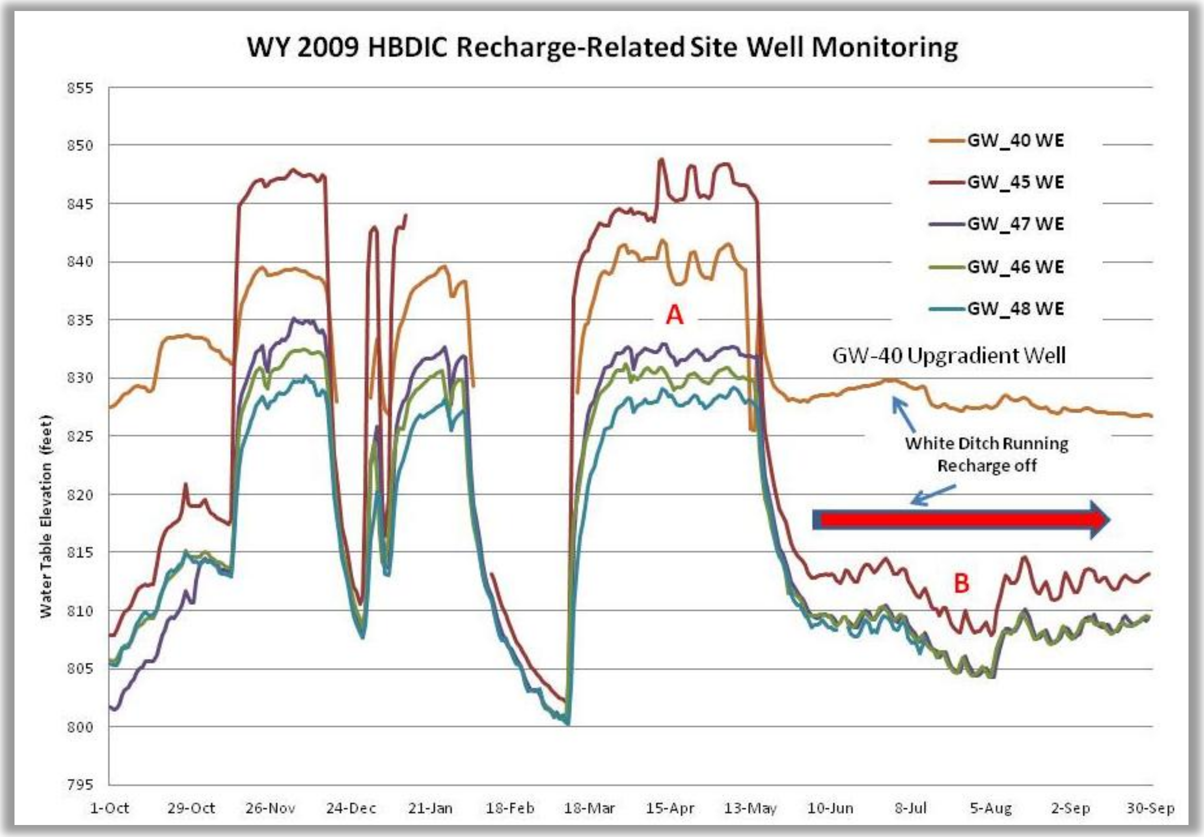


Figure 35. HBDIC Site Monitoring Wells and Various Sources of Recharge

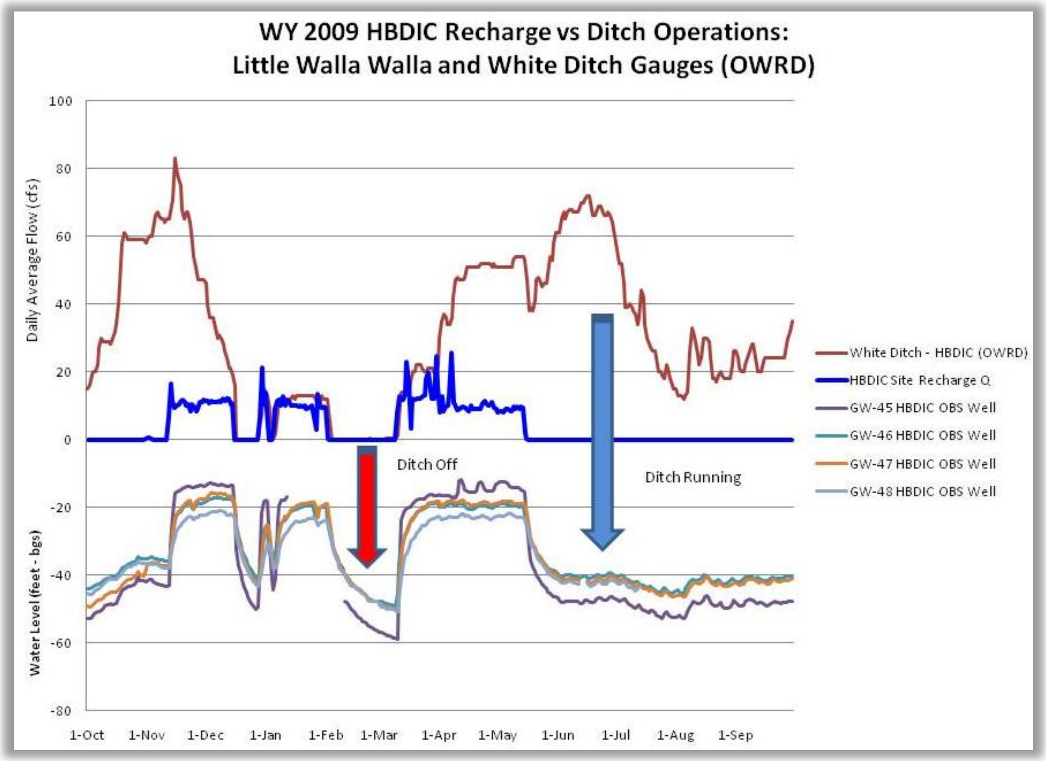


Figure 36. Comparison of White ditch and HBDIC recharge site operations to Groundwater Response

After the HBDIC recharge operations are turned off (May 15th), the HBDIC White Ditch continues operating into the late spring and early summer. In 2009 the system ran for the entire irrigation season due to an exceptional snow pack; however this is not typical of most years. **Figure** 36 illustrates the groundwater response to operation of the White Ditch (OWRD Gauge #) and HBDIC recharge site. When the White Ditch operation ceases the aquifer responds with declines in water level. Subsequently when the ditch is operating and HBDIC recharge is not occurring, the aquifer rises, to a higher level, which does appear to stabilize; suggesting an equilibrium between seepage and water level is reached. The data indicates that canals and ditch systems provide recharge water that if piped, will need to be replaced in order to achieve the purpose of aquifer stabilization and recovery.

Next, we shift our analysis to determine if there are any visible signs of water table recovery over the first 6 seasons of operations. **Figure**s 37 and 38, respectively, show groundwater levels (2004-9) during low flow periods and peak recharge periods. During the low-flow period (June 1st through September 30th) the recharge site is not operating but the White Ditch and surrounding groundwater pumping are underway. WY 2005 was a drought year during which surface water irrigation was drastically reduced due to lower than average Walla Walla River flows and additional groundwater pumping was done by many water users. Contrasting WY2005 to WY2009 (when strong Walla Walla River flow allowed HBDIC to operate the White Ditch for the entire summer) groundwater levels remained high. Conclusively determining groundwater recovery is difficult in this highly interconnected and volatile aquifer system, due to season by season changes in surface and groundwater conditions.

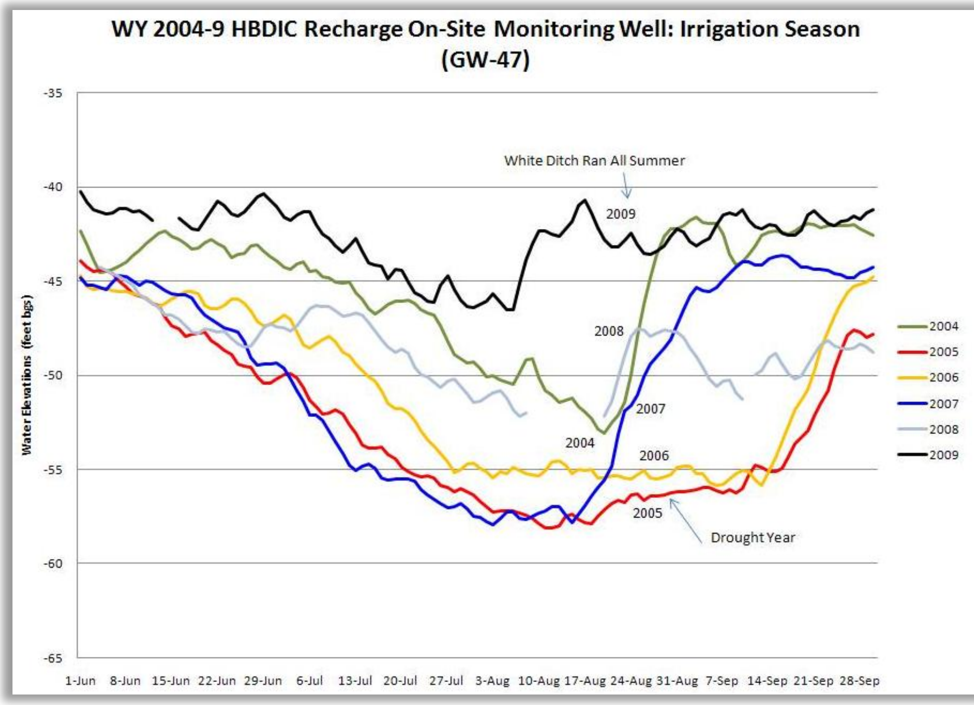


Figure 37. HBDIC Site Observation wells Irrigation Season water levels (2004-9)

Shifting the focus to the water table peak elevations when the HBDIC Recharge site is operating may indicate a general trend toward higher water table elevations at the site. While this could be tied to recovery of the localized water table it is also likely linked to the expanding infiltration area getting closer to the GW-45 well head. It appears there may be some correlation between rates of *effective* recharge and the height of the mounding at the site. Also it appears that the closer the infiltration area gets to this well higher water levels are observed. Further, investigations using this well and the horizontal distance to infiltration water may provide insights into actual depth to water mounding at the HBDIC site.

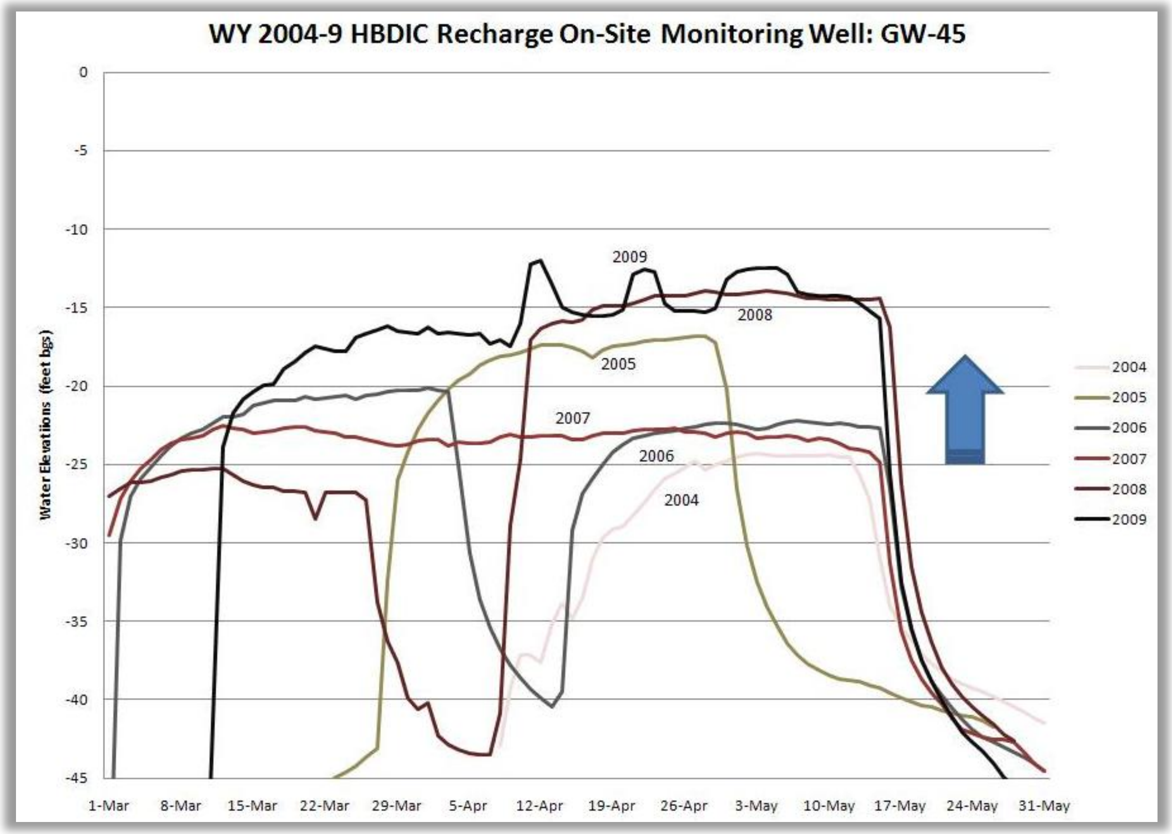


Figure 38. Water Table Response to HBDIC Recharge Operations: May 1st- May 31st

System Wide Groundwater Response to Spreading Basin Operations

Starting in 2001 the WWBWC working with its partners at OWRD, WDOE and OWEB began to put together a bi-state well monitoring system through state and federal grant funding. The purpose of this system is to better document overall shallow alluvial groundwater conditions as well as monitor subsurface responses to water management activities such as aquifer recharge and ditch piping. When the program started there were approximately 11 OWRD observation wells in Oregon and 1 WDOE well in the Washington portion of the Walla Walla River Valley. As of 2010, there are over 110 wells in the WWBWC's Bi-state well monitoring system that include dedicated (**Figure** 39) and existing wells that are either instrumented for continuous data or measured quarterly for static water levels (Bower R. , 2009; Patten S. , 2009). **Figure** 40 shows the extent of the monitoring system and their placement relative to the alluvial aquifer system in the Walla Walla River Valley.

Figure 39. WDOE Funded Dedicated Observation Well at Pepper Bridge Vineyards Road Grange Hall (Washington)

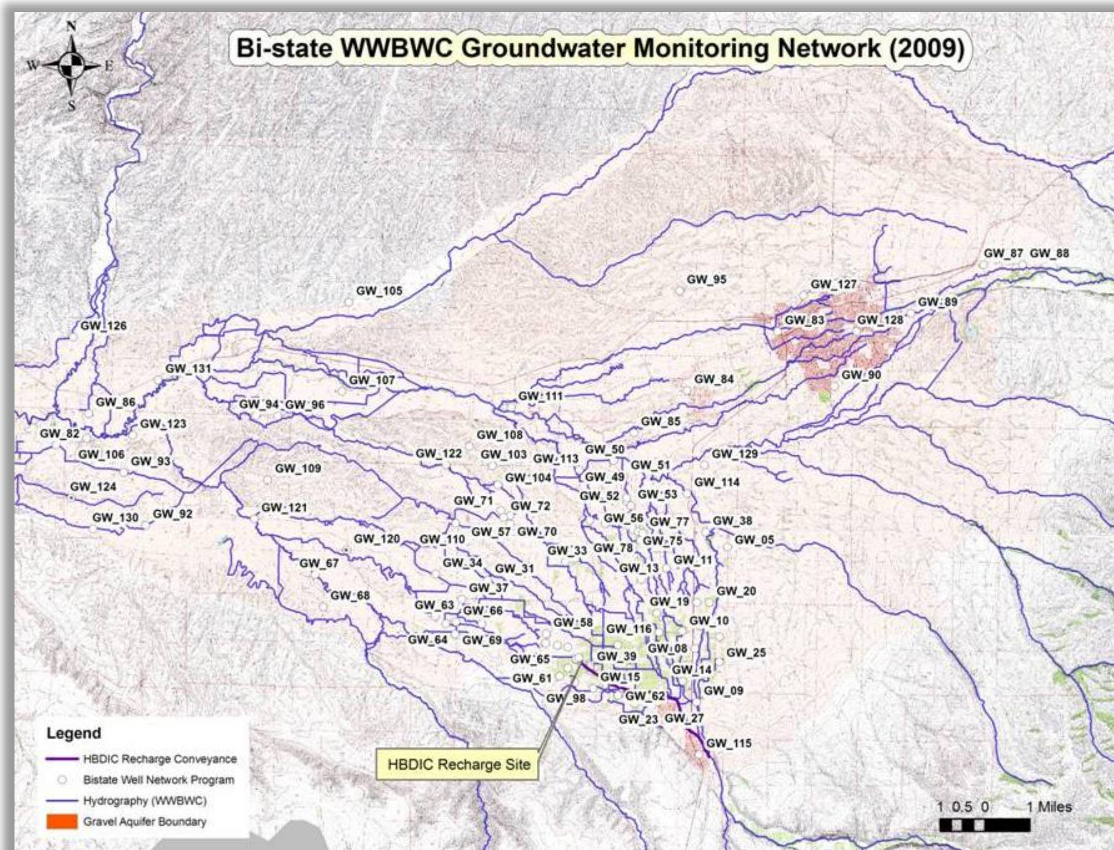


Figure 40. Map depicting WWBWC's Bi-state Well Monitoring System of the Walla Walla River valley Shallow Aquifer System

In the area interpreted to be down gradient of the Site water level data was examined to evaluate aquifer response, if any, to site recharge operations. By looking in the Johnson Creek area, we can focus on an area where recharge mounding more distally from the site should be seen in the water table response. To do this, several transects were selected. Moving up gradient from the HBDIC site, transect A on **Figure** 41 starts at the HBDIC up gradient control well GW-14 which shows no visible signs of HBDIC recharge activities. This well is directly underneath irrigated orchards near the Walla Walla River. Influences from irrigation are suggested by water level recovery during spring and summer irrigation activities. Additionally, GW-14 may show signs of decreasing groundwater levels in the Little Walla Walla River area (**Figure** 42). Transect A parallels the White Ditch that delivers the source water from the Walla Walla River to the HBDIC Recharge Site. The elevation difference along Transect A is from 910 (GW-14) to 817 feet (GW-40).

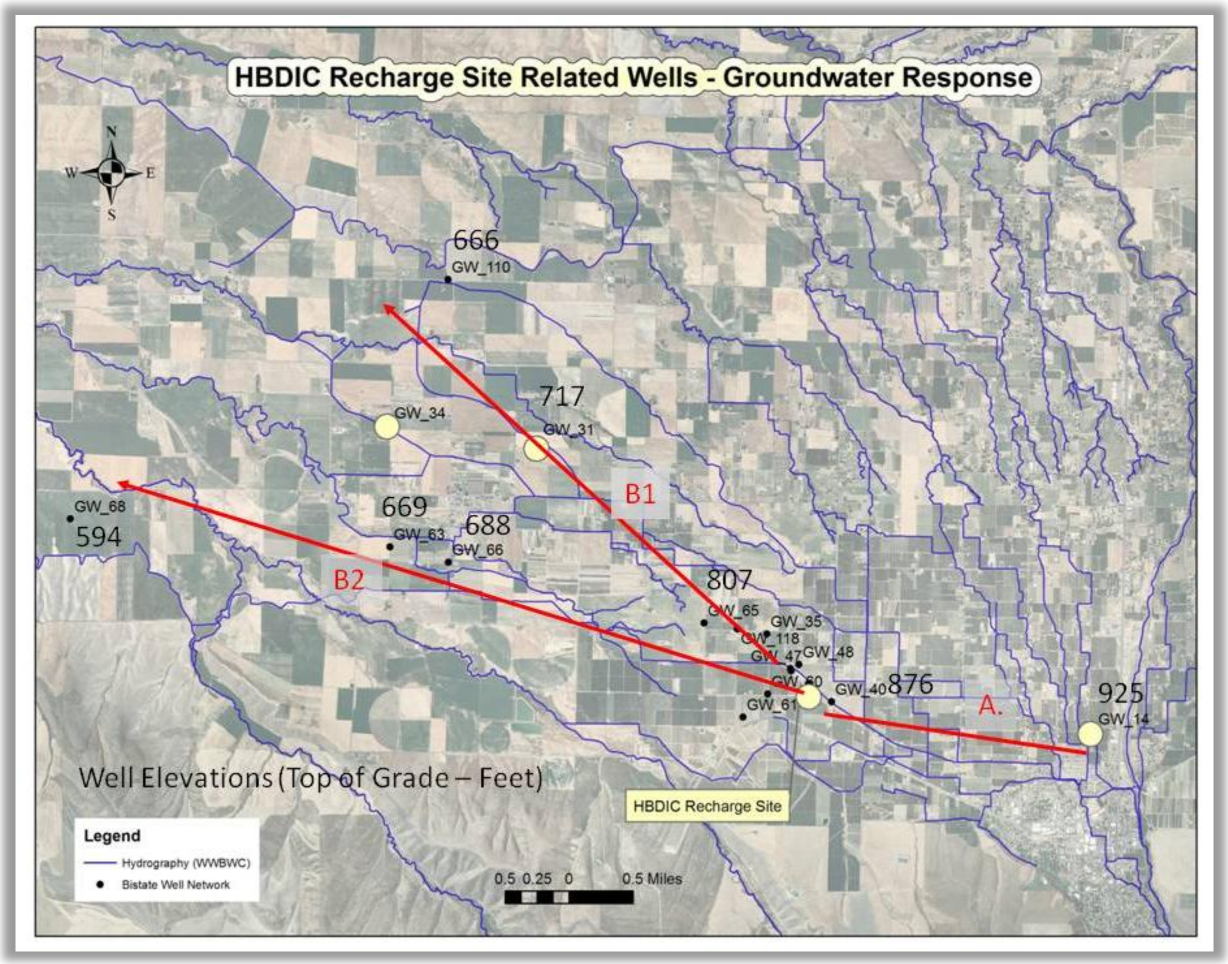


Figure 41. WWBWC Monitoring Wells and Transects Relative Recharge System Response

Moving down gradient from the HBDIC recharge project and GW-45 (**Figure** 41) two transects were selected in which to track groundwater response. An earlier 2005 HBDIC Recharge Site Monitoring report (Bower R. , 2005) documented the pressure wave from HBDIC recharge activities in wells in the Johnson and Dugger Spring-Creeks areas. Transect B1 generally follows the monitoring wells paralleling the Johnson Spring-Creek with transect B2 paralleling the Dugger Spring-Creek system. Monitoring wells GW-31 (**Figure** 43) and GW-34 (**Figure** 44) in the Johnson Creek sub-basin show indications of possible groundwater recovery albeit with the incomplete continuous dataset sets, it makes it more difficult to be conclusive. Note the arrow lines provided on each graph are for trend-visualization only and are not linear regressions of the data. This is an area where extensive piping has occurred in recent years (e.g. HBDIC's Richartz Ditch-to-Pipeline conversion) which would seem counter intuitive to what appears to be gradual groundwater recovery. Coupling these results with those of increasing water table levels at the HBDIC recharge site will be something to continue to monitor as the project progresses.

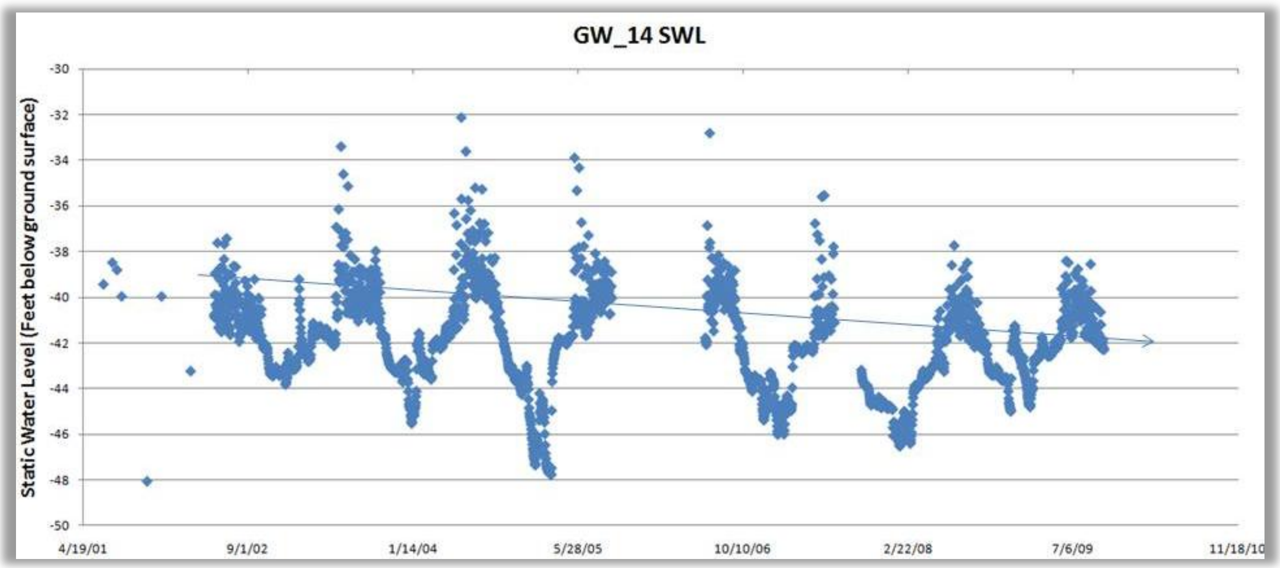


Figure 42. WWBWC Dedicated Monitoring Well used as up gradient Control for HBDIC Recharge Groundwater Response (2001-9)

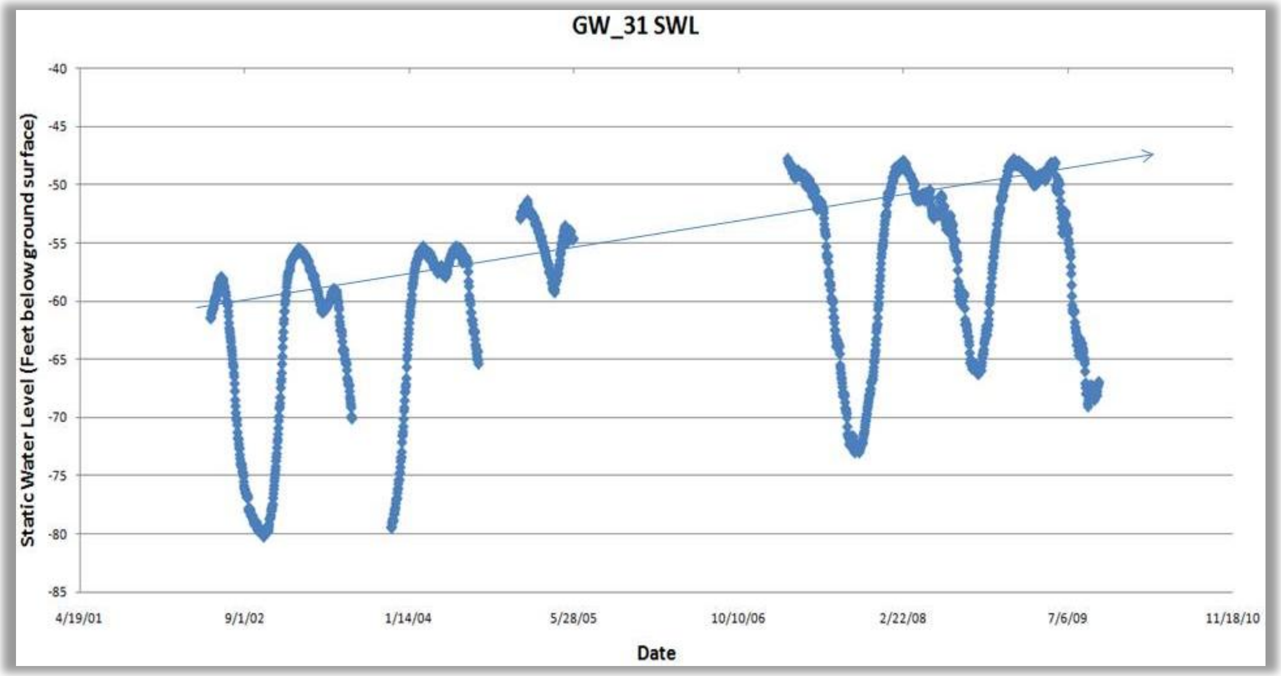


Figure 43. Water Levels at WWBWC Monitoring Well GW-31 (2002-9)

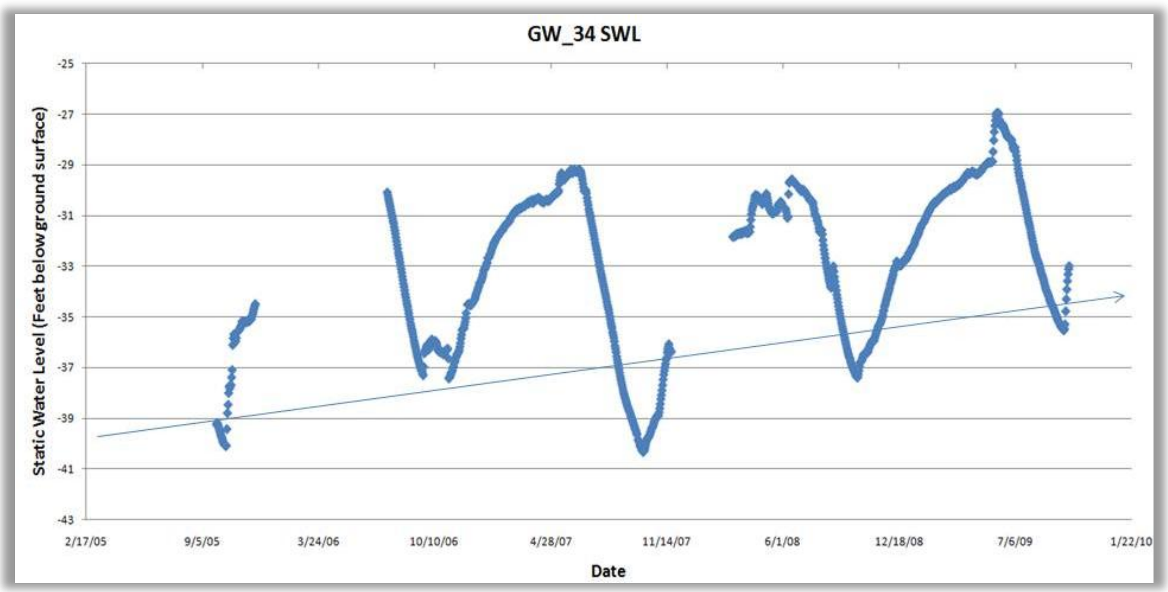


Figure 44. Water Levels at WWBWC Monitoring Well GW-34

Plotting all the groundwater elevation data for transects A to B1-B2 for water year 2009 (November 1st 2008 through September 30th 2009) helps show the spatial response of this area to HBDIC operations. **Figure** 45 clearly shows that GW-14 provides a representative up gradient control well for the purposes of documenting HBDIC operations. Wells GW-40, GW-45, GW-46 GW-48 representing the on-site HBDIC operations monitoring wells document the near-basin mounding effects of aquifer recharge. Down gradient and away from the site, wells GW-35, GW-118, GW-60, GW-61 and GW-65 show the height of the mounding decreases with horizontal distance. GW-65 clearly shows that by approximately one mile down gradient (GW-45 to GW-65), the mounding is still visually apparent.

Moving toward the outer boundary of the each of the transects B1 and B2, wells GW-110, GW-63, GW-31 all show an increase in head during the upgradient recharge operations (**Figure** 45). However, with numerous users of the HBDIC ditch also operating during this period of active infiltration from the project, recharge from up gradient water users and the Little Walla Walla River system likely plays a role in a portion of this recovery. From the extensive aquifer testing done at the project site OSU-WWBWC estimated groundwater velocity to be approximately 1 meter/day. This is significantly less than the measured response seen in the water table around the project as the project has turned on and off. The water table response to recharge changes propagates through the aquifer many times faster than the water actually moves. The next step in the process of linking recharge operations to directly helping to restore spring-creeks in the basin is to link these change in water table head to the changes in flow that occur at the down gradient springs.

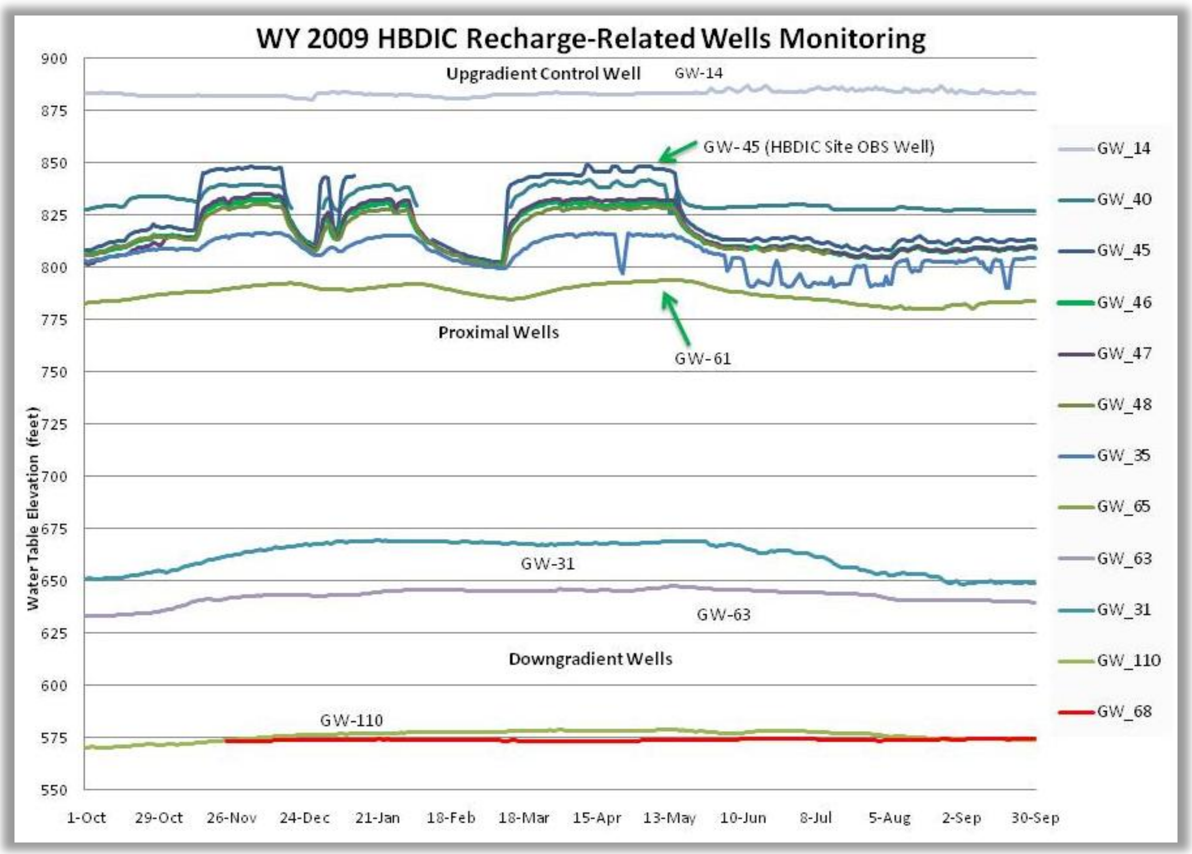


Figure 45. Groundwater Response to recharge in Johnson and Dugger Spring-Creeks Subbasins (2009)

A groundwater flow model is being constructed to assess groundwater responses to the HBDIC Recharge project, particularly overall groundwater storage and spring flow restoration. Utilizing finite-element IWFM modeling work by OSU (Petrides, 2008), WWBWC GIS water table mapping using data from the well network (Baker T. , 2010) and other USGS hydrologic studies and models, **Figure** 46 was created to show the water table contours and general flow direction relative to the HBDIC recharge site during September 2009. Generally groundwater flows in a west to northwest direction. Additionally, specific conductance (uS) collected from groundwater monitoring sites was assessed using Arch GIS Spatial Analyst to help depict groundwater movement (**Figure** 47). HBDIC recharge site shows lower values indicating the recharge of surface water at site and down gradient movement.

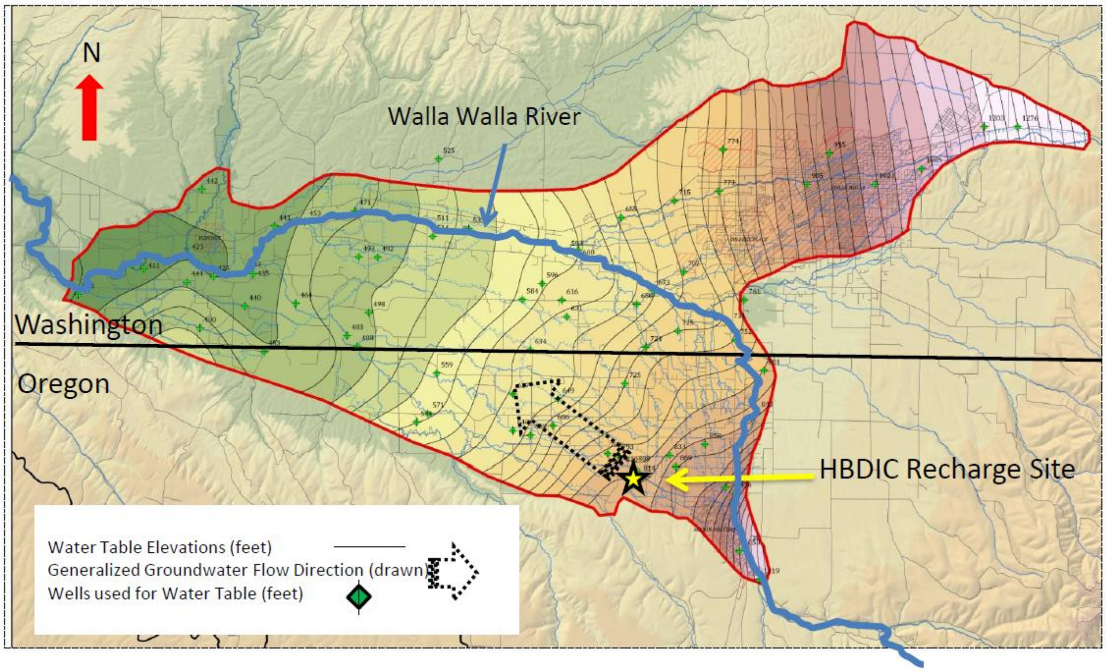


Figure 46. HBDIC Recharge Site Flow Direction(September 2009)

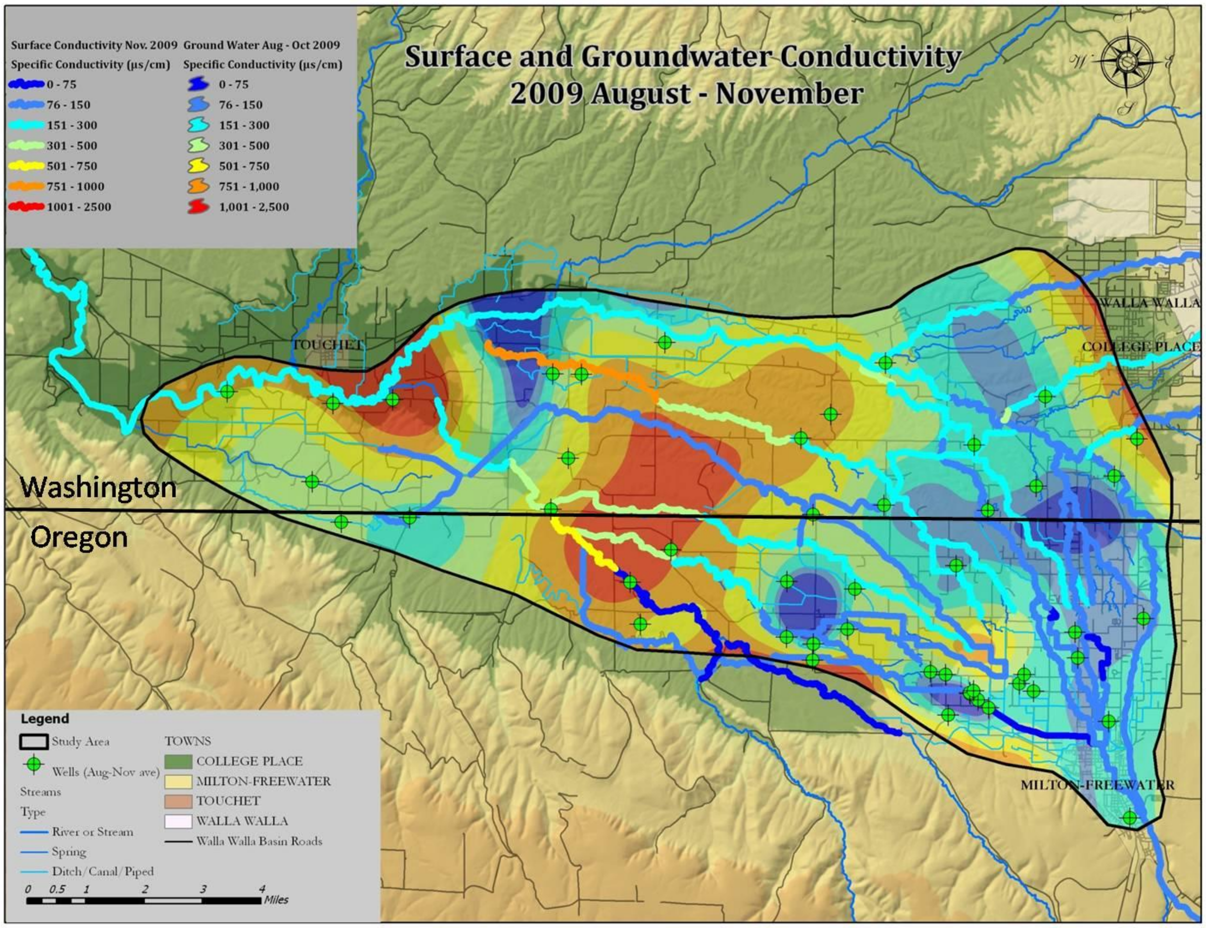


Figure 47. Groundwater Specific Conductance Map (Baker T., 2010)

Spring-Creek Responses

Since one of the stated purposes of the aquifer recharge is to stabilize and restore historic spring flows, an important part of documenting the system wide responses is to link groundwater changes interpreted to be caused by recharge operations, to the springs that flow from this aquifer system. OSU's IWFM modeling work in 2008 provided us some the first supporting evidence linking both HBDIC operations and the operation of unlined canals to the recharge of the shallow aquifer system. **Figure** 48 depicts the three scenarios run by the 2008 model for the flow in the Johnson Spring-Creek system which included; 1) Johnson Creek flow without HBDIC recharge site operations, 2) Johnson Creek flow with HBDIC recharge site operations and 3) Johnson Creek flow with the lining of the canals and without HBDIC recharge site operations (Petrides, 2008). The HBDIC recharge site clearly played a role in why Johnson Creek was running again after 25 years of being dry (**Figure** 48). However other factors helping to restore a partial amount of flow from Johnson Springs were at work preceding the 2004 HBDIC recharge operations. Possibly, with the emerging awareness of the irrigation community that ditches played a positive role in groundwater supply encouraged them to increase the amount and duration of seasonal canal usage. Also this IWFM scenario underlines the importance the man-made canals play in recharging the groundwater system-from which the historic springs are dependent on for their flow.

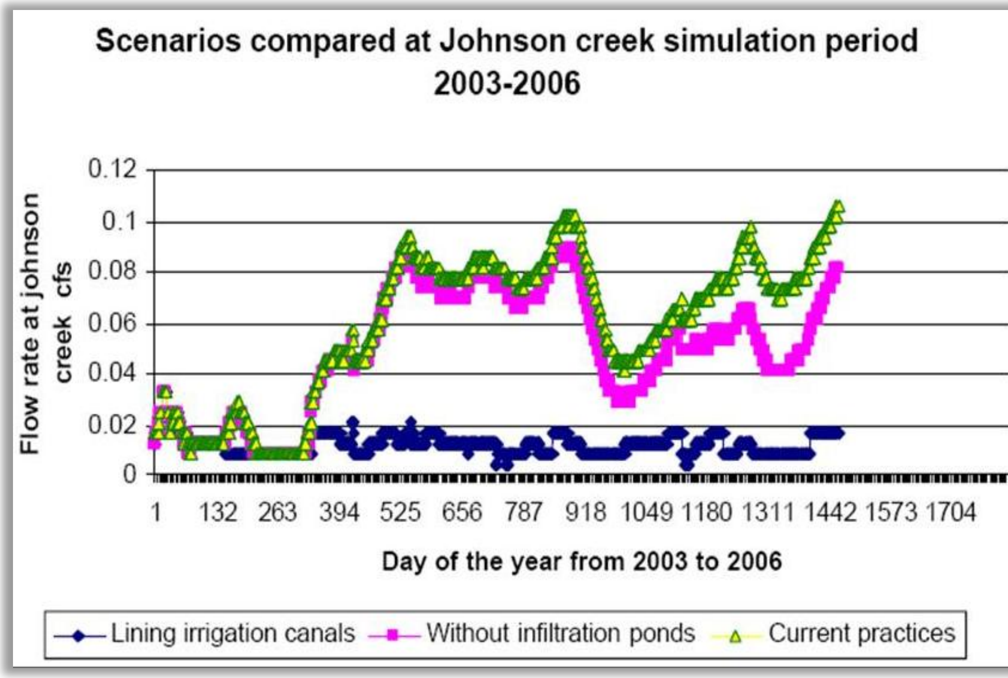


Figure 48. 2008 OSU IWFM Modeling Scenario for Johnson Creek (Petrides, 2008)

Utilizing the transect B2 from the prior groundwater response section, **Figure** 49 illustrates the groundwater and springs monitoring sites from the HBDIC Recharge site to the spring heads of Johnson and Dugger Springs. Plotted next to each of the well sites is the elevation of the ground surface (top of grade) that was surveyed by WWBWC staff during summer 2009 (Patten S. , 2010). Moving down gradient, Transect B2 covers a total distance of about 0.9 miles with a total change in topographic surface of about 70 feet from the HBDIC recharge site (~793 feet) to both flow gauges on Johnson Creek (~723 feet) and Dugger Creek Springs (724 feet). This translates into about a 1.3 % grade of topographic slope.

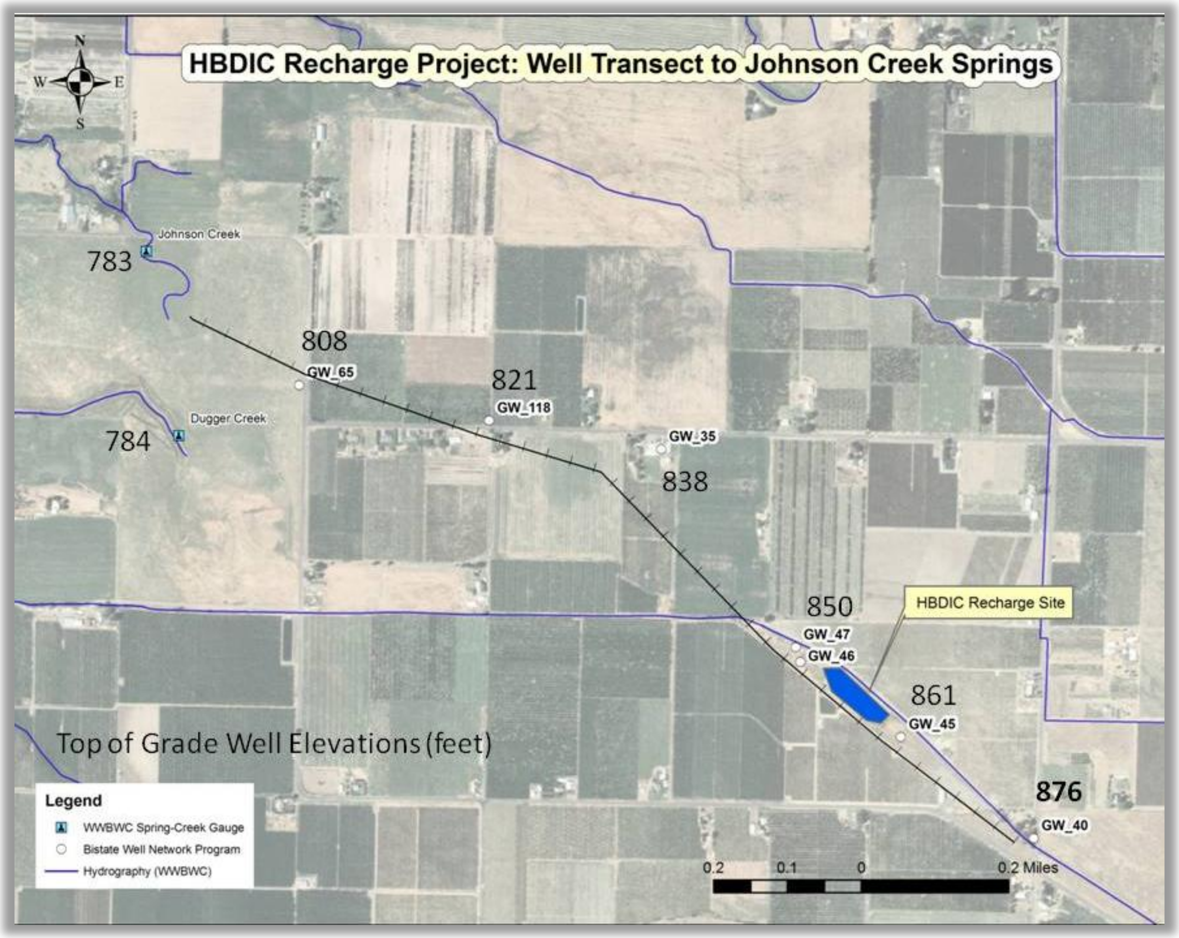


Figure 49. Transect from HBDIC project site headwaters of Johnson and Dugger Creek Springs

Figure 50 shows hydrographs for WWBWC monitoring wells from GW-40 to GW-65 along this transect with GW-65 being the closest to the headwaters of both springs. The groundwater infiltration pressure perturbations (denoted here at R-1, R-2, and R-3) can be tracked down gradient through the water table toward the near-spring well site, GW-65. It should be noted that GW-35 is a shallow well that has some use associated with it, which explains the periodic drawdown in it.

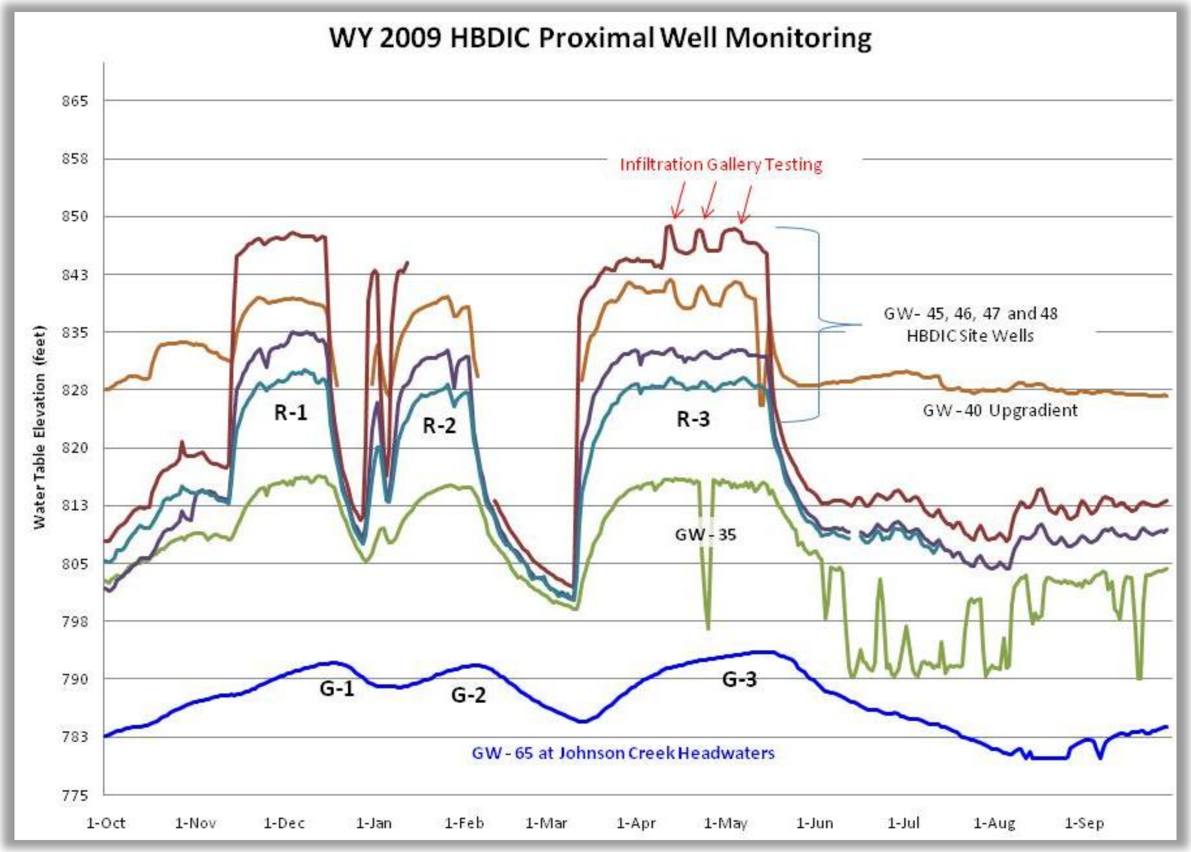


Figure 50. WWBWC Monitoring Wells (Transect B2) from HBDIC Site to near Headwaters of Johnson Creek Springs

Utilizing the changes in water level from recharge operations at GW-65 we now can look to the WWBWC spring gauges for signs of groundwater-to-spring-discharge similarities. **Figure** 51 shows this well site relative to the headwaters of both Johnson and Dugger creek springs. The horizontal distances between this well site and the actual spring heads were not surveyed as a part of this project, but were measured using the Arc-GIS distance tool. Johnson Creek's South Fork springs are approximately 1059 feet from GW-65 with a slope of 2.4% (25 feet vertical in 1059 feet horizontal). Dugger Creek spring is approximately 929 feet from GW-65 with a slope of 2.6%. These marked increases in topographic slopes relative to the estimated 1.43% slope from GW-45 to GW-65 (4780 feet) may help explain why these springs emerge at this point in the aquifer system. Other factors likely playing a role in where springs emerge are changes in stratigraphy that may decrease the permeability of the saturated and unsaturated zones. With an increase in groundwater slope and a decrease in permeability (e.g. likely due to cataclysmic Missoula flood deposition of clays and Touchet bed materials) faster moving groundwater would be forced upward (mounding) toward the topographic surface producing the historic springs that the USGS (Piper, 1933) likened to 'spillways on a reservoir'.

The WWBWC surface-groundwater monitoring network also includes more than 50 small-order springs, creeks and ditch sites throughout the Walla Walla River Valley (Lewis, 2009). The WWBWC has three relevant gauge sites to monitor spring and creek flow in these two subbasins. WWBWC gauge # LWSJ (South Fork Johnson Creek spring) measures the elevation of a pond fed exclusively by South Fork Johnson Springs (**Figure** 52). This site along with the other gauge sites were surveyed (Patten S. , 2010) with the purpose of tracking these recharge-to-spring physical connections. WWBWC gauge #LWDC1 measures flow (cfs) out of a series of springs at the headwaters of Dugger creek. The WWBWC installed a weir structure at the site and placed a water level logger and staff gauge at the site. Periodic in-stream stage measurements are recorded and used to calculate flow data. While the site does not capture all of the numerous springs along the headwaters of Dugger Creek, it does provide an understanding of the timing and volumes of flow arising from groundwater changes. WWBWC site #LWJG is a continuous level logger placed in the engineered intake weir for the Johnson Creek reconnection pipeline (Bower R. , 2008). It was installed in 2007 with the first two full years of data being 2008 and 2009. It should be noted however that this site is downstream from the springs and there are a number of active surface water rights that may influence the data recorded at this site. The map also shows other unmapped spring-seeps that likely provide some flow to Johnson and Dugger creeks. These features can be seen as wetland type swales in the fields near GW-65.

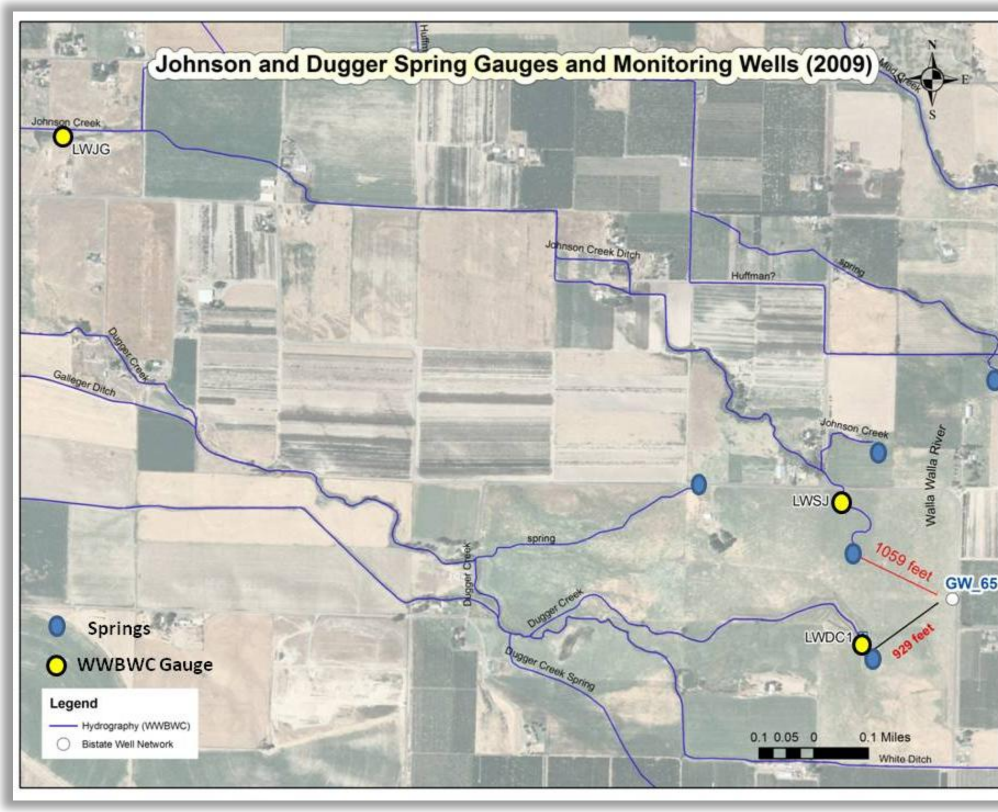


Figure 51. Aerial Map of GW-65 and Gauges-Springs on Johnson and Dugger Creeks

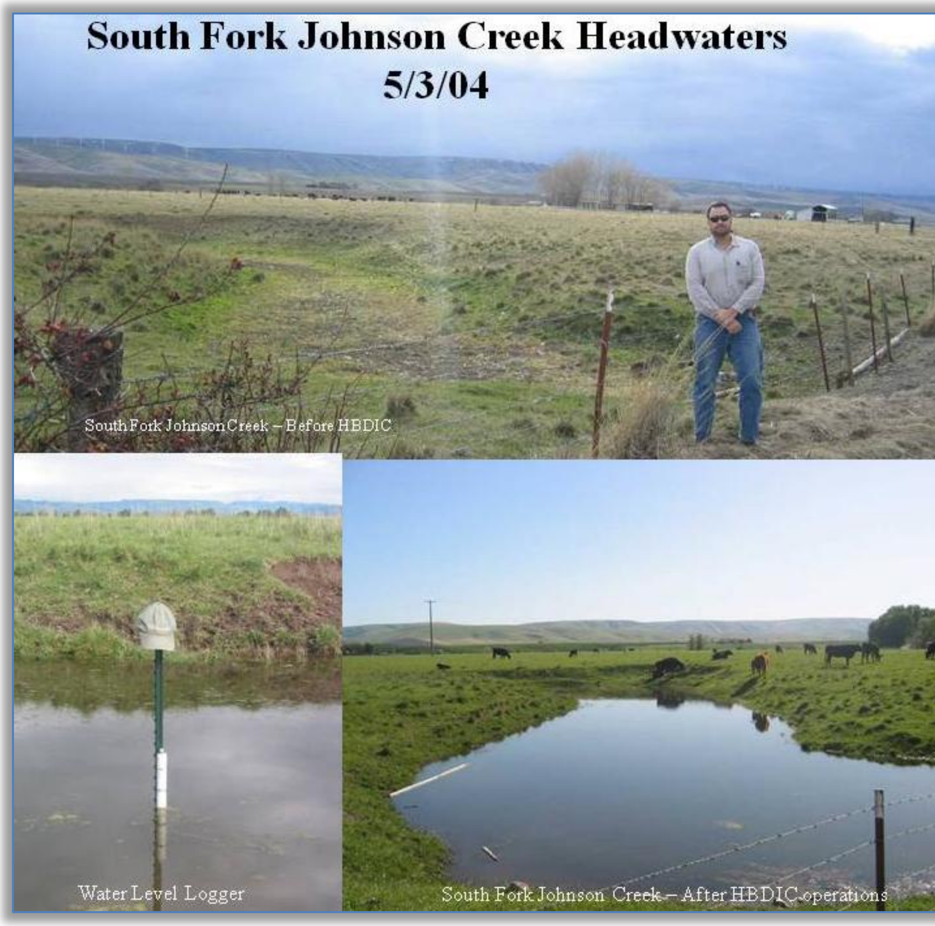


Figure 52. South Fork Johnson Springs (Pond) – Before and After HBDIC Operations (Bower)

Utilizing the water level elevation data from WY 2009 (October 1st 2008 through September 30th 2009) for both GW-65 and the spring-pond level data from LWSJ a graphical comparison was done (**Figure** 53). Groundwater level peaks G-1, G-2 and G-3 appear to correspond directly to pond water levels peaks Sp-1, Sp-2 and Sp-3 in the spring-fed pond. Therefore with this data set we can demonstrate the following logic:

Recharge Action = Groundwater Response = Spring Response

R-1 = G-1 = SP-1

R-2 = G-2 = SP-2

R-3 = G-2 = SP-3

Therefore:

Recharge Action = Spring Response

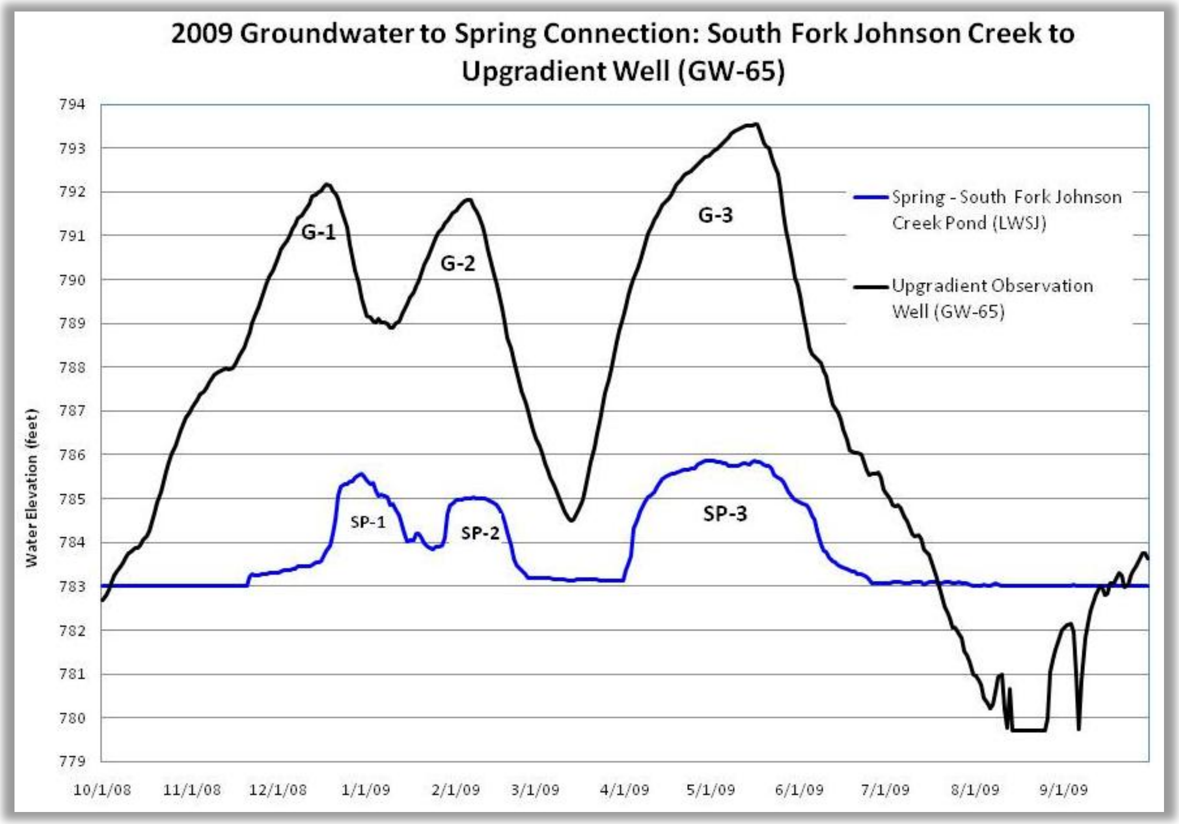


Figure 53. GW-65 vs LWJS Comparison of Groundwater to Spring Response to HBDIC Recharge Project Operations

Starting in the early 1930s some historic data was collected by the USGS (Piper, 1933) in support of the Supreme Court case Oregon v. Washington over management of the Bi-state Walla Walla and Little Walla Walla River system. The State of Oregon continued collecting both surface and groundwater data on many of the springs until the middle 1940s, and contined some of the well monitoring sites until present. Using historic data collected from 1932 through 1942 and WWBWC gauge data for Johnson Creek we made a comparision of historic versus current flow conditions. Historic grab sample data was compared against daily-average data that the WWBWC has collected. In order to graph them together, WWBWC data was averaged to monthly values that could be compared with the cooresponding values of the historic dataset. **Figure** 54 shows this comparison for historic water years 1932-34, 36-43 against current data from water years 2008 and 2009. For the water years 2008 and 2009 we utilized the WWBWC gauge data from LWJG as well as a gauge measuring the tail-water from the HBDIC Richartz Pipeline. The tail water was subtracted from the Johnson Creek flow as it is there artifically and would not represent a true comparison to historic conditions.

Historical data shows a relatively constant flow throughout the year which corresponds to more total groundwater storage available to provide this baseflow. The current data mimics the general pattern of the historic flows where a smaller peak flow value in the fall (November-December) and a large peak flow during the spring freshet (April-June). WY 2008 appears to be lower than the subsequent

WY 2009 flows for Johnson Creek. The early season WY 2009 data was not available due to a faulty logger. Clearly the groundwater to spring pattern for this location helped to better understand that groundwater recharge and discharge up gradient lead to flows in the down gradient Johnson Creek springs.

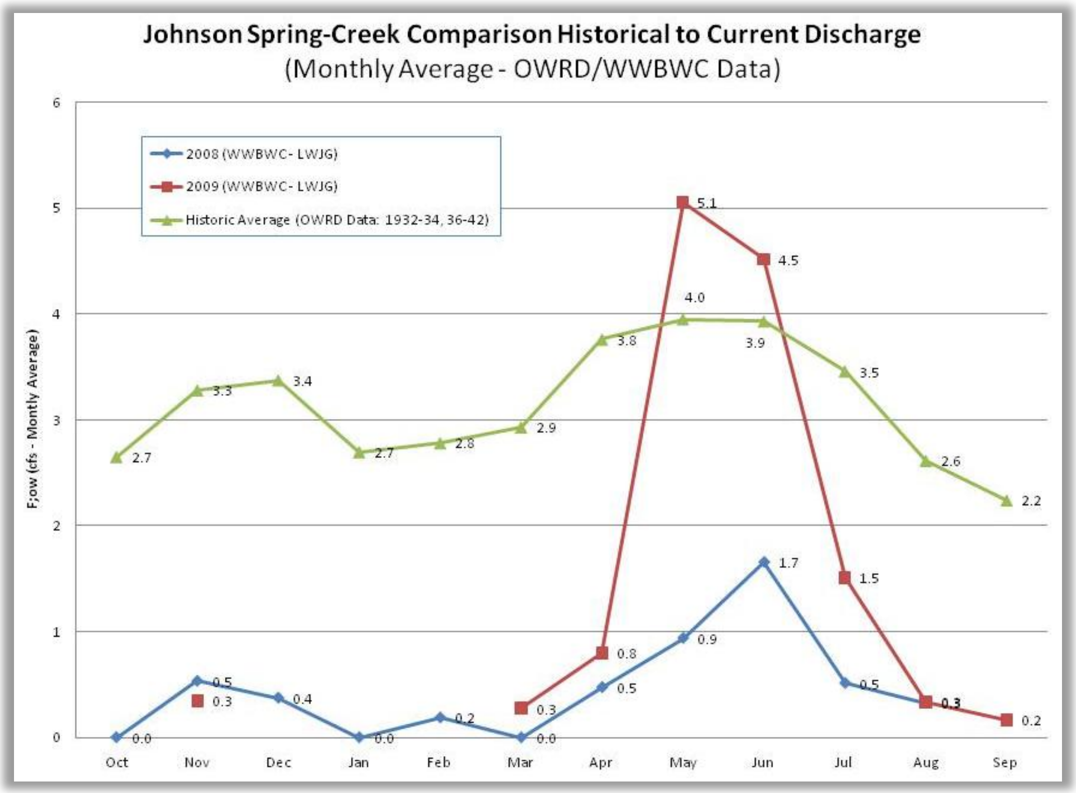


Figure 54. Comparison of Historic versus Current Johnson Spring-Creek flows (OWRD/USGS and WWBWC).

Turning to the other proximal springs relative to the GW-65, Dugger Creek Springs; **Figure** 55 shows the 2008 water year flow data for the spring gauge at Dugger Creek Springs relative to the groundwater pertubations from HBDIC recharge activities (GW-65). Similar to that shown in the Johnson Creek datasets, Dugger Creek surface flows also seem to correspond directly to HBDIC recharge site operations.

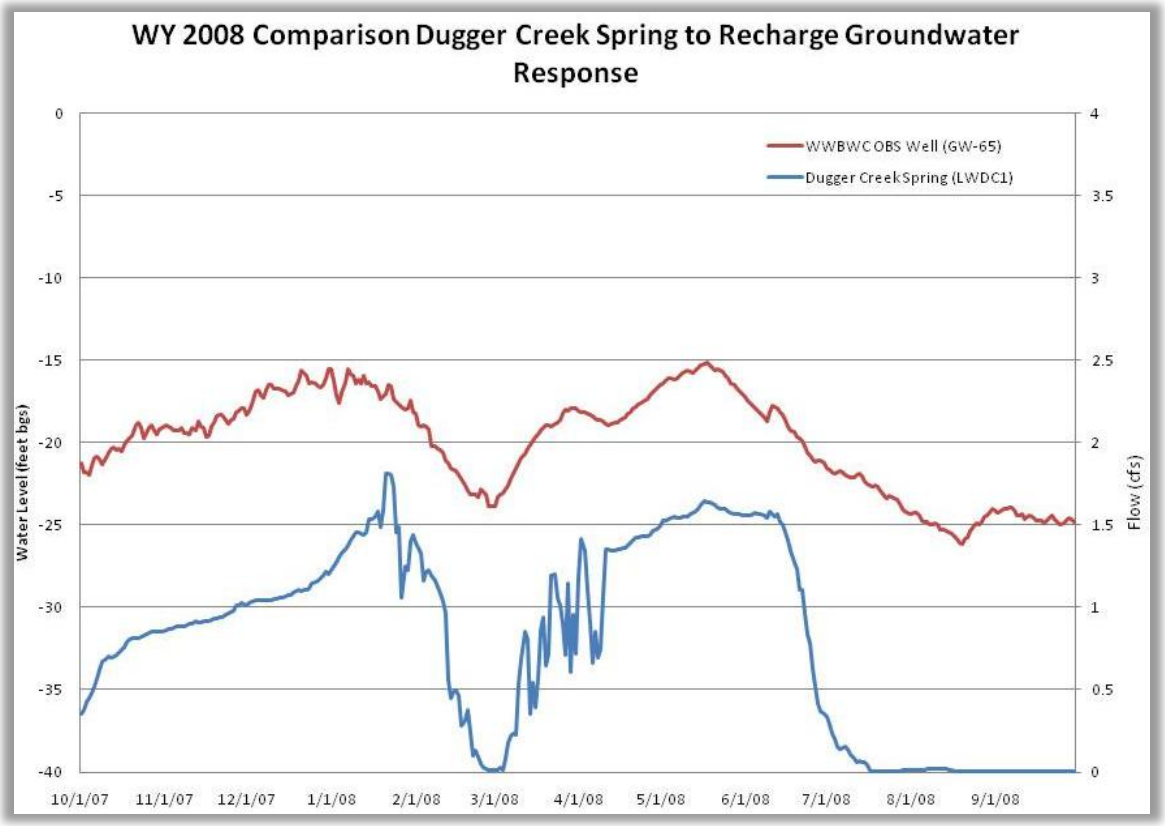


Figure 55. Comparison of Recharge Groundwater Response to Dugger creek Flow (WY 2008)

Linking Spring Responses to Declines in Groundwater Storage

The seasonal fluctuations of the water table in the sub-catchments discussed in the previous sections can be shown to link both the infiltration of water from recharge to the discharge of water through groundwater extraction. However with a system appearing this responsive to change, how is groundwater storage as described in the previous sections actually expressed?

In an early section, **Figure**s 8 and 9 showed that the historic static water table readings showed high variably in levels for any given water year. This variability can be further defined by plotting the values by month to show seasonal change. **Figure 56** shows a summary of water table measurements taken at the OWRD State Observation Well #850 from the 1930's until present. Years with the most monthly static water measurements were selected and synthetic data was generated to map the seasonal trend apparent in the entire dataset. Starting in the 1930s through early 2000 the seasonal pattern of the water table are reasonably consistent across the period of record. However, while the pattern is similar the height of a given year (Y-axis) decreases through time toward the bottom of the well, which subsequently went dry. This overall drop in average readings represents the historical loss of storage in the aquifer system. As spring flow has been shown to be linked to elevation of the groundwater this explains why springs such as Dugger or Johnson Creeks flowed perennially in the past but now flow only when the elevation of the peaks (**Figure** 56) are above the required elevation at the surface. This helps us better understand the role storage plays in the base flows of springs and likely the Walla Walla River.

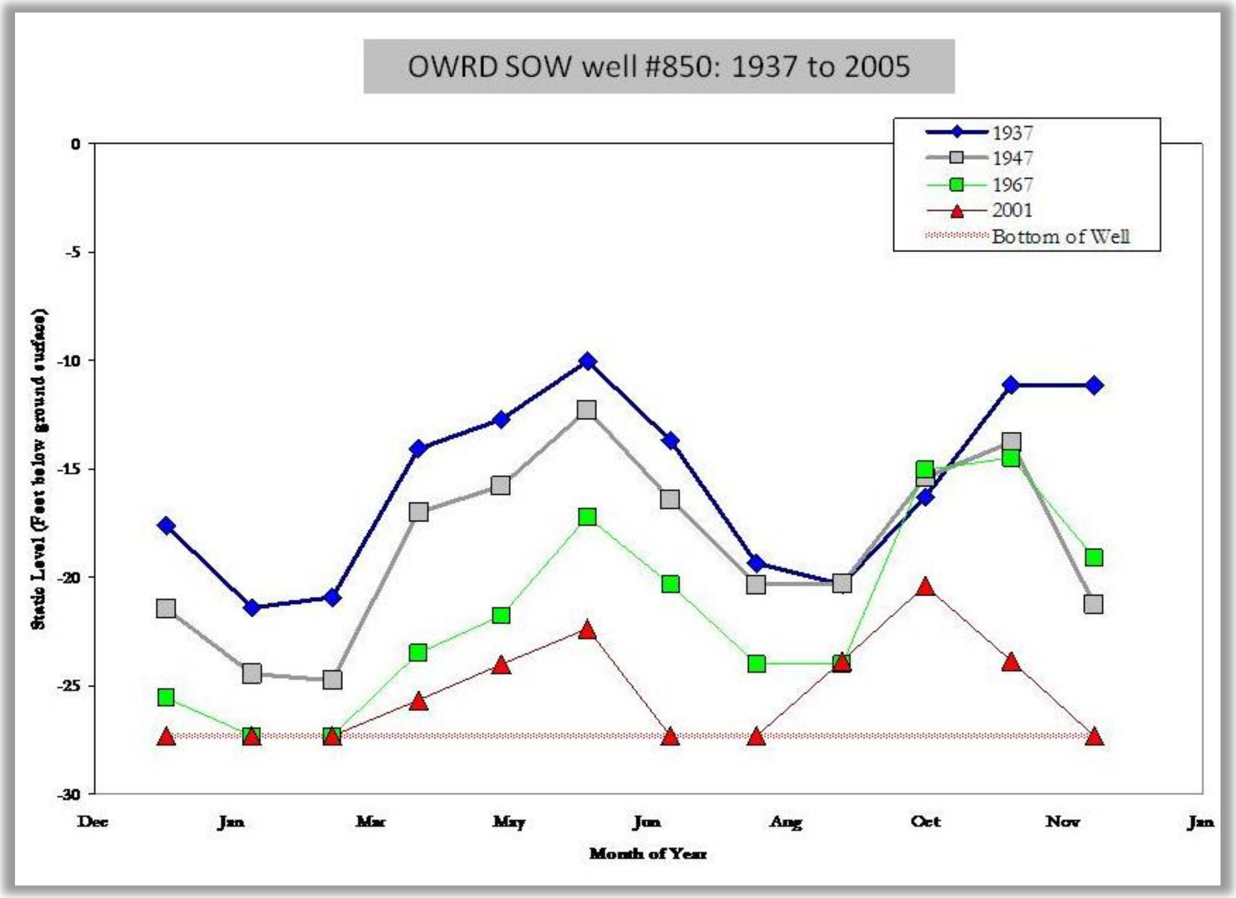


Figure 56. Walla Walla Basin Aquifer Water Table Fluctuations and Historical Trends

Other Recharge Results: Johnson Creek Recovery

In the early 1930s, just one of the three springs that feed Johnson Creek was measured to range between 2-4 cfs during the summer months. During that time, Johnson Creek served a series of water rights through and past the town of Umapine and most likely was the primary water supply during the establishment of the town in the mid-1800s. For decades what little water came out of the springs, didn't make it down to the lower end of the system.

Starting in 2003, the flows are returning to Johnson Creek after being dry for nearly three decades and appeared to incrementally increase from the subsequent year. The headwaters of Johnson Creek, like the observation well SOW #853 discussed earlier, are directly down gradient from both the Hudson Bay District Improvement Company Aquifer Recharge project and the other up gradient water management changes mentioned earlier. During the winter of 2007, the WWBWC, HBDIC and citizens from the town of Umapine, using OWEB funding, worked together to reconnect this disconnected tributary to the Walla Walla River via the Dugger-Schwartz-Pine Creek tributary system. Today Johnson Creek flows for a portion of the water year directly to Dugger Creek (**Figure** 57). This is water that had not been historically available for down gradient flow restoration before the HBDIC testing site operations. These results emphasize both the ability of recharge to play a role in helping to restore flow to historic springs and serve as a cautionary note on recharge and down gradient springs that have been abandoned due to declining flows.

Figure 57. Johnson Creek flowing again after 25 years (Umapine, Oregon – Bower)

Summary of Spreading Basins Testing and Recommendations

Spreading basins are effective at HBDIC and have shown their ability to move large amounts of water into the groundwater system. Relative to the value of the water being stored, this tool can be considered the preferred method of water storage. Results from the 2004-9 testing indicate that clogging and/or subsurface mounding of groundwater are issues that will need to be addressed for the long term operations of this site. Off-season treatment and removal of the sediment layers that appear to be accumulating is recommended as first steps toward this goal. There are numerous techniques used by larger recharge programs that can help address these issues of long term operations. Water quality for the site, both source and recharged groundwater, has shown itself to be of good and consistent quality. On-site water table monitoring may indicate that localized groundwater storage is recovering from HBDIC recharge activities, although additional years of monitoring will help confirm this trend. Additional site upgrades should include a reexamination of the intake structure and its ability to measure flow more effectively with regards to White Ditch fluctuations as well as water backing up from the first spreading basin. The overflow flume site should also be upgraded from a portable weir to a concrete structure to ensure that excessive water leaving the site is measured.

PART III. INFILTRATION GALLERIES

Infiltration Gallery Testing

Overview

Making irrigation systems more efficient through the lining and piping of irrigation canals is another tool for water management. While you lose the aquifer recharge benefits you gain more surface water volume with which to irrigate. Irrigation efficiency in these terms does provide the Walla Walla basin with a method to better manage surface waters. However with the urgency of addressing the declining aquifer system and drying up of spring-creeks, developing methods of incorporating managed aquifer recharge into piped and lined canals systems is critical. The idea is to save water during times of scarcity without losing the ability to replenish the natural groundwater storage of the system. Furthermore the availability of acres of open ground, such as used for spreading basins is not always available or cost effective. Subsequently numerous smaller recharge areas spread spatially in watershed may be helpful to reduce the subsurface mounding created by larger projects and better disperse the storage of water.

The concept of recharging groundwater in subsurface galleries or chambers is not a new one. For years storm water managers in municipalities and along road systems have devised ways to collect run-off from impervious surfaces and infiltrate that water into the subsurface so as to avoid overland flow and flooding. In these situations the water can often contain pollutants and suspended solids that make their deposal difficult. The risk of toxic water quality issues along with the clogging of disposal area makes this a unique water management challenge. More recently many municipalities in water restricted areas of the world are developing these subsurface recharge galleries to be used in parks, golf courses, and in some cases for capturing run-off from roof tops for backyard recharge programs.

The methods and designs utilized in the infiltrating of storm water can be built upon in the case of recharging with clean winter source water such as the case at the HBDIC recharge site. The HBDIC team decided that there was a need to test the varying methods and materials for infiltrating recharge water into the subsurface. A number of designs and materials were reviewed to determine which infiltration galleries were tested including material costs versus their perceived effectiveness at recharging groundwater. From reviewing other recharge testing projects we knew that the most difficult challenge for these systems was clogging. The presence of suspended solids in the source water along with the possibility of biological clogging from algae growth in the galleries was an issue that has thwarted effectiveness of these projects in the past. In designing the testing galleries, collaboration was established with Adam Hutchinson who leads the Orange County Water District's managed aquifer recharge (MAR) program. The Orange County team has been testing infiltration galleries type MAR projects under golf courses, in city parks and in other locations where small, discreet subsurface recharge sites were needed to maximize the programs ability to recharge and store water. Information from their experiences was used extensively to design the galleries as well as develop the testing methodology for the project.

Infiltration Gallery Designs, Permitting and Testing

Four types of subsurface materials were used to design for infiltration galleries at the upper end of the HBDIC recharge site (See **Figure** 25). The materials were chosen primarily to compare the cost of materials relative to their anticipated effective recharge rates and how those rates may decrease through time due to clogging. Infiltration gallery # 1 (IG-1) was constructed using 4" perforated pipe (ADS) that can be purchased inexpensively from any home builder supply and its easy installation allowed for low labor costs. Infiltration Gallery #2 (IG-2) utilized 4 inch perforated PVC pipe typically used in domestic septic-tiling systems. This was also fairly easy to install; also keeping the overall constructions costs down. Galleries #3 and #4 both utilized materials developed by companies designing subsurface infiltration methods for the storm water industry. Infiltration Gallery #3 (IG-3) was built with *Stormtech Chambers* that are open bottomed allowing the water to infiltrate downward. Further, they can be designed to be periodically cleaned of sediment and debris. Infiltration gallery #4 (IG-4) utilized *Atlantis Raintanks* which resemble boxes that are open on all sides allowing for intra-chamber water exchange, but the 336 “tanks” each require assembly making their installation costs the highest of the four designs**.** Preliminary trials of these ‘tank’ style galleries were conducted successfully in the City of Adelaide Australia (Higginson, 2007)**.**

Figure 58 shows the general schematic of the completed IG testing area while engineered designs for the galleries, turnout and other structures can be found at the WWBWC offices. Water is diverted from the White Ditch via a self-cleaning, screened weir (A) situated on the bottom of the canal. Water moves down gradient through the 21 inch main pipe to a stilling well which has the primary control valve (butterfly) to release water in to the testing galleries (B). An *YSI* Model # 6920 V2 turbidity-temperature-conductivity meter is at this location allowing continuous data recording during the operation of the galleries. IG-1, 2, 3, and 4 are supplied water from the main pipeline via 5” connector pipes (C) that have 5 inch butterfly control valves and *McCrometer* (Model #EO3000) propeller-style flow meters that measure both instantaneous flow rates (gallons per minute) as well as totalize the inflow (total gallons x 100). Each set of galleries were installed with air-release vents that also provide a method by which to visually inspect inside the gallery. These vents are located in different locations depending on the type of gallery. At the end of the main line is an overflow basin (D) that allows a location to drain any accumulated sediment from the intake and main pipeline structure prior to turning on the infiltration galleries. Adjacent to the gallery testing area HBDIC Observation Well #4 (GW-45) is located just downgradient (E). **Figures** 59 and 60 show the materials and installation of the IG-3 and IG-4 galleries.

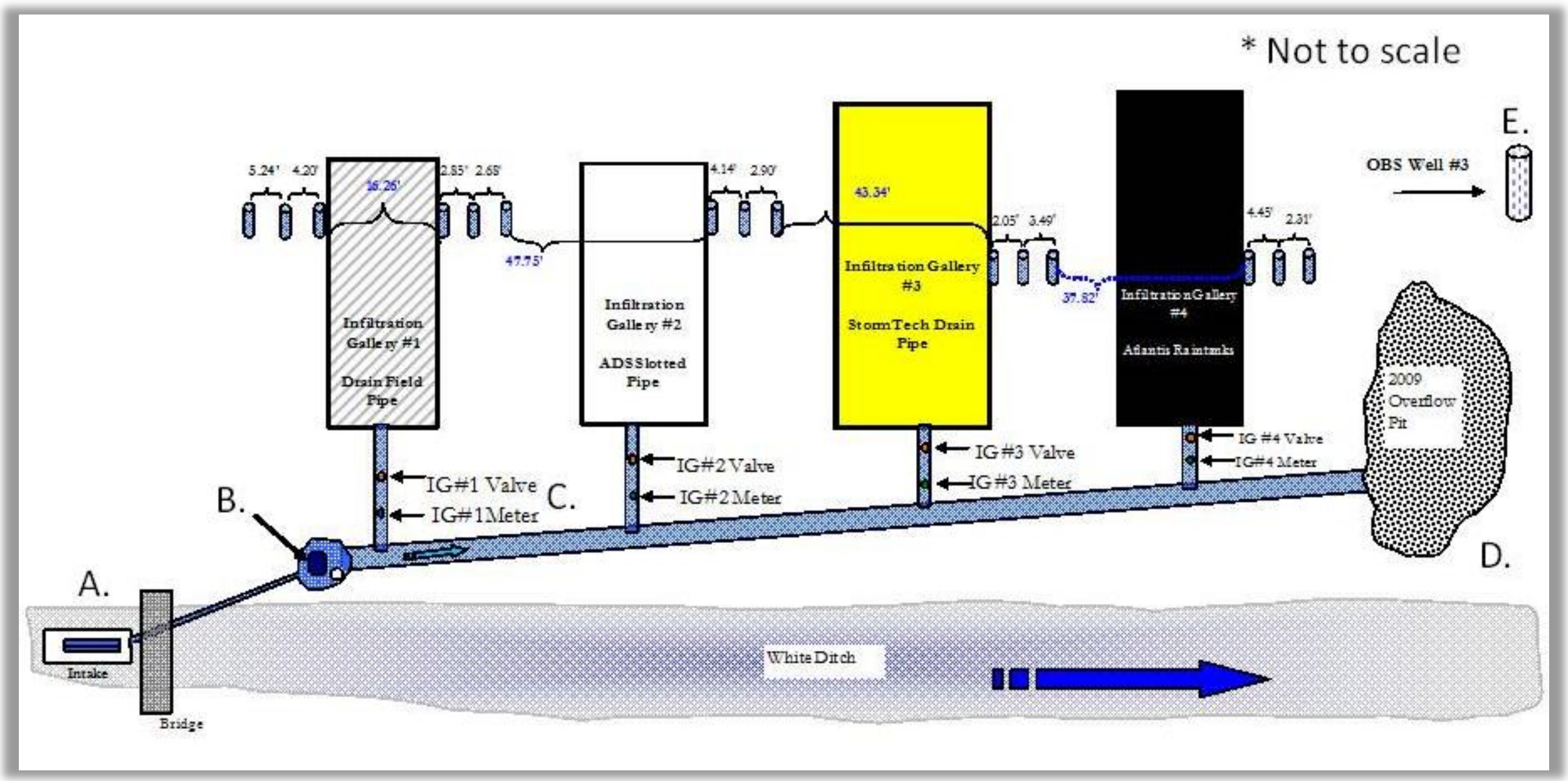


Figure 58 Infiltration Gallery Testing Area (HBDIC Site)

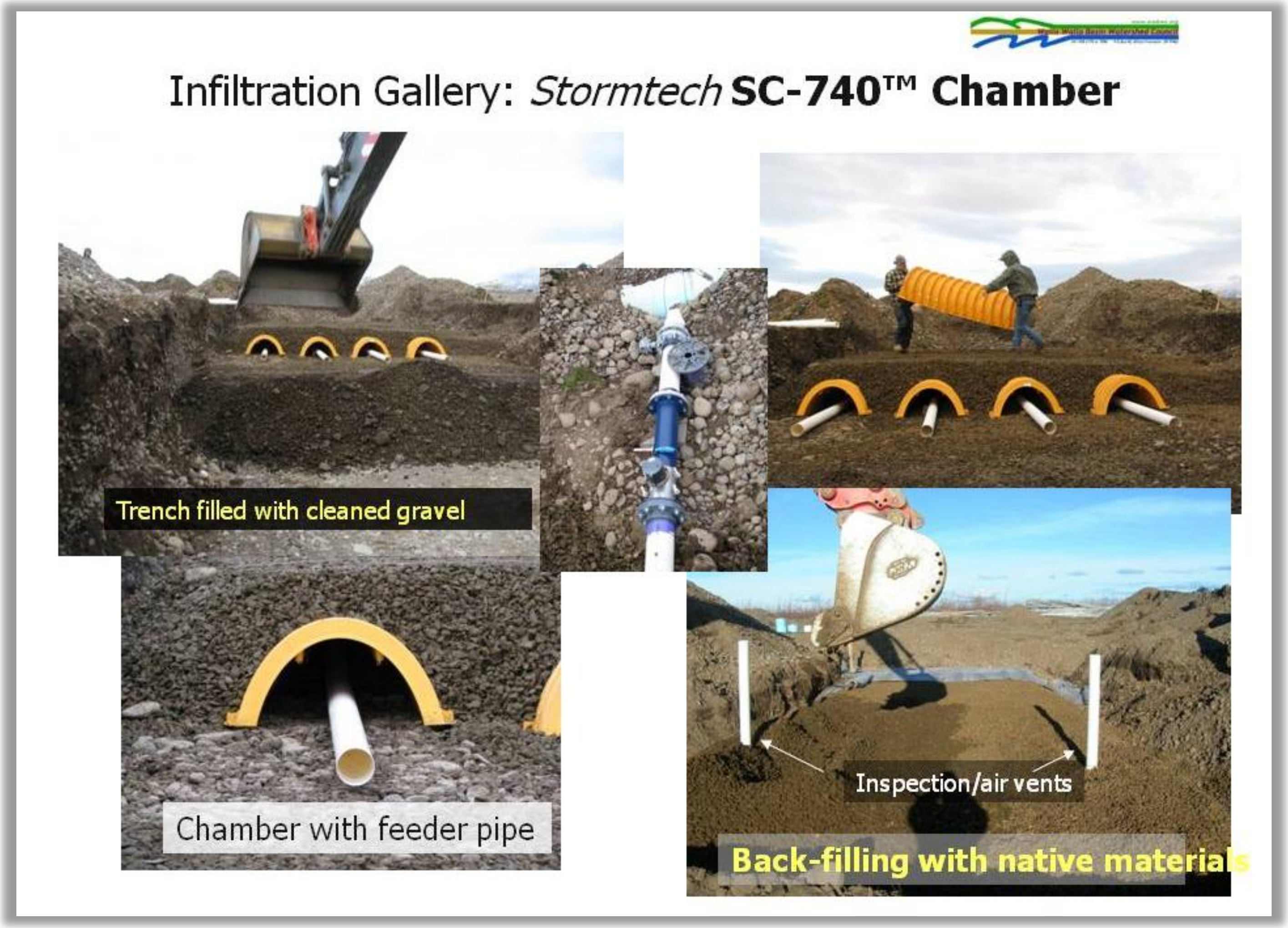


Figure 59. Infiltration Gallery #3 - Stormtech Chamber Installation (2008)

Figure 60. Infiltration Gallery #4 - Atlantis Raintanks Installation (2008)

Next to each of the galleries piezometers were installed in perpendicular transects away from the galleries in order to measure both groundwater mounding as well as water quality (PZ-1 through PZ-15). The piezometers varied on depth from approximately 4 to 11 feet in length with a horizontal spacing of 2 to 5 feet between each gallery with the first piezometer located directly adjacent to the infiltration gallery. Water level recorders (*In-situ Inc. LT100, Unvented, pressured transducers)* were used to measure water levels and temperatures during each of the individualized gallery testing. Each piezometer was outfitted with pre-packed mesh screens so that samples could be extracted effectively from each measurement point**. Figure** 61 shows the various gallery-specific monitoring equipment installed at the site.

Water recharged below the ground surface is classified by the State of Oregon and the Federal Environmental Protection Agency as requiring special permitting and review under the Underground Injection Control (UIC) permitting program. The HBDIC team worked with the Department of Environmental Quality (ODEQ) to apply for and receive a UIC permit to test all four galleries (2009, ODEQ's UIC # 13233-1, 13233-2, 13233-3, 13233-4). Under this approved application (Bower R. , WWBWC-HBDIC's Infiltration Gallery Testing Project: Application for UIC Permit (ODEQ), 2008) a summary of results for the HBDIC site water quality monitoring program and the results to-date were supplemented with detailed gallery designs and additional turbidity, total suspended solids (TSS) and total organic carbon (TOC) testing to track potential clogging of the galleries. As the HBDIC recharge site already has a permit from Oregon Water Resource Department (OWRD #LL1189) to divert water for testing, no further water use permits were required. The galleries were specifically designed to have a separate water intake from that of the site's spreading basins so they could be tested independently. While the water recharged would be important to helping the overall goal of recharging the aquifer, the main purpose of this installation was for testing purposes. After receiving the permit in December 2008, they were constructed over an 8 week period and were ready for testing starting in late January 2009.

Infiltration Gallery Testing Plan

The scheduled testing for the first recharge session aimed to accomplish two main goals. First, each gallery would be initially run independently of the others to measure the individual recharge rates and monitor any immediate changes relative to clogging during the first week of operations. Each gallery was to be run for a week and then turned off for 24 hours before the next down gradient gallery was turned on. Operating more than one gallery at once also created the potential problem of cross influencing each other through the mounding of subsurface water due the close proximity of the galleries therefore, individualized testing was preferred. The testing would take a total of 5 weeks to complete. After this initial individualized testing the galleries were to be all operated in tandem for the remaining portion of 2009 to track any long-term changes in recharge rates over a recharge season or from year to year.

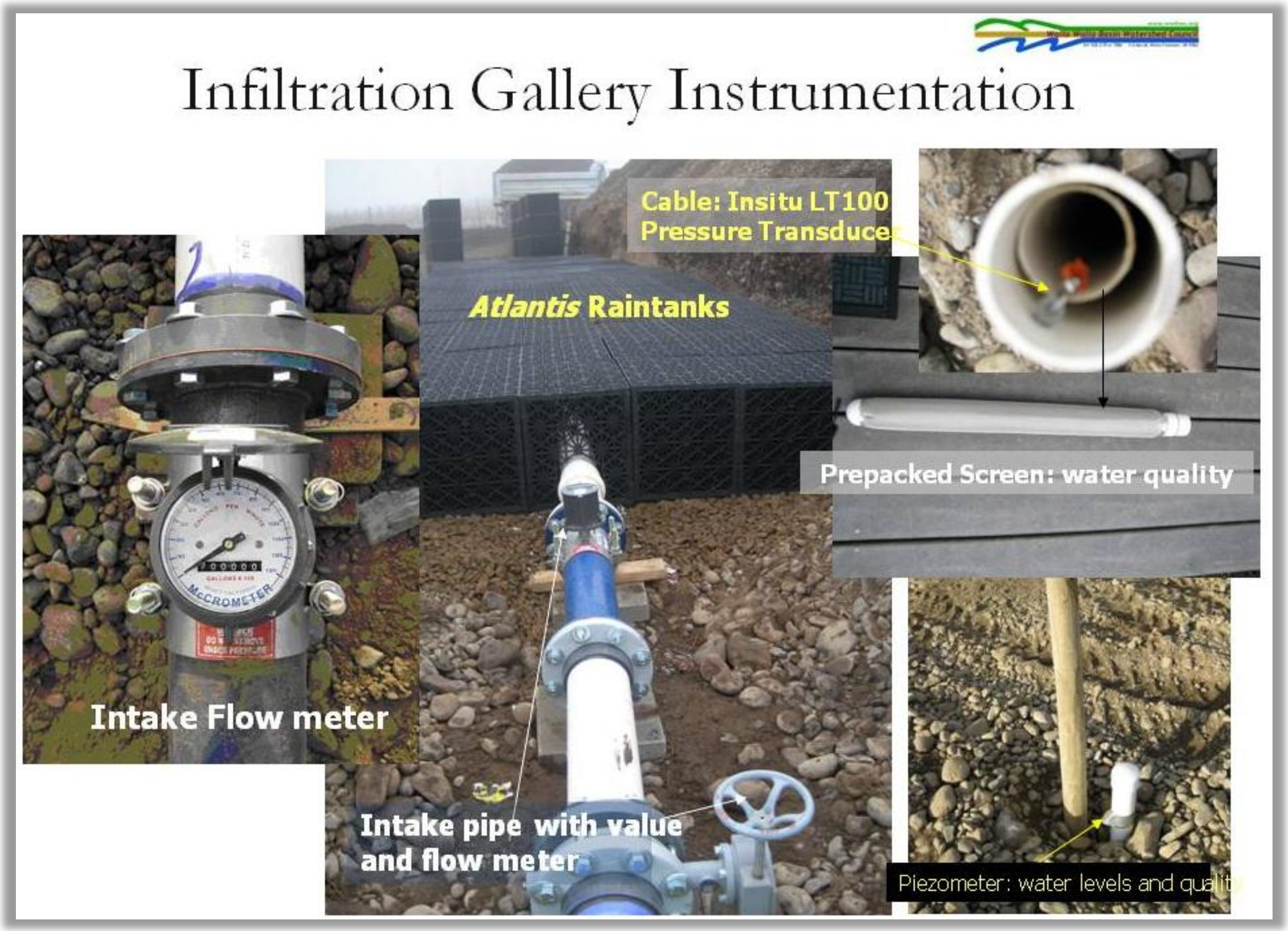


Figure 61. Infiltration Gallery monitoring equipment (2009)

Turbidity, TSS and TOC measurements were to be taken during both the individualized and tandem testing at several pertinent locations and sent to *Edge Analytical Inc.* in Burlingame, Washington. Samples were collected in sterile, 250 ml bottles from the channels edge at the Little Walla Walla River diversion from the source waters of the Walla Walla River. Measurements were also taken at the intake structure of the galleries where the YSI continuous meter was recording turbidity and total dissolved solids in 15-minute intervals during operations. These samples could then be compared to build a regression relationship between TSS and turbidity. By characterizing this relationship the use of turbidity meter can help both with the testing of the galleries as well as establishing water quality guidelines by which to operate the HBDIC and other future MAR sites in the basin. When this information is further linked to mainstem flow, real-time monitoring could help to automate a basin wide recharge system. The purpose of measuring at both the Walla Walla River and at the HBDIC site was to further investigate and potential change in TSS and TOC values as the water moved through the conveyance system.

Infiltration Gallery Testing Results – Preliminary

Construction of the site lasted until late January 2009, just a few days before the Little Walla Walla diversion annual shut down. This allowed only a short test of IG-1 to start the season. Later in February all the galleries were operated for 5-7 days to test all of their individual recharge rates and map the mounding with the piezometers. It was found during the operations of IG-2, the meter's totalizer was not operating. This made the instantaneous portion of the meter the only way by which to monitoring operations. At IG-3 and IG-4 it was found that the 5" feeder pipe was sized too small for these two galleries as air vents at the far end of the galleries showed water was not making to the gallery ends. Therefore, the results for these two galleries under-estimate the true operation rates for *Stormtech* and *Atlantis* style designs. After the individual gallery testing was completed, galleries were operated as spaced pairs (IG-1 and IG-3, IG-2 and IG-4). Lastly, the YSI turbidity meter had power-source difficulties that limited the 2008-9 water quality monitoring to TSS lab sample source to intake comparisons.

At the time of this report the 2010 season has not been completed, so the 2008-9 results are shown along with preliminary information for 2009-10 season (**Table** 6). The galleries have different infiltration areas (due to the materials used and restriction on the site area) and once the rates were normalized by infiltration-area IG-2 seems to have the highest average infiltration rate (2008-9) of 1.67 cfs. Of course with IG-3 and IG-4 having a restricted inflow pipe, their values are likely to be significantly higher than shown here. The galleries combined to recharge approximately 180 acre-feet of additional recharge water (2008-9) during a very limited operation period. Preliminary 2009-10 results show some potential changes in flow rates with all galleries appearing to lose 10-20 gpm from the prior season. IG-1 appears to be operating at about 1/3 of the prior season but it is unclear if that is a factor of clogging or some influence of individual versus dual (IG-1 and IG-3) gallery operations. The galleries have contributed approximately 488 acre-feet of additional recharge at the HBDIC site to date.

Reviewing the preliminary TSS samples from the Little Walla Walla Diversion and the IG gallery intake, it appears there may be a weak correlation between sites suggesting some attenuation of suspended solids between locations **(Figure** 62). Water level data at all 15 piezometers provided detailed water mounding profiles for each of the galleries during the 2008-9 seasons as shown for IG-1 in **Figure** 63**.**

Recharge Season	Infiltration Gallery #	Average Flow (gpm)	Average Flow (cfs)	Infiltration Area ($feet^2$)	Average Flow (cfs) - Area adjusted (1086 feet)	Total Volume (2009) (gallons)	Total Volume (2009) (acre-feet)	**Comments**
2008-9	IG - 1	371.3	0.83	667	1.35	9,160,000	28.1	Piezometers with TSS sampling
2008-9	IG - 2	460.0	1.02	667	1.67	*10,156,800*	31.2	*Estimated Volume (days x average rate)*
2008-9	IG - 3	539.4	1.20	**1,086**	1.20	15,882,700	48.7	5" intake constricts total rate
2008-9	IG - 4	568.2	1.27	1,008	1.36	23,379,400	71.8	5" intake constricts total rate
					Season Total Recharge Volume	58,578,900	**179.8**	IG-2 and Overflow pit not included
Recharge Season	Infiltration Gallery #	Flow (gpm)	Average Flow (cfs)	Infiltration Area ($feet^2$)	Average Flow (cfs) - Area adjusted	Total Volume (2009-10) (gallons)	Volume To Date (acre-feet)	**Comments**
2009-10	IG - 1	***115.0***	0.26	667	0.4	22,425,200	69	Reduced Rate - clogging or dual operations?
2009-10	IG - 2	452.0	1.01	667	1.6	N/A	N/A	Volume not estimated
2009-10	IG - 3	520.0	1.16	1,086	**1.2**	22,428,500	68.8	5" intake constricts total rate
2009-10	IG - 4	560.0	1.25	1,008	1.3	30,495,400	93.6	5" intake constricts total rate
2009-10	Overflow Basin	190.0	0.42	N/A	N/A	25,131,000	77.1	Area changed between seasons
					Total Recharge Volume - To Date	159,059,000	**488.2**	IG-2 not included

Table 6 Infiltration Gallery Testing Preliminary Results

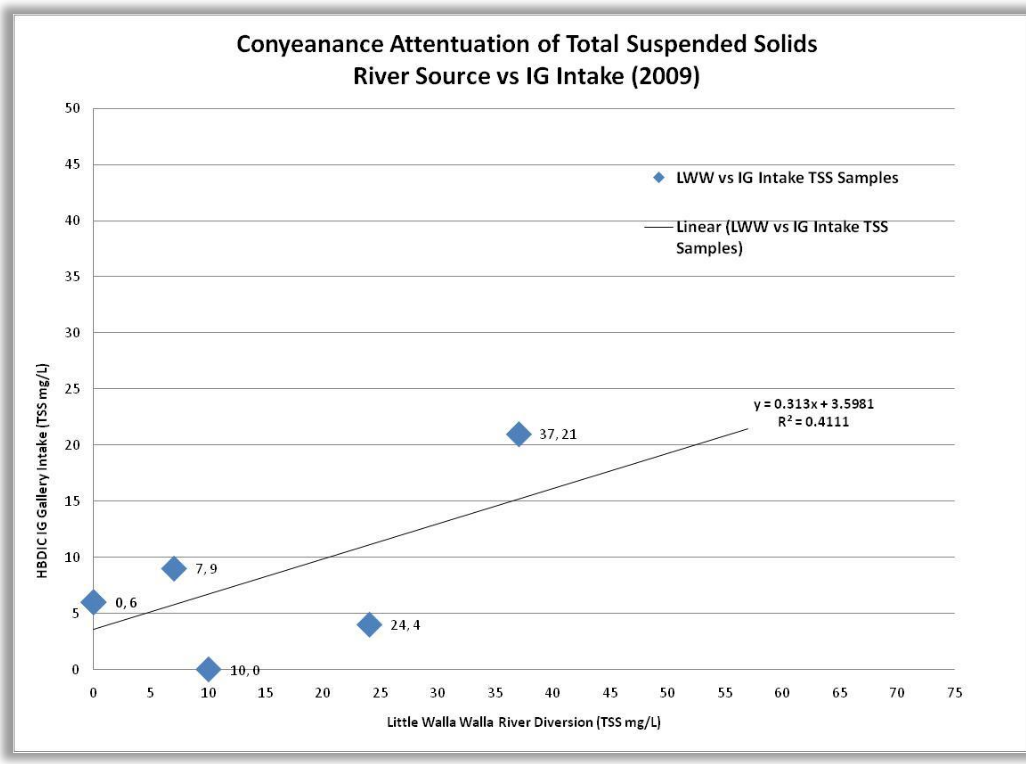


Figure 62. Preliminary Results of TSS and Conveyance Attenuation from Source to HBDIC Recharge Site

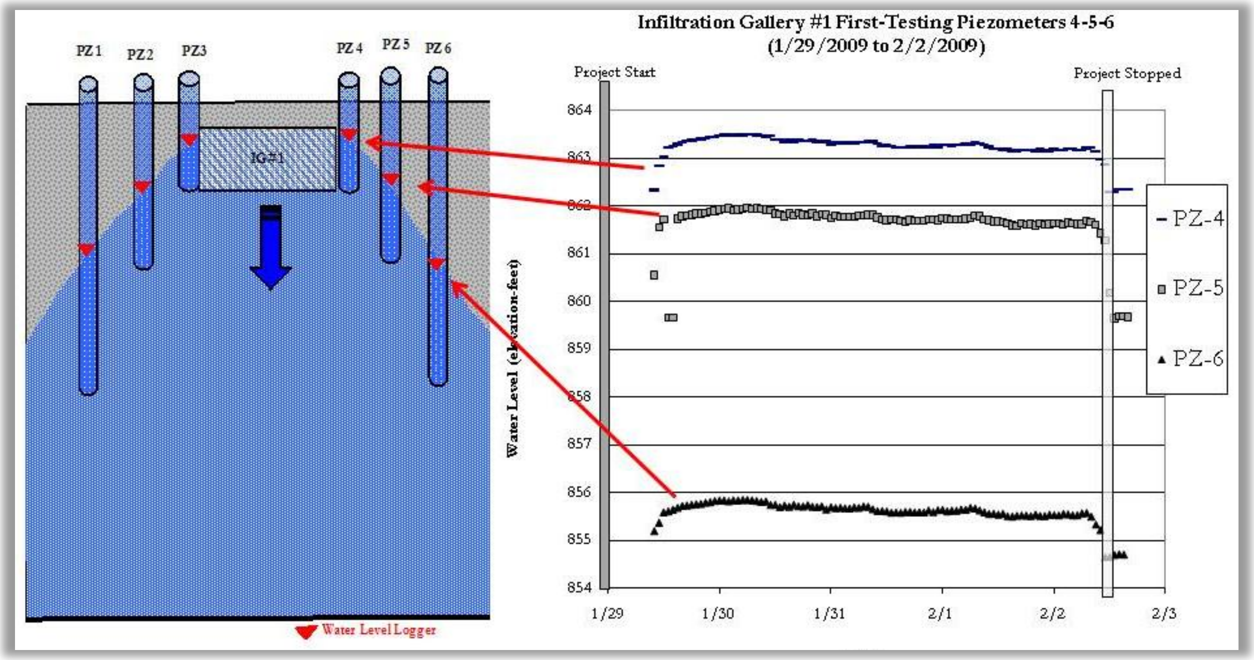


Figure 63. Piezometer water level results from initial operations of IG-1 gallery (2009)

Cost-Effectiveness Summary

The limitations poised by the small intake feeder pipes combined with the galleries being limited in mounding area make doing a straight forward cost-benefit (recharge rate vs. costs) analysis impractical. If the galleries are operated and tested individually in the future, and larger feed pipes are installed in IG-3 and 4, perhaps an estimate can be generated. The galleries as currently configured will serve to test the clogging issue, which is really the most pressing of the original research questions. Table 7 provides a basic break-down of the overall costs of materials for the IG testing as well as a $/foot value for each gallery. Labor should be considered in the construction of these galleries, particularly if numerous galleries were installed around a watershed. It is estimated that labor costs were significantly higher for the IG-3 and IG-4 with the *Raintanks* taking approximately 60 man-hours. Exact labor and materials costs will differ by region and supplier; an extensive analysis was not undertaken for this report.

Infiltration Galleries Materials	Total Material Costs (2008)	Cost/infiltration Area ($/foot)
Inlet Structure	$4,300	n/A
Mainline Pipe	$14,200	n/A
Main Value Structure	$3,330	n/A
IG #1 Perforated Pipe	$2,211	$3.32
IG #2 Drain Tile (septic)	$2,274	$3.41
IG #3 Stormtech Chambers	$7,764	$7.15
IG#4 Atlantis Rain Tanks	$10,078	$10.00
Total	$44,157	

Table 7 General costs breakdown for Infiltration Galleries (does not include gravel).

Summary of Infiltration Gallery Testing and Recommendations

Infiltration gallery testing includes not only the physical monitoring and water quality monitoring of various gallery designs but also the process by which they are permitted for operations. The HBDIC recharge team was successful in obtaining UIC permits for the testing site which coupled with the OWRD limited testing license allowed the system to be built for testing. Initial results on recharge rates show that these galleries have the potential to recharge considerable amounts of water if spaced sufficiently from other areas where surface water is infiltrating (e.g. ditches, ponds or natural water bodies). Issues with pipe sizing, meter failures and site placement limited the independent testing results of the galleries. However even with these issues all the galleries will provide long-term clogging information to the HBDIC team over the life of the testing project. Recharge notes do not appear to have varied greatly between the various materials; however the limitations mentioned previously make any firm predictions tenuous. When funding is secured, it is recommend that the faulty flow meter (IG-2) and the limiting 5” feeder pipes (IG-3 and 4) are replaced so that actual flow rates and volumes can be accurately recorded over the next 5 years of the limited testing license. Establishing the TSS to Turbidity Meter rating curve and keeping careful records of operation times, rates and volumes is critical to better assess the most critical issue, clogging.

PART IV. SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary of Results

The HBDIC recharge site has been operated for six recharge seasons totaling 602 days of operations. On-site recharge spreading basins and infiltration galleries have recharged the aquifer with more than 13,500 acre-feet of water, which represents more than 21 square-miles a foot deep of water. The OWRD limited testing license that the HBDIC Site operates under (LL-1159) requires that ditch conveyance losses be included under the 50 cfs maximum use quantity, taking the projects total recharged volume to 25,000 acre-feet (40 square-miles a foot deep of water.) Onsite recharge rates have varied by year depending on the water year availability and the infiltration area with *effective average* values between 5.7 to 15 cfs. Basin clogging and water table recovery may also be acting to slightly reduce the surface infiltration rates on site.

Water quality monitoring performed at the site has shown an ambient low-level fecal coliform contamination in the surface water and surrounding shallow aquifer system. Surface water to groundwater treatment through recharge activities may indicate that natural attenuation processes are applicable for the HBDIC site operations. General chemistry results showed no significant findings while only two low-level detections were made of any Soluble Organic Compounds (e.g. pesticides, etc) during this testing period. Water quality of both the source water and groundwater appear to be stable and predictable during the recharge season. Recharge did not degrade groundwater quality.

WWBWC monitoring wells have helped track the recharged water as it moved into the groundwater system. Pressure perturbations directly linked to HBDIC recharge activities were used to track the recharge influence on groundwater response and to down-gradient springs. The springs were showing recovery when compared directly to historic flows recorded during the 1930s and 1940s. From these results the WWBWC-HBDIC team believes the HBDIC recharge site has been successfully testing aquifer recharge and is recharging a portion of the shallow aquifer system. The benefits of groundwater recovery while helping to restore historic spring flows also appear to be linked to HBDIC recharge site operations (**Figure** 64). We believe these results provide the basis by which to pursue the Bi-state ARSR program outlined in the following section of this document.

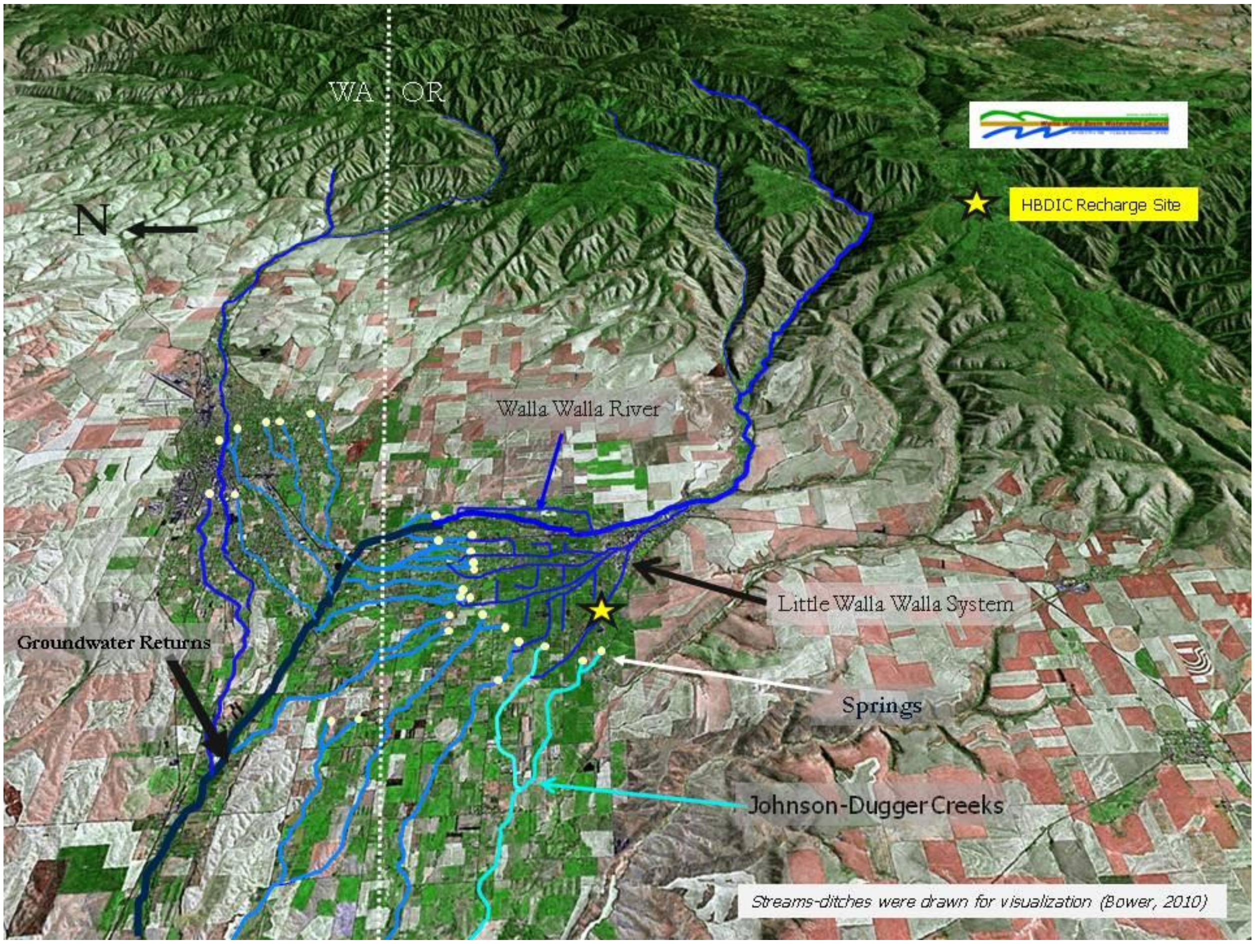


Figure 64. Walla Walla River Basin springs and groundwater returns to the Walla Walla River.

Managed Aquifer Recharge – Balancing Storage

The results of testing at the HBDIC site indicate that MAR can be a useful water management tool in the Walla Walla basin. When considering numerous historical as well as new stresses that face the storage of water in the shallow aquifer system, MAR should be considered (**Figure** 65). Other options currently being considered include surface water storage behind dams, large pumping exchanges with the Columbia River and/or curtailment of existing water rights, both irrigation and domestic. Some of these other options require hundreds of millions of dollars while others threaten political polarization of the community. None of the options in themselves can guarantee that the balance of water in this highly interconnected surface-groundwater system will be sustainable for fish and people into the future.

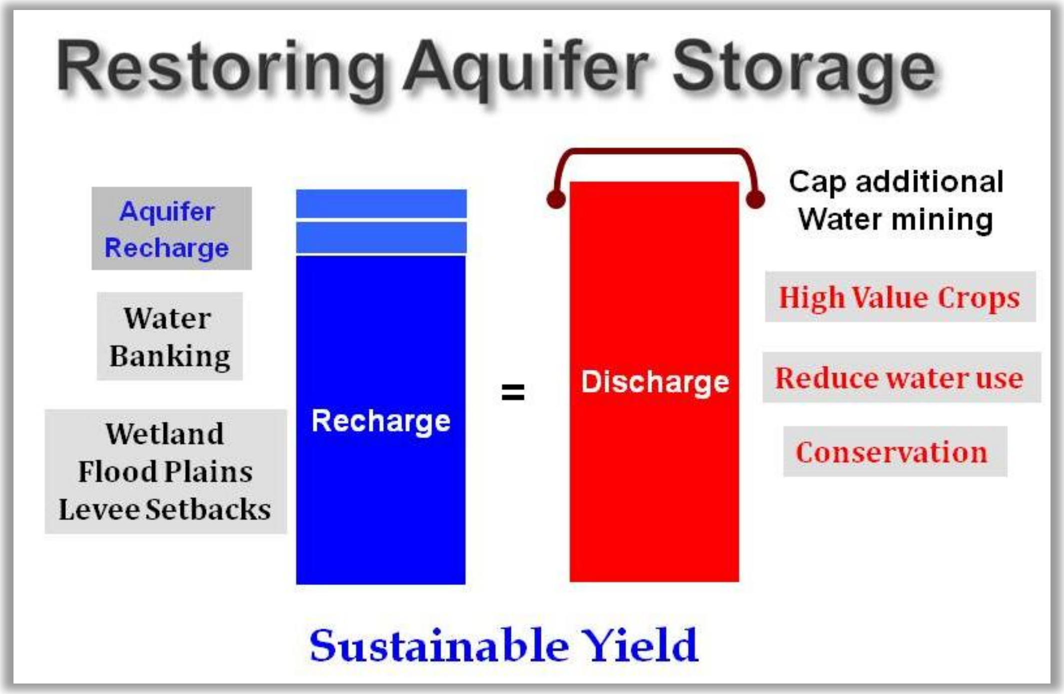


Figure 65. Balancing Storage with Managed Aquifer Recharge and other methods.

Managed Aquifer recharge has shown positive results toward being a water management tool for the Walla Walla Basin. As a tool it can be used as it is designed and for nothing more. Other water management strategies that could ensure better management includes restoring wetlands, river and creek flood plains through levee setback projects. Slowing water down after decades of making it move faster through the basin seems the best strategy as these activities also improve the habitat of wildlife and increase the quality of life of the residents of the basin. As supplies of water decrease the value of water will increase, making it more useful to buy and sell water (water banking) or utilizing it with crops of higher commercial value. Finally, using less water through conservation is always the least expensive alternative to all of the above mentioned and should be part of the overall Walla Walla basin strategy.

Moving Forward: From Testing to Programmatic Response

The operations, analysis, and modeling of the HBDIC Recharge testing site coupled with the information collected at the other 2 Walla Walla basin's recharge sites has provided critical answers to the most pressing questions about aquifer recharge for this basin, including;

1. Aquifer recharge has been shown to effectively transfer seasonally available surface water into the shallow aquifer for the purposes of storage
2. Aquifer recharge has been shown to help restore flows in historical springs that are tributaries to steelhead and redband trout creeks
3. Source water used for aquifer recharge should be shown to have good and consistent quality

4. Aquifer properties have been measured showing this system can provide a viable water storage
5. Continued piping coupled with over-allocated well pumping without mitigation will result in continued spring declines and threatens to jeopardize instream flows throughout the system.

The information generated by this monitoring along with applied research conducted by the WWBWC and its partners has led to vast improvements in our understanding of groundwater conditions and characteristics. Complementing our scientific understanding of the hydrology within the Walla Walla basin, the WWBWC and its partners have also been moving forward with policy development for the Aquifer Recharge and Spring Restoration (ARSR) program. Supporting this effort, in 2009 the State of Washington passed legislation creating the Walla Walla Watershed Management Partnership.[20] The Partnership is a public agency operating under RCW 90.92 (2SHB 1580, Chapter 183, Session Laws of 2009) and is charged with piloting local water management in the Walla Walla Basin. Efforts leading up to the formation of the Partnership were made up of community members including landowners, local governments, conservation groups, tribes, state and federal agencies, and many other entities working to develop local solutions to the unique water issues in the Walla Walla Basin. In Washington, the Partnership integrates local water and watershed management with state oversight, providing a primary governance structure for improved water management and ensuring that local and statewide interests are protected.

In spring 2009, the WWBWC hosted a Bi-state Groundwater Status meeting where hydrogeologists representing both states (OWRD/WDOE) met with WWBWC technical staff and discussed basin monitoring, aquifer trend analysis, and regulatory and enforcement tools by which the system can be better managed. In Washington the shallow aquifer is closed to further irrigation appropriations and has recently restricted the amount of water new exempt wells can utilize. In Oregon the shallow aquifer is still officially open to new well applications. However, new applications are being reviewed under a more detailed evaluation and additional scrutiny.

The WWBWC is also working with Oregon and Washington Water Trusts to create a bi-state water banking system in order to create 'cap-n-trade' mechanism. By creating a water banking system the intent is to create a system where new wells are required to mitigate for their use by purchasing mitigation credits through the Trusts. This system can help create revenue by which to help support the implementation of the ARSR program.

Progressive water management on the Oregon side of the basin is represented in the Umatilla Critical Groundwater Task Force[21] recently completed 2050 Plan[22] and its primary goal:

[20] http://www.wallawallawatershed.org/
[21] http://umatillacounty.net/planning/Groundwater.htm
[22] http://www.co.umatilla.or.us/planning/Groundwater.htm

"… ensure a coordinated, integrated response with maximum use of all water resources and to mitigate the effects of water declines impacting Umatilla County."(Umatilla County CGT, 2009)

This forward thinking plan proposes the creation of water management districts, encouraging the construction and operations of aquifer recharge projects and working to create revenue streams from which funding can be acquired to implement more management projects in Umatilla County. The ARSR goals for the Walla Walla Basin follow those of the Umatilla County plan and have support for further development at the county level.

Water management efforts in both states have been working together to come up with programmatic solutions to addressing this bi-state hydrologic, biologic and economic issue. The Walla Walla Basin Aquifer Replenishment and Spring Restoration Program intends to build on all of these efforts by creating a coordinated bi-state approach to address the legal, design, distribution, timing, habitat, water quality and quantity issues that are anticipated in creating an aquifer and river system that is managed in a sustainable fashion. The overall goal, as illustrated in Figure 66, is to first *stabilize* the declining aquifer and then move toward *recovery* of lost storage.

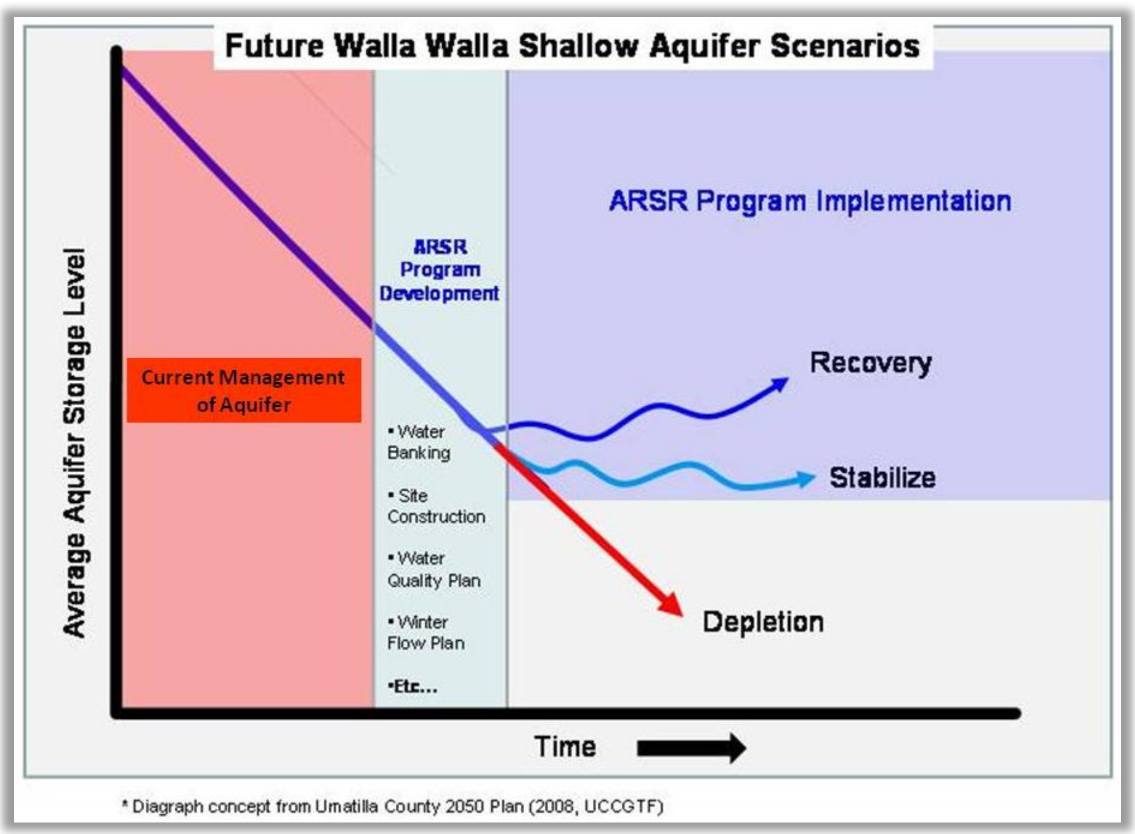


Figure 66. Conceptual Graph depicting goals of ARSR program

The goals of the ARSR program are to:

1. Build adequate recharge capacity to first stabilize and then recover shallow aquifer storage to historic levels**.**
2. Recovered groundwater storage will lead to the recovery of the natural springs which provide cool baseflow back to the Walla Walla River and its distributaries.
3. Whenever possible, refine and enhance current management of surface and groundwater capacities to support goal #1 (e.g. better management of Little Walla Walla River during non-irrigation season)
4. Work with water conservation efforts to design and build water systems that conserve water during times of scarcity and recharge water during times of abundance
5. Educate the general public on the complexity of surface water-groundwater management in the Walla Walla Valley

This ambitious program will not be done unless the WWBWC and its partners pursue its creation and application. There are no state or federal programs that are set up to address this critical issue and without action now, the aquifer and related springs will continue to decline along with the fish and farms that depend on them. This program represents a clear and present need in the Walla Walla basin.

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* Electronic aerial photos of basin provided by: Dr. William Bowen California Geographical Survey (http://geogdata.csun.edu) 10907 Rathburn Avenue Northridge, CA 91326 william.bowen@csun.edu

Appendices Available at:

www.wwbwc.org

541-938-2170

Appendix F

Application and Supporting Documents for

Limited License LL-1189

State of Oregon Water Resources Department
725 Summer Street NE, Suite A
Salem, Oregon 97301-1271
(503) 986-0900

Application for Limited Water Use License

A summary of review criteria and procedures that are generally applicable to these applications is available at www.wrd.state.or.us/OWRD/PUBS/forms.shtml.

License No. LL-1189

Applicant(s): Hudson Bay District Improvement Co. (HBDIC)

Contact Person: John Zerba - HBDIC (Bob Bower - WWBWC)

Mailing Address: 144 Main str. Milton-Freewater, OR 97862

Telephone No: 541-938-6105 (Zerba) / 541-938-2170 (Bower)

I (We) make application for a Limited License to use or store the following described surface waters or groundwater-not otherwise exempt, or to use stored water of the State of Oregon for a use of a short-term or fixed duration :

1. SOURCE(S) OF WATER for the proposed use: Walla Walla River a tributary of Columbia River.

2. TOTAL AMOUNT OF WATER to be diverted: 50 cubic feet per second, or 22440 gallons per minute. If water is to be used from more than one source, give the quantity from each: -0-.

3. INTENDED USE(S) OF WATER: (check all that apply)
   - ☐ Road construction or maintenance;
   - ☐ General construction;
   - ☐ Forestland and rangeland management; or
   - ☒ Other: Aquifer Recharge

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4. DESCRIPTION OF PROPOSED PROJECT: Include a description of the intended place of use as shown on the accompanying site map, the method of water diversion, the type of equipment to be used (including pump horsepower, if applicable), length and dimensions of supply ditches and pipelines:
   * See Attached cover letter & support materials.

LL-1189

5. PROJECT SCHEDULE: (List day, month, and year)
Date water use will begin Feb. 19th 2009
Date project will be completed Feb 18th 2014
Date water use will be completed Feb 18th 2014

PLEASE READ CAREFULLY

NOTE: A completed water availability statement from the local watermaster, Land Use Information Form completed by the local Planning Department, fees and site map meeting the requirements of OAR 690-340-030 must accompany this request. The fee for this request is $150 for the first point of diversion plus $15 for each additional point of diversion. *Failure to provide any of the required information will result in return of your application.* The license, if granted, will not be issued or replaced by a new license for a period of more than five consecutive years. The license, if granted, will be subordinate to all other authorized uses that rely upon the same source, or water affected by the source, and may be revoked at any time it is determined the use causes injury to any other water right or minimum perennial streamflow.

If water source is a well, well logs or adequate information for the Department to determine aquifer, well depth, well seal and open interval, etc. are required. The licensee shall indicate the intended aquifer. If for multiple wells, each map location shall be clearly tied to a well log.

If a limited license is approved, the licensee shall give notice to the Department (Watermaster) at least 15 days in advance of using the water under the Limited License and shall maintain a record of use. The record of use shall include, but need not be limited to, an estimate of the amount of water used, the period of use and the categories of beneficial use to which the water is applied. During the period of the Limited License, the record of use shall be available for review by the Department upon request.

REMARKS: OWRD Water Master (Tony Justus) sending his water availability report (separately) to Salem, for this application.

SIGNATURE of Applicant: [signature] DATE: 1-21-09
Title: HBDIC manager

Mapping Requirements (OAR 690-340-0030):
(1) A request for a limited license shall be submitted on a form provided by the Water Resources Department, and shall be accompanied by the following:
(c) A site map of reproducible quality, drawn to a standard, even scale of not less than 2 inches = 1 mile, showing:
(A) The locations of all proposed points of diversion referenced by coordinates or by bearing and distance to the nearest established or projected public land survey corner;
(B) The general course of the source for the proposed use, if applicable;
(C) Other topographical features such as roads, streams, railroads, etc., which may be helpful in locating the diversion points in the field.

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This page to be completed by the local Watermaster.

WATER AVAILABILITY STATEMENT

Name of Applicant: Hudson Bay Improvement Company Limited License Number: LL-1189

1. To your knowledge, has the stream or basin that is the source for this application ever been regulated for prior rights?

☒ Yes ☐ No

If yes, please explain:

The Walla Walla River is typically short of water to serve all water rights in July, August, September and October.

2. Based on your observations, would there be water available in the quantity and at the times needed to supply the use proposed by this application?

☒ Yes ☐ No

3. Do you observe this stream system during regular fieldwork?

☒ Yes No

If yes, what are your observations for the stream?

Typically, there can be water available November thru June. OAR Division 33 may also dictate restrictions on period of use dates.

4. If the source is a well and if WRD were to determine that there is the potential for substantial interference with nearby surface water sources, would there still be ground water and surface water available during the time requested and in the amount requested without injury to existing water rights?

☐ Yes ☐ No ☒ N/A

What would you recommend for conditions on a limited license that may be issued approving this application?

Allow diversion only when by-pass flows are met below Nursury Bridge Dam. Restrict with by-pass flows similar to the flows in Permit 53662. November- 64 cfs, December & January- 95 cfs, February thru May 15-132 cfs.

5. Any other recommendations you would like to make?

Subordinate to any other limited license from the same source issued prior to this one.

Signature ______________________ WM District #:________ Date:______________

This page to be completed by the local Watermaster.

WATER AVAILABILITY STATEMENT

Name of Applicant: Hudson Bay Improvement Company   Limited License Number: LL-1189

1. To your knowledge, has the stream or basin that is the source for this application ever been regulated for prior rights?

☒ Yes   ☐ No

If yes, please explain:

The Walla Walla River is typically short of water to serve all water rights in July, August, September and October.

2. Based on your observations, would there be water available in the quantity and at the times needed to supply the use proposed by this application?

☒ Yes   ☐ No

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3. Do you observe this stream system during regular fieldwork?

☒ Yes   No

If yes, what are your observations for the stream?

Typically, there can be water available November thru June. OAR Division 33 may also dictate restrictions on period of use dates.

4. If the source is a well and if WRD were to determine that there is the potential for substantial interference with nearby surface water sources, would there still be ground water and surface water available during the time requested and in the amount requested without injury to existing water rights?

☐ Yes   ☐ No   ☒ N/A

What would you recommend for conditions on a limited license that may be issued approving this application?

Allow diversion only when by-pass flows are met below Nursury Bridge Dam. Restrict with by-pass flows similar to the flows in Permit 53662. November- 64 cfs, December & January- 95 cfs, February thru May 15-132 cfs.

5. Any other recommendations you would like to make?

Subordinate to any other limited license from the same source issued prior to this one.

Signature Tony Justus   WM District #: 5   Date: January 30, 2009

LL-1189

Oregon Water Resources Department
Land Use Information Form

THIS FORM IS NOT REQUIRED IF: 1) water is to be diverted, conveyed, and/or used only on federal lands; or 2) the application is for a water-right transfer, allocation of conserved water, exchange, permit amendment, or ground water registration modification, and all of the following apply: a) only the place of use is proposed for change, b) there are no structural changes, c) the use of water is for irrigation, and d) the use is located in an irrigation district or exclusive farm-use zone.

Applicant Name: Hudson Bay District Improvement Company

Mailing Address: 144 Main Str.

City: Milton-Freewater State: OR Zip: 97862 Day Phone: 541-938-6105

A. Land and Location

Please include the following information for all tax lots where water will be diverted (taken from its source), conveyed (transported), or used. Applicants for municipal use, or irrigation uses within irrigation districts may substitute existing and proposed service-area boundaries for the tax-lot information requested below.

Township	Range	Section	¼ ¼	Tax Lot #	Plan Designation (e.g. Rural Residential/RR-5)	Water to be: N/A	Proposed Land Use:
6N	35E	33	NE	900	N/A	Diverted Conveyed Used	N/A
						Diverted Conveyed Used	
						Diverted Conveyed Used	
						Diverted Conveyed Used	

List all counties and cities where water is proposed to be diverted, conveyed, or used. N/A

B. Description of Proposed Use

Type of application to be filed with the Water Resources Department:

- ☐ Permit to Use or Store Water
- ☐ Water-Right Transfer
- ☐ Exchange of Water
- ☐ Allocation of Conserved Water
- ☒ Limited Water Use License
- ☐ Permit Amendment or Ground Water Registration Modification

Source of water: Reservoir/Pond ☐ Ground Water ☒ Surface Water (name) Walla Walla River

Estimated quantity of water needed: 50 ☒ cubic feet per second ☐ gallons per minute ☐ acre-feet

Intended use of water: ☐ Irrigation ☐ Commercial ☐ Industrial ☐ Domestic for ______ household(s) ☐ Municipal ☐ Quasi-municipal ☐ Instream ☒ Other Recharge

Briefly describe: HBDIC Aquifer Recharge site will recharge water to shallow aquifer for community and ecological benefits.

Note to applicant: *If the Land Use Information Form cannot be completed while you wait, please have a local government representative sign the receipt below and include it with the application filed with the Water Resources Department.*

Receipt for Request for Land Use Information

State of Oregon Water
Resources Department
725 Summer Street NE, Suite A
Salem, OR 97301-1266

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SALEM, OREGON

LL-1189

For Local Government Use Only

The following section must be completed by a planning official from each county and city listed unless the project will be located entirely within the city limits. In that case, only the city planning agency must complete this form.

This deals only with the local land-use plan. Do not include approval for activities such as building or grading permits.

Please check the appropriate box below and provide the requested information

Land uses to be served by proposed water uses (including proposed construction) are allowed outright or are not regulated by your comprehensive plan. Cite applicable ordinance section(s): 152.056 .

Land uses to be served by proposed water uses (including proposed construction) involve discretionary land-use approvals as listed in the table below. (Please attach documentation of applicable land-use approvals which have already been obtained. Record of Action/land-use decision and accompanying findings are sufficient.) **If approvals have been obtained but all appeal periods have not ended, check "Being pursued".**

Type of Land-Use Approval Needed (e.g. plan amendments, rezones, conditional-use permits, etc.)	Cite Most Significant, Applicable Plan Policies & Ordinance Section References	Land-Use Approval:	
N/A	N/A	Obtained Denied	Being pursued Not being pursued
		Obtained Denied	Being pursued Not being pursued
		Obtained Denied	Being pursued Not being pursued
		Obtained Denied	Being pursued Not being pursued
		Obtained Denied	Being pursued Not being pursued

Local governments are invited to express special land-use concerns or make recommendations to the Water Resources Department regarding this proposed use of water below, or on a separate sheet.

This project previously approved by Planning. Umatilla County Planning is supportive of developing innovative, multi-Beneficial water storage projects. We believe we can be the "Showcase" county for innovative water management solutions.

Name: J. R. Cook Title: Asst. Planning Dir.

Signature: [signature] Phone: 541.278.6251 Date: 1-26-09

Government Entity: Umatilla County

Note to local government representative: *Please complete this form or sign the receipt below and return it to the applicant. If you sign the receipt, you will have 30 days from the Water Resources Department's notice date to return the completed Land Use Information Form or WRD may presume the land use associated with the proposed use of water is compatible with local comprehensive plans.*

Receipt for Request for Land Use Information

Applicant name: ______________________

City or County: ______________ Staff contact: ______________

Signature: ______________ Phone: ______________ Date: ______________

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To: Water Rights Section
Oregon Water Resources Department
158 12th St NE
Salem, OR 97310

From: Walla Walla Basin Watershed Council (WWBWC)/Hudson Bay District Improvement Company (HBDIC)
810 South Main Street
Milton-Freewater, Oregon 97862

RE: ***New*** Limited Testing License Application for HBDIC Recharge Site (Final Order 758).

To Whom It May Concern:

This letter and attached documents are being submitted in support of our application for a new limited testing license for aquifer recharge at the HBDIC Recharge project, in Umatilla County Oregon. The actual recharge site is located in the NE ¼, of Section 33, Township 6 North, and Range 35 East. The project has been in operation for nearly 5 years and has shown to effectively recharge water to the aquifer, help restore baseflows to downgradient streams and recharge good quality surface water in to the shallow aquifer system. Through a series of Rules Advisory Committee (RAC) meetings last spring and early summer the OWRD worked to add aquifer recharge to the basin rules[1] along with surface storage. The RAC was decided that the decision to add aquifer recharge and surface storage for the Walla Walla basin would be delayed pending the US Army Corp of Engineers (CTUIR) Feasibility study project being completed in 2010. Therefore to continue to test aquifer recharge at the HBDIC recharge site we are submitting a new limited testing license for the site (see attached).

We are also submitting the support materials (study plan, etc) from the original application titled *Hudson Bay Aquifer Recharge Project: An application for AR Testing Limited License to Oregon Water Resource Department (OWRD)* (October, 20th 2003, **Attachment A**). In this new limited testing license application we request to follow the **same** operations, monitoring and reporting plan that was outlined in this original application. ODEQ (Phil Richerson, Pendleton-ODEQ) was contacted this week regarding this new application and gave a verbal permission to submit the same water quality plan that was developed with ODEQ (2003) and submitted with our original application.

We are also requesting that the new limited license has **the same** water-use conditions of Final Order #758 including:

- ☐ Water Use time period: **November 1st through May 15th**
- ☐ Maximum Water Use Allocation of **50 cfs.**
- ☐ **Seasonal Minimum Instream flow requirements** (Walla Walla River) as were determined by ODFW and CTUIR in original application which were:
    - o November 1st through November 31st = 64 cfs

[1] Mike Ladd, Tony Justus at OWRD Pendleton office can be contacted regarding this process.

- December 1st through January 31st = 95 cfs
- February 1st through May 15th = 150 cfs

Final Order #758 Final Requirements stated that "*The licensee shall meter all water use and maintain a record of use, including the total number of hours of diversion and an estimate of the total quantity diverted. During the period of the limited license, the record of use shall be available for review by the Department upon request and shall be submitted to the Watermaster upon request. Upon project completion, the license shall submit the record of use to the Water Resources Department.*"

At the time of this letter, the project was still in operations (2008-9 recharge season), but a summary for the *record of use* (as outlined above) can be found in **Attachment B**. The attachment outlines both the water use from the Walla Walla River (POD) to the HBDIC Recharge Project (as estimated conveyance loss of 10 cfs) and the actual water use at the HBDIC recharge site. Following the completion of final order #758, a summary of all water use 2004-2009 will be provided to the department. All water use meter records are available to OWRD staff at any time, upon request. As the HBDIC site has gone through several expansions during this 2004-2008 period, **Attachment C** outlines some additional information that will help assess the changes in water use at the site over the period of record. The HBDIC recharge project managers intend to further develop this site for recharge testing upon approval of a new limited testing license.

You will find the following Attachments in support of this new application:

- ❑ **Attachment A-C:** Original Application Supporting document that includes:
  - Maps of site as required by OWRD application
  - ODEQ Water Quality Monitoring Plan (and supplementary changes)
- ❑ **Attachment D**: Copy of Current OWRD Limited Testing License (Final Order#758)
- ❑ **Attachment E:** Original Water availability report from OWRD water master (New one being sent to Salem from Pendleton Office)

Also attached you will find the application fee for $165 dollars to cover new limited license application. As there are now two separate diversions at the recharge site, we added the additional $15 for this application to ensure the proper fee was submitted.

Thank you for your continued support.

Robert J. Bower
Senior Hydrologist/HBDIC Project Co-manager
Walla Walla Basin Watershed Council

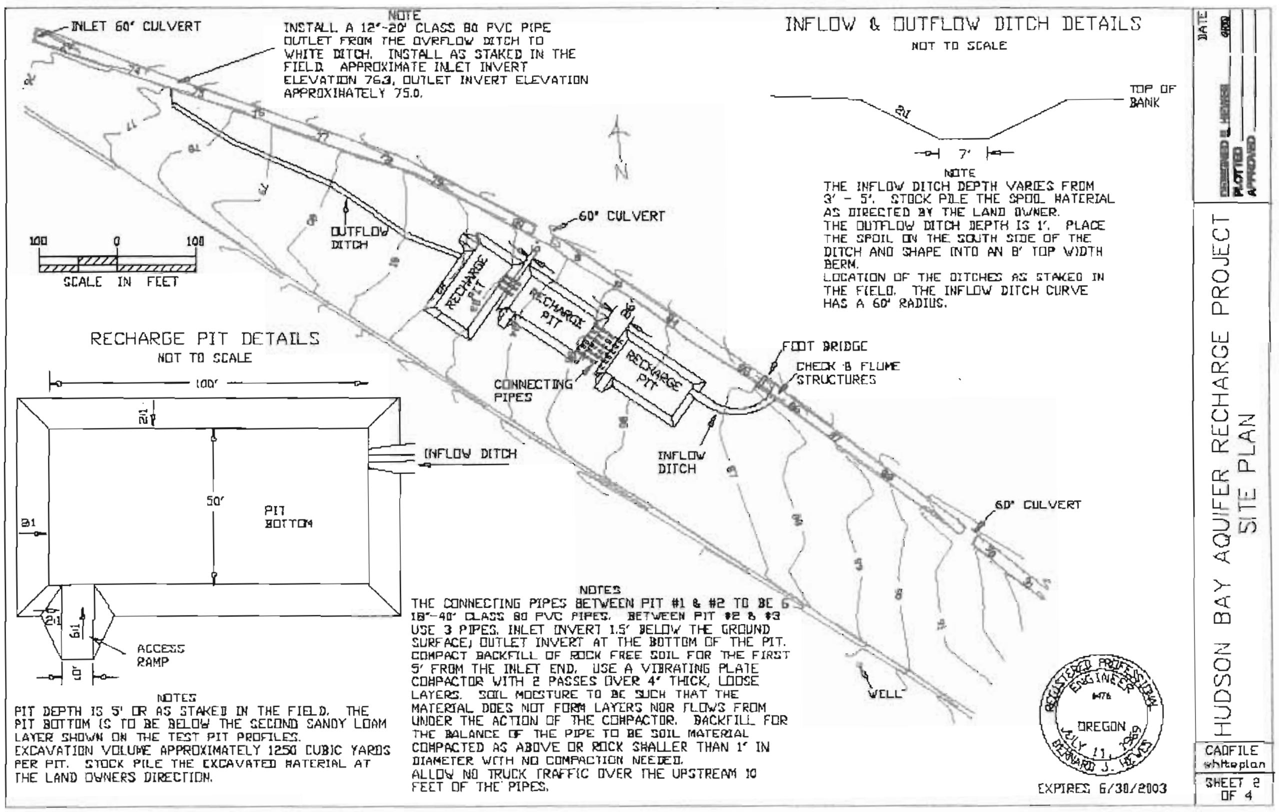
Cc: Tony Justus, OWRD Pendleton
Rick George, CTUIR, Mission
Phil Richerson, ODEQ, Pendleton
Bill Duke, ODFW, Pendleton

Attachment A

Limited License Supplemental Application Materials
10/16/03

Hudson Bay Aquifer Recharge Project

An application for ASR Testing Limited License to Oregon Water Resources Department (OWRD) (OAR 690-350-0020)



Prepared for the HBDIC by:

Walla Walla Basin Watershed Council
Kennedy and Jenks Consultants, Inc.

October 20, 2003

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Introduction

The Walla Walla Basin Watershed Council (WWBWC), in cooperation with the Hudson Bay District Improvement Company (HBDIC), has proposed to test shallow aquifer recharge at a site located adjacent to the HBDIC's *White Ditch* in section 33, T6N, R35E. At the test site a series of three infiltration pits will be built. Water will be supplied to these pits via a diversion from the canal. Recharge activities are proposed during the winter and spring months, when the Walla Walla River (the source of water for the canal) is running at higher flows. The proposed shallow aquifer recharge testing would be done under an ASR Testing Limited License granted by Oregon Water Resources Department (OWRD) (OAR 690-350-0020). By recharging shallow groundwater it is hoped that a portion of the recharge water will return to restore diminished spring-creek and Walla Walla River baseflows. Testing <u>will not include</u> removal of stored water by pumping or other artificial means.

The Limited License Application requires several supporting documents be attached (690-350-0020 (3)(b)), including (but not limited to) those describing proposed testing, groundwater conditions (including hydrogeologic conditions and groundwater quality), and source water quality. Information not included in this assessment report, but still needed for the application, will be collected during proposed site-specific hydrogeologic characterization, monitoring, and testing process. This limited license application is to gain approval of the proposed shallow aquifer recharge testing. The complete list of Attachments as called for in include:

Attachment 1. Project Layout and Size, 690-350-0020(3)(a)(E) and (I) and 690-350-0020(3)(b)(B)
Attachment 2. Water Rights Statement, 690-350-0020(3)(a)(F) and (G)
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Attachment 6. Site Hydrogeology, 690-350-0020(3)(b)(C), (E), and (G)
Attachment 7. Source Water Quality, 690-350-0020(3)(b)(D)

Overview of Watershed Conditions

The quantity, storage, timing, and availability of water are several major challenges facing watershed managers in the Walla Walla River Basin. The relationship between the Walla Walla River and its distributaries with that of the shallow alluvium aquifer has been shown to be highly interdependent (Piper, 1933, Newcomb, 1965, Barker & McNish, 1975, Bower et. al., 2001). The Walla Walla Basin Watershed Council, Walla Walla Watershed Alliance, and Hudson Bay District Improvement Company (HBDIC), working with their partners in OWRD, ODEQ and ODFW, propose to explore the utility of artificially recharging the shallow alluvial aquifer as a way to help offset the loss of natural recharge opportunities throughout the basin.

Surface water and shallow groundwater in the Walla Walla Basin (the Basin) form an interconnected system. In some areas, especially upstream areas where streams leave the mountains and highlands surrounding the Basin to flow out onto the Basin floor, streams historically probably branched out onto the Basin floor and some of the water they carried seeped into the ground, recharging the shallow groundwater system. This shallow groundwater, recharged near the edge of the Basin, formed the main source of clean, cool groundwater found further down basin where it returned to the surface via springs and base flow to the Walla Walla River. Through the years, the issuance of hundreds of surface and groundwater rights has resulted in the allocation of nearly all of the naturally available water in the basin. These allocations have pressured water resources, compelling the

Washington State Department of Ecology to close ground waters to further appropriations due to concerns about dropping water table levels. Other indicators of overstressed water resources include: (1) dry or dropping well levels, some wells in OWRD's inventory of state-observation-wells, (2) dry or dropping flow volumes in the spring branches, and (3) loss of natural and artificial groundwater recharge opportunities through irrigation efficiency and improved surface water management.

The state of Oregon has recognized use of artificial recharge as a tool "that can be an effective and efficient method for storing water for futures uses."(OWRD, Umatilla Basin Report, 1988). Artificial recharge has been shown to work in other areas of Umatilla County such as the County Line Water Improvement District Project, in operation since 1977. An OWRD review of this project states "It has been instrumental in arresting and reversing ground water level declines in a portion of the Ordnance Critical Ground Water Area." (OWRD, 1988). The USGS also noted the need for artificial recharge in the Walla Walla valley to offset increased water demands and loss of natural and artificial recharge mechanisms: "(Irrigation efficiency measures) can diminish the infiltration to recharge the ground water," wrote Newcomb in his important 1965 report. "Consequently, any such plans for changes in river regimen could well be required to provide for compensatory recharge or to sustain counter charges for their diminution of natural recharge and storage.

This project will comprise of three major components: Construction-Operation, Monitoring-Evaluation and Outreach-Education.

Construction-Operation: After receiving the appropriate permits and/or approval from OWRD, OWDF, ODEQ, USFWS, NOAA Fisheries and the Umatilla County Planning Department, a series of three pits specifically designed for passive artificial recharge will be constructed on land provided by the Hudson District Improvement Company (HBDIC). The land is being leased from one of the district's patrons by the HBDIC and a written agreement for the lease has been secured. The pits will be constructed in such a way to maximize recharge rates while minimizing the ground water quality impacts during the winter/spring recharge period. Project features include a concrete check structure in adjacent White Ditch, a concrete flow-measuring flume, an open connection ditch, three excavated pits, pipes connecting the pits and an outflow ditch from the down stream pit. These pits are designed to handle 50 cubic feet per second (cfs) of water anticipated to be available during the winter/spring Walla Walla River runoff. The actual volume of winter-spring water delivered will depend on the above-mentioned permitting and review process and the actual field verified constraints once in operation. Operation of this structure will be based on the instructions provided by OWRD in the operation permit and agreed to by the various project partners and agencies.

Monitoring-Evaluation: Monitoring of project will be conducted at several levels including: (1) on-site subsurface hydrologic and hydrogeologic monitoring, (2) off-site subsurface hydrologic and hydrogeologic monitoring, (3) off-site surface monitoring of springs through flow and photo-point measurements, (4) on/off-site water quality monitoring of key physical and chemical properties. The results of this intensive monitoring will be evaluated to identify impacts of the proposed project on groundwater levels and flow beneath and around the site, on surface water and spring discharges down gradient of the site, and on base flow to the Walla Walla River. Monitoring will also identify potential problems associated with the project

Outreach-Education: This project will also serve as an important outreach and education tool for the general public and water users of the Walla Walla valley. Particular focus and time will be spent on utilizing the site and the results for the recharge analysis to educate people on the role that ground water plays in the rivers and streams of the Walla Walla Watershed.

This project meets all of the habitat restoration actions from the *Oregon Aquatic Habitat Restoration and Enhancement Guide* including:

1. Change the trend of aquatic habitat function from one of a diminishing ability to support salmonids and other organisms to one that supports a complex, self-sustaining system. Such systems provide high quality habitat and ecological capacity for salmonids and other species; or
2. Correct or improve conditions caused by past management and/or disturbance events; or
3. Maximize beneficial habitat in the short term where watershed degradation has been extensive and natural processes will need substantial time to restore habitat; or
4. Create beneficial habitat and restore stream function to the fullest extent possible within developed areas where no reasonable expectation of returning to natural conditions exists.

HUDSON BAY AQUIFER RECHARGE PROJECT
LOCATED IN THE NE$\frac{1}{4}$ OF SEC33, T6 N, R35E W.M.

Figure 1 Scaled Map of Project and Surrounding Area

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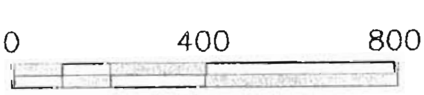


SCALE IN FEET

ONE INCH EQUALS 400FT

NOTE
THE PURPOSE OF THIS MAP IS TO IDENTIFY THE APPROXIMATE LOCATION OF THE PROJECT. IT IS NOT INTENDED TO PROVIDE INFORMATION RELATIVE TO THE EXACT LOCATION OF PROPERTY OWNERSHIP BOUNDERY LINES OR ANY OTHER SIGNIFICANT MAP SUBJECTS

LEGEND

POWELL PV CANAL

TAX LOT BOUNDERY LINES

QUARTER QUARTER LINES

SECTION CORNER

HUDSON BAY AQUIFER RECHARGE PROJECT
LOCATED IN THE NE1/4 OF SEC33, T6 N, R35E W.M.
FIGURE 1A

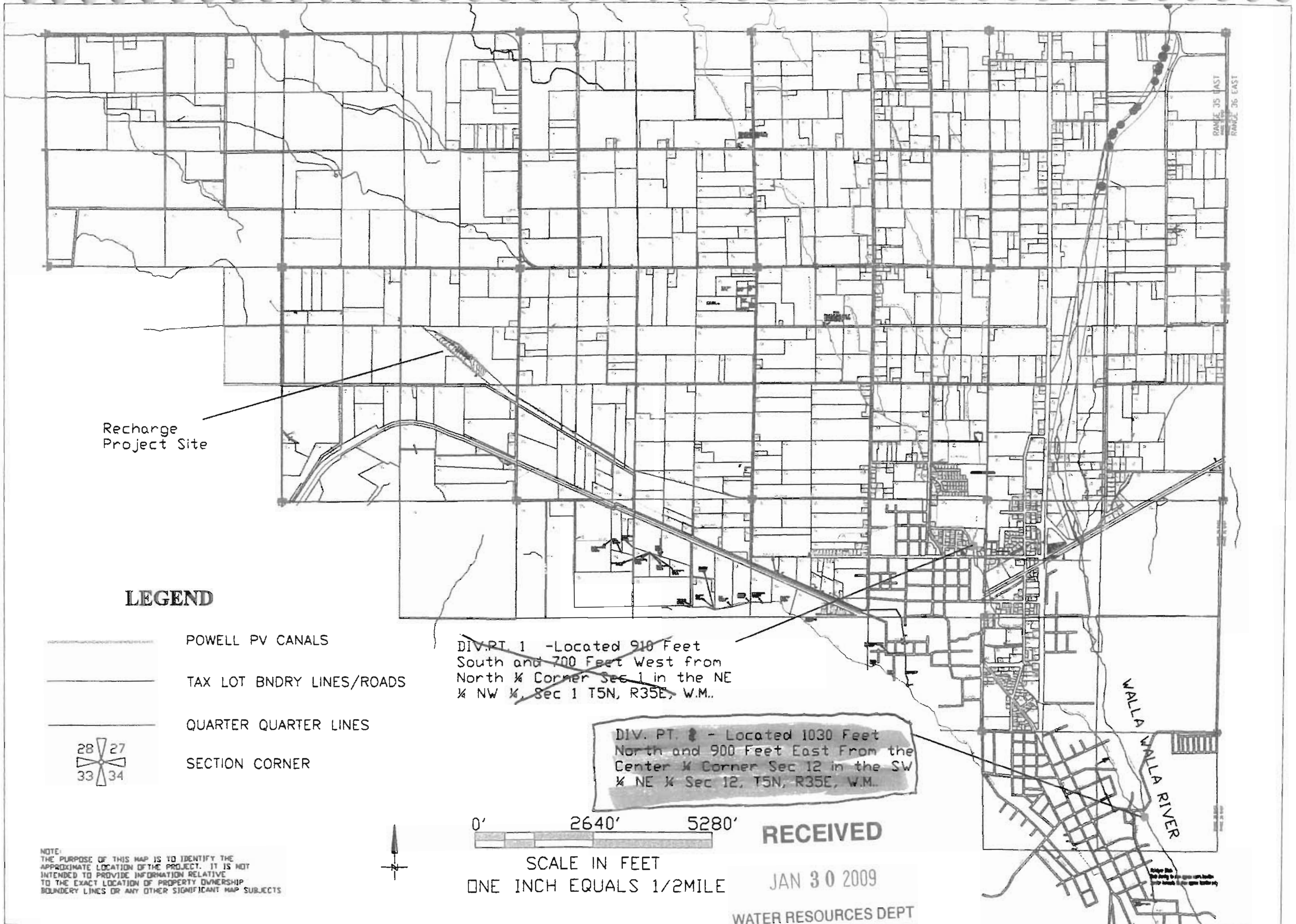
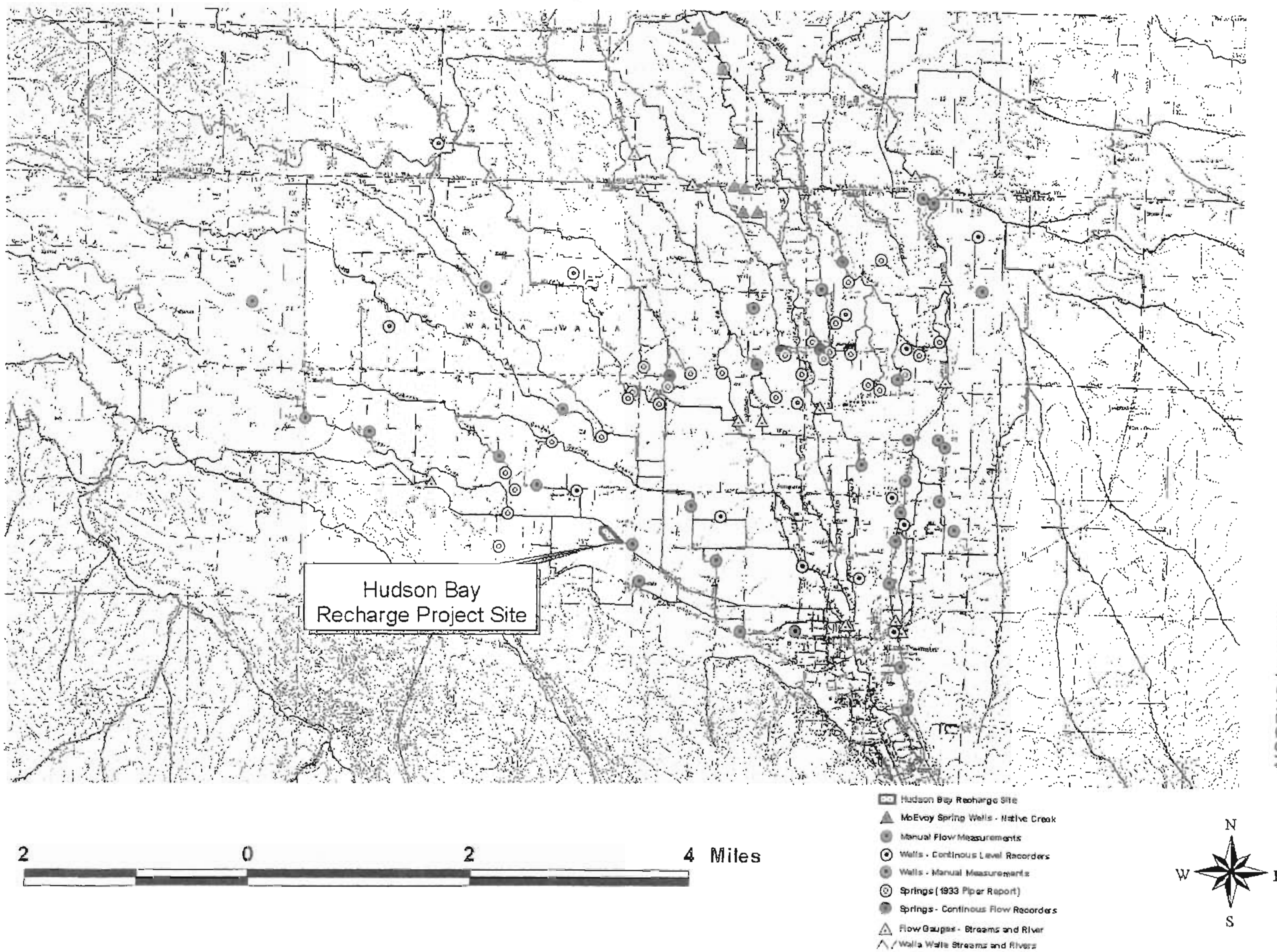


Figure 2 WWBW Monitoring and Recharge Site Map

FIGURE 2. WWBWC Monitoring Network and Hudson Bay Recharge Project 2003



Attachment 1. Project Layout, 690-350-0020(3)(a)(E) and (I) and 690-350-0020(3)(b)(B)

Prepared by Bernard Hewes, Licensed Engineer in the State of Oregon.

This project entails diverting water from an existing irrigation ditch to three pits to be excavated for the purpose of infiltrating the water into the shallow aquifer. Project features include a concrete check structure in the existing White Ditch, a concrete flow measuring flume, an open ditch, three excavated pits, pipes connecting the pits and an outflow ditch from the down stream pit.

These items were sized to handle 50 cubic feet per second (cfs) of water. This is the amount anticipated will be available from excess flow in the Walla Walla River and that the Hudson Bay District is able to deliver.

Data gathered to design the project consisted of a site topographic survey and installing two sites for testing the water infiltration capacity of the natural materials and determining the layers in the soil profile. In addition the Soil Survey of Umatilla County Area, Oregon was consulted. This is a US Dept. of Agriculture, Natural Resources Conservation Service publication giving general soils information.

The topographic survey data was used to prepare a topographic map with one foot contour intervals at a scale of 1" = 60'. This information was used to help determine the location of the project features.

Two test pits were excavated to a depth of 6'-7' each. A 24" diameter by 5' long section of corrugated metal pipe was set on end in the bottom of the pit and about one foot of fill placed around it to hold it in place. Water was pumped into the pipe at a rate that would sustain a water depth of one foot in the pipe. Both flow rate and total flow was measured. The test was run for 6.25 hours in the first pit and 3.5 hours for the second pit.

PIT #1
Soil profile:
0-12" sandy loam
12"-36" gravelly sandy loam, approximately 50% of the material volume is gravel size particles with an estimated D 50 size of about 0.75"
36"-48" sandy loam, in parts of the trench this layer does not exist
48"-?" gravelly sandy loam approximately 20% of the volume is gravel size particles

The inflow rate at the end of the test period was 4.0 gallons per minute (gpm). This resulted in an infiltration rate of 1.7 gpm/sq. ft./ foot of head.

PIT #2
Soil profile:
0"-13" gravelly sandy loam
13"-39" cobbly sandy loam, the D50 of the gravel is approximately 1"
39"-52" gravelly sandy loam
52"-? sand gravel mix D 50 estimated to be about 0.25"

In this pit the inflow rate of 11.9 gpm was maintained for 3.5 hours and at no time did water puddle in the bottom of the pipe. The infiltration rate is in excess of 3.8 gpm/sq. ft.

The area needed for infiltrating the water was determined assuming an infiltration rate for the entire area of 3.0 gpm/sq.ft./ per foot of head. For an inflow rate of 50 cfs the infiltration area needs to be

7480 square feet. The infiltration rate of 3.0 gpm/sq.ft. was chosen because the pits will be located in the area with soil surface texture similar to test pit #2.

Due to the possibility of fine soil particles plugging the infiltration area, unknowns concerning the long-term infiltration rate and that the amount of water available is not yet known extra infiltration area is being provided. Three separate pits with bottom dimensions of 50 feet X 100 feet are proposed. This will provide an infiltration area of 15,000 square feet.

The pits will be excavated to a depth of about 5 feet to get below the second sandy loam layer noted in both test pits. This will allow the water depth to be 2.5 feet - 3.5 feet. That will increase the rate of infiltration over the test values derived with one foot of water depth. The overall safety factor for the infiltration area is well over 2.

Inflow to the system will be measured with a ramp flume and continuously recorded. The ramp flume is sized to provide 5% flow rate accuracy over a flow range of 10 cfs-50 cfs

Any outflow from the last pit will be safely returned to the White Ditch through a 12-inch pipe. The pipe will be on a slope that will keep water from flowing out of White Ditch.

Engineering Attachments:

Attachment 1A: Location Map
Attachment 1B: Site Plan
Attachment 1C: Structure Details
Attachment 1D: Structure Reinforcing Steel
Attachment 1E: Signed and Stamped Copy of *Project Engineering Report*

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Attachment 2. Water Rights Statement, 690-350-0020(3)(a)(F) and (G)

Water Right Applicant:

Hudson Bay District Improvement Co.

P.O. Box 110
Milton-Freewater, Oregon 97862
Project Contact: John Zerba, WBDIC Board Member
Telephone: (541)-938-6100
Operations Contact: Jon Brough, WBDIC District Manager
Telephone: (541)-520-2856
Recharge Project Manager (WWBWC), Bob Bower, Hydrologist
Telephone: (541)-938-2170

Source of Water:

Walla Walla River, a tributary of the Colombia River, within the Umatilla River Basin.

Purpose of Use:

Artificial Groundwater Recharge using water diverted during the fall, winter, and spring freshet flows on the Walla Walla River and utilizing the HBDIC recharge structure near Milton-Freewater, Oregon.

Proposed Period of Use:

November 1 through May 15 and as Further limited below

Point of Diversion Location:

~~NE ¼ NW ¼, Section 1, SW ¼ NE ¼~~ Section 12, T5N, R35E, W.M.; ~~DIV.PT. 1 910 Feet South and 700 Feet West from North ¼ Corner Section 1~~; DIV. PT. 2 – 1030 Feet North and 900 Feet East From the Center ¼ Corner Section 12.

Minimum Instream Flow Information:

When water is diverted under this permit, the use is further limited to times when there is, at a minimum, the following streamflows in the Tum-a-lum branch (mainstem) of the Walla Walla River, between the Little Walla Walla River diversion and Nursery Bridge Dam and flowing past Nursery Bridge Dam.

Utilizing the Minimum Perennial Streamflows information (table 1, page 31) in OWRD Umatilla Basin Report (OWRD, 1988) and HBDIC's current winter water diversion permit (Permit Number 53662) the following represent the minimum instream flows at Nursery Bridge Dam:

- November – 64 cfs
- December through January – 95 cfs
- February through May 15 – 132 cfs

Nursery Bridge is located just downstream of Nursery Bridge and is downstream of the Little Walla Walla Diversion, the East Side Canal and the District's Canal, also described as point of diversion 1 in this application.

In order for diversion to occur under this permit, the above described streamflows must be met in the Tum-a-lum branch of the Walla Walla River, between the Little Walla Walla River diversion and Nursery Bridge Dam and following past Nursery Bridge Dam (see OWRD permit (Permit Number 53662 for operating and maintenance requirements for this station). Said streamflows shall be measured at the gauging station described below. In the event the primary gage experiences mechanical difficulties, stream flows at Nursery Bridge Dam shall be calculated by subtracting from the streamflows at Little Walla Walla Diversion (Cemetery Bridge) from those streamflows recorded at either the WWBWC gauge at Grove School Bridge or a combination of streamflows at OWRD's North and South Fork stations (#s).

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Attachment 3. Land Use Approval, 690-350-0020(3)(a)(H)

The HBDIC recharge project staff has consulted with both the Umatilla County Planning department and the current landowner (Hulette Johnson). Attached you will find two documents addressing the anticipated land use and zoning issues needed for construction and operation of this project. The first (Attachment 3A) a Land Use Form approved by the Umatilla County Planning Department. This was originally submitted as a requirement in the funding request to the Oregon Watershed Enhancement Board. The second Attachment (Attachment 3B) was is a lease agreement between the HBDIC and the current landowner and water right holder, Hulette Johnson.

Land Use Attachments

Attachment 3A: Umatilla County Land Use Approval
Attachment 3B: Lease Agreement with Landowner

Attachment 4. Proposed Test Program, 690-350-0020(3)(b)(A)

Introduction

The Walla Walla Basin Watershed Council (WWBWC), in cooperation with the Hudson Bay Improvement District (HBID), has proposed to test shallow aquifer recharge at a site located adjacent to the Hudson Bay Canal in section 33, T6N, R35E. At the test site a series of three infiltration pits will be built. Water will be supplied to these pits via a diversion from the canal. Recharge activities are proposed for winter and spring months when the Walla Walla River (the source of water for the canal) is at peak annual flows. The proposed shallow aquifer recharge testing will be done under an ASR Testing Limited License granted by Oregon Water Resources Department (OWRD) (OAR 690-350-0020).

Preliminary Test Site-Specific Hydrogeologic Characterization

Site-specific hydrogeologic characterization is designed to identify and define local conditions to provide a technical basis for designing the monitoring which will be used to evaluate testing. For this project a number of characterization needs are outlined in the 3 July 2003 hydrogeologic assessment letter report (Attachment 6). These needs include determining the physical properties of the geologic units underlying the test site, investigating the presence of a possible semi-confined aquifer in the upper part of the suprabasalt aquifer system, identifying aquifer hydraulic properties, and establishing suprabasalt aquifer baseline conditions, including seasonal variation, for groundwater depth, flow direction, and quality. These, and other site characterization issues, will be addressed using test site-specific hydrogeologic characterization data collected predominantly using:

1. Test pits, boreholes, and wells constructed for the direct observation of ` subsurface conditions
2. Infiltration tests (constant and falling head) designed to evaluate spatial variability at a site both laterally and vertically (note, the water source for this activity may require a temporary permit)
3. Aquifer testing and water level measurements to evaluate baseline aquifer physical conditions before testing
4. Surface and ground water quality data collected to evaluate the affect (if any) of test site operation on area groundwater quality
5. Well and canal records describing water use in the project area
6. Water flow metering at the test site that indicates surface water in-flow and out-flow during testing

At this time, geophysical investigations are not being considered because of the lack of subsurface control and ground truth data that could be used to constrain geophysical interpretations. The following sections describe proposed soils, geologic, hydrogeologic, surface water, and water quality characterization for this project.

Soil Characteristics

The HBDIC recharge project will be constructed by excavating the top 5 feet (72 inches) of soil from each of the recharge pits (See Engineering Design Report, ATTACHMENT 1). Test Pits constructed and evaluated in the Engineering Design Report provide site-specific soil profile information. Additionally, the "Soil Survey of Umatilla County Area, Oregon, (USDA, 1988) provides some general information about soil in the upper 60 inches at the project site. The two soils present at the site are: Freewater (29A) and Cowsly (22C). As the entire soil layer will be removed during construction, it was not found useful to further characterize the specific soil properties further.

Geology

Geologic features control the physical characteristics of aquifer hosting materials, and therefore the distribution and movement of groundwater through an aquifer. Understanding the nature and occurrence of these features, both regionally and locally, provide constraints on testing, data interpretation, monitoring, mitigation, and final design. The objective of geologic characterization is to develop a three dimensional physical framework that describes the materials hosting the vadose zone and groundwater at the test site. Within this framework, or conceptual model, the nature and distribution of those factors thought to control groundwater movement and distribution will be evaluated.

Site-specific geologic characterization will be accomplished largely through the analysis of data collected during the drilling of several proposed boreholes at the site and comparison of that data to information collected during the preparation of the hydrogeologic assessment report. A minimum of three boreholes are proposed for the immediate vicinity of the test site. One of these boreholes will be located on the inferred up-gradient side of the test site, two will be located on the inferred down-gradient side (Attachment 5C). As testing progresses, additional boreholes may be drilled to collect additional characterization, testing, and/or monitoring data. Subsurface hydrogeologic conditions will be interpreted via drilling cuttings and spilt-spoon sample logging.

The project hydrogeologic assessment identified work needed to complete site-specific hydrogeologic characterization. Hydrogeologic characterization targets, and the rational for them, are described below.

It is likely that the uppermost, unconfined part of the shallow aquifer system, is hosted by predominantly uncemented alluvial gravel beneath the test site. However, it is not clear from the available data how deep the alluvial gravels extend and what their properties are beneath the test site. Identifying the three-dimensional extent of these strata is critical to the proposed testing because water probably will move more rapidly through these uncemented strata, both downwards and laterally, then in the deeper, more cemented Mio-Pliocene conglomerate that comprises the majority of the shallow aquifer system in the area.

Area data indicates that, if present, the unconfined part of the shallow aquifer system at the site may be relatively thin and underlain by a semi-confined zone at depths of less than 75 feet. Characterization will identify if this semi-confined zone is actually present, and if found, the nature of the confining layer separating it from the overlying unconfined zone and the basic hydrologic properties of the semi-confined zone. Knowing the nature and extent of the confined aquifer underlying the site is critical in evaluating if the proposed recharge will affect this deeper aquifer. If data collected indicates that the project could potentially affect this deeper aquifer, monitoring will need to be designed to not only assess shallower unconfined aquifer impacts but deeper confined aquifer impacts as well.

The nature and distribution of the confining layer atop the confined aquifer should be identified in order to support evaluation of the thickness and distribution of the unconfined aquifer (if present). If the unconfined aquifer is absent, or only present seasonally, we will still need to identify the nature and extent of the confining layer because, just as it inhibits upward movement of groundwater, it will restrict the downward movement of recharge water. Knowing where the confining layer is will provide information on where recharge water may potentially collect atop this layer and where it will potentially spread to.

Mapping for the assessment identified a potential depression in the top of the older Mio-Pliocene conglomerate below the western end, and west of, the test site. The depth, shape, and orientation of this feature will need to be evaluated because it will effect how the aquifer(s) underlying the test site responds to the testing. If an unconfined aquifer indeed underlies the site, this depression may act as a "reservoir" for water introduced into this aquifer. Alternatively, it may serve as a recharge pathway, hydrologically connecting the upper, unconfined part of the suprabasalt aquifer system with deeper, confined parts of the aquifer system.

Hydrogeology

Piezometers and/or observation wells will be constructed in the borings drilled for geologic characterization. If additional geologic characterization boreholes are drilled (either close to or more distal from the test site) one or more of these also may be converted to observation wells. All but one of the boreholes converted to monitoring wells will be completed as 2-inch observation wells that fully penetrate the unconfined aquifer (if present) or above the confining layer (if unconfined aquifer not present). At least one of the geologic characterization boreholes should be of sufficient size to accommodate a 4-inch diameter well which will be used for aquifer testing.

Test site-specific hydrogeologic work would be done, in large part, concurrently with the site-specific geology work. The hydrogeologic assessment concluded that the following information must be collected for the uppermost part of the suprabasalt system at the test site:

1. Depth, thickness, and lateral and vertical extent of the vadose zone and the uppermost aquifer(s) underlying a site.

2. Nature and effect of perching layers (if any) in the vadose zone.

3. Aquifer and vadose zone physical and hydrologic properties - including, grain size, matrix content, induration, hydraulic conductivity, transmissivity, and porosity

4. Groundwater flow direction and velocity, including both spatial and temporal variation

5. Anthropomorphic effects, primarily changes in groundwater pumping, surface water (including canals), and irrigation activities.

For characterization it is important to build monitoring (or observation) wells in such a way as to provide means for accurately measuring the target aquifer. Well construction considerations are listed below:

1. Most project observation wells will probably be 2 inch-diameter piezometer type installations. These should be built to ensure that they are monitoring the anticipated aquifer targets, and we recommend building to well construction standards and avoiding cost cutting measures designed to get more/cheaper wells (these commonly result in poorly built wells unsuitable for collection of the high quality data we feel is necessary to support the project).

2. For aquifer testing, a 4 inch-diameter observation well is the minimum recommended diameter and at least one such well should be built.

3. The minimum number of observation wells at the test site is 3, one up-gradient and 2 down-gradient. If funding can be procured we recommend that more than 3 observation wells be installed. Most, if not all, of these additional observation wells could be built in geotechnical borings drilled for geologic characterization.

In addition to the observation wells built near the test site, it seems likely that observation wells will eventually need to be built more distant from the site. The purpose of these observation wells would be to more accurately trace the down gradient migration of recharge water away from the test site. A minimum of 3 more distant observation wells, 1 up-gradient and 2 down-gradient is again recommended. These might include at least some previously built groundwater supply wells that would be available for use. However, these should only be used if construction details can be verified and if they are not being used as water supply wells. Access to offsite observation well drilling locations will need to be acquired from willing landowners. The WWBWC currently has a network of existing wells that could be used for the purpose of tracking the recharge water distally from the site.

Aquifer testing designed to collect aquifer hydraulic property data will be part of site characterization. During aquifer testing, the 2-inch observation wells will be monitored to observe the effects of testing on the surrounding aquifer. Aquifer testing would include an 8-hour step-drawdown test to establish probable sustainable yields in the suprabasalt aquifer, followed by a 24 to 72 hour constant discharge test. Water level data collected during aquifer testing will be analyzed using standard analysis techniques.

Combining the interpretations developed in the completed hydrogeologic assessment with the drilling and testing data collected during site-specific characterization, a conceptual model of test site hydrogeologic conditions will be prepared.

Surface Water

One of the main objectives of the project is to increase surface water quantity (base flow) and improve its quality (temperature). To document that, surface water bodies that the project may influence need to be identified and monitoring points on them established and characterized (includes collection of baseline data). These locations will be used as monitoring locations during subsequent testing.

The hydrogeologic assessment identified three, down gradient, spring-feed streams, Goodman Spring Branch, Johnson Creek, and Dugger Creek, which are most likely to be affected by recharging the shallow aquifer. During test-site specific characterization these streams will be examined and monitoring points identified. At these points stream conditions will be photographed and stream conditions documented prior to the initiation of testing that will include the following parameters:

Flow volume and discharge

Water temperature

Water quality (temperature)

Hydrophilic plants and habitat quality

Sampling frequency will be designed to collect enough data to demonstrate the range of conditions likely at the monitoring points so that site background conditions can be documented enough to provide an adequate baseline to measure test results against.

Water Quality

Both surface and groundwater quality at the test site, and at likely down-gradient discharge points, needs to be documented. There are several reasons for this, including:

1. We do not want to introduce contaminated water into the shallow aquifer via recharge activities and violate antidegradation rules. We need to establish background water quality parameter concentrations and monitor source-water quality periodically during testing and operations.

2. Certain source-water conditions (e.g., turbidity) have the potential to degrade or even "plug" the recharge system. From an operational standpoint, one would monitor for those conditions and halt test operations when the source-water exceeded those conditions.

3. Up-gradient groundwater quality needs to be monitored so that the effects of recharge on water quality can be differentiated from those water quality conditions caused by recharge activities, including leaching of vadose zone constituents by recharge water.

Sampling Quality Assurance and Quality Control (QA/QC) protocols will need to be established and followed for characterization and later monitoring. QA/QC for the project, which is described in Attachment 5, includes:

- Sampling equipment
- Measurement techniques for field parameters
- Decontamination procedures
- Well purging guidance for groundwater samples
- Sampling methods
- Chain of custody and sample handling procedures
- Record keeping
- QA/QC guidelines

Characterization Conclusions

With the completion of site-specific characterization, updated monitoring and test plans will be prepared if necessary. These monitoring and test plans will be based on the results of the characterization effort which includes the generation of a site conceptual groundwater flow model that describes probable aquifer conditions, suprabasalt aquifer water level(s) and groundwater flow direction(s) (including seasonal variations), and discharge points for recharge water.

Preliminary Test Site Operation Plan

The objective of proposed artificial groundwater recharge testing to be done under the limited license is to evaluate the feasibility of restoring diminished shallow aquifer water levels and increasing decreased spring creek flows using infiltration pits and winter high flow water diverted from the Walla Walla River to these pits. Testing will be done over five years. If testing indicates shallow aquifer recharge and spring creek flow restoration is feasible using infiltration, test results will be used to design and implement larger scale artificial groundwater recharge at this, and potentially other sites in the area. Testing **will not include** removal of stored water by pumping or other artificial means.

This preliminary test plan describes how the test site will be operated during testing. Elements included in the preliminary test plan include: (1) site construction, (2) test operations, (3) mitigation activities, and (4) reporting. The preliminary test plan may be modified as testing proceeds.

Site Construction

The basic layout of the test site is shown on Figure 1. The site, located adjacent to the Hudson Bay Canal, will consist of three infiltration pits excavated approximately 3 feet into Quaternary alluvial gravel which immediately underlies the test site (Attachment 6). Water will be delivered to the pits via a diversion structure in the canal. Any water that does not infiltrate into the ground from these pits will be returned to the canal via a return ditch or pipe.

More detailed site construction information describing: (1) test site survey and layout (2) specifications for pits/basins/pits used for infiltration (3) water supply design (including diversion from canals if appropriate) (4) monitoring points (both on and off site) and (5) site access controls (fences, etc.) are described in detail in Attachment 1, (1A-1E), Engineering Design.

Test Operations

Test operations describe how the site will be used during testing and possible reasons for changing the test as new data and information is collected during the test. Test operations include:

1. Test timing, including timing of recharge and monitoring frequencies

2. Quantities of water used

3. Outside influences that effect test, including weather (probably freezing), elevated river turbidity, river flooding, trip wires for identifying potential offsite impacts before they occur so they can be mitigated and or testing suspended to prevent worsening conditions

4. Responsible parties for diversion and delivery of water, operation of test, monitoring, and data review

5. Permissions required to access offsite monitoring points

These are discussed further in the following paragraphs.

Test Timing, Monitoring, and Water Quantities

Testing is tentatively planned to begin in the winter of 2003/2004 and continue for 5 years. Test operation will generally be conducted in the winter when Walla Walla River flows are at their highest and irrigation activities are at their lowest. A maximum of approximately 50 cfs will be delivered to the test site during normal operation. However, in the event minimum Walla Walla River flows are not meet, water will not be diverted from the river for test site use. Depending on stream flows in any given year, recharge water may be delivered as early as December to as late as March/April. In addition, in the event of prolonged freezing weather, test site operation may be temporally suspended to avoid ice damage to the canal diversion on the Walla Walla River, the canal system itself, and/or the recharge pits and related structures.

Water quantities delivered to the test site will be monitored via a gauge at the diversion from the canal into the test site. The return canal from the test site back into the canal will also be monitored to determine the quantity of water that leaves the test site (if any) because it did not infiltrate into the ground. Based on this monitoring data, and estimated evaporation loses that could occur during operation; water quantities discharged to the ground will be calculated.

Groundwater levels in the immediate vicinity of the test site will be monitored before, during, and following recharge test events via three (at a minimum) observation wells constructed during characterization, potentially via existing water wells in the area if any can be found that can be used for shallow aquifer water level monitoring, and potentially with new observation wells built as the test progresses. During the recharge test event, tentatively scheduled for the winter/spring of 2003/2004 water levels will be measured as follows:

1. Throughout the calendar year water levels will be measured at least weekly, beginning with the granting of the limited license.

2. In the month prior to the anticipated start of recharge activity and in the month following the termination of recharge, water levels will be measured daily.

3. During recharge water levels will be measured daily, at a minimum.

Based on preliminary engineering design studies (Attachment 1) and the hydrogeologic assessment (Attachment 6) most, if not all, of the water delivered to the test site will probably infiltrate into the ground. However, because this project is a test project, the current plan is to initially operate the test site at approximately half capacity. The quantity of water discharged to the site will than be increased or decreased as experience and observations dictate. Final operating quantities will determined based on test results.

Water quality data will also be collected before, during, and following recharge events. Parameters to be collected, sampling timing, and other water quality monitoring information are presented in the Monitoring Plan (Attachment 5).

Outside Influences

The primary currently identified outside influences on testing are Walla Walla River flow levels, freezing conditions, source water turbidity levels, and increased groundwater water levels resulting from testing that impact surface activities and conditions. The likely effects of these on testing, and possible mitigation actions to be implemented during testing, are as follows:

Low flows in the Walla Walla River will impact testing because the use of Walla Walla River water for recharge will be conditional, based on river flows exceeding a certain threshold. When flows do not, water will not be delivered to the test site and testing will not occur.

High Walla Walla River flows may also effect testing. In the event of high flow during a flood or rapid snow melt event, turbidity will generally increase. The repeated delivery of turbid water to the test site infiltration pits may eventually lead to plugging of pore space and reduced infiltration capacity. To mitigate against this, delivery of recharge water may be terminated or scaled back during high flow events. Alternatively, the pits may be periodically re-excavated to remove these fines. The preferred mitigation strategy for dealing with this will be based on monitoring and performance data collected during testing.

The effects of freezing on the test are outlined earlier in this Attachment and repeated here. In the event of prolonged freezing weather, test site operation may be temporally suspended to avoid ice damage to the canal diversion on the Walla Walla River, the canal system itself, and/or the recharge pits and related structures and to avoid the risk of ice jams forming in the canal, backing up water in the canal, and causing flooding adjacent to the canal.

It is possible that recharge testing could cause groundwater levels to reach the ground surface at locations where human activity and habitat is negatively impacted. One of the main purposes of groundwater level monitoring is to identify increasing water levels in the test site area in order to: (1) directly observe the effects of recharge on water levels (2) use these observations (in conjunction with characterization data) to evaluate whether or not recharge is having an impact on groundwater levels that could lead to surface problems, and (3) identify when and where this type of problem may occur. If water level monitoring data suggest increased groundwater levels are approaching the ground surface and that flooding of low lying areas seems possible, the quantity of recharge test water being delivered to the infiltration pits will be reduced or, if necessary, terminated.

Responsible Parties and Access Permission

The test will be managed primarily by the Hudson Bay District Irrigation Company, lead by John Brough, Operations Manager, and the Walla Walla Basin Watershed Council (WWBWC) technical staff, lead by Mr. Bob Bower, Hydrologist. HBDIC and WWBWC staff (or a subcontractor working for the HBDIC and WWBWC) will compile monitoring and testing data, prepare reports as necessary to meet license requirements, and in consultation with Hudson Bay Irrigation District (HBDIC) staff make decisions regarding timing and quantity of water delivered to the site and when to suspend recharge activities. Submittal of all monitoring reports to OWRD will be the responsibility of HBDIC and WWBWC staff. The HBDIC and WWBWC may choose to subcontract report preparation and delivery to a subcontractor.

HBDIC staff will be responsible for operating all facilities associated with removing recharge test water from the Walla Walla River and delivering it to the test site, including operation of the diversion structure which routes water from the canal into the pits. HBDIC staff also will maintain all equipment associated with water delivery and pit operation, including reexcavation of the pits, if necessary.

Mitigation

As stated above, one of the objectives of monitoring is to identify likely unintended consequences of recharge testing before they occur. When the precursors to these consequences, such as changing water quality detrimental to aquatic habitat or groundwater levels rising to close to the surface in areas where shallow groundwater is not desired, can be detected soon enough via monitoring, recharge activities will be modified and/or terminated to mitigate against these effects.

Reporting

Data and observations collected during testing, including monitoring data, will be compiled into reports. The basic objective of these reports will be to describe what was done during the test, what was observed at the monitoring points, interpret the data collected, and recommend changes to testing, monitoring, and mitigation plans. These reports will be produced annually. Based on the proposed recharge schedule, annual reports will be submitted to OWRD in the summer following each winter recharge test.

More frequent reporting will be done when monitoring reveals the presence of an undesired effect from testing. If monitoring reveals that undesired consequences of testing are likely to occur, WWBWC staff (or designated representative) will report the monitoring information to OWRD staff.

At the conclusion of the 5-year recharge testing done under the limited license a final report will be prepared. The final reports will describes the project, data colleted during testing and monitoring, interpretations of how well the recharge project worked in achieving project goals, and recommendations for future operations. The final report will be submitted to OWRD in the summer following the fifth annual winter recharge event.

Attachment 5. Proposed Monitoring Program, 690-350-0020(3)(b)(A)

Overview of Basin Wide Monitoring Plan

In 2003, the WWBWC expanded its watershed monitoring strategy to include collecting basin line information for the numerous spring-creeks and district ditches spread out across the Walla Walla River valley (Oregon). Starting in June 2003, many new flow stations (15-minute stage and temperature recorders) were installed at or near the sources of nearly all the springs in the Oregon portion of the system (Figure 2). The WWBWC monitoring program has a total of 28 continuous flow stations with additional 15 continuous static well recorders with many more manual measurement locations. The objectives of this monitoring (specifically for the spring-creek and shallow aquifer system) is to accomplish the following:

1. Be able to discern between Walla Walla River Water (coming from districts water rights and use) and spring waters (emerging strictly from the shallow aquifer). It is understood that the application of irrigation water will undoubtedly show up as spring returns, but this monitoring is intended as a beginning to understanding this complicated system.
2. Collect baseline information on spring flow as it relates to seasonal and yearly fluctuations.
3. Many of the spring-creek monitoring stations were sited based on the presence of historical data collected by Piper (USGS, 1933). Where Piper had collected spring-creek flow, we attempted to locate our gauges as near as possible to his historic data sites. The intention is to allow us the ability to compare and contrast historical and current spring-creek conditions based on a significant period of time. Most of these Piper's original sites were located upstream of any irrigation with draws, making them key locations for us in this type of comparison.
4. Monitor water table levels continuously for daily, seasonal and yearly fluctuations and timing. Some of the wells being recorded have periods of record dating back to the 1930s, allowing us some opportunity to understand any long-term changes in the aquifer system.

Recharge Project Monitoring Plan

The proposed ground water recharge project exists inside this larger monitoring network and it is expected that this will help provide useful information in testing of the proposed testing (see below). Some of the sites shown in this larger network were specifically located to provide proximal and distal pre-construction and operation information for this project (Figure 2). Site specific monitoring includes observation wells and surface monitoring stations (Attachment 5B).

Monitoring for the site-specific proposed testing is designed to meet four basic objectives. These are to identify: (1) changes in the natural system caused by factors other than those related to testing, (2) changes in the natural system caused by the testing (track the test performance), (3) potential problems caused by the testing that may require modification or termination of the test and/or mitigation actions, and (4) events that effect test operations, such as a freezing or a flooding. To meet these objectives, monitoring will track:

1. Source water quality and volume coming onto the test site

2. Up-gradient groundwater water quality

3. Up-gradient groundwater level changes to provide the information needed to differentiate recharge test effects from other, natural and artificial, effects on the groundwater levels beneath test site

4. Down-gradient groundwater quality and levels, both near and distal to the test site

5. Surface water discharge and quality changes

Four basic types of monitoring points are planned for this project:

1. Source water

2. Test site groundwater

3. Distal groundwater

4. Surface water (e.g., springs).

Monitoring data collected at these points during testing will be evaluated against what is known about pre-test conditions to identify testing effects on the surrounding environment, differentiate those effects from others in the environment, and identify when changes in test operations appear necessary. Pre-test conditions will be determined during the planned site-specific characterization activities described in Attachment 4 and are partially described in the preliminary hydrogeologic assessment (Attachment 6).

This preliminary monitoring plan discusses monitoring activities to be undertaken at the four types of monitoring points and sampling and QA/QC protocols.

Sampling and Analysis Program

The groundwater-monitoring program proposed for the test project is outlined in the following sections. Annual reporting is proposed and a Water Quality Analysis Report will be prepared following five years of testing.

<u>As stated in the introduction, four types of monitoring are proposed:</u> (1) source water at the test site (2) site-specific groundwater (3) distal groundwater and (4) surface water (springs).

(1) Source Water at Test Site
Source water monitoring will be at the point of diversion onto the test site. Monitoring will include both water quantity and quality. The volume of water delivered to the test site will be monitored via a gauge at the diversion. Water quality samples will be collected at the gauge.

Proposed monitoring frequency is as follows:

> Gauge data will be recorded 15-minute readings via a continuous recording data logger. Rating measurements and tables will be generated for each surface flow site and continuously checked for shifts.
>
> Three source water quality-sampling events are proposed for each yearly seasonal recharge period. They are proposed for approximately: (1) one month prior to the projected beginning of the recharge period (2) during the mid part of the recharge period and (3) approximately one month following the end of the recharge period. The exact timing of these will be based on predicted Walla Walla River flows and may vary from year-to-year. OWRD and ODEQ staff will be notified by WWBWC staff of pending sampling events at least two weeks prior to each sampling event.

The results of source water quality monitoring will be used to determine if modifications to test operations are warranted. During testing different sampling frequencies may be tried to identify those that are most effective.

(2) Site Groundwater

Site groundwater monitoring, consisting of the collection of water quality and water level data, will be conducted at the three observations wells built during characterization. The purpose of site groundwater monitoring is to establish water quantity and quality impacts from testing to groundwater in the immediate vicinity of the site. In addition, up-gradient monitoring will be used to differentiate test impacts from those caused by other activities not controlled by the testing.

Proposed monitoring frequency is as follows:

> Water levels will be measured weekly throughout the year when recharge testing is not underway.
>
> In the month prior to, during, and the month following the yearly seasonal recharge period, water levels will be collected daily (at a minimum) for the first year of testing. Measurement frequency during subsequent years will be based on previous observations and proposed in annual reports.
>
> Three groundwater quality sampling events are proposed for each yearly seasonal recharge period. They are proposed for approximately: (1) one month prior to the projected beginning of the recharge period (2) during the mid part of the recharge period and (3) approximately one month following the end of the recharge period. The exact timing of these will be based on predicted Walla Walla River flows and may vary from year-to-year. OWRD and ODEQ staff will be notified by WWBWC staff of pending sampling events at least two weeks prior to each sampling event.

The proposed locations of site-specific groundwater observation wells are shown on Figure 1. The results of groundwater quality and level monitoring will be used to determine if modifications to test operations are warranted. During testing different sampling frequencies may be tried to identify those that are most effective.

(3) Distal Groundwater

Distal groundwater monitoring, consisting of the collection of water quality and water level data, will be conducted at observation wells more distal from the test site than the site observation wells. Initially, during the first year of recharge testing, these wells will probably be previously constructed water supply wells that can be used by WWBWC staff and can be shown to be open to only the shallow aquifer. If funding for new wells can be procured for subsequent years, dedicated distal groundwater observations wells may be built to improve the monitoring coverage.

A minimum of 3 distal observation wells will be used, 1 up-gradient and 2 well down-gradient. The locations of these will be determined during site specific characterization currently planned for the winter of 2003. Monitoring frequency is the same as proposed for site-specific groundwater monitoring. Figure 5B shows the approximate site locations for the site-specific observation wells.

Distal monitoring will be used to identify longer term quantity impacts from testing. This includes the formation and migration of a groundwater mound and recharge water plume at, and away from, the test site, towards intended and unintended receptors. Up-gradient monitoring will be a part of this so that testing effects can be differentiated from offsite events. Sampling frequency will be determined from characterization data and modified as more is learned during testing.

(4) Surface Water (Springs)

The WWBWC is currently monitoring most of the surface springs, creeks and rivers of Oregon's lower Walla Walla River basin (See Figure 2.) While this project will specifically Surface water monitoring in Dugger, Johnson and Goodman Spring-Creeks will be done to identify the effects of recharge on flow. This monitoring will include the collection of both water quality (specifically temperature), flow and habitat improvements (photo-documentation). As with groundwater monitoring, surface water monitoring will need up-gradient and pre-project condition monitoring information so that effects unrelated to test site operations/testing can be differentiated from those due to testing. Pre-project surface flow monitoring was started during the 2003 summer irrigation season at Dugger and Johnson Spring-Creeks in the form of a continuous.

Sampling Parameters

Sampling methods are specified in the following sections. The chemical monitoring parameters are to be conducted on a two-tiered system. Level 1 monitoring will be conducted during all three water quality-monitoring events (each recharge period). Consistently elevated concentrations of nitrate will be initiate the level 2 chemical analysis. Samples will be tested for chemicals in the level 2 list. Operation of the recharge project will depend on the absence/presence of the chemical parameters on this list. ATTACHMENT 5B describes the specific method and documents used to determine the level 1 and 2 chemical parameters (pesticides, herbicides, insecticides, fungicides, etc.) listed below.

Monitoring is proposed for the following parameters:

Physical Parameters (all monitoring types)

Static water level (in observation and WWBWC network well)

Standard field parameters, including pH, turbidity, electrical conductance, and temperature

Flow (in cubic feet per second)

Chemical Parameters –Level 1 (On-site monitoring only)

Total nitrogen as nitrate (screening parameter for Level 2 Chemical screening)

TKN

Total dissolved solids

Chemical oxygen demand

Chloride

Orthophosphate

Fecal Coliforms (Presence/absence only)

Chemical Parameters –Level 2 (On-site monitoring only)

Rubigan (Fenarimol)

Ridomil (Metalxyl)

Systhane/Rally (Myclobutanil)

Devrinol (Napropamide)

DDD-DDE-DDT

Elgetol (DNOC sodium salt)

Alar/B-Nine (Daminozide)

Lindane (Lindane)

Sampling dates will be coordinated for all monitoring points used in the project.

This list of analytes was selected to optimize routine sampling to address constituents commonly of concern (nutrients and salt) and provide prompt indication of potential impacts by analyzing for anions (nitrate and chloride) that are known as groundwater tracers (DEQ, 1995). Additional parameters will be proposed for future sampling if the results of the initial proposed sampling indicate this is necessary.

Sampling Procedure
Equipment and sampling procedures proposed for recharge test monitoring are provided in the following sections.

Equipment
This section lists the equipment for groundwater monitoring.

Submersible pump (*Grundfos* or similar) or dedicated bailers/sampling line

Temperature measuring instrument (*Vemco* data logger)

pH and conductivity meter(s) with calibration reagents

Water level and flow meters (*Tru-traks, In-situ Mini-trolls, Stevens 420 loggers,* 0.01 foot resolution required)

Shipping cooler with ice packs or ice

Five-gallon pail marked at the 5-gallon level, stopwatch

Laboratory supplied sample containers with appropriate preservatives

Tap water, deionized water, phosphate-free soap, cleaning brushes, field note book, log sheets

Water Level
An electronic water level meter will be used to measure the depth to groundwater in each observation well to the nearest 0.01 foot. Static water levels must be measured at the indicated reference point prior to purging any water from the well. The reference points will be on the top of the observation well casings. The static water levels in all wells should be measured on the same day for each site. Coordination with quarterly sampling of other wells in the vicinity should be attempted. Accumulation of sediment in the well should also be checked by lowering a weighted tape to the bottom of the well, reading the depth at the well casing's reference point, and comparing this value to the as-built well depth.

Decontamination
All non-disposable field equipment that may potentially come in contact with any soil or water sample shall be decontaminated in order to minimize the potential for cross-contamination between sampling locations. Thorough decontamination of all sampling equipment shall be conducted prior to each sampling event. In addition, the sampling technician shall decontaminate all equipment in the field as required to prevent cross-contamination of samples collected in the field. The procedures described in this section are specifically for field decontamination of sampling equipment. At a minimum, field-sampling equipment should be decontaminated following these procedures:

1. Wash the equipment in a solution of non-phosphate detergent (Liquinox® or equivalent) and distilled/deionized water. All surfaces that may come in direct contact with the samples shall be washed. Use a clean Nalgene and/or plastic tub to contain the wash solution and a scrub brush to mechanically remove loose particles. Wear clean latex or plastic gloves during all washing and rinsing operations.

2. Rinse twice with distilled/deionized water.

3. Dry the equipment before use, to the extent practicable.

Purging and Field Parameters (On site wells only)
Sufficient water will be purged to ensure that the sample collected represents water from the geological formation. Borehole volumes are calculated as the volume of water in the casing and the volume of water in the filter pack.
During purging, measure pH, temperature, and electrical conductivity of the water removed. At a minimum, these parameters are measured at the start of purging and after each successive borehole volume is removed. Temperature should be measured first because it changes most rapidly. Purging continues until at least three borehole volumes have been purged and the field parameters are established to within ± 10 percent over three consecutive measurements. At this point, the observation well is considered adequately purged and can be sampled.
Occasionally, observation wells installed in low permeability formations may be purged nearly dry (within 6 inches of bottom of well) prior to stabilization of groundwater parameters and prior to purging at least three borehole volumes. If this happens at least one set (more if possible) of purge water groundwater parameters (pH, temperature, EC) need to be measured. Sample collection can be done after the water level has recovered at least 75 percent of the drawdown ensuring most of the well water is from the formation. Prior to groundwater sample collection several measurements are required as explained above. These include static water level and total depth, pH, temperature, and electrical conductivity.
All field instruments should be calibrated each day prior to sample collection. Instrument calibration and maintenance should precisely follow the manufacturers recommended procedures. Electrical conductivity and pH standards used to calibrate the instruments should be within the range encountered at the monitoring sites. Calibration records should be recorded on the sample collection forms.

Water Sampling
Samples will be collected after sufficient water has been purged according to the procedure described above. Samples will be collected from the discharge end of the pump hose after the flow rate has been reduced to less than approximately 0.2 gallons per minute. Discharge from a bailer should be controlled to minimize agitation and aeration. Sample containers should be sealed with tape, labeled, and immediately placed in a cooler with ice. Sample containers should be filled completely to eliminate head space. Sample containers should be provided by the analytical laboratory and should be requested at least one week in advance of the sampling. The containers should be appropriate for

the parameters analyzed and all shipping coolers should have chain-of-custody seals placed on them prior to shipping.

One additional sample should be collected from one of the sample points for quality control purposes. This sample should be evaluated as a "blind duplicate."

Sample Preservation and Holding Time. Samples should be stored immediately after collection in an ice chest containing sufficient ice to cool the samples to 4 degrees Celsius (°C). Use "blue ice" if possible. If water ice must be used, the ice should be sealed in plastic bags, as should the sample bottles. Samples should remain cooled at 4°C and delivered to the laboratory within 24 hours of collection. Sample receipt at the laboratory must be sooner if analysis includes parameters with a shorter holding time. Care should be taken to prevent excessive agitation of samples or breakage/leakage of containers. Samples should be analyzed within the specified holding time for each constituent.

Resampling

In accordance with OAR 340-40-030(5), resampling is done if monitoring indicates a significant increase (or decrease for pH) in the concentration of a monitored parameter at a sampling point. Determining if a significant increase in parameter concentration has occurred is customarily done either by assessing concentrations in relation to established concentration limits or by using a statistical analysis. Since background or baseline conditions have yet to be established for the test site a concentration limit has not been set and insufficient data exists upon which to base a statistical analysis. The criteria to guide resampling decisions will be reevaluated is subsequent test project annual reports.

Chain of Custody and Sample Handling

A chain-of-custody form should be completed and signed by the sampler on the day samples are collected. The chain-of-custody form must be signed by laboratory personnel upon receipt and any other individuals that maintain custody of the samples in the interim. Coolers should be sealed and shipped or driven to the lab as soon as possible. The method of shipping (bus, next day air, etc.) is usually determined by the parameter having the shortest holding time. In any case, shipping times of more than 24 hours should not be used as the cooler(s) may warm and compromise sample quality.

Field Records and Data Validation

All field notes, analytical results, and other pertinent data associated with the project should be maintained in a secure location and be archived for at least a five-year period. Data validation for both field and lab Quality Assurance and Quality Control (QA/QC) will be performed using a checklist. All pertinent information with respect to QA/QC will be checked.

The following items are included on the QA/QC review checklist:

1. Field data sheets (or notebooks) and observations (observations are used to check for potentially erroneous data) will be reviewed to make sure they are completely filled out.

2. Chain-of-custody forms will be completed, being signed by all sample handlers.

3. Holding times for all constituents will be met.

4. Field blind duplicate results will be evaluated to make sure they are compatible.

5. Laboratory method blanks, matrix spike, matrix spike duplicates, and surrogate percent recovery data supplied by the analytical laboratory will be evaluated to make sure they are compatible.

Data Reporting and Statistical Analysis
The following procedures for reporting analysis are proposed for this project.

Record Keeping
All field notes, laboratory results, critical calculations, and published reports will be maintained at the WWBWC office for a period of five years following completion of the final testing and monitoring report. If possible, both paper and electronic copies will be maintained.

Evaluation
Monitoring data and observations should be evaluated when they are received from the sampler and laboratory.

Materials to be received include:
Field monitoring and sample collection records

Original laboratory reporting sheets

Data evaluation will include:

1. Verification of analytical methods and detection limits, along with the date the analysis was performed

2. Review of document handling, sampling and analytical problems, and actions taken to correct any problems

3. Summarizing water level data in tabular and/or graphical form

4. Summarizing water quality analytical results in tabular form and/or graphical form

5. Performing data validation checks, as appropriate to the data set

6. Identifying any significant increases in parameter concentrations (will be done later in project only after enough data has been collected to warrant)

Annual Review and Reporting
All monitoring activities performed during the previous monitoring year will be included in an annual report to be submitted to OWRD during the summer following the preceding seasonal recharge period. The annual report will present the following information:

Water quality data, including duplicate sample results in tabular form and time-series plots for specific parameters

Water level data, including hydrographs showing water level changes over time

Basic statistical parameters for each parameter of interest: mean, median, maximum, minimum, standard deviation, number of data points, and number of non-detects

Evaluation of all field and laboratory data, including observed changes and groundwater flow direction and gradient

Discussion and conclusions, including recommended changes to recharge testing

The methods needed to evaluate water quality and water level data will depend on the objectives of the evaluation. In general, the principal objective is to evaluate whether or not recharge tests have affected groundwater levels and quality. Evaluation methods include: a comparison of water quality data with a concentration limit or with background water quality; comparison of water quality over time; or comparison of water quality between up-gradient and down-gradient wells. For the test site, insufficient data are available for a statistical analysis to be performed because concentration limits have not yet been established. Until that time, evaluation of dataset trends will be solely qualitative, but revisited in each annual report until a database has been compiled that is sufficient for statistical analysis.

Final Recharge Test Project Report

At the conclusion of five years of recharge testing under the limited license a final report will be prepared. The report will contain the data collected for the test project; analysis and interpretation of that data (including statistical analysis as appropriate), and a recommendation for proposed future artificial groundwater recharge activities at the test site. The report will be complete enough to serve as supplemental material to a permanent artificial groundwater recharge permit under OAR 690-350-0110, if such a permit is sought following completion of the test project.

Monitoring Plan Attachments

Attachment 5A. Methodology Water Quality Assessment and Evaluation
Attachment 5B. Figure 5A Map of On-site Recharge Well Locations
Attachment 5C Chemicals of interest for Hudson Bay Recharge Project

Attachment 6. Site Hydrogeology, 690-350-0020(3)(b)(C), (E), and (G) (attached)

Attachment 7. Source Water Quality, 690-350-0020(3)(b)(D)

Overview

This project will utilize winter-spring flow from the Walla Walla River as the *source* water for recharge during the project operation. The time period that Walla Walla River water will be used is November 15th through May 15th. A review of existing reports and data was conducted to identify any areas of concern regarding source water quality for the recharge project. What little information that exists for source water quality conditions is discussed below.

In 2003, the WWBWC tracked turbidity levels through a winter storm event (1/27/3 through 2/3/3) and found turbidity levels to be a potential issue on the Walla Walla River (mainstem) during peak flow events (WWBWC, Unpublished data). Turbidity could be problematic for project operations, as it may act to decrease the rate of infiltration by plugging and layering the bottom of the recharge pits. Turbidity may also be a preliminary screen for fecal contamination issues, as bacteria may use the large particles as a vector for mobilization.

The other known source water quality information was obtained from the Environmental Protection Agencies STORET database. STORET provided some historical water quality data that showed several parameters (circa 1960s) that were accounted for in the recharge project's monitoring plan (ATTACHMENT 5). STORET data that was collected nearest to the source water POD at the Little Walla Walla Diversion (*NE ¼ NW ¼, Section 1, SW ¼ NE ¼ Section 12, T5N, R35E, W.M.; DIV.PT. 1*) is attached in table form as ATTACHMENT 7A.

From the review of all known source water information, the parameters that appeared to be of concern are:

1. Fecal Coliforms
2. Turbidity

There was no other relevant information found for source water quality conditions. The monitoring plan covers the establishment of source water quality conditions during operation of the recharge facility. This will insure safe water quality conditions for the recharge project.

Attachment 7A Source Water Quality Information

Resources and References:

Cooperative Extension Washington State University. 2002. *2002 Crop Protection Guide for Tree Fruits in Washington.* Washington State University EB0419.

Darnell, T., Topielec, R. 1996, October. *Nitrates and Bacteria in Groundwater: A Second Look, Milton-Freewater Area, Umatilla County, Oregon.* Oregon State University Extension Service Water Quality Program.

Darnell, T. Hart, J. Vomocil, Jim. 1989. *Nitrates and Bacteria in Groundwater: Milton-Freewater, Umatilla County Oregon.* Oregon State University Extension Service.

Darnell, T., Montgomery, M. L., Witt, J. M., 1989, July. *Pesticides in Groundwater: Milton-Freewater, Umatilla County, Oregon.* Oregon State University

EPA STORET Water Quality Database information (http://www.epa.gov/storet/)

Jenkins, J. J., Thomson P. A., 1999, January. *OSU Extension Pesticide Properties Database.* . Oregon State University Extension EM 8709

Kerle, E.A., Vogue, P. A., Jenkins, J. J., 1996, October. *Understanding pesticide persistence and mobility for groundwater and surface water protection.* Oregon State University Extension EM 86561

MacNish, R.D. and R.A. Barker. *Digital model of the gravel aquifer, Walla Walla Basin.* United States Geological Survey, 1976.

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Newcomb, R.C. *Geology and Groundwater Resources of the Walla Walla River Basin.* Water Supply Bulletin #21. Washington Department of Conservation, Division of Water Resources, 1965.

Oregon Water Resources Department. *Umatilla Basin Report.* 1988. *Government Printing Office 774-398/20006 Region NO. 8*

Piper, A.M., T.W. Robinson, and H.E. Thomas. *Groundwater in the Walla Walla Basin, OR-WA-Part I.* Department of the Interior, United States Geological Survey, 1933.

Piper, A.M., T.W. Robinson, and H.E. Thomas. *Groundwater in the Walla Walla Basin, OR-WA-Part II.* Department of the Interior, United States Geological Survey, 1933.v

Richerson, P., Cole, D. 2000, June April 1999 Milton-Freewater Groundwater Quality Study: As part of the Statewide Groundwater Monitoring Program. State of Oregon Department of Environmental Quality

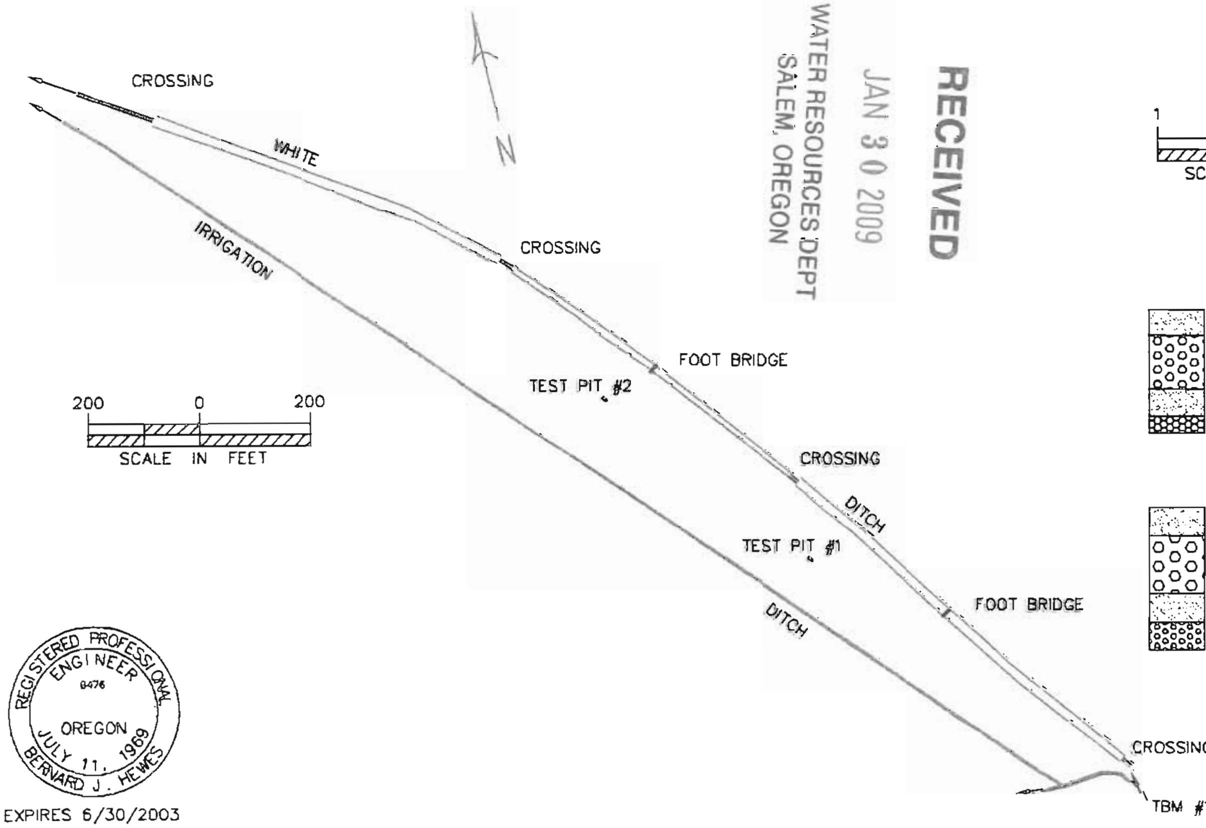
U.S. Department of Agriculture (USDA), Soil Conservation Service. Nov, 1988. *Soil Survey of Umatilla County Area, Oregon.* WWBWC technical library

U.S. Geological Survey 1996, July. Fact Sheet 171-96: <u>Article:</u> *The Nitrate Connection.* US Government Printing Office 774-398/20006 Region NO. 8

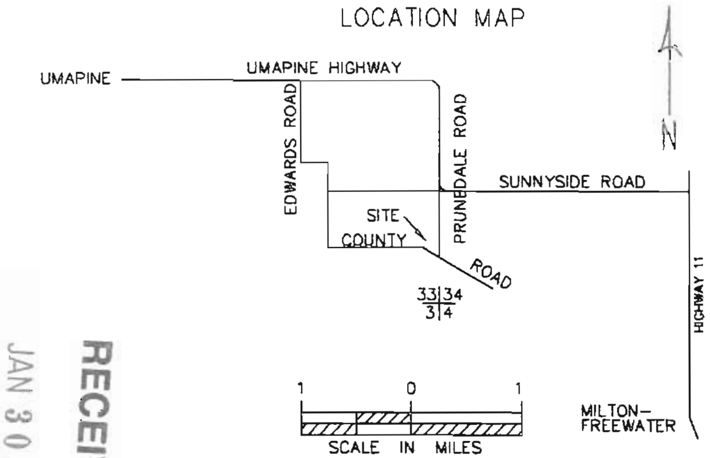
Attachments

Attachment 1A

SITE PLAN VIEW



LOCATION MAP



TOWNSHIP 6N
RANGE 35E

TEST PIT #1

0-12" SANDY LOAM

12"-36" GRAVELLY SANDY LOAM. APPROX. 50 % OF THE VOLUME IS GRAVEL SIZE PARTICLES WITH AN ESTIMATED D_{50} SIZE OF ABOUT 0.75".

36"-48" SANDY LOAM

48"-? GRAVELLY SANDY LOAM APPROX. 20% OF THE VOLUME IS GRAVEL SIZE PARTICLES.

TEST PIT #2

0-13" GRAVELLY SANDY LOAM

13"-39" COBBLY SANDY LOAM. THE D_{50} OF THE GRAVEL IS APPROXIMATELY 1"

39"-52" GRAVELLY SANDY LOAM

52"-? SAND GRAVEL MIX D_{50} ESTIMATED TO BE ABOUT 0.25".

TBM #1 LOCATION IS AT THE TOP OF THE WALL ON THE NORTH WEST CORNER OF A CONCRETE TURNOUT BOX ON THE LEFT SIDE OF WHITE DITCH NEAR THE UPSTREAM END OF A 44"X72" CMP. PAINTED RED SPOT, ELEVATION 100.00.

REGISTERED PROFESSIONAL ENGINEER
8476
OREGON
JULY 11, 1969
BERNARD J. HEWES

EXPIRES 6/30/2003

HUDSON BAY AQUIFER RECHARGE PROJECT
SITE PLAN & LOCATION MAP

DATE
DESIGNED B. HEWES 4/03
PLOTTED
APPROVED

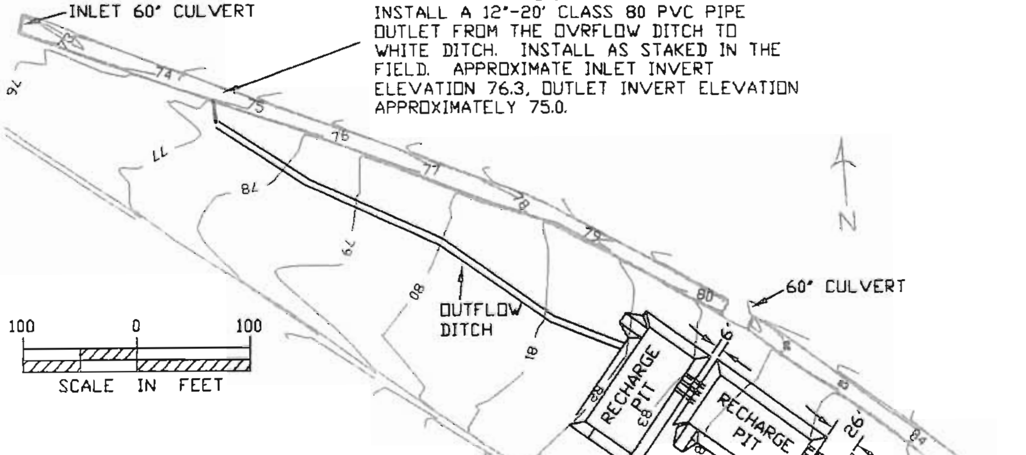
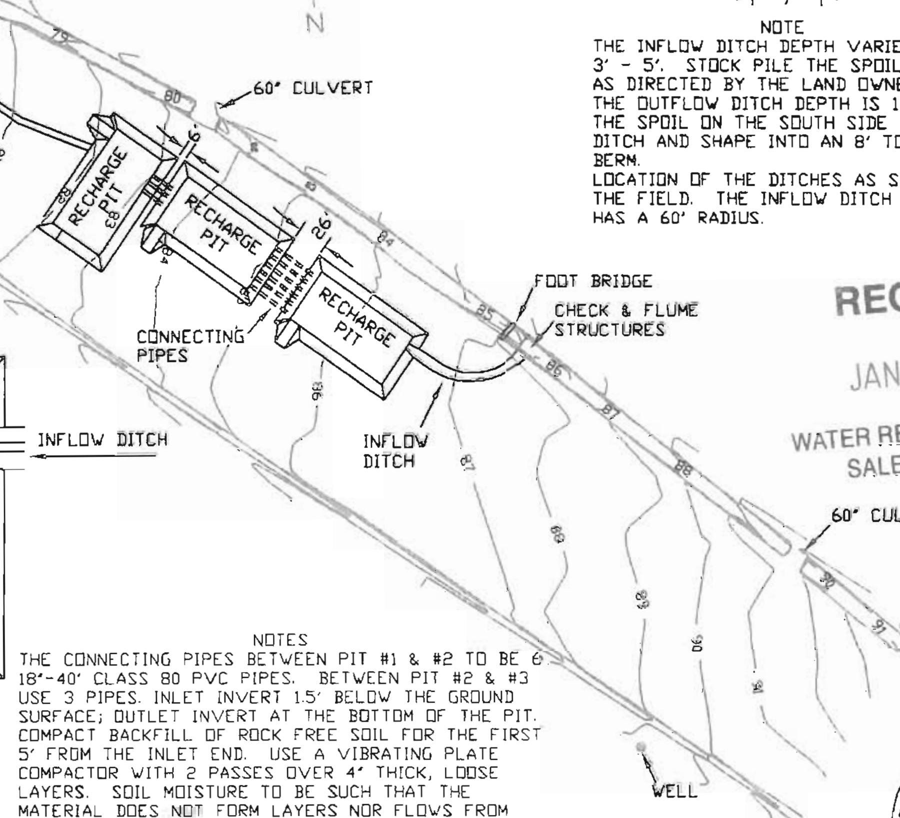
CADFILE whitereloc

SHEET 1 OF 4

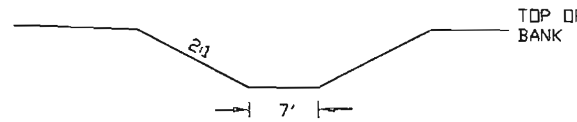
Attachment 1B

HUDSON BAY AQUIFER RECHARGE PROJECT
SITE PLAN

NOTE
INSTALL A 12"-20' CLASS 80 PVC PIPE OUTLET FROM THE OVRFLOW DITCH TO WHITE DITCH. INSTALL AS STAKED IN THE FIELD. APPROXIMATE INLET INVERT ELEVATION 76.3, OUTLET INVERT ELEVATION APPROXIMATELY 75.0.

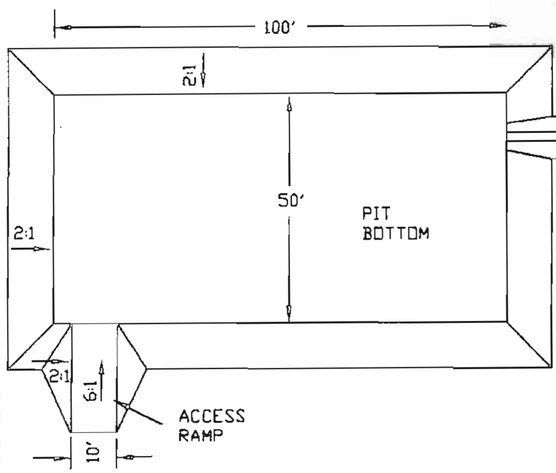



INFLOW & OUTFLOW DITCH DETAILS
NOT TO SCALE



NOTE
THE INFLOW DITCH DEPTH VARIES FROM 3' - 5'. STOCK PILE THE SPOIL MATERIAL AS DIRECTED BY THE LAND OWNER.
THE OUTFLOW DITCH DEPTH IS 1'. PLACE THE SPOIL ON THE SOUTH SIDE OF THE DITCH AND SHAPE INTO AN 8' TOP WIDTH BERM.
LOCATION OF THE DITCHES AS STAKED IN THE FIELD. THE INFLOW DITCH CURVE HAS A 60' RADIUS.

RECHARGE PIT DETAILS
NOT TO SCALE



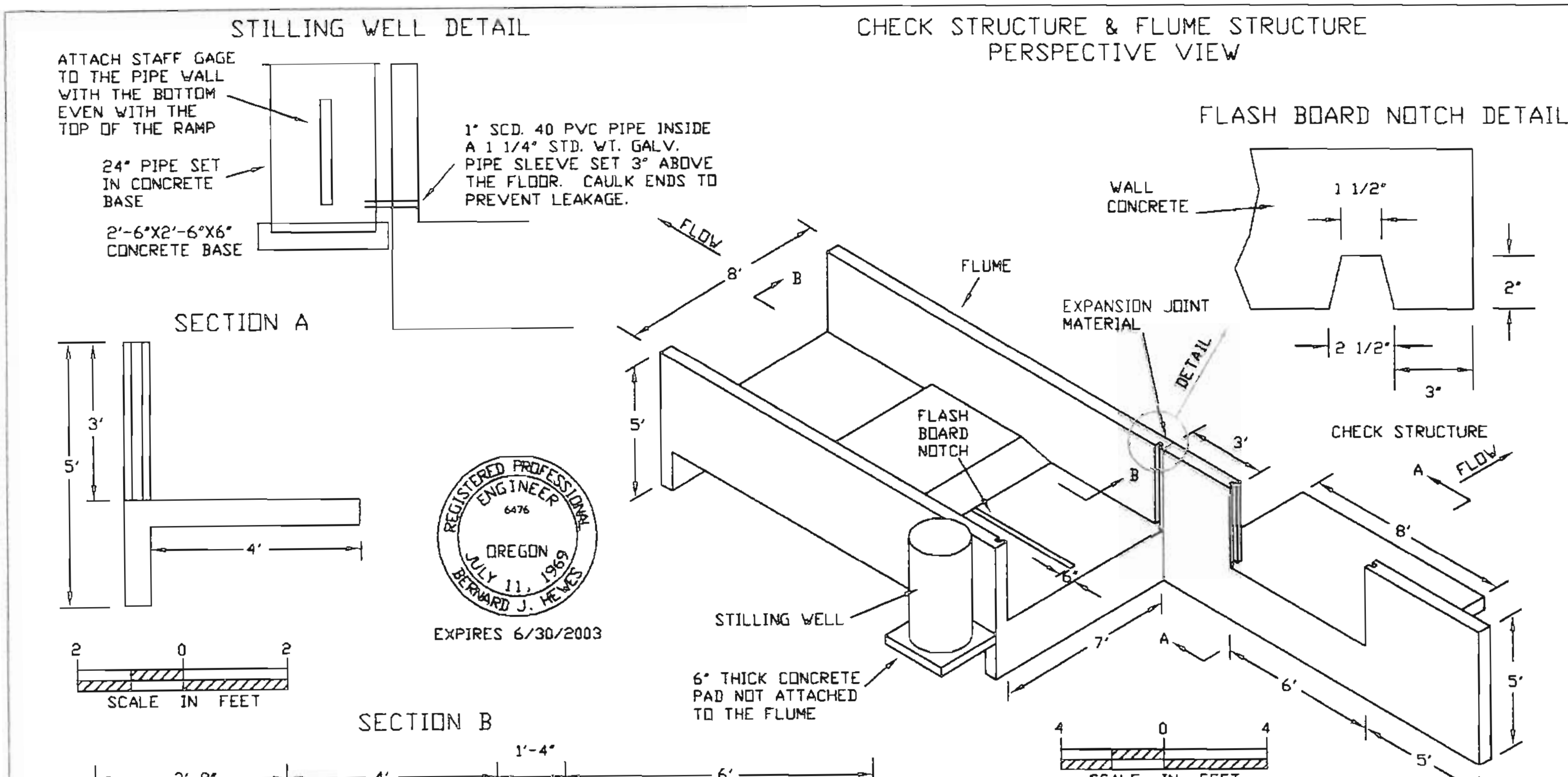
NOTES
PIT DEPTH IS 5' OR AS STAKED IN THE FIELD. THE PIT BOTTOM IS TO BE BELOW THE SECOND SANDY LOAM LAYER SHOWN ON THE TEST PIT PROFILES.
EXCAVATION VOLUME APPROXIMATELY 1250 CUBIC YARDS PER PIT. STOCK PILE THE EXCAVATED MATERIAL AT THE LAND OWNERS DIRECTION.

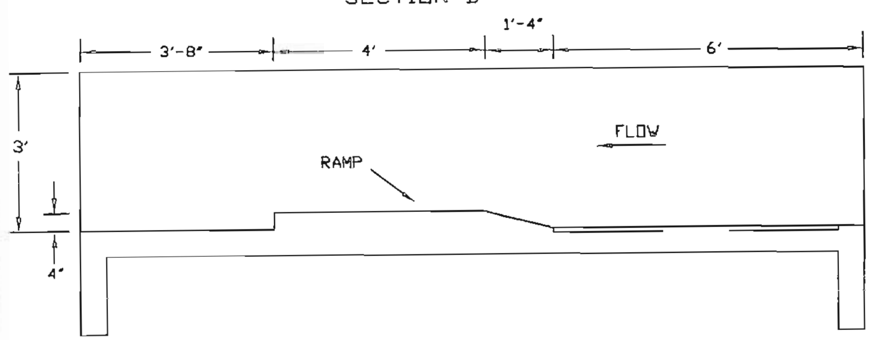
NOTES
THE CONNECTING PIPES BETWEEN PIT #1 & #2 TO BE 6 18"-40' CLASS 80 PVC PIPES. BETWEEN PIT #2 & #3 USE 3 PIPES. INLET INVERT 1.5' BELOW THE GROUND SURFACE; OUTLET INVERT AT THE BOTTOM OF THE PIT. COMPACT BACKFILL OF ROCK FREE SOIL FOR THE FIRST 5' FROM THE INLET END. USE A VIBRATING PLATE COMPACTOR WITH 2 PASSES OVER 4" THICK, LOOSE LAYERS. SOIL MOISTURE TO BE SUCH THAT THE MATERIAL DOES NOT FORM LAYERS NOR FLOWS FROM UNDER THE ACTION OF THE COMPACTOR. BACKFILL FOR THE BALANCE OF THE PIPE TO BE SOIL MATERIAL COMPACTED AS ABOVE OR ROCK SMALLER THAN 1" IN DIAMETER WITH NO COMPACTION NEEDED.
ALLOW NO TRUCK TRAFFIC OVER THE UPSTREAM 10 FEET OF THE PIPES.

REGISTERED PROFESSIONAL ENGINEER 6476
OREGON
JULY 11, 1969
BERNARD J. HEWES
EXPIRES 6/30/2003

DATE 4/03
DESIGNED B. HEWES
PLOTTED
APPROVED

CADFILE whiteplan
SHEET 2 OF 4





NOTES

INSTALL THE CONCRETE IN ACCORDANCE WITH CONSTRUCTION SPECIFICATION 42, ATTACHED.
ALL WALLS AND FLOORS TO BE 6" THICK.
USE 4000 PSI STRENGTH CONCRETE. 1.6 CUBIC YARDS NEEDED FOR THE CHECK STRUCTURE AND 4.9 CUBIC YARDS NEEDED FOR THE FLUME.
SEPARATE THE TWO STRUCTURES USING A 6'X 1/2"X 5' STRIP OF ASPHALT EXPANSION JOINT FILLER.
THE STILLING WELL PIPE MAY BE CORRUGATED METAL OR CLASS 80, MINIMUM, PVC PIPE.
THE FLASH BOARD NOTCH IN THE BOTTOM OF THE FLUME IS TO HOLD THE BOTTOM OF A SPLITTER WALL. USE 2 PIECES OF 3/4" MARINE PLYWOOD. HOLD THE TOP AT THE DOWNSTREAM END WITH A 2"X8"X8' WITH 2-2"X4"X8" CLEATS. AT THE UPSTREAM END USE 2-2"X12"X8' WITH 2-2"X4"X24" CLEATS.

DATE 4/03
DESIGNED B. HEWES
PLOTTED
APPROVED

HUDSON BAY AQUIFER RECHARGE PROJECT
STRUCTURE DETAILS

CADFILE whiteck

SHEET 3 OF 4

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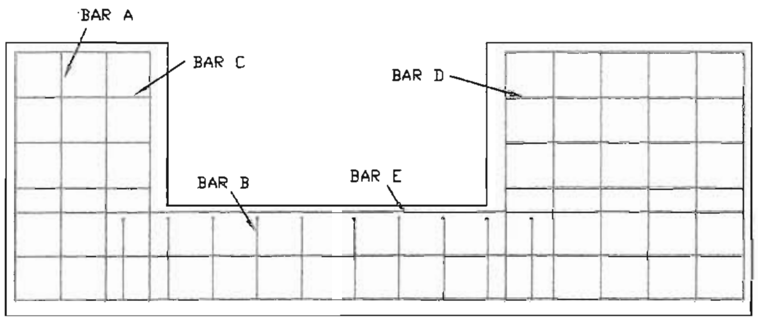
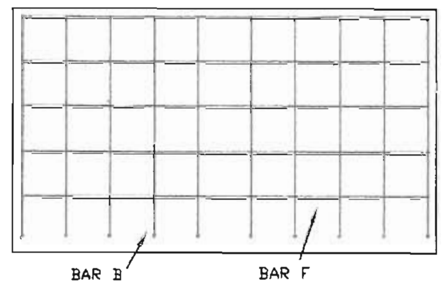
SALEM, OREGON

Attachment 1D

CHECK STRUCTURE ELEVATION VIEW



APRON PLAN VIEW



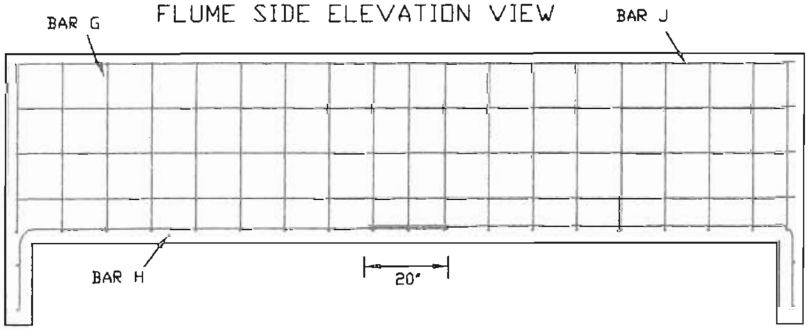
REINFORCING STEEL SCHEDULE

BAR	NO.	SHAPE	A	B	C
CHECK					
A	10	STRAIGHT	4'-7"	-	-
B	10	A⌊B	1'-7"	4'-1"	-
C	4	STRAIGHT	2'-6"	-	-
D	4	STRAIGHT	4'-6"	-	-
E	3	STRAIGHT	13'-8"	-	-
F	5	STRAIGHT	7'-8"	-	-
FLUME					
G	19	A⌊B⌋C	3'-1"	7'-6"	3'-1"
H	20	A⌊B	1'-6"	8'-1"	-
I	4	STRAIGHT	7'-6"	-	-
J	8	STRAIGHT	14'-6"	-	-

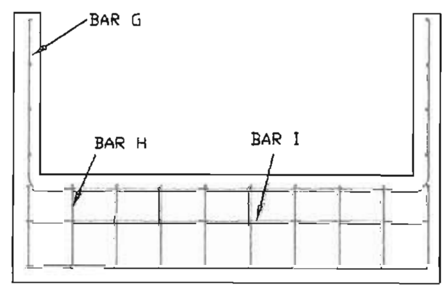
NOTES
ALL BARS TO BE NUMBER 4.
BARS TO BE PLACED IN THE CENTER OF THE WALLS AND FLOOR.
NEED 820 LINEAL FEET OF REINFORCING BARS WITHOUT ANY WASTE.

REGISTERED PROFESSIONAL ENGINEER 6476 OREGON JULY 11, 1969 BERNARD J. HEWES
EXPIRES 6/30/2003

FLUME SIDE ELEVATION VIEW



FLUME END WALL ELEVATION VIEW



DATE 4/03
DESIGNED B. HEWES
PLOTTED
APPROVED

HUDSON BAY AQUIFER RECHARGE PROJECT
STRUCTURE REINFORCING STEEL

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SHEET 4 OF 4

Attachment 1 E

HUDSON BAY AQUIFER RECHARGE PROJECT

ENGINEERING REPORT

This project entails diverting water from an existing irrigation ditch to three pits to be excavated for the purpose of infiltrating the water into the shallow aquifer. Project features include a concrete check structure in the existing White Ditch, a concrete flow measuring flume, an open ditch, three excavated pits, pipes connecting the pits and an outflow ditch from the down stream pit.

These items were sized to handle 50 cubic feet per second (cfs) of water. This is the amount anticipated will be available from excess flow in the Walla Walla River and that the Hudson Bay District is able to deliver.

Data gathered to design the project consisted of a site topographic survey and installing two sites for testing the water infiltration capacity of the natural materials and determining the layers in the soil profile. In addition the Soil Survey of Umatilla County Area, Oregon was consulted. This is a US Dept. of Agriculture, Natural Resources Conservation Service publication giving general soils information.

The topographic survey data was used to prepare a topographic map with one foot contour intervals at a scale of 1" = 60'. This information was used to help determine the location of the project features.

Two test pits were excavated to a depth of 6'-7' each. A 24" diameter by 5' long section of corrugated metal pipe was set on end in the bottom of the pit and about one foot of fill placed around it to hold it in place. Water was pumped into the pipe at a rate that would sustain a water depth of one foot in the pipe. Both flow rate and total flow was measured. The test was run for 6.25 hours in the first pit and 3.5 hours for the second pit.

PIT #1

Soil profile:
0-12" sandy loam
12"-36" gravelly sandy loam, approximately 50% of the material volume is gravel size particles with an estimated D_{50} size of about 0.75"
36"-48" sandy loam, in parts of the trench this layer does not exist
48"-?" gravelly sandy loam approximately 20% of the volume is gravel size particles

The inflow rate at the end of the test period was 4.0 gallons per minute (gpm). This resulted in an infiltration rate of 1.7 gpm/sq. ft./ foot of head.

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PIT #2
Soil profile:
0"-13" gravelly sandy loam
13"-39" cobbly sandy loam, the D_{50} of the gravel is approximately 1"
39"-52" gravelly sandy loam
52"-? sand gravel mix D_{50} estimated to be about 0.25"

In this pit the inflow rate of 11.9 gpm was maintained for 3.5 hours and at no time did water puddle in the bottom of the pipe. The infiltration rate is in excess of 3.8 gpm/sq. ft.

The area needed for infiltrating the water was determined assuming an infiltration rate for the entire area of 3.0 gpm/sq.ft./ per foot of head. For an inflow rate of 50 cfs the infiltration area needs to be 7480 square feet. The infiltration rate of 3.0 gpm/sq.ft. was chosen because the pits will be located in the area with soil surface texture similar to test pit #2.

Due to the possibility of fine soil particles plugging the infiltration area, unknowns concerning the long term infiltration rate and that the amount of water available is not yet known extra infiltration area is being provided. Three separate pits with bottom dimensions of 50 feet X 100 feet are proposed. This will provide an infiltration area of 15,000 square feet.

The pits will be excavated to a depth of about 5 feet to get below the second sandy loam layer noted in both test pits. This will allow the water depth to be 2.5 feet - 3.5 feet. That will increase the rate of infiltration over the test values derived with one foot of water depth. The overall safety factor for the infiltration area is well over 2.

Inflow to the system will be measured with a ramp flume and continuously recorded. The ramp flume is sized to provide 5% flow rate accuracy over a flow range of 10 cfs-50 cfs

Any outflow from the last pit will be safely returned to the White Ditch through a 12-inch pipe. The pipe will be on a slope that will keep water from flowing out of White Ditch.

By: Bernard J. Hewes Date: 8/21/03
Bernard J. Hewes

REGISTERED PROFESSIONAL ENGINEER
6476
OREGON
JULY 11, 1980
BERNARD J. HEWES

Attachment 3A

LAND USE
INFORMATION SHEET

This information is needed to determine if the proposed project complies with statewide planning goals and is compatible with local comprehensive plans (ORS 192.180)

CITY/COUNTY LAND USE INFORMATION (to be completed by local planning official):

Recharge Hudson Bay project

Please check below the one that applies:

☐ This project is not regulated by the local comprehensive plan and zoning ordinance.

☒ This project has been reviewed and is compatible with the local comprehensive zoning ordinance. (Please cite appropriate plan policies, ordinance section, and case numbers.) 152.056

☐ This project has been reviewed and is not compatible with the local comprehensive plan and zoning ordinance. (Cite appropriate plan policies, ordinance section, and case numbers).

☐ Compatibility of this project with the local planning ordinance cannot be determined until the following local approvals are obtained:

_______ Conditional Use Permit _______ Development Permit
_______ Plan Amendment _______ Zone Change
_______ Other

An application has ___ has not ___ been made for the local approvals checked above.

* Signature of Local Official: Patty Perry

Title: Senior Planner Date: 5-27-03

Must be authorized signature from your local City/County Planning Department

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ATTACHMENT 5A: Methodology to Determine Chemical Constituents for Water Quality Assessment and Evaluation

Introduction:

The Artificial Groundwater Recharge rules (OAR 690-350-120) require both up front water quality and a water quality-monitoring plan. Further, for any recharge project the rules (OAR 690-350-120 (3) (b) require an applicant to either obtain a water quality permit (typically a water pollution control facility (WPCF) permit) or show that a permit is not necessary. Also, rules OAR 690-350-120 (3)(g) require a "Project Description Report" (ATTACHMENT 5) that outlines the proposed groundwater quality-monitoring plan. This attachment is intended to specifically help clarify the method by which the list of chemical constituents was determined.

Project Area Sample Chemical Review Methodology

Working with Tom Darnell, OSU Extension agent in Milton-Freewater, a chemical constituents review was conducted in order to determine what types of chemicals should be examined in the surface and groundwater monitoring for the project. Several steps were followed to determine which chemicals were of interest.

Review Steps

1. Reviewed the ODEO Report: *April 1999 Milton-Freewater Groundwater Quality Study: As part of the Statewide Groundwater Monitoring Program* (Richardson, et. al., 2000). Particular attention was focused on the constituents tested, testing protocol and timing, and the results-conclusions.
2. Reviewed *OSU Extension Pesticide Properties Database* and determined which were used in the Milton-Freewater area and a list was comprised. (Table 4A1, 4A2)
3. Determined which were currently and/or historically used in the area utilizing past chemical studies in the basin (see references). This included interviewing the current landowner on the site-specific history of chemical use on that property (see signed written statement below).
4. Determined which chemicals were important to monitor for during the recharge period (winter-spring). Considered each chemical's typical seasonal application period, solubility in water, soil half-life, and soil movement ratings.
5. Considered project design (top soil removed), and finalized list of chemicals of interest.

Final List of Chemicals to Monitor for Recharge Project

Chemicals Currently Used:

Rubigan (Fenarimol)
Ridomil (Metalxyl)
Systhane/Rally (Myclobutanil)
Devrinol (Napropamide)

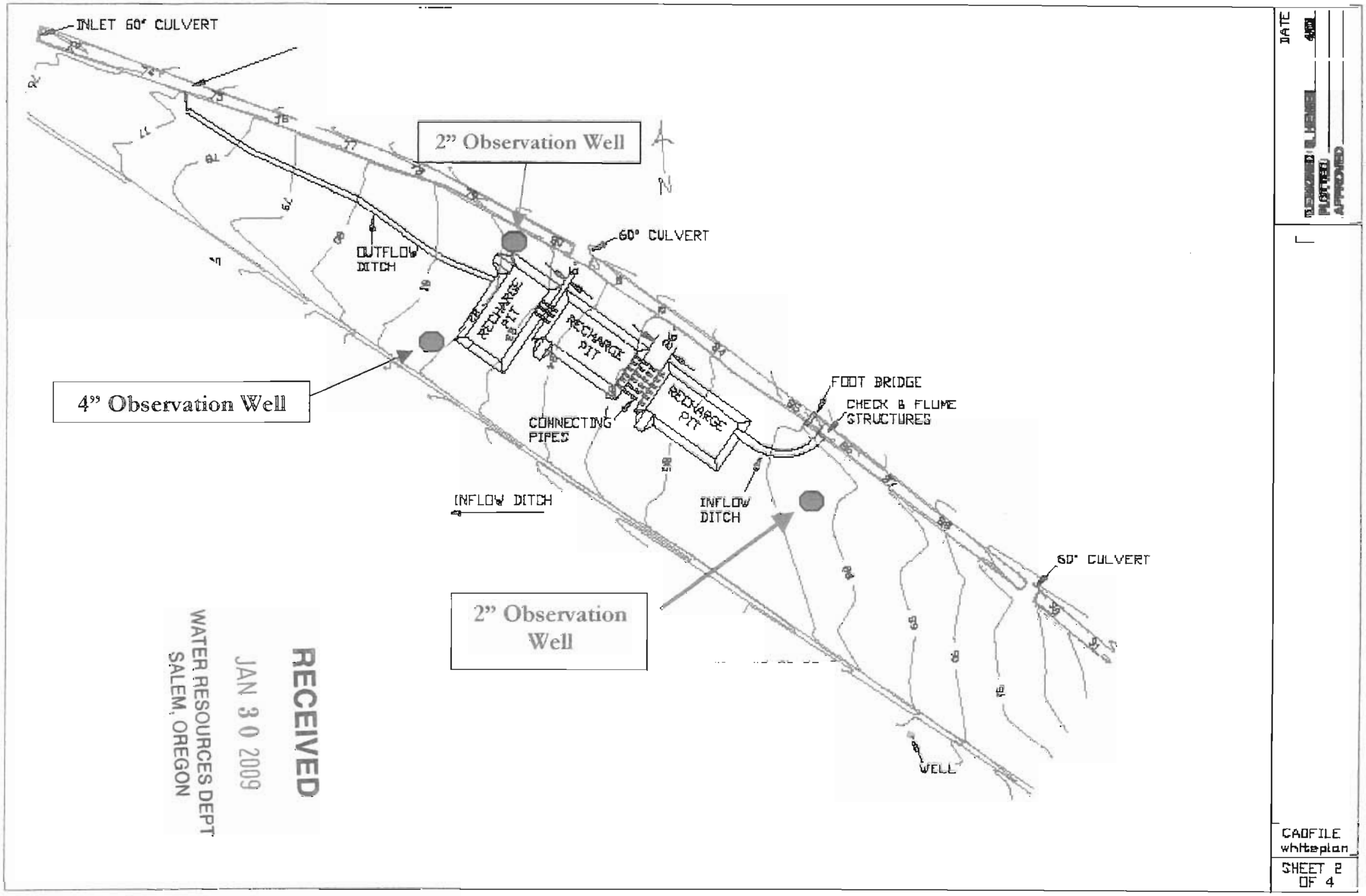
Chemicals Historically Used:

DDD-DDE-DDT
Elgetol (DNOC sodium salt)
Alar/B-Nine (Daminozide)
Lindane (Lindane)

Laboratory Resources

Nitrate Analysis:	Walla Walla County-City Health Department 310 W. Popular, P. O. Box 1753 Walla Walla, WA 99362 Telephone (509) 527-3290
Chemical Analysis:	KUO Testing Labs, INC. 337 south 1st Avenue Othello, WA 99344 Telephone: (509)-488-0118

Attachment 5B Map of On-Site Monitoring Well Locations



Attachment 5D

History of Chemical[1] Use: Recharge Site Specific

Landowner Statement of Past Use:

"Gentleman,

I have been the owner of a certain parcel of land in the valley with an address known as 84140 Prunedale Rd., Milton-Freewater, Oregon, 97862.

I have owned this land since 1978 at which time we took over the existing orchard of apples and farmed it for two years at which time we began removing various blocks of tress and replanting with new varieties. In the past few years we raised Nursery Tree Stock and began leveling the land to its present condition, letting it lay in a dormant stage for a year and then planting cover crops to enrich the soil for a future cherry orchard.

The pesticides applications were the normal tree fruit pesticides as allowed by regulations of the industry. The herbicide applications were Round-Up, Simizine and Paraquat. No other chemicals were used on this parcel of land during my ownership. If you should have other questions, please contact me at the following: (541)-278-6305, (509)-386-6175, or (541)-558-3752 or email at:
Hjohnson@co.umatilla.or.us"

Landowner: [signature] Date: 10-17-03

[1] Chemical is defined here to include insecticides, fertilizers, herbicides, rodenticides, fungicides, and all other non-natural chemicals.

ATTACHMENT 7A: Source Water Quality Data

1STORET RETRIEVAL DATE 99/06/23
402388 28AWALL03780
46 01 08.6 118 24 45.1 4
WALLA WALLA RIVER AT HWY 11 (MILTON-FREEWATER)
41059 OREGON UMATILLA
PACIFIC NORTHWEST 131007
COLUMBIA RIVER BASIN BELOW YAKIMA RIVER
21400000 17070102007 00
0000 FEET DEPTH

Grey areas samples that correspond to Recharge Project

INITIAL DATE	67/04/24	67/08/21	67/12/11	68/04/02	68/08/05	68/12/16	69/03/04	69/12/10	70/04/28
INITIAL TIME	1235	1400	1440	1615	1750	1100	1510	1145	930
MEDIUM	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER
00010 WATER TEMP CENT	8	25.5	7	8.5	25	5	8.6	5	6
00011 WATER TEMP FAHN	46.4$	77.9$	44.6$	47.3$	77.0$	41.0$	47.5$	41.0$	42.8$
00027 COLLECT AGENCY CODE	10	10	10	10	10	10	10	10	10
00070 TURB JKSN JTU	250	2		10	3	8		7	1
00080 COLOR PT-CO UNITS	20	4		3	5	3		1	3
00095 CNDUCTVY AT 25C MICROMHO	67	225	200	72	243	69	95		71
00300 DO MG/L	10.3	12.2	10.6	11.4	10.7	12.2	11.6	11.7	12.7
00301 DO SATUR PERCENT	89	150	89	99	131	95	99	94	105
00310 BOD 5 DAY MG/L	0.7	1.3	0.9	0.5	1.3	1.6	0.8	1.5	1.5
00400 PH SU	7.3	8.3	7.7	7.5	8.40L	7.2	7.6	7.5	7.5
00410 T ALK CACO3 MG/L	30	108		33	105	30		54	31
00500 RESIDUE TOTAL MG/L	518			99	184	101		118	87
00530 RESIDUE TOT NFLT MG/L	368	11		10	10	21		18	12
00610 NH3+NH4- N TOTAL MG/L	0.13	0.34		0.38	0.32	0.17		0.08	0.12
00612 UN-IONZD NH3-N MG/L	.0004$	.036$		.002$	.040$	.0003$		.0003$	.0005$
00619 UN-IONZD NH3-NH3 MG/L	.0005$	.043$		.002$	.049$	.0004$		.0004$	.0006$
00620 NO3-N TOTAL MG/L	0.03	0.02		0.07	0.38	0.54		0.73	0.13
00660 ORTHOPO4 PO4 MG/L	0.06	0.16		0.1	0.18	0.56		0.16	0.03
00760 SWL PBI MG/L	1K	1K	29	1K					
00940 CHLORIDE TOTAL MG/L	2			1	8	2		2	1
00945 SULFATE SO4-TOT MG/L	8	33		4	14	4		6	3
22413 HARDNESS TOTLDISS WTR MG/L	28			37	99	35		49	24
31505 TOT COLI MPN CONF /100ML	620	2400	7000	60	230	2300	620	450K	620
31615 FEC COLI MPNECMED /100ML			230						60
31677 FECSTREP MPNADEVA /100ML								240	

ATTACHMENT 7A: Source Water Quality Data

INITIAL DATE	70/07/13	70/11/30	71/05/11	71/08/16	72/02/28	72/08/30	73/02/12	73/06/13	73/09/24
INITIAL TIME	1400	1645	2000	1620	1610	1130	845	1055	1400
MEDIUM	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER
00010 WATER TEMP CENT	24	5.5	15.5	26	9	20.5	2.5	16.5	16
00011 WATER TEMP FAHN	75.2$	41.9$	59.9$	78.8$	48.2$	68.9$	36.5$	61.7$	60.8$
00027 COLLECT AGENCY CODE	10	10	10	10	10	10	10	10	10
00070 TURB JKSN JTU		5	3	1	28	2	15	3	2
00080 COLOR PT-CO UNITS		0	1	2	10	5	5	5	0
00094 CNDUCTVY FIELD MICROMHO							90		
(SAMPLE CONTINUED FROM PREVIOUS PAGE)									

INITIAL DATE	70/07/13	70/11/30	71/05/11	71/08/16	72/02/28	72/08/30	73/02/12	73/06/13	73/09/24
INITIAL TIME	1400	1645	2000	1620	1610	1130	845	1055	1400
MEDIUM	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER
00095 CNDUCTVY AT 25C MICROMHO	236	66	51	200	67	221	87		
00300 DO MG/L	12.5	11.5	9.5	14.2	11	12.5	12.9	11.7	11.5
00301 DO SATUR PERCENT	151	95	99	172	97	137	97	117.0$	115.0$
00310 BOD 5 DAY MG/L	2	0.7	0.8	2.3	0.7	0.9	1.4		
00400 PH SU	8.6	7.5	7.3	8.9	7.1	8.4	7.3		
00410 T ALK CACO3 MG/L		29	21	96	23	92	29	82	95
00500 RESIDUE TOTAL MG/L		89	75	172	280	170	100	153	164
00530 RESIDUE TOT NFLT MG/L		12	12	4	106	8	32	10	3
00610 NH3+NH4- N TOTAL MG/L		0.34	0.06	0.66	0.09	0.14	0.04	0.1	0.17
00612 UN-IONZD NH3-N MG/L		.001$	.0003$	.215$	.0002$	.013$	.00008$		
00619 UN-IONZD NH3-NH3 MG/L		.002$	.0004$	.261$	.0002$	.016$	.00010$		
00620 NO3-N TOTAL MG/L		0.02	0.1	0.15	0.3	0.51	0.14	0.36	0.39
00625 TOT KJEL N MG/L							0.2		
00650 T PO4 PO4 MG/L							0.3		
00660 ORTHOPO4 PO4 MG/L		0.06	0.09	0.13	0.09	0.04	0.09	0.1	0.14
00930 SODIUM NA,DISS MG/L					2.4		2.8		
00935 PTSSIUM K,DISS MG/L					2		1.5		
00940 CHLORIDE TOTAL MG/L		1	0.7	5	0.8	3	1	6	4
00945 SULFATE SO4-TOT MG/L		3	.1K	11	3	11	2	6	4
22413 HARDNESS TOTLDISS WTR MG/L		26	19	80	22	84	28	71	79
31505 TOT COLI MPN CONF /100ML	230	2400	2400	230	620	620	290		
31615 FEC COLI MPNECMED /100ML	230	45K	45K	45K	45K		60		

ATTACHMENT 7A: Source Water Quality Data

1STORET RETRIEVAL DATE 99/06/23
402389 28AWALL04860
45 54 13.6 118 22 02.9 4
WALLA WALLA RIVER U/S MILTON-FREEWATER
41059 OREGON UMATILLA
PACIFIC NORTHWEST 131007
COLUMBIA RIVER BASIN BELOW YAKIMA RIVER
21400000 17070102011 00
0000 FEET DEPTH

INITIAL DATE	67/04/24	67/08/21	67/12/11	68/04/03	68/08/06	68/12/16	69/03/04	69/12/10
INITIAL TIME	1300	1520	1700	810	905	1030	1540	1055
MEDIUM	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER
00010 WATER TEMP CENT	6	21	5	6.5	16	5	6.4	3
00011 WATER TEMP FAHN	42.8$	69.8$	41.0$	43.7$	60.8$	41.0$	43.5$	37.4$
00027 COLLECT AGENCY CODE	10	10	10	10	10	10	10	10
00070 TURB JKSN JTU	5	7	15	2	5	9	12	2
00080 COLOR PT-CO UNITS	6	2	4	4	4	3	2	0
00095 CNDUCTVY AT 25C MICROMHO	59	180	69	57	93	57	63	
00300 DO MG/L	11.2	8.7	11.9	11.6	9.7	11.1	11.6	12.9
00301 DO SATUR PERCENT	94	101	98	98	102	87	99	100
00310 BOD 5 DAY MG/L	0.6	0.8	1.1	0.6	0.4	0.2	0.7	1.2
00400 PH SU	7.4	7.5	7.5	7.3	7.3	7	7.5	7.7
00410 T ALK CACO3 MG/L	26	32	32	26	40	16	27	33
00500 RESIDUE TOTAL MG/L	89	101	83	113	98	92	81	67
00530 RESIDUE TOT NFLT MG/L	2	8	6	7	22	26	7	6
00610 NH3+NH4- N TOTAL MG/L	0.14	0.17	0.32	0.12	0.18	0.11	0.06	0.03
00612 UN-IONZD NH3-N MG/L	.0005$	.002$	.001$	.0003$	.001$	.0001$	.0003$	.0002$
00619 UN-IONZD NH3-NH3 MG/L	.0006$	.003$	.002$	.0004$	.001$	.0002$	.0003$	.0002$
00620 NO3-N TOTAL MG/L	0.01	0.02	0.02	0.03	0.04	0.39	0.3	0.12
00660 ORTHOPO4 PO4 MG/L	0.02	0.1	0.1	0.07	.01K	0.01	0.11	0.1
00760 SWL PBI MG/L	8	1K	1					
00940 CHLORIDE TOTAL MG/L	1	5	1	1	6	2	2	0.8
00945 SULFATE SO4-TOT MG/L	3	0.6	4	2	15	3	1	3
22413 HARDNESS TOTLDISS WTR MG/L	23	36	29	24	32	25	26	31
31505 TOT COLI MPN CONF /100ML	230	620	210	230	620	210	60	60
31615 FEC COLI MPNECMED /100ML			210					
31677 FECSTREP MPNADEVA /100ML								5K

ATTACHMENT 7A: Source Water Quality Data

INITIAL DATE	74/05/06	74/07/30	74/11/11	75/05/27	75/07/08	75/11/10
INITIAL TIME	1420	1745	1630	1930	1745	1745
MEDIUM	WATER	WATER	WATER	WATER	WATER	WATER
00010 WATER TEMP CENT	10.5	20.5		10.5	27	4.7
00011 WATER TEMP FAHN	50.9$	68.9$		50.9$	80.6$	40.5$
00027 COLLECT AGENCY CODE	10	10	10	10	10	10
00070 TURB JKSN JTU	7	2	1	1	2	1.0K
00080 COLOR PT-CO UNITS	5	5	1K	5	15	1K
00094 CNDUCTVY FIELD MICROMHO	49	80		55	170	80
00095 CNDUCTVY AT 25C MICROMHO	53	90		54	195	72
00300 DO MG/L	10.8	9		10.8	8.7	11.9
00301 DO SATUR PERCENT	101	103		102	106	95
00310 BOD 5 DAY MG/L	1	0.3		0.6	3	0.4
00400 PH SU	7.5	8		7.3	8	7.7
00410 T ALK CACO3 MG/L	17	34	33	20	65	34

INITIAL DATE	74/05/06	74/07/30	74/11/11	75/05/27	75/07/08	75/11/10
INITIAL TIME	1420	1745	1630	1930	1745	1745
MEDIUM	WATER	WATER	WATER	WATER	WATER	WATER
00500 RESIDUE TOTAL MG/L	62	76	68	64	180	87
00530 RESIDUE TOT NFLT MG/L	39	4	1K	5	38	3
00610 NH3+NH4- N TOTAL MG/L	0.03	0.02	0.06	0.01	0.19	0.02
00612 UN-IONZD NH3-N MG/L	.0002$	.0008$		.00004$	.012$	.0001$
00619 UN-IONZD NH3-NH3 MG/L	.0002$	.0010$		.00005$	.014$	.0001$
00620 NO3-N TOTAL MG/L	0.01	0.05	0.06	0.1	0.72	0.12
00650 T PO4 PO4 MG/L	0.2	0.2		0.3	0.5	0.1
00660 ORTHOPO4 PO4 MG/L	0.01	0.14	0.08	0.09	0.08	0.11
00930 SODIUM NA,DISS MG/L	2.1	3		2.4	8.4	3
00935 PTSSIUM K,DISS MG/L	1.6	2.4		1.3	3.5	2
00940 CHLORIDE TOTAL MG/L	0.4	0.9	1	1	6	1
00945 SULFATE SO4-TOT MG/L	2	1	2	2	8	2
22413 HARDNESS TOTLDISS WTR MG/L	14	27	27	19	60	27
31505 TOT COLI MPN CONF /100ML	60	7000L		230	7000	2400
31615 FEC COLI MPNECMED /100ML	45K	620		45	7000	230

Attachment 3B

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LAND LEASE

1. PARTIES

The parties to this Lease are HULETTE M. JOHNSON, SHIRLEY A. JOHNSON, and H. MARC JOHNSON, hereinafter referred to as Landlord, and HUDSON BAY DISTRICT IMPROVEMENT COMPANY, and Oregon Non-profit Improvement District, hereinafter referred to as Tenant.

2. DATE

This Lease will begin the first of the following month, after the Tenant has obtained a water right certificate for the purpose of ground water recharge for this site from the State of Oregon.

3. DESCRIPTION OF LEASED PREMISES

Landlord leases to Tenant and Tenant leases from Landlord, under the terms and conditions stated herein, the real property in Umatilla County, State of Oregon, described in Exhibit "A" attached hereto and by such reference incorporated herein.

4. TERM OF LEASE

The term of this Lease will be from the date of this lease for a period of five(5) years. Tenant shall have the option to renew this lease with notice to Landlord of not less than 90 days prior to the end of the initial term and any renewal terms for future additional five year terms upon the mutual agreement of renegotiated rental terms for each renewal period.

5. POSSESSION

The Tenant shall be granted possession of the property upon execution of this document by all parties, together with the receipt of the initial lease payment as prescribed in RENT.

6. RENT

Tenant shall pay advance annual rent payments in the amount of three thousand six hundred dollars($3,600) plus annual assessment for irrigation water for surface water rights delivered by Tenant to 84140 Prunedale Road, beginning with INV # 1276C for 2003. Landlord shall pay same assessment to Tenant upon receipt of said annual assessment payment from Tenant. Tenant shall make each annual payment for the term of this lease to Landlords address, 52833 Sunquist Road, Milton-Freewater, Oregon, 97862, or otherwise as notified. The initial payment shall be due on the date this agreement is executed by Tenant and Landlord, and Tenant it therefore granted possession to said real property.

7. INSURANCE

Tenant shall maintain liability insurance on the leased property in an amount acceptable to the Landlord and shall provide proof of such insurance naming Landlords as additional insureds. Tenant shall also be responsible for necessary insurance on laborers. Tenant shall also be responsible for insurance coverage on personal property kept or installed upon this leased premises.

8. USE OF PREMISES

Tenant agrees that they will use the property for ground water recharge/storage, ponding.

9. LANDLORDS OBLIGATIONS

Landlord shall install electricity, pump, collection pond and mainline with the assistance of Tenant necessary to connect the source of irrigation water provided by Tenant to the existing delivery systems of Landlord's.

If there is a mortgage or other encumbrance on said premises, Landlord covenants to keep same in good standing, at all times, to make payments when due and not to suffer or permit default in said encumbrance.

Landlord shall pay all property taxes upon the real property subject to this lease in a timely manner.

10. TENANT'S OBLIGATIONS

Tenant shall provide all labor and materials for the construction of the ground water recharge pond, Landlord's irrigation collection pond and pumping station or other improvements required by Tenant, including maintenance of bridges and culverts.

Tenant shall pay all taxes of any kind and necessary insurance for labor to maintain to maintain improvements including any increase in property taxes as a result of said improvements as made by Tenant.

Tenant shall pay for all maintenance and operation of improvements constructed on said premises.

Tenant agrees that earth material excavated from the recharge pond shall be placed along the edges of the recharge area to produce a basin-like pond. Excess material shall be placed in other areas of Landlords property as directed by Landlord and spread evenly where located so that agricultural activities may continue.

Tenant upon termination of lease, shall replace all soil to a level topography using stored material from the sides of said 'recharge' pond, together with other off site soil as approved by Landlord, necessary to return the recharge pond to a level premise ~~for agricultural growing activities.~~

Tenant shall pay for all costs incurred for control of noxious weeds and vegetation around perimeter of ponding areas, and shall spray the perimeter of said pond including the banks of the Hudson Bay Canal and the Pleasantview Canal including bridges and culverts to maintain a clean ground cover as directed by Landlord

Tenant shall provide signage for trespass prevention and notice of man-made hazard upon premises at the commencement of work efforts at the recharge area.

Tenant shall install any and all fences and gates necessary as may be required by an insurance company or others around the recharge pond.

11. LIENS

Tenant shall pay, as due, all claims for work done on and for services rendered or materials furnished to the leased premises incurred and owing by Tenant and shall keep the premises free of any liens resulting from acts of the Tenant.

12. COVENANTS OF TITLE

Landlord covenants that he is the owner of the above described property free of any encumbrance that would impair or interfere with Tenant's rights under this Lease, and that Landlord has full right and authority to lease the premises described herein.

13. WASTE

Tenant shall not commit or permit to be committed any waste, strip, damage to or misuse of the premises.

14. INDEMNIFICATION

Tenant shall indemnify, hold harmless and defend Landlords from all claims, loss or liability arising out of or related to any activity of Tenant on the leased premises or any condition of the leased premises in the possession or under the control of the Tenant.

15. ASSIGNMENT

No part of the leased property may be assigned, mortgaged, or subleased, nor may a right of use of any portion of the property be conferred on any third person by any other means without the prior written consent of Landlord. This provision shall apply to all transfers to and by trustees in bankruptcy, receivers, administrators, executors, and legatees. No consent in one instance shall prevent the provision from applying to a subsequent instance.

16. DEFAULT

The following shall be events of default:

Failure to pay rent when due.

Failure of either Landlord or Tenant to comply with any other term or condition or fulfill any other obligation of this Lease within twenty(20) days after written notice by Landlord or Tenant specifying the nature of the default with reasonable particularity.

Abandonment by the Tenant of the property

If the default is of such a nature that it cannot be completely remedied within the twenty-day period and the defaulting party thereafter proceeds with reasonable diligence and in good faith to effect the remedy as soon as practicable, default shall not be declared unless the defaulting party ceases to effect the remedy.

17. TAXES

The Landlord shall pay all real property taxes for real property for the term of this Lease. Tenant shall be liable to pay any taxes, personal or real, incurred as a result of improvements placed upon the leased premises.

18. NONWAIVER

Waiver by either party of strict performance of any provision of this Lease shall not be a waiver of or prejudice the party's right to require strict performance of the same provision in the future or of any other provision of this Lease.

19. ATTORNEY FEES

If suit or action is instituted in connection with any controversy arising out of the Lease, the prevailing party shall be entitled to recover, in addition to costs, such sums as the Court may adjudge reasonable as attorney fees.

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20. SUCCESSION

Subject to the above-stated limitations on transfer of Tenant's interest, this Lease shall be binding upon and inure to the benefit of the parties, their respective successors and assigns.

21. INSPECTION OF PREMISES

The Landlord reserves the right to themselves and their agents to go upon the premises at reasonable and proper times to inspect the same for the purpose of determining that the Lease is being properly observed and that all of the terms of this lease are being performed by the Tenant.

22. IMPROVEMENTS

Any improvements to the real property by Tenant shall remain the property of the Landlord upon termination of this Lease, unless the Tenant obtains the written consent of Landlord to remove said improvements prior to the time the improvements are placed on the property. However, Tenant shall be responsible for refilling the recharge "pond" as set forth in paragraph 10 above.

23. TERMINATION

The Tenant agrees to deliver the property to the Landlord at the end of the term of this Lease and in as good a condition as when accepted, and pursuant to paragraph 10 above.

24. TIME IS OF THE ESSENCE

The parties acknowledge and agree that time is of the essence with respect to all of the terms, conditions, and provisions of this Lease.

25. NOTICES

Any notice required or permitted under this Lease shall be given when actually delivered or when deposited in the United States Mail as certified mail, addressed as follows:

LANDLORD: HULETTE M. JOHNSON, et., al.
52833 Sunquist Road
Milton-Freewater, Oregon 97862

TENANT: HUDSON BAY DISTRICT IMPROVEMENT COMPANY
P.O. Box 110
Milton-Freewater, Oregon 97862

26. WATER DUES

The annual irrigation water dues as billed to Landlord by Tenant shall be paid by Landlord to Tenant as billed. As part of the rent agreement in paragraph 6 above, Tenant shall pay Landlord an equal amount of said water dues within thirty(30) days of receipt of said water dues from Landlord, during the term of this Lease and any renewals thereof.

27. CAPTIONS AND HEADINGS

The captions and headings throughout this Lease are for convenience and reference only and the words contained therein shall in no way be held or deemed to define, limit, describe, explain or modify the meaning of any provisions of or the scope or intent of this Lease.

28. ENTIRE AGREEMENT

This document is the entire, final, and complete agreement of the parties pertaining to the Lease of the premises described herein, and supersedes and replaces all written and oral agreements theretofore made or existing by and between the parties or their representatives in so far as the premises are concerned.

IN WITNESS WHEREOF, the parties have executed this Lease on the 15th day of October, 2003.

LANDLORD:

HULETTE M. JOHNSON,

SHIRLEY M. JOHNSON

H. MARC JOHNSON

TENANT:

HUDSON BAY IMPROVEMENT CO.

BY:
it's Secretary/Treasurer

STATE OF OREGON)
)ss.
County of Umatilla)

On this 15th day of Oct 2003 personally appeared before me the above named HULETTE M. JOHNSON, SHIRLEY M. JOHNSON, and H. MARC JOHNSON and acknowledged the foregoing to be a voluntary act and deed.

OFFICIAL SEAL
KATHLEEN F. YENNEY
NOTARY PUBLIC-OREGON
COMMISSION NO. 337142
MY COMMISSION EXPIRES SEPT. 24, 2004

NOTARY PUBLIC FOR OREGON

My commission expires: 9-24-2004

STATE OF OREGON)
)ss.
County of Umatilla)

On this 15th day of Oct 2003, personally appeared before me the above named John C. Zerba, in his capacity as Secretary/Treasurer of HUDSON BAY IMPROVEMENT CO. and acknowledged the foregoing to be a voluntary act.

NOTARY PUBLIC FOR OREGON
My Commission expires: 9-24-2004

OFFICIAL SEAL
KATHLEEN F. YENNEY
NOTARY PUBLIC-OREGON
COMMISSION NO. 337142
MY COMMISSION EXPIRES SEPT. 24, 2004

STATE OF OREGON)
)ss
County of Umatilla)

OFFICIAL SEAL
JACQUELINE A. BUTTS
NOTARY PUBLIC-OREGON
COMMISSION NO. 368700
MY COMMISSION EXPIRES MAY 15, 2007

On this 22 day of october 2003, personally appeared before me the above named H. Marc Johnson, and acknowledged the foregoing to be a voluntary act and deed.

Jacqueline A Butts
NOTARY PUBLIC FOR OREGON

My commission expires may 15, 2007.

R 42 PAGE 1265 Exhibit "A"

TRACT I:

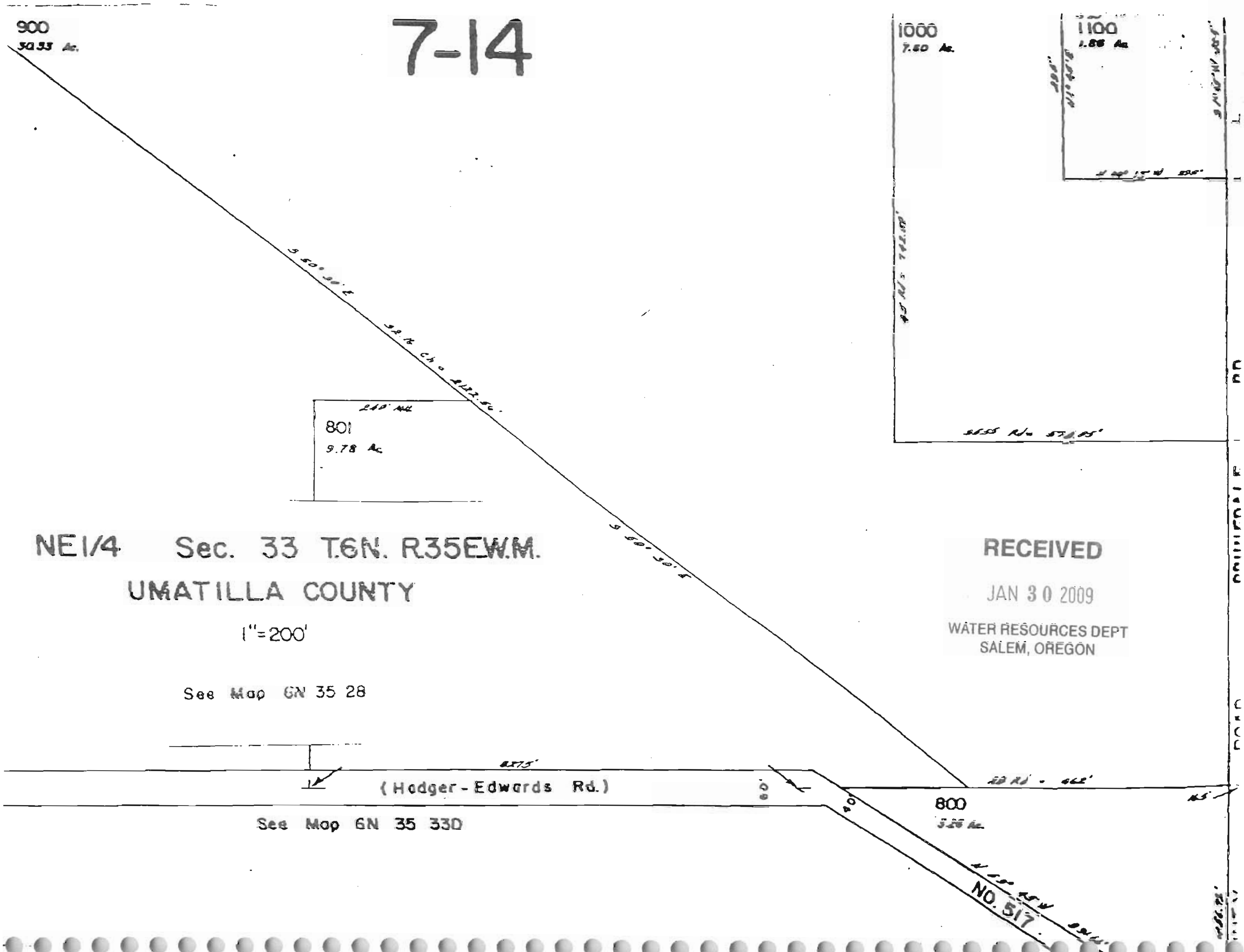
Township 6 North, Range 35, East of the Willamette Meridian:
Section 33: A tract of land located in the South Half of the Northeast Quarter, and being a portion of that tract of land conveyed to William J. Jackson, by Deed recorded in Book 369, Page 267, Deed Records, and being described as follows, to-wit:

Commencing at the quarter section corner on the line between Sections 33 & 34; running thence North 20 chains: thence West 33-16/100 chains; thence Southeasterly 32-16/100 chains, more or less, to a point on the center line; running East and West through said Section 33, said point being 7 chains West of the point of beginning; thence East 7 chains to the point of beginning. Excepting Therefrom, beginning at the Northeast corner of the Southeast Quarter of the Northeast Quarter of said Section 33: and running thence South 45 rods: then West 35-5/9 rods; thence North 45 rods; thence East 33-5/9 rods to the place of beginning. All being East of the Willamette Meridian, Umatilla County, Oregon. Subject to any and all water rights of way and roads.

TRACT III:

Beginning at the Northeast corner of the Southeast Quarter of the Northeast Quarter of Section 33, Township 6 North, Range 35; running thence South 45 rods; thence West 35 and 5/9 rods; thence North 45 rods; thence East 35 and 5/9 rods to the place of beginning. Excepting therefrom that tract of land conveyed to the State of Oregon, by and through its State Highway Commission by deed recorded in Book 130, Page 573 of the Deed Records of Umatilla County, Oregon. Also, excepting any portion of said premises lying within that strip of land conveyed to Walla Walla and Columbia River Railroad Company, by deed recorded in Book "D", Page 834 of the said Deed Records. All being East of the Willamette Meridian, in the County of Umatilla and State of Oregon;

Excepting any and all water rights of way.


7-14
900
30.33 Ac.
1000
7.50 Ac.
1100
1.86 Ac.
801
9.78 Ac.
NE1/4 Sec. 33 T.6N. R.35E.W.M.
UMATILLA COUNTY
1"=200'
See Map 6N 35 28
(Hodger-Edwards Rd.)
See Map 6N 35 33D
800
NO. 517
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License No. ________

STATE OF OREGON

WATER RESOURCES DEPARTMENT

APPLICATION FOR LIMITED WATER USE LICENSE

Applicant(s): Hudson Bay District Irrigation Company

Contact Person: Jon Brough / John Zerba

Mailing Address: P.O. Box 110

Telephone No: 541 938-6105

I (We) make application for a Limited License to use or store the following described surface waters or groundwater-not otherwise exempt, or to use stored water of the State of Oregon for a use of a short-term or fixed duration:

1. **SOURCE(S) OF WATER for the proposed use:** Walla Walla River **a tributary of** Colombia River.

2. **TOTAL AMOUNT OF WATER to be diverted:** 50 **cubic feet per second, or** 50 **gallons per minute. If water is to be used from more than one source, give the quantity from each:** ________.

3. **INTENDED USE(S) OF WATER: (check all that apply)**
   - [ ] **Road construction or maintenance;**
   - [ ] **General construction;**
   - [ ] **Forestland and rangeland management; or**
   - [x] **Other:** Artificial Ground water Recharge

4. **DESCRIPTION OF PROPOSED PROJECT: Include a description of the intended place of use as shown on the accompanying site map, the method of water diversion, the type of equipment to be used (including pump horsepower, if applicable), length and dimensions of supply ditches and pipelines:** See attached application document

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5. **PROJECT SCHEDULE:** (List day, month, and year)
Date water use will begin 11-04
Date project will be completed 11-09
Date need for water will be completed 11-09

NOTE: A completed water availability statement from the local watermaster, fees and a site map meeting the requirements of OAR 690-340-030 must accompany this request. The fee for this request is $100 for the first point of diversion plus $10 for each additional point of diversion. The license, if granted, will not be issued or replaced by a new license for a period of more than five consecutive years. The right granted will be subordinate to all other authorized uses that rely upon the same source, or water affected by the source, and may be revoked at any time it is determined the use causes injury to any other water right or minimum perennial streamflow.

REMARKS:
____
____

SIGNATURE of Applicant: [signature] **DATE:** 10-23-08
Title: Sec-Pres

I certify that I have examined the foregoing application and accompanying data, and hereby grant a Limited License to use said water as described in the application, subject to all water rights of record, and subject to any valid public interest concerns which may become evident.

This license shall be in effect beginning ______________, 20___, and shall expire ______________, 20___.

WITNESS my hand this ____________________, 20___.

____
Paul R. Cleary
Water Resources Department
Director

The licensee shall give notice to the Department (Watermaster) at least 15 days in advance of using the water under the Limited License and shall maintain a record of use. The record of use shall include, but need not be limited to, an estimate of the amount of water used, the period of use and the categories of beneficial use to which the water is applied. During the period of the Limited License, the record of use shall be available for review by the Department upon request.

The application was first received at the Water Resources Department at Salem, Oregon, on the _________ day of ______________, 20___, at ________ o'clock, ___M.

2/5/04

To: Department of Environmental Quality
Eastern Region Pendleton Office
700 SE Emigrant, Suite 330
Pendleton, OR 97801

ATTENTION: Phil Richardson, (OWRD File # LL-758)

From: Hudson Bay District Irrigation Company (HBDIC)
P.O. Box 110
Milton-Freewater, Oregon 97862

RE: Request for additional information; Artifical Ground Water Recharge Testing Project (OWRD File # LL-758)

To Whom It May Concern:

The purpose of this letter is to provide the additional information requested by ODEQ for the Artifical Ground Water Testing Project (Attachment 5A: Methodology to Determine Chemical Constituents For Water Quality Assessment and Evaluation and Attachment 5C: Chemicals of Interest for Hudson Bay Recharge Project). The following addresses each of the items requested in the 2/3/4 letter.

- Simazine has been included in Attachment 5C (see attached) along with the chemical properties needed to screen the chemical. If deemed appropriate, the chemical could be added to the final screening list. Also, ODEQ had sampled for this analyte during the 1999 study, and was found not to be a risk. (ODEQ, 1999).
- We concur that the four sampling events (once before, once shortly after, once during and once shortly before the end of the project) would be a more comprehensive way to screen for chemicals during the project. The final chemical list and their cost to process may pose some limitations as to the amount of samples we can collect. After we receive the final list, we can assess costs and notify ODEQ as to our financial constraints of adding a fourth sample.
- Nitrate has been used as a surrogate for solubility in other pesticides studies. However, we concur that unless it was possible to also know how it was applied and which chemicals most resembled its physical properties, that it may have less application for this project. We will still intend however to collect nitrate samples during recharge event(s) as a parameter of general water quality concern.

The additional information requested on the physical properties of the chemicals of concern is provided below.

Objective: In order to assess the **parameters of use** for each of the chemicals of concern (yellowed in Attachment 5C) in the project area. An assessment was conducted to better quantify the definition of "project area" and the types of crops/chemicals used over that area. The additional information requested on the chemicals of interest were:

- Application Method (see below)
- Time of year chemical applied (see below)
- Volume of chemical used per acre (see below)
- Concentration of chemical in application (see below)
- Percentage of project area receiving chemical (see below)
- Recharge site irrigation method (see below)
- Onsite use or offsite use (see below)
- Current or historic use (see Attachment 5C)

Collaborators: Bob Bower (Hydrologist/Artifical Recharge Testing Project Manager), WWBWC and Tom Darnell (Oregon State University Extension Agent).

Project Area: The project area was quantitatively defined to include the recharge testing site and the areas along that the ditch providing the surface recharge water. Total ditch length and land use was determined using a combination of recent aerial photographs (map wheel) and GIS mapping software. In order to calculate total project area, a 20-yard streamside buffer[1] was applied to both sides of the ditch for total area calculations.

- Total Length of Recharge Project area: 3.7 Miles
    - 2 miles in ag area (54% of total length)
    - 1.7 miles (46%) in Milton-Freewater city limits (no buffer value available).
- Total Ag chemical interest area: 14.6 acres
    - Apples: 5 acres
    - Cherries: 1.8 acres
    - Pasture/open ground: 7.7 acres (no chemicals of interest used)
    - Grapes: < 0.1 acre (minute use of chemicals of interest)
- Total of Project area with *potential* to receive chemicals: 47.3 % (city not included).

Specific area and use information:

APPLE ACRES

PRODUCT	SEASON	RATE/ACRE (MATERIAL)	%ACTIVE INGREDENT	AI/ACRE	TOTAL AMOUNT[2] 5 ACRES
Amid-Thin	May	.25 lb	8.4	.021 lb	.105 lb
Rally	April-May	5.0 oz	40.0	2.0 oz	10.0 oz
Rubigan	April-May	12.0 oz	12.0	1.44 oz	7.2 oz
Ridomil[3]	Oct	1.5 fl oz/1000sqft	49.0	32.0 oz	32.0 oz
Procure	April-May	12.0 oz	50.0	6.0 oz	30.0 oz
Intrepid	May	16.0 fl oz	22.6	3.6 oz	18.0 oz
Success	April	8.0 fl oz	22.8	1.8 oz	9.0 oz
Bayleton	April-May	6.0 oz	50.0	3.0 oz	15.0 oz
Provado	May	8.0 oz	17.4	1.4 oz	7.0 oz
Elgetol[4]	April	1.0 gal	N/A	N/A	N/A

[1] A recent United States District Court decision (Case No. CO1-0132C) stated: "The Court further finds that 20-yard buffer zones for ground use... will substantially contribute to the prevention of jeopardy." (http://agr.wa.gov/PestFert/EnvResources/docs/FinalOrder01-22-04.pdf)

[2] Total amount on five acres is the probable maximum amount of material (active ingredient). Actual use depends on variety, weather conditions and disease pressure. Rally, Rubigan. Procure and Bayleton are fungicides used to control apple scab and/or mildew. Apple orchards do not receive an application of each fungicide each season. The fungicides and insecticides are applied by air blast sprayer.

[3] Ridomil is soil applied, either by hand gun or herbicide sprayer, at the base of the tree. Total amount used is figured on 20 percent of the soil surface treated.

[4] Elgetol use was discontinued in 1986.

CHERRY ACRES

PRODUCT	SEASON	RATE/ACRE (MATERIAL)	%ACTIVE INGREDENT	AI/ACRE	TOTAL AMOUNT[5] 1.8 ACRES
Success	March-April	7.0 fl oz	22.8	1.6 fl oz	2.88 fl oz
Rally	March-April	5.0 oz	40.0	2.0 oz	3.6 oz
Rubigan	March-April	9.0 oz	12.0	1.08 oz	1.9 oz
Procure	March-April	13.0 oz	50.0	6.5 oz	11.7 oz

OTHER PROJECT AREA ACRES

The other project areas were estimated not to have any of the chemicals of interested (yellowed, Attachment 5C). The portion of the ditch passing through the city of Milton-Freewater was not considered for the agricultural chemicals of interest. This portion of the ditch would predominantly be surrounded by lawns and gardens. The types of chemicals used in these areas would include three from our original list: Dacamine (2,4 D), Round Up and Diazinon. These chemicals not typically applied during the recharge project time period and were thus determined to pose little risk. No chemicals were estimated to be used on the pasture/open acreage areas.

Project site irrigation method: Landowner has informed us that sprinkler irrigation has been used at the recharge site.

Project area irrigation method: All of the project Ag areas are in sprinkler irrigation. The small parcel with grapes are on a drip irrigation system.

Onsite use or offsite use: A letter from the landowner described the onsite use in which Simazine was listed. This chemical has been added to the comprehensive list.

Current or historic use: The original Attachment 5A and 5C included an assessment and categorization of chemicals based on historic and current use.

Thank you for your time and attention.

John Brough HBDIC manager

John Brough, HBDIC Director

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CC: Don Miller – OWRD
Tim Bailey – ODFW

[5] Total amount on 1.8 acres is the probable maximum amount of material (active ingredient). Actual use depends on pest populations and pressure and weather conditions. All pesticides are applied on ground by air blast sprayer.

2|5|+

ATTACHMENT 5A: Methodology to Determine Chemical Constituents for Water Quality Assessment and Evaluation

Introduction:

This attachment is intended to specifically help clarify the process by which the proposed list of chemical constituents were determined and to show that a ODEQ water quality permit will not be needed for this limited license groundwater recharge project.

Chemical Constituents Review Methodology

It should be **clearly reiterated** that during construction of the recharge pits/ponds, the top 60 inches (5 feet) of topsoil would be **removed**. This construction criteria assists the project in two ways: (1) it minimizes the chance of site specific chemicals being leached into the ground water during the recharge process, (2) it increases the rate at which recharge water can be applied by exposing the more transmissive substrate below this top soil layer.

Working with our local pesticides expert, (Tom Darnell, OSU Extension Agent in Milton-Freewater) a review was conducted to determine the types of chemicals to consider for during this project's water quality monitoring plan. A description of this review processed is presented below.

Chemical Review Process

1. Using the proposed water diversion time period (Nov 1st through May 15th), a comprehensive list of chemicals[1] was compiled for the project area. This included interviewing the current landowner on the site-specific history of chemical use on that property (see attached signed, written statement).
2. Chemicals were broken down into two classes: **current** chemicals were determined to be those that have been used in the past several years in the project area, and **historical** chemicals are not currently in use, but have were used at some point in the past. This "project area" is defined as the area starting at the Little Walla Walla diversion (on the Walla Walla River) through the lands adjacent to the ditch network to the project site. **Attachment** 5C lists this comprehensive list of chemicals in table form.
3. Reviewed the ODEO Report: *April 1999 Milton-Freewater Groundwater Quality Study: As part of the Statewide Groundwater Monitoring Program* (Richardson, et. al., 2000). ODEQ's well # UMA298 is located proximal to the proposed recharge site which provides excellent preexisting information for this project. **Attached** is a copy of the results and conclusions from that study.
4. Using information from OSU Pesticides database (and several other websites), the complete list of chemicals was further screened based on a set of sequential screening steps. Chemicals were selected for the final monitoring list if they appeared to meet all of the criteria listed below.

   a. Currently and Historically used chemicals were choosen if:
      i. Soil ½ life = > period when last used, and if
      ii. Pesticide Movement Rating[2] > **or** = **moderate**, and if
      iii. ODEQ **did not** sample for it in 1999 study (UMA 298 well)
5. Exception to above selection process
   a. ODEQ sampled and found a "positive" detection of **Dathal & Metabolites** as a part of the Phenoxyherbicide screen tests (ODEQ, 1999). The results noted:

   " Dacthal and its metabolites were detected in six samples as part of the Phenoxyherbicide screen. The maximum concentration detected (24.6 micrograms per liter) was much less than the 4,000 micrograms per liter healthy advisory level. Therefore, the concentration of dacthal and metabolites is not believed to represent problems to human health or the environment." (ODEQ, 1999)

---

[1] Chemicals defined to include fungicides, herbicides, miticides, pesticides, and growth regulators.
[2] The Pesticide Movement Rating as reported in OSU report, *(OSU, 1999)*

The plan **is to test** for this group of chemicals during the water quality monitoring portion of this project.

6. The final step in the review process was to evaluate **if** the final list of chemicals were "testable". Two private water quality-testing laboratories (Kuo and Edge Analytical) were contacted and asked if they were able to test for these chemicals in water samples. The results are noted in attachment 5C.

Screening process conclusions:

The final list of chemicals for testing is shown below. Screening and/or testing information for the chemicals Myclobutanil (Systhane, Rally), Triflumizole (Procure), Triadimefon (Bayleton), Imidacloprid (Provado), Methoxyfenozide (Intrepid), and Spinosad (Success)_was not available at the time this document was completed. If this information becomes available in the future, and shows evidence that they should not or cannot be screened for, they would be dropped from the final testing list. Chemicals can also be added or deleted from the final list per request by ODEQ review staff.

Proposed List of Chemicals to Monitor for Recharge Project

Fenarimol (Rubigan)
DNOC sodium salt (Elgetol)
Metalxyl (Ridomil)
DCPA, (Dacthal @ Metabolites)
1-Naphthaleneacetamide (Amid-thin)
Myclobutanil (Systhane, Rally)
Triflumizole (Procure)
Triadimefon (Bayleton)
Imidacloprid (Provado)
Methoxyfenozide (Intrepid)
Spinosad (Success)

Pre-conditions: Using Nitrate as the Indicator

Agricultural fertilizers are the primary source of nitrate in groundwater. Nitrate concentrations greater than 2-3 mg/L in well water indicate that chemicals applied to the land surface are reaching the gorund water system, so detection of pesticides in these wells may be more likely. This relationship between nitrate concentration and pesticide detection may help identify wells at risk for contamination by pesticides. Laboratory analysis for nitrate is simpler and less costly than analysis of pesticides. Consequently, many more Central Columbia Plateau wells have been sampled for nitrate. (See attached report and *Rkyer, S.J. and Jones, J.L., 1995, Nitrate concentrations in ground water of the Central Columbia Plateau: U.S. Geological Survey Open-File Report 95-445, 4 p.)*

After the monitoring wells and recharge facility has been constructed and before operation of the project, a **preconditions water quality test** will be conducted of all chemical constituents (Levels 1 and 2 from Attachment 5 Monitoring Plan). Samples will be collected from the (1) source water entering project site, (2) upgradient on-site observation well, and (3) one of the two down gradient on-site observation wells.

Working in consultation with ODEQ staff, nitrate concentrations collected from this preconditions water quality test will used along with other published information in order to determine a Warning Concentration Level (WCL). This warning concentration level will be used to screen water quality during and after operation of the recharge project. If concentrations exceed this level, operation of the recharge facility will be stopped and a Level II water quality sampling will be done on both surface and groundwater location to determine if chemicals are present. Working with ODEQ, results will be reviewed and any operation changes will implemented to avoid chemical contamination of the groundwater.

Laboratory Resources

Nitrate Analysis: Walla Walla County-City Health Department
310 W. Popular, P. O. Box 1753
Walla Walla, WA 99362
Telephone (509) 527-3290

Chemical Analysis: KUO Testing Labs, INC.
337 south 1st Avenue
Othello, WA 99344
Telephone: (509)-488-0118

Edge Analytical
1151 Knudson
Burlington, WA 98233
(360) 757-1400
(800) 755-9295

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References and additional chemical resources used for the screening process:

Darnell, T., Topielec, R. 1996, October. *Nitrates and Bacteria in Groundwater: A Second Look, Milton-Freewater Area, Umatilla County, Oregon.* Oregon State University Extension Service Water Quality Program.

Darnell, T. Hart, J. Vomocil, Jim. 1989. *Nitrates and Bacteria in Groundwater: Milton-Freewater, Umatilla County Oregon.* Oregon State University Extension Service.

Darnell, T., Montgomery, M. L., Witt, J. M., 1989, July. *Pesticides in Groundwater: Milton-Freewater, Umatilla County, Oregon.* Oregon State University

U.S. Geological Survey 1996, July. *Fact Sheet 171-96: Article: The Nitrate Connection.* US Government Printing Office 774-398/20006 Region NO. 8

Kerle, E.A., Vogue, P. A., Jenkins, J. J., 1996, October. *Understanding pesticide persistence and mobility for groundwater and surface water protection.* Oregon State University Extension EM 86561

Jenkins, J. J., Thomson P. A., 1999, January. *OSU Extension Pesticide Properties Database.* . Oregon State University Extension EM 8709

Cooperative Extension Washington State University. 2002. *2002 Crop Protection Guide for Tree Fruits in Washington.* Washington State University EB0419.

Richerson, P., Cole, D. 2000, June *April 1999 Milton-Freewater Groundwater Quality Study: As part of the Statewide Groundwater Monitoring Program.* State of Oregon Department of Environmental Quality

http://www.cdpr.ca.gov/docs/publicreports/5698.pdf
http://www.fruit.wsu.edu/labels/insecticides.htm#S
http://ace.orst.edu/info/extoxnet/
http://www.pesticideinfo.org/Index.html

Attachment B

ATTACHMENT B: RECORD OF USE (2004-2008)

Recharge Seasons	Period of Operation	Hours of Diversion (actual)	Total Water Use ON HBDIC Recharge Site (acre-feet)	Water Use: Little Walla Walla Diversion to HBDIC Recharge (Conveyance Loss) (acre-feet)
Spring 2004	4/8/4 to 5/14/4	888	409	714
2004-2005	12/1/4 to 2/3/5	672	388	540
2004-2005	3/27/5 to 4/30/5	720	650	579
2005-2006	11/1/5 to 5/15/6	2544	2,813	2,046
2006-2007	11/1/6 to 5/15/7	3072	3,278	2,470
2007-2008	11/14/7 to 3/25/7	2400	1,939	1,930
2007-2008	4/10/8 to 5/15/8	840	820	676
	Total	11,136	10,297	8,955
			Sum of Recharge Project and Conveyance	19,252

Attachment C

Attachment C: HBDIC Recharge On-Site Operations and Expansions (2004-2008)

Recharge Seasons	Period of Operation	Days of Operation (actual)	Peak Recharge Rate (cfs)	Site Expansion Phase	Infiltration Area (feet²)	Infiltration Area (acres)	Total Recharge Volume (acre-feet)	Total Recharge Volume (Gallons x 1,000)	Total Rechage (acre-feet (season))
Spring 2004	4/8/4 to 5/14/4	37	8.0	I	15,000	0.3	409	133,273	409 (2004)
2004-2005	12/1/4 to 2/3/5	28	6.8	I	15,000	0.3	388	126,398	1038(2004-5)
2004-2005	3/27/5 to 4/30/5	30	12.1	II	47,420	1.1	650	211,803	
2005-2006	11/1/5 to 5/15/6	106	13.2	II	47,420	1.1	2,813	916,619	2813 (2005-6)
2006-2007	11/1/6 to 5/15/7	128	12.8	II	47,420	1.1	3,278	1,068,140	3278 (2006-7)
2007-2008	11/14/7 to 3/25/7	100	18.4	II	61,987	1.4	1,939	631,962	2759 (2007-8)
2007-2008	4/10/8 to 5/15/8	35	16.8	III	61,987	1.4	820	267,125	
	Total	464					10,297	3,355,320	

Attachment D

Oregon Water Resources Department

Final Order
Regarding Limited License Request 758

Requested Water Use

On November 11, 2003 the Water Resources Department received completed LL request 758 from Hudson Bay District Irrigation Company for the use of 50.0 cfs from the Walla Walla River, located in the SW1/4, NE1/4, Section 12, Township 5 North, Range 35 East, W.M., for the purpose of artificial ground water recharge testing, for a period of five years, pursuant to ORS 537.143 and 537.144.

Department Review

The Department, in consultation with Oregon Department of Fish and Wildlife (ODFW), Oregon Department of Environmental Quality (ODEQ), and Confederated Tribes of the Umatilla Indian Reservation (CTUIR), has determined that the requested use may be approved as conditioned and limited below.

The use of water for artificial ground water recharge testing, as requested in limited license application 758, is a use allowed under ORS 537.143.

Sufficient water is available, as required under 690-340-0030(1)(b), for this short-term, fixed duration use. The Director may revoke the right to use water for any reason described in ORS 537.143(2).

The Department provided public notice of the application in the Department's weekly public notice as required by OAR 690-340-0030(2). The Department has received comments related to the issuance of the limited license. The authorization of limited license 758, as conditioned below, will satisfactorily address the issues raised in those comments.

Conditions and Limitations

The use of water from the Walla Walla River shall be limited to 50.0 cfs for the purpose of testing artificial ground water recharge during a testing season of November 1 through May 15. Water may only be diverted when there is adequate flow in the Walla Walla River to honor all existing water rights. When water is diverted under this limited license, the use is further limited to times when there is, at a minimum, the following streamflows in the Tum A Lum reach of the Walla Walla River, between the Little Walla Walla River diversion and Nursery Bridge Dam and flowing past

This is a final order in other than contested case. Pursuant to ORS 536.075 and OAR 137-004-080 and OAR 690-01-005 you may either petition the Director for reconsideration of this order or petition for judicial review of this order. As provided in ORS 536.075, this order is subject to judicial review under ORS 183.484. Any petition for judicial review of the order must be filed within the 60 day time period specified by ORS 183.484(2).

Nursery Bridge Dam: November - 64 cfs, December and January - 95 cfs, February to May 15 - 150 cfs. Nursery Bridge Dam is located just downstream of Nursery Bridge and is downstream of the Little Walla Walla diversion. The District 5 Watermaster, based on gage and/or streamflow measurements, shall make the determination that the above described streamflows are flowing past Nursery Bridge Dam. Diversion under this limited license shall cease when said streamflows are not being met.

Based on a review of water quality information generated during the term of this limited license or from other sources, ODEQ can require the licensee to terminate the diversion of water into the recharge area. If monitoring data or other information results in identification of potential water quality concerns ODEQ may require modifications to the existing limited license and/or require a permit to address the water quality concerns prior to reinitiating artificial ground water recharge.

The licensee shall install, maintain and operate fish screening and by-pass devices as required by the Oregon Department of Fish and Wildlife to prevent fish from entering the proposed diversion. See copy of enclosed fish screening criterial for information.

The use of water under a limited license shall not have priority over any water right exercised according to a permit or certificate, and shall be subordinate to all other authorized uses that rely upon the same source. The Director may be prompted by field regulatory activities or by any other reason to revoke the right to use water (ORS 537.143 (2) and OAR 690-340-0030 (6)).

The licensee shall give notice to the Watermaster at least 15 days, but no more than 60 days, in advance of using water. The notice shall include the location of the diversion, place of recharge, the quantity of water to be diverted and the intended use.

ORS 537.143(8) provides that a limited license cannot be issued for the same use for more than five consecutive years. This limited license provides for the maximum allowable time.

The licensee shall meter all water use and maintain a record of use, including the total number of hours of diversion and an estimate of the total quantity diverted. During the period of the limited license, the record of use shall be available for review by the Department upon request and shall be submitted to the Watermaster upon request.

Upon project completion, the licensee shall submit the record of use to the Water Resources Department.

The licensee shall conduct artificial ground water recharge testing in a manner consistent with the license application proposal. This includes monitoring the amount of water diverted from the Walla Walla River and the amount delivered to the recharge pits from the ditch.

This is a final order in other than contested case. Pursuant to ORS 536.075 and OAR 137-004-080 and OAR 690-01-005 you may either petition the Director for reconsideration of this order or petition for judicial review of this order. As provided in ORS 536.075, this order is subject to judicial review under ORS 183.484. Any petition for judicial review of the order must be filed within the 60 day time period specified by ORS 183.484(2).

Order

Therefore, pursuant to ORS 537.143 and ORS 537.144, limited license 758 is issued as conditioned and limited above.

Issued February 18, 2004

Paul R. Cleary, Director
Water Resources Department

Enclosures - limited license and fish screen criteria

cc: Tony Justus, Watermaster, District 5
Tim Bailey, ODFW
Phil Richerson, ODEQ
Rick George, CTUIR

File

If you need further assistance, please contact the Water Rights Section at the address, phone number, or fax number below. When contacting the Department, be sure to reference your limited license number for better service.

Remember, the use of water under the terms of this limited license is not a secure source of water. Water use can be revoked at any time. Such revocation may be prompted by field regulatory activities or by any other reason.

Water Rights Section
Oregon Water Resources Department
158 12th ST NE
SALEM, OR 97310

Phone: (503)378-8455
Fax: (503)378-6203

FISH SCREENING CRITERIA FOR WATER DIVERSIONS

This summary describes ODFW fish screening criteria for all fish species.

Screen material openings for ditch (gravity) and pump screens must provide a minimum of 27% open area:

> **Perforated plate**: Openings shall not exceed 3/32 or 0.0938 inches (2.38 mm).
> **Mesh/Woven wire screen**: Square openings shall not exceed 3/32 or 0.0938 inches (2.38 mm) in the narrow direction, e.g., 3/32 inch x 3/32 inch open mesh.
> **Profile bar screen/Wedge wire**: Openings shall not exceed 0.0689 inches (1.75 mm) in the narrow direction.

Screen area must be large enough not to cause fish impact. Wetted screen area depends on the water flow rate and the approach velocity.

> **Approach velocity**: The water velocity perpendicular to and approximately three inches in front of the screen face.
> **Sweeping velocity**: The water velocity parallel to the screen face.
> **Bypass system**: Any pipe, flume, open channel or other means of conveyance that transports fish back to the body of water from which the fish were diverted.
> **Active pump screen**: Self cleaning screen that has a proven cleaning system.
> **Passive pump screen**: Screen that has no cleaning system other than periodic manual cleaning.

Screen approach velocity for ditch and active pump screens shall not exceed 0.4 fps (feet per second) or 0.12 mps (meters per second). The wetted screen area in square feet is calculated by dividing the maximum water flow rate in cubic feet per second (1 cfs = 449 gpm) by 0.4 fps.

Screen sweeping velocity for ditch screens shall exceed the approach velocity. Screens greater than 4 feet in length must be angled at 45 degrees or less relative to flow. An adequate bypass system must be provided for ditch screens to safely and rapidly collect and transport fish back to the stream.

Screen approach velocity for passive pump screens shall not exceed 0.2 fps or 0.06 mps. The wetted screen area in square feet is calculated by dividing the maximum water flow rate by 0.2 fps. Pump rate should be less than 1 cfs.

For further information please contact:

Bernie Kepshire
Oregon Department of Fish and Wildlife
7118 NE Vandenberg Avenue
Corvallis, OR 97330-9446
(541)757-4186 x255
bernard.m.kepshire@state.or.us

Attachment E

This page to be completed by the local Watermaster.

WATER AVAILABILITY STATEMENT

Name of Applicant: Hudson Bay District Irrigation Co. Application Number: ____________

1. To your knowledge, has the stream or basin that is the source for this application ever been regulated for prior rights?

   ☑ Yes ☐ No

   If yes, please explain:

   The Walla Walla River is typically short of water to serve all rights in July, August, September and October.

2. Has the stream or basin that is the source for this application ever been regulated for minimum stream flows?

   ☐ Yes ☑ No

   If yes, please explain:

3. Do you observe this stream system during regular fieldwork?

   ☑ Yes ☐ No

   If yes, what are your observations for the stream?

   Typically there is extra water from November to June.

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4. Based on your observations, would there be water available in the quantity and at the times needed to supply the development proposed by this application?

   ☑ Yes ☐ No

   What would you recommend for conditions on a permit that may be issued approving this application?

   Limit diversion similarly to Hudson Bays permit #53662. Allow diversion when flows are in excess of 64cfs in November, 95cfs in December and January, and 132 cfs in February to May 15 each year.

5. Any other recommendations you would like to make?

Signature: Tony Justo WM District #: 5 Date: 10/31/03

Appendix G

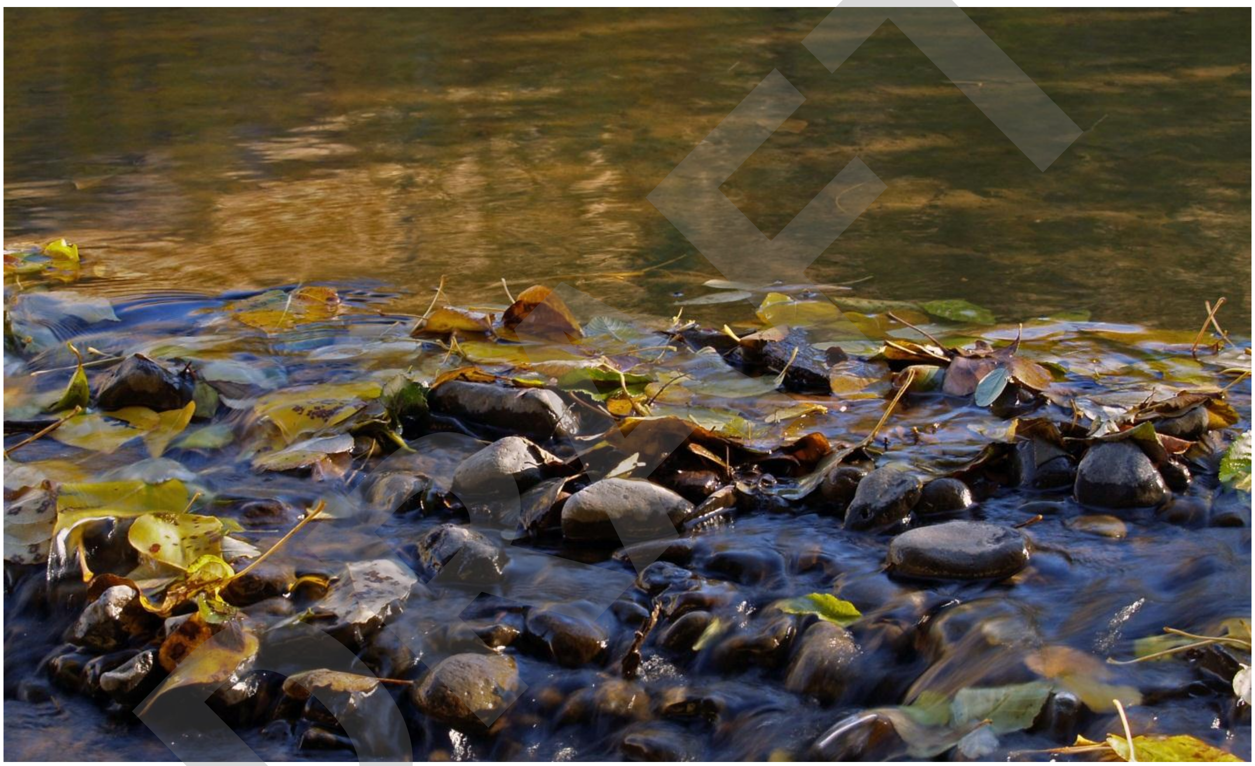
WWBWC Watershed Monitoring Program

Standard Operating Procedures (DRAFT)

www.wwbwc.org
Walla Walla Basin Watershed Council
541-938-2170 or 7086 P.O.Box 68, Milton-Freewater, OR 97862

WWBWC Watershed Monitoring Program

Standard Operating Procedures



Steven Patten
Senior Environmental Scientist - WWBWC

Draft Standard Operating Procedures

December 2012

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SOP Revision History

Revision Date	Revision Number	Summary of Changes	Sections Changed	Reviser(s)
11/2012	1.0	Creation of SOP document	All	Steven Patten

DISTRIBUTION LIST

This document will be made available to the public, agencies and grant funders through the Walla Walla Basin Watershed Council's website (www.wwbwc.org). Internal distribution of the document will occur through the WWBWC's internal server. All field and technical personnel will be given an electronic copy of this document. A printed version will be available in the WWBWC office. This document will be redistributed to personnel and uploaded to the WWBWC server and website upon revision.

Background and Project Description

The Walla Walla Basin Watershed Council's Watershed Monitoring Program includes more than 60 surface water sites, more than 100 groundwater sites, 10 water temperature sites, and more than a dozen water quality sites. The monitoring program covers almost the entire watershed starting in the upper reaches of the rivers and extending to the valley floor near where the Walla Walla River drains to the Columbia River. This document describes the WWBWC's Watershed Monitoring Program and includes the standard operating procedures used to collect environmental and hydrologic data.

Program Area

The area of study for the Walla Walla Basin Watershed Council's Quality Assurance Program Plan includes the entire Walla Walla Watershed (Figure 1).

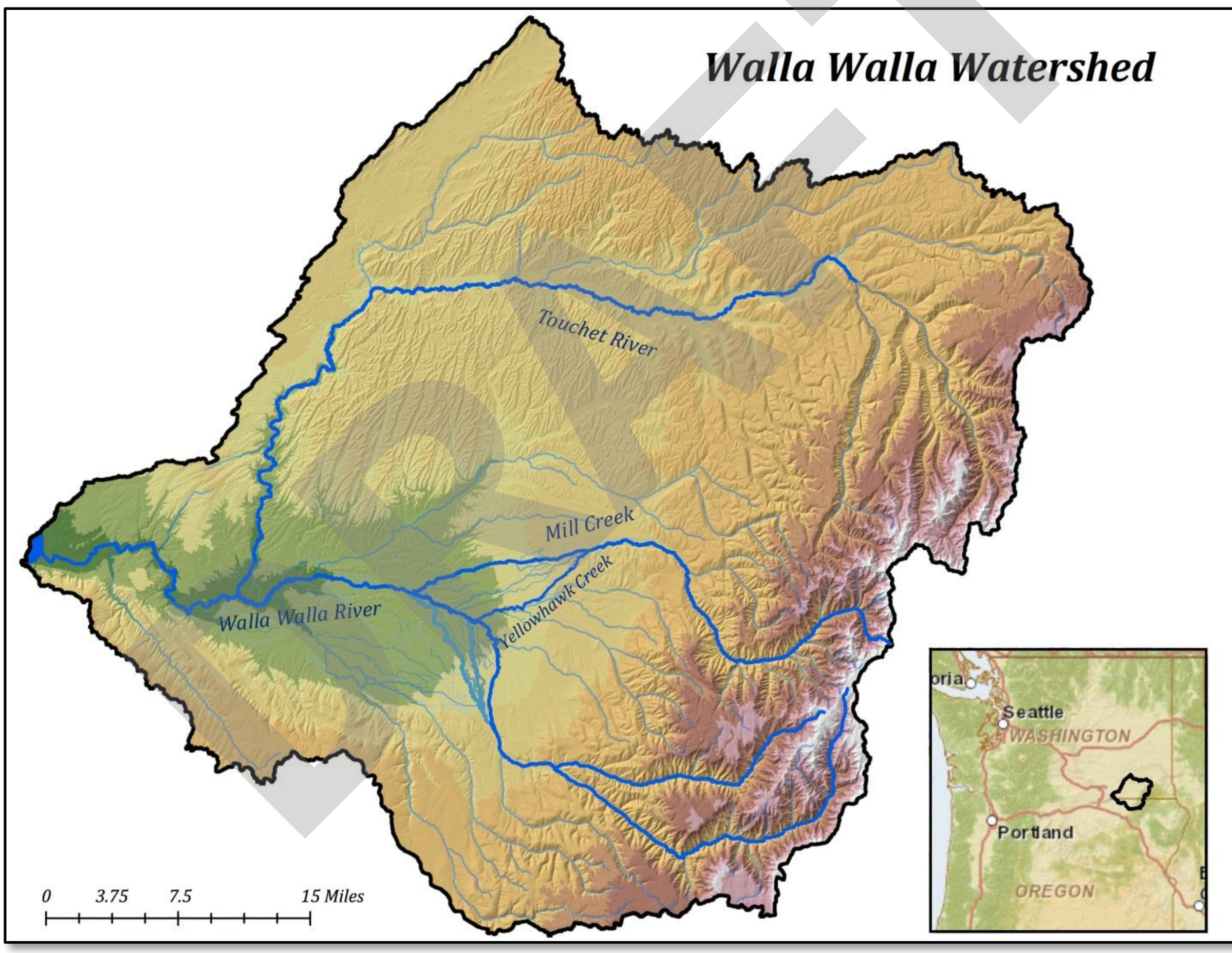

Figure 1. Map of the Walla Walla Watershed.

Monitoring locations for this program are spread throughout the valley (Figure 2), however the majority of the work conducted under this plan will take place on the valley floor Northwest of Milton-Freewater, OR, Southwest of Walla Walla, WA, and East of Touchet, WA. Aspects of the program (i.e. seepage runs) encompass other portions of the basin including almost the entire lengths of the Walla Walla River, the Touchet River and Mill Creek.

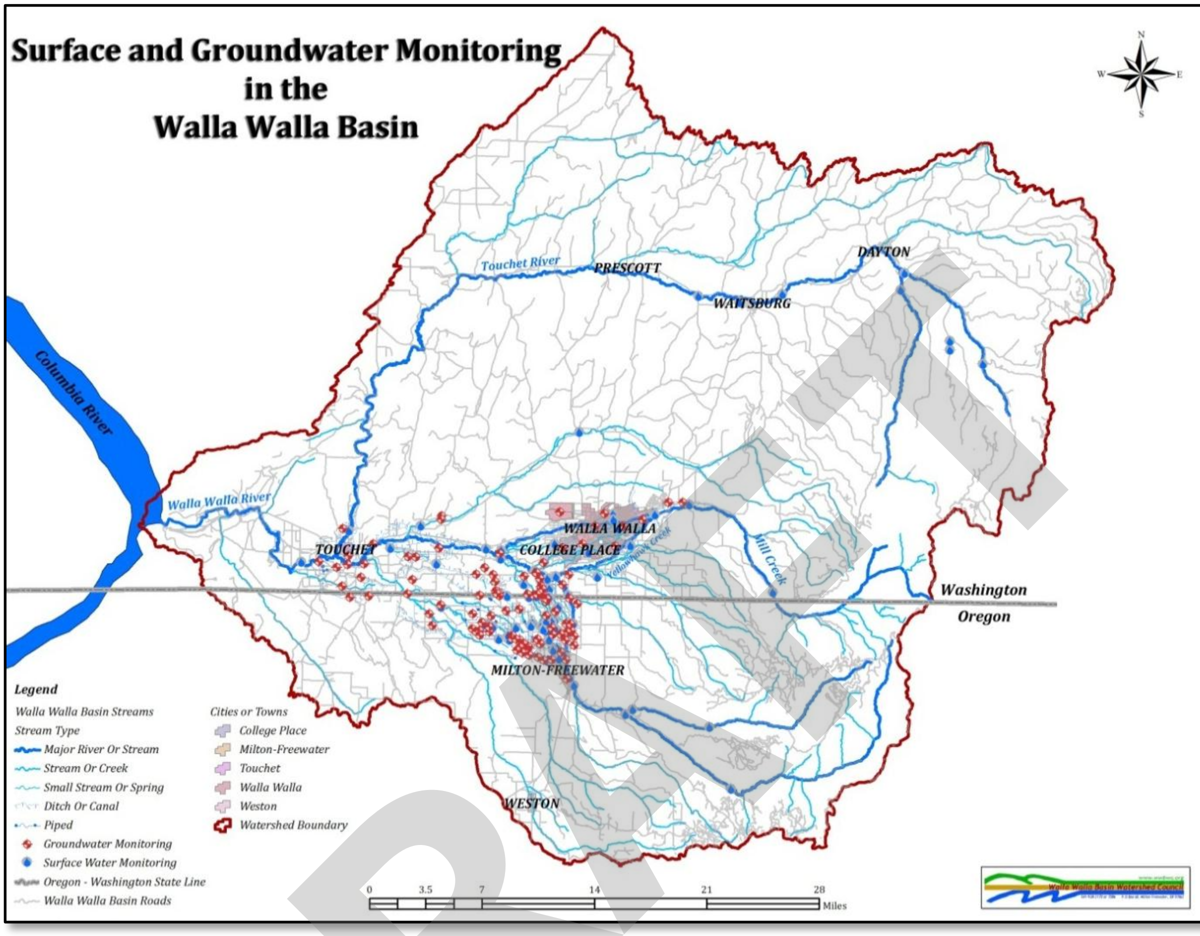

Figure 2. WWBWC Watershed Monitoring Program surface and groundwater monitoring locations.

PROJECT GOALS & OBJECTIVES

This monitoring program's goal is collect, organize, analyze and distribute hydrology related data for use by the WWBWC and other partners as projects are located, designed, installed and monitored so restoration in the Walla Walla Basin moves forward with knowledge of current and historic trends. The following objectives will achieve the program's goal.

- Collection of quality data utilizing well-established scientific protocols for monitoring activities.
- Organization of data into a functional system to allow use and analysis of data. Data must be organized and accessible for it to be useful.
- Analyzing data allows for trends and patterns to be determined. From these analysis we can determine how the basin is responding to changes (both environmental and project based).
- Distribution of data is critical. All of the above objectives can be completed, but without distribution of the data to other partners there cannot be a cohesive direction for restoration in the basin.

ORGANIZATION AND SCHEDULE

WALLA WALLA BASIN WATERSHED COUNCIL PERSONNEL

Name	Position	Main Tasks	Email
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The Walla Walla Basin Watershed Council's phone number is: 541-938-2170

PROGRAM PARTNERS

The Walla Walla Basin Watershed Council works with many partners throughout the basin to collect the monitoring data in the program. Program partners include: Hudson Bay District Improvement Company (HBDIC), Walla Walla River Irrigation District (WWRID), Gardena Farms Irrigation District #13 (GFID), Oregon Water Resources Department (OWRD), Washington Department of Ecology (WDOE), Confederated Tribes of the Umatilla Indian Reservation (CTUIR), City of Walla Walla, City of Milton-Freewater, City of College Place, Walla Walla Watershed Management Partnership (WWWMP), Tri-State Steelheaders (TSS), Oregon Department of Fish and Wildlife (ODFW), Washington Department of Fish and Wildlife (WDFW), Washington Water Trust, The Freshwater Trust, Walla Walla University, Whitman College, Oregon Department of Environmental Quality (ODEQ), and many businesses and individual landowners in the basin.

Program Schedule

The WWBWC's monitoring program is an on-going process. A general schedule of activities is described in the table below:

Monitoring Activity	Year-round or Seasonal	General Schedule
Surface Flow (River)	Year-round and Seasonal	Sites are visited every other week to collect staff gauge measurements and perform general site maintenance. Manual discharge measurements and other data are collected during ~6 visits each year. A few river sites are only monitored seasonally during summer and fall base flows.
Surface Flow (Streams, Springs & Ditches)	Year-round	Sites are visited 4-5 times a year to download data, conduct manual flow measurements, perform site maintenance and collect other data.
Groundwater Level Monitoring	Year-round	Sites are visited ~4 times a year to download data, conduct manual groundwater level measurements, perform site maintenance and collect other data.
Water Temperature (River)	Seasonal	Data loggers are deployed in late spring or early summer and retrieved late fall or early winter dependent upon river flows.
ET Stations	Year-round	Sites are visited ~3-4 times a year to download data and perform site maintenance.
Scour Chains and Bed Stability	Seasonal	Sites are visited ~2-3 times a year to collect data, conduct channel survey and perform any maintenance.
Seepage Analysis	Seasonal	Seepage runs occur twice a year on each river system. Typically runs are conducted late spring or early summer and late summer or early fall.
Water Quality Sampling (SAR)	Seasonal	Water quality sampling is done during the shallow aquifer recharge season which typically starts in November and continues through May.
Water Quality Sampling (PSP)	Seasonal	Water quality sampling is done from March till June during the typical pesticide application time period.
Data Analysis and Distribution	Year-round	As data are collected, analyzed and incorporated into the WWBWC's database as provisional. Data are reviewed at the end of each water year.

Quality Objectives

Parameter	Check Standard	Duplicate Samples
Water Temperature	± 0.5 °C (NIST Thermometer)	± 0.2 °C
pH	± 0.1 pH units	± 0.1 pH units
Specific Conductance	± 5% of standard	± 5% of reading
Dissolved Oxygen	± 0.2 mg/L	± 0.1 mg/L
Groundwater Level Measurement	N/A	± 0.01 feet
Manual Discharge Measurement	N/A	± 10%
Tape Down Measurement	N/A	± 0.02 feet
Vertical Staff Gauge Measurement	N/A	± 0.02 feet

Experimental Design

Monitoring locations were determined by availability to measure parameter of interest (e.g. groundwater can only be measured at wells or bore holes or high discharge measurements can only be taken at bridges). Professional judgment was also utilized in the placement of monitoring locations if multiple sites were available. Many monitoring locations were determined based upon anthropogenic changes to the system (e.g. irrigation diversions, flood control structures or restoration projects).

Sampling locations and frequency cover temporal and spatial variability within the valley. For example, monitoring surface flow sites 4-6 times per year allows for data collection to include high and low flow periods based upon environmental changes. The schedule provided for each sampling parameter tries to accommodate temporal variability throughout the year.

Field Measurements

The majority of sampling for this program will occur in the field. Refer to the table below for which samples will be collected in the field and a sampling schedule for each.

Measurement Parameter	Monitoring Program	Schedule
River/Stream Discharge	Surface Flow Monitoring	4-6 times per year
Water Temperature	Surface Flow Monitoring	4-6 times per year
Specific Conductance	Surface Flow Monitoring	4-6 times per year
Staff Gage Reading	Surface Flow Monitoring	4-6 times per year (20+ for mainstem gage locations)
Elevation Reference Checks	Surface Flow Monitoring	4-6 times per year
Channel Survey	Surface Flow Monitoring	1 every 2-3 years
Groundwater Level Measurement	Groundwater Monitoring	4 times per year
Groundwater Temperature	Groundwater Monitoring	4 times per year
Specific Conductance	Groundwater Monitoring	4 times per year
Surface/Groundwater Temperature	Recharge Water Quality Monitoring	2-3 times per year

Measurement Parameter	Monitoring Program	Schedule
Surface/Groundwater Specific Conductance	Recharge Water Quality Monitoring	2-3 times per year
Surface/Groundwater Dissolved Oxygen	Recharge Water Quality Monitoring	2-3 times per year
Surface/Groundwater pH	Recharge Water Quality Monitoring	2-3 times per year
Channel Survey	Scour Chains & Bed Stability	2-3 times per year
Scour Chain Measurement	Scour Chains & Bed Stability	2-3 times per year
Pebble Counts	Scour Chains & Bed Stability	1-2 times per year
Longitudinal Survey	Scour Chains & Bed Stability	1 time per year
Water Temperature	River Temperature Monitoring	2-3 time per year
River/Stream Discharge	Seepage Runs	2 times per year per river
Water Temperature	Seepage Runs	2 times per year per river
Specific Conductance	Seepage Runs	2 times per year per river

LABORATORY MEASUREMENTS

Some of the water quality sampling that is conducted under this plan requires laboratory level analysis. The sampling parameters and schedules are listed in the table below.

Sampling Parameter	Monitoring Program	Schedule
pH	Recharge Water Quality Monitoring	2-3 times per year
Electrical Conductivity	Recharge Water Quality Monitoring	2-3 times per year
Dissolved Oxygen	Recharge Water Quality Monitoring	2-3 times per year
Nitrate-N	Recharge Water Quality Monitoring	2-3 times per year
Total Organic Carbon	Recharge Water Quality Monitoring	2-3 times per year
Total Kjehldahl Nitrogen (TKN)	Recharge Water Quality Monitoring	2-3 times per year
Sulfate	Recharge Water Quality Monitoring	2-3 times per year
Chloride	Recharge Water Quality Monitoring	2-3 times per year
Calcium	Recharge Water Quality Monitoring	2-3 times per year
Alkalinity	Recharge Water Quality Monitoring	2-3 times per year
Ortho-Phosphate	Recharge Water Quality Monitoring	2-3 times per year
Sodium	Recharge Water Quality Monitoring	2-3 times per year
Potassium	Recharge Water Quality Monitoring	2-3 times per year
Magnesium	Recharge Water Quality Monitoring	2-3 times per year
Aluminum	Recharge Water Quality Monitoring	2-3 times per year
Iron (dissolved)	Recharge Water Quality Monitoring	2-3 times per year
Manganese (dissolved)	Recharge Water Quality Monitoring	2-3 times per year

SAMPLING PROCEDURES

WATER QUALITY SAMPLING (GROUNDWATER)

Groundwater sampling is conducted utilizing the following procedures. The general overview of groundwater sampling includes gathering equipment, measuring the initial water level, installing a submersible pump in the well, purging the well at a low flow rate, collecting and labeling all required samples and delivering them to the lab or shipping company. Details on parameters sampled for each site can be found in its monitoring and reporting plan.

Note: this procedure is a modified from:

Marti, 2011. Standard Operating Procedure for Purging and Sampling Monitoring Wells. Washington State Department of Ecology – Environmental Assessment Program. EAP078.

EQUIPMENT

- Sampling field data sheets (see below) or field notebook
- Chain of Custody form
- Water level measuring equipment (e-tape)
- Water quality meters and probes (Temperature, Specific Conductance, pH & Dissolved Oxygen)
- Submersible pump
- Pump controller
- Tubing and connectors
- Sample bottles/containers
- Cooler
- Ice
- Deionized water
- Diluted Bleach solution
- Non-phosphate soap
- Nitrile or latex gloves
- First aid kit
- Well keys
- Camera
- Paper towels or clean rags
- Plastic sheet for keeping equipment clean
- Buckets (5-gallon or similar for purge volumes)
- 1 liter container (for purge volumes)
- Socket set
- Screwdriver(s)

PURGING AND SAMPLING

1. Check well for any changes or potential hazards.
2. Make sure equipment has been cleaned and decontaminated (see below for details). Spread plastic or other material if needed to keep equipment clean.
3. Wear clean disposable gloves (latex or Nitrile) while performing purging and sampling. If gloves become contaminated or dirty replace with new gloves.

4. Make sure field water quality meters are calibrated according to the manufacturer's instructions.
5. If well is equipped with a pressure transducer, note how it is installed and its position to replace it after sampling. Remove the pressure transducer from the well. Note the time the pressure transducer was removed from the well on the data sheet or in the field notebook.
6. Measure the static water level in the well (see Groundwater Level and Temperature protocol below for details).
7. Measure the depth of the well or refer to the well log to determine the depth of the well.
8. Calculate the length of the water column. Calculate the volume of water in the well using the following values: 2" well = 0.1631 gallons per linear foot, 4" = 0.6524 gallons per linear foot (Equation used for water volume calculation – Volume (gal/ft) = $\pi r^2(7.48\ \text{gal/ft}^3)$ where r is the radius of the well and 7.48 is the conversion factor).
9. Install the submersible pump into the well. Be sure to slowly lower the pump into the well and through the water to avoid stirring up particulates. Place the pump in the middle of the screen section of the well (refer to well log to determine the open interval for pump placement).
10. Once the pump is installed correctly re-measure the static water level to monitor during purging.
11. Start purging. Set the pump controller to the desired pumping rate (~1 liter/minute). See notes from previous sampling for pumping rate.
12. Ideally, wells should be purged and sampled at flow rates at or less than the natural flow conditions of the aquifer in the screen interval to avoid drawing down the water level in the well. Use water level measurements to help adjust pumping rates to prevent well drawdown. Purging should not cause significant drawdown (considered to be 5% of the total height of the water column). If drawdown is significant, reduce pumping rate until water levels stabilize at an appropriate level.
13. Record pumping rate on the data sheet or field notebook.
14. Discharge evacuated water as far as possible from the wellhead and work area.
15. During purging and sampling water flow should be smooth and consistent without bubbles in the tubing.
16. Once pumping rate has been determined and flow has stabilized, start collecting field parameters (water temperature, specific conductance, pH and dissolved oxygen) at regular intervals. The measurement interval will depend upon the pumping rate (typically 2-5 minutes between measurements).
17. Record field parameters, water level measurement, and estimated amount of water purged. Note any changes in purged water's appearance (clear, turbid, odor, etc.).
18. Continue purging well until field parameters stabilize. Parameters should be considered to be stabilized when 3 consecutive measurements fall within the following ranges:

Field Parameter	Stabilized Range
Temperature	± 0.1 ° Celsius
Specific Conductance <1000 μs/cm	± 10 μs/cm
Specific Conductance >1000 μs/cm	± 20 μs/cm
Dissolved Oxygen < 1 mg/L	± 0.05 mg/L
Dissolved Oxygen > 1 mg/L	± 0.2 mg/L
pH	± 0.1 pH units

19. Collect samples once field parameters have stabilized. Do not stop or change pumping rate during the final phase of purging and sampling.
20. Collect most sensitive analytes first (i.e. organics) followed by less sensitive analytes (i.e. nutrients). This order can be modified if using sulfuric or nitric acid preservatives to prevent contamination of sulfate and/or nitrogen samples.
    Collect any duplicate or quality control samples (see below for details).
21. Place samples in an ice-cooled cooler for delivery to the lab or shipping company. Make sure samples do not freeze during transport.
22. Complete chain of custody form. Record sample date and time, final water level and estimated total purge volume on the data sheet or in the field notebook. Also record any comments or observations regarding the purging and sampling process.
23. Replace pressure transducer if the well was equipped with one. Note re-install time on the data sheet or in the field notebook.
24. Clean and disinfect sampling equipment for next sampling event.

DECONTAMINATION

All non-disposable field equipment that may potentially come in contact with any soil or water sample shall be decontaminated in order to minimize the potential for cross-contamination between sampling locations. Thorough decontamination of all sampling equipment shall be conducted prior to each sampling event. In addition, the sampling technician shall decontaminate all equipment in the field as required to prevent cross-contamination of samples collected in the field. The procedures described in this section are specifically for field decontamination of sampling equipment.

At a minimum, field-sampling equipment should be decontaminated following these procedures:

- Wash the equipment in a solution of non-phosphate detergent (Liquinox® or equivalent) and distilled or deionized water. All surfaces that may come in direct contact with the samples shall be washed. Use a clean Nalgene and/or plastic tub to contain the wash solution and a scrub brush to mechanically remove loose particles. Wear clean latex, plastic, or equivalent gloves during all washing and rinsing operations.
- Rinse twice with distilled or deionized water.
- Dry the equipment before use, to the extent practicable.

WATER QUALITY SAMPLING (SURFACE WATER)

Surface water sampling is conducted utilizing the following procedures.

Note: this procedure is a modified from:

Anderson, 2011. Standard Operating Procedure for Sampling of Pesticides in Surface Waters. Washington State Department of Ecology – Environmental Assessment Program. EAP003.

Equipment

- Sampling field data sheets (see below) or field notebook
- Chain of Custody form
- Water quality meters and probes (Temperature, Specific Conductance, pH & Dissolved Oxygen)
- Sample bottles/containers
- Cooler
- Ice
- Deionized water
- Diluted Bleach solution
- Non-phosphate soap
- Nitrile or latex gloves
- First aid kit
- Camera
- Paper towels or clean rags
- Plastic sheet for keeping equipment clean
- Screwdriver(s)

Sampling

1. Check for any changes or potential hazards.
2. Make sure equipment has been cleaned and decontaminated (see below for details). Spread plastic or other material if needed to keep equipment clean.
3. Wear clean disposable gloves (latex or Nitrile) while performing purging and sampling. If gloves become contaminated or dirty replace with new gloves.
4. Make sure field water quality meters are calibrated according to the manufacturer's instructions.
5. Collect required field water quality parameters and record on data sheet. Also note weather conditions
6. Fill out labels on each sample bottle with all necessary information.
7. Carefully collect samples by filling each container with water from the site. Note marked fill lines or preservatives to prevent over or under filling of the sample bottle.
8. Collect any duplicate or quality control samples (see below for details).
9. Place samples in an ice-cooled cooler for delivery to the lab or shipping company. Make sure samples do not freeze during transport.
10. Complete chain of custody form. Record sample date and time on the data sheet or in the field notebook. Also record any comments or observations regarding the sampling process.
11. Clean and disinfect sampling equipment for next sampling event.

Decontamination

All non-disposable field equipment that may potentially come in contact with any soil or water sample shall be decontaminated in order to minimize the potential for cross-contamination between sampling locations. Thorough decontamination of all sampling equipment shall be conducted prior to each sampling event. In addition, the sampling technician shall decontaminate all equipment in the field as required to prevent cross-contamination of samples collected in the field. The procedures described in this section are specifically for field decontamination of sampling equipment.

At a minimum, field-sampling equipment should be decontaminated following these procedures:

- Wash the equipment in a solution of non-phosphate detergent (Liquinox® or equivalent) and distilled or deionized water. All surfaces that may come in direct contact with the samples shall be washed. Use a clean Nalgene and/or plastic tub to contain the wash solution and a scrub brush to mechanically remove loose particles. Wear clean latex, plastic, or equivalent gloves during all washing and rinsing operations.
- Rinse twice with distilled or deionized water.
- Dry the equipment before use, to the extent practicable.

MEASUREMENT PROCEDURES

SURFACE WATER MONITORING

Note: These procedures are based on and modified from:

Myers, J. 2009. Standard Operation Procedure for Conducting Stream Hydrology Site Visits. Version 1.0. Washington Department of Ecology – Environmental Assessment Program. EAP057.

Rantz, S. E., and others. 1982 Measurement and Computation of Streamflow: Volume I. Measurment of Stage and Dischage. U.S. Geological Survey Water-Supply Paper 2175.

Rantz, S. E., and others. 1982 Measurement and Computation of Streamflow: Volume II. Computation of Discharge. U.S. Geological Survey Water-Supply Paper 2175.

Shedd, J. R. 2011. Standard Operating Procedure for Measuring and Calculating Stream Discharge. Version 1.1. Washington Department of Ecology – Environmental Assessment Program. EAP056.

Shedd, J.R. 2008. Standard Operating Procedure for Measuring Gage Height of Streams. Version 1.0. Washington Department of Ecology – Environmental Assessment Program. EAP042.

EQUIPMENT

— Four foot top set wading rod
— Mechanical Current Meter (Price AA or pygmy) or Marsh-McBirney Velocity Meter
— AquaCalc computer
— Bridge Board
— Sounding Reel
— Columbus sounding weight
— Tape Down Measuring Tape (with weight attached)
— Laser Level
— Stadia Rod
— NIST Thermometer
— YSI-30 Temperature and Conductivity Meter
— Measuring tape (100’ or 200’)
— Chest or Hip Waders
— Laptop Computer

- Cables for connecting to Data logger
  - LT-300 Cable
  - LT-500 Cable
  - WaterLog Cable or Memory Card
  - Campbell Scientific Cable or Card
- Pen or Pencil
- Data sheets

VERTICAL STAGE MEASUREMENT

Vertical stage measurements are obtained from mounted staff gauges. Most staff gauges used by the WWBWC are graduated in 0.01 feet increments. Measurements should be recorded to 0.01 feet resolution. Below is a photo of a typical WWBWC staff gauge.

1. Read the water level on the staff gauge to the nearest 0.01. If the water level is fluctuating during the reading take the average water level and note the range of fluctuation (1.25 ±0.04 where 1.25 is the average water level and 0.04 is the range above or below the average).
2. If water level fluctuations are excessive you can create a temporary stilling well around the staff gauge to get a more accurate reading. You can use a 5-gallon bucket with the bottom cut out for the temporary stilling well.
3. Take the necessary time to obtain an accurate staff gauge reading – both the water level and uncertainty.
4. Record the date, time and measurement data on the data sheet.

TAPE-DOWN STAGE MEASUREMENT

Measuring tape-down stage involves lowering a measuring tape with a weight attached to the end to the water surface from a reference point. Often the reference point is a metal washer attached to a bridge railing.

1. Locate the reference point
2. Lower the weighted tape down to the water surface. The weight should only just touch the water surface creating a small "V" shape on the water surface.
3. Read the tape at the edge of the reference point and record to the nearest 0.01. Include uncertainty caused by wave action or wind.

4. Because the weight is attached to the end of the measuring tape, record the correction factor that needs to be applied to the reference point reading.

LASER LEVEL STAGE MEASUREMENT

Laser levels are used to measure stage height from a known elevation and allow a check on the vertical staff gauge elevation.

1. Place the laser level on the platform of known elevation.
2. Confirm that the platform's elevation has not changed by measuring the elevation of reference marks/points with the stadia rod. Record data on the Stream Gage Logger Notes datasheet. Reference marks or points are placed near the laser level platform and are typically bolts in large boulders or other stable objects. Compare reference point elevations to ensure platform has not moved.
3. Place the stadia rod as close as possible to the primary staff gauge (typically the vertical staff gauge).
4. Read the laser level using the laser sensor on the stadia rod. Record level.
5. Observe and record the water level (including level of uncertainty) on the stadia rod.
6. Complete the calculations on the Stream Gage Logger Notes datasheet to compute the laser level stage. For the calculations you take the laser rod reading minus the depth of water and that equals the differential laser to water surface. Take the elevation of the laser beam minus the differential to get the laser level stage.

DISCHARGE MEASUREMENT (WADING)

1. Select an appropriate location to perform a discharge measurement (refer to Rantz, 1982 for full details). A good cross section will typically have the following characteristics: relatively straight channel with parallel edges, defined edges, uniform shape, free of vegetative growth and large cobbles or boulders, free of eddies, slack water and turbulence, depths greater than 0.5 feet, velocities greater than 0.5 feet per second that are evenly distributed, close to the gauging station. Often some or many of the above criteria cannot be met. The best available cross section location should be chosen.
2. Stretch a measuring tape across the channel where the measurement will be taken. The tape should be perpendicular to as much of the flow as possible to reduce oblique flow angles.
3. Determine the width of the wetted channel and divide the width into 25-30 segments. Cells should be divided such that each cell has approximately 5% of the total flow and no more than 10%. Segments should be shorter where flow is more concentrated or the bottom is irregular. The width of any segment should not be less than three tenths of a foot (0.3 feet).
4. Start at either the right or left edge of water (REW or LEW). Record tape distance for edge of water.
5. Set wading rod at location for the first measurement. Determine the depth of water.
6. If depth is less than 1.5 feet use the one point method of measuring velocity at 0.6 of the depth.
7. If depth is equal to or greater than 1.5 feet use the two point method of measuring at both 0.2 and 0.8 of the depth and average the velocities.
8. In cases where there is no logarithmic relationship to the velocities in the water column (this is when the 0.2 velocity is less than the 0.8 velocity or the 0.2 velocity is more than twice the 0.8 velocity) the three point method should be used. The three point method measures at 0.2, 0.6 and 0.8. The 0.2 and 0.8 velocities should be averaged and then that

result should be averaged with the 0.6 velocity. This weights the 0.6 velocity at 50% and the 0.2 and 0.8 each at 25%.

9. Each velocity measurement should average velocity data for 40 seconds to address variations in water velocity over time at a single measurement point.
10. If water flow direction is not perpendicular to the measuring tape the meter should be pointed directly into the direction of flow. Use the data sheet to measure the angle coefficient (and apply a correction to the velocity) for velocity measurements not perpendicular to the measuring tape (see figure below). Align the point of origin on the measuring tape. Rotate the data sheet until the opposite long edge is parallel to the direction of flow (the same direction the meter is pointed). The angle coefficient is read where the measuring tape intersects the data sheet. Multiply the velocity measurement by the angle coefficient to calculate the perpendicular velocity.

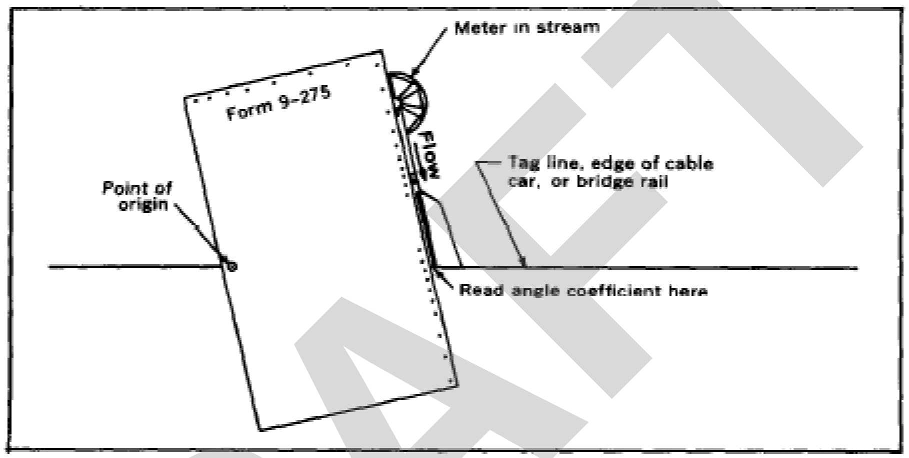


Figure taken from Rantz, 1982.

11. Repeat steps 5-10 for each of the subsequent measurement locations across the cross section until you reach the opposite edge of water.
12. Rate the measurement on a scale from excellent to poor. Rating can be based upon observed conditions as well as information from the AquaCalc file. Observations that can influence the rating of a measurement include (but are not limited to): channel characteristics, proximity to bridges or other structures, number and degree of oblique current angles, condition of equipment, weather, water level bounce and velocity pile up on wading rod and others. Use observations and professional judgment in rating a measurement. Measurements are rated excellent if the discharge value is with 2% of the actual flow value, good if within 5%, fair if within 8% and poor if within 13%.

DISCHARGE MEASUREMENT (BRIDGE)

This section will describe differences between wading and bridge discharge measurements. Follow the procedure for wading discharge measurements above with the following changes:

1. The choice of cross section locations is obviously limited when measuring from a bridge.
2. Use a bridge board, sounding reel, and Columbus weight instead of a wading rod
3. Increase velocities measurements near bridge piers

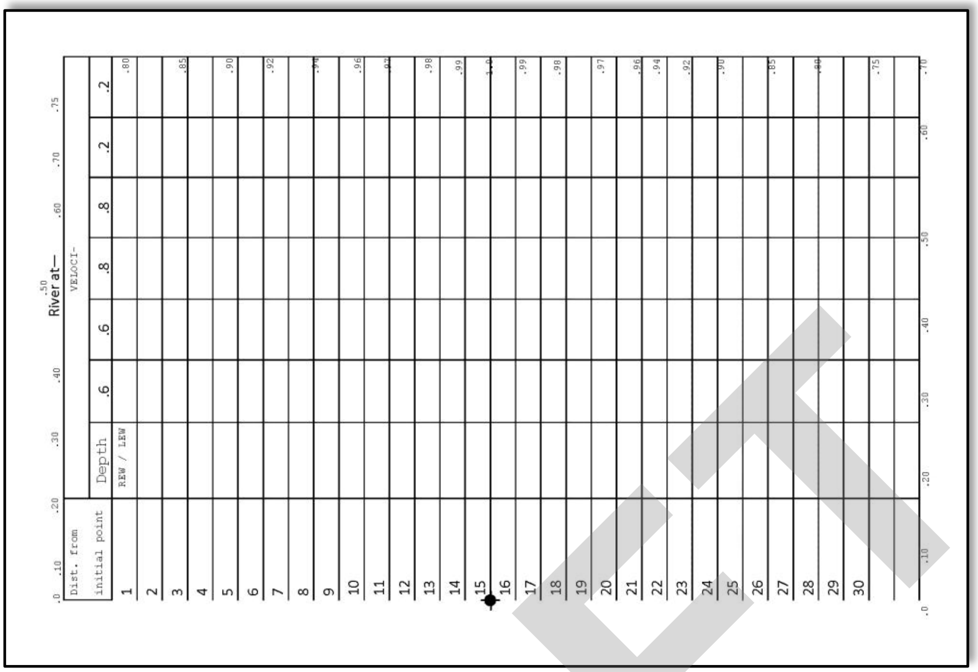
4. Use the one point method on depths less than 2.5 feet and the two point method on depths equal to or greater than 2.5 feet.
5. Sometimes, water flow direction is all oblique to the bridge. In these cases multiply the raw average velocity of the measurement by the cosine of the angle between current direction and the cross section.

STATION VISIT (WITHOUT DISCHARGE MEASUREMENT)

River gauging stations and real-time stations are visited twice a month to collect staff gauge readings, perform any site maintenance and download data. These visits do not include a discharge measurement.

1. Open gauge station and retrieve data sheet.
2. Record primary gauge reading in the PGI row (see above for procedure). This is often a vertical staff gauge.
3. Record secondary gauge reading in the SGI row (see above for procedure). Often this is a tape-down measurement.
4. Record auxiliary gauge reading if present in the AUX row. Used for alternate staff gauge readings.
5. Record water temperature from the gauge station.
6. Record water temperature with the NIST thermometer or the YSI-30.
7. Record air temperature from the gauge station.
8. Record air temperature from the NIST thermometer or the YSI-30.
9. Record battery volts.
10. Download data from the data logger and record on the data sheet.
11. Purge the pressure sensor (if equipped).
12. Record battery minimum and maximum.
13. Reset Stats screen.
14. Note any problems, maintenance issues or other information at the bottom of the data sheet.
15. Close and secure the gauge station.

DISCHARGE NOTES DATA SHEET



River at—

Dist. from initial point	Depth (REW / LEW)	VELOCI- .6	.6	.8	.8	.2	.2
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							
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17							
18							
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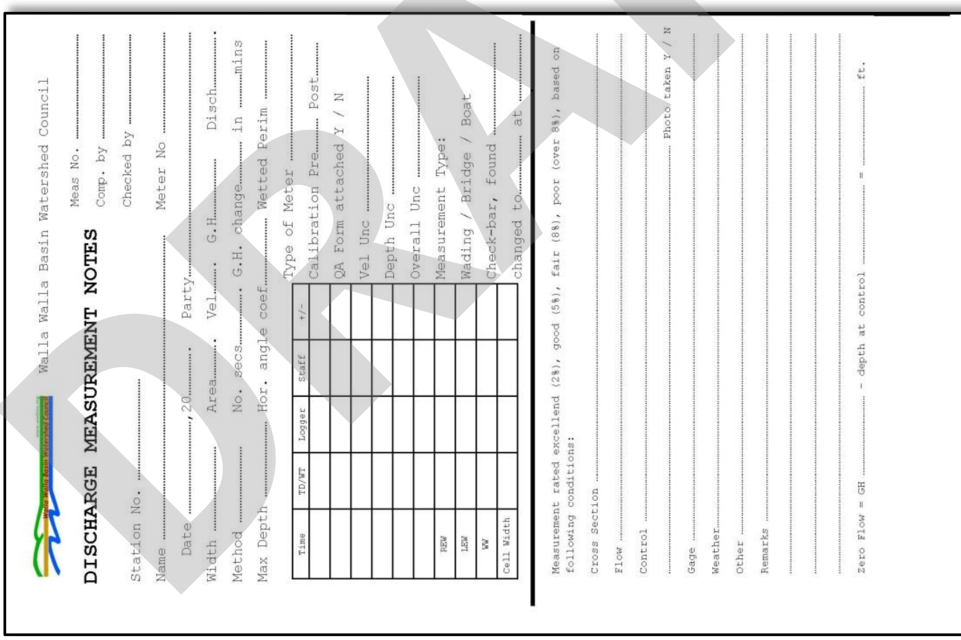


Walla Walla Basin Watershed Council

DISCHARGE MEASUREMENT NOTES

Meas No. ....

Comp. by ....

Checked by ....

Station No. ....

Name .... Meter No ....

Date ...., 20.......... Party..........

Width .... Area.......... Vel.......... G.H.......... Disch..........

Method .... No. secs.......... G.H. change.......... in ....mins

Max Depth .... Hor. angle coef.......... Wetted Perim ....

Time	TD/WT	Logger	Staff	+/-
REW				
LEW				
WW				
Cell Width				

Type of Meter ....

Calibration Pre.......... Post..........

QA Form attached Y / N

Vel Unc ....

Depth Unc ....

Overall Unc ....

Measurement Type:

Wading / Bridge / Boat

Check-bar, found ....

changed to.......... at ....

Measurement rated excellend (2%), good (5%), fair (8%), poor (over 8%), based on following conditions:

Cross Section ....

Flow ....

Control ....

.... Photo taken Y / N

Gage ....

Weather..........

Other ....

Remarks ....

Zero Flow = GH .... - depth at control .... = ... ft.

GAGING STATION LOG DATA SHEET

Walla Walla Basin Watershed Council

Gaging Station Log

Station Name: ____________________ Station Number ______________ Water Year _________

Party												
Date												
Time												
PGI												
SGI												
AUX												
LOGGER												
H20 TEMP.												
THERMISTOR												
AIR TEMP.												
THERMISTOR												
BATT. V												
REPLACED (Y / N)												
DOWNLOADED (Y / N)												
PURGE (Y / N)												
SYNCED (Y / N)												
SYSTEM RESETS												
BATT. V (MIN/MAX)												
RESET STAT SCREENS (Y / N)												
MEASUREMENT (Y / N)												
MGH												
MEASURED Q												
PROFESSIONAL RATING												
METHOD												
LOCATION												
MAX DEPTH												
MAX VELOCITY												
PZF												
CONTROL (LOCATION, CONDITION, ETC.)												

STREAM GAGE NOTES DATA SHEET

Batt V .... Min .... Max ....

Reset Stats Y / N Batt Replaced Y / N

GOES Time OK Y / N

Data Downloaded Y / N .NEW File Erased Y / N

Desiccant Condition .... Changed Y / N

CSG checked Y / N

HWM .... ft on stick + Ref Elev .... ft

= HWM Elev .... ft. Cleaned Y / N

Added Cork Y / N

Remarks:..................

Walla Walla Basin Watershed Council

WWBWC Stream Gage Logger Notes

Station name ....

Station # .... Party ....

DATE					
TIME (PST)					
LOGGER					
STAFF GAGE					
WIRE WEIGHT					
CHECK BAR					
TAPE DOWN					
CORR. FACTOR					
CORRECTED TD					
TD RP ELEVATION					
CORRECTED TD					
= WS ELEV @ TD					
LASER: LASER ROD READING					
- WATER SURFACE, ROD READING					
= DIFFERENTIAL, LASER TO WATER SURFACE					
LASER BEAM ELEVATION					
DIFFERENTIAL					
= STAGE					
WATER TEMP				ELEVATION	READING
THERMISTER			LL RP1		
AIR TEMP			LL RP2		
THERMISTER			LL RP3		

DRAFT

GROUNDWATER MONITORING

These procedures are for monitoring groundwater levels and groundwater temperature and specific conductivity. The procedure covers equipment needed, establishing a measuring point, manual water level measurements, pressure transducer deployment, download and maintenance, groundwater grab samples for temperature and specific conductivity and site maintenance.

Note: These procedures are modified from Drost, B.W., 2005, Quality-assurance plan for ground-water activities, U.S. Geological Survey, Washington Water Science Center: U.S. Geological Survey Open-File Report 2005-1126, 27 p.

EQUIPMENT

- E-tape (Solinst model 102 Water Level Meter)
- Laptop
- Extra pressure transducers (if available)
- Cables for downloading pressure transducers
  - LT-300
  - MicroDiver/Solinst
  - MicroDiver (direct connect cable)
  - Solinst (direct connect cable)
  - MiniTroll
- Bailer
- Graduated Cylinder
- Temperature and Conductivity meter (YSI 30)
- Sounding Tape
- Measurement tape (measured in tenths of a foot)
- Data sheet (waterproof paper)
- Pen (waterproof) or pencil
- Well keys
- Battery removal tool for MiniTroll pressure transducers
- GPS
- Extra Batteries (AA lithium for pressure transducers & 9v for E-tape)
- Flashlight
- Screwdrivers
- Hammer
- Pipe wrench
- Socket set
- Crescent wrench
- Cable snips
- Pliers (preferably needle-nose)
- Camera
- Well Field Instructions and Procedures binder
- WellNet binder for site references and maps
- Business cards
- U-bolts and cable crimps
- Inverter (for charging laptop from vehicle)
- Cable (speaker wire or 1/16" aviation cable)
- Extra sacrificial weights for E-tape
- Work gloves

- Disposable gloves (latex or nitrile)
- Disinfectant (Lysol or diluted bleach)
- Sharpie or other marking device (for measuring point)
- WD-40

Establishing a Measuring Point

This procedure is for establishing a measuring point on wells from which all water level are measured.

1. Measuring point (MP) must be permanent as possible, clearly defined and easily located. Typical locations include the top of the well casing or access ports.
2. MP should be located so that the measuring tape can hang freely during water level measurements.
3. Mark MP with Sharpie or other marker (paintstick, etc).
4. Measure distance from the MP to the land surface and record on the data sheet. This measurement is called the top of grade (TOG) for the well. MP's located below the land surface are positive and MP's located above the land surface are negative. If the well has been GPS surveyed, measure TOG from the MP to the surveyed elevation.
5. Take a photograph of the MP to document location Well Network Database or in case the marker wears off.

Manual Groundwater Level Measurement (E-tape)

1. Before measuring the water level in a well utilized for drinking-water supply, disinfect the first 5-10 feet of the E-tape with diluted bleach water and dry with single-use towels (e.g. Kimwipes). Use latex or nitrile gloves for drinking-water supply wells and disinfection.
2. Review well info page in the Well Network binder for the MP.
3. Record if the Pump is On (1) or Off (0) in the "Pump" field.
4. Test the E-tape by turning it to "test" or by pressing the "test" button. If the E-tape does not buzz, check the battery. Start with sensitivity set to the mid-range and adjust as necessary.
5. Carefully lower the tape (and weight) into the well. The tape should be lowered slowly to prevent splashing or excess wear on the E-tape.
6. When the E-tape buzzes, pull the tape up and down a few inches to determine the exact level. Hold the tape at the MP and record the value to the nearest 0.01 feet in the "Static" field.
7. Repeat water level measurement. If measurements differ by more than 0.02 feet determine why (well pumping, well recovering, etc) and document reason on data sheet.
8. Periodically check the E-tape to make sure it is in good working condition.

Pressure Transducer Deployment

1. Sound well and record measurement or, if available, consult the well log to determine well depth and pump location.
2. Take a manual water level measurement (see above) and record measurement on data sheet.
3. Program and start the pressure transducer. Pressure transducers should collect data every 15 minutes. Pressure transducer should be started so that data will be recorded on the hour (i.e. 12:00, 12:15, 12:30, 12:45, 13:00…). Program transducer with the well's GW

number. Follow the manufacturer's instructions on how to program and start the transducer.

4. Attached pressure transducer to one end of the cable using two wire crimps and a stainless steel U-bolt. Do not use crimps and do not over tighten the U-bolt if using a communication cable.
5. Measure and cut aviation cable or speaker wire to suspend the pressure transducer approximately 5-10 feet above the bottom of the well. This value can change depending upon the depth of the well and the pressure range of the pressure transducer. Make sure to not deploy the pressure transducer below its rated pressure range (typically marked on the side of the device). If the well is deeper than the pressure range, place the pressure transducer at a depth so there is 10-15 feet of pressure range still available (to account for potential water level increases). Pressure transducers should not rest on the bottom of the well or be surrounded by silts/fines that have accumulated in the well. Remember to account for the length of the logger when measuring the length of the cable.
6. If using a communication cable for the manufacturer, following the steps above to determine cable length.
7. Record length of cable, pressure transducer serial number and communication cable serial number if used.
8. Slowly lower pressure transducer and cable into the well making sure the transducer is not free falling. Take extra care as the transducer passes through the water-air interface to prevent damage to the transducer or entrainment of air bubbles.
9. Attach cable to the well at the surface using wire crimps and a stainless steel U-bolt.
10. Mark the cable so that cable slippage, if it occurs, can be accounted for during future site visits.
11. Make sure that all of the cable is deployed and the transducer is hanging on the cable rather than caught on a pump or some other obstruction.
12. Photograph the well to document the pressure transducer deployment and well. Try to capture the area around the well, any well apparatus and the measuring point. Multiple photos may be required.

Pressure Transducer Download and Maintenance

1. Record manual water level measurement, date, time and whether the well is being pumped.
2. Retrieve pressure transducer to the surface (if not attached to a communication cable).
3. Connect the pressure transducer, using the appropriate cable, to the field laptop.
4. Record the following information on the data sheet: Download start time (DL), Logger Time (LT – difference between pressure transducer time and computer time), Restart Time (RT – if the pressure transducer was stopped and restarted), Serial number (S#), Battery level (Batt - % of battery left or if batteries were replaced) and U-bolt and crimp conditions (Ubolts).
5. Follow manufacturer's protocol for downloading, saving and exporting data from the pressure transducer. Data should be saved in the proprietary format and in comma separated value format (.csv). File names should be in the following format: GW_xx_Data start date_Data end date_data collector's initials (For example: GW_129_3-3-11_7-6-11_sp – This file is for well GW_129 and the data in the file is from March 3rd through July 6th and was collected by Steven Patten).
6. Visually check the graphed data to ensure there are not any major issues that should be addressed. Raw data visual checks may be able to determine if the transducer came out of the water, the cable slipped/shifted or other issues that can be resolved through site

maintenance. Potential fixes could include readjusting/lengthening cable length or tighten U-bolts.

7. Note when the pressure transducer will run out of memory so a future visit will occur before that time.
8. Examine the pressure transducer for indications of damage or wear. Make sure access ports for the pressure diaphragm are clear of obstructions so the pressure transducer performs correctly.
9. Slowly lower transducer back into the well taking extra care as it transitions between air and water.

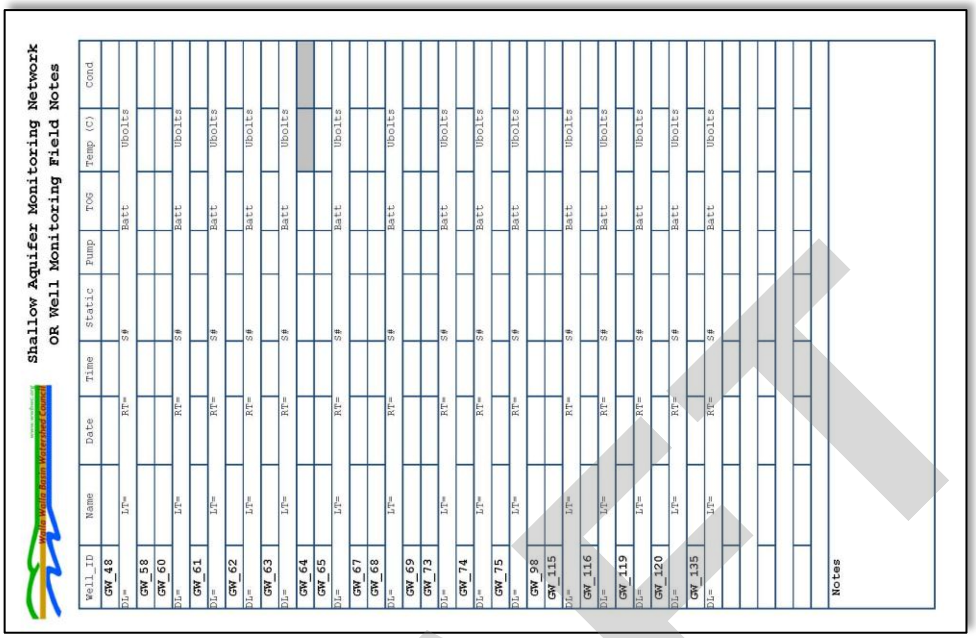
Grab Samples for Groundwater Temperature and Specific Conductivity

1. Check the bailer to determine if the string/cable is attached properly and that it is not frayed or damaged and that the bailer is in proper working order.
2. Slowly lower the bailer into well until is below the water level and fills with water. NOTE: Do not put the bailer down access or vent holes. If unsure do not put the bailer down the well. The data sheet indicates which wells should have water grab samples taken – if the temperature and conductivity fields are grayed out do not take a sample. The Well Network database also indicates whether a water grab sample should be collected.
3. Slowly reel the bailer back to the surface taking care to limit it banging/hitting the well casing.
4. Empty the water in the bailer into the graduated cylinder.
5. Put the temperature/EC probe into the water in the graduated cylinder.
6. Turn on the YSI-30 (temperature/EC meter). Ensure that the meter is correctly set to measure temperature in degrees Celsius and specific conductivity in µs/cm.
7. Wait for the reading to stabilize and then record temperature and conductivity values in their appropriate fields on the data sheet. In the summer or winter water temperature may increase or decrease depending upon the ambient air temperature. If the reading does not stabilize in 15-20 seconds, record the mean value over the 15-20 second period.
8. Turn off the YSI-30.
9. Discard water from the graduated cylinder.

Site Maintenance

1. Check the well casing and surrounding area for any changes that have occurred since the last field visit. If needed document the changes on the data sheet and with photographs.
2. Check TOG measurement approximately once a year to determine if there are any changes.
3. If well has not been surveyed in, survey well using Magellan ProMark 3 GPS system at earliest opportunity.
4. Check cable integrity and other well monitoring components for wear or damage. Replace as needed.
5. Photograph the site during every field visit to visually track changes to the site.

GROUNDWATER MONITORING DATA SHEETS



Shallow Aquifer Monitoring Network
OR Well Monitoring Field Notes

Well_ID	Name	Date	Time	Static	Pump	TOG	Temp (C)	Cond
GW_48								
DL=	LT=	RT=		S#		Batt	Ubolts	
GW_58								
GW_60								
DL=	LT=	RT=		S#		Batt	Ubolts	
GW_61								
DL=	LT=	RT=		S#		Batt	Ubolts	
GW_62								
DL=	LT=	RT=		S#		Batt	Ubolts	
GW_63								
DL=	LT=	RT=		S#		Batt	Ubolts	
GW_64								
GW_65								
DL=	LT=	RT=		S#		Batt	Ubolts	
GW_67								
GW_68								
DL=	LT=	RT=		S#		Batt	Ubolts	
GW_69								
GW_73								
DL=	LT=	RT=		S#		Batt	Ubolts	
GW_74								
DL=	LT=	RT=		S#		Batt	Ubolts	
GW_75								
DL=	LT=	RT=		S#		Batt	Ubolts	
GW_98								
GW_115								
DL=	LT=	RT=		S#		Batt	Ubolts	
GW_116								
DL=	LT=	RT=		S#		Batt	Ubolts	
GW_119								
DL=	LT=	RT=		S#		Batt	Ubolts	
GW_120								
DL=	LT=	RT=		S#		Batt	Ubolts	
GW_135								
DL=	LT=	RT=		S#		Batt	Ubolts	

Notes

Shallow Aquifer Monitoring Network
OR Well Monitoring Field Notes

Well_ID	Name	Date	Time	Static	Pump	TOG	Temp (C)	Cond
GW_04								
GW_05								
DL=	LT=	RT=		S#		Batt	Ubolts	
GW_06								
GW_07								
DL=	LT=	RT=		S#		Batt	Ubolts	
GW_08								
DL=	LT=	RT=		S#		Batt	Ubolts	
GW_09								
DL=	LT=	RT=		S#		Batt	Ubolts	
GW_10								
GW_11								
GW_13								
GW_14								
DL=	LT=	RT=		S#		Batt	Ubolts	
GW_28								
DL=	LT=	RT=		S#		Batt	Ubolts	
GW_31								
DL=	LT=	RT=		S#		Batt	Ubolts	
GW_33								
DL=	LT=	RT=		S#		Batt	Ubolts	
GW_34								
DL=	LT=	RT=		S#		Batt	Ubolts	
GW_35								
DL=	LT=	RT=		S#		Batt	Ubolts	
GW_36								
GW_37								
GW_38								
DL=	LT=	RT=		S#		Batt	Ubolts	
GW_39								
GW_40								
DL=	LT=	RT=		S#		Batt	Ubolts	
GW_41								
GW_45								
DL=	LT=	RT=		S#		Batt	Ubolts	
GW_46								
DL=	LT=	RT=		S#		Batt	Ubolts	
GW_47								
DL=	LT=	RT=		S#		Batt	Ubolts	

Water Temperature Monitoring

This procedure is for monitoring water temperature in rivers and streams using data loggers. The procedure covers equipment needed, pre & post deployment accuracy check, field accuracy check (site visits), deployment, and recovery.

Note: this procedure is modified from the Water Quality Monitoring – Technical Guide Book, 2001. Oregon Watershed Enhancement Board.

Equipment

- Data Logger (Vemco, Tidbit, etc)
- Laptop/Computer
- Computer interface cable for Data Logger
- NIST-traceable thermometer
- 1 medium sized cooler
- Ice
- Temperature Accuracy Check form (see below)
- 1 ½" PVC Pipe (to reduce temperature variations due to solar radiation)
- 1/16" aviation cable
- Wire cutters
- Cable crimps
- Pliers or other device to secure crimps and cut the cable
- Forestry Flagging/Surveyors Tape
- GPS unit
- Camera
- Waders
- Field Notebook
- First Aid Kit

Pre & Post Deployment Accuracy Check

1. For 20°C calibration test, pour room temperature water into the cooler. Adjust temperature in the cooler with ice, cold water or hot water to the desired 20°C. If ice is used make sure it is completely melted. Close lid.
2. Insert the NIST thermometer probe into the cooler. Pull it through enough so that when the lid is closed, the probe will be suspended midway (or slightly lower) in the water bath.
3. Use the computer and manufacturer's software to start the temperature data loggers and set them to record data every 1-minute.
4. Place temperature data loggers directly into the water bath.
5. Allow water bath to stabilize (for 15-30 minutes) before recording NIST thermometer temperatures. After stabilization, record temperatures from the NIST thermometer every minute for ten minutes. More readings may be necessary if there is suspicion the water bath temperature changed or was not stabilized.
6. Download data from the temperature data loggers and audit thermometer results with time of record on an audit form. Water temperatures should not vary more than ± 0.5°C between the NIST thermometer and the data logger's temperature. Units not passing this accuracy test should not be used.
7. Repeat accuracy test for cold water bath at 5°C.

Field Accuracy Checks (Site visits)

During a typical season of water temperature monitoring (June-November), two field accuracy checks will be conducted using the following procedure:

1. Determine if the data logger is still adequately placed in the river (see deployment procedure for details) to record water temperatures.
2. Place field thermometer (NIST thermometer) in the water directly next to the temperature data logger. (Note: if a NIST thermometer is not available use a thermometer with an accuracy of ± 0.5°C and a resolution of ± 0.2°C)
3. Allow field thermometer to stabilize and then record the temperature reading.
4. After the temperature data loggers have been retrieved and data download, compare the field thermometer's reading to that from the temperature data logger. Data accuracy should be ± 0.5°C.

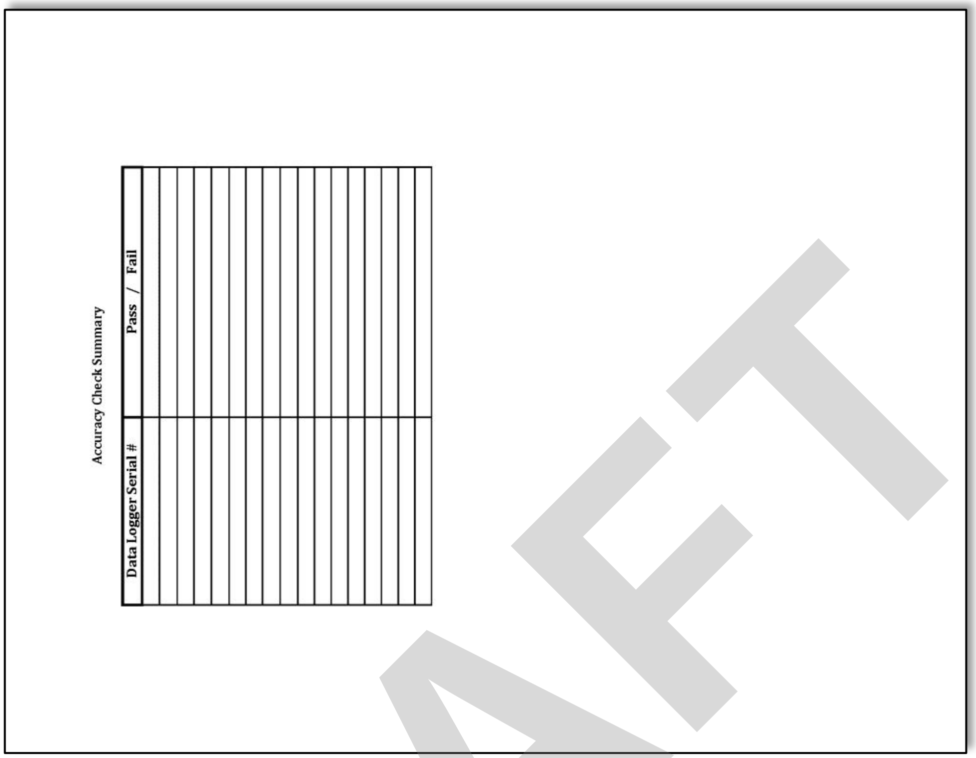
Deployment

1. Start temperature data logger either prior to going to the field or in the field with a laptop. Data loggers should be set to record data every thirty minutes. Data loggers should be set to start collecting data either at the hour or half hour (e.g. 12:00 or 12:30).
2. Secure data logger inside of the 1 ½" PVC pipe using the aviation cable ensuring that then entire length of the logger is covered by the PVC.
3. Secure data logger at the site using the aviation cable. Often the cable can be secured to trees, logs, large rocks or other stable structures. Make sure that the logger is in a well-mixed portion of the river to ensure accurate readings. Also, place the data logger to ensure that it will stay submerged in the water as river flows drop.
4. Record in the fieldbook the time of deployment and when the data logger will run out of memory for logging data. Record site name and data logger serial number. Check stream temperature as an additional accuracy check.
5. Record site GPS coordinates using a GPS unit.
6. Take pictures of site for future reference and recovery.
7. Write a short description and create a sketch of the site including approximate distances from structures (bridges, log jams, etc.).

Recovery

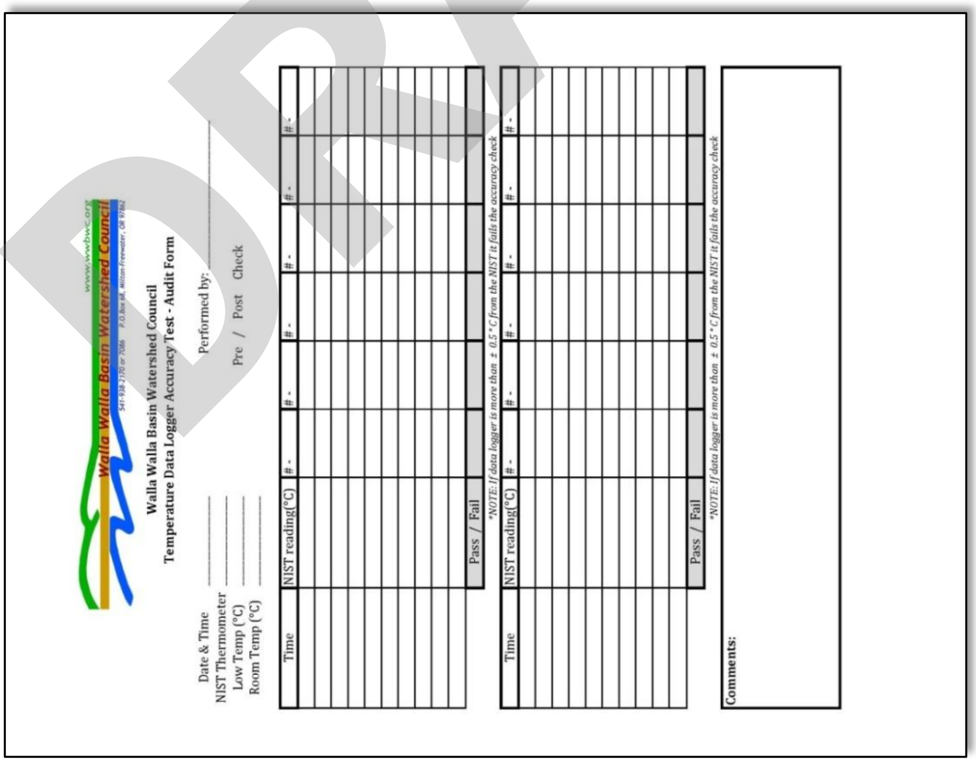
1. Locate Temperature data logger and check stream temperature with a field thermometer.
2. Record time of data logger recovery and note any site conditions that may have affected data accuracy or reliability. Cut the cable to free the data logger and return to the office and download the data. Data loggers should be stopped after data download to prevent unnecessary battery use.

PRE & POST DEPLOYMENT ACCURACY CHECK DATA SHEET



Accuracy Check Summary

Data Logger Serial #	Pass / Fail



Walla Walla Basin Watershed Council
Temperature Data Logger Accuracy Test - Audit Form

Date & Time ____________ Performed by: ____________
NIST Thermometer ____________
Low Temp (°C) ____________ Pre / Post Check
Room Temp (°C) ____________

Time	NIST reading(°C)	# -	# -	# -	# -	# -	# -	# -
	Pass / Fail							

NOTE: If data logger is more than ± 0.5 °C from the NIST it fails the accuracy check

Time	NIST reading(°C)	# -	# -	# -	# -	# -	# -	# -
	Pass / Fail							

NOTE: If data logger is more than ± 0.5 °C from the NIST it fails the accuracy check

Comments:

Scour Chains and Bed Stability

This procedure is for monitoring bed scour and fill to look at river bed stability and river bed conditions. The procedure covers the construction, installation and monitoring of scour chains (including cross-sectional surveys) and pebble counts.

Note: Scour chain procedures were based upon the following sources:

Lisle and Eads. 1991 Methods to measure sedimentation of spawning gravels. Res. Note PSW-411. Berkley, CA: Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture; 7 p.

Nawa and Frissell. 1993. Measuring Scour and Fill of Gravel Streambeds with Scour Chains and Sliding-Bead Monitors. North American Journal of Fisheries Management. 13: 634-639.;

Leopold, Wolman and Miller. 1964. Fluvial Process in Geomorphology. Freeman, San Francisco.

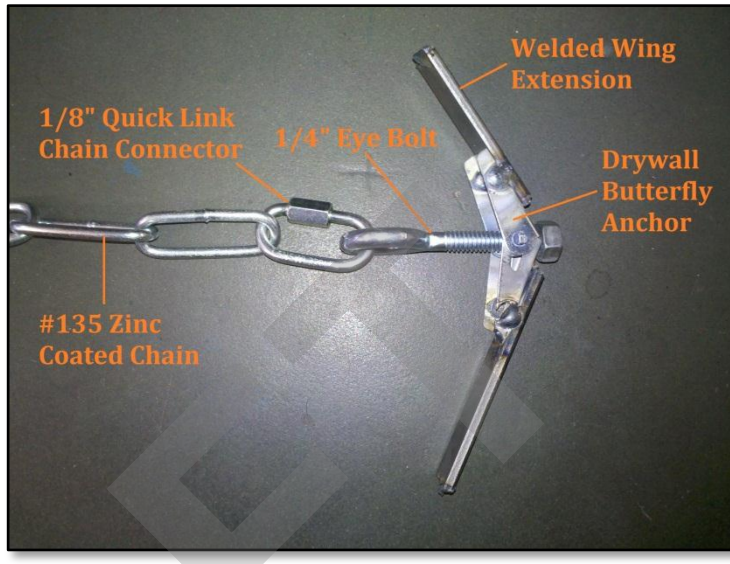
Pebble count procedures where based upon Wolman, M.G. 1954. A Method of Sampling Coarse River-Bed Material. Transactions of the American Geophysical Union. 35(6):951-956.

Equipment

- Scour Chains
  - 2.5-3.0 feet of #135 Zinc Coated Chain (links are ~1.5")
  - Chain Quick-Link Connector (1/8")
  - Anchor (Modified Drywall Butterfly Anchor)
  - Eye bolts
- 100' or 200' tape
- Waders (hip or chest)
- Laser Level with Stadia rod
- Flow meter
- Shovel
- Hand Trowel
- Fence Post Driver
- 1 ½" galvanized steel pipe
- 1" metal rod
- Rubber bands
- Fishing line
- Forestry Flagging Tape
- Pipe Wrenches
- Data Sheets or Field Notebooks
- Pen or Pencil
- First Aid Kit

Scour Chain Construction

Scour chains are constructed by WWBWC staff to help reduce costs. Scour chain anchors are created by modifying drywall butterfly anchors (1/4" bolt/screw). Extensions (1/2" flat metal) are welded to each wing of the anchor creating ~2-3 inch wing on each side. Eye bolts are then welded on to the anchor to prevent them from detaching. A ~2.5-3.0 foot section of #135 chain is attached to the eye bolt with a quick link chain connector. See figures below.



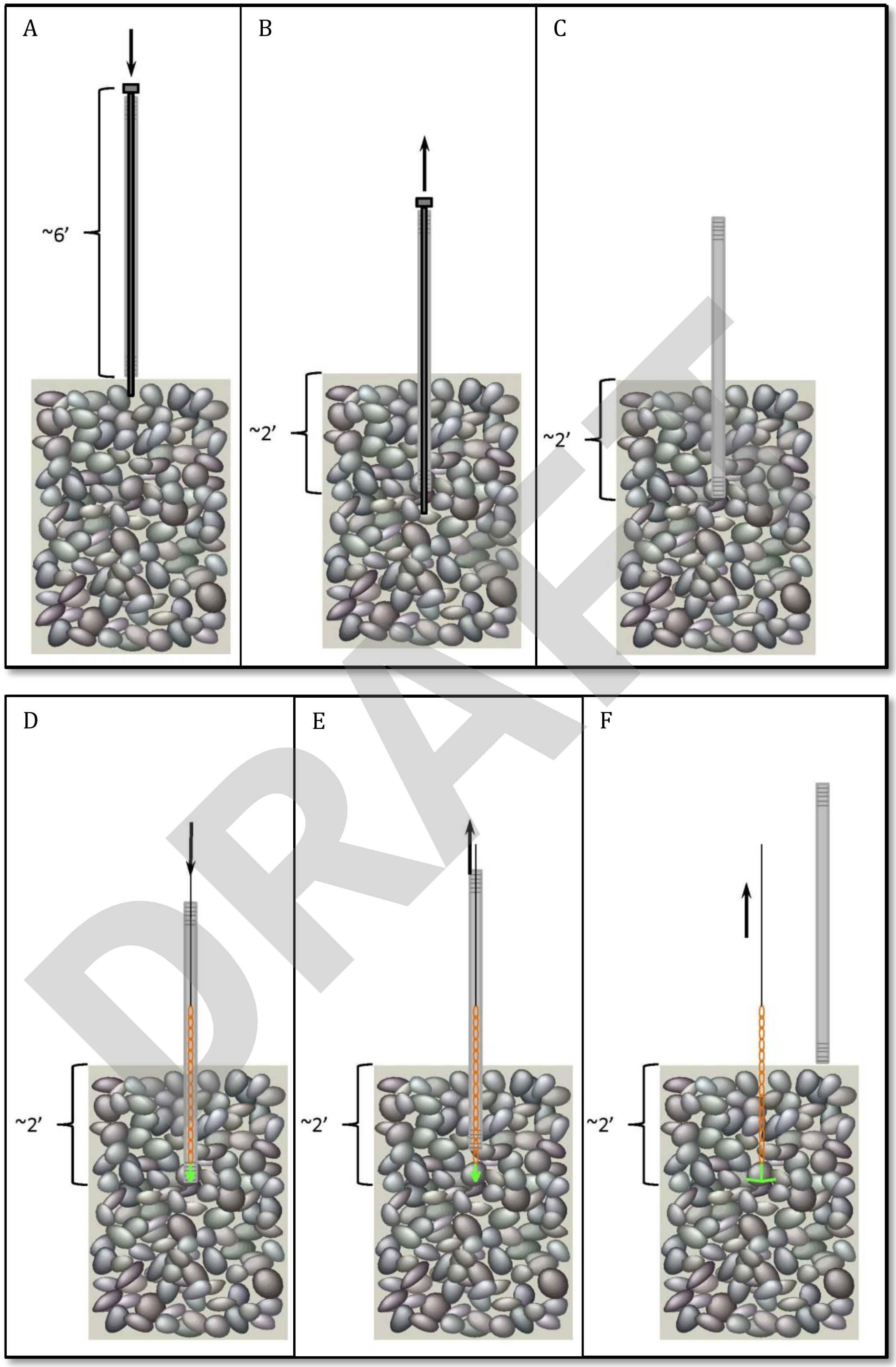
SCOUR CHAIN INSTALLATION

Scour chains are installed perpendicular to the direction of flow in the river (similar to a discharge measurement). 4-5 chains are typically installed across the width of the river, but this will increase or decrease depending upon the width of the river. Chains are installed approximately 10-12 feet apart across the channel.

1. Determine location for scour chain installation.
2. Establish a control point on both banks. Make sure the location of each control point is as stable as possible and will not be damaged by higher flows. Preferably the control points should be located above the bank full width to avoid frequent flood damage. Drive a piece of ½" rebar into the ground as far as possible. Place a blue WWBWC control point marker on the end of the rebar and flag it with forestry flagging.
3. Run a tape across the width of the channel between the control points on either bank. You can tie off the tape to the control points or to rocks/trees on the shore. If not tying off to the control points make sure the tape goes directly over each of the control points.
4. Determine the width of the river – typically this will be the bank full width as to capture river scour/fill influences during frequent high flow events.
5. Decide how many scour chains to install based upon width. Chains are installed ~10 feet apart. So if the river is 40 feet across plan on installing 4 chains.
6. Divide the river into approximately even sections and make note where each scour chain should be installed. The exact location of each chain will vary side to side by a small amount based upon sediments present at each location (see 7 below).
7. Drive pipe and metal rod into the river bed substrate using the fence post driver to a depth of ~2 feet. Because river bed sediments in the Walla Walla Basin are often gravels and

cobbles (and sometime boulders) you may have to try multiple locations to find a successful spot where the pipe can be driven in ~2 feet (Figure A).

8. Remove metal rod from inside the pipe. Be sure to not remove the pipe. You may have to turn the metal rod using pipe wrenches to loosen it before it can be removed. (Figure B & C)
9. Prepare a scour chain anchor with ~2.5-3.0 feet of chain attached to it with the 1/8" quick link connector. Attach fishing line to the end of the chain to allow it to be lowered into the pipe. Count the number of links and record on the datasheet or in the field notebook.
10. Use a small rubber band to hold the two wings of the anchor device together so it will slide down into the pipe. When the anchor wings are held together the anchor is considered "closed" and when the rubber band is removed to allow the wings to spring apart the anchor is considered "open." Tie fishing line on to the rubber band so it can be pulled off and allow the wings to spread and anchor the device.
11. Slowly slide the "closed" anchor down the inside of the pipe (Figure D).
12. Once the anchor is at the bottom of the pipe (make sure by slowly pulling up and dropping the anchor) gently lift the pipe 6-8" upwards. This should allow the "closed" anchor to be exposed to the sediments (Figure E).
13. Pull on the fishing line attached to the rubber band to release the wings and "open" the anchor.
14. Remove the pipe completely making sure to keep holding the fishing line attached to the chain to prevent the chain from falling into the hole.
15. Gently pull up on the chain/fishing line to set the anchor in the sediments. Once the anchor is set you can pull harder to verify it is solidly anchored (Figure F).
16. Count the number of links that are exposed above the river bed and lay chain downstream. Record number of links on the data sheet or in the field notebook (Figure G).
17. Take note of the distance from both the left and right bank control points to the scour chain.
18. Repeat process for the other scour chains to be installed in the set.
19. After all scour chains have been installed conduct a perpendicular channel survey (see below for procedure). Scour chain location accuracy is extremely important for finding each scour chain in the future especially since some chains will be covered by sediments.
20. Also conduct a river discharge measurement at or near the site (see above for procedure).


A
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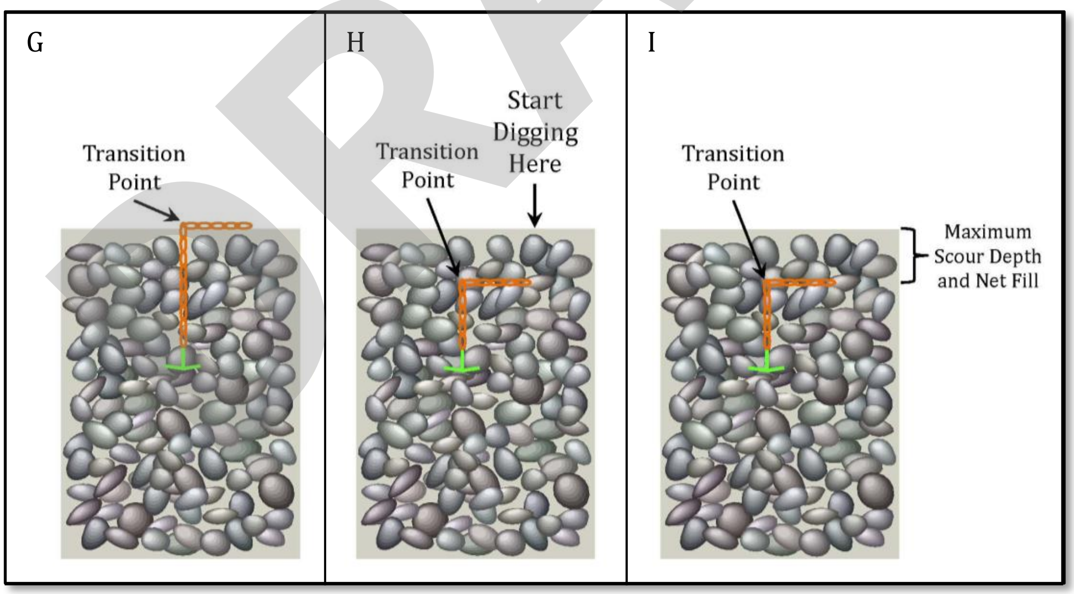
SCOUR CHAINS SCOUR/FILL MONITORING

This procedure will provide information on how to locate and measure scour chain data. Data collected at each chain will provide information on maximum scour since the last monitoring and net fill since last monitoring.

1. Locate both left and right bank control points.
2. Using a 100' or 200' tape, measure from the control points to the find the scour chain closest to the right bank (you can also start near the left bank if that is more convenient). Note – refer back to installation notes on datasheet or the field notebook to determine the location for each scour chain.
3. Once you have determined the location for the first scour chain, look to see if the chain is exposed. If the chain is not exposed on the river bed it may be buried under the sediments. Carefully and slowly dig just downstream of where the chain was installed. Dig until you find the chain and then slowly work upstream until the chain changes from lying horizontally to vertical. This transition point is the maximum scour depth. (Figure G & H)
4. Measure the vertical distance between the transition point and the river bed surface (see figures below). (Figure I)
5. Count the number of links from the transition point to the end of the chain. This can be used to verify the vertical measurement taken in step 4.
6. Hold scour chain vertically while excavated sediments are replaced.
7. Count the number of links that are exposed above the transition point (on the river bed surface).
8. Place the exposed chain on the river bed surface facing downstream.
9. Repeat process for other scour chains in the set.



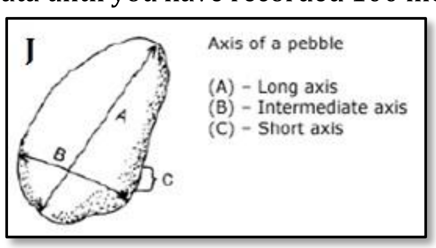
CHANNEL SURVEY

This procedure provides information for preforming a channel survey for scour/fill within a scour chain set. All changes are relative to the control point(s) established for the scour chain set (see above).

1. Place the laser level in a location where it will be visible when measuring at each scour chain in the set and visible at each control point.
2. Adjust laser as close to level as possible.
3. Turn on laser and allow it to auto level. Once the laser has leveled it should start spinning. If it does not the laser may be tilted too much and cannot level itself – turn the laser off, readjust it and turn it back on to auto level.
4. Stretch a 100’ or 200’ tape across the channel. Make sure the tape goes directly over each of the control points.
5. Take the stadia rod with the laser sensor attached to the control point on the right bank (you can start on the left bank if that is more convenient). Place the stadia rod on the control point and read the height with the laser sensor. Record laser height value, depth of water and the tape distance on the datasheet or field notebook.
6. Continue measuring height and tape distance values as you move across the channel until you reach the opposite control point. Make sure to capture changes in the river bed as well as important locations such as edge of water, gravel bars, thalweg and each scour chain.
7. Return to the first control point and measure the height and tape distance a second time to verify that the tape or the laser has not moved.

PEBBLE COUNTS

1. Select reach of the river for sediment particle size distribution (typically between two closely spaced scour chains sets).
2. Start transect randomly between the scour chain sets by throwing a rock along the stream edge. Take a step into the river, perpendicular to the flow, from that point and pick up the first pebble you touch with your index finger next to your big toe. Avert your eyes to prevent as much bias as possible when pick up pebbles.
3. Measure the intermediate axis (see Figure J below) by determining the smallest hole the pebble will fit through using the gravelometer. For embedded pebbles or those too large to pick up, use the side of the gravelometer to measure the shortest visible axis
4. Record info on the datasheet.
5. Take another step across the river and repeat the steps of picking and measuring pebbles until you reach the opposite bank. Once you reach the opposite bank, throw another rock and start back towards the first bank repeating the steps above.
6. Continue collecting pebble data until you have recorded 100 measurements.



PEBBLE COUNT DATA SHEETS

Data Computation

Inches	PARTICLE	Millimeters		Particle Count	Total #	Item %	% Cum
< 0.08	Sand	< 2	Silt/Clay/Sand				
0.08—0.16	Very Fine	2—4	Gravels				
0.16—0.22	Fine	4—5.7					
0.22—0.31	Fine	5.7—8					
0.31—0.44	Medium	8—11.3					
0.44—0.63	Medium	11.3—16					
0.63—0.89	Coarse	16—22.6					
0.89—1.26	Coarse	22.6—32					
1.26—1.77	Very Coarse	32—45					
1.77—2.5	Very Coarse	45—64					
2.5—3.5	Small	64—90	Cobbles				
3.5—5.0	Small	90—128					
5.0—7.1	Large	128—180					
7.1—10.1	Large	180—256					
10.1—14.3	Small	256—362	Boulders				
14.3—20	Small	362—512					
20—40	Medium	512—1024					
40—80	Large	1024—2048					
80—160	Very Large	2048—4096					
	Bedrock		Bedrock				
			TOTALS				

Walla Walla Basin Watershed Council
www.wwbwc.org
541-938-2170 or 7086 P.O.Box 68, Milton-Freewater, OR 97862

Walla Walla Basin Watershed Council

Pebble Count Datasheet

Date & Time ____________ Site Name: ____________

Data Collected by: ____________ GPS Coord: ____________ River/Stream: ____________

Data #	Largest Size b-axis will fit through	Data #	Largest Size b-axis will fit through	Data #	Largest Size b-axis will fit through	Data #	Largest Size b-axis will fit through
1		26		51		76	
2		27		52		77	
3		28		53		78	
4		29		54		79	
5		30		55		80	
6		31		56		81	
7		32		57		82	
8		33		58		83	
9		34		59		84	
10		35		60		85	
11		36		61		86	
12		37		62		87	
13		38		63		88	
14		39		64		89	
15		40		65		90	
16		41		66		91	
17		42		67		92	
18		43		68		93	
19		44		69		94	
20		45		70		95	
21		46		71		96	
22		47		72		97	
23		48		73		98	
24		49		74		99	
25		50		75		100	

NOTES:

SEEPAGE ANALYSIS

Seepage analysis protocols are discussed in the Seepage Report (found on the WWBWC website – www.wwbwc.org). The WWBWC performs seepage analyzes on multiple stream systems within the Walla Walla Basin to determine the water budget for each system and to determine gain/loss reaches. The primary measurement procedure used during a seepage analysis is a stream discharge measurement. The procedure described above for stream discharge measurements is used during seepage measurements.

WATER QUALITY MONITORING (FIELD MEASUREMENTS)

WATER TEMPERATURE AND CONDUCTIVITY (YSI-30)

1. Check sensor calibration to NIST thermometer and standard conductivity solution (typically done in the office before field visit). Recalibrate if necessary.
2. Turn the YSI-30 unit on.
3. Make sure units are set to °C for temperature and to µs for conductivity.
4. Gently place the sensor in the water. Make sure that the sensors are completely covered by water.
5. Allow the values to stabilize and then record on the data sheet or field notebook.
6. Replace the sensor in the holder and turn the unit off.

DISSOLVED OXYGEN

1. Connect the dissolved oxygen sensor to the meter.
2. Turn on the Thermo Scientific Orion 5-Star meter.
3. Check sensor calibration (typically done in the office before field visit). Recalibrate if necessary.
4. Make sure units are set correctly for dissolved oxygen (mg/L).
5. Gently place the sensor in the water. Make sure that the sensor is completely covered by the water.
6. Allow the value to stabilize and then record on the data sheet or field notebook.
7. Replace the sensor in the holder and turn the unit off.

PH

1. Connect the pH sensor to the meter.
2. Turn on the Thermo Scientific Orion 5-Star meter.
3. Check sensor calibration using a standard pH solution (typically done in the office before field visit). Recalibrate if necessary.
4. Gently place the sensor in the water. Make sure that the sensor is completely covered by the water.
5. Allow the value to stabilize and then record on the data sheet or field notebook.
6. Replace the sensor in the holder and turn the unit off.

Conductivity

1. Connect the conductivity sensor to the meter.
2. Turn on the Thermo Scientific Orion 5-Star meter.
3. Check sensor calibration using a standard conductivity solution (typically done in the office before field visit). Recalibrate if necessary.
4. Gently place the sensor in the water. Make sure that the sensor is completely covered by the water.
5. Allow the value to stabilize and then record on the data sheet or field notebook.
6. Replace the sensor in the holder and turn the unit off.

Turbidity

1. Turn on the Hach 2100P Turbidimeter.
2. Check sensor calibration using a standard turbidity solution (typically done in the office before field visit). Recalibrate if necessary.
3. Collect water sample in glass vial and wipe clean. Insert the vial into the turbidimeter, cover and read the sample.
4. Record the value on the data sheet or field notebook.
5. Empty the vial and turn on the meter.

Quality Control

Quality Control for Laboratory Measurements

Field duplicates and blanks will be used to ensure quality control for lab samples.

- Field blanks: Once per sampling even a blank sample with known concentrations of the monitored constituent will be included in the samples sent to the analytical laboratory. The field blank will be purchased from a scientific supply vender.
- Field duplicates: Once per sampling event one additional sample will be collected from one of the sites.
- Analytical laboratory will also have internal QA/QC procedures to ensure data validation.

Quality Control for Field Measurements

Field Records

Field notes and other pertinent data associated with the monitoring program will be maintained at the WWBWC office and archived for reference. Completeness of data sheets and chain of custody forms and verifying holding times for samples will also be used for data validation.

Surface Water Monitoring

Surface water monitoring will use the following quality control measures:

- Measure a duplicate discharge measurement on approximately 5% of field visits.
- Field equipment will be maintained and calibrated to ensure proper operation and accuracy.
- Comparison of equipment to other equipment or rated structures (such as flumes, etc).
- Primary and secondary stage height values are referenced to benchmarks to ensure no elevation changes.
- Comparison of primary, secondary and laser level stage height values.

Groundwater Monitoring

Groundwater monitoring will use the following quality control measures:

- Yearly comparison of E-tape measurements against other tapes.
- Duplicate groundwater level measurements during every field visit.
- If available, comparison of manual measurements to other agencies' data.
- Duplicate water sample for groundwater temperature and conductivity at approximately 5% of the sites.

Water Temperature Monitoring

Water temperature monitoring will use the following quality control measures:

- Pre and Post data logger accuracy testing.
- Manual field checks during deployment.

Water Quality Monitoring

Water quality monitoring will use the following quality control measures:

- Field equipment will be maintained and calibrated to ensure proper operation and accuracy.
- Duplicate samples will be taken at approximately 5% of the sites.
- Comparison of field and laboratory values.

Data Management Procedures

Field Notes

In The Field

Data should be recorded on WWBWC datasheets (if available) printed on waterproof paper (Rite-in-the-Rain). Notes should be clearly and legibly written so data and remarks are easily read and interpreted. If a mistake is made, draw a single line through the bad data and record the data next to it. Do not erase or completely mark out mistakes. All datasheets should be completed as fully as possible during data collection.

At The Office

Upon returning to the office scan all datasheets and place a scanned copy on the WWBWC server in the appropriate location and incorporated into the AQUARIUS database. After scanning the datasheets, use them to input the data into the appropriate software (AQUARIUS, Excel, etc.). After all data from the datasheet has been incorporated into the software, place the datasheet in the projects 3-ring binder.

Data Loggers

In The Field

Data loggers should be downloaded during every site visit if practical. Data from the data logger should be downloaded and saved to the field laptop before the data logger file(s) is deleted or restarted to ensure data is not lost. After restarting a data logger take note of when the logger's memory will be full so a site visit can be scheduled before that date. Files should be saved in the following format: type of file (gh = gauge height, mmt = measurement and temp = temperature)_site number_data start date_data end date_downloader's initials. For a surface water example the file format for site S105 with stage data from March 1st, 2012 through July 15th, 2012 and downloaded by Steven Patten would look like: gh_S105_3-1-12_7-15-12_sp. For a groundwater example the file format for site GW_115 with water level (stage) data from May 1st, 2012 through September 29th, 2012 and downloaded by Steven Patten would look like: gh_GW115_5-1-12_9-29-12_sp.

At The Office

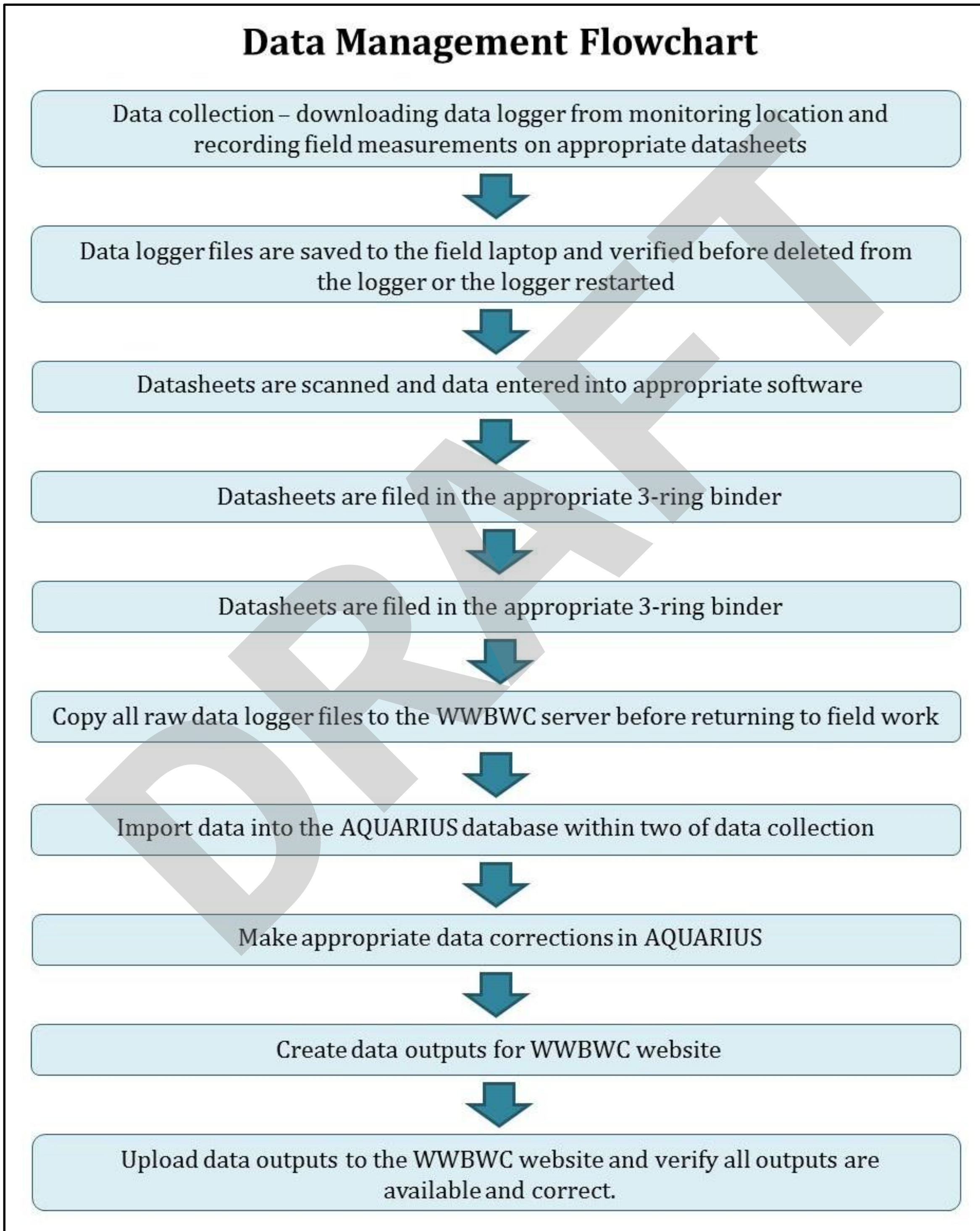
All raw data logger files collected during a day of field work should be transferred to the WWBWC server before going back out in the field to ensure data is not lost due to laptop failure or damage.

Data Input (AQUARIUS)

Data should be incorporated into the AQUARIUS database within two weeks of data collection. Both manually collected data and data logger files should be imported into the AQUARIUS database. After data has been imported, data should be adjusted to account for stage shifts or cable length corrections. For surface monitoring locations, the rating curve should be checked to ensure the new discharge measurement does not indicate a change in the stream channel. If needed, adjust the rating curve with the new discharge measurement. After data are imported and corrected, outputs should be created including a hydrograph (or similar data graph), hourly data set for the entire range of data, and daily average data set for the entire range of data. All data in AQUARIUS should be rated as "unverified" until the end of the water year (Sept 30th) and a review of the entire water year's data can be completed.

Data Access (WWBWC Website)

AQUARIUS data outputs should be uploaded to the WWBWC's website (typically accomplished through Fling software). Verify that all data outputs have been successfully uploaded to the website for public and agency access. Data and information for each surface monitoring location includes: current hydrograph, hourly data set, daily average data set, rating curve, metadata and site photograph. Data and information for each groundwater monitoring location includes: current hydrograph, hourly data set, daily average data set, metadata and manual water level measurements.



Data Security and Backups

All data incorporated into the AQUARIUS database or located on the WWBWC server has redundancy backup (i.e. stored on multiple hard drives through the use of RAID). The WWBWC server and AQUARIUS database are backed-up monthly and stored at the WWBWC office and off-site for additional security.

Data Quality Assessment

Initial Posting of Data/Near-Real Time Data

All data posted to the WWBWC website should be considered provisional unless otherwise stated. Near-real time data from surface gauges and other sites goes through an automated process without constant human oversight. Data discrepancies will be fixed as soon as possible. Until data is reviewed and published (see below) data quality will remain "unverified" or "provisional" and are subject to change. Data may be given an initial estimated data quality (estimated excellent, good, fair or poor) however this quality rating should be considered provisional and subject to change during review.

Data Quality Review

After each water year (typically in October), "unverified" or "provisional" data will be reviewed by WWBWC staff and any necessary changes will be made. After any revisions, data quality will be changed to "published" and a quality grade will be assigned. The published data will be available at the WWBWC's website

Data Quality Rating

Surface Water

Surface water data will be given a quality rating based upon the following factors:

- Rating curve distribution and number of discharge measurements for rating curve development.
- Accuracy of discharge measurements to calculated discharge flow from stage data.
- Site maintenance issues including sediment build-up, vegetation growth, channel migration and other localized influences.
- Accuracy of individual discharge measurements including variation in duplicate discharge measurements.
- Gauge location (e.g. concrete structure, silty channel, or stable stream bed).
- Site manipulation (especially in irrigation canals or ditches).
- Data set completeness.

All stage height measurements will include a margin of error.

GROUNDWATER

Groundwater data will be given a quality rating based upon the following factors:

- Number of manual water level measurements.
- Accuracy of manual water level measurements to cable-length adjusted transducer data.
- Accuracy of manual water level measurements (e.g. cascading well, pumping well, etc.).
- Data set completeness

All manual water level measurements will include a margin of error.

TEMPERATURE

Temperature data will be given a quality rating based upon the following factors:

- Accuracy of data logger's Pre and Post deployment accuracy checks.
- Accuracy of field accuracy checks with thermometer (NIST or YSI-30).
- Data set completeness.