EXHIBIT 2-A

SUMMARY OF OPERATIONS
WELL CONSTRUCTION AND TESTING
SANTA MARGARITA TEST INJECTION WELL NO.2

Prepared for:
MONTEREY PENINSULA WATER MANAGEMENT DISTRICT

August 2007

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August 23, 2007
Project No. 06-0021

Monterey Peninsula Water Management District
Post Office Box 85
Monterey, California 93942

Attention: Mr. Joe Oliver, Senior Hydrogeologist

Subject: Draft Summary of Operations Report; Well Construction and Testing, Santa Margarita Test Injection Well No. 2

Dear Joe:

For your review and comment, we are transmitting one (1) electronic (PDF) copy of the subject draft report documenting the design, construction, development, and production testing of Santa Margarita Test Injection Well No. 2 (SMTIW No. 2) and associated monitor well. Well construction was completed successfully, and production testing results exceeded expectations. Based on analysis of the testing results, the well is capable of a nominal long-term sustainable production rate of between approximately 3,000 to 5,000 gallons per minute (gpm). Based on the production capacity, the well is anticipated to be capable of injection/recharge rates in excess of 1,500 gpm (6.6 acre-feet per day) and meeting the Phase 1 ASR Project objectives for the well.

We appreciate the opportunity to provide assistance to the District on this important community water supply project.

Sincerely,

PUEBLO WATER RESOURCES, INC.

Robert C. Marks, P.G., C.Hg.
Principal Hydrogeologist

Stephen P. Tanner, P.E.
Principal Engineer

RCM

Copies Submitted (1 PDF)

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INTRODUCTION

GENERAL STATEMENT

Presented in this report is a summary of hydrogeologic and engineering services provided during the drilling, completion, development, and production testing of Santa Margarita Test Injection Well No. 2 (SMTIW No. 2) and associated monitoring well (MW-1). The wells were constructed as part of the Monterey Peninsula Water Management District's (District) Phase 1 Aquifer Storage and Recovery Project. The well site is located on a parcel leased by the District on former Fort Ord property along General Jim Moore Boulevard adjacent the northeast corner of the City of Seaside, California. The site's location is shown on Plate 1 - Site Location Map. The elevation of the SMTIW No. 2 well site is approximately 360 feet above mean sea level (msl).

Observation of contractor activities during the project was provided by Pueblo Water Resources, Inc. (PWR). The wells were constructed and tested between December 12, 2006 and May 3, 2007. This report documents drilling operations, as-built construction, well development, water quality sampling and analysis, geologic interpretation, production testing, and aquifer analysis. This report also presents recommendations for long-term operational capacities for the well based on the testing results.

BACKGROUND

The District has undertaken a Water Supply Augmentation Plan, which includes the evaluation of the feasibility of recharging treated potable water originating from the Carmel River and Carmel Valley aquifer system into the aquifer system in the Seaside Groundwater Basin (SGB or Basin). In general, the project concept (a.k.a. Aquifer Storage and Recovery [ASR]) involves the diversion, treatment, and conveyance of excess winter flows of the Carmel River system to the SGB for recharge and storage. The water is delivered via the California American Water (CAW) existing distribution system, which connects Carmel Valley to the Seaside/Monterey area. During periods of high demand, the same well(s) used for recharge and/or existing CAW production wells are used to recover the stored water. The recharged water could ultimately restore groundwater conditions in the Basin and increase the Basin yield, which would reduce extractions on the Carmel River system during dry periods and preserve fisheries habitat in critical reaches of the river.

The District has been evaluating the feasibility of an ASR project since 1996. Efforts have included hydrogeologic testing and construction of pilot and full-scale test ASR wells in the coastal area of the SGB. The Santa Margarita Test Injection Well No. 1 (SMTIW No. 1) well was constructed in the spring of 2001. The well is constructed to a total depth of 720 feet, and is perforated solely in the Santa Margarita Sandstone aquifer to accurately assess the hydrogeologic conditions of this formation for recharge and recovery operations. Since its construction, formal testing of the SMTIW No.1 has been performed in Water Years (WY) 2002 thru 2006, with a total of approximately 1,279 acre-feet (AF) of water successfully diverted from the Carmel River system to recharge the SGB at SMTIW No.1.

The SMTIW No. 2 well is part of the District's Phase 1 ASR Project, which consists of expanding the successful SMTIW No. 1 project to include the addition of a second ASR well and associated facilities in an expanded site area contiguous to the existing SMTIW site. The design recharge and recovery capacities of SMTIW No. 2 are nominally 1,500 and 3,000 gallons per minute (gpm), respectively. The addition of the SMTIW No. 2 well is intended to increase the existing recharge capacity of the site from approximately 1,000 gpm up to 2,500 to 3,000 gpm (3.6 to 4.3 million gallons per day [MGD], or 11.1 to 13.2 acre feet per day [AFD]).

Hydrogeologic Setting

The project area is located over the SGB, which underlies an approximately 19-square mile area at the northwest corner of the Salinas Valley, adjacent to the Monterey Bay. The geology and hydrogeology of the SGB are well documented in past studies by the California Department of Water Resources (1974), Staal, Gardner & Dunne, Inc. (1987 and 1990), Fugro West, Inc. (1997), and Yates and others (2005). These documents describe the stratigraphy, structure, and hydraulic characteristics of the aquifer systems of the SGB.

The SGB has traditionally been subdivided into several subbasins and subareas within those subbasins for hydrologic analysis. These divisions reflect a combination of hydrogeologic and jurisdictional boundaries, and the configuration of the subarea boundaries has evolved slightly over time. A hydrogeologic boundary created by the Laguna Seca anticline divides the basin into Northern and Southern Subbasins. The anticline lifts the relatively impermeable shales of the Monterey Formation above the regional water table along its length, including the segment where it is offset by the Ord Terrace fault.

Each of the two subbasins is further divided into Coastal and Inland Subareas. The dividing line parallels General Jim Moore Boulevard (previously North-South Road), which was formerly the jurisdictional boundary between the Fort Ord military base and the communities of Seaside and Del Rey Oaks. In the Southern Subbasin, the inland part is the Laguna Seca Subarea, and in the Northern Subbasin it is the Northern Inland Subarea. The coastal subareas are simply referred to as the Southern and Northern Coastal Subareas, respectively. The project site is located in the Northern Subbasin, just east of the boundary between the Coastal and Inland Subareas (i.e., General Jim Moore Blvd.).

The SGB consists of a sedimentary sequence of water-bearing materials that overlie the low-permeability shales of the Monterey Formation. Although the Monterey Formation is capable of yielding small quantities of water in many locations, the Monterey Shale has been traditionally considered non-water-bearing in the SGB, and has been designated as the “effective base of freshwater” in the SGB.

The uppermost formations in the SGB are the Aromas Sand and Older Dunes. These surficial deposits are of minor importance to groundwater resources in the basin as they are unconfined, in direct hydraulic communication with the ocean and are only saturated in the extreme coastal portion of the basin. These characteristics make them susceptible to water quality degradation, either from seawater intrusion or surface-derived contaminants.

Underlying the Aromas Sand and Older Dunes is a formation referred to as Tertiary and Quaternary “continental deposits” (Dupré, 1990; Clark and others, 1997, 2000). This formation consists of a complex sequence of interbedded sand, gravel and clay deposits. These deposits are more than 600 feet thick in some portions of the SGB. Because of the fluvial depositional environment, gravel deposits encountered in wells are not easily correlated between wells for any appreciable distances. The water-bearing portions of this formation are lenses of sand and gravel of limited areal extent and as a group are commonly referred to as the “Paso Robles aquifer” by local hydrogeologists.

The formation underlying the Paso Robles aquifer and directly overlying the Monterey Formation is the Santa Margarita Sandstone as mapped by Clark and others (1997, 2000), and it corresponds to the “Santa Margarita aquifer”. The Santa Margarita aquifer is the target aquifer for the proposed ASR project. This sedimentary unit is a loose to weakly cemented sandstone with a stratigraphic thickness of approximately 200 to 300 feet. The upper portion of this deposit is medium- to coarse-grained clean sand. With increasing depth and proximity to the underlying Monterey Formation, the clay content of the formation increases.

Basis-of-Design

PWR personnel[1] prepared a Basis-of-Design for the new SMTIW No. 2 well as part of the SMTIW WY2004 report, dated January 2005. The Basis-of-Design included an evaluation of the existing hydrogeologic information, assessment of the feasibility of constructing and operating a well at the site, and a preliminary design for the well. As presented in the Basis-of-Design, the available data suggested that the depth to the base of the Santa Margarita aquifer at the site was approximately 740 feet. Based on the assessment of existing data, the specific capacity[2] of the SMTIW No. 2 well was expected to be in the range of 30 to 40 gallons per minute per foot of drawdown (gpm/ft) with an operational production rate of approximately 3,000 to 4,000 gpm.

PURPOSE AND SCOPE

The purpose of this report is to document the drilling and construction of the SMTIW No. 2 and MW-1 wells, summarize well production testing operations, present the analysis of the test data, provide conclusions developed through the testing program, and develop recommendations regarding the utilization and future testing requirements of the SMTIW No. 2 well.

The scope of work was developed through discussions and correspondence with PWR and Mr. Joe Oliver, Senior Hydrogeologist, and included the following:

- Confirmation of the Basis-of-Design;
- Preparation of well construction specifications and bid documents;
- Assistance with the bidding process;
- Well construction management and hydrogeologic documentation and interpretation;
- Development and coordination of the baseline well testing program, and;
- Preparation of a Summary of Operations Report.

[1] While under previous employment with Padre Associates, Inc.
[2] Specific capacity is the ratio of well discharge to drawdown. Units are typically expressed as gallons per minute per foot of drawdown (gpm/ft). The value is useful for normalizing and comparing performance between different wells and for predicting the performance of a given well at differing discharge rates.

dominated by montmorillonite (3 to 4 percent), illite/mica (1 percent) with trace amounts of kaolinite. The intergranular porosity is estimated at 24 to 28 percent.

The detailed mineralogical analyses are presented in Appendix A - Mineralogy Analytic Results (not included in draft). These data should be used in future geochemical analyses consisting of 3-component reactivity analyses between injected water, native groundwater, and the aquifer minerals. This will be particularly important in evaluating the feasibility of injecting source waters other than those derived from the Carmel River system, such as from Marina Coast Water District and/or CAW's Coastal Water Project desalination water.

The pilot hole was drilled to a total depth of approximately 847 feet below ground surface (bgs). Drilling was terminated at this depth upon confirmation of consolidated bedrock material (shale belonging to the Monterey Formation) in the cuttings samples. Upon reaching the total depth on January 9, 2007, a geophysical log was performed consisting of resisitivity, spontaneous potential (SP), and gamma surveys. Review of the lithologic and geophysical logs confirmed the presence of Monterey Formation shale at a depth of approximately 840 feet bgs.

The lithologic and geophysical logs of the SMTIW No. 2 are presented on Plate 2 - Graphic Logs and As-Built Completion, and in Appendix B - Lithologic and Geophysical Logs (not included in draft). Review of the geophysical logs in conjunction with the lithologic log suggests the following geologic formation interpretation.

Table 1. Geologic Formation Delineation
SMTIW No. 2

Formation Name	Depth (feet)	Thickness (feet)
Older Dune Sand/Aromas Sand (Qar)	0 to 285	285
Paso Robles Formation (QTp)	285 to 530	245
Santa Margarita Sandstone (Tsm)	530 to 840	310
Monterey Formation (Tm)	840 to 847*+	7+

* Total depth of pilot hole

As noted previously, the Basis-of-Design for the SMTIW No. 2 anticipated bedrock would be at a depth of approximately 760 feet bgs; however, bedrock at the site was encountered approximately 80 feet deeper than was anticipated. Taking into account ground surface elevations, these findings suggest an average apparent dip in the bedrock surface at the site (i.e. between SMTIW Nos. 1 and 2) of approximately 12 degrees north/northeast.

Following revision of the well design by PWR, in consultation with the District, the Contractor initiated pilot hole reaming operations on January 10, 2007. Reaming was performed in one pass to a diameter of 32 inches. During reaming, drilling fluid properties were generally maintained in compliance with the specifications.

After reaching final reamed depth of approximately 810 feet bgs on January 15, 2007, a caliper survey was performed to assess the condition of the borehole and to allow refinement of gravel and cement volume calculations. The caliper survey revealed the borehole to be essentially in gauge, with only one minor washout zone between approximately 60 and 70 feet (i.e., below the conductor casing). Overall, the condition of the borehole was very good and within specifications. The caliper log is included in Appendix B (not included in draft).

Following the caliper survey, the Contractor initiated casing operations. Casing and screen were manufactured by Roscoe Moss Co. of Los Angeles, CA. The upper (0 to 535 feet bgs) blank casing sections consist of 22.75-inch outside diameter (OD), 0.375-inch wall thickness, stainless-steel (ASTM A778, Type 304). Below 535 feet is a 5-feet long, 22.75- x 20.0-inch OD reducer. Perforations begin at approximately 540 feet bgs, and consist of 20-inch OD, stainless-steel (Type 304), wire-wrapped, well screen with 0.050-inch slots. The screen was placed between the following depth intervals:

- 540 to 650 feet
- 670 to 770 feet

The well was equipped with a 20-foot, stainless-steel, cellar pipe, and the total casing depth is approximately 790 feet. Each casing joint was welded and centralizers were placed at approximately 60-feet and 80-feet spaced intervals in the screen and blank sections, respectively.

Gravel pack was installed through a construction tremie from the bottom of the hole to a depth of approximately 490 feet bgs. The gravel pack consists of an 8 x 16 gradation ‘Texas Silica’ supplied by Oglebay Norton Industrial Sands - Colorado Silica Sand, Inc. Sodium hypochlorite was added to the gravel pack during emplacement for disinfection in accordance with State Water Well Standards and to facilitate breakdown of the polymeric drilling fluid. Upon completion of gravel packing, approximately 10 feet of fine-grained “transition” sand was tremied into place to provide separation of the cement grout and gravel pack. The concrete seal, consisting of 10-sack sand slurry, was placed in two separate “lifts” on January 18 and 19, 2007, via positive displacement pumping. Two separate lifts were required in order to prevent casing collapse. The first lift was from the top of the transition sand (480 feet bgs) to a depth of approximately 198 bgs. The second lift brought the concrete seal to the surface. Total seal volume pumped was approximately 48 cubic yards (yds^3), which was within approximately 10 percent of the calculated annular volume based on the caliper log.

An as-built schematic of the well is presented on Plate 2. A summary comparison of the preliminary design and As-Built well features is presented below in Table 2:

Table 2. Summary Comparison of Preliminary Design and As-Built Construction

Design Consideration	Preliminary Design	As-Built	Comment
Total Well Depth (ft bgs)	720	790	70 ft. Deeper than anticipated
Seal Depth (ft)	460	480	20 ft. Deeper than anticipated
Casing Material	Stainless Steel	Stainless Steel	22-inch Blank and 20-inch Screen
Perforated Intervals (ft bgs)	480-590	540-650	Upper Tsm
	610-700	670-770	Lower Tsm
Total Perforation Length (feet)	200	210	10 feet more than anticipated
Cellar Section (ft bgs)	700-720	770-790	20 feet (later filled w/concrete)
Perforation Aperture	0.050-inch slots	0.050-inch slots	Roscoe Moss Co., Wire-Wrapped
Gravel Pack (gradation)	8 x 16	8 x 16	Oglebay Norton 'Texas Silica'

Well Development

The SMTIW No. 2 was developed by swabbing and air-lifting, and by pumping and surging using a vertical, line-shaft, turbine pump. A chemical dispersant (AquaClear PFD, manufactured by Baroid Industrial Drilling Products) was also used to facilitate well development.

Air-lift, Zone-Pumping Development Well development was initiated on January 20, 2007. Initial development consisted of air-lift, zone pumping while swabbing. Air-lift, zone pumping was performed utilizing an approximate 20-foot long, 8-inch diameter, perforated, dual-swab assembly with two 20-inch, nominal-diameter wipers with a 5-foot separation. This tool was placed on the string of 8-inch diameter drill pipe. The assembly was moved up and down through the perforated intervals while simultaneously air-lifting. Zone pumping was initiated at the top of the perforations (540 feet bgs) and moved progressively deeper. Each interval was swabbed and pumped for approximately 3 hours for each 30-foot interval of screen until discharge was relatively clear.

Upon reaching the bottom, the development tool was utilized to inject a solution of AquaClear PFD (a dispersant polymer) incrementally into the well screen sections to aid further removal of clays and fines from the gravel pack and near-bore, formation materials. The AquaClear PFD was introduced into the well in concentration of 1 gallon per 500 gallons of water in the screened sections and "dry" swabbed for a period of approximately 20 minutes per 30-foot, screened section.

Following introduction of the AquaClear PFD, the solution was allowed to remain in the well for a period of 12 hours, during which the screen was dry swabbed every 2 hours to further agitate the solution. After this 12-hour period, a second pass of air-lift, zone pumping, as described above, was performed on January 21 and 22, 2007; however, an additional hour per 30-foot screen section was performed during this second pass to provide additional removal of fines. At the completion of air-lift development, discharge was relatively clear with no measurable sand. Total active mechanical development time was approximately 49 hours.

Initial Pumping and Surging Development. After completion of air lifting, final development was performed by pumping and surging. A 16-inch diameter, engine driven vertical line shaft turbine pump was installed on 12-inch diameter column pipe to a depth of approximately 500 feet. The discharge line was equipped with an instantaneous/totalizing flow meter, a Rossum Centrifugal Sand Sampler, and various sample ports. Discharge was routed to a location approximately 600 feet south of the well location, and was allowed to travel as sheet flow and percolate into the ground in an undeveloped area.

Pumping and surging development was initiated on February 5, 2007, and generally consisted of starting and stopping the pump (surging) several times, followed by periods of approximately 10 to 30 minutes of continuous pumping, then repeated. Discharge rates varied between approximately 400 and 3,700 gpm. During development pumping, sand production was measured with the Rossum tester. A graphical summary of well development and performance data is presented on Plate 3, showing well specific capacity versus sand production and discharge rates as development progressed.

As shown, the initial production rate and specific capacity were approximately 400 gpm and 4 gpm/foot of drawdown (gpm/ft), respectively. Sand production was initially as high as 12 parts per million (ppm) directly following surging, becoming less than 1 ppm after several hours of pumping. After approximately 36 hours of pumping and surging, the production rate and specific capacity had increased to approximately 2,100 gpm and 16 gpm/ft, respectively. While this represented a significant improvement in performance, it was still below the targeted performance of approximately 3,000 gpm and a specific capacity of 30 to 40 gpm/ft; therefore, it was decided to lower the pump bowl assembly setting to create additional available drawdown above the pump bowls to allow for an increased pumping rate and efficiency of the development operations.

Pump Dropping Incident. The contractor placed additional pump column pipe to the assembly on February 12 and 13, 2007, lowering the bowl assembly to a depth of approximately 650 feet bgs (i.e., within the intermediate blank casing section). On February 13, just as the contractor had set the final section of column pipe into the well, the column pipe unexpectedly disengaged approximately 340 feet down and the pump assembly fell to the bottom of the well. The contractor subsequently began retrieving (“fishing”) the lost portion of the assembly on February 15, 2007; however, upon “landing” the column pipe at the surface, the assembly again disengaged at another location down hole and the pump assembly fell to the bottom of the well a second time. Examination of the threaded connections at the separated locations did not indicate the precise reason for the column pipe having disengaged; therefore, it is not known whether the cause was due to worn threads or improperly tightened joints, or a combination of both factors.

The contractor completed fishing of the remaining portions of the pump assembly from the well on February 20, 2007, and a downhole video survey of the well was subsequently performed to assess the well condition and determine if any damage had occurred. The results of the video indicated that no visible damage had occurred to the blank casing or perforations; however, approximately 4 feet of fill had accumulated in the cellar, which prevented the viewing of the very bottom of the well.

Bailing of fill material from the bottom of the well was initiated on February 26, and continued until February 27, 2007. During this operation, approximately 8 to 10 ft^3 of material, consisting primarily of gravel pack with minor amounts of formation sand and gravel, was removed from the well; however, the fill level inside the well did not decrease commensurately with this volume, indicating that the bottom plate had likely been separated from the cellar pipe as a result of the pump impact, thereby allowing material to enter the well. As a result, the contractor installed approximately 9 ft^3 of concrete (Sakrete High Strength Concrete, mixed on site) with a "dump" bailer in the cellar in an effort to form an estimated 4 vertical feet plug in the bottom of the well to prevent additional material from entering.

Final Pumping and Surging Development. Reinstallation of the development pump was completed on March 2, 2007, with the pump bowls set to only 540 feet bgs (versus 630 feet) and on 10-inch diameter column pipe (versus 12-inch), with an extended suction to approximately 631 feet bgs. Development pumping was resumed at a rate of approximately 1,000 gpm. Initially, sand production was very high (at times greater than 150 ppm), consisting predominantly of fine formation sand with minor medium sized grains, and some grains of gravel pack material. Over the course of the next 14 hours of pumping (without surging), the sand production gradually decreased while the pumping rate and specific capacity increased to values similar to those prior to the lowering of the pump and pump dropping incident.

As shown on Plate 3, pumping and surging continued for an additional 76 hours before being terminated. During this period, the pumping rate reached rates as high as approximately 3,700 gpm, while the specific capacity increased steadily to over 50 gpm/ft and the sand content became less than 1 ppm. Although the developing pumping continued to result in gradual improvement in specific capacity, the well's performance (as measured by specific capacity) had reached the targeted goal and development pumping was terminated, due to budgetary constraints, on March 21, 2007. Total pumping and surging development time was approximately 126 hours.

Monitor Well Construction

A monitoring well (MW-1) was also drilled and constructed at the site to monitor aquifer hydraulic responses and water-quality changes during ASR operations. Drilling and construction of MW-1 were performed by Bradley & Sons Drilling of Madera, California, under MCDEH Permit No. 06-10985.

Work commenced on December 15, 2006, with the drilling of an approximate 21-inch diameter conductor casing hole using the bucket auger rig. A 14-inch outside diameter steel conductor casing was installed to a depth of approximately 20 feet. After the conductor casing was installed, it was sealed by filling the annular space between the borehole and the casing with 10-sack sand slurry concrete.

After setting the conductor casing, a direct-rotary rig was mobilized onto the well location. Drilling of a $12^1/_4$-inch diameter, pilot hole commenced on January

15, 2007. Drilling and construction operations were conducted on a 12-hour-per-day (i.e., daylight hours) basis. During drilling, the Contractor collected samples of the cuttings at 10-foot intervals from the drilling-fluid discharge. The cuttings were logged by a field geologist. The drilling fluid was bentonite-based (Quik-Gel, manufactured by Baroid Industrial Drilling Products), and the fluid properties were generally maintained within the criteria required by the specifications throughout the drilling process.

The pilot hole was drilled to a total depth of approximately 806 feet bgs. Upon reaching the total depth on January 17, 2007, a geophysical log was performed consisting of resisitivity, spontaneous potential (SP), and gamma surveys. Review of the geophysical logs indicated the presence of Monterey Formation shale at a depth of approximately 802 feet bgs.

The lithologic and geophysical logs of MW-1 are presented on Plate 4 - Graphic Logs and As-Built Completion, and in Appendix B - Lithologic and Electric Logs (not included in draft). Review of the geophysical logs in conjunction with the lithologic log suggests the following geologic formation interpretation:

**Table 3. Geologic Formation Delineation
Monitoring Well No. 1**

Formation Name	Depth (feet)	Thickness (feet)
Older Dune Sand/Aromas Sand (Qar)	0 to 290	290
Paso Robles Formation (QTp)	290 to 500	210
Santa Margarita Sandstone (Tsm)	500 to 802	302
Monterey Formation (Tm)	802 to 806*+	4+

* Total depth of pilot hole

As noted previously, the anticipated depth to bedrock at the site was approximately 760 feet bgs; therefore, bedrock at MW-1 was encountered approximately 40 feet deeper than was anticipated, but approximately 40 shallower that at SMTIW No. 2.

Following revision of the well design and conducting a “wiper” run of the drill hole, the Contractor initiated casing operations. Casing and screen were flush-threaded, 4-inch diameter, Schedule 80 PVC (ASTM F480). Stainless-steel centralizers were placed at approximately 60 and 80-feet spaced intervals in the screen and blank sections, respectively. The screen was machine-cut slots with a slot size of 0.040-inch, and was placed between the following depth intervals:

- 500 to 610 feet
- 640 to 730 feet

The well was equipped with a 10-foot cellar pipe, making the total casing depth approximately 740 feet.

Gravel pack was installed through a construction tremie from the bottom of the hole to a depth of approximately 450 feet bgs. The gravel pack consists of an 8 x 16 gradation supplied by Silica Resources, Inc. The concrete seal, consisting of 10-sack sand slurry, was placed on January 19, 2007, via positive displacement pumping. Total seal volume pumped was approximately 10 yds^3. An as-built schematic of MW-1 is presented on Plate 4.

Well development, consisting of air-lift pumping, was initiated on January 22, 2007. Discharge was initially very turbid, becoming cloudy within approximately 4 hours. Air-lift pumping continued on January 23, until discharge was relatively clear and no sand was being produced. Total development time for MW-1 was approximately 12 hours.

PRODUCTION TESTING

Baseline production testing of the SMTIW No. 2 was conducted following development, and consisted of two step discharge tests and a 24-hour continuous discharge test. During the final step drawdown test, a downhole velocity (spinner) survey was also performed. The primary purpose of the production testing of the SMTIW No. 2 was to:

- Determine the recovery and backflush pumping capacities of the well;
- Estimate aquifer parameters for the materials in which the well is completed;
- Determine the location and quantitative production from each screened interval in the well;
- Estimate the hydraulic efficiency of the well, and;
- Evaluate the baseline water quality of the produced “native” groundwater.

Water-level data were automatically collected from the SMTIW No. 2 using a pressure transducer coupled to a continuous-recording data logger and were periodically manually verified with an electric sounder during testing. Water levels at MW-1 and SMTIW No. 1, located at distances of approximately 195 and 282 feet, respectively, were also monitored during testing. Water-level measurements were taken from the top of the casing of each well. Discharge rate was measured with a propeller-type, totalizing, flow meter. Field-data sheets for the well testing are included in Appendix C – Well-Testing Data and Field Documentation (not included in draft).

Step Testing

An initial 12-hour, step-discharge test was performed on March 22, 2007. The primary purpose of the step-drawdown test was to assess variations in well specific capacity at differing discharge rates. Throughout the test, water levels in the pumping well were measured and recorded using the pressure transducer/data logger, and the discharge rate was measured using the totalizing flow meter.

The test consisted of four steps, each at a successively-higher rate. The duration of each step was approximately 3 hours. The four test rates were approximately 1,483, 2,100, 2,811 and 3,528 gpm. The static water level in the well prior to the test was 372.8 feet below top of casing (btoc). The resulting drawdowns and specific capacities associated with each of these steps are shown on Plate 5 – Step-Production Test, and are summarized in Table 4 - Specific Capacity Summary, Production-Test Results. Sand testing performed throughout the step test indicated that sand production from the well was minimal (trace amounts).

Response to step-production pumping of the SMTIW No.2 was observed at MW-1 and SMTIW No.1. At the MW-1, approximately 6.4 feet of drawdown was observed at the end of the first step, and approximately 18.1 feet of drawdown was observed at the end of the final step. At SMTIW No.1, approximately 5.9 feet of drawdown was observed at the end of the first step, and approximately 15.2 feet of drawdown was observed at the end of the final step.

Constant Rate Testing

A 24-hour, constant rate test was performed following the step test and a period of water level recovery to assess aquifer parameters and determine long-term production capacities for both recovery and backflush pumping.

The constant-rate test was initiated on March 26, 2007. The discharge was maintained at an average rate of approximately 3,033 gpm during the 24-hour test. Throughout the test, water levels in the pumping well were measured and recorded using the transducer and data logger, and the discharge rate was measured using the totalizing flow meter. Recovery data were collected after pumping was terminated.

Drawdown data for the SMTIW No. 2 Constant Rate Test are graphically presented on Plate 6. As shown, the static water level in the well prior to pumping was approximately 371.6 feet. The pumping level recorded after 24 hours was approximately 439.7 feet, corresponding to a drawdown of 68.1 feet, and a 24-hour specific capacity of 44.5 gpm/ft. Sand testing performed throughout this test also indicated that sand production from the well was minimal (trace amounts).

Response to the continuous discharge test was observed at MW-1 and SMTIW No. 1, with approximately 17.7 and 17.1 feet of drawdown, respectively, observed at the end of the 24-hour test.

The resulting drawdown and specific capacities associated with each of the various tests are summarized below in Table 4 - Specific Capacity Summary, Production-Test Results:

Table 4. Specific Capacity Summary, Production-Test Results

Test	Duration (hours)	Rate (gpm)	Drawdown (feet)	Specific Capacity (gpm/ft)
Step Production				
• Step 1	3	1,483	25.8	54.5
• Step 2	3	2,100	40.7	51.6
• Step 3	3	2,811	59.1	47.6
• Step 4	3	3,528	77.5	45.5
Constant Rate	24	3,033	68.1	44.5

As presented in Table 4, the specific capacity ranged between 44.5 and 54.5 gpm/ft, depending on the discharge rate and duration of pumping. As shown, the specific capacity generally decreases with increasing discharge rate and duration of pumping. For comparison, SMTIW No.1 displayed an 8-hour specific capacity of 55.1 gpm/ft following its construction in 2001. It is important to note that the pumping water level (and, therefore, specific capacity) of a well for a given production rate decreases as pumping duration increases; therefore, it is important to consider the test duration when comparing specific capacity values.

Supplemental Step Testing

Following the constant-rate test, the contractor raised the pump-bowl assembly up to 440 feet bgs in order to place it above the perforations and the entry point of the external sounding tube. A supplemental step production test was subsequently performed with the new pump setting, and a downhole-velocity (spinner) survey was performed to assess variations in well specific capacity, and the locations and quantitative production from each screened interval at differing discharge rates.

The test consisted of three steps, each at a successively-higher rate that was comparable to the first three rates during the initial step-production test. The duration of each step was approximately 100 minutes. The three test rates were approximately 1,410, 2,120, and 2,830 gpm. The static water level in the well prior to the test was approximately 372.2 feet btoc. The resulting specific capacities associated with each of these steps were 51.8, 49.2, and 46.9 gpm/ft. These values are comparable to the initial step-test results, indicating that pump placement did not have a significant effect on well performance.

Downhole-Velocity Testing. A downhole flowmeter (spinner) survey was performed during the supplement step-production test. The purpose of the spinner survey was to profile and delineate the location and quantitative production from the perforated intervals at various discharge rates. The spinner flowmeter measures the movement of water by the use of a low-inertia impeller, from which uphole fluid velocity can be measured. The results of the production spinner survey can be compared to a future similar survey performed during injection testing in order to evaluate any differences in which aquifer zones are yielding and taking water during production versus injection modes, respectively, as well as future production surveys to assess locations of well fouling/production losses that may occur.

A velocity profile was performed during each of the three discharge steps. The results of the surveys are presented in Appendix D - Velocity Profile Logs (not included in draft), and are summarized below in Table 5 - Production Velocity-Profile Testing Results.

Table 5. Production Velocity-Profile Testing Results

Screen Interval (ft bgs)	Thickness (ft)	Percent of Total Production		
		Step 1 1,410 gpm	Step 2 2,120 gpm	Step 3 2,830 gpm
540-600	60	0	2	0
600-650	50	17	15	17
670-720	50	9	9	6
720-770	50	74	74	77
Total	**210**	**100**	**100**	**100**

Review of the spinner-survey results indicates that the relative contributions from each zone did not change significantly as the pumping rate increased. As shown, the upper 60 feet of screen does not contribute significantly to total production. The middle two intervals combined contribute roughly 25 percent of the total production. The lower 50 feet of screen contributes most significantly, with approximately 75 percent of total production coming from this zone. These results compare favorably to a similar survey performed during injection testing at SMTIW No. 1 in 2001, which showed approximately 20 to 30 percent of the total injection volume being provided to the middle 60 feet of screen, and 60 to 70 percent of the volume being provided to the lower 70 feet of screen.

Aquifer Analysis

Drawdown and recovery data from the SMTIW No. 2 and the MW-1 and SMTIW No. 1 observation wells were analyzed to derive aquifer parameters of transmissivity and storativity.

Jacob's approximation (Cooper and Jacob, 1946) to the Theis non-equilibrium well equation (Theis, 1935) was used to derive aquifer parameters. The analyses of the drawdown and recovery data are presented on Plates 6 through 11. The results of the analyses are summarized below in Table 6 - Summary of Aquifer Parameter Estimates.

Table 6. Summary of Aquifer Parameter Estimates

Aquifer Parameter	Data Set						Average
	Drawdown			Recovery			
	SMTIW No. 2	MW-1	SMTIW No. 1	SMTIW No. 2	MW-1	SMTIW No. 1	
Transmissivity (gpd/ft)	125,111	148,280	142,984	142,984	148,280	148,280	**142, 653**
Storativity (dimensionless)	--	4.0×10^{-4}	1.9×10^{-4}	--	4.8×10^{-4}	4.6×10^{-4}	**3.8×10^{-4}**

As shown in Table 6, aquifer testing of the SMTIW No. 2 yielded transmissivity values ranging between approximately 125,000 and 148,000 gpd/ft, averaging approximately 142,650 gpd/ft (19,070 square feet per day [ft^2/d]). The storage coefficient derived from the monitor well data was estimated to be approximately 3.8×10^{-4} (dimensionless), indicative that groundwater conditions are confined. Utilizing a saturated thickness of 210 feet (i.e., total screen length), an average hydraulic conductivity value of the aquifer materials was calculated to be approximately 680 gpd/ft^2 (90.8 feet/day [ft/d]).

The transmissivity/hydraulic conductivity values are somewhat greater than those derived from testing of SMTIW No. 1 in 2001, which yielded values of approximately 104,000 gpd/ft and 63.4 ft/d for transmissivity and hydraulic conductivity, respectively; however, that test was limited to only 8 hours duration and did not include any monitor wells. The aquifer parameters derived from testing SMTIW No. 2 are generally consistent with those utilized in recent analytic modeling of ASR in the SGB (ASR Systems LLC, 2005). However, it should be noted that these values are an order of magnitude greater than those utilized in the recently prepared report, *Seaside Groundwater Basin: Update on Water Conditions* (Yates, et al, 2005), which utilized hydraulic conductivity values of 3 to 5 ft/d to estimate groundwater flow in the Santa Margarita aquifer.

Well Efficiency

Hydraulic efficiency is an important consideration for pumping wells, as inefficient wells create excessive drawdown and higher pumping lifts, which increase the power consumption and costs per unit of production. Well efficiency is defined as the ratio of the actual to the theoretical specific capacity, expressed as a percentage. The theoretical specific capacity is the specific capacity that would be observed if no additional hydraulic losses occur as water moves through the aquifer/well interface (i.e., well losses).

There are always some hydraulic well losses associated with water moving through the near-bore, invaded zone of the aquifer, gravel pack, and well screen openings. Therefore, in practice, a 100-percent efficient, gravel-envelope production well does not exist. These hydraulic losses can be minimized through proper well design (e.g., gravel pack and screen selection) and construction techniques (e.g., control of drilling-fluid properties and adequate well development). Typical well efficiencies for properly-designed and constructed, high-capacity production wells are in the range of 60 to 80 percent.

Utilizing the aquifer parameters derived from the testing of the SMTIW No. 2, the theoretical specific capacity can be determined from equations presented by Walton (1991). The result of the well-efficiency estimate is presented in Table 7 – Well-Efficiency Estimate.

Table 7. Well-Efficiency Estimate

24-hr Specific Capacity (gpm/ft)		Efficiency (%)
Actual	Theoretical	
44.6	69.3	64

As shown, the estimated efficiency of the SMTIW No. 2 is approximately 64 percent, which is considered to be at the low end of typical values, suggesting that additional development pumping could potentially increase the hydraulic efficiency of the well (recall that development pumping was terminated before the well performance had stabilized, due to budgetary considerations).

Well Production Capacity

Recovery Pumping Capacity. The long-term production capacity of a well is a function of the well's specific capacity and the available drawdown in the well for pumping. While this relationship seems relatively straightforward, it is complicated by the fact that both factors vary with the duration of pumping. While no strict guidelines exist for determining the recommended long-term pumping rate values, a typical 'rule of thumb' for estimating the long-term production rate of a well is to multiply the 24-hour specific capacity by two-thirds of the available drawdown. Utilizing two-thirds of the available drawdown is a conservative way to account for variations in pumping durations, seasonal changes (long-term or short-term) in aquifer water levels, and gradual losses in well efficiency that may occur over the life cycle of the well.

The best operational practice for pumping wells is to maintain pumping water levels above the perforations in order to avoid cascading water conditions, which can result in air entrainment, customer acceptance issues, and increased wear on the pump and discharge piping. The available drawdown in the well is, therefore, typically defined to be the amount of water above the top of the perforations.

The total available drawdown in the SMTIW No. 2 is approximately 170 feet, based on the top of perforations at 540 feet and a static water level of approximately 370 feet. As presented previously, the SMTIW No. 2 displays a 24-hour specific capacity of 44.6 gpm/ft. Two-thirds of the available drawdown of 170 feet is approximately 113 feet, which yields a theoretical long-term production/recovery capacity estimate for the SMTIW No. 2 of approximately 5,040 gpm. This theoretical capacity far exceeds the design capacity of 3,000 gpm; therefore, while the well is not as hydraulically efficient as may be possible, it is nonetheless quite capable of meeting the project objectives.

Backflush Pumping Capacity. No source of injection water is completely free of particulates; therefore, backflushing (i.e., pumping) of injection wells is routinely performed to create flow reversals in the well, which removes particles introduced into the well during injection (this is analogous to backwashing of media filters to affect particulate removal). Periodic, vigorous backflushing is absolutely necessary to maintain injection capacity and remove the particulate loading of the gravel pack and well bore. The ability to adequately backflush ASR wells while maintaining a flooded perforated section, therefore, is a critically important consideration when designing and operating injection well facilities.

Based on experience at other injection wells, it has been shown that it is desirable to backflush injection wells at rates twice the rate of injection in order to maximize backflushing effectiveness. This is done in order to create pore throat velocities that are sufficient to remove particulates introduced during injection that have filled pore spaces and cling to grains of sand. This criterion is considered to be the most conservative and important for maintaining long-term injection performance, and has, therefore, been adopted as the limiting backflushing criteria utilized for this project. The design recharge rate for SMTIW No. 2 is approximately 1,500 gpm, corresponding to the design pumping capacity of 3,000 gpm (minimum).

Backflush pumping is typically a short-duration operation of one to two hours; therefore, estimating the backflushing capacity by multiplying the 24-hour specific capacity by the entire available drawdown is a conservative way to account for variations in aquifer water levels and gradual losses in well efficiency that may occur over the life cycle of the well.

As noted above, the total available drawdown in the SMTIW No. 2 is approximately 170 feet, and the well displays a 24-hour specific capacity of 44.6 gpm/ft, which yields a theoretical backflushing capacity estimate of approximately 7,580 gpm. Again, this theoretical capacity far exceeds the minimum design capacity of 3,000 gpm.

In summary, the SMTIW No. 2 is theoretically capable of instantaneous production rates ranging between approximately 5,000 and 7,500 gpm, depending on the pumping scenario. However, the actual pumping capacity will be constrained by other factors, such as the available electrical power, discharge-pipe sizing and friction losses, and the installed permanent pump capacity, rather than the production capacity of the aquifer or the well itself.

Water Quality

During testing, a variety of both field and laboratory water-quality data was collected. At the end of the 24-hour, constant-rate, production test, samples of the produced water were collected and transported to State Certified Laboratory (MBAS in Monterey) for a variety of drinking-water constituents as well as other inorganic compounds pertinent to geochemical-stability analysis. In addition, field water-quality parameters were measured periodically during production testing. Pertinent water-quality data are summarized in Table 8. Complete analytic results are included in Appendix E – Water-Quality Data (not included in draft).

Table 8. Water-Quality Summary

Constituent	State MCL (mg/l)	Results (mg/l*)	
		Lab	Field (range)
TDS	1,000	647	n/a
EC (umhos/cm)	1,600	1035	1102 to 1146
pH	n/a	7.1	6.9 to 7.1
Ca	n/a	92	n/a
Cl	500	131	n/a
Alk	n/a	225	n/a
Na	n/a	86	n/a
SO_4	500	107	n/a
Fe	0.3	ND	n/a
Mn	0.05	ND	n/a
NO_3 (as $N0^3$)	45	0.9	n/a
S^{2-}	n/a	0.304	0.36 to 0.46
ORP (mV)	n/a	n/a	-96 to -135
TOC	n/a	0.68	n/a
Iodide	n/a	0.028	n/a
TTHM	0.080	0.0061	n/a
HAAs	0.060	ND	n/a
Total Coliform	Absent	Absent	n/a

Notes: * - unless otherwise noted
ND – Not Detected
n/a - no standard or not applicable
Values in **BOLD** type exceed State Water Quality Standards

Water quality met all State Title 22, primary drinking-water standards; however, the presence of sulfide ion at approximately 0.3 to 0.4 mg/l demerit the water with respect to secondary (aesthetic) standards. In addition, the presence of low levels of total trihalomethanes suggest that some portion of the produced water from SMTIW No. 2 included Carmel River system water recharged into the aquifer via SMTIW No. 1 in previous years. In summary, the water is considered typical for the Santa Margarita Sandstone aquifer in the SGB, displaying a moderate salinity, neutral pH, reduced ORP, and low levels of sulfide.

Disinfection

Following completion of the 24-hour pumping test, the well was disinfected on March 27, 2007. The general disinfection procedure consisted of introducing approximately twenty gallons of sodium hypochlorite (12.5 percent available chlorine) into the well, equivalent to a concentration of approximately 240 ppm available chlorine in the well. The solution was then agitated within the well by surging with the pump, and then allowed to remain in the well for a period of approximately 24 hours. The produced water was tested for both Total and E. coli Coliform at the end of the 24-hour pumping test, and the test result was negative; therefore, additional sampling and analysis following disinfection were not conducted. Additional sampling for Coliform will, however, be required following permanent pump installation and prior to placing the well into service.

Cellar Assessment and Repair

Following removal of the test pump, the fill level in the bottom of the well was sounded at a depth of approximately 766 feet bgs, indicated approximately 20 feet of material had accumulated in the well. Bailing and removal of fill material from the well was initiated on April 4, 2007, and a total of approximately 22 ft^3 of material was removed, consisting of coarse aquifer sands and gravels, as well as significant amounts of gravel-pack material. Some of the aquifer gravels were as large as approximately 1- to 2-inches in diameter. The size of the grains removed indicated that an enlarged opening existed in the well allowing this material to enter (i.e., the grains were much larger than the screen slot openings). The fill was tagged at approximately 776 feet, indicating approximately 10 vertical feet had been cleared, which is consistent with the volume of material removed that day.

Bailing resumed on April 5, 2007. An additional approximately 15 ft^3 was removed from the well and the fill level was lowered to approximately 781 feet bgs. At this point, the Contractor did not want to perform additional bailing due to concerns about destabilizing the well and/or external sediments and possibly causing additional damage to the well.

A downhole video survey was subsequently performed on April 10, 2007, to assess the condition of the well. The clarity of the video was good, and satisfactorily verified the as-built construction and condition of the well. The video survey is provided in DVD format in Appendix F – Video Survey (not included in draft). The results of the survey did not reveal any damage to the casing or screen above the fill level, which was confirmed to be at a depth of approximately 781 feet bgs.

A final repair plan was developed through discussions between the contractor, PWR, and the District, which consisted of 'swaging' an approximate 18-inch diameter, ½-inch thick, stainless steel plate into the bottom at the fill level, followed by the emplacement of 7 vertical feet (minimum) of concrete to form a stable plug in the bottom of the well.

The steel plate was swaged in place at a depth of approximately 781 feet on April 23, 2007. Approximately 15 ft^3 of 10-sack sand slurry concrete was subsequently emplaced on May 2, 2007, via tremie pipe and positive displacement pumping. Following emplacement of the concrete plug, the bottom was sounded on May 3, 2007, at a depth of approximately 771 feet bgs, indicating that approximately 10 linear feet of plug material had been emplaced.

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

General Statement

Santa Margarita Test Injection Well No. 2 (SMTIW No. 2) was constructed during the winter/spring of 2007. The well is completed to a total depth of approximately 790 feet in the Santa Margarita Sandstone aquifer in the Seaside Groundwater Basin (SGB). The well was designed to be utilized as a dual-purpose injection/extraction (a.k.a. Aquifer Storage and Recovery [ASR]) well for purposes of artificially recharging the groundwater basin with 'excess' Carmel River system water supplies when available.

Well Performance and Capacity

The well displays an extraction specific capacity of approximately 44.6 gpm/ft (as measured after 24 hours), which is higher than most other wells in the SGB (exceeded only by SMTIW No. 1 when it was newly constructed). The well efficiency is within, but at the low end of, typical values. However, the well has a theoretical long-term pumping capacity of approximately 5,000 gpm, which exceeds the minimum design recovery pumping capacity of 3,000 gpm. Given the pumping capacity, the well is anticipated to be capable of recharge rates in excess of the design capacity of 1,500 gpm[3] and meeting the Phase 1 ASR Project objectives.

Water Quality

Water quality meets State Title 22, primary drinking-water standards; however, as is typical for the Santa Margarita aquifer in the SGB, it is demerited by elevated levels of sulfide ion, a secondary (aesthetic) standard.

RECOMMENDATIONS

Based on the production testing results and our experience with similar projects, we offer the following recommendations:

- For planning purposes, a long-term operational pumping capacity of approximately 3,000 to 5,000 gpm is recommended.

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3 Testing for ASR operational capabilities was not performed as part of this project, but is planned for the future.

- The District should conduct recharge testing of the SMTIW No. 2 during the upcoming Water Year 2008 recharge season. This testing should include simultaneous recharge operations with SMTIW No. 1 in order to determine interference effects and general operational parameters for the Phase 1 ASR Project site.
- A downhole velocity survey should be conducted during injection operations for comparison with the production survey and the injection survey conducted on SMTIW No. 1.
- Future ASR testing at the site should include comprehensive water-quality sampling and analysis of MW-1 to investigate water-quality changes, in particular disinfection byproduct degradation, that may be occurring in the subsurface at distances away from the ASR wells.
- Geochemical interaction modeling, consisting of 3-component reactivity analyses between various potential injection source waters (e.g., derived from Carmel River system, CWP desalination, and/or Marina Coast Water District), the native groundwater, and the aquifer minerals, should be performed utilizing the baseline water quality and mineralogical data developed from this project.

CLOSURE

This report has been prepared exclusively for the Monterey Peninsula Water Management District for the specific application to the District's Santa Margarita Test Injection Well No. 2. The findings, conclusions, and recommendations presented herein were prepared in accordance with generally accepted hydrogeologic and civil engineering practices. No other warranty, express or implied, is made.

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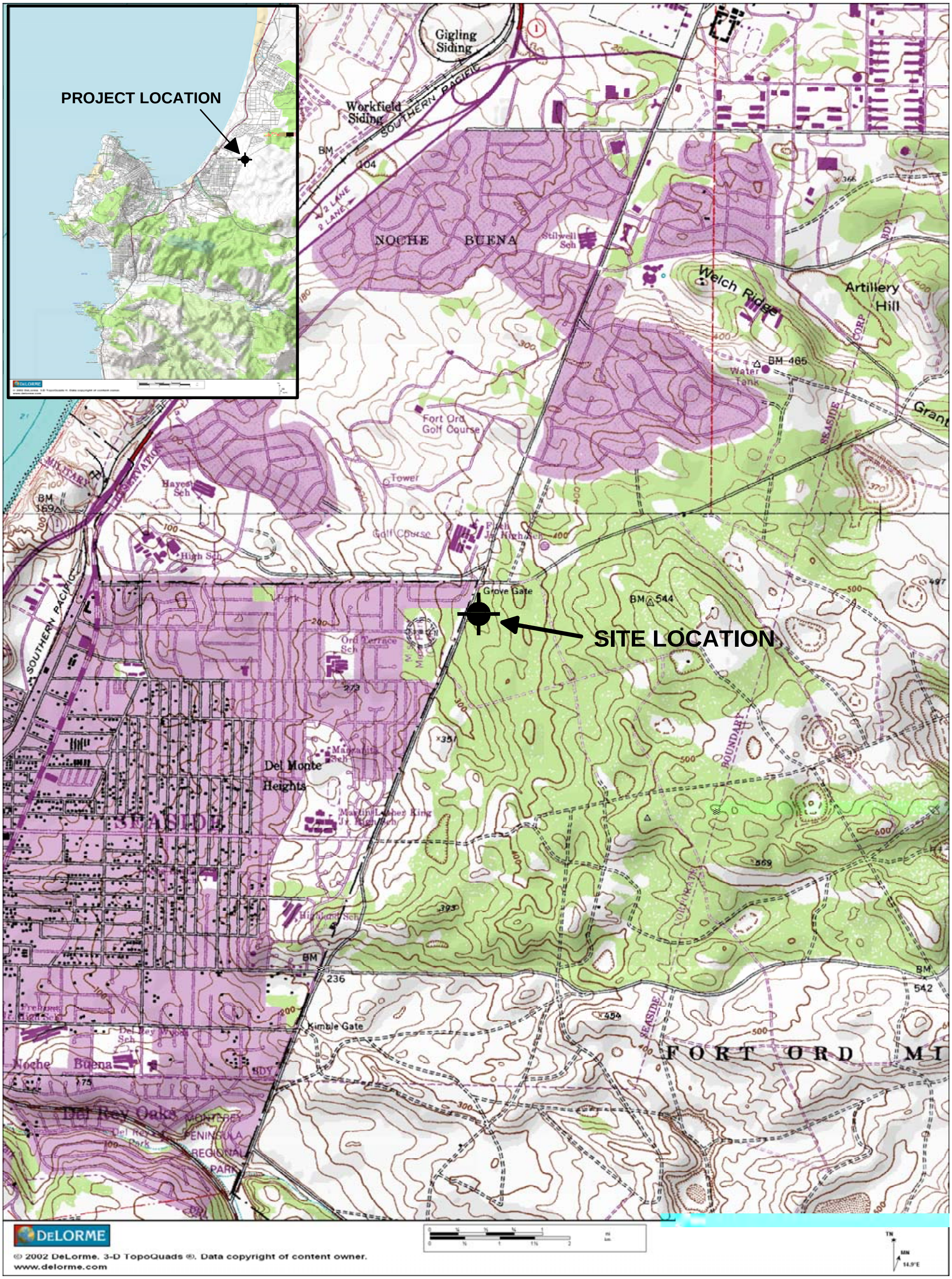
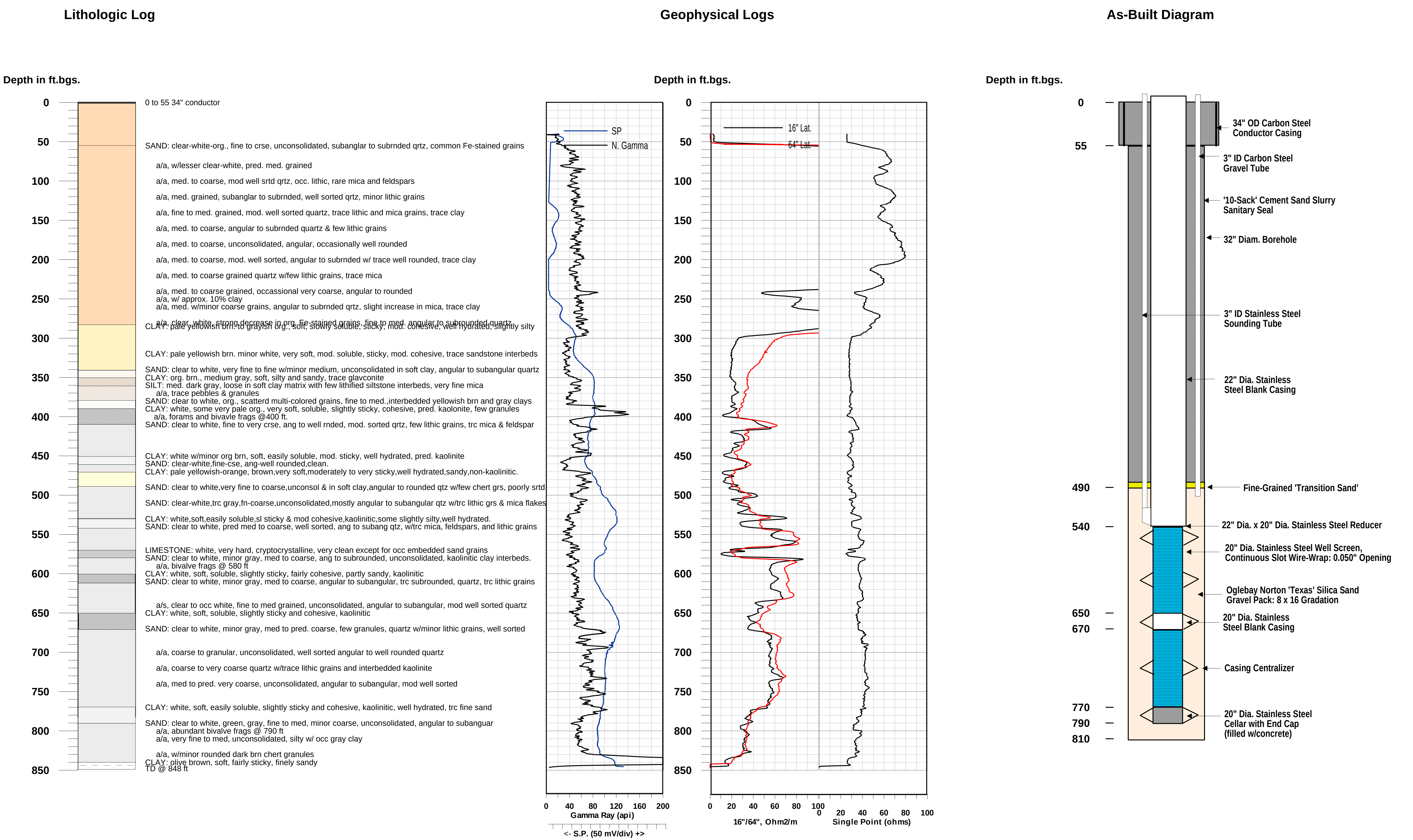
PLATES



PUEBLO water resources

SITE LOCATION MAP
PLATE 1

August 2007
Project No. 06-0021

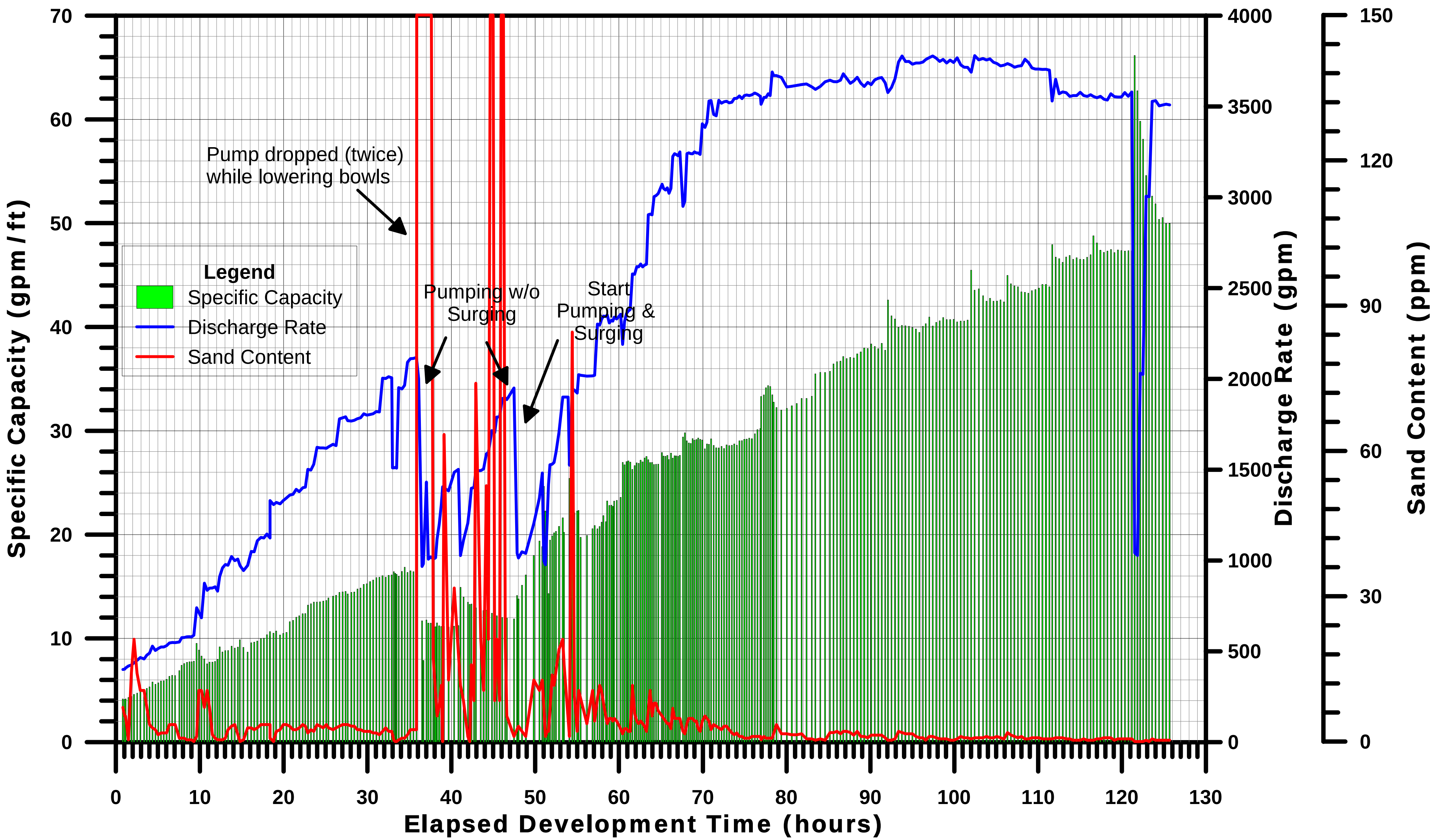


PUEBLO
water resources

MPWMD - Phase 1 ASR Project

SMTIW NO. 2
GRAPHIC LOGS AND AS-BUILT COMPLETION
PLATE 2

August 2007
Project No. 06-0021

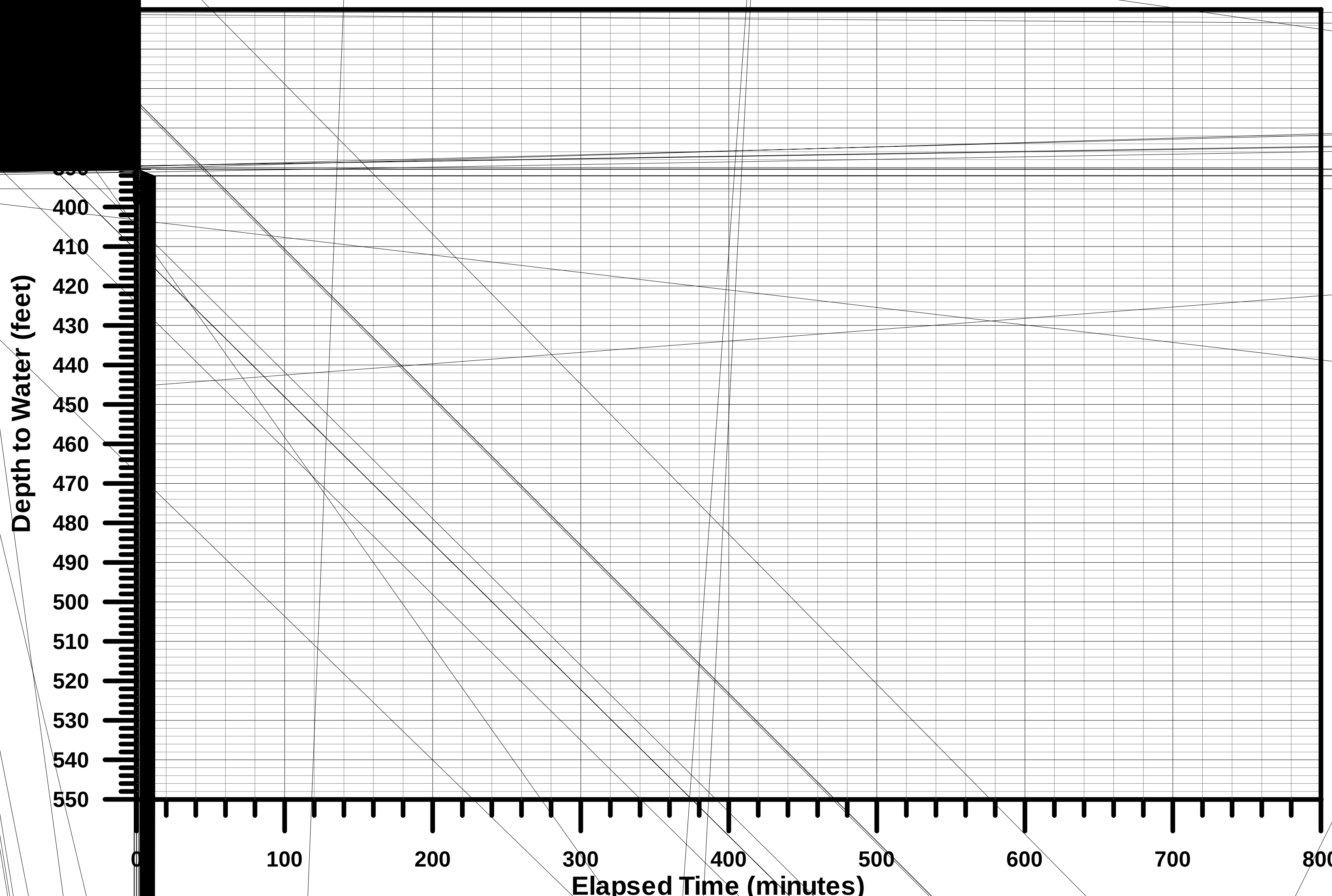


PUEBLO water resources

MPWMD - Phase 1 ASR Project

SMTIW NO. 2
WELL DEVELOPMENT DATA
PLATE 3

August 2007
Project No. 06-0[redacted]1



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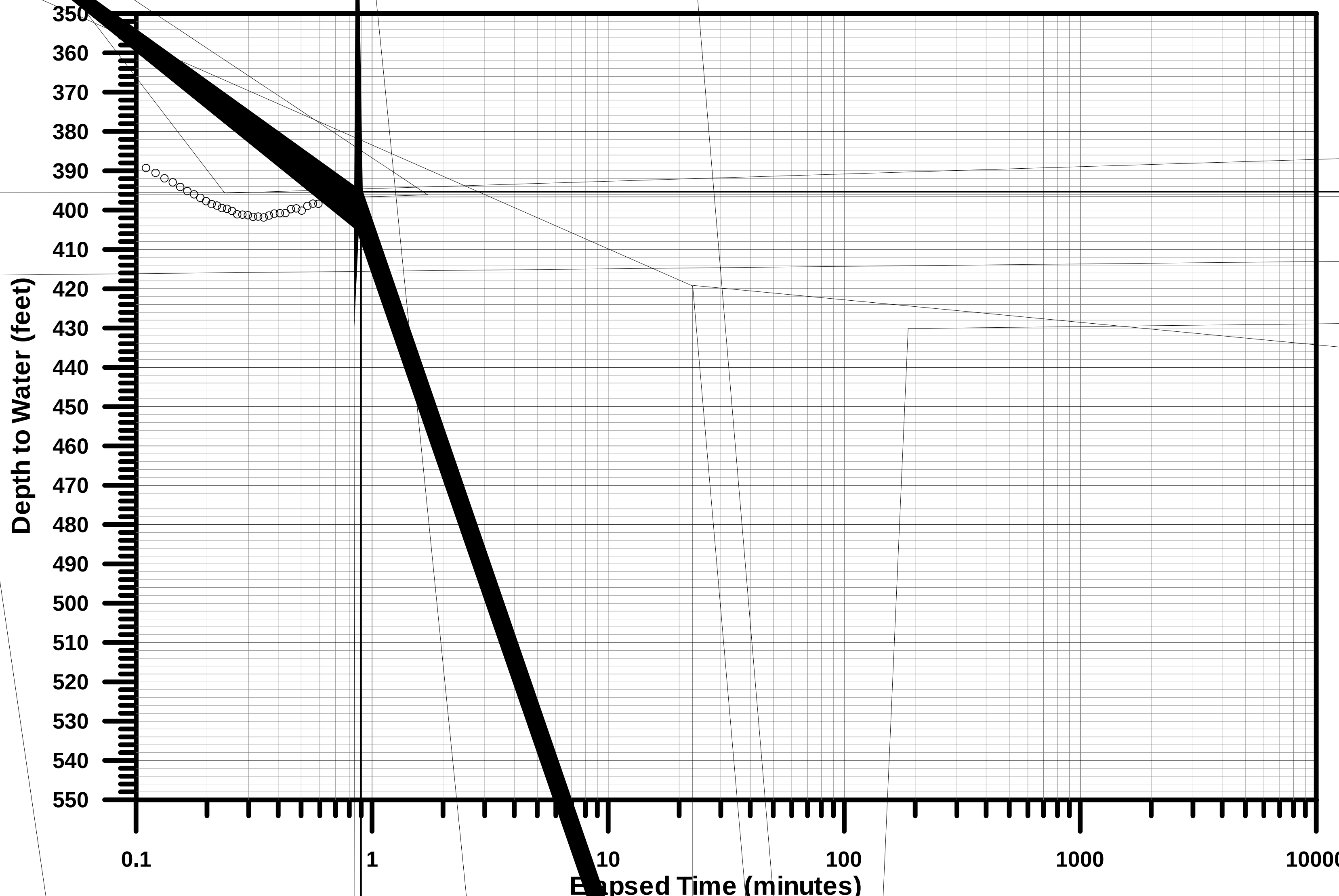

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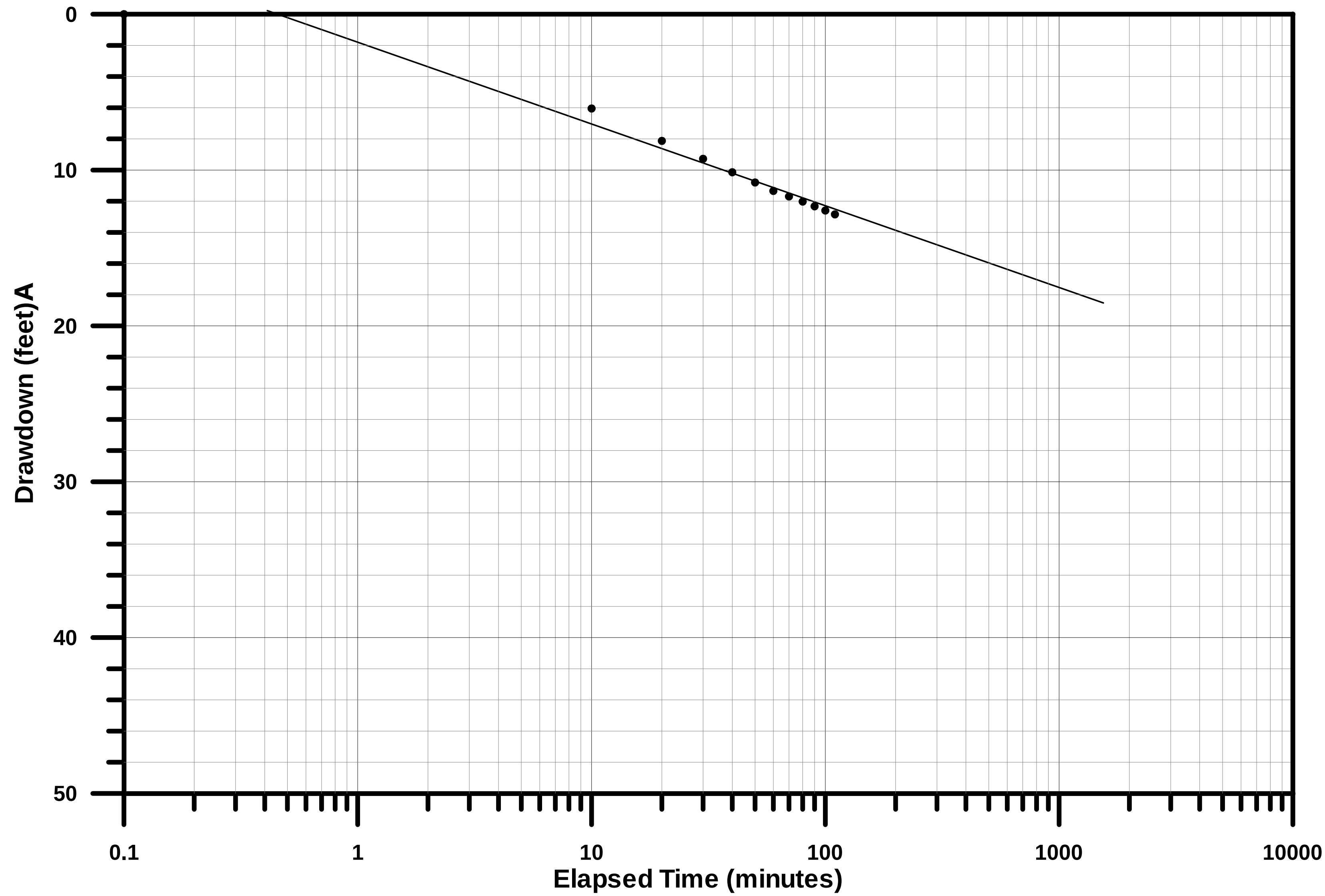

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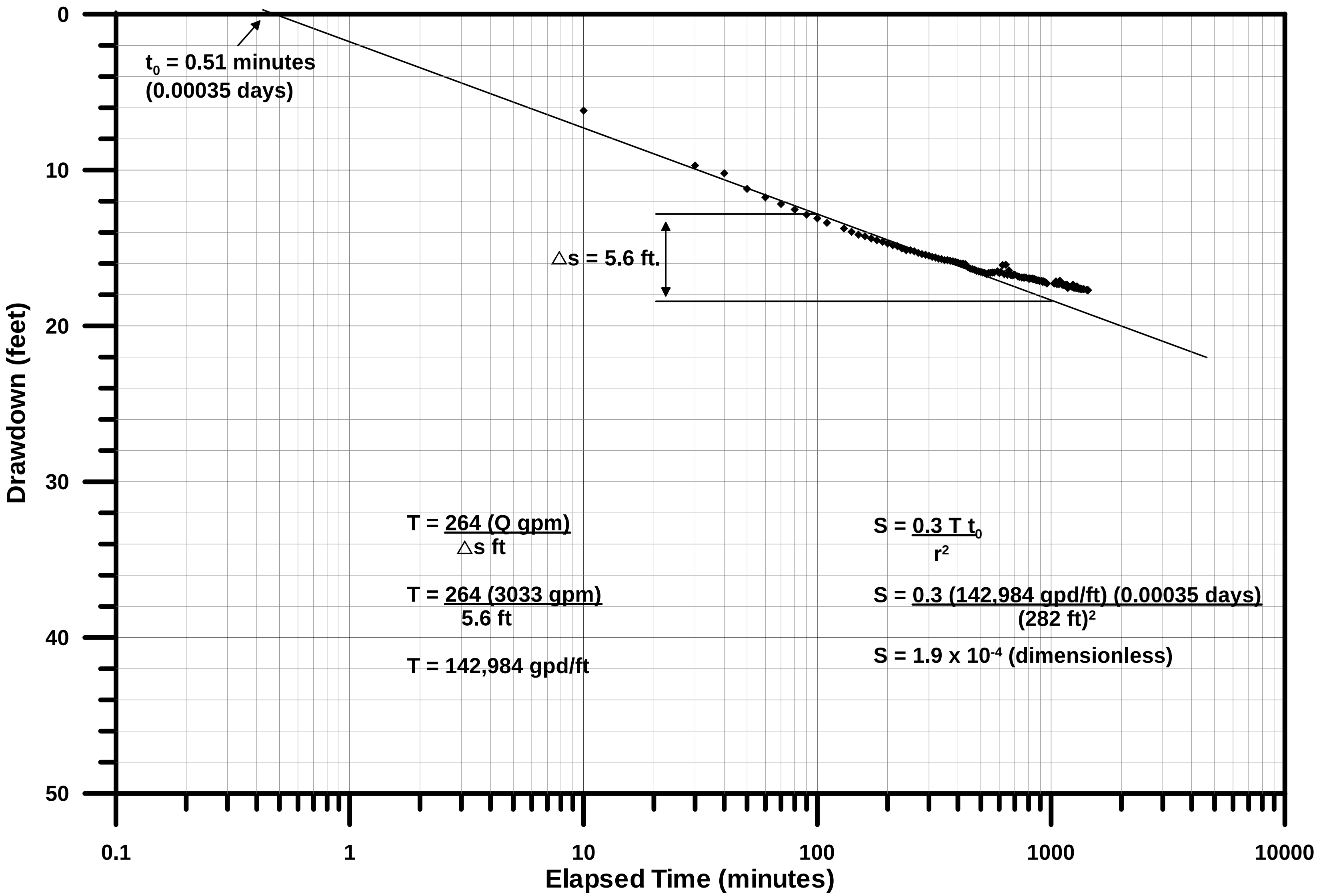

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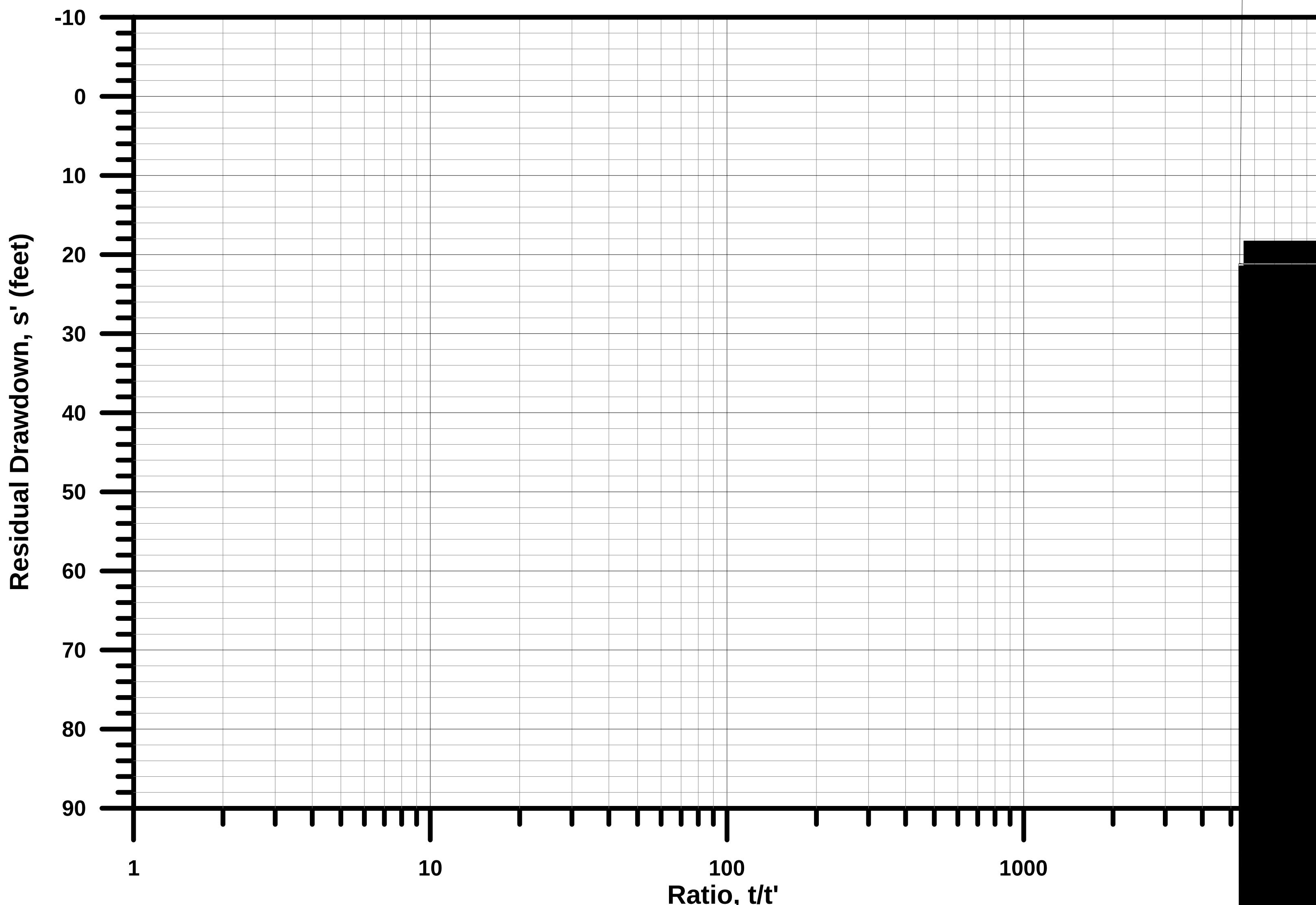
MPWMD - Phase 1 ASR Project

SMTIW NO. 2
24-HOUR CONSTANT RATE PRODUCTION TEST, SMTIW NO. 1 DATA
PLATE 8



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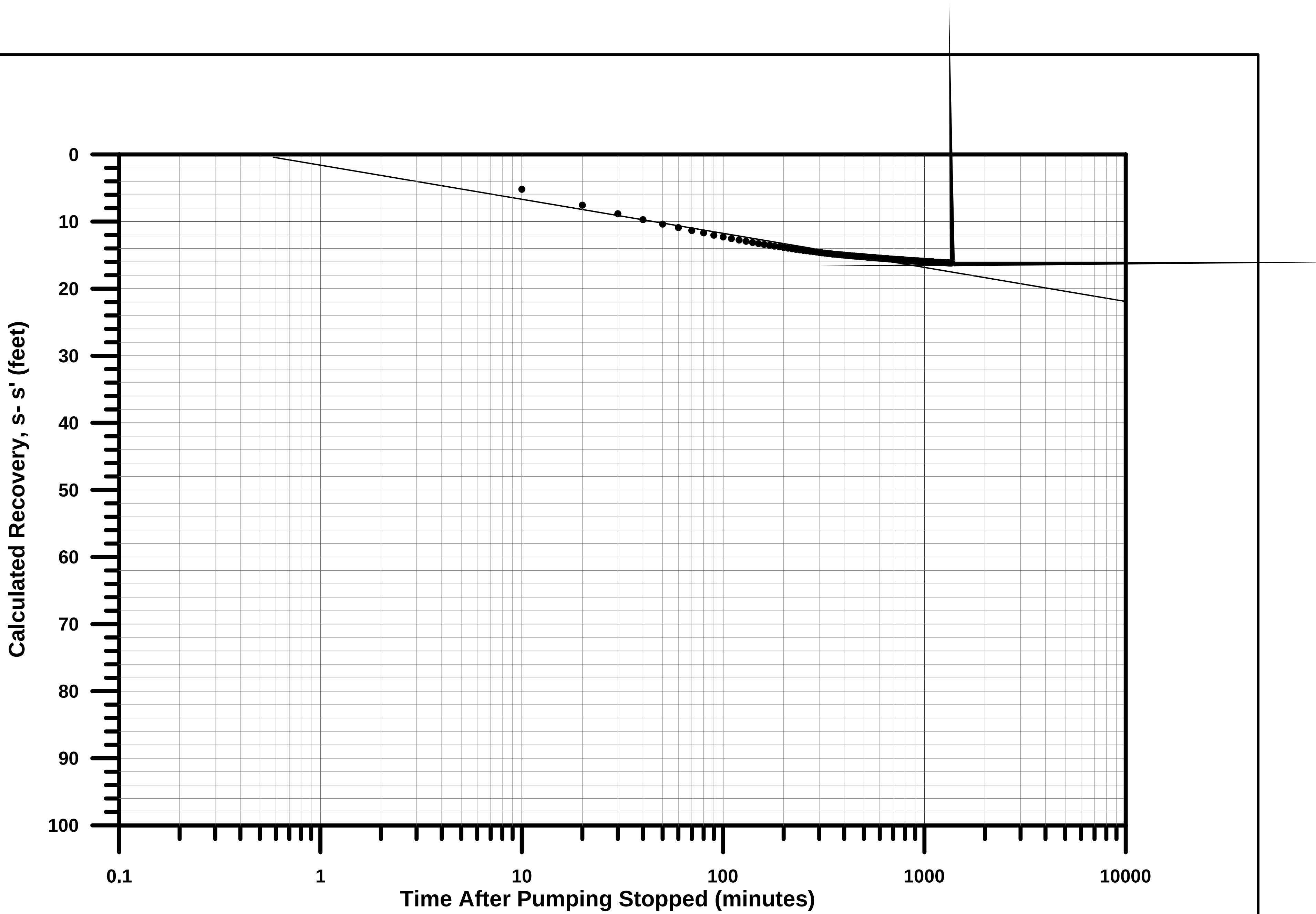

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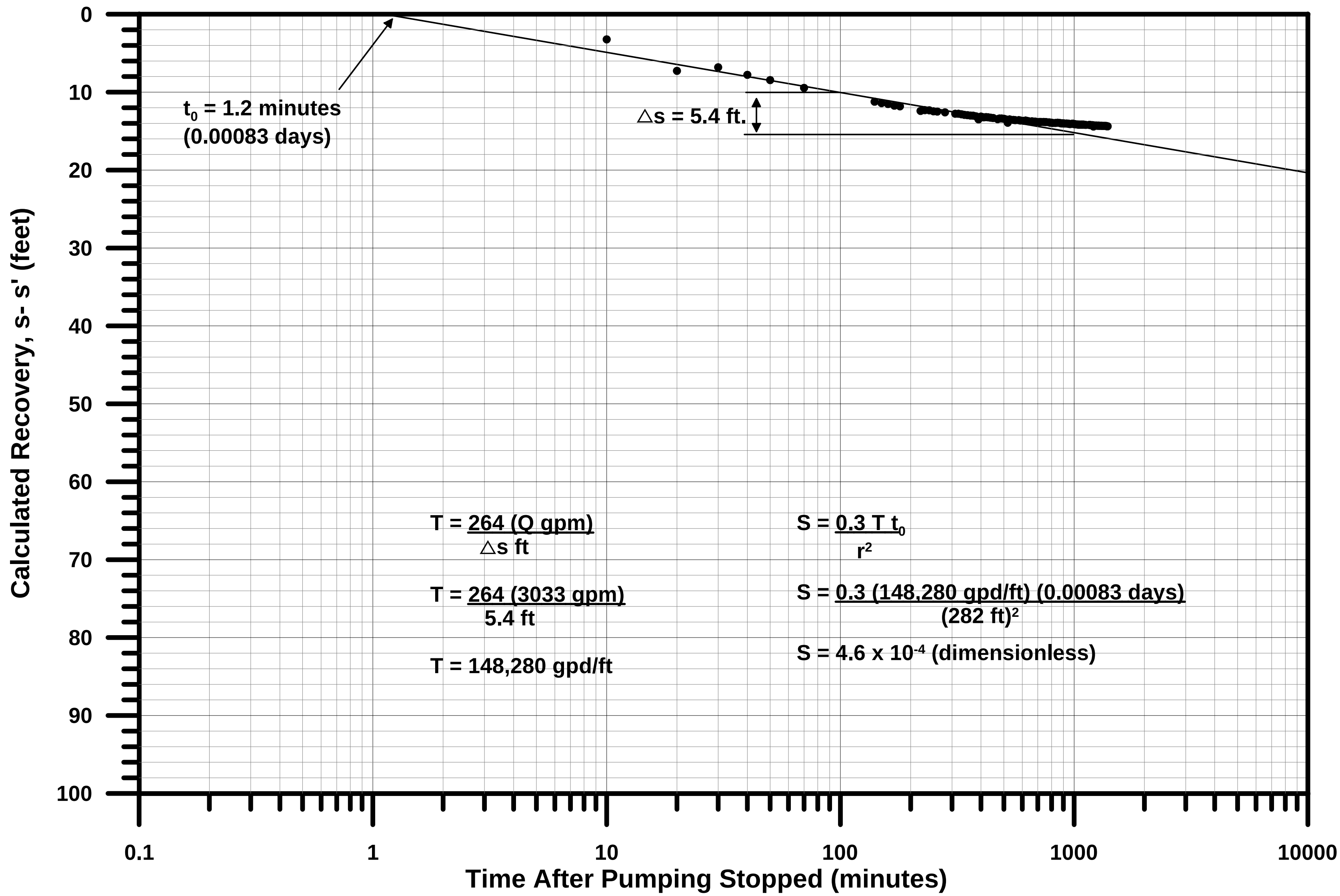

PUEBLO water resources

MPWMD - Phase 1 ASR Project

SMTIW NO. 2

24-HOUR CONSTANT RATE PRODUCTION TEST - RECOVERY, SMTIW NO. 1 DATA

PLATE 11

APPENDIX A
MINERALOGY ANALYTIC RESULTS
(not included in draft)

APPENDIX B
LITHOLOGIC AND GEOPHYSICAL LOGS
(not included in draft)

APPENDIX C
WELL TESTING DATA AND FIELD DOCUMENTATION
(not included in draft)

APPENDIX D
VELOCITY PROFILE LOGS
(not included in draft)

APPENDIX E
WATER QUALITY DATA
(not included in draft)

APPENDIX F
VIDEO SURVEY
(not included in draft)