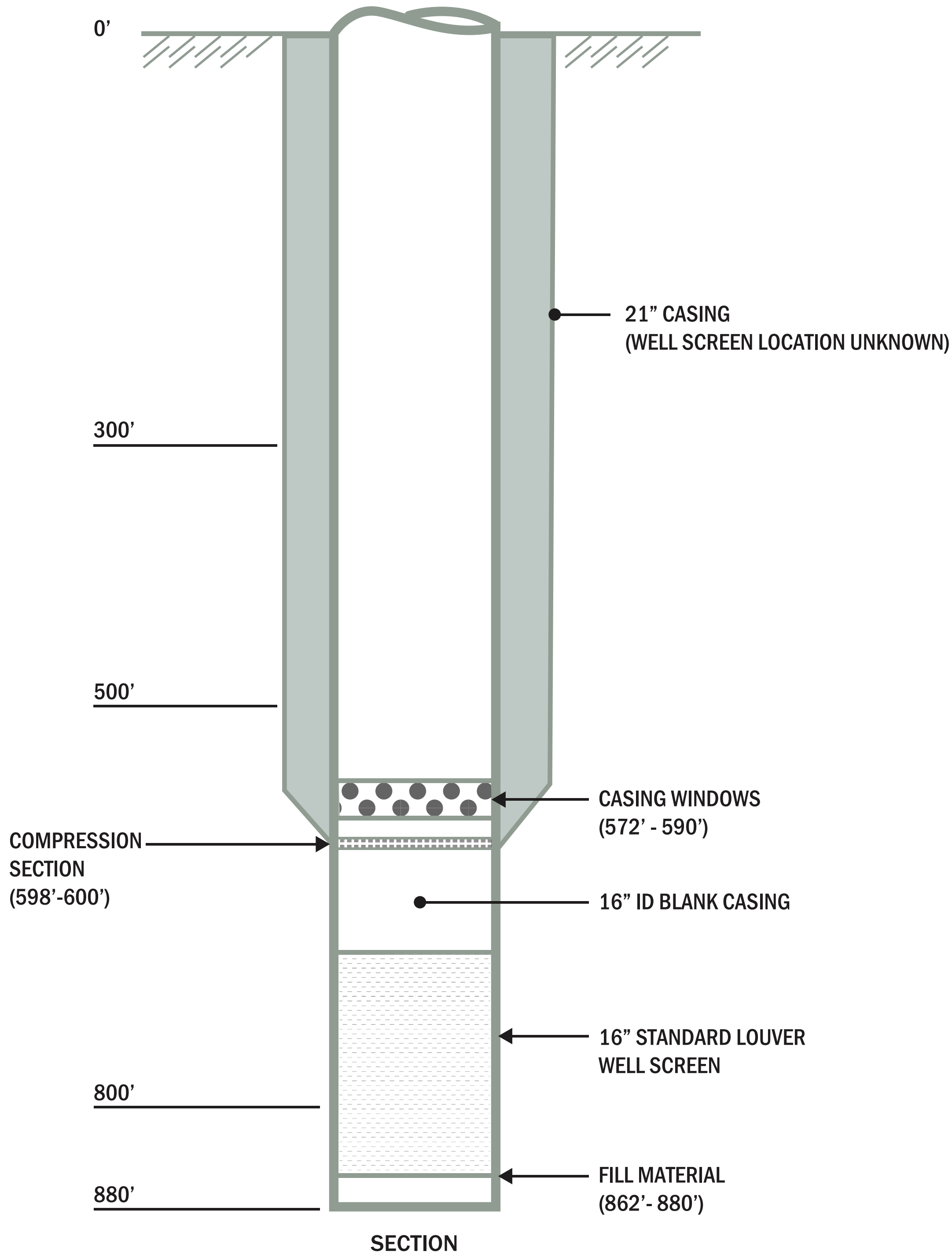


Brown AND Caldwell	PROJECT 148685	SITE Westlands Water District Pilot ASR Study	Figure ES-4
	DATE 4/11/2016	TITLE Construction Details for ASR Pilot Well	

ES-3. Monitoring Program

The major elements of the monitoring program are listed in Table ES-1. Microbial analysis included microscopic particulate analysis (MPA) as surrogates for *giardia* and *cryptosporidium* pathogens.

Table ES-1. Major Elements of the Monitoring Program

Parameter Category	Measurement
Injection Operation	Flow, pressures, turbidity, Electrical Conductivity (EC)
Injection Well Water Level	Level transducer
Nearby Well Water Level	Sounder
Injection Water Quality	Samples and analyses, including microbial testing
Nearest Drinking Water Well	EC of samples as intrinsic tracer
Backflush Water Quality	EC (meter), chlorine (test strips)
Recovery Water Quality	EC monitoring, samples and analyses (including intrinsic tracers and microbial testing)

ES-4. Injection and Recovery Operations

Injection was performed during an 84 day period from 19 June 2017 through 11 September 2017. A total of approximately 178 acre-feet were injected. Water originating from the San Luis Canal was directed to the ASR well for 66 days, and water from the Kings River (upstream end of Mendota Pool) was directed to the ASR well for 18 days. Due to lag times for district pipeline conveyance and mixing in portions of the system, injected water was sometimes a blend of both water sources.

The well was backflushed every 1 to 2 weeks during the injection period. Sodium hypochlorite was injected prior to backflushing on 5 occasions to help prevent downhole slime formation. Magnesium chloride was injected after backflushing on three occasions to test whether stabilization of interlayer clays was helpful for maintaining injection capacity.

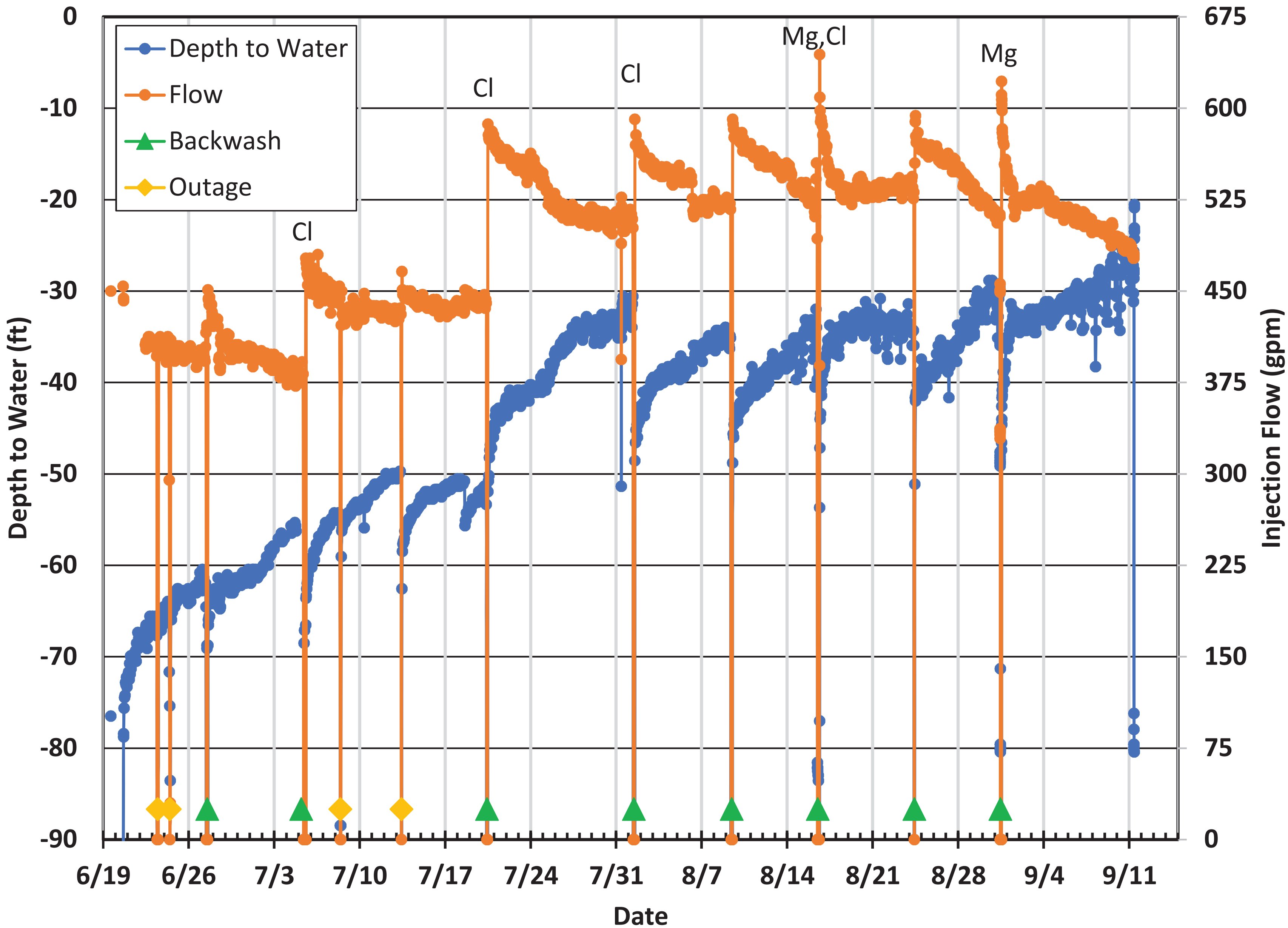
Recovery of the volume of injected water occurred over a 64 day period from 19 September 2017 through 22 November 2017. Water was discharged back into the Westlands system for use by other farmers on the District water supply lateral.

ES-5. Operational Results

Although the injection capacity was slightly below original expectations, the overall ASR pilot well performance was good. The maximum possible injection rate without having the water level rise to the ground surface was around 650 gpm. Average injection rates during the injection phase started at approximately 400 gpm and were gradually increased to approximately 550 gpm during the latter half of the injection phase. The sequence of events and water level results during the injection phase are shown on Figure ES-5.

The filters performed reasonably, removing about 1/3 of the incoming turbidity. Intermittent chlorination was effective at preventing slime buildup. Well specific capacity decreased somewhat during the injection phase, but recovered partially during the water recovery period. The data indicate that more frequent backflushing could have been helpful. Overdosing of magnesium chloride may also have caused some of the capacity reduction. Based on experience during initial well development and at other ASR well sites, more intense surging and pumping would likely have recovered most of the original capacity measured after the initial well development in June 2017.

Figure ES-5. Flows, Depths, and Major Events During Injection Phase



ES-6. Water Quality Results

The major conclusions from the water quality and microbial test results are as follows:

- Water quality used for injection was excellent in terms of minerals and bio-indicators. Water from the Kings River had elevated turbidity, which could cause operational and capacity concerns.
- Based on the use of sulfate and EC as intrinsic parameters, approximately 60% of the injected water was recovered during the 9 weeks of recovery. This 60% reflects the actual molecules of water recovered. 100% of the quantity injected was recovered, keeping the aquifer in hydraulic balance.
- Recovered water salinity was much better than background groundwater for both irrigation and municipal usage. Mobilization of arsenic, chromium, and uranium were not problematic. Some elevated manganese was detected late in recovery, but that was most likely reflective of background groundwater conditions.
- The intermittent chlorination and backflush recovery did not result in disinfection byproduct concentrations of any significance.
- The injected water most likely did not reach the closest domestic well, which was 1.2 miles away, during the injection and recovery operations.
- After only one day of recovery pumping, the recovered water was essentially free of microbes and bio-indicators. This would indicate that the risk of migration of pathogenic microbes was very low for the aquifer tested.

ES-7. Recommendations

The results indicate not only low risks to beneficial uses of groundwater, but potential substantial benefits to groundwater quality from ASR wells. Results may vary depending upon aquifer conditions in different areas, but the potential benefits to water resource management appear to justify expanded application of ASR in agricultural areas.

Some of the major practical recommendations based on the study results include:

- Injection at roughly one-third to one-half of the well's normal pumping flow is a reasonable target range for future ASR wells, and reserving extra pumping capacity for backflushing is recommended. Ideally, backflush pumping should occur approximately twice a week, with duration a function of backflush frequency.
- Intermittent chlorination prior to backflushing or at least once every three weeks is recommended to minimize slime development.
- Having better details on well construction and hydrogeology characteristics by screened zone would be very helpful in future wells, and enable better design of injection and recovery facilities.
- Well casing protection such as a removable PVC inner liner or other measures should be considered for future wells.
- Cell phone data uplink and cloud based data storage service was very helpful at a reasonable price. Remotely monitoring the performance of future ASR wells is highly recommended.

Westlands should consider the development of a new District-wide ASR program to provide groundwater recharge and improve the sustainability of overall water resources consistent with the formation of a new Groundwater Sustainability Agency (GSA). Programmatic compliance with regulatory directives and CEQA would simplify the ability of individual well owners to implement ASR.

This page intentionally left blank.

Section 1

General Information

1.1 Introduction

Westlands Water District (Westlands or District) has been evaluating possible means to improve groundwater sustainability in their district through recharge of surface water into groundwater aquifers during times when surplus or supplemental surface water may be available.

Westlands does not have groundwater recharge facilities within the District's boundary. The geology in portions of the District's service area makes surface percolation impractical for groundwater recharge. Another difficulty with surface recharge of the Lower Aquifer is the presence of the subsurface Corcoran Clay layer, which serves as a barrier to prevent surface recharge water from reaching deeper groundwater producing zones. Subsurface injection of water is a potentially attractive alternative for recharging the Lower Aquifer below the Corcoran Clay and/or for creating regions of higher quality water above the Corcoran Clay in the Upper Aquifer.

There are hundreds of irrigation wells in the District, most owned by individual landowners. Converting many of these wells to aquifer storage and recovery (ASR) wells could provide a substantial source of supplemental water for drought years and maintain sustainability as defined under the new California Groundwater Sustainability Management Act.

The purpose of the ASR Pilot Study was to determine the general feasibility of injection and recovery, investigate water quality impacts, evaluate performance, address unforeseen issues, and provide a basis for estimating costs for injection and recovery of surface water using groundwater wells in the District.

1.2 Background

1.2.1 Regional Hydrogeology

The pilot ASR well was located in the Westside Subbasin of the San Joaquin Valley Groundwater Basin (Subbasin Number 5-22.09). The following description of the regional hydrogeology is mostly taken from DWR Bulletin 118 (2006).

The aquifer system comprising the Westside Subbasin consists of unconsolidated continental deposits of Tertiary and Quaternary age. The deposits form an unconfined to semi-confined Upper Aquifer and a confined Lower Aquifer. The Upper and confined Lower Aquifers are separated by the Corcoran Clay (E-Clay) member of the Tulare Formation.

The confined aquifer (Lower Aquifer) consists of the lower part of the Tulare Formation and possibly the uppermost part of the San Joaquin Formation. This unit is composed of lenticular beds of silty clay, clay, silt, and sand interbedded with occasional strata of well-sorted sand. Brackish or saline water underlies the Base of Freshwater in the Lower Aquifer.

The Corcoran Clay is a lacustrine diatomaceous clay unit that underlies much of the subbasin. Within the subbasin it varies in thickness from 20 to 120 feet (ft). Prior to groundwater development, the Corcoran Clay effectively separated the Upper and Lower Aquifers. Numerous wells penetrate the clay, allowing for partial interaction between the zones.

1.2.2 Westlands Hydrogeology

The groundwater basin underlying Westlands is comprised of the same two water-bearing zones identified in Bulletin 118: (1) an Upper Aquifer above a nearly impervious Corcoran Clay layer containing the Coastal and Sierran aquifers and (2) a Lower Aquifer below the Corcoran Clay containing the Sub-Corcoran aquifer (Westlands, 2013). An east-west cross section showing these water-bearing zones is provided in Figure 1-1. These aquifers are recharged by subsurface inflow from the east and northeast, the compaction of water-bearing sediments, percolation of pumped groundwater, and percolation from imported and natural surface water.

The Tulare Formation, which extends to the base of freshwater throughout most of the area, extends to as much as 2,400 ft deep in parts of the region and is comprised of stratigraphic layers of clays, silts, sands, and gravels and includes the Corcoran Clay (aka E-Clay) member, a diatomaceous clay or silty clay of lake bed origin which is a prominent aquitard in the region that separates the upper zone from the lower zone and distinguishes the Upper Aquifer from the Lower Aquifer (Carollo, 2015).

According to Central Valley Hydraulic Model data, the vertical hydraulic conductivity of the Corcoran Clay is on the order of 100 times less than the vertical hydraulic conductivity of the very shallow groundwater and Upper Aquifer.

Recharge for the lower confined aquifer comes generally from east of the District, below the Corcoran Clay. Recharge of the confined aquifer might also possibly occur in areas on the western edge of the District, near the coast range, where the boundary of the Corcoran Clay is irregular. (Westlands, 2013)

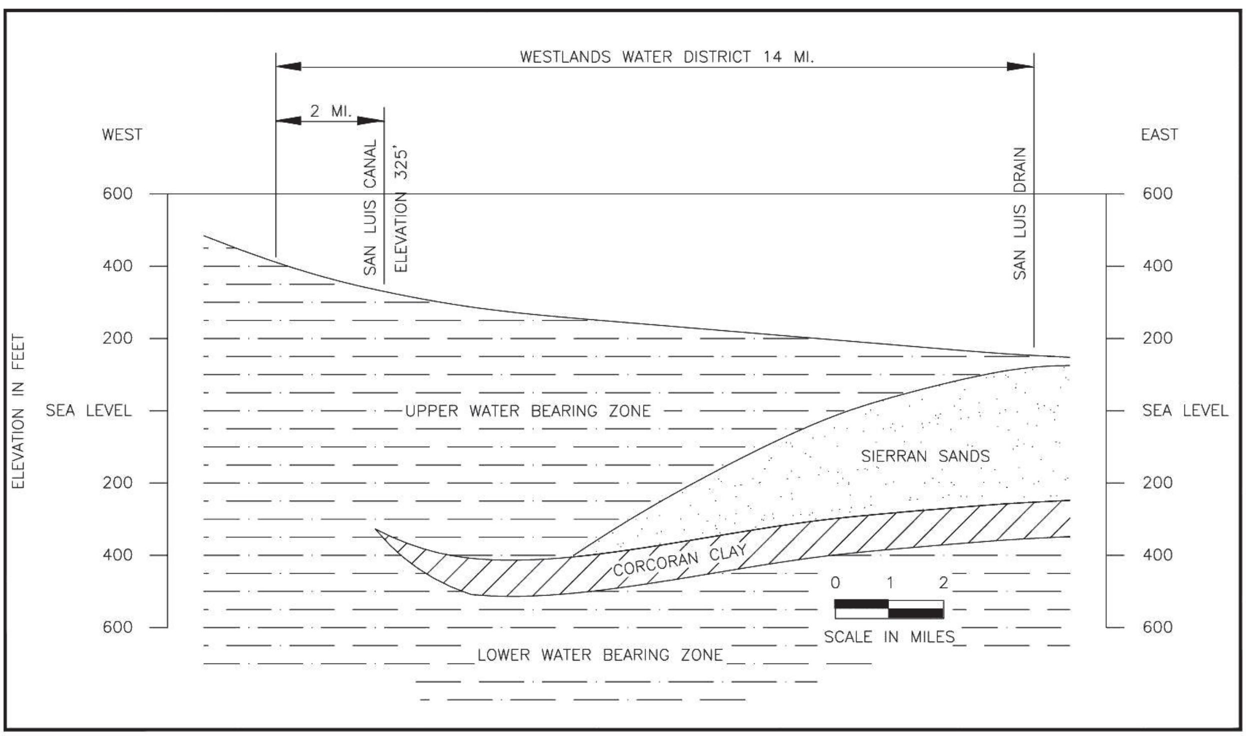


Figure 1-1. Generalized Hydrogeological Cross Section for Westlands Water District

(Westlands, 2013)

District analyses of data indicate an estimated safe groundwater yield of between 200,000 to 250,000 AF (Westlands, 2013). Groundwater producing zones above the Corcoran Clay tend to have water with marginal quality for irrigation, especially in the middle portion of the District's service area.

1.2.3 Selected ASR Pilot Well

Potential wells were evaluated based on site access, potential water sources, construction, and distance from domestic wells. Wells screened only below the Corcoran Clay or that could be easily modified to be screened only below the Corcoran Clay were given preference. In terms of water sources, wells that could be supplied with water from either the San Luis Canal or Kings River were also given preference. Also incorporated in the sources ranking was the proximity to the tank used for Kings River water.

The evaluation process in the Work Plan (BC, 2016) resulted in the selection of a well located at 36°39'41"N, 120°25'26.1"W, near the south end of the Mendota Subarea as defined by K. Schmidt (2009). The ground surface elevation at the well site is approximately 224 ft above mean sea level (AMSL). The location of the well, other nearby wells and surface water sources is shown on Figure 1-2.

The construction details for the selected well were as follows:

- 16-inch inside diameter well casing
- Small casing hole at 198 ft at a welded pipe joint
- Windows cut out of casing from 572 to 590 ft – 3 per row and 120 degrees apart – about 1 ft long (can be easily patched off)
- Compression section 598 to 600 ft
- Standard louvers start at 683 ft and continue to the bottom at 862 ft (reported depth = 880 ft)
- Pieces of PVC pipe at well bottom
- Well bottom is soft fill
- Static Water Level = 101 ft on 1/27/2016

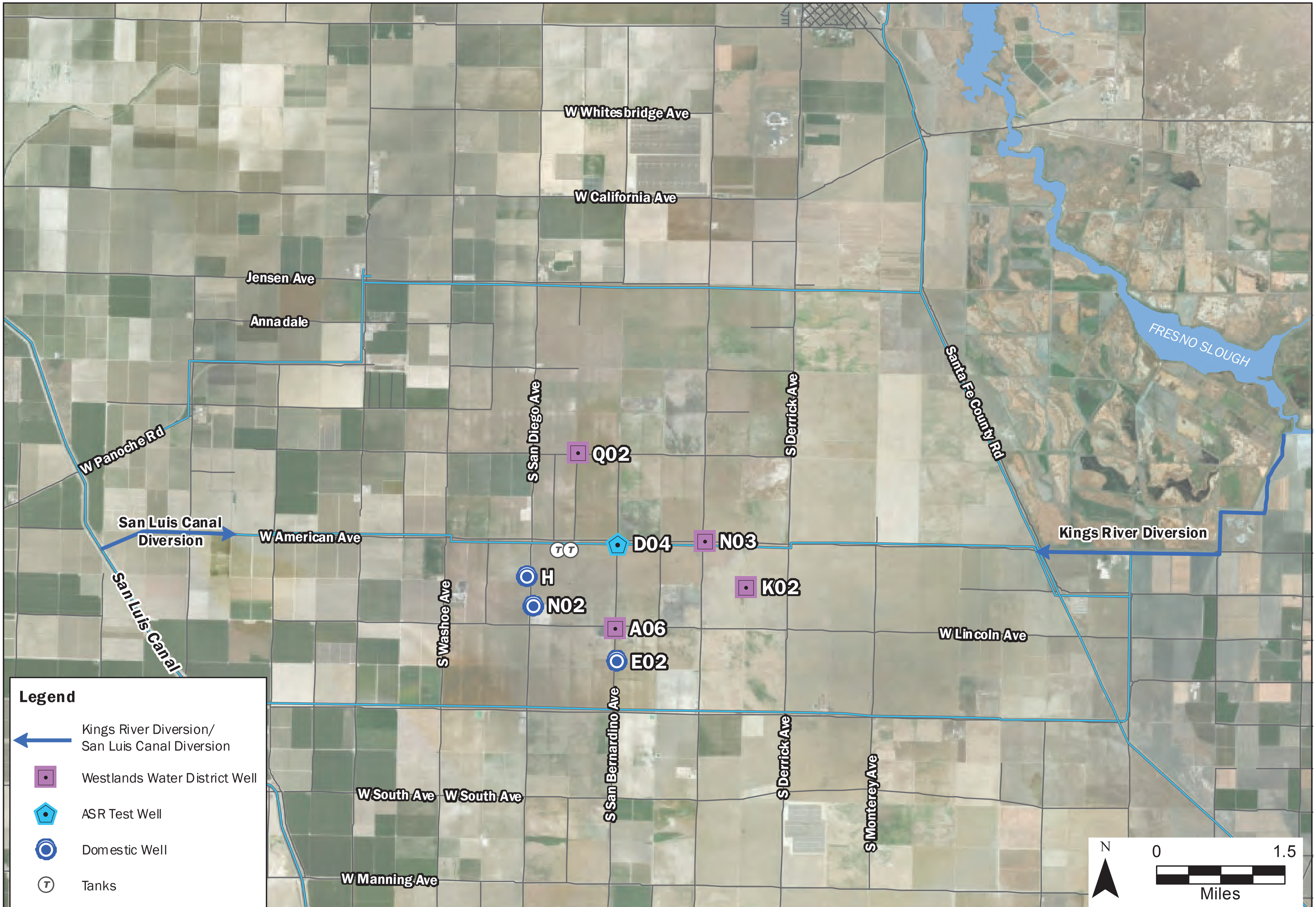
1.2.4 Surface Water Sources

The District wanted to use two different water sources for the ASR Pilot Study – San Luis Canal water and Kings River water.

Water from the San Luis Canal is provided under terms of Westlands' Central Valley Project allocation from the U.S. Bureau of Reclamation. Water from the San Luis Canal was conveyed in the District's underground pipe system directly to the well site.

Water from the Kings River is available in the form of flood flows or transfer water. Water from the Kings River at the Mendota Pool was pumped into a storage tank approximately ½ mile west of the well site and then through the District's underground pipe system to the well site as shown on Figure 1-2.

Document Path: \\bcdavfp01\projects\48000\148685 - Westlands ASR Pilot Study\GIS_MAPDOCS\WORKING\Fig1-2_PilotTestWell_8x11_20180403.mxd



Brown AND Caldwell	PROJECT 148685	SITE Westlands Water District Pilot ASR Study	Figure 1-2
	DATE 04/03/2018	TITLE ASR Pilot Test Well Location, Nearby Wells and Water Sources	

1.3 Local Groundwater Conditions

Local groundwater conditions were evaluated to provide initial estimates of the performance of the pilot test well and the fate of injected water.

1.3.1 Local Hydrogeology

A drilling log showing formations encountered was not available for the selected pilot test well. The available logs for wells closest to the site showed alternating sand and clay layers, with the Corcoran Clay manifesting as a 100 ft thick layer of blue clay at approximately 600 ft bgs. The closest well completed to the same depth as the pilot test well showed sand and gravel layers totaling approximately 60 ft thick below the Corcoran Clay.

1.3.1.1 Nearby Wells

Two domestic wells are located along San Diego Avenue approximately 1 mile west and ¼ mile or more south of the pilot test well (see Figure 1-2), and a third domestic well on San Bernardino Avenue. Most of these wells were completed to a depth of 360 ft, with one completed to 460 ft. There was one other structure that could have a domestic well about 1.5 miles northwest of the pilot test well. Other than these, there were no other habitable structures visible within approximately 2 miles of the site.

1.3.2 Groundwater Elevations Gradient

Groundwater elevation contours in the vicinity of the site for 2013 through 2015 were provided in the Work Plan (BC, 2016). Based on the groundwater elevation contours, average historical groundwater gradients in the vicinity of the site are shown in Table 1-1.

Table 1-1. Background (2013 – 2015) Horizontal Groundwater Gradients and Directions

Zone	Horizontal Gradient	Direction of Flow
Shallow	0.38%	E
Intermediate (aka Upper)	1.8%	NNW
Sub-Corcoran (aka Lower)	0.66%	WNW

For the 2013 - 2015 data, the vertical piezometric elevation differential across the Corcoran Clay (Upper minus Sub-Corcoran) was approximately 135 ft downward at the site. For wells that have been completed with well screen above and below the Corcoran Clay, such as the pilot test well, this means that some water in the immediately vicinity of the well likely reflects the quality of water typically found above the Corcoran Clay due to past downward movement of water through the unused well.

1.3.3 Groundwater Quality

Most wells in the very shallow (< 200 ft) groundwater zone have high salinity, with TDS concentrations above 2,000 mg/L, some over 6,000 mg/L. TDS concentrations in Upper Aquifer (~200 – 600 feet bgs) wells are generally lower than for those in the shallow groundwater. Groundwater quality in the Lower (sub-Corcoran) aquifer zone is generally better than the Upper Aquifer, with TDS ranging from about 750 to 1,420 mg/L in the Mendota subarea and 720 to 1,100 mg/L in the Tranquillity subarea (K. Schmidt, 2009). The waters of the Upper Aquifer are generally high in calcium and magnesium sulfate. Most of the groundwater of the Lower Aquifer is of the sodium sulfate type (DWR, 2006).

Another good measure of salinity is electrical conductivity. A map showing electrical conductivity (EC) ranges by location for the lower (sub-Corcoran) zone is shown in Figure 1-3. The location of the pilot test well is also indicated on Figure 1-3.

The United States Geological Survey (USGS, 2013) performed extensive analysis of water quality parameters from Lower Aquifer wells about 20 miles south-southeast of the pilot well site. Of particular note, silica (as SiO_2) was 17.6 to 26.6 mg/L, uranium 0.08 to 0.14 ug/L, manganese 29 to 60 ug/L, pH 8.3 to 8.6, water temperature at about 30 degrees C, and dissolved oxygen at 0.2 or less mg/L. The GAMA data also includes stable isotopes, which can be useful as intrinsic tracers.

Additional local and regional water quality information was provided in the Groundwater Quality Assessment Report (Carollo, 2015) and the ASR Pilot Study Work Plan (BC, 2016).

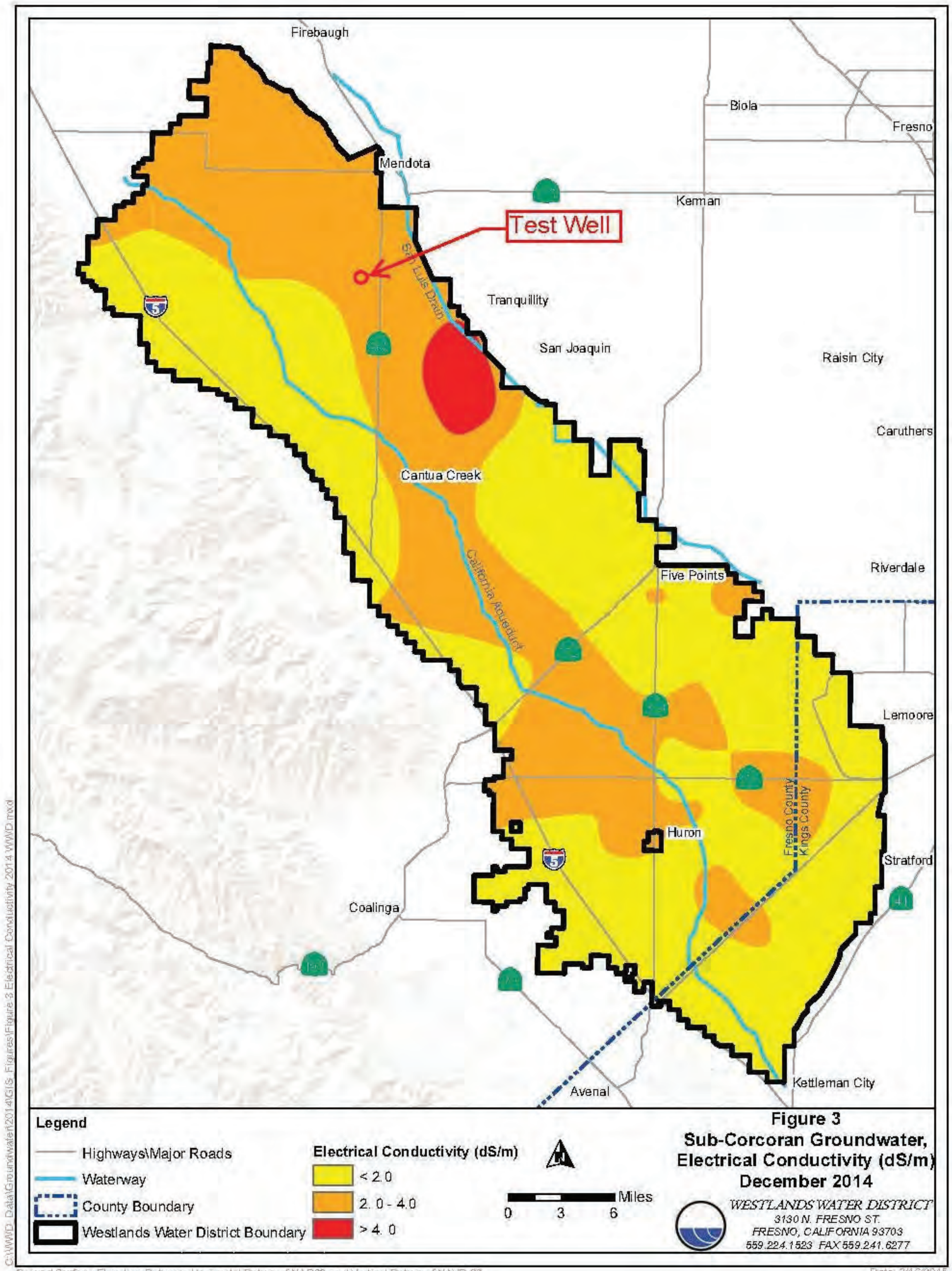


Figure 1-3. The Sub-Corcoran Groundwater, Electrical Conductivity (dS/m), December 2014.

(Source: Westlands Water District)

This page intentionally left blank.

Section 2

Pilot Study Planning and Facilities

The planning and design of the ASR Pilot Study was based mostly on the 2016 Work Plan (BC, 2016), with modifications to reflect the subsequent 2017 Detailed Operations and Water Quality Monitoring Plan (BC, 2017) and actual field conditions encountered.

2.1 Regulatory Considerations

ASR using agricultural wells and surface waters is not covered by the new ASR general order (Water Quality Order 2012-0010), which applies primarily to municipal water suppliers using treated drinking water. The California Water Code for indirect potable reuse for groundwater recharge (Water Code, § 13561(c)) also would not apply.

An ASR well can be authorized by rule under EPA's Underground Injection Control program and the Class V Injection Well category if both:

- The owner or operator submits the well information
- The well does not endanger an underground source of drinking water (USDW)

The EPA guidance also states that a primacy state or EPA may require an individual permit. At the state level, California Water Code section 13260 requires a report of the discharge from any person operating or proposing to construct an injection well. A letter waiver can be used for special short-term cases such as a pilot test. Long term injection would need to be covered under an order from the Regional Water Quality Control Board (Regional Board).

Therefore, the pilot study well was regulated under the category of an EPA Class V injection well associated with a waiver approval letter from the Regional Board, who in turn incorporated recommendations from the Division of Drinking Water (DDW). Other issues of concern listed by the EPA were addressed in the ASR Pilot Study Work Plan (BC, 2016).

Compliance with CEQA was accomplished using the exemption for pilot studies in accordance with:

"Categorical Exemption (if project includes pilot studies, test wells, grading, boreholes, etc.) Class 6, Information Collect LRQ (CCR, title 14, Article 19, Section 15306)"

2.2 Injection Hydraulic Design Criteria

The planned hydraulic design criteria for the pilot test well are shown in Table 2-1. These were based on the initial assumption that the well would have a nominal extraction capacity of 1,500 gallons per minute (gpm). Field conditions and aquifer responses determined actual operating criteria.

Table 2-1. Initial Hydraulic Design Criteria

Parameter	Design Criteria
Injection Flow	375 to 750 gpm
Approximate Recovery Extraction Flow	1,500 gpm
Target Backflush Pumping During Injection Phases	90 minutes total once per week

2.3 Initial Estimates of Injection Effects

An initial evaluation of injection effect was presented in the ASR Pilot Study Work Plan (BC, 2016). The effects evaluated included:

- Water level effects
- Aquifer flow and transport
- Aquifer geochemical effects
- Well and formation physical/biological plugging effects

Means for preventing well and formation physical/biological plugging effects are addressed later in the Design section.

2.3.1 Aquifer Characteristics

Schmidt (2009) gave an average transmissivity for the Upper Aquifer in the Mendota Subarea of approximately 125,000 gallons per day (gpd) per ft and an average hydraulic conductivity of the coarse grained deposits of about 1,900 gpd per square ft. Schmidt referenced a broad scale typical transmissivity of about 120,000 gpd/ft for the Lower Aquifer. Carollo (2015) showed a gross (sands and clays) horizontal hydraulic conductivity of 20 to 40 ft/day for the Upper Aquifer and approximately 15 ft/day for the Lower Aquifer in the general vicinity of the pilot test well.

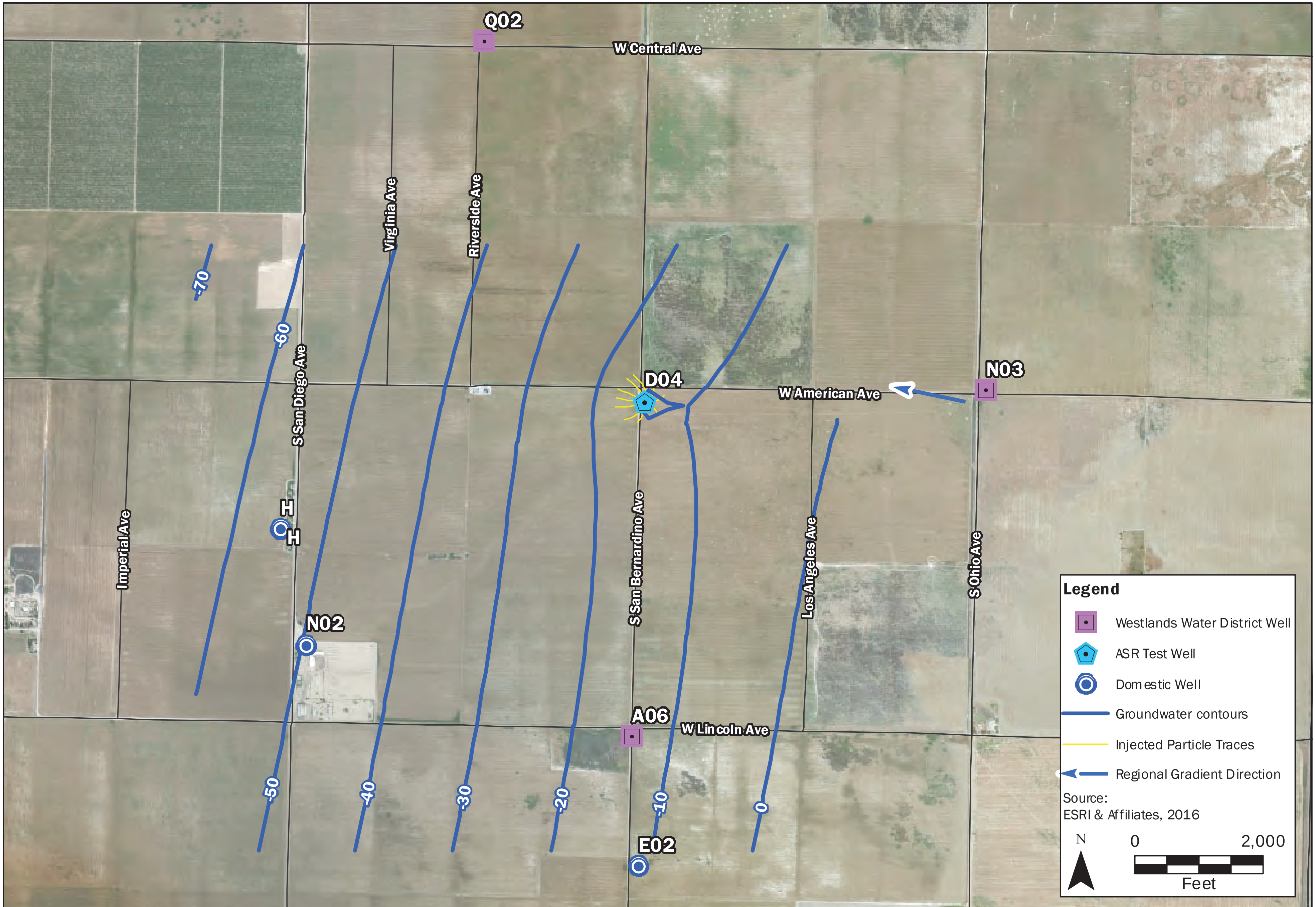
Schmidt (2009) reported a 2008 specific capacity of 38 gpm/ft for Lower Aquifer Well 151420D in the Mendota Subarea and 13 gpm/ft for Lower Aquifer Well 151413B1 in the northern part of the Tranquillity Subarea. A 1958 pumping test performed on nearby 900 ft Lower Aquifer Well 151401K02 gave a specific capacity of approximately 22 gpm/ft of drawdown.

2.3.2 Initial Projected Injection Effects on Groundwater Levels and Flow

The groundwater mounding effects were modeled using the 2-dimensional analytical AquiferWin32 model (Environmental Simulations, 2013) with the Theis (1935) solution for fully penetrating wells into a confined aquifer. Model assumptions included an aquifer thickness of 55 feet and a hydraulic conductivity of 120 feet per day, based on the aquifer characteristics given above and the well log for nearby Well 141427Q02. The assumed injection flow rate was the maximum potential rate of 750 gpm. Additional modeling details were provided in the Work Plan (BC, 2016).

The first simulation was run for a period of 70 days of injection at the full 750 gpm. The combined effect of the mounding (not including well losses) with the background groundwater gradient given previously in Table 1-1 is shown in Figure 2-1. Figure 2-1 also shows particle traces that indicate the average distance of travel of the injected water. Water recovery model results were also presented in the Work Plan (BC, 2016).

Document Path: bcsac01 \\bcdavfp01\projects\48000\148685 - Westlands ASR Pilot Study\GIS_MAPDOCS\WORKING\Fig2-1_Gradient_8x11_20180403.mxd



Brown AND Caldwell	PROJECT 148685	SITE **Westlands Water District Pilot ASR Study**	**Figure 2-1**
	DATE 04/03/2018	TITLE **Initial Modeled Mounding with Regional Gradient and Particle Traces for 70 Days of Injection**	

2.3.3 Injection Effects on Geochemistry

Geochemical reactions are a generally a function of the difference in water quality between the injected water and the existing groundwater. Anticipated concentrations of minerals in existing groundwater and planned injection water were provided in the Work Plan.

Geochemical reactions of most concern for ASR physical operation and sustainability were precipitation reactions, with some concern for dispersion reactions in interbedded clays. Precipitation or scaling reactions can involve calcium, silica, and other minerals forming scale on the well screen and in the formation near the well. Given the GAMA results showing groundwater silica concentration of less than 30 mg/L, geochemical reactions were not expected to cause silica precipitation.

Carbonate precipitation can plug an aquifer if the injectate is alkaline and/or has a high concentration of calcium. Magnesium carbonate precipitation can also be problematic, but not until a higher concentration (approximately 100 mg/L as $MgCO_3$) compared to calcium carbonate. Based on the data available, carbonate precipitation was not anticipated.

The potential for interbedded clays to disperse when the low salinity soft water replaced higher salinity water in the formation was an initial concern, especially for Kings River source water. Additional samples were obtained from source waters prior to the startup of ASR operations. The results of calculations for sodium adsorption ratio (SAR) and adjusted SAR are shown in Table 2-2. SAR values above 6 indicated some potential for clay dispersion and values above 15 indicate high potential for clay dispersion. Despite the low total salinities for the San Luis Canal and Kings River, the SAR values were low. There was still some concern about the SAR of a mix of groundwater and injected surface water.

Table 2-2. Sodium Adsorption Ratios of Waters

	Groundwater	San Luis Canal	Kings River (Historical)	Kings River 2017
TDS (mg/L)	1,100	350	50	50
Na (meq)	15.2	2.2	0.4	0.2
Ca (meq)	2	1.25	0.25	0.25
Mg (meq)	0.82	1.23	0.08	0.16
EC (umhos/cm)	1,600	550	70	70
pH	8.1	8	7.5	7.5
Bicarbonate (mg/L)	150	50	10	10
SAR	12.81	1.95	1.07	0.38
Adj. SAR	14	1.6	0.4	0.4

Other geochemistry reactions of concern included mobilization of arsenic, hexavalent chromium, and uranium by high redox injection water.

2.4 Anticipated Water Quality Effects on Nearby Wells

Potential water quality effects on nearby domestic wells were evaluated in the Work Plan. Based on the plan to inject water only below the Corcoran Clay and the long distance to the domestic wells (est. > 5 years horizontal travel time), no adverse water quality impacts were anticipated to the domestic wells.

2.5 Well Rehabilitation and Modifications

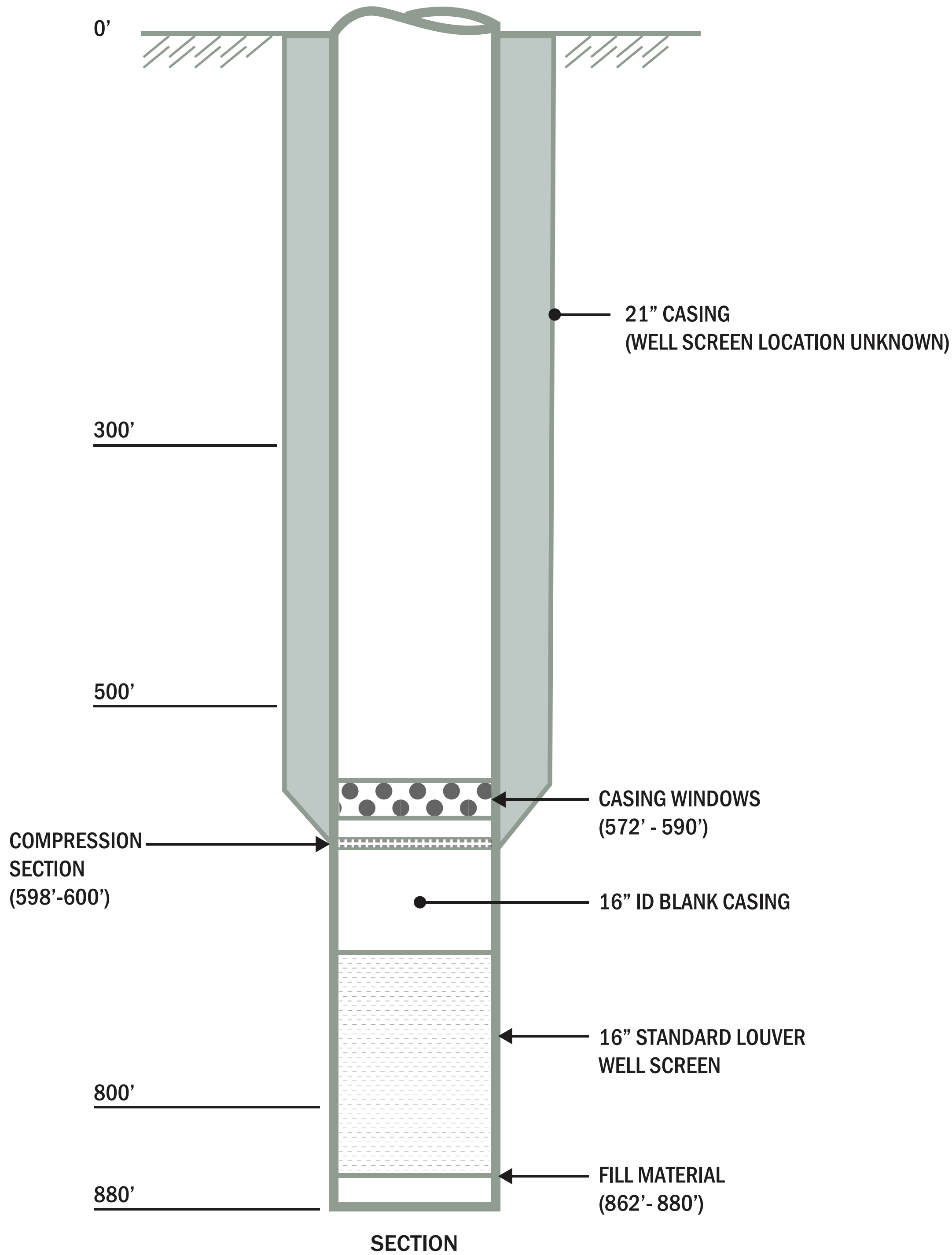
Well modifications, rehabilitation, immediate wellhead equipment, and engine operation were provided by Zim Industries of Fresno, California.

2.5.1 Pilot Test Well Construction Background and Details

According to a State of California, Department of Water Resources (DWR) “Well Data” form, the pilot test well (Well 151402D04) was constructed in April 1991 by Myers Brothers Drilling Company of Hanford, California. The gravel packed well was constructed with 16-inch and 21-inch diameter casing to a depth of 880 ft using the reverse circulation rotary drilling method.

Although the DWR form indicates that the 21-inch diameter casing is perforated from a depth of 280 to 800 ft, this is unlikely since there are casing windows cut into the 16-inch diameter casing from a depth of 572 to 590 ft. The well was constructed as a “casing path” well, which allows a shallow aquifer(s) located above the Corcoran Clay and above the pumping water level to contribute to the well’s overall production without causing air entrainment in the pumped water due to cascading groundwater. Under pumping conditions, groundwater enters a shallow perforated interval(s) in the 21-inch diameter casing, flows downward in the annular space between the casings, and enters the well through the casing windows. Since the two casings are sealed airtight at the ground surface, groundwater initially pumped from the shallow aquifer(s) quickly absorbs the air between the casings, creating a partial vacuum in the annulus that prevents further air entrainment. It is more likely that the 21-inch diameter pipe terminates just below the deepest casing windows at 590 ft and not deeper since it would then overlap and negate the effectiveness of the compression joint located in the 16-inch diameter casing from 598 to 600 ft. Also, there would be no reason to extend the 21-inch diameter casing beyond that depth since the 16-inch diameter casing shallowest well screen is located at a well depth of 683 ft. Figure 2-2 shows a photograph of the well at the ground surface with the cover removed and Figure 2-3 shows a sketch of the well’s construction features and dimensions.

Figure 2-2. Existing Wellhead with Cover Removed



Brown AND Caldwell	PROJECT 148685	SITE Westlands Water District Pilot ASR Study	Figure 2-3
	DATE 4/11/2016	TITLE Construction Details for ASR Pilot Well	

2.5.2 Pilot Test Well Rehabilitation, Development and Testing

The first step in preparing Well 151402D04 (pilot test well) for surface water injection was to remove fill material and pieces of PVC pipe from the well bottom by bailing. Bailing was the preferred method for the well fill/PVC removal since it generates the least amount of wastewater. Initially the well's bottom was measured at a depth of 862 ft, which was 18 ft shallower than the DWR-reported well total depth of 880 ft, and the fill appeared to be comprised of soft materials. The well fill and PVC pieces were successfully removed from the well.

Additional well rehabilitation, development and testing procedures that were performed to prepare the pilot test well for surface water injection were;

1) **Scratching** – The horizontally-oriented louver style well perforations (located from a well depth of 683 ft to the well bottom) were cleaned of mineral deposition with a steel wire scratcher. The scratcher was rotated during the cleaning process to facilitate the "scraping off" of deposition that was plugging the louver openings. Figure 2-4 shows the pre-cleaning condition of the well's perforations and Figure 2-5 shows a steel wire well scratcher. After the cleaning process was completed, the well was re-bailed to clean newly-deposited fill material.

Figure 2-4. Plugged Louvered Perforations

Figure 2-5. Steel Wire Scratcher

2) **Acid Treatment** – Inhibited hydrochloric acid and an acid enhancer were placed in equal doses throughout the well's perforations using a tremie pipe and the well water was agitated using a line swab. The acid products were specifically designed to dissolve any additional mineral deposits and biofilm that had accumulated on the well perforations and in the gravel pack that surrounds the perforations.

3) **Air-lift Swab the Well Perforations** – Following the acid treatment, the well perforations were air-lift swabbed from top-to-bottom and then from bottom-to-top. The air-lifting tool was a double-flanged swab assembly with the swab flanges situated 10 ft apart. The bottom of the tool was closed. Air-lift swabbing is used to focus well development efforts on a small portion of the well screen. Figure 2-6 shows an air-lift swab assembly.

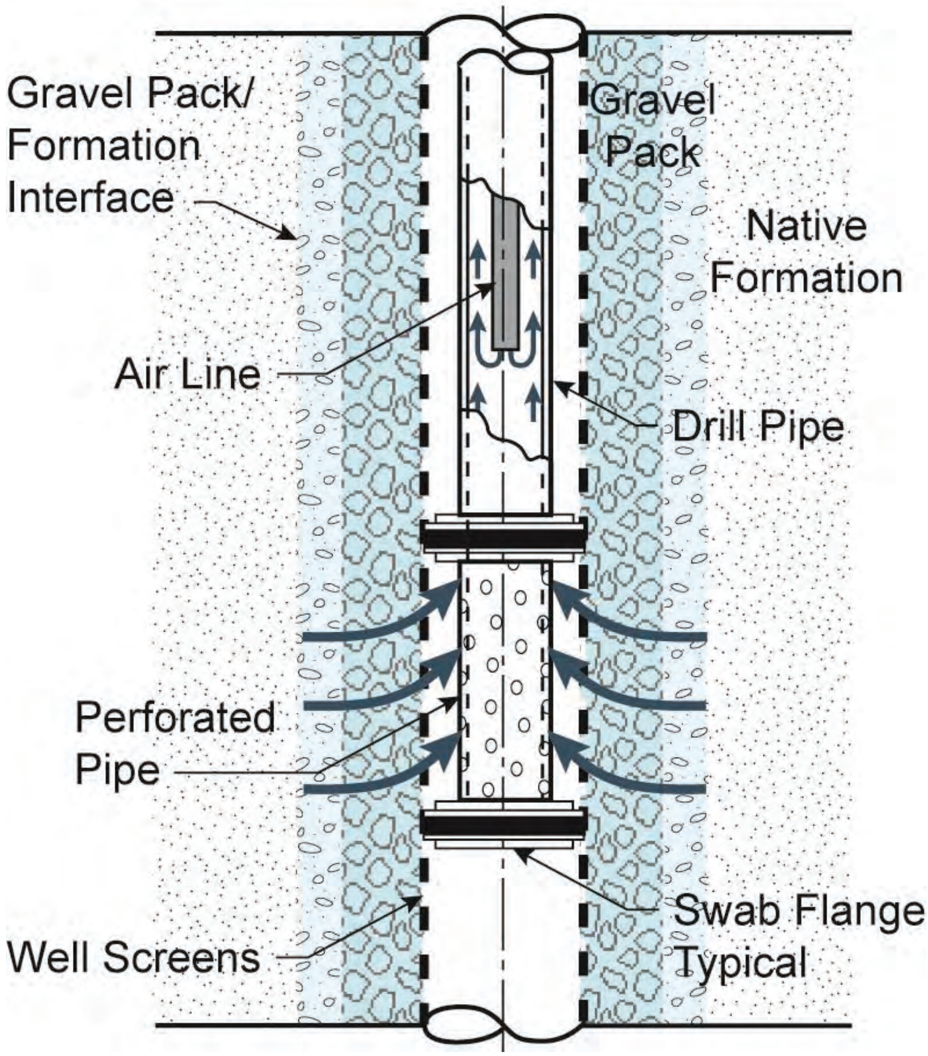


Figure 2-6. Air-Lift Swab Assembly

4) **Post-rehabilitation TV survey** – A downhole TV survey was conducted on the pilot test well to evaluate the effectiveness of the rehabilitation activities and to assess the condition of the blank casing and louvered well screen. The survey was used to identify potential problems such as poorly welded casing joints and small holes in the casing, and to confirm the depth of the casing hole that was known to exist.
5) **Casing patch installation** – The existing casing hole located at a well depth of 198 ft and the casing windows located from a well depth of 572 to 590 ft were covered over with casing patches so that the injected water would only penetrate aquifers located below the Corcoran Clay. The casing hole is shown in Figure 2-7 and the casing windows are shown in Figure 2-8. A hydraulically-activated swage was used to lower the casing patch to the desired well depth and to enlarge it by pressing it outward against the well casing.

Figure 2-7. Casing Hole

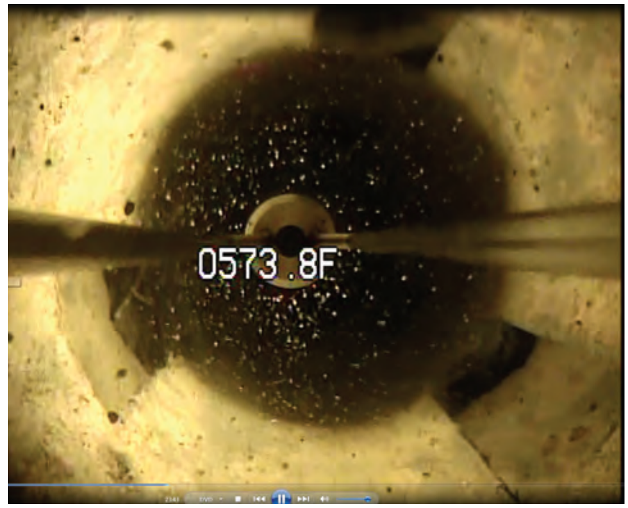


Figure 2-8. Casing Windows

6) **Test pump development and test pumping** – After the casing patches were installed, an engine-driven vertical turbine line-shaft test pump was installed in the well and additional development was performed by surging and over-pumping the well. The rate of water being pumped from the well at the start of development pumping was about 300 gpm and was gradually increased as the water cleared to a rate of about 2,000 gpm. Every 15 to 30 minutes, the pump was stopped and the water in the pump column was allowed to flow back through the pump bowls and through the louvered well screen into the aquifer. This procedure, with increasing pumping rates, was repeated until the produced groundwater was free of sand and turbidity. When well development with the test pump was finished, pumping tests were performed. The pumping tests were comprised of an 8-hour step-drawdown pumping test, an 8-hour constant-rate pumping test, and a recovery test. The collective results of the pump tests were used to establish the pre-injection hydraulic properties of the well and aquifers, to determine the well's efficiency at varying flow rates, and to calculate the optimal yield of the well.

2.6 Pilot Test Well Injection Equipment

2.6.1 Injection Tubes

To maintain a positive injection pressure and avoid air entrainment resulting from cascading water, the injected water was pumped through two 3-inch diameter injection tubes installed in the pilot test well. The injection tubes were PVC, banded to the extraction pump, and set to staggered depths of 200 and 220 ft. Each tube was calculated to be able to accommodate an injection rate of up to approximately 375 gpm, depending upon well water level.

2.6.2 Extraction Pump and Right Angle Gear Drive

The pilot test well was equipped with an engine-driven line-shaft vertical turbine pump and right angle gear drive (extraction pump) to allow for periodic back flushing of the well to minimize plugging. The extraction pump was also used to regularly monitor the well's pumping characteristics.

Based on static water level measurements, the extraction pump bowl assembly was set at a well depth of 400 ft versus the original target depth of 600 ft. The pump was set on 8" x 2 ½" x 1 ½" column pipe and inner-column, and an 8” extended pump suction pipe was also installed. Additional details were provided in the Work Plan (BC, 2016).

The extraction pump’s above ground discharge piping included a combination air release/vacuum breaker, a flow meter, a sample tap, pressure gauge, gate valve and piping to a water discharge location several hundred feet east of the well in the field.

2.6.3 Water Level Measuring Tube and Data Logger

To monitor the pilot test well’s water level while injecting or extraction pumping, a 1-inch diameter Schedule 80 PVC sounding pipe was installed in the well. The sounding pipe was strapped to the extraction pump and set at a depth of 400 ft. The water level was monitored with an In-Situ Level TROLL 400 data logger capable of measuring a 200 meter (658 ft) pressure range. The logger also monitored the water temperature. The inside diameter of the 1-inch diameter PVC was 0.957-inches and the outside diameter of the data logger was 0.72-inches.

2.7 General Infrastructure for ASR Well Operation

The well was located at about 30 ft east of San Bernardino Avenue and 130 ft south of American Avenue, both of which are dirt roads at that location. The site plan is shown in Drawing G1 in Appendix A. The installed equipment and related facilities are shown in Figure 2-9.

2.7.1 Water Supply Pressure

When the water supply was from the San Luis Canal, the pressure was on the order of approximately 25 psi. When the water supply is from the Kings River diversion, the available pressure was a function of the height of water in the storage tank. The maximum theoretical pressure was approximately 12 psi with the water in the storage tank at its maximum allowable level.

The District’s lateral pipeline is reportedly 45 inch diameter, and the riser supplying water to the site is 12 inch diameter.

2.7.2 Backwash Pumping Water Handling

An extended temporary aluminum pipeline was used to convey ASR well backflush water far enough east into the field to prevent flooding of the ASR well site. Backflush water from the aboveground filters was discharged just east of the ASR well site.

2.7.3 Power

Although there are power poles near the site, the lead time required to get a power drop at the site was much longer than desired. Therefore, the well pump was a trailer mounted 200 HP engine driven pump. A propane powered engine drive was provided for a booster pump needed during Kings River source water injection.

The filter controller, valves, injection pumps, monitoring systems, and other miscellaneous items were all selected to be 12 VDC or 24 VDC powered by a 1 kW solar array with battery storage and inverter. The solar control panel related equipment included a 24V storage battery bank, 24 to 12V DC to DC converter and a 120 VAC inverter available for temporary needs.

2.7.4 Security

The site needed to be secured to prevent theft or vandalism to equipment. The well pump engine was anchored to the concrete pad. A temporary razor wire fence was installed around all the equipment.

Figure 2-9. Installed Equipment and Related Facilities

2.8 Above-Ground Equipment and Control

Other than equipment at the immediate wellhead, all above-ground equipment was provided by Pacific Southwest Irrigation of Stockton, California.

Key equipment such as filtration, control valves, chlorine injection, and injection water conditioning are called out on the process and instrumentation diagram (P&ID) from the Work Plan, shown in Drawing D1 in Appendix A.

The preliminary mechanical site plan for the injection facilities is shown in Drawing M1 in Appendix A. Drawing M1 shows more details for the piping, filters, valves, injection facilities, and other relevant equipment.

2.8.1 Booster Pump

A booster pump was provided to enable continued injection during periods of low mainline pressure. Low water pressure was expected to be encountered when water from the Kings River was directed to the ASR well. The pressure was often limited to less than 10 psi based on the height of water in the supply tank approximately ½ mile to the west of the site. The booster pump was a Berkeley B4Z powered by a propane fueled engine to provide an extra 10 to 20 psi at up to 750 gpm, depending upon engine speed. The booster pump and upstream valves are shown in Figure 2-10.

Figure 2-10. Booster Pump and Upstream Valves at Initial Installation

2.8.2 Filtration

The purpose of the filtration selected was to simulate a realistic filtration system that would be used for agricultural drip irrigation on a field supplied by an ASR well. The filtration included six Lakos brand 48 inch diameter agricultural sand media filters with #20 sand and a surface area of 75 square feet. These were selected to operate at 5 to 10 gpm per square foot for injection and at a hypothetical 20 gpm per square foot for recovery and drip irrigation at 1,500 gpm. It was hoped that the relatively lower loading rate for injection would provide good removal of suspended solids from the source water without using coagulants. While the use of coagulants would provide best removal of suspended solids, the use of chemicals in a treatment process require more operational attention and water treatment expertise than is typically available in an agricultural setting.

2.8.3 Air Release

It is important to remove as much dissolved air as possible from water prior to injection to prevent air-locking of the formation. A low velocity air release chamber with a continuing acting air vent was installed downstream of the filters and upstream of the flow meter. Injection tube discharge depths were staggered 20 feet apart to allow air to be flushed out sequentially on startup under minimum downward water velocities, enabling bubbles to escape upward in the well. In addition, the depth of the injection zone was expected to help keep any remaining air in solution. The filters and air release chamber are shown in Figure 2-11.

Figure 2-11. Filters and Air Release Chamber

2.8.4 Pressure Control Valves

A main pressure reducing valve upstream of the filters was provided to keep system pressures relatively constant despite the expected fluctuations in the mainline pressure. A low pressure Nelson 800 pressure reducing valve was provided immediately downstream of the filters to further control injection pressure.

2.8.5 Injection Water Flow Control

Injection flow rate was controlled by the friction loss and differential pressure across two 3” PVC injection tubes. The design wellhead injection pressure was kept low to facilitate better air removal and to enable the use of the expected static pressure available in the water supply mainline. Butterfly valves just upstream of the injection tubes enabled final adjustment of injection pressure. Vacuum vents with isolation valves enabled vacuum relief when closing one of the control butterfly valves. Part way through the injection phase of the pilot test, combination pressure/vacuum gauges were added to the injection tubes to allow finer control of flow rates using partial vacuum pressure at the top of the injection tubes. Injection flow rate was measured using a Seametrics flow meter upstream of the injection control gate valves. Wellhead control and other equipment are shown in Figures 2-12 and 2-13.

Figure 2-12. Wellhead Control and Other Equipment

Figure 2-13. Injection Control and Air Bleed Valves with Added Combination Pressure/Vacuum Gauges

2.8.6 Chemical Injection

Pumps for injection of sodium hypochlorite and magnesium chloride solutions were provided. The sodium hypochlorite was used to prevent biological film formation in the ASR well. The magnesium chloride was used to test the effect of magnesium injection for stabilizing interlayer clays. The pumps utilized were low cost 12 Volt DC sprayer style Shurflo diaphragm pumps with compatible materials for the solutions to be injected and cooling fins for continuous operation. Chemical storage tanks included a 330 gallon replaceable tote for sodium hypochlorite and a 4,000 gallon tank for $MgCl_2$.

2.9 Monitoring and Control Instrumentation

The major online monitoring instrumentation is listed in Table 2-3. The instrumentation is also shown schematically on the process and instrumentation diagram in Drawing D1 in Appendix A. Except for the flow meter, monitoring equipment was purchased directly by Westlands.

Table 2-3. Major Elements of the Proposed Monitoring Program

Parameter Category	Measurement
Injection Operation	Flow, pressures, turbidity, EC
Injection Well Water Level	Level transducer
Recovery Water Quality	EC monitoring

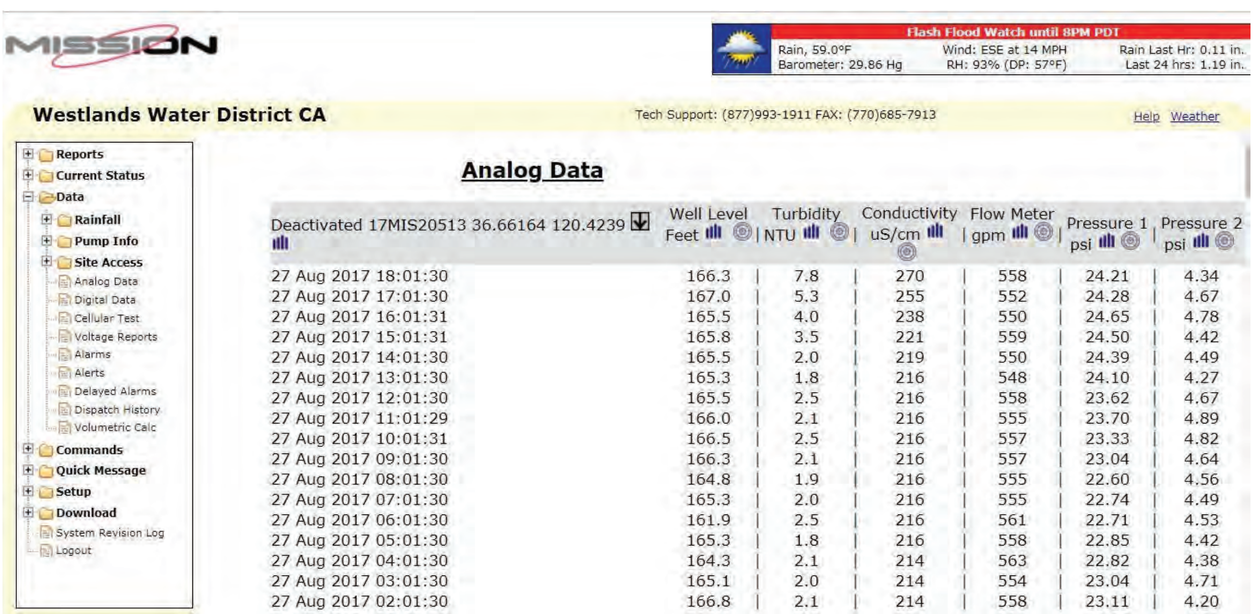
Injectate turbidity (after filtration) was monitored using a Hach 5300 continuous sampling meter, and electrical conductivity (EC) was monitored using a Hach 2468 probe in a flow-through pipe sleeve. Data was relayed through a Hach SC-200 controller to an M110 Mission Remote Terminal Unit (RTU) for upload via an integral cell phone data radio to cloud based data storage and access. Pressures were measured using transducers upstream of the filters and at the discharge of the downstream pressure reducing valve. Flow data from the Seametrics flow meter was also relayed to the Mission RTU. Water level data in the ASR well was monitored using an In-Situ LevelTroll 400. All instrumentation was set up to output 4-20 mA signals to the Mission RTU. The instrument readings and power supply status were recorded hourly and were available for instantaneous reading through the Mission Web interface. The flow meter, instrumentation shed, instruments inside the shed, and Mission Web interface are shown in Figures 2-14, 2-15, 2-16, and 2-17, respectively.

Chemical injection points were installed downstream of the air release chamber. The chemical injection points were subsequently moved downstream of the flow meter after it was discovered that the chemical injection hampered the functionality of the flow meter. Water quality sample ports were also installed downstream of the flow meter.

Figure 2-14. Flow Meter, Sampling Ports, and Bio-Indicators Sample Filter

Figure 2-15. Instrument Shed and Surroundings

Figure 2-16. Instruments Inside Instrument Shed



Deactivated 17MIS20513 36.66164 120.4239	Well Level Feet	Turbidity NTU	Conductivity uS/cm	Flow Meter gpm	Pressure 1 psi	Pressure 2 psi
27 Aug 2017 18:01:30	166.3	7.8	270	558	24.21	4.34
27 Aug 2017 17:01:30	167.0	5.3	255	552	24.28	4.67
27 Aug 2017 16:01:31	165.5	4.0	238	550	24.65	4.78
27 Aug 2017 15:01:31	165.8	3.5	221	559	24.50	4.42
27 Aug 2017 14:01:30	165.5	2.0	219	550	24.39	4.49
27 Aug 2017 13:01:30	165.3	1.8	216	548	24.10	4.27
27 Aug 2017 12:01:30	165.5	2.5	216	558	23.62	4.67
27 Aug 2017 11:01:29	166.0	2.1	216	555	23.70	4.89
27 Aug 2017 10:01:31	166.5	2.5	216	557	23.33	4.82
27 Aug 2017 09:01:30	166.3	2.1	216	557	23.04	4.64
27 Aug 2017 08:01:30	164.8	1.9	216	555	22.60	4.56
27 Aug 2017 07:01:30	165.3	2.0	216	555	22.74	4.49
27 Aug 2017 06:01:30	161.9	2.5	216	561	22.71	4.53
27 Aug 2017 05:01:30	165.3	1.8	216	558	22.85	4.42
27 Aug 2017 04:01:30	164.3	2.1	214	563	22.82	4.38
27 Aug 2017 03:01:30	165.1	2.0	214	554	23.04	4.71
27 Aug 2017 02:01:30	166.8	2.1	214	558	23.11	4.20

Figure 2-17. Example RTU Cloud Data Access Web Page

2.10 Regulatory Submittals and Approvals

The Work Plan for the ASR Pilot test was submitted to the Regional Board on 5 May 2016. After a subsequent meeting with the Regional Board staff, a letter with a summary of the meeting questions and additional considerations for the ASR Pilot Project was submitted on 7 July 2016. Some of the changes to the initial work plan included:

- Intermittent chlorination instead of continuous chlorination to minimize the potential for chlorination byproducts formation
- Use of intrinsic tracers for determining percentage of injected water in the water recovered
- Additional monitoring for trace minerals and constituents of concern that could possibly be mobilized by the differing quality of the injected water
- Additional monitoring for pathogens and pathogen surrogates

Based on the information submitted, the DDW and Regional Board approved the proposed pilot study in a letter dated 3 October 2016. The recommendations in the approval letter included:

> *"…only using NSF/ANSI Standard 60 chemicals, collecting sufficient information during the pilot study to enable RWQCB and DDW to adequately evaluate potential impacts to an aquifer with a MUN designation, and to insure that injected surface water is not experiencing an algal bloom.*
>
> *DDW also requests that the District develop a model to quantify the recovery of the injectate during the test pumping phase of the project, develop a water quality test plan to determine initial and post pilot project groundwater quality, and to collect sufficient information to determine if riverbank filtration credit is appropriate for future ASR projects."*

A Detailed Operations and Water Monitoring Plan (BC, 2017) was subsequently submitted to the Region Board and DDW on 23 May 2017.

Approval of the well as an EPA Class V injection well was also subsequently granted on 22 February 2017. Fresno County acknowledged that the project would be exempt from CEQA in an email dated 3 April 2017.

Section 3

Monitoring and Sampling

Monitoring and sampling were performed during setup, injection, and recovery, following the Detailed Operations and Water Quality Test Plan (BC, 2017) as closely as possible.

3.1 Physical Parameters and Water Quality

The monitoring program included data gathering to monitor proper operation of injection facilities and to determine the well performance, aquifer effects, and fate and transport of water and constituents. The major elements of the monitoring program are listed in Table 3-1. Online instrumentation and SCADA operation were described above in Section 2.9.

Table 3-1. Major Elements of the Monitoring Program

Parameter Category	Measurement
Injection Operation	Flow, pressures, turbidity, EC
Injection Well Water Level	Level transducer
Nearby Well Water Level	Sounder
Injection Water Quality	Samples and analyses, including microbial testing
Nearest Drinking Water Well	EC of samples as intrinsic tracer
Backflush Water Quality	EC (meter), chlorine (test strips)
Recovery Water Quality	EC monitoring, samples and analyses (including intrinsic tracers and microbial testing)

3.2 Intrinsic Tracers

Electrical conductivity, sulfate, and stable isotopes were used as intrinsic tracers for the study. Sulfate was viewed as the best intrinsic tracer because native groundwater is very high in sulfate relative to injected surface waters, and sulfate has relatively low reactivity compared to its groundwater concentration.

3.3 Microbial Testing

The DDW indicated interest in obtaining data on fate and transport of cryptosporidium, giardia, and surrogates in the aquifer receiving the injected water. Microscopic particulate analysis (MPA) of collected samples provides good surrogates for giardia and cryptosporidium in terms of the fate of similar sized microbial particles. Biovir Labs (Benicia, CA) tested for MPA and for MPA with Cryptosporidium and Giardia on samples taken at intervals throughout the project. Total coliform bacteria was also measured periodically from samples during the injection and recovery phases of the project.

This page intentionally left blank.

Section 4

Injection and Recovery Operations Overview

Pilot study operations consisted of setup, injection, and recovery. Setup of major equipment was completed by 19 June 2016. Some modifications were made to the injection related facilities as the injection phase progressed.

4.1 Monitoring Equipment Adjustments

The 4-20 mA scaling for the Mission RTU data conversion had to be adjusted after the first week of operation to match field calibration readings. Prior data was back-corrected. The groundwater level transducer direct output malfunctioned a few weeks into the injection phase. Readings using the 4-20 mA output to the Mission RTU continued to function properly.

4.2 Injection Operations

Injection was performed during an 84 day period from 19 June 2017 through 11 September 2017. A total of approximately 178 acre-feet were injected. Water originating from the San Luis Canal was directed to the ASR well for 66 days, and water from the Kings River (upstream end of Mendota Pool) was directed to the ASR well for 18 days. Due to lag times for district pipeline conveyance and mixing in portions of the system, injected water was sometimes a blend of both water sources.

To start injection, the butterfly valve upstream of the air bleed valve for the first (deeper) injection tube was gradually opened, allowing injection flow and initially pulling a vacuum through air bleed valve, then bleeding air out the air bleed valve as flow increased. After all air was expunged, the air bleed valve was closed and injection allowed to stabilize. After several minutes to allow any air bubbles to escape up the well, flow was initiated in the second (shallow) injection tube using the same procedure. Injection pressures were then adjusted using the butterfly valves to provide the desired flow rate as measured at the flow meter. Water level in the well was monitored to insure the rate of rise was not excessive.

The well was backflushed every 1 to 2 weeks during the injection period. The injection air bleed/vent tubes were left open during backflush pumping. The backflush pumping consisted of step ramps of pumping at typical flow rates of approximately 1,000, 1,500, and 1,800 gpm and about 20 minutes at each flow. On some occasions the sequence was repeated a second time and pump start/stop surges were included. As mentioned previously, backflush water was conveyed out into the adjacent field to the east.

Sodium hypochlorite was injected for times ranging from 20 minutes to 2.5 hours prior to backflushing on 5 occasions to help prevent downhole slime formation. The 12.5% sodium hypochlorite was injected at a point downstream of the sand media filters and flow meter at a rate of approximately 2 gpm.

Magnesium chloride was injected after backflushing on three occasions to test whether stabilization of interlayer clays was helpful for maintaining injection capacity. A total of 2,600 gallons of 30% rated solution was injected, once for a brief 45 minute period on July 5, 18 hours (1100 gallons) starting on

August 16 and then for a 22 hour period (1,400 gallons) starting August 31 at a rate of slightly over 1.0 gpm.

4.3 Recovery Operations

Approximately the same amount of water was recovered as had been injected. Recovery occurred over a 64 day period from 19 September 2017 through 22 November 2017. Recovery pumping mostly occurred only during weekdays, for a total of 45 pumping days at a typical pumping rate of approximately 1200 gpm. Water was discharged back into the Westlands system for use by other farmers on the District water supply lateral. A record of recovery pumping is provided in Appendix B.

Supply tubing to the online turbidity and EC meters was rerouted to receive water from the well discharge. Issues with the recovery water monitoring are discussed below in Section 5, Operational Results.

Section 5

Operational Results

The focus of this section is on the pilot study physical results including flow rates, water levels, plugging, and other practical implementation related factors. Water quality results are discussed in Section 6.

5.1 Well Rehabilitation Phase Results

As discussed in Section 2.5, the well was scratched, acid treated, air lifted, and then further redeveloped by pumping. Measurements taken during this phase provide some context for performance during injection and recovery.

5.1.1 Initial Well Capacities

The estimated normalized specific capacities at 20 minutes after startup or flow changes before and after development pumping are shown in Table 5-1. While 20 minute specific capacities are not a standardized test, they can be useful for ASR performance comparison purposes over time (Morris, 2018). As can be seen in Table 5-1, the surges and repeated pumping cycles were very successful in further developing the well capacity compared to the capacity after air lifting alone.

Table 5-1. Calculated Normalized Initial 20 Minute Specific Capacities

Date	Flow (gpm)	Specific Capacity (gpm/ft)	Notes
6/12/2017	1,385	9.40	Beginning of development, before surging
6/13/2017	1,492	13.2	After 3 sets of pumping, multiple surges each on second day
6/15/2017	1,400	13.5	First step test after 3 days development

Step test results for June 15, 2017 were also used to derive best fit aquifer characteristics as described below in Section 5.6, Plugging and Backflushing.

5.1.2 Pumping Effects on Groundwater Levels Above the Corcoran Clay

Well A06 was an existing unused well approximately 1 mile south of the ASR pilot well (see Figure 1-2 for well location). Well A06 was completed down to the top of the Corcoran Clay at approximately 640 feet below ground surface. Water level in well A06 was monitored using a downhole transducer during ASR well development pumping to see if there was any effect on groundwater levels. Between 2:30 PM on June 11, 2017 (the Sunday before development pumping) and 2:30 PM on June 15, 2017 (end of development and test pumping), the water level in A06 increased by 0.09 feet (including barometric adjustment) despite the pumping at the ASR well. This would indicate that pumping in the ASR well had no significant effect on piezometric pressures above the Corcoran Clay.

5.2 Injection Phase Results

Injection phase results included water level responses to injection, plugging, and chemical effects.

5.2.1 General Results and Observations

Water from the San Luis Canal was used as the water source for most of the injection period. Water diverted from the Kings River at the Mendota Pool was directed to the ASR well for 2 periods during the injection phase. Kings River water arrived at the well after approximately 3 day long conveyance lags for a 7 day period in early July and a 5 day period around the end of August. For the first several days of September, injectate was likely a mix of Kings River water and water originally from the San Luis Canal, due to the long residence time of San Luis Canal water in the distribution system.

One difficulty encountered early in the injection phase was the inability to inject the maximum targeted rate of 750 gpm on the injection startup date of June 19. When the valve to the second injection tube was opened to allow 750 gpm of flow, the water level in the well rose to the ground surface. Later attempts during the injection phase were successful in temporarily injecting nearly 700 gpm, but consistent injection rates rarely exceeded 600 gpm for any significant duration. These results indicated a high natural well loss exponent and turbulence at the higher flows rates. Average injection rates during the injection phase were therefore started at approximately 400 gpm and were gradually increased to approximately 550 gpm during the latter half of the injection phase.

The sequence of events and water level results during the injection phase are shown on Figure 5-1. The figure shows injection flow, depth to water, and dates for backwashes, outages, chlorination, and magnesium injection. Implications based on the data shown in Figure 5-1 are discussed in later subsections.

Water levels shown in Figure 5-1 were not adjusted for barometric pressure. Based on barometric pressures measured at nearby Hanford, the maximum effect of barometric variations during all the days of measurement would have been 0.27 feet, with the majority of days less than 0.1 feet. Therefore, barometric effects on water level measurements in the ASR well were ignored.

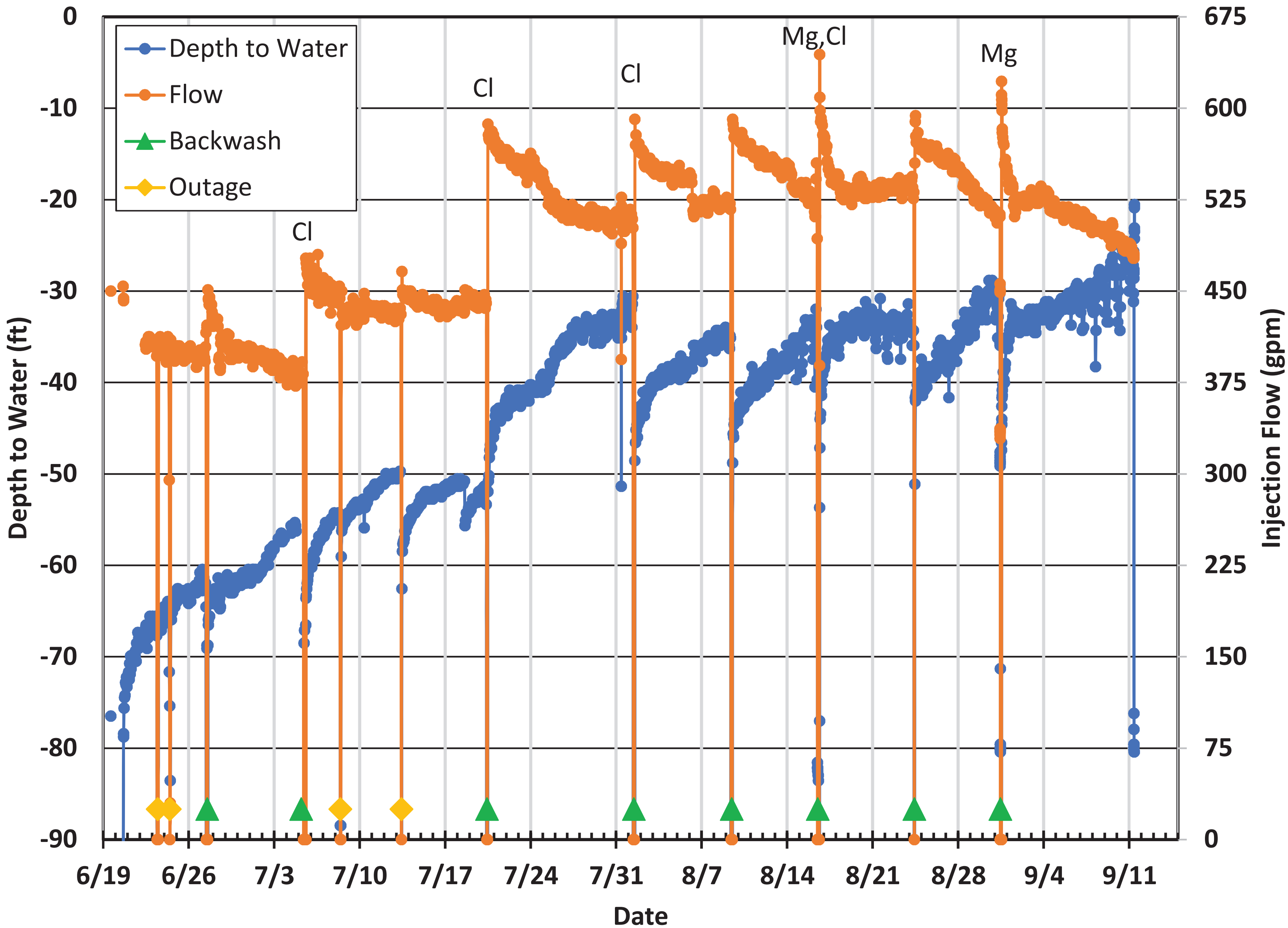
One other interesting phenomena regarding water level measurements was some apparent surging during injection. Even water level measurements taken with sounders would sometimes exhibit variability of up to one foot or more during repeated rapid measurements. No explanation was determined for the apparent surging.

5.3 Recovery Phase Results

Recovery began on September 19 after leaving the well idle for a little over a week to allow piping and other changes so that recovery water could be reliably sent back into the Westlands distribution system. Recovery pumping was only performed during weekdays and during periods of water demand on the Westlands distribution lateral. Table B-1 in Appendix B documents recovery operations. The operator noted that the first recovered water after the well had been inactive for over a week was exceptionally dirty with a red colored tinge.

Water quality samples were taken from the well discharge on a periodic basis. Although the feed to the turbidity and EC meters had been re-routed to sample the well discharge, reliability problems were encountered. Problems included inadvertent supply tubing pinching and rodent damage to the supply tubing. The extended periods of low or no supply to the instruments caused the turbidity meter to fall out of calibration, and it could not be recovered with field re-calibration. The online EC readings were supplemented with frequent manual readings of well discharge water using a portable meter. Water quality results during recovery are discussed in Section 6, Water Quality Results.

Figure 5-1. Flows, Depths, and Major Events During Injection Phase



No additional well redevelopment pumping or surging was performed at the end of the recovery phase. Step-drawdown tests were performed several days after the end of the recovery period to provide a comparison with the step drawdown tests after initial well development. These results are discussed in Section 5.6, Plugging and Backflushing.

5.4 Filtration Effectiveness

Turbidity of injected water over the injection period is shown in Figure 5-2. Water from the Kings River in late June – early July was especially high in turbidity, with much of the turbidity appearing to be from very fine suspended silt and clay particles.

Average turbidity of the injected water was 7.3 NTU. Turbidity upstream and downstream of the sand media filters was measured several times during injection. Those results are shown in Table 5-2. Filter performance seemed to improve over time, possibly due to some ripening effects. For comparison purposes, average turbidity of the recovered water (not including backflushing) was 0.39 NTU.

Table 5-2. Turbidity Removal in Sand Media Filters

Date	Turbidity, NTU		% Removal	Notes
	Upstream	Downstream		
7/5/2017	29.4	25.9	11.9%	Very fine silts and clays (Kings River)
8/1/2017	3.8	2.7	28.9%	
8/16/2017	14.7	6.96	52.7%	
8/31/2017	18.3	13.5	26.2%	Very fine silts and clays (Kings River)
8/31/2017	17	6	64.7%	During upstream $MgCl_2$ injection

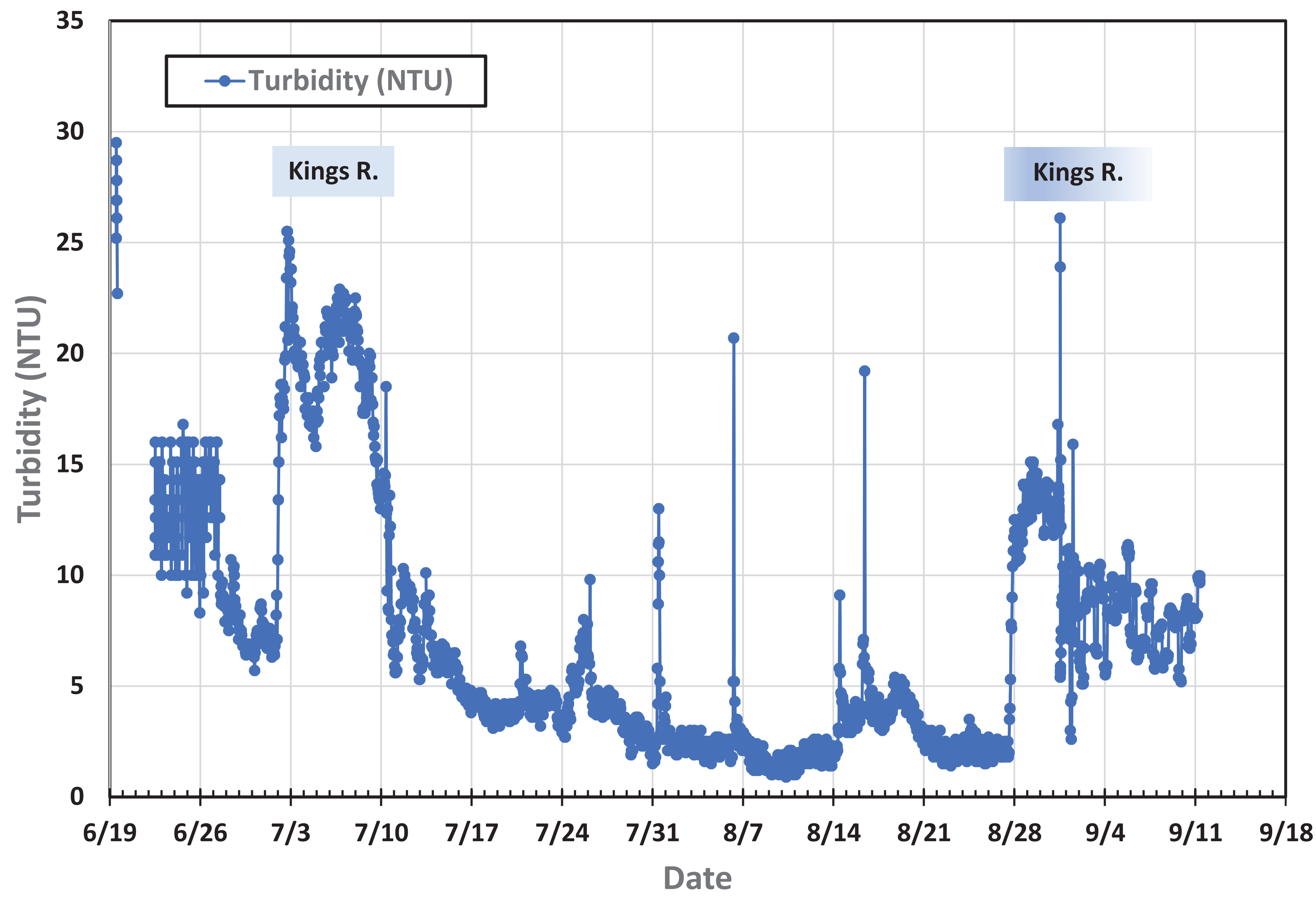
A 2” diameter column with zeolite (Clack Filter-Ag Plus) was assembled to compare potential zeolite media performance with the performance of the sand filters. On August 16, turbidity upstream of the sand filters was 14.4 NTU. Downstream of the zeolite column loaded at 8 gpm/square foot, turbidity was 10.3 NTU compared to 6.6 NTU downstream of the sand filters. Therefore, zeolite was not considered worth further evaluation as an alternative filter medium.

Injectate from Kings River sourced water was further filtered once in the office and once in the field to gain some idea of particle size range. For a sample taken on July 5, injectate was 20.3 NTU, while samples filtered through 0.2 micron and 0.45 micron filters had turbidities of 0.57 and 0.71 NTU, respectively. On August 31, water from upstream of the sand filters was run through a 5 micron filter. Turbidity was 4.5 NTU versus 17 NTU inlet turbidity. Based on these informal tests, somewhere on the order of 25% of the particles in Kings River source water were probably between 1 and 5 micron in size. The remaining 75% of particles passing the sand filters were likely in the range of approximately 5 to 50 microns.

5.5 Injection Well Loss Exponent

Injection well losses are typically assumed to be a function of the square of flow rate, but well loss exponents can range from less than 1.5 to 3.5 (Rorabaugh, 1953) depending upon the turbulence of flow conditions.

Figure 5-2. Turbidity During Injection



Injection water levels versus flow were checked immediately prior to backflushing on two occasions to provide an indication of the hydraulic well loss exponent during injection. Figure 5-3 shows the water level (WL rise) response to varying flow rates on June 27. The theoretical predicted aquifer mounding (Pred. Mounding) modeled using parameters derived from the initial step test results is also shown. The difference between the actual water level rise and the predicted aquifer mounding reflects hydraulic losses in the well and media near the well screen. Figure 5-4 shows the results for the later data points at each flow rate minus the predicted aquifer mounding. The curve fit shown for the flow rates over 500 gpm show a steepening well loss exponent with flow, with a best fit exponent of 2.79. Data taken on August 31 for lower flow rates gave a best fit exponent of 1.4. The steepening well loss exponent with flow is consistent with the observed difficulty experienced when trying to inject water at a rate greater than 700 gpm without having the water level rise to the ground surface.

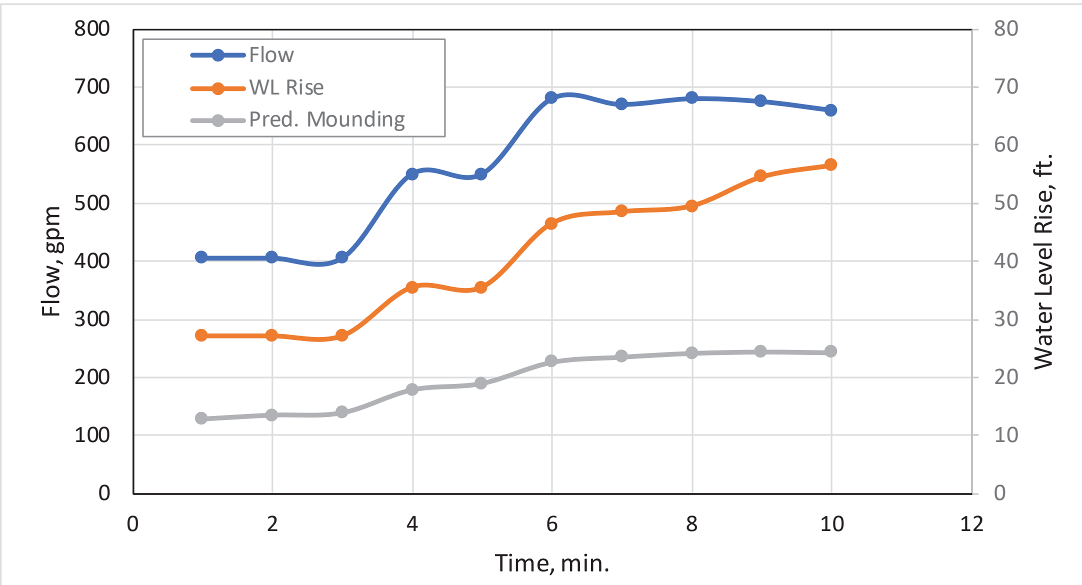


Figure 5-3. Water Levels versus Injection Flow for 6/27/17 Prior to Backflushing

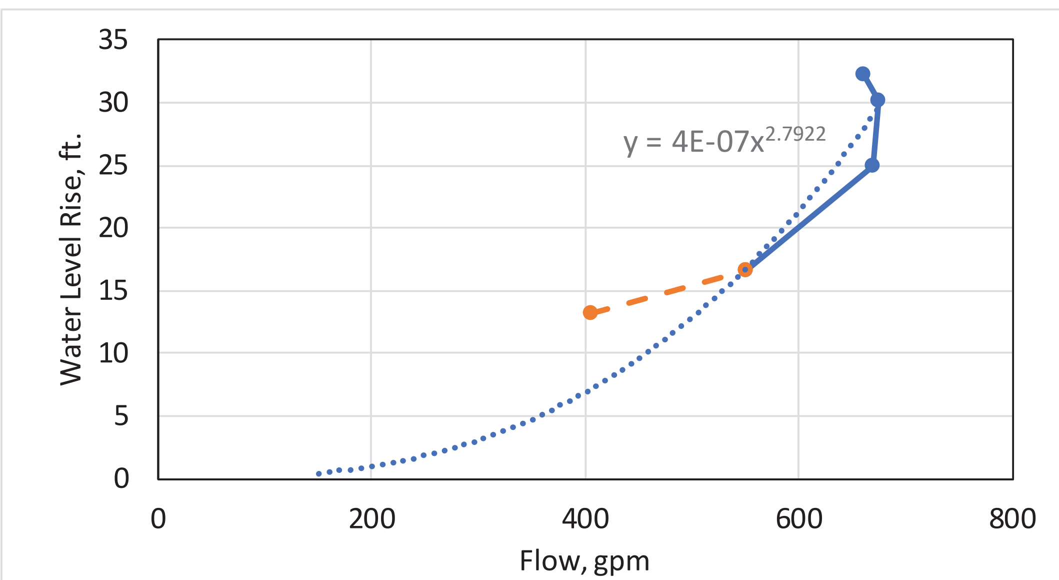


Figure 5-4. Calculated Well Loss Effects versus Flow for 6/27/17

5.6 Plugging and Backflushing

In an injection well, the aquifer material near the well gradually accumulates solids from the injection water and plugs over time. Backflush pumping is used to remove accumulated solids. Backflush intervals for the injection phase can be seen on Figure 5-1.

Looking closely at Figure 5-1, the water level data for several of the intervals between backflush events show inflection points at about 5 days after backflushing where the slope of the water level rise increases, indicating an accelerating rate of restriction. This would indicate that the ideal backflush frequency would probably be somewhere on the order of once every 5 days.

Also looking at both Figure 5-1 and Figure 5-2, periods of higher turbidity generally correlated with steeper increases in water level rises and vice-versa. Injection performance during the period of July 20 through August 28 was generally stable at relatively higher flow rates during a period of lower turbidity.

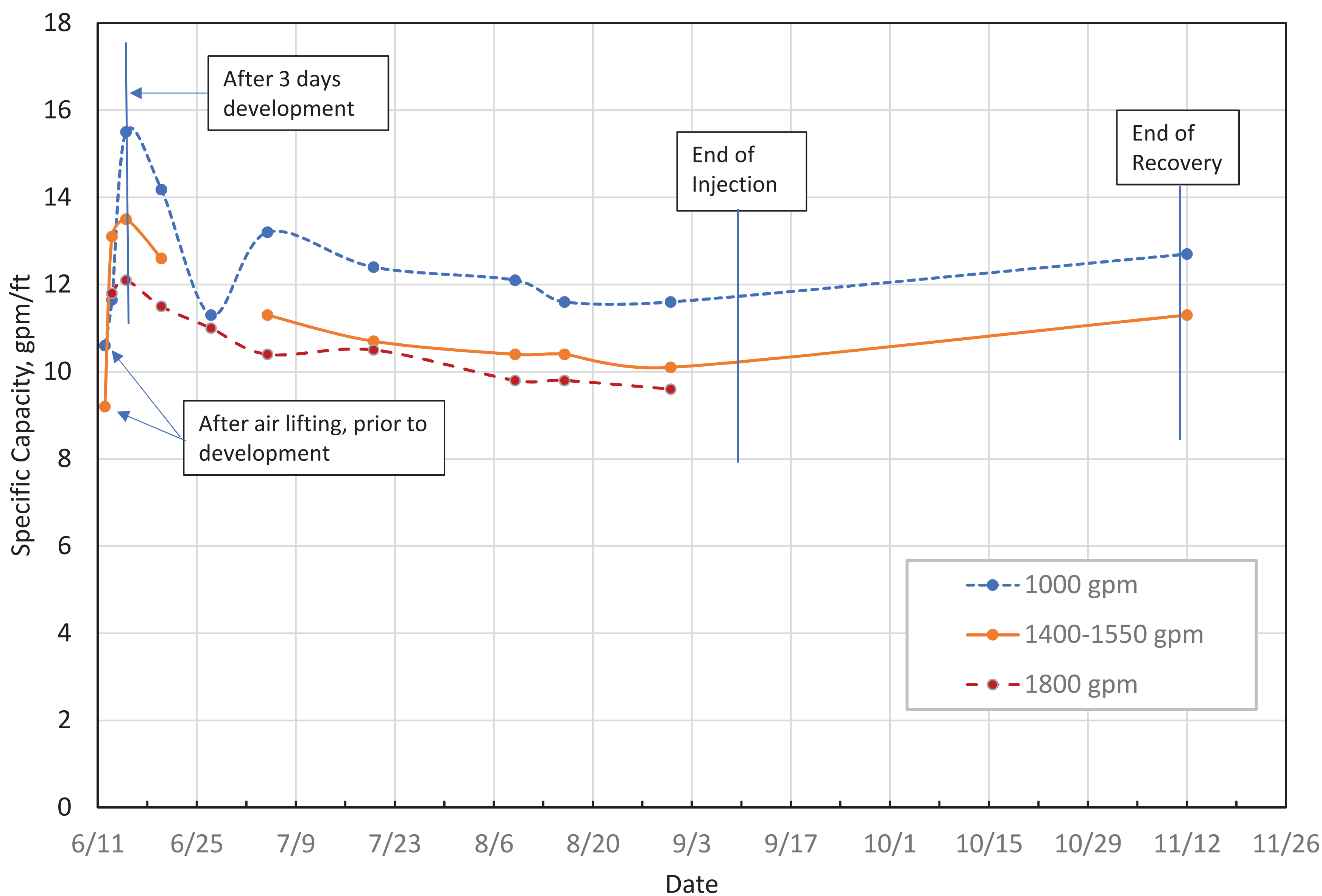
Backflushing effectiveness can be gauged by flow rates versus water depth, and the removal of material based on backflush water turbidity. Examples of turbidity changes with time for a constant rate of pumping during backflushing are shown in Figure 5-5. Examples of backflush pumping logs (Appendix C) also show the progression of turbidity versus time during backflushing and show improved backflush effectiveness with repeated sets of flow steps and surges up to the maximum reasonably obtainable pumping flow rate.

Figure 5-5. Examples of Turbidity versus Time During Backflush Pumping

5.6.1 Overall Capacity Changes

Changes in 20 minute specific capacity over the course of the well redevelopment, injection, and recovery are shown in Figure 5-6. For the injection phase, these values are based on drawdown during backflush pumping. The data used for Figure 5-6 is provided in Table C-1 in Appendix C. As can be seen in the figure, initial development pumping and surging increased specific capacities by approximately 40% compared to the first pumping after air lifting had been completed. Pumping specific capacities gradually dropped by about 20% to 25% during the injection phase and partially recovered by the end of the recovery phase. Specific capacities at the end of the recovery phase were roughly midway between the original specific capacities prior to initial well development pumping and surging and the peak specific capacities after complete initial well development.

Figure 5-6. Changes in 20 Minute Specific Capacities During Study



Best fit aquifer properties and well loss coefficient for the step-drawdown test at the end of recovery are shown in Appendix D. These can be compared with the properties from the initial step-drawdown test immediately after full well development (also in Appendix D). Best fit transmissivity had dropped from 6,600 ft/d to 5,000 ft/d and well loss coefficient had increased from 0.014 to 0.018. No intensive redevelopment style pumping was performed during the recovery phase prior to the final step-drawdown test in November 2016.

While pumping capacities were still quite reasonable at the end of recovery, these results indicate that more intense well redevelopment and surge techniques may be worthwhile after a long injection period to restore optimal production. Some of the loss of capacity could have also been due to overdosing of $MgCl2$ and precipitation of $MgCO3$, as discussed in Section 5.7. Some ongoing sand discharge during the recovery period also indicated that additional targeted surge techniques could be important for stabilizing aquifer materials after a long injection period.

5.7 Chemical Injection Effects

Sodium hypochlorite (bleach) and magnesium chloride were injected and the effects evaluated during the pilot study injection phase in an effort to maintain well capacity.

5.7.1 Chlorination

Chlorine was injected downstream of filters about every 3 weeks before backflushing. The filters were left unchlorinated to allow some biological slime to develop for improved solids capture. Although no actual measurements or estimates of biological slime formation in the aquifer material surrounding the well were performed, the results in Figure 5-1 does not show a spike in plugging such as would accompany microbial proliferation. Microbial data during the recovery phase (discussed later) also show no evidence of bacterial proliferation.

The event on July 20 serves as an illustration of injection and recovery of chlorine. 110 gallons of chlorine were injected over an hour at an average concentration of 600 mg/L. The recovery concentrations were checked using high range test strips. The backflush water free chlorine concentration with time shown in Figure 5-7 indicates that essentially all the chlorine was recovered within 45 minutes from the start of backflush pumping. It also shows that the chlorine concentration was substantially attenuated by chlorine demand, dilution, and dispersion.

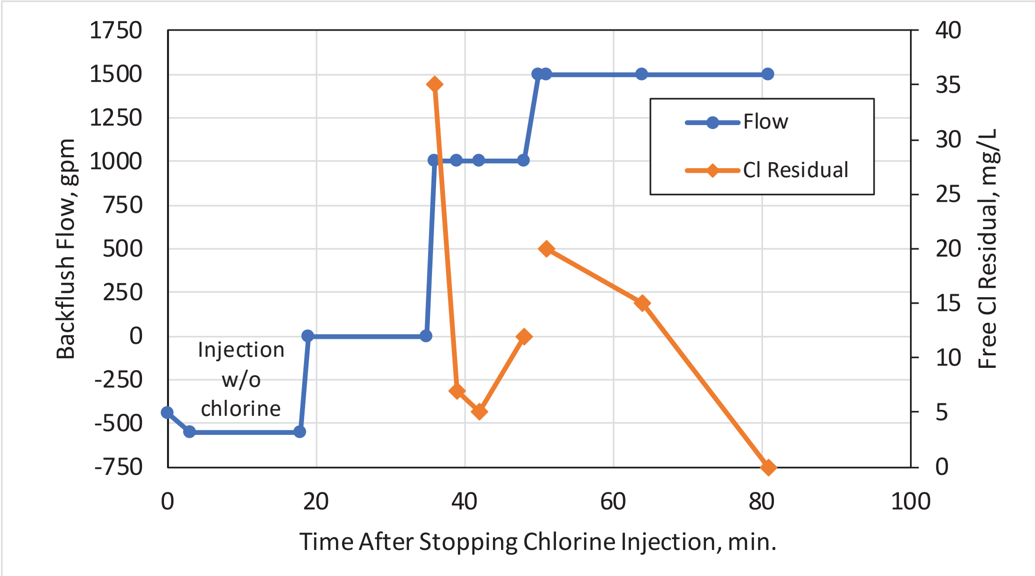


Figure 5-7. Free Chlorine Recovery during Backflush Pumping

Although other effects of chlorination on capacity are not obvious in Figure 5-1, anecdotally the backflush pump operator indicated that backflush performance was better after chlorine injection than for backflushes without prior chlorination.

5.7.2 Magnesium Chloride Injection

As can be seen in Figure 5-1, the times immediately after the large $MgCl_2$ injections on 8/16 and 8/31 show relatively steep increases in water level compared with other periods after backflushes. The slope of water level increase levelled out a few days after the 8/16 backflush. Although not initially recognized for the 8/16 injection event, the concentration of $MgCl_2$ in the injectate must have been much higher than expected, likely resulting in the precipitation of $MgCO_3$ in the aquifer near the well. This was discovered when the $MgCl_2$ injection point was moved upstream of the filters and EC meter prior to the 8/31 injection start. During the 8/31 event, the EC of injectate jumped from 250 umhos/cm to 1750 umhos/cm due to $MgCl_2$ injection, corresponding to a $MgCl_2$ concentration of approximately 800 mg/L (200 mg/L Mg). The turbidity of filtrate also dropped from about 12 to 6 NTU at the start of $MgCl_2$ injection, indicating that the Mg concentration was high enough to induce flocculation upstream of the filters. The higher than expected $MgCl_2$ concentration in the injectate was due to changes from the initial planning that had not been captured in revised calculations. Although this was recognized on 8/31, the $MgCl_2$ pumping continued because the $MgCl_2$ tank needed to be drained, and the effects of $MgCl_2$ over-injection could be evaluated.

Section 6

Water Quality Results

Water quality results from sampling and direct measurements throughout the pilot study were compiled and plotted. BSK Associates Laboratory in Fresno, California performed most of the sampling and provided the water constituents analytical testing and coliform testing. Biovir Labs in Benicia, California performed the analysis of samples for protozoa and bio-indicators. Isotech Laboratories of Champaign, Illinois provided the stable isotope analysis.

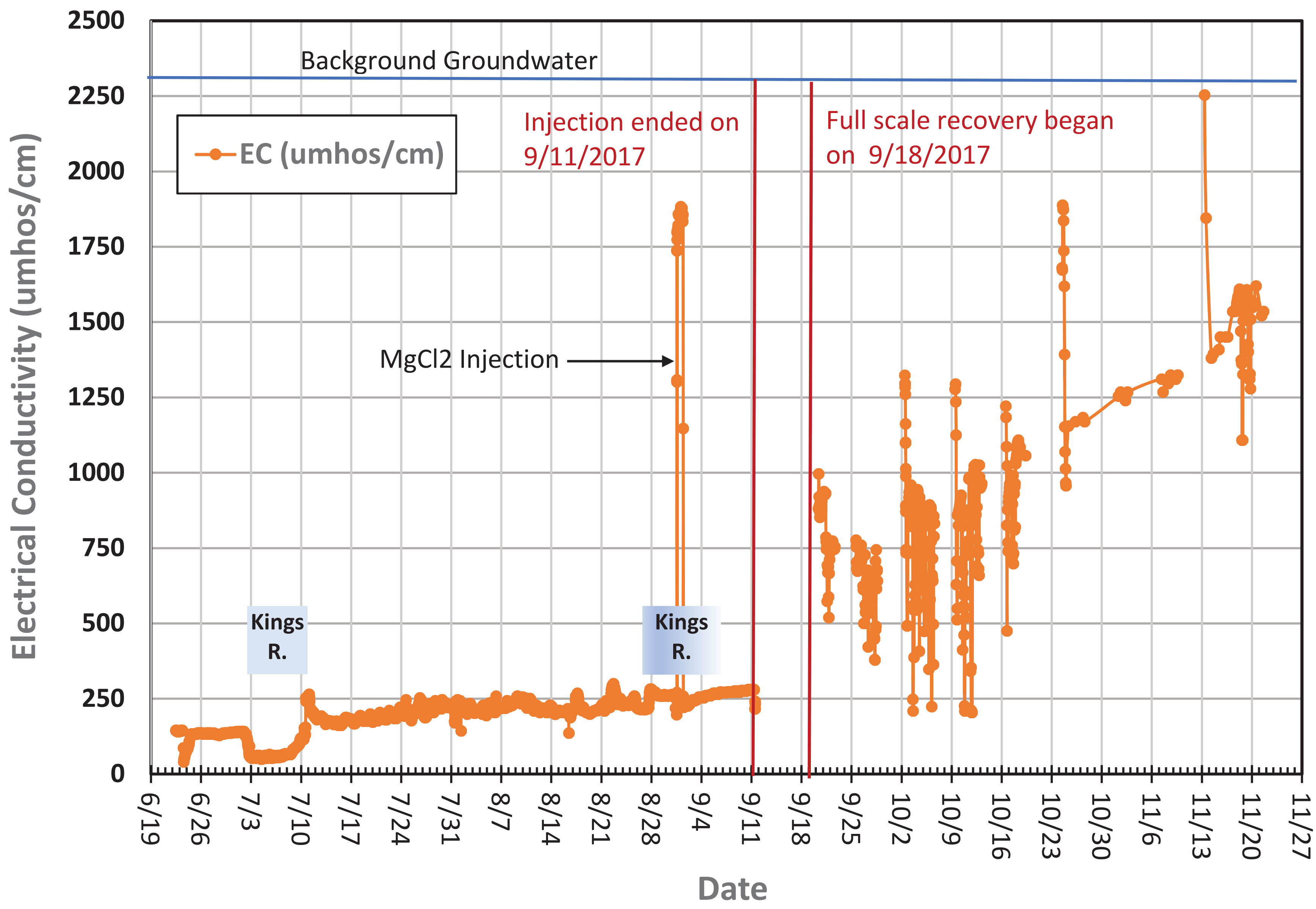
6.1 Intrinsic Tracers

EC, sulfate, and stable isotopes of oxygen and hydrogen were used as intrinsic tracers to estimate the amount of injected surface water that was recovered during the recovery pumping phase.

6.1.1 EC as an Intrinsic Tracer

EC from the beginning of injection through recovery is plotted in Figure 6-1. EC data after 17 September was mostly based on handheld meter readings because of damage to the sampling tubing for the online meter. Average EC of injected water was 219 umhos/cm. The two-day spike in EC during the injection period (8/31 – 9/1) was due to the addition of $MgCl_2$ to the injectate. The spikes in EC during the recovery period were at startup after weekend shutdowns. The spikes during recovery could have been due to diffusion from lower permeability zones surrounding the aquifer and possibly some migration of groundwater down through the gravel pack during weekend shutdown periods. Using EC as an intrinsic tracer, the water tested at the end of the recovery period was roughly 63% native groundwater.

Figure 6-1. Electrical Conductivity



6.1.2 Sulfate as an Intrinsic Tracer

Sulfate concentrations versus time for both the injection and recovery phase are plotted in Figure 6-2. Average measured sulfate concentration of injected water was 11.9 mg/L, and average measured concentration of recovered water was 360 mg/L. Water sampled on both 11/7 and 11/14 were 49% native groundwater.

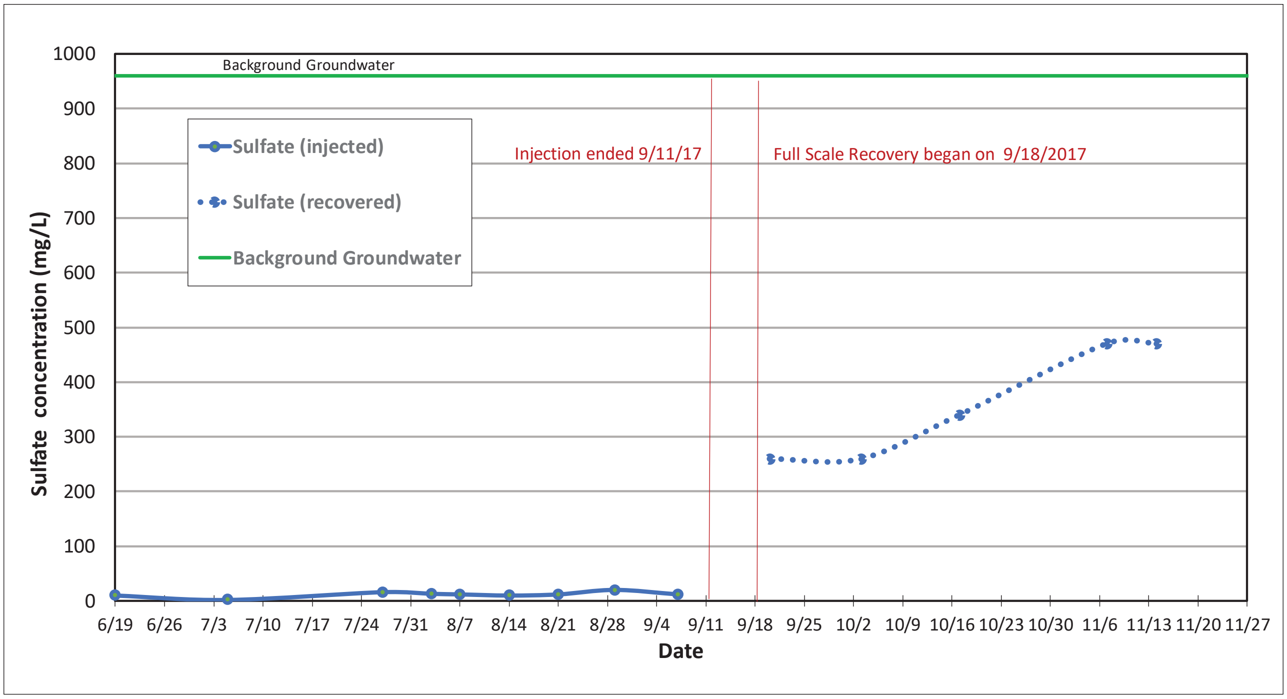


Figure 6-2. Sulfate Concentrations versus Time

Sulfate concentration versus the total volume of recovered water is shown in Figure 6-3. Average flow-weighted concentration of recovered water was 368 mg/L. Based on the 960 mg/L background groundwater sulfate concentration and the 11.9 mg/L injected water concentration, 62% of the recovered water was from the injected water.

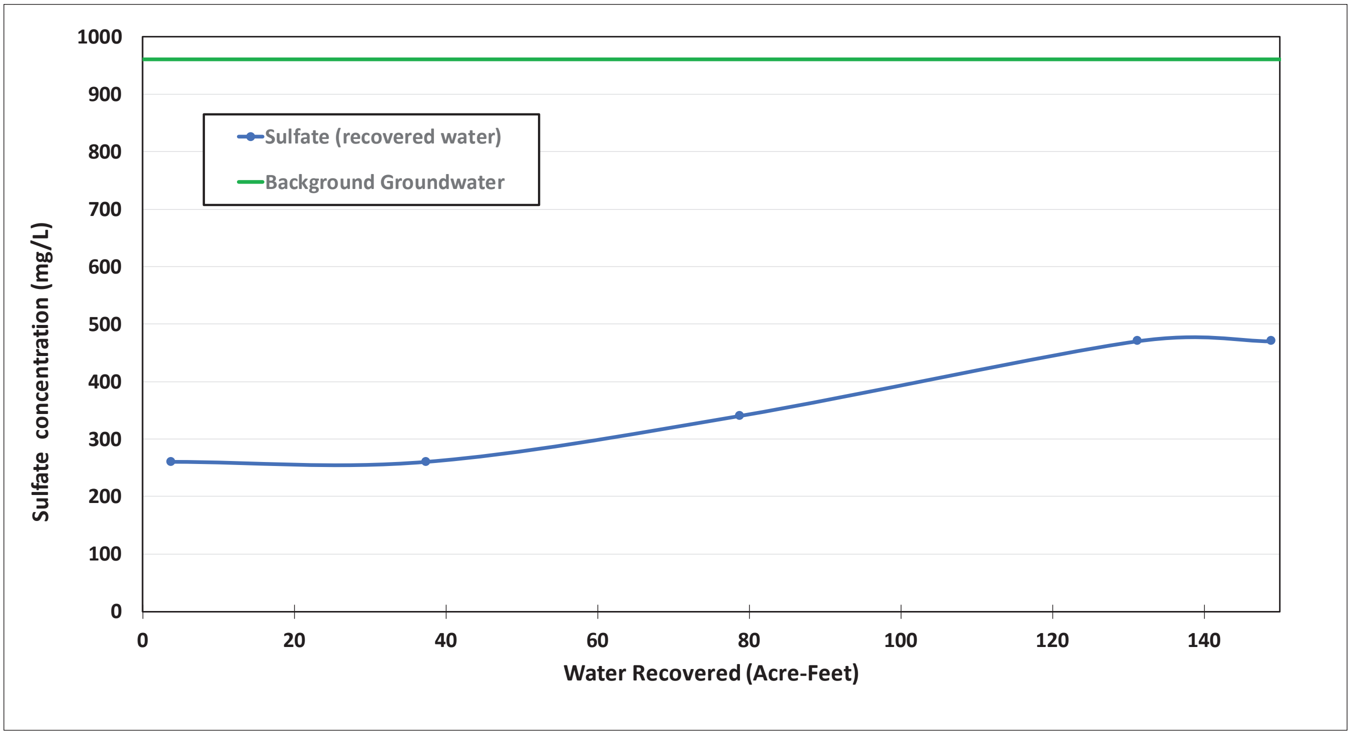


Figure 6-3. Sulfate Concentrations versus Recovered Water Volume

6.1.3 Stable Isotope Results and Use as Intrinsic Tracers

Stable isotopes of hydrogen and oxygen provide a means of evaluating the sources and evaporative history of water that is unaffected by chemical reactions. The stable isotope oxygen-18 tends to become enriched by evaporation compared to the meteoric water line relationship between oxygen-18 and deuterium (H-2). Stable isotope values are plotted alongside the meteoric water line in Figure 6-4. Numerical results are provided in Table E-1 in Appendix E.

In theory, the average difference of the recovered water values from the background groundwater water values divided by difference between the injection water values and the background groundwater values would give an indication of the percentage of surface water in the pumped recovery water. Unfortunately, the Kings River source water sample taken on July 5 had a dramatically different stable isotope signature than the samples from San Luis Canal source water. Using an average of all the values would give a recovery percentage of 53%, but this result is much less accurate than the sulfate and EC intrinsic tracer results.

It is interesting (Figure 6-4) to see the isotopic difference between the Kings River water from cold recent snowmelt versus the San Luis Canal water from reservoir storage. The groundwater values reflect warmer, more evaporated source conditions.

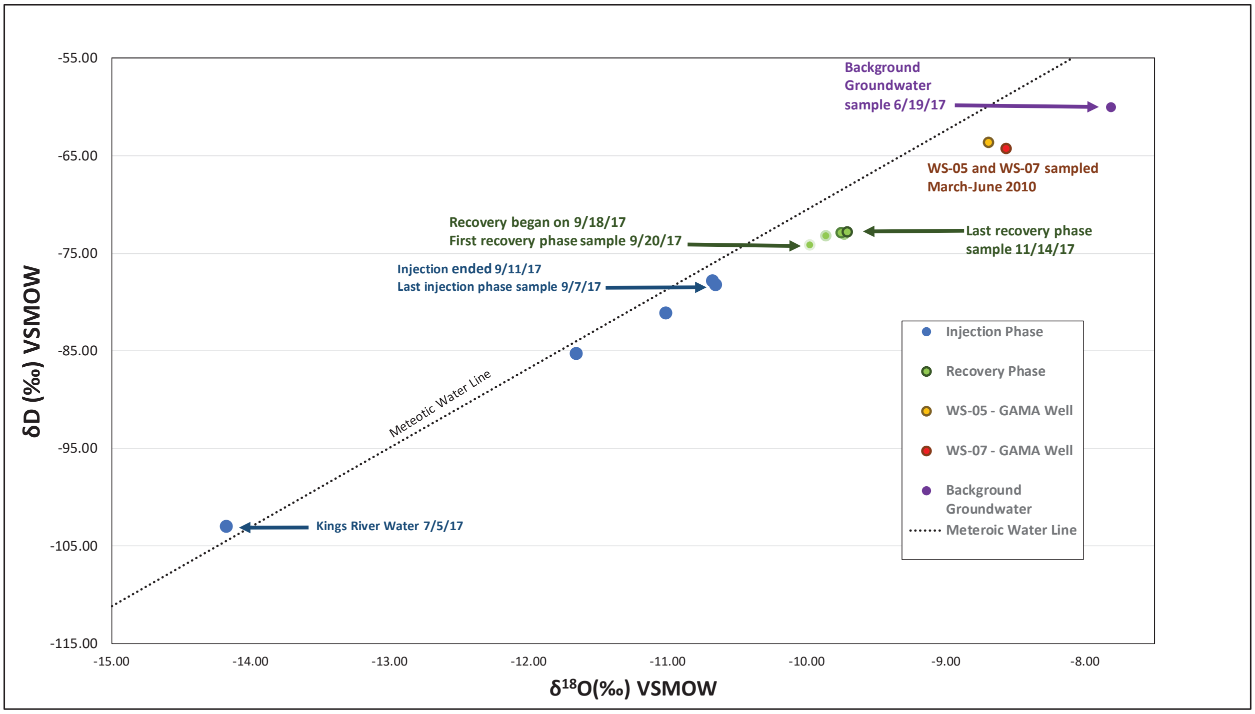


Figure 6-4. Stable Isotope Results

6.2 Other Minerals

Results of water quality sampling and analysis for major minerals and parameters are shown in Table 6-1. Results for minor minerals are shown in Table E-2 in Appendix E. Averages during injection and recovery are shown in Table 6-1. Concentration plots of the major minerals and uranium during the injection and recovery period are shown in Figure 6-5. Plots of TDS and nitrate-N versus time for injection and recovery phases are shown in Figures E-1 and E-2 in Appendix E.

Table 6-1. Mineral Water Quality and Related Parameters – Averages

Parameter	Units	Background Groundwater	Injection Average	Recovery Average	Primary MCL	Secondary MCL
Arsenic	ug/L	ND (1.0)	0.74	1.6	10	-
Boron	mg/L	2.1	ND (0.05)	0.76	-	-
Calcium	mg/L	150	10.5	65.6	-	-
Chloride	mg/L	107	19.8	74.6	-	250/500/600[b]
Hex. Chrome	ug/L	NA	NA	0.185	50, 10[a]	-
Iron	mg/L	ND (0.015)	0.12	ND (0.015)	-	0.3
Magnesium	mg/L	150	5.0	55.2	-	-
Manganese	mg/L	0.045	ND (0.005)	0.100	-	0.050
Nitrate-N	mg/L	1.3	0.07	0.61	10	-
pH	STD	7.9	7.75	7.8	-	-
Phosphorus	mg/L	ND (0.05)	0.1	0.06	-	-
Silica	mg/L	50	9.3	26	-	-
Sodium	mg/L	200	16.8	87.2	-	-
Sulfate	mg/L	960	11.9	360	-	250/500/600[b]
TDS	mg/L	1,800	105	752	-	500/1000/1500[b]
TOC	mg/L	NA	2.46	1.03	-	-
Uranium	ug/L	11	ND (0.5)	5.4	30[c]	-

Notes:

a. 50 ug/L Total Cr California MCL; 10 ug/L recent Hex. Cr California MCL (limit currently suspended)

b. Recommended/Short Term/Long Term

c. USEPA MCL and approx. equal to California MCL

Averages of Measurements, not volume-weighted

All constituents measured as dissolved phase

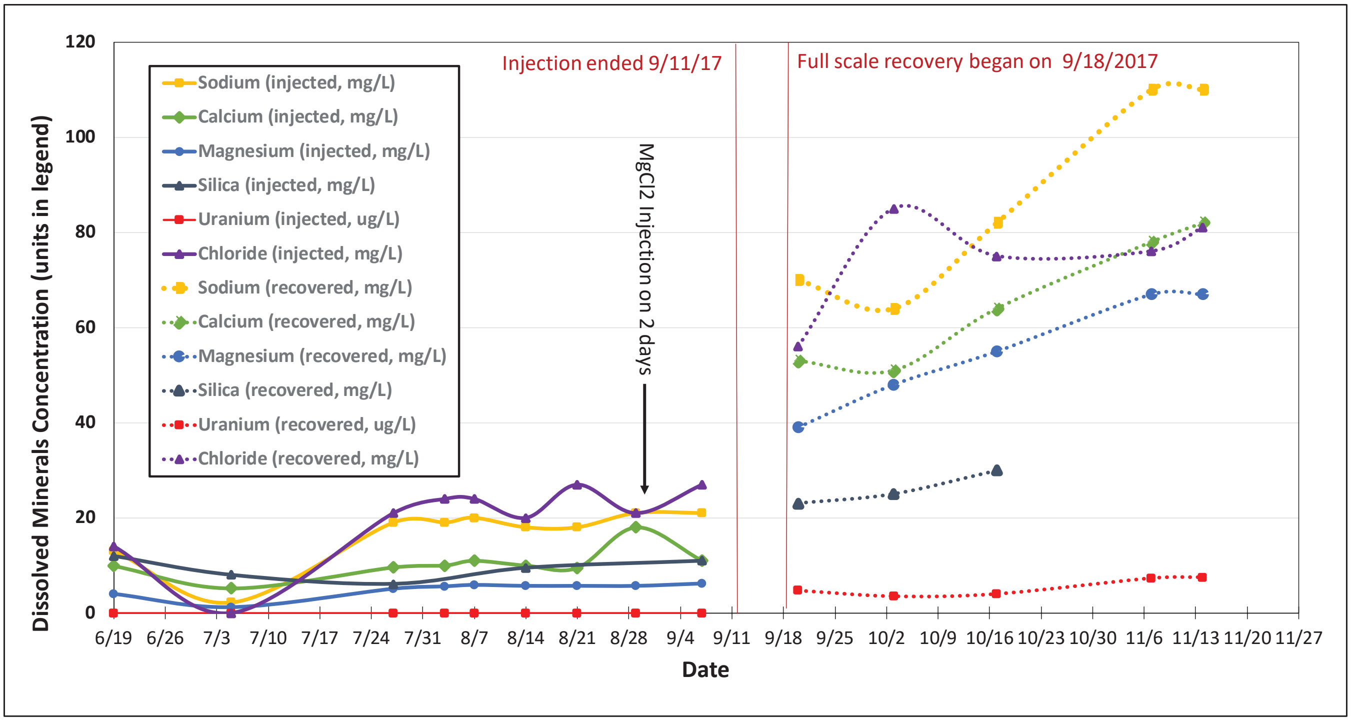


Figure 6-5. Concentrations of Major Minerals and Uranium versus Time

All mineral constituents in the recovered water were below the concentrations in groundwater, except for manganese and arsenic. Arsenic concentrations in the recovered water averaged only 1.6 ug/L, far below the MCL.

Concentrations of dissolved manganese in the recovered water averaged 0.10 mg/L, which is above the secondary drinking water MCL of 0.050 mg/L. This would seem contrary to expectations because the injected water and the occasional chlorine would have produced higher oxidative conditions and less dissolved manganese than would be expected in deep natural groundwater. More likely, the sample on June 19 for native groundwater had probably been affected by prior airlift and other development of the well, which may have precipitated out manganese near the well. Evidence supporting this hypothesis is the fact that the first 3 recovered water samples had non-detect or low concentrations of manganese and the last 2 samples had concentrations of 0.21 and 0.26 mg/L. The latter samples may have been more reflective of natural groundwater with more electrochemically reducing conditions.

One other interesting item to note in Figure 6-4 is the upward blip in chloride in the 10/3 sample (16 total days, 10 pumping days after start of recovery). This probably reflects influence of the $MgCl_2$ injection on 8/31 through 9/1 (11 days prior to the end of injection. This effect can also be seen in Figure A-2 as the spike in EC for those days.

In general, mobilization of minerals and trace constituents does not seem to have been problematic as a result of ASR operations.

6.3 Disinfection Byproducts

Results of sampling for chlorine residual and disinfection byproducts is shown in Table 6-2. Low concentrations of chloroform were present in the first 4 recovery samples. The highest concentration was on 10/17 at 3.8 ug/L, far below the 80 ug/L drinking water MCL.

Table 6-2. Chlorine Residual and Disinfection Byproducts

Date Sampled	Residual Chlorine (mg/L)	Bromodichloromethane (µg/L)	Bromoform (µg/L)	Chloroform (µg/L)	Dibromochloromethane (µg/L)	Total Trihalomethanes (µg/L)
Groundwater (6/19/2017)	-	ND (0.25)	0.67	ND (0.25)	ND (0.25)	1.30
6/19/2017	-	ND (0.25)	0.67	ND (0.25)	ND (0.25)	0.67
7/5/2017	-	ND (0.25)	ND (0.25)	ND (0.25)	ND (0.25)	ND (0.25)
7/27/2017	-	ND (0.25)	ND (0.25)	ND (0.25)	ND (0.25)	ND (0.25)
8/14/2017	-	ND (0.25)	ND (0.25)	ND (0.25)	ND (0.25)	ND (0.25)
9/7/2017	-	ND (0.25)	ND (0.25)	ND (0.25)	ND (0.25)	ND (0.25)
9/20/2017	0.35	ND (0.25)	ND (0.25)	0.60	ND (0.25)	0.60
10/3/2017	ND (0.05)	ND (0.25)	ND (0.25)	1.00	ND (0.25)	1.00
10/17/2017	ND (0.05)	ND (0.25)	ND (0.25)	3.80	ND (0.25)	3.80
11/7/2017	-	ND (0.25)	ND (0.25)	0.53	ND (0.25)	0.53
11/14/2017	-	ND (0.25)	ND (0.25)	ND (0.25)	ND (0.25)	ND (0.25)

Note: Light green signifies injection dates, light blue signifies recovery dates.

It is interesting to note that a small amount of chlorine residual was detected in the 9/20 sample (first full day of pumping during recovery). That would indicate that the remaining concentration of oxidizable organic compounds in the vicinity of the well were minimal.

Generation and retention of THMs from intermittent chlorination appears to be inconsequential. Recovery of most injected chlorine during backflush pumping appears to have been an effective practice.

6.4 Microbial and Microbial Surrogates Results

The main concerns expressed by DDW at the beginning of the project were regarding the fate of pathogenic microbes such as *Giardia* and *Cryptosporidium*. Results for those microbes and other primary bio-indicators of potential surface water biocontamination are provided in Table 6-3. Secondary bio-indicators of surface water influence are shown in Table 6-4. Results for detected indicators are plotted in Figure E-3 in Appendix E. An interpretation guide sheet from Biovir is provided at the back of Appendix E. Results for coliform bacteria are shown in Table 6-5 and Figure 6-6.

Table 6-3. Primary Bio-indicators								
Date Sampled	Sample Size (gal filtered)	Giardia (in L cysts)	Cryptosporidium (in L oocysts)	Diatoms (per 100 gal)	Insect/Larvae (per 100 gal)	Plant Debris (per 100 gal)	Other Algae (per 100 gal)	Rotifers (per 100 gal)
6/19/2017	359	0 in 984	0 in 984	0	0	0	0	3
6/27/2017	412	0 in 100	0 in 100	12	1	0	TNTC	11
7/5/2017	251	0 in 100	0 in 100	0	0	0	193	0
7/13/2017	30	0 in 76	0 in 76	0*	0*	0*	0*	0*
7/27/2017	25	0 in 57	0 in 57	0*	0*	0*	150*	0*
8/3/2017	25	0 in 57	0 in 57	0*	0*	0*	0*	0*
8/7/2017	25	0 in 57	0 in 57	0	0	0	TNTC	5
8/14/2017	599	0 in 1889	0 in 1889	0	0	0	TNTC	18
8/21/2017	849	0 in 2835	0 in 2835	0	0	0	TNTC	24
8/29/2017	500	0 in 1514	0 in 1514	0	0	0	TNTC	12
9/7/2017	497	0 in 1503	0 in 1503	0	0	0	TNTC	5
9/11/2017**	30	0 in 76	0 in 76	0	0	0	10	40
9/20/2017	303	0 in 768	0 in 768	0	0	0	0	0
10/3/2017	962	0 in 3263	0 in 3263	0	0	0	0	0
10/17/2017	292	0 in 727	0 in727	0	0	0	0	0
11/14/2017	256	0 in 590	0 in 590	0	0	0	0	0

** per 10 gallons*

*** during first 1.25 hours of backflush pumping after end of injection*

Other Notes:

Light green signifies injection dates, light blue signifies recovery dates.

TNTC is too numerous to count

Table 6-4. Secondary Bio-indicators								
Date Sampled	Amorphous Debris (per 100 gal)	Plant Pollen (per 100 gal)	Crustacea (per 100 gal)	Cillates/Flagellates (per 100 gal)	Minerals (per 100 gal)	Nematodes (per 100 gal)	Amoeba (per 100 gal)	Other Organisms (per 100 gal)
6/19/2017	TNTC	12	77	0	TNTC	0	0	0
6/27/2017	TNTC	1	1	0	TNTC	0	0	0
7/5/2017	TNTC	3	28	0	TNTC	0	0	0
7/13/2017	TNTC	0*	0*	0*	TNTC	0*	0*	0*
7/27/2017	TNTC	0*	0*	0*	TNTC	0*	0*	0*
8/3/2017	0*	0*	0*	0*	0*	0*	0*	0*
8/7/2017	TNTC	0	0	0	TNTC	0	0	0
8/14/2017	TNTC	1	0	0	TNTC	0	0	0
8/21/2017	TNTC	0	0	0	TNTC	0	0	0
8/29/2017	TNTC	0	25	0	TNTC	1	0	0
9/7/2017	TNTC	0	0	0	TNTC	0	0	0
9/11/2017	TNTC	0	20	0	TNTC	0	0	0
9/20/2017	TNTC	0	0	0	TNTC	0	0	0
10/3/2017	TNTC	0	0	0	TNTC	0	0	0
10/17/2017	TNTC	0	0	0	TNTC	0	0	0
11/14/2017	TNTC	0	0	0	TNTC	0	0	0

** per 10 gallons*

Other Notes:

Light green signifies injection dates, light blue signifies recovery dates.

TNTC is too numerous to count

Table 6-5. Total Coliform Bacteria	
Date Sampled	Total Coliform (MPN/100mL)
Groundwater (6/19/2017)	NA
6/19/2017	NA
7/5/2017	110
7/27/2017	11
8/14/2017	23
9/7/2017	7.8
9/20/2017	<1.8
10/3/2017	<1.8
10/17/2017	<1.8
11/7/2017	<1.8
11/14/2017	<1.8

Note: Light green signifies injection dates, light blue signifies recovery dates.

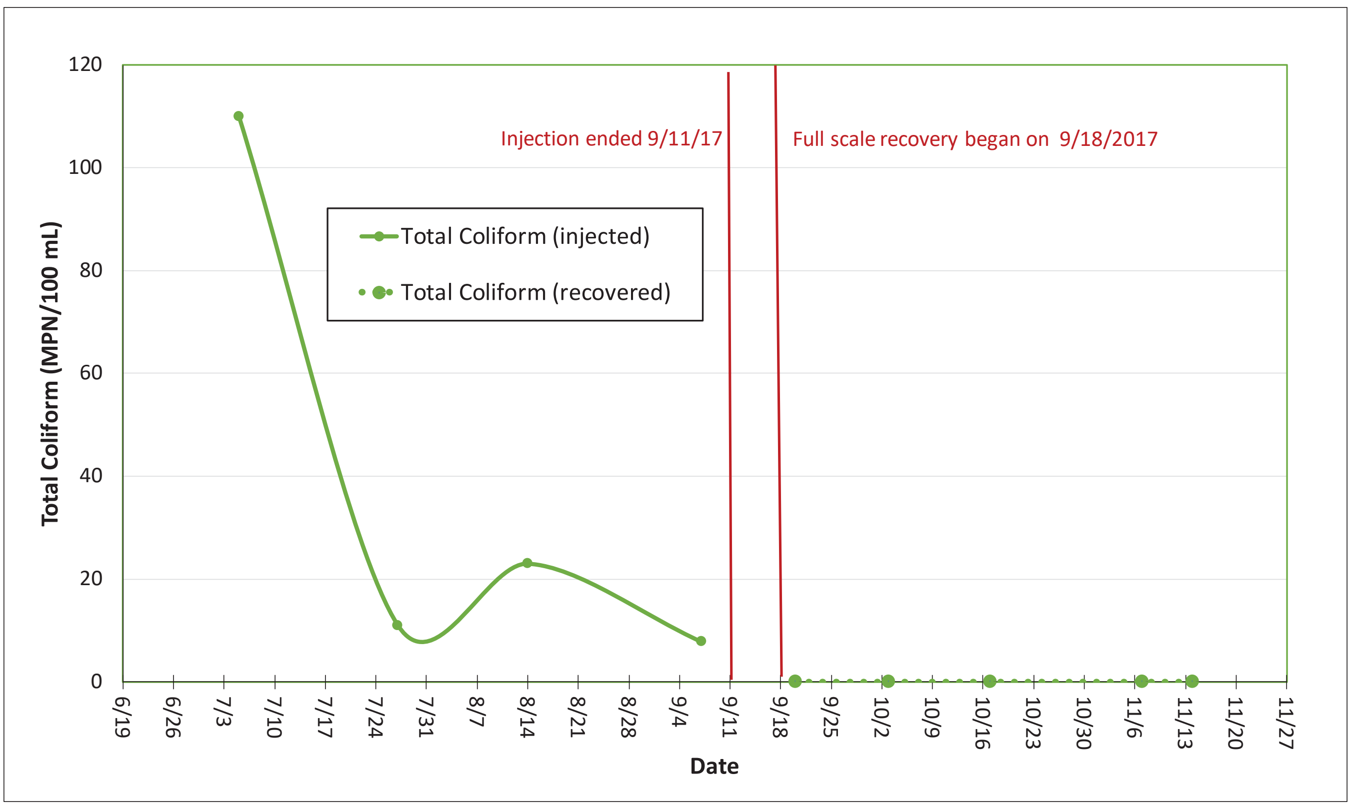


Figure 6-6. Total Coliform

No giardia or cryptosporidium were detected in the injected or recovered water. With the exception of other algae, primary and secondary bio-indicators and coliform bacteria concentrations were relatively low in both of the surface water sources used for injection. The only detected bio-indicators during recovery were in the first 1.25 hours of backflush pumping on 9/11, and those counts were not much different than the injection water. Higher counts would normally be expected during backflush pumping because of likely retention of bioparticulates filtered out by the aquifer materials near the well and subsequent release during backflushing.

No bio-indicators or coliform bacteria were detected in the 9/20 sample (first full day of recovery pumping) or any subsequent samples of recovered water.

The reservoir storage, lined canals, dilution, and ripened sand media filters probably all contributed to making the source waters relatively clean in terms of microbes and bio-indicators. The natural filtration in the aquifer appears to have been highly effective for minimizing transport of bio-indicators.

6.5 Evaluation of Contamination Risks to Closest Domestic Wells

EC was also measured as an intrinsic tracer in domestic well 5S/14E-04H02 approximately 1.2 miles to the west-southwest of the ASR well. As shown in Table 6-6, EC of the domestic well showed no significant change through October 2017 compared to the EC of the injected water. This would imply that injected water likely did not reach the domestic well during the monitoring period.

Table 6-6. Domestic Well EC Results

Date	EC (umohs/cm)
8/11/2017	2970
9/19/2017	2660
10/18/2017	2630

As was discussed in Section 5.1.2, measurement of water level in well A06 approximately 1 mile south of the ASR well showed no effect on piezometric level during development pumping of the ASR well in June. Since well A06 was screened immediately above the Corcoran Clay layer and the active ASR well screen was only below the Corcoran Clay layer, this indicated good hydraulic separation across the Corcoran Clay. Because the domestic wells were also only screened above the Corcoran Clay, this would also indicate that risks to the domestic wells were low.

The lack of migration of coliform bacteria and bio-indicators from the ASR well as discussed above in Section 6.4 also provides good evidence of protection for domestic wells, which would be at far greater groundwater travel times than the water recovered at the ASR well, even if the separation across the Corcoran Clay were not considered.

Section 7

Conclusions

7.1 Operational Conclusions and Considerations for Future Wells

Although the injection capacity was slightly below original expectations, the overall ASR pilot well performance was good. Over the course of the study period, there were modest capacity losses in the well due to gradual plugging and probably also partially due to magnesium carbonate scaling, which could have been prevented. Most of the modest loss would probably be recoverable with rehabilitation style surging and pumping.

Other conclusions and recommendations are as follows:

Injection Flows and Control

1. Injection at roughly one-third to one-half of the normal pumping rate of the well is a reasonable target range.
2. Injection losses seemed to transition from laminar to steeply turbulent (exponent > 2) at higher flows. During planning, anticipate that a steepening well loss exponent versus flow could limit injection capacity.
3. If injection tubes are used for downhole injection and control, the injection tube depths need to be staggered for air release and should be set deeper than the lowest anticipated water level during backflush pumping. Using downhole control valves would eliminate this concern, but would introduce other operational considerations.

Backflushing

1. Having extra well pump capacity for higher flows is helpful for backflushing.
2. Higher frequency backflush pumping (~ every 5 days or shorter) would have been good for the source waters tested, and would have likely maintained higher injection capacities. At higher frequencies, backflush pumping durations could probably be shorter.
3. Ramping up flows and surging are helpful for maximum backflush effectiveness.

Chemical Injection

1. Intermittent chlorination is good practice for preventing bioslime development in the well. Some level of chlorination prior to every backflush would be ideal. If chlorination is performed every few weeks, a 500 mg/L injection concentration carries good residual into the gravel pack and immediate adjacent formation. Targeted dosing rates can be developed based on residual chlorine measured during backflushing. Chlorination should be downstream of filters to allow the filters to ripen (i.e. develop some slime layer to improve capture).
2. Magnesium chloride addition was not necessary to prevent clay dispersion for the pilot ASR well. Low dosage rates could be considered at other sites if a cation balance indicates risks.

Filtration and Solids Removal

1. Kings River water contains relatively elevated levels of fine suspended solids. The use of coagulants at the District diversion might be worth further investigation.

2. #20 sand in agricultural sand media filters running at a low rate provided decent removal of suspended solids from the source waters. Testing with other media to further improve injectate turbidity could be considered. Unripened zeolite media did not improve turbidity as much as ripened #20 sand.

Hydrogeology

1. Having better details on well construction and hydrogeology characteristics by screened zone would be very helpful in future wells, and enable better design of injection and recovery facilities. This could be obtained from drilling and completion logs and from additional downhole tests.
2. Consider using borehole velocity measurements to obtain horizontal groundwater velocity and gradient for future wells to provide better site-specific information on likely injectate lateral movement for both performance and regulatory considerations.

Other

1. Well casing corrosion is accelerated by the high redox surface water and periodic chlorination. Well casing protection such as a removable PVC inner liner should be considered for future wells. For new wells, materials with greater corrosion resistance should be considered. Sacrificial anode protection could also be investigated.
2. Cell phone data uplink and cloud based data storage service was very helpful at a reasonable price. It should be strongly considered for monitoring the performance of future ASR wells.

7.2 Water Quality Conclusions

The major conclusions from the water quality and microbial test results are as follows:

- Water quality used for injection was excellent in terms of minerals and bio-indicators. Water from the Kings River had elevated turbidity, which could cause operational and capacity concerns. Obtaining membrane filter index (MFI) values for source waters could be helpful for future wells planning.
- Based on the use of sulfate and EC as intrinsic parameters, approximately 60% of the actual injected water was recovered. 100% of the quantity injected was recovered consistent with sustainable management of the total groundwater volume in storage.
- Recovered water was of much higher quality than background groundwater for both irrigation and municipal usage. Mobilization of arsenic, chromium, and uranium were not problematic. Some elevated manganese was detected late in recovery, but that was most likely reflective of background groundwater conditions.
- The intermittent chlorination and backflush recovery did not result in disinfection byproduct concentrations of any significance.
- The injected water most likely did not reach the closest domestic well during the injection and recovery operations.
- After only one day of recovery pumping, the recovered water was essentially free of microbes and bio-indicators. This would indicate that the risk of migration of pathogenic microbes was very low for the aquifer tested.

The data from this ASR Pilot Study Results report could be used to develop preliminary guidelines for other ASR wells in the Westlands area. The results indicate not only low risks to beneficial uses of groundwater, but potential substantial benefits to groundwater quality from ASR wells. Results may vary depending upon aquifer conditions in different areas, but the potential benefits to water resource management appear to justify expanded application of ASR in agricultural areas.

7.3 Program Expansion Steps

Westlands could consider the development of a new District-wide ASR program to provide groundwater recharge and improve the sustainability of water resources. Programmatic compliance with regulatory directives and CEQA would simplify the ability of individual well owners to implement ASR.

The first step would be pursuing regulatory approval of a programmatic approach. This will likely require application for new programmatic Westlands-specific discharge requirements from the Regional Board in conjunction with DDW. Development of a model, guidelines, and/or other tools related to pathogen fate and transport in new ASR wells could be an important aspect of obtaining regulatory approval. Safeguards for protection of other water quality parameters could also be developed in conjunction with the Regional Board and DDW.

Either in parallel with the waste discharge application or shortly after requirements are received from the Regional Board, additional study could be considered using existing operational wells. This would provide further testing and refinement of packages that would simplify and standardize well modifications, wellhead equipment, and operations for District well owners. After development of appropriate guidelines and tools and regulatory approval, the program could be opened to well owners District-wide.

In parallel with the above steps, it would also be advisable to begin negotiations with water suppliers to obtain diversions over a time frame appropriate to ASR operations. This could involve reoperation of reservoirs providing water to the District.

This page intentionally left blank.

Section 8

References

Brown and Caldwell (2016). Final Aquifer Storage and Recovery Pilot Study Workplan. Prepared for Westlands Water District, Fresno, California. May 5.

Brown and Caldwell (2016). Letter to Lonnie Waas, Central Valley Regional Water Quality Control Board, re: Summary of Questions and Additional Considerations for Westlands Aquifer. July 7.

Brown and Caldwell (2017). Final Aquifer Storage and Recovery Pilot Study Detailed Operations and Water Quality Monitoring Plan. Prepared for Westlands Water District, Fresno, California. May 23.

Carollo and Luhdorff and Scalmanini, 2015. "Groundwater Quality Assessment Report for the Western Tulare Lake Basin Area". Prepared for the Westlands Water Quality Coalition. February.

DWR, 2006. California's Groundwater - Bulletin 118

Environmental Simulations, 2013. Aquifer Win32. Version 4.06. Reinholds, PA.

Morris, T. (2018). Aquifer Storage Recovery (ASR): How to Identify and Resolve Technical and Other Issues Associated with Successful Groundwater Recharge Through Wells. Presented at Biennial Symposium on Managed Aquifer Recharge, San Diego, California. March 5.

Rorabaugh, M.I., 1953. Graphical and theoretical analysis of step-drawdown test of artesian wells. Transactions, American Society of Civil Engineers, 79(separate 362):1-23.

Schmidt, K. 2009. "Groundwater Conditions Beneath District Owned Lands in the Westlands Water District". Prepared for Westlands Water District, Fresno, California. April.

Theis, Charles V. (1935). "The relation between the lowering of the piezometric surface and the rate and duration of discharge of a well using ground-water storage". Transactions, American Geophysical Union 16: 519–524.

USGS, 2013. "Groundwater-Quality Data in the Western San Joaquin Valley Study Unit, 2010: Results from the California GAMA Program". Data Series 706. Reston, Virginia: 2013

Westlands, 2013. Water Management Plan – 2012. Westlands Water District, Fresno, California. Ed. R. Freeman. April 9.

This page intentionally left blank.

Section 9

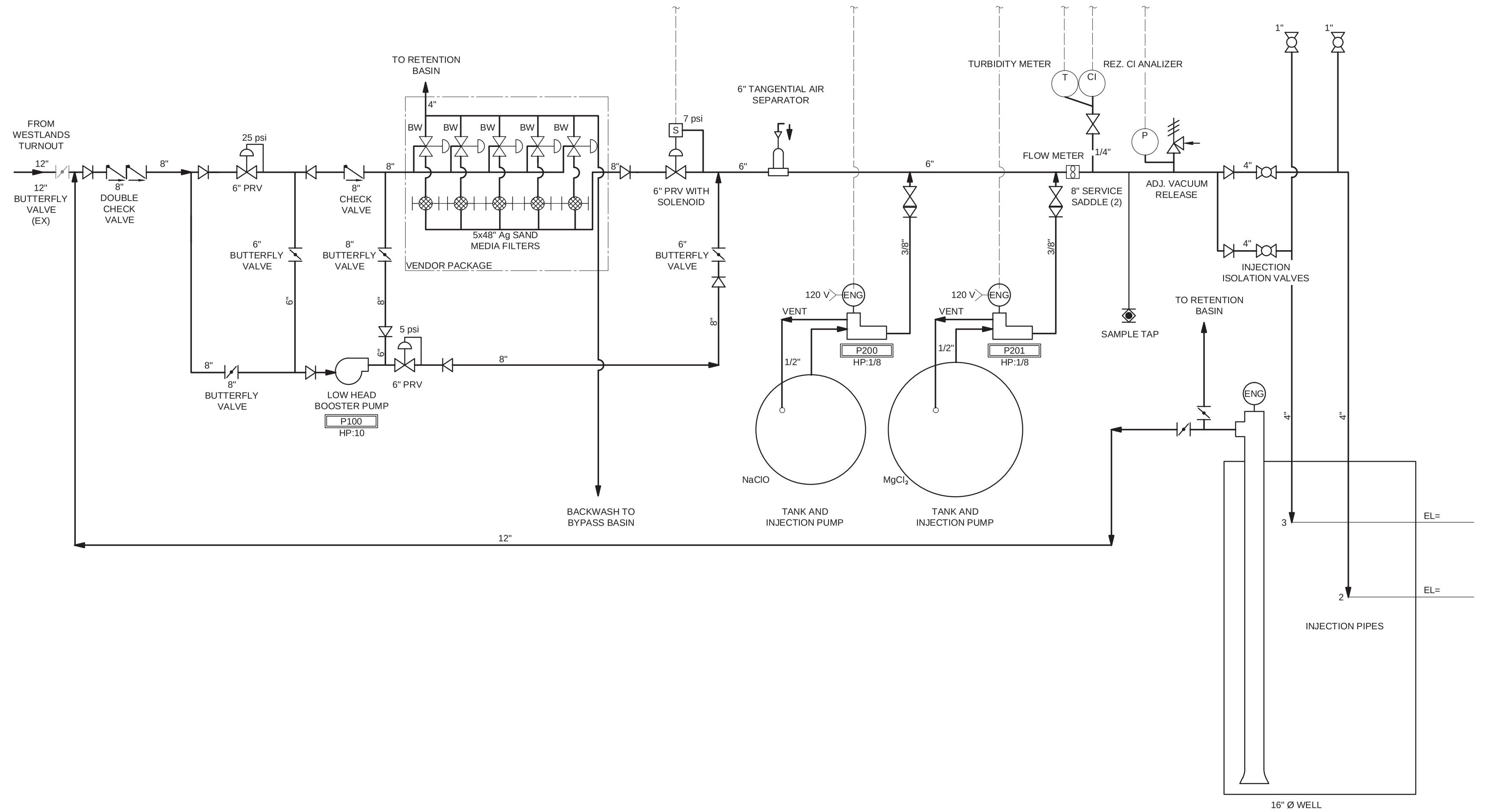
Limitations

This document was prepared solely for Westlands Water District in accordance with professional standards at the time the services were performed and in accordance with the agreement between Westlands Water District and Brown and Caldwell dated December 10, 2015. This document is governed by the specific scope of work authorized by Westlands Water District; it is not intended to be relied upon by any other party except for regulatory authorities contemplated by the scope of work. We have relied on information or instructions provided by Westlands Water District and other parties and, unless otherwise expressly indicated, have made no independent investigation as to the validity, completeness, or accuracy of such information.

This page intentionally left blank.

Appendix A: ASR Pilot Plan Drawings

This page intentionally left blank.



Brown AND Caldwell

DAVIS, CA

WESTLANDS WATER DISTRICT PILOT ASR

REVISIONS

REV	DATE	DESCRIPTION

LINE IS 2 INCHES AT FULL SIZE

DESIGNED: DM
DRAWN: IP
CHECKED:
CHECKED:
APPROVED:

FILENAME D-001.DWG
BC PROJECT NUMBER 148685
CLIENT PROJECT NUMBER
CLIENT PROJECT NUMBER

PROCESS

PRELIMINARY P&ID

DRAWING NUMBER
D1

SHEET NUMBER
1 OF

1 2 3 4 5 6
D C B A

Brown AND Caldwell

DAVIS, CA

WESTLANDS
WATER DISTRICT
PILOT ASR

REVISIONS		
REV	DATE	DESCRIPTION

LINE IS 2 INCHES AT FULL SIZE

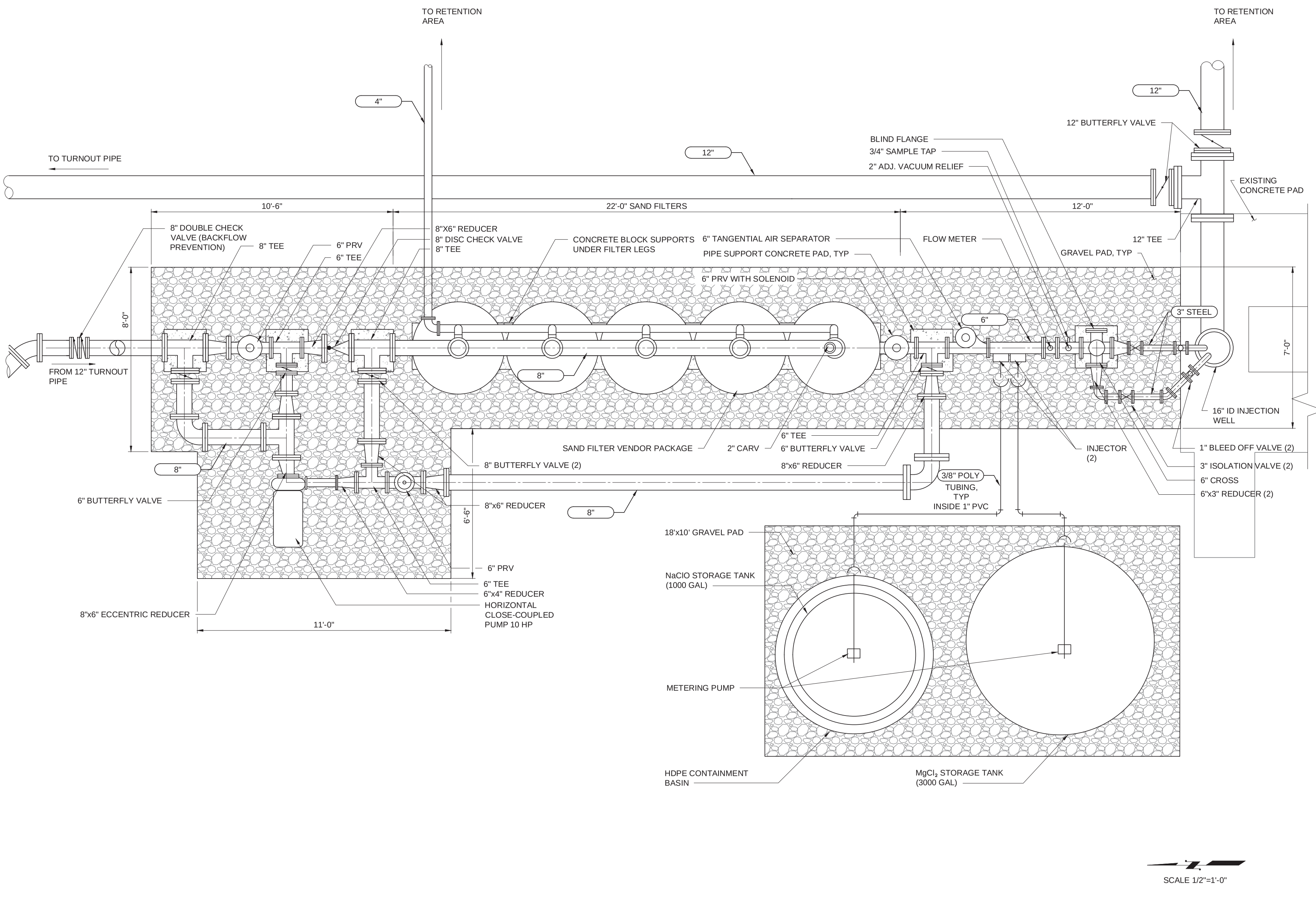
DESIGNED: DM
DRAWN: IP
CHECKED:
CHECKED:
APPROVED:

FILENAME
G-1.DWG
BC PROJECT NUMBER
148685
CLIENT PROJECT NUMBER
CLIENT PROJECT NUMBER

GENERAL

SITE PLAN

DRAWING NUMBER
G1
SHEET NUMBER
---- OF



Brown AND Caldwell

DAVIS, CA

WESTLANDS WATER DISTRICT PILOT ASR

REVISIONS		
REV	DATE	DESCRIPTION

LINE IS 2 INCHES AT FULL SIZE

DESIGNED: DM
DRAWN: IP
CHECKED:
CHECKED:
APPROVED:

FILENAME M-101.DWG
BC PROJECT NUMBER 148685
CLIENT PROJECT NUMBER
CLIENT PROJECT NUMBER

MECHANICAL

SITE LAYOUT

DRAWING NUMBER
M1
SHEET NUMBER
---- OF

Path: \\BCDAV01\PROJECTS\48000\148685 - WESTLANDS ASR PILOT STUDY_CAD\2-SHEETS\M-MECHANICAL FILENAME: M-101.DWG PLOT DATE: 4/22/2016 8:08 AM CAD USER: IRINA POPESCU

Appendix B: Recovery Operation Details

This page intentionally left blank.

Table B-1. ASR Pilot Project Recovery Operational Data

Date	Time	ASR WELL	Flow meter reading	Water Level Reading Detail			EC meter	TDS meter	Notes
				Water Level	Engine RPM	Flow rate (CFS)			
9/19/2017		Off	0.2						Opening Reading
9/20/2017		On							
9/21/2017		On	3.7						L6 Demands
9/22/2017	10:00	On	8.8						Inlet
9/22/2017	15:30	Off	9.86						L6 Demands
9/25/2017	9-9:20 AM	On							Flushing
9/25/2017	9:20AM	On	9.86						Inlet
9/26/2017	10:15 AM	On	15.77	240.35	1650	2.71			inlet
9/26/2017	10:45	On	15.83						Inlet & L7 Demands
9/26/2017	15:30	On							Inlet & PP 7 off overnight
9/27/2017	8:30	On							Inlet & L7 Demands
9/27/2017	10:00	On	20.98	235.71	1650	2.62			Inlet & PP 7 off overnight
9/27/2017	15:30	On							Inlet
9/28/2017	7:00	On							Inlet & Yribarren 24 hour 2 cfs Demand
9/28/2017	8:11	On	25.64	228.8	1650	2.51			L6 Yribarren 24 hour 2 cfs Demand & L7 demands
9/28/2017	10:30	On							L6 Yribarren 24 hour 2 cfs Demand & L7 demands
9/28/2017	15:30	On							L6 Demands
9/29/2017	10:00 AM	Off	30.57	211.38					ASR site ran out of gas Friday morning
10/2/2017	8:30 AM	Off	30.57	191.87					Water Level beforeflushing
10/2/2017	9-9:30	On							Flushing 1100 RPM for 15min 1650 RPM for 15 min
10/2/2017	9:30	On	30.57		1650	3			L6 demand using PP6-2
10/2/2017	10:00	On							
10/2/2017	2:25 PM	On	31.81						Inlet
10/3/2017	7:40	On	35.91	240.41	1650	2.5			Inlet
10/3/2017	2:20 PM	On	37.42			2.6			Inlet
10/4/2017	8:00 AM	On	41.39	238.06	1650	2.6			Inlet
10/4/2017	2:00 PM	On	42.68			2.5			Inlet
10/5/2017	8:20 AM	On	46.63	230.71	1650	2.5			Inlet
10/6/2017	8:00 AM	On	51.55		1650	2.5			L6 Demand
10/6/2017	9:00 AM	On	51.74	231.54	1675	2.6			Inlet
10/6/2017	2:30 PM	Off	52.82						Inlet and turned off at 2:30 PM
10/6/2017	2:40 PM	Off	52.82	221.92					Pump was off for 10 minutes before Water Level
10/9/2017	10:00 AM	off	52.82	193.33					
10/9/2017	10:20-10:40	On							Flushed 10 min at 1100 RPM & 10 min at 1650RPM
10/9/2017	11:30 AM	On	52.89		1650	2.9			
10/9/2017	3:15 PM	On	53.61	241	1650	2.8			

Date	Time	ASR WELL	Flow meter reading	Water Level Reading Detail			EC meter	TDS meter	Notes
				Water Level	Engine RPM	Flow rate (CFS)			
10/10/2017	10:30 AM	on	57.93		1650	2.8	0967µS	650 TDS	reading taken on two difference meters
10/10/2017	2:20 PM	on	59.23		1650	2.7			
10/11/2017	9:10 AM	on	63.44	235.6	1650	2.7			
10/11/2017	2:00 AM	on	64.55		1650	2.6			
10/12/2017	8:58 AM	on	68.65	228.3	1650	2.59			L6 5 AF
10/12/2017	9:08 AM	on					1.001		
10/12/2017	2:00 PM	on	69.72	225.78	1650	2.5			inlet
10/13/2017	5:06 AM	off	72.84						turn off at ~5 AM reasoning is unknown
10/13/2017	8:00 AM	off	72.84	210.38					
10/16/2017	2:00 PM	on	73.06		1650	3			
10/17/2017	8:20 AM	on	77.84	241.5	1650	2.8			
10/17/2017	2:00 AM	on	78.78	236.27	1650	2.7			
10/18/2017	9:10 AM	on	83.09	236.6	1650	2.7		780ppm	factory settings on the TDS meter confirmed
10/18/2017	2:00 PM	on	84.14	233.59	1650	2.7		770ppm	
10/19/2017	8:00 AM	on	88.16						PP7 on to meet L7 demands
10/19/2017	9:00 AM	on	88.39	231.78	1650	2.6		750ppm	
10/19/2017	2:00 PM	on	89.54	227.02	1650	2.5		740ppm	
10/20/2017	4:00 AM	on	93.33						PP7 turn off due to issue
10/20/2017	8:00 AM	off	93.33						ASR well motor was surging and died
10/20/2017	8:50 AM	off	93.33	216.92					
10/20/2017	9:30 AM	off	93.33	215.23					
10/20/2017	10:00 AM	off	93.33						PP7 back on
10/20/2017	10:30 AM	on	93.33	211.29					Zim turned the ASR site on for 15min but motor was still having issues
10/20/2017	10:45 AM	off	93.33						
10/20/2017	3:30 PM	off	93.33						
10/23/2017		off	93.33						
10/24/2017	12:00 AM	on	93.33	192.43					Flush pumping 1000 rpm at 15min &1650rpm at 15 min
10/24/2017	12:30 PM	on	93.33	237.8					
10/24/2017	12:35 PM	on	93.33		1650	2.9		1270ppm	
10/24/2017	2:45 AM	on	93.93	236.7	1650	2.8		1290ppm	
10/25/2017	8:02 AM	on	97.96	231.2	1650	2.7		820ppm	
10/26/2017	7:02 AM	on	103.09		1650				PP7-1 on
10/26/2017	8:00 AM	on	103.15	230.92	1650	2.6		830ppm	
10/26/2017	2:45 PM	on	104.54		1650	2.6			
10/27/2017	8:45 AM	on	108.43	224.75	1650	2.5		840ppm	
10/27/2017	3:40 PM	on	109.8	223.78	1650	2.5		830ppm	
10/30/2017	7:45 AM	off	109.8	197.95					static water level from the weekend

Date	Time	ASR WELL	Flow meter reading	Water Level Reading Detail			EC meter	TDS meter	Notes
				Water Level	Engine RPM	Flow rate (CFS)			
10/30/2017	8:00 AM	on	109.8		1650	1.89			
	1:00 PM								PP7-1 on
10/30/2017	3:30 PM	on	110.8	496.91	1650	0.87			
	4:00 PM	off	110.8						PP7-1 OFF
10/31/2017	8:45 AM	off	110.8	196.91					static water level
10/31/2017	9:35 AM	on	110.8	200.56	1650	2.3			
10/31/2017	2:44 AM	on	111.88	197.06	1650	2.24			
10/31/2017	3:45 PM	on	112.07						PP7-1 off
11/1/2017	8:01 AM	on	114.96					890	
11/1/2017	8:05 AM	on	114.96	195.97	1650	2.18	702	891 ppm	shed readings
11/1/2017	2:00 PM	on	116	193.33	1650	2.12		890	
11/2/2017	8:30 AM	on	123.36	189.4	1650	2.05		880	
11/2/2017	2:50 PM	on	124.46	189.18	1650	2.05	1030	900	
11/2/2017	3:08 PM	off	124.46	220.89					well off at 2:50 PM
11/6/2017	8:10 AM	off	124.46	191.24					Flushed 10min at 1100RPM & 10 min at 1650RPM
11/6/2017	9:10 AM	on	124.46	238.09	1650	3			
11/7/2017	7:50 AM	on	129	232.47	1650	2.75	1550	930	
11/7/2017	2:05 AM	on	131.17	231.44	1650	2.67		900	
11/8/2017	8:10 AM	on	135.3	225.23	1650	2.64		920	
11/8/2017	2:50 AM	on	136.57	229.16	1650	2.61	1540	940	
11/9/2017	7:30 AM	on	141.95	227.89	1650	2.6	1810	930	turbidity reading not showing
11/9/2017	4:00 PM	on	141.94	223.31	1650	2.56		940	Off over the weekend
11/13/2017	8:20 AM	off	141.95	194.49					30 minutes of flush pumping 15min 1100 rpm and 15min 1650rpm
11/13/2017	9:00 AM	on	141.95	235.46	1650	2.99		1600	turbidity reading not showing
11/13/2017	2:00 PM	on	143.09	234.12	1650	2.85		1310	
11/14/2017	7:50 AM	on	147.27	231.95	1650	2.76		980	turbidity reading not showing
11/14/2017	3:10 PM	on	148.9	228.18	1650	2.7		990	
11/15/2017	8:30 AM	on	152.74	228.16	1650	2.67		1000	
11/15/2017	2:00 PM	on	153.97	225.78	1650	2.63		1030	
11/16/2017	8:20 AM	on	157.96	225.19	1650	2.63		1030	
11/16/2017	2:15 PM	on	159.23	223.14	1650	2.57		1030	
11/17/2017	8:00 AM	on	163	222	1650	2.55		1090	
11/17/2017	2:30 PM	on	164.37	221.17	1650	2.53		1090	
11/20/2017	8:30 AM	off	164.37	193.76	1650				Flushed 10min at 1100RPM & 10 min at 1650RPM
11/20/2017	9:00 AM	on	164.37		1650	2.88			
11/20/2017	2:45 PM	on	165.75	224.83	1650	2.69		1150	

Date	Time	ASR WELL	Flow meter reading	Water Level Reading Detail			EC meter	TDS meter	Notes
				Water Level	Engine RPM	Flow rate (CFS)			
11/21/2017	8:50 AM	on	169.68	223.51	1650	2.61		1080	
11/21/2017	3:10 AM	on	171.05	222.79	1650	2.6		1090	
11/22/2017	not avail.								
11/22/2017	not avail.								
Averages				225	1650	2.58	1106	1026	

ASR pilot ended 11/22. Step-drawdown test scheduled for the following week.

Appendix C: Operations Results Data

This page intentionally left blank.

Table C-1. Changes in Normalized 20 Minute Pumping Specific Capacity

Date, Phase	Speed	Flow	DTW	Sp. Capacity	Notes
	(RPM)	(gpm)	(ft)	(gpm/ft)	
Before Development Surging					
6/12/2017	static		93.71		
	1355	1002	188	10.63	
	1505	1202	214	9.99	
	1670	1385	241	9.40	
	1800	1550	263	9.16	
After 1 Day of Development					
6/13/2017	static		93.65		
6/13/2017	1345	1006	180	11.65	first time
6/13/2017	1505	1221	207	10.77	first time
6/13/2017	1505	1492	207	13.16	third time, many surges
6/13/2017	1640	1714	231	12.48	third time, many surges
6/13/2017	1800	1937	258	11.79	third time, many surges
After 2 Days Development					
	static		93.2		
6/14/2017	1800	1989	256	12.22	
6/14/2017	1750	1900	249	12.20	
Step Test after Development					
	static		97.5		
6/15/2017	1020	600	129	19.05	
6/15/2017	1210	1000	162.1	15.48	adjusted level to account for drawdown after 20 min. for the 600 gpm
6/15/2017	1435	1400	201	13.53	adjusted level to account for drawdown after 20 min. for earlier steps
6/15/2017	1700	1800	245.7	12.15	adjusted level to account for drawdown after 20 min. for earlier steps
Injection Phase					
6/20/17	static		93.5		Based on recovery from injection on 6/13 (email 6/15) and field notes for 6/19
6/20/17	1230	1000	164	14.18	second time, lots of surges
6/20/17	1505	1503	212.5	12.63	second time, lots of surges
6/20/17	1800	1952	263	11.52	second time, lots of surges
6/27/17	static		91.5		Est. for 15 min. after injection stopped from Troll data, Zim Logs and 7/13 rate of recovery
6/27/17	1280	1000	179.8	11.33	first time
6/27/17	1280	1111	171.4	13.90	second time, also surges
6/27/17	1800	1946	268.7	10.98	first time

Date, Phase	Speed	Flow	DTW	Sp. Capacity	Notes
	(RPM)	(gpm)	(ft)	(gpm/ft)	
7/5/2017	static		87		after 15 min.
7/5/2017	1260	1060	167	13.25	second time
7/5/2017	1550	1525	222	11.30	second time
7/5/2017	1800	1885	269	10.36	
7/20/2017	static		85.05		after 15 min.
7/20/2017	1240	980	164	12.41	first time
7/20/2017	1535	1405	216	10.73	
7/20/2017	1800	1870	264	10.45	Operator mentioned some plugging "broke loose" after taking it up to 1800 RPM
8/1/2017	static		81.2		after 15 min.
8/1/2017	1220	815	148.8	12.06	first time
8/1/2017	1430	1347	204	10.97	second time
8/1/2017	1800	1890	274	9.80	second time
8/9/2017	static		82.4		after 15 min.
8/9/2017	1280	1010	166	12.08	first time
8/9/2017	1570	1540	231	10.36	second time
8/9/2017	1800	1880	274	9.81	second time
8/16/2017	static		82		Est. from SCADA
8/16/2017	1270	1056	173	11.60	second time
8/16/2017	1600	1540	229.6	10.43	second time
8/16/2017	1800	1850	271.3	9.77	second time
8/31/2017	static		80		after 15 min.
8/31/2017	1235	997	166	11.59	first time
8/31/2017	1580	1550	233	10.13	second time, after one surge
8/31/2017	1800	1850	272	9.64	first time
Step Test at End of Recovery Pumping					
11/29/2017	static		93.82		
11/29/2017	1025	600	131.75	15.82	
11/29/2017	1405	1000	172.5	12.71	adjusted level to account for drawdown after 20 min. for the 600 gpm
11/29/2017	1740	1400	217.6	11.31	adjusted level to account for drawdown after 20 min. for earlier steps

Example Backflush Logs

This page intentionally left blank.

ZIM INDUSTRIES, INC.

4545 Lincoln • Fresno 93725
Ph: (559) 834-1551 • FAX: (559) 834-5156
E-mail: zim@zimindustries.com • ww.zimindustries.com

WELL DEVELOPMENT LOG

DATE: 7/5/2017
S.W.L.: 87.00
PUMP OPERATOR: Horton

WELL LOCATION: [illegible]
OWNER OR JOB NAME: [illegible]
JOB NUMBER: 17004

TIME	R.P.M.	G.P.M.	P.W.L.	SAND	COMMENTS
9:00	—	—	55.44	—	
9:13	—	—	—	—	WATER TURNED OFF GOING DOWN
—	—	—	—	—	WELL
9:18	—	—	85.82	—	RECOVERY
9:23	—	—	86.55	—	RECOVERY
9:28	START	PUMP	87.00	WATER	
9:33	1260	1010	170.67	.4 42.267 PPM	WATER CLEAR THEN BROWN
9:38	1260	1005	171.18	1.18 124.65 PPM	WATER BROWN
9:43	1260	1022	171.93	.42 44.381 PPM	WATER CLOUDY
9:48	1550	1523	227.90	.31 32.757 PPM	WATER BROWN
9:53	1550	1518	229.30	2. 211.338 PPM	WATER LIGHT BROWN
9:58	1550	1512	229.90	.71 75.025 PPM	WATER CLOUDY
10:03	1800	1887	276.56	.81 85.592 PPM	WATER BROWN
10:08	1800	1872	276.10	2.7 [illegible] PPM	WATER LIGHT BROWN
10:13	1800	1849	276.36	1.15 [illegible] PPM	WATER LIGHT BROWN
10:18	1800	1851	276.70	.33 [illegible] PPM	WATER LIGHT BROWN
10:23	—	—	103.71	—	RECOVERY
10:28	—	—	99.35	—	RECOVERY
10:33	—	—	97.07	—	RECOVERY / WATER STILL GOING DOWN WELL
10:48	—	—	70.00	—	
12:08	—	—	—	—	WATER SHUT OFF GOING TO WELL
12:15	START	PUMP	89.42	WATER	
12:20	1260	1076	166.22	.4 42.267 PPM	WATER CLOUDY THEN BROWN
12:25	1260	1038	167.43	.67 70.798 PPM	WATER BROWN
12:30	1260	1057	167.94	.16 16.907 PPM	WATER LIGHT BROWN
12:35	1550	1534	220.20	.39 41.211 PPM	WATER LIGHT BROWN
12:40	1550	1524	221.67	1.3 137.370 PPM	WATER LIGHT BROWN
12:45	1550	1525	222.30	.36 38.040 PPM	WATER LIGHT BROWN
12:50	1900	1919	266.24	.47 47.661 PPM	WATER LIGHT BROWN

TOTAL DEVELOPMENT HOURS ON THIS PAGE ________

ZIM INDUSTRIES, INC.

4545 Lincoln • Fresno 93725
Ph: (559) 834-1551 • FAX: (559) 834-5156
E-mail: zim@zimindustries.com • www.zimindustries.com

WELL DEVELOPMENT LOG

DATE: 7/5/2017
S.W.L.: 87.00
PUMP OPERATOR: Horton

WELL LOCATION: MENDOTA
OWNER OR JOB NAME: WESTLAND WAT.
JOB NUMBER: 17004

TIME	R.P.M.	G.P.M.	P.W.L.	SAND	COMMENTS
12 55	1800	1905	267.55	1.2 126.50 PPM	WATER IS LIGHT BROWN
1 00	1800	1899	268.35	.61 64.458 PPM	
1 05	1800	1891	268.76	.43 45.437 PPM	
1 10	1800	1885	269.05	.39 41.211	WATER HAS A BROWN TINT TO IT.
1:15	–	–	105.01	–	RECOVERY
1 20	–	–	100.96	–	START PUMPING WATER DOWN WELL.
1 25	–	–	76.00	–	
1:30	–	–	71.61	–	
1:35	–	–	69.94	–	
1:40	–	–	69.00	–	466 GPM
1 45	–	–	68.07	–	
1 55	–	–	66.59	–	
2 05	–	–	65.85	–	
2 15	–	–	65.34	–	468 GPM

TOTAL DEVELOPMENT HOURS ON THIS PAGE 4 3/4

ZIM INDUSTRIES, INC.

4545 Lincoln • Fresno 93725
Ph: (559) 834-1551 • FAX: (559) 834-5156
E-mail: zim@zimindustries.com • www.zimindustries.com

WELL DEVELOPMENT LOG

DATE: 8/31/2017
S.W.L.: 80.31
PUMP OPERATOR: HORTON

WELL LOCATION: MENDOTA
OWNER OR JOB NAME: WESTLAND
JOB NUMBER: 17004

TIME	R.P.M.	G.P.M.	P.W.L.	SAND	COMMENTS
9:02	–	–	28.90	–	510 GPM
9:12	–	–	28.80	–	517 GPM
9:22	–	–	28.65	–	512 GPM
9:32	–	–	28.72	–	510 GPM
9:52	–	–	28.72	–	521 GPM
10:12	–	–	28.75	–	515 GPM
10:20	–	–	28.70	–	515 GPM
10:28	–	–	34.61	–	450 GPM
10:30	–	–	35.73	–	
10:32	–	–	35.87	–	447 GPM
10:35	–	–	35.80	–	454 GPM
10:40	–	–	35.76	–	
10:44	–	–	47.70	–	
10:46	–	–	48.69	–	338 GPM
10:50	–	–	48.75	–	338 GPM
10:53	–	–	48.74	–	338 GPM
10:56	–	–	74.29	–	WATER OFF
11:01	–	–	79.43	–	
11:05	–	–	79.86	–	
11:10	–	–	80.0	–	
11:15	–	–	80.15	–	
11:20	START	PUMP	80.31	WATER	
11:25	1235	1009	164.95	.91 96.159 PPM	WATER CLOUDY THEN BROWN
11:30	1235	1003	165.10	5.7 602.314 PPM	WATER BROWN
11:35	1235	996	165.59	3.2 338.141 PPM	WATER LIGHT BROWN
11:40	1235	993	165.90	2.4 253.606 PPM	WATER LIGHT BROWN
11:45	1235	997	166.11	1.6 169.070 PPM	WATER LIGHT BROWN
11:50	1235	992	166.40	1.3 137.370 PPM	WATER LIGHT BROWN
11:55	1560	1500	225.47	26 274.740 PPM	WATER BROWN

TOTAL DEVELOPMENT HOURS ON THIS PAGE ________.

ZIM INDUSTRIES, INC.

4545 Lincoln • Fresno 93725
Ph: (559) 834-1551 • FAX: (559) 834-5156
E-mail: zim@zimindustries.com • ww.zimindustries.com

WELL DEVELOPMENT LOG

DATE: 8/31/2017
S.W.L.: 80.31
PUMP OPERATOR: HOLTON

WELL LOCATION: MENDOTA
OWNER OR JOB NAME: WESTLAND
JOB NUMBER: 17004

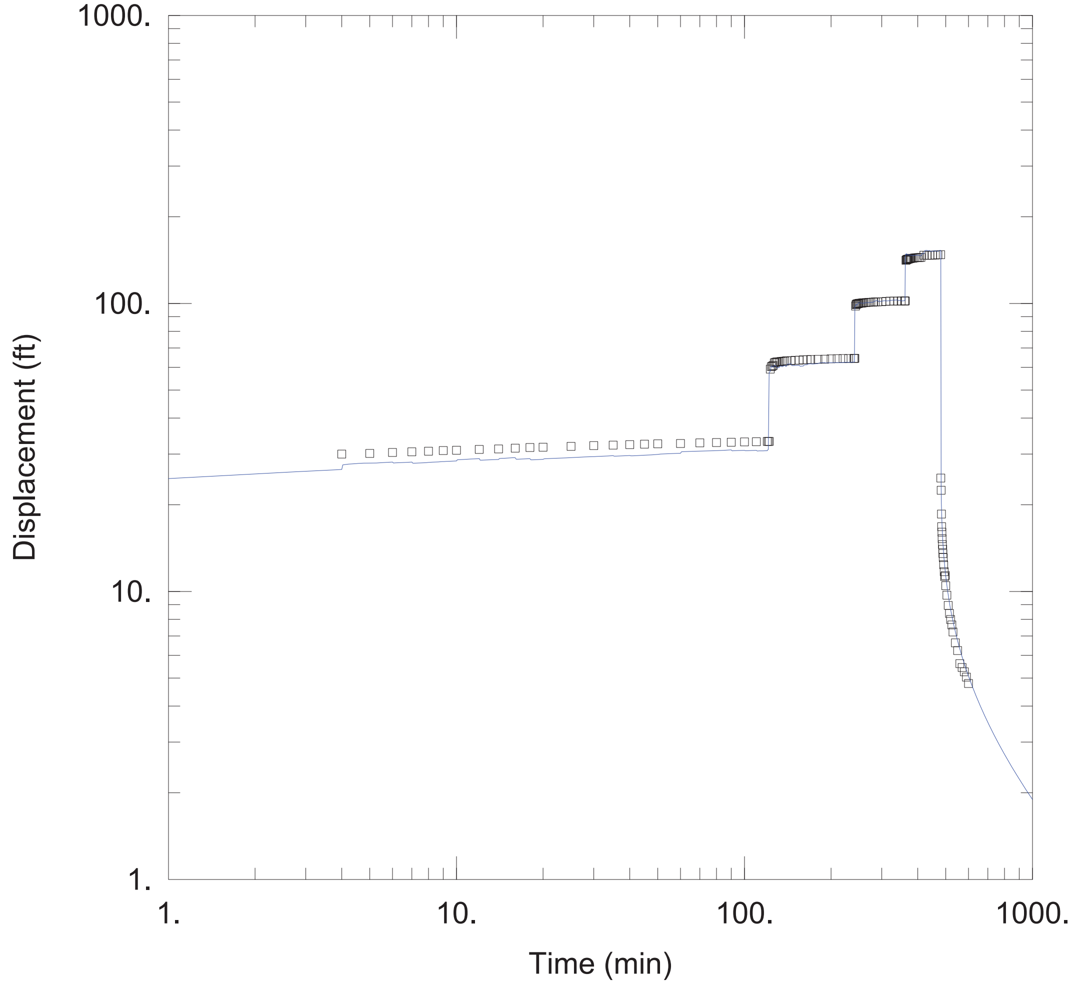
TIME	R.P.M.	G.P.M.	P.W.L.	SAND	COMMENTS
12:00	1580	1525	230.63	7.7 813.653 PPM	WATER BROWN
12:05	1580	1515	231.37	4.2 443.810 PPM	WATER LIGHT BROWN
12:10	1580	1527	231.78	2. 211.338 PPM	WATER LIGHT BROWN
12:15	1580	1516	232.10	1.8 190.204 PPM	WATER LIGHT BROWN
12:20	1800	1854	271.67	1.95 206.05 PPM	WATER BROWN
12:25	1800	1855	272.27	4.1 433.243 PPM	WATER LIGHT BROWN
12:30	1800	1850	272.45	2.3 243.035 PPM	WATER LIGHT BROWN
12:35	1800	1845	272.71	1.95 206.055 PPM	WATER LIGHT BROWN
–	–	–	–	–	SURGE 1 TIME
12:46	1580	1561	231.49	1.5 158.503 PPM	WATER LIGHT BROWN
12:51	1580	1551	232.51	1.95 206.055 PPM	WATER LIGHT BROWN
12:56	1580	1550	233.39	1.1 116.236 PPM	WATER CLOUDY
1:01	–	–	101.08	–	RECOVERY
1:06	–	–	96.08	–	RECOVERY
1:11	–	–	95.0	–	RECOVERY
1:16	–	–	94.01		RECOVERY

TOTAL DEVELOPMENT HOURS ON THIS PAGE 1¼

Appendix D: Aquifer Properties Fitted to Step-Drawdown Tests

This page intentionally left blank.

Fitting Aquifer Parameters to Step-Drawdown Test Results after Initial Well Development



WELL TEST ANALYSIS

Data Set: C:\Users\ktidwell\Desktop\Step 1.aqt
Date: 03/07/18 Time: 13:29:32

PROJECT INFORMATION

Company: BC
Client: Westlands
Project: 148685
Location: Mendota
Test Well: D04
Test Date: 06/15/2017

AQUIFER DATA

Saturated Thickness: 585.4 ft Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
New Well	0	0

Observation Wells

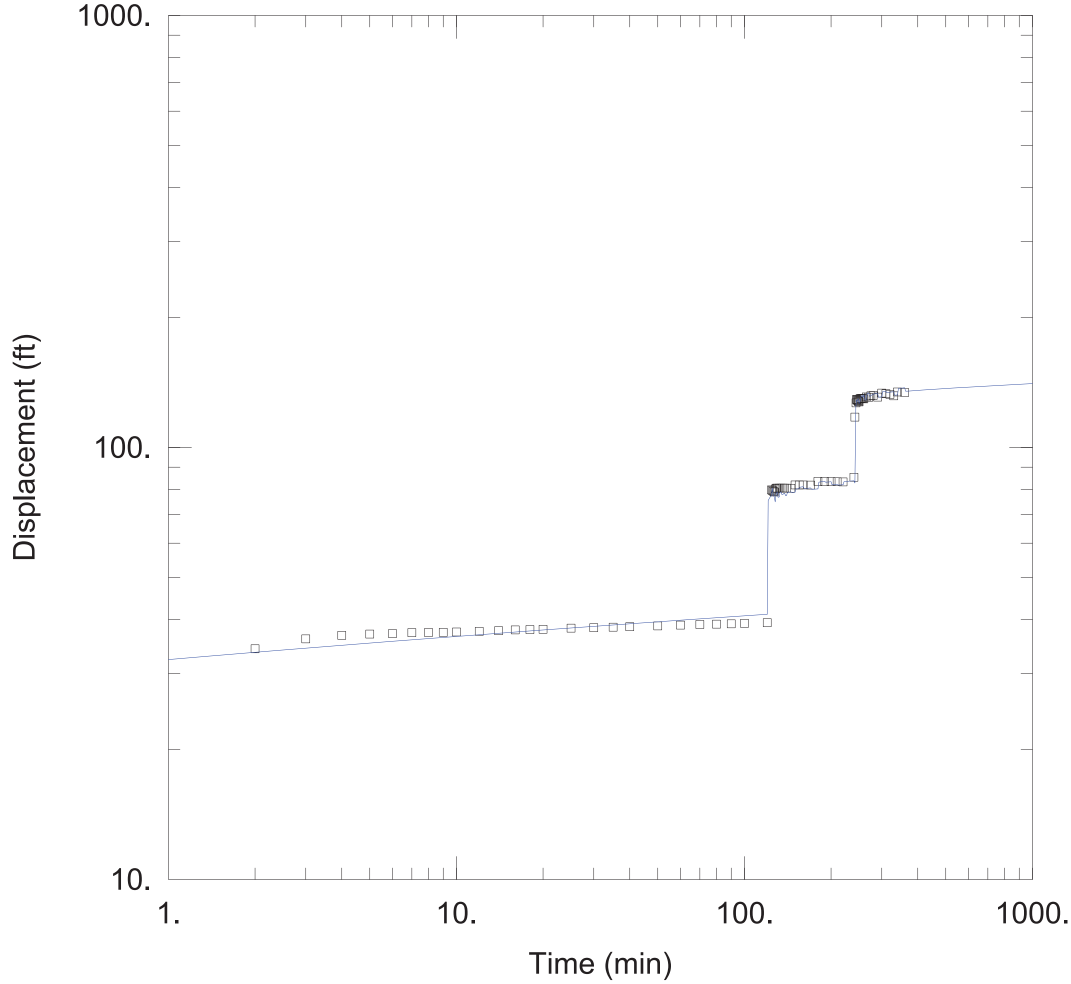
Well Name	X (ft)	Y (ft)
□ New Well	0	0

SOLUTION

Aquifer Model: Confined Solution Method: Theis (Step Test)

T = 6800. ft^2/day
S = 0.0001
Sw = 0.
C = 0.0014 min^2/ft^5
P = 2.

Fitting Aquifer Parameters to Step-Drawdown Test Results after Final Recovery Pumping



WELL TEST ANALYSIS

Data Set: C:\Users\ktidwell\Desktop\Step Test West.aqt
Date: 03/07/18 Time: 13:30:02

PROJECT INFORMATION

Company: BC
Client: Westlands
Project: 148685
Location: Mendota
Test Well: D04
Test Date: 11/29/2017

AQUIFER DATA

Saturated Thickness: 585.4 ft Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
New Well	0	0

Observation Wells

Well Name	X (ft)	Y (ft)
□ New Well	0	0

SOLUTION

Aquifer Model: Confined Solution Method: Theis (Step Test)

T = 5000. ft^2/day S = 0.0001
Sw = 0. C = 0.0018 min^2/ft^5
P = 2.

Appendix E: Additional Water Quality Results

This page intentionally left blank.

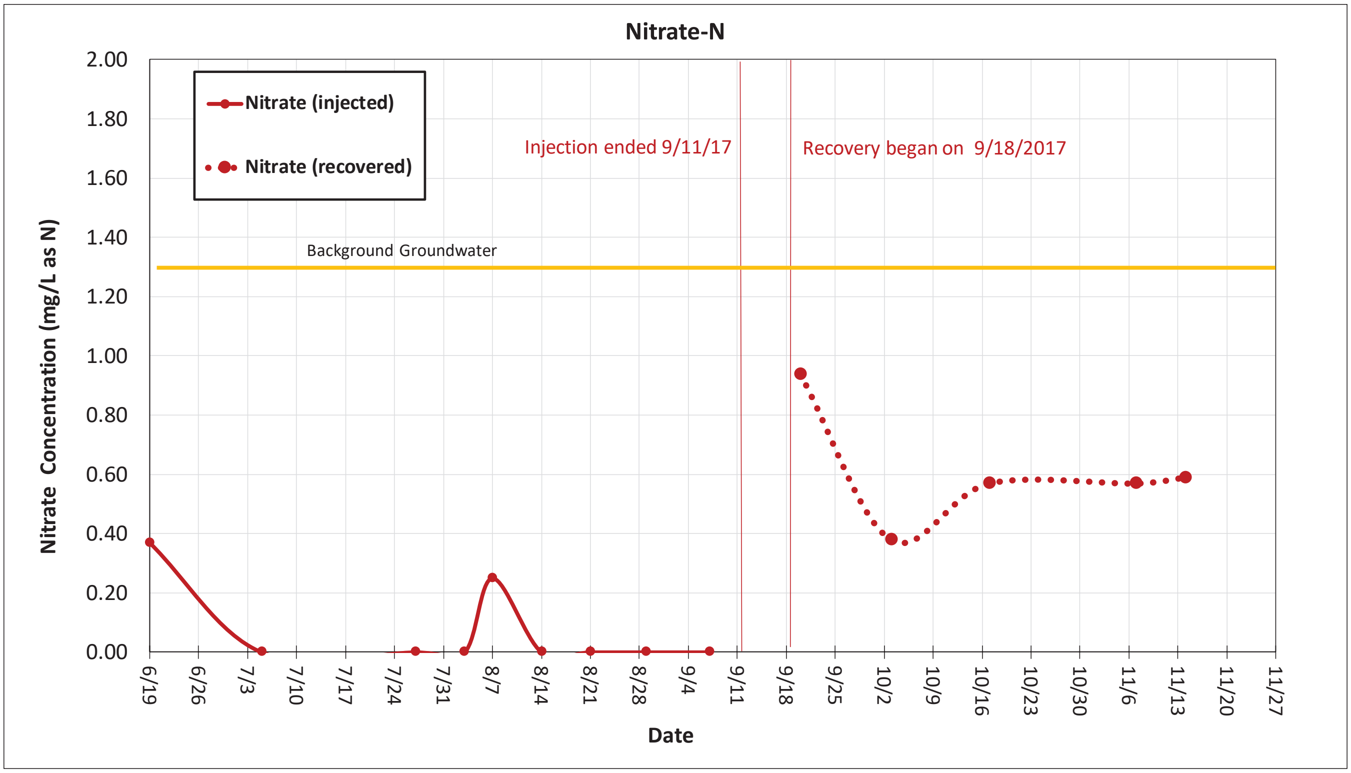


Figure E-1. Nitrate-N Concentrations During Injection and Recovery

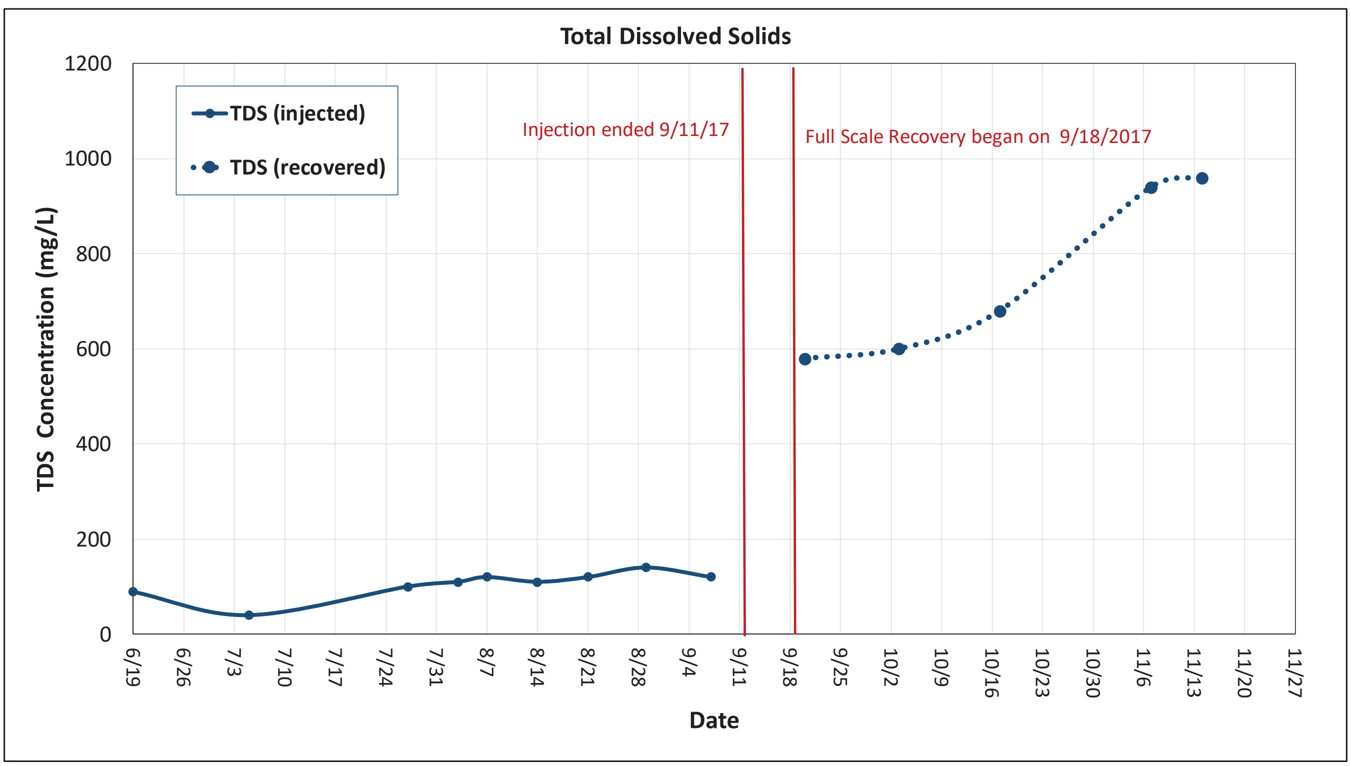


Figure E-2. Total Dissolved Solids Concentration During Injection and Recovery

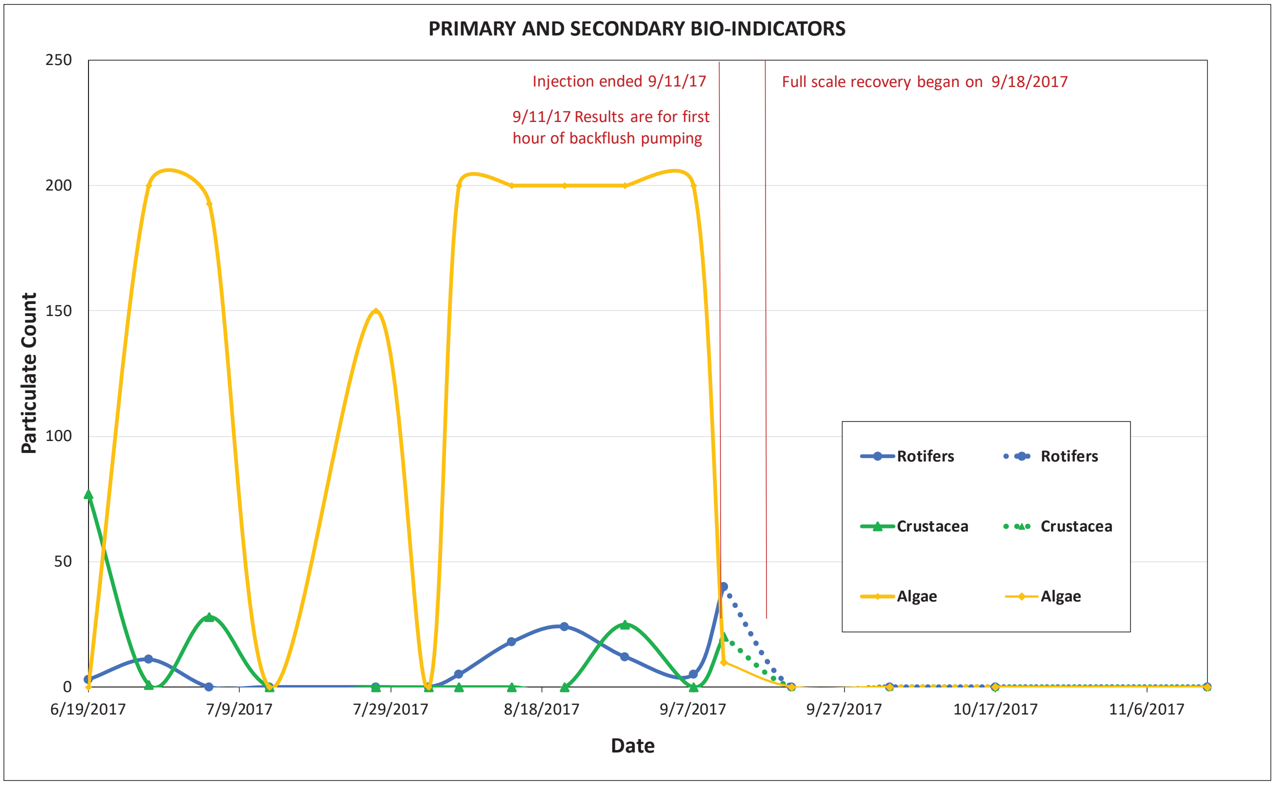


Figure E-3. Primary and Secondary Bio-Indicators

Table E-1. Stable Isotope Results - Westlands ASR: Isotopes

Date Sampled	δD of Water (‰)*	$\delta^{18}O$ (‰)*
6/19/2017	-85.20	-11.66
7/5/2017	-102.90	-14.18
7/27/2017	-81.10	-11.02
8/3/2017	-	-
8/7/2017	-	-
8/14/2017	-78.20	-10.66
8/21/2017	-	-
8/29/2017	-	-
9/7/2017	-77.80	-10.68
9/20/2017	-74.20	-9.98
10/3/2017	-73.10	-9.73
10/17/2017	-73.20	-9.86
11/7/2017	-72.90	-9.75
11/14/2017	-72.80	-9.71

**Results in Per Mil (‰) Relative to VSMOW*
Note: Light green signifies injection dates, light blue signifies recovery dates.

Table E-2. Minor and Trace Constituents									
Date Sampled	Arsenic (µg/L)	Boron (mg/L)	Bromide (mg/L)	Hex. Chrome (ug/L)	Iron (mg/L)	Manganese (mg/L)	Silica (mg/L)	TOC (mg/L)	Uranium (µg/L)
Groundwater (6/19/2017)	NA	2.10	0.530	NA	ND (0.015)	0.045	50	NA	11
6/19/2017	2.2	ND (0.05)	0.043		0.45	ND (0.005)	12	2.9	ND (0.5)
7/5/2017	ND (1.0)	ND (0.05)	-		0.036	ND (0.005)	8.0	1.9	ND (0.5)
7/27/2017	ND (1.0)	ND (0.05)	-		0.036	ND (0.005)	6.1	2.5	ND (0.5)
8/3/2017	-	ND (0.05)	-		-	-	-	-	-
8/7/2017	-	ND (0.05)	-		-	-	-	-	-
8/14/2017	ND (1.0)	ND (0.05)	-		0.048	ND (0.005)	9.5	2.6	ND (0.5)
8/21/2017	ND (1.0)	ND (0.05)	-		-	-	-	-	-
8/29/2017	ND (1.0)	ND (0.05)	-		-	-	-	-	-
9/7/2017	ND (1.0)	ND (0.05)	-		ND (0.015)	ND (0.005)	11	2.4	ND (0.5)
Injection Avg.	0.74	ND (0.05)	0.43	NA	0.1	ND (0.005)	9.3	2.46	ND (0.5)
9/20/2017	ND (1.0)	0.57	-		ND (0.015)	ND (0.005)	23	1.5	4.7
10/3/2017	2.3	0.60	-		ND (0.015)	ND (0.005)	25	1.3	3.5
10/17/2017	ND (1.0)	0.76	0.68		ND (0.015)	0.023	30	1.1	4.0
11/7/2017	2.3	0.92	-	0.19	ND (0.015)	0.21	-	1.2	7.3
11/14/2017	2.2	0.96	-	0.18	ND (0.015)	0.26	-	ND (0.10)	7.5
Recovery Avg.	1.56	0.76	0.68	0.19	ND (0.015)	0.10	26	1.03	5.4

Note: Metals reported as dissolved concentrations.
Note: Light green signifies injection dates, light blue signifies recovery dates.

MPA Interpretation Guide

BioVir LABORATORIES ®
IEH-BioVir Laboratories
EPA ID# 01401, CA-ELAP #179
685 Stone Road, Unit 6 • Benicia, CA 94510 • (707) 747-5906 • 1-800-GIARDIA • FAX (707) 747-1751 • WEB: www.biovir.com

LAB Sample ID: 171421-001

Page 2 of 2

MICROSCOPIC PARTICULATE ANALYSIS RISK FACTORS
(Consensus Method for Determining Groundw aters Under the Direct Influence of Surface Water Using Microscopic Particulate Analysis (MPA) - EPA 910/9-92-029

PRIMARY BIO-INDICATORS: Numerical range of each primary bio-indicator based on numbers counted per 378.5 Liters (100 gallons) sampled

	EH (Extremely Heavy)	H (Heavy)	M (Moderate)	R (Rare)	NS
Giardia	>30	16 - 30	6 - 15	1 - 5	None Seen
Coccidia/Crypto	>30	16 - 30	6 - 15	1 - 5	None Seen
Diatoms	>150	41-149	11 - 40	1 - 10	None Seen
Other Algae	>300	96-299	21 - 95	1 - 20	None Seen
Insects/Larvae	>100	31-99	16 - 30	1 - 15	None Seen
Rotifers	>150	61-149	21 - 60	1 - 20	None Seen
Plant Debris	>200	71-199	26 - 70	1 - 25	None Seen

SECONDARY BIO-INDICATORS: Secondary bio-indicators are reported as a number based on relative concentration per 378.5 Liters (100 gallons) sampled and should be used only to support information derived from the primary bio-indicator category

RELATIVE SURFACE WATER RISK FACTOR ASSOCIATED WITH SCORING OF PRIMARY BIO-INDICATORS

	EH	H	M	R	NS
Giardia	40	30	25	20	0
Coccidia/Crypto	35	30	25	20	0
Diatoms	16	13	11	6	0
Other Algae	14	12	9	4	0
Insects/Larvae	9	7	5	3	0
Rotifers	4	3	2	1	0
Plant Debris	3	2	1	0	0

RISK OF SURFACE WATER CONTAMINATION

High Risk	Moderate Risk	Low Risk
20 or Greater	10 - 19	0 - 9

SAMPLE EVALUATION PERFORMANCE CRITERIA: The precise rates of recovery of organisms from environmental samples cannot be determined. B ioVir Laboratories has analyzed your sample(s) in accordance with the method described with each analyte above, however, due to inherent limitations of these methods organisms may avoid detection. For additional information regarding the limitations of the method(s) referred to above please call us at 1-800-GIARDIA.
COMPANY IS NOT AN INSURER: BioVir Laboratories is not an insurer or guarantor of the quality and/or purity of water, wastewater, biosolid or other material from which the sample was taken. BioVir offers no express or implied warranties whatsoever concerning the quality or purity of any water, wastewater, biosolid or other material which is ultimately consumed, distributed, applied or disposed.
MAINTENANCE OF RECORDS: BioVir Laboratories, Inc. shall maintain records pertaining to the historical reconstruction of client's data for a minimum of five years from the date of issuance of the final report. Records m ay be destroyed after that date unless a written client's request for records transfer is received by BioVir which requests otherwise. Records transfer or storage charges may apply after the 5 year period. THIS REPORT SHALL NOT BE REPRODUCED, EXCEPT IN FULL, WITHOUT THE WRITTEN APPROVAL OF BIOVIR LABORATORIES, INC.

7/24/2017
Report Date

Signature

Quality Checked ANovac

This page intentionally left blank.

Brown AND Caldwell

Sacramento

11020 White Rock Road, Suite 200
Rancho Cordova, CA 95670
Tel: 916.444.0123

APPENDIX L

Stakeholder Communication and Engagement Plan

DRAFT – 8/19/19

Westlands Water District

GROUNDWATER SUSTAINABILITY PLAN: STAKEHOLDER COMMUNICATION AND ENGAGEMENT PLAN

"Stakeholder engagement is defined as efforts made to understand and involve stakeholders and their concerns in the activities and decision-making of an organization or group."

Collaborating for Success: Stakeholder Engagement for Sustainable Groundwater Management Act Implementation, July 2015

I. INTRODUCTION

A stakeholder engagement effort described by the Department of Water Resources (DWR) requires a communication program that reaches out to all interested parties and is fully coordinated with the development of the Groundwater Sustainability Plan (GSP). DWR defines "stakeholder" as individuals who can affect or be affected by an organization's activities; or individuals or groups with an interest or "stake" in what happens as a result of any decision or action. For the purposes of this communications plan, all interested parties will be referred to as "stakeholders." The communication program needs to include a process to reach out to the public and potentially-affected individuals and communities in the Groundwater Sustainability Agencies (GSA) area to solicit input and communicate all developments in the GSP. In addition, there must be a specific effort to inform disadvantaged communities directly and through tailored communication channels. Finally, the communication effort must document all the efforts to inform the public and the results of those efforts in terms of participation and input.

II. GOALS AND DESIRED OUTCOMES

This communication program is designed to inform and activate the public and specific stakeholders to engage in the process to develop a GSP that will benefit the region by halting overdraft and bringing the groundwater basin into balanced levels of pumping and recharge by 2040. The Sustainable Groundwater Management Act (SGMA) requires designated GSAs, in this instance, Westlands Water District (WWD) to consider effects to other stakeholders in or around the groundwater basin. In addition, the regulations require the WWD to document all opportunities for public engagement and active involvement of stakeholders representing the diverse social, cultural, and economic elements of the population within the Basin.

a. **Description of the GSA.** WWD has the responsibility to engage a very diverse population that is geographically spread through Fresno and Kings counties. WWD intends to use a variety of communication tools and channels to reach the general public and specific audiences.

b. **Decision-making authority.** The Board of Directors of the Westlands Water District will be responsible for the implementation of the GSP and making decisions establishing the direction of the plan, overseeing the implementation, and allocating resources appropriately.

c. **The goal of the communication plan.** The goal of this plan is to outline the process WWD will follow in order to solicit input and keep the public informed about the progress in developing the plan, the subject areas where input is necessary, the timeline for public input, public events, and decision-making.

d. **Recognize and seek to overcome challenges.** This outreach program will need to overcome several challenges. First, there are communities where English is not the primary language so special attention and effort will be made to make sure all stakeholders in these communities receive timely information and can effectively provide their input. WWD will make every effort to be inclusive; this plan lays out several approaches to do so. Second, the area covered by the GSA is large, which will require some stakeholders to travel distances to be part of the public process. Third, the residents of the area are involved in farming, small business, and other labor-intensive work. While some residents may have the ability to participate online and through representative organizations, many residents may not have the time or resources to engage in the process.

III. PRELIMINARY LIST OF STAKEHOLDERS

An important preliminary action item is the development of a comprehensive list of stakeholders that will receive regular information about the process, the plan, and its implementation. Those stakeholders will be encouraged to engage in the process and provide their views on the formation and development of the GSP.

a. General public
b. Holders of groundwater rights
   i. Ag users
   ii. Domestic well users
c. Disadvantaged Communities (a community with an annual median household income that is less than 80 percent of the statewide annual median household income) and Severely Disadvantaged Community (a community with a median household income of less than 60 percent of the statewide). Those areas include but are not limited to Cantua Creek, El Porvenir and O'Neil Farms
d. Local community groups such as the Fresno and Kings counties Chambers of Commerce, Fresno County Farm Bureau, Kings County Farm Bureau, etc.
e. California Native American Tribes/tribe historian
   i. Maidu
   ii. Yokuts
   iii. Miwok
   iv. Dumna Wo Wah
f. Congressional Representatives, Senate and Assembly members
g. Local elected officials
   i. Mayors and City Council members of Fresno, Huron, Coalinga, Kerman, San Joaquin, Mendota, Firebaugh
   ii. Board of Supervisors for Fresno and Kings counties
   iii. City and county officials in Fresno and Kings County

h. Fresno Council of Governments (COG)
i. Regional land use agencies (need names)
j. Private water users not part of a water district
k. Sensitive receptors
    i. Fresno and Kings County Schools and colleges
    ii. Hospitals in Fresno and Kings County
    iii. Churches and religious organizations
    iv. Daycare facilities
    v. Elderly housing facilities
l. Other water agencies, irrigation districts, municipal water companies, and small community systems
m. Local non-governmental organizations such as conservation organizations, environmental and social justice organizations, water and environmental policy organizations, technical assistance organizations, and legal assistance organizations (Leadership Counsel for Justice and Accountability, Sierra Club, the Western Center on Law and Poverty, the California Rural Legal Assistance)
n. Neighboring GSA's
o. Federal and state agencies involved in water supply issues, including the Lemoore Naval Air Station

IV. ENCOURAGING STAKEHOLDER PARTICIPATION

As stated above, many stakeholders in the GSA have physical, language and economic challenges that will require a combination of communication tools to contact those entities and to solicit and receive their regular input. Given these limitations, it is critically important to engage the leadership of organizations that represent these communities and work with them to develop a method of communicating to the target population. For example, some use social media to receive critical information impacting their operations, others ask that communications continue to be mailed to their farms. Contacting stakeholders will involve a one or more of the following:

a. Public outreach
    i. Reach out to local media with information about the program and encourage them to provide the public with information about the process and contact information from WWD
    ii. Send direct mail to holders of groundwater rights within defined parameters
    iii. Secure paid advertisements (print and digital) in local newspapers in advance of public meetings
    iv. Send regular GSP update; E-blasts to database
    v. Maintain regularly-updated social media presence in line with GSP development
    vi. Seek earned media opportunities
        i. Seek out and maintain stakeholder partnerships

b. Organizational outreach
    i. Meet with the organizational leaders about the process and the need for input from their organization and membership
    ii. Encourage organizations to send out information through their newsletter and member communication channels

c. **Public officials and government agencies outreach**
   i. Meet with elected and appointed officials regarding the process and the role they can play in the development of the GSP

d. **Survey and data collection of stakeholders and public**
   i. WWD will develop a list of questions (survey) that can be used with all audiences to develop a matrix that contains information about stakeholders, their contact information, level of desired engagement, and limitations on their time

e. **Create an Advisory Committee**
   i. WWD will create an Interested Parties Advisory Committee comprised of community leaders and local organizations to provide focused outreach efforts and provide input and advice on the Draft GSP.

f. **Receive and respond to comments**
   i. WWD currently operates and monitors a SGMA specific email address (SGMA@wwd.ca.gov)
   ii. WWD will establish an online portal for comment submission
   iii. WWD will distribute and collect comment cards at meetings conducted as part of this program

V. MESSAGES AND TALKING POINTS

As stated above, messages for the outreach effort must be made in multiple languages to have the highest chance of reaching all stakeholders in the region, including the Disadvantaged Communities (DAC) and Severely Disadvantaged Communities (SDAC).

a. **Messages and materials tailored to audiences.**
   i. WWD will develop a "message tree" that will contain vital information for each target audience that is drafted in a culturally-relevant and effective manner. The potential documents might include the following:
      i. Fact sheet for individuals and organizations that plan to participate in the process on a regular basis.
      ii. Infographic for individuals and groups to understand the process and may be inclined to provide comments and participate.
      iii. Basic explanation of the purpose of the process and a request that they be part of a network that receives information and provides input on a regular basis.
      iv. Timeline for public opportunity to participate or provide comments, with follow-up notices that provide specific dates and times of public events.
      v. Q&A that covers issues to be resolved in the GSP.

VI. VENUES FOR PUBLIC ENGAGEMENT

The engagement part of this communication plan will require WWD to meet in person or through digital channels with the public and stakeholders.

a. **Meetings.** Throughout the course of the development of the GSP, WWD will be coordinating smaller meetings with stakeholders throughout the basin. The meetings will be held with groups that have indicated a desire to be part of the process and notices for these meetings will include a reminder that all meetings are open to the public.
    i. At the outset of the public outreach phase, local California Native American tribes will be contacted for a meeting and then included as members of the advisory committee.
    ii. Where indicated on the timeline, WWD will hold larger meetings as a means of sharing information on the development of the plan and to seek public input. Given the size of the GSA, WWD will need to strategically conduct a series of meetings in order to ensure the greatest degree of participation. Prior to the public meetings, members of the advisory committee will be invited to participate in a smaller group meeting. Here, advisory committee members will receive a preview of what will be shared at the public meeting, as well as provided with outreach materials to share with their constituency.
    iii. Public meetings will be held within the GSA's boundaries and in other areas of Fresno and Kings counties, and with appropriate notice, prior publication of an agenda and background materials, and specific time set aside for public participation and comment.
b. **Video participation.** WWD will also consider the use of tele-town halls and video conferencing for audiences that indicate (on the survey mentioned above) that they prefer to participate digitally. The recorded video of the meeting will then be housed online and shared across social media.
c. **Digital efforts.** WWD will use its website (wwd.ca.gov/SGMA) and consider the use of specific "landing page" for all presentations and other documents related to the GSP. WWD will provide notice and links to documents through the website, newsletter, and 2500(+) mailing list of district contacts in the region.
d. **Social media engagement.** WWD will use its social media assets (Twitter and Facebook) to reach audiences' search for information about the GSP and also to direct public to the documents available on the website.
e. **Advertisements.** Utilize targeted radio and print ads to reach audiences that are not likely to learn about the process through organizations or more traditional means.
f. **Outreach to Disadvantaged and Severely Disadvantaged Communities**. As stated above, WWD will develop materials specifically for communities that are beyond some of the traditional media tools and may not receive notice of the process through traditional channels. WWD will work through organizations such as churches, ethnic and cultural associations, non-governmental advocacy groups, and other organizations that have connections with disadvantaged communities.

VII. IMPLEMENTATION TIMELINE

The GSP has a specific timeline established by the Department of Water Resources to meet the obligations of the SGMA. Phase 1 involved formation of the GSA and was completed in 2016.

a. **Phases 2-4**

i. Phase 2, 2017-2020. During this phase, WWD will be preparing the necessary documents to explain the GSP process, identifying key stakeholders, implementing the plan to reach out to the stakeholders, cataloguing the different levels of participation from the audiences. This phase will also involve actual outreach through all communication channels, public and stakeholder involvement in the issues, and public and stakeholder involvement in decision-making process.
ii. Phase 3, 2018 and beyond. This phase continues the public outreach efforts and begins the formal process of gathering input from stakeholders through face-to-face meetings and digital and social media platforms.
iii. Phase 4, 2019 and beyond. WWD conducts meetings and reviews the GSP with stakeholders and the public.

b. Supporting tactics

i. Preparation of materials/translation into Spanish
ii. Website/landing page resources
iii. Initial outreach and meetings
iv. Media outreach
v. Matrix of stakeholder information/engagement levels
vi. Notice of events through email or other digital communication
vii. Publication of relevant documents

VIII. EVALUATION AND ASSESSMENT

WWD will utilize traditional and new media tools to assess success in achieving its communication goals. The assessment will include the following:

a. Numeric measurements such as the number of people contacted, the number that attended a meeting, the number of “click-through” to the website, the number of people that searched for terms relating to groundwater sustainability, and the number of comments submitted about the GSP.
b. Media coverage of the issues being addressed in the GSP.
c. Review of the specific engagement of Disadvantaged Communities and Severely Disadvantaged Communities.

APPENDIX M

Westlands Water District Amended GSP Adoption Resolution (GSA-105-22)

LSCE

STATE OF CALIFORNIA)
)ss
COUNTY OF FRESNO)

I, Bobbie Ormonde, do hereby certify that I am the duly appointed, qualified and acting District Secretary of Westlands Water District serving as the Groundwater Sustainability Agency of the Westside Subbasin, a public district organized under the laws of the State of California with its offices at Fresno, California; that Resolution No. GSA 105-22 was duly and regularly adopted by the Board of Directors of Westlands Water District serving as the Groundwater Sustainability Agency of the Westside Subbasin duly called and held on the 21st of June 2022, at which a quorum of said Directors was present and acting; and that said Resolution is still in full force and effect.

IN WITNESS WHEREOF, I have hereunto set my hand and seal as District Secretary of said District this 29th day of June 2022.

Bobbie Ormonde, District Secretary
Westlands Water District Serving as the Groundwater Sustainability Agency of the Westside Subbasin

RESOLUTION NO. GSA-105-22

A RESOLUTION OF THE BOARD OF DIRECTORS CLARIFYING AND AMENDING CERTAIN CHAPTERS OF THE WESTSIDE SUBBASIN GROUNDWATER SUSTAINABILITY PLAN AND AUTHORIZING SUBMISSION OF THE WESTSIDE SUBBASIN GROUNDWATER SUSTAINABILITY PLAN TO THE CALIFORNIA DEPARTMENT OF WATER RESOURCES AND RELATED ACTIONS

WHEREAS, the Sustainable Groundwater Management Act (SGMA), California Water Code section 10720, et seq., authorizes local Groundwater Sustainability Agencies (GSAs) to manage groundwater basins in a sustainable manner and pursuant to a Groundwater Sustainability Plan (GSP); and

WHEREAS, the legislative intent of SGMA is to provide for sustainable management of groundwater basins, to enhance local management of groundwater, to establish standards for sustainable groundwater management, and to provide local agencies with the authority to sustainably manage groundwater; and

WHEREAS, DWR has designated the Westside Subbasin of the San Joaquin Valley Groundwater Basin (Subbasin No. 5-22.09) (Westside Subbasin) as a high-priority basin experiencing critical overdraft; and

WHEREAS, on July 19, 2016, Westlands Water District (District) Board of Directors (Board) adopted Resolution No. 111-16, electing to become the GSA for the Subbasin; and

WHEREAS, on October 18, 2016, the District and County of Fresno (Fresno) entered into a Memorandum of Understanding to ensure areas within the Westside Subbasin outside of the District's Service Area are covered by a Westside Subbasin GSP; and

WHEREAS, on November 1, 2016, DWR deemed the District the GSA for the Westside Subbasin, authorizing the District to exercise the powers and authorities described in Water Code Sections 10725 to 10726.9 and to prepare a Westside Subbasin GSP consistent with Water Code Sections 10727 to 10728.6 and DWR's GSP Regulations (Cal. Code Regs., tit 23, § 350 et seq.) (GSP Regulations); and

WHEREAS, on January 7, 2020, after following the public process required by SGMA and the GSP Regulations, Fresno County approved Resolution No. 20-014, adopting the Westside Subbasin GSP for portions of Fresno County in the Westside Subbasin where the Fresno County serves as the GSA; and

WHEREAS, on January 8, 2020, after following the public process required by SGMA and the GSP Regulations, the District Board approved Resolution No. GSA 101-20, adopting the Westside Subbasin GSP and authorizing submission of the Westside Subbasin GSP to DWR; and

WHEREAS, on January 23, 2020, the District submitted Westside Subbasin GSP to DWR to commence the public and DWR review period; and

WHEREAS, on January 21, 2022, DWR issued a determinization letter finding the Westside Subbasin GSP "Incomplete" (Incomplete Letter) and recommending potential corrective actions to address DWR's identified deficiencies; and

WHEREAS, the District prepared revisions to the Westside Subbasin GSP to clarify and amend the Westside Subbasin GSP in response to DWR's Incomplete Letter (Revised Westside Subbasin GSP); and

WHEREAS, the Revised Westside Subbasin GSP adds clarifying text to further describe the process to set the sustainable management criteria for chronic lowering of groundwater levels and incorporates additional monitoring and sustainable management criteria for domestic and municipal and industrial wells that avoid impacts to these beneficial uses; and

WHEREAS, the Revised Westside Subbasin GSP adds clarifying text and proposes amendments to the sustainable management criteria for groundwater quality degradation and land subsidence to address DWR's identified deficiencies; and

WHEREAS, the Revised Westside Subbasin GSP adds text to Chapter 4 Project and Management Action No. 2 (Groundwater Allocation Program) and No. 4 (Subsidence Prone Area) to clarify the Board's discretion to not implement an aquifer-specific allocation in certain areas where additional Upper Aquifer pumping may cause or contribute to subsidence until data gaps can be addressed; and

WHEREAS, the Revised Westside Subbasin GSP revises Chapter 6 (Governance) to clarify and harmonize certain provisions with the District's adopted Rules and Regulations, consistent with SGMA; and

WHEREAS, the District provided notice to the cities and counties within the Subbasin on March 3, 2022, to provide logical agencies with 90 days' notice of the proposed Revised Westside Subbasin GSP for the purposes of consultation consistent with Water Code Section 10728.4; and

WHEREAS, the District published a draft of the Revised Westside Subbasin GSP for public review on June 16, 2022, and has noticed a Public Hearing, as required by Water

Code section 10728.4, for the purposes of considering adoption of the Revised Westside Subbasin GSP; and

WHEREAS, at the Public Hearing, the District Board of Directors considered the Westside Subbasin GSP and the comments from the public thereon; and

WHEREAS, the Revised Westside Subbasin GSP contains all the elements required by Water Code sections 10727.2 and 10727.4 and the GSP Regulations; and

WHEREAS, the Revised Westside Subbasin GSP is consistent with the purposes and intent of SGMA and the GSP Regulations to avoid the occurrence of undesirable results defined in Water Code section 10721(x) in the Westside Subbasin; and

WHEREAS, implementation of the Revised Westside Subbasin GSP, based on the best available information and best available science, shall achieve sustainable groundwater management, as defined in Water Code section 10721(v), during the fifty (50) year planning and implementation horizon; and

WHEREAS, the Revised Westside Subbasin GSP establishes a groundwater sustainability plan that facilitates the reasonable and beneficial use of the maximum quantity of groundwater in the basin, including temporary surplus, that may be annually withdrawn from the Westside Subbasin GSP over long-term conditions without causing undesirable results in accordance with Article X, section 2 of the California Constitution; and

WHEREAS, the Revised Westside Subbasin GSP does not declare, determine or alter common law water rights and is consistent with the requirements of Water Code section 10720.5; and

WHEREAS, from time to time, implementation of the Revised Westside Subbasin GSP may require the imposition of management measures that maximize the reasonable and beneficial use of groundwater and avoid undesirable results by requiring reasonable accommodations among groundwater users; and

WHEREAS, after its filing with DWR, the Revised Westside Subbasin GSP shall be subject to further public review through the DWR comment process and shall undergo review by DWR; and

WHEREAS, the Revised Westside Subbasin GSP shall be updated and amended, periodically, as deemed necessary by the District to respond to changing conditions and new information; and

WHEREAS, Fresno shall consider adoption of the Revised Westside Subbasin GSP at a public meeting on or about July 12, 2022 and, if adopted, implement the plan within the portions of the Westside Subbasin outside of the District's Service Area; and

WHEREAS, the District Board determined that it is in the best interest of the District, its landowners, and beneficial water uses and users in the Westside Subbasin to adopt the Revised Westside Subbasin GSP.

NOW, THEREFORE, BE IT AND IT IS HEREBY RESOLVED as follows:

1. All the Recitals in this resolution are true and correct, and supported by findings and substantial evidence in the record, attached hereto as Exhibit A.

2. The District adopts the Revised Westside Subbasin GSP in substantially the same form as Exhibit B, to implement sustainable groundwater management in the Westside Subbasin pursuant to SGMA and California law.

3. The General Manager or his designee shall submit the Revised Westside Subbasin GSP to the California Department of Water Resources, pursuant to Water Code Section 10733.4.

4. The General Manager and General Counsel are hereby authorized and directed to take such other actions as may be necessary or appropriate to implement the intent and purposes of this resolution, including but not limited to, making further clarifications and revisions to the Revised Westside Subbasin GSP consistent with the Board's direction and coordinating with Fresno to finalize the Revised Westside Subbasin GSP.

Adopted following a public hearing held during a regular meeting of the Board of Directors, at Fresno, California, this 21st day of June 2022.

AYES: Directors Anderson, Assemi, Bourdeau, Coelho, Errotabere, Ferguson Fortune, Howe and Nunn

NOES: None

ABSENT: None

Bobbie Ormonde

Bobbie Ormonde, District Secretary

APPENDIX N

Fresno County Amended GSP Adoption Resolution (22-226)

LSCE

BEFORE THE BOARD OF SUPERVISORS

OF THE COUNTY OF FRESNO

STATE OF CALIFORNIA

RESOLUTION APPROVING AMENDMENTS TO THE WESTSIDE SUBBASIN GROUNDWATER SUSTAINABILITY PLAN FOR PORTIONS OF FRESNO COUNTY IN THE WESTSIDE SUBBASIN AND AUTHORIZING SUBMISSION OF THE WESTSIDE SUBBASIN GROUNDWATER SUSTAINABILITY PLAN TO THE CALIFORNIA DEPARTMENT OF WATER RESOURCES

WHEREAS, the Sustainable Groundwater Management Act (SGMA), California Water Code section 10720, et seq., authorizes local Groundwater Sustainability Agencies (GSAs) to manage groundwater basins in a sustainable manner and pursuant to a Groundwater Sustainability Plan (GSP); and

WHEREAS, the legislative intent of SGMA is to provide for sustainable management of groundwater basins, to enhance local management of groundwater, to establish standards for sustainable groundwater management, and to provide local agencies with the authority to sustainably manage groundwater; and

WHEREAS, the Department of Water Resources (DWR) has designated the Westside Subbasin of the San Joaquin Valley Groundwater Basin (DWR Bulletin 118 Basin No. 5-22.09) (Westside Subbasin) as a high-priority basin experiencing critical overdraft; and

WHEREAS, the County is the GSA for those portions of the Westside Subbasin that are within the County's jurisdictional boundaries, including the areas within the City of Huron's jurisdictional boundaries, but outside the boundaries of the Westlands Water District (District), while the District is the GSA for those portions of the Westside Subbasin that are within the District's jurisdictional boundaries;

WHEREAS, on January 7, 2020, after following the public process required by SGMA and the GSP Regulations, Fresno County approved Resolution No. 20-014, adopting the Westside Subbasin GSP for portions of Fresno County in the Westside Subbasin where the Fresno County serves as the GSA; and

WHEREAS, on January 8, 2020, after following the public process required by SGMA and the GSP Regulations, the District Board approved Resolution No. GSA 101-20, adopting the Westside Subbasin GSP and authorizing submission of the Westside Subbasin GSP to DWR; and

WHEREAS, on January 23, 2020, the District submitted Westside Subbasin GSP to DWR to commence the public and DWR review period; and

WHEREAS, on January 21, 2022, DWR issued an "'Incomplete' Determination of the 2020 Westside Subbasin Groundwater Sustainability Plan" (Incomplete Letter), which stated that the Westside Subbasin GSP does not satisfy the objectives of the SGMA nor substantially comply with the GSP Regulations, and recommended corrective actions to address DWR's identified deficiencies; and

WHEREAS, the District prepared revisions to the Westside Subbasin GSP to clarify and amend the Westside Subbasin GSP (Revised Westside Subbasin GSP) in response to DWR's Incomplete Letter; and

WHEREAS, the Revised Westside Subbasin GSP adds clarifying text to further describe the process to set the sustainable management criteria for chronic lowering of groundwater levels and incorporates additional monitoring and sustainable management criteria for domestic and municipal and industrial wells that avoid impacts to these beneficial uses; and

WHEREAS, the Revised Westside Subbasin GSP adds clarifying text and proposes amendments to the sustainable management criteria for groundwater quality degradation and land subsidence to address DWR's identified deficiencies; and

WHEREAS, the Revised Westside Subbasin GSP adds text to Chapter 4 Project and Management Action No. 2 (Groundwater Allocation Program) and No. 4 (Subsidence Prone Area) to clarify the GSA's discretion to not implement an aquifer-specific allocation in certain areas where additional Upper Aquifer pumping may cause or contribute to subsidence until data gaps can be addressed; and

WHEREAS, the Revised Westside Subbasin GSP revises Chapter 6 (Governance) to clarify and harmonize certain provisions with the District's adopted Rules and Regulations, consistent with SGMA; and

WHEREAS, after its filing with DWR, the Revised Westside Subbasin GSP will be subject to further public review through the DWR comment process and will undergo review by DWR; and

WHEREAS, the Revised Westside Subbasin GSP must be updated and amended, periodically, as deemed necessary by the Subbasin to respond to changing conditions and new information; and

WHEREAS, the District determined, by resolution of its board of directors on June 21, 2022, that it is in the best interest of the District, its landowners, and beneficial water uses and users in the Westside Subbasin to adopt the Revised Westside Subbasin GSP.

NOW, THEREFORE, IT IS HEREBY RESOLVED, that the foregoing recitals are true and correct; and

IT IS HEREBY FURTHER RESOLVED, that the County of Fresno hereby adopts the Revised Westside Subbasin GSP for those portions of Fresno County within the Westside Subbasin where the County serves as the GSA, and will support its continuing development and implementation; and

IT IS HEREBY FURTHER RESOLVED, that the County of Fresno hereby authorizes the District's General Manager or his designee to submit the Revised Westside Subbasin GSP to the California Department of Water Resources, pursuant to Water Code Section 10733.4.

THE FOREGOING, was passed ad adopted by the following vote of the Board of Supervisors of the County of Fresno on this 12th day of July, 2022, to wit:

AYES: Supervisors Brandau, Magsig, Mendes, Pacheco, Quintero
NOES: None
ABSENT: None
ABSTAINED: None

[signature]

Brian Pacheco, Chairman of the Board of Supervisors of the County of Fresno

ATTEST:
Bernice E. Seidel
Clerk of the Board of Supervisors
County of Fresno, State of California

By [signature]
Deputy

APPENDIX O

Fresno County Letter of Support for the Sustainable Management Criteria Updates

County of Fresno

DEPARTMENT OF PUBLIC WORKS AND PLANNING
STEVEN E. WHITE, DIRECTOR

June 20, 2022

Westlands Water District Groundwater Sustainability Agency
Attn: Katarina Campbell
3130 N Fresno Street
Fresno, CA 93703

Subject: Support for the Sustainable Management Criteria Updates

Dear Ms. Campbell:

The purpose this letter is to inform Westlands Water District Groundwater Sustainability Agency (District) of the County of Fresno's support of the proposed updates to Sustainable Management Criteria (SMC). The County of Fresno is the Groundwater Sustainability Agency (Fresno County GSA) for areas within the Westside Subbasin outside of the District's boundary. The County's Department of Public Health also permits wells in the Subbasin. The District and Fresno County GSA (collectively GSAs) are working in partnership to develop revisions to the Groundwater Sustainability Plan (GSP) for the Westside Groundwater Subbasin based on comments received by the California Dept of Water Resources (DWR).

The authorities granted to the GSAs allow for management of water quality only through regulation of groundwater extraction influences on SMC. Further it is the County's understanding that total dissolved solids (TDS) can be used as a proxy for other constituents of interest in the Subbasin due to the correlation and presence of TDS to other constituents of interest to agriculture, domestic, and urban beneficial users in the Westside Subbasin. The wells included in the Groundwater Sustainability Plan's representative monitoring network in the Subbasin are widely monitored for TDS due to the fact (described above) that TDS can be used as a proxy for other water quality constituents of interest in the Subbasin and is often associated with undesirable impacts on agricultural crop needs. Given the aforementioned factors, the County supports the GSAs approach to annually monitor TDS and use TDS as a proxy for other constituents, such as boron, chloride, sulfate, and other constituents of interest.

It is also the County's understanding that SMC for TDS will continue to be used in those areas where domestic and urban use of groundwater exists and that the SMCs will represent long-term and short-term drinking water standards for those domestic and urban beneficial users. Monitoring of the representative monitoring network locations in the Subbasin will be conducted to assess any changes in groundwater quality and occurrence of undesirable results. However, the Minimum Threshold and Measurable Objectives will not be established for monitoring network locations that already exceed the TDS maximum contaminant level. The County also finds the exclusion of established Minimum Thresholds and Measurable Objectives from areas of the Subbasin that are already degraded a reasonable approach given the pertinent beneficial uses in the basin.

Thank you for cooperating with the County of Fresno in the revisions to the GSP. We look forward to continuing to work with the District on the implementation of the GSP.

Sincerely,

Bernard Jimenez
Planning and Resource Management Officer

G:\4360WaterNaturalResources\SGMA\Westside Basin\WWD Ltr of Support SMC Updates 06.22 .docx

Appendix 3-A

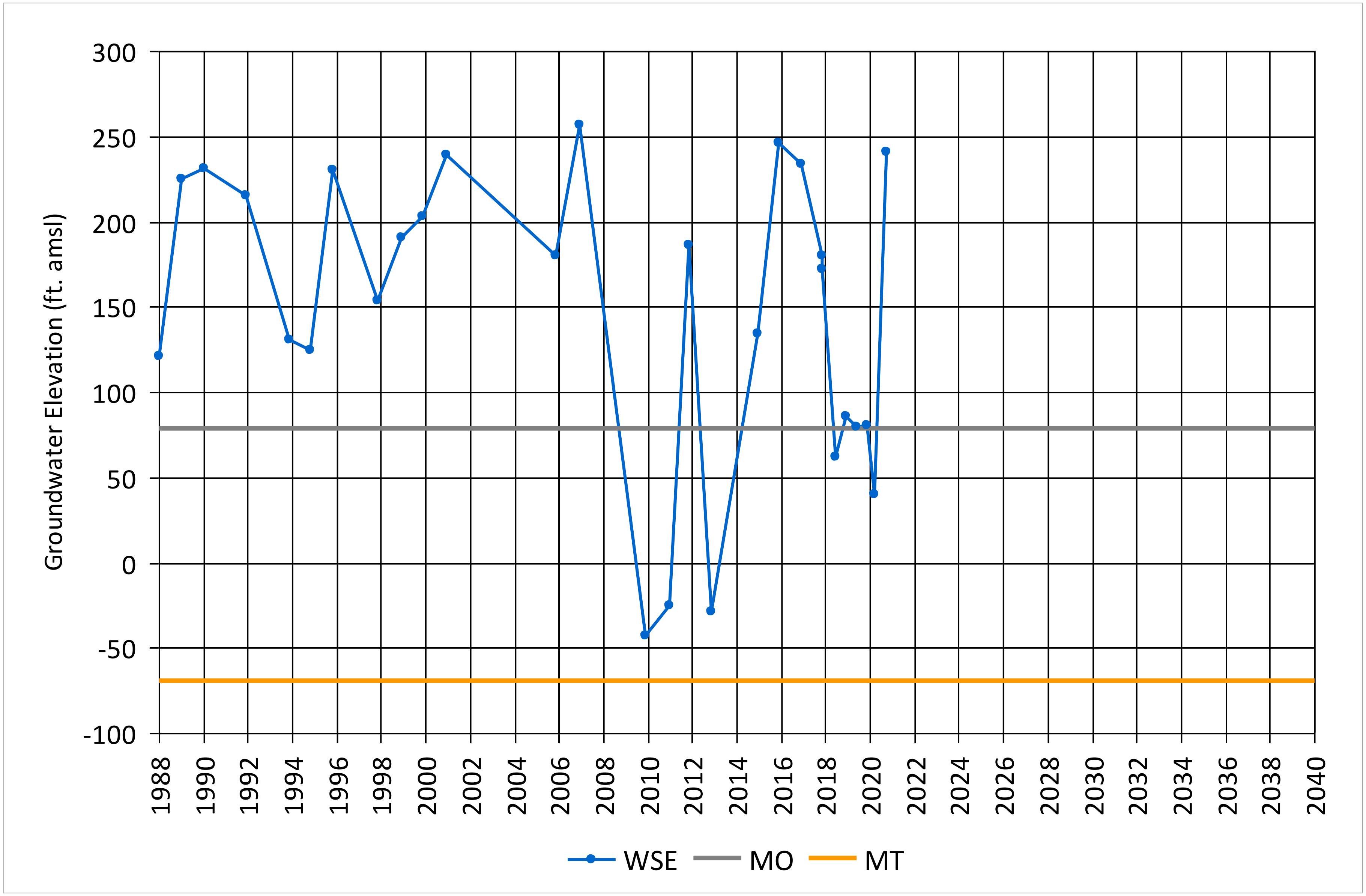
Measurable Objectives and Minimum Thresholds for Groundwater Levels

LSCE

Aquifer: Upper
Perforations: 326-716 ft

14S/13E-23E02

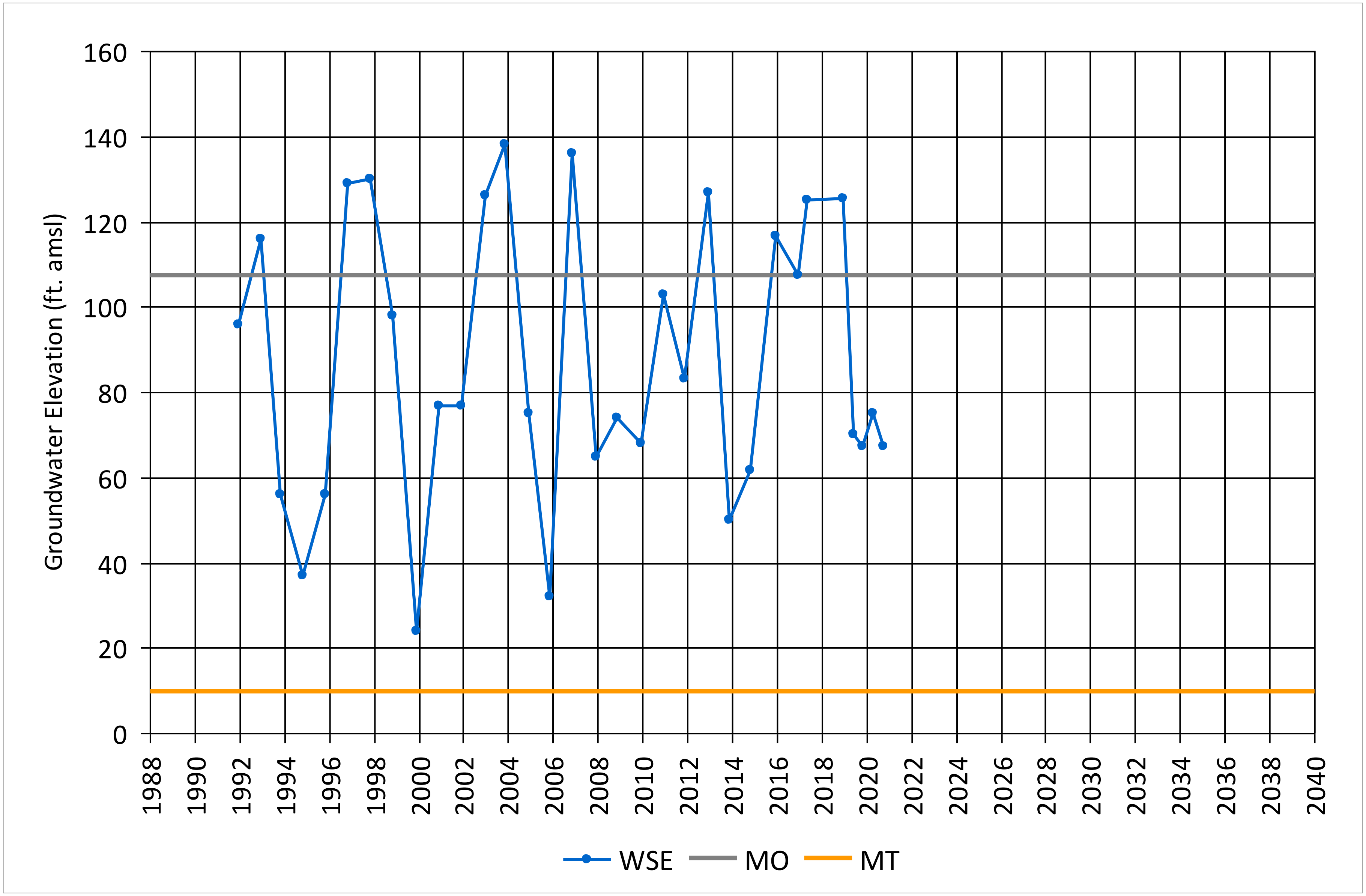
MO: 78.8 MT: -69
Depth: 716 ft



Aquifer: Upper
Perforations: 115-205 ft

14S/15E-20Q01

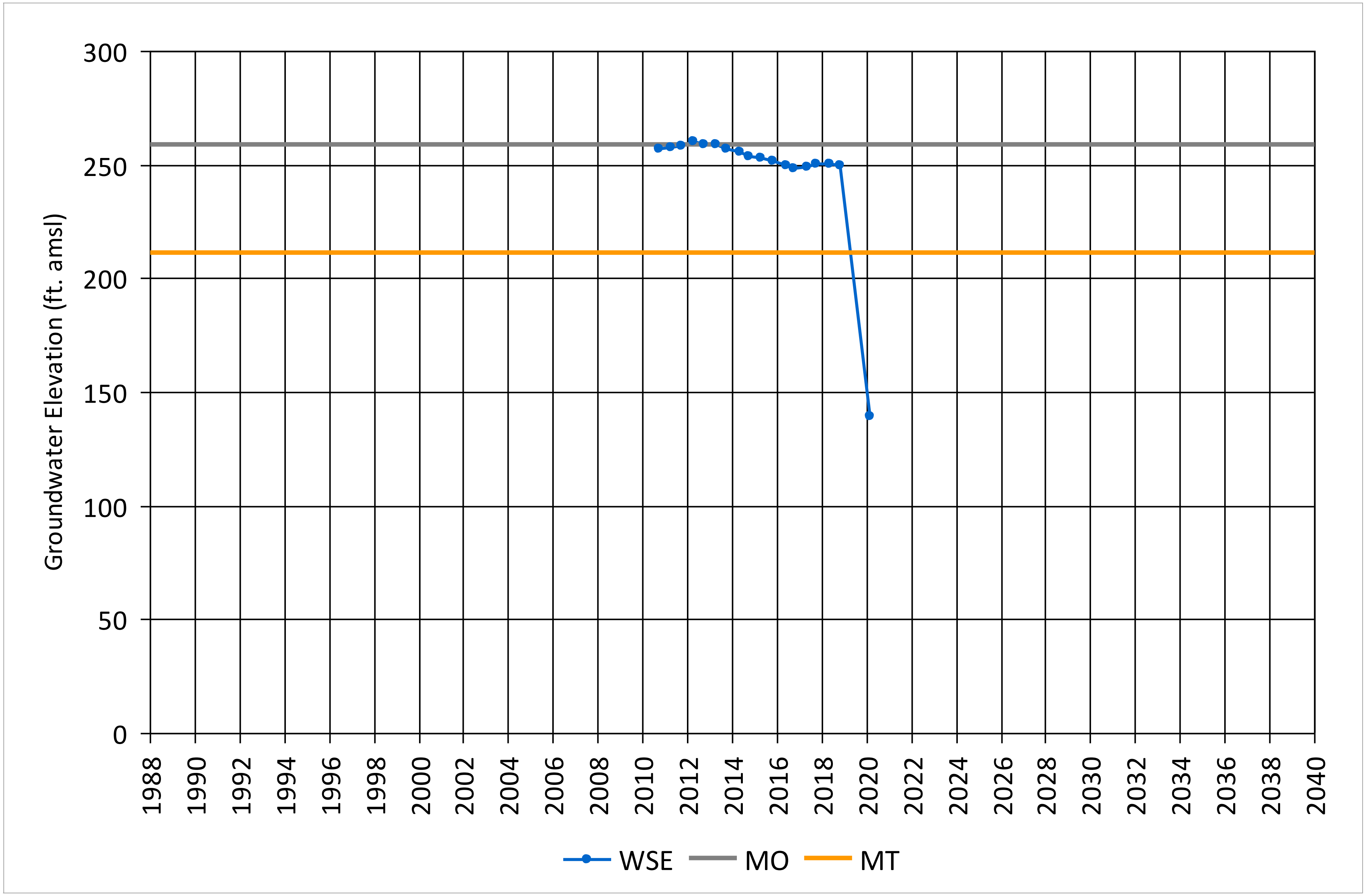
MO: 107.4 MT: 10
Depth: 205 ft



Aquifer: Upper
Perforations: 199-209 ft

15S/13E-05F04

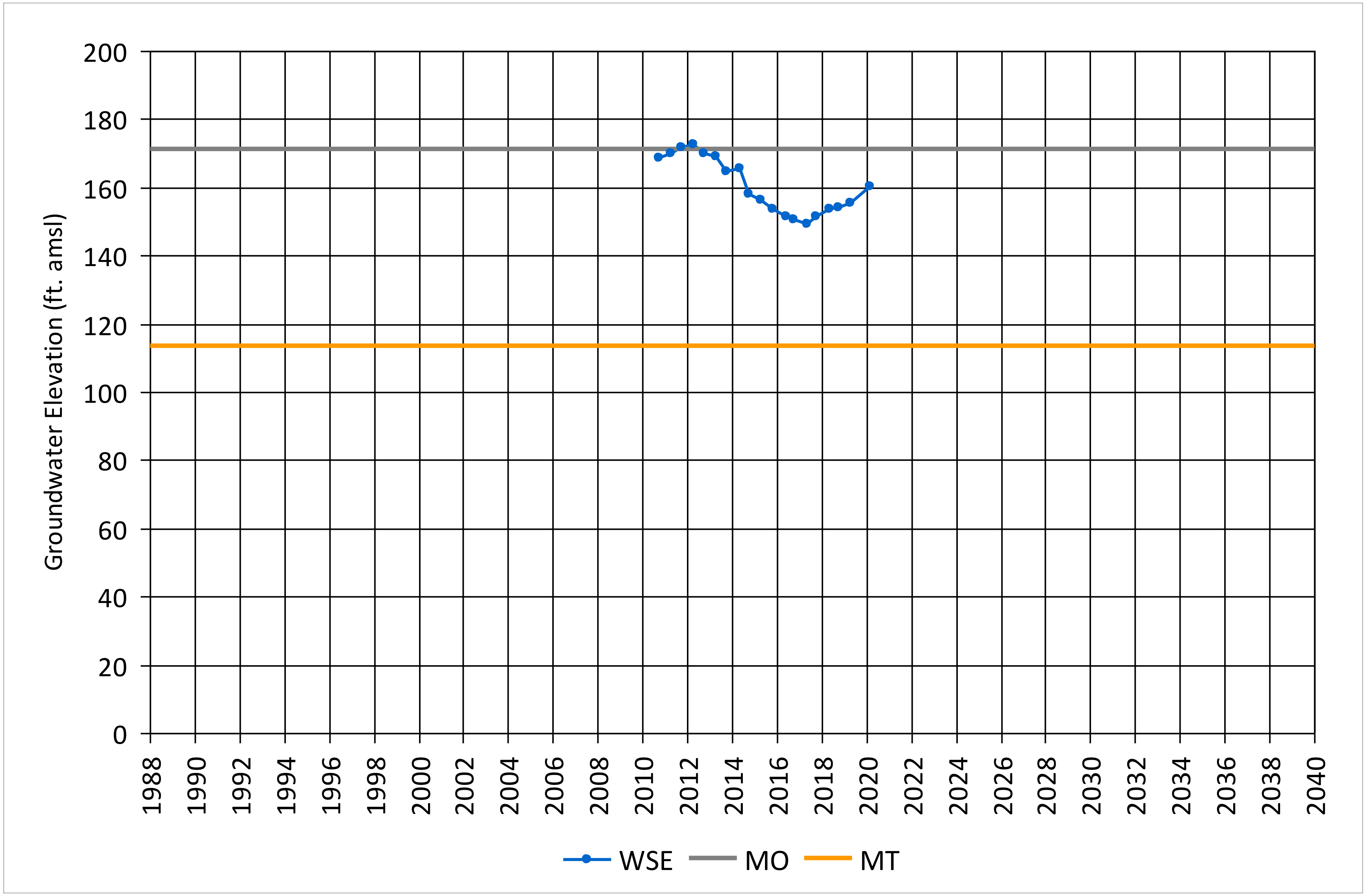
MO: 259.2 MT: 211.4
Depth: 215 ft



Aquifer: Upper
Perforations: 363-373 ft

15S/13E-22A01

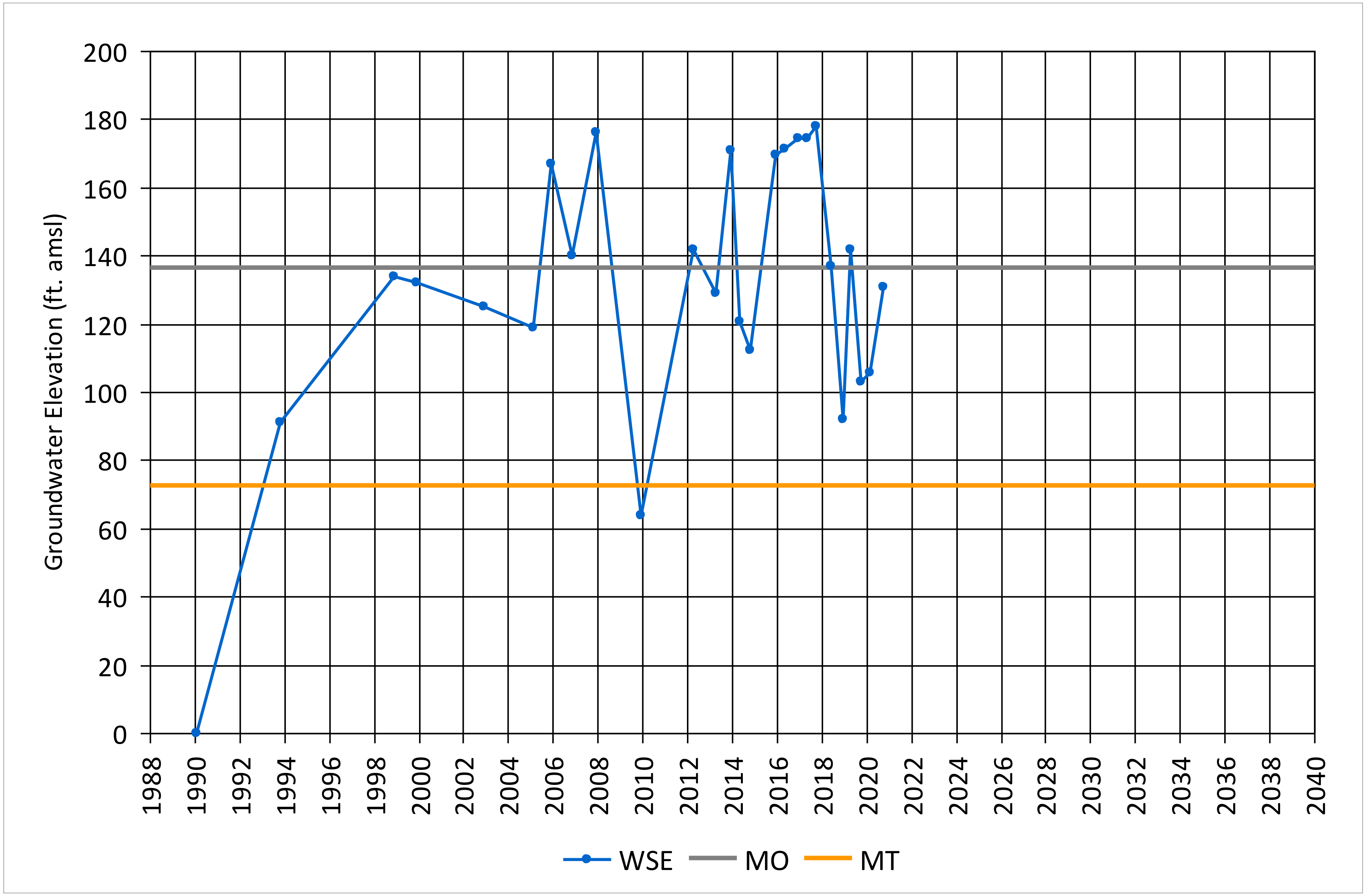
MO: 171.2 MT: 113.6
Depth: 379 ft



Aquifer: Upper
Perforations: 150-582 ft

15S/14E-10A06

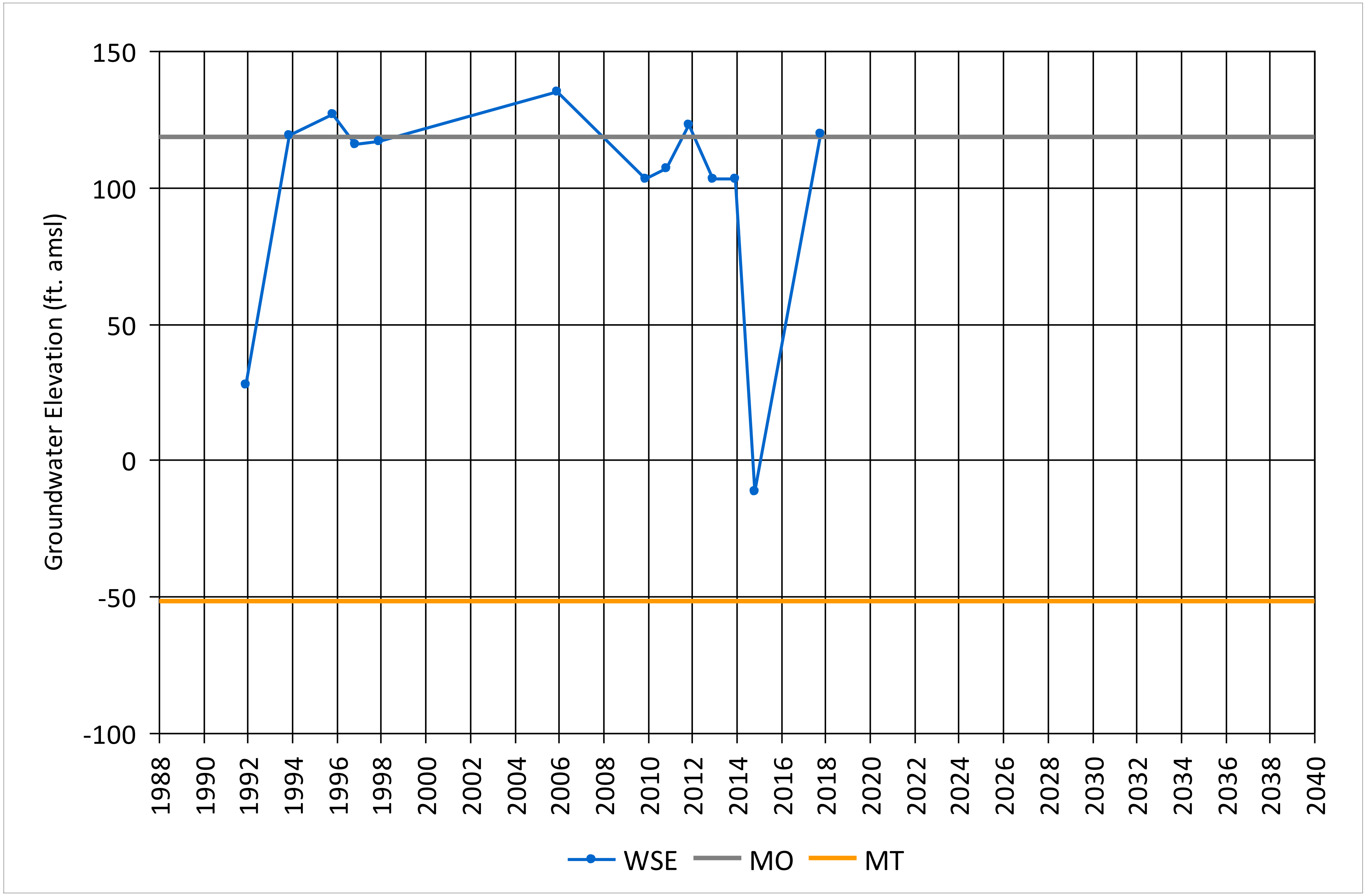
MO: 136.4 MT: 72.5
Depth: 582 ft



Aquifer: Upper
Perforations: 465-1055 ft

15S/14E-14R01

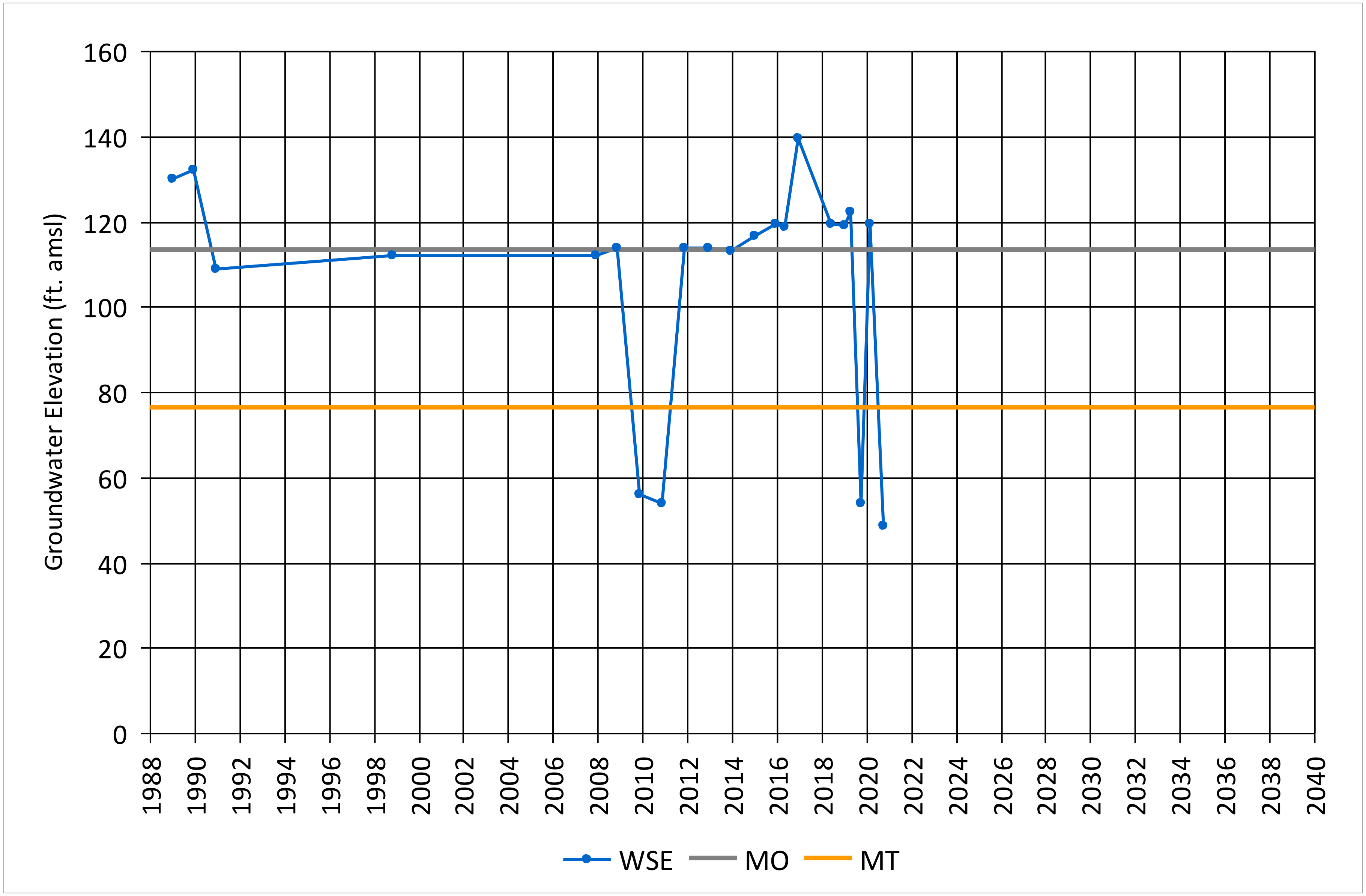
MO: 118.5 MT: -51.4
Depth: 1055 ft



15S/15E-16K01

Aquifer: Upper
Perforations: 300-500 ft

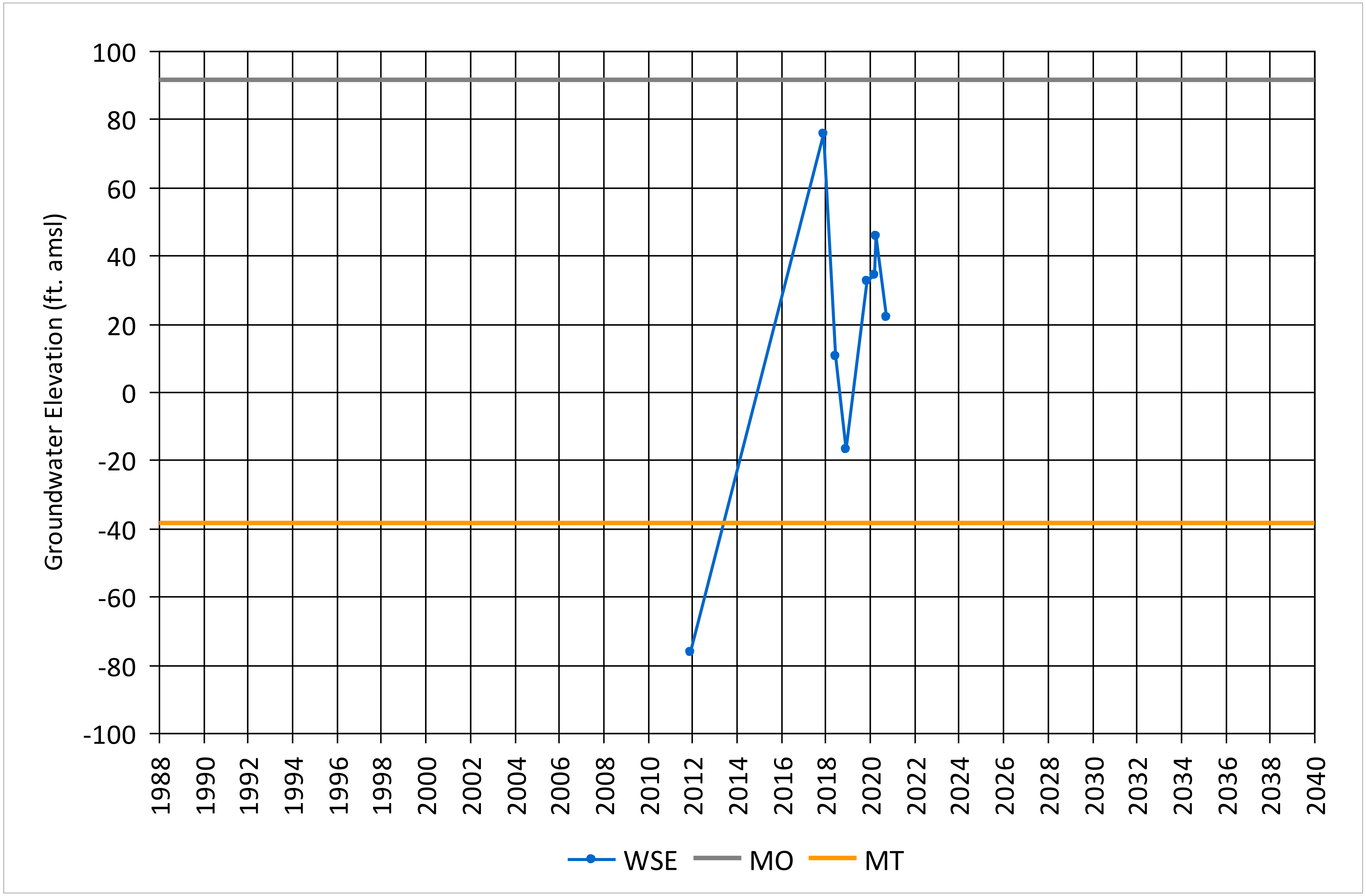
MO: 113.5 MT: 76.6
Depth: 500 ft



Aquifer: Upper
Perforations: 320-540 ft

16S/15E-10M01

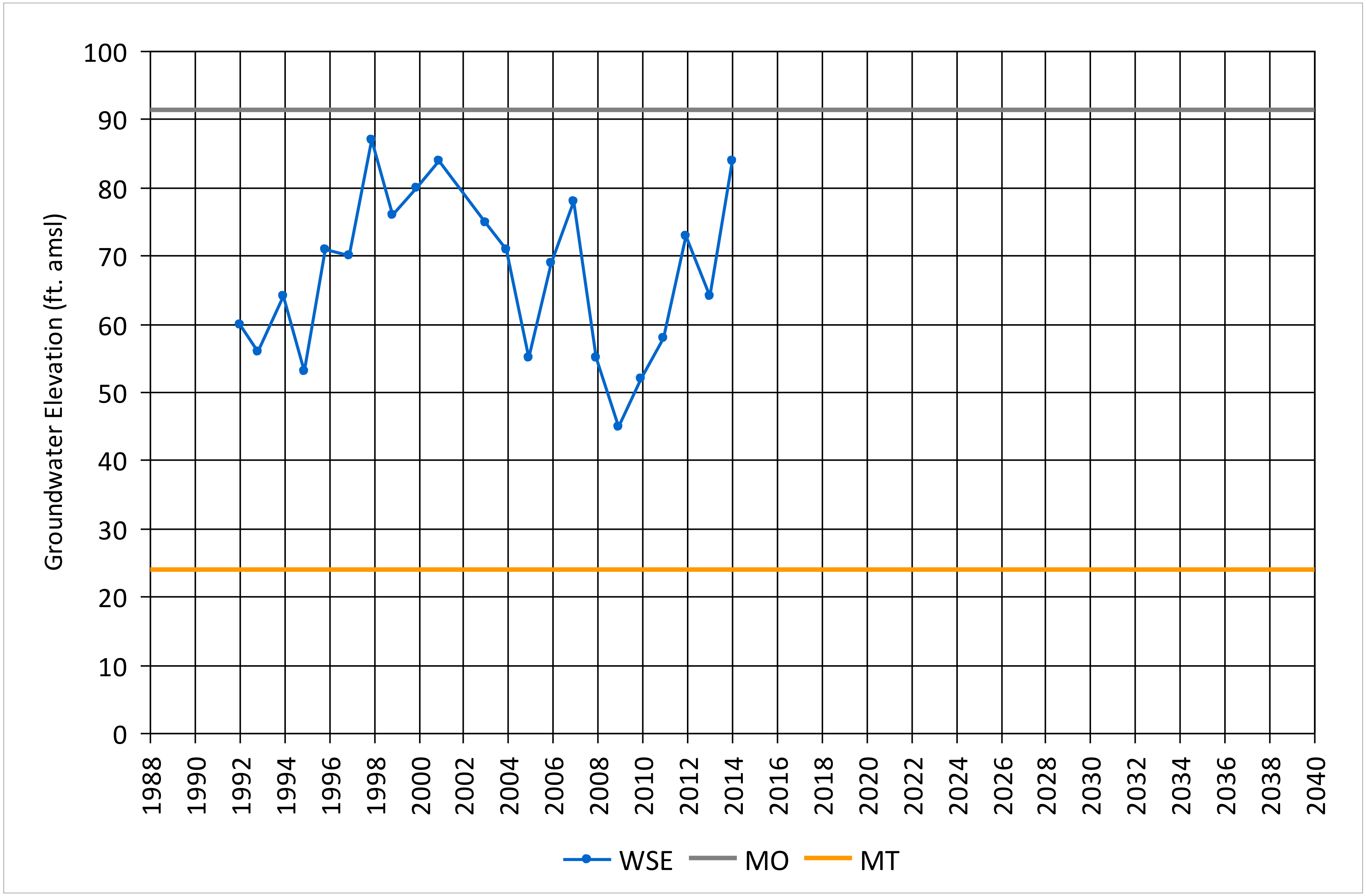
MO: 91.5 MT: -38.4
Depth: 560 ft



Aquifer: Upper
Perforations: 280-560 ft

16S/16E-09Q01

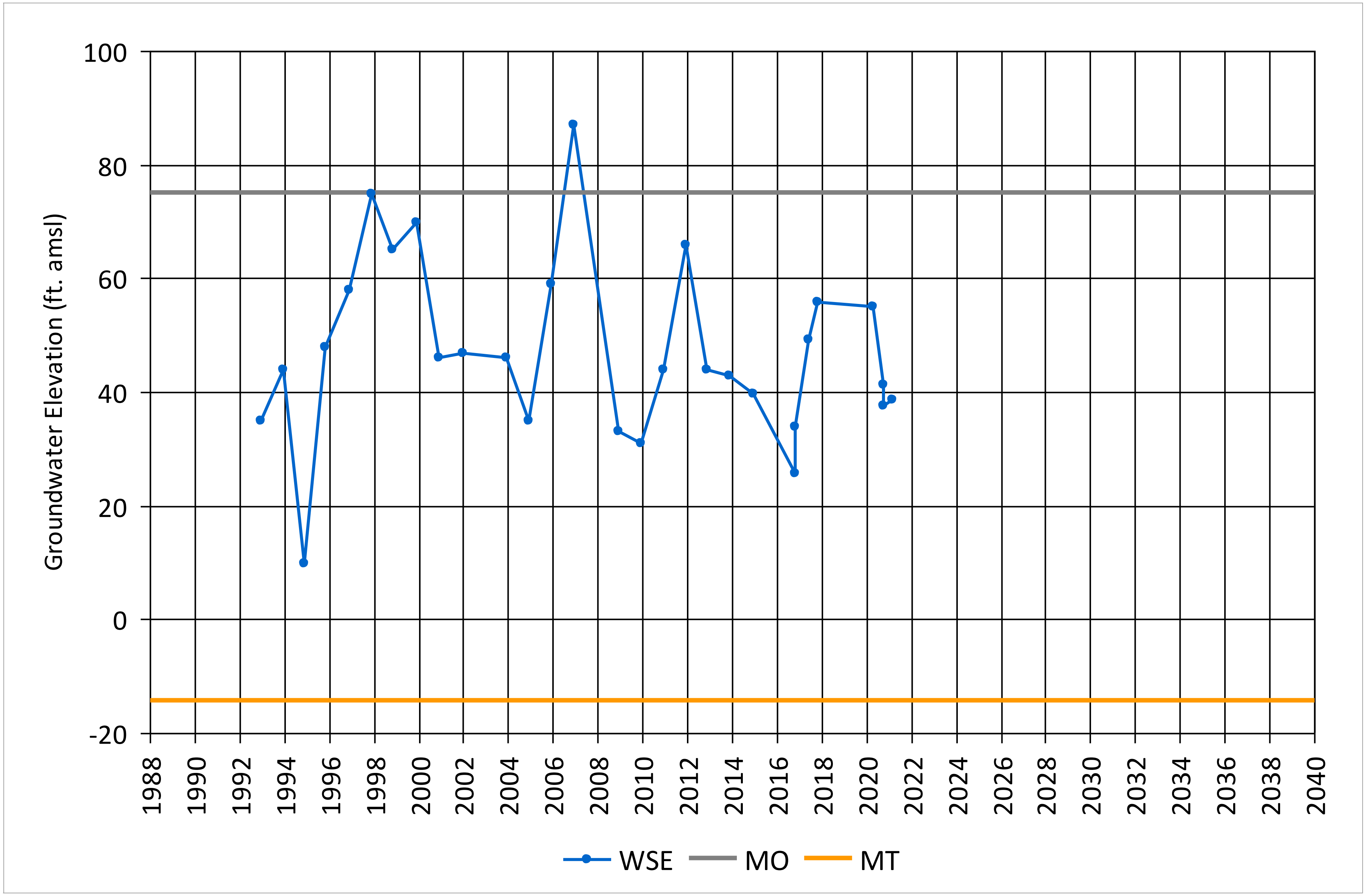
MO: 91.5 MT: 24
Depth: 580 ft



Aquifer: Upper
Perforations: 300-520 ft

16S/16E-33G01

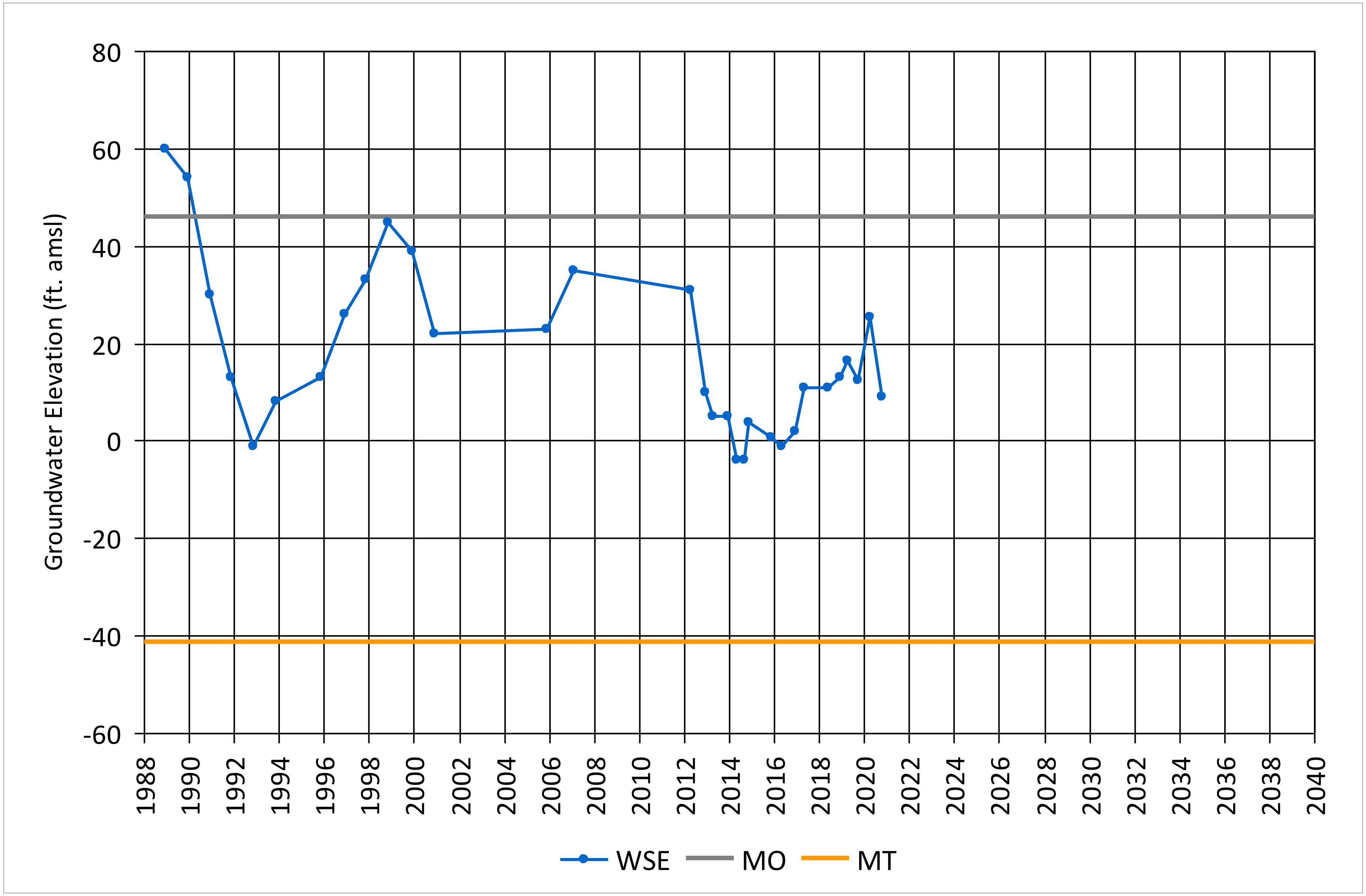
MO: 75.2 MT: -14.2
Depth: 520 ft



Aquifer: Upper
Perforations: 270-480 ft

17S/17E-16C01

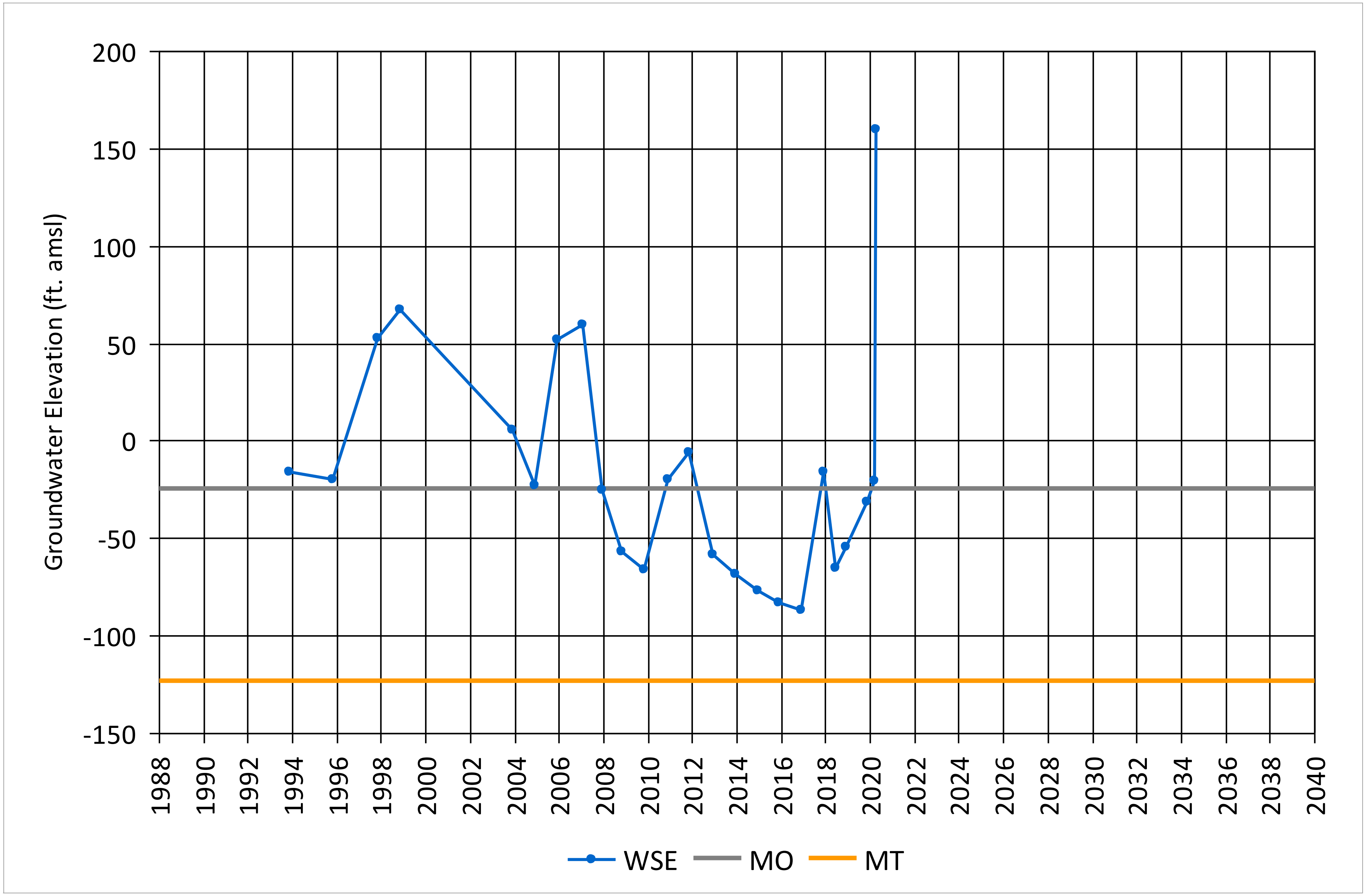
MO: 46 MT: -41.1
Depth: 480 ft



Aquifer: Upper
Perforations: 498-738 ft

17S/17E-31N03

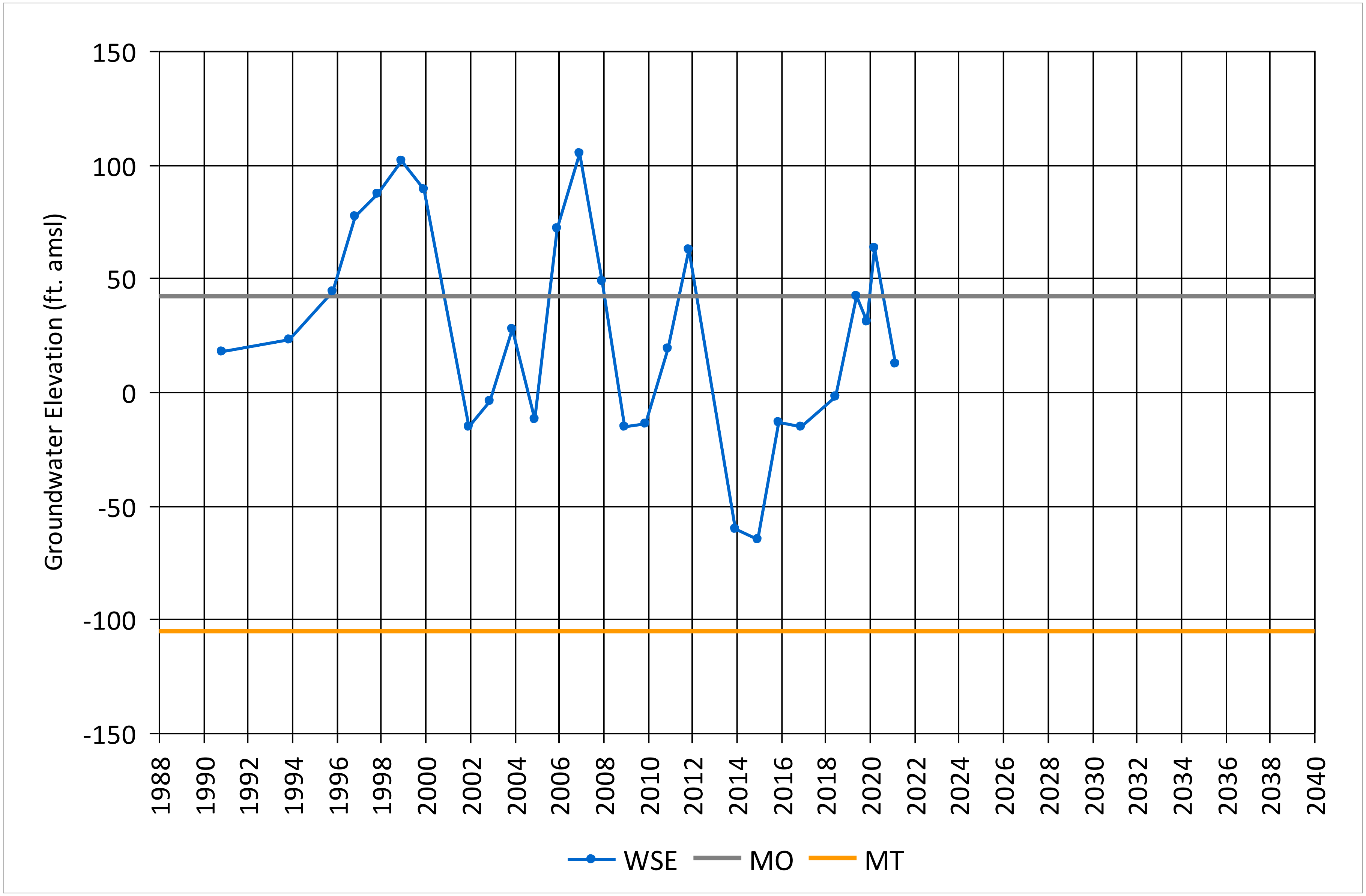
MO: -24.5 MT: -123
Depth: 780 ft



Aquifer: Upper
Perforations: 280-400 ft

18S/16E-22Q03

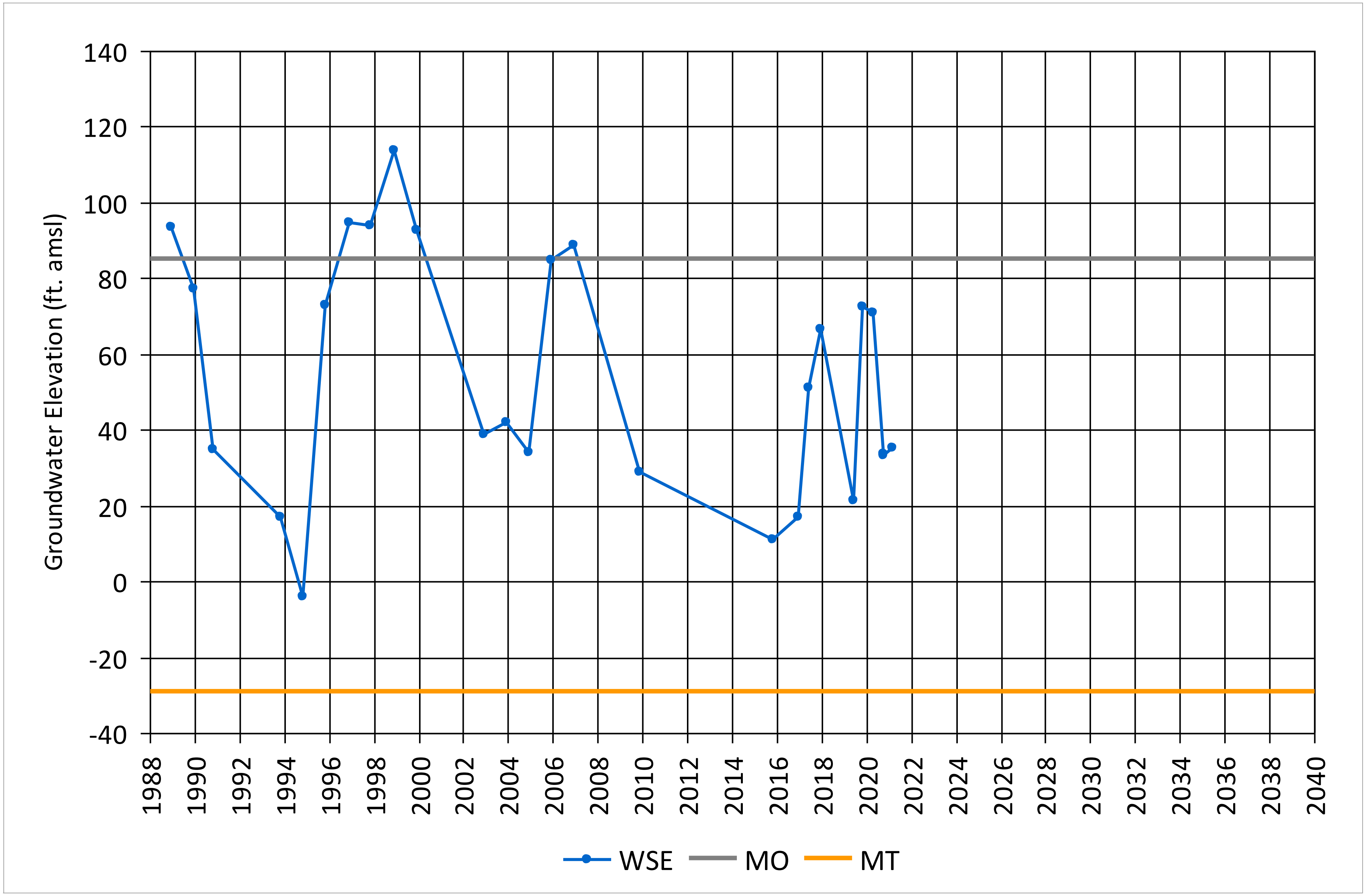
MO: 42.6 MT: -104.9
Depth: 400 ft



Aquifer: Upper
Perforations: 350-630 ft

18S/17E-11Q01

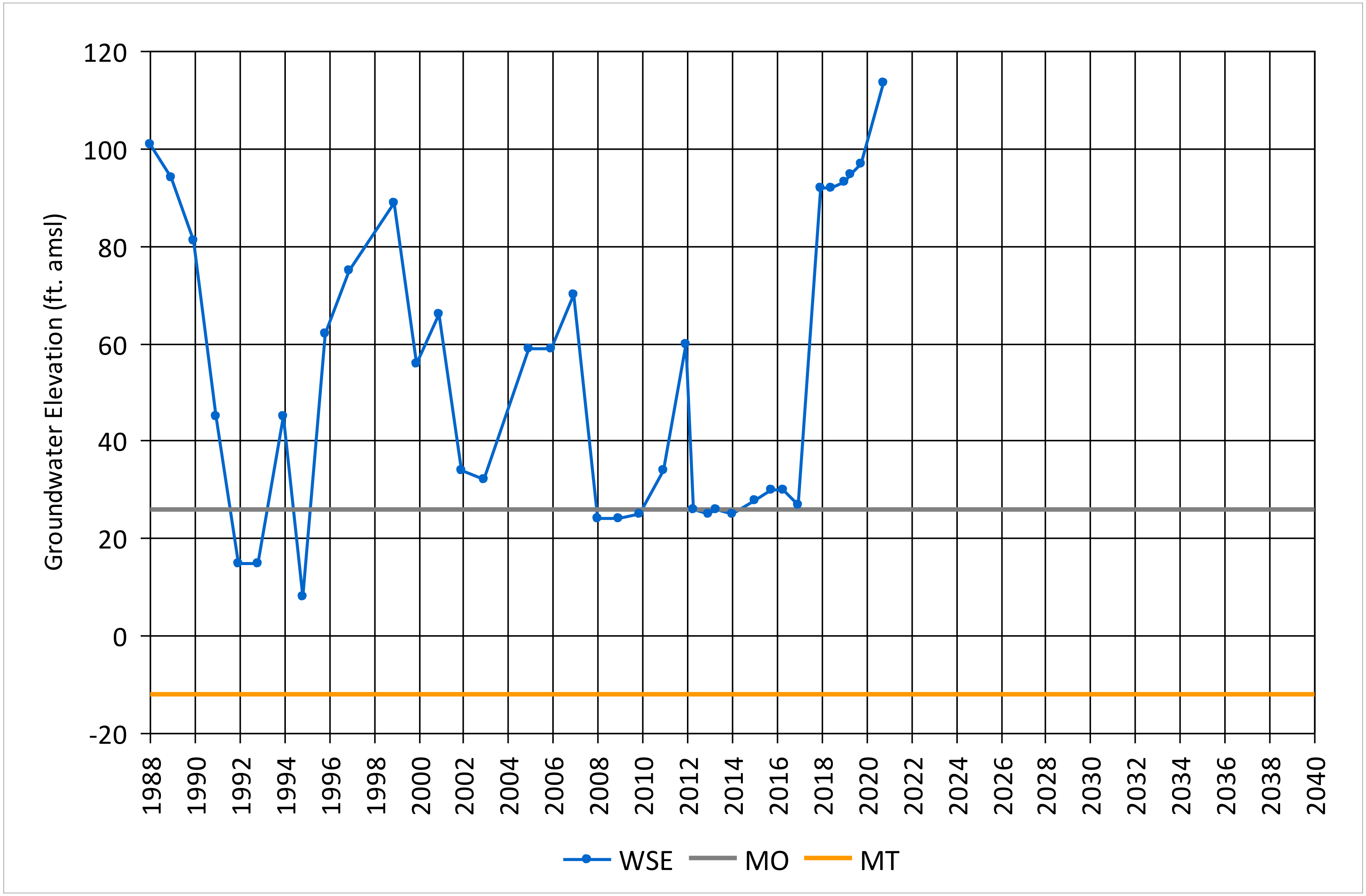
MO: 85.2 MT: -29
Depth: 630 ft



Aquifer: Upper
Perforations: 342-643 ft

18S/18E-05K01

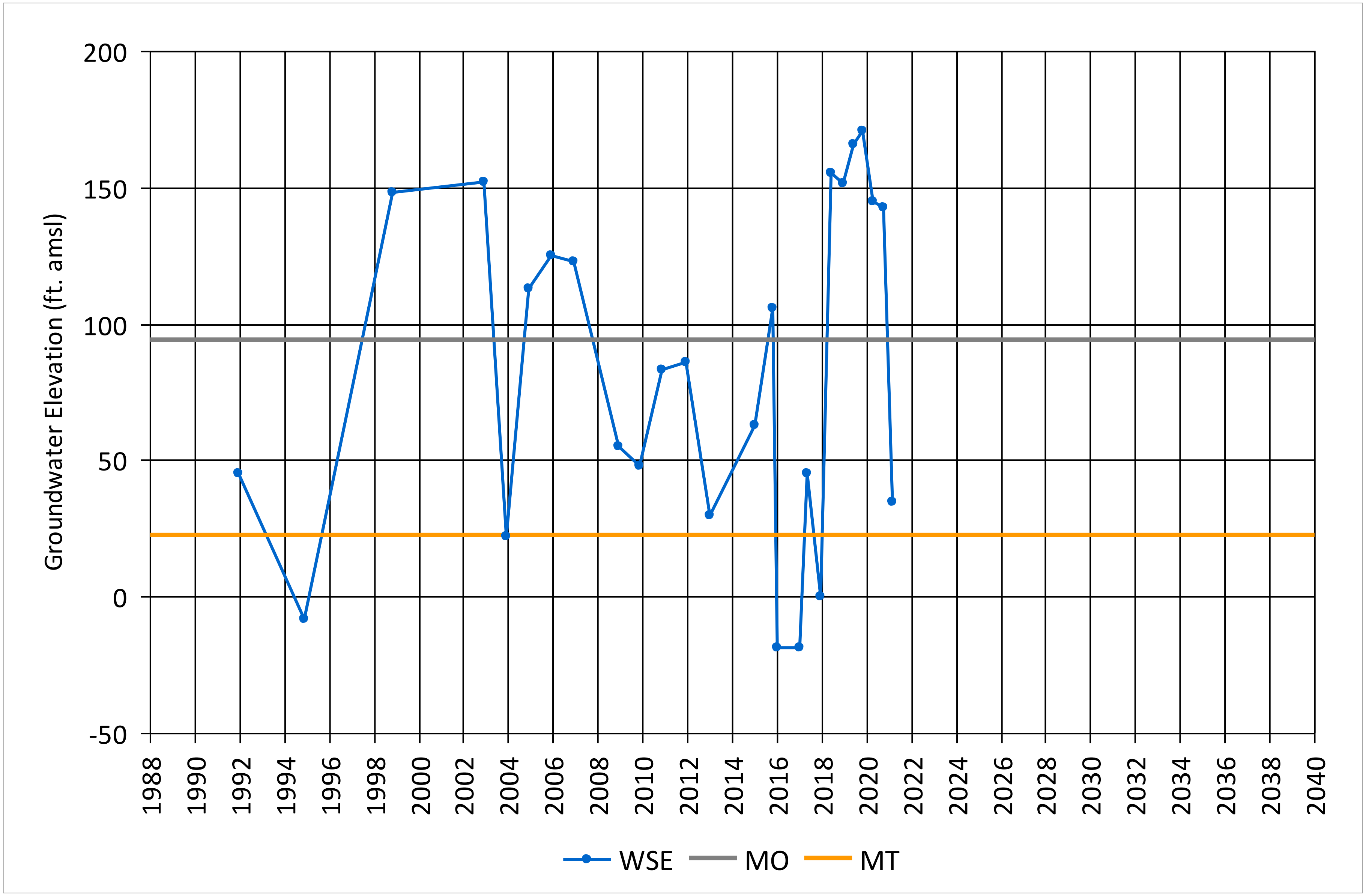
MO: 26 MT: -12.1
Depth: 652 ft



Aquifer: Upper
Perforations: 300-660 ft

18S/18E-28N04

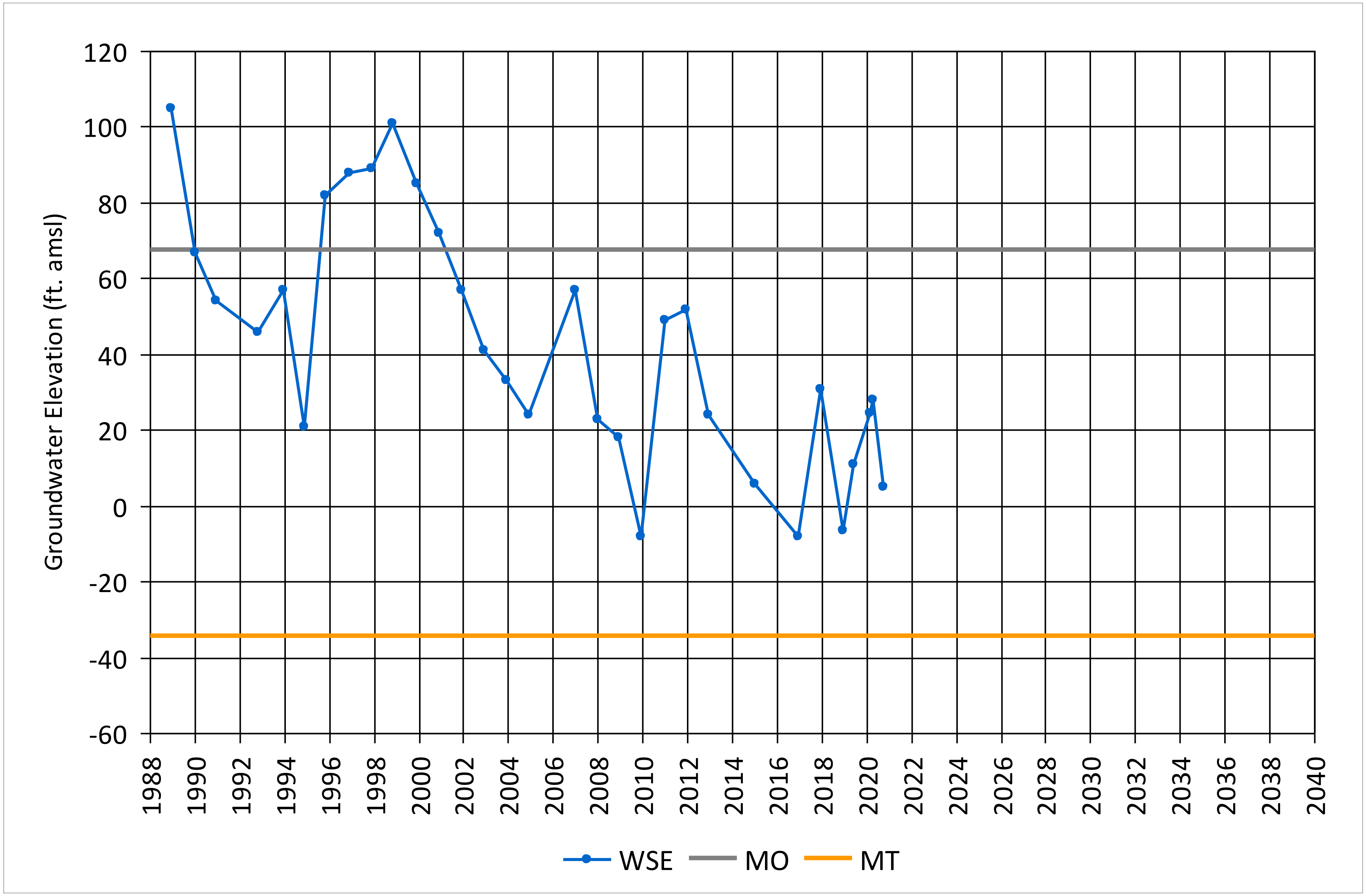
MO: 94.2 MT: 22.9
Depth: 670 ft



Aquifer: Upper
Perforations: 244-604 ft

18S/19E-20F01

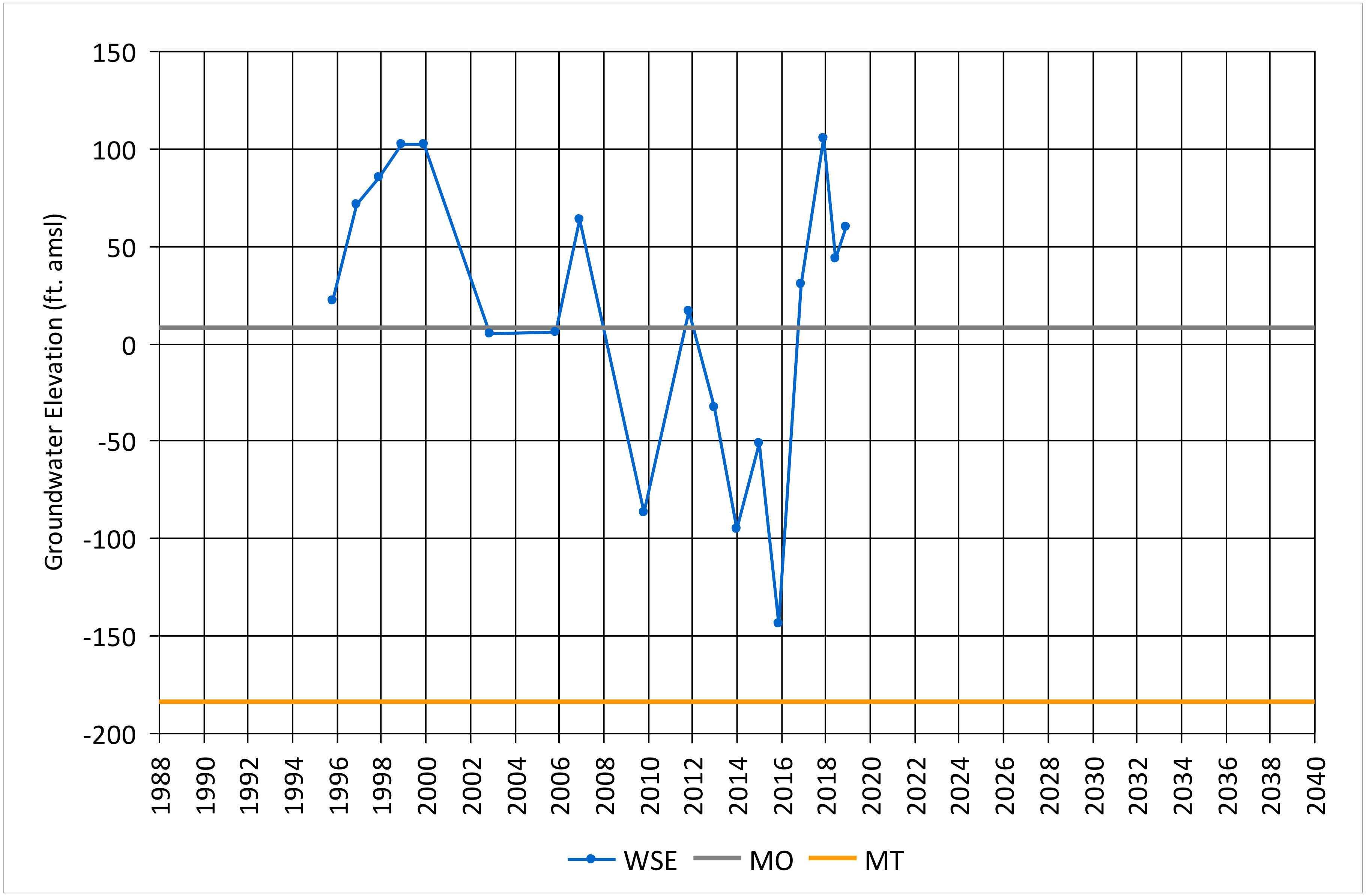
MO: 67.6 MT: -34.1
Depth: 604 ft



Aquifer: Upper
Perforations: ft

19S/18E-34N04

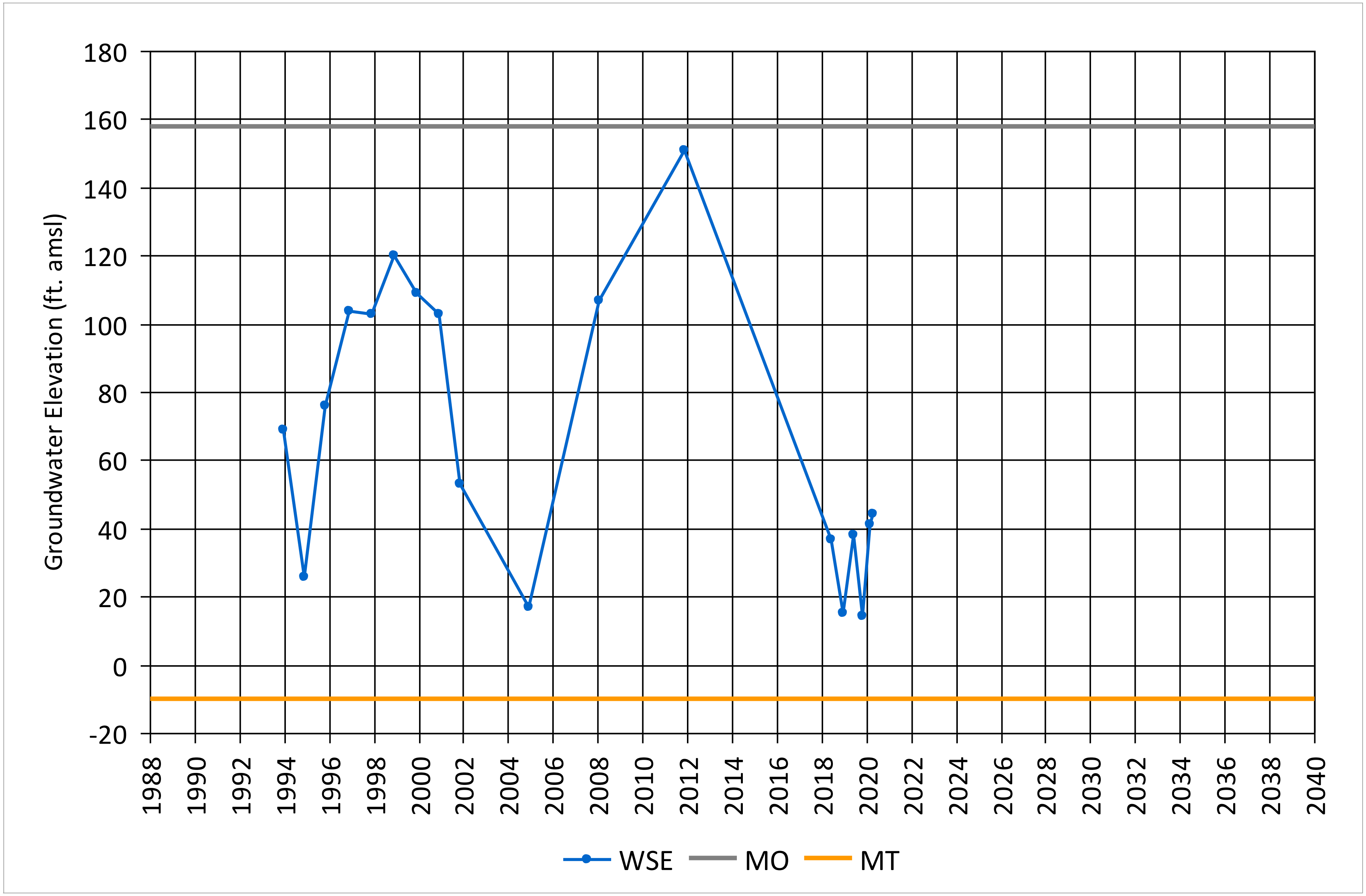
MO: 8
MT: -184.1
Depth: 0 ft



Aquifer: Upper
Perforations: 300-620 ft

19S/19E-08N04

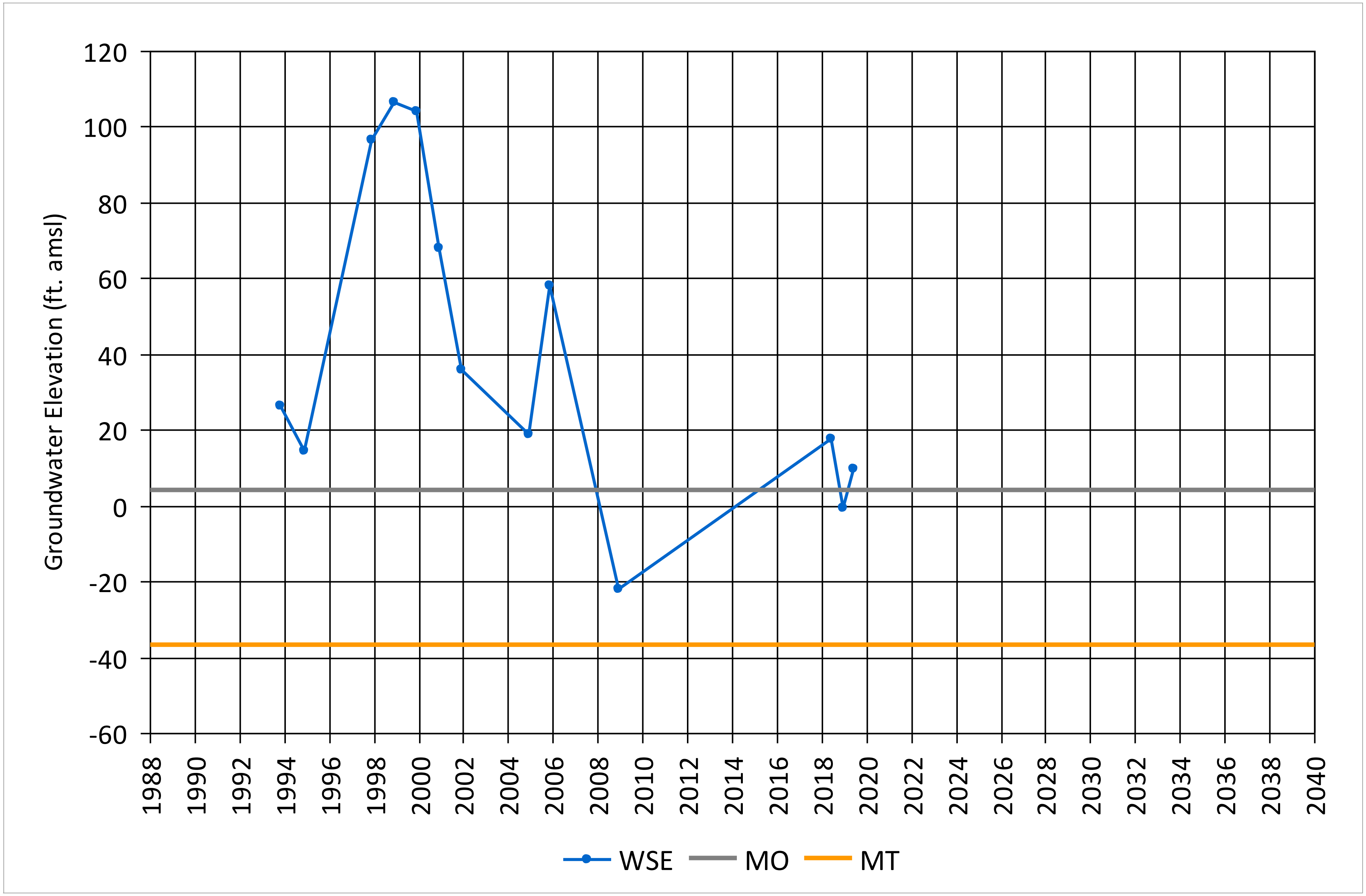
MO: 158 MT: -10
Depth: 620 ft



Aquifer: Upper
Perforations: 300-580 ft

19S/19E-26D02

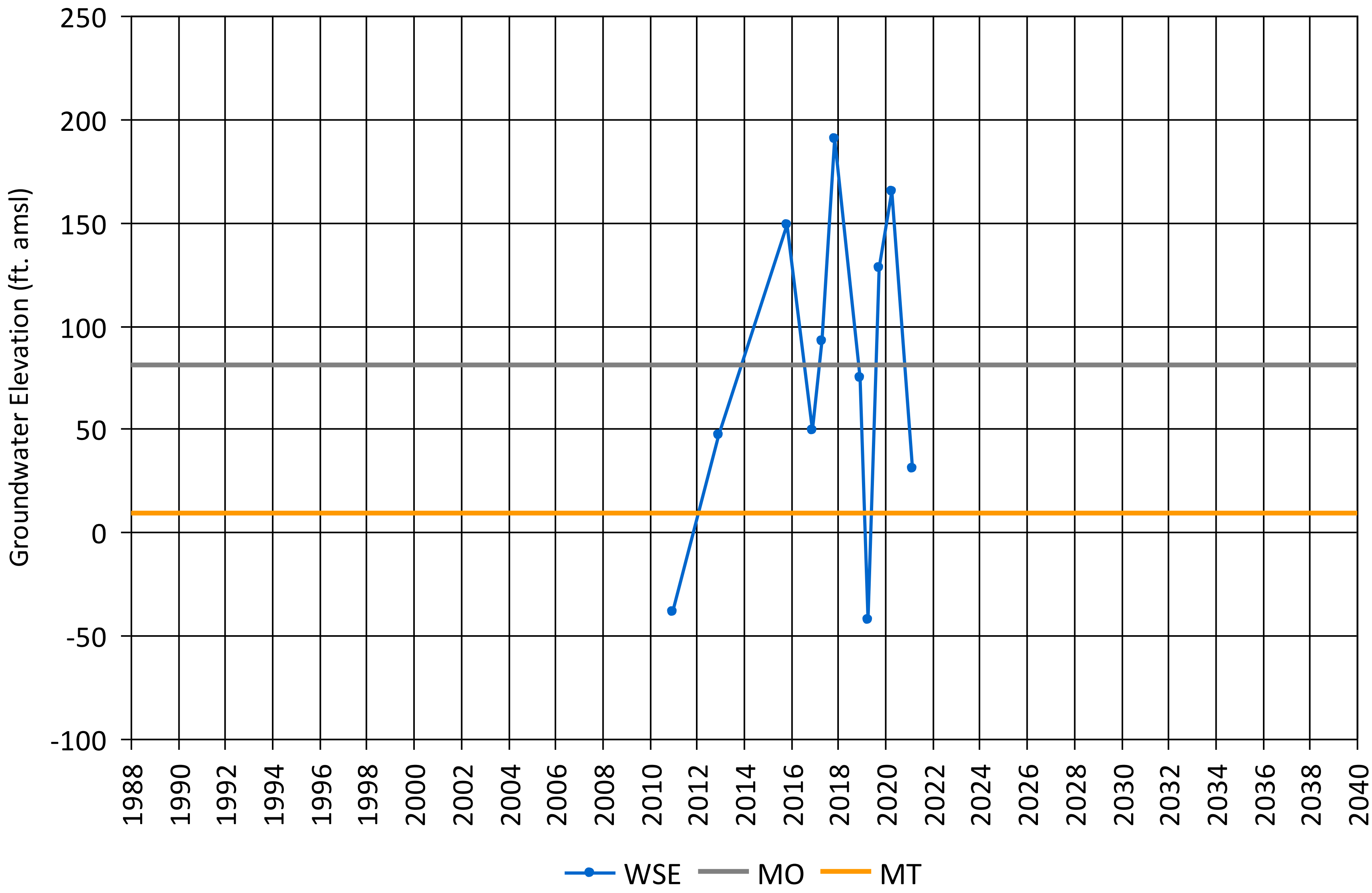
MO: 4.1 MT: -36.8
Depth: 580 ft



Aquifer: Upper
Perforations: 175-670 ft

20S/19E-07G02

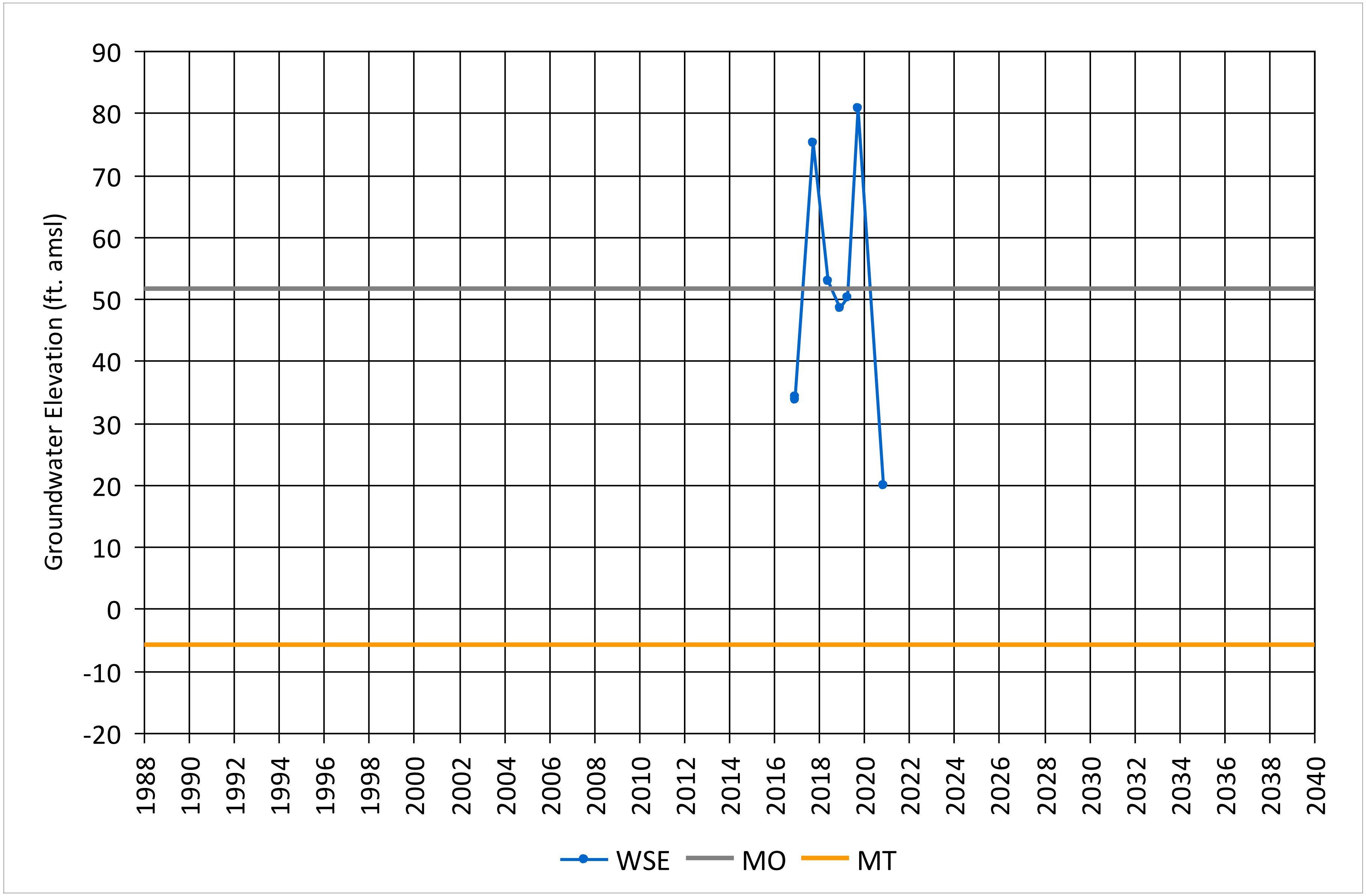
MO: 81.5 MT: 9.5
Depth: 690 ft



Aquifer: Upper
Perforations: 286-770 ft

21S/19E-07H01

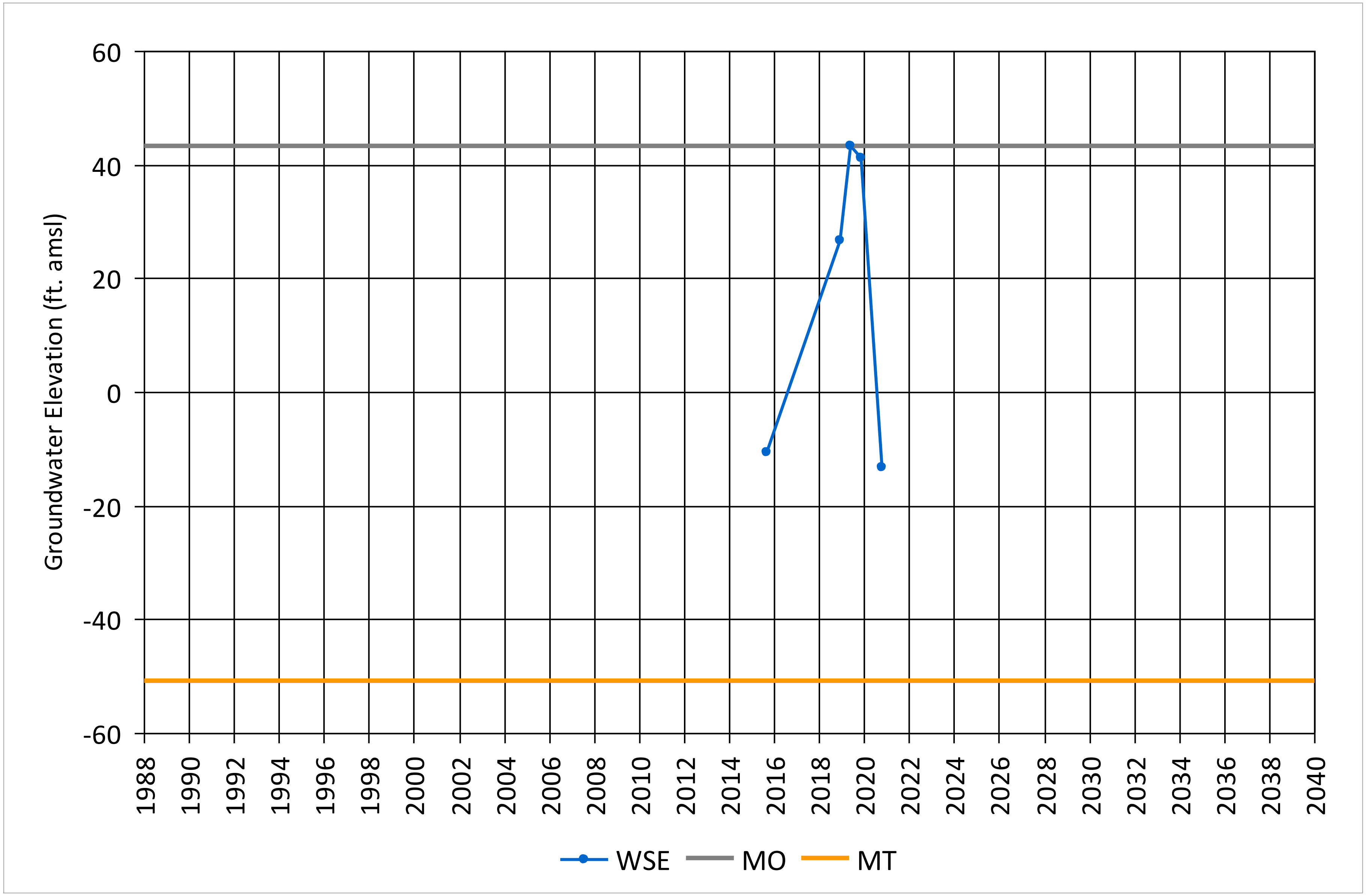
MO: 51.6 MT: -5.8
Depth: 790 ft



Aquifer: Lower
Perforations: 560-780 ft

13S/13E-24E02

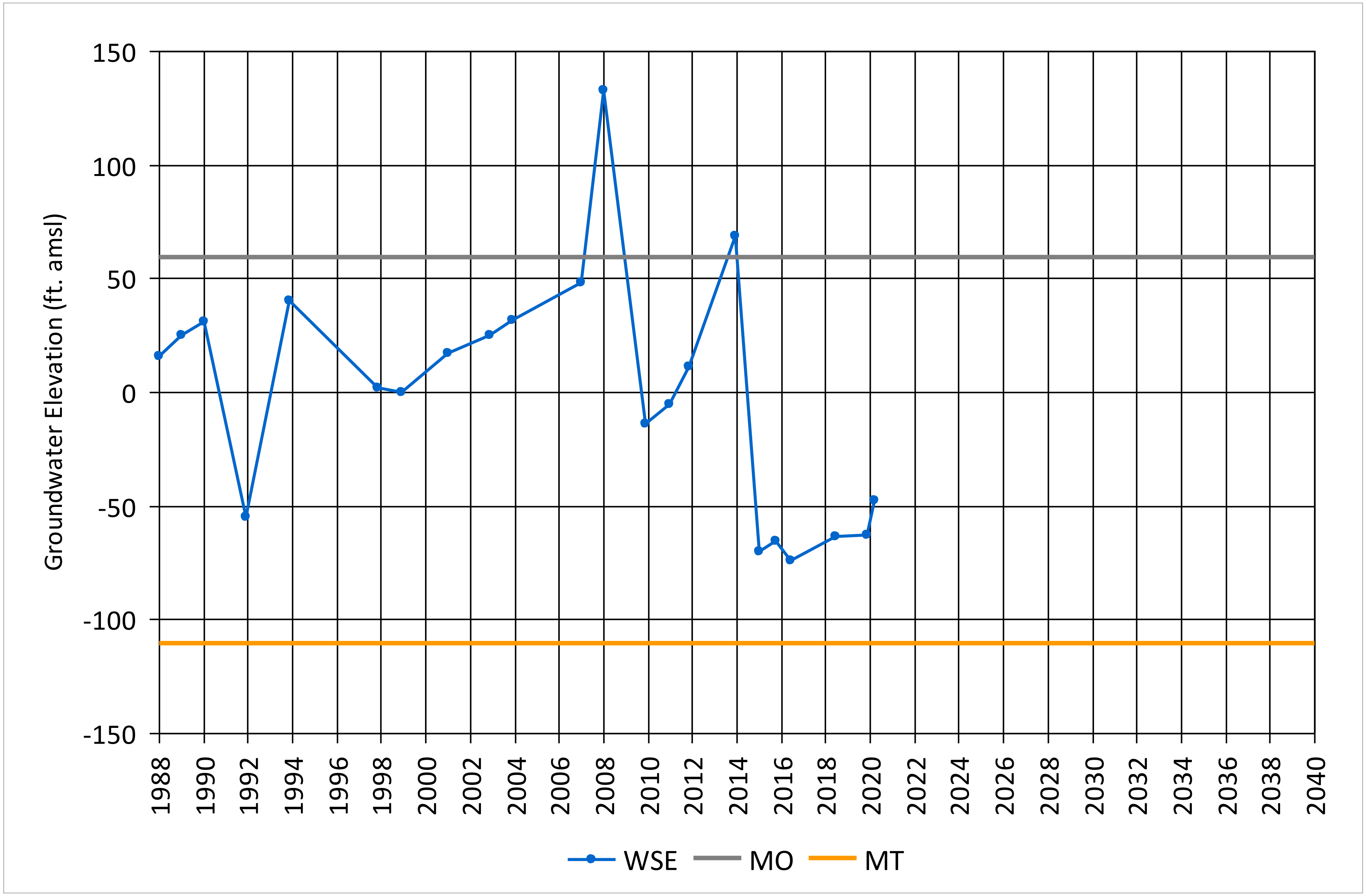
MO: 43.4 MT: -50.7
Depth: 860 ft



Aquifer: Lower
Perforations: 654-1035 ft

14S/12E-35J01

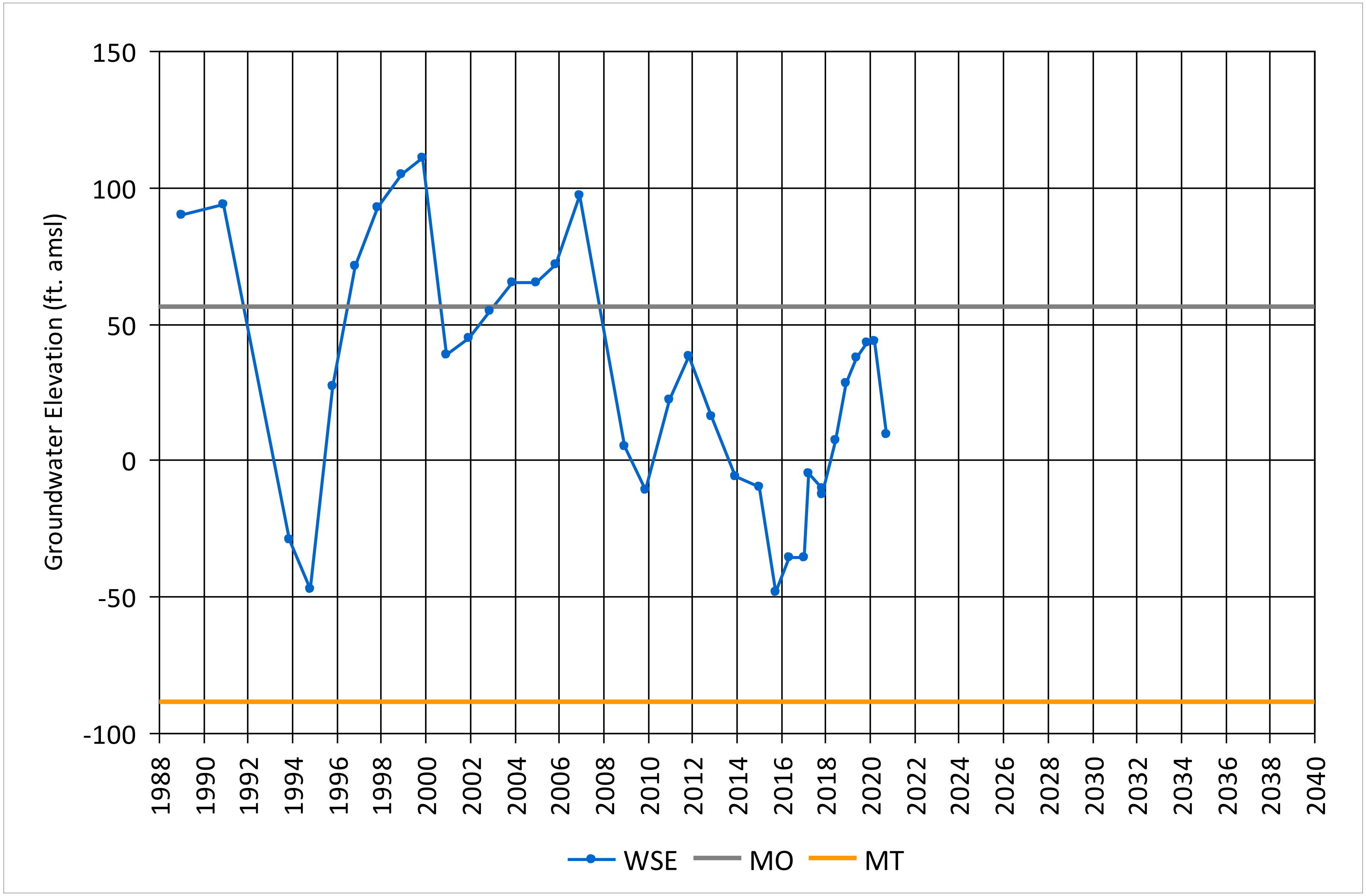
MO: 59.3 MT: -110.2
Depth: 1035 ft



Aquifer: Lower
Perforations: 702-1214 ft

14S/13E-06P02

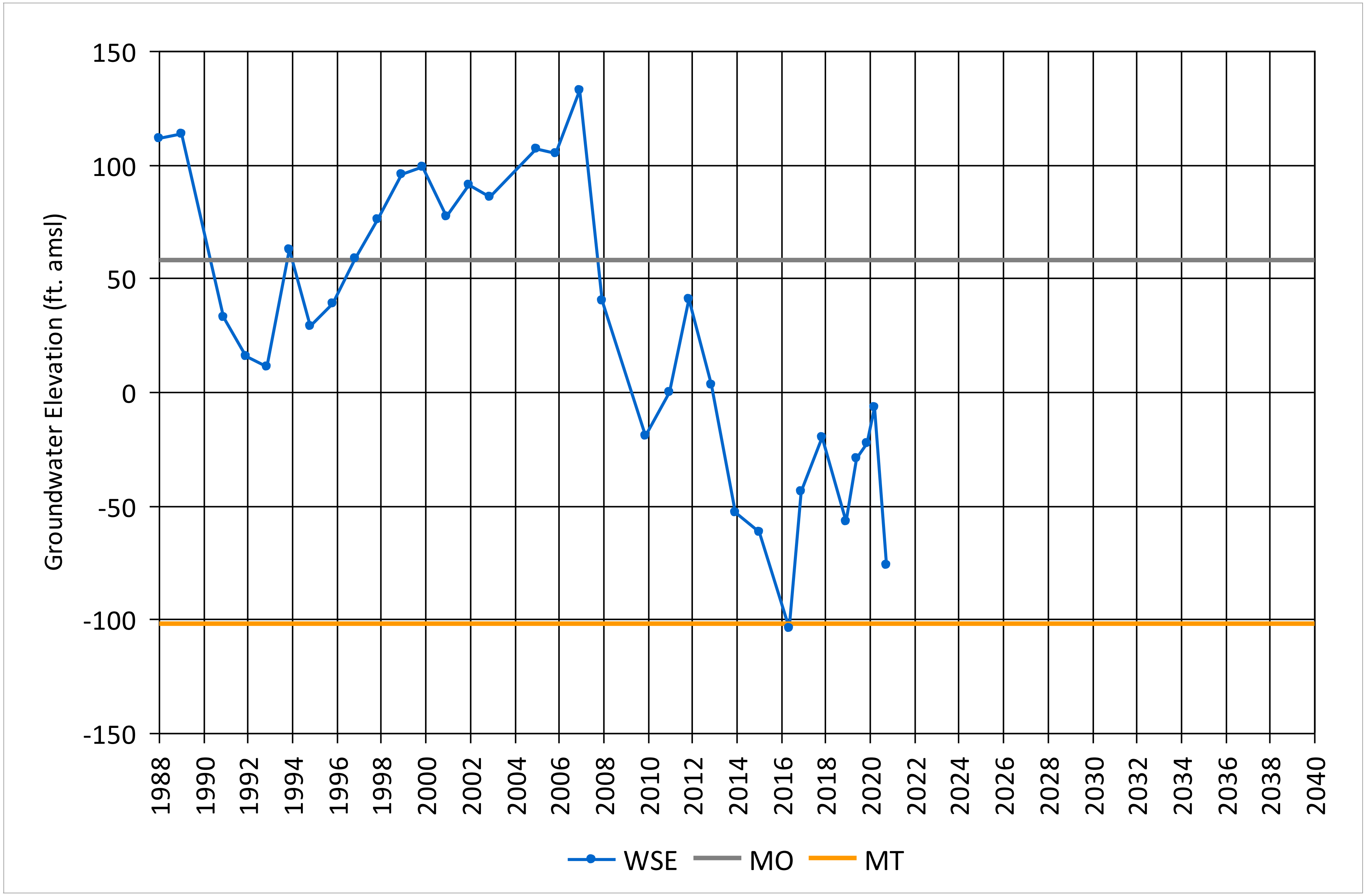
MO: 56.2 MT: -88.5
Depth: 1214 ft



Aquifer: Lower
Perforations: 700-1400 ft

14S/13E-12P01

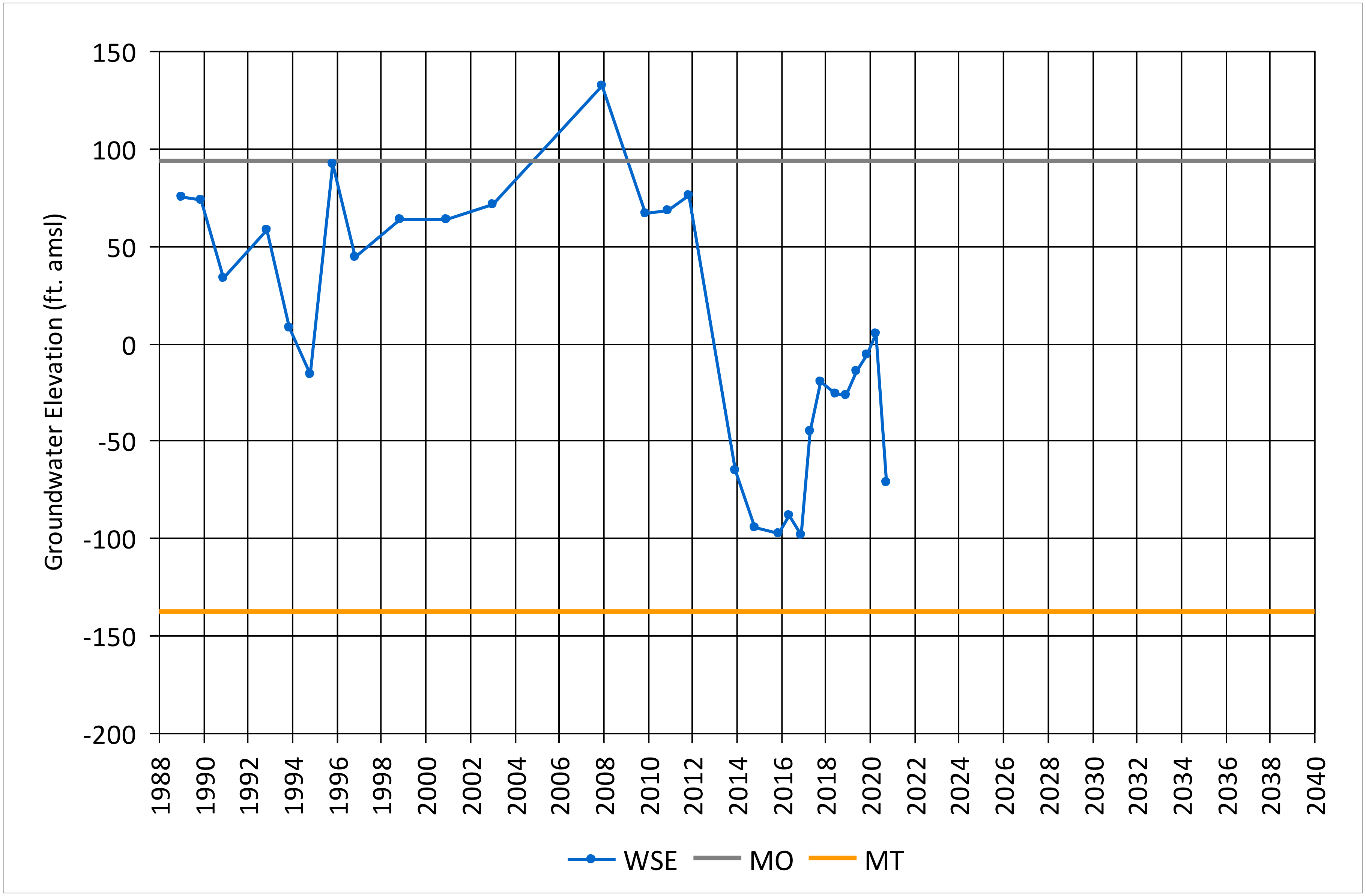
MO: 57.9 MT: -101.5
Depth: 1520 ft



Aquifer: Lower
Perforations: 544-986 ft

14S/15E-32N02

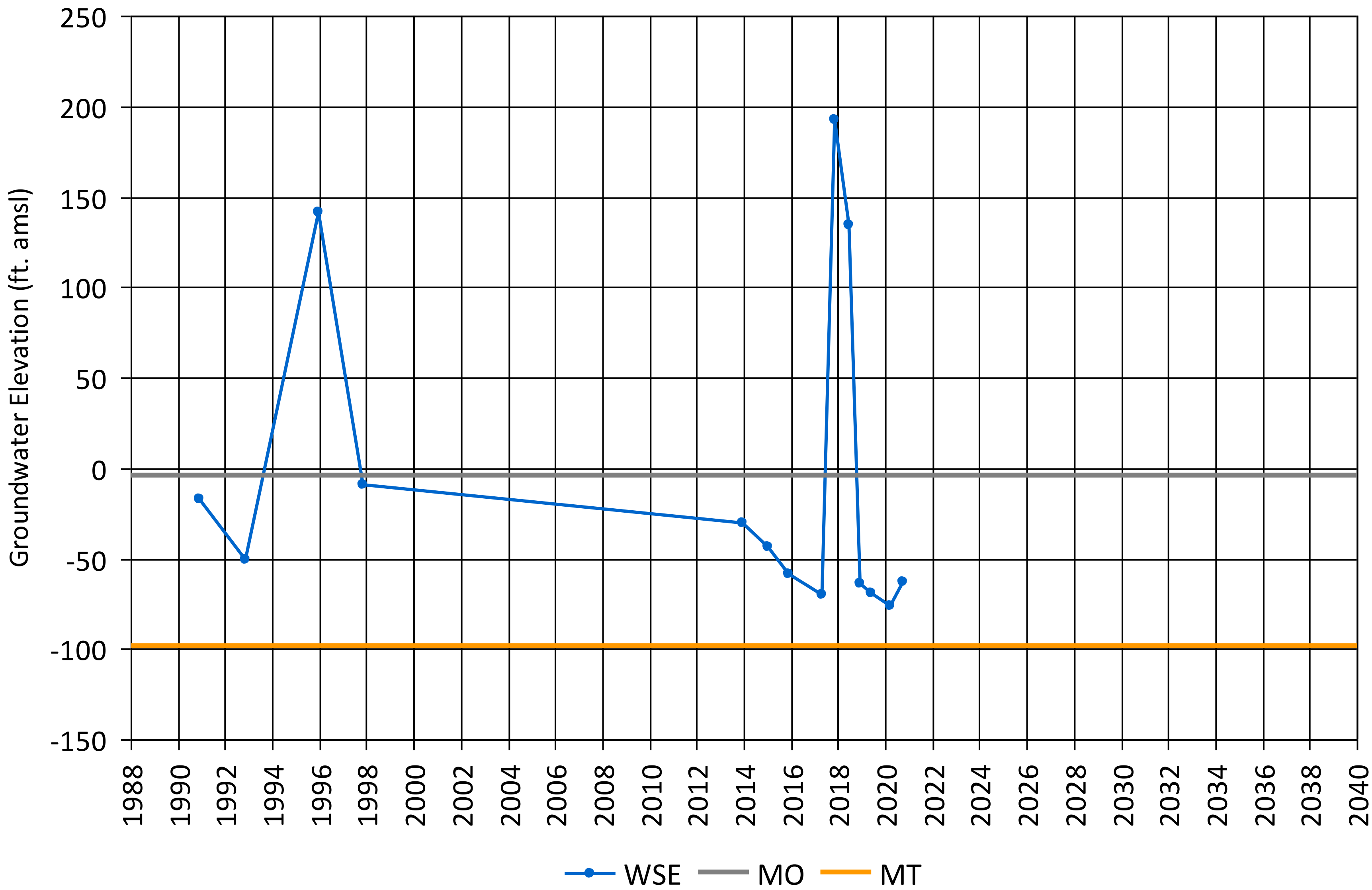
MO: 93.9 MT: -137.5
Depth: 986 ft



Aquifer: Lower
Perforations: 698-998 ft

15S/12E-13D01

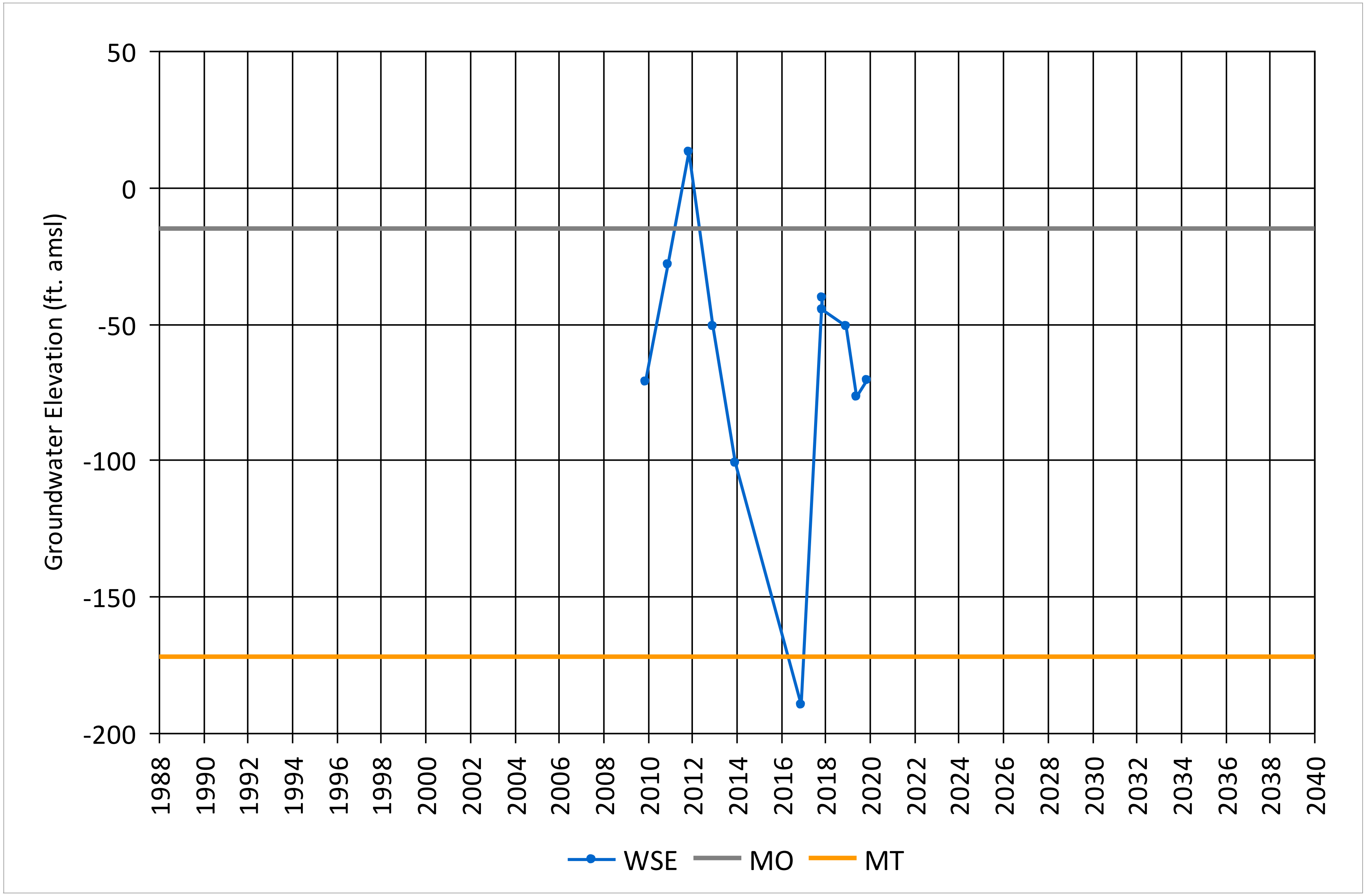
MO: -3.4 MT: -98.2
Depth: 998 ft



Aquifer: Lower
Perforations: 884-1244 ft

15S/13E-02P01

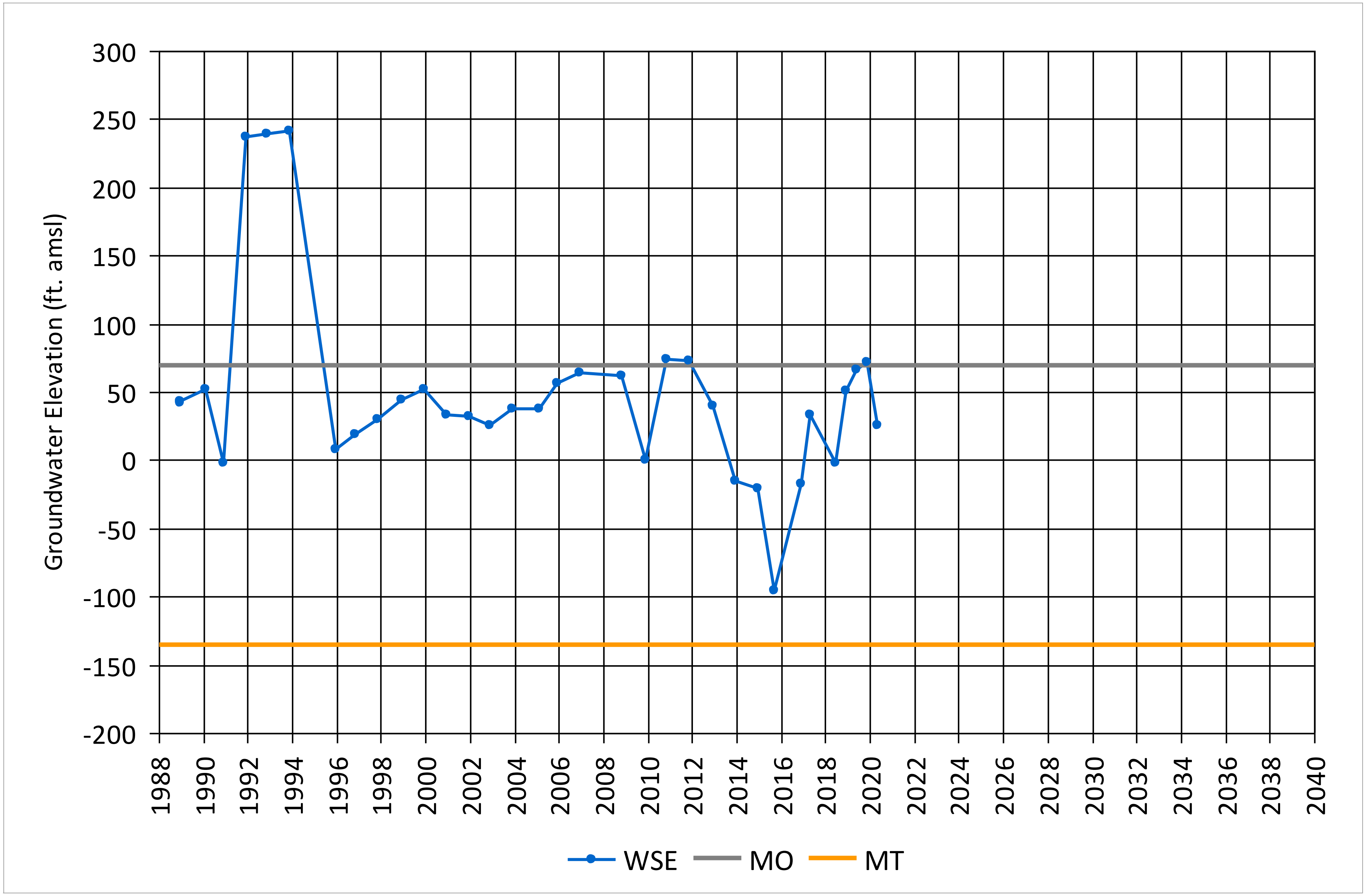
MO: -14.9 MT: -172
Depth: 1244 ft



Aquifer: Lower
Perforations: 917-1849 ft

15S/13E-24N01

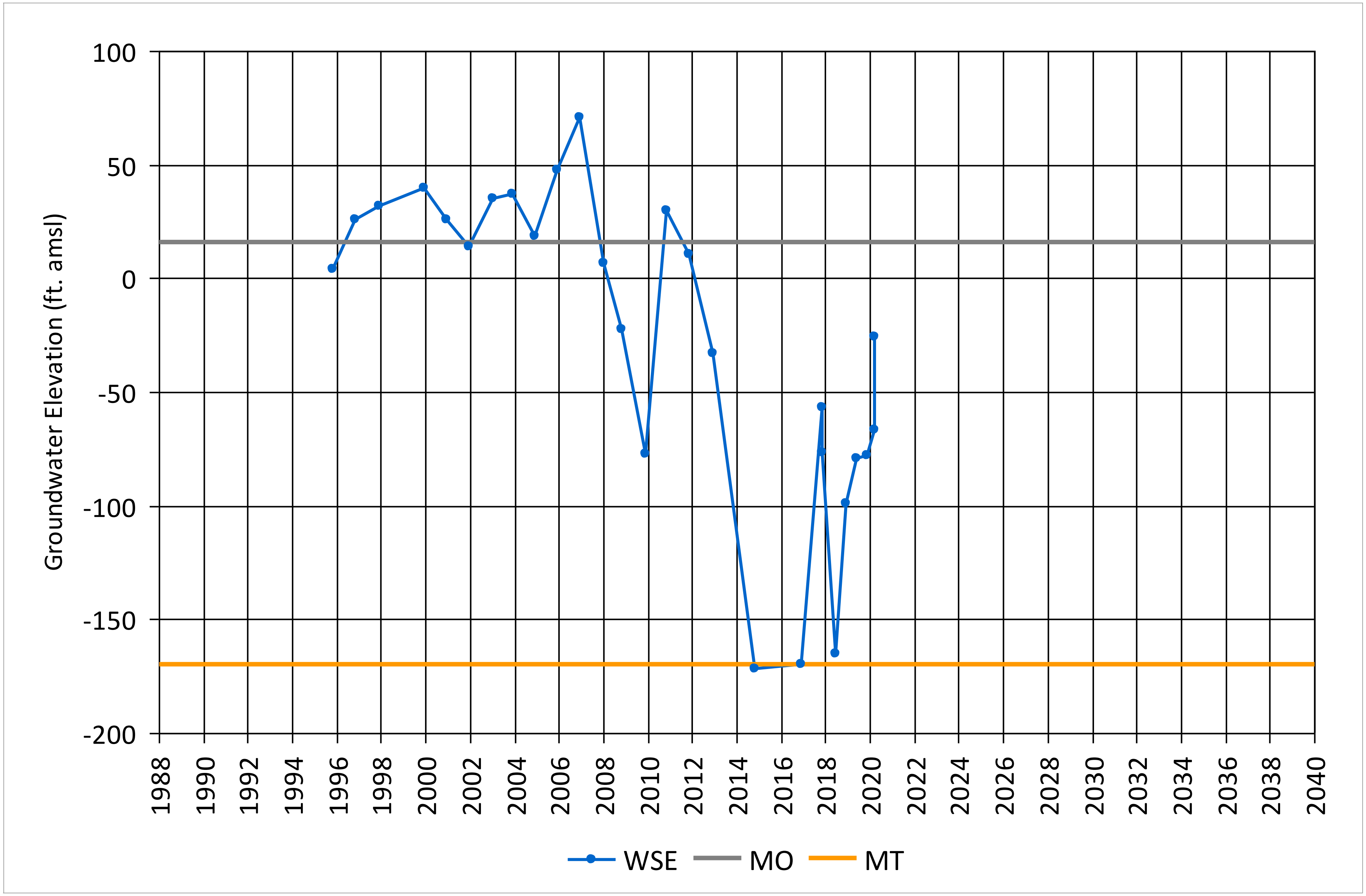
MO: 70.2 MT: -135.3
Depth: 1849 ft



Aquifer: Lower
Perforations: 865-1265 ft

15S/14E-19Q01

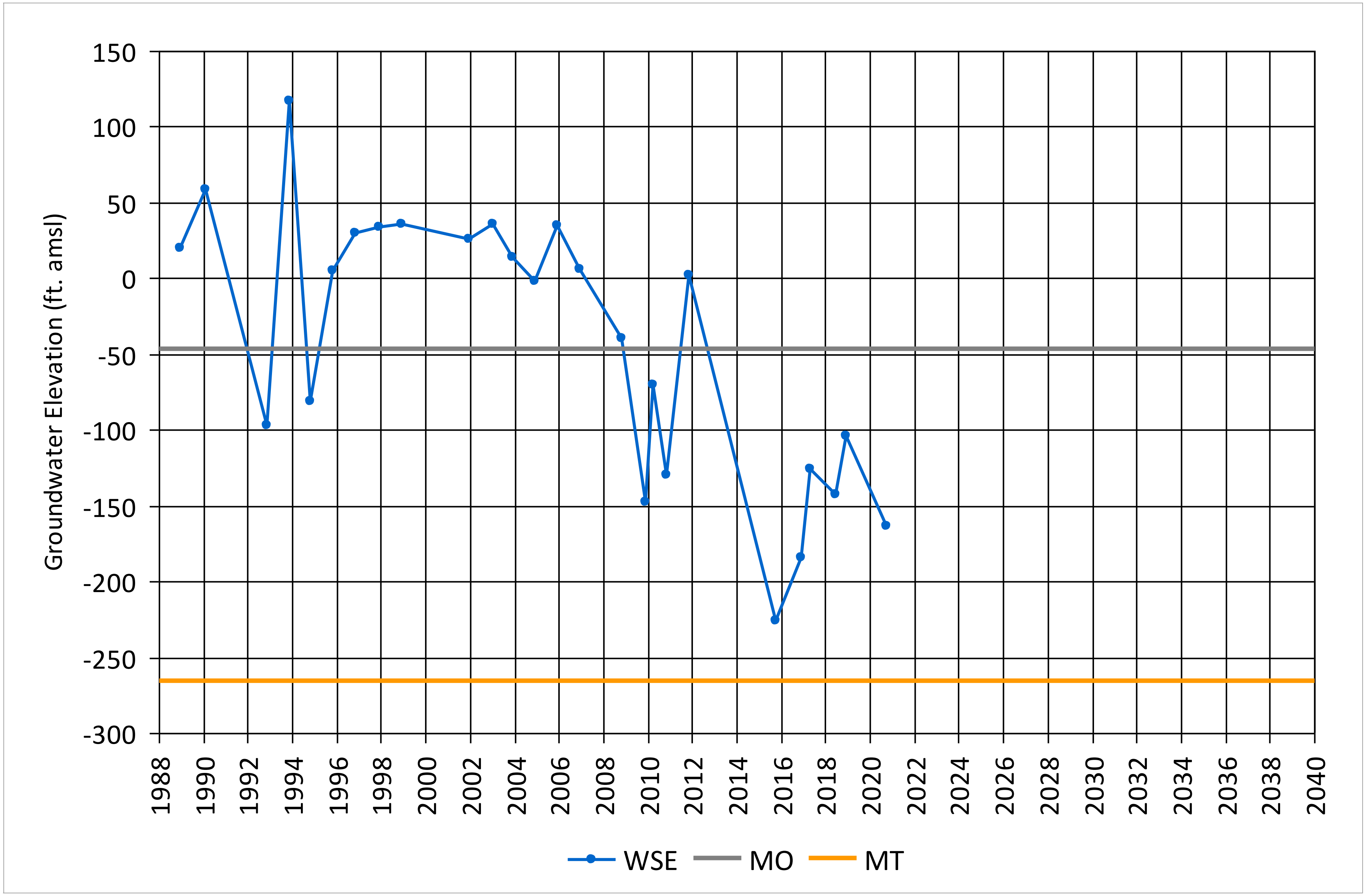
MO: 15.9 MT: -169.4
Depth: 1265 ft



Aquifer: Lower
Perforations: 700-1500 ft

15S/14E-26N02

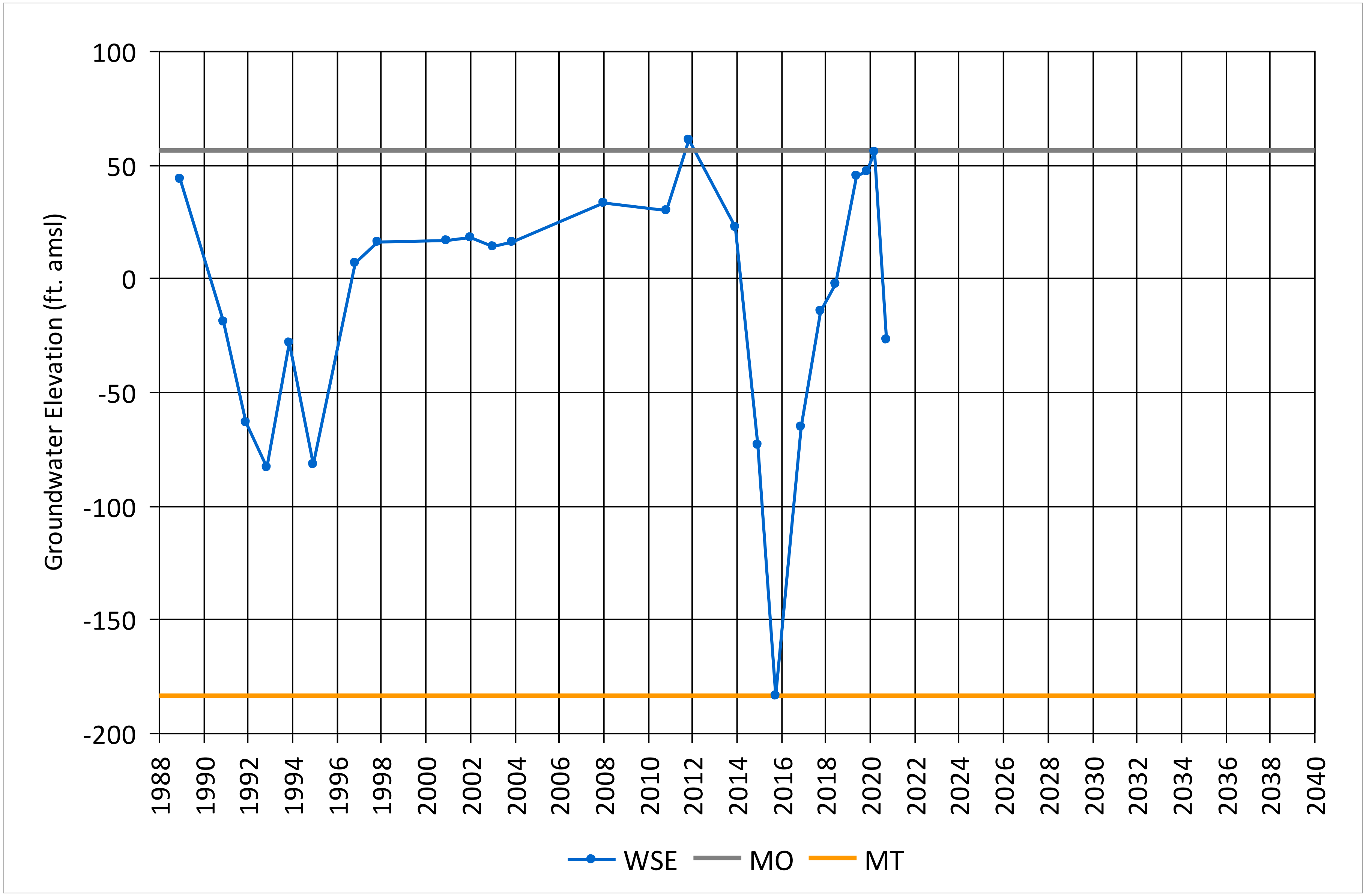
MO: -45.8 MT: -265.3
Depth: 1500 ft



Aquifer: Lower
Perforations: 915-1800 ft

15S/14E-31N03

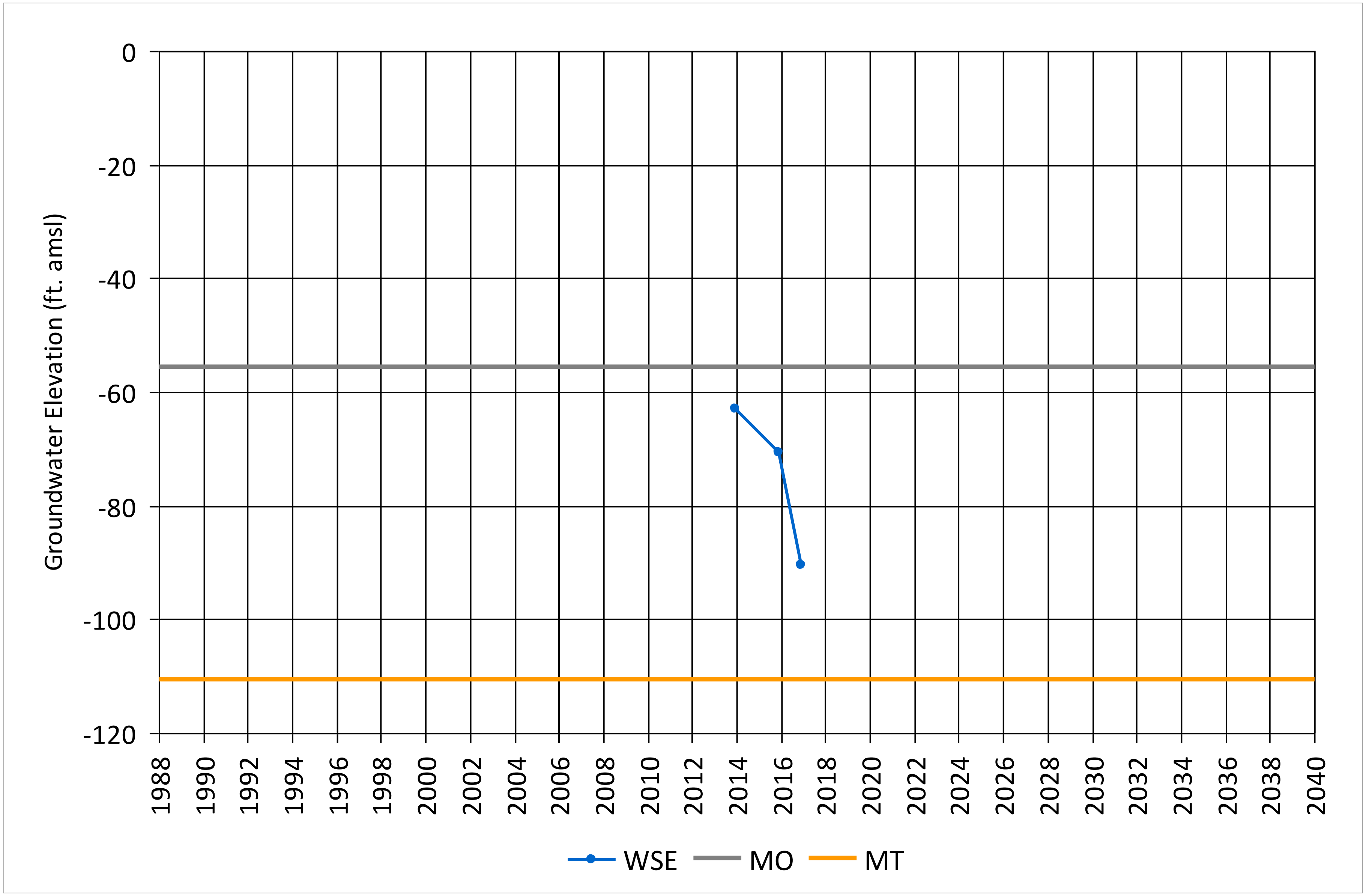
MO: 56.7 MT: -183.2
Depth: 1918 ft



Aquifer: Lower
Perforations: 600-1000 ft

15S/15E-04A03

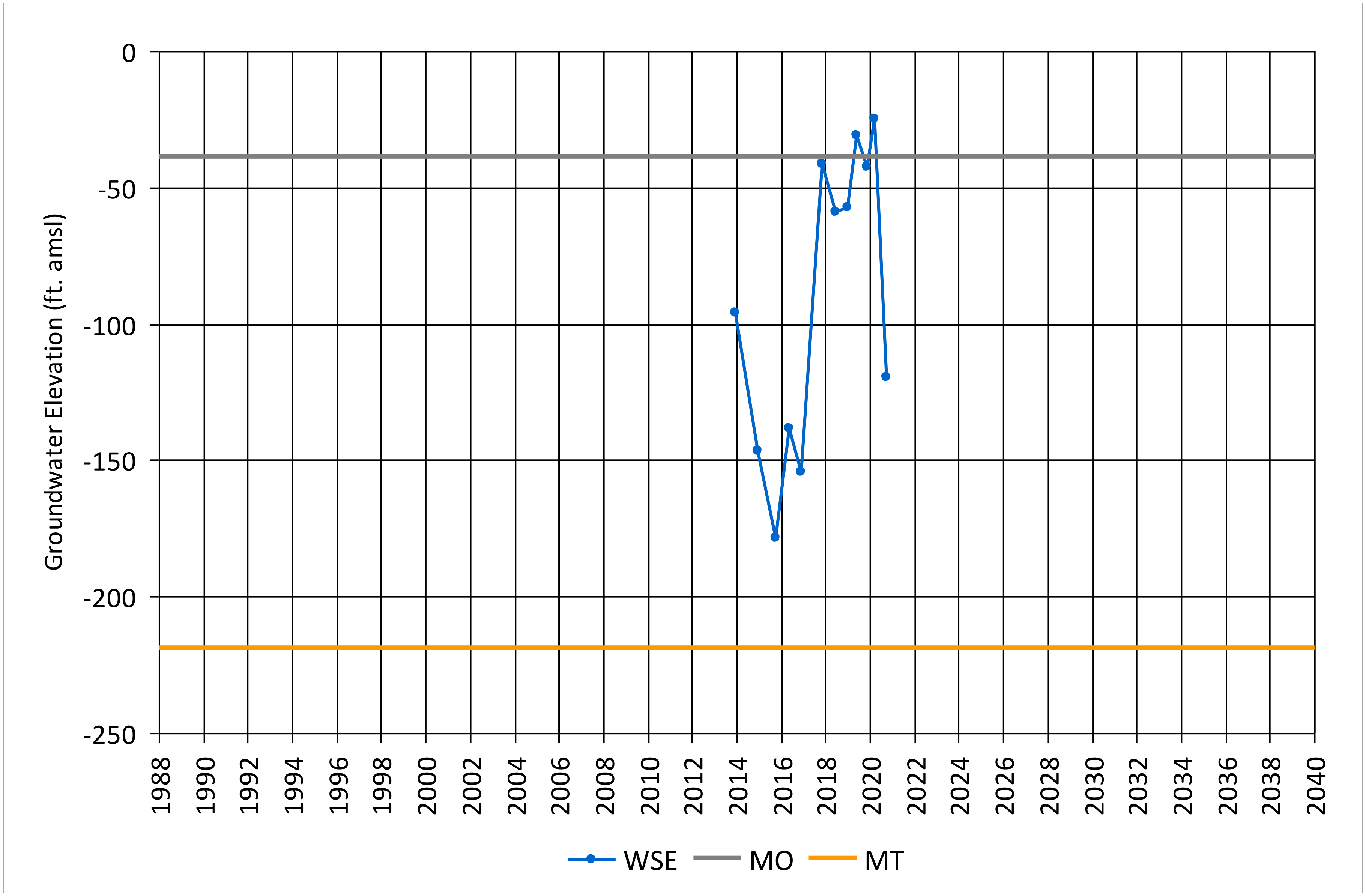
MO: -55.5 MT: -110.5
Depth: 1000 ft



Aquifer: Lower
Perforations: 600-1162 ft

15S/15E-29K01

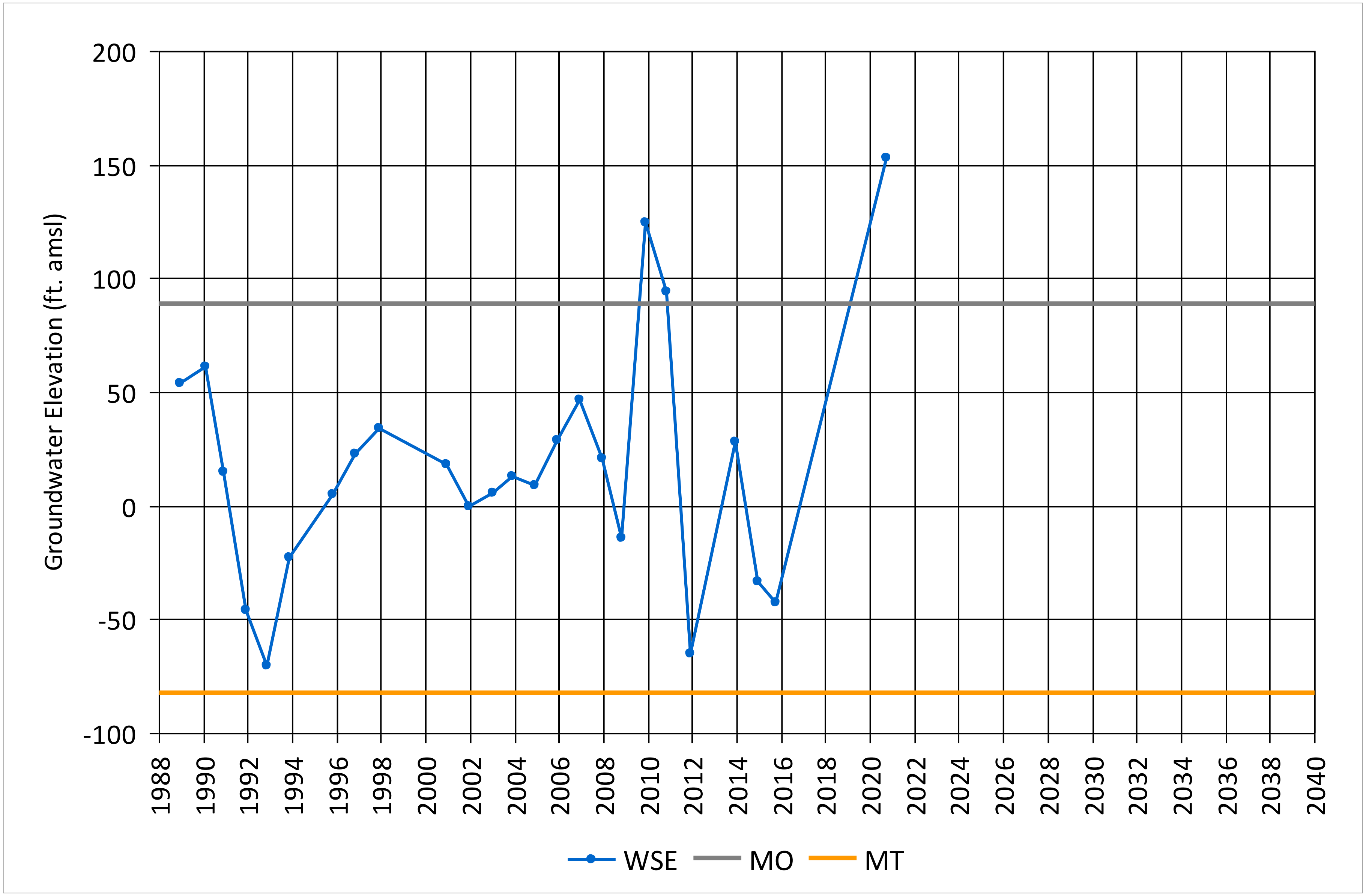
MO: -38.4 MT: -218.4
Depth: 1162 ft



Aquifer: Lower
Perforations: 718-2018 ft

16S/14E-03H01

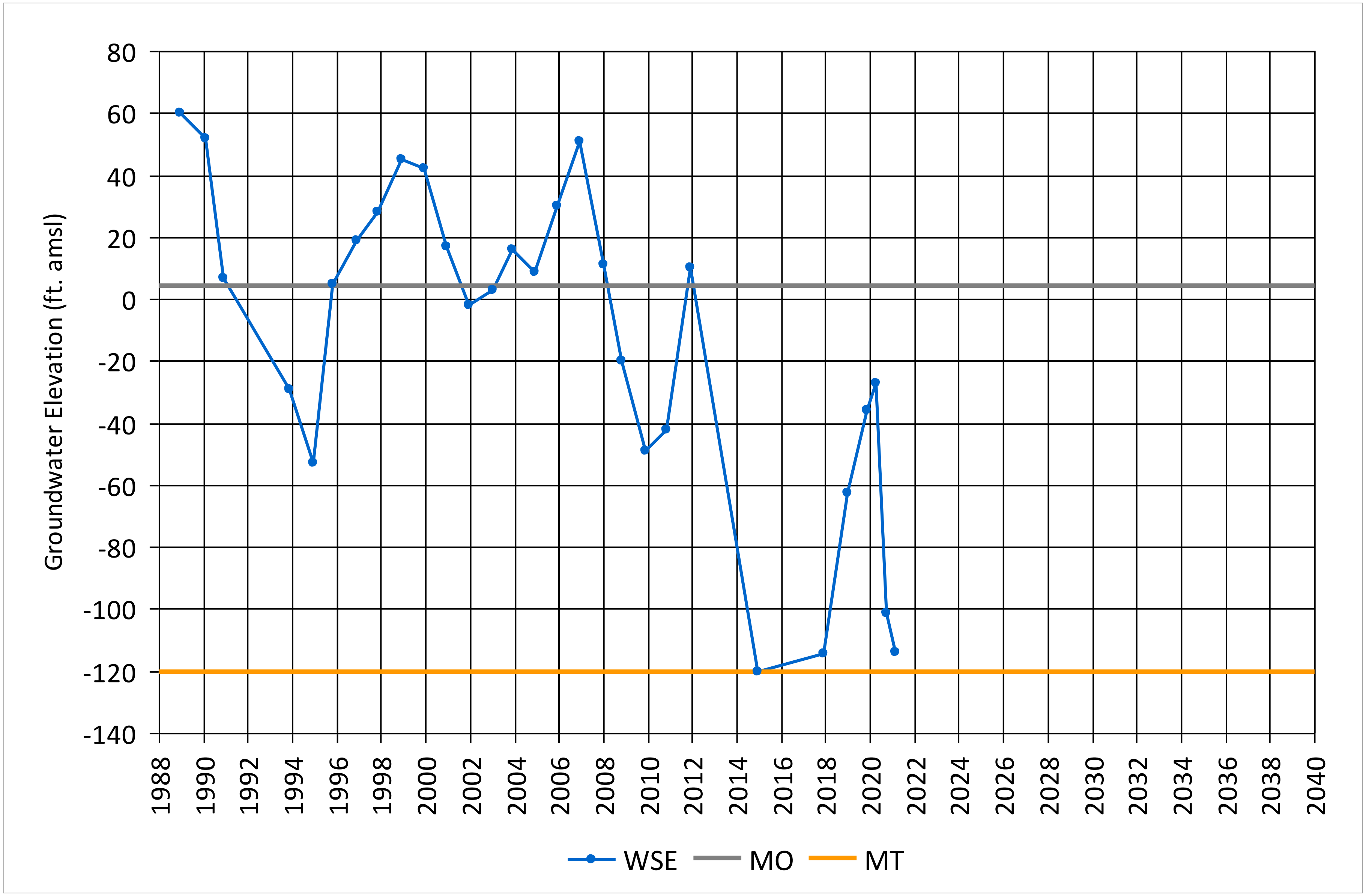
MO: 88.8 MT: -82.3
Depth: 2018 ft



Aquifer: Lower
Perforations: 1000-2803 f

16S/14E-14F01

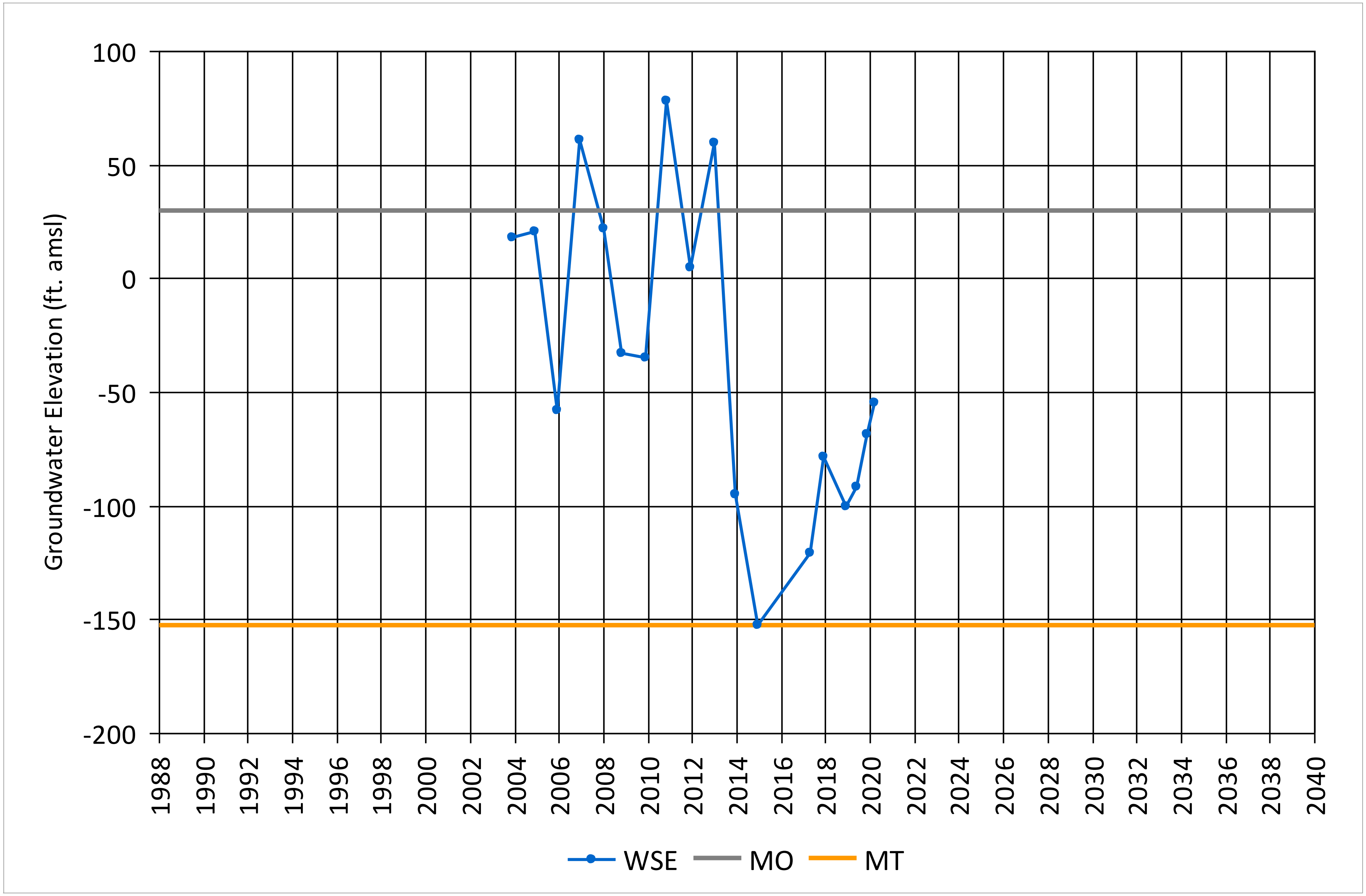
MO: 4.6 MT: -120.2
Depth: 2803 ft



Aquifer: Lower
Perforations: 930-2210 ft

16S/14E-17A01

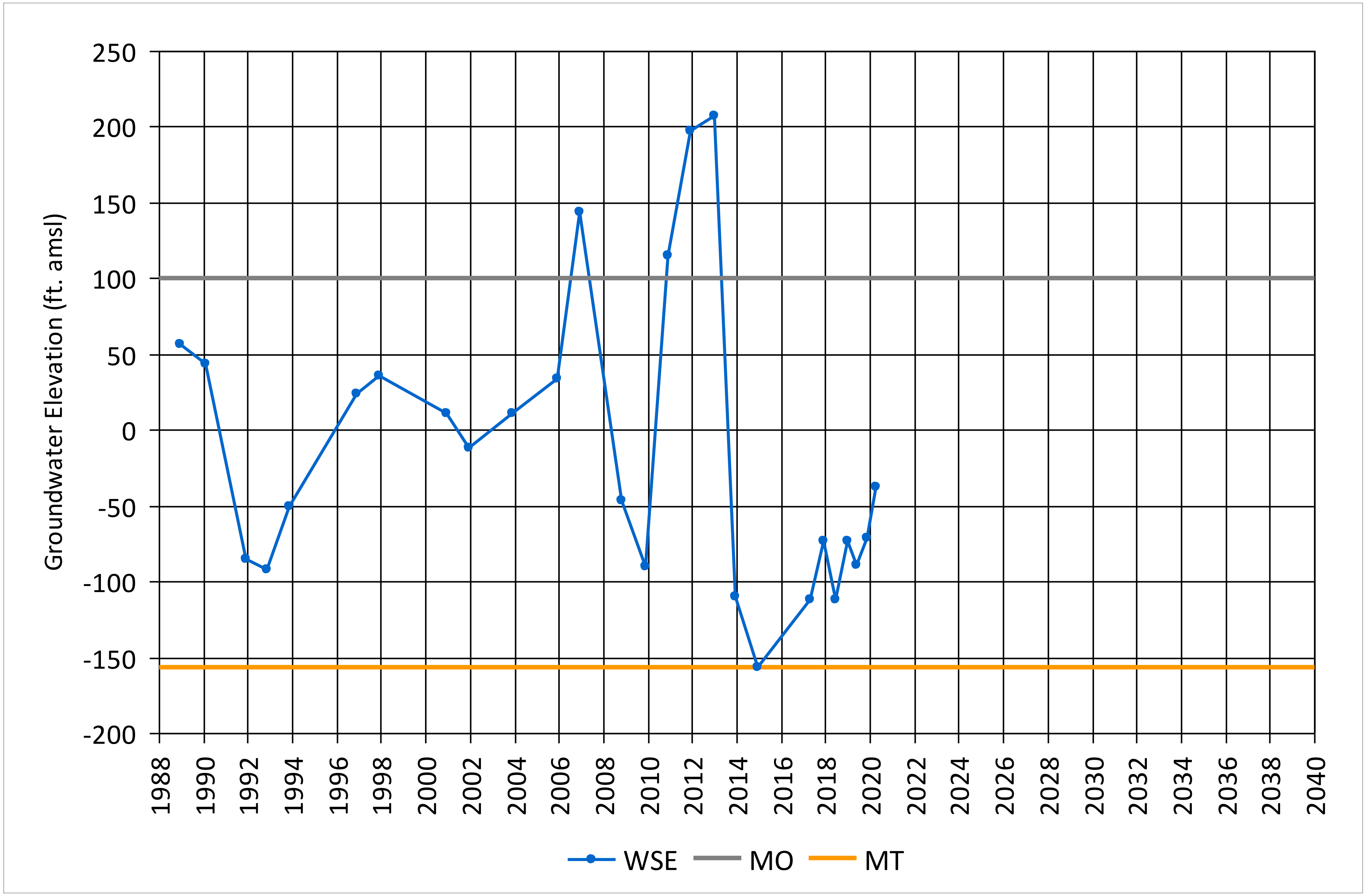
MO: 29.7 MT: -152.1
Depth: 2230 ft



Aquifer: Lower
Perforations: 841-2104 ft

16S/14E-36E01

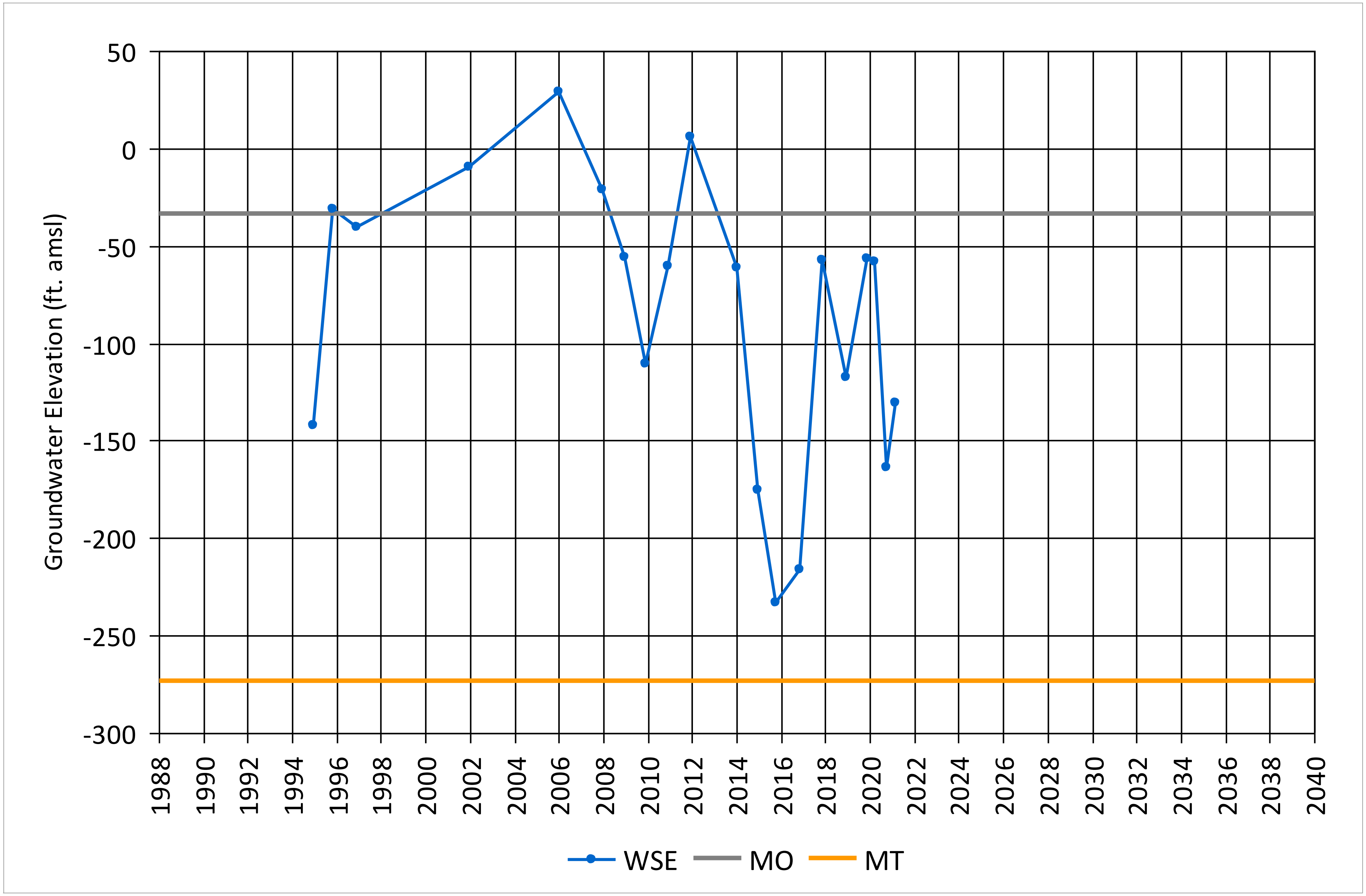
MO: 100 MT: -156.1
Depth: 2200 ft



Aquifer: Lower
Perforations: 840-1200 ft

16S/15E-16E01

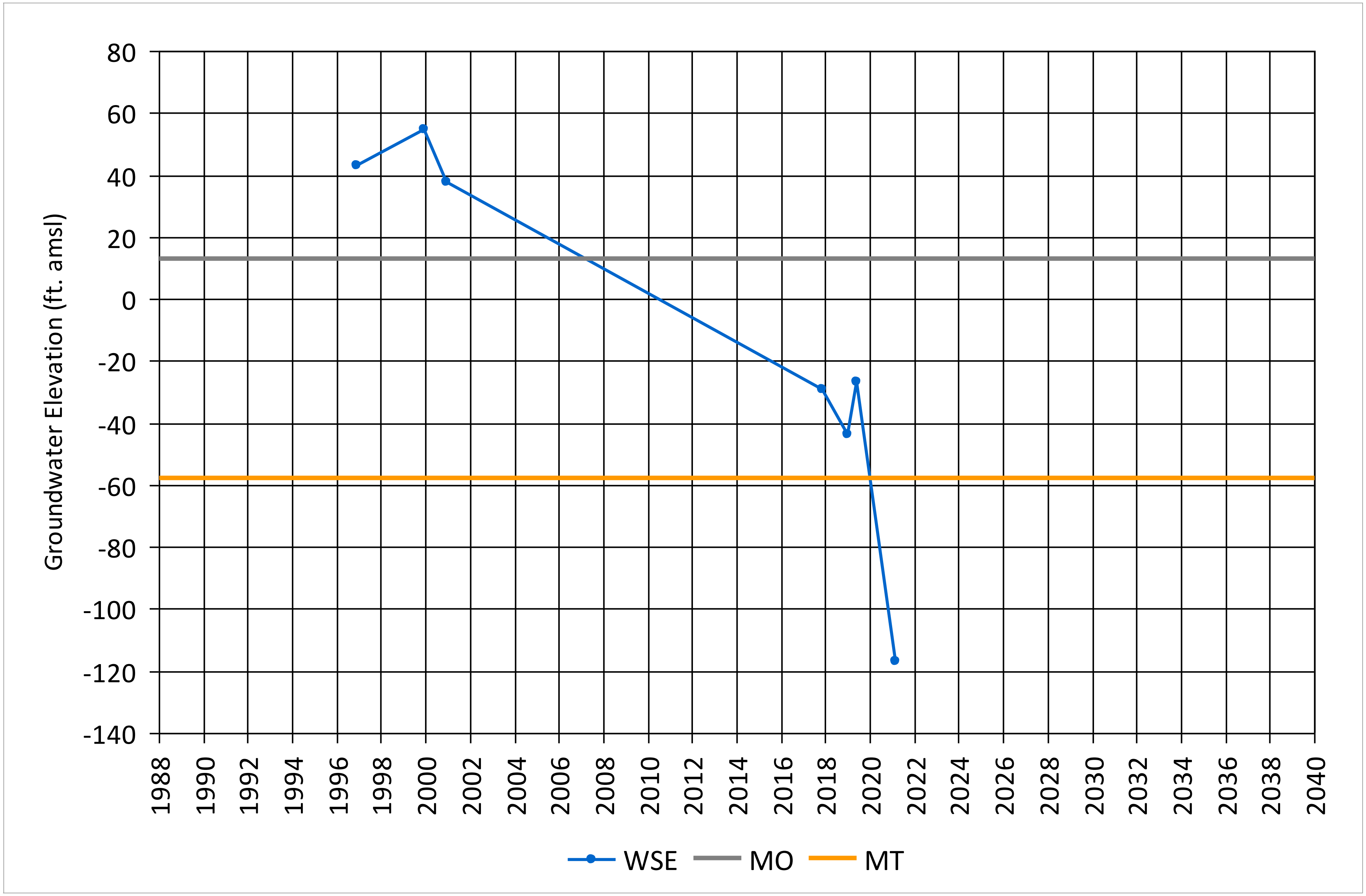
MO: -33.3 MT: -273.3
Depth: 1200 ft



Aquifer: Lower
Perforations: 618-1218 ft

16S/15E-32A06

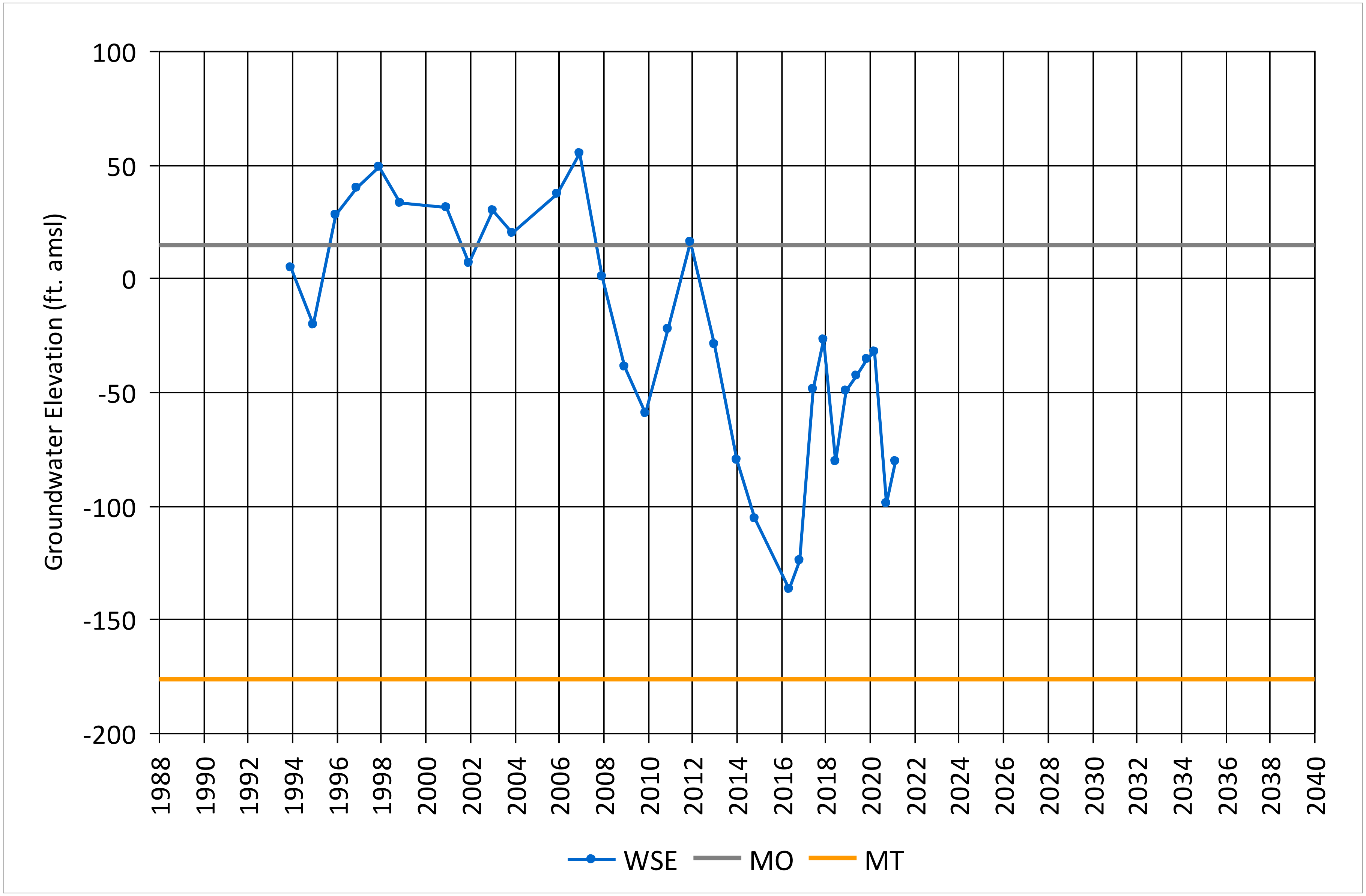
MO: 13 MT: -57.4
Depth: 1218 ft



Aquifer: Lower
Perforations: 645-945 ft

16S/16E-10Q01

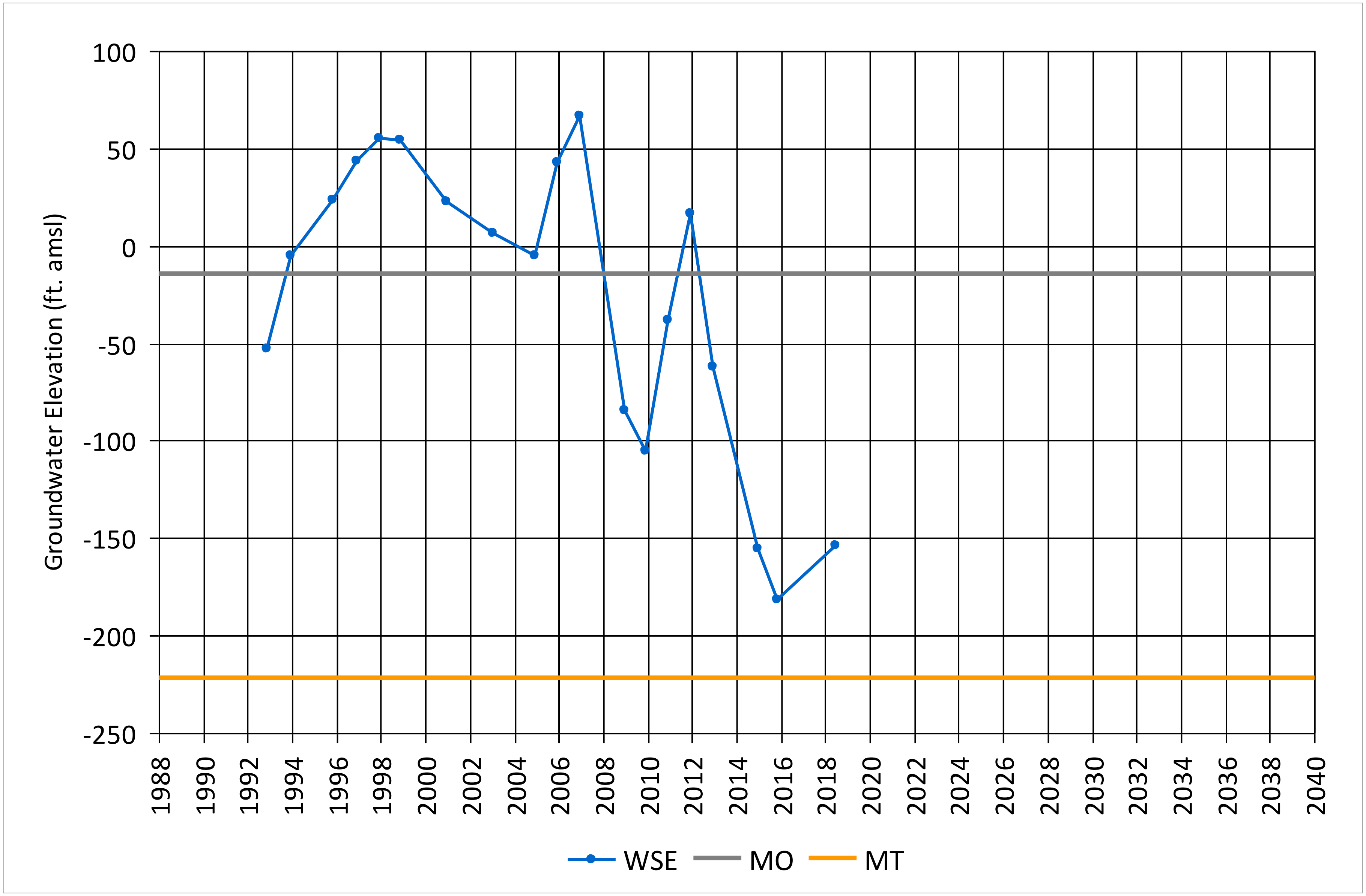
MO: 15 MT: -176.3
Depth: 965 ft



Aquifer: Lower
Perforations: 675-995 ft

16S/16E-29E01

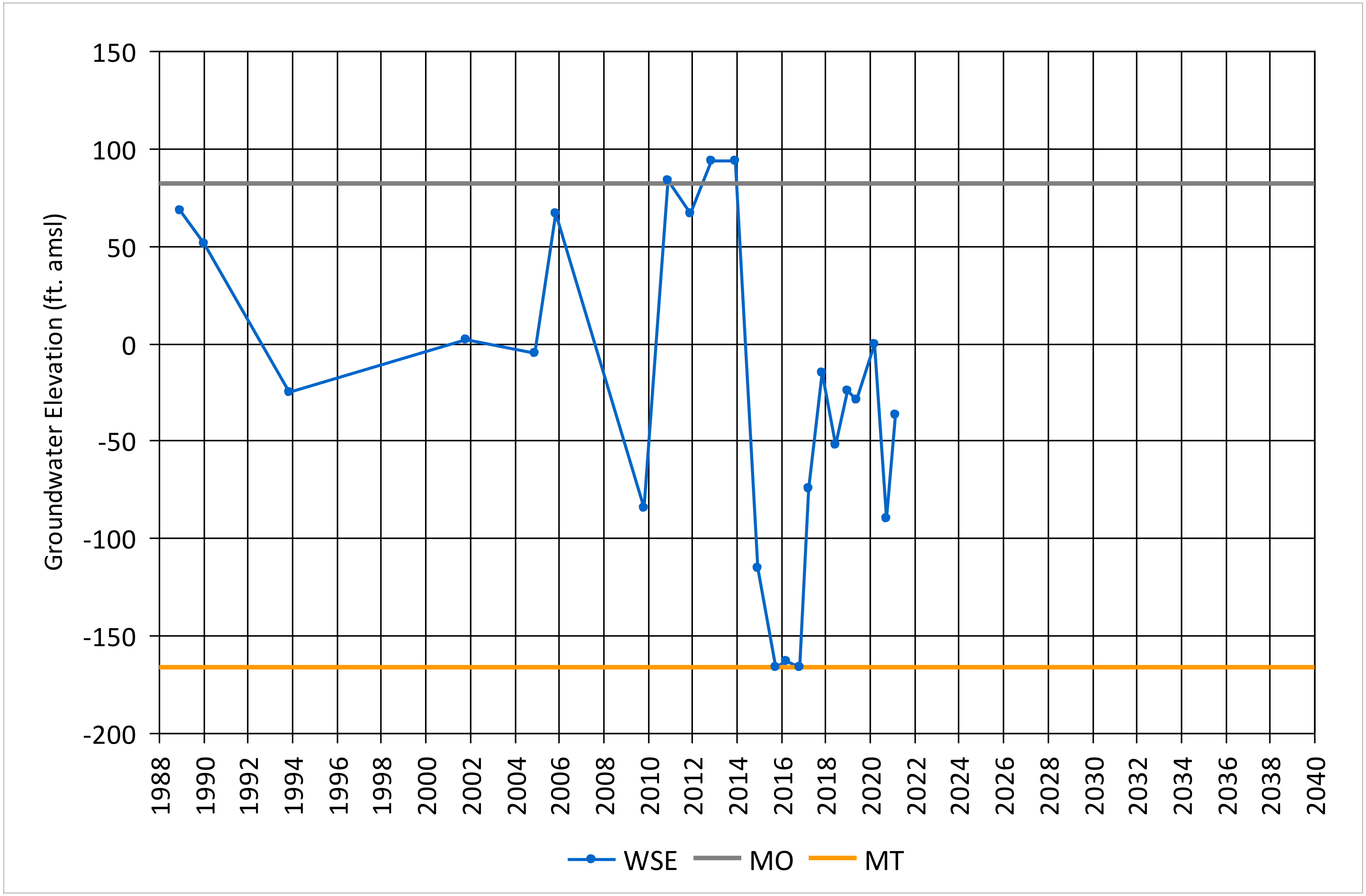
MO: -14 MT: -221.2
Depth: 995 ft



Aquifer: Lower
Perforations: 861-2529 ft

17S/15E-09N02

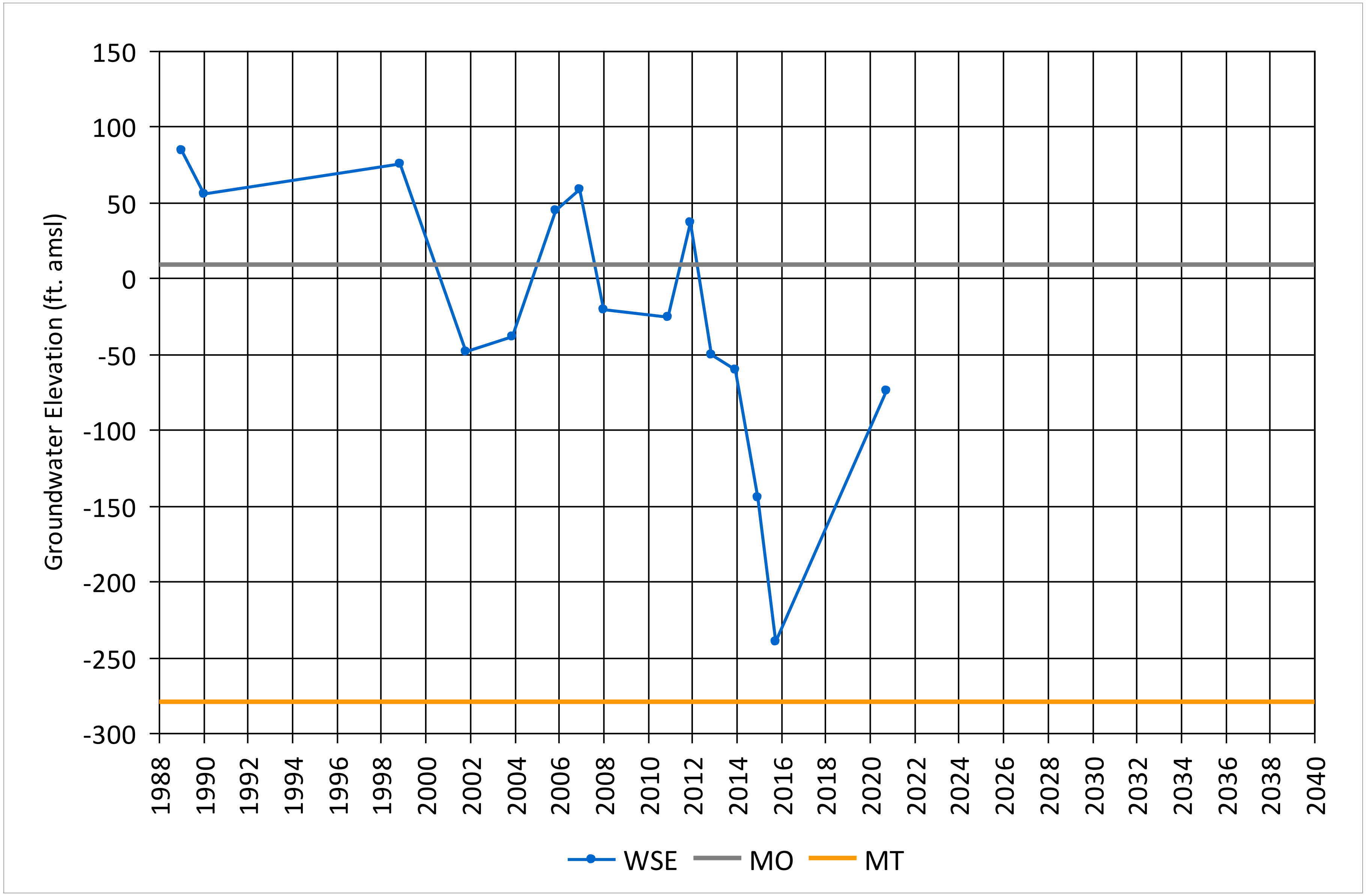
MO: 82.1 MT: -166.1
Depth: 2529 ft



Aquifer: Lower
Perforations: 842-1500 ft

17S/15E-23D01

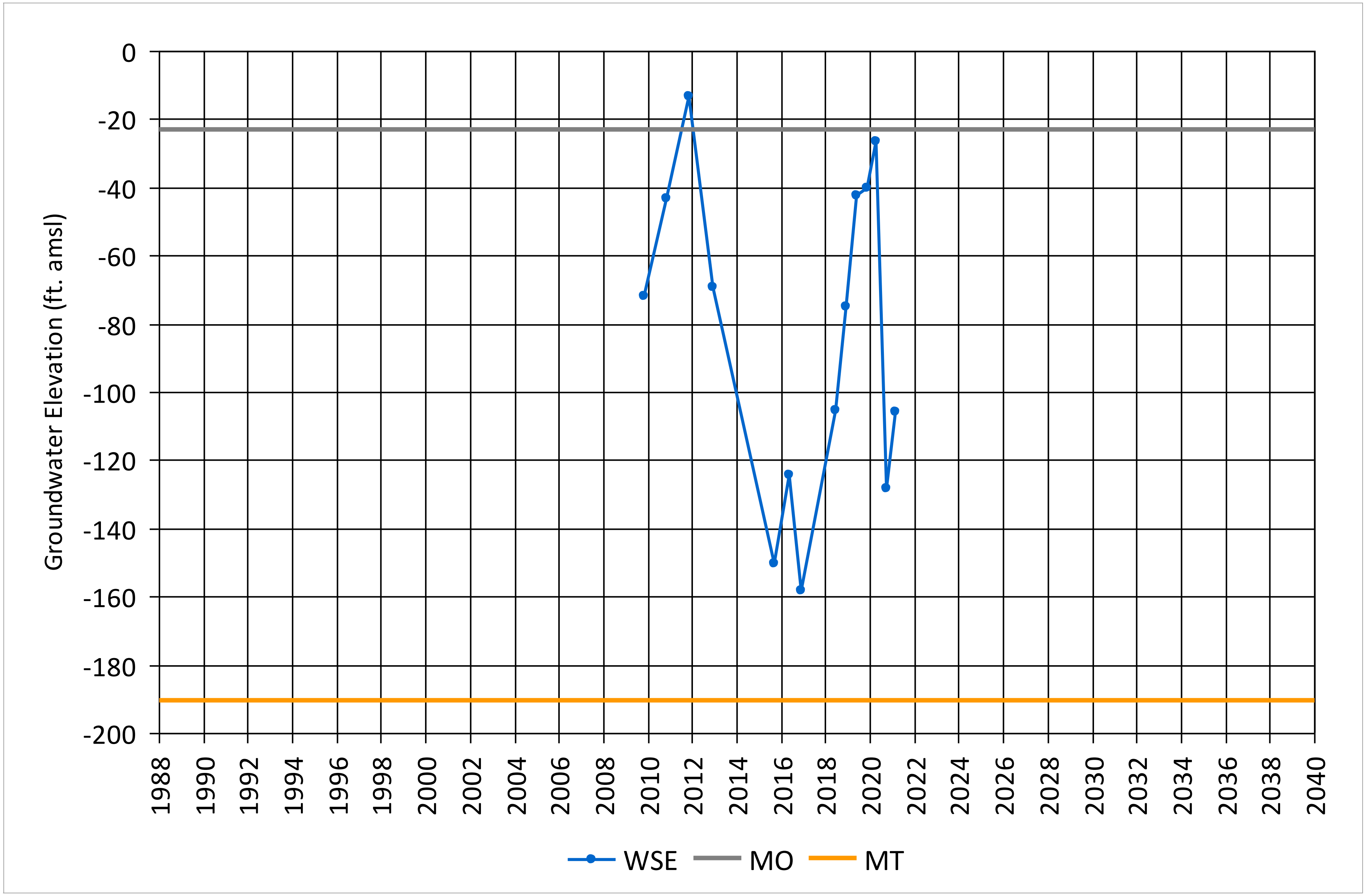
MO: 9.2 MT: -279.1
Depth: 1500 ft



Aquifer: Lower
Perforations: 602-1002 ft

17S/17E-09Q01

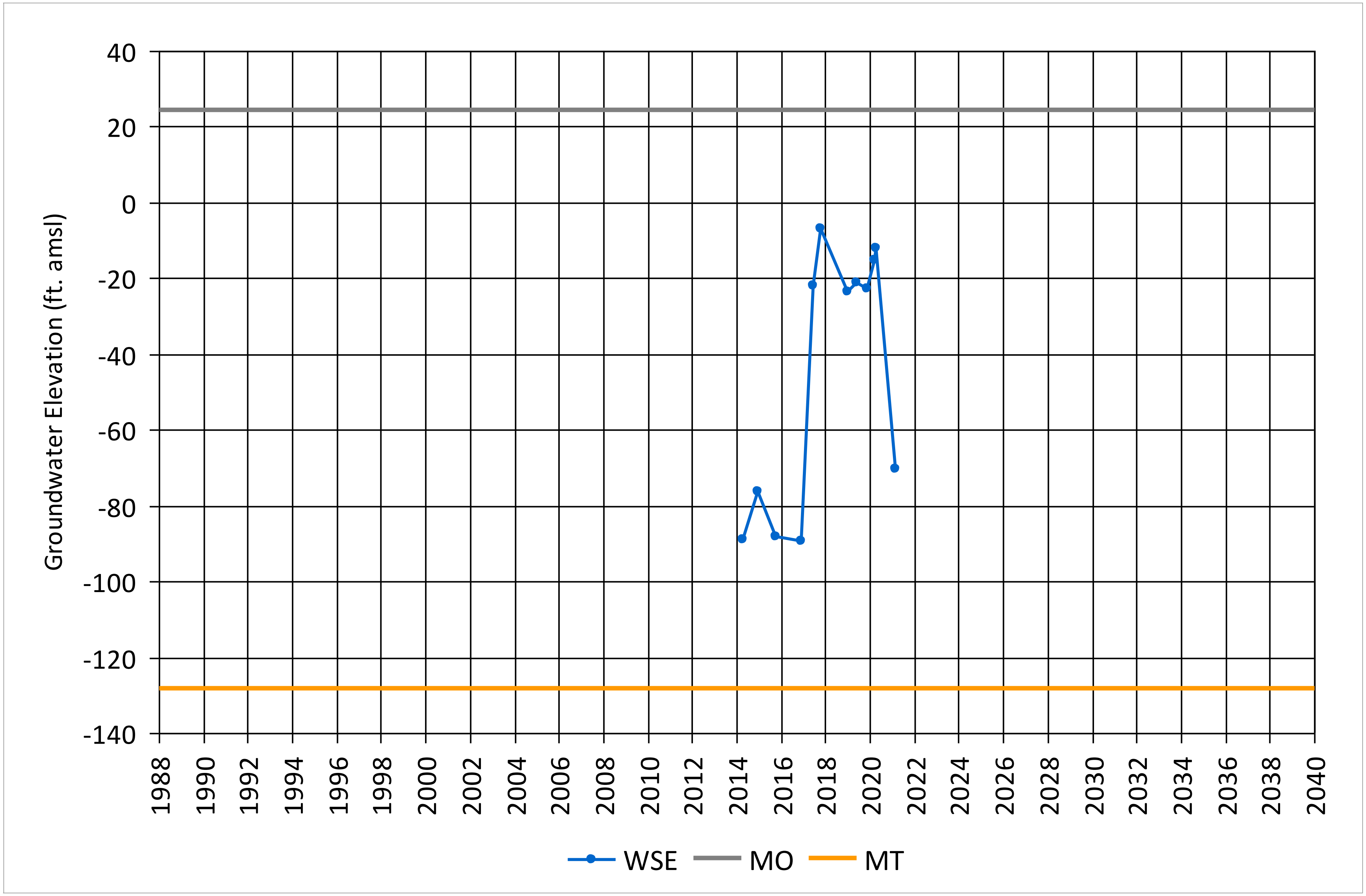
MO: -22.9 MT: -190.1
Depth: 1002 ft



Aquifer: Lower
Perforations: 600-1310 ft

17S/18E-33H02

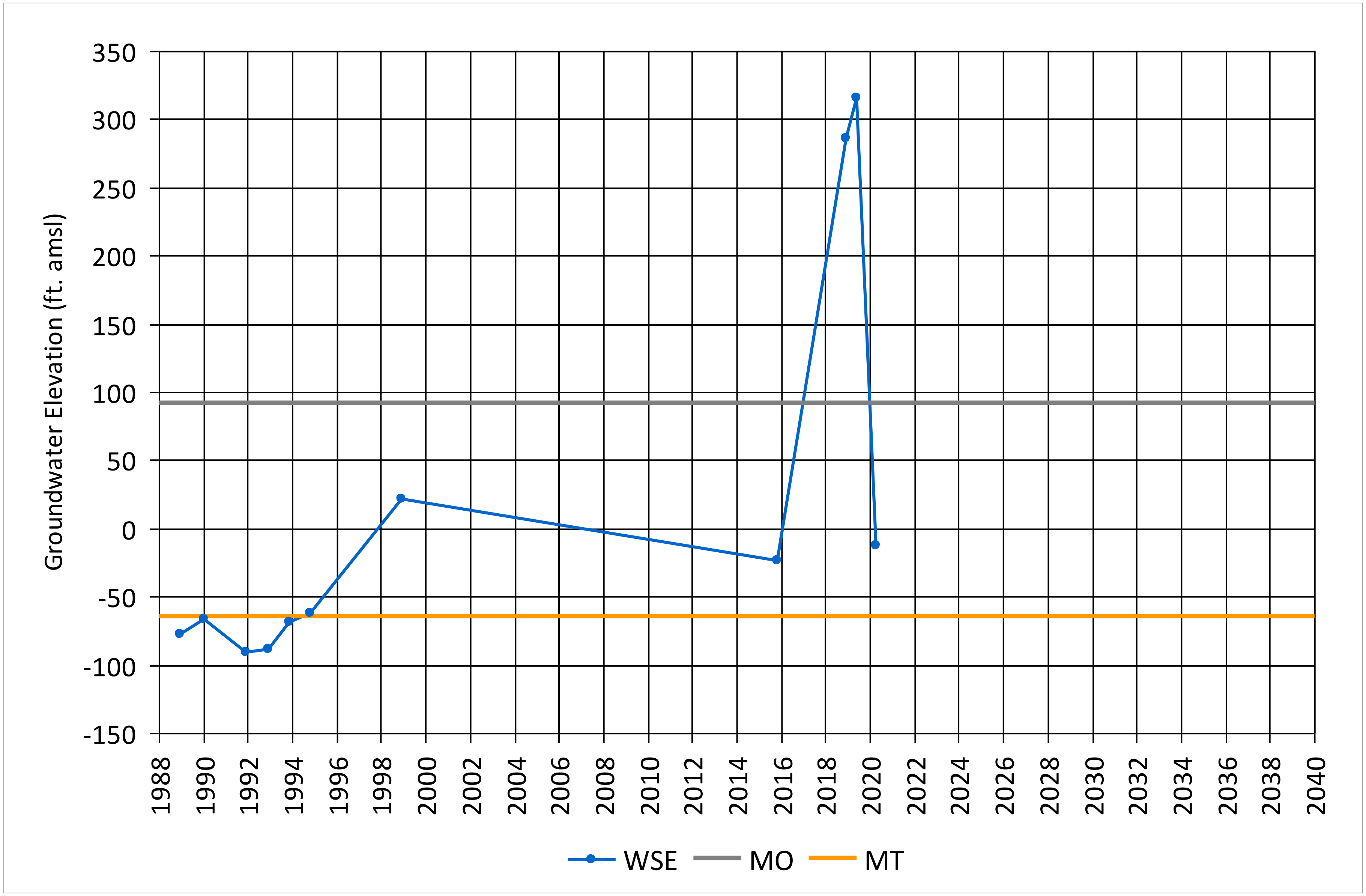
MO: 24.6 MT: -128.1
Depth: 1340 ft



Aquifer: Lower
Perforations: 1788-2488 f

18S/15E-15D01

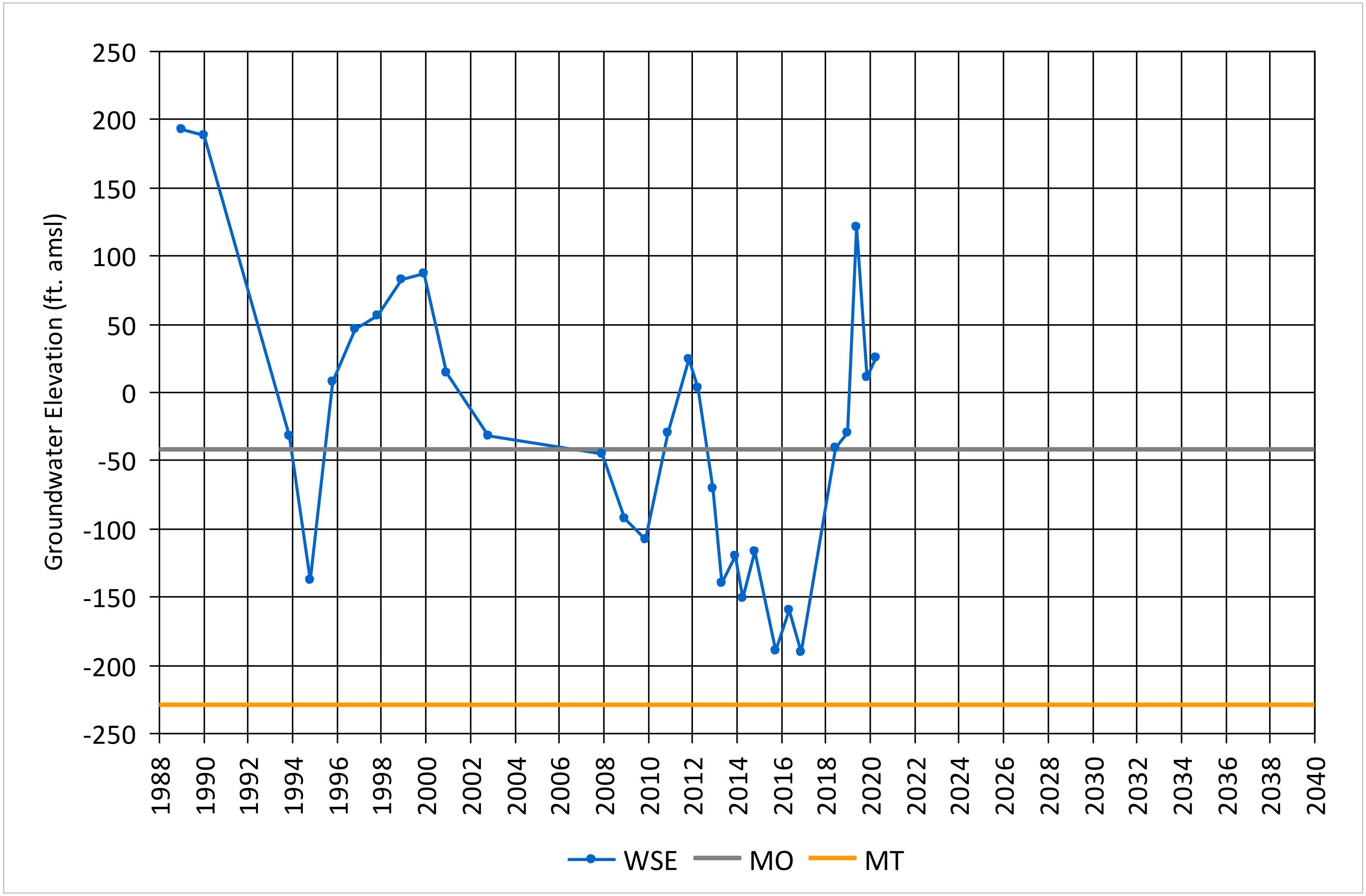
MO: 92.4 MT: -63.6
Depth: 2583 ft



Aquifer: Lower
Perforations: 942-1720 ft

18S/16E-04N02

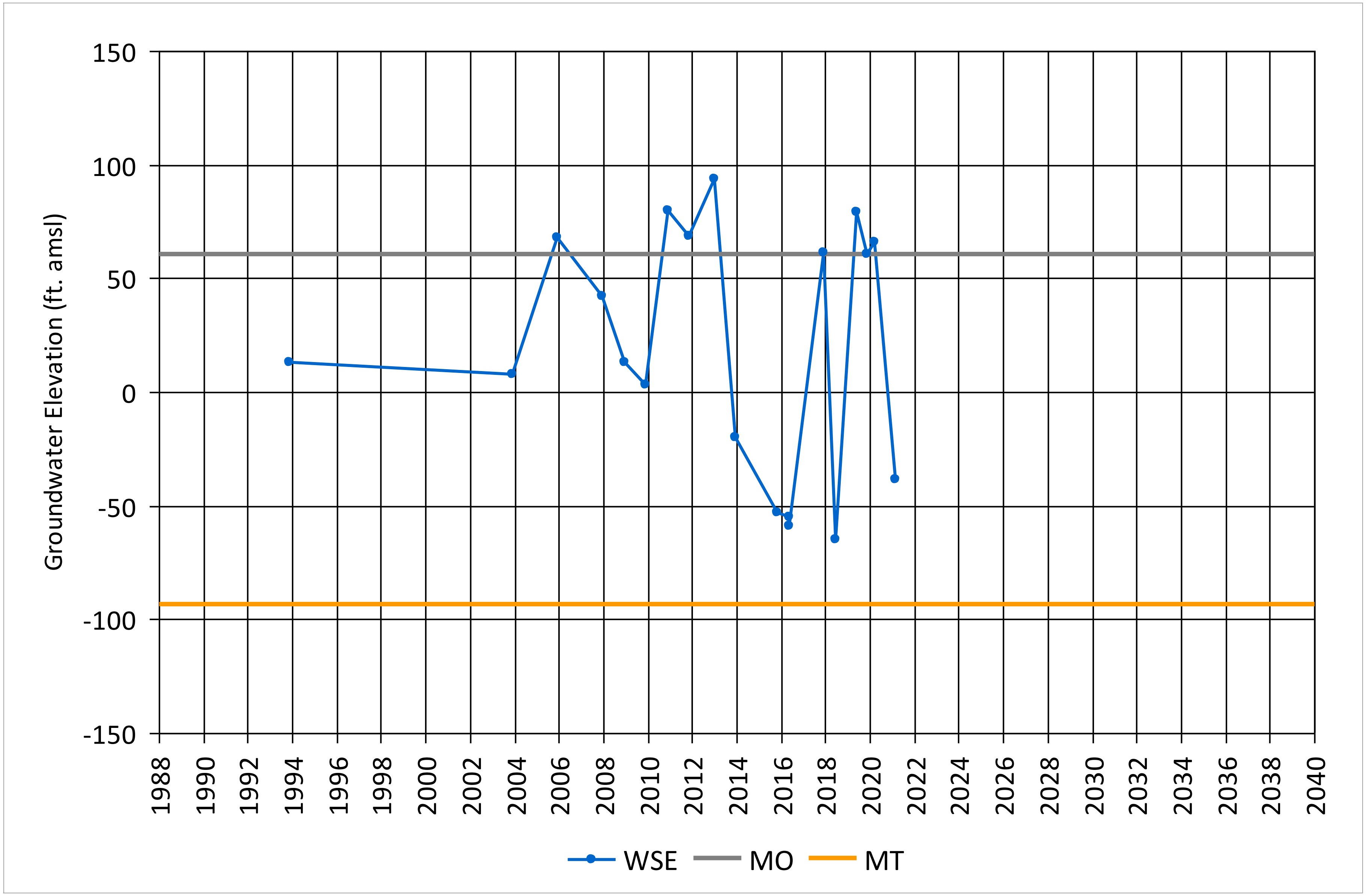
MO: -42.4 MT: -228.9
Depth: 1760 ft



Aquifer: Lower
Perforations: 800-2000 ft

18S/16E-34N02

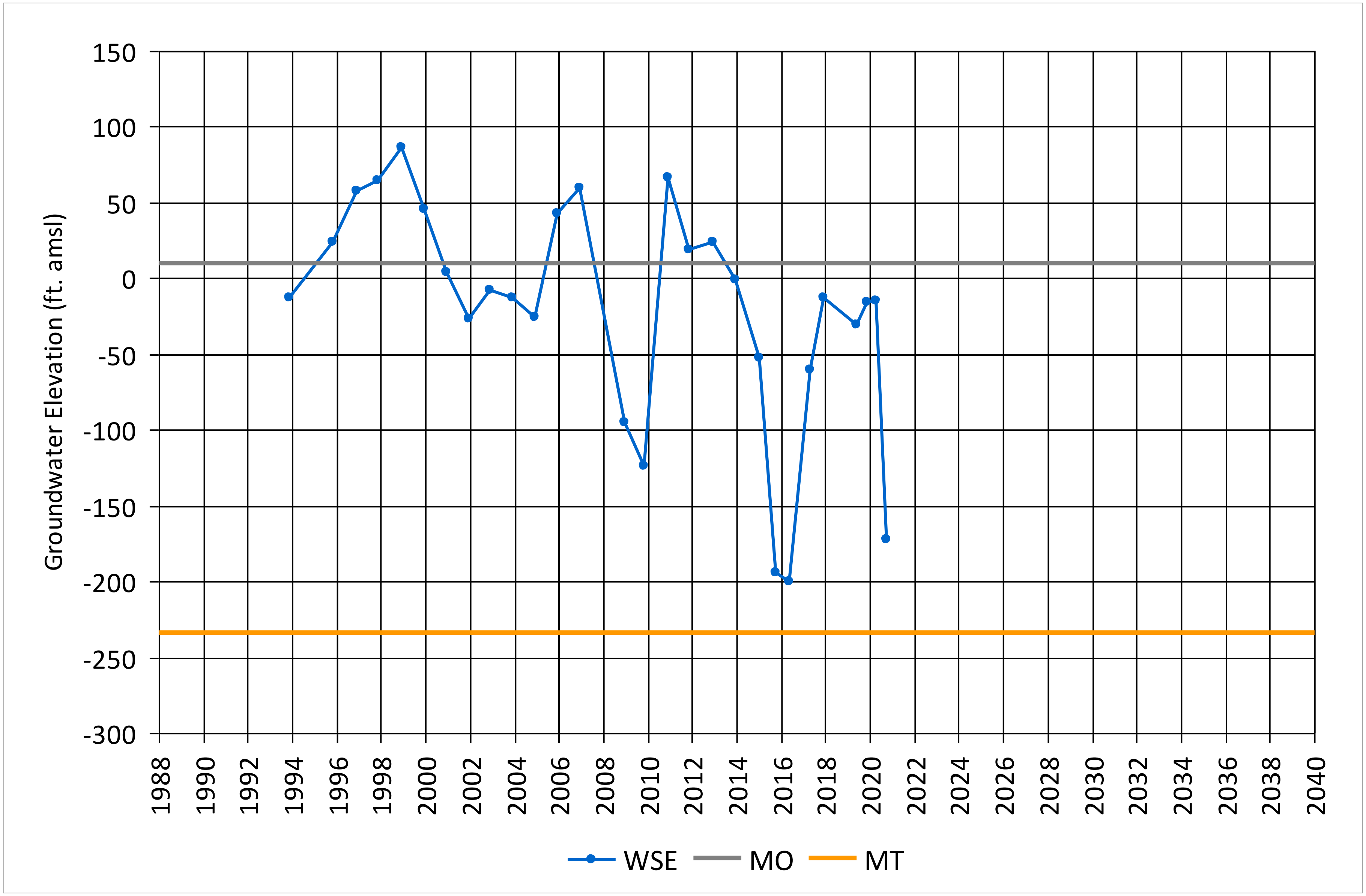
MO: 60.6 MT: -92.9
Depth: 2000 ft



Aquifer: Lower
Perforations: 700-1150 ft

18S/17E-09P01

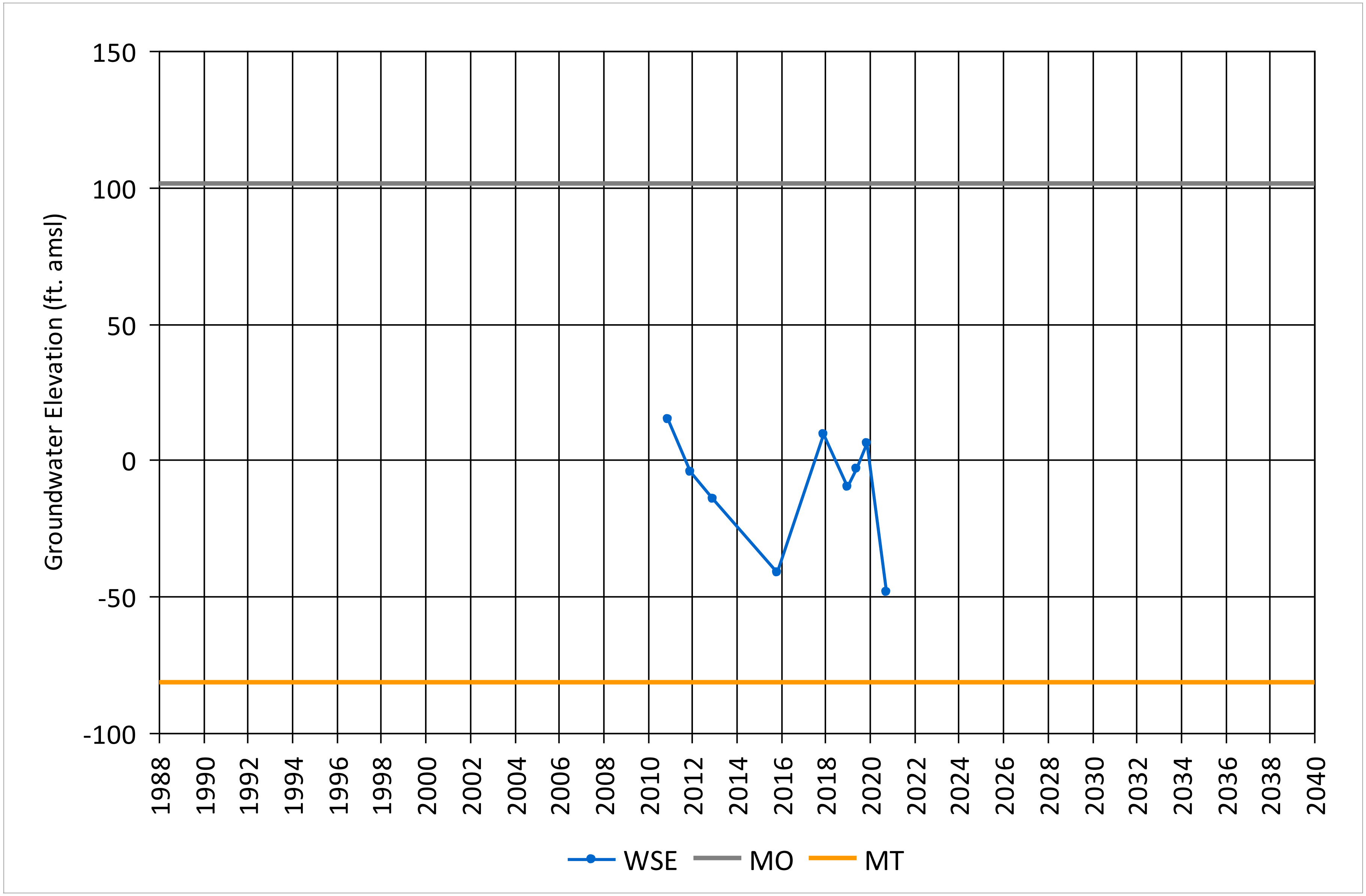
MO: 10.5 MT: -234
Depth: 1187 ft



Aquifer: Lower
Perforations: 598 ft

18S/18E-01R02

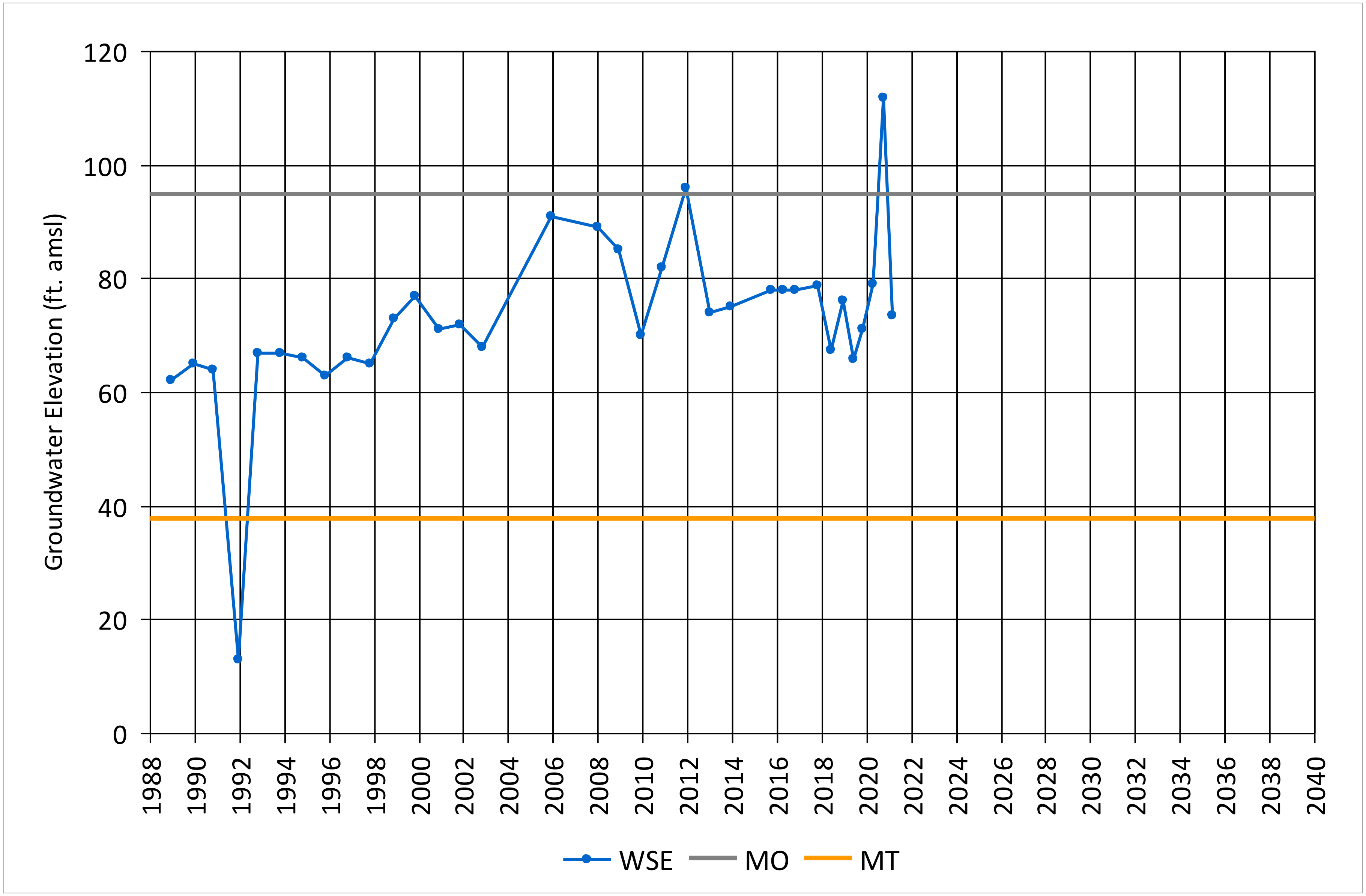
MO: 101.8 MT: -81.2
Depth: 1281 ft



Aquifer: Lower
Perforations: 719-2035 ft

19S/16E-35N01

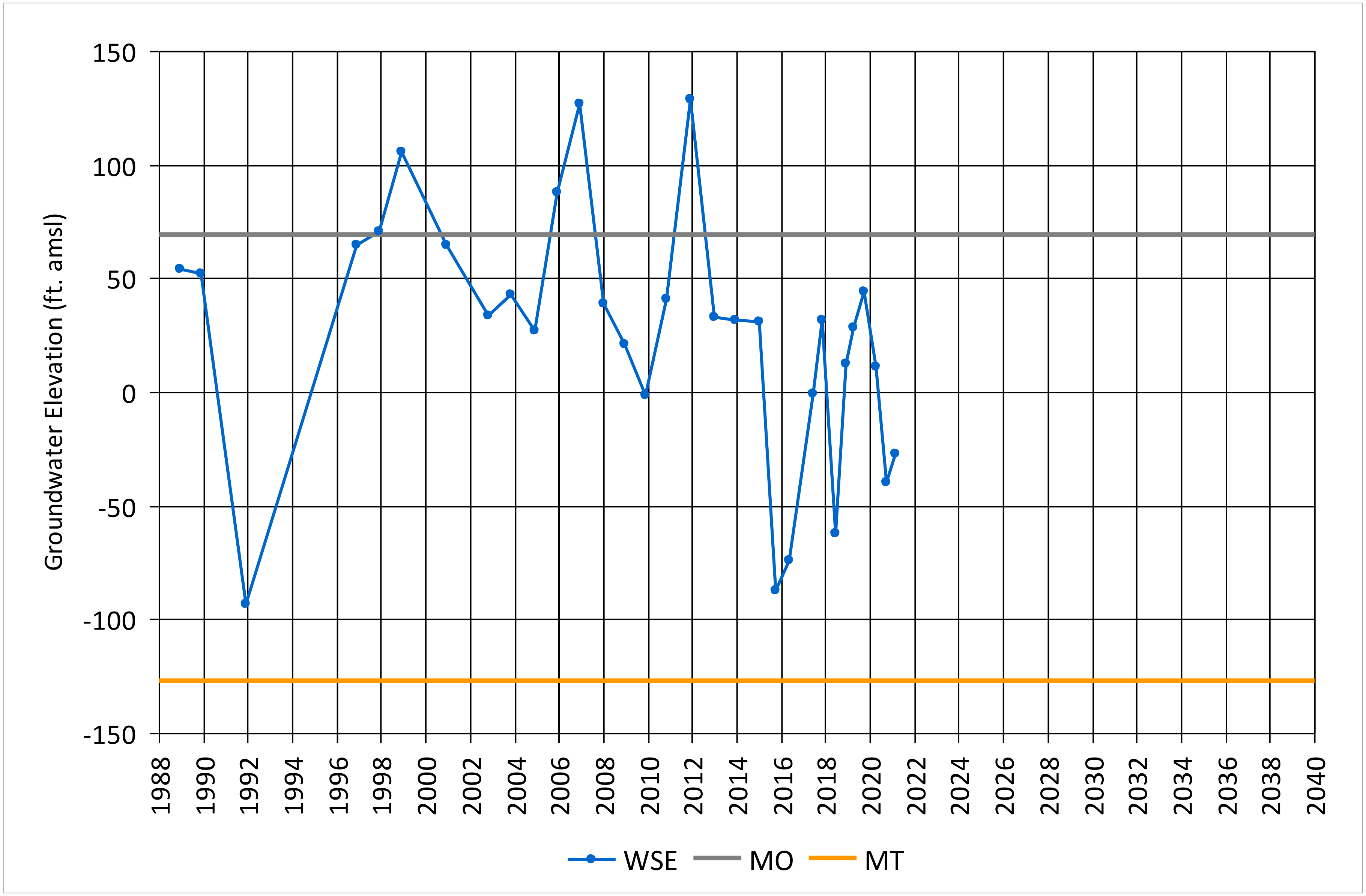
MO: 95 MT: 37.9
Depth: 2035 ft



Aquifer: Lower
Perforations: 716-2005 ft

19S/17E-28P01

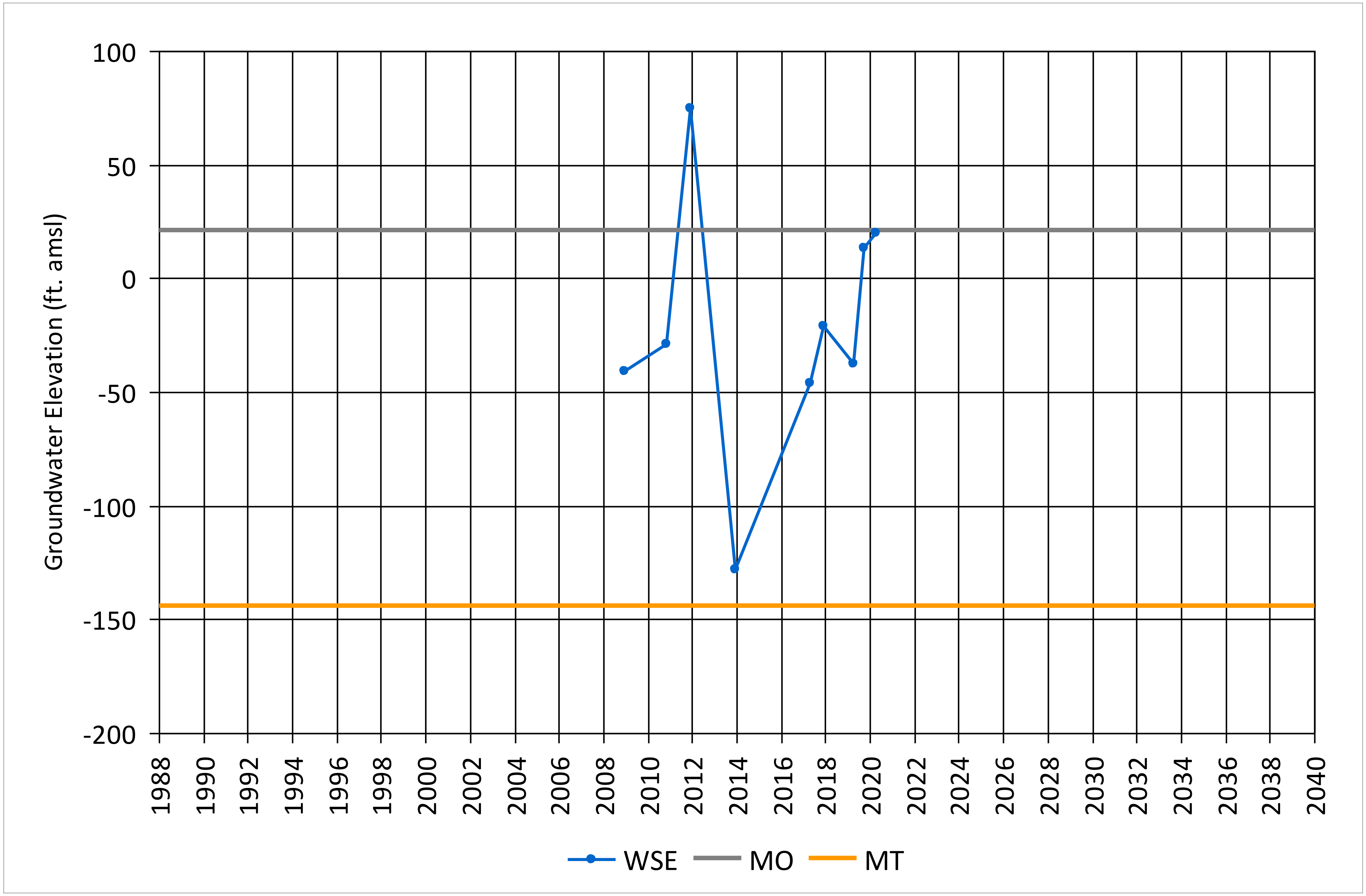
MO: 69.1 MT: -127
Depth: 2018 ft



Aquifer: Lower
Perforations: 866-1600 ft

19S/18E-04C01

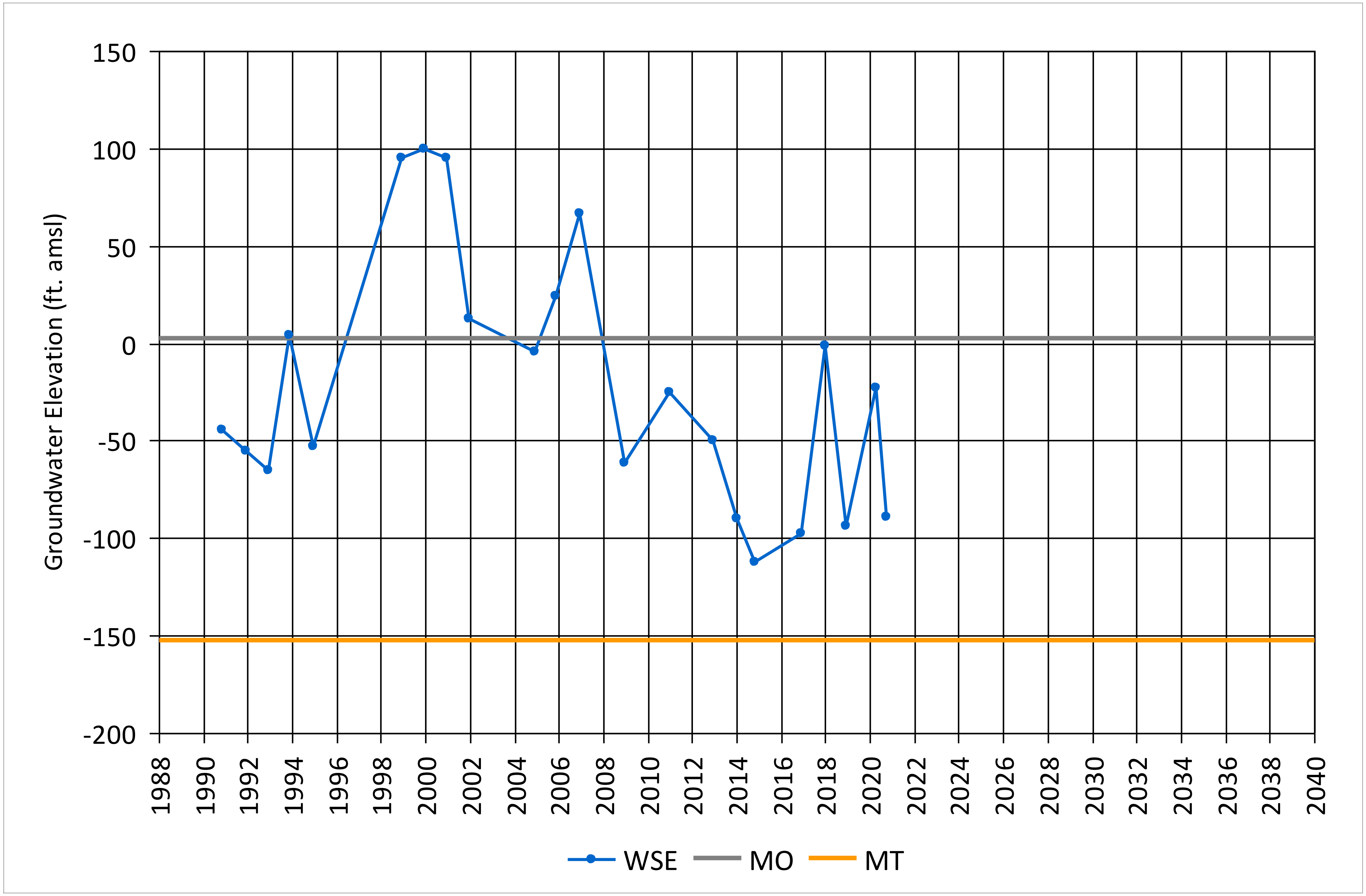
MO: 21.2 MT: -143.6
Depth: 1620 ft



Aquifer: Lower
Perforations: 718-1423 ft

19S/19E-29A01

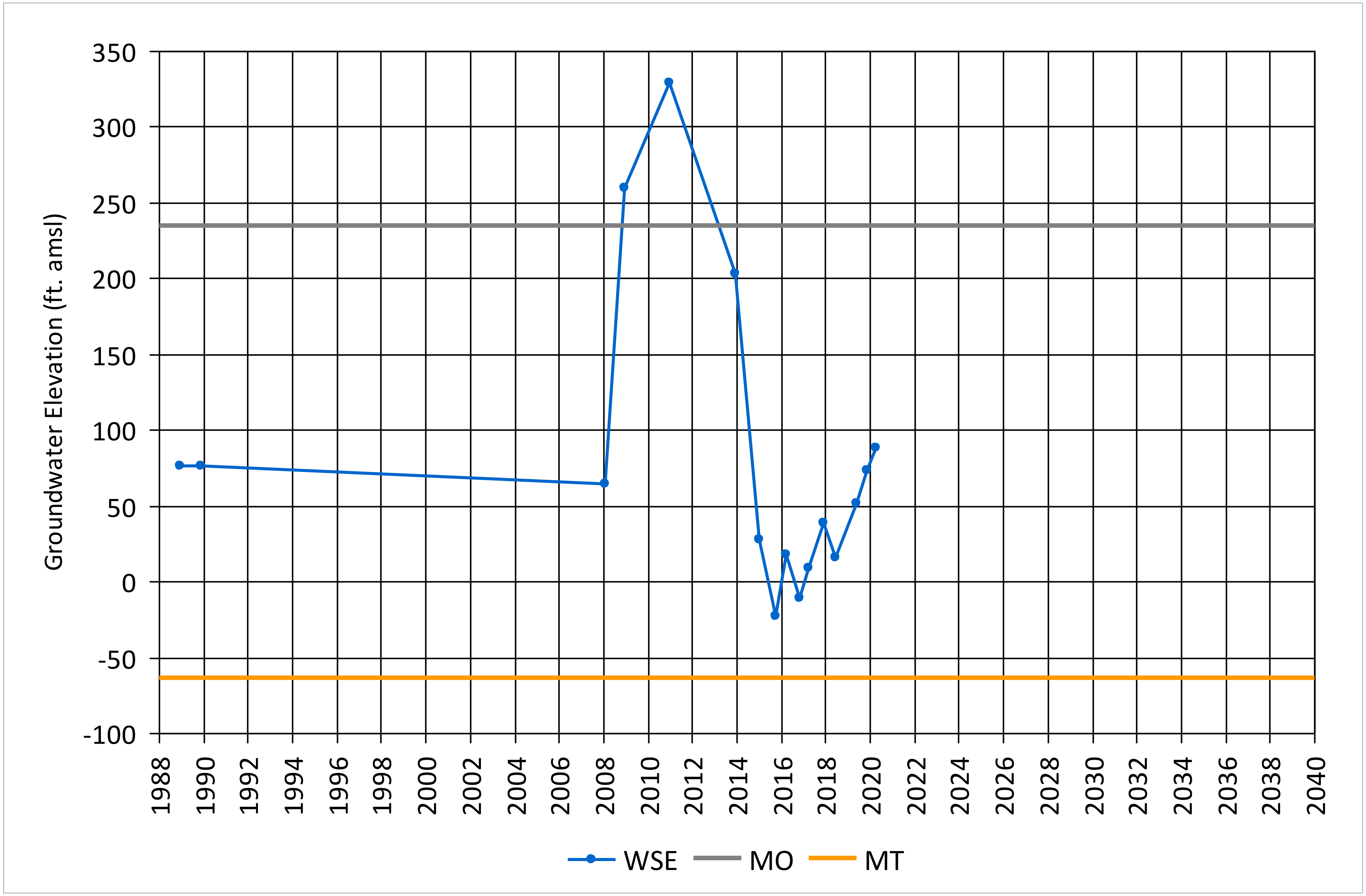
MO: 2.5 MT: -152.1
Depth: 1423 ft



Aquifer: Lower
Perforations: 601-1406 ft

20S/16E-21R01

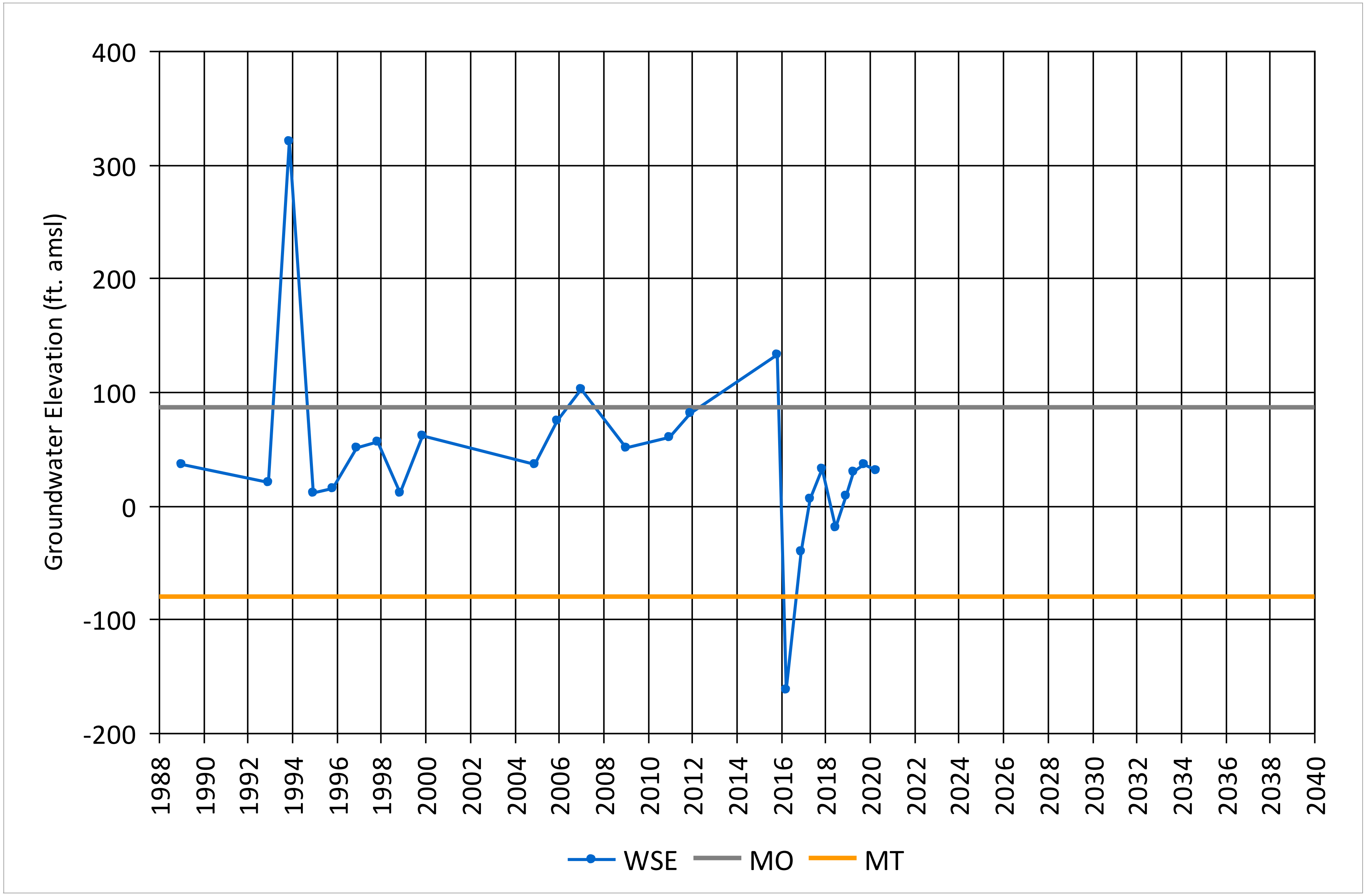
MO: 235.4 MT: -63
Depth: 1418 ft



Aquifer: Lower
Perforations: 801-2067 ft

20S/17E-09N03

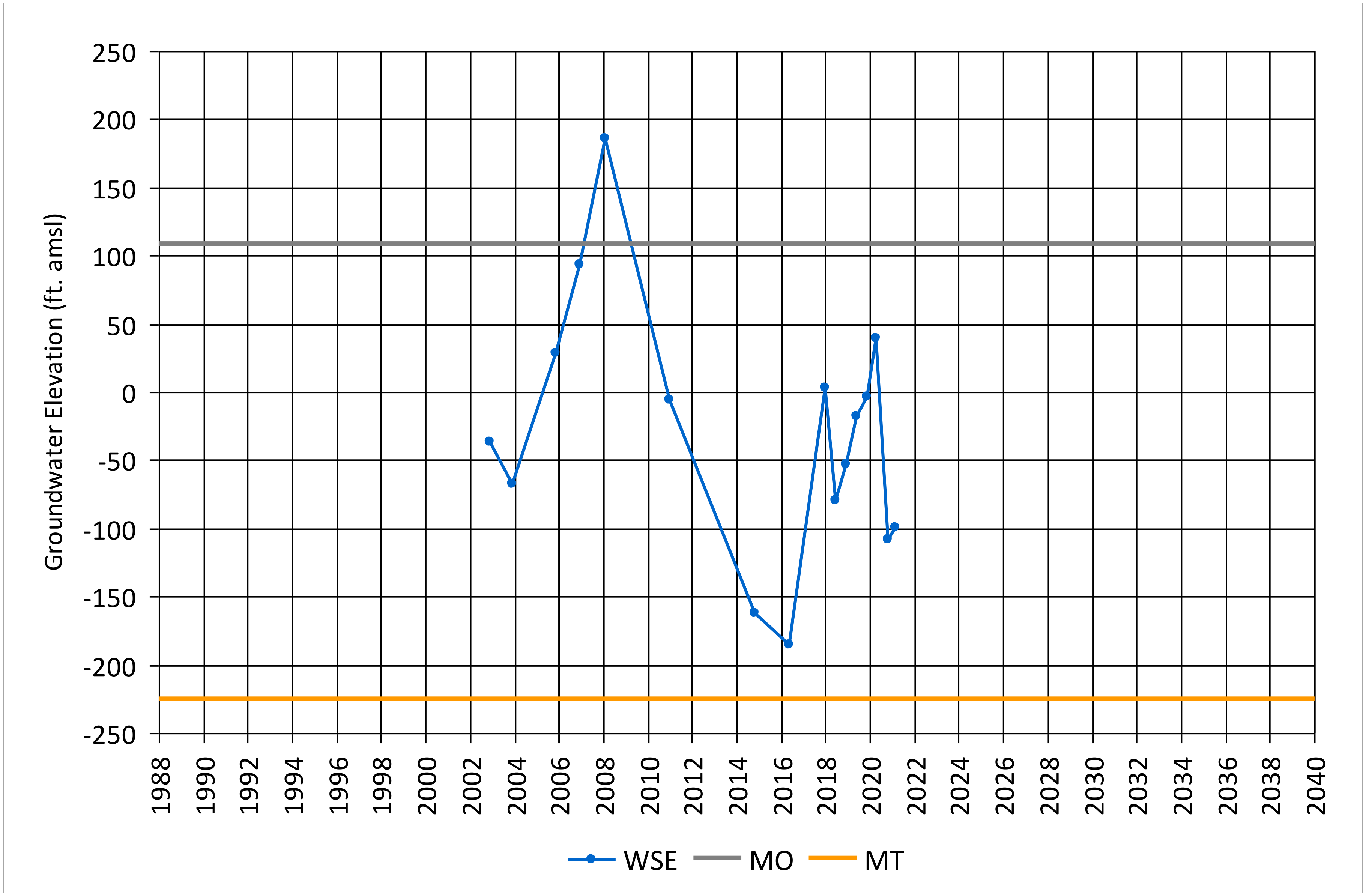
MO: 87.2 MT: -79.8
Depth: 2100 ft



Aquifer: Lower
Perforations: 600-1040 ft

20S/18E-04G01

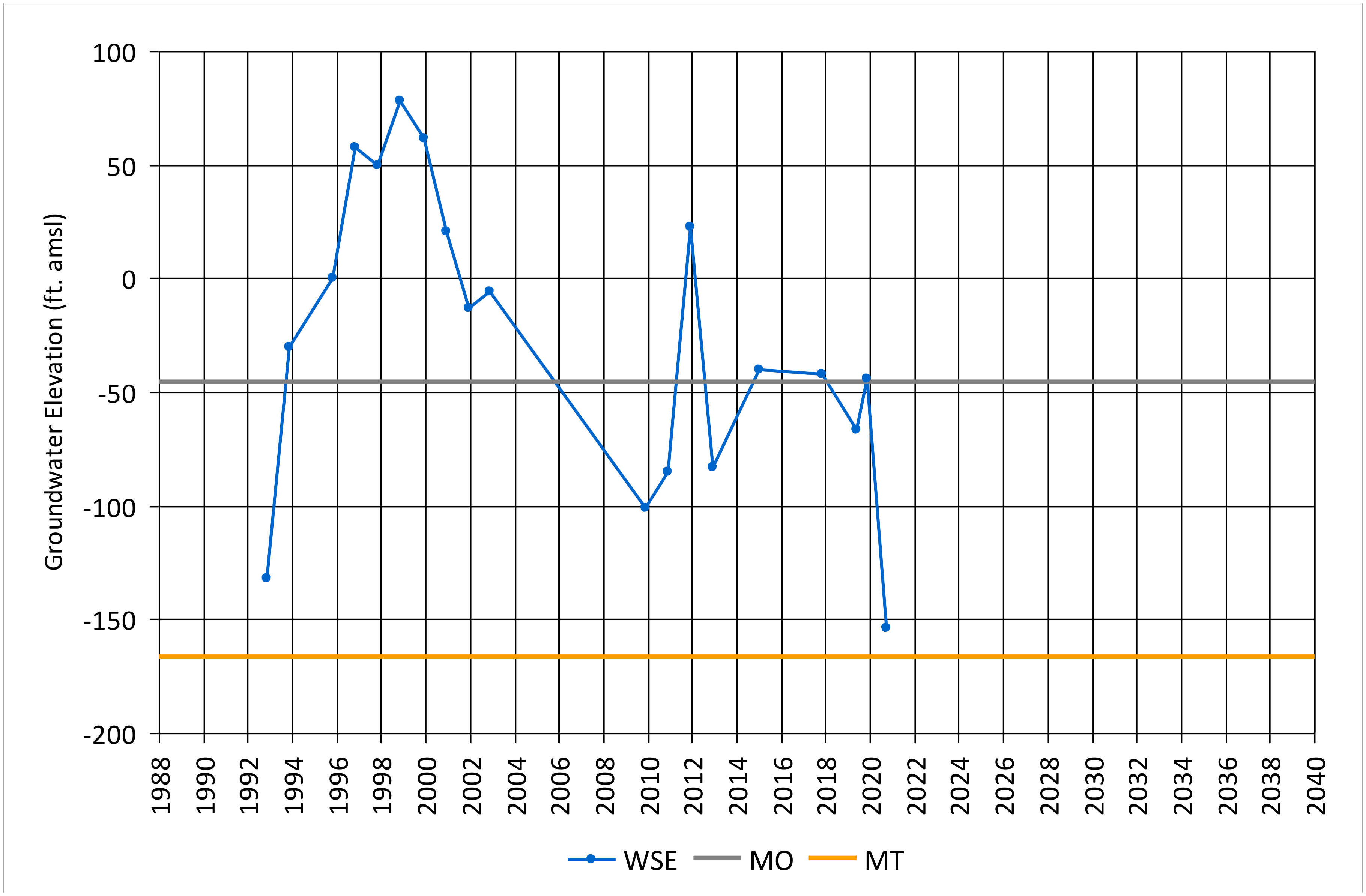
MO: 108.9 MT: -225.1
Depth: 1040 ft



Aquifer: Lower
Perforations: 700-1700 ft

20S/18E-35D02

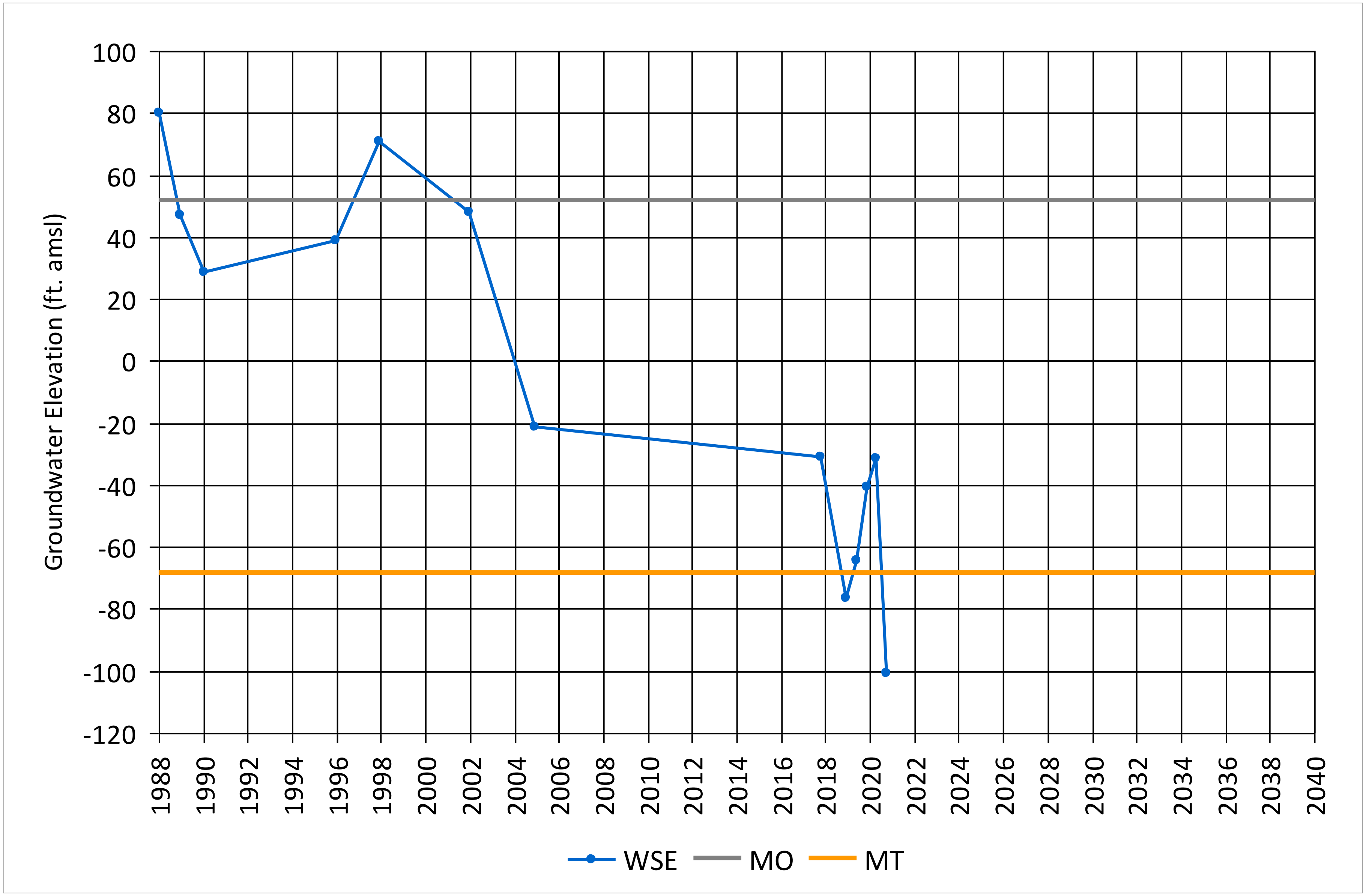
MO: -45.7 MT: -166
Depth: 1700 ft



Aquifer: Lower
Perforations: 869-2090 ft

20S/19E-02A01

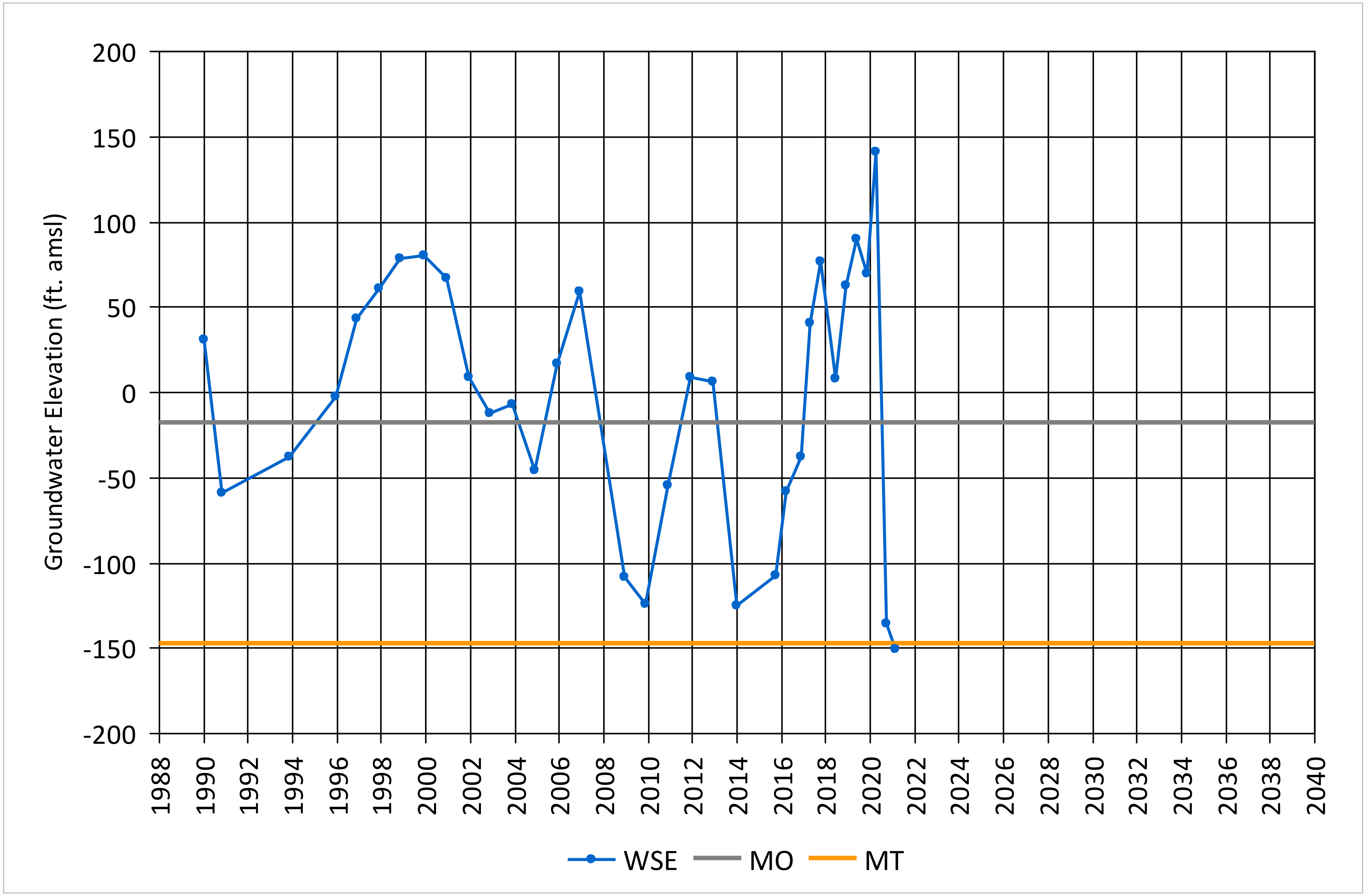
MO: 52.2 MT: -68.3
Depth: 2130 ft



Aquifer: Lower
Perforations: 700-1000 ft

20S/19E-17M01

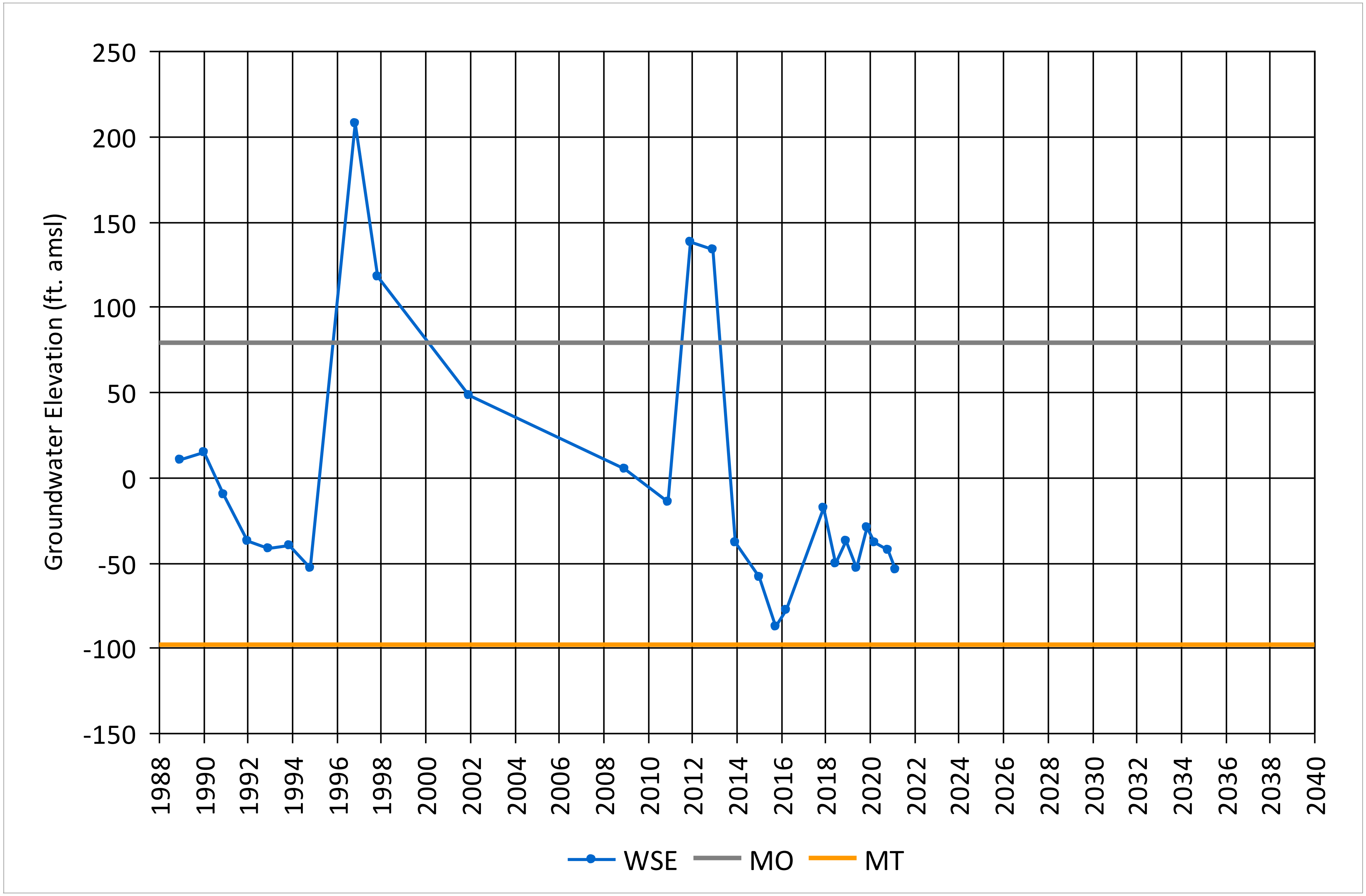
MO: -18 MT: -147.1
Depth: 1000 ft



Aquifer: Lower
Perforations: 628-1989 ft

21S/17E-11N01

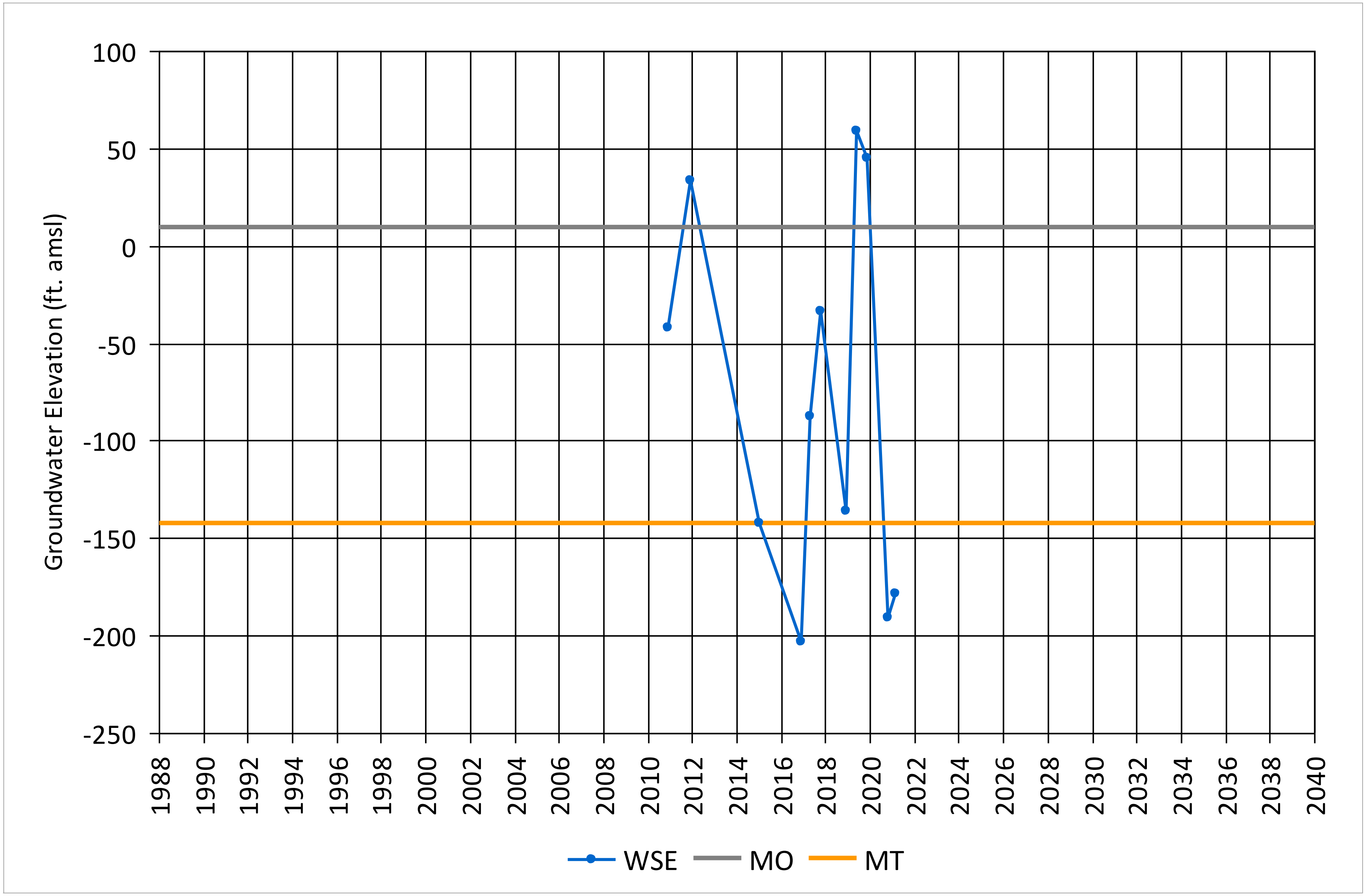
MO: 79.1 MT: -98.1
Depth: 2008 ft



Aquifer: Lower
Perforations: 720-1780 ft

21S/18E-22E01

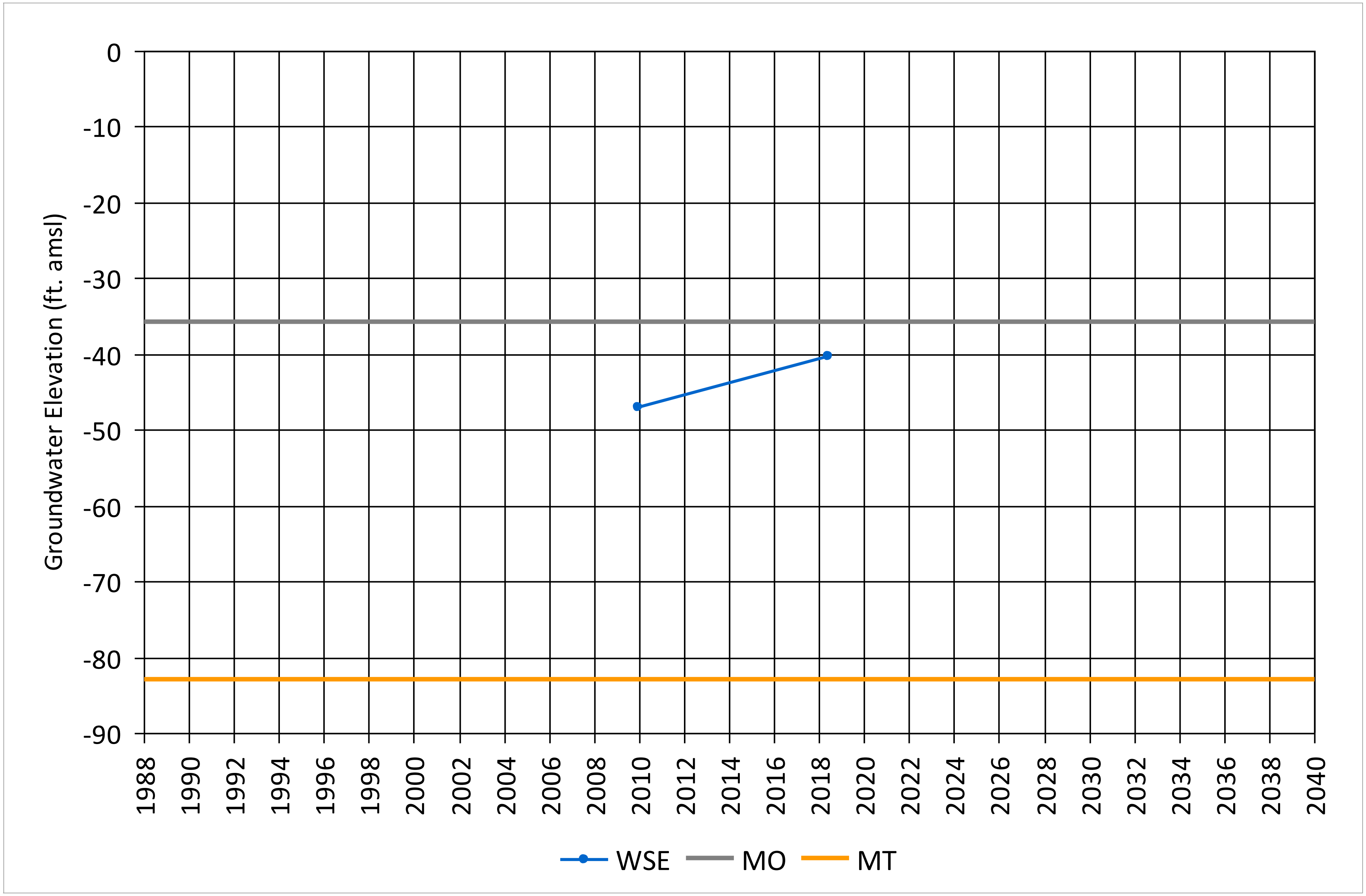
MO: 9.7 MT: -142.1
Depth: 1800 ft



Aquifer: Lower
Perforations: 600-1180 ft

21S/18E-35Q02

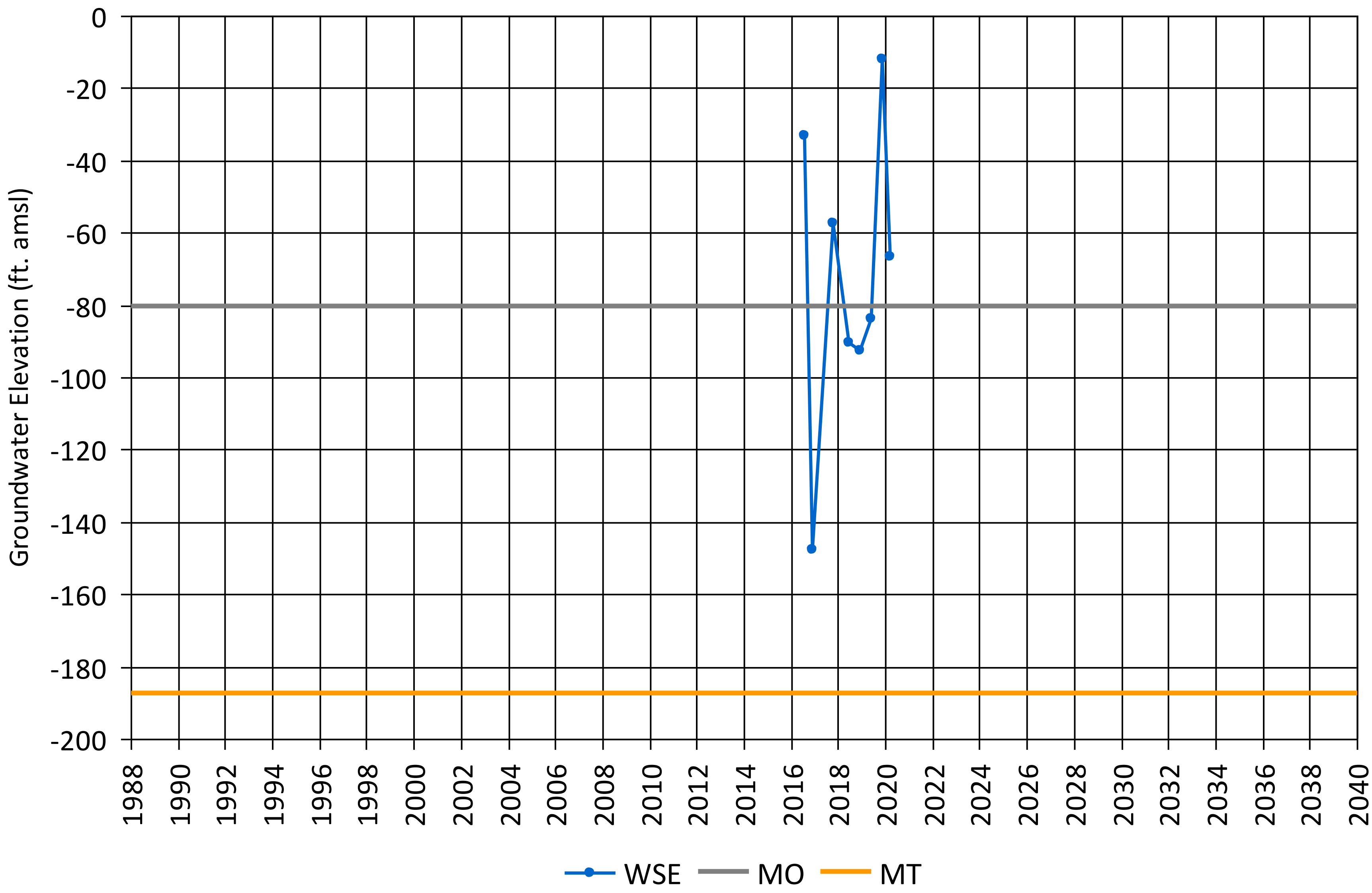
MO: -35.7 MT: -82.9
Depth: 1180 ft



Aquifer: Lower
Perforations: ft

21S/19E-20D02

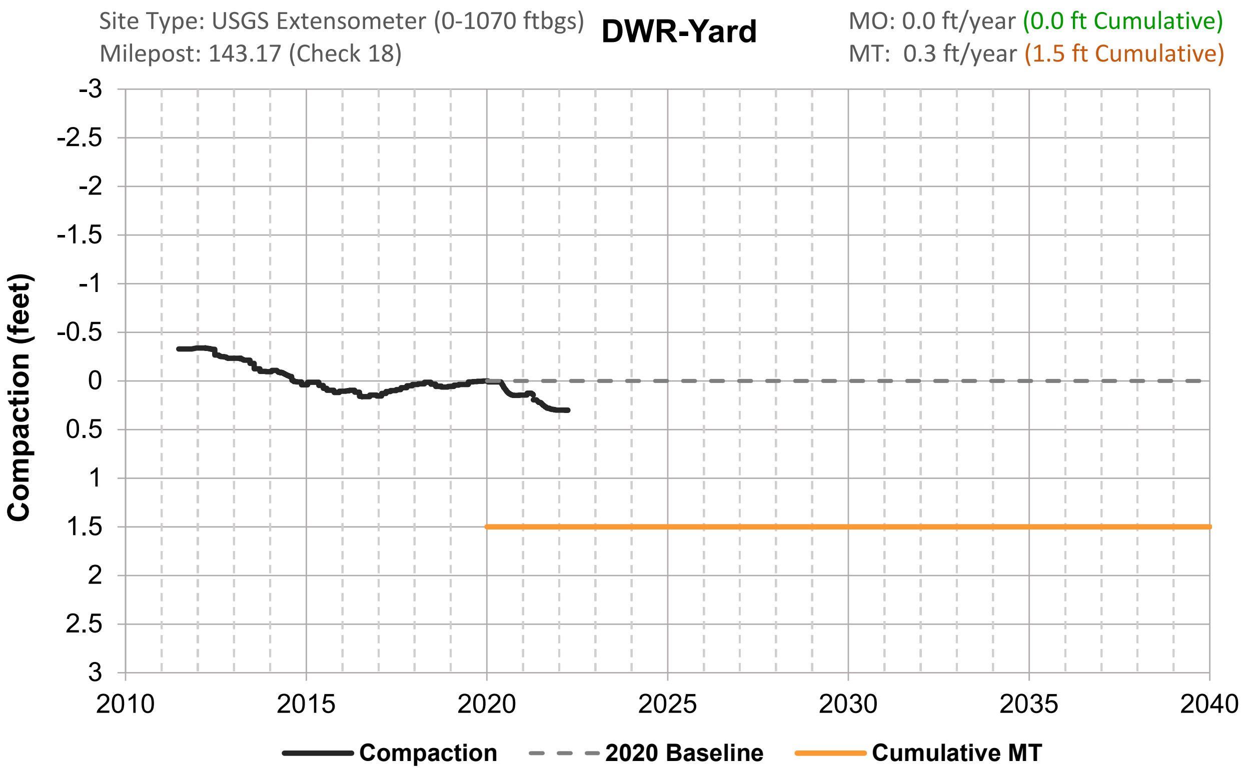
MO: -80.3 MT: -187.4
Depth: ft

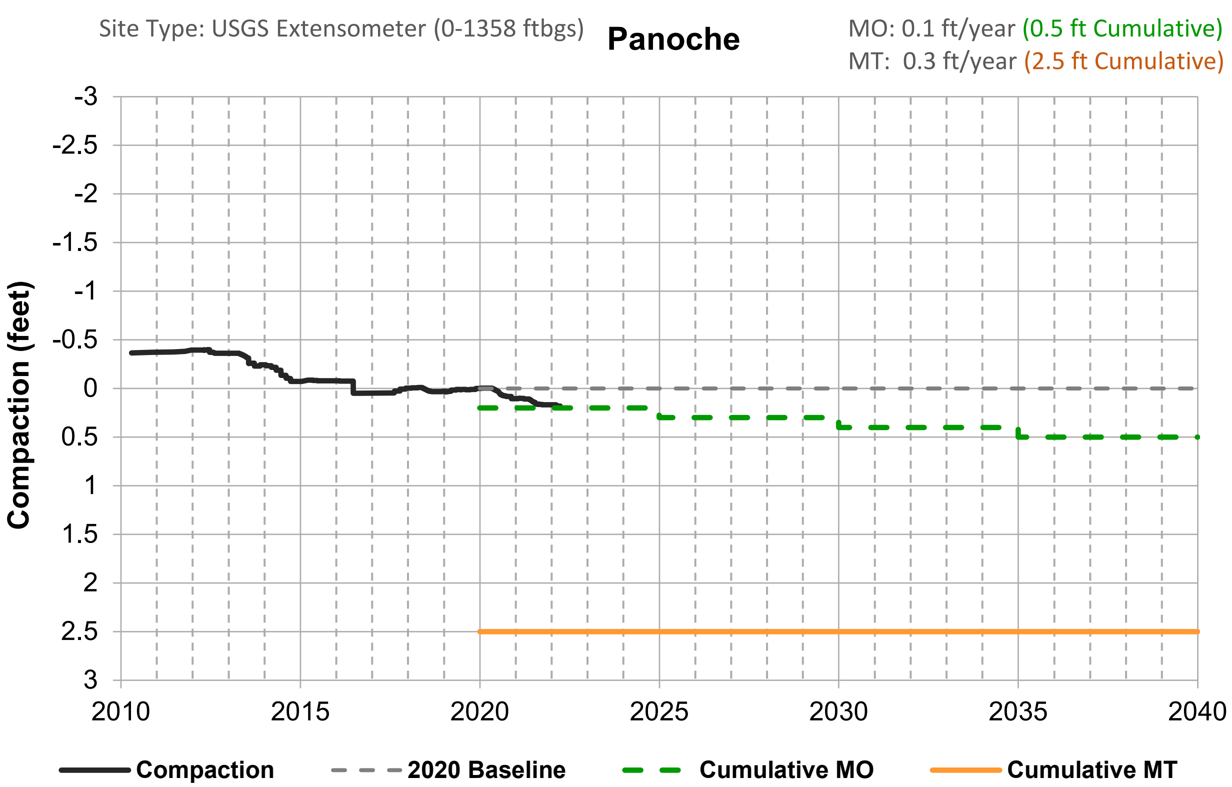


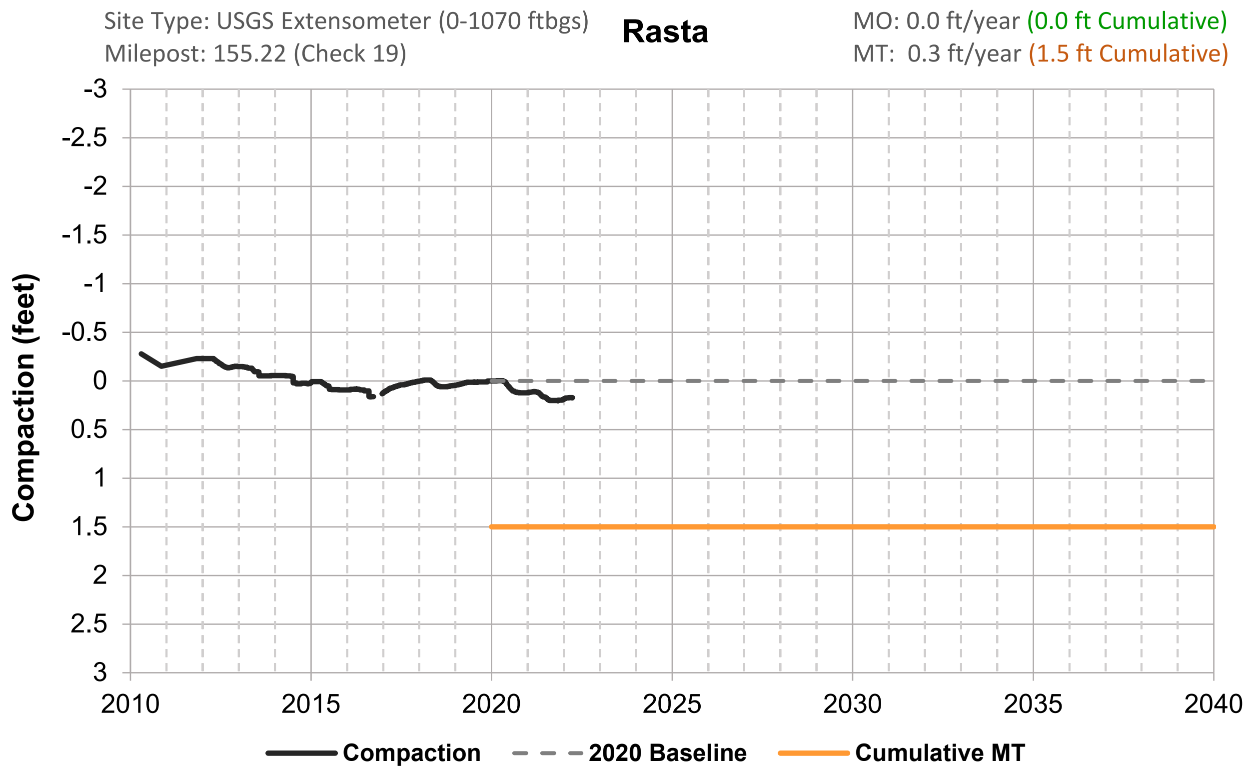
Appendix 3-B

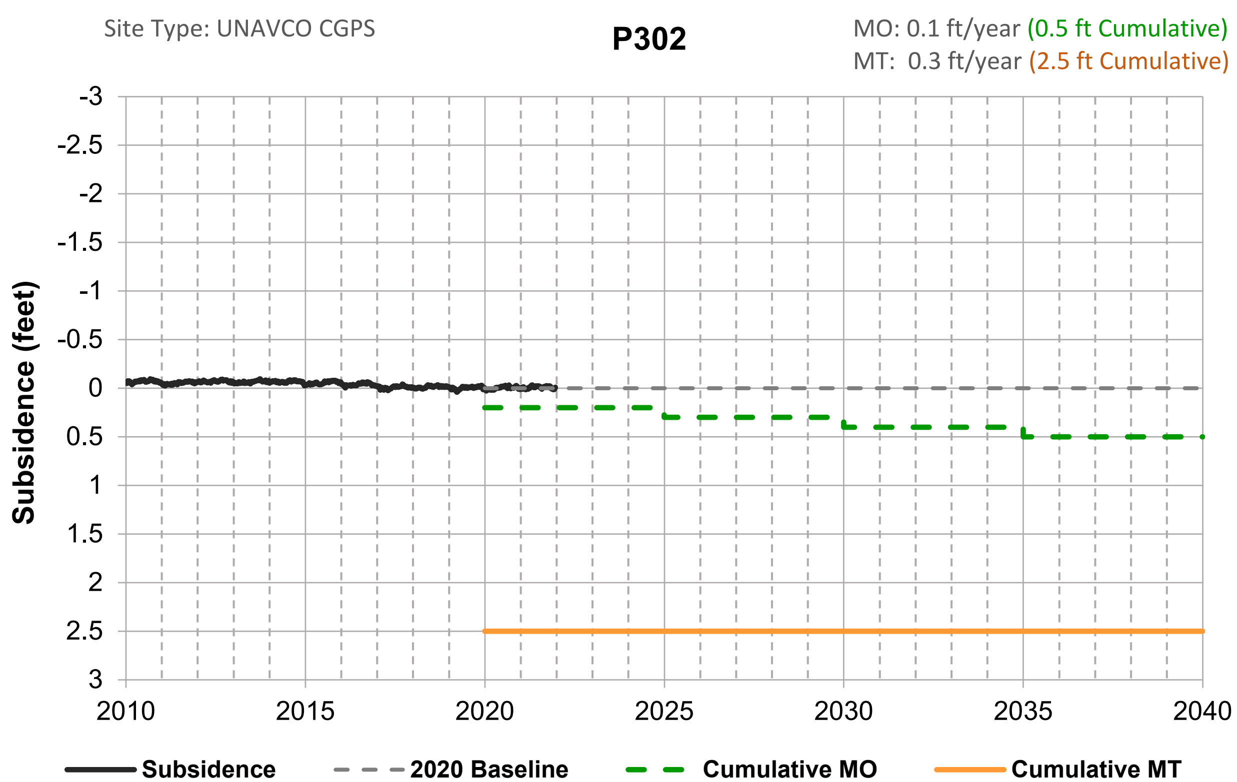
Measurable Objectives and Minimum Thresholds for Subsidence

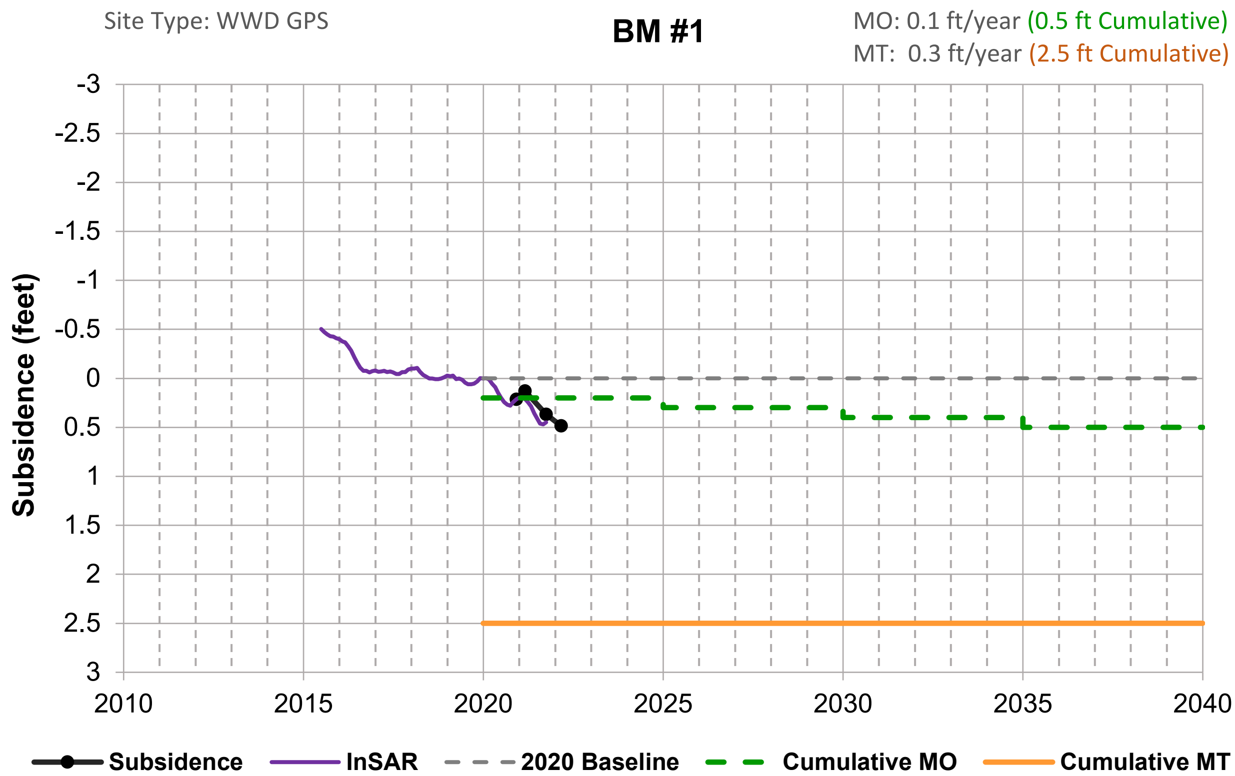
LSCE

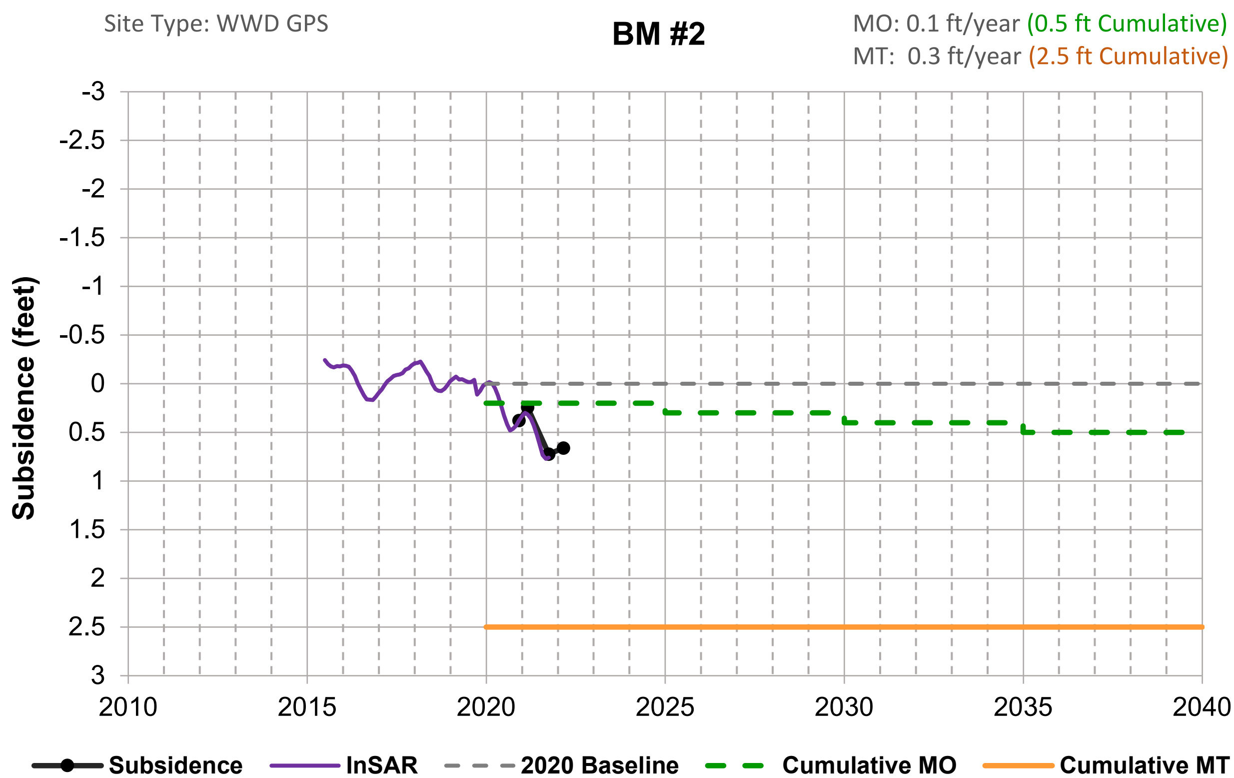

Site Type: USGS Extensometer (0-1070 ftbgs)
Milepost: 143.17 (Check 18)
DWR-Yard
MO: 0.0 ft/year (0.0 ft Cumulative)
MT: 0.3 ft/year (1.5 ft Cumulative)
Compaction (feet)
-3
-2.5
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2
2.5
3
2010
2015
2020
2025
2030
2035
2040
Compaction
2020 Baseline
Cumulative MT

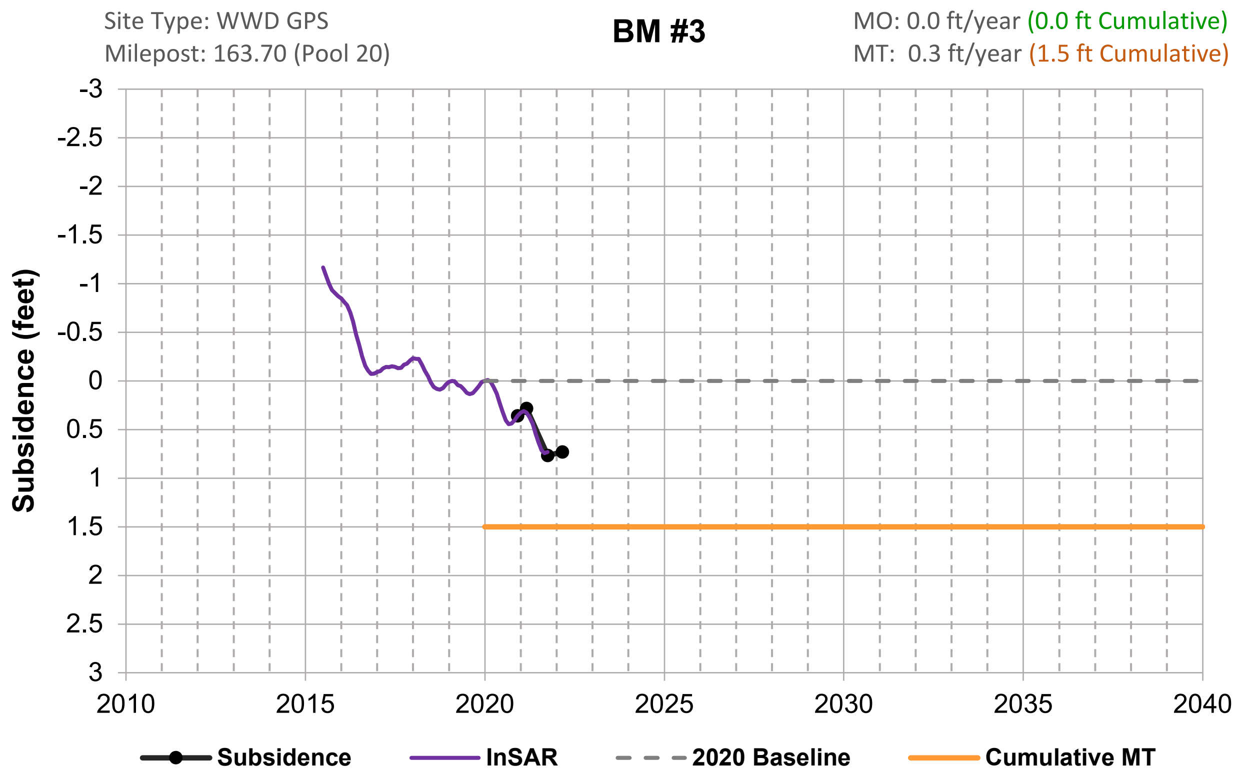

Site Type: USGS Extensometer (0-1358 ftbgs)
Panoche
MO: 0.1 ft/year (0.5 ft Cumulative)
MT: 0.3 ft/year (2.5 ft Cumulative)
Compaction (feet)
-3
-2.5
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2
2.5
3
2010
2015
2020
2025
2030
2035
2040
Compaction
2020 Baseline
Cumulative MO
Cumulative MT

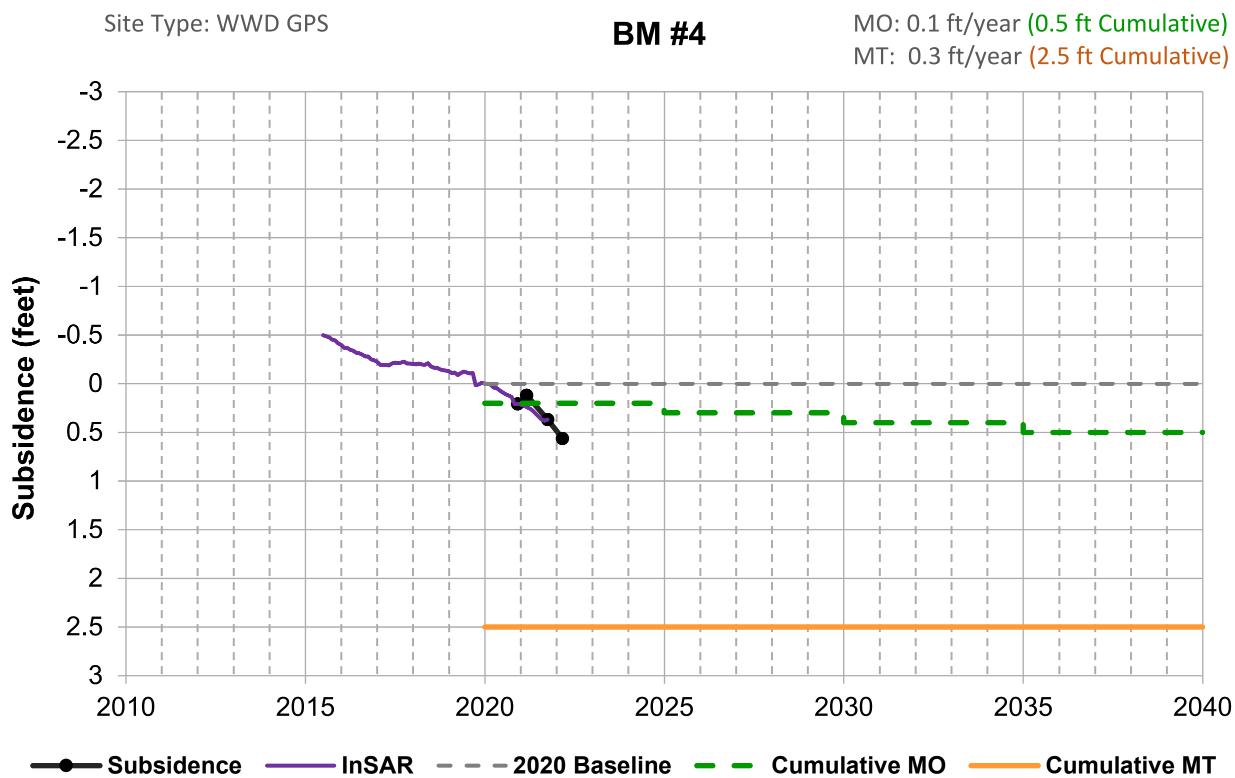

Site Type: USGS Extensometer (0-1070 ftbgs)
Milepost: 155.22 (Check 19)
Rasta
MO: 0.0 ft/year (0.0 ft Cumulative)
MT: 0.3 ft/year (1.5 ft Cumulative)
Compaction (feet)
-3
-2.5
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2
2.5
3
2010
2015
2020
2025
2030
2035
2040
Compaction
2020 Baseline
Cumulative MT

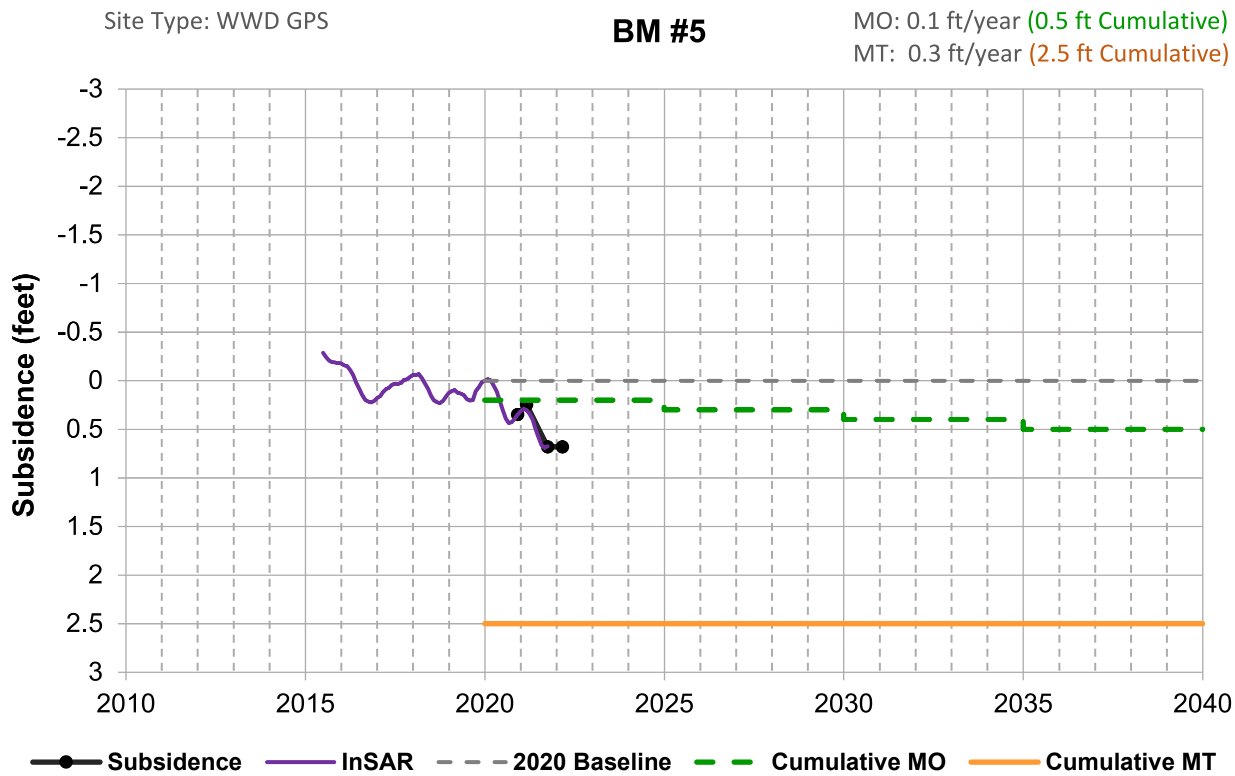

Site Type: UNAVCO CGPS
P302
MO: 0.1 ft/year (0.5 ft Cumulative)
MT: 0.3 ft/year (2.5 ft Cumulative)
Subsidence (feet)
-3
-2.5
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2
2.5
3
2010
2015
2020
2025
2030
2035
2040
Subsidence
2020 Baseline
Cumulative MO
Cumulative MT

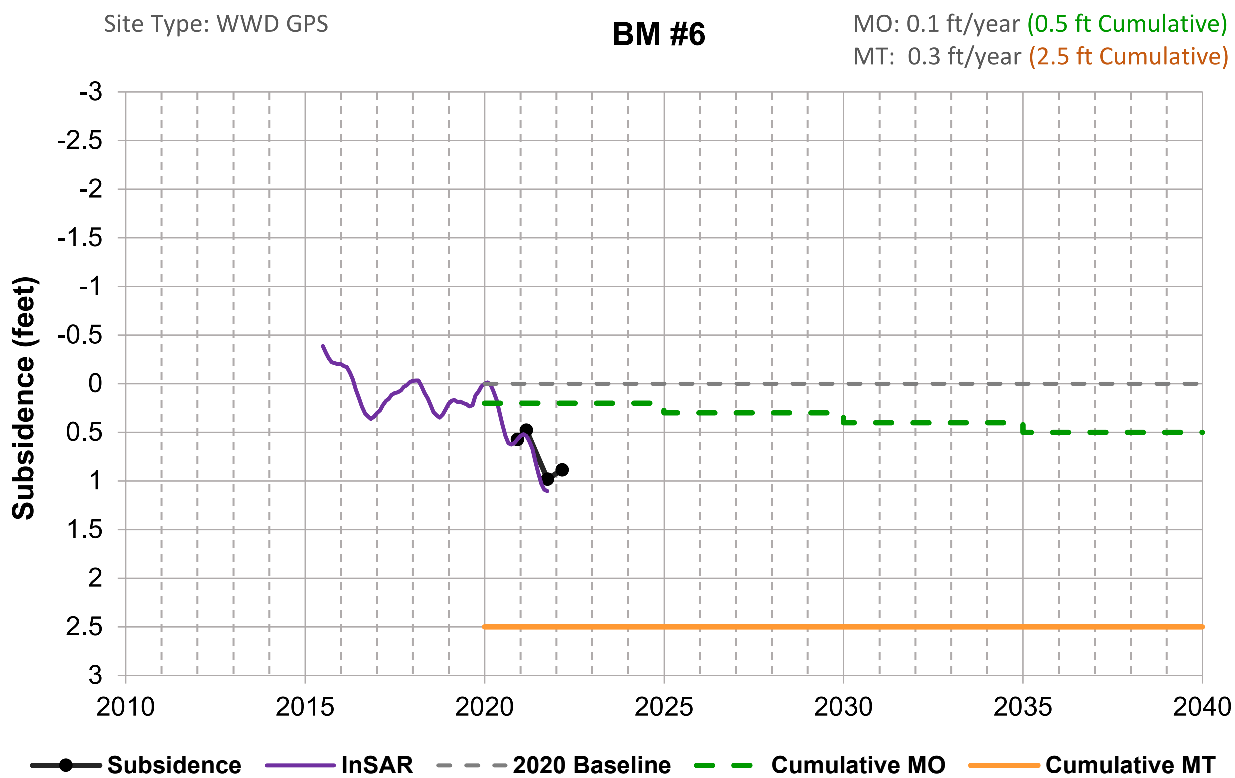

Site Type: WWD GPS
BM #1
MO: 0.1 ft/year (0.5 ft Cumulative)
MT: 0.3 ft/year (2.5 ft Cumulative)
Subsidence (feet)
-3
-2.5
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2
2.5
3
2010
2015
2020
2025
2030
2035
2040
Subsidence
InSAR
2020 Baseline
Cumulative MO
Cumulative MT

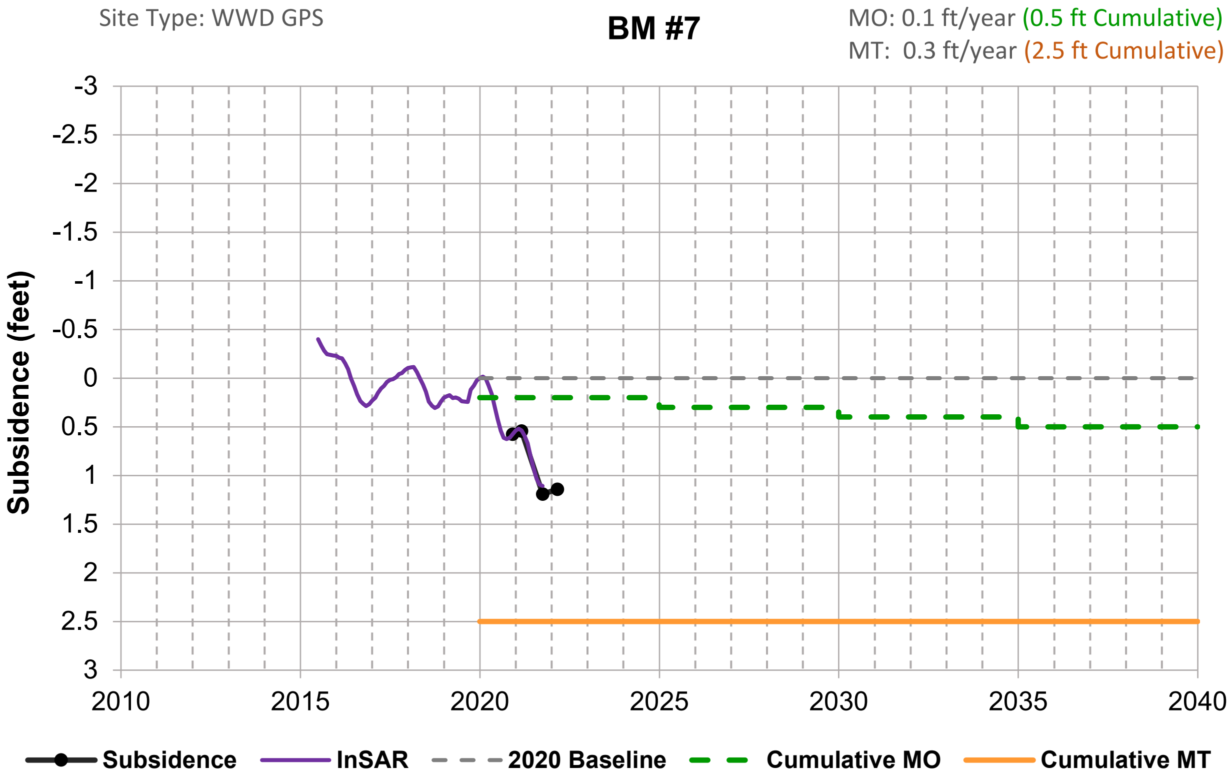

Site Type: WWD GPS
BM #2
MO: 0.1 ft/year (0.5 ft Cumulative)
MT: 0.3 ft/year (2.5 ft Cumulative)
Subsidence (feet)
-3
-2.5
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2
2.5
3
2010
2015
2020
2025
2030
2035
2040
Subsidence
InSAR
2020 Baseline
Cumulative MO
Cumulative MT

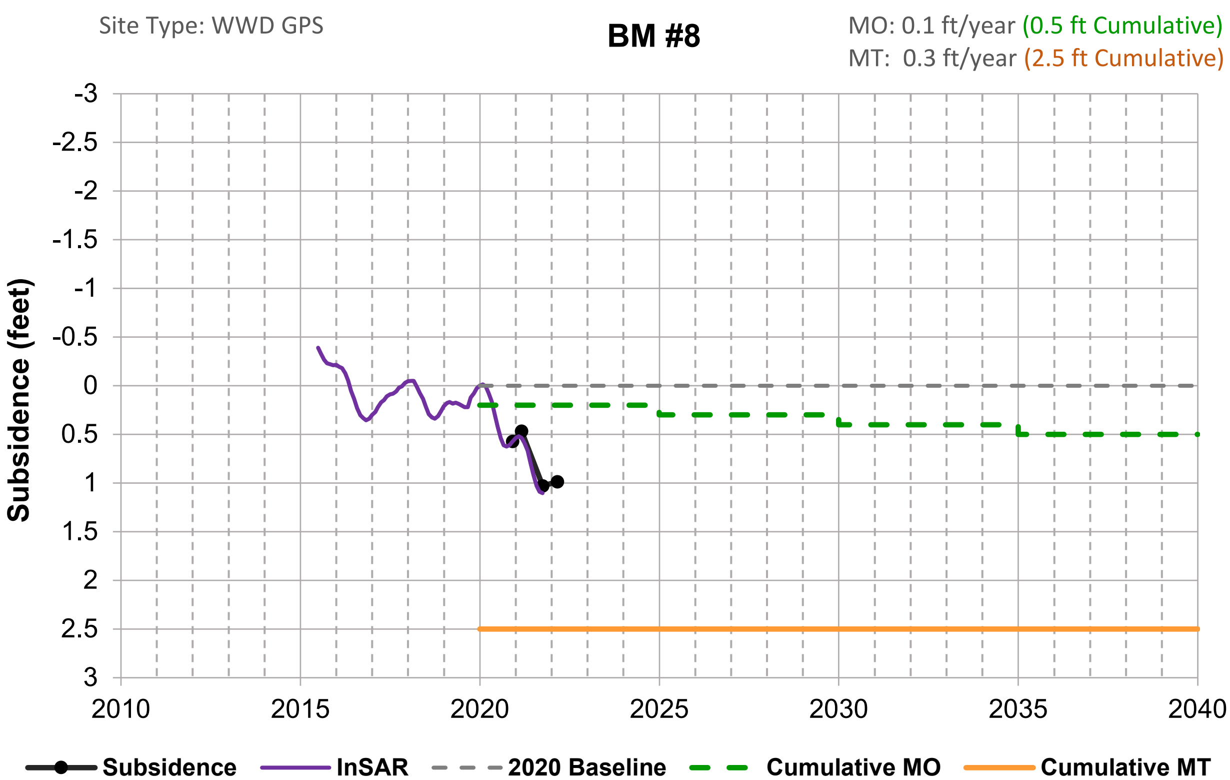

Site Type: WWD GPS
Milepost: 163.70 (Pool 20)
BM #3
MO: 0.0 ft/year (0.0 ft Cumulative)
MT: 0.3 ft/year (1.5 ft Cumulative)
Subsidence (feet)
-3
-2.5
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2
2.5
3
2010
2015
2020
2025
2030
2035
2040
Subsidence
InSAR
2020 Baseline
Cumulative MT

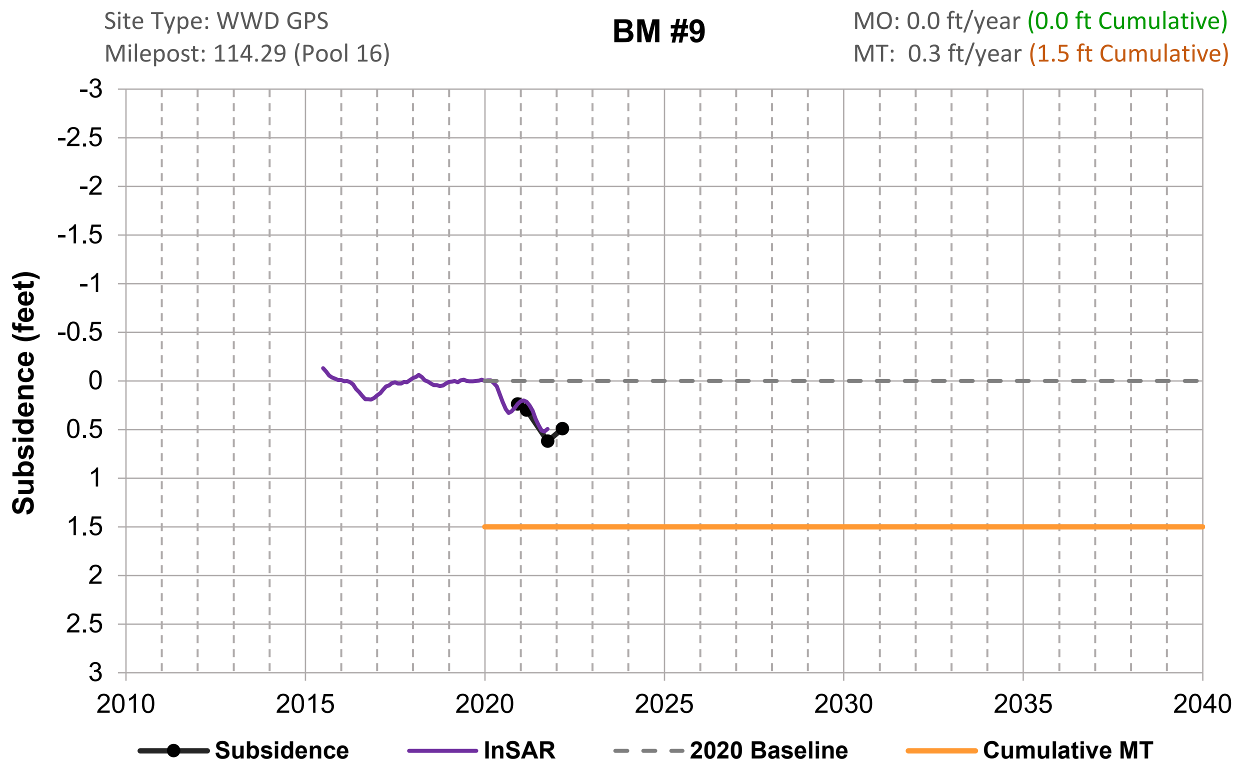

Site Type: WWD GPS
BM #4
MO: 0.1 ft/year (0.5 ft Cumulative)
MT: 0.3 ft/year (2.5 ft Cumulative)
Subsidence (feet)
-3
-2.5
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2
2.5
3
2010
2015
2020
2025
2030
2035
2040
Subsidence
InSAR
2020 Baseline
Cumulative MO
Cumulative MT

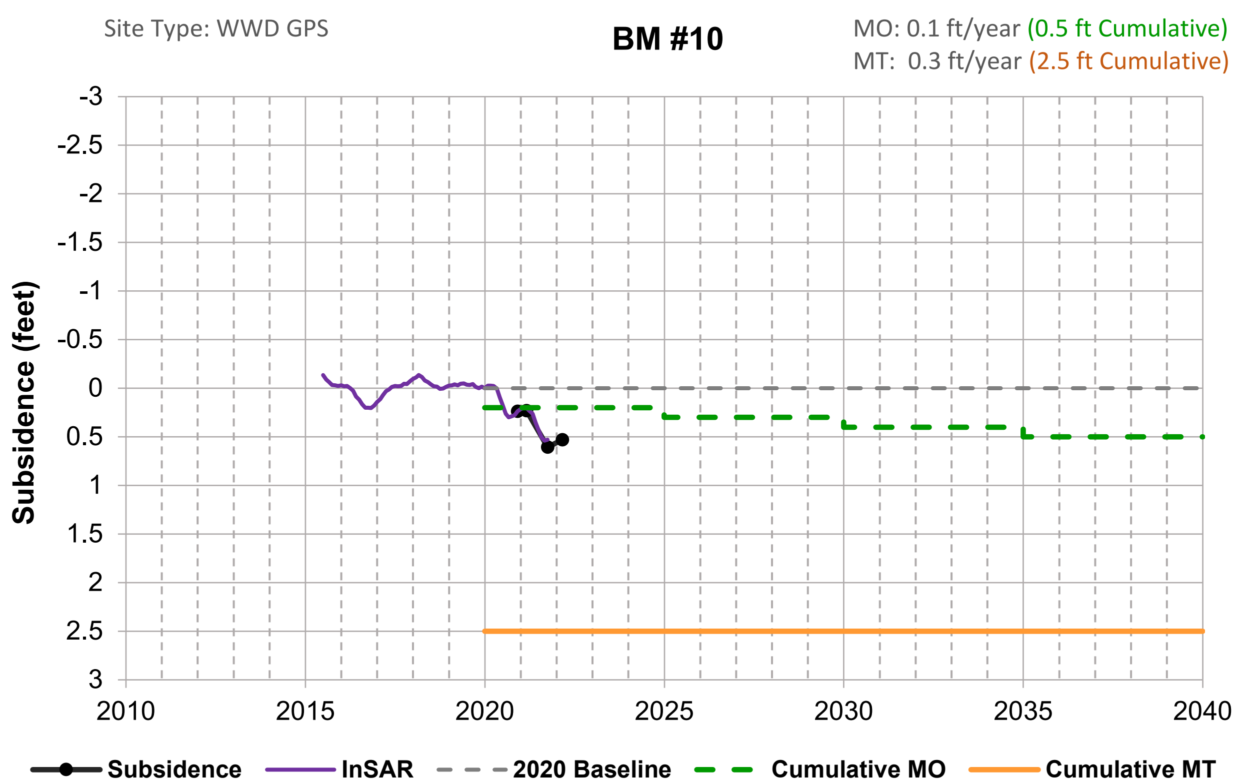

Site Type: WWD GPS
BM #5
MO: 0.1 ft/year (0.5 ft Cumulative)
MT: 0.3 ft/year (2.5 ft Cumulative)
Subsidence (feet)
-3
-2.5
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2
2.5
3
2010
2015
2020
2025
2030
2035
2040
Subsidence
InSAR
2020 Baseline
Cumulative MO
Cumulative MT

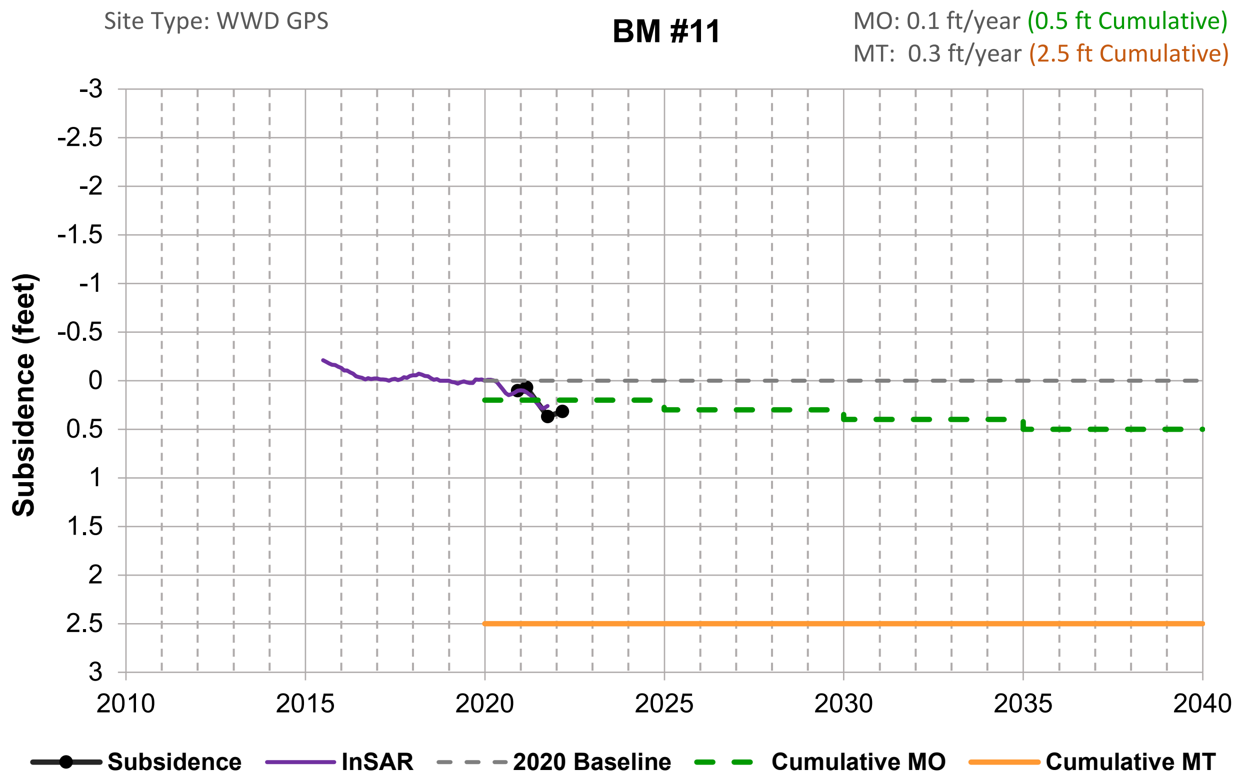

Site Type: WWD GPS
BM #6
MO: 0.1 ft/year (0.5 ft Cumulative)
MT: 0.3 ft/year (2.5 ft Cumulative)
Subsidence (feet)
-3
-2.5
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2
2.5
3
2010
2015
2020
2025
2030
2035
2040
Subsidence
InSAR
2020 Baseline
Cumulative MO
Cumulative MT

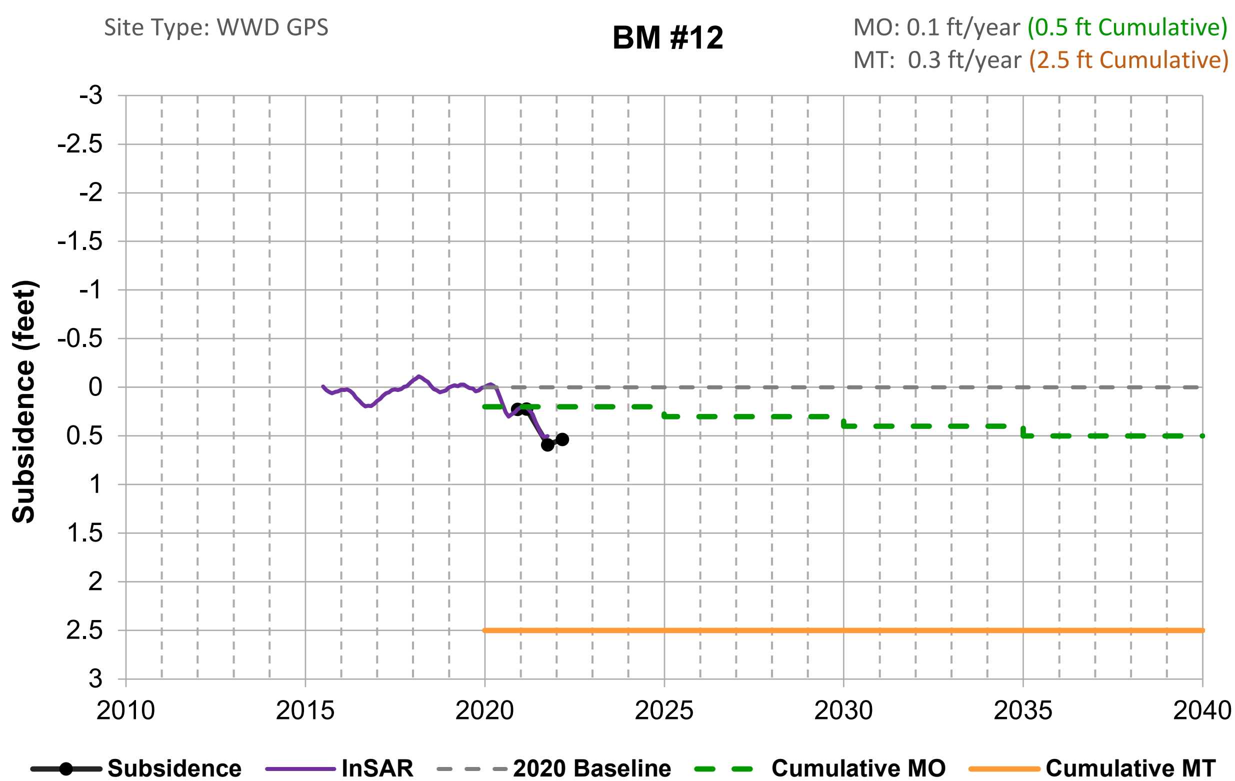

Site Type: WWD GPS
BM #7
MO: 0.1 ft/year (0.5 ft Cumulative)
MT: 0.3 ft/year (2.5 ft Cumulative)
Subsidence (feet)
-3
-2.5
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2
2.5
3
2010
2015
2020
2025
2030
2035
2040
Subsidence
InSAR
2020 Baseline
Cumulative MO
Cumulative MT

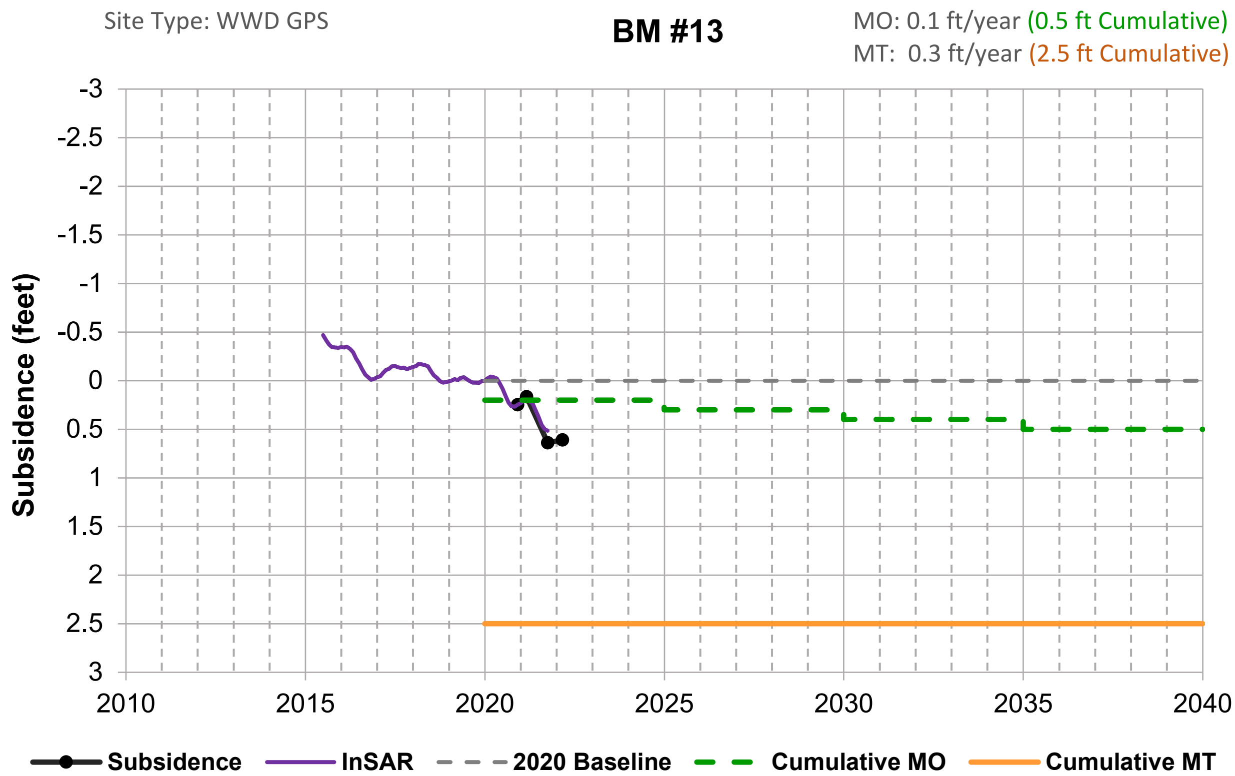

Site Type: WWD GPS
BM #8
MO: 0.1 ft/year (0.5 ft Cumulative)
MT: 0.3 ft/year (2.5 ft Cumulative)
Subsidence (feet)
-3
-2.5
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2
2.5
3
2010
2015
2020
2025
2030
2035
2040
Subsidence
InSAR
2020 Baseline
Cumulative MO
Cumulative MT

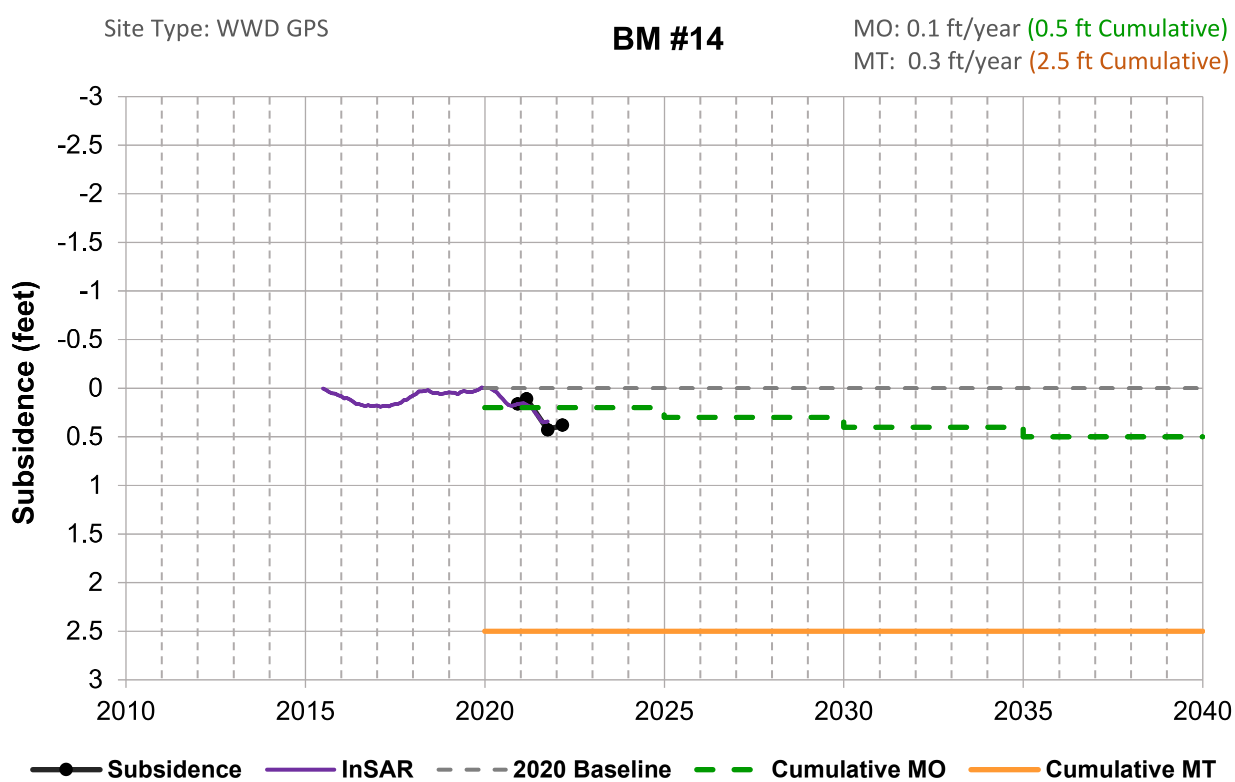

Site Type: WWD GPS
Milepost: 114.29 (Pool 16)
BM #9
MO: 0.0 ft/year (0.0 ft Cumulative)
MT: 0.3 ft/year (1.5 ft Cumulative)
Subsidence (feet)
-3
-2.5
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2
2.5
3
2010
2015
2020
2025
2030
2035
2040
Subsidence
InSAR
2020 Baseline
Cumulative MT

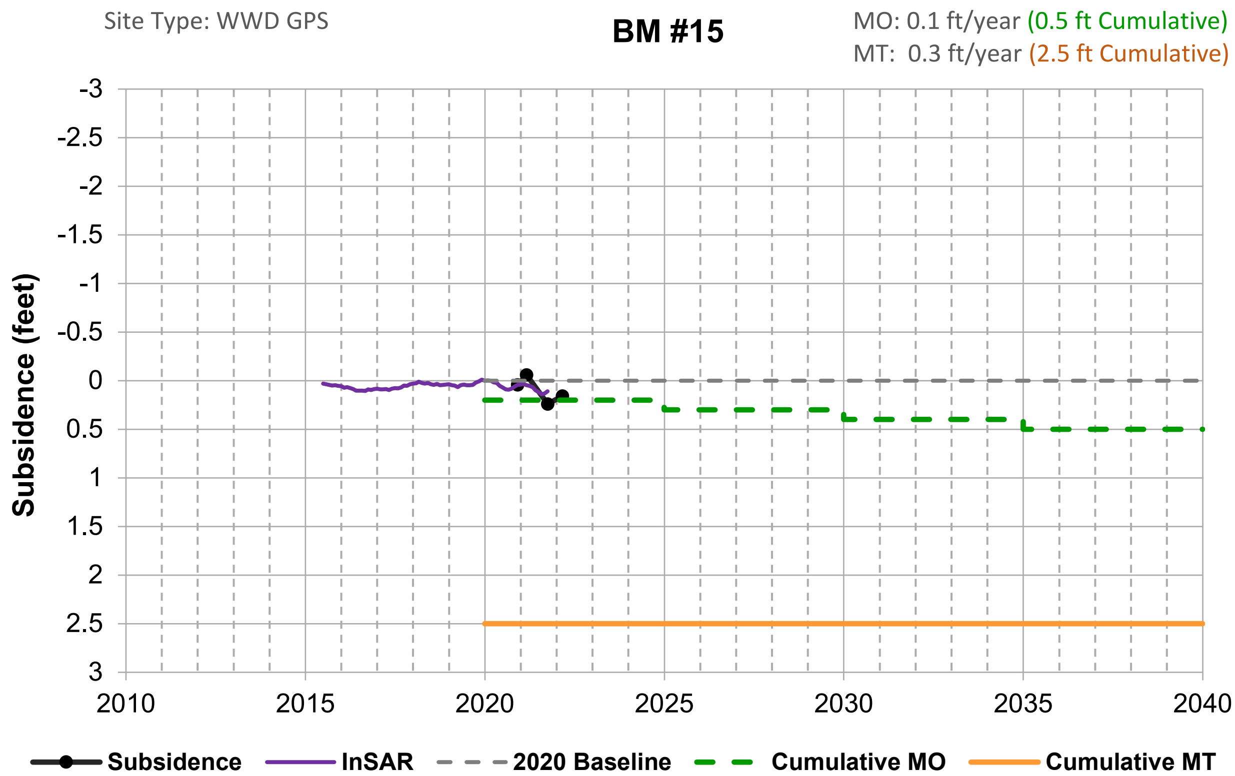

Site Type: WWD GPS
BM #10
MO: 0.1 ft/year (0.5 ft Cumulative)
MT: 0.3 ft/year (2.5 ft Cumulative)
Subsidence (feet)
-3
-2.5
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2
2.5
3
2010
2015
2020
2025
2030
2035
2040
Subsidence
InSAR
2020 Baseline
Cumulative MO
Cumulative MT

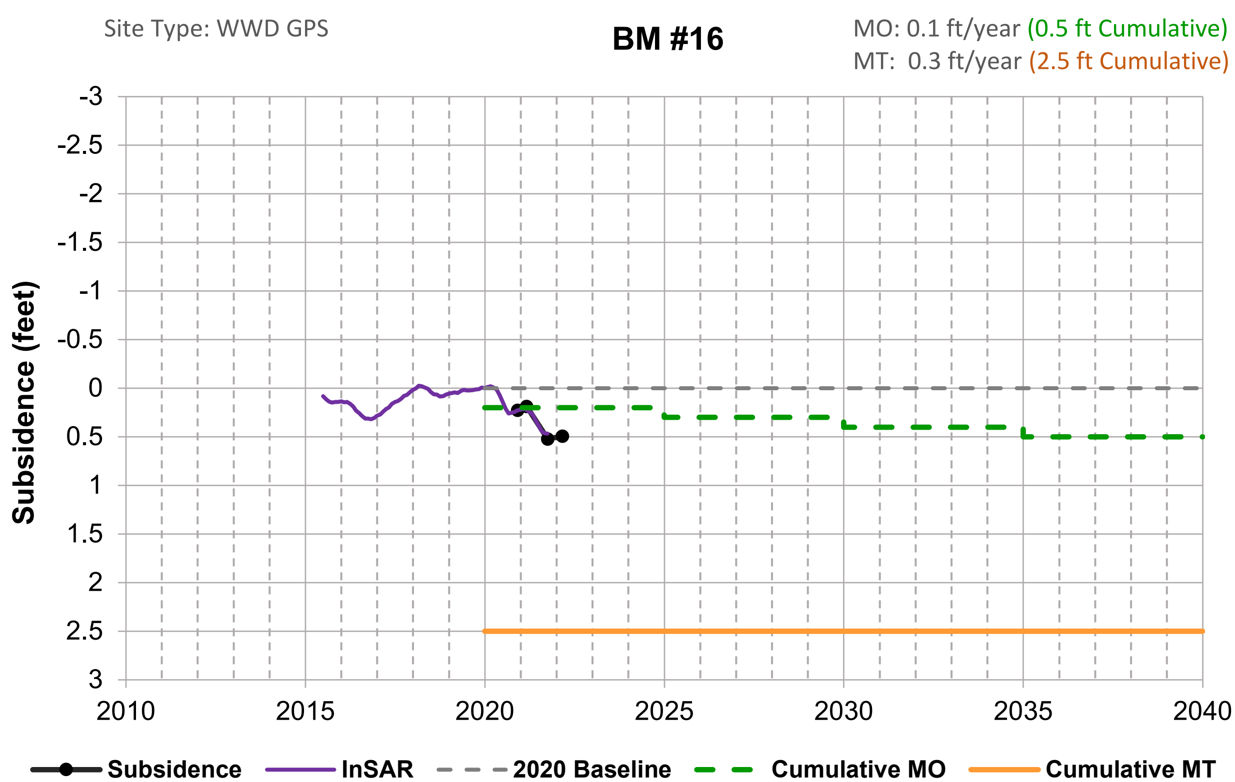

Site Type: WWD GPS
BM #11
MO: 0.1 ft/year (0.5 ft Cumulative)
MT: 0.3 ft/year (2.5 ft Cumulative)
Subsidence (feet)
-3
-2.5
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2
2.5
3
2010
2015
2020
2025
2030
2035
2040
Subsidence
InSAR
2020 Baseline
Cumulative MO
Cumulative MT

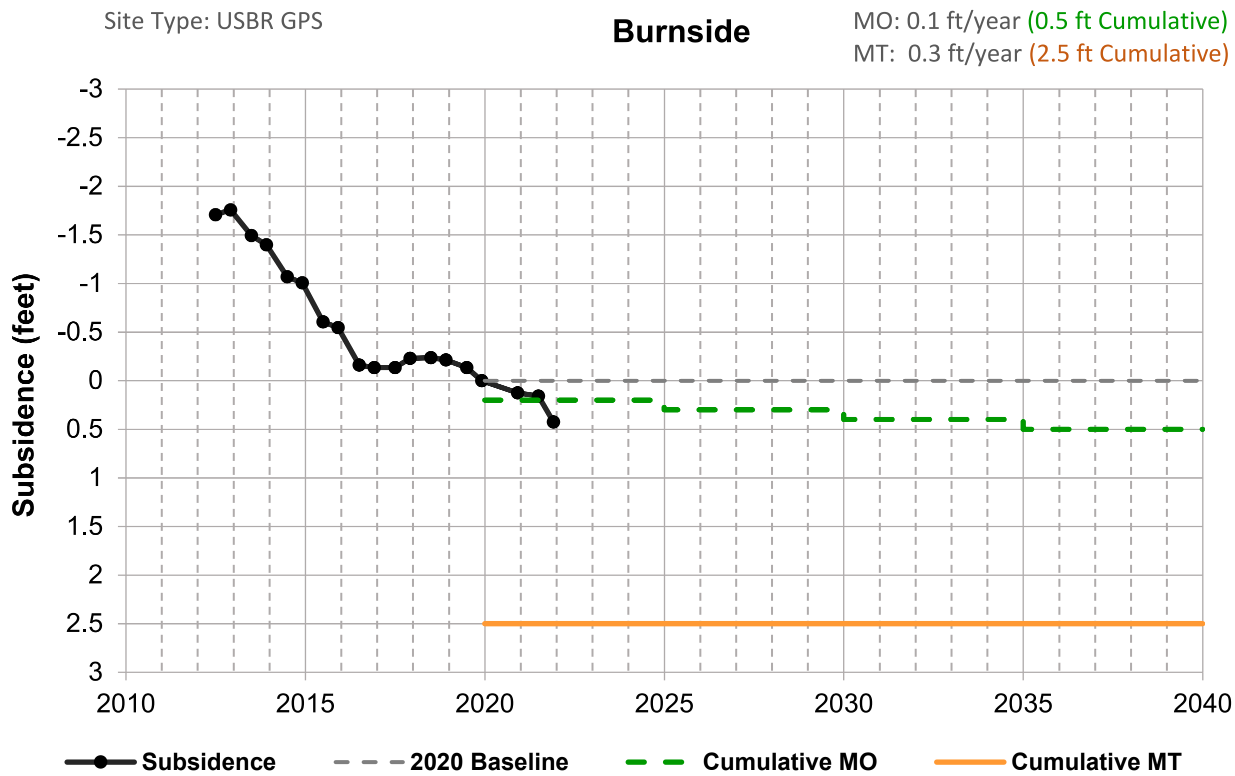

Site Type: WWD GPS
BM #12
MO: 0.1 ft/year (0.5 ft Cumulative)
MT: 0.3 ft/year (2.5 ft Cumulative)
Subsidence (feet)
-3
-2.5
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2
2.5
3
2010
2015
2020
2025
2030
2035
2040
Subsidence
InSAR
2020 Baseline
Cumulative MO
Cumulative MT

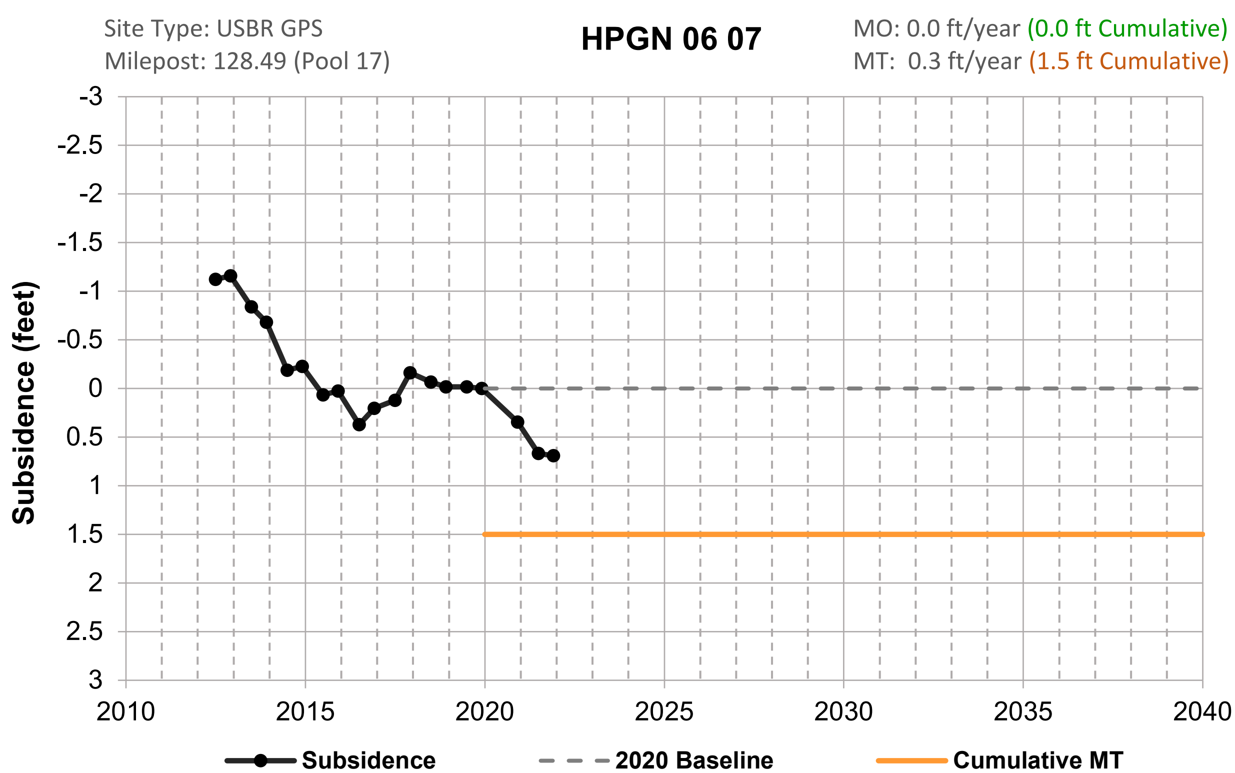

Site Type: WWD GPS
BM #13
MO: 0.1 ft/year (0.5 ft Cumulative)
MT: 0.3 ft/year (2.5 ft Cumulative)
Subsidence (feet)
-3
-2.5
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2
2.5
3
2010
2015
2020
2025
2030
2035
2040
Subsidence
InSAR
2020 Baseline
Cumulative MO
Cumulative MT

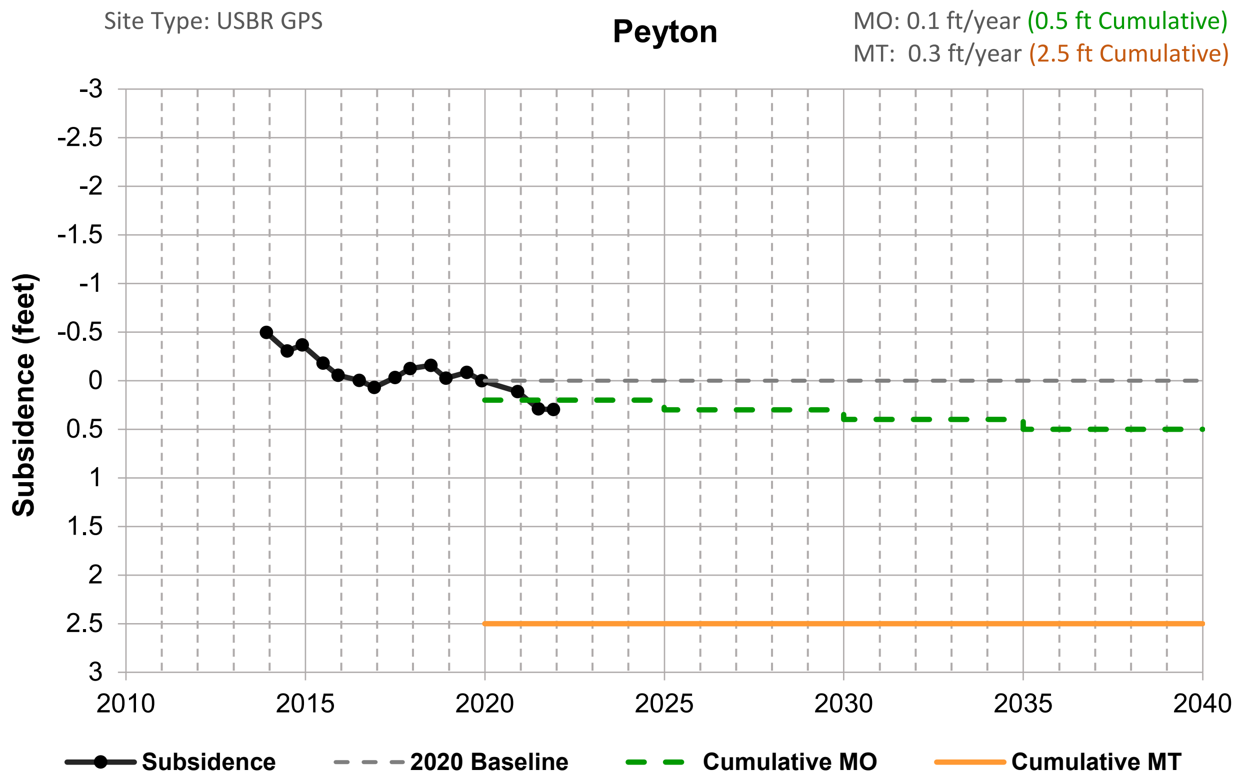

Site Type: WWD GPS
BM #14
MO: 0.1 ft/year (0.5 ft Cumulative)
MT: 0.3 ft/year (2.5 ft Cumulative)
Subsidence (feet)
-3
-2.5
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2
2.5
3
2010
2015
2020
2025
2030
2035
2040
Subsidence
InSAR
2020 Baseline
Cumulative MO
Cumulative MT

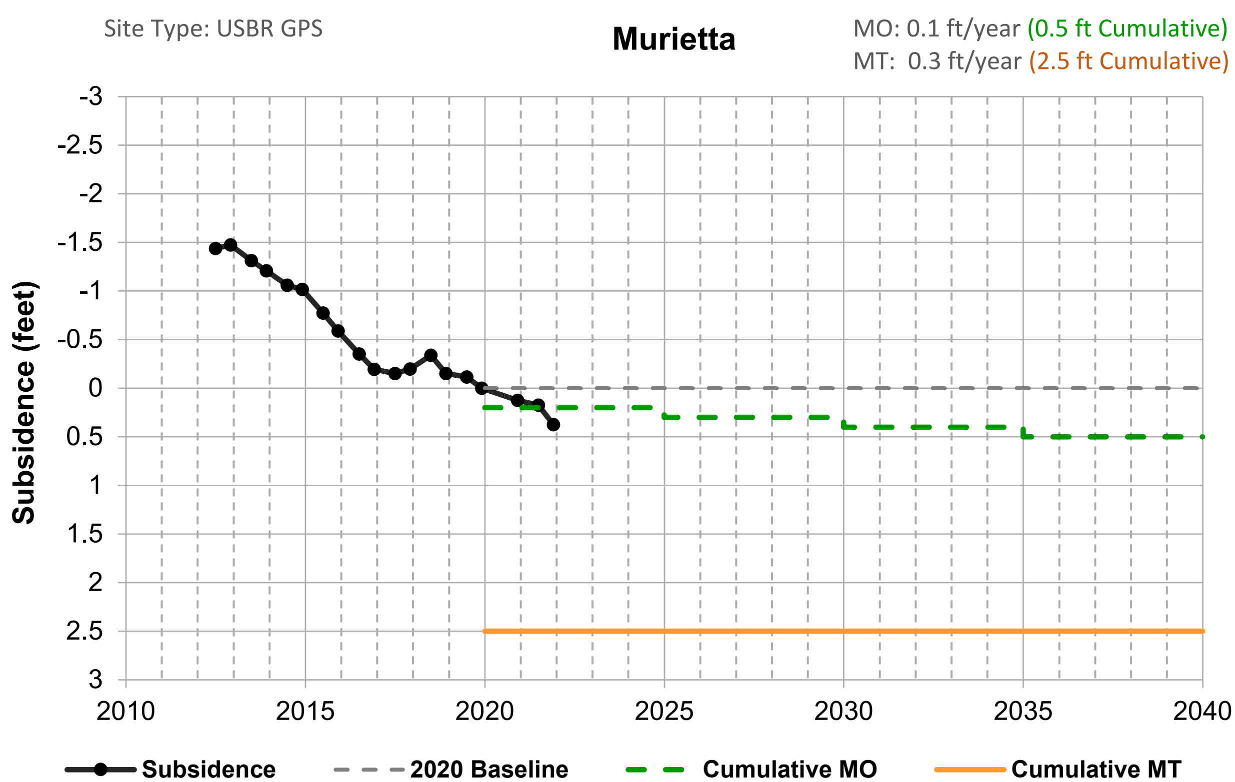

Site Type: WWD GPS
BM #15
MO: 0.1 ft/year (0.5 ft Cumulative)
MT: 0.3 ft/year (2.5 ft Cumulative)
Subsidence (feet)
-3
-2.5
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2
2.5
3
2010
2015
2020
2025
2030
2035
2040
Subsidence
InSAR
2020 Baseline
Cumulative MO
Cumulative MT

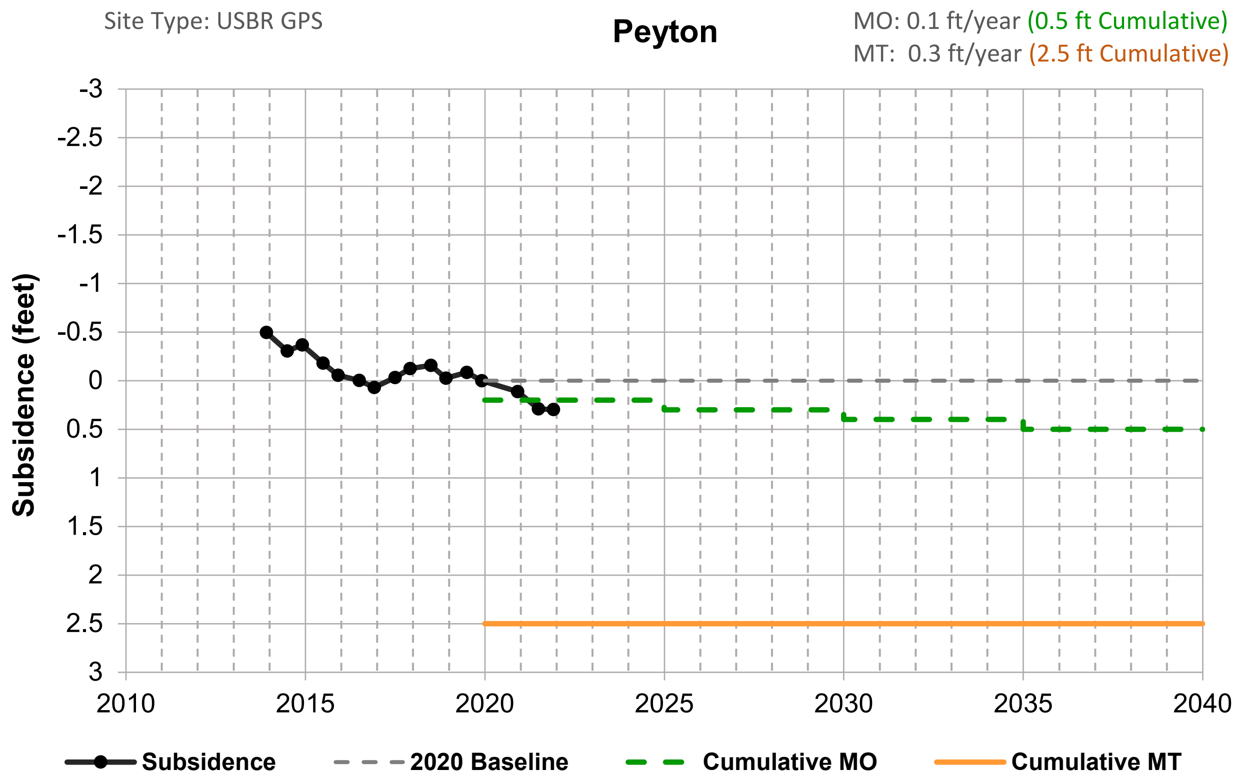

Site Type: WWD GPS
BM #16
MO: 0.1 ft/year (0.5 ft Cumulative)
MT: 0.3 ft/year (2.5 ft Cumulative)
Subsidence (feet)
-3
-2.5
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2
2.5
3
2010
2015
2020
2025
2030
2035
2040
Subsidence
InSAR
2020 Baseline
Cumulative MO
Cumulative MT

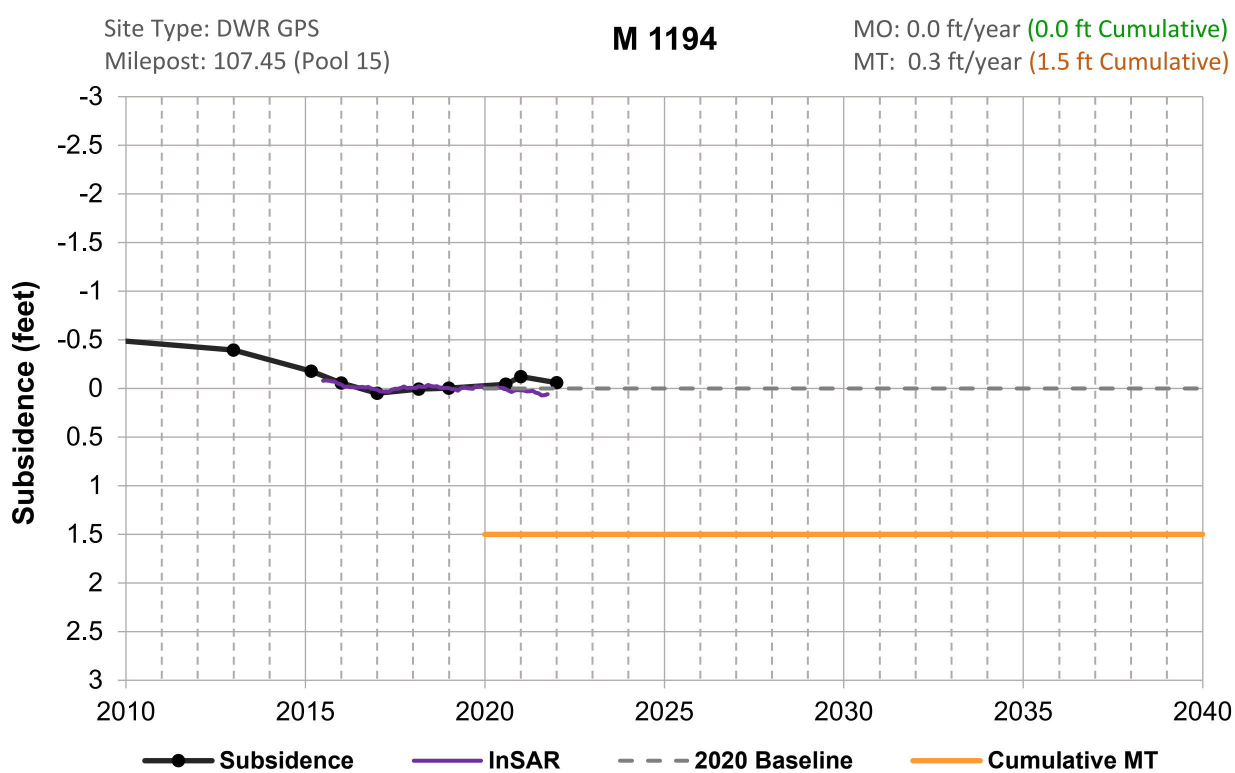

Site Type: USBR GPS
Burnside
MO: 0.1 ft/year (0.5 ft Cumulative)
MT: 0.3 ft/year (2.5 ft Cumulative)
Subsidence (feet)
-3
-2.5
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2
2.5
3
2010
2015
2020
2025
2030
2035
2040
Subsidence
2020 Baseline
Cumulative MO
Cumulative MT


Site Type: USBR GPS
Milepost: 128.49 (Pool 17)
HPGN 06 07
MO: 0.0 ft/year (0.0 ft Cumulative)
MT: 0.3 ft/year (1.5 ft Cumulative)
Subsidence (feet)
-3
-2.5
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2
2.5
3
2010
2015
2020
2025
2030
2035
2040
Subsidence
2020 Baseline
Cumulative MT


Site Type: USBR GPS
Peyton
MO: 0.1 ft/year (0.5 ft Cumulative)
MT: 0.3 ft/year (2.5 ft Cumulative)
Subsidence (feet)
-3
-2.5
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2
2.5
3
2010
2015
2020
2025
2030
2035
2040
Subsidence
2020 Baseline
Cumulative MO
Cumulative MT


Site Type: USBR GPS
Murietta
MO: 0.1 ft/year (0.5 ft Cumulative)
MT: 0.3 ft/year (2.5 ft Cumulative)
Subsidence (feet)
-3
-2.5
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2
2.5
3
2010
2015
2020
2025
2030
2035
2040
Subsidence
2020 Baseline
Cumulative MO
Cumulative MT


Site Type: USBR GPS
Peyton
MO: 0.1 ft/year (0.5 ft Cumulative)
MT: 0.3 ft/year (2.5 ft Cumulative)
Subsidence (feet)
-3
-2.5
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2
2.5
3
2010
2015
2020
2025
2030
2035
2040
Subsidence
2020 Baseline
Cumulative MO
Cumulative MT


Site Type: DWR GPS
Milepost: 107.45 (Pool 15)
M 1194
MO: 0.0 ft/year (0.0 ft Cumulative)
MT: 0.3 ft/year (1.5 ft Cumulative)
Subsidence (feet)
-3
-2.5
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2
2.5
3
2010
2015
2020
2025
2030
2035
2040
Subsidence
InSAR
2020 Baseline
Cumulative MT