Santa Ana River Groundwater Recharge Optimization Study

Final Report

San Bernardino Valley Water Conservation District and San Bernardino Valley Municipal Water District

June 2009

MWH
BUILDING A BETTER WORLD

Prepared in association with GEI Consultants

Santa Ana River Groundwater Recharge Optimization Study

Final Report

June 2009

Project Number 1343019

Prepared for:

San Bernardino Valley Water Conservation District
and
San Bernardino Valley Municipal Water District

Prepared by:

MWH
618 Michillinda Avenue, Suite 200
Arcadia, CA 91007

Table of Contents

Section Name **Page Number**

List of Figures

Appendices

Section 1
Introduction

The San Bernardino Valley Water Conservation District (Conservation District) and the San Bernardino Valley Municipal Water District (Municipal District), "Districts," retained MWH Americas, Inc., in association with GEI Consultants (collectively referred to as the MWH team) to evaluate the capacity of the existing Conservation District facilities along the Santa Ana River to capture and store the proposed spreading objectives identified in the Upper Santa Ana River Watershed Integrated Regional Water Management Plan (IRWMP). The IRWMP established target amounts for groundwater recharge in the project area. The maximum yearly volume identified under "Scenario A" of the IRWMP is 80,000 acre-feet. The maximum instantaneous flow rate, as defined by the Districts based on the Environmental Impact Report for the Santa Ana River Water Right Applications for Supplemental Water Supply (SBVMWD, 2007), is 500 cubic feet per second (cfs). Although it is understood that this maximum flow rate is anticipated for short periods only, it is desirable for the Districts to have the capability to accommodate this flow on a temporary basis to maximize storage of surface water when it is available.

The goals of this project are to evaluate the ability of the existing facilities to meet the recharge objective of 500 cfs, recommend and provide conceptual designs for improvements to meet the objective of 500 cfs (if needed), and provide recommendations on the operations and maintenance activities that will maximize recharge capacity.

1.1 PROJECT BACKGROUND

The Conservation District owns and operates surface water diversion and conveyance facilities and groundwater recharge spreading facilities adjacent to the Santa Ana River (SAR) along Greenspot Road, south and west of the Seven Oaks Dam in Mentone, San Bernardino County, California (**Figure 1-1**). The Conservation District was formed in 1932 to obtain water for conservation purposes, essentially replacing the Water Conservation Association formed in 1910 (SBVWCD, 1994). The majority of the Conservation District facilities have been in place since the 1930s for the purpose of diverting and recharging water from the Santa Ana River.

A relatively recent development in recharge operations is the construction of the Seven Oaks Dam, which is an earth and rock fill dam located approximately 1 mile upstream of the Conservation District's diversion. Construction of the dam by the United States Army Corps of Engineers (USACE), began in August 1994 and was completed in November 1999. Material was excavated for the dam from an approximately 240 acre area (herein called the "Borrow Pit") that formerly contained a series of recharge ditches and ponds operated by the Conservation District. Subsequent to the completion of the dam, three infiltration ponds were constructed at the east end of the Borrow Pit (labeled Ponds 1 through 3 on Figure 1-1).

Key to Existing Features

● Spreading Pond Number

▨ Spreading Ponds

☐ Water Conservation Facilities Evaluation Phase Areas

Document: SBVWCD_LocationMap.mxd

Date: April 24, 2009

Location Map

Figure 1-1

Santa Ana River Groundwater Recharge Optimization Study

The remaining recharge basins (Ponds 9 through 17) and the Borrow Pit are located south and west of Greenspot Road, and north of the Santa Ana River. Flow from the Santa Ana River below the Seven Oaks Dam is diverted at a concrete structure (Intake Structure) behind a small dam-like impoundment called the Cuttle Weir. From the Intake Structure, water flows through various culverts, tunnels and other structures where it can be diverted to various ponds including those in the Borrow Pit.

The Santa Ana River Groundwater Recharge Optimization Study consists of three primary tasks:

Task 1: Evaluate Existing Groundwater Recharge Spreading Facilities and Operations
Task 2: Establish Spreading Objectives
Task 3: Perform Feasibility Analysis and Prepare Conceptual Design to Meet Spreading Objectives

In April and May 2008, the MWH team reviewed pertinent existing information and prepared a workplan for collection of additional field data and reporting the results of the field data. This information was contained in Technical Memorandum 1 (TM-1, MWH, 2008). TM-1 is included to this final report as **Appendix A**. The field work was designed to identify factors which may limit the volume of water that could be recharged, including:

- Inadequate capacity of diversion or conveyance facilities
- Compaction of shallow soils in the Borrow Pit due to heavy equipment use during construction of the pit
- Presence of fine-grained material that "clog" the surface of the Borrow Pit
- Shallow groundwater which mounds to the surface
- Presence of horizontal or vertical barriers to groundwater flow, such as clay layers or faults

The field work was also designed to gather additional data on shallow soil and aquifer conditions and resolve data gaps regarding well locations and surface elevations at the site.

Results of the field investigation is provided in Technical Memorandum 2 (TM-2) which describes factors which limit recharge, and documents the recharge capacity of the existing facilities. TM-2 is summarized in the following section of this introduction, and is included in its entirety as **Appendix B**.

This final report provides recommendations for improvement of existing facilities, conceptual design of new facilities, and maintenance and operational methods to increase recharge capacity.

1.2 SUMMARY OF FIELD TESTING AND ANALYSIS

Field testing and analysis described in TM-2 was conducted for the purpose of quantification of the capacity of the existing diversion, conveyance and percolation facilities. This was accomplished by review of pertinent historical information and reports, preparation of a workplan for collection of field data, collection of field data, and analysis of the existing and new field data. TM-2 (**Appendix B**) presents the methods and results of collection of field data, analysis of the data, conclusions relative to the capacity of existing facilities. The following is a brief summary of the testing activities and the conclusions of that work.

The field work was conducted during June through December, 2008 and consisted of:

- Field flow testing of the diversion and conveyance facilities
- Survey of diversion works and conveyance (measurements of dimensions and slopes)
- Soil investigation consisting of:
    - Excavation of 15 trenches.
    - Collection of 72 surface soil samples.
    - Drilling, sampling, and lithologic logging of 7 borings to a maximum depth of 157 feet.
    - Laboratory analysis of 75 samples for grain size analysis, and 16 of these samples for analysis of hydraulic conductivity.
- Construction of 6 monitoring wells and installation of automated monitoring equipment
- Several types of percolation tests at existing recharge ponds
- Physical surveys of existing well locations and elevations

Significant conclusions from the field testing and analysis include:

- The sedimentary materials underlying the recharge facilities form an unconfined aquifer consisting of permeable, coarse, sandy gravel and/or gravelly sand. No significant, laterally-continuous strata of low permeability were found that would prevent the downward percolation of recharge water.

- Some existing ponds have a thin layer of silt and/or clay derived from the introduction of turbid recharge water which limits percolation capacity.

- Faulting associated with the San Andreas Fault Zone has created a groundwater barrier which limits recharge capacity on the eastern portion of the site causing shallow groundwater that surfaces or “daylights” east (up-gradient) of this barrier.

- During high runoff periods such as those that occurred in 1980, 1993, 1998 and 2005, the regional area in the vicinity of the recharge facilities may become saturated with shallow groundwater, limiting recharge in all of the facilities. However, these events have been temporary, and may occur at a different frequency depending on the operation of the Seven Oaks Dam. This finding is consistent with regional groundwater modeling studies, which predict saturated conditions for very short durations during wet years (SAIC, 2007).

- The yearly recharge goal of 80,000 acre-feet identified in the IRWMP is possible with the construction of new infiltration, diversion, and conveyance facilities, assuming ambient groundwater levels west of the groundwater barrier are approximately 200 feet below ground level to accept this water.

- Groundwater mounding (whereby the water table rises to the ground surface) may to occur even under relatively dry conditions if a percolation rate of 500 cfs is sustained for more that approximately 30 days. (**Appendix B**).

- Downstream of the Intake Structure and Cuttle Weir, earthen canals limit the capacity of the conveyance facilities to approximately 300 cfs.

- The recharge capacity of the existing percolation ponds at the SAR recharge facility west of the groundwater barrier is approximately 195 cfs.

Existing spreading grounds operation and maintenance procedures were evaluated in comparison to “best management practices” of other agencies in California and the southwestern United States. This evaluation concluded that the Conservation District is generally following good operations and maintenance practices. However, a lack of data collection limits the ability to quantify spreading grounds performance. Recommendations are presented in Section 3 regarding improved operations and monitoring. In particular, care should be taken to avoid recharging water that has high levels of suspended solids and turbidity.

1.3 CEQA ISSUES RELATED TO THE CONCEPTUAL DESIGN

The expansion of additional basins and other facilities within the area known as Phases 1 through 3 (Figure 2-1) was analyzed as part of the programmatic Final Environmental Impact Report for the Upper Santa Ana River Wash Land Management and Habitat Conservation Plan (Wash Plan) project (SBVWCD, 2008), which evaluated the potential biological impacts from percolation facilities described in this report. Biological impacts were assessed by projecting the same ratio of ground disturbance for future facilities as exist presently in the Conservation District’s spreading area. The current ratio of wetted and maintained area is approximately 31 percent of the overall land area. This wetted area ratio has been used in the conceptual design of additional facilities in accordance with the Wash Plan EIR.

Other impacts associated with the conceptual designs described in this report, include the areas of noise, air quality, hydrology, and traffic. The Conservation District will need to undertake tiered additional environmental review of future construction based on the project description contained in Section 2 of this report. In particular, the proposed modification of earthen canals described in this report may require additional analysis.

The conceptual design of the modification to the recharge facilities to accommodate 500 cfs described in this report constitutes a detailed enough project description for CEQA purposes. The MWH team recommends that the Districts have a legal review and finding for the Districts’ adoption. This legal review should provide a statement indicating the extent to which project level environmental analysis is required in consideration of the work already completed programmatic Wash Environmental Impact Report (EIR).

1.4 FINAL REPORT ORGANIZATION

This final report provides conceptual design and operational recommendations to meet the IRWMP short-term maximum flow rate of 500 cfs and annual maximum volume of 80,000 acre-feet, and is organized as follows:

Section 1 introduces the project goals, presents background information, CEQA-related issues, and provides a summary of previous reports which are included in the final report as appendices.

Section 2 provides the recommendations and conceptual design of physical improvements to meet the project goals.

Section 3 provides the recommendations of operational maintenance and monitoring methods recommended to meet the recharge goal defined in the IRWMP.

Section 4 provides a list of the cited references.

Previous technical memoranda, Technical Memorandum-1 and Technical Memorandum-2, completed during the conduct of this work are included in Appendix A and B, respectively. Appendix C contains cost estimating details.

Section 2
Conceptual Design

This section describes the improvements and additional facilities recommended to achieve three different flow rates of 195 cfs, 300 cfs, and 500 cfs. These discreet flow rates were selected for analysis for the following reasons:

- The flow rate of 195 cfs was selected because it is the estimated infiltration capacity of existing recharge facilities.

- The flow rate of 300 cfs was considered because it is the practical maximum flow rate of many of the diversion and conveyance facilities, in particular the earthen canals which currently convey water to the recharge ponds.

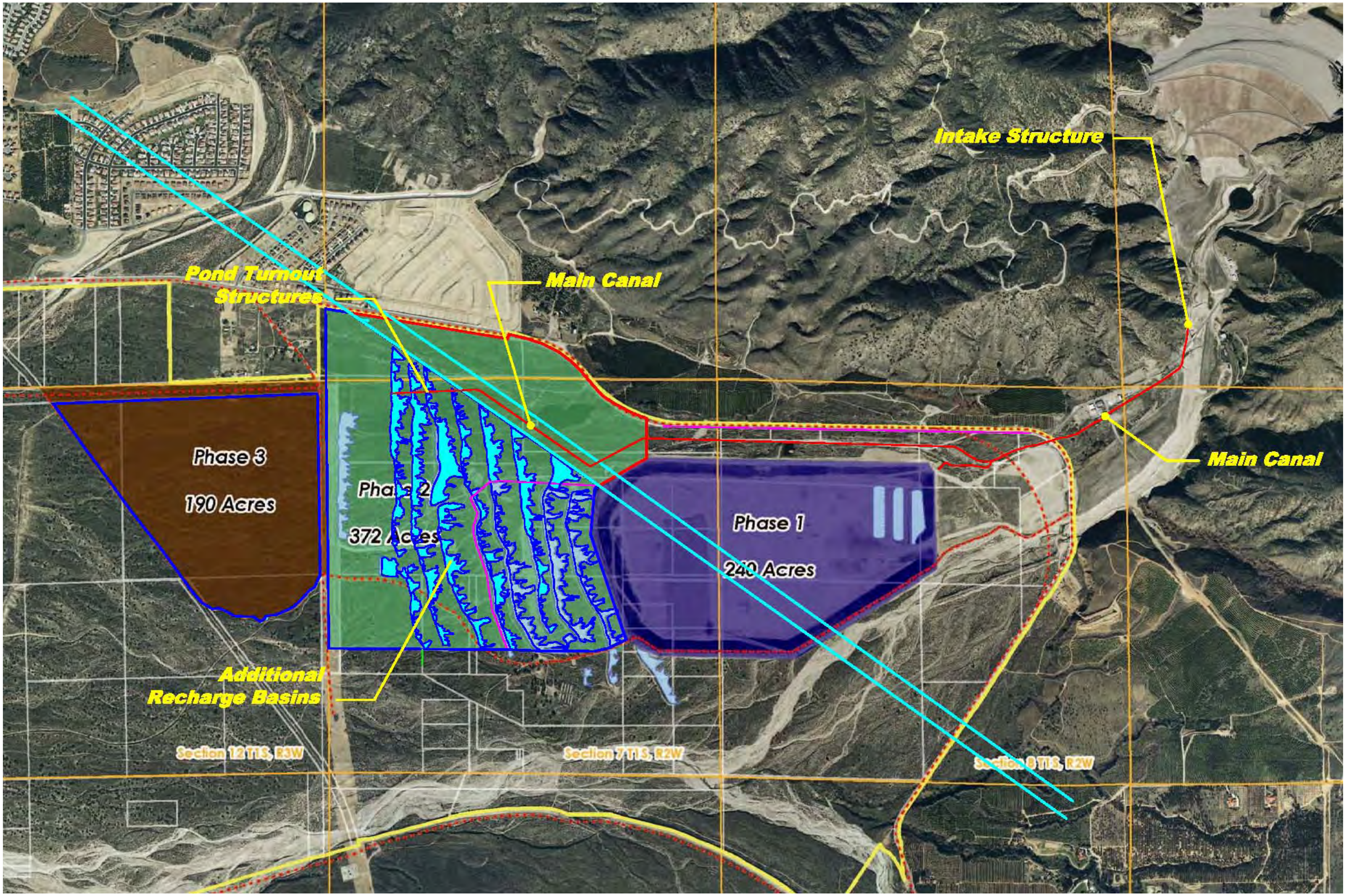
- A flow rate of 500 cfs was considered because it is the ultimate goal of the project.

Figure 2-1, Figure 2-2 and Figure 2-3 provide an overview of the locations of facilities for which modifications are recommended. New recharge ponds will not be located east of the vertical barrier identified as part of TM-2, but within areas identified as Phase 1 through 3. More detail on physical dimensions and estimated capacities of existing facilities are given in **Appendix B**.

2.1 CONVEYANCE OF 195 CFS

The existing recharge facilities consist of the Borrow Pit and recharge ponds (Ponds) 9 through 17 and D west of the Borrow Pit (Figure 1-1). Estimates of percolation rates at Ponds 9 through 17 and D were obtained using the percolation testing methods as described in **Appendix B**. From these tests, the total combined recharge rate of the Ponds is approximately 145 cfs. The additional capacity of the west end of the Borrow Pit (not including Ponds 1 through 3) is estimated by the Conservation District to be approximately 50 cfs. Therefore, the current recharge capacity of the Borrow Pit and ponds is estimated to be 195 cfs (**Appendix B**).

As described in **Appendix B**, the practical conveyance limitation for most of the diversion and conveyance facilities is approximately 300 cfs. Above this flow rate, high velocity and turbulent flow in unlined channel sections is observed. However, modifications to the conveyance system will not be required to convey 195 cfs to the Borrow Pit and existing recharge ponds.



SBV WATER CONSERVATION DISTRICT
OUR NAME IS OUR MISSION

Valley
SAN BERNARDINO MUNICIPAL WATER DISTRICT

- - - Trails
🟨 Wash Plan Boundary
🟧 TR Section

Phases

🟦 PHASE 1 - BORROW PIT
🟩 PHASE 2 - SECTION 7
🟫 PHASE 3 - SECTION 12

Document: FinalReport_Fig2-1.pub

Date: May 20, 2009

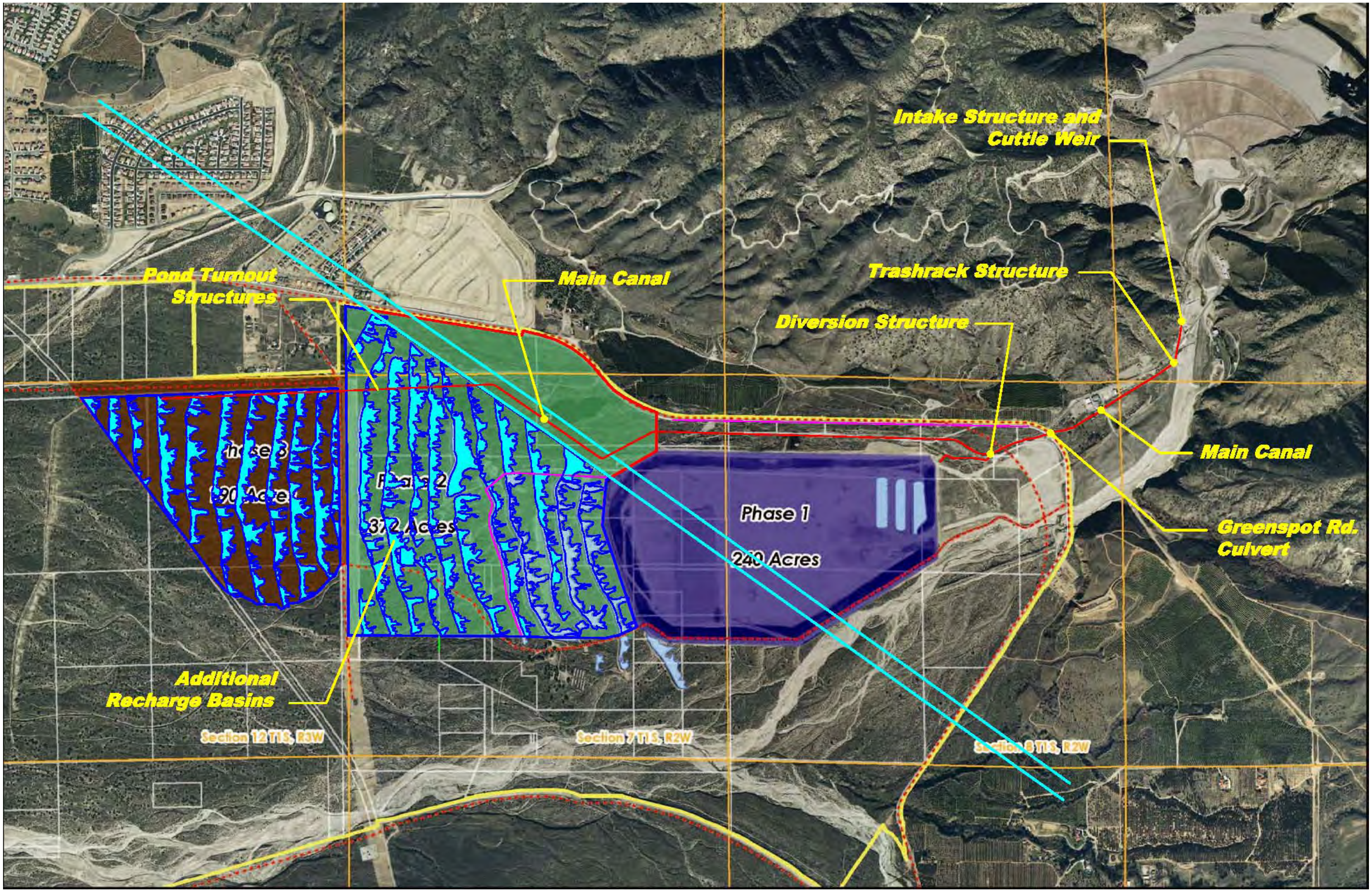
Proposed Water Facilities Phases
300 cfs

Figure 2-1

Santa Ana River Groundwater Recharge
Optimization Study

MWH

GEI Consultants



- Trails
- Wash Plan Boundary
- TR Section

Phases

- PHASE 1 - BORROW PIT
- PHASE 2 - SECTION 7
- PHASE 3 - SECTION 12

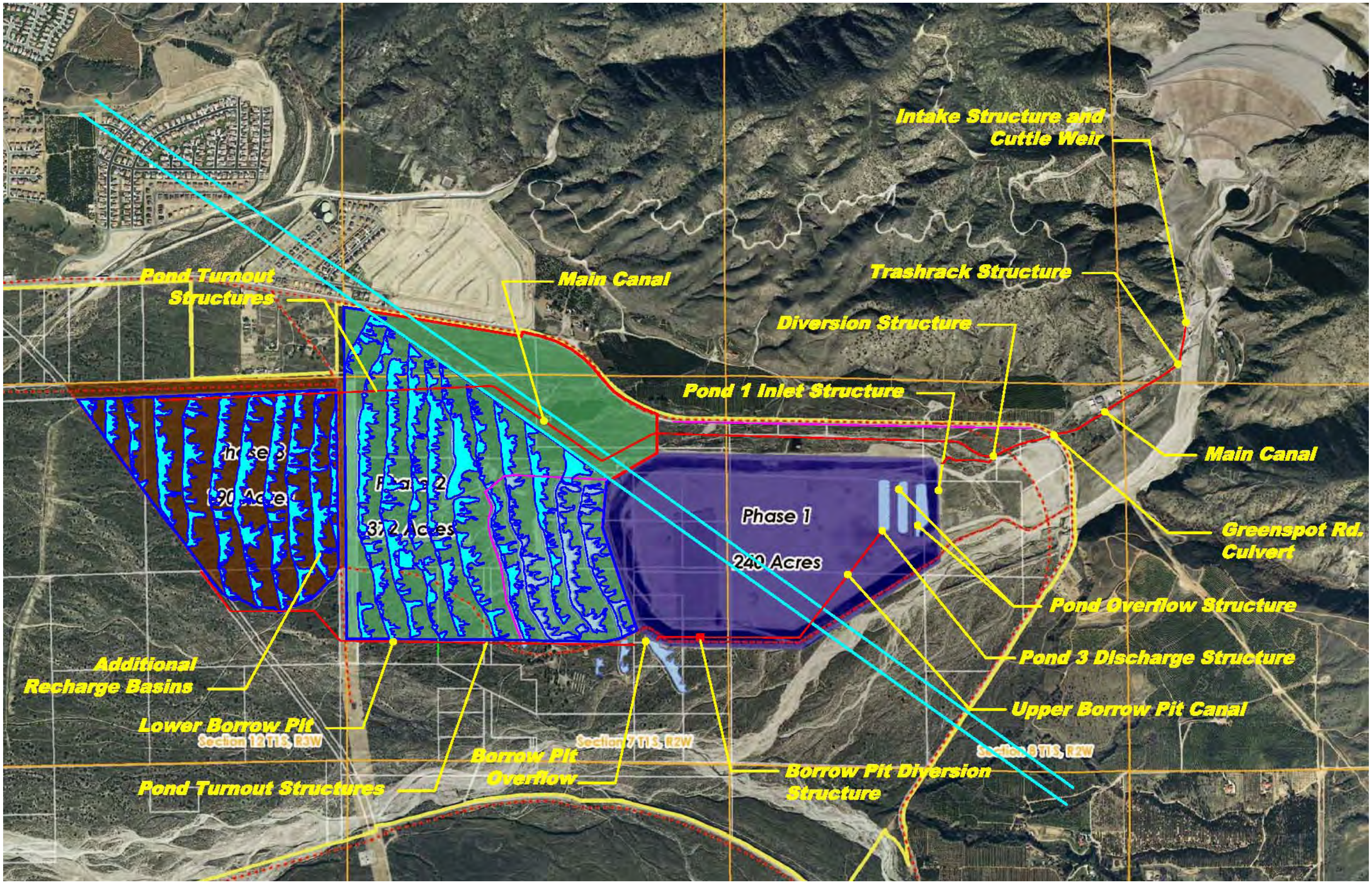
Document: FinalReport_Fig2-2.pub

Date: May 20, 2009

Proposed Water Facilities Phases
500 cfs

Figure 2-2

Santa Ana River Groundwater Recharge
Optimization Study



SBV WATER CONSERVATION DISTRICT
OUR NAME IS OUR MISSION

San Bernardino Valley Municipal Water District

- - - - Trails
▭ Wash Plan Boundary
▭ TR Section

Phases

■	PHASE 1 - BORROW PIT
■	PHASE 2 - SECTION 7
■	PHASE 3 - SECTION 12

Document: FinalReport_Fig2-3.pub

Date: May 20, 2009

Proposed Water Facilities Phases 500 cfs with Optional Facilities

Figure 2-3

Santa Ana River Groundwater Recharge
Optimization Study

MWH

GEI Consultants

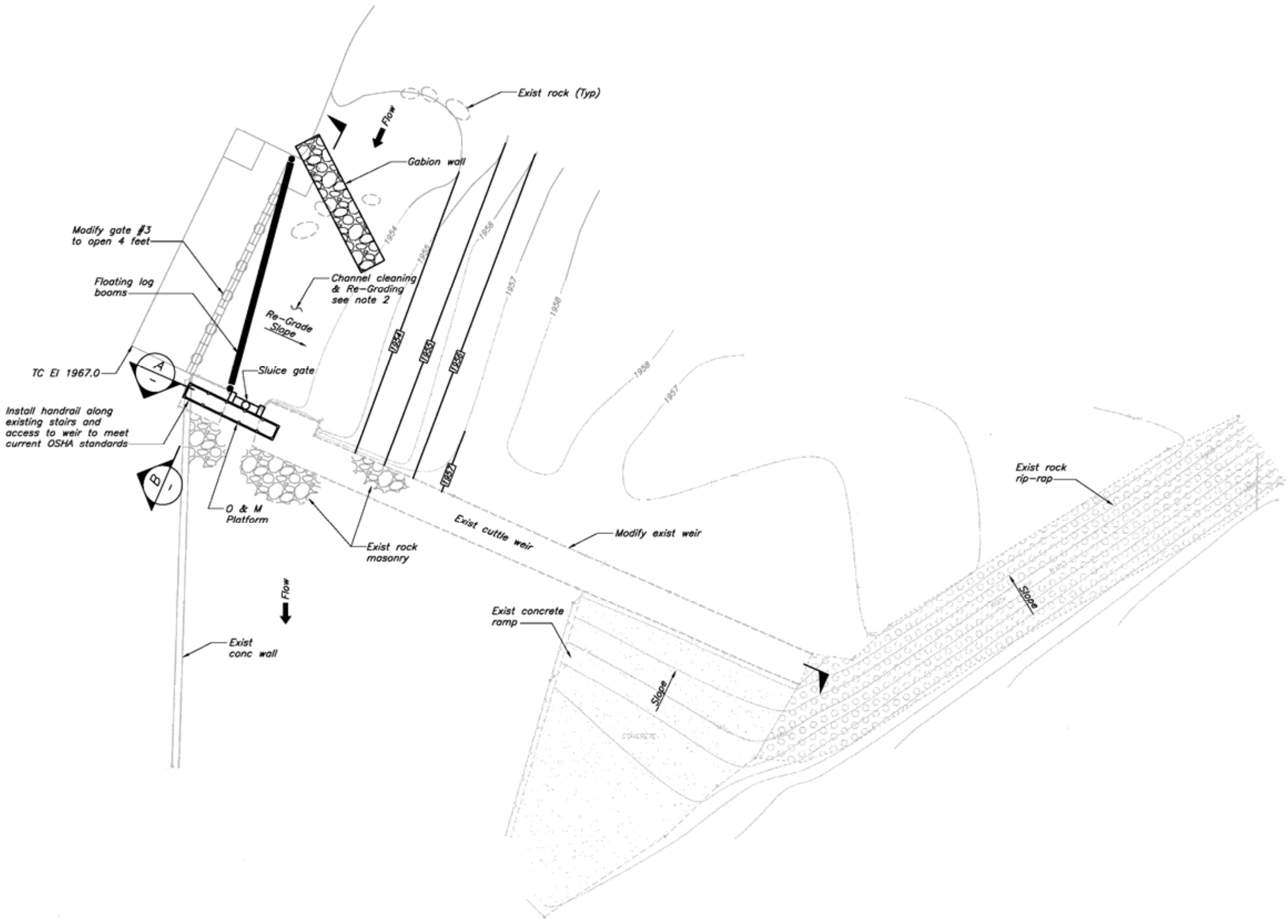
2.2 CONVEYANCE OF 300 CFS

A flow rate of 300 cfs is considered as part of the conceptual design based on the limitations of the existing earthen conveyance canal. At 300 cfs, the calculated canal velocities exceed the maximum recommended velocity for canals consisting of rocks and cobbles (**Appendix B**). Observations made during the flow test noted that erosion of channel and movement of boulders started at approximately 300 cfs and was pronounced at flows greater than 300 cfs. Therefore, maintaining a flow rate of less than 300 cfs is desired to prevent canal erosion. At a flow rate of 300 cfs, additional recharge ponds will be required to utilize the conveyance system to its full capacity. Modifications to the Intake Structure will also be required as described below.

Modification of the Intake Structure

The hydraulic capacity of the Cuttle Weir and the Intake Structure are interrelated. If the height of the Cuttle Weir was increased, the resulting increased water surface elevation would allow greater flow rates through the Intake Structure. At an elevation of 1954.75 feet, water levels reached the top of the Cuttle Weir at a flow rate of approximately 300 cfs with plywood in place at the weir notch as noted in the adjacent photo. The corresponding theoretical total discharge through the six gates is approximately 362 cfs at this elevation. However, due to the accumulation of debris and boulders in front of the Intake Structure's gates, the MWH team concluded that the practical flow capacity for diversion of flow into the Intake Structure is 250 cfs. In order to meet the 300 cfs capacity, the modifications described below are recommended to eliminate debris accumulation in front of the Intake Structure. As noted above, a flow rate of approximately 300 cfs was reached with the plywood in place at the weir notch. Therefore, no modifications to the Cuttle Weir are required to reach a flow rate of 300 cfs.

In order to prevent accumulation of boulders and debris in front of the Intake Structure, the MWH team recommends re-grading the river channel to slope away from the structure and constructing a gabion deflection wall as shown in **Figure 2-4**. The gabion deflection wall would deflect the boulders at high flows and guide them toward the river bank on the opposite side from the Intake Structure. The sloped channel should be steep enough to prevent rocks from migrating from the opposite river bank to the Intake Structure at flows higher than 250 cfs. The MWH team recommends that the river sediment and rock loading be evaluated during final design to provide design criteria for the channel re-grading, gabion wall and other related facilities. The evaluation will also provide the District's with an idea of the amount of maintenance that will be required (excavating boulders etc.).



Notes:

1. Topography and existing facilities shown are approximate and based on 2000 survey performed by Schmidt and field visits.
2. Channel in front of intake and to the limits shown shall be cleaned of large loose rocks, boulders and vegetation. Channel shall be re-graded to slope away from intake structure.

N

10' 0' 10' 20'

SCALE: 1" = 10'

Document: FinalReport_Fig2-4.pub

Date: May 20, 2009

Intake and Cuttle Weir Plan

Figure 2-4

Santa Ana River Groundwater Recharge
Optimization Study

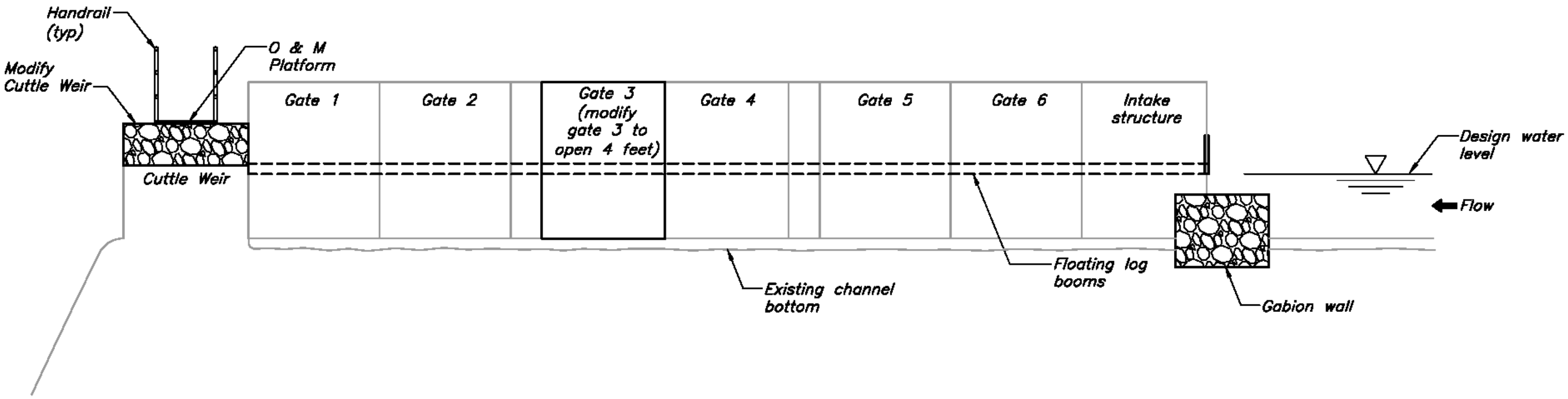
Floating debris accumulation at the Intake Structure's gates also reduces the diversion capacity. The MWH team recommends installing a floating log boom as shown in Figures 2-4 **and 2-5**. The floating log boom is a low cost and effective solution to controlling floating debris. The log boom would be connected to the northeast corner of the Intake Structure and run diagonally toward the Cuttle Weir notch. It would be connected to the Cuttle Weir just west of the notch. This way the debris could be flushed downstream thru the notch by removing stop logs. At extremely high flows the log boom would be removed to prevent damage.

Additional Facilities

To fully utilize the conveyance capacity of the existing facilities at a flow rate of 300 cfs, additional recharge ponds west of the Borrow Pit will be required. An additional 52.1 wetted acres is recommended as part of this expansion. The additional ponds will only be a portion of the proposed Phase 2 recharge ponds as shown on Figure 2-1. The additional recharge ponds would allow for percolation of the additional 105 cfs of capacity needed to add to the existing capacity of 195 cfs, reaching a total of 300 cfs.

Because of the additional recharge ponds, modifications of the existing (earthen) Main Canal will be required. The Main Canal runs from the end of the Sand Box to the northwest corner of the Borrow Pit. At this location, the existing canal divides into two separate canals, one continuing west to Ponds 13 and 17 and one running to Pond 10. A new canal that runs west along the recharge ponds within the proposed Phase 2 recharge basins will be required and the existing canals west of the Borrow Pit will no longer be needed, as shown on Figure 2-1.

This new portion of the Main Canal will consist of pond turnout structures that would allow separate discharge to each of the proposed recharge basins; therefore, providing the capability of isolating each pond during maintenance. The structures will be constructed of concrete with Waterman C-10 canal gates, as shown on **Figure 2-6**. Each turnout structure will be sized to allow flow that is twice the percolation rate, which assumed to be 4 feet/day, and the wetted area of the recharge pond(s) fed by that turnout. The additional flow will be used to fill the proposed recharge ponds to their required depths and then the gates will be used to reduce the flow to the percolation rate of each pond. As noted in Section 3, flow measuring devices are recommended at each turnout structure to monitor flows to discreet recharge areas. The installation of flow measuring devices will allow for monitoring percolation rates and potential degradation of percolation rates, which is important information needed for adaptive management of operations and maintenance.



0 2' 4' 8' 12'

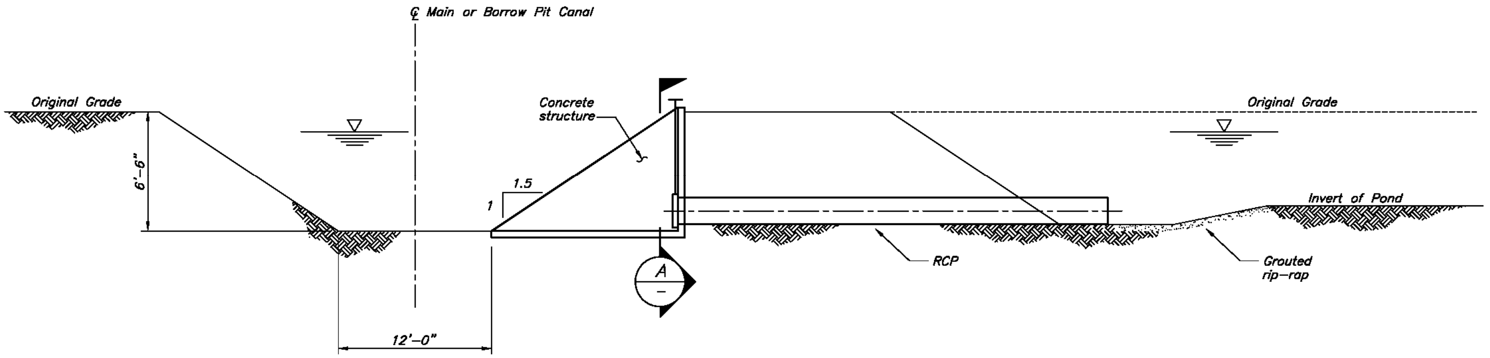
Document: FinalReport_Fig2-6.pub

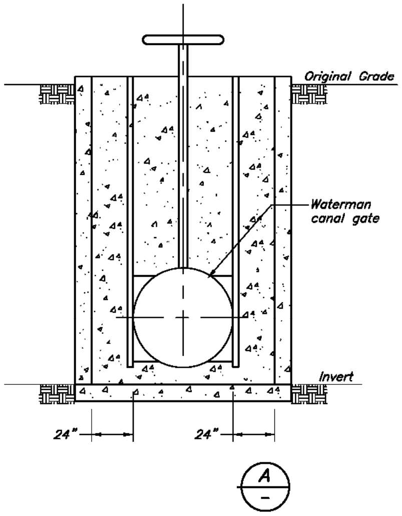
Date: May 20, 2009

Intake and Cuttle Weir Plan B

Figure 2-5

Santa Ana River Groundwater Recharge
Optimization Study





No. of Turnouts Main & Borrow Pit Canal	Gate Size
2	18"
4	24"
18	30"
14	36"

No Scale

Document: FinalReport_Fig2-21.pub

Date: May 20, 2009

Pond Turnout Structure

Figure 2-6

Santa Ana River Groundwater Recharge
Optimization Study

2.3 CONVEYANCE OF 500 CFS

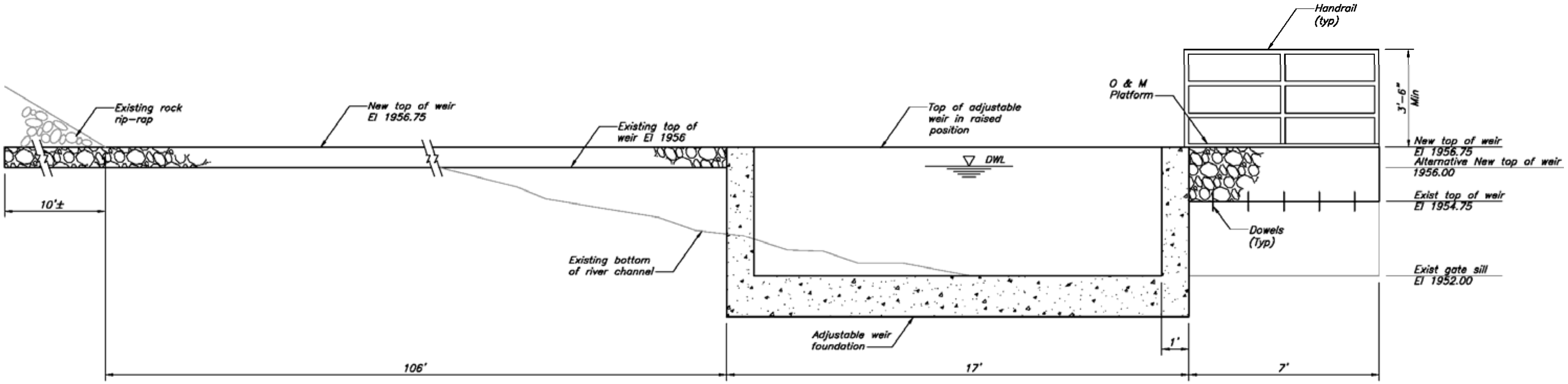
Improvements will be required for the existing diversion and conveyance facilities to convey a flow of 500 cfs, which is the ultimate goal of the Districts. The maximum instantaneous flow rate is based on the Environmental Impact Report for the Santa Ana River Water Right Applications for Supplemental Water Supply (SBVMWD, 2007). Review of the future frequency and duration of the 500 cfs estimate was not a portion of this study. Figure 2-1 shows locations of the facilities to be improved. As stated above, the practical conveyance limitation for most of the conveyance system was reached at approximately 300 cfs. However, the Rock Structure and the Parshall Flume have the capability to convey greater than 1,000 cfs (**Appendix B**), and will not require modifications. A description of the improvements and additional facilities recommended to achieve a flow rate of 500 cfs are provided below.

Modifications of Existing Diversion and Conveyance Facilities

Intake Structure and Cuttle Weir

The Cuttle Weir/Intake Structure in its current configuration has an estimated capacity of 250 cfs. If the improvements made for boulder and debris handling as recommended in the 300 cfs alternative are made, then the capacity could theoretically be increased to 362 cfs at a water level elevation of 1954.75. In addition to these improvements, the water level in the intake forebay will need to be raised to an elevation of 1955.6 in order to convey 500 cfs thru the Intake Structure. In order to accomplish this, it is recommended that the Cuttle Weir be raised to an elevation of 1956.75. This provides at least 12 inches of freeboard to provide flexibility and spillage over the weir due to turbulent water. The weir would be raised using reinforcement and rock masonry (same as existing) as shown in Figure 2-5 and **Figure 2-7**. A sluice gate would be installed in the notch to allow water to be passed downstream and to control water level elevations. An access platform with handrail would be constructed over the notch to allow access to the sluice gate operator. Improvements will also be required to the existing weir access to bring it up to current OSHA standards. This includes additional handrails and ladder cage. As part of these improvements, Gate #3 at the intake would be modified to allow it to open 4 feet.

As an alternate to the sluice gate, the Districts may want to consider installing an adjustable weir as shown on **Figures 2-8** and **2-9**. This is a more expensive option than the sluice gate and will require substantial modifications to the existing weir structure. A structural engineer and geotechnical foundation engineer will be required to investigate the existing structure foundation and make recommendations for the adjustable weir foundation. The adjustable weir would be approximately 17 feet long and almost 5 feet high at maximum height. The weir operates by adjusting the air volume in a rubber bladder to raise or lower the weir plate. This air volume would be controlled from a panel and air compressor located on the top deck of the intake. The advantage of the adjustable weir over a sluice gate is that it provides more water level control and can be completely lowered to allow boulders and other debris to pass over it.



0 1' 2' 4' 6'

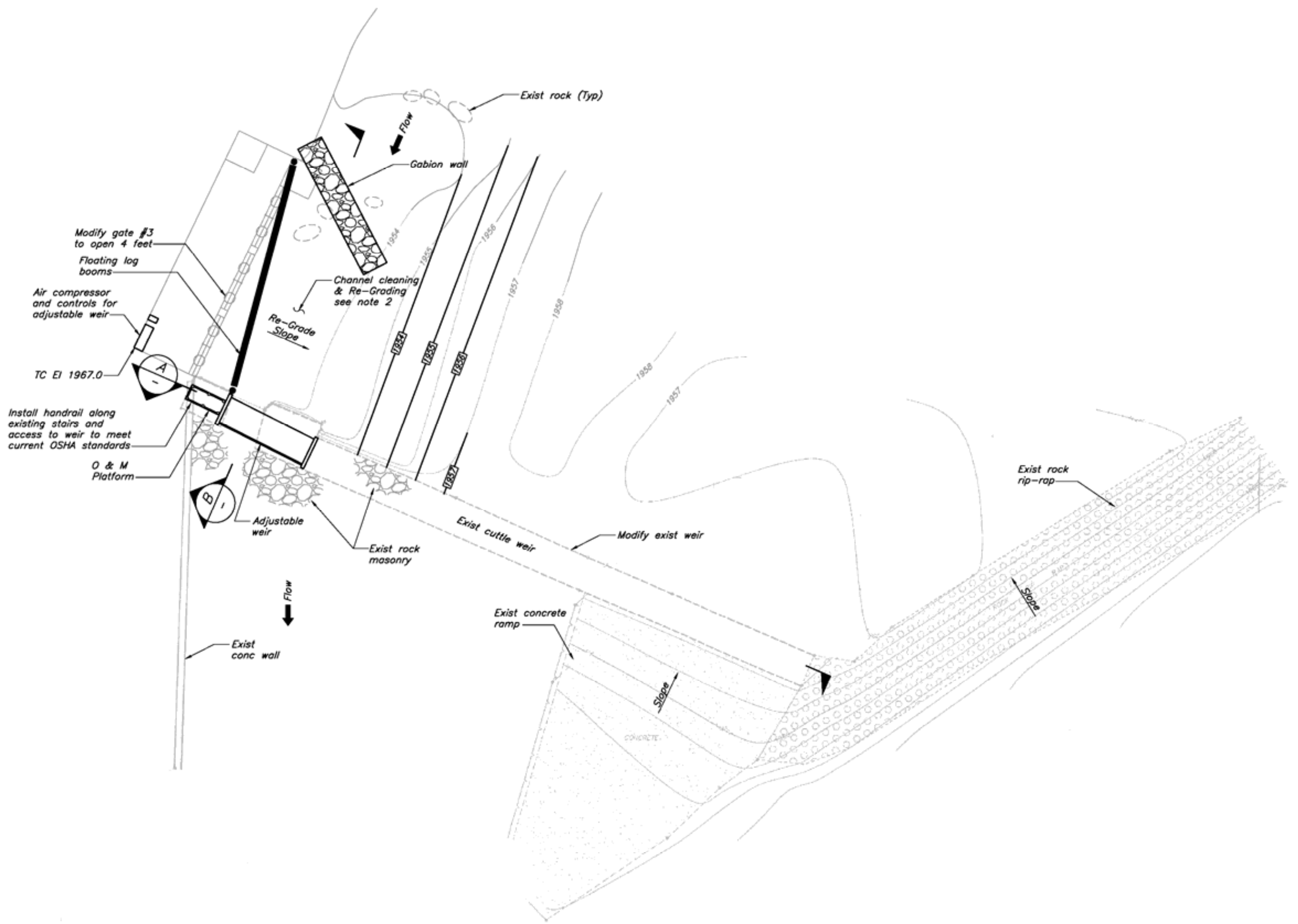
Document: FinalReport_Fig2-5.pub

Date: May 20, 2009

Intake and Cuttle Weir Plan C

Figure 2-7

Santa Ana River Groundwater Recharge
Optimization Study



Notes:

1. Topography and existing facilities shown are approximate and based on 2000 survey performed by Schmidt and field visits.
2. Channel in front of intake and to the limits shown shall be cleaned of large loose rocks, boulders and vegetation. channel shall be re-graded to slope away from intake structure.

N

10' 0' 10' 20'

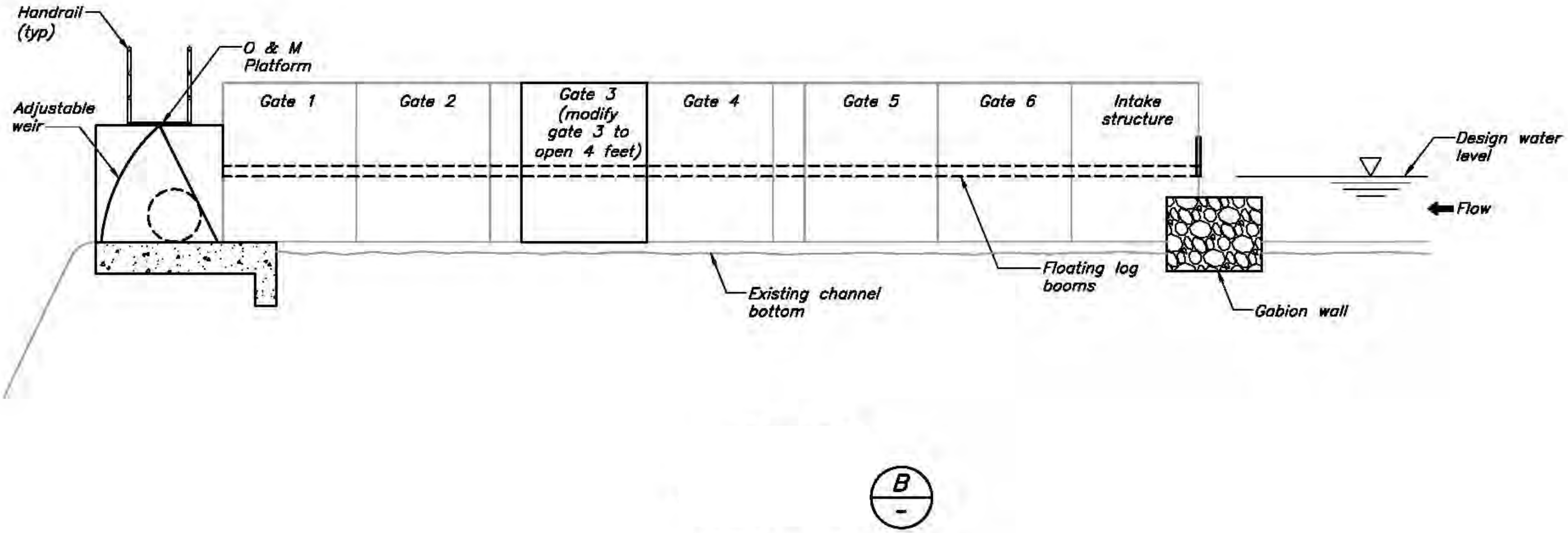
Document: FinalReport_Fig2-8.pub

Date: May 20, 2009

Alternate Intake and Cuttle Weir
Plan D

Figure 2-8

Santa Ana River Groundwater Recharge
Optimization Study



0 2' 4' 8' 12'

Alternate Intake and Cuttle Weir Plan E

Document: FinalReport_Fig2-9.pub

Figure 2-9

Date: May 20, 2009

Santa Ana River Groundwater Recharge Optimization Study

Closed Conduit (Tunnel) and Sand Box

As described in **Appendix B**, the calculated capacity of the Closed Conduit/Tunnel is greater than 500 cfs for open channel flow with the 50-foot long overflow section. Therefore, improvements to the Closed Conduit/Tunnel are not required to achieve the desired capacity of 500 cfs.

The Sand Box capacity is currently limited by the maximum gate opening at the structure's downstream end. The structure consists of two 6 feet wide bulkhead gates, each having a maximum opening of 4 feet based on thread measurements taken on each gate stem. The hydraulic model described in Appendix B suggests that at a flow rate of 500 cfs, the water depth at the Sand Box gate structure would be about 4.8 feet. Therefore, the gates will require modification to increase the gate opening heights to 5 feet in order to increase this facility's carrying capacity to 500 cfs, as shown on **Figure 2-10**.

Figure 2-10 also shows a trashrack structure downstream of the Sand Box. This structure is provided as an option to the Districts to capture any debris not caught by the log booms before it enters the earthen canal. There is an existing 50 foot overflow section in the Sand Box that will provide overflow into the Santa Ana River in the event that the trash rack gets clogged.

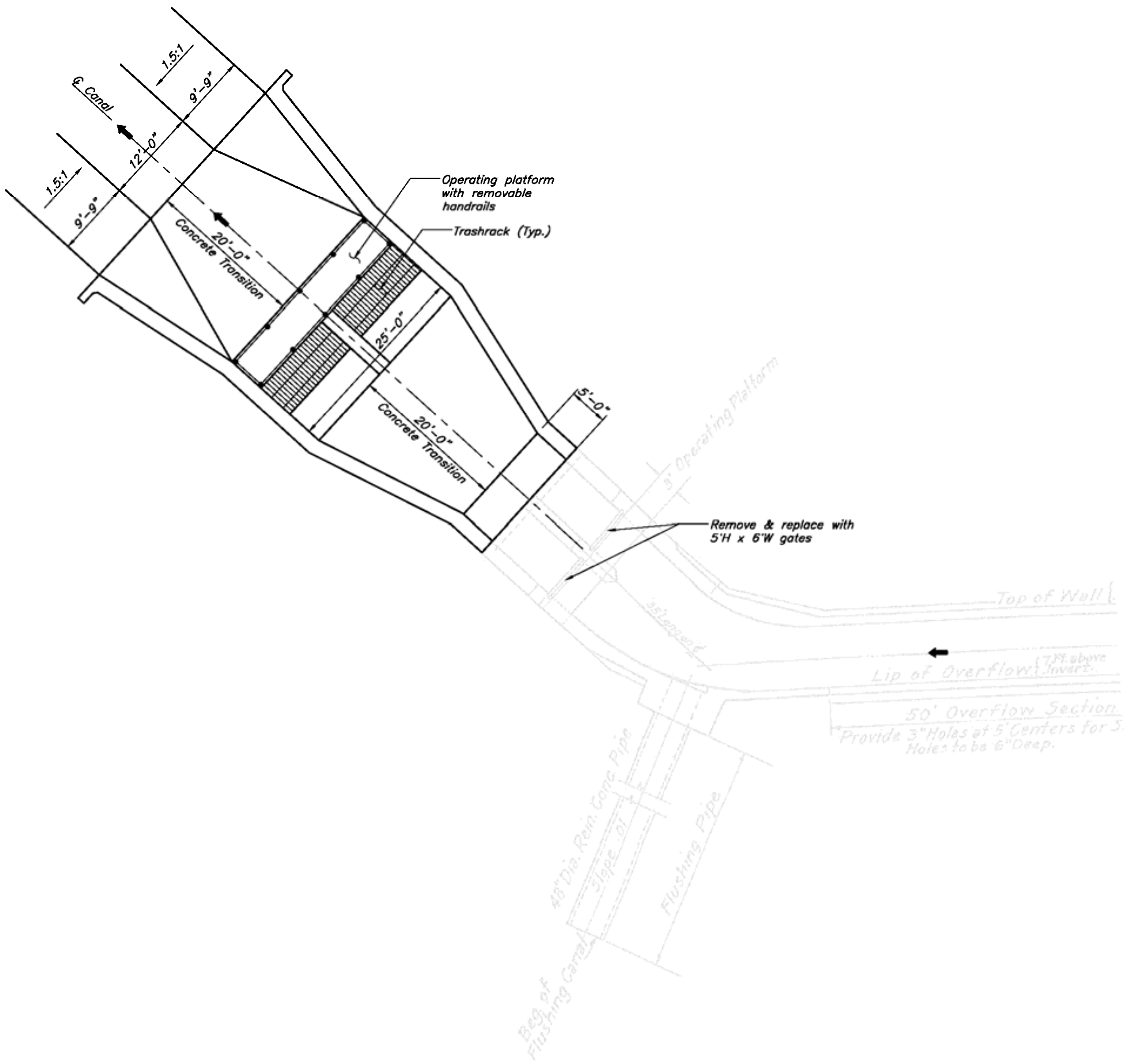
Earthen Canal

The existing Main Canal has a practical conveyance limitation of 300 cfs due to high velocity and turbulent flow (**Figure 2-11**). Therefore, improvements are required to increase the carrying capacity of the canal as well as prevent canal erosion. The canal considered for this section starts at the end of the sand box and terminates at the Phase 3 recharge ponds.

In order to reduce the velocity in the canal, the addition of drop structures (**Figure 2-12**) and a decrease in the canal slope are recommended, which will lead to changes in the canal cross section (**Figure 2-13**). The slope of the canal was evaluated using Bentley FlowMaster Version 8 software (Flowmaster). Using the following parameters, canal slopes varying from 1% to 3% were considered:

- Flow capacity of 500 cfs
- Maximum velocity of 6.5 feet per second
- Published an n-value of 0.050 (Daugherty and Franzini, 1979)
- Canal side slopes of 1.5 horizontal to 1 vertical (practical standard for earthen canals)

At a 1% slope, a canal bottom width of 12 feet is required to meet the parameters listed above. The normal water depth in the channel would be 4.41 feet deep. Therefore, the canal will be designed with a depth of 6.5 feet, which would provide 2 feet of freeboard (**Figure 2-13**). With a slope of 3%, the canal bottom width of 60 feet is required and the channel will have a normal water depth of 1.33 feet. Providing the same amount of freeboard as the 1% slope, the depth of the canal would be 3.5 feet. The canal bottom width and depth for various slopes are shown on **Table 2-1** below along with the number of drop structures required for each slope. Ten foot drop structures are recommended.



0 4' 8' 16' 32'

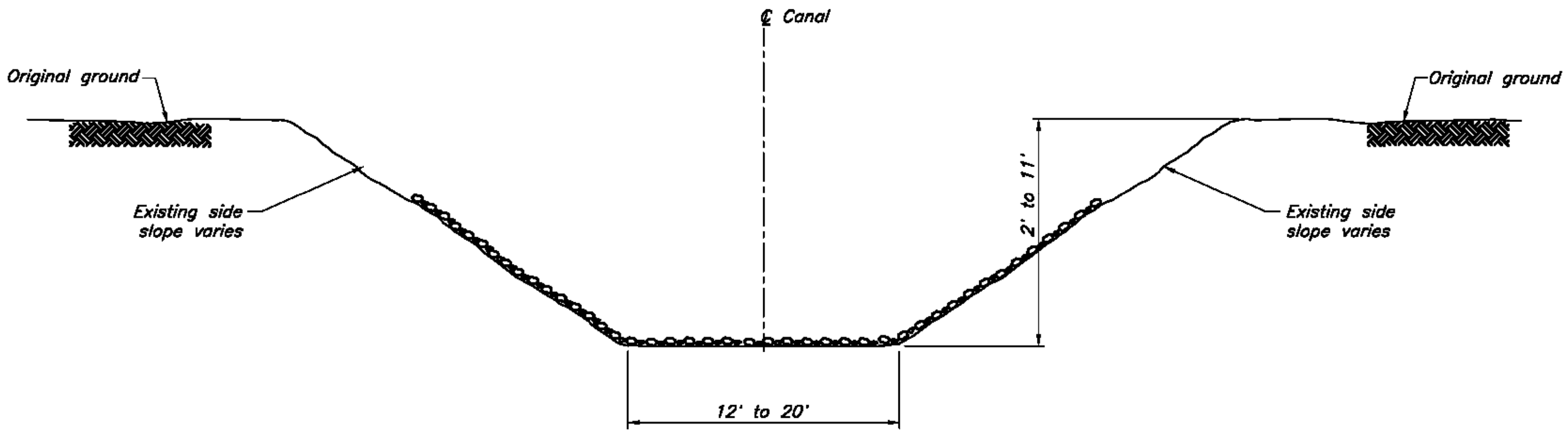
Trashrack Structure Plan

Document: FinalReport_Fig2-10.pub

Figure 2-10

Date: May 20, 2009

Santa Ana River Groundwater Recharge
Optimization Study



No Scale

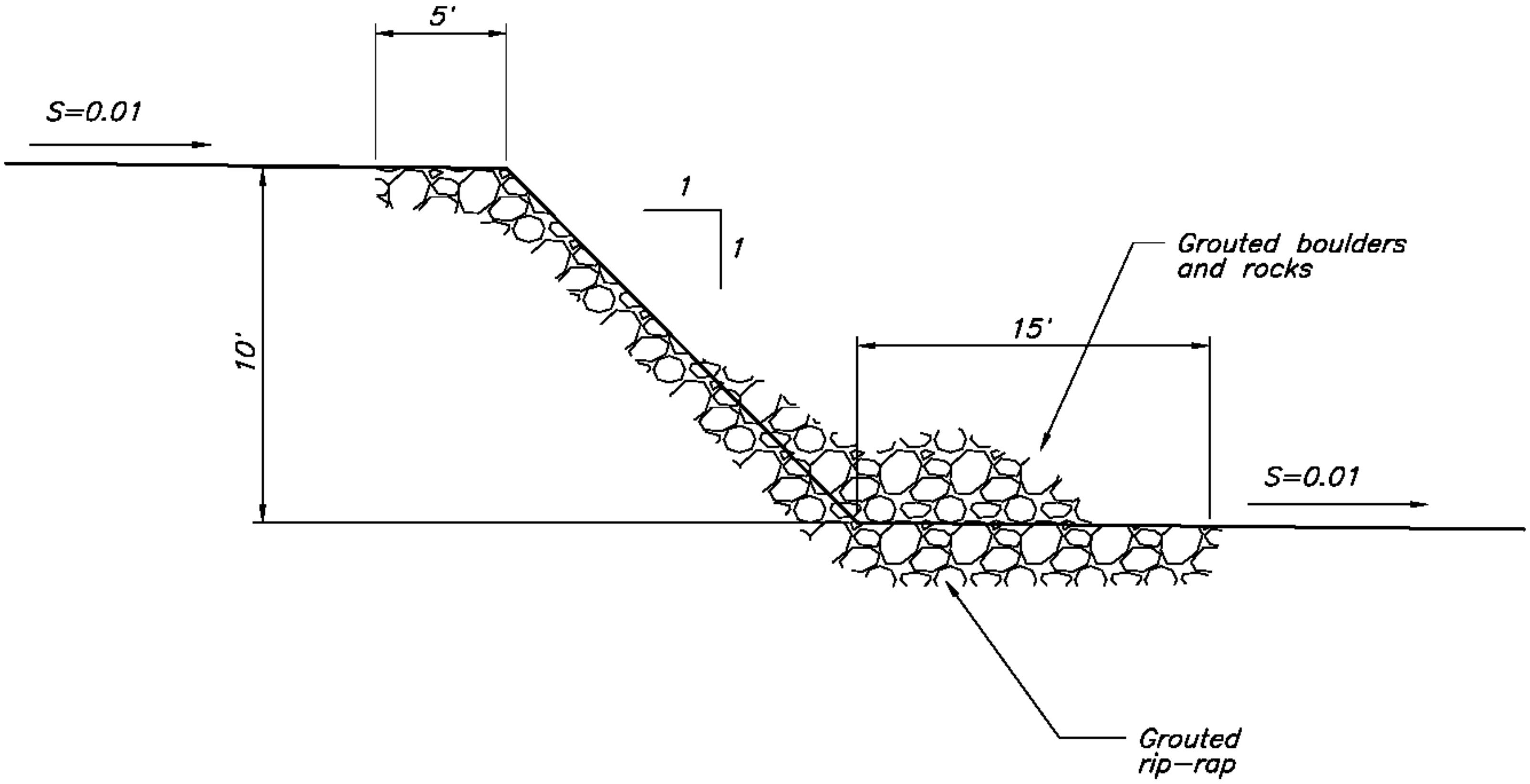
Document: FinalReport_Fig2-12.pub

Date: May 20, 2009

Existing Earthen Canal Section

Figure 2-11

Santa Ana River Groundwater Recharge
Optimization Study



No Scale

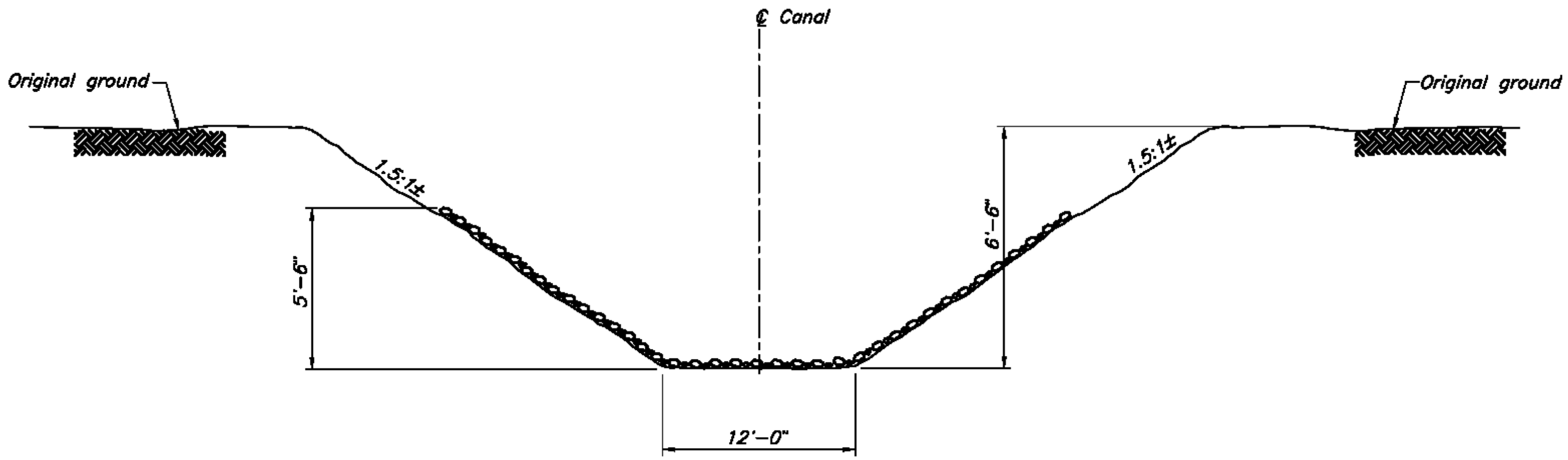
Document: FinalReport_Fig2-11.pub

Date: May 20, 2009

Drop Structure

Figure 2-12

Santa Ana River Groundwater Recharge
Optimization Study



No Scale

Document: FinalReport_Fig2-13.pub

Date: May 20, 2009

Proposed Typical Earth Lined Canal Section

Figure 2-13

Santa Ana River Groundwater Recharge
Optimization Study

Table 2-1
Estimated Costs of Drop Structures Based on Canal Slope

Canal Slope	Bottom Width (feet)	Normal Water Depth (feet)	Canal Depth (feet)	No. of Drop Structures	Estimated Costs
1%	12	4.41	6.5	36	$1,850,000
1.5%	30	2.46	4.5	28	$2,100,000
2%	40	1.91	4	20	$2,200,000
2.5%	50	1.57	3.5	13	$2,100,000
3%	60	1.33	3.5	5	$2,000,000

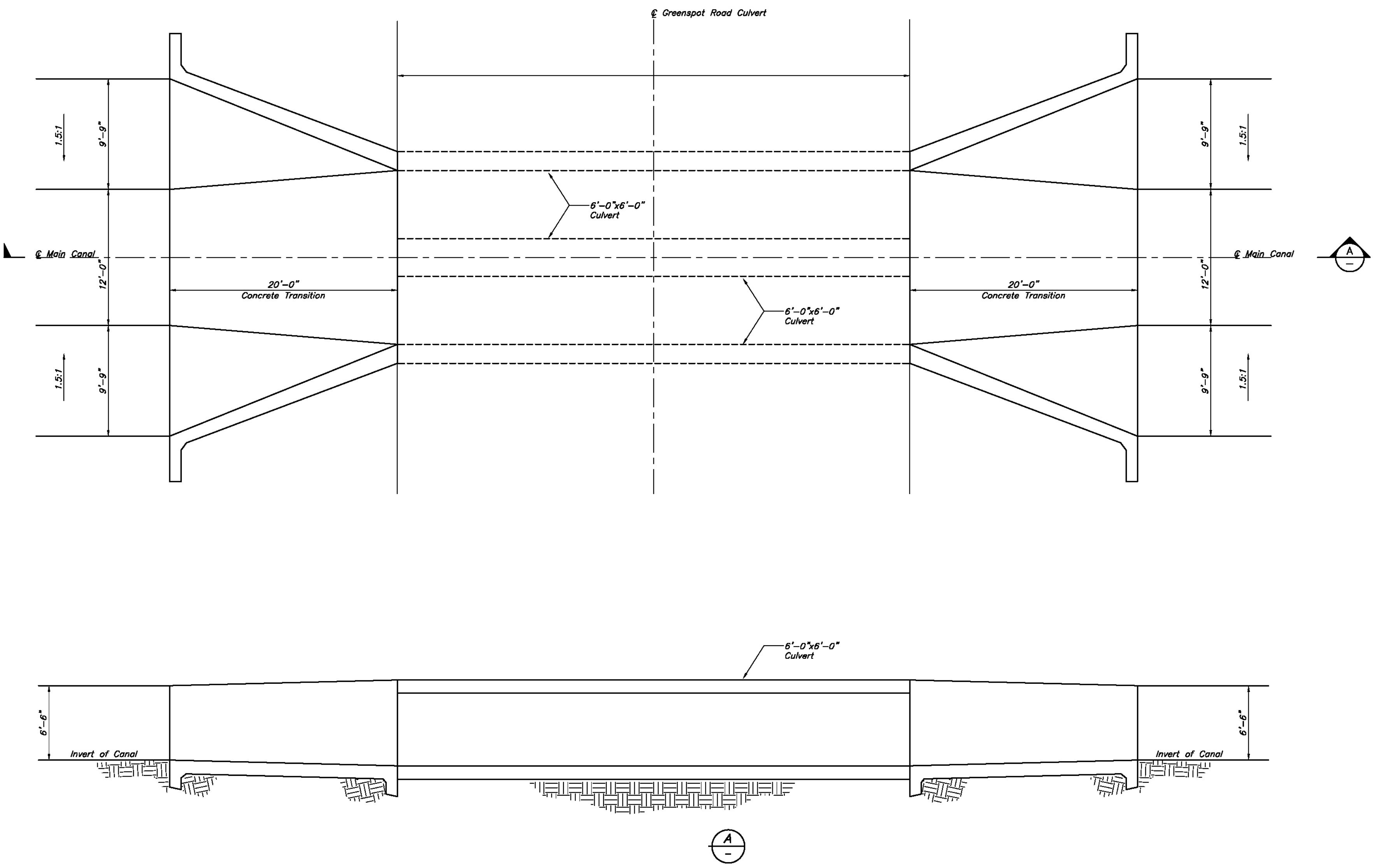
Canal widths of 30 feet and greater are not recommended because a uniform water depth may not be obtained throughout the width of the canal. The existing rocks and boulders in the earthen canal cause irregularities in the canal invert; therefore, a small meandering stream may develop. Subsequently, high velocities may develop causing erosion in the canal.

The estimated costs for the different canal sections are also provided in the **Table 2-1**. The 12-foot bottom canal is the lowest cost alternative. The MWH Team recommends the 12-foot bottom width canal for the conveyance of 500 cfs to the existing and new groundwater recharge facilities.

Greenspot Road Culvert

A point of congestion or obstruction in the conveyance system is the culvert at Greenspot Road. The hydraulic analysis determined that the maximum capacity of the culvert is approximately 372 cfs.

Recommended modifications of the culvert include replacing the 10 feet wide by 4 feet high culvert with two 6 feet wide by 6 feet high box culverts. This would increase the culvert capacity to 500 cfs. Modifications will also include a 20-foot long “broken back” concrete transition upstream and downstream of the culvert. The transitions will provide gradual change from the canal section to the box culverts (**Figure 2-14**).



No Scale

Document: FinalReport_Fig2-14.pub

Date: May 20, 2009

Greenspot Road Culvert Plan

Figure 2-14

Santa Ana River Groundwater Recharge
Optimization Study

Diversion Structure

The existing diversion structure consists of two 4 feet by 8 feet diversion gates mounted on a concrete structure to the west (North Diversion Structure) and one 4 feet by 8 feet gate mounted on a concrete structure to the south (South Diversion Structure). See **Figure 2-15** for the layout of the existing diversion structure. As described in **Appendix B,** the North Diversion Structure was able to pass 300 cfs with 2 feet of free board flow testing. Theoretical calculations show that the North Diversion Structure could pass 500 cfs at approximately 3 feet of water depth. However, this was analyzed based on existing canal slopes downstream remaining at approximately 3 percent grade. The canal slope being recommended by the MWH Team downstream of the North Diversion Gate is 1 percent. Because of this, the water level in the canal creates a backwater effect in the diversion structure thus increasing the water level required to convey 500 cfs. Based on theoretical calculations, the water depth through the North Diversion Structure needs to be 4.5 feet to convey 500 cfs. Currently, the diversion structure depth is 5 feet. At this time the MWH Team does not recommend raising the diversion structure walls. However, the existing gates should be modified to increase the opening from 4 feet to 5 feet. Also, a concrete diverging cone should be constructed at the entrance to the North Diversion Structure to allow smooth water separation and reduce turbulence.

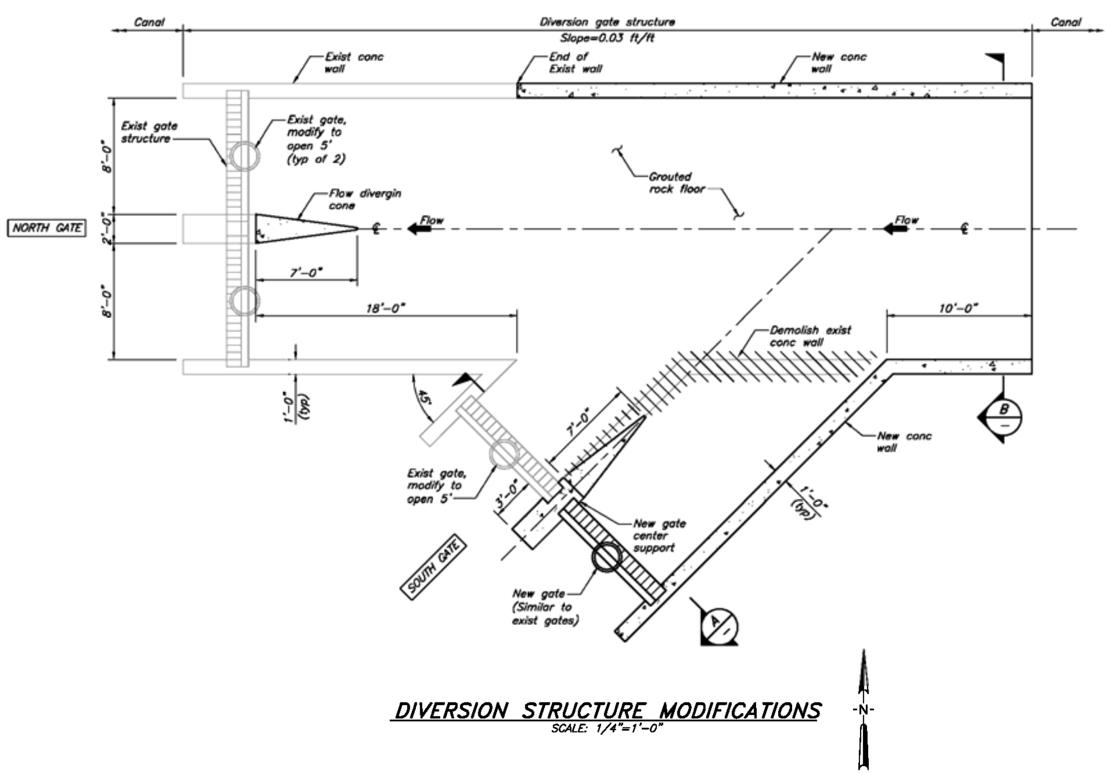
The South Diversion Structure should be modified to add a second gate as shown on **Figure 2-15**. This will require the construction of a concrete foundation and wall. Otherwise, the modifications are similar to those recommended for the North Diversion Structure.

Currently, the bottom of the diversion structure is native rock and earth. It is recommended that the existing rock and earth be excavated and replaced with grouted rock. This will provide protection to the side walls and structures against scouring due to high velocities in the channel.

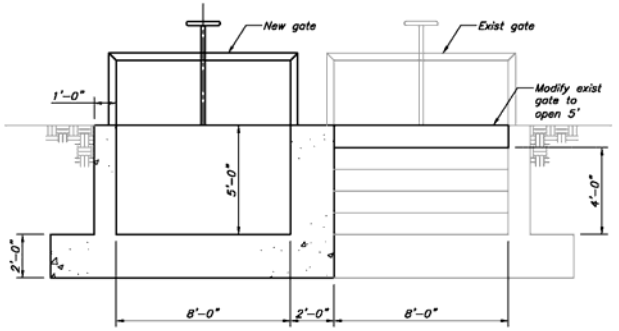
Additional Facilities

Improvements recommended above will be required to convey a flow of 500 cfs to the existing and new recharge ponds in the proposed Phases 1 through 3. To fully utilize the conveyance capacity of the existing facilities at a flow rate of 500 cfs, additional recharge ponds west of the Borrow Pit will be required. An additional 151.2 wetted acres will be required as part of this expansion. The additional recharge ponds would allow for percolation of the additional 305 cfs of capacity needed to add to the existing capacity of 195 cfs, reaching a total of 500 cfs. The additional recharge and conveyance facilities needed for this flow will be similar to the additional facilities needed for the flow of 300 cfs.

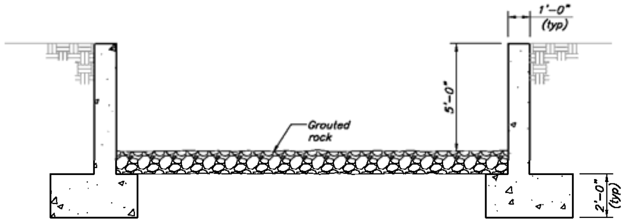
Because of the additional recharge ponds, modifications of the existing earth canal, the (earthen) Main Canal, will be required. Currently, the Main Canal divides into two separate canals at the northwest corner of the Borrow Pit, one continuing west to Ponds 13 and 17 and one running to Pond 10. At this location, a new canal that runs west along the recharge ponds within the proposed Phases 1 through 3 will be required (Figure 2-3) and the existing canals west of the Borrow Pit will no longer be needed. This new portion of the Main Canal, east of the Borrow Pit, will also consist of pond turnout structures that would allow separate discharge to each recharge pond. This will provide the capability of isolating each pond during maintenance, as well as a means to monitor flow to each pond (Figure 2-6).



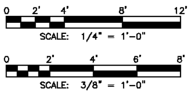
DIVERSION STRUCTURE MODIFICATIONS
SCALE: 1/4"=1'-0"



SECTION A
SCALE: 3/8"=1'-0"



SECTION B
SCALE: 3/8"=1'-0"



Diversion Structure Modification

Document: FinalReport_Fig2-15.pub

Figure 2-15

Date: May 20, 2009

Santa Ana River Groundwater Recharge
Optimization Study

2.4 OPTIONAL FACILITIES

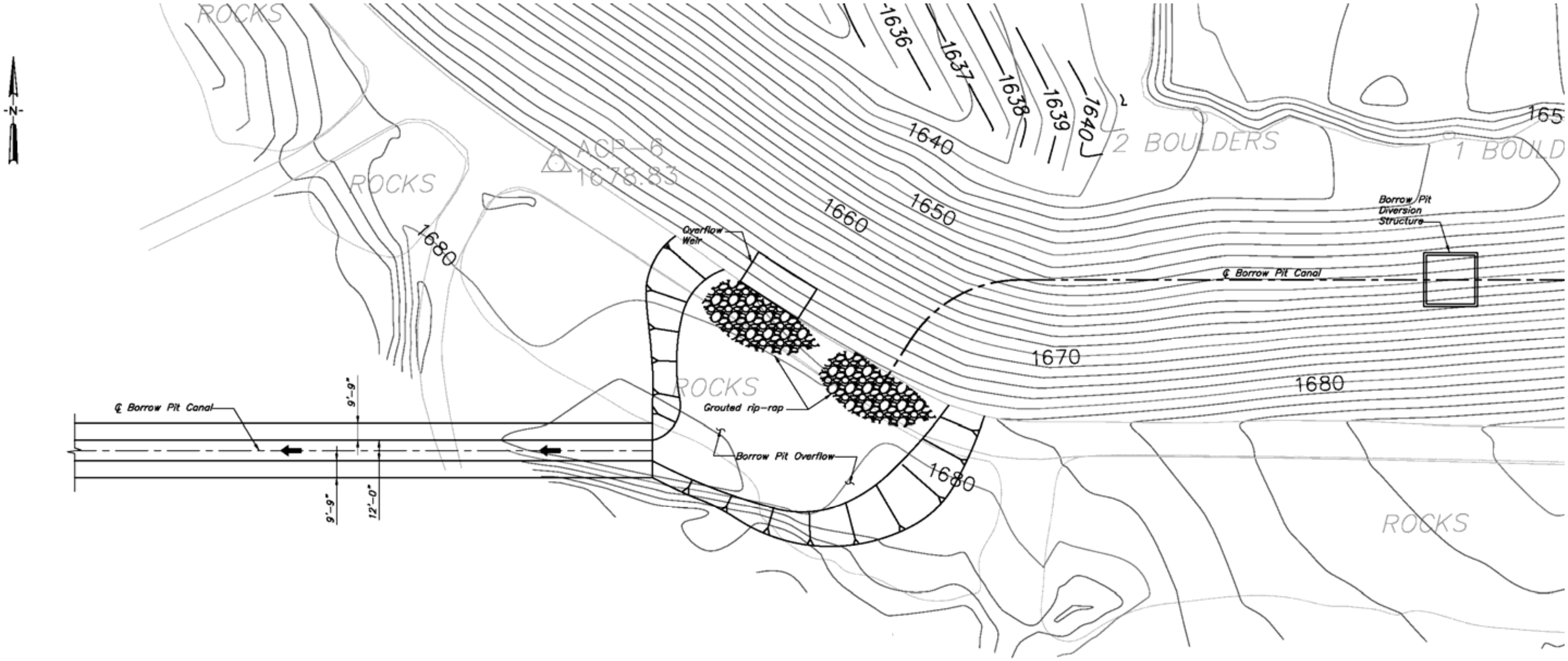
During the conceptual design phase, several alternatives or optional design features were identified which the Districts may wish to consider during the detailed design phase. As an option, a second canal south of the recharge basins in the proposed Phases 1 through 3 was considered during the conceptual design. This second canal, the Lower Borrow Pit Canal shown on Figure 2-1, will provide additional conveyance to the recharge ponds in the proposed Phases 1 through 3. This would provide operational flexibility and redundancy by allowing the Main Canal to be shutdown and dewatered for maintenance purposes without losing the ability to recharge. It will also provide a way to capture any overflow from the Borrow Pit and the ability to use the overflow for recharge. The proposed Lower Borrow Pit Canal will require modifications to existing facilities along with the addition of new facilities to the Borrow Pit, including Ponds 1, 2 and 3. These features are described in more detail below.

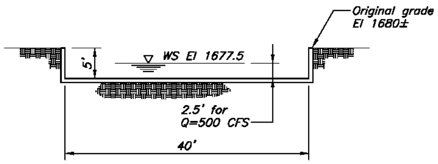
Several options including sedimentation ponds and chemical treatment were also discussed during the conceptual design. Since the completion of Seven Oaks Dam, there has been a degradation of the water quality of Santa Ana River characterized by significantly increased turbidity. The District plans to use Ponds 1 through 3 as sedimentation ponds; however, Ponds 1, 2 and 3 will not provide enough detention time to settle out the silt in the water. In order to increase the detention time, the Conservation District has the option to construct sedimentation ponds east of the Borrow Pit. These features are described in more detail below.

Lower Borrow Pit Canal

As shown on Figure 2-3, the Lower Borrow Pit Canal will provide the Conservation District with an additional conveyance facility to the recharge ponds in the proposed Phases 1 through 3. The Lower Borrow Pit Canal will have a flow capacity of 500 cfs. Flows to the Lower Borrow Pit Canal would be accomplished by conveying water through the Borrow Pit, which overflows into the proposed Borrow Pit Overflow and discharges into the Lower Borrow Pit Canal. The Borrow Pit Overflow is an overflow weir on the southwest corner of the Borrow Pit (**Figure 2-16**). Currently, the Conservation District discharges to the Borrow Pit for recharge and any excess flow would overflow the Borrow Pit and discharge directly into the Santa Ana River. The Borrow Pit Overflow will capture and convey any excess flow to the recharge basins.

Conveyance to the Lower Borrow Pit Canal will require modifications to the structures at Ponds 1, 2 and 3 along with new facilities in the Borrow Pit as discussed below. The Lower Borrow Pit Canal will also consist of pond turnout structures similar to the Main Canal. This would allow separate discharge to each of the recharge ponds; therefore, providing the capability of isolating each pond during maintenance.





No Scale

Document: FinalReport_Fig2-20.pub

Date: May 20, 2009

Borrow Pit Overflow

Figure 2-16

Santa Ana River Groundwater Recharge
Optimization Study

Ponds 1, 2 and 3

The south gate at the Diversion Structure is used to divert water to the Borrow Pit, which includes Ponds 1, 2 and 3. If water is diverted to Ponds 1, 2, and 3, they may function as settling basins to remove a portion of the suspended sediments that contribute to basin clogging. The south gate of the Diversion Structure does not have the capacity to divert 500 cfs to the Borrow Pit. Therefore, improvements, described above, will be needed along with improvements to the facilities that convey water from the Diversion Structure to the Borrow Pit. The facilities include the open channel on the east side of the Borrow Pit to Pond 1, the inlet structure from the open channel to Pond 1, and the overflow structures at Ponds 1, 2 and 3.

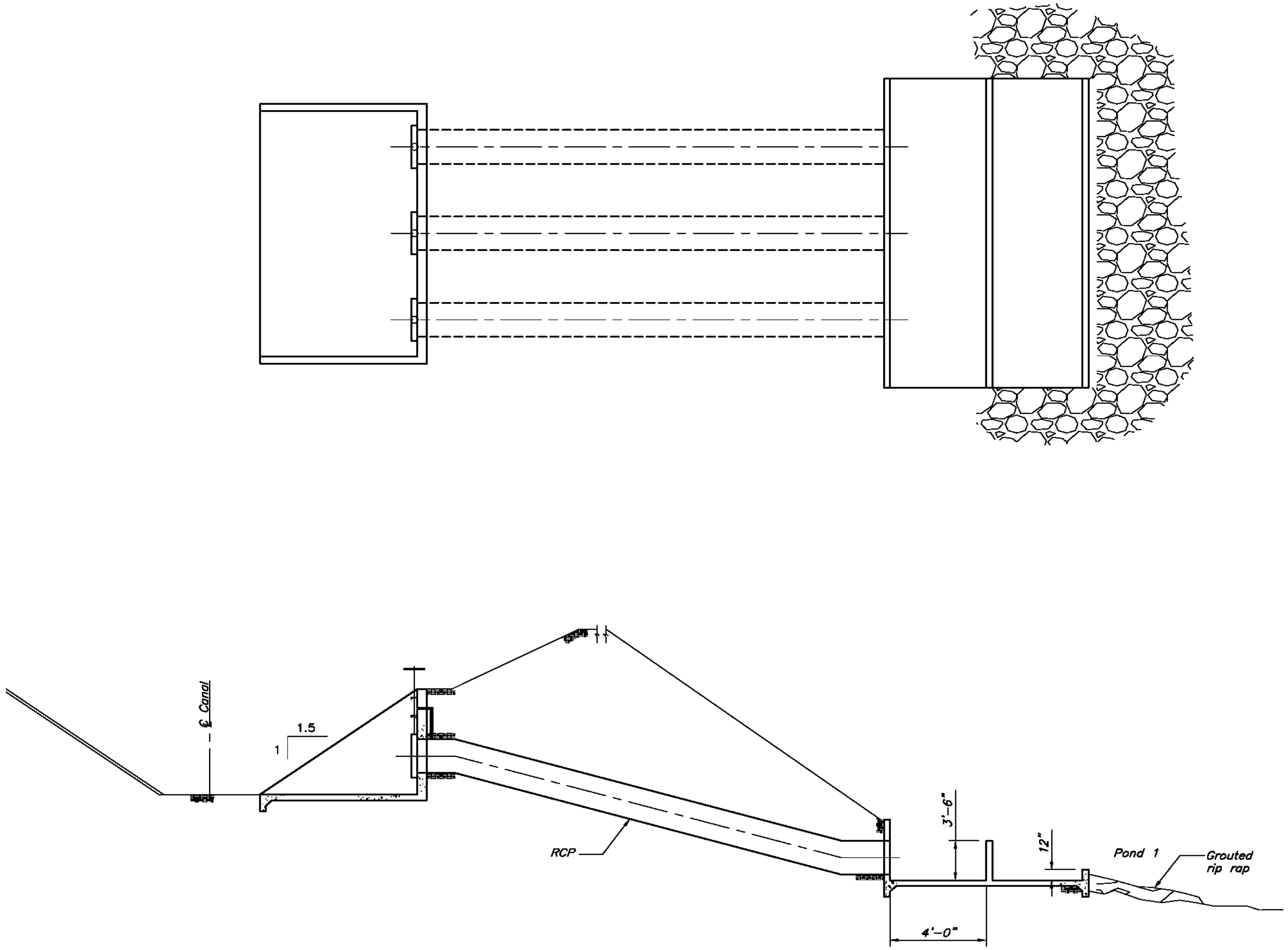
The open channel that conveys water from the Diversion Structure to the Borrow Pit will be modified to have the same cross section as the Main Canal. A new Pond 1 inlet structure from the open channel to Pond 1 will be required to convey 500 cfs (**Figure 2-17**). The inlet structure will be constructed of concrete with three 42-inch Waterman C-10 canal gates. The canal gates will provide control on the discharge to Ponds 1 through 3. Three 42-inch diameter reinforced concrete pipes will discharge to an outlet at Pond 1 that consists of a buffer wall and riprap to dissipate the energy due to the high velocities and the difference in elevation from the open channel to Pond 1.

Currently, the existing pond overflow structures that allow water to flow from Pond 1 to Pond 2 and from Pond 2 to Pond 3 are not adequate for the desired capacity of 500 cfs. The new overflow structures will be required and will be designed similar to the existing structures. The structures will be box-shaped structures with one side consisting of removable five foot wide flashboards. Openings wider than five feet will make it difficult to remove the boards by hand. In order to convey 500 cfs, a total of four structures constructed side by side will be needed. Four 42-inch diameter reinforced concrete pipes will discharge into the succeeding pond that consists of grouted riprap and large boulders at the outlets to dissipate the energy due to the elevation difference (**Figure 2-18**).

Borrow Pit

The improvements at Ponds 1 through 3 will only allow flow from Pond 1 to Pond 2 and from Pond 2 to Pond 3. In order to convey water from Pond 3 to the Lower Borrow Pit Canal, an open ditch, the Upper Borrow Pit Canal, will be needed to deliver water from Pond 3 to the canal and the recharge area in the Borrow Pit. Existing flows from Pond 2 to the recharge area will be eliminated.

The Upper Borrow Pit Canal will consist of a discharge structure at Pond 3 and a diversion structure at the southwest end of the Borrow Pit. See Figure 2-3 for the locations of these facilities. The discharge structure at Pond 3 would provide control of water into the open ditch with three 72-inch diameter Waterman C-10 canal gates. Water will discharge through three 72-inch reinforced concrete pipes to an outlet that consists of grouted riprap to prevent erosion in the Upper Borrow Pit Canal (**Figure 2-19**).



No Scale

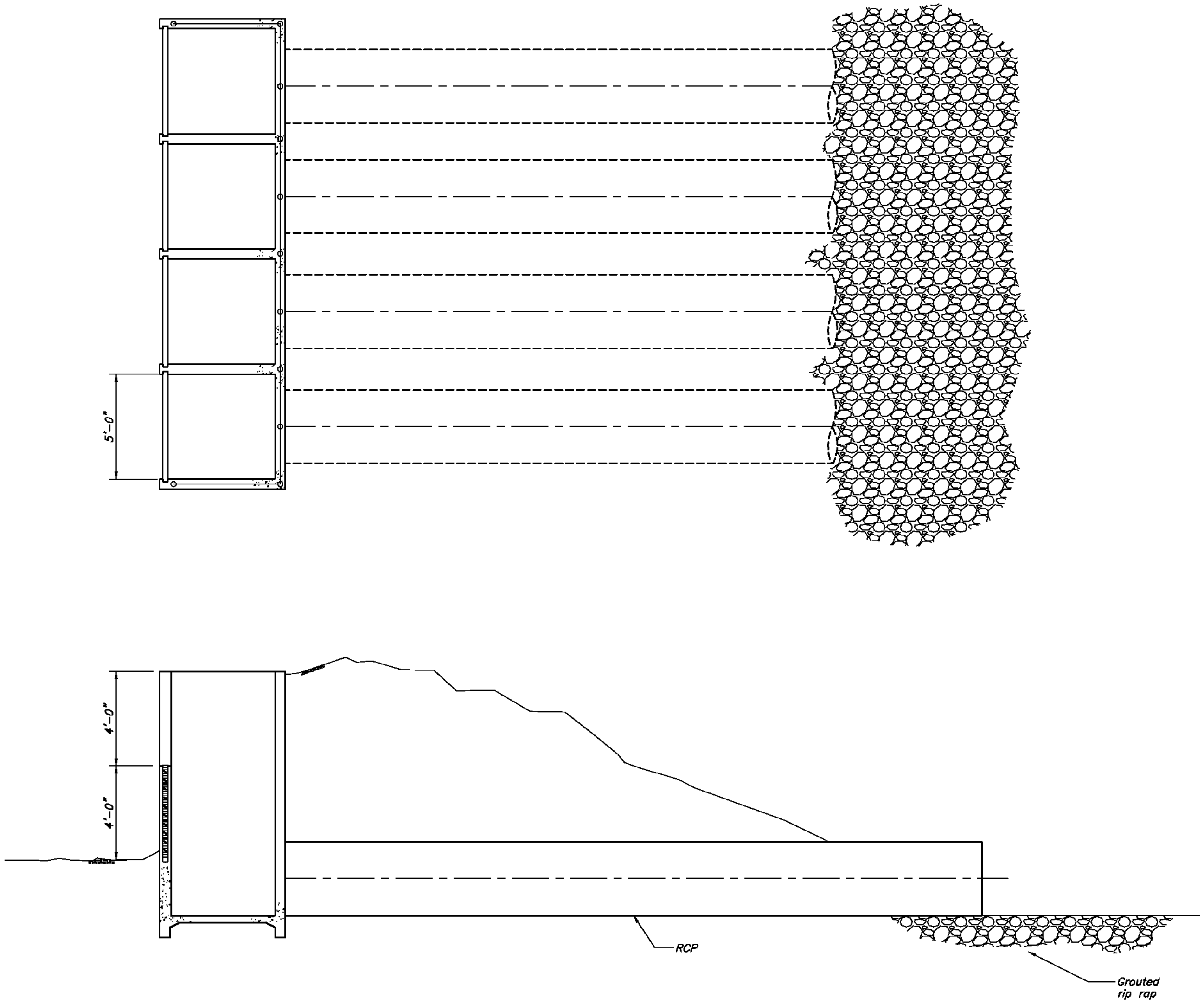
Document: FinalReport_Fig2-16.pub

Date: May 20, 2009

Pond Inlet Plan and Profile

Figure 2-17

Santa Ana River Groundwater Recharge
Optimization Study



No Scale

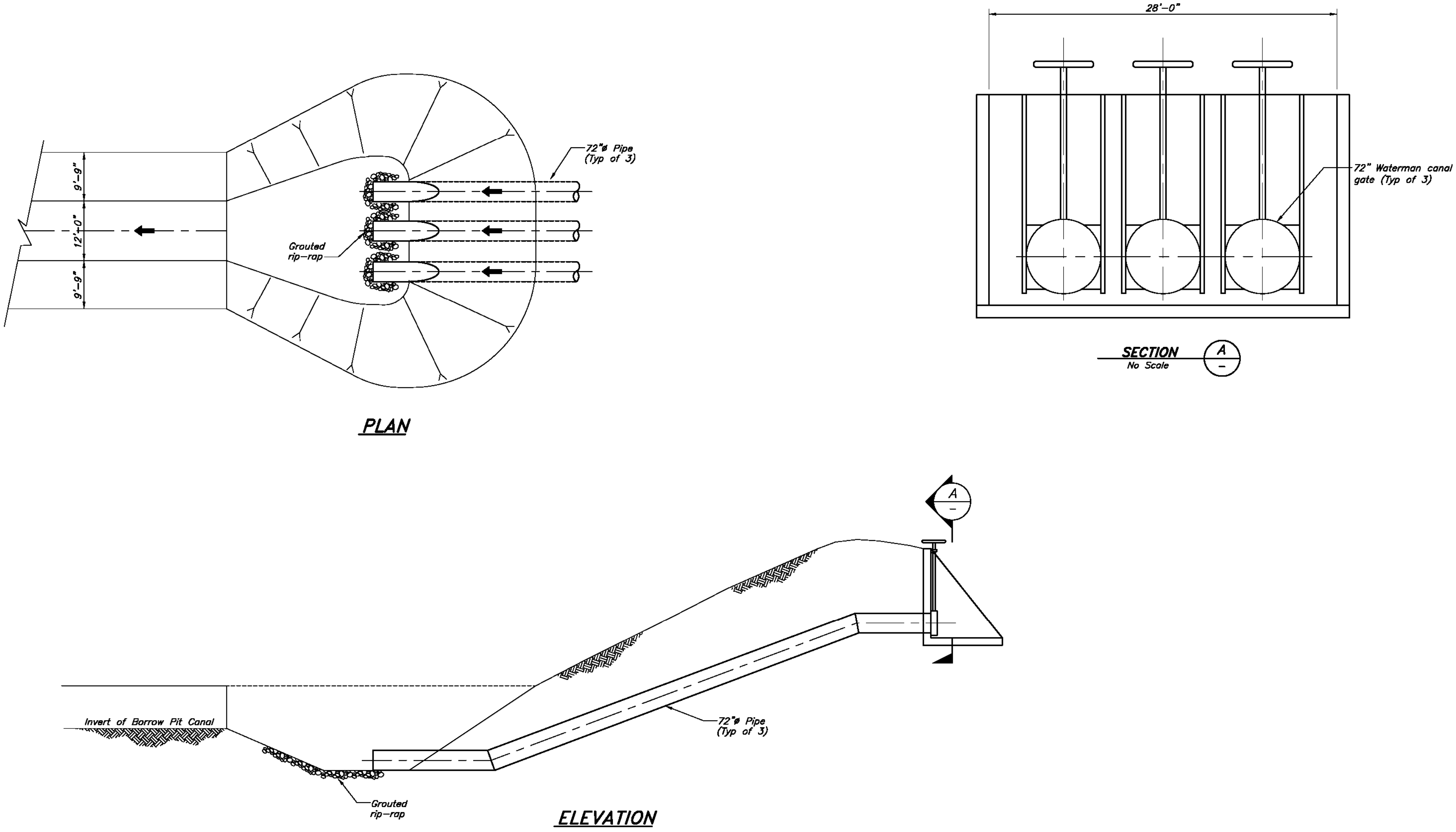
Document: FinalReport_Fig2-17.pub

Date: May 20, 2009

Pond Overflow Plan and Profile

Figure 2-18

Santa Ana River Groundwater Recharge
Optimization Study



PLAN

SECTION A
No Scale

ELEVATION

No Scale

Document: FinalReport_Fig2-18.pub

Date: May 20, 2009

Pond 3 Discharge Structure

Figure 2-19

Santa Ana River Groundwater Recharge
Optimization Study

The Borrow Pit Diversion Structure will consist of six 72-inch canal gates, three discharging to the Borrow Pit and three discharging to the Lower Borrow Pit Canal as shown on **Figure 2-20**. The gates will provide the capability to control flows to the recharge area in the Borrow Pit and the Lower Borrow Pit Canal. The structure will allow the entire flow of 500 cfs to be diverted in either direction.

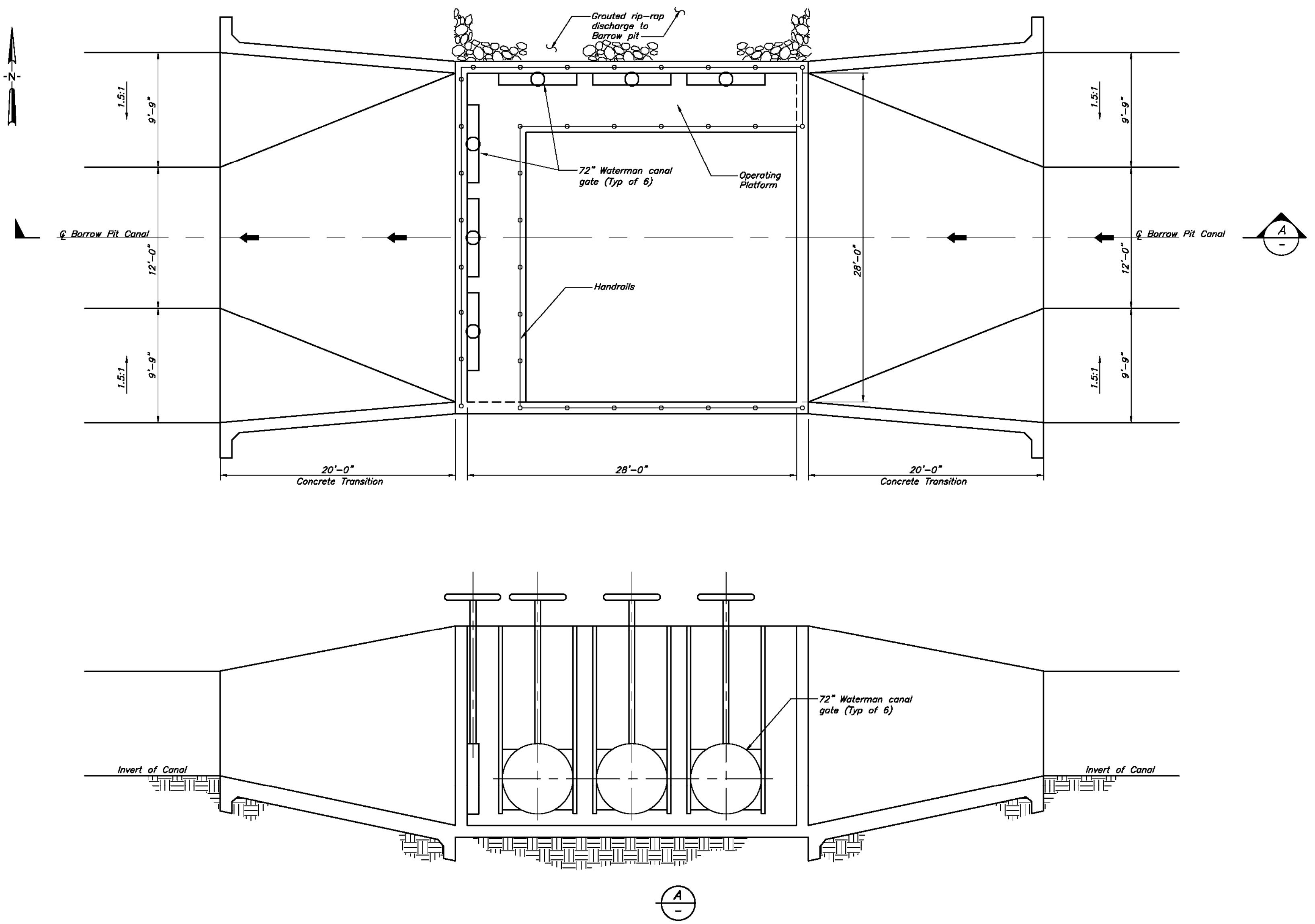
Borrow Pit capacity values, provided by the SBVWCD, indicated that the recharge rate of the Borrow Pit is 50 cfs. Therefore, the Borrow Pit will not be able to recharge the desired flow of 500 cfs. As stated above, excess flow would overflow the Borrow Pit and discharge directly the Borrow Pit Overflow, where the water will be captured and conveyed along the Lower Borrow Pit Canal to the recharge ponds (Figure 2-16). Flows from the Upper Borrow Pit Canal will also discharge into the Borrow Pit Overflow before it reaches the Lower Borrow Pit Canal. As an optional item for future consideration, flows leaving Pond 3 could also be placed in a pipe and delivered by gravity to Valley District's Foothill Pump Station for delivery throughout the Valley.

Additional Sedimentation Ponds

Since the completion of Seven Oaks Dam, there has been a degradation of the water quality of Santa Ana River characterized by significantly increased turbidity. Several options including chemical treatment and sedimentation have been proposed (CDM 2005). Although an evaluation of pre-treatment is beyond the scope of this investigation, the following discussion indicates the potential magnitude of facilities required.

Sedimentation efficiency is a function of the surface loading rate which is the flowrate divided by the surface area of the settling basin. For typical water treatment applications where coagulants are used, the surface loading rate is 0.5 to 1.0 gallons per minute per square feet (gpm/ft^2) (MWH 2005). Assuming a conservative rate of 0.5 gpm/ft^2 and a flowrate of 500 cfs, approximately 10.5 acres of sedimentation ponds would be required. Detention times are typically 1.5 to 4 hours (MWH 2005). At a design flowrate of 500 cfs, approximately 165 acre-feet of storage would be required to provide 4 hrs of detention time.

The Conservation District plans to use Ponds 1 through 3 as sedimentation ponds. These ponds have a wetted surface area of 7.0 acres, which is less than the desired surface area. With a desired flow of 500 cfs, the average detention time in each pond would be approximately 21 minutes. The pond detention time was determined by dividing the pond's storage volume by a design flow of 500 cfs and taking the average of the results. This would provide a total detention time of 63 minutes before water is discharged into the Upper Borrow Pit Canal. It will not be enough time to settle out the silt in the water, even with chemical coagulation. The existing configuration of the ponds is not conducive to good settling due to poor inlet design and the turbulence created as water flows from pond to pond.



No Scale

Borrow Pit Diversion Structure Plan

Document: FinalReport_Fig2-19.pub

Figure 2-20

Date: May 20, 2009

Santa Ana River Groundwater Recharge
Optimization Study

In order to increase the surface area and detention time, the Conservation District has the option to construct sedimentation ponds east of the Borrow Pit, and west of Greenspot Road (**Figure 2-21**). An existing 42-inch diameter pipeline that runs south-easterly splits the proposed area into two, creating two ponds with a combined area of approximately 29 acres, more than sufficient for adequate settling. With a proposed pond depth of 10 feet, the ponds east and west of the pipeline will have a detention time of about five and two hours, respectively. This would provide a total detention time of seven hours. Ideally, the basins should be 10 to 16 feet deep, with a length to width ration of 4 to 5 to 1. The settling ponds would also need to be designed to allow periodic removal of silts without impacting recharge operations.

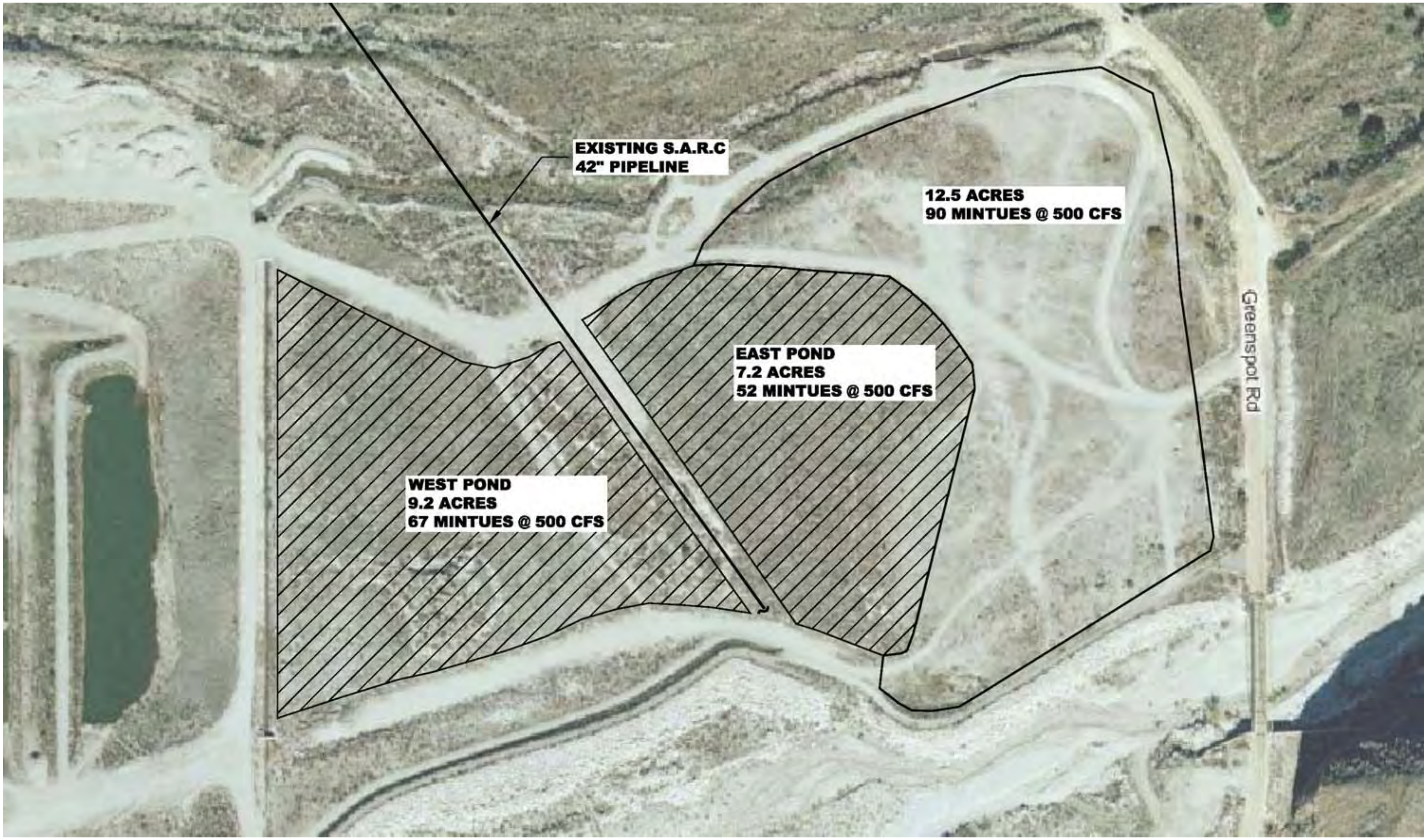
In order to divert flows to these ponds, a new open channel from the Main Canal to the pond east of the pipeline will be required downstream of the Parshall Flume. The open channel will need a concrete outlet structure with canal gates at the Main Canal to control flows to the proposed east pond. A new overflow structure on the south end of the east pond will be required to convey water to the west pond. Additional open channels will also be needed to convey water in the west pond to the Borrow Pit and/or to the Main Canal. The channels need to have uniform flow distribution to minimize turbulence as the water enters the basins, with an overflow structure out of the ponds back into the main channel. The conveyance to and from the sedimentation ponds can be done without the need of pumping facilities.

In addition to settling ponds, provisions may need to be made for coagulant addition. CDM report (2005) indicated that 10-15 mg/L of ferric chloride or 25-30 milligrams per liter (mg/L) of alum plus a coagulant aid may be needed to reduce turbidity from as much as 500 nephelometric turbidity units (NTU) to a range of 3-7 NTU. At a design flow rate of 500 cfs, chemical usage could be in the range of 13 to 40 tons per day. This would require significant chemical storage feed and mixing facilities prior to settling. Provisions for sludge removal, drying and disposal would also be required. Since ferric and alum sludges are quite gelatinous, dewatering may be difficult. In addition, the Regional Board may require that the settling ponds be lined to prevent iron or alum from migrating into the aquifer.

It should be noted that the use of settling ponds may not be sufficient to control turbid water and reduce clogging. A number of California agencies are investigating engineered treatment systems to pre-treat water prior to percolation to maximize infiltration rates.

2.5 SUMMARY AND ESTIMATED COSTS

Cost estimates for the additional and modified facilities for the three different flow rates are presented in **Figure 2-22.** The recommended modifications and additional facilities discussed above would provide the Districts with the ability to reach their established target amounts for groundwater recharge along with operational flexibility and redundancy. The District's ultimate goal is to convey a maximum flow of 500 cfs for recharge. It is understood that this flow rate is anticipated for short periods only; however, the improvements would provide the Districts with the capability to accommodate this flow on a temporary basis to maximize storage of surface water when it is available.



No Scale

Document: FinalReport_Fig2-22.pub

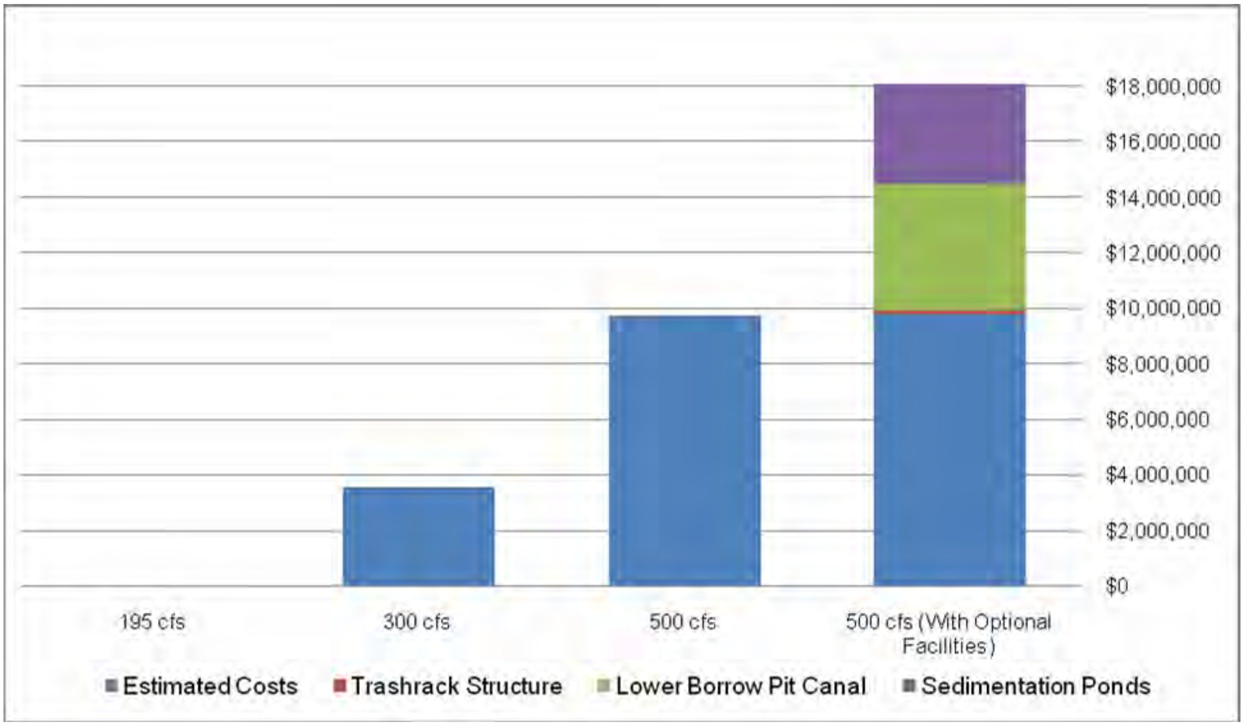
Date: May 20, 2009

Additional Settling Facilities

Figure 2-21

Santa Ana River Groundwater Recharge
Optimization Study

Figure 2-22
Estimated Costs at Different Flow Rates



As discussed above, additional and modified facilities are not required to convey 195 cfs to the existing groundwater recharge facilities. At a flow rate of 300 cfs, modifications to the Intake Structure will be required along with additional recharge ponds at a cost of $3,600,000.

In order to convey 500 cfs to the existing and new recharge ponds in the proposed Phases 1 through 3, modified and additional facilities described in the section above would cost approximately $9,800,000. The alternate design would cost approximately $9,800,000. Total costs to convey 500 cfs with optional facilities would cost approximately $18,100,000. The costs for the optional facilities are as follows:

Trashrack Structure	$181,000
Lower Borrow Pit Canal	$4,500,000
Sedimentation Ponds	$3,600,000

Details of the cost estimates are provided in **Appendix C**. Figure 2-22 includes the optional facilities noted above. The intent of these estimates is to provide a budgetary estimate only for the conceptual design of this project.

Section 3
Operations, Maintenance, and Monitoring

An important component in an overall plan to maximize spreading grounds recharge rates is an operations, maintenance and monitoring (OM&M) plan. Implementation of routine procedures that are uniformly followed will provide a means for recognizing the need for adjustments or maintenance in a timely manner to ensure optimal recharge rates are maintained. This section describes the mechanisms of clogging and key preventative measures. The combined experiences of many agencies are summarized in developing a list of "Best Management Practices" (BMPs) for recharge basin operations and maintenance. These BMPs are reviewed in light of site-specific conditions to develop a set of recommended measures for operations, maintenance and monitoring.

3.1 MECHANISMS AFFECTING INFILTRATION RATES

The infiltration rate is the volume of water moving into the soil or aquifer per unit of area and per unit of time. Infiltration rates are commonly expressed in units of length/time, such as inches per hour or feet per day. Infiltration rates in uniform soils without surface clogging are about equal to the vertical hydraulic conductivity of the soil (Bouwer, 1978). Hydraulic conductivities can vary from less than 4 inches per day for clay soils to more than 30 feet per day for coarse sands (Bouwer, 1999). A number of mechanisms affect the infiltration rate of a recharge facility including clogging, soil compaction, depth to groundwater, the presence of rocks, water quality vegetation, and subsurface geology including silt and clay lenses. The following briefly describes these mechanisms.

Clogging

The primary cause of infiltration problems for surface recharge operations is clogging. Clogging is most frequently caused by inorganic (such as silt and clay) and organic (such as algae and fine plant material) suspended solids in water accumulating on the surface of the infiltration surface. In addition to suspended matter in the water itself, additional suspended matter can be added by erosion within the basin due to excessive inflow rates, wave action and windblown dust. Biofilms forming on the basin bottom can contribute to clogging layers and reduce soil pore size (Bouwer, 1999).

Another cause of clogging is the precipitation of minerals such as calcium carbonate, and other less common mineral within the soil. This type of clogging generally occurs where the infiltration rates are low and evaporation rates are high. Source waters high in total dissolved solids can greatly increase chemical clogging. Chemical clogging is usually treated in the same way as physical clogging by the physical removal of the clogging material.

Because the clogging layers are much less permeable than the natural soil material, they reduce infiltration rates and limit the amount of water that can enter an aquifer. The thickness of clogging layers can range from 1 millimeter or less (biofilms, thin clay and silt layers) to several centimeters for thick deposits (Bouwer, 1999). Fine particles can also move downward into the soil accumulating on subsoil materials forming subsurface clogging layers.

Periodic removal of clogging layers is critical to maintaining infiltrations rates. However, cleaning activities such as disking and ripping without removal of the fine materials can drive clogging particles deeper into the soils making subsequent removal more difficult. Disking and ripping can leave the soil in a rough, loose condition creating high initial infiltration rates. However, when water is applied, the resulting soil ridges can cave and slough off, re-suspending fine particles. The muddy water redistributes and settles causing a new round of clogging (Bouwer, 1999).

The frequency in which the ponds are cleaned is dependent on the rate at which the percolation rate degrades. As noted in the following section discussing monitoring, it is important to develop information on percolation rates of the discrete basins and changes in those percolation rates with time. For example, a typical percolation rate in an unclogged pond at the recharge facilities is approximately 4 feet/day. If percolation rates are observed to be below 2 feet/day, the District may consider cleaning of the basins. However, this frequency of cleaning should be based on monitoring data collected and practical experience.

Soil Compaction

In addition to clogging from suspended materials, soils can become compacted due to mechanical cleaning and excessive water depths in the basins. The frequent use of mechanical equipment to clean basins can lead to compaction of the underlying soils by the weight of the equipment. Both wheeled and tracked maintenance vehicles cause soil compaction; however, tracked vehicles tend to cause less compaction due to their larger surface contact area compared to wheeled vehicles. Surface compaction tends to occur in the top six inches of soil (MWH, 2003).

Pond Depth

There is often a delicate balance between the need to store water in recharge basins during storms for later recharge and the effect of greater water depth on infiltration. Studies investigating the relationship between pond depth and infiltration rates have shown varying results. In some studies, infiltration rates increased due to the greater driving force as the water depth is increased. However, the increase is not linear (Bouwer, 1999). If the clogging layers are compressible, infiltration rates were observed to decrease with greater depth due to compaction of the clogging layers making them less permeable. If increased water depth does not result in greater infiltration rates, the hydraulic retention time in the basin (retention time = volume divided by inflow rate) will increase offering the water more exposure to sunlight and algae greater opportunities to grow. With infiltration, the algae can collect on the pond bottom forming a clogging layer which reduces infiltration. During photosynthesis, algae absorb carbon dioxide from the water increasing the pH and cause precipitation of dissolved calcium carbonate in the water forming a crust layer in the soil. In general, Bouwer recommends that water depths should not exceed 1 foot to minimize algal growth and soil compaction (Bouwer, 1999). Maintaining a shallow water depth is more beneficial in basins where infiltration rates are low as a means of reducing retention time.

Depth of Groundwater

When the depth to groundwater is sufficiently below ground surface and the water is clear, flow to the underlying water table is controlled by gravity and the infiltration rate is unaffected by depth to groundwater. As the depth to the water table decreases, flow becomes more lateral until it is controlled by the gradient away from the basin. Modeling has shown the transition from gravity to gradient controlled flow occurs when the depth to groundwater is about twice the width of the recharge facility. Thus, for a 50-foot wide recharge facility, a depth of water of less than about 100 feet would tend toward gradient-controlled flow. In this case, infiltration rates tend to decrease linearly, reaching zero when the water table is the same as the depth of water in the basin. Shallow groundwater levels also inhibit the draining and drying process that is necessary to restore infiltration rates (Bouwer, 1999).

In basins where clogging is present, unsaturated flow predominates and depth to the water table does not affect infiltration rates as long as the capillary fringe above the water table is below the bottom of the basin. Since the capillary fringe may be about 1 foot thick in medium sands (more for fine soils and less for coarse), as long as the depth to the water table water is more than about 3 feet, infiltration should be unaffected by depth to water. Based on this factor, it is important to monitor groundwater depths outside of the basin area to ensure that there is adequate depth to avoid infiltration rate reductions.

Presence of Rocks

If the soil contains a significant amount of large cobbles and boulders, disking or harrowing is not possible and ripping is needed to restore infiltration rates. However, ripping also causes the upward movement of stones in the soil profile causing them to accumulate at the surface. When sufficient stones cover the surface, infiltration can occur only between the stones reducing the effective infiltration area and the net infiltration rate. Suspended material accumulates in the soil between the stones where the fine materials cannot be easily removed by drying and scraping. One solution is to remove the stones to expose as much soil as possible (Bouwer, 1999). However, in basins where subsurface cobbles dominate as with the Santa Ana River facilities, cobble removal may not be practical.

Vegetation

Vegetation growth has been used in some locations to improve infiltration rates but can slow the drying process and inhibit cleaning as the vegetation must be removed to effectively remove the clogging layers. Vegetation provides shade that could reduce algal growth in the water and on the basin bottom. Root activity may keep fine soils more open increasing permeability. Several successful recharge programs utilize vegetation to enhance infiltration. However, the vegetation must be able to survive repeated and extended flooding. Typical vegetation that has been used includes Bermuda grass (*Cynodon dactylon*), para grass (*Panisum* purpurascens), bulrush (*Scirpus spp.*), meadow rush (*Juncus spp.*) and cattail (*Typha spp.*) (MWH, 2003).

Excessive vegetation can create wildlife habitat that then may become difficult to eliminate, especially if endangered species are present (Zimmer, 2009). Non-native invasive species, such as arundo, salt cedar (*Tamarix*), castor bean, and pampas grass can become established. Vegetation in the basins provides increased potential for insect breeding and rodent activity. Vegetation can also increase evapotranspiration losses. When removing vegetation, it is important that it be removed and disposed off-site to avoid creating a clogging layer caused by decomposing vegetation.

3.2 PREVENTATIVE MEASURES

Clogging is best controlled by prevention, removing the underlying cause of the clogging. A variety of mechanisms are available to prevent or reduce the impact of clogging. For surface water infiltration systems such as the Santa Ana River Recharge Facilities, pre-sedimentation to settle clay, silt and other suspended material frequently offers the best preventive measure. The use of coagulants such as alum or polymers can provide more efficient settling. To accomplish effective settling, it is important that dedicated desilting basins be provided. Desilting basins should be designed with adequate surface area to settle out the smallest anticipated particles. Jar testing is typically performed to evaluate chemical dosage and settling characteristics. For Santa Ana River water, CDM conducted bench scale testing to determine the approximate chemical dosages required to reduce turbidities to acceptable levels (CDM, 2005). Where present, removal of nutrients can reduce growth of algae or other forms of biological clogging. Disinfection has also been used to control biological activity especially with recycled water (Bouwer, 1999). Disinfection would not be desirable where the water has significant organic content that could result in formation of disinfection by-products.

A number of approaches have been used to combat clogging. Clogging in recharge basins can be controlled by periodically drying the basins and letting the clogging layer dry out, shrink, crack and curl up. This exposes underlying soil that is more conducive to infiltration. A secondary benefit of periodic drying is the interruption of the growth cycles of vectors such as midge flies and mosquitoes and reduction in algal growth.

For most basins, it is necessary to experiment with various wet and dry cycles to determine the optimum balance that maximizes recharge. Extended wet periods allow continued recharge at gradually decreasing rates as clogging occurs. The use of wet/dry cycles prolongs acceptable infiltration rates but the wetted acreage must be increased to allow basins to drain and dry out before they are returned to service. Wet/dry cycles also interrupt vector breeding cycles. Wet/dry cycle durations range from short (1-2 days each) to long (up to continuous). The most typical wet/dry cycles are in the 5-10 day range.

If periodic drying is not sufficient to restore infiltration rates, mechanical cleaning is the most effective method for removal of clogging layers. This is accomplished by mechanical scraping the top layer of soil using front-end loaders, graders or scrapers. Following removal, the surface is typically disked or harrowed to loosen any soil compaction caused by cleaning. However, the cost of cleaning must be weighed against the benefits derived from increased infiltration. If cleaning is carried out too frequently, the value of the water that cannot be percolated while the basins are out of service may outweigh the increased benefit of a higher infiltration rate.

Soil conditioners such as polymers and gypsum have been used successfully in the agricultural industry to condition hardened soils and may have an application at spreading facilities where soil conditions need to be improved. This measure is potentially useful in fine textured soils or waters that have a high sodium absorption ratio. Consequently, soil conditioners are not likely to be useful at the Santa Ana River facilities.

Basin cleaning and grading techniques can restore and maintain infiltration rates. As discussed previously, clogging layers should be physically removed by scraping and removal of the clogging material. Ripping of the basin bottoms should be minimized and only performed in the upper six inches to reduce the potential for rocks migrating to the surface.

Several recharging agencies have successfully utilized a ridge and furrow grading technique to maintain infiltration rates. At the Leaky Acres Facility in Fresno, CA, the City of Fresno uses a system that has proven effective in keeping at least half of the basin bottom relatively free of fines and permeable. After removal of accumulated fines and ripping, motor graders are used to cut furrows that are 6-8 inches, 10 feet wide and spaced on 30-foot centers. The edge of each furrow is sloped at a 6-10 percent grade. Spreading basins are kept full to allow wind-driven wave action to move accumulated fines to the bottoms of the furrows (MWH, 2003). The narrow configuration of most SAR basins may make furrow construction difficult and minimize wave action.

The Arvin-Edison Water Storage District operates a large water spreading facility in Kern County, approximately 25 miles southeast of Bakersfield. When infiltration rates decline, the District uses motor graders to scrape fines into windrows. Then, a paddle wheel scraper removes the windrows which deposits the fines on the tops of the levees. The basins are then ripped to mitigate the compaction caused by the heavy equipment (MWH 2003). This method may not be practical at the Santa Ana River recharge facilities, because of the physical configuration of the basins and the presence of large boulders. Disposal of fines on the levees may result in reintroduction of clogging materials due to erosion from rainfall.

Vegetation can be managed by either physical removal or chemical control. Physical removal of vegetation is typically performed when basins are cleaned. Vegetation debris should be removed and disposed of rather than buried. Chemical control of vegetation using herbicides can be performed without significant environmental impact. In an investigation of recharge for LACDPW, MWH contacted an independent pest control advisor, Robert Brenton, who has worked with LACDPW in an advisory role for nearly 20 years. Mr. Brenton identified three acceptable herbicides:

Glyphosate (Trade name: Roundup, Rodeo and Accord)
Imazapyr (Trade name: Stalker)
Triclopyr (Trade name: Garlon and Pathfinder).

It was recommended that these herbicides are best applied prior to the rainy season and when depth to groundwater is likely to be greatest (MWH 2003).

MWH's review of basin management practices with Conservation District staff suggests that vegetative growth is not a significant factor in limiting recharge operations. Therefore, we do not recommend the routine use of herbicides at the recharge facilities. Notwithstanding Mr. Brenton's findings described above, if herbicides are contemplated, the potential environmental and water quality impacts should be carefully reviewed.

3.3 BEST MANAGEMENT PRACTICES

Based on the extensive collective experience gained from the evaluation of recharge basin operation by many agencies, Dr. Herman Bouwer developed the following list of design and management best practices:

1. Use shallow level basins and water depth not exceeding one foot.
2. Design inlets and banks to minimize erosion.
3. Pre-treat water to remove suspended solids and, if desirable, nitrogen phosphorus and organic carbon.
4. Develop an optimum sequence of flooding drying and cleaning of basins. Remove clogging layers before disking or ripping, and then smooth and slightly compact the soil before refilling.
5. Keep groundwater levels at least 3 feet below the basin bottom if infiltration is controlled by a clogging layer and the soil below the clogging layer is unsaturated, and at least one infiltration system width below the bottom some distance away from the basin if the basin bottom is clean and there is direct hydraulic connection between the basin and the aquifer
6. Design the system with an adequate number of basins and total surface area so that basins can be properly dried and cleaned for infiltration recovery. Base land requirements on the lowest anticipated infiltration rates (winter, rainy period, low quality water, etc.). Select sites with good soil and groundwater conditions. Test changes in basin management first on a small basin before changing the entire system (the land area limitations at the Santa Ana River recharge facilities may preclude use of this particular BMP).

Some of these recommendations may be applicable to the Conservation District's facilities while others are not. Specifically, the Conservation District operates their basins at greater water depths than the 1 foot recommended by Dr. Bouwer without adverse results. Design of banks and inlets to minimize erosion is a reasonable goal that must be weighed against land availability topography. Consequently, no changes are recommended to the existing practice.

Pre-treatment of water prior to recharge is expected to have a significant effect on infiltration rates by minimizing a significant source of clogging. As discussed in Section 2, construction of engineered desilting basins is recommended. However, adequate jar testing and evaluation must be performed prior to detailed design to ensure that the proposed design will perform as desired.

Determining the proper groundwater level criteria will require experimentation and monitoring. The Conservation District will need to implement the monitoring program as described in Section 3.5 and evaluate the results to determine specific criteria for depth to groundwater. Once these criteria are established, they can be used to control basin operations.

3.4 CURRENT PRACTICES

The current OM&M practices of the Conservation District consist of:

- Checking the source water for clarity – The Conservation District visually observes the water clarity to determine its acceptability for recharge. This approach is very subjective, dependent on the observer and type of sediment content. However, no specific numerical objectives have been established. At times, highly turbid water has been recharged resulting in clogging.
- Periodic rotation of the basins when infiltration rates decline – The Conservation District typically operates basins continuously for 3-4 weeks before allowing them to dry. Since vectors are not a significant issue more frequent drying has not been required.
- Removal of vegetation overgrowth – The District periodically removes vegetation; however, vegetation growth is minimized by keeping the basins flooded for extended time periods.
- Removal of accumulated sediment – The Conservation District typically removes accumulated sediment about every three years. The cost of sediment removal and disposal has impeded more frequent cleaning.
- Monitoring – Total flows are monitored at the Parshall Flume. However, water quality and infiltration rates are not monitored limiting data that can be analyzed to evaluate system performance. Groundwater levels are monitored at approximately monthly intervals.

The current O&M practices are generally acceptable. However, the Conservation District should avoid recharging water that contains high levels of suspended solids and turbidity without pre-treatment. In addition, the lack of sufficient monitoring activities limits the ability to evaluate the performance of the basins and the improvements that are obtained following basin maintenance. Specific recommendations are presented in the following section.

3.5 RECOMMENDATIONS

The following daily and periodic activities are recommended to maintain the recharge goal of 500 cfs. While not absolutely required for recharge, these recommendations reflect best management practices to optimize recharge and minimize required maintenance.

Operations

The following recommendations apply to routine operations of the spreading facilities.

Water Quality

A critical factor in maintaining infiltration capacity is to recharge the best quality water. It is recommended that the following criteria be used to determine when to divert water:

- Collect samples of sediment from the watershed and prepare a set of sample bottles containing varying amounts of sediment to use as a visual reference to estimate the sediment content of the water.
- Utilize turbidity or visual comparisons to determine the acceptability of the current recharge water.
- Avoid recharging water containing more than 200 mg/L of suspended solids or having a turbidity exceeding 100 Nephelometric Turbidity Units (NTU). This is important for keeping silt and clay from depositing around the rocks and cobbles and clogging the basins.
- Bypass water not meeting this criterion or divert to settling ponds.
- Conduct jar testing of potential coagulants to determine the effectiveness of pre-treatment.
- Evaluate the design parameters for desilting and evaluate the cost of treatment.

Pond Depth

Seepage into the Borrow Pit has been observed when water is recharged for extended periods of time in Basin 10. To assure the stability of the Borrow Pit levee, recharge should be discontinued in this basin if seepage occurs.

Wet/Dry Cycles

The following criteria should be used to determine whether particular basins should be used for recharge:

- Monitor groundwater levels and infiltration rates to determine when to initiate basin drying. Once a pattern of infiltration rate performance is established, implement a wet/dry cycle that maintains relatively high infiltration rates. Discontinue recharge and commence dewatering and drying at a point prior to significant infiltration rate decline.
- Experiment with different durations of wet and dry cycles and maintain adequate monitoring records to document infiltration performance.
- Establish an optimal wet/dry ratio based on monitoring results. Using the current infiltration rates, it is expected that a 2:1 or 3:1 cycle may be suitable. For example, recharge would take place for 2-3 weeks followed by one week to drain and dry. This may allow a monthly rotation of basin operations.

Maintenance

The following activities should be undertaken to maintain the recharge facilities:

- At least once a year, remove and physically dispose of vegetation along the clogging layer.
- Eliminate dense vegetation that can hide carcasses and result in the introduction of botulism into the aquatic food chain. In the event of severe botulism, drain the basin and notify the Department of Fish and Game.
- Control vegetation above the water line. Do not allow basins to become habitat for sensitive species.
- Scrape and remove the clogging layer from basins once a year or as indicated by declining infiltration rates and dispose of fines.
- Following scraping, rip top six inches to loosen deeper soils.
- Utilize tracked equipment for basin cleaning to limit the amount of soil compaction.
- Select one or two basins having adequate size to experiment with ridge and furrows to evaluate their effectiveness in extending basin operations.
- If rock cover in recharge basins becomes excessive, large rocks should be removed and transported off-site.

Physical maintenance of equipment (Cuttle Weir, diversion structure, Parshall flume, canals, tunnels and culverts) should include:

- Periodic inspection of equipment operability
- Removal of rocks, vegetation and debris – Following installation of the gabion barrier and log boom, the diversion facilities should be maintained to clear any accumulated debris and rocks.

Monitoring

Monitoring of recharge basin performance is valuable for determining the effectiveness of operations and maintenance procedures. Data will be used to ensure that methods being employed are continuing to maintain expected infiltration rates and quality of water being diverted.

The following water quality data should be regularly monitored:

- Turbidity – Because turbidity can be easily monitored in the field it is recommended that the Conservation District purchase a field turbidity meter to measure turbidity data. The Hach Model 2100P is a battery-operated field turbidity meter that can be carried by Conservation District operating staff. Turbidity should be measured and recorded daily at the Cuttle Weir. During storm events turbidity should be monitored hourly. In the absence of treatment, highly turbid water should be bypassed down the river channel.

- Suspended solids – Suspended solids is measured by laboratory analysis of water samples. Since suspended solids results cannot be obtained immediately for operation decision making, it is not useful for routine operations. However, a correlation can be made between suspended solids and turbidity so that turbidity can be used for operations. As discussed previously, sample bottles containing varying amounts of suspended solids can also be used as a visual indicator of water quality. Suspended solids should be visually checked and recorded daily.
- Data logging – Water quality data should be stored in a database or spreadsheet to allow evaluation in comparison to infiltration rates. Note the flow rate, source of water (dam release, storm flows, and imported flows), date, time, and weather conditions (raining, drizzle, clear).

The following recommendations are made regarding monitoring of infiltration rates:

- The Conservation District should consider the installation of V-notch or other weirs appropriate for the anticipated flow ranges at each basin inlet and outlet to allow measurement of flow rates into recharge basins to compute infiltration rates.
- Infiltration rates should be calculated based on the difference between basin inflows and outflows divided by the wetted area of the basin. Infiltration rates should be computed and recorded for each operating basin at weekly intervals.
- Infiltration rates should be reviewed to determine when to discontinue recharge at specific basins and commence drying.
- The Conservation District should evaluate the correlation between turbidity data and infiltration rates annually.

High groundwater levels due to groundwater mounding can significantly reduce infiltration rates. The Conservation District should monitor groundwater levels and note when the elevation of the water table approaches typical ground surface elevations. There are two general locations where mounding is expected to occur; east of the fault identified in TM-2 (Appendix B), and west of the fault. For monitoring of groundwater levels east of the fault, the Conservation District should monitor MW-1, MW-3, SB-1, and SB-2 which were installed during this study. All of these monitoring wells were fitted with automated dataloggers and transducers by the MWH Team.

For monitoring of groundwater elevations west of the fault, the Conservation District should monitor wells SB-3 and MW-2 (also fitted with automated dataloggers and transducers), as well as SBVWCD #3 and SBVWCD #2 as shown on Figure 3-1 of TM-2 (Appendix B).

When groundwater elevations approach approximately 3 feet below the ground surface elevation, recharge operations should be moved to locations where the depth to groundwater is greater. As record keeping of flows and groundwater elevations are developed, it will be possible to predict the rate of groundwater mounding and the approximate flows which will result in groundwater levels at or near the ground surface.

Anticipated Performance

Implementation of the recommendations made in this section is expected to improve the performance of the recharge basins. However, it is not possible to estimate the improvement that would occur with implementation. MWH recommends that the Conservation District and Valley District commence monitoring of basin performance as soon as practicable to establish a baseline for measuring performance. As individual measures are implemented, improvements in performance can be documented and operations and maintenance methods modified accordingly.

Section 4
References

Asano, Takashi 1985. *Artificial Recharge of Groundwater*. Butterworth Publishers. Stoneham, MA.

Bouwer, Herman, 1978. *Groundwater Hydrology*. McGraw-Hill, New York, NY.

Bouwer, Herman , 1999. Chapter 24 - Hydraulic Design of Infiltration Systems for Artificial Recharge of Groundwater and Water Reuse. *Hydraulic Design Handbook*. Larry W. Mays, Editor-in-Chief. McGraw-Hill, New York, NY.

CDM, 2005. Seven Oaks Dam Water Impacts Study. Prepared for the Upper Santa Ana Water Resource Association in conjunction with East Valley Water District. December 8, 2005.

MWH, 2003. Percolation Optimization Study – Final Report. Prepared for Los Angeles County Department of Public Works. November 2003.

MWH, 2005. *Water Treatment Principles and Design*. Second Edition. John Wiley & Sons.

MWH, 2008. Santa Ana River Groundwater Recharge Optimization Study, Technical Memorandum 1 – Documentation of Existing Information and Field Work Plan – June 16, 2008. (Note: This memorandum is included in this document as Appendix A)

MWH, 2009. Santa Ana River Groundwater Recharge Optimization Study, Technical Memorandum 2 – Documentation of Field Work and Recharge Capacity Estimate – Draft, January 6, 2009. (Note: This memorandum is included in this document as Appendix B)

Science Applications International Corporation (SAIC), 2007. Technical Memorandum: Seven Oaks Dam Economic Analyses, December 2007.

SBVMWD and WMWD, 2007. Santa Ana River Water Right Applications for Supplemental Water Supply: Community Report. January 2007.

SBVWCD, 2008. Final Environmental Impact Report for the Upper Santa Ana River Wash Land Management and Habitat Conservation Plan, #SCH2004051023. November 2008.

Zimmer, Ken, 2009. Personal communication. April 3, 2009.

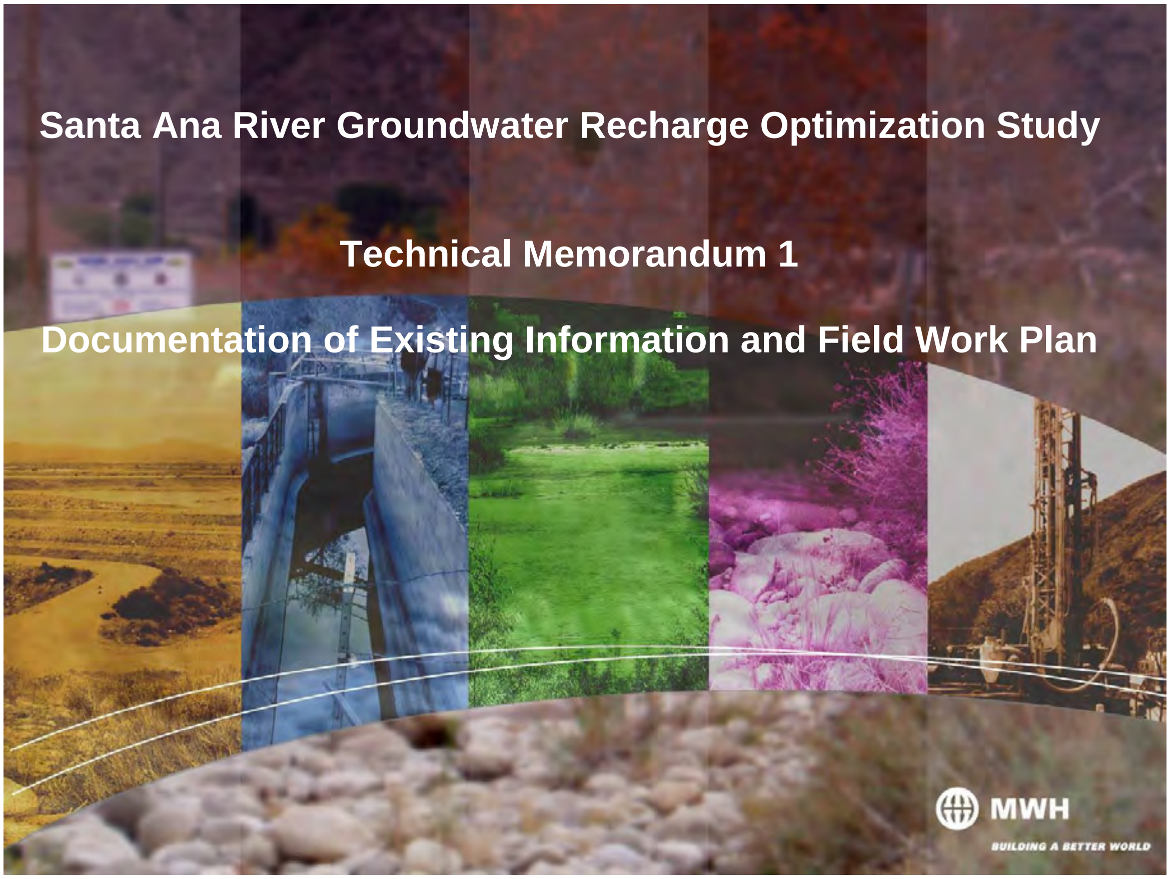
Appendix A

Technical Memorandum 1:
Documentation of Existing Information and Field Work Plan

Santa Ana River Groundwater Recharge Optimization Study

Technical Memorandum 1

Documentation of Existing Information and Field Work Plan



Prepared for:

San Bernardino Valley Water Conservation District
And
San Bernardino Valley Municipal Water District

By:

MWH Americas, Inc.
GEI Consultants

Revision 1 -- June 16, 2008

Table of Contents

Section Name **Page Number**

Section 1
Introduction

The San Bernardino Valley Water Conservation District (SBVWCD), in association with the San Bernardino Valley Municipal Water District (SBVMWD), "Districts" retained MWH Americas, Inc. (MWH) and GEI Consultants (collectively referred to as the MWH team) to evaluate the Districts recharge facilities adjacent to the Santa Ana River in San Bernardino County, California. The general purpose of this work is to determine the need for and technical viability of additional or modified facilities to capture native and imported surface waters for groundwater recharge to meet the recently-adopted Upper Santa Ana Integrated Regional Water Management Plan (IRWMP). This work is being completed under a contract for the ***Santa Ana River Groundwater Recharge Optimization Study*** dated April 16, 2008 between MWH Americas, Inc. and the San Bernardino Valley Water Conservation District.

1.1 BACKGROUND

SBVWCD owns and operates surface water diversion and conveyance facilities and groundwater recharge spreading facilities at the project site (define the project site). The SBVWCD recharge facilities have been in place since the 1930s, for the purpose of diverting and recharging water from the Santa Ana River. The SBVWCD was formed in 1932 to obtain water for conservation purposes, essentially replacing the Water Conservation Association formed in 1910 (SBVWCD, 1994). A relatively new development in recharge operations is the construction of the Seven Oaks Dam, approximately 1 mile upstream of SBVWCD's diversion. Construction of the dam began in August of 1994, supervised by U.S. Army Corps of Engineers (USACE). The dam is an earth and rock fill type, and during construction of the dam, material was excavated for the dam from an approximately 120 acre area that formerly contained recharge ditches operated by the SBVWCD, referred to herein as the "Borrow Pit". The dam was completed in November of 1999. Subsequent to that time, three infiltration ponds were constructed at the east end of the Borrow Pit.

The remaining recharge basins and the Borrow Pit (Figure 1) are located west of Greenspot Road and north of the Santa Ana River. Flow from the Santa Ana River below the Seven Oaks Dam is diverted at a structure where water flows through an underground box culvert (Intake Structure). This culvert connects to a concrete "sandbox" structure which allows for the expulsion of excess debris or sand in the water. Flow then crosses beneath Greenspot Road where flow can be measured at the Parshall Flume. Water can then be diverted to various basins including the Borrow Pit.

1.2 PURPOSE AND SCOPE

The MWH team is completing a number of tasks to assess the current capabilities of diversion, conveyance, and recharge facilities and determine what improvements, if any, are required to achieve the recharge goals of the IRWMP. This assessment includes extensive field work. The purpose of this document is to summarize existing information gathered to date, and to provide a work plan for field investigation efforts planned in the near future based on that information. Initial efforts of the MWH team have consisted of:

- Meeting with SBVWCD and SBVMWD staff to review the nature and amount of existing data about the site
- Site reconnaissance of diversion, conveyance, and recharge facilities
- Review of data housed in SBVWCD's extensive library
- Review of data and meeting with Mr. Wes Danskin, of the U.S. Geological Survey (USGS)
- Review of data on the Borrow Pit from the USACE
- Requests for geologic data from the California Department of Water Resources (DWR) - data still pending
- Interviews with facilities operators and staff on field conditions and typical recharge operations and field observations
- Completion of diversion and conveyance flow testing
- Completion of initial percolation testing and analysis

The purpose of the workplan is to summarize this existing data to the extent that it guides future field testing and data collection efforts. More detailed evaluation of this data will be provided in subsequent reports. The field work is designed to evaluate the ability of the existing facilities to meet the recharge objectives identified in the IRWMP and resolve currently-existing data gaps regarding site conditions.

1.3 WORKPLAN ORGANIZATION

This workplan is organized as follows:

- Section 1 introduces the project goals and provides background information;
- Section 2 provides a summary of the existing information on conveyance and diversion construction, flow analysis, geological conditions, and the field testing goals;
- Section 3 discusses the proposed field testing program;
- Section 4 describes the scheduling and reporting of field work; and
- Section 5 provides references utilized during development of this work plan.

A Health and Safety Plan is provided as Appendix A.

Figure 1. SBVWCD Facilities Location Map

Section 2
Summary of Existing Information

This section provides a summary of existing information on the SBVWCD recharge facilities, description of field testing to date, summary of existing geologic data, and outlines the goals of further field testing designed to fill data gaps in existing information.

2.1 CONVEYANCE AND DIVERSION

Prior to development of this data summary and work plan, water needed to be released from Seven Oaks Dam, providing the opportunity to conduct flow testing of the diversion and conveyance works at relatively high flow rates. After this testing, water released from the dam at lower flow rates provided an opportunity to conduct initial percolation testing of existing percolation ponds and ditches. This section discusses historical documentation of conveyance and diversion facilities, as well as the results of flow testing of both the diversion and conveyance facilities, and existing percolation ponds and ditches.

2.1.1 Construction History and As-Built Information

The SBVWCD library contains a variety of historical information and drawings of existing facilities. The most relevant of these are summarized in Table 1.

Table 1 - Summary of Pertinent Information in SBVWCD Files

Title	Date	Description
Borrow Pit Topo	4/18/2008	DWG file, ESRI ArcMap Document
IRWM Plan	11/2007	Upper Santa Ana Watershed Integrated Regional Water Management Plan
USA IRWMP Highlights	11/21/2007	Highlights of the Upper SA Watershed Integrated Regional Water Management Plan
Optimization Study	4/23/2008	JPG file, Basin 3; Diversion Gates; SWP pipe
Observation Well MPE		SBVWCD
WCD Santa Ana Spreading		From 1912 to 2008
Basin 10 Head Wall 1		
Basin 10 Head Wall 2		
Conduits Plans Santa Ana Weir	5/1/1930	Design
Cone Camp Hydrographs		June 1998 ~September 2007
District Spreading Basin Storage Capacity	1/8/2008	
Diversion Tunnel Profile and Outlet Work details		SBVWCD
Draft 2008 EI	2007-2008	Engineering Investigation Bunker Hill Basin

Title	Date	Description
Existing facilities	12/1/2007	SA River Spreading Grounds Existing Facilities and Improvement Project
Facilities Overview	1/1/2008	Diversions and Canals Leading into SBVWCD Facilities
General Layout Santa Ana Weir	5/1/1930	
Headworks Plan -1930	5/1/1930	
Headworks Plan -1930- Alternate	5/1/1930	
Parshall Flume Readings from SA River	1/14/2008	From 1938 to 2007
Map Archive Index		
Monitoring Wells DTW		Observation Data
Operations Manual	3/1/1994	Operational Management Manual SBVWCD
Overview of Diversion Points		Overview of SBVWCD Diversion Points
Profile of Alternate Conduit 1930		
Proposed Build Out of the Borrow Pit	10/18/2007	Design
Santa Ana River Historical Spreading		From 1938 to 2007
SBVWCD Basin Storage		SBVWCD Basin Storage Capacity for SAR and MC
SBVWCD 4 Well Log	4/19/1974	One Driller's Lithology Log to 240 ft bgs
SAR1_SAR2_Lithology		Driller's log and E-log for SAR1 and SAR2
Schematic of Water Control Features		Figure 2.2-1 Schematic of Water Control Features and Gages in the SA River Canyon
Topo West of Borrow Pit		Scale 1" = 200'
Venturi Flume 1933	3/1/1933	Design
Weir Structure Topo 2000	2/9/2000	by Schmidt Geomatic Mapping

2.2 SITE TESTING AND OBSERVATIONS

A flow test was conducted by the Districts on March 27, 2008, in coordination with a variety of other agencies. This testing allowed the MWH team to observe flow conditions in the conveyance facilities between the Diversion Works and the SBVWCD recharge facilities. Interaction between the MWH team and the Districts staff during the preparation and conducting of the field test allowed for an exchange of operational knowledge of the conveyance system.

During the flow test, MWH and Districts staff observed the physical condition of diversion and conveyance facilities; photographs were taken and recorded. at the following facility locations (Figure 1):

- Pool behind Seven Oaks Dam
- Plunge pool – outlet release point from Seven Oaks Dam
- Cuttle Weir – intake structure with six gates
- Conduit – tunnel between the river intake structure and Sandbox

- Sandbox – Sandbox structure with two outlet gates
- Rock Structure – Rock structure near northfork outlet, downstream of Sandbox
- Bridge over Canal – downstream of Rock structure
- Greenspot Road – culvert under Greenspot road
- Parshall Flume – flow measurements were automatically recorded
- Diversion Structure (Borrow Pit gate was opened when flow reached ~320 cubic feet per second (cfs) at the Parshall Flume)

Dam Release Rate and Flow Measurements

The flow test involved communication between Districts personnel and dam operators such that various release rates from the dam could be tested. The dam tenders (reservoir regulation staff) provided the requested flow by executing the settings needed to obtain the release flow rate using a rating curve and reservoir water was released into the plunge pool below the dam. The resulting flow rate was measured downstream from the point of release by the United States Geological Surve (USGS) gage number 11051499 (Mentone Station), located immediately upstream of the Cuttle Weir. Flow was also monitored throughout the test at the Parshall Flume located downstream of the Greenspot Road culvert.

Observations were made of the conveyance facilities during five requested dam release rates of: 150, 200, 250, 325, and 400 cubic feet per second (cfs), as shown in Table 2 (Eftehari, 2008).

Table 2- Seven Oaks Dam Release Summary

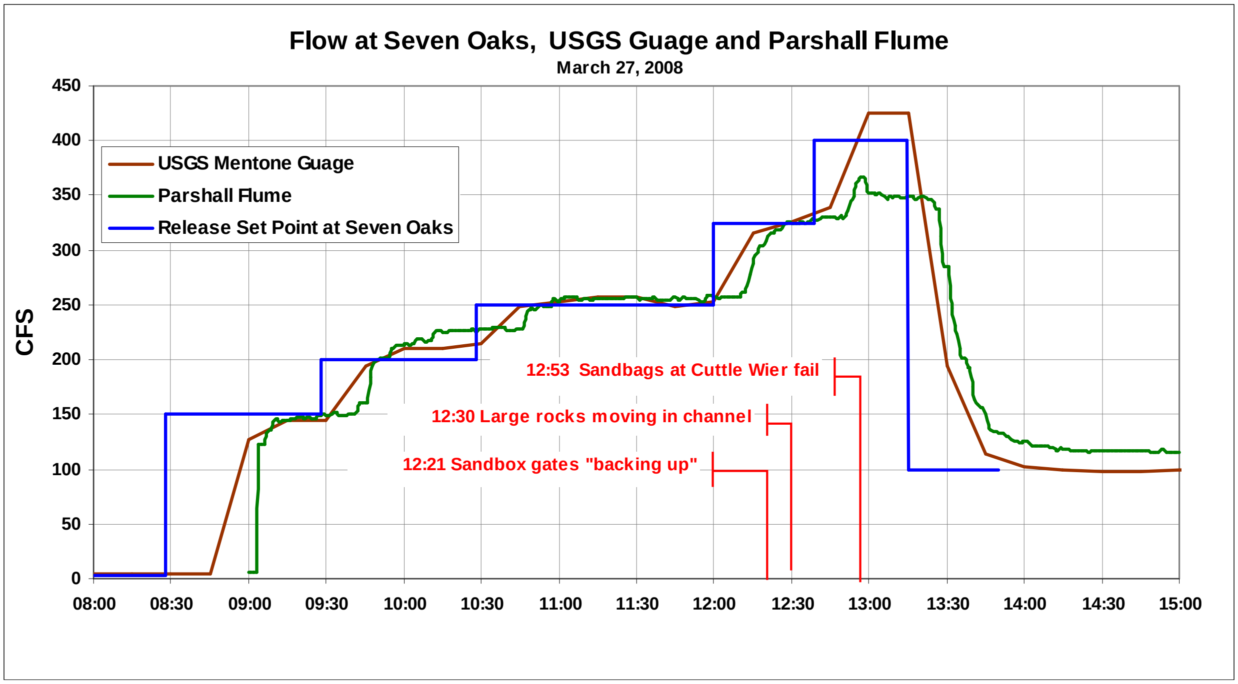
Date	Time	Reservoir Level (Staff)	Reservoir Level (Digital)	Release (cfs)
03/27/2008	0730	2259.50	2259.31	3.0
	0828	-	2259.26	150.0
	0928	-	2259.17	200.0
	1028	-	2259.90	250.0
	1200	-	2258.98	325.0
	1239	-	2258.98	400.0
	1315	-	2258.62	100.0
	1350	2259.00	2258.58	100.0

Release rates at the Seven Oaks Dam, as well as flow measured at the USGS Mentone Station (Agajanian, 2008), and measured at the Parshall Flume (Flordelis, 2008) are summarized in Figure 2. Figure 2 also shows the times of key observations during the flow test (which are discussed in more detail below).

Following the dam release setting of 400 cfs, the temporary sand bag dam that increased the height of the Cuttle Weir gave way at a measured flow of 390 cfs; a peak flow of 414 cfs was measured at the USGS gage prior to the end of the test. A peak flow of 367 cfs was measured downstream at the Parshall Flume that corresponded to approximately the same time as the USGS gage peak flow.

Districts staff provided a summary of photos taken at the Cuttle Weir and the Greenspot Road culvert for each of the flow release set points. The MWH team collected all field notes recorded for each observation point and have consolidated them into an Excel file for record keeping. Time and flow were written on corresponding representative photos of the observation points as a visual reference for the flow test. Preliminary hydraulic calculations were made by the MWH team that utilized the recorded flow test information and the as-built design drawings provided by SBVWCD.

Figure 2 - Flow Measurements During the March 27 Flow Test



Key observations of the diversion works and conveyance facilities during the March 27 flow test follows include:

- The silt and sand content of water at the diversion structure was high the first hour to hour and a half. The color initially was “chocolate milk”, but eventually cleared to “milky green”.

- The “practical” flow limit for most of the conveyance system was reached at approximately 300 cfs due to high velocity and turbulent flow in unlined channel sections. The “practical” flow limit is loosely defined as the flow at which field observations suggest a high flow may cause conveyance failure such as overflow or erosion. Erosion of channel and movement of boulders started at about 300 cfs and was pronounced at flows greater than 300 cfs. Locations where rocks were heard during observations (as the flow reached 300 cfs and above) were downstream of the Sandbox, upstream and downstream of the Rock structure, the bridge over the canal, near Greenspot Road, upstream of the Parshall Flume, and upstream of the Diversion Structure.

- At the Diversion Structure, the canal gate to the spreading grounds below the Borrow Pit was limited to roughly 300 cfs and the South Gate structure was opened for flows above 300 cfs.

- The field observations combined with a reported weakness located at a sharp curve in the canal downstream from the Diversion Structure indicated flow in the canal to the west spreading grounds would not be advisable over 300 cfs.

- The intake structure above the Cuttle Weir was affected by trash and debris during the flow testing which “backed up” water and caused higher water levels behind the Cuttle Weir (contributing to failure of the weir). Potential short term solutions to this may be to remove some sediment behind weir, increase the height of weir structure, and/or remove the I-beams at the weir so that debris passes through the diversion structure.

- The Greenspot Road culvert had little freeboard room in case of any debris clogging part of the opening. Only 3-4 inches were left on the upstream opening at the highest flow for the test, which was reported to be 414 cfs at the USGS Mentone Station and 367 cfs at the Parshall Flume.

Subsequent Flow Measurements

On April 18, 2008, water level and structural measurements were made on the conveyance and diversion system to better appreciate the capacity of the SBVWCD facilities. The results of these flow measurements are currently being evaluated. Water levels at the flow rate of 140 cfs were taken at the flowing areas:

- The Cuttle Weir
- The Sandbox
- The Rock Structure below the Sandbox
- The channel below the Rock Structure
- The Bridge over Canal

- The Greenspot Road culvert
- The Parshall Flume
- The diversion structure below the Parshall Flume

2.3 INITIAL PERCOLATION TESTING

After completion of the high flow test, estimates of percolation rates at selected ponds downstream of the Borrow Pit were obtained using the percolation testing methods described in the following sections. The percolation tests generally consisted of a constant flow test for SBVWCD recharge ponds 9 through 17, and D west of the Borrow Pit, and specific percolation testing of Pond 17 and Borrow Pit Pond 1 using a falling-head test. From March 28 to April 21, the flow rate into the recharge pond west of the Borrow Pit was approximately 140 cfs, or 280 acre-feet/day (AF/day). Recharge pond capacity values provided by the SBVWCD indicate that the total wetted area for ponds 9 through 17, and D is about 56.7 acres. This acreage does not include conveyance and diversion facilities between individual ponds. No outflow occurred from the last pond (D), suggesting a percolation rate for the system during this time period was about 4.9 feet per day (ft/day, 280 AF/day divided by 36.7 acres). No outflow occurring from Pond D suggests that the wetted area could still have been increasing during this period and that the total wetted area could have been less that the estimated 56.7 acres. Because the wetted area does not include conveyance and diversion facilities, the percolation rate is likely less on a per acre basis.

Percolation Testing Pond 17

A falling-head percolation test was performed on Pond 17 using a pressure transducer and remote telemetry data logger that transmitted water level data via a modem. For these falling-head tests, Pond 17 was filled by Districts staff and allowed to percolate during which time water levels were recorded every ten minutes. The rate of decrease in water level provides an estimate of the percolation rate. A falling-head percolation test is a very useful and reliable method for obtaining percolation rates, particularly when inflow and outflow from the test pond can not be reliably measured, or then the wetted area is not accurately known. Because the recharge ponds are designed to operate at full water levels, and percolation rates are a function of area and water level head, only about the first eight hours of percolation were used to estimate percolation rates. After about eight hours, percolation rates at Pond 17 decreased due to decreases in area and in water level head. Plots of water level over time produce a linear water level decline which is a function of percolation rate and evaporation rate. Evaporation rates over an eight hour period with percolation rates greater than one foot per day are considered negligible. A plot of the first test on Pond 17 is provided in Figure 3 as an example.

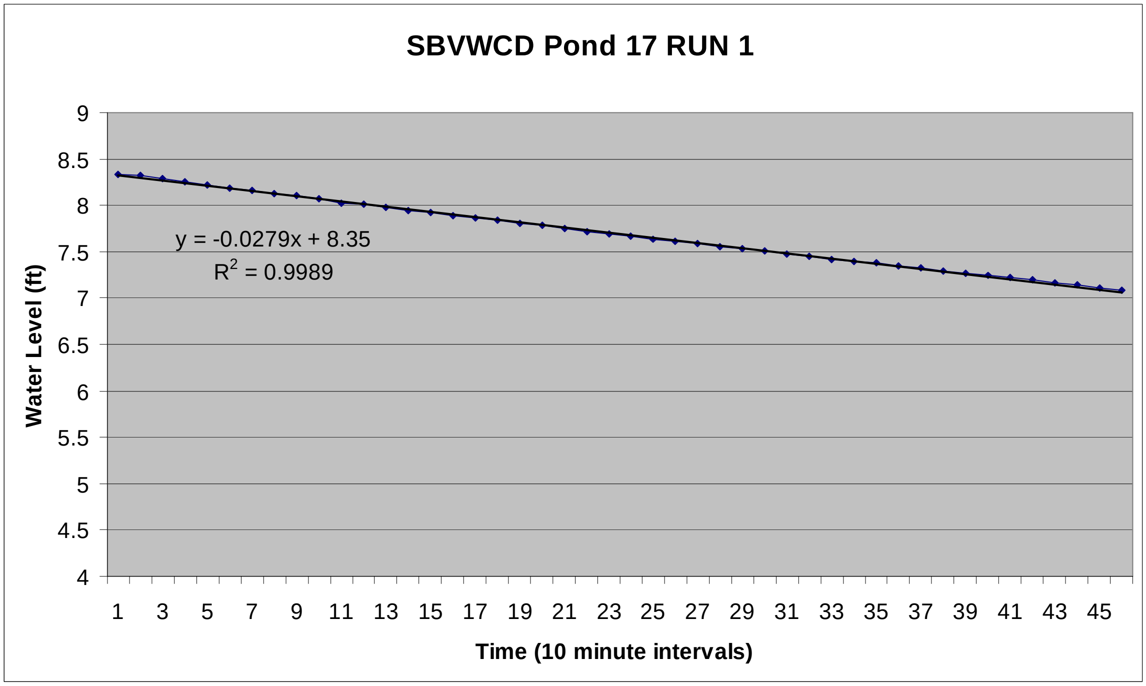


Figure 3 - Percolation at Pond 17

Percolation rates at Pond 17 ranged from about 3.83 to 4.19 ft/day and averaged about 4 ft/day.

Percolation Testing at Borrow Pit

Percolation testing at Borrow Pit Pond 1, was in progress during writing of this document. The procedure for percolation rate testing at Borrow Pit Pond 1 is the same as that used in Pond 17. Results from percolation testing of Borrow Pit Pond 1 produced an estimated percolation rate of about 1.2 ft/day. This percolation rate is much slower than the 4 ft/day estimated at Pond 17 and the estimated 4.9 ft/day for the SBVWCD basin system, excluding conveyance and diversion facility areas. The slower percolation rate may be partially due to the design of Borrow Pit Pond 1. Long narrow deep ponds like Pond 17 tend to have a higher percolation rate than do large rectangular shallow ponds like Borrow Pit Pond 1, potentially due to "edge effects" of water leaking laterally as well as horizontally.

Observations of Rising Groundwater during Borrow Pit Pond 1 Testing

Rising groundwater was observed and photographed flowing into Borrow Pit Pond 3 during the installation of the telemeter equipment in Borrow Pit Pond 1 on May 10. The source of this groundwater is apparently from the east or north of Pond 3. The rising water started in Borrow Pit Pond 3 before the filling of Borrow Pit Pond 1, meaning that it is not completely associated with the testing of Pond 1. However, during a second visit to Pond 3 on May 19, during the testing in Borrow Pit Pond 1, the rate of rising water in Pond 3 did appear to be higher. This suggests that some leakage from Pond 1 was occurring. The location of the rising groundwater in Borrow Pit Pond 3 is at the northeastern end of the pit at its lowest level. Large areas of rising groundwater were also noted and photographed in the main Borrow Pit area near the center.

This rising water then flows west to the end of the main Borrow Pit where a large pond has developed.

2.4 SUMMARY OF EXISTING DATA ON HYDROGEOLOGIC CONDITIONS

The following section provides a summary of the general geologic conditions that exist at the site, observations noted by field personnel, and a summary of available information gathered to date.

2.4.1 General Geology

The Santa Ana River recharge facilities are located in the northeastern portion of the Bunker Hill groundwater basin near the boundary of relatively impermeable basement rocks of Mesozoic age and relatively recent fluvial and alluvial deposits which fill the groundwater basin. This boundary is formed by active faulting along the San Andreas Fault zone. The San Andreas Fault zone consists of two nearly parallel branches through the most of the San Bernardino area. In the vicinity of the recharge facility, the fault zone trends in a trends southeast-northwest direction, with the main San Andreas fault crossing near the northeast extent of Greenspot Road, and a splay of the fault crossing through the northeastern portion of the Borrow Pit (Figure 4).

The Quaternary age alluvium was formed as the ancestral Santa Ana River migrated across the alluvial fan, variously incising channels or depositing sediments in a braided stream environment through Quaternary time as the San Andreas Fault went through periods of activity and relative quiescence. The USGS has identified at least five separate alluvial sequences that are present near the recharge facilities. The youngest of these are very young Holocene surficial deposits consisting of sediment transported and deposited in channels and washes, or surfaces of alluvial fans and alluvial valleys. These are typically very coarse and permeable, with no soil development.

The older alluvial deposits consist of sedimentary units that are slightly to moderately consolidated and slightly to moderately dissected. The upper surfaces of these deposits are commonly capped by slight to moderately developed soil profiles.

Underlying the Holocene deposits near the surface, are yet older alluvial fan deposits of mid to late Pleistocene age. These deposits would be expected to be slightly more consolidated, and also contain soil horizons on their upper surfaces.

The significance of this geologic environment is that all of the sediments underlying the recharge facilities would be expected to have relatively high hydraulic conductivity and percolation capacity. The most permeable materials would be expected to be in proximal (toward Seven Oaks Dam) portions of the Santa Ana River alluvial fan(e.g., the Borrow Pit), becoming slightly finer in the distal (southwestern – away from the apex of the fan) portions of the fan. Although no thick laterally-extensive clay layers are expected (or have been reported), the soil zones developed on the surface of older alluvial fan deposits may contain clay or silt materials produced by mineral weathering in a soil zone that could locally retard downward movement of water. These older soil zones would not be expected to be laterally continuous because they would have been eroded by active stream channels through time as the thalweg of the Santa Ana River migrated across the fan. (USGS, 2003a and b).

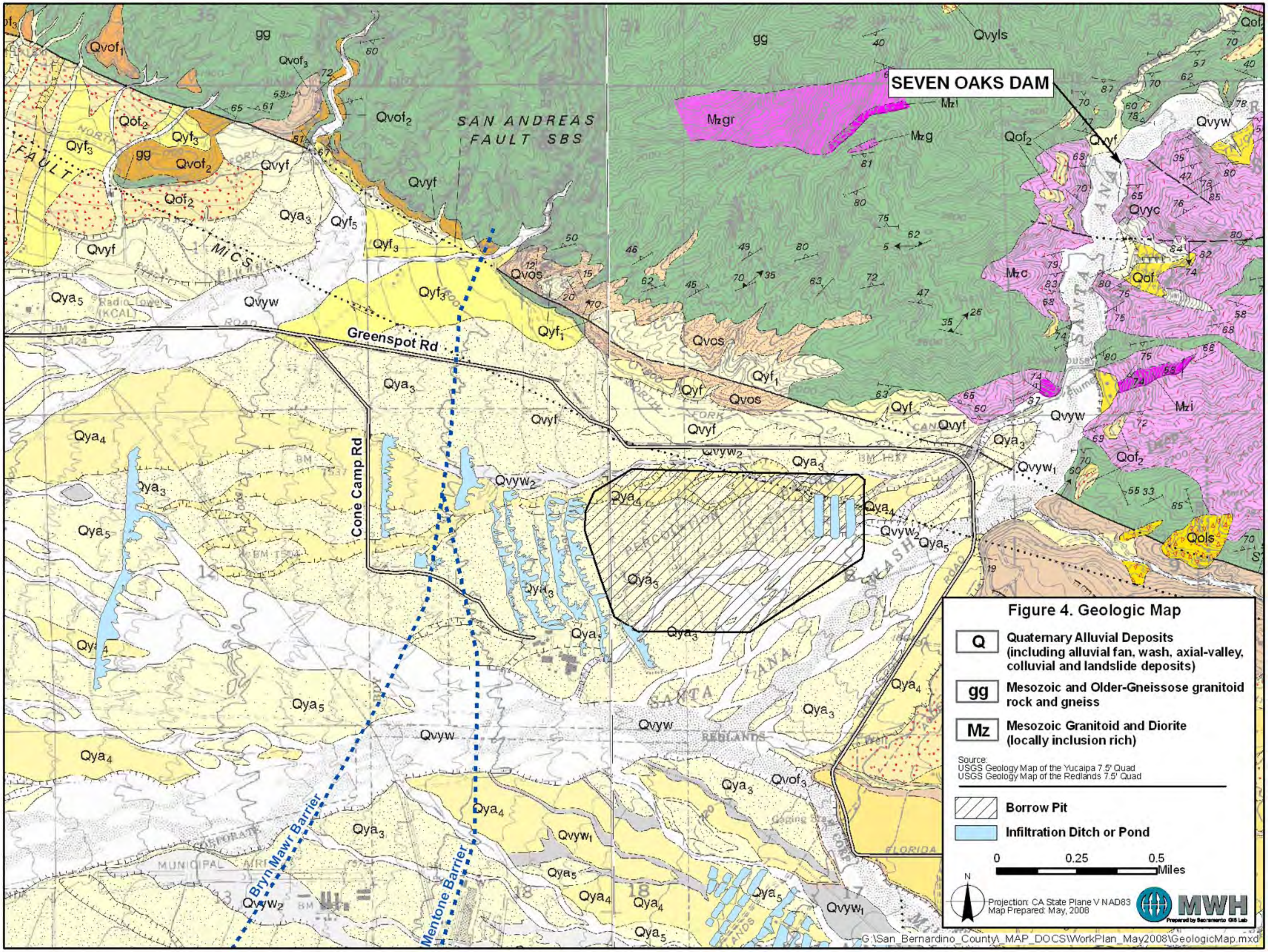


Figure 4. Geologic Map

Source:
USGS Geology Map of the Yucaipa 7.5' Quad
USGS Geology Map of the Redlands 7.5' Quad

Projection: CA State Plane V NAD83
Map Prepared: May, 2008

G:\San_Bernardino_County_MAP_DOCS\WorkPlan_May2008\GeologicMap.mxd

2.4.2 Anecdotal Observations

As previously noted, the SBVWCD recharge facilities have been in operation since the 1930s. During this time, information on the total amount of water percolated at the facilities was recorded at the Parshall Flume. However, because it is unclear which individual ponds were used during this time, and the total acreage over which recharge occurred, it is difficult to reconstruct what the percolation rate was for a particular area. Records are not detailed enough to enable calculation of percolation rate in feet per day.

However, several of the SBVWCD staff have many years of experience operating the conveyance and recharge system, and their expertise provides valuable information which will be used to guide future field work. On May 2, the MWH Team met and discussed observations noted in the field by SBVWCD personnel. The following are some key observations that were noted in this discussion and on previous field visits:

- Prior to construction of the Borrow Pit, percolation rates at ponds formerly in the area that was to become the Borrow Pit were significantly higher than observed in the Borrow Pit today.
- During relatively wet periods, it is common to observe water “daylighting”, or surfacing groundwater along the north wall of the Borrow Pit. This appears to be independent of use of the Borrow Pit for recharge.
- Because of the low percolation rates in this area, shallow bedrock is suspected towards the east end of the Borrow Pit.
- Relative to when Ponds 1, 2, or 3 are used in the Borrow Pit:
    a. When Ponds 1, 2, or 3 are filled, water daylights near the middle of the main area of the Borrow Pit west of the Ponds.
    b. Borrow Pit Pond 1 will percolate approximately 3.5 cfs on a continuous basis. If the amount of water added is increased to about 5 cfs, water typically spills into the next pond within 2 days, but will not spill into Pond 3.
    c. Ponds below the Borrow Pit (Ponds 10-12) appear to percolate at a higher rate after a period of approximately 2 to 3 days.
    d. Ponds 10-12 would take approx 40 cfs (as measured at the Parshall Flume) for weeks and will not spill.
    e. Borrow Pit Pond 2 is thought to have the best percolation rate of the three ponds in the Borrow Pit.

2.4.3 Existing Subsurface Information

Compilation of existing data on the subsurface conditions of the recharge facilities is critical to guide field efforts. In general, all of what is known about the subsurface hydrogeologic conditions at the site is derived from drilling (well construction) or trenching information.

The MWH team compiled subsurface information from a variety of sources, including the Districts files, the USGS and USACE. Approximately 35 wells have been identified within a mile of the SBVWCD recharge facilities. However, the location of many of these wells is uncertain, and it is possible that many of them have been abandoned or destroyed. The MWH team contacted the California Department of Water Resources (DWR) and requested well completion reports for that 2 mile area of the Borrow Pit. However, this information was not available at the time of production of this workplan and therefore will be included in subsequent reports.

The MWH team also contacted Mr. Robert Kwan, of the USACE, who provided data from investigations of the Borrow Pit area conducted in 1986 in preparation for construction of the Seven Oaks Dam. Field tests for determining the characteristics of the borrow area were developed specifically to evaluate the large size and percentage of rocks present in the borrow area; no borings were conducted. Five test pits were excavated in the SBVWCD recharge area using a Catepillar 235 backhoe to depths of 18 to 24 feet. Tests were conducted for gradation analysis, triaxial compression, permeability, and dry density. The gradational analysis indicated that the amount of the material larger than three inches ranged from 49 to 59 percent of the total sample. The maximum size of the rock in the samples ranged from 20 to 36 inches in diameter, although rocks up to 72 inches in diameter were observed. It is notable that virtually no fine material that might retard downward percolation was found. In all cases, fine material (passing U.S. Standard sieve number 200) was less than five percent. Permeability values from samples from one of the pits ranged from approximately 23 to 315 ft/day.

A key aspect of evaluating recharge rates at the site is the potential for groundwater mounding which would reduce recharge rates. MWH reviewed available recent groundwater level measurements from the Districts and the USGS and developed a map of equal groundwater elevation. This data indicates that in May of 2008, the water table is close to the surface in the vicinity of the Borrow Pit. However, it is difficult to resolve the exact depth to water because the topographic information at the relatively new Ponds 1, 2, and 3 in the Borrow Pit is not available.

2.5 FIELD TESTING GOALS

Review of existing data, coupled with the overall goals of the project highlight some specific goals of further field efforts. Available geologic data (Section 2.3.1) and soil testing by the USACE in the Borrow Pit area (Section 2.3.3) suggest that percolation rates in the Borrow Pit should theoretically be equal or greater than those in the western percolation ponds. However, comparative testing and anecdotal information indicates that percolation rates are much lower in the Borrow Pit.

In addition, although much subsurface information has been found in the vicinity of the SBVWCD recharge facilities, the exact location of existing wells is uncertain.

Based on these and other issues identified during the review of previous information, the general goals of the field investigation include:

- Evaluate the extent to which the shallow soils in the Borrow Pit have been altered by deposited fine materials (silts and clay) or algae.
- Evaluate the extent to which compaction of shallow soils in the Borrow Pit by heavy equipment has caused abnormal compaction which would slow percolation rates.
- Determine the presence or absence of shallow (less than 50 feet) layers of clay or other low-permeability material that would retard downward percolation of water. In particular, determine the cause of surfacing groundwater in the west-central portion of the Borrow Pit and the north face of the Borrow Pit.
- Determine the presence or absence of shallow bedrock on the eastern edge of the Borrow Pit that would limit the transmissivity of alluvial materials.
- Determine the presence or absence of shallow groundwater in the immediate vicinity of the Borrow Pit.
- Collect soils samples for laboratory gradation analysis to quantify the soil parameters at various locations inside and outside of the Borrow Pit, and allow for interpolation of patterns in shallow soils based on quantitative and visual descriptions of the soils.
- Locate and determine the coordinates of existing wells in the alluvial materials north of the Santa Ana River and east of Cone Camp Road.
- Conduct percolation testing in the Borrow Pit Pond 1 after cleaning of the bottom of the pond.
- Determine the elevation of the bottoms of Ponds 1, 2, and 3 in the Borrow Pit, and reference point elevations of selected wells where depth to water measurements are taken.

No additional flow testing goals have been identified for the conveyance and diversion system. Enough information was obtained during the March 27, 2008 release flow test and subsequent measurements that the system can be fully evaluated as to its capacity, limitation, and expansion needs.

Section 3
Proposed Field Testing Program

This section describes the proposed field testing program designed to accomplish the goals outlined in the previous section, and to fill critical data gaps associated with the understanding of the recharge facilities.

3.1 SEQUENCE OF WORK

The fundamental rationale for sequencing of field work is to begin with an extensive shallow soil sampling effort, followed by a focused sampling effort using methods that allow deeper exploration. The proposed sequence of field work is as follows:

- Shallow surface sampling of soils, followed by
- Trenching, followed by
- Sonic borings, followed by
- Monitoring well installation, followed by
- Percolation testing

Based on the information gained in preparation of this technical memorandum Table 3 provides a comparison of the changed to the contract submittal and this technical memorandum.

Table 3. Comparison of Proposed Field Testing Program, Contract versus TM-1.

Contract Scope of Work	TM-1
65 soil samples from shallow pits and trenches	More soils samples will be collected and stored (80+, 65 soil samples to be submitted for analytical analysis.
Up to 10 trenches	Same
5 Sonic borings to 50 feet	5 Sonic borings to 50 feet, completed as a peizometer.
1 MWl to 300 feet	2 MW to 150 feet

Ait percussion or rotary/foam drilling method with geophysics	Sonic drilling without geophysical
40 survey points in the Borrow Pint, MW locatons, and conveyance faacities	40 survey points focused on Borrow Pit topography and MWs
3 (2- ½ acre pits side by side) test pits to be constructed	Test western ditches, and Pond 1 in the Borrow Pit before and after cleaning. Additional testing may be recommended based on soil sampling.

The following is a description of the field activities. Proposed sampling locations are shown on Figure 5. The sampling program targets those areas of concern as noted in Section 2 to better identify and understand the hydrogeologic conditions in the vicinity of the Borrow Pit. It is important to note that although preliminary sample locations are identified in this work plan, the field program is intended to be adaptive in that the site geologist may modify sample locations based on what is discovered during the field program.

3.2 SHALLOW SOIL SAMPLE COLLECTION FROM HAND-DUG PITS

The purpose of shallow soil sampling is to characterize the very shallow (less than 12 inches) layer of the bottom of existing recharge facilities where clogging is most likely to occur. The intent of this sampling is to characterize a wide area for relative comparison. Samples will be collected on a grid rectangular grid system at approximately 500 foot centers in the Borrow Pit. Additional samples will be taken in western pond bottoms for comparison. During collection of the samples, the on-site geologist will observe:

- Depth of various soil horizons
- Algal growth
- Soil type
- Visual classification of gradation
- Color
- Apparent moisture content

Samples will be described in accordance with the American Society for Testing and Material ASTM) D2487-06 Standard Practice for Classification of Soils for Engineering Purposes

(Unified Soil Classification System). Samples will be collected from hand dug pits using a shovel.

Samples will be collected in one quart Ziplock freezer bags and retained at the SBVWCD offices. Selected shallow soil samples will be sent to a soils laboratory for analysis, as described in Section 3.10.

3.3 TRENCHING

Up to ten trenches will be excavated in the existing percolation basins to a maximum depth of five feet at each location. Figure 5 identifies the preliminary locations of the trenches, which may be modified by the field geologist based on observations from shallow soil sampling or previous trenches. The trench side wall will be logged under the oversight of a Professional Geologist registered in the State of California. A graphic depiction of the trench wall will be sketched on the trench log (Attachment 1) by the on-site geologist showing the thickness, depth, and relationship of various soil layers, and the presence of oversize material . Particular attention will be focused on evidence of shallow clogging by fine material and/or algal growth. Sample locations and depths will be noted on the trench log and photographs of the trench wall will be taken.

Representative samples of each soil type observed in the trench will be collected in one quart Ziplock freezer bags and retained at the SBVWCD offices. Selected soil samples from the trenches will be sent to a soils laboratory for analysis as described in Section 3.10.

The soils at the project site are known to be loose and unconsolidated, and contain a high percentage of oversize material. These conditions may make trenching unpractical or unsafe. Under no conditions will trenching be continued if the conditions appear unsafe, and no trench will be completed deeper than five feet. If conditions are deemed unsafe, trenching will be terminated immediately.

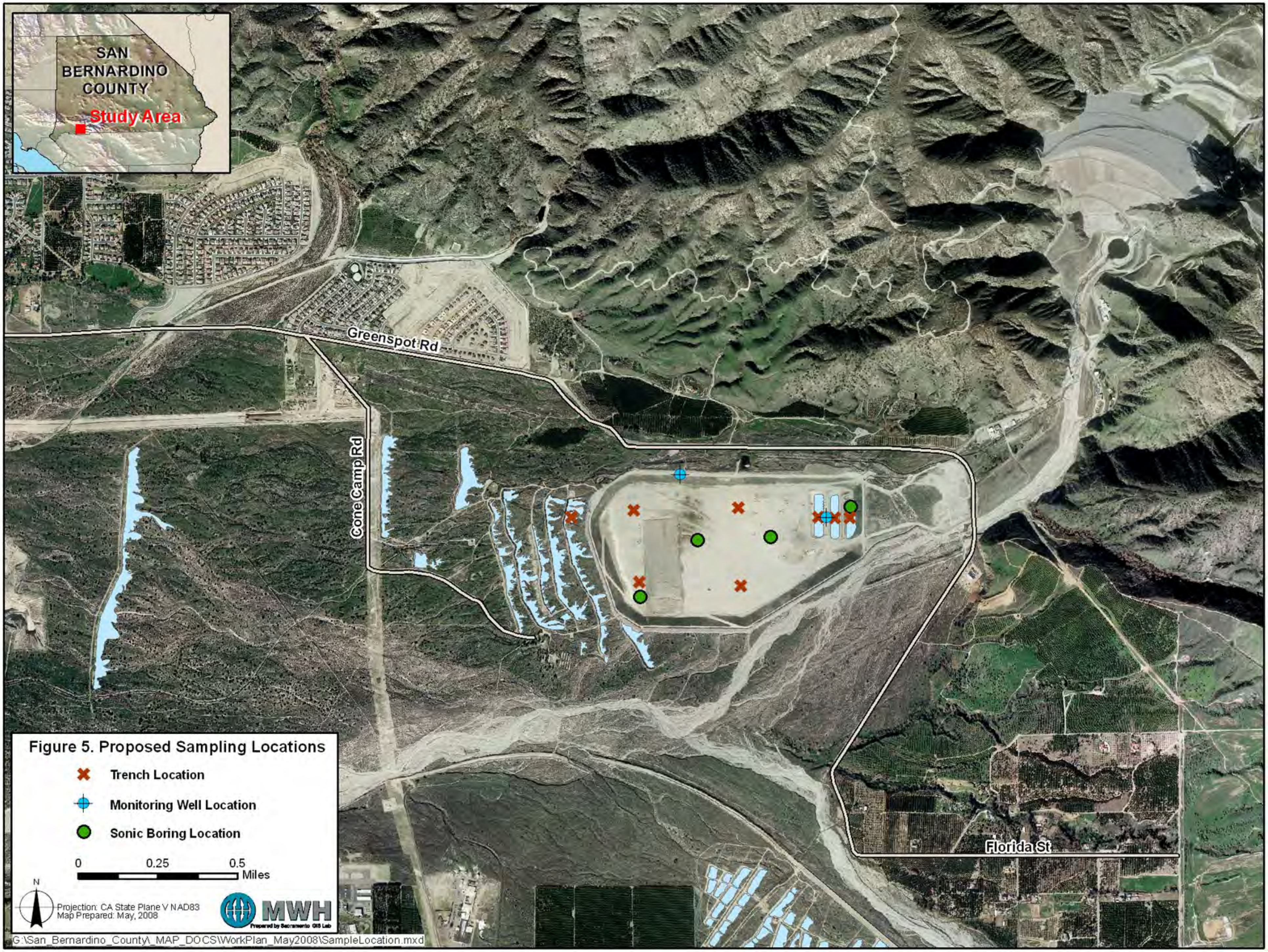


Figure 5. Proposed Sampling Locations

3.4 SONIC DRILLING

Sonic drilling is a relatively new exploration technique that has some particular advantages for investigation of the Santa Ana River site. The method provides continuous (disturbed) samples in a wide range of soil types, including soils with large particles that preclude sampling by many other techniques. The drill stem and sampler barrel are vibrated vertically at frequencies between about 50 and 180 Hz (hence the name sonic) such that the sampler barrel normally advances by slicing through the soil. The sampler can often cut through large soil particles with the resulting sample providing a valuable view of the soil stratigraphy that other techniques could not provide. This data will be carefully noted by the onsite geologist on a detailed boring log (Attachment 1).

A total of seven sonic borings will be conducted along the long axis of the Borrow Pit. Preliminary locations of the borings are identified on Figure 5. Soil samples will be collected and described as discussed in Section 3.1 at each major change in stratigraphy. The field team will pay particular attention to stratigraphic layers of low permeability, and the existence of older soil horizons, based on grain size, color, and evidence of weathering and staining. Sonic borings will be advanced to a maximum depth of 50 feet, or to refusal. An exception to this is that two of the borings will be converted to monitoring wells, as discussed below.

3.5 MONITORING WELL INSTALLATION

Existing information indicates that the regional groundwater table is relatively close to the surface in the vicinity of the Borrow Pit. Surfacing groundwater has been noted in the west-central portion of the Borrow Pit, the northern face, and in Borrow Pit Pond 3. However, existing well information is not of great enough resolution to accurately determine the groundwater elevation in the Borrow Pit to discern if the surfacing groundwater is perched water or representative of the regional water table. Therefore, it is recommended that two of the sonic borings be converted to monitoring wells -- one well would be located midway between Borrow Pit Pond 2 and 3, and the other would be located on the west end of the northern edge of the Borrow Pit.

The monitoring wells will be constructed using the sonic drilling method, as described above, to provide information on the stratigraphy of the basin at depth, and will be used later for documentation of the water table elevation underlying the sites during recharge operations.

Cuttings or cores from the boring excavated for installation of monitoring wells will be logged by the onsite geologist as described above. Because the sonic method allows for close observation of the soil stratigraphy, geophysical logging will not be necessary. The wells will be completed with a 2 inch PVC casing, surface seal and protective barrier or flush mount completion. The monitoring wells will be drilled to a depth of at least 25 feet below the water table, or to 150 feet, whichever is shallower.

3.6 PERCOLATION TESTING

As previously noted, percolation testing has been completed in the western recharge ponds outside of the Borrow Pit, and at Pond 1 inside the Borrow Pit. Because preliminary information suggests that the shallow layer of the ponds within the recharge pit are clogged (Section 2.4), the concept is to perform percolation tests before and after cleaning of the ponds to evaluate the effectiveness of removing the clogged layer.

Percolation testing of Pond 1 in the Borrow Pit will be conducted using similar methods, as described in Section 2.2, after the SBVWCD has had the opportunity to remove the shallow surface layer from Pond 1. About 65 acre-feet of water will be required for testing Pond 1 after cleaning. The MWH team will provide guidance on the cleaning of Pond 1 depending upon the results of the soil sampling conducted in the pond.

If additional information from drilling and sampling identifies a more favorable area in the Borrow Pit, it may be desirable to construct a new percolation test pond to see if percolation rates in the Borrow Pit could be improved. The most favorable area of Borrow Pit should be chosen for the pond and ½ to 1 acre test pond constructed. The falling-head test procedure used in the current testing of Borrow Pit Pond 1 should be used.

3.7 INTERACTION WITH DISTRICTS STAFF

The MWH team will maintain communication with Districts personnel regarding scheduling, sampling activities, and needs. During periods of field activity, the field team will complete daily field reports describing the work completed each day, special challenges or issues, and planned activities for the next day. MWH will provide oversight and direction to the contractor regarding the location of sampling sites and depth of investigation.

In general, the MWH team will not require extensive assistance from Districts staff during completion of the field work, with the possible exception of percolation testing, which will require diversion of water in a controlled fashion to Borrow Pit Pond 1. The MWH team will request access to the sites during field work.

Visitors to field activities are, of course, welcome. However, it should be recognized that the on-site geologist will be focused on sampling tasks at hand and direction of excavation contractors and, therefore, may not have time for extended discussions with Districts staff. It would be advisable to arrange field trips to review site activities in advance so that the MWH team can have adequate personnel on site to review field activities and to maintain safe working conditions.

3.8 MAPPING AND SURVEYING

All locations of surface soil sampling, trenches, sonic borings, and monitoring wells completed by the field team will be surveyed using a hand-held global positioning system, with a minimum horizontal accuracy of five feet. In addition, the location will be sketched on an aerial photograph of the site. These methods will also be used to locate all existing, and suspected, wells that are believed to be at the site. . The surface completion, condition of the casing, and any identifying markers will be noted on field logs.

More precise surveying by a professional surveyor will be completed at selected locations at the site to determine the topographic elevation and existing wells. Up to 40 survey points will be selected by the field team during the sampling activities. The points are expected to include:

- Elevation of the lowest portion(s), and transects of Borrow Pit Ponds 1, 2 and 3
- Elevation of the reference point for depth-to-water measurements on the new wells and selected existing wells

3.9 SAMPLE NUMBERING

All samples will be marked in the field immediately after collection using a permanent marker. An example of the sample numbering system is as follows:

T-1 /5’-A

Where “T” denotes “trench”; the number after the T indicates the trench number (numbered sequentially, i.e., Trench 1, 2, …); and the number after the slash indicates the depth (in feet) below ground surface of the sample; the letter after the depth would be used if more than one sample was collected at a particular depth. Other sample types will include:

“S” for surface soil samples
“B” for sonic boring samples
“MW” for monitoring well samples

All samples collected will be noted on field logs, boring logs, and trench logs, with notation as to the total number of samples collected at each location.

3.10 LABORATORY SOIL ANALYSIS

Representative soil samples of each distinct soil horizon will be collected by the onsite geologist at all shallow surface, trench, and boring locations such that each soil type at the particular location is represented. These samples will then be stored at the SBVWCD offices for comparison and cataloging.

After collection of all samples, a subset of approximately 65 soil samples will be selected from this group of samples to be transported to the laboratory for gradation analysis, in accordance with ASTM D-4411 and ASTM D-4464, by a qualified laboratory.

Ten of the 65 soil samples will also be tested for saturated hydraulic conductivity using ASTM-5084. These samples will be transported to:

PTS Laboratories, Inc.
8100 Secura Way
Santa Fe Springs, CA 90670 USA
(562) 907-3607
(562) 907-3610 (Fax)

3.11 CLEAN UP AND INVESTIGATION-DERIVED WASTE

Subsurface exploration at the site will generate soil spoils from trenches and borings. Because the site has been protected from development and is actively used for recharge operations, no contamination of this soil is expected. In general, after a trench or boring is completed, soils will be backfilled into the hole from which they originated. However, if significant fine material, or other material of low permeability is encountered, the field crew will attempt to segregate this soil for movement to a berm or to other areas designated by the Districts.

Waste from the monitoring well will not be returned to the hole from which it was originated. These soils will also be moved to a berm or other area designated by the Districts.

Section 4
Project Schedule and Reporting

Proposed field sampling activities for the SAR Optimization Study will commence upon approval by the SBVWCD and the SBVMWD of this work plan.

As previously noted, field activities will be sequential, such that each activity can take advantage of the information acquired from the previous activity. The estimated duration of each activity is shown in Table 4; however, the actual timing will be dependent on the availability of contractors and equipment. The MWH team will advise the Districts of significant changes in schedule.

Table 4 - Estimated Schedule of Field Work

Activity	Duration (Weeks)	Approximate Start	Approximate Finish	Notes
Surface Sampling	1	16-June-08	20-June-08	Assumes workplan accepted by June 9
Trenching	1	23-June-08	27-June-08	
Sonic Boring and MW Installation	2	30-June-08	4-July-08	Dependent on availability of drilling rig
Percolation Testing	2	27-June-08	4-July-08	Dependent on completion of cleaning Pond 1 in the Borrow Pit and availability of SA River Water

[use US dating above – June 16?]

A description of the field activities and associated sampling results will be presented in the TM-2 [TM?). The TM-2 will be submitted for review and comment by the SBVWCD and theSBVMWD. This document will present the findings of the field work and an analysis of the percolations tests and recharge capacity estimates. In addition, the TM-2 will describe methods and implementation of the field program.

Section 5
References

ACOE, 2003. Water Control Manual, Seven Oaks Dam & Reservoir, Santa Ana River, San Bernardino County, California. September.

Agajanian, Jefferey (U.S. Geological Survey), 2008. Data on flow at the Mentone gauging station (USGS No. 11051499) during the March 27 field test. E-mail correspondence.

Danskin, Wes (U.S. Geological Survey), 2008. Personal communication regarding the geology of the Santa Ana river area near Cone Camp.

Efthari, Aram (Orange County Resource Development and Management Department), 2008. Data on release rate from the Seven Oaks Dam during the March 27 field test. E-mail correspondence.

Flordelis, Cisco (SBVMWD), 2008. Data on flow at the SBVWCD Parshall Flume during the March 27 field test. E-mail correspondence.

Kwan, Robert (U.S. Army Corps of Engineers), 2008. Personal communication regarding geotechnical testing of the Borrow Pit site for the Seven Oaks Dam. E-mail correspondence.

SBVWCD, 1994. Operational Management Manual of the San Bernardino Valley Water Conservation District. March

USGS, 1975. Artificial Recharge in the Upper Santa Ana River Area, San Bernardino County, California. USGS Water-Resources Investigations 15-75. 27 p.

USGS, 2003a. Geologic Map of the Redlands 7.5’ Quadrangle, San Bernardino and Riverside Counties, California.

USGS, 2003b. Geologic Map of the Yucaipa 7.5’ Quadrangle, San Bernardino and Riverside Counties, California.

ATTACHMENT 1
Trench Log and Boring Log

FIELD TRENCH LOG

MWH

Project Name

Trench Number

Project Number

Elevation and Datum

Location

Sheet ________ of ________

Equipment Supplier

Operator

Date and Time Started

Date and Time Completed

Refusal? (Circle One) Yes No If Yes Depth =

Equipment Type

Trench Orientation

Total Depth

Total Number of Samples

Photo? (Circle One) Yes No No.

Bucket Width

Trench Length

Trench Width

No. of Samples

Bulk

Grab

Drive

Hand Auger

% Man-Made Debris

Geologist or Hydrogeologist/Date

Checked by/Date

Wall of Trench Shown (Circle One) N S E W NE NW SE SW

Plan View-Site Location
(Provide Sketch)

LENGTH (FEET)

DEPTH (FEET)

ENTER TRENCH DIRECTION
SCALE:

EXPLANATION

———	SOIL TYPE CONTACT (SHARP)
– – –	OTHER CONTACT (AS INDICATED ON LOG)
— — —	FILL/NATIVE BOUNDARY
X	ANALYTICAL SAMPLE LOCATION (WRITE SAMPLE NUMBER OUT TO SIDE)
G	GEOTECHNICAL SAMPLE LOCATION (WRITE SAMPLE NUMBER OUT TO SIDE)
////	SHADING TO DENOTE STAINING
\\\\\\\\	BASE OF EXCAVATION
◎	SHOW LOCATIONS AND TYPES OF ALL MAJOR DEBRIS

MWH

Boring #: MW#: Sheet 1 of

Project: SAR Groundwater Recharge Optimization Study

Job #: 1343019 Site:

Logged By: Reviewed By:

Drilling Contractor: Boart Longyear

Drill Rig Type/Method: Sonic Drilling

Drillers Name:

Borehole Diam./Drill Bit Type:

Total Depth

Ref. Elev.

Site Sketch Map

Sampler Type:

Depth to 1st Water (▽): Time/Date:

Drill Start Time/Date: Drill Finish Time/Date:

Depth to Water After Drilling (▼): Time/Date:

Well Completion Time/Date:

Depth to other Water Bearing Zones:

Soil Boring Backfill Time/Date:

PID/OVA	Sample Interval	Recovered (in.)	Blow Counts / 6 in.	Retained for Analysis	Casing Type & Size	Annulus Filler	Depth (Feet)	USCS Soil Type	Soil Description	Estimated % Of				
											Sand			
										Gravel	Coarse	Medium	Fine	Silt/clay
							1							
							2							
							3							
							4							
							5							
							6							
							7							
							8							
							9							
							10							
							11							
							12							

Boring #: MW#: Project: Sheet of

PID/OVA	Sample Interval	Recovered (in.)	Blow Counts / 6 in.	Retained for Analysis.	Casing Type & Size	Annulus Filler	Depth (Feet)	USCS Soil Type	Soil Description	Estimated % Of				
											Sand			
										Gravel	Coarse	Med.	Fine	Silt/Clay
							2							
							3							
							4							
							5							
							6							
							7							
							8							
							9							
							0							
							1							
							2							
							3							
							4							
							5							
							6							
							7							
							8							
							9							
							0							
							1							
							2							

QA/QC

Appendix B

Technical Memorandum 2: Documentation of Field Work and Recharge Capacity Estimate

Santa Ana River Groundwater Recharge Optimization Study

Technical Memorandum 2

Conveyance and Recharge Capacity Estimate

Prepared for:

San Bernardino Valley Water Conservation District
and
San Bernardino Valley Municipal Water District

By:

MWH Americas, Inc.
in association with
GEI Consultants

June 2009

Table of Contents

Section Name **Page Number**

Table of Contents

List of Tables

List of Figures

Executive Summary

The San Bernardino Valley Water Conservation District (Conservation District) in association with the San Bernardino Valley Municipal Water District (Municipal District) retained MWH Americas, Inc., in association with GEI Consultants to evaluate the Conservation District's recharge facilities adjacent to the Santa Ana River in San Bernardino County, California. The Agencies are seeking to evaluate the capability of the existing Conservation District facilities along the Santa Ana River to capture and store the proposed spreading objectives identified in the Upper Santa Ana River Watershed Integrated Regional Water Management Plan (IRWMP). Should the existing facilities be inadequate, MWH will prepare conceptual designs for the improvements necessary to meet the proposed spreading objectives. The maximum instantaneous flow rate, as defined by the Districts and based on the Environmental Impact Report for the Santa Ana River Water Right Applications for Supplemental Water Supply (SBVMWD, 2007), is 500 cubic feet per second (cfs). The maximum yearly volume identified under "Scenario A" of the IRWMP is 80,000 acre-feet.

This Technical Memorandum (TM) covers the first phase of the study involving quantification of the capacity of the existing diversion, conveyance and percolation facilities. This was accomplished by review of pertinent historical information and reports, preparation of a workplan for collection of field data, collection of field data, and analysis of the existing and new field data. This report presents the methods and results of collection of field data, analysis of the data, conclusions relative to the capacity of existing facilities.

The field work was conducted during March through December, 2008 and consisted of :

- Field flow testing of the diversion and conveyance facilities
- Survey of diversion works and conveyance (measurements of dimensions and slopes)
- Soil investigation consisting of:
    - Excavation of 15 trenches
    - Collection of 72 surface soil samples
    - Drilling, sampling, and lithologic logging of 7 borings to a maximum depth of 157 feet
    - Laboratory analysis of 75 samples for grain size analysis, and 16 of these samples for analysis of hydraulic conductivity.
- Construction of 6 monitoring wells and installation of automated monitoring equipment
- Several types of percolation tests at existing recharge ponds
- Physical surveys of existing well locations and elevations

Major conclusions of the study are:

- The sedimentary materials underlying the recharge facilities form an unconfined aquifer consisting of permeable, coarse, sandy gravel and/or gravelly sand. No significant, laterally-continuous strata of low permeability are present that would prevent the downward percolation of recharge water.

- Some existing ponds have a thin layer of silt and/or clay derived from the introduction of turbid recharge water which limits percolation capacity.
- Faulting associated with the San Andreas Fault Zone has created a groundwater barrier which limits recharge capacity on the eastern portion of the site, causing shallow groundwater that surfaces or “daylights” east (upgradient) of this barrier.
- During high runoff periods such as those that occurred in 1980, 1993, 1998 and 2005, the regional area in the vicinity of the recharge facilities may become saturated with shallow groundwater, limiting recharge in all of the facilities. For example, groundwater elevations at Well SBVWCD #3 came within 40 feet of the ground surface and groundwater elevations at the Cone Camp well came within 25 feet of the ground surface during some of these periods. In areas of lower topographic location that these wells the groundwater elevation was probably at or near the surface. However, these events have been very temporary, and may occur at a different frequency depending on the operation of the Seven Oaks Dam.
- The yearly recharge goal of 80,000 acre-feet identified in the IRWMP is possible with the construction of new infiltration, diversion, and conveyance facilities, assuming ambient groundwater levels are low enough to accept this water.
- Groundwater mounding (whereby the water table rises to the ground surface) may to occur if a percolation rate of 500 cfs is sustained.
- The current intake capacity of the Intake Structure without modification is approximately 150 cfs.
- Downstream of the Intake Structure and Cuttle Weir, earthen canals limit the capacity of the conveyance facilities to approximately 300 cfs.
- The recharge capacity of the existing percolation ponds at the SAR recharge facility west of the groundwater barrier is approximately 145 cfs. With additional capacity of 50 cfs in the eastern portion of the Borrow Pit, the total estimated recharge capacity of existing facilities is 195 cfs.

The final report will include recommendations and conceptual design of any physical improvements or change in maintenance and operational methods required to meet the recharge goal defined in the IRWMP.

Section 1
Introduction

The San Bernardino Valley Water Conservation District (Conservation District), in association with the San Bernardino Valley Municipal Water District (Municipal District), "Districts," retained MWH Americas, Inc., in association with GEI Consultants (collectively referred to as the MWH team) to evaluate the capability of the existing Conservation District facilities along the Santa Ana River to capture and store the proposed spreading objectives identified in the Upper Santa Ana River Watershed Integrated Regional Water Management Plan (IRWMP). Should the existing facilities be inadequate, MWH will prepare conceptual designs for the improvements necessary to meet the proposed spreading objectives. The maximum instantaneous flow rate, as defined by the Agencies and based on the Environmental Impact Report for the Santa Ana River Water Right Applications for Supplemental Water Supply (SBVMWD, 2007), is 500 cubic feet per second (cfs). The maximum yearly volume identified under "Scenario A" of the IRWMP is 80,000 acre-feet.

1.1 BACKGROUND

The Conservation District owns and operates surface water diversion and conveyance facilities and groundwater recharge spreading facilities adjacent to the Santa Ana River along Greenspot Road, south and west of the Seven Oaks Dam in Mentone, San Bernardino County, California (**Figure 1-1**). The Conservation District was formed in 1932 to obtain water for conservation purposes, essentially replacing the Water Conservation Association formed in 1910 (SBVWCD, 1994). The majority of the Conservation District facilities have been in place since the 1930s for the purpose of diverting and recharging water from the Santa Ana River. A relatively recent development in recharge operations is the construction of the Seven Oaks Dam, which is a earth and rock fill dam located approximately 1 mile upstream of the Conservation District's diversion. Construction of the dam, supervised by the United States Army Corps of Engineers (USACE), began in August 1994 and was completed in November 1999. Material was excavated for the dam from an approximately 240 acre area (herein called the "Borrow Pit") that formerly contained a series of recharge ditches and ponds operated by the Conservation District. Subsequent to the completion of the dam, three infiltration ponds were constructed at the east end of the Borrow Pit (labeled Ponds 1 through 3 on Figure 1-1).

The remaining recharge basins (Ponds 9 through 17) and the Borrow Pit are located south and west of Greenspot Road, and north of the Santa Ana River. Flow from the Santa Ana River below the Seven Oaks Dam is diverted at a concrete structure ("Intake Structure") behind a small dam-like impoundment called the Cuttle Weir. From the Intake Structure, water flows through various culverts, tunnels and other structures where it can be diverted to various ponds including those in the Borrow Pit.

Key to Features

① Spreading Pond Number

▨ Spreading Ponds

Document: SBVWCD_LocationMap.mxd

Date: December 22, 2008

Location Map

Figure 1-1

Santa Ana River Groundwater Recharge
Optimization Study

1.2 PURPOSE AND SCOPE

The Santa Ana River Groundwater Recharge Optimization Study consists of three primary tasks:

Task 1: Evaluate Existing Groundwater Recharge Spreading Facilities and Operations
Task 2: Establish Spreading Objectives
Task 3: Perform Feasibility Analysis and Prepare Conceptual Design to Meet Spreading Objectives

Appendix A includes the approved scope of work and schedule for the Santa Ana River Optimization Study. Task 1 includes a review of the pertinent historical information and reports, preparation of a workplan for collection of field data, collection of field data, and reporting the results of that field data regarding the diversion, conveyance, and infiltration capacity of the existing facilities.

The MWH team reviewed pertinent information and prepared a work plan which was contained in Technical Memorandum 1 (TM-1, MWH, 2008). The field work was designed to identify factors which may limit the volume of water that could be recharged, including:

- Inadequate capacity of diversion or conveyance facilities
- Compaction of shallow soils in the Borrow Pit due to heavy equipment use during construction of the pit
- Presence of fine-grained material that “clog” the surface of the Borrow Pit
- Shallow groundwater which mounds to the surface
- Presence of horizontal or vertical barriers to groundwater flow, such as clay layers or faults

The field work was also designed to gather additional data on shallow soil and aquifer conditions and resolve data gaps regarding well locations and surface elevations at the site.

The purpose of this document (TM-2) is to document the results of the field investigation, describe factors which limit recharge, and document the recharge capacity of the existing facilities.

The final report will involve recommendations for improvement of existing facilities, conceptual design of new facilities, and maintenance and operational methods to increase recharge capacity.

Section 2

Summary of Field Investigation – Methods and Results

The field work performed at the SAR recharge facilities included:

- Field flow testing of the diversion and conveyance facilities
- Survey of diversion works and conveyance
- Soil investigation consisting of:
    - Trenching
    - Collection of surface soil samples
    - Borehole drilling
- Monitoring well construction
- Percolation testing
- Physical surveys

The bulk of the field investigation occurred between March and August 2008, with the specific testing milestones shown below in Table 2-1.

Table 2-1
Summary of Field Testing Activities

Date	Activity
March 27, 2008	Flow testing to observe flow conditions in the conveyance facilities between the Intake Structure and the Conservation District recharge facilities
March 27-May 9, 2008	Percolation testing of Ponds 9 through 17, and Dike D
May 10-22, 2008	Percolation testing of Borrow Pit, Pond 1
June 18-June 26, 2008	Surface soil sampling conducted of Borrow Pit and adjacent ponds
June 19-20, 2008	Trenching (Larry Jacinto Construction, Inc.) and sampling
June 23-July 10, 2008	Sonic Drilling and monitoring well installation (Boart Longyear Company)
July 14-August 1, 2008	Percolation testing of Borrow Pit, Pond 1 after approximately 1 foot of basal material was removed
July 31, 2008	Samples submitted to PTS Laboratories, Inc. for grain size distribution and hydraulic conductivity analysis
August 7-8 2008	Survey conducted (Calvada Surveying, Inc.)
August 22, 2008	Installation of transducers at monitoring wells
September 19, 2008	Field visit and survey of existing well locations with the Conservation District
October 13-24, 2008	Percolation testing of linear trench excavated in Pond 1
December 5, 2008	Transfer of transducer data logging equipment to the Conservation District

These events are described in more detail in the following sections.

2.1 SURVEY OF DIVERSION AND CONVEYANCE FACILITIES

A flow test was conducted on March 27, 2008 that allowed the Districts and the MWH team to observe flow conditions in the diversion and conveyance facilities between the Seven Oaks Dam and the Conservation District recharge facilities. A summary of the flow test and key observations was provided in TM-1 (MWH, 2008). Subsequent to that test, more detailed physical surveys of the diversion and conveyance facilities were performed.

The following is a summary of the physical survey of the diversion and conveyance facilities to collect the data needed to calculate each facility's current capacity. The locations of the diversion works and conveyance facilities are shown in **Figure 2-1**. Diversion and conveyance dimensions were compiled from record drawings and/or field measurements to produce channel cross-sections at the locations shown on **Figure 2-2.** The cross-sections are shown on **Figure 2-3** (these field measurements were used to calculate theoretical capacities for typical sections). Details of selected diversion and conveyance facilities are shown on **Figure 2-4.** Photos taken during the physical survey are included as **Appendix E**.

The record drawings of the recharge facility were reviewed, and field measurements of the facilities were taken to supplement information that was lacking in the record drawings provided by the Conservation District and the Municipal District. Information gathered included canal channel and side slopes as well as maximum gate openings at control structures. Because earthen canal sections along the conveyance system varied, several canal cross-sections were surveyed.

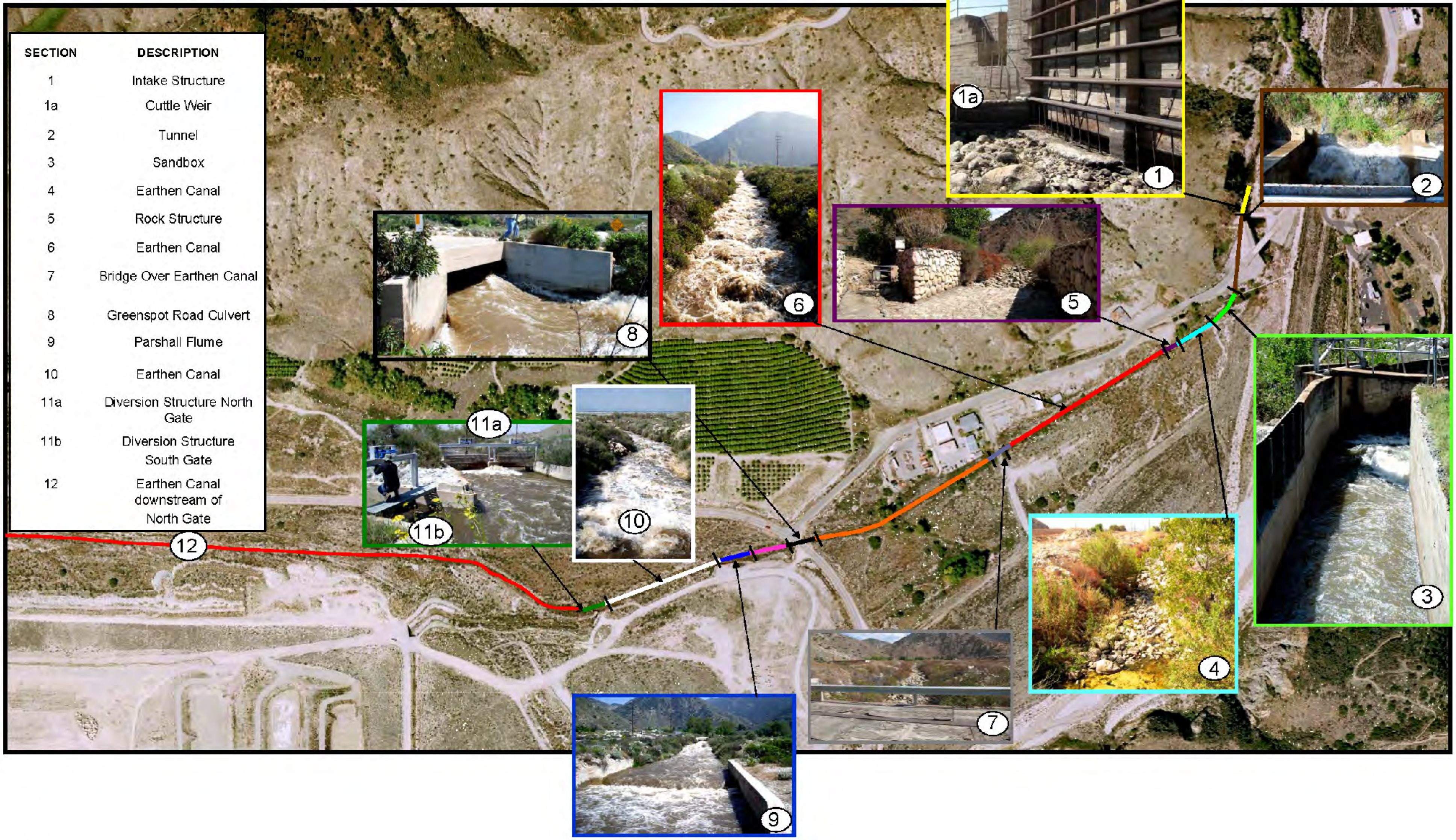
Provided below is a description of information on the diversion and conveyance facilities collected during the field investigation. Key features are listed on Figure 2-1.

Intake Structure

Flow to the recharge basin conveyance system is initiated by diverting water released from the Seven Oaks Dam into the Intake Structure (Figure 2-1). The diversion occurs by water backing up behind the Cuttle Weir, which is a dam-like structure perpendicular to the river channel. The Intake Structure is composed of six gates, each 6 feet wide. The gates are raised to allow flow into a concrete channel that slopes to a tunnel. The intake structure record drawings show the general dimensions and elevations of the structure. Verification of the elevation difference between the gate sills (elevation 1952.0 feet per record drawing) and the top of the Cuttle Weir was made during field surveys conducted on September 30 and October 7, 2008.

Key information that was not shown in the records drawings was the maximum height at which each gate could open. The maximum height each gate could open was determined by measuring the thread lengths of each gate stem. With Gate 1 being the gate closest to the tunnel entrance and Gate 6 being the furthest, Gates 1 and 2 can be opened by about 4.5 feet, Gate 3 by 2.25 feet, and Gates 4 to 6 by 4.0 feet.

SBVWCD GROUNDWATER RECHARGE DIVERSION & CONVEYANCE MAXIMUM CAPACITY



SECTION	DESCRIPTION
1	Intake Structure
1a	Cuttle Weir
2	Tunnel
3	Sandbox
4	Earthen Canal
5	Rock Structure
6	Earthen Canal
7	Bridge Over Earthen Canal
8	Greenspot Road Culvert
9	Parshall Flume
10	Earthen Canal
11a	Diversion Structure North Gate
11b	Diversion Structure South Gate
12	Earthen Canal downstream of North Gate

N

No Scale

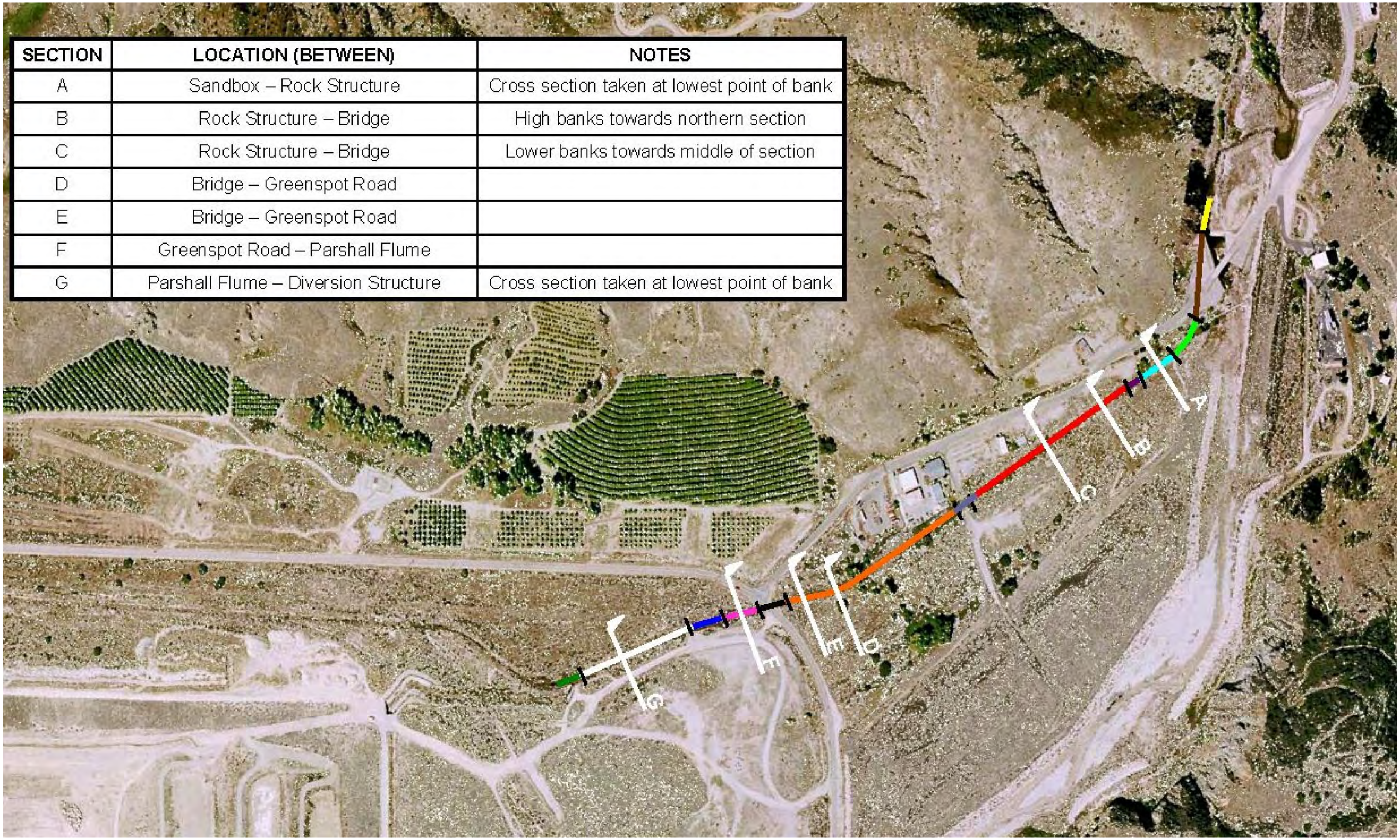
Document: SBVWCD_DiversionConveyance.mxd

Date: December 22, 2008

Site Plan of Diversion and Conveyance Facilities

Figure 2-1

Santa Ana River Groundwater Recharge Optimization Study



SECTION	LOCATION (BETWEEN)	NOTES
A	Sandbox – Rock Structure	Cross section taken at lowest point of bank
B	Rock Structure – Bridge	High banks towards northern section
C	Rock Structure – Bridge	Lower banks towards middle of section
D	Bridge – Greenspot Road	
E	Bridge – Greenspot Road	
F	Greenspot Road – Parshall Flume	
G	Parshall Flume – Diversion Structure	Cross section taken at lowest point of bank

N

No Scale

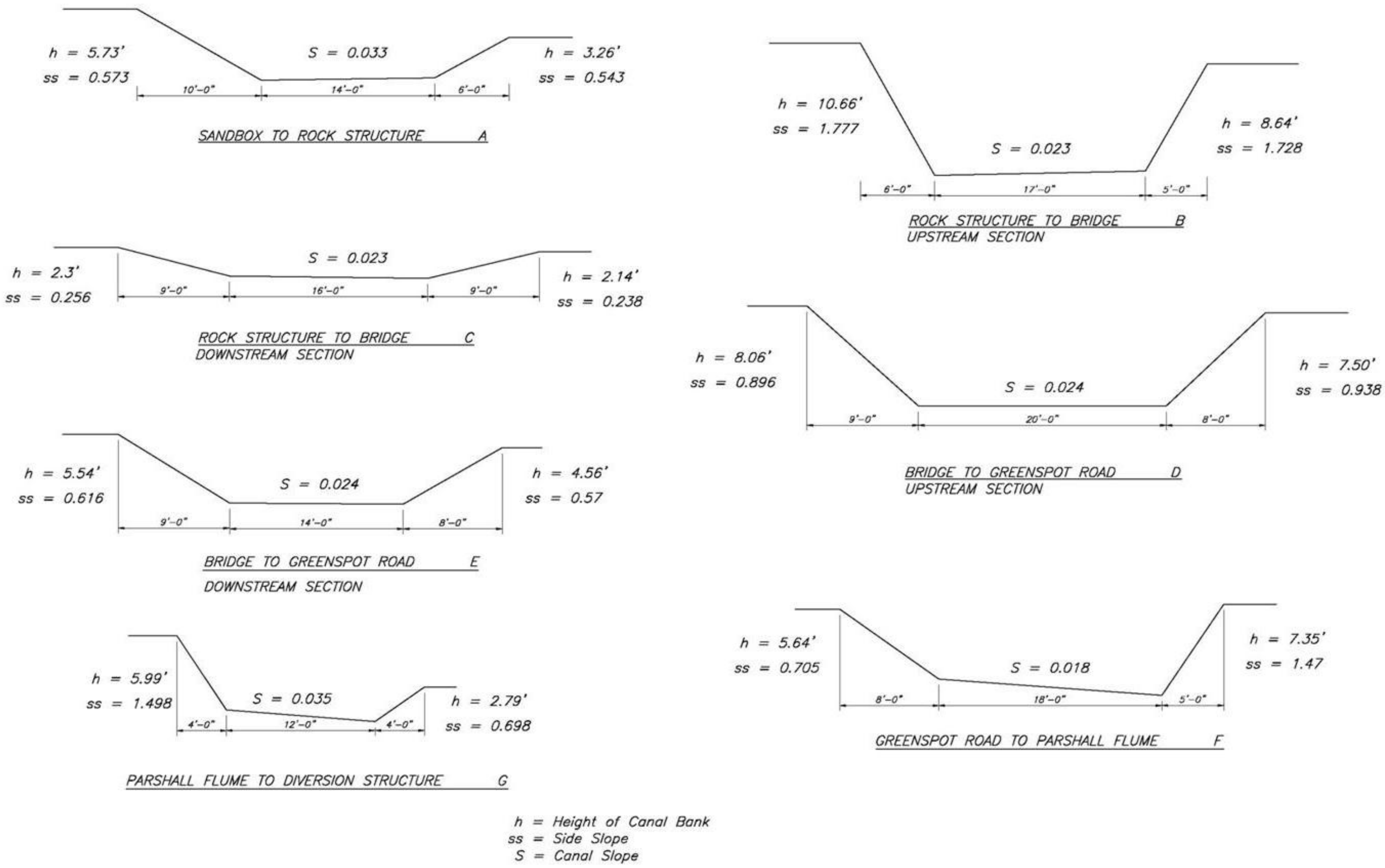
Document: SBVWCD_ProfileLocations Fig2-2.mxd

Date: December 22, 2008

Profile Locations

Figure 2-2

Santa Ana River Groundwater Recharge Optimization Study



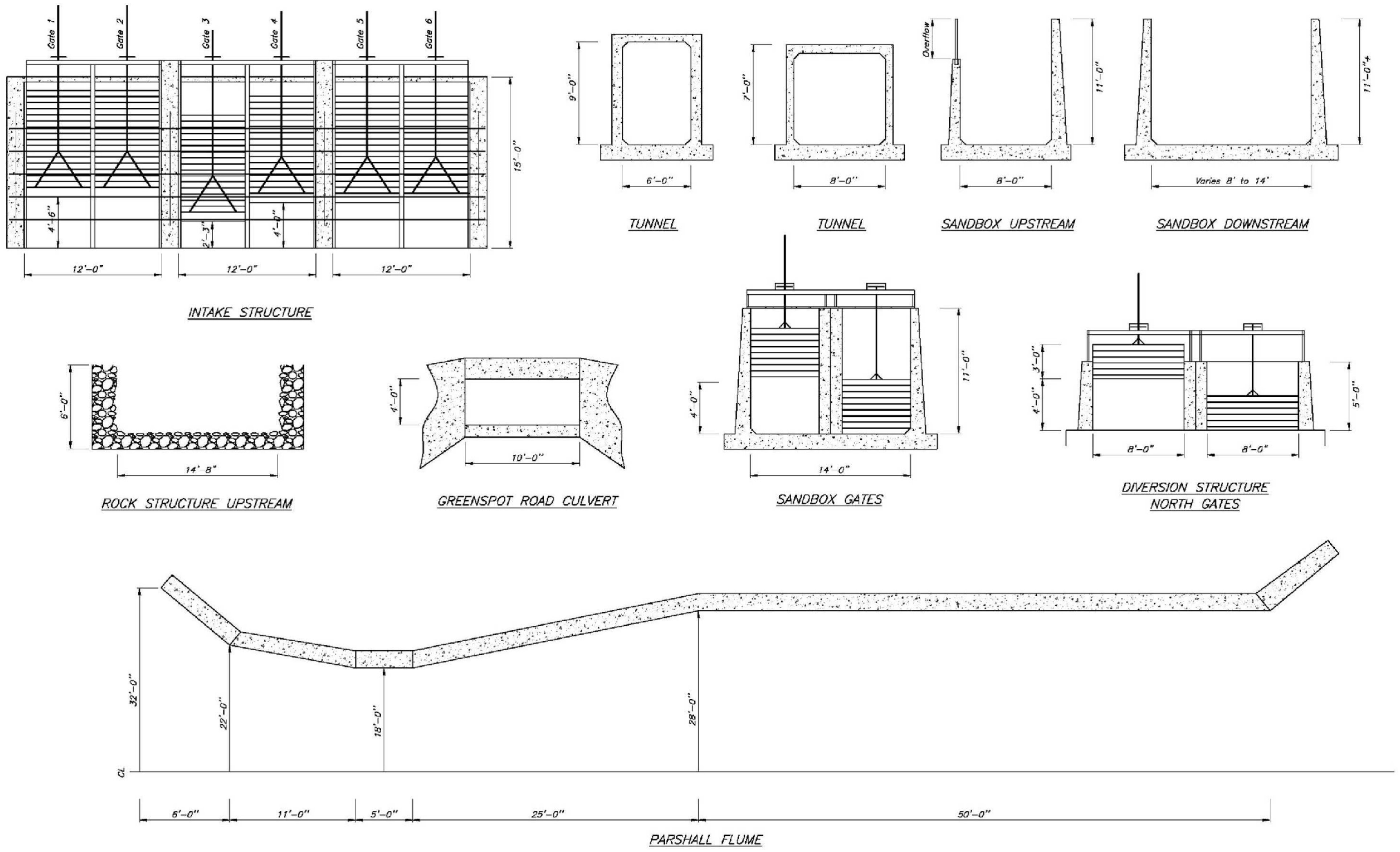
Profiles of Conveyance Facilities

Document: SBVWCD_ProfileConveyance Fig2-3.mxd

Figure 2-3

Date: December 22, 2008

Santa Ana River Groundwater Recharge Optimization Study



Detail of Selected Facilities

Figure 2-4

Santa Ana River Groundwater Recharge
Optimization Study

Document: SBVWCD_DetailSeletected
FacilitiesFig2-4.mxd

Date: December 22, 2008

The Gate 3 stem appears to have been altered, which limits its opening height in relationship to the other gates. The difference in elevation between the gate bottom sill and the Cuttle Weir was measured and compared to the spot elevations shown on the record drawings. The field survey data revealed that the bottom elevation of the gates was 2 feet 8 inches lower than top of the lowest section the Cuttle Weir with an elevation of 1954.7. Pictures taken during the field survey show some large boulders directly in front of the intake structure which could obstruct water from flowing freely through the gate openings (Appendix E).

Closed Conduit (Tunnel) and Sand Box

Water enters the Intake Structure and discharges into a sloped concrete channel that varies in depth from 7 to 13 feet below the Intake Structure's bottom sill. The discharge end of the channel is connected to a reinforced concrete structure made up of two closed conduit sections with a slope of 0.5%. The first is a rectangular 6 feet by 9 feet, approximately 200 feet long section. The second is a rectangular 8 feet by 7 feet, approximately 100 feet long section. These structures discharge into the Sand Box, an initially 8 feet wide open channel with 11 feet high concrete walls (except at the overflow section which has a 7 feet wall section). The Sand Box is approximately 110 feet in length and expands to a width of 14 feet just downstream of a 48 inch diameter sluice gate that could be used to flush water into the Santa Ana River.

The Sand Box structure contains two 6 feet wide bulkhead gates at its downstream end, after which it discharges into an earthen canal. Physical measurements were taken at the 6 feet gate structures by measuring the gate stems' threads to determine their opening height. The measurements taken suggest that both gates can open to a maximum of 4 feet. The slope of the closed conduit and Sand Box were taken from record drawing information.

Canal Section between Sandbox and Rock Structure

Beyond the Sandbox gates is an earthen canal. The typical canal section shown on record drawings for "Conduit Santa Ana Weir," dated May 1930, is not representative of the existing canal. Therefore, cross-sections and slopes of the existing canal were measured to more accurately determine its capacity. Slopes were measured using a level and rod. To find the representative slope of a particular reach of canal, the elevation difference of two points 100 feet apart was measured. Canal cross-sections were obtained by measuring the elevation differences at the bottom corners and top edges of the canal with the level and rod. The horizontal lengths of the cross-section were then measured by hand with a measuring tape. This procedure was used to obtain slopes and cross-sections of earthen canals throughout the conveyance system.

The representative slope of the earthen canal measured between the Sandbox and Rock Structure is 0.033 vertical foot per horizontal foot (unitless). The cross-section taken for this canal section was at a point where the banks of the canal appeared to be at its lowest. The canal contains various sized boulders with high and low points due to uneven erosion.

Rock Structure

Between two sections of the earthen canal is a structure built out of rocks that has been mortared together to form a rectangular channel (Rock Structure). The Rock Structure measures 14 feet wide by 6 feet tall. On the structure's north side is an inlet with a gauging station. On the south side is a gate that opens into the Santa Ana River. At the Rock Structure's downstream end there are two 7 feet wide gate openings. No record drawings of the Rock Structure are available, so physical measurements were taken of the Rock Structure as shown on Figure 2-4.

Canal Section between Rock Structure and Bridge

After the Rock Structure, water flows into an earthen canal. The beginning of this canal appears to have eroded approximately 1 to 1.5 feet below the invert at the inlet of the Rock Structure. Two cross-sections were surveyed between the Rock Structure and the bridge as shown in Figure 2-3. The representative slope measured through this reach was 0.023.

Bridge

A deteriorated wooden bridge with steel I-beams spans across the canal downstream of the Rock Structure. No record drawings of the bridge are available. A vertical distance of 8 feet was measured from the bottom of the bridge to the canal invert. The approximate widths of the top and bottom of the canal at the bridge are 32 and 14 feet, respectively.

Canal Section between Bridge and Greenspot Road

The concrete abutments and pier to an old bridge are present in the canal approximately 200 feet upstream of Greenspot Road. The slope of the canal measured along this reach is 0.024. The approximate locations of the cross-sections are located in Figure 2-2.

Greenspot Road Culvert

The culvert at Greenspot Road is 10 feet wide by 4 feet high (Figure 2-4). The top (road) is 1 foot 10 inches thick. The concrete on the downstream end of the culvert is eroded and washed out, leaving a depression in the canal. This depression indicates that water flows through this culvert at high velocities.

Canal Section between Greenspot Road and Parshall Flume

The slope of the earthen canal between Greenspot Road and the Parshall Flume was measured to be 0.018 feet (Figure 2-3). The approximate location of the cross-section is shown on Figure 2-2.

Parshall Flume

Figure 2-4 shows the Parshall Flume's overall dimensions taken from a record drawing. The structure is 97 feet long with an initial width of 28 feet with 6 feet high concrete walls. The

Parshall Flume necks down to 18 feet before it expands to a width of 32 feet at its downstream end.

Canal Section between Parshall Flume and Diversion Structure

The slope of the earthen canal between the Parshall Flume and the Diversion structure is 0.035. The location of a cross-section measured at the Canal Section is shown on Figure 2-2, while the cross-section measurements that were taken at the bank's lowest points are shown on Figure 2-3.

Diversion Structure

The Diversion Structure consists of three gates: two gates side by side on the north and one gate on the canal's southerly side. Record drawings of this structure are not available, so field measurements were recorded. The gate to the south is used to divert water to the Borrow Pit, which includes Ponds 1, 2, and 3, while the north gates discharge water to the spreading grounds west of the Borrow Pit. The width of the canal measured upstream of the diversion structure is 14 feet. Each gate is 8 feet wide by 3 feet tall, and opens to a maximum height of 4 feet (Figure 2-4).

2.2 SOIL INVESTIGATION METHODS

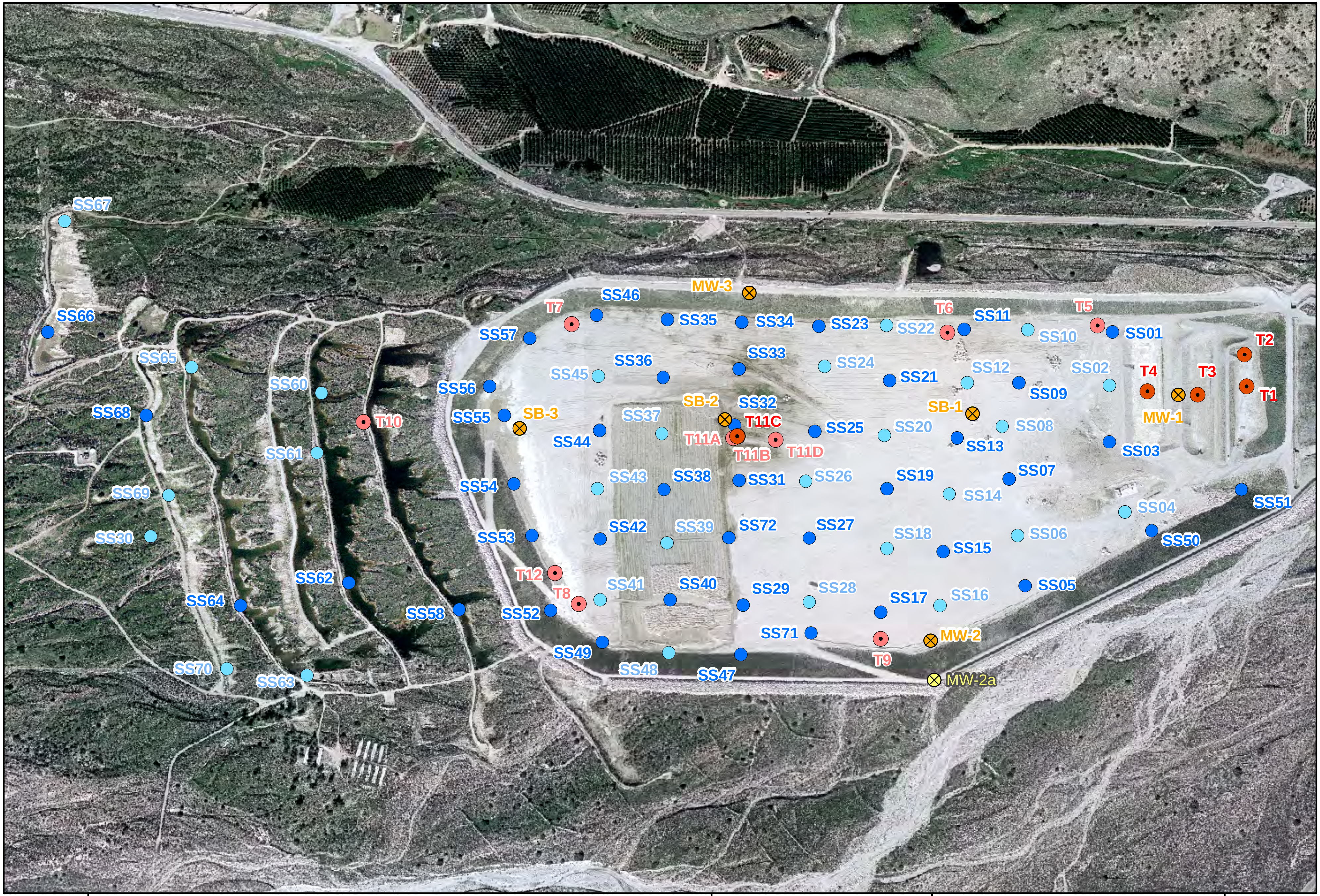
In June and July 2008, MWH conducted a soil investigation as described in the field work plan (MWH, 2008). The soil investigation consisted of surface soil sampling, trenching, and sonic drilling. The investigation was performed under the supervision of a registered Professional California Geologist in accordance with the American Society for Testing and Materials (ASTM) Method D 2487-06 and the Unified Soil Classification System (USCS). The various sample locations are shown on in **Figure 2-5**. Trench logs and boring logs are included as **Appendix C and D**, respectively. Selected photos of the soil sample, trenching and sonic drilling taken during the soil investigation are included in Appendix E.

Surface Soil Sampling

Seventy-two surface soil samples were collected at a depth of approximately one foot along a rectangular pattern within the Borrow Pit and from Ponds 10 through 17 to the west of the Borrow Pit (Figure 2-5). The soils encountered during this sampling were visually classified using ASTM methods, and selected samples were sent to a soils laboratory for more quantitative testing. Visual soil descriptions noted during surface soil sampling are provided in **Appendix D**.

Trenching

Ten trenches were proposed in the field work plan (MWH, 2008). However, to provide better definition of the area and to investigate specific areas of interest, a total of 15 trenches (T1 – T15) were excavated at 12 locations in the study area as shown on Figure 2-5 and described below:



Key to Features

- ⊗ Monitoring Wells Installed During This Study
- ● Soil Sample Sent For Lab Analysis
- ● Soil Sample Not Sent For Lab Analysis
- ⊙ Trench Location Sample Sent For Lab Analysis
- ⊙ Trench Location Sample Not Sent For Lab Analysis
- ⊗ Boring not completed as well

N

0 200 400 800 Feet

Document: SBVWCD_TrenchFig2-5.mxd

Date: December 22, 2008

Surface Soil Sample, Trench, and Monitoring Well Locations

Figure 2-5

Santa Ana River Groundwater Recharge
Optimization Study

- Two of the trenches (T1 and T2) were in Pond 1 to investigate the soils in this pond and to attempt to observe evidence of a splay of the San Andreas Fault system which was shown to transect Pond 1 in existing literature (USGS, 2003b).
- A trench was excavated in both Pond 2 (T3) and Pond 3 (T4) to characterize surface and shallow sediments in these ponds.
- Three trenches (T5 through T7) along the north wall of the Borrow Pit were excavated to evaluate the cause of surfacing groundwater historically observed on the north wall.
- A trench (T8) was located in the southwest corner of the Borrow Pit where water was often observed to surface or “daylight” by the Conservation District staff.
- A trench (T9) was located in the southeast corner of the Borrow Pit to characterize soils at that location.
- A trench (T10) was located outside the Borrow Pit at Pond 10 to compare the sediments with those located within the Borrow Pit.
- Four trenches were excavated in the center portion of the Borrow Pit to investigate the surfacing groundwater noted during field efforts (T11A through T11D).
- A final trench (T12) was located northwest of T8 to confirm soil conditions where water historically ponds.

All trenches were excavated using a backhoe operated by Larry Jacinto Construction, Inc. under contract to MWH to an approximate depth of 5 feet. An on-site geologist logged the side wall of the trenches to observe stratification, clay seams, or other pertinent features (Appendix C). At the location of T11, 4 trenches were excavated (T11A, T11B, T11C, and T11D). Water was observed to percolate into the trenches at depths of 2.5, 2.9, 3.0 and 4.5 feet, respectively. Water was not seeping into the trenches at any other locations. Soil samples were collected at depths of approximately 1 foot and 5 foot or just above water. Once logged and sampled, the trenches were backfilled.

Sonic Drilling

Five borings and two monitoring wells were proposed in the field work plan (MWH, 2008). However, based on the field observations of MWH geologists, and to provide more data for soil and aquifer analysis, a total of seven borings were completed, six of which were completed as monitoring wells. Drilling was conducted using the sonic drilling method as described in TM-1 (MWH, 2008), by Boart Longyear Company, under contract to MWH. The rationale for location of the borings and monitoring wells is described below.

- Three sonic borings were excavated along the long axis (east-west) of the Borrow Pit (SB-1, SB-2, and SB-3) to evaluate changes in soil properties from east to west. These borings were completed as shallow monitoring wells for future monitoring to evaluate aquifer conditions and depth to groundwater.
- One sonic boring was excavated between Ponds 2 and 3 in the Borrow Pit (MW-1) and completed as a monitoring well for observation of changes in groundwater levels during

subsequent percolation testing.

- One sonic boring was excavated on the northern boundary of the Borrow Pit (MW-3) and completed as a monitoring well to assess why groundwater surfaces along the north wall of the Borrow Pit.
- One sonic boring was completed (MW-2a) on the upper elevations of the perimeter access road on the southern edge of the Borrow Pit to evaluate soil and aquifer conditions on the southern edge of the Borrow Pit. This boring met refusal at a depth of 90 feet. To complete a monitoring well at this location, a second borehole was completed at lower elevation on the southern edge, and within the Borrow Pit (MW-2).

The sonic boring method consists of a 6 inch diameter barrel with a 4 inch diameter barrel sampler and a cutting bit at the lower end. MWH's on-site geologists logged the samples and transferred the samples into a sample box for storage. Per the direction of the Conservation District, the samples were stored at a facility owned by the Conservation District located at the Seven Oaks Dam. The boring information is summarized in **Table 2-2**. More detail on construction of the monitoring wells is provided in Section 2.4 below.

Table 2-2
Summary of Borings and Depths

Boring/Monitoring Well Designation	Date Installed	Depth (feet below ground surface)	Completed as a Monitoring Well?
SB-1	7/3/2008	50	Yes
SB-2	7/3/2008	50	Yes
SB-3	7/7/2008	50	Yes
MW-1	6/30/2008	150	Yes
MW-2a	6/26/2008	90	No
MW-2	6/26/2008	102	Yes
MW-3	7/9/2008	157	Yes

Sample Selection for Laboratory Analysis

MWH selected representative soil samples for laboratory analysis and submitted seventy-five soil samples for grain size analysis distribution by ASTM Method D422/4464M. Sixteen of the 75 samples were also submitted for hydraulic conductivity analysis by ASTM Method D5084. Among the 75 samples selected for analysis, 43 of them were from surface soil sampling locations, 10 were from the trenches, and 22 were from boreholes. The rationale for sample selection for laboratory analysis was to focus on locations where groundwater had historically surfaced in the Borrow Pit, to focus on the three existing ponds in the Borrow Pit and the western end of the Borrow Pit, and to provide a reasonable geographic and vertical distribution of samples.

2.3 SOIL INVESTIGATION RESULTS

Sample identification, depth, median grain size, and particle size distribution in weight percent are summarized in **Table 2-3** for all samples submitted for laboratory analysis.

Table 2-3
Sample Particle Size Summary

Sample ID	Depth (foot)	Description USCS(1)	Median Grain Size (mm)	Particle Size Distribution, wt. percent				
				Gravel	Sand Size			Silt/Clay
					Coarse	Medium	Fine	
MW-1-52	52	Medium sand	0.924	17.73	13.25	44.41	16.94	7.67
MW-1-57	57	Gravel	N/A	71.59	8.58	10.01	7.54	2.28
MW-1-72	72	Coarse sand	0.899	27.34	6.9	32.23	24.55	8.97
MW-1-75	75	Gravel	5.699	53.74	15.96	24.16	5.7	0.43
MW-1-91	91	Medium sand	0.586	6.63	4.67	46.34	33.78	8.58
MW-2-3	3	Coarse sand	0.696	26.23	9.26	22.82	26.14	15.55
MW-2-32	32	Gravel	0.904	34.12	5.43	23.96	24.81	11.67
MW-3-102	102	Medium sand	0.661	8.62	12.54	41.69	28.57	8.57
MW-3-104	104	Medium sand	0.637	3.49	12.66	46.07	28.56	9.22
MW-3-116	116	Medium sand	0.67	7.95	8	47.77	26.99	9.29
MW-3-30	30	Fine sand	0.297	0	2.88	36.81	42.11	18.2
MW-3-38	38	Gravel	0.667	33.99	2.02	24.16	30.63	9.2
MW-3-43	43	Medium sand	0.701	5.38	13.16	49.23	27.77	4.45
MW-3-58	58	Coarse sand	1.625	31.63	14.03	31.93	16.42	5.99
MW-3-91	91	Medium sand	0.589	0.67	12.43	48.52	31.36	7.02
SB-1-40	40	Gravel	3.772	46.79	11.89	27.66	12.28	1.38
SB-1-47	47	Gravel	14.125	61.49	7.84	17.46	10.72	2.48
SB-1-5	5	Gravel	2.184	42.31	8.54	18.7	19.51	10.94
SB-2-18	18	Medium sand	1.191	12.48	19.15	46.95	15.75	5.68
SB-2-3	3	Gravel	2.596	43.6	9.3	23.39	17.33	6.38
SB-3-43	43	Medium sand	0.725	21.65	11.83	28.32	27.15	11.05
SB-3-7	7	Gravel	1.395	38.77	6.76	27.21	21.19	6.07
SS-01	1	Gravel	1.984	39.95	9.91	27.68	16.41	6.05
SS-03	1	Gravel	1.321	30.83	11.26	31.04	19.53	7.32
SS-05	1	Coarse sand	1.114	24.8	13.5	31.31	21.67	8.72
SS-07	1	Medium sand	0.754	12.14	15.21	37.68	25.49	9.49
SS-09	1	Medium sand	0.912	15.66	14.91	39.44	22.32	7.68
SS-11	1	Gravel	1.683	37.62	9.71	28.33	18.84	5.49
SS-13	1	Medium sand	0.843	19.45	12.47	35.36	23.97	8.75
SS-15	1	Medium sand	1.085	14.32	18.26	43.35	15.8	8.28
SS-17	1	Medium sand	0.837	14.05	14.25	39.57	24.02	8.11
SS-19	1	Gravel	7.249	56.55	9.29	18.44	11.24	4.49
SS-21	1	Medium sand	0.979	13.23	18.72	39.31	21.19	7.55
SS-23	1	Coarse sand	1.051	23.43	11.58	39.48	19.65	5.85
SS-25	1	Coarse sand	1.062	22.04	14.25	37.61	20.49	5.61
SS-27	1	Coarse sand	1.628	31.93	14.05	28.84	20.93	4.26
SS-29	1	Coarse sand	1.358	26.51	15.05	33.25	21.86	3.33
SS-31	1	Coarse sand	1.177	19.29	18.69	36.03	20.85	5.14
SS-32	1	Coarse sand	1.097	24.22	13.75	33.62	20.01	8.39

Sample ID	Depth (foot)	Description USCS(1)	Median Grain Size (mm)	Particle Size Distribution, wt. percent				
				Gravel	Sand Size			Silt/Clay
					Coarse	Medium	Fine	
SS-33	1	Coarse sand	1.099	22.21	15.57	34.22	21.26	6.74
SS-34	1	Coarse sand	0.934	23.49	9.77	35.88	21.4	9.46
SS-35	1	Coarse sand	1.104	26.17	11.26	34.43	20.8	7.34
SS-36	1	Gravel	2.783	43.27	11.16	27.9	13.6	4.06
SS-38	1	Medium sand	1.036	20.74	14.45	32.31	22.74	9.76
SS-40	1	Medium sand	0.757	13.73	14.2	34.34	25.19	12.53
SS-42	1	Medium sand	0.777	13.09	16.11	34.5	27.93	8.37
SS-44	1	Coarse sand	1.138	24.98	14.45	31.77	21.55	7.25
SS-46	1	Medium sand	0.795	20.58	10.6	34.16	24.49	10.18
SS-47	1	Medium sand	0.438	4.25	4.37	43.17	39.64	8.58
SS-49	1	Medium sand	0.438	3.96	7.86	39.52	37.35	11.31
SS-50	1	Medium sand	0.71	5.24	11.6	48.23	30.06	4.88
SS-51	1	Medium sand	0.59	0.78	9.77	51.84	32.91	4.7
SS-52	1	Medium sand	1.133	14.83	18.21	46.63	19.63	0.69
SS-53	1	Fine sand	0.05	0	2.03	16.58	20.66	60.73
SS-54	1	Medium sand	0.329	6.83	7.13	30.72	29.88	25.43
SS-55	1	Medium sand	0.423	6.09	10.82	33.21	27.01	22.88
SS-56	1	Medium sand	0.652	17.52	7.89	36.5	25.38	12.71
SS-57	1	Gravel	0.926	30.55	6.84	31.7	23.31	7.6
SS-58	1	Coarse sand	1.191	26.8	10.42	43.37	15.55	3.85
SS-62	1	Coarse sand	1.176	24.57	10.55	44.53	16.55	3.79
SS-64	1	Gravel	0.996	32.78	4.17	34.27	22.71	6.07
SS-66	1	Gravel	2.419	32.29	26.21	23.1	9.58	8.82
SS-68	1	Medium sand	0.881	16.02	6.69	55.17	16.39	5.72
SS-71	1	Medium sand	1.033	13.51	16.03	47.39	19.18	3.9
SS-72	1	Medium sand	0.786	14.58	13.35	39.69	24.46	7.91
T1-1	1	Coarse sand	1.009	29.49	8.75	29.47	18.94	13.34
T11C-1	1	Gravel	2.242	39.35	12.29	23.69	16.96	7.7
T11C-3	3	Gravel	N/A	74.72	5.31	16.18	3.3	0.5
T1-5	5	Coarse sand	1.654	31.03	13.28	46.7	7.8	1.18
T2-1	1	Medium sand	0.862	19.88	10.52	39.07	25.45	5.08
T2-5	5	Coarse sand	1.384	17.91	20.4	47.65	12.4	1.64
T3-1	1	Gravel	14.397	62.01	4.41	18.39	10.55	4.64
T3-5	5	Coarse sand	1.553	22.96	17.37	49.17	9.11	1.39
T4-1	1	Medium sand	0.914	14.5	14.95	41.77	21.82	6.96
T4-5	5	Gravel	1.782	36.64	11.1	34.99	14.74	2.54

(1) Unified Soil Classification System

For comparison to field results, standardized USCS size ranges are provided in **Table 2-4**.

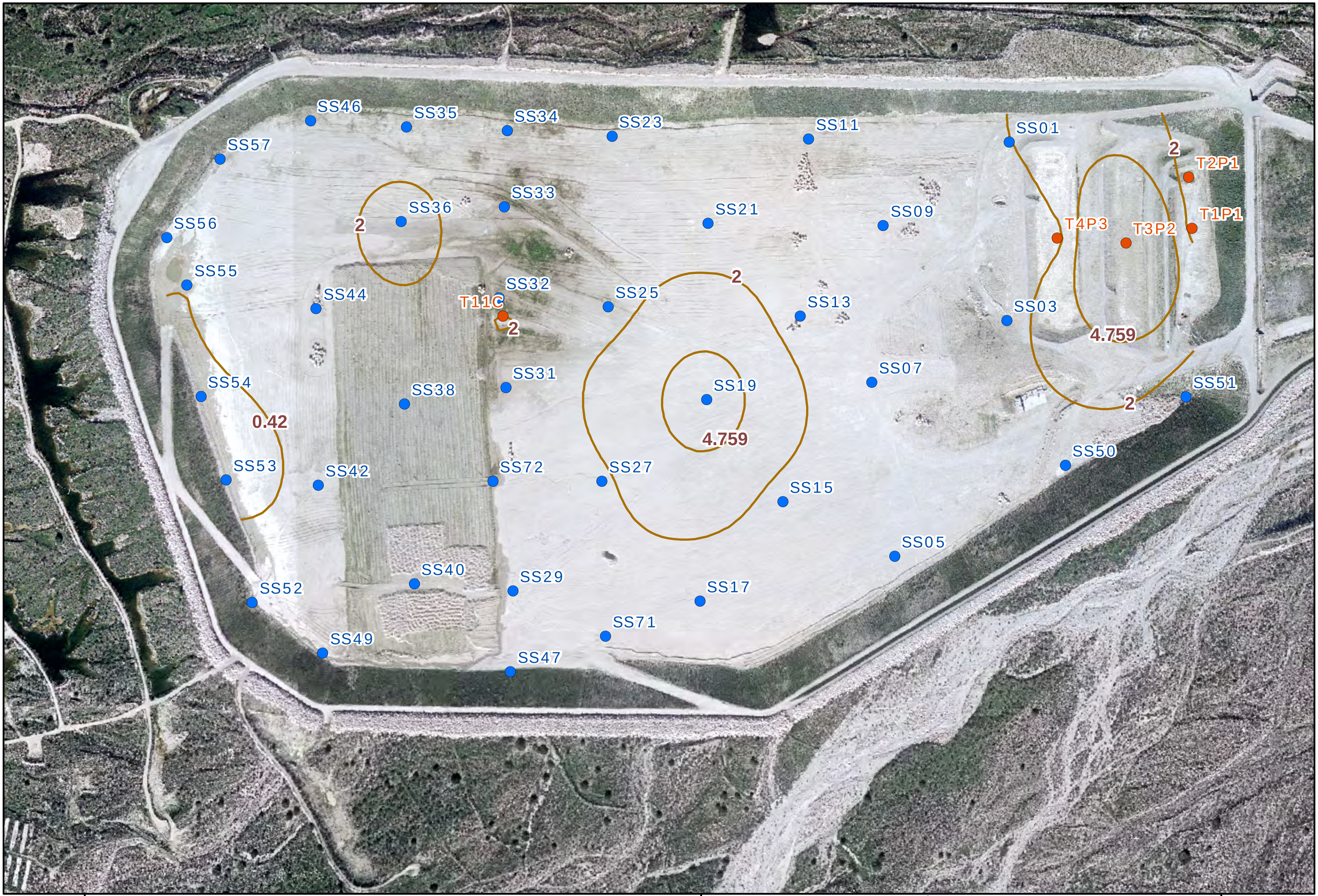
Table 2-4
Unified Soil Classification System

Classification	Size Range
Cobbles	Above 3 inches
Gravel • Coarse • Fine	3 inches to No. 4 sieve • 3 inches to ¾ inch • ¾ inch to No. 4 sieve
Sand • Coarse • Medium • Fine	No. 4 to No. 200 sieves • No. 4 to No. 10 sieves • No. 10 to No. 40 sieves • No. 40 to No. 200 sieves
Fines (clay or silt)	Below No. 200 sieve (no minimum size)

Forty-eight (43 from the Borrow Pit and 5 from outside the Borrow Pit) surface soil samples and trench samples collected and analyzed at a depth of one foot, and were classified as follows:

- 10 are classified as gravel
- 14 are classified as coarse sand
- 23 are classified as medium sand
- 1 is classified as fine sand

Figure 2-6 illustrates the estimated contours of equal median size based on samples from a depth of 1 foot in the Borrow Pit. The contours suggest that grain size is finer at the western edge of the Borrow Pit, where water has historically ponded. The 3 surface soil samples from Pond 1 and 3 also have relatively fine grain size distribution. Excluding the 2 abnormally greater median grain size of samples SS-19 and T3P2, the remaining 41 samples from the Borrow Pit have an average median grain size of 1.02 millimeter (mm), and the average median grain size for the 5 samples from the ponds outside the Borrow Pit is 1.33 mm (31 mm coarser). Contours of equal fine particle (silt and clay) percentage of surface soil samples in the Borrow Pit are illustrated in **Figure 2-7**, showing that most areas of the Borrow Pit have a fine particle percentage of less than 6 percent. However, along the western end where water has historically ponded, two anomalously high fine particle percentage ranges (as high as 60 percent) exist. On average, samples from the Borrow Pit contain 9.32 percent of fine particles, while those from the outside the Borrow Pit contain an average of 5.65 percent fine particles (**Table 2-5**). The relative finer surface soil grain size in the Borrow Pit may be responsible for the low percolation rate as compared to ponds outside the Borrow Pit.



Key to Features

● Surface Soil Samples

● Trench Location Samples

Contours of Equal Grain Size (mm)

Grain Size Definitions
> 4.759 mm Gravel
2 - 4.759 mm Coarse Sand
0.42 - 2 mm Medium Sand
0.074 - 0.42 mm Fine Sand
<0.074 mm Silt and Clay

N
0 150 300 600 Feet

Document:SBVWCD_Median GrainSizeContours.mxd

Date: December 22, 2008

Contours of Equal Median Grain Size - Surface Soil Samples in the Borrow Pit

Figure 2-6

Santa Ana River Groundwater Recharge Optimization Study

Key to Features

● Surface Soil Samples

● Trench Location Samples

— Contours of Equal Fine Particle Percentage

Document: SBVWCD_FineParticleContours.mxd

Date: December 8, 2008

Contours of Equal Fine Particle Percentage - Surface Soil Samples in the Borrow Pit

Figure 2-7

Santa Ana River Groundwater Recharge
Optimization Study

Table 2-5
Average Median Grain Size and Weight Percentage of Silt/Clay

Sample Location	Number of Samples	Average Median Grain Size (mm)	Average Weight Percentage of Silt/Clay (%)
Borrow Pit	43	1.02*	9.32
Outside Borrow Pit	5	1.33	5.65

NOTE * Average of 41 of the 43 surface soil samples, where the samples were taken at a depth of approximately one foot. Samples SS-19 and T3 have been excluded because they have an anomalously high median grain size.

The four soil samples taken at a depth of five feet in trenches have been classified as either coarse sand with a median grain size of 1.654 mm, 1.384 mm, and 1.553 mm, or gravel with a median grain size of 1.782 mm. Of the remaining 22 sonic drilling samples, nine (9) are classified as gravel, 3 coarse sand, 9 as medium sand, and only 1 fine sand.

Table 2-6 summarizes median grain sizes, silt and clay weight percentage, and hydraulic conductivity of the 16 samples collected from trenching and sonic drilling. Laboratory-measured hydraulic conductivity ranges from 0.00274 to 19.7 feet/day.

Table 2-6 also illustrates that the hydraulic conductivity is more dependent on the percentage of fine particles than median grain size and overall grain size distribution. For example, sample SB-2-3 contains 6.38% silt and clay, but has a relatively large median grain size and is classified as gravel. However, this sample has a much lower hydraulic conductivity than sample SB-2-18, even though SB-2-18 has a smaller median grain size and is classified as medium sand.

In general, samples from Pond 2 have larger median grain size, less fine particles (surface samples) and higher hydraulic conductivity (samples at a depth of 5 feet) than those from Ponds 1 and 3. This result is consistent with the Conservation District staff’s observation that Pond 2 has the fastest percolation rate of the three ponds in the Borrow Pit.

Table 2-6
Summary of Laboratory Analysis Results

Sample ID	Depth (feet)	Description (USCS)	Median Grain Size (mm)	Silt /Clay wt. percent	Hydraulic Conductivity (feet/day)
T1-P1-1	1	Coarse sand	1.009	13.34	0.066
T1-P1-5	5	Coarse sand	1.654	1.18	7.26
T2-P1-1	1	Medium sand	0.862	5.08	0.374
T2-P1-5	5	Coarse sand	1.384	1.64	19.7
T3-P2-1	1	Gravel	14.397	4.64	0.0346
T3-P2-5	5	Coarse sand	1.553	1.39	1.01
T4-P3-1	1	Medium sand	0.914	6.96	0.283
T4-P3-5	5	Gravel	1.782	2.54	6.72
T11C-1	1	Gravel	2.242	7.70	0.0788
T11C-3	3	Gravel	N/A	0.50	15.1
SB-2-3	3	Gravel	2.596	6.38	0.0955
SB-2-18	18	Medium sand	1.191	5.68	0.349
MW-1-72	72	Coarse sand	0.899	8.97	0.113
MW-3-30	30	Fine sand	0.297	18.20	0.0371
MW-3-38	38	Gravel	0.667	9.20	0.00274
MW-3-102	102	Medium sand	0.661	8.57	0.00371

Note - Hydraulic conductivity values are obtained from laboratory analysis on disturbed samples which may differ from in-situ conditions.

2.4 MONITORING WELL CONSTRUCTION

As previously noted, 6 of the 7 sonic borings were completed as monitoring wells for future monitoring of groundwater levels. Deeper monitoring wells were installed to a depth of approximately 150 feet or to the water table and identified as MW-1 through MW-3. Shallower monitoring wells were installed to a depth of 50 feet below ground surface and identified as SB-1 through SB-3 (Figure 2-5) as designated in the work plan (MWH, 2008).

Monitoring wells were constructed using 2 inch PVC casing with a 0.010 inch slotted screen. Wells were screened from the bottom of the borehole to a depth approximately 15 feet below ground surface. A blank casing was installed from 15 feet below ground surface to either ground surface (flush-mounted) or 3 feet above ground surface. The annular space between the borehole wall and the screened casing was packed with #2 Monterey Sand from the bottom of the borehole to a depth of approximately 10 feet below ground surface. Bentonite clay was used to seal the casing above the sand to ground surface. The surface seal used for MW-1 and MW-3 was concrete and completed as flush-mount. SB-1, SB-2, SB-3 and MW-2 were completed with a riser to approximately 3 feet above ground surface, enclosed in a 6 inch steel pipe with cap and surrounded by four protective bollards (4 inch steel pipe sealed on top with concrete). Well completion logs are provided in **Appendix F**.

At each new well location, groundwater levels were measured on July 8, 2008 using a manual electronic sounding tool. On August 22, 2008, MWH completed a second round of manual groundwater level measurements and installed six transducers to automatically record groundwater level measurements. The transducers installed are Level Troll® 100 models manufactured by In-Situ Inc., of Fort Collins, Colorado. Results of the two manual measurement events are summarized in **Table 2-7**.

Table 2-7
Manual Groundwater Level Measurements in Monitoring Wells

Well	Surface Point Elevation[1]	Depth to Groundwater on July 8, 2008[2]	Groundwater Elevation on July 8, 2008[1]	Depth to Groundwater on August 22, 2008[2]	Groundwater Elevation on August 22, 2008[1]
MW-1	1765.74	67.3	1698.4	75.99	1689.75
MW-2	1700.38	DRY	---	DRY	---
MW-3	1729.03	53.0	1676.0	64.50	1664.53
SB-1	1718.17	23.7	1694.5	35.56	1682.61
SB-2	1673.77	2.8	1671.0	7.37	1666.40
SB-3	1632.80	DRY	---	DRY	---

1 - feet above mean sea level
2 - feet below measuring point

Hydrographs taken from the transducers for these locations are given in **Appendix G**.

2.5 PERCOLATION TESTING AND CONVEYANCE TESTING

The Conservation District percolated water in Ponds 9 through 17, and Dike D west of the Borrow Pit from March 27 to May 9, 2008. During this period, the percolation rate of the ponds and the conveyance system were recorded and subsequently analyzed. A separate percolation rate test was conducted on Pond 17 from April 26, 2008 to May 6, 2008.

On May 9, 2008, the release from Seven Oaks Dam was decreased to conserve water for percolation testing of Borrow Pit Pond 1, which occurred from May 10, 2008 to May 22, 2008. At the completion of this initial percolation test, Pond 1 was cleaned by removing approximately 1 foot of basal material. The pond was then retested using imported water from the State Water Project from July 14, 2008 to August 1, 2008.

The initial percolation rate of Pond 1 was approximately 1.2 feet/day. After cleaning, the percolation rate increased to about 2.6 feet/day. However, this rate was still significantly slower than the percolation rate at Pond 17 of approximately 4.0 feet/day. To evaluate the effect that pond dimensions have on percolation rate (rectangular, as opposed to more linear), a third test was conducted on a portion of Pond 1. For example, Pond 1 is a large rectangular pond with an average water depth of about 4 feet, whereas Pond 17 was constructed by excavating a 15 feet deep linear trench. The third test on Pond 1 consisted of constructing a 6 feet wide, 4 feet deep linear trench that was approximately 550 feet long. Percolation testing of the Pond 1 linear trench was from October 13, 2008 to October 24, 2008.The following sections describe the percolation testing methods and details the percolation testing results on the Conservation District ponds and conveyance system, Pond 17 and Pond 1.

Percolation Testing Methods

Two testing methods were used for estimating percolation rates: (1) falling-head percolation tests and (2) constant-head or constant-rate percolation tests.

Falling-Head Percolation Tests

In falling-head percolation tests, ponds are filled and then the water supply is shutoff. The water levels are allowed to drop due to infiltration and evaporation. Evaporation is considered minimal with infiltration rate greater than 1 foot/day and is generally within the error of the analysis. The percolation rates are estimated by plotting water levels over time. The benefits of a falling-head percolation test are:

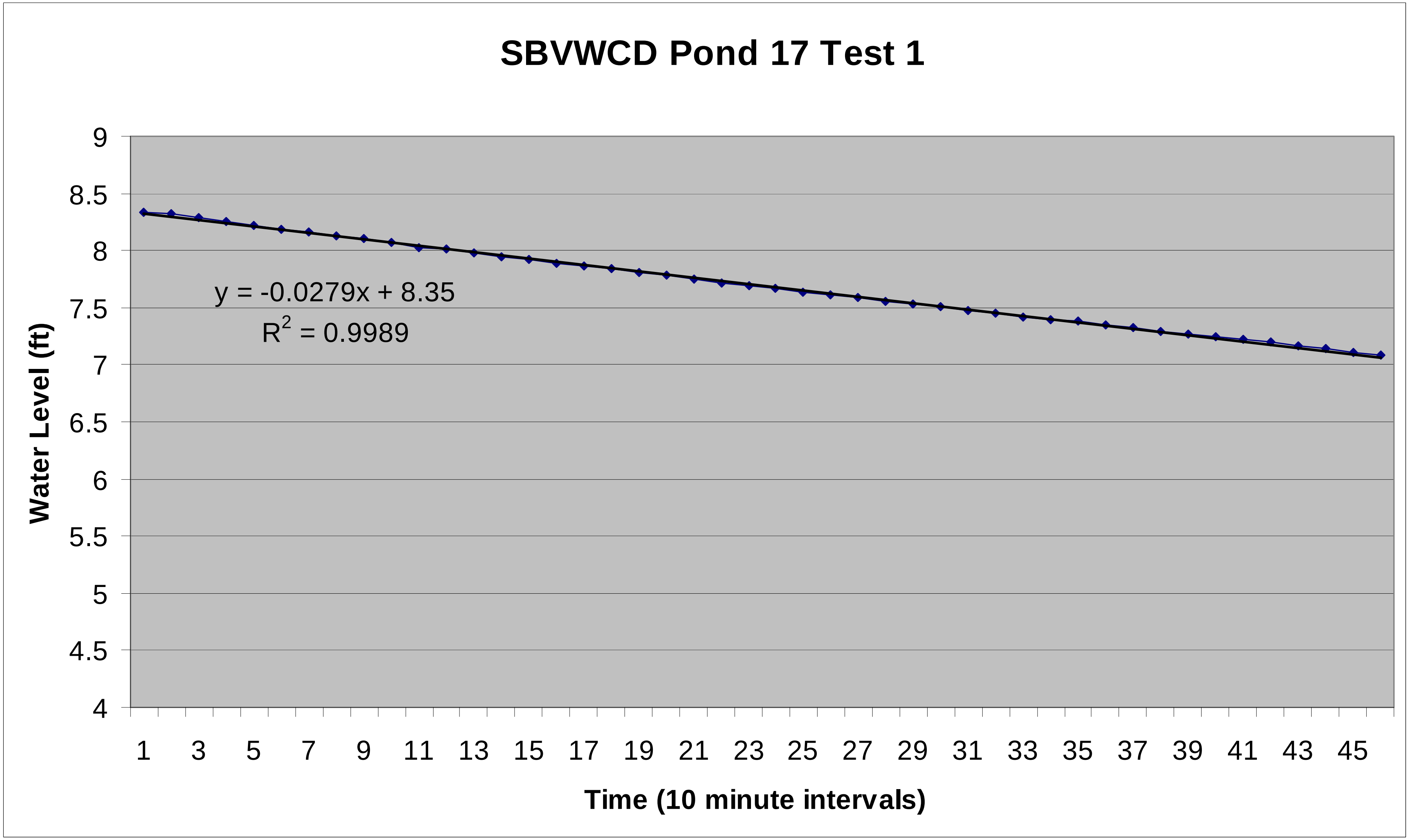
1. Water supply inflows in to the test pond do not need to be accurately measured. Flow meters generally produce large errors when used to calculate recharge rates in small test basins. This is due to inaccuracies at low flows when a constant water level is being maintained.
2. Tests generally require less water for testing than constant rate tests generally because they are run for a shorter time period.
3. This method works well on small, irregularly shaped test basins where the wetted area may be difficult to determine.
4. The wetted area does not need to be determined with great accuracy.

During the testing, water levels were measured and recorded electronically using a pressure transducer and data logger. Percolation rates were calculated over a 24-hour period using water level measurements. In the test ponds, water level measurements were recorded using this method every 10 minutes for a 24 hour period. Because the wetted area of the test ponds tended to decrease with time, the first 5 to 7 hours of water level measurements were used to estimate the percolation rate for the 24 hour period **(Figure 2-8)**. The initial measurements represent pond percolation rates at a near constant-rate with maximum wetted area. The process of filling and percolating is then repeated to obtain a consistent estimate of the percolation rate. A consistent rate is determined when the running average and the daily average are nearly the same over several days.

Constant-Head Percolation Tests

Constant-head or constant-rate percolation tests utilize water levels that are maintained at a consistent level. Water inflows are measured daily, and there is no outflow from the area. The wetted area for each of the ponds must be known and is used to calculate the percolation rate for the area.

Errors in water supply measurements, wetted area, and changing percolation rates produce errors in the calculation of the daily percolation rates. However, for a large test area, a constant-rate test over a long period of time generally produces reliable rate results.



Calculation of Daily Percolation Rates

Figure 2-8

Document: Figure2-8_
SBVWCD_DailyPercRatePond17.pub

Date: December 22, 2008

Santa Ana River Groundwater Recharge
Optimization Study

Water Level Measurements and Analysis Methods for Calculating Percolation Rates

Test pond water levels were determined with the use of a 15 pounds per square inch (psi) MiniTroll pressure transducer manufactured by In-Situ, Inc. The MiniTroll was installed in 2 inch diameter perforated polyvinyl chloride (PVC) pipe. The PVC pipe was placed vertically in the recharge basin, with the pressure sensor positioned near ground level to give a zero water level reading at zero depth of water. The transducer reads water levels as the height of water column above the pressure sensor read every 10 minutes.

The MiniTroll transducer was connected via SD12 cable to a Campbell Scientific, Inc. CR510 Datalogger. The CR510 Datalogger provided data storage and transmitted water level data to the MWH Team using a modem. The CR510 Datalogger and modem were powered by a 12 volt battery and solar panel. The telemetry station, consisting of datalogger, modem, battery, solar panel, and modem antenna, were housed within a ¼ inch steel-cased protective box.

Water level measurements are used to calculate the percolation rate. Changes in this wetted area or precipitation cause a corresponding change in the percolation rate. Test ponds generally have a consistent wetted area until a particular water level is reached. For Pond 17, the wetted area remained fairly consistent for about 8 hours of percolation, and then decreased. Percolation rates and the wetted area of Pond 1 were consistent for approximately the first 5 hours of percolation, and then decreased.

Summary of Percolation Testing

The following sections summarize the percolation testing results conducted at the recharge facilities. A complete set of water level plots for the tests are included in **Appendix B**.

Percolation Testing at Ponds 9 through 17, Dike D, and Conveyance System

A constant-head flow test was conducted on Ponds 9 through 17, Dike D, and the conveyance system. From March 31, 2008 to April 17, 2008 the flow rate as measured at the Parshall flume into the recharge area west of the Borrow Pit was approximately 145 cubic feet per second (cfs), or 288 acre feet per day (acre-feet/day). Recharge pond capacity values provided by the Conservation District indicate that the total wetted area of Ponds 9 through 17, and Dike D is about 57.5 acres. This wetted area does not include conveyance and diversion facilities between individual ponds. No outflow occurred from Dike D, which could suggest that the wetted area was still increasing during this period or that the inflow equaled the percolation rate. Based on this information, the percolation rate during this time period was about 5 feet per day (288 acre-feet/day divided by 57.5 acres). Because the wetted area does not include the conveyance and diversion facilities, the percolation rate is likely less on a per acre basis for the ponds alone. A rough estimate of the conveyance and diversion facilities used during the test is about 3.1 acres (about 34,000 ft total length by 4ft width). If you assume a percolation of 4 ft/day for the conveyance and diversion facilities this would account for about 12.5 acre-feet/day, and suggest that the ponds recharged at a rate of about 4.8 ft/day ((288-12.5) acre-feet/day divided by 57.5 acres).

Four falling-head percolation tests were performed on Pond 17. Pond 17 is typical of the ponds located west of the Borrow Pit area and was selected for testing because the water flow to the pond could be stopped without affecting other ponds. Pond 17 has a more linear pond design, which is conducive to greater percolation rates, than those ponds located within the borrow pit (Ponds 1-3). This is probably due to "edge effects" of water leaking laterally as well as horizontally.

The results of the four falling-head tests are presented in **Table 2-8** below. As noted previously, the wetted area of Pond 17 remained generally consistent for about the first 8 hours of percolation test, and these measurements were used to estimate the percolation rate of the pond. Based on these tests the percolation rate for the ponds outside the Borrow Pit area appears to be about 4 feet/day.

Table 2-8
Summary of Pond 17 Percolation Testing

Test #	Date	Test Drawdown Time (hours)	Recharge Rate (feet/day)	Running Average (feet/day)
1	April 26, 2008	7.7	4.02	4.02
2	April 29, 2008	7.7	3.83	3.92
3	May 2, 2008	7.5	3.92	3.92
4	May 6, 2008	7.7	4.19	3.98

Percolation Testing at Pond 1

Pond 1 was chosen for percolation testing due to its proximity to available water and it is representative of three ponds located at the east end of the Borrow Pit. Pond 1 was tested "as is," meaning that no cleaning of the bottom of the pond was done before testing. The ponds in the Borrow Pit have been used for recharge, and a noticeable layer of fine white clay and silt size material, locally up to 1/16 inch thick, was observed to be common on the floor of pond.

During the first five tests of Pond 1, some leakage out of the pond occurred between the wooden boards used to prevent water from flowing to Pond 2. The leakage was visually estimated at approximately 0.5 cfs and later adjusted to 0.55 cfs to better approximate the later test results. The pond did not dry between tests.

Based on the test results, Pond 1 had a percolation rate of about 1.2 feet/day in its initial condition. Results from the percolation testing are provided in **Table 2-9**, and plots of water level over time are included in Appendix B.

Table 2-9
Summary of Pond 1 Percolation Testing (not cleaned)

Test #	Date	Test Drawdown Time (Approx. hours)	Comments	Recharge Rate (feet/day)	Running Average (feet/day)
1	May 10, 2008	5	Leakage to Pond #2	1.37	1.37
2	May 12, 2008	5	Leakage to Pond #2	1.25	1.31
3	May 13, 2008	5	Leakage to Pond #2	1.13	1.25
4	May 14, 2008	5	Leakage to Pond #2	1.18	1.23
5	May 15, 2008	5	Leakage to Pond #2	1.18	1.22
6	May 19, 2008	5	No Leakage to Pond #2	1.12	1.17
7	May 20, 2008	5	No Leakage to Pond #2	1.34	1.19
8	May 21, 2008	5	No Leakage to Pond #2	1.20	1.19
9	May 22, 2008	5	No Leakage to Pond #2 Rain Events	1.21	1.20

Pond 1 was retested by the falling-head method after cleaning. Cleaning consisted of the removal of approximately 1 foot of material from the bottom of the pond and stockpiled outside of the pond in the Borrow Pit area. Pond 1 had a percolation rate of about 2.6 feet/day after cleaning. This is an increase of over 110 percent from the Pond's initial percolation rate of 1.2 feet/day. Results from the percolation testing of the cleaned pond are provided in **Table 2-10** below, and plots of water level over time are included in Appendix B.

Table 2-10
Summary of Pond 1 Percolation Testing (cleaned)

Test #	Date	Test Drawdown Time (Approx. hours)	Comments	Recharge Rate (feet/day)	Running Average (feet/day)
1	July 14, 2008	5	Dry from May 27. Cleaned	2.76	2.76
2	July 16, 2008	5	1.3 ft of water at filling	2.62	2.69
3	July 18, 2008	5	Dry for 12 hr before filling	2.56	2.65
4	July 21, 2008	5	Dry for 35 hr before filling	2.51	2.61
5	July 23, 2008	5	Dry for 10 hr before filling	2.62	2.62
6	July 25, 2008	5	Dry for 5 hr before filling	2.66	2.59
7	July 28, 2008	5	Dry for 27 hr before filling	2.53	2.58
8	July 30, 2008	5	Dry for 3 hr before filling	2.51	2.57
9	Aug. 1, 2008	5	Dry for 4 hr before filling	2.53	2.56

Water Levels during Percolation Testing of Pond 1 (cleaned)

During the percolation testing of Pond 1 (clean), groundwater levels in the newly constructed MW-1 were measured. On July 10, 18 and 20, 2008 water levels were measured by hand and were relatively consistent at 67.3, 66.5, and 66.1 feet below ground surface, respectively. From July 20, 2008 to August 22, 2008, groundwater levels in MW-1 were measured every 30 minutes using a temporary MiniTroll pressure transducer. Depth to groundwater during testing of Pond 1 (clean) from July 14, 2008 to August 1, 2008 generally ranged between 66 and 67 feet below ground surface. However, the groundwater level in MW-1 rose in response to recharge at Pond 1. After pond testing, groundwater levels continued to decline and measured at 76 feet below ground surface on August 22, 2008 when the MiniTroll pressure transducer was removed. On August 22, 2008 the MiniTroll pressure transducer was replaced with the permanent transducers (Level Troll 100).

Pond 1 Linear Trench

A linear trench measuring 6 feet wide by 4 feet deep, and running approximately the length of the Pond 1 was constructed to test if pond design contributed to the slower percolation rate of Pond 1 compared to Pond 17. Falling-head percolation rate testing results indicate that pond design may play a significant role in percolation rates. The percolation rate of the linear trench was about 8 feet/day compared to the cleaned Pond 1 which was about 2.6 feet/day. This is an increase of over 200 percent, and 100 percent better than Pond 17 at 4 feet/day. The higher percolation rate is most likely due to increased lateral infiltration in the trench. Percolation testing results for the linear trench are provided in **Table 2-11**, and plots of water level over time are included in Appendix B.

Table 2-11
Summary of Pond 1 Linear Trench Percolation Testing

Test #	Date	Test Drawdown Time (Approx. hours)	Comments	Recharge Rate (feet/day)	Running Average (feet/day)
1	October 13, 2008	7.2	Dry - Newly Constructed	10.84	10.84
2	October 14, 2008	8.3	Dry 14.5 hours	9.43	10.14
3	October 15, 2008	8.3	Dry 13.2 hours	9.29	9.85
4	October 16. 2008	8.7	Dry 13.7 hours	9.06	9.66
5	October 17. 2008	8.8	Dry 13.7 hours	8.76	9.48
6	October 20. 2008	8.2	Dry 62.8 hours	9.30	9.17
7	October 21. 2008	8.3	Dry 11.2 hours	8.45	8.97
8	October 22. 2008	8.7	Dry 11.3 hours	8.16	8.84
9	October 23. 2008	9.7	Dry 11.3 hours	7.88	8.60
10	October 24. 2008	7.5	Dry 9.0 hours	7.88	8.50

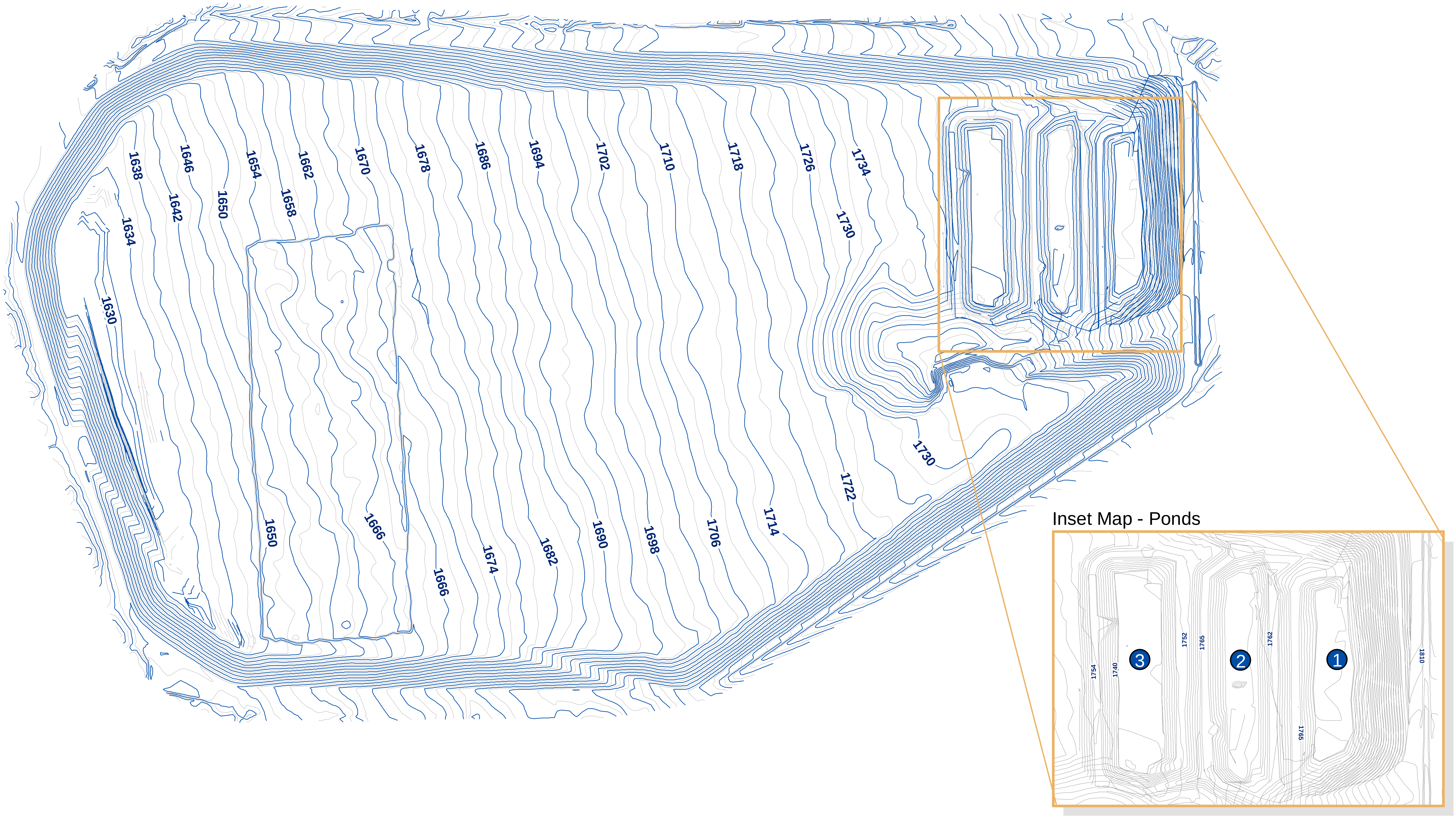
Observations of Rising Groundwater During Pond 1 Testing

Rising groundwater was observed flowing into Pond 3 on May 10, 2008 prior to the first percolation testing at Pond 1. The source of this water is not believed to be directly related to the percolation testing, because the presence of rising water occurred in Pond 3 before the filling of Pond 1. However, during a second visit to Pond 3 on May 19, 2008 during the testing in Pond 1, the flow rate of the rising water in Pond 3 did appear to be higher. The location of the rising groundwater in Borrow Pit Pond 3 is at the northeastern end of the pit at its lowest level. The fact that this location is the lowest elevation of Ponds 1 through 3 is consistent with a rising groundwater source, but this cannot be confirmed based on monitoring well data because the monitoring wells were not installed yet. Large areas of rising groundwater were also noted in the main Borrow Pit area near the center during May 2008. This rising water then flows west along the ground surface to the end of the main Borrow Pit where a large pond has developed.

No rising groundwater in Pond 3 was observed during the subsequent testing (clean and linear trench) at Pond 1 in July and October of 2008. However, hydrographs of existing wells and monitoring wells installed during this study indicate that groundwater levels were generally declining from March 2008 into the Fall of 2008. During the testing in July and October of 2008, the lower ambient groundwater levels probably prevented groundwater from rising to the surface during percolation testing performed in the Fall.

2.6 PHYSICAL SURVEYS

On August 7, 2008, Calvada Surveying, Inc., under contract to MWH conducted a survey of the new monitoring wells installed as part of the SAR optimization investigation. Additional surveys were completed in Ponds 1 through 3 in the Borrow Pit, and an area in the north-central portion of the Borrow Pit where water has been observed to surface (this area is visible as green vegetation on aerial photographs (e.g. Figure 2-7). The survey information was combined with existing topographic data available (**Figure 2-9**). On September 19, 2008, MWH and the Conservation District staff conducted a field survey of surrounding wells in the vicinity of the Borrow Pit (**Figure 3-1** in the following section). These locations were surveyed using a hand held global positioning system (GPS) and the common names used for each well were confirmed with the Conservation District staff.



① Borrow Pit Pond Number

— 4 Foot Contours

— 2 Foot Contours

0 150 300 600 Feet

N

Document: SBVWCD_BorrowPitTopo.mxd

Date: December 22, 2008

Topography of Borrow Pit

Figure 2-9

Santa Ana River Groundwater Recharge
Optimization Study

Section 3
Aquifer Characteristics

Understanding of the characteristics of the aquifer underlying the SAR recharge facilities is critical to the evaluation of the facilities ultimate recharge capacity. This section describes how the physical characteristics of the aquifer underlying the SAR recharge facilities relate to percolation of water at existing recharge facilities. The understanding of aquifer conditions at the recharge facilities is based on review of existing literature and data, as well as new information collected during field work described in the previous section.

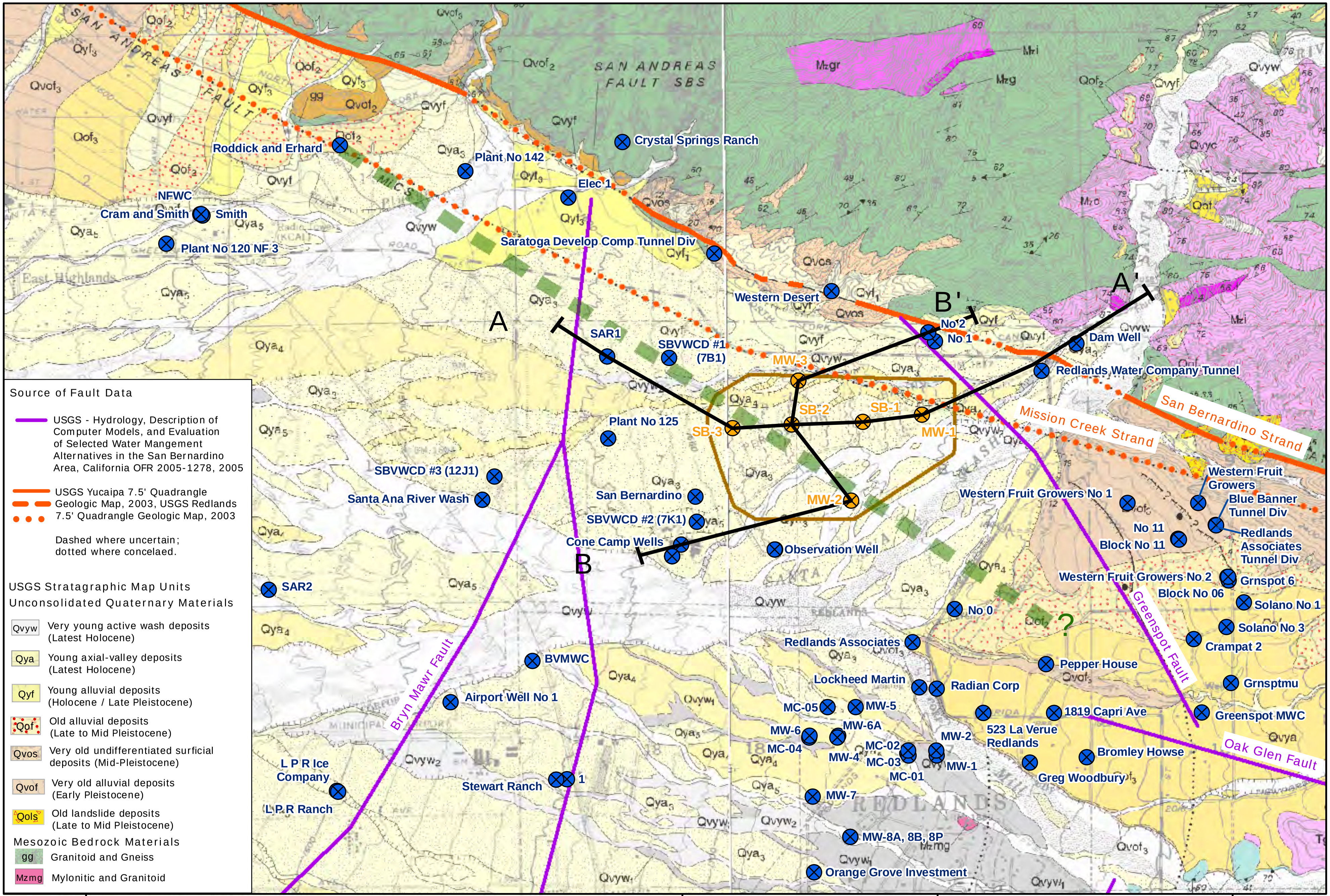
3.1 GEOLOGIC SETTING

Figure 3-1 is a geologic map of the project area compiled from mapping performed by the U.S. Geological Survey (USGS, 2003a, and 2003b). Figure 3-1 also shows mapped or suspected faults in the area (USGS, 2005), known existing wells in the vicinity of the recharge facilities, and the locations of geologic profiles developed during this study. Each of these is described in more detail below.

Figure 3-1 also illustrates the distribution of two general rock types which occur in the vicinity of the SAR recharge facilities. The two general rock types are unconsolidated Quaternary deposits and Mesozoic bedrock material. Bedrock materials consisting of older (Mesozoic) igneous and metamorphic rocks are located in the topographic highlands northeast of the site. These materials are relatively impermeable and do not percolate or store appreciable amounts of water.

The other general rock type is relatively recent unconsolidated alluvial material where the existing recharge facilities are located, that forms the aquifer that receives, stores, and transmits recharge water. The USGS identified at least five separate alluvial sequences that are present near the recharge facilities. These separate alluvial sequences are identified on Figure 3-1 using the symbol convention “Q” (for Quaternary) followed by an abbreviation of a description of the deposits, such as very young wash deposits (Qvyw). The youngest of these is a Holocene surficial deposits consisting of sediment transported and deposited in channels and washes (Qvyw) of the Santa Ana River, or surfaces of alluvial fans (Qvyf), and alluvial valleys (Qvya). These deposits are typically very coarse and permeable, with no soil development. Within and surrounding the Borrow Pit, Qvyw consists of cobble-boulder-gravel and poorly-sorted gravelly sand that contains boulders as much as one meter or more in diameter.

Older surficial deposits consist of sediment that is slightly to moderately consolidated and slightly to moderately dissected. These alluvial valley deposits are exposed at the ground surface within and in the vicinity of the Borrow Pit. The upper surfaces of these deposits are commonly capped by slight to moderately developed soil profiles.



Key to Features

● Existing Wells

● Monitoring Wells Installed During This Study

🟩 🟩 Potential Barrier Based on Groundwater Elevation Data

A—A' Location of Profiles

▭ Borrow Pit

N

0 750 1,500 3,000 Feet

Document: SBVWCD_CrossSectionFig3-1.mxd

Date: December 22, 2008

Geologic Map with Additional Fault Locations from Various Sources

Figure 3-1

Santa Ana River Groundwater Recharge Optimization Study

MWH

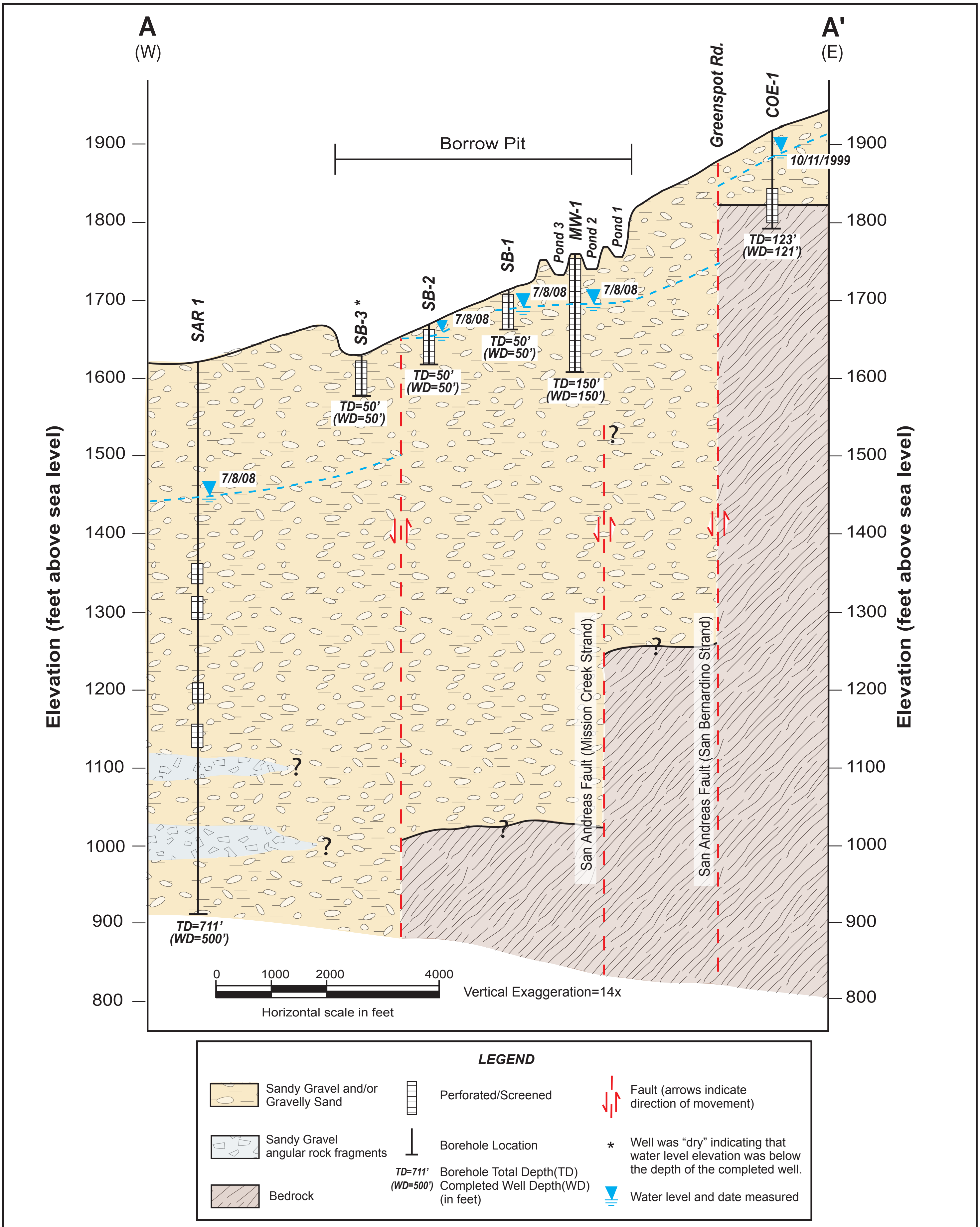
GEI Consultants

The presence of the San Andreas Fault Zone in the vicinity of the recharge facilities is an important component not only in the physical configuration of the unconsolidated deposits, but also in the groundwater flow regime. The main San Andreas Fault Zone consists of two nearly parallel branches through most of the San Bernardino area. In the vicinity of the recharge facility, the fault zone trends in a southeast-northwest direction, with the main San Andreas Fault (San Bernardino Strand) crossing near the northeast extent of Greenspot Road, and a splay of the fault (Mission Creek Strand) crossing through the northeastern portion of the Borrow Pit (Figure 3-1).

The San Andreas Fault is one of the most significant geologic features in California in terms of displacement and recent activity. It is a tectonic plate boundary in the earth’s crust between the North American and Pacific Plates. It is termed a “fault zone” because it consists of numerous faults, or “splays” or strands, instead of a single discreet linear fault. Several faults associated with the San Andreas Fault System have been mapped or postulated in the vicinity of the SAR recharge facilities, including the Bryn Mawr Fault, the Oak Glen Fault, and the Greenspot Fault, as shown on Figure 3-1. Based on groundwater data collected during this study, there is evidence of yet another splay which trends northwest and dissects alluvial deposits under the Borrow Pit (discussed in more detail below).

The MWH team reviewed well information for approximately 85 wells in the vicinity of the recharge facilities and noted (where available) lithologic and/or borehole geophysical information from these wells. These data, combined with surface geologic mapping and drilling data collected during this study, were used to develop two geologic cross-sections (A-A’ and B-B’) near the Borrow Pit. The locations of the cross-sections are shown on Figure 3-1, and the profiles are given in **Figures 3-2** and **3-3**. Based on these cross-sections and supporting data, there are several key observations that can be made about the aquifer underlying the SAR recharge facilities:

- The alluvial materials underlying the Borrow Pit, and much of the area surrounding it, consist of coarse, sandy gravel and/or gravelly sand. This material is expected to be highly permeable, and is consistent with an active alluvial fan environment.
- No significant, laterally-continuous strata of low permeability are present that would prevent the downward percolation of recharge water. Relatively fine deposits of clayey sand are reported in deeper portions of the Corps of Engineers Well No. 1 near the mouth of the SAR, and at the USGS Cone Camp wells southwest of the Borrow Pit, but they are not observed to be continuous from well to well, and are expected to be limited in areal extent, which is also consistent with an active alluvial fan environment.
- Faulting associated with the San Andreas Fault Zone dissects all but the most recent of alluvial deposits.



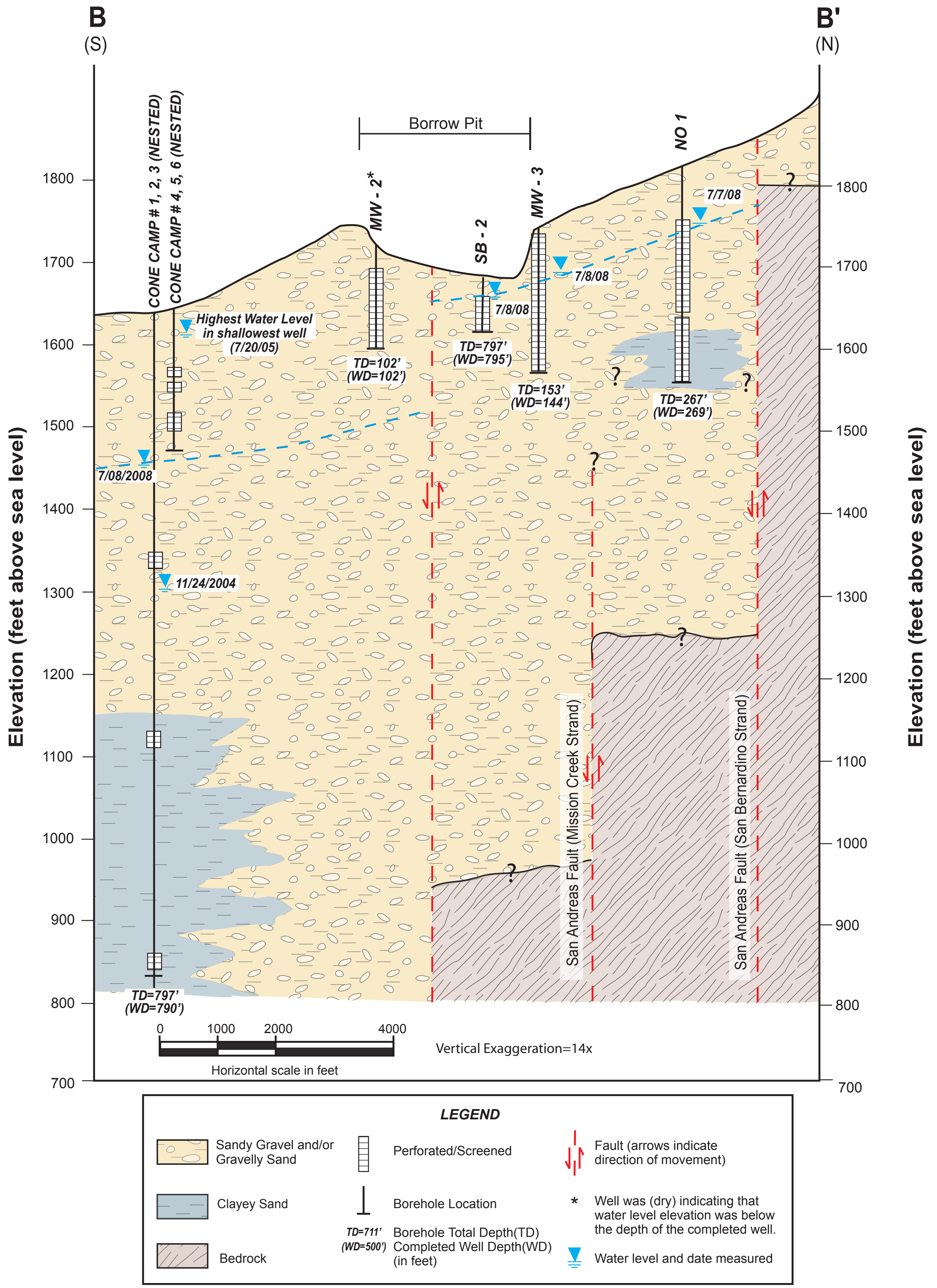
Profile A-A'

Figure 3-2

Santa Ana River Groundwater Recharge Optimization Study

Document: Figure3-2_SBVWCD_ProfileA-A'.pdf

Date: December 22, 2008



Document: Figure 3-3_SBVWCD_ProfileB-B'.pdf

Date: December 22, 2008

Profile B-B'

Figure 3-3

Santa Ana River Groundwater Recharge Optimization Study

MWH

GEI

3.2 GROUNDWATER MIGRATION CONDITIONS

Groundwater elevation data is available from existing wells and new monitoring wells constructed as part of the SAR Recharge Optimization field program. **Figure 3-4** shows a hydrograph (record of groundwater elevation measurements) for well SBVWCD #3 from 1980 to present, while **Figure 3-5** shows hydrographs from June 1998 to June 2008 of the USGS Cone Camp multipiezometers which are completed at depths of 65 to 75, 91 to 101, 124 to 144, 280 to 300, 500 to 520, and 770-790 feet below ground surface (bgs). These representative hydrographs suggest two key observations about groundwater conditions in the vicinity of the SAR recharge facilities:

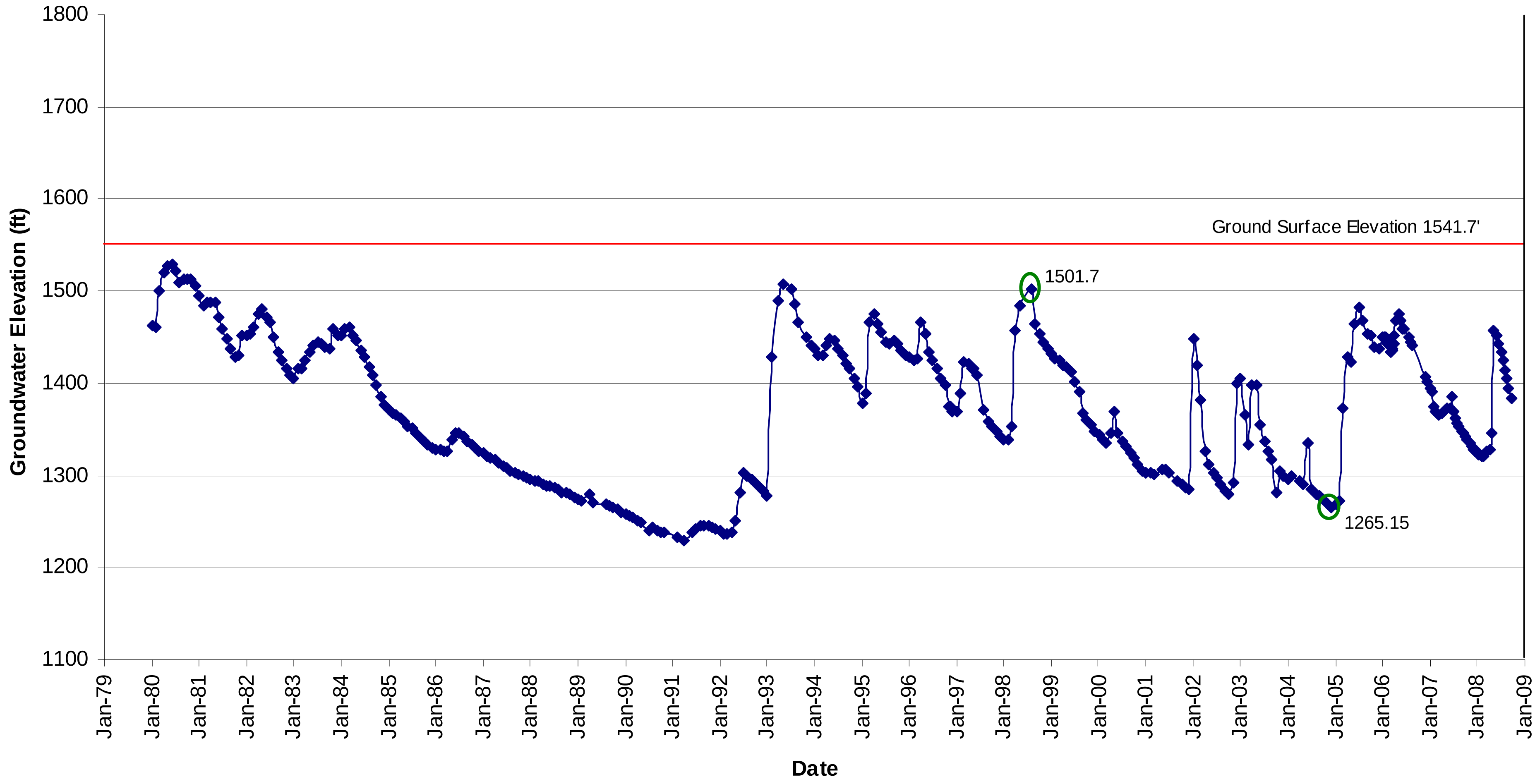
- During periods of high rainfall and runoff (which also coincide with periods of high recharge natural and artificial recharge activity) such as in 1980, 1993 and 1998, groundwater levels approach the ground surface to the southwest and west of the recharge facilities. For example, groundwater elevations at Well SBVWCD #3 came within 40 feet of the ground surface and groundwater elevations at the Cone Camp well came within 25 feet of the ground surface during some of these periods. In areas of lower topographic location that these wells the groundwater elevation was probably at or near the surface. However, these events have been very temporary, and may occur at a different frequency depending on the operation of the Seven Oaks Dam.
- The USGS multipiezometers indicate a consistent pattern in which the groundwater elevation in deeper piezometers is lower than the groundwater elevation in shallower piezometers. This indicates a downward vertical gradient representative of recharge occurring at the surface and flowing to deeper portions of the aquifer where the ground water elevation potential is lower.

Groundwater elevation data from these and other wells in the vicinity of the recharge facilities have been utilized to construct regional contours of equal groundwater elevation for the “wet” (high runoff) and “dry” (low runoff) periods of 1998 and 2004, respectively (identified as green circles on Figure 3-4). These contours of equal groundwater elevation are shown in **Figures 3-6 and 3-7**. The contours of equal groundwater elevation indicate that groundwater in the study area flows from the north and east to the west-southwest, similar to the flow path of the Santa Ana River.

3.3 GROUNDWATER BARRIER

The installation of monitoring wells during this study allows more detailed examination of groundwater elevations in the vicinity of the Borrow Pit. The geologic cross-sections shown in Figures 3-2 and 3-3 show groundwater elevation data from the recently-installed monitoring wells on July 8, 2008. These data confirm a generally westward groundwater flow direction, but also show something else that is not evident from the regional data: a rapid decline in groundwater elevation between monitoring wells SB-3 and MW-2, and new wells located northeast of these two wells. This relatively sharp decline in groundwater elevation over a short horizontal distance suggests the presence of a barrier to groundwater flow which trends to the northwest.

San Bernardino Valley Water Conservation District
SBVWCD #3
SWN 01S03W12J01S



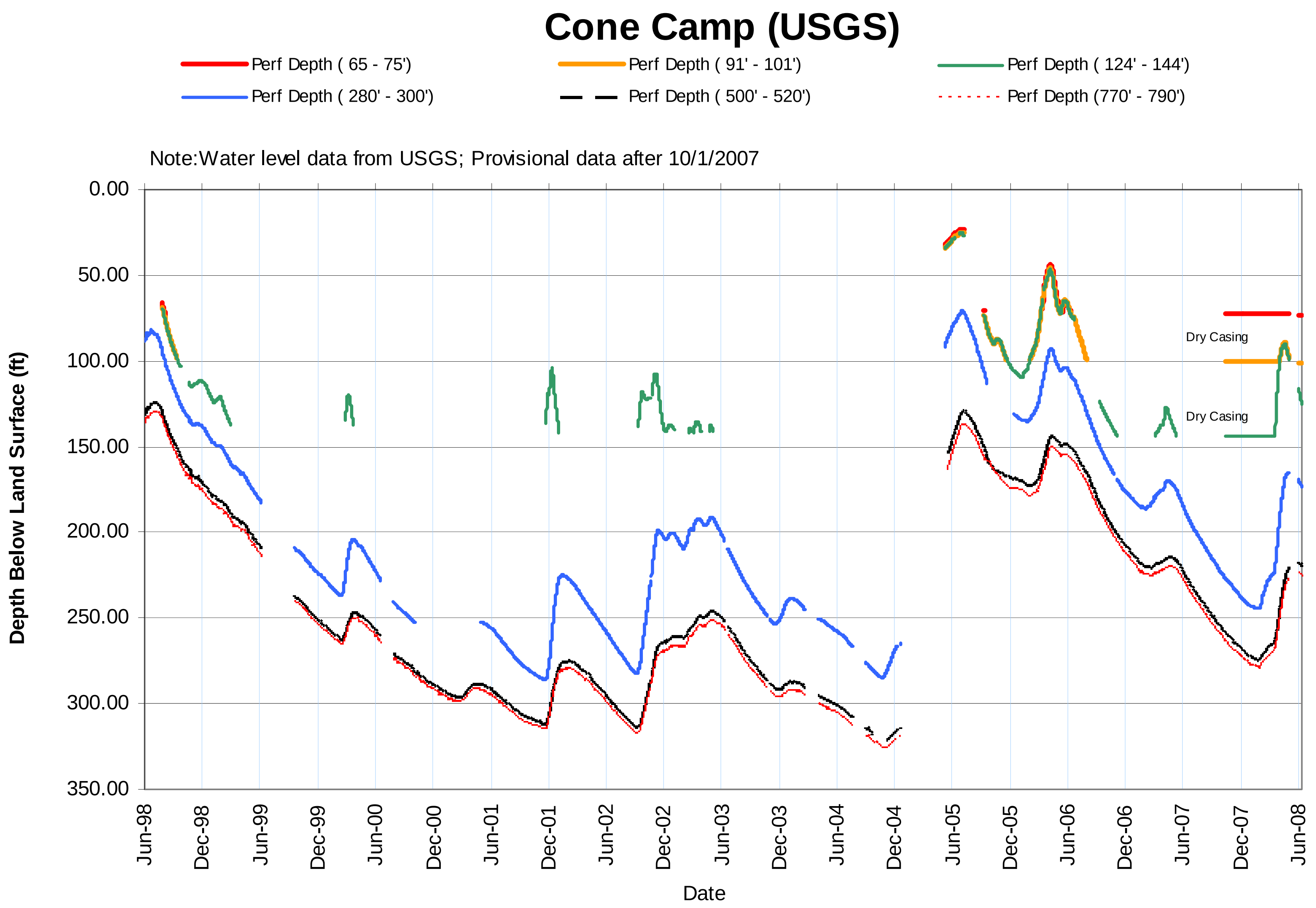
Groundwater Elevations for Well SBVWCD #3

Figure 3-4

Santa Ana River Groundwater Recharge Optimization Study

Document: Fig3-4_ SBVWCD3Hydrograph.pub

Date: December 22, 2008



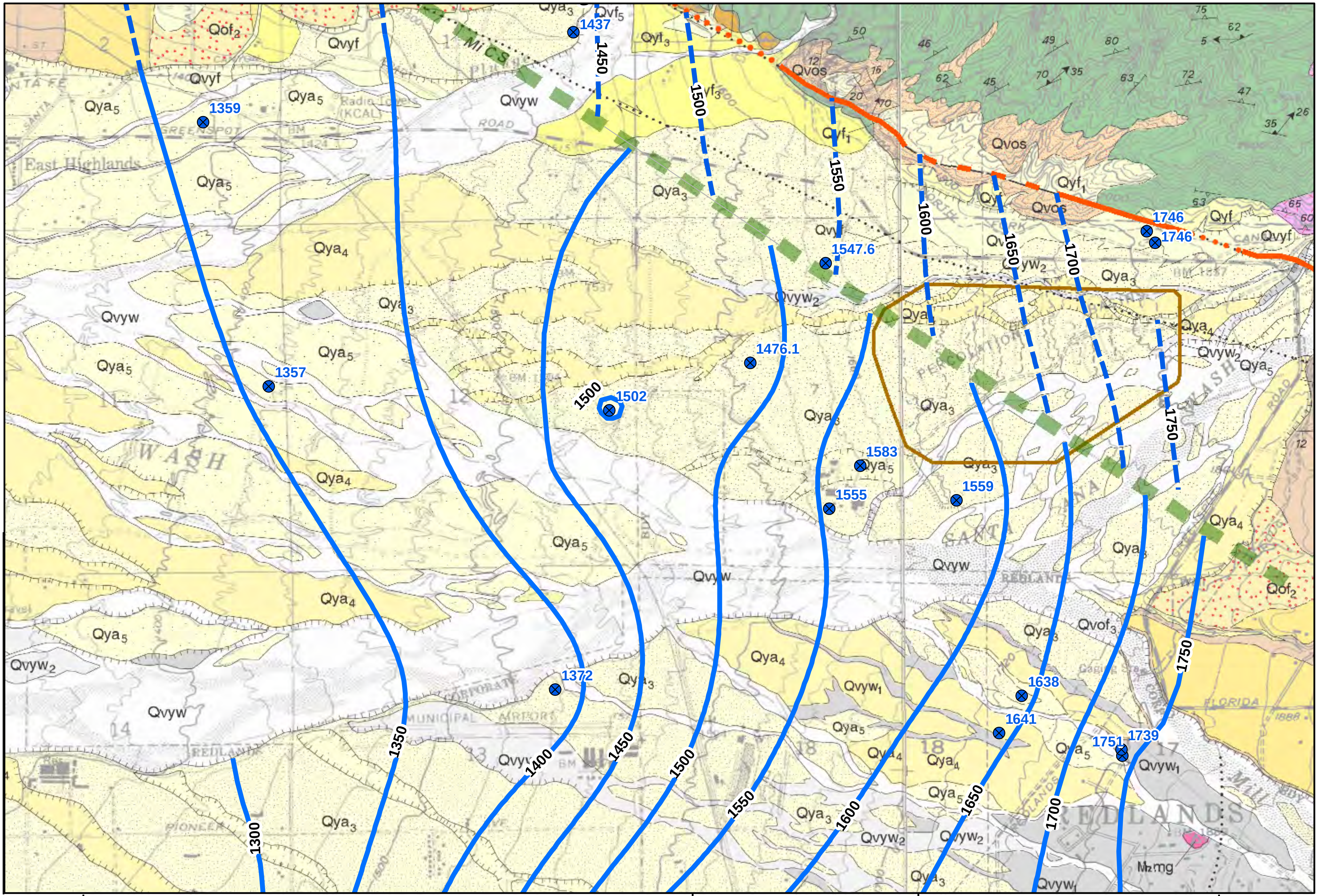
Hydrograph of Cone Camp Wells

Document: Fig3-5_
SBVWCD_Hydrograph_ConeCamp.pub

Figure 3-5

Date: December 22, 2008

Santa Ana River Groundwater Recharge
Optimization Study



Key to Features

- ⊗ Wells with Groundwater Elevation Data (in feet above sea level)
- ━ Contours of Equal Groundwater Elevation (Dashed where uncertain)
- 🟩 Potential Barrier Based on Groundwater Elevation Data
- ▭ Borrow Pit

N

0 500 1,000 2,000 Feet

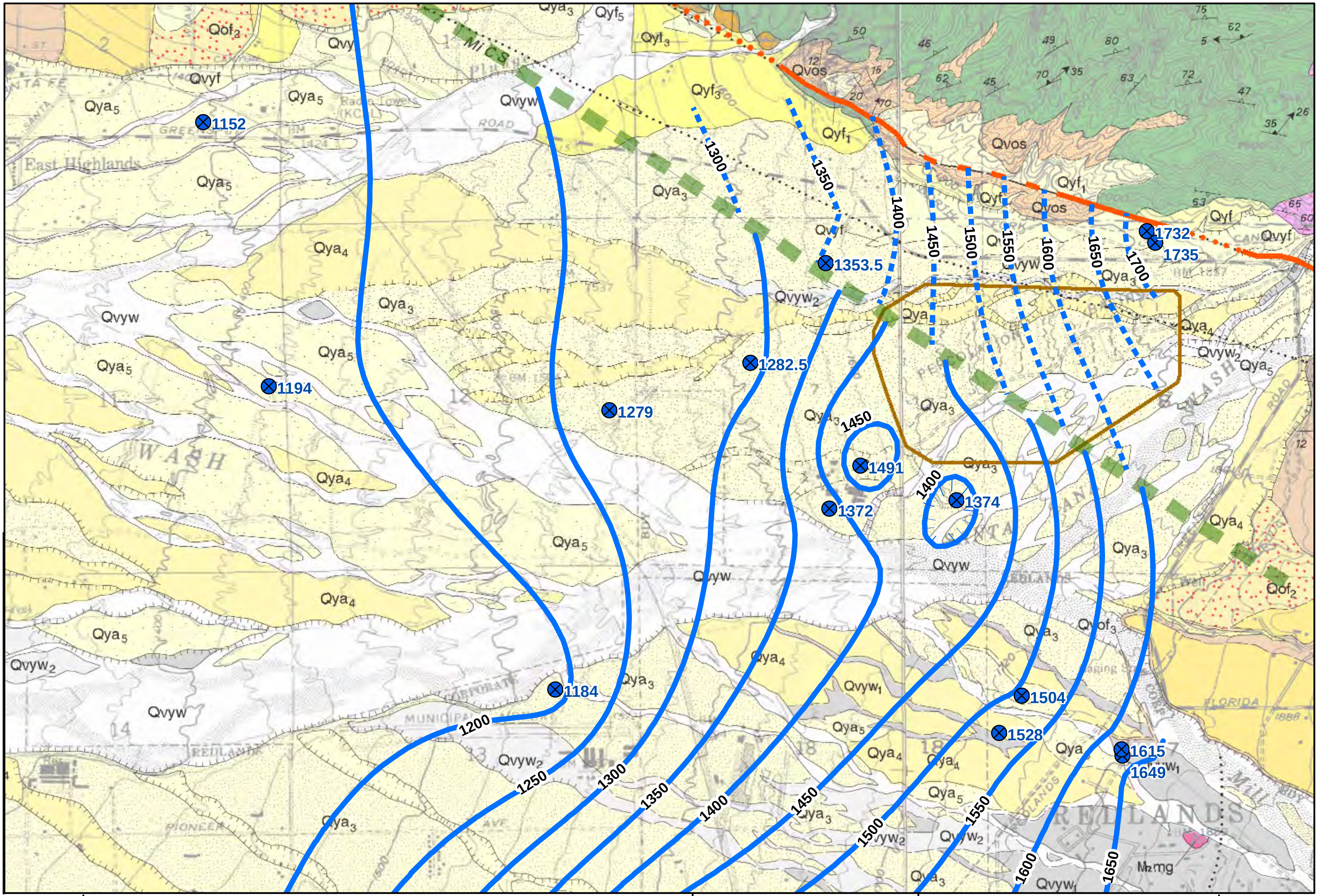
Document: SBVWCD_GWContours.mxd

Date: December 8, 2008

Groundwater Contours
August 1, 1998 - Wet Year

Figure 3-6

Santa Ana River Groundwater Recharge
Optimization Study



Key to Features

- ● Wells with Groundwater Elevation Data (in feet above sea level)
- Contours of Equal Groundwater Elevation (Dashed where uncertain)
- 🟩 Potential Barrier Based on Groundwater Elevation Data
- ▭ Borrow Pit

N
0 500 1,000 2,000 Feet

Document: SBVWCD_GWContours.mxd

Date: December 8, 2008

Groundwater Contours
December 1, 2004 - Dry Year

Figure 3-7

Santa Ana River Groundwater Recharge Optimization Study

MWH

GEI Consultants

Given that no significant laterally-extensive clay layers were encountered during the field investigation that would impede groundwater flow, the groundwater barrier in the western portion of the Borrow Pit is interpreted as a splay of the San Andreas Fault, shown as a dashed green line on Figures 3-6 and 3-7**.** The orientation of the barrier is consistent with it being a previously unmapped splay of the San Andreas Fault Zone. Although the nature and extent of the fault are not completely known, groundwater movement across the fault in the unconsolidated sediments may be impeded due to the presence of clayey fault gouge, cementation along the fault zone, or displacement of permeable strata. A fault trace was not observed at the surface, suggesting concealment by recent surficial deposits. The depth at which the fault becomes an effective groundwater flow barrier is unknown, but it is clear that groundwater elevations are significantly higher to the northeast of the suspected fault trace.

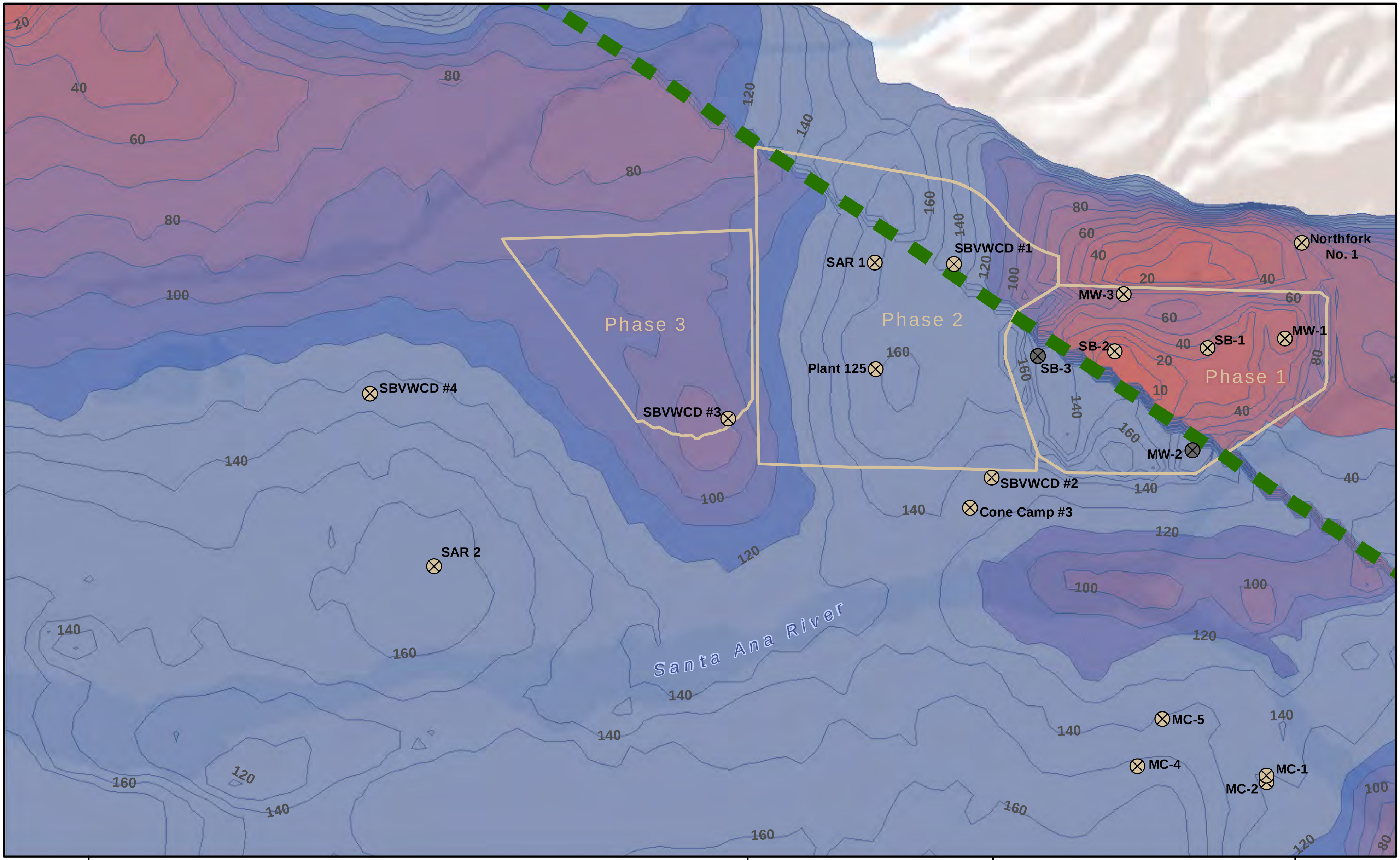
Figure 3-8 depicts estimated contours of equal depth to water which illustrate that groundwater is much shallower northeast of the groundwater barrier. This figure was developed by mathematically subtracting a grid of estimated groundwater elevations using new monitoring wells and existing wells on July 8, 2008 from a grid of topographic elevation contours from the field survey and USGS digital terrain data. From this data, it is clear that groundwater is much shallower in the eastern portion of the Borrow Pit upgradient of the groundwater barrier.

The shallow groundwater northeast of the suspected fault explains surfacing groundwater historically observed by the Conservation District staff in Pond 3, the north wall of the Borrow Pit, and the north central area of the Borrow Pit visible as green vegetation on aerial photographs (e.g. Figure 2-7), all of which are upgradient of the groundwater barrier.

3.4 AQUIFER CHARACTERISTICS

As previously noted, groundwater in the vicinity of the Borrow Pit occurs primarily in the unconsolidated deposits which form an unconfined aquifer. Among many hydraulic parameters, hydraulic conductivity (ease of which groundwater can flow through these deposits) are most important because it determines the height and extent of how groundwater rises, or “mounds” during recharge. Provided below is a review of collected hydraulic conductivity data obtained either from studies in and surrounding the SAR recharge facilities.

Well completion reports provided by the Conservation District include pumping test data for Wells SAR 1 and SAR 2 (locations are shown on Figure 3-1). The hydraulic conductivity was estimated from continuous pumping data using the Cooper-Jacob aquifer test analysis method. The hydraulic conductivity is averaged for aquifers at depths from 215 to 490 feet bgs. SAR 1 is located at a distance of approximately 2,110 feet to the west-northwest of the Borrow Pit, whereas SAR 2 is approximately 8,900 feet to the west-southwest of the Borrow Pit. These data are summarized in **Table 3-1**.



Key to Features

🟫 Water Conservation Facilities Evaluation Phase Areas

🟩 🟩 Potential Barrier Based on Groundwater Elevation Data

Contours of Equal Depth to Groundwater (feet below ground)

Determined from monitoring well data (July 8, 2008).

⊗ Monitoring Wells Used in Determining Contours

⊗ Monitoring Wells Not Used in Determing Contours

N

0 500 1,000 2,000 Feet

Document: SBVWCD_DTWContoursFig3-8.mxd

Date: December 22, 2008

Depth to Groundwater Contours

Figure 3-8

Santa Ana River Groundwater Recharge Optimization Study

Table 3-1
Summary of Aquifer Test Data

Well Number	Depth (feet)	Perforated Interval(s)	Static Water Level (May 2005, feet bgs)	Hydraulic Conductivity (feet/day)
SAR 1	500	260 to 285, 305 to 330 415 to 440, 465 to 490	217	7 to 33
SAR 2	420	215 to 245, 340 to 410	213	52 to 160

For reference, previous U.S. Geological Survey investigations (USGS, 2005) conducted approximately 11.5 miles to the west of the Borrow Pit along with published data for gravelly sand and sandy gravel are summarized in **Table 3-2**. With some exceptions (surface soil samples and three samples at MW-3 at 30, 38, and 102 feet bgs), field program data indicate that measured hydraulic conductivity values generally fall within the range from 0.113 to 19.7 feet/day. The laboratory results of hydraulic conductivity analysis collected during this study is generally lower than field measurements reported by Conservation District and USGS. Several of the samples were taken from areas where ponding water deposited silts, which are not representative of deep aquifer conditions. It is therefore concluded that a typical hydraulic conductivity value for the aquifer underlying the recharge facilities is on the order of 50 feet/day and may range from a few feet to several hundred feet/day.

Table 3-2
Hydraulic Conductivity for Selected Unconsolidated Sediments

References	Materials	Hydraulic Conductivity (feet/day)
USGS, 1975	Upper unconsolidated water-bearing sediments	120
USGS, 2005	Upper unconsolidated water-bearing sediments, Newmark area	40 to 100
Walton, 1988	Sand and gravel mixtures	13 to 668
Davis, 1966; page 164	Clayey sands to clean gravel	10^{-3} to 10^{5}

Section 4
Analysis of Diversion and Conveyance Capacity

This section describes the analysis of the maximum capacity of the diversion and conveyance facilities, based on the flow testing and physical survey described in Section 2. Parameters (channel slope, roughness coefficient, etc.) gathered from as-builts and the flow test were used in the hydraulic analysis to calculate maximum flow capacities for discrete conveyance facilities. Field data from the flow testing was used to reconcile actual conditions with calculated conditions. Each structure's maximum capacity were calculated, and a description of their respective limitations is provided next in the following order:

- Intake Structure and Cuttle Weir
- Discharge Conduit (Closed Conduit/Tunnel and Sandbox)
- Canal Sections
- Rock Structure
- Greenspot Road Culvert
- Parshall Flume
- Diversion Structure

4.1 INTAKE STRUCTURE AND CUTTLE WEIR

Hydraulic Analysis

The hydraulic capacity of the Cuttle Weir and the Intake Structure are interrelated. If the height of the Cuttle Weir were increased, the resulting increased water surface elevation would allow greater flow rates through the Intake Structure. Similarly, if constrictions or limitations to flow carrying capacity at the Intake Structure (due to gate opening height, number of gates opened, or debris accumulation) were to occur, then the water level at the structure's entrance would need to rise to provide the head needed to overcome these limitations.

A hydraulic analysis was performed to confirm flow test conditions observed in the field and to extrapolate to greater flow volumes. The hydraulic analysis included determination of the flow characteristics of the following three components when passing various flows:

- Discharge conduit (or Closed Conduit/Tunnel and Sand Box)
- Collection channel (concrete channel on downstream side of Intake Structure)
- Intake structure (and influence from Cuttle Weir elevation)

The flow rates selected for analysis included: 500 cfs and the rate of flow corresponding to the existing facility's capacity.

The analysis began by determining the backwater curve along the conduit (downstream of the gates at the Intake structure) and determined the theoretical flow depth where the collection channel feeds the tunnel (**Figure 4-1**). For a flow rate of 500 cfs, the estimated water depth at the upstream end of the tunnel is approximately 7.5 feet). Head loss at the tunnel entrance (k = 0.5 and velocity head of 2 feet, k=head loss coefficient) equals one foot, resulting in a depth of flow upstream of the tunnel entrance (at the downstream end of the collection channel) of roughly 8.5 feet (**Figure 4-2**).

Because flow into the Intake Structure discharges perpendicularly to the collection channel axis, this structure acts as a typical side-channel spillway collector. Therefore, water depth at each end must differ significantly to provide the momentum needed to move flow along the collector. Using a downstream depth of 8.5 feet or water surface elevation of 1947.5 feet where the flow enters the tunnel, the backwater calculation yields a corresponding upstream water profile of elevation 1949.6 feet (**Figure 4-3**). The water level profile represents the tailwater depths on the downstream side of the six gates.

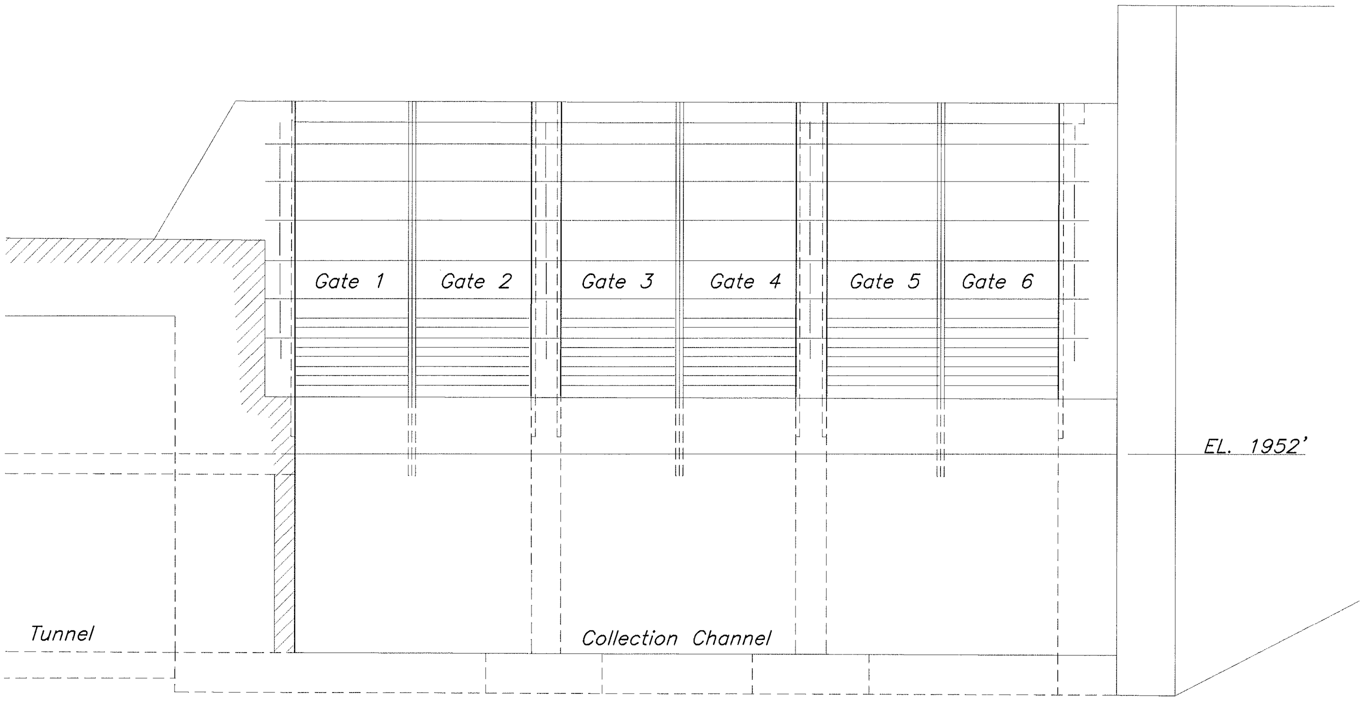
The Intake Structure analysis determined the discharge capacity of the six gates, considering the upstream water level (formed by the pool behind the Cuttle Weir) and the downstream or tailwater levels (formed by flow in the collection channel). Each gate's hydraulic performance is governed by the gate opening, a discharge coefficient, and the net head between upstream and downstream water levels. When a gate is opened to a point above the upstream pool's water level it discharges as a weir, whereas a partially opened gate can be inundated and would function according to orifice flow and a differing set of hydraulic criteria. The MWH team developed a spreadsheet model that accounts for both flow regimes and includes definitions of: sill elevation, gate opening, shape of the discharge passageway (in this case it is a flat broad-crested weir as opposed to an ogee, a double curve in the shape of an elongated 'S', or stepped overflow), and the head- and tailwater levels.

Observed Capacity and Limitations

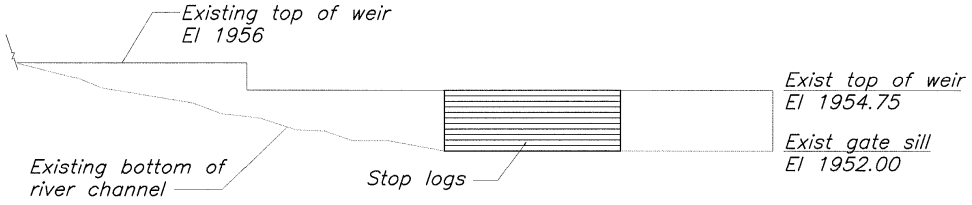
Historical diversion operations, as discussed with facility operators indicated that a flow capacity of 150 cfs could be diverted at the Cuttle Weir by placing stop logs in the weir notch.

The hydraulic analysis of the Intake Structure determined that in order to achieve a total flow of 500 cfs through all six gates, a headwater elevation of approximately 1949.6 feet would be required. This headwater level is approximately 5.1 feet below the top of the lowest section of the Cuttle Weir (Figure 4-1). Gates 1, 2, 4, 5 and 6 were found to have discharge capacities of about 85.1 cfs. Gate 3 discharge would reduce to about 73.9 cfs since it can only be opened 2.25 feet (Figure 4-3).

From field observations during the flow test and the above analysis, the current configuration of the Cuttle Weir and Intake Structure is not adequate to convey the requisite 500 cfs. To analyze the theoretical capacity of the currently configured Intake Structure and Cuttle Weir, a water level elevation of 1954.7 ft, which corresponds to the top of the lowest section of the Cuttle Weir, was used (Figure 4-1). With gates opened to at least the headwater level or each gate's maximum (maximum opening of each gate is limited and differs), the corresponding theoretical total discharge through the six gates is approximately 362 cfs (**Figure 4-4**).



INTAKE STRUCTURE



CUTTLE WEIR

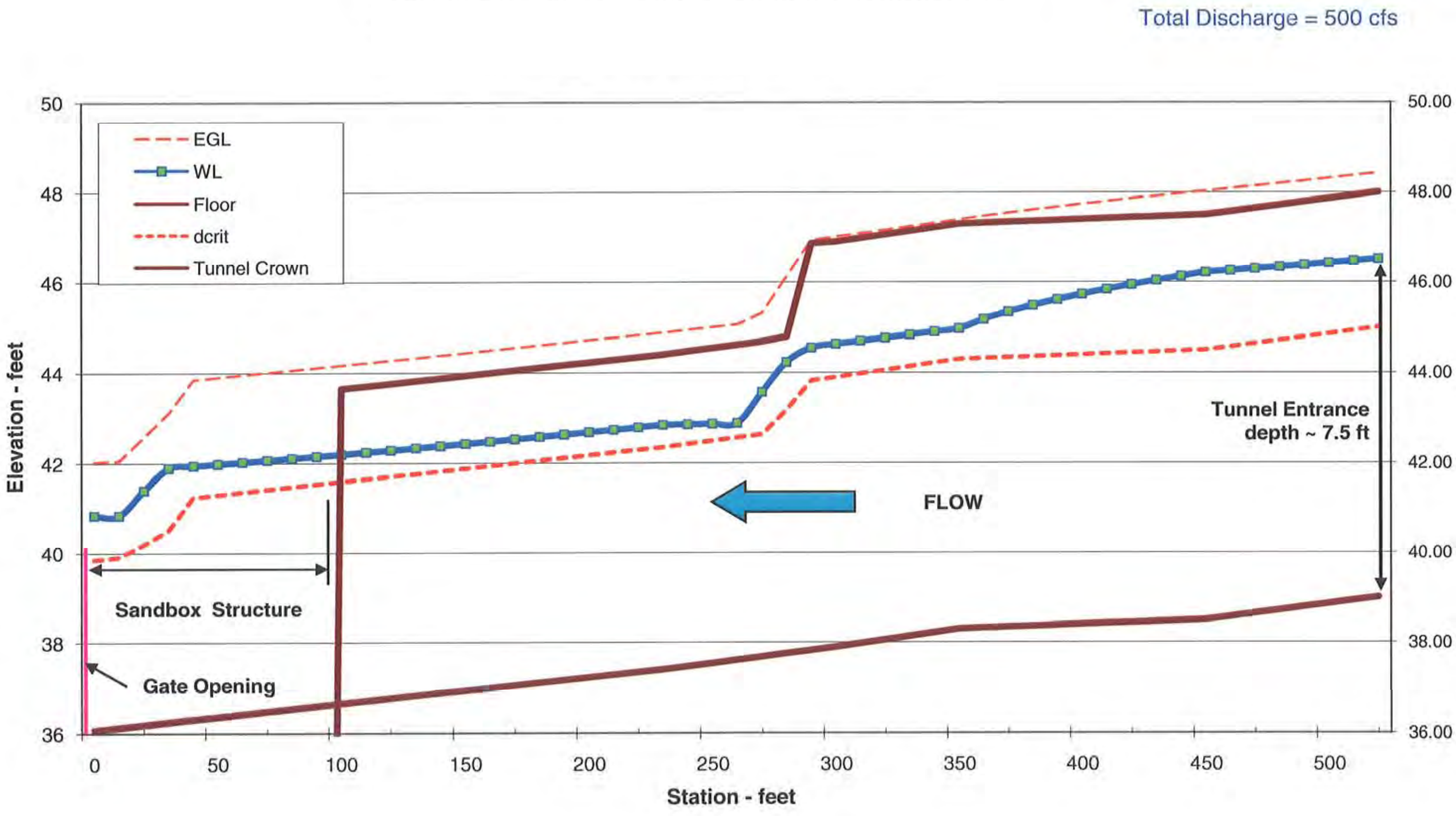
Cuttle Weir Typical Section

Document: CuttleWeirTypicalSection.pub

Figure 4.1

Date: March 4, 2009

Santa Ana River Groundwater Recharge
Optimization Study



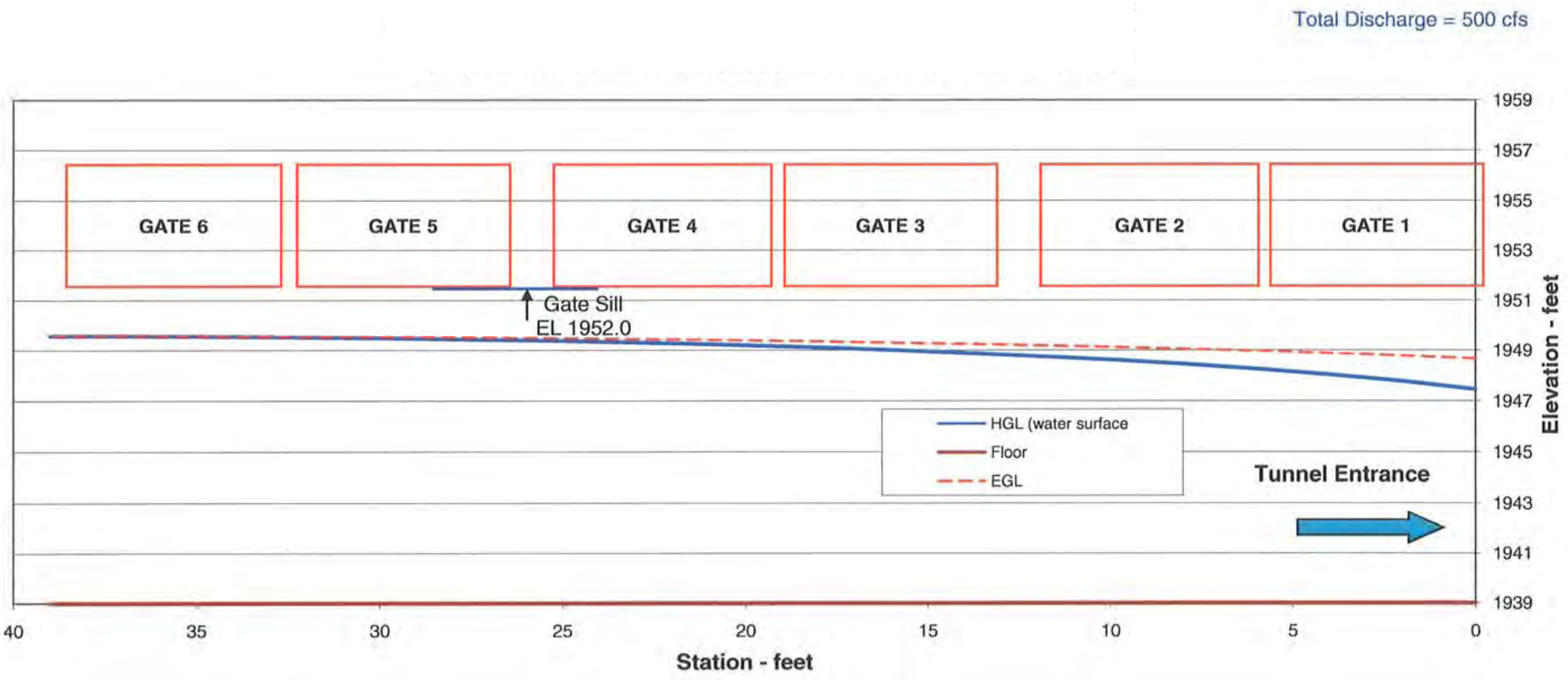
Conservation District Diversion Structure Discharge Conduit – Backwater Curve

Document: DischargeConduit500cfs.pub

Figure 4.2

Date: March 4, 2009

Santa Ana River Groundwater Recharge
Optimization Study



AVERAGE TAILWATER LEVELS AT GATES   Using HWL 1955.42

GATE	STA u/s ft	STA d/s ft	*CL STA ft	*CL STA (% of length)	TWL ft	Gate Flow cfs	
G1	39.0	33.0	36.0	7.7%	1947.9	85.1	
G2	33.0	27.0	30.0	23.1%	1948.5	85.1	
G3	25.5	19.5	22.5	42.3%	1949.0	73.9	**
G4	19.5	13.5	16.5	57.7%	1949.3	85.1	
G5	12.0	6.0	9.0	76.9%	1949.5	85.1	
G6	6.0	0.0	3.0	92.3%	1949.6	85.1	
						499	cfs

*CL = centerline of gate

** G3 only open 2'-3", orifice flow

Profile shown plotted above

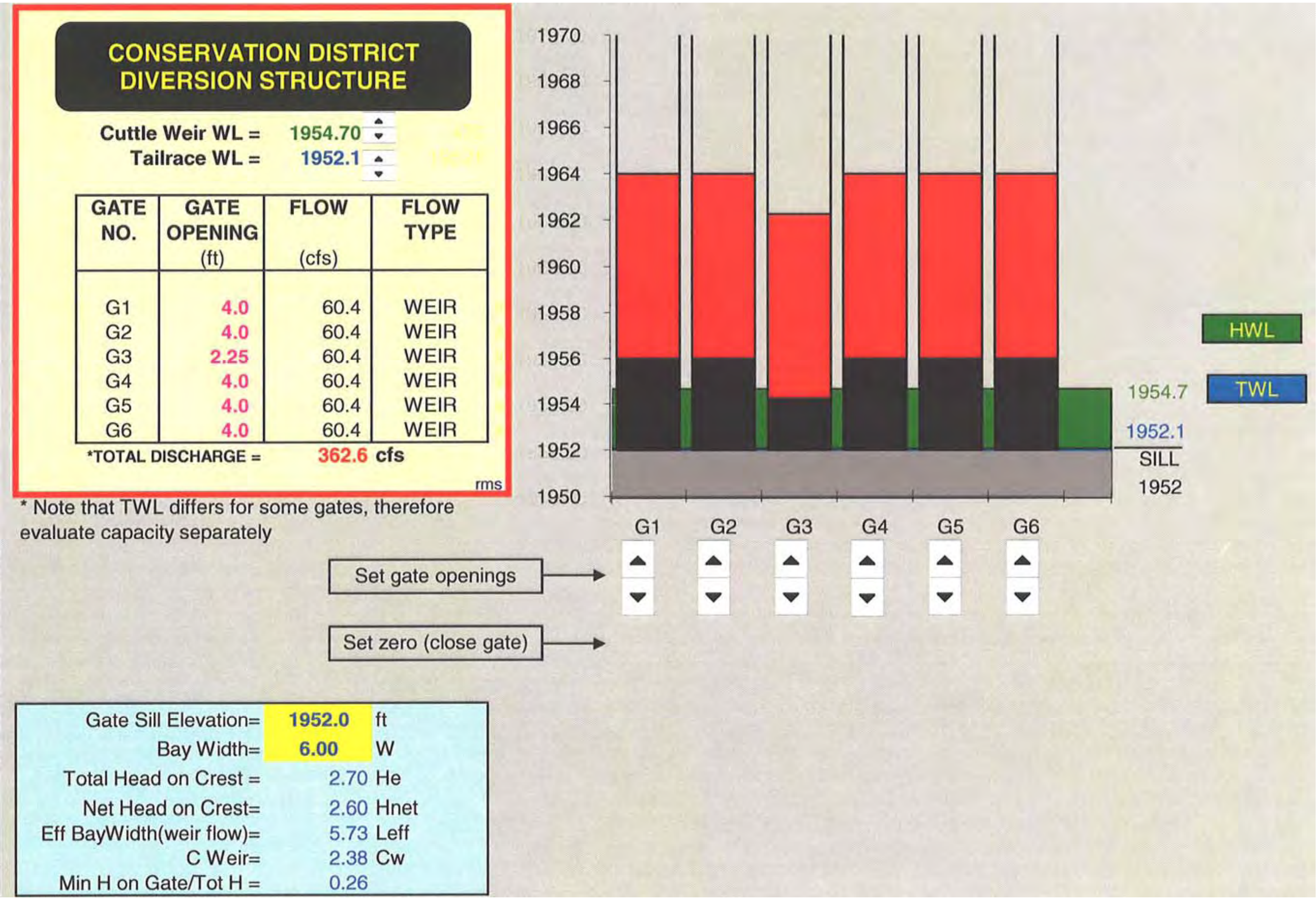
Conservation District Diversion Structure
Collection Channel Behind Gates—Backwater Curve

Document: CollectionChannel500cfs.pub

Figure 4.3

Date: March 4, 2009

Santa Ana River Groundwater Recharge
Optimization Study



CONSERVATION DISTRICT DIVERSION STRUCTURE

Cuttle Weir WL = 1954.70

Tailrace WL = 1952.1

GATE NO.	GATE OPENING (ft)	FLOW (cfs)	FLOW TYPE
G1	4.0	60.4	WEIR
G2	4.0	60.4	WEIR
G3	2.25	60.4	WEIR
G4	4.0	60.4	WEIR
G5	4.0	60.4	WEIR
G6	4.0	60.4	WEIR

*TOTAL DISCHARGE = 362.6 cfs

rms

* Note that TWL differs for some gates, therefore evaluate capacity separately

Gate Sill Elevation=	1952.0	ft
Bay Width=	6.00	W
Total Head on Crest =	2.70	He
Net Head on Crest=	2.60	Hnet
Eff BayWidth(weir flow)=	5.73	Leff
C Weir=	2.38	Cw
Min H on Gate/Tot H =	0.26	

Present Calculated Flow Rate

Document: PresentCalculated-FlowRate.pub

Figure 4.4

Date: March 4, 2009

Santa Ana River Groundwater Recharge Optimization Study

Review of the flow test field notes and time stamped photos reveal that water levels reached the top of the Cuttle Weir at a flow rate of around 300 cfs with the plywood in place at the weir notch. The difference in the theoretical capacity and observed capacity appears to be due to the accumulation of debris and boulders at the Intake Structure's bar screens. Therefore, in order to meet the theoretical capacity, a means of eliminating material accumulation on the gates' upstream side would be required. Given the potential for material accumulation and its impact on the flow characteristics, the MWH team conclude that the practical flow capacity for diversion of flow into the Intake Structure, given the current configuration, is 250 cfs.

4.2 DISCHARGE CONDUIT

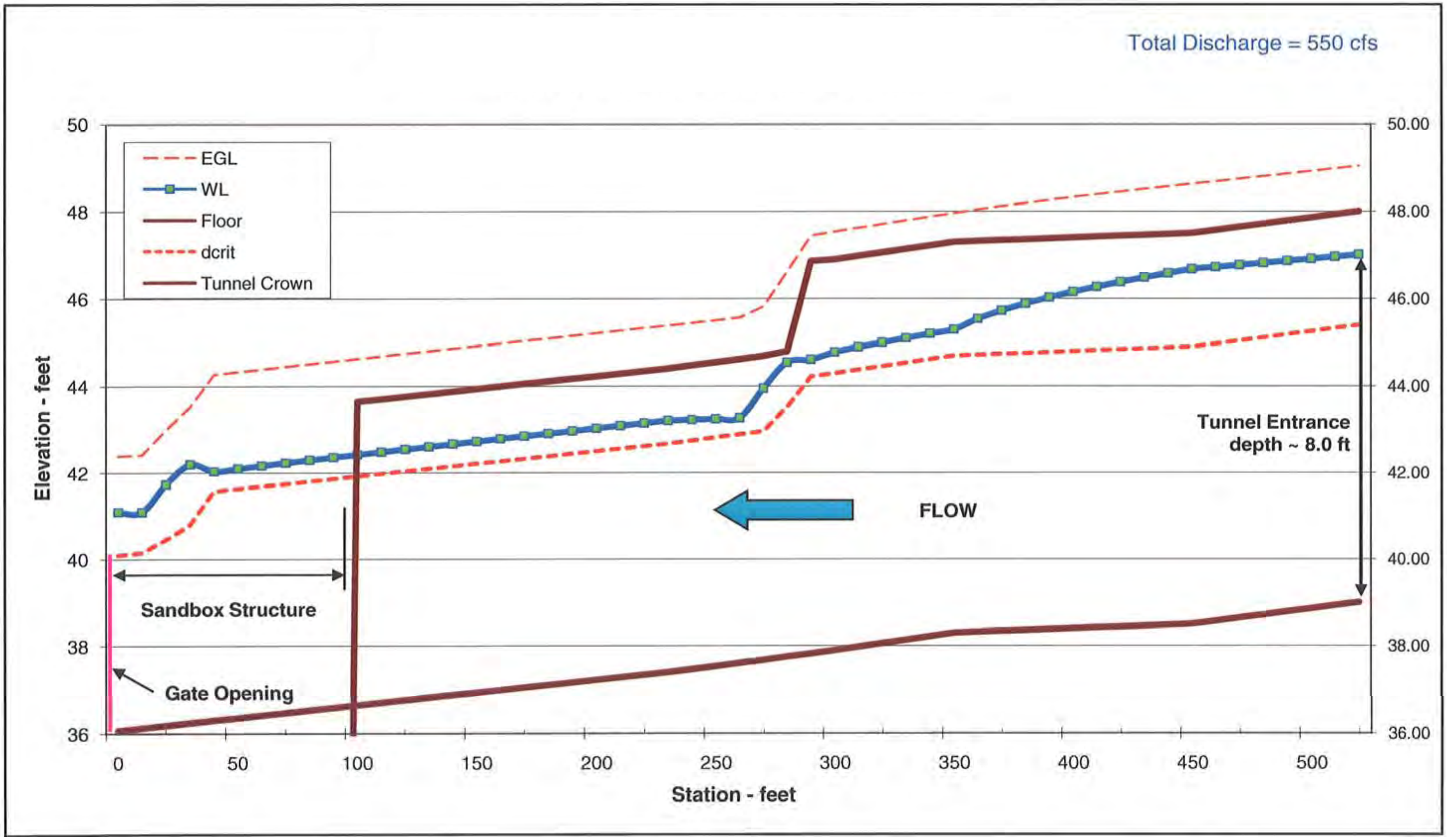
Hydraulic Analysis

Due to the interrelationship between the Cuttle Weir and the Discharge Conduit (Closed Conduit/Tunnel and Sand Box) the hydraulic analysis for the interrelated components is presented above.

Capacity and Limitations

The capacity of the Closed Conduit/Tunnel was determined by calculating the maximum free water surface in the structure. This free water surface would correspond with open channel flow. Additional capacity could be realized by allowing flow in the Closed Conduit/Tunnel to be under pressure. However, if this were the case, the transition from open channel to closed conduit flow would be unstable, causing considerable variations in water surface elevations within and upstream of the structure. The calculated capacity of the Closed Conduit/Tunnel is therefore 550 cfs for open channel flow (**Figure 4-5**).

The Sand Box capacity is currently limited by the maximum gate opening at the structure's downstream end. The record drawings did not indicate the maximum height each gate can be opened. Thread measurement taken on each gate stem revealed that the gates have a maximum opening of 4 feet. The hydraulic model showed (**Figure 4-6**) that at a flow rate of 362 cfs the corresponding water elevation upstream of the Sand Box gate structure would be 4 feet. For a flow rate of 500 cfs, the water depth at the Sand Box gate structure would be about 4.8 feet (Figure 4.2). Therefore, the gates would need to be modified to increase this facility's carrying capacity to 500 cfs. Without the gate limitations, the Sand Box has a capacity of 550 cfs which is greater than the desired capacity of 500 cfs. With modifications to the 50-foot long overflow section, in order to eliminate this overflow, the capacity could be increased to 825 cfs.



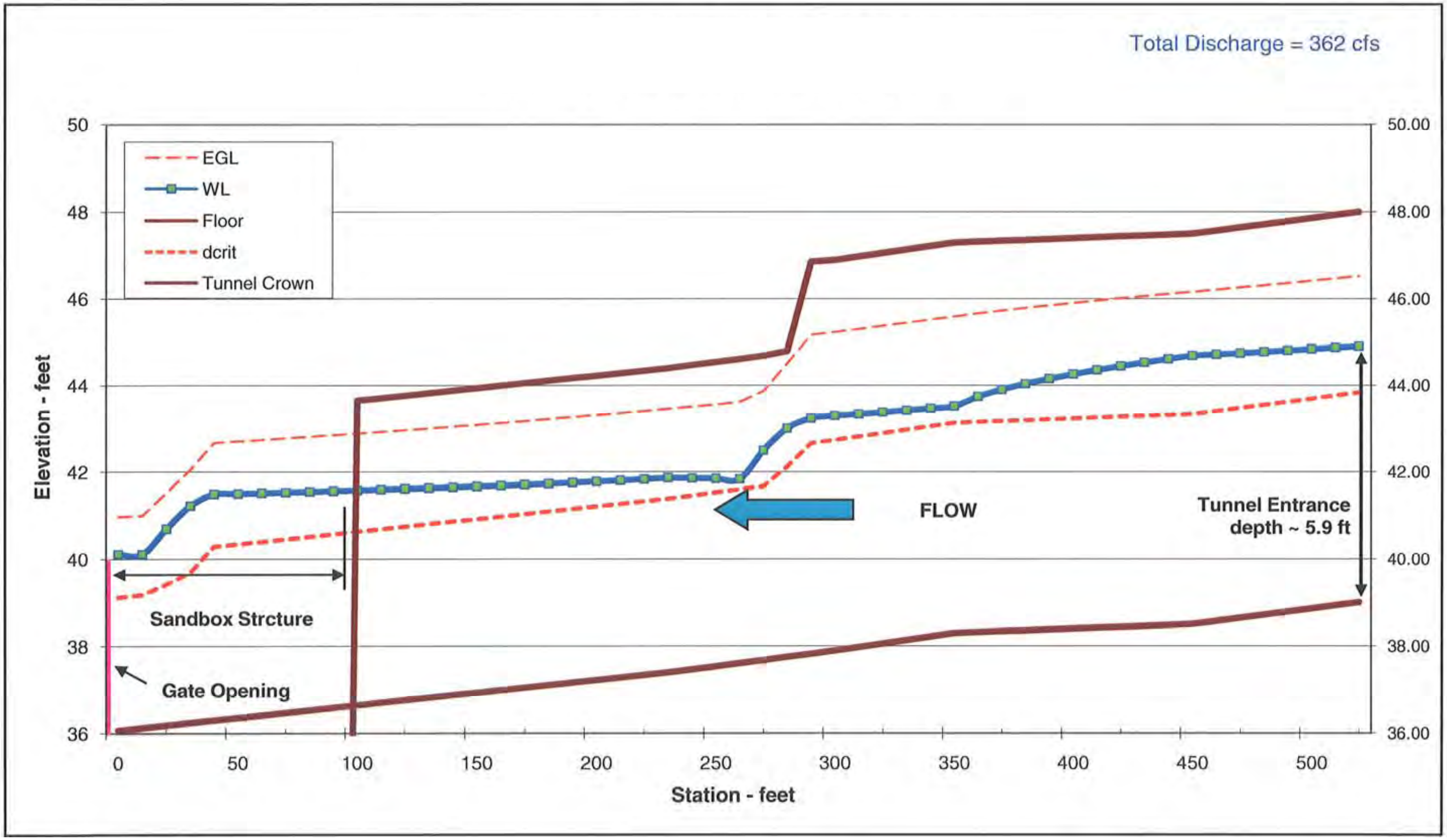
Conservation District Diversion Structure
Discharge Conduit – Backwater Curve

Document: DischargeConduit550cfs.pub

Figure 4.5

Date: March 4, 2009

Santa Ana River Groundwater Recharge
Optimization Study



Conservation District Diversion Structure Discharge Conduit—Backwater Curve

Document: DischargeConduit362cfs.pub

Figure 4-6

Date: March 4, 2009

Santa Ana River Groundwater Recharge
Optimization Study

4.3 CANAL SECTIONS

Hydraulic Analysis

Because the typical canal section shown on the record drawing Plan for Conduit Santa Ana Weir, (May 1930) is not representative of the existing canal, a survey was conducted to determine the typical parameters of the various canal sections (Section 2). Representative sections of the canal were known, so Manning's equation was used to determine the capacity.

Manning's equation:
(Q=1.486/n * AR^2/3 * S^1/2)
Q=Flow, A=Area, R=Hydraulic Radius, S=Slope, and n=roughness coefficient

One parameter required to apply Manning's equation that cannot be physically measured is Manning's roughness coefficient, n. There are published guidelines as to the range of typical n-values based on the canal physical properties. Due to the variation of the canal cross-section, the information obtained during the flow tests is insufficient to assess the n-value. During future flow conditions it is advisable that velocity measurements be made in the channels. With the velocity measurements and the documented canal cross-sections, more representative n-values could be determined.

Using published data an n-value of 0.050 (Daugherty and Franzini, 1979) was estimated. The estimated n-value and the typical canal sections and slopes obtained from the field survey were then used to estimate the capacity of the existing canal using Bentley FlowMaster Version 8 software (Flowmaster).

Capacity and Limitations

The calculations showed that most of the canal sections had banks high enough to convey the desired maximum flow rate of 500 cfs; however, the high velocities reached in many sections of the canal caused significant potential for channel erosion. The calculated velocities for 300 cfs were in excess of 6.19 feet/second. At a rate of 500 cfs the calculated velocities exceeded 7.73 feet/second with some sections near 10 feet/second. The maximum recommended velocity for canals of this type (cobbles and shingles) is 6.5 feet/second (King, 1939), whereby velocities exceeding this amount will likely cause canal erosion. Correspondingly, observations made during the flow test noted that rocks and boulders could be heard moving in the canal starting at a flow rate of approximately 300 cfs.

Due to its slope, the existing canal has a practical conveyance limitation of 300 cfs. Future improvements to increase the carrying capacity of the facilities could include: (1) adding drop structures and decreasing the channel slope, (2) improving the channels, and (3) increasing the channel width. Detailed recommendations for proposed improvements will be provided in the final report.

4.4 ROCK STRUCTURE

Hydraulic Analysis

Data obtained from a flow test and the dimensions of the Rock Structure were used to determine its capacity. At a flow rate of 241 cfs, the water depth in the structure is approximately 1.6 feet. The measured dimensions of the structure are 14 feet wide and 6 feet high. Using a slope of 0.032, an n-value of 0.029 was determined. This value corresponded with the grouted rip rap value given in FlowMaster's library of roughness coefficients.

Capacity and Limitations

Utilizing the above roughness coefficient, the capacity of the structure was determined for an assumed maximum water depth of 5 feet, which is equal to the height of the gate openings. The structure's capacity was estimated to be 1,268 cfs.

4.5 GREENSPOT ROAD CULVERT

Hydraulic Analysis

A clear choke point, or point of congestion or obstruction, in the conveyance system is the culvert under Greenspot Road. During the March 27, 2008 flow test it was observed that for a flow rate of approximately 350 cfs there was only 4 to 6 inches of freeboard available. To further analyze the culvert, its dimensions were measured. The culvert was measured to be 10 feet wide and 4 feet and 2 inches high. A roughness coefficient of 0.015 was selected for this concrete structure. The FlowMaster program was then used to calculate the culvert's slope by using the normal depth of 2.1 feet that was measured at a flow rate of 141 cfs at 9:05 a.m., on March 27, 2008. A slope of 0.00273 was then calculated. The FlowMaster program was run again with the calculated slope and roughness coefficient of 0.015 to solve for a normal depth at 330 cfs (flow that was measured at 12:45 pm). The "normal depth" is the depth of flow in the channel or culvert when the slope of the water surface and channel bottom is the same and the water depth remains constant. Normal depth occurs when the gravitational force of the water is equal to the friction drag along the culvert and there is no acceleration of flow. The calculated normal depth was 3.8 feet and the observed normal depth was recorded as 3.6 feet. The depth measured during the flow test and the calculated depth generally agree. Therefore the roughness coefficient and calculated slope appear to be reasonable.

Capacity and Limitations

Once the slope and roughness coefficient were checked and confirmed, the normal depth was solved using a desired flow rate of 500 cfs. The normal depth at 500 cfs was calculated to be 5.18 feet, which is higher than the available 4 feet 2 inches. Therefore, it is not possible to convey 500 cfs through this culvert without the water hitting the top slab. The maximum capacity of the culvert was then solved using a normal depth of 4.16 feet, and the maximum capacity at this depth is 372 cfs. This result is confirmed by observations from the flow test. The culvert was near capacity at a flow rate of 367 cfs, which was measured just downstream of the culvert at the Parshall Flume.

4.6 PARSHALL FLUME

Hydraulic Analysis

The original design drawings for the Parshall Flume (*Venturi Flume, March 1933*) contain a table based on the equation $Q=4WH_a^{1.522W^{0.026}}$ (Q=Flow, W=width, H=Height) that provides a maximum flow through the Parshall Flume of 1,405 cfs. This value assumes that the flow would be at the top of the structure. If a freeboard of 6-inches is used, the capacity would be 1,214 cfs.

Capacity and Limitations

The maximum capacity of the Parshall flume is 1405 cfs. A capacity of 1,214 cfs is provided when a free board of six inches is used.

4.7 DIVERSION STRUCTURE

Hydraulic Analysis

During the March 27, 2008 flow test the flow through the Diversion Structure north gates located northeast of the Borrow Pit to the existing westerly spreading ponds was limited to roughly 300 cfs. This upper limit was based on historical operator knowledge of the downstream conveyance system limitations. When the flow rate reached 300 cfs, the southerly gate was opened and flow was discharged into the Borrow Pit. There was 2 feet of freeboard on the channel walls prior to the southerly gate being opened.

Preliminary analyses indicate that 500 cfs could be directed through the northerly gates to the existing westerly spreading grounds. Ultimate configuration of the spreading ponds will determine how the water will be directed through the diversion structure to the spreading facilities.

Capacity and Limitations

The channel has the requisite capacity for conveyance of flows to 500 cfs; however, modifications to the gate structure may be required to reduce hydraulic losses along the center pier. Due to the complexity of this facility, additional analysis will be required once the ultimate configuration of the spreading facilities and the flow distribution requirements are known. The distribution of flow will be dependent on the ultimate spreading ground and conveyance system layouts to be provided in the final report.

4.8 SUMMARY

Table 4-1 shows the maximum conveyance capacity for each of the Conversation District's conveyance facilities.

Table 4-1
Maximum Conveyance of Groundwater Recharge Facilities

Description	Qmax
Intake Structure	150 cfs (1) 250 cfs (2) 362 cfs (3)
Cuttle Weir	362 cfs (4)
Tunnel	550 cfs
Sandbox	825 cfs (5)
Earthen Canal	300 cfs
Rock Structure	1268 cfs (5)
Greenspot Road Culvert	372 cfs
Parshall Flume	1214 cfs (6)
Diversion Structure North Gate	500 cfs
Diversion Structure South Gate	253 cfs

(1) Existing capacity using stop logs instead of plywood at weir notch.
(2) Practical capacity given the potential for material accumulation and its impact on the flow characteristics.
(3) Theoretical capacity through the six gates to maximum gate height.
(4) Theoretical capacity without the use of sandbags.
(5) Requires modifying the 50-ft long overflow section, otherwise practical capacity is 550 cfs with minor gate modifications.
(6) Capacity corresponding to a water depth of 5.5 ft, thus allowing 5 inches of free board.
(7) Capacity dependent upon maintaining existing slope of canal downstream of diversion structure.

From the analyses described above the MWH team concludes that the Cuttle Weir will need to be raised to increase the capacity to 500 cfs. Although it appears that modifications to the Cuttle Weir could be made inexpensively, additional analyses are required to determine whether it can be raised without causing environmental impacts or structural instability to the existing weir dam.

The existing gates at the Intake Structure have the capacity to move 500 cfs and greater flows. The Cuttle Weir height and Intake Structure are interdependent. So, although the Intake Structure has substantial excess capacity, the only way to realize this capacity would be by raising the Cuttle Weir. Managing and controlling debris at the gate structure or downstream will be addressed in the final report.

The Intake Conduits, Sandbox, Rock Structure and Parshall Flume all have sufficient capacity to convey flows of 500 cfs and greater. Modifications of the gates and possibly improvements to the overflow section of the Sandbox are the only recommended future improvements for these facilities.

The existing earthen channels generally experience velocities greater than recommended values at flows of 300 cfs and greater. Future improvements could include the installation of drop structures and lessening of the existing slopes or widening of the existing channels. Detailed recommendations for improvements will be addressed in the final report.

The Diversion Structure appears to have capacity to convey flows of 500 cfs, however, additional analysis will be done once the configuration and flow regime of the ultimate spreading facilities is known.

Section 5
Analysis of Percolation Capacity

The field work was designed to identify the relative significance of factors which may limit the percolation capacity of existing recharge ponds at the SAR recharge facility. Potential limiting factors identified the planning phase of the study included:

- Presence of fine-grained material that “clog” the surface of the Borrow Pit
- Compaction of shallow soils in the Borrow Pit due to heavy equipment use during construction of the pit
- Presence of horizontal or vertical barriers to groundwater flow, such as clay layers or faults
- Shallow groundwater which mounds or rises to the surface

Based on the field work described in Section 2, more is known about the significance of these potential limiting factors, as described in the following sections.

5.1 SURFACE CLOGGING BY FINE PARTICLES

Shortly after the completion of the Seven Oaks Dam, it was reported that silt-laden water was delivered to the Borrow Pit. Fine particles of silt and clay may have settled out of this water and formed a thin layer of relatively impermeable soil which significantly reduces infiltration rates. Field data collected during this study suggest that this was indeed a factor in reducing infiltration rates in the Borrow Pit. Observations that support this conclusion include:

- Visual observations during physical surveys suggest that at locations where water ponds, a fine silt/clay layer is observed which is much finer than that of adjacent native soils is present.

- An anomalously high percentage of silt or clay was noted in grain size analyses from sample locations where water historically ponds on the western edge of the Borrow Pit. Whereas a typical fine particle percentage for most areas of the Borrow Pit is less than 6 percent, areas where water ponds have fine particle percentage as high as 50 percent. Comparison of hydraulic conductivity and fine particle percentage data collected during this study indicate that fine particle percentage is a very significant factor limiting hydraulic conductivity.

- Tests at Pond 1 in the Borrow Pit where the shallowest soils were removed resulted in a significantly higher percolation rate.

5.2 COMPACTION OF SOILS

Soil compaction can occur when the weight of machinery or other forces compress the soil causing it to lose porosity, leaving little space for air and water. One hypothesis is that during construction of the Seven Oaks Dam, the very heavy earthmoving equipment used for excavation in the Borrow Pit may have compacted the shallow soils, thereby reducing their infiltration capacity. The degree of compaction caused by heavy equipment is dependent on the weight of the equipment and the prevailing soil moisture content. Contact pressure of the equipment is determined by the overall weight of the vehicle and its footprint. The greater the contact pressure and/or the more frequently the vehicle passes over a particular area in the field, the greater and deeper the resulting compaction. The soil moisture content at the time the equipment is driven over the soils is also a factor, whereby the greatest amount of compaction occurs when the soil is wet. However, details regarding the type of equipment and frequency of use of equipment used during construction of the Seven Oaks Dam is generally not available, so that estimates of the amount of compaction that occurred cannot be reliably made.

Although no quantitative data on soil density was collected during the field effort, during shallow soil sampling and trenching, no visual evidence of severe compaction such as loss of granular soil structure or crushed or hardened soils was observed. If compaction did occur, it is not expected to be significant more than a few feet below the surface, particularly because of the coarse nature of native soils (which are less compressible). Based on these factors, soil compaction by heavy equipment is not considered to be a significant factor in reducing infiltration rates in the Borrow Pit. The potential effects of soil compaction in the Borrow pit may be somewhat of a moot point if shallow fine-grained soils need to be removed in any case.

5.3 PRESENCE OF VERTICAL OR HORIZONTAL GROUNDWATER MOVEMENT

Two types of barriers to groundwater flow may be present at the SAR recharge facilities; horizontal barriers that retard downward flow of groundwater, or vertical barriers that retard lateral or horizontal flow of groundwater. The evidence for the presence or absence of each of these types of barriers is discussed in the following sections.

Horizontal Barriers

As noted in Section 2, there is no evidence of a laterally-continuous strata of low hydraulic conductivity which would inhibit infiltration of recharge water regionally. This is consistent with the active alluvial fan depositional environment of the unconsolidated deposits underlying the recharge facilities. The depositional environment also suggests that discontinuous layers of silt and clay are present locally, and that the horizontal hydraulic conductivity is probably one or more orders of magnitude higher than the vertical hydraulic conductivity. The discontinuous layers of fine material could be cause by soil zones developed on older fan deposits or overbank deposits along active alluvial channels.

Thus, it is concluded that the presence of a horizontal barrier to groundwater flow is not a significant limitation to recharge at the SAR facilities.

Vertical Barriers

As noted in Section 2, groundwater elevation data collected during this study provides good evidence for the presence of a vertical barrier to groundwater flow which dissects the Borrow Pit and trends in a northwesterly direction parallel to the San Andreas Fault. This vertical barrier is interpreted as being a previously unmapped splay of the San Andreas Fault. During the Spring of 2008, this groundwater barrier impeded the westward flow of groundwater enough to cause groundwater to rise to the surface in Pond 3 and the central section of the Borrow Pit immediately northeast of the fault. Based on observations of the Conservation District staff and the presence of semi permanent vegetation in these areas, this is a relatively common occurrence.

In the Spring of 2008, infiltration occurring in unlined canals and the Santa Ana River east of the barrier during recharge operations provides enough groundwater to “fill” the aquifer east of the fault. This is evidenced by the fact that groundwater surfaces even before water was added to Ponds 1, 2, or 3 in the Borrow Pit. Because the monitoring wells east of the barrier are new, there is no data to evaluate how often this has occurred in the past, but it is believed to be relatively common. The net effect of this phenomenon is that the entire eastern portion of the Borrow Pit (Phase 1 Area) has a very low percolation rate and is of minimal value for additional percolation ponds, although other facilities such as settling basin could be located in the area.

5.4 GROUNDWATER MOUNDING LIMITATIONS

During artificial recharge operations where a high volume of water is recharged to a finite region, the groundwater rises and forms a mound beneath the region or recharge area. If ambient groundwater levels are relatively high, the artificial recharge may cause groundwater to rise to the ground surface, thus reducing infiltration capacity. For this reason, it is generally advisable to avoid this situation in order to optimize recharge operations. During the testing of Pond 1, groundwater mounding was observed in MW-1, and, although the groundwater did not rise to the surface underlying the pond, recharge in Pond 1 caused rising groundwater in Pond 3 and the central portion of the Borrow Pit.

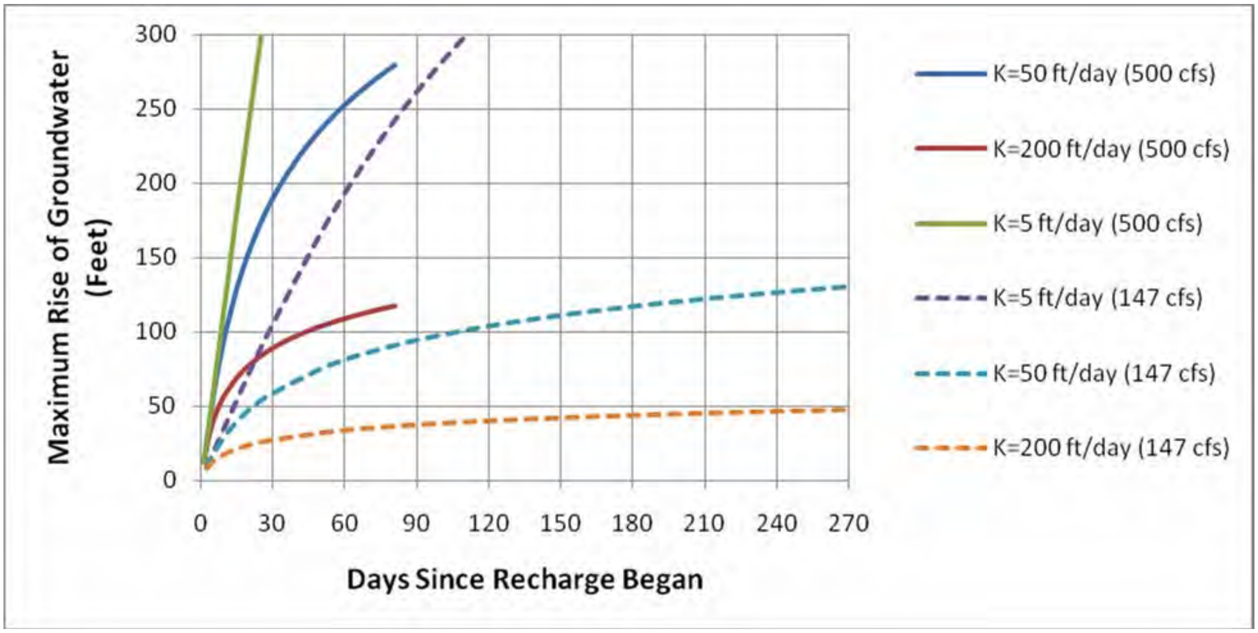
Southwest of the groundwater barrier however, the depth to the ambient groundwater elevation is much greater, which is a more desirable condition in order to prevent the groundwater mound from reaching the surface (Figure 3-8**)**. Long-term hydrographs of well SBVWCD 3 and the Cone Camp wells indicate a typical depth to water of approximately 200 feet in the area southwest of the barrier, and during the summer of 2008, depth-to-groundwater ranged from 100 to 160 feet.

The method of Hantush (1967) has been used to estimate the rate of groundwater mounding at the highest point on the mound. The input variables in the Hantush model include the pre-recharge thickness of the aquifer, specific yield, aquifer hydraulic conductivity, length and width of the recharge ponds, and average recharge rate. The length and width of the recharge facilities was estimated using the total area available for recharge west of the fault in the Borrow Pit. The average rate was derived by dividing 500 cubic feet per second (desired maximum recharge rate) by the total area (resulting in an average rate over the entire area). This average rate over the total area is less than what would occur in individual ponds, but simulates the infiltration of 500 cubic feet per second (cfs) over the total area. The following inputs to the model where used, based on aquifer conditions described in Section 3:

Initial thickness of aquifer	500 feet
Specific Yield	15 percent
Length of Recharge Pond	6,494 feet
Width of Recharge Pond	3603 feet
Average Recharge Rage	1.85 feet per day

The IRWMP "Scenario A" calls for a total of 80,000 acre-ft in one year. From a groundwater mounding perspective, the worst-case scenario would be that this volume of water was recharged at a continuous maximum rate of 500 cfs, which equates to 81 days. Therefore, the Hantush model was run for a period of 81 days at 500 cfs. The largest uncertainty using this model is the average hydraulic conductivity of the aquifer. As noted in Section 3, a typical hydraulic conductivity value for the aquifer underlying the recharge facilities is estimated at 50 feet/day, but may range from a few feet to several hundred feet/day. **Figure 5-1** depicts the calculated maximum rise in the water table based on the Hantush method using a range of assumed hydraulic conductivities.

Figure 5-1
Change in Groundwater Elevation Assuming Various K Values



The Hantush model indicates that using the best estimate of hydraulic conductivity of 50 feet per day, the infiltration of 500 cfs will not cause groundwater to reach the surface for approximately 30 days of continuous recharge (assuming a starting groundwater depth of 200 feet). If the average hydraulic conductivity of the aquifer is higher than 50 feet per day, this time period would be longer, and if it is as high as 200 feet per day, it would not reach the surface at all. These calculations probably underestimate potential mounding because the Hantush method assumes idealized aquifer conditions which do not include the boundary conditions present at the site. However, it does suggest that if the starting groundwater level is below approximately 200 feet, it is possible to recharge 80,000 acre-feet in one year. However, continuous percolation at the maximum rate of 500 cfs may cause groundwater mounding, which limits percolation.

A more realistic number of days for the recharge of 80,000 acre-feet is over a longer period of approximately nine months. This would mean that the average percolation rate would drop to 147 cfs, or 0.54 feet per day. Change in groundwater elevation at this percolation rate is also depicted in Figure 5-3. The Hantush method suggests that at this lower average percolation rate, groundwater will not reach the surface assuming the average hydraulic conductivity of 50 feet/day or higher.

It is very important to note, however, that in very high runoff periods, the entire Phase 1, Phase 2, and Phase 3 area west of the barrier may be saturated because of the combined effect of natural and artificial recharge along the Santa Ana River. Hydrographs of well SBVWCD 3 and the Cone Camp wells indicate that in 1980, 1993, 1998, and 2005, the groundwater came to within approximately 50 of the surface for short periods of time. During these periods, recharge may be limited by groundwater mounding even west of the barrier which dissects the Borrow Pit. Under these saturated conditions, it is certain that a percolation rate of 500 cfs will cause groundwater mounding that will limit percolation rates. This is consistent with regional groundwater modeling studies, which predict saturated conditions for very short durations during wet years (SAIC, 2007).

5.5 ESTIMATION OF PERCOLATION CAPACITY OF EXISTING FACILITIES

In 1975, the USGS reported that an average long-term infiltration rate in the range of 0.7 feet (with silt clogging) to as high as 10 feet/day (for well maintained surface) could be expected for the SAR recharge facilities. In addition, the USGS reported that on average, typical long-term infiltration rates are on the order of 3 feet/day. Relatively short-term testing conducted during this study indicated rates of approximately 4 feet/day for the area west of the groundwater barrier. Therefore, a conservative range of typical infiltration rates for well-maintained existing or new ponds west of the Borrow Pit barrier would be 3 to 4 feet/day. The maximum infiltration capacity of the existing pond facilities outside the Borrow Pit can be estimated based on various infiltration rates as shown in **Table 5-1**.

Testing of the Pond 17 west of the Borrow Pit resulted in a calculated infiltration rate of 4 feet per day. Combining this calculated rate with the total area of Ponds 9-17 and Dike D estimated by the Districts results in a calculated percolation capacity of 116 cfs. However, it was noted that during testing of Ponds 9-17 and Dike D in April of 2008 that 145 cfs could be added to these ponds without spilling water from Dike D. This apparent discrepancy might be explained in several ways:

1. Significant percolation occurs in unlined conveyance facilities not accounted for in the pond area calculations.
2. The average percolation rate of Ponds 9-17 and Dike D is higher than 4 feet/day measured in Pond 17, and could be as high as 5 feet/day.
3. During testing in April of 2008, some water was still being added to storage in the soil zone and/or the wetted area was increasing, suggesting a percolation rate higher than would occur during long-term operation.

Table 5-1
Maximum Infiltration Capacities

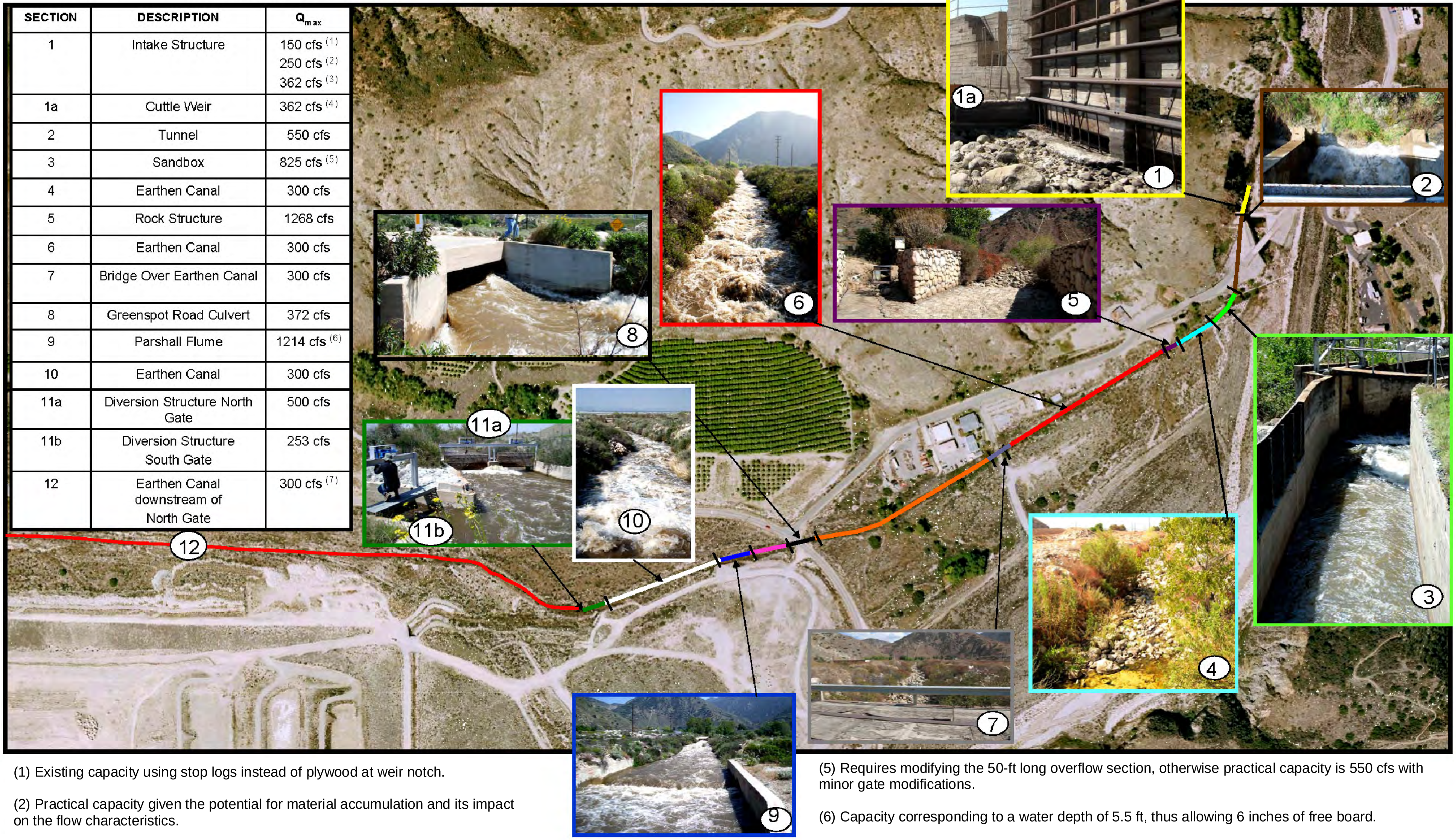
Existing Percolation Pond	Wetted Area (feet^2)	Percolation Capacity in cfs (Rate of 3 feet/day)	Percolation Capacity in cfs (Rate of 4 feet/day)	Percolation Capacity in cfs (Rate of 5 feet/day)	Notes
1	94,633	3.3	4.4	5.5	May not be usable due to high groundwater
2	99,616	3.5	4.6	5.8	May not be usable due to high groundwater
3	110,152	3.8	5.1	6.4	May not be usable due to high groundwater
9	104,264	3.6	4.8	6.0	Outside of Phase 1, 2, and 3 areas
10	258,916	9.0	12.0	15.0	--
10-S	42,343	1.5	2.0	2.5	Outside of Phase 1, 2, and 3 areas
11	282,525	9.8	13.1	16.3	--
11-S	15,322	0.5	0.7	0.9	Outside of Phase 1, 2, and 3 areas
12	97,038	3.4	4.5	5.6	--
13	298,083	10.4	13.8	17.3	--
14	186,068	6.5	8.6	10.8	--
15	203,764	7.1	9.4	11.8	--
16	65,692	2.3	3.0	3.8	--
17	213,808	7.4	9.9	12.4	--
Dike D	735,002	25.5	34.0	42.5	Outside of Phase 1, 2, and 3 areas
Total	**2,807,227**	**97.5**	**130.0**	**162.5**	
Pond 9-17, Dike D Only Total	**2,502,826**	**86.9**	**115.9**	**144.8**	

Notes: Total acres = 64.4
Total acres of Pond 9-17 and Dike D only = 57.5

Given that the testing occurred over a period of over 2 weeks, factors 1 and 2 appear most significant, and it seems the a combination of the two is most probable. Therefore, it is estimated that the total long-term percolation capacity of the existing ponds and unlined conveyance system outside the Borrow Pit (**Figure 5-2**) is approximately 145 cfs (**Figure 5-3**), and an additional 50 cfs of long-term percolation capacity is estimated for the west end of the Borrow Pit, being the total percolation capacity to 195 cfs, except during very high runoff periods when the regional area experiences shallow groundwater conditions for temporary periods.

SBVWCD GROUNDWATER RECHARGE DIVERSION & CONVEYANCE MAXIMUM CAPACITY

SECTION	DESCRIPTION	Q_{max}
1	Intake Structure	150 cfs $^{(1)}$ 250 cfs $^{(2)}$ 362 cfs $^{(3)}$
1a	Cuttle Weir	362 cfs $^{(4)}$
2	Tunnel	550 cfs
3	Sandbox	825 cfs $^{(5)}$
4	Earthen Canal	300 cfs
5	Rock Structure	1268 cfs
6	Earthen Canal	300 cfs
7	Bridge Over Earthen Canal	300 cfs
8	Greenspot Road Culvert	372 cfs
9	Parshall Flume	1214 cfs $^{(6)}$
10	Earthen Canal	300 cfs
11a	Diversion Structure North Gate	500 cfs
11b	Diversion Structure South Gate	253 cfs
12	Earthen Canal downstream of North Gate	300 cfs $^{(7)}$



(1) Existing capacity using stop logs instead of plywood at weir notch.

(2) Practical capacity given the potential for material accumulation and its impact on the flow characteristics.

(3) Theoretical capacity through the six gates upon to full height.

(4) Theoretical capacity without the use of sandbags.

(5) Requires modifying the 50-ft long overflow section, otherwise practical capacity is 550 cfs with minor gate modifications.

(6) Capacity corresponding to a water depth of 5.5 ft, thus allowing 6 inches of free board.

(7) Canal slope is approximately 3%, therefore capacity is limited by flow velocity.

(8) Capacity estimated from recharge tests.

(9) Capacity estimated from SBVWCD staff experience.

N

No Scale

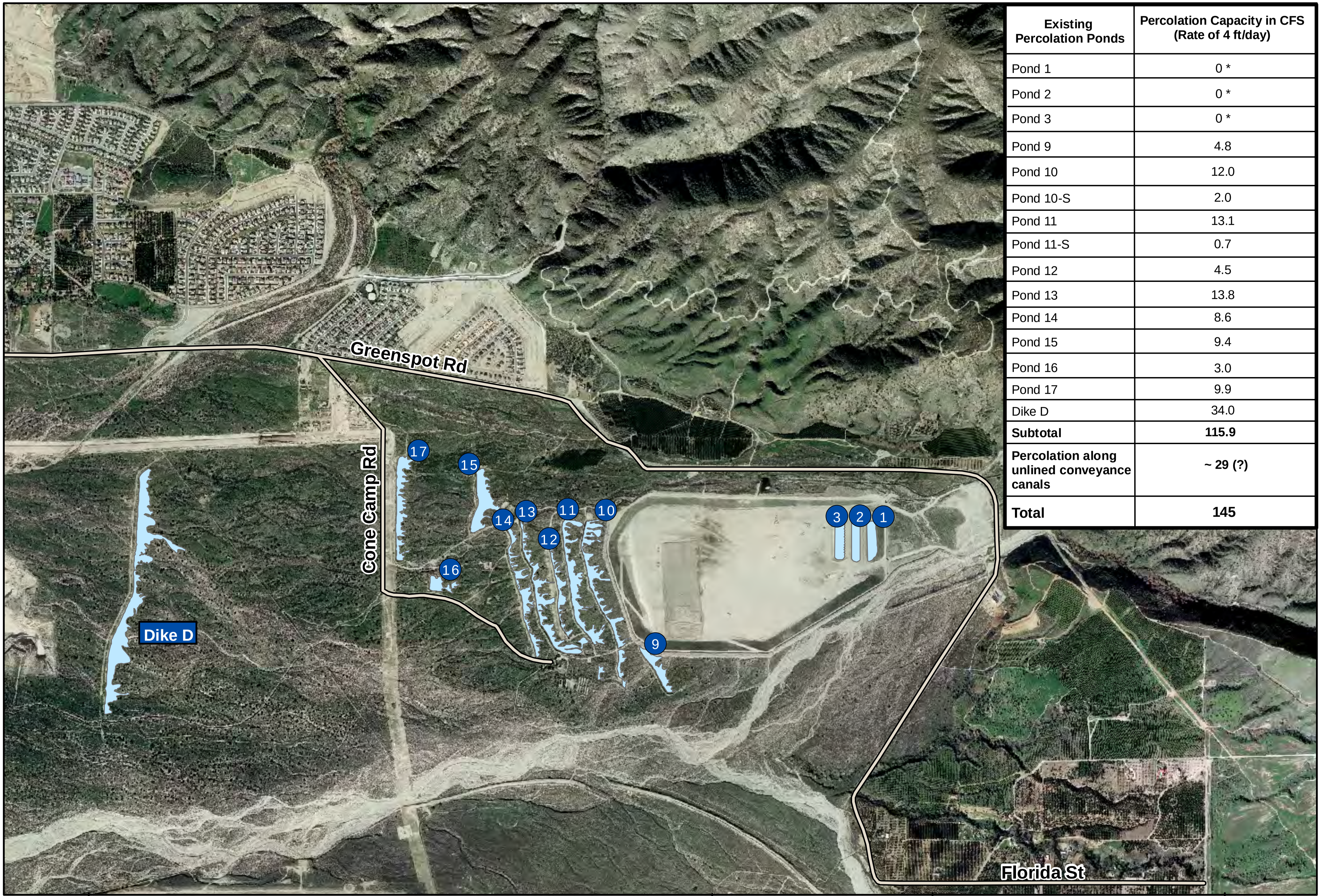
Document: SBVWCD_DiversionConveyance Details_Fig5-1.mxd

Date: December 22, 2008

Capacity of Diversion and Conveyance Facilities

Figure 5-2

Santa Ana River Groundwater Recharge Optimization Study



Existing Percolation Ponds	Percolation Capacity in CFS (Rate of 4 ft/day)
Pond 1	0 *
Pond 2	0 *
Pond 3	0 *
Pond 9	4.8
Pond 10	12.0
Pond 10-S	2.0
Pond 11	13.1
Pond 11-S	0.7
Pond 12	4.5
Pond 13	13.8
Pond 14	8.6
Pond 15	9.4
Pond 16	3.0
Pond 17	9.9
Dike D	34.0
Subtotal	**115.9**
Percolation along unlined conveyance canals	**~ 29 (?)**
Total	**145**

Key to Features

① Spreading Pond Number

🟦 Spreading Ponds

* Percolation capacity assumed to be zero due to high groundwater conditions

0 500 1,000 2,000 Feet

N

Document: SBVWCD_PercCapacityFig5-2.mxd

Date: December 22, 2008

Capacity of Existing Percolation Ponds

Figure 5-3

Santa Ana River Groundwater Recharge Optimization Study

Section 6
Summary of Conclusions

6.1 CAPACITY OF EXISTING DIVERSION, CONVEYANCE, AND RECHARGE FACILITIES

Based on previously-available data and the results of field work conducted as part of this study, the estimated capacity of the SAR recharge facilities can be compared to the short-term instantaneous flow rate goal identified in the IRWMP of 500 cubic feet per second (cfs). The following is concluded about physical conditions and capacity of both the diversion and conveyance facilities, and the percolation ponds at the SAR recharge facilities:

Diversion and Conveyance

- The current intake capacity of the Intake Structure without modification is approximately 150 cfs.
- Downstream of the Intake Structure and Cuttle Wier, earthen canals limit the capacity of the conveyance facilities to approximately 300 cfs.

Percolation Ponds

- The is no evidence of a continuous strata of low hydraulic conductivity that would limit downward percolation of recharge water.
- Percolation in portions of the Borrow Pit is currently limited by the presence of a thin layer of silt and clay, probably deposited when silty water was added to the Borrow Pit.
- The presence of a vertical barrier to groundwater flow (probably a fault), causes groundwater to rise in the Borrow Pit and limits the recharge capacity of the western 2/3rd of the Borrow Pit.
- The recharge capacity of the existing percolation ponds at the SAR recharge facility west of the fault is approximately 145 cfs. The recharge capacity of the borrow pit is approximately 50 cfs for a total current recharge capacity of 195 cfs.

Section 7
References

Daugherty and Franzini, 1979. Water Resources Engineering, 3rd ed., McGraw-Hill, New York, New York.

Davis, S. N., 1966. Hydrogeology, John Willey & Sons, Inc.

Hantush, M.S., 1967. Growth and Decay of Groundwater-Mounds in Response to Uniform Percolation, Water Resources Research, vol. 3, no. 1, pp. 227-234.

King, Horace Williams, 1993, Handbook of Hydraulics, McGraw-Hill, New York, New York.

Muckel, G.B. (Editor), Understanding Soil Risks and Hazards, Using Soil Survey to Identify Areas with Risks and Hazards to Human Life and Property. United States Department of Agriculture, Natural Resources Conservation Service, National Soil Survey Center, Lincoln, Nebraska. Online Publication.

MWH, 2008, Santa Ana River Groundwater Recharge Optimization Study, Technical Memorandum 1 – Documentation of Existing Information and Field Work Plan – June 16.

SBVMWD and WMWD, 2007, Santa Ana River Water Right Applications for Supplemental Water Supply: Community Report. January 2007.

SBVWCD, 1994. Operational Management Manual of the San Bernardino Valley Water Conservation District. March 1994.

SBVWCD, 2007. Miscellaneous documents related to hydrologic investigations related Wells SAR1 and SAR2, undated.

Science Applications International Corporation (SAIC), 2007. Technical Memorandum: Seven Oaks Dam Economic Analyses, December 2007.

USGS, 1975. Artificial Recharge in the Upper Santa Ana River Area, San Bernardino County, California. USGS Water-Resources Investigations 15-75. 27 p.

USGS, 2003a. Geologic Map of the Redlands 7.5’ Quadrangle, San Bernardino and Riverside Counties, California.

USGS, 2003b. Geologic Map of the Yucaipa 7.5’ Quadrangle, San Bernardino and Riverside Counties, California.

USGS, 2005. Hydrology, Description of Computer Models, and Evaluation of Selected Water-Management Alternatives in the San Bernardino Area, California. USGS Open-File Report 2005-1278.178 p.

Walton, WC, 1988. Practical Aspects of Groundwater Modeling. National Water Well Association, Worthington, Ohio. 588 pps.

Appendix A
Water Level Plots

Attachment 1.

Santa Ana River Groundwater Recharge Optimization

Scope of Work

The scope of work consisting of the following main Tasks:

- **Task 1:** Evaluate Existing Groundwater Recharge Spreading Facilities and Operations
- **Task 2:** Establish Spreading Objectives
- **Task 3:** Perform Feasibility Analysis and Prepare Conceptual Design to Meet Spreading Objectives
- **Task 4:** Draft and Final Report
- **Task 5:** Project Management

The work that the MWH will complete for each of these tasks is described in detail in the following sections.

Task 1: Evaluate Existing Groundwater Recharge Spreading Facilities and Operations

The Task 1 objective is to evaluate existing spreading facilities (diversion works, conveyance and basins) along with the current maintenance and operations practices to determine their maximum estimated capacity. Work under this task will consist of performing the field tests and quantitative analyses necessary to achieve this objective.

MWH team will evaluate the recharge facility capacity by addressing each component of the facility individually. Four steps will be generally included for evaluation of each component of the facility:

- Data compilation and review
- Field data collection
- Field flow verification
- Capacity estimation

The individual tasks to be performed using this general approach will be as follows:

Task 1.1: Data Compilation and Review

This task will consist of compilation of information from previous investigations and construction activities in the vicinity of the SAR recharge facility. MWH will review data from the USGS, U.S. Army Corps of Engineers (USACE), and additional studies, reports, and data available from SBVWCD and SBVMWD. MWH will establish a secure project FTP site which will serve as a data repository for all information and data used by the team. MWH team will compile these data into a Technical Memorandum (TM) for future use and reference.

This task will also involve meetings with SBVWCD and SBVMWD staff to obtain records and verbal information on past recharge operations. MWH anticipates that much of the operations information obtained will not be documented, but will include important observations by the operators regarding system response to historic recharge practices. The MWH team will document this anecdotal information for use in future phases of the work. The MWH team will document and present the data compiled for this project and approach to field data collection before field work begins.

A description of data compilation and review activities anticipated for each facility component is provided below.

Task 1.1.1: Diversion Works and Conveyance **–** The MWH team will compile and review the following information:

- Available record drawings and related information for all diversion and conveyance facilities
- Existing elevations for key points of diversion and along the conveyance route
- Operations information obtained for diversion records and interviews with operations staff

Task 1.1.2: Recharge Basins **–** The MWH team will compile and review the following information:

- Available record drawings and related information for the recharge basins
- Operations information obtained for spreading records and interviews with available operations staff
- Current and past groundwater elevation records for wells in the project area
- Lithologic logs for wells in the project area
- Shallow borings performed by USACE prior to construction of the Borrow Pit (if available)
- Groundwater modeling assumptions by Geoscience and USGS
- Existing elevation records for key locations at the current and potential future locations of recharge basins in the project area
- Previous hydrogeologic investigations in the area to obtain information on subsurface conditions that govern recharge rates (i.e. soil grain size distribution, total alluvial thickness, vertical and horizontal hydraulic conductivity of soil and aquifer materials, aquifer transmissivity, location and thickness of aquitards)

Task 1.2: Completion of TM-1 – Documentation of Existing Information and Field Work Plan

This Technical Memorandum will consist of:

- Summary of data compiled and reviewed including a catalog of material referenced
- Work plan for the acquisition of subsequent field data documenting:

    - the rationale, location and methodology for field data collection
    - the schedule for field data collection
    - coordination needed with SBVWCD and SBVMWD staff during completion of the field work
- Health and Safety Plan to be followed by field personnel

Task 1.3: Field Data Collection

A description of proposed field data collection activities for each facility component is provided below.

Task 1.3.1: Diversion Works and Conveyance – The MWH team will obtain the following field information:

- Inspect, photograph and document physical condition of diversion and conveyance facilities
- Physical measurement of diversion works and conveyance facilities (i.e. length, width, height, channel condition, debris and obstructions)
- Survey selected locations to verify latitude, longitude and elevation (to nearest 0.1 foot for horizontal and 0.01 of a foot for vertical control). For cost estimating purposes, it is assumed that 20 points will be required.
- Profile of canal facilities with cross-sections at each major change in channel geometry

The MWH Team will conduct field flow testing of the diversion works when water is available. Focus will be on the potential flow limitation at the Cuttle Weir, which is now choked with sediment. During the long-term percolation testing described below, observations will be made of the diversion and conveyance works for a variety of flow rates.

Task 1.3.2 – Recharge Basins – The MWH team will perform the following field activities:

Basin Physical Survey

- Inspect, photograph and document the physical condition of each recharge basin noting type and thickness of clogging layer (if present), vegetation, algae, evidence of side wall erosion, and other features pertinent to recharge capacity.
- Physical measurement of recharge basins (i.e. length, width, height) or estimation from existing maps.
- Measurement of depth to water in project and private wells identified near the project facilities (for budgeting purposes, we have assumed five wells).
- Survey of key elevations at recharge basins and existing monitoring well locations to verify latitude, longitude and elevation (to nearest 0.1 foot for horizontal and 0.01 of a foot for vertical control). For cost estimating purposes, it is assumed that 20 points will be required.

Shallow Soil Sampling and Quantitative Soil Characterization

Soil samples will be collected for quantitative laboratory analysis of soil grain size gradation. These samples will be collected in the following manner:

Trenching

Up to 10 trenches will be excavated in the existing percolation basins to a maximum depth of 5 feet at locations described in the field work plan (TM-1). The side walls of the trenches will be logged by a professional geologist (PG). Types of soil information will consist of:

- Depth of various soil horizons
- Soil type
- Visual classification of gradation
- Color
- Apparent moisture content

Sample descriptions will be in accordance with the American Society for Testing and Materials (ASTM) D2487-06 ***Standard Practice for Classification of Soils for Engineering Purpose***s (Unified Soil Classification System).

Areal Shallow Soil Sampling

Shallow soil samples will be collected by the on-site geologist at selected locations identified in TM-1 and described using ASTM D2487-06.

Up to 65 soil samples from trench and shallow soil sample locations and borings will be analyzed for gradation analysis in accordance with ASTM D-422 and ASTM D-4464 by a qualified laboratory. Ten (10) of the 65 soil samples collected will also be tested for saturated hydraulic conductivity using ASTM-5084.

Gradation analysis will be collected and analyzed at the test pit locations described below. Two (2) samples will be conducted at each test pit.

Sonic Drilling

Five sonic borings will be conducted along the long axis of the borrow pit. This type of drilling allows for representative core sampling in rocky terrain. Five borings will be completed to a maximum of 50 feet below ground surface for deeper correlation of sediments below the borrow pit.

Construction of Monitoring Wells

MWH will install one (1) monitoring well (MW) in the immediate vicinity of existing and potential basins to the water table (assume 300 feet below ground surface). The MW will be located in areas that will not affect recharge operations such as berms and sides of existing roads. Data will provide information on the stratigraphy of the basins, and will be used later for documentation of the water table elevation underlying the sites during recharge operations. The MWs will be installed using air percussion or rotary/foam methods to a maximum depth of 300 feet.

The cuttings from the borings excavated for installation of monitoring wells will be logged by a Professional Geologist using ASTM D5434-97 (2003) ***Standard Guide for Field Logging of Subsurface Explorations of Soil and Rock***. In addition, the boreholes will be logged using geophysical methods of spontaneous potential, long and short normal resistivity, and point resistivity. These geophysical methods will provide a quantitative assessment of the resistivity of the materials underlying the basin, which can be correlated to the lithology and relative hydraulic conductivity of the materials. The wells will be completed with 2-inch PVC casings, surface seals, and protective barriers or flush completions as appropriate.

Percolation Testing and Conveyance Testing

The MWH team will design and site three test pits. Each of these test pits will consist of a pair of half acre pits side-by-side, one containing existing material at it's below bottom, the other "cleaned", with fine shallow material removed. It is assumed that the District will provide conveyance of State Water Project water for these tests.

The MWH Team will identify the locations to be tested and the detailed testing methods in TM-1, after consultation with the Districts. SBVWCD will construct and operate the diversion facilities and conduct flow measurement during the testing. The MWH team will be responsible for developing the detailed construction drawings, testing methods, and supervision of collection of field data during the tests. Locations, construction designs, testing methods and data compilation needs will be defined in TM-1.

***Task 1.3.3 Capacity Estimation* –** A description of work proposed to estimate the capacity for each facility component is provided below.

Diversion Works and Conveyance

The MWH team will:

- Prepare channel cross sections and estimate roughness
- Make estimates of channel losses (percolation)
- Estimate the capacity and operational limitations based on theoretical capacity (using percolation tests as calibration) and an evaluation of historical data

Recharge Basins

The field data collected in Task 1.3 will allow MWH to evaluate each one of these potential limitations. The analysis of this data will consist of the following:

- Estimates of aquifer characteristics will be made by development of two geologic cross-sections, one perpendicular to the SAR, and another parallel to the long axis of the recharge facilities. These sections will include the following information as available:

    - Ground surface elevation

  - Groundwater surface – historic high and low
  - Lithology – thickness and extent of high permeability and low permeability units based on information obtained during drilling and trenching
  - Bedrock depth (from lithologic logs)
  - Mounding estimates in response to recharge
  - Groundwater flow direction
  - Well locations

- Total aquifer flow estimates will be prepared for the perpendicular section described above. Estimates will be made using Darcy's Law and these flow estimates will be compared with numerical estimates that may be generated using the Geoscience model described in the RFP.

- Piezometric surface maps of groundwater elevations for project area will be constructed for both wet and dry initial conditions. These initial conditions are critical to the mounding effects and ultimate capacity of the facilities.

- Mounding estimates based on aquifer properties and calculated diversion and conveyance capacity will be completed. Experience has shown that mounding needs to be considered on time steps as short as one week. The impact of mounding is more critical in Borrow Pit grounds than for the surface spreading grounds because of the pit's lower elevation. The MWH team will use the Hantush analytical method for estimating mounding beneath the spreading basins. Mounding estimates will be illustrated on the sections described above. Decay rates of mounds will also be estimated.

- Total theoretical capacity will be estimated by comparison of measured percolation rates during field testing to total area of similar shallow soil characteristics. This will be compared to historical maximum percolation rates based on observations of operators.

- Estimates of mounding impacts will be used to estimate groundwater elevations under "wet" scenarios. This data will be used to evaluate potential off-site impacts to mining operations and other stakeholders.

TM-2 Recharge Characterization and Capacity Summary

The results of field surveys and analytical evaluation methods will be documented in TM-2. This document will contain the results of field work and recharge capacity estimates. The information included in this document will consist of:

- **Field documentation**
  - Results of physical surveys (maps, observations, and photographs)
  - Trench logs

    - Maps showing soil sampling locations
    - Laboratory results and tabular summaries
    - Monitoring well lithologic and geophysical logs
    - Monitoring well completion as-builts
    - Observations of testing of conveyance and diversion tests
    - Results of percolation testing

- **Analysis of Existing Spreading Capacity**
    - Surface clogging
    - Diversion or conveyance limitations
    - Groundwater mounding limitations
    - Evaluation of off-site impacts (e.g. gravel mining)
    - Relationship of initial groundwater elevation conditions to spreading capacity
    - Estimate of the range of maximum percolation rates as a function of groundwater depth

TM-2 will be provided in draft form for review and comment by SBVWCD and SBVMWD. The MWH team will meet with representatives of these agencies to discuss the results of the field work and analysis. MWH assumes a time period of two weeks for the District's review. After incorporation of the comments, the TM will be produced in final form.

Task 2: Establish Spreading Objectives

The objective of Task 2 is to compare the capacity of the existing spreading grounds (evaluated in Task 1) to the amount of water set forth as spreading objectives.

Objectives to be evaluated were established in the IRWMP and are as follows:

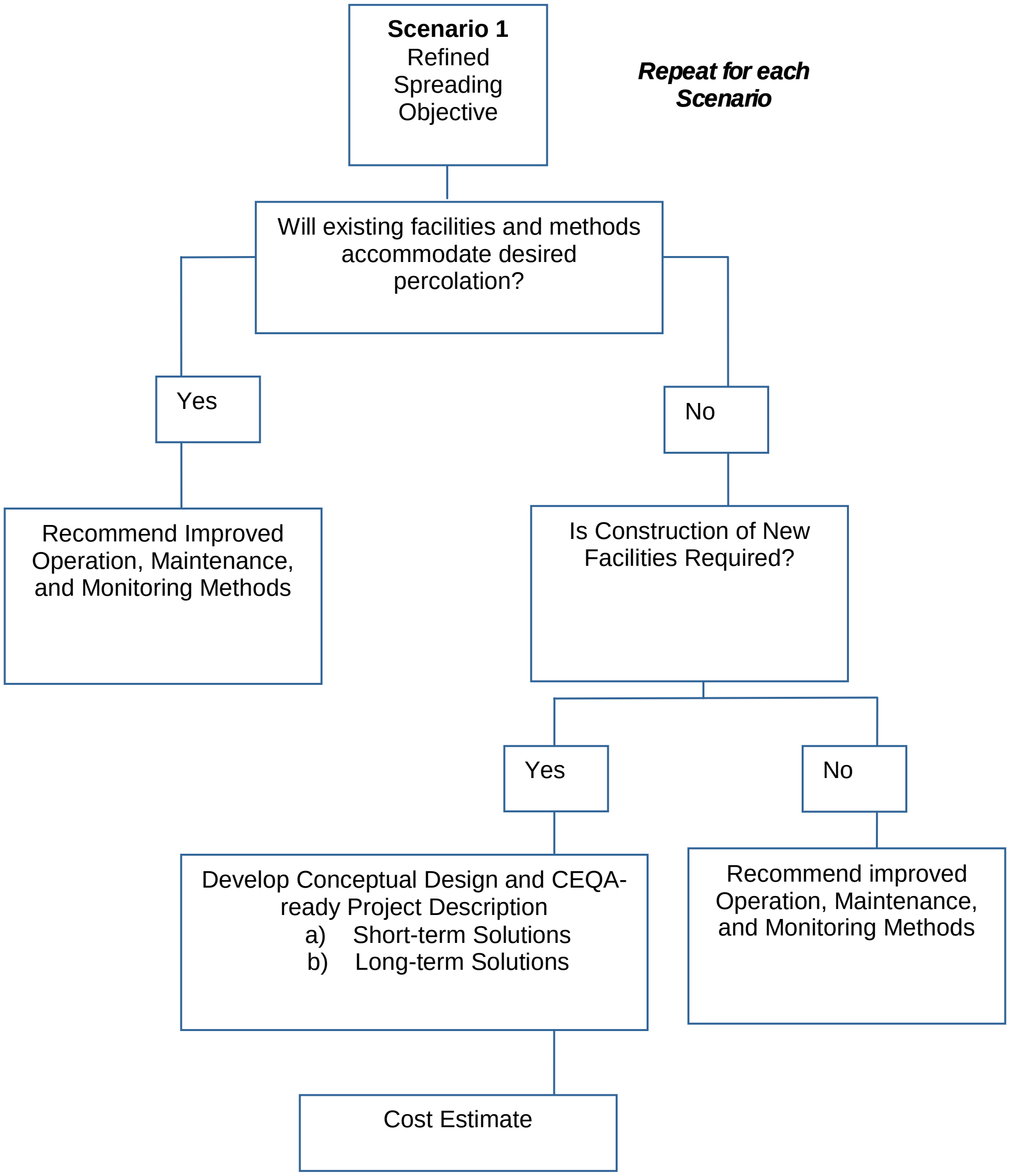
- **IRWMP Baseline Scenario** – Total water needed to be spread in the SAR spreading grounds for this scenario (ultimate demands for the Valley). The annual flow data are presented in Exhibit A to the RFP.

- **IRWMP Scenario A** – Total water needed to be spread in the SAR spreading grounds to achieve the objectives for this scenario (additional yield of 40,000 acre-feet). These data is provided in Exhibit B to the RFP.

- **Maximum Instantaneous Spreading Scenario** – Instantaneous flow rate of 500 cubic feet per second (cfs) for a limited duration.

Task 3: Perform Feasibility Analysis and Prepare Conceptual Design to Meet Spreading Objectives

The completion of Task 2 will allow for a comparison of the three refined spreading objectives to the capability of the existing facilities documented in TM 2. Each of the three scenarios identified in the RFP will be evaluated. Outcomes possible for each scenario are illustrated below:



Operation, Maintenance, and Monitoring Recommendations

Our preliminary evaluation of the recharge facilities indicates that improved operation, maintenance, and monitoring methods will substantially improve the capacity of the existing facilities. MWH will build upon the collective experience of our work at 27 groundwater recharge facilities operated by Los Angeles County Department of Public Works, and 11 outside agencies polled during the Percolation Optimization Investigation to recommend Best Management Practices to SBVWCD. MWH will also use the experience of Dr. Herman Bouwer, to assist with these recommendations. MWH will make these recommendations regardless of the estimated capacity of the outcome of the comparison of existing capacity to spreading objectives.

Conceptual Designs

If it is determined that new construction is required to meet the objectives of any of the three scenarios, MWH will develop conceptual designs for both short-term and long-term facilities for each of the three scenarios.

Conceptual designs will show the limits of work, primary improvement requirements and approximate facility sizes. The conceptual designs will provide a clear understanding of the required improvements and will be used as the basis for estimating construction improvement quantities and associated construction costs opinions and will be appropriate for use for the succeeding environmental work. For work within the Borrow Pit, the background information from the District's drawing "Proposed Build Out of the Borrow Pit" will be evaluated and used to the extent appropriate.

USGS mapping information, supplemented with field measurements by the MWH team, will be used for other conceptual drawing backgrounds. MWH will also explore and use U.S. Army Corps of Engineers as-built data. MWH assumed that adequate topographic mapping is available to the project team, and that the area will not require re-mapping.

Conceptual designs will be prepared to show improvements to fix the existing conveyance system's choke points and to strengthen the canal in areas where erosion has occurred. The MWH team assumed that the conceptual designs will also show:

- New basins in the Borrow Pit
- Conveyance system in Borrow Pit area for basin flow management
- Basin overflow and flow control facility details
- Extent of removal of fine material in the Borrow Pit
- Typical sections of the basin dikes
- Dike profiles
- Extent of material excavation and disposition at Cuttle Weir
- Construction of a new higher capacity box culvert at Greenspot Road
- Construction of an intake and pipeline from Cuttle Weir to the Foothill and Santa Ana River crossing pipelines downstream. This will allow SBVMWD to deliver water to other spreading basins and/or treatment plants in the area

Conceptual design requirements will be determined based on Task 1 and 2 activities. The following discussion provides background on our project approach for all potential conceptual design items.

Improvements to the diversion works would be dependent on the interaction of the existing weir, channel geometry and terrain, gate structure capacity and conveyance system inlet capacity. Should improvements be needed, a site plan and plan drawings of the proposed improvements will be prepared. More detailed drawings, as needed by the MWH Team to clearly define the work, will also be included. For example, if channel improvements were determined to be required, the conceptual drawings will define the limits of the work and the new and existing cross sections. These items will be used to calculate the required earthwork quantities.

Conveyance capacity improvements may consist of expansion of the existing channel prism, improvements to improve channel roughness coefficients (such as lining or use of alternative materials) or replacement or improvements to the existing transition structures. Improvements to the transition structure at Greenspot Road are anticipated due its planned realignment. An increase to the transition structure's width will increase its flow carrying capacity. Improved transitions into and out of the box channel will decrease the erosion occurring on the downstream end.

Conceptual design for conveyance system improvements will include a general site plan identifying the existing facilities that will highlight the planned areas of improvement. Specific cross sections of proposed channels and box structures will be prepared. Drawings showing modifications or improvements to control structures (such as the addition or replacement of gates) will be added as needed by the MWH team to clearly define the work.

Spreading ground drawings will show the overall spreading ground layout, proposed basin limits and interior dike requirements. Typical dike cross sections will be prepared to show the maximum height, side slope and roadway width. Details of flow control structures will be prepared. These structures could vary from simple overflow weirs to more complicated weir boxes depending on operational and flow variation requirements.

Flow control structures within the spreading facilities will also be detailed. These facilities will allow refinement of flows into the spreading ground to bypass and isolate basins for cleaning and system management. The number and type of facilities needed will be dependent on operational criteria established for the work. With development of the conceptual plans for spreading facilities an approximation will be prepared of the additional land owned or controlled by SBVWCD that is available for construction of spreading facilities.

CEQA-Compliant Project Description

Although preparation of CEQA documents is not included in the Scope of Work, MWH will supply a separate project description for each of three scenarios that are appropriate for use in subsequent CEQA documents. MWH will also identify potential environmental issues with construction that become apparent, or based on our experience with these types of projects.

Cost Estimates (Opinion of Probable Construction Cost)

The Opinion of Probable Construction Cost to be developed for necessary facility improvements under each of the three scenarios will be prepared in accordance with the cost estimate classes defined by the Association for the Advancement of Cost Engineering for Conceptual Design Phase - “Class 5” level estimates. The MWH Team will use the services of experienced cost estimators working within the construction group of MWH (MWH Constructors) to insure realistic estimates of construction costs.

Task 4: Draft and Final Report

The MWH Team will prepare a draft report for review by SBVMWD and SBVWCD staff. The report will include:

- Operations, maintenance, and monitoring recommendations
- Conceptual design of recommended additional facilities needed under each of the three Scenarios
- CEQA-compliant project descriptions for the three scenarios
- Cost estimates for the facilities necessary for each of the three scenarios

Technical Memoranda 1 and 2 will be included as an appendix to the report, as will meeting minutes from the Workshop held in Task 2 to refine spreading objectives.

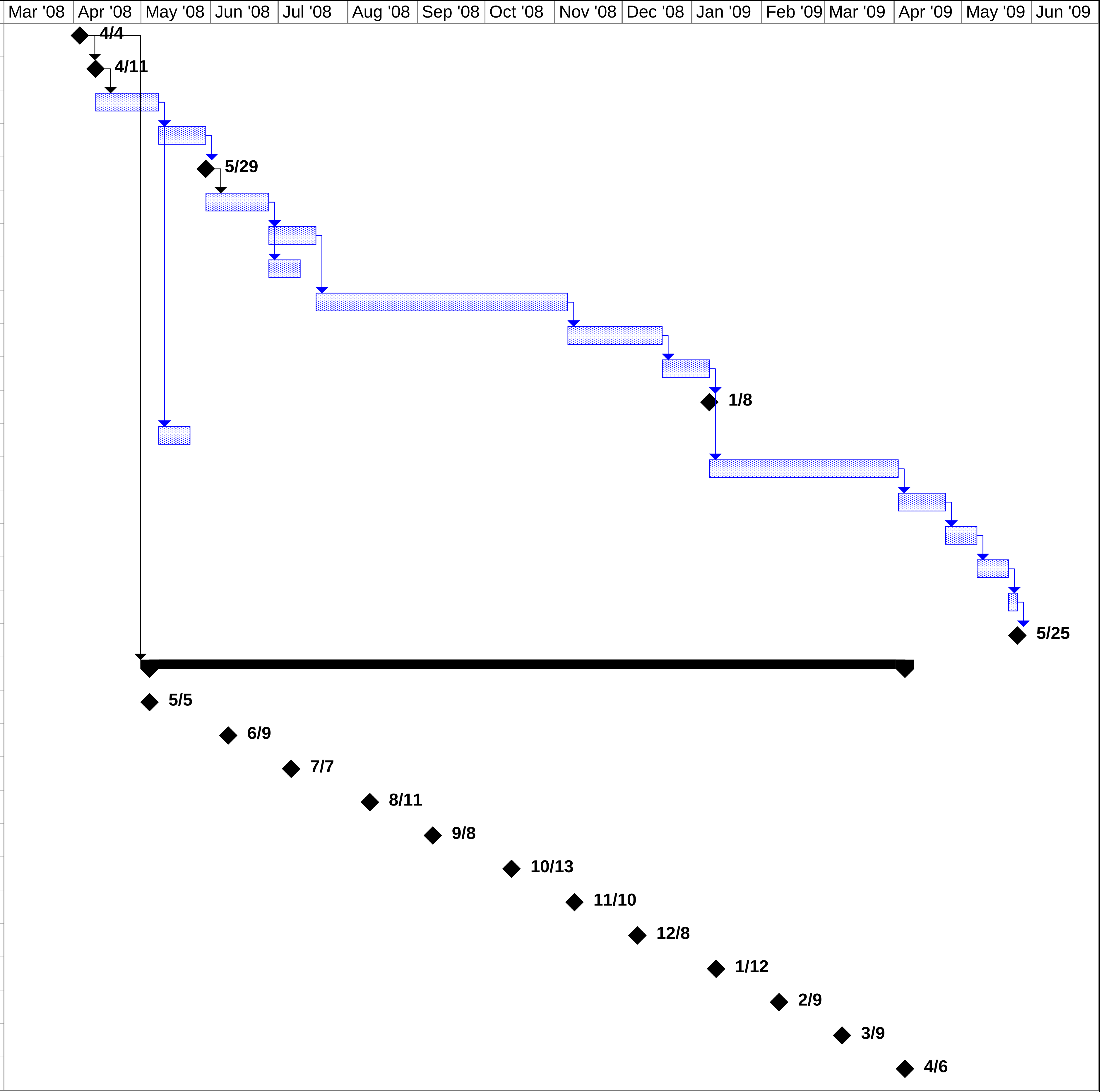
Task 5: Project Management

Mr. Victor Harris will be the primary point of contact with SBVMWD and SBVWCD staff. Mr. Harris will ensure the completion of the following during execution of the work:

- At the commencement of the project, Mr. Harris will facilitate a "kickoff" meeting to discuss the scope and parameters of the project. Specific goals and milestones required accomplishing the project, and details of project communication will be reviewed and refined.
- Mr. Harris will develop a project execution plan which details specific requirements of the project, points of contact, schedule, required documentation, and roles and responsibilities.
- Mr. Harris will be responsible for monthly reports to SBVMWD and SBVWCD that will detail the activities completed during that month, anticipated activities for the next month, unique challenges or problems with recommended actions, and schedule and budget tracking.
- Mr. Harris will facilitate periodic project meetings to be held with SBVMWD and SBVWCD staff for the duration of the project. These project meetings will be used to coordinate and guide conduct of the work, and necessary coordination with other agencies. These meetings will also be the forum for review of interim deliverables, concepts, drawings, and maps such that materials are previewed and accepted prior to formal submittal. MWH assumed that 12 meetings will be required over the course of the project.

Santa Ana River Groundwater Recharge Optimization Schedule

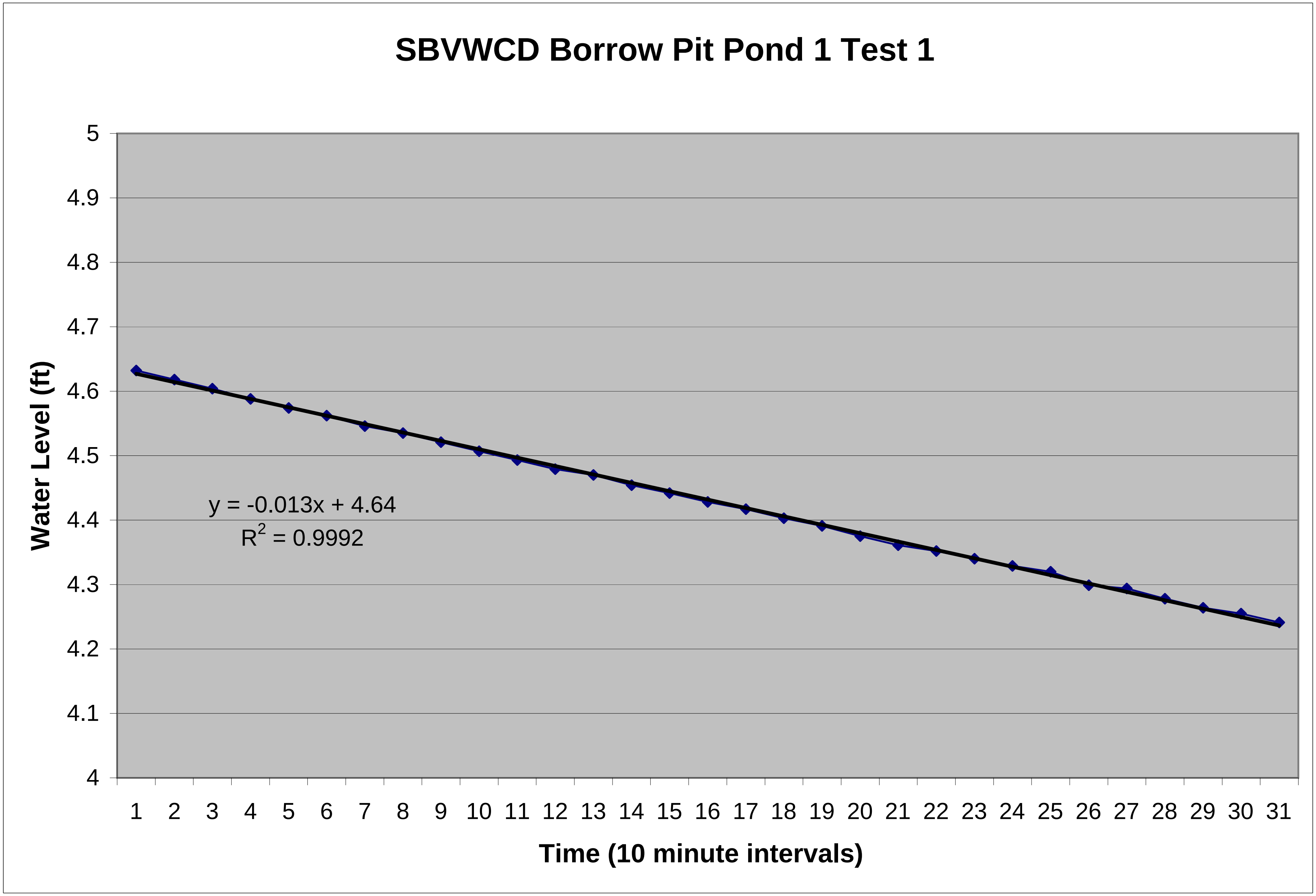
Start	Finish	Task Name
Fri 4/4/08	Fri 4/4/08	Notice to Proceed
Fri 4/11/08	Fri 4/11/08	Kick-Off Meeting
Fri 4/11/08	Thu 5/8/08	Data Compilation and Review
Fri 5/9/08	Thu 5/29/08	TM 1- Data Collection W.P. and H.S.P.
Thu 5/29/08	Thu 5/29/08	Submit TM 1
Fri 5/30/08	Thu 6/26/08	Diversion Works and Conveyance
Fri 6/27/08	Thu 7/17/08	Trenching, Sample Collection, and Analysis
Fri 6/27/08	Thu 7/10/08	Construction of Monitoring Well/Sonic Drilling
Fri 7/18/08	Thu 11/6/08	Percolation Testing
Fri 11/7/08	Thu 12/18/08	Capacity Estimation
Fri 12/19/08	Thu 1/8/09	TM 2-Capacity of Existing Facilities
Thu 1/8/09	Thu 1/8/09	Submit TM 2
Fri 5/9/08	Thu 5/22/08	Establish Spreading Objectives
Fri 1/9/09	Thu 4/2/09	Feasibility Analysis and Concep. Design Prep.
Fri 4/3/09	Thu 4/23/09	Write Draft Report
Fri 4/24/09	Thu 5/7/09	Client Review
Fri 5/8/09	Thu 5/21/09	Write Final Draft
Fri 5/22/09	Mon 5/25/09	Print Final Report
Mon 5/25/09	Mon 5/25/09	Submit Final Report to Client
Mon 5/5/08	**Mon 4/6/09**	**Project Management**
Mon 5/5/08	Mon 5/5/08	Progress Report/Meeting #1
Mon 6/9/08	Mon 6/9/08	Progress Report/Meeting #2
Mon 7/7/08	Mon 7/7/08	Progress Report/Meeting #3
Mon 8/11/08	Mon 8/11/08	Progress Report/Meeting #4
Mon 9/8/08	Mon 9/8/08	Progress Report/Meeting #5
Mon 10/13/08	Mon 10/13/08	Progress Report/Meeting #6
Mon 11/10/08	Mon 11/10/08	Progress Report/Meeting #7
Mon 12/8/08	Mon 12/8/08	Progress Report/Meeting #8
Mon 1/12/09	Mon 1/12/09	Progress Report/Meeting #9
Mon 2/9/09	Mon 2/9/09	Progress Report/Meeting #10
Mon 3/9/09	Mon 3/9/09	Progress Report/Meeting #11
Mon 4/6/09	Mon 4/6/09	Progress Report/Meeting #12

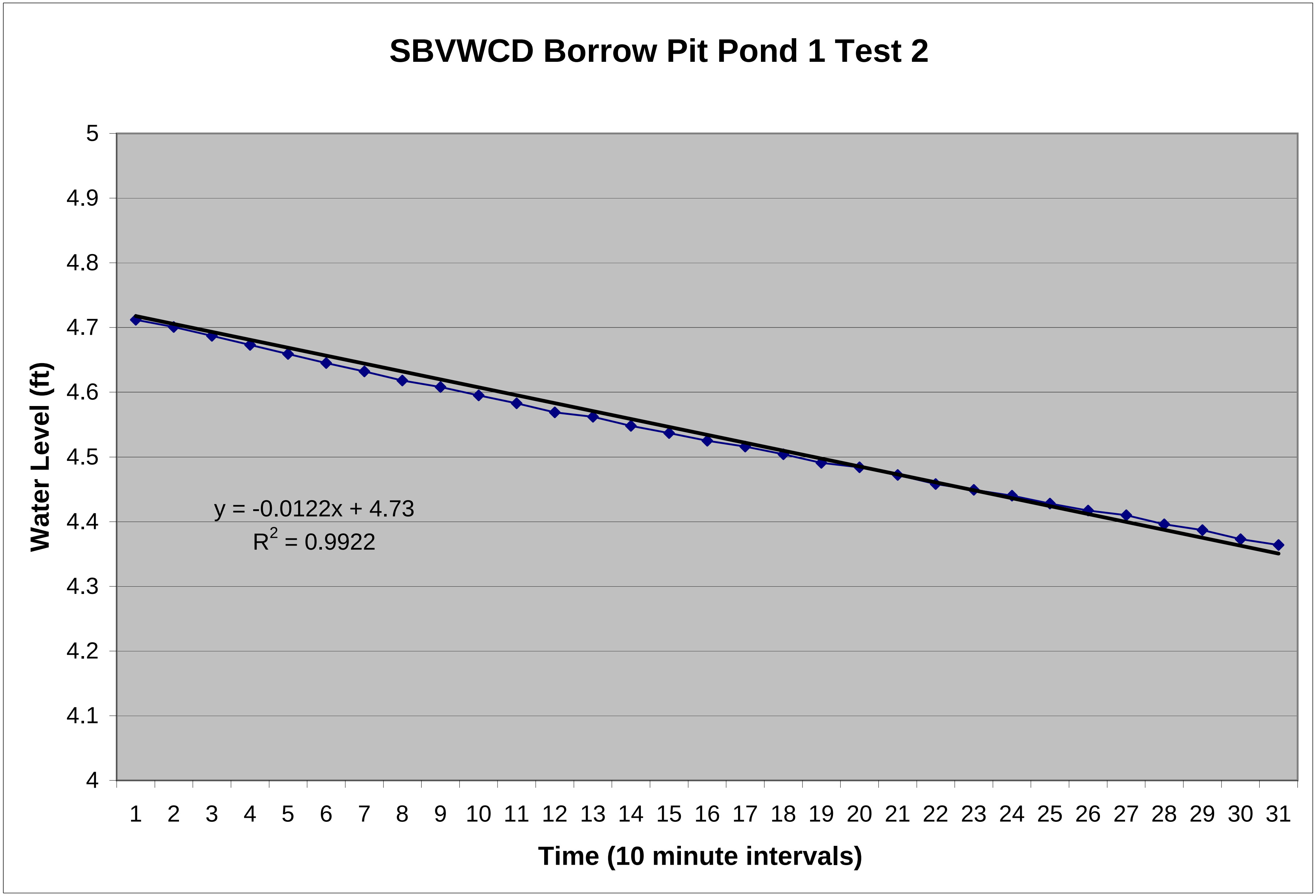


Project: SanBernardinoSantaAnaRive
Date: Mon 4/21/08

Task	▨	Progress	▬	Summary	▬	External Tasks	▭	Deadline	⇩
Split	⋯	Milestone	◆	Project Summary	▬	External Milestone	◆		

Appendix B
Water Level Plots


SBVWCD Borrow Pit Pond 1 Test 1
Water Level (ft)
5
4.9
4.8
4.7
4.6
4.5
4.4
4.3
4.2
4.1
4
y = -0.013x + 4.64
R^2 = 0.9992
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
Time (10 minute intervals)

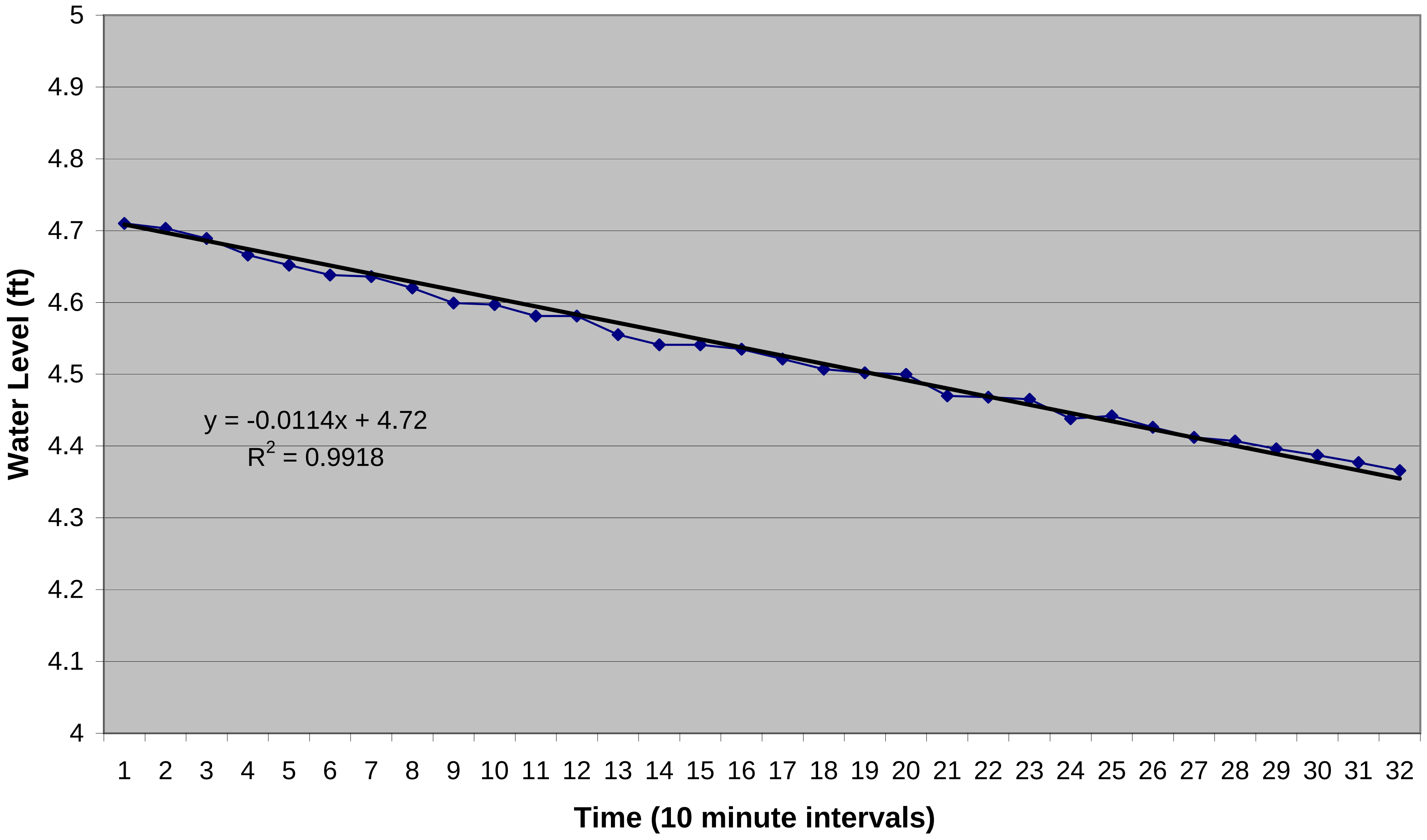


SBVWCD Borrow Pit Pond 1 Test 2

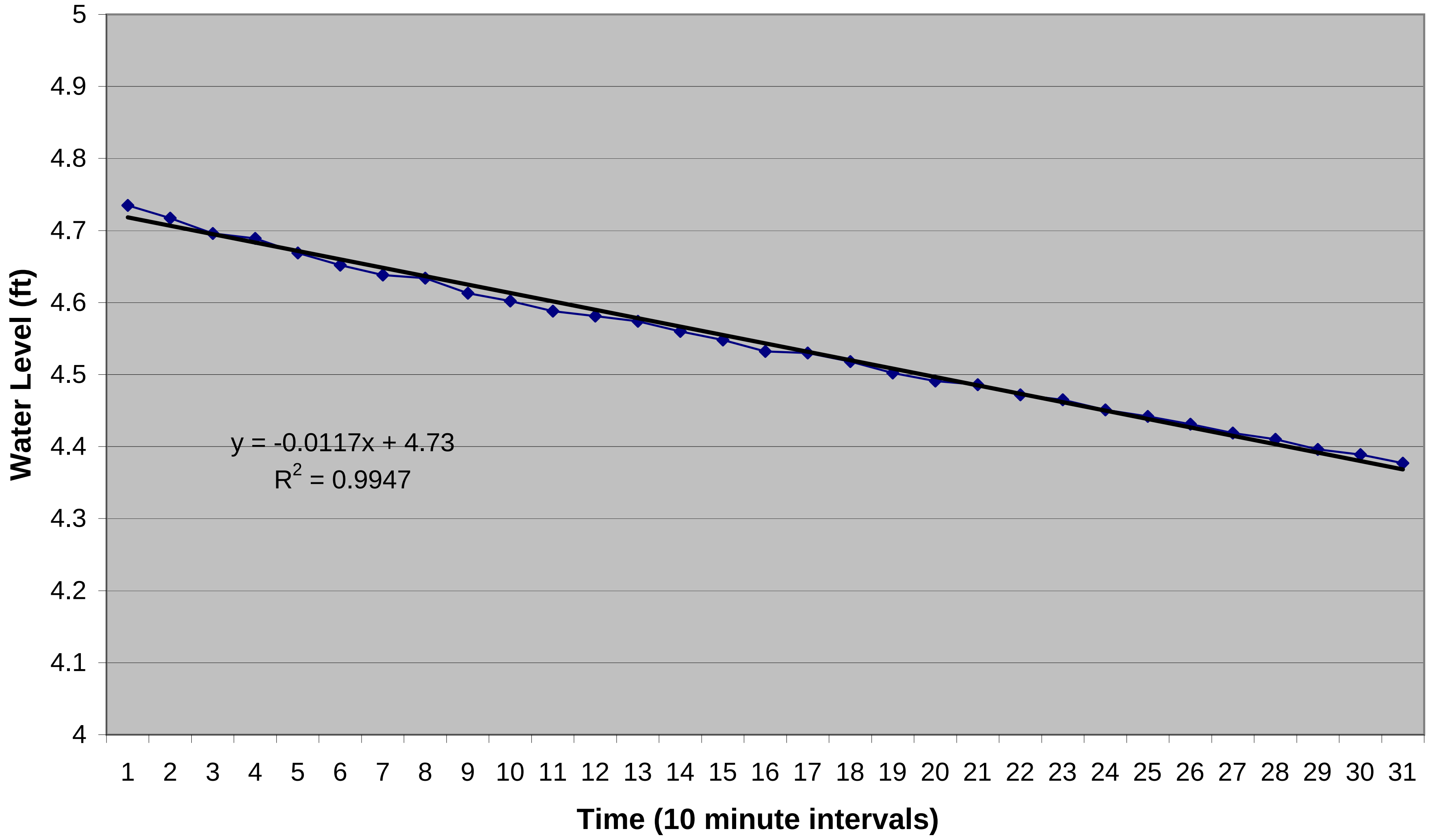
y = -0.0122x + 4.73

$R^2 = 0.9922$

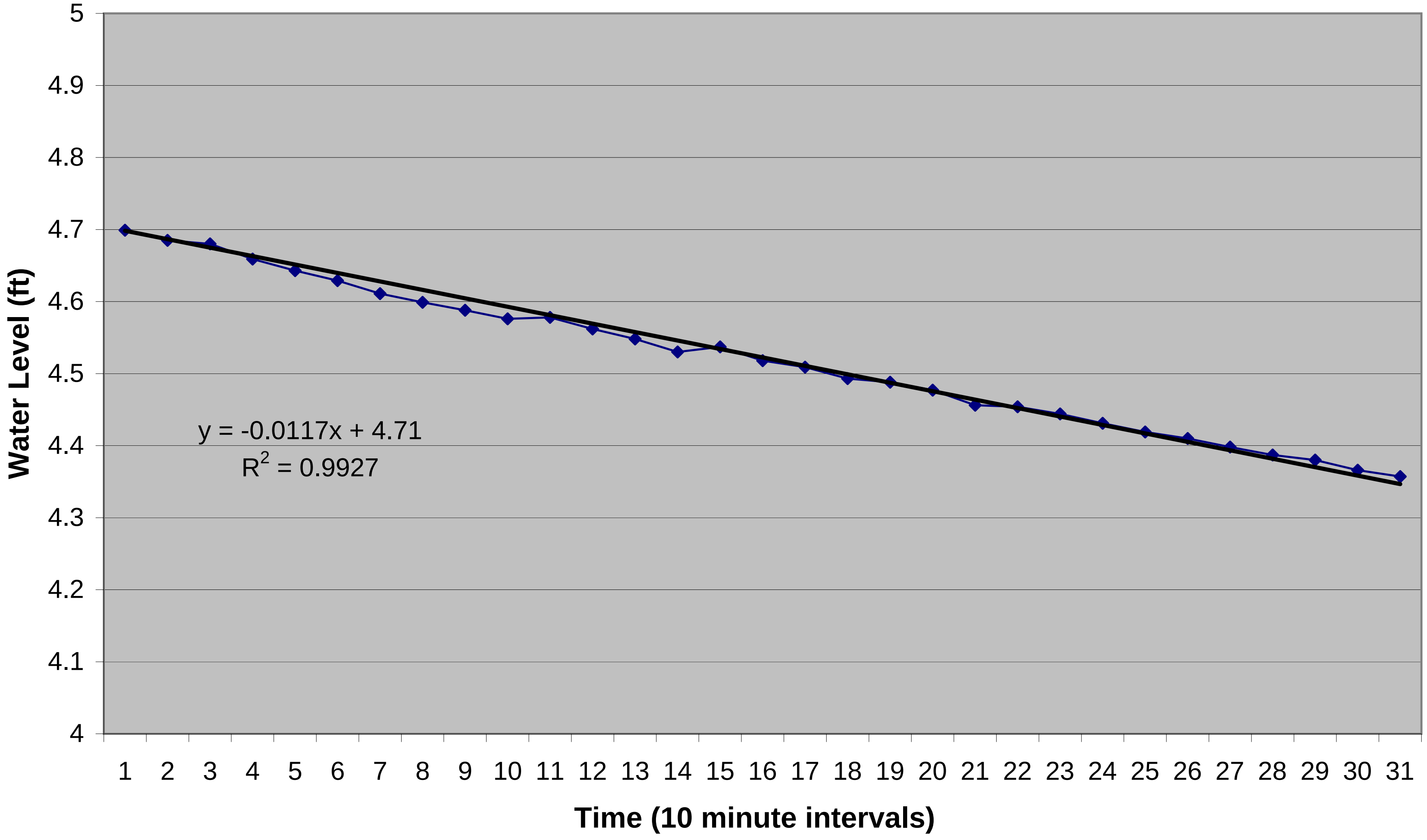
SBVWCD Borrow Pit Pond 1 Test 3



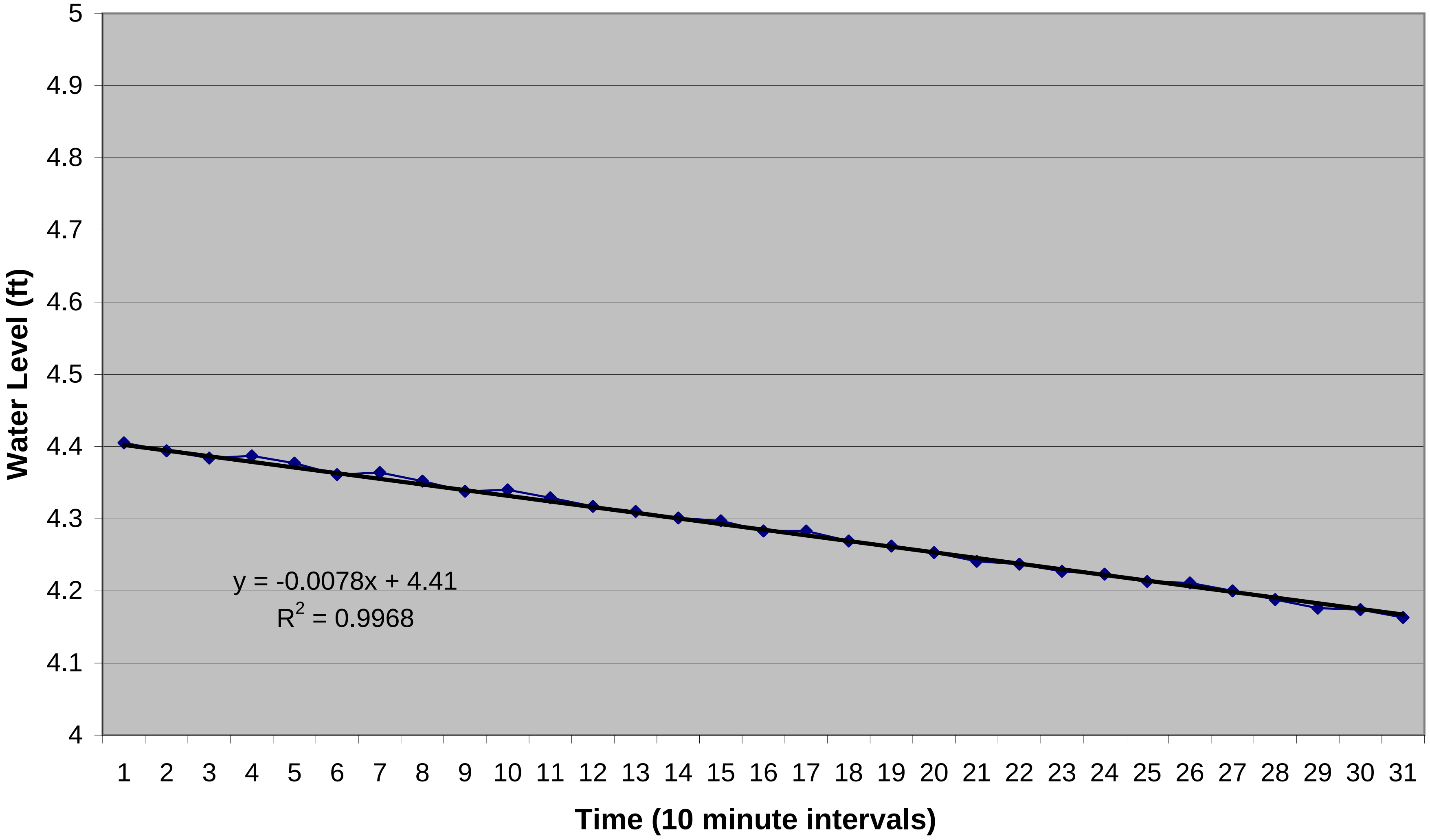
SBVWCD Borrow Pit Pond 1 Test 4



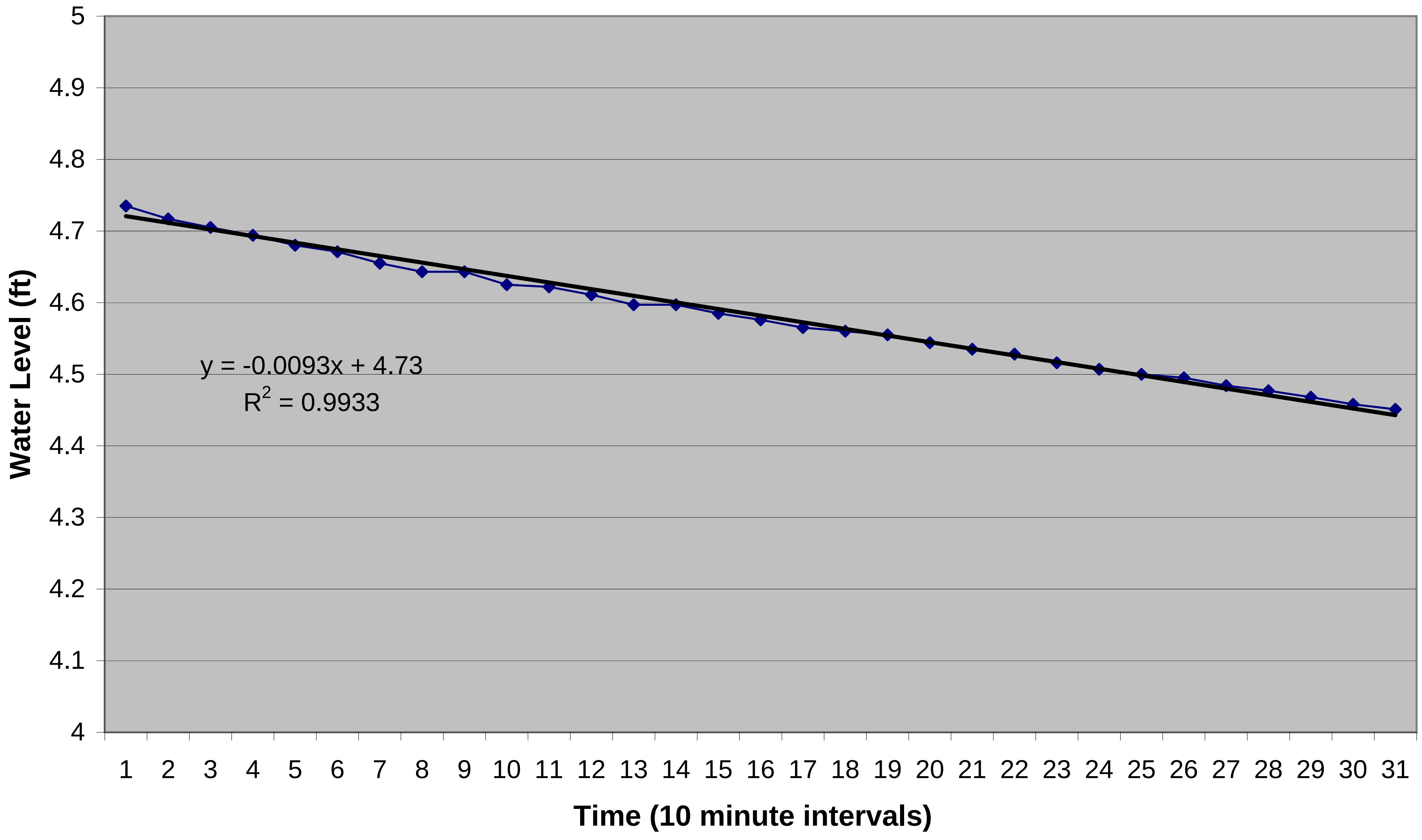
SBVWCD Borrow Pit Pond 1 Test 5

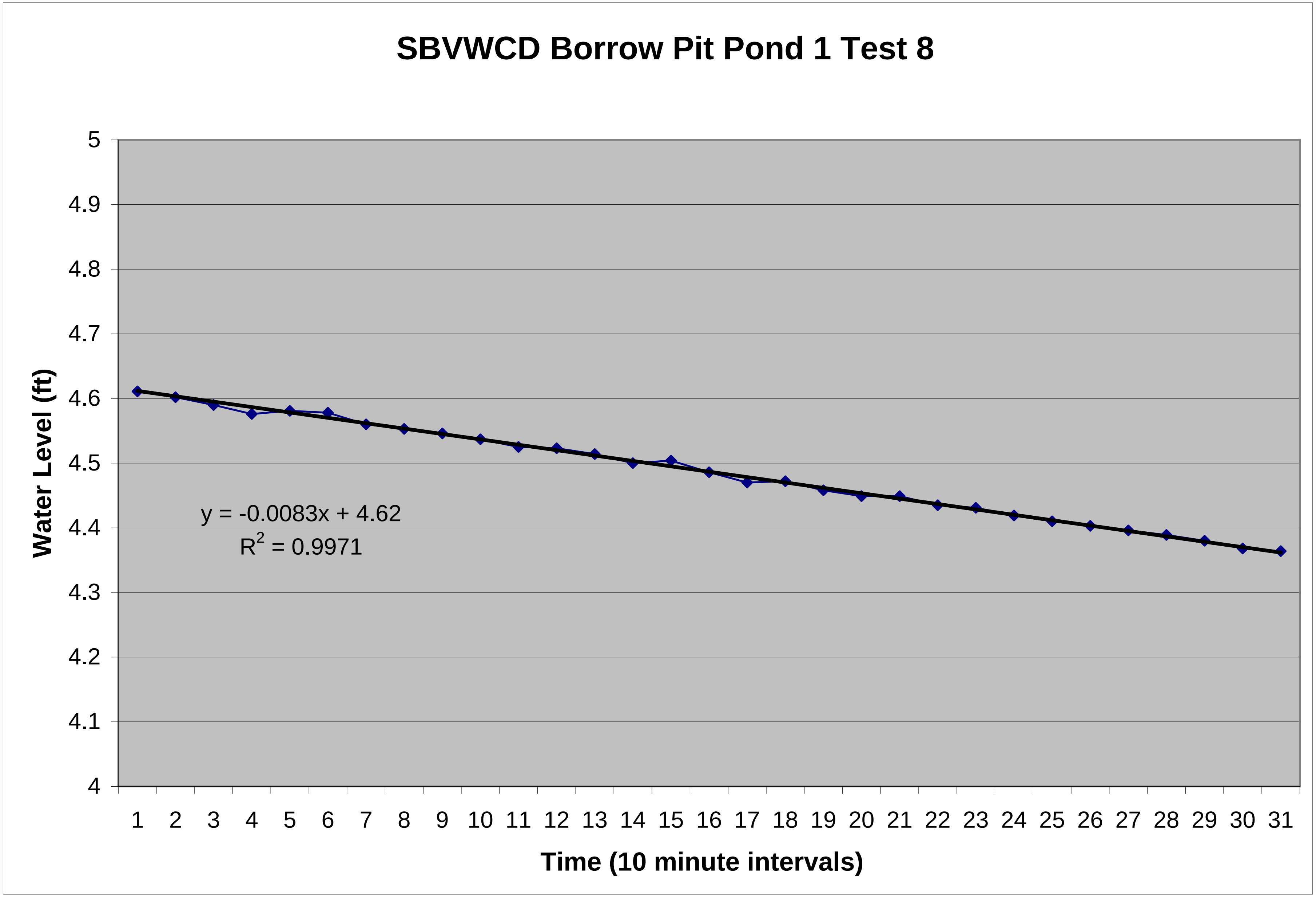


SBVWCD Borrow Pit Pond 1 Test 6

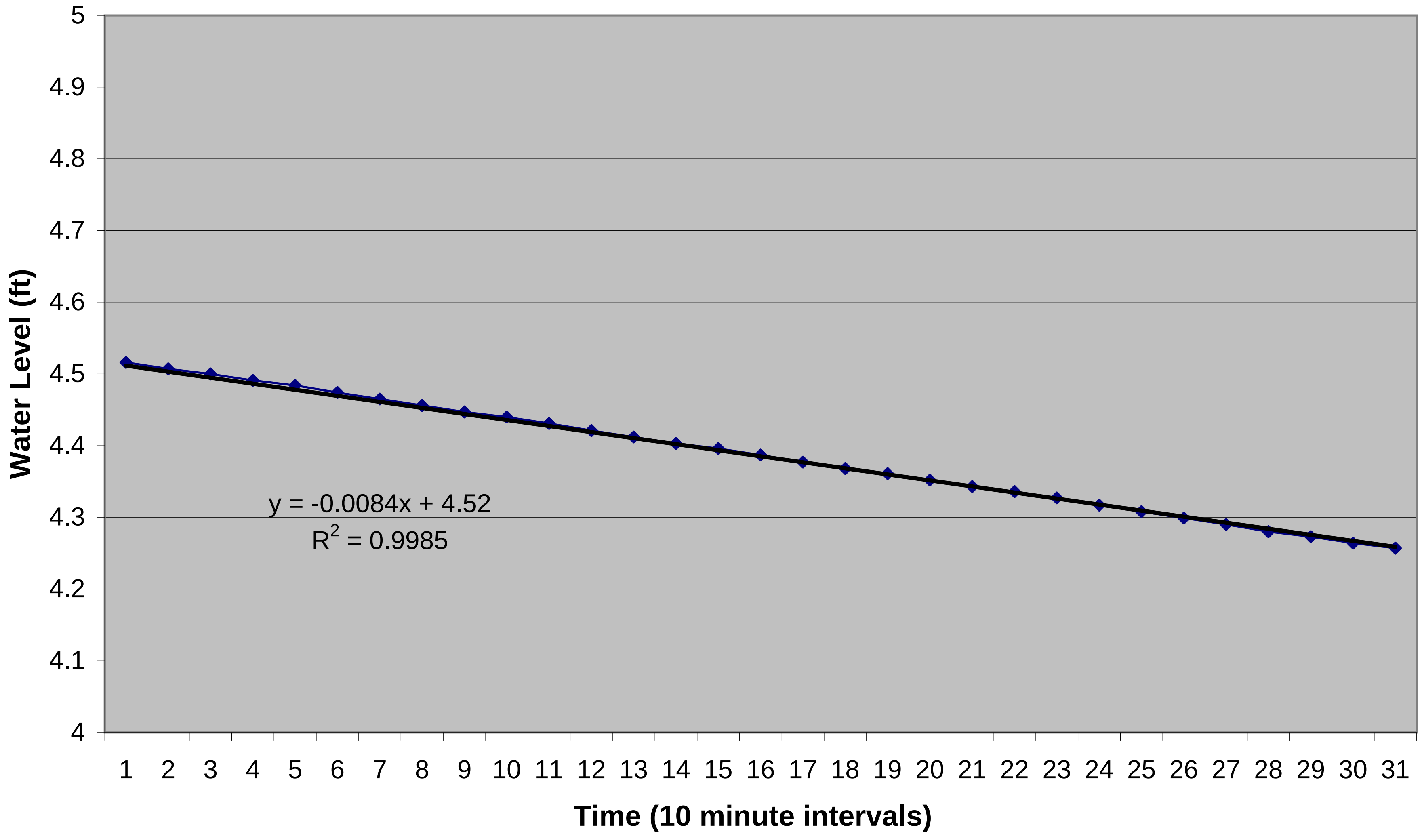


SBVWCD Borrow Pit Pond 1 Test 7

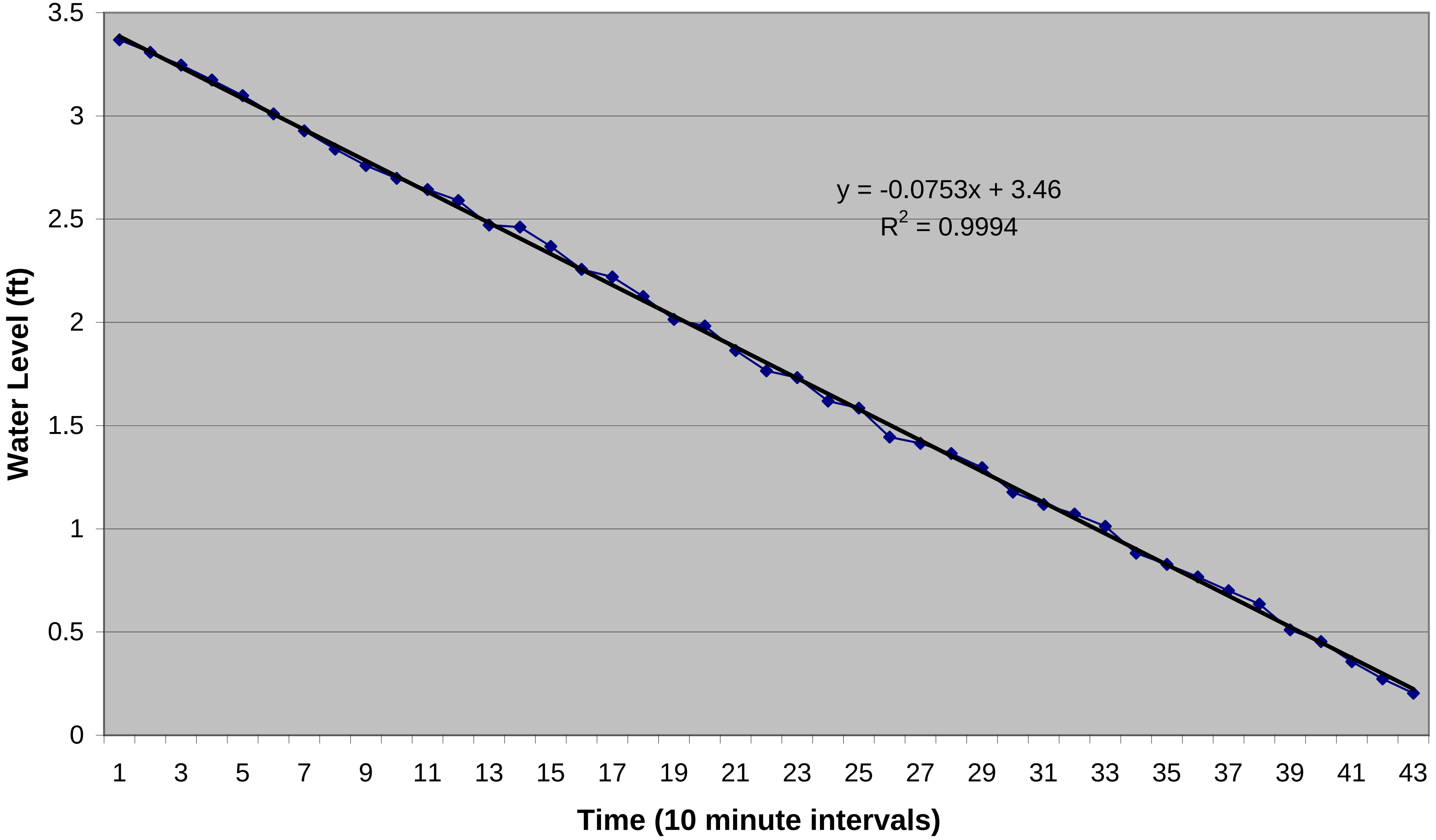



SBVWCD Borrow Pit Pond 1 Test 8
Water Level (ft)
5
4.9
4.8
4.7
4.6
4.5
4.4
4.3
4.2
4.1
4
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
Time (10 minute intervals)
y = -0.0083x + 4.62
R2 = 0.9971

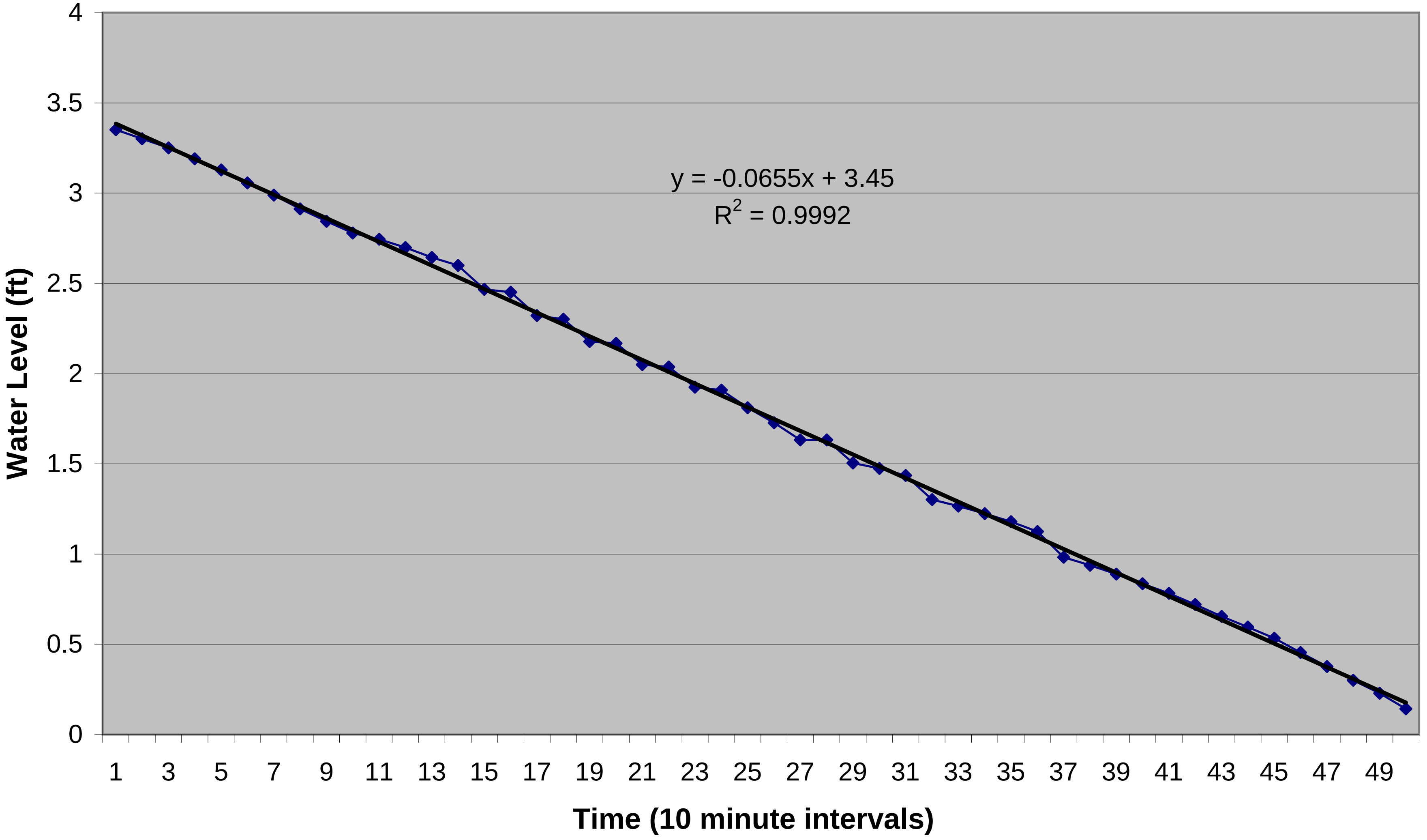
SBVWCD Borrow Pit Pond 1 Test 9



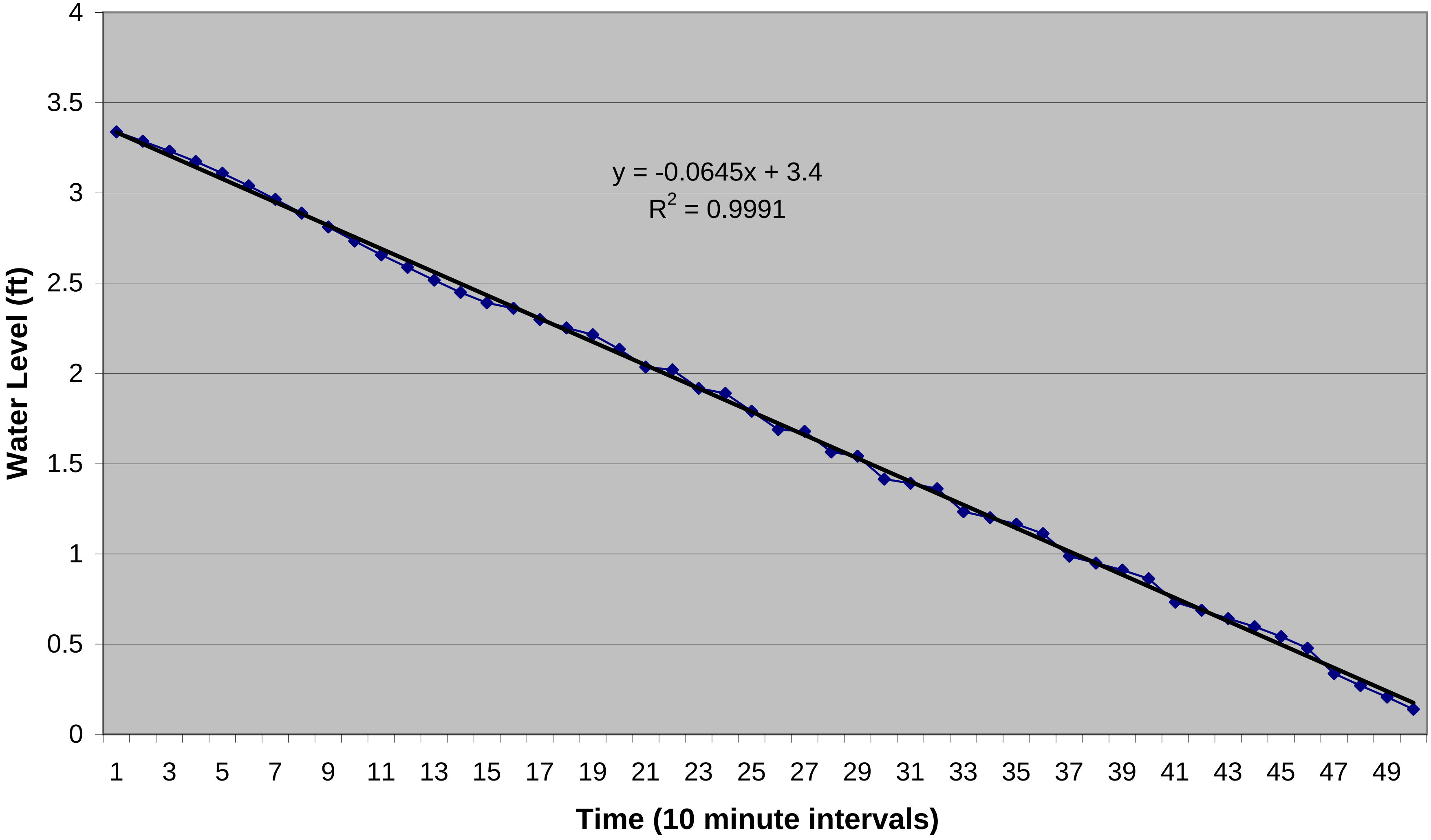
SBVWCD Borrow Pit Pond 1 Linear Trench Test 1



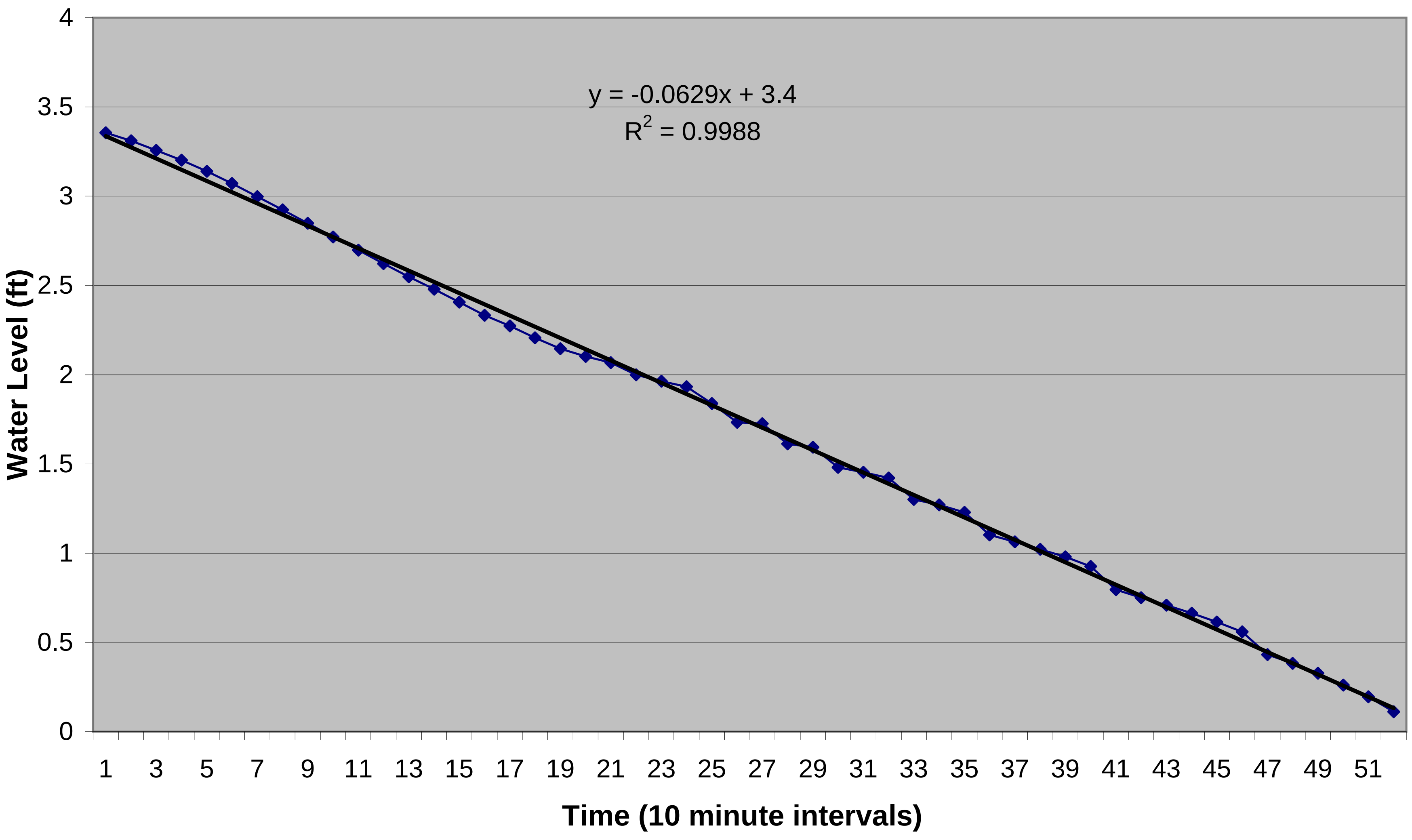
SBVWCD Borrow Pit Pond 1 Linear Trench Test 2

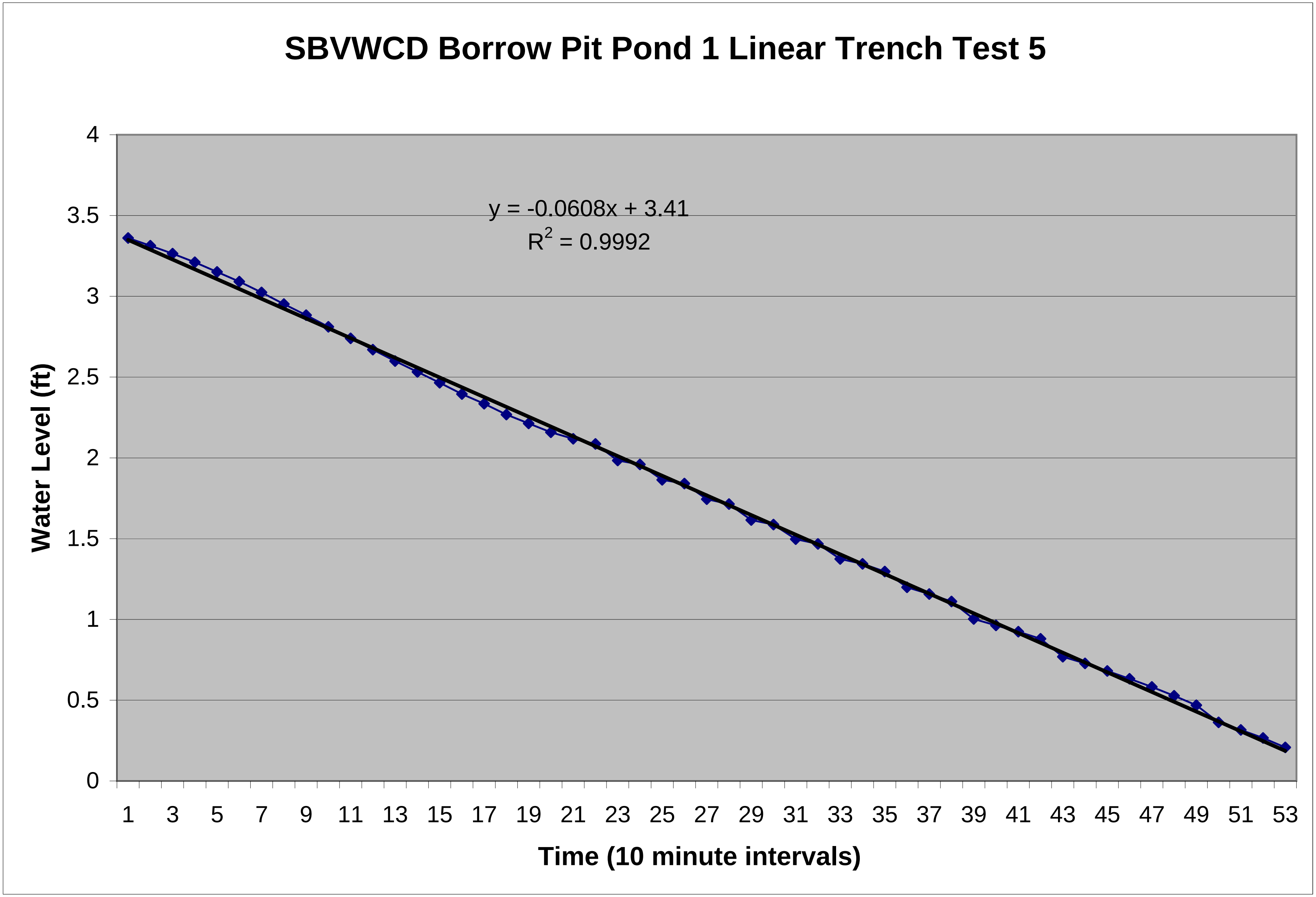


SBVWCD Borrow Pit Pond 1 Linear Trench Test 3

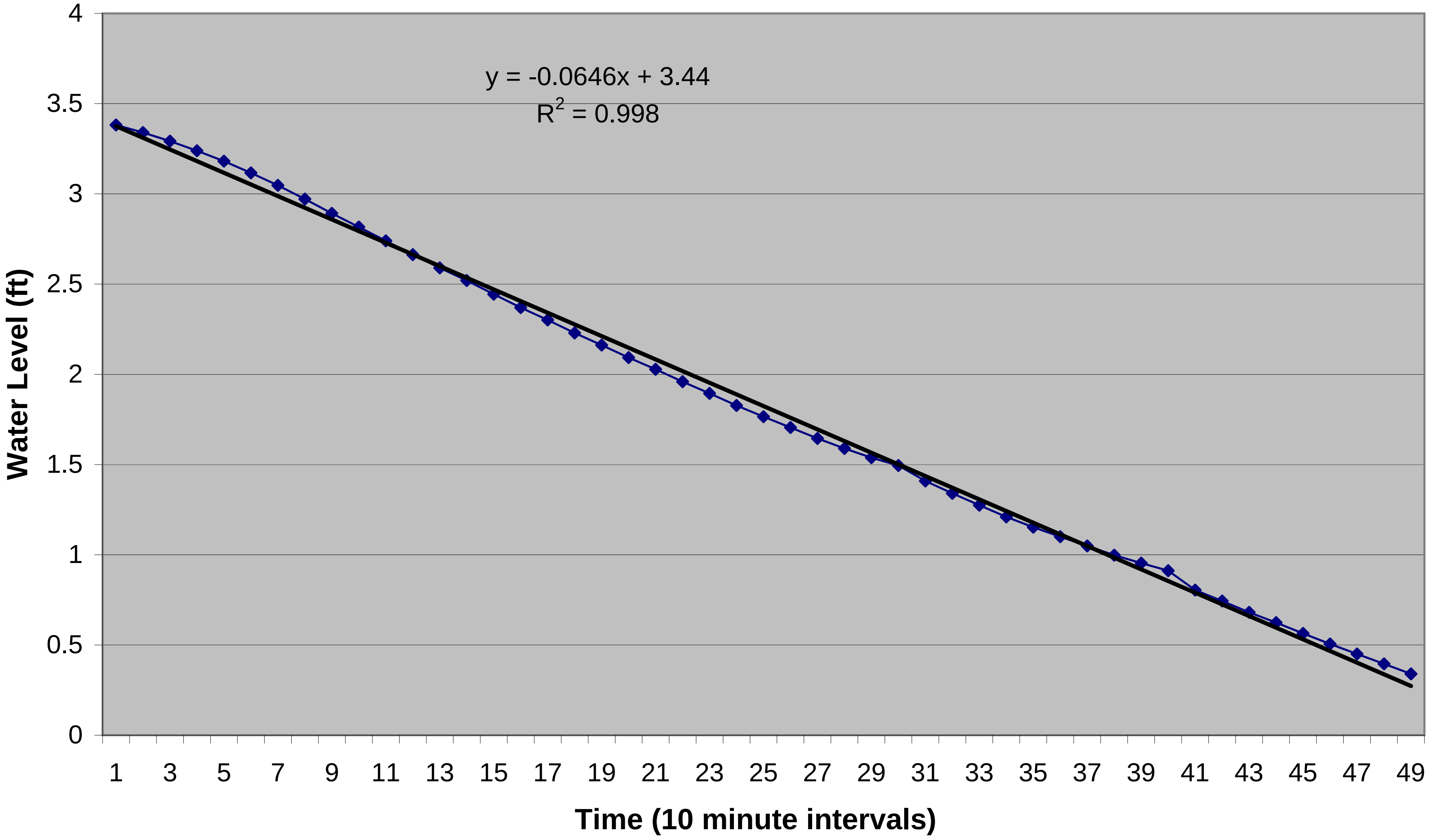


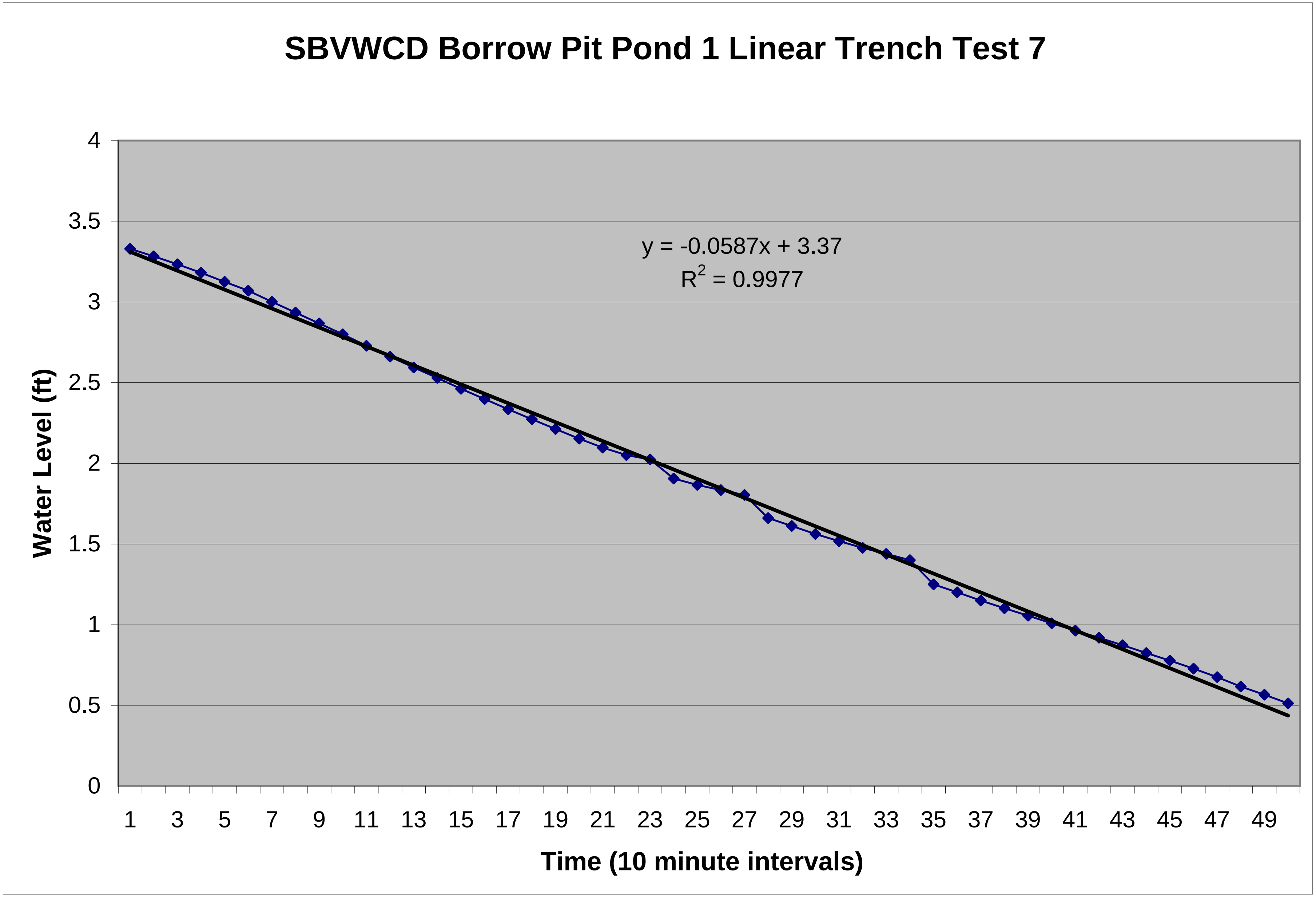
SBVWCD Borrow Pit Pond 1 Linear Trench Test 4

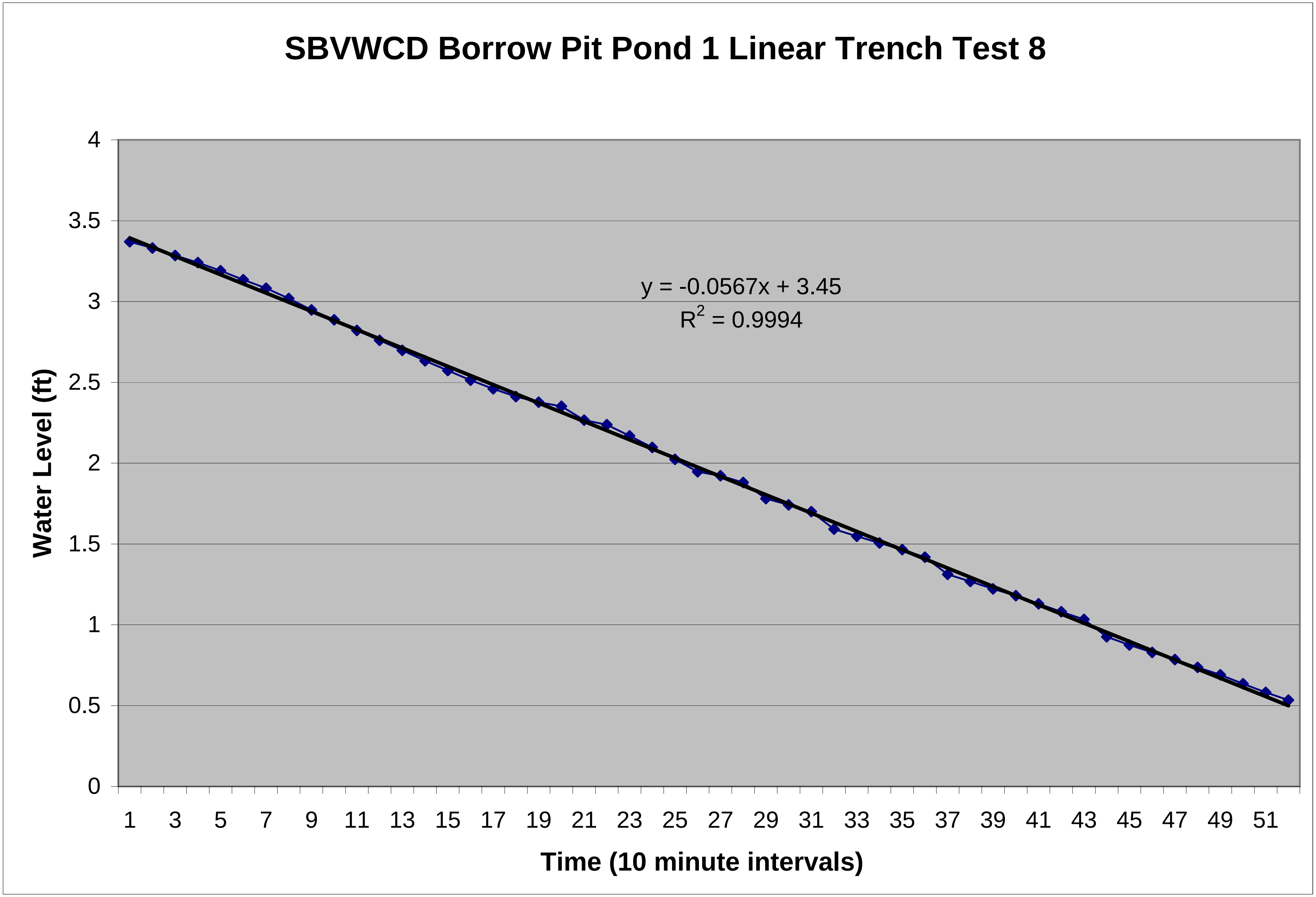



SBVWCD Borrow Pit Pond 1 Linear Trench Test 5
y = -0.0608x + 3.41
R^2 = 0.9992
Water Level (ft)
0
0.5
1
1.5
2
2.5
3
3.5
4
Time (10 minute intervals)
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
31
33
35
37
39
41
43
45
47
49
51
53

SBVWCD Borrow Pit Pond 1 Linear Trench Test 6

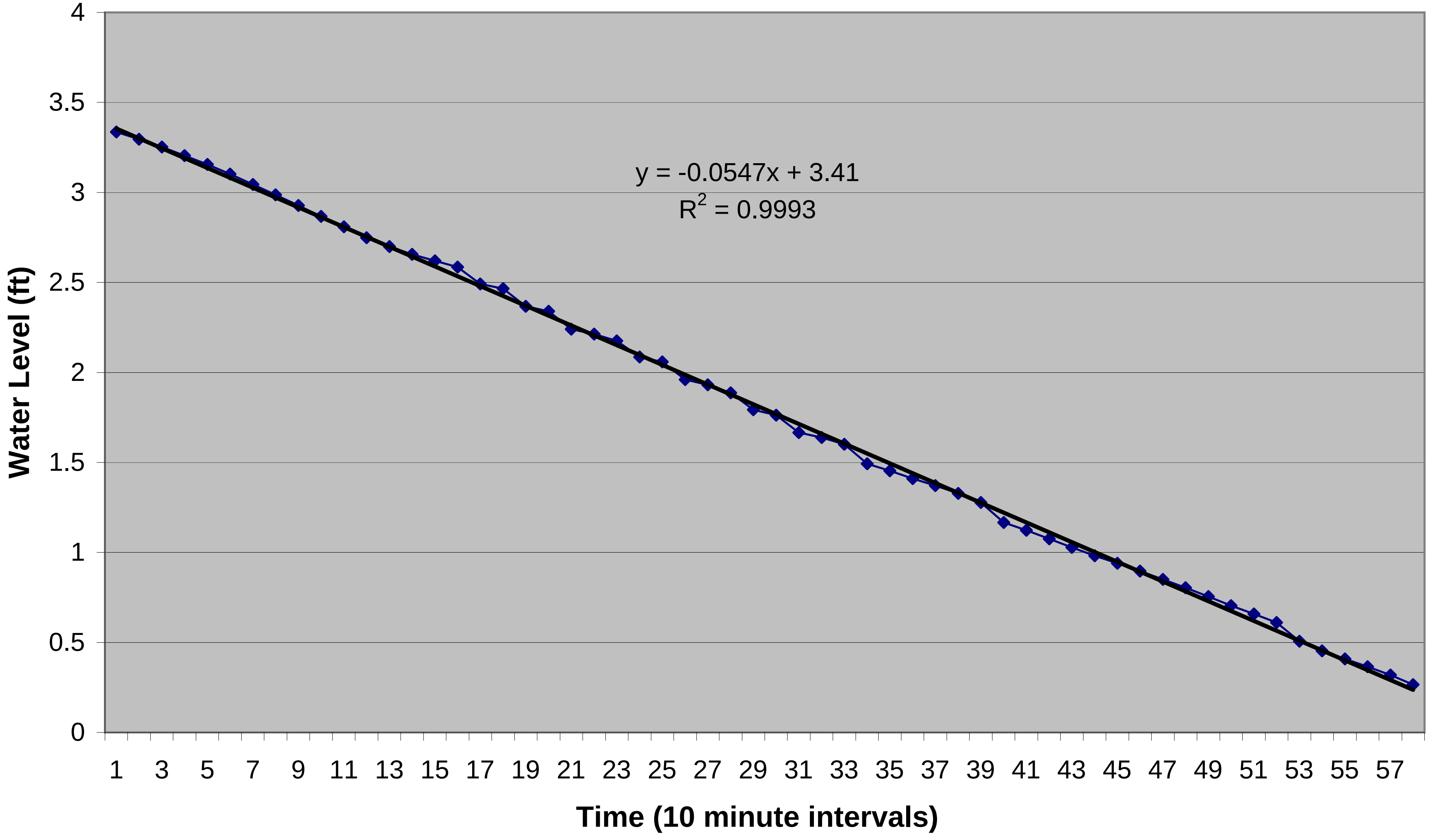



SBVWCD Borrow Pit Pond 1 Linear Trench Test 7
y = -0.0587x + 3.37
R^2 = 0.9977
Water Level (ft)
0
0.5
1
1.5
2
2.5
3
3.5
4
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
31
33
35
37
39
41
43
45
47
49
Time (10 minute intervals)

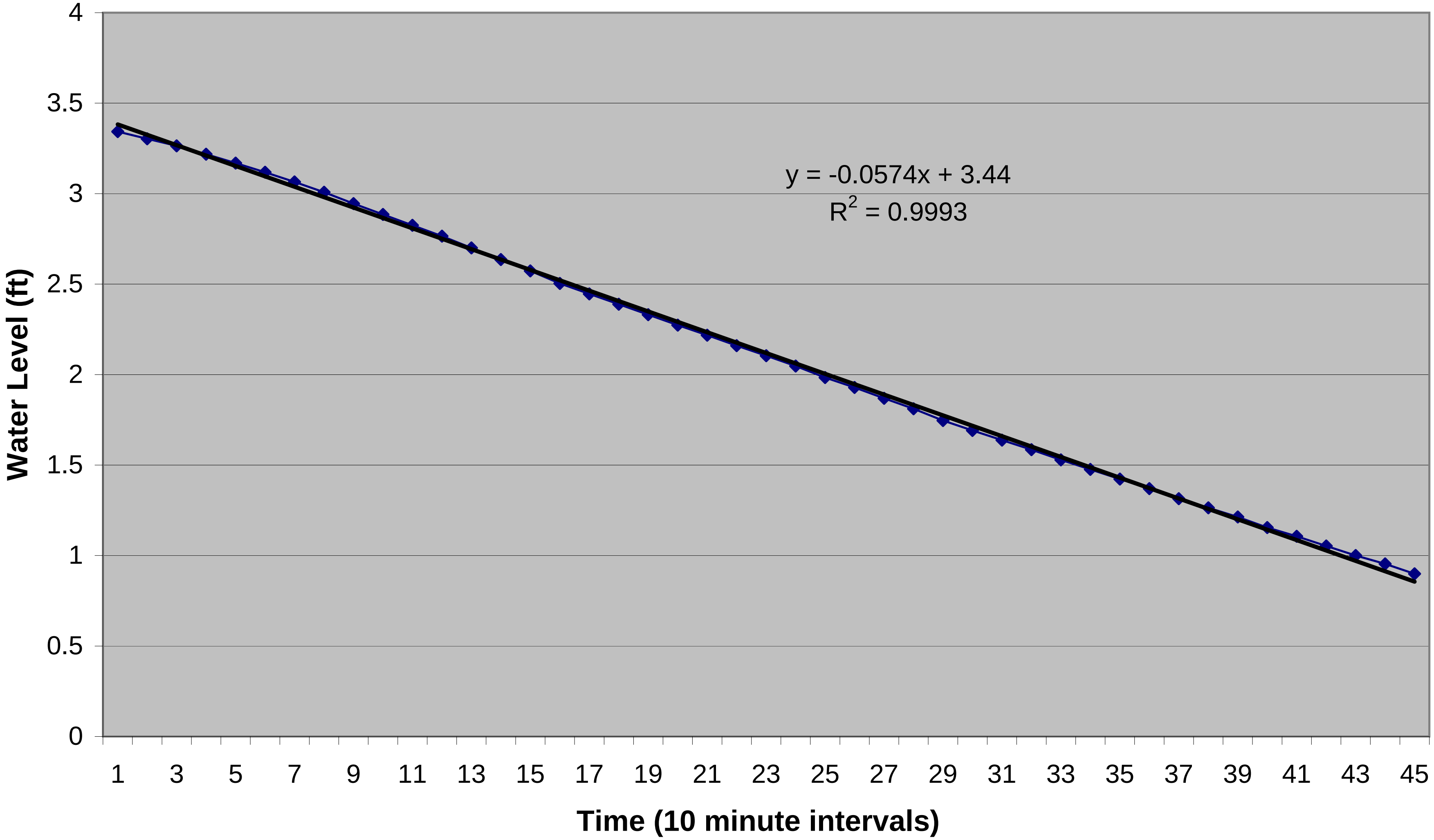


SBVWCD Borrow Pit Pond 1 Linear Trench Test 8

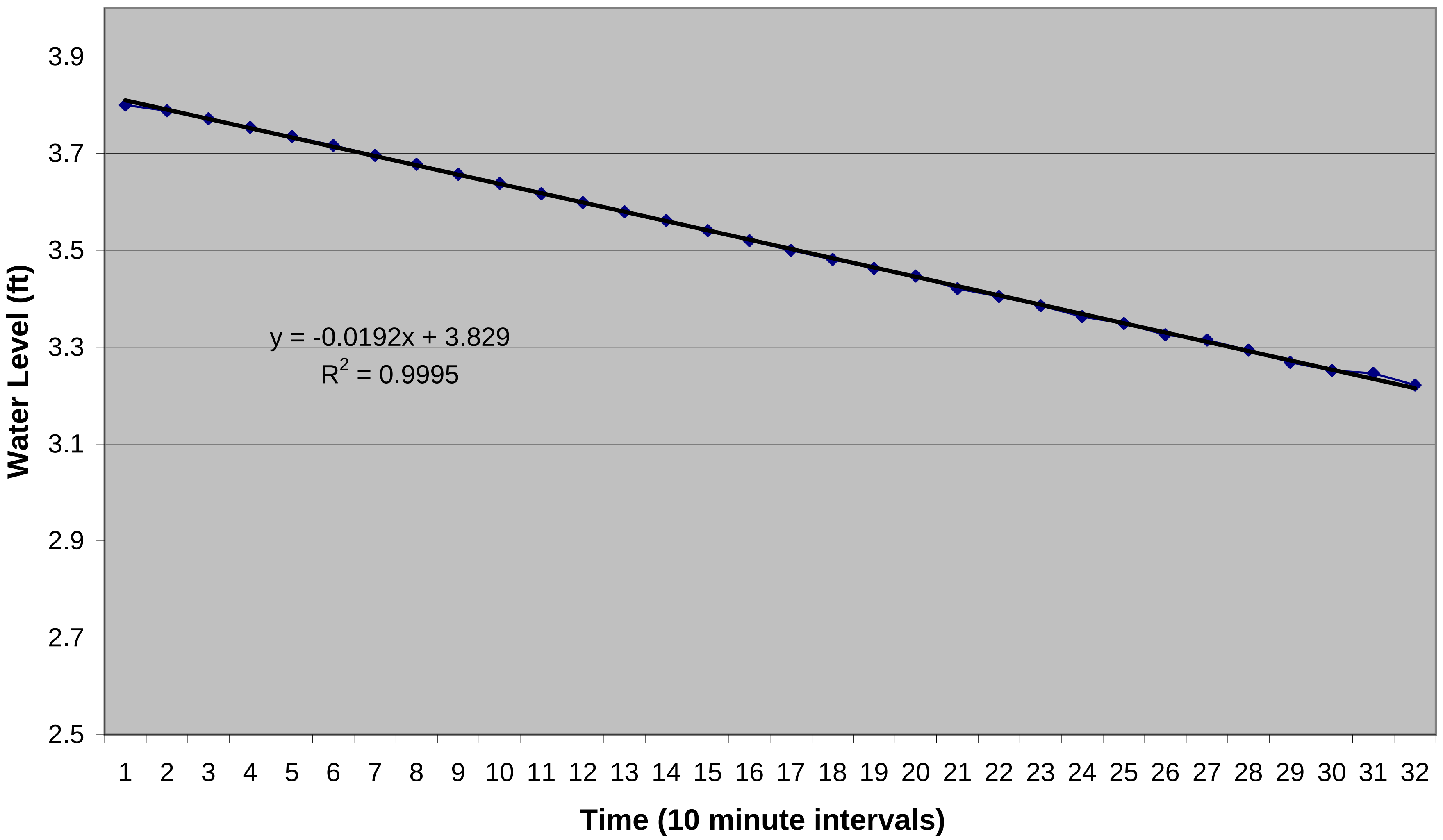
SBVWCD Borrow Pit Pond 1 Linear Trench Test 9

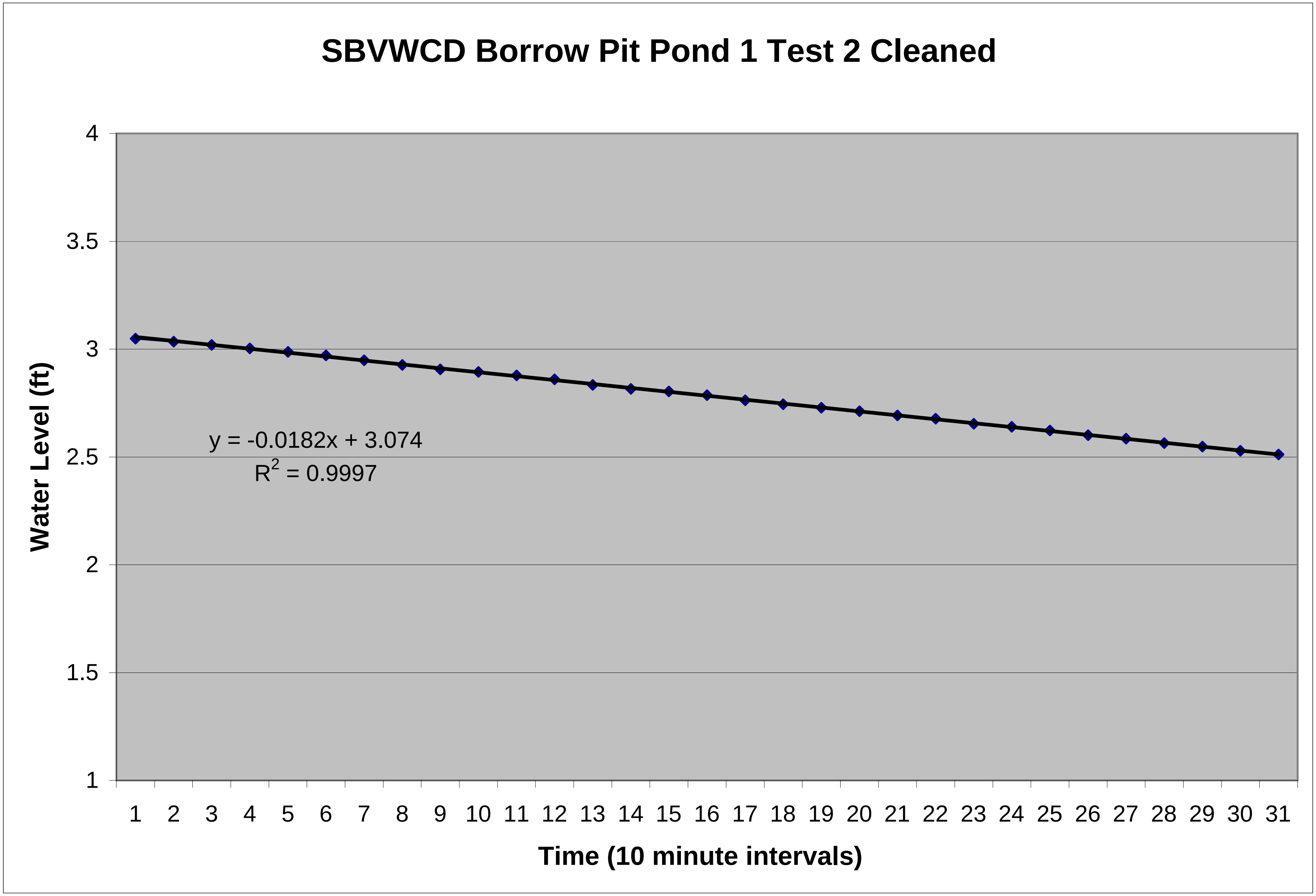


SBVWCD Borrow Pit Pond 1 Linear Trench Test 10

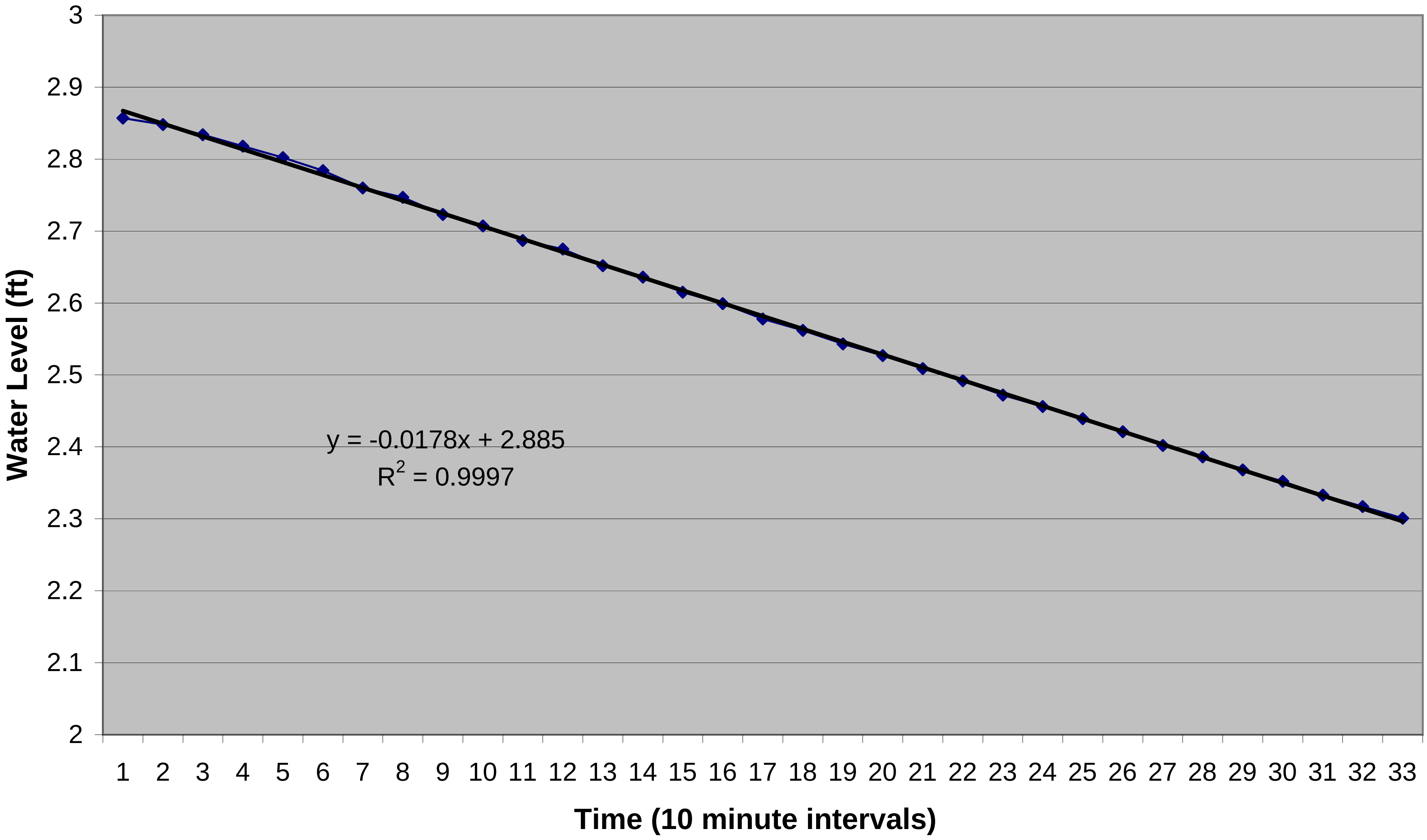


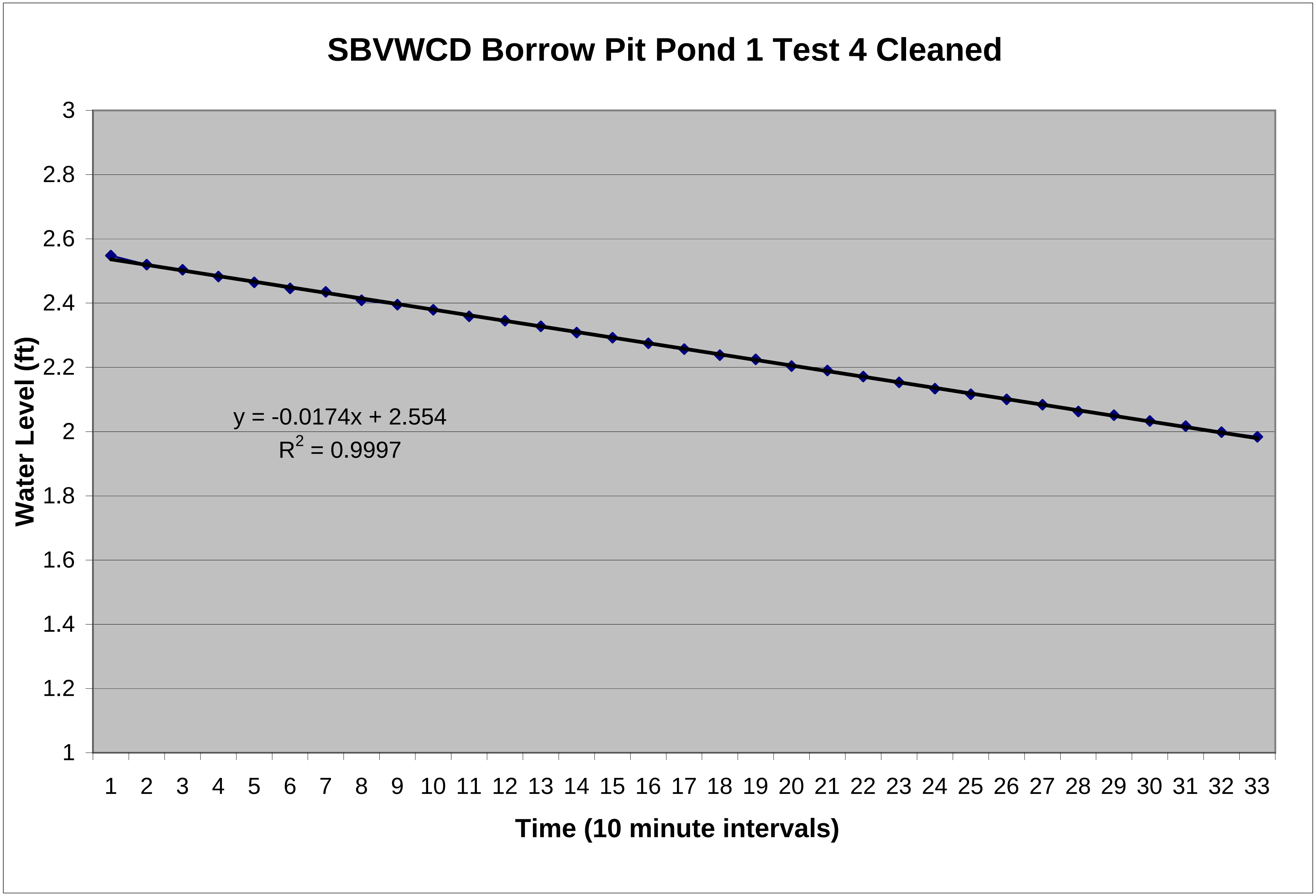
SBVWCD Borrow Pit Pond 1 Test 1 Cleaned

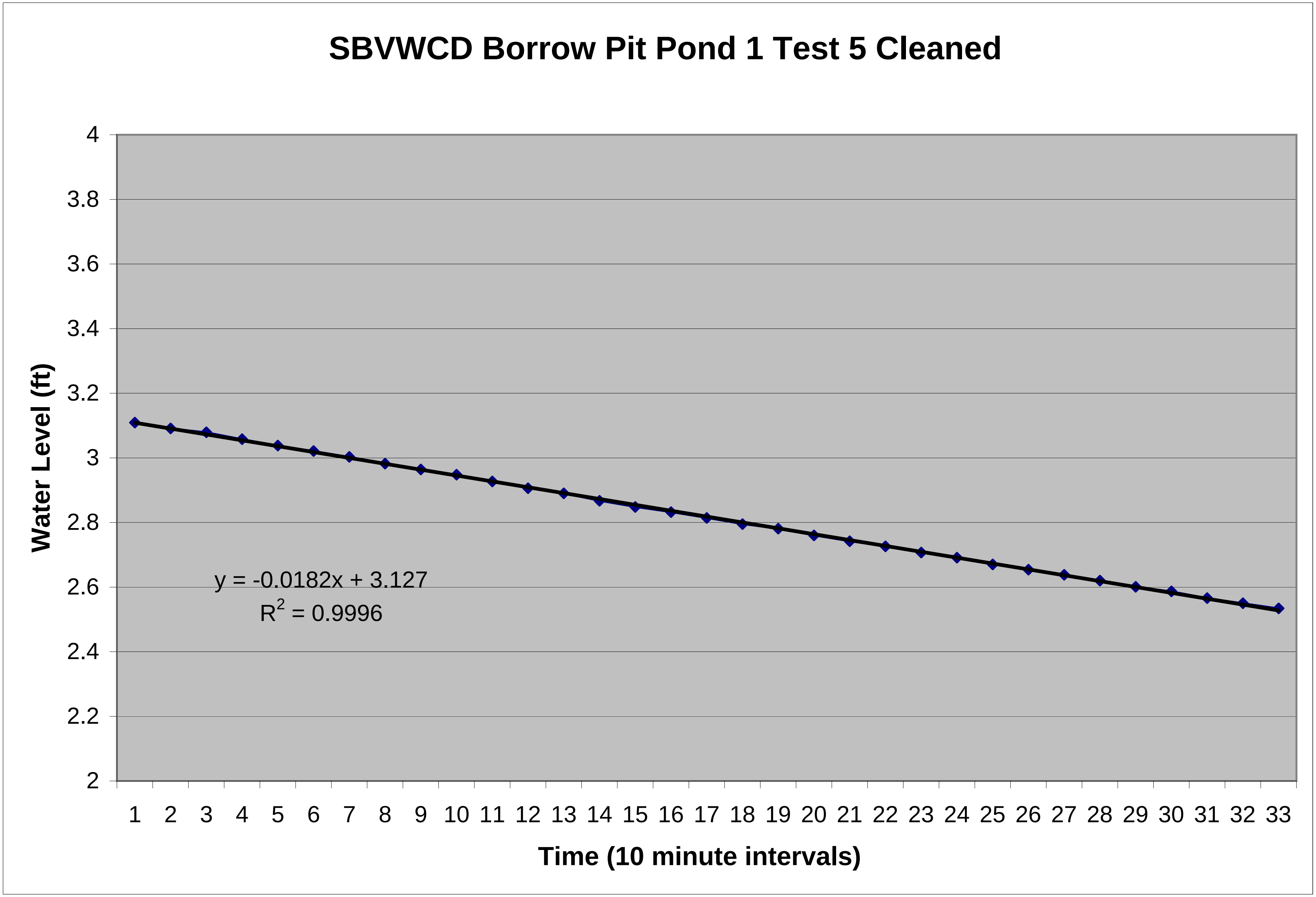



SBVWCD Borrow Pit Pond 1 Test 2 Cleaned
Water Level (ft)
4
3.5
3
2.5
2
1.5
1
y = -0.0182x + 3.074
R^2 = 0.9997
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
Time (10 minute intervals)

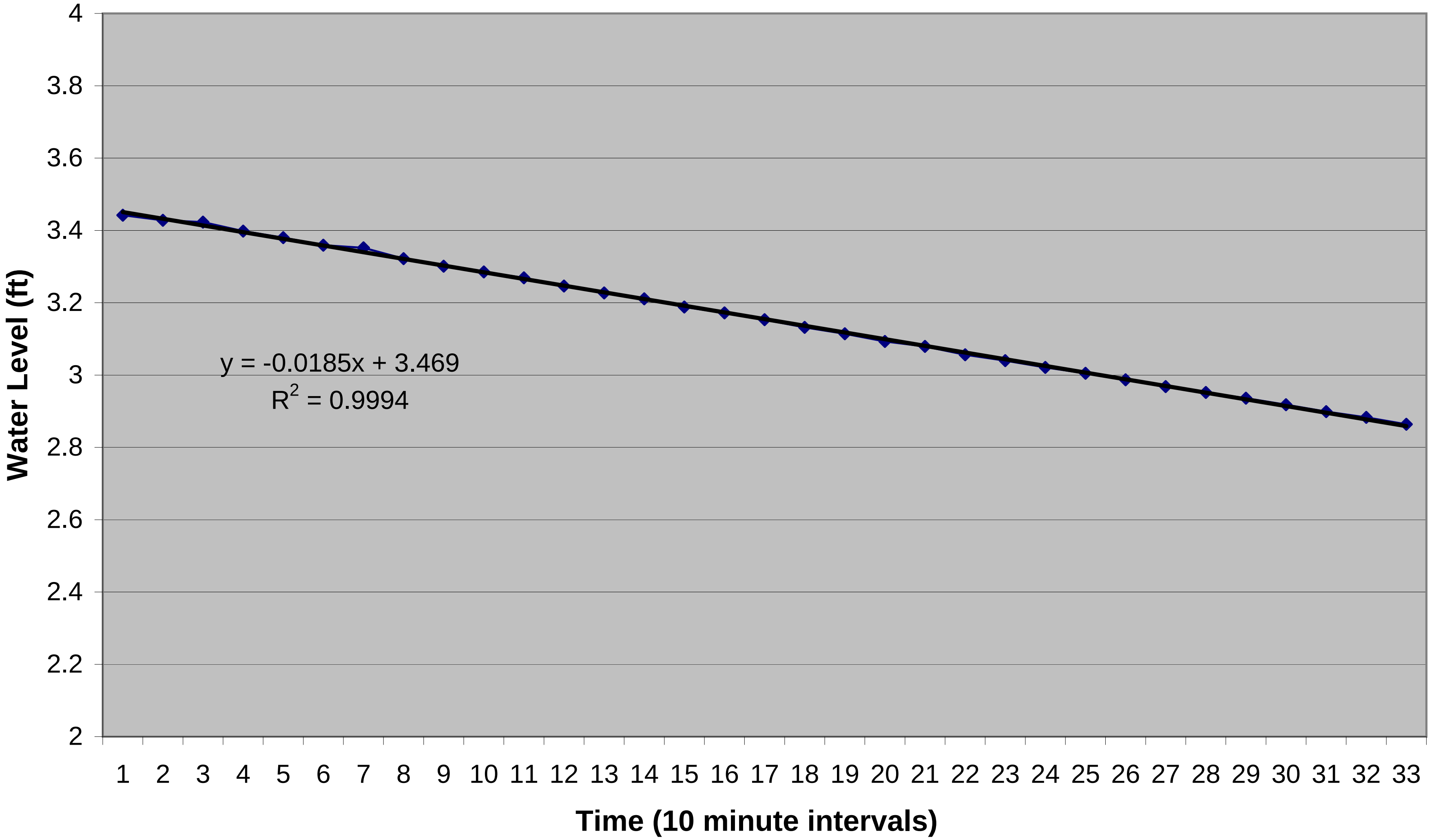
SBVWCD Borrow Pit Pond 1 Test 3 Cleaned

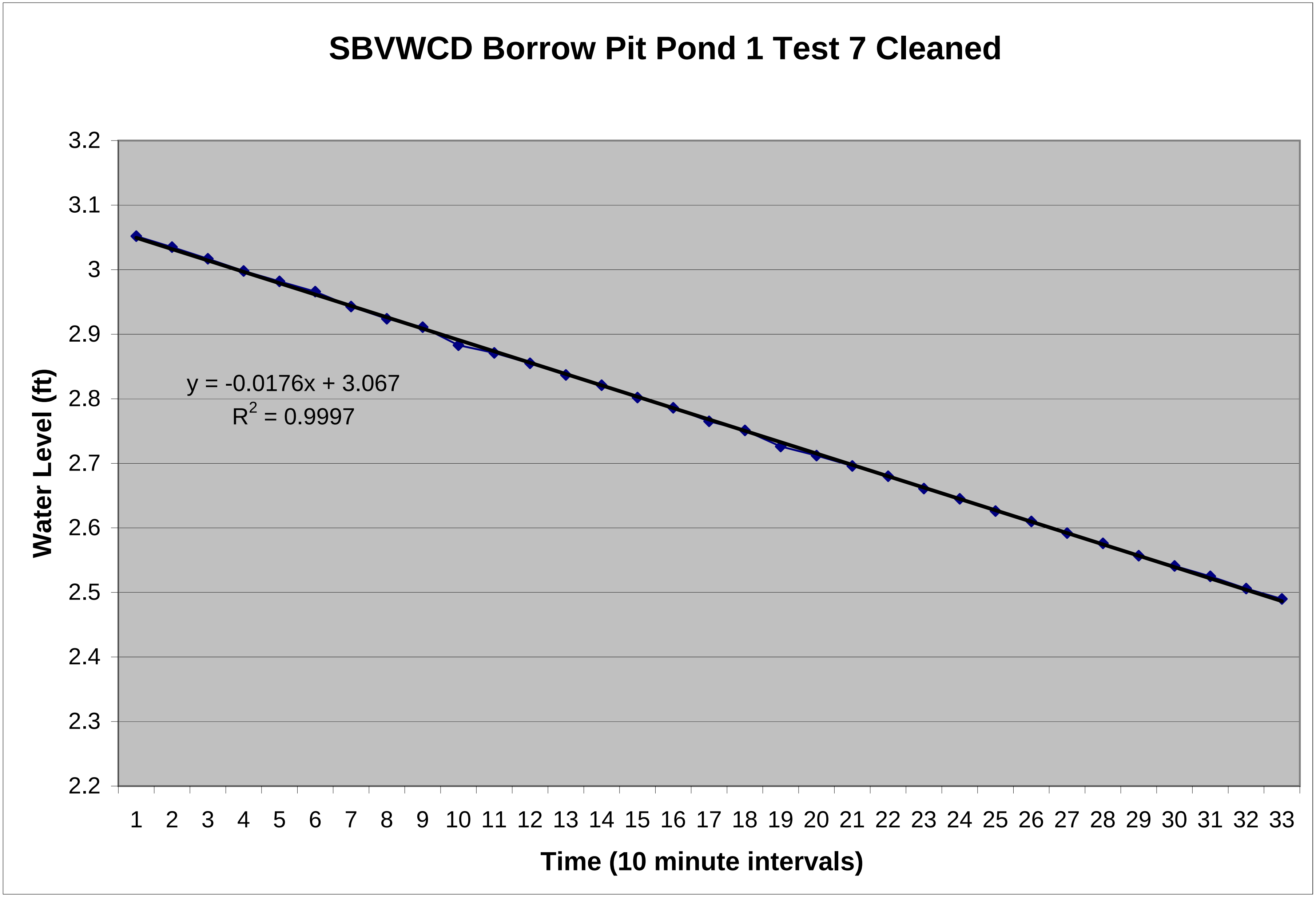



SBVWCD Borrow Pit Pond 1 Test 4 Cleaned
Water Level (ft)
3
2.8
2.6
2.4
2.2
2
1.8
1.6
1.4
1.2
1
y = -0.0174x + 2.554
$R^2 = 0.9997$
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
Time (10 minute intervals)


SBVWCD Borrow Pit Pond 1 Test 5 Cleaned
Water Level (ft)
4
3.8
3.6
3.4
3.2
3
2.8
2.6
2.4
2.2
2
y = -0.0182x + 3.127
R2 = 0.9996
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33
Time (10 minute intervals)

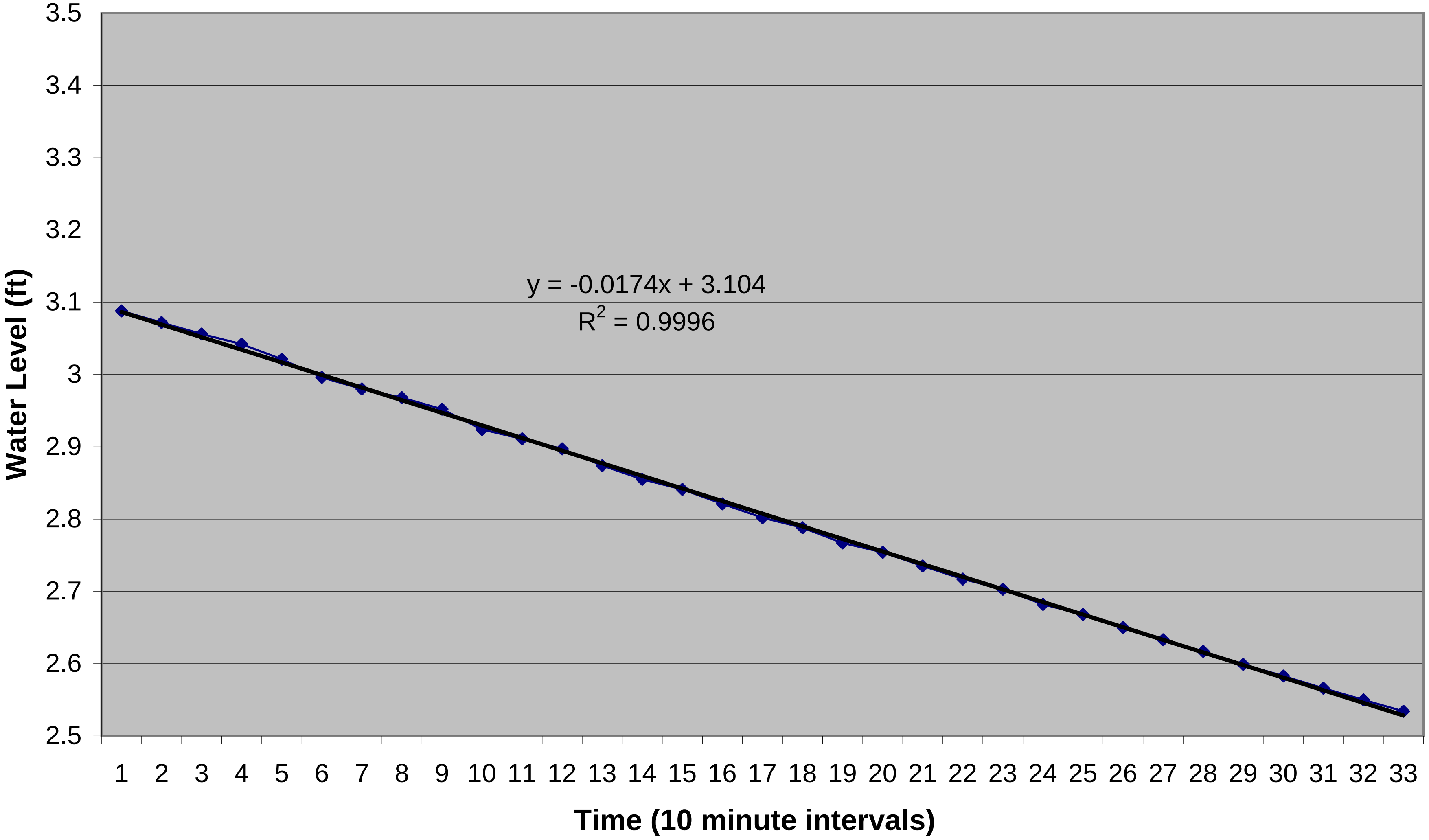
SBVWCD Borrow Pit Pond 1 Test 6 Cleaned

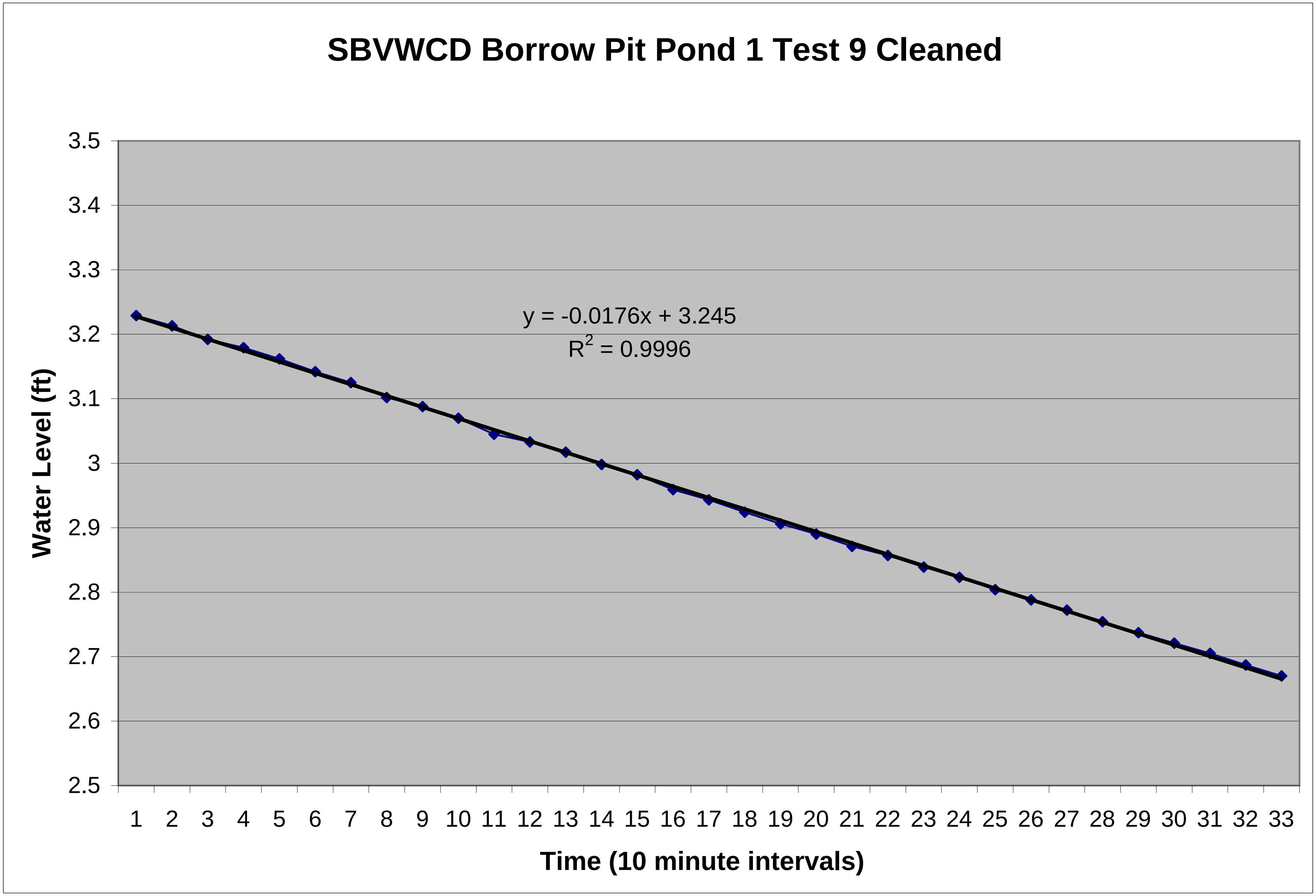




SBVWCD Borrow Pit Pond 1 Test 7 Cleaned

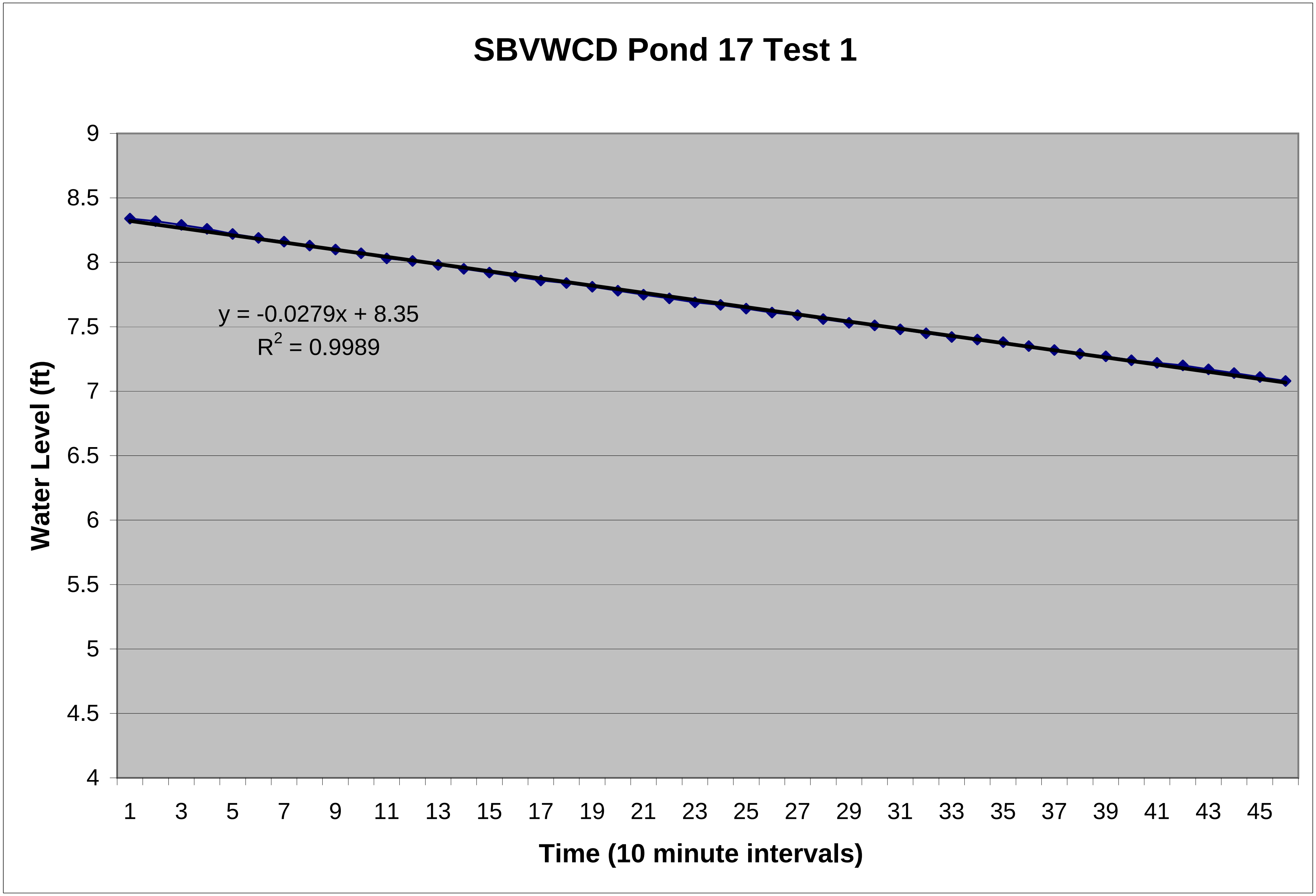
SBVWCD Borrow Pit Pond 1 Test 8 Cleaned



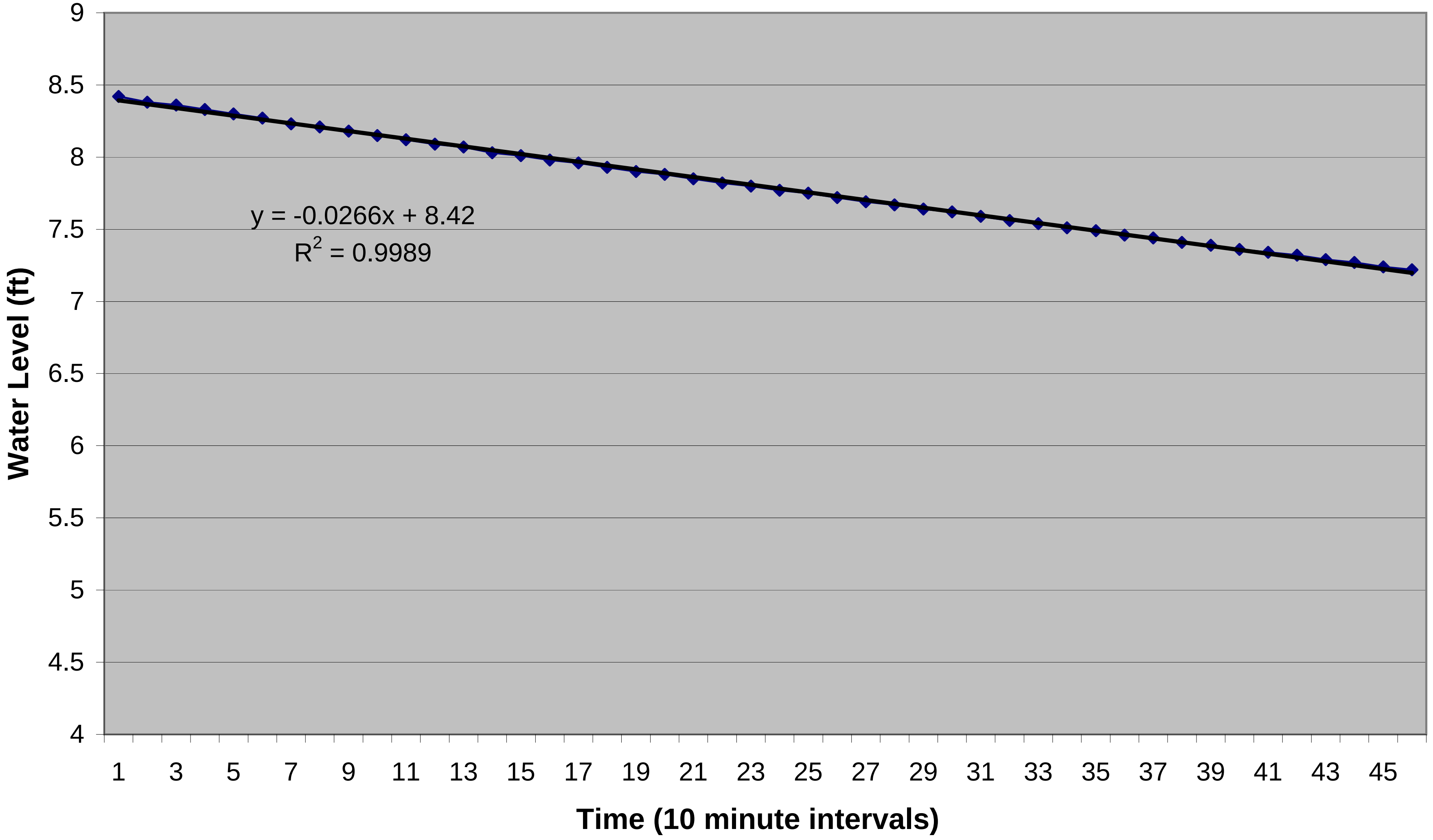


SBVWCD Borrow Pit Pond 1 Test 9 Cleaned

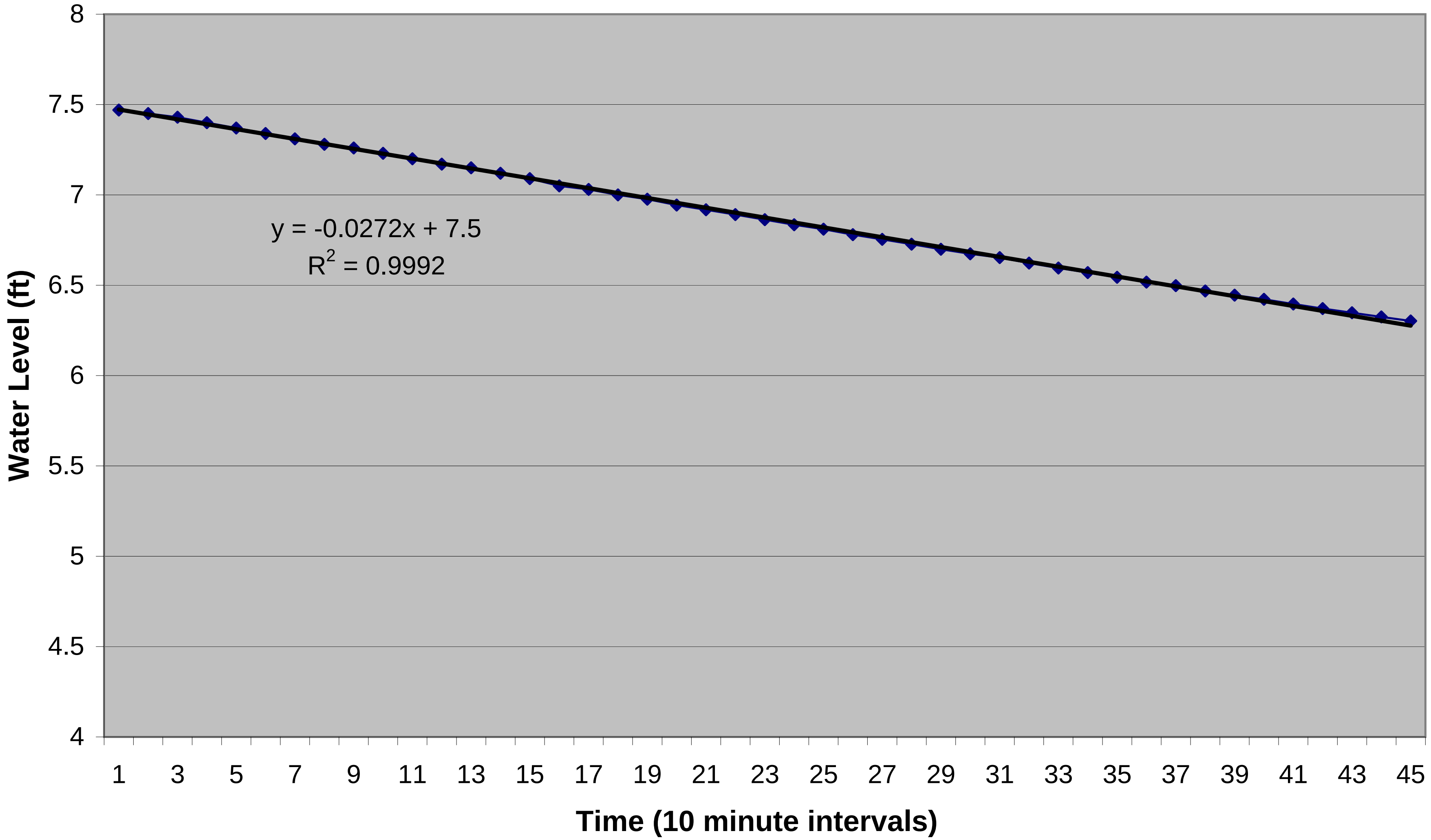
$y = -0.0176x + 3.245$
$R^2 = 0.9996$

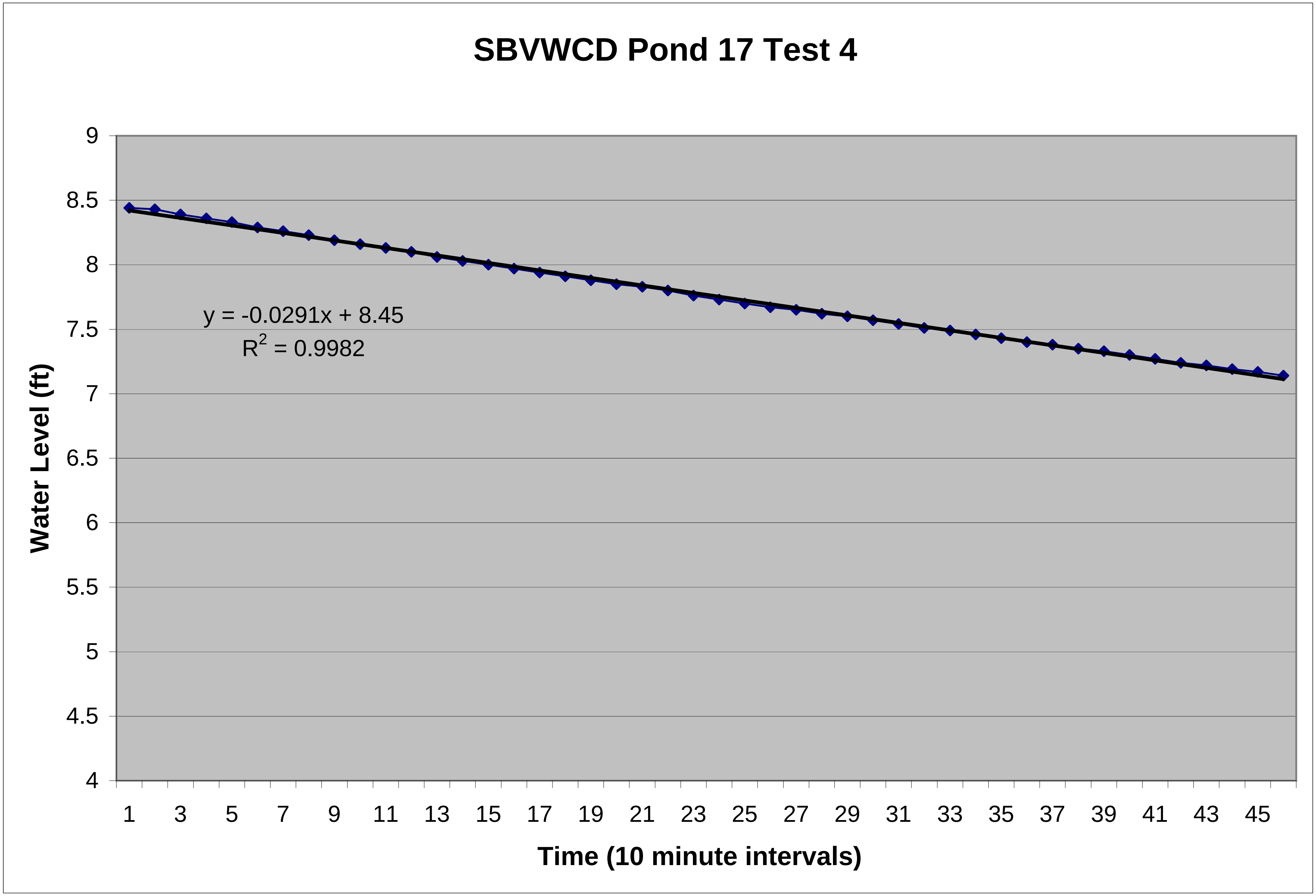

SBVWCD Pond 17 Test 1
y = -0.0279x + 8.35
$R^2 = 0.9989$
Water Level (ft)
9
8.5
8
7.5
7
6.5
6
5.5
5
4.5
4
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
31
33
35
37
39
41
43
45
Time (10 minute intervals)

SBVWCD Pond 17 Test 2



SBVWCD Pond 17 Test 3




SBVWCD Pond 17 Test 4
y = -0.0291x + 8.45
R2 = 0.9982
Water Level (ft)
9
8.5
8
7.5
7
6.5
6
5.5
5
4.5
4
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
31
33
35
37
39
41
43
45
Time (10 minute intervals)

Appendix C
Trench Logs

FIELD TRENCH LOG

MWH

Project Name: SAR Groundwater Recharge Optimization Study

Trench Number: T1P1

Project Number: 134 3019

Elevation and Datum:

Location: Pit 1

Sheet 1 of 1

Equipment Supplier:

Operator: Dan Clark

Date and Time Started: 6-19-08

Date and Time Completed: 6-19-08

Refusal? (Circle One) Yes [✓ No] If Yes Depth =

Equipment Type: back hoe

Trench Orientation: N-S

Total Depth: 5' ~~10~~ 4 ASC 8"

Total Number of Samples: 2

Photo? (Circle One) [✓ Yes] No No.

Bucket Width:

Trench Length: 25'

Trench Width: 10'

No. of Samples: 2

Bulk:

Grab: 2

Drive: NA

Hand Auger: NA

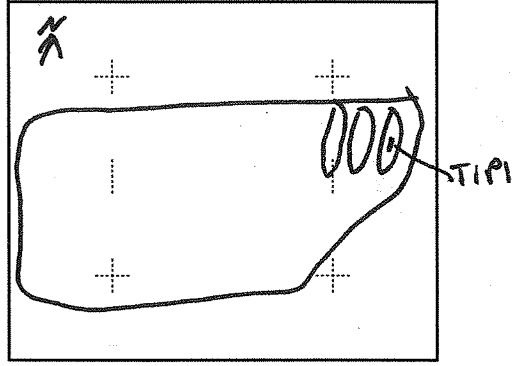
% Man-Made Debris:

Geologist or Hydrogeologist/Date: Andrew Leavitt / Chaoying Jiao 6-19-08

Checked by/Date:

Wall of Trench Shown (Circle One) N S E [✓ W] NE NW SE SW

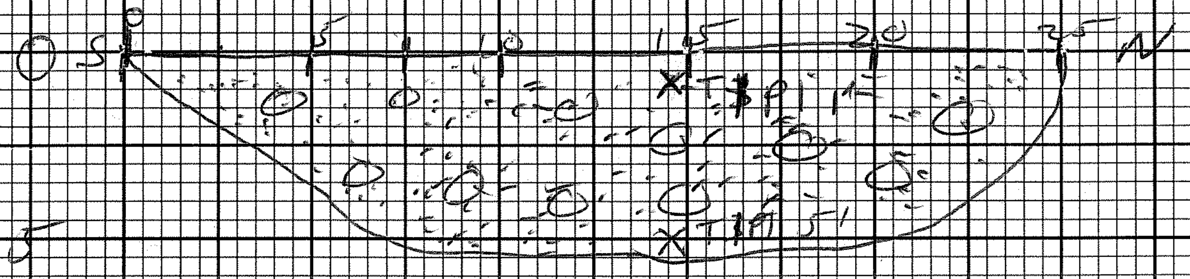
Plan View-Site Location
(Provide Sketch)



LENGTH (FEET)

ENTER TRENCH DIRECTION
SCALE:

DEPTH (FEET)



0-2' - sand well graded with gravel, dry, light brown (10YR 7/2), loose, rocks up to 8", angular to rounded. Some roots down to 9".

2'-on grain size spreads out more evenly and less silt, color change to 10YR 4/2, cobbles and boulders up to 3'.

EXPLANATION

———	SOIL TYPE CONTACT (SHARP)
- - -	OTHER CONTACT (AS INDICATED ON LOG)
———·	FILL/NATIVE BOUNDARY
X	ANALYTICAL SAMPLE LOCATION (WRITE SAMPLE NUMBER OUT TO SIDE)
G	GEOTECHNICAL SAMPLE LOCATION (WRITE SAMPLE NUMBER OUT TO SIDE)
////	SHADING TO DENOTE STAINING
⧹⧹⧹⧹⧹	BASE OF EXCAVATION
◎	SHOW LOCATIONS AND TYPES OF ALL MAJOR DEBRIS

FIELD TRENCH LOG

MWH

Project Name: SAR Groundwater Recharge Optimization Study

Trench Number: T2P1

Project Number: 1343019

Elevation and Datum:

Location: Pit 1

Sheet 1 of 1

Equipment Supplier:

Operator: Dan Clark

Date and Time Started: 6-19-08

Date and Time Completed: 6-19-08

Refusal? (Circle One) Yes [✓ No]

If Yes Depth =

Equipment Type: backhoe

Trench Orientation: N-S

Total Depth: 5' ~~10~~ ASL 8"

Total Number of Samples: 2

Photo? (Circle One) [✓ Yes] No

No.

Bucket Width:

Trench Length: 30'

Trench Width: 10'

No. of Samples: 2

Bulk:

Grab: 2

Drive: NA

Hand Auger: NA

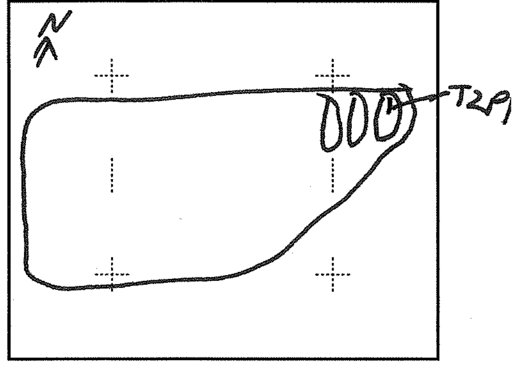
% Man-Made Debris:

Geologist or Hydrogeologist/Date: Andrew Leavitt / Chaoying Jiao 6-19-08

Checked by/Date:

Wall of Trench Shown (Circle One) N S E [✓ W] NE NW SE SW

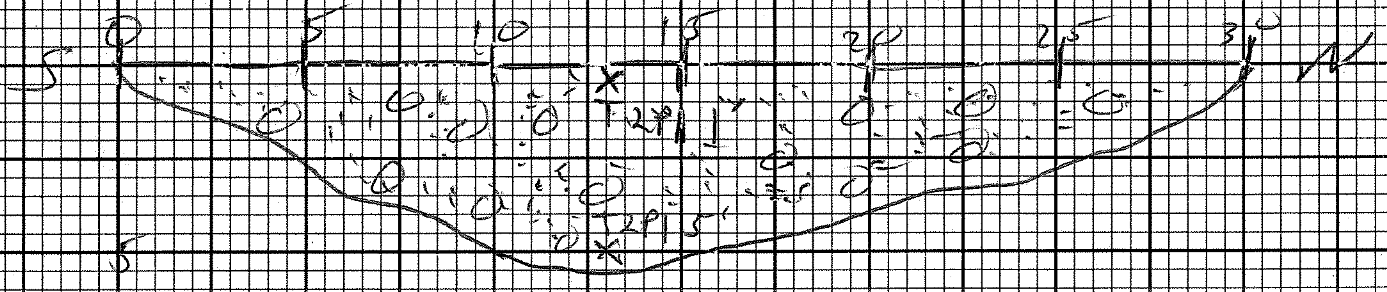
Plan View-Site Location
(Provide Sketch)



LENGTH (FEET)

DEPTH (FEET)

ENTER TRENCH DIRECTION
SCALE:



0-2' sand well graded with gravel, dry, light brown (10YR 7/2), loose, rock chips up to 7", angular to rounded

☆ going from N-S, the contact seen in previous trenches seems to get deeper @ the southern end (4').

2'-on color change to 10YR 4/2, less silt, more gravel, cobbles and boulders up to 3'

EXPLANATION

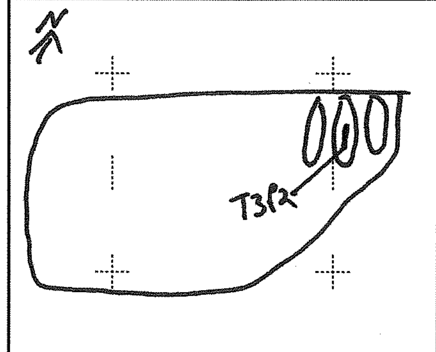
- SOIL TYPE CONTACT (SHARP)
- OTHER CONTACT (AS INDICATED ON LOG)
- FILL/NATIVE BOUNDARY
- X ANALYTICAL SAMPLE LOCATION (WRITE SAMPLE NUMBER OUT TO SIDE)
- G GEOTECHNICAL SAMPLE LOCATION (WRITE SAMPLE NUMBER OUT TO SIDE)
- //// SHADING TO DENOTE STAINING
- BASE OF EXCAVATION
- SHOW LOCATIONS AND TYPES OF ALL MAJOR DEBRIS

FIELD TRENCH LOG

MWH

Project Name SAR Groundwater Recharge Optimization Study					
Trench Number T3 P2	Project Number 1343019	Elevation and Datum	Location Pit 2	Sheet 1 of 1	
Equipment Supplier	Operator Dan Clark	Date and Time Started 6-19-08	Date and Time Completed 6-19-08	Refusal? (Circle One) Yes [✓ No]	If Yes Depth =
Equipment Type back hoe	Trench Orientation N-S	Total Depth 5'10"	Total Number of Samples 2	Photo? (Circle One) [✓ Yes] No	No.
Bucket Width	Trench Length 26'	Trench Width 10'	No. of Samples 2 | Bulk | Grab 2	Drive NA | Hand Auger NA	% Man-Made Debris
Geologist or Hydrogeologist/Date Andrew Leavitt / Chaoying Jiao 6-19-08			Checked by/Date		Wall of Trench Shown (Circle One) N S E [✓ W] NE NW SE SW

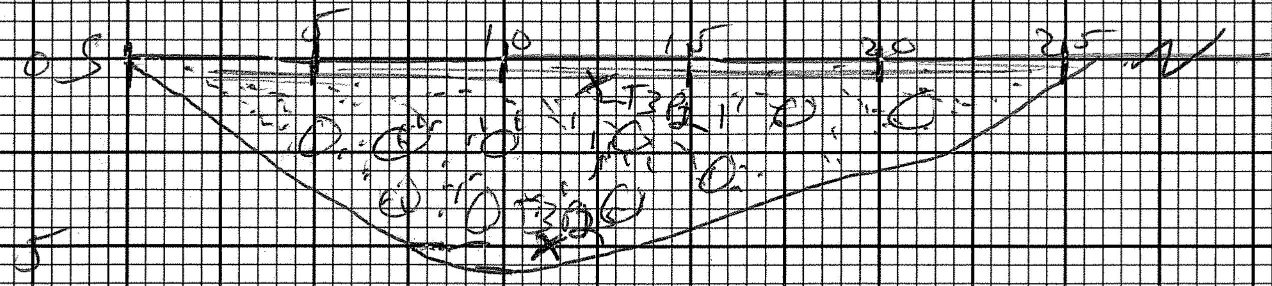
Plan View-Site Location
(Provide Sketch)



LENGTH (FEET)

ENTER TRENCH DIRECTION
SCALE:

DEPTH (FEET)



0-1' - Sand well graded, with gravel, dry, light brown, (10YR?/2), loose, rocks up to 1', angular to rounded.

~~0~~1'-2' - transition to bigger grains, slighty darker, less silt.

2'on - sand well graded, with gravel, dry, color change to 10YR 4/2, cobbles and boulders up to 3', angular to rounded.

EXPLANATION

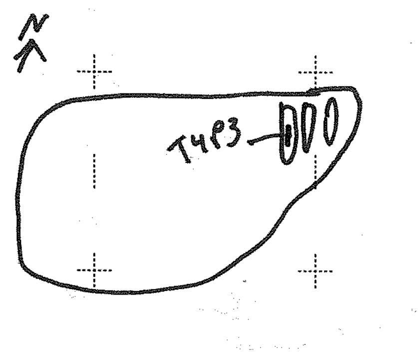
- ——— SOIL TYPE CONTACT (SHARP)
- – – – OTHER CONTACT (AS INDICATED ON LOG)
- —·—·— FILL/NATIVE BOUNDARY
- X ANALYTICAL SAMPLE LOCATION (WRITE SAMPLE NUMBER OUT TO SIDE)
- G GEOTECHNICAL SAMPLE LOCATION (WRITE SAMPLE NUMBER OUT TO SIDE)
- //// SHADING TO DENOTE STAINING
- ⟋⟋⟋ BASE OF EXCAVATION
- ◎ SHOW LOCATIONS AND TYPES OF ALL MAJOR DEBRIS

FIELD TRENCH LOG

MWH

Project Name SAR Groundwater Recharge Optimization Study					
Trench Number T4P3	Project Number 1343019	Elevation and Datum	Location Pit 3	Sheet 1 of 1	
Equipment Supplier	Operator Dan Clark	Date and Time Started 6-19-08	Date and Time Completed 6-19-08	Refusal? (Circle One) Yes [✓ No]	If Yes Depth =
Equipment Type backhoe	Trench Orientation N-S	Total Depth 5' 10"	Total Number of Samples 2	Photo? (Circle One) [✓ Yes] No	No.
Bucket Width	Trench Length 35'	Trench Width 10"	No. of Samples 2 | Bulk | Grab 2	Drive NA | Hand Auger NA	% Man-Made Debris
Geologist or Hydrogeologist/Date Andrew Leavitt / Chaoying Jiao 6-19-08			Checked by/Date	Wall of Trench Shown (Circle One) N S E [✓ W] NE NW SE SW	

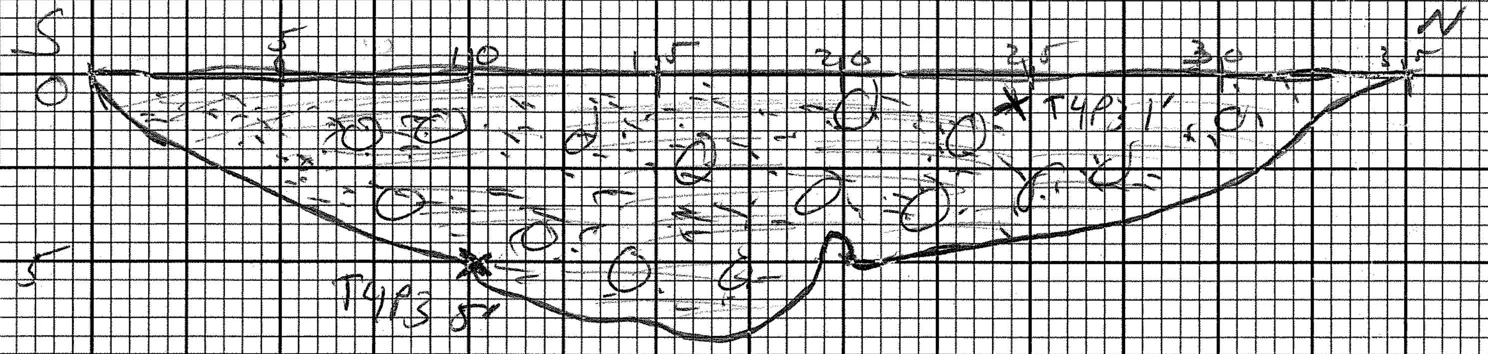
Plan View-Site Location
(Provide Sketch)



LENGTH (FEET)

ENTER TRENCH DIRECTION
SCALE:

DEPTH (FEET)



0'-1' - SW, sand well graded, dry, loose, light brown, rocks up to 10", angular to rounded.

1'-5.5' - SW, sand well graded with gravel, little to no silt, dry, slighty darker in color, cobble and boulders up to 3', angular to rounded.

EXPLANATION

- SOIL TYPE CONTACT (SHARP)
- OTHER CONTACT (AS INDICATED ON LOG)
- FILL/NATIVE BOUNDARY
- X ANALYTICAL SAMPLE LOCATION (WRITE SAMPLE NUMBER OUT TO SIDE)
- G GEOTECHNICAL SAMPLE LOCATION (WRITE SAMPLE NUMBER OUT TO SIDE)
- //// SHADING TO DENOTE STAINING
- BASE OF EXCAVATION
- ◎ SHOW LOCATIONS AND TYPES OF ALL MAJOR DEBRIS

MWH

FIELD TRENCH LOG

Project Name: SAR Groundwater ~~Opt~~ Recharge Optimization Study

Trench Number: T5

Project Number: 1343019

Elevation and Datum:

Location: Borrow Pit

Sheet 1 of 1

Equipment Supplier:

Operator: Dan Clark

Date and Time Started: 6-19-08

Date and Time Completed: 6-19-08

Refusal? (Circle One) Yes [✓ No]

If Yes Depth =

Equipment Type: Backhoe

Trench Orientation: N-S

Total Depth: 6'

Total Number of Samples: 2

Photo? (Circle One) [✓ Yes] No

No.

Bucket Width:

Trench Length: 30

Trench Width: 10'

No. of Samples: 2

Bulk:

Grab: 2

Drive: NA

Hand Auger: NA

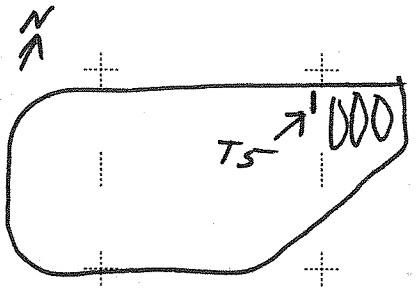
% Man-Made Debris:

Geologist or Hydrogeologist/Date: Andrew Leavitt / Chaoying Jiao 6-19-08

Checked by/Date:

Wall of Trench Shown (Circle One) N S E [✓ W] NE NW SE SW

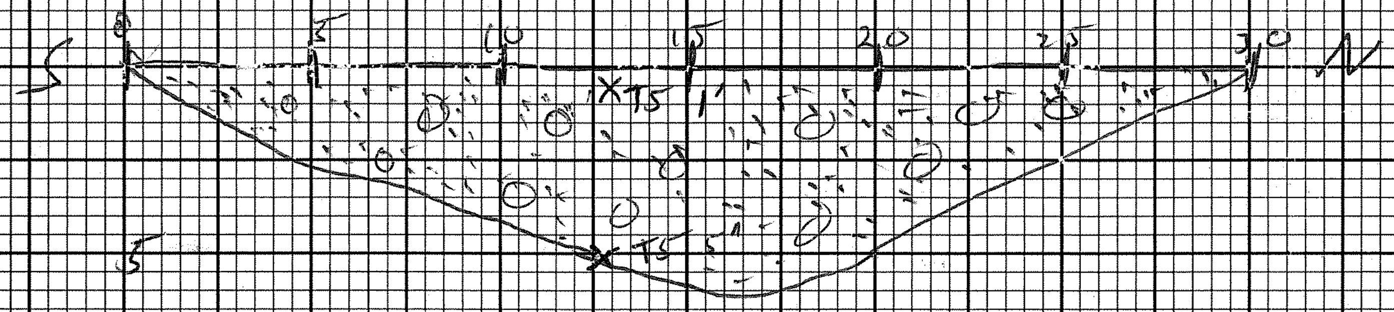
Plan View-Site Location
(Provide Sketch)



LENGTH (FEET)

ENTER TRENCH DIRECTION
SCALE:

DEPTH (FEET)



0-1.5' - sand well graded with gravel, dry, light brown (10 YR 7/2), rocks up to 8", angular to rounded.

@1.5' color change to 10 YR 4/2, grain size change -> more evenly spread out, less silt / more gravel, cobbles and boulders up to 3'

EXPLANATION

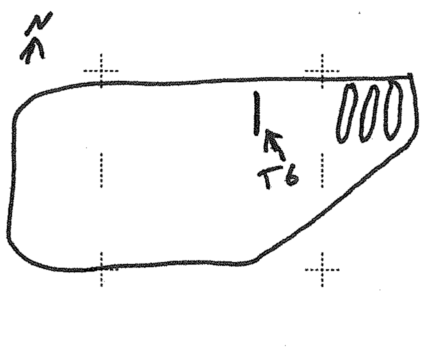
———	SOIL TYPE CONTACT (SHARP)
– – –	OTHER CONTACT (AS INDICATED ON LOG)
—·—·—	FILL/NATIVE BOUNDARY
X	ANALYTICAL SAMPLE LOCATION (WRITE SAMPLE NUMBER OUT TO SIDE)
G	GEOTECHNICAL SAMPLE LOCATION (WRITE SAMPLE NUMBER OUT TO SIDE)
////	SHADING TO DENOTE STAINING
⫽⫽⫽	BASE OF EXCAVATION
◎	SHOW LOCATIONS AND TYPES OF ALL MAJOR DEBRIS

FIELD TRENCH LOG

MWH

Project Name SAR Groundwater Recharge Optimization study					
Trench Number T6	Project Number 1343019	Elevation and Datum	Location Borrow pit		Sheet 1 of 1
Equipment Supplier	Operator Dan Clark	Date and Time Started 6-19-08	Date and Time Completed 6-19-08		Refusal? (Circle One) Yes [✓ No] If Yes Depth =
Equipment Type back hoe	Trench Orientation N-S	Total Depth 6'	Total Number of Samples 2		Photo? (Circle One) [✓ Yes] No No.
Bucket Width	Trench Length 30'	Trench Width 10'	No. of Samples 2 / Bulk / Grab 2	Drive NA / Hand Auger NA	% Man-Made Debris
Geologist or Hydrogeologist/Date Andrew Leavitt / Chaoying Jiao 6-19-08		Checked by/Date			Wall of Trench Shown (Circle One) N S E [✓ W] NE NW SE SW

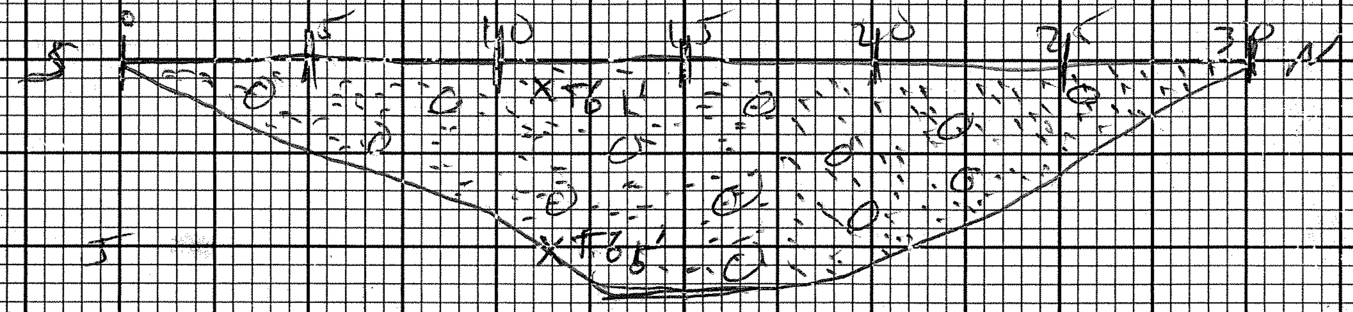
Plan View-Site Location
(Provide Sketch)



LENGTH (FEET)

ENTER TRENCH DIRECTION
SCALE:

DEPTH (FEET)



0-2' sand well graded with gravel, dry, light brown (10YR 7/2), loose, rocks up to 1", angular to rounded.

@2' grain size change - less silt / more gravel, color change to 10YR 4/2, cobbles and boulders up to 2'.

EXPLANATION

- SOIL TYPE CONTACT (SHARP)
- OTHER CONTACT (AS INDICATED ON LOG)
- FILL/NATIVE BOUNDARY
- X ANALYTICAL SAMPLE LOCATION (WRITE SAMPLE NUMBER OUT TO SIDE)
- G GEOTECHNICAL SAMPLE LOCATION (WRITE SAMPLE NUMBER OUT TO SIDE)
- //// SHADING TO DENOTE STAINING
- BASE OF EXCAVATION
- SHOW LOCATIONS AND TYPES OF ALL MAJOR DEBRIS

FIELD TRENCH LOG

MWH

Project Name: SAR Groundwater Recharge Optimization Study

Trench Number: T7

Project Number: 1343019

Elevation and Datum:

Location: Borrow Pit

Sheet 1 of 1

Equipment Supplier:

Operator: Dan Clark

Date and Time Started: 6-19-08

Date and Time Completed: 6-19-08

Refusal? (Circle One) Yes [✓ No]

If Yes Depth =

Equipment Type: Backhoe

Trench Orientation: N-S

Total Depth: 6'

Total Number of Samples: 2

Photo? (Circle One) [✓ Yes] No

No.

Bucket Width:

Trench Length: 30'

Trench Width: 10'

No. of Samples: 2

Bulk:

Grab: 2

Drive: NA

Hand Auger: NA

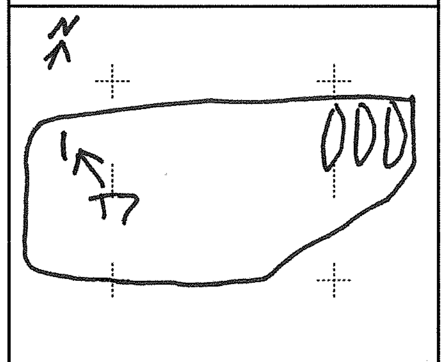
% Man-Made Debris:

Geologist or Hydrogeologist/Date: Andrew Leavitt / Chaoying Jiao 6-19-08

Checked by/Date:

Wall of Trench Shown (Circle One) N S E [✓ W] NE NW SE SW

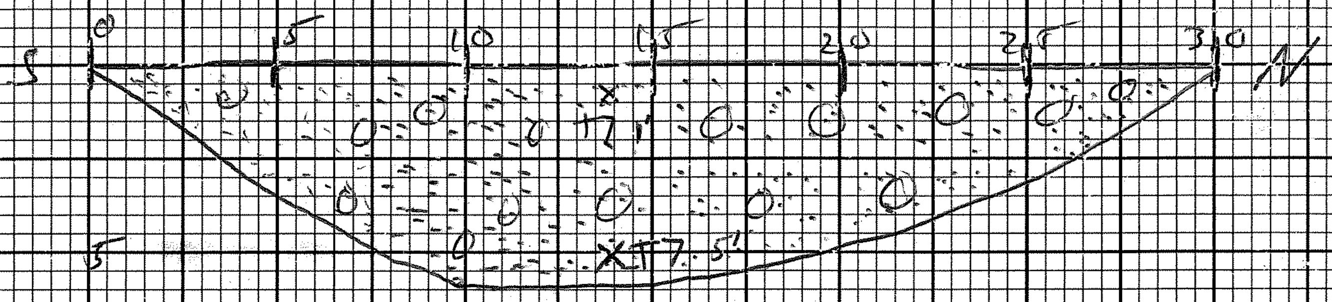
Plan View-Site Location
(Provide Sketch)



LENGTH (FEET)

ENTER TRENCH DIRECTION
SCALE:

DEPTH (FEET)



0-1.5' Sand well graded with gravel, dry, light brown (10YR 7/2), loose, rocks up to 1.5', angular to rounded.

@1.5' grain size change - less silt / more gravel, color change to 7.5YR 5/6 + 10YR 4/2, cobbles and boulders up to 3', ☆
☆ more matrix - boulders more evenly spread out.

EXPLANATION

——— SOIL TYPE CONTACT (SHARP)

- - - OTHER CONTACT (AS INDICATED ON LOG)

—·—·— FILL/NATIVE BOUNDARY

X ANALYTICAL SAMPLE LOCATION (WRITE SAMPLE NUMBER OUT TO SIDE)

G GEOTECHNICAL SAMPLE LOCATION (WRITE SAMPLE NUMBER OUT TO SIDE)

//// SHADING TO DENOTE STAINING

⊥⊥⊥⊥ BASE OF EXCAVATION

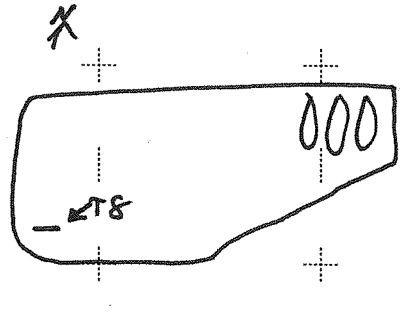
◎ SHOW LOCATIONS AND TYPES OF ALL MAJOR DEBRIS

MWH

FIELD TRENCH LOG

Project Name: SAR Groundwater Recharge Optimization Study			Location: Borrow Pit	Sheet 1 of 1	
Trench Number: T8	Project Number: 134 3019	Elevation and Datum:		Refusal? (Circle One) Yes [✓ No]	If Yes Depth =
Equipment Supplier:	Operator: Dan Clark	Date and Time Started: 6-20-08	Date and Time Completed: 6-20-08	Photo? (Circle One) [✓ Yes] No	No.
Equipment Type: Backhoe	Trench Orientation: W-E	Total Depth: 6'	Total Number of Samples: 2	% Man-Made Debris:	
Bucket Width: / Trench Length: 25'	Trench Width: 10'	No. of Samples: 2 / Bulk: / Grab: 2	Drive: NA / Hand Auger: NA		
Geologist or Hydrogeologist/Date: Andrew Leavitt / Chaoying Jiao 6-20-08		Checked by/Date:		Wall of Trench Shown (Circle One) [✓ N] S E W NE NW SE SW	

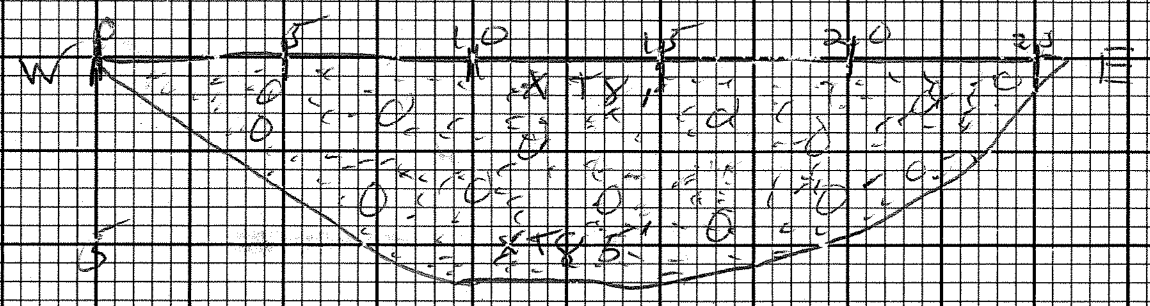
Plan View-Site Location
(Provide Sketch)



LENGTH (FEET)

ENTER TRENCH DIRECTION
SCALE:

DEPTH (FEET)



0-2.5' sandwell graded with gravel, dry, light brown (10YR 7/2),
loose, rocks up to 8", sub angular to rounded

@2.5' grainsize change to mo silt / more gravel, color change
to 10YR 4/2, cobbles and boulders up to 2.5'

EXPLANATION

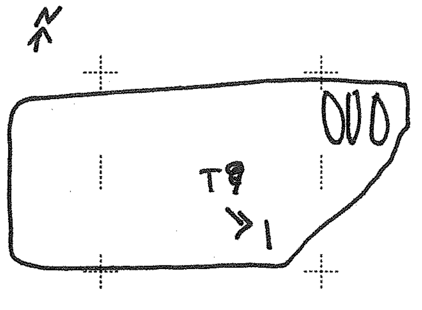
———	SOIL TYPE CONTACT (SHARP)
– – –	OTHER CONTACT (AS INDICATED ON LOG)
—.—.—	FILL/NATIVE BOUNDARY
X	ANALYTICAL SAMPLE LOCATION (WRITE SAMPLE NUMBER OUT TO SIDE)
G	GEOTECHNICAL SAMPLE LOCATION (WRITE SAMPLE NUMBER OUT TO SIDE)
////	SHADING TO DENOTE STAINING
⟋⟋⟋⟋	BASE OF EXCAVATION
◎	SHOW LOCATIONS AND TYPES OF ALL MAJOR DEBRIS

FIELD TRENCH LOG

MWH

Project Name SAR Groundwater Recharge Optimization Study				Location Soil borrow	Sheet 1 of 1	
Trench Number T9	Project Number 1343019	Elevation and Datum				
Equipment Supplier	Operator Dan Clark	Date and Time Started 6-20-08		Date and Time Completed 6-20-08	Refusal? (Circle One) Yes [✓ No]	If Yes Depth =
Equipment Type Backhoe	Trench Orientation N-S	Total Depth 5'10"		Total Number of Samples 2	Photo? (Circle One) [✓ Yes] No	No.
Bucket Width	Trench Length 25'	Trench Width 10'	No. of Samples 2	Bulk	Grab 2	Drive NA
Hand Auger NA	% Man-Made Debris					
Geologist or Hydrogeologist/Date Andrew Leavitt / Chaoying Jiao 6-20-08		Checked by/Date			Wall of Trench Shown (Circle One) N S E [✓ W] NE NW SE SW	

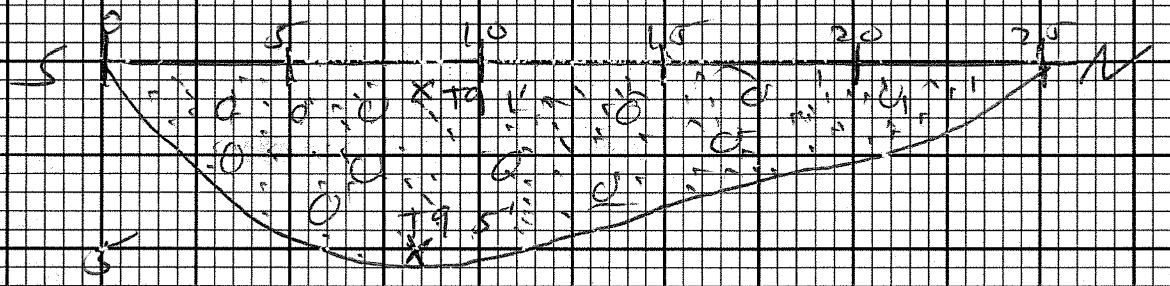
Plan View-Site Location
(Provide Sketch)



LENGTH (FEET)

DEPTH (FEET)

ENTER TRENCH DIRECTION
SCALE:



0-1' sand well graded with gravel, dry, light brown (10YR 7/2) loose, rocks up to 1', angular to rounded.

@1' grain size change - [illegible] silt / more gravel, color change to 7.5YR 5/6 + 10YR 4/2, cobbles and boulders up to 3'

EXPLANATION

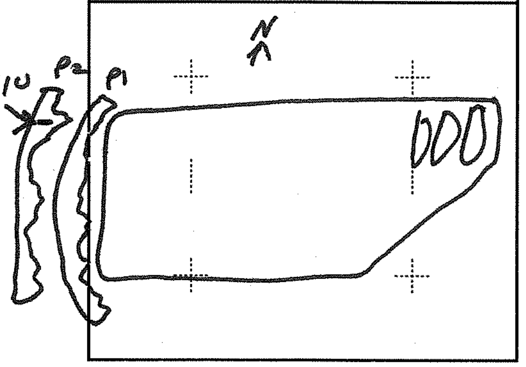
———	SOIL TYPE CONTACT (SHARP)
– – –	OTHER CONTACT (AS INDICATED ON LOG)
—·—·—	FILL/NATIVE BOUNDARY
X	ANALYTICAL SAMPLE LOCATION (WRITE SAMPLE NUMBER OUT TO SIDE)
G	GEOTECHNICAL SAMPLE LOCATION (WRITE SAMPLE NUMBER OUT TO SIDE)
////	SHADING TO DENOTE STAINING
\\\\\\\\	BASE OF EXCAVATION
◎	SHOW LOCATIONS AND TYPES OF ALL MAJOR DEBRIS

FIELD TRENCH LOG

MWH

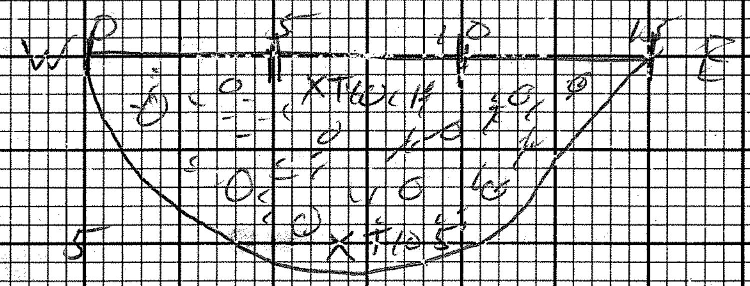
Project Name: SAR Groundwater Recharge Optimization Study				Location: Outer Pond 2	Sheet 1 of 1	
Trench Number: T10	Project Number: 134 3019	Elevation and Datum:			Refusal? (Circle One): Yes [✓ No]	If Yes Depth =
Equipment Supplier:	Operator: Dan Clark	Date and Time Started: 6-20-08		Date and Time Completed: 6-20-08	Photo? (Circle One): [✓ Yes] No	No.
Equipment Type: backhoe	Trench Orientation: W-E	Total Depth: 5'5"		Total Number of Samples: 2	% Man-Made Debris:	
Bucket Width:	Trench Length: 15'	Trench Width: 10'	No. of Samples: 2	Bulk:	Grab: 2	
				Drive: NA	Hand Auger: NA	
Geologist or Hydrogeologist/Date: Andrew Leavitt / Chaoying Jiao 6-20-08		Checked by/Date:			Wall of Trench Shown (Circle One): [✓ N] S E W NE NW SE SW	

Plan View-Site Location
(Provide Sketch)



LENGTH (FEET)

ENTER TRENCH DIRECTION
SCALE:



0-5' sand well graded, dry, light brown (10YR7/2), lots of pebbles and cobbles + boulders up to 3' but very little gravel, angular to rounded.

DEPTH (FEET)

EXPLANATION

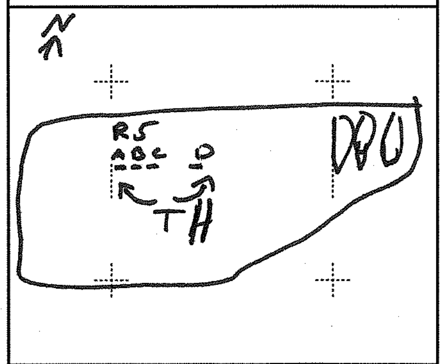
- SOIL TYPE CONTACT (SHARP)
- OTHER CONTACT (AS INDICATED ON LOG)
- FILL/NATIVE BOUNDARY
- X ANALYTICAL SAMPLE LOCATION (WRITE SAMPLE NUMBER OUT TO SIDE)
- G GEOTECHNICAL SAMPLE LOCATION (WRITE SAMPLE NUMBER OUT TO SIDE)
- SHADING TO DENOTE STAINING
- BASE OF EXCAVATION
- SHOW LOCATIONS AND TYPES OF ALL MAJOR DEBRIS

FIELD TRENCH LOG

MWH

Project Name: SAR Groundwater Recharge Optimization Study				Sheet 1 of 1	
Trench Number: T11A,B,C,D	Project Number: 1343019	Elevation and Datum:	Location: Borrow Pit		
Equipment Supplier:	Operator: Dan Clark	Date and Time Started: 6-20-08	Date and Time Completed: 6-20-08	Refusal? (Circle One) Yes [✓ No]	If Yes Depth =
Equipment Type: Back hoe	Trench Orientation: W-E	Total Depth: 3', 3.2', 3.7', 5'	Total Number of Samples: 3	Photo? (Circle One) [✓ Yes] No	No.
Bucket Width:	Trench Length: 15,20,20,25	Trench Width: 10'	No. of Samples: 3 Bulk: Grab: 3	Drive: NA Hand Auger: NA	% Man-Made Debris
Geologist or Hydrogeologist/Date: Andrew Leavitt / Chaoying Jiao 6-20-08			Checked by/Date:	Wall of Trench Shown (Circle One) [✓ N] S E W NE NW SE SW	

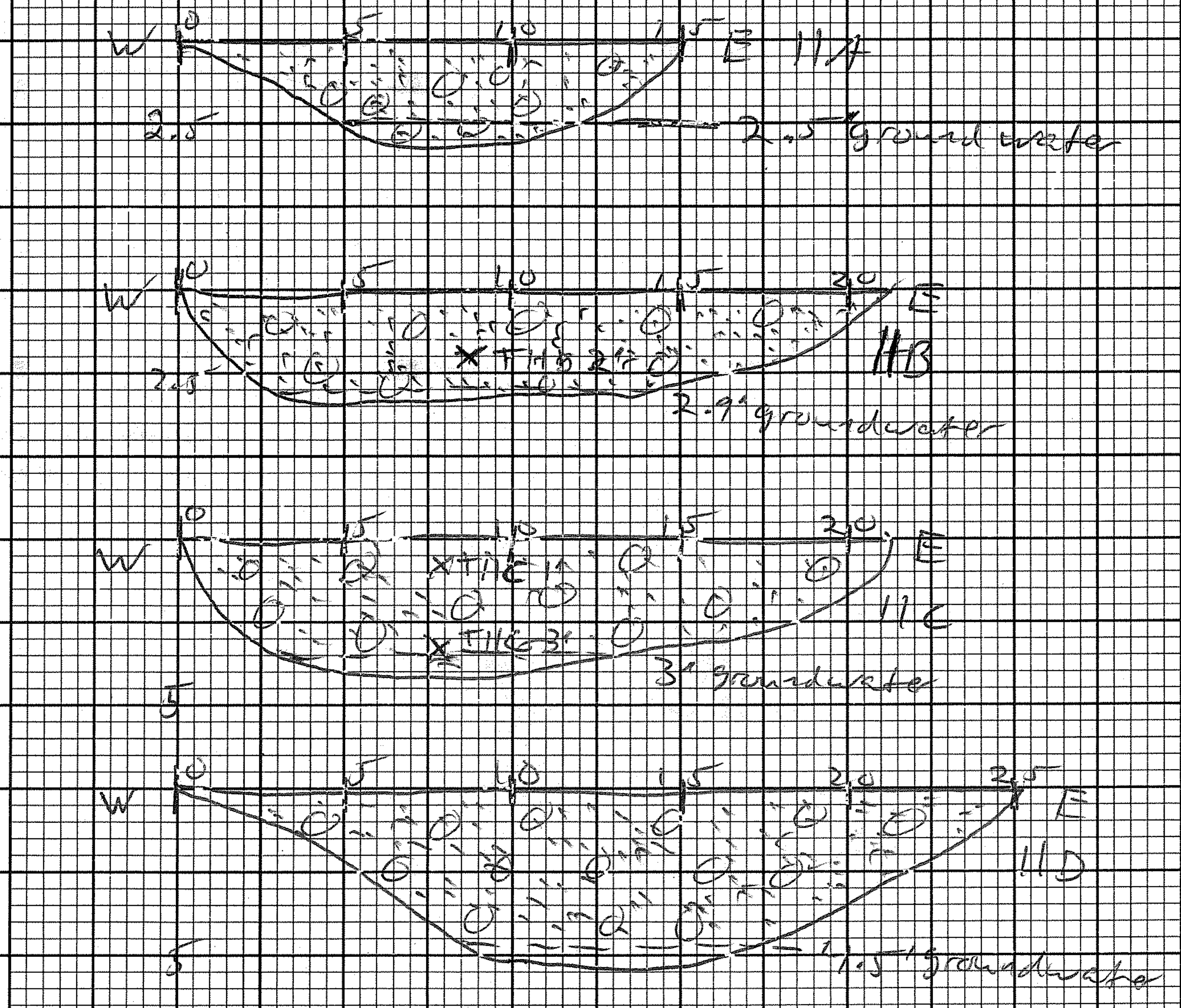
Plan View-Site Location
(Provide Sketch)



LENGTH (FEET)

ENTER TRENCH DIRECTION
SCALE:

DEPTH (FEET)



(T11A) Plants on surface, soil is much softer and moist, sand well graded with gravel, moist to 1.5', wet @ 1.5', groundwater @ 2', dark greyish brown (2.5Y 4/2) loose, rocks up to 1', subangular to rounded.

(T11B) Sand well graded ~~with~~ with gravel, dry, light brown (10YR 7/2), loose, rocks up to 6", subangular to rounded.

@6" grain size change to less silt / more gravel, color change to 10YR 4/2.

@1.5' moist

@2.5' wet

@ 2'10" groundwater

(T11C) Same as 11B only groundwater is @ 3.5'.

(T11D) sand well graded with gravel, dry, light brown (10YR 7/2), rocks up to 8", angular to rounded.

@1.5' soil grain size change to less silt / more gravel, color change to 10YR 4/2, cobbles up to 2'.

@1.5' soil is moist.

@4' soil is wet

@4.5' groundwater

EXPLANATION

——— SOIL TYPE CONTACT (SHARP)

- - - OTHER CONTACT (AS INDICATED ON LOG)

—·—·— FILL/NATIVE BOUNDARY

X ANALYTICAL SAMPLE LOCATION (WRITE SAMPLE NUMBER OUT TO SIDE)

G GEOTECHNICAL SAMPLE LOCATION (WRITE SAMPLE NUMBER OUT TO SIDE)

//// SHADING TO DENOTE STAINING

⟋⟋⟋ BASE OF EXCAVATION

◎ SHOW LOCATIONS AND TYPES OF ALL MAJOR DEBRIS

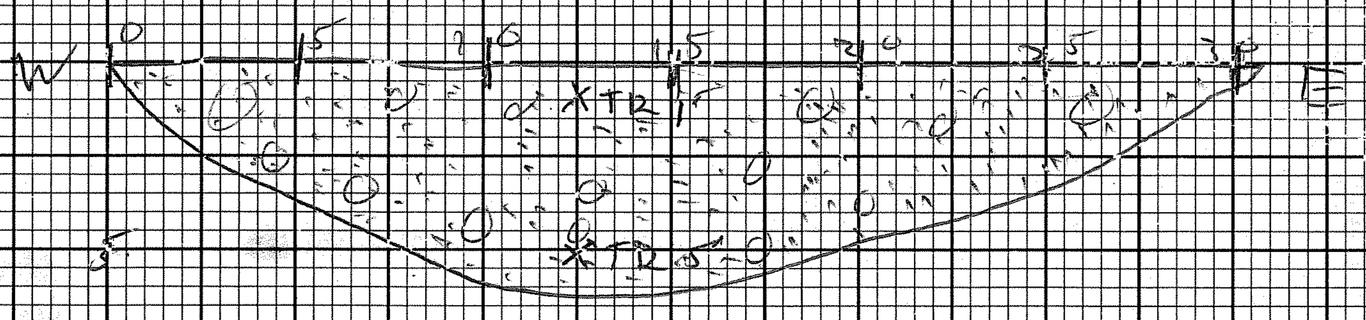
FIELD TRENCH LOG

MWH

Project Name: SAR Groundwater Recharge Optimization Study					
Trench Number: T 12	Project Number: 1343019	Elevation and Datum:	Location: Borrow Pit	Sheet 1 of 1	
Equipment Supplier:	Operator: Dan Clark	Date and Time Started: 6-20-08	Date and Time Completed: 6-20-08	Refusal? (Circle One) Yes [✓ No]	If Yes Depth =
Equipment Type: backhoe	Trench Orientation: W-E	Total Depth: 6'2"	Total Number of Samples: 2	Photo? (Circle One) [✓ Yes] No	No.
Bucket Width:	Trench Length: 30'	Trench Width: 10'	No. of Samples: 2	Bulk:	Grab: 2
Drive: NA	Hand Auger: NA	% Man-Made Debris:			
Geologist or Hydrogeologist/Date: Andrew Leavitt / Chaoying Jiao 6-20-08		Checked by/Date:		Wall of Trench Shown (Circle One): [✓ N] S E W NE NW SE SW	

LENGTH (FEET)

ENTER TRENCH DIRECTION
SCALE:



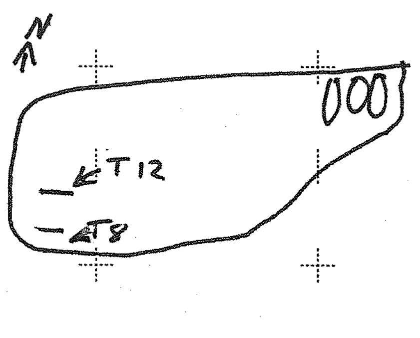
DEPTH (FEET)

first 3" is a pure silt mud crack layer

@3" sand well graded with gravel, dry, light brown (10YR 7/2), loose, rocks up to 7", subangular to rounded.

@1.5' grain size change - no silt / more gravel, color change to 10YR 4/2, boulders up to 3'

Plan View-Site Location
(Provide Sketch)

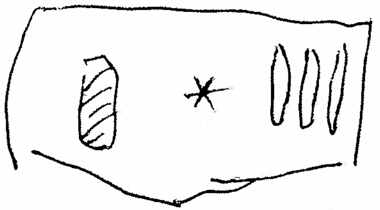


EXPLANATION

———	SOIL TYPE CONTACT (SHARP)
- - -	OTHER CONTACT (AS INDICATED ON LOG)
— — —	FILL/NATIVE BOUNDARY
X	ANALYTICAL SAMPLE LOCATION (WRITE SAMPLE NUMBER OUT TO SIDE)
G	GEOTECHNICAL SAMPLE LOCATION (WRITE SAMPLE NUMBER OUT TO SIDE)
////	SHADING TO DENOTE STAINING
\\\\\\	BASE OF EXCAVATION
◎	SHOW LOCATIONS AND TYPES OF ALL MAJOR DEBRIS

Appendix D
Boring Logs

MWH



N 34° 06.056'
W 117° 07.050'

Site Sketch Map 1711 FT

Boring #: SB-1 MW#: Sheet 1 of 3

Project: SAR Groundwater Recharge Optimization Study

Job #: 1343019 Site.

Logged By: CJ Reviewed By:

Drilling Contractor: Boart Longyear

Drill Rig Type/Method: Sonic Drilling

Drillers Name: JOSE

Borehole Diam./Drill Bit Type: 4" CUTTING BIT

Total Depth

Ref. Elev.

Sampler Type:

Depth to 1st Water (∇): Time/Date:

Depth to Water After Drilling (▼): Time/Date:

Depth to other Water Bearing Zones:

Drill Start Time/Date: 7-2-08 13:

Drill Finish Time/Date: 7-2-08 16:45

Well Completion Time/Date: 7-3-08 7:30

Soil Boring Backfill Time/Date:

PID/OVA	Sample Interval	Recovered (in.)	Blow Counts / 6 in.	Retained for Analysis	Casing Type & Size	Annulus Filler	Depth (Feet)	USCS Soil Type	Soil Description	Estimated % Of				
											Sand			
										Gravel	Coarse	Medium	Fine	Silt/clay
	0							SW	LIGHT BROWN WELL GRADED SAND WITH BOULDERS	20	20	35	20	5
							1							
							2							
							3							
		7'4"					4							
							5							
							6							
	7 7						7	GW	BROWN. LIGHT GRAY WELL GRADED GRAVEL WITH COBBLES BOULDERS	35	20	20	15	10
							8							
							9							
							10							
		5'2"					11							
							12							

QA/QC

Boring #: SB-1 MW#: Project: Sheet 2 of 3

PID/OVA	Sample Interval	Recovered (in.)	Blow Counts / 6 in.	Retained for Analysis.	Casing Type & Size	Annulus Filler	Depth (Feet)	USCS Soil Type	Soil Description	Estimated % Of				
											Sand			
										Gravel	Coarse	Med.	Fine	Silt/Clay
							12							
	13													
	13						13	GW	SAME AS ABOVE	35	20	20	15	10
							14							
		4'8"												
							15							
							16							
	17													
							17	GW	COARSER THAN ABOVE					
									TOP 9" BROWN	50	20	20	10	
							18		BOTTOM GRAY					
							19							
							20							
		4'8"												
							21							
							22							
							23							
	24													
	24						24	RX	ROCK CORE					
									GRAY					
							25							
		3'												
							26							
	27													
	27						27	GW	BROWN WITH COBBLES	35	25	20	15	5
									FINER DOWN.					
							28	SC	FINER BUT WITH COBBLES	15	20	25	20	20
		4'8"												
							29	GW	BROWN WITH COBBLES	35	25	20	15	5
							30							
							31							
	32						32							

QA/QC

Boring #: SB-1 MW#: Project: **Sheet** 3 **of** 3

PID/OVA	Sample Interval	Recovered (in.)	Blow Counts / 6 in.	Retained for Analysis.	Casing Type & Size	Annulus Filler	Depth (Feet)	USCS Soil Type	Soil Description	Estimated % Of Gravel	Sand Coarse	Sand Med.	Sand Fine	Silt/Clay
	32						32	RX	TOP 1'8"					
									ROCK CORE					
							33							
		6'					34	GW	BROWN WELL GRADED	35	30	25	10	
									MINOR FINES					
							35	SW	LIGHT GRAY WITH SILT	20	25	25	20	10
									AND BOULDER.					
							36							
	37						37	SW	TOP 3'5" BROWN	15	20	25	20	20
									WELL GRADED SAND					
							38		WITH GRAVELS AND					
									SILT. MINOR COBBLES					
							39							
							40							
		6'6"												
							41	SC	HALF FOOT SANDY SILT	10	20	20	25	25
									SILTY SAND. HARD					
							42		GRAY					
	43													
	43						43	SW	BROWN LIGHT GRAY	15	20	35	20	20
							44		WELL GRADED SAND					
									WITH COBBLES					
							45		BOULDERS AND SILT					
							46							
		6'												
							47							
							48							
							49							
	50						50							
							1							
							2							

MWH

Boring #: SB-2 MW#: Sheet 1 of 3

Project: SAR Groundwater Recharge Optimization Study

Job #: 1343019 Site:

Logged By: C J Reviewed By:

Drilling Contractor: Boart Longyear

Drill Rig Type/Method: Sonic Drilling

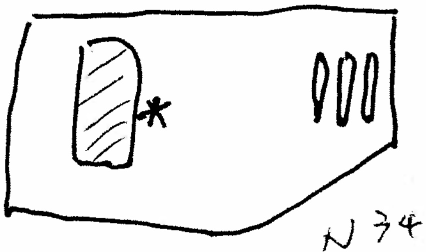
Drillers Name: JOSE

Borehole Diam./Drill Bit Type: 4" CUTTING

Total Depth

Ref. Elev.

Sampler Type: SONIC CONSECUTIVE



N 34° 06.049'
W 117° 07.315'
1643

Site Sketch Map

Depth to 1st Water (▽): Time/Date:

Depth to Water After Drilling (▼): Time/Date:

Depth to other Water Bearing Zones:

Drill Start Time/Date: 7-3-08 8:15 Drill Finish Time/Date: 7-3-08 11:00

Well Completion Time/Date:

Soil Boring Backfill Time/Date:

PID/OVA	Sample Interval	Recovered (in.)	Blow Counts / 6 in.	Retained for Analysis	Casing Type & Size	Annulus Filler	Depth (Feet)	USCS Soil Type	Soil Description	Estimated % Of Gravel	Sand Coarse	Sand Medium	Sand Fine	Silt/clay
	0							SW	BROWN WELL GRADED SAND WITH GRAVEL, TO THE BOTTOM INCREASED GRAIN SIZE TO BOULDER, LESS SAND AND FINES	25	35	25	10	5
							1							
							2							
		5'7"					3	GW	BOULDERS WITH MINOR SANDS	65	20	10	5	
							4							
							5							
	6 6	1'7"					6	GW	SAME AS ABOVE	60	25	10	5	
	7 7						7	SW	TOP 1 FT SW	25	35	25	10	5
							8	Rk	2 FT BOULDERS					
							9	&						
							10	GW	BOULDERS, GRAVELS, SAND MIXTURE, MINOR FINES	60	25	10	5	
							11							
							12							

QA/QC

Boring #: SB-2 MW#: Project: **Sheet** 2 **of** 3

PID/OVA	Sample Interval	Recovered (in.)	Blow Counts / 6 in.	Retained for Analysis.	Casing Type & Size	Annulus Filler	Depth (Feet)	USCS Soil Type	Soil Description	Estimated % Of				
										Gravel	Sand			Silt/Clay
											Coarse	Med.	Fine	
		9'7"					12							
							13							
							14	SM	SILTY SAND WITH BOULDERS : GRAY. 6" THICK	30	30	20	10	10
							15	SW	WELL GRADED SAND WITH COBBLES, GRAVELS	25	35	25	10	5
							16							
	12													
	12						17	SP	TOP 3'9" BROWN SAND WITH COBBLES	15	45	25	10	5
							18		VERY TOP 1' POORLY					
								SW	GRADED. TO THE BOTTOM					
							19		MORE GRAVEL, COBBLES AND FINES	30	25	25	15	5
							20							
		7'4"												
							21	SM	SILTY SAND WITH GRAVELS, COBBLES	15	20	25	20	20
							22	GW	BROWN, WELL GRADED WITH COBBLES	40	25	25	10	
							23	RX	9" LONG ROCK CORE BROWN, LIGHT GRAY					
	24													
	24						24	SW	BROWN WELL GRADED SAND, COARSE SAND					
							25		WITH GRAVELS, COBBLES AND ROCK CORES	15	30	25	25	5
		3'9"												
							26							
	27						27	SP	BROWN POORLY GRADED COARSE SAND WITH GRAVEL	20	60	15	5	
							28	SW	LIGHT GRAY WELL GRADED SAND WITH GRAVELS	25	30	25	15	5
							29		COBBLES AND MORE FINES					
							30							
							31	SM	SILTY SAND WITH GRAVELS	20	20	25	20	15
		10'4"					32		COBBLES, GRADED TO					

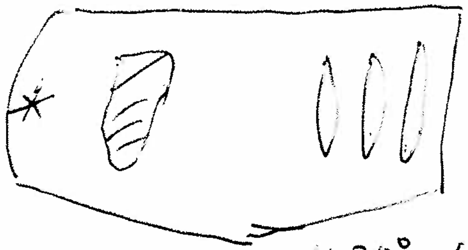
QA/QC

Boring #: MW#: Project: Sheet 3 of 3

PID/OVA	Sample Interval	Recovered (in.)	Blow Counts / 6 in.	Retained for Analysis.	Casing Type & Size	Annulus Filler	Depth (Feet)	USCS Soil Type	Soil Description	Estimated % Of				
											Sand			
										Gravel	Coarse	Med.	Fine	Silt/Clay
							32		BOULDERS (ROCK CORE)					
							33							
							34	RX						
							35	SW	BROWN WELL GRADED SAND WITH GRAVELS COBBLES AND BOULDERS	25	30	25	15	5
							36							
	37 37						37	GW	TOP 17" LIGHT BROWN WELL GRADED GRAVELS WITH COBBLES	20	35	20	20	5
							38							
							39	SW	MIDDLE 4'3" GRAY WELL GRADED SAND WITH COBBLES AND SILTS	15	20	25	25	15
		6'7"					40							
							41							
							42							
							43	SW	BOTTOM 10" BROWN WITH COBBLES	15	30	25	25	5
	44 44						44	RX	TOP 2' GRAY ROCK CORE WITH FEW GRAVELS AND SANDS					
							45							
							46	SW	BROWN SAND WITH COBBLES. GRAVELS	15	25	30	20	10
		5'7"					47							
							48							
							49							
	50						50							
							1							
							2							

QA/QC

MWH


N 34° 06.040'
W 117° 07.533'

Site Sketch Map

Boring # SB-3 MW#: **Sheet** 1 **of** 3

Project: SAR Groundwater Recharge Optimization Study

Job #: 1343019 Site:

Logged By: CJ Reviewed By:

Drilling Contractor: Boart Longyear

Drill Rig Type/Method: Sonic Drilling

Drillers Name: JOSE

Borehole Diam./Drill Bit Type: 4" CUTTING

Total Depth

Ref. Elev.

Sampler Type: CONSECUTIVE SONIC

Depth to 1st Water (▽): Time/Date:

Depth to Water After Drilling (▼): Time/Date:

Depth to other Water Bearing Zones:

Drill Start Time/Date: 7-7-08 7:30 Drill Finish Time/Date: 11:30 7/7/08

Well Completion Time/Date: 12:15 7-7-08

Soil Boring Backfill Time/Date:

PID/OVA	Sample Interval	Recovered (in.)	Blow Counts / 6 in.	Retained for Analysis	Casing Type & Size	Annulus Filler	Depth (Feet)	USCS Soil Type	Soil Description	Estimated % Of Gravel	Sand Coarse	Sand Medium	Sand Fine	Silt/clay
	0							SW	LIGHT BROWN WELL GRADED SAND WITH COBBLES, GRAVELS AND BOULDERS TO 10" LONG ROCK CORE	30	20	20	20	10
							1							
		6'6"					2							
							3							
							4	SP	BOTTOM 1'6" POORLY GRADED BROWN COARSE SAND WITH GRAVELS	15 ~~15~~	35 ~~35~~	30 ~~35~~ 35	20 ~~20~~	
	5 5						5	SW	LIGHT BROWN WELL GRADED SAND WITH GRAVELS & COBBLES	25	25	20	20	10
		1'11"					6							
	7 7						7	SW	TOP 1'2" SAME AS ABOVE FOLLOWED BY BOULDERS (ROCK CORE TO 9" IN LENGTH)	25	25	20	20	10
							8							
							9							
							10	SW	BOTTOM 3 FT COARSE SAND BROWN WITH GRAVELS AND COBBLES	25	25	25	20	5
							11							
							12							

CJ

QA/QC

Boring #: SB-3 MW#: Project: Sheet 2 of 3

PID/OVA	Sample Interval	Recovered (in.)	Blow Counts / 6 in.	Retained for Analysis.	Casing Type & Size	Annulus Filler	Depth (Feet)	USCS Soil Type	Soil Description	Estimated % Of Gravel	Sand Coarse	Sand Med.	Sand Fine	Silt/Clay
		5'8"					12							
	13	↓												
	13	↑					13	RX	ROCK CORE AND CUTTING					
									POWDER. TOP 4'3"					
							14							
		6'2"												
							15	GW	BOTTOM 1'8" WELL GRADED	40	25	20	10	5
									GRAVEL WITH COBBLES					
							16		BOULDERS LIGHT BROWN					
	17	↓												
	17	↑					17	SW	LIGHT GRAY. WELL	15	30	25	20	10
									GRADED COARSE SAND					
							18		WITH GRAVELS, COBBLES					
									MINOR FINES, DAMP					
							19							
		7'												
							20							
							21							
							22							
							23	RX	BOTTOM 2 FT BOULDER					
									ROCK CORE AND POWDER					
							24							
	25	↓												
	25	↑					25	GW	GRAY GRAVELS WITH	70	15	10	5	
		1'10"							COBBLES AND BOULDERS					
							26							
	27	↓												
	27						27	SW	TOP 1'8" BROWN					
									DAMP WELL GRADED					
							28		SAND WITH GRAVELS	15	25	25	20	15
									COBBLES AND SILT/CLAY					
							29		BALLS					
									TO THE BOTTOM MORE	15	20	25	25	15
							30		FINE GRAY					
							31							
							32							

QA/QC

Boring #: SB-3 MW#: Project: **Sheet** 3 **of** 3

PID/OVA	Sample Interval	Recovered (in.)	Blow Counts / 6 in.	Retained for Analysis.	Casing Type & Size	Annulus Filler	Depth (Feet)	USCS Soil Type	Soil Description	Estimated % Of Gravel	Sand Coarse	Sand Med.	Sand Fine	Silt/Clay
		3'7"					32							
							33							
	34													
	34						34	ML	TOP 2 FT GRAY CLAYEY				10	90
									SILT WITH MINOR SAND					
		4'9"					35		COARSE DOWN GRADED					
									TO SILTY SAND AND					
							36	GW	GRAVEL. BOTTOM 2'5"	60	15	10	10	5
	37								COBBLES AND BOULDERS					
	37						37	SW	TOP 1 FT. GRAY WITH	25	25	20	20	10
									GRAVELS					
							38	GW	GRAY. WITH COBBLES	60	15	10	10	5
									AND BOULDERS					
							39	SW	BROWN WELL GRADED	25	35	20	15	5
									SAND WITH GRAVELS					
		7'11"					40		AND COBBLES					
							41							
							42							
							43							
	44													
	44						44	ML	TOP 1'4" GRAY SILT				10	90
									WITH MINOR CLAY AND					
							45		SAND. FISHY SMELL					
									DRY. HARD					
							46	SW	LIGHT GRAY WELL GRADED	10	25	35	20	10
		7'6"							MEDIUM SAND. COARSER					
							47		DOWNWARD GRADED					
									TO SANDY GRAVEL	30	25	25	20	
							48							
							49	GW	GRAVEL WITH COBBLES	60	15	15	10	
	50								AND BOULDERS					
	TD						50							
							1							
							2							

QA/QC

MWH

Boring #: 1 MW#: 1 Sheet 1 of 8

Project: SAR Groundwater Recharge Optimization Study

Job #: 1343019 Site:

Logged By: CT Reviewed By:

Drilling Contractor: Boart Longyear

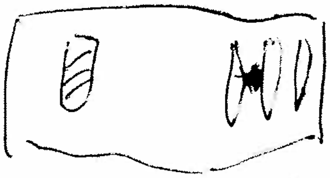
Drill Rig Type/Method: Sonic Drilling

Drillers Name: JOSE

Borehole Diam./Drill Bit Type: 4"/CUTTING BIT

Total Depth

Ref. Elev.



N34° 06.074'
W117° 06.831'
1761

Site Sketch Map

Sampler Type:

Depth to 1st Water (∇): Time/Date:

Drill Start Time/Date: 06-30-08 8:30 Drill Finish Time/Date:

Depth to Water After Drilling (▼): Time/Date:

Well Completion Time/Date:

Depth to other Water Bearing Zones:

Soil Boring Backfill Time/Date:

PID/OVA	Sample Interval	Recovered (in.)	Blow Counts / 6 in.	Retained for Analysis	Casing Type & Size	Annulus Filler	Depth (Feet)	USCS Soil Type	Soil Description	Estimated % Of Gravel	Sand Coarse	Sand Medium	Sand Fine	Silt/clay
	0							SW	WELL GRADED SAND WITH GRAVEL, TOP 3" MORE GRAVEL	50	20	20	5	5
		5'					1	GW	~50%, FOLLOWED BY 14" SAND, THEN GRAVELLY SAND DRY	20	20	30	10	10
							2							
							3							
	4 4	2'11"					4	GW	DRY, GRAY WELL GRADED GRAVEL	50	20	20	5	5
							5							
							6							
	7 7						7	GW	GRAY, DRY WELL GRADED GRAVEL, WELL ROUNDED SUBANGULAR	60	20	15	5	
							8							
		84"					9							
							10							
							11							
							12							

QA/QC

Boring #: MW#: 1 Project: Sheet 2 of 8

PID/OVA	Sample Interval	Recovered (in.)	Blow Counts / 6 in.	Retained for Analysis.	Casing Type & Size	Annulus Filler	Depth (Feet)	USCS Soil Type	Soil Description	Estimated % Of	Sand			
										Gravel	Coarse	Med.	Fine	Silt/Clay
							12							
							13							
							14							
							15							
							16							
	17 17						17	Rx	ROCK PIECES & POWDER					
							18							
		7'1"					19							
							20							
							21							
							22							
	23 23						23	Rx						
		3'6"					24							
							25	GW	Bottom 1'6".	60	25	15		
							26							
	27 27	1'1"					27	GW	WITH BOULDERS	60	25	15		
							28							
	29 29						29	Rx	ONLY ROCK CORE. NO FINES RECOVERED. BEEN WASHED OUT BY APPLYING WATER					
		1'9"					30							
							31							
							32							

QA/QC

Boring #: MW#: [redacted] Project: Sheet 3 of 8

PID/OVA	Sample Interval	Recovered (in.)	Blow Counts / 6 in.	Retained for Analysis.	Casing Type & Size	Annulus Filler	Depth (Feet)	USCS Soil Type	Soil Description	Estimated % Of				
										Gravel	Sand			Silt/Clay
											Coarse	Med.	Fine	
							32							
							33							
							34							
							35							
							36							
	37													
	37						37	RX	UP TO 10" ROCKCORE					
		1'9"												
							38							
	39													
	39	15"					39	Rx	ROCK POWDER + PIECES					
	40								(CORE)					
	40						40	SC	SANDY CLAY AND	5	20	20	20	35
							41		CLAYEY SAND WITH	10	25	25	25	15
									GRAVEL. BROWN					
							42		FISHY SMELL					
									DRY					
		6'8"					43							
							44							
							45							
							46							
	47													
							47	GW	TOP 19" COARSER THAN	50	20	20	5	5
							48	SC	BOTTOM.	10	25	25	25	15
		4'4"						CL						
							49							
							50							
							51							
							52							

QA/QC

Boring #: MW#: 1 Project: Sheet 4 of 8

PID/OVA	Sample Interval	Recovered (in.)	Blow Counts / 6 in.	Retained for Analysis.	Casing Type & Size	Annulus Filler	Depth (Feet)	USCS Soil Type	Soil Description	Estimated % Of Gravel	Sand Coarse	Sand Med.	Sand Fine	Silt/Clay
							52							
	53						53	GW	TOP 18"	40	30	20	5	5
								SP	MIDDLE 26"	10	35	35	15	5
		5'4"					54	SC	BOTTOM 15"	20	25	20	20	20
							55							
	56													
	56	20"					56	GW	TOP 12"	40	30	20	5	5
	57							RX	BOTTOM 8"					
	57			X	Undisturbed Sample		57	GW	CLAY GRAVEL MIXTURE WITH SAND	40	20	10	10	20
							58							
							59							
		3'9"												
							60							
	61													
	61						61							
							62	RX	APPLY WATER, ALL FINES HAS BEEN WASHED OUT ONLY COBBLES BOULDERS HAVE BEEN RECOVERED					
							63							
		19"					64							
							65							
							66							
	67													
	67						67	RX	TOP 14" COBBLES					
							68	GW	BOULDERS GRAVELS MINOR SAND AND FINES					
							69	SC	BOTTOM 17" GRAY CLAYEY SAND FISHY SMELL	5	25	30	25	15
		3'					70							
							71							
	72						72							

Boring #: MW#: Project: Sheet 5 of 8

PID/OVA	Sample Interval	Recovered (in.)	Blow Counts / 6 in.	Retained for Analysis.	Casing Type & Size	Annulus Filler	Depth (Feet)	USCS Soil Type	Soil Description	Estimated % Of Gravel	Sand Coarse	Sand Med.	Sand Fine	Silt/Clay
	72	↑					72	SC	TOP 14" CLAYEY SAND	5	25	30	25	15
									WITH GRAVEL					
		5'5"					73	GW	MIDDLE 21", COARSER	40	20	20	10	10
							74		WITH ROCK CORES UP					
		↓							TO 7" LONG					
	75							SC	BOTTOM 17" MORE FINES	5	25	30	25	15
	75	↑					75	GW	TOP 14" COARSER THAN	40	20	20	10	10
		2'4"					76	RX	ABOVE BOTTOM ROCK					
									CORES ~6" LONG					
	77	↓												
	77	↑					77	RX	ROCK CORE AND WELL					
							78	GW	GRADED GRAVEL AT THE					
		1'11"							BOTTOM 6"	40	20	20	10	10
	79	↓												
	79	↑					79	GW	GRAY WELL GRADED	40	20	20	10	10
							80		GRAVEL WITH BOULDERS					
		1'2"												
							81							
	82	↓												
	82	↑					82	GW	TOP 2'6"	40	20	20	10	10
							83	SW	MIDDLE 7", LESS COARSE	15	35	35	10	5
		5'6"							LESS FINE					
							84	SC	BOTTOM 25".	5	25	30	25	15
								RX	VERY BOTTOM ROCK CORE					
	85	↓					85							
	85	↑						SW	TOP 15" SW GRADED	5	40	30	20	5
		2'8"					86		TO GW TO THE BOTTOM					
								GW		30	25	25	20	
	87	↓					87							
		↑						SW	TOP 1'5" SW GRADED	5	40	30	20	5
							88		TO GW TO THE BOTTOM	30	25	25	20	
								GW						
		2'1"					89							
							90							
	91	↓												
	91	↑ 1'8"					91	GW	TOP 1'2" GW	35	20	20	20	5
	92	↓					92	RX	BOTTOM ROCK CORE					

QA/QC

Boring #: MW#: 1 Project: Sheet 6 of 8

PID/OVA	Sample Interval	Recovered (in.)	Blow Counts / 6 in.	Retained for Analysis.	Casing Type & Size	Annulus Filler	Depth (Feet)	USCS Soil Type	Soil Description	Gravel	Coarse	Med.	Fine	Silt/Clay
											Estimated % Of Sand			
	92	↑					92	GW	TOP 9" GRAY	35	20	20	20	5
							93		FOLLOWED BY 2'2"					
									ROCK CORE.					
							94	GW	BOTTOM	35	20	20	20	5
		4'10"												
							95							
							96							
	97	↓												
	97	↑					97	SP	TOP 9"	5	20	35	30	
							98	ML	FOLLOWED BY 7'7"					
									SANDY SILT WITH					
							99		GRAVELS AND COBBLES	15	10	20	20	35
									BOULDERS. DARK GRAY					
									FISHY SMELL					
							100	ML	8" DARK GRAY SILT	5	10	15	20	50
									WITH SAND AND CLAY					
							101		FISHY SMELL					
								RX	1'3" GRAVELS, COBBLES					
							102		AND ROCK CORE					
	10'5"													
							103							
							104							
							105							
							106	CT						
	107	↓												
	107	↑					107	~~GW~~ SW	~~GW~~ GRAY BROWN	10	20	25	20	25
									SILTY SAND WITH					
							108		GRAVEL					
									FISHY SMELL					
							109		~~At~~ TOP ONE FOOT MORE					
									GRAVEL.					
							110		MIDDLE 4' REDUCED					
									GRAIN SIZE, MORE FINES					
							111		BOTTOM MORE COBBLES					
							112							

Boring #: MW#: Project: Sheet 7 of 8

PID/OVA	Sample Interval	Recovered (in.)	Blow Counts / 6 in.	Retained for Analysis.	Casing Type & Size	Annulus Filler	Depth (Feet)	USCS Soil Type	Soil Description	Gravel	Coarse	Med.	Fine	Silt/Clay
										Estimated % Of				
											Sand			
		7'					112							
	113 113						113	RX	BROWN COLOR @ 114' TOP GRAY.					
		5'11"					114	GW	BROWN, SANDY GRAVEL ROCK PIECES (CORE)	50	20	20	10	
							115							
							116							
	117 117						117	SP	TOP 14" MIDIUM SAND BROWN	5	20	50	20	5
		4'					118	SP	10" COARSE SAND	10	35	30	20	5
								GW	BOTTOM 26" COARSER GRAINSIZE	55	15	10	10	10
							119							
							120							
	121 121						121	GW	TOP 39" BROWN	55	15	10	10	10
							122	GW	MIDDLE 12" GRAY, MORE FINES	25	20	20	15	20
							123							
		7'					124	GW	BOTTOM 2'7" BROWN	55	15	10	10	10
							125							
							126							
	127 127						127	SW	BROWN, LIGHT GRAY WELL GRADED MEDIUM SAND WITH GRAVELS COBBLES AND SILTS	15	20	35	20	10
		3'9"					128							
							129	SC	MIDDLE ONE FOOT MORE FINES, HARD GRAY	15	20	20	20	25
							130							
	131 131						131	GW	BOTTOM 8"	25	20	20	20	15
							132							

Boring #: MW#: 1 Project: **Sheet** 8 **of** 8

PID/OVA	Sample Interval	Recovered (in.)	Blow Counts / 6 in.	Retained for Analysis	Casing Type & Size	Annulus Filler	Depth (Feet)	USCS Soil Type	Soil Description	Estimated % Of Gravel	Sand Coarse	Sand Med.	Sand Fine	Silt/Clay
							132	GW	WITH ROCK CORES AND SILT. GRAY. LIGHT BROWN	25	25	20	20	10
		6'3''					133							
							134							
							135							
							136							
	137 137						137	SP	TOP 3' POORLY GRADED BROWN COARSE SAND WITH BOULDERS (ROCK CORE) TRACE FINES	10	35	20	20	5
							138							
		9'					139							
							140	SC	MIDDLE 4' SILTY SAND GRAY. MORE COBBLES	15	20	20	20	25
							141							
							142							
							143							
							144	GW	MORE GRAVEL	30	25	20	20	5
							145	RX	ROCK CORE					
	146 146						146	GW	TOP 1'	30	25	20	20	5
							147	SC	SILTY SAND FOR 1'					
		7'					148	GW	BROWN FOLLOWED BY POORLY GRADED MEDIUM	30	25	20	20	5
							149	SP	SAND	15	25	35	20	5
	150						150	GW	BROWN	30	25	20	20	5
							1							
							2							

QA/QC

MWH

Boring #: 2 MW#: 2 **Sheet** 1 **of** 6

Project: SAR Groundwater Recharge Optimization Study

Job #: 1343019 Site:

Logged By: CJ Reviewed By:

Drilling Contractor: Boart Longyear

Drill Rig Type/Method: Sonic Drilling

Drillers Name: JOSE

Borehole Diam./Drill Bit Type: 4" / CUTTING BIT

Total Depth

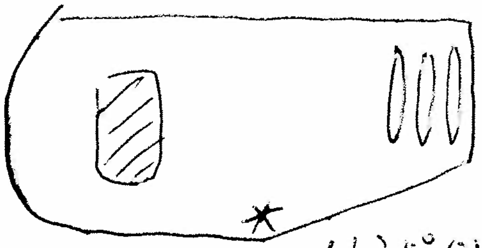
Ref. Elev.

Sampler Type: CONSECUTIVE

Drill Start Time/Date: 06-26-08 10:30 Drill Finish Time/Date:

Well Completion Time/Date:

Soil Boring Backfill Time/Date:



N 34° 05.814'
W 117° 07.095'
1702 FT

Site Sketch Map

Depth to 1st Water (▽): Time/Date:

Depth to Water After Drilling (▼): Time/Date:

Depth to other Water Bearing Zones:

PID/OVA	Sample Interval	Recovered (in.)	Blow Counts / 6 in.	Retained for Analysis	Casing Type & Size	Annulus Filler	Depth (Feet)	USCS Soil Type	Soil Description	Estimated % Of Gravel	Sand Coarse	Sand Medium	Sand Fine	Silt/clay
	0							~~GW~~ SW	SUBROUNDED TO WELL ROUNDED SANDS GRAVELS AND FINES THE BOTTOM 2 FEET CONTAINS MORE GRAVELS PEBBLES AND ROCK PIECES	20	25	30	20	5
							1							
							2							
		4'6"												
							3	GW	ROCK PIECES GRAVELS COARSE SANDS AND MINOR FINES	50	15	15	10	10
							4							
	5													
	5						5	GW	SAME AS ABOVE	50	15	15	15	5
		3'10"					6							
	7													
							7	GW	SAME AS ABOVE	50	15	15	15	5
							8							
							9							
		5'6"					10							
							11							
	12						12							

QA/QC

Boring #: MW#: Project: Sheet 2 of 6

PID/OVA	Sample Interval	Recovered (in.)	Blow Counts / 6 in.	Retained for Analysis.	Casing Type & Size	Annulus Filler	Depth (Feet)	USCS Soil Type	Soil Description	Estimated % Of				
											Sand			
										Gravel	Coarse	Med.	Fine	Silt/Clay
	12						12	RX	TOP ONE FOOT ROCK CONE					
								SW	FOLLOWED BY 3'8"					
							13		WELL GRADED SAND	30	30	20	15	5
									WITH GRAVELS AND					
							14		COBBLES. BOTTOM IS					
									ROCK PIECES, COBBLES					
		7'4"					15		GRAVELS AND SAND					
									MIXTURE					
							16							
	17													
	17						17	RX	DRY BROWN ROCK					
							18	GW	PIECES, POWDER, GRAVEL	50	20	20	10	
								SW	COBBLE, SAND TRACE					
									FINES					
							19							
		7'10"												
							20							
							21							
							22							
	23													
	23						23	RX	DRY ROCK PIECES					
							24		AND POWDER					
							25							
		4'												
							26							
	27													
	27						27	RX						
							28							
							29							
		3'5"												
							30							
	31													
	31						31	SW	DRY WELL GRADED SAND	30	30	20	10	10
		4'7"					32		WITH GRAVELS & COBBLES					

Boring #: MW#: Project: **Sheet** 3 **of** 6

PID/OVA	Sample Interval	Recovered (in.)	Blow Counts / 6 in.	Retained for Analysis.	Casing Type & Size	Annulus Filler	Depth (Feet)	USCS Soil Type	Soil Description	Estimated % Of Gravel	Sand Coarse	Sand Med.	Sand Fine	Silt/Clay
							32							
	33													
	33						33	RX	TOP HALF FOOT. ROCK					
								SW	PIECE. FOLLOWED BY WELL					
							34		GRADED SAND WITH					
		4'							GRAVELS AND COBBLES					
							35	?	BROWN WET. AT 36'					
							36	∇	DRISSLED. SATURATED					
									06-26-08 14:42					
	37													
	37						37	RX	UP TO 15" ROCK CORE					
		2'6" CJ					38	∇?	GRANITOID					
									06-27-08 7:15AM					
	39													
CJ 39	~~34~~	CJ					39		UP TO 10" CORE					
								RX	GRANITOID					
		1'9"					40							
							41							
	42													
	42	2'3"					42	RX	UP TO 9" CORE					
	43								GRANITOID					
	43		6-27-08 14:18	∇			43	∇ RX	TOP 2'4" ROCKS UP					
									TO 18" CORE					
							44	SW	MIDDLE 2'2" SAND	30	30	20	10	10
		6'5"							WITH GRAVELS AND					
							45		COBBLES					
								RX	Bottom 1'9" ROCK					
							46							
	47													
	47						47	RX	TOP 3" TO 4".					
							48	SW	FOLLOWED BY SILTY CLAYEY	10	30	30	20	10
									SAND. FISHY SMELL					
							49		DARK GRAY. WET 8'~9'					
		5'7"							THE LEFT IS WELL GRADED	40	20	20	15	5
							50		SAND WITH GRAVEL. COBBLE					
									AND ROCK PIECES. BROWN					
							51		DRY					
	52						52							

QA/QC

Boring #: MW#: Project: Sheet 4 of 6

PID/OVA	Sample Interval	Recovered (in.)	Blow Counts / 6 in.	Retained for Analysis.	Casing Type & Size	Annulus Filler	Depth (Feet)	USCS Soil Type	Soil Description	Estimated % Of Gravel	Sand Coarse	Sand Med.	Sand Fine	Silt/Clay
	52 53	3'9"					52	Rx	ROCKS AND SOME SIDE FALL FROM ABOVE. WET					
							53	SP	DARK GRAY. FISHY SMELL FOR 1.5'	10	40	30	15	5
		6'4"					54	GW	WITH POCKETS OF CLAYEY SILT	35	20	20	15	10
							55							
							56							
	57 57						57	Rx						
		8"					58							
	59						59	Rx						
							60							
							61		6" TO ONE FOOT SOIL DRILL RIG GOES FASTER NO SAMPLE					
		3'7"					62	Rx						
							63							
							64		~8" SOIL. NO SAMPLE EASY DRILLING					
							65	Rx						
							66							
	67 67						67		ROCK PIECES INTERSPERSED WITH SOILS					
							68							
							69							
							70							
							71							
							72							

QA/QC

Boring #: MW#: Project: Sheet 5 of 6

PID/OVA	Sample Interval	Recovered (in.)	Blow Counts / 6 in.	Retained for Analysis.	Casing Type & Size	Annulus Filler	Depth (Feet)	USCS Soil Type	Soil Description	Estimated % Of				
											Sand			
										Gravel	Coarse	Med.	Fine	Silt/Clay
		3'6"					72							
							73							
							74							
							75							
							76							
	77 77						77		SAME AS ABOVE, FINE					
							78		MATERIALS WASHED OUT					
							79							
		4'4"					80							
							81							
							82							
							83							
	84 84						84	SP	TOP TWO FEET BROWN	10	30	30	20	10
		6'6"					85	RX	EASY DRILLING, TRACE FINES BOTTOM ONE FOOT					
							86		ROCK CORE					
	87 87						87							
							88							
							89							
							90							
							91							
							92							

Boring #: MW#: Project: Sheet 6 of 6

PID/OVA	Sample Interval	Recovered (in.)	Blow Counts / 6 in.	Retained for Analysis.	Casing Type & Size	Annulus Filler	Depth (Feet)	USCS Soil Type	Soil Description	Gravel	Estimated % Of Sand Coarse	Med.	Fine	Silt/Clay
	92						92	SP	10" SP.	15	35	35	10	5
							93		14" SP, ROCK PIECES MIXTURE					
		7'4"					94	SP	16" SP 3F7" ROCK PIECES MINOR SP					
							95							
							96							
	97 97						97		NO SAMPLE RECOVERED					
							98							
							99							
							100							
							101							
							102		TD=102					
							3							
							4							
							5							
							6							
							7							
							8							
							9							
							0							
							1							
							2							

QA/QC

MWH

Boring #: MW#: -3 Sheet 1 of 9

Project: SAR Groundwater Recharge Optimization Study

Job #: 1343019 Site:

Logged By: Reviewed By:

Drilling Contractor: Boart Longyear

Drill Rig Type/Method: Sonic Drilling

Drillers Name: JOSE

Borehole Diam./Drill Bit Type: 4'' CUTTING

Total Depth

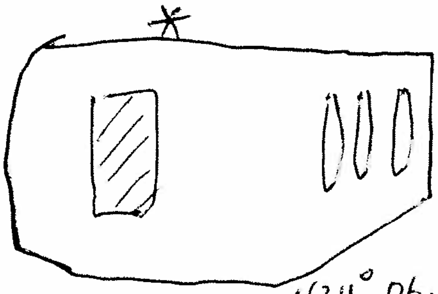
Ref. Elev.

Sampler Type:

Drill Start Time/Date: 7-7-08 13:12 Drill Finish Time/Date:

Well Completion Time/Date: 7-9-08 / 13:10

Soil Boring Backfill Time/Date:



N34° 06.185'
W117° 07.288'

Site Sketch Map

Depth to 1st Water (▽): Time/Date:

Depth to Water After Drilling (▼): Time/Date:

Depth to other Water Bearing Zones:

PID/OVA	Sample Interval	Recovered (in.)	Blow Counts / 6 in.	Retained for Analysis	Casing Type & Size	Annulus Filler	Depth (Feet)	USCS Soil Type	Soil Description	Estimated % Of				
											Sand			
										Gravel	Coarse	Medium	Fine	Silt/clay
	0	↑						SW	TOP 4 FT TAN WELL GRADED SAND WITH GRAVELS, COBBLES AND MINOR BOULDERS	15	25	25	20	15
							1							
							2							
							3							
		7'					4	RX	BOULDERS TOTAL 2 FT THICK					
							5							
		↓					6	GP	GRAVELS, COBBLES MINOR BOULDER	75	20	5		
	7 7	↑					7	RX	TOP 10" BOULDER					
							8	SP	POORLY GRADED TAN COARSE SAND WITH GRAVEL	30	45	20	5	
		5'					9	GP	GRAVELS COBBLES, MINOR BOULDERS	75	20	5		
							10							
							11							
	12	↓					12							

QA/QC

Boring #: MW#: 3 Project: Sheet 2 of 9

PID/OVA	Sample Interval	Recovered (in.)	Blow Counts / 6 in.	Retained for Analysis.	Casing Type & Size	Annulus Filler	Depth (Feet)	USCS Soil Type	Soil Description	Estimated % Of Gravel	Sand Coarse	Sand Med.	Sand Fine	Silt/Clay
	12						12	SW	TOP 1 FT TAN LIGHT	15	35	25	20	5
									GRAY WELL GRADED					
							13		COARSE SAND WITH					
									GRAVELS FOLLOWED					
		5'6"					14	SC	BY 8" SILT, SANDY SILT				35	65
								GP	GRAVELS, COBBLES AND	70	20	5	5	
							15		BOULDERS					
							16							
	17													
	17						17	RX	TOP 18" UP TO 10" LONG					
									ROCK CORE, BOULDERS					
							18	SW	TAN LIGHT GRAY	15	25	25	25	10
									WELL GRADED SAND					
							19		WITH GRAVELS, COBBLES					
									MINOR BOULDERS					
		6'4"					20							
							21							
							22							
							23							
	24													
	24						24	GW	WELL GRADED GRAVEL	60	15	15	10	
							25		WITH COBBLES AND					
		2'8"							BOULDERS, LIGHT GRAY					
							26							
	27													
	27						27	GW	<6" GRAVEL, FOLLOWED					85 CJ
							28	ML	BY GRAY SANDY CLAYEY			5	10	~~90~~
									SILT, DRY, FISHY SMELL					
							29	~~SC~~	GRADED TO SANDY SILT		~~5~~			
									BROWN SILTY SAND					
								SC			5	15	20	60
							30							
							31	GP	GRAVEL COBLES					
							32		BOULDERS					

QA/QC

Boring #: MW#: -4 Project: **Sheet** 3 **of** 9

PID/OVA	Sample Interval	Recovered (in.)	Blow Counts / 6 in.	Retained for Analysis.	Casing Type & Size	Annulus Filler	Depth (Feet)	USCS Soil Type	Soil Description	Estimated % Of Gravel	Sand Coarse	Sand Med.	Sand Fine	Silt/Clay
		6'					32							
	33 33						33	RX	TOP ONE (1) FOOT ROCK CORE + CUTTINGS					
		4'4"					34	GW	TAN WELL GRADED	40	20	20	10	10
							35							
							36							
	37 37						37	ML	GRAY SANDY CLAYEY SILT, TRACE GRAVELS			5	10	85
							38		DRY HARD					
		4'7"					39	SC	GRADED TO SILTY SAND FOR 6", FOLLOWED BY	5	15	25	25	30
							40	RX	BOULDERS					
							41							
	42	3'					42	GW	LIGHT GRAY GRAVELS WITH COBBLES AND BOULDERS	60	15	15	10	
							43							
	44 44	1'9"					44	GW	SAME AS ABOVE	60	15	15	10	
							45							
	46 46						46	SW?	WASHED OUT, DRILLER REPORTS SAND.					
							47							
							48							
							49							
							50							
		1'5"					51							
							52							

Boring #: MW#: -3 Project: Sheet 4 of 9

PID/OVA	Sample Interval	Recovered (in.)	Blow Counts / 6 in.	Retained for Analysis.	Casing Type & Size	Annulus Filler	Depth (Feet)	USCS Soil Type	Soil Description	Estimated % Of Gravel	Estimated % Of Sand: Coarse	Med.	Fine	Silt/Clay
							52							
							53							
							54							
	55 55						55	RX	1'5" LONG ROCK CORE					
		3'6"					56		POWDER AND COBBLES SANDS, GRAY					
	57 57						57	GW	BROWN, TAN WELL	35	25	20	15	5
							58		GRADED GRAVEL TOP 3 FT LESS FINES					
							59		MIDDLE 3 FT MORE FINES					
		8'5"					60		BOTTOM 2 FT MORE COBBLES	30	20	20	15	15
							61							
							62							
							63							
							64							
							65			45	30	20	5	
							66							
	67 67						67	GW	TAN, LIGHT GRAY	35	25	20	15	5
							68		WELL GRADED GRAVEL WITH COBBLES AND					
							69		BOOLDERS, ROCK CORE UP TO 6" LONG					
							70							
							71							
							72							

QA/QC

Boring #: MW#: 3 Project: **Sheet** 5 **of** 9

PID/OVA	Sample Interval	Recovered (in.)	Blow Counts / 6 in.	Retained for Analysis.	Casing Type & Size	Annulus Filler	Depth (Feet)	USCS Soil Type	Soil Description	Estimated % Of				
											Sand			
										Gravel	Coarse	Med.	Fine	Silt/Clay
		8'7"					72							
							73							
							74							
							75							
							76							
	77 77						77	SC	TOP 2 FT, TAN SILTY SAND WITH GRAVEL AND CLAY HARD. DRY	5	15	15	40	25
							78							
							79	SW	MORE COARSE GRAVEL	15	25	20	20	20
							80	SC	LIGHT GRAY. HARD	5	15	15	35	30
							81	GW	BROWN. LIGHT GRAY GRAVELS, COBBLES AND BOULDERS	30	20	20	20	10
		10'1"					82							
							83							
							84							
							85							
							86							
	87 87						87	SP	TOP 1'8" POORLY GRADED MEDIUM SAND. FOLLOWED BY ROCK CORE	5	20	45	20	10
							88							
		2'8"					89							
							90							
							91							
	92						92							

Boring #: **MW#:** 3 **Project:** **Sheet** 6 **of** 9

PID/OVA	Sample Interval	Recovered (in.)	Blow Counts / 6 in.	Retained for Analysis.	Casing Type & Size	Annulus Filler	Depth (Feet)	USCS Soil Type	Soil Description	Estimated % Of Gravel	Sand Coarse	Sand Med.	Sand Fine	Silt/Clay
	92	↑					92	SW	TAN, LIGHT GRAY WELL GRADED SAND WITH GRAVELS AND SILTS	20	20	20	20	20
							93							
		5'2"					94							
							95							
		↓					96							
	97 97	↑					97	SW	SAME AS ABOVE	15	25	25	25	10
		4'					98							
							99							
		↓					100							
	101 101	↑					101	SW	TOP 4". GRAY	15	25	25	25	10
								SC	SILTY SAND GRAY HARD	5	20	25	25	25
		7'					102							
							103	GW	TAN, LIGHT GRAY	45	20	20	10	5
								SC	GRAY SILTY CLAYEY SAND,	5	20	25	30	20
							104							
							105							
	107	↓					106	GW	BOTTOM 1', LIGHT GRAY	45	20	20	10	5
	107	↑					107	GW	TOP 1'5" THE SAME AS ABOVE	45	20	20	10	5
							108	SC	GRAY SILTY SAND WITH GRAVELS, FISHY SMELL, INTERLAYERED	5	10	20	25	40
							109							
							110	ML	WITH SANDY SILT					
							111	SW	COBBLES, GRAVELS, SANDS AND FINES MIXTURE FINE DOWN	15	20	20	25	20
		↓					112							

Boring #: **MW#:** 7 **Project:** **Sheet** 7 **of** 9

PID/OVA	Sample Interval	Recovered (in.)	Blow Counts / 6 in.	Retained for Analysis.	Casing Type & Size	Annulus Filler	Depth (Feet)	USCS Soil Type	Soil Description	Estimated % Of				
											Sand			
										Gravel	Coarse	Med.	Fine	Silt/Clay
							112	SC ML	GRAY INTERLAYERED	5	10	20	25	40
		9'5"					113	SW	GRAY WITH COBBLES GRAVELS	15	20	20	25	20
							114							
							115	SP	POORLY GRADED BROWN COARSE SAND, MINOR GRAVEL AND FINES	10	45	35	10	
	117						116							
	117						117	SC ML SW	TOP 2 FT INTERLAYERED SILTY SAND, SANDY SILT AND WELL GRADED SAND GRAY	10	20	20	25	25
							118							
							119	ML	GRAY MORE FINE AND GRAVELS, HARD	15	10	10	25	40
							120							
							121							
							122	SC SW	INTERLAYERED GRAY SILTY SAND AND WELL GRADED SAND WITH GRAVELS	10	20	20	25	25
							123							
		9'6"					124							
							125							
	127						126							
	127						127	SW	BROWN, WITH COBBLES AND INTERLAYERED WITH SILTY SAND	15	20	20	20	25
							128							
							129							
		5'6"					130							
							131							
	132						132							

Boring #: **MW#:** -3 **Project:** SBVWCD **Sheet** 8 **of** 9

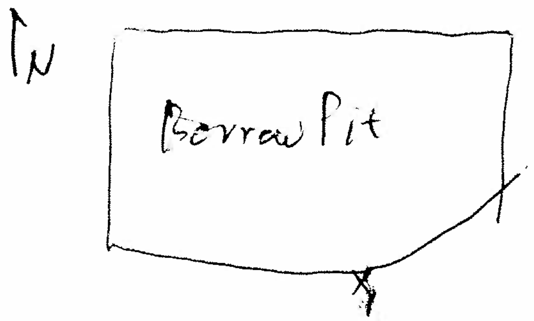
PID/OVA	Sample Interval	Recovered (in.)	Blow Counts / 6 in.	Retained for Analysis.	Casing Type & Size	Annulus Filler	Depth (Feet)	USCS Soil Type	Soil Description	Gravel	Estimated % Of Sand Coarse	Med.	Fine	Silt/Clay
	132	↑					132	MH	GRAY CLAYEY SILT			5	15	80
							133		FISHYSMELL HARD					
		5'							1'5'					
							134	SW GW	BROWN WELL GRADED	25	25	25	20	5
									COARSE SAND WITH					
							135		GRAVELS, COBBLES					
									AND BOULDERS, TRACE					
							136		FINES					
	137	↓												
	137	↑					137	RX	GRANITOID BOULDER					
									CUTTINGS					
		3'2"					138							
							139							
	140	↓												
	140	↑					140	RX	TOP 1 FT					
							141	SC	3 FT SILTY SAND WITH	10	15	20	25	40
							142		GRAVELS, COBBLES, GRAY					
							143							
							144	SW	BROWN 1 FT WELL	15	30	25	20	10
		8'4"					145		GRADED COARSE SAND					
									WITH GRAVELS, COBBLES					
							146	MH	GRAY CLAYEY SILT	10	10	10	10	60
									WITH GRAVELS, COBBLES					
							147		HARD 1'6"					
								SW	WITH GRAVELS, COBBLES	15	30	25	25	5
							148		BROWN					
							149							
	150	↓												
	150	↑					150	SP	TOP 2 FT BROW	5	35	35	20	5
							151		POORLY GRADED COARSE					
		7'							SAND					
							152							

QA/QC

Boring #: MW#: -3 Project: SBVWCD Sheet 9 of 9

PID/OVA	Sample Interval	Recovered (in.)	Blow Counts / 6 in.	Retained for Analysis.	Casing Type & Size	Annulus Filler	Depth (Feet)	USCS Soil Type	Soil Description	Estimated % Of Gravel	Sand Coarse	Med.	Fine	Silt/Clay
							2	GW	1 FT, LIGHT GRAY COBBLES, BOUDERS	60	20	15	5	
							3	SW	LIGHT GRAY. ~~ALL~~ GRAIN SIZES VARY FROM FINE TO COBBLES	20	20	20	20	20
							4							
							5							
	157						6							
	TD						7							
							8							
							9							
							0							
							1							
							2							
							3							
							4							
							5							
							6							
							7							
							8							
							9							
							0							
							1							
							2							

MWH



Site Sketch Map

Boring #: 1 MW#: 2 Sheet 1 of 5

Project: SAR Groundwater Recharge Optimization Study

Job #: 1343019 Site: SB

Logged By: CJ/AL Reviewed By:

Drilling Contractor: Boart Longyear

Drill Rig Type/Method: Sonic Drilling

Drillers Name: Jose

Borehole Diam./Drill Bit Type: 4"/CUT BIT

Total Depth

Ref. Elev.

Sampler Type: Consecutive

Drill Start Time/Date: 6-23-08 9:00 AM Drill Finish Time/Date:

Well Completion Time/Date: ABANDONED

Soil Boring Backfill Time/Date: 6-26-08 9:10 AM

Depth to 1st Water (▽): Time/Date:

Depth to Water After Drilling (▼): Time/Date:

Depth to other Water Bearing Zones:

PID/OVA	Sample Interval	Recovered (in.)	Blow Counts / 6 in.	Retained for Analysis	Casing Type & Size	Annulus Filler	Depth (Feet)	USCS Soil Type	Soil Description	Estimated % Of Gravel	Sand Coarse	Sand Medium	Sand Fine	Silt/clay
	0	↑						GW	WELL GRADED BROWN SANDY	20	25	30	20	5
									GRAVEL, GRAVEL ~3"-4"					
							1		MORE FINE THE TOP 1~2'					
									BELOW MORE GRAVEL, DRY					
							2		WEATHERED GRANOID.	↑	↑	↑	↑	↑
									QUARTZ, FELDSPAR, LESS					
							3		MINOR MAFIC MINERALS					
		4'9"							TRACE MICA					
							4							
		↓	~~4~~				5							
										40	25	15	15	5
							6							
	7	↓								↓	↓	↓	↓	↓
	7	↑					7	GW	SAME AS ABOVE, MORE	↑	↑	↑	↑	↑
									BOULDERS, PEBBLES, COBBIES	45	30	10	10	5
							8							
		7'					9							
							10							
		↓					11			↓	↓	↓	↓	↓
	12						12	RX	6.5" GRANOID					

QA/QC

Boring #: 1 MW#: 2 Project: SBVMWD **Sheet** 2 **of** 5

PID/OVA	Sample Interval	Recovered (in.)	Blow Counts / 6 in.	Retained for Analysis.	Casing Type & Size	Annulus Filler	Depth (Feet)	USCS Soil Type	Soil Description	Estimated % Of Gravel	Sand Coarse	Sand Med.	Sand Fine	Silt/Clay
	12 13	12"					12	GW RX	SAME AS ABOVE, ROCK POWDER	45	30	10	10	5
	13	↑					13		SAME AS ABOVE MORE GRAVELS, COBBLES AND BOULDERS	↕				
		3'5"					14			50	25	10	10	5
		↓					15			↓				
	17						16							
	17	↑					17		SAME AS ABOVE	45	30	10	10	5
							18			↓	↓	↓	↓	↓
							19							
							20							
		8'8"					21							
		↓					22							
							23	SW	~~W~~ELL GRADED SAND WITH CLAY AND GRAVEL. BROWN MORE FINE	15	20	30	20	15
							24			↓	↓	↓	↓	↓
	26						25	RX	ROCKS, ~~BOTTOM 8" MORE FINE.~~	50	25	10	10	5
	26 27	1'8"					26	GW	BOTTOM 8" MORE FINE	30	20	20	15	15
	27	↑					27	GW RX GW	BOULDER, GRAVEL, SAND AND CLAY MIXTURE	50	20	10	10	15
		1'					28							
		↓					29							
	31						30							
	31	↑					31	RX	TRUNCATES OF BOULDERS AND ROCK POWDER	30	20	10	10	15
							32							

Boring #: 1 MW#: 2 Project: SBVMWD Sheet 3 of 5

PID/OVA	Sample Interval	Recovered (in.)	Blow Counts / 6 in.	Retained for Analysis.	Casing Type & Size	Annulus Filler	Depth (Feet)	USCS Soil Type	Soil Description	Estimated % Of	Sand			
										Gravel	Coarse	Med.	Fine	Silt/Clay
		1'7"					32	GW	FEW GRAVELS SANDS AND FINES.					
							33							
							34							
	36						35							
	36 37	3'					36	RX GW	CYLINDRICAL ROCKS + POWDER. FEW SANDS AND FINES	80	5	5	5	5
	37						37							
		1'3"					38	RX GW	SAME AS ABOVE	80	5	5	5	5
							39							
	41						40							
	41						41	GW RX	CONE FROM BOULDER GRAVELS FEW SANDS AND FINES	80	5	5	5	5
							42							
		8'2"					43							
							44							
							45							
	47						46							
	47						47	GW RX	SAME AS ABOVE.					
	47' To ~~48~~ 52'						48							
							49							
							50							
		1'6"					51							
							52							

QA/QC

Boring #: 1 MW#: 2 Project: SBVMWD Sheet 4 of 5

PID/OVA	Sample Interval	Recovered (in.)	Blow Counts / 6 in.	Retained for Analysis.	Casing Type & Size	Annulus Filler	Depth (Feet)	USCS Soil Type	Soil Description	Estimated % Of Gravel	Sand Coarse	Med.	Fine	Silt/Clay
	52						52	GW	COBBLES, PEBBLES	70	10	10	5	5
		2'						RX	GRAVELS AND SANDS					
							53		MINOR FINES					
	54													
							54	GW	SAME AS ABOVE	60	15	15	5	5
								RX	SLIGHTLY MORE FINE					
		4'11"					55							
							56							
	57													
	57						57	RX	BROKEN ROCK PIECES	70	10	10	5	5
								GW	GRAVELS, MINOR FINES					
							58							
							59							
		1'3"												
							60							
							61							
	62													
	62						62	RX	BROKEN ROCK PIECES					
									CORE					
							63							
							64							
		5'												
							65							
							66							
	67													
	67						67	RX	BROKEN ROCK PIECES					
									CORE					
							68							
							69							
		1'3"												
							70							
							71							
	72						72							

Boring #: 1 MW#: 2 Project: Sheet 5 of 5

PID/OVA	Sample Interval	Recovered (in.)	Blow Counts / 6 in.	Retained for Analysis.	Casing Type & Size	Annulus Filler	Depth (Feet)	USCS Soil Type	Soil Description	Estimated % Of				
											Sand			
										Gravel	Coarse	Med.	Fine	Silt/Clay
	72 73	1'7"					72	RX	ROCK PIECES AND POWDER					
							73	GW	MIXTURE OF SAND GRAVEL	60	15	15	5	5
		2'7"					74	RX	BROKEN ROCK PIECES AND POWDER					
							75							
	76 76	1'11"					76	RX	BROKEN ROCK PIECES AND POWDER					
	77 77						77	GW RX	MIXTURE OF SAND GRAVEL, BOTTOM ROCK PIECES	60	15	15	5	5
							78							
		2'2"					79							
							80							
							81							
	82 82						82	RX	BROKEN RX, POWDER					
							83							
		4'4"					84							
							85							
							86							
	87 87						87	RX GW	SAND GRAVEL RX PIECES, POWDER	60	15	15	5	5
							88							
							89							
		7'					90							
							91							
	92						92							

QA/QC

MWH

Boring #: SS01 MW#: Sheet 1 of 1

Project: SAR Groundwater Recharge Optimization Study

Job #: 1343019 .0101 Site: Soil Borrow

Logged By: A. Leavitt Reviewed By:

Drilling Contractor: ~~Boart Longyear~~ MWH

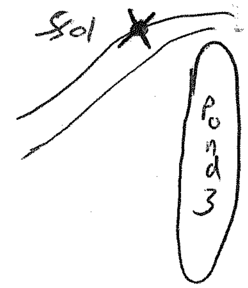
Drill Rig Type/Method: ~~Sonic Drilling~~ hand sampling

Drillers Name: A. Leavitt

Borehole Diam./Drill Bit Type:

Total Depth 1'

Ref. Elev. -



Site Sketch Map

Sampler Type: hand sample

Depth to 1st Water (▽): - Time/Date: -

Drill Start Time/Date: 6-18-08 Drill Finish Time/Date: 6-18-08

Depth to Water After Drilling (▼): - Time/Date: -

Well Completion Time/Date: —

Depth to other Water Bearing Zones: -

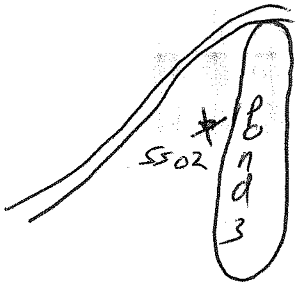
Soil Boring Backfill Time/Date: 6-18-08

PID/OVA	Sample Interval	Recovered (in.)	Blow Counts / 6 in.	Retained for Analysis	Casing Type & Size	Annulus Filler	Depth (Feet)	USCS Soil Type	Soil Description	Estimated % Of				
										Gravel	Sand			Silt/clay
											Coarse	Medium	Fine	
	X	X						SW	tan/brown, dry, poorly cemented, loose, quartz/feldspar, mica, rock chips, up to 6".	15	20	25	30	10
							1							
							2							
							3		GPS: 001 - N 34° 06.143' W 117° 06.901'					
							4							
							5							
							6							
							7							
							8							
							9							
							10							
							11							
							12							

QA/QC

MWH

Boring #: SS-02 MW#:	Sheet 1 of 1
Project: SAR Groundwater Recharge Optimization Study	
Job #: 1343019	Site: Soil borrow
Logged By: A. Leavitt	Reviewed By:
Drilling Contractor: ~~Boart Longyear~~ MWH	
Drill Rig Type/Method: ~~Sonic Drilling~~ hand sampling	
Drillers Name: A. Leavitt	
Borehole Diam./Drill Bit Type: —	Total Depth 1'
	Ref. Elev. —
Sampler Type: hand sampling	
Drill Start Time/Date: 6-18-08	Drill Finish Time/Date: 6-18-08
Well Completion Time/Date: —	
Soil Boring Backfill Time/Date: 6-18-08	



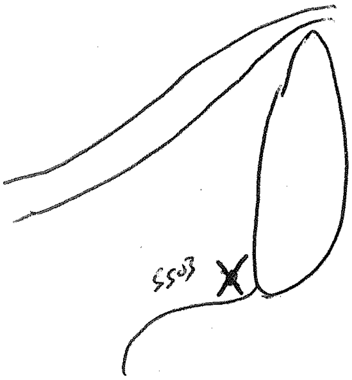
Site Sketch Map

Depth to 1st Water (▽):	—	Time/Date:	—
Depth to Water After Drilling (▼):	—	Time/Date:	—
Depth to other Water Bearing Zones:	—		

PID/OVA	Sample Interval	Recovered (in.)	Blow Counts / 6 in.	Retained for Analysis	Casing Type & Size	Annulus Filler	Depth (Feet)	USCS Soil Type	Soil Description	Estimated % Of Gravel	Sand Coarse	Sand Medium	Sand Fine	Silt/clay
	X	X						SW	sand well graded with gravel, dry, Yellowish brown, loose,	15	20	25	30	10
							1		quartz/feldspar/mica, rock chips up to 6", rounded to					
							2		angular,					
							3		- first 3" surface with Plant roots					
							4		- surface hard compacted					
							5		with desert plants					
							6		GPS :002 - N 34° 06.086 W 117°06.904					
							7							
							8							
							9							
							10							
							11							
							12							

QA/QC

MWH



Site Sketch Map

Boring #: SS03 MW#: **Sheet** 1 **of** 1

Project: SAR Groundwater Recharge Optimization Study

Job #: 1343019 Site: Soil Borrow

Logged By: A. Leavitt Reviewed By:

Drilling Contractor: ~~Boart Longyear~~ MWH

Drill Rig Type/Method: ~~Sonic Drilling~~ hand sampling

Drillers Name: A. Leavitt

Borehole Diam./Drill Bit Type: —

Total Depth 1'

Ref. Elev. —

Sampler Type: hand sampling

Drill Start Time/Date: 6-18-08 Drill Finish Time/Date: 6-18-08

Well Completion Time/Date: —

Soil Boring Backfill Time/Date: 6-18-08

Depth to 1st Water (▽): — Time/Date: —

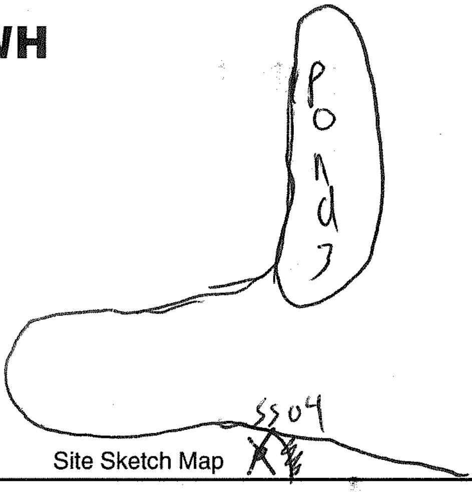
Depth to Water After Drilling (▼): — Time/Date: —

Depth to other Water Bearing Zones: —

PID/OVA	Sample Interval	Recovered (in.)	Blow Counts / 6 in.	Retained for Analysis	Casing Type & Size	Annulus Filler	Depth (Feet)	USCS Soil Type	Soil Description	Estimated % Of				
											Sand			
										Gravel	Coarse	Medium	Fine	Silt/clay
	X	X						SW	Sand well graded with gravel, dry, yellowish brown, loose,	20	20	25	25	10
							1		quartz/feldspar/mica, rock chips up to 4", angular to					
							2		rounded					
							3		- first 3" surface with plantroots					
							4		- surface hard compacted with desert plants					
							5		GPS: 003- N 34° 06.026'					
							6		W 117° 06.904					
							7							
							8							
							9							
							10							
							11							
							12							

QA/QC

MWH



Site Sketch Map

Boring #: SS04 MW#: **Sheet** 1 **of** 1

Project: SAR Groundwater Recharge Optimization Study

Job #: 1343019 Site: Soil Borrow

Logged By: A. Leavitt Reviewed By:

Drilling Contractor: ~~Boart Longyear~~ MWH

Drill Rig Type/Method: ~~Sonic Drilling~~ hand sampling

Drillers Name: A. Leavitt

Borehole Diam./Drill Bit Type: —

Total Depth 1'

Ref. Elev. -

Sampler Type: hand Sampling

Drill Start Time/Date: 6-18-08 Drill Finish Time/Date: 6-18-08

Well Completion Time/Date: —

Soil Boring Backfill Time/Date: 6-18-08

Depth to 1st Water (▽): — Time/Date: —

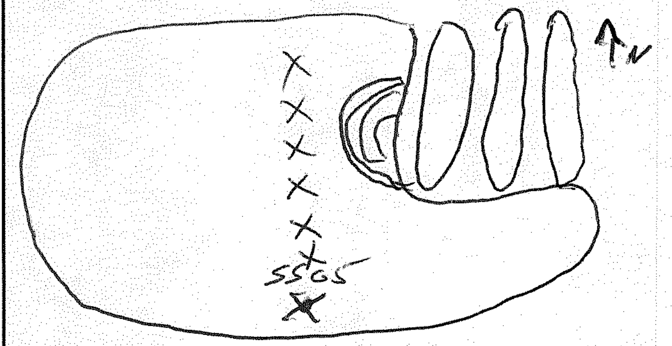
Depth to Water After Drilling (▼): — Time/Date: —

Depth to other Water Bearing Zones: —

PID/OVA	Sample Interval	Recovered (in.)	Blow Counts / 6 in.	Retained for Analysis	Casing Type & Size	Annulus Filler	Depth (Feet)	USCS Soil Type	Soil Description	Estimated % Of Gravel	Sand Coarse	Sand Medium	Sand Fine	Silt/clay
	X	X						sw	Sand well graded with gravel, dry, yellowish brown, loose,	25	20	20	25	10
							1		quartz/feldspars/mica, rock chips up to 4", angular to					
							2		rounded					
							3		- first 3" surface with plant roots					
							4		-surface hard compacted with desert plants					
							5							
							6		-GPS: 004 - N34° 05.951 W117° 06.888					
							7							
							8							
							9							
							10							
							11							
							12							

QA/QC

MWH



Site Sketch Map

Boring #: SS05 MW#: **Sheet** 1 **of** 1

Project: SAR Groundwater Recharge Optimization Study

Job #: 1343019 Site: Soil borrow

Logged By: A. Leavitt Reviewed By:

Drilling Contractor: ~~Boart Longyear~~ MWH

Drill Rig Type/Method: ~~Sonic Drilling~~ hand sampling

Drillers Name: A. Leavitt

Borehole Diam./Drill Bit Type: —

Total Depth 1'

Ref. Elev. -

Sampler Type: hand Sampling

Drill Start Time/Date: 6-18-08 Drill Finish Time/Date: 6-18-08

Well Completion Time/Date: —

Soil Boring Backfill Time/Date: 6-18-08

Depth to 1st Water (▽): — Time/Date: —

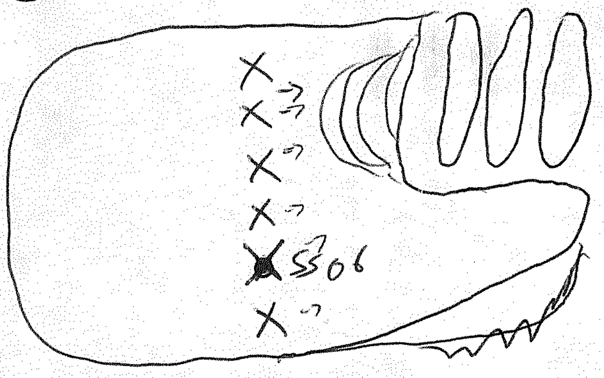
Depth to Water After Drilling (▼): — Time/Date: —

Depth to other Water Bearing Zones: —

PID/OVA	Sample Interval	Recovered (in.)	Blow Counts / 6 in.	Retained for Analysis	Casing Type & Size	Annulus Filler	Depth (Feet)	USCS Soil Type	Soil Description	Estimated % Of				
											Sand			
										Gravel	Coarse	Medium	Fine	Silt/clay
	X	X						sw	Sand well graded with gravel, dry, yellowish brown, loose,	20	20	25	25	10
							1		quartz/feldspar/mica, rock chips up to 2", angular to					
							2		rounded.					
							3		-first 2" surface with plant roots.					
							4		-surface hard compacted with desert plants					
							5							
							6		GPS: 005 - N 34° 05.872' W 117° 06.999'					
							7							
							8							
							9							
							10							
							11							
							12							

QA/QC

MWH



Site Sketch Map

Boring #: SS06 MW#: **Sheet** 1 **of** 1

Project: SAR Groundwater Recharge Optimization Study

Job #: 1343019 Site: Soil Borrow

Logged By: A. Leavitt Reviewed By:

Drilling Contractor: ~~Boart Longyear~~ MWH

Drill Rig Type/Method: ~~Sonic Drilling~~ hand sampling

Drillers Name: A. Leavitt

Borehole Diam./Drill Bit Type: — **Total Depth** 1'

Ref. Elev. —

Sampler Type: hand sampling

Drill Start Time/Date: 6-18-08 Drill Finish Time/Date: 6-18-08

Well Completion Time/Date: —

Soil Boring Backfill Time/Date: 6-18-08

Depth to 1st Water (▽): — Time/Date: —

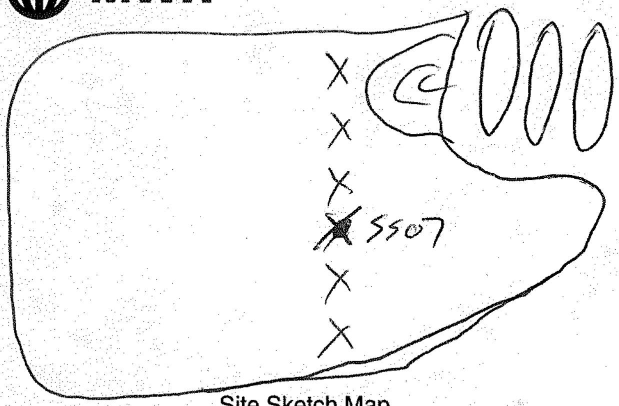
Depth to Water After Drilling (▼): — Time/Date: —

Depth to other Water Bearing Zones: —

PID/OVA	Sample Interval	Recovered (in.)	Blow Counts / 6 in.	Retained for Analysis	Casing Type & Size	Annulus Filler	Depth (Feet)	USCS Soil Type	Soil Description	Estimated % Of				
											Sand			
										Gravel	Coarse	Medium	Fine	Silt/clay
	X	X						Gw	Sand well graded with gravel, dry, yellowish brown, loose,	25	20	20	25	10
							1		quartz/feldspar/mica, rock chips up to 2", angular to					
							2		rounded - very compacted and hard to get through					
							3		- surface is gravelly, hard					
							4		compacted.					
							5		GPS: 006 - N34° 05.926'					
							6		W117° 07.002'					
							7							
							8							
							9							
							10							
							11							
							12							

QA/QC

MWH



Site Sketch Map

Depth to 1st Water (▽): — Time/Date: —

Depth to Water After Drilling (▼): — Time/Date: —

Depth to other Water Bearing Zones: —

Boring #: SS07 MW#: Sheet 1 of —

Project: SAR Groundwater Recharge Optimization Study

Job #: 1343019 Site: Soil Borrow

Logged By: A. Leavitt Reviewed By:

Drilling Contractor: ~~Boart Longyear~~ MWH

Drill Rig Type/Method: ~~Sonic Drilling~~ hand sampling

Drillers Name: A. Leavitt

Borehole Diam./Drill Bit Type: —

Total Depth: 1'

Ref. Elev.: —

Sampler Type: hand sampling

Drill Start Time/Date: 6-18-08 Drill Finish Time/Date: 6-18-08

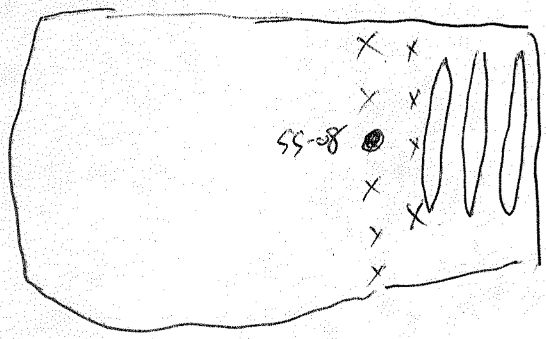
Well Completion Time/Date: —

Soil Boring Backfill Time/Date: 6-18-08

PID/OVA	Sample Interval	Recovered (in.)	Blow Counts / 6 in.	Retained for Analysis	Casing Type & Size	Annulus Filler	Depth (Feet)	USCS Soil Type	Soil Description	Estimated % Of				
											Sand			
										Gravel	Coarse	Medium	Fine	Silt/clay
	X	X						SW	sand well graded with gravel, dry, yellowish brown/greyish	15 ~~20~~	25 ~~20~~	25	25	10
							1		brown, loose, quartz/ feldspar/mica, rock chips					
							2		up to 2", angular to rounded, very compacted and hard					
							3		to dig through.					
							4		-surface hard/compacted					
							5							
							6		GPS: 007 - N 34° 05.986' W 117° 07.011'					
							7							
							8							
							9							
							10							
							11							
							12							

QA/QC

MWH



Site Sketch Map

Boring #: SS-08 MW#: **Sheet** 1 **of** 1

Project: SAR Groundwater Recharge Optimization Study

Job #: 1343019 Site: Soil Borrow

Logged By: A. Leavitt Reviewed By:

Drilling Contractor: ~~Boart Longyear~~ MWH

Drill Rig Type/Method: ~~Sonic Drilling~~ hand sampling

Drillers Name: A. Leavitt

Borehole Diam./Drill Bit Type: — **Total Depth** 1'

Ref. Elev. —

Sampler Type: hand sampling

Drill Start Time/Date: 06-18-08 Drill Finish Time/Date: 6-18-08

Depth to 1st Water (▽): — Time/Date: —

Depth to Water After Drilling (▼): — Time/Date: —

Depth to other Water Bearing Zones: —

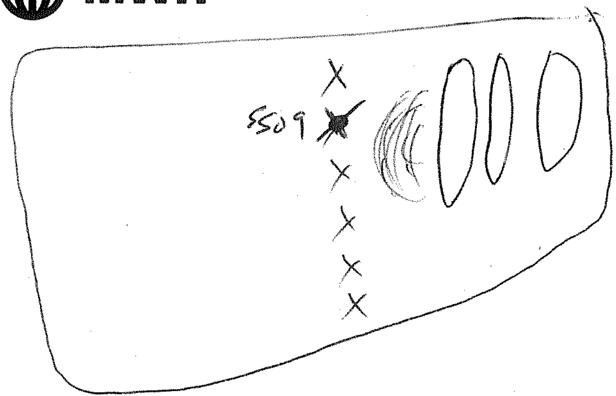
Well Completion Time/Date: —

Soil Boring Backfill Time/Date: 6-18-08

PID/OVA	Sample Interval	Recovered (in.)	Blow Counts / 6 in.	Retained for Analysis	Casing Type & Size	Annulus Filler	Depth (Feet)	USCS Soil Type	Soil Description	Estimated % Of				
											Sand			
										Gravel	Coarse	Medium	Fine	Silt/clay
	X	X						SW	Sand well graded with gravel, dry, yellowish brown/light brown,	15	25	25	25	10
							1		loose, quartz/feldspar/mica, rock chips up to 4", angular					
							2		to rounded.					
							3		-first 2"-3" plant roots -surface hard compacted					
							4		with desert plants					
							5		GPS: 008 - N 34° 06.042'					
							6		W 117° 07.019'					
							7							
							8							
							9							
							10							
							11							
							12							

QA/QC

MWH



Site Sketch Map

Boring #: SS-09 MW#: **Sheet** 1 **of** 1

Project: SAR Groundwater Recharge Optimization Study

Job #: 1343019 Site: Soil Borrow

Logged By: A. Leavitt Reviewed By:

Drilling Contractor: ~~Boart Longyear~~ MWH

Drill Rig Type/Method: ~~Sonic Drilling~~ hand sampling

Drillers Name: A. Leavitt

Borehole Diam./Drill Bit Type: — **Total Depth** 1'

Ref. Elev. —

Sampler Type: hand sampling

Drill Start Time/Date: 6-18-08 Drill Finish Time/Date: 6-18-08

Well Completion Time/Date: —

Soil Boring Backfill Time/Date: 6-18-08

Depth to 1st Water (▽): — Time/Date: —

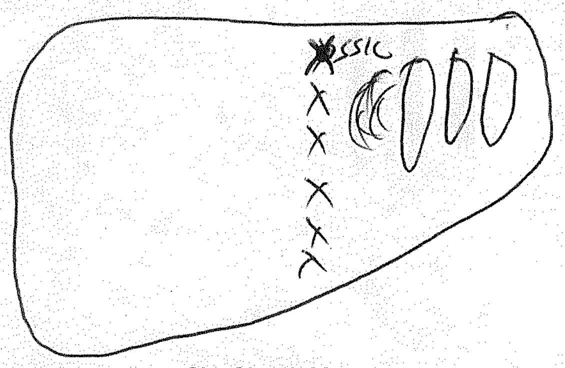
Depth to Water After Drilling (▼): — Time/Date: —

Depth to other Water Bearing Zones: —

PID/OVA	Sample Interval	Recovered (in.)	Blow Counts / 6 in.	Retained for Analysis	Casing Type & Size	Annulus Filler	Depth (Feet)	USCS Soil Type	Soil Description	Estimated % Of Gravel	Estimated % Of Sand Coarse	Estimated % Of Sand Medium	Estimated % Of Sand Fine	Estimated % Of Silt/clay
	X	X						SW	sand well graded with gravel, dry, yellowish brown. >slightly	15	25	25	25	10
							1		damp 6" down, loose, quartz/ feldspars/mica, rock chips					
							2		up to 1", angular to subrounded					
							3		-surface compacted/hard with desert plants					
							4							
							5		GPS: 009 - N 34° 06.089' W 117° 07.001'					
							6							
							7							
							8							
							9							
							10							
							11							
							12							

QA/QC

MWH



Site Sketch Map

Boring #: SS10 MW#: **Sheet** 1 **of** 1

Project: SAR Groundwater Recharge Optimization Study

Job #: 1343019 Site: Soil Borrow

Logged By: A. Leavitt Reviewed By:

Drilling Contractor: ~~Boart Longyear~~ MWH

Drill Rig Type/Method: ~~Sonic Drilling~~ hand sampling

Drillers Name: A. Leavitt

Borehole Diam./Drill Bit Type: —

Total Depth 1'

Ref. Elev. —

Sampler Type: hand sampling

Drill Start Time/Date: 6-18-08 Drill Finish Time/Date: 6-18-08

Well Completion Time/Date: —

Soil Boring Backfill Time/Date: 6-18-08

Depth to 1st Water (▽): — Time/Date: —

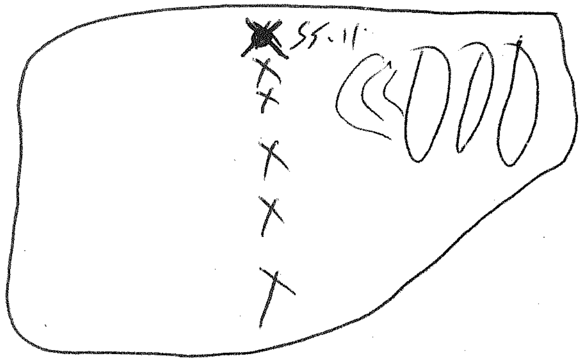
Depth to Water After Drilling (▼): — Time/Date: —

Depth to other Water Bearing Zones: —

PID/OVA	Sample Interval	Recovered (in.)	Blow Counts / 6 in.	Retained for Analysis	Casing Type & Size	Annulus Filler	Depth (Feet)	USCS Soil Type	Soil Description	Estimated % Of				
											Sand			
										Gravel	Coarse	Medium	Fine	Silt/clay
	X	X						SV	Sand (gravelly) well graded with gravel, dry, yellowish brown,	30	25	20	20	5
							1		loose, quartz/feldspar/mica, ~~angular~~ rock chips up to 7";					
							2		angular to rounded.					
							3		-surface hard/compacted, with desert plants (minor)					
							4		☆ much more gravel, especially					
							5		large gravel, than the rest of the row!					
							6							
							7		GPS: 010 - N 34° 06.145' W 117° 06.991'					
							8							
							9							
							10							
							11							
							12							

QA/QC

MWH



Site Sketch Map

Boring #: SS 11 MW#: **Sheet** 1 **of** 1

Project: SAR Groundwater Recharge Optimization Study

Job #: 1343019 Site: Soil Borrow

Logged By: A. Leavitt Reviewed By:

Drilling Contractor: ~~Boart Longyear~~ MWH

Drill Rig Type/Method: ~~Sonic Drilling~~ hand sampling

Drillers Name: A. Leavitt

Borehole Diam./Drill Bit Type: —

Total Depth 1'

Ref. Elev. —

Sampler Type: hand sampling

Depth to 1st Water (▽): — Time/Date: —

Drill Start Time/Date: 6-18-08 Drill Finish Time/Date: 6-18-08

Depth to Water After Drilling (▼): — Time/Date: —

Well Completion Time/Date: —

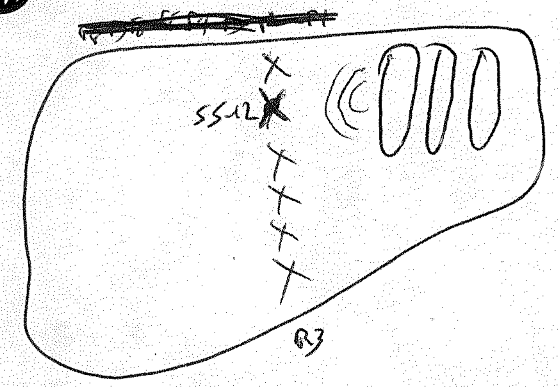
Depth to other Water Bearing Zones: —

Soil Boring Backfill Time/Date: 6-18-08

PID/OVA	Sample Interval	Recovered (in.)	Blow Counts / 6 in.	Retained for Analysis	Casing Type & Size	Annulus Filler	Depth (Feet)	USCS Soil Type	Soil Description	Estimated % Of Gravel	Estimated % Of Sand Coarse	Estimated % Of Sand Medium	Estimated % Of Sand Fine	Estimated % Of Silt/clay
	X	X						SW	sand well graded with gravel, dry, yellowish brown, loose,	20	25	25	25	5
							1		quartz/feldspars/mica, rock chips up to 6", angular to					
							2		rounded					
							3		-surface hard/compacted with minor desert plants					
							4							
							5		GPS: 011 - N 34° 06.146' W 117° 07.059'					
							6							
							7							
							8							
							9							
							10							
							11							
							12							

QA/QC

MWH



Site Sketch Map

Boring #: SS-12 MW#: **Sheet** 1 **of** 1

Project: SAR Groundwater Recharge Optimization Study

Job #: 1343019 Site: Soil Borrow

Logged By: A. Leavitt Reviewed By:

Drilling Contractor: ~~Boart Longyear~~ MWH

Drill Rig Type/Method: ~~Sonic Drilling~~ hand sampling

Drillers Name: A. Leavitt

Borehole Diam./Drill Bit Type: –

Total Depth 1'

Ref. Elev. –

Sampler Type: hand sampling

Drill Start Time/Date: 6-18-08 Drill Finish Time/Date: 6-18-08

Well Completion Time/Date: –

Soil Boring Backfill Time/Date: 6-18-08

Depth to 1st Water (∇): – Time/Date: –

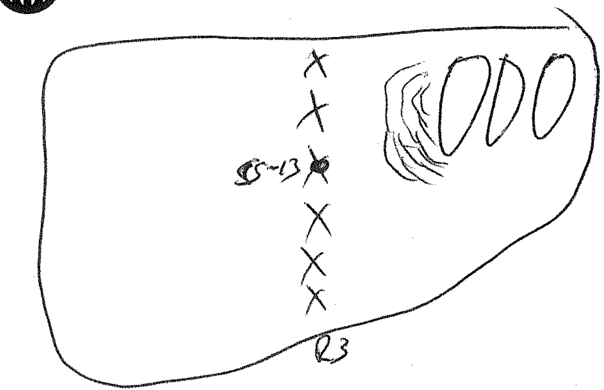
Depth to Water After Drilling (▼): – Time/Date: –

Depth to other Water Bearing Zones: –

PID/OVA	Sample Interval	Recovered (in.)	Blow Counts / 6 in.	Retained for Analysis	Casing Type & Size	Annulus Filler	Depth (Feet)	USCS Soil Type	Soil Description	Estimated % Of				
											Sand			
										Gravel	Coarse	Medium	Fine	Silt/clay
	X	X						SW	sand well graded with gravel, dry, yellowish brown, loose,	20	20	25	25	10
							1		quartz/feldspars/mica, rock chips upto 3", angular to					
							2		rounded.					
							3		-surface hard and compacted					
							4		GPS:012 : N34° 06.089					
							5		W117° 07.056					
							6							
							7							
							8							
							9							
							10							
							11							
							12							

QA/QC

MWH



Site Sketch Map

Boring #: SS13 MW#: **Sheet** 1 **of** 1

Project: SAR Groundwater Recharge Optimization Study

Job #: 1343019 Site: Soil Borrow

Logged By: A. Leavitt Reviewed By:

Drilling Contractor: ~~Boart Longyear~~ MWH

Drill Rig Type/Method: ~~Sonic Drilling~~ hand sampling

Drillers Name: A. Leavitt

Borehole Diam./Drill Bit Type: —

Total Depth 1'

Ref. Elev. —

Sampler Type: hand sampling

Drill Start Time/Date: 6-18-08 Drill Finish Time/Date: 6-18-08

Depth to 1st Water (▽): — Time/Date: —

Depth to Water After Drilling (▼): — Time/Date: —

Depth to other Water Bearing Zones: —

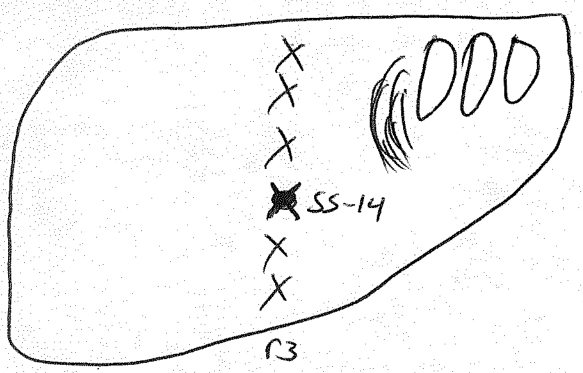
Well Completion Time/Date: —

Soil Boring Backfill Time/Date: 6-18-08

PID/OVA	Sample Interval	Recovered (in.)	Blow Counts / 6 in.	Retained for Analysis	Casing Type & Size	Annulus Filler	Depth (Feet)	USCS Soil Type	Soil Description	Estimated % Of				
											Sand			
										Gravel	Coarse	Medium	Fine	Silt/clay
	X	X						SW	sand well graded with gravel, dry, yellowish brown, loose,	15	20	25	30	10
							1		quartz, feldspar, mica, rock chips up to 4", angular to					
							2		rounded					
							3		-surface hard but not as compacted as the other					
							4		holes thus far (rows 1, 2, and the first holes in row 3).					
							5							
							6		GPS: 013 - N34° 06.030' W117° 07.067'					
							7							
							8							
							9							
							10							
							11							
							12							

QA/QC

MWH



Site Sketch Map

Boring #: SS14 MW#: **Sheet** 1 **of** 1

Project: SAR Groundwater Recharge Optimization Study

Job #: 1343019 Site: Soil Borrow

Logged By: A. Leavitt Reviewed By:

Drilling Contractor: ~~Boart Longyear~~ MWH

Drill Rig Type/Method: ~~Sonic Drilling~~ Handsampling

Drillers Name: A. Leavitt

Borehole Diam./Drill Bit Type: –

Total Depth 1'

Ref. Elev. –

Sampler Type: handsampling

Drill Start Time/Date: 6-18-08 Drill Finish Time/Date: 6-18-08

Well Completion Time/Date: –

Soil Boring Backfill Time/Date: 6-18-08

Depth to 1st Water (▽): – Time/Date: –

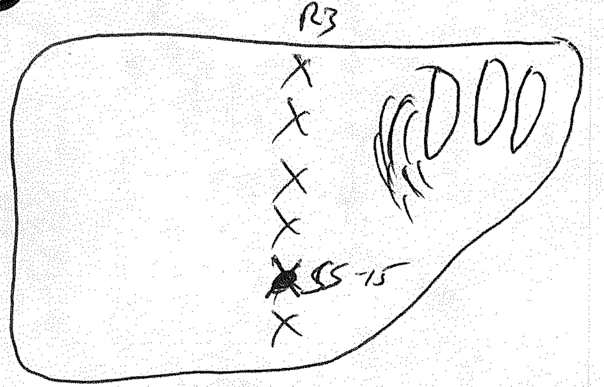
Depth to Water After Drilling (▼): – Time/Date: –

Depth to other Water Bearing Zones: –

PID/OVA	Sample Interval	Recovered (in.)	Blow Counts / 6 in.	Retained for Analysis	Casing Type & Size	Annulus Filler	Depth (Feet)	USCS Soil Type	Soil Description	Estimated % Of				
											Sand			
										Gravel	Coarse	Medium	Fine	Silt/clay
	X	X						SW	sand well graded with gravel, dry, Yellowish brown, loose,	15	25	25	25	10
							1		quartz/feldspar/mica, rock chips up to 2", angular to					
							2		rounded					
							3		Surface is hard and compacted, with some desert plants					
							4							
							5		GPS; 014 - N34°05.970' W117°07.075'					
							6							
							7							
							8							
							9							
							10							
							11							
							12							

QA/QC

MWH



Site Sketch Map

Boring #: SS-15 MW#: **Sheet** 1 **of** 1

Project: SAR Groundwater Recharge Optimization Study

Job #: 1343019 Site: Soil Borrow

Logged By: A. Leavitt Reviewed By:

Drilling Contractor: ~~Boart Longyear~~ MWH

Drill Rig Type/Method: ~~Sonic Drilling~~ hand sampling

Drillers Name: A. Leavitt

Borehole Diam./Drill Bit Type: — **Total Depth** 1'

Ref. Elev. —

Sampler Type: hand sampling

Drill Start Time/Date: 6-18-08 Drill Finish Time/Date: 6-18-08

Well Completion Time/Date: —

Soil Boring Backfill Time/Date: 6-18-08

Depth to 1st Water (▽): — Time/Date: —

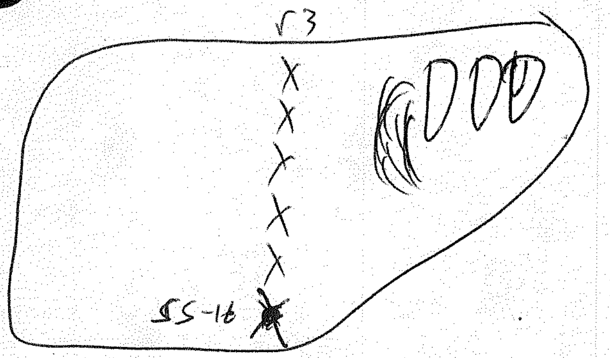
Depth to Water After Drilling (▼): — Time/Date: —

Depth to other Water Bearing Zones: —

PID/OVA	Sample Interval	Recovered (in.)	Blow Counts / 6 in.	Retained for Analysis	Casing Type & Size	Annulus Filler	Depth (Feet)	USCS Soil Type	Soil Description	Estimated % Of				
											Sand			
										Gravel	Coarse	Medium	Fine	Silt/clay
	X	X					1	SW	sand well graded with gravel, dry, Yellowish brown, loose,	15	25	25	25	10
							2		Quartz/feldspar/mica, rock chips up to 2.5", angular to					
							3		rounded					
							4		surface hard/compacted, with some desert plants					
							5							
							6		GPS: 015 - N34°05.909' W117°07.082'					
							7							
							8							
							9							
							10							
							11							
							12							

QA/QC

MWH



Site Sketch Map

Boring #: SS-16 MW#: Sheet 1 of 1

Project: SAR Groundwater Recharge Optimization Study

Job #: 1343019 Site: Soil Borrow

Logged By: A. Leavitt Reviewed By:

Drilling Contractor: ~~Boart Longyear~~ MWH

Drill Rig Type/Method: ~~Sonic Drilling~~ hand sampling

Drillers Name: A. Leavitt

Borehole Diam./Drill Bit Type: –

Total Depth 1'

Ref. Elev. –

Sampler Type: hand sampling

Drill Start Time/Date: 6-18-08 Drill Finish Time/Date: 6-18-08

Well Completion Time/Date: –

Soil Boring Backfill Time/Date: 6-18-08

Depth to 1st Water (▽): – Time/Date: ~

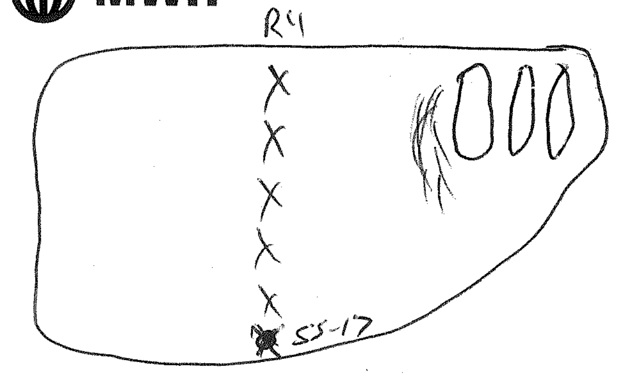
Depth to Water After Drilling (▼): – Time/Date: –

Depth to other Water Bearing Zones: –

PID/OVA	Sample Interval	Recovered (in.)	Blow Counts / 6 in.	Retained for Analysis	Casing Type & Size	Annulus Filler	Depth (Feet)	USCS Soil Type	Soil Description	Estimated % Of				
											Sand			
										Gravel	Coarse	Medium	Fine	Silt/clay
	X	X						SW	sand well graded with gravel, dry, yellowish brown, loose,	15	25	25	25	10
							1		quartz/feldspar/mica, rock chips upto 2", angular to					
							2		rounded					
							3		surface hard /compacted, with some desert plants					
							4							
							5		GPS: 016 – N34°05.851' W117°07.085'					
							6							
							7							
							8							
							9							
							10							
							11							
							12							

QA/QC

MWH



Site Sketch Map

Depth to 1st Water (▽): — Time/Date: /

Depth to Water After Drilling (▼): — Time/Date: /

Depth to other Water Bearing Zones: —

Boring #: SS17 MW#: **Sheet** 1 **of** 1

Project: SAR Groundwater Recharge Optimization Study

Job #: 1343019 Site: Soil Borrow

Logged By: A. Leavitt Reviewed By:

Drilling Contractor: ~~Boart Longyear~~ MWH

Drill Rig Type/Method: ~~Sonic Drilling~~ hand sampling

Drillers Name: A. Leavitt

Borehole Diam./Drill Bit Type: —

Total Depth 1'

Ref. Elev. —

Sampler Type: hand sampling

Drill Start Time/Date: 6-18-08 Drill Finish Time/Date: 6-18-08

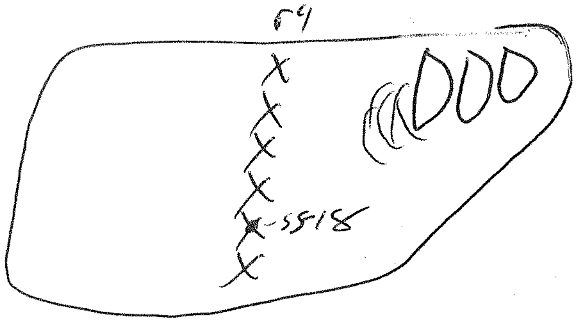
Well Completion Time/Date: —

Soil Boring Backfill Time/Date: 6-18-08

PID/OVA	Sample Interval	Recovered (in.)	Blow Counts / 6 in.	Retained for Analysis	Casing Type & Size	Annulus Filler	Depth (Feet)	USCS Soil Type	Soil Description	Estimated % Of					
										Gravel	Sand			Silt/clay	
											Coarse	Medium	Fine		
	X	X						SW	sand well graded w/ ~~silt~~ gravel, dry, yellowish brown, loose,	30	25	20	20	5	0"–6"
							1		quartz/feldspar/mica, rock chips up to 3", angular to	15	25	25	25	10	6"–1'
							2		rounded						
							3		- ~~After~~ @ 6" decrease in gravel						
							4		-surface hard/compacted, lots of gravel						
							5								
							6		GPS: 017 - N34°05.844' W117°07.148'						
							7								
							8								
							9								
							10								
							11								
							12								

QA/QC

MWH



Site Sketch Map

Boring #: SS18 MW#:	Sheet 1 of 1
Project: SAR Groundwater Recharge Optimization Study	
Job #: 1343019	Site: Soil Borrow
Logged By: A. Leavitt Reviewed By:	
Drilling Contractor: ~~Boart Longyear~~ MWH	
Drill Rig Type/Method: ~~Sonic Drilling~~ ~~Soil Borrow~~ hand sample	
Drillers Name: A. Leavitt	
Borehole Diam./Drill Bit Type: —	Total Depth 1'
	Ref. Elev. —
Sampler Type: hand sample	
Drill Start Time/Date: 6-18-08	Drill Finish Time/Date: 6-18-08
Well Completion Time/Date: —	
Soil Boring Backfill Time/Date: 6-18-08	

Depth to 1st Water (▽): — Time/Date: —

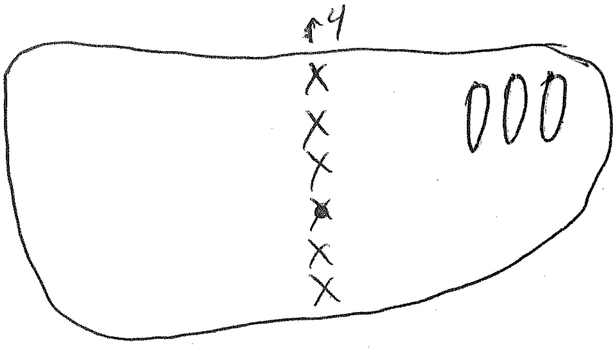
Depth to Water After Drilling (▼): — Time/Date: —

Depth to other Water Bearing Zones: —

PID/OVA	Sample Interval	Recovered (in.)	Blow Counts / 6 in.	Retained for Analysis	Casing Type & Size	Annulus Filler	Depth (Feet)	USCS Soil Type	Soil Description	Estimated % Of				
											Sand			
										Gravel	Coarse	Medium	Fine	Silt/clay
	X	X						SW	sand well gradad w/ gravel, dry, yellowish brown, loose,	15	25	25	25	10
							1		Quartz/feldspars/mica, rock chips up to 3", angular					
							2		to roundad					
							3		surface hard/compactal, with some desert plants					
							4							
							5		GPS: 018 - N34° 05.912 W117° 07.141					
							6							
							7							
							8							
							9							
							10							
							11							
							12							

QA/QC

MWH



Site Sketch Map

Boring #: ES-19 MW#:

Sheet 1 of 1

Project: SAR Groundwater Recharge Optimization Study

Job #: 1343019 Site: Soil Borrow

Logged By: A. Leavitt Reviewed By:

Drilling Contractor: ~~Boart Longyear~~ MWH

Drill Rig Type/Method: ~~Sonic Drilling~~ hand sampling

Drillers Name: A. Leavitt

Borehole Diam./Drill Bit Type: –

Total Depth 1'

Ref. Elev. –

Sampler Type: hand sampling

Drill Start Time/Date: 6-18-08 Drill Finish Time/Date: 6-18-08

Well Completion Time/Date: –

Soil Boring Backfill Time/Date: 6-18-08

Depth to 1st Water (▽): – Time/Date: –

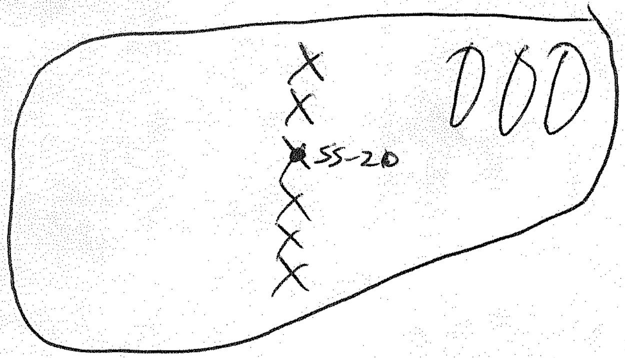
Depth to Water After Drilling (▼): – Time/Date: –

Depth to other Water Bearing Zones: –

PID/OVA	Sample Interval	Recovered (in.)	Blow Counts / 6 in.	Retained for Analysis	Casing Type & Size	Annulus Filler	Depth (Feet)	USCS Soil Type	Soil Description	Estimated % Of				
											Sand			
										Gravel	Coarse	Medium	Fine	Silt/clay
	X	X						SW	Sand well graded,	10	25	25	30	10
									dry, Yellowish brown, loose, Quartz					
							1		feldspars/mica, rock chips					
									up to 4", angular to rounded					
							2							
									surface hard/compacted,					
							3		w/ some desert plants					
							4		GPS:019 – N 34° 05.976'					
									W117° 07.141'					
							5							
							6							
							7							
							8							
							9							
							10							
							11							
							12							

QA/QC

MWH



Site Sketch Map

Boring #: SS20 MW#: Sheet 1 of 1

Project: SAR Groundwater Recharge Optimization Study

Job #: 1343019 Site: Soil Borrow

Logged By: A. Leavitt Reviewed By:

Drilling Contractor: ~~Boart Longyear~~ MWH

Drill Rig Type/Method: ~~Sonic Drilling~~ hand Sampling

Drillers Name: A. Leavitt

Borehole Diam./Drill Bit Type: —

Total Depth 1'

Ref. Elev. —

Sampler Type: hand sampling

Drill Start Time/Date: 6-18-08 Drill Finish Time/Date: 6-18-08

Well Completion Time/Date: —

Soil Boring Backfill Time/Date: 6-18-08

Depth to 1st Water (▽): — Time/Date: —

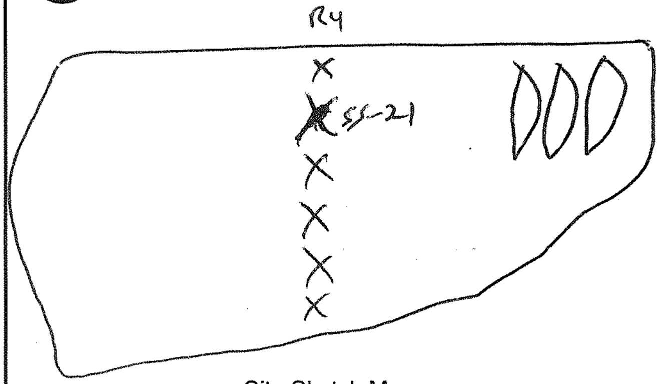
Depth to Water After Drilling (▼): — Time/Date: —

Depth to other Water Bearing Zones: —

PID/OVA	Sample Interval	Recovered (in.)	Blow Counts / 6 in.	Retained for Analysis	Casing Type & Size	Annulus Filler	Depth (Feet)	USCS Soil Type	Soil Description	Estimated % Of				
											Sand			
										Gravel	Coarse	Medium	Fine	Silt/clay
	X	X						SW	sand well ~~sorted~~ graded, dry, Yellowish brown, loose, Quartz/feldspars/	10	20	30	30	10
							1		micas, rock chips up to 2", angular to rounded					
							2		-surface hard/compacted,					
							3		with some desert plants					
							4							
							5		GPS'020 - N34° 06.033' W117° 07.144'					
							6							
							7							
							8							
							9							
							10							
							11							
							12							

QA/QC

MWH



Site Sketch Map

Boring #: SS-21 MW#: **Sheet** 1 **of** 1

Project: SAR Groundwater Recharge Optimization Study

Job #: 1343019 Site: Soil Borrow

Logged By: A. Leavitt Reviewed By:

Drilling Contractor: ~~Boart Longyear~~ MWH

Drill Rig Type/Method: ~~Sonic Drilli~~ng hand sampling

Drillers Name: A. Leavitt

Borehole Diam./Drill Bit Type: —

Total Depth 1'

Ref. Elev. —

Sampler Type: hand sampling

Drill Start Time/Date: 6-18-08 Drill Finish Time/Date: 6-18-08

Well Completion Time/Date: —

Soil Boring Backfill Time/Date: 6-18-08

Depth to 1st Water (▽): — Time/Date: —

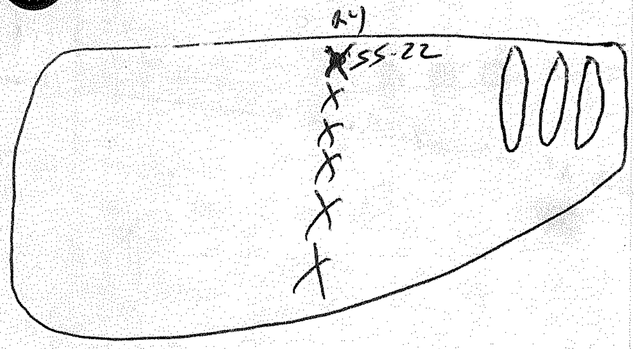
Depth to Water After Drilling (▼): — Time/Date: —

Depth to other Water Bearing Zones: —

PID/OVA	Sample Interval	Recovered (in.)	Blow Counts / 6 in.	Retained for Analysis	Casing Type & Size	Annulus Filler	Depth (Feet)	USCS Soil Type	Soil Description	Estimated % Of				
											Sand			
										Gravel	Coarse	Medium	Fine	Silt/clay
	X	X						SW	Sand well graded with gravel, dry, yellowish brown, loose,	15	25	25	25	10
							1		Quartz/feldspars/mica, rock chips up to 3", angular to					
							2		rounded					
							3		-surfece hard/compacted, with some desert plants					
							4		- noticing that @ 6"-8" it					
							5		gets extremely hard and its difficult to get through with					
							6		pickaxe.					
							7		GPS: 021 - N34° 06.091 W117° 07.139'					
							8							
							9							
							10							
							11							
							12							

QA/QC

MWH



Site Sketch Map

Boring #: SS-22 MW#: Sheet 1 of 1

Project: SAR Groundwater Recharge Optimization Study

Job #: 1343019 Site: Soil Borrow

Logged By: A. Leavitt Reviewed By:

Drilling Contractor: ~~Boart Longyear~~ MWH

Drill Rig Type/Method: ~~Sonic Drilling~~ hand sampling

Drillers Name: A. Leavitt

Borehole Diam./Drill Bit Type: —

Total Depth 1'

Ref. Elev. —

Sampler Type: handsampling

Drill Start Time/Date: 6-18-08 Drill Finish Time/Date: 6-18-08

Well Completion Time/Date: —

Soil Boring Backfill Time/Date: 6-18-08

Depth to 1st Water (▽): — Time/Date: —

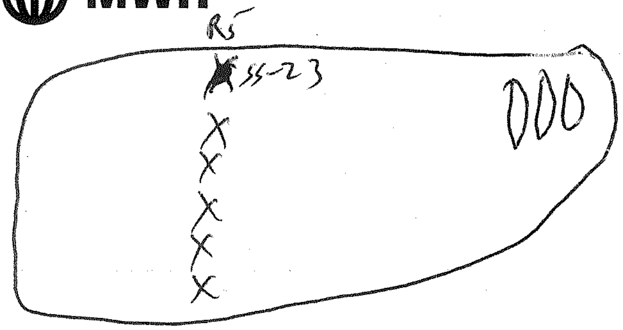
Depth to Water After Drilling (▼): — Time/Date: —

Depth to other Water Bearing Zones: —

PID/OVA	Sample Interval	Recovered (in.)	Blow Counts / 6 in.	Retained for Analysis	Casing Type & Size	Annulus Filler	Depth (Feet)	USCS Soil Type	Soil Description	Estimated % Of Gravel	Sand Coarse	Sand Medium	Sand Fine	Silt/clay
	X	X						sw	sand well graded w/ gravel, dry, yellowish brown, loose,	15	25	25	25	10
							1		quartz/feldspar/mica, rock chips up to 6", angular to					
							2		rounded					
							3		surface is hard/compacted, w/ some desert plants					
							4							
							5		GPS: 022 - N34° 06.150' W117° 07.142'					
							6							
							7							
							8							
							9							
							10							
							11							
							12							

QA/QC

MWH



Site Sketch Map

Boring #: SS-23 MW#: Sheet 1 of 1

Project: SAR Groundwater Recharge Optimization Study

Job #: 1343019 Site: Soil Borrow

Logged By: A. Leavitt Reviewed By:

Drilling Contractor: ~~Boart Longyear~~ MWH

Drill Rig Type/Method: ~~Sonic Drilling~~ hand sampling

Drillers Name: A. Leavitt

Borehole Diam./Drill Bit Type: –

Total Depth 1'

Ref. Elev. –

Sampler Type: hand sampling

Depth to 1st Water (▽): – Time/Date: –

Drill Start Time/Date: 6-18-08 Drill Finish Time/Date: 6-18-08

Depth to Water After Drilling (▼): – Time/Date: –

Well Completion Time/Date: –

Depth to other Water Bearing Zones: –

Soil Boring Backfill Time/Date: 6-18-08

PID/OVA	Sample Interval	Recovered (in.)	Blow Counts / 6 in.	Retained for Analysis	Casing Type & Size	Annulus Filler	Depth (Feet)	USCS Soil Type	Soil Description	Estimated % Of				
											Sand			
										Gravel	Coarse	Medium	Fine	Silt/clay
	X	X						SW	sand well ~~sorted~~ graded with gravel, dry, yellowish brown,	15	25	25	25	10
							1		loose, Quartz/feldspars/mica, rock chips up to 4", angular					
							2		to rounded					
							3		surface hard/compacted, w/ some desert plants					
							4							
							5		GPS: 023 – N 34° 06.149' W 117° 07.214'					
							6							
							7							
							8							
							9							
							10							
							11							
							12							

QA/QC

MWH

Boring #: SS-24 MW#:

Sheet 1 of 1

Project: SAR Groundwater Recharge Optimization Study

Job #: 1343019 Site: Soil Borrow

Logged By: A. Leavitt Reviewed By:

Drilling Contractor: ~~Boart Longyear~~ MWH

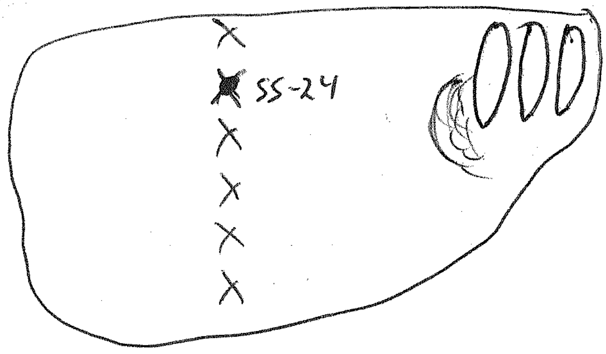
Drill Rig Type/Method: ~~Sonic Drilling~~ hand Sampling

Drillers Name: A. Leavitt

Borehole Diam./Drill Bit Type: —

Total Depth 1'

Ref. Elev. —



Site Sketch Map

Sampler Type: hand Sampling

Drill Start Time/Date: 6-23-08 Drill Finish Time/Date: 6-23-08

Well Completion Time/Date: —

Soil Boring Backfill Time/Date: 6-23-08

Depth to 1st Water (▽): — Time/Date: —

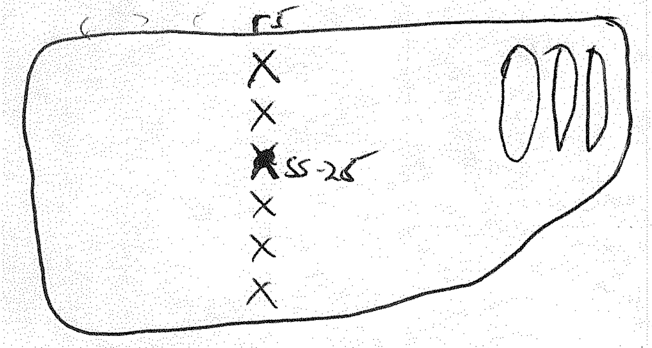
Depth to Water After Drilling (▼): — Time/Date: —

Depth to other Water Bearing Zones: —

PID/OVA	Sample Interval	Recovered (in.)	Blow Counts / 6 in.	Retained for Analysis	Casing Type & Size	Annulus Filler	Depth (Feet)	USCS Soil Type	Soil Description	Estimated % Of				
											Sand			
										Gravel	Coarse	Medium	Fine	Silt/clay
	X	X						SW	sand well graded with gravel, dry, light (yellowish) brown -	15	25	25	25	10
							1		10YR 7/2 - loose but compacted, rock chips up to 5", angular					
							2		to rounded,	20	30	30	20	0
							3	SW	@ 10" color Δ to 10YR4/2 and grain change → less					
							4		fine grained and silt.					
							5		- surface is hard/compacted, some desert plants.					
							6		- GPS: 024 N34° 06.106'					
							7		W117° 07.208'					
							8							
							9							
							10							
							11							
							12							

QA/QC

MWH



Site Sketch Map

Boring #: SS-25 MW#: **Sheet** 1 **of** 1

Project: SAR Groundwater Recharge Optimization Study

Job #: 1343019 Site: Soil Burrow

Logged By: A. Leavitt Reviewed By:

Drilling Contractor: ~~Boart Longyear~~ MWH

Drill Rig Type/Method: ~~Sonic Drilling~~ hand sampling

Drillers Name: A. Leavitt

Borehole Diam./Drill Bit Type: —

Total Depth 1'

Ref. Elev. —

Sampler Type: hand sampling

Drill Start Time/Date: 6-23-08 Drill Finish Time/Date: 6-23-08

Depth to 1st Water (▽): — Time/Date: —

Depth to Water After Drilling (▼): — Time/Date: —

Depth to other Water Bearing Zones: —

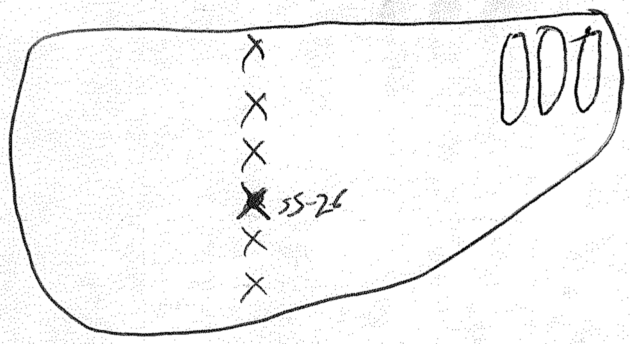
Well Completion Time/Date: —

Soil Boring Backfill Time/Date: 6-23-08

PID/OVA	Sample Interval	Recovered (in.)	Blow Counts / 6 in.	Retained for Analysis	Casing Type & Size	Annulus Filler	Depth (Feet)	USCS Soil Type	Soil Description	Estimated % Of				
											Sand			
										Gravel	Coarse	Medium	Fine	Silt/clay
	X	X					1	SW	sand well graded w/ gravel, dry, light brown -10YR7/2,	15	25	25	25	10
							2		loose but compacted, rock chips up to 4", angular to					
							3		rounded					
							4		·color and grain change @ 1' just after sample.					
							5		·surface is hard and compacted					
							6		w/ small # of desert plants.					
							7		GPS: 25 - N34° 06.037' W117° 07.218'					
							8							
							9							
							10							
							11							
							12							

QA/QC

MWH



Site Sketch Map

Boring #: SS-26 MW#: Sheet 1 of 1

Project: SAR Groundwater Recharge Optimization Study

Job #: 1343019 Site: Soil Borrow

Logged By: A. Leavitt Reviewed By:

Drilling Contractor: ~~Boart Longyear~~ MWH

Drill Rig Type/Method: ~~Sonic Drilling~~ hand sampling

Drillers Name: A. Leavitt

Borehole Diam./Drill Bit Type: —

Total Depth: /

Ref. Elev.: —

Sampler Type: hand sampling

Depth to 1st Water (▽): — Time/Date: —

Drill Start Time/Date: 6-23-08 Drill Finish Time/Date: 6-23-08

Depth to Water After Drilling (▼): — Time/Date: —

Well Completion Time/Date: —

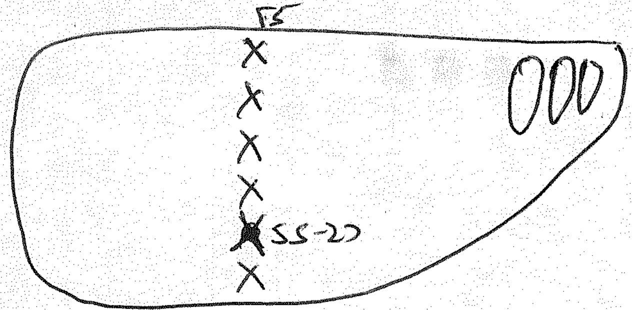
Depth to other Water Bearing Zones: —

Soil Boring Backfill Time/Date: 6-23-08

PID/OVA	Sample Interval	Recovered (in.)	Blow Counts / 6 in.	Retained for Analysis	Casing Type & Size	Annulus Filler	Depth (Feet)	USCS Soil Type	Soil Description	Estimated % Of Gravel	Sand Coarse	Sand Medium	Sand Fine	Silt/clay
	X	X						SW	sandwell graded with gravel, dry, light brown-10YR7/2,	15	25	25	25	10
							1		loose but compacted, rock chips up to 6", angular to rounded,					
							2							
									- surface hard/compacted					
							3		with some desert plants					
							4		GPS: 026 — N34° 05.984' W117° 07.228'					
							5							
							6							
							7							
							8							
							9							
							10							
							11							
							12							

QA/QC

MWH



Site Sketch Map

Boring #: SS-27 MW#: **Sheet** 1 **of** 1

Project: SAR Groundwater Recharge Optimization Study

Job #: 1343019 Site: Soil Borrow

Logged By: A. Leavitt Reviewed By:

Drilling Contractor: ~~Boart Longyear~~ MWH

Drill Rig Type/Method: ~~Sonic Drilling~~ hand sampling

Drillers Name: A. Leavitt

Borehole Diam./Drill Bit Type: — **Total Depth** 1'

Ref. Elev. —

Sampler Type: hand sampling

Drill Start Time/Date: 6-23-08 Drill Finish Time/Date: 6-23-08

Depth to 1st Water (▽): — Time/Date: —

Depth to Water After Drilling (▼): — Time/Date: —

Well Completion Time/Date: —

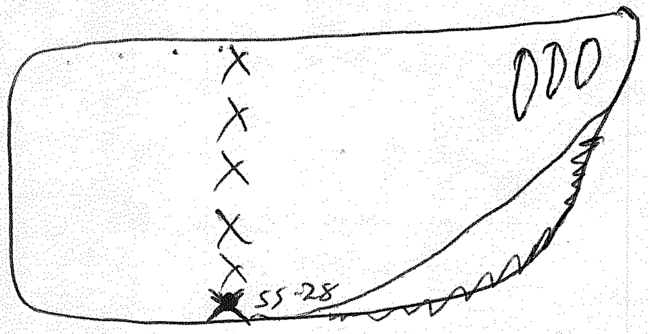
Depth to other Water Bearing Zones: —

Soil Boring Backfill Time/Date: 6-23-08

PID/OVA	Sample Interval	Recovered (in.)	Blow Counts / 6 in.	Retained for Analysis	Casing Type & Size	Annulus Filler	Depth (Feet)	USCS Soil Type	Soil Description	Estimated % Of				
											Sand			
										Gravel	Coarse	Medium	Fine	Silt/clay
	X	X						SW	sand well graded with gravel, dry, light brown -10YR 7/2,	15	25	25	25	10
							1		loose but compacted, rock chips upto 2", angular to rounded.					
							2		- Surface hard/compacted,					
							3		with some desert plants					
							4		GPS: 027 - N34° 05.923' W117° 07.224'					
							5							
							6							
							7							
							8							
							9							
							10							
							11							
							12							

QA/QC

MWH



Site Sketch Map

Boring #: SS-28 MW#: **Sheet** 1 **of** 1

Project: SAR Groundwater Recharge Optimization Study

Job #: 1343019 Site: Soil Borrow

Logged By: A. Leavitt Reviewed By:

Drilling Contractor: ~~Boart Longyear~~ MWH

Drill Rig Type/Method: ~~Sonic Drilling~~ hand Sampling

Drillers Name: A. Leavitt

Borehole Diam./Drill Bit Type: —

Total Depth 1'

Ref. Elev. —

Sampler Type: hand Sampling

Depth to 1st Water (▽): — Time/Date: —

Depth to Water After Drilling (▼): — Time/Date: —

Depth to other Water Bearing Zones: —

Drill Start Time/Date: 6-23-08 Drill Finish Time/Date: 6-23-08

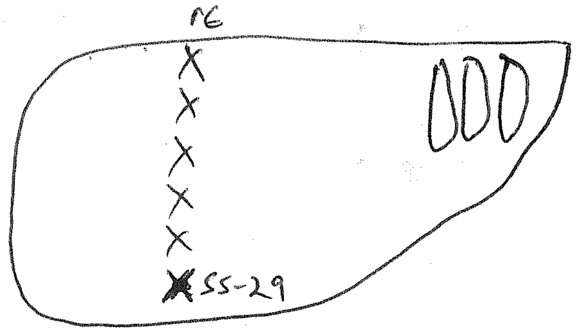
Well Completion Time/Date: —

Soil Boring Backfill Time/Date: 6-23-08

PID/OVA	Sample Interval	Recovered (in.)	Blow Counts / 6 in.	Retained for Analysis	Casing Type & Size	Annulus Filler	Depth (Feet)	USCS Soil Type	Soil Description	Estimated % Of				
											Sand			
										Gravel	Coarse	Medium	Fine	Silt/clay
	X	X						SW	Sand well graded with gravel, dry, light brown -10YR7/2, loose but compacted, rock chips up to 2", angular to rounded	15	25	25	25	10
							1							
							2							
							3		-surface hard/compacted, with some desert plants					
							4							
							5		GPS: 028 — N34° 05.855' W117° 07.224'					
							6							
							7							
							8							
							9							
							10							
							11							
							12							

QA/QC

MWH



Site Sketch Map

Boring #: SS-29 MW#: **Sheet** 1 **of** 1

Project: SAR Groundwater Recharge Optimization Study

Job #: 1343019 Site: Soil Borrow

Logged By: A. Leavitt Reviewed By:

Drilling Contractor: ~~Boart Longyear~~ MWH

Drill Rig Type/Method: ~~Sonic Drilling~~ hand sampling

Drillers Name: A. Leavitt

Borehole Diam./Drill Bit Type: —

Total Depth 1'

Ref. Elev. —

Sampler Type: hand sampling

Drill Start Time/Date: 6-23-08 Drill Finish Time/Date: 6-23-08

Depth to 1st Water (∇): — Time/Date: —

Depth to Water After Drilling (▼): — Time/Date: -

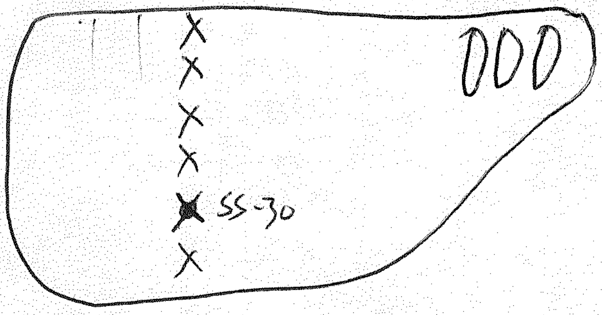
Depth to other Water Bearing Zones: —

Well Completion Time/Date: —

Soil Boring Backfill Time/Date: 6-23-08

PID/OVA	Sample Interval	Recovered (in.)	Blow Counts / 6 in.	Retained for Analysis	Casing Type & Size	Annulus Filler	Depth (Feet)	USCS Soil Type	Soil Description	Estimated % Of Gravel	Sand Coarse	Sand Medium	Sand Fine	Silt/clay
	X	X						SW	Sand well graded with gravel, dry, light brown -10YR7/2,	15	25	25	25	10
							1		loose but compacted, rock chips up to 3", angular					
							2		to rounded.					
							3		•surface hard/compacted, with desert plants.					
							4							
							5		GPS: 029 - N34° 05.852' W117° 07.295'					
							6							
							7							
							8							
							9							
							10							
							11							
							12							

MWH



Site Sketch Map

Boring #: SS-30 MW#:	Sheet 1 of 1
Project: SAR Groundwater Recharge Optimization Study	
Job #: 1343019	Site: Soil Borrow
Logged By: A. Leavitt	Reviewed By:
Drilling Contractor: ~~Boart Longyear~~ MWH	
Drill Rig Type/Method: ~~Sonic Drilling~~ hand sampling	
Drillers Name: A. Leavitt	
Borehole Diam./Drill Bit Type: —	Total Depth 1'
	Ref. Elev. —
Sampler Type: hand sampling	
Drill Start Time/Date: 6-23-08	Drill Finish Time/Date: 6-23-08
Well Completion Time/Date: —	
Soil Boring Backfill Time/Date: 6-23-08	

Depth to 1st Water (▽): — Time/Date: —

Depth to Water After Drilling (▼): — Time/Date: —

Depth to other Water Bearing Zones: —

PID/OVA	Sample Interval	Recovered (in.)	Blow Counts / 6 in.	Retained for Analysis	Casing Type & Size	Annulus Filler	Depth (Feet)	USCS Soil Type	Soil Description	Estimated % Of Gravel	Sand Coarse	Sand Medium	Sand Fine	Silt/clay
	X	X						Sw	sand well graded with gravel, dry, light Brown-10YR 7/2, ~~dry~~, loose but compacted, rock chips upto 10", angular to rounded.	25	25	20	20	10
							1							
							2							
							3		surface hard/compacted, with plants					
							4							
							5		GPS: 030 – N34° 05.924' W117° 07.926'					
							6							
							7		– much more gravel than other areas → still visible silt and large amount of fine/medium grained sand, but higher gravel %.					
							8							
							9							
							10							
							11							
							12							

QA/QC

MWH

Boring #: SS-31 MW#: Sheet 1 of 1

Project: SAR Groundwater Recharge Optimization Study

Job #: 1343019 Site: Soil Borrow

Logged By: A. Leavitt Reviewed By:

Drilling Contractor: ~~Boart Longyear~~ MWH

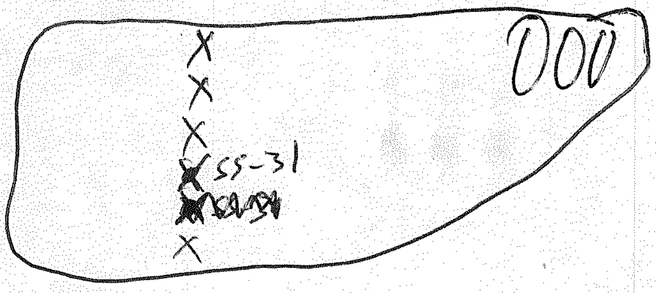
Drill Rig Type/Method: ~~Sonic Drilling~~ hand sampling

Drillers Name: A. Leavitt

Borehole Diam./Drill Bit Type: —

Total Depth 1'

Ref. Elev. —



Site Sketch Map

Sampler Type: hand sampling

Depth to 1st Water (▽): — Time/Date: —

Drill Start Time/Date: 6-23-08 Drill Finish Time/Date: 6-23-08

Depth to Water After Drilling (▼): — Time/Date: —

Well Completion Time/Date: —

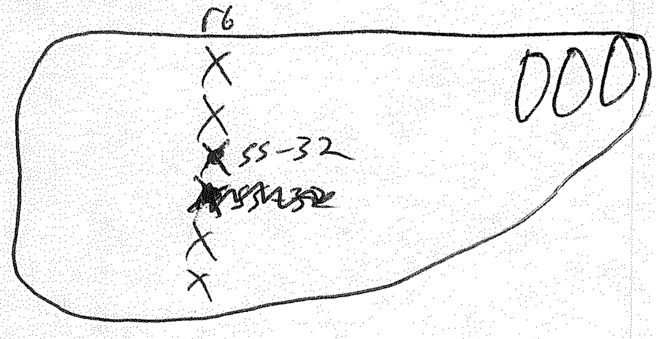
Depth to other Water Bearing Zones: —

Soil Boring Backfill Time/Date: 6-23-08

PID/OVA	Sample Interval	Recovered (in.)	Blow Counts / 6 in.	Retained for Analysis	Casing Type & Size	Annulus Filler	Depth (Feet)	USCS Soil Type	Soil Description	Estimated % Of				
											Sand			
										Gravel	Coarse	Medium	Fine	Silt/clay
	X	X						SW	sand well graded, dry to slightly damp, olive brown, loose	5	30	30	30	5
							1		but compacted, some rock chips up to 1.5", roots down					
							2		to 5", subangular to rounded.					
							3		•surface compacted but					
							4		not as hard as the others, lots of plant material.					
							5							
							6		gps :031 - N34° 05.985' W117° 07.299'					
							7							
							8							
							9							
							10							
							11							
							12							

QA/QC

MWH



Site Sketch Map

Boring #: SS-32 MW#: **Sheet** 1 **of** 1

Project: SAR Groundwater Recharge Optimization Study

Job #: 1343019 Site: Soil Borrow

Logged By: A. Leavitt Reviewed By:

Drilling Contractor: ~~Boart Longyear~~ MWH

Drill Rig Type/Method: ~~Sonic Drilling~~ hand sampling

Drillers Name: A. Leavitt

Borehole Diam./Drill Bit Type: —

Total Depth 1'

Ref. Elev. —

Sampler Type: hand sampling

Depth to 1st Water (∇): — Time/Date: —

Drill Start Time/Date: 6-23-08 Drill Finish Time/Date: 6-23-08

Depth to Water After Drilling (▼): — Time/Date: —

Well Completion Time/Date: —

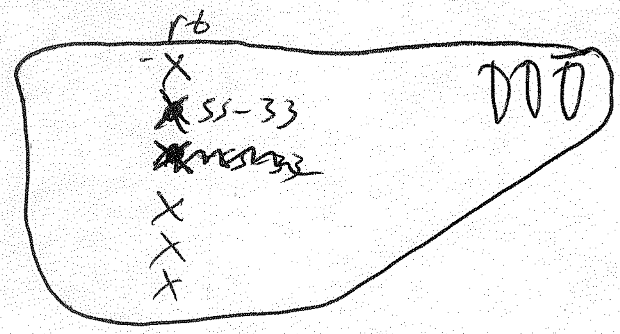
Depth to other Water Bearing Zones: —

Soil Boring Backfill Time/Date: 6-23-08

PID/OVA	Sample Interval	Recovered (in.)	Blow Counts / 6 in.	Retained for Analysis	Casing Type & Size	Annulus Filler	Depth (Feet)	USCS Soil Type	Soil Description	Estimated % Of				
											Sand			
										Gravel	Coarse	Medium	Fine	Silt/clay
	X	X						SW	Sand well graded with gravel, moist, olive brown,	25	25	25	25	–
							1		loose but compacted, rock chips up to 3", angular to					
							2		rounded					
							3		-surface hard/compacted, some desert plants					
							4							
							5		GPS: 032 – N34° 06.044' W117° 07.304'					
							6							
							7							
							8							
							9							
							10							
							11							
							12							

QA/QC

MWH



Site Sketch Map

Boring #: SS-33 MW#: **Sheet** 1 **of** 1

Project: SAR Groundwater Recharge Optimization Study

Job #: 1343019 Site: Soil Borrow

Logged By: A. Leavitt Reviewed By:

Drilling Contractor: ~~Boart Longyear~~ MWH

Drill Rig Type/Method: ~~Sonic Drilling~~ hand sampling

Drillers Name: A. Leavitt

Borehole Diam./Drill Bit Type: -

Total Depth 1'

Ref. Elev. -

Sampler Type: hand sampling

Drill Start Time/Date: 6-23-08 Drill Finish Time/Date: 6-23-08

Depth to 1st Water (▽): — Time/Date: —

Depth to Water After Drilling (▼): — Time/Date: —

Depth to other Water Bearing Zones: —

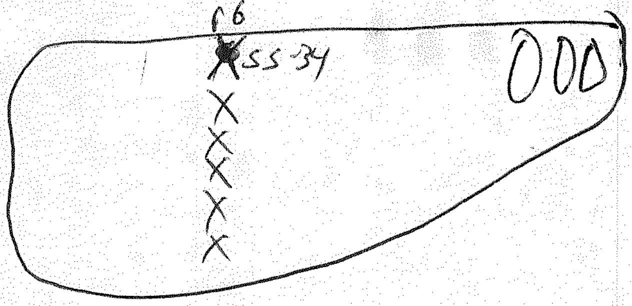
Well Completion Time/Date: —

Soil Boring Backfill Time/Date: 6-23-08

PID/OVA	Sample Interval	Recovered (in.)	Blow Counts / 6 in.	Retained for Analysis	Casing Type & Size	Annulus Filler	Depth (Feet)	USCS Soil Type	Soil Description	Estimated % Of				
											Sand			
										Gravel	Coarse	Medium	Fine	Silt/clay
	X	X						SW	sand well graded with gravel, slightly damp, olive brown, loose but compacted, rock chips up to 2", angular to rounded	15	25	25	25	10
							1							
							2							
							3		-surface hard/compacted, with some desert plants					
							4							
							5		GPS: 033 - N34° 06.103' W117° 07.299'					
							6							
							7							
							8							
							9							
							10							
							11							
							12							

QA/QC

MWH



Site Sketch Map

Boring #: SS-34 MW#:

Sheet 1 of 1

Project: SAR Groundwater Recharge Optimization Study

Job #: 1343019 Site: Soil Burrow

Logged By: A. Leavitt Reviewed By:

Drilling Contractor: ~~Boart Longyear~~ MWH

Drill Rig Type/Method: ~~Sonic Drilling~~ hand Sampling

Drillers Name: A. Leavitt

Borehole Diam./Drill Bit Type: –

Total Depth 1'

Ref. Elev. –

Sampler Type: hand sampling

Depth to 1st Water (▽): – Time/Date: –

Drill Start Time/Date: 6-23-08 Drill Finish Time/Date: 6-23-08

Depth to Water After Drilling (▼): – Time/Date: –

Well Completion Time/Date: –

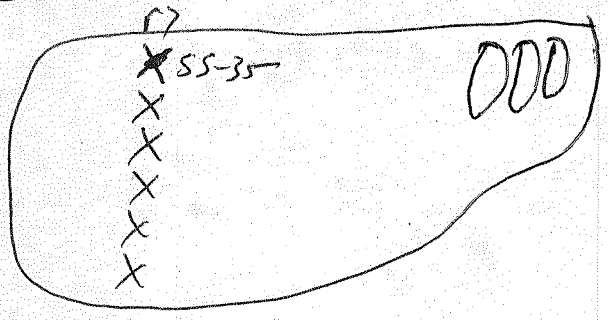
Depth to other Water Bearing Zones: –

Soil Boring Backfill Time/Date: 6-23-08

PID/OVA	Sample Interval	Recovered (in.)	Blow Counts / 6 in.	Retained for Analysis	Casing Type & Size	Annulus Filler	Depth (Feet)	USCS Soil Type	Soil Description	Estimated % Of Gravel	Sand Coarse	Sand Medium	Sand Fine	Silt/clay
	X	X						SW	Sand well graded with gravel, dry, light brown - 10YR 7/2,	15	25	25	25	10
							1		loose but compacted, rock chips up to 2.5", angular to rounded,					
							2							
							3		surface hard/compacted, with some desert plants					
							4							
							5		GPS: 034 - N34° 06.153' W117° 07.296'					
							6							
							7							
							8							
							9							
							10							
							11							
							12							

QA/QC

MWH



Site Sketch Map

Boring #: SS-35 MW#: **Sheet** 1 **of** 1

Project: SAR Groundwater Recharge Optimization Study

Job #: 1343019 Site: Soil Borrow

Logged By: A. Leavitt Reviewed By:

Drilling Contractor: ~~Boart Longyear~~ MWH

Drill Rig Type/Method: ~~Sonic Drilling~~ hand sampling

Drillers Name: A. Leavitt

Borehole Diam./Drill Bit Type: – **Total Depth** 1'

Ref. Elev. –

Sampler Type: hand sampling

Depth to 1st Water (▽): – Time/Date: –

Drill Start Time/Date: 6-23-08 Drill Finish Time/Date: 6-23-08

Depth to Water After Drilling (▼): – Time/Date: –

Well Completion Time/Date: –

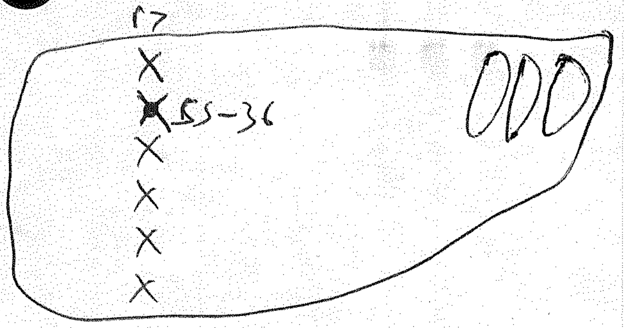
Depth to other Water Bearing Zones: –

Soil Boring Backfill Time/Date: 6-23-08

PID/OVA	Sample Interval	Recovered (in.)	Blow Counts / 6 in.	Retained for Analysis	Casing Type & Size	Annulus Filler	Depth (Feet)	USCS Soil Type	Soil Description	Estimated % Of				
											Sand			
										Gravel	Coarse	Medium	Fine	Silt/clay
	X	X						sw	sand well graded with gravel, dry, light brown - 10YR 7/2, loose but compacted, rock chips up to 3", angular to rounded.	15	25	25	25	10
							1							
							2							
							3		surface is hard/compacted, with some desert plants					
							4							
							5		GPS: 035 - N34° 06.156' W117° 07.375'					
							6							
							7							
							8							
							9							
							10							
							11							
							12							

QA/QC

MWH



Site Sketch Map

Boring #: SS-36 MW#: Sheet 1 of 1

Project: SAR Groundwater Recharge Optimization Study

Job #: 1343019 Site: Soil Borrow

Logged By: A. Leavitt Reviewed By:

Drilling Contractor: ~~Boart Longyear~~ MWH

Drill Rig Type/Method: ~~Sonic Drilling~~ hand Sampling

Drillers Name: A. Leavitt

Borehole Diam./Drill Bit Type: —

Total Depth 1

Ref. Elev. —

Sampler Type: hand Sampling

Drill Start Time/Date: 6-23-08 Drill Finish Time/Date: 6-23-08

Depth to 1st Water (▽): — Time/Date: —

Depth to Water After Drilling (▼): — Time/Date: —

Well Completion Time/Date: —

Depth to other Water Bearing Zones: —

Soil Boring Backfill Time/Date: 6-23-08

PID/OVA	Sample Interval	Recovered (in.)	Blow Counts / 6 in.	Retained for Analysis	Casing Type & Size	Annulus Filler	Depth (Feet)	USCS Soil Type	Soil Description	Estimated % Of				
											Sand			
										Gravel	Coarse	Medium	Fine	Silt/clay
	X	X						SW	sand well graded with gravel, dry, light brown-10YR 7/2, loose but compacted, rock chips up to 4", angular to rounded.	15	25	25	25	10
							1							
							2							
							3		surface hard (compacted, with some desert plants.					
							4							
							5		GPS: 036 — N34°06.094' W117°07.380'					
							6							
							7							
							8							
							9							
							10							
							11							
							12							

QA/QC

MWH

Boring #: SS-37 MW#: **Sheet** 1 **of** 1

Project: SAR Groundwater Recharge Optimization Study

Job #: 1343019 Site: Soil Borrow

Logged By: A. Leavitt Reviewed By:

Drilling Contractor: ~~Boart Longyear~~ MWH

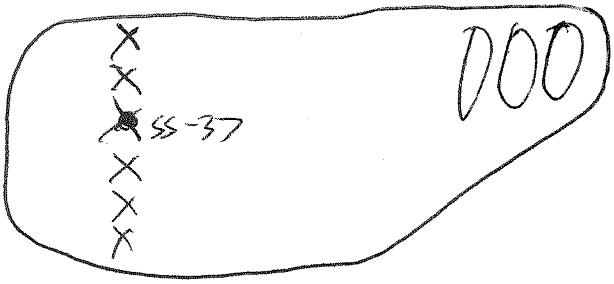
Drill Rig Type/Method: ~~Sonic Drilling~~ hand Sampling

Drillers Name: A. Leavitt

Borehole Diam./Drill Bit Type: —

Total Depth 1'

Ref. Elev. —



Site Sketch Map

Sampler Type: hand sample

Depth to 1st Water (▽): — Time/Date: —

Drill Start Time/Date: 6-23-08 Drill Finish Time/Date: 6-23-08

Depth to Water After Drilling (▼): — Time/Date: —

Well Completion Time/Date: —

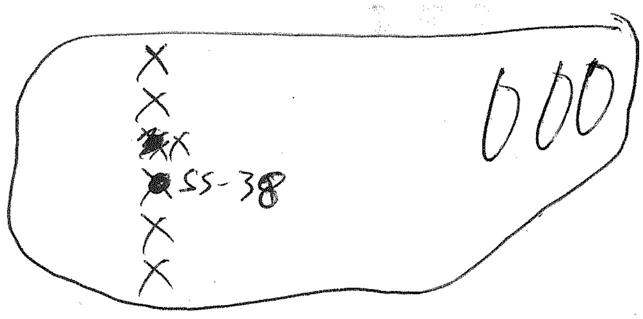
Depth to other Water Bearing Zones: —

Soil Boring Backfill Time/Date: 6-23-08

PID/OVA	Sample Interval	Recovered (in.)	Blow Counts / 6 in.	Retained for Analysis	Casing Type & Size	Annulus Filler	Depth (Feet)	USCS Soil Type	Soil Description	Estimated % Of Gravel	Sand Coarse	Sand Medium	Sand Fine	Silt/clay
	X	X						SW	Sandwell graded with gravel, dry, light olive brown, loose	15 ~~20~~	20	25 ~~20~~	25	15 ~~20~~
							1		but compact, rock chips up to 2", angular to rounded.					
							2							
							3		surface hard/compacted, with some desert plants.					
							4							
							5		GPS: 037 – N34° 06.035' W117° 07.381'					
							6							
							7							
							8							
							9							
							10							
							11							
							12							

QA/QC

MWH



Site Sketch Map

Boring #: SS-38 MW#: **Sheet** 1 **of** 1

Project: SAR Groundwater Recharge Optimization Study

Job #: 1343019 Site: Soil Borrow

Logged By: A. Leavitt Reviewed By:

Drilling Contractor: ~~Boart Longyear~~ MWH

Drill Rig Type/Method: ~~Sonic Drilling~~ hand sampling

Drillers Name: A. Leavitt

Borehole Diam./Drill Bit Type: –

Total Depth 1'

Ref. Elev. –

Sampler Type: hand sampling

Drill Start Time/Date: 6-23-08 Drill Finish Time/Date: 6-23-08

Well Completion Time/Date: –

Soil Boring Backfill Time/Date: 6-23-08

Depth to 1st Water (▽): – Time/Date: –

Depth to Water After Drilling (▼): – Time/Date: –

Depth to other Water Bearing Zones: –

PID/OVA	Sample Interval	Recovered (in.)	Blow Counts / 6 in.	Retained for Analysis	Casing Type & Size	Annulus Filler	Depth (Feet)	USCS Soil Type	Soil Description	Estimated % Of				
											Sand			
										Gravel	Coarse	Medium	Fine	Silt/clay
	X	X					1	SW	sand well graded with gravel, dry, light olive brown, loose but compact, rock chips up to 2", angular to rounded	15	20	25	25	15
							2							
							3							
							4		-Surface hard/compacted, with some desert plants					
							5							
							6		GPS: 039 - N34° 05.975' W117° 07.379'					
							7							
							8							
							9							
							10							
							11							
							12							

MWH

Boring #: SS-39 MW#: Sheet 1 of 1

Project: SAR Groundwater Recharge Optimization Study

Job #: 1343019 Site: Soil Burrow

Logged By: A. Leavitt Reviewed By:

Drilling Contractor: ~~Boart Longyear~~ MWH

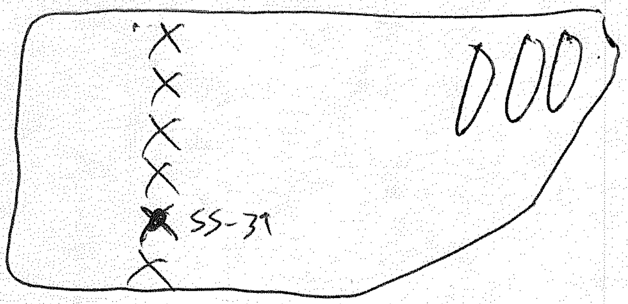
Drill Rig Type/Method: ~~Sonic Drilling~~ hand sampling

Drillers Name: A. Leavitt

Borehole Diam./Drill Bit Type: —

Total Depth 1'

Ref. Elev. –



Site Sketch Map

Sampler Type: hand sampling

Drill Start Time/Date: 6-23-08 Drill Finish Time/Date: 6-23-08

Depth to 1st Water (▽): – Time/Date: –

Depth to Water After Drilling (▼): – Time/Date: –

Well Completion Time/Date: –

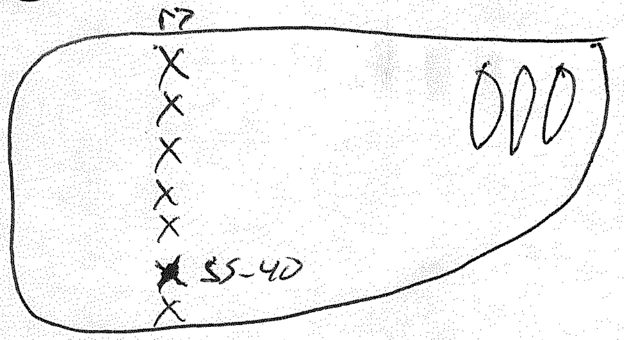
Depth to other Water Bearing Zones: –

Soil Boring Backfill Time/Date: 6-23-08

PID/OVA	Sample Interval	Recovered (in.)	Blow Counts / 6 in.	Retained for Analysis	Casing Type & Size	Annulus Filler	Depth (Feet)	USCS Soil Type	Soil Description	Estimated % Of				
											Sand			
										Gravel	Coarse	Medium	Fine	Silt/clay
	X	X						SW	sand well graded with gravel, dry, light olive brown, loose but compact, rock chips up to 2", angular to rounded.	15	20	25	25	15
							1							
							2							
							3		-surface hard/compacted, with some desert plants					
							4							
							5		GPS: 039 – N34° 05.918' W117° 07.376'					
							6							
							7							
							8							
							9							
							10							
							11							
							12							

QA/QC

MWH



Site Sketch Map

Boring #: SS-40 MW#: **Sheet** 1 **of** 1

Project: SAR Groundwater Recharge Optimization Study

Job #: 1343019 Site: Soil Borrow

Logged By: A. Leavitt Reviewed By:

Drilling Contractor: ~~Boart Longyear~~ MWH

Drill Rig Type/Method: ~~Sonic Drilling~~ hand sampling

Drillers Name: A. Leavitt

Borehole Diam./Drill Bit Type: –

Total Depth 1'

Ref. Elev. –

Sampler Type: hand sampling

Drill Start Time/Date: 6-24-08 Drill Finish Time/Date: 6-24-08

Well Completion Time/Date: –

Soil Boring Backfill Time/Date: 6-24-08

Depth to 1st Water (▽): – Time/Date: –

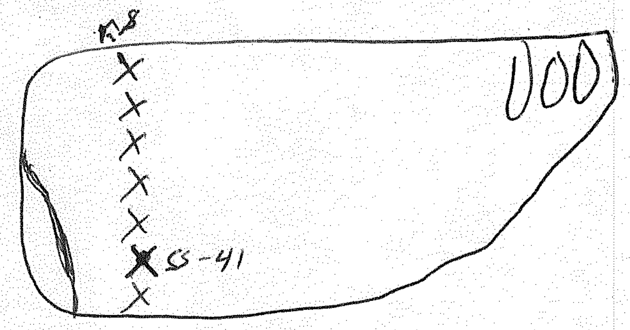
Depth to Water After Drilling (▼): – Time/Date: –

Depth to other Water Bearing Zones: –

PID/OVA	Sample Interval	Recovered (in.)	Blow Counts / 6 in.	Retained for Analysis	Casing Type & Size	Annulus Filler	Depth (Feet)	USCS Soil Type	Soil Description	Estimated % Of Gravel	Sand Coarse	Sand Medium	Sand Fine	Silt/clay
	X	X						SM	Silty sand Sand ~~poorly~~ well graded, dry, olive 5Y 5/3-5/4, loose but compacted,	10	15	20	35	20
							1		rock chips upt 1', subangular to rounded.					
							2		surface not as hard and					
							3		compacted as the other hole, lots of desert plants.					
							4							
							5		GPS: 040 – N34°05.857' W117°07.372'					
							6							
							7							
							8							
							9							
							10							
							11							
							12							

QA/QC

MWH



Site Sketch Map

Boring #: SS-41 MW#: Sheet 1 of 1

Project: SAR Groundwater Recharge Optimization Study

Job #: 1343019 Site: Soil Borrow

Logged By: A. Leavitt Reviewed By:

Drilling Contractor: ~~Boart Longyear~~ MWH

Drill Rig Type/Method: ~~Sonic Drilling~~ hand sampling

Drillers Name: A. Leavitt

Borehole Diam./Drill Bit Type: –

Total Depth 1'

Ref. Elev. –

Sampler Type: handsampling

Depth to 1st Water (▽): – Time/Date: –

Drill Start Time/Date: 6-24-08 Drill Finish Time/Date: 6-24-08

Depth to Water After Drilling (▼): – Time/Date: –

Well Completion Time/Date: –

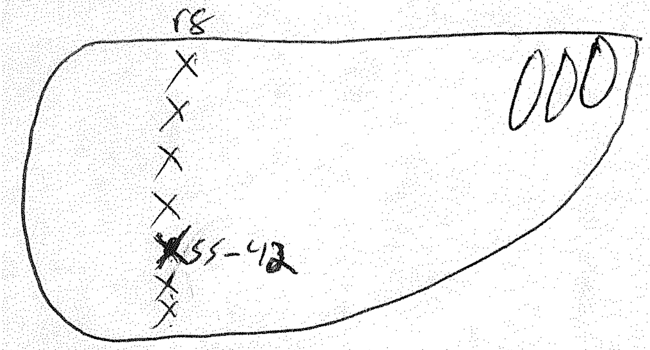
Depth to other Water Bearing Zones: –

Soil Boring Backfill Time/Date: 6-24-08

PID/OVA	Sample Interval	Recovered (in.)	Blow Counts / 6 in.	Retained for Analysis	Casing Type & Size	Annulus Filler	Depth (Feet)	USCS Soil Type	Soil Description	Estimated % Of Gravel	Sand Coarse	Sand Medium	Sand Fine	Silt/clay
	X	X					1	SW	Sand well graded with gravel, dry, light brown - 10YR 7/2,	15	20	20	30	15
							2		loose but compacted, rock chips up to 2", angular to					
							3		rounded,					
							4		• surface hard/compacted, desert plants					
							5							
							6		GPS: 041 - N34° 05.857' W117° 07.447					
							7							
							8							
							9							
							10							
							11							
							12							

QA/QC

MWH



Site Sketch Map

Boring #: SS-42 MW#: **Sheet** 1 **of** 1

Project: SAR Groundwater Recharge Optimization Study

Job #: 1343019 Site: Soil Borrow

Logged By: A. Leavitt Reviewed By:

Drilling Contractor: ~~Boart Longyear~~ MWH

Drill Rig Type/Method: ~~Sonic Drilling~~ handsampling

Drillers Name: A. Leavitt

Borehole Diam./Drill Bit Type: –

Total Depth 1'

Ref. Elev. –

Sampler Type: hand Sampling

Drill Start Time/Date: 6-24-08 Drill Finish Time/Date: 6-24-08

Well Completion Time/Date: –

Soil Boring Backfill Time/Date: 6-24-08

Depth to 1st Water (▽): – Time/Date: –

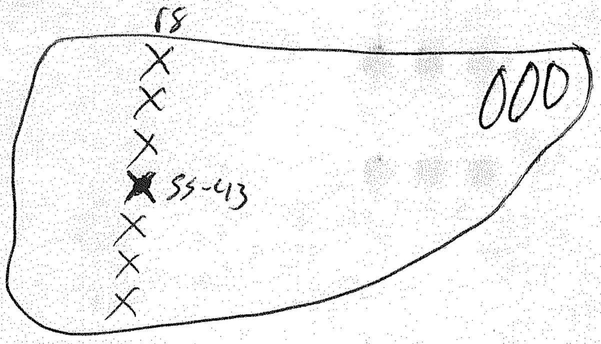
Depth to Water After Drilling (▼): – Time/Date: –

Depth to other Water Bearing Zones: –

PID/OVA	Sample Interval	Recovered (in.)	Blow Counts / 6 in.	Retained for Analysis	Casing Type & Size	Annulus Filler	Depth (Feet)	USCS Soil Type	Soil Description	Estimated % Of				
											Sand			
										Gravel	Coarse	Medium	Fine	Silt/clay
	X	X						SW	sand well graded with gravel, dry, light brown – 10YR 7/2, loose	15	20	20	30	15
							1		but compacted, rock chips up to 2", angular to rounded.					
							2							
							3		surface hard/compacted; with some desert plants.					
							4							
							5		GPS: 042 – N34° 05.922' W117° 07.447'					
							6							
							7							
							8							
							9							
							10							
							11							
							12							

QA/QC

MWH



Site Sketch Map

Boring #: SS-43 MW#: **Sheet** 1 **of** 1

Project: SAR Groundwater Recharge Optimization Study

Job #: 1343019 Site: Soil Borrow

Logged By: A. Leavitt Reviewed By:

Drilling Contractor: ~~Boart Longyear~~ MWH

Drill Rig Type/Method: ~~Sonic Drilling~~ Soil Borrow

Drillers Name: A. Leavitt

Borehole Diam./Drill Bit Type: — **Total Depth** 1'

Ref. Elev. —

Sampler Type: hand Sampling

Drill Start Time/Date: 6-24-08 Drill Finish Time/Date: 6-24-08

Depth to 1st Water (▽): — Time/Date: —

Depth to Water After Drilling (▼): — Time/Date: —

Depth to other Water Bearing Zones: —

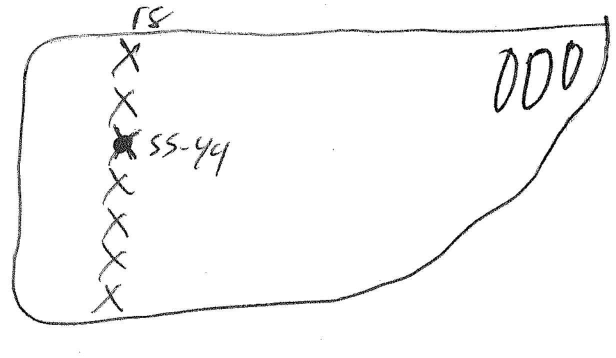
Well Completion Time/Date: —

Soil Boring Backfill Time/Date: 6-24-08

										Estimated % Of				
											Sand			
PID/OVA	Sample Interval	Recovered (in.)	Blow Counts / 6 in.	Retained for Analysis	Casing Type & Size	Annulus Filler	Depth (Feet)	USCS Soil Type	Soil Description	Gravel	Coarse	Medium	Fine	Silt/clay
	X	X						SW	sand well graded with gravel, dry, light brown -10YR 7/2,	15	20	20	30	15
							1		loose, rock chips up to 3", ~~rock chips~~ angular to rounded.					
							2							
							3		• surface is hard/compacted, with some desert plants					
							4							
							5		GPS: 043 - N34° 05.976' W117° 07.450'					
							6							
							7							
							8							
							9							
							10							
							11							
							12							

QA/QC

MWH



Site Sketch Map

Boring #: SS-44 MW#: **Sheet** 1 **of** 1

Project: SAR Groundwater Recharge Optimization Study

Job #: 1343019 Site: Soil Borrow

Logged By: A. Leavitt Reviewed By:

Drilling Contractor: ~~Boart Longyear~~ MWH

Drill Rig Type/Method: ~~Sonic Drilling~~ hand sampling

Drillers Name: A. Leavitt

Borehole Diam./Drill Bit Type: –

Total Depth 1'

Ref. Elev. –

Sampler Type: hand sampling

Drill Start Time/Date: 6-24-08 Drill Finish Time/Date: 6-24-08

Well Completion Time/Date: –

Soil Boring Backfill Time/Date: 6-24-08

Depth to 1st Water (▽): – Time/Date: –

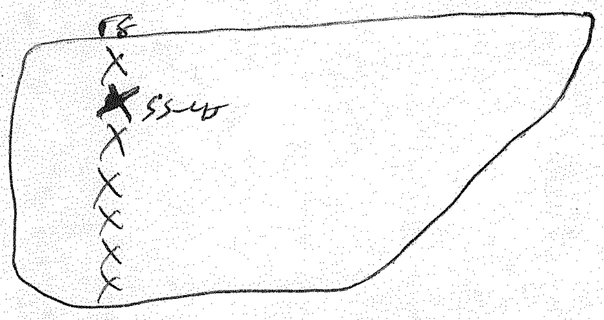
Depth to Water After Drilling (▼): – Time/Date: –

Depth to other Water Bearing Zones: –

PID/OVA	Sample Interval	Recovered (in.)	Blow Counts / 6 in.	Retained for Analysis	Casing Type & Size	Annulus Filler	Depth (Feet)	USCS Soil Type	Soil Description	Estimated % Of				
											Sand			
										Gravel	Coarse	Medium	Fine	Silt/clay
	X	X						SW	sand well graded with gravel, dry, very pale brown - 10YR 7/4, loose, rock chips up to 4", angular to rounded.	15	25	25	25	10
							1							
							2							
							3		surface is hard/compacted, with some desert plants.					
							4							
							5		GPS: 044 - N34° 06.038' W117° 07.448'					
							6							
							7							
							8							
							9							
							10							
							11							
							12							

QA/QC

MWH



Site Sketch Map

Depth to 1st Water (∇): – Time/Date: –

Depth to Water After Drilling (▼): – Time/Date: –

Depth to other Water Bearing Zones: –

Boring #: SS-45 MW#: Sheet 1 of 1

Project: SAR Groundwater Recharge Optimization Study

Job #: 1343019 Site: Soil Borrow

Logged By: A. Leavitt Reviewed By:

Drilling Contractor: ~~Boart Longyear~~ MWH

Drill Rig Type/Method: ~~Sonic Drilling~~ hand sampling

Drillers Name: A. Leavitt

Borehole Diam./Drill Bit Type: –

Total Depth 1'

Ref. Elev. –

Sampler Type: hand sampling

Drill Start Time/Date: 6-24-08 Drill Finish Time/Date: 6-24-08

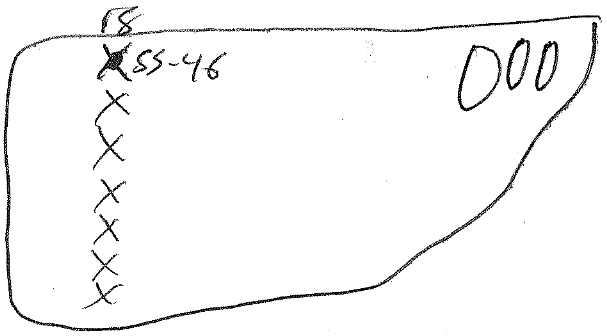
Well Completion Time/Date: –

Soil Boring Backfill Time/Date: 6-24-08

PID/OVA	Sample Interval	Recovered (in.)	Blow Counts / 6 in.	Retained for Analysis	Casing Type & Size	Annulus Filler	Depth (Feet)	USCS Soil Type	Soil Description	Estimated % Of				
											Sand			
										Gravel	Coarse	Medium	Fine	Silt/clay
	X	X						SW	sand well graded with gravel, dry, very pale brown - 10YR 7/4,	15	25	25	25	10
							1		loose, rock chips up to 4", angular to rounded.					
							2							
							3		surface is hard/compacted, with some desert plants					
							4							
							5		GPS: 045 - N34° 06.096' W117° 07.449'					
							6							
							7							
							8							
							9							
							10							
							11							
							12							

QA/QC

MWH



Site Sketch Map

Depth to 1st Water (▽): – Time/Date: –

Depth to Water After Drilling (▼): – Time/Date: –

Depth to other Water Bearing Zones: –

Boring #: SS-46 MW#: **Sheet** 1 **of** 1

Project: SAR Groundwater Recharge Optimization Study

Job #: 1343019 Site: Soil Borrow

Logged By: A. Leavitt Reviewed By:

Drilling Contractor: ~~Boart Longyear~~ MWH

Drill Rig Type/Method: ~~Sonic Drilling~~ handsampling

Drillers Name: A. Leavitt

Borehole Diam./Drill Bit Type: – **Total Depth** 1' **Ref. Elev.** –

Sampler Type: hand sampling

Drill Start Time/Date: 6-24-08 Drill Finish Time/Date: 6-24-08

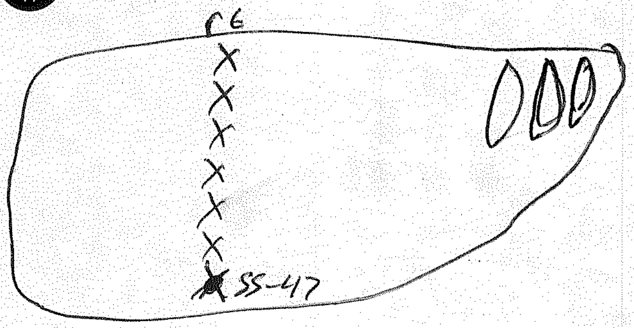
Well Completion Time/Date: –

Soil Boring Backfill Time/Date: 6-24-08

PID/OVA	Sample Interval	Recovered (in.)	Blow Counts / 6 in.	Retained for Analysis	Casing Type & Size	Annulus Filler	Depth (Feet)	USCS Soil Type	Soil Description	Estimated % Of				
											Sand			
										Gravel	Coarse	Medium	Fine	Silt/clay
	X	X						SW	sand well graded with gravel, dry, very pale brown - 10YR 7/4,	15	25	25	25	10
							1		loose, rock chips up to 4", angular to rounded.					
							2							
							3		surface is hard/compacted, some desert plants.					
							4							
							5		GPS: 046 - N34° 06.161' W117° 07.451'					
							6							
							7							
							8							
							9							
							10							
							11							
							12							

QA/QC

MWH



Site Sketch Map

Boring #: SS-47 MW#:	**Sheet** 1 **of** 1
Project: SAR Groundwater Recharge Optimization Study	
Job #: 1343019	Site: Soil Borrow
Logged By: A. Leavitt	Reviewed By:
Drilling Contractor: ~~Boart Longyear~~ MWH	
Drill Rig Type/Method: ~~Sonic Drilling~~ hand sampling	
Drillers Name: A. Leavitt	
Borehole Diam./Drill Bit Type: —	**Total Depth** 1' **Ref. Elev.** —
Sampler Type: hand sampling	
Drill Start Time/Date: 6-24-08	Drill Finish Time/Date: 6-24-08
Well Completion Time/Date: —	
Soil Boring Backfill Time/Date: 6-24-08	

Depth to 1st Water (▽): — Time/Date: -

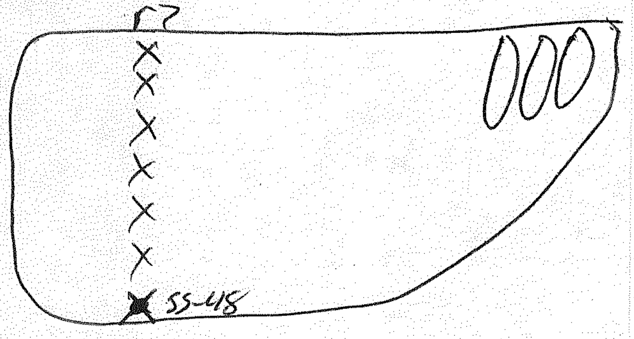
Depth to Water After Drilling (▼): — Time/Date: -

Depth to other Water Bearing Zones: —

PID/OVA	Sample Interval	Recovered (in.)	Blow Counts / 6 in.	Retained for Analysis	Casing Type & Size	Annulus Filler	Depth (Feet)	USCS Soil Type	Soil Description	Estimated % Of Gravel	Sand Coarse	Sand Medium	Sand Fine	Silt/clay
	X	X						SW	sand well graded, dry, light yellowish brown - 2.5Y 6/4, loose,	10	25	30	30	5
							1		rock chips up to 1", sub angular to rounded.					
							2							
							3		surface hard but not to compacted, with some					
							4		desert plants.					
							5		GPS: 047 - N34°05.799' W117°07.297'					
							6							
							7							
							8							
							9							
							10							
							11							
							12							

QA/QC

MWH



Site Sketch Map

Boring #: SS-48 MW#: **Sheet** 1 **of** 1

Project: SAR Groundwater Recharge Optimization Study

Job #: 1343019 Site: Soil Borrow

Logged By: A. Leavitt Reviewed By:

Drilling Contractor: ~~Boart Longyear~~ MWH

Drill Rig Type/Method: ~~Sonic Drilling~~ hand sampling

Drillers Name: A. Leavitt

Borehole Diam./Drill Bit Type: -

Total Depth 1'

Ref. Elev. -

Sampler Type: hand sampling

Depth to 1st Water (▽): - Time/Date: -

Drill Start Time/Date: 6-24-08 Drill Finish Time/Date: 6-24-08

Depth to Water After Drilling (▼): - Time/Date: -

Well Completion Time/Date: -

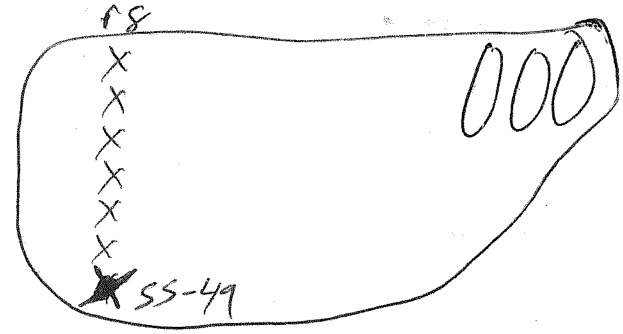
Depth to other Water Bearing Zones: -

Soil Boring Backfill Time/Date: 6-24-08

PID/OVA	Sample Interval	Recovered (in.)	Blow Counts / 6 in.	Retained for Analysis	Casing Type & Size	Annulus Filler	Depth (Feet)	USCS Soil Type	Soil Description	Estimated % Of				
											Sand			
										Gravel	Coarse	Medium	Fine	Silt/clay
	X	X						SW	Sand well graded with gravel, dry, light brown - 10YR 8/2,	15	25	25	25	10
							1		loose, rock chips up to 3", angular to rounded.					
							2							
							3		Surface is hard and compacted and some desert plants. → This					
							4		sample was taken in a drainage that is dry. lots of rocks that					
							5		seem mildly cemented on the surface. I removed them first.					
							6							
							7		GPS: 048 - N34° 05.809' W117° 07.374'					
							8							
							9							
							10							
							11							
							12							

QA/QC

MWH



Site Sketch Map

Boring #: SS-49 MW#: **Sheet** 1 **of** 1

Project: SAR Groundwater Recharge Optimization Study

Job #: 1343019 Site: Soil Borrow

Logged By: A. Leavitt Reviewed By:

Drilling Contractor: ~~Boart Longyear~~ MWH

Drill Rig Type/Method: ~~Sonic Drilling~~ hand sampling

Drillers Name: A. Leavitt

Borehole Diam./Drill Bit Type: –

Total Depth 1'

Ref. Elev. –

Sampler Type: hand sampling

Drill Start Time/Date: 6-24-08 Drill Finish Time/Date: 6-24-08

Well Completion Time/Date: –

Soil Boring Backfill Time/Date: 6-24-08

Depth to 1st Water (▽): – Time/Date: –

Depth to Water After Drilling (▼): – Time/Date: –

Depth to other Water Bearing Zones: –

PID/OVA	Sample Interval	Recovered (in.)	Blow Counts / 6 in.	Retained for Analysis	Casing Type & Size	Annulus Filler	Depth (Feet)	USCS Soil Type	Soil Description	Estimated % Of Gravel	Sand Coarse	Sand Medium	Sand Fine	Silt/clay
	X	X						SW	sandwell graded with gravel, dry, light brown - 10YR 7/2,	15	25	25	25	10
							1		loose, rock chips up to 3", angular to rounded.					
							2							
							3		Surface was not very hard or compacted, plants near					
							4		by but not on sample point.					
							5		GPS: 049 - N34°05.812' W117°07.495'					
							6							
							7							
							8							
							9							
							10							
							11							
							12							

QA/QC

MWH

Site Sketch Map

Boring #: SS-50 MW#: Sheet 1 of 1

Project: SAR Groundwater Recharge Optimization Study

Job #: 1343019 Site: Soil Borrow

Logged By: A. Leavitt Reviewed By:

Drilling Contractor: ~~Boart Longyear~~ MWH

Drill Rig Type/Method: ~~Sonic Drilling~~ hand sampling

Drillers Name: A. Leavitt

Borehole Diam./Drill Bit Type: –

Total Depth 1'

Ref. Elev. –

Sampler Type: hand sampling

Drill Start Time/Date: 6-24-08 Drill Finish Time/Date: 6-24-08

Depth to 1st Water (▽): – Time/Date: –

Depth to Water After Drilling (▼): – Time/Date: –

Depth to other Water Bearing Zones: –

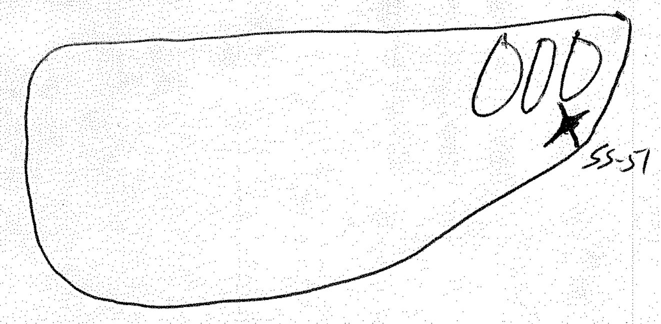
Well Completion Time/Date: –

Soil Boring Backfill Time/Date: 6-24-08

PID/OVA	Sample Interval	Recovered (in.)	Blow Counts / 6 in.	Retained for Analysis	Casing Type & Size	Annulus Filler	Depth (Feet)	USCS Soil Type	Soil Description	Estimated % Of				
											Sand			
										Gravel	Coarse	Medium	Fine	Silt/clay
	X	X						SW	sand well gradad, dry, pale brown - 10YR 6/3, loose, ~~rock~~	5	30	30	30	5
							1		~~chips~~ ~~[illegible]~~ subrounded-rounded.					
							2		surface is same ~~[illegible]~~ as it is @ 1', no plants just					
							3		sand.					
							4		GPS: 050 - N34° 05.931' W117° 06.859'					
							5							
							6							
							7							
							8							
							9							
							10							
							11							
							12							

QA/QC

MWH



Site Sketch Map

Boring #: SS-51 MW#: **Sheet** 1 **of** 1

Project: SAR Groundwater Recharge Optimization Study

Job #: 1343019 Site: Soil Burrow

Logged By: A. Leavitt Reviewed By:

Drilling Contractor: ~~Boart Longyear~~ MWH

Drill Rig Type/Method: ~~Sonic Drilling~~ hand sampling

Drillers Name: A. Leavitt

Borehole Diam./Drill Bit Type: —

Total Depth 1'

Ref. Elev. —

Sampler Type: hand sampling

Drill Start Time/Date: 6-24-08 Drill Finish Time/Date: 6-24-08

Depth to 1st Water (∇): — Time/Date: —

Depth to Water After Drilling (▼): — Time/Date: —

Depth to other Water Bearing Zones: —

Well Completion Time/Date: —

Soil Boring Backfill Time/Date: 6-24-08

										Estimated % Of				
											Sand			
PID/OVA	Sample Interval	Recovered (in.)	Blow Counts / 6 in.	Retained for Analysis	Casing Type & Size	Annulus Filler	Depth (Feet)	USCS Soil Type	Soil Description	Gravel	Coarse	Medium	Fine	Silt/clay
	X	X						SW	sand well graded, dry, pale brown - 10YR 6/3, loose, sub-	5	30	30	30	5
							1		rounded to rounded.					
							2		surface is same as 1' - just the sand, no plants					
							3							
							4		GPS: 051 - N34°05.975' W117°06.769'					
							5							
							6							
							7							
							8							
							9							
							10							
							11							
							12							

QA/QC

MWH

Boring #: SS-52 MW#:

Sheet 1 of 1

Project: SAR Groundwater Recharge Optimization Study

Job #: 1343019 Site: Soil Borrow

Logged By: A. Leavitt Reviewed By:

Drilling Contractor: ~~Boart Longyear~~ MWH

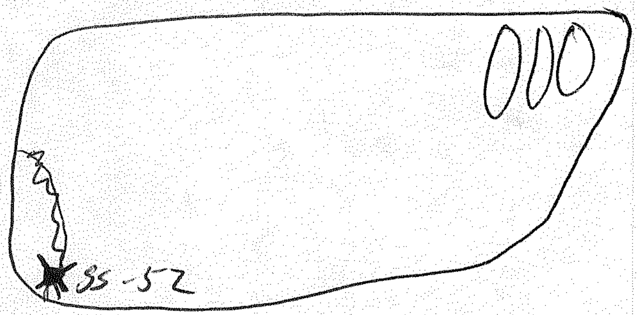
Drill Rig Type/Method: ~~Sonic Drilling~~ Hand Sampling

Drillers Name: A. Leavitt

Borehole Diam./Drill Bit Type: —

Total Depth 1'

Ref. Elev. —



Site Sketch Map

Sampler Type: Hand Sampling

Depth to 1st Water (▽): — Time/Date: -

Drill Start Time/Date: 6-25-08 Drill Finish Time/Date: 6-25-08

Depth to Water After Drilling (▼): — Time/Date: -

Well Completion Time/Date: -

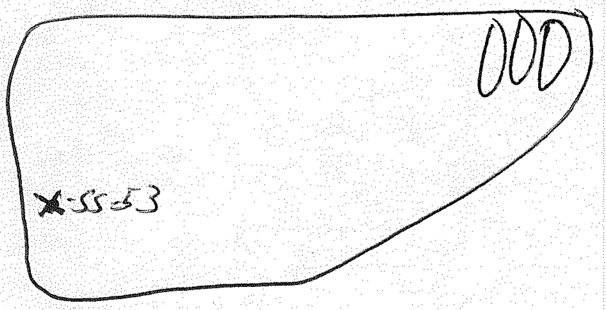
Depth to other Water Bearing Zones: —

Soil Boring Backfill Time/Date: 6-25-08

PID/OVA	Sample Interval	Recovered (in.)	Blow Counts / 6 in.	Retained for Analysis	Casing Type & Size	Annulus Filler	Depth (Feet)	USCS Soil Type	Soil Description	Estimated % Of Gravel	Sand Coarse	Sand Medium	Sand Fine	Silt/clay
	X	X						SW	Sand well graded with gravel, dry, pale brown - 10YR 6/3, loose, sub angular to rounded	15	25	30	30	—
							1							
							2		-Surface is just sand → all the way down to 1'.					
							3							
							4		GPS: 052 - N34° 05.846' W117° 07.500'					
							5							
							6							
							7							
							8							
							9							
							10							
							11							
							12							

QA/QC

MWH



Site Sketch Map

Boring #: SS-53 MW#: **Sheet** 1 **of** 1

Project: SAR Groundwater Recharge Optimization Study

Job #: 1343019 Site: Soil Borrow

Logged By: A. Leavitt Reviewed By:

Drilling Contractor: ~~Boart Longyear~~ MWH

Drill Rig Type/Method: ~~Sonic Drilling~~ hand sampling

Drillers Name: A. Leavitt

Borehole Diam./Drill Bit Type: —

Total Depth 1'

Ref. Elev. —

Sampler Type: hand sampling

Drill Start Time/Date: 6-25-08 Drill Finish Time/Date: 6-25-08

Well Completion Time/Date: —

Soil Boring Backfill Time/Date: 6-25-08

Depth to 1st Water (▽): — Time/Date: —

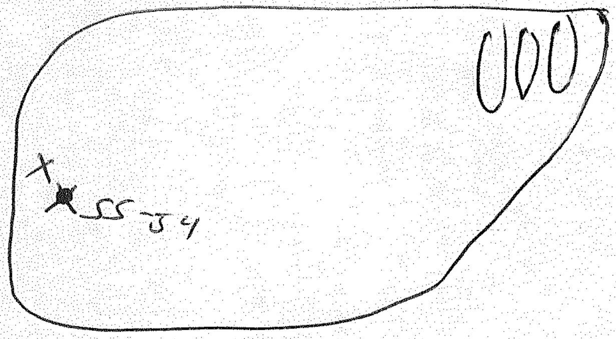
Depth to Water After Drilling (▼): — Time/Date: —

Depth to other Water Bearing Zones: —

PID/OVA	Sample Interval	Recovered (in.)	Blow Counts / 6 in.	Retained for Analysis	Casing Type & Size	Annulus Filler	Depth (Feet)	USCS Soil Type	Soil Description	Estimated % Of Gravel	Sand Coarse	Sand Medium	Sand Fine	Silt/clay
	X	X						SM	Siltysand/sand-silt mixture, dry, pale olive - 5Y 6/3,	—	—	—	50	50
							1		loose, weakly cemented.					
							2		-surface was mudcracks and little to no plant life.					
							3							
							4		GPS: 053 - N34° 05.926 W117° 07.520					
							5							
							6							
							7							
							8							
							9							
							10							
							11							
							12							

QA/QC

MWH



Site Sketch Map

Boring #: SS-54 MW#: **Sheet** 1 **of** 1

Project: SAR Groundwater Recharge Optimization Study

Job #: 1343019 Site: Soil Borrow

Logged By: A. Leavitt Reviewed By:

Drilling Contractor: ~~Boart Longyear~~ MWH

Drill Rig Type/Method: ~~Sonic Drilling~~ hand sampling

Drillers Name: A. Leavitt

Borehole Diam./Drill Bit Type: –

Total Depth 1'

Ref. Elev. –

Sampler Type: hand sampling

Drill Start Time/Date: 6-25-08 Drill Finish Time/Date: 6-26-08

Well Completion Time/Date: –

Soil Boring Backfill Time/Date: 6-25-08

Depth to 1st Water (▽): – Time/Date: –

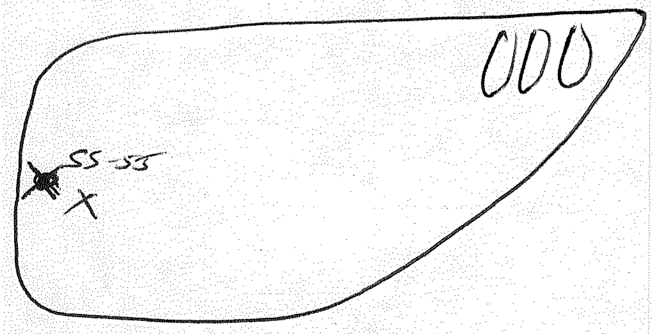
Depth to Water After Drilling (▼): – Time/Date: –

Depth to other Water Bearing Zones: –

PID/OVA	Sample Interval	Recovered (in.)	Blow Counts / 6 in.	Retained for Analysis	Casing Type & Size	Annulus Filler	Depth (Feet)	USCS Soil Type	Soil Description	Estimated % Of				
											Sand			
										Gravel	Coarse	Medium	Fine	Silt/clay
	X	X						SM	silty sand, dry to slightly damp, light olive brown - 2.5Y 5/3,	5	tr	5	50	40
							1		loose.					
							2		- mud cracks on surface - no plants.					
							3							
							4		GPS: 054 - N34° 05.981' W117° 07.539'					
							5							
							6							
							7							
							8							
							9							
							10							
							11							
							12							

QA/QC

MWH



Site Sketch Map

Boring #: SS-55 MW#: Sheet 1 of 1

Project: SAR Groundwater Recharge Optimization Study

Job #: 1343019 Site: Soil Borrow

Logged By: A. Leavitt Reviewed By:

Drilling Contractor: ~~Boart Longyear~~ MWH

Drill Rig Type/Method: ~~Sonic Drilling~~ hand sampling

Drillers Name: A. Leavitt

Borehole Diam./Drill Bit Type: —

Total Depth 1'

Ref. Elev. —

Sampler Type: hand sample

Drill Start Time/Date: 6-25-08 Drill Finish Time/Date: 6-25-08

Depth to 1st Water (▽): — Time/Date: —

Depth to Water After Drilling (▼): — Time/Date: —

Well Completion Time/Date: —

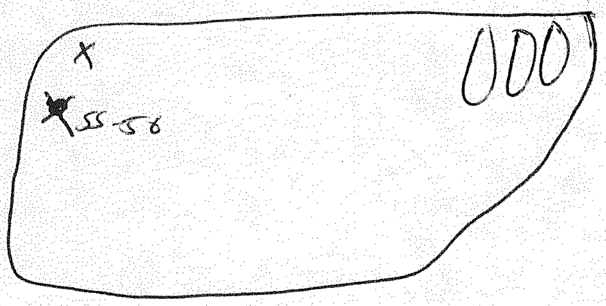
Depth to other Water Bearing Zones: —

Soil Boring Backfill Time/Date: 6-25-08

PID/OVA	Sample Interval	Recovered (in.)	Blow Counts / 6 in.	Retained for Analysis	Casing Type & Size	Annulus Filler	Depth (Feet)	USCS Soil Type	Soil Description	Estimated % Of				
											Sand			
										Gravel	Coarse	Medium	Fine	Silt/clay
	X	X						SM	silty sand, dry to slightly damp, light olive brown - 2.5Y5/3	5	tr	5	50	40
							1		loose.					
							2		- mud cracks on surface - no plants.					
							3							
							4		gps: 055 - N34° 06.054' W117° 07.549'					
							5							
							6							
							7							
							8							
							9							
							10							
							11							
							12							

QA/QC

MWH



Site Sketch Map

Boring #: SS-56 MW#:

Sheet 1 of 1

Project: SAR Groundwater Recharge Optimization Study

Job #: 1343019 Site: Soil Borrow

Logged By: A. Leavitt Reviewed By:

Drilling Contractor: ~~Boart Longyear~~ MWH

Drill Rig Type/Method: ~~Sonic Drilling~~ hand sampling

Drillers Name: A. Leavitt

Borehole Diam./Drill Bit Type: —

Total Depth 1'

Ref. Elev. —

Sampler Type: hand sampling

Drill Start Time/Date: 6-25-08 Drill Finish Time/Date: 6-25-08

Well Completion Time/Date: —

Soil Boring Backfill Time/Date: 6-25-08

Depth to 1st Water (▽): — Time/Date: —

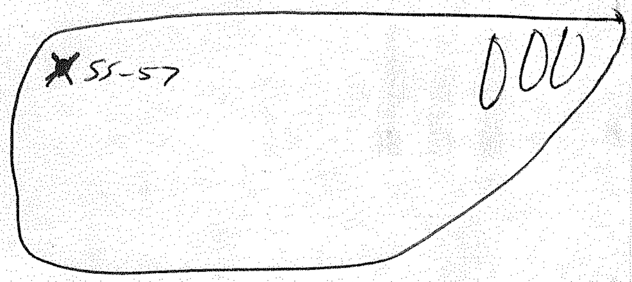
Depth to Water After Drilling (▼): — Time/Date: —

Depth to other Water Bearing Zones: —

PID/OVA	Sample Interval	Recovered (in.)	Blow Counts / 6 in.	Retained for Analysis	Casing Type & Size	Annulus Filler	Depth (Feet)	USCS Soil Type	Soil Description	Estimated % Of				
											Sand			
										Gravel	Coarse	Medium	Fine	Silt/clay
	X	X						SM	silty sand, slightly damp, light olive brown-2.5Y5/4,	5	5	5	50	35
							1		loose.					
							2		-mud cracks on surface - no plants.					
							3							
							4		-GPS: 056 N34°06.085' W117°07.565'					
							5							
							6							
							7							
							8							
							9							
							10							
							11							
							12							

QA/QC

MWH



Site Sketch Map

Boring #: SS-57 MW#:

Sheet 1 of 1

Project: SAR Groundwater Recharge Optimization Study

Job #: 1343019 Site: Soil Borrow

Logged By: A. Leavitt Reviewed By:

Drilling Contractor: ~~Boart Longyear~~ MWH

Drill Rig Type/Method: ~~Sonic Drilling~~ hand sampling

Drillers Name: A. Leavitt

Borehole Diam./Drill Bit Type: —

Total Depth 1'

Ref. Elev. —

Sampler Type: hand sampling

Drill Start Time/Date: 6-25-08 Drill Finish Time/Date: 6-25-08

Depth to 1st Water (▽): — Time/Date: —

Depth to Water After Drilling (▼): — Time/Date: —

Depth to other Water Bearing Zones: —

Well Completion Time/Date: —

Soil Boring Backfill Time/Date: 6-25-08

PID/OVA	Sample Interval	Recovered (in.)	Blow Counts / 6 in.	Retained for Analysis	Casing Type & Size	Annulus Filler	Depth (Feet)	USCS Soil Type	Soil Description	Estimated % Of Gravel	Sand Coarse	Sand Medium	Sand Fine	Silt/clay
	X	X						SM	silty sand, dry, light olive brown 2.5Y 5/4, loose, rock chips up to	5	5	10	50	30
							1		2", subangular to rounded.					
							2		- minor mudcracks on surface, some desert plants.					
							3							
							4		GPS: 057 - N34° 06.136' W117° 07.522'					
							5							
							6							
							7							
							8							
							9							
							10							
							11							
							12							

QA/QC

MWH

Site Sketch Map

Boring #: SS-58 MW#: **Sheet** 1 **of** 1

Project: SAR Groundwater Recharge Optimization Study

Job #: 1343019 Site: outer pond 1

Logged By: A. Leavitt Reviewed By:

Drilling Contractor: ~~Boart Longyear~~ MWH

Drill Rig Type/Method: ~~Sonic Drilling~~ hand Sample

Drillers Name: A. Leavitt

Borehole Diam./Drill Bit Type: —

Total Depth 1'

Ref. Elev. -

Sampler Type: hand sampling

Drill Start Time/Date: 6-26-08 Drill Finish Time/Date: 6-26-08

Well Completion Time/Date: —

Soil Boring Backfill Time/Date: 6-26-08

Depth to 1st Water (▽): — Time/Date: -

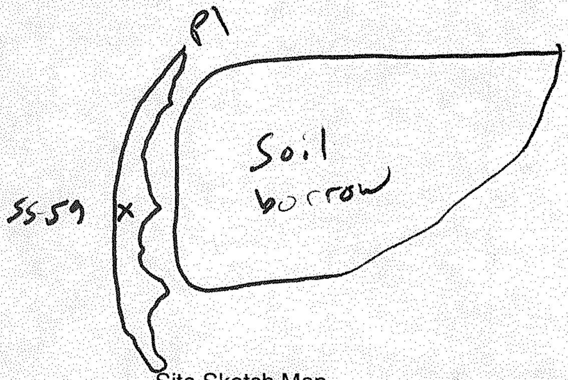
Depth to Water After Drilling (▼): — Time/Date: -

Depth to other Water Bearing Zones: —

PID/OVA	Sample Interval	Recovered (in.)	Blow Counts / 6 in.	Retained for Analysis	Casing Type & Size	Annulus Filler	Depth (Feet)	USCS Soil Type	Soil Description	Estimated % Of				
											Sand			
										Gravel	Coarse	Medium	Fine	Silt/clay
	X	X						SW	Sandwell graded with gravel, moist, olive brown (2.5Y4/4),	30	30	25	15	—
							1		loose, rockchips up to 3", subangular to ~~angular~~ ASC					
							2		rounded.					
							3		• surface had mudcracks and dried algae.					
							4							
							5		• GPS: 058 - N34°05.847' W117°07.597					
							6							
							7							
							8							
							9							
							10							
							11							
							12							

QA/QC

MWH



Site Sketch Map

Boring #: SS-59 MW#:

Sheet 1 of 1

Project: SAR Groundwater Recharge Optimization Study

Job #: 1343019 Site: outer pond ~~1~~

Logged By: A. Leavitt Reviewed By:

Drilling Contractor: ~~Boart Longyear~~ MWH

Drill Rig Type/Method: ~~Sonic Drilling~~ hand sampling

Drillers Name: A. Leavitt

Borehole Diam./Drill Bit Type: -

Total Depth 1'

Ref. Elev. -

Sampler Type: hand sampling

Depth to 1st Water (▽): - Time/Date: -

Drill Start Time/Date: 6-26-08 Drill Finish Time/Date: 6-26-08

Depth to Water After Drilling (▼): - Time/Date: -

Well Completion Time/Date: -

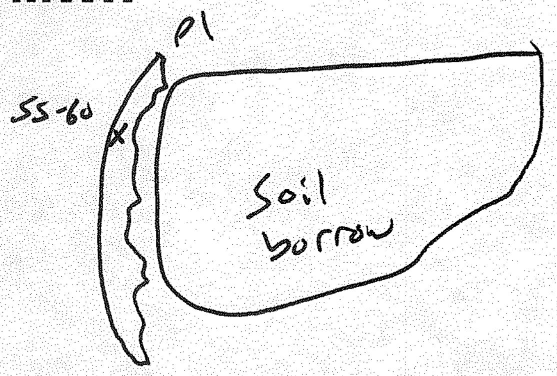
Depth to other Water Bearing Zones: -

Soil Boring Backfill Time/Date: 6-26-08

PID/OVA	Sample Interval	Recovered (in.)	Blow Counts / 6 in.	Retained for Analysis	Casing Type & Size	Annulus Filler	Depth (Feet)	USCS Soil Type	Soil Description	Estimated % Of				
										Gravel	Sand			Silt/clay
											Coarse	Medium	Fine	
	X	X						SW/SM	Silty sand / sand well graded, moist, olive brown (2.5Y 4/4), loose / soft, weekly cemented.	10	20	20	30	20
							1							
							2							
							3		- surface had dried algae.					
							4		- GPS: 059 - N 34° W 117°					
							5							
							6							
							7							
							8							
							9							
							10							
							11							
							12							

QA/QC

MWH



Site Sketch Map

Boring #: SS-60 MW#: **Sheet** 1 **of** 1

Project: SAR Groundwater Recharge Optimization Study

Job #: 1343019 Site: outer Pond 1

Logged By: A. Leavitt Reviewed By:

Drilling Contractor: ~~Boart Longyear~~ MWH

Drill Rig Type/Method: ~~Sonic Drilling~~ hand sampling

Drillers Name: A. Leavitt

Borehole Diam./Drill Bit Type: –

Total Depth 1'

Ref. Elev. –

Sampler Type: hand sampling

Drill Start Time/Date: 6-26-08 Drill Finish Time/Date: 6-26-08

Well Completion Time/Date: –

Soil Boring Backfill Time/Date: 6-26-08

Depth to 1st Water (▽): — Time/Date: –

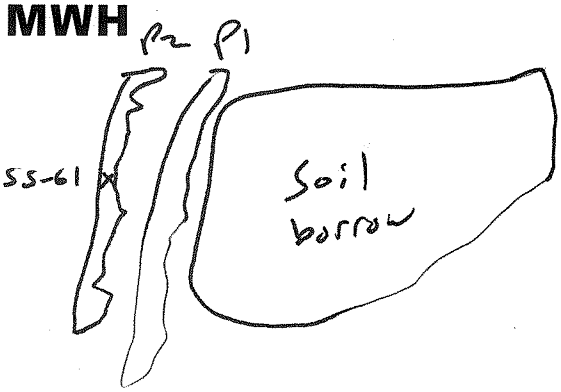
Depth to Water After Drilling (▼): – Time/Date: –

Depth to other Water Bearing Zones: –

PID/OVA	Sample Interval	Recovered (in.)	Blow Counts / 6 in.	Retained for Analysis	Casing Type & Size	Annulus Filler	Depth (Feet)	USCS Soil Type	Soil Description	Estimated % Of				
											Sand			
										Gravel	Coarse	Medium	Fine	Silt/clay
	X	X						SW	Sand well graded, moist, Yellowish brown (10YR 5/6),	5	25	25	35	10
							1		loose.					
							2		- surface had thin silty mudcrack layer and algae					
							3							
							4		GPS: 060 – N34°06.078' W117°07.744'					
							5							
							6							
							7							
							8							
							9							
							10							
							11							
							12							

QA/QC

MWH



Site Sketch Map

Depth to 1st Water (▽): — Time/Date: —

Depth to Water After Drilling (▼): — Time/Date: —

Depth to other Water Bearing Zones: —

Boring #: SS-61 MW#: **Sheet** 1 **of** 1

Project: SAR Groundwater Recharge Optimization Study

Job #: 1343019 Site: outer Pond 2

Logged By: A. Leavitt Reviewed By:

Drilling Contractor: ~~Boart Longyear~~ MWH

Drill Rig Type/Method: ~~Sonic Drilling~~ handsampling

Drillers Name: A. Leavitt

Borehole Diam./Drill Bit Type: —

Total Depth 1'

Ref. Elev. —

Sampler Type: hand sampling

Drill Start Time/Date: 6-26-08 Drill Finish Time/Date: 6-28-08

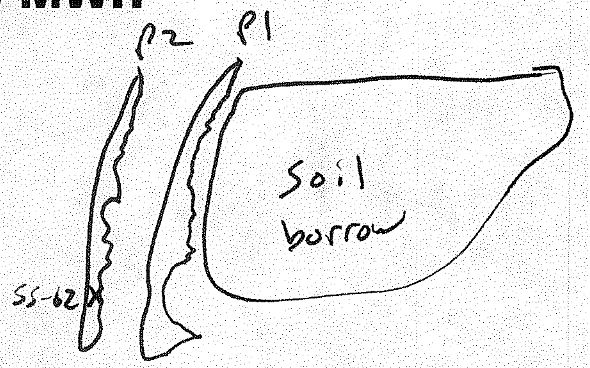
Well Completion Time/Date: —

Soil Boring Backfill Time/Date: 6-26-08

PID/OVA	Sample Interval	Recovered (in.)	Blow Counts / 6 in.	Retained for Analysis	Casing Type & Size	Annulus Filler	Depth (Feet)	USCS Soil Type	Soil Description	Estimated % Of				
										Gravel	Sand			Silt/clay
											Coarse	Medium	Fine	
	X	X						SW	Sand well graded with gravel, dry, pale brown (10YR 6/3), rock chips up to 1.5", sub angular to rounded	15	25	25	25	10
							1							
							2							
							3		• surface had thin layer of silty mudcracks and algae.					
							4							
							5		• GPS: 061 - N34° 06.019' W117° 07.749'					
							6							
							7							
							8							
							9							
							10							
							11							
							12							

QA/QC

MWH



Site Sketch Map

Boring #: SS-62 MW#:
Sheet 1 of 1

Project: SAR Groundwater Recharge Optimization Study

Job #: 1343019 Site: outer Pond 2

Logged By: A. Leavitt Reviewed By:

Drilling Contractor: ~~Boart Longyear~~ MWH

Drill Rig Type/Method: ~~Sonic Drilling~~ hand sampling

Drillers Name: A. Leavitt

Borehole Diam./Drill Bit Type: —

Total Depth 1'

Ref. Elev. —

Sampler Type: hand sampling

Drill Start Time/Date: 6-26-08 Drill Finish Time/Date: 6-26-08

Well Completion Time/Date: —

Soil Boring Backfill Time/Date: 6-26-08

Depth to 1st Water (▽): — Time/Date: —

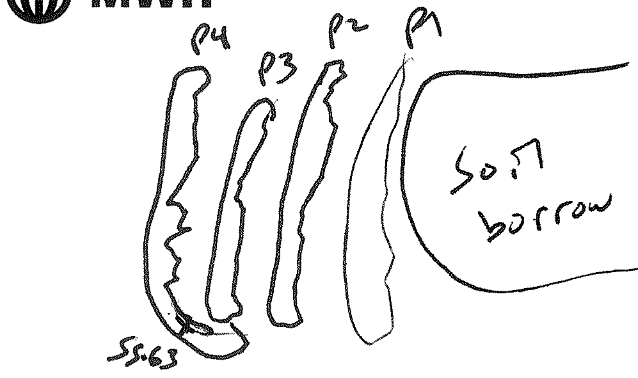
Depth to Water After Drilling (▼): — Time/Date: —

Depth to other Water Bearing Zones: —

PID/OVA	Sample Interval	Recovered (in.)	Blow Counts / 6 in.	Retained for Analysis	Casing Type & Size	Annulus Filler	Depth (Feet)	USCS Soil Type	Soil Description	Estimated % Of				
											Sand			
										Gravel	Coarse	Medium	Fine	Silt/clay
	X	X						SW	Sand well graded with gravel and silt, dry, yellowish brown (10YR 5/6), loose rock chips up to 2", sub-angular to rounded.	15	20	20	25	20
							1							
							2							
							3		• surface had a thin layer of silty mudcracks and algae.					
							4							
							5		• GPS: 062 – N34° 05.876' W117° 07.715'					
							6							
							7							
							8							
							9							
							10							
							11							
							12							

QA/QC

MWH



Site Sketch Map

Boring #: SS-63 MW#: Sheet 1 of 1

Project: SAR Groundwater Recharge Optimization Study

Job #: 1343019 Site: outer Pond 4

Logged By: A. Leavitt Reviewed By:

Drilling Contractor: ~~Boart Longyear~~ MWH

Drill Rig Type/Method: ~~Sonic Drilling~~ hand sampling

Drillers Name: A. Leavitt

Borehole Diam./Drill Bit Type: -

Total Depth 1'

Ref. Elev. -

Sampler Type: hand sampling

Drill Start Time/Date: 6-26-08 Drill Finish Time/Date: 6-26-08

Well Completion Time/Date: -

Soil Boring Backfill Time/Date: 6-26-08

Depth to 1st Water (▽): - Time/Date: -

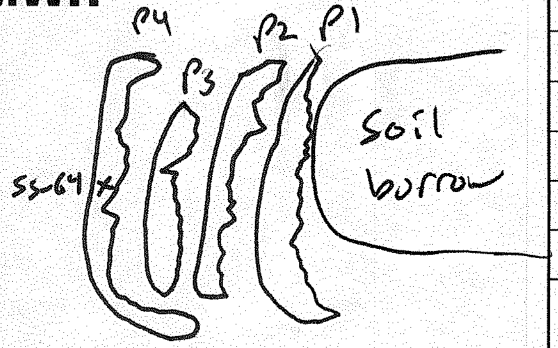
Depth to Water After Drilling (▼): - Time/Date: -

Depth to other Water Bearing Zones: -

PID/OVA	Sample Interval	Recovered (in.)	Blow Counts / 6 in.	Retained for Analysis	Casing Type & Size	Annulus Filler	Depth (Feet)	USCS Soil Type	Soil Description	Estimated % Of				
											Sand			
										Gravel	Coarse	Medium	Fine	Silt/clay
	X	X						SW	Sand well graded, dry, Yellowish brown (10YR 5/6), loose, rock chips up to 1.5", subangular to rounded.	10	25	25	25	15
							1							
							2							
							3		-surface had thin layer of silty mudcracks and algae.					
							4							
							5		-GPS: 063 - N34° 05.777' W117° 07.760'					
							6							
							7							
							8							
							9							
							10							
							11							
							12							

QA/QC

MWH



Site Sketch Map

Boring #: SS-64 MW#: Sheet 1 of 1

Project: SAR Groundwater Recharge Optimization Study

Job #: 1343019 Site: outer Pond 4

Logged By: A. Leavitt Reviewed By:

Drilling Contractor: ~~Boart Longyear~~ MWH

Drill Rig Type/Method: ~~Sonic Drilling~~ hand sampling

Drillers Name: A. Leavitt

Borehole Diam./Drill Bit Type: –

Total Depth 1'

Ref. Elev. –

Sampler Type: hand Sampling

Depth to 1st Water (▽): – Time/Date: –

Drill Start Time/Date: 6-26-08 Drill Finish Time/Date: 6-26-08

Depth to Water After Drilling (▼): – Time/Date: –

Well Completion Time/Date: –

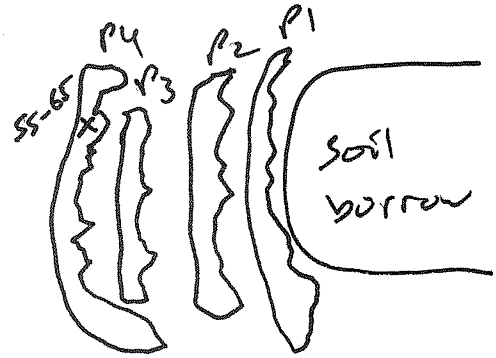
Depth to other Water Bearing Zones: –

Soil Boring Backfill Time/Date: 6-26-08

PID/OVA	Sample Interval	Recovered (in.)	Blow Counts / 6 in.	Retained for Analysis	Casing Type & Size	Annulus Filler	Depth (Feet)	USCS Soil Type	Soil Description	Estimated % Of				
											Sand			
										Gravel	Coarse	Medium	Fine	Silt/clay
	X	X						SW	Sand well graded, moist, dark yellowish brown (10YR 3/6), loose, rock chips up to 2", subangular to rounded.	10	25	25	25	15
							1							
							2							
							3		- surface had thin layer of silty mudcracks and algae.					
							4							
							5		- GPS: 064 – N34°05.851' W117°07.830'					
							6							
							7							
							8							
							9							
							10							
							11							
							12							

QA/QC

MWH



Site Sketch Map

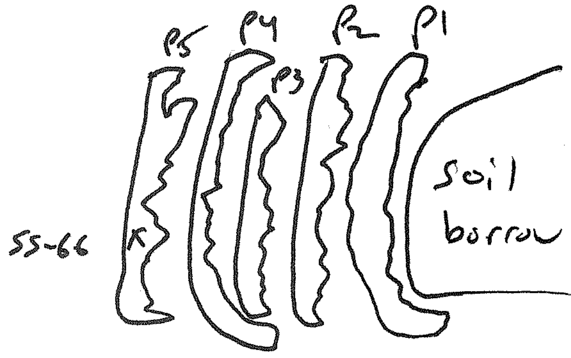
Boring #: SS-65 MW#:
Sheet 1 of 1
Project: SAR Groundwater Recharge Optimization Study
Job #: 1343019 Site: outer Pond 4
Logged By: A. Leavitt Reviewed By:
Drilling Contractor: ~~Boart Longyear~~ MWH
Drill Rig Type/Method: ~~Sonic Drilling~~ hand sampling
Drillers Name: A. Leavitt
Borehole Diam./Drill Bit Type: —
Total Depth 1'
Ref. Elev. —
Sampler Type: hand sampling
Drill Start Time/Date: 6-26-08 Drill Finish Time/Date: 6-26-08
Well Completion Time/Date: —
Soil Boring Backfill Time/Date: 6-26-08

Depth to 1st Water (▽): — Time/Date: —
Depth to Water After Drilling (▼): — Time/Date: —
Depth to other Water Bearing Zones: —

PID/OVA	Sample Interval	Recovered (in.)	Blow Counts / 6 in.	Retained for Analysis	Casing Type & Size	Annulus Filler	Depth (Feet)	USCS Soil Type	Soil Description	Estimated % Of				
											Sand			
										Gravel	Coarse	Medium	Fine	Silt/clay
	X	X						SW	sand well graded, moist, dark, Yellowish brown (10YR4/6),	10	25	25	25	15
							1		loose, rock chips up to 2", sub angular to rounded.					
							2							
							3		-Surface had Thin layer of silty mudcracks and algae.					
							4							
							5		- GPS - 065 - N34°06.105' W117°07.882'					
							6							
							7							
							8							
							9							
							10							
							11							
							12							

QA/QC

MWH



Site Sketch Map

Boring #: SS68 MW#: **Sheet** 1 **of** 1

Project: SAR Groundwater Recharge Optimization Study

Job #: 1343019 Site: outer Ponds

Logged By: A. Leavitt Reviewed By:

Drilling Contractor: ~~Boart Longyear~~ MWH

Drill Rig Type/Method: ~~Sonic Drilling~~ hand sampling

Drillers Name: A. Leavitt

Borehole Diam./Drill Bit Type: — **Total Depth** 1'

Ref. Elev. —

Sampler Type: hand sampling

Drill Start Time/Date: 6-26-08 Drill Finish Time/Date: 6-26-08

Well Completion Time/Date: —

Soil Boring Backfill Time/Date: 6-26-08

Depth to 1st Water (▽): — Time/Date: —

Depth to Water After Drilling (▼): — Time/Date: —

Depth to other Water Bearing Zones: —

PID/OVA	Sample Interval	Recovered (in.)	Blow Counts / 6 in.	Retained for Analysis	Casing Type & Size	Annulus Filler	Depth (Feet)	USCS Soil Type	Soil Description	Estimated % Of Gravel	Sand Coarse	Sand Medium	Sand Fine	Silt/clay
	X	X						SW	Sand well graded, moist, dark Yellowish brown (10YR4/4),	10	25	25	25	15
							1		loose, rock chips up to 2", sub angular to rounded.					
							2							
							3		• surface had thin layer of silty mudcracks and					
							4		algae.					
							5		• GPS: 066 - N34°06'143' W117 08.036'					
							6							
							7							
							8							
							9							
							10							
							11							
							12							

QA/QC

MWH

Boring #: SS-67 MW#:

Sheet 1 of 1

Project: SAR Groundwater Recharge Optimization Study

Job #: 1343019

Site: outer ponds

Logged By: A. Leavitt

Reviewed By:

Drilling Contractor: ~~Boart Longyear~~ MWH

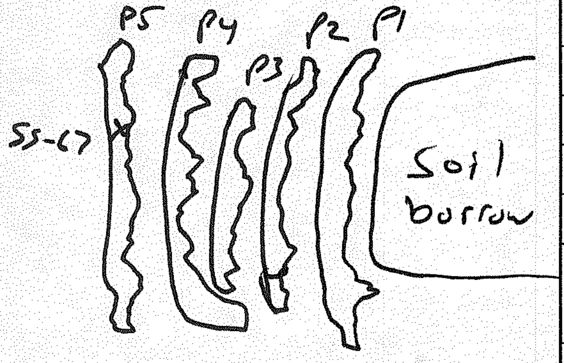
Drill Rig Type/Method: ~~Sonic Drilling~~ hand sampling

Drillers Name: A. Leavitt

Borehole Diam./Drill Bit Type: –

Total Depth 1'

Ref. Elev. –



Site Sketch Map

Sampler Type: hand sampling

Drill Start Time/Date: 6-26-08

Drill Finish Time/Date: 6-26-08

Depth to 1st Water (▽): –

Time/Date: –

Depth to Water After Drilling (▼): –

Time/Date: –

Well Completion Time/Date: –

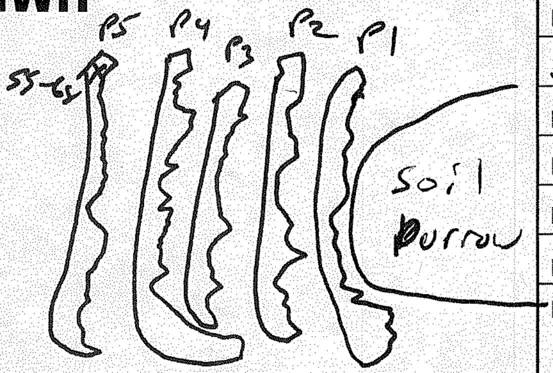
Depth to other Water Bearing Zones: –

Soil Boring Backfill Time/Date: 6-26-08

PID/OVA	Sample Interval	Recovered (in.)	Blow Counts / 6 in.	Retained for Analysis	Casing Type & Size	Annulus Filler	Depth (Feet)	USCS Soil Type	Soil Description	Estimated % Of				
											Sand			
										Gravel	Coarse	Medium	Fine	Silt/clay
	X	X						SW	Sand well graded, dry, light Yellowish brown (10YR 6/4),	10	25	25	25	15
							1		loose, rock chips up to 1.5", subangular to rounded.					
							2							
							3		- Surface had Thin layer of Silty mudcracks and					
							4		algae.					
							5		- GPS: 067 – N 34° 06.261' W117° 08.018'					
							6							
							7							
							8							
							9							
							10							
							11							
							12							

QA/QC

MWH



Site Sketch Map

Boring #: SS-68 MW#: Sheet 1 of 1

Project: SAR Groundwater Recharge Optimization Study

Job #: 1343019 Site: outer Pond 5

Logged By: A. Leavitt Reviewed By:

Drilling Contractor: ~~Boart Longyear~~ MWH

Drill Rig Type/Method: ~~Sonic Drilling~~ hand sampling

Drillers Name: A. Leavitt

Borehole Diam./Drill Bit Type: —

Total Depth 1'

Ref. Elev. —

Sampler Type: hand sampling

Drill Start Time/Date: 6-26-08 Drill Finish Time/Date: 6-26-08

Well Completion Time/Date: —

Soil Boring Backfill Time/Date: 6-26-08

Depth to 1st Water (▽): — Time/Date: —

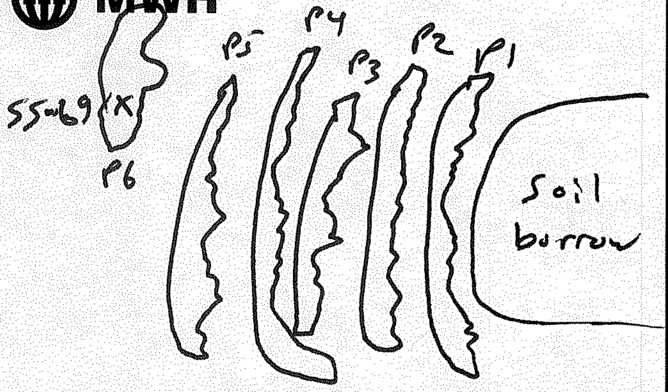
Depth to Water After Drilling (▼): — Time/Date: —

Depth to other Water Bearing Zones: —

PID/OVA	Sample Interval	Recovered (in.)	Blow Counts / 6 in.	Retained for Analysis	Casing Type & Size	Annulus Filler	Depth (Feet)	USCS Soil Type	Soil Description	Estimated % Of				
											Sand			
										Gravel	Coarse	Medium	Fine	Silt/clay
	X	X						SW	Sand well graded, dry, yellowish brown (10YR5/4), loose, rock	5	25	25	30	15
							1		chips up to 1.5", subangular to rounded.					
							2							
							3		- Surface had thin layer of silty, mudcracks and					
							4		algae.					
							5		- GPS: 068 - N34° 06.054' W117° 07.931'					
							6							
							7							
							8							
							9							
							10							
							11							
							12							

QA/QC

MWH



Site Sketch Map

Boring #: SS-69 MW#:

Sheet 1 of 1

Project: SAR Groundwater Recharge Optimization Study

Job #: 1343019 Site: outer pond 6

Logged By: A. Leavitt Reviewed By:

Drilling Contractor: ~~Boart Longyear~~ MWH

Drill Rig Type/Method: ~~Sonic Drilling~~ hand sampling

Drillers Name: A. Leavitt

Borehole Diam./Drill Bit Type: —

Total Depth 1'

Ref. Elev. —

Sampler Type: hand sampling

Drill Start Time/Date: 6-26-08 Drill Finish Time/Date: 6-26-08

Well Completion Time/Date: —

Soil Boring Backfill Time/Date: 6-26-08

Depth to 1st Water (∇): — Time/Date: —

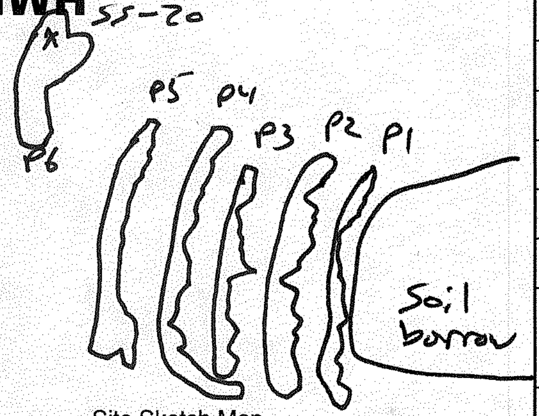
Depth to Water After Drilling (▼): — Time/Date: —

Depth to other Water Bearing Zones: —

PID/OVA	Sample Interval	Recovered (in.)	Blow Counts / 6 in.	Retained for Analysis	Casing Type & Size	Annulus Filler	Depth (Feet)	USCS Soil Type	Soil Description	Estimated % Of Gravel	Sand Coarse	Sand Medium	Sand Fine	Silt/clay
	X	X						SW	Sand well graded, dry, yellowish brown (10YR 5/4),	5	25	25	30	15
							1		loose, rock chips up to 1.5", subangular to rounded.					
							2							
							3		-Surface had thin layer of silty mudcracks and					
							4		algae.					
							5		-GPS: 069 - N34° 05.969' W117° 07.907'					
							6							
							7							
							8							
							9							
							10							
							11							
							12							

QA/QC

MWH



Site Sketch Map

Boring #: SS-70 MW#: Sheet 1 of 1

Project: SAR Groundwater Recharge Optimization Study

Job #: 1343019 Site: outer pond 6

Logged By: A. Leavitt Reviewed By:

Drilling Contractor: ~~Boart Longyear~~ MWH

Drill Rig Type/Method: ~~Sonic Drilling~~ hand sampling

Drillers Name: A. Leavitt

Borehole Diam./Drill Bit Type: –

Total Depth 1'

Ref. Elev. –

Sampler Type: hand Sampling

Depth to 1st Water (▽): – Time/Date: –

Drill Start Time/Date: 6-26-08 Drill Finish Time/Date: 6-26-08

Depth to Water After Drilling (▼): – Time/Date: –

Well Completion Time/Date: –

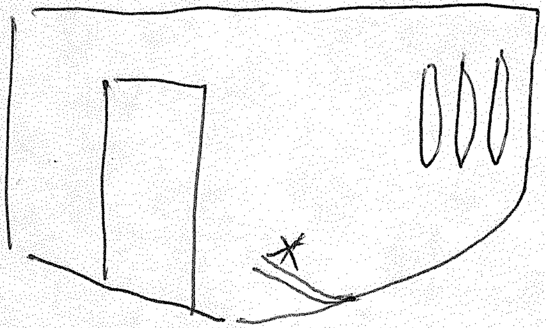
Depth to other Water Bearing Zones: –

Soil Boring Backfill Time/Date: 6-26-08

PID/OVA	Sample Interval	Recovered (in.)	Blow Counts / 6 in.	Retained for Analysis	Casing Type & Size	Annulus Filler	Depth (Feet)	USCS Soil Type	Soil Description	Estimated % Of				
											Sand			
										Gravel	Coarse	Medium	Fine	Silt/clay
	X	X					1	SW	Sand well graded, dry, Yellowish brown (10YR5/4), loose, rock	5	25	25	30	15
							2		chips up to 1.5", subangular to rounded.					
							3							
							4		• surface had Thin layer of silty mudcracks and					
							5		algae.					
							6		• GPS: 070 - N34°05.784' W117°07.845'					
							7							
							8							
							9							
							10							
							11							
							12							

QA/QC

MWH



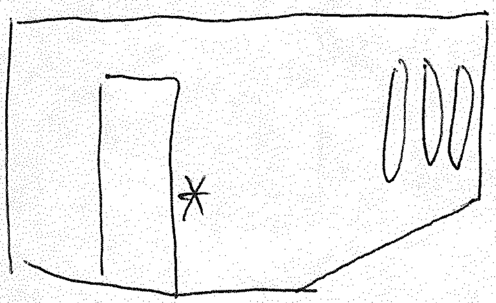
Site Sketch Map

Boring #: SS-71 MW#:
Sheet 1 of 1
Project: SAR Groundwater Recharge Optimization Study
Job #: 1343019 -0101 Site: Borrow Pit
Logged By: Reviewed By:
Drilling Contractor: ~~Boart Longyear~~
Drill Rig Type/Method: ~~Sonic Drilling~~
Drillers Name:
Borehole Diam./Drill Bit Type:
Total Depth 1'
Ref. Elev.
Sampler Type:
Depth to 1st Water (▽): Time/Date:
Depth to Water After Drilling (▼): Time/Date:
Depth to other Water Bearing Zones:
Drill Start Time/Date: Drill Finish Time/Date:
Well Completion Time/Date:
Soil Boring Backfill Time/Date:

PID/OVA	Sample Interval	Recovered (in.)	Blow Counts / 6 in.	Retained for Analysis	Casing Type & Size	Annulus Filler	Depth (Feet)	USCS Soil Type	Soil Description	Estimated % Of				
										Gravel	Sand			Silt/clay
											Coarse	Medium	Fine	
								SW	GRAVELLY SAND, 10YR-5-3 SUBROUNDED TO WELL ROUNDED COBBLES, BOULDERS UP TO 10-INCH DIAMETER	30	25	20	20	5
							1							
							2							
							3		GPS: N 34° 05.822' W 117° 07.222'					
							4							
							5							
							6							
							7							
							8							
							9							
							10							
							11							
							12							

QA/QC

MWH



Site Sketch Map

Boring #: SS-72 MW#: **Sheet** 1 **of** 1

Project: SAR Groundwater Recharge Optimization Study

Job #: 1343019 Site: Borrow Pit

Logged By: Reviewed By:

Drilling Contractor: ~~Boart Longyear~~

Drill Rig Type/Method: ~~Sonic Drilling~~

Drillers Name:

Borehole Diam./Drill Bit Type: **Total Depth** 1'

Ref. Elev.

Sampler Type:

Depth to 1st Water (▽): Time/Date:

Depth to Water After Drilling (▼): Time/Date:

Depth to other Water Bearing Zones:

Drill Start Time/Date: Drill Finish Time/Date:

Well Completion Time/Date:

Soil Boring Backfill Time/Date:

PID/OVA	Sample Interval	Recovered (in.)	Blow Counts / 6 in.	Retained for Analysis	Casing Type & Size	Annulus Filler	Depth (Feet)	USCS Soil Type	Soil Description	Estimated % Of				
											Sand			
										Gravel	Coarse	Medium	Fine	Silt/clay
								GW	TAN/BROWN, DRY, SURROUNDED BY GRASS, AT THE VEY SURFACE	20	20	20	20	20
							1		10YR-6-3 45/15/15/15/10 AT ONE(1) FOOT 10YR-5-2					
							2							
							3		GPS: N34° 05.924' W117° 07.310'					
							4							
							5							
							6							
							7							
							8							
							9							
							10							
							11							
							12							

QA/QC

Appendix E
Photographic Logs

Photographic Log - SAR Optimization Study TM-2

Customer: SBVWCD-SBVMWD
Project Number: 1343019
Site Name: Santa Ana River Borrow Pit
Site Location: San Bernardino County, CA

Photograph ID: GEI-1
Date: Sept. 30, 2008
Location:
Gate
Direction:
Comments:
The maximum height each gate could open was determined by measuring the thread lengths of each gate stem.

Photograph ID: GEI-2
Date: March 27, 2008
Location:
Gate
Direction:
Comments:
Large boulders directly in front of intake structure after March 27th flow test.

Photographic Log - SAR Optimization Study TM-2

Customer: **SBVWCD-SBVMWD**
Project Number: **1343019**
Site Name: Santa Ana River Borrow Pit
Site Location: **San Bernardino County, CA**

Photograph ID: GEI-3

Date: Sept. 30, 2008

Location:
Earthen Canal

Direction:

Comments:
Typical canal section shown on record drawing is not representative of the existing canal.

Photograph ID: GEI-4

Date: Sept. 30, 2008

Location:
Rock Structure

Direction:

Comments:
Built out of rocks that have been mortared together to form a 14 feet wide by 6 feet tall regular structure.

Customer: SBVWCD-SBVMWD		**Project Number:**	**1343019**
Site Name: Santa Ana River Borrow Pit		**Site Location:**	**San Bernardino County, CA**

Photograph ID: GEI-5

Date: Sept. 30, 2008

Location:
Bt.Bridge & Greespot Rd

Direction:

Comments:
Concrete abutments and pier to old bridges.

Photograph ID: GEI-6

Date: Sept. 30, 2008

Location:
Greespot Road Culvert

Direction:

Comments:
The culvert was measured to be 10 feet wide by 4 feet high.

The asphalt on the downstream end of the culvert is eroded and washed out.

Customer: SBVWCD-SBVMWD		**Project Number:**	**1343019**
Site Name: Santa Ana River Borrow Pit		**Site Location:**	**San Bernardino County, CA**

Photograph ID: GEI-7

Date: March 27, 2008

Location:

Direction:

Comments:
Water level measurement system consisted of PVC pipe, transducer, datalogger, modem, software and computer.

Photograph ID: GEI-8

Date: Sept. 30, 2008

Location:
Borrow Pit Pond 1 Trench

Direction:

Comments:
Linear trench of 6 feet wide by 4 feet deep in Pond 1 to test percolation rate.

Photographic Log - SAR Optimization Study TM-2

Customer: **SBVWCD-SBVMWD** | **Project Number:** **1343019**

Site Name: Santa Ana River Borrow Pit | **Site Location:** **San Bernardino County, CA**

Photograph ID: GEI-9

Date: March 27, 2008

Location:

Diversion Structure

Direction:

Comments:
Flow through the Diversion Structure north gates, to the existing westerly spreading ponds.

Photograph ID:

Date:

Location:

Direction:

Comments:

MWH

Photographic Log - SAR Optimization Study TM-2

Customer: SBVWCD-SBVMWD
Project Number: 1343019
Site Name: Santa Ana River Borrow Pit
Site Location: San Bernardino County, CA

Photograph ID: 1

Date: June 26, 2008

Location:
MW-2

Direction:
Looking south

Comments:
Vibrated vertically, sampler barrel sampler barrel normally advances by slicing through the soil. Drillers are retrieving the sampler barrel.

Background is the southern boundary of the Borrow Pit.

Photograph ID: 2

Date: June 26, 2008

Location:
MW-2

Direction:

Comments:
Continuous disturbed soil samples are pushed out from sampler barrel into plastic sleeves.

Driller marks depths on the sleeves.

Customer: SBVWCD-SBVMWD

Project Number: 1343019

Site Name: Santa Ana River Borrow Pit

Site Location: San Bernardino County, CA

Photograph ID: 3

Date: June 30, 2008

Location:
MW-1

Direction:
Looking west-southwest

Comments:
Sonic drilling is in operation.

Background is the Pond 3.

Photograph ID: 4

Date: June 30, 2008

Location:
MW-1

Direction:

Comments:
Continuous disturbed soil samples in plastic sleeves. After logging, the samples were transferred into storage boxes.

Upper left is the Pond 3.

Traffic cone for scale.

Customer: SBVWCD-SBVMWD		**Project Number:**	**1343019**
Site Name: Santa Ana River Borrow Pit		**Site Location:**	**San Bernardino County, CA**

Photograph ID: 5

Date: June 19, 2008

Location:
Trench 1 in Pond 1

Direction:
Looking west

Comments:
North-south trench, fine dark colored materials at the top one foot, followed by boulder, cobble, gravel and coarse sand mixture, dry.

Stake for scale.

Photograph ID: 6

Date: June 19, 2008

Location:
Trench 2 in Pond 1

Direction:
Looking west

Comments:
North-south trench, fine dark colored materials at the top one foot, followed by boulder, cobble, gravel and coarse sand mixture, dry.

Stake for scale.

Photographic Log - SAR Optimization Study TM-2

Customer: SBVWCD-SBVMWD		**Project Number:**	**1343019**
Site Name: Santa Ana River Borrow Pit		**Site Location:**	**San Bernardino County, CA**

Photograph ID: 7

Date: June 19, 2008

Location:
Trench 3 in Pond 2

Direction:
Looking west

Comments:
North-south trench, fine dark colored materials at the top one foot, followed by boulder, cobble, gravel and coarse sand mixture, dry.

Stake for scale.

Photograph ID: 8

Date: June 19, 2008

Location:
Trench 5

Direction:
Looking west

Comments:
North-south trench, Light brown boulder, cobble, gravel and coarse sand mixture, dry.

Stake for scale.

Customer: SBVWCD-SBVMWD		**Project Number:**	**1343019**
Site Name: Santa Ana River Borrow Pit		**Site Location:**	**San Bernardino County, CA**

Photograph ID: 9

Date: June 19, 2008

Location:
Trench 6

Direction:
Looking west

Comments:
Light brown boulder, cobble, gravel and coarse sand mixture, dry.

Stake for scale.

Photograph ID: 10

Date: June 19, 2008

Location:
Trench 7

Direction:
Looking west

Comments:
North-south trench, fine dark colored materials with grass at the top, followed by boulder, cobble, gravel and coarse sand mixture, dry.

Stake for scale.

Customer: **SBVWCD-SBVMWD** **Project Number:** **1343019**
Site Name: Santa Ana River Borrow Pit **Site Location:** **San Bernardino County, CA**

Photograph ID: 11
Date: June 22, 2008
Location:
Trench 8
Direction:
Looking north
Comments:
West-east trench, brown boulder, cobble, gravel and coarse sand mixture, dry.

Stake for scale.

Photograph ID: 12
Date: June 22, 2008
Location:
Trench 9
Direction:
Looking east
Comments:
North-south trench, light gray, brown boulder, cobble, gravel and coarse sand mixture, dry.

Stake for scale.

Customer: SBVWCD-SBVMWD		**Project Number:**	1343019
Site Name: Santa Ana River Borrow Pit		**Site Location:**	San Bernardino County, CA

Photograph ID: 13

Date: June 19, 2008

Location:
Trench 10 in Pond 10

Direction:
Looking north

Comments:
East-west trench, few fine materials at the top, followed by light brown boulder, cobble, gravel and coarse sand mixture, dry.

Stake for scale.

Photograph ID: 14

Date: June 19, 2008

Location:
Trench 11A near wet spot

Direction:
Looking west

Comments:
East-west trench
Well sorted coarse sand in the top layer, followed by boulder, cobble, gravel and sand mixture, water encountered at a depth of less than 3 feet below ground surface.

Stake for scale.

Photographic Log - SAR Optimization Study TM-2

Customer: SBVWCD-SBVMWD		**Project Number:**	**1343019**
Site Name: Santa Ana River Borrow Pit		**Site Location:**	**San Bernardino County, CA**

Photograph ID: 15

Date: June 19, 2008

Location:
Trench 11D

Direction:
Looking north

Comments:
East-west trench,
Well sorted coarse
sand in the top layer,
followed by boulder,
cobble, gravel and
sand mixture,
water encountered
at a depth of
approximately 3 feet
below ground surface.

Stake for scale.

Photograph ID: 16

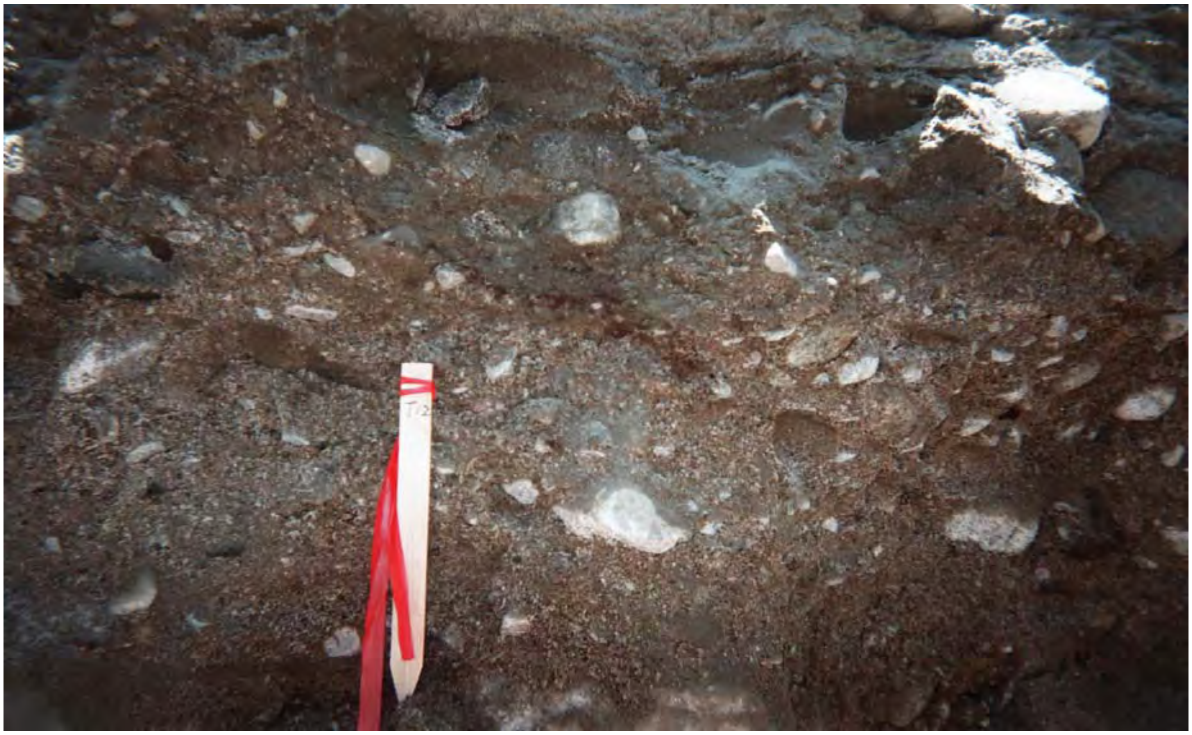
Date: June 19, 2008

Location:
Trench 12

Direction:
Looking north

Comments:
At the western end of
the Borrow Pit,
fine dark colored
materials at the top
and soil compaction
is observed. Close to
surface ponding, no
water was encountered
to a depth of 6 feet
below ground surface.

Stake for scale.



Photographic Log - SAR Optimization Study TM-2

Customer: **SBVWCD-SBVMWD**
Project Number: **1343019**
Site Name: Santa Ana River Borrow Pit
Site Location: **San Bernardino County, CA**

Photograph ID: 17
Date: June 18, 2008
Location:
Surface Sampling SS-13
Direction:

Comments:
Hard dry cobble, gravel and sand to a depth of approximately one foot below ground surface.

Stake for scale.

Photograph ID: 18
Date: June 18, 2008
Location:
Surface Sampling SS-14
Direction:

Comments:
Hard dry cobble, gravel and sand to a depth of approximately one foot below ground surface.

Stake for scale.

Photographic Log - SAR Optimization Study TM-2

Customer: SBVWCD-SBVMWD		**Project Number:**	**1343019**
Site Name: Santa Ana River Borrow Pit		**Site Location:**	**San Bernardino County, CA**

Photograph ID: 19

Date: June 18, 2008

Location:
Surface Sampling SS-15

Direction:

Comments:
Hard dry cobble, gravel and sand to a depth of approximately one foot below ground surface.

Stake for scale.

Photograph ID: 20

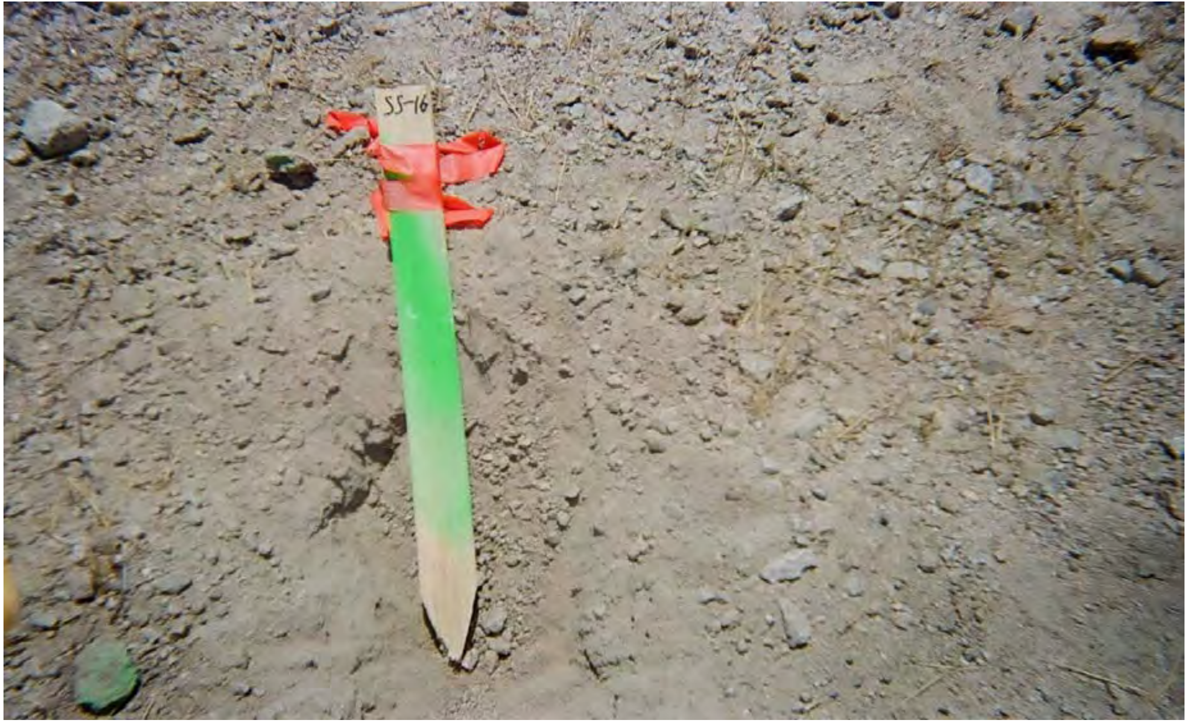
Date: June 18, 2008

Location:
Surface Sampling SS-16

Direction:

Comments:
Hard dry cobble, gravel and sand to a depth of approximately one foot below ground surface.

Stake for scale.



Customer: SBVWCD-SBVMWD		**Project Number:**	**1343019**
Site Name: Santa Ana River Borrow Pit		**Site Location:**	**San Bernardino County, CA**

Photograph ID: 21

Date: June 18, 2008

Location:
Surface Sampling SS-17

Direction:

Comments:
Hard dry cobble, gravel and sand to a depth of approximately one foot below ground surface.

Stake for scale.

Photograph ID: 22

Date: June 18, 2008

Location:
Surface Sampling SS-18

Direction:

Comments:
Hard dry cobble, gravel and sand to a depth of approximately one foot below ground surface.

Stake for scale.

Customer: SBVWCD-SBVMWD		**Project Number:**	**1343019**
Site Name: Santa Ana River Borrow Pit		**Site Location:**	**San Bernardino County, CA**

Photograph ID: 23

Date: June 18, 2008

Location:

Surface Sampling SS-19

Direction:

Comments:
Hard dry cobble, gravel and sand to a depth of approximately one foot below ground surface.

Stake for scale.

Photograph ID: 24

Date: June 18, 2008

Location:
Surface Sampling SS-20

Direction:

Comments:
Hard dry cobble, gravel and sand to a depth of approximately one foot below ground surface.

Stake for scale.

Photographic Log - SAR Optimization Study TM-2

Customer: SBVWCD-SBVMWD	**Project Number:** 1343019
Site Name: Santa Ana River Borrow Pit	**Site Location:** San Bernardino County, CA

Photograph ID: 25

Date: June 18, 2008

Location:
Surface Sampling SS-21

Direction:

Comments:
Hard dry cobble, gravel and sand to a depth of approximately one foot below ground surface.

Stake for scale.

Photograph ID: 26

Date: June 18, 2008

Location:
Surface Sampling SS-22

Direction:

Comments:
Hard dry cobble, gravel and sand to a depth of approximately one foot below ground surface.

Stake for scale.

Customer: **SBVWCD-SBVMWD** **Project Number:** **1343019**
Site Name: Santa Ana River Borrow Pit **Site Location:** **San Bernardino County, CA**

Photograph ID: 27
Date: June 18, 2008
Location:
Surface Sampling SS-23
Direction:

Comments:
Hard dry cobble, gravel and sand to a depth of approximately one foot below ground surface.

Stake for scale.

Photograph ID: 28
Date: June 18, 2008
Location:
Surface Sampling SS-24
Direction:

Comments:
Hard dry cobble, gravel and sand to a depth of approximately one foot below ground surface.

Stake for scale.

Customer: SBVWCD-SBVMWD		**Project Number:**	**1343019**
Site Name: Santa Ana River Borrow Pit		**Site Location:**	**San Bernardino County, CA**

Photograph ID: 29

Date: June 21, 2008

Location:
Surface Sampling SS-25

Direction:

Comments:
Dry cobble, gravel and sand to a depth of approximately one foot below ground surface.

Stake for scale.

Photograph ID: 30

Date: June 21, 2008

Location:
Surface Sampling SS-26

Direction:

Comments:
Dry cobble, gravel and sand to a depth of approximately one foot below ground surface.

Stake for scale.

Photographic Log - SAR Optimization Study TM-2

Customer: SBVWCD-SBVMWD
Project Number: 1343019
Site Name: Santa Ana River Borrow Pit
Site Location: San Bernardino County, CA

Photograph ID: 31

Date: June 21, 2008

Location:
Surface Sampling SS-27

Direction:

Comments:
Dry cobble, gravel and sand to a depth of approximately one foot below ground surface.

Stake for scale.

Photograph ID: 32

Date: June 21, 2008

Location:
Surface Sampling SS-28

Direction:

Comments:
Dry cobble, gravel and sand to a depth of approximately one foot below ground surface.

Stake for scale.

Photographic Log - SAR Optimization Study TM-2

Customer: SBVWCD-SBVMWD
Project Number: 1343019
Site Name: Santa Ana River Borrow Pit
Site Location: San Bernardino County, CA

Photograph ID: 33

Date: June 21, 2008

Location:
Surface Sampling SS-29

Direction:

Comments:
Dry cobble, gravel and sand to a depth of approximately one foot below ground surface.

Stake for scale.

Photograph ID: 34

Date: June 21, 2008

Location:
Surface Sampling SS-30

Direction:

Comments:
Dry boulder, cobble, gravel and sand to a depth of approximately one foot below ground surface.

Stake for scale.

Customer: SBVWCD-SBVMWD		**Project Number:**	**1343019**
Site Name: Santa Ana River Borrow Pit		**Site Location:**	**San Bernardino County, CA**

Photograph ID: 35

Date: June 21, 2008

Location:
Surface Sampling SS-31

Direction:

Comments:
Some fine material at the surface, followed by gravelly sand to a depth of approximately one foot below ground surface.

Stake for scale.

Photograph ID: 36

Date: June 21, 2008

Location:
Surface Sampling SS-32

Direction:

Comments:
Some fine material at the surface, followed by gravelly sand to a depth of approximately one foot below ground surface.

Stake for scale.

Photographic Log - SAR Optimization Study TM-2

Customer: **SBVWCD-SBVMWD** | **Project Number:** **1343019**

Site Name: Santa Ana River Borrow Pit | **Site Location:** **San Bernardino County, CA**

Photograph ID: 37

Date: June 21, 2008

Location:
Surface Sampling SS-33

Direction:

Comments:
Hard dry cobble, gravel and sand to a depth of approximately one foot below ground surface.

Stake for scale.

Photograph ID: 38

Date: June 21, 2008

Location:
Surface Sampling SS-34

Direction:

Comments:
Hard dry cobble, gravel and sand to a depth of approximately one foot below ground surface.

Stake for scale.

Customer: **SBVWCD-SBVMWD** **Project Number:** **1343019**
Site Name: Santa Ana River Borrow Pit **Site Location:** **San Bernardino County, CA**

Photograph ID: 39

Date: June 21, 2008

Location:
Surface Sampling SS-35

Direction:

Comments:
Hard dry cobble, gravel and sand to a depth of approximately one foot below ground surface.

Stake for scale.

Photograph ID: 40

Date: June 21, 2008

Location:
Surface Sampling SS-36

Direction:

Comments:
Dry cobble, gravel and sand to a depth of approximately one foot below ground surface.

Stake for scale.

Photographic Log - SAR Optimization Study TM-2

Customer: SBVWCD-SBVMWD		**Project Number:**	**1343019**
Site Name: Santa Ana River Borrow Pit		**Site Location:**	**San Bernardino County, CA**

Photograph ID: 41

Date: June 21, 2008

Location:
Surface Sampling SS-37

Direction:

Comments:
Dry fine materials at the surface, followed by cobble, gravel and sand to a depth of approximately one foot below ground surface.

Stake for scale.

Photograph ID: 42

Date: June 21, 2008

Location:
Surface Sampling SS-38

Direction:

Comments:
Dry cobble, gravel and sand to a depth of approximately one foot below ground surface.

Stake for scale.

Customer:	**SBVWCD-SBVMWD**	**Project Number:**	**1343019**
Site Name:	**Santa Ana River Borrow Pit**	**Site Location:**	**San Bernardino County, CA**

Photograph ID: 43

Date: June 21, 2008

Location:
Surface Sampling SS-39

Direction:

Comments:
Dry cobble, gravel and sand to a depth of approximately one foot below ground surface.

Stake for scale.

Photograph ID: 44

Date: June 22, 2008

Location:
Surface Sampling SS-40

Direction:

Comments:
Dry cobble, gravel and sand to a depth of approximately one foot below ground surface.

Stake for scale.

Customer: SBVWCD-SBVMWD		**Project Number:**	**1343019**
Site Name: Santa Ana River Borrow Pit		**Site Location:**	**San Bernardino County, CA**

Photograph ID: 45

Date: June 22, 2008

Location:
Surface Sampling SS-41

Direction:

Comments:
Dry gravelly sand with obbles and silt to a depth of approximately one foot below ground surface.

Stake for scale.

Photograph ID: 46

Date: June 22, 2008

Location:
Surface Sampling SS-42

Direction:

Comments:
Dry gravelly sand with obbles and silt to a depth of approximately one foot below ground surface.

Stake for scale.

Photographic Log - SAR Optimization Study TM-2

Customer: SBVWCD-SBVMWD

Project Number: 1343019

Site Name: Santa Ana River Borrow Pit

Site Location: San Bernardino County, CA

Photograph ID: 47

Date: June 22, 2008

Location:
Surface Sampling SS-43

Direction:

Comments:
Some fine material at the surface, followed by gravelly sand to a depth of approximately one foot below ground surface.

Stake for scale.

Photograph ID: 48

Date: June 22, 2008

Location:
Surface Sampling SS-44

Direction:

Comments:
Some fine material at the surface, followed by gravelly sand to a depth of approximately one foot below ground surface.

Stake for scale.

Customer: SBVWCD-SBVMWD

Project Number: 1343019

Site Name: Santa Ana River Borrow Pit

Site Location: San Bernardino County, CA

Photograph ID: 49

Date: June 22, 2008

Location:
Surface Sampling SS-45

Direction:

Comments:
Hard dry cobble, gravel and sand to a depth of approximately one foot below ground surface.

Stake for scale.

Photograph ID: 50

Date: June 22, 2008

Location:
Surface Sampling SS-46

Direction:

Comments:
Hard dry cobble, gravel and sand to a depth of approximately one foot below ground surface.

Stake for scale.

Customer: SBVWCD-SBVMWD		**Project Number:**	**1343019**
Site Name: Santa Ana River Borrow Pit		**Site Location:**	**San Bernardino County, CA**

Photograph ID: 51

Date: June 22, 2008

Location:
Surface Sampling SS-47

Direction:

Comments:
Hard dry cobble, gravel and sand to a depth of approximately one foot below ground surface.

Stake for scale.

Photograph ID: 52

Date: June 22, 2008

Location:
Surface Sampling SS-48

Direction:

Comments:
Dry boulder and cobble, less gravel and sand to a depth of approximately one foot below ground surface.

Stake for scale.

Photographic Log - SAR Optimization Study TM-2

Customer: SBVWCD-SBVMWD		**Project Number:**	**1343019**
Site Name: Santa Ana River Borrow Pit		**Site Location:**	**San Bernardino County, CA**

Photograph ID: 53

Date: June 22, 2008

Location:
Surface Sampling SS-49

Direction:

Comments:
Dry fine materials at the surface, followed by gravelly sand to a depth of approximately one foot below ground surface.

Stake for scale.

Photograph ID: 54

Date: June 22, 2008

Location:
Surface Sampling SS-50

Direction:

Comments:
Dry fine materials at the surface, followed by gravelly sand to a depth of approximately one foot below ground surface.

Stake for scale.

Customer: SBVWCD-SBVMWD		**Project Number:**	**1343019**
Site Name: Santa Ana River Borrow Pit		**Site Location:**	**San Bernardino County, CA**

Photograph ID: 55

Date: June 22, 2008

Location:

Surface Sampling SS-51

Direction:

Comments:
Dry gravelly sand to a depth of approximately one foot below ground surface.

Stake for scale.

Photograph ID: 56

Date: June 23, 2008

Location:
Surface Sampling SS-52

Direction:

Comments:
Dry gravelly sand to a depth of approximately one foot below ground surface.

Stake for scale.

MWH

Photographic Log - SAR Optimization Study TM-2

Customer: SBVWCD-SBVMWD
Project Number: 1343019
Site Name: Santa Ana River Borrow Pit
Site Location: San Bernardino County, CA

Photograph ID: 57

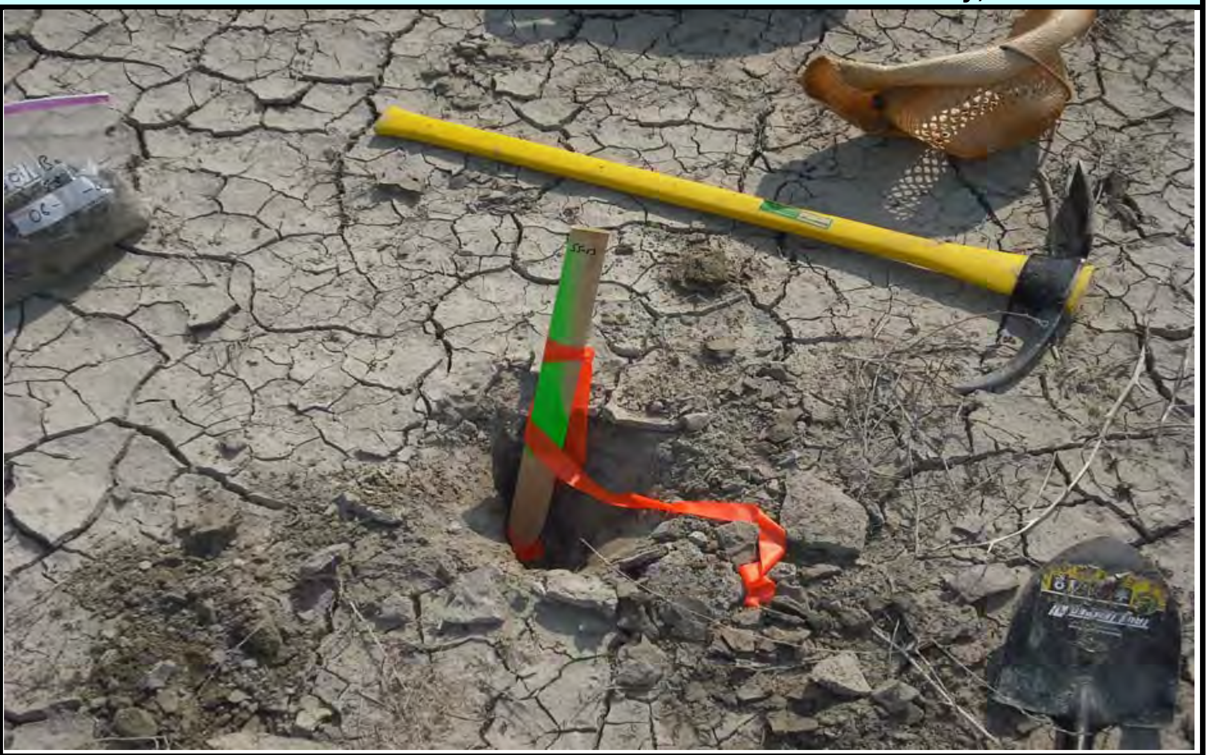
Date: June 23, 2008

Location:
Surface Sampling SS-53

Direction:

Comments:
Dry silty sand and sandy silt to a depth of approximately one foot below ground surface.

Stake for scale.



Photograph ID: 58

Date: June 23, 2008

Location:
Surface Sampling SS-54

Direction:

Comments:
Dry sandy silt to a depth of approximately one foot below ground surface.

Stake for scale.

Customer: SBVWCD-SBVMWD		**Project Number:**	**1343019**
Site Name: Santa Ana River Borrow Pit		**Site Location:**	**San Bernardino County, CA**

Photograph ID: 59

Date: June 23, 2008

Location:
Surface Sampling SS-55

Direction:

Comments:
Dry clayey sandy silt and silty sand to a depth of approximately one foot below ground surface.

Stake for scale.

Photograph ID: 60

Date: June 23, 2008

Location:
Surface Sampling SS-56

Direction:

Comments:
Some fine material at the surface, followed by gravelly sand to a depth of approximately one foot below ground surface.

Stake for scale.

Photographic Log - SAR Optimization Study TM-2

Customer: SBVWCD-SBVMWD		**Project Number:**	**1343019**
Site Name: Santa Ana River Borrow Pit		**Site Location:**	**San Bernardino County, CA**

Photograph ID: 61

Date: June 23, 2008

Location:
Surface Sampling SS-57

Direction:

Comments:
Hard dry cobble, gravel and sand to a depth of approximately one foot below ground surface.

Stake for scale.

Photograph ID: 62

Date: June 24, 2008

Location:
Surface Sampling SS-59

Direction:

Comments:
Some fungas on the surface, followed by gravelly sand to a depth of approximately one foot below ground surface.

Stake for scale.

Customer: SBVWCD-SBVMWD		**Project Number:**	**1343019**
Site Name: Santa Ana River Borrow Pit		**Site Location:**	**San Bernardino County, CA**

Photograph ID: 63

Date: June 24, 2008

Location:
Surface Sampling SS-60

Direction:

Comments:
Some fungas on the surface, followed by gravelly sand to a depth of approximately one foot below ground surface.

Stake for scale.

Photograph ID: 64

Date: June 24, 2008

Location:
Surface Sampling SS-62

Direction:

Comments:
Some fungas on the surface, followed by gravelly sand to a depth of approximately one foot below ground surface.

Stake for scale.

Customer: SBVWCD-SBVMWD		**Project Number:**	**1343019**
Site Name: Santa Ana River Borrow Pit		**Site Location:**	**San Bernardino County, CA**

Photograph ID: 65

Date: June 24, 2008

Location:
Surface Sampling SS-63

Direction:

Comments:
Dry fine materials at the surface, followed by gravelly sand to a depth of approximately one foot below ground surface.

Photograph ID: 66

Date: June 24, 2008

Location:
Surface Sampling SS-65

Direction:

Comments:
Dry fine materials at the surface, followed by gravelly sand to a depth of approximately one foot below ground surface.

Customer: **SBVWCD-SBVMWD** **Project Number:** **1343019**

Site Name: **Santa Ana River Borrow Pit** **Site Location:** **San Bernardino County, CA**

Photograph ID: 67

Date: June 24, 2008

Location:
Surface Sampling SS-66

Direction:

Comments:
Some fungas at the surface, followed by silty sand with gravel and cobble to a depth of approximately one foot below ground surface.

Photograph ID: 68

Date: June 24, 2008

Location:
Surface Sampling SS-67

Direction:

Comments:
Dry gravelly sand with cobble to a depth of approximately one foot below ground surface.

Customer: SBVWCD-SBVMWD		**Project Number:**	**1343019**
Site Name: Santa Ana River Borrow Pit		**Site Location:**	**San Bernardino County, CA**

Photograph ID: 69

Date: June 24, 2008

Location:
Surface Sampling SS-68

Direction:

Comments:
Dry gravelly sand
with cobble
and silt to a depth of
approximately one
foot below ground
surface.

Photograph ID: 70

Date: June 24, 2008

Location:
Surface Sampling SS-69

Direction:

Comments:
Some fungas
at the surface,
followed by
gravelly sand
with cobblest
to a depth of
approximately one
foot below ground
surface.

Photographic Log - SAR Optimization Study TM-2

Customer: SBVWCD-SBVMWD		**Project Number:**	**1343019**
Site Name: Santa Ana River Borrow Pit		**Site Location:**	**San Bernardino County, CA**

Photograph ID: 71

Date: June 24, 2008

Location:

Surface Sampling SS-70

Direction:

Comments:
Some fungas at the surface, followed by gravelly sand with cobblest to a depth of approximately one foot below ground surface.

Shavel for scale.

Photograph ID:

Date:

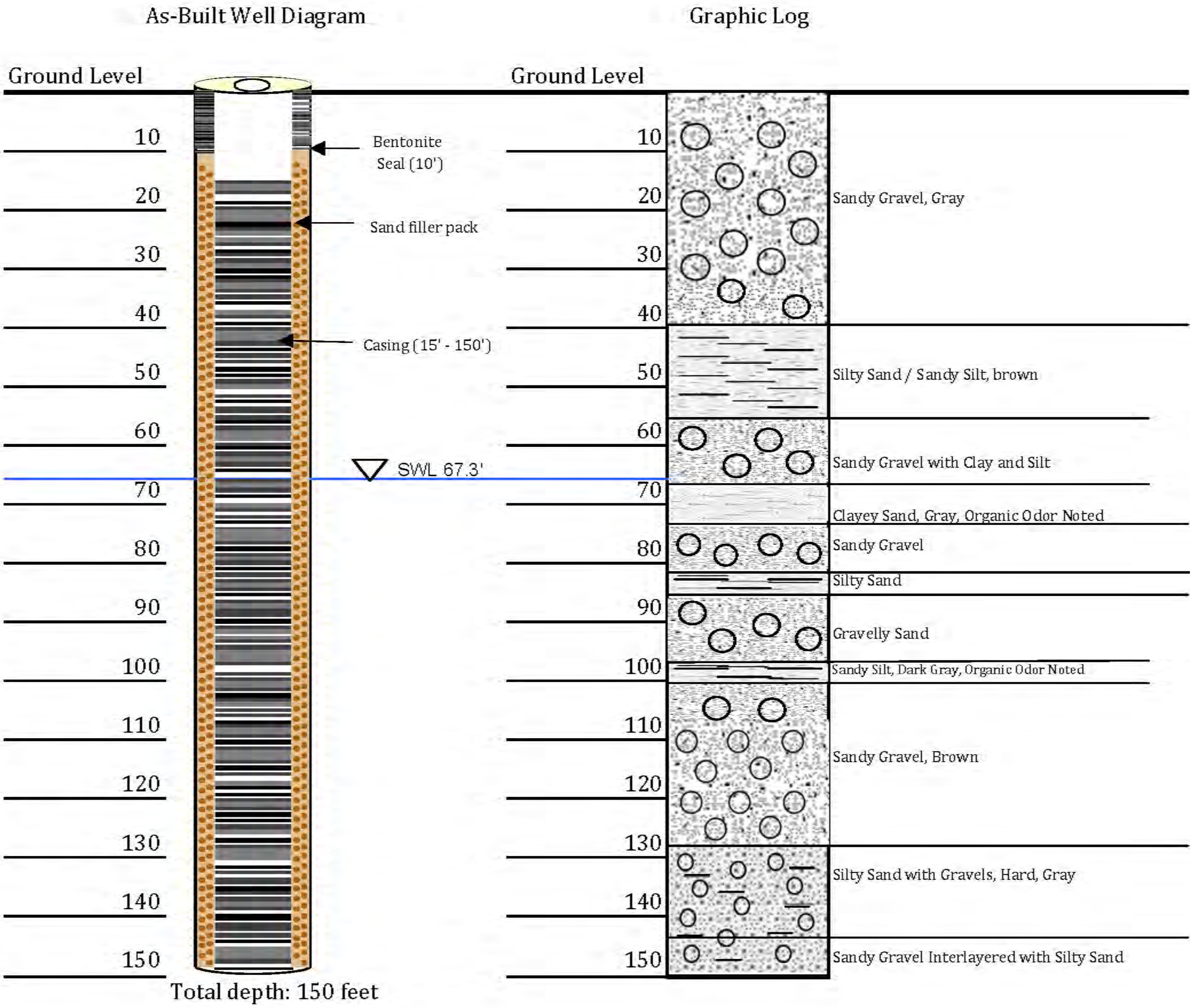
Location:

Direction:

Comments:

Appendix F
Monitoring Well As-Built and Lithology Logs

Monitoring Well #1



Notes: Drilled by Boart Longyear by Sonic Drilling.
Well installed June 30, 2008

Latitude: 34.10127
Longitude: -117.11385
SWL - Static Water Level

Lithologic Log and As-Built Well Completion Diagram for MW-1

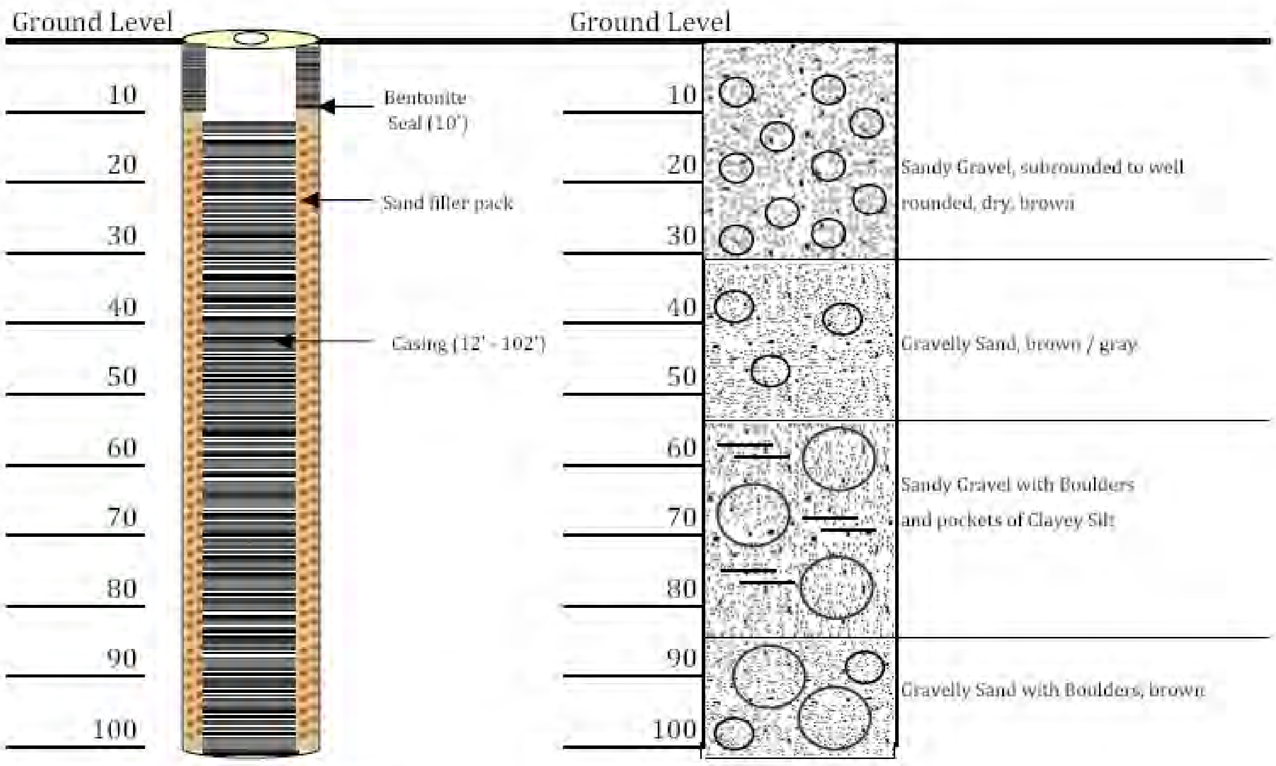
Document: Appendix_E-1_SBVWCD_MW-1.pub

Appendix F-1

Date: December 22, 2008

Santa Ana River Groundwater Recharge Optimization Study

Monitoring Well #2



As-Built Well Diagram

Graphic Log

Total depth: 102 feet

Notes: Drilled by Boart Longyear by Sonic Drilling.
Well installed June 26, 2008
Latitude: 34.0969
Longitude: -117.11825

Lithologic Log and As-Built Well Completion Diagram for MW-2

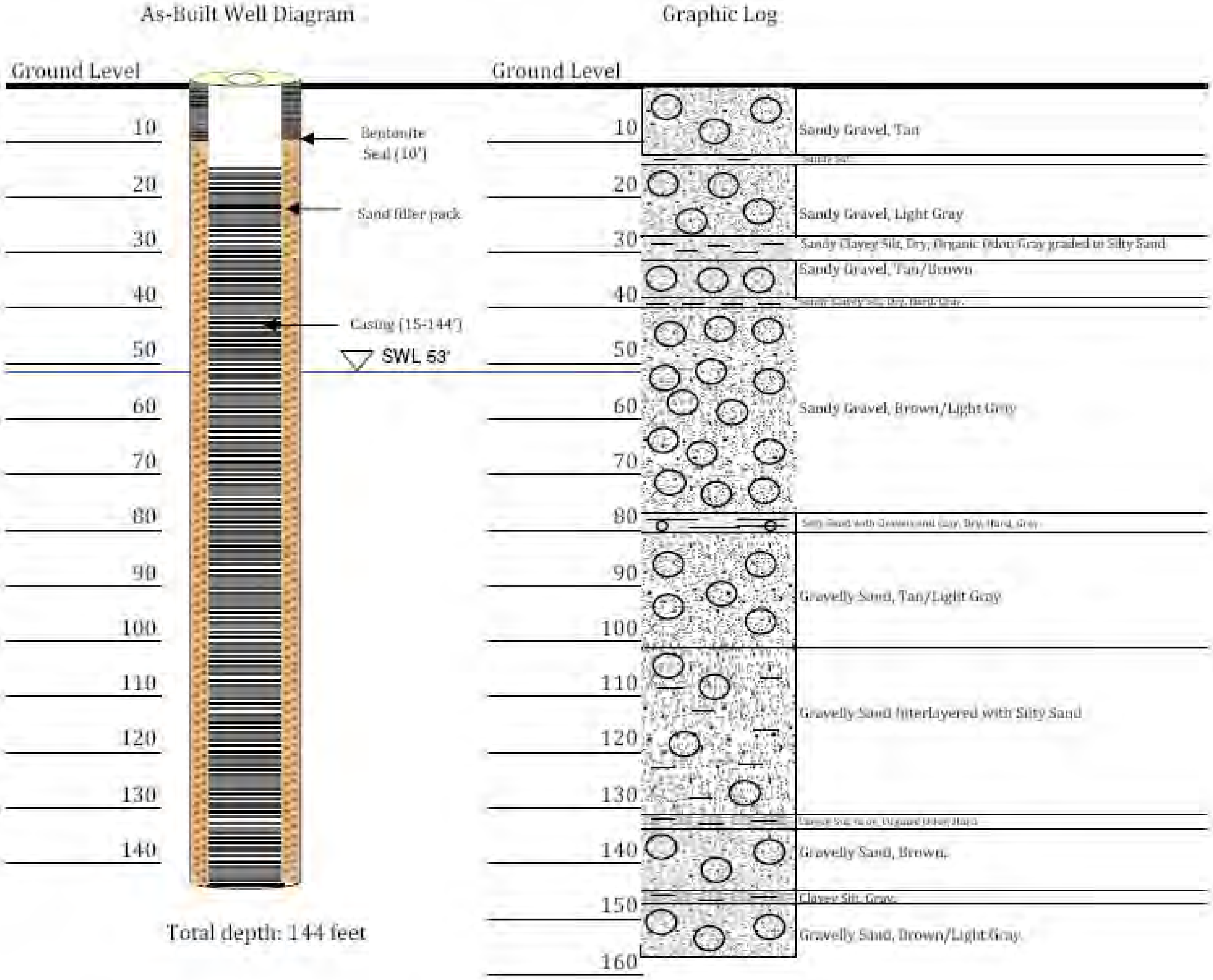
Document: Appendix_E-2_SBVWCD_MW-2.pub

Appendix F-2

Date: December 22, 2008

Santa Ana River Groundwater Recharge Optimization Study

Monitoring Well #3



Notes:
Drilled by Boart Longyear by Sonic Drilling.
Well installed July 7, 2008
Latitude: 34.10308
Longitude: -117.12147
SWL - Static Water Level

Lithologic Log and As-Built Well Completion Diagram for MW-3

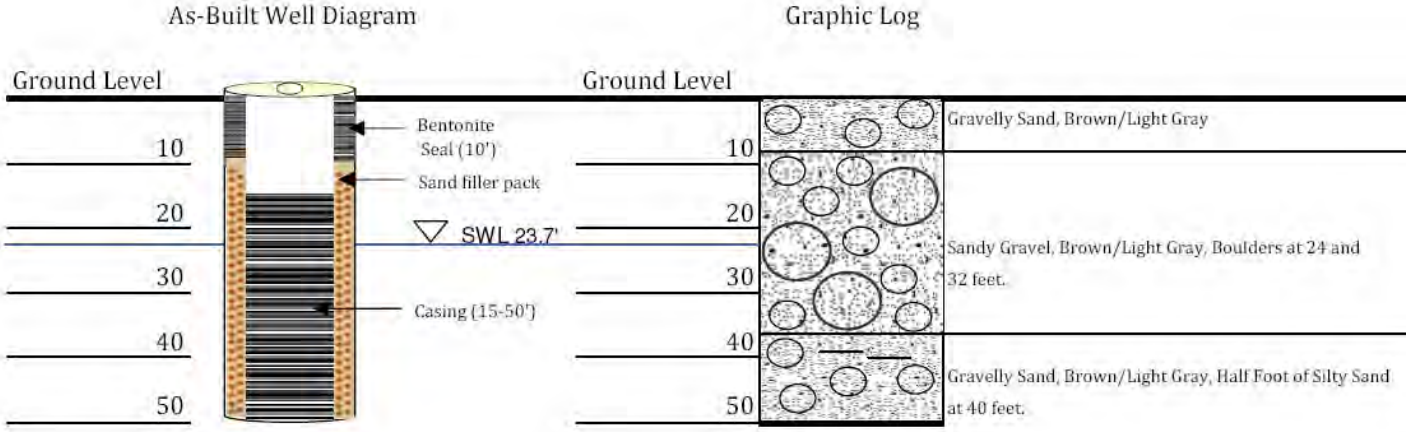
Document: Appendix_E-3_SBVWCD_MW-3.pub

Appendix F-3

Date: December 22, 2008

Santa Ana River Groundwater Recharge Optimization Study

Sonic Boring #1

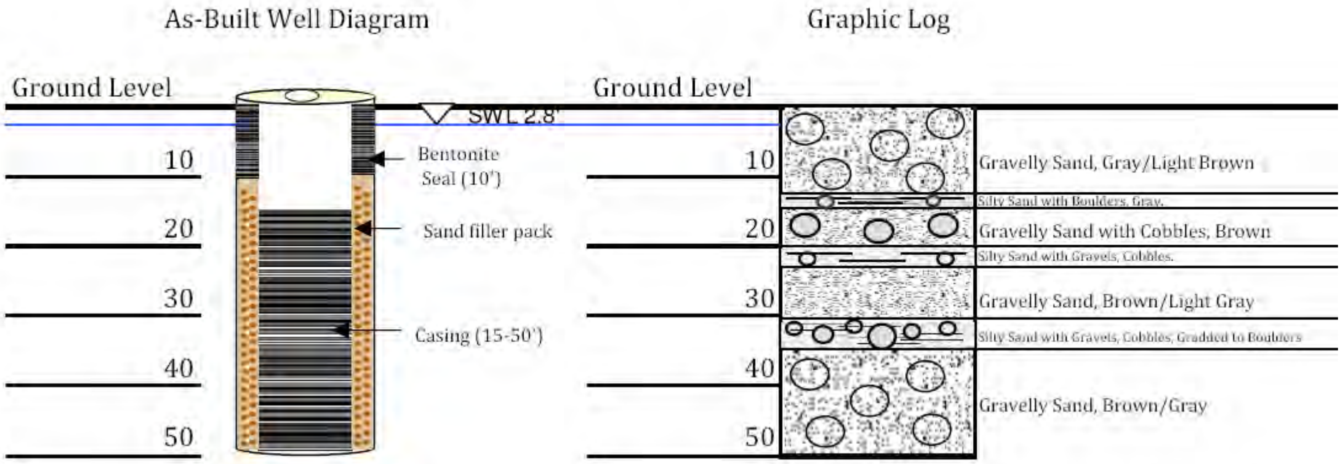


Total depth: 50 feet

Notes: Drilled by Boart Longyear by Sonic Drilling.
Well installed July 7, 2008
Latitude: 34.10093
Longitude: -117.1175
SWL - Static Water Level

		Lithologic Log and As-Built Well Completion Diagram for SB-1
	Document: Appendix_E-4_SBVWCD_SB-1.pub	**Appendix F-4**
	Date: December 22, 2008	Santa Ana River Groundwater Recharge Optimization Study

Sonic Boring #2



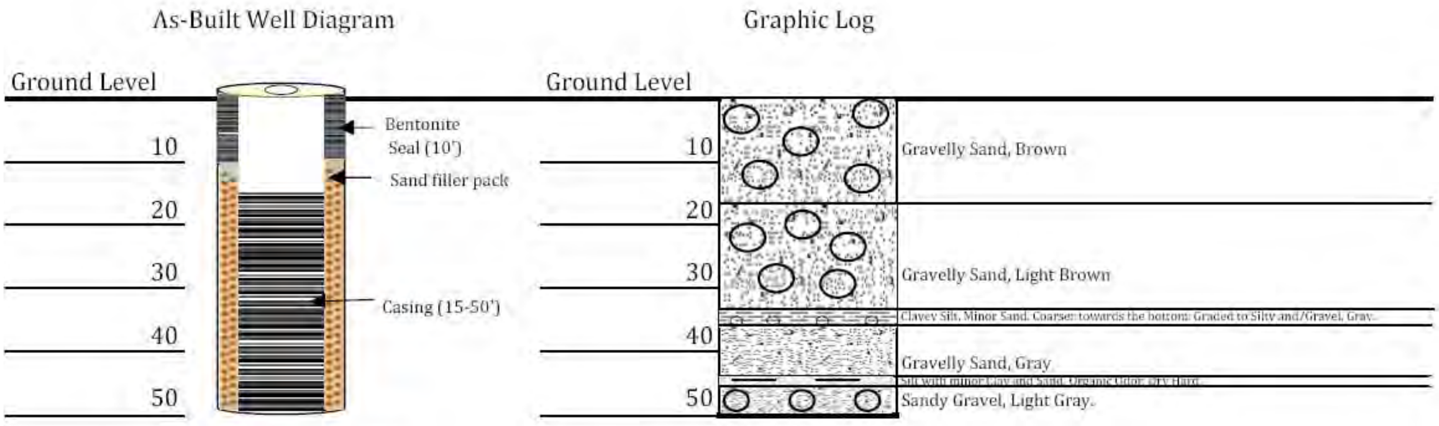
Total depth: 50 feet

Notes:
Drilled by Boart Longyear by Sonic Drilling.
Well installed July 3, 2008
Latitude: 34.10083
Longitude: -117.1219
SWL - Static Water Level

MWH

SBV WATER CONSERVATION DISTRICT OUR NAME IS OUR MISSION Valley			**Lithologic Log and As-Built Well Completion Diagram for SB-2**	MWH GEI Consultants
		Document: Appendix_E-5_SBVWCD_SB-2.pub	**Appendix F-5**	
		Date: December 22, 2008	Santa Ana River Groundwater Recharge Optimization Study	

Sonic Boring #3

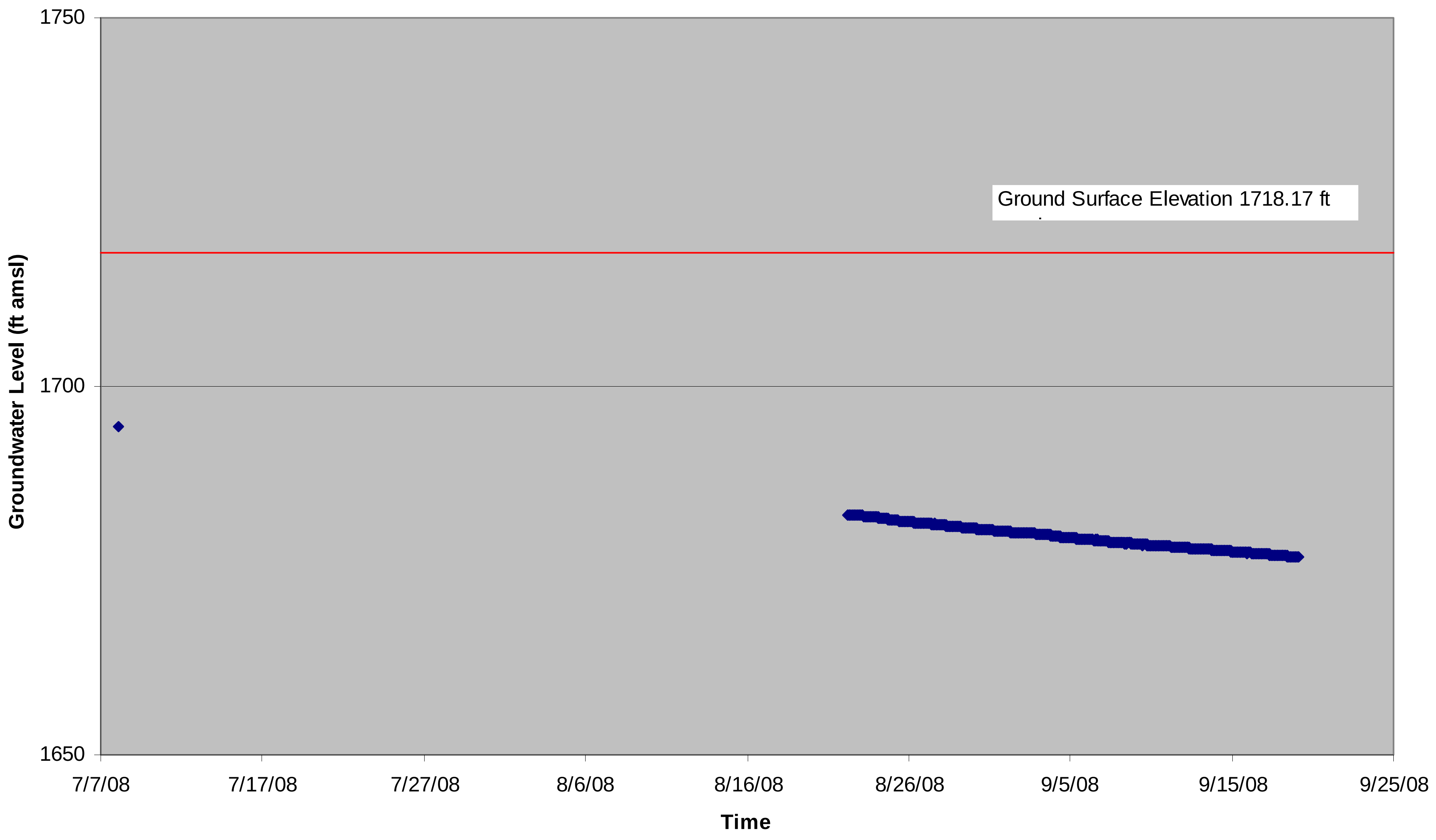


Total depth: 50 feet

Notes:
Drilled by Boart Longyear by Sonic Drilling.
Well installed July 7, 2008
Latitude: 34.10067
Longitude: -117.12555

	Lithologic Log and As-Built Well Completion Diagram for SB-3
Document: Appendix_E-6_ SBVWCD_SB-3.pub	**Appendix F-6**
Date: December 22, 2008	Santa Ana River Groundwater Recharge Optimization Study

Appendix G
Hydrographs



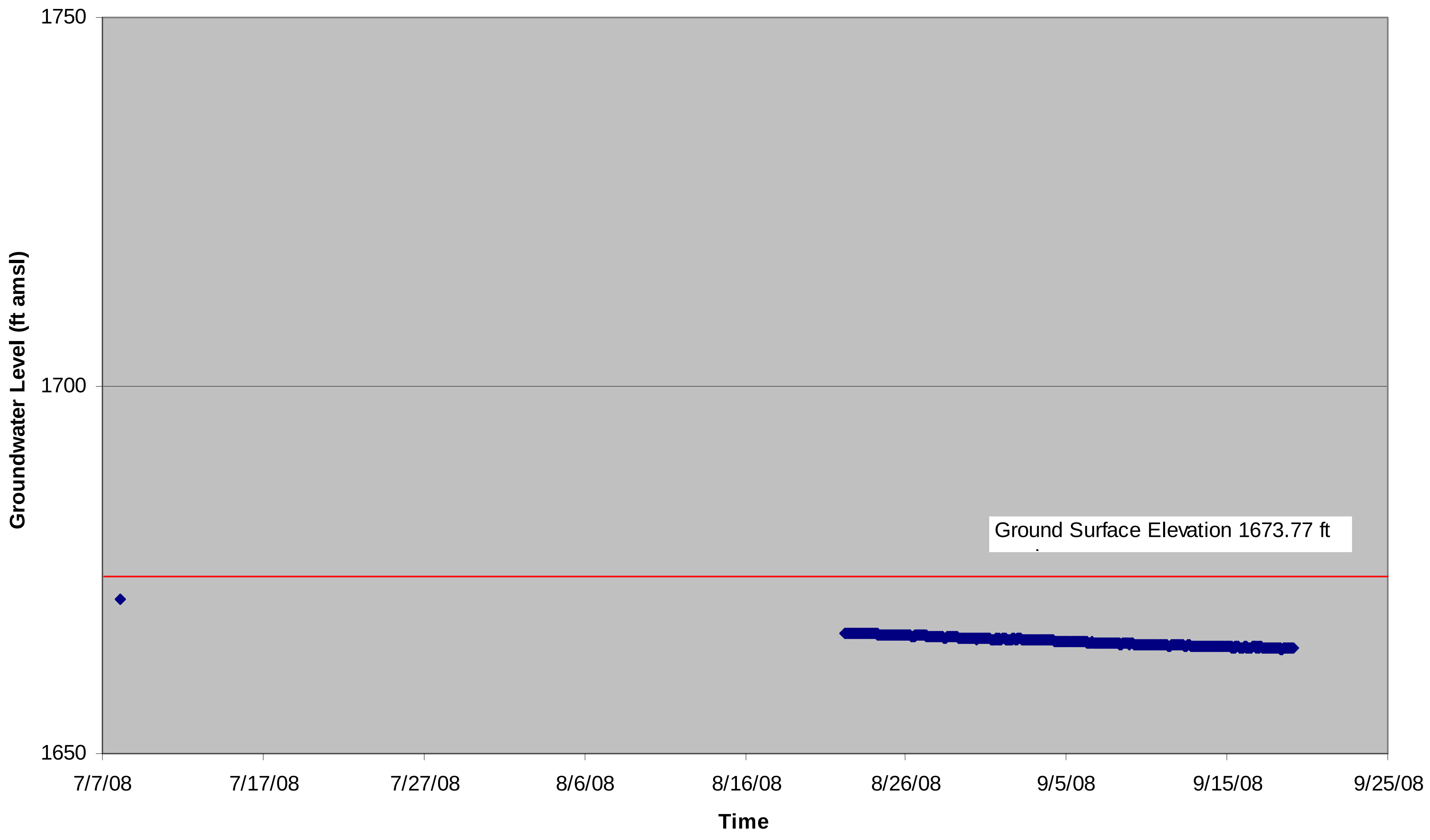
Document: Appendix_F-1_
SBVWCD_Hydrograph_SB-1.pub

Date: December 22, 2008

Hydrograph of SB-1

Appendix G-1

Santa Ana River Groundwater Recharge
Optimization Study



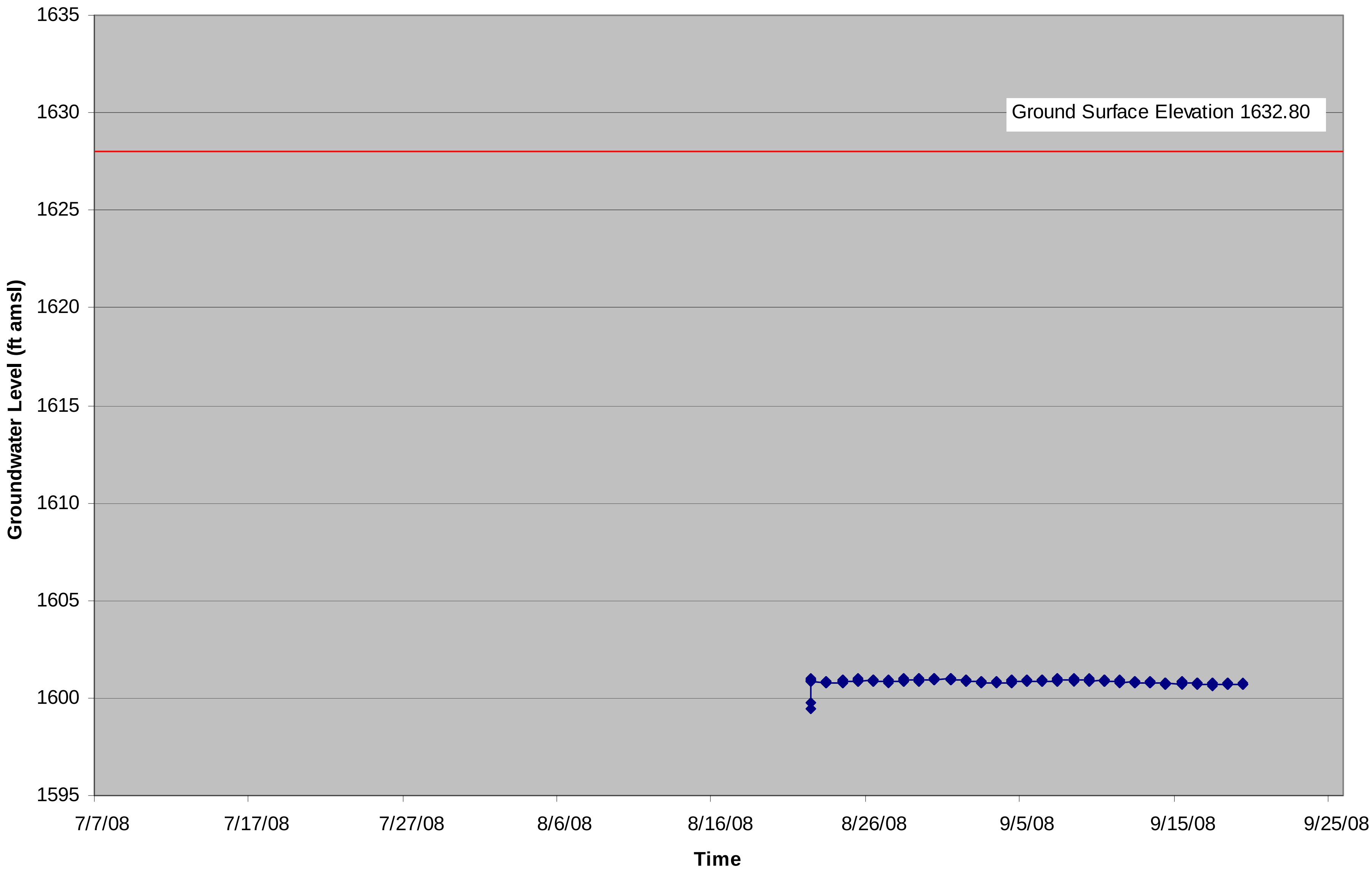
Document: Appendix_F-2_
SBVWCD_Hydrograph_SB-2.pub

Date: December 22, 2008

Hydrograph of SB-2

Appendix G-2

Santa Ana River Groundwater Recharge
Optimization Study



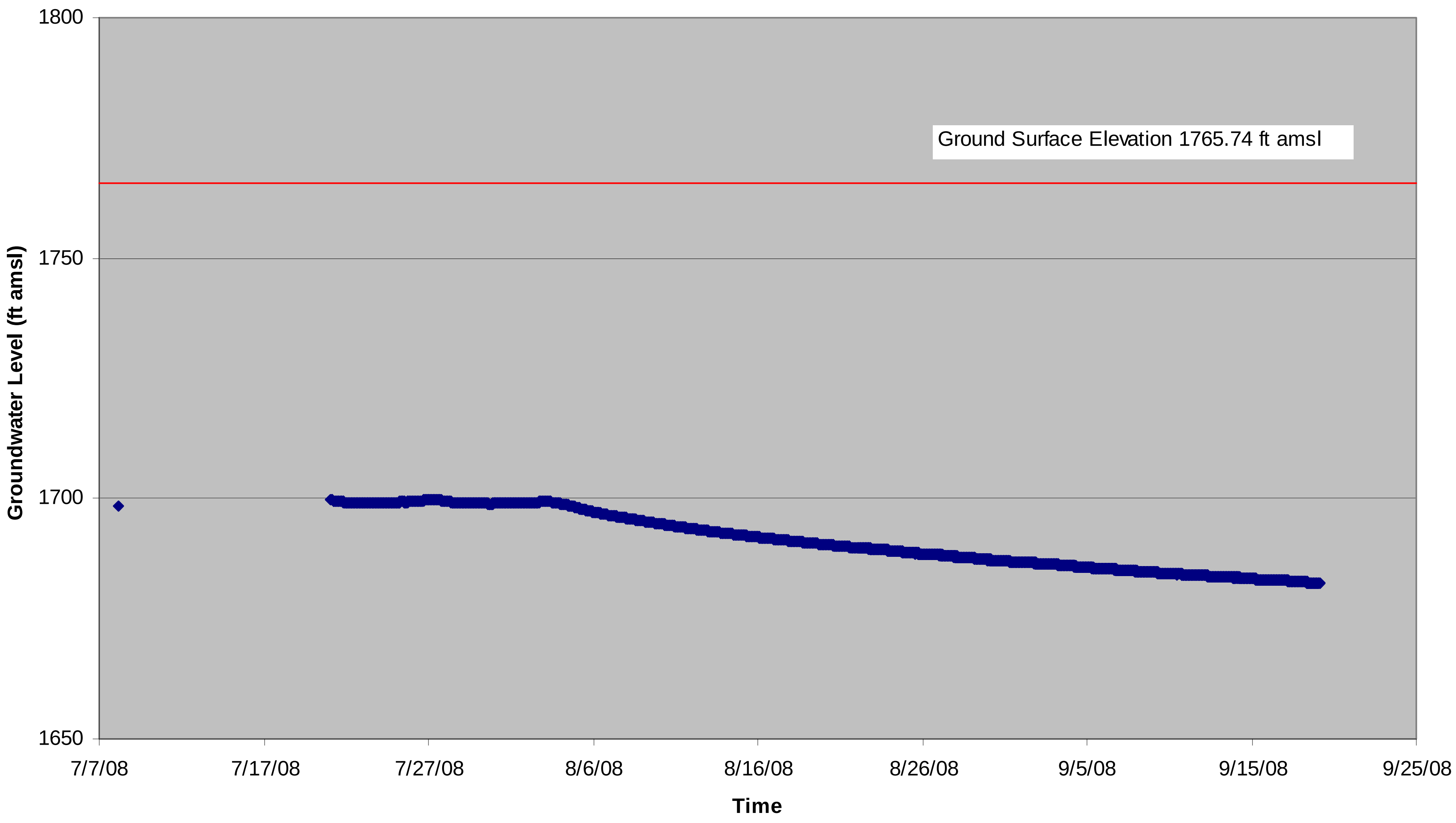
Hydrograph of SB-3

Appendix G-3

Santa Ana River Groundwater Recharge
Optimization Study

Document: Appendix_F-3_
SBVWCD_Hydrograph_SB-3.pub

Date: December 22, 2008



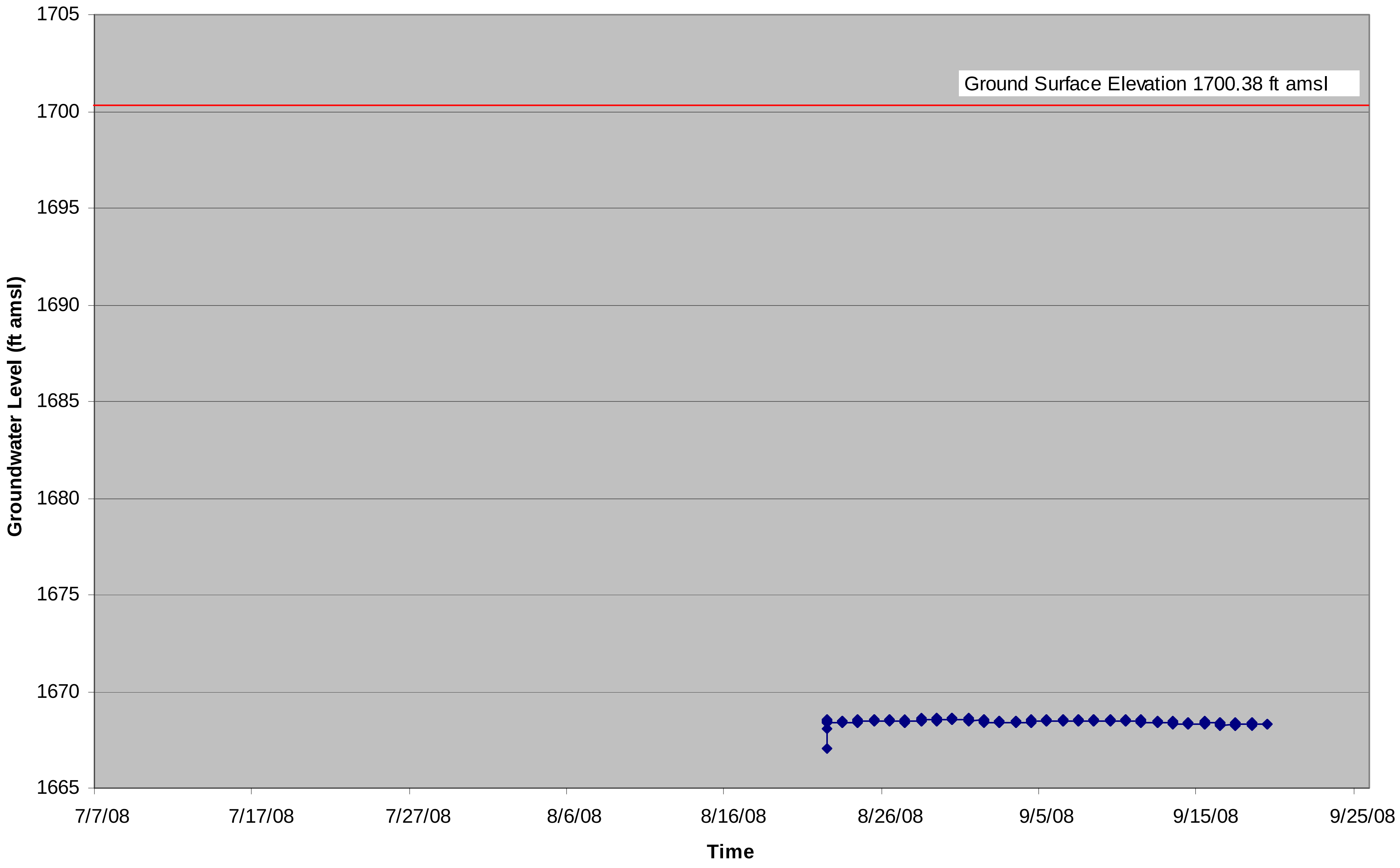
Document: Appendix_F-4
SBVWCD_Hydrograph_MW-1.pub

Date: December 22, 2008

Hydrograph of MW-1

Appendix GGG-4

Santa Ana River Groundwater Recharge
Optimization Study



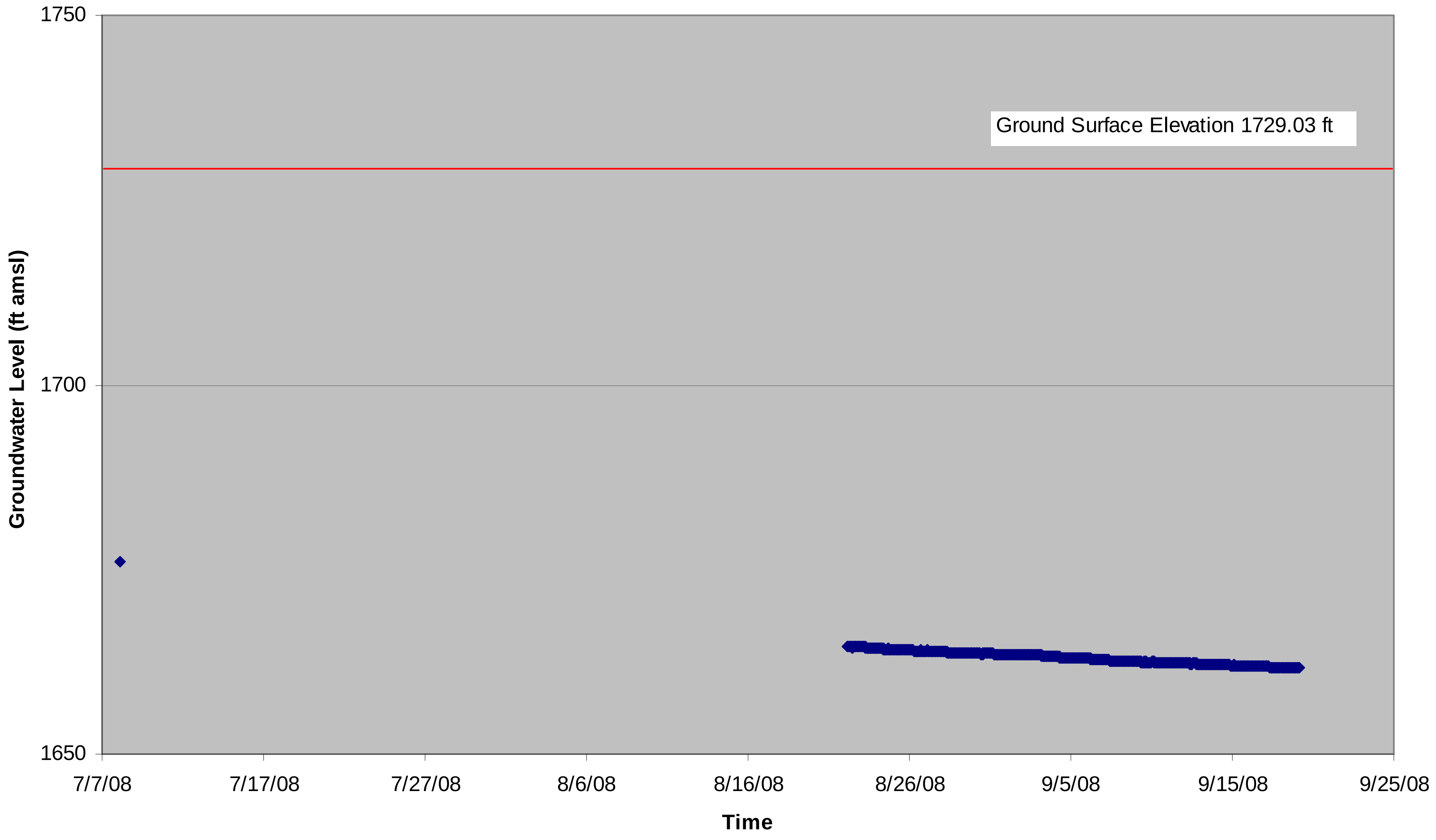
Hydrograph of MW-2

Document: Appendix_F-5_
SBVWCD_Hydrograph_MW-2.pub

Appendix G-5

Date: December 22, 2008

Santa Ana River Groundwater Recharge
Optimization Study



Document: Appendix_F-6_
SBVWCD_Hydrograph_MW-3.pub

Date: December 22, 2008

Hydrograph of MW-3

Appendix G-6

Santa Ana River Groundwater Recharge
Optimization Study

Appendix C

Cost Estimate Details

San Bernardino Valley Water Conservation District
and
San Bernardino Valley Municipal Water District
Santa Ana River Groundwater Recharge Optimization Study

Construction Costs for Recharge Facilities - 300 cfs

Item No.	Description	Units	Quantity	Unit Price	Total
	Common				
1	Mobilization (~ 10% of Construction Costs)	LS	1		$ 257,190
	Intake/Cuttle Weir Modifications				
2	Modify Gate No. 3 on Intake	EA	1	$ 1,000	$ 1,000
3	Channel Cleaning and Re-Grading	CY	122	$ 24	$ 2,928
4	Gabion Wall	LF	27	$ 238	$ 6,426
5	Log boom	LS	1	$ 2,032	$ 2,032
	Main Canal Modifications				
6	Canal Excavation - From Diversion to End of Phase II	CY	50,643	$ 4.75	$ 240,554
7	10 ft drop structure	EA	5	$ 26,101	$ 130,505
8	Pond Turnout Structures (30")	EA	3	$ 12,674	$ 38,022
9	Pond Turnout Structures (36")	EA	6	$ 14,131	$ 84,786
10	30-inch RCP, plus Trench	LF	150	$ 147	$ 22,050
11	36-inch RCP, plus Trench	LF	300	$ 199	$ 59,700
	Recharge Ponds				
12	Recharge Pond Excavation - Phase II	CY	420,270	$ 4.75	$ 1,996,283
	Sub-total				**$ 2,841,476**
13	**Construction Contingency (25% of Construction)**	$	$ 2,841,476	25%	$ 710,000
	Total Construction Cost				**$ 3,551,476**

Notes:

1. Construction Costs shown are based on coceptual level design drawings and analysis.
2. Construction Contingency applied is standard industry for conceptual level cost estimating. Contingency accounts for items not known at conceptual level design phase.
3. This cost estimate of the conceptual design is a Class 5 Cost Estimate as defined by the Association for the Advancement of Cost Engineering. The MWH team has no control over costs of construction labor, materials, competitive bidding environments and procedures, unidentified field conditions, financial and/or market conditions, or other factors likely to affect the Opinion of Probable Construction Cost developed, all of which are and will unavoidably remain in a state of change, especially in light of the high volatility of the market attributable to Acts of God and other market events beyond the control of the parties. This cost estimate prepared during the work is a “snapshot in time” and that the reliability of this Opinion of Probable Construction Cost will inherently degrade over time.

San Bernardino Valley Water Conservation District
and
San Bernardino Valley Municipal Water District
Santa Ana River Groundwater Recharge Optimization Study

Construction Costs for Recharge Facilities - 500 cfs

Item No.	Description	Units	Quantity	Unit Price	Total
	Common				
1	Mobilization (~ 10% of Construction Costs)	LS	1		$ 708,753
	Intake/Cuttle Weir Modifications				
2	Modify Gate No. 3 on Intake	EA	1	$ 1,000	$ 1,000
3	Channel Cleaning and Re-Grading	CY	122	$ 24	$ 2,928
4	Gabion Wall	LF	27	$ 238	$ 6,426
5	Log boom	LS	1	$ 2,032	$ 2,032
6	Raise Cuttle Weir (rock masonry)	CY	29	$ 532	$ 15,428
7	Sluice Gate and Related Installation Work	LS	1	$ 36,284	$ 36,284
8	O&M Platform	LS	1	$ 8,384	$ 8,384
9	OSHA Improvements (Caged Ladder and Handrail)	LS	1	$ 2,720	$ 2,720
	Sandbox Modifications				
10	Remove existing gate	EA	2	$ 500	$ 1,000
11	Install 5 ft x 6 ft sluice gate	EA	2	$ 30,000	$ 60,000
	Main Canal Modifications				
12	Canal Excavation	CY	194,039	$ 4.75	$ 921,685
13	5 ft drop structure	EA	1	$ 19,576	$ 19,576
14	10 ft drop structure	EA	35	$ 26,101	$ 913,535
15	Pond Turnout Structures (18")	EA	1	$ 9,947	$ 9,947
16	Pond Turnout Structures (24")	EA	2	$ 11,298	$ 22,596
17	Pond Turnout Structures (30")	EA	9	$ 12,674	$ 114,066
18	Pond Turnout Structures (36")	EA	7	$ 14,131	$ 98,917
19	18-inch RCP, plus Trench	LF	50	$ 73	$ 3,650
20	24-inch RCP, plus Trench	LF	100	$ 85	$ 8,500
21	30-inch RCP, plus Trench	LF	450	$ 147	$ 66,150
22	36-inch RCP, plus Trench	LF	350	$ 199	$ 69,650
	Greenspot Road Culvert Modification				
23	6 ft x 6 ft Precast Concrete Box Culvert, plus Trench	LF	100	$ 707	$ 70,700
24	Concrete transition structures	CY	48	$ 1,200	$ 57,600
	Diversion Structure Modification				
25	Excavation	CY	65	$ 17	$ 1,105
26	Concrete retaining walls	CY	36	$ 1,200	$ 43,200
27	Grouted rock floor	SY	130	$ 123	$ 15,990
28	North and South Gate concrete diverging cones	CY	3	$ 1,200	$ 3,600
29	South Gate concrete structure	CY	9	$ 1,200	$ 10,800
30	5 ft x 8 ft gate	EA	1	$ 35,000	$ 35,000
31	Existing Gate Modifications	EA	3	$ 2,000	$ 6,000
	Recharge Ponds				
32	Recharge Pond Excavation - Phase II	CY	526,140	$ 4.75	$ 2,499,165
33	Recharge Pond Excavation - Phase III	CY	412,610	$ 4.75	$ 1,959,898
	Sub-total				$ 7,796,285
34	**Construction Contingency (25% of Construction)**	$	$ 7,796,285	25%	$ 1,949,000
	Total Construction Cost				**$ 9,745,285**

Notes:

1. Construction Costs shown are based on conceptual level design drawings and analysis.
2. Construction Contingency applied is standard industry for conceptual level cost estimating. Contingency accounts for items not known at conceptual level design phase.
3. This cost estimate of the conceptual design is a Class 5 Cost Estimate as defined by the Association for the Advancement of Cost Engineering. The MWH team has no control over costs of construction labor, materials, competitive bidding environments and procedures, unidentified field conditions, financial and/or market conditions, or other factors likely to affect the Opinion of Probable Construction Cost developed, all of which are and will unavoidably remain in a state of change, especially in light of the high volatility of the market attributable to Acts of God and other market events beyond the control of the parties. This cost estimate prepared during the work is a “snapshot in time” and that the reliability of this Opinion of Probable Construction Cost will inherently degrade over time.

San Bernardino Valley Water Conservation District
and
San Bernardino Valley Municipal Water District
Santa Ana River Groundwater Recharge Optimization Study

Construction Costs for Recharge Facilities - 500 cfs (Alternate)

Item No.	Description	Units	Quantity	Unit Price	Total
	Common				
1	Mobilization (~ 10% of Construction Costs)	LS	1		$ 709,787
	Intake/Cuttle Weir Modifications (ALTERNATE MODIFICATIONS)				
2	O&M Platform	LS	1	$ 4,538	$ 4,538
3	Ajustable Weir and Related Improvements	LS	1	$ 81,000	$ 81,000
	Sandbox Modifications				
4	Remove existing gate	EA	2	$ 500	$ 1,000
5	Install 5 ft x 6 ft sluice gate	EA	2	$ 30,000	$ 60,000
	Main Canal Modifications				
6	Canal Excavation	CY	194,039	$ 4.75	$ 921,685
7	5 ft drop structure	EA	1	$ 19,576	$ 19,576
8	10 ft drop structure	EA	35	$ 26,101	$ 913,535
9	Pond Turnout Structures (18")	EA	1	$ 9,947	$ 9,947
10	Pond Turnout Structures (24")	EA	2	$ 11,298	$ 22,596
11	Pond Turnout Structures (30")	EA	9	$ 12,674	$ 114,066
12	Pond Turnout Structures (36")	EA	7	$ 14,131	$ 98,917
13	18-inch RCP, plus Trench	LF	50	$ 73	$ 3,650
14	24-inch RCP, plus Trench	LF	100	$ 85	$ 8,500
15	30-inch RCP, plus Trench	LF	450	$ 147	$ 66,150
16	36-inch RCP, plus Trench	LF	350	$ 199	$ 69,650
	Greenspot Road Culvert Modification				
17	6 ft x 6 ft Precast Concrete Box Culvert, plus Trench	LF	100	$ 707	$ 70,700
18	Concrete transition structures	CY	48	$ 1,200	$ 57,600
	Diversion Structure Modification				
19	Excavation	CY	65	$ 17	$ 1,105
20	Concrete retaining walls	CY	36	$ 1,200	$ 43,200
21	Grouted rock floor	SY	130	$ 123	$ 15,990
22	North and South Gate concrete diverging cones	CY	3	$ 1,200	$ 3,600
23	South Gate concrete structure	CY	9	$ 1,200	$ 10,800
24	5 ft x 8 ft gate	EA	1	$ 35,000	$ 35,000
25	Existing Gate Modifications	EA	3	$ 2,000	$ 6,000
	Recharge Ponds				
26	Recharge Pond Excavation - Phase II	CY	526,140	$ 4.75	$ 2,499,165
27	Recharge Pond Excavation - Phase III	CY	412,610	$ 4.75	$ 1,959,898
	Sub-total				$ 7,807,655
28	**Construction Contingency (25% of Construction)**	$	$ 7,807,655	25%	$ 1,952,000
	Total Construction Cost				**$ 9,759,655**

Notes:

1. Construction Costs shown are based on conceptual level design drawings and analysis.
2. Construction Contingency applied is standard industry for conceptual level cost estimating. Contingency accounts for items not known at conceptual level design phase.
3. This cost estimate of the conceptual design is a Class 5 Cost Estimate as defined by the Association for the Advancement of Cost Engineering. The MWH team has no control over costs of construction labor, materials, competitive bidding environments and procedures, unidentified field conditions, financial and/or market conditions, or other factors likely to affect the Opinion of Probable Construction Cost developed, all of which are and will unavoidably remain in a state of change, especially in light of the high volatility of the market attributable to Acts of God and other market events beyond the control of the parties. This cost estimate prepared during the work is a “snapshot in time” and that the reliability of this Opinion of Probable Construction Cost will inherently degrade over time.

San Bernardino Valley Water Conservation District
and
San Bernardino Valley Municipal Water District
Santa Ana River Groundwater Recharge Optimization Study

Construction Costs for Recharge Facilities - Optional Facilties

Item No.	Optional Facilities Description	Units	Quantity	Unit Price	Total
	Trashrack Structure				
1	Trashrack Structure	LS	1	$ 144,646	$ 144,646
	Sub-total - Optional Facilities				$ 144,646
2	**Construction Contingency (25% of Construction)**	$	$ 144,646	25%	$ 36,000
	Total Construction Cost				**$ 180,646**
	Sedimentation Ponds				
1	Pond Excavation	CY	466,311	$ 4.75	$ 2,214,977
2	Canal Excavation - To and From Ponds	CY	5,100	$ 4.75	$ 24,225
3	Concrete - For Overflow and Gate Structures	CY	100	$ 1,200	$ 120,000
4	72" Canal Gates	EA	6	$ 26,000	$ 156,000
5	72" RCP	LF	360	$ 752	$ 270,720
6	42" RCP	LF	440	$ 232	$ 102,080
7	Rip Rap, non-grouted	SY	150	$ 93	$ 13,950
	Sub-total - Optional Facilities				$ 2,901,952
8	**Construction Contingency (25% of Construction)**	$	$ 2,901,952	25%	$ 725,000
	Total Construction Cost				**$ 3,626,952**
	Lower South Canal				
	Borrow Pit Ponds 1, 2, and 3				
1	Canal Excavation - From South Diversion to Pond 1	CY	6,912	$ 4.75	$ 32,832
2	Pond 1 Inlet Structure	EA	1	$ 316,292	$ 316,292
3	Pond Overflow Structure	EA	2	$ 205,467	$ 410,934
	Borrow Pit Canal				
4	Pond 3 Discharge Structure	LS	1	$ 218,360	$ 218,360
5	72-inch RCP	LF	730	$ 535	$ 390,550
6	Canal Excavation	CY	166,394	$ 4.75	$ 790,369
7	5 ft drop structure	EA	4	$ 19,576	$ 78,304
8	10 ft drop structure	EA	12	$ 26,101	$ 313,212
9	Pond Turnout Structures (18")	EA	1	$ 9,947	$ 9,947
10	Pond Turnout Structures (24")	EA	2	$ 11,298	$ 22,596
11	Pond Turnout Structures (30")	EA	9	$ 12,674	$ 114,066
12	Pond Turnout Structures (36")	EA	7	$ 14,131	$ 98,917
13	18-inch RCP, plus Trench	LF	50	$ 73	$ 3,650
14	24-inch RCP, plus Trench	LF	100	$ 85	$ 8,500
15	30-inch RCP, plus Trench	LF	450	$ 147	$ 66,150
16	36-inch RCP, plus Trench	LF	350	$ 199	$ 69,650
	Borrow Pit Diversion Structure				
17	Diversion Structure	LS	1	$ 381,952	$ 381,952
18	Rip-rap, grouted	CY	83	$ 123	$ 10,209
	Borrow Pit Overflow Structure				
19	Excavation	CY	7,000	$ 17	$ 119,000
20	Rip-Rap, grouted	CY	1,100	$ 123	$ 135,300
21	Concrete weir	CY	34	$ 1,200	$ 40,800
	Sub-total				$ 3,631,590
22	**Construction Contingency (25% of Construction)**	$	$ 3,631,590	25%	$ 908,000
	Total Construction Cost				**$ 4,539,590**

Notes:
1. Construction Costs shown are based on conceptual level design drawings and analysis.
2. Construction Contingency applied is standard industry for conceptual level cost estimating. Contingency accounts for items not known at conceptual level design phase.
3. This cost estimate of the conceptual design is a Class 5 Cost Estimate as defined by the Association for the Advancement of Cost Engineering. The MWH team has no control over costs of construction labor, materials, competitive bidding environments and procedures, unidentified field conditions, financial and/or market conditions, or other factors likely to affect the Opinion of Probable Construction Cost developed, all of which are and will unavoidably remain in a state of change, especially in light of the high volatility of the market attributable to Acts of God and other market events beyond the control of the parties. This cost estimate prepared during the work is a “snapshot in time” and that the reliability of this Opinion of Probable Construction Cost will inherently degrade over time.