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Hudson Bay Aquifer Recharge Testing Project

2004 Annual Report

11/22/2004

<u>Project Team</u>

Construction/Operation: Jon Brough, Hudson Bay District Improvement Company

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November 22, 2004

TO: Hudson Bay District Improvement Company (HBDIC)
Oregon Water Resources Department (OWRD)
Oregon Department of Environmental Quality (ODEQ)
Oregon Department of Fish and Wildlife (ODFW)
Confederated Tribes of the Umatilla Indian Reservation (CTUIR)
Washington Department of Ecology (WDOE)
Walla Walla Watershed Alliance (WWWA)
Oregon State University

From: Bob Bower, Hydrologist-WWBWC (Principal Author)

RE: **2004 Annual Report**: ***Hudson Bay Aquifer Recharge Project.***

Table of Contents:

Introduction:

The Hudson Bay Aquifer Recharge project was designed to test aquifer recharge as a tool to stabilize and restore declining aquifer levels and spring flows in the Walla Walla River valley. This project has been developed as a collaborative effort between the Walla Walla Basin Watershed Council (WWBWC) and Hudson Bay District Improvement Company (HBDIC). Funding, technical-support and permitting has been provided by the Oregon Watershed Enhancement Board (OWEB), Walla Walla Watershed Alliance (NRCS funds), Oregon Water Resources Department (OWRD), Oregon Department of Environmental Quality (ODEQ), Oregon State University Extension, HBDIC and the WWBWC. *In-Situ Inc* also provided a reduction in cost of the monitoring equipment for the project. This report was generated as outlined in the HBDIC Recharge Project monitoring plan application to OWRD.

The Hudson Bay Aquifer Recharge Project was operated from April 8th until May 15th, 2004 under a Limited License Request (#758) from Oregon Water Resources Department. The conditions and limitation of the permit included: "The use of water from the Walla Walla River shall be limited to 50 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 stream flows 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 Nursery Bridge Dam: November – 64 cfs, December and January – 95 cfs, February to May 15 – 150 cfs."

The HBDIC Aquifer Recharge Project is operating over a 5 years period as allowed under the OWRD limited license. Management of site operations and monitoring will be adapted to issues and opportunities in each successive recharge season. Project information will be shared as it becomes available.

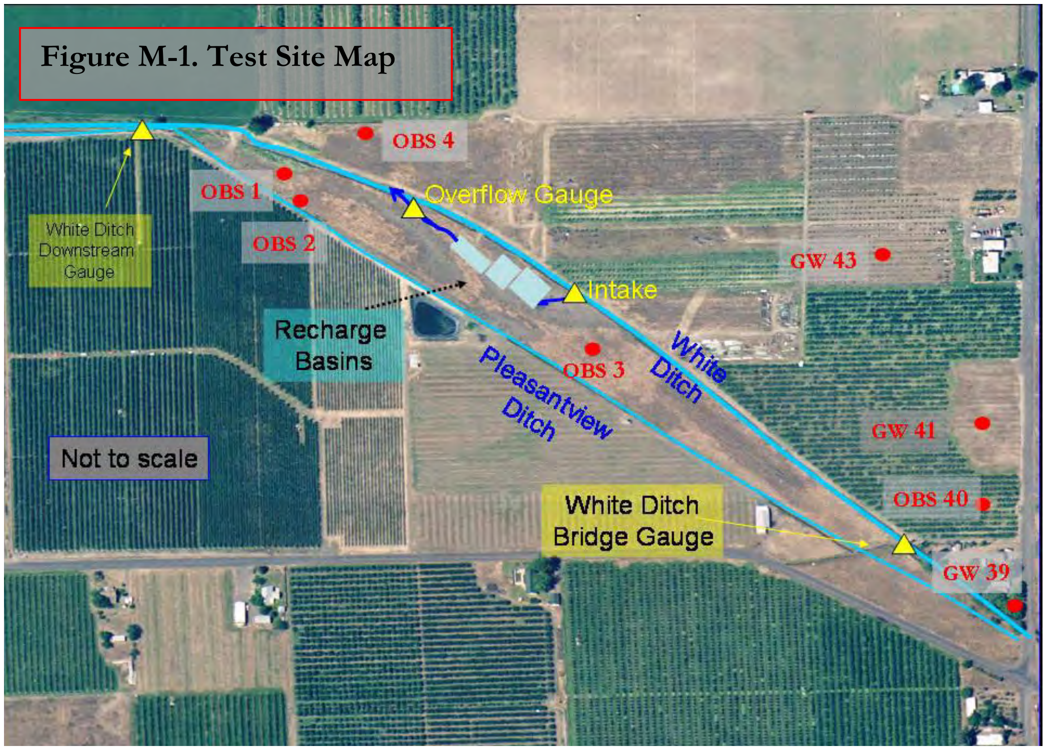
Spring 2004 Project Timeline:

1. Application sent to OWRD for limited license on October 20th, 2003
2. Limited License Application approved on February 18th, 2004.
3. Monitoring well construction completed on March 10th, 2004
4. Concrete intake structure completed on/around March 25th, 2004
5. Monitoring equipment installed March 10th to April 8th, 2004
6. Water Quality sampling March 10th, 2004 (OBS-1)
7. Recharge basins and overflow construction period April 4th to April 20th, 2004
8. Recharge Project begins operation April 8th, 2004
9. Water Quality sampling April 13th, 2004 (OBS-1, Intake)
10. Recharge Project shutdown May 15th, 2004
11. Water Quality sampling May 21st, 2004 (OBS-1)

Recharge Test Site Construction

The project was built to specifications outlined in the original OWRD application (Bower et. al., 2003). An aerial map with graphical representation of the general site lay out shows the approximate locations of the three recharge basins (50 x 100'), intake structure, overflow Ditch and the four on-Test Site monitoring wells (OBS-1, 2, 3, 4)[1] (see Figure M-1) . The location of the Ditch flow gauges (for Ditch loss analysis) and other shallow aquifer wells currently being monitored by the WWBWC are also shown.

[1] This report was authored jointly and notation for the Test Site observation (monitoring) wells varied by author. The wells are as follows OBS-1 = MW-1, OBS-2 = MW-2, OBS-3 = MW-3 and OBS-4 = MW-4.



Monitoring Well Construction

Four monitoring wells, MW-1 (OBS-1), MW-2 (OBS-2), MW-3 (OBS-3) and MW-4 (OBS-4), were drilled and built at the Test Site between 09 March 2004 and 10 March 2004. The figure above shows the approximate locations of these wells. Well construction information for each well is shown on Figures 2 (in Appendix A) through 5 and summarized below.

- Well MW-1 (OBS-1) (Figure 2 in Appendix A) is a 4-inch diameter well installed to a total depth of 67.75 feet bgs. The screened interval extends from 17 to 67.75 feet bgs.

- Well MW-2 (OBS-2) (Figure 3 in Appendix A) is a 2-inch diameter well installed to a total depth of 60 feet bgs. The screened interval extends from 15 to 60 feet bgs.

- Well MW-3 (OBS-3) (Figure 4 in Appendix A) is a 2-inch diameter well installed to a total depth of 71 feet bgs. The screened interval extends from 16 to 71 feet bgs.

- Well MW-4 (OBS-4) (Figure 5 in Appendix A) is a 2-inch diameter well installed to a total depth of 61 feet bgs. The screened interval extends from 16 to 61 feet bgs.

All four wells have 0.02 slot screen and 10-20 silica sand filter pack that extends from the bottom of the well to approximately 2 feet above the top of the screen. A bentonite seal extends from the top of the sand filter pack to the base of the concrete surface monument in all four wells. All surface monuments are flush with the ground surface and all four wells were drilled using a reverse air-rotary, dual-wall drilling system.

Overview of Test-Site Geology and Hydrogeology

Test Site hydrogeology was initially reviewed in a 03 July 2003 letter report to the Walla Walla Basin Watershed Council (Kennedy/Jenks, 2003). No fieldwork or invasive investigations were done for the initial hydrogeologic review. Such work was planned for later Test Site investigations associated with construction, characterization, and baseline (background) data collection. Hydrogeologic data collected during characterization and background data compilation work, which began in the spring of 2004, is discussed later in this report.

The initial hydrogeologic review concluded the following for the uppermost 200 feet of the suprabasalt sediment sequence underlying the Test Site:

- The uppermost geologic unit in the Test Site area is a sequence of interstratified silt and sand called Touchet Beds. At the Test Site this unit appears to be absent. However, Touchet Beds are found northwest and south of the Test Site where the unit is 6 to 18 feet thick and less than 5 feet-thick, respectively. Given this distribution, this unit should play no role in effecting recharge at the Test Site.

- The uppermost unit at the Test Site was interpreted to consist of basaltic, sandy, uncemented gravel. These strata are assigned to the Quaternary coarse alluvial gravel unit and it is essentially at the ground surface at the Test Site. Beneath the Test Site, these uncemented strata are interpreted to range from approximately 30 feet-thick at the east end to over 60 feet-thick at the west end. Based on interpretations of well logs in the vicinity, this east to west thickening is inferred to be the result of these strata filling a depression in the top of the underlying, indurated Mio-Pliocene conglomerate.

- The remainder of the upper 200 feet of the sediment sequence underlying the Test Site was interpreted to consist predominantly of silty, sand, indurated gravel (conglomerate). These strata are assigned to the Mio-Pliocene conglomerate.

- The origin of the depression inferred to be in the top of the Mio-Pliocene conglomerate is not known. The location of the Test Site, near the fault zone that bounds the base of the Horse Heaven Hills, suggests this depression could be a fault-controlled feature formed in the top of the conglomerate. Alternatively, given the variable quality of driller's geologic descriptions, one can not completely discount the possibility that this depression is real, instead being the interpreted to be present as the result of poor or inaccurate driller's descriptions. One of the objectives of site-specific characterization work will be to verify the presence of this feature.

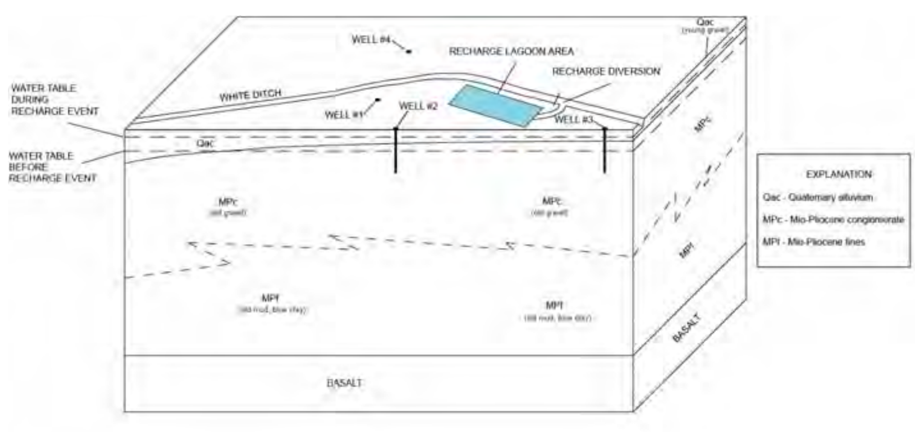
In the immediate vicinity of the Test Site, the initial hydrogeologic review concluded that the suprabasalt aquifer water table appeared to be between 30 and 55 feet below ground surface (bgs). This placed the water table predominantly within the Mio-Pliocene conglomerate beneath the easternmost portion of the Test Site. To the west, where the Quaternary coarse alluvial gravel was inferred to thicken, the suprabasalt aquifer water table was interpreted to be within this unit. In the Test Site area, suprabasalt aquifer groundwater flow was inferred to be generally east to west-northwest.

Review of depth to first water and depth to final water reported on well logs in the immediate vicinity of the Test Site was interpreted in the initial hydrogeologic review to suggest that the suprabasalt aquifer at the Test Site consisted of an unconfined zone overlying a deeper, semi-confined zone. The transition between these zones was inferred to lie approximately 75 feet bgs. The nature of the "confining" horizon(s) that caused this apparent change in aquifer character is not known, but inferred to be well cemented and/or fine grained layers within the upper 20 to 50 feet of the Mio-Pliocene conglomerate. Within the depression in the top of the Mio-Pliocene conglomerate that is inferred to underlie and be situated west of the Test Site, this confining zone would be displaced to depths greater than 95 ft bgs or absent.

The initial hydrogeologic assessment did not find any site-specific hydraulic property data for the aquifer(s) or the vadose zone underlying the Test Site. The only hydraulic property data found are general estimates provided in the regional hydrogeology discussions. These suggest average porosity, hydraulic conductivity, and transmissivity for all gravelly strata in the Basin (Quaternary and Mio-Pliocene) are 5%, 12 to 600 ft/d, and 10,000 to 60,000 ft^2/d, respectively.

One of the objectives of site-specific monitoring well drilling, proposed in the project monitoring and test plan included in the Limited License application, was to better characterize site-specific hydrogeologic conditions. The remainder of this section presents hydrogeologic information collected from well drilling and other characterization efforts. Based on this information several interpretations made in the initial hydrogeologic assessment are modified. Figure M-2 shows the general test site layout along with the subsurface geologic layers.

Figure M-2 Three-dimensional conceptual drawing of test site lay out and subsurface geology.



Geology

All four monitoring wells penetrate a thin (0.5 to 4 feet thick) surface layer consisting of unconsolidated, loose, gravelly silty sand. This stratum is interpreted to consist of underlying pebble-cobble gravel and recent (Holocene) wind blown sand and silt mixed together by pedogenic and agricultural activity. The surface deposit rapidly grades downwards into a sequence of uncemented, basaltic, sandy gravel. This basaltic sandy gravel is generally gray to gray black in color and gravel cuttings suggest pebbles and cobbles are the predominant clast sizes. Together this gravel and the overlying gravelly silty sand are interpreted to comprise the Quaternary coarse alluvial gravel unit. Note that the silty surface layer was removed during the recharge basin construction.

The data used to compile the initial Test Site hydrogeologic assessment suggested that the contact between Quaternary coarse alluvial gravel and underlying Mio-Pliocene conglomerate dipped to the west beneath the Test Site. Based on this information this contact was projected to be approximately 30 feet bgs beneath the eastern part of the Test Site and 60 feet bgs beneath the western part of the Test Site. Geologic logging of drill cuttings collected from the four Test Site monitoring wells lead the project team to reevaluate this interpretation.

The Quaternary coarse alluvial gravel – Mio-Pliocene conglomerate contact was found to be readily identifiable from drill cuttings and well driller's observations. The 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

Based on these observations this contact is interpreted to be at depths of approximately 20, 18, 18, and 18 feet bgs in wells MW-1, MW-2, MW-3 and MW-4, respectively. Given these observations the Quaternary coarse alluvial gravel unit has a relatively uniform thickness, approximately 20 feet, at the Test Site (Figure 6 in Appendix A) and the top of the Mio-Pliocene conglomerate generally dips to the west and northwest roughly parallel to the ground surface (Figure 7 in Appendix A). If the depression interpreted to be in the top of the Mio-Pliocene conglomerate in the initial hydrogeologic assessment is in fact present, the data reported here indicates that this surface does not begin to dip downwards into it beneath the Test Site (Figure 7).

Hydrogeology

Initial Test Site hydrogeologic interpretations suggested the suprabasalt aquifer water table sloped and flowed generally to the northwest. Data collected from Test Site monitoring wells in the spring of 2004 verified this general condition. In addition, the data collected during testing showed the suprabasalt water table changed significantly during testing.

Immediately following completion of the monitoring wells on 10 March 2004, the suprabasalt water table was located approximately 48.9, 50.2, 59.6, and 49.27 feet bgs in wells MW-1, MW-2, MW-3, and MW-4, respectively. At this time the canal and Test Site ponds did not contain water (Figure 8 in Appendix A). Late in testing, on 03 May 2004 the suprabasalt aquifer water level was at 17.0, 19.0, 24.0, and 22.0 feet bgs, respectively (Figure 8). Following the end of testing (on 15 May 2004), but while the canal still contained water, water level in the suprabasalt aquifer beneath the Test Site declined to a depth intermediate between the 10 March and 03 May readings (see Section Spring 2004 Operation Results for a complete description of water level data collected at the Test Site). Water level increases seen at the Test Site are therefore interpreted to be the result of both seepage from the canal which supplies water to the Test Site and water infiltrating out of the recharge test ponds. Aquifer testing to collect site-specific hydrologic physical data for the suprabasalt aquifer was not done during the first year of the project because of limited funding.

Monitoring Parameters and Methodologies

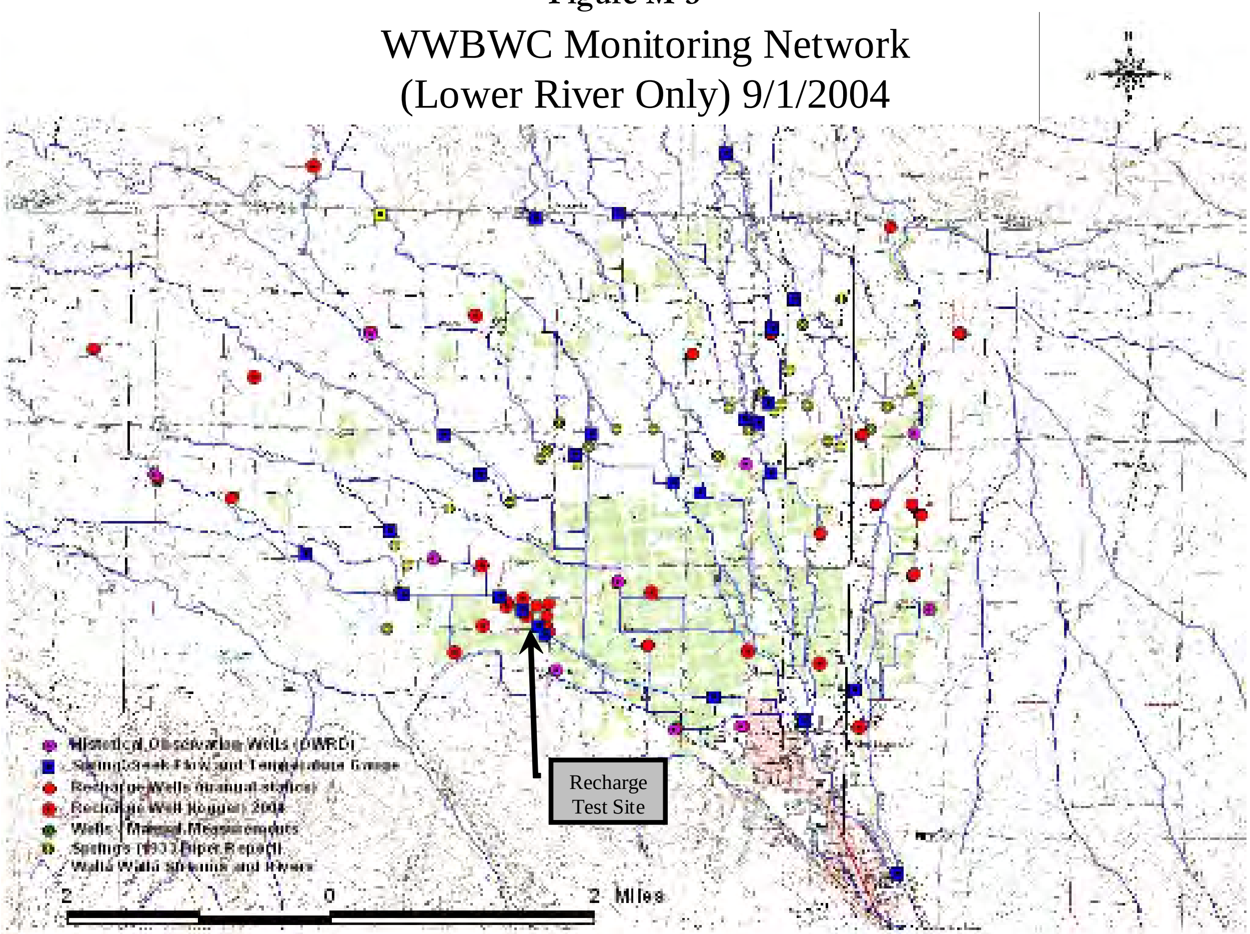
Starting in 2002 the WWBWBC began setting up a network of surface and ground water monitoring stations throughout the Oregon portion of the Walla Walla Basin. This work was done for an ongoing surface-groundwater study being conducted by the WWBWC (OWEB funding). The study involved adding new shallow aquifer monitoring wells to the existing OWRD observation well network in order to get good spatial representation of the entire valley's surface-groundwater interactions. It also utilized a USGS (Piper, 1933) and other studies of the surface and groundwater in this area to locate surface flow sites with preexisting information. Flow and well loggers were coupled with this historical well data in order to identify possible changes in conditions influenced by the Hudson Bay Project. During this first year of operation, a subset of the complete data set was processed for this first annual report due to time limitations. In the coming years of the project, it is anticipated that all data will be processed and used to monitor changes from the recharge project.

The Hudson Bay Recharge Project was operated for approximately a 5-week period from April 8th until May 15th, 2004. During this time, the WWBWC monitored both surface and ground water to ascertain recharge-related changes at both the Test Site and throughout the Oregon portion of the basin (**Figure M-3**). Specifically the WWBWC monitoring the following items:

1. Surface Flow
    a. Intake Water was measured using a *Trutrack WT-HR 1000 Meter* stage recorder in 15-minute intervals. A predetermined rating table for the intake flume was used along with continuous stage data to calculate cfs and total acre-feet.
    b. White Ditch was measured upstream (WD-1, at Bridge) and downstream (WD-2 at downstream pipe entrance) of the recharge project using two *Trutrack WT-HR 1000 Meter* stage recorders. A predetermined rating for WD-1 will be used with stage data to calculate cfs and total acre-feet. At WD-1 measurements were made of the channel at varying flows and a rating of the gauge calculated for cfs. (Data being processed)
    c. Overflow water was measured in a 2.0 cfs flume using a *Trutrack WT-HR 1.0 Meter* stage recorder in 15 minute samples. A predetermined rating for the flume was used with stage data to calculate cfs. (Data being processed)
2. Water Table
    a. Observation Wells 1, 2 and 3 were measured using *Insitu Minitroll 9000 Professionals* pressure transducers (vented to atmosphere changes) installed in each well and networked to a central hub at the intake board. Water depth readings recorded every 15-minutes were adjusted to top-of-grade and datum (elevation).
    b. Observation Well 4 (OBS-4) was measured using in *Insitu Minitroll 9000 (nonvented)* and installed on a metal cable. A second *Minitroll* was kept at the WWBWC offices to account for changes in atmospheric pressure were used to calibrate the water level data. Water depth reading were recorded every 15-minutes and adjusted to top-of-grade and datum (elevation).
    c. WWBWC Well Network wells (GW-1 through GW-63) being measured using a combination of *Insitu Minitrolls* loggers and manual static measurements. (Data being processed).
3. Surface and Ground Water Quality
    a. Water was monitored at the intake, observation well (OBS-1) was tested for:

i. Chemical oxygen demand (COD) (mg/l)
ii. Total Kjehdahl nitrogen (TKN) (mg/l)
iii. Chloride (mg/l)
iv. Soluble reactive phosphorus (SRP) (mg/l)
v. Total dissolved solids (TDS) (mg/l)Nitrate-N (mg/l)
vi. Fecal Coliforms (MPN/100 ml)
vii. Soluble Organic Compounds: 85 total analytes shown in Table 2A
viii. Temperature
ix. Specific Conductivity

Figure M-3

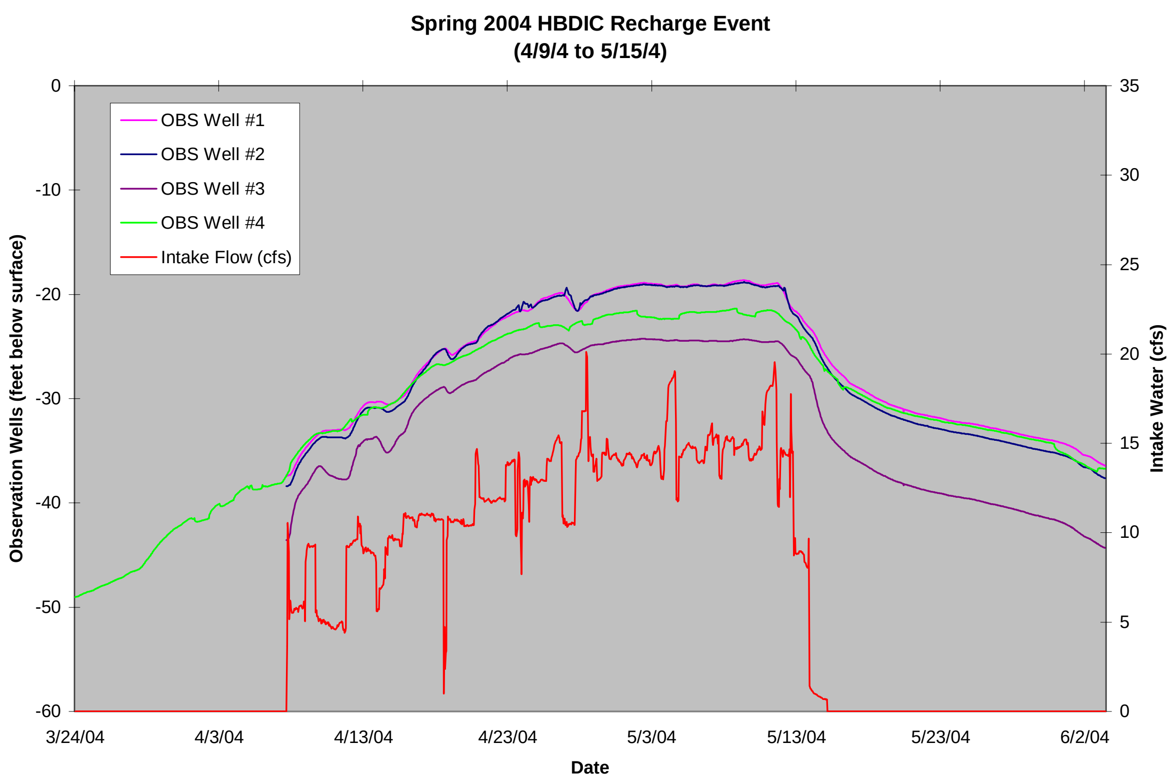


Spring 2004 Test Site Operation Results

During the period of operation a total of approximately **860 acre-feet** of water was passively recharged to the shallow aquifer system. **Figure M-4** shows water flowing into the project (at intake) and the four monitoring wells (OBS#1-4) during operations. The static logger on well OBS-4 was deployed before project operations and shows shallow aquifer water table rising prior to operation. It is assumed that water infiltrating from the White Ditch (estimated at a 5 cfs loss) was driving a majority this rise. Intake flow was slowly ramped up during operation because basins 2 and 3 were being constructed as the first basin began operations (**Figure M-5**).

OBS-3 (MW-3) (upgradient) was installed originally as an upgradient control well. However **Figure M-4** clearly shows that static levels in the wells reacted in concert with the rate changes in intake water. During operation well static levels increased approximately 19 feet and immediately began to fall after project operation. The project also appears[2] to have reached equilibrium between the rate of intake water and the observation well static levels. This equilibrium was reached after all three recharge basins were completed and the intake versus overflow balance established. The average intake rate was approximate 14 cfs (4/26/4 to 5/13/4). There were some peaks and dips in the intake rate due to the changes in head at the intake and on the White Ditch which are mutually dependent using head boards. The estimated White Ditch loss from the point of diversion to the Test Site is approximately 5 cfs. Therefore the project, when operating at full capacity utilizes approximately 19 cfs which is well within the 50 cfs water right allotted.

Figure M-4. On-site Observations wells and intake water gauge

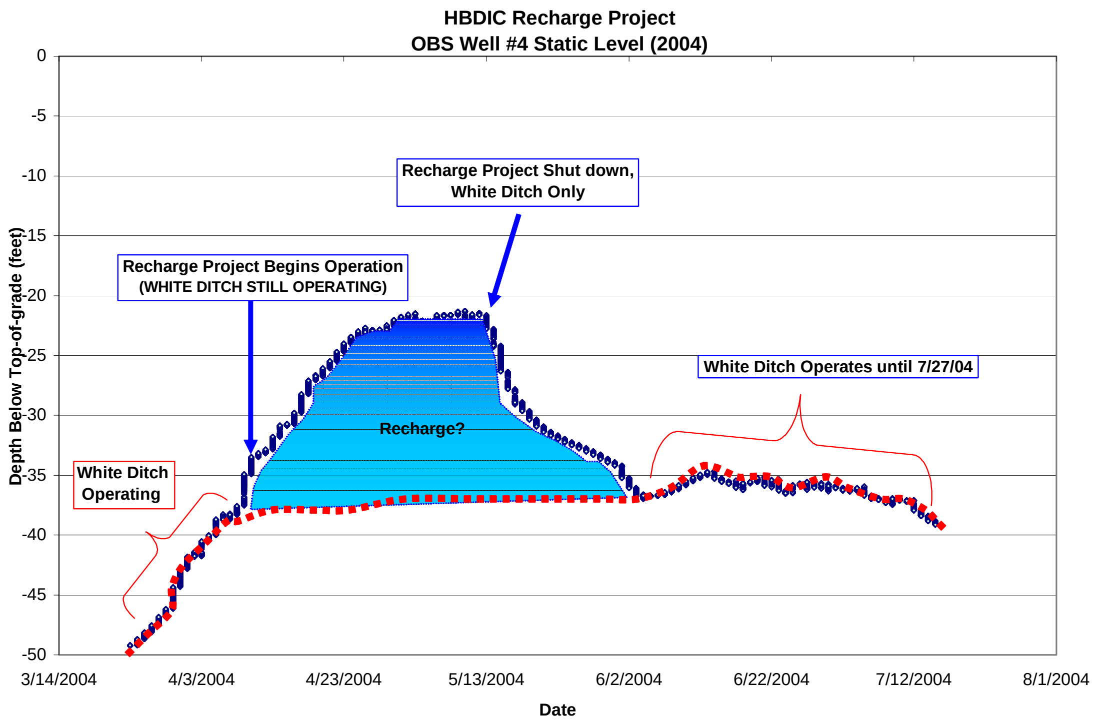


[2] 2004-5 recharge operations will test this equilibrium condition with a much longer operations window.

Figure M-5. Recharge Basin #1 being filled as second recharge basin being built 4/8/4.

Figure M-6 relates the changes in static levels (Well OBS-4) to the timing of the recharge project and White Ditch operations. The aquifer water level appears to rise before operating the project and this is assumed to be water infiltrating from the White Ditch. Using the pre and post operation information a theoretical static level can be envisioned (red line in Figure M-6) that roughly discerns project water from ditch water. Notice the abrupt increase in static levels when the project begins operation (4/8/4) and a fairly rapid decline in static levels once the project ceased operation (5/15/4). The gain in static levels (highlighted in blue) during operation is assumed to be influenced by project operation and its distinctive shape can also be seen in other down gradient sites (See Section: Down-Gradient Monitoring Results). Also, the post-project-operation static levels appear to reach equilibrium during the continued running of the White Ditch.

Figure M-6



Water Quality Monitoring Results:

There is little water quality data for the area except what is reported in Richerson and Cole (ODEQ, 2000). That report shows TDS and nitrate-N concentrations in groundwater beneath the Test Site area to be approximately 125 to 150 mg/l and 2 to 2.5 mg/l, respectively. These parameter concentrations compare to those of approximately 55 mg/l and <0.25 mg/l at Milton-Freewater, where the Walla Walla River enters the Basin.

During testing, water quality data was collected from Wells OBS-1 and the recharge pond intake for the following constituents:

- Chemical oxygen demand (COD) (mg/l)
- Total Kjehdahl nitrogen (TKN) (mg/l)
- Chloride (mg/l)
- Soluble reactive phosphorus (SRP) (mg/l)
- Total dissolved solids (TDS) (mg/l)
- Nitrate-N (mg/l)

Laboratory results for these samples are summarized below and listed on Table 1A. Well OBS-1 was sampled three times, on 10 March, 13 April, and 21 May 2004. Recharge source water was sampled once at the intake onto the Test Site on 13 April 2004. The results of sampling are summarized below:

- In Well OBS-1 values for TKN, chloride, TDS, and nitrate-N in were at the MDL in each sampling event. SRP concentrations fluctuated between 0.190 and 0.206 mg/l. COD ranged from 11 to 55 mg/l in the three sampling events.

- Like the samples from well OBS-1, TKN, chloride, TDS, and nitrate-N were at the MDL in intake water samples. SRP and COD were detected at concentrations similar to those seen in well OBS-1, 21 mg/l and 0.210 mg/l for COD and SRP, respectively.

Given that the recharge test began on 08 April 2004, the data collected for TKN, chloride, TDS, nitrate-N, COD, and SRP suggests recharge had little or no impact on groundwater quality as the pre-test groundwater water quality looks very similar to groundwater water quality during testing.

Fecal Coliforms and Fecal E. Coli bacteria[3] were sampled for in two Test Site wells (OBS-1 and OBS-3), at the intake, at two locations in the canal upstream of the intake, and in three water supply wells in the project area (Table 1C). Early in the project, fecal sampling consisted of present/absent testing (3/10/4 and 4/13/) but was changed to concentration testing to identify the magnitude of the fecal presence.

In the two Test Site monitoring wells fecal bacteria was variable, in fecal coliform testing it ranged from the MDL of <2.0 CFU/100 ml to a high of 14.8 CFU/100 ml in a total of 6 samples> In fecal E. coli sampling the wells showed a range of values from 2 MPN/100 ml to 11 MPN/100 ml. Intake water, sampled four times, shows a higher range of variability, ranging from 40 to 130 CFU/100 ml and 1 to 24 MPN/100 ml. Samples collected from the canal upstream of the intake range from 4.1 MPN/100 ml and 12.2 CFU/100 ml in two samples. The three samples from offsite water supply wells are all <2 MPN/100 ml. However, given water well construction standards (screen shouldn't be open across the water table) these wells may be drawing water from deeper in the suprabasalt aquifer than Test Site monitoring wells. If so, drawing water from deeper in the aquifer should result in more filtering and could account for the coliform reading being less than the MDL. Also at the time of this sampling, it was thought that well OBS-3 represented an upgradient background condition.

EPA methods (SOC's: 515.2, 525.2, 531, 547 and 549) were used to test for herbicides, pesticides, Adipate, PAH's, Carbamates, Glyphosate, Paraquat and Diquat. The maximum contaminant level MCL) for each analyte was reported in reference to EPA Drinking Water Standards (Tables 1B and 2A).

SOC samples were collected once at the intake and three times at OBS-1. From the 84 total analytes tested, Di(ethylhexyl)-phthalate was the only detection during the 4 sampling events (Table 2A, Intake). Di(ethylhexyl)-phthalate detected at 2.2 ug/L is under the EPA MCL of 6.0 ug/L. Di(ethylhexyl)-phthalate is primarily used as one of several plasticizers in polyvinyl chloride (PBC) resins for fabricating flexible vinyl products.

[3] Miscommunication between lab doing analysis and WWBWC lead to sampling of both Fecal Coliforms and Fecal E. Coli. In the future, only Fecal E. Coli will be tested for according to the new Water Quality standards.

Table 1A. Water quality by constituent

Well ID	Date	COD (mg/l)	TKN (mg/l)	Chloride (mg/l)	Soluble Reactive Phosphorus (mg/l)	TDS (mg/l)	Nitrate-N (mg/l)
OBS Well #1	3/10/2004	20	<0.72	ND	0.206	<20.3	1.64
	4/13/2004	55	<0.72	ND	0.19	<20.3	ND
	5/21/2004	11	<0.72	ND	0.2	<20.3	ND
Intake	4/13/2004	21	<0.72	ND	0.21	<20.3	ND

Table 1B. Soluble Organic Compounds

Well ID	Date	Soluble Organic Compounds (ug/L)
OBS Well #1	3/10/2004	No Detections
	4/13/2004	Di(ethylhexyl)-phthalate
	5/21/2004	No Detections
Intake	4/13/2004	No Detections

Table 1C. Fecal Coliform data

Location ID	Date	Fecal Coliform (CFU/100mL)	E. Coli (MPN/100ml)	Coliforms/E. Coli (present/absent)
OBS Well #1	3/10/2004			Absent/absent
	4/13/2004			Present / Absent
9:35pm	4/20/2004	3.1	2.0	
6:40am	4/29/2004		11.0	
	4/29/2004		5.2	
	4/30/2004		9.7	
	5/7/2004		<2.0	
	5/7/2004	<2.0		
	5/21/2004	<2.0		
OBS Well #3	4/20/2004	14.8	7.5	
	4/29/2004		2.0	
	4/29/2004		3.1	
9:00pm	4/29/2004		3.0	
6:30am	4/30/2004		5.2	
	5/7/2004	<2.0	2.0	
	5/21/2004	<2.0		
intake	4/13/2004			Present/Present
	4/20/2004	40.0	24.1	
	4/29/2004		1.0	
	5/21/2004	130.0		
Frog	4/29/2004	12.2		
Winesap Rd.	4/29/2004		4.1	
Well GW-40	4/29/2004		<1.0	
Well GW-39	4/29/2004		<1.0	
Well GW-60	4/29/2004		<1.0	

Table 2A. List of Synthetic Organic Compound Analysis and only detection during spring 2004 operation
(Intake water on 4/13/2004)

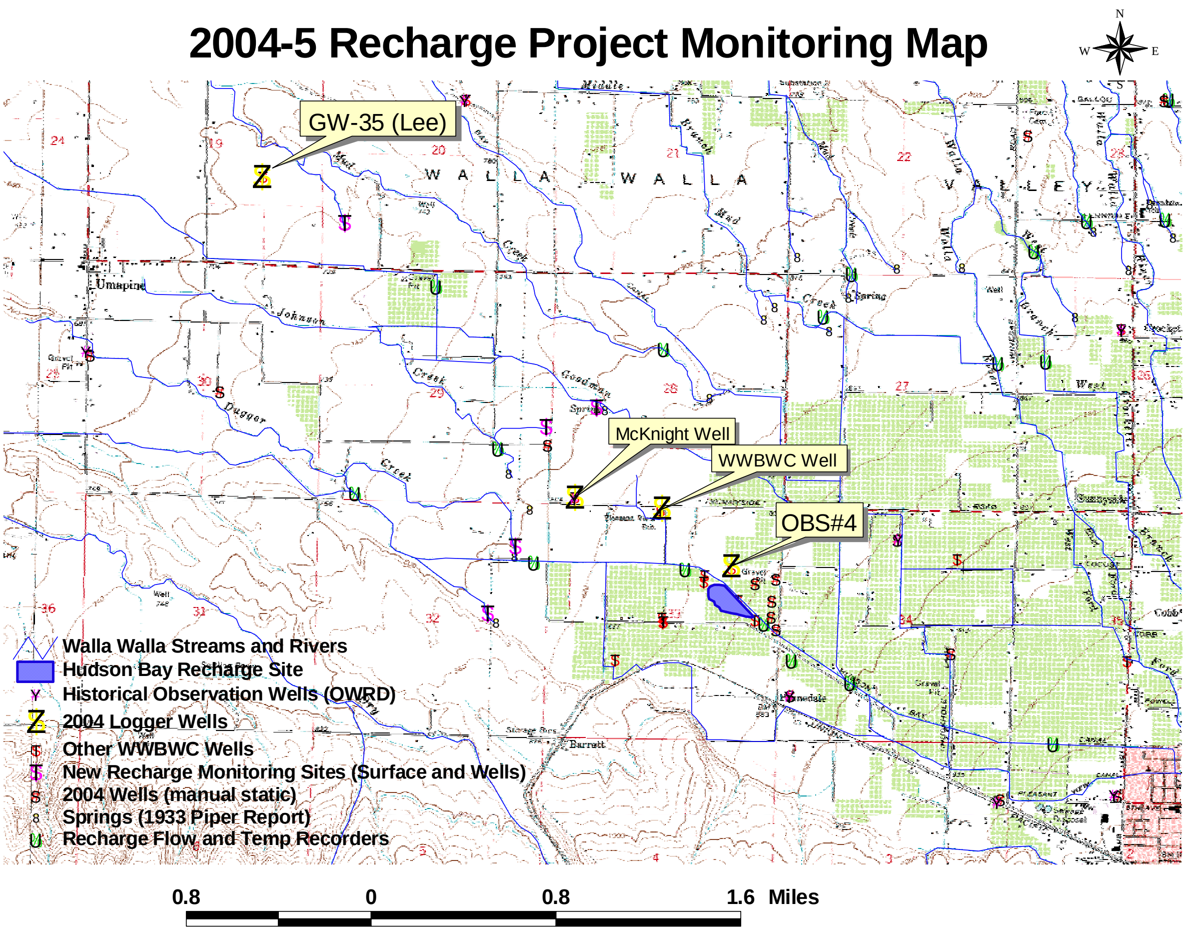
DOH#	Compounds	Results	Units	SRL	Trigger	MCL	Comments
	Carbamates in Drinking water						
146	Carbofuran	ND	ug/L	1.8	1.8	40.0	EPA Regulated
148	Oxymal	ND	ug/L	4.0	4.0	200.0	EPA Regulated
141	3-Hydroxycarbofuran	ND	ug/L	2.0	2.0		EPA Unregulated
142	Aldicarb	ND	ug/L	1.0	1.0		EPA Unregulated
143	Aldicarb Sulfone	ND	ug/L	1.6	1.6		EPA Unregulated
144	Aldicarb Sulfoxide	ND	ug/L	1.0	1.0		EPA Unregulated
145	Carbaryl	ND	ug/L	2.0	2.0		EPA Unregulated
147	Methomyl	ND	ug/L	1.0	4.0		EPA Unregulated
326	Propoxur(Baygon)	ND	ug/L	1.0			State Unregulated
327	Methiocarb	ND	ug/L	4.0			State Unregulated
	Synthetic Organic Compounds						
33	Endrin	ND	ug/L	0.02	0.02	2.0	EPA Regulated
34	Lindane (BHC-Gamma)	ND	ug/L	0.04	0.04	0.2	EPA Regulated
35	Methoxychlor	ND	ug/L	0.20	0.20	40.0	EPA Regulated
117	Alachlor	ND	ug/L	0.40	0.40	2.0	EPA Regulated
119	Atrazine	ND	ug/L	0.20	0.20	3.0	EPA Regulated
120	Benzo(a)pyrene	ND	ug/L	0.04	0.04	0.2	EPA Regulated
122	Chlordane Technical	ND	ug/L	0.40	0.40	2.0	EPA Regulated
124	Di(ethylhexyl)-Adipate	ND	ug/L	1.30	1.30	400.0	EPA Regulated
125	Di(ethylhexyl)-phthalate	2.2	ug/L	1.30	1.30	6.0	EPA Regulated
126	Heptachlor	ND	ug/L	0.08	0.08	0.4	EPA Regulated
127	Heptachlor epoxide (A & B)	ND	ug/L	0.04	0.04	0.2	EPA Regulated
128	Hexachlorobenzene	ND	ug/L	0.20	0.20	1.0	EPA Regulated
129	Hexachlorocyclo-Pentadiene	ND	ug/L	0.20	0.20	50.0	EPA Regulated
133	Simazine	ND	ug/L	0.15	0.15	4.0	EPA Regulated
118	Aldrin	ND	ug/L	0.20	0.20		EPA Unregulated
121	Butachlor	ND	ug/L	0.40	0.40		EPA Unregulated
123	Dieldrin	ND	ug/L	0.20	0.20		EPA Unregulated
130	Metolachlor	ND	ug/L	1.00	1.00		EPA Unregulated
131	Metribuzin	ND	ug/L	0.20	0.20		EPA Unregulated
132	Propachlor	ND	ug/L	0.20	0.20		EPA Unregulated
179	Bromacil	ND	ug/L	0.20	0.20		State Unregulated
183	Prometon	ND	ug/L	0.20	0.20		State Unregulated
190	Terbacil	ND	ug/L	0.20	0.20		State Unregulated
202	Diazinon	ND	ug/L	0.20	0.20		State Unregulated
208	EPTC	ND	ug/L	0.30	0.30		State Unregulated
232	4,4-DDD	ND	ug/L	0.20	0.20		State Unregulated
233	4,4-DDE	ND	ug/L	0.20	0.20		State Unregulated
234	4,4_DDT	ND	ug/L	0.20	0.20		State Unregulated
236	Cyanazine	ND	ug/L	0.20	0.20		State Unregulated
239	Malathion	ND	ug/L	0.20	0.20		State Unregulated
240	Parathion	ND	ug/L	0.20	0.20		State Unregulated
243	Trifluralin	ND	ug/L	0.20	0.20		State Unregulated
96	Napthalene	ND	ug/L	0.10	0.10		PAHs
154	Fluorene	ND	ug/L	0.20	0.20		PAHs
244	Acenaphthylene	ND	ug/L	0.20	0.20		PAHs
245	Acenaphthene	ND	ug/L	0.20	0.20		PAHs
246	Anthracene	ND	ug/L	0.20	0.20		PAHs
247	Benz(a)anthracene	ND	ug/L	0.10	0.10		PAHs
248	Benzo(b)fluoranthene	ND	ug/L	0.20	0.20		PAHs
249	Benzo(g,h,i)perylene	ND	ug/L	0.20	0.20		PAHs
250	Benzo(k)fluoranthene	ND	ug/L	0.20	0.20		PAHs
251	Chrysene	ND	ug/L	0.20	0.20		PAHs
252	Dibenzo(A,H)anthracene	ND	ug/L	0.20	0.20		PAHs
253	Fluoranthene	ND	ug/L	0.20	0.20		PAHs
255	Indeno(1,2,3-CD)Pyrene	ND	ug/L	0.20	0.20		PAHs
256	Phenanthrene	ND	ug/L	0.20	0.20		PAHs
257	Pyrene	ND	ug/L	0.20	0.20		PAHs
258	Benzyl Butyl Phthalate	ND	ug/L	0.60	0.60		Phthalates
259	Di-N-Butyl Phthalate	ND	ug/L	0.60	0.60		Phthalates
260	Diethyl Phthalate	ND	ug/L	0.60	0.60		Phthalates
261	Dimethyl Phthalate	ND	ug/L	0.60	0.60		Phthalates
36	Toxaphene	ND	ug/L	2.0	2.0	3.0	PCBs/Tocxaphene
173	Aroclor 1221	ND	ug/L	20.0	20.0		PCBs/Tocxaphene
174	Aroclor 1232	ND	ug/L	0.5	0.5		PCBs/Tocxaphene
175	Aroclor 1242	ND	ug/L	0.5	0.3		PCBs/Tocxaphene
176	Aroclor 1248	ND	ug/L	0.1	0.1		PCBs/Tocxaphene
177	Aroclor 1254	ND	ug/L	0.1	0.1		PCBs/Tocxaphene
178	Aroclor 1260	ND	ug/L	0.2	0.2		PCBs/Tocxaphene
180	Aroclor 1016	ND	ug/L	0.1	0.1		PCBs/Tocxaphene
	Herbicides in Drinking Water						
37	2,4-D	ND	ug/L	0.2	0.2	70.0	EPA Regulated
38	2,4,5-TP (Silvex)	ND	ug/L	0.4	0.4	50.0	EPA Regulated
134	Pentachlorophenol	ND	ug/L	0.1	0.1	1.0	EPA Regulated
137	Dalapon	ND	ug/L	2.0	2.0	200.0	EPA Regulated
139	Dinoseb	ND	ug/L	0.4	0.4	7.0	EPA Regulated
140	Picloram	ND	ug/L	0.2	0.2	500.0	EPA Regulated
138	Dicamba	ND	ug/L	0.2	0.2		EPA Unregulated
135	2,4 DB	ND	ug/L	1.0	1.0		State Unregulated
136	2,4,5 T	ND	ug/L	0.4	0.4		State Unregulated
220	Bentazon	ND	ug/L	0.5	0.5		State Unregulated
221	Dichloroprop	ND	ug/L	0.5	0.5		State Unregulated
223	Actiflorfin	ND	ug/L	2.0	2.0		State Unregulated
225	Dacthal (DCPA)	ND	ug/L	0.1	0.1		State Unregulated
226	3,5-Dichlorobenzoic Acid	ND	ug/L	0.5	0.5		State Unregulated

Down-Gradient Methods and Monitoring Results

It should be noted that this was a **wetter year** in the Walla Walla basin than has been experienced in recent history and this may have both a direct and indirect effect on the monitoring results. Rainfall could have a direct effect on stream flow and aquifer levels by means of natural infiltration. Estimates on the ratio of the amount of precipitation that makes it to the aquifer versus what occurs ranges between 1/10 to 1/3. An indirect influence of a **wet year** would be that irrigators (particularly well users) would use less surface and ground water in a wet year which would act to decrease the water withdrawn from the aquifer. Weather, Evapotranspiration, and well-consumptive use information available from other WWBWC studies will be used as available in future annual reports.

Figure M-7 shows a reference map for current and planned monitoring that the WWBWC will conduct for the aquifer recharge project. The four wells processed for this report are: Observation Well #4 (Test Site), WWBWC office well (domestic, shallow), McKnight Well (OWRD Historical Well, hand dug,) and GW-35 (WWBWC network well, open). These wells were chosen based the availability of data and their spatial relationship to the project (approximate linear inclination).

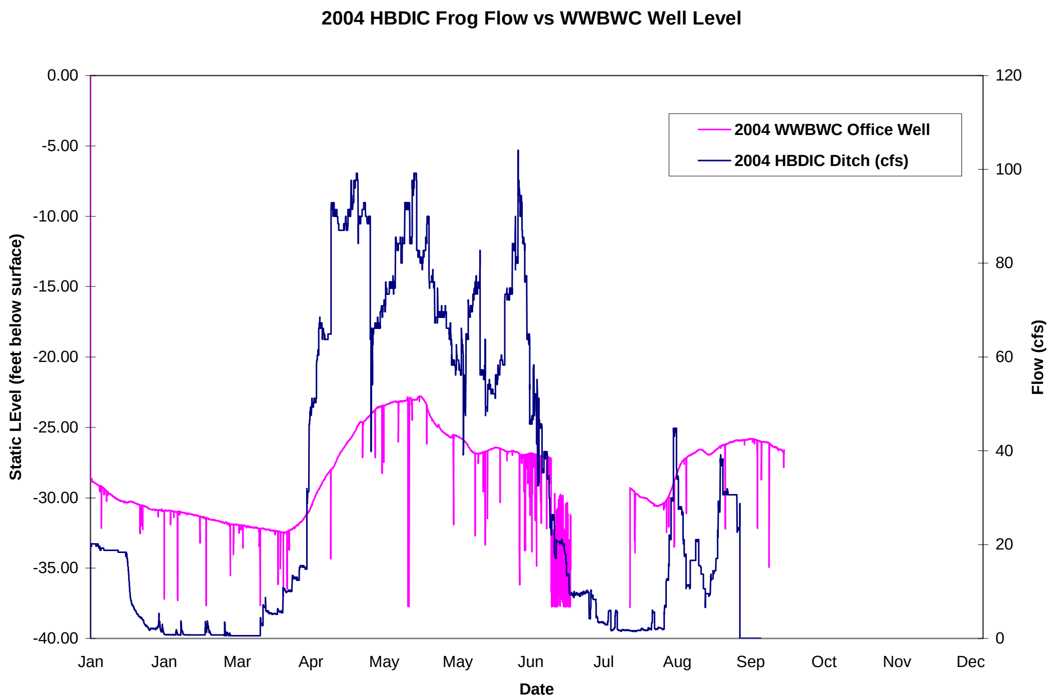
Figure M-7



In summer 2003, a well recorder was deployed at the WWBWC office well set to collect static readings hourly. This site is approximately 0.4 miles downgradient from the Test Site. White Ditch flow was measured by 15-minute stage data from the OWRD gauge station[4] (shown on Figure M-3) on the Little Walla Walla River (OWRD# 1401230 Hudson Bay @ Frog). This stage height data was rated (Bower) using OWRD rating measurements and transformed into cubic-feet-per-second. Its location is upgradient from the recharge project and therefore represents a good indicator of ditch operations.

Figure M-8 shows a strong correlation between White Ditch operation and the rise and fall of the WWBWC office well's static water level[5]. From mid-January to March the ditch was not being operated and the aquifer appears be declining during that period. This is of particular interest because the Walla Walla River was experiencing much higher flows during this same period (winter-spring run-off). The distinctive recharge peak (as described in **Figure M-6**) is evident in the WWBWC static data during the recharge period (April-May).

Figure M-8



A comparison of White Ditch and WWBWC well data from 2003 and 2004 reinforces the strong correlation between ditch operations and the down gradient well levels **(Figure M-9)**

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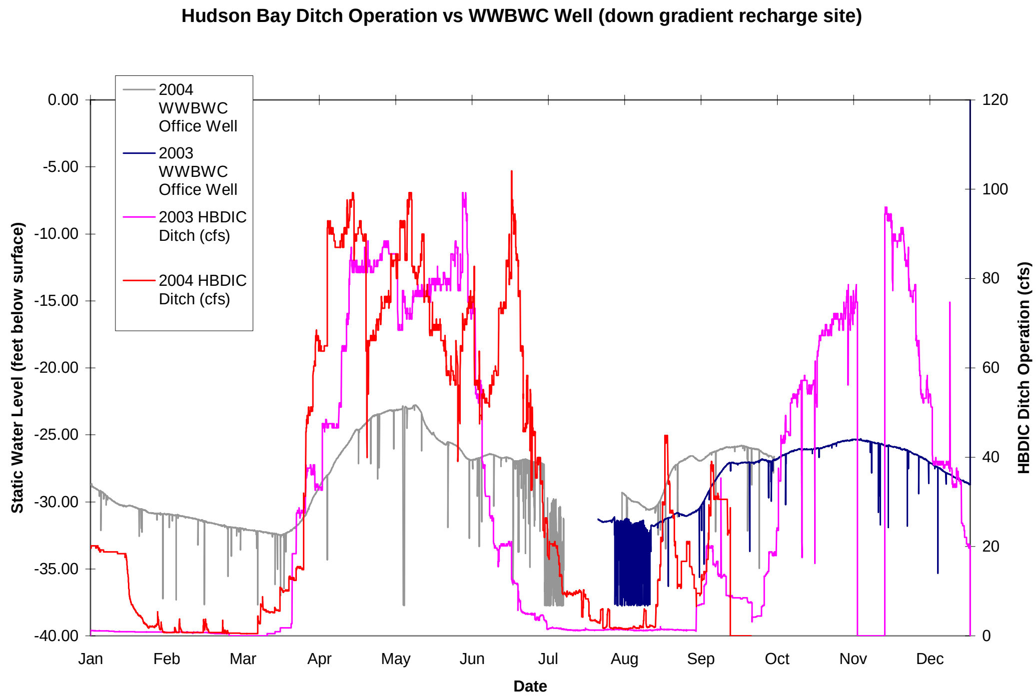
[4] This gauge represents a majority of the water entering this portion of the watershed because the Duff diversion (located between Prunedale and Winesap roads) is the central distribution point for all major HBDIC ditches.

[5] WWBWC office well is a domestic well supplying water for domestic and grounds-irrigation purposes, draw down of depicted in graph from well use. It appears that static levels recover quickly in this transmissive aquifer system.

Figure M-9

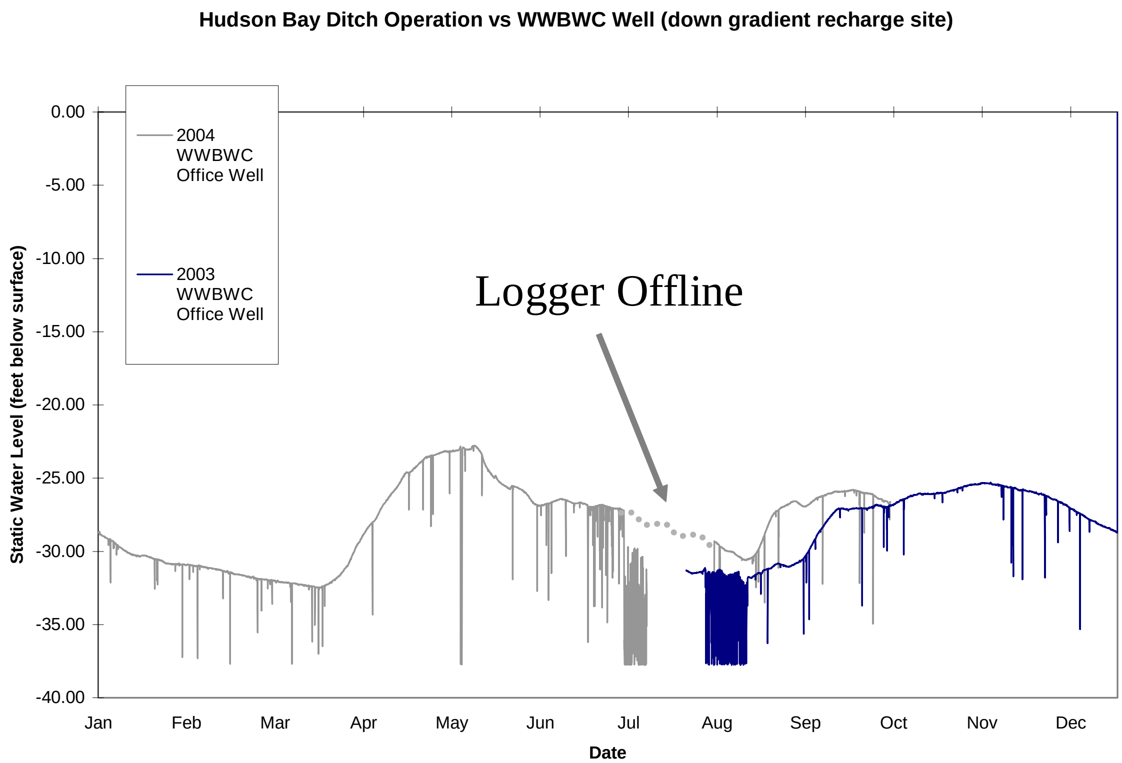


A 2003/2004 comparison of WWBWC well static levels during the late summer (August[6]) in 2003 shows higher levels in the recharge year (2004) than in the ditch-operation-only year **(Figure M-10).** While this is not conclusive[7] evidence that the improved aquifer rise in 2004 is related to exclusively to recharge, it does suggest that the aquifer has the ability to retain water during dry, non-recharge time periods. If this is in fact shown to be true in coming testing, it would confirm that aquifer recharge and spring restoration is possible in the project area.

[6] White Ditch off both of years compared.

[7] Wetter 2004 summer coupled with possible lower irrigation well use has to be considered.

Figure M-10



Moving downgradient from the recharge project, the McKnight well (OWRD # UMAT-4790) that has been used for OWRD's water table observations since 1933. It is a 27 foot deep, hand dug well, that has been abandoned for years. During the operation of the recharge project the static level was observed to be considerably higher than other OWRD measurements done over the past 20-30 years. **Figure M-11** compares historical measurements in May compared to the 2004 May reading. A continuous logger was deployed at this location for 2004-5 downgradient monitoring.

Newcomb discussed the transmission of ground water in the "old gravel" (shallow) aquifer in 1965 (USGS, 1965). Recharge water entering shallow aquifer would percolate downslope through the system along "porous and permeable zones of loose gravel". He went on to describe "After each separate addition of water, the ground water level rises nearer the surface; the 'rise' progresses outward and down the gradient as a wave." Further he described the movement for these "waves" as "The waves in the water table spread out from beneath the streams during periods of great stream-flow and move downgradient at an average rate estimated to be about a **mile a week**."(Newcomb, 1965, page 44)

Using the difference in the peaks and lows in static level response times between observation well #4 (MN-4) and the WWBWC office well and their approximate distances from each other, a preliminary transmission "wave" rate of **0.9 miles a week** was calculated **(Figure M-12).** This rate will need to be tested more thoroughly in the 2004-5 recharge test period.

Figure M-11

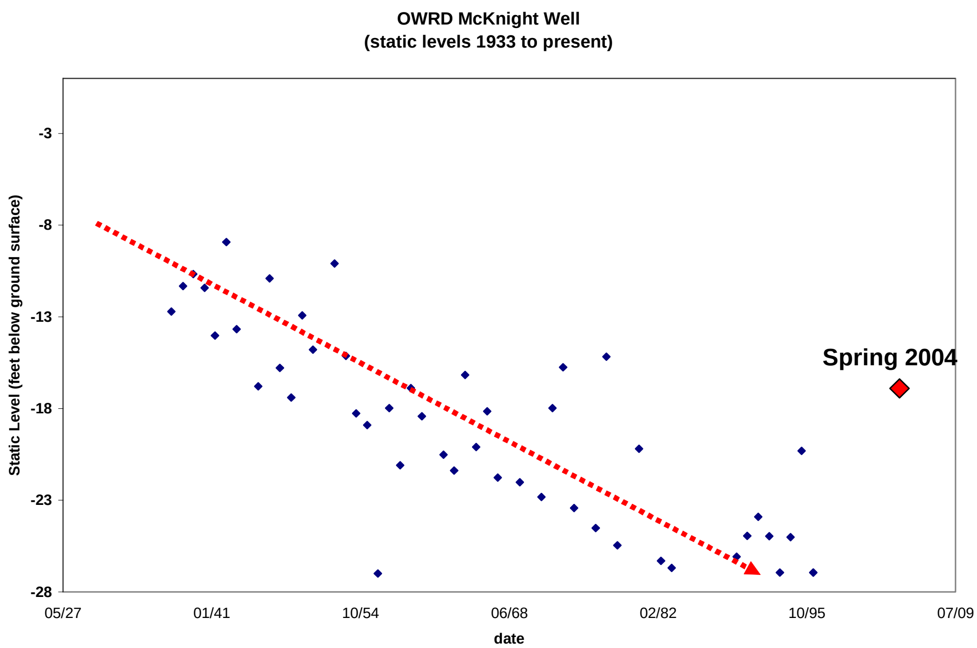
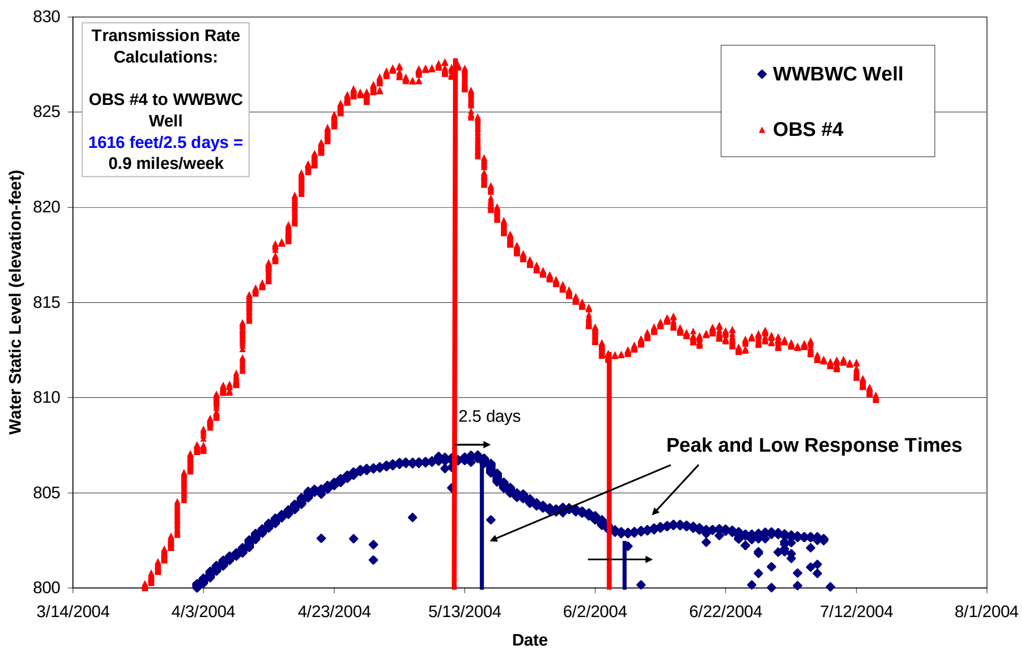


Figure M-12

Down Gradient Analysis for Transmission Computations (OBS 4 to WWBWC)

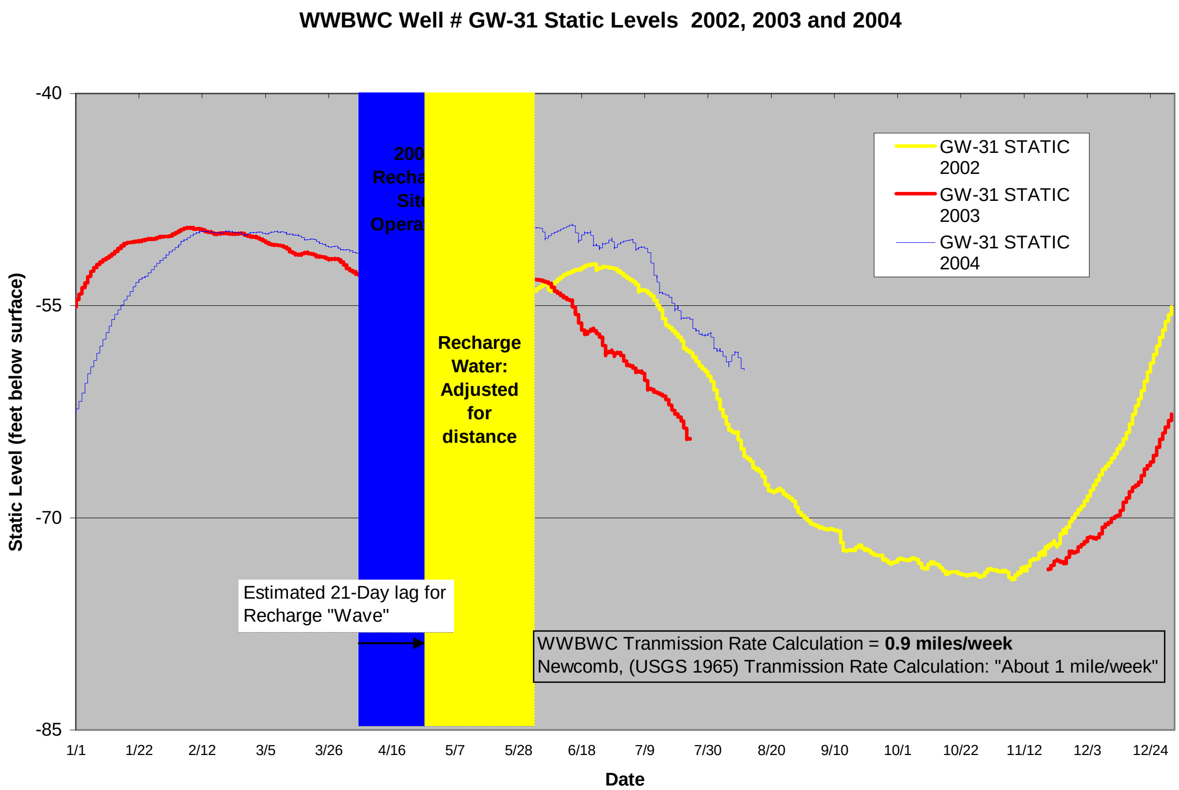


Moving approximately 2.6 miles downgradient from the recharge project we have data from our next WWBWC monitoring well # GW-31 **(Figure M-7).** This is an open well has been provided by a cooperating landowner and has had a logger recording data every 30 minutes[8] since 2002 **(Figure M-13).**

[8] A logger malfunction in 2003 created a sizeable block of missing data.

Logger data is plotted in reference to feet (negative value) below ground surface for presentation purposes. The recharge water from Test Site operation (blue area) is shown (yellow) after adjusting for distance to well GW-31 (yellow) (Figure M-13). The GW-31 static levels appear to rise throw the expected transmission-adjusted project operation window. Aquifer levels at this site do appear to be variable from year to year. The 2004-5 recharge season should provide much more detail information for tracking the recharge water downgradient.

Figure M-13



Conclusions

The spring 2004 operation of the Hudson Bay Recharge Project was an abbreviated test period from 4/8/4 to 5/15/4. The project was operated for 5 weeks and passively recharge about 860 acre-feet into the shallow aquifer system. The project appeared to reach a maximum recharge rate of 14 cfs (Test Site) + 5 cfs (estimated delivery Ditch loss) = 19 cfs. While most water quality results revealed ‘”no detections”, fecal bacteria were detected episodically in the White Ditch and surrounding wells. A monitoring well specifically drilled as an upgradient control was found to be to close to the project to be considered an upgradient control for measuring background water conditions during testing. Both Test Site and distal monitoring showed recharge water moving through the aquifer and that water table were levels higher than in previous year, possibly as a result of testing.

2004-5 Recommendations

Operation/Construction:

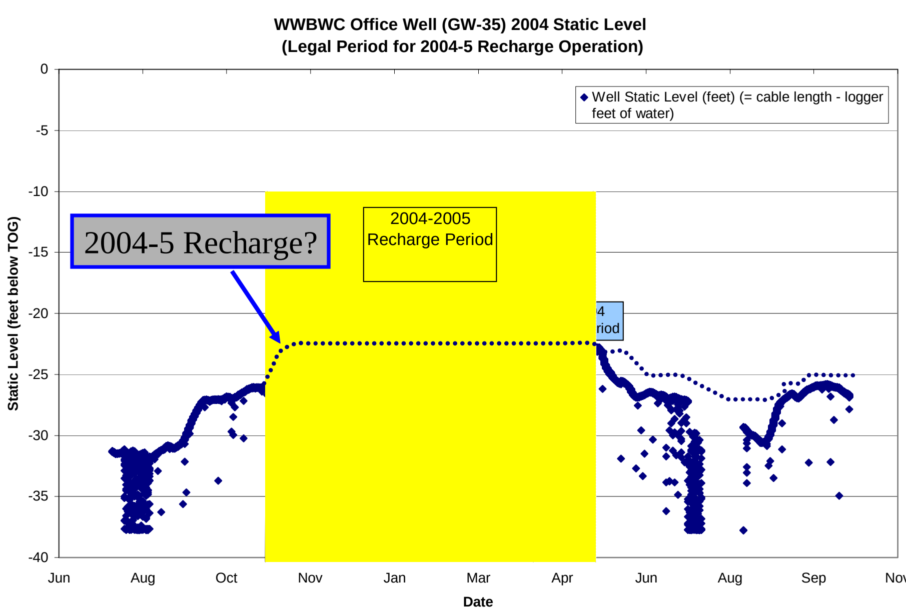
1. The Hudson Bay District Improvement company is excited about the results of this test recharge project. Anecdote accounts from districts members about "higher well levels" and "streams running higher" has increased support for this project. The HBDIC and WWBWC would like to expand the size of the recharge basins in order to increase the volume of water recharged to the aquifer. As they are presently constructed the Test Sites' calculated rate of recharge (14 cfs) estimates for 2004-5 testing period are:

    a. Entire period (November 1st to May 15, 198 days) ≈ 6000 acre-feet

    b. Period allowing for fish screen cleaning and potential cold conditions (120 days) ≈ 3300 acre-feet.

    The HBDIC-WWBWC team would like to double the sizes of all three basins from 50 x 100 feet to 100 x 100 feet. While we don't expect the actual rate of recharge to double, it would help to get the Test Site operations toward half of its allotted water right (~25 cfs) and provided a potentially bigger test to monitor. **Figure M-14** depicts the recharge testing time window and a hypothetical aquifer recovery current estimated rate of aquifer rise.

Figure M-14



Monitoring:

1. Given that well OBS-3 responded to the recharge test a well further to the east needs to be identified to serve as the upgradient well during testing. This well may be a pre-existing well (if constructed properly) or purpose built. Several upgradient wells have been identified as potential controls.

2. Aquifer testing to identify site-specific aquifer properties needs to done to support any modeling that could be done in the future. This testing will be contingent on finding funding.

3. Test site and nearby surrounding wells will be surveyed for elevation and distance in order to map out the *recharge mound*. This information will be used for tracking water movement/benefits and for establishing upgradient sampling control well(s).

4. The HBDIC-WWBWC team requests to change the timing and frequency for the water quality testing based on the spring 2004 results as follows:

    a. Frequency: testing of all constituents (see fecal below) in OBS-#1 (MN-1) twice during project operation:

        i. 1-2 days after recharge project begins (fall 2004).

        ii. 1-2 days before project shuts down (5/15/4).

    b. Constituents remain the same as 2004.

    c. Fecal Coliforms: testing of fecal coliforms is increased from 2004. Samples collected at least 10 upgradient wells in order to discern background fecal coliform conditions. Fecal coliform testing will be continued at a minimum time interval of **monthly** through the entire recharge period. Each monthly sampling includes fecal samples from observation well #1 and intake water.

2004-5 Analysis Work

1. Ditch loss from WWBWC flow stations as well as other studies data will be used to quantify and track ditch water loss.

2. Temperature and Specific Conductivity will be used to assist the tracking of project water in the shallow aquifer.

3. Remaining WWBWC and OWRD well data will be processed and used to track project water.

4. New and existing WWBWC surface flow stations at spring will be processed and used to track project water

References:

Newcomb, R.C. Geology and Groundwater Resources of the Walla Walla Basin. Water Supply Bulletin #21. Washington Department of Conservation, Division of Water Resources and United State Geological Survey, 1965.

Oregon Department of Water Resources, *Shallow aquifer water level data.* Chambers, Jim Assistant Watermaster, Milton-Freewater, Oregon.

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

Piper, A.M., T.W. Robinson, and H.E. Thomas. *Groundwater in the Walla Walla Basin, Oregon-Washington-Part I.* Department of the Interior, United States Geoloical Survey, 1933.

Piper, A.M., T.W. Robinson, and H.E. Thomas. *Groundwater in the Walla Walla Basin, Oregon-Washington-Part II.* Department of the Interior, United States Geoloical Survey, 1933.

Bower, R. J., Lindsey, K., *Hudson Bay Aquifer Recharge Project: An application for AR Testing Limited License to Oregon Water Resources Department (OWRD) (OAR 690-350-0020). 10/20/2003 (Copy on file at WWBWC offices.)*

Hudson Bay Aquifer Recharge Testing Project

2004 Annual Report

Appendix A: Geology Figures 1 – 8


SUNNYSIDE
852
U6377
U5512
Test Site Ponds
A
MW-4
U4903
Gravel
Pit
MW-1
MW-2
MW-3
33
A'
U4917
U6377
White Ditch
U4897
U6053
TN
MN
17°
0
1000 feet

Figure 1. Map illustrating well and geologic cross section locations.

Kennedy/Jenks Consultants

Engineers & Scientists

1020 N. Center Parkway, Suite F
Kennewick, Washington 99336
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FAX 509-734-9764
www.kennedyjenks.com

Borehole Log: MW-1

Project #: 026046*30
Project Name: HB Recharge Site
Client: WWBWC
Project Geologist: Terry Tolan R.G.

SUBSURFACE PROFILE				SAMPLE			Well Completion Details
Depth (bgs)	Lithology	Description	Depth (bgs)	Depth (bgs)	Type of Sample	Static Water Level	
							flush mount with steel post
0		Ground Surface	0				Concrete pad and seal (0-1′)
		Quaternary Coarse Alluvium sandy gravel					
				2.5-3	cutting		
		eolian fines (0-2′)					
5							Bentonite seal (1-15′)
		dark olive gray		8	cutting		4″ blank PVC (0-17′)
10				10	cutting		
15		dark olive gray to very dark gray silty sand and gravel		15	cutting		
		color lightening		17	cutting	17′ (5/3/04)	
		becoming more dark to very dark brown silty sand and gravel					
20			20	20			
		Mio-Pliocene Conglomerate rounded pebble gravel					4″ 0.02 slot PVC (17-67.75′)
				22.5			Sand (15-67.75′)
				24			
25				25			

Drilled By: Environmental West Exploration, Inc.
Drill Method: reverse air rotary
Drill Date: 3/9/2004
Type: Monitoring

Ground Elevation:
Reference Point Elevation: 849.7′
Northing:
Easting:

Figure 2. Well log for MW-1.

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Borehole Log: MW-1

Project #: 026046
Project Name: HB Recharge Site
Client: WWBWC
Project Geologist: Terry Tolan, R.G.

SUBSURFACE PROFILE				SAMPLE			
Depth (bgs)	Lithology	Description	Depth (bgs)	Depth (bgs)	Type of Sample	Static Water Level	Well Completion Details
25		**Mio-Pliocene Conglomerate** rounded pebbles and cobbles		27	cutting		
30				30	cutting		
		clayey matrix brown, dark brown and dark yellow brown		32.5	cutting		
35				36	cutting		0.02 slot PVC (17-67.75')
				37	cutting		
				39	cutting		Sand (15-67.75')
40				41	cutting		
45		strong brown color lithic sand, silt and gravel		45	cutting		
50				50	cutting	48.9' (3/10/04)	

Drilled By: Environmental West Exploration, Inc.	Ground Elevation:
Drill Method: reverse air rotary	Reference Point Elevation: 849.7'
Drill Date: 3/9/2004	Northing:
Type: Monitoring	Easting:

Figure 2. Well log for MW-1 (continued).

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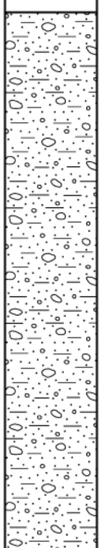
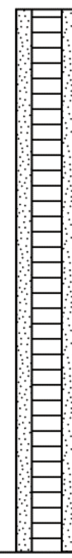
Borehole Log: MW-1

Project #: 026046*30
Project Name: HB Recharge Site
Client: WWBWC
Project Geologist: Terry Tolan R.G.

SUBSURFACE PROFILE				SAMPLE			
Depth (bgs)	Lithology	Description	Depth (bgs)	Depth (bgs)	Type of Sample	Static Water Level	Well Completion Details
50		**Mio-Pliocene Conglomerate** rounded pebbles and cobbles					
				54	cutting		
55							
				57	cutting		0.02 slot PVC (17-67.75′)
				59	cutting		Sand (15-67.75′)
60							
		dark brown mudy sand and gravel		62	cutting		
65							
				66	cutting		
							Total Depth: 67.75′
70							
75							

Drilled By: Environmental West Exploration, Inc.
Drill Method: reverse air rotary
Drill Date: 3/9/2004
Type: Monitoring

Ground Elevation:
Reference Point Elevation: 849.7′
Northing:
Easting:

Figure 2. Well log for MW-1 (continued).

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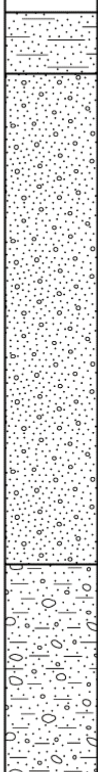
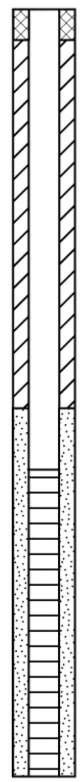
Borehole Log: MW-2

Project #: 026046*30
Project Name: HB Recharge Site
Client: WWBWC
Project Geologist: Terry Tolan, R.G.

SUBSURFACE PROFILE				SAMPLE			Well Completion Details
Depth (bgs)	Lithology	Description	Depth (bgs)	Depth (bgs)	Type of Sample	Static Water Level	
							flush mount with steel post
0		Ground Surface	0				Concrete pad and seal (0-1′)
		Quaternary Coarse Alluvium sandy gravel					
		muddy, pebbly sand (0-2′)					
5							Bentonite seal (1-12′)
							2″ blank PVC (0-15′)
10		sandy gravel gray		11	cutting		
15				15	cutting		
		Mio-Pliocene Conglomerate rounded pebble gravel	18	19	cutting	19′ (5/3/04)	
20				21	cutting		2″ 0.02 slot PVC (15-60′)
		color change brown - yellow brown		24	cutting		Sand (12-60′)
25							





Drilled By: Environmental West Exploration, Inc.
Drill Method: reverse air rotary
Drill Date: 3/9/2004
Type: Monitoring

Ground Elevation:
Reference Point Elevation: 850.8′
Northing:
Easting:

Page 1 of 3

Figure 3. Well log for MW-2.

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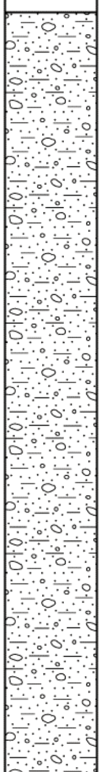
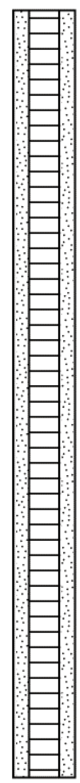
Borehole Log: MW-2

Project #: 026046*30
Project Name: HB Recharge Site
Client: WWBWC
Project Geologist: Terry Tolan, R.G.

SUBSURFACE PROFILE				SAMPLE			Well Completion Details
Depth (bgs)	Lithology	Description	Depth (bgs)	Depth (bgs)	Type of Sample	Static Water Level	
25		**Mio-Pliocene Conglomerate** rounded pebbles and cobbles					
		more grey silty sand matrix		29	cutting		
30							
				34	cutting		
35							2" 0.02 slot PVC (15-60')
				38	cutting		Sand (12-60')
40							
				43	cutting		
45				46	cutting		
50				50	cutting		

Drilled By: Environmental West Exploration, Inc.
Drill Method: reverse air rotary
Drill Date: 3/9/2004
Type: Monitoring

Ground Elevation:
Reference Point Elevation: 850.8'
Northing:
Easting:

Figure 3. Well log for MW-2 (continued).

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Borehole Log: MW-2

Project #: 026046*30
Project Name: HB Recharge Site
Client: WWBWC
Project Geologist: Terry Tolan, R.G.

SUBSURFACE PROFILE				SAMPLE			Well Completion Details
Depth (bgs)	Lithology	Description	Depth (bgs)	Depth (bgs)	Type of Sample	Static Water Level	
50–60		**Mio-Pliocene Conglomerate** rounded pebbles and cobbles				50.2′ (3/10/04)	2" 0.02 slot PVC (15-60′) Sand (12-60′)
				54	cutting		
				59	cutting		
60							Total Depth: 60′
65							
70							
75							

Drilled By: Environmental West Exploration, Inc.
Drill Method: reverse air rotary
Drill Date: 3/9/2004
Type: Monitoring

Ground Elevation:
Reference Point Elevation: 850.8′
Northing:
Easting:

Figure 3. Well log for MW-2 (continued).

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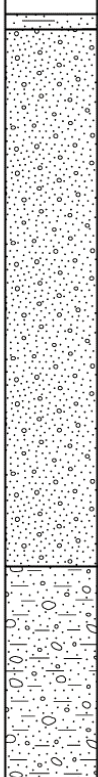
Borehole Log: MW-3

Project #: 026046*30
Project Name: HB Rechange Site
Client: WWBWC
Project Geologist: Terry Tolan, R.G.

SUBSURFACE PROFILE / SAMPLE / Well Completion Details



Depth (bgs)	Description	Depth (bgs)
0	Ground Surface	0
0	Quaternary Coarse Alluvium sandy gravel	
	sandy silt (0-0.5′)	
	sand and gravel gray	
18	Mio-Pliocene Conglomerate rounded pebble gravel	18
	silty sandy gravel	

Depth scale (bgs): 0, 5, 10, 15, 20, 25

Sample Depth (bgs)	Type of Sample	Static Water Level
7.5	cutting	
12	cutting	
18	cutting	
		24′ (5/3/04)

Well Completion Details

flush mount with steel post

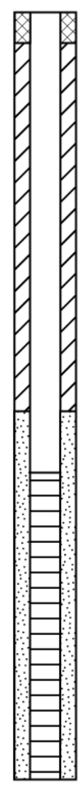
Concrete pad and seal (0-1′)

Bentonite seal (1-14′)

2″ blank PVC (0-16′)

2″ 0.02 slot PVC (16-71′)

Sand (14-71′)



Drilled By: Environmental West Exploration, Inc.
Drill Method: reverse air rotary
Drill Date: 3/9/2004 - 3/10/2004
Type: Monitoring

Ground Elevation:
Reference Point Elevation: 860.8′
Northing:
Easting:

Figure 4. Well log for MW-3.

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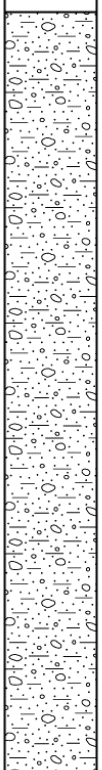
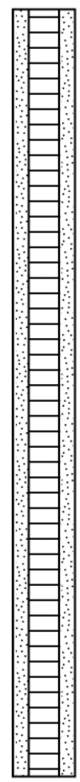
Borehole Log: MW-3

Project #: 026046*30
Project Name: HB Recharge Site
Client: WWBWC
Project Geologist: Terry Tolan, R.G.

SUBSURFACE PROFILE				SAMPLE			
Depth (bgs)	Lithology	Description	Depth (bgs)	Depth (bgs)	Type of Sample	Static Water Level	Well Completion Details
25		**Mio-Pliocene Conglomerate** rounded pebbles and cobbles					
				28	cutting		
30							
				32	cutting		
35							2" 0.02 slot PVC (16-71')
		silty sandy gravel brown - yellow brown		37.5	cutting		Sand (14-71')
40							
				42	cutting		
45							
				46	cutting		
50		dark yellow brown		50	cutting		

Drilled By: Environmental West Exploration, Inc.
Drill Method: reverse air rotary
Drill Date: 3/9/2004 - 3/10/2004
Type: Monitoring

Ground Elevation:
Reference Point Elevation: 860.8'
Northing:
Easting:

Figure 4. Well log for MW-3 (continued).

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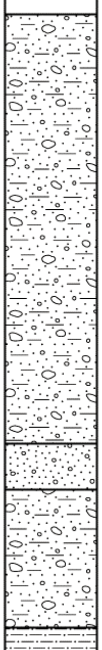
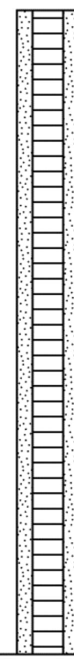
Borehole Log: MW-3

Project #: 026046*30
Project Name: HB Recharge Site
Client: WWBWC
Project Geologist: Terry Tolan, R.G.

SUBSURFACE PROFILE				SAMPLE			
Depth (bgs)	Lithology	Description	Depth (bgs)	Depth (bgs)	Type of Sample	Static Water Level	Well Completion Details
50		**Mio-Pliocene Conglomerate** rounded pebbles and cobbles					
				54	cutting		
55							
				59	cutting	59.6′ (3/10/04)	2″ 0.02 slot PVC (16-71′)
60							Sand (14-71′)
				64	cutting		
65		gravelly sand					
				68	cutting		
70		clayey silt		70	cutting		
							Total Depth: 71′
75							

Drilled By: Environmental West Exploration, Inc.
Drill Method: reverse air rotary
Drill Date: 3/9/2004 - 3/10/2004
Type: Monitoring

Ground Elevation:
Reference Point Elevation: 860.8′
Northing:
Easting:

Figure 4. Well log for MW-3 (continued).

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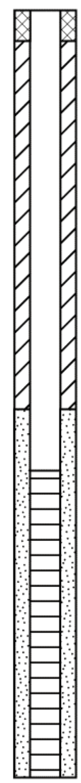
Borehole Log: MW-4

Project #: 026046*30
Project Name: HB Recharge Site
Client: WWBWC
Project Geologist: Terry Tolan, R.G.

SUBSURFACE PROFILE				SAMPLE			Well Completion Details
Depth (bgs)	Lithology	Description	Depth (bgs)	Depth (bgs)	Type of Sample	Static Water Level	
							flush mount with steel post
0		Ground Surface	0				Concrete pad and seal (0-1′)
		Quaternary Coarse Alluvium sandy gravel silty soil (0-4′)					
5				5	cutting		Bentonite seal (1-14′)
							2″ blank PVC (0-16′)
10		sand and gravel gray		12	cutting		
15		color change 18′	18	18	cutting		
20		Mio-Pliocene Conglomerate rounded pebble gravel					2″ 0.02 slot PVC (16-61′)
							Sand (14-61′)
25		silty sandy gravel		24	cutting		



Drilled By: Environmental West Exploration, Inc.	Ground Elevation: ~846′
Drill Method: reverse air rotary	Reference Point Elevation:
Drill Date: 3/10/2004	Northing:
Type: Monitoring	Easting:

Figure 5. Well log for MW-4.

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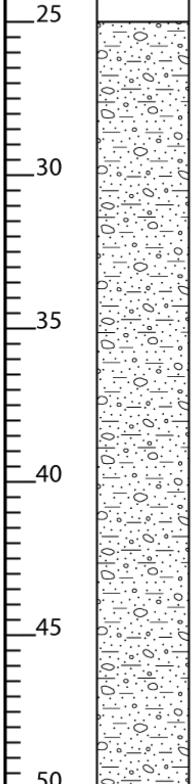
Borehole Log: MW-4

Project #: 026046*30
Project Name: HB Recharge Site
Client: WWBWC
Project Geologist: Terry Tolan, R.G.

SUBSURFACE PROFILE / SAMPLE / Well Completion Details

Lithology:



Mio-Pliocene Conglomerate (25–50 ft bgs)
rounded pebbles and cobbles

silty sandy gravel
brown - yellow brown

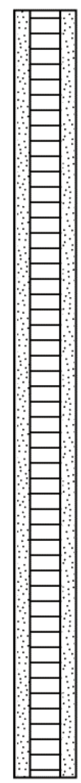
grayer

Depth (bgs)	Type of Sample	Static Water Level
29	cutting	
33	cutting	
36	cutting	
39-40	cutting	
42	cutting	
46	cutting	
48	cutting	
50	cutting	49.27′ (3/10/04)

Well Completion Details:

2" 0.02 slot PVC
(16-61′)

Sand (14-61′)



Drilled By: Environmental West Exploration, Inc.
Drill Method: reverse air rotary
Drill Date: 3/10/2004
Type: Monitoring

Ground Elevation: ~846′
Reference Point Elevation:
Northing:
Easting:

Figure 5. Well log for MW-4 (continued).

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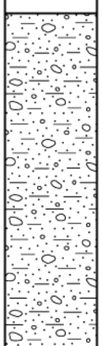
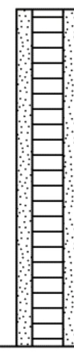
Borehole Log: MW-4

Project #: 026046*30
Project Name: HB Recharge Site
Client: WWBWC
Project Geologist: Terry Tolan, R.G.

SUBSURFACE PROFILE				SAMPLE			
Depth (bgs)	Lithology	Description	Depth (bgs)	Depth (bgs)	Type of Sample	Static Water Level	Well Completion Details
50–61		Mio-Pliocene Conglomerate rounded pebbles and cobbles		52	cutting		2" 0.02 slot PVC (16-71') Sand (14-71')
		silty sandy gravel		55	cutting		
				60	cutting		
65, 70, 75							Total Depth: 61'

Drilled By: Environmental West Exploration, Inc.
Drill Method: reverse air rotary
Drill Date: 3/10/2004
Type: Monitoring

Ground Elevation: ~846'
Reference Point Elevation:
Northing:
Easting:

Figure 5. Well log for MW-4 (continued).

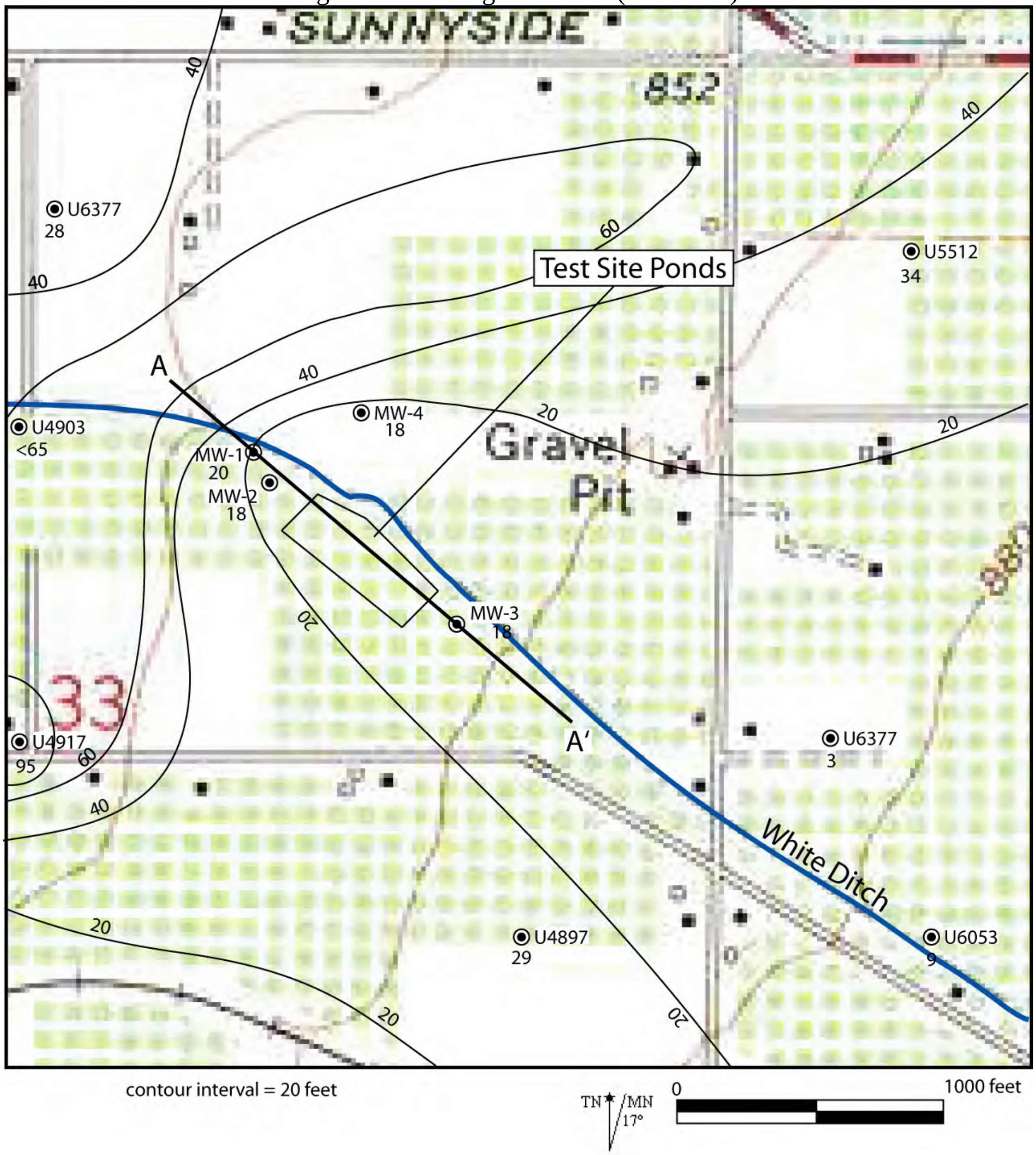


Figure 6. Thickness map of Quaternary coarse alluvium.

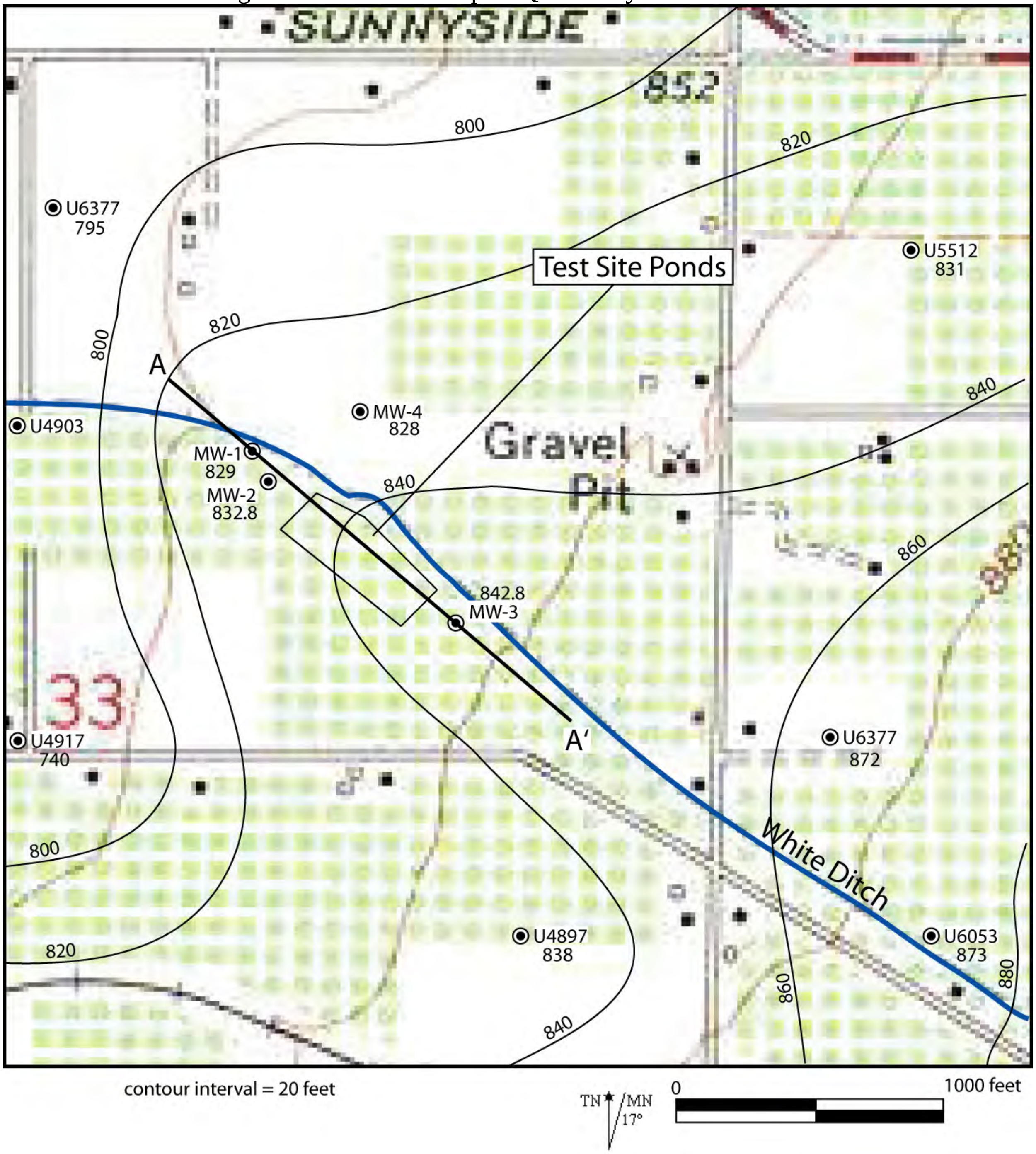


Figure 7. Map of the elevation of the top of the Mio-Pliocene conglomerate in feet above mean sea level.

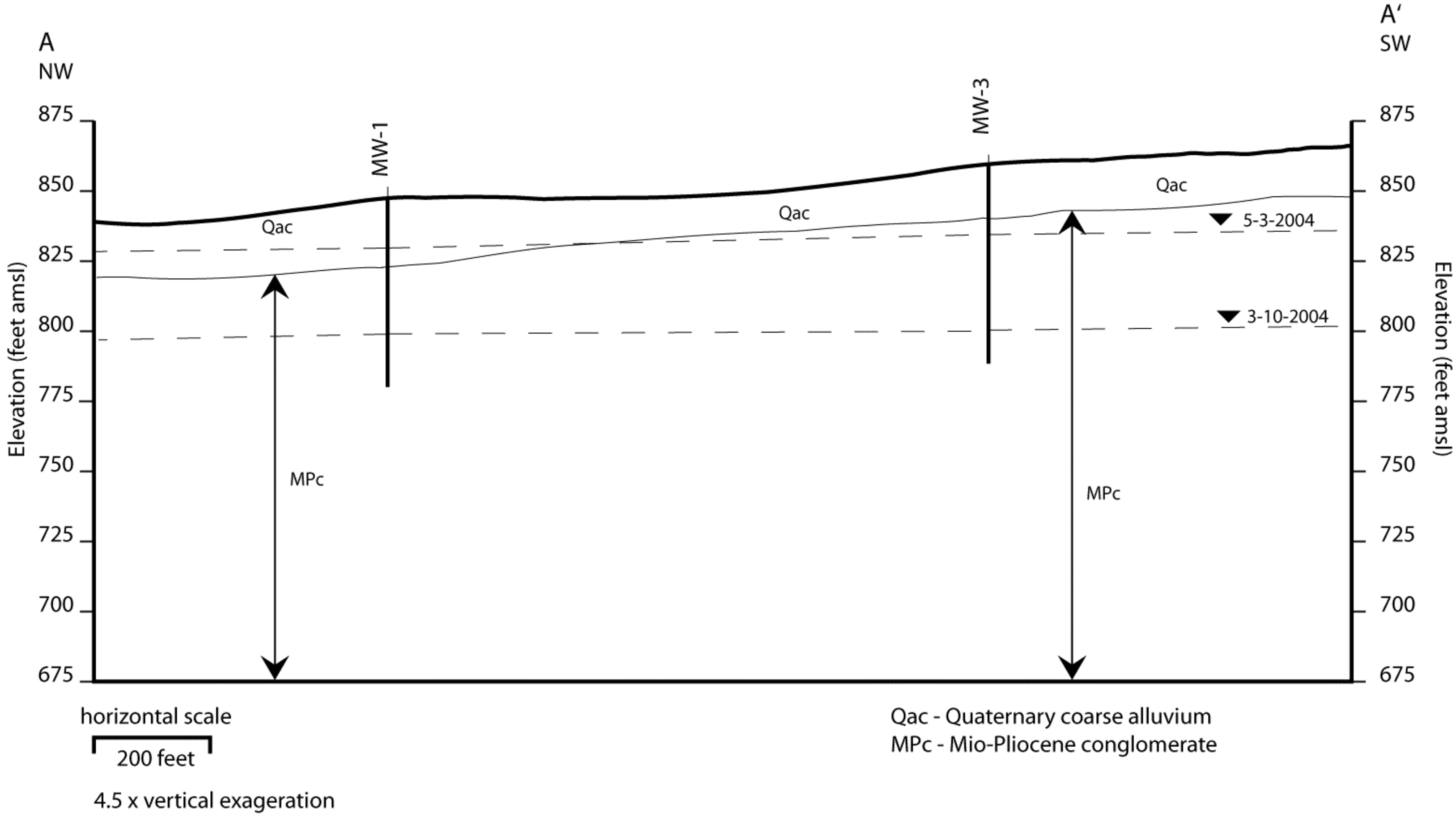


Figure 8. Geologic cross section through wells MW-1 and MW-3, displaying March 10, 2004 water table and May 3, 2004 water table.