FINAL Report

Assessment of the Hydrogeologic Characteristics of the Chorro Valley

Morro Bay, California

Prepared for

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Prepared by

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Introduction

This report presents the results of our assessment of the hydrogeologic characteristics of the Chorro Valley east of the City of Morro Bay (City) with the goal of cost-effectively reusing recycled water from a forthcoming water reclamation facility to enhance the City's water supply. This report consists of two sections:

1. A technical analysis of the basin specifically related to the City's interest in supplementing its water supply with the reuse of highly treated recycled water.

2. A screening-level analysis of several potential projects to cost-effectively reuse recycled water to enhance the City's water supply. This section summarizes recycled water reuse alternatives relevant to the Chorro Valley, which include: active recharge, in-lieu deliveries, and direct injection and subsequent recovery of recycled water (i.e. indirect potable reuse [IPR]).

1. Technical Analysis of the Chorro Valley Basin

The City operates two well fields in the Chorro Valley, from which historical production has been dependent to some degree on streamflow within Chorro Creek. The relationship between production from the two well fields and streamflow within the creek was previously documented, but is updated herein based on the hydrologic conditions of the recent serious drought. This analysis considers the proposed use of the alternatives for recycled water reuse discussed later in Section 2. This technical analysis includes:

- Discussion of local geology;
- Description of the producing aquifer in the valley;
- Analysis of recent flow data in Chorro Creek, and interaction of surface water and groundwater;
- Consideration of the recycled water reuse to supplement the City's water supply; and
- consideration of the use of the County of San Luis Obispo's golf course irrigation well for City supply, possibly in exchange for City recycled water.

Local Geology

The Chorro Valley Groundwater basin (DWR Basin Number 3-42) covers an area of 5 square miles (3,200 acres) east of the City of Morro Bay along the Highway 1 corridor. Impermeable rocks of the Franciscan Group and Miocene intrusive rocks bound the basin. On the west end of the basin, the aquifer is in hydraulic communication with the ocean at the mouth of Chorro Creek where it enters Morro Bay. The groundwater-bearing portion of the basin consists of interbedded clay, sand, and gravel of thicknesses reaching a maximum of 70 feet (DWR, 2004). The water-bearing portion of the basin covers a smaller area of approximately 3 square miles, or 1,900 acres (CHG, 2009).

Chorro Valley and the Producing Aquifer

Within the Chorro Valley Groundwater Basin, the total groundwater storage capacity is approximately 9,600 acre-feet (DWR, 1975), which is equivalent to an average aquifer thickness of 50 feet (specific yield of 12 percent [DWR, 1958]). Of the 9,600 acre-feet of total storage capacity, the estimated perennial yield of the basin is 2,210 acre-feet per year (AFY) (CH2MHILL, 2011; Dudek 2012).

The irregularly shaped 1,900-acre water-bearing portion of the basin follows Chorro Creek and its tributaries for total length of almost 9 miles. The basin generally consists of clayey materials overlying interbedded sand and gravelly sand. The principal aquifer in the Chorro Valley is the underlying sand and gravelly sand, which is present between depths of 20 to 50 feet below ground surface in the area of the City's two well fields, where it reaches a maximum aquifer thickness of 25 to 30 feet. Discontinuous layers of clay interrupt the lateral extent of the aquifer. The locations of the two well fields are presented on Figure 1. A representative geologic cross section is presented on Figure 2.

In the area of the Ashurst wells, the producing aquifer is present at an elevation of approximately 10 to 40 feet below sea level. The Romero well field is located 1.25 miles inland from (east of) the Ashurst well field at a higher elevation. Following the change in surface elevation, the same aquifer at the Romero well field is present at higher elevation of approximately 40 to 10 feet above sea level, or approximately 50 feet higher than at the Ashurst well field (see Figure 2).

Groundwater flows through the Chorro Valley basin toward the west at a gradient that varies from a low of 0.003 to 0.005 feet per foot, which is representative of static conditions, to a high of 0.025 feet per foot under conditions when the City's wells are pumping (CHG, 2009). During September 2015, the hydraulic gradient between the well fields was 0.005 feet per foot toward the west when water levels were low and the wells were not pumping.

The City has a right to pump 1,142.5 AFY from the Chorro Valley. This right to produce groundwater from the Chorro Valley is constrained to times when surface flow within the adjacent Chorro Creek is flowing at least 1.4 cubic feet per second (equal to 628 gallons per minute [gpm]). The City has pumped much less than their permitted volume recently, but did pump more than 1,000 AFY during the decade prior to receiving State Water Project deliveries. The Ashurst well field has provided more water to the City supply than the Romero well field. Before implementation of the State Water Project in late 1997, the Ashurst well field produced an average of 579 AFY, while the Romero well field produced an average of 380 AFY. For the 11 years between 1998 and 2008, pumpage has dropped significantly, with an average combined production of only 96 AFY. Currently, three wells are active in the Ashurst well field (Wells No. 9, 10 and 16), while in the Romero well field, only Well 11A is active.

Although the concern about seawater intrusion is elevated during times of drought, when static and pumping water level conditions in the Ashurst well field are significantly below sea level for short periods, seawater intrusion has not been noted, as it has in the State Park wells in the Morro Flat area nearer the estuary (CHG, 2009). Indeed, although the primary aquifers in the Chorro Valley are in hydraulic connection to the ocean, there has been no documented evidence of seawater intrusion in the City's wells within the Chorro Creek groundwater basin (Fugro 2012a, 2012b). Recent water levels for the Ashurst well field have been above sea level by 12 to 20 feet, which reflect the lack of significant pumpage from these wells. Recent hydrographs of wells in the Ashurst well field are presented as Figures 3, 4 and 5. Water levels in the Romero well field are significantly higher at 50 to 55 feet above sea level, as presented on Figure 6.

During periods of lowered water levels, water produced from the City's wells in the Chorro Valley has exceeded the State of California Maximum Contaminant Level (MCL) for nitrate, most notably at the Ashurst well field but also at the upstream Romero well field. Because the City does not currently treat the produced water for nitrates, the wells have not been used for water supply.

Groundwater Recharge

Recharge to the groundwater basin and the two City well fields within the Chorro Valley occurs principally by percolation of streamflow within Chorro Creek and its tributaries, which from west to east are San Bernardo, San Luisito, Pennington and Dairy Creeks (refer to Figure 1). Recharge also occurs from percolation of precipitation, irrigation return flow and underflow to varying degrees (CHG, 2009).

Interaction of Surface Flow and Groundwater

Ashurst Well Field. Streamflow in San Bernardo Creek, which is the farthest west of the tributaries to Chorro Creek, flows into Chorro Creek just upstream of the Ashurst well field and recharges the main producing aquifer in the valley. Recharge from San Bernardo Creek flow occurs due to the inferred presence of a buried channel near Highway 1 connecting surface flow in San Bernardo Creek with the main aquifer in the Chorro Valley beneath the shallow clays (CHG, 2014). Surface flow in the Chorro Creek in the area of the Ashurst well field is somewhat separated from the main Chorro Valley aquifer by the presence of the shallow clays, which preclude significant recharge to the Ashurst wells (CHG, 2009).

Average flow in San Bernardo Creek is approximately:

- 275 AFY during dry years,
- 1,160 AFY during normal years, and
- 3,450 AFY during wet years (Morro Group, 1990).

During normal to wet conditions, the recharge from San Bernardo Creek surface flow exceeds recharge from either flow in Chorro Creek or subsurface inflow. During normal to wet conditions, and when the Ashurst well field is pumping at 1,150 gpm, recharge from San Bernardo Creek is at least 780 gpm. Recharge from flow within Chorro Creek is approximately 250 gpm.

The source of recharge to these wells is from "local" sources, that is, water other than State Project Water, which is used and discharged as treated wastewater effluent from the far-upstream California Men's Colony Wastewater Treatment Plant (CHG, 2009). This further supports the fact that this wellfield derives its recharge principally from San Bernardo Creek flow ("local " sources.) That is, flow from the Chorro Creek skirts over the Ashurst Wells due to the presence of the shallow clays. On this basis, potential projects focused on recharge to these wells should be located within the San Bernardo Creek watershed.

Romero Well field. Farther upstream at the Romero well field, recharge to the main aquifer occurs principally from percolation of streamflow within the Chorro Creek and its upstream tributaries: San Luisito, Pennington and Dairy Creeks. The Romero well field differs from the downstream Ashurst well field in that:

- Flow within the Chorro Creek both recharges the Romero well field and is depleted while the Romero well field is in operation, and
- The ultimate source of recharge to the Romero wells is from a combination of State Project Water return flows (California Men's Colony), and "local" sources, which are from percolation of streamflow in upstream tributaries, percolation of irrigation water or underflow. This point strongly suggests that the well field receives a large portion of its recharge directly from the Chorro Creek.

The County of San Luis Obispo measures and records streamflow within Chorro Creek at the Canet Road Bridge upstream of the Romero well field. Average annual streamflow varies between:

- 400 to 600 AFY during dry years,
- 1,500 to 4,000 AFY during normal years, and
- 12,000 to 24,000 AFY during wet years.

Hydrographs of average annual streamflow, precipitation and recent water level in the Romero well field are presented as Figure 7. Water levels in the Romero Well No. 11A have varied narrowly in the past two decades. Prior to the period of the presented water level data, water levels declined to as low as 35 feet above sea level. However, following significant flow in Chorro Creek, water levels appear to fully recover to 55 feet above sea level (refer to Figure 8).

Percolation of Precipitation

Approximately 8 to 10 percent of the precipitation that falls on the area in and around the two City well fields percolates into the producing aquifer. Based on this, percolation of precipitation contributes approximately 10 AFY of precipitation recharge the aquifer in the Chorro Valley (CHG, 2009).

Underflow

Underflow to the Ashurst well field varies between 75 AFY when the Ashurst wells are not pumping and as much as several hundred AFY when the Ashurst wells are pumping and water levels are relatively low (CHG, 2009). Based on aquifer configurations, gradients and aquifer parameters, similar underflow volumes recharge the aquifer in the area of the Romero well field. Therefore, the underflow to the combined well fields varies between 150 AFY during static conditions to as much as 500 AFY when pumping.

Use of the Golf Course Well

A potential opportunity for the City is to utilize the County of San Luis Obispo's golf course well as a potential water supply source. To that end, we have compiled information for that single well and summarize it here. The so-called "84" well is the sole water source for the Morro Bay Golf Course and is located along South Bay Boulevard in the "Domenghini Flat" (aka Chorro Flat) area of the Chorro Creek near the Morro Estuary Natural Preserve. The well is 100 feet deep and has a cement surface sanitary seal to a depth of 20 feet. The well pumps 250 gpm with an apparent drawdown of approximately 30 feet.

Over the past decade, the well has pumped an average of 173 AFY, which has varied between 130 and 212 AFY. Golf course operations staff believes that the well could produce as much as 300 AFY if some undetermined facilities constraints could be resolved.
The close proximity of the well to the estuary and bay cause concern over the possibility of seawater intrusion. This concern elevated during times of drought, as has been noted in the State park wells nearby (CHG, 2009). However, water levels in the well have remained high in recent years despite the recent serious drought.Between the mid-1980s and 1990, during a period of drought and relatively high volumes of annual pumpage of the City's wells in the Chorro Valley, water levels in the Golf Course well were below sea level by as much as 15 feet. Since that time, measured water levels in the well have remained above sea level. Coincident with the delivery of State Project Water to the Chorro Valley in 1997, pumpage from the City's two well fields upstream of this well decreased significantly, especially so in the closer Ashurst well field. Recent static water levels in the well are above sea level by approximately 7 to 9 feet.

The use of the "84" well for City supply is possible, albeit with the understanding that a potential for seawater intrusion to this well may exist during low water level conditions. Any recycled water reuse projects may raise water levels throughout the Chorro Creek Basin during drought and thereby in the Chorro Flat area. Operationally, any recharge to the basin may increase water levels in the Ashurst and/or Romero well fields first, which may reach downstream to this well, but with some delay. This delay of response to any applied recharge may be significant if the Ashurst wells intercept a significant amount of the water.

2. Recycled Water Reuse Alternatives

The proposed water reclamation facility will produce recycled water that may be reused in the Morro and/or Chorro Valleys to supplement the City water supply. The goal of this project is to cost-effectively reuse 2.75 acre-feet per day (1,000 AFY) of recycled water in a manner that will enhance the City's water supply. Of several potential projects to reuse the recycled water to enhance the City's water supply, the principal alternatives considered herein include:

1. Active recharge through infiltration basins
2. In-lieu recharge
3. Injection and recovery at City production wells

The results of analyses performed for each of three principal alternatives are presented on the attached tables and discussed below. The discussion summarizes the screening-level analysis and is meant to supplement the tables. Active recharge through application of recycled water directly to the Chorro Creek has been the subject of a previous study (CHG, 2014). Although active recharge into infiltration basins is discussed, the direct discharge to the creek itself is not analyzed further in this report.

Active Recharge through Infiltration Basins

This alternative involves active recharge through surface application of recycled water into infiltration basins within the Chorro Valley. Conceptually, water directed into infiltration basins would recharge the aquifer, bank the recycled water as stored groundwater, and increase the volume of available groundwater in the alluvial system for subsequent extraction by City wells.

For the purposes of this analysis, a large portion of the Chorro Valley is considered available for construction of infiltration basins. A 2008 irrigated crop survey indicated that a total of 644 acres in and immediately surrounding the Chorro Valley were irrigated agriculture. In the past, this area has been as large as 820 acres in 1995 (CHG, 2009, Figure 6 and Table 2). This range of acreage corresponds to 34 to 43 percent of the water-bearing portion of the basin. While a variety of crops was present, the predominant uses were truck crops and vineyards, which required an average of 2 AFY of applied irrigation.

The ability to effectively construct infiltration basins is directly influenced by the nature of the surficial materials in the Chorro Valley. The surficial materials in the Chorro Valley are described on the boring logs for wells throughout the basin as predominantly "clayey." The geologic cross sections through the Chorro and San Bernardo Creek areas (Figures 1 and 2) indicate that the clay materials are present at the surface generally throughout the valley. As discussed in Section 1 above, the deeper materials below this clay layer consist of 20 to 30 feet of sands and gravels in which Ashurst and Romero wells are screened. In the area of the Ashurst well field in the western portion of the basin, the aquifer materials are interbedded with laterally discontinuous layers of brown clay. The interbedded clay layers do not appear to exist in the area of the Romero well field in the central portion of the basin.

Based on the historical land use and geologic constraints, the installation of active infiltration basins in the valley upstream of the existing City well fields could accept a minimum of 2 acre-feet per acre per year without being significantly impeded by the thick clay layers at the surface. However, the “clayey” nature of the surficial materials would limit higher percolation rates. Percolation into active infiltration basins into the clayey materials would be able to accept approximately 2 AFY per acre during drought conditions, or as much as 1,000 AFY if 500 acres were converted to infiltration basins. This percolation volume may decline to zero AFY during wet periods when the impeding clay layer becomes saturated and the underlying aquifer materials are filled. Therefore, recharge into infiltration basins is considered infeasible.

Percolation of recycled water into the active channel of parts of Chorro and San Bernardo Creeks would recharge the Chorro Valley aquifer, as discussed in previous studies (CHG, 2014), and would therefore benefit the City’s water supply. The previous study analyzed the discharge of a smaller quantity of recycled water discharged at the specific location of the California Men’s Colony in the Chorro Valley. However, the benefit to the City may be maximized by percolating water into the active channels of the tributaries to the Chorro Creek including the San Bernardo, San Luisito, Pennington and Dairy Creeks, which was not analyzed further in this screening-level analysis.

Seasonal constraints would be high; during the wet season and all non-drought times, this storage decreases to near zero as the coarse aquifer materials become fully saturated.

Because it is the goal of this alternative to recharge potable water supplies with basins within proximity of the City’s wells, it would require Regional Water Quality Control Board (RWQCB) permitting for recycled water reuse and California Department of Drinking Water (DDW) for compliance with residence time and any Total Organic Carbon (TOC) removal requirements.

Agreements with private well owners downgradient from the infiltration basins would be required, if the residence time from the basins is determined to be short enough that direct service agreements would be required. Significant property acquisition would be required for infiltration sites.

The City currently has a permit to extract 1,142.5 AFY of underflow from the Chorro Valley. Active recharge upstream of the City’s wells would likely increase the City’s right and ability to pump underflow by an equal volume, minus some calculated loss factor.

Water quality of produced groundwater from City wells would slowly and eventually improve through recycled aquifer flushing of better quality water than native groundwater, which would likely take many years.

Assuming 500 acres are converted into infiltration basins in the Chorro and San Bernardo valleys, the advantages of this alternative are that it would create a mechanism to reuse at least 1,000 AFY of recycled water during drought. In turn, this would increase the City's water supply in drought times by adding groundwater to the underflow and eventually recharging the City's wells with high quality water.

However, the alternative would require high land acquisition costs. Furthermore, the alternative could create potential residence time constraints because of proximity to nearby private wells. Lastly, the alternative creates potential need to serve private landowners with City water outside of City boundaries because of these residence time limitations.

Analysis of this alternative suggests that the alternative of groundwater recharge through infiltration basins is likely not feasible.

In-Lieu Recharge Program – Exchange for Reduced Groundwater Pumping

An in-lieu recharge program would provide valley growers with an irrigation water supply in exchange for a reduction in groundwater pumping. The recycled water would be delivered to growers located generally between the Ashurst and Romero well fields where truck crops are concentrated for direct application to crops in exchange for reduced groundwater pumping. If most or all of the 650 acres of agricultural land documented in 2008 in and surrounding the Chorro Valley were supplied with in-lieu sources of high quality recycled water, it is feasible that a large proportion of the recycled water could be delivered for agricultural use. Such reduction in pumpage would conceivably result in a much greater volume of groundwater available to the City by extraction from the City wells.

The principal advantage of the alternative is that, depending on the location of growers/customers and their willingness to participate, there is the potential to utilize a large percentage of the recycled water flow volume, if seasonality constraints and/or wet weather storage can be resolved. Furthermore, an in-lieu exchange program is generally the most effective means to maintain water levels (groundwater in storage) in a basin, and can be particularly effective at increasing groundwater in storage.

There are a large number of unknowns relative to the potential benefits to the City. The potential benefit depends on where the in-lieu growers are located in the valley and their willingness and ability to exchange groundwater pumping for in-lieu water. Currently, in the absence of an adequate groundwater management plan, many of the growers only stop pumping when their wells dry up. An in-lieu program may only extend the time before their wells dry up, at which time they would have to resume groundwater production .

An in-lieu program would require a valley-wide basin management plan, with cooperation agreements by virtually all growers, whether or not they received in-lieu water. All growers would have to cooperate in order for the City to realize a water supply benefit, particularly at the downstream end of the valley where the Ashurst wells are located. The management plan and cooperation agreements would likely result in reduced demand, management constraints, and possibly in a valley-wide Water Supply Analysis.

Feasibly, significant off-stream storage would be required to accept water during wet weather to mitigate the seasonality constraints, or an associated alternative would have to be pursued such as direct application of the recycled water to the Chorro Creek and several of its tributaries.

Numerous water rights issues may exist related to this alternative. It is likely that the City would be able to claim credit for the exchanged water, then pump it from their wells, and thereby exceed their State permit which allows 1,143 AFY of pumpage. While most of the growers pump according to riparian rights, some may also have a State permit to pump underflow. If so, these growers would likely be unwilling to reduce their pumping for fear of losing that established right. If the growers did not stop (or reduce) pumping, the benefit to the City would be diminished.

There are numerous significant constraints to the effectiveness of this alternative in enhancing the City's water supply. Obstacles may include a requirement of the creation of a basin-wide SGMA-type management plan, which would include all growers and pumpers in the basin, not just the recipients of the in-lieu water. A plan would have to be developed that would result in a net reduction in groundwater pumping by the private users in order for the City to realize a water supply benefit at the downstream end of the basin. Lastly, an extensive distribution system would be required to deliver the in-lieu water to each individual grower.

The direct exchange of recycled water in-lieu of reduced pumping is considered technically achievable, but the numerous significant constraints and water rights concerns make the alternative likely and reasonably infeasible.

Injection and Recovery at City Pumping Wells

This alternative considers the feasibility of injection of recycled water into the lower permeable horizons of the aquifer for storage and subsequent extraction by the City's water supply wells (i.e. indirect potable reuse [IPR]). This analysis was based principally on review of water level data for the period of 1960 to present (CHG, 2009, Appendix A and recent County of SLO flow gauge data; Figures 2 through 6). In concept, this alternative would inject water into the basin while the active well fields would draw down the water in the aquifer, thereby increasing the available storage capacity of the aquifer, potentially increasing the benefit to the City. As presented on Figure 7, precipitation occurs in cyclic patterns of subsequent wet and dry periods. Based on precipitation data in Morro Bay, which starts in 1959, dry periods have occurred between calendar years 1984 to 1989 (five years) and the recent overall drought period between 2002 and 2015, which is punctuated by two wet years.

Water levels during the 1984 to 1989 drought declined up to 40 feet at the Ashurst well field. During that drought, water levels in the Ashurst wells were as low as 10 feet below sea level for short periods while the well field was pumping, which is significantly lower than the current elevation at the end of 2015 when the wells were not pumping. Even during the historic low water levels, the water elevation still provided 15 to 20 feet of saturated aquifer material.

However, at the Romero well field, water levels during the drought of 1984 to 1989 declined up to 20 feet to an elevation of 35 feet above sea level for short periods. During these times, the saturated thickness of aquifer in Well 11A decreased to within about 5 feet of the bottom of the wells (Fugro, 2012b), significantly decreasing production.

Based on the historic water levels at Ashurst well field, the thickness of unsaturated aquifer material has not become sufficiently dewatered to allow any potential benefit to the City's water supply by injection of recycled water directly into the aquifer.

At the Romero wells during drought conditions and while the wells are pumping, sufficient volume of unsaturated aquifer was present only for short periods. However, the limited duration of periods when water levels were low enough to fill any unsaturated aquifer volume with recycled water, even while pumping the Romero wells, would minimize the benefit of injection and make its use infeasible. At both well fields, the unsaturated volume would decrease to zero, even with subsequent pumpage, during all but the most severe drought.

The alternative would require high capital costs and high operations and maintenance costs. Lastly, residence time and TOC removal requirements may limit the feasibility of the alternative.

Therefore, the estimated net benefit to the City's water supply during drought would be limited and would only be available during periods of drought.

The water quality of produced groundwater from City wells conceivably would slowly and eventually improve through recycled aquifer flushing of better quality water than native groundwater. This would likely take many years, however, particularly because upstream recharge may continue to be high in nitrates if an associated alternative in that area is not pursued. Assumptions could be made through comparison of anticipated quality of recycled water with native groundwater and mass volume calculation and/or water quality model to simulate long-term changes to water quality.

This alternative would require Regional Water Quality Control Board (RWQCB) permitting for recycled water reuse and California Department of Drinking Water (DDW) for compliance with residence time and Total Organic Carbon (TOC) removal requirements.

Summary

A summary of the water supply benefits associated with the three alternatives discussed is presented on Table 1 - Preliminary Alternatives for Recycled Water Reuse, Chorro Valley. A comparison of the benefit of these alternatives to the similar benefit in the Morro Valley is presented as Table 2 - Summary of Annual Water Supply Benefit, Chorro and Morro Valleys.

Of the alternatives considered in this screening-level analysis, the active recharge into infiltration basins is likely not feasible because of high land acquisition costs, potential residence time constraints because of proximity to nearby private wells, and the potential need to serve private landowners with City water outside of City boundaries.

In-lieu exchange with agricultural users is technically achievable and would likely be able to reuse a majority of the recycled water while benefiting the City water supply, but the numerous and significant constraints and water rights concerns make the alternative likely not feasible.

The use of IPR to inject and subsequently extract recycled water in the Chorro Valley aquifers is infeasible because the unsaturated volume of the aquifer in both well fields would decrease to zero during all but the most severe drought even with pumpage from the City's wells.

Consideration of using multiple alternatives of recycled water reuse will likely be required to satisfy the goals of the City in a manner that maximizes the benefit to the City's water supply.

References

CH2MHILL, 2011. *2010 Urban Water Management Plan, City of Morro Bay*, prepared for the City of Morro Bay, June.

Cleath-Harris Geologists, Inc., 2009. *Ashurst Well Field Nitrate Study, Chorro Valley, San Luis Obispo County*, prepared for the City of Morro Bay, May.

------, 2014. *Hydrologic evaluation of the potential benefits to the City water supply from increasing reclaimed wastewater discharge to Chorro Creek, San Luis Obispo County*, prepared for the City of Morro Bay, November 6.

------, 2014b. *Hydrologic evaluation of the potential benefits to the City water supply from reclaimed water use in the Morro Valley, San Luis Obispo County*, consultant report prepared for the City of Morro Bay, November 7.

Department of Water Resources (DWR), State of California, 1975. *Sea-Water Intrusion in California: Inventory of Coastal Ground Water Basins*, Bulletin 63-5.

------, 2004. *California's Groundwater, Bulletin 118*.

Dudek, 2012. *Draft Recycled Water Feasibility Study*, prepared for the City of Morro Bay and Cayucos Sanitary District, March.

Fugro, 2012a. *Chorro Valley Groundwater Basin Ashurst Well Field Area Hydrogeologic Assessment and Well Construction Work Plan*, prepared for the City of Morro Bay, September.

------, 2012b. *Chorro Valley Groundwater Basin Romero Well Field Area Hydrogeologic Assessment and Well Construction Work Plan*, prepared for the City of Morro Bay, September.

Morro Group, 1990. *Freshwater influences on Morro Bay*, June.

TABLES

Table 1 - Preliminary Alternatives for Recycled Water Reuse, Chorro Valley
City of Morro Bay

Goal: Cost-effectively dispose of 2.75 acre-feet per day (1,000 acre-feet per year, AFY) of treated effluent in a manner that will enhance the City's water supply
All units in AFY unless stated otherwise

Alternative	Volume of Wastewater Managed	Net Water Supply Benefit	Regulatory and Permitting Requirements	Cooperation Agreements Required	Seasonality Constraints	Available Storage	Water Rights Issues	Environmental Impacts	Water Quality Impacts	Capital and O&M Cost	Advantages	Disadvantages
1) Groundwater Recharge Through Infiltration Basins	Drought: 1000 AFY Wet: Limited	0 - 1,000 AFY	RWQCB - effluent disposal DDW - Residence time	Well owners for residence time and property acquisition	Significant. No storage in wet season		Could increase right/ability to pump underflow	Little to none	Gradual improvement at Ashurst well field	High	Reuse of 1,000 AFY during drought Increases supply to City wells	High land acquisition costs
2) In-Lieu Recharge Program - Exchange for Reduced Groundwater Pumping	Unknown (pending customers)	0 - 1,000 AFY		Valley-wide basin management plan & extensive agreements	Significant. Dependent on crops and irrigation schedules	Wet-weather storage required or additional alternative (stream recharge)	Numerous and potentially complicated.	Little to none	Little to none	High	Generally most effective means to maintain groundwater levels	Numerous constraints: basin plan, agreements, wet-season storage, water rights. Distribution system req.
3) Injection and Recovery at City Pumping Wells	Limited	Limited	RWQCB SWRCB DDW	Well owners for residence time	Significant. No storage in wet season	Limited to none excpet during extreme drought and pumpage	Could increase City's right to pump beyond current limit	Little to none	Gradual improvement	High	Alternative not feasible	High capital / operations cost.

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Table 2 - Summary of Annual Water Supply Benefit, Chorro and Morro Valleys

Values in acre-feet per year

Alternative	Drought Conditions		Normal to Wet Conditions	
	Chorro Valley Permit: 1,143	**Morro Valley** Permit: 585	**Chorro Valley** Permit: 1,143	**Morro Valley** Permit: 585
	Acre-feet per year			
In-lieu delivery up to 1.5 MGD (1)	900	585	515	1,160
Active Recharge 2.75 AF / Day	1,000	0 - 180	Limited	None
In-lieu delivery 2.75 AF / Day	1,000	Limited	Limited	Limited
Injection 2.75 AF / Day	Limited	1,000	Limited	0 - 500

Source: 1. CHG, 2014 and 2014b

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FIGURES

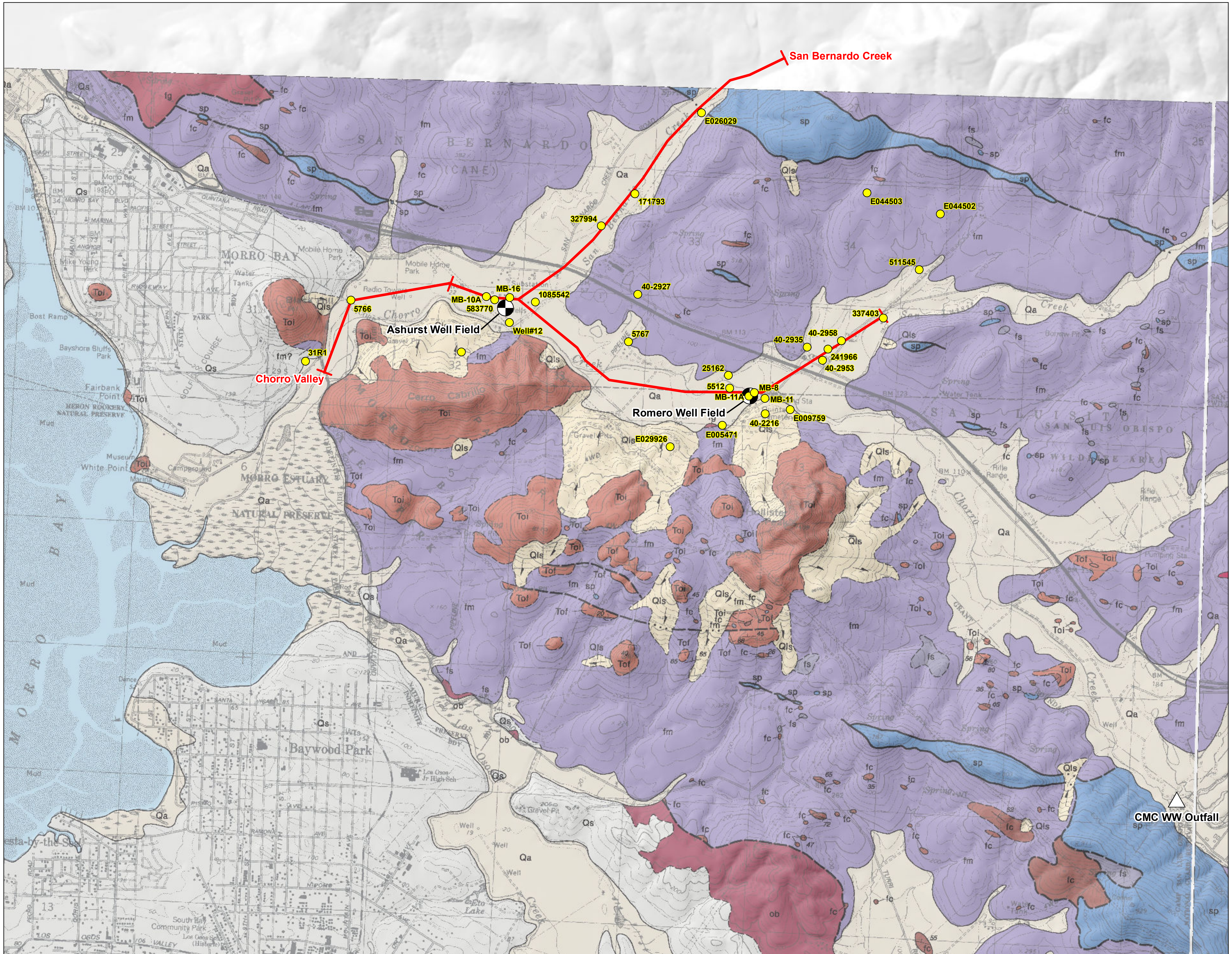

FIGURE 1

Chorro Valley Study Area

Morro Bay

LEGEND

- Cross Section Lines
- Well Logs
- Existing Well Fields
- California Men's Colony Wastewater Treatment Plant Outfall

Geologic Map Legend

Qa - alluvium
Qs - beach and dune sand
Qls - land slide deposits
Toi - Dacite; volcanic intrusive into Franciscan assemblage
sp - Serpentine
fm - Franciscan rocks; submetamorphosed marine sedimentary and mafic volcanic rocks

N

0 1,250 2,500 3,750
Feet

Date: July 15, 2016
Data Sources: USGS

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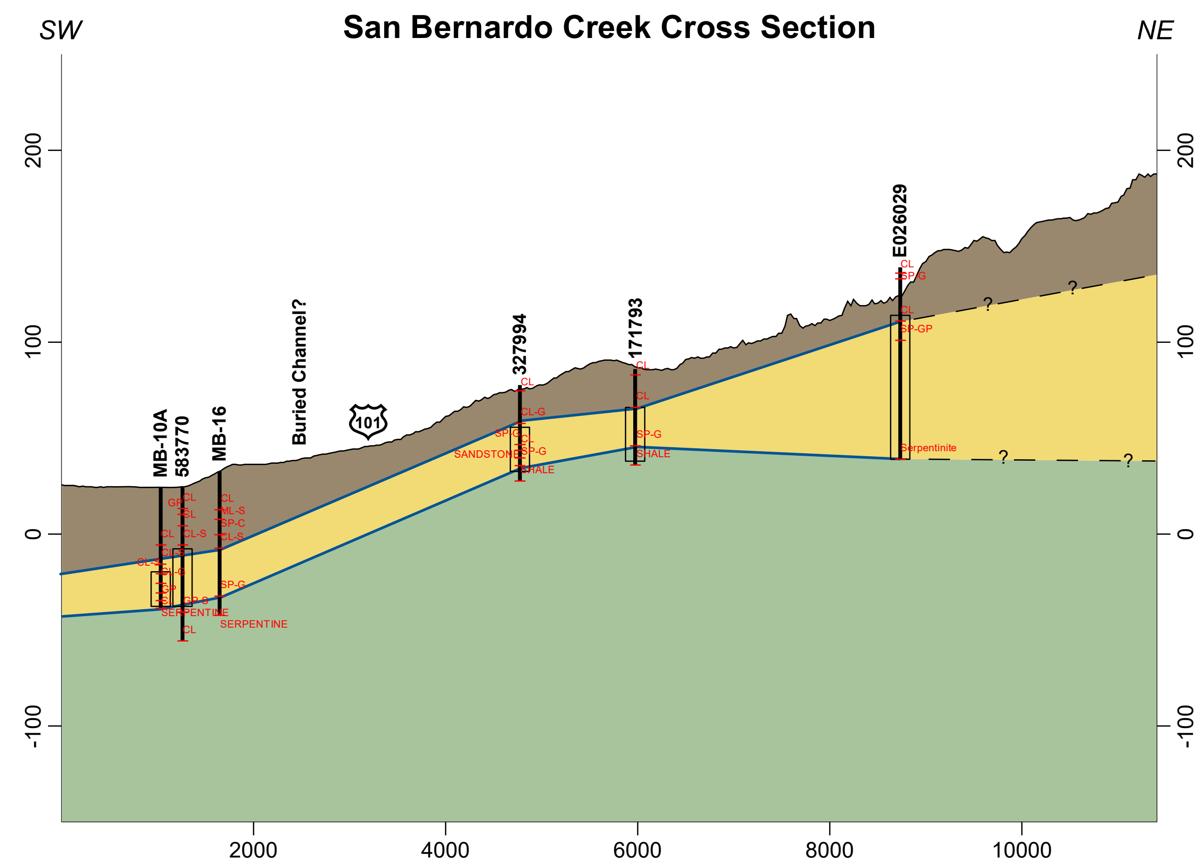

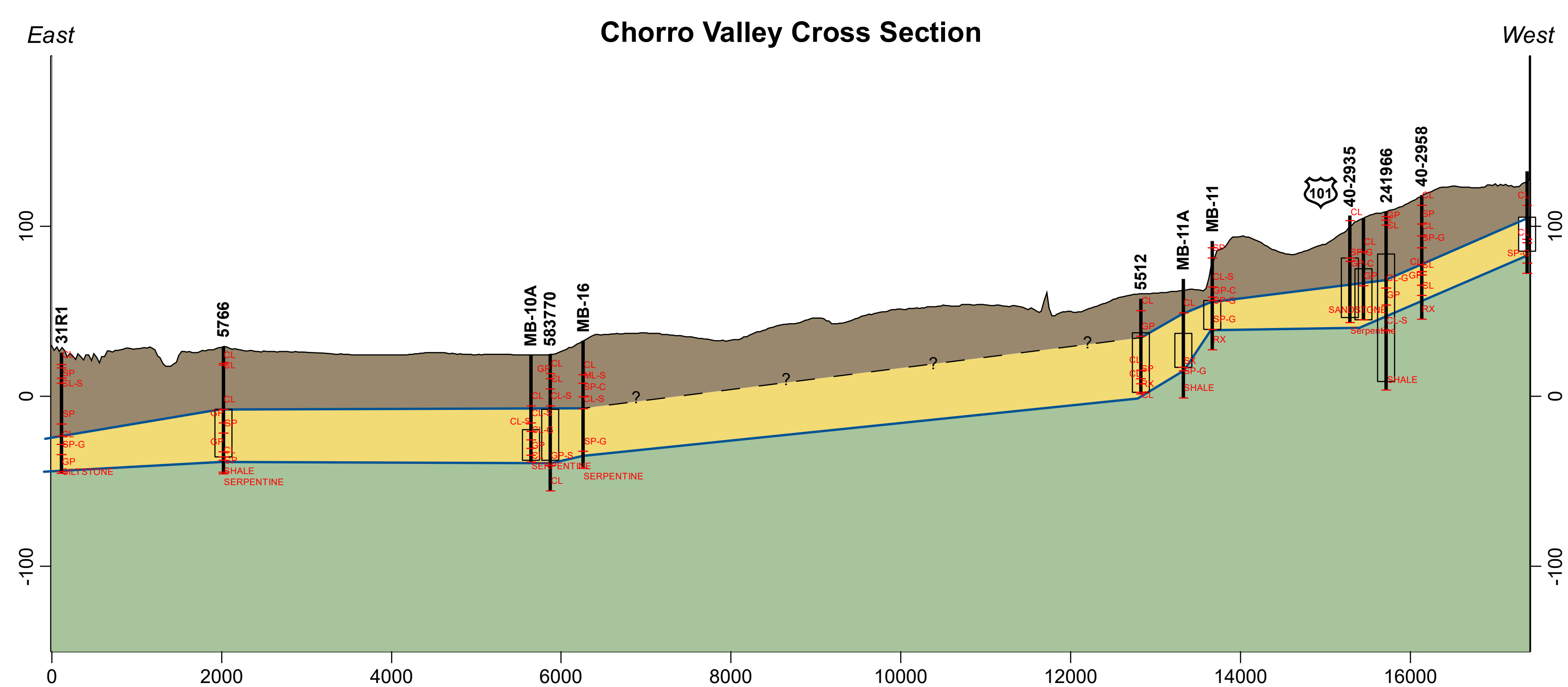

FIGURE 2

Geologic Cross Sections

Morro Bay

LEGEND

- Ground Surface Elevation
- Primary Aquifer
- Interbedded Alluvial Clay
- Interbedded Alluvial Sand and Gravel
- Bedrock

SCALE

100 feet

20x Vertical Exaggeration

2000 feet

Date: May 25, 2017

GSI Water Solutions, Inc.

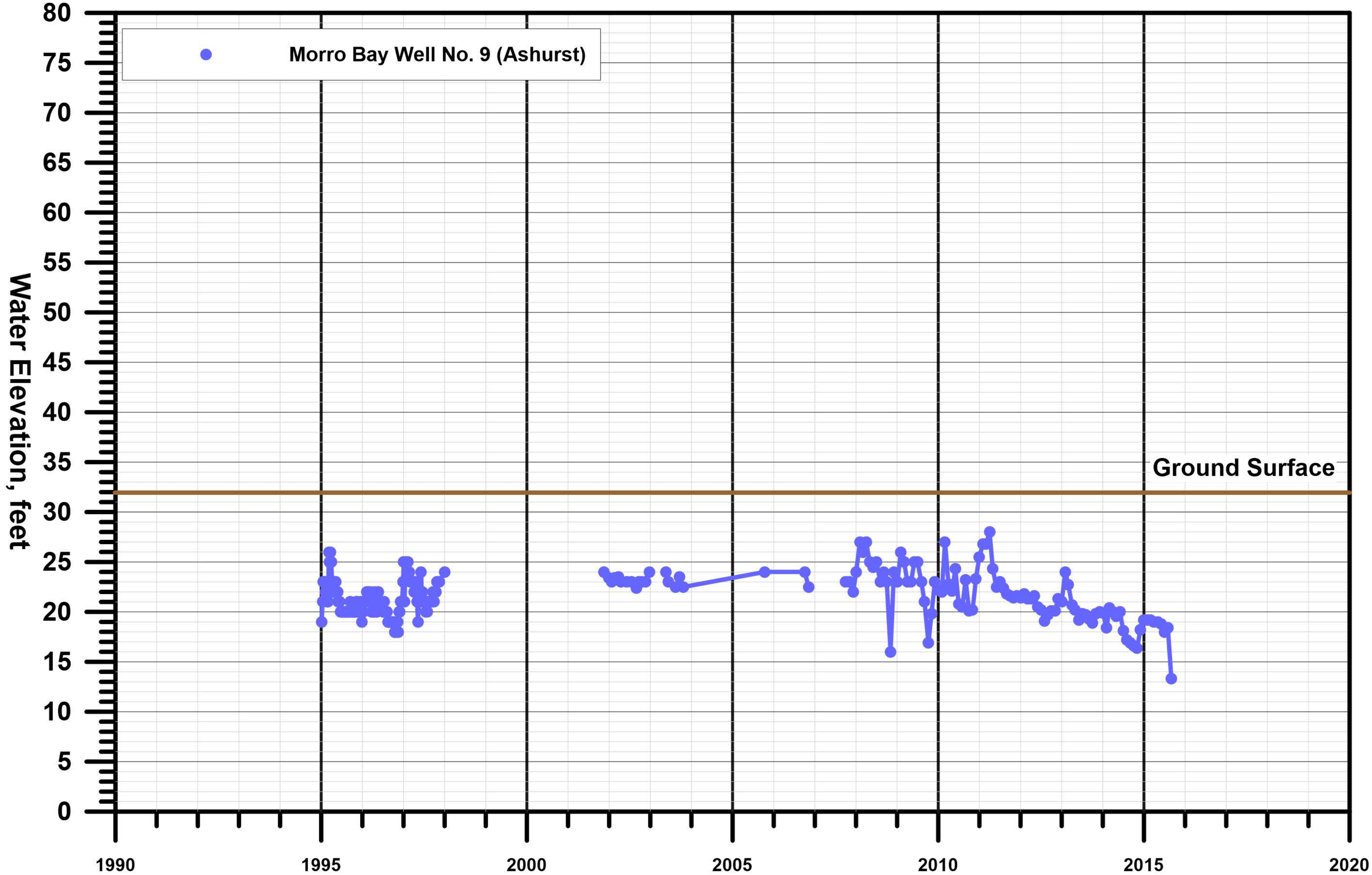

FIGURE 3

Ashurst Well No. 9 Hydrograph

Assessment of the Hydrogeologic Characteristics of the Chorro Valley

Morro Bay, California

GSI Water Solutions, Inc.

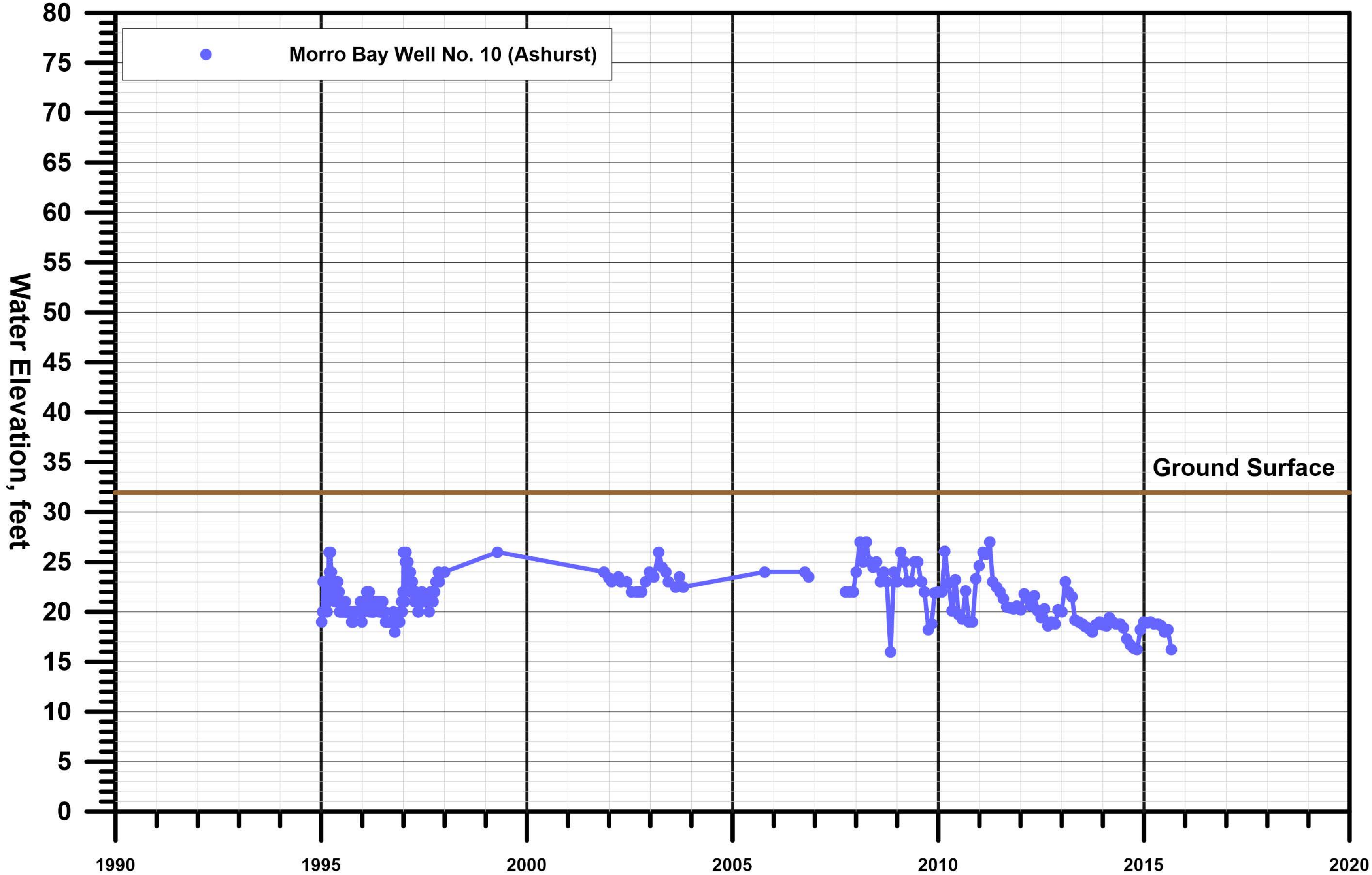

FIGURE 4
Ashurst Well No. 10 Hydrograph
Assessment of the Hydrogeologic Characteristics of the Chorro Valley
Morro Bay, California

GSI Water Solutions, Inc.

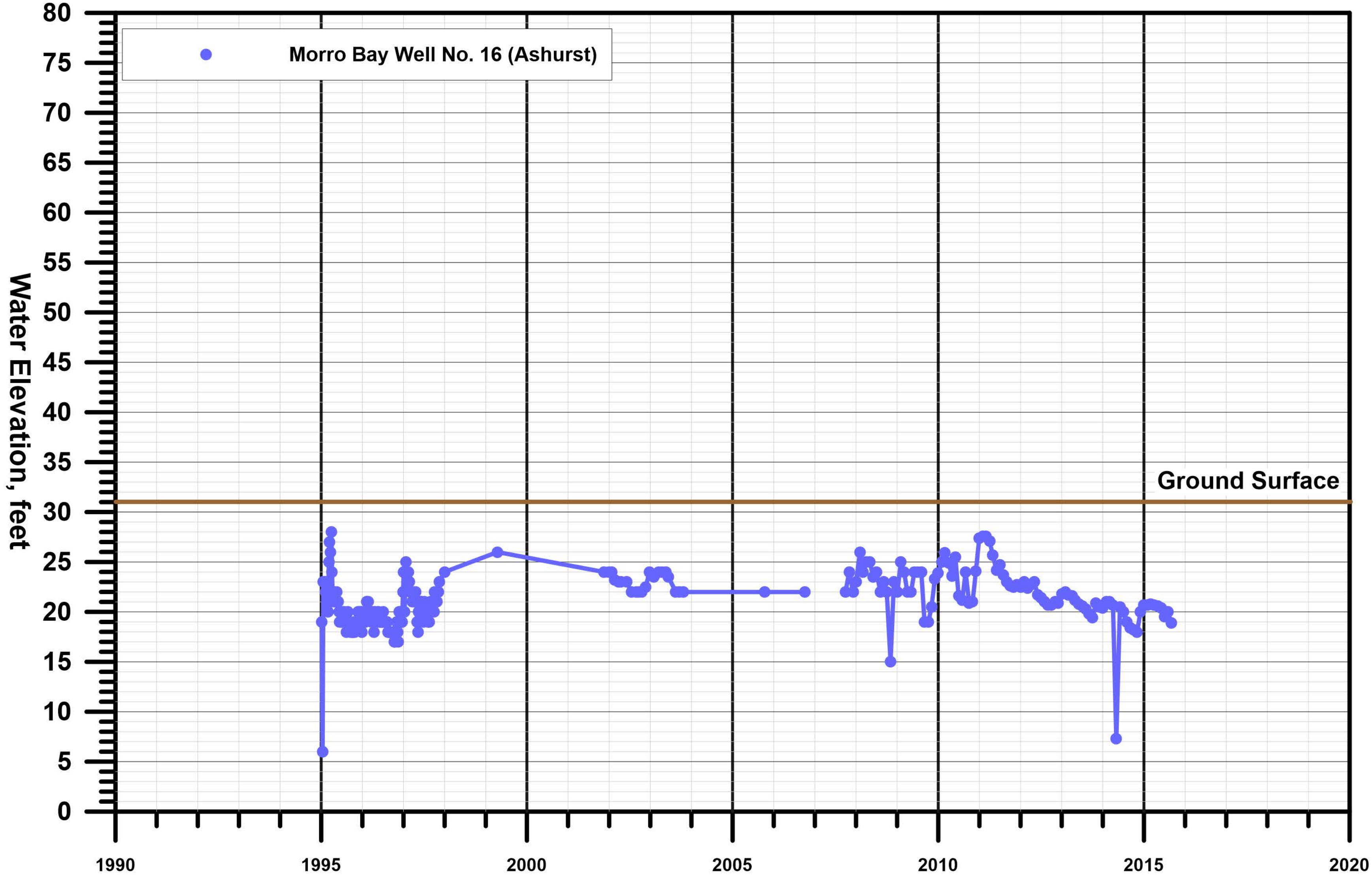

FIGURE 5

Ashurst Well No. 16 Hydrograph

Assessment of the Hydrogeologic Characteristics of the Chorro Valley

Morro Bay, California

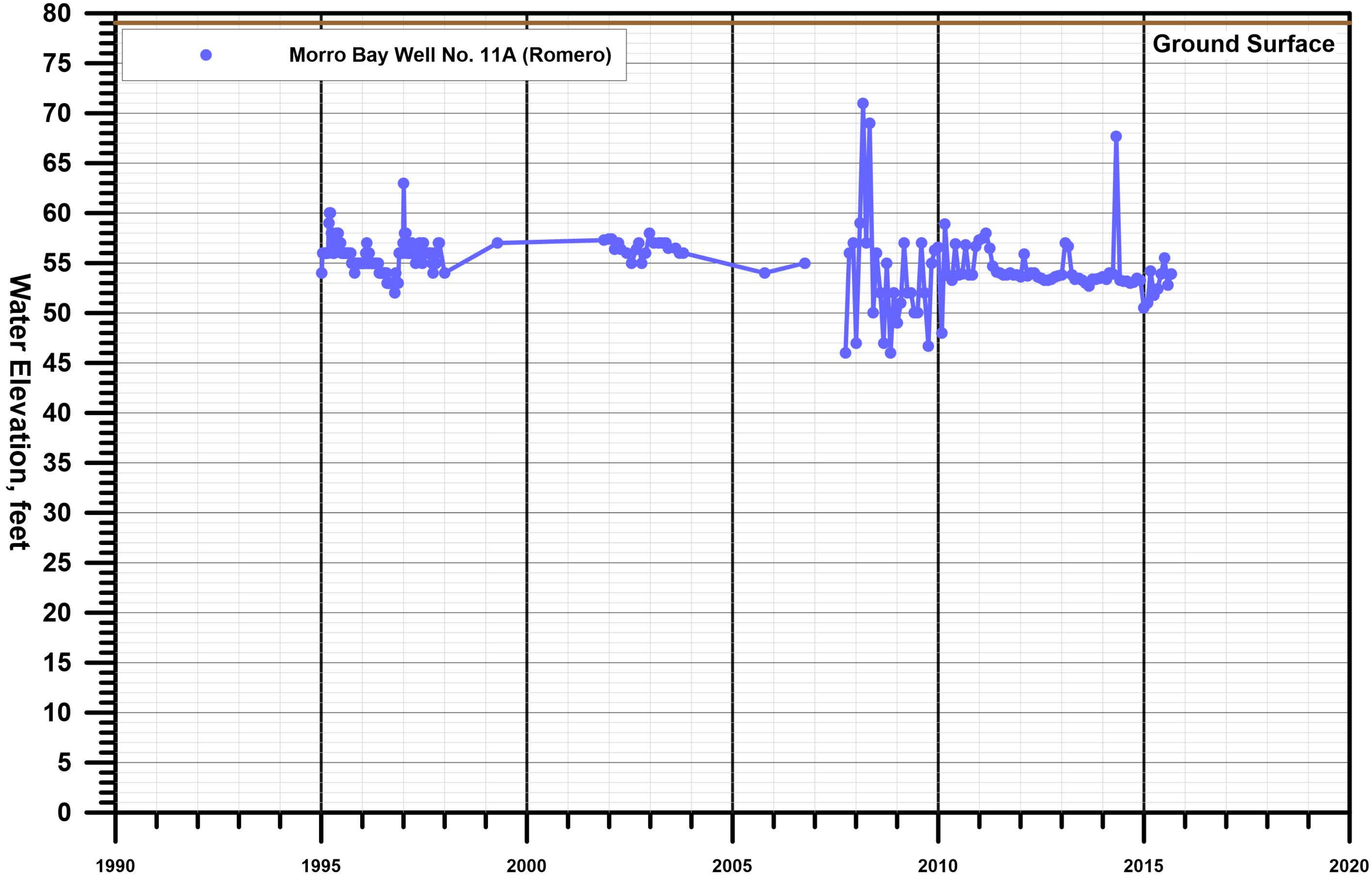

FIGURE 6

Romero Well No. 11A Hydrograph

Assessment of the Hydrogeologic Characteristics of the Chorro Valley

Morro Bay, California

GSI Water Solutions, Inc.

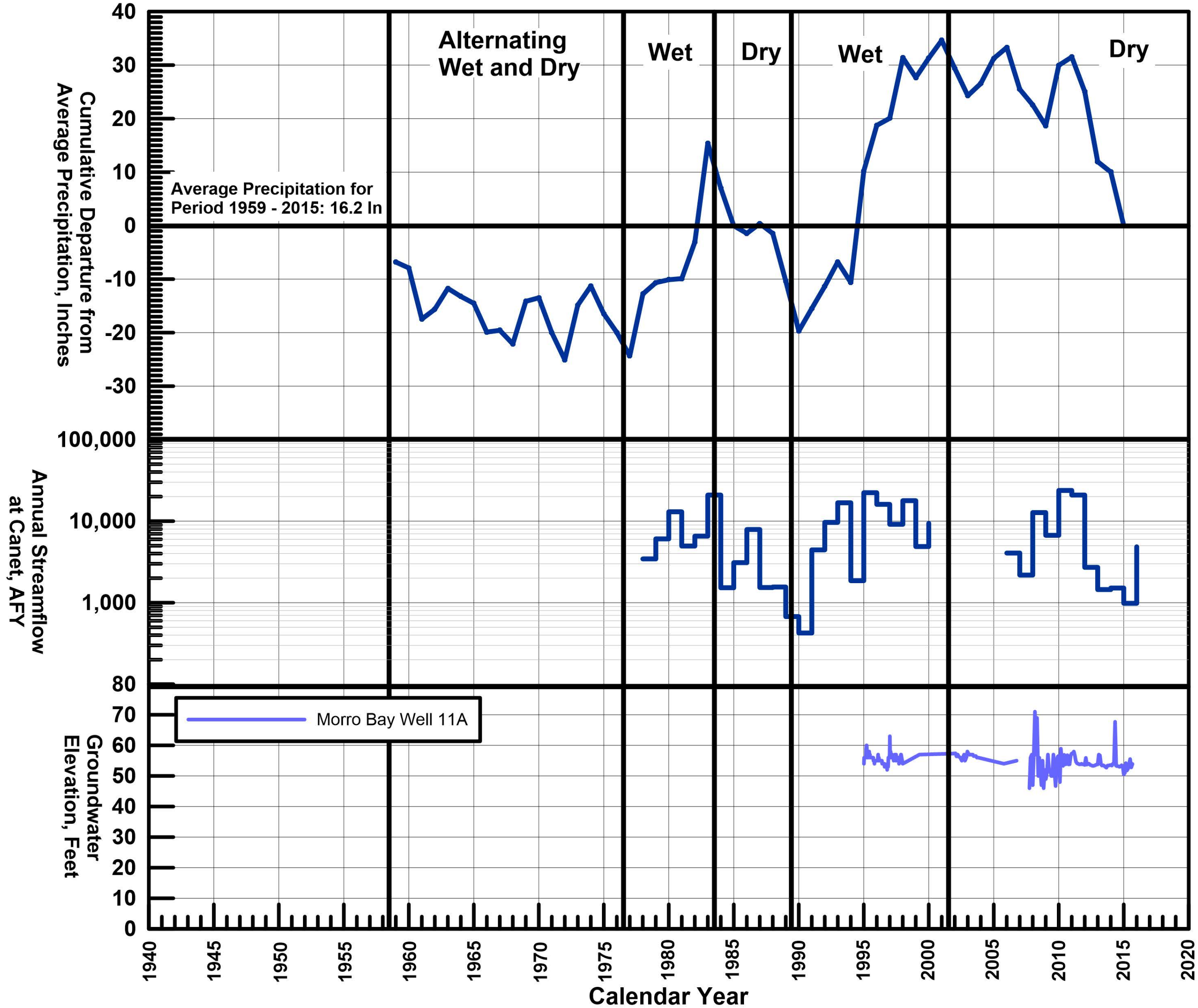

FIGURE 7

Precipitation, Streamflow and Romero Well No. 11A Hydrograph

Assessment of the Hydrogeologic Characteristics of the Chorro Valley

Morro Bay, California

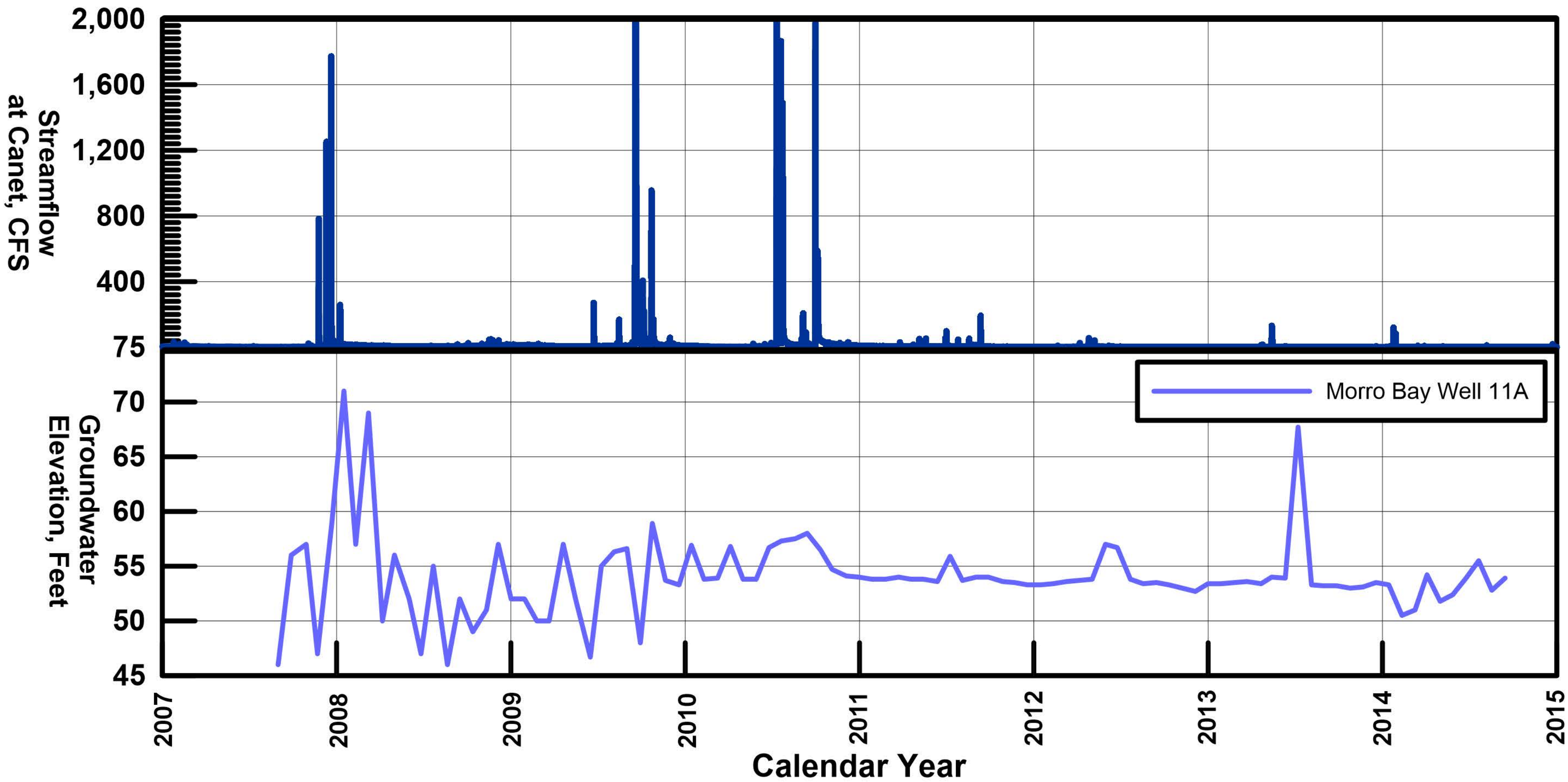

FIGURE 8

Daily Streamflow and Romero Well No. 11A Hydrograph

Assessment of the Hydrogeologic Characteristics of the Chorro Valley

Morro Bay, California

GSI Water Solutions, Inc.