**EXHIBIT 8-A**

# SUMMARY OF OPERATIONS

# MONTEREY PENINSULA
# ASR PROJECT

# WATER YEAR 2017

Prepared for:

Monterey Peninsula Water Management District

JUNE 2018
**DRAFT**

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**EXHIBIT 8-A**

PUEBLO
water resources

June 30, 2018
Project No. 12-0049

Monterey Peninsula Water Management District
Post Office Box 85
Monterey, California 93942-0085

Attention: Mr. Jonathan Lear, Senior Hydrogeologist

Subject: Monterey Peninsula ASR Project; Draft Water Year 2017 Summary of Operations Report

Dear Jon:

We are transmitting one digital image (PDF) of the subject draft report documenting operations of the Monterey Peninsula ASR Project during Water Year 2017 (WY 2017) for your review and comments. WY 2017 was classified as an "Extremely Wet" Water Year on the on the Monterey Peninsula, and as a result a commensurately significant volume of water totaling 2,345 acre-feet (af) was able to be diverted from the Carmel River system for recharge in the Seaside Groundwater Basin (SGB) via the ASR-1 through ASR-4 wells. To date, a total volume of approximately 7,430 of excess Carmel River system water has been successfully injected, stored, and recovered in the SBG since the ASR project was initiated in 2001.

We appreciate the opportunity to provide ongoing assistance to the District on this important community water-supply project. Please contact us with any questions.

Sincerely,

PUEBLO WATER RESOURCES, INC.

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

Stephen P. Tanner, P.E.
Principal Engineer

Copies submitted: 1 digital (PDF)

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# INTRODUCTION

## GENERAL STATEMENT

Presented in this report is a summary of operations of the Monterey Peninsula Aquifer Storage and Recovery (ASR) Project during Water Year 2017 (WY 2017)[1]. During WY 2017, approximately 2,345 acre-feet (af) of excess flows were diverted from the Carmel River system for recharge, storage, and subsequent recovery in the Seaside Groundwater Basin (SGB). This report presents a summary of the project operations during WY 2017, an assessment of ASR well performance, aquifer response and water-quality data, and provides recommendations for ongoing operation of the project.

## BACKGROUND

The Monterey Peninsula ASR Project is cooperatively implemented by the Monterey Peninsula Water Management District (MPWMD or District) and California American Water (CAW) and involves the diversion of excess winter and spring time flows from the Carmel River system for recharge and storage in the Seaside Groundwater Basin (SGB). The excess water is captured by CAW wells in the Carmel Valley during periods when flows in the Carmel River exceed fisheries bypass flow requirements, treated to potable drinking water standards, and then conveyed through CAW's distribution system to ASR facilities in the SGB.

Aquifer recharge is accomplished via injection of these excess flows into specially designed ASR wells drilled in the SGB. The locations of the ASR wells and associated project monitoring wells in the SGB are shown on **Figure 1**. The recharged water is temporarily stored underground utilizing the available storage space within the aquifer system. During periods of high demand, other existing CAW production wells in the SGB and/or the ASR wells can be used to recover the previously recharged water, which in turn allows for reduced extractions from the Carmel River system during seasonal dry periods.

The District and CAW have been cooperatively developing an ASR project on the Monterey Peninsula since 1996. These efforts have evolved over time, from the performance of various technical feasibility investigations, leading to the construction and testing of pilot- and then full-scale ASR test wells to demonstrate the viability and operational parameters for ASR wells in the SGB. Based on the success of the ASR demonstration testing program, MPWMD and CAW are in the process of implementing a full-scale permanent ASR Project.

The Phase 1 ASR Project (a.k.a. Water Project 1) includes two ASR wells (ASR-1 and ASR-2) located at the Santa Margarita (SM) ASR Facility at 1910 General Jim Moore Blvd. in Seaside. The Phase 1 Project is capable of recharging up to the State Water Resources Control

[1] Water Year 2017 is the period of October 1, 2016 through September 30, 2017.

Board (SWRCB) water right[2] maximum annual diversion limit of 2,426 acre-feet per year (afy) at a combined permitted injection rate of approximately 3,000 gallons per minute ([gpm] maximum diversion rate of 6.7 cubic feet per second [cfs]), with an average annual yield of approximately 920 afy. ASR-1 is designed for an injection capacity of 1,000 gpm and ASR-2 is designed for an injection capacity of 1,500 gpm. As-built schematics of ASR-1 and ASR-2 are presented on **Figures 2 and 3**, respectively.

The Phase 2 ASR Project (a.k.a. Water Project 2) also includes two ASR wells (ASR-3 and ASR-4) located at the Seaside Middle School (SMS) ASR Facility at 2111 General Jim Moore Blvd. in Seaside. The Phase 2 Project is designed to be capable of recharging up to the SWRCB water right[3] maximum annual diversion limit of 2,900 afy at a combined permitted injection rate of approximately 3,600 gpm (maximum diversion rate of 8.0 cfs), with an average annual yield of approximately 1,000 afy. ASR-3 and ASR-4 are both designed for injection capacities of 1,500 gpm. As-built schematics of ASR-3 and ASR-4 are presented on **Figures 4 and 5**, respectively.

A graphical summary of historical ASR operations in the SGB is shown on **Figure 6**. Shown are the annual injection and recovery volumes since the inception of injection operations at the Santa Margarita ASR Facility in WY 2001 through the current period of WY 2017. Also presented is a delineation of the various phases of project implementation, starting with the Santa Margarita Test Injection Well (SMTIW) in 2001, which became ASR-1 as the project transitioned from a testing program to a permanent project in WY 2008 (Phase 1 ASR Project), through construction and operation of the second well (ASR-2) at the facility in 2010. As shown, having the Santa Margarita Facility in full operation with both ASR-1 and ASR-2 injecting simultaneously in WY 2010 and WY 2011 (combined with above normal rainfall and Carmel River flows during those years) resulted in significant increases in the annual volume injected. During WY 2012 through WY 2015, relatively low volumes were injected due to the extended drought conditions during that period.

WY 2017 was the first year of above normal rainfall and Carmel River flows with all four ASR wells in full operation, and as shown on **Figure 6** over 2,300 af of excess river flows were captured and successfully injected into the SGB. This volume represents over twice the previous largest annual volumes injected (in WY 2010 and WY 2012), and approximately one quarter of the Monterey Peninsula's average annual water supply. Commensurate annual injection volumes are expected to occur in the future (depending on hydrologic conditions in any given year) as the project continues to operate at full capacity.

## PURPOSE AND SCOPE

The overall purpose of the ongoing ASR program is to recharge the SGB with excess treated Carmel River system water when it is available during wet periods for storage and later

[2] SWRCB water right 20808A for the Phase 1 ASR Project is held jointly by MPWMD and CAW.
[3] The SWRCB water right 20808C for the Phase 2 ASR Project is held jointly by MPWMD and CAW.

extraction (recovery) during dry periods. ASR benefits the resources of both systems by raising water levels in the SGB during the recharge and storage periods and reducing extractions from the Carmel River System during dry periods.

The scope of the ongoing data collection, analysis, and reporting program for the ASR program can be categorized into issues generally associated with:

1) ASR well hydraulics and performance;
2) Aquifer response to injection, and;
3) Water-quality issues associated with geochemical interaction and mixing of injected and native groundwaters.

The ongoing data collection and reporting program is intended to monitor and track ASR well performance and aquifer response to injection (both hydraulic and water quality) and to comply with the requirements of the Central Coast Regional Water Quality Control Board (RWQCB) for submitting annual technical reports for the project pursuant to Section 13267 of the California Water Code[4] and the existing General Waiver for Specific Types of Discharges (Resolution R3-2008-0010).

## FINDINGS

## WY 2017 ASR OPERATIONS

### General Recharge Procedures

Recharge of the SGB occurs via injection of diverted flows from the CAW distribution system into ASR wells during periods of available excess Carmel River system flows. The ASR recharge source water is potable (treated) water provided from the CAW distribution system. The water is currently diverted by various production well sources in Carmel Valley and (after treatment and disinfection to potable standards) then conveyed through the Segunda-Crest pipeline network to the ASR Pipeline in General Jim Moore Blvd and then to the Santa Margarita and Seaside Middle School ASR facilities.

Injection water is introduced into the ASR wells via the pump columns. Injection rates are controlled primarily by downhole flow control valves (FCV's) installed on the pump columns, and secondarily by modulating the automatic flow control valves (i.e., Cla-Vals) installed on the ASR wellhead piping. Injection flow rates and total injected volumes are measured with rate and totalizing meters at each of the wellheads. Positive gauge pressures are maintained at the wellheads during injection to prevent cascading of water into the wells (which can lead to air-binding). Continuous water-level data at each of the ASR wells are collected with submersible pressure transducer data loggers.

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[4] Letter from Roger W. Briggs, Executive Officer of the Central Coast RWQCB, to Joseph Oliver, Water Resources Manager for MPWMD, dated April 29, 2009.

Injection generally occurs at each of the ASR wells on a continuous basis when flows are available, interrupted only for periodic backflushing, which typically occurs on an approximate weekly basis. Most sources of injection water contain trace amounts of solids that slowly accumulate in the pore spaces in the well's gravel pack and adjacent aquifer materials, and the CAW source water is no exception. Periodic backflushing of the ASR wells is therefore necessary to maintain well performance by removing materials deposited/accumulated around the well bore during injection. The procedure is similar to backwashing a media filter to remove accumulated material deposited during filtration.

The trigger for backflushing is when the amount of water-level drawup during injection equals the available drawdown (as measured from the static water level to the top of the pump bowls) in the well for backflushing, or one week of continuous injection, whichever occurs first. This helps to avoid over-pressurization and compression of plugging materials, thereby maximizing the efficiency of backflushing and limiting the amount of residual plugging. This factor is the basis for the maximum recommended drawup levels referenced in the following section.

The general procedure consists of temporarily stopping injection and then pumping the wells at rates of approximately 2,000 to 3,000 gpm (i.e., at least twice the rate of injection) for a period of approximately 15 to 20 minutes, and repeated as necessary to effectively remove particulates from the well screen / gravel pack / aquifer matrix. Backflush water is discharged to the Santa Margarita ASR Facility backflush pit, where it percolates back into the groundwater basin.

**Injection Operations Summary**

A summary of injection operations at the four ASR wells is presented in **Table 1** below. Field data collected during injection operations are presented in **Appendix A** (not included in draft).

**Table 1. WY 2017 Injection Operations Summary**

| Well | Injection Season | | Active | Injection Rate (gpm) | | | Total Vol |
|---|---|---|---|---|---|---|---|
| | Start | End | Days | Min | Max | Avg | (af) |
| ASR-1 | 12/20/16 | 5/31/17 | 93 | 270 | 1,868 | 1,434 | 543.0 |
| ASR-2 | 12/17/16 | 5/30/17 | 155 | 337 | 1,944 | 1,449 | 981.6 |
| ASR-3 | 12/17/16 | 5/22/17 | 134 | 600 | 1,405 | 996 | 577.9 |
| ASR-4 | 4/5/17 | 5/19/17 | 45 | 142 | 1,590 | 1,257 | 242.9 |
| | | | | | | **Total** | **2345.4** |

As shown in **Table 1**, recharge operations were performed nearly continuously in WY 2017 during the period December 17, 2016 through May 31, 2017. WY 2017 was classified as an “Extremely Wet” Water Year[5] on the Carmel River with up to 155 days of active injection and a total volume of approximately 2,345 acre-feet (af) of water was available for diversion from the CAW system for recharge in the SGB. The recharge water was injected at all four ASR wells into the Santa Margarita Sandstone aquifer with per-well average injection rates ranging from approximately 140 to 1,950 gpm (approximately 0.62 to 8.6 acre-feet per day [afd]).

It is noted that the variability in injection rates at the ASR wells during the injection season is controlled by various factors, including the number of active sources to the CAW system, customer demands on the CAW system, and the ability of CAW’s distribution system to maintain piping pressure at the ASR wellheads.

Water-level data collected at ASR-1 through ASR-4 during WY 2017 are presented in **Figures 7 through 10**, respectively, and briefly summarized below:

- ASR-1: The minimum injection water-level was approximately 250 feet below ground surface (bgs) on a relatively consistent basis during the injection season, corresponding to a maximum water-level drawup of approximately 110 feet, which exceeded the maximum recommended drawup level of approximately 100 by 10 feet.

- ASR-2: The minimum injection water-level was approximately 220 feet bgs on a relatively consistent basis during the injection season, corresponding to a maximum water-level drawup of approximately 160 feet, which exceeded the maximum recommended drawup level of approximately 130 by 30 feet.

- ASR-3: The minimum injection water-level was approximately 170 feet bgs on a relatively consistent basis during the injection season, corresponding to a maximum water-level drawup of approximately 190 feet, which exceeded the maximum recommended drawup level of approximately 170 feet by 20 feet.

- ASR-4: The minimum injection water-level was typically maintained approximately 200 to 300 feet bgs, corresponding to water-level drawup of approximately 60 to 160 feet, well below the maximum recommended drawup level of approximately 200 feet; however, on one occasion the injection water level reached a maximum drawup of approximately by 200 feet with a minimum depth to water of approximately 160 ft bgs.

In summary, injection water levels at ASR-1 through ASR-3 frequently exceeded the respective maximum drawup levels by approximately 10 to 30 feet during WY 2017. Injection water levels at ASR-4 were generally maintained below the recommended minimum level below ground surface. The effects of these injection water levels on residual well plugging and well performance is discussed below.

[5] Based on 196,291 af of unimpaired Carmel River flow at the Sleepy Hollow Weir in WY 2017.

### Recovery Operations Summary

When the injected water is recovered via delivery through the CAW system, the recovered water is offset by reduced pumping by CAW from the Carmel River system during the low-flow, high demand periods of the year. During WY 2017, other CAW wells in the SGB were utilized for recovery of previously injected water (ASR-1 was inactive due to a failed FCV). As shown on **Figure 6**, 1,182 af of water recharged during WY 2017 was recovered into the CAW system, with 1,163 af left in aquifer storage and carried over into WY 2018.

It is noted that in this context, ASR recovery is essentially an accounting / allocation of CAW's various water rights and pumping from the SGB and does not represent a "molecule-for-molecule" recovery of the injected water. Rather, the volume recharged in any given year increases the operational yield of the SGB by the same amount and can be "recovered" by any of CAW's wells in the SGB and / or the ASR wells themselves.

## WELL PERFORMANCE

Well performance is generally measured by specific capacity (pumping) and / or specific injectivity (injection), which is the ratio of flow rate (pumping or injection) to water-level change in the well (drawdown or drawup) over a specific elapsed time. The value is typically expressed as gallons per minute per foot of water level change (gpm/ft). The value normalizes well performance by taking into account differing static water levels and flow rates. As such, specific capacity / injectivity data are useful for comparing well performance over time and at differing flow rates. Decreases in specific capacity / injectivity are indicative of decreases in the hydraulic efficiency of a well due to the effects of plugging and/or particle rearrangement.

### Injection Performance

Injection performance has been tracked at ASR-1 since the inception of the ASR program in WY 2002 by measurement and comparison of 24-hour injection specific injectivities (a.k.a. injection specific capacity).

**ASR-1.** A summary of 24-hour specific injectivity for ASR-1 for WY 2002 through 2017 is presented in **Table 2** below:

**Table 2. Injection Performance Summary - ASR-1**

| Water Year | Injection Rate (gpm) | 24-hour DUP (feet) | Specific Injectivity (gpm/ft) | Water Year Change | Comments |
|---|---|---|---|---|---|
| **WY2002** | | | | | |
| Beginning Period | 1,570 | 81.7 | **19.2** | | FCV not installed yet in WY2002. No recovery pumping performed. |
| Ending Period | 1,164 | 199.8 | **6.4** | **-67%** | |
| **WY2003** | | | | | |
| Beginning Period | 1,070 | 70.0 | **15.5** | | Recovery pumping performed following |

| Water Year | Injection Rate (gpm) | 24-hour DUP (feet) | Specific Injectivity (gpm/ft) | Water Year Change | Comments |
|---|---|---|---|---|---|
| Ending Period | 1,007 | 49.7 | **20.3** | **+31%** | WY2003 Injection |
| **WY2004** | | | | | |
| Beginning Period | 1,383 | 183.4 | **7.5** | | Recovery pumping performed following WY2004 Injection |
| Ending Period | 1,072 | 67.4 | **15.9** | **+112%** | |
| **WY2005** | | | | | |
| Beginning Period | 1,045 | 46.6 | **22.4** | | Injectate dechlorinated in WY2005. No recovery pumping performed. |
| Ending Period | 976 | 94.1 | **10.4** | **-54%** | |
| **WY2006** | | | | | |
| Beginning Period | 1,039 | 71.5 | **15.0** | | Injection procedures consistent and performance stable in WY2006. No recovery pumping performed. |
| Ending Period | 1,008 | 62.2 | **17.5** | **+17%** | |
| **WY2007** | | | | | |
| Beginning Period | 1,098 | 92.4 | **11.9** | | Only one injection period in WY2007. No recovery pumping performed. |
| Ending Period | -- | -- | **--** | **--** | |
| **WY2008** | | | | | |
| Beginning Period | 979 | 25.5 | **38.4** | | Formal rehabilitation performed prior to WY2008 injection |
| Ending Period | 1,063 | 33.4 | **31.8** | **-17%** | |
| **WY 2009** | | | | | |
| Beginning Period | 1,119 | 56.1 | **19.9** | | Beginning period low specific injectivity due to high plugging rate during initial injection period. No recovery pumping performed. |
| Ending Period | 1,069 | 34.3 | **31.1** | **+56%** | |
| **WY 2010** | | | | | |
| Beginning Period | 1,080 | 35.6 | **30.3** | | Observed decline in performance due to residual plugging. |
| Ending Period | 1,326 | 54.0 | **24.6** | **-19%** | |
| **WY 2011** | | | | | |
| Beginning Period | 1,367 | 53.0 | **25.8** | | Observed decline in performance due to residual plugging. |
| Ending Period | 1,454 | 63.7 | **22.8** | **-10%** | |
| **WY 2012** | | | | | |
| Beginning Period | NA | NA | NA | | No injection at this well this year. |
| Ending Period | NA | NA | NA | **NA** | |
| **WY 2013** | | | | | |
| Beginning Period | NA | NA | NA | | No injection at this well this year. |
| Ending Period | NA | NA | NA | **NA** | |

| Water Year | Injection Rate (gpm) | 24-hour DUP (feet) | Specific Injectivity (gpm/ft) | Water Year Change | Comments |
|---|---|---|---|---|---|
| **WY 2014** | | | | | |
| Beginning Period | NA | NA | NA | **NA** | No injection at this well this year. |
| Ending Period | NA | NA | NA | | |
| **WY 2015** | | | | | |
| Beginning Period | NA | NA | NA | **NA** | No beginning period due to datalogger malfunction. |
| Ending Period | 1,018 | 40.7 | **25.0** | | |
| **WY 2016** | | | | | |
| Beginning Period | NA | NA | NA | **NA** | No beginning period due to datalogger malfunction. |
| Ending Period | 460 | 14.4 | **31.9** | | |
| **WY 2017** | | | | | |
| Beginning Period | 970 | 39.5 | **24.6** | **-13%** | **See discussion below** |
| Ending Period | 1,295 | 60.2 | **21.5** | | |

As shown in **Table 2**, the 24-hour specific injectivity at the beginning of WY 2017 was 24.6 gpm/ft and at the end of WY 2017 it was 21.5 gpm/ft, representing a decrease of approximately 13 percent, indicating that some residual plugging occurred at ASR-1 over the course of the WY 2017 injection season (discussed further in a following section).

**ASR-2.** A summary of the beginning and ending injection performance at ASR-2 for WY 2010 through WY 2017 is presented in **Table 3** below:

**Table 3. Injection Performance Summary - ASR-2**

| Water Year | Injection Rate (gpm) | 24-hour DUP (feet) | Specific Injectivity (gpm/ft) | Water Year Change | Comments |
|---|---|---|---|---|---|
| **WY 2010** | | | | | |
| Beginning Period | 1,017 | 156.5 | **6.5** | **-57%** | Significant residual plugging. |
| Ending Period | 237 | 85.0 | **2.8** | | |
| **WY 2011** | | | | | |
| Beginning Period | 1,497 | 39.5 | **37.9** | **-0.5%** | Significant improvement as a result of well rehabilitation. No residual plugging during year. |
| Ending Period | 1,292 | 34.3 | **37.7** | | |
| **WY 2012** | | | | | |
| Beginning Period | 1,830 | 56.1 | **32.6** | **-12%** | Observed decline in performance due to residual plugging. |
| Ending Period | 1,817 | 63.4 | **28.7** | | |
| **WY 2013** | | | | | |

| Water Year | Injection Rate (gpm) | 24-hour DUP (feet) | Specific Injectivity (gpm/ft) | Water Year Change | Comments |
|---|---|---|---|---|---|
| Beginning Period | 1,087 | 32.7 | **33.2** | | No residual plugging during year. |
| Ending Period | 1,508 | 44.2 | **34.1** | **+3%** | |
| **WY 2014** | | | | | |
| Beginning Period | NA | NA | NA | | No injection at this well this year. |
| Ending Period | NA | NA | NA | **NA** | |
| **WY 2015** | | | | | |
| Beginning Period | 1,456 | 38.9 | **37.4** | | Observed decline in performance due to residual plugging. |
| Ending Period | 1,574 | 49.1 | **32.1** | **-14%** | |
| **WY 2016** | | | | | |
| Beginning Period | 1,270 | 34.9 | **36.4** | | Observed decline in performance due to residual plugging. |
| Ending Period | 1,620 | 63.9 | **25.4** | **-30%** | |
| **WY 2017** | | | | | |
| Beginning Period | 822 | 24.2 | **33.9** | | **See discussion below** |
| Ending Period | 907 | 30.7 | **29.5** | **-13%** | |

As shown in **Table 3**, the 24-hour specific injectivity at the beginning of WY 2017 was 33.9 gpm/ft and at the end of WY 2017 it was 29.5 gpm/ft, representing a decrease of approximately 13 percent, indicating that some residual plugging occurred at ASR-2 over the course of the WY 2017 injection season (discussed further in a following section).

**ASR-3.** A summary of the beginning and ending injection performance at ASR-3 for WY 2013 through WY 2017 is presented in **Table 4** below:

**Table 4. Injection Performance Summary – ASR-3**

| Water Year | Injection Rate (gpm) | 24-hour DUP (feet) | Specific Injectivity (gpm/ft) | Water Year Change | Comments |
|---|---|---|---|---|---|
| **WY 2013** | | | | | |
| Beginning Period | 1,044 | 87.0 | **12.0** | | See discussion below. |
| Ending Period | 822 | 99.6 | **8.3** | **-31%** | |
| **WY 2014** | | | | | |
| Beginning Period | NA | NA | NA | | No injection at this well this year. |
| Ending Period | NA | NA | NA | **NA** | |
| **WY 2015** | | | | | |
| Beginning Period | NA | NA | NA | | No beginning period data. |

| Water Year | Injection Rate (gpm) | 24-hour DUP (feet) | Specific Injectivity (gpm/ft) | Water Year Change | Comments |
|---|---|---|---|---|---|
| Ending Period | 892 | 90.3 | **9.9** | **NA** | |
| **WY 2016** | | | | | |
| Beginning Period | 948 | 83.6 | **11.3** | | Slight increase observed. |
| Ending Period | 897 | 74.1 | **12.1** | **+7%** | |
| **WY 2017** | | | | | |
| Beginning Period | 936 | 107.5 | **8.7** | | **See discussion below.** |
| Ending Period | 986 | 105.2 | **9.4** | **+8%** | |

As shown in **Table 4**, the 24-hour specific injectivity at the beginning of WY 2017 was 8.7 gpm/ft and at the end of WY 2017 it was 9.4 gpm/ft, representing a slight increase of approximately 8 percent, indicating that no residual plugging occurred at ASR-3 over the course of the WY 2017 injection season.

### ASR-4 Baseline Injection Testing

WY 2017 was the first year that ASR-4 was able to be placed in full operational mode following the injection "conditioning" conducted at the well in WY 2016 (refer to the WY 2016 Summary of Operations Report). Prior to long-term continuous injection operations in WY 2017, a baseline injection testing program was conducted. The primary purpose of the baseline injection testing was to establish the baseline injection well hydraulics and performance of the new well. Primary issues to be investigated include:

- Determination of injection well efficiency and specific injectivity;
- Evaluation of injection well plugging rates (both active and residual);
- Determination of optimal rates, frequency, and duration of backflushing in order to maintain long-term injection capacity, and;
- Determination of long-term sustainable injection rates.

The baseline testing program included the following steps:

1. Pre-injection pumping performance testing;
2. 8-hr step-rate injection testing;
3. 24-hr constant-rate injection test;
4. 6-day constant-rate injection test;
5. Backflushing between each injection test, and;
6. Post-injection pumping performance testing

**Pre-Injection Pumping Performance Test.** A pre-injection performance test was conducted on April 4, 2016, which consisted of a 10-minute specific capacity test. As discussed in the following section, 10-minute specific-capacity tests are typically performed at all project ASR wells following routine backflushing operations to track well pumping performance (and evaluate residual plugging), similar to the tracking of injection performance from 24-hour specific injectivity discussed above.

The static water level in ASR-4 prior to pumping was approximately 333.7 feet bgs[6]. The discharge was maintained at an average rate of approximately 3,000 gpm during the 10-minute test. The pumping level after 10-minutes was approximately 455.5 feet bgs, corresponding to a drawdown of 121.8 feet and a 10-minute specific capacity of approximately 24.6 gpm/ft.

**8-hr Step-Rate Injection Test.** A variable rate injection test was performed on April 5, 2016. The primary purpose of the test was to assess variations in well specific injectivity (the converse of specific capacity) at differing injection rates and to determine a suitable rate for long-term injection testing. The test consisted of four steps, each at a successively higher rate. The duration of each step was 2 hours. The four test rates were approximately 740, 1130, 1500, and 1860 gpm (i.e., approximately 50, 75, 100 and 125 percent of the design injection capacity of 1,500 gpm). The static water level in the well prior to the test was 331.3 feet bgs. The resulting water-level drawup and specific injectivities associated with each of these steps are shown on **Figure 11** and are summarized below in **Table 5**.

**24-hr Constant-Rate Injection Test.** Following the step-rate injection test, backflushing (discussed below), and a period of water level recovery overnight, a 24-hour constant rate injection test was initiated on April 6, 2018. This phase of testing consisted of a continuous rate injection test performed at an average injection rate of approximately 1,506 gpm (i.e., the design injection rate). Water-level data for the 24-hour constant-rate injection test are graphically presented on **Figure 12**.

As shown, the static water level in the well prior to injection was 335.9 feet bgs. The injection water level recorded after 24 hours was 244.6 feet bgs, corresponding to a drawup of 91.3 feet and a 24-hour specific injectivity of approximately 16.5 gpm/ft. This value represents approximately 56 percent of the 24-hour pumping specific capacity of 29.4 gpm/ft[7].

**6-day Constant Rate Injection Test.** A 6-day constant-rate injection was initiated on April 9 and continued until April 25, 2017. This phase of testing consisted of a continuous rate injection test performed at an average injection rate of approximately 1,490 gpm, with a total volume of approximately 38.2 af injected.

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[6] ASR-3 was actively injecting at approximately 1,000 during the ASR-4 Baseline Injection Testing program, which causes approximately 30 feet in water level interference (drawup) at ASR-4. Typical static water levels at ASR-4 are approximately 360 feet bgs.

[7] Pueblo Water Resources, Inc. (2015), *Summary of Operations, Well Construction and Testing, Seaside Middle School ASR-4 Well*, prepared for Monterey Peninsula Water Management District.

During injection, drawup in the well was approximately 66.1, 79.8 and 115.5 feet after 100 minutes, 24 hours and 6 days of injection; respectively, corresponding to specific injectivities of approximately 22.6, 18.7 and 12.9 gpm/ft, respectively. The 24-hour value during this test (18.7 gpm/ft) was slightly greater than the specific injectivities observed during the 24-hour injection test (16.5 gpm/ft), indicating that backflushing of the well between tests (discussed below) was effective at removing plugging materials.

The resulting drawup and specific injectivities associated with each of the various ASR-4 baseline injection tests are summarized below in **Table 5**:

**Table 5. ASR-4 Baseline Injection Testing Specific Injectivity Summary**

| Test | Duration | Rate (gpm) | Drawup (ft) | Q/s (gpm/ft) |
|---|---|---|---|---|
| Step-Rate | | | | |
| Step 1 | 2 hrs | 742 | 21.8 | 34.0 |
| Step 2 | 2 hrs | 1,133 | 43.7 | 25.9 |
| Step 3 | 2 hrs | 1,500 | 76.5 | 19.6 |
| Step 4 | 2 hrs | 1,858 | 124.7 | 14.9 |
| 24-hr Constant | 1 day | 1,506 | 91.3 | 16.5 |
| 6-day Constant | 6 days | 1,493 | 115.7 | 12.9 |

As presented in **Table 5**, the specific injectivity ranged between approximately 12.9 and 34.0 gpm/ft, depending on the injection rate and duration of injection. It is important to note that according to well hydraulic theory, specific injectivity is expected to generally decrease with increasing injection rate and duration of injection; therefore, it is important to consider the test duration and injection rate when comparing specific injectivity values.

**Backflushing.** Following each injection test, backflushing was performed on the well. Backflushing operations consisted of pumping the well to waste at a rate of approximately 3,000 for 20 minutes until discharge clarity had significantly improved. The pump was then stopped and the well allowed to recover for approximately 20 minutes, then the pump was restarted and run for another 20 minutes as described above. This process was performed a total of three times (i.e., a triple-backflush).

During backflushing after the 8-hr step- and 24-hr constant-rate injection tests, the well discharge was initially only slightly turbid (approximately 10 to 20 NTU) followed by a decrease in turbidity to less than 3 NTU after 20 minutes. Discharge water during the subsequent (second and third) pumping/surging cycles was essentially clear, indicating that the majority of particulates were removed from the well during the initial 20 minutes of backflushing. After the 6-day constant-rate injection test, however, the initial backflushing discharge was very turbid (73 NTU), but became essentially clear by the end of the third backflush cycle.

Following each backflushing event, controlled 10-minute specific capacity tests were performed to track well performance and the efficacy of backflushing. The 10-minute specific capacity results are summarized in **Table 6** below:

**Table 6. ASR-4 10-Minute Specific Capacity Summary**

| Test | Rate (gpm) | Drawdown (ft) | Q/s (gpm/ft) | % Change[1] |
|---|---|---|---|---|
| Pre-Injection | 3000 | 121.8 | 24.6 | -- |
| Post 8-hr Step-Rate Injection | 3000 | 187.5 | 16.0 | -35.0 |
| Post 24-hr Constant-Rate Injection | 3000 | 200.1 | 15.0 | -39.1 |
| Post 6-Day Constant-Rate Injection | 3100 | 222.9 | 13.9 | -43.5 |

Notes:
1 - Compared to pre-injection baseline.

As shown, the well displayed a pre-injection 10-minute specific capacity of approximately 24.6 gpm/ft. Following the initial 8-hr step-rate injection test, the 10-minute specific had declined to approximately 16.0 gpm/ft, representing a loss in performance of approximately 35 percent, indicating that that backflushing was not effective at restoring performance, despite the relatively low turbidity levels observed during backflushing (discussed above). Following the 6-day constant-rate injection test, the specific capacity had declined to 13.9 gpm, representing a total loss in performance over the course of the baseline injection testing program of approximately 44 percent. It is notable that the majority of the total performance occurred after the relatively short-duration 8-hr step-rate injection test. This observation, combined with the very low particulate levels in the injectate throughout the baseline injection testing period, suggest that the loss in performance is not due to particulate plugging, but some other mechanism, such as particle rearrangement and/or geochemical reactions (e.g., solids precipitation or clay swelling).

**Plugging Rate Analysis.** Experience at injection sites around the world shows that all injection wells are subject to some amount of plugging because no water source is completely free of particulates. During injection, trace amounts of suspended solids are continually being deposited in the gravel pack and aquifer pore spaces, much as a media filter captures particulates in the filter bed. The effect of plugging is to impede the flow of water from the injection well into the aquifer, causing increased injection heads in the well to maintain a given injection rate, or reduced injection rates at a given head level. Well plugging reduces injection and extraction capacity, and consequently, well life.

Plugging can occur due to poor water quality, improper system operation, or poor design practices. In general, plugging issues fall into four general categories: physical plugging (by particulate matter), chemical reaction (between the injectate and native waters or aquifer minerals), biofouling (the proliferation of bacteria in the gravel pack or aquifer), and gas binding (the vapor locking of the aquifer by entrained or evolved gasses in the injectate).

Relative measurements of the particulate matter in the injectate were made through silt density index (SDI) testing during injection. The SDI was originally developed to quantitatively assess particulate concentrations in reverse osmosis feed waters. The SDI involves pressure filtration of source water through a 0.45 micron membrane, and observation of the decrease in flow over time; the resulting value of SDI is dimensionless, and used as a comparative value for tracking relative well plugging rates versus water quality or other parameters. SDI test results are summarized in **Table 7** below:

**Table 7. ASR-4 Summary of Silt Density Index (SDI) Test Results**

| Injection Test | No. of Tests | Values[1] High | Low | Average |
|---|---|---|---|---|
| 8-hr Step-Rate | 2 | 2.42 | 0.88 | 1.65 |
| 24-hr Constant-Rate | 2 | 0.46 | 0.20 | 0.33 |
| 6-Day Constant-Rate | 1 | 0.20 | 0.20 | 0.20 |

Notes:
1 - Dimensionless

As shown in **Table 7**, SDI values during injection testing consistently decreased with duration of the testing program, ranging between approximately 0.2 and 1.7. Values within this range are generally representative of source waters with a very low amount of particulates.

Plugging rate during injection testing of ASR-4 was estimated utilizing the Graphical Observed vs. Theoretical Drawup Method. Water-level rise in an injection well is a combination of both aquifer response and well losses. Theoretically, at any given constant injection rate, well losses should remain constant; therefore, in the absence of plugging, any water level rise in the well would be due only to aquifer response. The difference between the theoretical water level and the observed water can be presumed to be caused by plugging.

It is important to note that the theoretical water level rise corresponds to the water level that would occur if well losses were negligible and well efficiency was 100 percent. In order to account for well efficiency losses, the graphical method involves drawing a straight line through moderate elapsed time data points (e.g., 10 to 1,000 minutes). Assuming no plugging is occurring, the theoretical water level rise during injection would plot on along a straight line on a semi-log plot. The variance from the straight line is assumed to be indicative of the amount of plugging.

The amount of plugging, in feet of water level rise, was calculated for the 6-day constant-rate injection test and the plugging rate analysis is presented graphically on **Figure 13**. As shown, there was approximately 28 feet of plugging observed during the 6-day injection test.

**ASR-4 WY 2017 Injection Performance.** Following the Baseline Injection Testing Program, ASR-4 was placed into injection operational mode. WY 2017 was the first injection season when 24-hr continuous injection operations occurred at ASR-4, and a summary of the beginning and ending injection performance for WY 2017 is presented in **Table 8** below:

**Table 8. Injection Performance Summary – ASR-4**

| Water Year | Injection Rate (gpm) | 24-hour DUP (feet) | Specific Injectivity (gpm/ft) | Water Year Change | Comments |
|---|---|---|---|---|---|
| **WY 2017** | | | | | |
| Beginning Period | 1,506 | 91.3 | **16.5** | | **See discussion below.** |
| Ending Period | 1,068 | 41.3 | **25.9** | **+58%** | |

As shown in **Table 8**, the 24-hour specific injectivity at the beginning of WY 2017 was 16.4 gpm/ft and at the end of WY 2017 it was 23.8 gpm/ft, representing a significant increase of approximately 58 percent.

**Injection Performance Summary.** The above results indicate a pattern in ASR well performance, with ASR-1 through ASR-4 all having experienced comparably significant declines in performance following initial injection (i.e., the initial variable-rate injection tests performed at each well), followed by a period of relative stability in performance. It was hypothesized that the observed loss in performance may be due to particle rearrangement (mechanical jamming) and/or geochemical reactions (e.g., solids precipitation and/or clay swelling), as opposed to the normal and relatively slow plugging caused by particulates. This phenomenon is the reason for the well "conditioning" effort performed at ASR-4 during WY 2015 and WY 2016.

As shown in **Tables 5 and 6** previously, however, ASR-4 appeared to experience the same initial decline in performance as the other three ASR wells despite the thorough condition effort. These findings suggest that the initial and significant decline in performance consistently observed at all four ASR wells following initial injection testing is likely not due to particle rearrangement, but rather due to a geochemical reaction(s) (e.g., solids precipitation and/or clay swelling). It is also noted that while ASR-3 and ASR-4 have experienced a significant decline in performance following initial injection, (which limits their injection capacities) it is expected that rehabilitation will result in significantly improved performance as has been observed at both ASR-1 and ASR-2.

### Pumping Performance and Residual Plugging

Experience at injection well sites around the world shows that all injection wells are subject to some amount of plugging, because no water source is completely free of particulates, bionutrients, or oxidants, all of which can contribute to well plugging; the CAW source water is no exception. During injection, trace amounts of suspended solids are continually being deposited in the gravel pack and aquifer pore spaces, much as a media filter captures particulates in the filter bed. The effect of plugging is to impede the flow of water from the injection well into the aquifer, causing increased injection heads in the well to maintain a given injection rate, or reduced injection rates at a given head level. Well plugging reduces injection and extraction capacity and can result in decreased useful well life if not mitigated.

Relative measurements of the particulate matter in the injectate have historically been made at the Santa Margarita site through Silt Density Index (SDI) testing during the injection season. The SDI was originally developed to quantitatively assess particulate concentrations in reverse-osmosis feed waters. The SDI test involves pressure filtration of source water through a 0.45-micron membrane, and observation of the decrease in flow rate through the membrane over time; the resulting (dimensionless) value of SDI is used as a comparative value for tracking relative declines in well plugging rates associated with particulate plugging during an injection season (i.e., plugging rates tend to increase directly with SDI). During WY 2017 injection operations, SDI values were only measured at the beginning of the injection season and was approximately 4.1 at that time. Other than the SDI testing conducted during the ASR-4 baseline injection testing discussed previously, the SDI during the remainder of the injection season is not known (was not measured).

Following routine backflushing operations and periods of water-level recovery, controlled 10-minute specific-capacity tests are typically performed to track well pumping performance, similar to the tracking of injection performance from 24-hour specific injectivity discussed above. Residual plugging is the plugging that remains following backflush pumping. Residual plugging increases drawdown during pumping and drawup during injection and is manifested as declining specific capacity / injectivity. The presence of residual plugging is indicative of incomplete removal of plugging particulates during backflushing and has the cumulative effect of reducing well performance and capacity over time.

As discussed previously, routine 10-minute specific capacity tests were performed at the ASR wells as part of backflushing events during WY 2017. Presented in **Table 9** below is a summary of the residual plugging calculations for the ASR wells during WY 2017.

**Table 9. Pumping Performance and Residual Plugging Summary**

| Well | Test | Pumping Rate (gpm) | 10-min Drawdown (ft) | 10-min Q/s[1] (gpm/ft) | Normalization Ratio[2] | Normalized Drawdown[2] (ft) | Residual Plugging (ft) |
|---|---|---|---|---|---|---|---|
| ASR-1 | Pre-Injection | 4,600 | 116.7 | 39.4 | 0.65 | 76.1 | -- |
| | Post-Injection | 3,200 | 103.0 | 31.1 | 0.94 | 96.6 | 20.5 |
| ASR-2 | Pre-Injection | 2,600 | 76.7 | 33.9 | 1.15 | 88.5 | -- |
| | Post-Injection | 2,700 | 100.2 | 26.9 | 1.11 | 111.3 | 22.8 |
| ASR-3 | Pre-Injection | 1,500 | 82.9 | 18.1 | 1.33 | 110.5 | -- |
| | Post-Injection | 1,600 | 117.0 | 13.7 | 1.25 | 146.3 | 35.7 |
| ASR-4 | Pre-Injection | 3,000 | 121.8 | 24.6 | 1.00 | 121.8 | -- |
| | Post-Injection | 2,900 | 164.4 | 17.6 | 1.03 | 170.1 | 48.3 |

Notes:
1 - Specific Capacity. Ratio of pumping rate to drawdown.
2 - Normalized based on ratio of 3,000 gpm to actual test pumping rate for ASR-1, -2 and -4. Based on 2,000 gpm for ASR-3.

As shown on **Figures 7 through 9**, injection water levels were not maintained below the recommended maximum available drawup levels at ASR-1 through ASR-3 during WY 2017, and as shown in **Table 9**, all three wells experienced residual plugging ranging between approximately 20 and 50 feet and commensurate declines in pumping specific capacity. Although as shown on **Figure 10** and discussed previously, injection water levels and performance at ASR-4 were generally maintained at acceptable levels throughout most of WY 2017, based on the pumping performance shown in **Table 9**, ASR-4 also experienced residual plugging of approximately 50 feet. These results indicate that:

1. Injection water levels should be maintained below the recommended minimum levels below ground surface during the injection season to avoid excessive drawup and over pressurization of plugging constituents. These thresholds should not be adjusted during the injection season due to apparent changes in static water levels, and;
2. More intensive backflushing (e.g., multiple backflush cycles as opposed to a single cycle) should be implemented at all four ASR wells during WY 2018 to limit residual plugging and maintain performance.

## AQUIFER RESPONSE TO INJECTION

The response of the regional aquifer system to injection has been monitored since the SMTIW project was initiated in WY 2002. Submersible water-level transducer/data logger units have been installed at seven offsite monitoring well locations in the SGB as well as three onsite monitoring wells. The locations of each offsite monitoring well are shown on **Figure 1**, and water-level hydrographs for the monitoring wells during WY 2017 are graphically presented on **Figures 14 through 22**. A summary of the regional water-level observations during the WY 2017 injection season is presented in **Table 10** below.

As shown on the water-level hydrographs, water levels in the Santa Margarita Sandstone (Tsm) aquifer at the start of the WY 2017 recharge season ranged between approximately 20 to 50 feet below sea level. Positive response to injection during WY 2017 was observed at 8 of the 9 monitoring wells completed in the Santa Margarita Sandstone aquifer, with apparent water-level responses ranging between approximately 11 to 92 feet, generally decreasing with distance from the ASR wells, which is the typical and expected aquifer response to hydraulic stresses (i.e., injection or pumping). The WY 2017 responses are comparable to those observed in previous water years.

The available water-level data also continue to show that at the majority of the offsite Tsm-only monitoring wells, water levels consistently remained below sea level throughout the injection season. Notable exceptions included the Paralta Test and FO-9 wells, which showed water levels as much as approximately 10 to 8 feet above sea level, respectively. Under these overall basin water-level conditions, little to no offshore groundwater flow from the Tsm aquifer would be expected to occur and any “losses” associated with ASR project operations from water potentially migrating offshore are likely limited.

**Table 10. Aquifer Response Summary**

| Well ID | Distance from Nearest Active ASR Well (feet) | Aquifer Monitored | Fig. No. | Pre-Injection DTW (ft. bgs) | Shallowest Injection DTW (ft. bgs) | Maximum Drawup Response (ft.) |
|---|---|---|---|---|---|---|
| SMS (Shallow) | 25 (ASR-3) | QTp | **14** | No Discernable Response | | |
| SMS (Deep) | | Tsm | | 371.4 | 279.7 | **91.7** |
| SM MW-1 | 190 (ASR-2) | Tsm | **15** | 363.7 | 313.3 | **50.4** |
| Paralta Test | 650 (ASR-2) | QTp & Tsm | **16** | 348.3 | 318.9 | **29.4** |
| Ord Grove Test | 1,820 (ASR-2) | QTp & Tsm | **17** | No Discernable Response | | |
| Ord Terrace (Shallow) | 2,550 (ASR-2) | Tsm | **18** | 258.0 | 246.9 | **11.1** |
| FO-7 (Shallow) | 3,700 (ASR-3) | QTp | **19** | No Discernable Response | | |
| FO-7 (Deep) | | Tsm | | 496.4 | 472.7 | **23.7** |
| FO-9 (Deep) | 6,130 (ASR-3) | Tsm | **20** | 33.8 | 10.0 | **23.8** |
| PCA East (Shallow) | 6,200 (ASR-3) | QTp | **21** | No Discernable Response | | |
| PCA East (Deep) | | Tsm | | 94.9 | 70.2 | **24.7** |
| FO-8 (Deep) | 6,450 (ASR-3) | Tsm | **22** | 404.9 | 384.1 | **20.8** |

**Notes**:
QTp – Quaternary / Tertiary-age Paso Robles Formation aquifer
Tsm – Tertiary-age Santa Margarita Sandstone aquifer
DTW – Depth to Water

The limited available data for wells completed in the Paso Robles Formation (QTp) also continue to show no discernible response to injection and water levels in this aquifer remained above the water levels in the underlying Tsm aquifer during WY 2016. Under these water-level conditions, little to no flow of water from the Tsm to the QTp aquifer would be expected to occur.

It is further noted that the Ord Grove Test monitoring well (**Figure 17**) continues to show no discernible response to injection operations, as has been observed during previous injection seasons. In addition, most project monitoring wells show no discernible response to the pumping of CAW's Ord Grove production well. These observations suggest that the Ord Terrace Fault or a parallel branch of the fault may represent a hydraulic barrier in the Tsm aquifer.

## WATER QUALITY

### General

Source water for injection is supplied from the CAW municipal water system, primarily from Carmel River system wells, which is treated at the CAW Begonia Iron Removal Plant (BIRP) for iron and manganese removal. The BIRP product water is also disinfected and maintains a free chlorine residual. A phosphate-based corrosion inhibitor (Zinc Orthophosphate) is also added to the filtered water before entering the CAW distribution system. The finished product water meets all California Department of Public Health (CADPH) Primary and Secondary water quality standards.

As in previous years, water quality was routinely monitored at the ASR well sites during WY 2017 injection and aquifer storage operations. Far-field water quality was also monitored at the CAW Paralta production well and at the PCE-East Deep monitoring well (PCA-E Deep). Summaries of the collected water-quality data during WY 2017 are presented in **Tables 11 through 18** below. Analytic laboratory reports are presented in **Appendix B** (not included in draft). A discussion of the water-quality data collected during WY 2017 is presented below.

**Injection Water Quality**

Injection water quality from the CAW system during WY 2017 is presented in **Table 11** below, and the data show injection water quality was typical of recent years. Levels of Trihalomethanes (THM) and Haloacetic Acid (HAA) compounds, as well as bionutrients (oxygen, nitrogen, phosphorous, and organic carbon), were all present at levels similar to previous years.

**Water Quality During Aquifer Storage**

**Tables 12 through 15** present summaries of water-quality data collected at the four ASR wells. **Tables 16 and 17** present similar data collected at the on-site monitoring wells SM MW-1 and SMS Deep, respectively; and **Table 18** presents the water-quality data collected at the off-site monitoring wells (PCA-E Deep and Paralta). Data for the ASR wells include baseline water quality taken prior to WY 2017 injection (end of WY 2016 Storage) and stored water quality (WY 2017 Storage) collected periodically from the aquifer after WY 2017 injection operations were terminated.

Review of water-quality parameters gathered at the ASR wells, including major anions and cations, redox potential (ORP), and conductivity all showed relatively limited effects of dilution / intermixing of injected water with native groundwater (NGW) during aquifer storage compared to previous water years. The apparent lack of mixing during the WY 2017 storage period is not unexpected, given the significantly greater volume and duration of injection, and the associated relatively short storage period, compared to previous years.

Disinfection Byproducts (DBPs) parameters for the on-site wells collected during the WY 2017 storage period are graphically presented on **Figures 23 through 28** and are summarized below:

- ASR-1: One sample was collected from ASR-1 after approximately 30 days of storage, which showed significant ingrowth of THMs at 89 micrograms per liter (ug/L), exceeding the Maximum Contaminant Level (MCL) of 80 ug/L. As a result of a failure of the pump assembly FCV, no additional samples were collected from this well during WY 2017.

## Table 11. Summary of WY 2017 Water Quality Data – Injectate

| Parameter | Unit | PQL | MCL | Results | | | |
|---|---|---|---|---|---|---|---|
| | | | | CAW Injectate | | | |
| | | | | 12/16/16 | 1/17/17 | 3/10/17 | 4/11/17 |
| | | | Sample Description | Injectate | | | |
| **Major Cations** | | | | | | | |
| Calcium | mg/L | *0.5* | | 49 | | | 33 |
| Magnesium | mg/L | *0.5* | | 16 | | | 12 |
| Potasium | mg/L | *0.5* | | 3.2 | | | 2.6 |
| Sodium | mg/L | *0.5* | | 55 | | | 1 |
| **Major Anions** | | | | | | | |
| Alkalinity, Total (as CaCO3) | mg/L | *2* | | 144 | | | 127 |
| Chloride | mg/L | *1* | *250* | 32 | | 27 | 27 |
| Sulfate | mg/L | *1* | *250* | 85 | | | 66 |
| Nitrate (as NO3) | mg/L | *1* | *45* | ND | | | 1 |
| Nitrite (as NO2-N) | mg/L | *1* | *1* | 0.3 | | | 0.5 |
| **General Physical** | | | | | | | |
| pH | Std Units | | | 7.6 | | | 7.4 |
| Specific Conductance (EC) | uS | *1* | *900* | 555 | | | 466 |
| Total Dissolved Solids | mg/L | *10* | *500* | 348 | | | 280 |
| **Metals** | | | | | | | |
| Arsenic (Total) | ug/L | *1* | *10* | ND | | | ND |
| Barium (Total) | ug/L | *10* | *1000* | 0.061 | | | 57 |
| Iron (Dissolved) | ug/L | *10* | | ND | | | ND |
| Iron (Total) | ug/L | *10* | *300* | 10 | | | ND |
| Lithium | ug/L | *1* | | 10 | | | 6 |
| Manganese (Dissolved) | ug/L | *10* | | ND | | | ND |
| Manganese (Total) | ug/L | *10* | *50* | 13 | | | ND |
| Mercury | ug/L | *0.5* | *2* | ND | | | ND |
| Molybdenum | ug/L | *1* | *1000* | ND | | | 2 |
| Nickel | ug/L | *10* | *100* | ND | | | ND |
| Selenium | ug/L | *2* | *50* | ND | | | 2 |
| Strontium (Total) | ug/L | *5* | | 270 | | | 230 |
| Uranium (by ICP/MS) | ug/L | *1* | *30* | ND | | | ND |
| Vanadium (Total) | ug/L | *1* | *1000* | ND | | | ND |
| Zinc (Total) | ug/L | *10* | *5000* | 243 | | | 268 |
| **Miscellaneous** | | | | | | | |
| Ammonia-N | mg/L | *0.05* | | ND | | | ND |
| Boron | mg/L | *0.05* | | ND | | | ND |
| Chloramines | mg/L | *0.05* | | 0.12 | 0.06 | 0.18 | 0.18 |
| Gross Alpha | pCi/L | | *15* | 1.23 +/- 1.13 | | | 1.27 +/- 1.09 |
| Kjehldahl Nitrogen (Total) | mg/L | *0.5* | | ND | | | 0.5 |
| Methane | ug/L | *0.1* | | 2.7 | | | 1.3 |
| Nitrogen (Total) | mg/L | *0.5* | | ND | | | 1.3 |
| o-Phosphate-P | mg/L | *0.05* | | 0.4 | | | 0.2 |
| Phosphorous (Total) | mg/L | *0.03* | | 0.46 | | | 0.4 |
| Radium 226 | pCi/L | | *3* | 0.295 +/- 0.246 | | | 0.066 +/- 0.129 |
| **Organic Analyses** | | | | | | | |
| Haloacetic Acids (Total) | ug/L | *1.0* | *60.0* | 23.0 | 9.0 | 11.9 | 8.0 |
| *Dibromoacetic Acid* | *ug/L* | *1.0* | | *3.0* | *2.0* | *2.1* | *2.0* |
| *Dichloroacetic Acid* | *ug/L* | *1.0* | | *10* | *4.0* | *5.5* | *2.0* |
| *Monobromoacetic Acid* | *ug/L* | *1.0* | | *1.0* | *ND* | *ND* | *ND* |
| *Monochloroacetic Acid* | *ug/L* | *2.0* | | *ND* | *ND* | *ND* | *ND* |
| *Trichloroacetic Acid* | *ug/L* | *1.0* | | *9.0* | *3.0* | *4.3* | *4.0* |
| Organic Carbon (Dissolved) | mg/L | *0.2* | | 1.5 | | | 1.5 |
| Organic Carbon (Total) | mg/L | *0.2* | | 1.4 | | | 1.5 |
| Trihalomethanes (Total) | ug/L | *1.0* | *80.0* | 47.9 | 23.1 | 23.4 | 18.7 |
| *Bromodichloromethane* | *ug/L* | *0.5* | | *15.4* | *8.0* | *7.8* | *6.3* |
| *Bromoform* | *ug/L* | *0.5* | | *1.8* | *1.0* | *0.69* | *0.7* |
| *Chloroform* | *ug/L* | *0.5* | | *18.8* | *7.2* | *9.2* | *6.9* |
| *Dibromochloromethane* | *ug/L* | *0.5* | | *11.9* | *6.9* | *5.7* | *4.8* |
| **Field Parameters** | | | | | | | |
| Temperature | $^0$ C | *0.1* | | 12.9 | 14.9 | 15.8 | 14.8 |
| Specific Conductance (EC) | uS | *1.0* | *900* | 491 | 458 | 450 | 442 |
| pH | Std Units | *0.1* | *6.5 - 8.5* | 7.4 | 7.0 | 7.1 | 7.4 |
| ORP | mV | *1.0* | | 507 | 664 | 727 | 717 |
| Free Chlorine Residual | mg/L | *0.1* | *2 - 5* | 1.0 | 1.9 | 1.1 | 1.3 |
| Dissolved Oxygen | mg/L | *0.01* | | 5.2 | 3.9 | 4.1 | 3.6 |
| Silt Density Index | Std Units | *0.1* | | 4.1 | | | |
| $H_2S$ | mg/L | *0.1* | | ND | ND | | ND |

**Notes:**
Constituents exceeding MCLs denoted in **BOLD** type

## Table 12. Summary of WY 2017 Water-Quality Data – ASR-1

| Parameter | Unit | PQL | MCL | Results | | | |
|---|---|---|---|---|---|---|---|
| | | | | SM ASR-1 | | | |
| | | | | 3/21/01 | 9/21/16 | 12/2/16 | 6/28/17 |
| | | ASR Operational Phase | | NGW | WY 2016 Storage | | WY 2017 Storage |
| Elapsed Storage Time | Days | | | -- | 170 | 242 | 29 |
| **Major Cations** | | | | | | | |
| Calcium | mg/L | *0.5* | | 85 | 68 | 81 | 41 |
| Magnesium | mg/L | *0.5* | | 19 | 17 | 20 | 13 |
| Potasium | mg/L | *0.5* | | 5.3 | 4 | 4.6 | 2.8 |
| Sodium | mg/L | *0.5* | | 88 | 71 | 72 | 43 |
| **Major Anions** | | | | | | | |
| Alkalinity, Total (as CaCO3) | mg/L | *2* | | 224 | 180 | 228 | 138 |
| Chloride | mg/L | *1* | *250* | 120 | 72 | 112 | 28 |
| Sulfate | mg/L | *1* | *250* | 95 | 96 | 100 | 68 |
| Nitrate (as NO3) | mg/L | *1* | *45* | ND | 1 | 1.0 | 1 |
| Nitrite (as NO2-N) | mg/L | *1* | *1* | | 0.3 | 0.3 | 0.2 |
| **General Physical** | | | | | | | |
| pH | Std Units | | | 7.1 | 7.4 | 7.2 | 7.5 |
| Specific Conductance (EC) | uS | *1* | *900* | **1015** | 763 | **962** | 496 |
| Total Dissolved Solids | mg/L | *10* | *500* | **618** | 471 | **583** | 320 |
| **Metals** | | | | | | | |
| Arsenic (Total) | ug/L | *1* | *10* | ND | 1 | 1 | 1 |
| Barium (Total) | ug/L | *10* | *1000* | 52 | 55 | 71 | 58 |
| Iron (Dissolved) | ug/L | *10* | | | ND | 12 | ND |
| Iron (Total) | ug/L | *10* | *300* | 120 | ND | 16 | 20 |
| Lithium | ug/L | *1* | | | 19 | 29 | 7 |
| Manganese (Dissolved) | ug/L | *10* | | | ND | 22 | ND |
| Manganese (Total) | ug/L | *10* | *50* | 40 | ND | 21 | ND |
| Mercury | ug/L | *0.5* | *2* | | ND | ND | ND |
| Molybdenum | ug/L | *1* | *1000* | | 6 | 7 | 3 |
| Nickel | ug/L | *10* | *100* | | ND | ND | 2 |
| Selenium | ug/L | *2* | *50* | ND | 2 | 2 | 6 |
| Strontium (Total) | ug/L | *5* | | | 308 | 402 | 210 |
| Uranium (by ICP/MS) | ug/L | *1* | *30* | | 1 | 1 | ND |
| Vanadium (Total) | ug/L | *1* | *1000* | | ND | ND | 1 |
| Zinc (Total) | ug/L | *10* | *5000* | 10 | 87 | 70 | 202 |
| **Miscellaneous** | | | | | | | |
| Ammonia-N | mg/L | *0.05* | | 0.33 | ND | 0.09 | 0.1 |
| Boron | mg/L | *0.05* | | 0.14 | 0.08 | 0.11 | ND |
| Chloramines | mg/L | *0.05* | | | ND | ND | ND |
| Gross Alpha | pCi/L | | *15* | | 2.52 +/- 1.55 | 2.64 +/- 1.89 | 1.97 +/- 1.27 |
| Kjehldahl Nitrogen (Total) | mg/L | *0.5* | | | ND | 0.5 | ND |
| Methane | ug/L | *0.1* | | | 2.2 | 3.9 | 0.77 |
| Nitrogen (Total) | mg/L | *0.5* | | | 0.5 | 1 | 0.5 |
| o-Phosphate-P | mg/L | *0.05* | | 0.46 | 0.1 | ND | 0.3 |
| Phosphorous (Total) | mg/L | *0.03* | | | 0.13 | 0.13 | 0.3 |
| Radium 226 | pCi/L | | *3* | | 0.758 +/- 0.437 | 1.33 +/- 0.340 | 0.044 +/- 0.104 |
| **Organic Analyses** | | | | | | | |
| Haloacetic Acids (Total) | ug/L | *1.0* | *60.0* | | ND | 0 | 6 |
| *Dibromoacetic Acid* | *ug/L* | *1.0* | | | *ND* | *ND* | *ND* |
| *Dichloroacetic Acid* | *ug/L* | *1.0* | | | *ND* | *ND* | *2* |
| *Monobromoacetic Acid* | *ug/L* | *1.0* | | | *ND* | *ND* | *ND* |
| *Monochloroacetic Acid* | *ug/L* | *2.0* | | | *ND* | *ND* | *ND* |
| *Trichloroacetic Acid* | *ug/L* | *1.0* | | | *ND* | *ND* | *4* |
| Organic Carbon (Dissolved) | mg/L | *0.2* | | | 1.0 | 1.4 | 1.8 |
| Organic Carbon (Total) | mg/L | *0.2* | | 6.3 | 1.0 | 1.3 | 1.5 |
| Trihalomethanes (Total) | ug/L | *1.0* | *80.0* | | 28.9 | 14.8 | **89** |
| *Bromodichloromethane* | *ug/L* | *0.5* | | | 7.6 | *4.0* | *22* |
| *Bromoform* | *ug/L* | *0.5* | | | 0.5 | *ND* | *1* |
| *Chloroform* | *ug/L* | *0.5* | | | 18.8 | *10.1* | *56* |
| *Dibromochloromethane* | *ug/L* | *0.5* | | | 2 | *0.7* | *10* |
| **Field Parameters** | | | | | | | |
| Temperature | $^{0}$C | *0.1* | | | 19.4 | | 16.6 |
| Specific Conductance (EC) | uS | *1.0* | *900* | 1015 | 667 | | 440 |
| pH | Std Units | *0.1* | *6.5 - 8.5* | 7.1 | 7.03 | | 7.3 |
| ORP | mV | *1.0* | | | -243 | | 220 |
| Free Chlorine Residual | mg/L | *0.1* | *2 - 5* | | ND | | 0.23 |
| Dissolved Oxygen | mg/L | *0.01* | | | 1.17 | | 3.12 |
| Silt Density Index | Std Units | *0.1* | | | | | |
| $H_2S$ | mg/L | *0.1* | | 1.5 | ND | | ND |

**Notes:**
Constituents exceeding MCLs denoted in **BOLD** type

## Table 13. Summary of WY 2017 Water Quality Data – ASR-2

| Parameter | Unit | PQL | MCL | Results | | | |
|---|---|---|---|---|---|---|---|
| | | | | SM ASR-2 | | | |
| | | | | 9/27/2016 | 12/6/16 | 6/28/17 | 10/4/17 |
| | | ASR Operational Phase | | WY 2016 Storage | | WY 2017 Storage | |
| Elapsed Storage Time | Days | | | **176** | **246** | **29** | **127** |
| **Major Cations** | | | | | | | |
| Calcium | mg/L | 0.5 | | 60 | 66 | 41 | 38 |
| Magnesium | mg/L | 0.5 | | 19 | 19 | 13 | 14 |
| Potasium | mg/L | 0.5 | | 3.8 | 4.5 | 2.9 | 2.8 |
| Sodium | mg/L | 0.5 | | 64 | 59 | 44 | 43 |
| **Major Anions** | | | | | | | |
| Alkalinity, Total (as CaCO3) | mg/L | 2 | | 180 | 209 | 134 | 134 |
| Chloride | mg/L | 1 | 250 | 64 | 102 | 28 | 28 |
| Sulfate | mg/L | 1 | 250 | 81 | 71 | 69 | 70 |
| Nitrate (as NO3) | mg/L | 1 | 45 | 1 | ND | 1 | 0.2 |
| Nitrite (as NO2-N) | mg/L | 1 | 1 | 0.3 | 0.3 | 0.2 | ND |
| **General Physical** | | | | | | | |
| pH | Std Units | | | 7.5 | 7.3 | 7.5 | 7.4 |
| Specific Conductance (EC) | uS | 1 | 900 | 707 | 864 | 488 | 495 |
| Total Dissolved Solids | mg/L | 10 | 500 | 431 | **514** | 308 | 297 |
| **Metals** | | | | | | | |
| Arsenic (Total) | ug/L | 1 | 10 | 1 | 1 | ND | ND |
| Barium (Total) | ug/L | 10 | 1000 | 83 | 106 | 59 | 62 |
| Iron (Dissolved) | ug/L | 10 | | ND | ND | ND | 11 |
| Iron (Total) | ug/L | 10 | 300 | 66 | 67 | 57 | 66 |
| Lithium | ug/L | 1 | | 14 | 26 | 6 | 7 |
| Manganese (Dissolved) | ug/L | 10 | | 10 | 15 | ND | ND |
| Manganese (Total) | ug/L | 10 | 50 | 11 | 16 | ND | ND |
| Mercury | ug/L | 0.5 | 2 | | **2** | ND | ND |
| Molybdenum | ug/L | 1 | 1000 | 6 | 10 | 4 | 6 |
| Nickel | ug/L | 10 | 100 | ND | ND | 2 | 2 |
| Selenium | ug/L | 2 | 50 | 2 | 2 | 2 | 3 |
| Strontium (Total) | ug/L | 5 | | 300 | 374 | 210 | 208 |
| Uranium (by ICP/MS) | ug/L | 1 | 30 | 1 | 1 | ND | 2.4 |
| Vanadium (Total) | ug/L | 1 | 1000 | ND | ND | 1 | ND |
| Zinc (Total) | ug/L | 10 | 5000 | 317 | 360 | 257 | 272 |
| **Miscellaneous** | | | | | | | |
| Ammonia-N | mg/L | 0.05 | | ND | 0.08 | 0.1 | ND |
| Boron | mg/L | 0.05 | | 0.06 | 0.07 | ND | ND |
| Chloramines | mg/L | 0.05 | | ND | ND | ND | ND |
| Gross Alpha | pCi/L | | 15 | 2.59 +/- 2.16 | 2.24 +/- 1.91 | 0.775 +/- 0.946 | 2.04 +/- 1.15 |
| Kjehldahl Nitrogen (Total) | mg/L | 0.5 | | 1 | 0.9 | ND | ND |
| Methane | ug/L | 0.1 | | 1.7 | 1.9 | 1.5 | 0.7 |
| Nitrogen (Total) | mg/L | 0.5 | | 1.5 | 1.3 | ND | ND |
| o-Phosphate-P | mg/L | 0.05 | | 0.3 | 0.2 | 0.3 | 0.26 |
| Phosphorous (Total) | mg/L | 0.03 | | 0.25 | 0.23 | 0.4 | 0.3 |
| Radium 226 | pCi/L | | 3 | 0.000 +/- 0.246 | 0.170 +/- 0.132 | 0.109 +/- 0.128 | 0.090 +/- 0.124 |
| **Organic Analyses** | | | | | | | |
| Haloacetic Acids (Total) | ug/L | 1.0 | 60.0 | 0.0 | 0.0 | 30.0 | 4.0 |
| *Dibromoacetic Acid* | ug/L | 1.0 | | ND | ND | 2.0 | ND |
| *Dichloroacetic Acid* | ug/L | 1.0 | | ND | ND | 14.0 | ND |
| *Monobromoacetic Acid* | ug/L | 1.0 | | ND | ND | ND | ND |
| *Monochloroacetic Acid* | ug/L | 2.0 | | ND | ND | ND | ND |
| *Trichloroacetic Acid* | ug/L | 1.0 | | ND | ND | 14.0 | 4.0 |
| Organic Carbon (Dissolved) | mg/L | 0.2 | | | 1.2 | 2.0 | 1.4 |
| Organic Carbon (Total) | mg/L | 0.2 | | 1.10 | 1.2 | 1.5 | 1.9 |
| Trihalomethanes (Total) | ug/L | 1.0 | 80.0 | 47.9 | 25.3 | **97.0** | **87.0** |
| *Bromodichloromethane* | ug/L | 0.5 | | 12.0 | 6.7 | 26.0 | 21.0 |
| *Bromoform* | ug/L | 0.5 | | 0.60 | ND | 1.0 | 1.00 |
| *Chloroform* | ug/L | 0.5 | | 29.8 | 15.4 | 58.0 | 55.0 |
| *Dibromochloromethane* | ug/L | 0.5 | | 5.5 | 3.2 | 12.0 | 10.0 |
| **Field Parameters** | | | | | | | |
| Temperature | $^0$C | 0.1 | | 18.0 | 20.4 | 16.4 | 19.4 |
| Specific Conductance (EC) | uS | 1.0 | 900 | 610 | 568 | 460 | 428.0 |
| pH | Std Units | 0.1 | 6.5 - 8.5 | 6.5 | 7.2 | 7.3 | 7.1 |
| ORP | mV | 1.0 | | -202.5 | -232 | 470 | |
| Free Chlorine Residual | mg/L | 0.1 | 2 - 5 | 0.24 | ND | 0.2 | |
| Dissolved Oxygen | mg/L | 0.01 | | 1.01 | 3.98 | 3.28 | 2.03 |
| Silt Density Index | Std Units | 0.1 | | | | | |
| $H_2S$ | mg/L | 0.1 | | 0.02 | 0.09 | ND | |

**Notes:**
Constituents exceeding MCLs denoted in **BOLD** type

## Table 14. Summary of WY 2017 Water Quality Data – ASR-3

| Parameter | Unit | PQL | MCL | Results | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | SMS ASR-3 | | | | |
| | | | | 10/22/10 | 9/21/16 | 12/9/16 | 6/27/17 | 9/6/17 |
| | | ASR Operational Phase | | NGW | WY 2016 Storage | | WY 2017 Storage | |
| Elapsed Storage Time | Days | | | | **170** | **249** | **28** | **99** |
| **Major Cations** | | | | | | | | |
| Calcium | mg/L | *0.5* | | 76 | 53 | 60 | 43 | |
| Magnesium | mg/L | *0.5* | | 18 | 17 | 18 | 14 | |
| Potasium | mg/L | *0.5* | | 5 | 4 | 4 | 3.0 | |
| Sodium | mg/L | *0.5* | | 102 | 59 | 66 | 46 | |
| **Major Anions** | | | | | | | | |
| Alkalinity, Total (as CaCO3) | mg/L | *2* | | 304 | 171 | 178 | 134 | |
| Chloride | mg/L | *1* | *250* | 107 | 58 | 75 | 28 | 36 |
| Sulfate | mg/L | *1* | *250* | 56 | 72 | 71 | 71 | 68 |
| Nitrate (as NO3) | mg/L | *1* | *45* | 1 | 1 | ND | 1 | |
| Nitrite (as NO2-N) | mg/L | *1* | *1* | ND | 0.3 | 0.3 | 0.2 | |
| **General Physical** | | | | | | | | |
| pH | Std Units | | | 7.7 | 7.5 | 7.3 | 7.5 | |
| Specific Conductance (EC) | uS | *1* | *900* | **954** | 657 | 740 | 497 | 507 |
| Total Dissolved Solids | mg/L | *10* | *500* | **575** | 426 | 437 | 314 | |
| **Metals** | | | | | | | | |
| Arsenic (Total) | ug/L | *1* | *10* | 4 | 6 | 5 | 6 | |
| Barium (Total) | ug/L | *10* | *1000* | 50 | 78 | 88 | 61 | |
| Iron (Dissolved) | ug/L | *10* | | 21 | ND | 13 | ND | ND |
| Iron (Total) | ug/L | *10* | *300* | 21 | 56 | 208 | 173 | |
| Lithium | ug/L | *1* | | 36 | 14 | 22 | 6 | |
| Manganese (Dissolved) | ug/L | *10* | | 27 | 12 | 15 | 10 | ND |
| Manganese (Total) | ug/L | *10* | *50* | 27 | 13 | 16 | 10 | |
| Mercury | ug/L | *0.5* | *2* | | | 1 | ND | ND |
| Molybdenum | ug/L | *1* | *1000* | -- | 21 | 9 | 56 | |
| Nickel | ug/L | *10* | *100* | ND | ND | ND | 2 | 2.9 |
| Selenium | ug/L | *2* | *50* | ND | 3 | 3 | 8 | |
| Strontium (Total) | ug/L | *5* | | 403 | 281 | 322 | 211 | |
| Uranium (by ICP/MS) | ug/L | *1* | *30* | -- | 3 | 2 | 1 | |
| Vanadium (Total) | ug/L | *1* | *1000* | -- | ND | ND | 1 | |
| Zinc (Total) | ug/L | *10* | *5000* | -- | 266 | 241 | 256 | 250 |
| **Miscellaneous** | | | | | | | | |
| Ammonia-N | mg/L | *0.05* | | 249 | ND | ND | 0.1 | |
| Boron | mg/L | *0.05* | | ND | 0.05 | 0.07 | ND | |
| Chloramines | mg/L | *0.05* | | 0.08 | ND | ND | ND | |
| Gross Alpha | pCi/L | | *15* | -- | 4.28 +/- 1.73 | 4.79 +/- 1.87 | 0.894 +/- 0.980 | |
| Kjehldahl Nitrogen (Total) | mg/L | *0.5* | | ND | 1 | ND | ND | |
| Methane | ug/L | *0.1* | | ND | 1.4 | 0.31 | 1.7 | |
| Nitrogen (Total) | mg/L | *0.5* | | ND | 1.5 | ND | ND | |
| o-Phosphate-P | mg/L | *0.05* | | ND | 0.2 | 0.2 | 0.1 | |
| Phosphorous (Total) | mg/L | *0.03* | | 0.03 | 0.27 | 0.19 | 0.37 | |
| Radium 226 | pCi/L | | *3* | -- | 0.178 +/- 0.302 | 0.100 +/- 0.139 | 0.066 +/- 0.114 | |
| **Organic Analyses** | | | | | | | | |
| Haloacetic Acids (Total) | ug/L | *1.0* | *60.0* | ND | 3 | 0.0 | 17.0 | |
| *Dibromoacetic Acid* | *ug/L* | *1.0* | | *ND* | 1 | *ND* | *ND* | |
| *Dichloroacetic Acid* | *ug/L* | *1.0* | | *ND* | *2* | *ND* | *2.0* | |
| *Monobromoacetic Acid* | *ug/L* | *1.0* | | *ND* | *ND* | *ND* | *ND* | |
| *Monochloroacetic Acid* | *ug/L* | *2.0* | | *ND* | *ND* | *ND* | *ND* | |
| *Trichloroacetic Acid* | *ug/L* | *1.0* | | *ND* | *ND* | *ND* | *15* | |
| Organic Carbon (Dissolved) | mg/L | *0.2* | | 0.71 | *0.9* | 1.3 | 2.0 | |
| Organic Carbon (Total) | mg/L | *0.2* | | 0.70 | 1.00 | 1.4 | 1.6 | 1.0 |
| Trihalomethanes (Total) | ug/L | *1.0* | *80.0* | ND | 61.40 | 46.2 | **112.0** | |
| *Bromodichloromethane* | *ug/L* | *0.5* | | *ND* | 15.9 | *12.0* | *28.0* | |
| *Bromoform* | *ug/L* | *0.5* | | *ND* | *0.8* | *0.6* | *1.0* | |
| *Chloroform* | *ug/L* | *0.5* | | *ND* | *36.7* | *27.3* | *71.0* | |
| *Dibromochloromethane* | *ug/L* | *0.5* | | *ND* | *8* | *6.3* | *12.0* | |
| **Field Parameters** | | | | | | | | |
| Temperature | $^0$C | *0.1* | | 26.2 | 17.3 | 19.9 | 18.1 | 19.4 |
| Specific Conductance (EC) | uS | *1.0* | *900* | 991 | 588 | 426 | 462 | 467 |
| pH | Std Units | *0.1* | *6.5 - 8.5* | 7.0 | 7.07 | 7.0 | 7.1 | 7.1 |
| ORP | mV | *1.0* | | -82 | -171.0 | -93 | 166 | 85 |
| Free Chlorine Residual | mg/L | *0.1* | *2 - 5* | ND | ND | ND | 0.23 | 0.26 |
| Dissolved Oxygen | mg/L | *0.01* | | -- | 4.67 | 3.74 | 3.26 | 3.58 |
| Silt Density Index | Std Units | *0.1* | | -- | | | | |
| $H_2S$ | mg/L | *0.1* | | 0.60 | ND | ND | ND | ND |

**Notes:**
Constituents exceeding MCLs denoted in **BOLD** type

## Table 15. Summary of WY 2017 Water Quality Data – ASR-4

| Parameter | Unit | PQL | MCL | Results ASR-4 9/21/2016 | 12/2/2016 | 3/7/2017 | 6/27/2017 | 10/4/17 |
|---|---|---|---|---|---|---|---|---|
| | | ASR Operational Phase | | WY 2016 Storage | | | WY 2017 Storage | |
| Elapsed Storage Time | Days | | | **170** | **242** | **337** | **28** | **127** |
| **Major Cations** | | | | | | | | |
| Calcium | mg/L | *0.5* | | 76 | 68 | 49 | 40 | 36 |
| Magnesium | mg/L | *0.5* | | 16 | 14 | 6 | 13 | 13 |
| Potasium | mg/L | *0.5* | | 4.6 | 4.0 | 4.2 | 2.8 | 2.7 |
| Sodium | mg/L | *0.5* | | 103 | 88 | 76 | 42 | 39 |
| **Major Anions** | | | | | | | | |
| Alkalinity, Total (as CaCO3) | mg/L | *2* | | 234 | 231 | 176 | 134 | 134 |
| Chloride | mg/L | *1* | *250* | 121 | 123 | 77 | 27 | 27 |
| Sulfate | mg/L | *1* | *250* | 55 | 53 | 48 | 69 | 70 |
| Nitrate (as NO3) | mg/L | *1* | *45* | 1.0 | 2.0 | 1.0 | 1 | 0.2 |
| Nitrite (as NO2-N) | mg/L | *1* | *1* | 0.3 | 0.3 | ND | 0.2 | ND |
| **General Physical** | | | | | | | | |
| pH | Std Units | | | 7.5 | 7.3 | 7.6 | 7.5 | 7.5 |
| Specific Conductance (EC) | uS | *1* | *900* | **924** | **937** | 689 | 497 | 487 |
| Total Dissolved Solids | mg/L | *10* | *500* | **563** | **537** | 437 | 311 | 297 |
| **Metals** | | | | | | | | |
| Arsenic (Total) | ug/L | *1* | *10* | 5 | 5 | 7 | **22** | 8 |
| Barium (Total) | ug/L | *10* | *1000* | 54 | 52 | 29 | 58 | 60 |
| Iron (Dissolved) | ug/L | *10* | | ND | 23 | ND | ND | 18 |
| Iron (Total) | ug/L | *10* | *300* | 144 | 153 | 135 | 114 | 201 |
| Lithium | ug/L | *1* | | 32 | 34 | 24 | 7 | 7 |
| Manganese (Dissolved) | ug/L | *10* | | 21 | 21 | ND | ND | 13 |
| Manganese (Total) | ug/L | *10* | *50* | 21 | 22 | ND | ND | 14 |
| Mercury | ug/L | *0.5* | *2* | | ND | 0.2 | ND | ND |
| Molybdenum | ug/L | *1* | *1000* | 6 | 6 | 24 | 62 | 55 |
| Nickel | ug/L | *10* | *100* | 58 | 68 | 25 | 9 | 23 |
| Selenium | ug/L | *2* | *50* | 2 | 2 | 5 | 12 | 10 |
| Strontium (Total) | ug/L | *5* | | 444 | 497 | 456 | 214 | 206 |
| Uranium (by ICP/MS) | ug/L | *1* | *30* | 1 | 1 | 3 | 1 | 1.7 |
| Vanadium (Total) | ug/L | *1* | *1000* | ND | 7 | 5 | 1 | ND |
| Zinc (Total) | ug/L | *10* | *5000* | ND | ND | 20 | 190 | 104 |
| **Miscellaneous** | | | | | | | | |
| Ammonia-N | mg/L | *0.05* | | ND | ND | ND | 0.1 | ND |
| Boron | mg/L | *0.05* | | 0.11 | 0.09 | 0.08 | ND | ND |
| Chloramines | mg/L | *0.05* | | ND | ND | ND | ND | ND |
| Gross Alpha | pCi/L | | *15* | 3.01 +/- 2.64 | 3.91 +/- 2.17 | 1.01 +/- 1.67 | 5.07 +/- 1.71 | 2.02 +/- 1.14 |
| Kjehldahl Nitrogen (Total) | mg/L | *0.5* | | 0.5 | 1.3 | 0.8 | ND | ND |
| Methane | ug/L | *0.1* | | 1.7 | 1.20 | 0.51 | 1.5 | 0.98 |
| Nitrogen (Total) | mg/L | *0.5* | | 1.00 | 2.1 | 1.1 | ND | ND |
| o-Phosphate-P | mg/L | *0.05* | | ND | ND | 0.1 | ND | 0.16 |
| Phosphorous (Total) | mg/L | *0.03* | | ND | 0.04 | 0.03 | 0.24 | 0.17 |
| Radium 226 | pCi/L | | *3* | 0.760 +/- 0.438 | 0.578 +/- 0.234 | 0.318 +/- 0.171 | 0.000 +/- 0.074 | 0.000 +/- .088 |
| **Organic Analyses** | | | | | | | | |
| Haloacetic Acids (Total) | ug/L | *1.0* | *60.0* | 0.0 | 0.0 | 0.0 | 12.0 | 2.0 |
| *Dibromoacetic Acid* | *ug/L* | *1.0* | | *ND* | *ND* | *ND* | *ND* | *ND* |
| *Dichloroacetic Acid* | *ug/L* | *1.0* | | *ND* | *ND* | *ND* | *2.0* | *ND* |
| *Monobromoacetic Acid* | *ug/L* | *1.0* | | *ND* | *ND* | *ND* | *ND* | *ND* |
| *Monochloroacetic Acid* | *ug/L* | *2.0* | | *ND* | *ND* | *ND* | *ND* | *ND* |
| *Trichloroacetic Acid* | *ug/L* | *1.0* | | *ND* | *ND* | *ND* | *10* | *2.0* |
| Organic Carbon (Dissolved) | mg/L | *0.2* | | | 0.9 | 0.9 | 1.6 | 1.7 |
| Organic Carbon (Total) | mg/L | *0.2* | | 0.6 | 0.9 | 0.8 | 1.6 | 1.3 |
| Trihalomethanes (Total) | ug/L | *1.0* | *80.0* | 0.0 | 0.0 | 19.3 | **98** | 59 |
| *Bromodichloromethane* | *ug/L* | *0.5* | | *ND* | *ND* | *5.6* | *23* | *16* |
| *Bromoform* | *ug/L* | *0.5* | | *ND* | *ND* | *0.8* | *1.0* | *ND* |
| *Chloroform* | *ug/L* | *0.5* | | *ND* | *ND* | *9.4* | *62* | *34* |
| *Dibromochloromethane* | *ug/L* | *0.5* | | *ND* | *ND* | *3.5* | *12* | *9.0* |
| **Field Parameters** | | | | | | | | |
| Temperature | $^0$C | *0.1* | | 25.1 | 26.0 | 25.6 | 18.5 | 18.5 |
| Specific Conductance (EC) | uS | *1.0* | *900* | 564 | 859 | 680 | 423 | 415 |
| pH | Std Units | *0.1* | *6.5 - 8.5* | 7.08 | 7.2 | 7.3 | 7.2 | 6.4 |
| ORP | mV | *1.0* | | -262.0 | -297 | 54 | 159 | 31 |
| Free Chlorine Residual | mg/L | *0.1* | *2 - 5* | ND | 0.2 | | 0.21 | 0.51 |
| Dissolved Oxygen | mg/L | *0.01* | | 0.97 | 0.52 | | ND | 1.87 |
| Silt Density Index | Std Units | *0.1* | | | | | | |
| $H_2S$ | mg/L | *0.1* | | 0.01 | 0.14 | | ND | ND |

**Notes:**
Constituents exceeding MCLs denoted in **BOLD** type

## Table 16. Summary of WY 2017 Water Quality Data – SM MW-1

| Parameter | Unit | PQL | MCL | Results | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | SM MW-1 | | | | | | |
| | | | | 12/1/16 | 2/1/17 | 4/11/17 | 6/28/17 | 7/18/17 | 9/18/17 | 10/2/17 |
| | | | Sample Description | WY 2016 Storage | WY 2017 Injection | | WY 2017 Storage | | | |
| Elapsed Storage Time | Days | | | 241 | 0 | 0 | 29 | 49 | 111 | 125 |
| **Major Cations** | | | | | | | | | | |
| Calcium | mg/L | 0.5 | | 74 | | 40 | 44 | | | 48 |
| Magnesium | mg/L | 0.5 | | 22 | | 10 | 11 | | | 13 |
| Potasium | mg/L | 0.5 | | 4.6 | | 2.5 | 2.7 | | | 3.2 |
| Sodium | mg/L | 0.5 | | 67 | | 41 | 43 | | | 48 |
| **Major Anions** | | | | | | | | | | |
| Alkalinity, Total (as CaCO3) | mg/L | 2 | | 209 | | 134 | 135 | | | 137 |
| Chloride | mg/L | 1 | 250 | 109 | | 28 | 28 | | | 28 |
| Sulfate | mg/L | 1 | 250 | 75 | | 68 | 69 | | | 69 |
| Nitrate (as NO3) | mg/L | 1 | 45 | ND | | 1 | 1 | | | 0.3 |
| Nitrite (as NO2-N) | mg/L | 1 | 45 | 0.3 | | 0.5 | 0.2 | | | ND |
| **General Physical** | | | | | | | | | | |
| pH | Std Units | | | 7.3 | | 7.7 | 7.5 | | | 7.5 |
| Specific Conductance (EC) | uS | 1 | 900 | 890 | | 493 | 489 | | | 491 |
| Total Dissolved Solids | mg/L | 10 | 500 | **517** | | 288 | 297 | | | 326 |
| **Metals** | | | | | | | | | | |
| Arsenic (Total) | ug/L | 1 | 10 | 2 | | 2 | 2 | | | 2 |
| Barium (Total) | ug/L | 10 | 1000 | 66 | | 20 | 21 | | | 26 |
| Iron (Dissolved) | ug/L | 10 | | ND | | ND | ND | | | 14 |
| Iron (Total) | ug/L | 10 | 300 | ND | | 72 | ND | | | ND |
| Lithium | ug/L | 1 | | 25 | | 9 | 7 | | | 4 |
| Manganese (Dissolved) | ug/L | 10 | | 16 | | ND | ND | | | ND |
| Manganese (Total) | ug/L | 10 | 50 | 17 | | ND | ND | | | ND |
| Mercury | ug/L | 0.5 | 2 | | | 0.4 | ND | | | ND |
| Molybdenum | ug/L | 1 | 1000 | 10 | | 3 | 3 | | | 5 |
| Nickel | ug/L | 10 | 100 | ND | | ND | 1 | | | ND |
| Selenium | ug/L | 2 | 50 | 2 | | 2 | 9 | | | 3 |
| Strontium (Total) | ug/L | 5 | | 388 | | 282 | 245 | | | 213 |
| Uranium (by ICP/MS) | ug/L | 1 | 30 | 2 | | 2 | 1 | | | 1 |
| Vanadium (Total) | ug/L | 1 | 1000 | ND | | ND | 2 | | | ND |
| Zinc (Total) | ug/L | 10 | 5000 | ND | | ND | ND | | | 40 |
| **Miscellaneous** | | | | | | | | | | |
| Ammonia-N | mg/L | 0.05 | | ND | | ND | 0.1 | | | ND |
| Boron | mg/L | 0.05 | | 0.08 | | ND | ND | | | ND |
| Chloramines | mg/L | 0.05 | | ND | 0.08 | 0.08 | ND | ND | ND | ND |
| Gross Alpha | pCi/L | | 15 | 4.70 +/- 2.20 | | 2.31 +/- 1.29 | 1.77 +/- 1.15 | | | 2.88 +/- 1.29 |
| Kjehldahl Nitrogen (Total) | mg/L | 0.5 | | ND | | 0.6 | ND | | | 0.8 |
| Methane | ug/L | 0.1 | | 0.92 | | 0.68 | 0.74 | | | ND |
| Nitrogen (Total) | mg/L | 0.5 | | ND | | 1.4 | ND | | | |
| o-Phosphate-P | mg/L | 0.05 | | 0.1 | | ND | ND | | | ND |
| Phosphorous (Total) | mg/L | 0.03 | | 0.11 | | 0.04 | 0.1 | | | 0.07 |
| Radium 226 | pCi/L | | 3 | 0.878 +/- 0.282 | | 0.164 +/- 0.170 | 0.044 +/- 0.104 | | | 0.050 +/- 0.120 |
| **Organic Analyses** | | | | | | | | | | |
| Haloacetic Acids (Total) | ug/L | 1.0 | 60.0 | 0.0 | 21.0 | 18.0 | 2.0 | 12.0 | 1.6 | 0.0 |
| *Dibromoacetic Acid* | *ug/L* | 1.0 | | *ND* | *2.0* | *2.0* | *ND* | *ND* | *ND* | *ND* |
| *Dichloroacetic Acid* | *ug/L* | 1.0 | | *ND* | *9.0* | *8.0* | *ND* | *3.0* | *1.6* | *ND* |
| *Monobromoacetic Acid* | *ug/L* | 1.0 | | *ND* | *ND* | *ND* | *ND* | *ND* | *ND* | *ND* |
| *Monochloroacetic Acid* | *ug/L* | 2.0 | | *ND* | *ND* | *ND* | *ND* | *ND* | *ND* | *ND* |
| *Trichloroacetic Acid* | *ug/L* | 1.0 | | *ND* | *10.0* | *8.0* | *2.0* | *9.0* | *ND* | *ND* |
| Organic Carbon (Dissolved) | mg/L | 0.2 | | 1.3 | | 1.3 | 1.4 | | | 1.8 |
| Organic Carbon (Total) | mg/L | 0.2 | | 1.0 | | 1.2 | 1.3 | | | 1.20 |
| Trihalomethanes (Total) | ug/L | 1.0 | 80.0 | 26.7 | 69.6 | 58.0 | 66.0 | 77.0 | **80.8** | 71.0 |
| *Bromodichloromethane* | *ug/L* | 0.5 | | *6.7* | *14.8* | *14* | *17* | *17* | *17* | *16* |
| *Bromoform* | *ug/L* | 0.5 | | *ND* | *1.2* | *1.0* | *1.0* | *ND* | *0.57* | *ND* |
| *Chloroform* | *ug/L* | 0.5 | | *16.9* | *45.6* | *35* | *39* | *52* | *57* | *50* |
| *Dibromochloromethane* | *ug/L* | 0.5 | | *3.1* | *8.0* | *8.0* | *9.0* | *8.0* | *6.2* | *5.0* |
| **Field Parameters** | | | | | | | | | | |
| Temperature | $^{0}$C | 0.1 | | 20 | 17.2 | 18.3 | 18.8 | 18.3 | 19.1 | 19.5 |
| Specific Conductance (EC) | uS | 1.0 | 900 | 741 | 469 | 444 | 426 | 433 | 426 | 475 |
| pH | Std Units | 0.1 | 6.5 - 8.5 | 7.0 | 7.5 | 7.5 | 7.3 | 7.5 | 7.4 | 7.27 |
| ORP | mV | 1.0 | | -164 | 35 | 688 | 265 | 178 | 55 | 91 |
| Free Chlorine Residual | mg/L | 0.1 | 2 - 5 | 0.2 | 0.37 | 0.21 | 0.1 | 0.43 | 0.29 | 0.39 |
| Dissolved Oxygen | mg/L | 0.01 | | 1.99 | 4.23 | 3.94 | 3.08 | 1.2 | 3.99 | 3.19 |
| Silt Density Index | Std Units | 0.1 | | | | | | | | |
| $H_2S$ | mg/L | 0.1 | | ND | ND | ND | ND | ND | ND | ND |

**Notes:**
Constituents exceeding MCLs denoted in **BOLD** type

## Table 17. Summary of WY 2017 Water Quality Data – SMS Deep

| Parameter | Unit | PQL | MCL | Results | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | SMS Deep | | | | |
| | | | | 1/18/17 | 4/11/17 | 7/18/17 | 9/18/17 | 10/2/17 |
| | | Sample Description | | WY 2017 Injection | | WY 2017 Storage | | |
| Elapsed Storage Time | Days | | | 0 | 0 | 49 | 111 | 125 |
| **Major Cations** | | | | | | | | |
| Calcium | mg/L | 0.5 | | 51 | 41 | | | 48 |
| Magnesium | mg/L | 0.5 | | 13 | 12 | | | 14 |
| Potasium | mg/L | 0.5 | | 3.3 | 2.7 | | | 3.2 |
| Sodium | mg/L | 0.5 | | 48 | 39 | | | 48 |
| **Major Anions** | | | | | | | | |
| Alkalinity, Total (as CaCO3) | mg/L | 2 | | 145 | 138 | | | 143 |
| Chloride | mg/L | 1 | 250 | 31 | 27 | | | 29 |
| Sulfate | mg/L | 1 | 250 | 82 | 66 | | | 70 |
| Nitrate (as NO3) | mg/L | 1 | 45 | ND | 1.0 | | | 0.3 |
| Nitrite (as NO2-N) | mg/L | 1 | 1 | ND | 0.5 | | | ND |
| **General Physical** | | | | | | | | |
| pH | Std Units | | | 7.7 | 7.6 | | | 7.7 |
| Specific Conductance (EC) | uS | 1 | 900 | 533 | 490 | | | 505 |
| Total Dissolved Solids | mg/L | 10 | 500 | 331 | 300 | | | 308 |
| **Metals** | | | | | | | | |
| Arsenic (Total) | ug/L | 1 | 10 | 1 | 1 | | | 6 |
| Barium (Total) | ug/L | 10 | 1000 | 45 | 43 | | | 56 |
| Iron (Dissolved) | ug/L | 10 | | ND | ND | | | ND |
| Iron (Total) | ug/L | 10 | 300 | ND | ND | | | ND |
| Lithium | ug/L | 1 | | 6 | 7 | | | 4 |
| Manganese (Dissolved) | ug/L | 10 | | ND | ND | | | ND |
| Manganese (Total) | ug/L | 10 | 50 | ND | ND | | | ND |
| Mercury | ug/L | 0.5 | 2 | ND | ND | | | ND |
| Molybdenum | ug/L | 1 | 1000 | 3 | 3 | | | 25 |
| Nickel | ug/L | 10 | 100 | ND | ND | | | ND |
| Selenium | ug/L | 2 | 50 | 2 | 2 | | | 4 |
| Strontium (Total) | ug/L | 5 | | 325 | 277 | | | 250 |
| Uranium (by ICP/MS) | ug/L | 1 | 30 | 1 | 1 | | | 1 |
| Vanadium (Total) | ug/L | 1 | 1000 | ND | ND | | | ND |
| Zinc (Total) | ug/L | 10 | 5000 | ND | 56 | | | 61 |
| **Miscellaneous** | | | | | | | | |
| Ammonia-N | mg/L | 0.05 | | ND | 0.05 | | | ND |
| Boron | mg/L | 0.05 | | ND | ND | | | ND |
| Chloramines | mg/L | 0.05 | | 0.19 | 0.14 | ND | ND | ND |
| Gross Alpha | pCi/L | | 15 | 2.84 +/- 1.45 | 2.20 +/- 1.33 | | | 1.80 +/- 1.09 |
| Kjehldahl Nitrogen (Total) | mg/L | 0.5 | | ND | 0.5 | | | ND |
| Methane | ug/L | 0.1 | | 0.60 | 1.3 | | | 0.39 |
| Nitrogen (Total) | mg/L | 0.5 | | ND | 1.3 | | | |
| o-Phosphate-P | mg/L | 0.05 | | 0.2 | 0.2 | | | ND |
| Phosphorous (Total) | mg/L | 0.03 | | 0.26 | 0.29 | | | 0.09 |
| Radium 226 | pCi/L | | 3 | 0.000 +/- 0.171 | 0.066 +/- 0.129 | | | 0.149 +/- 0.154 |
| **Organic Analyses** | | | | | | | | |
| Haloacetic Acids (Total) | ug/L | 1.0 | 60.0 | 16.0 | 11.0 | 12.0 | 3.0 | 6.0 |
| *Dibromoacetic Acid* | *ug/L* | 1.0 | | *2.0* | *2.0* | *ND* | *ND* | *ND* |
| *Dichloroacetic Acid* | *ug/L* | 1.0 | | *6.0* | *3.0* | *3.0* | *2.0* | *1.0* |
| *Monobromoacetic Acid* | *ug/L* | 1.0 | | *1.0* | *1.0* | *ND* | *ND* | *ND* |
| *Monochloroacetic Acid* | *ug/L* | 2.0 | | *ND* | *ND* | *ND* | *ND* | *ND* |
| *Trichloroacetic Acid* | *ug/L* | 1.0 | | 7.0 | 5.0 | 9.0 | 1.0 | 5 |
| Organic Carbon (Dissolved) | mg/L | 0.2 | | 1.6 | 1.4 | | | 1.7 |
| Organic Carbon (Total) | mg/L | 0.2 | | 1.5 | 1.4 | | | 1.3 |
| Trihalomethanes (Total) | ug/L | 1.0 | 80.0 | 41.0 | 27.0 | **81.0** | **81.0** | **86.0** |
| *Bromodichloromethane* | *ug/L* | 0.5 | | *13.5* | *9* | *21* | *24* | *22* |
| *Bromoform* | *ug/L* | 0.5 | | *1.2* | *ND* | *1.0* | *1.0* | *1.0* |
| *Chloroform* | *ug/L* | 0.5 | | *16.5* | *12* | *49* | *45* | *52* |
| *Dibromochloromethane* | *ug/L* | 0.5 | | *9.8* | *6* | *10* | *11* | *11* |
| **Field Parameters** | | | | | | | | |
| Temperature | °C | 0.1 | | 16.1 | 16.8 | 17.1 | 18.2 | 18.1 |
| Specific Conductance (EC) | uS | 1.0 | 900 | 490 | 429 | 437 | 447 | 444 |
| pH | Std Units | 0.1 | 6.5 - 8.5 | 7.5 | 7.7 | 7.3 | 7.3 | 7.1 |
| ORP | mV | 1.0 | | 637 | 731 | 166 | 217 | 148 |
| Free Chlorine Residual | mg/L | 0.1 | 2 - 5 | 1.4 | 0.94 | 0.4 | 0.27 | 0.41 |
| Dissolved Oxygen | mg/L | 0.01 | | 4.36 | 4.16 | 3.68 | 3.94 | 3.48 |
| Silt Density Index | Std Units | 0.1 | | | | | | |
| $H_2S$ | mg/L | 0.1 | | ND | ND | ND | ND | ND |

**Notes:**
Constituents exceeding MCLs denoted in **BOLD** type

- ASR-2: Two samples were collected from ASR-2; one after approximately 30 days and another after approximately 130 days of storage. Although some decline in THMs was observed during the period after the initial ingrowth, both samples exceeded the THM MCL with levels of 97 and 87 ug/L, respectively.
- ASR-3: One sample was collected from ASR-3 after approximately 30 days of storage, which showed significant ingrowth of THMs at 112 ug/L, exceeding the MCL of 80 ug/L. The pump was removed from ASR-3 in late September 2017 for well rehabilitation, and no additional samples were collected from this well during WY 2017.
- ASR-4: Two samples were collected from ASR-4; one after approximately 30 days and another after approximately 130 days of storage. The initial sample at 30 days showed significant ingrowth exceeding the THM MCL with a level of 98 ug/L, followed by more significant decline than observed at ASR-2 declining to below the MCL at a level of 59 ug/L.
- SM MW-1: Four samples were collected at SM MW-1 on an approximate monthly basis during the storage period, which showed steady ingrowth of THMs over a period of approximately 110 days reaching a level of 81 ug/L, followed a slight decline after 125 days of storage to a level of 71 ug/L.
- SMS Deep: Three samples were collected at SMS Deep during the storage period, which showed steady ingrowth of THMs over the period of 125 days reaching a level of 86 ug/L.

Historically, THMs at the ASR wells typically show an initial and significant ingrowth during the storage period, which is a result of free chlorine and trace levels of organic carbon in the injected water. THM ingrowth typically peaks in concentration approximately 60 to 120 days after the cessation of injection, followed by a gradual decline during the remainder of the storage period. After approximately 150 to 180 days of storage, THMs typically degrade to below the initial injection levels.

As discussed above, THMs during the WY 2017 storage period showed the above-described typical initial and significant ingrowth; however, their persistence this season differed from the typical pattern of significant degradation after several months of aquifer storage (with the possible exception of ASR-4). The lack of THM degradation observed during the WY 2017 storage period is likely attributable to the significantly greater volume and duration of injection, and the relatively short storage period, compared to previous years. Historically, THM degradation at ASR-1 appeared to have a direct relationship to intermixing with native ground waters, especially from gradient-induced mixing resulting from nearby pumping. Other ASR locations have postulated that changes in aquifer redox conditions and/or bioactivity from subsurface organisms such as Iron Dissimilatory Bacteria facilitate the degradation of the more robust THM compounds (i.e., chloroform and dichlorobromomethane). The large amount of recharge this season would thoroughly purge the proximate well bore areas with highly oxidized and oxygen-rich water, which would inhibit the above-noted degradation mechanisms; the persistence of elevated redox potential (ORP), dissolved oxygen levels, and measurable free chlorine residuals during this year's storage period confirm the persistence of this condition.

HAA levels at the wells (where sufficient data was collected) generally showed their typical pattern of limited (if any) ingrowth during the initial storage period, followed by complete to near-complete degradation by the end of the storage season. HAA's are much less stable compounds than THM's; their auto-degradation is therefore unremarkable.

**Water Quality at Off-Site Monitoring Wells**

Water-quality data collected from off-site wells in WY 2017 data are presented in **Table 18**. At PCA-E Deep, the absence of DBP's, in addition to an apparent increasing trend in chloride during the period, suggest that the influence of recharge operations is negligible to date at this location. Paralta is the nearest CAW production well to the ASR wells, and the available THM data show a potential trend of an increasing contribution of injected water quality over the WY 2017 storage season with levels increasing from 4 ug/L prior to the WY 2017 injection season to 15 ug/L near the end of the storage period. These levels are well below the MCL of 80 ug/L; however, the potential for an increasing trend in THMs at Paralta should be tracked during future ASR operations.

**Additional Water Quality Investigations**

As discussed in the WY 2015 Summary of Operations Report (SOR), at the commencement of WY 2013 recovery pumping of ASR-1, a sample collected by CAW[8] had a Mercury (Hg) concentration of 4 µg/L, exceeding the State MCL of 2 µg/L. Although the occurrence of Hg in surface water and groundwater has been documented elsewhere in the Monterey Bay region, the detection of Hg in SGB water was unusual. The initial Hg detection at ASR-1 was followed up with additional sampling to verify the presence of Hg, and the subsequent sampling identified detectable levels of Hg, although below the MCL. The fact that detectable Hg was identified, and at levels above historical NGW and injectate concentrations has led to the development of an ongoing investigation of Hg occurrence at the ASR wells.

As described in previous technical memoranda and reports regarding this issue, the origin of the detected Hg could be the result one or more mechanisms, including the following:

A. Soluble or insoluble Hg present in the Carmel River System source water that could have accumulated as particulate (insoluble) compounds in the well bore area, similar to the accumulation of other particulate matter present in the Carmel River injectate and CAW conveyance system. Such accumulation would be released during routine backflushing operations and/or early stages of stored water recovery operations.

[8] Collected on October 24, 2013.

## Table 18. Summary of WY 2017 Water Quality Data – Off-Site Monitoring Wells

| Parameter | Unit | PQL | MCL | Results | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | PCA-E Deep | | | Paralta | |
| | | | | 12/8/2016 | 4/10/2017 | 9/11/17 | 12/1/16 | 8/15/17 |
| | | ASR Operational Phase | | WY 2016 Storage | WY 2017 Injection | WY 2017 Storage | WY 2016 Storage | WY 2017 Storage |
| **Major Cations** | | | | | | | | |
| Calcium | mg/L | *0.5* | | 37 | 46 | 56 | 73 | 56 |
| Magnesium | mg/L | *0.5* | | 7 | 10 | 4.4 | 17 | 14 |
| Potasium | mg/L | *0.5* | | 3.5 | 4.4 | 4.4 | 4.7 | 4.1 |
| Sodium | mg/L | *0.5* | | 68 | 77 | 98 | 83 | 78 |
| **Major Anions** | | | | | | | | |
| Alkalinity, Total (as CaCO3) | mg/L | *2* | | 138 | 187 | 196 | 223 | 169 |
| Chloride | mg/L | *1* | *250* | 76 | 107 | 112 | 112 | 64 |
| Sulfate | mg/L | *1* | *250* | 22 | 31 | 32 | 66 | 71 |
| Nitrate (as NO3) | mg/L | *1* | *45* | ND | ND | ND | 3 | 1 |
| Nitrite (as NO2-N) | mg/L | *1* | *1* | 0.2 | ND | ND | 0.3 | ND |
| **General Physical** | | | | | | | | |
| pH | Std Units | | | 7.6 | 7.4 | 7.3 | 7.3 | 7.4 |
| Specific Conductance (EC) | uS | *1* | *900* | 578 | 760 | 764 | **912** | 652 |
| Total Dissolved Solids | mg/L | *10* | *500* | 291 | 440 | 463 | **557** | 403 |
| **Metals** | | | | | | | | |
| Arsenic (Total) | ug/L | *1* | *10* | 7 | 7 | 7 | 3 | 3 |
| Barium (Total) | ug/L | *10* | *1000* | 64 | 86 | 99 | 64 | 43 |
| Iron (Dissolved) | ug/L | *10* | | ND | ND | ND | 20 | 11 |
| Iron (Total) | ug/L | *10* | *300* | ND | 35 | 54 | 24 | ND |
| Lithium | ug/L | *1* | | 21 | 33 | 37 | 30 | 22 |
| Manganese (Dissolved) | ug/L | *10* | | ND | 121 | 157 | 30 | 11 |
| Manganese (Total) | ug/L | *10* | *50* | ND | 124 | 150 | 28 | 11 |
| Mercury | ug/L | *0.5* | *2* | ND | ND | ND | | ND |
| Molybdenum | ug/L | *1* | *1000* | 10 | 10 | 9 | 12 | 26 |
| Nickel | ug/L | *10* | *100* | 26 | ND | 4 | ND | ND |
| Selenium | ug/L | *2* | *50* | ND | ND | 1 | 2 | 2 |
| Strontium (Total) | ug/L | *5* | | 206 | 319 | 281 | 379 | 252 |
| Uranium (by ICP/MS) | ug/L | *1* | *30* | ND | ND | ND | 1 | 1 |
| Vanadium (Total) | ug/L | *1* | *1000* | ND | ND | ND | 5 | ND |
| Zinc (Total) | ug/L | *10* | *5000* | 24 | 27 | ND | ND | ND |
| **Miscellaneous** | | | | | | | | |
| Ammonia-N | mg/L | *0.05* | | ND | ND | ND | 0.1 | ND |
| Boron | mg/L | *0.05* | | 0.07 | 0.09 | 0.10 | 0.10 | 0.07 |
| Chloramines | mg/L | *0.05* | | ND | ND | ND | ND | ND |
| Gross Alpha | pCi/L | | *15* | 0.489 +/- 1.42 | 1.38 +/- 1.51 | 0.986 +/- 1.93 | 7.19 +/- 2.50 | 3.77 +/- 1.77 |
| Kjehldahl Nitrogen (Total) | mg/L | *0.5* | | ND | ND | ND | 1.2 | ND |
| Methane | ug/L | *0.1* | | ND | 2.2 | 2.8 | 3.7 | 1.6 |
| Nitrogen (Total) | mg/L | *0.5* | | ND | ND | ND | 1.7 | ND |
| o-Phosphate-P | mg/L | *0.05* | | ND | ND | | 0.2 | ND |
| Phosphorous (Total) | mg/L | *0.03* | | 0.03 | 0.05 | 0.02 | 0.03 | 0.02 |
| Radium 226 | pCi/L | | *3* | 0.050 +/- 0.120 | 0.164 +/- 0.170 | 0.56 +/- 0.134 | 1.39 +/- 0.349 | 0.978 +/- 0.285 |
| **Organic Analyses** | | | | | | | | |
| Haloacetic Acids (Total) | ug/L | *1.0* | *60.0* | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| *Dibromoacetic Acid* | *ug/L* | *1.0* | | *ND* | *ND* | *ND* | *ND* | *ND* |
| *Dichloroacetic Acid* | *ug/L* | *1.0* | | *ND* | *ND* | *ND* | *ND* | *ND* |
| *Monobromoacetic Acid* | *ug/L* | *1.0* | | *ND* | *ND* | *ND* | *ND* | *ND* |
| *Monochloroacetic Acid* | *ug/L* | *2.0* | | *ND* | *ND* | *ND* | *ND* | *ND* |
| *Trichloroacetic Acid* | *ug/L* | *1.0* | | *ND* | *ND* | *ND* | *ND* | *ND* |
| Organic Carbon (Dissolved) | mg/L | *0.2* | | 0.7 | 0.5 | 0.6 | 1.0 | 1.1 |
| Organic Carbon (Total) | mg/L | *0.2* | | 0.8 | 0.5 | 0.6 | 1.0 | 1.0 |
| Trihalomethanes (Total) | ug/L | *1.0* | *80.0* | 0.0 | 0.0 | 0.0 | 4.3 | 15.0 |
| *Bromodichloromethane* | *ug/L* | *0.5* | | *ND* | *ND* | *ND* | *0.6* | *3.0* |
| *Bromoform* | *ug/L* | *0.5* | | *ND* | *ND* | *ND* | *ND* | *ND* |
| *Chloroform* | *ug/L* | *0.5* | | *ND* | *ND* | *ND* | *3.7* | *12.0* |
| *Dibromochloromethane* | *ug/L* | *0.5* | | *ND* | *ND* | *ND* | *ND* | *ND* |
| **Field Parameters** | | | | | | | | |
| Temperature | $^{0}$ C | *0.1* | | 27.7 | 27.1 | 28.8 | 24.5 | 22 |
| Specific Conductance (EC) | uS | *1.0* | *900* | 554 | 525 | 660 | 785 | 455 |
| pH | Std Units | *0.1* | *6.5 - 8.5* | 7.5 | 7.7 | 7.4 | 7.2 | 7.4 |
| ORP | mV | *1.0* | | 68 | 75 | -64 | -211 | -47 |
| Free Chlorine Residual | mg/L | *0.1* | *2 - 5* | ND | ND | ND | 0.2 | 0.27 |
| Dissolved Oxygen | mg/L | *0.01* | | | 0.46 | 0.55 | 2 | 6.14 |
| Silt Density Index | Std Units | *0.1* | | | | | | |
| $H_2S$ | mg/L | *0.1* | | ND | ND | ND | | ND |

**Notes:**
Constituents exceeding MCLs denoted in **BOLD** type

B. Solubilization of naturally occurring Hg minerals present in the Tsm geologic matrix, which could result from geochemical interactions between the injection source water, NGW and aquifer minerals.

C. Mobilization of insoluble (i.e., particulate) Hg from the Tsm matrix via the dissolution of cementitous materials and subsequent migration of particulate Hg compounds during recovery/pumping operations.

D. Other anthropogenic sources of Hg in well components or other off-site sources.

During WY 2016, a Supplemental Sampling and Analysis Plan[9] (SSAP) was developed for additional investigation of the Hg occurrence. In addition to the collection of Hg samples utilizing a variety of EPA-approved laboratory methods and detections limits, the suite of analytes included a variety of constituents that are known to affect (or directly react with) Hg and/or Hg compounds. The sampling performed during WY 2016 resulted in the following preliminary findings:

- The ASR wells showed Hg levels below MCL's, but there was also a positive correlation between declining turbidity and decreasing Hg levels as the duration of pumping increased during well backflushing operations.
- Injection source waters from the Begonia Iron Removal Plant (BIRP) indicated detectable Hg levels in the raw well water plant influent and in the finished product water; however, the Hg levels were all far below MCL's, and even below the detection limits of conventional EPA 200.8 analysis methods, with the Hg detections at sub-parts-per-trillion levels.

The data collected during WY 2016 suggested that there was a meaningful correlation between Hg content, Turbidity, and pumping time in the produced water from ASR-1. The possible explanation for this phenomenon is that the trace-level Hg present in the Carmel River System injection source waters was accumulating in the near-well-bore area during injection operations, and then released when reverse flows associated with backflushing or recovery operations occurred (per hypothesis (A) above).

Because the occurrence of elevated Hg levels in ASR-1 appeared to be directly correlated to elevated turbidity levels in initial well flush waters, a revised protocol consisting of a new triple-surge well flushing procedure (refer to the WY 2016 SOR for details) was recommended for all regular and special operations in WY 2017. The addition of an on-line Turbidity analyzer at ASR-1 was also recommended to serve as a safeguard against the possible conveyance of turbid (and potentially Hg-noncompliant) waters into the distribution system during ASR recovery (ie production) operations.

**WY 2017 Investigation.** The Hg occurrence investigation continued in WY 2017 and consisted of the following activities:

[9] Dated September 4, 2015

- Collection of high-frequency (daily) samples of injectate during the Injection Season to monitor for the presence / absence of Hg in the injected water.
- Performance of 1-hr Cycle Tests for the collection of additional Hg data from all four of the ASR wells.
- Collection of water quality data on a monthly basis from all 4 ASR wells during the storage period to assess time- and mixing-dependant effects on the occurrence of Hg.
- "Breakthrough" sampling at ASR-4 to detect the arrival of the ASR-3 injection front and monitor for associated changes in Hg concentrations.
- Collection of ASR well backflush residue samples for evaluation by a specialty lab to establish if the samples have sufficient quantities of Hg-bearing particulates for further analysis via specialty analytical laboratory methods to determine the precise identification of Hg-bearing particulates (i.e., molecular composition and structure) to facilitate refined geochemical modeling to provide an improved understanding of the geochemical mechanism(s) responsible for Hg-occurrence.

The results to date of the WY 2017 Hg investigation activities are summarized below:

<u>High-Frequency Injectate Sampling.</u> High frequency sampling of the injectate during WY 2017 was performed to detect the presence of Hg in the injection source water. High frequency composite sampling of the injectate was performed to detect if high flows in the Carmel River Watershed was causing episodic releases of Hg into the river system from soil runoff in the watershed and/or stirring up sediments in the reservoir(s) or floodplains. It was assumed that if Hg was being released from the Carmel River System, the events would occur over several consecutive days when the river flows were high and sediments were being transported. Due to the assumed timing of the hypothetical Hg release mechanism, daily composite samples were used to detect if the events were occurring.

Composite samples of injectate were collected at the ASR-2 wellhead every day the project was operated in injection mode. An automated ISCO sampler was plumbed to the sample port at the ASR-2 wellhead and was programmed to pull 50 ml of water from the injectate stream at a 30-minute sample interval. An aliquot of the water collected by the ISCO was collected by operations staff and sent to the lab at roughly 24-hour intervals. A record of when the samples were collected and what time-period each of the samples represent is included in this report as **Appendix C** (not included in draft). In addition, a record of which Carmel River System wells were producing water to the CAW system was kept in case there was a Hg detection in the injectate. The Carmel Valley production records are also presented in **Appendix C** (not included in draft).

Over the WY 2017 project operation, no Hg was detected in any of the daily composite samples, indicating that the Carmel River System is likely not a source of Hg at the ASR wells as postulated in (A) above. Because no Hg was detected during this WY 2017 sampling, the District does not intend to continue composite sampling of injectate in future operational years.

1-Hr Cycle Testing. Additional Hg sampling and analysis was performed at ASR-2, and ASR-3 and ASR-4 during WY 2017 (prior to the injection season) as part of the expansion of the Hg occurrence investigation beyond ASR-1 to the other ASR project wells. The sampling consisted of 1-hr "Cycle Tests", similar to the sampling that has been conducted at ASR-1 previously, where samples were collected from each well at elapsed pumping/purge times of 0 (initial casing flush water), 1, 2, 5, 10, 30 and 60 mins. The results are summarized in **Table 19** below:

**Table 19. Hg "Cycle Test" Data Summary**

| Well | Sample Date | Cl- (mg/L) | % NGW[1] | Purge ET (mins) vs. Hg (ug/L)[2] | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 0 | 1 | 2 | 5 | 10 | 30 | 60 |
| ASR-2 | 11/3/2016 | 92 | 61 | 1.8 | 0.67 | 0.23 | 1.1 | **2.1** | **2.5** | **2.5** |
| | 12/6/2016 | 102 | 72 | 0.28 | 1.8 | 0.23 | 0.78 | **2.4** | **2.5** | **2.6** |
| ASR-3 | 11/1/2016 | 75 | 45 | 0.01 | 0.01 | 1.5 | 0.01 | 1.3 | 1.4 | 1.5 |
| | 12/9/2016 | 87 | 58 | 1.5 | 0.35 | 0.2 | 0.19 | 1.1 | 1.5 | 1.5 |
| ASR-4 | 11/1/2016 | 91 | 61 | **4.5** | 0.01 | 0.67 | 0.33 | 0.17 | 0.4 | 0.36 |
| | 12/9/2016 | 92 | 61 | **2.4** | 0.17 | 0.58 | 0.19 | 0.22 | 0.38 | 0.27 |

**Notes:**
Constituents exceeding MCLs denoted in **BOLD** type
1 - Percent of native groundwater (NGW) in based on Chloride (Cl-) data.
2 - Unfiltered EPA Method 200.8

The cycle test data did not show a correlation between Turbidity and Hg level as noted above during the 2016 testing program. This may be a result of the very low turbidities encountered throughout ASR operations during the 2017 year; it is possible that the Turbidity:Hg correlation is applicable only when there are substantial turbidity spikes at the wells. Because Turbidity is an indirect measurement of particulate matter in water, the correlation between possible Hg occurrence and higher Tu values would appear to be valid, at least at relatively high values, as detected occurrences of Hg have historically been predominantly in an insoluble (particulate) form.

Further analysis of the dataset does, however, suggest that the presence of Hg may have a correlation with the amount of mixing between injected and native ground waters; the magnitude of mixing is presented above in **Table 19** as a percent of NGW in the samples collected based on Chloride ion measurements. While the theory of possible Hg accumulation around the well bore opined in 2016 is not supported by the 2017 test data, the hypothesis of Hg solubilization and/or dissolution from the Tsm matrix (per (B) and (C) above) may still have merit. The data also indicate that during these testing sessions there were occasional occurrences of Hg above the EPA MCL of 2.0 ug/L. These occurrences were the only detections of Hg during WY 2017 that exceeded drinking water standards, and they occurred only at the ASR-2 and ASR-4 wells, which are not currently connected to pump recovery water into the CAW system. Although these samples were not collected during actual production operations, the data illustrate two important issues: (1) the implementation of mandatory flushing of any ASR wells before commencement of production into the Cal-Am potable system is still warranted; and (2) the ASR-2 exceedances occurred when the aquifer conditions contained predominantly older NGW that would be on the outer fringe of the recharge boundary.

Monthly Storage Testing. As described above, supplemental sampling was performed at the wells on a monthly basis during the aquifer storage period. The wells were flushed to waste and samples were collected at 4- and 20-minutes, with laboratory analyses for Hg, Cl- (as an indicator of the percentage of mixing with native ground waters), and a variety of divalent metal ions which are characteristically associated with Hg mineral chemistry – especially Copper (Cu) and Zinc (Zn) ion. The data collected indicated several trends which appear to support the hypothetical mechanisms of solubilization or dissolution of Hg from Tsm aquifer minerals ((B) and (C) above) based on the following:

- In all sample events, the (minor) increase in Cl levels indicated increased mixing of injected and native ground waters over time for all wells.
- In most cases, Hg levels increased over time, although in no cases were Hg levels detected at or above Drinking Water Standards.
- In most cases, concentrations of Copper ion (Cu) showed a corresponding increase in concentration when Hg levels increased.

ASR-4 was especially characteristic in this trend, as presented in **Figure 29**. Additional sampling under this protocol is warranted to further evaluate these relationships, as well as re-assessment of historical data, if available, to further confirm these trends.

"Breakthrough" Sampling at ASR-4. Because solubilization of naturally occurring Hg present in the Tsm minerals resulting from geochemical interactions between the injection source water, NGW, and aquifer minerals was identified as one potential mechanism for the Hg occurrences, sampling for Hg was performed at ASR-4 in an effort to observe the arrival of the ASR-3 injection front and any associated changes in Hg concentrations that could be attributable to solubilization and mobilization of naturally occurring Hg present in Tsm minerals.

ASR-3 began essentially continuous injection on January 4, 2017 (there was some minor intermittent injection at this well during the period December 17 and 21, 2016). First arrival time of ASR-3 injectate at ASR-4 was roughly estimated at approximately 30 days[10]. Chloride concentrations were intermittently monitored at ASR-4 to detect the arrival of ASR-3 injectate (the pre-injection groundwater concentration of chloride was approximately 120 mg/L, whereas the average injectate Cl- concentration was approximately 30 mg/L), after which samples were collected for Hg analysis.

The collected data are graphically presented on **Figure 30**. As shown, the chloride concentration at ASR-4 was observed to gradually decline as injectate from ASR-3 began to arrive. Samples were collected from ASR-4 for Hg analysis on March 7 and 15, 2017 (approximately 60 and 70 days after ASR-3 began injecting), with resulting Hg concentrations of 0.14 and 0.12 ug/L, respectively, which were significantly less than the pre-injection

[10] Based on the Calculated Fixed Radius (CFR) equation and an average ASR-3 injection rate of 1,000 gpm.

concentration of Hg (by as much as 0.40 ug/L). These observations suggest that injection at ASR-3 and the subsequent influx of Carmel River injected waters did not result in the direct/immediate solubilization and mobilization of Hg that would impact ASR-4. This is an important finding, but it does not rule out the solubilization or dissolution/mobilization mechanisms postulated in (B and (C) above; rather it demonstrates only that the geochemical processes may not be immediate.

Injection operations were subsequently initiated at ASR-4 on April 5, 2017. Samples were collected following backflushing of ASR-4 after an 8-hr Step-Rate Injection Test (April 5 and 6, 2017) for Hg analysis. As shown on **Figure 30**, the Hg concentration at ASR-4 was observed to essentially double compared to the pre-injection baseline, with both samples at concentrations of 0.80 ug/L. Although these concentrations are below the MCL of 2.0 ug/L, these observations suggest that the initial injection at ASR-4 in WY 2017 may have resulted in solubilization or dissolution of Hg from the Tsm mineralogy. This data warrants further geochemical assessment.

Further review of **Figure 30** shows that as injection at ASR-4 continued, and then into the storage period, samples collected from the well began to display essentially the pure Carmel River injectate concentrations of chloride and Hg, reflecting the essentially complete displacement of NGW from ASR-4 during WY 2017. Again, the return of Hg levels to background level further support the displacement mechanism.

Backflush Residue Sampling. A critical factor in the assessment of the occurrence of Hg and determination of the cause(s) and mitigation of the occurrences is to establish the geochemical mechanism(s) associated with the reactions. Although the investigation thus far has been successful in establishing the presence and quantification of the levels of Hg during the various operations of the ASR program, the precise speciation of the original Hg compounds has not been achieved. The reason for this is a result of the exceptionally low levels of Hg mineral occurrence and the lack of sufficiently large quantities of mineral samples for analysis.

In an effort to obtain solid residue samples of Hg-containing materials, the WY 2017 investigation focused on the capture of granular materials ejected from the wells during routine backflush operations. The technique utilized involved the routing of a slipstream of water from each well during the first minutes of backflushing into a clean 100-gallon Nalgene container; the flush water is then isolated and allowed to settle for several days, after which the supernatant water is decanted, and the granular sludge materials are captured and isolated for laboratory analysis. The sludge samples typically amount to less than 10 grams of material and are first analyzed for total Hg content to determine their suitability for further Hg speciation analyses. Current mineralogical analysis techniques are, however, limited to detection thresholds of >10-20 mg/kg levels for Hg compounds.

A total of 6 sludge samples were collected during WY 2017; 2 each from the ASR-2, -3, and -4 wells (no samples were able to be collected from ASR-1 due to mechanical problems at this well). The results ranged from a low of 1.4 mg/kg at ASR-3 to a high of only 11 mg/kg at ASR-4. The full analytic laboratory results are provided in **Appendix D** (not included in draft report). Note that in all sludge sampling cases, the supernatant was analyzed after separation and Hg levels were essentially non-detect.

Unfortunately, none of the WY 2017 collected samples had a high enough concentration of Hg to warrant additional speciation analysis. It is recommended that this program be continued in WY 2018 in the hopes of obtaining a sample with a sufficiently high Hg concentration for speciation analysis.

Another alternative for obtaining granular solids samples for mineralogical analysis is the collection of cuttings from other proximate wells soon to be drilled through the Tsm formation; such samples can be obtained in large quantities, and therefore easily analyzed for bulk Hg concentrations. If the initial screening analysis for Hg is sufficiently high, additional samples can be speciated. It is our understanding that this work can be implemented in Summer 2018.

**Next Steps.** The investigation of the occurrence of Hg has not yet sufficiently identified the source(s), mechanism(s), and potential mitigations for this issue, and it is therefore recommended that investigation be continued during the WY 2018 program. Based on the previous work and the information gleaned from the current study, we recommend the following activities be implemented during WY2018:

1. The water quality program outlined in the SSAP, specifically the collection of monthly 4- and 20-minute samples from each of the four ASR wells, should be continued for WY 2018.
2. Collection and screening analysis of Tsm cuttings from upcoming proximate wells should be implemented, with subsequent speciation analyses performed on samples with Hg concentrations > 20 mg/kg.
3. Geochemical interaction modeling of the ASR program should be performed in the event that mineralized Hg compounds can be positively identified or inferred from other sources.
4. If possible, perform extended pumping tests of ASR-2 and ASR-4 with SSAP analytic parameters analyses to assess the long-term water quality trends at these wells.

These recommended next steps are intended to facilitate long-term operational improvement considerations for the Aquifer Storage and Recovery program. As the Hg investigation continues, additional findings, conclusions, and recommendations will be documented in the WY 2018 SOR to facilitate ongoing operation of the ASR project.

## CONCLUSIONS

Based on the findings developed from operation of Monterey Peninsula ASR Project during WY 2017, we conclude the following:

### WY 2017 Recharge Operations

WY 2017 was classified as an Extremely Wet Water Year on the Monterey Peninsula and a total volume of 2,345 af of water was recharged into the Seaside Groundwater Basin at the Santa Margarita and Seaside Middle Schools ASR Facilities during the WY 2016 injection season.

### ASR Well Performance

**ASR-1.** Pertinent well performance conclusions for ASR-1 during WY 2017 are summarized below:

- Injection Rates: Ranged between approximately 270 to 1870 gpm, averaging approximately 1,435 gpm.
- Water Levels: Consistently less than 260 ft. bgs prior to backflushing, exceeding the recommended maximum drawup level of 100 ft.
- Specific Injectivity: Ranged between approximately 21 to 25 gpm/ft with an overall negative trend in 24-hr specific injectivity.
- Residual Plugging: Approximately 21 feet of residual plugging occurred.
- General Conclusions: ASR-1 performed well during WY 2017; however, the well did experience a moderate level residual plugging. The negative trend in performance at injection rates ranging up to 1,870 gpm suggests the injection rate at this well should be maintained at or below the design rate of 1,500 gpm in WY 2018.

**ASR-2.** Pertinent well performance conclusions for ASR-2 during WY 2017 are summarized below:

- Injection Rates: Ranged between approximately 340 to 1,940 gpm, averaging approximately 1,450 gpm.
- Water Levels: Consistently less than 250 ft. bgs prior to backflushing, exceeding the recommended maximum drawup level of 130 ft.
- Specific Injectivity: Ranged between approximately 30 to 34 gpm/ft with an overall negative trend in 24-hr specific injectivity.
- Residual Plugging: Approximately 23 feet of residual plugging occurred.

- General Conclusions: ASR-2 performed well during WY 2017; however, the well did experience a moderate level residual plugging. The negative trend in performance at injection rates ranging up to 1,940 gpm suggests the injection rate at this well should be maintained at or below the design rate of 1,500 gpm in WY 2018.

**ASR-3.** Pertinent well performance conclusions for ASR-3 during WY 2017 are summarized below:

- Injection Rates: Ranged between approximately 600 to 1,405 gpm, averaging approximately 995 gpm.

- Water Levels: Consistently less than 190 ft. bgs prior to backflushing, exceeding the recommended maximum drawup level of 170 ft.

- Specific Injectivity: Ranged between approximately 8.7 to 9.4 gpm/ft and overall stable trend in 24-hr specific injectivity.

- Residual Plugging: Approximately 36 feet of residual plugging occurred.

- General Conclusions: ASR-3 performance appeared to be relatively stable compared to the significant declines observed in WY 2012. The pattern of relative performance stabilization followed by the initial significant decline in well performance observed at ASR-3 is very similar to the pattern observed at both ASR-1 and ASR-2 when they were initially brought on-line. The stable performance at injection rates ranging between 700 to 1,010 gpm suggests the injection rate should be maintained at or below 1,000 gpm to maintain performance until the well is rehabilitated (planned for WY 2018).

**ASR-4.** Pertinent well performance conclusions for ASR-4 during WY 2017 are summarized below:

- Injection Rates: Ranged between approximately 140 to 1,860 gpm, averaging approximately 1,260 gpm.

- Water Levels: Generally maintained greater than 160 ft bgs, with approximately 50 feet of available "freeboard" remaining below the maximum recommended drawup level (when operated at the design injection rate of 1,500 gpm)

- Specific Injectivity: Ranged between approximately 16 to 26 gpm/ft with an overall increasing trend in 24-hr specific injectivity over the course of the injection season.

- Residual Plugging: Approximately 36 feet of residual plugging occurred.

- General Conclusions: ASR-4 performance appeared to decline significantly following the initial 8-hr step-rate injection test, then stabilize and actually increase during the course of the injection season, whereas the pumping performance decreased over the course of the injection season. At this time, it is unclear why this well displayed apparent contradictory performance during WY 2017. Accordingly, these observations suggest the injection rate should be maintained at or below the design rate of 1,500 gpm until the performance trends at this well can be evaluated more fully in WY 2018.

**Water Quality**

Significant conclusions regarding the water-quality investigation during WY 2017 include the following:

- Consistent with previous observations, no significant ion exchange, acid-base, or precipitation reactions were observed at the ASR sites.
- THMs during the WY 2017 storage period showed the typical initial and significant ingrowth; however, they differed from the typical pattern in that significant degradation of THMs was not observed during the storage period at most wells (with the possible exception of ASR-4). The lack of THM degradation observed during the WY 2017 storage period is attributable the significantly greater volume and duration of injection, and the relatively short storage period, compared to previous years.
- HAAs at the wells with sufficient data generally showed their typical pattern of limited (if any) ingrowth during the initial storage period, followed by complete to near-complete degradation by the end of the storage season.
- The investigation of sporadic occurrences of Hg in the various wells has not conclusively identified the origins and mechanisms of the process to date; however, the following conclusions were developed based on the current years' data:
    - High frequency source sampling of Carmel River waters established that the river does not appear to be the source of Hg at the wells.
    - Source water Hg levels were all below detection limits.
    - In contrast to earlier data, Hg occurrences in WY 2017 generally consisted of soluble Hg rather than Insoluble (particulate) Hg; this was particularly evident in ASR- 2 and ASR-3; whereas ASR-4 Hg occurrences were approximately 1:1 in soluble:insoluble speciation.
    - A trend was observed in increasing Hg levels over time during aquifer storage, and a corresponding increase in the presence of Cu ion. This may represent a possible geochemical reaction mechanism related to the solubilization of Hg from Tsm minerals.

## RECOMMENDATIONS

Based on the WY 2017 ASR program results and our experience with similar ASR projects, we offer the following recommendations for continued and future operations of the Monterey Peninsula ASR Project wells:

### ASR-1 Well Operational Parameters

- Injection Rate: Based on the amount of residual plugging that occurred during WY 2017 with the well injecting up to 1,870 gpm, we recommend the injection rate be limited to approximately **1,500 gpm or less** in order to limit residual plugging and maintain long-term performance.
- Water-Level Drawup: Under the present local water-level conditions, the amount of water-level drawup should be limited to approximately 100 feet. This amount of water-level drawup during injection equals the typical available drawdown in the well for backflushing. This helps to avoid over-pressurization and compression of plugging materials, thereby maximizing the efficiency of backflushing and limiting the amount of residual plugging. Furthermore, the drawup calculation should not be adjusted during the injection based on apparent changes in the static water level, and injection water levels should be maintained **greater than 260 feet bgs** at all times.
- Backflushing Frequency: During the recharge season, routine backflushing should continue to be performed on an approximate weekly basis, or when the amount of water-level drawup in the casing reaches a depth to water level of approximately **260 feet bgs**, whichever occurs first. Backflushing should consist of the triple-flush procedure initiated in WY 2017.

### ASR-2 Well Operational Parameters

- Injection Rate: Based on the amount of residual plugging that occurred during WY 2017 with the well injecting up to 1,945 gpm, we recommend the injection rate be limited to the design rate of approximately **1,500 gpm or less** in order to limit residual plugging and maintain long-term performance.
- Water-Level Drawup: Under the present local water-level conditions, the amount of water-level drawup should be limited to approximately 130 feet, which is equal to the typical amount of available drawdown in the well for backflushing. Again, this helps to avoid over-pressurization and compression of plugging materials and limiting the amount of residual plugging. Furthermore, the drawup calculation should not be adjusted during the injection based on apparent changes in the static water level, and injection water levels should be maintained **greater than 250 feet bgs** at all times.
- Backflushing Frequency: During the recharge season, routine backflushing should continue to be performed on an approximate weekly basis, or when the amount of

water-level drawup in the casing reaches a depth to water level of approximately **250 feet bgs**, whichever occurs first. Backflushing should consist of the triple-flush procedure initiated in WY 2017.

**ASR-3 Well Operational Parameters**

- Injection Rate: Based on the amount of residual plugging that occurred during WY 2017 with the well injecting up to 1,405 gpm, we recommend the injection rate continue to be limited to **1,000 gpm** in order to limit residual plugging and maintain long-term performance.
- Water-Level Drawup: Under the present local water-level conditions, the amount of water-level drawup should be limited to approximately 170 feet, which is equal to the typical amount of available drawdown in the well for backflushing. Again, this helps to avoid over-pressurization and compression of plugging materials and limiting the amount of residual plugging. Furthermore, the drawup calculation should not be adjusted during the injection based on apparent changes in the static water level, and injection water levels should be maintained **greater than 190 feet bgs** at all times.
- Backflushing Frequency: During the recharge season, routine backflushing should continue to be performed on an approximate weekly basis, or when the amount of water-level drawup in the casing reaches a depth to water level of approximately **190 feet bgs**, whichever occurs first. Backflushing should consist of the triple-flush procedure initiated in WY 2017.

ASR-3 should undergo formal rehabilitation to improve well performance and injection capacity, similar to that performed at ASR-1 and ASR-2. It is believed that following rehabilitation, the well will be able to operate at its design injection rate of 1,500 gpm (i.e., 50 percent greater than the current capacity of 1,000 gpm).

**ASR-4 Well Operational Parameters**

- Injection Rate: Based on the amount of residual plugging that occurred during WY 2017 with the well injecting up to 1,590 gpm, we recommend the injection rate be limited to the design rate of approximately **1,500 gpm or less** in order to limit residual plugging and maintain long-term performance.
- Water-Level Drawup: Under the present local water-level conditions, the amount of water-level drawup should be limited to approximately 200 feet, which is equal to the typical amount of available drawdown in the well for backflushing. Again, this helps to avoid over-pressurization and compression of plugging materials and limiting the amount of residual plugging. Furthermore, the drawup calculation should not be adjusted during the injection based on apparent changes in the static water level, and injection water levels should be maintained **greater than 160 feet bgs** at all times.

- Backflushing Frequency: During the recharge season, routine backflushing should continue to be performed on an approximate weekly basis, or when the amount of water-level drawup in the casing reaches a depth to water level of approximately **160 feet bgs**, whichever occurs first. Backflushing should consist of the triple-flush procedure initiated in WY 2017.

**Supplemental Water Quality Investigations**

1. The water quality program outlined in the SSAP, specifically the collection of monthly 4- and 20-minute samples from each of the four ASR wells, should be continued for WY 2018.
2. Collection and screening analysis of Tsm cuttings from upcoming proximate wells should be implemented, with subsequent speciation analyses performed on samples with Hg concentrations > 20 mg/kg.
3. Geochemical interaction modeling of the ASR program should be performed in the event that mineralized Hg compounds can be positively identified or inferred from other sources.
4. Data from the ASR-4 baseline injection testing should be further analyzed via geochemical modeling to evaluate the possible mechanism(s) associated with the anomalous spike in Hg immediately after initial injection testing.
5. If possible, perform extended pumping tests of ASR-2 and ASR-4 with SSAP analytic parameters analyses to assess the long-term water quality trends at these wells.

## CLOSURE

This report has been prepared exclusively for the Monterey Peninsula Water Management District for the specific application to the ASR Project on the Monterey Peninsula. The findings and conclusions presented herein were prepared in accordance with generally accepted hydrogeologic and engineering practices. No other warranty, express or implied, is made.

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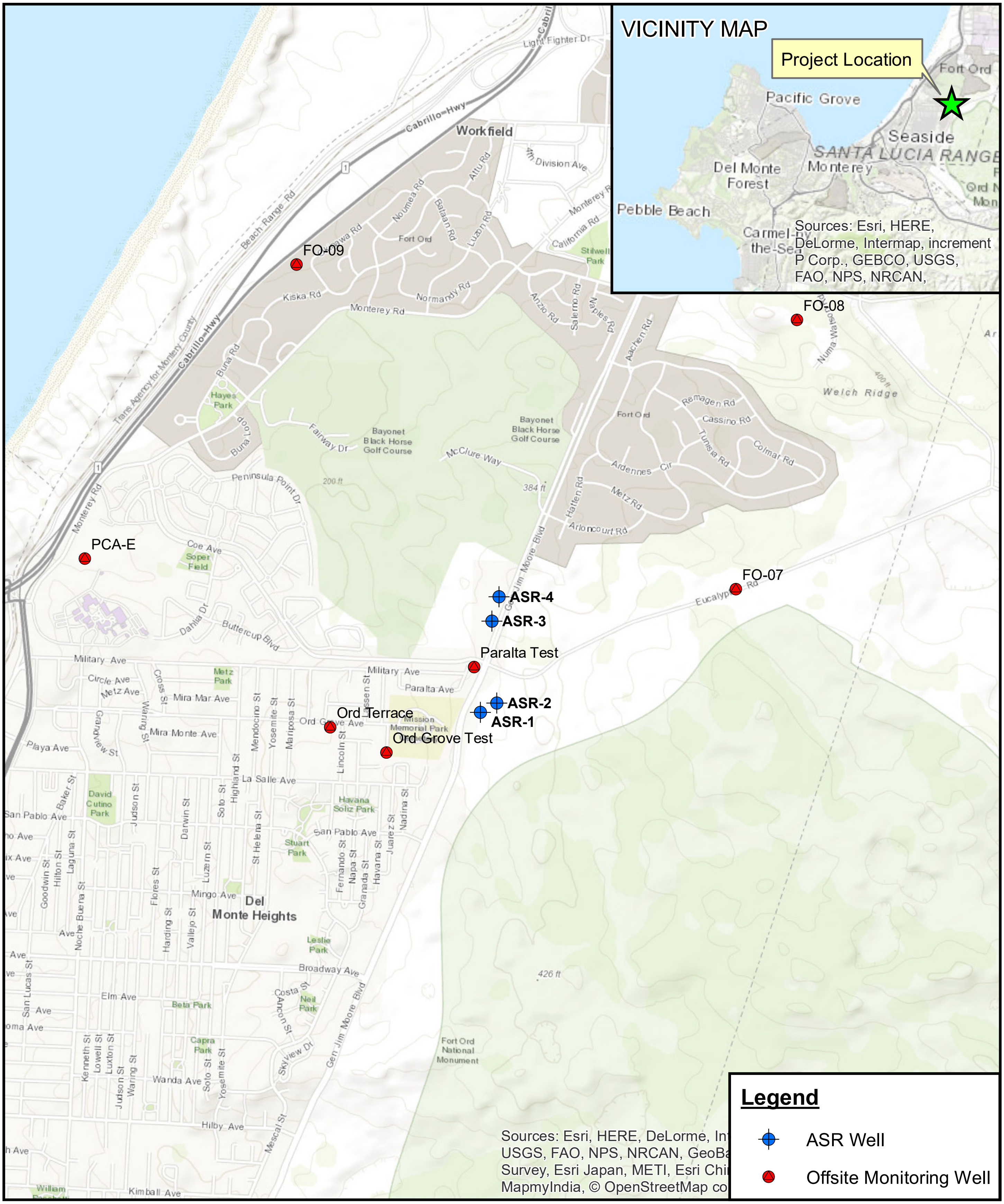
**EXHIBIT 8-A**

# FIGURES

June 2018
Project No. 12-0049

# EXHIBIT 8-A




PUEBLO water resources

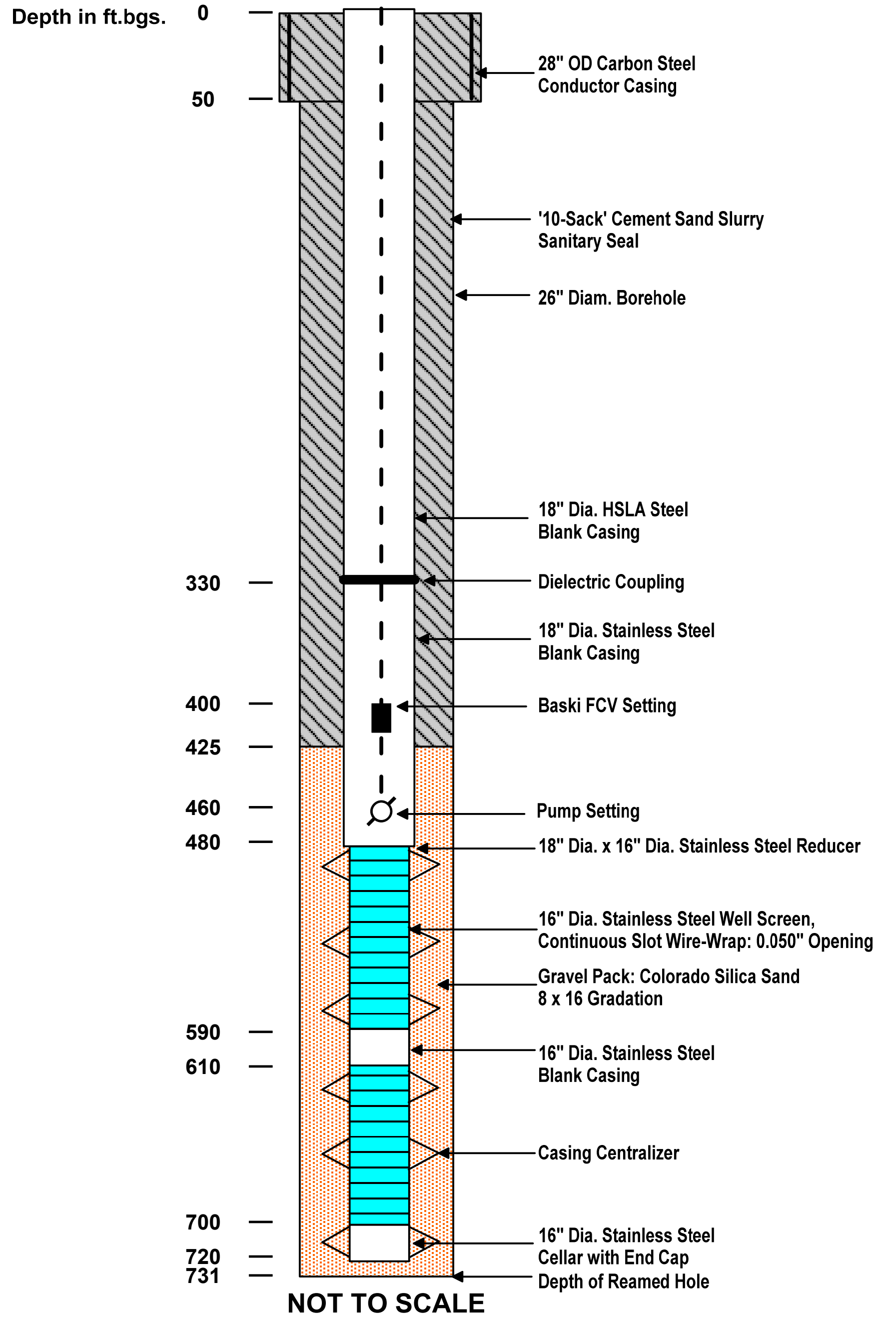
N
W E
S

1 inch = 2,000 feet
0 1,000 2,000 Feet

**FIGURE 1. SITE LOCATION MAP**
**WY 2017 ASR Program**
**Monterey Peninsula Water Management District**

June 2018
Project No. 12-0049

# EXHIBIT 8-A



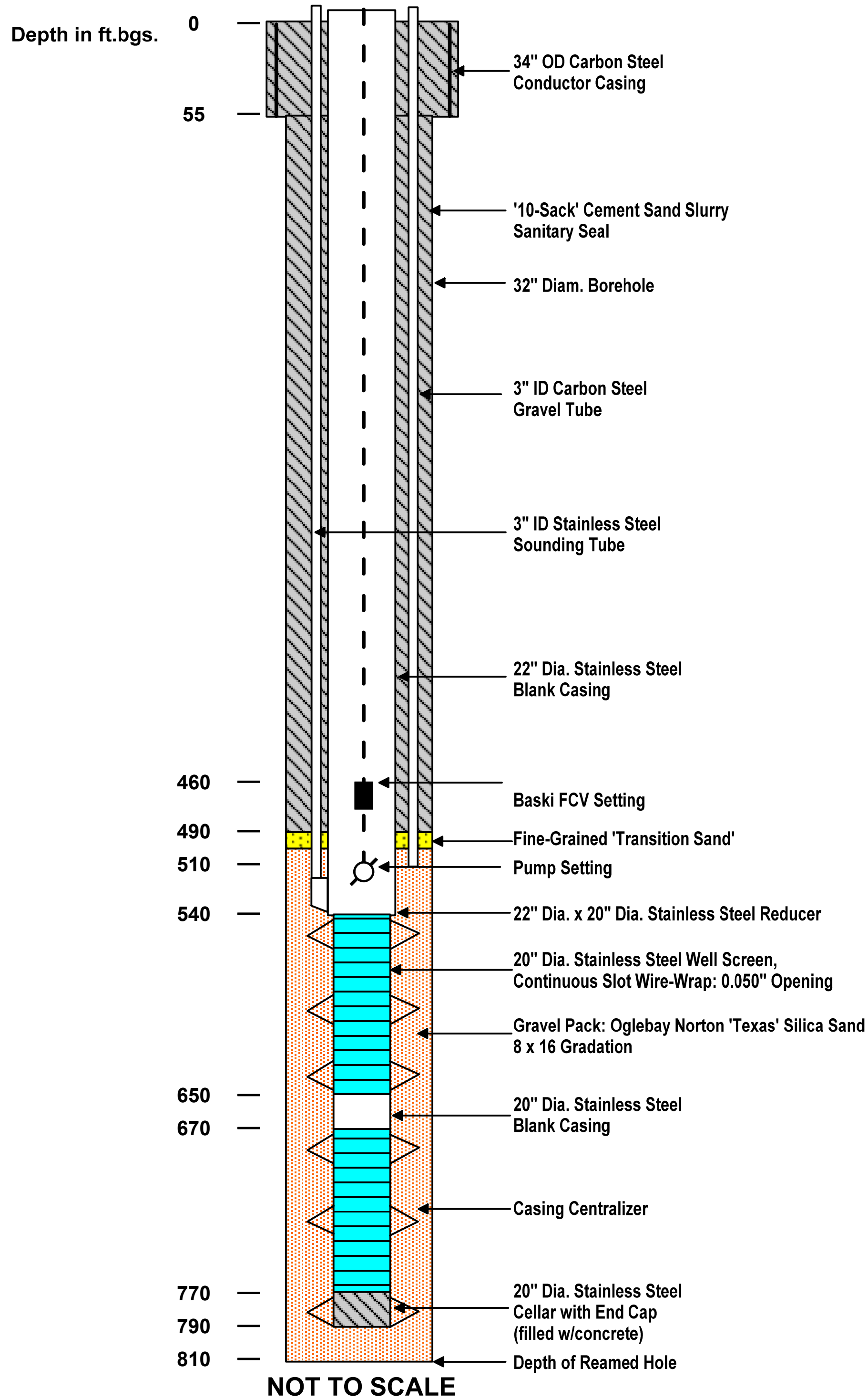

Pump Assembly Notes:
Hp: 600
Bowls: 16ENL, 7 stage
Col. Pipe Dia: 12"
Col. Pipe Length: 20'
Assy. Type: Water Lube/Open Shaft
Baski FCV Setting: 400' - 410'
Top of Bowls: 460'
Bowl Length: 10.5'
Suction Length: 10'
Intake: 480.5'

PUEBLO water resources

**FIGURE 2. ASR-1 AS-BUILT SCHEMATIC**
**WY 2017 ASR Program**
**Monterey Peninsula Water Management District**

June 2018
Project No. 12-0049

# EXHIBIT 8-A



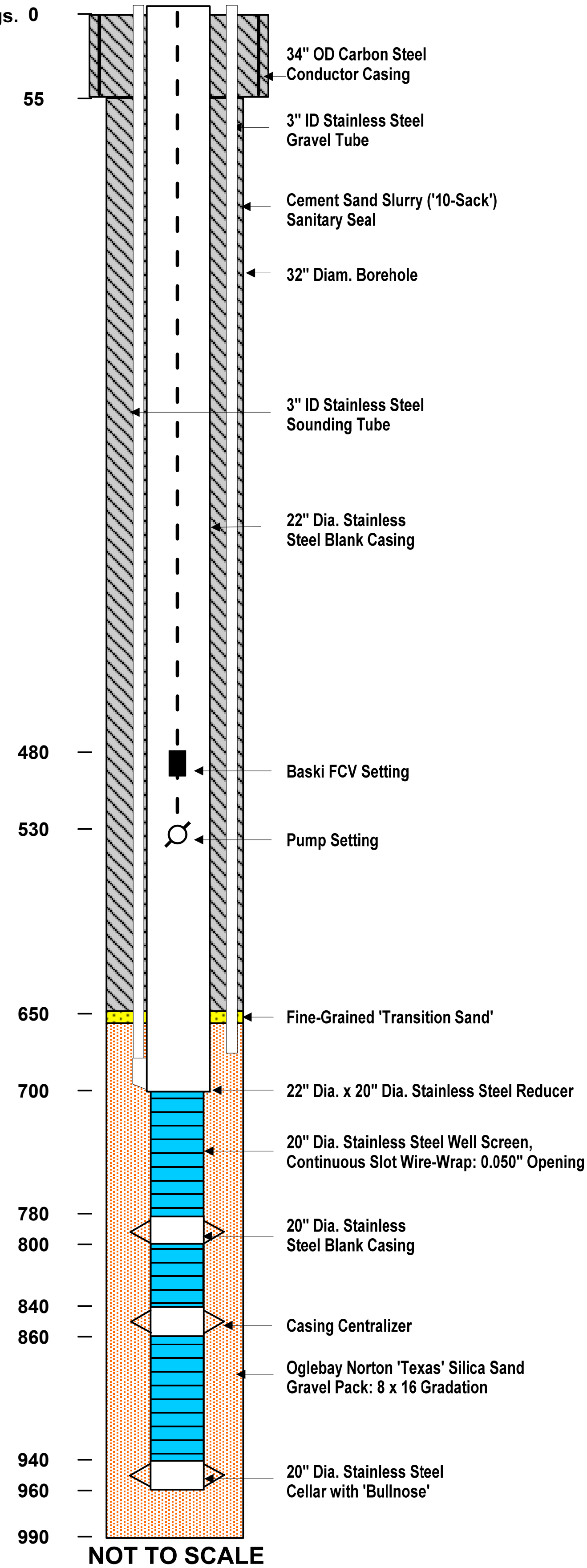

Pump Assembly Notes:
Hp: 600
Bowls: 16ENL, 7 stage
Col. Pipe Dia: 12"
Col. Pipe Length: 20'
Assy. Type: Water Flush/Enclosed Shaft
Baski FCV Setting: 460' - 470'
Top of Bowls: 510'
Bowl Length: 10.5'
Suction Length: 10'
Intake: 530.5'

PUEBLO water resources

**FIGURE 3. ASR-2 AS-BUILT SCHEMATIC**
**WY 2017 ASR Program**
**Monterey Peninsula Water Management District**

June 2018
Project No. 12-0049

# EXHIBIT 8-A

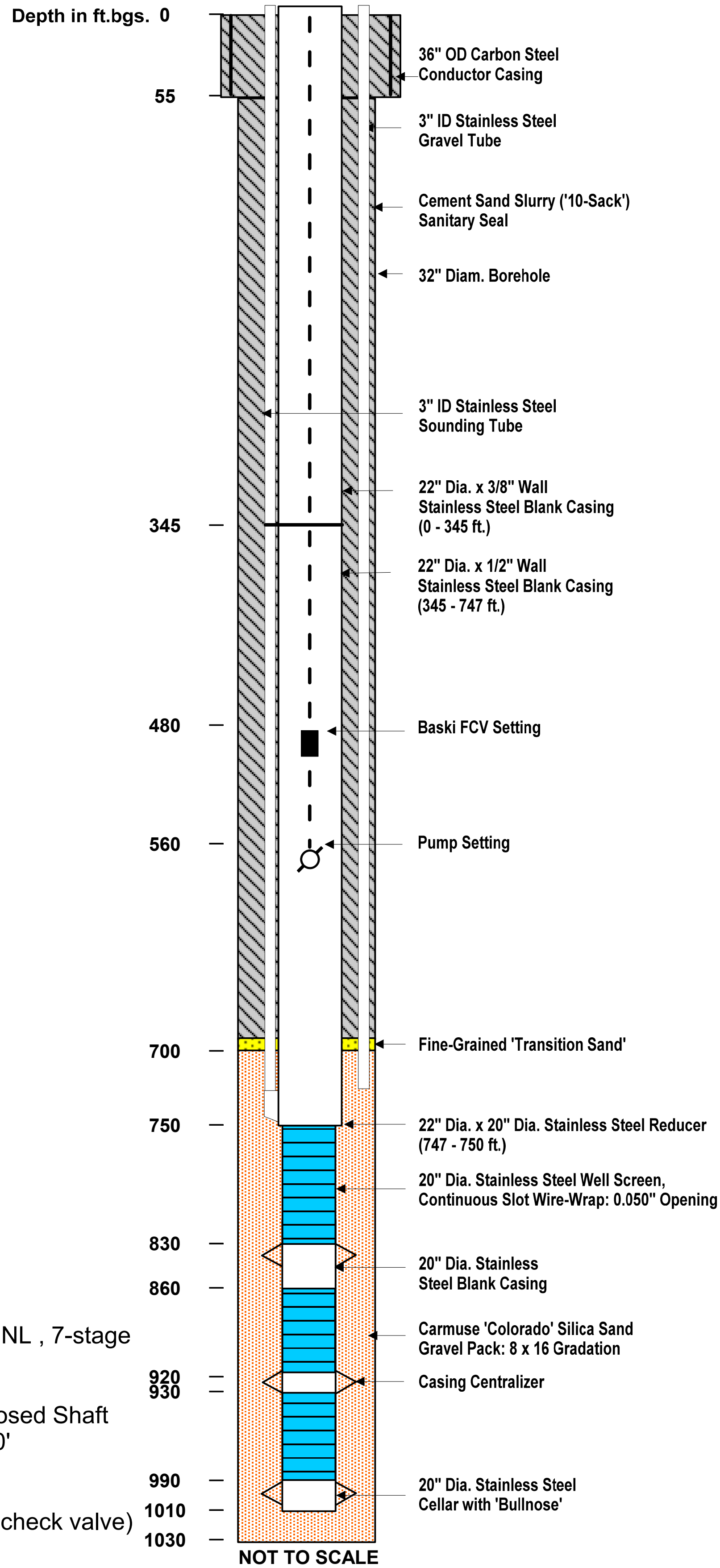



Pump Assembly Notes:
Hp: 600
Bowls: Flowserve Model 16 ENL , 7-stage
Col. Pipe Dia: 12"
Col. Pipe Length: 20'
Assy. Type: Water Flush/Enclosed Shaft
Baski FCV Setting: 482' to 492'
Top of Bowls: 532'
Bowl Length: 10.5'
Suction Length: 8'(including check valve)
Intake: 550.5'

PUEBLO water resources

**FIGURE 4. ASR-3 AS-BUILT SCHEMATIC**
**WY 2017 ASR Program**
**Monterey Peninsula Water Management District**

# EXHIBIT 8-A



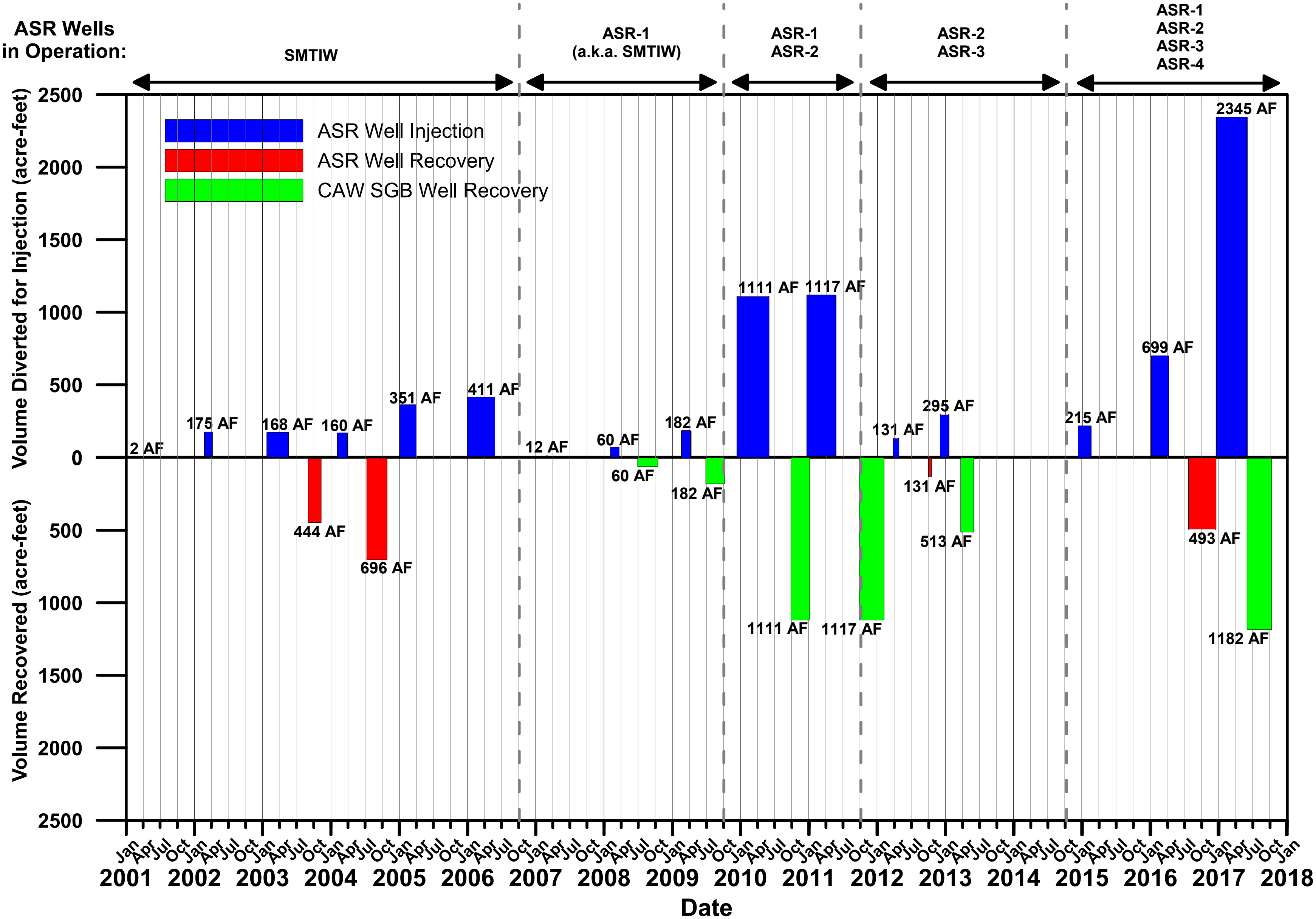

Pump Assembly Notes:
Hp: 600
Bowls: Flowserve Model 16 ENL , 7-stage
Col. Pipe Dia: 12"
Col. Pipe Length: 20'
Assy. Type: Water Flush/Enclosed Shaft
Baski FCV Setting: 480' to 490'
Top of Bowls: 562'
Bowl Length: 10.4'
Suction Length: 10' (including check valve)
Intake: 582.4'

PUEBLO water resources

**FIGURE 5. ASR-4 AS-BUILT SCHEMATIC**
**WY 2017 ASR Program**
**Monterey Peninsula Water Management District**

June 2018
Project No. 12-0049

# EXHIBIT 8-A




PUEBLO water resources

FIGURE 6. SUMMARY OF ASR OPERATIONS (WY 2001 - WY 2017)
WY 2017 ASR Program
Monterey Peninsula Water Management District

June 2018
Project No. 12-0049

**EXHIBIT 8-A**

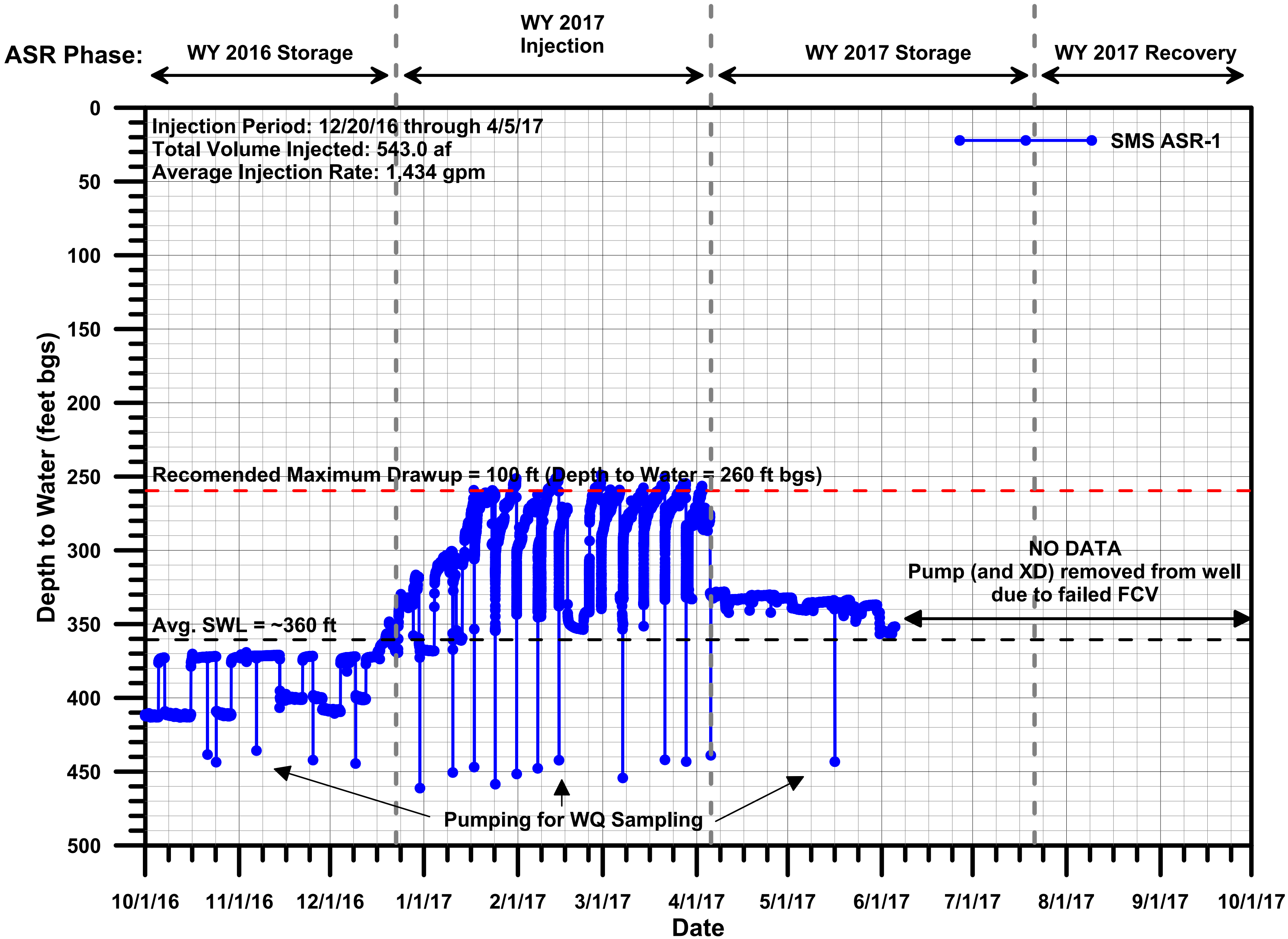



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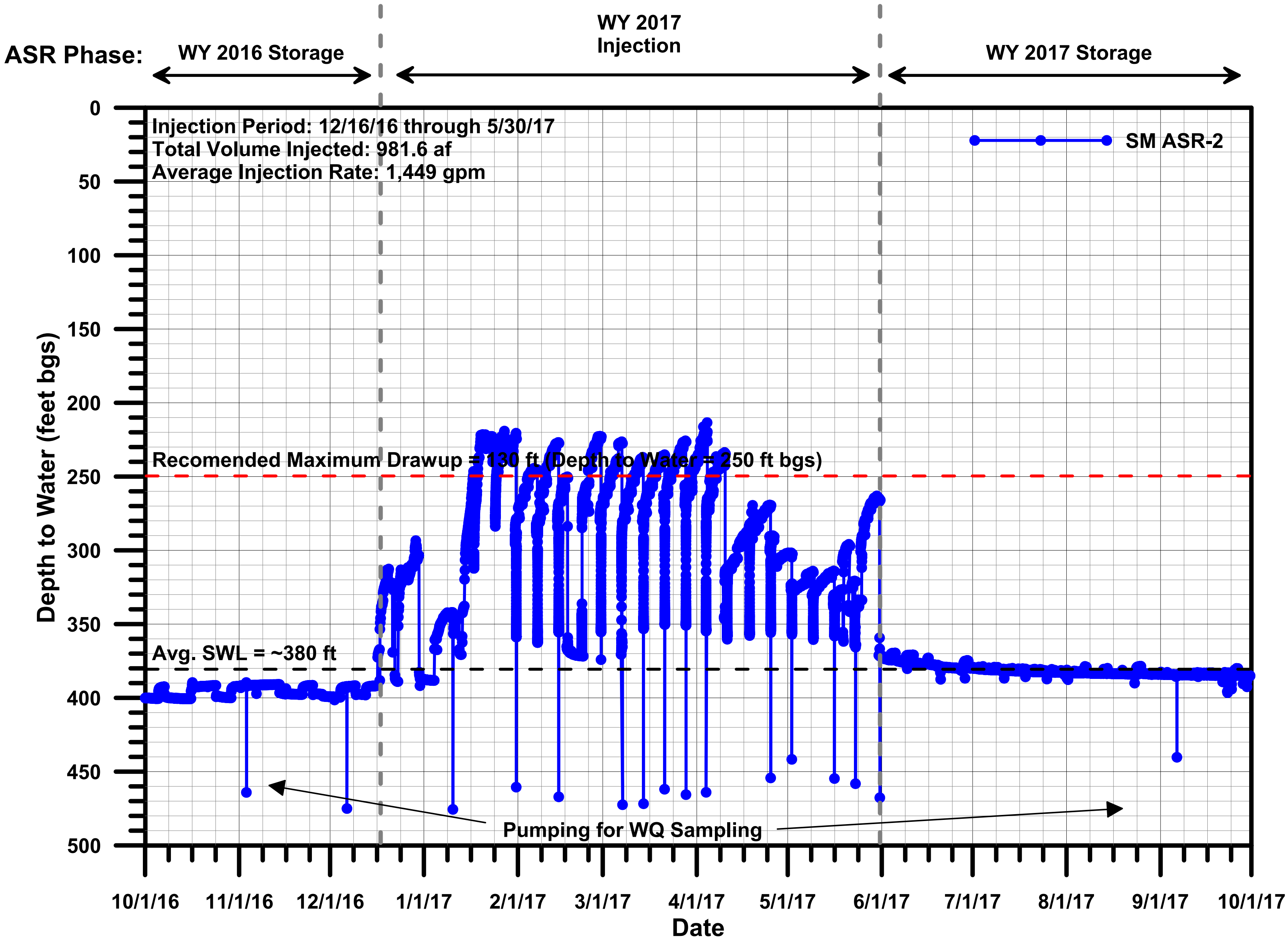
**FIGURE 7. ASR-1 WATER-LEVEL DATA**
**WY 2017 ASR Program**
**Monterey Peninsula Water Management District**

June 2018
Project No. 12-0049

# EXHIBIT 8-A

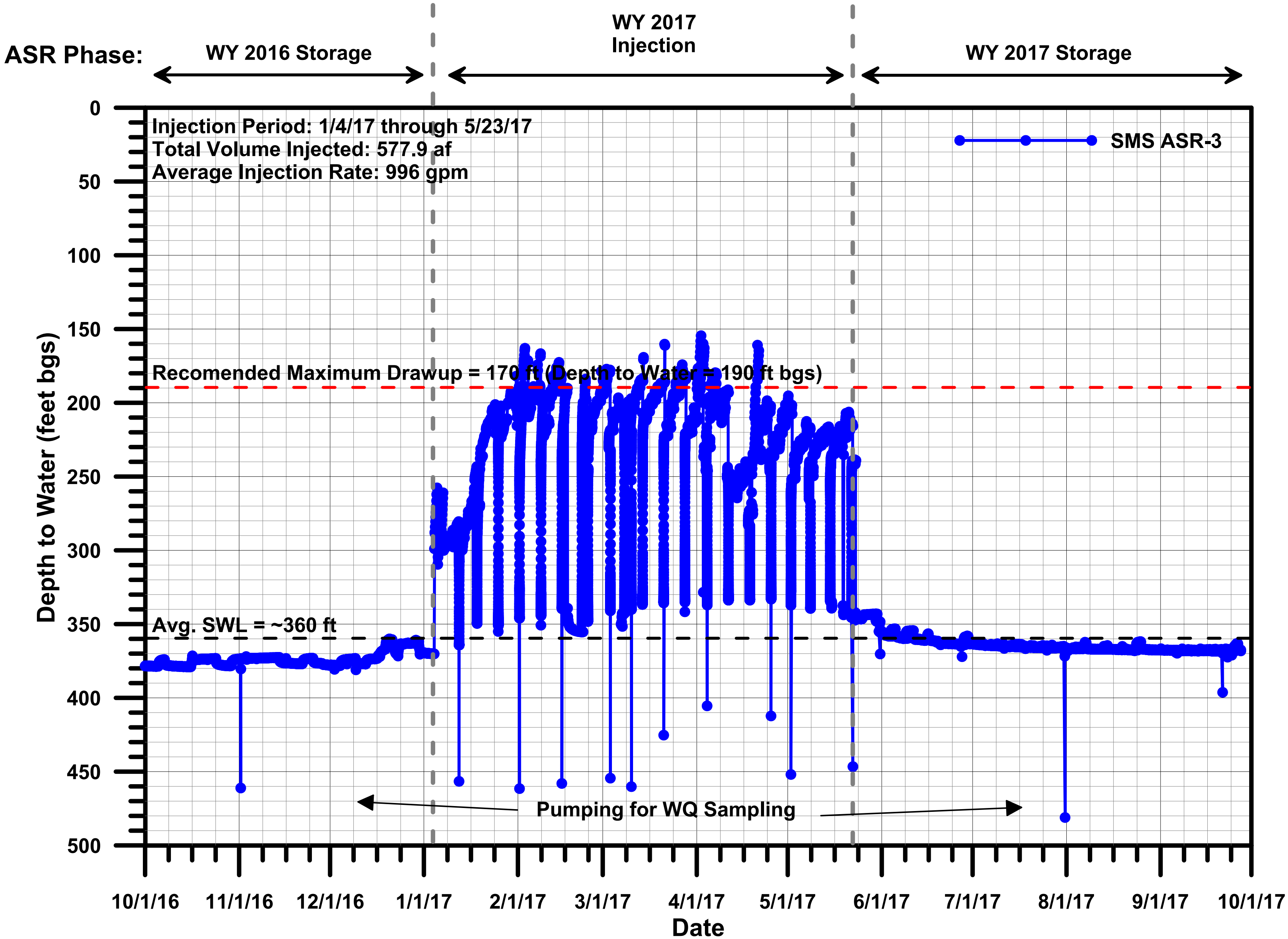



PUEBLO water resources

FIGURE 8. ASR-2 WATER-LEVEL DATA
WY 2017 ASR Program
Monterey Peninsula Water Management District

June 2018
Project No. 12-0049

**EXHIBIT 8-A**

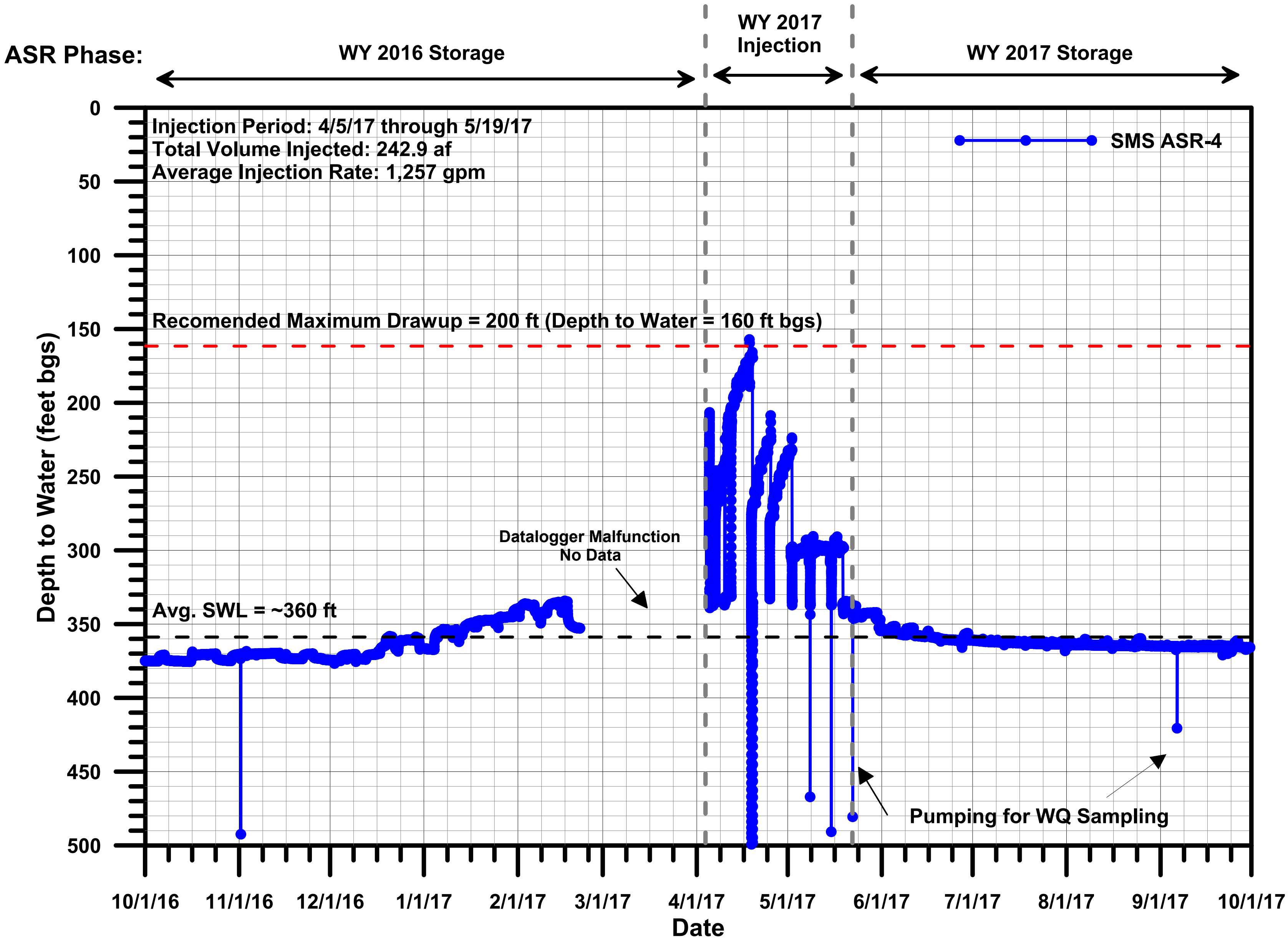



**PUEBLO** water resources

**FIGURE 9. ASR-3 WATER-LEVEL DATA**
**WY 2017 ASR Program**
**Monterey Peninsula Water Management District**

June 2018
Project No. 12-0049

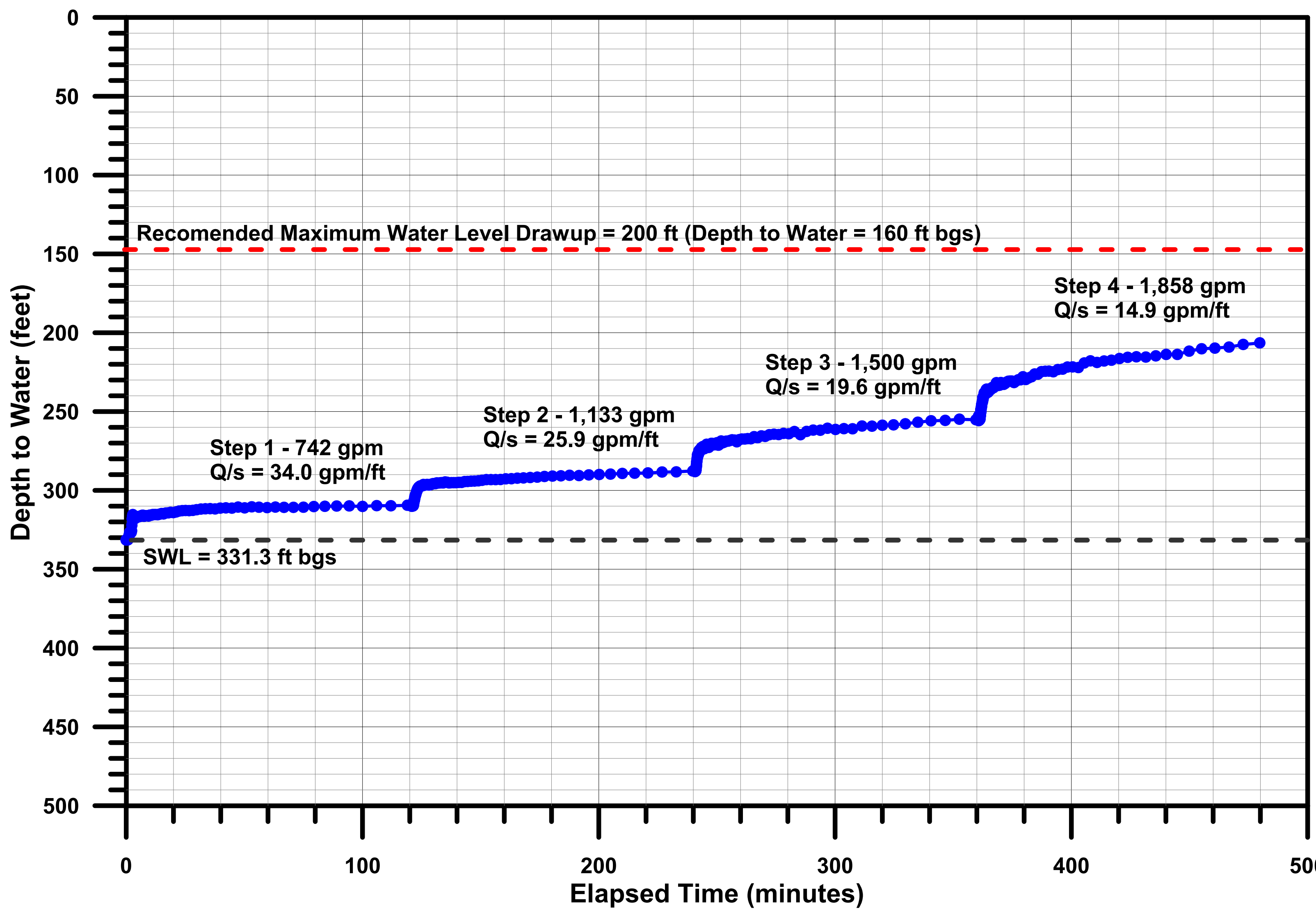
# EXHIBIT 8-A




PUEBLO water resources

**FIGURE 10. ASR-4 WATER-LEVEL DATA**
**WY 2017 ASR Program**
**Monterey Peninsula Water Management District**

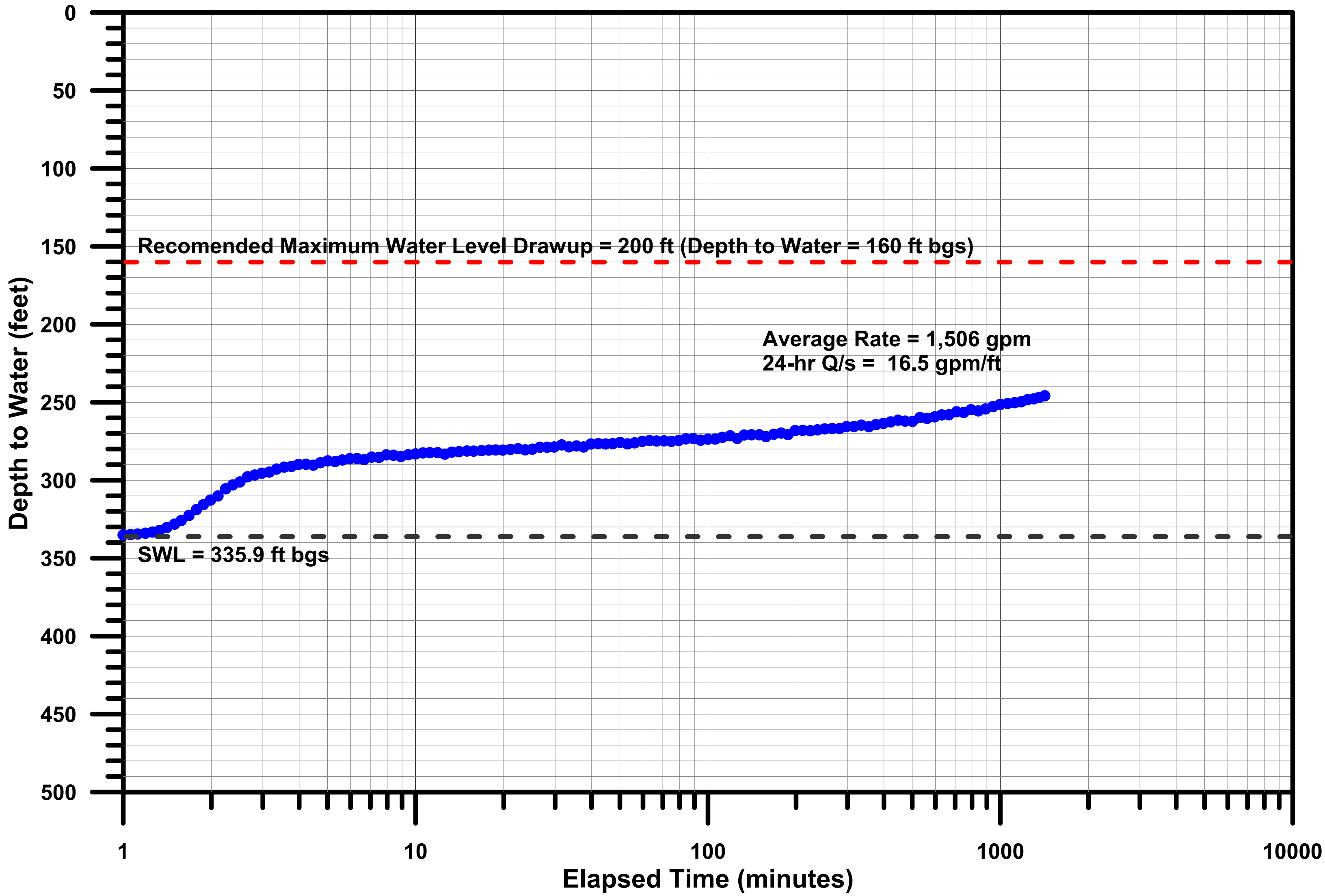
# EXHIBIT 8-A




PUEBLO water resources

**FIGURE 11. ASR-4 BASELINE INJECTION TESTING - 8-HR STEP-RATE INJECTION TEST**
**WY 2017 ASR Program**
**Monterey Peninsula Water Management District**

EXHIBIT 8-A




PUEBLO water resources

FIGURE 12. ASR-4 BASELINE INJECTION TESTING - 24-HR CONSTANT RATE INJECTION TEST
WY 2017 ASR Program
Monterey Peninsula Water Management District

**EXHIBIT 8-A**

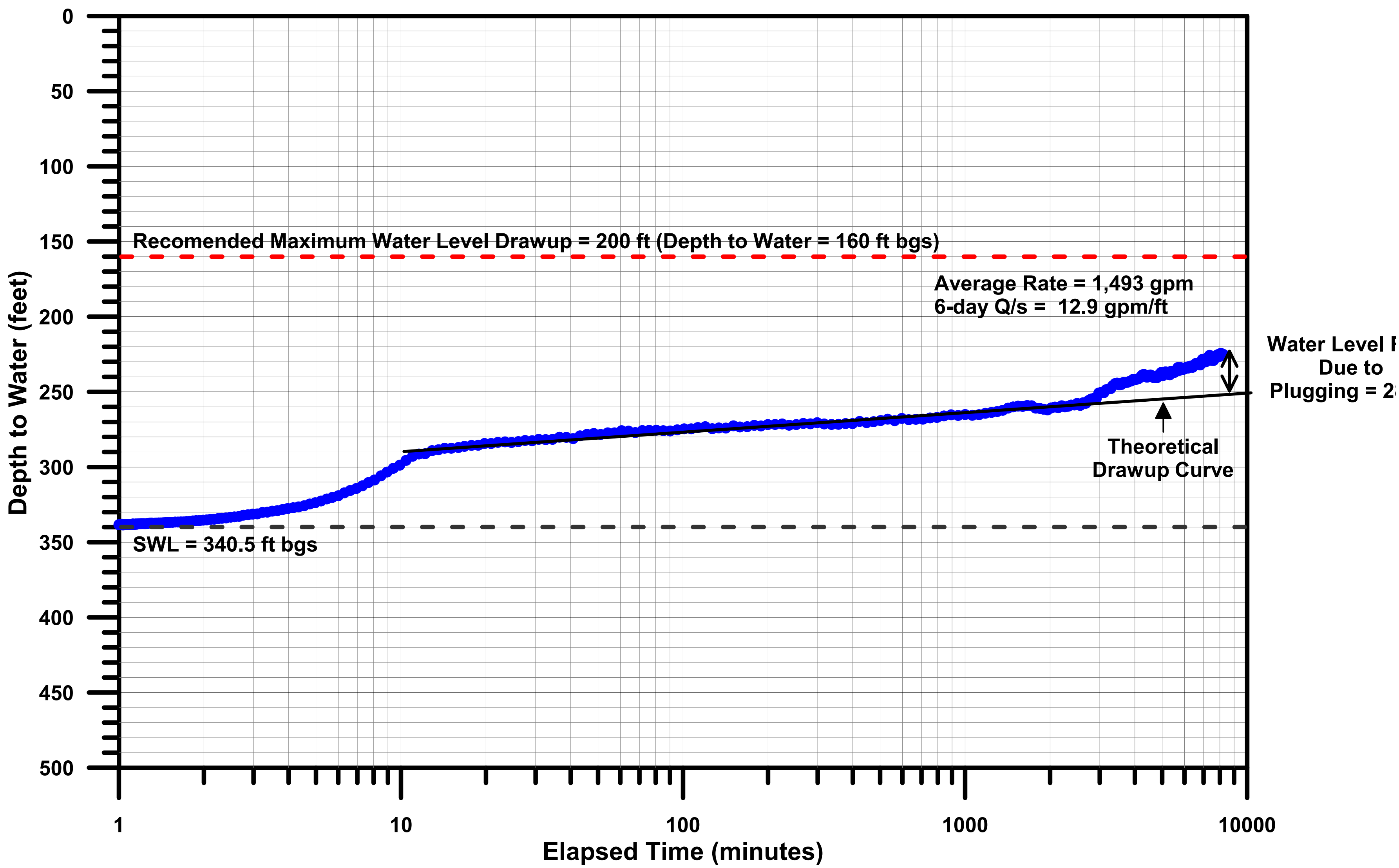



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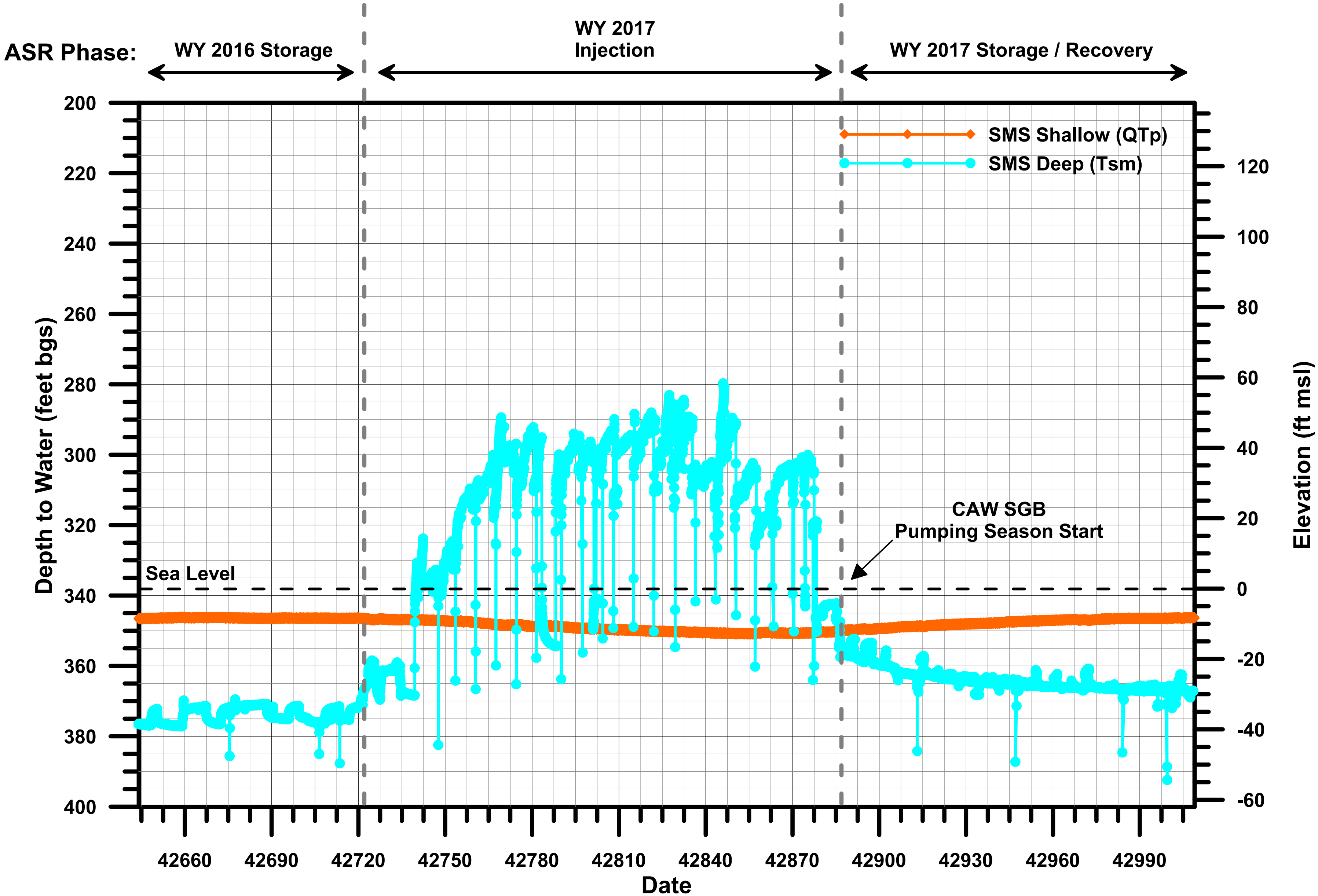
FIGURE 13. ASR-4 BASELINE INJECTION TESTING - 6-DAY CONSTANT RATE INJECTION TEST
WY 2017 ASR Program
Monterey Peninsula Water Management District

June 2018
Project No. 12-0049

# EXHIBIT 8-A

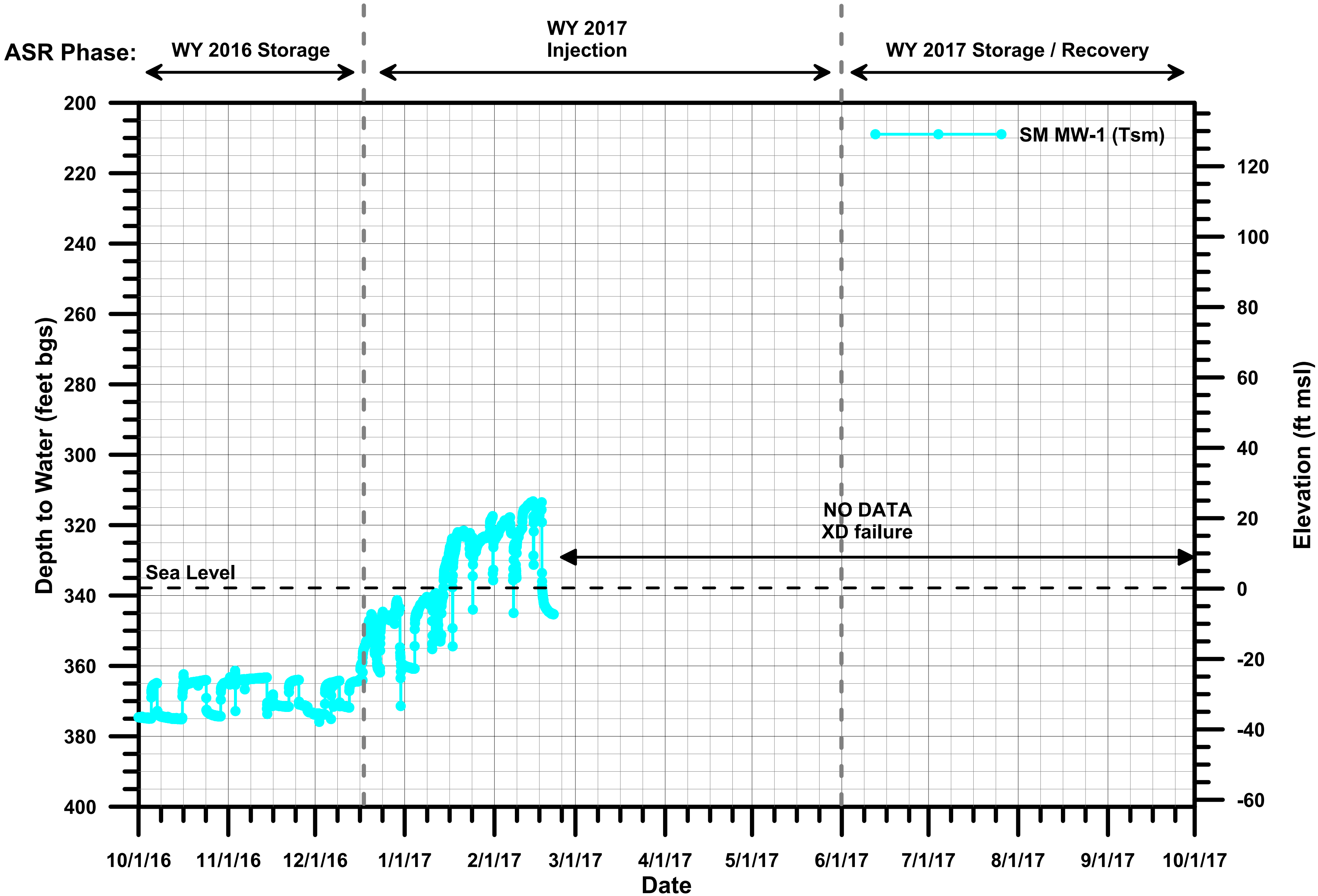



PUEBLO water resources

FIGURE 14. SMS MW WATER-LEVEL DATA
WY 2017 ASR Program
Monterey Peninsula Water Management District

June 2018
Project No. 12-0049

# EXHIBIT 8-A




PUEBLO water resources

**FIGURE 15. SM MW-1 WATER-LEVEL DATA**
**WY 2017 ASR Program**
**Monterey Peninsula Water Management District**

June 2018
Project No. 12-0049

# EXHIBIT 8-A

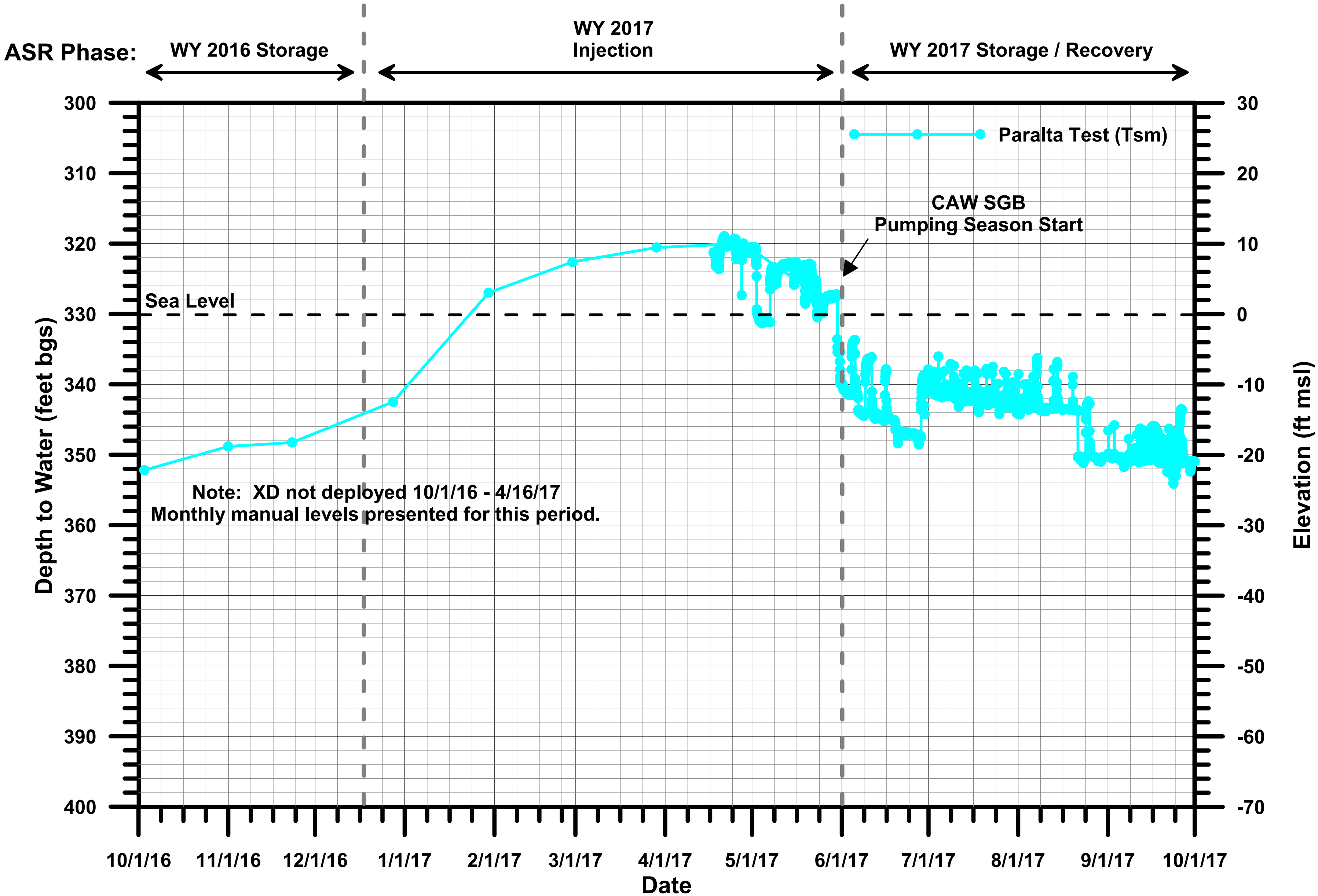



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**FIGURE 16. PARALTA TEST WATER-LEVEL DATA**
**WY 2017 ASR Program**
**Monterey Peninsula Water Management District**

June 2018
Project No. 12-0049

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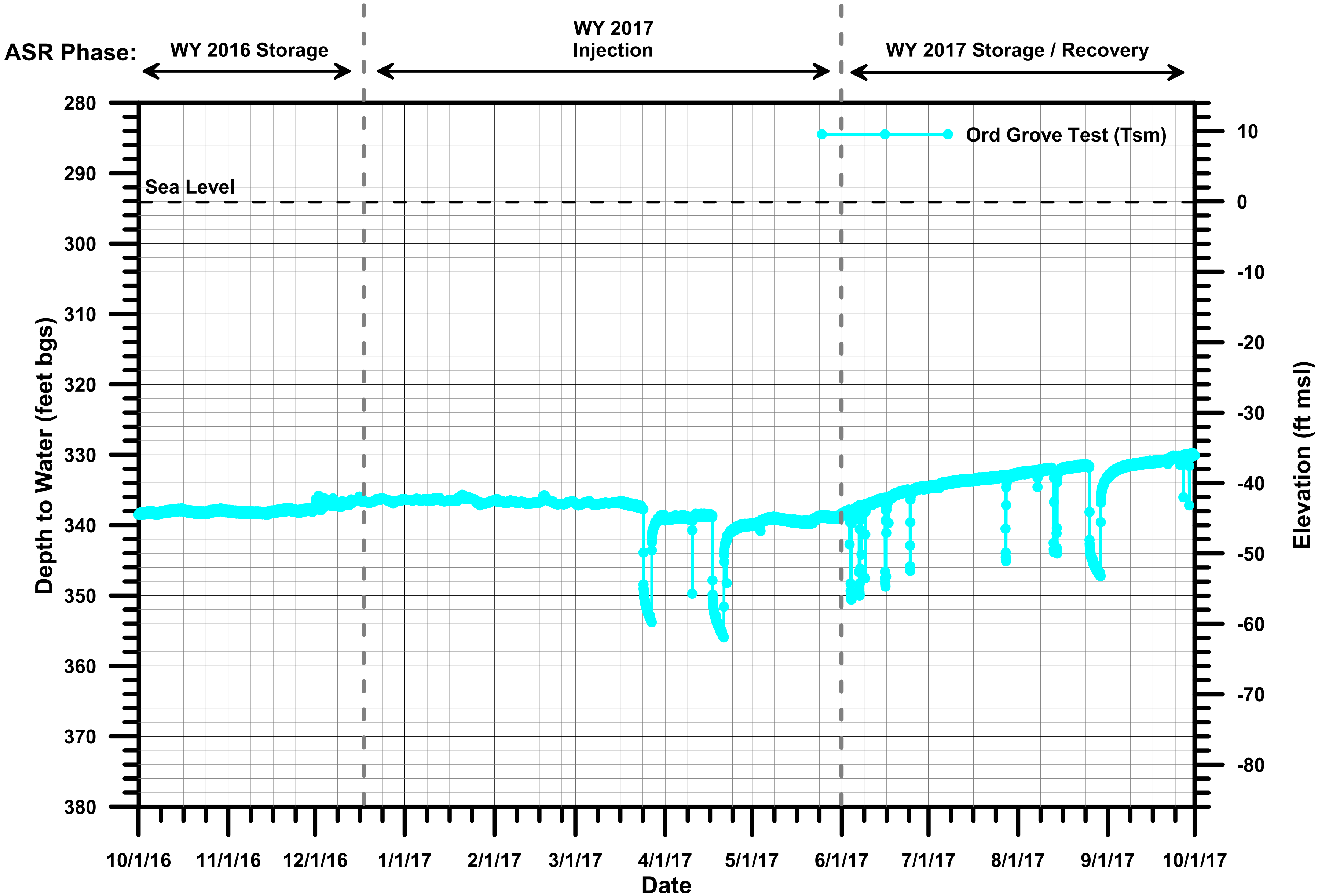


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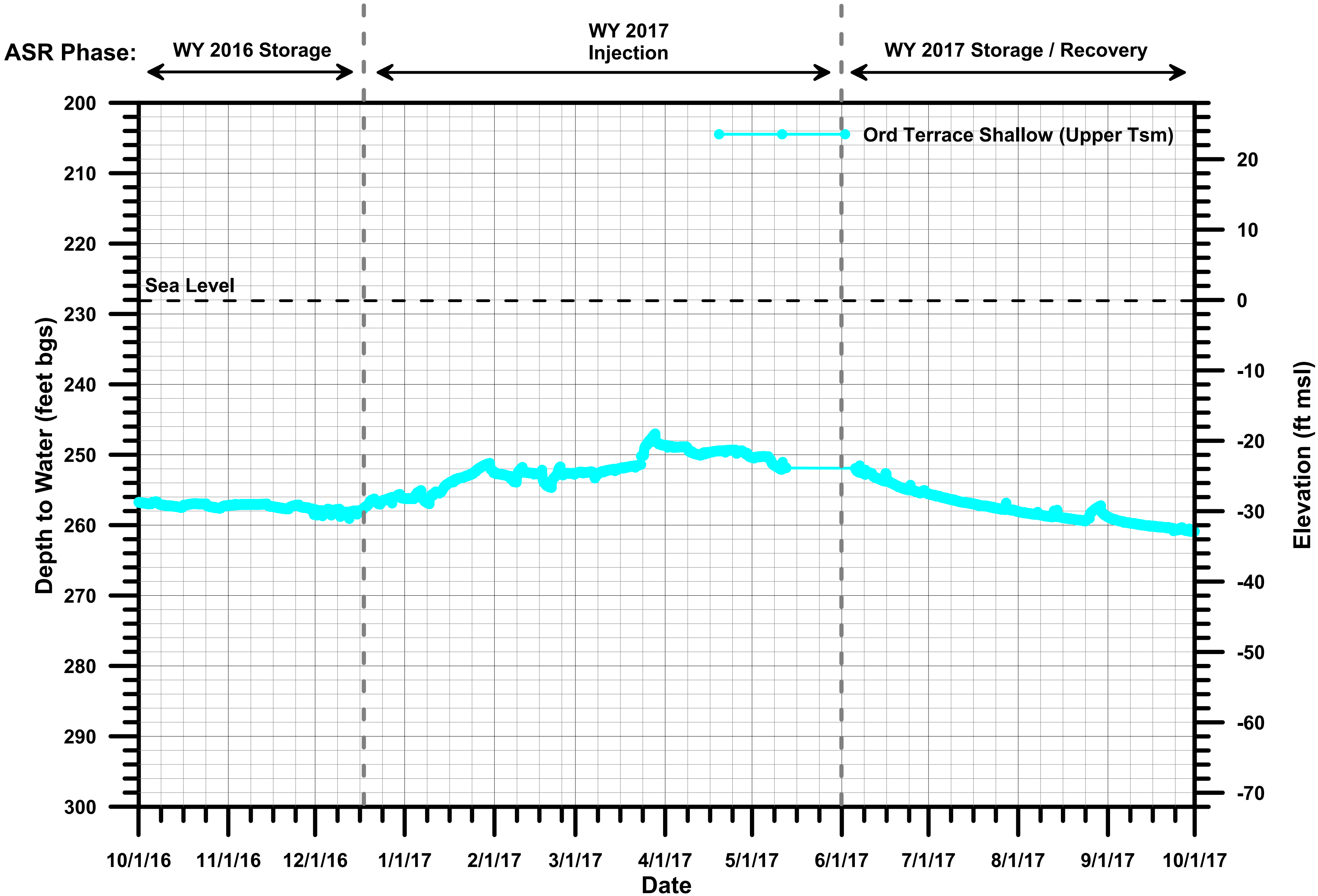
FIGURE 17. ORD GROVE TEST WATER-LEVEL DATA
WY 2017 ASR Program
Monterey Peninsula Water Management District

June 2018
Project No. 12-0049

**EXHIBIT 8-A**




PUEBLO water resources

FIGURE 18. ORD TERRACE WATER-LEVEL DATA
WY 2017 ASR Program
Monterey Peninsula Water Management District

June 2018
Project No. 12-0049

# EXHIBIT 8-A

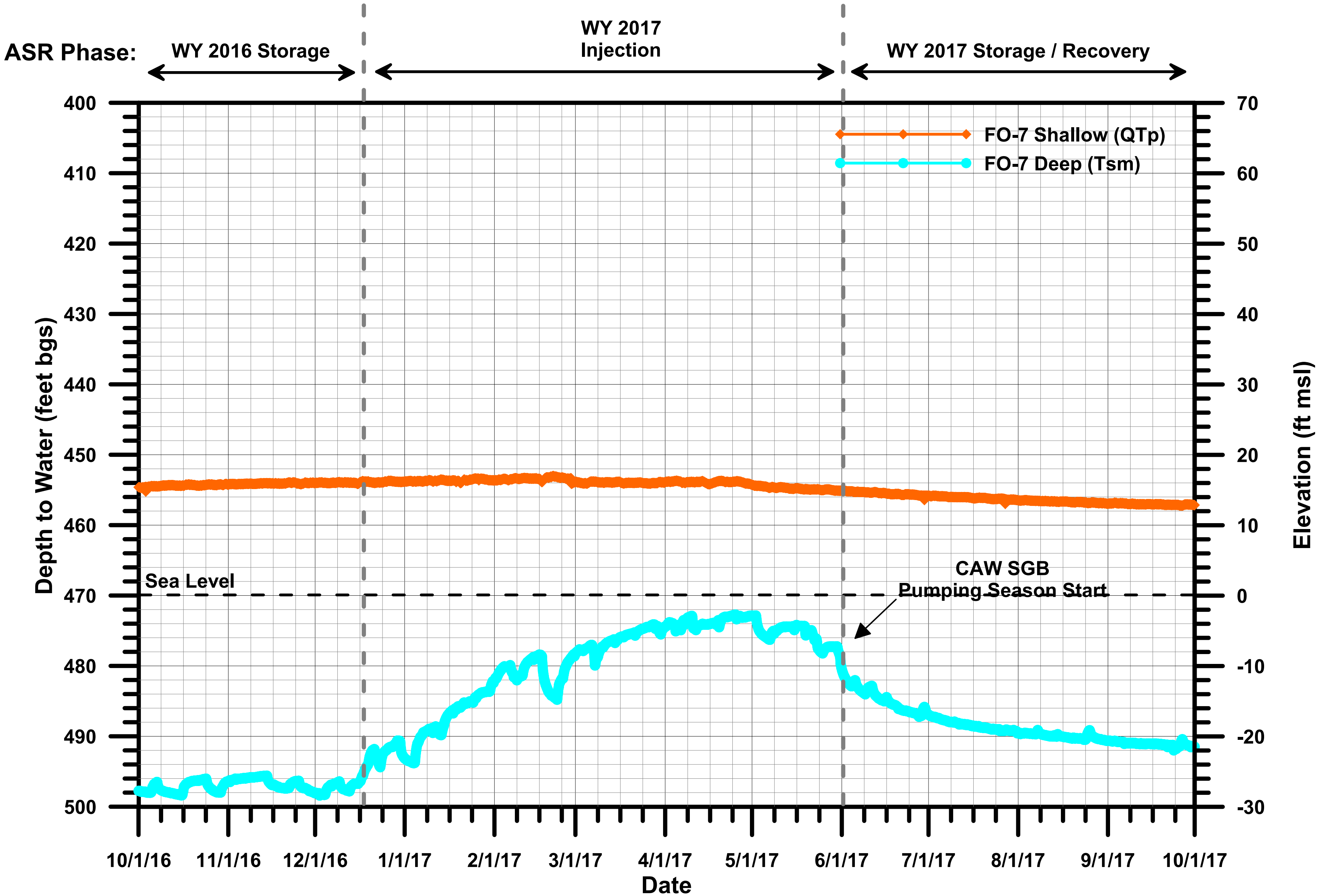



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**FIGURE 19. FO-7 WATER-LEVEL DATA**
**WY 2017 ASR Program**
**Monterey Peninsula Water Management District**

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Project No. 12-0049

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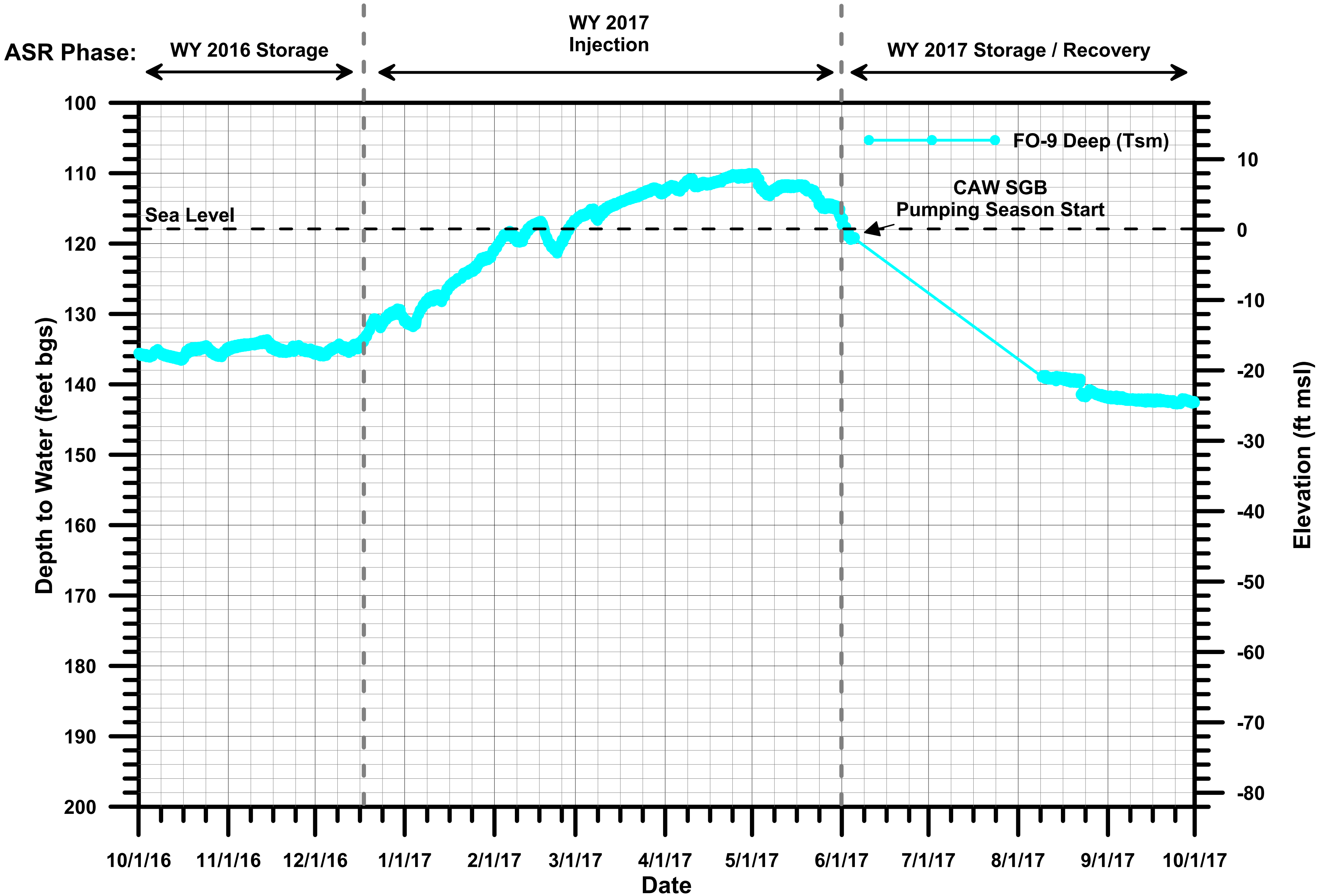


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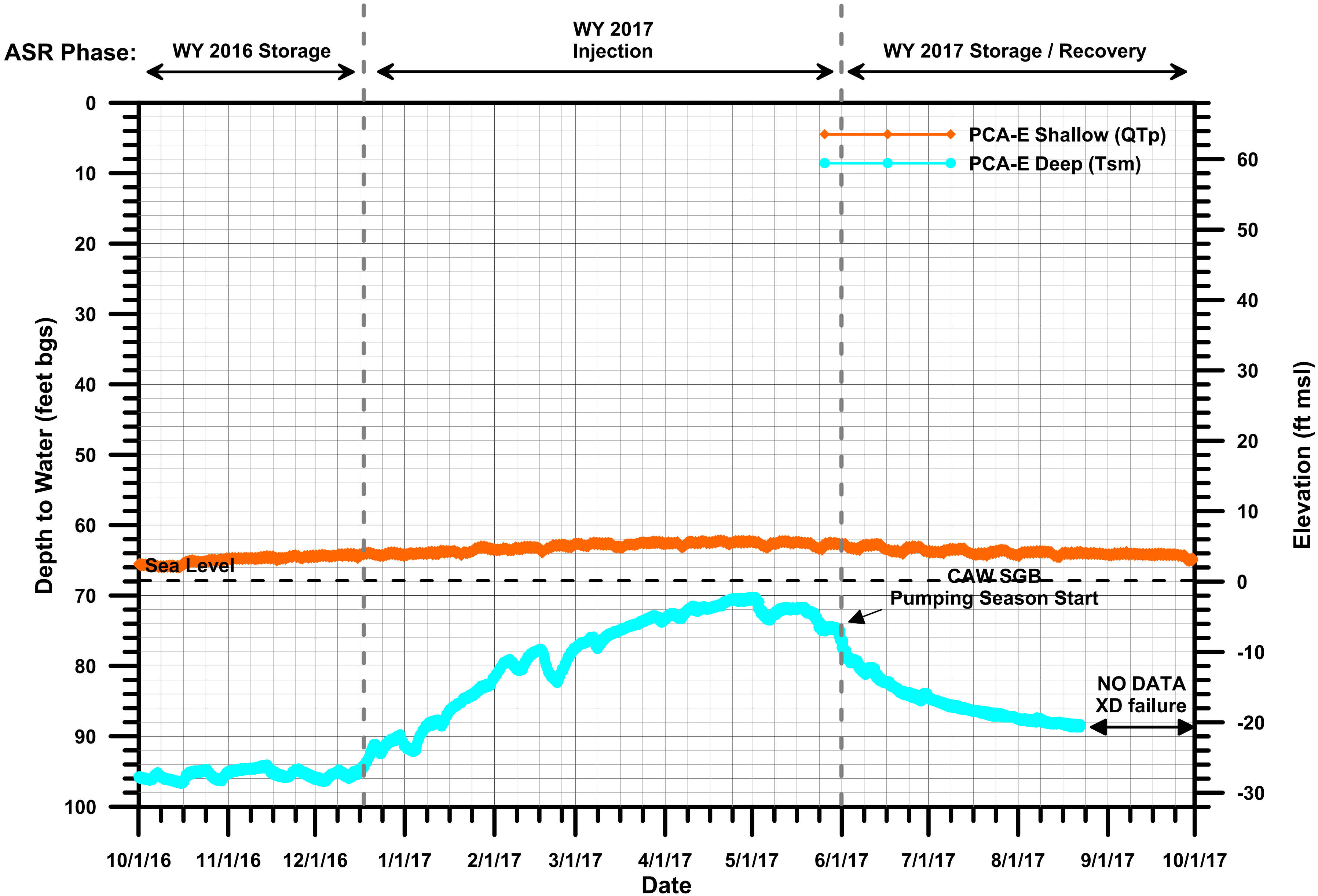
**FIGURE 20. FO-9 WATER-LEVEL DATA**
**WY 2017 ASR Program**
**Monterey Peninsula Water Management District**

June 2018
Project No. 12-0049

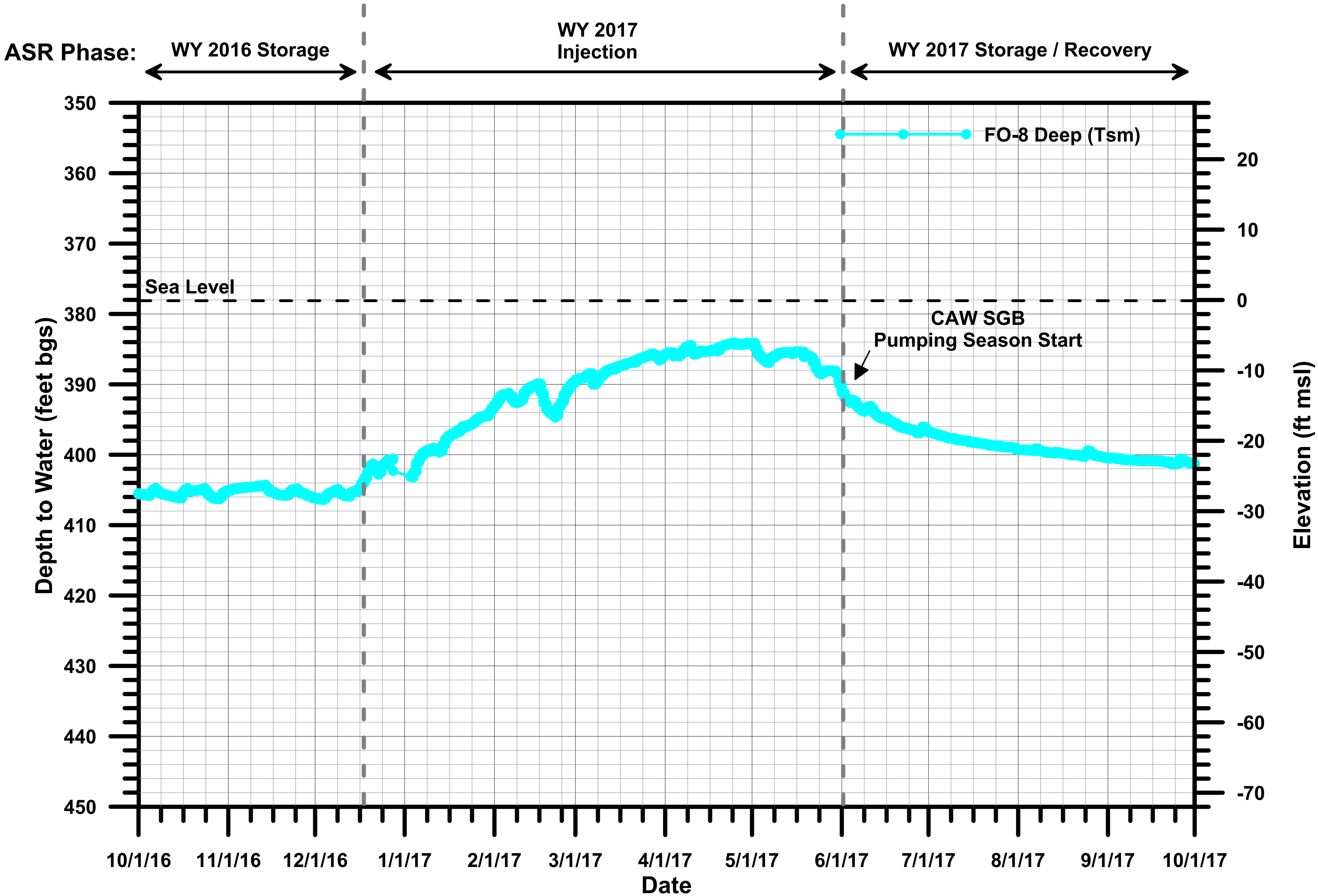
# EXHIBIT 8-A




PUEBLO water resources

FIGURE 21. PCA-EAST WATER-LEVEL DATA
WY 2017 ASR Program
Monterey Peninsula Water Management District

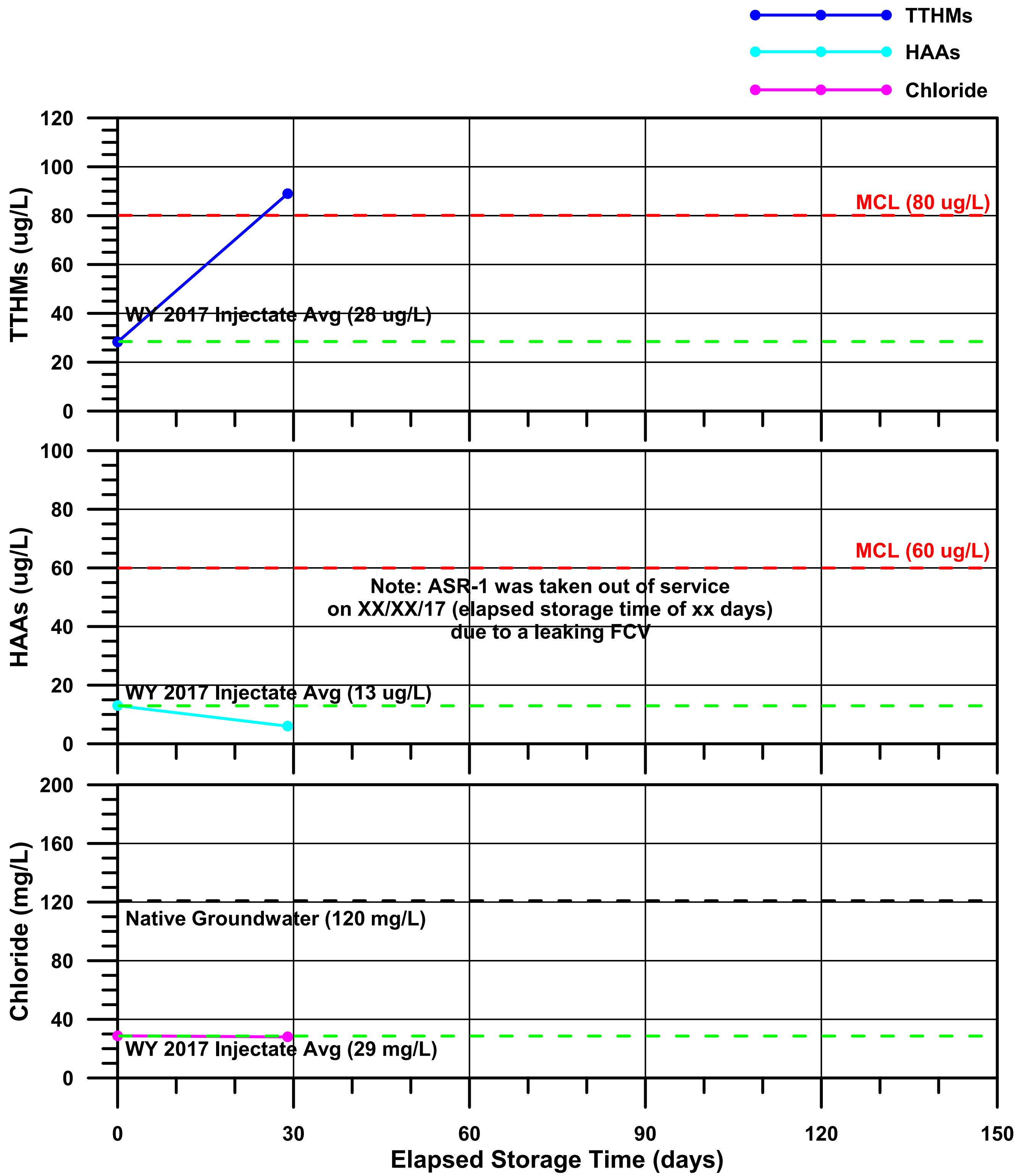
# EXHIBIT 8-A




PUEBLO water resources

FIGURE 22. FO-8 WATER-LEVEL DATA
WY 2017 ASR Program
Monterey Peninsula Water Management District

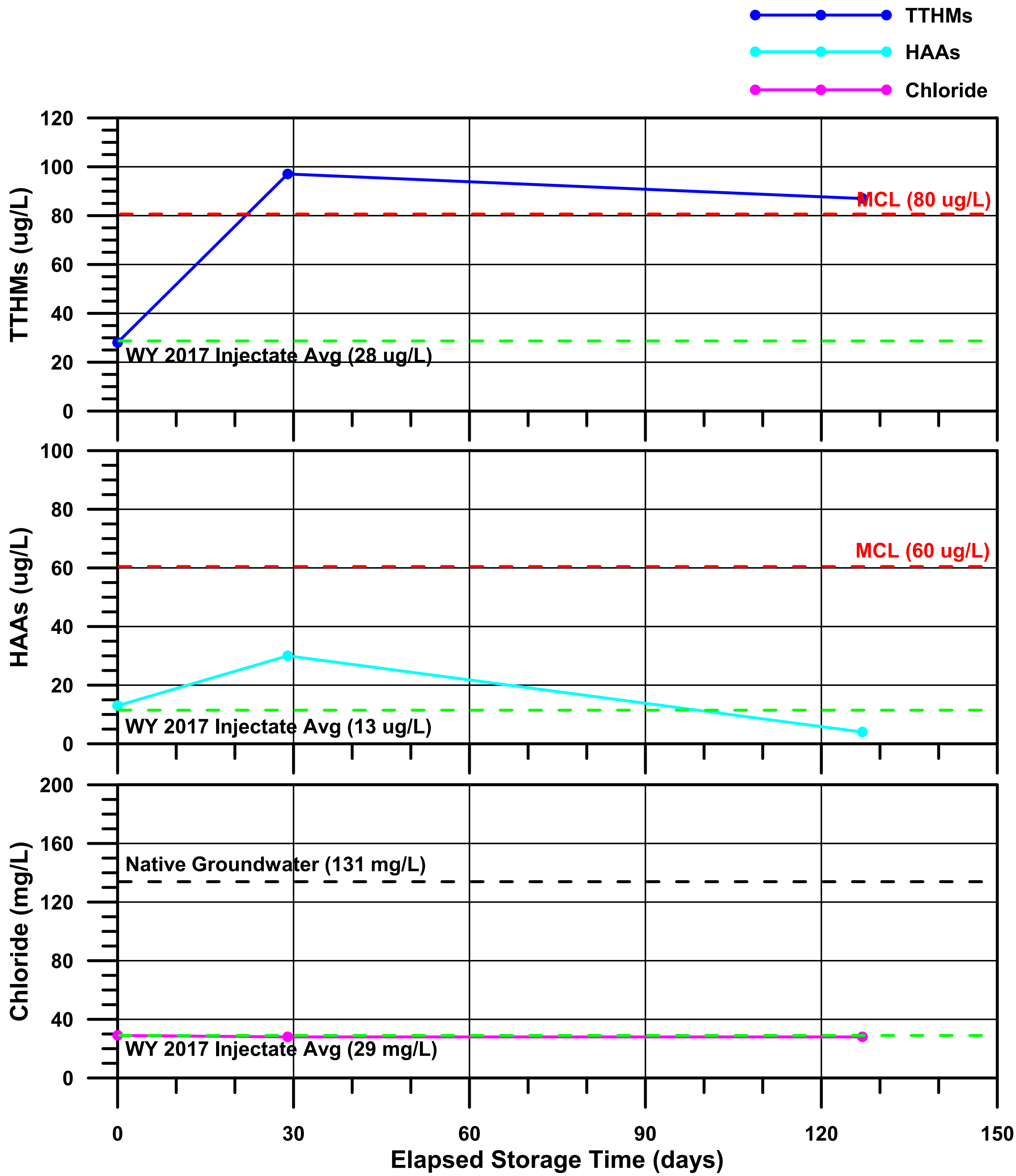
**EXHIBIT 8-A**




PUEBLO water resources

FIGURE 23. ASR-1 DISINFECTION BYPRODUCTS PARAMETERS
WY 2017 ASR Program
Monterey Peninsula Water Management District

# EXHIBIT 8-A




PUEBLO water resources

FIGURE 24. ASR-2 DISINFECTION BYPRODUCTS PARAMETERS
WY 2017 ASR Program
Monterey Peninsula Water Management District

# EXHIBIT 8-A

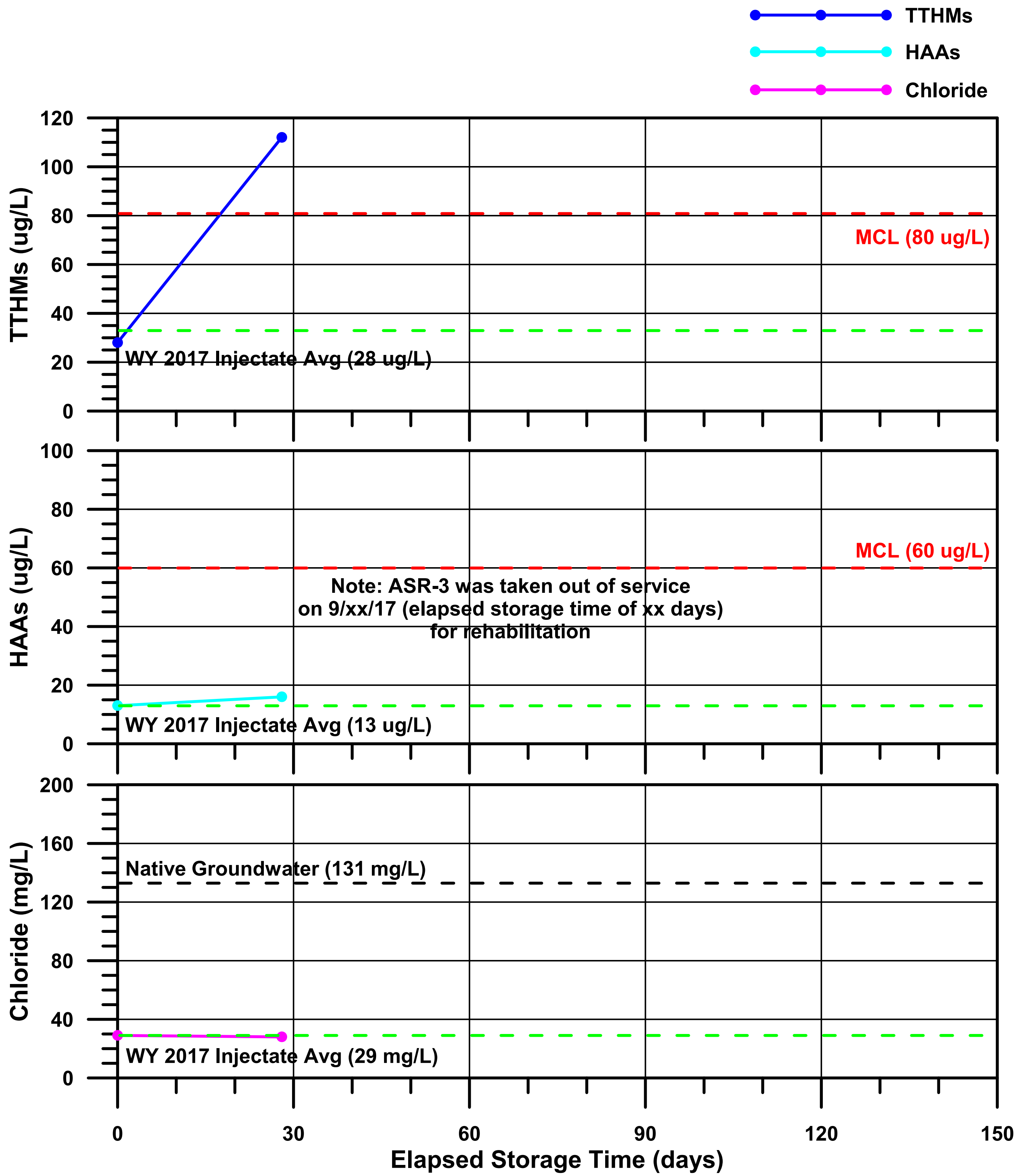
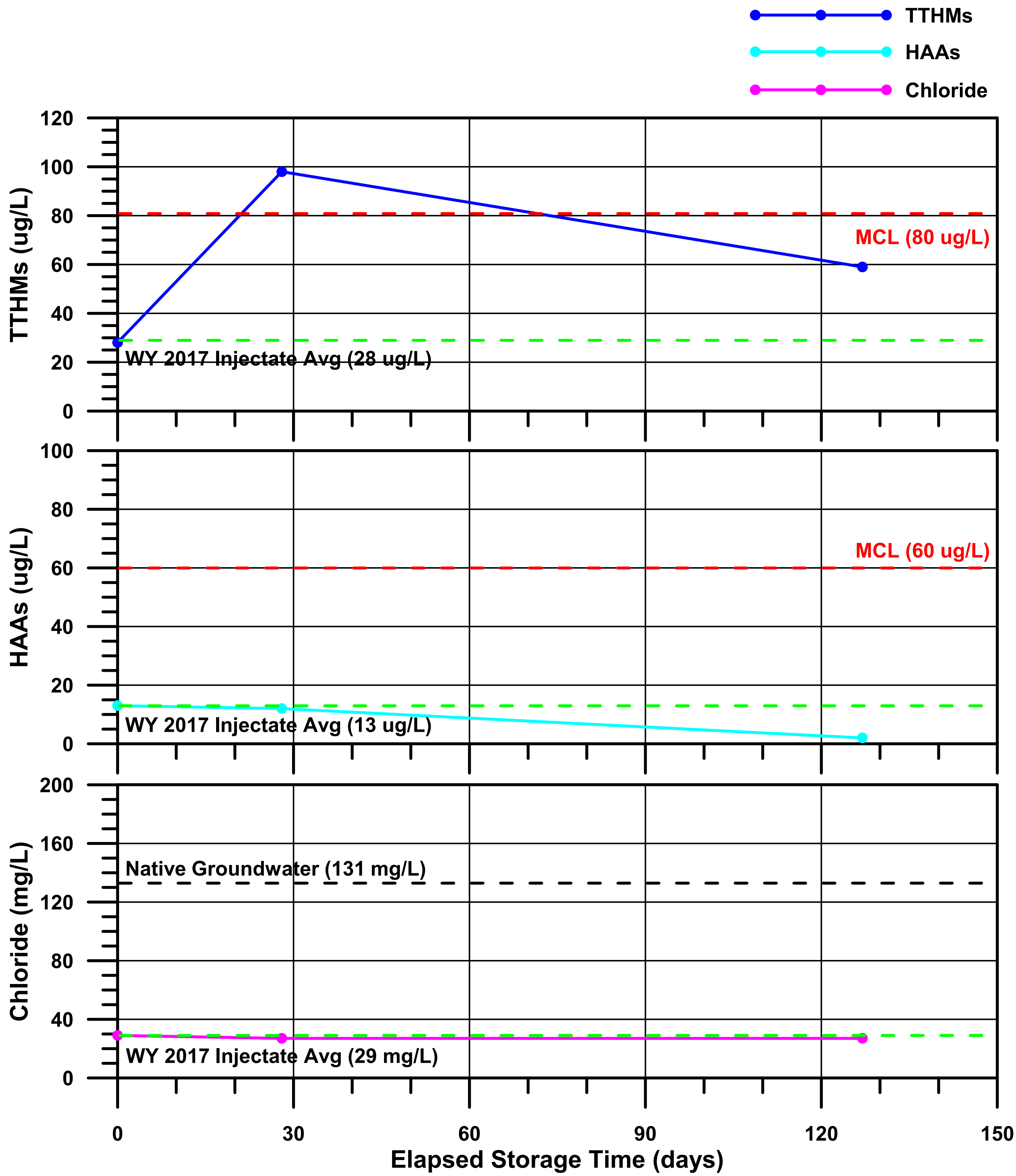



FIGURE 25. ASR-3 DISINFECTION BYPRODUCTS PARAMETERS
WY 2017 ASR Program
Monterey Peninsula Water Management District

**EXHIBIT 8-A**




PUEBLO water resources

**FIGURE 26. ASR-4 DISINFECTION BYPRODUCTS PARAMETERS**
**WY 2017 ASR Program**
**Monterey Peninsula Water Management District**

**EXHIBIT 8-A**

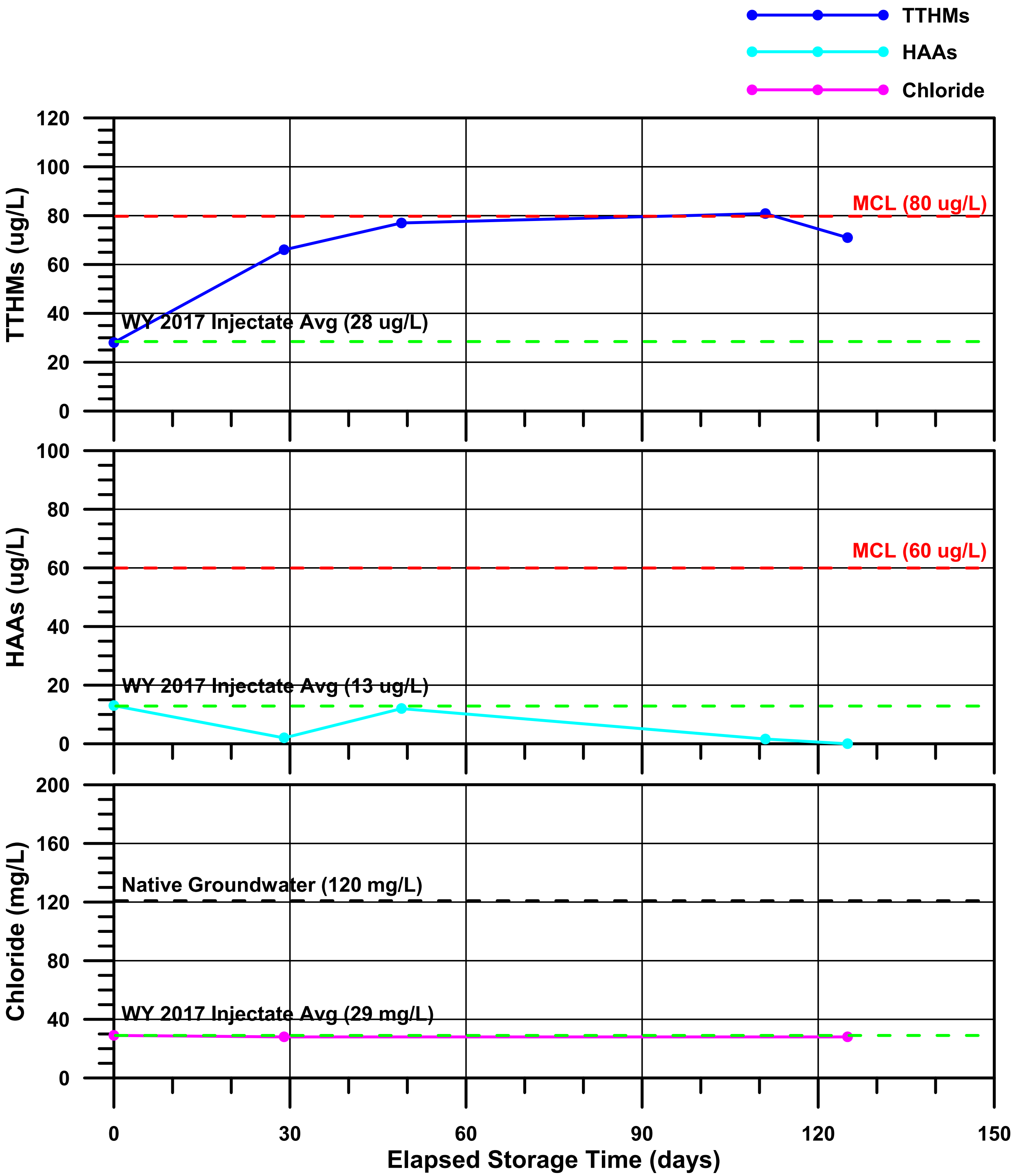



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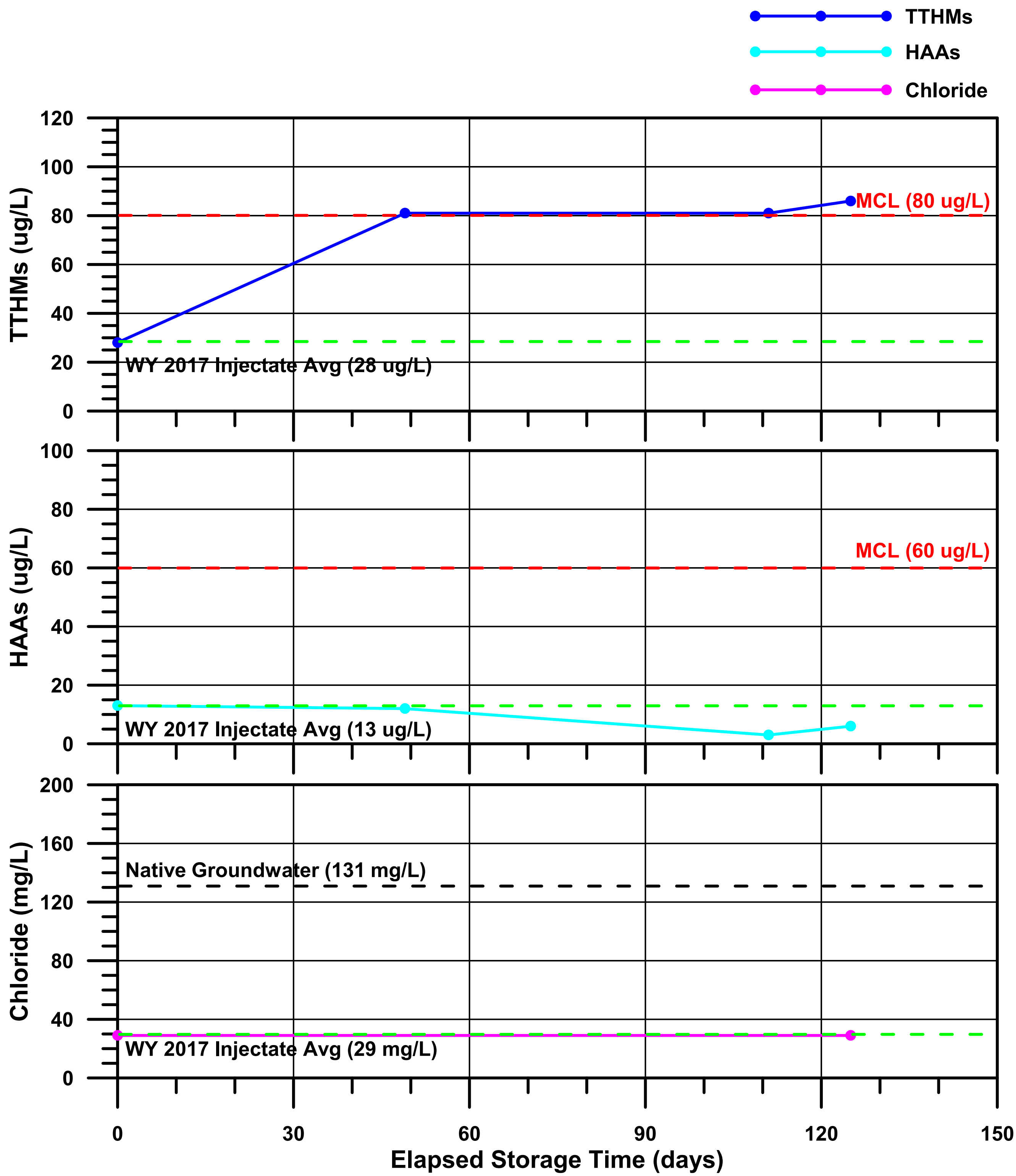
**FIGURE 27. SM MW-1 DISINFECTION BYPRODUCTS PARAMETERS**
**WY 2017 ASR Program**
**Monterey Peninsula Water Management District**

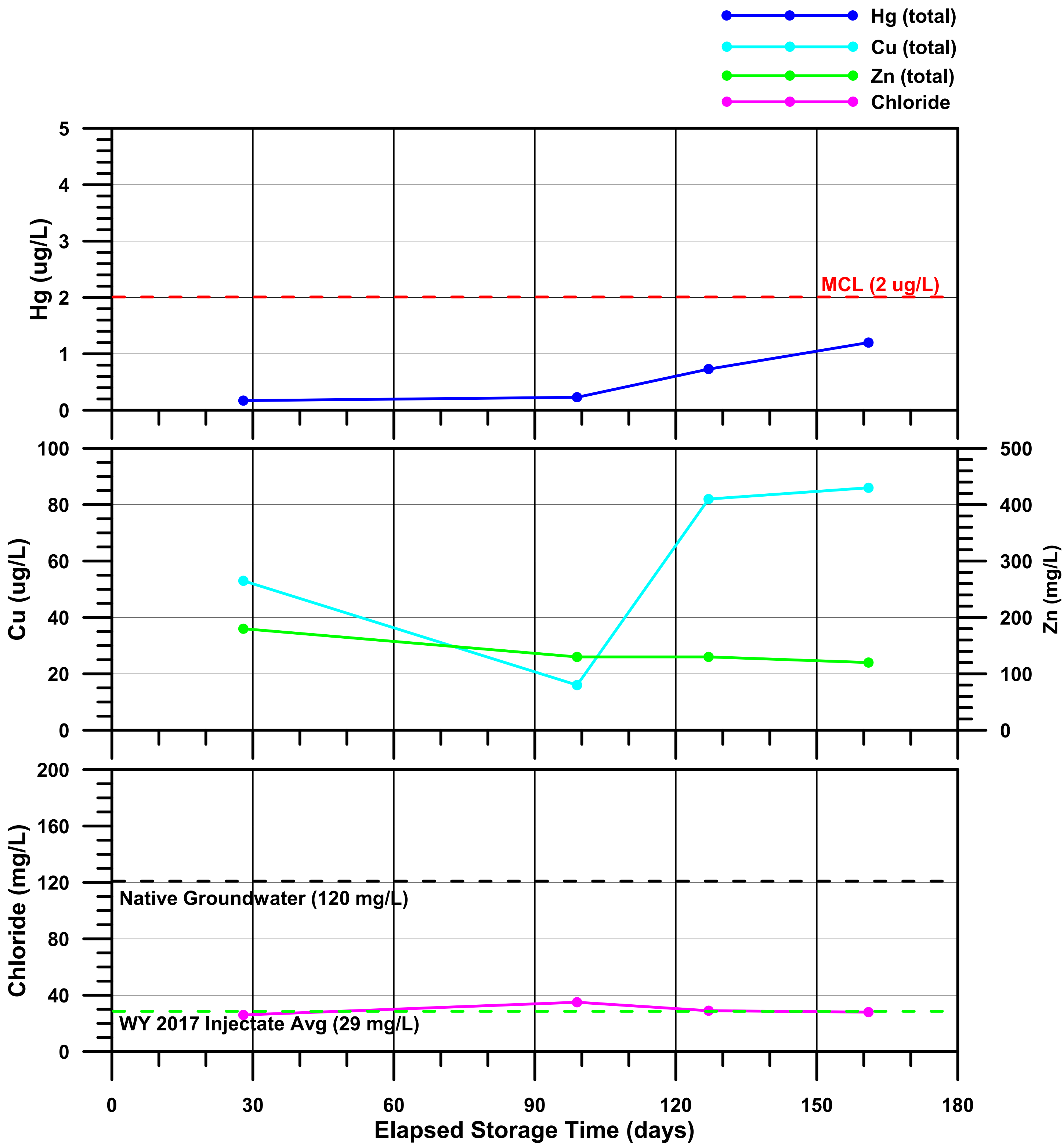
# EXHIBIT 8-A




PUEBLO water resources

FIGURE 28. SMS DEEP DISINFECTION BYPRODUCTS PARAMETERS
WY 2017 ASR Program
Monterey Peninsula Water Management District

EXHIBIT 8-A




PUEBLO water resources

FIGURE 29. ASR-4 HG MONTHLY STORAGE DATA
WY 2017 ASR Program
Monterey Peninsula Water Management District

June 2018
Project No. 12-0049

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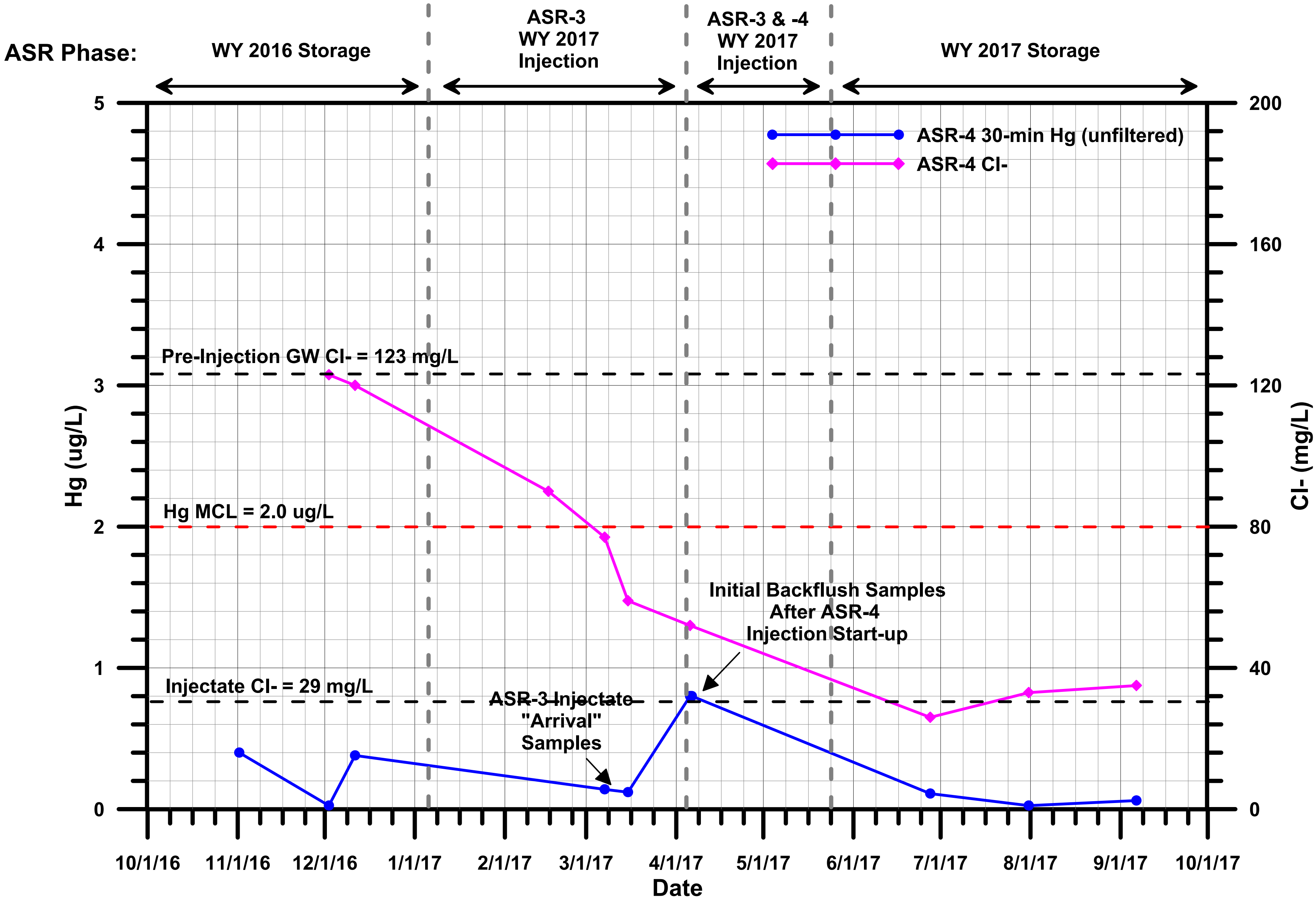


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FIGURE 30. ASR-4 - ASR-3 Hg "BREAKTHROUGH" MONITORING DATA
WY 2017 ASR Program
Monterey Peninsula Water Management District

# APPENDIX A - FIELD DATA
(not included in draft)

# APPENDIX B – WATER-QUALITY LABORATORY REPORTS
(not included in draft)

# APPENDIX C – HIGH-FREQUENCY INJECTATE SAMPLING DATA
(not included in draft)

# APPENDIX D – BACKFLUSH RESIDUE SAMPLING LABORATORY REPORTS
**(not included in draft)**