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## RESULTS FROM THE SECOND YEAR OF ASR PILOT TESTING AT THE CITY OF DALLAS, OREGON

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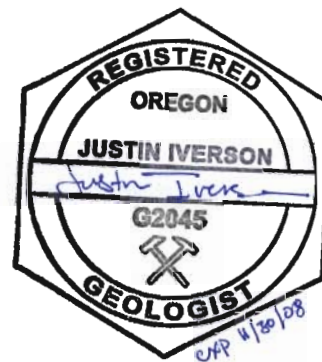
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**WATER RESOURCES DEPT  
SALEM, OREGON**

## EXECUTIVE SUMMARY

The City of Dallas has completed the second year of aquifer storage and recovery (ASR) pilot testing with favorable results. The City is conducting ASR pilot testing under ASR Limited License #011, issued in 2006 and valid for a 5-year testing period. The City has developed an ASR system as a method to help meet increasing water demand without developing a new water supply source. High-quality drinking water produced at the City's treatment plant is stored in the saline basalt aquifer system at the site using a well constructed for ASR operations (ASR No. 1). Year-2 pilot testing activities were designed to build on the results of the first year of pilot testing by evaluating aquifer hydraulic response to ASR operations under full-scale recharge and recovery periods, determining optimal recharge and recovery rates for full-scale operation, and initiating automated SCADA system operational control of the ASR system. Results from the second year of ASR pilot testing at the City of Dallas ASR No. 1 well indicate development of an annual full-scale ASR program at this location is feasible.

This report documents the results of Cycle 6, the first full-scale recharge, storage, and recovery cycle completed as part of pilot testing operations. Cycle 6 operations began the process of establishing a large freshwater storage zone that achieved the project target of storing approximately 50 million gallons at ASR No. 1. By the end of the recovery period, approximately 14.5 million gallons had been recovered from the aquifer, resulting in a recovery efficiency of approximately 28%. Once consecutive full-scale ASR cycles are completed, recovery efficiency is expected to progressively improve with successive cycles as demonstrated in Cycles 1 through 4 conducted during Year-1 pilot testing.

Wellhead monitoring data indicates the aquifer responded to ASR operations as anticipated, with water levels rising and falling in response to the pilot testing operations. Water levels at three of the twelve observation wells in the monitoring network show a response to ASR operations. The rise and fall of water levels at these locations has not interfered with normal well operations or had any apparent impact on drinking water quality.

A groundwater seep located approximately one-half mile to the northwest of ASR No. 1 was monitored with a piezometer during Cycle 6. Springs in this area previously supplied water to the Ellendale Water District. Water levels recorded in the piezometer installed in this area show that artesian pressure existed in the seep area before Year-2 pilot testing activities began (i.e., water levels in the piezometer were above ground surface). Water levels rose by 0.5 foot above background levels after recharge operations began, receded to pre-injection levels during the storage period, and fell below ground surface after recovery operations were initiated. Water levels in the piezometer began to rise again in response to precipitation in November and December 2007.

Laboratory analytical results indicate that recovered water quality from ASR No. 1 meets all primary drinking water standards for public water systems, and that the recovered water is suitable for delivery to the City's water distribution system. During Year-2 pilot testing, chloride and total dissolved solids (TDS) increased until concentrations exceeded secondary standards (SMCLs; non-enforceable, non-health-based guidelines) as a function of mixing with saline native groundwater. Recovery operations can easily be managed to ensure that recovered water does not compromise the City's high standards for delivered water quality. During Cycle 6, recovered water was mixed with water from the City's treatment plant water before delivery to the City's distribution system at a target ratio of 8:1 (8 parts treatment plant water, 1 part recovered ASR water), mitigating high TDS and chloride levels such that delivered water would not exceed SMCLs. During an approximate two-week period, the mixing ratio was lower due to a reduced demand associated with a period of cooler

weather. The City is currently evaluating methods to lower recovered water salinity and improve the recovery efficiency of subsequent cycles.

Year-3 pilot testing operations began with the initiation of recharge in mid-December 2007. Recovery operations are expected to begin in July 2008, and pilot testing results will be documented in the Year-3 ASR Pilot Test report in accordance with the City's Limited License.

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### **ATTACHMENTS**

Compact Disc Year-1 Water Quality Results – Analytical Laboratory Reports  
(enclosed at the back of the document)

## **1.0 PROJECT DESCRIPTION**

### **1.1 Introduction**

This report presents the results of the second year of aquifer storage and recovery (ASR) pilot testing conducted at the City of Dallas ASR No. 1 well during Water Year 2007 (October 1, 2006 through September 30, 2007). Pilot testing at ASR No. 1 is performed under ASR Limited License #011, issued to the City of Dallas (City) by the Oregon Water Resources Department (OWRD) on April 28, 2006 (OWRD, 2006). The pilot testing program has been conducted in accordance with the Limited License, Aquifer Storage and Recovery Pilot Test Work Plan, and Work Plan Addendum that have been approved for the project (Golder, 2005<sup>b</sup> and 2006<sup>b</sup>). For continuity and for the sake of presenting results during similar operational periods, this report also includes results and observations from pilot testing conducted during October and November 2007, which are formally considered part of Water Year 2008.

The overall objective of the pilot testing program is to evaluate ASR feasibility for the target aquifer system (basalt of the Siletz River Volcanics) and to develop operational criteria for the City's ASR program. The Year-2 pilot testing program consisted of a single full-scale recharge, storage, and recovery period conducted between December 2006 and November 2007. Operational control of the ASR system during Year-2 testing was largely performed via an automated SCADA system. The testing was conducted in a controlled manner to provide data necessary to evaluate ASR feasibility and to develop a long-term ASR operations plan. Specifically, the Year-2 pilot testing program met the following objectives:

- Confirm SCADA control of equipment and wellhead facility operations;
- Provide data to refine optimal rates of recharge and recovery;
- Evaluate the feasibility of developing a fresh-water storage zone within the native saline groundwater system;
- Evaluate aquifer hydraulic response to ASR; and,
- Evaluate well performance during ASR operations.

### **1.2 Existing Site Conditions and ASR Facility**

Details regarding the construction and development of the City of Dallas ASR No. 1 well and a description of the hydrogeologic setting are presented in the Aquifer Storage and Recovery Hydrogeologic Feasibility Study dated December 13, 2005 (Golder, 2005<sup>a</sup>). The results of the first year of pilot testing were presented in a February 12, 2007, report titled Results from the First Year of ASR Pilot Testing at the City of Dallas, Oregon (Golder, 2007). Only a brief description of the existing site conditions, ASR facility, and upgrades to equipment will be provided in this document; please refer to the referenced reports for additional information.

ASR No. 1 (POLK 52056) is located at the City of Dallas Water Treatment Plant (WTP; Public Water System No. 4100248), situated approximately 2-miles west of Dallas (Figure 1-1). The City's drinking water source, and the source of water for the ASR project, is from Rickreall Creek, which is treated through a combination of flocculation, filtration, disinfection, and fluoridation. ASR No. 1 was completed in the Siletz River Volcanics (SRV) basalt aquifer between February 25 and July 15, 2004, using a combination of direct mud-rotary and reverse circulation air-rotary drilling techniques. The well is cased and sealed to a depth of 501 feet below ground surface (feet bgs) with a 16-inch

steel production casing sealed in cement grout. ASR No. 1 is open to the Siletz River Volcanic basalt aquifer from 501 to 925 feet bgs (approximately 15-inch diameter) below the production casing.

Recharge is controlled by a Baski In-Flex flow control valve that regulates the recharge rate by means of a rubber element that is inflated (closed) and deflated (opened) via nitrogen gas. Nitrogen input and output is controlled at the wellhead via the Baski control panel manifold, which allows for either manual or SCADA programmed regulation of valve pressure (recharge rate). The pumping system consists of a 75-hp Goulds submersible pump with a 4-stage, 6-inch diameter bowl assembly. The pump intake is located at a depth of approximately 495 feet bgs. A variable frequency motor drive (VFD) was installed in August 2007, which allows for either manual or SCADA programmed regulation of motor speed and pumping rate.

ASR source water from the onsite 2-million gallon (MG) finished water reservoir enters the wellhouse through a 4-inch diameter steel pipe to an intersection with a three-way directional valve, set by hand to control the direction of flow, either to or from the well. The 2-MG reservoir is constructed of welded steel, and is located approximately 15 feet to the west of the ASR No. 1 wellhouse. After recharge to the aquifer has been completed, recovered water is routed to the City's distribution system via the 2-MG reservoir. Recovered water exits the wellhouse, passes through a re-chlorination system, and then mixes with treated water from the WTP in the 2-MG reservoir before delivery. An initial hydraulic evaluation of the City's storage and distribution system indicated that routing recovered water back to the 2-MG reservoir would result in mixing of treated drinking water from the WTP and the ASR system at a minimum ratio of approximately 4:1 (City of Dallas, 2006). Analysis of actual ASR well and WTP production rates during Cycle 6 showed that mixing occurred at a ratio of approximately 8:1 during Year-2 pilot testing.

A bi-directional Endress+Hauser electromagnetic flow meter with totalizer is installed at the wellhead to record flow rate and total volume of both recharge and recovery. A ½-inch copper sample port is plumbed at the wellhead for sample collection, and is fitted with a ball valve to control flow. An air release ball valve is also installed at the wellhead to allow for purging of any air bubbles in the pump column.

ASR No. 1 is monitored and controlled by the WTP SCADA system via several electronic sensors installed at the well head works. In addition to the bi-directional flow meter and totalizer, the following parameters are monitored and used to control recharge and recovery flow rates and volumes:

- ASR No.1 water level is monitored with an Endress+Hauser Water Pilot FMX167 300-psi pressure transducer. The transducer is installed in a dedicated 1.5-inch PVC access tube and set approximately 1.5 feet below the bottom of the pump motor (approximately 503 feet bgs).
- Recharge and recovery line pressure is monitored with pressure sensors set on both sides of the two-way directional valve. Nitrogen tank source pressure and Baski valve inflation pressure are monitored with pressure sensors set on both sides of the Baski control panel manifold.
- Recovered water electrical conductivity is monitored and recorded by the SCADA system with a Hach conductivity sensor mounted in the 6-inch pipe leading to the distribution system. In November 2007, the conductivity sensor was replaced with a unit capable of measuring values of conductivity up to 10,000 µS/cm.

In addition, manual water level and field parameter measurements were recorded during recharge and recovery periods, and are used to backup and confirm the electronic water level data provided by the

SCADA system. Manual water level measurements are collected with a Slope Indicator electric tape via a 1.5-inch PVC access tube installed to a depth of 503 feet bgs. Field parameter measurements are collected with a YSI 556 multi-parameter portable meter plumbed to the sample port with a flow-through-cell.

### **1.3 Year-2 Pilot Testing Program Description**

The Year-2 pilot testing program began with expansion of the monitoring network and collection of background water level data in late-November 2006. A single full-scale recharge, storage, and recovery cycle at ASR No. 1 began in December 2006 and continued until mid-November 2007.

#### **1.3.1 Monitoring Network Expansion**

An addendum to the pilot test work plan (Golder, 2006<sup>b</sup>) included recommendations to expand the water level monitoring network based on limited hydraulic response in the original network and visual observation of a seep/spring that may have responded to ASR operations during Year-1 pilot testing. The additional monitoring locations that were incorporated into the network consist of a shallow piezometer installed at the seep area near the intersection of Ellendale Road and Robb Mill Road, and three nearby domestic wells. The new monitoring locations are shown on Figure 1-1 along with the wells previously included in the Year-1 observation network. A detailed description of the observation network expansion, including well logs for the new observation wells and a construction diagram of the piezometer, are detailed in a letter report to OWRD dated January 5, 2007 (Golder, 2007<sup>a</sup>).

#### **1.3.2 Cycle 6 ASR Pilot Testing**

Between December 2006 and November 2007, the City initiated the first full-scale recharge, storage, and recovery cycle (Cycle 6) at ASR No. 1. Cycle 6 was designed to evaluate aquifer hydraulic response to ASR operations under full-scale recharge and recovery periods, determine optimal recharge and recovery rates for full-scale operation, and begin automated (SCADA system) control of the ASR system.

Recharge for Cycle 6 began on December 5, 2006, and continued until July 11, 2007, resulting in a total recharge volume of 52.5 MG. Recharged water was stored in the aquifer for 41 days, and recovery began on August 21, 2007, continuing until November 19, 2007. During recovery, water was re-chlorinated and pumped back to the 2-MG reservoir.

#### **1.3.3 SCADA Programming**

SCADA programming to facilitate automation of the recharge and recovery rates during Cycle 6 resulted in some telemetry data gaps and data value shifts. During Cycle 6, the SCADA system was reprogrammed to:

- Rectify differences between SCADA data records and parameter readouts from instrument panels in the well house (recalibrate transformation equations);
- Automate the recharge flow control valve to maintain constant recharge rates and to decrease the recharge rate in the event that water levels in the well approach ground surface; and
- Automate the control of the variable speed drive to maintain constant recovery rates and to decrease the recovery rate if water levels in the well approach the pump intake or if recovered water conductivity reached unacceptable levels.

## **2.0 YEAR 2 PILOT TEST RESULTS**

### **2.1 Cycle 6 Operations and Data Collection**

During Cycle 6, treated drinking water was injected for 218 days at an average rate of 167 gpm, with a recharge volume of approximately 52,541,000 gallons. Injected water was stored for 41 days, and then recovered over a period of 51 days primarily at a rate of 250 gpm. Approximately 72 percent of the recharge volume was left in the aquifer (38 MG). Table 2-1 provides a summary of the pilot testing operations conducted at ASR No.1 during Years 1 and 2, including information regarding the timing of operations, average recharge and recovery rates, and recharge and recovery volumes.

The sustainable recharge rate at ASR No. 1 is a function of aquifer transmissivity, the aperture of the down-hole flow control valve, and the difference in head between the 2-MG reservoir and the aquifer. During Cycle 6, the recharge rate was controlled by the SCADA system, which automatically adjusted the aperture of the recharge flow control valve to maintain a relatively constant recharge rate of 165 gpm, plus or minus 2 to 5 gpm (Figure 2-1). Similarly, the SCADA system controlled the recovery rate by automatically adjusting the speed of the pump motor with the variable frequency drive. Water was recovered at 250 gpm, with a short period of pumping at 125 gpm to assess the effect of lower pumping rates on the conductivity of recovered water (Figure 2-2). Two interruptions in recovery occurred due to an extended power outage (September 14-17, 2007) and operational management of the ASR system in conjunction with the City's water treatment plant and distribution system (September 25 to November 5, 2007).

ASR No. 1 was backflushed three times during the recharge period at near-maximum pumping rates to help maintain well performance and remove any suspended solids that may have entered the borehole during recharge. The first backflush event was performed in early-March, the second event was performed in late-May, and the third event was performed near mid-July at the end of the recharge period. The first and third backflush events were performed as routine maintenance, and the second in response to a minor clogging event in the well. Backflush events were conducted at rates between approximately 520 and 350 gpm for periods ranging between 30 and 120 minutes until visible turbidity was absent. Figure 2-3 presents a comparison plot of recharge specific capacity trends between backflush events, indicating some minor improvement of recharge specific capacity after each event.

Telemetry data from wellhead monitoring instrumentation were collected at 5-minute intervals by the WTP SCADA system. Manual data were used to validate the telemetry data and to fill any data gaps created during instrument maintenance periods and SCADA system downtimes. Field measurements of water quality parameters were collected at 15-minute intervals during both recharge and recovery cycles using a portable multi-parameter meter with built-in datalogger. Manual water level measurements were collected from ASR No. 1 on a daily basis during recharge and recovery periods.

### **2.2 Aquifer Response and Well Performance**

A hydrograph of water levels at ASR No. 1 illustrating pre-pilot testing water levels, water level response to ASR operations, and water level equilibrium after Year-2 pilot testing is provided in Figure 2-4. Recharge and pumping water levels were maintained within the sealed casing, which extends to a depth of approximately 500 feet bgs.

Water level buildup in ASR No. 1 during the Cycle 6 recharge period is presented in Figure 2-5. Water level buildup quickly increased to approximately 150 feet after the first few hours of recharge, and then slowly built to nearly 200 feet over the remainder of the recharge period. Automatic control of the recharge rate was initiated on December 8, 2006, three days after the initiation of Cycle 6. The

system was programmed to hold the recharge rate within 2 to 5 gpm of the target rate of 165 gpm, resulting in a more even buildup trend than was obtained in the first five cycles.

Drawdown in ASR No. 1 during Cycle 6 recovery is presented in Figure 2-6. The SCADA system was programmed to hold a target pumping rate of 250 gpm plus or minus 2 gpm for most of the recovery period, resulting in more even drawdown trends than were obtained in the first five cycles. During the recovery period, there were several pumping interruptions. Brief interruptions (events of a few hours or less) generally resulted from SCADA system malfunction or down-time. Two longer-term interruptions (lasting for 3 or more days) occurred during a sustained power outage and an operational management shut-down. Water levels in ASR No. 1 had recovered sufficiently during these longer-term shut-down periods that water level drawdown trends were re-plotted from elapsed time zero.

During Cycle 6 recovery pumping, approximately 250 feet of drawdown would occur within the first hour of pumping, and then gradually decrease to as much as 292 feet over the remainder of each recovery period (see Figure 2-6). Water levels were maintained at least 15 feet above the pump intake at all times to allow for adequate cooling of the pump motor. At the end of the final recovery cycle, the recovery rate was decreased to 125 gpm for a period of five days, which resulted in approximately 115 feet of drawdown (approximately 295 feet bgs).

Recharge specific capacity observed during Cycle 6 is presented in Figures 2-1 and 2-3. During Cycle 6, recharge specific capacity generally began near 1.1 gallons per minute per foot of buildup (gpm/ft) and slowly decreased during continued recharge operations to minimum levels of approximately 0.86 gpm/ft. As indicated in Section 2.1 above, the well was backflushed three times during the injection process, for routine maintenance of the well bore and after an apparent clogging event. Figure 2-3 presents a comparison plot of injection specific capacity trends between backflush events, indicating minor improvement of injection specific capacity of the well after the routine maintenance event (backflush #1) and restoration of specific capacity following the clogging event and backflush #2. No overall loss of well performance indicative of clogging or plugging during recharge is evident from the specific capacity record. Specific capacity values were comparable to those observed during Cycle 5 after similar duration of recharge, although slightly lower during Cycle 6 injection.

Pumping specific capacity during the Cycle 6 recovery period is presented in Figure 2-2. In general, the pumping specific capacity of ASR No. 1 began at approximately 1.1 gpm/ft, and then slowly decreased over the remainder of the recovery periods to approximately 0.85 gpm/ft. Pumping specific capacity was somewhat higher during the Cycle 6 recovery period compared to Cycle 5.

### **2.3 Water Level Monitoring**

An observation well network was developed by identifying private wells within a 2-mile radius of the project site. Well owners were contacted to solicit permission to monitor their wells as part of the ASR pilot testing program. Permission was ultimately granted for eleven wells at eight property locations (see Figure 1-1). In addition, a shallow piezometer was installed at a seep area identified near the intersection of Ellendale Road and Robb Mill Road (see Section 1.4.1 for details). In this report, observation wells are informally referred to by owner name, with relative modifiers added when more than one well exists on a property. Table 2-2 presents a summary of the wells in the monitoring network, including OWRD log and well identification codes when available, well head surface elevations estimated using USGS 7.5-minute quadrangle topographic maps, and reported well depths when available.



Six wells in the observation network are actively used for domestic supply, while the remaining five are not in active use. Manual water levels were measured at each of the wells using an electronic water level indicator as prescribed in the ASR Pilot Test Work Plan (Golder, 2005<sup>b</sup>) and Work Plan Addendum (Golder, 2006<sup>b</sup>). In addition, pressure transducers equipped with data loggers were installed in three of the unused domestic wells (Birko Upper, Lowe Upper, and Kowalczyk Upper) and the piezometer to record water levels at 1-hour intervals during the Year-2 pilot testing program. Barometric pressure was also recorded using a pressure transducer to evaluate potential barometric response in the wells. Transducer data gaps exist near the end of Cycle 6 recharge due to datalogger program capacity.

A long-term comparison plot of observation well water levels is presented in Figure 2-9, while water level records for individual observation wells compared with daily precipitation data are presented in Figures 2-10 through 2-21. All water level trend plots include vertical dashed lines indicating the recharge, storage, and recovery phases of Year-2 pilot testing. For reference, climate records from the Rockhouse weather station, located approximately 5 miles west of the City's water treatment plant, are presented in Figure 2-7 (daily and cumulative precipitation) and Figure 2-8 (minimum and maximum daily temperature).

### 2.3.1 Baseline Monitoring

Baseline monitoring in advance of Year-2 pilot testing was conducted between November 28 and December 5, 2006. Water levels in the observation wells measured during the baseline monitoring period were higher than those measured after the end of Cycle 5 in October 2006, as would be expected of regional water levels between fall and winter. The Anstine, Fitcha, and Jones wells were added to the monitoring network after the start of Cycle 6 recharge. .

### 2.3.2 Water Level Monitoring During Cycle 6 Pilot Testing

Three of the twelve wells in the monitoring network exhibited a hydraulic response to ASR operations; the Lowe Upper well (Figure 2-18), Piezometer 1 (Figure 2-20), and the Presser well (Figure 2-21). Water level trends in the remaining observation wells did not indicate response to Year-2 pilot testing activities at ASR No. 1. There is no apparent spatial pattern to explain the distribution of the wells that respond and those that did not. Hydraulic response to pilot testing operations at ASR No. 1 is likely related to an irregular distribution of fracturing and/or faulting within the Siletz River Volcanic Formation. The following sub-sections describe water level trends at each observation well.

#### 2.3.2.1 *Anstine Well*

The Anstine well is a relatively deep (448 feet) domestic well completed in the marine sedimentary Yamhill Formation overlying the Siletz River Volcanics (SRV). While individual water level measurements exhibited significant variability due to active domestic pumping general water level trends were dominantly influenced by seasonal precipitation patterns (Figure 2-10). In general, water levels were relatively high during the wet season early in Water Year 2007 (WY07), tapered-off during the dry season, and then rose with precipitation in WY08. While the owner reports that the pump is set near 435 feet bgs, an obstruction near 220 feet bgs prevented water levels from being collected below that level several times during the dry season. No hydraulic response to ASR operations is apparent in the Anstine water level data.

#### 2.3.2.2 *Birko Wells*

The Birko Lower well is an unused domestic well drilled at the base of a small hill and completed in the SRV. Birko Lower displays water level trends generally coincident with seasonal rainfall (Figure 2-11). Water levels were relatively high during the wet season, from November 2006 through March 2007. Response to lack of precipitation is apparent in late-January and early-February. Water levels steadily declined over the remainder of the water year until water levels began rising due to rainfall in October and November 2007. No response to ASR is apparent in the Birko Lower water level data.

The Birko Upper well is also an unused domestic well, drilled on a hillside and completed in the SRV at an elevation approximately 130 feet above Birko Lower wellhead. Water levels in Birko Upper (Figure 2-12) were also dependent on seasonal precipitation and exhibited a similar but slightly steeper water level trend as compared to the Birko Lower well. No response to ASR is apparent in the Birko Upper water level data.

#### 2.3.2.3 *Fitcha Well*

The Fitcha well is used intermittently for backup domestic supply. The well is completed in the Yamhill Formation, and has poor water quality. Water level trends in the Fitcha well are influenced by seasonal precipitation trends, being relatively high in the wet season and receding in the dry season (Figure 2-13). No response to ASR is apparent in the Fitcha water level data.

#### 2.3.2.4 *Jones Well*

The Jones well is completed in the SRV and is used for domestic supply well. Domestic use caused water level variability between individual measurements, and long-term water level trends in the Jones well indicate a relatively minor response to seasonal precipitation trends. Static water levels in the wet season are 4-5 feet higher than in the dry season (Figure 2-14). No response to ASR is apparent in the Jones water level data.

#### 2.3.2.5 *Kowalczyk Wells*

The Kowalczyk-Lower well is a domestic supply well completed in the SRV. Water level measurements in this well exhibited variability due to active domestic pumping at the well, as well as apparent interference from pumping at off-site well(s) (Figure 2-15). In general, water levels were high in the wet season and decreased over the course of the dry season, with a sharp decrease in early-July, coincident with the first heat-wave of the season (and presumably more pumping from the Kowalczyk Lower and other area wells). Water levels showed an upward trend for the remainder of WY07, recovering from the sharp July decrease through the summer and continuing upward after the fall rains. No response to ASR is apparent in the Kowalczyk-Lower water level data.

The Kowalczyk-Upper well is an unused well without a well log, but is presumably completed in the SRV. Water levels at this well were also variable during WY07 (Figure 2-16), and exhibited a similar trend though to a lesser degree than observed in the Kowalczyk Lower well. The timing of the trends observed in the Upper well corresponds with those in the Lower well, and thus it appears that the two wells are hydraulically connected. Water levels in Kowalczyk Upper continued to rise well into May, then dropped in a series of events that appear to be related to well interference. The source of the apparent pumping stress is unknown, whether from the Kowalczyk Lower well or other nearby wells. Water level trends at the Kowalczyk Upper well were also upward for most of the late summer after the water level decline observed in early-July. No response to ASR is apparent in the Kowalczyk-Upper water level data.

#### 2.3.2.6 *Lowe Wells*

The Lowe-Lower well is an active domestic supply well completed in the SRV. The water level at this well exhibits significant variability due to active domestic pumping and its low capacity (Figure 2-17). Water level data for the Lowe-Lower well predominantly reflected pumping water levels between approximately 120 and 170 feet bgs during the period of record. No hydraulic response or trends in the pumping water level in response to pilot testing at ASR No. 1 is apparent.

The Lowe-Upper well is an unused well completed in the SRV that continued to respond to pilot testing activities at ASR No. 1 during Cycle 6. This well exhibited rising water levels in response to recharge and declining trends in response to the storage period and recovery pumping (Figures 2-18). Compared to background water levels collected immediately preceding the initiation of Cycle 6 recharge, the Lowe-Upper well experienced approximately 19 feet of buildup by the end of the recharge phase. During the storage period, water levels receded to approximately 2 feet above the pre-recharge level. When recovery operations began, the water level in the Lowe Upper well declined to a maximum of approximately 21 feet below pre-recharge levels.

#### 2.3.2.7 *Parker Well*

The Parker well is an active domestic well completed in the SRV. Water levels at this well maintained a trend coincident with seasonal precipitation patterns (Figure 2-19), being above the top of the well casing after significant precipitation events and responding to the mid-winter dry-spell with decreasing water levels in late-January. After rising in response to rainfall in February, the water level continued to decline throughout the year until significant rainfall events occurred in the fall. No response to ASR is apparent in the Parker water level data.

#### 2.3.2.8 *Piezometer 1*

A groundwater seep located approximately one-half mile to the northwest of ASR No. 1 was identified in mid-August 2006 during the Cycle 5 recharge period. Because flow from the seep area appeared to be stable (was not increasing in magnitude with time) and, according to City staff, was a naturally-occurring historic source of water for the former Ellendale Water District, it was not clear whether flow from the seep was actually resulting from operations at the City's ASR well. A shallow water level monitoring piezometer (PZ-1) was installed at the seep location on November 28, 2006, and was monitored during Year-2 pilot testing operations to assess the potential for a hydraulic response to ASR operations (see Section 1.4.1).

Water was actively flowing from the seep area during piezometer installation, and water levels observed in the completed piezometer before the initiation of Cycle 6 recharge were between one-half and one foot above ground surface (-0.5 to -1 ft bgs, Figure 2-20). After the initiation of Cycle 6 recharge, water levels in the piezometer rose to 1.6 feet above ground surface, indicating an apparent one-half foot response to recharge at ASR No. 1. Water levels in PZ-1 remained near 1.5 feet above ground surface for the remainder of the recharge period, receded gradually to approximately 0.75 feet above ground surface during the storage period, then dropped below the screened interval (1.7 feet bgs) shortly after initiation of the recovery period. Water levels in the piezometer rose in response to winter precipitation at the end of the Cycle 6 recovery period and rose to levels above ground surface after the December 2007 storm event. Given the water level trends in PZ-1, it is apparent that the Ellendale road spring/seep responds both to seasonal precipitation as well as ASR pilot testing operations.

#### 2.3.2.9 *Presser Well*

The Presser well is an active domestic well completed in the SRV. Water levels in the Presser well continued to respond to pilot testing activities at ASR No. 1 during Cycle 6, exhibiting rising water level trends in response to recharge and declining trends in response to the storage period and recovery pumping (Figure 2-21). Water levels at the Presser well responded to pilot testing operations at a slower rate and with a smaller magnitude than observed at the Lowe Upper well (a maximum of approximately 15 feet as opposed to approximately 20 feet at the Lowe Well), but followed approximately the same water level trend. The Presser well pump is set at about 360 feet below ground surface, leaving approximately 200 feet of water above the pump during recovery periods.

The Presser well exhibited approximately 15 feet of water level buildup related to Cycle 6 recharge, receded to approximately 1 foot greater than pre-recharge levels during the storage period, and then declined to a maximum drawdown of approximately 13 feet during the recovery period. Two interruptions in pumping at ASR No. 1 (described in section 2.1 above) lead to temporary increases in water level in the Presser well during the Cycle 6 recovery period.

### 2.4 **Water Quality Monitoring**

Water quality was assessed at the ASR No. 1 well head and at the observation wells during Cycle 6 pilot testing in accordance with the Limited License, Pilot Test Work Plan, and Work Plan Addendum. Water quality results obtained during the second year of ASR pilot testing are summarized in Tables 2-3 and 2-4. Copies of all analytical laboratory reports are provided in electronic format on the compact disc enclosed at the back of the document.

#### 2.4.1 Safe Drinking Water Act Compliance

##### 2.4.1.1 *Source Water*

Recharge source water quality was first characterized as part of the initial feasibility studies, with samples collected from the City's WTP in November 2004 and July 2005, which were reported in the ASR Pilot Test Work Plan (Golder, 2005<sup>b</sup>). Another source water sample (sample ID C1PRESRC) was collected on April 27, 2006, prior to Year-1 ASR pilot testing. This sample was collected at the City's ASR wellhead facility to supplement previous water quality data and to demonstrate suitability of the City's treated drinking water for ASR pilot testing. Source water was again sampled during Year-2 pilot testing (sample ID C6RCGSRC, collected 7/11/07, see Table 2-3) to confirm compliance with recharge water standards. The analytical results from sample C6RCGSRC confirmed potability of the City's treated drinking water and compliance with OAR 690-350.

An additional source water sample was collected at the wellhead during pilot testing (sample ID C6PRESRC), which was analyzed for geochemical constituents. The results of this analysis are summarized in Table 2-3, and indicate that the source water from the City's treatment plant exhibited consistent chemistry during the second year of pilot testing. Relative to groundwater, source water TDS was low, ranging from 34 to 60 mg/L. Peak measured calcium and chloride concentrations were 8.8 and 6.6 mg/L, respectively, which are orders of magnitude lower than native groundwater concentrations. Iron and manganese (total and dissolved phases) were consistently below detectable limits in the source water. Nutrient concentrations also were low in recharge water, with nitrate and nitrite being consistently below detectable limits (<0.1 mg/L-N). Ammonia was not detected in source water during Year-2 pilot testing and phosphorus was detected once at concentration of 0.13 mg/L. Total organic carbon (TOC) concentrations in the source water were stable, averaging approximately 0.66 mg/L. Regulated metals were below detectable limits in the source water and

disinfection byproducts (total trihalomethanes/TTHMs and total haloacetic acids/HAA-5) were present in small concentrations below their respective drinking water standards.

#### 2.4.1.2 *Native Groundwater*

Groundwater quality at ASR No.1 was characterized previously with two separate samples. The first sample (sample ID 99041) was collected at the termination of the aquifer test performed on September 9, 2004, after 48 hours of pumping. A second sample (sample ID DASR0705) was collected on July 8, 2005, to confirm pH, total iron, and dissolved iron. The results of these analyses are summarized in Table 2-3, and indicate that native groundwater is moderately alkaline ( $\text{pH} \geq 8.5$ ) and slightly reducing (Oxidation-Reduction Potential  $\leq -176$  mV). Synthetic organic compounds, volatile organic compounds, and radiological contaminants were not detected. No other primary contaminants were detected above their respective regulatory levels (MCLs). Some secondary contaminants were found at levels above their respective regulatory levels (SMCLs), such as chloride, total iron, and total dissolved solids (TDS). Concentrations for chloride, total iron, and TDS, relative to their SMCLs in parentheses, were 2,560 mg/L (250), 0.798 mg/L (0.3), and 4,190 mg/L (500), respectively. The presence of ammonia (0.39 mg/L-N) and absence of nitrate ( $<0.1$  mg/L-N) is consistent with reducing groundwater conditions. The concentrations of most metals measured in solution were below their respective detection limits. Dissolved iron and manganese concentrations were 13  $\mu\text{g/L}$  and 11.3  $\mu\text{g/L}$ , respectively.

A pre-recharge groundwater sample (C6PREGW, see Table 2-3) was collected before Cycle 6 recharge operations began. This sample is not representative of background groundwater quality, as recharged water remained in the aquifer after Cycle 5. Sample C6PREGW provides an indication of the initial water chemistry near the well prior to Cycle 6 injection. The results of this sample indicate that water quality in the aquifer prior to Cycle 6 recharge was quite similar to native groundwater, although somewhat diluted by the recharge water remaining in the aquifer after the Year-1 operations.

#### 2.4.1.3 *Recovered Water*

Per the water quality monitoring program established in the ASR Pilot Test Work Plan, "drinking-water" samples were collected (sample IDs C6REC02% and C6REC26%) and analyzed for DHS and DEQ regulated, unregulated, and secondary contaminants (as regulated by OAR 333-061-030 and OAR 340-040) on the third and last day of recovery during Cycle 6. The results of the recovered water analyses are summarized in Table 2-3.

Analytical laboratory results indicate that the recovered water quality from the City's ASR well meets all primary drinking water standards for public water systems, including synthetic organic compounds (SOCs), volatile organic compounds (VOCs), disinfection by-products (DBPs), radiological constituents, metals and inorganics, and coliform bacteria. The water quality data indicate that the recovered water is suitable for the City's water distribution system. Although low levels of DBPs were detected in recovered water, they were detected at levels well below drinking water standards.

Chloride and TDS exceeded their respective SMCL standards at the end of the Cycle 6 recovery period. Concentrations of chloride and TDS in sample C6REC26% were reported as 1650 mg/L and 2850 mg/L, respectively. However, mixing of recovered water with treatment plant water in the 2MG tank at a minimum ratio of 1:8 results in water delivered to utility customers with chloride and TDS concentrations less than established SMCLs, estimated to be approximately 190 and 370 mg/L, respectively. The 1:8 mixing ratio between recovered (ASR) water and water produced from the treatment plant was determined from the volumetric production rates of the treatment plant and the recovery rate from the ASR well. Recovery efficiency also affected by the demand during recovery.

To optimize recovery, ASR recovery should coincide with the highest demand period affording maximum dilution.

#### 2.4.2 Field Parameter Monitoring

General water quality field parameters, including pH, temperature, dissolved oxygen (DO), oxidation-reduction potential (ORP), and specific conductance, were measured from source water and recovered water using a YSI-556 Multi-Probe System™ and a closed flow-through cell. A data logger was used to record field parameter data on an hourly basis during most of Cycle 6. A summary of field parameter monitoring at ASR No. 1 is provided below.

##### 2.4.2.1 *Source Water*

###### *pH*

Source water pH showed some minor variability during Year-2, ranging mostly between 6.5 and 7.5 with an average value of 7.0 (Figure 2-22). During Cycle 6, source water pH was lowest in the early spring, and rose steadily through the end of recharge in July.

###### *Temperature*

Source water temperature during Year-2 ranged between approximately 3 and 21 degrees Celsius (°C) (Figure 2-23). During Cycle-6 recharge, source water temperature was lowest in February 2007, and then rose steadily for the remainder of the recharge period to reach the highest temperatures in July 2007.

###### *Dissolved Oxygen*

Dissolved oxygen (DO) concentrations in the recharge water remained near saturation levels during most of Year-2 operations, ranging between 7 and 14 mg/L (Figure 2-24). DO saturation varied inversely with water temperature, being highest in February 2007 and lowest in July 2007.

###### *Oxidation-Reduction Potential*

Oxidation-reduction potential (ORP) is a relative indicator of a water's capacity to oxidize (remove electrons) or reduce (add electrons) ionic species dissolved in the water. ORP is therefore related to the amount of oxidizing agents in water, such as oxygen, chlorine, hypochlorite compounds, and peroxide compounds. Source water exhibited high ORP during Year-2 (Figure 2-25), generally ranging between 725 and 825 mV, which is indicative of the relatively high levels of dissolved oxygen (see Figure 2-24) and chlorination.

###### *Specific Conductance*

Specific conductance is a measure of the ability of water (and its dissolved ionic constituents) to conduct an electrical current. Pure liquid water has a very low capacity to conduct electrical current, thus specific conductance is an indirect gauge of the amount of ions dissolved in the water (i.e., total dissolved solids). Figure 2-26 illustrates that the source water has relatively low specific conductance and is representative of water with low dissolved solids. During Year-2 pilot testing specific conductance ranged between 60 and 90 micro-Siemens per centimeter (µS/cm). Specific conductance values were relatively stable during the first five months of recharge, and then exhibited a slight rising trend beginning in May and continuing through the remainder of the recharge period into mid-summer with a final value of about 90 µS/cm. This increasing SC trend denotes a slight increase in dissolved ionic constituents, likely related to rising source water temperature.



#### 2.4.2.2 Recovered Water

Field measurements of recovered water pH, temperature, DO, ORP, and specific conductance are plotted against percent recovery (volume recovered relative to total recharge volume) in Figures 2-27 through 2-31. Field parameter records for previous cycles, native groundwater (before pilot testing), and recharged water are also plotted for comparison between cycles. Note that while percent recovery during Cycles 5 and 6 was roughly half of that during Cycles 1 through 4, the volume of water recovered and the residence time of the last water recovered was significantly larger than that of the initial four cycles (see Table 2-1). Also, because water recovered from the ASR system is mixed directly with water from the City's water treatment plant (within the 2-MG reservoir at a ratio of at least 1:8), the influence of native groundwater characteristics on the properties of recovered water is attenuated to more neutral levels before delivery to the distribution system.

##### *pH*

Recovered water pH exhibited primarily a declining trend from 8.5 to 8 pH units during Cycle 6 (Figure 2-27). Within the first hour of the recovery period, pH rapidly rose from a value of 7 (consistent with the source water pH) and began to stabilize toward 8.5. Recovered water pH also continued a trend of progressively diminishing pH with successive ASR cycle. Elevated pH values observed during previous cycles are believed to have resulted from mixing with alkaline water associated with the cement grout used to abandon the lower portion of the borehole in 2005. The decreasing pH trend with continued ASR cycles indicates that the elevated alkalinity attributed to the cement grout has dissipated during pilot testing.

##### *Temperature*

Recovered water temperatures range from approximately 15 to 13 degrees C over the course of Cycle 6 recovery (Figure 2-28). Recovered water temperature trends indicate mixing between native groundwater (15.5 deg. C) and predominantly cooler recharge source water (from 3.5 to 21 deg. C over the injection period).

##### *Dissolved Oxygen*

The dissolved oxygen (DO) concentration of recovered water during Cycle 6 exhibited a rapidly declining trend from saturated source water concentration (approximately 10 mg/L) to nearly depleted DO conditions (near 0.1 mg/L) typical of native groundwater (Figure 2-29). This is consistent with trends observed during previous cycles. Attenuation of dissolved oxygen present in source water near saturation values occurs rapidly within the aquifer where it is either mixed with reducing native groundwater (containing very little DO and with little or no oxidation potential) or is consumed chemically.

##### *Oxidation-Reduction Potential*

Figure 2-30 presents recovered water oxidation-reduction potential (ORP) trends along with baseline groundwater ORP (near -200 mV) and Cycle 6 recharge source water ORP (near 800 mV). Similar to the DO trend, recovered water ORP values initially begin somewhat lower than source water values due to attenuation during the storage period, then rapidly declined to levels consistent with background groundwater conditions by 2% recovery. This response is caused by the rapid attenuation of dissolved oxygen and chlorine in the aquifer. The slight increase in ORP observed during the latter portion of Cycles 5 and 6 may be related to higher ORP in source water in the earlier phases of recharge during those cycles.

##### *Specific Conductance*

Specific conductance is used as a field proxy for total dissolved solids (TDS) in order to assess recovered water quality rapidly at the wellhead (the degree of mixing between recharge water and native groundwater) and to determine the end point of recovery operations. Figure 2-31 shows that



recovered water specific conductance values observed during Cycle 6 began at recharge source water levels (approximately 110  $\mu\text{S}/\text{cm}$ ) and increased toward background groundwater levels (approximately 6500  $\mu\text{S}/\text{cm}$ ) with continued recovery. On a percent recovery basis, the amount of mixing between source water and groundwater (as measured with specific conductance) has increased with the scale and duration of recharge. A progressive diminishment in the specific conductance trends (trends becoming less steep) was observed from the first to the fourth ASR cycle, indicating aquifer conditioning at the scale and duration of these initial cycles. Aquifer conditioning and improvement in recovery efficiency occurred during the course of the first four cycles because the recharge volumes and recharge rates were maintained for each cycle. However, progressively larger recharge periods and recharge volumes during Cycles 5 and 6 led to increased mixing and lower recovery efficiency because of the volumetric increase and the extended residence times in the aquifer. This results from interaction with native groundwater in previously un-conditioned portions of the aquifer due to the larger recharge volumes, and from the longer residence time that allows increased dispersion and diffusion to occur between the groundwater and recharge water. Re-evaluation of the production rate at the City's water treatment plant (approximately 3 to 4 MGD during the summer of 2007) in relation to the operational recovery rate at ASR No. 1 of 250 gpm (0.36 MGD) indicated that water from the City's treatment plant mixed with recovered ASR water at a minimum ratio of approximately 8:1 before delivery to customers (as opposed to the previous mixing ratio estimate of 4:1 [City of Dallas, 2006]). Therefore, the specific conductance threshold used for Cycle 6 (the end-point for recovery operations) that would result in an approximate TDS concentration of 500 mg/L in the distribution system was 6,100  $\mu\text{S}/\text{cm}$ , which was reached at approximately 26% recovery.

After the specific conductance threshold was met during Cycle 6 recovery, the recovery rate was reduced from 250 gpm to 125 gpm to assess the influence of pumping rate on the salinity of the recovered water. As a result of decreasing the recovery rate, the specific conductance (and the salinity/TDS) of the recovered water decreased rapidly to approximately 5,000  $\mu\text{S}/\text{cm}$  by 27% recovery.

Combined with declines in specific conductance following pumping interruptions, the observed reduction in recovered water salinity may result from vertical stratification in the aquifer and changes in the contributing area of the aquifer to the well with different pumping rates. Vertical stratification of recharge water and native groundwater in the aquifer may occur due to density differences, resulting in lower density fresh water preferentially displacing saline groundwater in the upper portion of the aquifer. During recovery, the pumping cone of depression creates a zone of relatively low pressure in the vicinity of the well, which may allow the saline water present below the recharged fresh water lens to flow upward to the well at a higher rate, changing the relative recovered proportion of recharged water and native groundwater. Decreasing the recovery rate from 250 gpm to 125 gpm during Cycle 6 recovery resulted in a corresponding rise in water level of approximately 160 feet, and this additional head in the vicinity of the well may have significantly changed the vertical position of the fresh/saline interface, resulting in a larger proportion of stored fresh water being recovered from the upper portions of the aquifer. This observation indicates that further modification of the recharge and recovery schemes may improve recovery efficiency by maximizing the thickness of the stored fresh water lens during recharge and targeting the upper portions of the aquifer as the dominant source of recovered water.

#### 2.4.3 Geochemical Assessment of Recovered Water

This section provides a geochemical assessment of water quality data collected during the second year of ASR pilot testing. Prior to pilot testing, baseline water quality analyses were conducted on both the source water to be recharged and the native groundwater in the aquifer. Throughout pilot

testing, water quality analyses were conducted on additional recharge water samples and recovered water samples.

During recharge, treated drinking water stored in the basalt aquifer will displace native groundwater in the area surrounding the ASR No. 1 well. Advection and dispersion will result in some mixing of recharge water and groundwater as the recharge water flows through the aquifer. For constituents that behave conservatively (i.e., do not participate in chemical reactions that result in a change in dissolved phase concentrations), concentrations in recovered water will be directly proportional to the mixing ratios between groundwater and recharge water. For constituents that participate in chemical reactions during ASR operations, concentrations in recovered water will deviate from ideal mixing behavior. For constituents whose concentrations showed a decline or an increase in concentration during storage, the data evaluation focused on identification of possible geochemical reactions responsible for the observed change.

Water quality data for the recharge source water and the recovered water during the second year of pilot testing are shown in Tables 2-3 and 2-4, respectively. Figure 2-32 presents a Piper diagram that illustrates the water quality of the source water and the recovered water during Cycles 5 and 6. This type of diagram shows the relative concentrations of major cations and anions from numerous water samples, and allows major groupings or trends in water quality to be discerned visually. Figure 2-32 shows the source water samples (circles) plotting in a tight cluster, illustrating the consistent calcium bicarbonate-type water chemistry of the City's treated drinking water. Native groundwater (black square) is classified as a calcium chloride-type water.

If recovered water quality was solely controlled by mixing, recovered water samples would plot on a line between source water and groundwater. As they plot on the Piper diagram, the recovered water samples (triangle symbols) illustrate that a minor shift in water quality occurred during Year-1 as a result of chemical interaction between the source water, groundwater, and the aquifer matrix. The first recovered water sample during Cycle 5 (C5REC02%) exhibited a sodium/potassium bicarbonate signature, a change from the calcium bicarbonate signature of source water. However, as recovery operations continued during Cycle 5, the chemical signature of the recovered water samples became increasingly like that of groundwater with a calcium chloride signature. Samples collected during Cycle 6 recovery operations indicate that recovered water primarily exhibits the chemical signature of native groundwater, as evidenced by the cluster of samples near the groundwater identifier (black square), and that recovered water quality is primarily controlled by mixing.

#### *2.4.3.1 Cycle 6 Groundwater and Recharge Water Quality*

A sample was collected from ASR No. 1 (C6PREGW) to document the water quality conditions in the aquifer prior to Cycle 6 recharge. Sample C6PREGW had a chloride concentration approximately ten times lower than the pre-ASR testing groundwater concentration. This indicates that water quality in the aquifer prior to Cycle 6 had not returned to background (i.e., pre ASR testing). The pre-Cycle 6 groundwater quality results may be representative of a fresh water lens (from natural recharge) or the presence of recharge water remaining in the aquifer from Year-1 activities.

Cycle 6 source water samples (C6PRERCG and C6RCGSRC) confirmed that the water quality of the recharge water was consistent with that observed during Year-1.

#### 2.4.3.2 *Cycle 6 Recovered Water Quality*

##### Alkalinity and pH

During the first five ASR cycles of Year-1, the pH of recovered water was consistently higher than that of both recharge water and groundwater. The first sample collected during each recovery cycle reported alkalinity values higher than both groundwater and recharge water. During the course of the recovery period for each of these cycles, alkalinity concentrations declined to levels intermediate to groundwater and surface water concentrations. The high pH and elevated alkalinity concentrations observed during the early stages of recovery were attributed to the cement grout used to backfill the lower portion of the well. The overall decreasing pH trend observed between Cycles 1 and 5 suggested that over time, impacts to recovered water quality due to cement dissolution would decrease (Golder, 2007<sup>b</sup>).

Alkalinity and pH trends for Cycle 6 are shown in Figure 2-33. The decreasing pH trend in recovered water observed for the first five cycles continued during Cycle 6. Cycle 6 pH values were intermediate to background groundwater (pre-ASR testing) and source water values. Cycle 6 recovered water alkalinity values were lower than those observed during Cycles 1 to 5 at an equivalent percent recovery, which suggests that the impacts to recovered water quality from cement dissolution have decreased.

##### Metals

Consistent with the Year-1 results, the following metals were below detectable limits in recovered water, suggesting no increase in metals mobility due to ASR operations: Ag, Ba, Be, Cd, Cr, Hg, Ni, Pb, Sb, Tl and Zn. Selenium was detected at a low concentration in sample C6REC26% near the reporting limit (3.5 µg/L). An isolated selenium detection near the reporting limit also occurred during Cycle 5.

##### Arsenic

During Year-1, arsenic was consistently detected in samples collected from the early stages of recovery. For Cycles 1 to 4, recovery samples reported low arsenic concentrations near the detection limit (i.e., less than 2 µg/L). Sample R-C5 (14%) reported a dissolved arsenic concentration of 6 µg/L. In an effort to identify a possible source of the detected arsenic, the frequency of arsenic sampling was increased during Cycle 6 recovery. Arsenic was consistently below detectable limits in all Cycle 6 recovered water samples (arsenic reporting limit ranged from 1 to 3 µg/L, see Table 2-4). Cement dissolution was proposed as one of the possible sources of trace levels of arsenic (Golder, 2007). The absence of arsenic would be consistent with a decrease in impacts from cement dissolution, as indicated by the pH and alkalinity trends in recovered water, which suggests that the cement grout used to abandon the lower portion of the well may have been the source of arsenic.

##### General Chemistry

ORP measurements for groundwater and recharge water indicate recharge of oxidized water into a more reduced aquifer (Figure 2-34). Consistent with Cycles 1 to 5, Cycle 6 ORP during recovery demonstrated a decreasing trend. The final recovered water sample ORP was most similar to native groundwater.

During Cycles 1 and 2, total organic carbon (TOC) concentrations in recovered water samples were initially similar to recharge concentrations and then declined to below detectable limits (<0.5 mg/L) (Figure 2-35). For Cycles 3 to 5, the first recovery water samples reported TOC concentrations higher than observed in the recharge water, ranging from 0.9 to 1.4 mg/L. For all three cycles, the late time recovery samples reported similar TOC concentrations (approximately 0.5 mg/L). These

results suggested that reactions that initially resulted in depletion of TOC were less significant as pilot testing continued. During Cycle 6, TOC was below detectable limits in all recovered water samples even though TOC was present in Cycle 6 recharge water, indicating that TOC depletion is still occurring. The observed decline in TOC may be attributable to TOC sorption to aquifer solids (Lee and Jones, 2005) or dilution by groundwater. TOC monitoring should be continued as it is important in the evaluation of redox reactions in the aquifer and the potential formation of disinfection by-product, as discussed below.

The C6REC26% sample reported elevated dissolved iron and manganese, in comparison to background groundwater and other recovery samples. However, elevated iron and manganese is attributed to an increase in the pumping rate during collection of this sample (as noted by the field hydrogeologist), which likely dislodged particulate iron and manganese from the aquifer matrix.

#### Disinfection By-Products (DBPs)

DBP data are shown in Table 2-3. THMs and HAAs were analyzed in a recharge sample and two recovery samples. Detections were well below drinking water standards. Consistent with the 2006 results, two THMs were reported above detectable limits in the recharge water sample: chloroform and bromodichloromethane. The total THM concentration was 0.0247 mg/L. Total THMs in the first recovered water were slightly lower at 0.0229 mg/L. The final recovery water sample indicated a further decline in total THMs to 0.0115 mg/L, as would be expected due to dilution from groundwater.

Consistent with the 2006 results, two HAAs were reported above detectable limits in the recharge water sample: dichloroacetic acid and trichloroacetic acid. The total HAA concentration was 0.0188 mg/L. Total HAA concentrations were lower in the recovered water samples.

These data indicate no significant formation of THMs and HAAs during ASR operations at ASR No. 1. Recovered DBP concentrations were compliant with drinking water standards.

#### 2.4.4 Water Quality Monitoring at Observation Wells

Because groundwater in some areas of the local aquifer is known to be saline, water quality monitoring was performed at operational wells within the observation network to evaluate any potential changes in salinity at local domestic wells during the ASR pilot testing program. In accordance with the work plan, field parameter information was collected prior to recharge, at the end of the recharge period, and at the end of the recovery period. Field parameter monitoring at new observation wells (Anstine, Jones, and Fitcha wells) began following the initiation of Year-2 pilot testing after access agreements were finalized with the well owners, and therefore have only two records. Outdoor taps at the Anstine residence were winterized before the end of the Cycle 6 recovery period, and therefore no final water quality observation was made at that location. Monitored field parameters include temperature, dissolved oxygen, pH, and specific conductance, which were measured with a YSI-556 Multi-Probe System™, calibrated before each monitoring event per the manufacturer's instructions.

Field parameter measurements were collected from the tap closest to each of the respective wellheads, and were collected from the same tap at each location throughout Year-2 pilot testing. Table 2-2 indicates which observation wells have active pumps installed, and therefore which groundwater sources were tested at each property, with two exceptions. Domestic water supplies at the Birko property are produced from a third well, for which the owner did not grant access for water level monitoring. Domestic supplies at the Lowe property may at times consist of a blend of water from the Lowe Lower well and a third well on the property that did not have adequate access for

monitoring water levels. Domestic water supply at all wells that were monitored first passed either through a small holding tank (<1000 gallons) and/or pressure tank, and was therefore influenced by above-ground temperatures and aeration.

Field parameter measurements obtained during the salinity monitoring are presented in Figures 2-36 through 2-39. The results do not indicate that water quality at domestic observation wells was influenced as a result the ASR pilot testing operations. Monitored parameters were either measured at levels consistent with background conditions or exhibited trends consistent with pre-pilot testing observations. More detailed discussions of observations made for each of the monitored parameters are presented below.

#### *Temperature*

Water temperature measurements at the observation wells are presented in Figure 2-36, which indicates that temperature during Year-2 varied between approximately 7 and 20 degrees Centigrade, increasing in summer and decreasing in winter under the influence of atmospheric temperature variations. Wells with small holding tanks in poorly insulated well houses (e.g., the Kowalczyk property) displayed a greater range of temperature over the monitoring period between individual monitoring events than wells with large holding tanks in well-insulated well houses (e.g., the Presser well).

#### *Dissolved Oxygen*

Dissolved oxygen (DO) measurements at the observation wells are presented in Figure 2-37, and show concentrations during Year-2 ranging from near zero (depleted) to more than 12 mg/L (saturated). Measurements from systems with open holding tanks (e.g., Birko and Lowe properties) have significantly higher dissolved oxygen concentrations than from sources with closed pressure tanks (e.g., Fitcha and Kowalczyk properties), indicating that exposure to the atmosphere increased DO levels. The Parker well showed relatively high dissolved oxygen concentrations despite being pumped to a closed pressure tank, which suggests that the well either taps a shallower groundwater system and/or draws water from near the aquifer's recharge area.

#### *pH*

Measurements of pH at the observation wells are presented in Figure 2-38. Groundwater at the observation wells was neutral to basic, with pH values observed during Year-2 between 7.3 and 10.6, with the exception of the Parker well which had considerably lower pH between 5.2 and 5.5. Observed pH values during cycle testing activities remained fairly constant, within one pH unit of previous and subsequent measurements, with the exception of the Presser well. Values of pH measured at the Presser well demonstrated a decreasing trend from approximately 10.6 to 8.7 over the Year-2 cycle testing period.

#### *Specific Conductance*

Specific conductance measurements at the observation wells are presented in Figure 2-39. Specific conductance at the Parker, Jones, and Birko wells is relatively low (<120  $\mu\text{S}/\text{cm}$ ), and did not vary significantly during the monitoring period. Alternately, specific conductance at the Kowalczyk, Lowe, Presser, and Fitcha wells indicates significantly higher salinity (greater than 775  $\mu\text{S}/\text{cm}$ , indicating water above the TDS SMCL of 500 mg/L) and shows some seasonal variability. Trends in specific conductance at the higher conductivity wells do not appear to correlate with pilot testing activity.

## **2.5 Recovery Efficiency**

Recovery efficiency (as defined by the volume of water recovered for use as drinking water compared to the storage volume) for Cycle 6 was 28%. Factors that likely contributed to the relatively low

recovery efficiency include increased hydrodynamic dispersion caused by the much larger recharge volume, and the interaction between recharged water and a much larger portion of the aquifer compared to the preceding smaller cycles. Because dispersion is a scale-dependent process, the longer flow-paths associated with the full-scale recharge-storage-recovery cycle increased the amount of dispersion that occurred. In addition, the longer residence time of recharged water during the 218-day recharge period and the 41-day storage period likely contributed to greater mixing between recharged and native water. Cycle-to-cycle improvements in recovery efficiency will be evaluated once consecutive full-scale ASR cycles with relatively consistent recharge volumes are completed.

Improved recovery efficiency may also be possible through the management of the recharge and recovery rates based on the results of operational tests during the latter portion of the Cycle 6 recovery period. As indicated in Section 2.4.2.2, a significant control on recovery efficiency may be density-driven stratification, rather than simple differential mixing in the aquifer. Recovery operations during Cycle 7 will be used to further evaluate recovery rates designed to optimize recovery efficiency and recovered water conductivity. If stratification between deeper saline groundwater and fresh water is present in the borehole during recharge, it may also be possible to improve recovery efficiency by lowering the interface between saline and fresher water. The feasibility of approaches to accomplish this will be evaluated during Year-3.



### **3.0 SUMMARY**

#### **3.1 ASR No. 1 Operations**

Operational control of the ASR system during Year-2 testing was largely performed via an automated SCADA system, and pilot testing was conducted in a controlled manner to provide data necessary to evaluate ASR feasibility and develop a long-term ASR operations plan. The first full-scale ASR cycle (Cycle 6) was completed during the second year of pilot testing at ASR No. 1 between December 2006 and November 2007. During Cycle 6, treated drinking water was recharged over 218 days at an average rate of 167 gpm, with a recharge volume of approximately 52,541,000 gallons. Water was stored for 41 days, and then recovered over a period of 51 days primarily at a rate of 250 gpm. Of the total volume of water recharged during Cycle 6 (52.5 MG), approximately 72 percent remained in the aquifer (38 MG). During the last 5 days of the recovery period, the recovery rate was decreased to 125 gpm to evaluate any changes in water quality from the reduced pumping rate. As a result, recovered water specific conductance dropped rapidly, and indicates that the salinity of recovered water is influenced by the recovery rate. Observations suggest that the primary control on recovery efficiency may be density-driven stratification, rather than differential mixing in the aquifer.

Recovered water was delivered to the City's storage and distribution system. Because recovered water was routed back to the City's 2-MG reservoir, mixing with water from the treatment plant diluted the recovered ASR water at an approximate ratio of 8:1. Taking mixing into account, recovery during Cycle 6 continued until the estimated mixed water TDS concentration approached 500 mg/L, which initially occurred after recovery of approximately 26% of the recharged volume.

#### **3.2 Well Performance and Aquifer Response**

The water treatment plant SCADA system was used to automatically control Cycle 6 recharge rate, maintaining recharge at 165 gpm, plus or minus 5 gpm. Observed water level buildup was 150 feet after the first few hours of recharge, increasing to nearly 200 feet over the 7-month recharge period. Recharge specific capacity began at approximately 1.1 gpm/ft and gradually decreased to 0.85 gpm/ft by the end of the recharge period. The well was backflushed three times during Cycle 6 to maintain injection specific capacity, and there was no indication of clogging or loss in well performance at the end of recharge operations.

The SCADA system and a newly installed variable speed drive were used to maintain recovery rates near 250 gpm for most of the recovery period. Drawdown in ASR No. 1 was between 225 and 300 feet, and recovery specific capacity ranged from approximately 1.1 to 0.85 gpm/ft. Automatic control of recharge and recovery rates resulted in more even water level and specific capacity trends than were observed in the first year of pilot testing.

#### **3.3 Water Level Monitoring**

Four new observation wells were added to the project's monitoring network at the end of Year-1. The additional observation locations consist of a shallow piezometer installed at the seep area identified near the intersection of Ellendale Road and Robb Mill Road, and three nearby domestic wells in the vicinity of the City's ASR well. Three of the twelve wells in the monitoring network exhibited hydraulic response to ASR operations; the Lowe Upper well, the Presser well, and Piezometer 1. There is no apparent spatial pattern to explain the distribution of wells that respond and those that did not, so hydraulic response may be related to an irregular distribution of fractures, joints, and/or faults in the basalt aquifer.



### **3.4 Water Quality Monitoring**

Analytical laboratory results indicate that the recovered water quality from the City's ASR well meets all primary drinking water standards for public water systems, including synthetic organic compounds (SOCs), volatile organic compounds (VOCs), disinfection by-products (DBPs), radiological constituents, metals and inorganic constituents, and coliform bacteria. The water quality data indicate that the recovered water is suitable for distribution in the City's water distribution system.

Some "secondary contaminants" exceeded established standards during Cycle 6, including chloride and TDS. Though chloride and TDS exceeded Secondary Maximum Contaminant Levels (SMCLs) in recovered water, plant operations ensured that water delivered to utility customers has chloride and TDS concentrations less than the SMCL.

Geochemical analysis of the Year-2 water quality data indicate that recovered water quality is primarily the result of mixing between saline groundwater and fresh recharge water. Elevated levels of alkalinity and pH observed during Year-1 continued to decline during Year-2 operations, which indicates that the impacts from cement dissolution have decreased. In addition, frequent sampling showed arsenic to be consistently below detectable limits in all Cycle 6 recovered water samples.

Low concentrations of total organic carbon (TOC) are present in recharge water; however, TOC was not detected in Cycle 6 recovered water samples. The observed decline may be attributable to TOC sorption to aquifer solids or dilution by groundwater since concentrations in recharge water are near the laboratory reporting limit. While disinfection by-products (DBPs) are present in recharged and recovered water in low concentrations below applicable MCLs, recovered water quality data do not show excess disinfection by-products (DBPs) being formed during storage in the aquifer. This indicates that potential TOC sorption in the aquifer does not appear to be a concern for DBP production.

#### **3.4.1 Water Quality Monitoring at Observation Wells**

Because groundwater in some areas of the local aquifer is known to be saline, water quality monitoring was performed at operational wells within the observation network to evaluate any potential changes in salinity at local domestic groundwater supply wells during the ASR pilot testing program. The results of the monitoring do not indicate that water quality was influenced at the local domestic wells as a result the ASR pilot testing operations.

#### 4.0 CONCLUSIONS AND RECOMMENDATIONS

Pilot testing activities during Year-2 were designed to evaluate aquifer hydraulic response to ASR operations under full-scale recharge and recovery periods, determine optimal recharge and recovery rates for full-scale operation, and initiate automated SCADA system operational control of the ASR system. The results of the first two years of pilot testing have demonstrated that recovery efficiency at ASR No. 1 varies markedly with changes in dispersion related to recharge and recovery rates and volumes. The results of Year-2 pilot testing have further indicated that a significant control on recovery efficiency may be density-driven stratification, rather than differential mixing in the aquifer. To ensure that the system is a valuable part of the City's water supply infrastructure, it may be necessary to improve the recovery efficiency beyond the amount expected to occur over successive cycles. A plan for additional evaluation of downhole conditions and operational controls will be developed and implemented in 2008.

The Year-2 pilot test results indicate that injection rates around 165 gpm are sustainable for long-term injection periods and should limit excessive dispersion. Based on observed well performance, 250 gpm is a sustainable pumping rate for long-term recovery operations, however the City may choose to recovery at lower rates during at least a portion of the recovery period to increase the volume of water recovered with suitable TDS concentrations.

Water quality results from Year-2 further indicate that potable water can be recovered following injection and storage of treated water in the saline Siletz River Volcanics aquifer at ASR No. 1. Recovered water met all primary drinking water quality standards required for ASR systems in Oregon. Specific capacity data from ASR No. 1 during Year-2 pilot testing activities do not indicate that geochemical reactions or physical clogging are negatively impacting well performance. Arsenic was not detected in recovered water during Cycle 6 recovery.

Three additional wells and a piezometer were added to the observation network at the beginning of Year-2 pilot testing, which will continue to be monitored regularly with the other wells as part of the ongoing water level monitoring program. Regular water level monitoring will continue during future pilot testing activities to assess the potential for hydraulic response in the aquifer system.

Golder provides the following recommendations for Year-3 pilot testing:

- It is anticipated that Year-3 testing will be completed in one ASR cycle with a total recharge volume of approximately 50 million gallons. The established monitoring program should be carried out by City staff during Year-3, with support and periodic evaluation of hydraulic response provided to the City by Golder as needed.
- In order to minimize dispersion-driven mixing between fresh water and native groundwater during recharge and to maintain comparable rates between successive ASR cycles, the recharge rate should be maintained at 165 gpm during Cycle 7, unless findings from the conductivity survey indicate that a higher rate could be beneficial.
- In order to better evaluate improvements in recovery efficiency between successive ASR cycles, the volume of water recharged to the aquifer during Year-3 should be approximately the same as the Year-2 recharge volume of 52MG.
- In order to minimize diffusion-driven mixing and potential increases in density-stratification between fresh water and native groundwater in the aquifer, there should be a very brief storage period of only 1 to 2 days in order to assess residual water level buildup in the aquifer after the recharge period.

- Golder will develop and implement a plan to further characterize downhole conditions during recharge and recovery operations, and use this information to evaluate additional operational controls or modifications.
- The recovery rate should be managed to improve recovery efficiency. Pilot testing activities will incorporate either a programmed spreadsheet or customized programming in the City's Wonderware/SCADA system.

## 5.0 REFERENCES

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- Golder Associates Inc., 2007<sup>c</sup>. *ASR Limited License #011 - Notice of ASR Pilot Testing Recovery.* Notice Letter submitted to Oregon Water Resources Department, August 8, 2007.
- Golder Associates Inc., 2006<sup>a</sup>. *City of Dallas ASR Limited License #011 (Demonstration of Recovered Water Meeting Water Quality Standards).* Technical Memorandum to Oregon Water Resources Department, September 13, 2006.
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- Golder Associates Inc., 2006<sup>c</sup>. *ASR Limited License #011 - Notice of ASR Pilot Testing Injection.* Notice Letter submitted to Oregon Water Resources Department, November 20, 2006.
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- Golder Associates Inc., 2005<sup>b</sup>. *Aquifer Storage and Recovery Pilot Test Work Plan, City of Dallas, Oregon.* December 13, 2005.
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- Parkhurst, D.L. and Appelo, C.A.J., 1999, *User's guide to PHREEQC (Version 2)—a computer program for speciation, batch-reaction, one-dimensional transport, and inverse geochemical calculations:* U.S. Geological Survey Water-Resources Investigations Report 99-4259, 310 p.
- Washington State Department of Transportation, 2006. *WSDOT Pavement Guide, Module 3.* <http://training.ce.washington.edu/WSDOT/>. Downloaded August 12, 2006



Table 2-1

## City of Dallas ASR Year 2 Pilot Testing Summary

City of Dallas Year 2 Pilot Testing Report

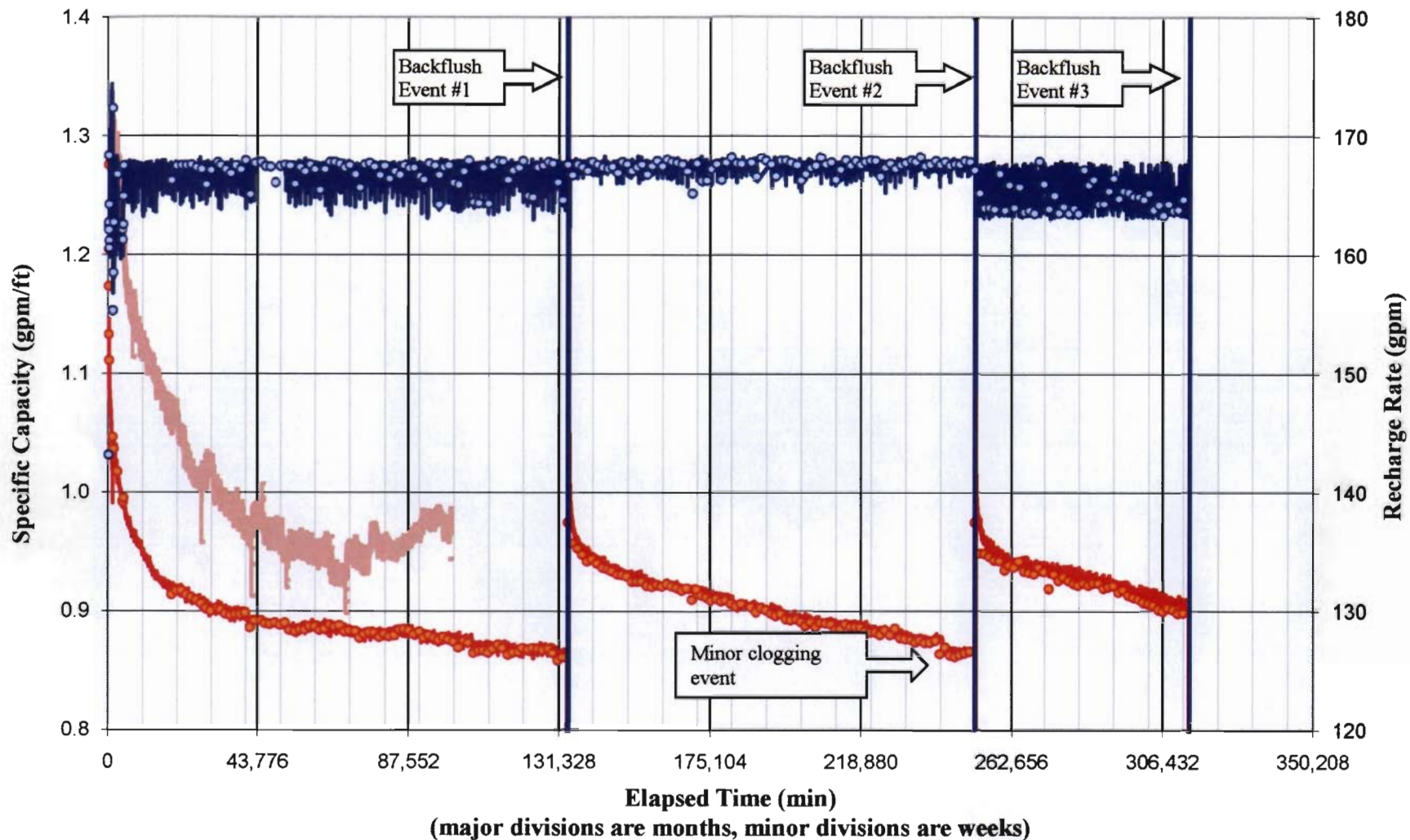
February, 2008

		Year 1					Year 2
		Cycle 1	Cycle 2	Cycle 3	Cycle 4	Cycle 5	Cycle 6
Recharge	BeginRecharge (Date & Time)	6/14/06 11:11	6/21/06 12:28	7/5/06 12:19	7/13/06 10:48	7/25/06 11:43	12/5/06 13:06
	Pause Recharge (Date & Time)		6/22/06 9:40				
	Resume Recharge (Date & Time)		6/22/06 11:29				
	End Recharge (Date & Time)	6/17/06 13:25	6/24/06 16:45	7/8/06 15:37	7/16/06 14:01	10/2/06 13:42	7/11/07 15:26
	Total Time (days)	3.09	3.18	3.14	3.13	69.08	218.10
	Total Volume (gal)	752,762	752,777	758,126	759,665	16,749,848	52,540,659
	Average Injection Rate (gpm)	169	169	168	168	168	167
Storage	Storage Time (days)	2	2	3	2	0	41
Recovery	Begin Recovery (Date & Time)	6/19/06 10:35	6/26/06 11:45	7/11/06 10:43	7/18/06 10:51	10/2/06 13:46	8/21/07 11:37
	Pause Recovery (Date & Time)	6/19/06 20:10					9/27/07 0:00
	Resume Recovery (Date & Time)	6/20/06 8:05					11/5/07 0:00
	End Recovery (Date & Time)	6/20/06 18:49	6/27/06 10:35	7/12/06 7:45	7/19/06 13:10	10/13/06 9:20	11/19/07 10:00
	Total Time (days)	0.85	0.95	0.88	1.10	10.82	50.93
	Total Volume (gal)	298,169	336,265	344,644	390,392	3,772,352	14,531,900
	Average Pumping Rate (gpm)	245	245	273	247	242	250/125*
	Percent Recovery (%)	40%	45%	45%	51%	23%	28%
Carryover	Injected Water Remaining in Aquifer (gal)	454,593	416,512	413,482	369,273	12,977,496	38,008,759
	Total Yearly Pilot Testing Carryover (gal)	14,631,356					

Note: Cycle 6 recovery rate was 250 gpm for the majority of the pumping period, with a short 5-day period of pumping at 125gpm at the end of recovery







Year 2 ASR Pilot Test Report  
City of Dallas, Oregon

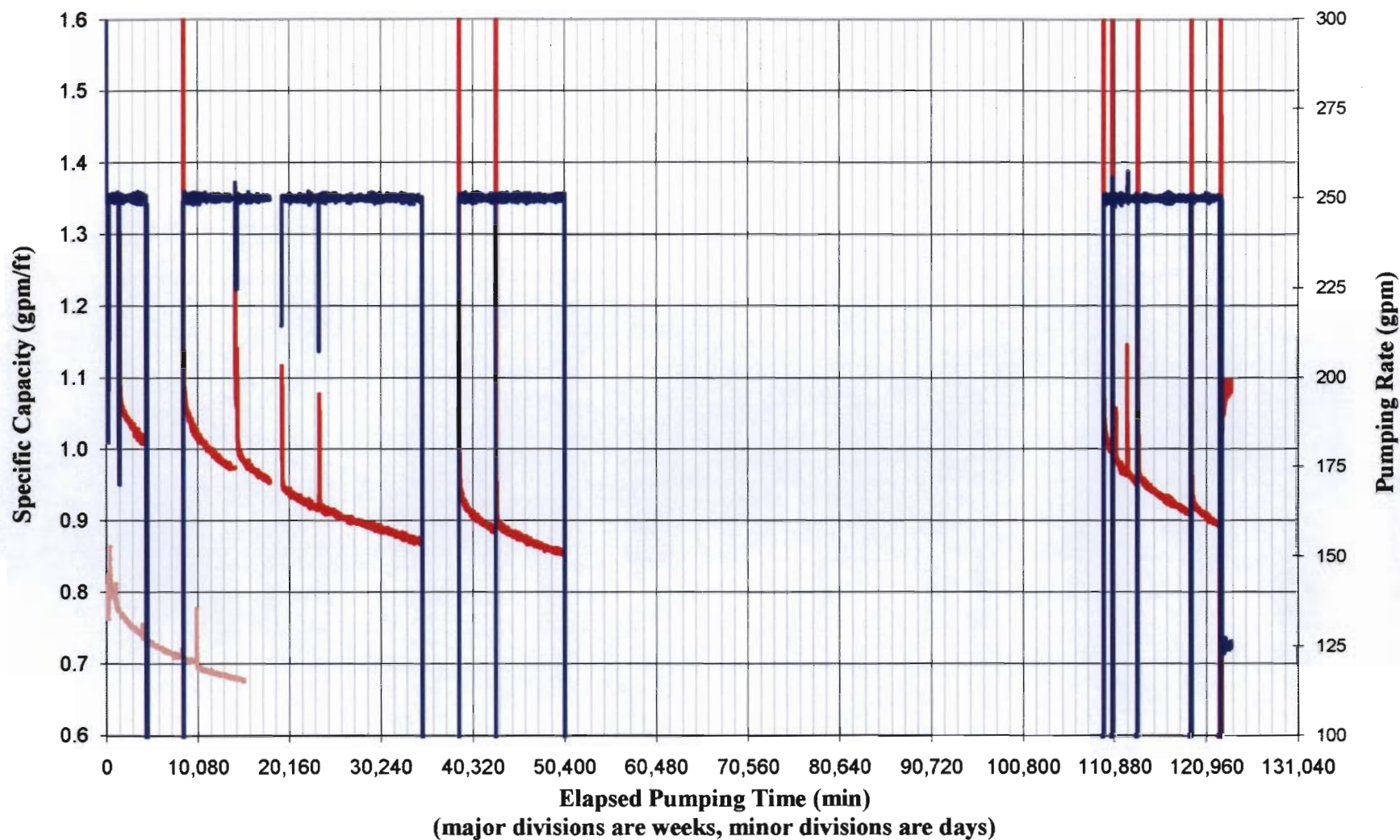
- Cycle 5 Telemetry SC
- Cycle 6 Telemetry SC
- Cycle 6 Manual SC
- Cycle 6 Telemetry Q
- Cycle 6 Manual Q

### ASR No. 1 Recharge Rate and Specific Capacity - Cycle 6

JOB NUMBER: 053-9747-200

DATE: February 11, 2008

FIGURE NO.: 2-1



Year 2 ASR Pilot Test Report  
City of Dallas, Oregon

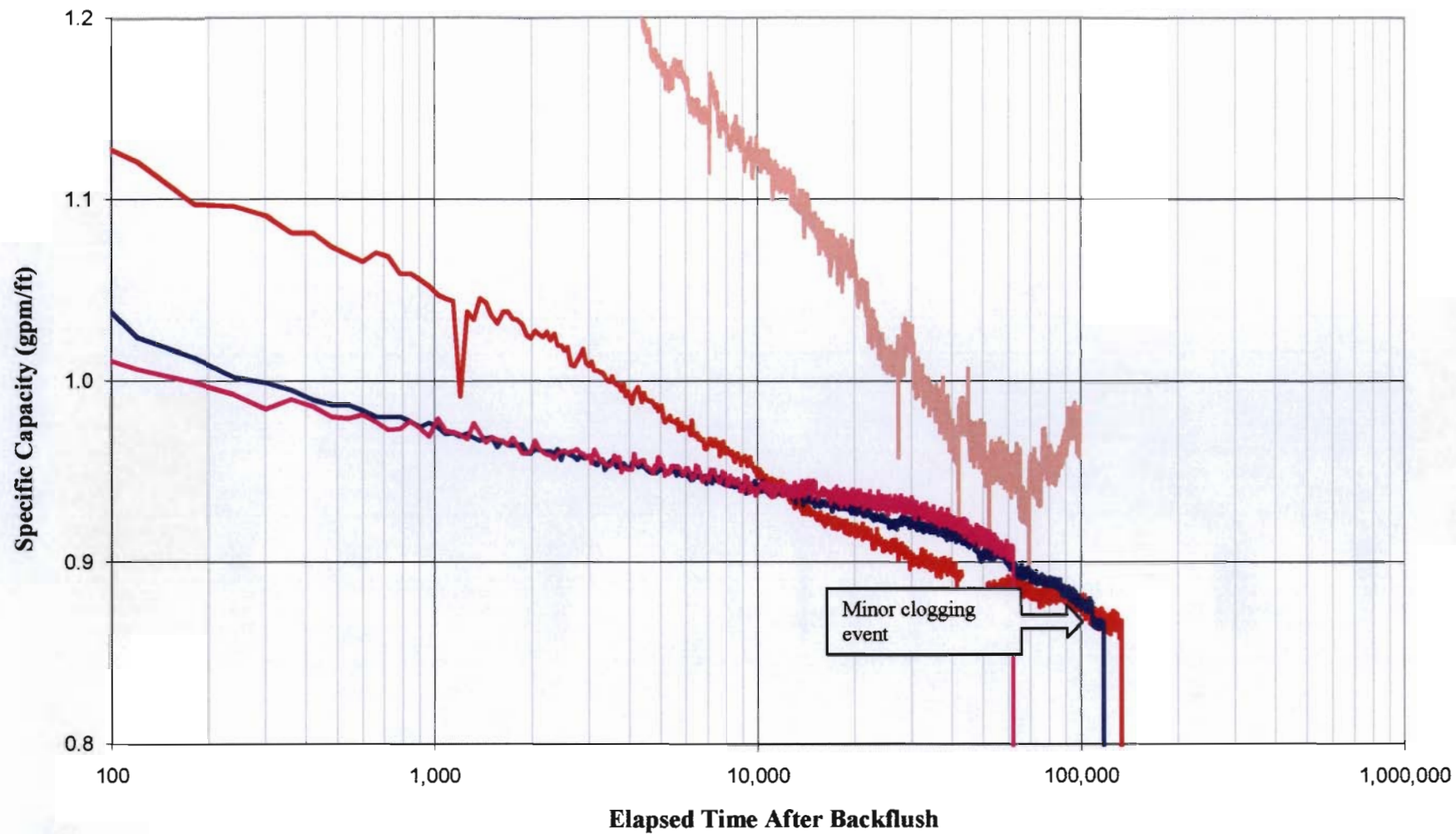
— Cycle 5 Telemetry SC  
— Cycle 6 Telemetry SC  
— Cycle 6 Telemetry Q

**ASR No. 1 Recovery Rate and Specific Capacity -  
Cycle 6 (with C5 data for comparison)**

JOB NUMBER: 053-9747-200

DATE: February 11, 2008

FIGURE NO.: 2-2



Year 2 ASR Pilot Test Report  
City of Dallas, Oregon

- Cycle 5 Telemetry SC
- Cycle 6 Telemetry SC - Initial
- Cycle 6 Telemetry SC - After BF#1
- Cycle 6 Telemetry SC - After BF#2

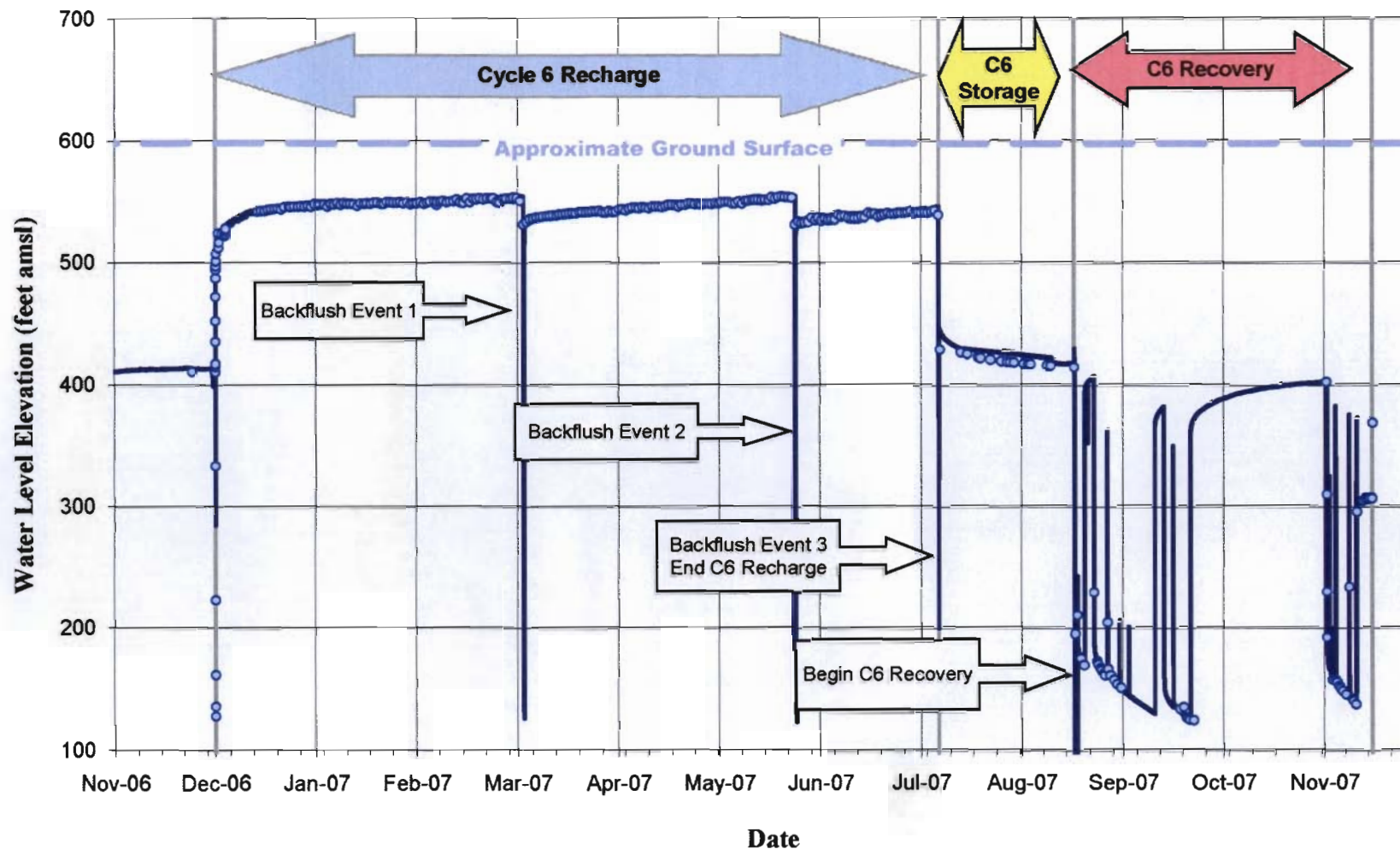
### ASR No. 1 Recharge Specific Capacity After Backflush Events - Cycle 6

JOB NUMBER: 053-9747-200

DATE: February 11, 2008

FIGURE NO.: 2-3





Year 2 ASR Pilot Test Report  
City of Dallas, Oregon

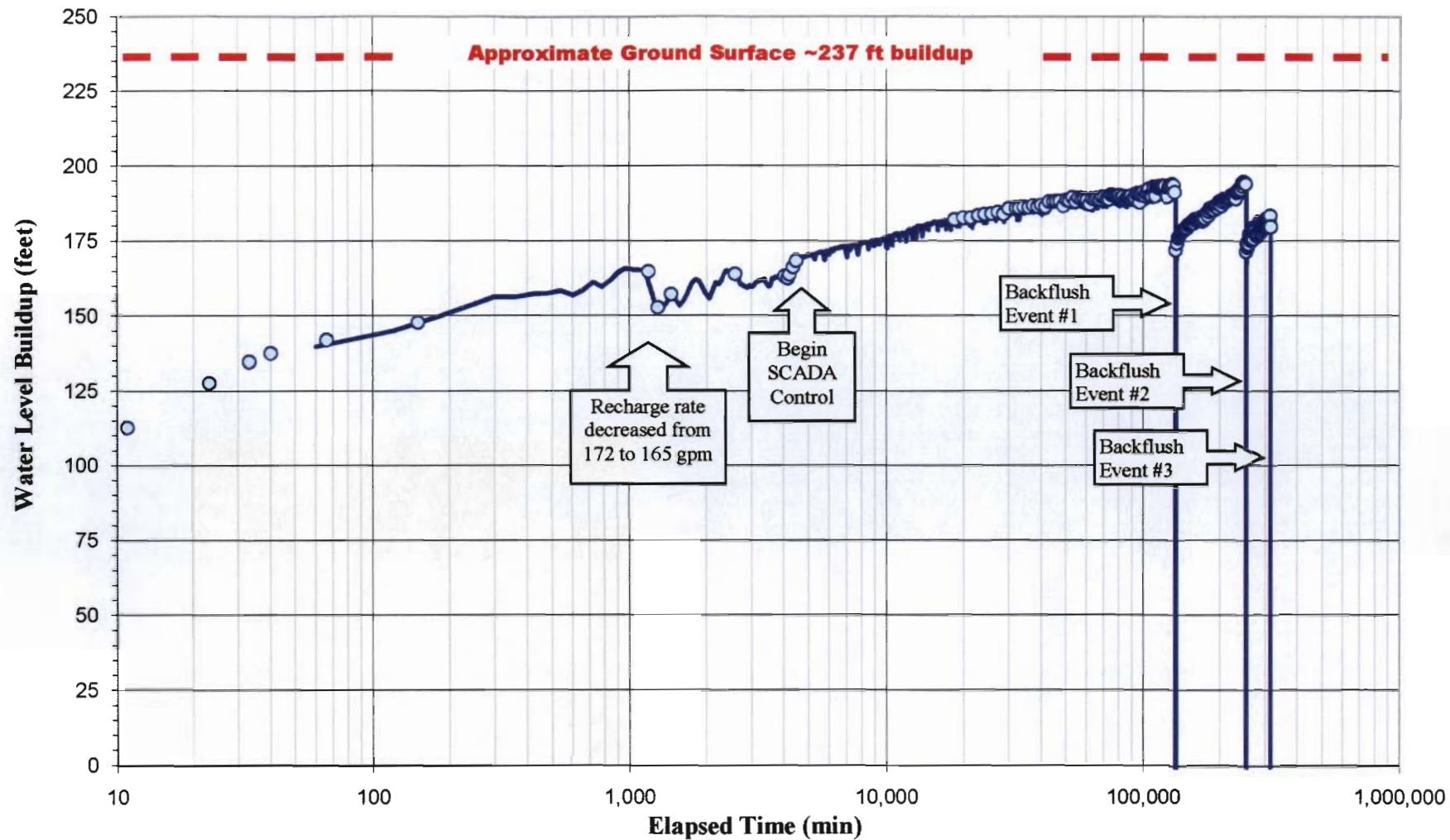
- Transducer Water Level
- - - Approximate Ground Surface Elevation
- Manual Water Level

### ASR No. 1 Pilot Testing Hydrograph - Cycle 6

JOB NUMBER: 053-9747-200

DATE: February 11, 2008

FIGURE NO.: 2-4



Year 2 ASR Pilot Test Report  
City of Dallas, Oregon

— Cycle 6 Telemetry Data

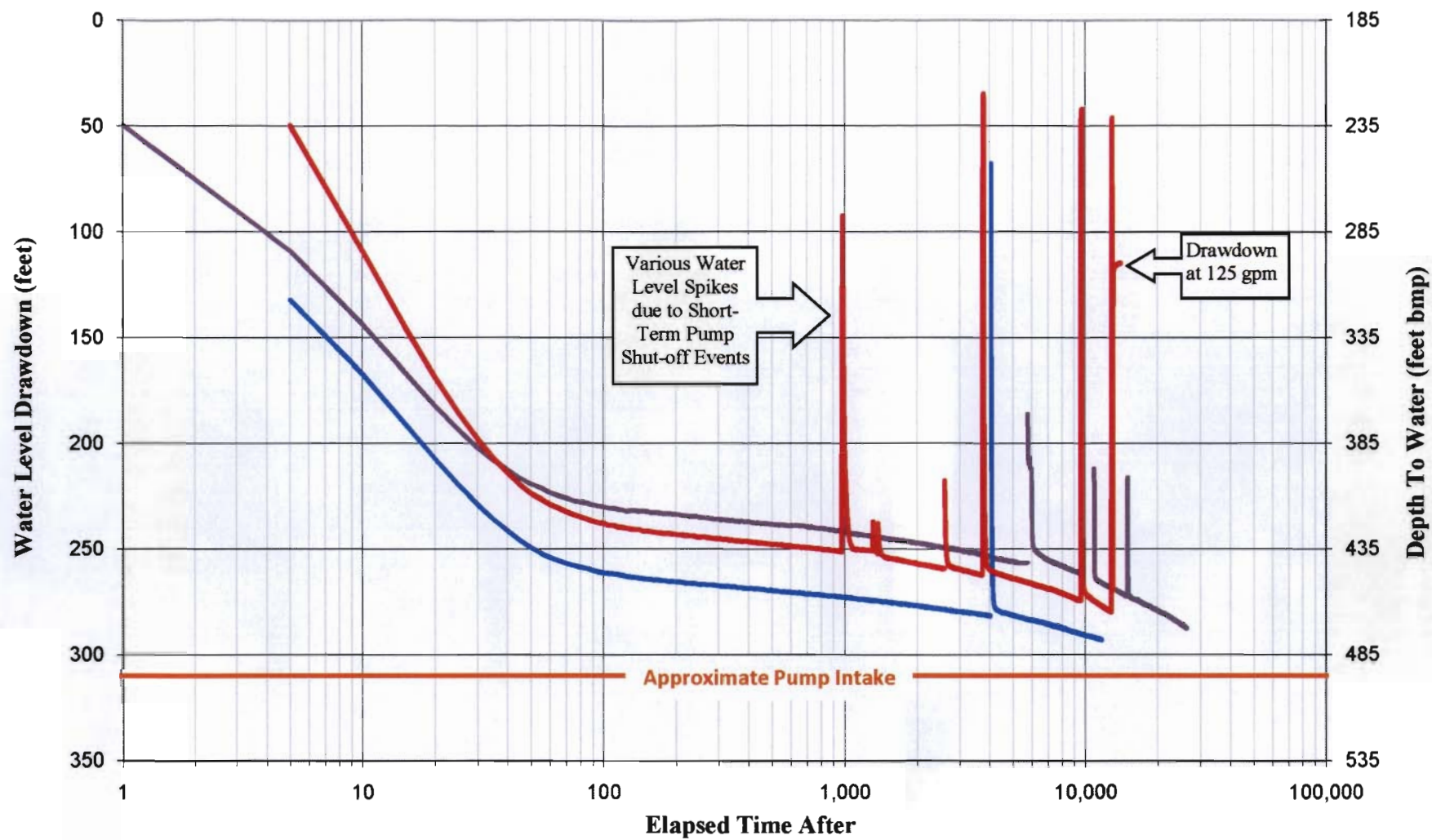
○ Cycle 6 Manual Data

### ASR No. 1 Recharge Buildup - Cycle 6

JOB NUMBER: 053-9747-200

DATE: February 11, 2008

FIGURE NO.: 2-5



Year 2 ASR Pilot Test Report  
City of Dallas, Oregon

- Cycle 6 Recovery - Initial Drawdown Trend
- Cycle 6 Recovery - After 3-Day Power Outage
- Cycle 6 Recovery - After 41-Day Operational Mgmt
- ASR No 1 Pump Intake Level

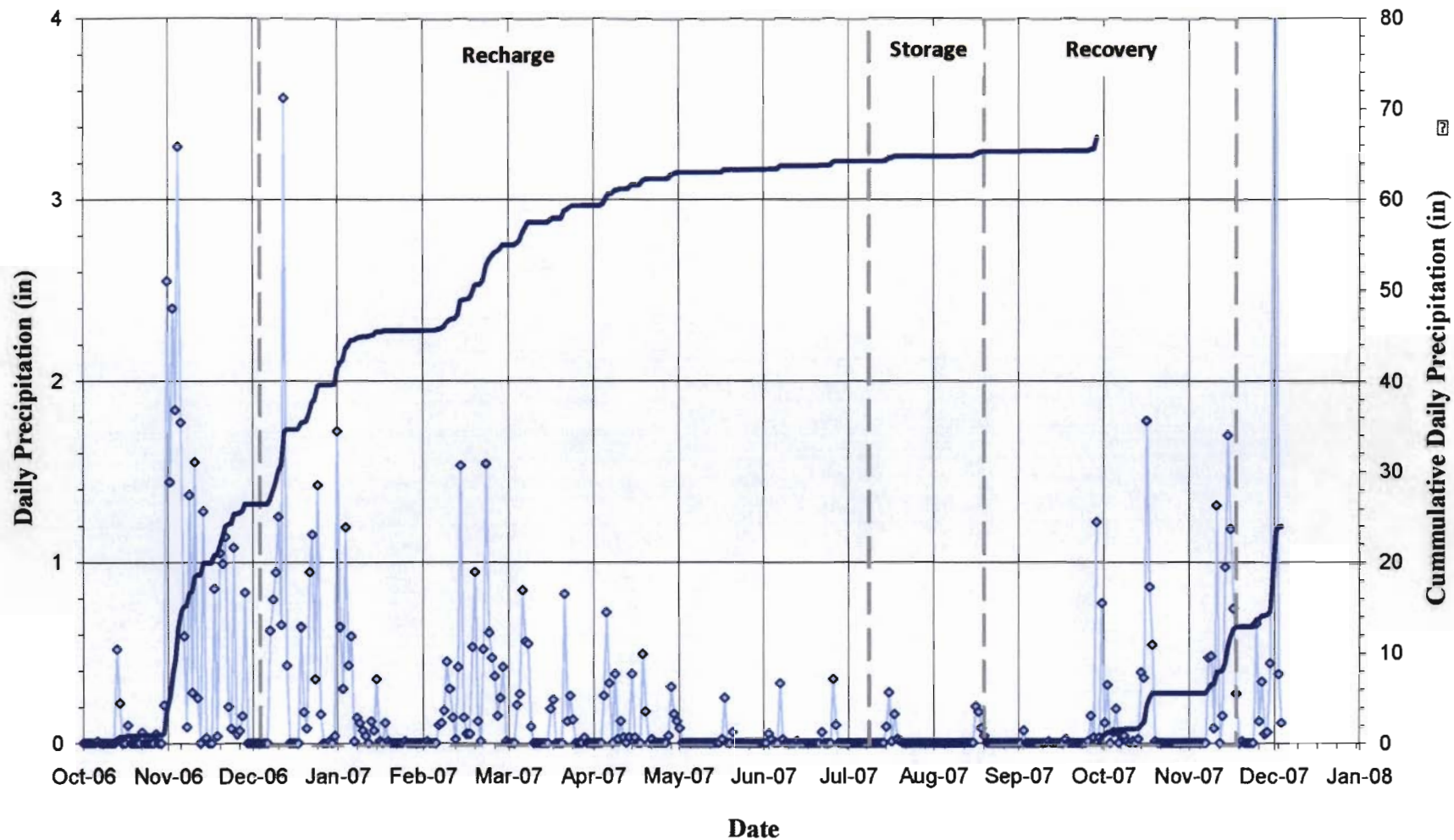
### ASR No. 1 Recovery Water Level Drawdown - Cycle 6

JOB NUMBER: 053-9747-200

DATE: February 11, 2008

FIGURE NO.: 2-6





Year 2 ASR Pilot Test Report  
City of Dallas, Oregon

◆ Daily Precipitation  
— Cumulative Precipitation (by Water Year)

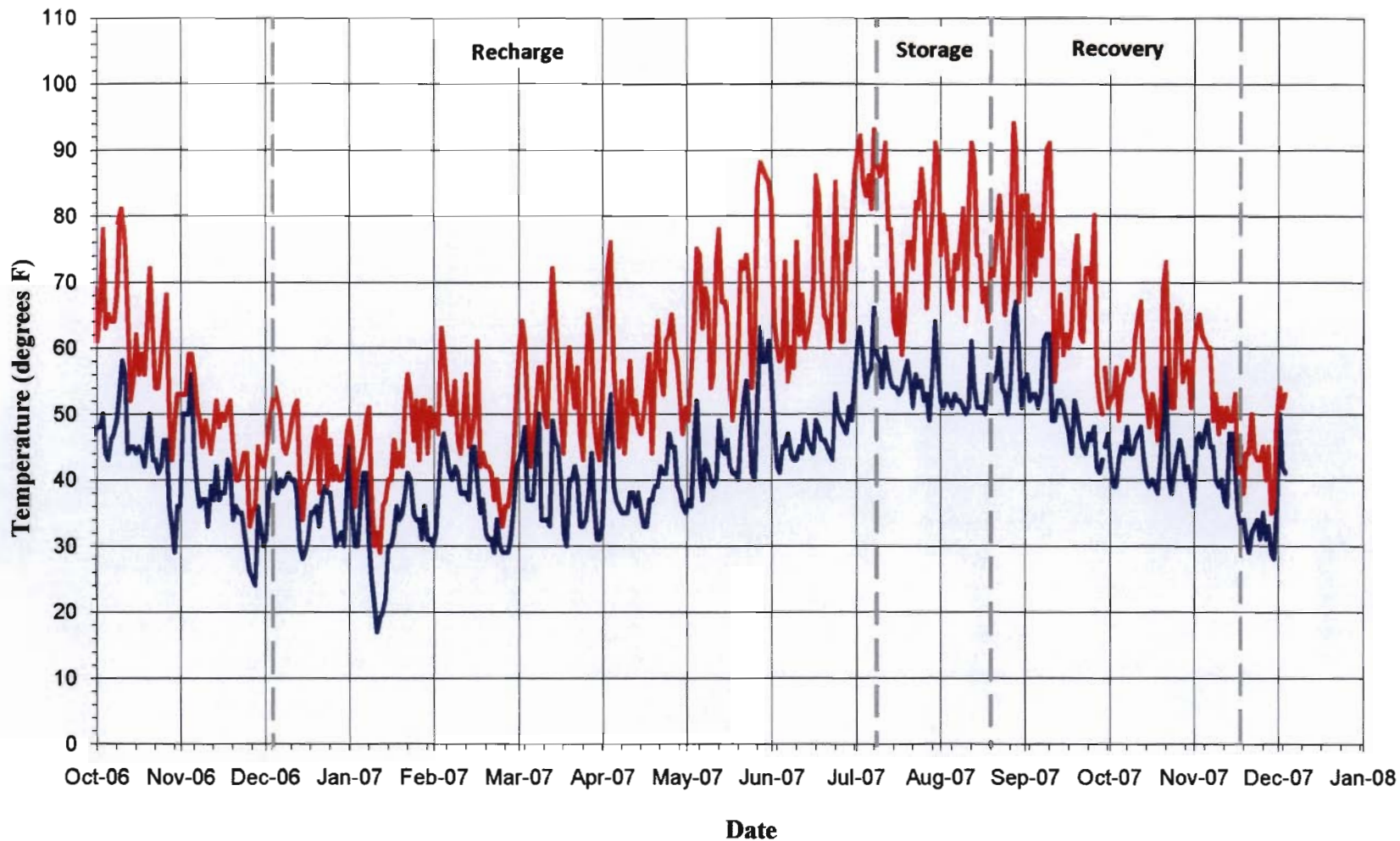
### Precipitation at Rockhouse Climate Station

JOB NUMBER: 053-9747-200

DATE: February 11, 2008

FIGURE NO.: 2-7





Year 2 ASR Pilot Test Report  
City of Dallas, Oregon

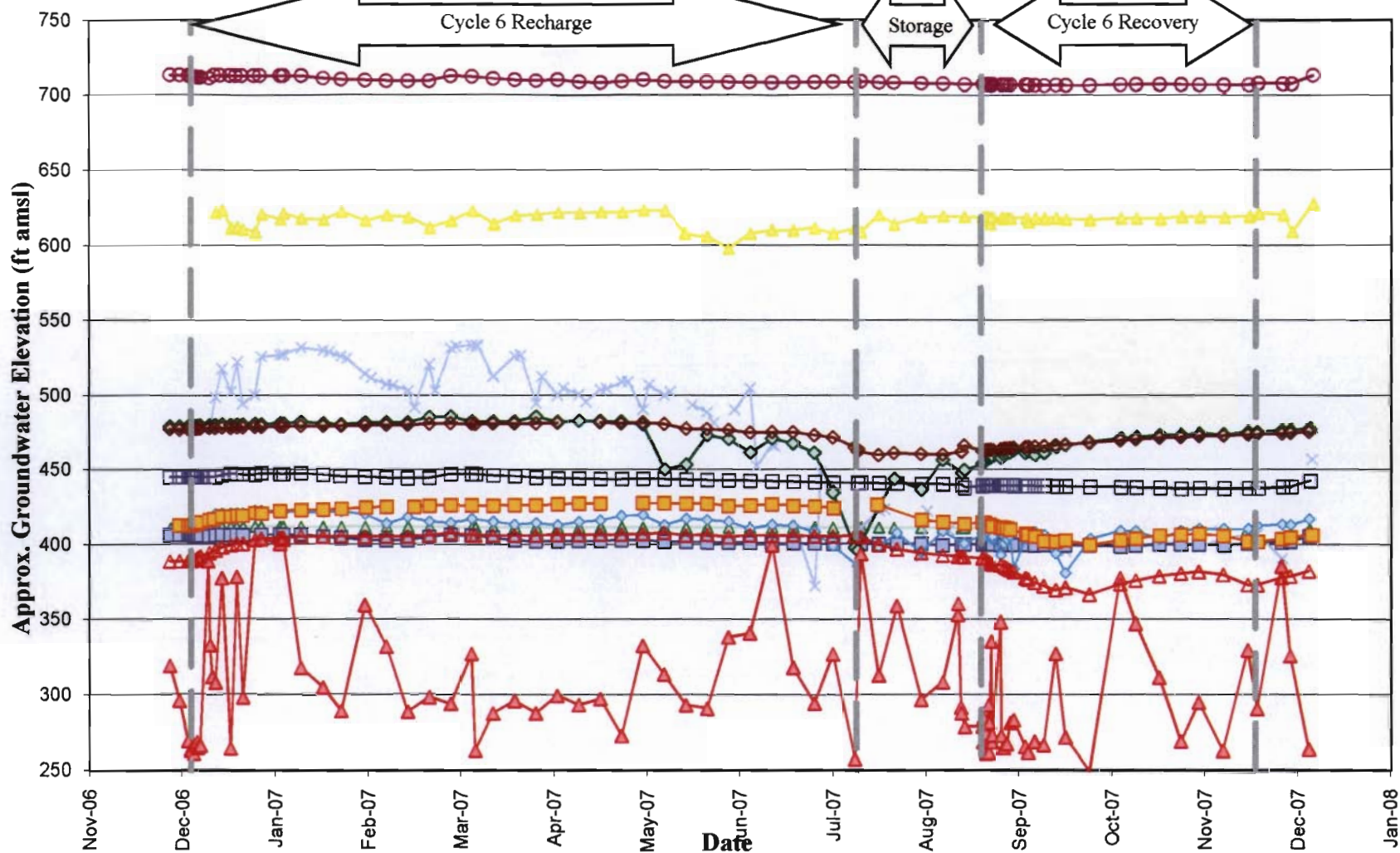
— Daily Minimum Temperature  
— Daily Maximum Temperature

### Temperature at Rockhouse Climate Station

JOB NUMBER: 053-9747-200

DATE: February 11, 2008

FIGURE NO.: 2-8



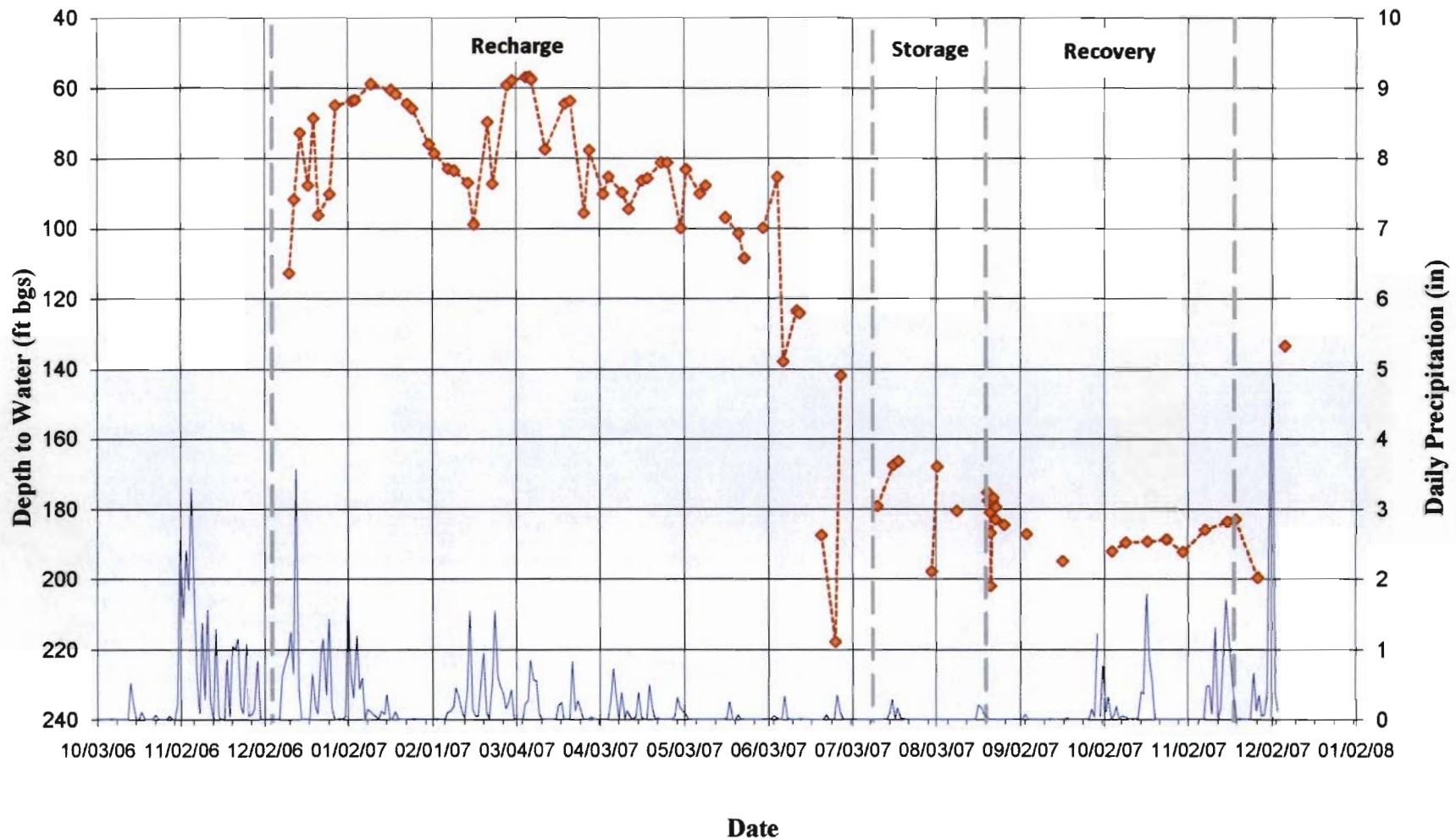
Year 2 ASR Pilot Test Report  
City of Dallas, Oregon

- △ PZ-1
- Birko Lower
- ◇ Fitcha
- ◇ Kowalczyk Lower
- △ Lowe Lower
- Parker
- × Anstine
- Birko Upper
- △ Jones
- ◇ Kowalczyk Upper
- △ Lowe Upper
- Presser

### Observation Well Water Level Elevations - Cycle 6 Comparative Trends

JOB 053-9747-200  
DATE: February 11, 2008

FIGURE NO.: 2-9



Year 2 ASR Pilot Test Report  
City of Dallas, Oregon

—◆— Anstine (Polk 368) - Manual Data  
— Daily Precipitation

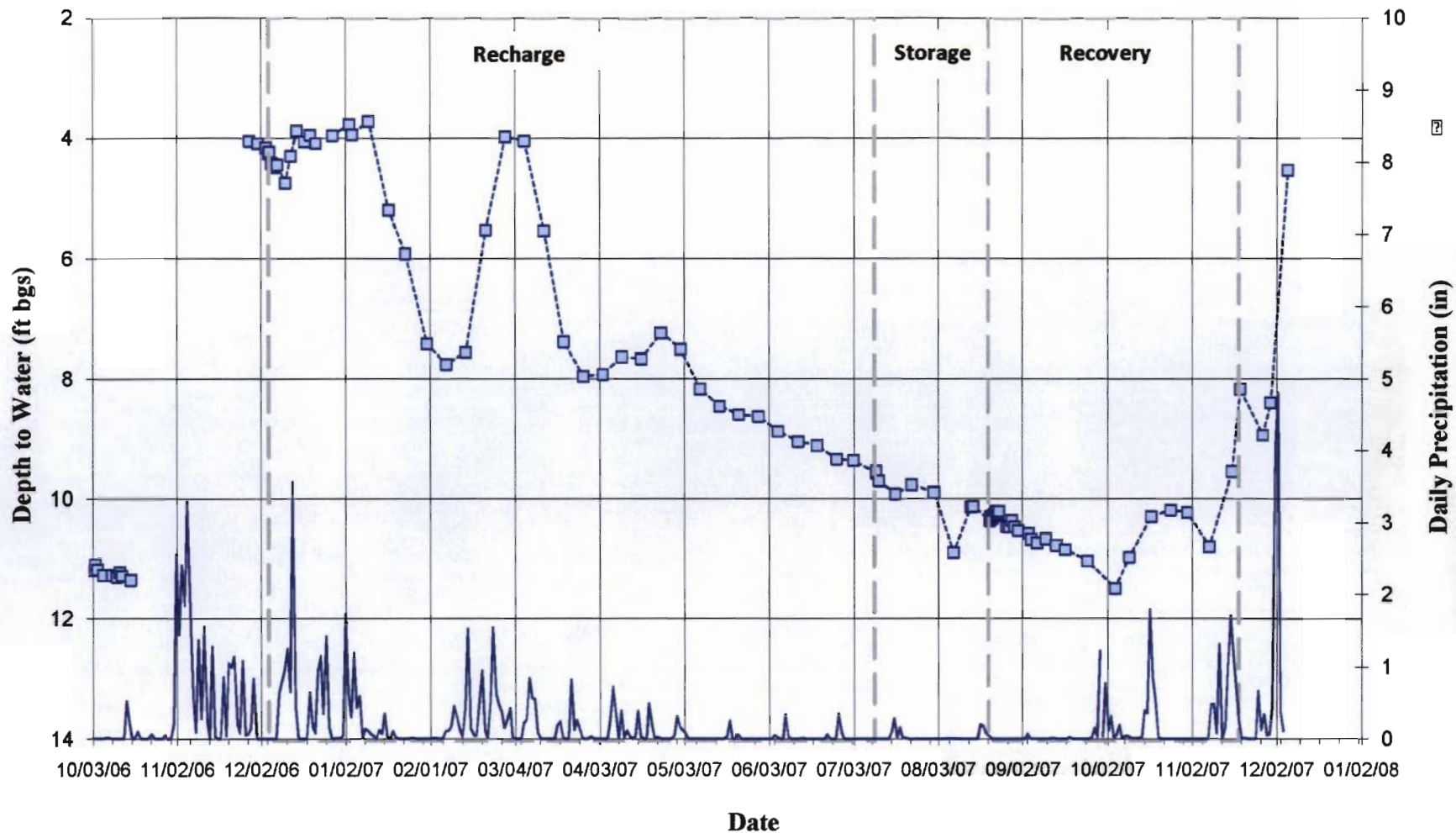
**Observation Well Water Levels with Daily Precipitation  
Anstine (Polk 368) - Manual Data**

JOB NUMBER: 053-9747-200

DATE: February 11, 2008

FIGURE NO.: 2-10





Year 2 ASR Pilot Test Report  
City of Dallas, Oregon

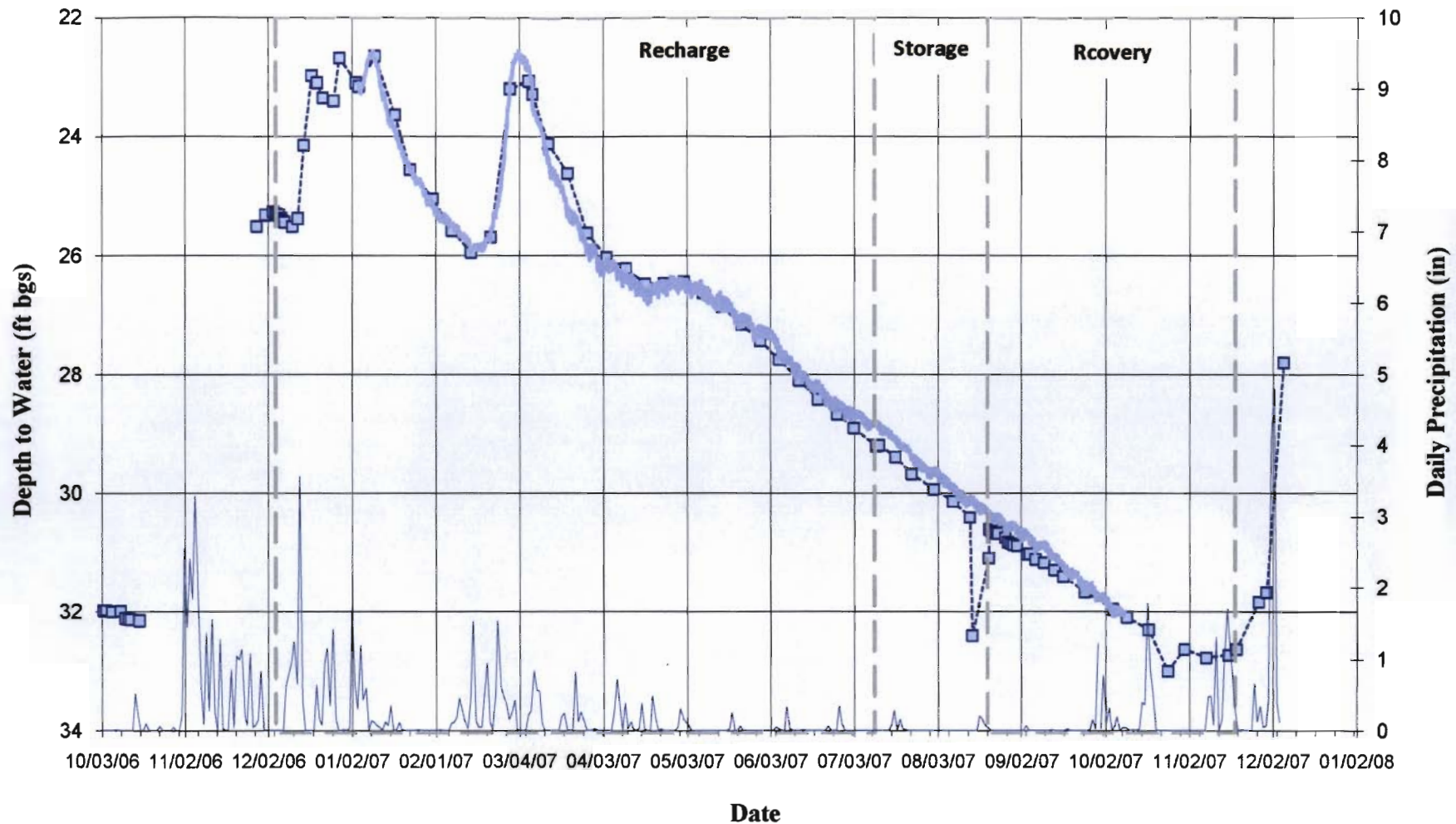
--- Birko Lower (Polk 572) - Manual Data  
— Daily Precipitation

**Observation Well Water Levels with Daily Precipitation  
Birko Lower (Polk 572) - Manual Data**

JOB NUMBER: 053-9747-200

DATE: February 11, 2008

FIGURE NO.: 2-11



Year 2 ASR Pilot Test Report  
City of Dallas, Oregon

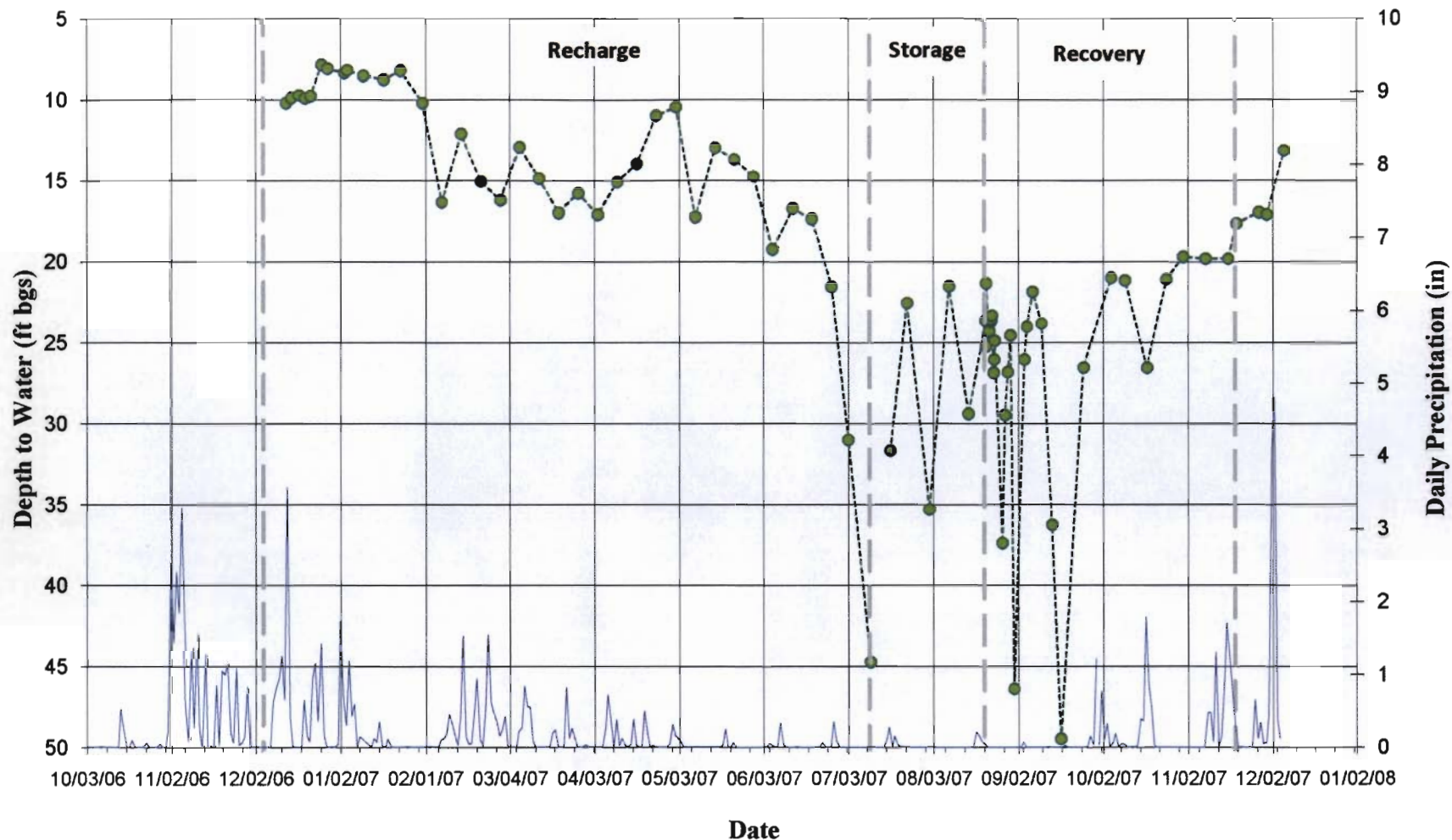
---□--- Birko Upper (Polk 539) - Manual Data  
— Birko Upper Transducer Data  
— Daily Precipitation

### Observation Well Water Levels with Daily Precipitation Birko Upper (Polk 539) - Manual Data

JOB NUMBER: 053-9747-200

DATE: February 11, 2008

FIGURE NO.: 2-12



Year 2 ASR Pilot Test Report  
City of Dallas, Oregon

---●--- Fitcha (Polk 2724) - Manual Data

— Daily Precipitation

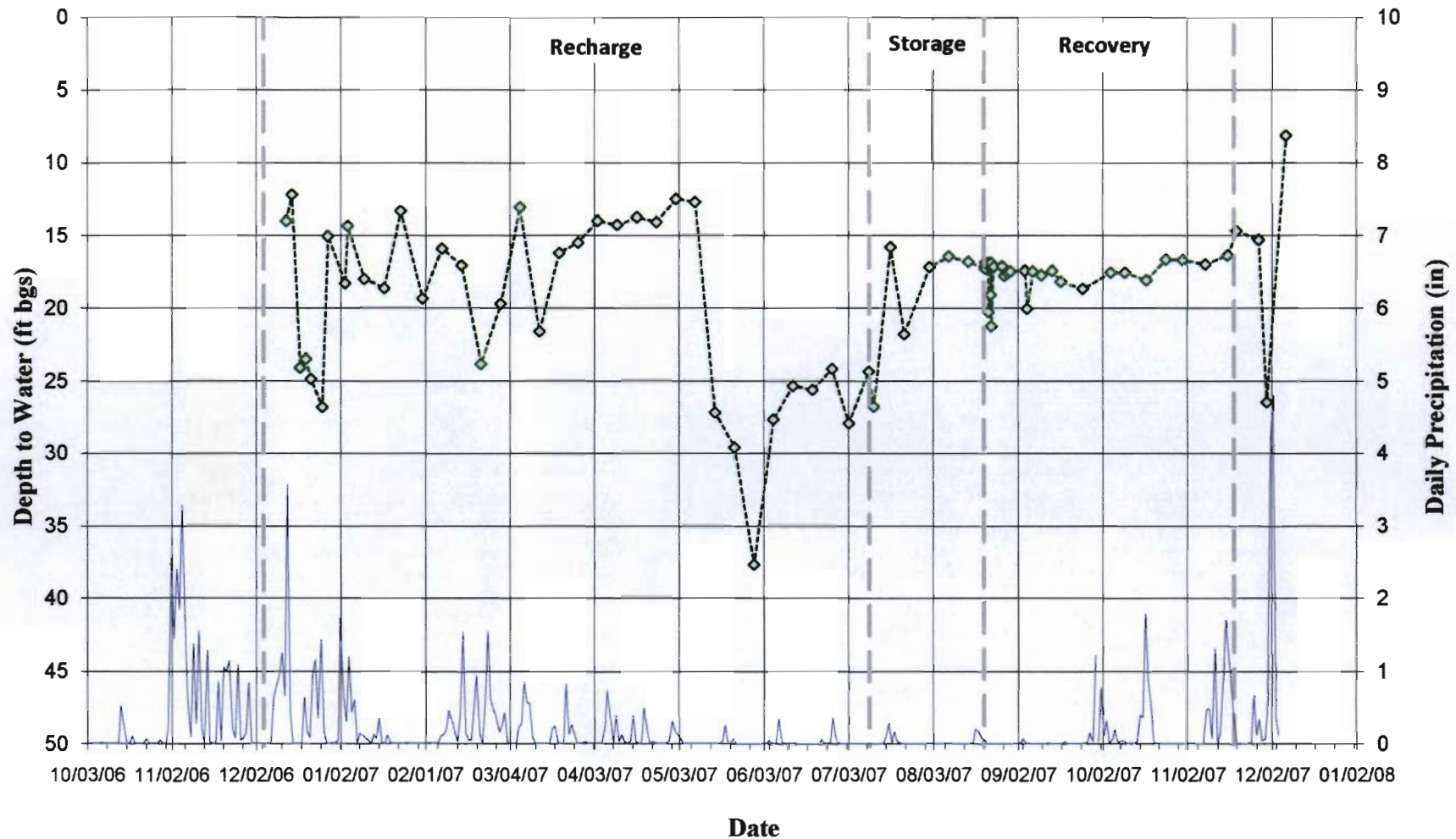
### Observation Well Water Levels with Daily Precipitation Fitcha (Polk 2724) - Manual Data

JOB NUMBER: 053-9747-200

DATE: February 11, 2008

FIGURE NO.: **2-13**





Year 2 ASR Pilot Test Report  
City of Dallas, Oregon

---◇--- Jones (Polk 51488) - Manual Data

— Daily Precipitation

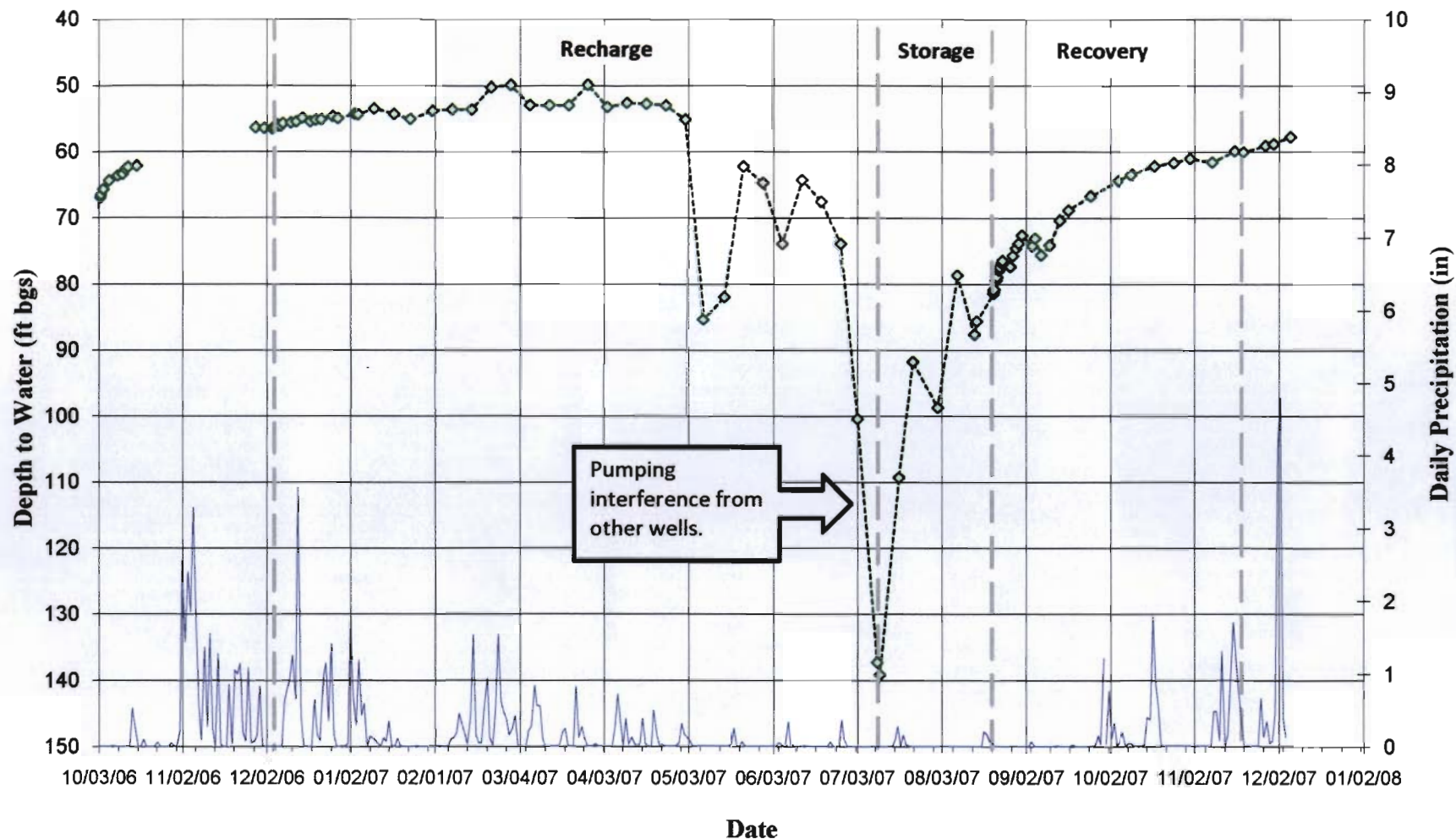
**Observation Well Water Levels with Daily Precipitation  
Jones (Polk 51488) - Manual Data**

JOB NUMBER: 053-9747-200

DATE: February 11, 2008

FIGURE NO.: 2-14





Year 2 ASR Pilot Test Report  
City of Dallas, Oregon

---◇--- Kowalczyk Lower (Polk 50936, #L08316) - Manual Data

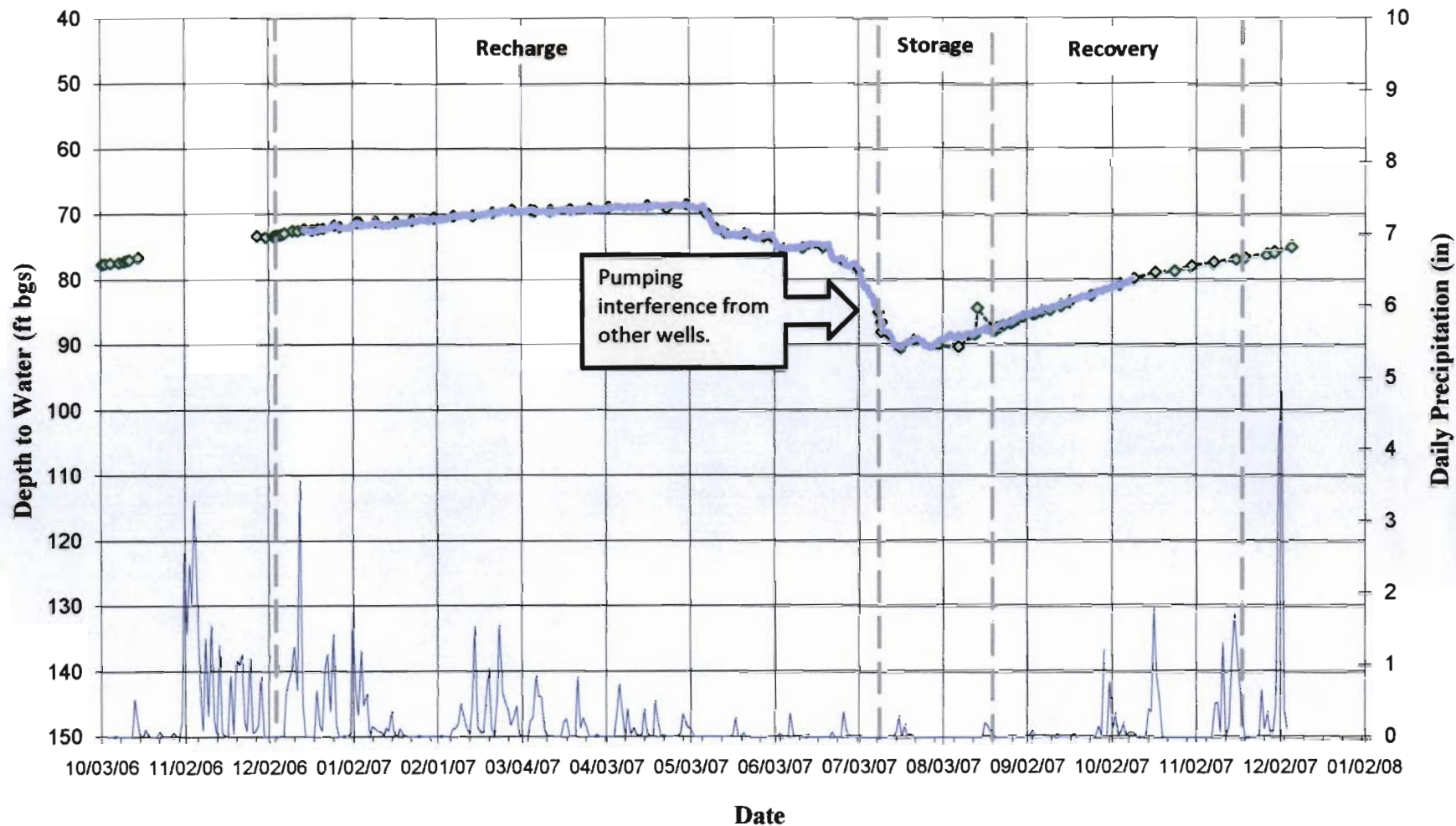
— Daily Precipitation

**Observation Well Water Levels with Daily Precipitation  
Kowalczyk Lower (Polk 50936, #L08316) - Manual Data**

JOB NUMBER: 053-9747-200

DATE: February 11, 2008

FIGURE NO.: 2-15



Year 2 ASR Pilot Test Report  
City of Dallas, Oregon

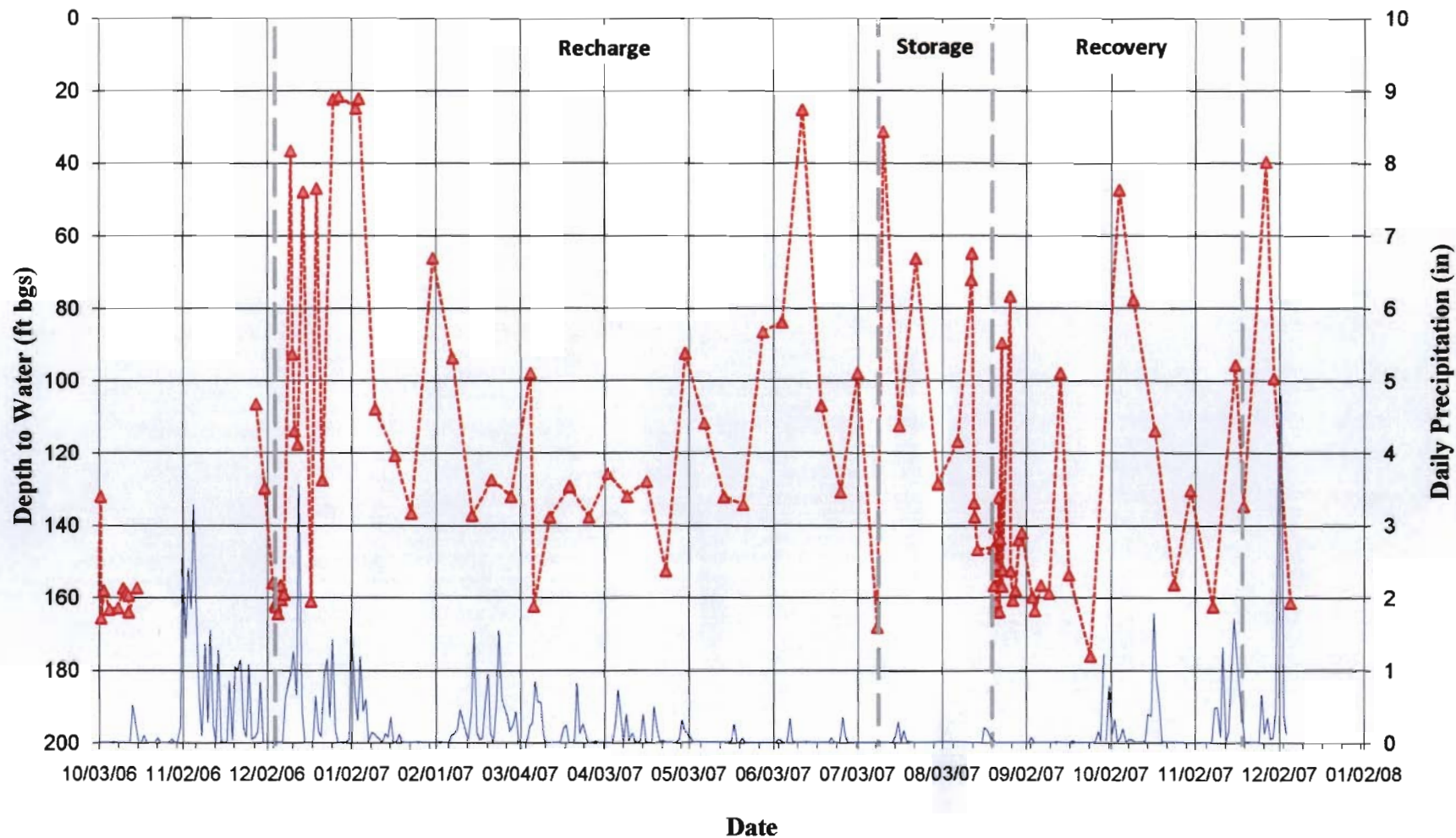
---◇--- Kowalczyk Upper (unknown log ID) - Manual Data  
— Kowalczyk Upper Transducer Data  
— Daily Precipitation

### Observation Well Water Levels with Daily Precipitation Kowalczyk Upper (unknown log ID) - Manual Data

JOB NUMBER: 053-9747-200

DATE: February 11, 2008

FIGURE NO.: 2-16



Year 2 ASR Pilot Test Report  
City of Dallas, Oregon

---▲--- Lowe Lower (Polk 51138, #L27491) - Manual Data

— Daily Precipitation

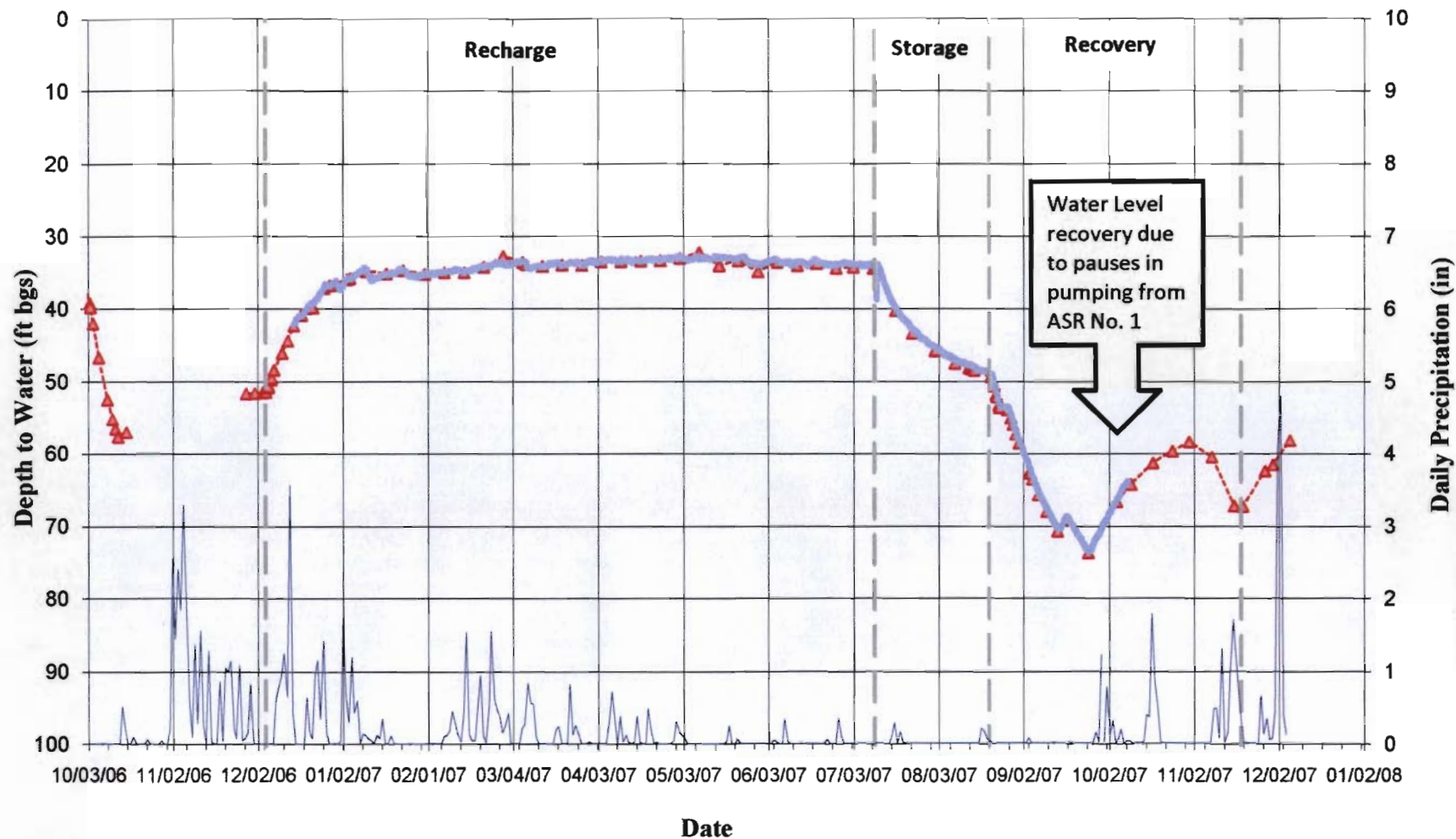
**Observation Well Water Levels with Daily Precipitation  
Lowe Lower (Polk 51138, #L27491) - Manual Data**

JOB NUMBER: 053-9747-200

DATE: February 11, 2008

FIGURE NO.: **2-17**





**Golder  
Associates**

Year 2 ASR Pilot Test Report  
City of Dallas, Oregon

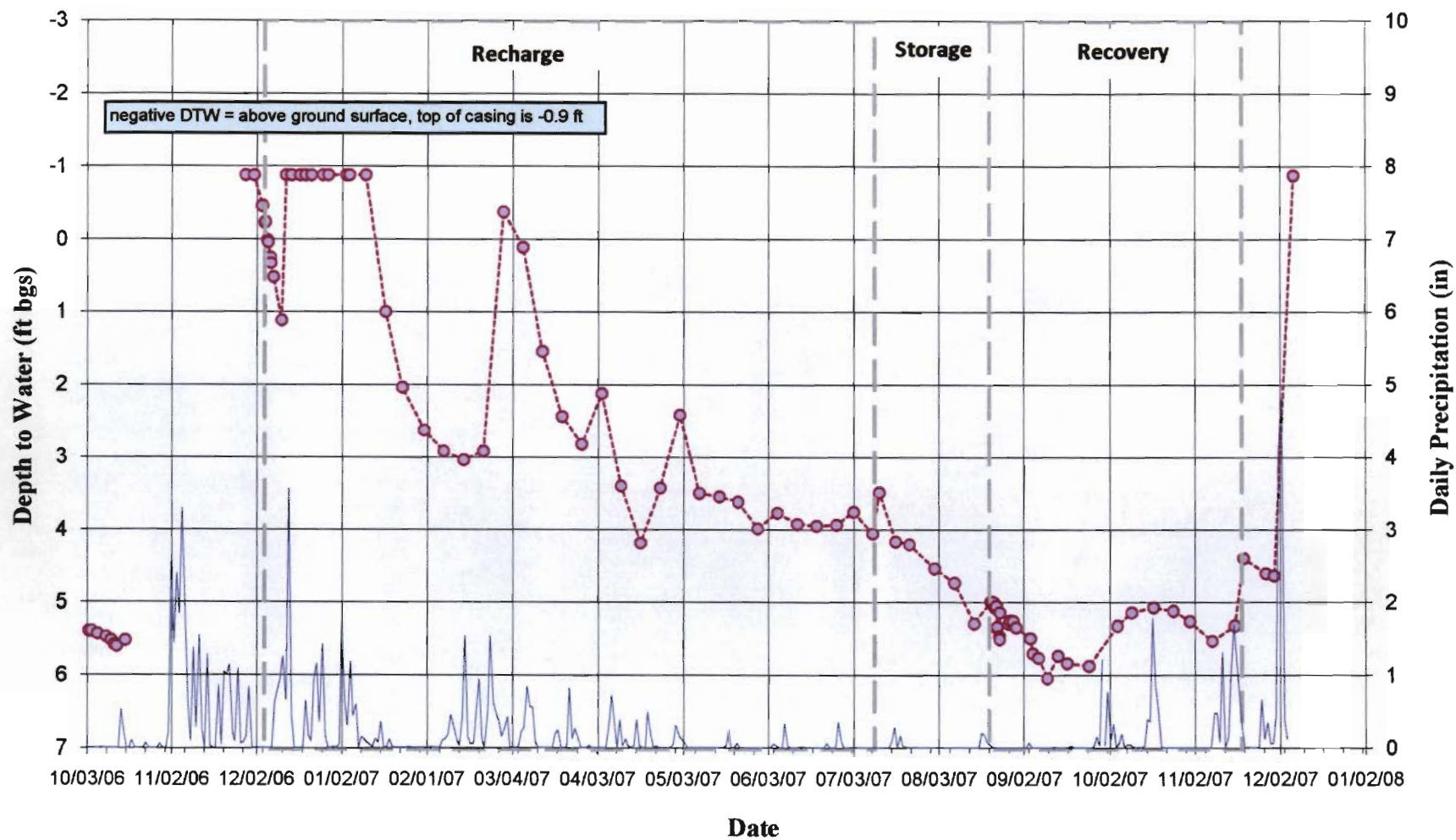
- ▲--- Lowe Upper (Polk 51112, #L39719) - Manual Data
- Lowe Upper Transducer Data
- Daily Precipitation

**Observation Well Water Levels with Daily Precipitation  
Lowe Upper (Polk 51112, #L39719) - Manual Data**

JOB NUMBER: 053-9747-200

DATE: February 11, 2008

FIGURE NO.: 2-18



Year 2 ASR Pilot Test Report  
City of Dallas, Oregon

—○— Parker (Polk 2762) - Manual Data

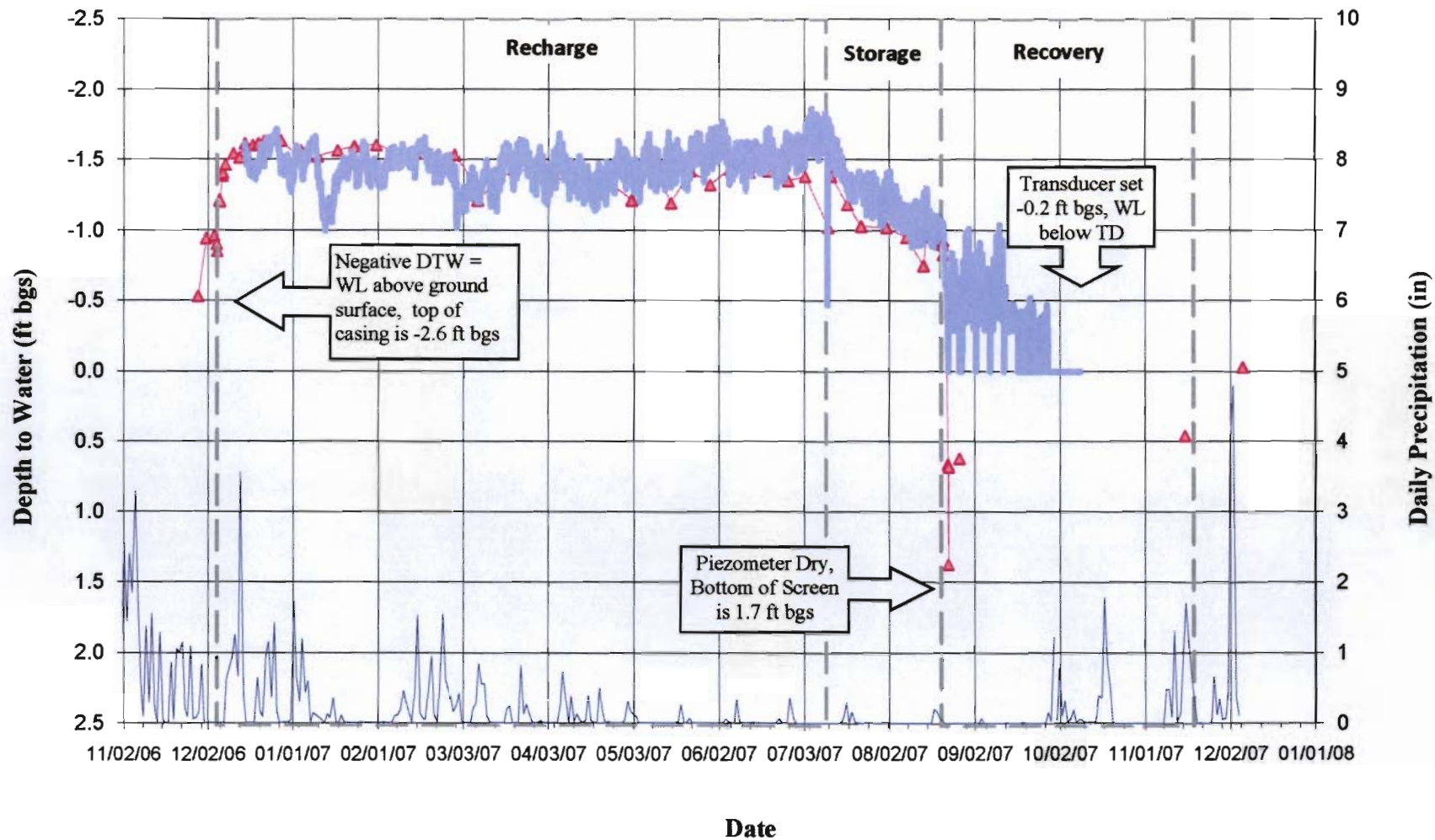
— Daily Precipitation

### Observation Well Water Levels with Daily Precipitation Parker (Polk 2762) - Manual Data

JOB NUMBER: 053-9747-200

DATE: February 11, 2008

FIGURE NO.: 2-19



Year 2 ASR Pilot Test Report  
City of Dallas, Oregon

—▲— PZ-1 (Polk 52465) - Manual Data  
— PZ-1 Transducer Data  
— Daily Precipitation

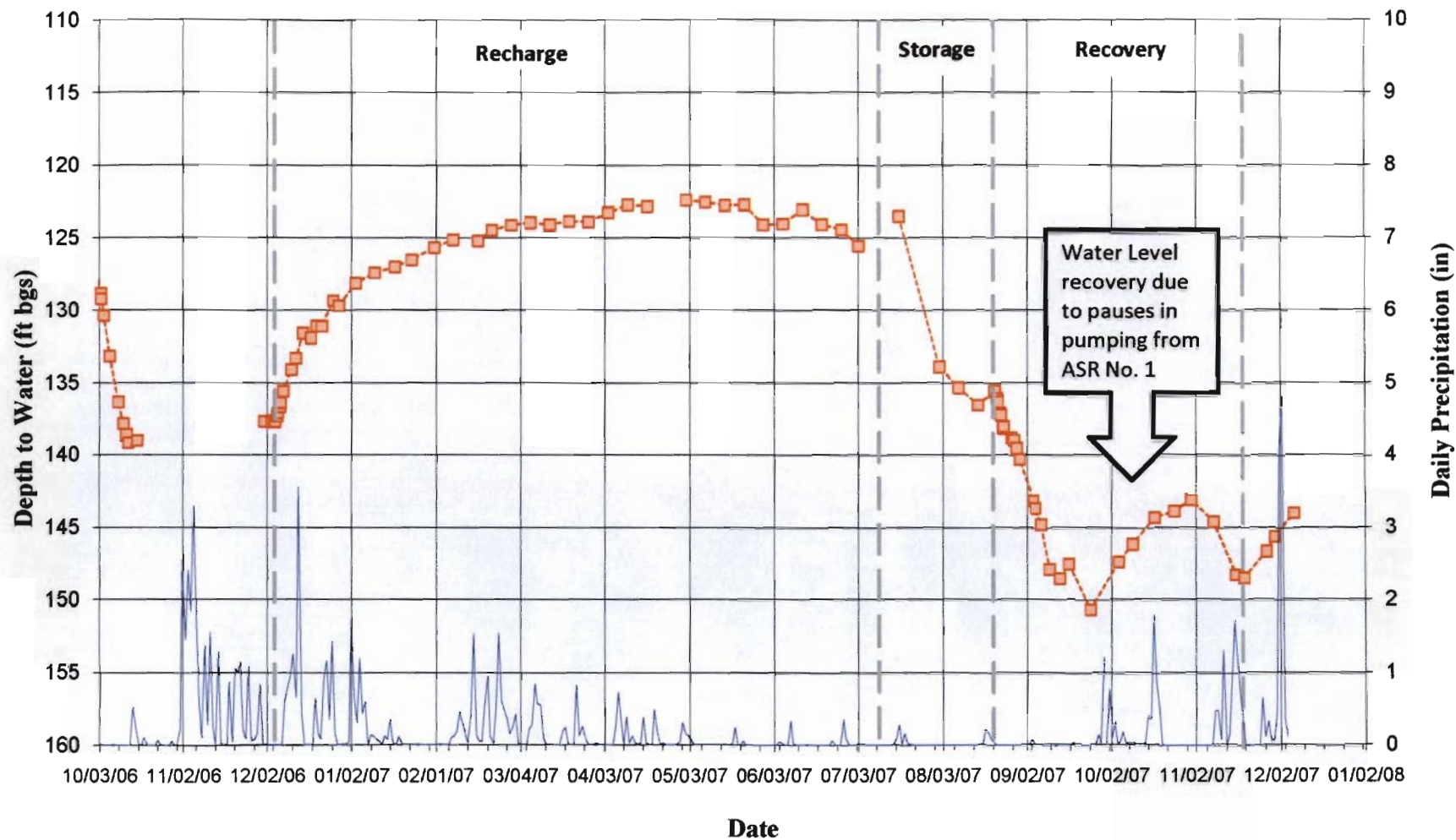
### Observation Well Water Levels with Daily Precipitation

JOB NUMBER: 053-9747-200

DATE: February 11, 2008

FIGURE NO.: 2-20





**Golder  
Associates**

Year 2 ASR Pilot Test Report  
City of Dallas, Oregon

--- Presser (Polk 51605) - Manual Data

— Daily Precipitation

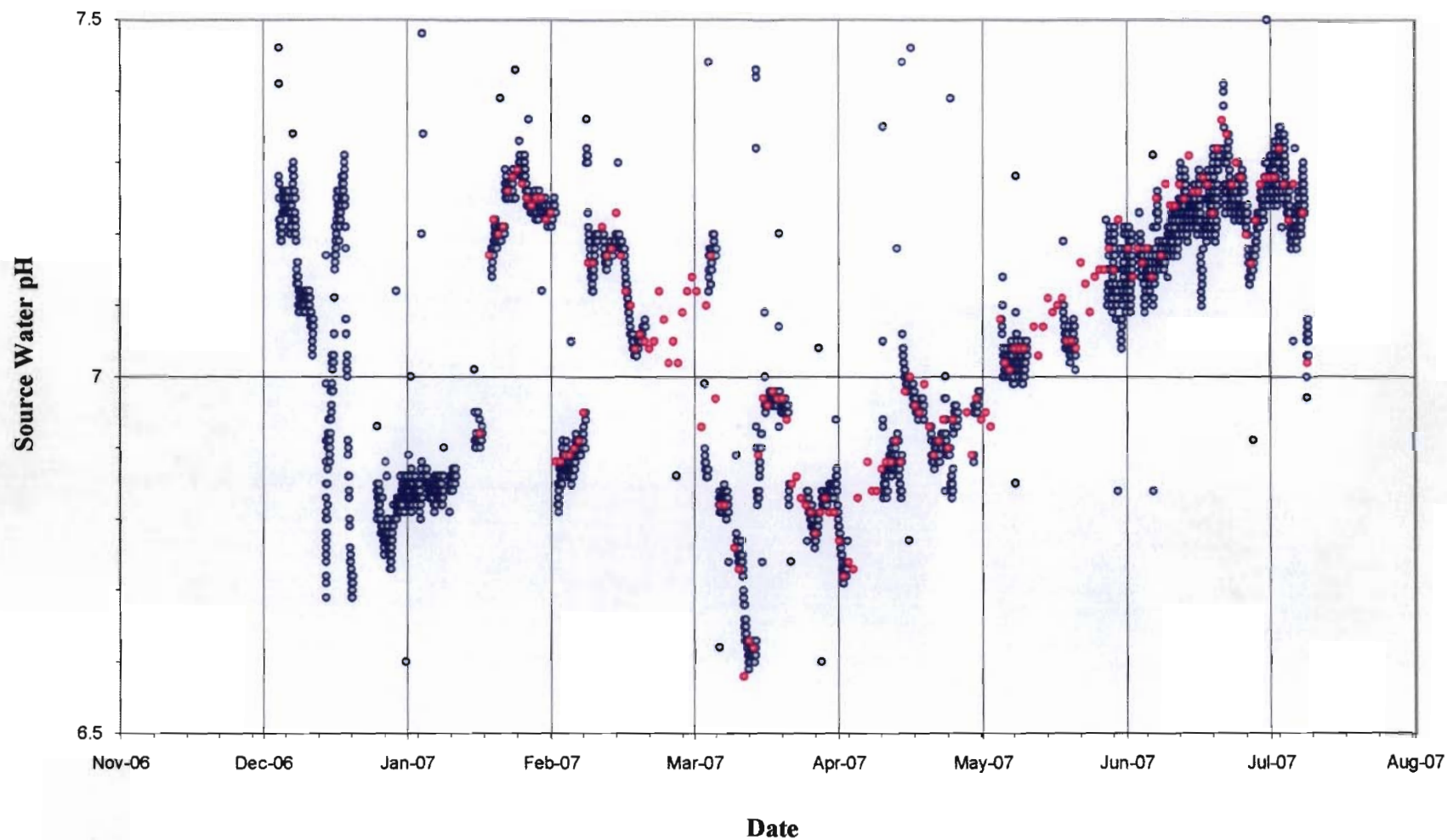
**Observation Well Water Levels with Daily Precipitation  
Presser (Polk 51605) - Manual Data**

JOB NUMBER: 053-9747-200

DATE: February 11, 2008

FIGURE NO.: 2-21





City of Dallas  
Year 2 ASR Pilot Test Report

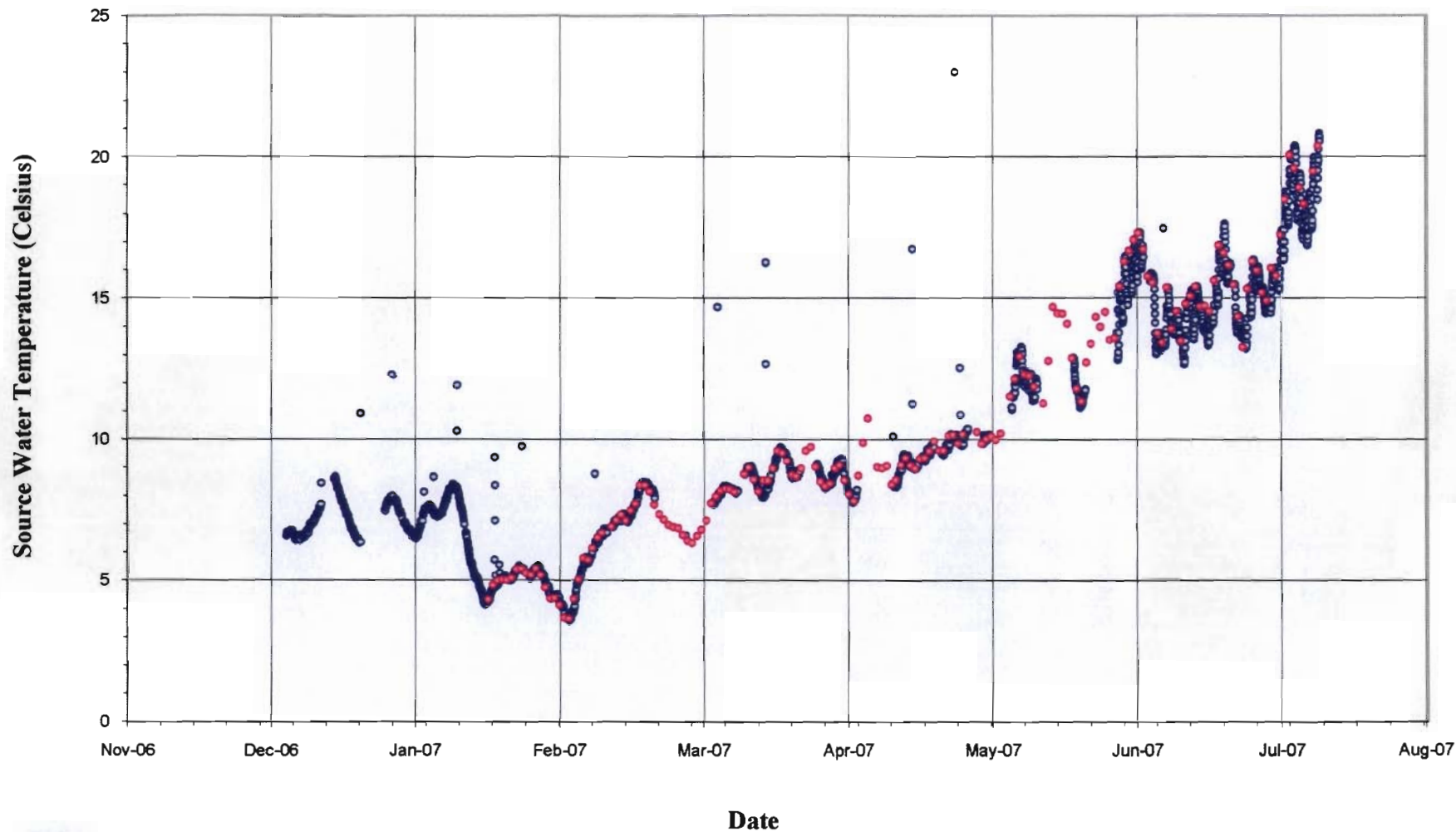
• YSI Data  
• Manual Data

### ASR No. 1 Source Water pH Cycle 6

JOB NUMBER: 053-9747-200

DATE: February 11, 2008

FIGURE NO.: 2-22



**Golder  
Associates**

City of Dallas  
Year 2 ASR Pilot Test Report

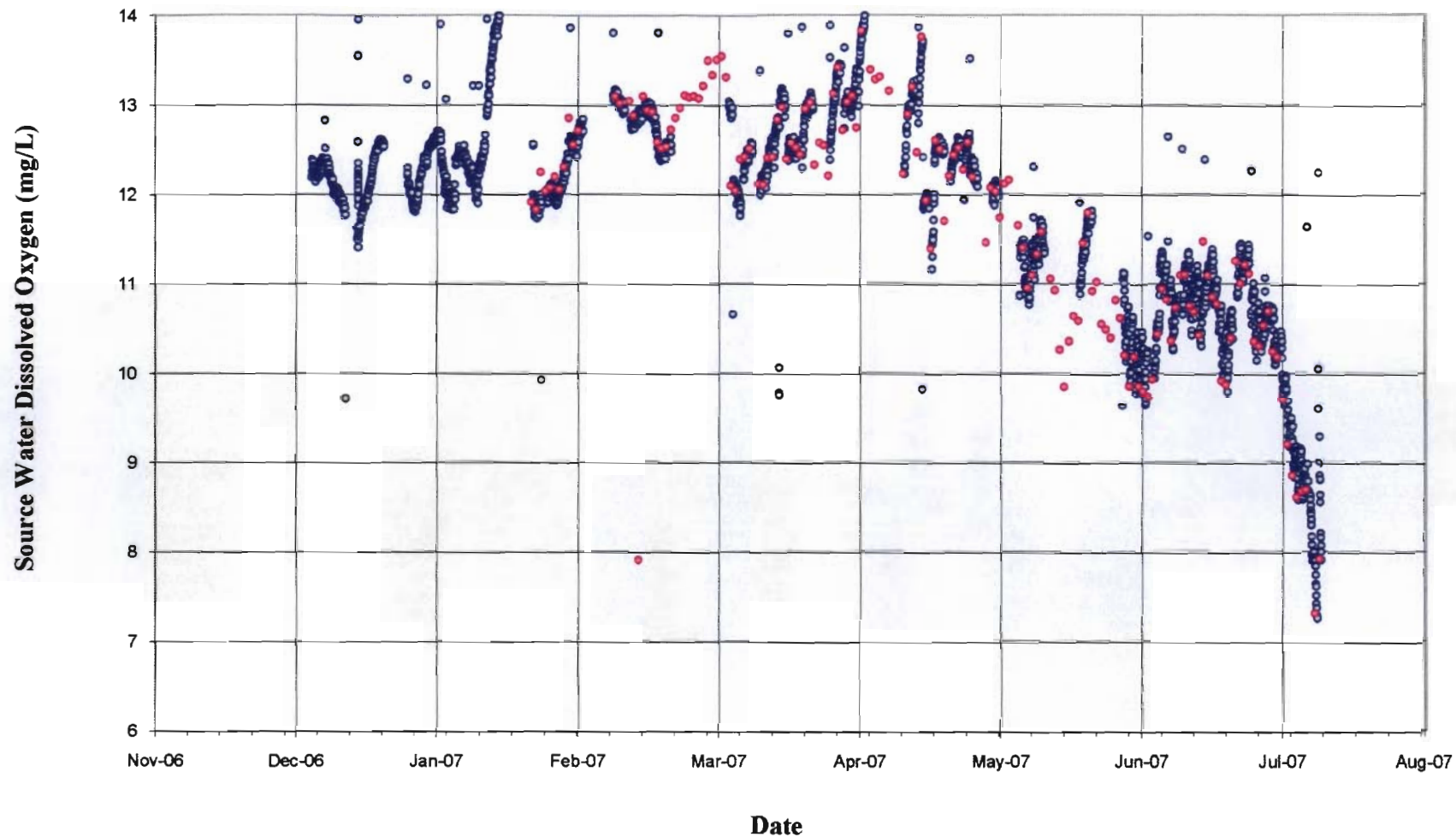
- YSI Data
- Manual Data

**ASR No. 1 Source Water Temperature  
Cycle 6**

JOB NUMBER: 053-9747-200

DATE: February 11, 2008

FIGURE NO.: **2-23**



City of Dallas  
Year 2 ASR Pilot Test Report

• YSI Data

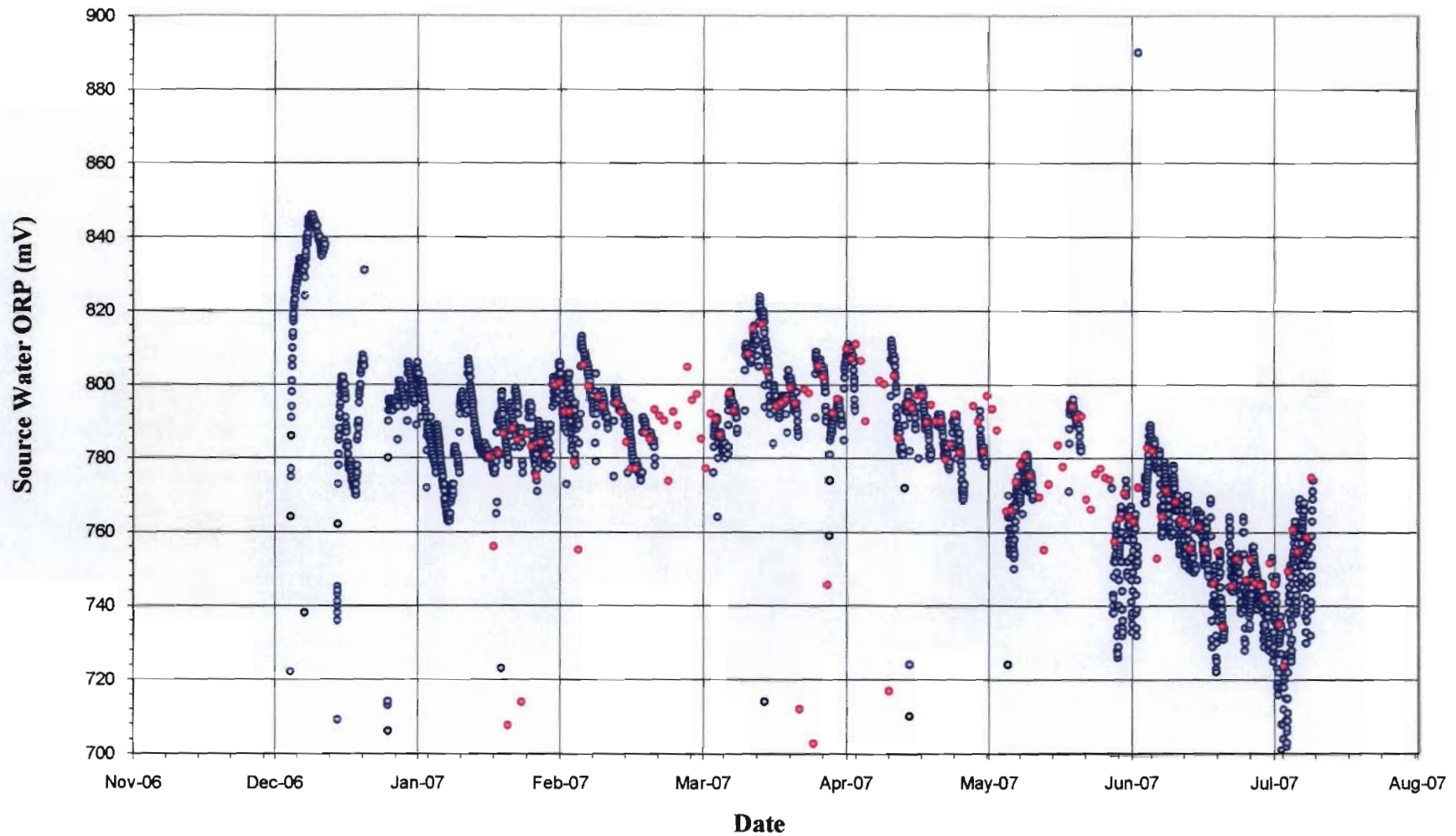
• Manual Data

### ASR No. 1 Source Water Dissolved Oxygen Cycle 6

JOB NUMBER: 053-9747-200

DATE: February 11, 2008

FIGURE NO.: 2-24



City of Dallas  
Year 2 ASR Pilot Test Report

• YSI Data

• Manual Data

### ASR No. 1 Source Water ORP Cycle 6

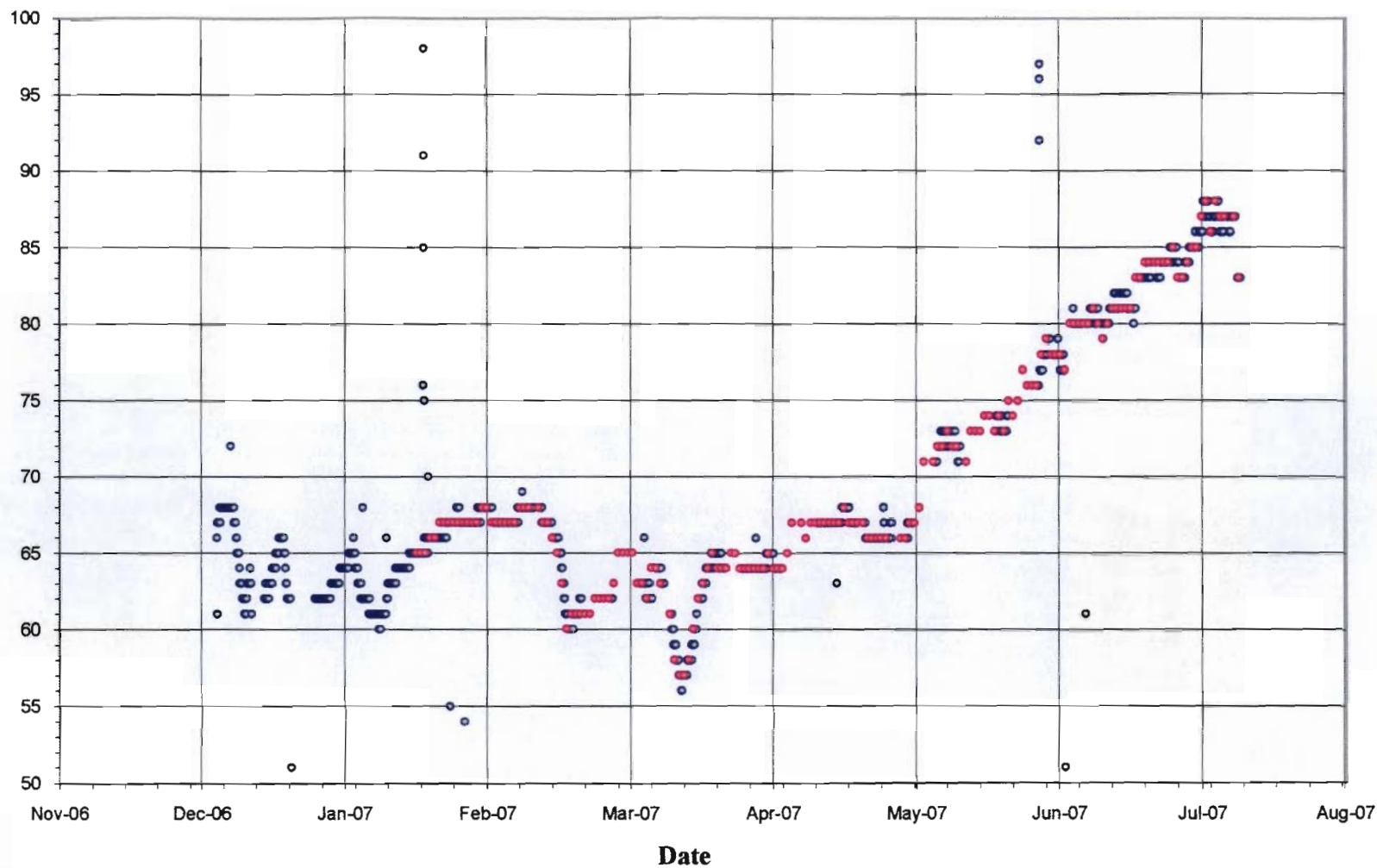
JOB NUMBER: 053-9747-200

DATE: February 11, 2008

FIGURE NO.: 2-25



Source Water Specific Conductance (uS/cm)



City of Dallas  
Year 2 ASR Pilot Test Report

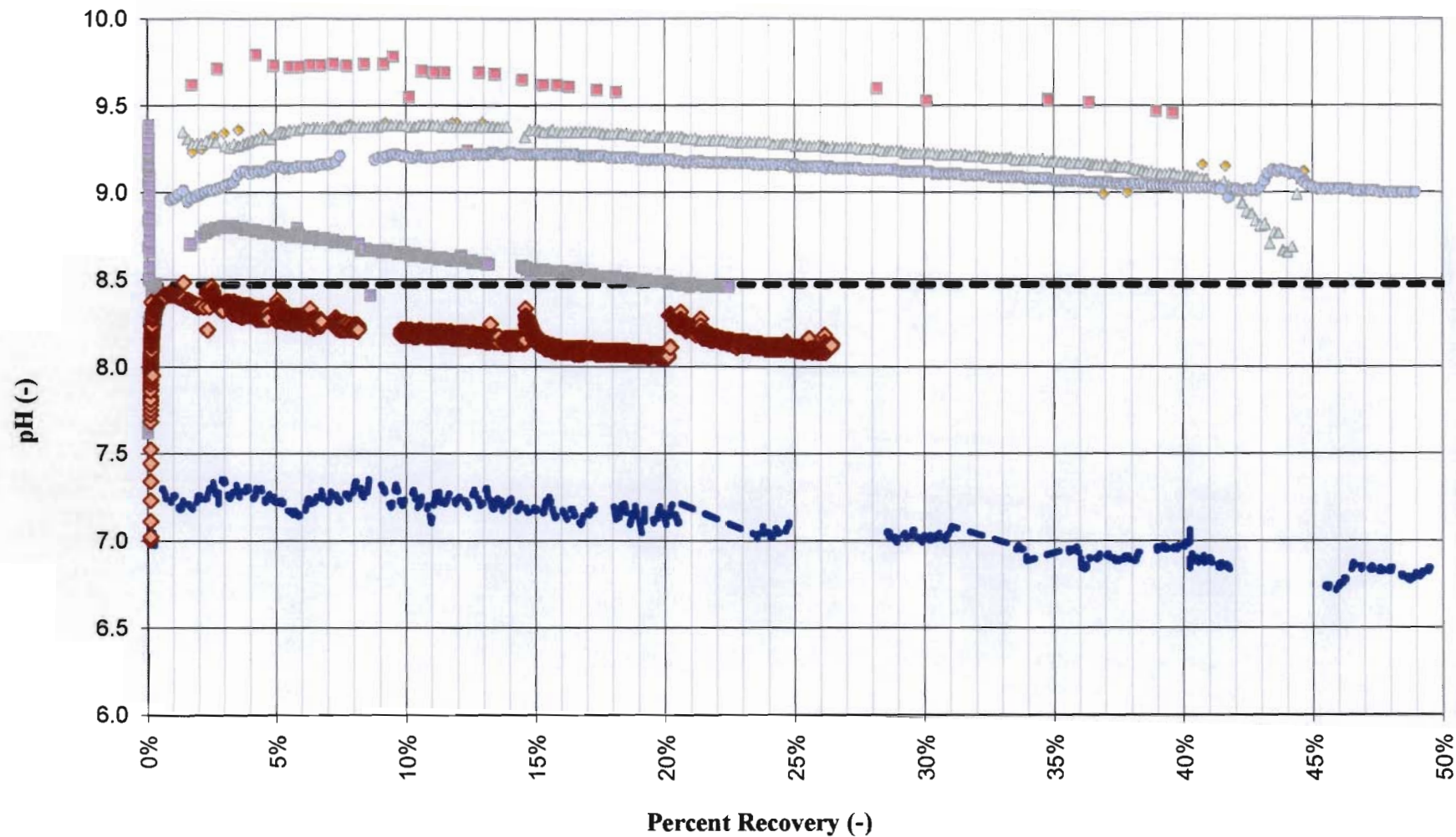
• YSI Data  
• Manual Data

### ASR No. 1 Source Water Specific Conductance Cycle 6

JOB NUMBER: 053-9747-200

DATE: February 11, 2008

FIGURE NO.: 2-26



Year 2 ASR Pilot Test Report  
City of Dallas, Oregon

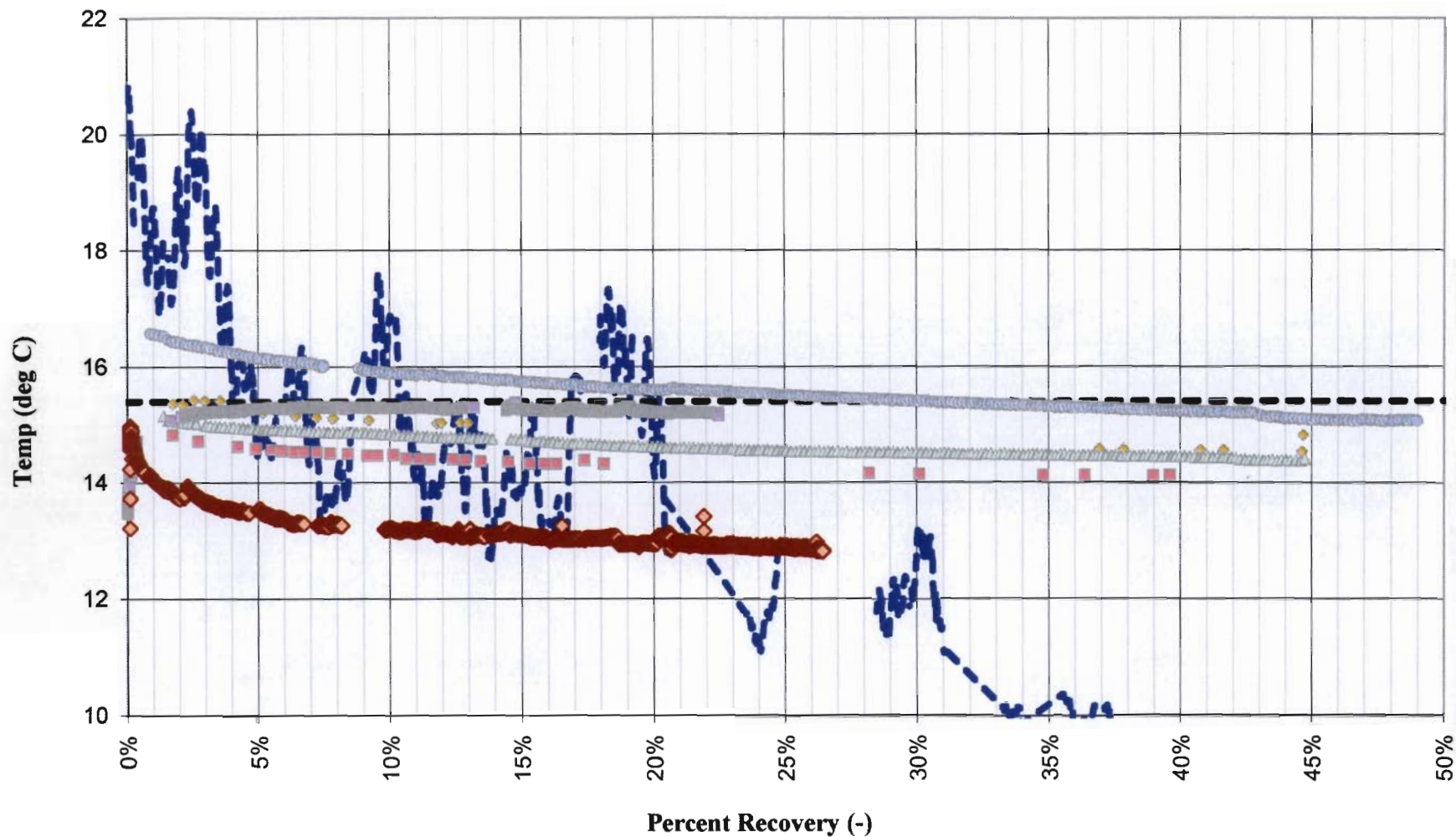
- C1 Recovery
- ◆ C2 Recovery
- ▲ C3 Recovery
- C4 Recovery
- C5 Recovery
- ◆ C6 Recovery
- C6 Injection Water
- Native Groundwater (Pre-Pilot Testing)

### ASR#1 Recovered Water Field Parameters pH (% Recovery)

JOB NUMBER: 053-9747-200

DATE: February 11, 2008

FIGURE NO.: 2-27



**Golder  
Associates**

Year 2 ASR Pilot Test Report  
City of Dallas, Oregon

- C1 Recovery
- ◆ C2 Recovery
- ▲ C3 Recovery
- C4 Recovery
- C5 Recovery
- ◆ C6 Recovery
- - - C6 Injection Water
- - - Native Groundwater (Pre-Pilot Testing)

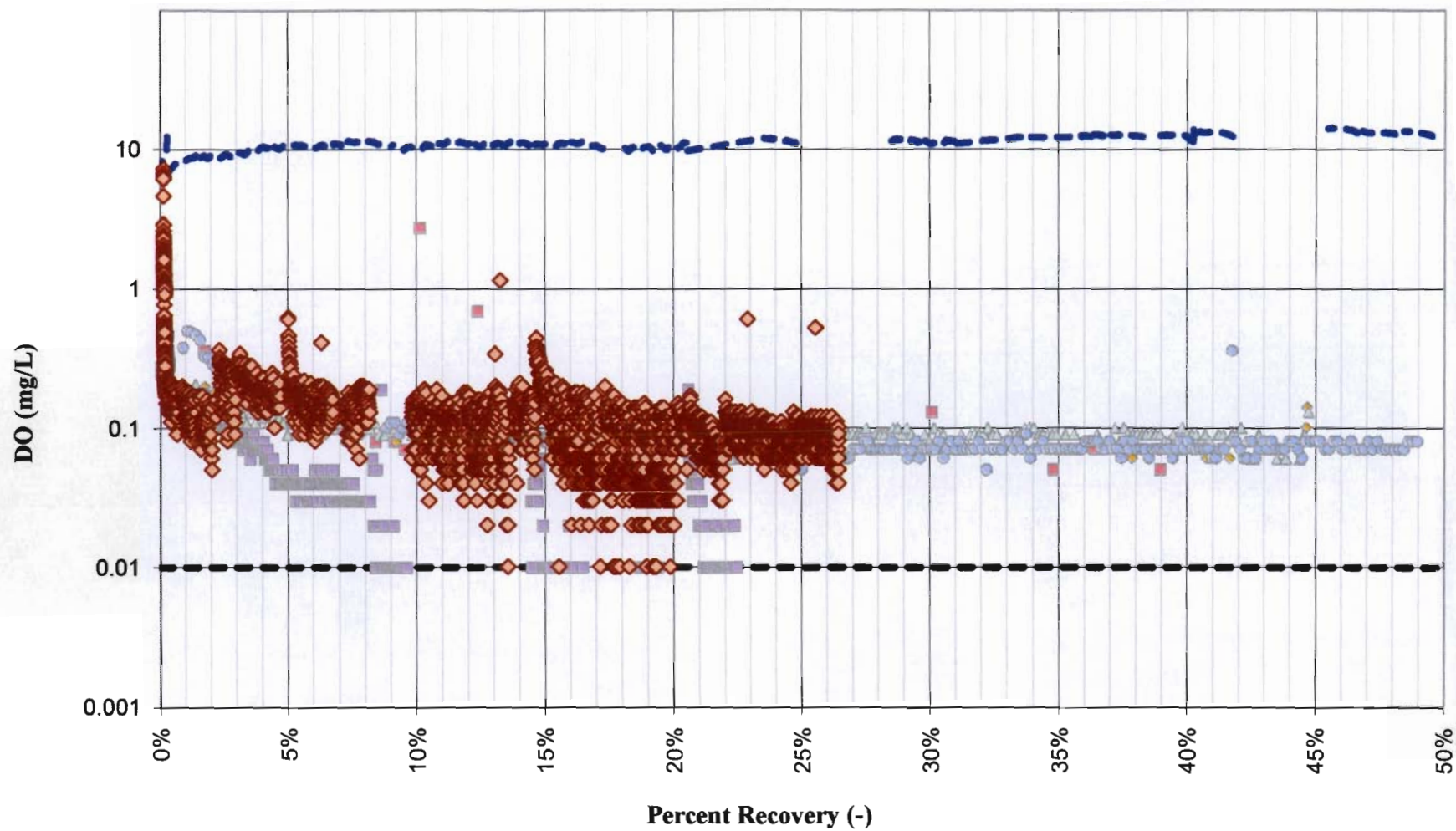
### ASR#1 Recovered Water Field Parameters Temp (% Recovery)

JOB NUMBER: 053-9747-200

DATE: February 11, 2008

FIGURE NO.: **2-28**





Year 2 ASR Pilot Test Report  
City of Dallas, Oregon

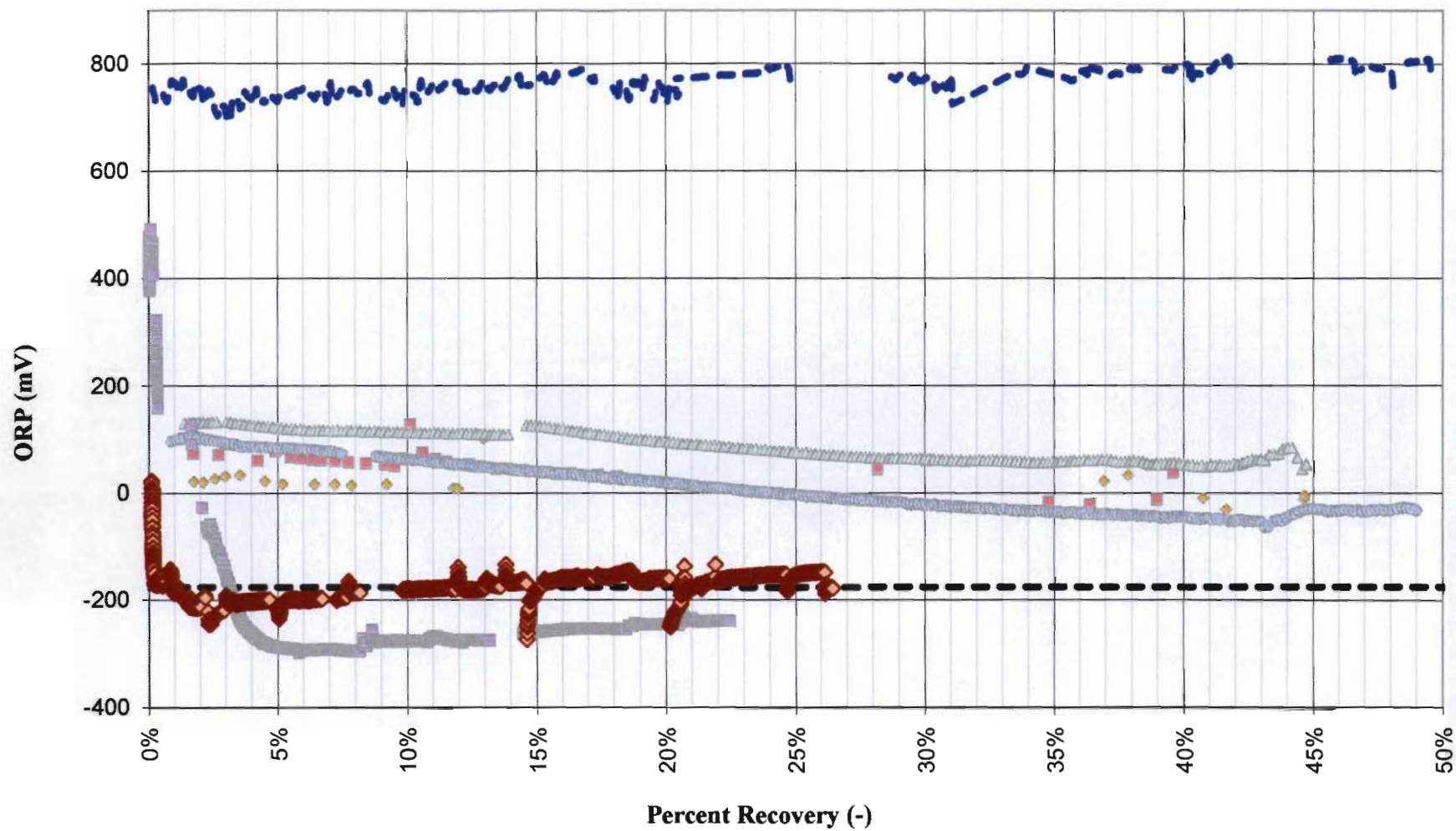
- C1 Recovery
- ◆ C2 Recovery
- ▲ C3 Recovery
- C4 Recovery
- C5 Recovery
- ◆ C6 Recovery
- C6 Injection Water
- Native Groundwater (Pre-Pilot Testing)

### ASR#1 Recovered Water Field Parameters DO (% Recovery)

JOB NUMBER: 053-9747-200

DATE: February 11, 2008

FIGURE NO.: 2-29



Year 2 ASR Pilot Test Report  
City of Dallas, Oregon

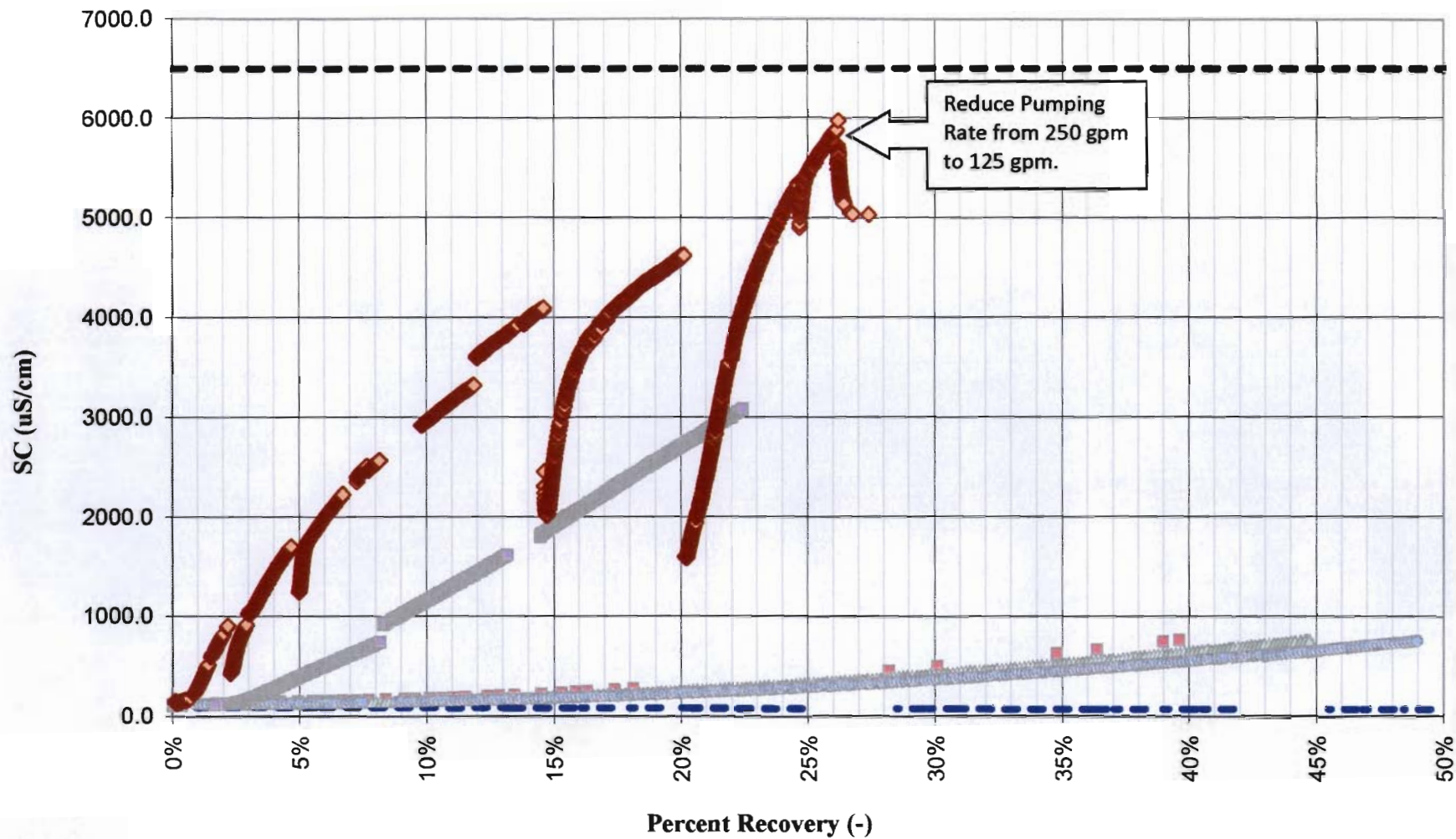
- C1 Recovery
- ◆ C2 Recovery
- ▲ C3 Recovery
- C4 Recovery
- C5 Recovery
- ◆ C6 Recovery
- C6 Injection Water
- Native Groundwater (Pre-Pilot Testing)

### ASR#1 Recovered Water Field Parameters ORP (% Recovery)

JOB NUMBER: 053-9747-200

DATE: February 11, 2008

FIGURE NO.: 2-30



**Golder  
Associates**

Year 2 ASR Pilot Test Report  
City of Dallas, Oregon

- C1 Recovery
- ◆ C2 Recovery
- ▲ C3 Recovery
- C4 Recovery
- C5 Recovery
- ◆ C6 Recovery
- C6 Injection Water
- Native Groundwater (Pre-Pilot Testing)

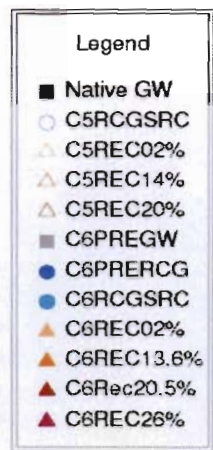
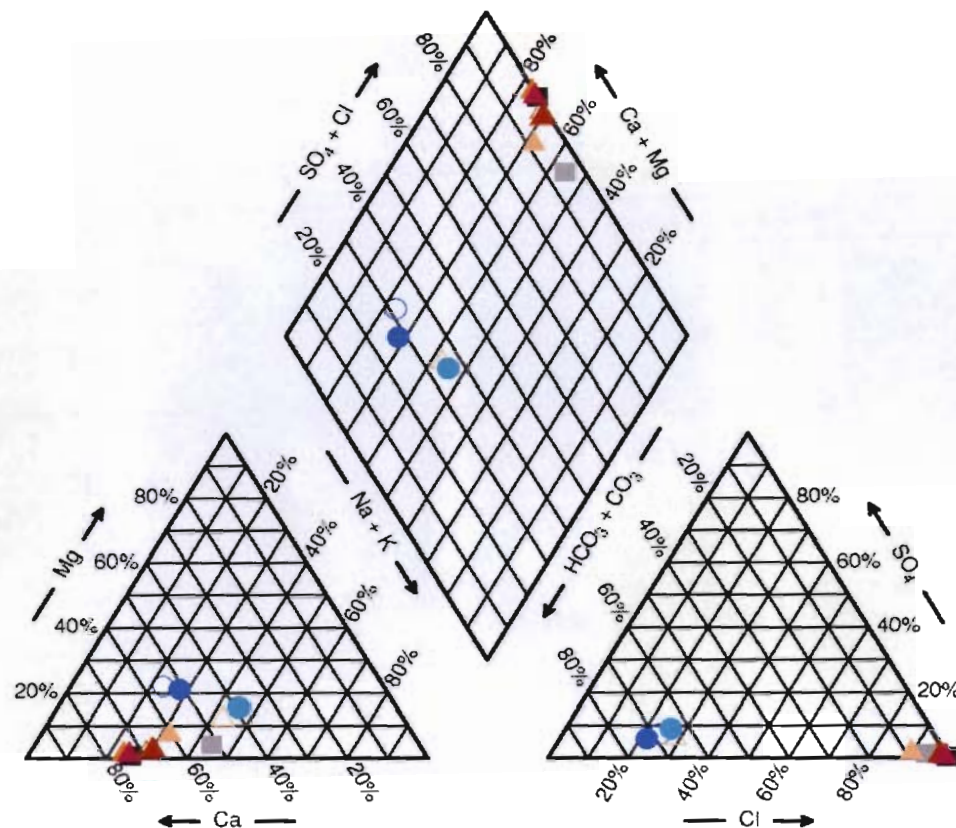
### ASR#1 Recovered Water Field Parameters SC (% Recovery)

JOB NUMBER: 053-9747-200

DATE: February 11, 2008

FIGURE NO.: **2-31**





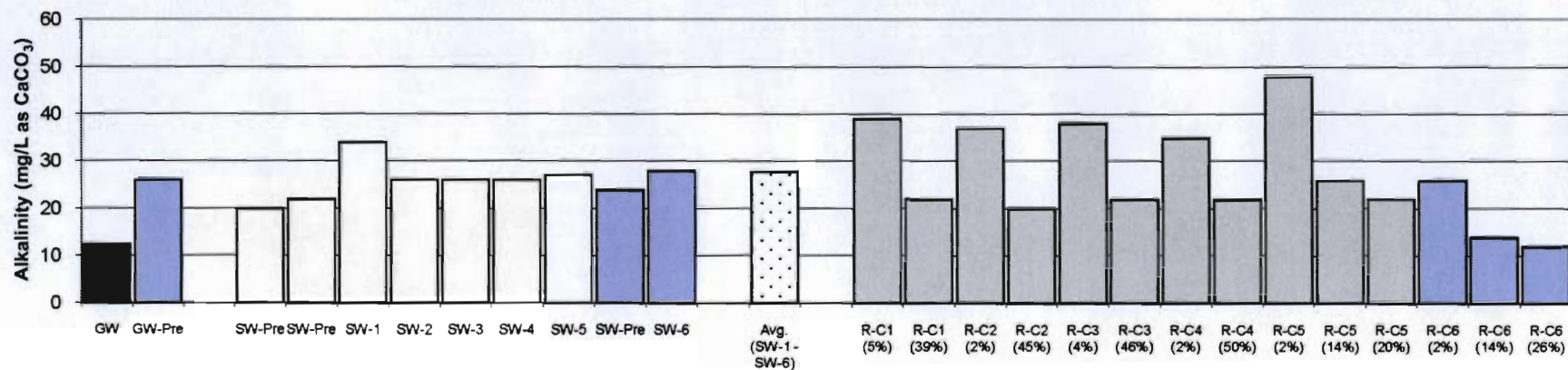
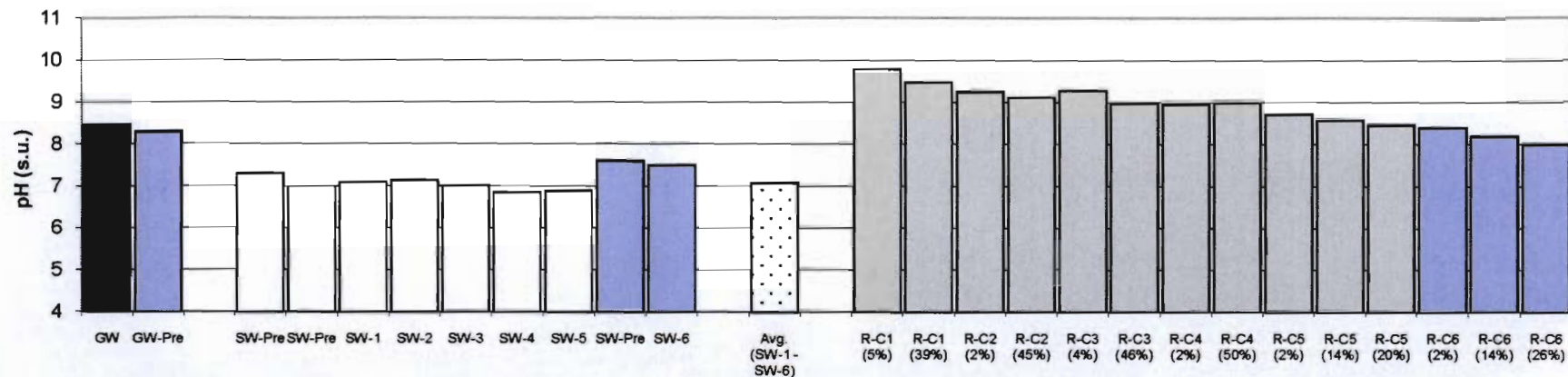
Year 2 ASR Pilot Test Report  
City of Dallas, OR

### ASR No. 1 Water Quality Piper Diagram Cycles 5 and 6

JOB NUMBER: 053-9747-200

DATE: 24-Apr-08

FIGURE NO.: 2-32



Year 2 ASR Pilot Test Report  
City of Dallas, OR

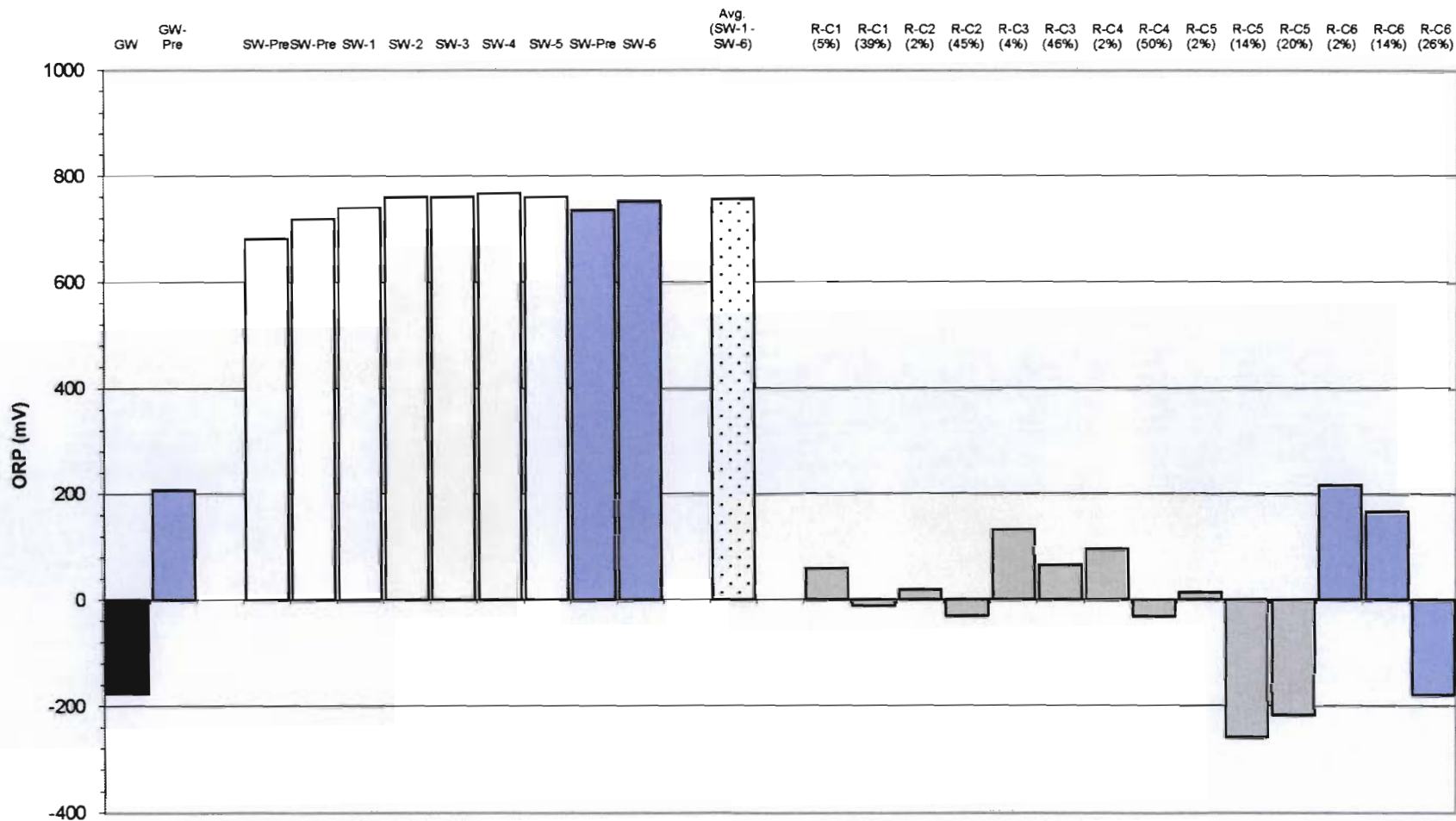
### ASR Water Quality - pH and Alkalinity

JOB NUMBER: 053-9747-200

DATE: February 11, 2008

FIGURE NO.: 2-33





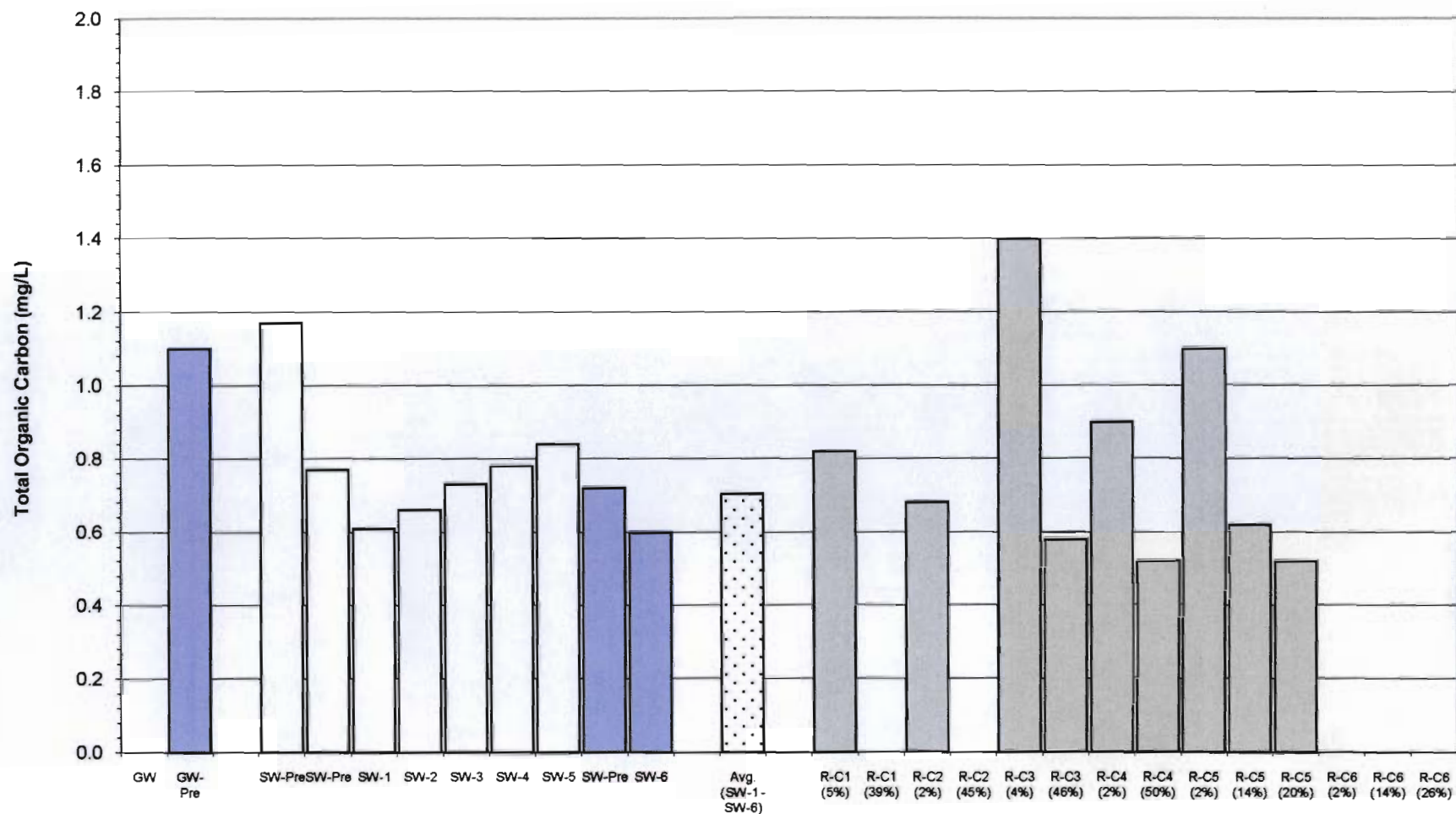
Year 2 ASR Pilot Test Report  
City of Dallas, OR

### ASR Water Quality - Oxidation Reduction Potential (ORP)

JOB NUMBER: 053-9747-200

DATE: February 11, 2008

FIGURE NO.: 2-34



Note: Non-detect concentrations shown as 0 mg/L.



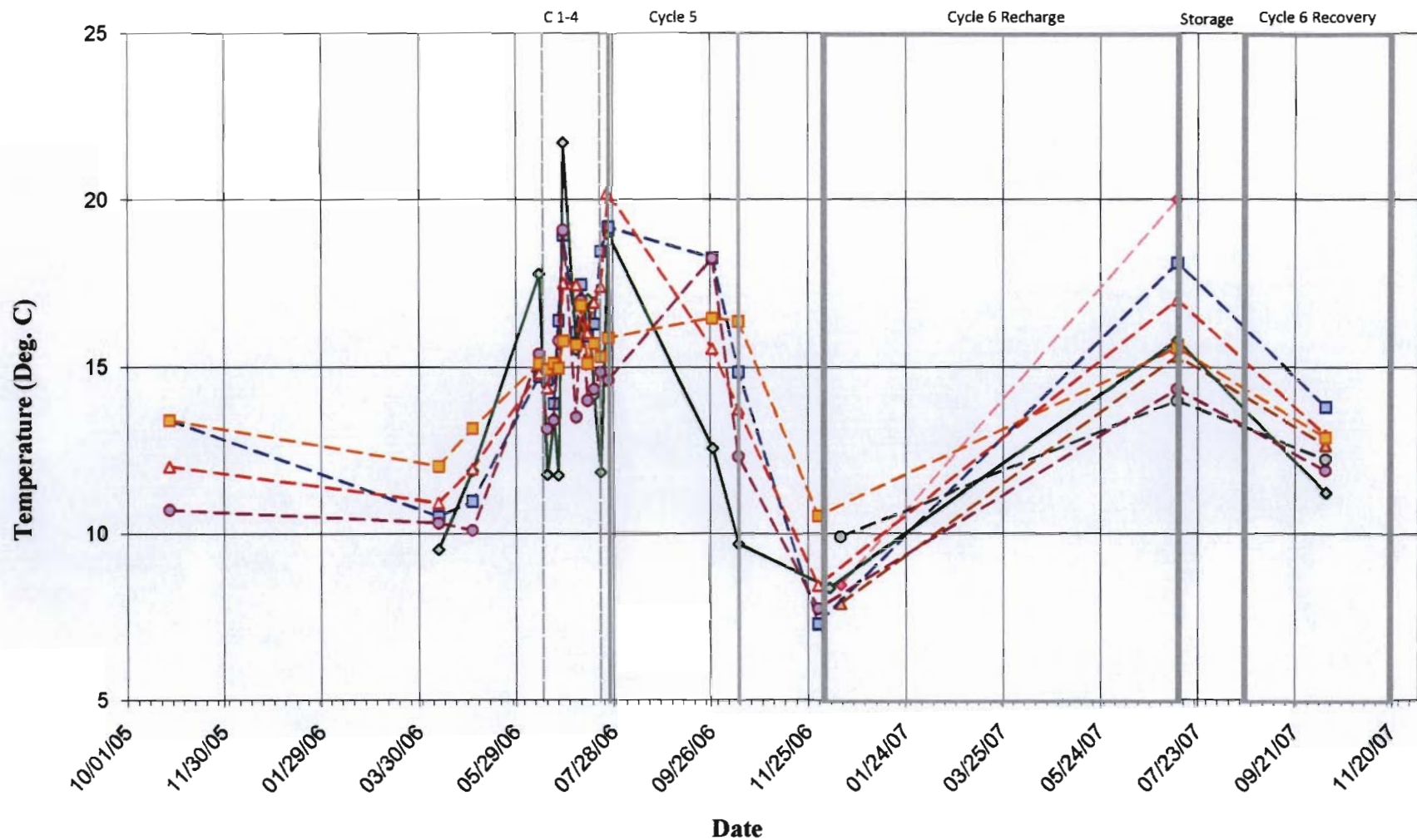
Year 2 ASR Pilot Test Report  
City of Dallas, OR

### ASR Water Quality - Total Organic Carbon (TOC)

JOB NUMBER: 053-9747-200

DATE: February 11, 2008

FIGURE NO.: **2-35**



Year 2 ASR Pilot Test Report  
City of Dallas, Oregon

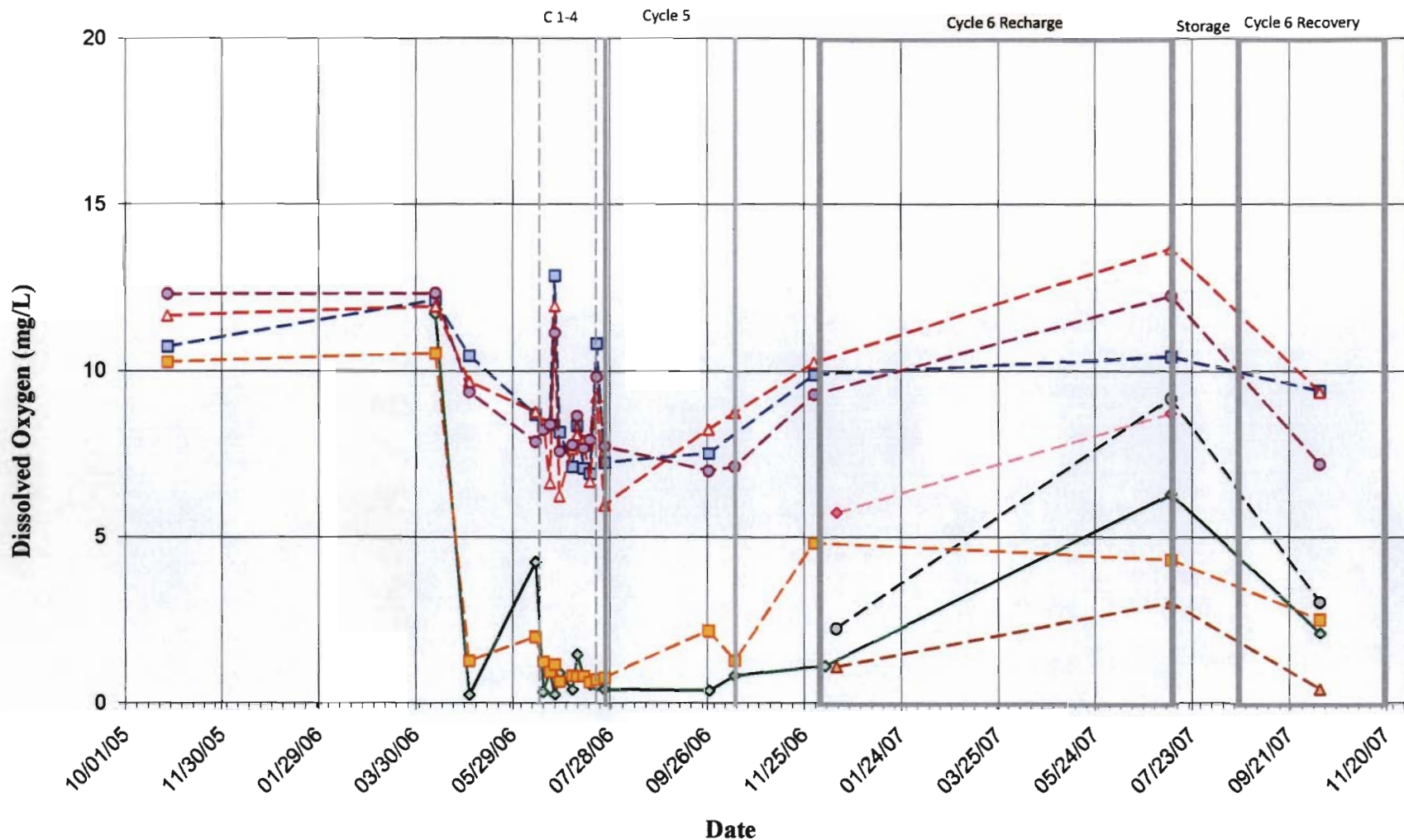
—◆— Anstine  
—★— Fitcha  
—□— Birko  
—○— Jones  
—◇— Kowalczyk  
—☆— Lowe  
—◇— Parker  
—□— Presser

### Observation Well Groundwater Quality - Temperature

JOB NUMBER: 053-9747-200

DATE: February 11, 2008

FIGURE NO.: 2-36



Year 2 ASR Pilot Test Report  
City of Dallas, Oregon

—◆— Anstine  
—★— Fitcha  
—■— Birko  
—○— Jones  
—●— Kowalczyk  
—☆— Lowe  
—◇— Parker  
—□— Presser

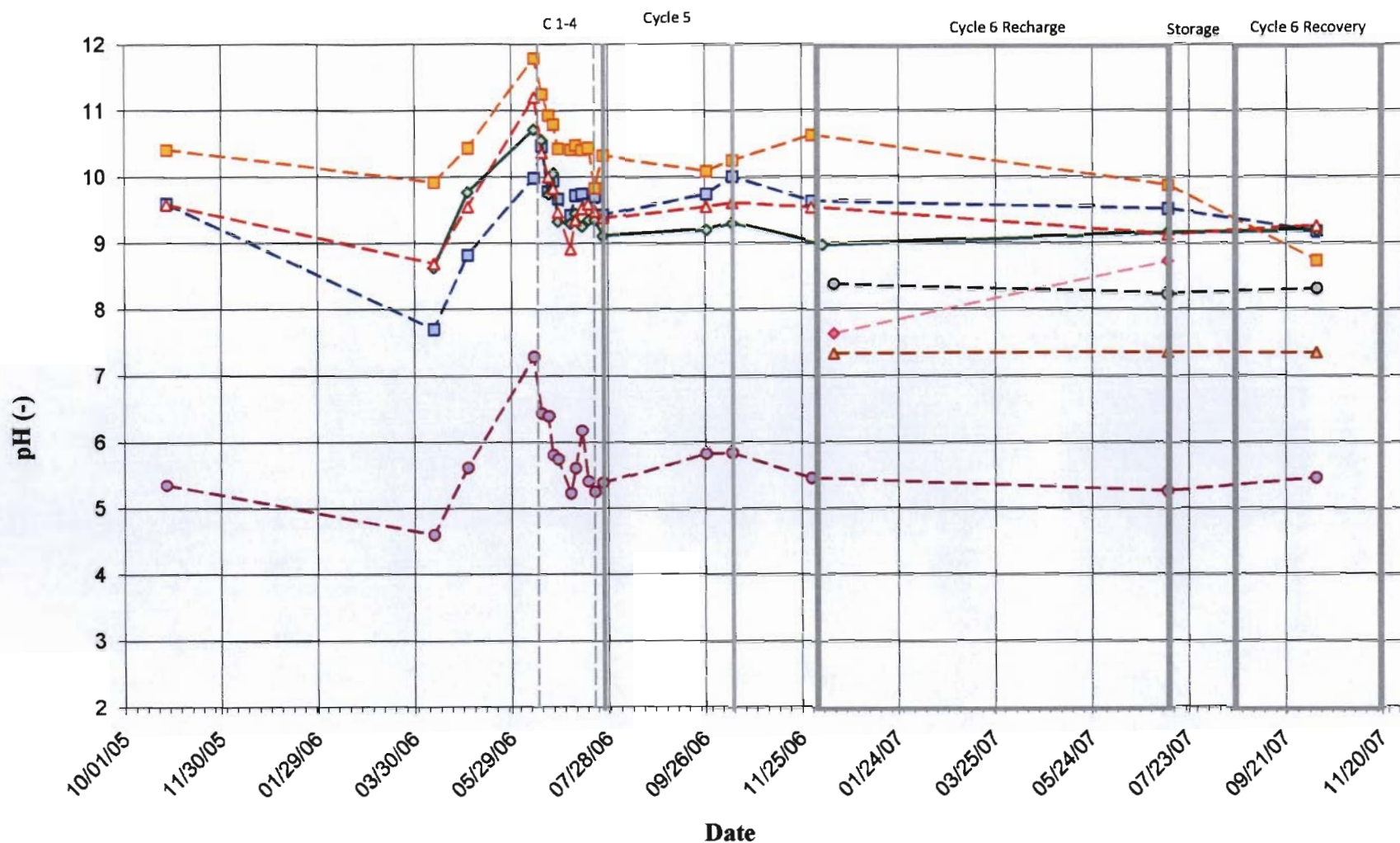
### Observation Well Groundwater Quality - Dissolved Oxygen

JOB NUMBER: 053-9747-200

DATE: February 11, 2008

FIGURE NO.: 2-37





Year 2 ASR Pilot Test Report  
City of Dallas, Oregon

—◆— Anstine  
—★— Fitcha  
—□— Birko  
—○— Jones  
—●— Kowalczyk  
—△— Lowe  
—●— Parker  
—□— Presser

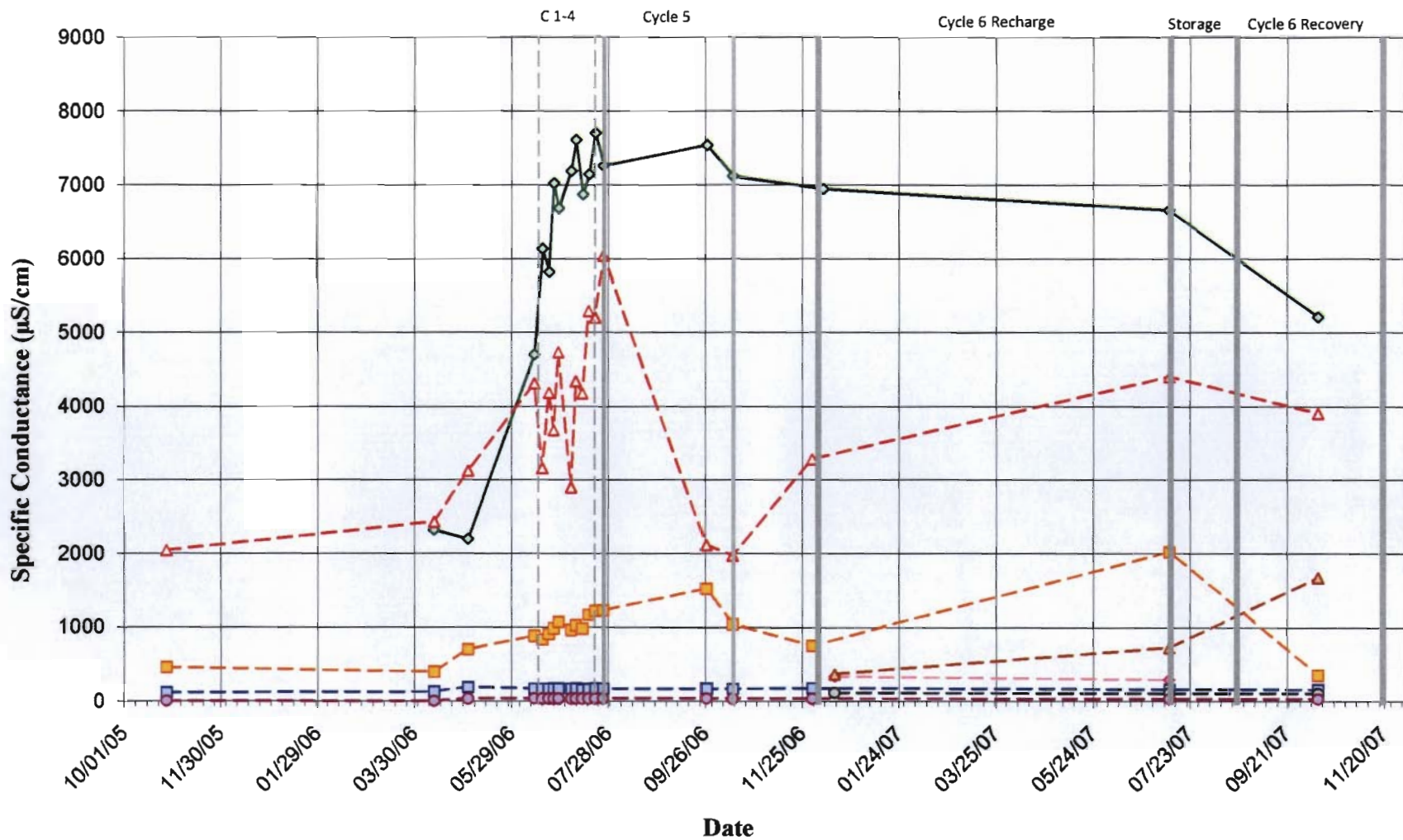
### Observation Well Groundwater Quality - pH

JOB NUMBER: 053-9747-200

DATE: February 11, 2008

FIGURE NO.: 2-38





Year 2 ASR Pilot Test Report  
City of Dallas, Oregon

- Anstine  
 - Fitcha  
 - Birko  
 - Jones  
 - Kowalczyk  
 - Lowe  
 - Parker  
 - Presser

### Observation Well Groundwater Quality - Specific Conductance

JOB NUMBER: 053-9747-200

DATE: February 11, 2008

FIGURE NO.: 2-39

Table 2-3  
Year-2 ASR Pilot Testing Water Quality  
City of Dallas ASR Project

			Native GW		Groundwater	SOURCE WATER			RECOVERED WATER		
			Pre-Pilot Testing		Pre-Recharge	Pre-Recharge	Cycle 6	Cycle 6			
Sample ID			99041	DASR0705	C6PREGW	C6PRESRC	C6RCGSRC	C6REC02%	C6ASR13.6%	C6REC26%	
Sample Date			9/9/2004	7/8/2005	12/4/2006	12/5/2006	7/11/2007	8/23/2007	9/13/2007	11/15/2007	
Lab ID					F304601	F305701	G215501	G242701	G257801	G316501	
Analyte	MCL/SMCL	RL									
REGULATED CONSTITUENTS											
SYNTHETIC ORGANIC COMPOUNDS											
2,4-D (mg/L)	0.07	0.0002	<0.0002	---	---	---	<0.0002	<0.0002	---	<0.0002	
2,4,5-TP (Silvex) (mg/L)	0.05	0.0004	<0.0004	---	---	---	<0.0004	<0.0004	---	<0.0004	
Di-(2-Ethylhexyl) adipate (mg/L)	0.4	0.001	<0.001	---	---	---	<0.001	<0.001	---	<0.001	
Alachlor (Lasso) (mg/L)	0.002	0.0004	<0.0004	---	---	---	<0.0004	<0.0004	---	<0.0004	
Atrazine (mg/L)	0.003	0.0002	<0.0002	---	---	---	<0.0002	<0.0002	---	<0.0002	
Benzo(a)pyrene (mg/L)	0.0002	0.00004	<0.00004	---	---	---	<0.00004	<0.00004	---	<0.00004	
BHC-gamma (Lindane) (mg/L)	0.0002	0.00002	<0.00002	---	---	---	<0.00002	<0.00002	---	<0.00002	
Carbofuran (mg/L)	0.04	0.001	<0.001	---	---	---	<0.001	<0.001	---	<0.001	
Chlordane (mg/L)	0.002	0.0004	<0.0004	---	---	---	<0.0004	<0.0004	---	<0.0004	
Dalapon (mg/L)	0.2	0.002	<0.002	---	---	---	<0.002	<0.002	---	<0.002	
Dibromochloropropane (DBCP) (mg/L)	0.0002	0.00002	<0.00002	---	---	---	<0.00002	<0.00002	---	<0.00002	
Dinoseb (mg/L)	0.007	0.0004	<0.0004	---	---	---	<0.0004	<0.0004	---	<0.0004	
Diquat (mg/L)	0.02	0.0004	<0.0004	---	---	---	<0.0004	<0.0004	---	<0.0004	
Endothall (mg/L)	0.1	0.01	<0.01	---	---	---	<0.01	<0.01	---	<0.01	
Endrin (mg/L)	0.002	0.00002	<0.00002	---	---	---	<0.00002	<0.00002	---	<0.00002	
Ethylene dibromide (EDB) (mg/L)	0.00005	0.00001	<0.00001	---	---	---	<0.00001	<0.00001	---	<0.00001	
Glyphosate (mg/L)	0.7	0.01	<0.01	---	---	---	<0.01	<0.01	---	<0.01	
Heptachlor epoxide (mg/L)	0.0002	0.00002	<0.00002	---	---	---	<0.00002	<0.00002	---	<0.00002	
Heptachlor (mg/L)	0.0004	0.00004	<0.00004	---	---	---	<0.00004	<0.00004	---	<0.00004	
Hexachlorobenzene (mg/L)	0.001	0.0001	<0.0001	---	---	---	<0.0001	<0.0001	---	<0.0001	
Hexachlorocyclopentadiene (mg/L)	0.05	0.0002	<0.0002	---	---	---	<0.0002	<0.0002	---	<0.0002	
Methoxychlor (mg/L)	0.04	0.0002	<0.0002	---	---	---	<0.0002	<0.0002	---	<0.0002	
Pentachlorophenol (mg/L)	0.001	0.00008	<0.00008	---	---	---	<0.00008	<0.00008	---	<0.00008	
Di-(2-Ethylhexyl) phthalates (mg/L)	0.006	0.0013	<0.0013	---	---	---	<0.0013	<0.0013	---	<0.0013	
Picloram (mg/L)	0.5	0.0002	<0.0002	---	---	---	<0.0002	<0.0002	---	<0.0002	
Polychlorinated Biphenyls - PCBs (mg/L)	0.0005	0.0002	<0.0002	---	---	---	<0.0002	<0.0002	---	<0.0002	
Simazine (mg/L)	0.004	0.0001	<0.0001	---	---	---	<0.0001	<0.0001	---	<0.0001	
Toxaphene (mg/L)	0.003	0.001	<0.001	---	---	---	<0.001	<0.001	---	<0.001	
Vydate (Oxamyl) (mg/L)	0.2	0.002	<0.002	---	---	---	<0.002	<0.002	---	<0.002	
VOLATILE ORGANIC COMPOUNDS											
1,1-Dichloroethene (µg/L)	7	0.5	<0.5	---	---	---	<0.5	<0.5	---	<0.5	
1,1,1-Trichloroethane (µg/L)	200	0.5	<0.5	---	---	---	<0.5	<0.5	---	<0.5	
1,1,2-Trichloroethane (µg/L)	5	0.5	<0.5	---	---	---	<0.5	<0.5	---	<0.5	
1,2-Dichloroethane (µg/L)	5	0.5	<0.5	---	---	---	<0.5	<0.5	---	<0.5	
1,2-Dichloropropane (µg/L)	5	0.5	<0.5	---	---	---	<0.5	<0.5	---	<0.5	
1,2,4-Trichlorobenzene (µg/L)	70	0.5	<0.5	---	---	---	<0.5	<0.5	---	<0.5	
1,2-Dichlorobenzene (µg/L)	600	0.5	<0.5	---	---	---	<0.5	<0.5	---	<0.5	
1,4-Dichlorobenzene (µg/L)	75	0.5	<0.5	---	---	---	<0.5	<0.5	---	<0.5	
Benzene (µg/L)	5	0.5	<0.5	---	---	---	<0.5	<0.5	---	<0.5	
Carbon tetrachloride (µg/L)	5	0.5	<0.5	---	---	---	<0.5	<0.5	---	<0.5	
Chlorobenzene (µg/L)	100	0.5	<0.5	---	---	---	<0.5	<0.5	---	<0.5	
cis-1,2-Dichloroethylene (µg/L)	70	0.5	<0.5	---	---	---	<0.5	<0.5	---	<0.5	
Ethylbenzene (µg/L)	700	0.5	<0.5	---	---	---	<0.5	<0.5	---	<0.5	
Methylene chloride (µg/L)	5	0.5	<0.5	---	---	---	<0.5	<0.5	---	<0.5	
Styrene (µg/L)	100	0.5	<0.5	---	---	---	<0.5	<0.5	---	<0.5	
Tetrachloroethylene (µg/L)	5	0.5	<0.5	---	---	---	<0.5	<0.5	---	<0.5	
Toluene (µg/L)	1000	0.5	<0.5	---	---	---	<0.5	<0.5	---	<0.5	
trans-1,2-Dichloroethylene (µg/L)	100	0.5	<0.5	---	---	---	<0.5	<0.5	---	<0.5	
Trichloroethylene (µg/L)	5	0.5	<0.5	---	---	---	<0.5	<0.5	---	<0.5	
Vinyl chloride (µg/L)	2	0.5	<0.5	---	---	---	<0.5	<0.5	---	<0.5	
m,p-Xylenes (µg/L)	**	0.5	<0.5	---	---	---	<0.5	<0.5	---	<0.6	
o-Xylene (µg/L)	**	0.5	<0.5	---	---	---	<0.5	<0.5	---	<0.5	
DISINFECTION BY-PRODUCTS (DBPs) & RESIDUAL DISINFECTANTS											
Chloroform (mg/L)		0.001	---	---	---	---	0.0198	0.0229	---	0.0115	
Bromodichloromethane (mg/L)		0.001	---	---	---	---	0.0049	<0.001	---	<0.001	
Dibromochloromethane (mg/L)		0.001	---	---	---	---	<0.001	<0.001	---	<0.001	
Bromoform (mg/L)		0.001	---	---	---	---	<0.001	<0.001	---	<0.001	
Total Trihalomethanes (mg/L)	0.08	0.001	---	---	---	---	0.0247	0.0229	---	0.0115	
Monochloroacetic Acid (mg/L)		0.001	---	---	---	---	<0.001	<0.001	---	<0.001	
Dichloroacetic Acid (mg/L)		0.001	---	---	---	---	0.0068	0.0013	---	0.0051	
Trichloroacetic Acid (mg/L)		0.001	---	---	---	---	0.012	0.0062	---	<0.001	
Monobromoacetic Acid (mg/L)		0.001	---	---	---	---	<0.001	<0.001	---	<0.001	
Dibromoacetic Acid (mg/L)		0.001	---	---	---	---	<0.001	<0.001	---	<0.001	
Total Haloacetic Acids (HAA-5) (mg/L)	0.06	0.001	---	---	---	---	0.0188	0.0075	---	0.0051	
Chlorine (mg/L as Cl2)	4	0.01	---	---	---	---	1.1	0.01	---	<0.01	
MICROBIAL											
Total Coliforms	<1/100 ml		---	---	---	---	ND	ND	---	ND	
Fecal Coliforms	presence		---	---	---	---	ND	ND	---	ND	
E. Coli	presence		---	---	---	---	ND	ND	---	ND	
RADIOLOGICAL											
Gross Alpha (pCi/L)	15	1	<1	---	---	---	<1	<1	---	1.7	
Gross Beta (pCi/L)	50	2	<2	---	---	---	<2	<2	---	<2	
Combined Radium 226/228 (pCi/L)	5		ND	---	---	---	---	---	---	---	
Combined Uranium (pCi/L)	30		ND	---	---	---	---	---	---	---	
Strontium-90 (pCi/L)	8		ND	---	---	---	---	---	---	---	
Tritium (pCi/L)			ND	---	---	---	---	---	---	---	
Iodine-131			ND	---	---	---	---	---	---	---	
MISCELLANEOUS											
Asbestos (MFL)	1.5		ND	---	---	---	---	---	---	---	
Total Organic Carbon (mg/L)		0.5	<0.5	---	1.1	0.72	0.6	<0.5	<0.5	<0.5	

Table 2-3  
Year-2 ASR Pilot Testing Water Quality  
City of Dallas ASR Project

			Native GW		Groundwater	SOURCE WATER		RECOVERED WATER		
			Pre-Pilot Testing		Pre-Recharge	Pre-Recharge	Cycle 6	Cycle 6		
Sample ID			99041	DASR0705	C6PREGW	C6PRESRC	C6RCGSRC	C6REC02%	C6ASR13.6%	C6REC26%
Sample Date			9/9/2004	7/8/2005	12/4/2006	12/5/2006	7/11/2007	8/23/2007	9/13/2007	11/15/2007
Lab ID					F304601	F305701	G215501	G242701	G257801	G316501
Analyte	MCL/SMCL	RL								
UNREGULATED CONSTITUENTS										
SYNTHETIC ORGANIC CHEMICALS (SOCs)										
Aldicarb (mg/L)		0.002	<0.002	---	---	---	<0.002	<0.002	---	<0.002
Aldicarb sulfoxide (mg/L)		0.003	<0.003	---	---	---	<0.003	<0.003	---	<0.003
Aldicarb sulfone (mg/L)		0.001	<0.001	---	---	---	<0.001	<0.001	---	<0.001
EXTENDED INORGANICS										
MBAS (mg/L as LAS)		0.02	<0.02	---	---	---	<0.02	<0.02	---	<0.02
Color (color units)	15		ND	---	---	---	0	0	---	0
Odor (Threshold Odor Number)	3		ND	---	---	---	2.4	0	---	0
Total Alkalinity (as CaCO3) (mg/L)		5	12.4	---	26	24	28	26	14	12
Corrosivity (Langelier saturation index)			---	---	1.16	-2.36	-1.59	-0.05	-0.02	-0.18
Chloride (mg/L)	250	0.1	2560	---	250	4.2	6.6	164	1240	1650
Hardness (mg CaCO3/L)		3.3	2000	---	230	24.2	30.9	178	1230	1630
Calcium (mg/L)		0.5	793	---	85.4	6.86	8.84	63.4	484	653
Aluminum (mg/L)	0.05 – 0.2	0.1	<0.1	---	<0.2	<0.2	<0.1	<0.1	<0.1	<0.1
Copper (mg/L)	1	0.01	0.0132	---	---	---	<0.01	<0.01	---	0.0117
Iron (Total) (mg/L)	0.3	0.1	---	0.798	3.69	<0.1	<0.1	<0.1	<0.1	<0.1
Iron (Dissolved) (mg/L)		0.1	---	0.013	0.194	<0.1	<0.1	<0.1	<0.1	0.458
Manganese (Total) (mg/L)	0.05	0.01	0.0148	---	0.11	<0.01	<0.01	<0.01	0.0156	0.0181
Manganese (Dissolved) (mg/L)		0.01	0.0113	---	0.0459	<0.01	<0.01	<0.01	0.0156	0.0774
Silver (mg/L)	0.1	0.01	<0.01	---	---	---	<0.01	<0.01	---	<0.01
Zinc (mg/L)	5	0.02	<0.02	---	---	---	<0.02	<0.02	---	<0.02
Total Dissolved Solids (mg/L)	500	5	4190	---	547	60	34	294	2530	2850
Total Suspended Solids (mg/L)		2	<2	---	13.2	<2	<2	<2	<2	<2
Bicarbonate (as CaCO3) (mg/L)		5	<5	---	22	24	28	26	14	12
Carbonate (as CaCO3) (mg/L)		5	<5	---	<5	<5	<5	<5	<5	<5
Ammonia (mg/L)		0.1	0.39	---	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1*
Total Phosphate (as P) (mg/L)		0.05	<0.05	---	<0.05	0.13	<0.05	<0.05	<0.05	<0.05
Potassium (mg/L)		0.2	1.15	---	1.25	0.222	0.355	0.615	2.07	2.79
Magnesium (mg/L)		0.5	5.75	---	4.15	1.71	2.14	4.72	5.48	5.86
INORGANIC CHEMICALS (IOCs)										
Turbidity (NTUs)	1	0.1	---	---	11.7	0.23	0.3	0.21	0.48	0.29
Antimony (mg/L)	0.006	0.0005	<0.0005	---	---	---	<0.0005	<0.0005	---	<0.0015
Arsenic (mg/L)	0.01	0.001	<0.001	---	<0.001	<0.001	<0.001	<0.001	<0.001	<0.003
Barium (mg/L)	2	0.025	<0.025	---	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025
Beryllium (mg/L)	0.004	0.004	<0.004	---	---	---	<0.004	<0.004	---	<0.004
Cadmium (mg/L)	0.005	0.005	<0.005	---	---	---	<0.005	<0.005	---	<0.005
Chromium (mg/L)	0.1	0.01	<0.01	---	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Lead (mg/L)	0.015	0.005	<0.005	---	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Mercury (mg/L)	0.002	0.0001	<0.0001	---	---	---	<0.0001	<0.0001	---	<0.0001
Nickel (mg/L)	0.1	0.02	<0.02	---	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Selenium (mg/L)	0.05	0.001	<0.001	---	---	---	<0.001	<0.001	---	0.0035
Sodium (mg/L)		1	321	---	84.5	4.33	11.8	36.7	176	256
Thallium (mg/L)	0.002	0.0005	<0.0005	---	---	---	<0.0005	<0.0005	---	<0.0015
Fluoride (mg/L)	4	0.1	0.44	---	0.17	0.64	0.42	0.13	<0.1	0.23
Nitrate (as N) (mg/L)	10	0.1	<0.1	---	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Nitrite (as N) (mg/L)	1	0.1	<0.1	---	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Nitrate+Nitrite (as N) (mg/L)	10	0.1	<0.1	---	---	---	<0.1	<0.1	---	<0.1
Sulfate (mg/L)	250	0.1	12.2	---	4.7	1.6	3.1	4.8	12.6	11.1
Cyanide (mg/L)	0.2	0.005	<0.005	---	---	---	<0.005	<0.005	---	<0.005
Silica (mg/L)		1.07	25.9	---	11.1	15.5	15.0	15.5	17.1	16.1
FIELD PARAMETERS										
pH (pH units)	6.5-8.5		8.47	8.8†	9.72	7.33	7.01	8.40	8.21	8.12
Dissolved Oxygen (mg/L)			---	---	1.53	12.3	7.7	0.1	0.1	0.8
Oxidation-Reduction Potential (millivolts)			-176.3	---	-206.9	735.3	752.2	-215.4	-144.6	-178.8
Temperature (C°)			15.4	15.7	14.47	6.56	19.39	13.86	13.06	12.85
Specific Conductance (µS/cm)			6490	---	815	66	84	626	3948	5124
NOTES:										
RL: Analytical Reporting Limit			< : Not Detected at the Reporting Limit, if value is greater than MRL, sample was diluted before analysis							
MCL: Maximum Contaminant Level			ND : Not Detected, no Reporting Limit indicated							
mg/L : milligrams per liter			--- : not analyzed or not measured							
µg/L : micrograms per liter			* : Measurement taken outside of holding time							
µS/cm : micro-Siemens per centimeter			** : 10,000 µg/L as total of m, p, and o isomers							
pC/L : picocuries per liter			# : sensor malfunctioning - no data							
MFL: millions of fibers per liter										

**Table 2-4**  
**Year-2 ASR Pilot Testing - Supplemental Arsenic Testing**  
City of Dallas ASR Project

			RECOVERED WATER - Arsenic Testing											
			Cycle 6											
Sample ID			C6AS00%	C6AS01%	C6ASR2.1%	C6ASR2.3%	C6ASR3.6%	C6ASR4.9%	C6ASR6.7%	C6ASR8.1%	C6ASR9.5%	C6ASR11.6%	C6ASR12.9%	C6ASR14.5%
Sample Date			8/21/2007	8/22/2007	8/24/2007	8/27/2007	8/29/2007	8/31/2007	9/3/2007	9/5/2007	9/7/2007	9/10/2007	9/12/2007	9/17/2007
Lab ID			G242601	G242602	G249701	G249702	G249703	G249704	G249705	G264101	G264102	G264103	G264104	G264105
Analyte	MCL	RL												
UNREGULATED CONSTITUENTS														
EXTENDED INORGANICS														
Total Alkalinity (as CaCO3) (mg/L)	5		42	34	25	26	22	21	19	19	18	14	15	15
Iron (Total) (mg/L)	0.3	0.1	0.114	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.154	0.163	<0.1
INORGANIC CHEMICALS (IOCs)														
Arsenic (mg/L)	0.01	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Sulfate (mg/L)	250	0.1	5.6	4.3	5.5	4.6	6.4	7.1	9.1	10.5	11.4	12.7	13.4	8.9
FIELD PARAMETERS														
pH (pH units)	6.5-8.5		8.19	8.40	8.35	8.43	8.28	8.32	8.24	8.21	8.19	8.19	8.17	8.26
Dissolved Oxygen (mg/L)			0.92	0.13	0.05	0.28	0.23	0.21	0.13	0.13	0.06	0.11	0.14	0.26
Oxidation-Reduction Potential (millivolts)			-118.7	-165	-214	-105.2	-203	-212	-197	-187	-183	-178.5	-176.9	-204.4
Temperature (C°)			14.79	14.16	13.72	13.9	13.55	13.54	13.26	13.26	13.18	13.17	13.18	13.13
Specific Conductance (µmho/cm)			124	183	824	459	1280	1531	2300	2560	2915	3289	3810	2022
NOTES:														
RL: Analytical Reporting Limit			ND : Not Detected at the Reporting Limit											
MCL: Maximum Contaminant Level			-- : not analyzed											
mg/L : milligrams per liter			* : Measurement taken outside of holding time											
µg/L : micrograms per liter			** : 10,000 µg/L as total of m, p, and o isomers											
µS/cm : micro-Siemens per centimeter			‡: Lab error suspected with the C2REC45% chloride value.											
pCi/L : picocuries per liter			#: sensor malfunctioning - no data											
MFL: millions of fibers per liter														