

2 WESTSIDE SUBBASIN PLAN AREA AND SETTING

2.1 Description of Plan Area

2.1.1 Summary of Jurisdictional and Plan Area (§354.8 (b))

The Westside Subbasin (Subbasin, [DWR Subbasin No. 5-22.09](#)) covers 972 square miles (622,215 acres) and spans approximately 17 miles east and west and 67 miles from Mendota to Kettleman City. The Subbasin lies within the western portion of the larger San Joaquin [Valley](#) Groundwater Basin- ([DWR Basin No. 5-22](#)). The Subbasin is bordered by the Diablo Range to the west and other groundwater subbasins along its north, east and southern boundaries: the Pleasant Valley Subbasin (DWR Subbasin No. 5-22.10) lies to the southwest, the Tulare Lake Subbasin (DWR Subbasin No. 5-22.12) to the south, the Kings Subbasin (DWR Subbasin No. 5-22.08) to the east, and the Delta-Mendota Subbasin (DWR Subbasin No. 5-22.07) to the east and north (**Figure 2-1**).

This GSP covers the entire Subbasin, the majority of which falls within the [District's District](#) boundaries. Several small areas along the western and eastern edge of the Subbasin extend past the [District's District](#) boundaries and fall within the jurisdiction of Fresno and Kings Counties. The County of Fresno serves as the GSA for the portions of the [Westside](#) Subbasin outside of the [District's District](#) boundaries that lie within Fresno County. The Kings County portion of the Subbasin that falls outside the [District's District](#) boundaries lies within Naval Air Station Lemoore (NASL), which is owned by the federal government and thus exempt from the requirements of SGMA.

There are no known adjudicated areas within or surrounding the Westside Subbasin.

Figure 2-2 titled, "Agencies in the GSP Area" depict all the known agencies in the [Westside](#) Subbasin per GSP [Emergency](#) Regulations Section 354.8 (a)(3). The agencies include Fresno County, Kings County, the City of Huron, the City of Avenal, NASL, Federal-Owned lands, and State-owned lands. Section 2.1.3 below includes additional information on the city and county agencies.

2.1.1.1 Summary of Existing Wells in Plan Area

Well types, well depth data, and well distribution data were obtained from [internal records from the District. These data were compared to](#) DWR's Well Completion Report [database, WWD pumping records, and from DWR's Well Completion Report \(WCR\)](#) Map Application (DWR, 2018). ~~DWR categorizes wells in the mapping application as Wells were categorized into three groups which includes domestic, production, or (agricultural and industrial), and public supply. The mapping application appears to underestimate the number of wells that exist in WWD (approximately 760 wells). Pumping records provided by WWD for 2015 indicate that approximately 930 wells were actively pumped during that year. The variation in the number of wells that exist in WWD is likely due to incomplete dataset or technical issues on the DWR Well Completion Report Application. This is a new application provided by DWR and is still under development.~~ [wells](#). **Table 2-1** summarizes the types of [wellwells](#) by [beneficial](#) use ~~for the wells that were in the DWR well log mapping application. We assume that the majority of the wells categorized on well logs as~~

production wells are used for irrigation. Most of the wells in the Subbasin are used for irrigation purposes.

Table 2-1: Types of Wells

Type of Well	Total Wells
Domestic	38
Production (Agricultural & Industrial)	930915
Public Supply & Municipal	116
TOTAL	979959

Figures 2-3 through 2-5 show the density of wells in the Subbasin by their type of use. DWR's data used to develop these maps are not necessarily the same set of well data held by the Counties or the District. DWR data were used to develop maps of well densities because they are organized for easy mapping of well density per square mile. These maps should be considered representative of well distribution, but not an accurate record of existing wells. The well density ranges from approximately 0.75 to 0.95 wells per square mile.

The District records indicate that there are 38 active domestic well sites in the Subbasin. The number of domestic sites is slightly different than the DWR SGMA Data Viewer because as of 2022. The District visits all the well locations designated for domestic use on an annual basis and records whether the sites are inactive or active. Based on the 2019 survey, The District also communicated with individual domestic wells owners to determine if the most recent drought impacted these domestic wells. The District determined that there are currently 38 none of the domestic well owners reported their wells as having gone dry during that time period. Additionally, DWR's Dry Wells Reporting System¹ has not reported dry wells in the Westside Subbasin. The District evaluated the screen intervals of all active domestic sites wells within the Westside Subbasin to determine the potential impact of selected Minimum Thresholds and 23 inactive domestic sites. this analysis is further discussed in Chapter 3. The domestic wells are considered de minimis extractors, pumping less than 2 Acre-Feet (AF) annually and collectively pumping up to 7876 Acre-Feet/Year (AFY). The domestic wells identified and evaluated by the District are distributed throughout the District, rather than located in discrete areas.

¹ <https://mydrywell.water.ca.gov/report/publicpage>

2.1.2 Water Resource Monitoring and Management Programs (§354.8 (c,d,e))

For the last four decades, the District has actively managed the Subbasin's groundwater resources. The District monitors and manages the Subbasin through its Groundwater Management Plan (GMP), Water Management Plan, the California Statewide Groundwater Elevation Monitoring (CASGEM) program, and Groundwater Quality Trend Monitoring Plan, and the Integrated Regional Water Management Plan. Implementing these programs, which are described below in detail, promote conjunctive use and preserve groundwater in the Westside Subbasin. The District does not believe any of these programs listed above limit the operation or implementation of the Subbasin's GSP. To the contrary, the existing water resources monitoring and management programs support the implementation of the GSP. The District utilized the existing programs detailed below to develop the monitoring network, described in Chapter 3, and added additional sites with sufficient historical data to fill in monitoring gaps.

2.1.2.1 Groundwater Management Plan (GMP)

The District developed and adopted its first GMP in 1996 pursuant to Assembly Bill 3030 (which was later codified under Part 2.75 of the Water Code). The main objective of the District's GMP is to preserve and enhance the long-term sustainability of the District's groundwater resources. The District's GMP outlined a comprehensive groundwater monitoring program which is described in this GSP.

"Pursuant to AB 3030, any local public agency which provides water service to all or a portion of its service area and whose service area includes all or a portion of a groundwater Subbasin, to adopt a groundwater management program. The law contains 12 components which may be included in a GMP. Each component may play some role in evaluating or operating a groundwater Subbasin so that groundwater can be managed to maximize the total water supply while protecting groundwater quality." (Westlands Water District, 1996).

Since 2012, the District has collected pumping data from all the accessible groundwater well meters on a quarterly basis. On average, this means collecting pumping data from 87 percent of groundwater well meters, since approximately 13 percent of the sites in the Subbasin are not accessible due to locked gates, inoperable meters or is an unmetered location. Prior to 2012, the District estimated groundwater pumping in the Subbasin based on the amount of groundwater pumped in the GMP-Groundwater Management Program (GWMP). Through its GMPGWMP, the District became the first water district in the state to integrate local groundwater resources into the District's water supply system. Through this program, the District acquires title to groundwater pumps, orders energy for the groundwater wells and integrates the groundwater pumped into the District's comprehensive water supply.

2.1.2.2 Water Management Plan

The District developed and implemented a Water Management Plan, which satisfies the requirements of the Agricultural Water Management Planning Act (Wat. Code, §§ 10800 et seq.), the Reclamation Reform Act of 1982 (P.L. 97-295-96, stat. 213), the Central Valley Project Improvement Act of 1992 (P.L. 102-575, 106 stat. 4713) and the Water Conservation Bill of 2009 (Wat. Code, § 10820). The Water Management

Plan provides information about current water uses and charts a course for water efficiency improvements, conservation activities, and water-reduction goals. The District relies on the information collected pursuant to the Water Management Plan to establish funding priorities for the District's water-efficiency projects that will provide the largest impact. [Water Management Plan objectives and goals:](#)

- [Conserve the available water supply](#)
- [Protect the integrity of water supply facilities](#)
- [Implement contingency plan in times of drought or water supply reduction](#)
- [Track Agricultural cropping patterns, changes in irrigated acres and anticipated land use changes within the District](#)
- [Measure the volume of water delivered to water users with accuracy](#)
- [Evaluate capital improvement projects with the potential to enhance reliable water supply](#)
- [Facilitate the financing of capital improvements for on-farm irrigation systems](#)
- [Pursues water transfers from other districts on an annual basis to supplement reduced contract deliveries to water users](#)
- [Facilitate individual water transfers between water users within the District or from other districts to supplement their water supply](#)
- [Promote and educate water users about water conservation and preventative measures to avoid wasteful use of water](#)
- [Participate in water quality monitoring practices](#)
- [Evaluate and improve efficiencies of District pumps](#)

[The Water Management Plan provides a framework of management practices, such as conjunctive use and conservation efforts, that help meet the water management goals and are consistent with the goals of the Westside Subbasin GSP.](#)

[2.1.2.2.1 Conjunctive Use](#)

The Westside Subbasin is comprised of approximately 93 percent farmland. The primary land use of the Westside Subbasin is for agricultural [purposes/beneficial uses](#) producing more than 60 high quality commercial food and fiber crops. The Subbasin's water users rely on surface water and groundwater to irrigate their crops. The Subbasin receives surface water supplies from the CVP through the Delta facilities and takes delivery from the SLC. The District has water service contracts with the USBR for 1.197 MAF. However, the District does not often receive the full contractual allocation. [Table 2-2 titled "WWD Historical CVP Supply" summarizes the District's CVP allocation per Water Year.](#)

The District's conjunctive use patterns fluctuate depending on available and utilized surface water supplies. Based on historical land use practices, the District's [agricultural](#) water users apply an average annual amount of approximately 960,000 AF to land overlying the Subbasin utilizing a combination of groundwater and imported surface water supplies. When surface water shortfalls exist, water users

utilize groundwater to offset the deficit in surface water supplies. The District developed a Water Management Plan and Groundwater Management Plan to promote conjunctive use in the Westside Subbasin, located in **Appendices E and F**. The District developed the plans and set the following primary goals:

- Preserve and enhance the reliability of groundwater in the Westside Subbasin;
- Ensure the long-term availability of high-quality groundwater;
- Maintain local control of groundwater resources in the District; and
- Minimize the cost and impacts of groundwater use.

Additionally, the District Board of Directors has taken progressive actions to promote conjunctive use and discourage groundwater pumping when surface water supplies are adequate.

Table 2-2 titled, “WWD Historical CVP Supply”, summarizes the historical allocation the District received since 1988 with the recent five- and ten-year averages yielding 3045% and 3540%, respectively.

Table 2-2: WWD Historical CVP Supply

Water Year	CVP Allocation	Water Year	CVP Allocation
1988	100%	2004	70%
1989	100%	2005	85%
1990	50%	2006	100%
1991	27%	2007	50%
1992	27%	2008	40%
1993	54%	2009	10%
1994	43%	2010	45%
1995	100%	2011	80%
1996	95%	2012	40%
1997	90%	2013	20%
1998	100%	2014	0%
1999	70%	2015	0%
2000	65%	2016	5%
2001	49%	2017	100%
2002	70%	2018	50%
2003	75%	2019	75%

2.1.2.2.2 Conservation Efforts

The District maintains aits water distribution system by balancing the following factors: meeting the water demand of thousands of turnouts simultaneously, with adequate water pressure at all locations to address water quantity and peak flow rates. With its history of pervasive water shortages, the District and its growers work together to ensure that water delivered through its comprehensive water supply system is

responsibly and sustainably managed. For example, most the District's distribution system is fully enclosed to eliminate losses from evaporation.

The District implemented the Expanded Irrigation System Improvement Program (EISIP) to provide funding assistance, through low interest equipment leases, to growers interested in installing high efficiency irrigation systems. Irrigation systems include drip, micro drip, center pivot sprinklers and aluminum pipes. The EISIP program was developed to support water conservation. Currently, more than 95 percent of District's land is irrigated with drip or sprinkler delivery systems. **Figure 2-13**, titled "Historical Change in Irrigation Practices", illustrates the shift in irrigation practices from 1985 to 2015. In 1985, less than 37 percent of landowners within the District employed efficient irrigation practices and over time that percentage has increased to 96 percent as of 2017. In addition to the changes in irrigation practices, the District also uses more than 3,300 water meters throughout the Subbasin to ensure conservation practices and that any losses due to leakage are immediately addressed.

2.1.2.3 California Statewide Groundwater Elevation Monitoring Program (CASGEM)

Since 2011, the District has participated in the CASGEM Program. In collaboration with DWR, the District developed a groundwater monitoring network which includes 151 wells. Under CASGEM, the District is required to measure and report groundwater levels annually. Since 2015, the District has monitored the CASGEM well sites twice a year to determine seasonal groundwater highs and lows. Some of the CASGEM monitoring wells were incorporated into the Plan's groundwater monitoring network. The Westside Subbasin GSP groundwater level monitoring network includes 20 wells from the CASGEM program. This includes 9 wells in the Upper Aquifer and 11 wells Lower Aquifer.

2.1.2.4 Groundwater Quality Trend Monitoring Plan

The Westlands Water Quality Coalition (Coalition) administers the Groundwater Quality Trend Monitoring Plan (GQTM) to determine groundwater quality conditions underlying irrigated agriculture and to develop long-term groundwater quality information that can be used to evaluate the regional effects (i.e., non-site-specific effects) of irrigated agriculture and its practices. The Coalition represents owners and operators of irrigated lands overlying the Subbasin, the Pleasant Valley Subbasin (DWR Subbasin No. 5-22.10), the Panoche Valley Subbasin (DWR Subbasin No. 5-23) and the Vallecitos Creek Valley Subbasin (DWR Subbasin No. 5-71) and assists members with the waste discharge requirements described in the Western Tulare Lake Subbasin General Order R5-2014-001. As part of the GQTM Program, the Coalition's primary objective is to develop a network of wells within both high and low vulnerable areas and to sample those wells for nitrate and nitrite as nitrogen and field parameters (including electrical conductivity (EC)) annually, and the above constituents, TDS, and general minerals every five years. The GQTM well network consists primarily of wells completed in the Upper Aquifer and is an evolving network based on consideration of data derived through the implementation of the GQTM Program. The District plans to incorporate these water quality results into the GSP's data management system. However, GQTM wells are not included in the Monitoring Network since the GQTM Program's objectives are different than the SGMA. The District will reconsider incorporating the GQTM well into the Monitoring Network during each

5-year amendment. Incorporation of the GQTM into the Monitoring Network will likely be driven by pumping from the Upper Aquifer.

2.1.2.5 Integrated Regional Water Management Plan (IRWM)

The Integrated Regional Water Management (IRWM) is a collaborative effort to manage all aspects of water resources in a region. The IRWM Plan that encompasses the Westside Subbasin is the Westside-San Joaquin (WSJ) IRWM Region and is illustrated in **Figure 2-4a** (below). The 2019 WSJ IRWM Plan emphasizes multi-agency collaboration, stakeholder involvement, regional approaches to water management, water management involvement in land use decisions, and project monitoring to evaluate results of current practices. The WSJ IRWM Plan identifies projects that help achieve regional objectives and targets while working to address water-related challenges in the region. No single project identified in the IRWM Plan can meet all the objectives of the WSJ IRWM Region; therefore, the IRWM Plan identifies projects that can accrue regional benefits when implemented together and projects that provide coaction in specific benefit areas.

The Aquifer Storage and Recovery and Groundwater Recharge Projects were identified in the 2019 IRWM Plan and were also identified in the GSP as Project and Management Actions described in Chapter 4 to ensure the implementation of both plans were complementary. Implementation of the GSP is expected to support the regional water management goals of the WSJ IRWM Plan in the Westside Subbasin.

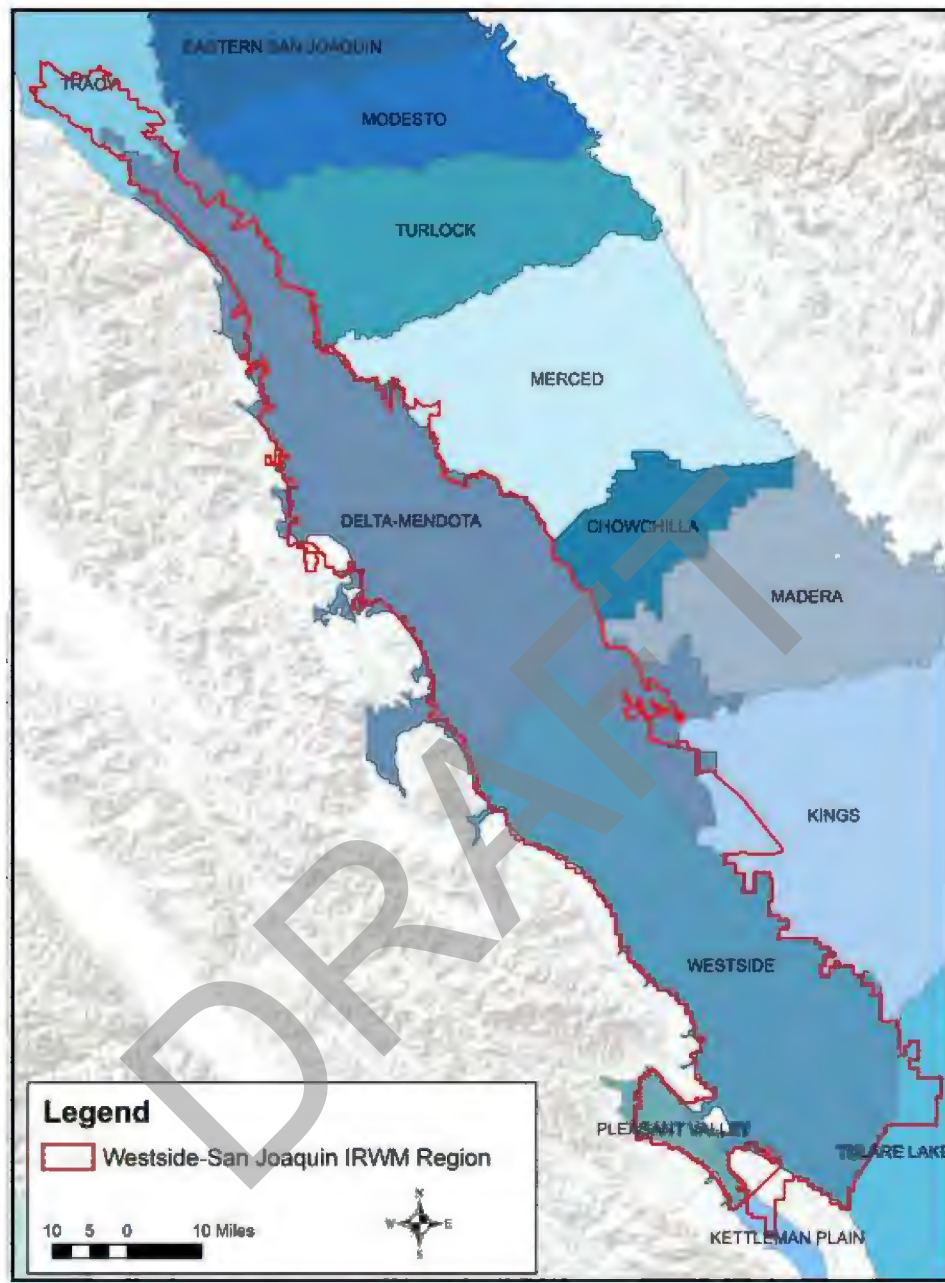


Figure 2-4a. Westside-San Joaquin IRWM Region overlying Groundwater Basins.

2.1.3 Land Use Elements or Topic Categories of Applicable General Plans (§354.8 (f))

2.1.3.1 The Economic Role of Agriculture

The District provides water to support the economies of two Central Valley counties—Fresno County and Kings County. While most of its operations lie within Fresno County, significant acreage is located within Kings County. The agricultural industry in Fresno and Kings Counties is a major driver of employment and economic activity (Shires, 2016, Appendix J).

On the agricultural side, the District's provision of water resources and infrastructure results in the direct creation of economic value in the form of crops and the business of creating them. The District plays a central role in the creation of farm products with measurable and direct economic benefits through the following District provisions:

- Direct delivery of CVP contract water, transfers, or purchased water;
- Conveyance and distribution infrastructure; or
- Measuring, tracking, and pricing locally-derived water supplies.

~~Westlands' irrigated agriculture is a significant contributor to both the regional and national economies. Crops produced within Westlands' boundaries produced an estimated 23.4 percent of the crop-related agricultural production in Fresno County in 2014 and 7 percent of the crop-related agricultural production in Kings County in 2014. Given that Fresno County ranked third in the state in 2014 for overall agricultural production and Kings County ranked 8th, this is a significant contribution (CDFA, 2015).~~

~~As a major agricultural production area, the District's economic impact is not only on local markets, but on regional and global markets. The District's almond production, for example, is one of the United States major export successes. Within Fresno and Kings Counties, Westlands directly accounts for some \$3.6 billion of economic output and nearly 30,000 jobs. This impact is through direct crop production and through the wide range of secondary and support activities that are possible because of the fruit and produce grown on farms within the District and Subbasin. Westlands growers provide more than 3 percent of the fruit and fresh produce nationally, 5 percent of the state's fruit and nut crops, and more than 7 percent of the state's production of States' major export successes.~~

~~Nationally, of the total domestic production, Westlands growers provide 3.5 percent of the fresh fruit and nuts and 5.4 percent of the~~ vegetables and melons. Growers in the District contribute significantly to the state's supply of nine key commodities, including almonds, wine (by providing wine grapes), pistachios, table grapes, processed tomatoes, cotton, lettuce, and seeds for sowing. Additionally, hay, grain, and feed production from farms within the District contribute to the beef industry.

~~Crops produced within Westlands' boundaries accounted for an estimated 28.1 percent of the crop-related agricultural production in Fresno County in 2019 and 13.1 percent of the crop related agricultural production in Kings County in the same year. Given that Fresno County ranked first in the state in 2019 (Fresno County Ranking) for overall agricultural production and Kings County ranked 8th (Kings County Ranking), this is a significant contribution.~~

~~Within Fresno and Kings Counties, Westlands directly accounts for some \$4.7 billion of economic output and over 35,000 jobs. This impact is through direct crop production and across the wide range of secondary and support activities that are possible because of the fruit and produce grown on farms within the District and Subbasin.~~

The communities within and adjacent to the District rely on the jobs and economic activity generated by agriculture in the District. School enrollment, tax base, and need for social services parallel the economic health and well-being of the industry.

2.1.3.2 Population Trends

Fresno and Kings Counties are expected to experience a small growth in population in the future. Fresno County is expected to grow by 606,200 people between 2015 and 2060, an annual average increase of approximately 1.1 percent (Fresno County 2040 General Plan Public Review Draft, 2017). Kings County is expected to grow from 149,702 people in 2015 to 204,649 people by 2050, an annual increase of approximately one percent as documented by the Department of Transportation (http://www.dot.ca.gov/hq/tpp/offices/eab/socio_economic_files/2017/Kings.pdf). A population growth of approximately 1 percent during the GSP implementation horizon is incorporated into the analyses prepared for this Plan as well as the projects and management actions.

2.1.3.3 Land Use

Land use is a key factor influencing water demand, including the amount and distribution of groundwater pumping across the Subbasin. Changing land use conditions and irrigation practices can also greatly change water demand from year to year. Historical data on land uses within the Subbasin are available from both District records and from periodic land use surveys conducted by DWR and the United States Department of Agriculture (“USDA”). General Land use conditions based on DWR survey data of Kings and Fresno Counties are illustrated in **Figure 2-6**. Most of the Westside Subbasin is designated as agricultural. Data representing agricultural cropping is available in aggregate for the Subbasin on an annual basis starting in the mid-1960s. More recent annual land use data is available in spatially referenced GIS data formats that are helpful in understanding the spatial patterns in land use that exist across the Subbasin. The District also has spatial land use data for 1999 through 2015. This spatial data includes information on irrigation practices. Irrigation data aggregated to the total number of irrigated acres by irrigation method is available from 1985 to the present.

DWR conducted ground surveys in 1986 and 1991 and developed spatial data for those years. Subsequently, DWR surveys were conducted in the mid-1990s, early 2000s, and most recently in 2009 for parts of Fresno County and in 2011 for Kings County. The land use surveys conducted by DWR in the early 2000s also documented irrigation methods. Since 2007, the USDA published annual spatial land use data (CropScape) for the area. CropScape data is developed from remote sensing information. The reported accuracy of the USDA CropScape data is typically between 70 and 90 percent, although this varies by year, crop, and location. The USDA land use data do not include any information on irrigation method.

Available land use data from the District, DWR, and USDA represent crops and other land uses following detailed and specific designations. For the purposes of understanding land use patterns and trends across the Subbasin as it relates to the conceptual model, these specific land use designations are grouped into general categories for the purposes of this summary.

2.1.3.4 Current and Historical Land Use Conditions

Land uses within the Westside Subbasin have changed considerably over the years. During recent decades farmers in the Westside Subbasin have shifted from grains and cotton as the major crops towards nut trees. **Table 2-3** titled, “Summary of Historical Land Use for Select Years (1988, 2000, and 2015), summarizes the historical land use conditions for select years between 1988 and 2015 based on available data from the District, DWR, and USDA. In 1988, approximately 535,000 acres overlying the Subbasin were cultivated for agriculture; close to 61 percent (about 326,000 acres) of which was planted in grains and cotton. By 2000, the number of acres devoted to grains/cotton had declined to around 244,000 acres, although this still represented more than 45 percent of the cultivated area within the Subbasin. During this same period, vegetables were planted in about 184,000 acres and approximately 35,000 acres were planted with nut trees. In 2015, the total number of cultivated acres totaled around 339,000; of this amount, only 47,000 acres were planted in grains/cotton whereas nearly 142,000 acres were nut trees (42 percent). Between 1988 and 2015, the number of acres of vegetables being grown has remained considerably more stable than acres devoted to either grains/cotton or nut trees during this same period. A more modest increase in the cultivation of grapes and citrus/subtropics is also evident since 1988, and especially since 2000, with a corresponding decrease in acres of seeds/beans (**Table 2-3**). In 2015, more than 207,000 acres were temporarily fallowed due to drought, a considerable increase from the approximately 46,000 acres of fallow/non-agricultural land in 1988 and 2000.

Table 2-3: Summary of Historical Land Use for Select Years (1988, 2000, and 2015)

Land Use Category	1988 (acres)	2000 (acres)	2015 (acres)
Citrus/Subtropics	1,174	1,853	6,695
Fruit Trees	364	2,261	3,653
Grains/Cotton	325,827	243,736	50,219
Grapes	5,796	9,790	16,818
Grasses	10,673	14,858	7,410
Nut Trees	10,016	34,768	117,851
Seeds/Beans	37,331	31,755	3,746
Vegetables	139,237	183,750	114,284
Miscellaneous	4,075	7,927	36,739
Fallow/Non-Agricultural	45,632	46,748	212,846
Total Cultivated Land	534,493	530,698	357,415

The spatial distribution of land uses across the Subbasin in the mid-1990s, as mapped by DWR, is displayed in **Figure 2-7 & Figure 2-8**. The prominence of grains/cotton and vegetable crops within the Subbasin during the 1990s is particularly evident in this map. As illustrated in **Figure 2-98**, the spatial distribution of land use in 2013 illustrates the trend of increasing acres of nut trees and fallowed land is apparent by 2013. By 2013, considerable parts of the western Subbasin converted to nut trees and large areas of

agricultural land along the western edge of the Subbasin had been fallowed. An even greater number of acres were fallowed in 2014 and 2015 whereas the number of acres of nut trees continued to increase. **Figure 2-109** presents the historical changes in land use since the 1960s, including: (1) a notable decline in grains/cotton from its peak of more than 400,000 acres in the early 1980s; and (2) a steady increase of vegetables from the 1960s until early 2000s and the more recent increase in nut trees starting in the 1990s.

A small portion of land that is non-agricultural has been mapped as native vegetation or native riparian (**Figure 2-76**). Along the western edge of the Subbasin, the boundary intersects with the Southwest San Joaquin Valley Habitat Conservation Plan & Natural Community Conservation Plan. This plan is being prepared by Aera Energy LLC and will serve as a basis for applications for incidental take permits from the U.S. Fish and Wildlife Service and California Department of Fish and Wildlife for threatened and endangered species. This conservation plan ~~is still in development and will be~~ became available for public review in Spring 2020. The focus of the plan is related to active and future oil fields outside of the Subbasin, but the goals of this conservation plan will be reviewed and considered in the five-year GSP update.

2.1.3.5 Current and Historical Irrigation Practices

Similar to land use conditions, considerable changes in historical irrigation practices have also occurred within the Subbasin. Different methods for irrigating crops have different irrigation efficiencies. Irrigation efficiency is the percentage of applied irrigation water that is taken up by the plants with the remainder of applied water predominantly recharging groundwater.

Several main types of irrigation methods are used within the Subbasin. These irrigation methods include drip/micro, sprinkler, and gravity irrigation consisting of furrow and border methods. Some other irrigation methods are also used but only on very small scales. Drip irrigation is the most efficient irrigation method in part because the application of water is more precise and targeted so that evaporative and leaching losses below the root zone are more limited. Although drip irrigation is the most efficient method, it is also the most expensive to install and maintain. Sprinkler irrigation systems are less efficient than drip irrigation systems but more efficient than gravity irrigation methods. In sprinkler irrigation water is applied to the field from a pressurized piping system with nozzles that spray water over large areas. Sprinkler irrigation requires high pumping energy and typically requires filtration. Gravity irrigation systems are less efficient than both sprinkler and drip irrigation methods. In gravity irrigation, water is applied to the field by gravity with water moving across the field from high points to lower elevation areas. Although gravity irrigation requires little capital investment and maintenance of equipment, these methods are less efficient due to the irrigation losses resulting from uneven application of water. Less efficient irrigation practices also result in increased percolation of applied water below the root zone (Westlands 2013).

Figure 2-110 displays the spatial distribution of irrigation practices in 1999. In 1999, the majority of the Subbasin was being irrigated by sprinkler and furrow irrigation. At that time, a relatively small number of acres were using drip irrigation methods. In 2013, a majority of the Subbasin transitioned to drip irrigation, as shown on **Figure 2-121**. From 1985 to the early 2000s the predominate irrigation methods in the

Subbasin were furrow and sprinkler irrigation. However, the current irrigation method in the Subbasin is predominately drip, as evident in the chart of historical irrigation practices presented as **Figure 2-1312**.

In 1985, furrow irrigation methods were used on about 60 percent of the irrigated acres with about 40 percent being irrigated with sprinkler. An increasing number of acres relying on sprinkler irrigation occurred during the 1990s during which more than 50 percent of the irrigated acres were irrigated with sprinklers. Through the 1990s drip irrigation methods were used on a relatively small fraction of irrigated acres and it ~~wasn't~~was not until after 2000 that the percentage of irrigated acres utilizing drip methods began to increase appreciably. By 2005, over 25 percent of crops used drip irrigation and the percent of crops using drip methods exceeded 65 percent by 2010. As of 2015, approximately 92 percent of irrigated acres were using drip irrigation methods. Trends in irrigation methods by percent of irrigated acres are displayed in **Figure 2-613**.

2.1.3.6 General Plan Considerations

The California Government Code ~~(§§~~§§ 65350-65362) requires that each county and city in the state develop and adopt a General Plan. The General Plan consists of a statement of development policies and includes a diagram or diagrams and text setting forth objectives, principles, standards, and plan proposals. It is a comprehensive long-term plan for the physical development of the county or city. In this sense, it is a "blueprint" for development.

The Westside Subbasin is subject to Fresno and Kings Counties' General Plans along with the General Plans of the City of Huron and the City of Avenal. Implementation of this GSP will support all goals and ~~polices~~policies established in the General Plans in the Subbasin consistent with SGMA and GSP Regulations. Development and implementation of this GSP has and will continue to consider the interests of all beneficial uses and users of groundwater, including agricultural water users, domestic, municipal water users, DACs, interconnected surface water habitats, groundwater dependent ecosystems, and other interested parties. The Fresno County General Plan is currently undergoing an update and it is not known how the updated General Plan may or may not affect water demands and/or ability to achieve sustainability in the Subbasin. Further discussion of each jurisdiction's plan is included below.

The portion of the Westside Subbasin within the District's jurisdictional boundary also is subject to the District's Rules and Regulations that cover the following:

- Regulations for Allocation and Use of Agricultural Water
- Terms and Conditions for Agricultural Water Service
- Regulations for Application and Use of Municipal and Industrial Water
- Terms and Conditions for Municipal and Industrial Water Service
- Allocation of Water When Lateral is at Maximum Design Capacity

These Rules and Regulations are referenced from <https://wwd.ca.gov/about-westlands/additional-information/rules-and-regulations/>.

The purpose of the District's Rules and Regulations is to establish rules and procedures for allocation and use of agricultural water. The Rules and Regulations consist of procedures regarding contract entitlements, water use, water transfers, payment for water/agreements, rescheduled water, and other guidelines that establish order within the District.

2.1.3.6.1 *Fresno County*

Land uses within the portion of the Subbasin located within the unincorporated area of Fresno County are governed by the Fresno County General Plan and Zoning Ordinance. The Fresno County General Plan provides policy direction for land use, development, open space protection, and environmental quality and sets out a vision reflected in goals, policies, programs and diagrams implemented primarily via the County's Zoning and Subdivision Ordinances. Fresno County's General Plan may be viewed here, <https://www.co.fresno.ca.us/departments/public-works-planning/divisions-of-public-works-and-planning/development-services-division/planning-and-land-use/general-plan-maps>.

The Fresno County General Plan is built on the following major themes:

- Land Use (LU) Element designates the general distribution and intensity of all uses of the land in the community. This includes residential uses, commercial uses, industrial uses, public facilities, and open space, among others.
- Circulation Element identifies the general location and extent of existing and proposed major transportation facilities, including major roadways, rail and transit, and airports.
- Housing Element assesses current and projected housing needs and sets out policies and proposals for the improvement of housing and the provision of adequate sites for housing to meet the needs of all economic segments of the community.
- Conservation Element addresses the conservation, development, and use of natural resources including water, forests, soils, rivers, and mineral deposits.
- Open Space (OS) Element details plans and measures for preserving open space for: protection of natural resources such as wildlife habitat; the managed production of resources such as agricultural and timber land; outdoor recreation such as parks, trails, and scenic vistas; and public health and safety such as areas subject to geologic hazards, flooding, and fires.
- Noise Element identifies and appraises noise problems and includes policies to protect the community from excessive noise.
- Safety Element establishes policies and programs to protect the community from risks associated with seismic, geologic, flood, and wildfire hazards.

Relating to resource protection, the Fresno County General Plan contains a host of policies and programs to protect and enhance the surface water and groundwater resources in the County as follows:

Policy LU-A.1 Fresno County shall maintain agriculturally-designated areas for agriculture use and shall direct urban growth away from valuable agricultural lands to cities, unincorporated communities, and other areas planned for such development where public facilities and infrastructure are available.

Policy LU-A.2 Fresno County shall allow by right in areas designated Agriculture activities related to the production of food and fiber and support uses incidental and secondary to the on-site agricultural operation. Uses listed in Table LU-3 are illustrative of the range of uses allowed in areas designated Agriculture.

Policy LU-A.6 Fresno County shall maintain twenty (20) acres as the minimum permitted parcel size in areas designated Agriculture, except as provided in Policies LU-A.9, LU-A.10, and LU-A.11. Fresno County may require parcel sizes larger than twenty (20) acres based on zoning, local agricultural conditions, and to help ensure the viability of agricultural operations.

Policy OS-A.1 Fresno County shall develop, implement, and maintain a plan for achieving water resource sustainability, including a strategy to address overdraft and the needs of anticipated growth.

Policy OS-A.3 Fresno County shall provide active leadership in efforts to protect, enhance, monitor, and manage groundwater resources within its boundaries.

Policy OS-A.17 Fresno County shall directly and/or indirectly participate in the development, implementation, and maintenance of a program to recharge the aquifers underlying the County. The program shall make use of flood and other waters to offset existing and future groundwater pumping.

Lands within the Subbasin are predominately designated as Agriculture in the General Plan and zoned AE-20 and AE-40 (Exclusive Agriculture, 20- or 40-acre minimum parcel sizes). This designation provides for the production of food and fiber and the raising of livestock and poultry, agricultural processing facilities, and certain non-agricultural activities. In addition, there are small clusters of non-agricultural and rural settlement areas within the Subbasin. The land use designations are implemented largely through zoning which are deemed compatible, conditionally compatible, or incompatible with the various General Plan land use designations.

2.1.3.6.2 *Kings County*

Land uses within the portion of the Subbasin located within the unincorporated area of Kings County are governed by the *2035 Kings County General Plan* which defines the goals, objectives, and policies that will guide the growth, use, and development of land under the jurisdiction authority of the Kings County through 2035. The priorities are to protect prime agricultural land and direct urban growth to existing cities and communities, and to increase economic and community sustainability. Similar to Fresno County, the General Plan contains information on: land use, resource conservation, open space, transportation, housing, health and safety, noise, air quality, dairies, and individual community plans. The portion of the Westside Subbasin within Kings County is subject to the County's authority with the exception of the NASL and the City of Avenal. Kings County's General Plan may be viewed here: <https://www.countyofkings.com/departments/community-development-agency/information/2035-general-plan>.

As it pertains to land use and resource conservation, the Kings County General Plan contains numerous policies to protect and enhance agricultural production and the surface water and groundwater resources in the County as follows:

Resource Conservation (RC) Policy A1.1.1: Cooperate with water purveyors and water management agencies to manage groundwater resources within the County to assure an adequate, safe and reliable groundwater supply for existing and future water users

RC Policy A1.1.6: Support expansion of joint management of surface water and groundwater supplies that contributes to the protection, reliability and sustainability of local and regional water supplies.

RC Policy A1.2.2: Require the use of low water consuming, drought-tolerant and native landscaping and other water conserving techniques, such as mulching, drip irrigation and moisture sensors, for new development.

RC Policy A1.3.1: Participate with and encourage all state, regional and local efforts to develop new or expanded water supplies that may serve Kings County.

LU Policy B1.1.1: Designate all agricultural and grazing land outside of planned urban areas as Limited Agriculture, General Agriculture, Exclusive Agriculture, or Natural Resource Conservation.

LU Policy B1.2.3: Land divisions involving Limited Agriculture designated land shall not result in the creation of a parcel(s) less than ten acres in size, or eleven acres in size when under a Williamson Act or Farmland Security Zone Contract. If land is classified as non-prime, the minimum shall be 41 acres except as provided in LU Policies B4.3.1, B4.3.2, and B4.3.3.

LU Policy B2.2.1: Apply the Limited Agriculture or Open Space land use designation around Community Districts and Urban Fringe areas to serve as a buffer between urban and intensive agricultural uses.

LU Policy B2.2.2: The designation of new residential land use designations in Agriculture OS areas shall be restricted in order to preserve productive agricultural land and discourage premature conversion to non-agricultural related land uses.

2.1.3.6.3 *City of Huron*

Land uses within the portion of the Subbasin located within the City of Huron are governed by the City of Huron General Plan and provides policy direction for land use, development, open space protection, and other policies. The General Plan may be viewed here:

<http://cityofhuron.com/wp-content/uploads/2014/08/City-of-Huron-General-Plan-2025-Policies-Statement1.pdf>.

The City of Huron General Plan is built on the following eight major elements:

1. Noise
2. Safety
3. Open Space, Conservation and Recreation

4. Air Quality
5. Circulation
6. Land Use
7. Public Services and Facilities
8. Housing

The City of Huron's public water supply is from imported water from the San Luis Canal/California Aqueduct with no municipal supply from groundwater.

2.1.3.6.4 City of Avenal

Land uses within the portion of the Subbasin located within the City of Avenal are governed by the City of Avenal General Plan and provides policy direction for land use, development, open space protection, and other policies. The General Plan may be viewed here: <https://www.cityofavenal.com/370/General-Plan>. The City of Avenal General Plan is built on the following seven major elements:

1. Land Use
2. Economic Development
3. Conservation, Natural Resources and Recreation
4. Circulation
5. Air Quality
6. Public Services
7. Safety

All the general plans identified above were reviewed and considered in the development of this GSP to ensure that the implementation of the GSP would not contradict any of the relevant general plan elements and policies. Land use plans for local agencies outside of the Subbasin were also determined not to significantly impact the Subbasin's ability to achieve sustainable management at this time.

2.1.4 Additional GSP Elements (§354.8 (g))

The additional GSP elements considered relevant for the Westside Subbasin are described below.

2.1.4.1 Well Permitting, Construction, Well Abandonment, Destruction, and Abandonment Permitting Process Updates Policies

2.1.4.1.1 Well Permitting

In order to obtain a permit to drill a well, a properly licensed contractor must submit a completed Well Permit Form with any applicable permit fees to Fresno County or Kings County (Fresno County Code Chapters 14.04 & 14.08 and Kings County Code Chapters, Chapter 14A). Contractors must possess an active C-57 Water Well Contractors License.

2.1.4.1.2 Well Construction

Well construction standards are consistent with the California Well Standards, Bulletin 74-81 and 74-90 (**Appendix G**). Bulletin 74-81 was published by DWR in December 1981 which sets the minimum standards for well construction throughout the State of California. These standards were supplemented by Bulletin 74-90 which was published by DWR in June 1991 to include additional information on the construction of monitoring and cathodic protection wells. The State of California is currently revising Bulletin 74 as a replacement for Bulletin 74-90. Below is a list of the topics covered in each of these bulletins regarding the construction standards used for well installation in the Subbasin.

- Well location with respect to pollutants and contaminants
- Sealing the upper annular space
- Surface construction features
- Disinfection
- Casing
- Sealing-off strata
- Well development
- Water quality sampling
- Special provisions for large diameter shallow wells
- Special provisions for driven wells
- Rehabilitation, repair and deepening of wells
- Temporary cover

2.1.4.1.3 Well Abandonment

In accordance with Section 115700 of the California Health and Safety Code, an inactive water well is considered abandoned if it has not been used for a period of one year and must be destroyed by a licensed C-57 water well contractor unless the owner demonstrates an intention to use the well again. The intention to use an inactive well again shall be demonstrated by the well owner by properly maintaining an inactive well for future use in such a way the following requirements are met:

- The well shall not impair the quality of water in the well and groundwater encountered by the well.
- The top of the well or well casing will be provided with a cover that is secured by a lock or by other means to prevent its removal without the use of equipment or tools, to prevent unauthorized access, to prevent a safety hazard to humans and animals, and to prevent illegal disposal of wastes in the well.
- The cover will be watertight where the top of the well casing or other surface openings to the well are below ground level, such as in a vault or below known levels of flooding. The cover will be watertight if the well is inactive for more than five consecutive years. A pump motor, angle drive,

or other surfaces feature of a well, when in compliance with the above provisions, shall suffice as a cover.

- The well will be marked so ~~as to~~it will be easily visible and located and labeled so ~~as to be~~it can easily be identified as a well.
- The area surrounding the well will be kept clear of brush, debris, and waste materials.

2.1.4.1.4 Well Destruction

These well destruction standards were based on California Well Standards Bulletins 74-82 and 74-90.

Only persons who possess an active C-57 Water Well Contractors License may perform well destructions. (Water Code (WC) §13750.5; Well Standards §2.4.3) Well destruction performed as an "incidental part" of a larger job by a contractor not possessing a C-57 license is **not** allowed.

No person shall destroy any well without first applying for and receiving a **Permit** issued by the Fresno County Department of Public Health. (Well Standards Ordinance (WSO) 14.04 and 14.08) All available well construction data shall be submitted with the application for a well destruction permit.

All well destructions shall be performed according to Part III, Sections 20-23, Bulletin 74-81 and 74-90 (WSO §3).

- A hole shall be excavated around the well casing to a depth of 5 feet (ft) below the ground surface (bgs) and the well casing removed to the bottom of the excavation (a variance to not excavate the casing may be requested for special circumstances).
- The sealing material used for the upper portion of the well shall be allowed to spill over the casing into the excavation to form a cap.
- After the well has been properly filled, including sufficient time for the sealing material in the excavation to set, the excavation shall be filled with native soil.
- A State of California Well Completion Report ("Well Log") shall be submitted to the Fresno County Department of Public Health within 30 days of the completion of any well destruction. (Water Code §13751; Well Standards §7.1).

Materials used for sealing and ~~fill materials~~filling are as follows:

- Impervious Sealing Materials. Approved impervious materials include neat cement, sand-cement grout, concrete, and bentonite clay.
- Filler Material. These include clay, silt, sand, gravel, crushed stone and clean native soils.

2.1.4.1.5 Permitting Process Updates

The District determined improving the well permitting process is one implementation measure that enhances the District's management of the Westside Subbasin. Thus, the GSP recommends Fresno and Kings County's permitting requirements include the following new construction standards for new wells drilled in the Westside Subbasin:

- Pump test results shall be submitted to the District within 60 days of completion. Pump testing results shall include the pump's capacity, well design, Horsepower, efficiency, specifications and a copy of the well completion report that describes the characteristics of the geologic materials encountered during the drilling of the borehole.
- Installation of equipment to collect continuous flow data during the pumping test, depth to water level data before, during, and after the pumping test, and surveyed ground surface elevation data information (NAVD88 datum).
- Furnish and install a data logger and an Automatic Meter Infrastructure (AMI) technology upon well completion. The data logger should capture continuous water level data and transmit the data to GSA monthly. The AMI must be approved by the District. The District will assume ownership of the meter upon well completion.

All new applicants are required to enter into an agreement to comply with the District's GSP.

2.1.4.1.5 Efficient Water Management Practices

~~Westlands' farmers are global leaders in water-efficient farming. A majority of the District's water supply is conveyed via a closed pipeline system and more than 95 percent is irrigated with drip or sprinkler delivery systems. The District not only uses an underground, fully-enclosed distribution system, but also uses more than 3,300 water meters throughout the District to ensure conservation practices and that any losses due to leakage are immediately addressed.~~

2.1.4.2 Impacts on Groundwater Dependent Ecosystems

Potential groundwater dependent ecosystems (GDEs) identified by The Nature Conservancy (TNC) are shown in **Figure 2-14**. ~~The coverage of potential for the existence of GDEs in the Westside Subbasin is limited due to the arid climatic conditions. Based on presence of streams that only flow periodically and are ephemeral in nature, the location of groundwater elevation pumping at vertical depth intervals in the Upper Aquifer which result in the lack of propagation of groundwater pumping to the land surface where the ephemeral streams are located, and the depth to groundwater. Based on depth to groundwater of the Upper Aquifer being deeper than 30 feet in the vicinity of the potential GDEs identified by TNC, the potential GDEs are not dependent on groundwater. Therefore, it is unlikely there are any GDEs in the Subbasin. The ecosystems that exist in the region are sustained by periodic rainfall events and ephemeral surface water.~~ However, because existing data is not available in sufficient detail to definitively identify all potential GDEs, the District ~~plans submitted a Technical Support Services request from DWR~~ to install shallow wells on the western part of the Subbasin ~~to address this data gap and~~ to determine if there are any GDEs that could be impacted by groundwater pumping.

2.1.4.3 Control of Saline Water Intrusion

As described in Chapter 3, the location of the Subbasin in the San Joaquin Valley, which is physically separated from the Pacific Ocean, precludes the existence or presence of seawater intrusion.

2.1.4.4 Wellhead Protection and Recharge Areas

As described in Section 2.1.3, this GSP will ~~follows~~follow the Counties' General Plans relevant to wellhead protection. Chapter 4 describes the recharge areas in the Westside Subbasin. Twice a year, the District conducts well monitoring. When the District comes across a well that has not been properly abandoned or capped, the water user is contacted via telephone and letter to address the issue in order to comply with Fresno and Kings Counties well standard ordinances.

2.1.4.5 Migration of contaminated groundwater

The GSA ~~are~~is not aware of any known ~~contaminants~~contaminant plumes in the Subbasin.

2.1.4.6 Relationships with State and Federal Regulatory Agencies

The GSA has developed relationships with the state and federal interests in the Westside Subbasin to ensure GSP information is communicated. Section 2.1.5.2, **Table 2-4** and **Figure 2-2**, details regulatory agencies in the Subbasin and the GSAs efforts to establish a relationship with the agencies.

2.1.4.7 Consideration of Land Use Existing Policies

The GSA considered the Land Use Policies on the cities and counties in the Subbasin. Detailed consideration is available in Section 2.1.3.

2.1.5 Notice and Communication (§354.10)

2.1.5.1 Identification of Groundwater Beneficial Uses/Interested Parties

Beneficial uses of groundwater in the Subbasin include domestic, urban and agricultural, consistent with California Code of Regulations ~~Tit., Title 23~~ §Section 354.10. Agricultural water users are likely to be the most affected by implementing the GSP because those beneficial users utilize the most groundwater and cover the vast majority of the Subbasin. Many farmers are heavily dependent on groundwater for irrigation and will be adversely affected if and when pumping restrictions are put in place during an extended drought period.

The Pilibos Wildlife Area, Mendota Wildlife Area, and the Pleasant Valley Ecological Area were evaluated as potential environmental beneficial users of groundwater. However, the District determined that there was no groundwater extraction occurring in these areas. Furthermore, GDEs were also evaluated for the potential of passive groundwater use (eg. Root zone uptake) but as mentioned in Section 2.1.3.8., due to the depth to groundwater in these areas, they are not dependent on groundwater.

The Westside Subbasin's groundwater resources are primarily used for agricultural purposes and the ~~typical~~beneficial users of groundwater include:²

- Agricultural Water Users. The largest groups of interested parties within the Subbasin are water users that extract groundwater for agricultural uses.

² There are no hydrologic surface water bodies or California tribes within the Subbasin.

- Domestic and Municipal & Industrial Well Users. The District identified approximately 38 active domestic well users wells and 13 active M&I wells within the Subbasin. (Table 2-1).
- ~~Municipal Well Operators~~. Public Water Systems. There are ten public water systems that deliver surface water within the Subbasin ~~underlies eight communities~~, including a ~~portion of the City of Avenal, the City of Huron and the communities of~~ Three Rocks, ~~Five Points~~, Cantua Creek, Turk, Calfax, O'Neil Farms, NASL, ~~and El Porvenir~~ and Five Points. There are three Public Water Systems that deliver groundwater with the surface water, Figure 2-5 shows the Public Water Supply wells location. To the District's knowledge, NASL has a well that operates as a backup water supply, and Cantua Creek and El Porvenir ~~are the only communities that plan~~ drilled wells to drill a well and extract groundwater for municipal use.
- ~~Public Water Systems~~. There are nine public water systems within the Subbasin, including Avenal, Huron, Three Rocks, Cantua Creek, Turk, Calfax, O'Neil Farms, ~~at a future date~~. The City of Huron also drilled a groundwater well as a backup supply. Cantua Creek, El Porvenir and Five Points. Huron's wells were constructed in 2021 but have not been furnished with above ground equipment and power. The aforementioned sites are expected to be active in 2024.
- Local Planning Agencies. Fresno and Kings Counties have local planning and land use authority on land overlying the Subbasin.
- ~~Environmental Users~~. ~~The Pilibos Wildlife Area, Mendota Wildlife Area and the Pleasant Valley Ecological Area overlie approximately 900 acres within the Subbasin.~~²
- Federal Government. NASL overlies approximately 11,500 acres, 8,500 of which are leased out to local farmers for agricultural purposes, along the Subbasin's eastern boundary. In addition to pumping groundwater for agricultural and domestic use, NASL also receives surface water from the District.
- Disadvantaged Communities (incorporated and unincorporated). According to the DWR Disadvantaged Community Mapping Tool, there are eight disadvantaged communities overlying the Subbasin, including, Avenal, Huron, Three Rocks, Cantua Creek, NASL, ~~Calfax, and Turk~~. The City of Huron is planning to drill a groundwater well as a backup supply Calfax, and Turk.

Table 2-4 identifies the interested parties that extract in the Westside Subbasin and if groundwater is extracted. The jurisdictional boundaries for each of these entities are illustrated in **Figure 2-2**.

² ~~The Pilibos Wildlife Area, Mendota Wildlife and the Pleasant Valley Ecological areas are not GDEs.~~

Table 2- 4: Agencies in the Westside Subbasin

Agency	Groundwater Extractor	TypeWater Use Category
Counties		
Fresno County	No	Not Applicable
Kings County	No	Not Applicable
Cities		
City of Avenal	No	Not Applicable
City of Huron	Potentially	Not Applicable
Communities		
Calfax	No	Not Applicable
Cantua Creek	Potentially	Municipal <u>Not</u> <u>Applicable*</u>
Three Rocks	No <u>Potentially</u>	Not Applicable*
Turk	No	Not Applicable
Westside (O'Neil Farms)	No	Not Applicable
Five Points	No	Not Applicable
Federal/ State Government		
Naval Air Station Lemoore (NASL)	Yes	Municipal and Agricultural
United State Bureau of Reclamation (USBR)	No	Not Applicable
Department of Water Resources (DWR)	No	Not Applicable
Wildlife User		
Pilibos Wildlife Area	No	Not Applicable
Pleasant Valley Ecological	No	Not Applicable
Mendota Wildlife Area	No	Not Applicable
Other Interested Parties		
Westlands' Water Users	Yes	Agricultural

*may change to a Public Supply well in the future.

2.1.5.2 Public Outreach

GSP Regulations Section 354.10 requires that the GSA consider the interest of all beneficial groundwater users. The GSA developed a Stakeholder Communication and Engagement Plan to ensure all interested parties were able to participate in GSP development. The Stakeholder Communication and Engagement Plan is posted on the District and GSA website, <https://wwd.ca.gov/water-management/groundwater-management-program/sustainable-groundwater-management-act/> and is attached in **Appendix L**.

Additionally, in order to encourage active involvement of a diverse social, cultural and economic elements of the population within the Subbasin, the District held all GSP development meetings publicly, allowed for public comment, collaborated with counties, state and federal agencies in the Westside Subbasin, maintained close communication with organizations representing disadvantaged and severely

disadvantaged communities, coordinated with neighboring GSA's, and provided monthly updates. The District held workshops during the development of this GSP, including bilingual (Spanish) workshops. **Appendix H** includes a summary of the workshop activities, attendees and comments received. All the workshops were posted on the District's website, emailed to the District's water users and other interested parties, community centers such as schools and churches in the Subbasin, and when timing permitted mailed to communities. The workshops provided the beneficial groundwater users and interested parties affected by the implementation of the GSP to voice concerns, articulate questions, and provide ideas and feedback to staff. During the workshops, staff provided a presentation on [SGMA](#) components, potential impacts to current land use activity and allowed for public comment. The workshops were held about three-months apart, allowing the District time to incorporate the feedback provided at the previous workshop and present updates. **Table 2-5** entitled "Public Outreach", lists the public meetings, workshops and outreach events hosted by the District.

Table 2-5: Public Outreach

Event	Date	Topic (s)
1	October 13, 2015	SGMA, Groundwater Rights, Groundwater Conditions, and Implementation
2	March 15, 2016	GSP Content, GSA Responsibilities, and SGMA Implementation
3	October 31, 2016	SGMA, GSP Regulations, and Content
4	December 21, 2016	GSP Development Schedule, Basin Settings, Management Area Potential, Undesirable Results, and Subbasin Projects
5	March 21, 2017	GSP Development and SGMA Implementation Schedule
6	June 22, 2017	GSP Outline, Groundwater Model Status, Subsidence, Water Budget, 10 Year Farm Plan, and Groundwater Credits Programs
7	September 22, 2017	Subsidence, Groundwater Model Status and Groundwater Credit Program
8	December 7, 2017	Groundwater Model Status, Sustainable Management Criteria, and Groundwater Credit Program
9	February 9, 2018	Groundwater Management Guiding Principles and GSP Conceptual Outline
10	April 6, 2018	Bilingual Workshop Introducing SGMA Requirements
11	May 3, 2018	Modeling Results Workshop
12	May 17, 2018	Bilingual Modeling Results Workshop
13	July 16, 2018	Westlands SGMA Groundwater Pumping Management and GSP Development
14	September 16, 2018	Bilingual Workshop the Westside Subbasin's Groundwater Model
15	April 3, 2019	Bilingual Forecast Scenarios and Augmentation Strategies Workshop

Event	Date	Topic (s)
District Board Meetings		
1	October 20, 2015 2015	Basin Boundary and Groundwater Modeling Recommendations
2	November 17, 2015	Basin Boundary Modification and Draft GSP Regulations Dates
3	December 15, 2015	Neighboring Subbasins Communication and Retaining a Groundwater Modeler
4	January 19, 2016	Communication efforts with neighboring subbasins
5	February 16, 2016	Resolution Authorizing the District's staff to submit the Westside Subbasin Boundary Modification
6	March 15, 2016	Resolution Authorizing the District's staff to submit the Westside Subbasin Boundary Modification and release of draft GSP Regulations
7	April 19, 2016	Status of the Basin Boundary Modification, GSP Regulation comments and recommendation for the District to serve as the GSA
8	May 17, 2016	Status of the Basin Boundary Modification, Final GSP Regulations and GSA procedures
9	June 21, 2016	Status of the Basin Boundary Modification, GSP Regulations and GSA hearing dates
10	July 19, 2016	Resolution Authorizing District staff to file as the GSA of the Westside Subbasin, status of the Basin Boundary Modification and GSP development
11	August 17, 2016	MOUs with Fresno and Kings Counties, GSA filing status and concerns on the extraction limits of groundwater in the Westside Subbasin
12	September 20, 2016	Fresno and Kings Counties MOU recommendation
13	October 18, 2016	Executing the Fresno County MOU and Groundwater Model update
14	November 21, 2016	Exclusive GSA of the Westside Subbasin, Groundwater Model update and summary of the October 2016 GSP workshop
15	December 20, 2016	DWR BMPs and Groundwater Model update
16	January 17, 2017	Hydrogeological Conceptual Model and summary of the December 2016 Basin Settings workshop
17	February 28, 2017	Groundwater Model Update and DWR's Water Available for Replenishment report
18	April 18, 2017	Groundwater Model Update and DWR's Water Available for Replenishment report
19	May 16, 2017	Groundwater Modeling Update and SGMA implementation
20	July 18, 2017	Summary of the June 2017 workshop and DWR's GSP grant funding
21	October 17, 2017	Numeric Flow Modeling Calibration Update, Summary of the September 2017 workshop, and DWR's GSP grant funding
22	November 21, 2017	Numeric Flow Modeling Final Stages of Development and Summary of the October 2017 workshop
23	December 19, 2017	Groundwater Model Results update, and submission of DWR Grant Package for GSP Development, and summary of December 2017 workshop
24	January 17, 2018	Groundwater Model Results and SGMA implementation
25	March 20, 2018	Groundwater Model update and SGMA implementation
26	April 17, 2018	Summary of the April 2018 Bilingual workshop
27	May 15, 2018	GSP Project Status Report
28	June 19, 2018	GSP Project Status Report- Updated the Board on Outreach Activities
29	July 17, 2018	GSP Project Status Report and SGMA Groundwater Pumping Management Strategies
30	August 14, 2018	Groundwater Allocation (3-year rolling average)

Event	Date	Topic (s)
31	September 18, 2018	Groundwater Allocation (5-year rolling average) and Alternative Groundwater Management Strategy (water levels)
32	October 16, 2018	Groundwater Management Strategy Example with Conceptual Minimum Threshold and GSA Actions
33	November 20, 2018	District's Groundwater Allocation Options and Tiered Pricing
34	December 18, 2018	Uniform Distribution of the District's Groundwater Allocation
35	January 15, 2019	Uniform Distribution of the District's Groundwater Allocation including District owned land
36	February 19, 2019	Management Areas Consolidation and Allocation by Aquifer
37	April 19, 2019	District's Augmentation Strategies Workshop Summary
38	May 21, 2019	Monitoring Network, Minimum Thresholds and Measurable Objectives
39	June 24, 2019	GSP Estimated Monitoring and Implementation Costs
40	July 16, 2019	GSP Annual and Implementation Cost Options
41	August 20, 2019	Chapter 5 on Implementation Cost Options
42	September 17, 2019	Chapter 5 on Implementation Cost Options
43	October 15, 2019	Draft GSP
44	October 30, 2019	Draft GSP Hearing
45	November 19, 2019	Summary of comments received and GSP finalization status
46	December 18, 2019	Public Hearing to Consider adoption of the Final GSP; Board did not adopt GSP
47	January 8, 2020	Public Hearing to Consider Adoption of the Final GSP; Board Adopted GSP

Comments that the District received regarding the Westside Subbasin GSP were compiled and considered in the preparation of the GSP by District staff and consultants. Items presented at public meetings that were ultimately eliminated from the GSP included: dividing the Subbasin into management areas and unique groundwater allocations by area. Based on public feedback the GSA offered translation services at the workshops.

The methodology described below was utilized in the review of comments received on the GSP.

- The comments comply with the GSP ~~Emergency~~ Regulations;
- The viability of implementing the comment in the GSP;
- Benefit to the beneficial users and interested parties in the Westside Subbasin; and
- Impacts on achieving Sustainability by 2040.
- Copies of the comment letters received, and the GSA's responses are found in **Appendix H**.

2.1.5.3 GSP Revision Public Meeting

On January 21, 2022, the District received an incomplete determination on the Westside Subbasin GSP from the Department of Water Resources and provided the District 180 days, or until July 20, 2022, to resubmit the revised Westside Subbasin GSP to address the identified deficiencies for DWR's review. The letter highlights areas of the Westside Subbasin groundwater sustainability plan that DWR has identified

as deficient and is recommending corrective actions. DWR identified subsidence, groundwater levels and water quality sustainable management criteria as deficient areas in the GSP.

In order to encourage public participation of the District’s strategy to address DWR’s comments, the District hosted public meetings, discussed its approach and held a public hearing to adopt the Water Quality Section’s sustainability management criteria. **Table 2-6** entitled “GSP Revision Meetings Summary”, lists the public meetings, workshops and outreach events hosted by the District.

Table 2-6: GSP Revision Meetings Summary

Event	Date	Topic (s)
<u>1</u>	<u>December 7, 2021</u>	<u>Joint Committee Meeting – AC and TAC Received an Update on the Department of Water Resource Staff’s Initial Review</u>
<u>2</u>	<u>January 18, 2022</u>	<u>January Board Meeting SGMA Update – Westlands Water District GSA Discussion</u>
<u>3</u>	<u>February 15, 2022</u>	<u>February Meeting SGMA Update on February AC and TAC Meetings and GSP proposed GSP revisions</u>
<u>4</u>	<u>February 22, 2022</u>	<u>AC and TAC Receive an Update on Potential Revisions to the Subsidence Sections of the Groundwater Sustainability Plan</u>
<u>5</u>	<u>March 15, 2022</u>	<u>March Meeting SGMA Update – Westlands Water District GSA Discussion and Potential Revisions to the GSP</u>
<u>6</u>	<u>April 19, 2022</u>	<u>April Meeting SGMA Update – Westlands Water District GSA Meeting to Consider and Provide Input on the Rules and Regulations and Related GSP Revisions on Subsidence</u>
<u>7</u>	<u>June 21, 2022</u>	<u>Public Hearing to Adopt GSP Amendments</u>

2.2 Hydrogeologic Conceptual Model (§354.14)

2.2.1.1 Background Information for Hydrogeologic Model

~~There are numerous geologic and hydrogeologic studies of the Valley, the most relevant of which were reviewed during the development of the Subbasin’s hydrogeologic conceptual model.~~Section 2.2 describes the physical and geologic setting (Hydrogeologic Conceptual Model) of the Subbasin and groundwater conditions. This section provides information about the setting and characteristics of the Westside Subbasin and includes both historical and current conditions of the Subbasin. This section includes identification of data gaps and levels of uncertainty which affect a complete characterization of the Subbasin. The information in this section will be used to help assess and define sustainable management criteria and projects and management actions to address undesirable results during the planning and implementation horizon.

Pioneering studies were conducted by Mendenhall (1908) and Mendenhall and others (1916). In 1949, the State of California and the United States Geological Survey (USGS) agreed to an investigation of the western Fresno County area of the San Joaquin Valley. A reconnaissance study of the entire Valley was

performed by Davis and others (1959), and a study of possible storage of water in the subsurface was presented by Davis and others (1964).

A series of reports covering sections of the Valley continued to be produced for 20 years by USGS authors. The first report was an initial effort in the Fresno County area by Davis and Poland (1957). Subsequent reports included: Wood and Davis (1959); Hilton and others (1963); Croft and Gordon (1968); Page and LeBlanc (1969); Mitten and others (1970); and Hotchkiss and Balding (1970). **Figure 2-15** depicts the cross-sections studied in each of these reports.

~~Other~~Another hydrogeologic ~~studies~~study that ~~are directly important to~~focused on the Subbasin and the surrounding area ~~include~~was produced by Miller, Green, and Davis (1971) which focused on the geology of the compacting deposits within the Subbasin. That report was a compilation by Davis of earlier (circa 1963) unpublished reports by Miller and Green. Croft ~~later~~ (1972) ~~later~~ presented a report summarizing the water-bearing deposits in the southern part of the Valley based on previous studies.

Page (1973) mapped the base of fresh water in the Valley. Page (1983) examined the nature of the Tulare Formation relationships in the Kettleman City area. Page (1986) compiled an opus of the water-bearing deposits, and Williamson and others (1989) examined groundwater flow of the entire Central Valley of California in the Regional Aquifer-Systems Analysis by the USGS. Bartow (1991) summarized the Cenozoic evolution of the Valley of California.

In 1954, the USGS began studying subsidence between Los Banos and Kettleman City, as well as in other areas throughout the Valley. A large number of historical reports on subsidence in this area were produced, but were only cursorily reviewed for this section of the GSP. The most significant of these reports are Bull (1964), Bull and Miller (1975); Bull (1975), and Bull and Poland (1975).

In the northeastern Valley, east of the San Joaquin River (SJR) and largely north of the Fresno County line, detailed mapping of the younger alluvium deposits was summarized by Marchland and Allwardt (1981). The mapping was based on topographic position, stratigraphic relationships, and soil mapping. Lettis (1982) performed similar detailed mapping and analysis west of the SJR extending north of Mendota in Fresno County. Lettis presented a detailed cross section of the stratigraphic units in northern Fresno County.

2.2.1 Topographic Information

The Subbasin is characterized by a relatively flat topographic setting along the west side of the Valley. Topography is highest along, and just outside, the western margins of the Subbasin and slopes gently eastward toward the center of the San Joaquin Valley with less than a two percent slope (**Figure 2-17**). The topography ranges from about 1,000 ft elevation along the western margin of the Subbasin to about 170 ft elevation along the Subbasin's eastern boundary (**Figure 2-18**). There is little change in slope or elevation in the Subbasin from north to south with elevations ranging from between 150 to 200 ft.

2.2.2 Surficial Geology

Surficial geology in the Subbasin is illustrated in **Figure 2-16A** with an explanation of map symbols in **Figure 2-16B**. The information presented in these figures was compiled from several sources from the California Geological Survey (Jennings and Strand, 1958; Jennings, 1958; and Matthews and Burnet, 1965) and the California Division of Mines and Geology (Smith, 1964). The Subbasin's surficial geology is primarily characterized by alluvial fan deposits of the Quaternary Great Valley Geologic Province with Pleistocene nonmarine deposits located in the southeastern portion of the Subbasin and along its western margins.

2.2.3 Regional Geologic Setting

The western portion of the central Valley where the Subbasin is located makes up the southern part of California's Great Valley Geologic Province. The Sierra Nevada Geologic Province begins to the east of the San Joaquin Groundwater Subbasin and the Coast Range Geologic Province sits to its west (**Figures 2-16A and 2-16B**).

2.2.3.1 Great Valley Geologic Province

The Valley is a broad, gentle, low relief, sediment-filled Subbasin between the mountainous terrains to the east and west (**Figure 2-16A**). The sedimentary deposits contain fresh groundwater, which is utilized, along with surface water, to support the extensive agricultural activities on the nutrient-rich soils of the valley floor. The Valley is comprised of four main geomorphic areas: the eastern and western alluvial plains, the central floodplain Subbasin, and the Tulare Lake Subbasin.

2.2.3.2 Eastern Alluvial Plains

These alluvial plains slope gently westward from the Sierra Nevada, which was formed by the coalescing alluvial fans from the major and minor drainages. Along the eastern margins of the Valley, older alluvial plains occur at higher elevation and with deep soil development. These older alluvial plains are partially dissected, incised and covered by deposits of younger alluvial plains. The SJR maintains a defined braided stream channel system to the center of the Valley and then flows northward, joined by tributary streams to the Sacramento/San Joaquin Delta.

The Kings River contains a broad alluvial plain area covered with a complex of distributary channels. The northern channels drain westward to the center of the Valley and flowsflow northward through the Fresno Slough to join the SJR in the Mendota area. The southern distributaries flow southwestward into the Tulare Lakebed. The Kings River alluvial plain had been extensively modified by both man-made channelization of the distributary and by construction of ditches to route water for irrigation.

2.2.3.3 Western Alluvial Plains

A similar alluvial plain occurs along the west side of the Valley, formed by smaller streams draining the Diablo Range. The Western Alluvial Plains slope eastward toward the center of the Valley and become narrower and steeper near the Valley's outer edges. Distributary channels are less numerous, and not as

well developed, as compared to the eastern alluvial plain. There are also areas of older alluvial fans, but these are smaller and less extensive than what occurs on the east side of the Valley.

To the south, the Valley has anticlinal structures in the Coalinga area and around Kettleman Hills. Here, small alluvial valleys are partially isolated as evidenced by the Pleasant Valley, Kettleman Plain, and Antelope Valley and Plain (**Figure 2-16A**). Drainage from the Pleasant Valley and the Kettleman Plain ~~occurs~~ occurs to the main Valley by narrow stream channels across the Kettleman Hills trend. Further south, the Antelope Valley and Plain ~~drains~~ drain eastward to the main Valley across a broader alluvial plain.

2.2.3.4 Central Floodplain

The Central Floodplain geomorphic area occurs in the center of the Valley and separates the Western and Eastern Alluvial Plains. The floodplain is a very-low northward gradient flatland area of fine-grained deposits of floodplains, marshlands, and wetlands. In the north, beyond where the SJR enters the floodplain, numerous stream channels and sloughs meander northward. Along the SJR, stream channel and natural levee deposits occur surrounded by the floodplain deposits.

South of the SJR, the Central Floodplain area lacks the numerous stream channels and sloughs until the Kings River area and the southern distributary channels of the Kings River. As described previously, the southern distributary channels drain southward towards the Tulare Lakebed. Much of the floodplain area has been modified by man-made channels and ditches for drainage control, irrigation distribution, and channelization of flood flows to protect agricultural lands.

2.2.3.5 Tulare Lakebed

South of the Central Floodplain, lies the Tulare Lakebed, which was historically the site of a perennial lake. Presently, however, the lake is dry except for during extremely wet periods. The floor of the lakebed is nearly flat with very low relief and close to twenty feet lower than adjacent land surfaces. During previously high lake stands, the lake may have drained northward through the Central Floodplain to the north. Over the years, however, the ~~lake bed~~ lakebed has been modified by canals, ditches and levees to direct flood waters and distribute irrigation waters to the area's extensive agricultural fields.

2.2.3.6 Sierra Nevada Geologic Province

The Sierra Nevada Geologic Province is a large fault-tilted mountain range rising to heights of over 10,000 ft at the crest. The Sierra Nevada is largely composed of granitic rocks with minor bodies of metamorphic rocks, such as along the western edge where the Sierra foothills are characterized by a band of strongly deformed metamorphosed formations. East of the Subbasin, these metamorphic rocks are largely covered by younger sedimentary deposits of the Valley.

The Sierra Nevada Geologic Province is drained by the major drainages of the Kings River, SJR, and Chowchilla River. During the Great Ice Age (Pleistocene 2.6 to 0.01 million years ago (mya)), the crest of the Sierra Nevada ~~was~~ was much larger and huge volumes of sediment was produced from erosion by alpine glaciers and ice sheets. During this geologic time period, streams discharged eroded sediment into

the Valley. The significance of this is that much of the younger sedimentary deposits in the Valley were sourced from rivers to the east of the Subbasin, as well as from a south-draining central river from further north of the Subbasin.

2.2.3.7 Coast Range Geologic Province

West of the San Joaquin Valley and the Subbasin lies the Diablo Range, which is part of the Coast Range Geologic Province. While rugged and steep topographically, the Diablo Range only rises to several thousand feet above sea level with its peaks topping out at around 4,000 ft. The western edge of the Diablo Range, to the west of the Subbasin, marks the northwest trending San Andreas Fault system. **(Figure 2-19).**

The rocks in the Diablo Range are subdivided into three broad groups. To the northwest of the Subbasin the core of the Diablo Range is formed of complex, tectonically mixed and deformed, deep-sea marine sedimentary rocks (Franciscan Complex). Further south, only small areas of the Franciscan rocks are exposed and mixed with large to small blocks of ultra-basic volcanic rocks of sea floor crust **(Figure 2-16A)**. Franciscan rocks are large to small blocks of ultra-basic volcanic rocks of sea floor crust.

As you move farther east, the Franciscan rocks of the Diablo Range are replaced by the Great Valley Sequence, characterized by consolidated marine sedimentary rocks **(Figure 2-16A)**. Although these rocks retain some bedding characteristics, they are highly deformed by faulting and folding.

Younger marine and non-marine sedimentary rocks overlie the Great Valley Sequence. These rocks are faulted and folded similar to the Great Valley Sequence. In the southwestern area, this rock group is exposed on the anticlinal features in the Coalinga and Kettleman Hills area **(Figure 2-16A, and 2-19)**. This area in the vicinity of Coalinga also separates the Westside Subbasin and the Pleasant Valley Subbasin to the west.

2.2.3.8 Surficial Soil Types

~~Surficial soils data were obtained from the Natural Resources Conservation Service (NRCS). As part of the NRCS soil surveys, soil map units are defined to express similarities between soils within similar landform and landscape positions. Each soil map unit is assigned ranges of physical properties by aggregating data collected for each soil map unit.~~

~~Various soil types are present in the Subbasin **(Figure 2-20)**. The dominant soil types within Subbasin include the Ciervo, Cerini, Tranquility, Lethnet, and Westhaven series. The Ciervo series is characterized by very deep, moderately well drained, clay soils and is found on the distal portions of alluvial fans along the center of the Subbasin but is absent in the southern portion of the Subbasin. The Cerini series is characterized by very deep, well drained, clay loam soils and is found on alluvial fans in the northwestern and south-central portions of the Subbasin. The Tranquility series is characterized by very deep, somewhat poorly draining clay soils and is found on distal portions of alluvial fans in the northeastern portion of the Subbasin. The Lethnet series is characterized by very deep, moderately well drained, clay loam soils and~~

is found on unburied fan remnants in the southeastern portion of the Subbasin. The Westhaven series is characterized by very deep, well drained, loam or clay loam soils and is found on alluvial fans in the south central and southwestern portions of the Subbasin.

2.2.3.8.1 Physical Soil Properties

Figure 2-21 shows the texture of surficial soils within the Subbasin as mapped by the NRCS. Clay loam, clay, and sandy loam are the most dominant soil textures found within the Subbasin. Clay loam soils are present throughout the Subbasin, while clay soils are predominantly located in the northwestern portion of the Subbasin and sandy loam soils are predominantly located along the western edge of the Subbasin. Loam is another notable texture present in the western portion of the Subbasin.

The saturated hydraulic conductivity of surficial soils as mapped by the NRCS is shown in **Figure 2-22** and ranges from less than 0.5 ft per day (ft/day) to over 4 ft/day. Hydraulic conductivity is highest along the western edge of the Subbasin corresponding to the sandy loam and loam soils and decreases towards the east where the soil contains more clay. The distribution of hydraulic conductivity throughout the Subbasin is related to the texture distribution of soils. Finer texture soils, such as clays, have low hydraulic conductivity while coarser texture soils, such as sandy loams, have higher hydraulic conductivity.

Figure 2-23 shows the spatial distribution of soil drainage characteristics throughout the Subbasin as mapped by NRCS. Similar in nature to saturated hydraulic conductivity properties, soils in the central and western portions of the Subbasin exhibit the highest drainage capability, while the soils occurring along the eastern portion of the Subbasin are generally poorly drained resulting in areas of low hydraulic conductivity. Poorly drained areas also correspond to fine clay zones. The soils with the poorest drainage properties are generally located near Highway 180 and the town of Helm (**Figure 2-23**).

2.2.3.8.2 Chemical Soil Properties

Soil salinity of surficial soils as mapped by the NRCS is shown in **Figure 2-24**. Salinity is a measurement of the amount of salt present in soil and is estimated by measuring the electrical conductivity (EC) of the soil. From an agricultural standpoint, salinity of the soil is important because it can greatly impact the ability of the soil to support crops. While crops vary in their tolerance for elevated soil salinity, the productivity of most crops becomes impacted when electrical conductivity (EC) levels are above 4 decisiemens per meter (dS/m), although some more sensitive crops may have declining yields at lower salinity levels (Waskom et al., 2012).

In general, soil salinity increases from west to east within the Subbasin, with the southern portion having lower salinity than the northern portion. Salinity appears to be related to both hydraulic conductivity and drainage characteristics; however, soils with salinity greater than 4 dS/m appear more widespread than soil with poor drainage and hydraulic conductivity. Areas with the highest salinity are located in the eastern portion of the Subbasin where salinity commonly exceeds 4 dS/m.

~~Figure 2-25 shows the spatial distribution of soil pH as mapped by the NRCS. Soil pH is a measurement of the concentration of hydrogen ions present in soil. A pH in the range of 7 is considered neutral with increasing pH levels indicating more alkaline soil conditions and decreasing pH values indicating more acidic soil conditions. Crops vary in their ability to tolerate levels of soil pH; however, most crops grow best when the soil pH is slightly acidic at a value between 6 and 7. Highly alkaline soils (pH > 7.8) can affect plant health. Soil pH throughout the Subbasin is predominantly slightly alkaline, with the exceptions occurring in the southwesterly and southeasterly portions where soils are slightly acidic (southwesterly area) and more alkaline with pH in excess of 8.5 (southeasterly area).~~

2.2.4 Identification/Differentiation of Hydrogeologic Units

With the late Pliocene isolation of the marine embayment in the southern Valley, the younger geologic history is dominated by non-marine sedimentary deposition. The depositional setting is similar to that seen in the Valley today with the eastern alluvial plain sourced from the Sierra Nevada and the western alluvial plain sourced from the Diablo Range. These two alluvial plains are separated by an axial fluvial/floodplain area which drained southward to the Tulare Lake area. It is from these younger geologic units that fresh ~~ground-water~~ groundwater is extracted by wells for ~~consumptive~~ beneficial uses.

Fresh groundwater bearing geologic deposits in the Subbasin have been subdivided by previous studies into two primary units: the Upper Aquifer and the Lower Aquifer, which are separated by the Corcoran Clay. **Figure 2-26** shows the map of the three geologic cross-sections prepared for this report, which depict the Upper Aquifer and Lower Aquifer units (**Figures 2-27, 2-28, and 2-29**). The Corcoran Clay was deposited in a widespread lake which inundated much of the Valley. The extent of the Corcoran Clay and depth to the top of this unit is presented in **Figure 2-30**. The Corcoran Clay underlies the entire Subbasin with the exception of a small area in the southwest. The depth to the Corcoran Clay generally increases in the western portion of the Subbasin and ranges from about 400 ft in the east to 800 ft or more at the Subbasin's western margins. The thickness of the Corcoran Clay varies in the Subbasin from less than 20 ft to more than 100 ft (**Figure 3-31**). Generally, the Corcoran Clay is thinner in the southern portion of the Subbasin compared to the northern portion.

The shallow zone is a portion zone within the Upper Aquifer which has been defined as the upper most 100 feet. In the Subbasin, groundwater production is not conducted in this zone, rather Upper Aquifer wells are commonly completed at deeper depths. Groundwater encountered in the Upper 100 feet ~~is not hydrologically connected~~ does not have a direct hydraulic connection to the rest of the Upper Aquifer ~~showing no as evidenced by a lack of~~ seasonal or long-term variation-groundwater level variations. Groundwater elevation in the upper most 100 feet ~~are likely supported~~ appear to be influenced by recharge from irrigation rather than groundwater pumping, therefore it is not defined as one of the primary aquifer units in the Subbasin. For the purpose of identifying groundwater GDEs dependent ecosystems and interconnected surface waters, the shallow zone of the Upper Aquifer was evaluated by determined analyzing first ~~encounter~~ encountered groundwater. **Figure 2-33B** compares the seasonal fluctuation of water levels in the shallow zone to the water levels in the Upper Aquifer.

The hydrogeologic conceptual model defined the primary aquifer units in the Subbasin as the Upper and Lower [Aquifers](#)[Aquifer](#), separated by the Corcoran Clay.

2.2.4.1 [Tulare Lake Beds](#)

The lacustrine, fine-grained silt and clay deposits are termed informally in this report as the 'Tulare Lake Beds', or simply 'Lake Beds'. The Tulare Lake Beds are a distinctive geologic unit composed of lake deposited silts and clays which extends over a period from late Pliocene (3-4 million years before present (mybp)) thru the Quaternary (2.6 million years (my) to present) and attains a net thickness of over 3,000 ft. In the Pleistocene, the upper Lake Beds expanded at least six times beyond the usual extent of the lower and middle Lake Beds. The most extensive high-level lake stand of the Corcoran or E-clay forms the main confining unit for the Lower Aquifers in much of the Valley. The importance of the [Tulare Lake Beds](#)[Beds](#) to the sedimentologic, stratigraphic, and geologic history of the Valley should make them more commonly known, and possibly raised to formal named formational or, at least, member status. The extent of the Lake Beds below Tulare Lake is shown on cross sections in Page (1986), Croft (1972), and Croft and Gordon (1968).

On geophysical logs, the Lake Beds are a monotonous thick (>3,000 ft) sequence of low resistivity units. Resistivity values are generally less than 10 ohms and mostly 5 ohms or less when viewed on geophysical logs of boreholes. Drillers' reports generally identify these clay beds as blue or gray clay. The beds appear to be largely composed of clay to silty clays, and clayey silts with some sandy clayey silts; there do not appear to be any sandy beds in the center of the lake.

At the northern edge, the Lake Beds interfinger and interbed with later Pliocene and younger sand units of stream origin. The [relationships](#)[relationship](#) between the sand sequences and the Lake Beds has informally allowed the subdivisions of lower Lake Beds, middle Lake Beds and upper Lake Beds (Croft, 1972). The sand sequences are several hundred feet thick of either delta or beach deposition origin. The first and second sequences interfinger with the lower Lake Beds. The first sand sequence appears to be beach deposits of the Pliocene marine deposits. The third and fourth sand sequences interfinger with the middle Lake Beds and extend further south into the Lake Beds than the previous sand sequences.

During lower and middle Lake Beds deposition, the relationship between the lake margin sand deposits remained relatively stable, except as noted above. Bartow (1991) postulated that the Tulare Lake drained westward across the San Andreas Fault Zone to the Salinas Valley. This drainage pattern persisted, at least intermittently through the period of deposition of the lower and middle Lake Beds. Some climate changes related to the Pleistocene (2.6 to 0.01 million years ago (mya)) glaciation of wetter and cooler conditions may also factor into the variations of Lake Beds.

With the onset of upper Lake Bed deposition, the nature of the lake margin sand beds changed to thinner beds that interfingered with thin lake bed clays. The Lake Beds appear to expand northward and northeastward. The first significant Lake Bed expansion was mapped by Croft and Gordon (1968; Plate 8) as the F-clay. The culmination of the Lake Bed expansion followed as the Corcoran Clay covered nearly all

of the Valley from Stockton south (Page 1986; plates 4 and 5). The Corcoran Clay has been long recognized as the main confining bed in the Valley separating the primary upper and lower water bearing units.

Subsequent Lake Bed expansions (A, B, C, and D-Clays) of Croft and Gordon (1968) and Croft (1972) appear to be less extensive than the Corcoran Clay (E-Clay). The A and C-Clays are restricted to a narrow band below the Fresno Slough floodplain area (Croft, 1972). The northern extent of these upper Lake Beds is not well known.

The significance of the Tulare Lake Beds through the Quaternary (2.6 mya to present) is that the lake water level would be the base level to which the streams and alluvial fans/plains would be graded. As the lakes expanded, the streams would aggrade by lessening their slope and depositing sediment higher on the fluvial or alluvial plains. When the lakes contracted, the streams would incise by steepening their slope and carrying the sediment further down slope towards the existing lower lake level.

2.2.4.2 Lower Aquifer

North of the Tulare Lake Beds below the Corcoran Clay is the lower water-bearing zone (Lower Aquifer) (**Figure 2-27, Cross-section 1-1'**). With the isolation of the Pliocene marine embayment, deposition in the Valley became non-marine sediments as alluvial plains, fluvial floodplain systems, and lake beds. Below these sedimentary units are the older Paleogene and Neogene non-marine and marine units of the older geologic history.

The Lower Aquifer consists of late Pliocene and Pleistocene nonmarine deposits. These deposits overlie and may interfinger with the last marine deposits of the isolated marine embayment of the San Joaquin Formation. The depositional model for the Lower Aquifer is of two source areas: one from the Sierra Nevada to the east and the second from the Diablo Range to the west (**Figure 2-28, 2-29, Cross Sections 2-2', 3-3'**).

The Sierra Nevada are dominated by granitic rocks, and the eroded sediments contain high percentages of quartz. The eroded sediments were deposited as alluvial fans, fluvial plains, and fluvial floodplains draining southward to the Tulare Lake Beds. Along the edge of the lake, four thick, massive sand sequences occur which appear to be deltaic, beach, and possibly dune deposits. To the north of the Tulare Lake Bed, these lake-margin sand sequences extend westward and span six to eight miles in width. They appear to consist of a massive lakeshore sand and a thick bedded sand zone, tapering to thin-bedded sands at the northern edge.

North of the lake-margin sand sequences, the Sierran-sourced deposits east of the Valley center appear to be alluvial/fluvial plain deposits. The Sierran-sourced deposits extend westward to near the western edge of the valley at depth and appear to be southward flowing fluvial/flood plain origins. Both of these areas have similar geologic character of numerous thin sand beds interbedded with thin silt and clay beds. Thick beds of either coarse or fine-grained materials appear to be lacking, and correlation of geologic units is relatively poor.

The relationship of Sierran-sourced units towards the Coast Range is not clear. The Pliocene and Pleistocene Sierran-sourced deposits in the Lower Aquifer have apparently not been named. Page (1986) related them to the similar-aged Laguna Formation to the north and the Kern River Formation of the southern Valley. In the Fresno, Kings, and Tulare County area these deposits are covered by younger deposits.

On the west side of the Valley, the deformation and uplift of the Diablo Range in the Pliocene appear to have increased the west-sourced sediment. The coarser upslope alluvial fans and plains appear to have been deposited west of the present edge of the Valley. Continued deformation and uplift caused the erosional removal of most of these late Pliocene sedimentary deposits. Small areas of older Paleogene and Neogene and Pliocene deposits are preserved in the Vallecitos syncline and erosional valleys of Little Panoche and Panoche Creeks. Davis & Poland (1959) and Miller and others (1971) noted that small, isolated exposures of late Pliocene alluvial deposits occur west of the edge of the present Valley but are too small to show on the maps.

The western-sourced alluvial deposits overlying the uppermost Pliocene marine unit (San Joaquin Formation) was named the Tulare Formation by Anderson (1905) in the Kettleman Hills area. Subsequent studies have extended the name Tulare Formation to similar deposits along the west side of the Valley. The Tulare Formation was also defined as the youngest deformed deposits along the west edge of the Valley. The age of the Tulare Formation is considered to be late Pliocene and Quaternary (Pleistocene). The Corcoran Clay is considered a member of the Tulare Formation and is age-dated between 700,000 to 600,000 years ago from volcanic ash beds.

The portion of the Tulare Formation below the Corcoran Clay has been intensively studied by the USGS as a result of deep groundwater level declines and subsidence in western Fresno County. The majority of these studies were based on collected geologic samples from boreholes drilled by governmental agencies. Detailed studies were made on the geologic character of the samples, petrology (rock type) of the sands, and mineralogy of the clays. Much of the information was summarized in Miller & others (1971), including thickness of Tulare Formation alluvial fan deposits.

The Diablo Range source rocks of Paleogene and older marine sedimentary units tend to yield fine-grained sediments from erosion. The alluvial fan/plain deposits beneath the Valley appear to be distal fan facies, fine-grained and thin bedded. These alluvial fan/plain deposits transition or interfinger with floodplain deposits eastward which are also largely fine-grained and thinly bedded.

Water wells drilled in western Fresno County are typically screened in the Lower Aquifer to achieve adequate yields; drilling by rotary drilling methods, coupled with normal driller's techniques for describing subsurface lithology, were inadequate in describing the occurrence of the fine-grained and thin-bedded nature of the geologic materials. Due to these factors, geophysical logging of deep water wells began earlier (late 1930's) than elsewhere in California.

All of the USGS geologic cross-sections covering the Subbasin used geophysical logs and [coreholeborehole](#) logs for correlations (Davis and Poland, 1957; Croft and Gordon, 1968; Miller and others, 1971; Croft, 1972). All of these cross sections were reviewed for this report and selection of the most applicable were modified for inclusion. Three cross-sections were selected from Miller and others (1971; A-A' B-B', & E-E'). Cross-section A-A' was selected to show the extent of the Corcoran clay north to south throughout the Subbasin (**Figure 2-27, Cross section 1-1'**). Cross sections B-B' and E-E' were selected to show the relationship of eastern versus western sourced units and depositional settings (**Figures 2-28 and 2-29, Cross-sections 2-2' and 3-3'**).

Selected geophysical logs from the Subbasin were also reviewed and were used to update the original cross sections as needed. Generally, the published cross sections represent the subsurface geologic conditions and validate the general interpretations made on the cross-sections.

2.2.4.3 [Upper Aquifer](#)

The upper water-bearing zone (Upper Aquifer) consists of the sedimentary deposits above the Corcoran Clay which are Quaternary to Holocene (late Pleistocene to present) in age. Throughout the Subbasin, these deposits consist of alluvial fan and lacustrine deposits with both Sierra and Coastal sourced sediments. (**Figure 2-27, Cross-section 1-1'**). To the south and beneath the Tulare Lake Bed area, lacustrine clays and silts extend to the surface above the Corcoran Clay (Croft, 1972). Croft and Gordon (1968) also identified four additional upper lake bed clays (A, B, C, D) which extend further north. The A- and C-Clays are the most extensive of these clays; although they are limited to a narrow (6 to 8 mile) band along the center of the Valley, they extend to (and possibly past) Fresno County's northern boundary (Croft, 1972).

The sedimentary deposits in the Upper Aquifer are up to 800 ft thick with the thickest portions of the Upper Aquifer occurring near the Coast Range. The depositional setting is similar to the Lower Aquifer as it is composed of eastern-sourced fluvial/alluvial plain deposits, western-sourced alluvial plain deposits, and a central fluvial/floodplain zone with interbedded thin lacustrine clays of the uppermost Lake Beds (A-, B-, and C-Clays).

The Sierra Nevada eastern-sourced sedimentary deposits occur as a westward thinning wedge to about 10 miles west of the valley axis overlying the Corcoran Clay. The thickest deposits (500 ft or more) are under the valley axis beneath the Fresno Slough (Miller and others, 1971) (**Figure 2-28, Cross-section 2-2'**). To the south, these deposits are less thick (200-300 ft) where they intertongue and interbed with the upper Tulare Lake Beds. With the expansion of the uppermost Tulare Lake Beds northward starting with the C-clay, the eastern-sourced sediments shift to the east of the Lake Beds (Croft, 1972). As the [Lake BedLakebed](#) high strands of C, B, and A clays occur, the eastern sourced deposits receded eastward, and then expanded westward as the lake contracted. Further north where only the A- and C-Clays of the Lake Beds extend, these clays are interbedded with the fluvial and floodplain deposits along the axis of the valley. Croft (1972) shows a gap in the A- and C-Clays to the north; however, this may be due to lack of well control. The A-, B-, C-, and D- Clays are not shown in any of the cross sections, but all the clays are

present in the southern portion of the Subbasin along the Kings River, and the A- and C- Clays and in the ~~north-eastern~~northeastern portion of the Subbasin near the confluence of the Fresno Slough and San Joaquin River. The upper most zone of the Upper Aquifer, informally named the “shallow one” consists of wells that are above the A-Clay, where present, screened generally within the first 100 ft from ground surface. This area is not considered a principal aquifer or hydrologically connected to a principal aquifer. Groundwater production does not occur, and seasonal pumping from the Upper Aquifer ~~does~~does not affect water levels in the shallow zone. The Sierran-sourced sedimentary deposits in the Upper Aquifer have not consistently been termed much more than Quaternary alluvium. Similarly, sourced age deposits in the northern Valley have been mapped (in ascending order) as Turlock Lake, Riverbank and Modesto Formations (Marchland and Allwadt, 1981). Lettis (1982) has extended this terminology south into the northern Fresno County area. These units were based on detailed soil mapping and surficial mapping in the northern portion of the Valley. In general, it is difficult to identify these named units from drillers reports or geophysical logs and often require detailed geologic sampling from coreholes. For this reason, the term Quaternary alluvium eastern-sourced or Sierran-sourced will be used.

The Diablo Range western-sourced sedimentary deposits in the Upper Aquifer consist of an eastward thin/thinning wedge (Miller and others, 1971). The wedge is thickest (up to 800 ft) south of Panoche Creek along the edge of the Valley. The wedge thins (to 200 ft) as it moves north to the Fresno County Line. Eastward the wedge thins to pinch out west of the Fresno Slough. The western-sourced wedge interfingers with and overlies the eastern-sourced Sierran sedimentary deposits (**Figures 2-28 and 2-29, Cross-sections 2-2', and 3-3'**).

Older studies (Miller and others, 1971 and Croft 1972) reported an area where the Corcoran Clay did not extend to the western edge of the Valley. Subsequent studies by Page (1983; 1986) filled in some of this gap, but an area west of Huron remained. The cause of this is not clear. It may be that the Corcoran Clay pinches out or was possibly removed by erosion caused by the folding of the Kettleman Hills area. As a result, the Upper Aquifer lies directly on top of the Lower Aquifer without the confining bed of the Corcoran Clay being present (**Figure 2-29, Cross Section 3-3'**).

The western-sourced, alluvial fan deposits in the Upper Aquifer are considered the upper Tulare Formation. The deformed Tulare Formation is exposed as a narrow band along the eastern edge of the Diablo Range. Above the upper Tulare Formation are undeformed, younger alluvial fan deposits which can be readily differentiated and mapped at the surface. In northern Fresno County, Lettis (1982) subdivided the younger alluvial fan deposits into Los Banos alluvium and San Luis Ranch alluvium based on detailed mapping and detailed corehole information.

In the subsurface along the western boundary of the Valley floor, it is difficult to differentiate the upper Tulare Formation from overlying younger alluvium from water well driller's reports and geophysical logs. The cause of this is the similar age, source of sediments (Coast Range), and depositional setting of alluvial fans. The geophysical log character of the west-sourced alluvial fans is of low resistivity sand with gravel beds that occur immediately above the Corcoran Clay. These are believed to be fan delta or lake margin deposits. While geophysical logs tend to show more complex thinner interbedded units, corehole logs

tend to show the sand units with silt and clay, and thick clayey units with sand. Contained gravel is generally reported in the uppermost younger alluvial fan deposits.

The western-sourced alluvial fans of the Upper Aquifer interfinger with eastern-sourced fluvial and delta sands which interfinger with upper Lake Beds further to the south (Croft, 1972). South of the Subbasin, the western-sourced alluvial fans interfinger directly with the upper Lake Beds (Bartow, 1972 C-C'). As the upper Lake Beds expanded northward as the C-, B- and A-Clays, the western alluvial fans extended or retreated as the Lake Beds varied.

Further north from the Lake Beds, the western-sourced alluvial fans initially spread eastward above the Corcoran Clay and then interfinger with the Sierran-sourced flood plain deposits (**Figures 2-29, Cross-sections 3-3'**). The western alluvial fans continue to extend eastward overlying the flood plain deposits. To the west, these alluvial fans appear to be locally slightly coarser by geophysical log, possibly representing the shift of the fans by uplift of the Diablo Range. Further east, the geophysical logs appear to show low resistivity thin bedding of distal alluvial fans blending into the flood plain deposits.

The northernmost cross-section (**Figure 2-28, Cross-section 2-2'**) shows a similar pattern of western-sourced alluvial fans extending eastward and interfingering and overlying the Sierran flood plain deposits. Geophysical logs tend to show low resistivity values and thin bedding character. Lettis (1982, cross section B-B') shows about 200 ft of upper Tulare alluvial fan overlying the Corcoran Clay at the valley margin. From a thin edge to the west, the overlying younger alluvial deposits (Los Banos and San Luis alluvium) thicken eastward to about 500 ft and then begin to interfinger and thin eastward above the Sierran-sourced sedimentary deposits and uppermost ~~Lake Bed~~~~lakebed~~ clays (A- and C-Clays). As mentioned previously, it is difficult to separate the upper Tulare Formation from the overlying younger alluvium based in the subsurface by water well Drillers reports and geophysical logs.

2.2.4.4 Base of Fresh Water

The base of fresh water has been defined as the bottom of the ~~basin~~~~Subbasin~~. The base of the freshwater in the Upper and Lower ~~Aquifers~~~~Aquifer system~~ has been defined by the USGS (Page, 1971; 1973) using geophysical logs from oil and gas boreholes. Fresh water was defined as having a maximum specific conductance (EC) of 3,000 micromhos per centimeter (umhos/cm) which is equivalent to a total dissolved solids (TDS) concentration of about 2,000 milligrams per liter (mg/L). The map of the base of freshwater (Page, 1973) (**Figure 2-32**) indicates that in the northern portion of the Subbasin, the base is at elevations of -1,000 ft to less than -400 ft, mean sea level (msl). To the south, the base of freshwater declines to -2,000 ft in a trough parallel to the trend of the Diablo Range. As a result, the base of freshwater in the southern portion of the Subbasin is up to 1,600 ft lower than the elevation at which it occurs in the Subbasin's north.

2.2.2—Groundwater Conditions

2.2.5 Soils

Surficial soils data were obtained from the Natural Resources Conservation Service (NRCS). As part of the NRCS soil surveys, soil map units are defined to express similarities between soils within similar landform and landscape positions. Each soil map unit is assigned ranges of physical properties by aggregating data collected for each soil map unit.

Various soil types are present in the Subbasin (**Figure 2-20**). The dominant soil types within Subbasin include the Ciervo, Cerini, Tranquility, Lethnet, and Westhaven series. The Ciervo series is characterized by very deep, moderately well drained, clay soils and is found on the distal portions of alluvial fans along the center of the Subbasin but is absent in the southern portion of the Subbasin. The Cerini series is characterized by very deep, well drained, clay loam soils and is found on alluvial fans in the northwestern and south-central portions of the Subbasin. The Tranquility series is characterized by very deep, somewhat poorly draining clay soils and is found on distal portions of alluvial fans in the northeastern portion of the Subbasin. The Lethnet series is characterized by very deep, moderately well drained, clay loam soils and is found on unburied fan remnants in the southeastern portion of the Subbasin. The Westhaven series is characterized by very deep, well drained, loam or clay loam soils and is found on alluvial fans in the south central and southwestern portions of the Subbasin.

2.2.5.1 Physical Soil Properties

Figure 2-21 shows the texture of surficial soils within the Subbasin as mapped by the NRCS. Clay loam, clay, and sandy loam are the most dominant soil textures found within the Subbasin. Clay loam soils are present throughout the Subbasin, while clay soils are predominantly located in the northwestern portion of the Subbasin, and sandy loam soils are predominantly located along the western edge of the Subbasin. Loam is another notable texture present in the western portion of the Subbasin.

The saturated hydraulic conductivity of surficial soils as mapped by the NRCS is shown in **Figure 2-22** and ranges from less than 0.5 ft per day (ft/day) to over 4 ft/day. Hydraulic conductivity is highest along the western edge of the Subbasin corresponding to the sandy loam and loam soils and decreases towards the east where the soil contains more clay. The distribution of hydraulic conductivity throughout the Subbasin is related to the texture distribution of soils. Finer texture soils, such as clays, have low hydraulic conductivity while coarser texture soils, such as sandy loams, have higher hydraulic conductivity.

Figure 2-23 shows the spatial distribution of soil drainage characteristics throughout the Subbasin as mapped by NRCS. Similar in nature to saturated hydraulic conductivity properties, soils in the central and western portions of the Subbasin exhibit the highest drainage capability, while the soils occurring along the eastern portion of the Subbasin are generally poorly drained resulting in areas of low hydraulic conductivity. Poorly drained areas also correspond to fine clay zones. The soils with the poorest drainage properties are generally located near Highway 180 and the town of Helm (**Figure 2-23**).

2.2.5.2 Chemical Soil Properties

Chemical Soil Properties Soil salinity of surficial soils as mapped by the NRCS is shown in **Figure 2-24**. Salinity is a measurement of the amount of salt present in soil and is estimated by measuring the electrical conductivity (EC) of the soil. From an agricultural standpoint, salinity of the soil is important because it can greatly impact the ability of the soil to support crops. While crops vary in their tolerance for elevated soil salinity, the productivity of most crops becomes impacted when electrical conductivity (EC) levels are above 4 dS/m, although some more sensitive crops may have declining yields at lower salinity levels (Waskom et al., 2012).

In general, soil salinity increases from west to east within the Subbasin, with the southern portion having lower salinity than the northern portion. Salinity appears to be related to both hydraulic conductivity and drainage characteristics; however, soils with salinity greater than 4 dS/m appear more widespread than soil with poor drainage and hydraulic conductivity. Areas with the highest salinity are located in the eastern portion of the Subbasin where salinity commonly exceeds 4 dS/m.

Figure 2-25 shows the spatial distribution of soil pH as mapped by the NRCS. Soil pH is a measurement of the concentration of hydrogen ions present in soil. A pH in the range of 7 is considered neutral with increasing pH levels indicating more alkaline soil conditions and decreasing pH values indicating more acidic soil conditions. Crops vary in their ability to tolerate levels of soil pH; however, most crops grow best when the soil pH is slightly acidic at a value between 6 and 7. Highly alkaline soils (pH > 7.8) can affect plant health. Soil pH throughout the Subbasin is predominantly slightly alkaline, with the exceptions occurring in the southwesterly and southeasterly portions where soils are slightly acidic (southwesterly area) and more alkaline with pH in excess of 8.5 (southeasterly area).

2.2.6 Groundwater Levels

The characterization of groundwater levels is essential to understanding groundwater conditions including flow directions, trends in levels over the course of time, areas integral to recharge and those involved in discharge, and other hydrogeologic conditions. Groundwater level data includes that were analyzed were obtained from several sources including the District's records, and data available from USGS, DWR, and the SWRCB Geotracker database.

The compiled data underwent a quality assurance/quality control (QA/QC) process whereby data were evaluated for completeness and duplication. This process also identified any erroneous data. The accuracy of well location data is very important for analysis of groundwater levels. To assess well location accuracy, available well location coordinates were checked against the Public Land Survey System (PLSS) and, whenever possible, assigned a State Well Number.

All groundwater level data were classified by aquifer based on available well construction information. The perforated intervals for wells were compared to the elevation of the top and bottom of the Corcoran Clay within the Subbasin (**Figures 2-30 and 2-31**). As mentioned above, the Corcoran Clay is absent in the south-western area of the Subbasin. Through this comparison, well data was classified into five depth

categories: shallow zone (upper 100 ft of the Upper Aquifer), Upper Aquifer, Lower Aquifer, composite (Upper and Lower Aquifer), and unknown (for those wells with no available well construction information). For wells located in areas where the Corcoran Clay is not present, wells with well construction information were designated as Upper Aquifer equivalent or Lower Aquifer equivalent, depending on the well perforated interval relative to the projected or nearby elevation of the Corcoran Clay. During the classification of wells by depth zone, wells with total depths or screen intervals at depths less than 100 ft were classified as the shallow zone. Wells with depths and intervals beyond 100 ft but above the Corcoran Clay layer were classified as Upper Aquifer and wells with depths and screen perforations below the Corcoran Clay were classified as being in the Lower Aquifer. Composite wells were classified as those with screen intervals spanning more than one aquifer. Wells lacking available well depth or screen perforation information were classified as unknown depth zone. For this GSP, the primary groundwater production aquifers are the upper and lower aquifers which will be the focus of the description of groundwater conditions. For contouring of groundwater elevations, only wells designated as Upper Aquifer or Lower Aquifer were utilized.

2.2.6.1 [Historical Groundwater Levels](#)

To gain a historical perspective of trends in groundwater levels in the Subbasin, groundwater level hydrographs were generated for wells with long-term data records. Panel maps presenting hydrographs of groundwater elevations through time in select wells are provided in **Figures 2-33 to 2-34**. These maps illustrate representative hydrographs of groundwater elevations and the locations of the specific wells used. Wells were selected based in part on their location within the Subbasin and the length of their data record.

Historical hydrographs of water level data for select wells in the Upper Aquifer are displayed in **Figure 2-33A**. Many of the wells with long-term water level data displayed on **Figure 2-33A** show increasing groundwater levels prior to the early 2000s, followed by stable water levels in some wells after 2000. Some wells in the Upper Aquifer, however, exhibit considerable fluctuations in water levels. Several hydrographs on **Figure 2-33A** illustrate water levels at specific depths within the Upper Aquifer. These data suggest that although temporal trends in groundwater levels may be similar at different depths within the Upper Aquifer, differences in groundwater elevations can exist within the Upper Aquifer. The reason for the different depths may be due to the well construction features of the wells and influences from groundwater pumping. Recent groundwater level data within the last ten years (2008-2018) indicate various degrees of groundwater elevation declines. The declines are indicative of many areas in the State that were impacted by the recent drought period and associated temporary increases in groundwater pumping, although a slight decreasing trend is observable in recent years, this trend is most evident in deeper wells within the Upper Aquifer. **Figure 2-33B** shows the relationship between the shallow zone and the rest of the Upper Aquifer. It is evident that groundwater elevations in the shallow zone [generally](#) do not [strongly](#) correlate with climatic conditions or seasonal pumping patterns. Of the eight examples presented, [depths to water for](#) seven of these shallow zone wells are within 40 feet of the ground surface. Each of these wells [shows almost](#) [show little to](#) no long-term decline or seasonal variation. The one shallow zone well [that was with depths to water](#) greater than 40 feet was screened between 80 and 90 feet below

ground surface. In this example, the well still also shows no seasonal variation with, very little variation from climatic conditions, and no long-term decline. Many of the Upper Aquifer wells screened below the shallow zone show significant seasonal variations of groundwater elevation up to hundreds of feet.

Figure 2-34 presents hydrographs for selectselected wells in the Lower Aquifer. Historical groundwater conditions in the Lower Aquifer show historically low groundwater levels in the 1950s and 1960s with the dramatic rise of water levels after the onset of CVP surface water deliveries in 1968. Although notable short-term fluctuations in some Lower Aquifer wells are evident from the 1980s through the early 2000s, groundwater levels remained relatively stable during this period. Since 2010, however, groundwater levels in the Lower Aquifer have declined considerably (**Figure 2-33A34**). For some wells, groundwater levels have declined by as much as 200 ft in the five years between 2010 and 2015- and have continued to vary with climatic conditions. Although these recent declines in groundwater elevations are dramatic, it is notable that these values represent potentiometric elevation changes in a confined aquifer which are not necessarily equivalent in terms of change in aquifer storage to elevation changes in an unconfined or semi-confined system such as the Upper Aquifer.

2.2.6.2 Historical and Current Groundwater Elevation Contours and Flow Directions and Gradients by Aquifer (§354.16(a)(1))

All available data for wells with aquifer designations was also utilized to create groundwater elevation contours. Groundwater elevation contours were initially developed using spatial analysis tools available in ArcGIS followed by technical review and adjustment based on professional judgement. Contours were created during three different time periods to obtain an understanding of groundwater elevations during dry years, wet years, and current conditions. Years were chosen based on hydrographs generated for all wells in the two aquifers. Data from Winter/Spring 2006/2007 was used to represent a typical wet year, Summer/Fall 2009 represented a typical dry year, and Winter 2014/2015 was used for current conditions.

Figures 2-35 to 2-37 depict conditions in the Upper Aquifer zone during the three time periods. Groundwater level data was sparse in some areas of the Subbasin for the Upper Aquifer (**Figure 2-39**). The majority of the control points lay in the vicinity of the eastern boundary of the Subbasin. Furthermore, no conclusions can be drawn about groundwater conditions in the area to the south of Huron as no data was available for any of the time frames examined. An increase in data collection effort is evident in **Figure 2-37**, as it contains more control points than either of the preceding two figures. Although **Figure 2-36** represents a dry year, water levels in the northern region of the Subbasin are similar to those seen in 2006/2007, with the highest levels being 250 ft. Current conditions show a high of 200 ft in the same region. Groundwater levels along the SLC are higher than in other areas of the Subbasin (**Figure 2-37**). Although a concrete flow direction cannot be attributed to this aquifer zone due to the incompleteness of the dataset, a general trend of decreasing water levels toward the Subbasin's eastern boundary can be observed throughout each time frame. This indicates that the groundwater flow directions are influenced by groundwater development in the adjoining Subbasins located east of the Westside Subbasin.

The Lower Aquifer had a relatively large amount of data available for contouring for Winter/Spring 2006/2007 and winter 2014/2015, however, data was sparse for fall 2009 and primarily confined to the southern portion of the Subbasin. Although the data is sparse in some areas of the Subbasin for winter/spring 2006/2007, **Figure 2-38** suggests that groundwater levels tend to decrease from west to east across the Subbasin and in and around the city of Huron during this time. In Summer/Fall 2009, the limited groundwater data shows water levels decreasing to the east and southeast (**Figure 2-39**). In both winter/spring 2006/2007 and Summer/Fall 2009, water level elevations are generally 100 ft msl or less within the Subbasin. **Figure 2-40** shows a substantial increase in the amount of monitoring data available during this period which represents recent drought conditions. Generally, the groundwater elevation contours show a trough of low groundwater elevations along a north to south orientation in the central portion of the Subbasin with groundwater levels at around -160 ft below sea level. Groundwater levels increase with distance from the center of the Subbasin towards the western and eastern boundaries of the Subbasin. The two winter/spring contours of groundwater elevations indicate that groundwater flow directions in the Lower Aquifer flow eastward out of the Subbasin during wet years and flow into the Subbasin during extended drought periods. Additional contouring of Lower Aquifer groundwater levels is recommended in the future to assess the variability and frequency of subsurface inflows and outflows to and from the Subbasin in order to assess the influence of groundwater pumping within the Subbasin and in adjacent subbasins on groundwater flow directions and sustainable yield estimates.

2.2.7 Water Quality (§354.16(d))

The evaluation of groundwater quality in the Subbasin included a review of regional investigations (USGS, 2017; Carollo and LSCE, 2015; and USGS, 2013) and data collected from the same data sources as were used for groundwater level data. Groundwater quality data was limited in geographic extent since 2000 when data was only available for small areas of dating back to the Subbasin. As a result, 1930's and the lack of recent data (since 2000) limits the ability to characterize collection of groundwater quality other than on a data, especially from the Upper Aquifer, has become more available since 2020 with the implementation of regional, basin water quality regulatory programs such as the Irrigated Lands Regulatory Program (ILRP). The collection of groundwater quality data has been sporadic over time with little groundwater quality data collected between 2000 and 2020. The analysis of Subbasin-wide scale conditions relied on the period from 1950 to 2020. Groundwater quality in the Subbasin is primarily characterized by the occurrence of total dissolved solids (TDS), boron, selenium, arsenic, and sulfate that in some locations may exceed drinking water standards in the shallow zone of the Upper Aquifer (Carollo and LSCE, 2015). The elevated concentrations of these constituents are primarily naturally occurring as a result of the geologic composition of the aquifer materials (from the Coast Range) (USGS, 2017). There is little evidence of groundwater quality degradation in the Subbasin that is a result of agricultural or industrial related activities. Nitrate is not a water quality concern in the Subbasin due to the oxidation/reduction conditions that exist in the aquifer system which result in denitrification (USGS, 2017). The occurrence and cause of nitrate concentrations that exceed drinking water standards are currently being investigated under the ILRP to assess areas where nitrate concentrations are a result of natural sources such as geologic materials or from agricultural land use practices. The data collected by the Westlands Water Quality Coalition demonstrates that the concentration of nitrate in groundwater in

the Westside Subbasin is generally at or below background concentrations meaning that it is not impacted by anthropogenic discharges. As result of the nitrate data and studies conducted by the Coalition, the Westside Subbasin is not prioritized under the Nitrate Control Program managed by the Central Valley Salinity Alternatives for Long-term Sustainability (CV-SALTS).

District farmers are currently implementing Best Management Practices (BMPs) such as switching to crops that can tolerate higher levels of salt, blending pumped groundwater with delivered surface water, and treatment, such as reverse osmosis, of groundwater. These BMPs allow farmers to continue to farm in areas where groundwater is affected by elevated TDS concentrations. Figures 2-4 and 2-6 depict the implementation of the BMP and that groundwater is beneficially used across the Subbasin.

Beneficial uses of groundwater in the Subbasin include agriculture, domestic, and municipal uses. There are not any environmental beneficial users of groundwater in the Subbasin as described in Section 2.1.5.1. For agricultural beneficial uses, available groundwater quality data and outreach efforts indicate that TDS is the primary constituent of concern. Constituents of concern for domestic and urban beneficial users are those constituents that are regulated under the State of California's drinking water standards. Analysis of existing groundwater quality data indicates that TDS is can be utilized as a proxy for other naturally occurring constituents and constituents of concern for domestic and urban beneficial users. Using TDS as a proxy for domestic and urban beneficial uses was justified from a correlation and spatial comparisons between TDS concentrations and other constituents of concern that occur in the Subbasin. Figures 2-41 and 2-42 show a correlation between TDS concentrations and two constituents of concern, nitrate and boron. Figures 2-43 to 2-45 show that, although there is, therefore, considered the primary constituent of concern, a lack of correlation between TDS and heavy metals of concern (selenium, arsenic, and chromium), high TDS (over 1000 mg/L) is present when heavy metals are present at elevated levels. These plots of TDS concentrations and concentrations of other constituents show that elevated TDS is a useful indicator of water quality impairment in the GSA as relates to agricultural and drinking water beneficial users.

The Subbasin includes a limited number of 38 known active domestic wells (38). Available data on domestic well construction and monitoring data is limited. Based on knowledge of domestic wells located in the Subbasin available data, most of these domestic wells are constructed in the Upper Aquifer or are composite wells that are constructed in the Upper Aquifer and Lower Aquifer with the shallow zone of the Upper Aquifer sealed to prevent downward percolation of poor-quality water. Groundwater quality data from private domestic wells is not readily available. As a result, the Groundwater quality constituents of most interest for this the drinking water beneficial use can be represented by ambient TDS. Due to the presence of oxidation and reduction conditions, nitrate is likely not a constituent of concern (monitored in both the Upper and Lower Aquifers. However, since the Subbasin predominantly includes agricultural land uses, the potential for nitrate to occur in the Upper Aquifer is possible should oxidation and reduction conditions vary in the Subbasin and near the vicinity of domestic wells. As a result, both nitrate and salinity in the form of TDS are the constituents of interest for the GSP monitoring program. available wells).

The District's groundwater quality monitoring during GSP implementation will be augmented by monitoring from the ~~groundwater quality trend monitoring program under the Irrigated Lands program. This monitoring will provide data which will help characterize groundwater quality in vulnerable areas, including areas where domestic wells may be located.~~ GQTM G program under the IRLP. This monitoring will provide data which will help characterize groundwater quality in the Subbasin, especially those areas of the Subbasin that have not experienced degradation of water quality due to the occurrence of marine sediments from the Coast Range and areas where domestic wells may be located. As stated in the IRLP General Order, "the trend monitoring program is designed to determine current water quality conditions of groundwater in the Third-Party area [e.g., the Subbasin], and to develop long-term groundwater quality information that can be used to evaluate the regional effects (not site-specific effects) of irrigated agriculture and its practices. Trend monitoring has been developed to answer Groundwater Monitoring Advisory Workgroup (GMAW) questions 1 and 4. At a minimum, trend monitoring must include annual monitoring for electrical conductivity, pH, dissolved oxygen, temperature, nitrate as nitrogen (N), and once every five-year monitoring for total dissolved solids, carbonate, bicarbonate, chloride, sulfate, boron, calcium, sodium, magnesium, and potassium."

Most municipal (community) water systems in the Subbasin rely on surface water from the California Aqueduct for urban supply and not on groundwater. The exception is Cantua Creek ~~and El Porvenir~~ which has historically used groundwater as a supplemental supply, however, currently ~~the well is~~ their wells are inactive. Fresno County is in the process of installing a new well for Cantua Creek and El Porvenir. Water systems are regulated by the State ~~Department~~ Water Resources Control Board Division of Drinking Water and are required to report the water quality of the sources used for supply on an annual basis.

As ~~a~~ discussed above, the groundwater quality data ~~focused on that was analyzed concluded that TDS (or salinity) can be used as represented by TDS concentrations along with EC measurements due to the influence these a proxy for other constituents have on existing land and water used detected~~ in the Subbasin. Prior to commencing any analysis on existing data, all EC data was converted to TDS (multiplied by a factor of 640 or 0.64 depending on the units of EC data) to create a uniform dataset. These records also underwent a QA/QC process during which duplicate records were deleted and all data was checked for accuracy and verified to the extent possible. ~~In contrast to the amount of groundwater level data, groundwater quality data was sparse spatially, temporally, and by aquifer. As a result, depiction of salinity over time on a map was grouped into three different time periods to try to represent snapshots of salinity concentrations over time.~~ These data were then used to develop the analysis below.

2.2.7.1 Historical Groundwater Quality by Aquifer with a Focus on Salinity

~~TDS hydrographs~~ Maps of TDS concentrations and time series charts of TDS concentrations (salinity) of well locations were constructed prepared using all available TDS and EC data ~~for each well.~~ A select number of wells are depicted in **Figures 2-4146 to 2-4247** to present a historical overview of TDS concentrations in the Upper Aquifer and Lower Aquifers Aquifer. Many of these wells lack continuous long-term data ~~and~~. However, the data likely represents local groundwater quality conditions because changes in groundwater quality that are caused by groundwater pumping and the migration of elevated

TDS is dependent on horizontal groundwater flow and gradients. When using Darcy's Law and examining the flow of water, the velocity is often have gaps of five years or more slow, with a likely range of between measurements.

about 1 and 5,000 feet per year. The Upper Aquifer does not have many wells with continuous data with the exception of two wells which have data from the ~~2000s~~2000's forward (19S/17E-11 and 18S/18E-34) (**Figure 2-41-46**).

These two wells both have measurements indicating increasing TDS concentration. The maps of TDS concentrations for the Upper Aquifer and Lower Aquifer were prepared to convey the areal extent of the aquifer system that has concentrations above 1,000 mg/L, which is the short-term maximum contaminant level for drinking water and is an important concentration level for domestic and urban beneficial users and also for agricultural beneficial uses for irrigation purposes on most crops (Figures 2-48 through 2-53). **Figures 2-48 through 2-50** show that the Upper Aquifer groundwater quality generally exceeds the drinking water standard of 1,000 mg/L with the exception of a few areas of the Subbasin.

The areas with elevated TDS concentrations above 1,000 mg/L represent baseline and historical conditions that are predominantly the result of the marine sediments of the Coast Range which compose many areas of the Upper Aquifer. The relatively poor water quality conditions of the Upper Aquifer are the primary reason why historical groundwater pumping has been less in these wells. the Upper Aquifer (approximately 15 percent of the total amount of Subbasin groundwater pumping) than in the Lower Aquifer.

The Lower Aquifer also has a lack of wells with continuous data (**Figure 2-42-47**). The available data showed a variation in trends throughout the Subbasin including increasing, decreasing, and stable salinity values. An assessment of trends in salinity concentrations is constrained due to the lack of data as well as the infrequent periods of data collection. Furthermore, in many cases, the most recent measurement pre-dates 2015 which prevents an assessment of current conditions. These data gaps in groundwater quality data will be addressed in the GSP monitoring network, similar to the Upper Aquifer data availability. However, when evaluating TDS concentrations spatially in the Lower Aquifer using all historical data (**Figures 2-51 through 2-53**), the occurrence of TDS in excess of 1,000 mg/L, representative of baseline conditions, reveals that many areas of the Lower Aquifer in the Subbasin have degraded water quality. However, the spatial distribution of degraded water quality in the Lower Aquifer is not as prevalent as in the Upper Aquifer and may be a primary reason why most groundwater pumping occurs from the Lower Aquifer in the Westside Subbasin.

All available data was also mapped to highlight areas with two or more exceedances of 1000 mg/L for both the Upper and Lower Aquifers (**Figure 2-53a and 2-53b**). Areas with two or more exceedances are displayed in grey whereas areas with less than two (2) exceedances are shown in green. Areas with insufficient data are depicted in white. These maps further highlight areas with elevated TDS due to the marine sediments of the Coast Range (two (2) or more exceedances) and areas that can be managed for TDS (less than two (2) exceedances), as discussed further in Chapter 3.

2.2.7.2 Historical and Current Occurrence of Salinity

The maps presented above illustrate the occurrence of TDS spatially utilizing all the historical data available. This section describes the occurrence of water quality data in a series of time blocks beginning in 1990 to provide an understanding of the amount and occurrence of water quality data collection from 1990 to 2015 which generally corresponds to the GSP's historical water budget period. Over the past several years since 2020, the District has implemented the GSP monitoring program to collect groundwater quality data ~~was~~ which also included the installation of 15 aquifer specific monitoring wells that enabled the collection of groundwater quality samples throughout the Subbasin. Currently, the available groundwater quality data collected over the past several years are being evaluated to compare recent data with historical data to identify time periods which would provide an indication of how salinity changes occurred spatially over time in each aquifer zone. Three time periods were selected for analysis (1990-1995, 2005-2009, 2010-2015) for which to display salinity data. Analysis of data collected since 2015 is currently in process and will be described fully in the 2025 GSP update.

Upper Aquifer TDS data is illustrated in **Figures 2-4348 to 2-4550**. The majority of the data available for the Upper Aquifer from 1990 to 1995 is concentrated along the eastern edge of the Subbasin. The majority of wells located north of Highway 198 and west of the Fresno-Kings county line have TDS concentrations below 1,000 mg/L. In contrast, wells along the eastern edge of the Subbasin, in the northern and central regions, have high densities of wells with TDS concentrations over 2,000 mg/L. The amount of data available for characterization decreases from 2005 to 2009 in the Upper Aquifer (**Figure 2-4449**). However, a cluster of high TDS concentration wells is still observed in the central portion of the Subbasin, along the eastern boundary. Similar to **Figure 2-4348**, the eastern boundary area intersecting with the Fresno-Kings county line shows that wells in that region have TDS concentrations below 1,000 mg/L. **Figure 2-4550** has the fewest data points available for analysis. However, most of the wells with data available have TDS concentrations exceeding 1,000 mg/L. Most of this data is concentrated along the eastern boundary of the Subbasin in the central and southern regions of the boundary. Similar to the shallow zone, a lack of data is evident west of the California Aqueduct. ~~Furthermore, there is a general data gap across the entire Subbasin, especially in recent years. More data in these areas would allow for a more complete analysis and determination of spatial variability in water quality conditions.~~

The majority of the wells providing TDS measurements in the Lower Aquifer are concentrated along the SLC and towards the Subbasin's western boundary. As seen in **Figure 2-4651**, the majority of the wells have TDS concentrations below 2,000 mg/L. There is a small collection of wells in the vicinity of Huron which exhibit concentrations above 2,000 mg/L. The area along the Fresno-Kings county line in the southern portion of the Subbasin has a high concentration of wells with TDS levels below 1,000 mg/L. **Figure 2-4752** continues the trends seen in **Figure 2-4651** with wells in the southern half of the Subbasin generally having lower TDS concentrations than those in the northern region. ~~The wells highlighted in Figure 2-47~~ These differences in groundwater quality in the Lower Aquifer are similar to the occurrence of groundwater pumping in the Lower Aquifer, with more pumping occurring in the southern half than the northern half of the Subbasin. The wells highlighted in Figure 2-52 also show an area with higher TDS concentrations than those observed in the same region in **Figure 2-4651**. Although a few wells to the west

of Huron can be seen with concentration above 2,000 mg/L, recent conditions, as depicted in **Figure 2-4853**, show more wells overall with TDS concentrations below 1,000 mg/L. Although there is less data in recent years, the available data suggests a slight improvement in TDS concentrations. The data gaps in the Lower Aquifer are not as apparent as in the Upper Aquifer. Although there is a decrease in the availability of data from the 1990s to the 2010s, a large amount of data across the Subbasin is still available. Future analyses, however, would benefit from an expansion of groundwater quality data from the northern and eastern parts of the Subbasin.

2.2.8 Subsurface Compaction and Land Subsidence

Land subsidence is a major concern for the Valley, and particularly for the Subbasin, due to the use of groundwater to supplement variable surface water supplies. Subsidence has the potential to damage local, state, and federal infrastructure, including reducing the freeboard and flow capacity of the SLC and Coalinga Canal, and irrigation water-delivery canals, bridges, roads and flood control structures. Subsidence in the Westside Subbasin is recognized to occur due to several factors including groundwater pumping, hydrocompaction, extraction from oil and gas fields, and tectonic plate movement (Ireland, 1984; Poland and Davis, 1969; Figure 2-54). While these contributing causes of subsidence are generally accepted, it is widely held that groundwater extraction is the primary cause of land subsidence in the Subbasin.

~~Land subsidence in the Valley commonly occurs due to fluid withdrawal (LSCE et al., 2013). Permanent land subsidence, resulting from inelastic compaction, is caused when fluid pressure within clay pore space declines, through groundwater pumping or oil and gas extraction. It may be difficult to distinguish subsidence resulting from hydrocarbon extraction from that resulting from groundwater pumping if they are in the same areas oil and gas fields are not currently operating in the Subbasin (Figure 2-49) but operating fields are located outside the Subbasin. In order to understand the deformation caused by each source, it is important to evaluate the location and production history and to obtain measurements of compaction over discrete subsurface intervals. During fluid withdrawal and reduction in pore pressure, the structure of the clays is rearranged and compacted with an inability to expand to its original structure and thickness even when groundwater levels rise.~~

~~As discussed above, the Subbasin's aquifer system includes fine grained sediments, including clays, silts, and sandy or silty clays that are susceptible to compaction if depressurized by pumping wells (LSCE, Borchers and Carpenter, 2014). In addition, the Corcoran Clay separates the unconfined to semi-confined Upper Aquifer from the lower confined aquifer. The Upper Aquifer only shows minor elastic compaction compared to irreversible compaction that has occurred in the Lower Aquifer (Figure 2-50). The majority of irrigation water is pumped from the Lower Aquifer due to its greater thickness and because of the better water quality and well yields compared to the Upper Aquifer (Ireland et al., 1984). Figure 2-50 compares the Fordel extensometer constructed in the zone above the Corcoran Clay with the Mendota Plate Boundary Observatory station (PBO 304) that measures total land subsidence. Although an extensometer measuring the zone above the Corcoran Clay does not exist within the Subbasin, these two sites are northeast and adjacent to WWD and are expected to represent the proportion of compaction~~

within the District. Since the start of the monitoring period, P304 has had about 0.64 ft of total inelastic compaction which is about 15 times more than was measured at the Fordel extensometer over the same period. A hydrograph of water levels below the Corcoran Clay at USGS monitoring well T13S/R15E-31J6 (31J6) is shown on the bottom of Figure 2-50. When the hydraulic head in the Lower Aquifer (e.g., 31J6) reaches historical lows, inelastic compaction is observed in the Lower Aquifer (as seen at P304). Faunt et al. (2009) found that most subsidence probably resulted from compaction of relatively thin aquitards within the Lower Aquifer system.

2.2.8.1.1 Types of Subsidence Monitoring within the Subbasin

2.2.8.1 Spirit leveling is the oldest method of measuring Physical Concepts

The mechanics of land subsidence due to groundwater extraction for irrigated agriculture is discussed below. The following summary is a brief description of the concepts that are used to quantify the physical relationship between groundwater extraction and subsidence.

2.2.8.1.1.1 Effective Stress

Land surface subsidence due groundwater pumping is attributable to the reduction in pore-water pressure predominantly in fine-grained materials within an aquifer system. This principle was initially developed by Terzaghi (1925), who related aquifer system compaction to pore-pressure and effective stress:

$$\sigma_e = \sigma_T - \rho \quad (1)$$

where: σ_e is the effective (intergranular) stress

σ_T is the total stress due to the geostatic load (downward force, as the weight of overlying sediments and water)

ρ is the pore-water pressure (buoyant upward force)

Under a constant geostatic load in a confined aquifer system, pumping induced deformation of the aquifer skeleton occurs due to a reduction in pore-water pressure, which causes an increase in the effective stress on the adjacent fine-grained interbeds leading to compaction of the skeletal framework of the interbeds. As water levels decline, the associated decrease in fluid pore-pressure transfers to a commensurate amount of the total (intergranular) stress between the contacts of the grains within the aquifer system. This increase in effective stress causes deformation (compaction) of the aquifer skeleton and especially fine-grained interbeds within or adjacent to the aquifers leading to land surface subsidence and possibly permanent loss of aquifer storage within fine-grained interbeds (Figure 2-55).

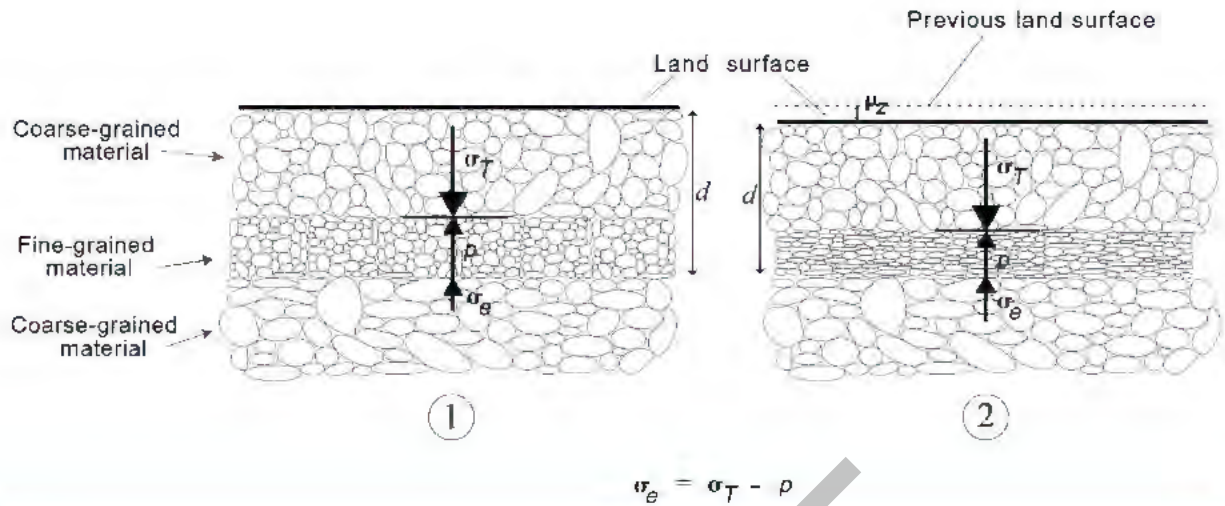


Figure 2-55. Increase in effective stress and vertical displacement (μ_z) of land surface (subsidence) as a result of a decrease in pore-water pressure for a confined aquifer layer (from Sneed and Galloway, 2000).

2.2.8.1.1 Elastic and Inelastic Deformation

In alluvial depositional environments, fine-grained materials are generally arranged in laterally extensive and/or discontinuous confining units referred to as “interbeds” within an aquifer system. For the purposes of evaluating subsidence in a precise way, the term “aquifer” refers to the water bearing interconnected coarse-grained material within the aquifer system where (due to larger hydraulic diffusivity) the majority of initial water level and groundwater storage changes occur due to pumping.

Compaction and land subsidence are due to obtain data for smaller areas such as elastic and inelastic deformation of the aquifer skeleton (Terzaghi, 1925). Inelastic deformation occurs predominantly in the fine-grained materials within an aquifer system (Ireland, 1984; Hanson 1989). Inelastic deformation occurs in cases where the effective stress within the interbeds exceeds the greatest effective stress ever experienced within interbeds, which is referred to as “pre-consolidation stress” (Holzer, 1981). This is triggered when the hydraulic head in the interbeds drops below historic levels referred to as “pre-consolidation head” (Jorgensen, 1980; Leake and Prudic, 1991; Hoffman et al., 2003). The pre-consolidation stress threshold is a combination of previous low groundwater levels (buoyant force) and any past increases in geologic loading from sedimentary deposition plus any potential lithification or cementation of the sediments that comprise the aquifer system. Inelastic deformation and compaction results in the irreversible rearrangement of the grains within aquifer skeleton leading to a permanent reduction in aquifer storage and compaction.

Elastic deformation occurs in both fine and coarse-grained materials comprising the aquifer system in cases where the effective stress is less than the pre-consolidation stress. Elastic deformation manifests to varying degrees in both fine and coarse-grained sediments. Unlike inelastic compaction, elastic compaction is reversible and commensurate to the changes in effective stress in the aquifer system.

2.2.8.1.2 Skeletal Specific Storage

Land subsidence and changes in groundwater storage due to water level changes within a confined aquifer system are dependent on the physical properties of the aquifer materials. The amount of water stored or released within a unit thickness of aquifer material due to a unit change in hydraulic head is defined as the specific storage (S_s):

$$S_s = S_{sk} + n \times S_{sw} \text{ [ft}^{-1}\text{]} \quad (2)$$

where: S_{sk} is the component of specific storage due to the compressibility of the aquifer skeleton (skeletal specific storage)

S_{sw} is the component of specific storage due to the compressibility of water

n is the total porosity

The skeletal specific storage can be further refined to account for elastic (S_{ske}) and inelastic (S_{skv}) components, which are dependent on the hydraulic head (Leake and Prudic, 1991). Under conditions where the hydraulic head (h) is greater than the pre-consolidation head (H_c), the skeletal specific storage is equal to the elastic specific storage only. Under conditions where the hydraulic head is less than the pre-consolidation head, the skeletal specific storage is equal to the sum of the elastic and inelastic specific storage (modified from Leake and Prudic, 1991):

$$S_{sk} = S_{ske} + S_{skv}, \quad h \leq H_c \text{ [ft}^{-1}\text{]} \quad (3)$$

Since inelastic compaction within interbeds is caused by permanent rearrangement of the grain structure, the inelastic skeletal specific storage is one to two orders of magnitude greater than the elastic skeletal specific storage (Riley, 1969; Helm, 1976; Riley, 1998).

2.2.8.1.1 Delayed Aquitard Drainage

Depending on the geometry (distribution and thickness) and hydraulic properties of the interbeds within an aquifer system, there may be a significant time-delay for hydraulic heads within interbeds to equilibrate with heads in adjacent aquifers (Terzaghi, 1925). As a result, so called “ultimate” amounts compaction may not be manifested until residual excess pore-pressure in the interbeds is released, which can occur much later than the initial decline in water levels within the adjacent aquifer. Recognition of this dynamic can be critical in slowly draining aquifer systems since the change in effective stress within interbeds (compaction) can continue to occur even when the measured hydraulic head within the aquifer does not exceed the pre-consolidation head as previous reductions of pore pressure from the adjacent aquifers are still propagating across the interior of the fine-grained beds (Sneed et al., 2018).

2.2.8.2 Subsidence Studies in the San Joaquin Valley

Early work from Mendenhall (1916) described in Bull and Miller (1975) indicates that the majority of the Westside Subbasin had flowing artesian wells prior to development of groundwater resources. By the early 1950's, groundwater extraction for irrigation in the west-central portion of the San Joaquin Valley

encompassing the approximate boundary of the Westside Subbasin was estimated to exceed 1 MAF per year – leading to considerable land subsidence in the Subbasin. Poland and others (1975) estimated total subsidence in the Subbasin between 1926 and 1972, which approached 30 feet in localized areas of the Subbasin.

While not initially considered in the initial development of the CVP, recognition of subsidence impacts on canal capacity led to the formation of the Inter-Agency Committee on Land Subsidence in 1954 prior to the construction of the San Luis Project. This led to a number of key studies spearheaded by the USGS and funded by DWR beginning in 1956. Key early studies are summarized in reports by Poland and Davis (1956) and Davis and others (1959). Concurrently, the U.S. Bureau of Reclamation (USBR) conducted subsidence studies in the 1960's which include estimates of the "ultimate" subsidence along the San Luis Canal (Propokovich, 1963; Propokovich 1969). Substantial efforts to characterize the rates and causes of subsidence are summarized in reports by Miller and others (1971), Bull and Miller (1975), Bull (1975) and Bull and Poland (1975), Poland and others (1975) and Ireland and others (1984) and Ireland (1986). A more detailed summary of these reports can be found in the USGS report on subsidence near the California Aqueduct. ~~The District~~ (Sneed et al., 2018).

Notable studies aimed at analyzing stress and strain relationships and developing estimates of the material properties of the aquifer system in the San Joaquin Valley were conducted in studies listed above as well as Lofgren (1961), Riley (1969), Helm (1975, 1976, 1978) and Johnson (1984). Estimates of physical properties were also derived from laboratory consolidation tests by Johnson and others (1968). Additional consolidation tests from cores were analyzed by the USGS during the installation of newer monitoring wells in 2011-2012 (Hanson written commun., 2022). A detailed summary of results from these and other significant studies is provided ~~elevation data for measuring points along the~~ in Sneed (2000).

Following the mid 1980's, there is a notable lack of significant subsidence-related studies in the San Joaquin Valley and abandonment of much of the subsidence monitoring network developed during planning and construction of the CVP. However, renewed interest in subsidence research and monitoring beginning in the early-2010's has led to several recent studies. Characterizations of subsidence near the Delta-Mendota Canal and California Aqueduct ~~from 1967 to 2015~~ were conducted using measured subsidence and water level data in conjunction with InSAR by the USGS in 2013 and 2018 (Sneed et al., 2013; Sneed et al., 2018). In 2017, the California Dept. of Water Resources published the California Aqueduct Subsidence Study. More recently, a one-dimensional modeling study was released in 2021 reproducing historical land subsidence rates in the San Joaquin Valley (Lees et al., 2021).

Several regional numerical models have also been developed in the Central and San Joaquin Valley aimed at quantifying groundwater storage and land subsidence. These include models developed as part of the Regional Aquifer System Analysis (RASA) by the USGS (Williamson et al., 1989; Belitz et al., 1993), WESTSIM developed by the Berkeley Nation Laboratory (Quinn and Faghih; 2001) and the Central Valley Hydrologic Model (CVHM) developed by the USGS (Faunt et al., 2009).

2.2.8.3 Subsidence Monitoring

2.2.8.3.1 Geodesic Surveys

Characterization of the rates and spatial distribution of subsidence prior to CVP deliveries in the San Joaquin Valley were based on measurements from benchmarks constructed in the early-1900's by the USGS and subsequent geodesic surveys conducted between the 1940's through the mid-1970's. Results of these surveys were used to map total subsidence between 1926 and 1972 (Ireland et al., 1984). These maps show significant amounts of subsidence throughout the central-west portion of the Subbasin with pockets of more severe subsidence approaching 30 feet locally south of Firebaugh and east of Huron (Figure 2-56). Ireland and others (1984) also produced transects of land subsidence over time between 1943 and 1975 in the more severely affected areas (Figure 2-57).

Surveys conducted during highway leveling are another useful source of information. Sneed and others (2018) developed transects of estimated vertical displacement from highway leveling on 198 north of Huron between the 1960s and 2004. These transects show a maximum of 3000mm (9.8 feet) at Highway 198 (Figure 2-58).

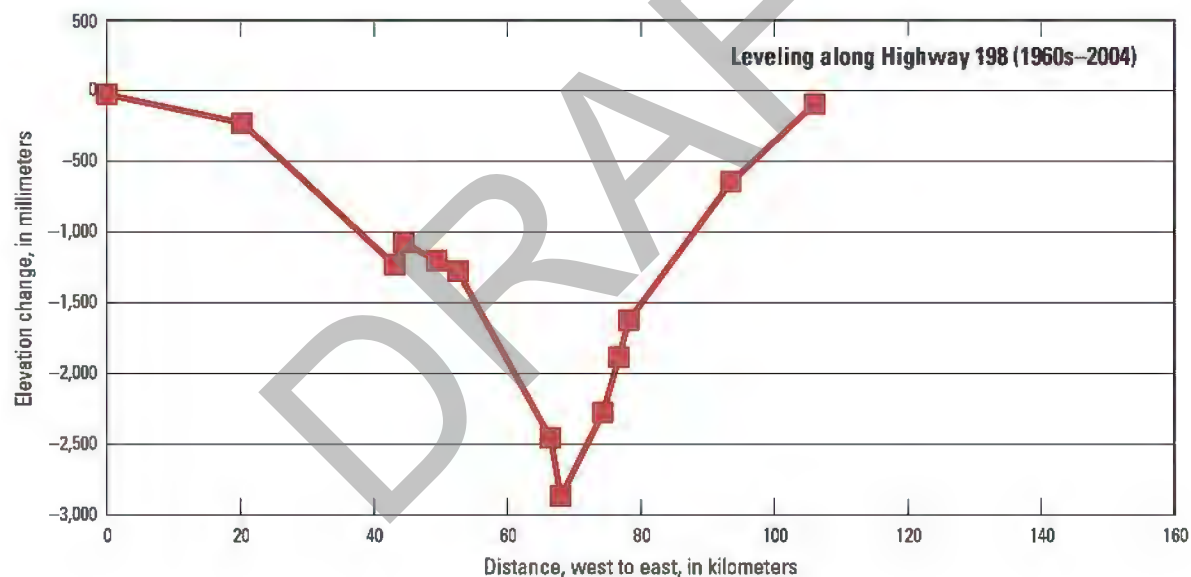


Figure 2-58. Vertical displacement estimated from highway leveling along 198 (1960s-2004) from Sneed and others (2018)

2.2.8.3.2 Extensometers

An extensometer measures the integrated vertical change in thickness (e.g., compaction and expansion) of a specified depth interval. ~~Ten~~In response to subsidence concerns in the west-central portion of the San Joaquin Valley, extensometers were constructed at eleven sites in vicinity of Westside Subbasin in the 1950s, 1960s, and 1970s by the USGS in cooperation with DWR (Ireland ~~and others, 1984~~) in the vicinity of the District. Since this time period, one ~~et al, 1984~~). An additional extensometer ~~has been~~(Fordel) was

constructed (~~Fordel~~); in the late-1990's (**Figure 2-59**). Timeseries of recorded water level, compaction and InSAR (where available) are presented from six key sites (**Figures 2-60 through 2-66**).

Of the twelve historical extensometer sites in the Westside Subbasin vicinity (**Table 2-7**), six sites are currently being measured for water-level changes and compaction (Oro Loma Deep, Panoche, Fordel, Yearout, DWR Yard, and Rasta), two are not operational (14S/12E-12H1 and 15S/16E-31N3), and four cannot be located (15S/13E-11D2, Cantua Creek, 17S/15E-14Q1, and 20S/18E-11Q1) as of 2016 (personal communication, M. Sneed, USGS, October 21, 2016). Four of the currently ~~six~~ monitored extensometers are being monitored in and adjacent to the target portions of the Lower Aquifer with depths that vary from about 1,000 to 2,000 feet (measuring only a percentage of the aquifer-system that is in places over 2,800 feet deep). Four extensometers were refurbished by the USGS in 2011- 2012 (Oro Loma, Panoche, DWR Yard and Rasta). Three extensometers (Oro Loma Shallow, Fordel and Yearout) target the Upper Aquifer with depths of about 450 feet and are outside the District's boundaries (**Figure 2-51**). boundary to the north and west. Properly operated and installed extensometers can achieve high degrees of accuracy down to the part-per million level of change in displacement.

Table 2-7. Extensometer Construction and Operational Status (West-Central San Joaquin Valley)

Well No.	Nickname	Aquifer	Location	Type	Extensometer Depth (feet)	Perforated Interval (feet)	Operational Status	Record Dates
Currently Operational								
12S/12E-16H2	Oro Loma	Lower	North of WWD	cable	1,000		Yes	1958-2000, 2009-current
12S/12E-16H3		Upper		cable	350		No	1958-1982, 1997-2000, 2009-2011
12S/12E-16H5		Lower		well		670-712	Yes	
13S/15E-31J17	Fordel	Upper	East of WWD	pipe	450		Yes	1999-2016
13S/15E-31J3		Upper		well		400-410	Yes	
13/15-35D5	Yearout	Upper	East of WWD	cable	440	373-433	Yes	1965 to 1982, 1999 to present
14S/13E-11D6	Panoche	Lower	Northern WWD	cable	1,358	1,133-1,196	Yes	1961-1998, 2002-current
18S/16E-33A1	DWR Yard	Lower	Central WWD	cable	1,070	858-1,070	Yes	1965-1998, 2011-current
20S/18-6D1	Rasta	Lower	Southern WWD	cable	1,007	760-835, 851-872	Yes	1965-1998, 2002-current
Not Operational or Not Found								
14S/12E-12H1		Lower	Northern WWD	Unknown	936	740-936	No	1964-1998
15S/13E-11D2		Lower	Northern WWD	Unknown	960	900-960	Not Found	1964-1988
15S/16E-31N3		Upper	Central WWD	Unknown	595		No	1967-1983
16S/15E-34N1	Cantua Creek	Lower	Central WWD	Unknown	2,007		Not Found	1958-1998
16S/15E-34N2		Lower		Unknown	703			
16S/15E-34N3		Upper		Unknown	503			
16S/15E-34N4		Lower		well		1,052-1,112		
16S/15E-34N5		Upper		well		240-300		
17S/15E-14Q1		Lower	Central WWD	Unknown	2,315	1,064-1,094	Not Found	1969-1998
20S/18E-11Q1			Southern WWD	Unknown	710	650-710	Not Found	
20S/18E-11Q2				Unknown	845		Not Found	
20S/18E-11Q3		Lower		Unknown	1,930	1,885-1,925	Not Found	

Source: Ireland et al., 1984 and USGS website (http://ca.water.usgs.gov/land_subsidence/california-subsidence-measuring.html)

2.2.8.3.3 California Aqueduct Spirit Leveling and GPS

Measurements of vertical displacement from approximately 500 locations along the California Aqueduct (San Luis Canal) were provided to the District by DWR (Figure 2-59). Early measurements of vertical displacement were obtained through leveling (1967, 1993, 2000, 2006, 2009 and 2013). Spirit leveling is the oldest method of measuring subsidence and is a precise way to obtain local vertical displacement data relative to a stable survey location. Subsequent measurements (2015, 2016, 2017, 2018 and 2019) were obtained from static GPS measurements. Estimates of cumulative subsidence are presented from 2000 through 2015 (Figure 2-67) and from 2016 through 2019 (Figure 2-68). The accuracy of Spirit leveling can be first or second order (given as $[4V(\text{Survey Distance})]/1000$, and $[10V(\text{Survey Distance})]/1000$, respectively) depending on the devices used and length of survey intervals. GPS vertical displacement accuracy is dependent on the kinematic differences of the reference points used in the survey network.

2.2.8.3.4 UNAVCO GPS

Continuous Global positioning systems (GPS) (PBO GPS stations) ~~has have~~ been installed throughout the western United States in recent years since the early-2000's by the Plate Boundary Observatory (PBO), which is a division of UNAVCO. The PBO's primary focus of a PBO is to monitor monitoring plate tectonics; from a network of mountain-based stations, but data from the high-definition-precision GPS recorders, ~~however,~~ are also useful for monitoring subsidence from stations located within alluvial sedimentary valleys like the Central Valley. The GPS stations monitor the total vertical displacement of the ground surface, which shows how much cumulative total compaction is occurring in from all depth zones and aquifers, including the Corcoran Clay and underlying clays in the Subbasin's Lower Aquifer. Three stations are located in or adjacent to the Subbasin (Figure 2-51). Two stations are in or adjacent to the Westside Subbasin in areas overlying compactable deposits. Of these, only P304 is located in an area experiencing significant rates of subsidence (Figure 2-59). Results from P304 are paired with water level and compaction data collected at the Fordel site (Figure 2-60). The other (P302), located near I-5 on Panoche Creek, has experienced less than 0.1 feet of subsidence since installation in December 2004. GPS accuracy of PBO sites is dependent on site installation.

2.2.8.3.5 Reclamation USBR (SJRRP) GPS Geodetic Control Network

The USBR established the San Joaquin River Restoration Program (SJRRP) Geodetic Control Network in 2011 to monitor subsidence within the SJRRP Restoration Area because subsidence affects infrastructure performance. The District's boundaries fall within USBR surveys over 70 control points in the San Joaquin Valley and the District overlaps the southern portion of this area. Between 2011 and 2016, Reclamation conducted bi-annual surveys (in July and December) using (Figure 2-59). The USBR relies on static GPS methods to investigate subsidence within the SJRRP study area. Six Reclamation SJRRP GPS benchmarks are located in and collects and around the northern portion releases data biannually in July and December. Results from the four sites of the SJRRP Geodetic Network located within the Subbasin (Figure 2-51) are presented in Figure 2-69. Reported vertical error from the survey in 2011 was estimated as 6.4 centimeters (0.21 feet) at static GPS sites within the USBR control points (USBR, 2011).

2.2.8.3.6 Westlands Water District Geodetic Control Network

A GPS Geodetic Control Network of 15 benchmark monuments and 1 checkpoint was established by the District in December of 2020 to enhance subsidence monitoring for GSP implementation. The sites were located in subsidence prone areas identified near SLC Checks 16 and 17 and Check 20 (Figure 2-59). Thirteen of the 15 benchmark monuments were set on the concrete meter base of the District's water delivery turnouts. The remaining benchmark monuments were set in concrete within form tubes to a depth of three feet to avoid shallow thermal effects. GPS measurements are tied to Continuously Operating Reference Stations (CORS) to calculate precise location information. Subsequent GPS surveys were conducted in March and October of 2021 and March of 2022 (Figure 2-70). Estimated vertical accuracy ranges from 0.5 to 2 centimeters (0.02 to 0.07 ft) (Blair, Church & Flynn, 2021). In addition to the fifteen (15) benchmark monuments, the District added ten (10) additional benchmark monuments to the

subsidence monitoring network. The additional monuments were installed in June of 2022 in areas of the Subbasin where data gaps were present.

2.2.8.3.7 Interferometric Synthetic Aperture Radar (InSAR)

InSAR imagery is produced by reflecting radar signals off an area and measuring the travel time of the radar reflection back to the satellite. Two InSAR images of the same area acquired at different times are used to calculate the travel-time difference ~~and~~. The resulting maps are called interferograms, ~~which that~~ show ground-surface displacement between the two time periods. calculated from the differences in reflection travel times. These can be used for broad regions of interest and can be used to position extensometers ~~and/or~~ GPS networks to precisely measure ~~deformation over a limited area~~. ~~InSAR measurements are made at four locations in and adjacent to the Subbasin (Figure 2-51).~~

2.2.8.1.2 Historical and Current Subsidence in Westside Subbasin

~~Subsidence related to groundwater withdrawal began in the mid 1920s and by 1972 had exceeded 28 ft in the District southwest of Mendota (Poland et al., 1975). Figure 2-52 shows contours of equal compaction from 1926 to 1972 based on a bench-mark network started in the San Joaquin Valley in the early 1900s. The National Geodetic Survey periodically resurveyed the Los Banos Kettleman City subsidence area from 1933 to 1978 (Ireland, 1984). In addition, 25 extensometers were constructed in the Valley by the USGS or subsidence in cooperation with DWR in the 1950s and 1960s, nine of which were located within the District's boundaries. The other two were placed just outside the District (i.e., Oro Loma and Yearout) (Figure 2-52). An additional extensometer (Fordel) located in Mendota was constructed by the Mendota Pool Group in 1999.~~

~~Of the twelve historical extensometer sites within the vicinity of the Subbasin (Table 2-6), six sites are currently being measured for water level changes and compaction (Oro Loma, Panoche, Fordel, Yearout, DWR Yard, and Rasta), two are not operational (14S/12E 12H1 and 15S/16E 31N3), and four cannot be located (15S/13E 11D2, Cantua Creek, 17S/15E 14Q1, and 20S/18E 11Q1, personal communication, M. Sneed, USGS, October 21, 2016). Four of the currently monitored extensometers target the Lower Aquifer with depths that vary from about 1000 to 2000 ft (measuring only a percentage of the aquifer system that is in places over 2,800 ft deep). These four extensometers were refurbished by the USGS in 2011-2012 (Oro Loma, Panoche, DWR Yard and Rasta). Three extensometers (Oro Loma, Fordel and Yearout) target the Upper Aquifer with depths of about 450 ft and are located north and east of the District. As indicated by the parallel tracking of water levels and compaction shown on Figure 2-50, water level measurements are also necessary in subsidence monitoring to determine the cause and effect of the subsidence process.~~

~~The District began receiving surface water from the SLC in 1968 and, with this diminished reliance on groundwater, water levels in the Subbasin began to recover and consequently funding for subsidence monitoring declined. The four graphs in Figure 2-52 demonstrate the dramatic rise in groundwater levels and slowing of compaction for the period starting around 1965 through the early 1980s to mid-1990s; unfortunately, these extensometers are no longer monitored. Although increasing water levels slowed the rate of subsidence throughout the Subbasin, land elevations continued to decline into the 1970s due to delayed drainage of water from clayey aquitards (LSCE et al., 2014).~~

During the droughts of 1976-1977, 1987-1992, 2007-2009, and 2012-2015 groundwater pumping increased to replace the reduction in surface water deliveries. This increased groundwater pumping caused the Subbasin's groundwater levels to near historical lows, triggering additional subsidence. **Figure 2-53** includes the three currently monitored extensometers in the District's Lower Aquifer (Panoche 1,358 ft deep, DWR Yard 1,070 ft deep, and Rasta 1,007 ft deep) and a fourth extensometer (Cantua Creek). The Cantua Creek (34N1) extensometer was not found by the USGS in August 2016; however, its 38-year historical record (1958 to 1996) can be compared to adjacent subsidence monitoring stations with current data. These include InSAR time series data (2003 to 2008) calculated at the Cantua Creek extensometer location and a benchmark (BM-63) monitored by Reclamation with measurements from July 2012 to December 2015. The Cantua Creek extensometer measured compaction into the Lower Aquifer (2,007 ft) and InSAR and the benchmarks measures total compaction. Also included, is a graph for the Oro Loma extensometers located north of the District's boundaries. Oro Loma has both Upper and Lower Aquifer extensometers that show the bulk of compaction occurring in the Lower Aquifer. Compaction at the five lower extensometer locations, from 2012 to 2016, ranges from about 0.25 to 0.75 ft.

Another source of subsurface compaction data for the Valley is InSAR, which uses radar signals from satellites to measure changes in land surface altitudes (USGS, 2016). InSAR data is calculated for a specific period and does not currently have a continuous dataset. The advantage of InSAR is that it shows deformation over a broader area of interest than the more precise measurement of an extensometer that covers a more limited area. In addition, using this data, the USGS (2016) calculated compaction for select locations coinciding with extensometers located within the Subbasin for a period that ranges from 2003 to 2010 (**Figure 2-53**, Cantua Creek and DWR Yard) area. Generally speaking, the accuracy of most InSAR interferometric estimates of changes in land surface are on the order of 10mm (0.04 in), however multiple factors can contribute to the accuracy of these differences, especially in agricultural setting where the land surface is displaced owing to cultivation and manual releveling. This analysis relies on InSAR data has been processed by NASA Jet Propulsion Laboratory (JPL) and TRE Altamira produced for DWR. For presentation purposes, InSAR data have been paired with annual groundwater extraction data provided in **Figures 2-71 through 2-80**.

Subsidence has shifted from its historical (1926 to 1972) location in the western Valley to two depressions in the central-eastern Valley near the towns of Corcoran and El Nido. **Figure 2-54** maps total subsidence for the period 2007 to 2011 and **Figure 2-55** quantifies total subsidence in the Valley from May 3, 2014 to January 22, 2015. Corcoran and an area south of El Nido are identified as being impacted by relatively high subsidence during both of these periods. Between 2007 and 2011, Corcoran saw over 3 ft of subsidence. Almost 2 ft of subsidence occurred in the El Nido area during this same period. During the second half of 2014 (and into early 2015), subsidence increased by an additional foot in the Corcoran area and by half a foot in the El Nido area. **Figure 2-55** also shows that subsidence is increasing around the California Aqueduct in the southern portion of the Subbasin.

Total subsidence was measured with UAVSAR along the California Aqueduct/SLC between July 2013 and March 2015 (Farr TG, et. al., 2015). UAVSAR is flown on a Gulfstream III aircraft at 41,000 ft and higher

signal-to-noise ratio than satellite SARs. A lower ratio would suggest there is more noise in the data collected, therefore less accurate. The surface change is measured between two radar image passes. The largest subsidence on the California Aqueduct (**Figure 2-56**) occurred near Check 20 (approximately 12.5 inches) and other areas with significant subsidence are located south of Check 15 to Check 17 (approximately 8 inches), and east of Check 20 (greater than 5 inches). DWR provided spirit leveling data for points along the California Aqueduct/SLC from 1968 to 2015. **Figure 2-56** shows compaction at each SLC spirit leveling station from 2013 to 2015 to correspond with the date range of the UAVSAR subsidence. Though the exact month and day of the spirit leveling along the SLC is not known, the amount of compaction (in most cases) is similar to and confirms (ground truths) the UAVSAR data.

Figure 2-57 provides a profile of subsidence along the SLC/California Aqueduct from 1967 to 2015. **Figure 2-58** provides a profile of subsidence along the SLC from 2000 to 2015. From 2000 to 2006 subsidence was less than 0.25 ft, and in some places even rebounded, due to the relatively stable amount of surface water deliveries (over 800,000 AF) and associated low levels of groundwater pumping. From 2006 to 2009, however, subsidence increased to over half a foot (total from 2000 to 2009 average of 0.05 feet per year) around Check 17 due to reduced surface water deliveries and an increase in groundwater pumping in 2008 and 2009 (from about 400,000 to 600,000 AFY). From 2009 to 2015 subsidence at most stations increased to over 1 foot between mile post 143 to 167 and a maximum of nearly 2 ft between mile post 129 to 133 (for the period 2000 to 2015, average of 0.125 feet per year). This recent increase in subsidence levels is also attributable to reductions in imported water in 2014 and 2015 and a resulting increase in groundwater pumping to over 600,000 AFY in the Subbasin.

2.2.8.2 Surface Water

2.2.8.2.1 Natural Surface Water Features and Flow

Surface water resources are limited by the arid climate and consist primarily of intermittent streams originating from the Coast Range. The main streams located in the Subbasin are the Little Panoche and Panoche Creeks, Arroyo Hondo, Cantua, Salt, Martinez, Domingue, and the Arroyo Pasajero (Los Gatos and Zapato Chino Creeks) which all flow eastward from the foothills. **Figure 2-59** shows the stream locations as well as the areas within the Subbasin with higher potential for groundwater recharge (Carollo and LSCE, 2015). Continuous flow measurements are only recorded at Panoche, Cantua, and Los Gatos Creeks. The remainder of creeks are either not gaged or are only measured for peak flows. Records indicate that flows are infrequent and are generally less than 100 cubic feet per second (cfs), with maximum peak flows of about 2,500 cfs (**Figure 2-59**).

To evaluate the potential occurrence of interconnected surface waters (ISW) surface water flows should be compared to shallow groundwater elevations. In the western portion of the Subbasin where streams are present, there are not any wells screened in the upper 100 feet. Where shallow wells are present, historic groundwater elevations in Shallow Zone show no relationship to climatic conditions and seasonal pumping mostly like due to recharge from irrigation (**Figure 2-33B**). The arid climate and intermittent stream flow most likely suggest that this area does not consist of ISW. To confirm the absence of any ISW, shallow piezometers (<40 ft bgs) along each stream should be installed to better characterize the

~~connection of surface water and groundwater. Once a period record is established for shallow groundwater elevations along streams including multiple year types, the GSA can determine whether ISWs are present.~~

~~Data from the NASA JPL were collected by satellite from the Canadian Radarsat-2 mission (May 2014 – January 2015) and the airborne UAVSAR mission launched by NASA (May 2013 – November 2018). UAVSAR is flown on a Gulfstream-III aircraft at 41,000 feet and has a higher ratio than satellite SARs (Farr et al., 2015). The NASA JPL also produced an InSAR imagery from Japanese PALSAR data (2006 – 2010), which were evaluated, but not used due to suspected issues with data accuracy and/or post-processing. Estimated vertical accuracy of the InSAR results were reported to be less than 1-inch (0.08 ft) for both Radarsat-2 and UAVSAR (Farr et al., 2015). Post-processed InSAR data were obtained through a Public Records Request to DWR made in March of 2022.~~

~~Data from TRE Altamira were collected from the Sentinel-1 satellite mission by the European Commission and European Space Agency (TRE Altamira, 2021). Data were post-processed using the proprietary SqueeSAR methodology to develop stable InSAR imagery at a 100-meter resolution and calibrated to Continuous GPS measurements collected UNAVCO and SOPAC with a reported vertical error of 18mm (0.06 ft) (Towhill, 2021). These data are publicly available and were downloaded through DWR (DWR, 2022).~~

2.2.8.4 Rates and Areas of Subsidence

2.2.8.4.1 Subsidence (1920's – 1989)

~~Groundwater withdrawal for irrigated agriculture in the Subbasin began in the mid-1920s and exceeded 960 TAF prior to CVP deliveries which began in 1968. By 1972, groundwater extraction led to large amounts of subsidence throughout the central portion of the Subbasin and led to the formation of three major subsidence bowls located southwest of Mendota (where subsidence exceeded 28 ft), in the Cantua Creek area and in the Huron area (**Figure 2-56**). Areas outside the Subbasin with high-rates of subsidence were located near Lemoore (up to 8 ft) and Pixley/Delano (up to 12 feet), which were also the subject of extensive study.~~

~~Following the start of CVP deliveries through the San Luis Canal in 1968, water levels began to stabilize and recover within the Subbasin until about 1989. During this period, rates of compaction measured at extensometers slowed considerably and generally ceased in about 1972 at the Rasta and Cantua Creek extensometers, about 1976 at the DWR Yard and Panoche extensometers and about 1980 at the Oro Loma Deep extensometer (**Figures 2-61 through 2-64**). An exception to this trend occurred in 1977 where surface water imports were reduced in response to the 1976-1977 drought resulting in increased rates of compaction recorded from extensometers. Inelastic subsidence of between roughly 0.1 and 1 feet continued to occur at these sites despite recovery in water levels due to delayed drainage of water from clayey aquitards resulting in a delay in equilibration of the pore-water pressure within compacting interbeds relative to pre-development conditions prior to the start of large-scale pumping. The variability~~

in delay is likely a function of local groundwater conditions and the geometry and material properties of the fine-grained interbeds at each site.

2.2.8.4.1 Subsidence (1990-2011)

Beginning in 1990, cycles of drought have led to periodic reductions in CVP deliveries resulting in roughly proportionate increases in groundwater pumping. Droughts occurred from 1990-1994, 2007-2010 and 2012-2016. Since 2016, surface water deliveries have alternated between above average (2017, 2019) and below average (2018; 2020-2021). The statewide climate trend reflected in CVP deliveries can be considered as dry since 2007 with many experts more broadly characterizing recent hydrologic conditions as an extended drought. Unlike the period of groundwater level recovery following the start of surface water imports in 1968 when extensometers show delayed subsidence, more recent inelastic compaction and subsidence has generally only occurred during drought periods.

The extent and amount of subsidence that occurred during the drought between 1990 and 1994 is challenging to accurately characterize as measurements are limited to measured compaction from extensometers. Estimates of District groundwater extraction ranged from 225 to 600 TAF and averaged 410 TAF. Extensometers suggest that the greatest compaction during this period was observed in the central portion of the Subbasin at DWR Yard and 17S/15E-14Q1 extensometers (>1 ft) and Cantua Creek (~0.75 ft). Other extensometers in the northern and southern portions of the Subbasin were generally less than 0.5 feet.

The drought from 2007 through 2010 was less pronounced than the early-1990s drought. Estimated District groundwater pumping ranged from 140 to 480 TAF and averaged 347 TAF. Most extensometers were inactive or discontinued by this period. As a result, subsidence which occurred is estimated from readings at PBO continuous GPS stations and InSAR derived from Environmental Satellite (ENVISAT) and Advanced Land Observing Satellite (ALOS) data summarized in Sneed and others (2018). Most areas of the Subbasin experienced less than 0.3 feet of subsidence during this period. However, locally higher amounts of subsidence were measured near Helm (0.57 ft) and Kettleman City (0.41 feet). Surveys along the California Aqueduct between 2006 and 2009 by DWR also reveal up to about 0.4 feet of subsidence between Check 19 and 20 as well as in the vicinity of Check 17 (**Figure 2-67**).

2.2.8.4.2 Subsidence (2012-2016)

The drought period from 2012 through 2016 provides many insights regarding compaction and land subsidence both because of the extreme hydrologic conditions experienced during this time and the increase in availability of data with respect to rates and distribution of subsidence and groundwater pumping.

Maps of the distribution of groundwater pumping on a quarter-township (3x3 miles) were prepared for the 2013 through 2016 federal water contract year (March-February). Estimated total District groundwater pumping ranged from 321 TAF in 2012 to 671 TAF in 2016 and averaged 543 TAF.

Groundwater extraction maps show relatively consistent high volumes of groundwater pumping over a widespread area surrounding the greater Huron and near and northwest of Cantua Creek.

Groundwater pumping amounts correlate well with areas experiencing high rates of land subsidence shown by the InSAR derived from Radarsat-2 data (Figure 2-71) for 2015, cumulative subsidence from InSAR derived from UAVSAR data from May 2013 through April 2017 (Figure 2-72 through 2-74) and annual subsidence from InSAR derived from Sentinel-1 data from March 2016 through March 2017 (Figure 2-76). Maps of subsidence from InSAR derived from UAVSAR InSAR are limited to an approximately 13.5-mile wide area surrounding the California Aqueduct. These maps illustrate two primary subsidence bowls used in 2020 by the District to identify subsidence prone areas. Subsidence in the northern bowl, in the vicinity of Check 16 and 17, totals up to 1.5 feet over the drought period as measured at USBR HPGN 06 07 near Cantua Creek (Figure 2-69). Subsidence in the southern bowl, located near Check 20, total up to approximately 3 feet. The greatest subsidence in the southern bowl correlates well with one township-quadrant where pumping regularly exceeded 2.5 acre-feet per acre. Subsidence captured by InSAR tends to correlate well with compaction measured at extensometers and with the DWR aqueduct surveys, although dates are not provided in the latter making it more challenging to differentiate inelastic and elastic subsidence.

As the area of interest focused on the SLC, InSAR derived from UAVSAR do not fully capture other notable areas which experienced large amounts of subsidence during the 2012-2016 drought. Subsidence in these areas is better illustrated through InSAR derived from Radarsat-2 and Sentinel-1 data and land surface measurements made by the USBR through the SJRRP static GPS benchmarks. These include a widespread area located on the Subbasin boundary west of Lemoore and Stratford. Up to 1.5 feet of subsidence also occurred in two localized areas in the vicinity of Helm and Tranquility as measured by the Burnside and Murrieta USBR static GPS benchmarks, respectively (Figure 2-69). Particularly near the Subbasin boundary, subsidence in these areas do not correspond as well with pumping within the District suggesting pumping and groundwater level declines within adjacent Subbasins may contribute to subsidence in these areas.

2.2.8.4.3 Recent Subsidence (2017-2021)

Climate patterns were mixed between 2017 and 2021 and include three dry years with much lower than average surface-water deliveries (2018, 2020, 2021) and average to higher than average deliveries in 2017 and 2019. Total estimated groundwater extraction was 87 and 93 TAF during wet water contract years in 2017 and 2019, respectively. Total estimated groundwater pumping during dry years was 330 TAF in 2018, 485 TAF in 2020 and 631 TAF in 2021.

Wet years in 2017 and 2019 are notable in that reduced groundwater pumping resulted in the reversal of a portion of the subsidence experienced during the previous drought due to elastic expansion of clay interbeds and (to a lesser extent) coarse grained materials in the Subbasin as water levels increased. However, water levels measured at active extensometer sites indicate that groundwater conditions did not return fully to pre-drought conditions (i.e., conditions prior to 2012) (Figures 2-61 through 2-64).

Notably, some areas outside the Subbasin (particularly in the Lemoore/Riverdale and El Nido) continued to experience relatively high rates of subsidence despite wetter than average statewide conditions (**Figures 2-76 and 2-78**). InSAR collected from Sentinel-1 suggests that the greatest increase in land surface elevation occurred in the middle of the central and southern portions of the Subbasin by as much as 0.3 to 0.5 feet from March 2017 to March 2018 roughly correlating with some areas which experienced the highest amounts of subsidence during the 2012-2016 drought (**Figure 2-76**). Elastic recovery of subsidence at the USBR HPGN 06 07 totaled about 0.5 feet where other USBR sites show much smaller recovery (between 0.1 and 0.25 feet). Elastic recovery was less between March 2019 and March 2020 totaling 0.1 to 0.2 feet at most and likely within the range of the vertical accuracy of both InSAR and GPS benchmarks (**Figure 2-78**).

Dry conditions beginning in the 2020 Water Year have led to renewed subsidence within most of the Subbasin. Similar pumping patterns to the 2012-2016 drought have emerged leading to a decline in water levels measured at extensometers which approach lows experienced during the 2012-2016 period. Within numerous portions of the Subbasin, groundwater pumping exceeded 2 acre-feet per acre. InSAR indicates that land subsidence has approached 0.75 feet near the southwestern boundary of the Subbasin and approaches or exceeds 0.5 feet along portions of the San Luis Canal from 2020-2021 (**Figures 2-79 and 2-80**). Subsidence measured at USBR GPS benchmarks between December 2019 and December 2020 totals 0.7 feet at HPGN 06 07, 0.5 feet at Burnside and 0.4 feet at Murietta (**Figure 2-69**). Rates of subsidence measured at WWD benchmarks between March of 2021 and March of 2021 located near Check 20 exceeds 0.4 feet at 7 of 8 sites (**Figure 2-70**).

2.2.8.4.4 Vertical Distribution of Compaction and Planning Considerations

As described in Faunt and others (2009), the greatest amount of subsidence in the San Joaquin Basin is thought to occur within aquitards (or interbeds) below the Corcoran clay. This is due to several factors including the level of confinement, amounts of groundwater extraction and relatively greater total thickness of fine-grained interbeds in the Lower Aquifer. Ireland and others (1984) compared compaction measured at numerous extensometers to surveyed subsidence, to develop a relationship between depth and proportion of total subsidence (**Figure 2-81**). Results indicated that perhaps 80 percent of total subsidence occurs due to compaction at depths below 500 feet. This relationship can also be observed in **Figure 2-60** comparing measured compaction at the Fordel extensometer (depth: 450 ft bgs) and subsidence at the nearby UNAVCO P304 site near Mendota and at the Oro Loma Shallow (375 ft bgs) and Deep (1,000 ft bgs) extensometers shown in **Figure 2-61**, which show relatively small amounts of compaction in the Upper Aquifer.

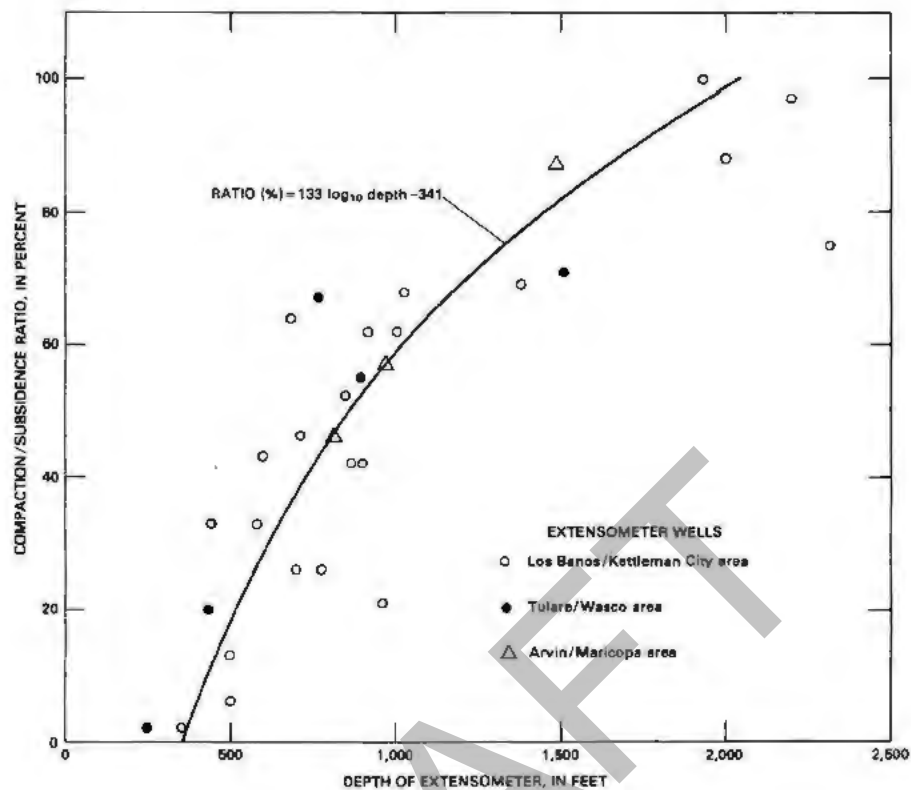


Figure 2-81. Relation of compaction/subsidence ratios to depth at extensometer wells in the San Joaquin Valley (from Ireland et al., 1984)

However, some portions of the Upper Aquifer may be susceptible to more significant amounts of compaction. Findings in Lees and others (2021) from modeling conducted near Hanford, CA suggest that that given "...significant head decline, it is possible for substantial subsidence to originate within the unconfined-to-semi-confined upper aquifer" (Lees et al., 2021). Areas of the Upper Aquifer may be locally prone to greater compaction where:

- The Upper Aquifer is appreciably thick (likely greater than 500 feet);
- The Upper Aquifer is composed of a significant fraction of fine-grained (compressible) interbeds that produce confined or semi-confined conditions;
- Groundwater withdrawal from the Upper Aquifer wells is great enough to reduce aquitard pore-pressure below the preconsolidation head. This can occur through long-term groundwater level declines (overdraft) or high rates of shorter-term (seasonal) pumping.

There is the potential that this risk may be mitigated through proper planning combined with measures to monitor compaction or subsidence where these conditions occur. The extent of subsidence as well as the potential efficacy of mitigation measures will be dependent upon both regional and site-specific information. Consequently, data pertinent to subsidence in the Upper Aquifer will continue to be collected and analyzed.

consolidation water levels higher than vertically adjacent developed portions of the aquifer system rendering them more susceptible to compaction due to groundwater extraction. Similar planning combined with adequate monitoring should be paired to mitigate subsidence concerns in these cases.

2.2.9 Water Supply

2.2.8.2.2.2.9.1.1 Imported Surface Water

Conjunctive use of surface and groundwater improves overall water supply reliability making more efficient use of water that is available. In wet periods, use of surface water is encouraged by WWD to preserve groundwater supplies (WWD, 2012). Imported surface water use within the Subbasin is derived largely from CVP water deliveries from the SLC and from other sources such as water transfers and exchanges. The District has an annual contract entitlement from Reclamation for 1,150,000 AF of water from the CVP; however, CVP allocations are often much lower (WWD, 2012). The District's surface water supply totals 1,197,000 AF which includes approximately 47,000 AF from CVP reassignment contracts.

2.2.8.2.32.2.9.1.2 Historical Surface Water Supplies

Surface water deliveries from the CVP began in 1968 with the goal to reduce groundwater pumping (WWD, 2016). Since 1990, however, CVP water supplies have been reduced annually due to drought and regulatory actions resulting from the Central Valley Project Improvement Act (CVPIA), the Endangered Species Act (ESA), Bay/Delta water quality requirements, and Court orders. The use of low salinity surface water for irrigation within the Subbasin has resulted in an increase in groundwater levels and decreasing trends in soil and shallow groundwater salinity in agricultural areas during the irrigation season (Carollo and LSCE, 2015). CVP water and other surface water supplies are carefully allocated, and all deliveries are metered. The annual imported water totals shown in **Figure 2-60** are 82 is the sum of water delivered within the District's boundaries (shown on **Figure 2-61**), including both CVP and other surface water supplies acquired by both landowners and the District (e.g., surplus water, supplemental supplies, and other adjustments). **Figure 2-60** shows the reduction of total surface water supplies in drought years (1991 to 1992, 2008 to 2009, and 2013 to 2015). Surface water deliveries have experienced a long-term declining trend since the mid-1980s to 1990s, from a high of almost 1.4 MAF in 1984 to a low of about 200,000 AF in 2014 and 2015.

2.2.8.32.2.9.2 Conveyance System and Distribution

The District is in the San Luis Unit of the CVP and includes the SLC and the 12-mile concrete-lined Coalinga Canal facilities. The District has a permanent distribution system that consists of a closed, 1,034-mile buried pipeline network that conveys irrigation water from the SLC, Coalinga Canal, and a 7.4-mile unlined canal from the Mendota Pool to agricultural land. The distribution system was built between 1965 and 1979 (WWD, 2012) and serves about 88 percent of the irrigable land within the District's boundaries. The distribution system includes metered deliveries that allows optimum water management with virtually no losses to seepage, evaporation, and spills. Most of the irrigated land is east of the SLC and slopes from an elevation of about 320 ft to about 180 ft at the eastern edge and are fed by gravity laterals. Lands west of the SLC sit at a higher elevation and are served by pumping from both the SLC and by gravity from the

Coalinga Canal. Lands not served by the distribution system use farmer-constructed temporary diversions. **Figure 2-6183** identifies the District's water conveyance system locations, the distribution system pipelines, and the delivery points.

2.2.10 Surface Water Bodies

Natural surface water bodies are limited by the arid climate and consist primarily of intermittent streams originating from the Coast Range. The main streams located in the Subbasin are the Little Panoche and Panoche Creeks, Arroyo Hondo, Cantua, Salt, Martinez, Domengine, and the Arroyo Pasajero (Los Gatos and Zapato Chino Creeks) which all flow eastward from the foothills. **Figure 2-84** shows the stream locations as well as the areas within the Subbasin with higher potential for groundwater recharge (Carollo and LSCE, 2015). Continuous flow measurements are only recorded at Panoche, Cantua, and Los Gatos Creeks. The remainder of creeks are either not gaged or are only measured for peak flows. Records indicate that flows are infrequent and are generally less than 100 cubic feet per second (cfs), with maximum peak flows of about 2,500 cfs (**Figure 2-84**).

2.2.8.42.2.10.1 Groundwater Dependent Ecosystems

Groundwater dependent ecosystems (GDEs), as defined under SGMA, are ecological communities of species that depend on groundwater emerging from aquifers or on groundwater occurring near the surface. (GSP Regulation, § 351(m).) GDEs are considered a beneficial user of groundwater and must be identified and considered in a Subbasin's GSP. In the Subbasin, which is predominantly agricultural land use with an arid climate, GDEs are sparse and cover small areas, primarily occurring along ephemeral streams in the western portion of the Subbasin. The potential occurrence of GDEs were initially identified from datasets produced by TNC which contained mapped vegetation and wetlands representing groundwater dependent ecosystem indicators (GDEi) (**Figure 2-14**) (Rohde and other, 2018). The methodology used to identify GDEs was adapted from Rohde and others, 2018. The first recommended step to determine whether the TNC "potential" GDEs exist was to evaluate depth to water in the Upper AquiferShallow Zone using 30 ft bgs as a threshold. Using depth to water measurements in winter of 2014/2015, groundwater depths were generally less than 30 ft bgs (**Figure 2-6285**).

As discussed in section 2.2.2.1.1 and displayed in **Figure 2-33B**, shallow zone groundwater elevations, in a few locations, are generally within 30 feet bgs. Unlike the rest of the Upper Aquifer, these groundwater elevations show very little variation over time in relation to seasonal pumping or climatic conditions. The most likely explanation for the consistent groundwater elevations in the shallow zone is the recharge from applied irrigation. For areas in the Subbasin where shallow groundwater wells are present, GDEs likely exist but are supported by irrigation, not naturally occurring groundwater. For this reason, where shallow wells are present, near GDEs, these wells will be incorporated in monitor GDEs as part of the monitoring network. In the event of land fallowing, shallow groundwater elevations could decline. Incorporating these GDEs could potentially complicate the GSP implementation as land fallowing may be necessary to conserve resources and prevent undesirable results in the Upper and Lower Aquifers.

Potential GDEs also are present along the streams in the western side of the Subbasin where shallow wells are not present. These streams have been designated as a data gap for ISWs due to a lack of shallow

groundwater elevation data. Once a period of record is established for shallow groundwater level elevations, the GSA will evaluate whether these potential GDEs rely on naturally occurring groundwater and, as needed, take steps to protect these beneficial uses of groundwater. If it is determined that naturally occurring groundwater supports GDEs along these streams, shallow wells and GDEs will be incorporated into the monitoring network for the existing data gap areas in future GSP updates.

2.2.8.52.2.10.2 Ecological Conditions

Ecological conditions were assessed to determine the conservation value of potential GDEs in the Westside Subbasin. Within the Subbasin, there are no critical habitats containing either threatened species or endangered species. Using publicly available datasets recommended by TNC (Rohde and others, 2018), **Figure 2-6386** shows the mapped critical habitats around the Westside Subbasin obtained from the US Fish and Wildlife Service's (USFWS) Environmental Conservation Online System. As shown in **Figure 2-6386**, there are no critical habitats identified in the Subbasin. While there are no critical habitats in the Subbasin, this does not exclude the possibility that endangered or threatened species may be present in the Subbasin.

2.3 Water Budget § 354.18

The hydrologic budget summarizes the inflows and outflows to and from the Subbasin (GSP Regulation §354.18(b)). For GSP planning purposes, hydrologic budgets have been prepared for a historical water budget period, a current water budget year, and projected water budget period, which includes the 50-year GSP planning and implementation horizon. For the purposes of GSP preparation the Subbasin water budget was derived primarily from output generated by the Westside Groundwater Model (WSGM) developed as part of the GSP preparation and described in **Appendix I**. The WSGM is an integrated hydrologic model where land surface and groundwater processes are calculated simultaneously through a tightly coupled numerical model approach. The Subbasin water budgets and a summary of the GSP water budget periods are described below. The groundwater budget results for the historical, current, and projected periods are summarized below for the entire Subbasin. Aquifer specific groundwater budgets are presented in **Appendix I**.

2.3.1 Hydrologic Budget Terms

Water budgets are similar to a bank account in that there are inflows, outflows, and a change in the bank account balance or storage. Inflows and outflows in the hydrologic system are largely driven by processes occurring on the land surface. Within the Subbasin, these inflows and outflows are dominated by land use, especially irrigated agriculture. The water budgets are segregated into a land surface budget and a groundwater budget as shown on **Figure 2-6487**. The primary inflows to the land surface budget include precipitation, imported surface water for farming operations and irrigation, and applied water for irrigation that is derived from groundwater pumping. Ephemeral streams which flow from the Coast Range in the west are also a part of the land surface system. These streams flow in wet years during the winter and spring and are an inflow to the land surface budget. Under other conditions, groundwater seepage from the streams ~~are~~^{is} an outflow from the land surface into the groundwater budget. These streams terminate within the Subbasin and there is no natural surface water outflow from the Subbasin.

Outflows from the land surface budget include evapotranspiration and percolation of applied water to the groundwater system. Surface water from streams and rivers do not flow out from the Subbasin. Water that flows in the San Luis Canal/California Aqueduct do enter and exit the Subbasin, however, this water is conveyed in a concrete-lined canal and is not separately accounted for in the land surface budget, only the amount from the canal that is conveyed to lands within the Subbasin. Groundwater and surface water imported for irrigation is used to satisfy crop demand and leaves the system due to plant transpiration and evaporation from the ground surface. A portion of the applied water is not used by the crops and instead percolates to the aquifer system as deep percolation. Similarly, precipitation is either consumed as evapotranspiration from crops and native vegetation or evaporates from bare soil. The portion of precipitation not consumed by evapotranspiration or evaporation percolates through the soil and recharges the groundwater system as deep percolation. During the water budget periods, any water that falls as precipitation or applied water that contributes to runoff or is collected by drains prior to recharging the aquifer system does not leave the Subbasin via the land surface. Diversion of agricultural tail water outside the Subbasin has been prohibited since the 1980's. As a result, the District has promoted efficient irrigation practices, reuse of tail water and has retired portions of the Subbasin impacted by historical drainage issues.

Direct uptake of groundwater for evapotranspiration acts as both an inflow and an outflow to the land surface budget. For simplicity, this is not directly reported in the land surface budget and is subtracted from the deep percolation term. As a result, deep percolation is reported as "Net Deep Percolation". Since streams act solely as a source of recharge to the groundwater system and terminate in the Subbasin, inflows and outflows of surface water is not reported in the land surface budget. The water exchanged between streams and the aquifer system is summarized in the "Stream Leakage" term in the groundwater budget.

The land surface system drives the stresses on the groundwater system. Inflows to the groundwater budget include areal recharge to the water table from deep percolation of applied water and precipitation described above, groundwater inflows into the Subbasin, and seepage from streams. The major outflows in the groundwater system are groundwater pumping to meet irrigation demand and lateral flow of groundwater to adjacent Subbasins.

2.3.2 Water Budget Estimation

The time period for calculating the historical water budget was selected to reflect overall average hydrologic conditions based on natural recharge through analysis of the cumulative departure from mean precipitation. The period selected for analysis spans from the 1989 through 2015 water years. In order to evaluate the system response to hydrologic variability, this timeframe contains a series of wet and dry years. The historical water budget period and a listing of the hydrologic year types used to define the historical period is shown in **Table 2-78**. Local hydrologic conditions influencing streamflow, precipitation and reference evapotranspiration are best reflected by the San Joaquin Valley water year type. The availability of surface water imports (which are largely from the Sacramento Valley watershed) affect land

use and consequently Sacramento Valley water year type is more representative of local hydrologic conditions than alternatives.

The 2016 water year was selected as the current water budget year. At the time of WSGM development, 2016 was the most current water budget year with complete data required for analysis. The water budget year was below normal in the Sacramento Valley and dry in the San Joaquin Valley.

The projected water budget period used to for GSP analysis spans a total of 54 water years beginning in 2017 and ending in 2070 (October 2016 – September 2070). Data used to define the hydrology and datasets over this period corresponds to October 1965 through September 2018 (**Table 2-89**). Data from this period contain wet and dry periods and are representative of overall average conditions based on water year type. Precipitation, reference evapotranspiration and streamflow assigned in the WSGM projected water budget period utilized historical data from the 1965 through 2018 period. In those months and/or years where historical data was not available, monthly and/or annual data from the most similar San Joaquin Water year type was used as a surrogate. Surface water data used in the projection were taken from the CalSim II 2030 Central Tendency Projection developed jointly by USBR and DWR for SGMA analysis (USBR, 2015). From the 2003 through 2018 historical period where CalSim data were not available, corresponding data from the nearest Sacramento Valley water year were used as a surrogate. Monthly CalSim II deliveries were aggregated by USBR contract water year and distributed in each month based on crop demand. CalSim II data deliveries were used in place of historical data because CalSim accounts for current factors such as the CVPIA that substantially reduced imports but are not included in the entire historical dataset.

The projected water budget must also consider the impacts of climate change and future projections of land use and population. For the purposes of the projected water budget analysis, climate change was the only factor that was considered to have a significant influence. The other variables, land use and population, are expected to remain relatively static over the projected water budget period.

Climate change influenced surface water deliveries, evapotranspiration, precipitation and natural streamflow. Variability due to climate change was incorporated into the WSGM using climate change factors and methodology outlined in the Climate Change Resource Guide and Guidance for Climate Change Data Use During Sustainability Plan Development prepared by DWR. (DWR, 2018). The 2030 and 2070 central tendency datasets were applied to WSGM data from March 2017 through October 2070. It is anticipated that SGMA and projected imported water supplies will have the largest influence on land use during the GSP 50-year planning and implementation horizon. Sustainable groundwater management will likely affect the amount of irrigated acreage within the Subbasin. For planning purposes, SGMA's impact on land use is evaluated in **Section 4.2**.

2.3.3 Historical Water Budget §354.18(c)(2)

The water budget for the historical water budget period (1989 through 2015) is summarized by water year and presented below. The water budget includes inflows, outflows summarized with respect to the land surface system and groundwater system. This information is calculated from results simulated in WSGM

based on hydrology, water supply and land use information from October 1989 through September 2015. Additional details with respect to modeling assumptions and simulated results are described in detail in **Appendix I**.

2.3.3.1 Land Surface System

Inflows of water into the land surface system budget in the Subbasin include precipitation, imported surface water and groundwater pumping. These are summarized annually in **Table 2-910** and **Figure 2-6588**. Total simulated inflows over the historical period ranges from 982,000 acre-feet per year (AFY) to 1,844,000 AFY and averages 1,502,000 AFY. Simulated precipitation ranges from 160,000 AFY to 847,000 AFY with an average of 389,000 AFY. Imported surface water ranges from 179,000 AFY to 1,373,000 AFY and averages 841,000 AFY. Throughout the historical period, the District maintained a CVP contract of 1,190,000 AF through the USBR. Groundwater pumping applied to the land surface system ranges from 79,000 AFY to 697,000 AFY and averages 325,000 AFY.

Outflows from the land surface system budget in the Subbasin includes evaporation and deep percolation and are summarized annually in **Table 2-910** and **Figure 2-6588**. Net deep percolation is equal to deep percolation to the aquifer system minus the direct groundwater uptake from plants and evaporation. Total simulated outflow ranges between 982,000 and 1,845,000 AFY and averages 1,503,000 AFY between 1989 through 2015. Total evapotranspiration ranges from 920,000 and 1,399,000 AFY and averages 1,185,000 AFY (**Table 2-910**). Net deep percolation ranges from 30,000 to 528,000 AFY and averages 317,000 AFY.

Throughout the historical period, the District maintained a CVP contract of 1,197,000 AF through the USBR. Over the most recent 10 years (2009 through 2018), the District received between 9,000 and 911,000 AFY of the District's total CVP contract. When summarized by USBR allocation water year (March through February) the average CVP delivery was 394,000 AFY (**Table 2-1011**). During this same ten-year period, the District and individual water users have imported between 86,000 and 252,000 AFY of additional water averaging 166,000 AFY. As a result, total imported supplies have ranged from 168,000 to 1,129,000 AFY (**Table 2-1011**). Generally, the reliability of surface water imports is a function of Sierra snowpack, runoff, reservoir levels and environmental constraints.

Table 2-4011. Imported Surface Water to the Westside Subbasin (2009-2018)

Water Year	WY Index ¹	CVP Allocation (%)	Net CVP (AF)	Water User Acquired (AF)	Total Imported Surface Water (AF)
2009	D	10%	203,000	138,000	341,000
2010	BN	45%	590,000	151,000	741,000
2011	W	80%	877,000	252,000	1,129,000
2012	BN	40%	405,000	235,000	640,000
2013	D	20%	188,000	245,000	434,000
2014	C	0%	99,000	86,000	185,000
2015	C	0%	82,000	86,000	168,000
2016	BN	5%	9,000	247,000	256,000
2017	W	100%	911,000	124,000	1,036,000
2018	BN	50%	580,000	98,000	678,000
Average	-	35%	394,000	166,000	560,000

¹ C is Critical, D is Dry, BN is Below Normal, W is Wet

2.3.3.2 Groundwater System

Groundwater inflows include net deep percolation from precipitation and irrigation, seepage from streamflow to the aquifer system from ephemeral streams and lateral subsurface flow and are summarized for the historical water budget in **Table 2-4112** and **Figure 2-6689**. Total simulated inflow to the groundwater system ranges from 159,000 to 747,000 AFY and averages 477,000 AFY. Simulated net deep percolation averages 317,000 AFY and ranges from 28,000 to 530,000 AFY. Simulated seepage from streams ranges from nearly none to 33,000 AFY and averages about 10,000 AFY. Lateral subsurface inflow from adjacent subbasins ranges from 88,000 AFY to 245,000 AFY and averages 151,000 AFY.

Outflows from the groundwater system include groundwater pumping and lateral subsurface outflow to adjacent subbasins and are summarized in **Table 2-4112** and **Figure 2-6689**. Total simulated outflow from the groundwater system ranges from 241,240,000 to 865,000 AFY and averages 493,000 AFY. Groundwater pumping ranges from 91,000 AF in 2005 to nearly 700,000 AF in 1991 and averages 324,000 AFY. Lateral subsurface outflow to adjacent subbasins averages 169,000 AFY with a range from 144,000 to 192,000 AFY. Annual declines in groundwater storage range up to 568,000 AF and with annual increases in storage of up to 427,000 AF and varies depending on hydrologic year type.

2.3.3.3 Estimated Groundwater Overdraft

On the scale of the Subbasin, WSGM simulates a decline in groundwater storage averaging 19,000 AFY. Over the entire historical water budget period the cumulative decline in groundwater storage was nearly 517,000 AF (**Table 2-4112**). While this measure of overdraft suggests the Subbasin was in an overdraft condition, this amount of groundwater storage decline represents less than 4% of total outflow and less

than 6% of total groundwater pumping; suggesting that the Subbasin groundwater budget is relatively balanced over the historical water budget period.

The spatial distribution of the total accumulated change in groundwater storage from WSGM is shown in **Figure 2-6790** to evaluate areas within the Subbasin that have experienced overdraft over the historical period. These results illustrate greater storage declines towards the central and southeastern portion of the Subbasin during the historical period and more stable groundwater levels to the west. This is consistent with the spatial distribution of subsidence, which is the primary indicator of overdraft in the Subbasin.

2.3.3.4 Estimated Sustainable Yield

Section 10721(w) of the California Water Code defines the sustainable yield as:

“the maximum quantity of water, calculated over a base period representative of long-term conditions in the basin and including any temporary surplus, that can be withdrawn annually from a groundwater supply without causing an undesirable result.”

Recognizing uncertainty resulting from data limitations and approach, multiple estimates of sustainable yield are provided. The sustainable yield provided includes previous estimates developed by the District and USBR, and an updated estimate derived from the WSGM.

- Previous estimates of sustainable yield (assuming “safe yield” or “perennial yield” are interchangeable) have varied to some degree. An internal estimate developed for the District’s 1996 Groundwater Management Plan estimated a perennial yield of 200,000 AFY using a “best fit line” approach, however, this estimate was for the Lower Aquifer portion of the Subbasin. An estimate developed for the USBR Special Task Force Report on the San Luis Unit estimated safe yield as high as 312,000 AFY.
- The Subbasin sustainable yield for the historical period can be approximated by the relationship between long-term pumping and groundwater storage change by:

$$\text{Sustainable Yield} = Q_h + \Delta S_h$$

where: Q_h is the average annual gross pumping within the Subbasin simulated in the historical period

ΔS_h is the average annual gross change in groundwater storage in the Subbasin simulated in the historical period

This approach is based on the expectation that a reduction in long-term groundwater pumping will produce a roughly commensurate increase in long-term groundwater storage such that a reduction in pumping will effectively offset a decrease in storage. Given a long-term average pumping of 324,000 AFY and a decline in storage of 19,000 AFY, the approximate sustainable yield for the basin estimated from WSGM is 305,000 AFY.

2.3.4 Current Water Budget Assessment (§354.18(c)(1))

The water budget for the 2016 water year (October 2015 through September 2016) is presented in **Table 2-1213** and **Table 2-1314**. The water budget includes inflows, outflows summarized with respect to the land surface system and groundwater system. Streamflow occurs from relatively small ephemeral streams which enter the Subbasin from the Coast Range in the west. This information is calculated from results simulated in WSGM based on 2016 water year hydrology, water supply and land use. More detailed budget information is provided in **Appendix I**.

2.3.4.1 Land Surface System

Inflows to the land surface system includes precipitation, imported surface water and groundwater pumping and summarized in **Table 2-1213**. Precipitation contributes 467,000 AF to the Subbasin in the current water budget year. Imported surface water totals 255,000 AF. Of this total, WSGM utilizes 252,000 AF during the simulation. Approximately 0.3 percent of the total was not used for evapotranspiration was likely utilized for other farming practices that utilize water but are not well documented such as leaching, frost protection, etc. This small amount does not have a significant influence on model results when compared to the total amount of water utilized. Groundwater pumping contributes a total of 564,000 AF.

Outflows to the land surface system includes evapotranspiration and net deep percolation and are summarized in **Table 2-1213**. WSGM simulates a total outflow of 1,321,000 AF for the land surface system in the 2016 water year. Evapotranspiration totals 1,081,000 AF. Net deep percolation from irrigation and precipitation totals 201,000 AF.

Table 2-4213: Current Year Land Surface Water Budget - Westside Subbasin (2016)

Water Budget Term	Volume (AF)
Precipitation	467,000
Imported Surface Water ¹	255,000
Utilized Surface Water ²	252,000
Groundwater Pumping	564,000
Total Inflow	1,321,000
Evapotranspiration	1,081,000
Net Deep Percolation ³	201,000
Total Outflow	1,321,000

1. Reported surface water imports from District records
2. Simulated surface water imports in WSGM (some water rejected)
3. Difference between deep percolation and direct groundwater uptake

2.3.4.2 Groundwater System

Groundwater inflows include net deep percolation from precipitation and irrigation, stream seepage from ephemeral streams and lateral subsurface flow and are summarized for the current water budget year in **Table 2-1314**. Total inflow for the current water budget year is 404,000 AF. Simulated net deep percolation totals 165,000 AF. Seepage from streams totals less than 1,000 AF. Lateral subsurface inflow from adjacent subbasins is 239,000 AF for the year.

Groundwater outflows include groundwater pumping, stream leakage (stream gain) and lateral subsurface outflow and are summarized in **Table 2-1314**. Total groundwater outflow totals 733,000 AF in the current water budget year. Outflow due to pumping totals 558,000 AF and occurs largely between May through August. Simulated flows from the aquifer to the stream system are negligible. Lateral subsurface outflow is 175,000 AF. The groundwater model simulates a groundwater storage decline of 330,000 AF for the current water budget year.

Table 2-1314: Current Year Groundwater Budget - Westside Subbasin (2016)

Water Budget Term	Volume (AF)
Net Deep Percolation (af)	165,000
Stream Leakage (af)	0
Lateral Subsurface Inflow (af)	239,000
Total Inflow (af)	404,000
Groundwater Pumping (af)	558,000
Lateral Subsurface Outflow (af)	175,000
Total Outflow (af)	733,000
Change in Groundwater Storage (af)	-330,000

2.3.5 Projected Water Budget (§354.18(c)(3))

The water budget for the projected period from 2017 through 2070 are summarized by water year and presented below. Results for the 2017 through 2019 water budget years are included in the results to summarize water budget period between the current and projected periods, but are not used in analysis of sustainability during the projected water budget period, rather the focus is on the 2020 through 2070 projected period. The water budget includes inflows, outflows summarized with respect to the land surface system and groundwater system. This information is calculated from results simulated in WSGM based on hydrology, water supply and land use information from October 2019 through September 2070. A detailed description of model assumptions, input, structure and results are described in detail in **Appendix I**.

2.3.5.1 Land Surface System

Inflows of water into the land surface system budget in the Subbasin include precipitation, imported surface water and groundwater pumping and are summarized annually in **Table 2-1415** and **Figure 2-6891**. Total simulated inflows over the projected water budget period ranges from 1,128,000 AFY to 1,666,000 AFY and averages 1,343,000 AFY.

Outflows from the land surface system budget in the Subbasin includes evaporation and deep percolation and are summarized annually in **Table 2-1415** and **Figure 2-6891**. Total simulated outflow ranges between 1,128,000 AFY to 1,666,000 AFY and averages 1,343,000 AFY.

2.3.5.2 Groundwater System

Groundwater inflows include net deep percolation from precipitation and irrigation, stream loss to the aquifer system from ephemeral streams and lateral subsurface flow and are summarized in **Table 2-1516** and **Figure 2-6992**. Total simulated inflow to the groundwater system ranges from 291,000 to 736,000 AFY and averages 451,000 AFY.

Outflows from the groundwater system include groundwater pumping and lateral subsurface outflow to adjacent subbasins and are summarized in **Table 2-1516** and **Figure 2-6992**. Total simulated outflow from the groundwater system ranges from 278,000 to 937,000 AFY and averages 501,000 AFY.

Projected subsurface inflow and outflow conditions are based on historical groundwater conditions in the adjacent basins. Projected subsurface inflows and outflows may, in the future amendments and interim updates to the GSP, need to be adjusted to account for sustainable management criteria in adjacent basins that permit groundwater conditions to fall below historical levels.

2.3.5.3 Projected Groundwater Overdraft

Given the conditions specified, the WSGM simulation projects a total decline in groundwater storage of 2,709,000 AF over the 50-year GSP planning horizon with an annual water balance deficit of 53,000 AFY **Table 2-1516**. However, it should be recognized that simulated net lateral subsurface outflow from the Subbasin increases annually by an average of 6,000 AFY when compared to the historical period (**Table 2-**

[1412](#) and [Table 2-1516](#)). This suggests that projected groundwater conditions in adjacent subbasins contribute to some extent to overdraft conditions within the Subbasin compared to the historical period.

2.3.5.4 Projected Sustainable Yield

The sustainable yield for the Subbasin under this baseline conditions was estimated using the following equation:

$$\text{Sustainable Yield} = Q_p + \Delta S_p + (L_h - L_p)$$

where: Q_p is the average annual groundwater pumping within the Subbasin simulated in the projected model

ΔS_p is the average annual change in groundwater storage in the Subbasin simulated in the projected model.

L_h is the average annual lateral subsurface inflow into the Subbasin from adjacent subbasins simulated during the historical water budget period.

L_p is the average annual lateral subsurface inflow into the Subbasin from adjacent subbasins simulated during the 2020 through 2070 projected water budget period.

One of the benefits of this methodology is that the resultant sustainable yield estimate accounts for gross differences between historical and projected lateral subsurface flow between the Subbasin and adjacent GSAs as compared to historical methodologies of safe yield that accounts for total amount of subsurface inflows as a component of safe yield.

Based on this methodology, the projected sustainable yield is 269,000 AFY from the equation above. This is based on projected groundwater pumping of 322,000 AFY and decline in projected groundwater storage of 53,000 AFY. Simulated average historical net lateral subsurface flow from 1989 through 2015 is 18,000 AFY out of the Subbasin, while projected net lateral subsurface flow from 2020 through 2070 is 25,000 AFY out of the Subbasin resulting in a net difference of 6,000 AFY.

2.3.6 Projected Water Budget - 2030 Central Tendency Climate Scenario

The water budget for the projected water budget period (2020 through 2070) assuming 2030 climate change factors are summarized by water year and presented below.

2.3.6.1 Land Surface System

Inflows of water into the land surface system budget in the Subbasin include precipitation, imported surface water and groundwater pumping and are summarized annually in [Table 2-1617](#) and [Figure 2-7093](#). Total simulated inflows over the projected water budget period ranges from 1,081,000 to 1,703,000 AFY and averages 1,330,000 AFY.

Outflows from the land surface system budget in the Subbasin includes evaporation and deep percolation and are summarized annually in **Table 2-1617** and **Figure 2-7093**. Total simulated outflow ranges between 1,081,000 to 1,703,000 AFY and averages 1,330,000 AFY.

2.3.6.2 Groundwater System

Groundwater inflows include net deep percolation from precipitation and irrigation, seepage to the aquifer system from ephemeral streams and lateral subsurface flow and are summarized for the current water budget year in **Table 2-1718** and **Figure 2-7194**. Total simulated inflow to the groundwater system ranges from 291,000 to 745,000 AFY and averages 451,000 AFY.

Outflows from the groundwater system include groundwater pumping, and lateral subsurface outflow to adjacent subbasins and are summarized in **Table 2-1718** and **Figure 2-7194**. Total simulated outflow from the groundwater system ranges from ~~281~~269,000 to 943,000 AFY and averages 496,000 AFY.

2.3.6.3 Projected Groundwater Overdraft

Given the conditions specified, the WSGM simulation projects a total decline in groundwater storage of 2,413,000 AF over the 50-year GSP planning horizon with an annual water balance deficit of 47,000 AFY **Table 2-1718**.

2.3.6.4 Projected Sustainable Yield

Based on the methodology presented in **Section 2.3.5.4**, the projected sustainable yield assuming 2030 climate change factors is 271,000 AFY. This assessment is based on projected groundwater pumping of 313,000 acre-feet and decline in projected groundwater storage of 47,000 AFY. Simulated average historical net lateral subsurface flow from 1989-2015 were 18,000 acre-feet out of the Subbasin while projected net lateral subsurface flow from 2020-2070 is 23,000 AFY out of the Subbasin resulting in a net difference of 5,000 acre-feet.

2.3.7 Projected Water Budget - 2070 Central Tendency Climate Scenario

The water budget for the projected water budget period (2020 through 2070) assuming 2070 climate change factors are summarized by water year and presented below.

2.3.7.1 Land Surface System

Inflows of water into the land surface system budget in the Subbasin include precipitation, imported surface water and groundwater pumping and are summarized annually in **Table 2-1819** and **Figure 2-7295**. Total simulated inflows over the projected water budget period ranges from 1,188,000 to 1,801,000 AFY and averages 1,424,000 AFY.

Outflows from the land surface system budget in the Subbasin includes evaporation and deep percolation and are summarized annually in **Table 2-1819** and **Figure 2-7295**. Total simulated outflow ranges between 1,188,000 to 1,801,000 AFY and averages 1,424,000 AFY.

2.3.7.2 [Groundwater System](#)

Groundwater inflows include net deep percolation from precipitation and irrigation, stream loss to the aquifer system from ephemeral streams and lateral subsurface flow and are summarized for the projected water budget in **Table 2-1920** and **Figure 2-7396**. Total simulated inflow to the groundwater system ranges from 361,000 to 840,000 AFY and averages 547,000 AFY.

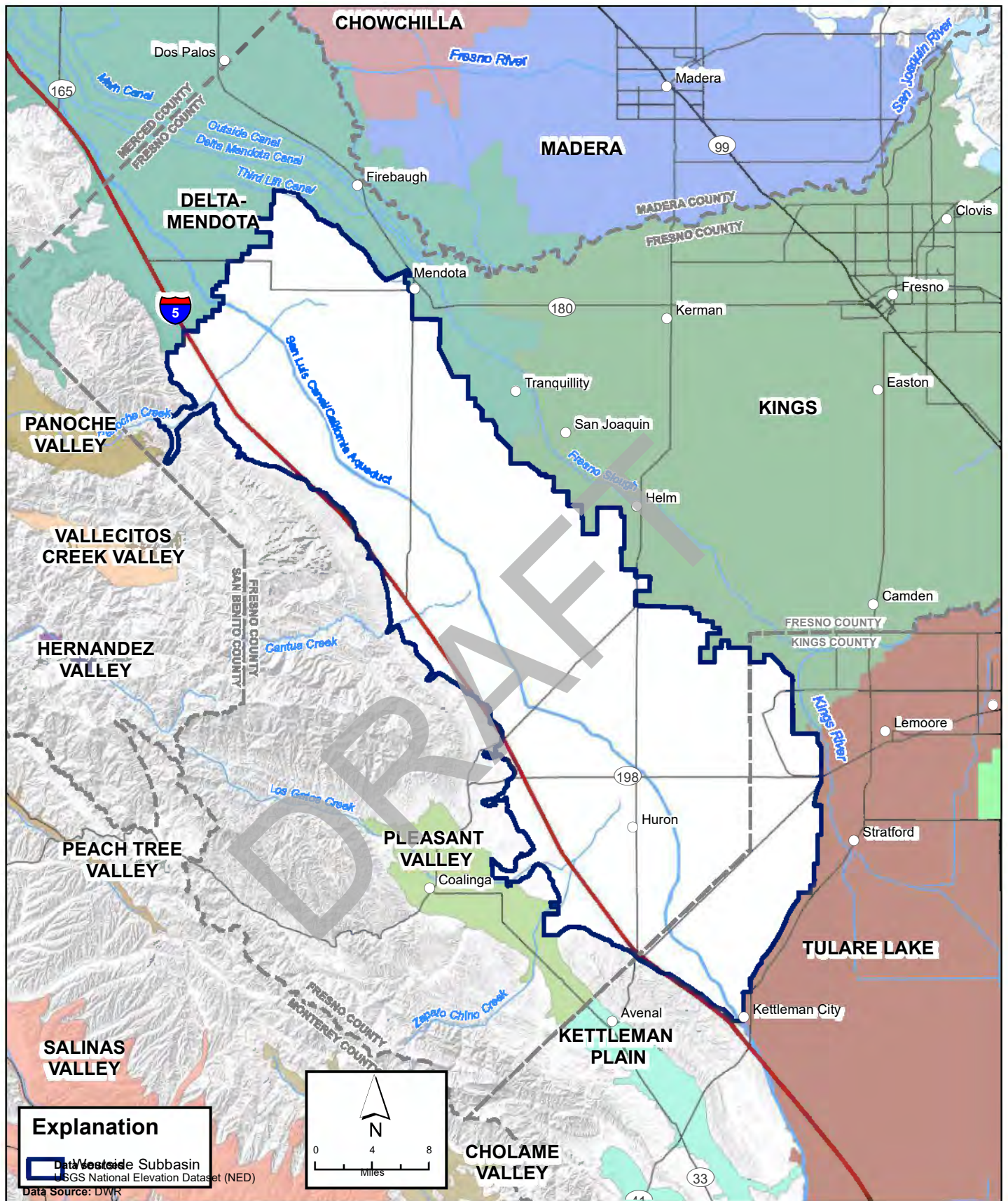
Outflows from the groundwater system include groundwater pumping and lateral subsurface outflow to adjacent subbasins and are summarized in **Table 2-1920** and **Figure 2-7396**. Total simulated outflow from the groundwater system ranges from 289,000 to 1,054,000 AFY and averages 656,000 AFY.

2.3.7.3 [Projected Groundwater Overdraft](#)

Given the conditions specified, the WSGM simulation projects a total decline in groundwater storage of 5,736,000 AF over the 50-year GSP planning horizon with an annual water balance deficit of 112,000 AFY **Table 2-1920**.

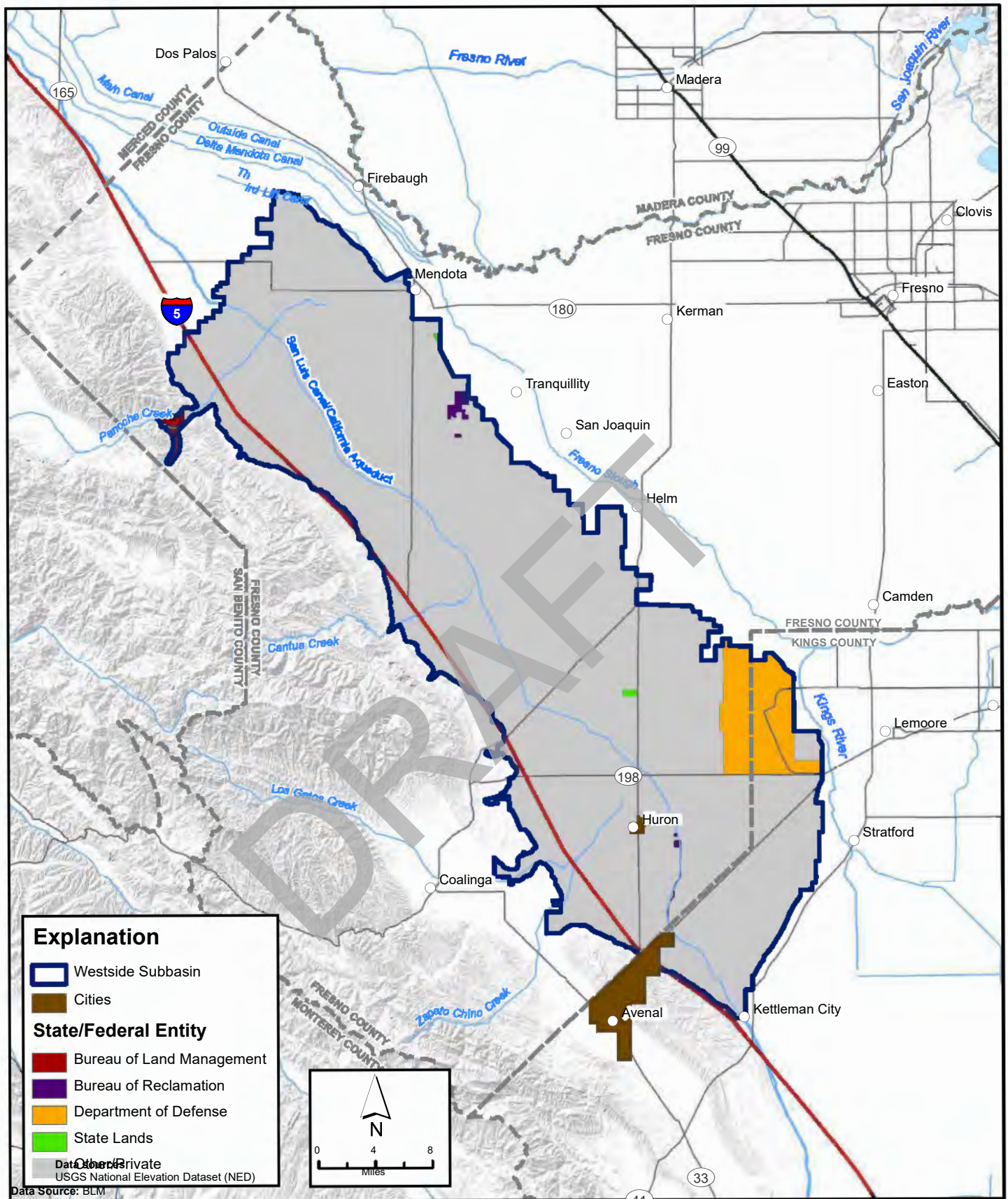
2.3.7.4 [Projected Sustainable Yield](#)

Based on the methodology presented in **Section 2.3.5.4**, the projected sustainable yield assuming 2070 climate change factors is 294,000 AFY. This assessment is based on projected groundwater pumping of 467,000 AFY and decline in projected groundwater storage of 112,000 AFY. Simulated average historical net lateral subsurface flow from 1989-2015 were 18,000 AFY out of the Subbasin while projected net lateral subsurface flow from 2020-2070 is 42,000 AFY into the Subbasin resulting in a net difference of - 61,000 AFY. However, it should be noted that this projection does not consider the implementation of project and management actions and was modeled consistent with §354.18(c)(3).



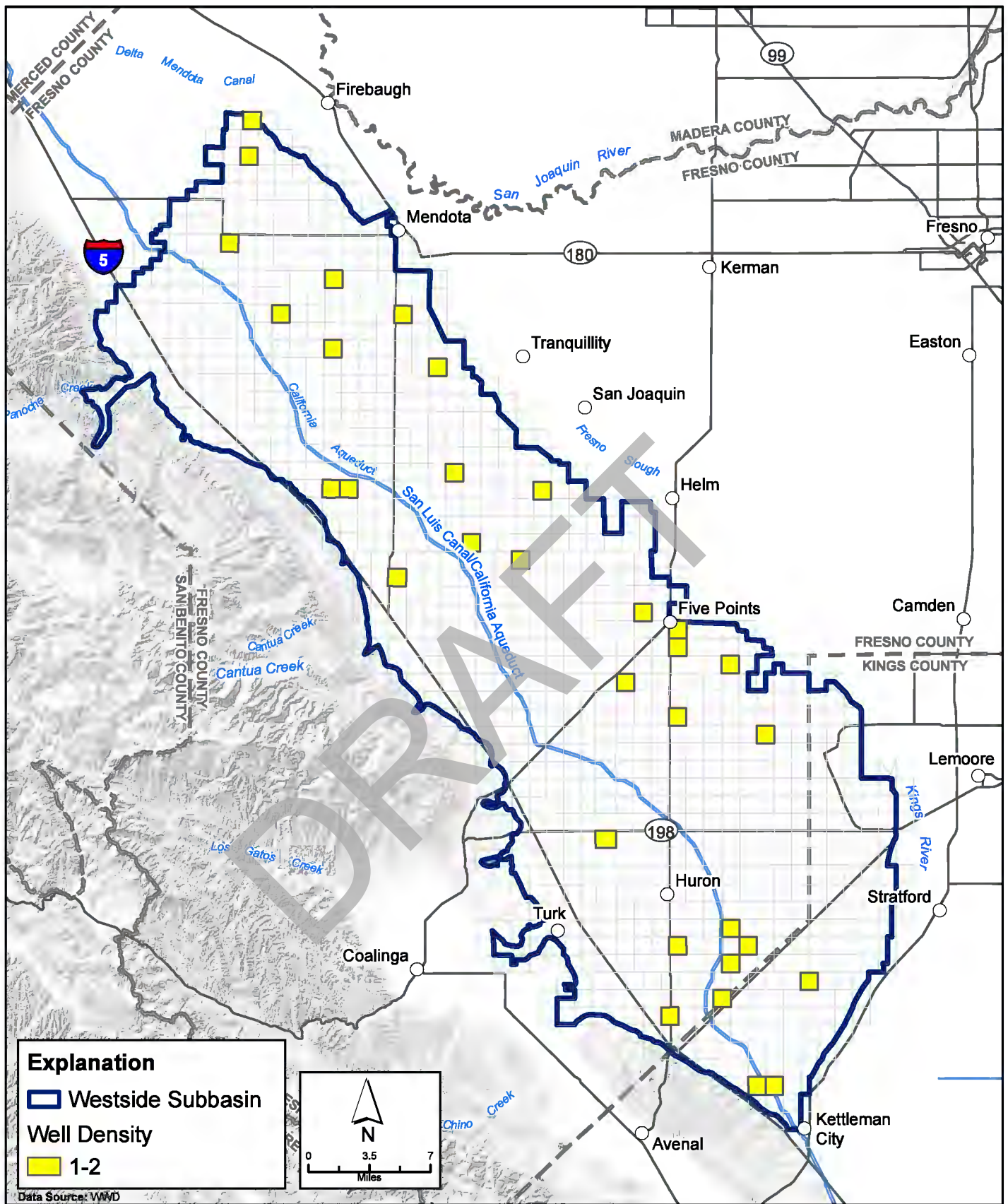
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FIGURE 2-1



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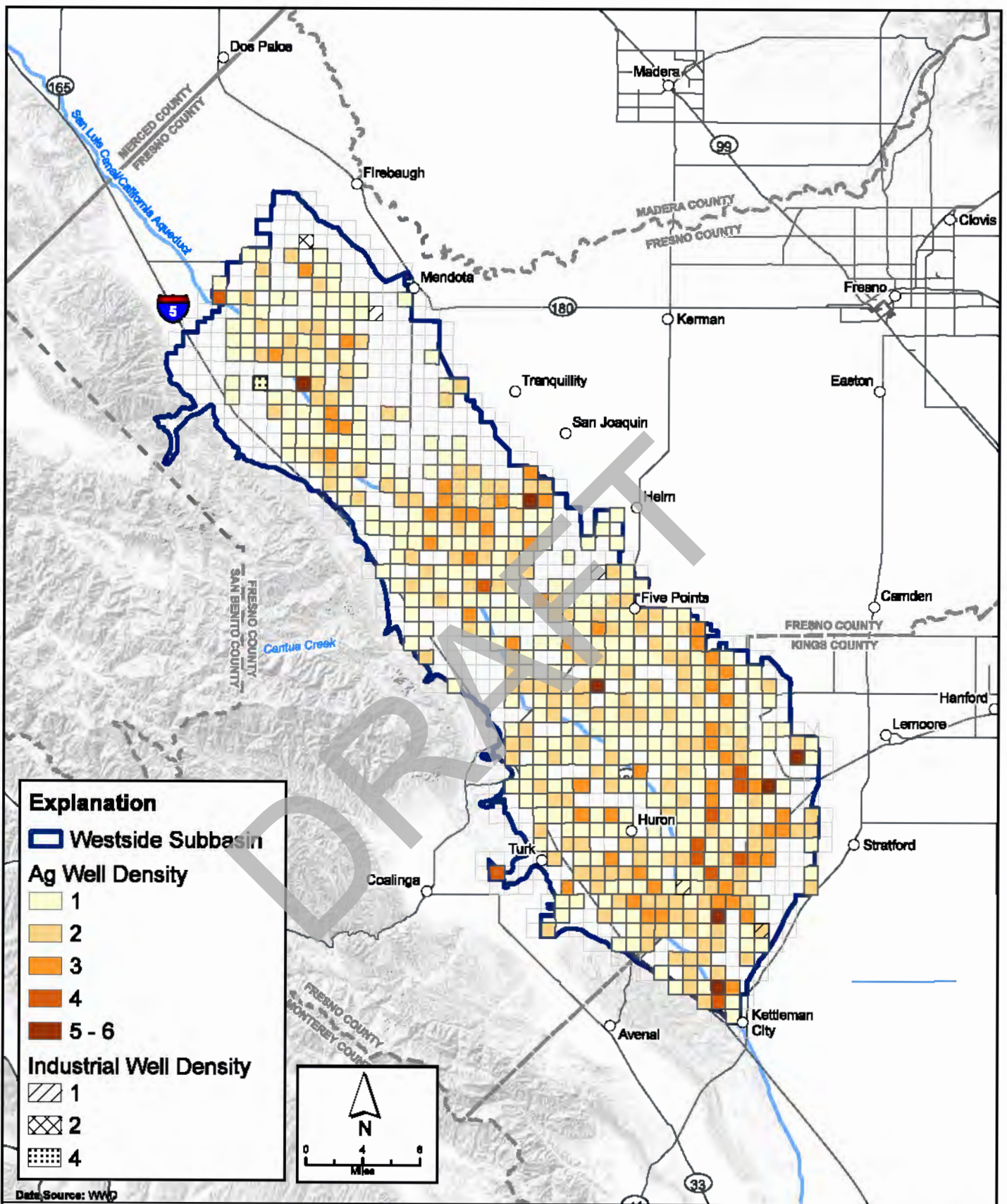
FIGURE 2-2
Agencies in the GSP Area



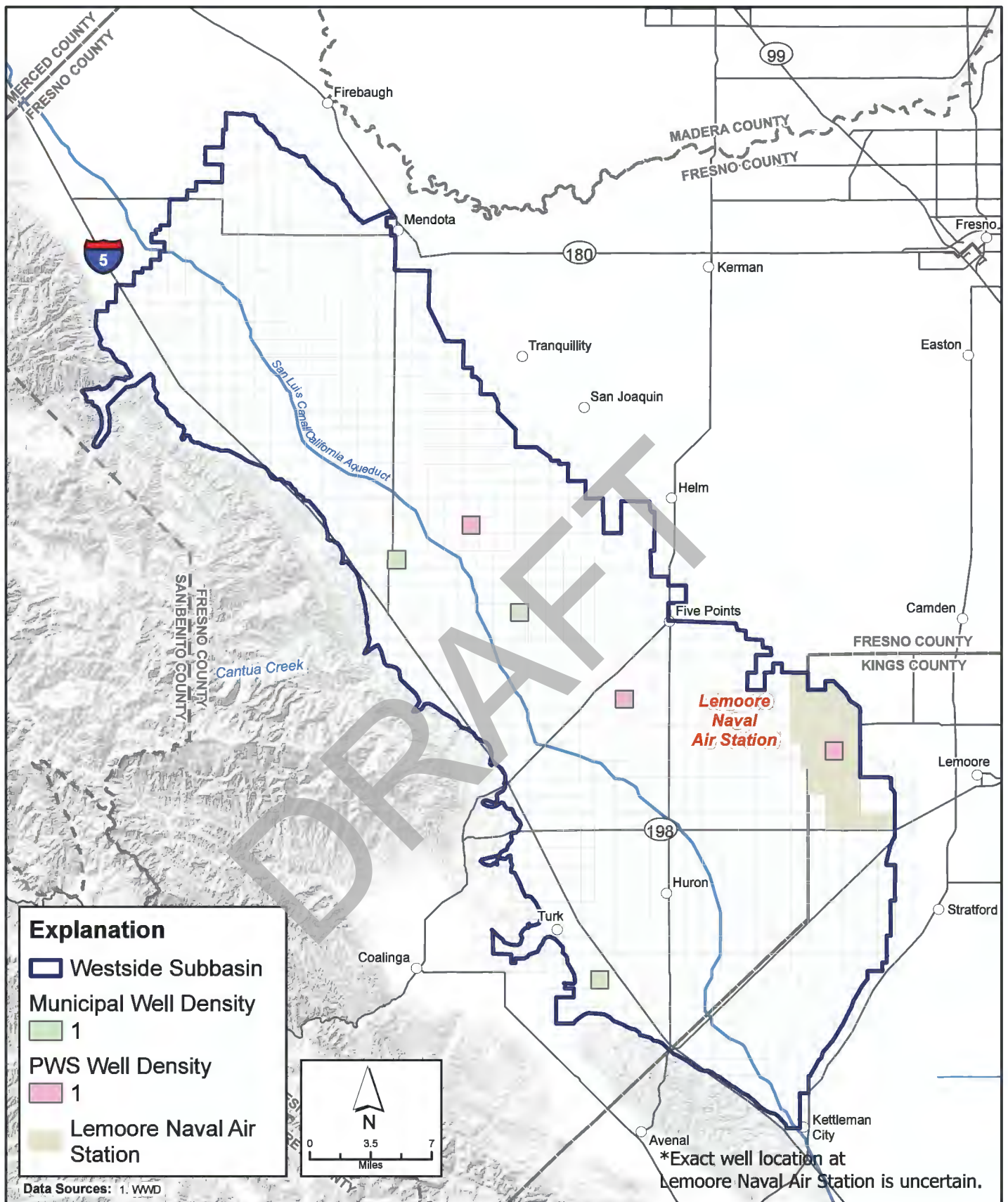
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FIGURE 2-3

Domestic Well Information from Westlands WD Field Survey

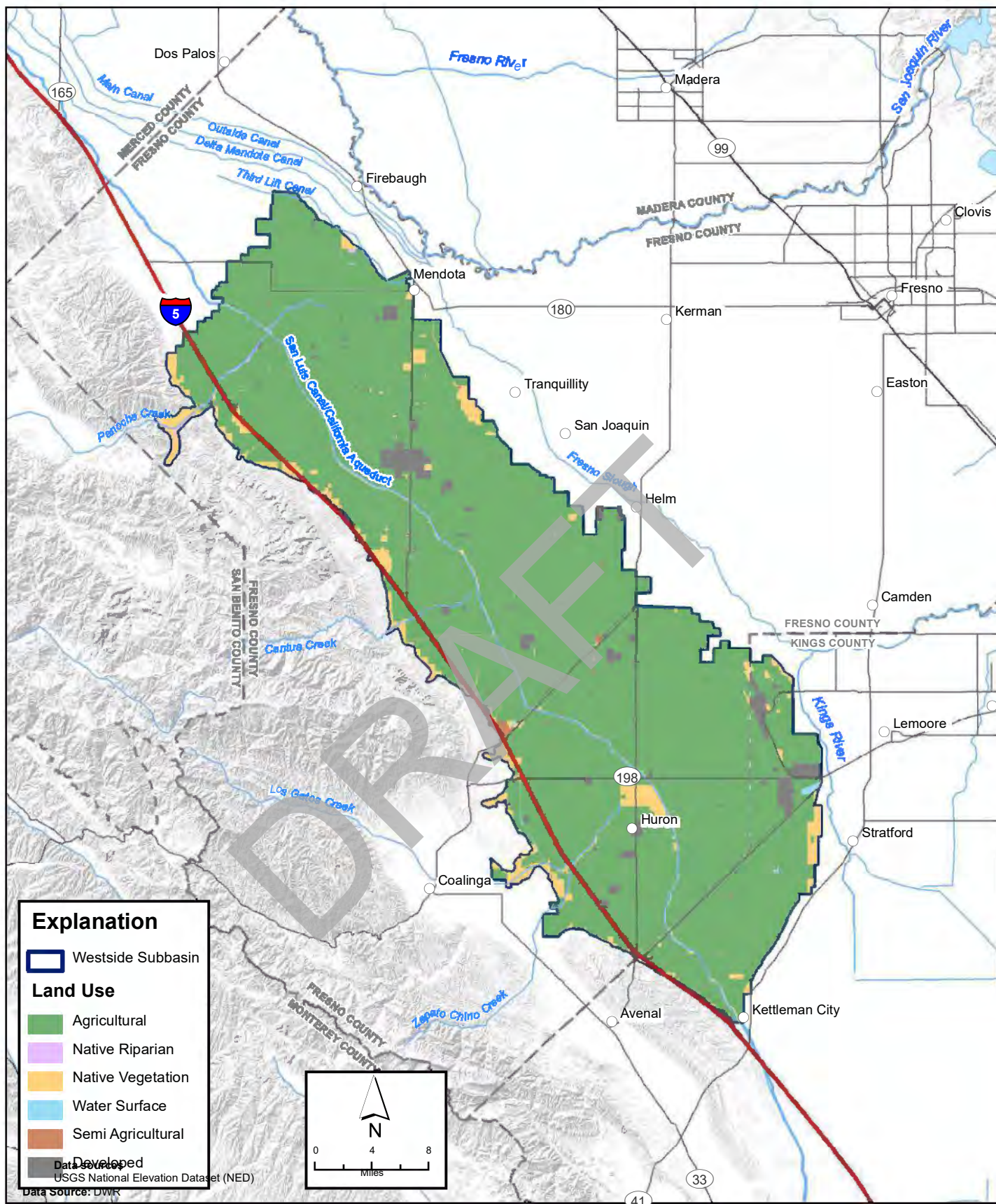


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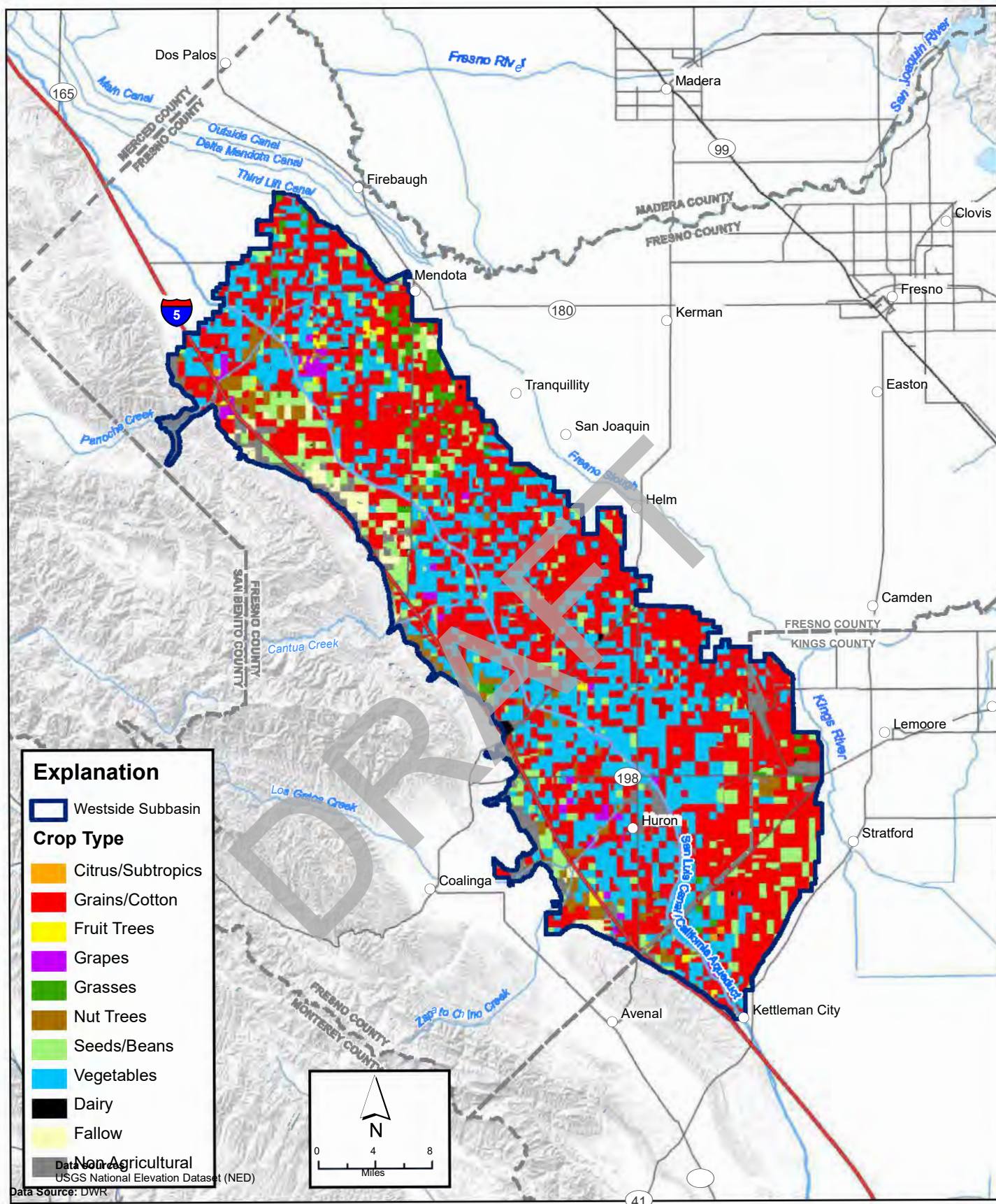
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FIGURE 2-5



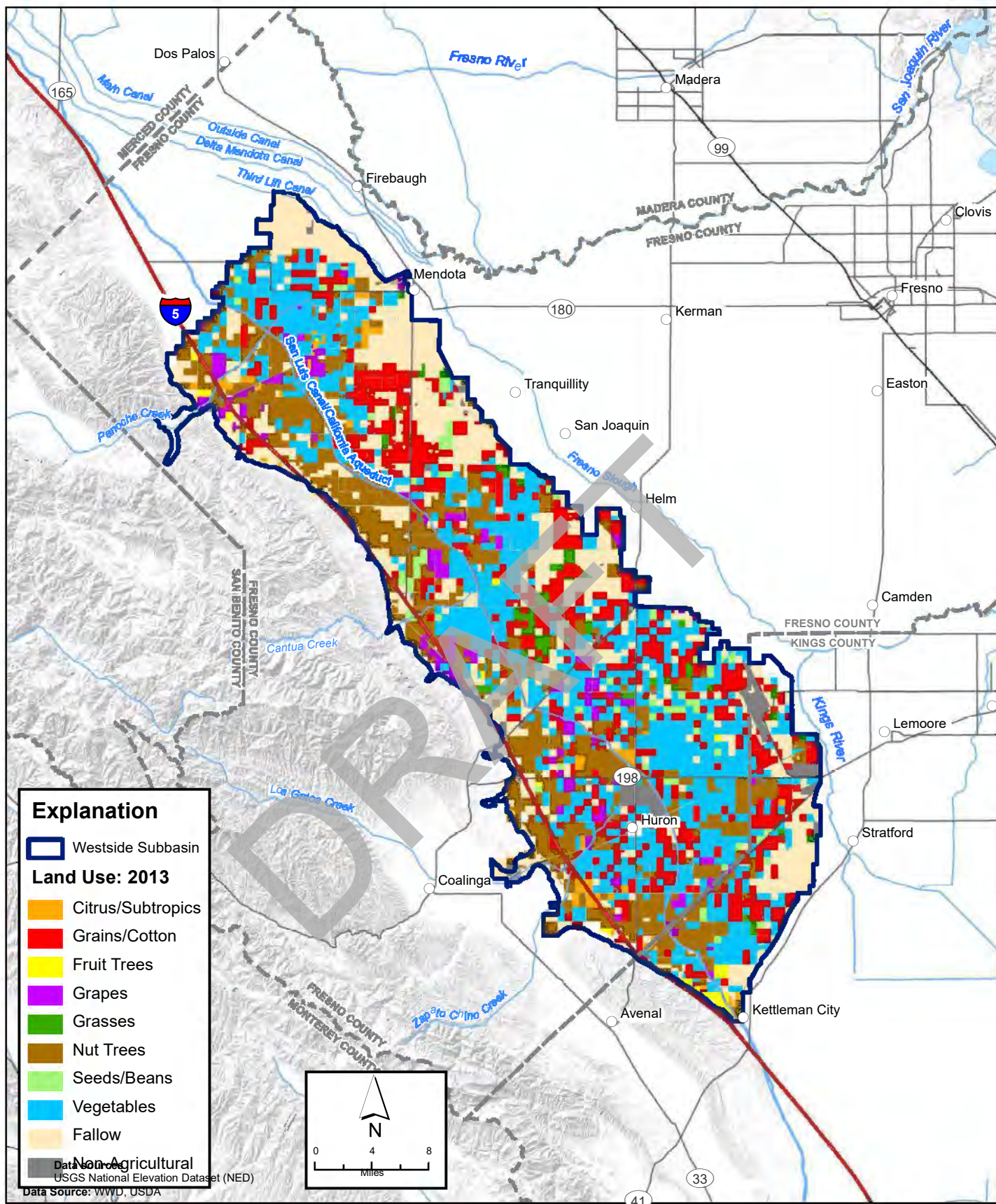
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FIGURE 2-6
General Land Use Designations



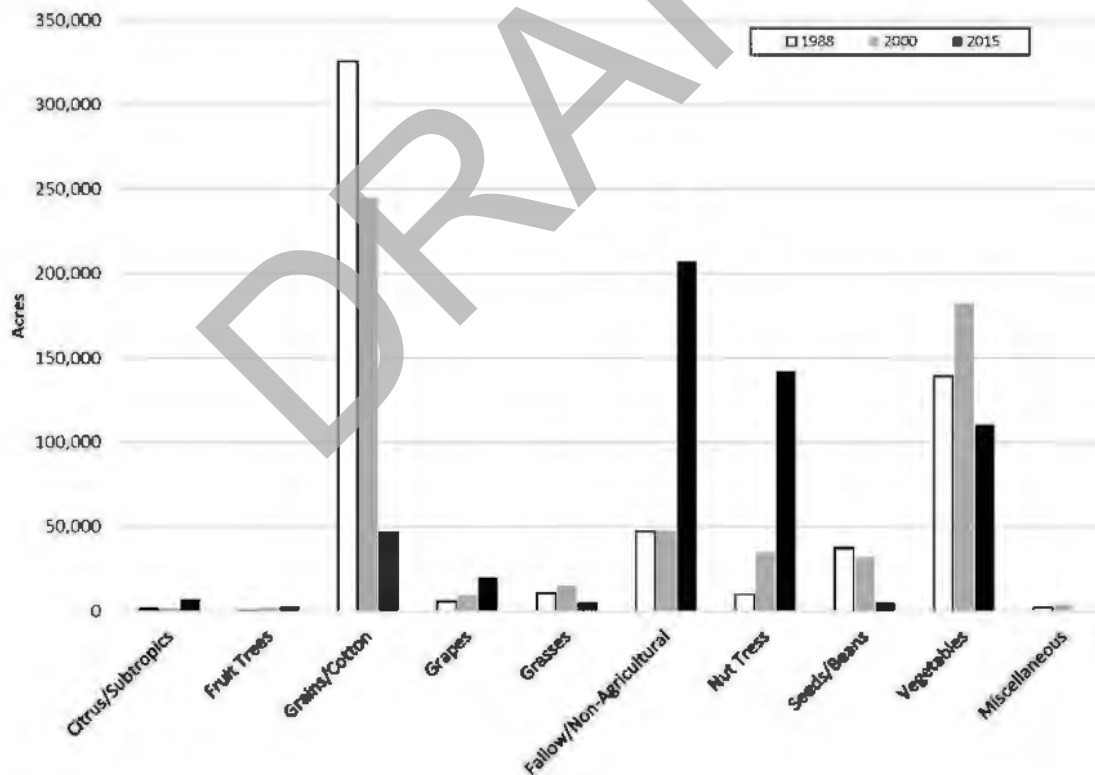
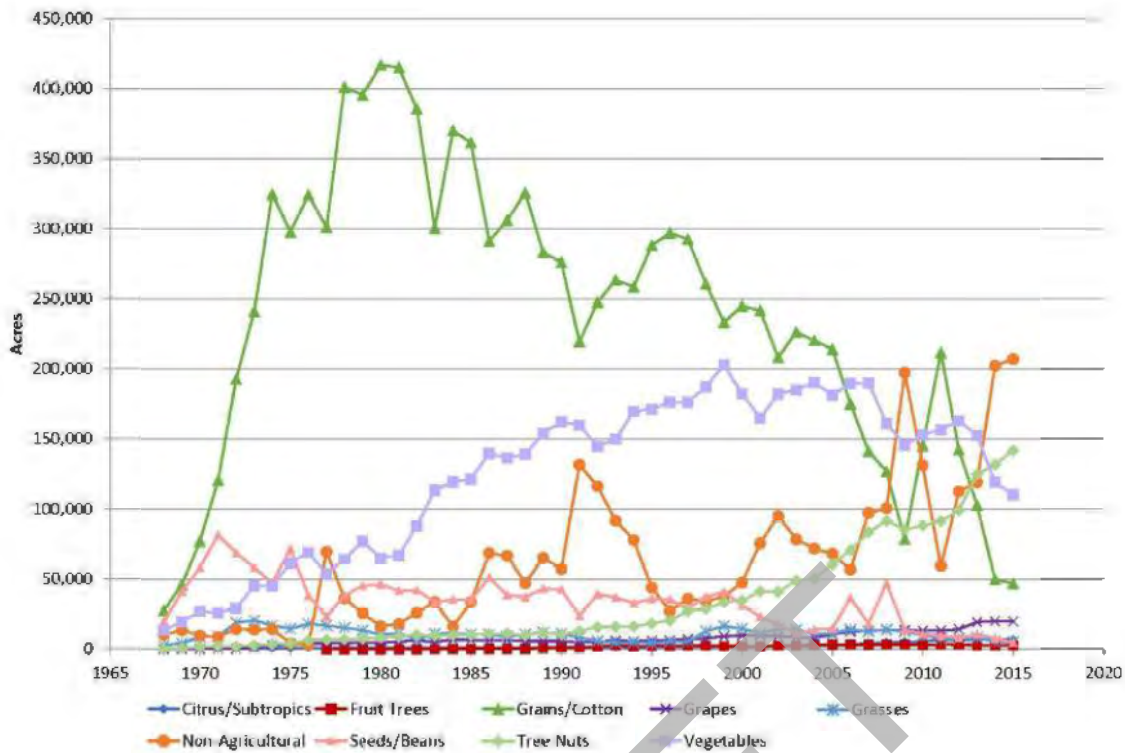
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FIGURE 2-7

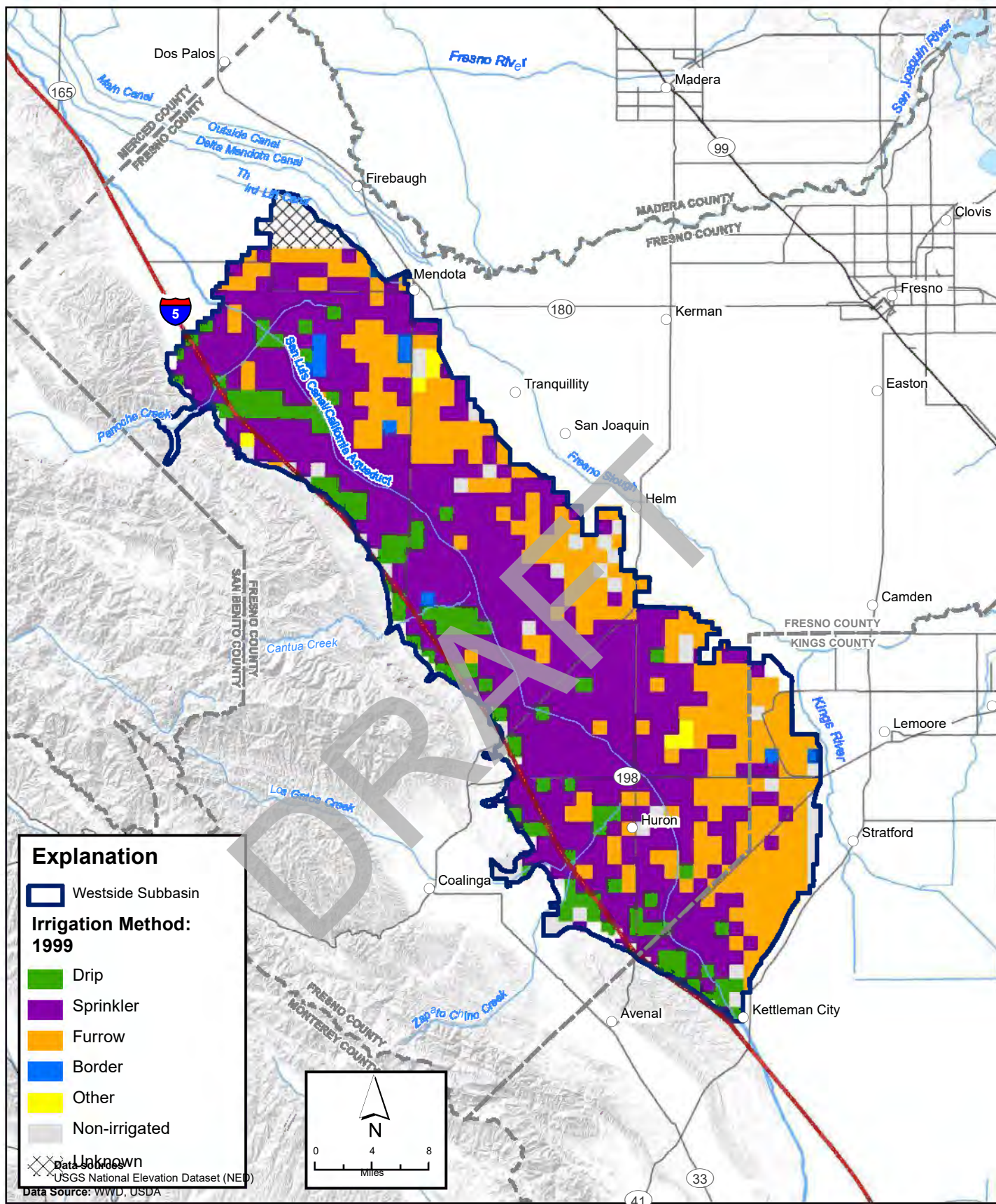


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FIGURE 2-8
Map of Land Use: 2013

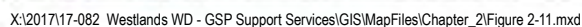


X:\2017\17-082 Westlands WD - GSP Support Services\GIS\MapFiles\20190417_edits\Figure 2-9 Historical Change in Land Uses.mxd

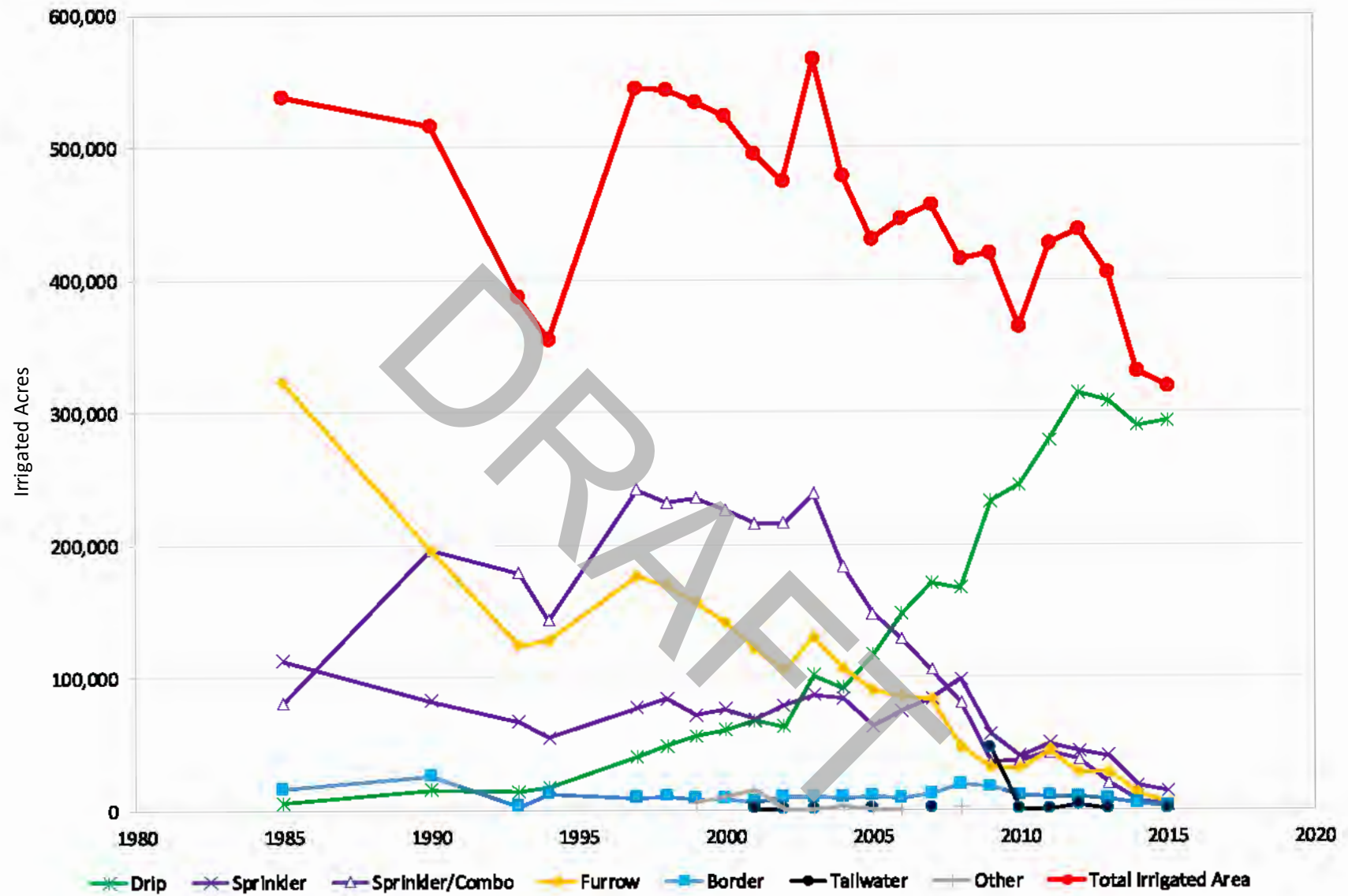


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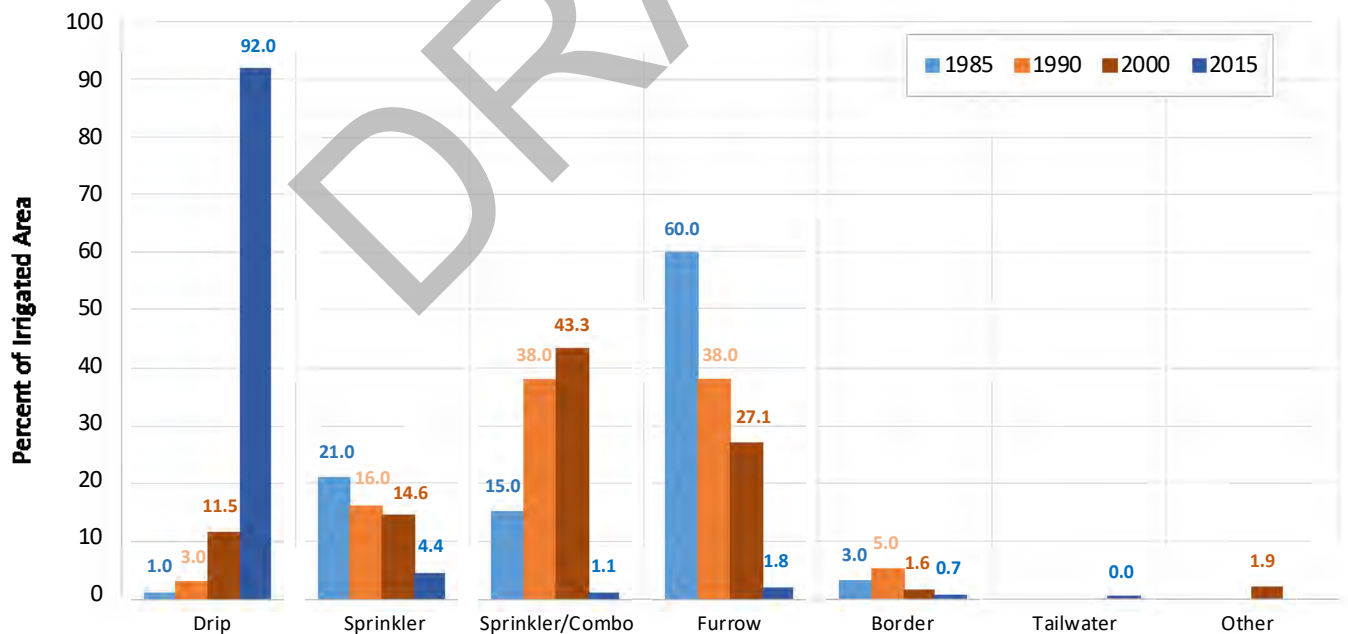
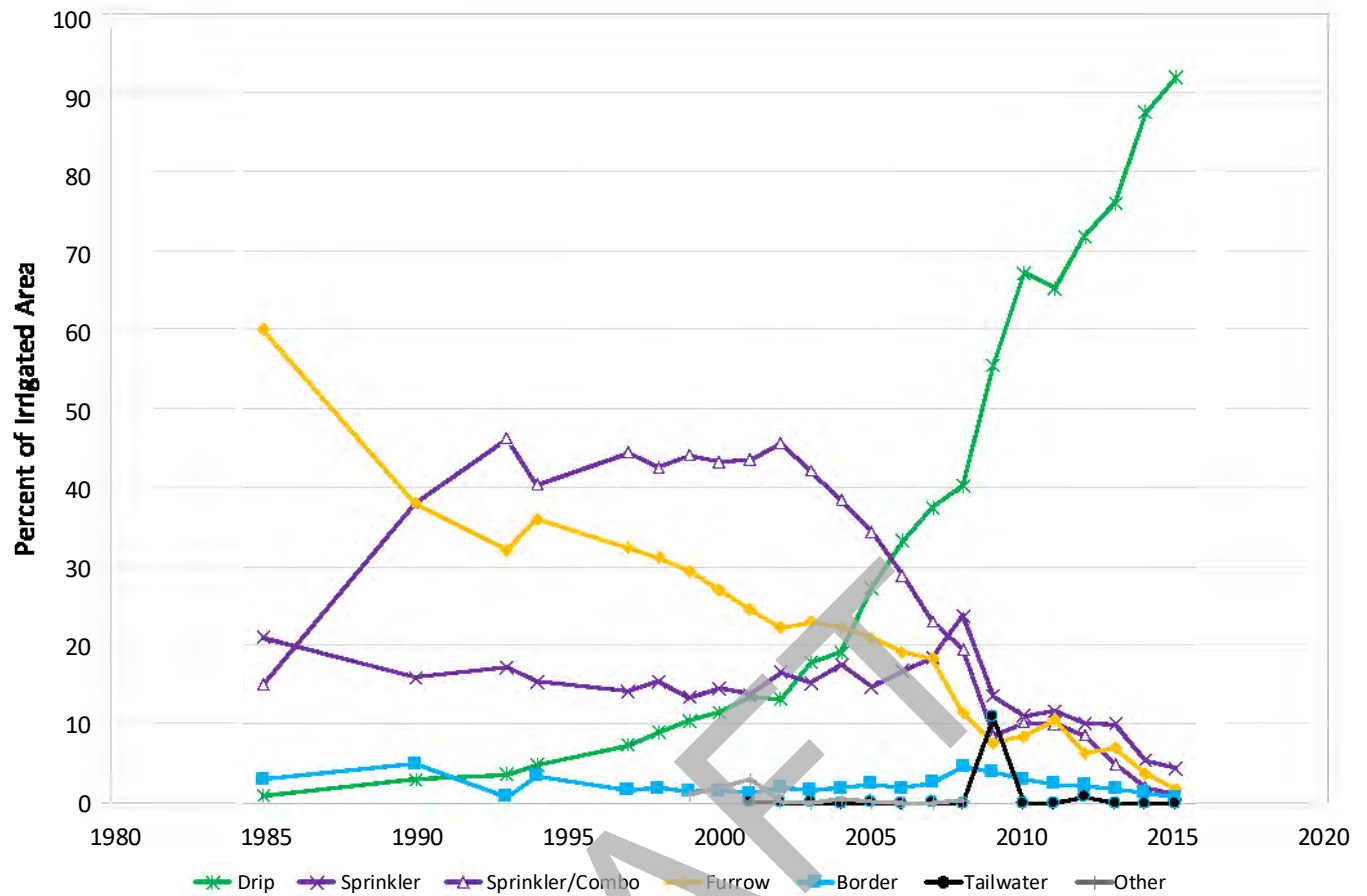
FIGURE 2-10
Map of Irrigation Practices: 1999



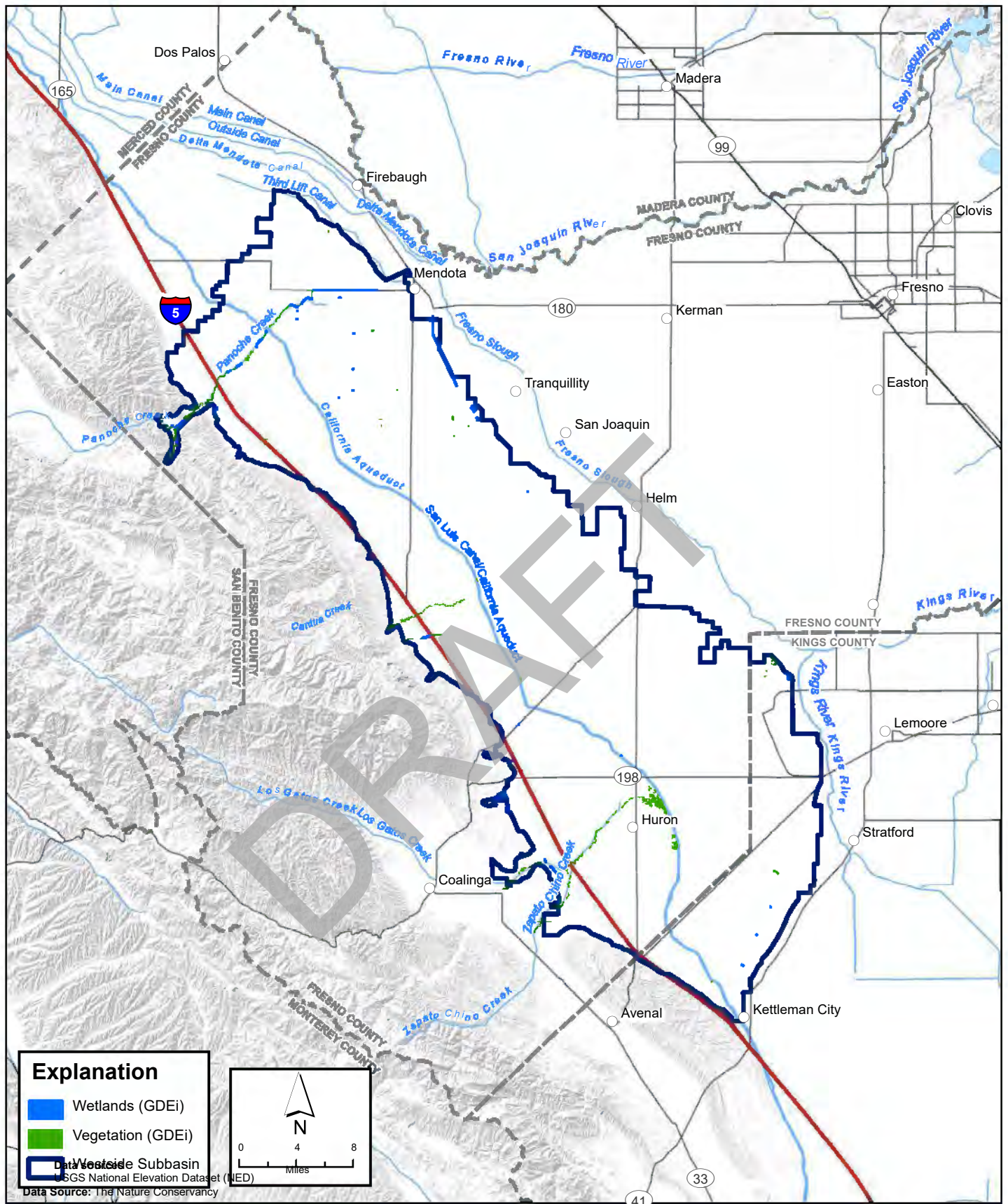
*Groundwater Sustainability Plan
Westside Subbasin*



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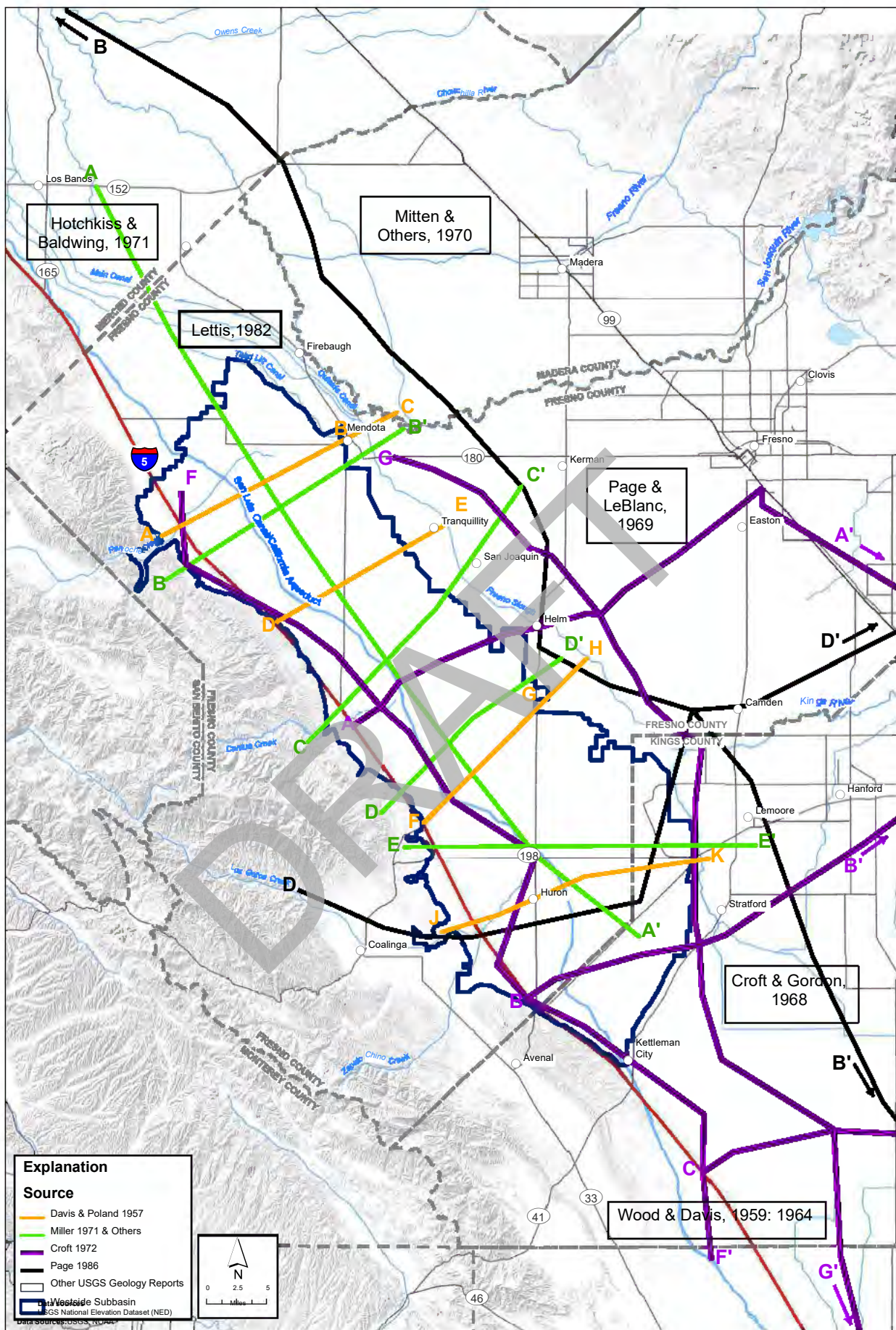


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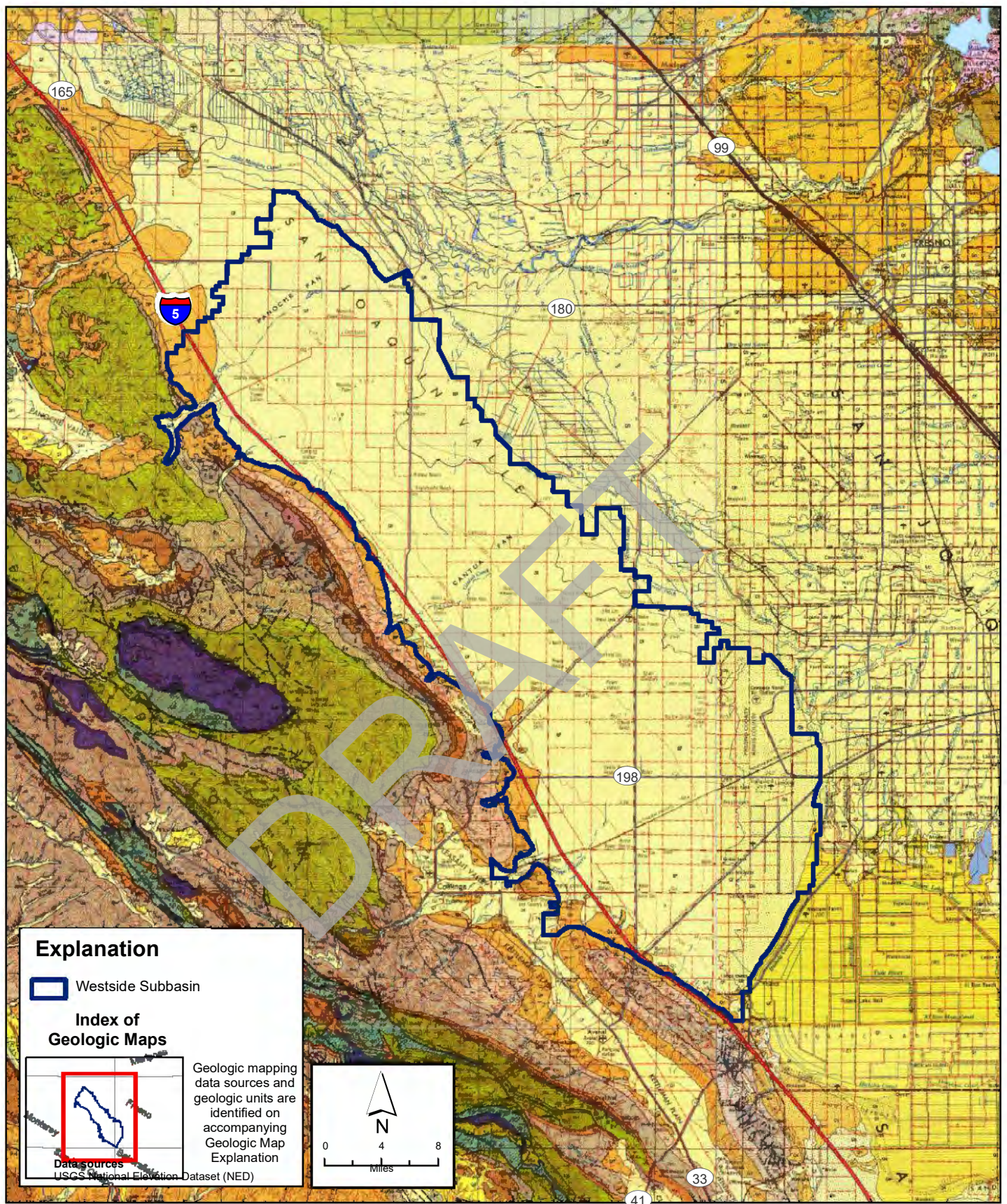


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FIGURE 2-14
Potential Groundwater Dependent Ecosystems



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FIGURE 2-16A
Geologic Map, Vicinity of Westlands Water District
 Groundwater Sustainability Plan
 Westside Subbasin

Compiled Geologic Map Explanation

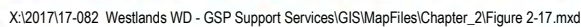
Santa Cruz, San Luis Obispo, Bakersfield, and Fresno Quadrangles

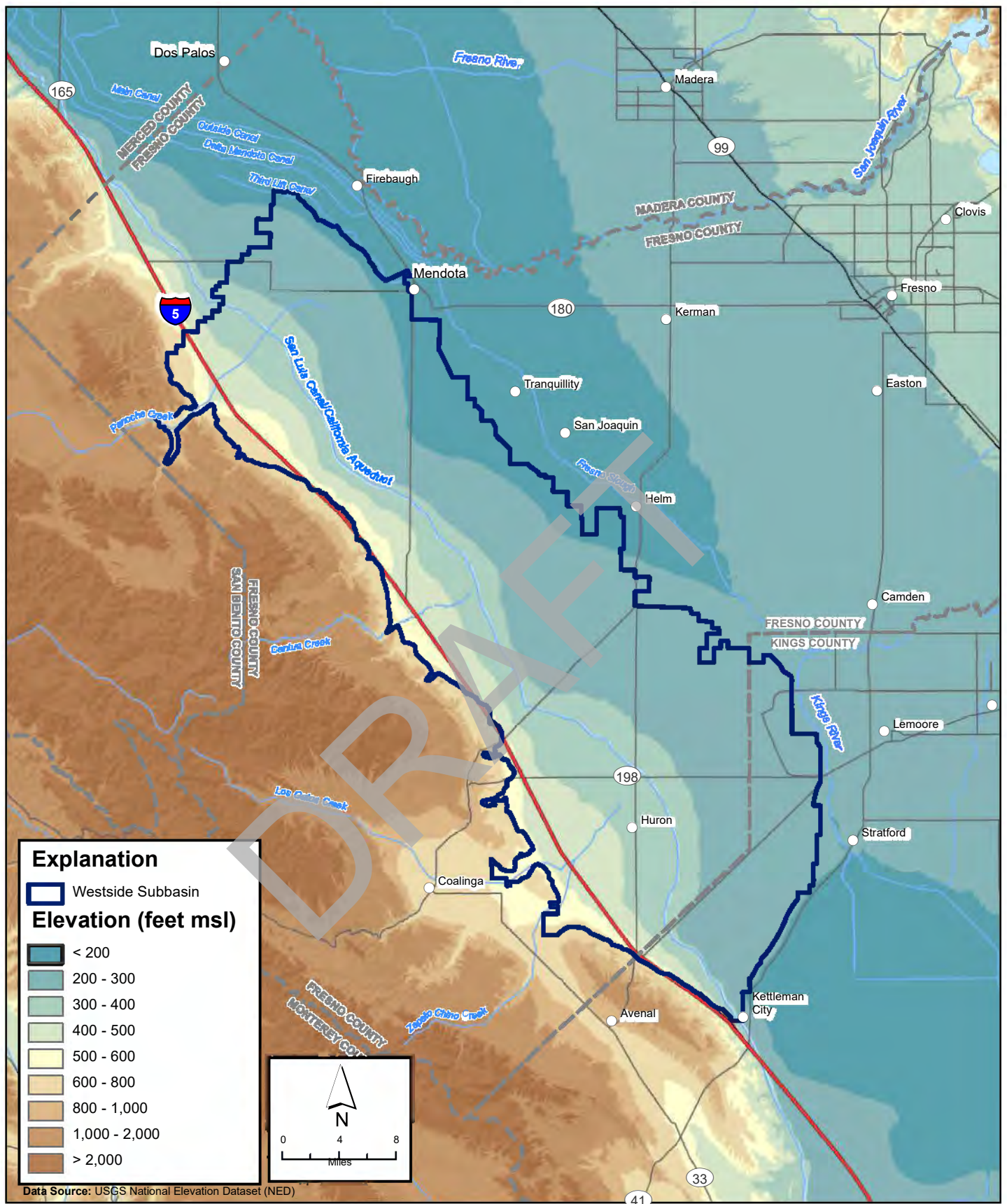
	Alluvium		Upper Cretaceous marine
	Stream channel deposits		Lower Cretaceous marine
	Fan deposits		Franciscan Group
	Basin deposits		Franciscan volcanic and metavolcanic rocks
} GREAT VALLEY			Mesozoic granitic rocks
			Mesozoic ultrabasic intrusive rocks
	Quaternary lake deposits		
	Quaternary nonmarine terrace deposits		
	River terrace deposits		
	Pleistocene nonmarine		
	Plio-Pleistocene nonmarine		
	Undivided Pliocene nonmarine		
	Upper Pliocene marine		
	Middle and/or lower Pliocene nonmarine		
	Middle and/or lower Pliocene marine		
	Undivided Miocene nonmarine		
	Upper Miocene nonmarine		
	Upper Miocene marine		
	Miocene volcanic: Mv ^r —rhyolite; Mv ^a —andesite; Mv ^b —basalt; Mv ^p —pyroclastic rocks		
	Middle Miocene nonmarine		
	Middle Miocene marine		
	Lower Miocene marine		
	Oligocene marine		
	Eocene marine		
	Paleocene marine		

Geologic Map compiled from:

1. Jennings, C.W. and Strand, R.G., 1958, Geologic Atlas of California - Santa Cruz Quadrangle, California Geological Survey, Geologic Atlas of California Map No. 020, 1:250,000 scale.
2. Jennings, C.W., 1958, Geologic map of California - San Luis Obispo Quadrangle, California Division of Mines and Geology, 1:250,000 scale.
3. Smith, A.R., 1964, Geologic map of California - Bakersfield Quadrangle, California Division of Mines and Geology, 1:250,000 scale.
4. Matthews, R.A. and Burnett, J.L., 1965, Geologic Atlas of California - Fresno Quadrangle, California Geological Survey, Geologic Atlas of California Map No. 005, 1:250,000 scale.

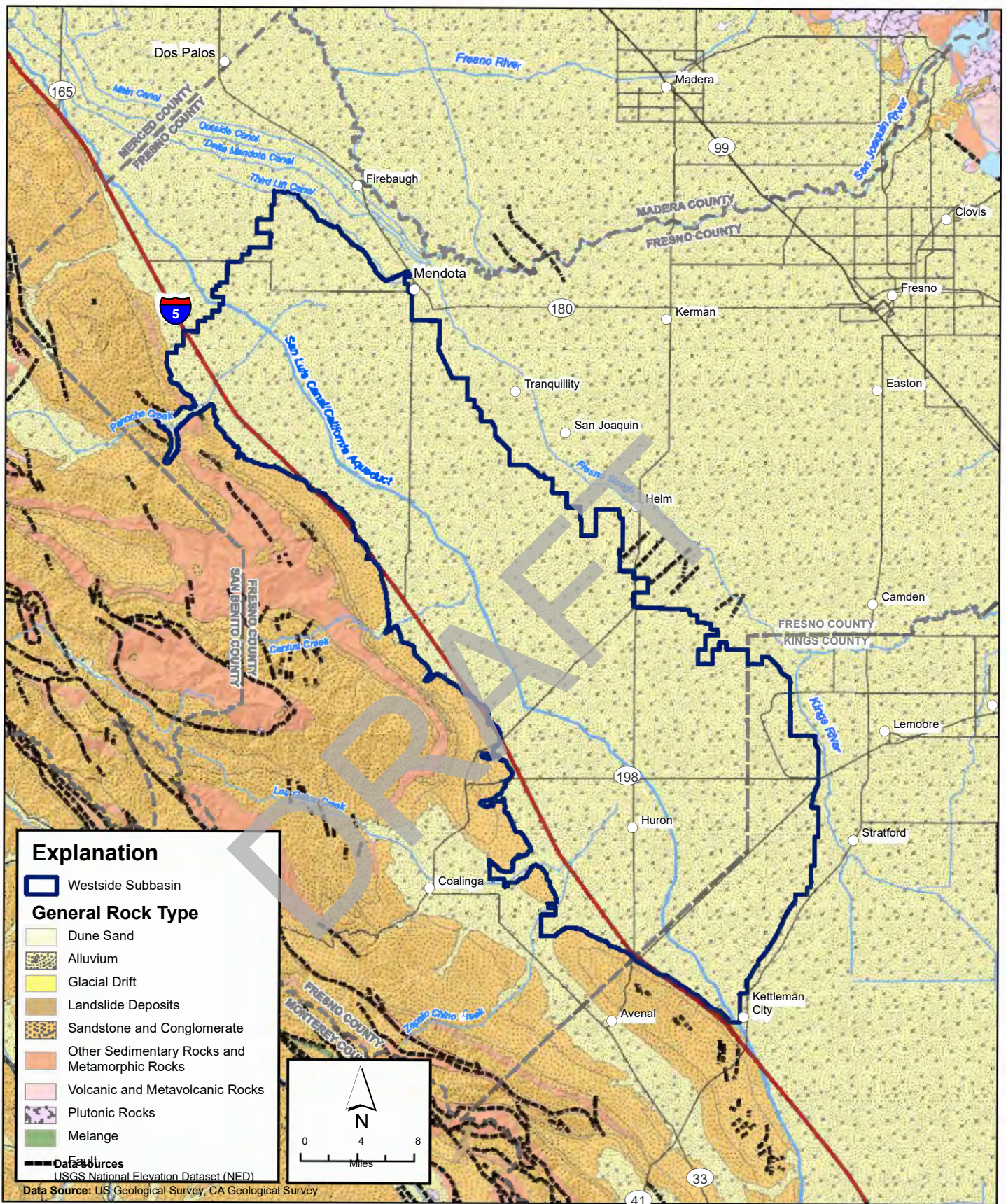
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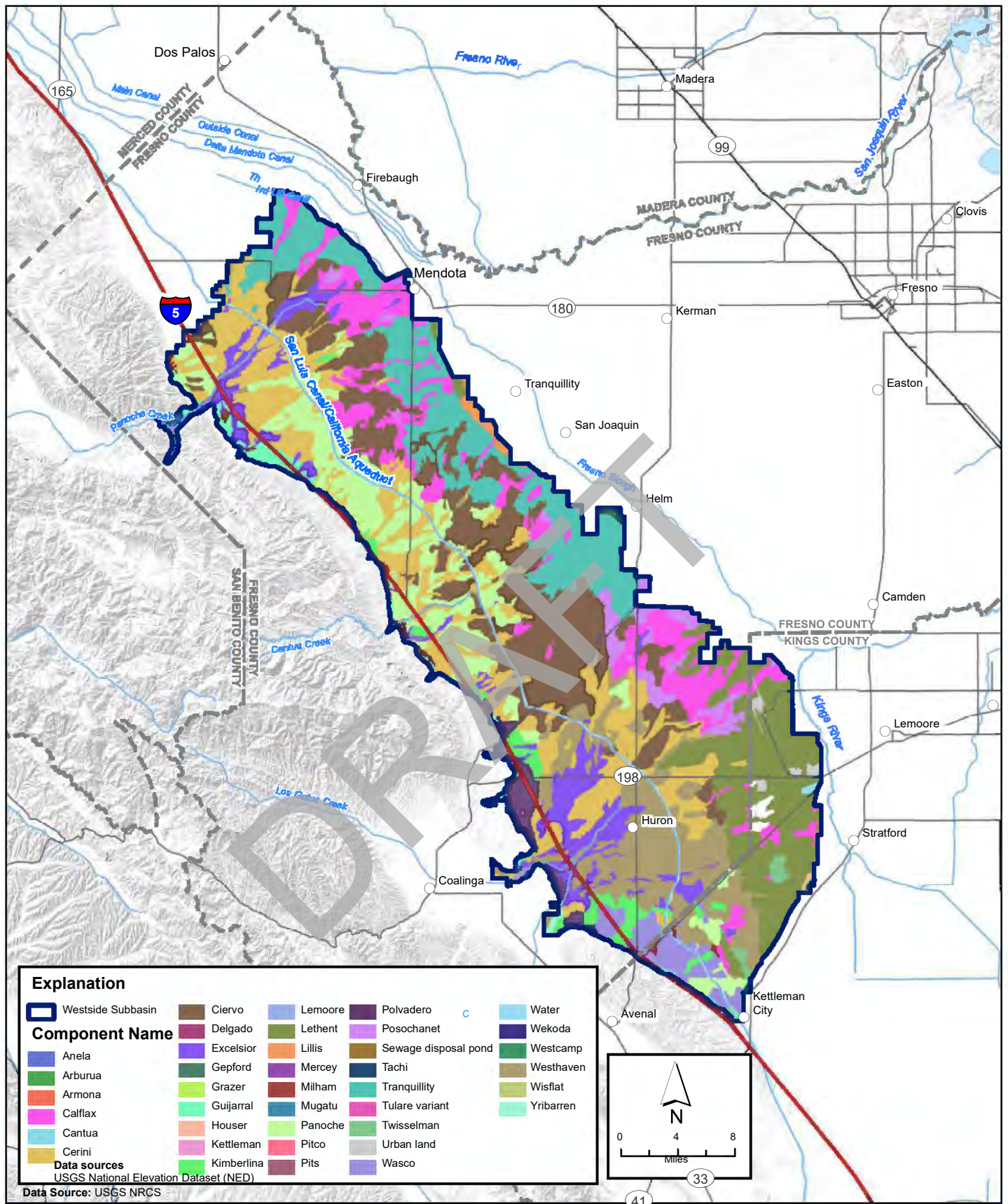
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FIGURE 2-18
Map of Ground Surface Elevation



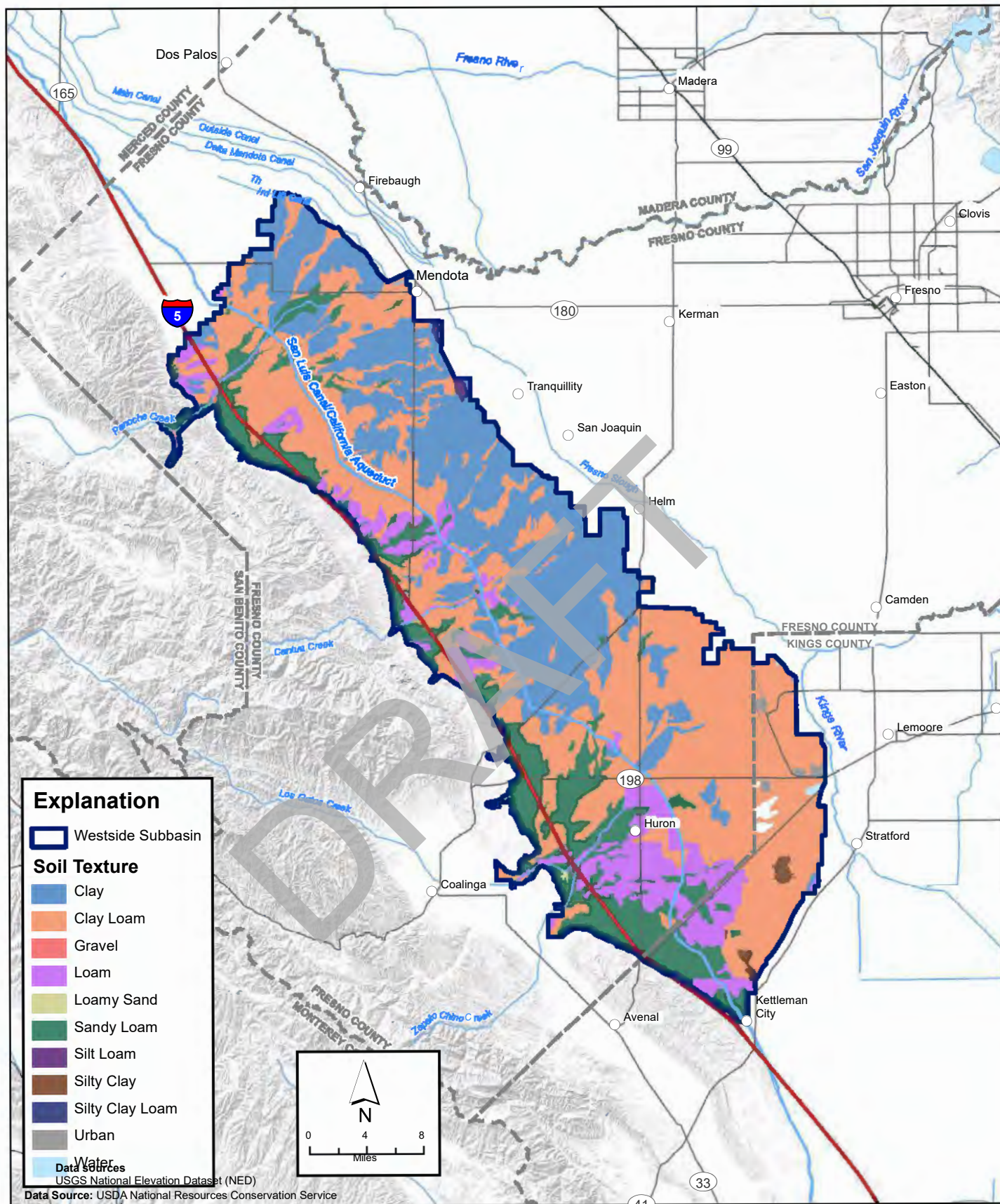
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FIGURE 2-19
Geologic Map with Faults, Vicinity of WWD



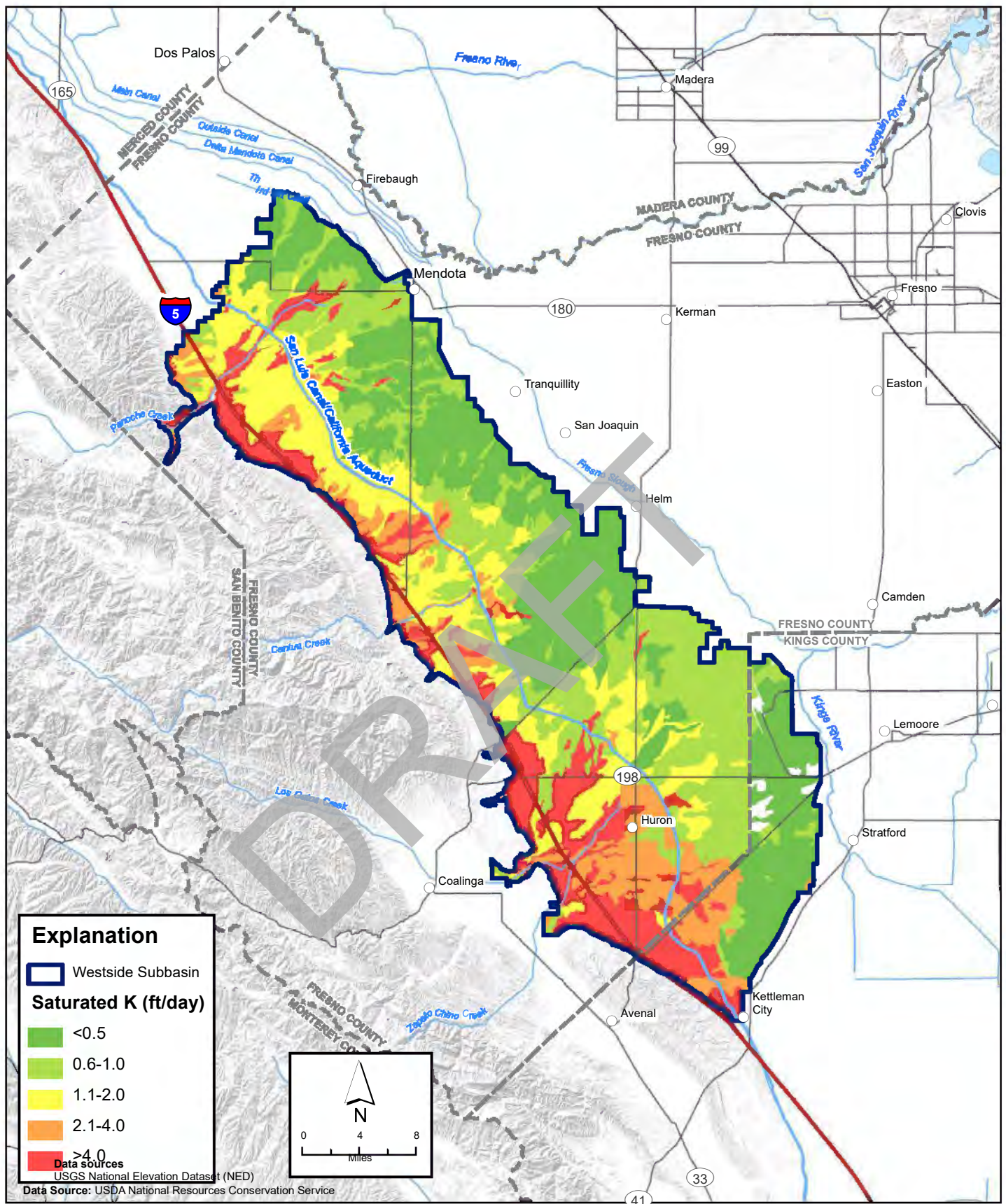
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FIGURE 2-20
Soils - Type



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FIGURE 2-21
Soils - Texture

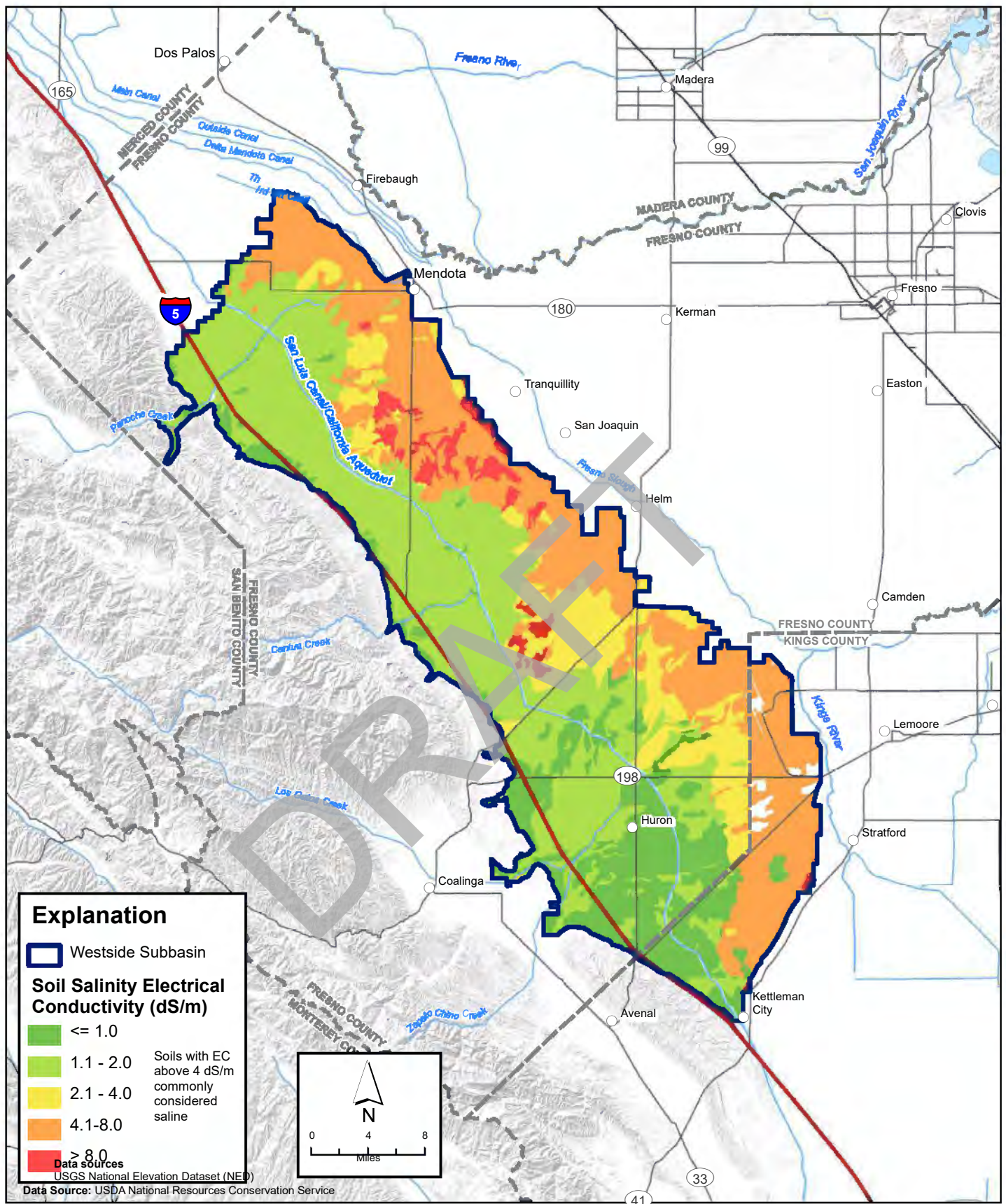


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FIGURE 2-22
Soils - Hydraulic Conductivity

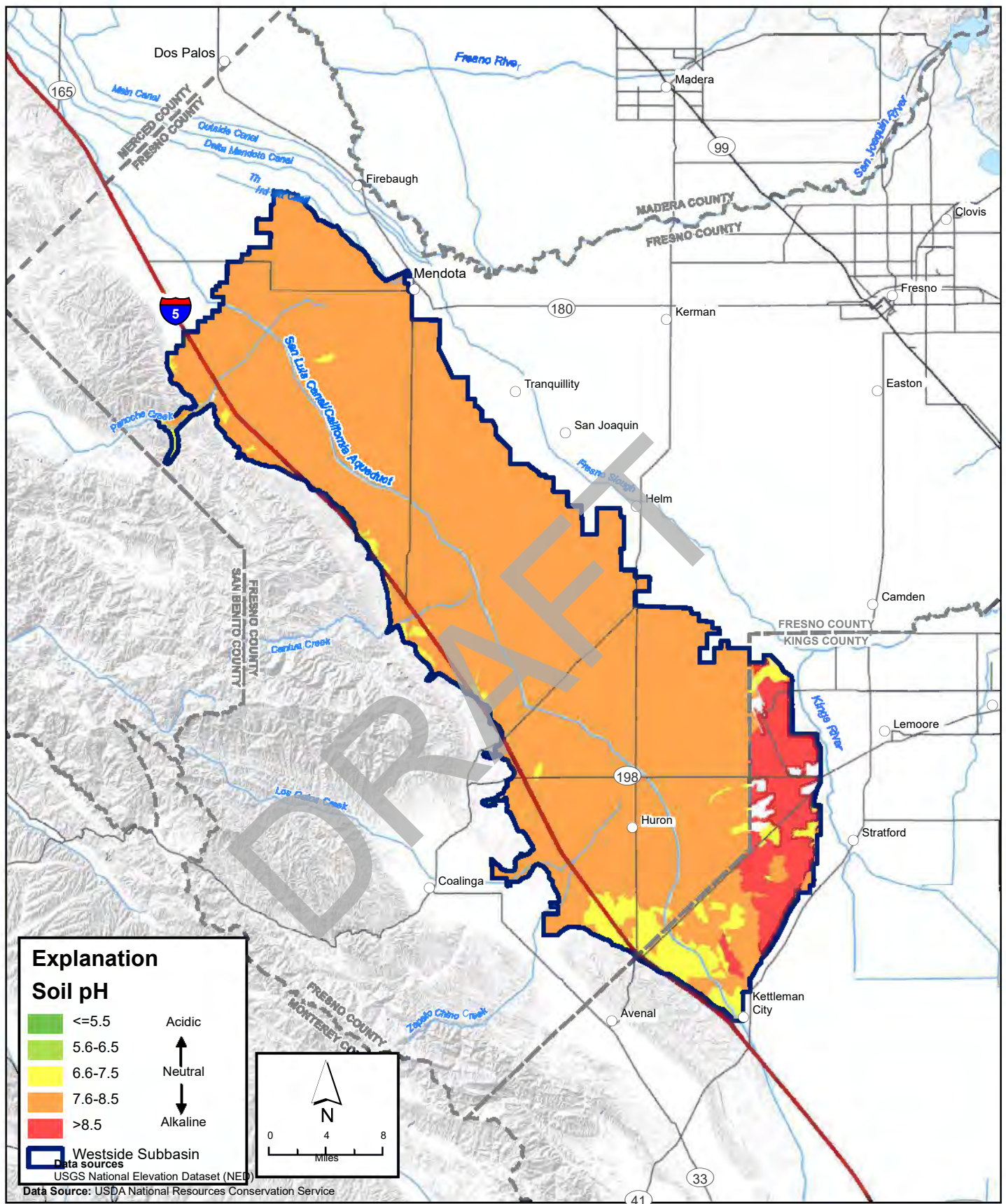


*Groundwater Sustainability Plan
Westside Subbasin*



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FIGURE 2-24
Soils - Electrical Conductivity (EC)



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FIGURE 2-25
Soils - pH

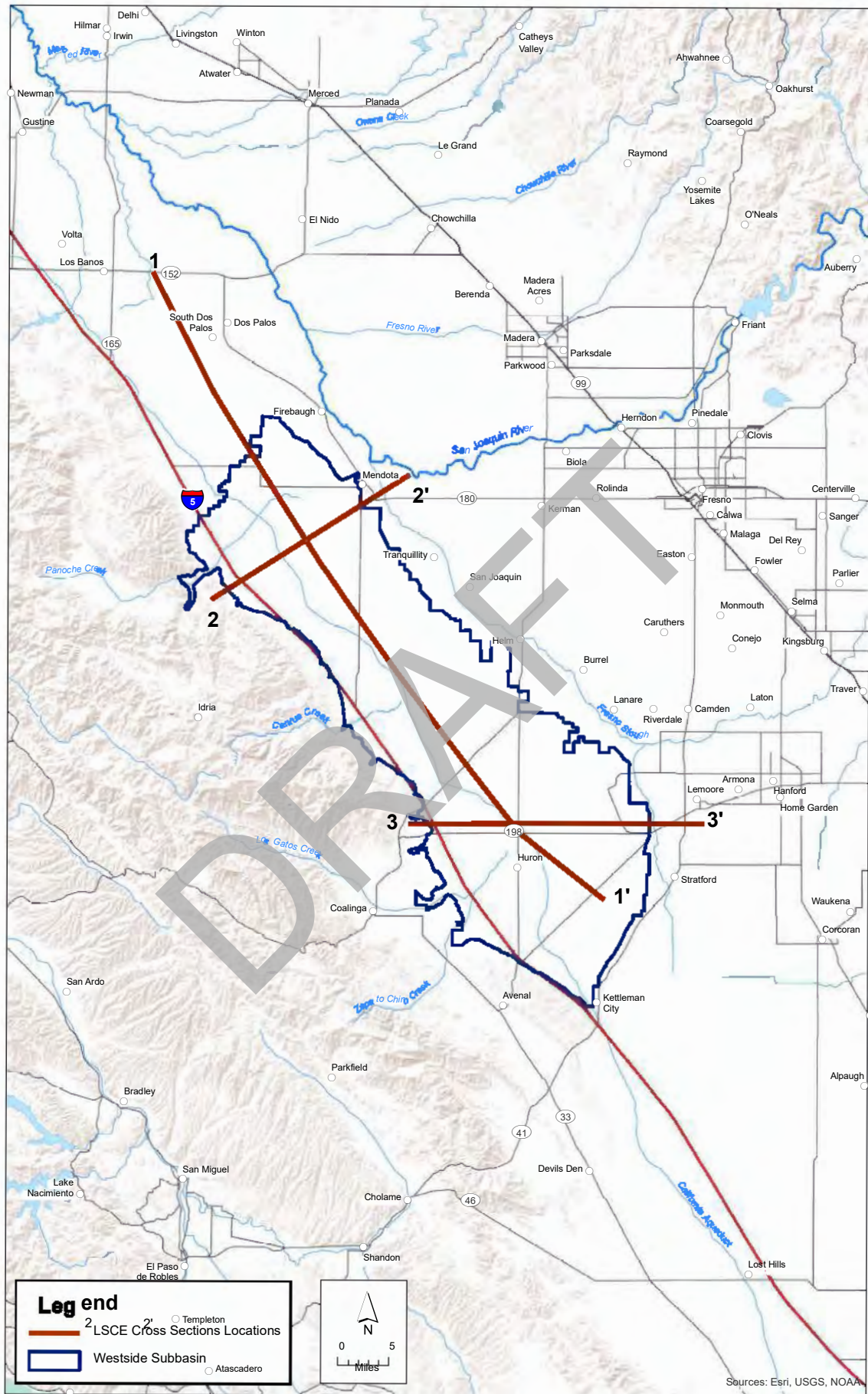
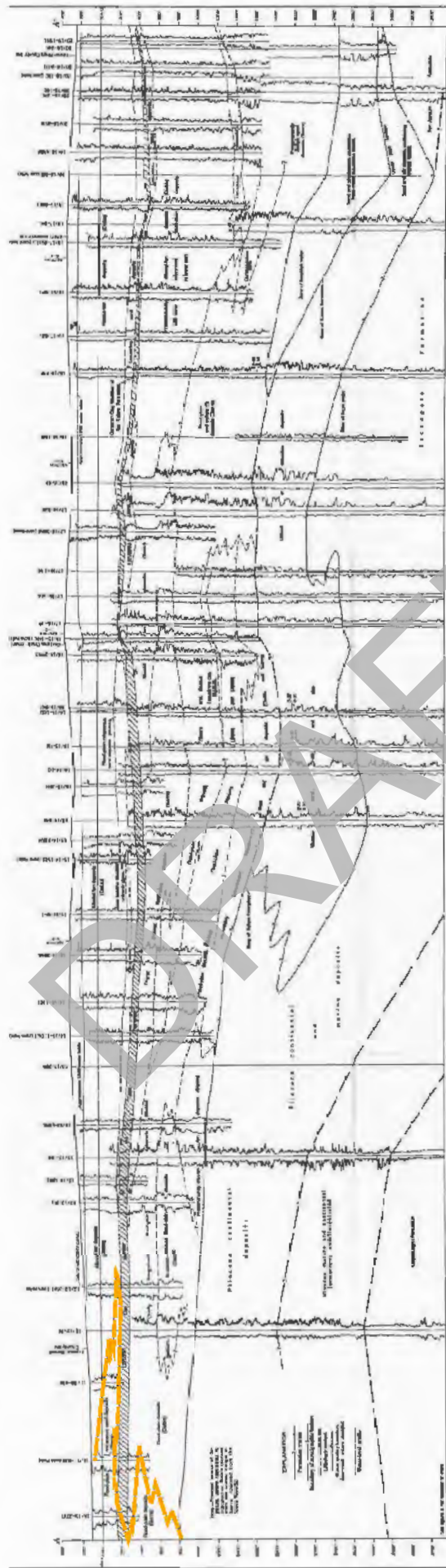


FIGURE 2-26
LSCE Geologic Cross Section Location Map



EXPLANATION

Formation contact
 Boundary of stratigraphic horizon
 Lithologic contact

Geophysical Log
 Left Self-potential
 Right Resistivity

Note - Principal source of deposits, where identified, is indicated as Diablo (derived from the Diablo Range) or Sierra Nevada (derived from the Sierra Nevada)

Edge of Coast Range Scarred Units

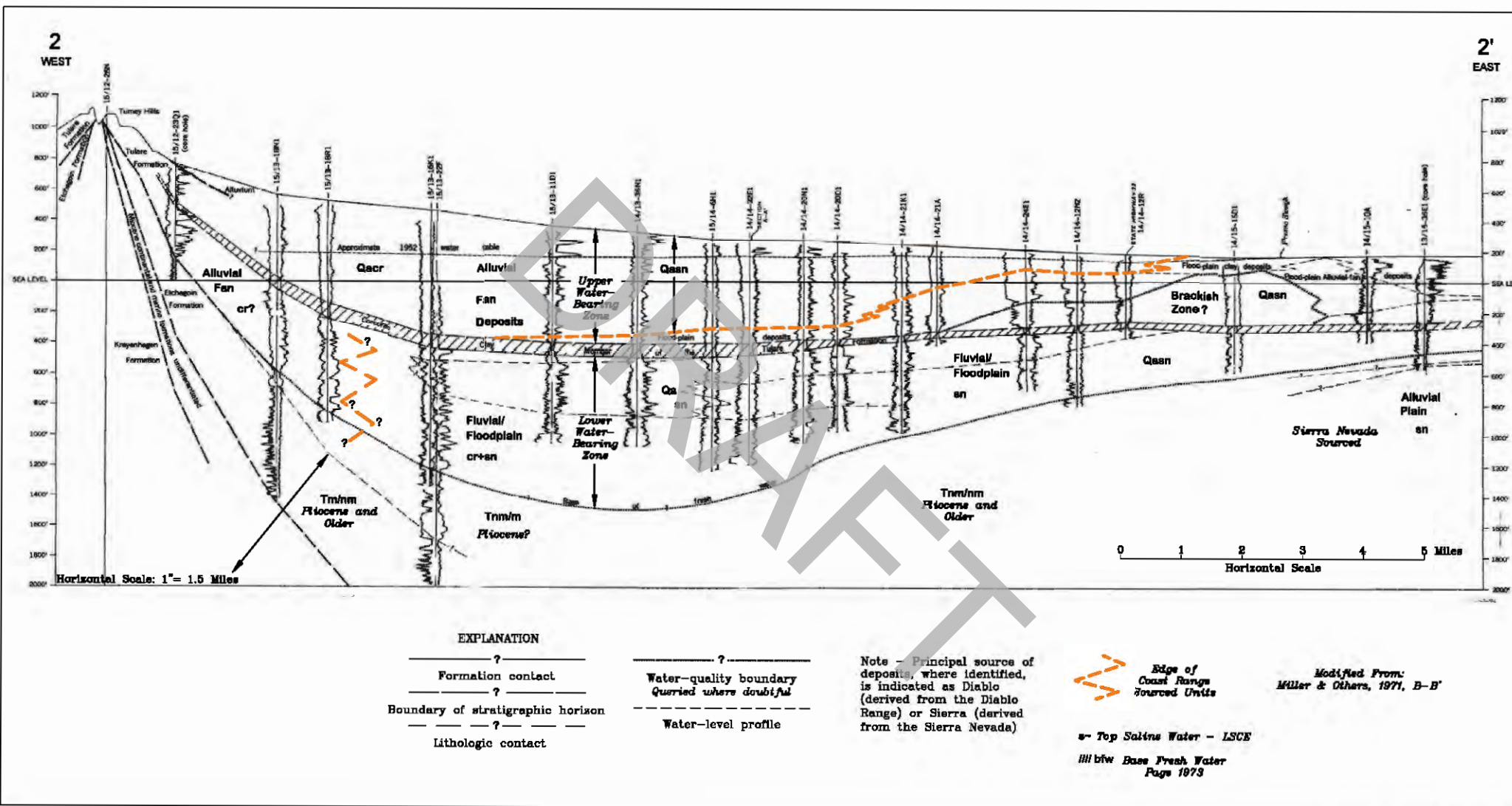
100 ft Base Fresh Water
 Page 1373

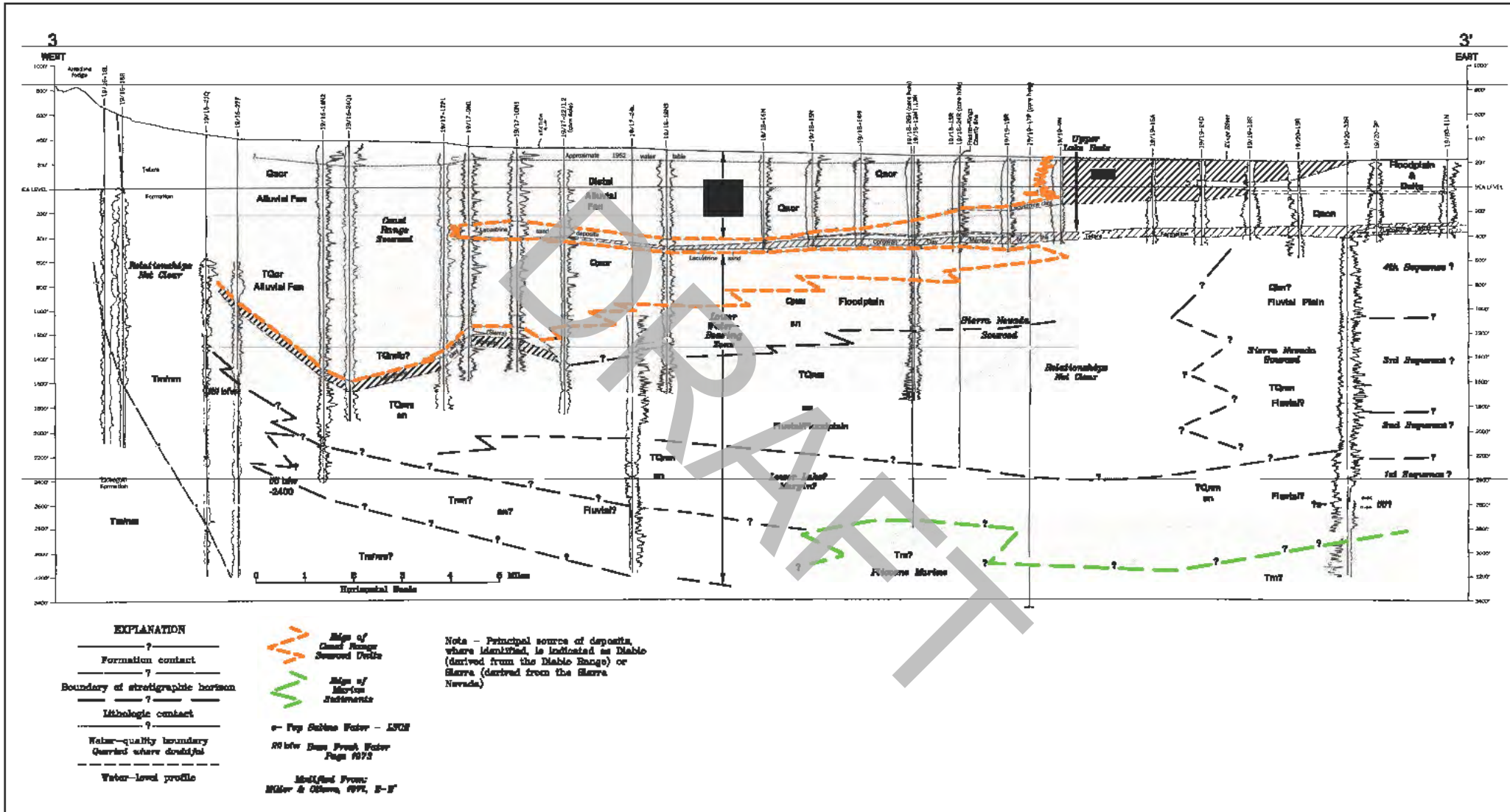
Modified from:
 Miller & Others, 1971 A-1

0 1 2 3 4 5 6 Miles

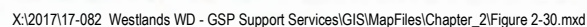
FIGURE 2-37
 Geologic Cross Section 1-1'

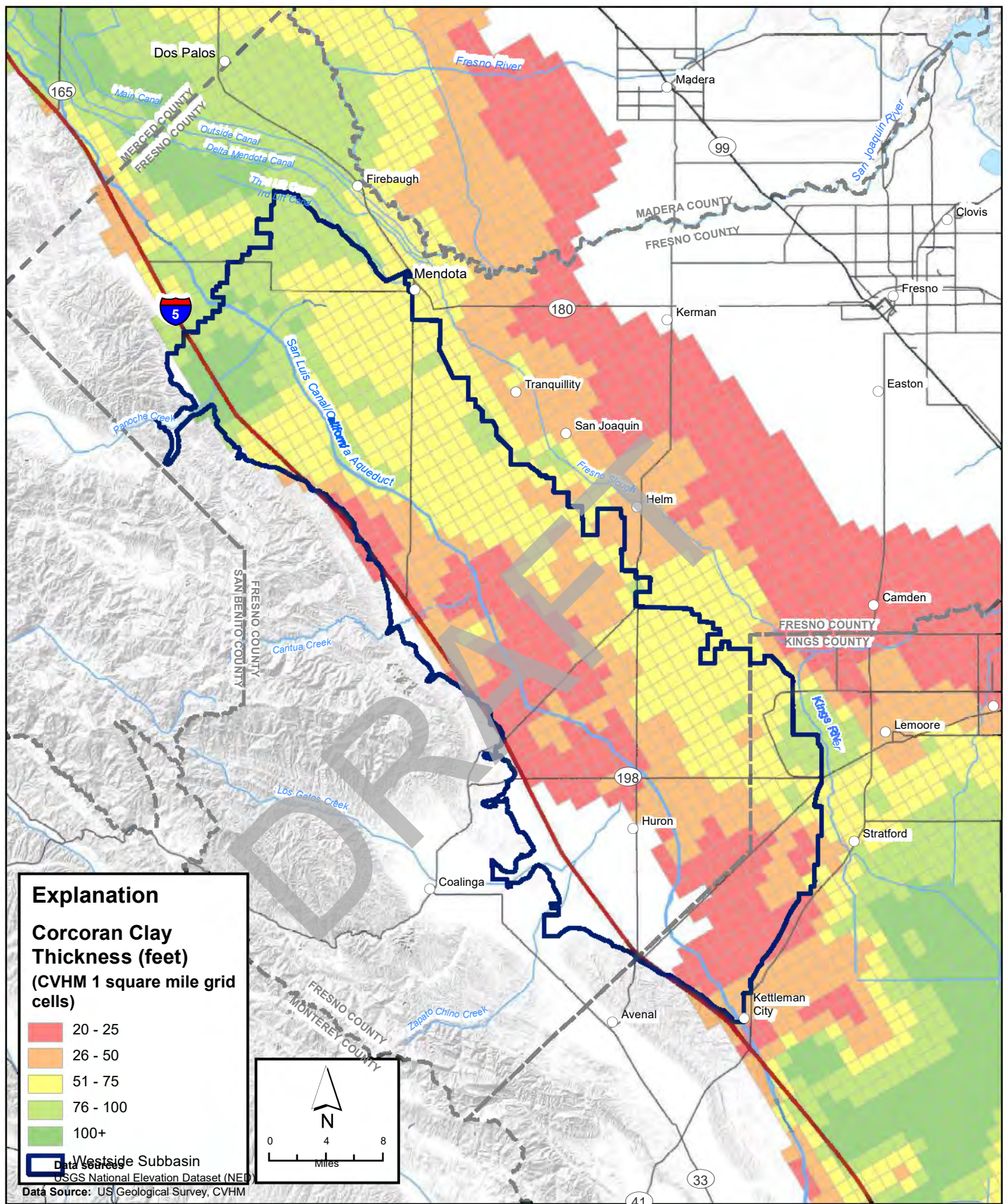
Groundwater Sustainability Plan
 Western Water Center





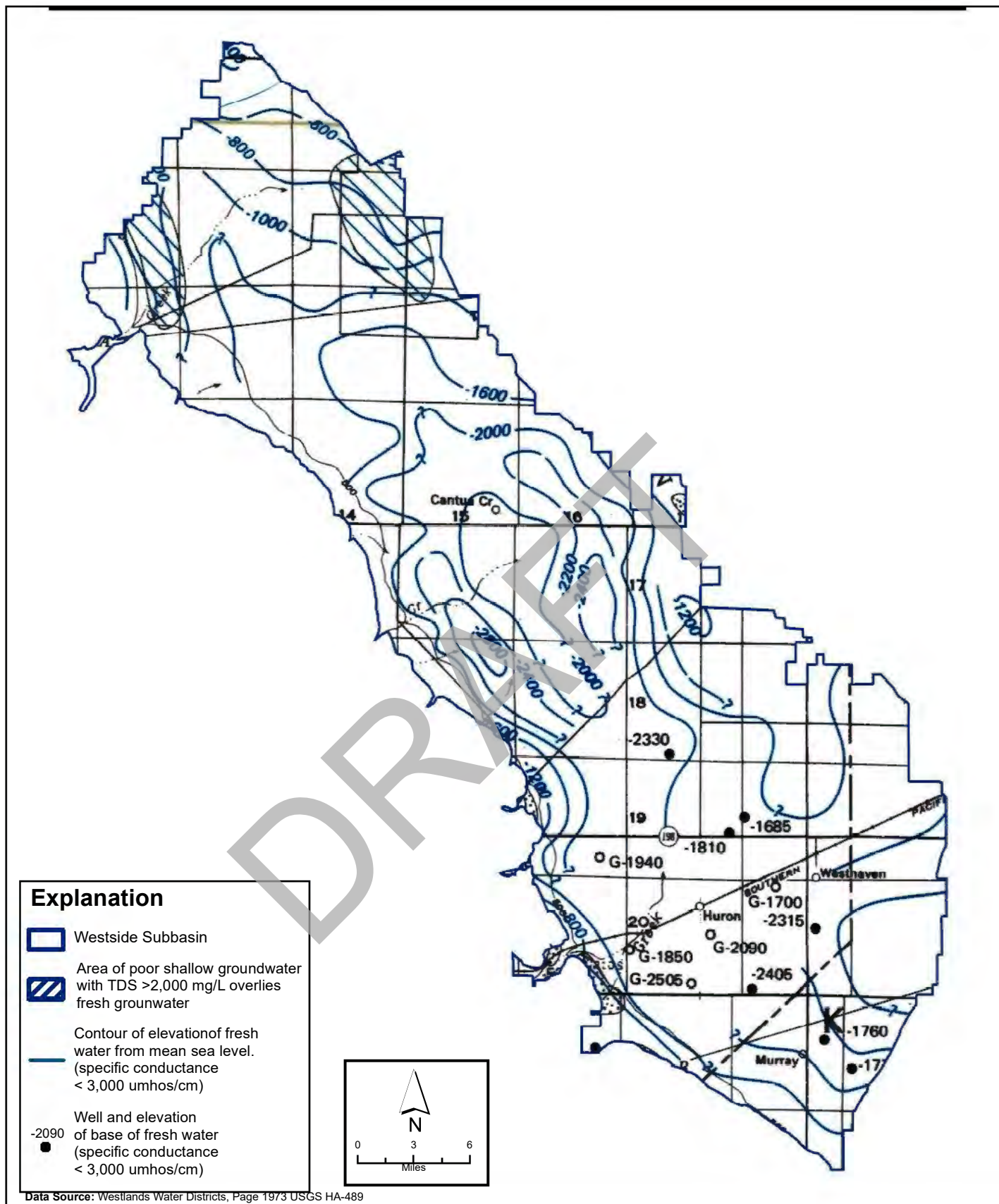
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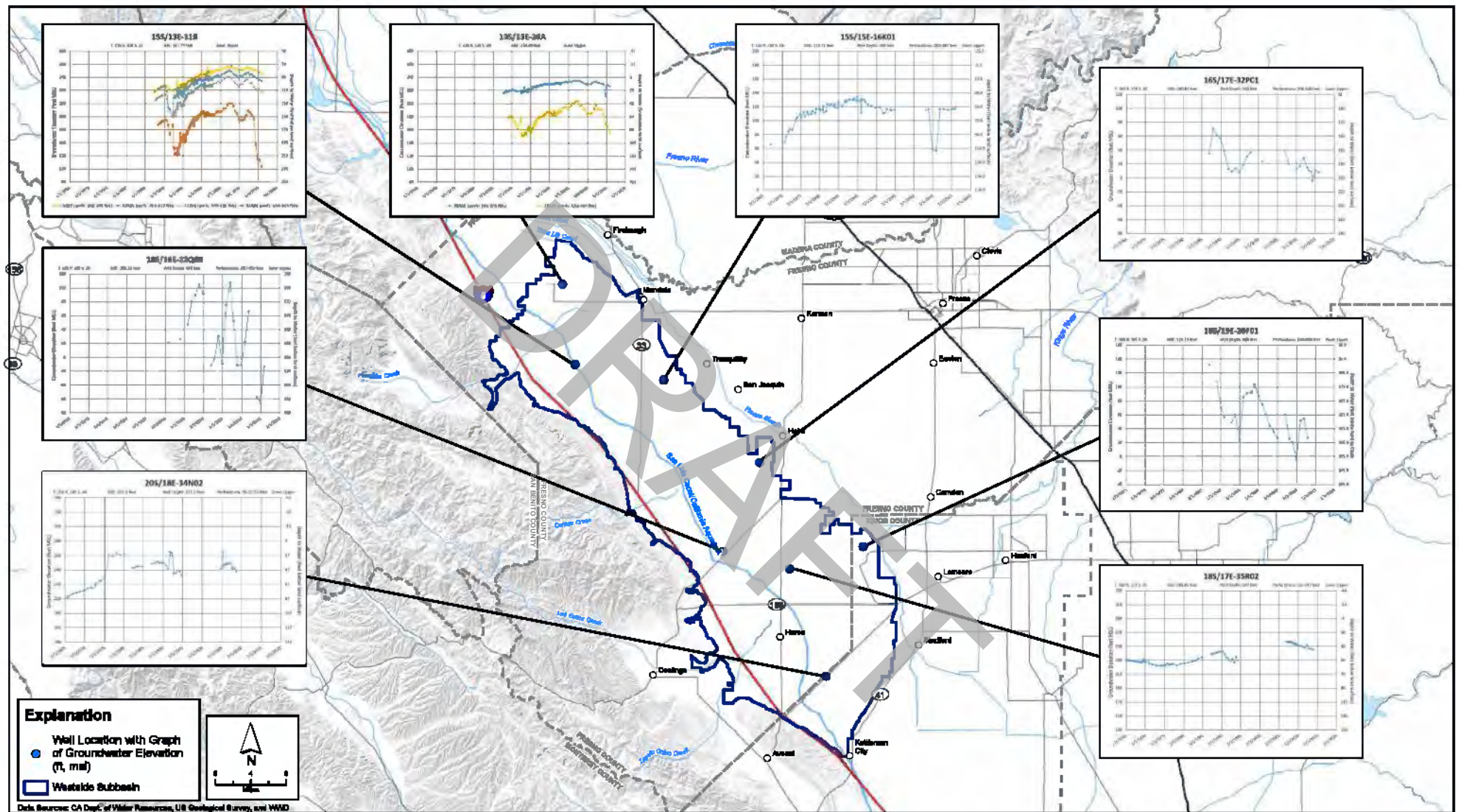
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FIGURE 2-31
Map of the Thickness of Corcoran Clay

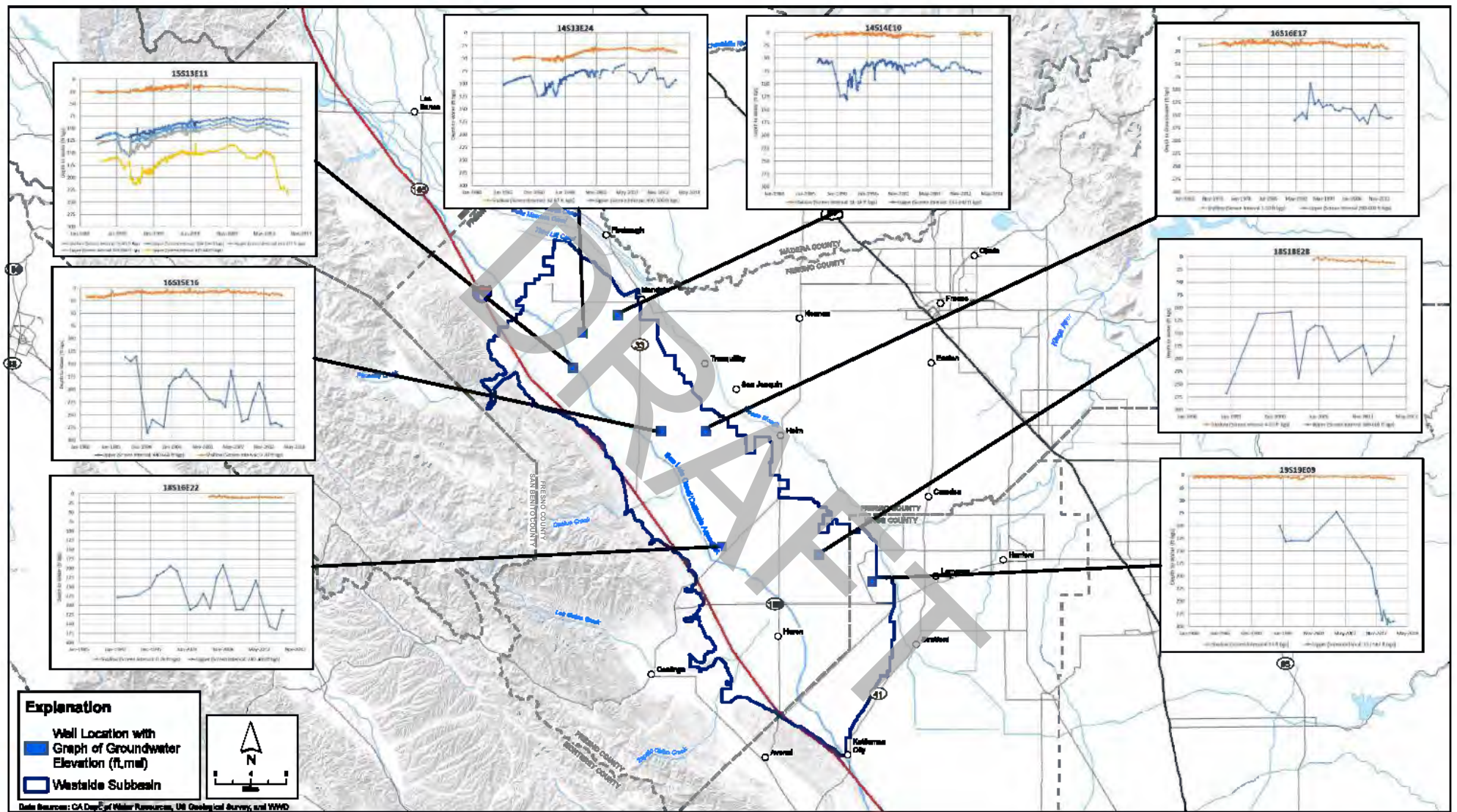


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FIGURE 2-32
Base of Fresh Water



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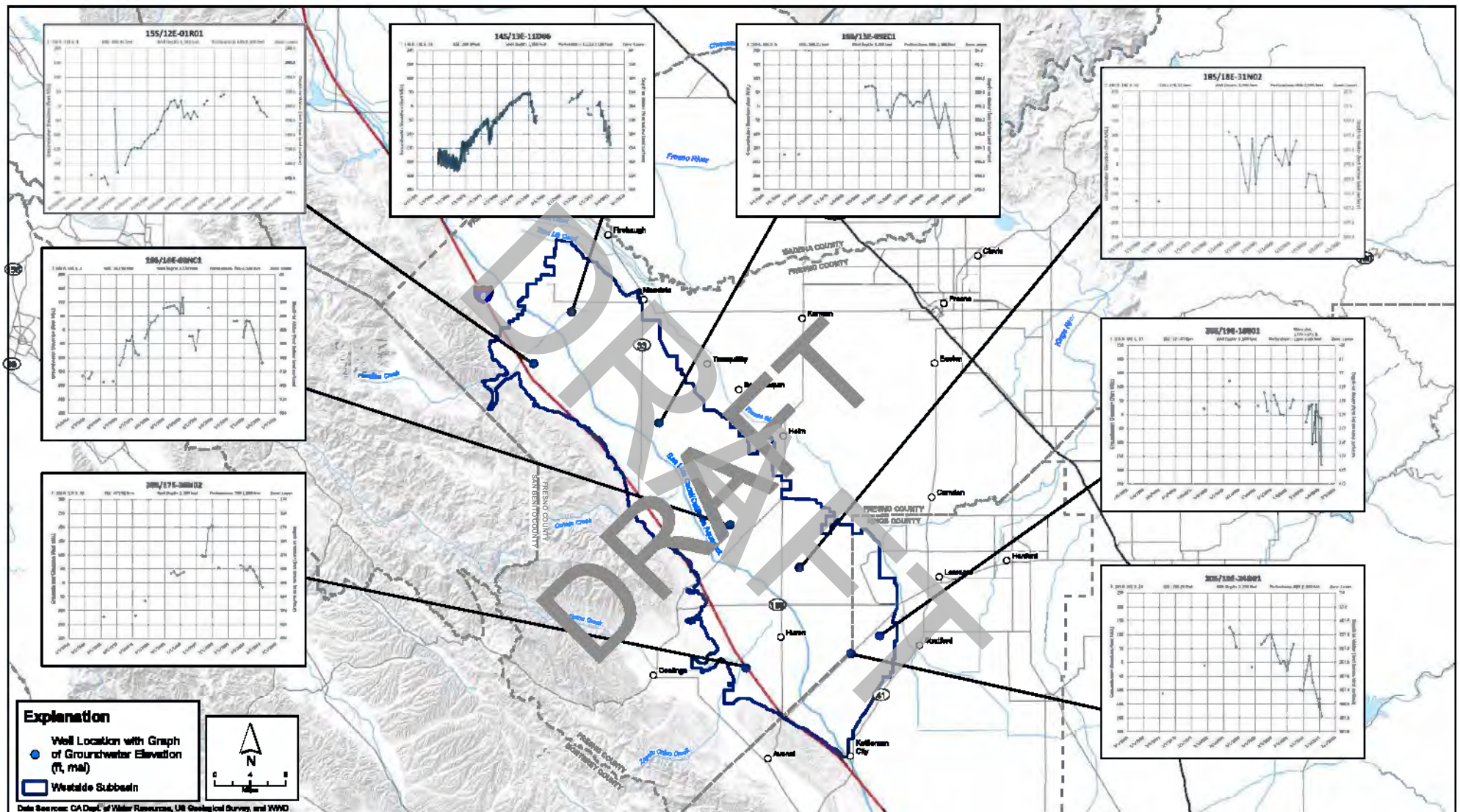
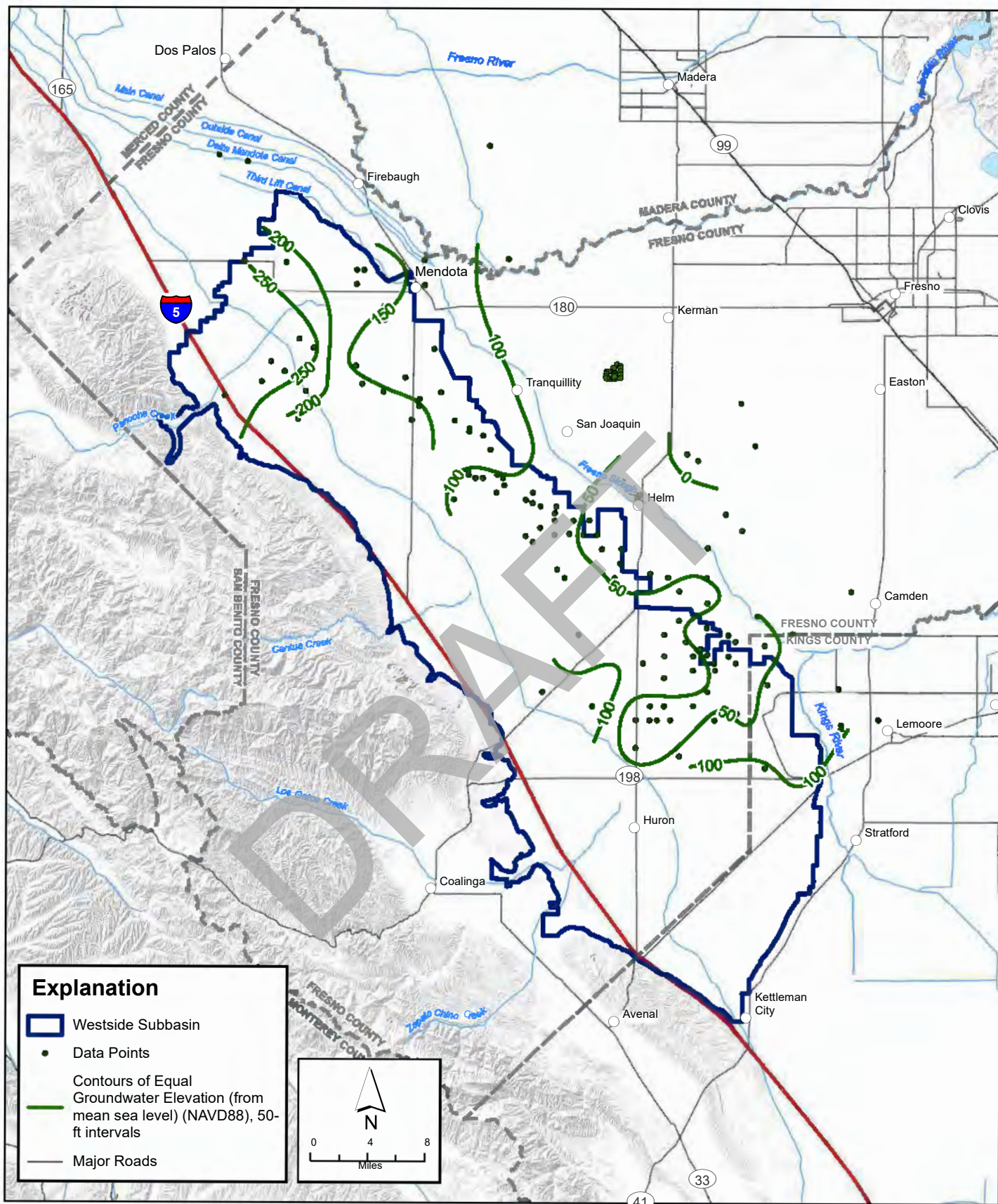
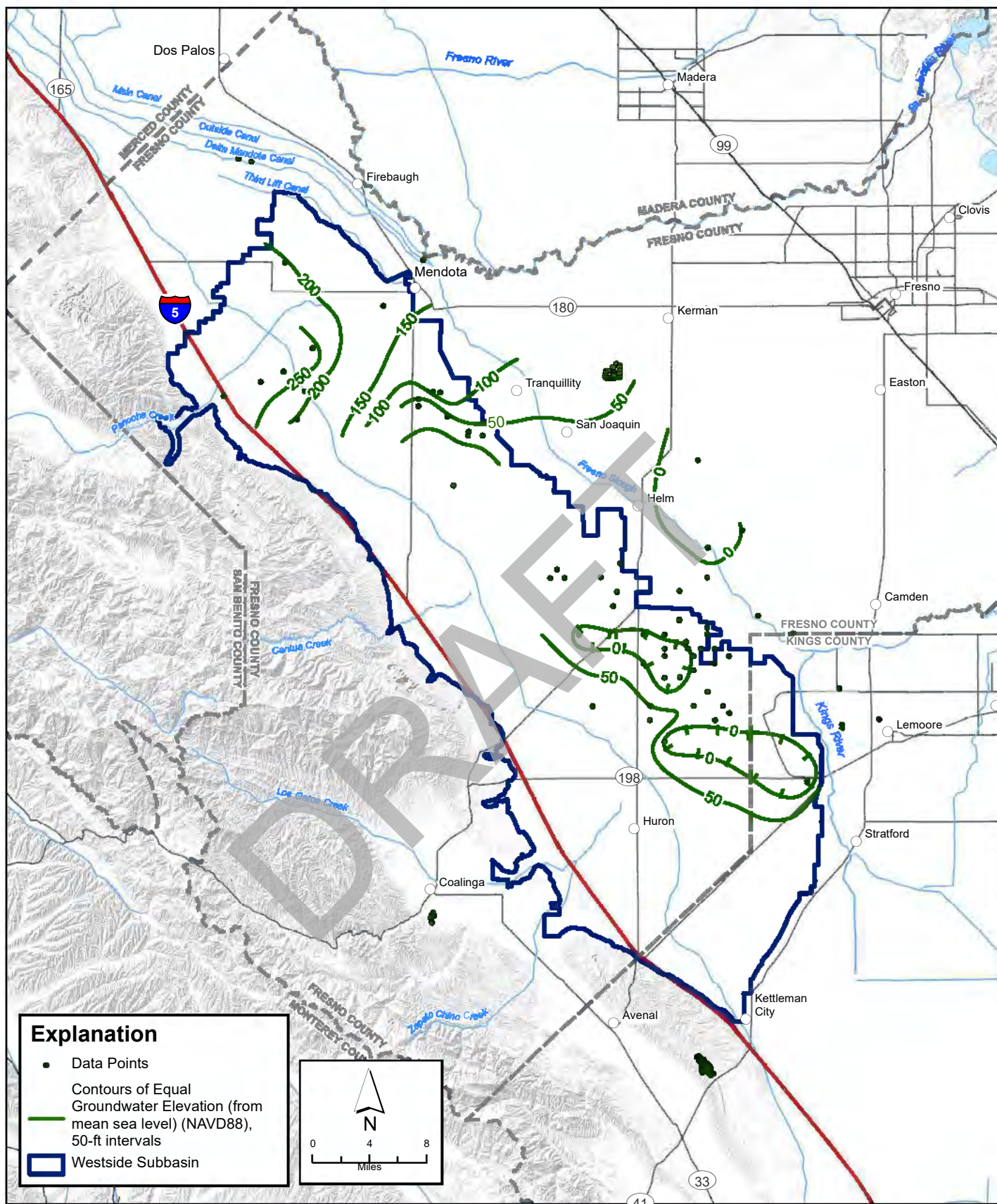


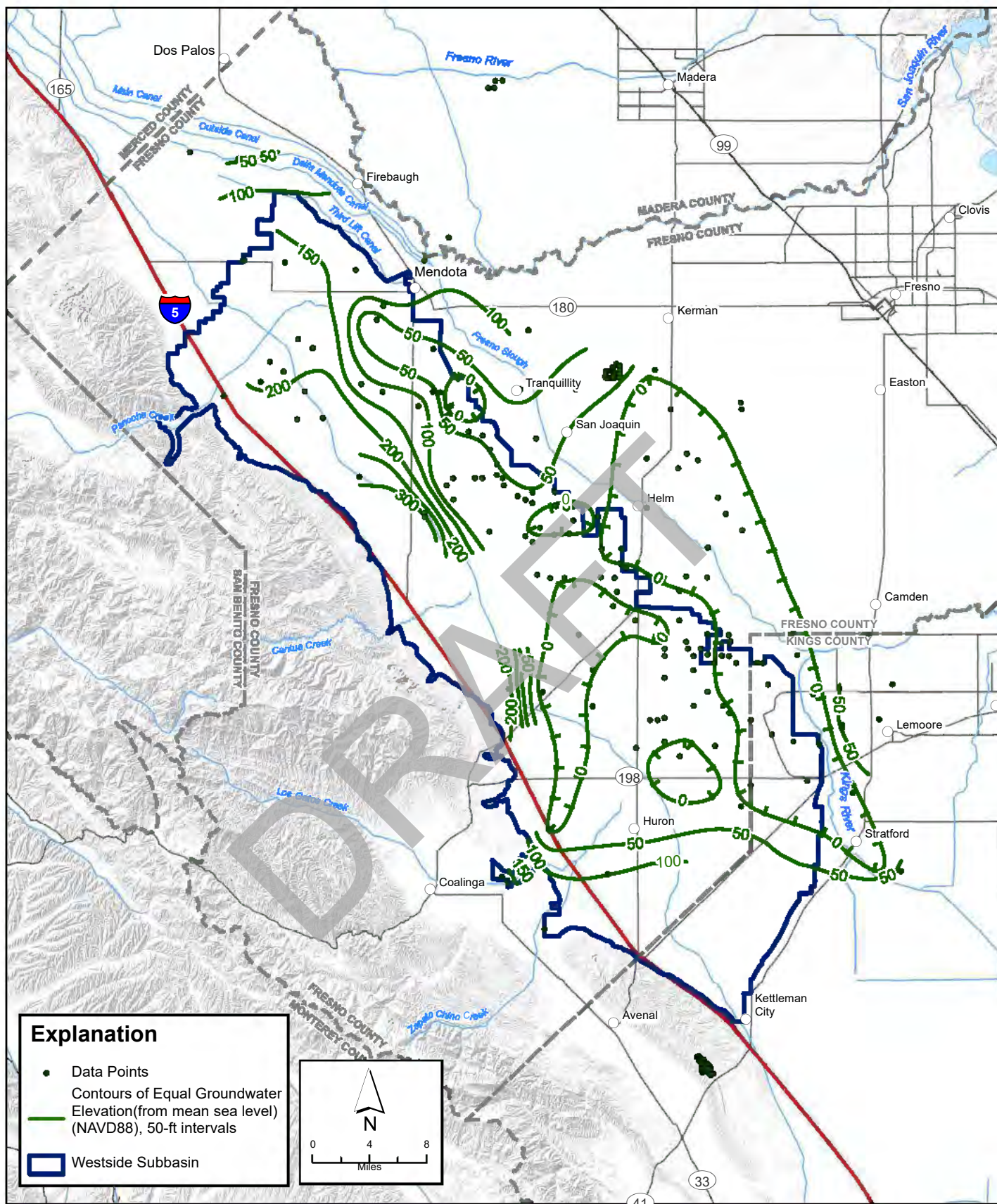
FIGURE 2-34
Panel Map of Selected Graphs of Groundwater Elevations
Lower Aquifer
Groundwater Sustainability Plan
Westside Subbasin



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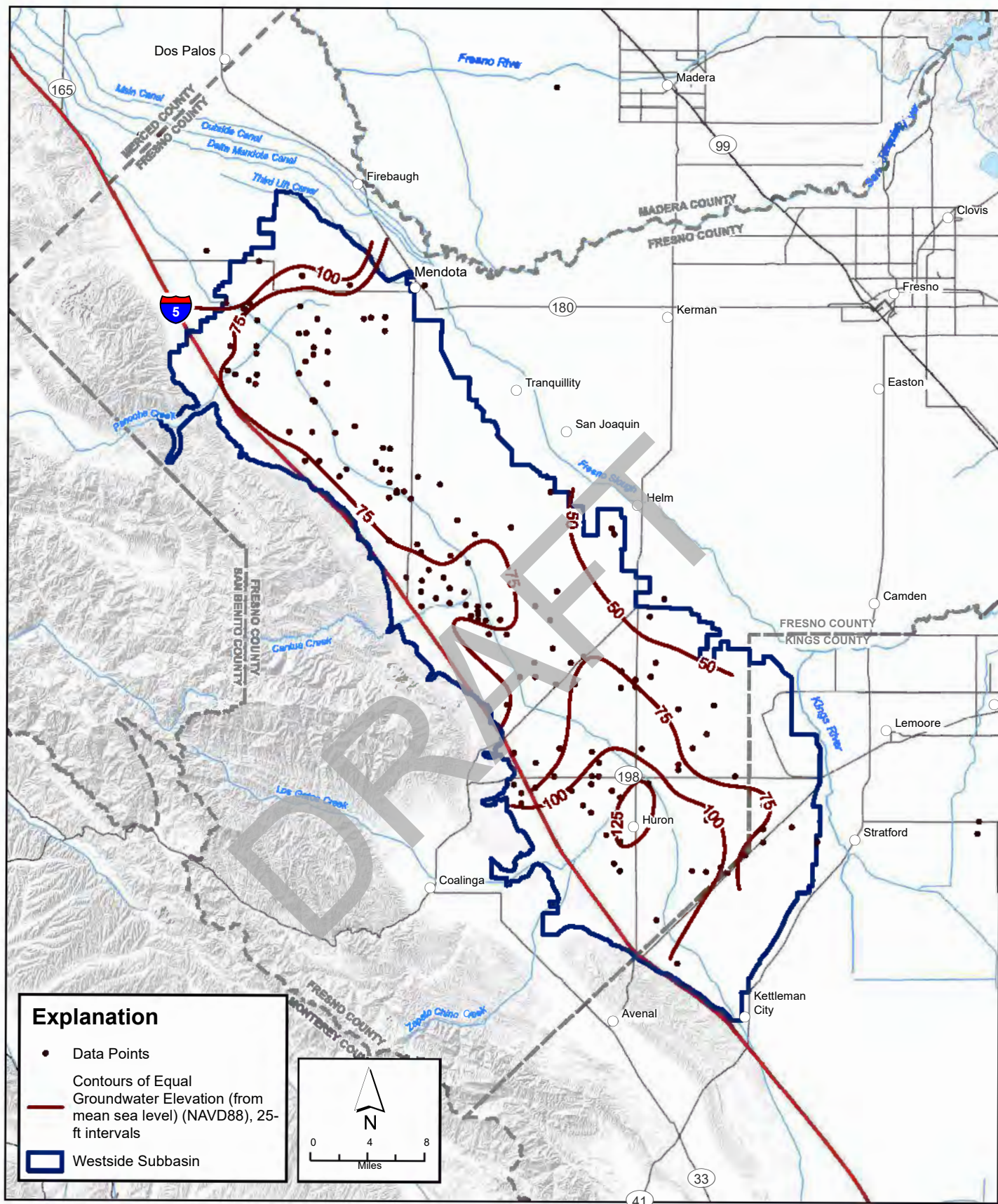
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FIGURE 2-37
Contours of Equal Groundwater Elevation
Upper Aquifer, Winter 2014/2015

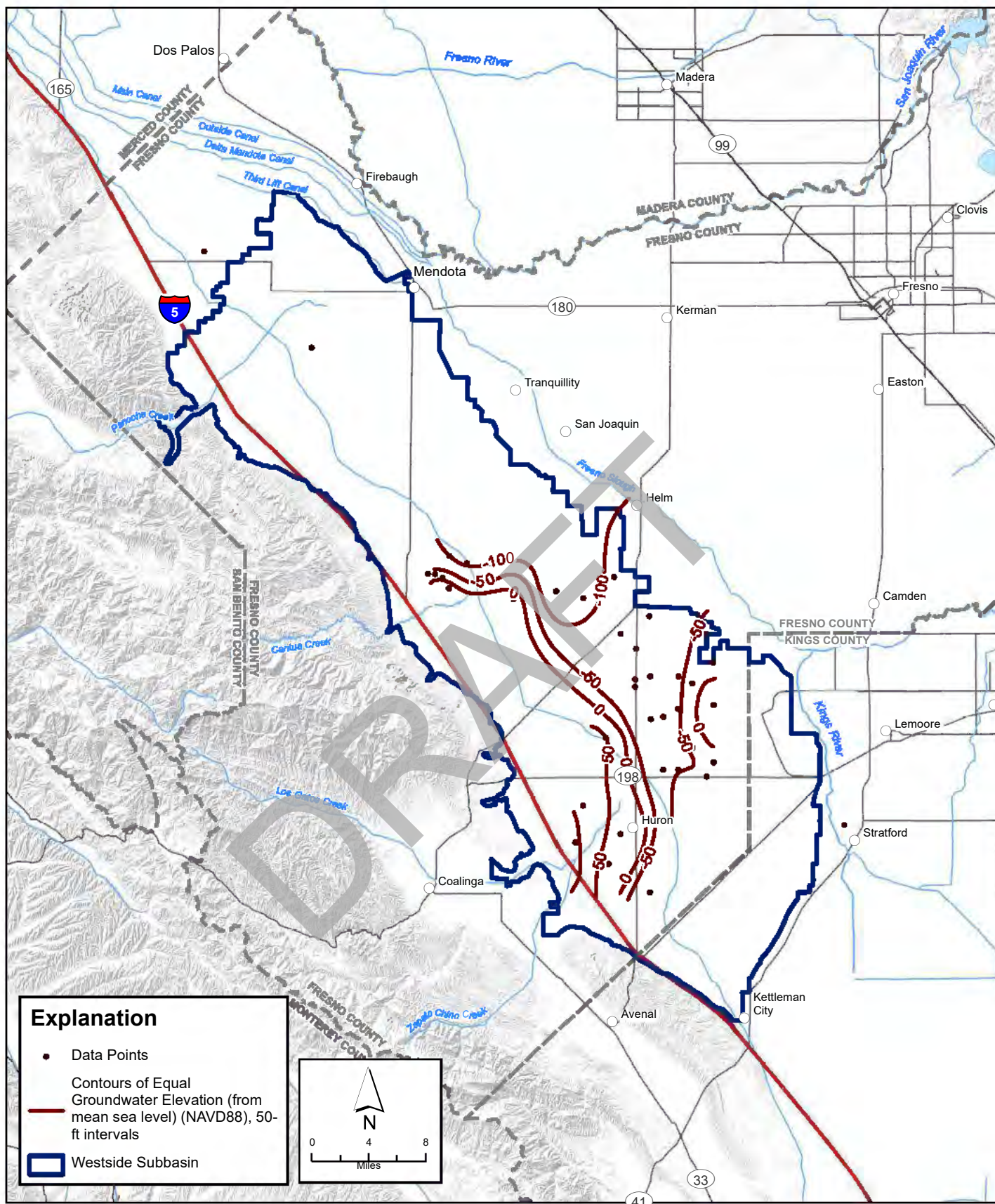
*Groundwater Sustainability Plan
 Westside Subbasin*



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FIGURE 2-38
Contours of Equal Groundwater Elevation
Lower Aquifer, Winter/Spring 2006/2007

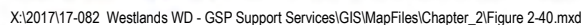
Groundwater Sustainability Plan
Westside Subbasin



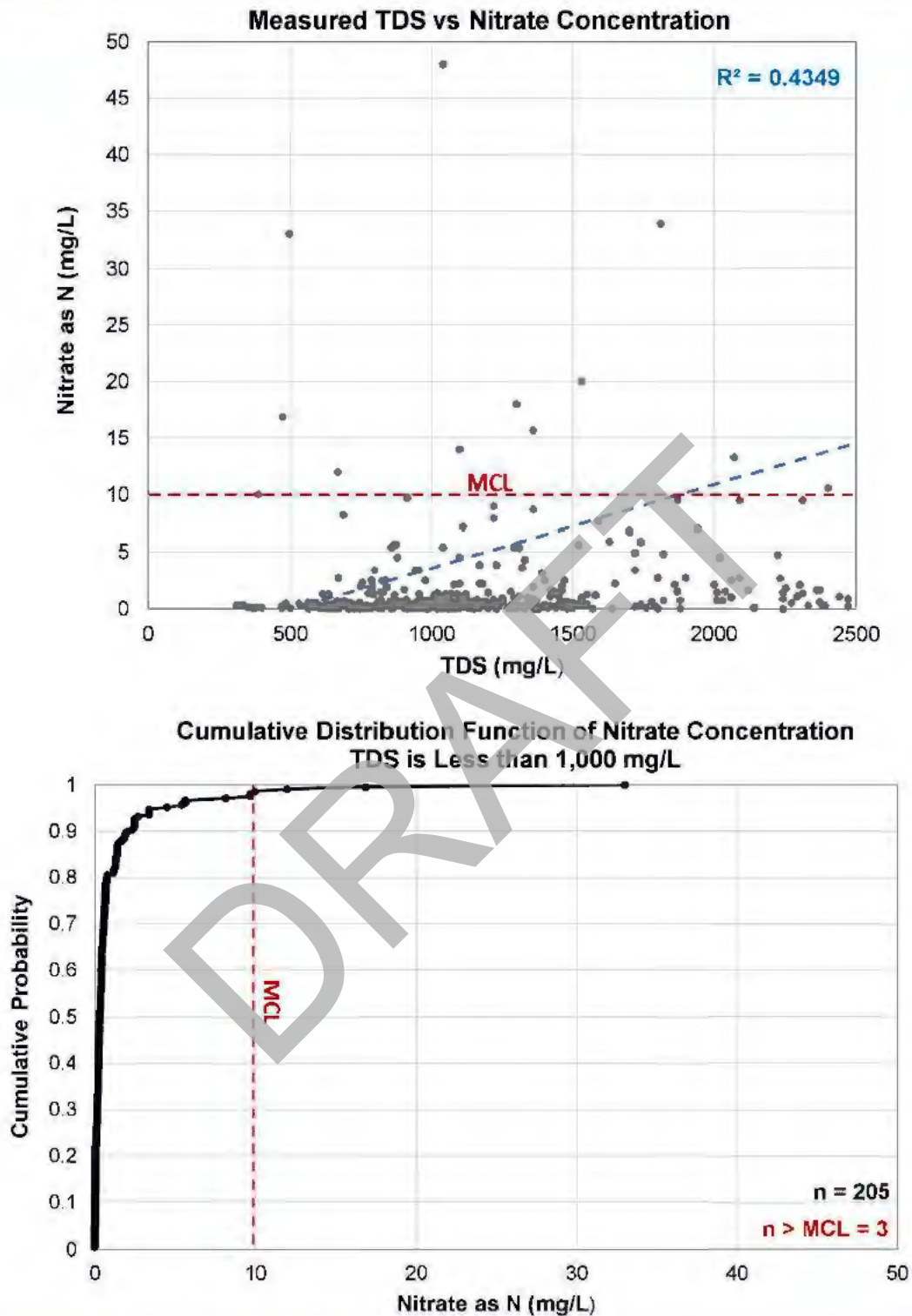
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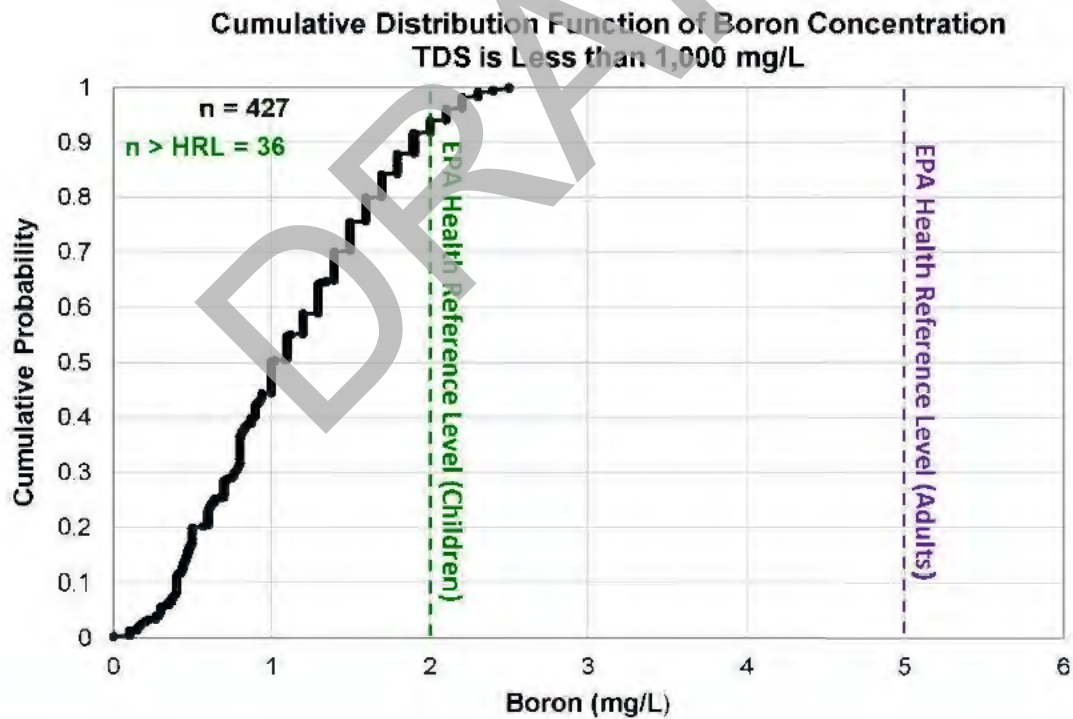
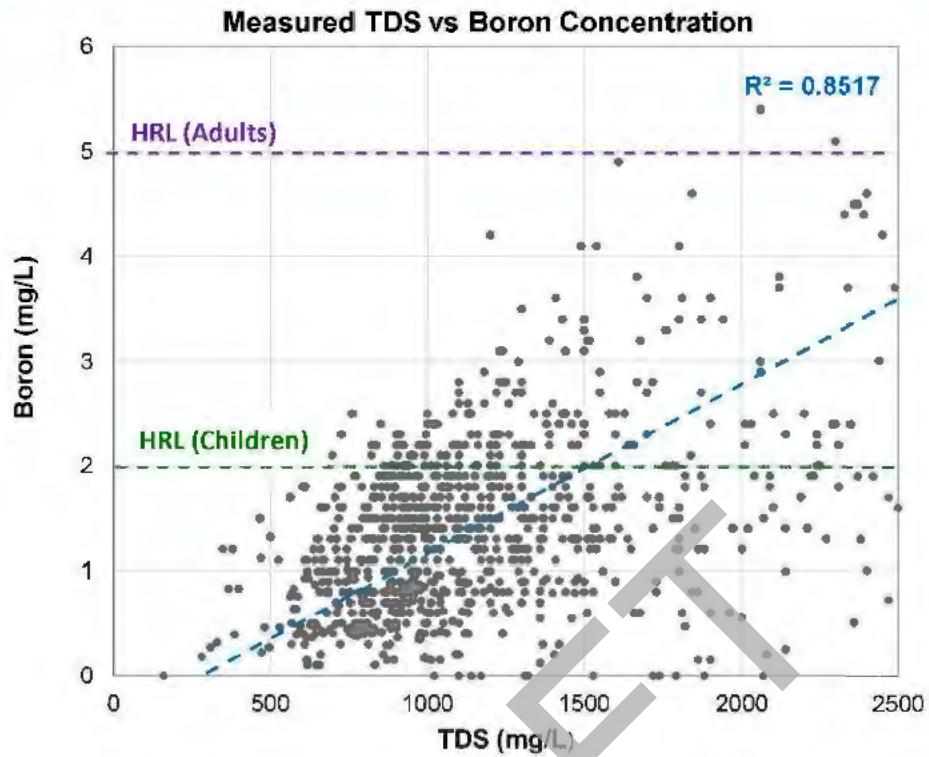
FIGURE 2-39
Contours of Equal Groundwater Elevation
Lower Aquifer, Summer/Fall 2009

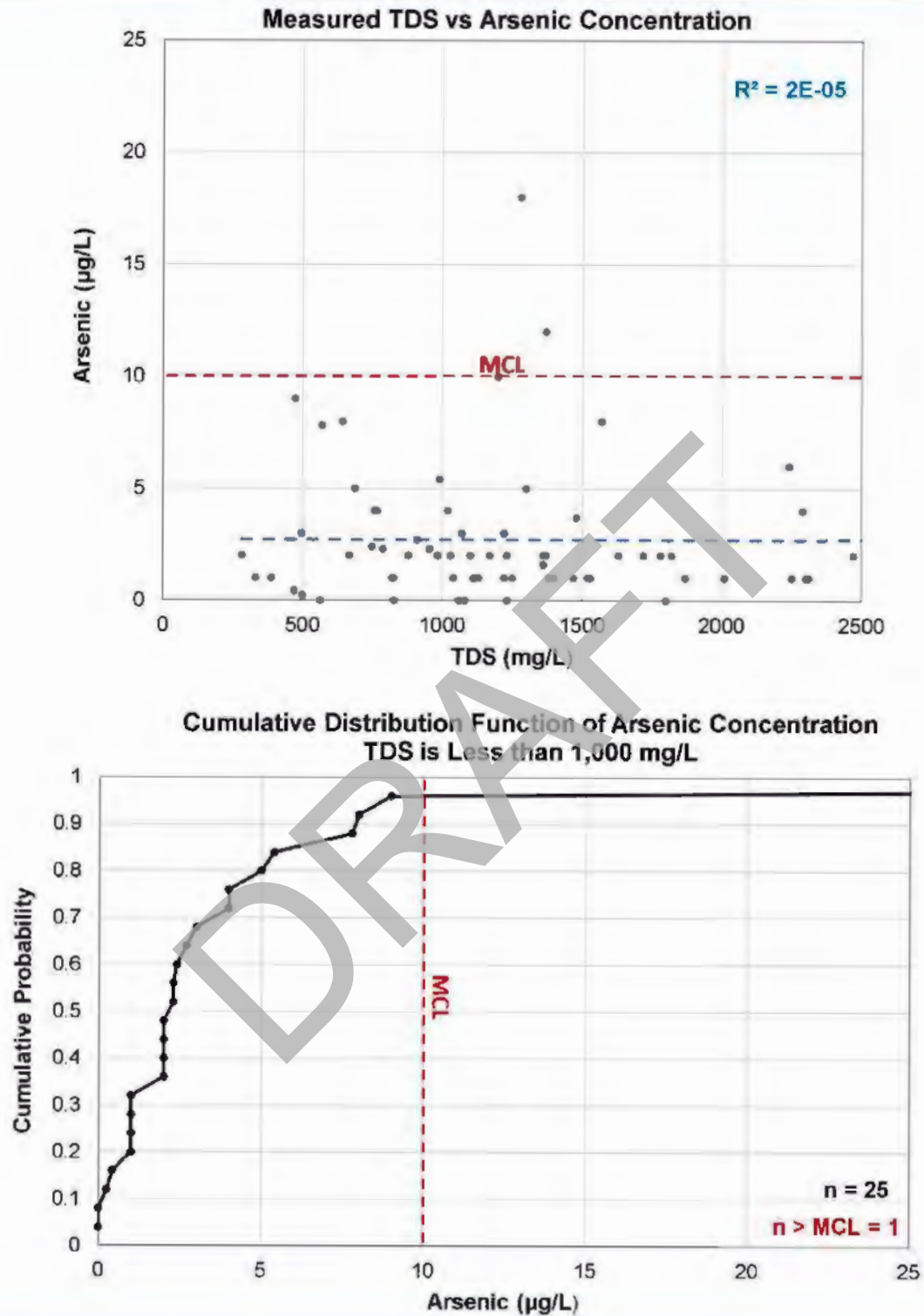
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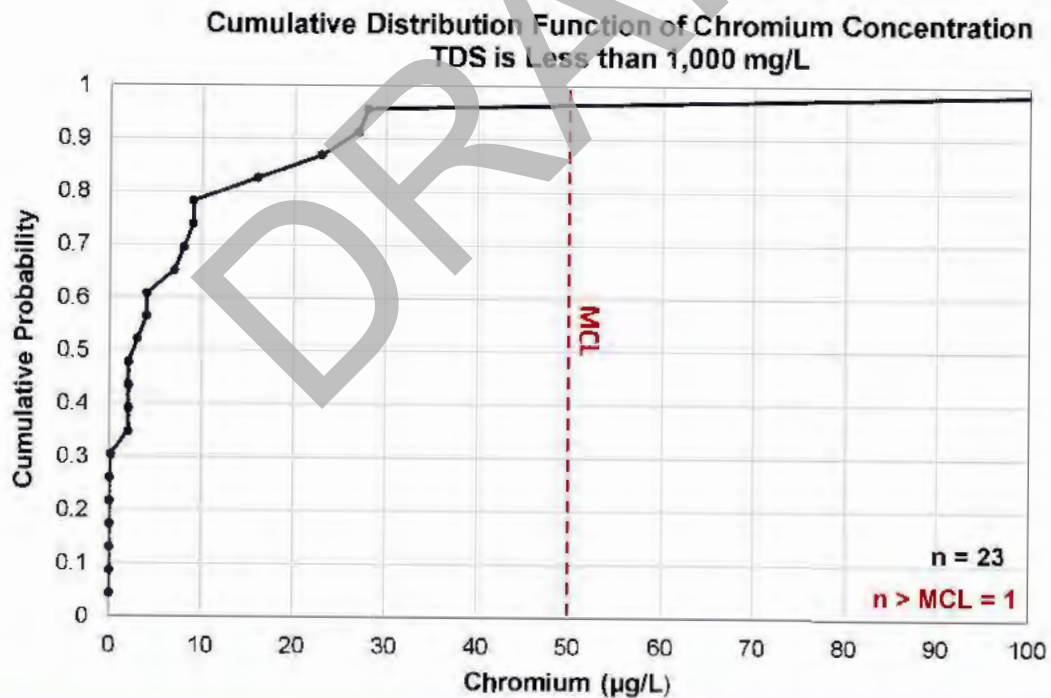
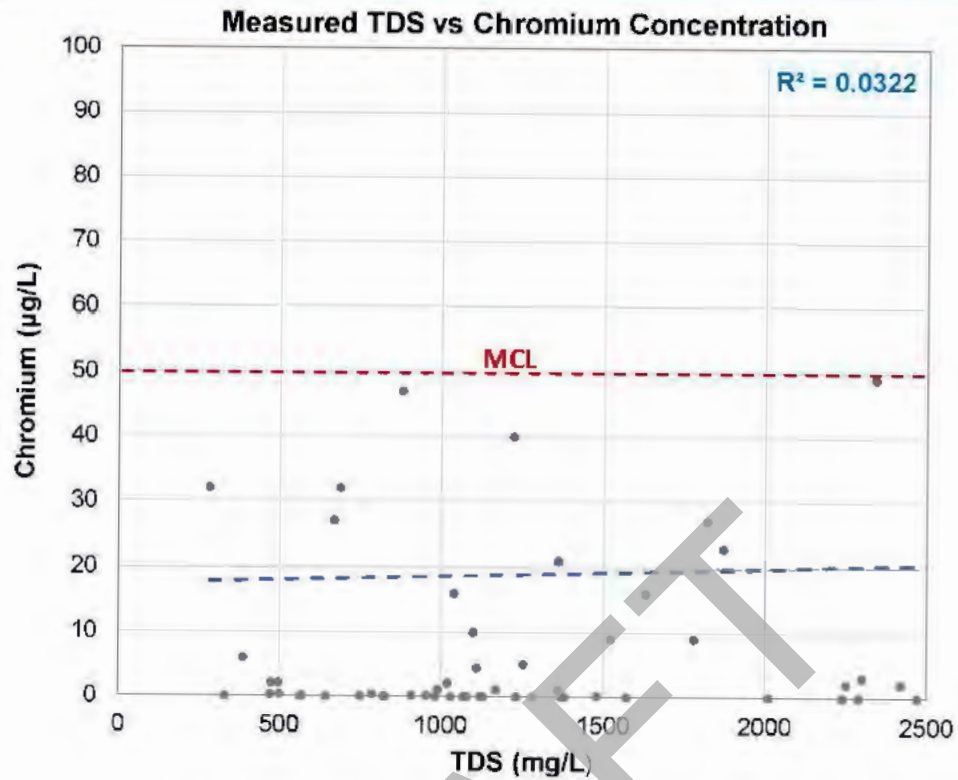


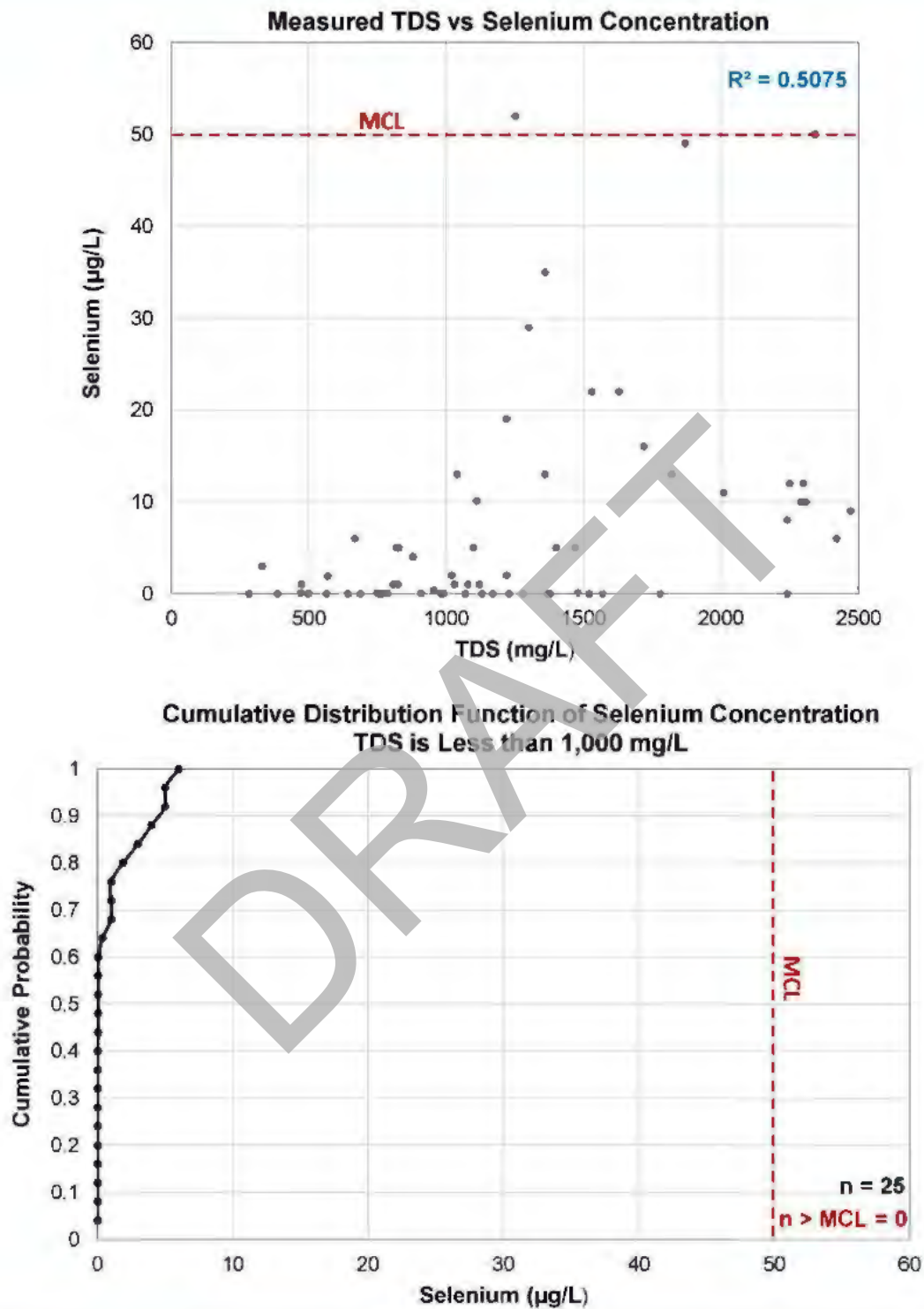
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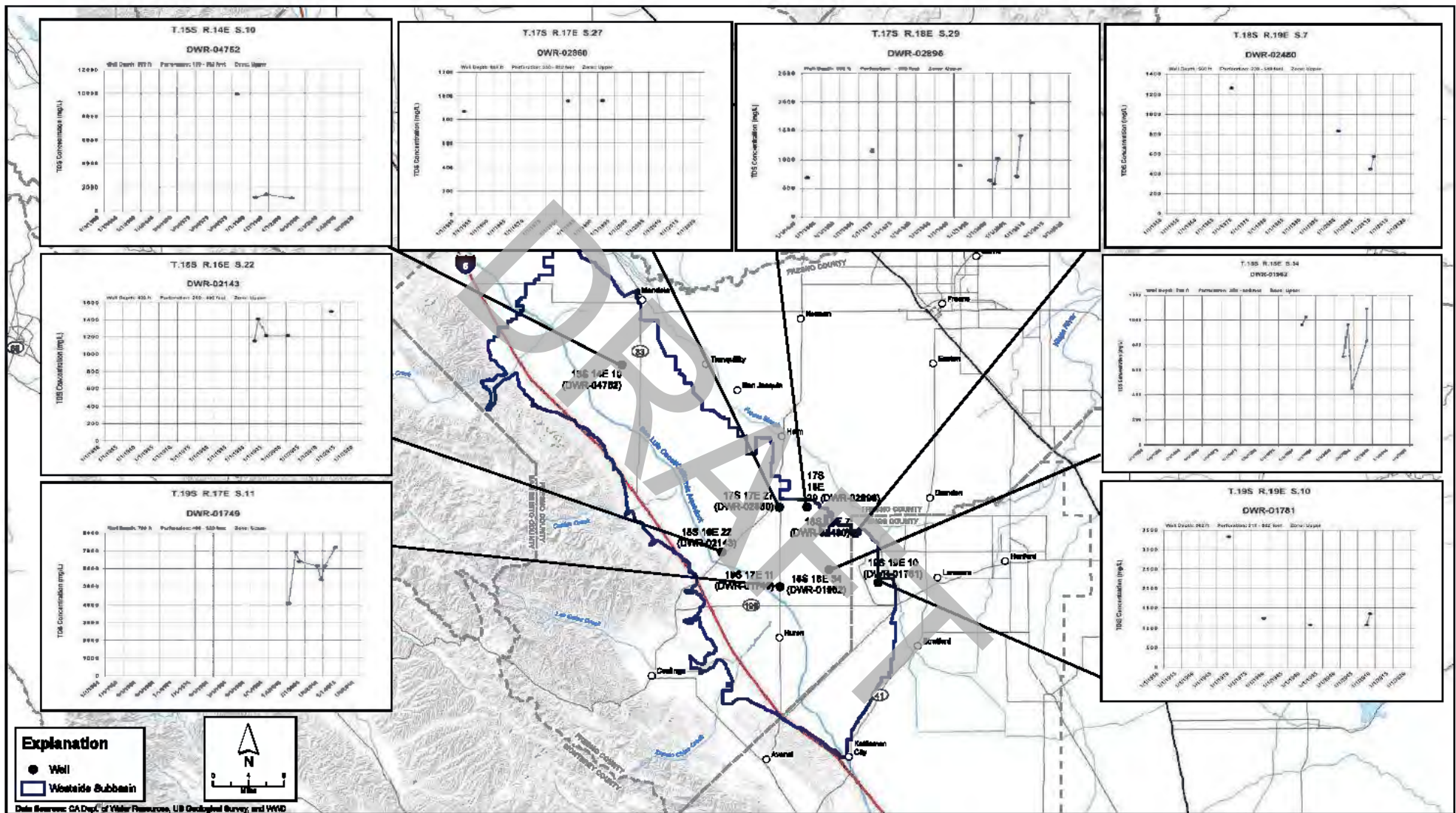








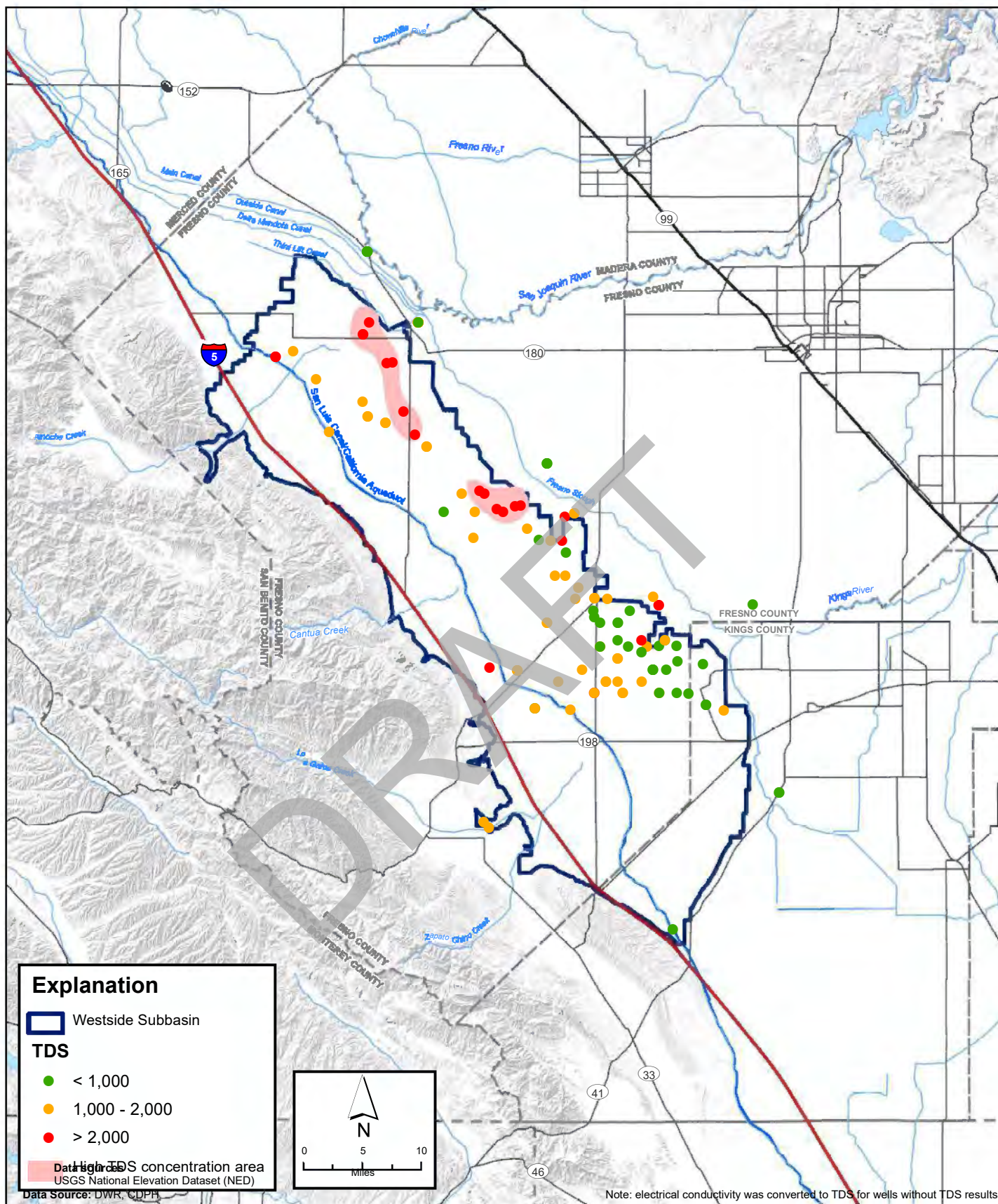




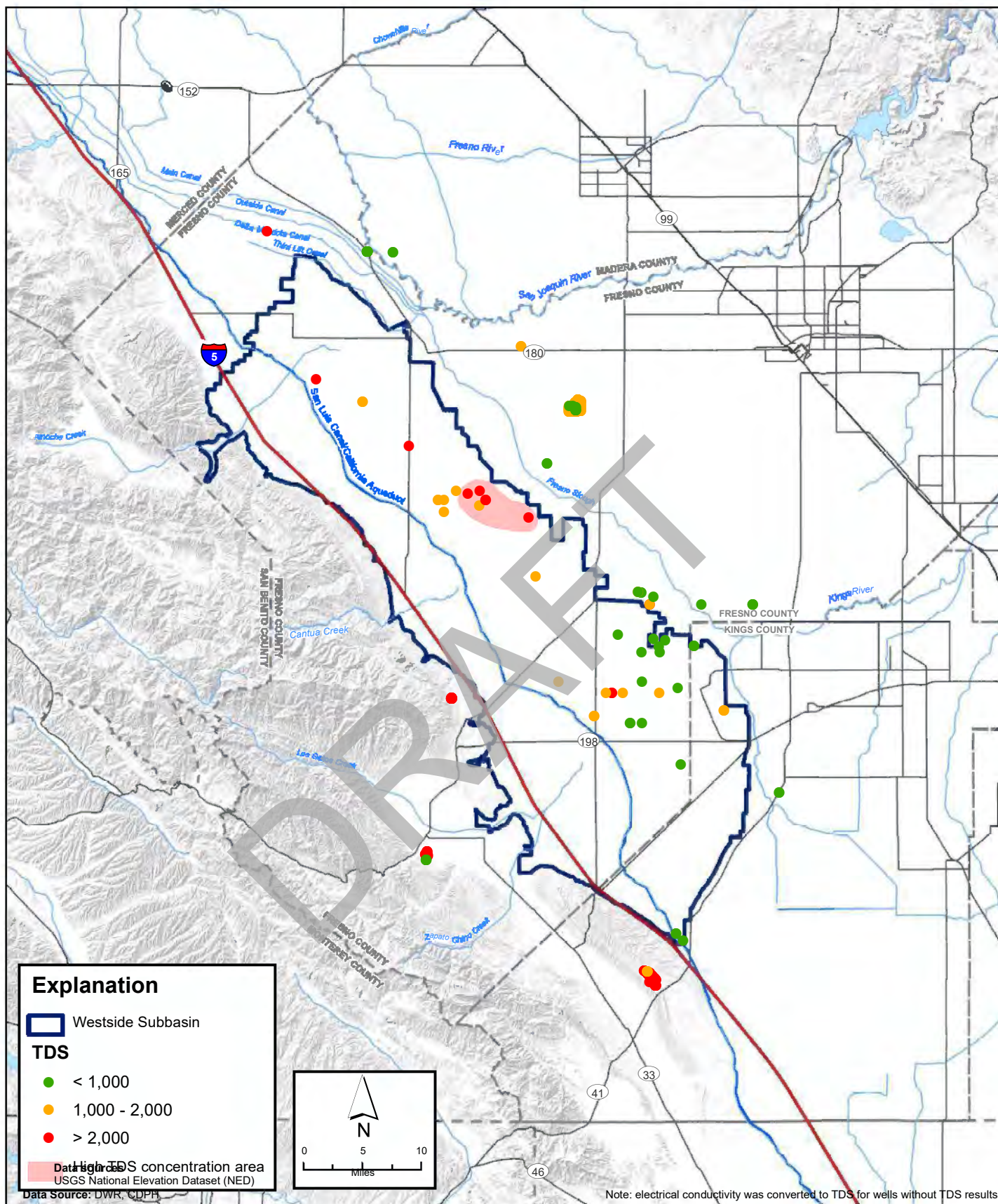
**FIGURE 2-41
SELECT GRAPHS OF TDS CONCENTRATION
UPPER AQUIFER**

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Westside Subbasin*

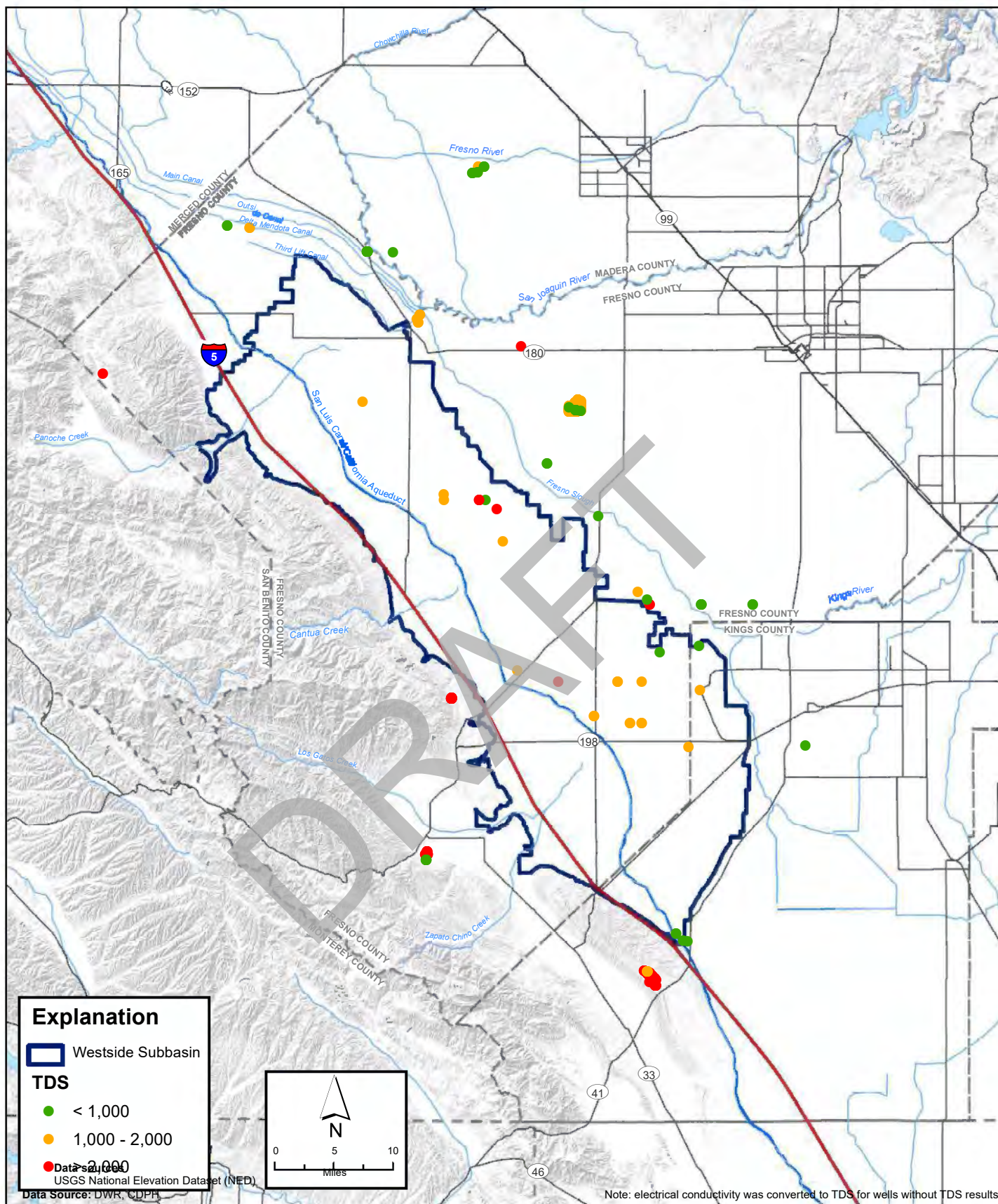
Groundwater Sustainability Plan
Monte Subbasin



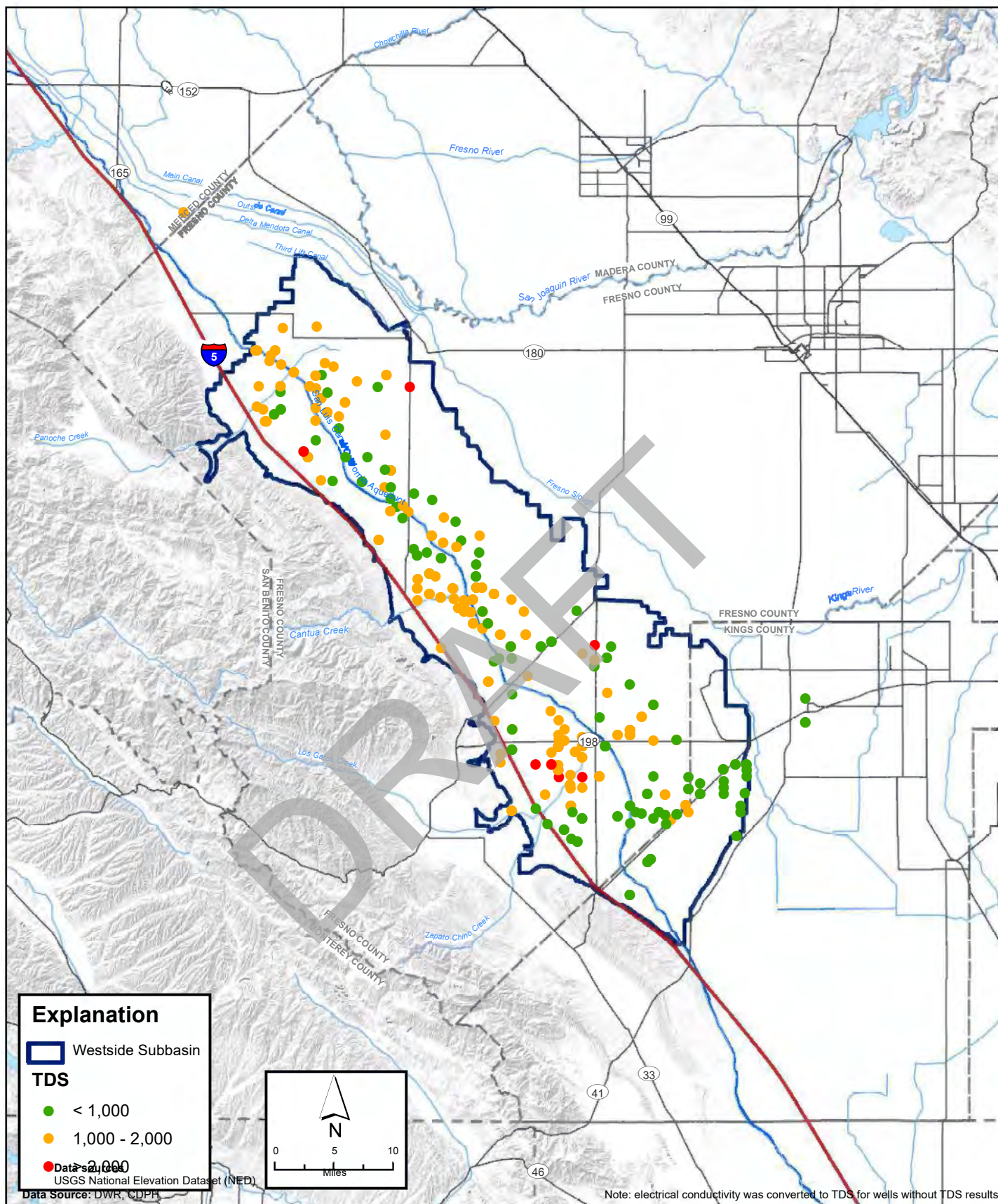
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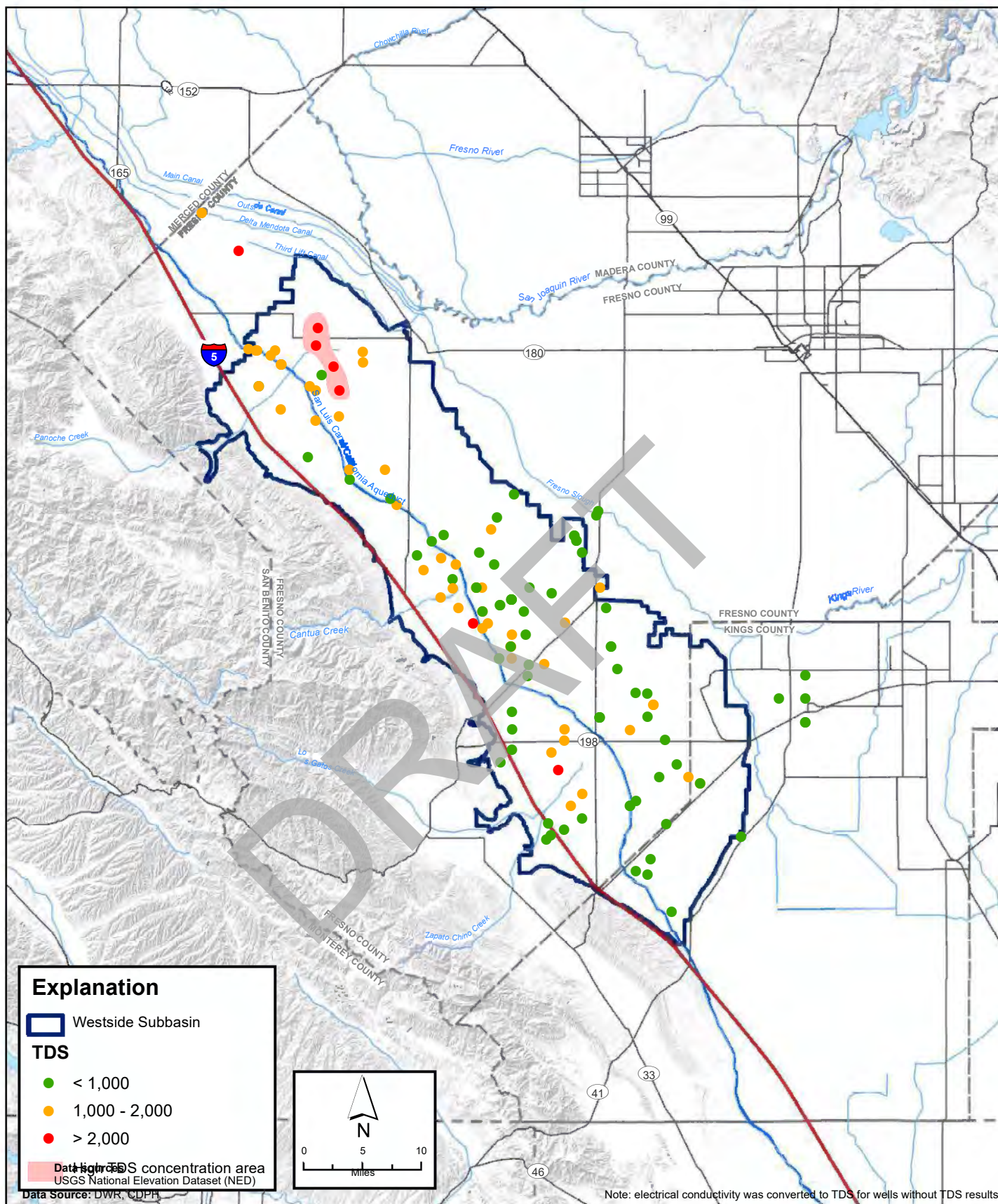
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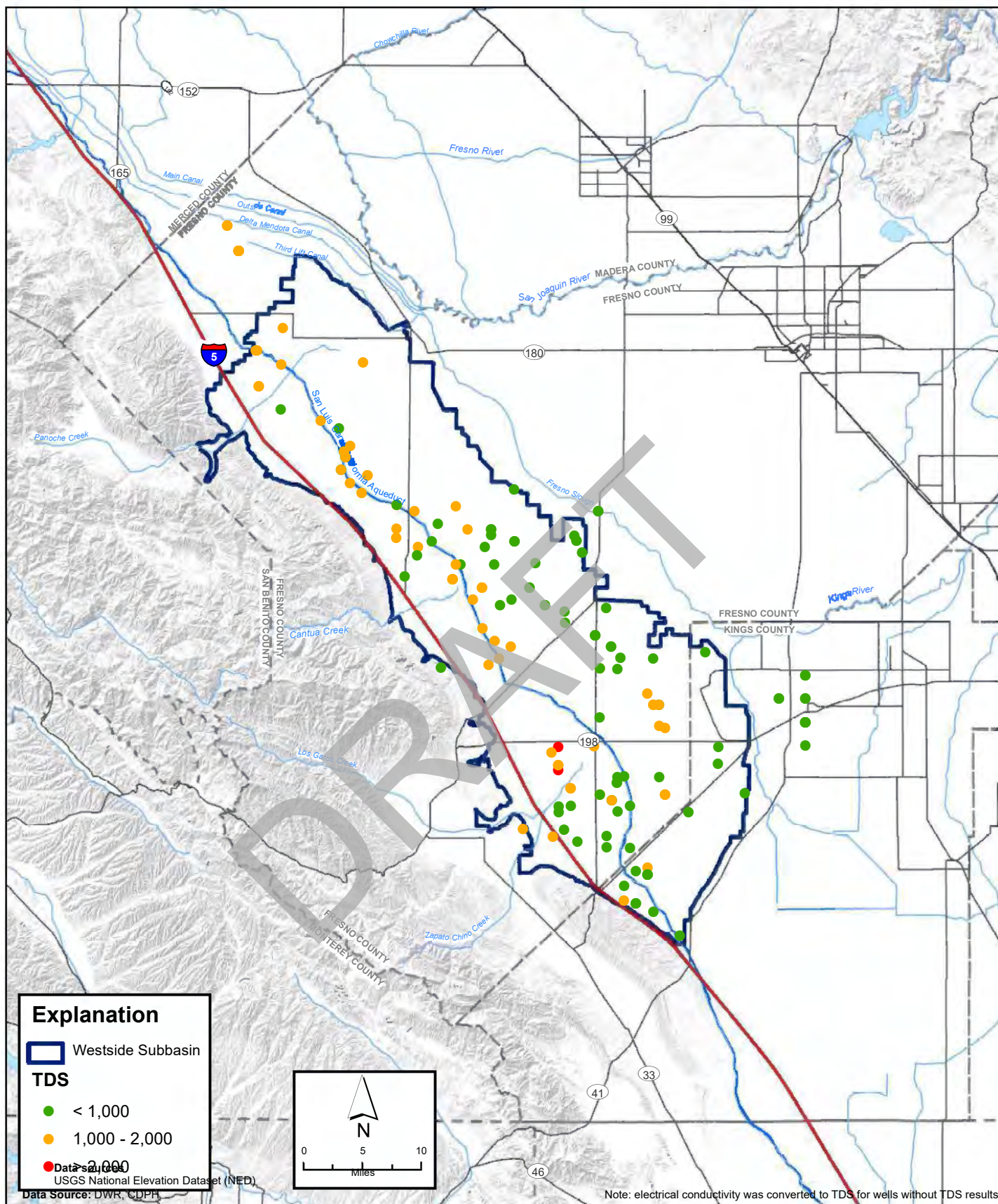
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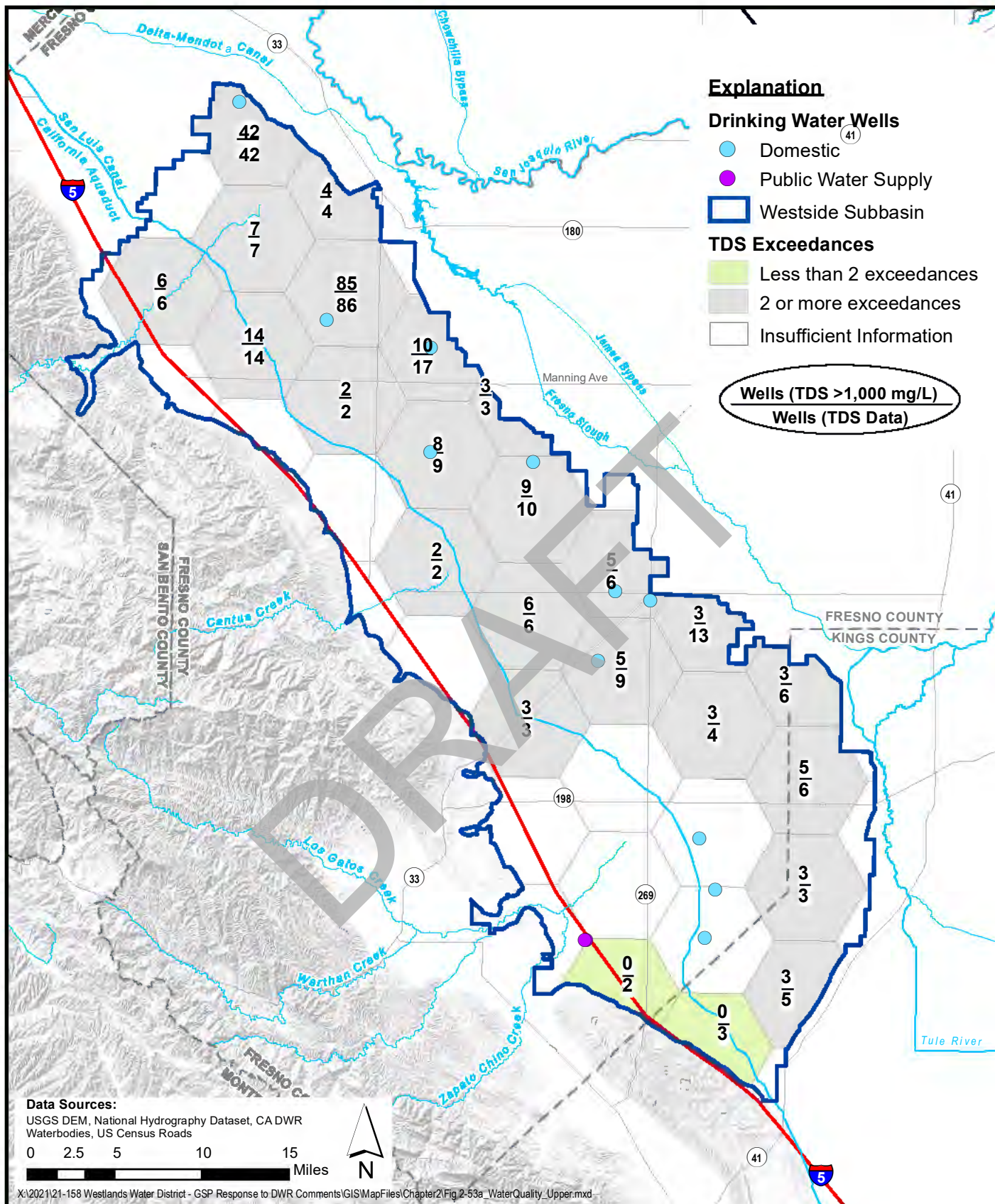
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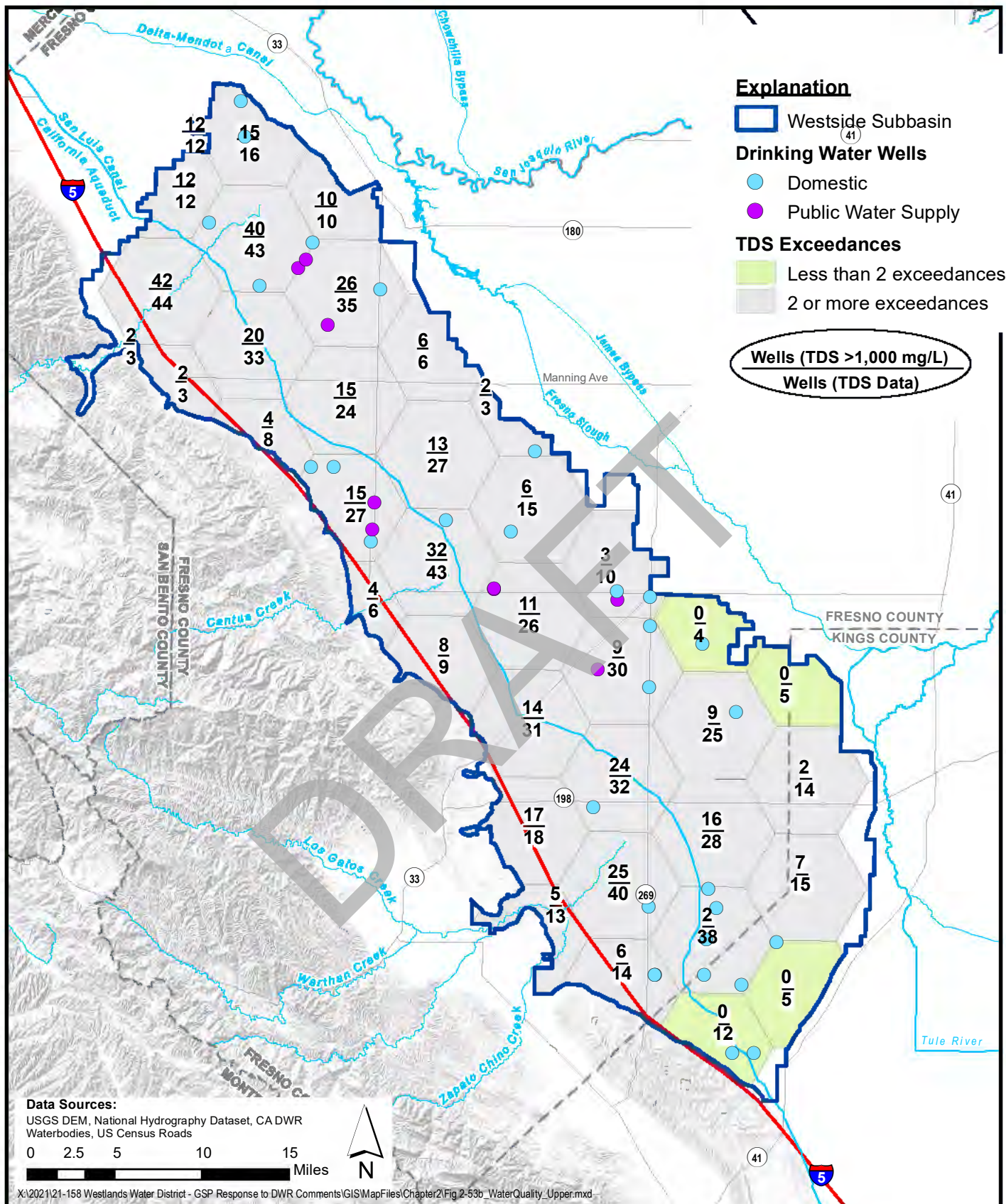
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Summary of Measured TDS in Groundwater Wells (Upper Aquifer)

SGMA Sustainability Analyses
Westside Subbasin

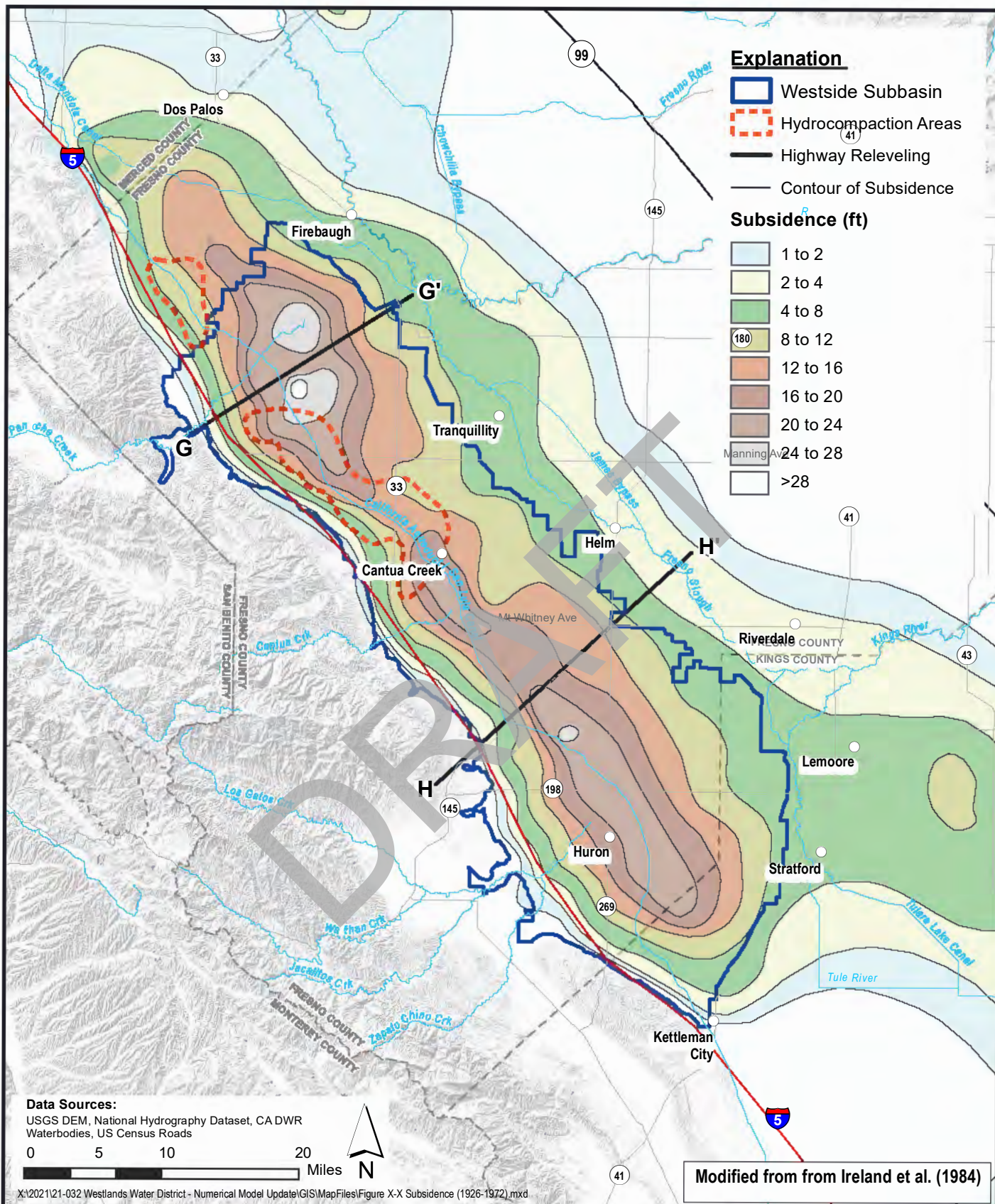
Figure 2-53a



Summary of Measured TDS in Groundwater Wells (Lower Aquifer)

SGMA Sustainability Analyses
 Westside Subbasin

Figure 2-53b



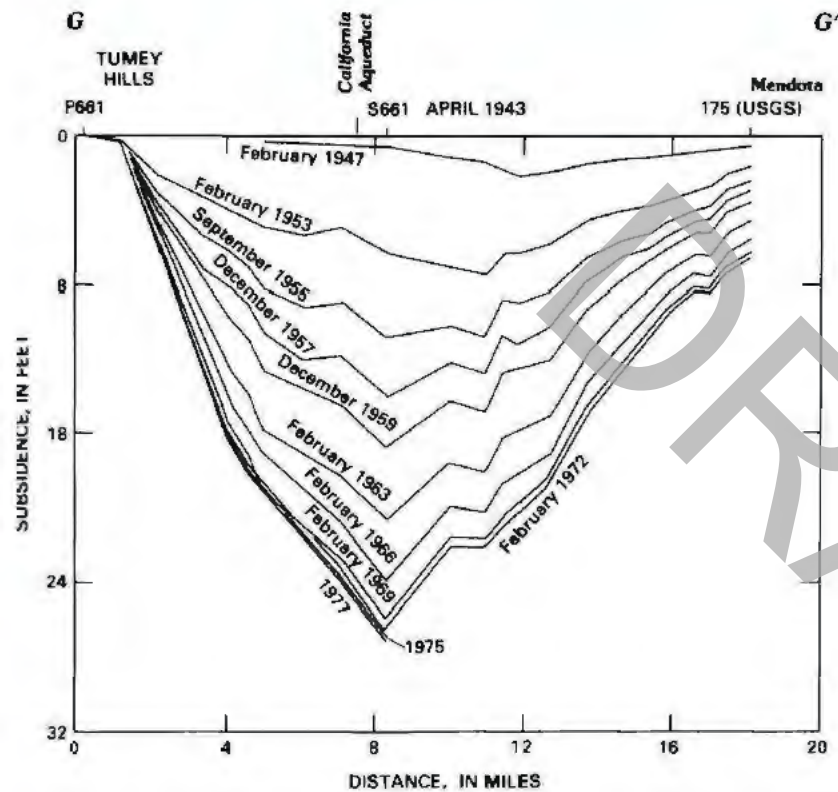


FIGURE 18.—Profiles of subsidence, 1943-77, Tumey Hills to Mendota.

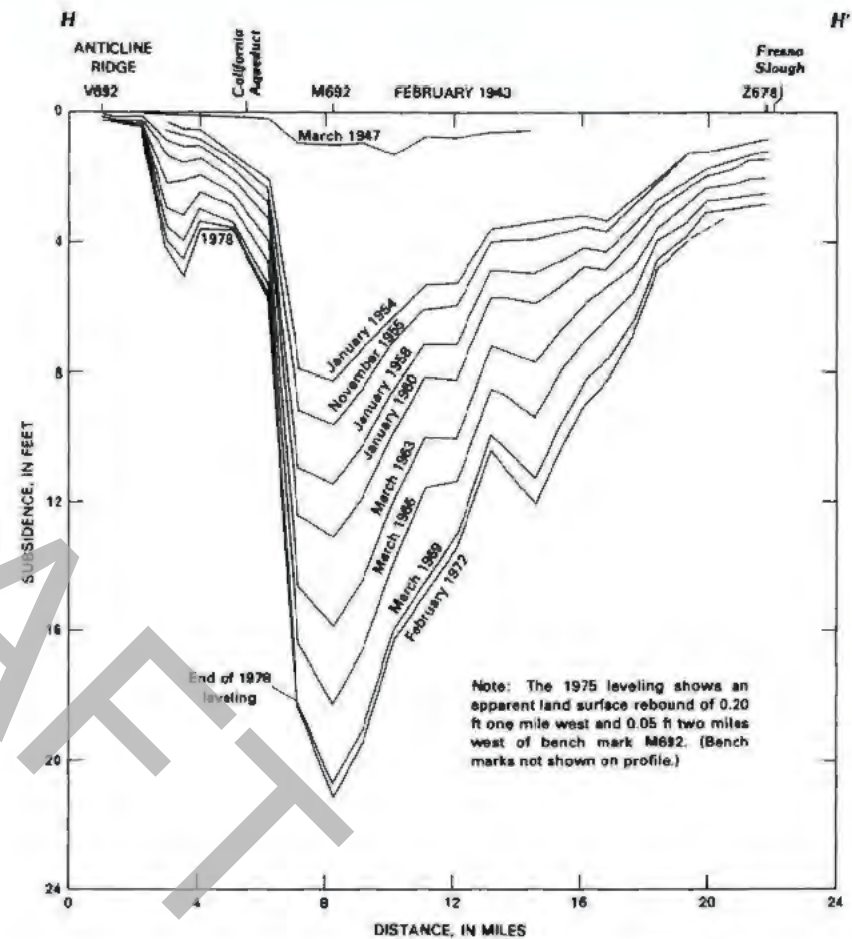
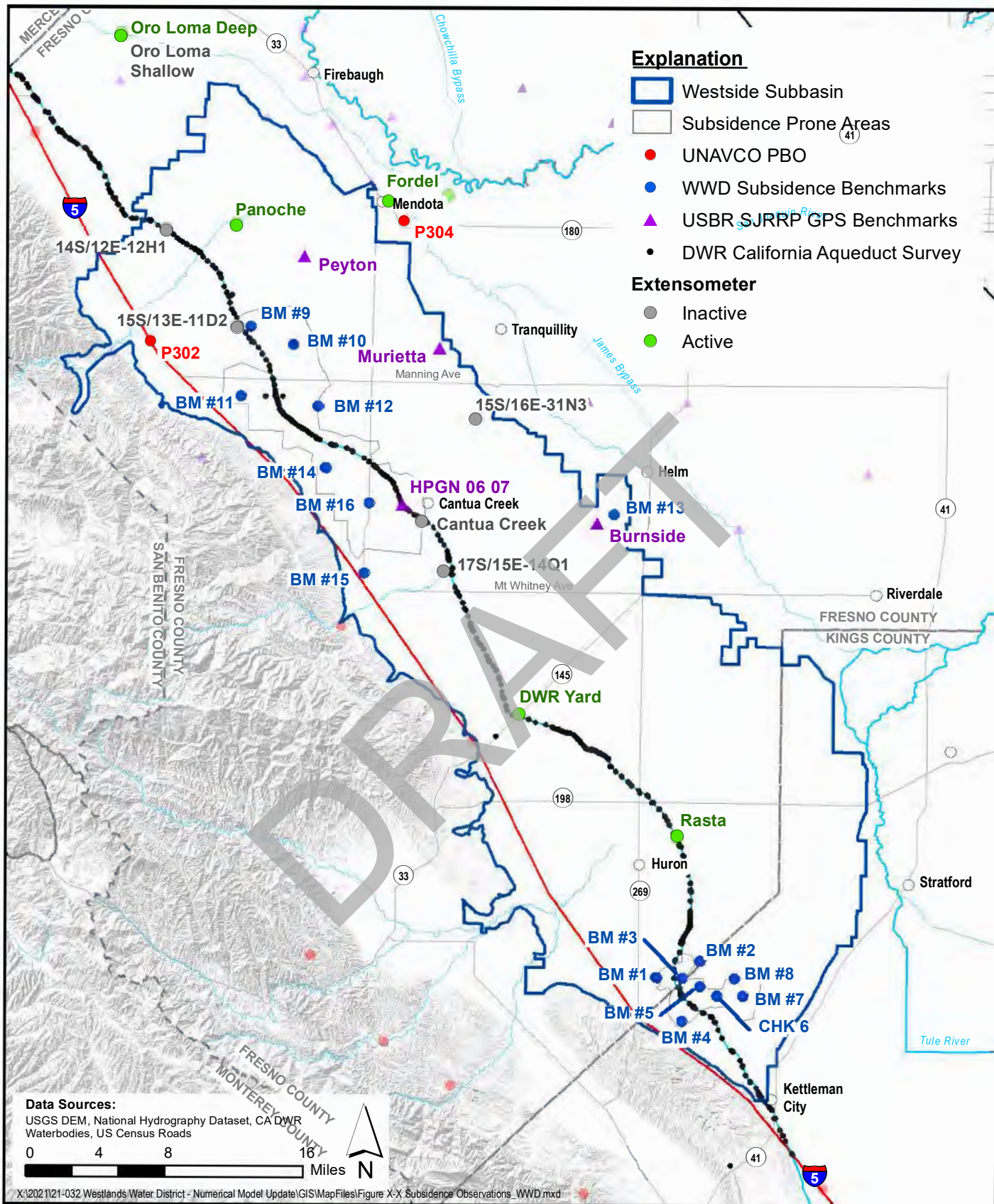


FIGURE 19.—Profiles of subsidence, 1943-78, Anticline Ridge to Fresno Slough.

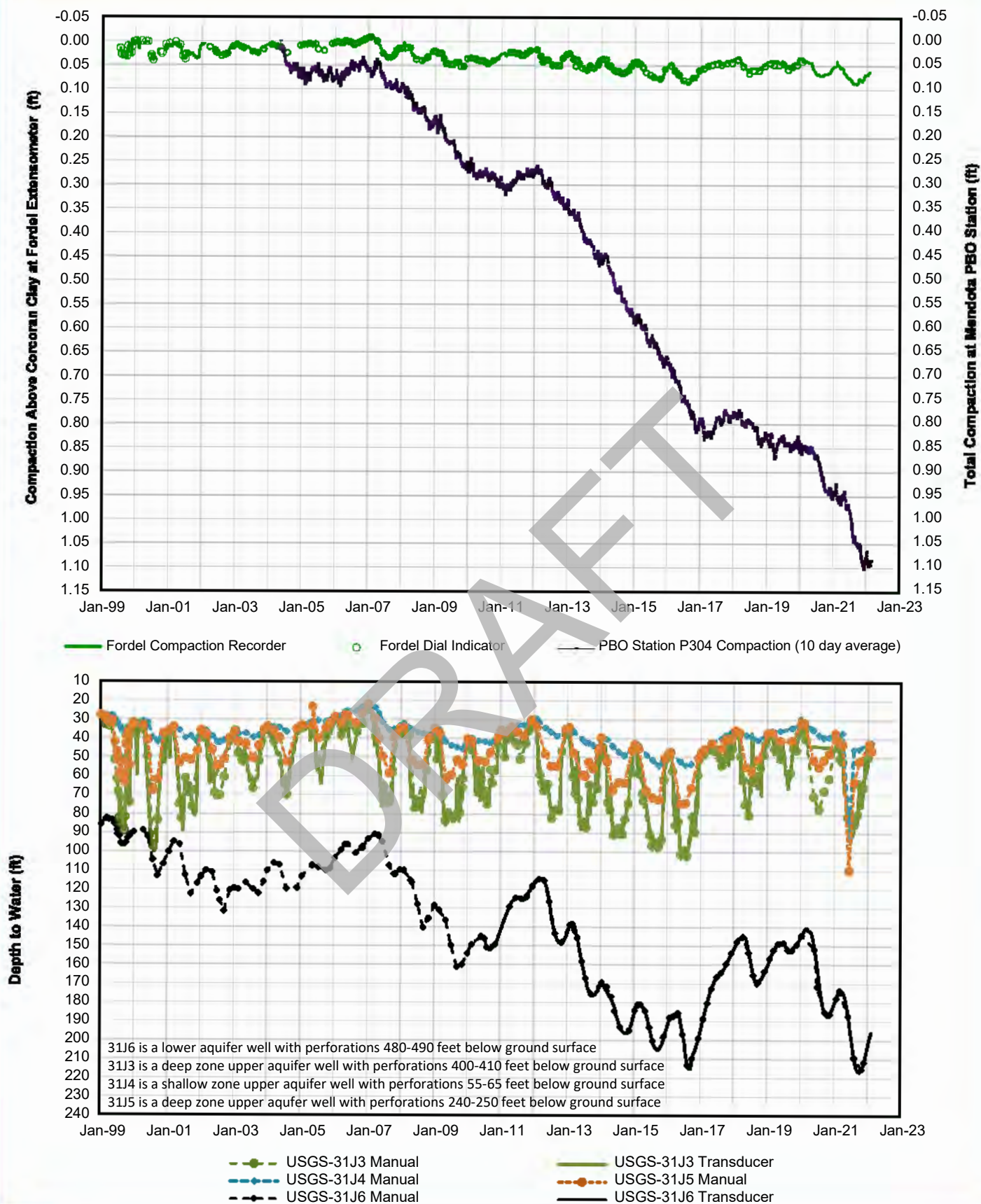
From Ireland et. al (1984)

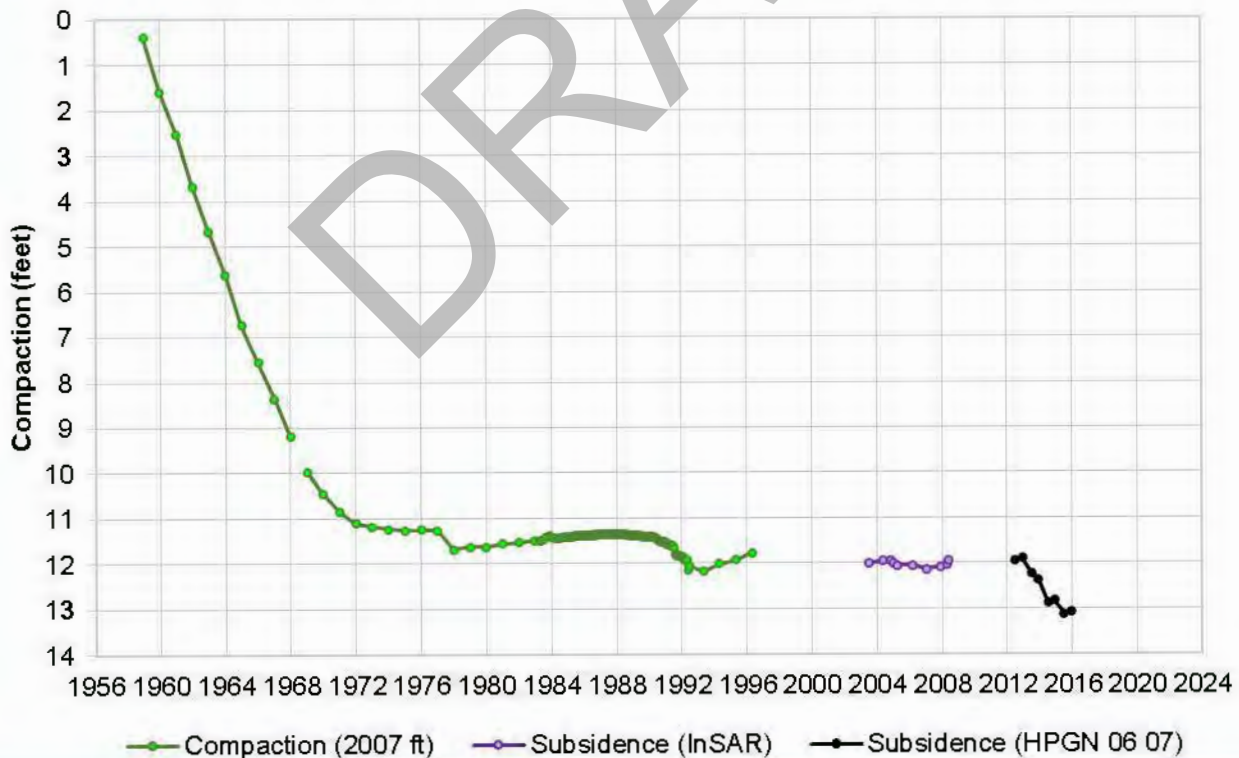
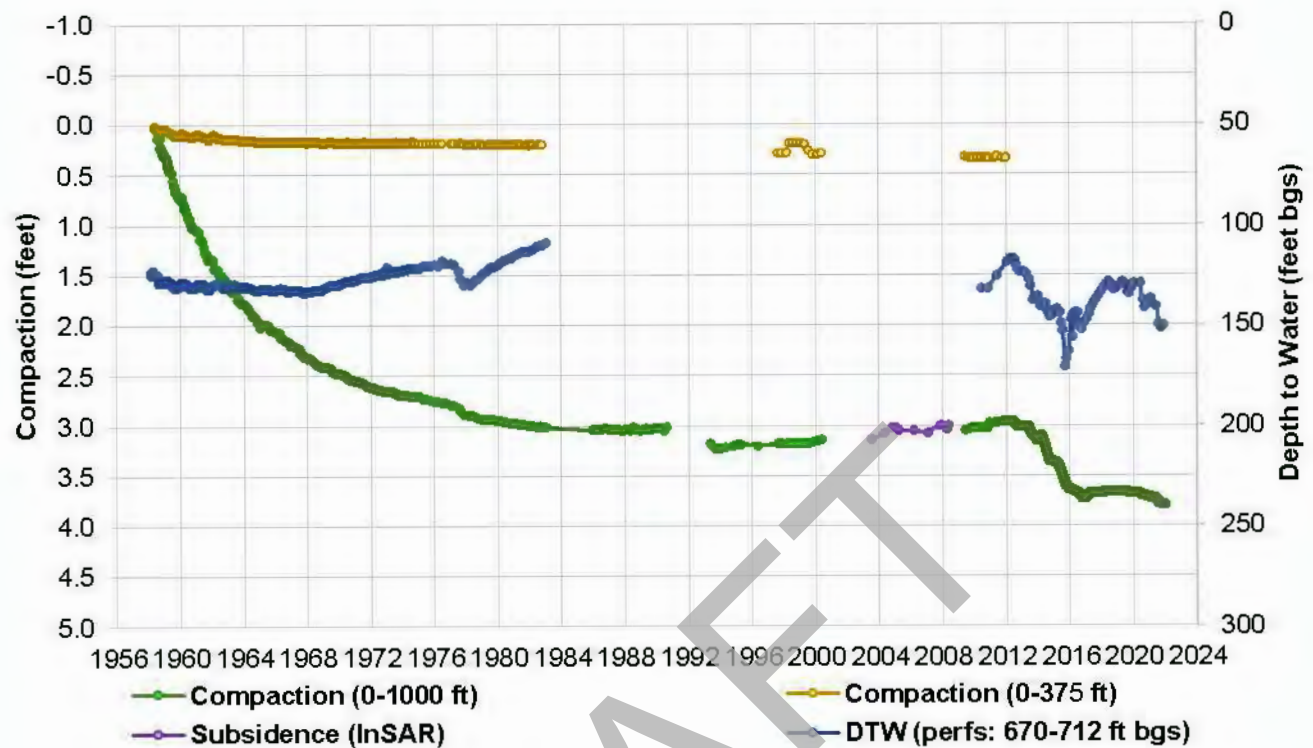


Subsidence Observations in and Adjacent to the Westside Subbasin

SGMA Sustainability Analyses
Westside Subbasin

Figure 2-59

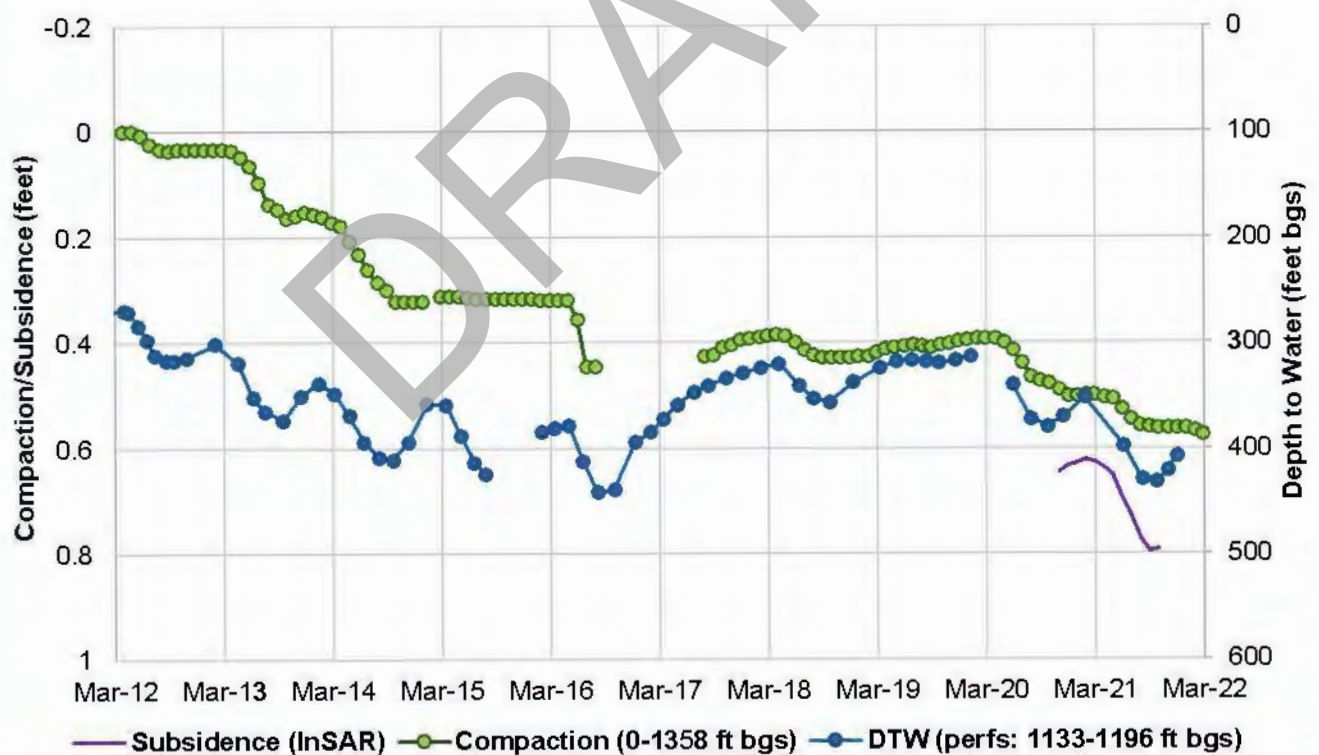
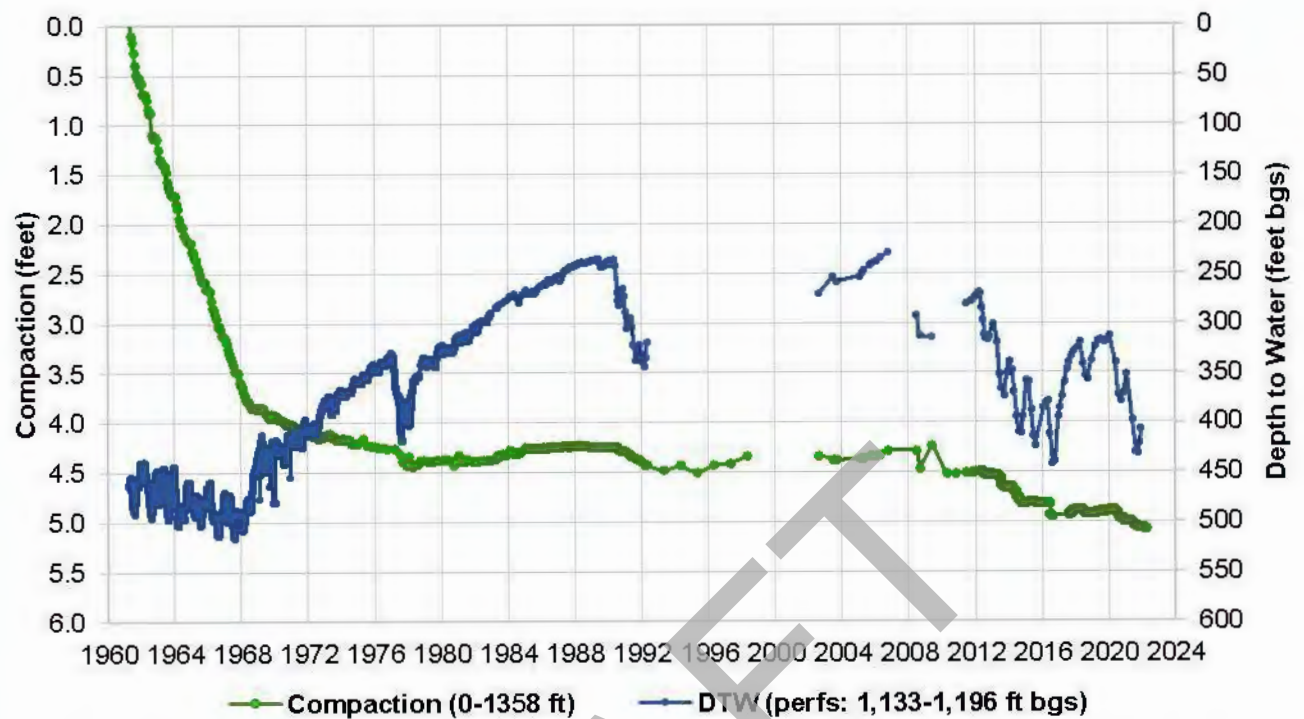


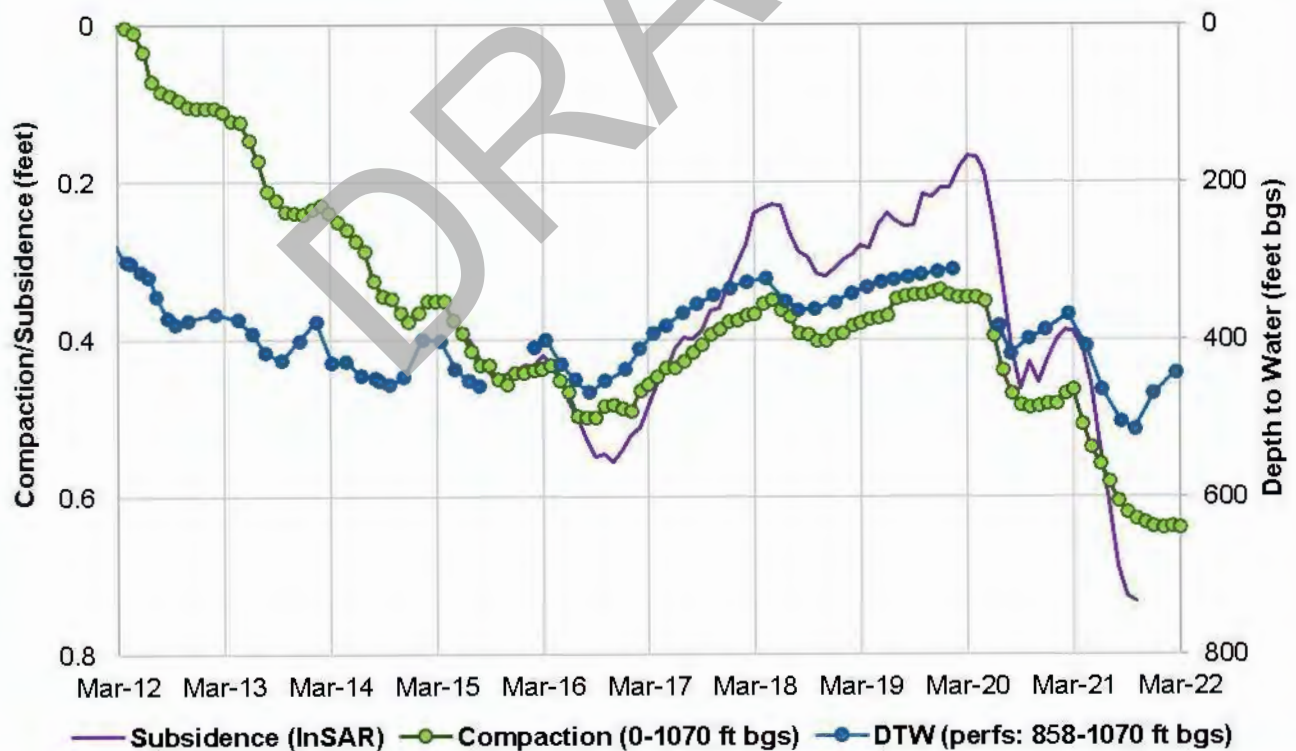
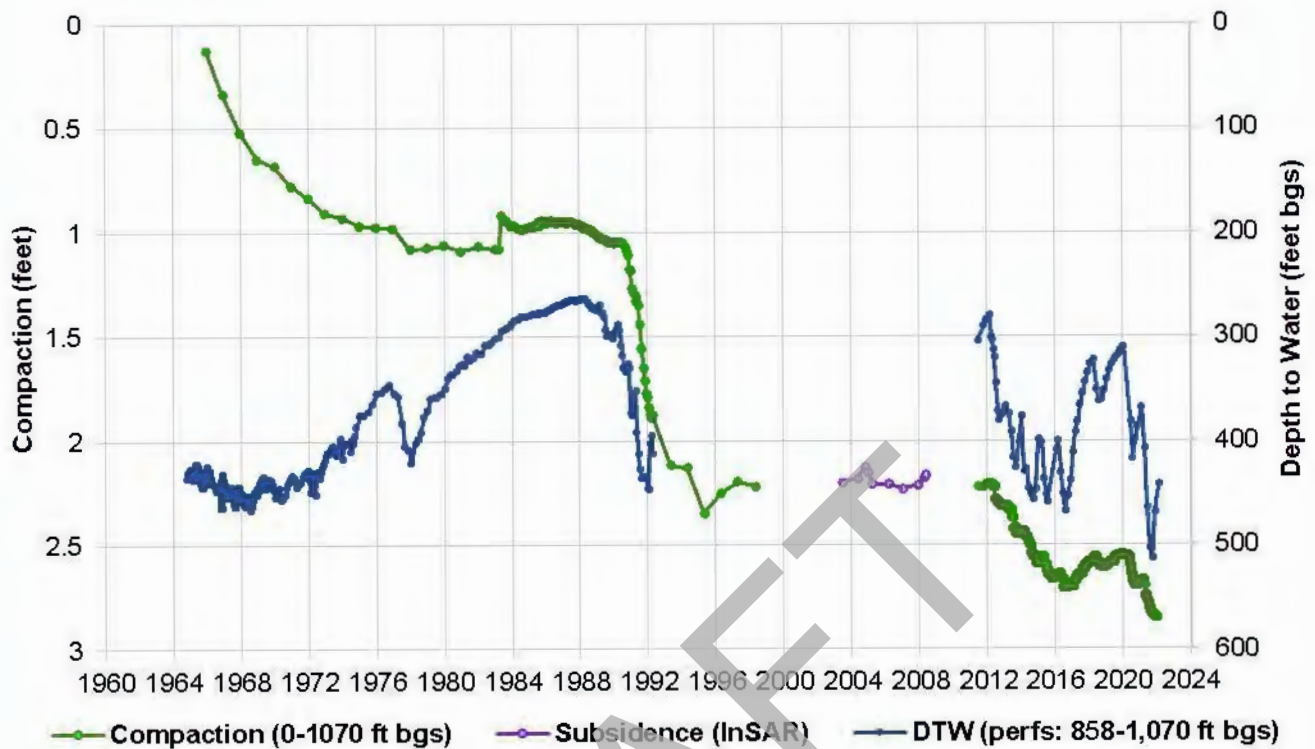


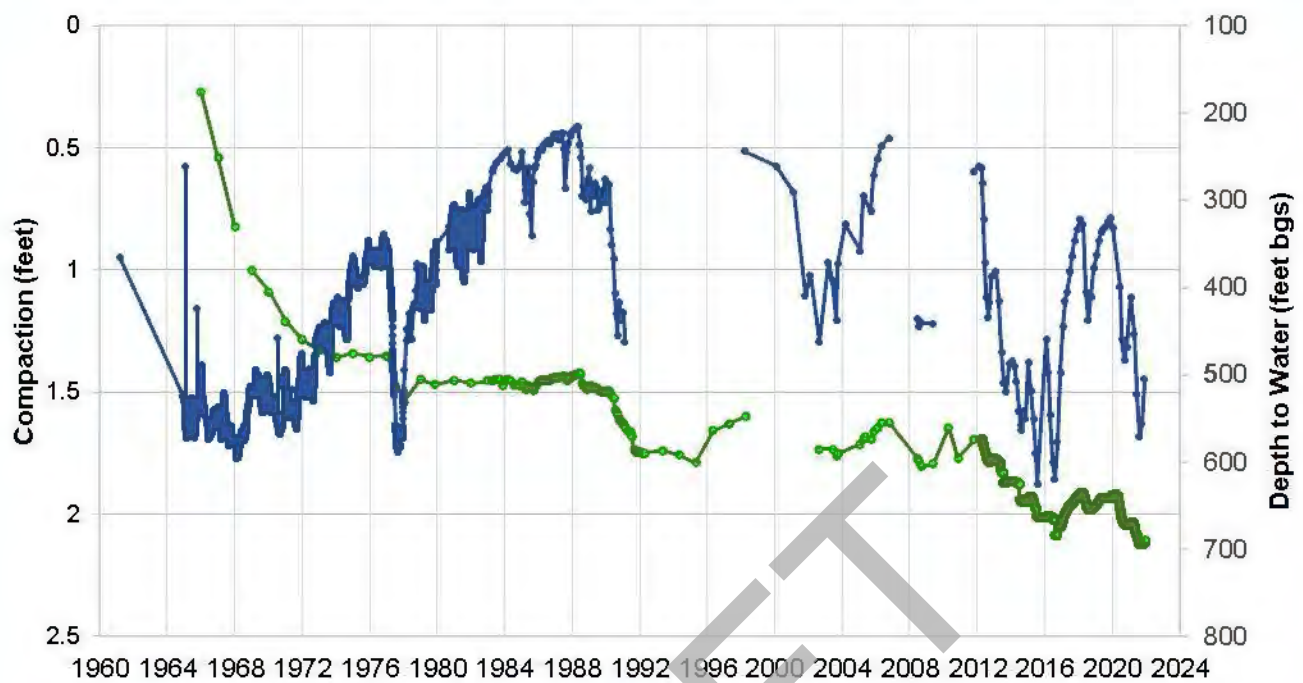
**Luhdorff &
Scalmanini**
Consulting Engineers

**Compaction, Subsidence and Depth to Water
Oro Loma (12S/12E-16H) and Cantua Creek (16S/15E/34N)
Extensometers**
SGMA Sustainability Analysis
Westside Subbasin

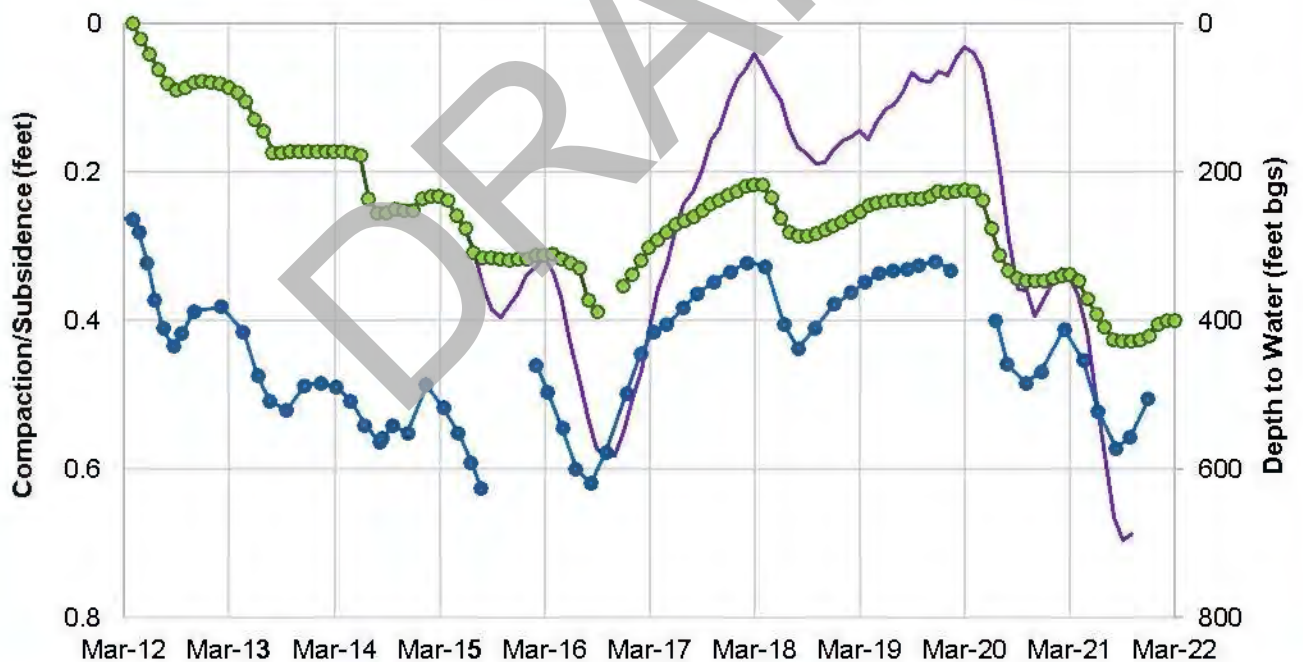
Figure 2-61



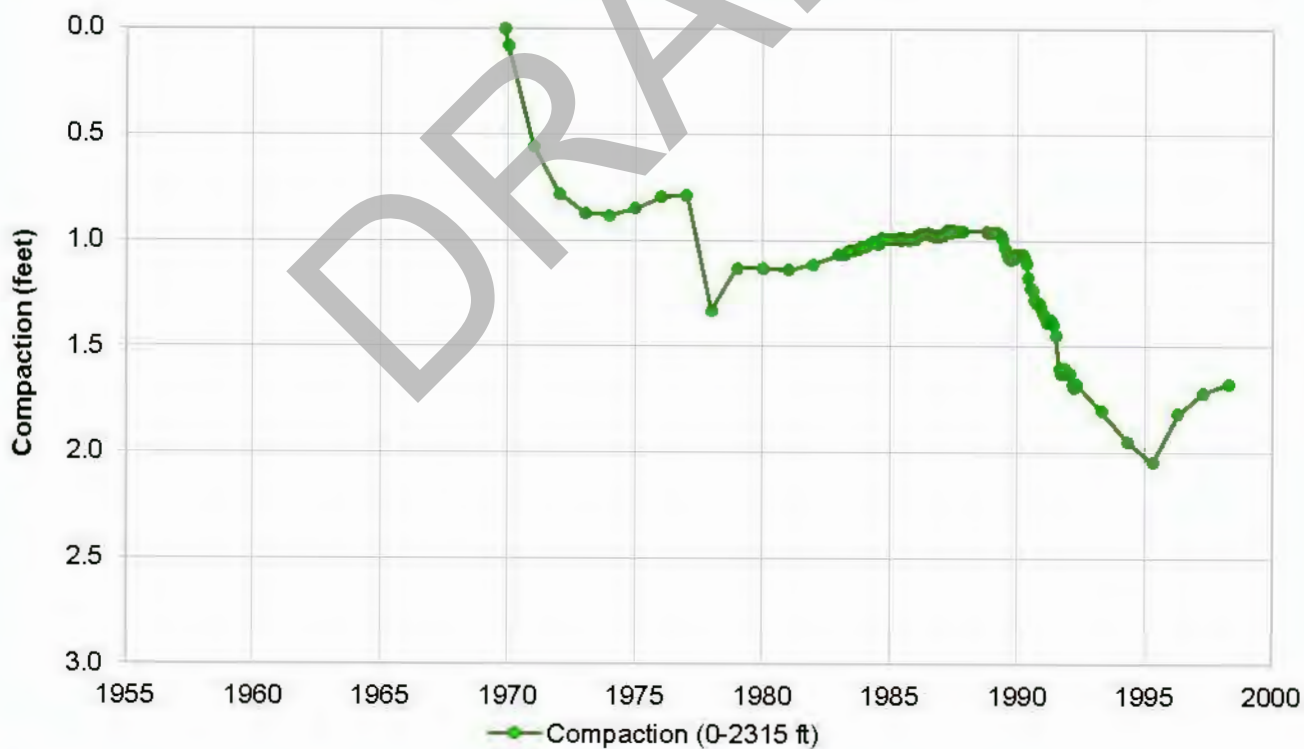


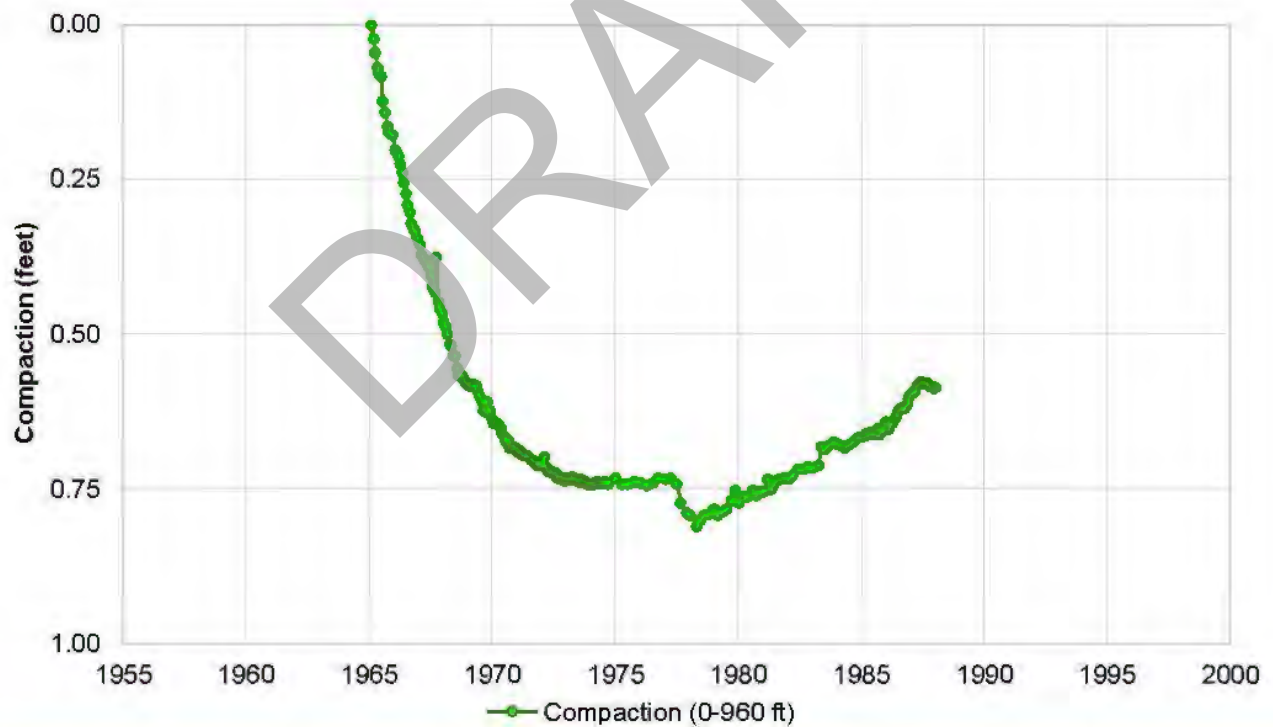
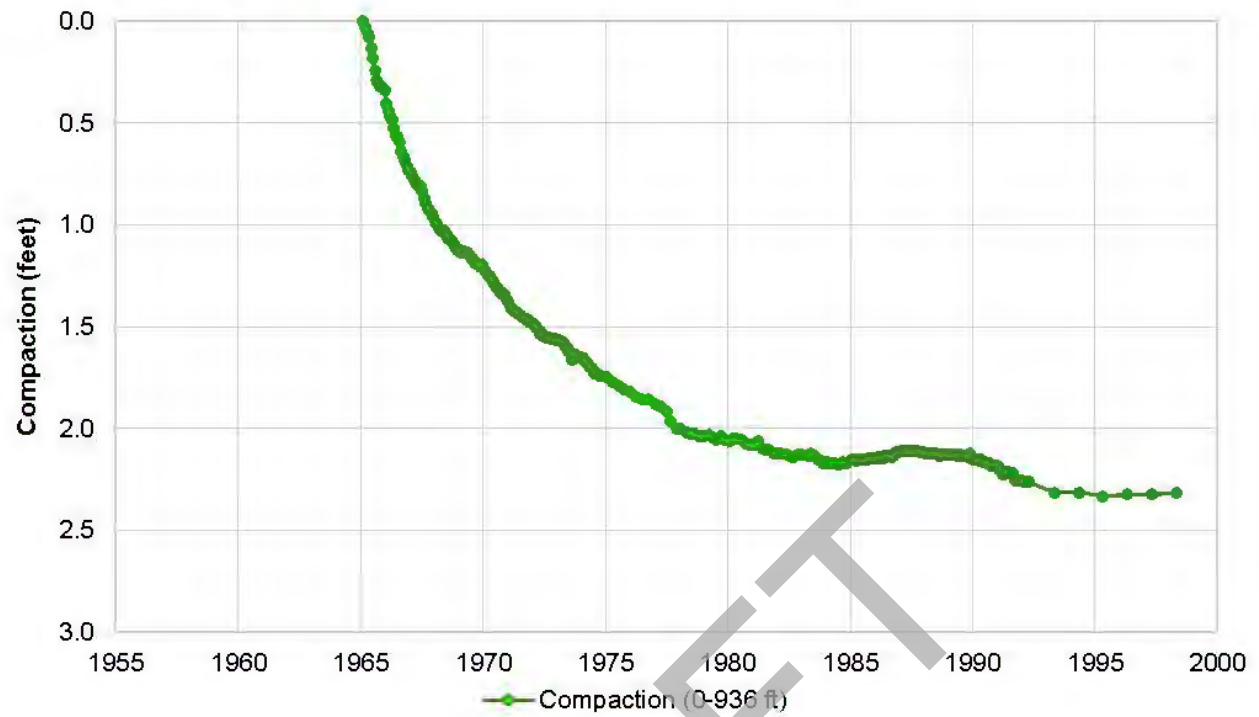


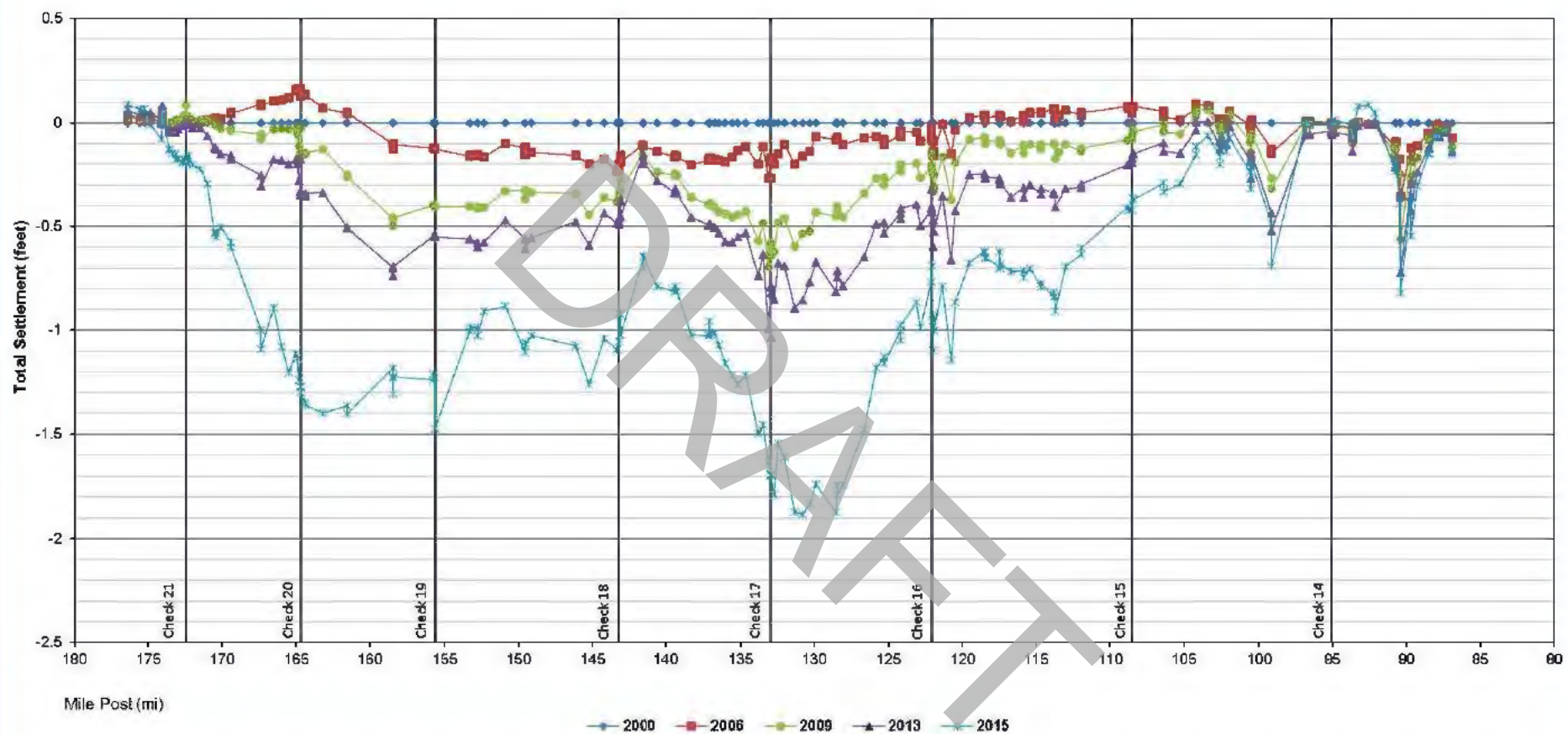
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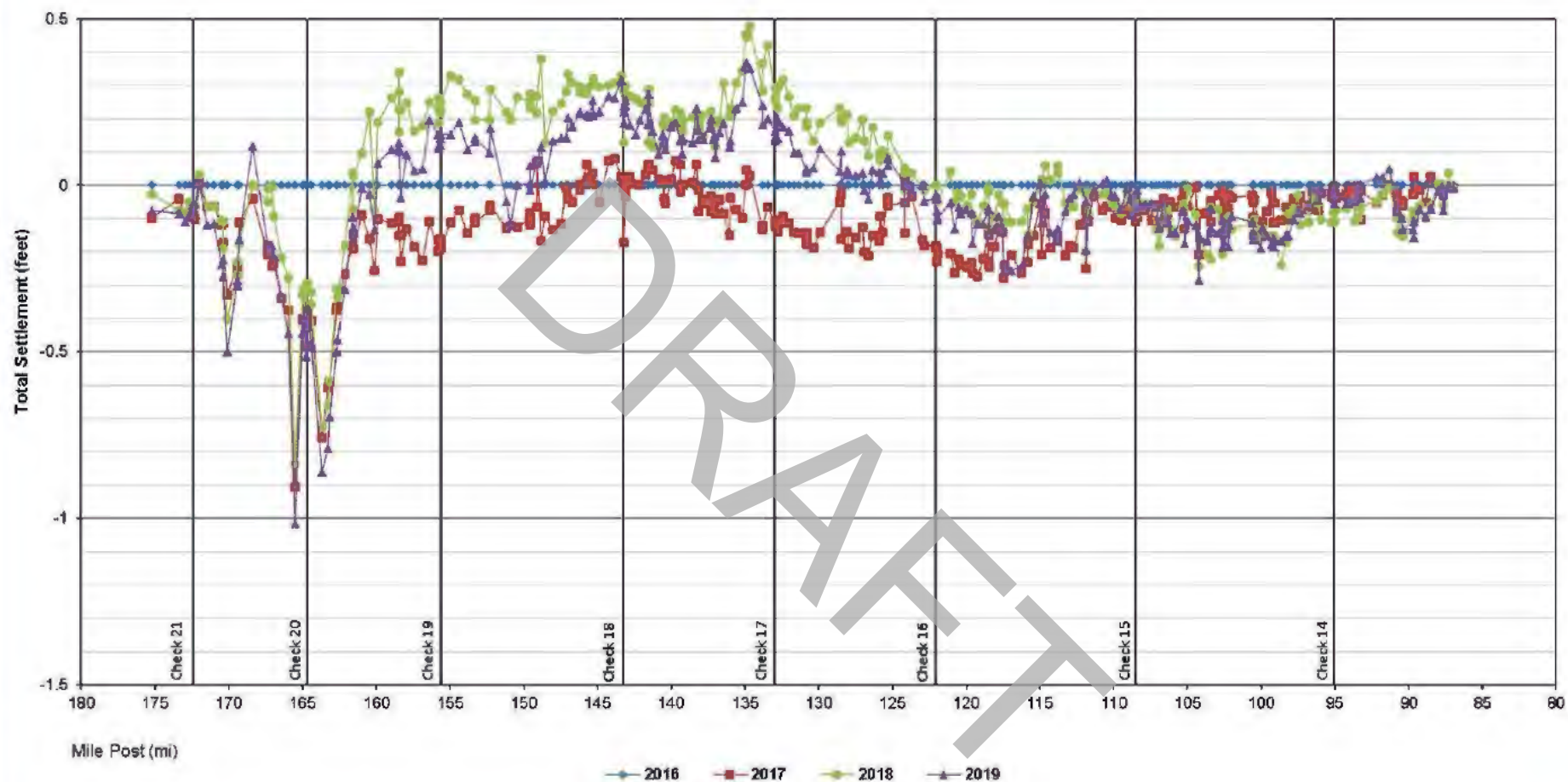


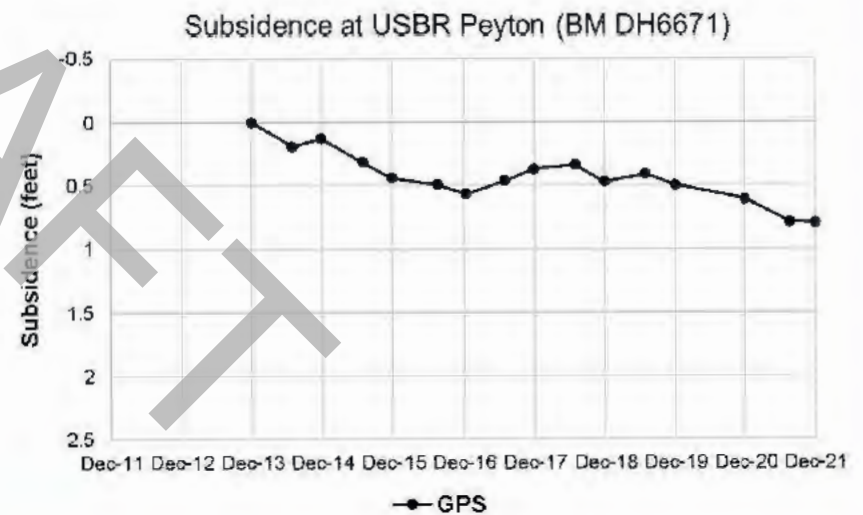
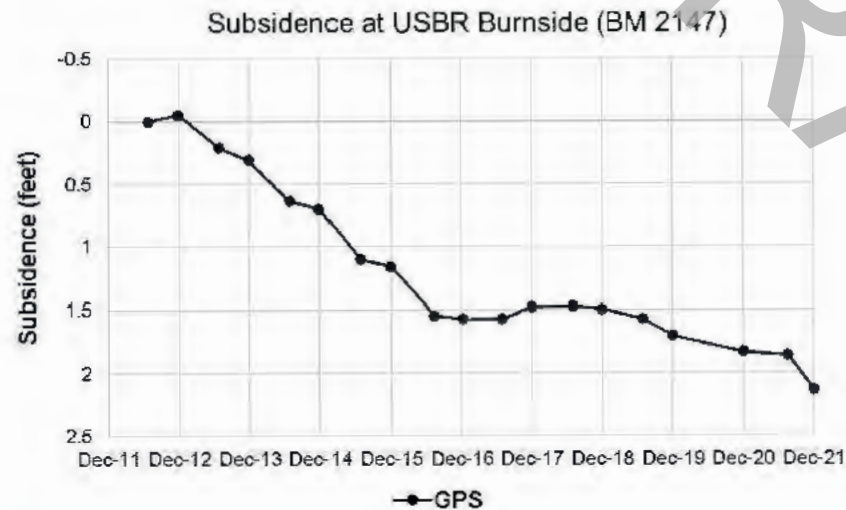
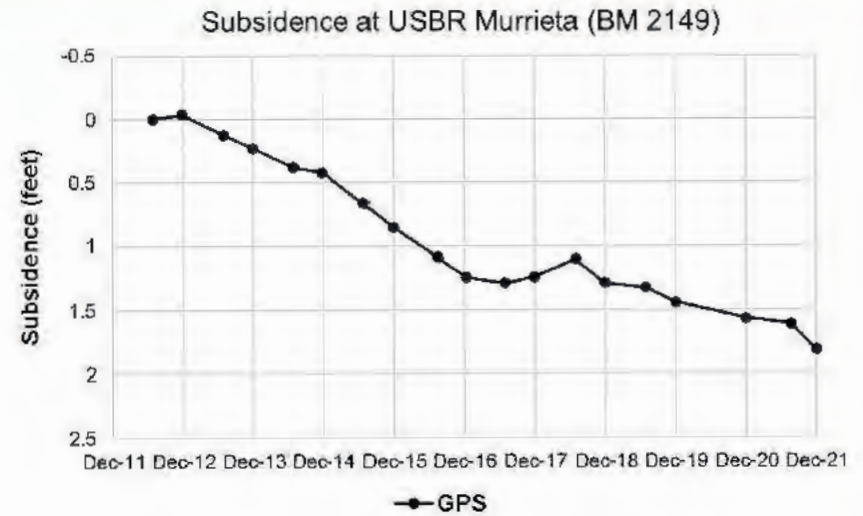
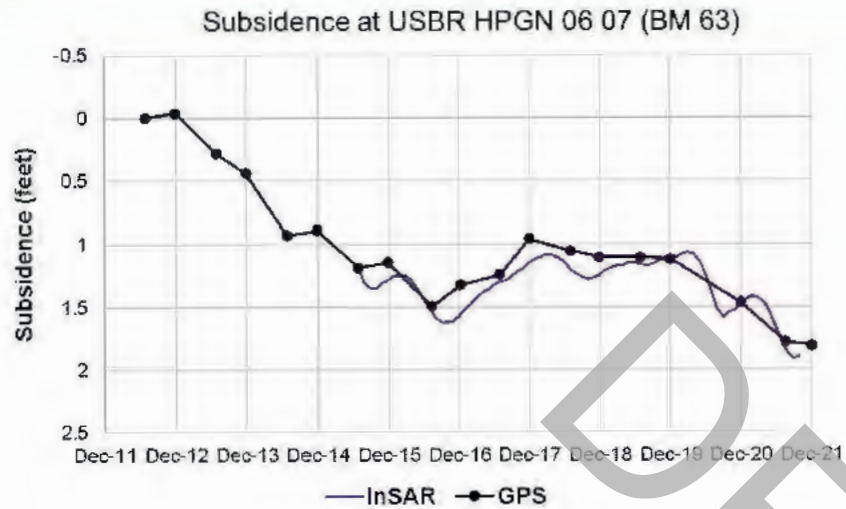
—●— Subsidence (InSAR) —●— Compaction (0-1007 ft bgs) —●— DTW (perfs: 760-835; 851-872 ft bgs)

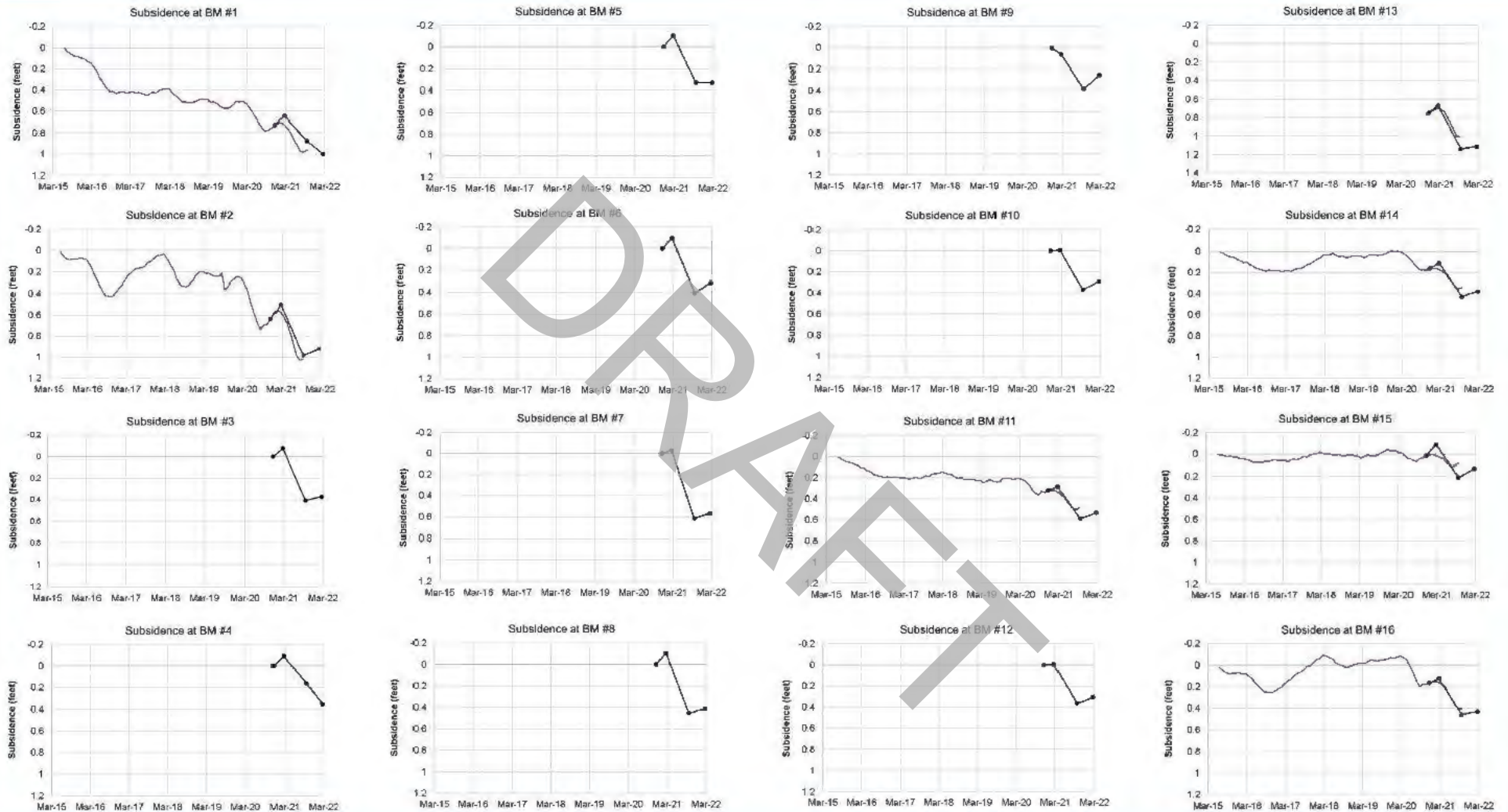


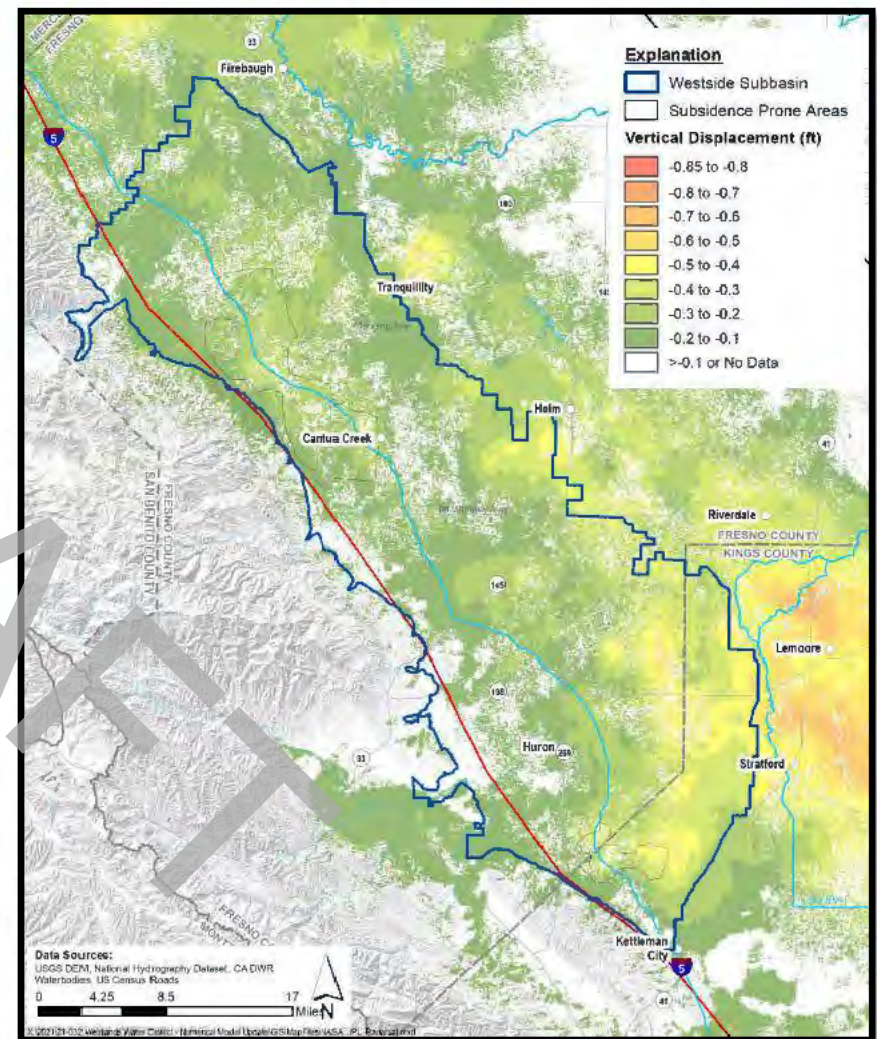
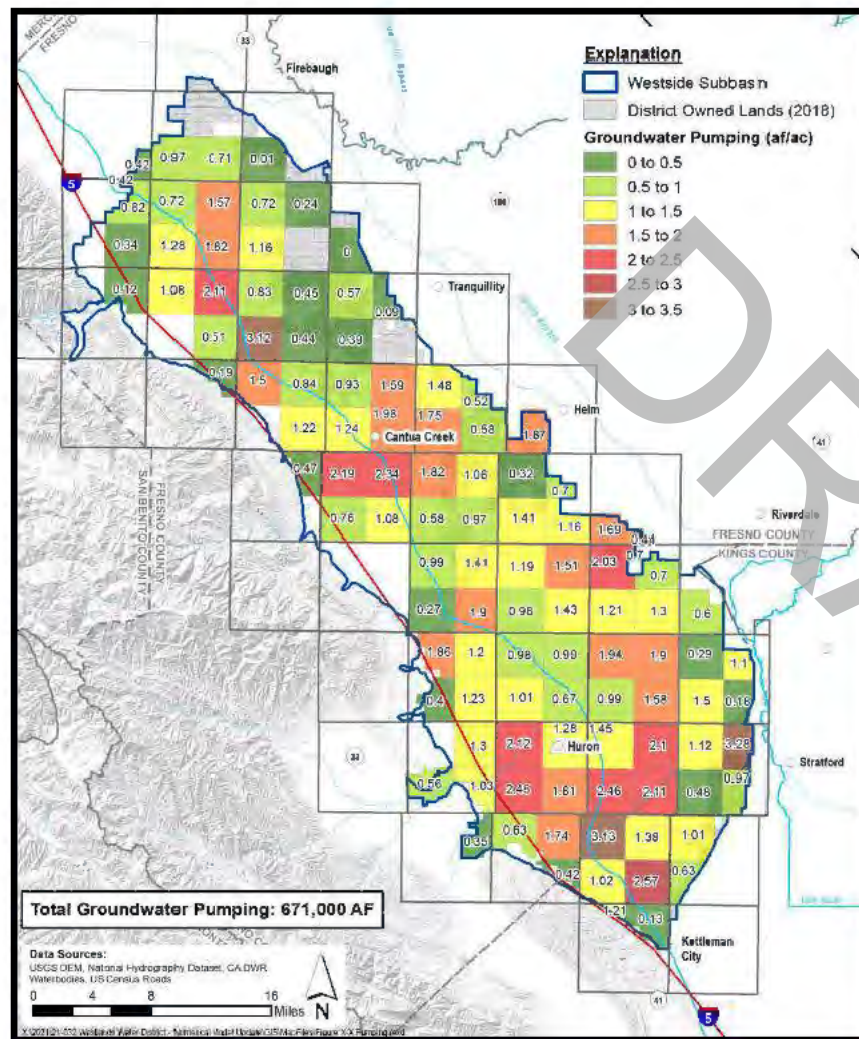


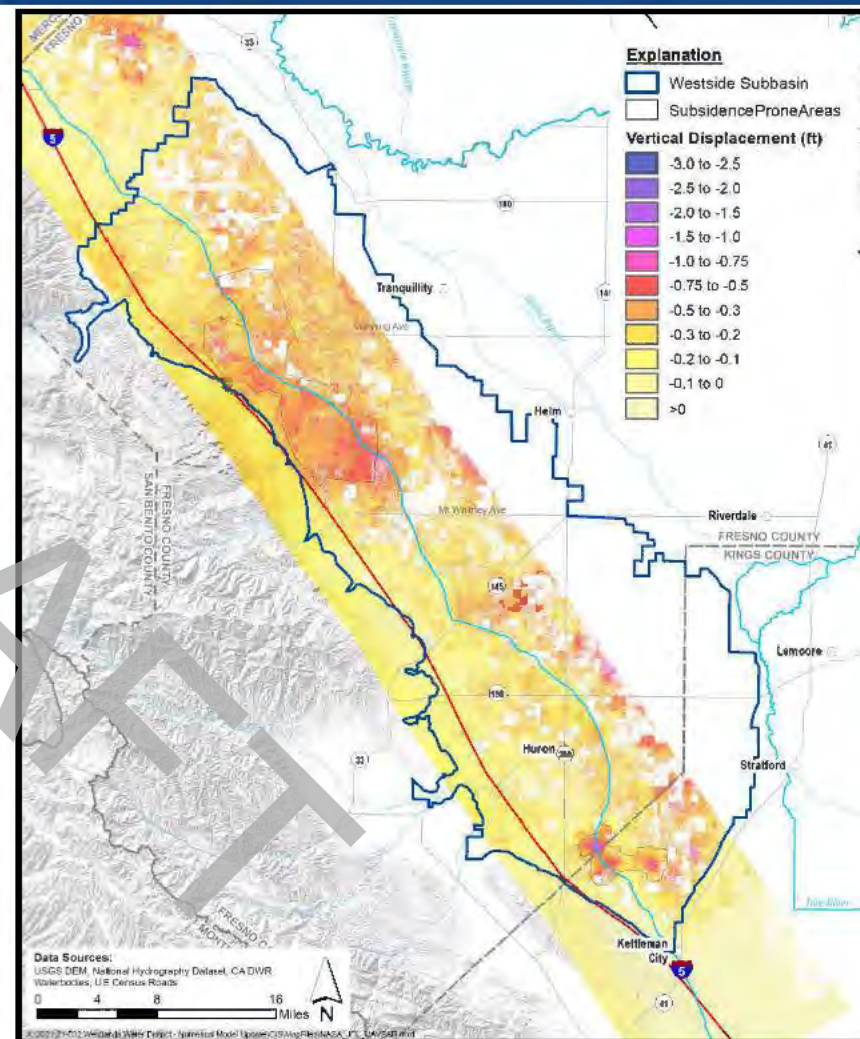
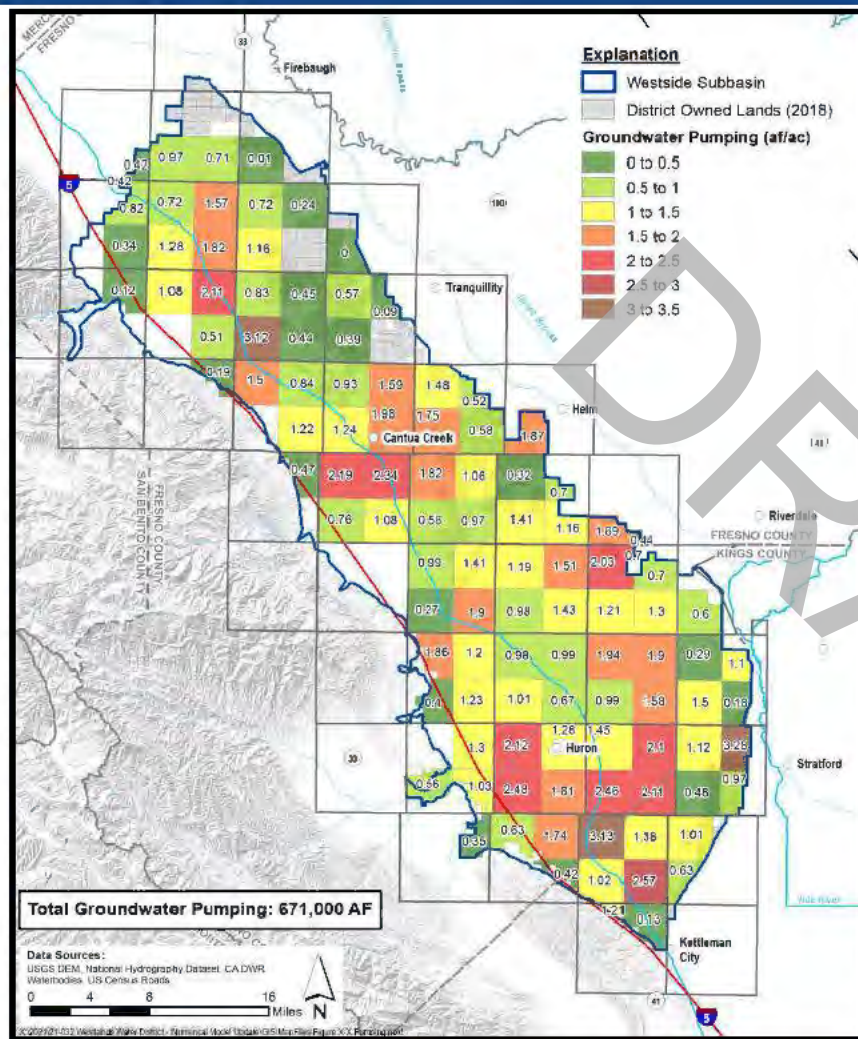


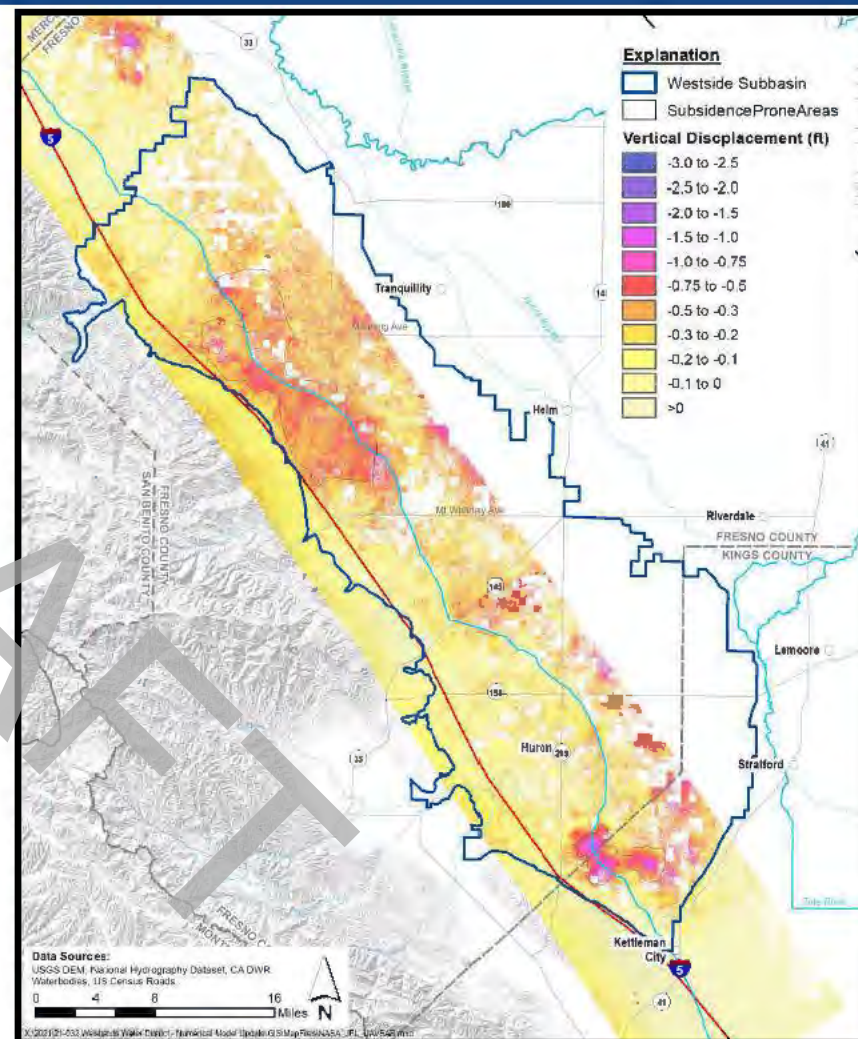
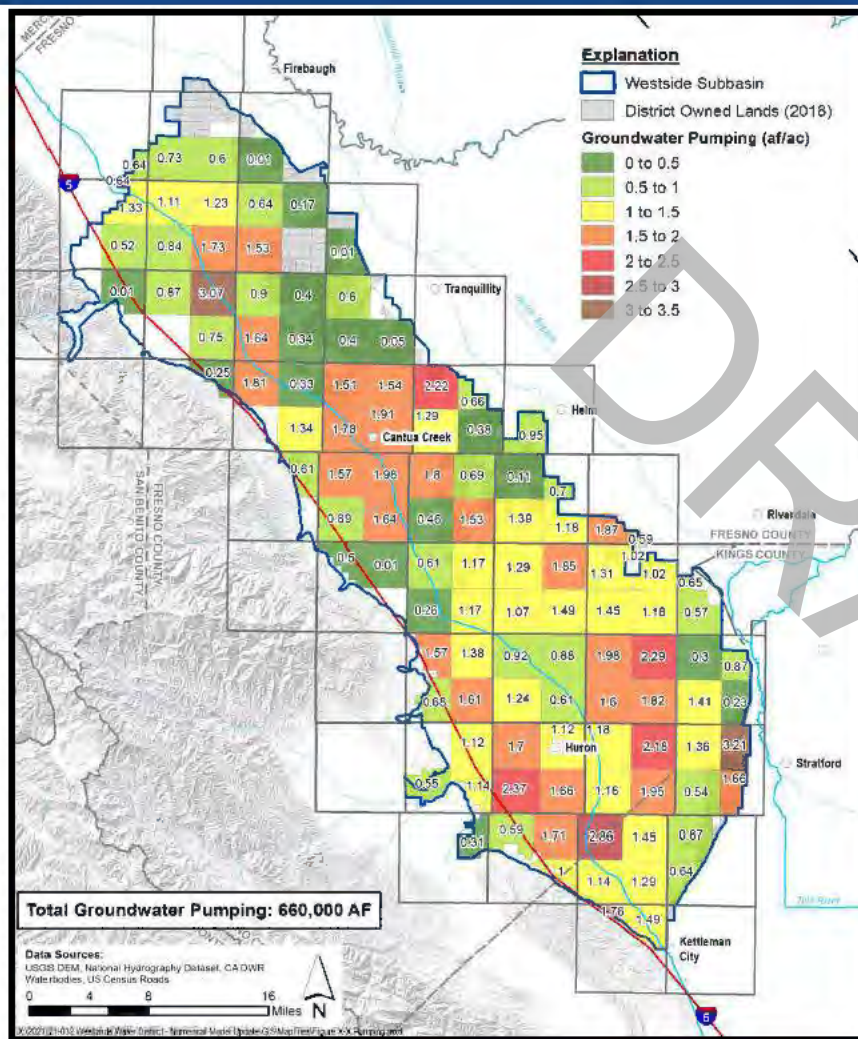


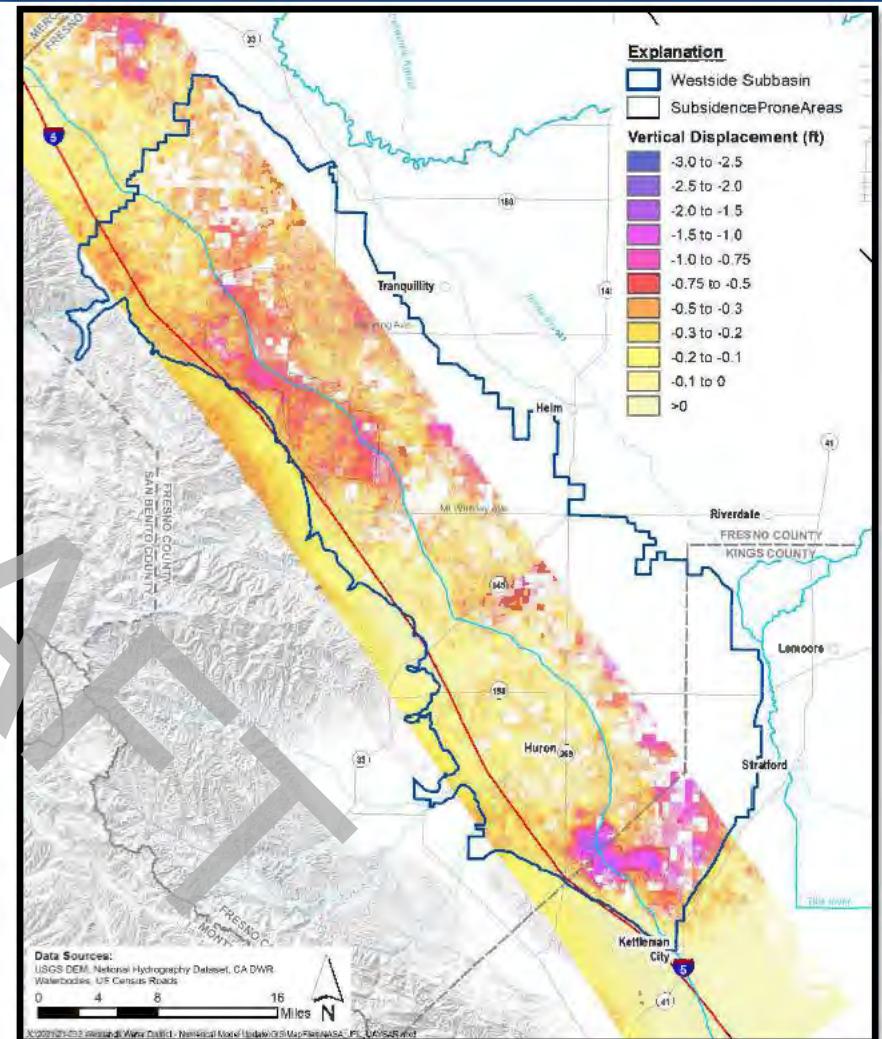
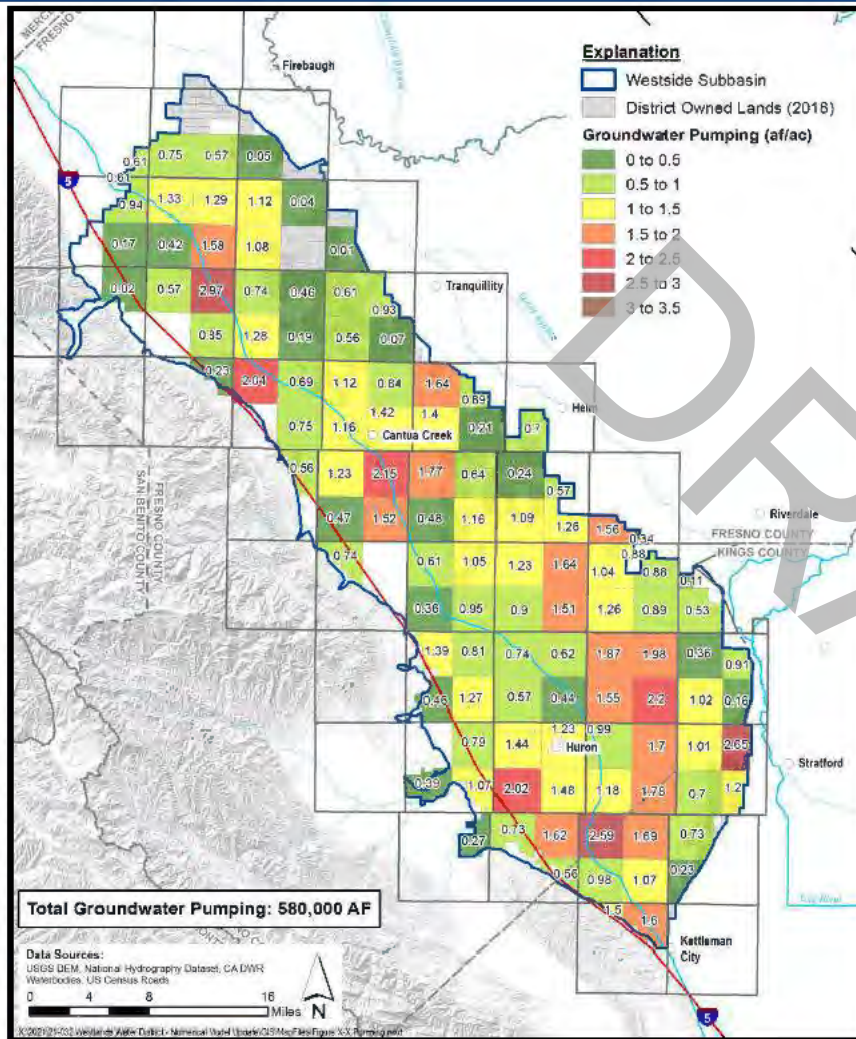


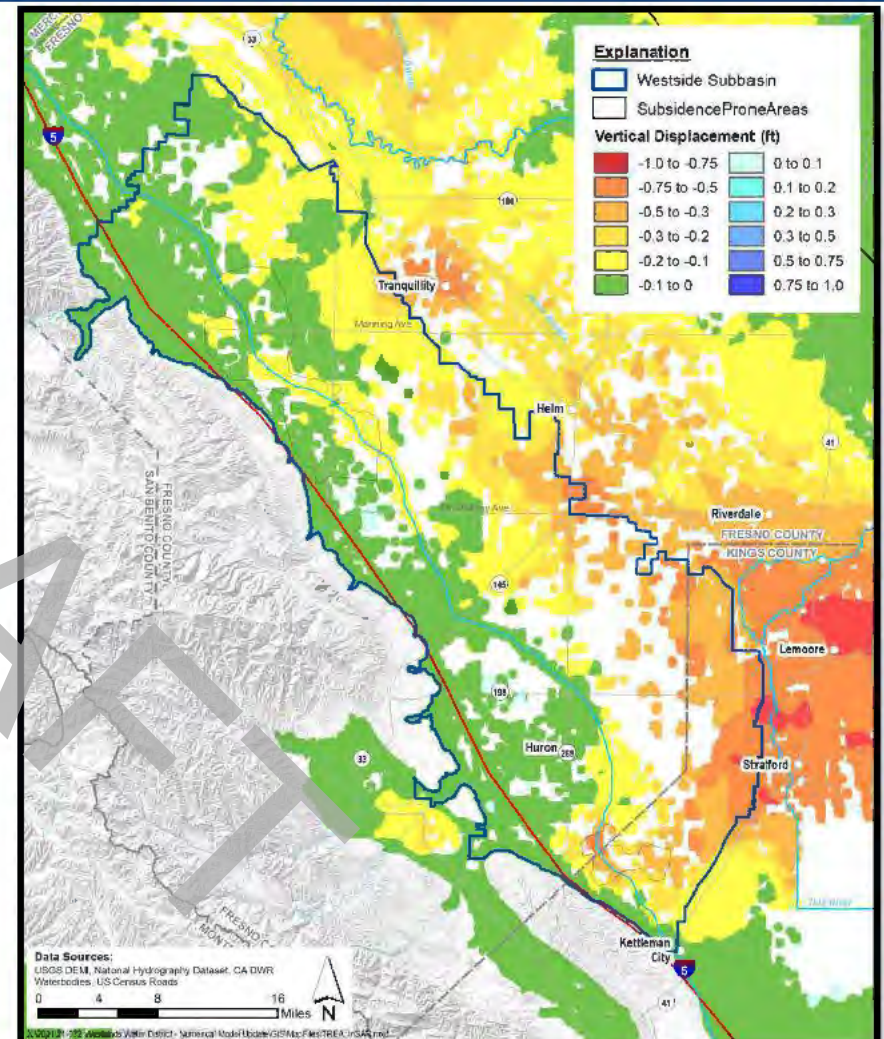
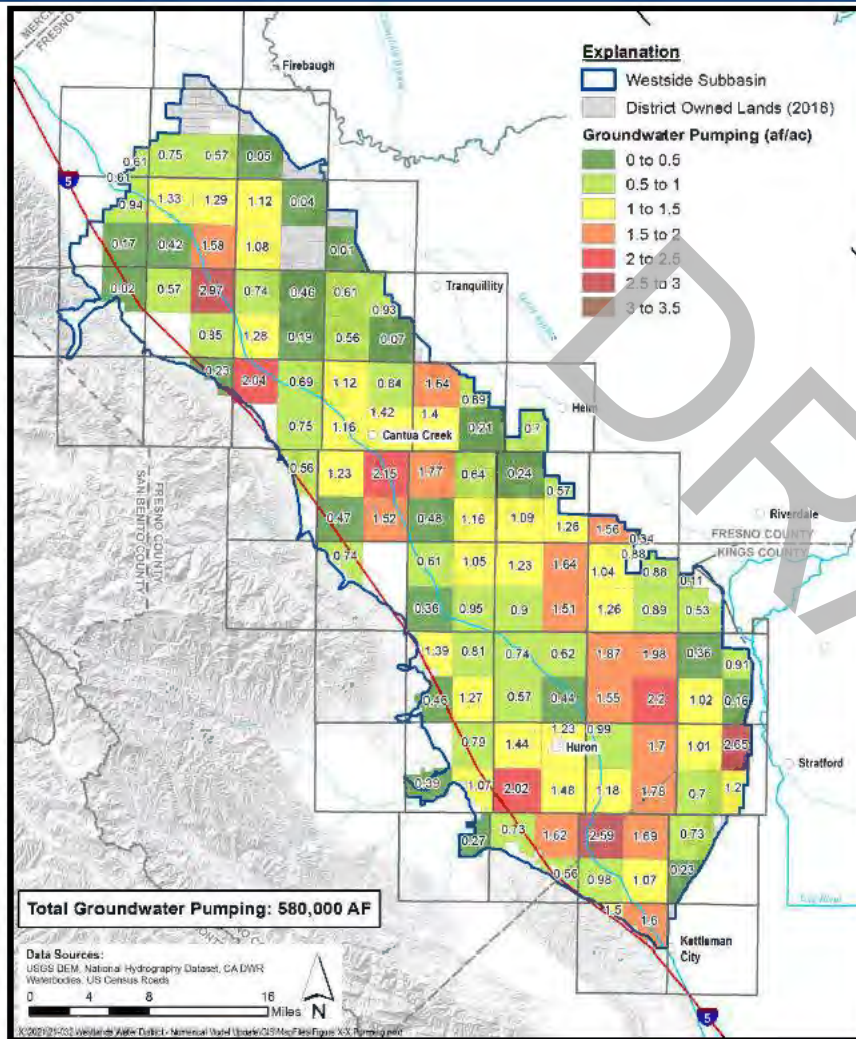


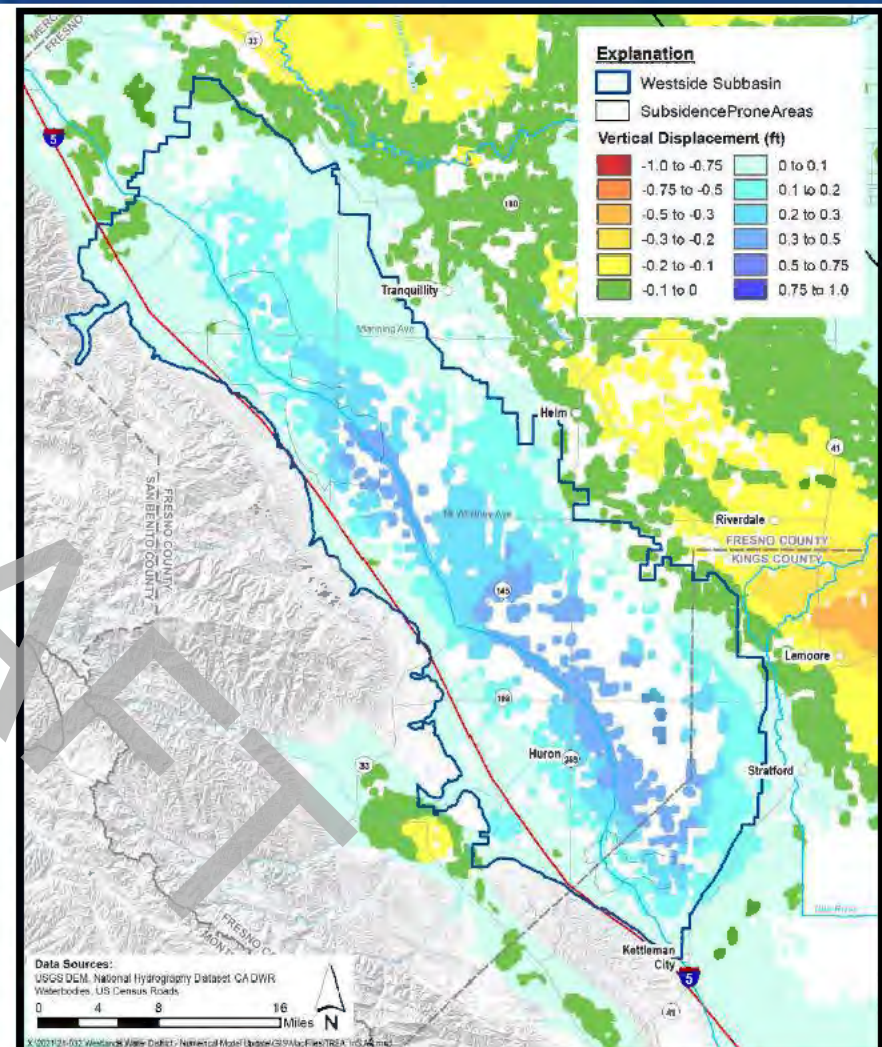
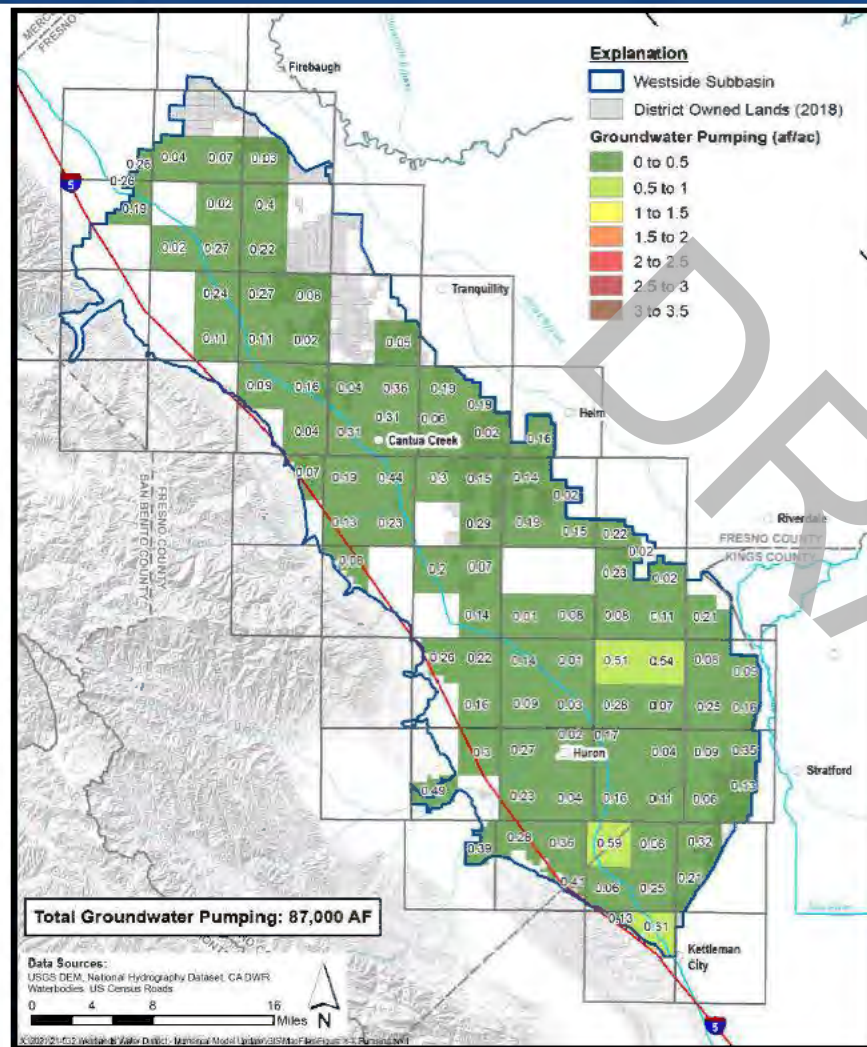


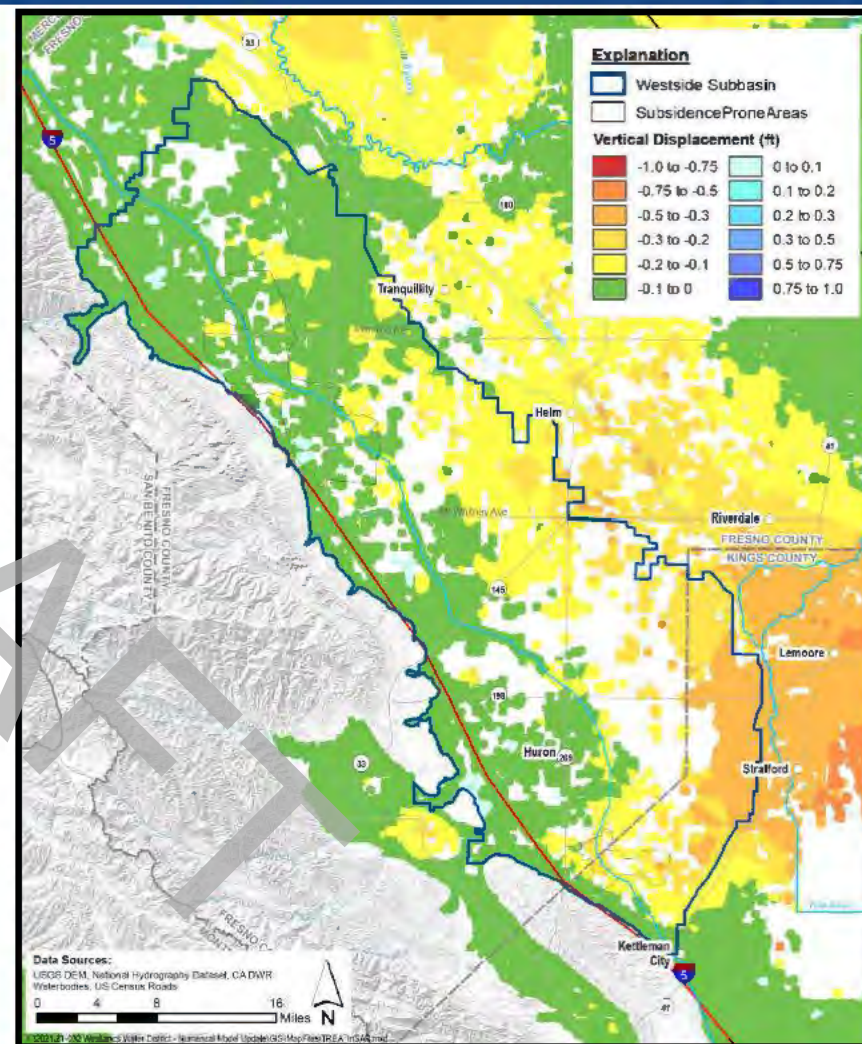
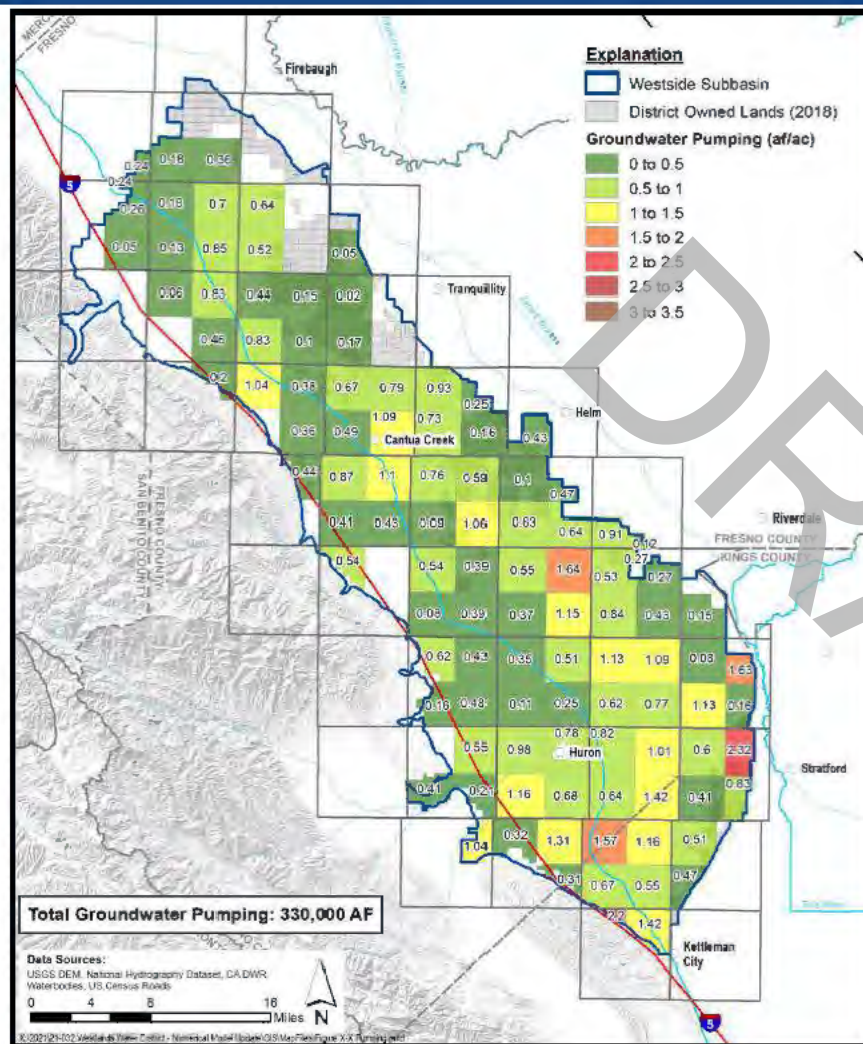


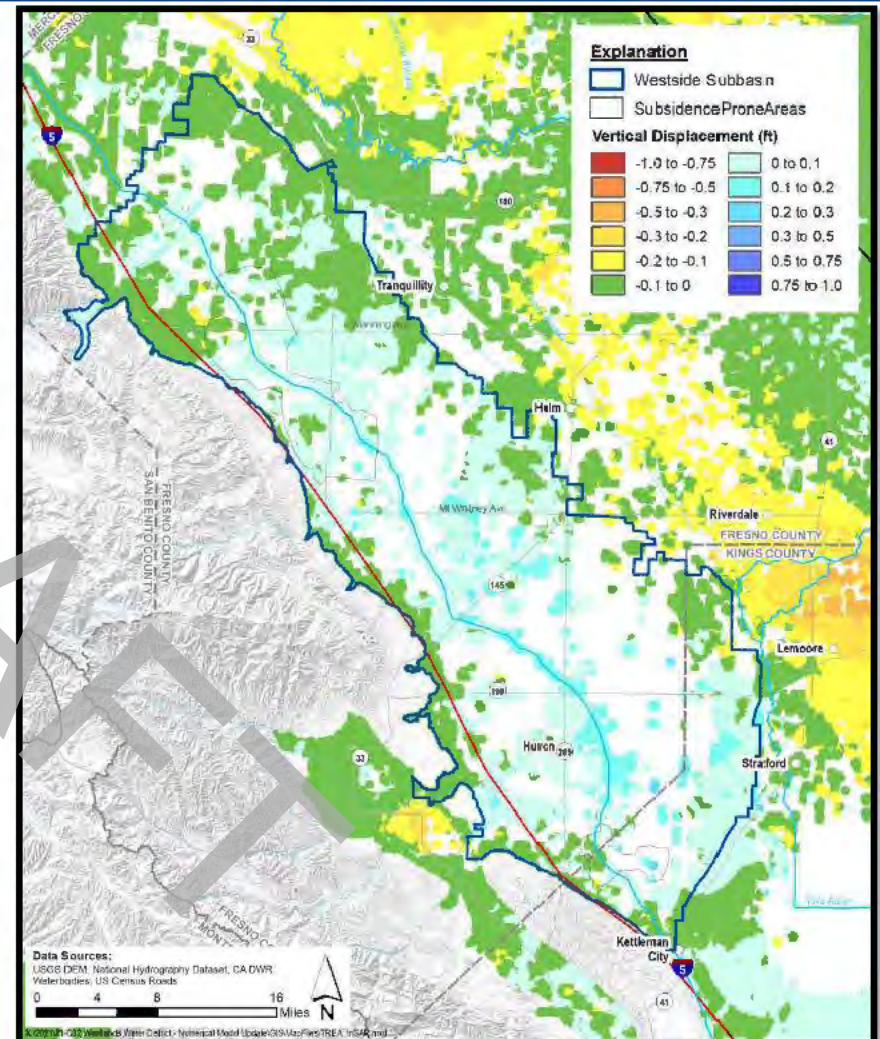
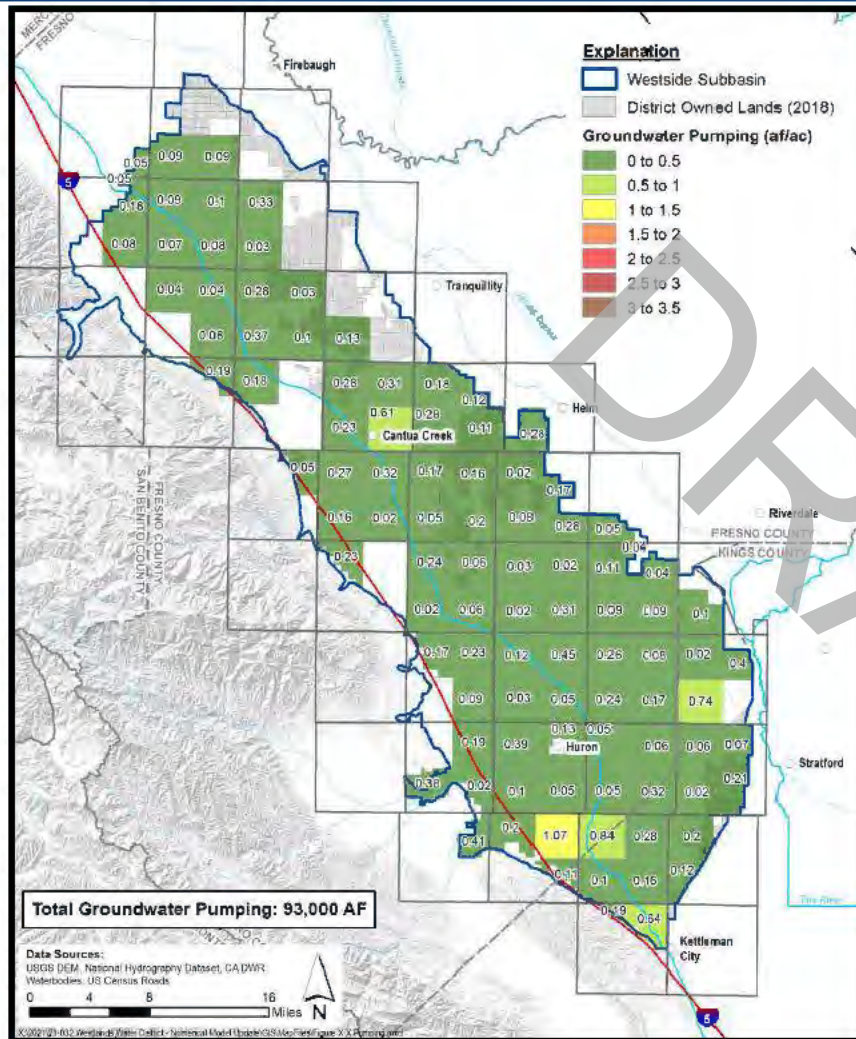


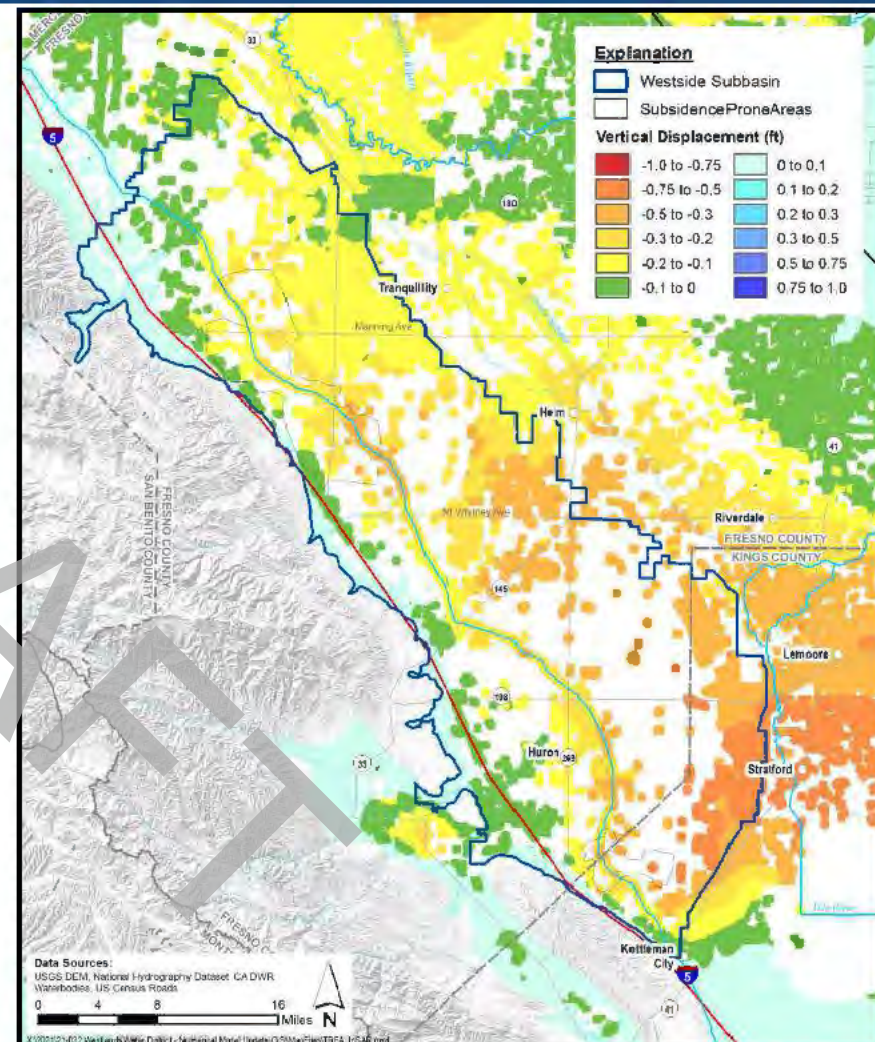
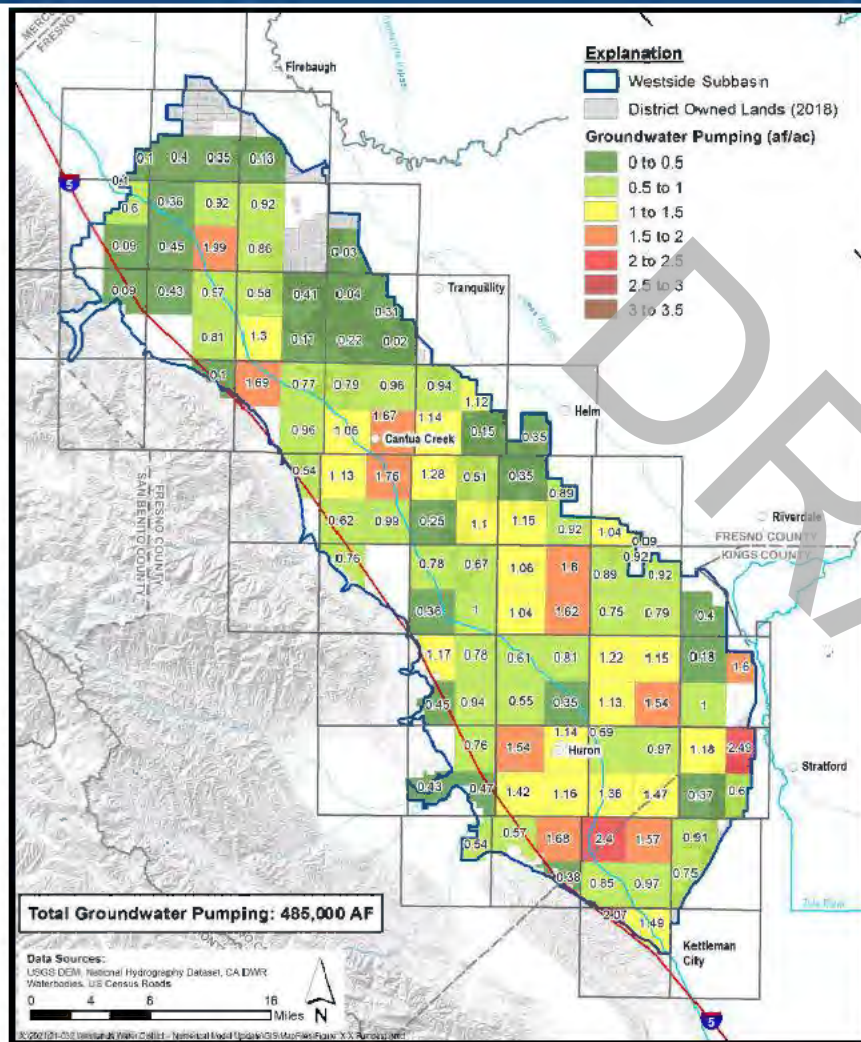


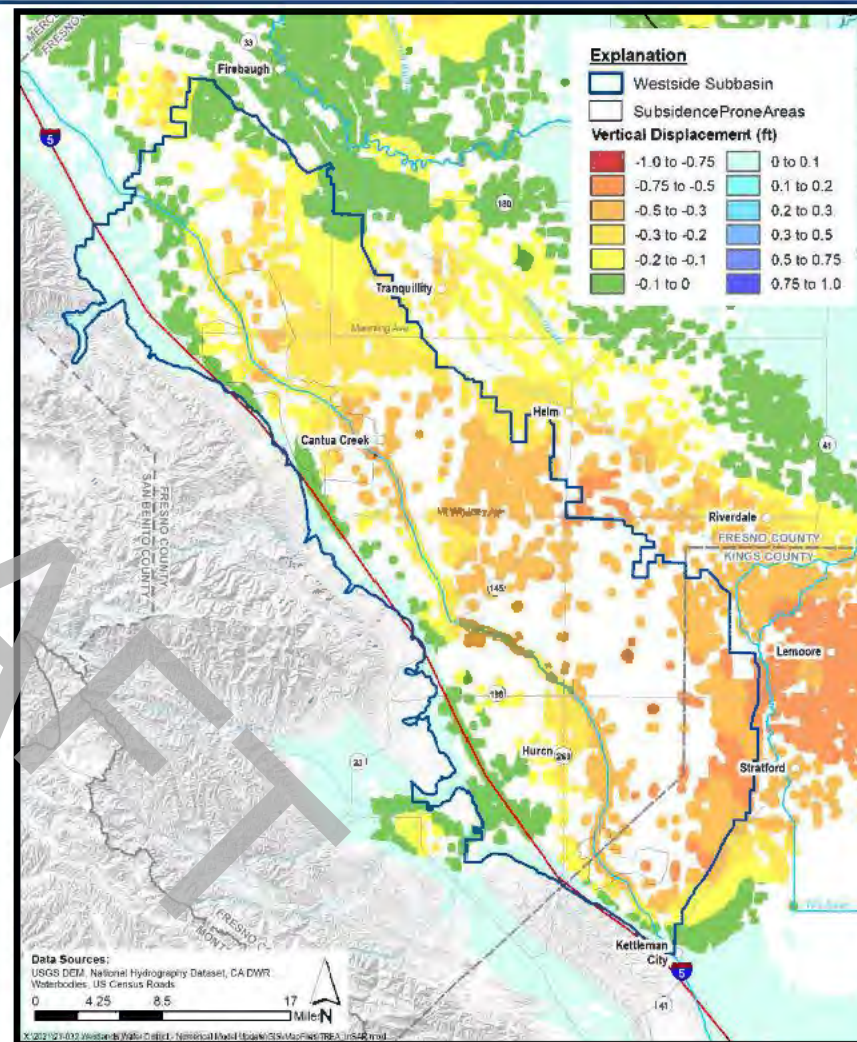
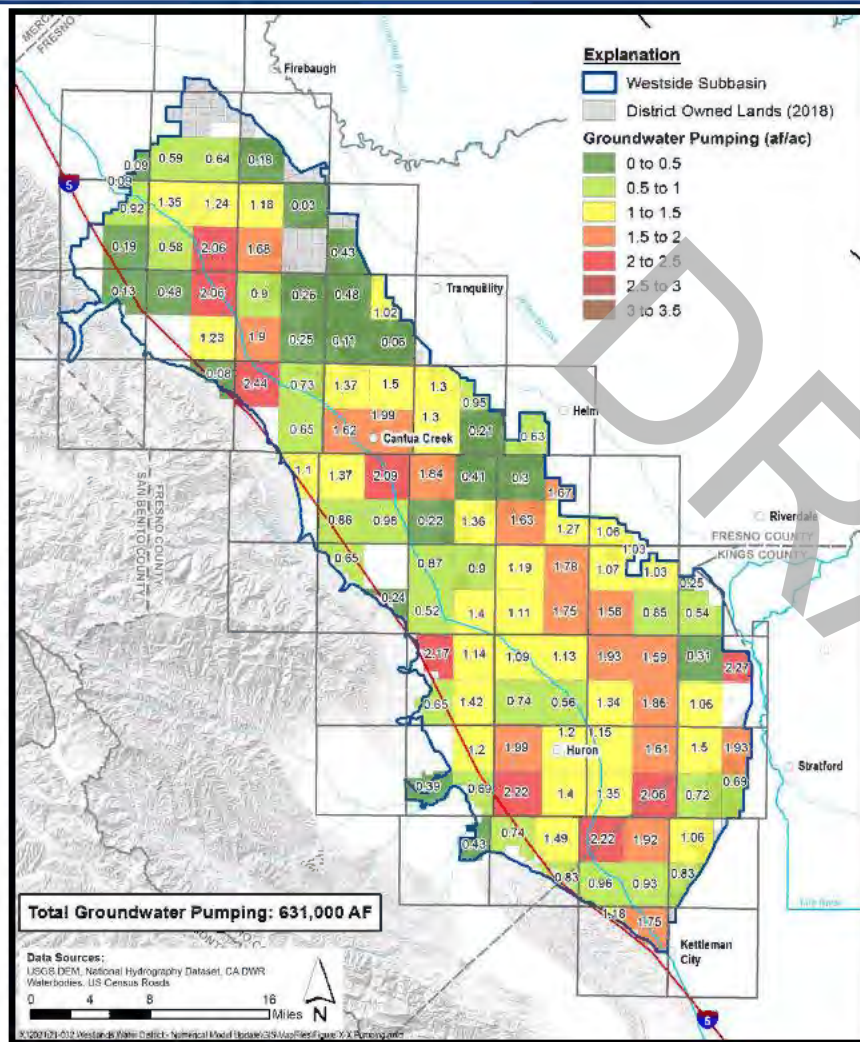




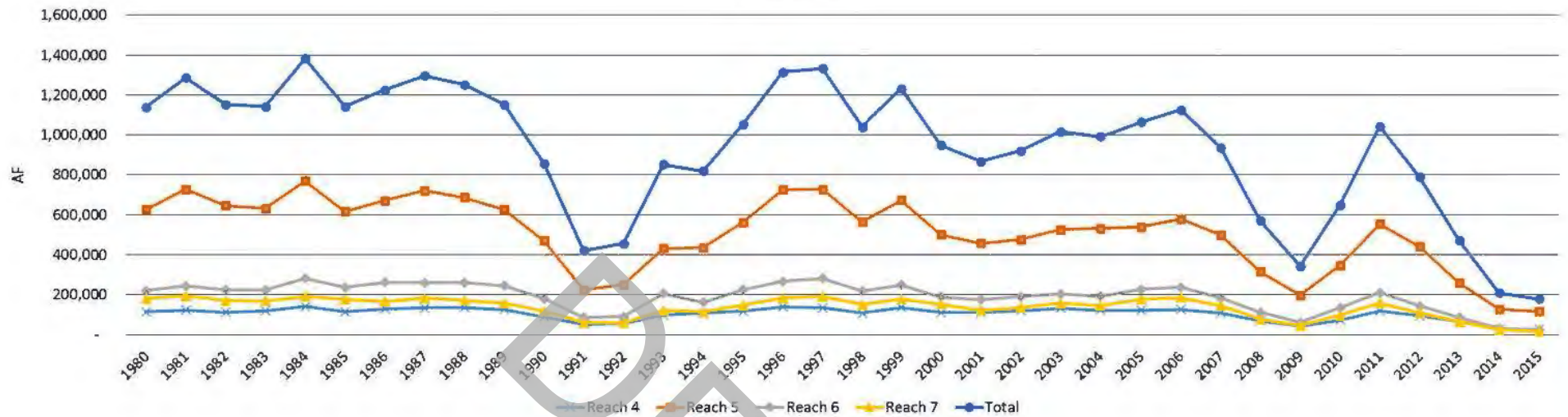




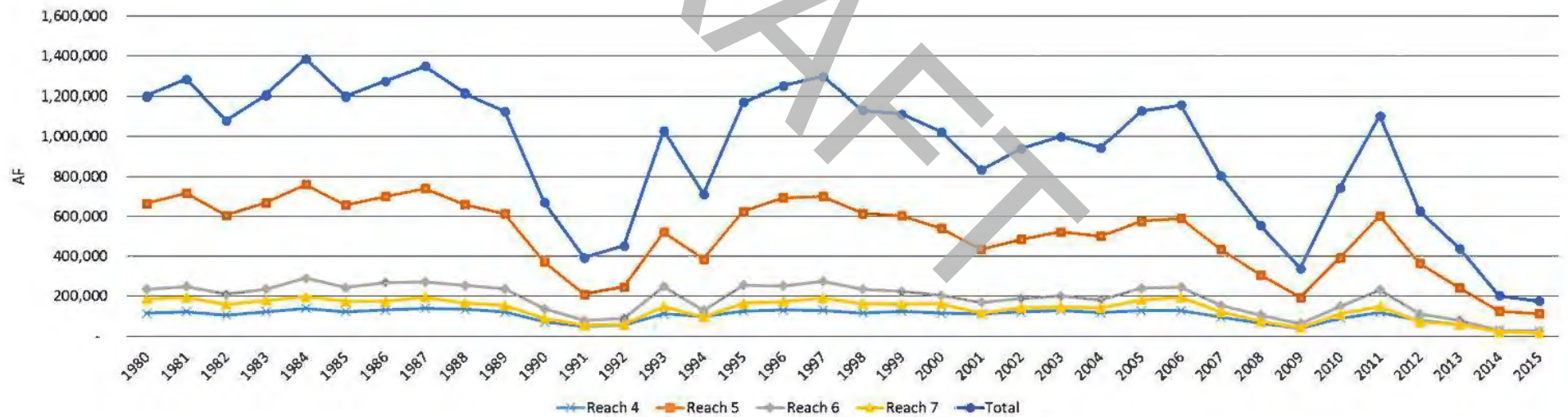




Westlands Water District
Surface Water Delivered by Reach
Calendar Year

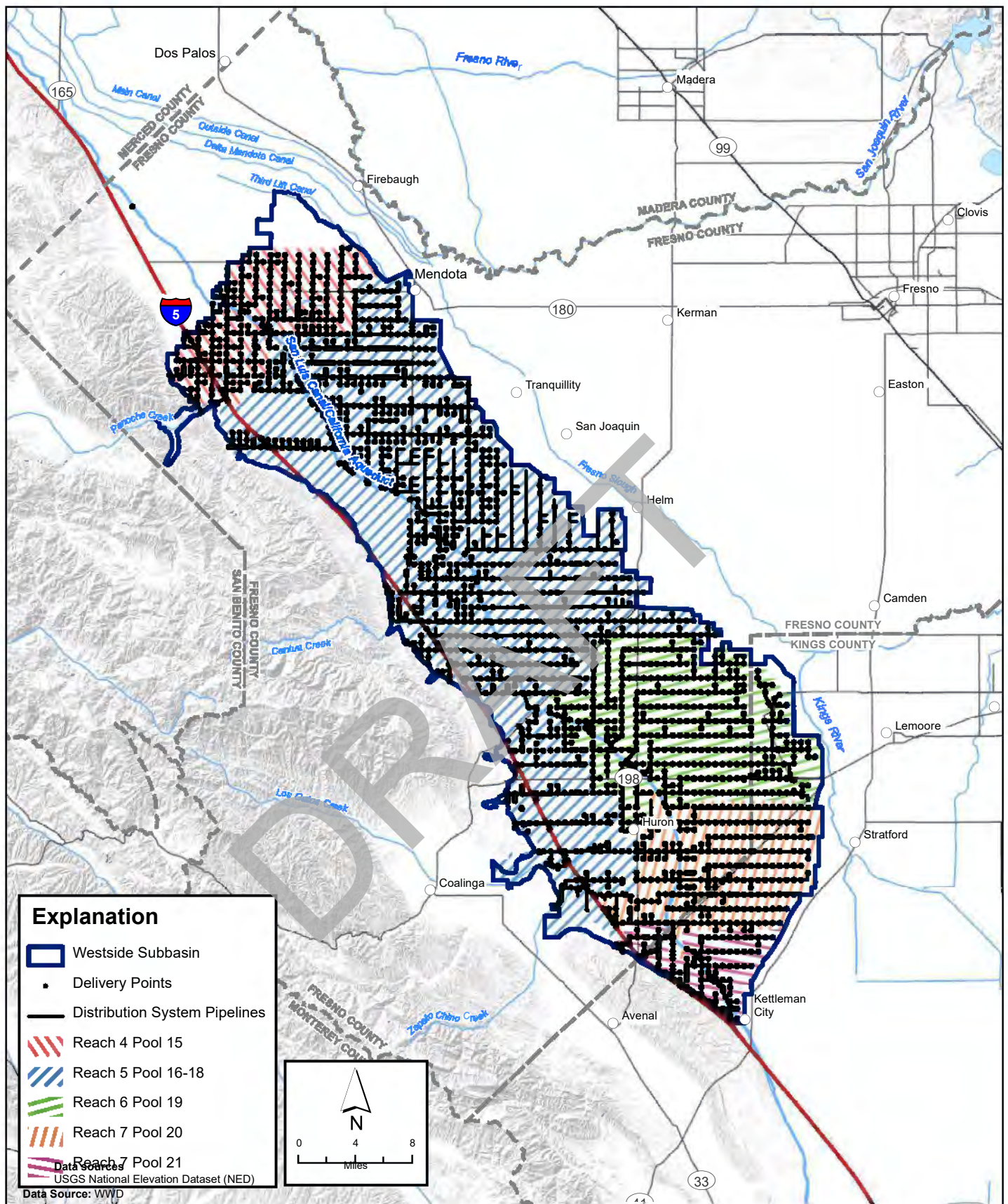


Westlands Water District
Surface Water Delivered by Reach
Water Year

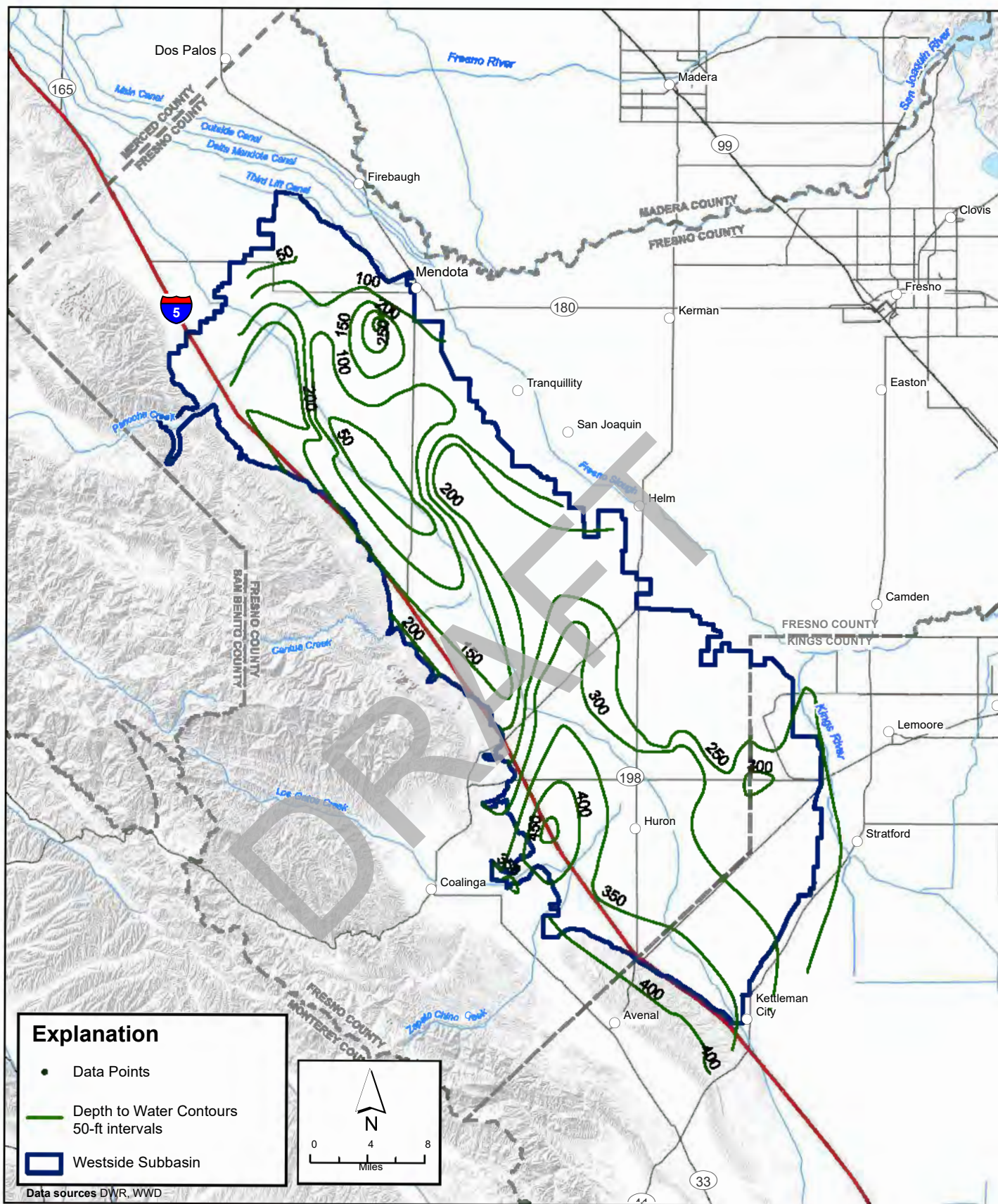


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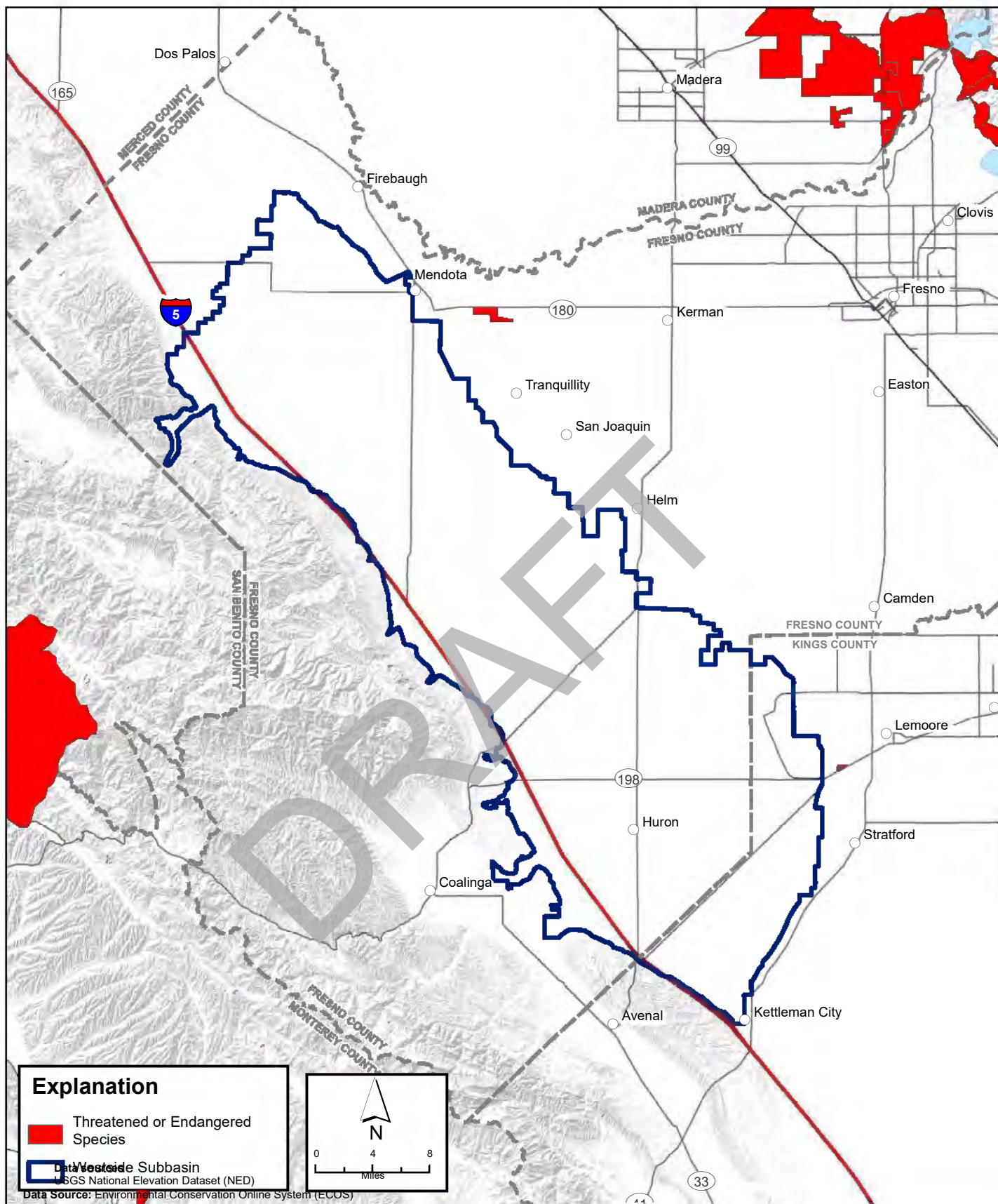
FIGURE 2-82
Graph of Annual Imported Water



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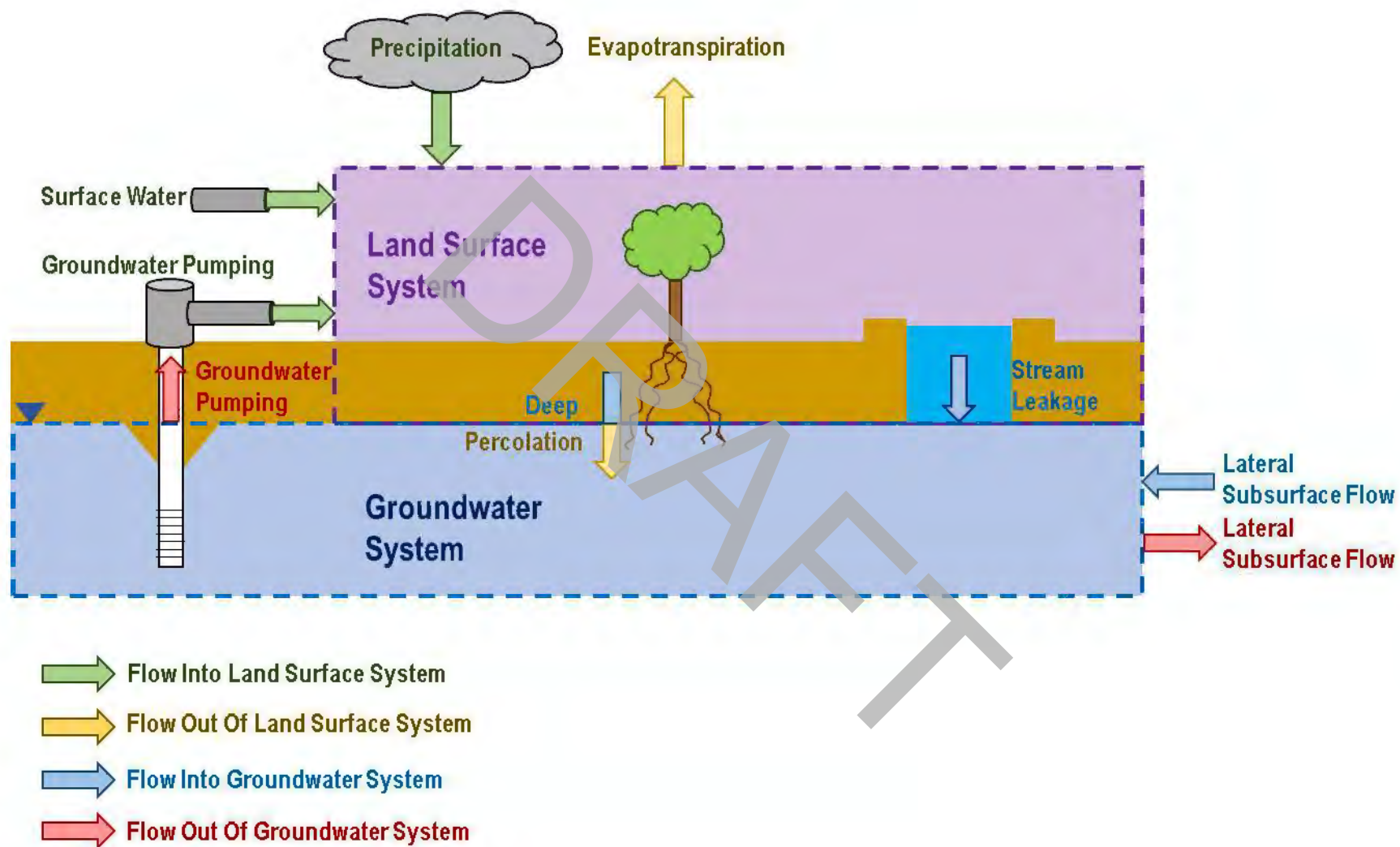


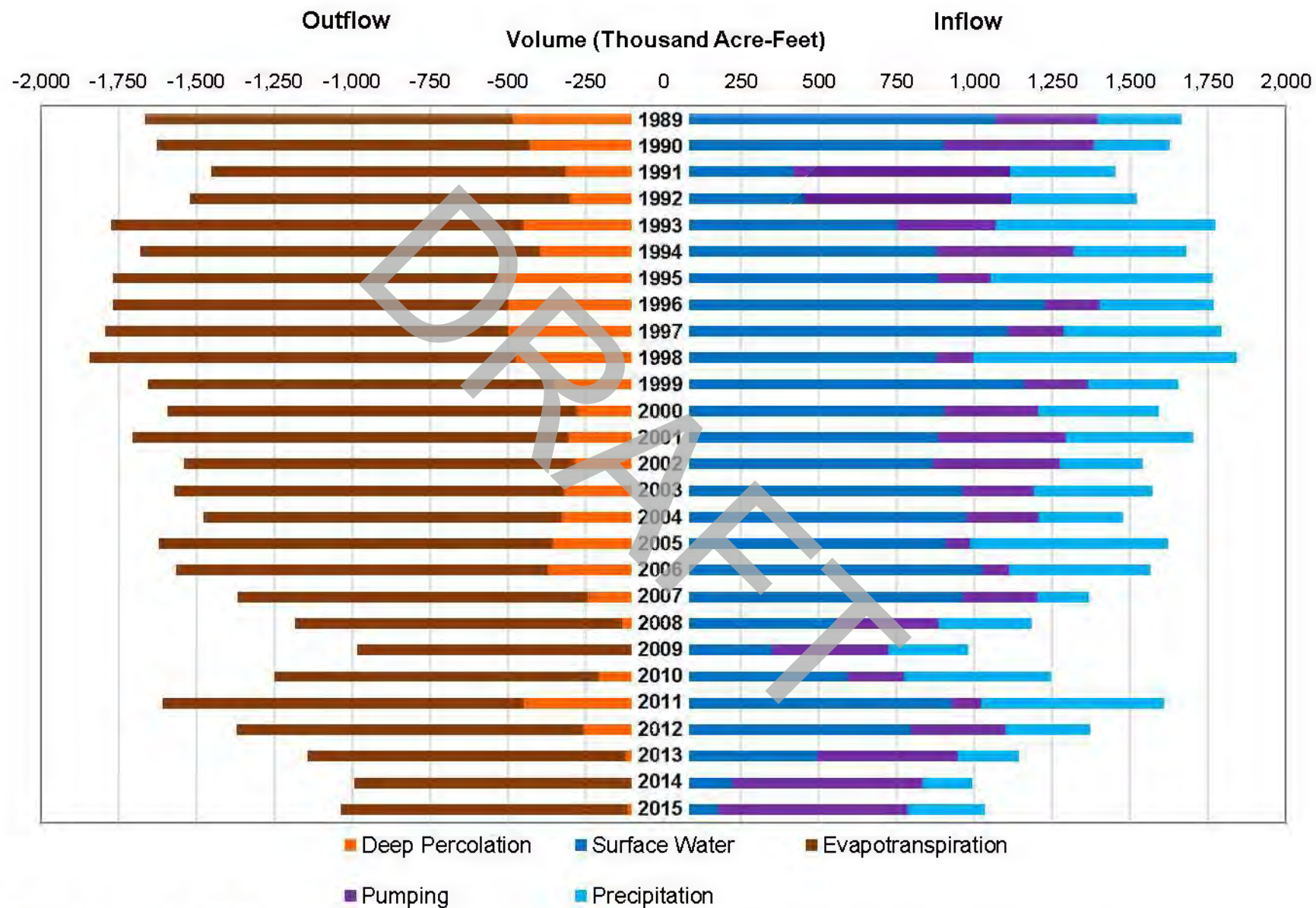
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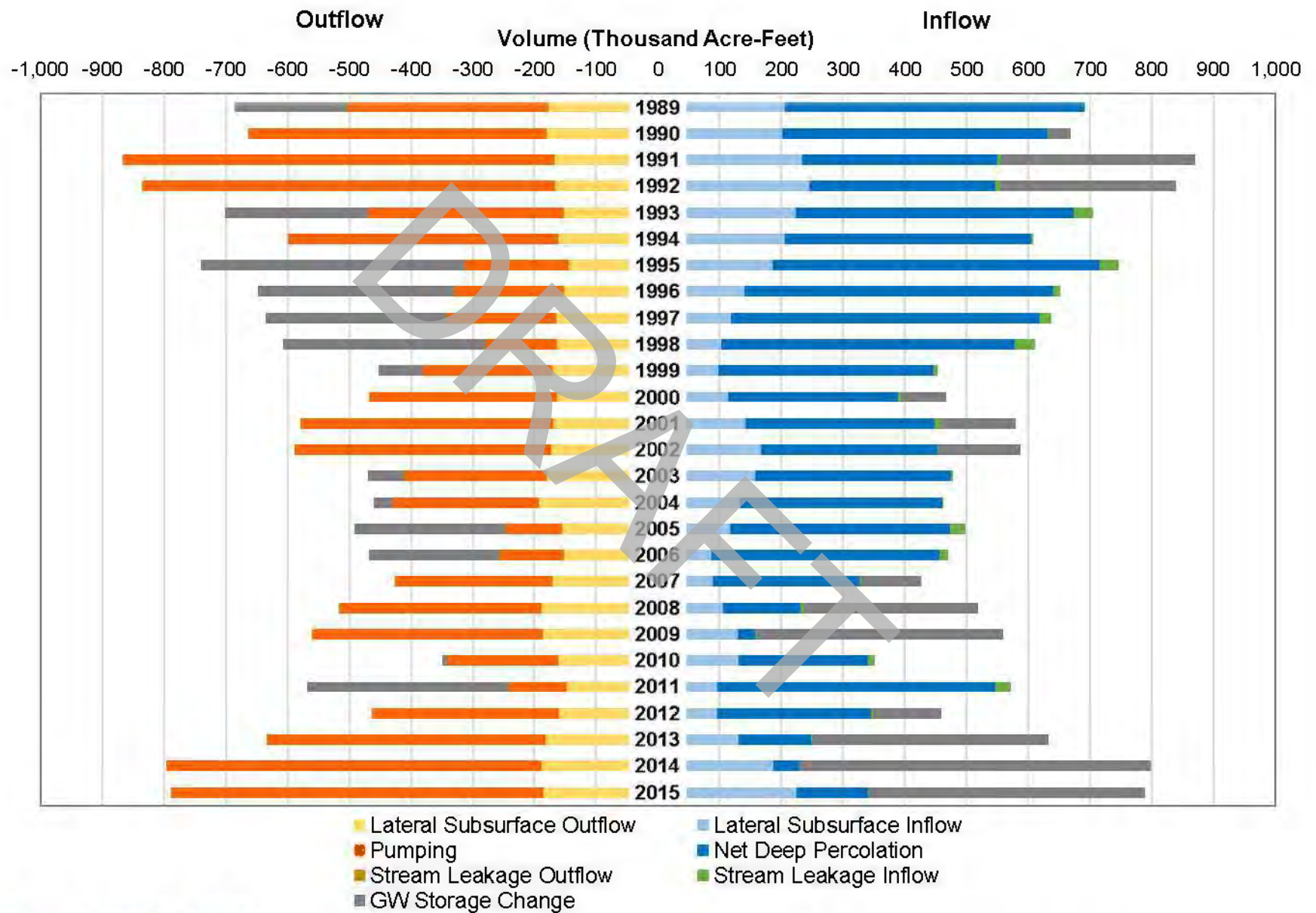


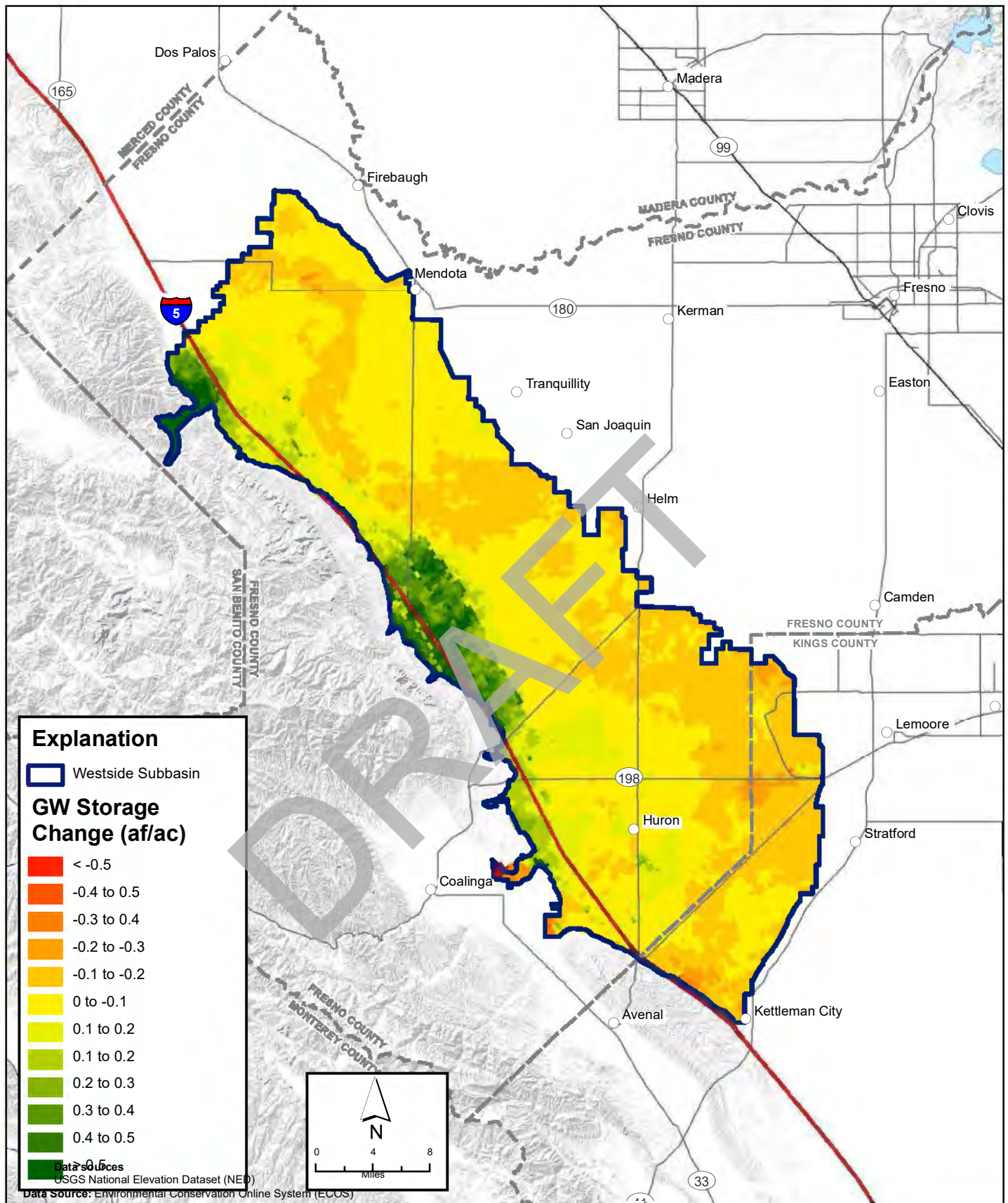
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FIGURE 2-86
Critical Habitats

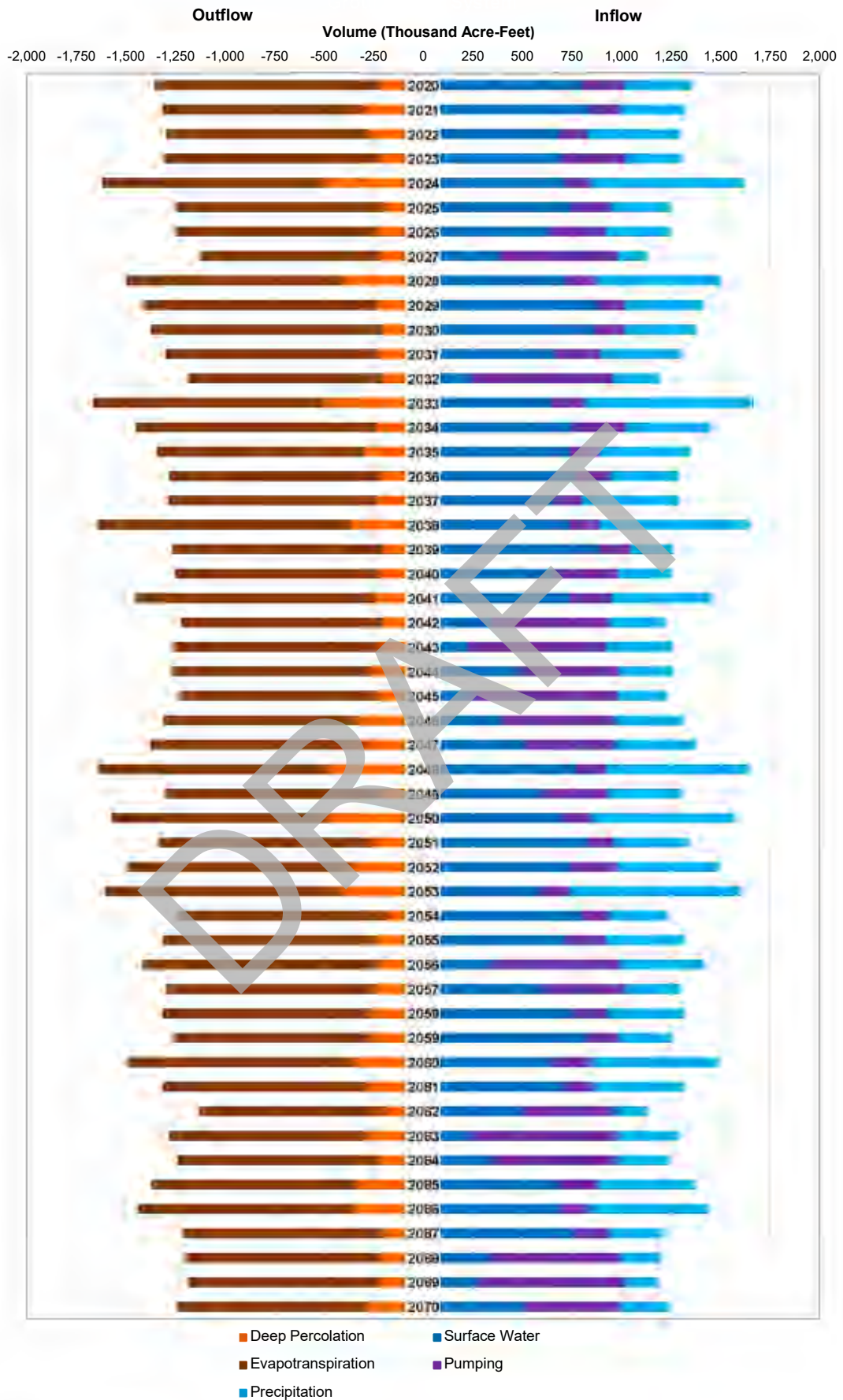




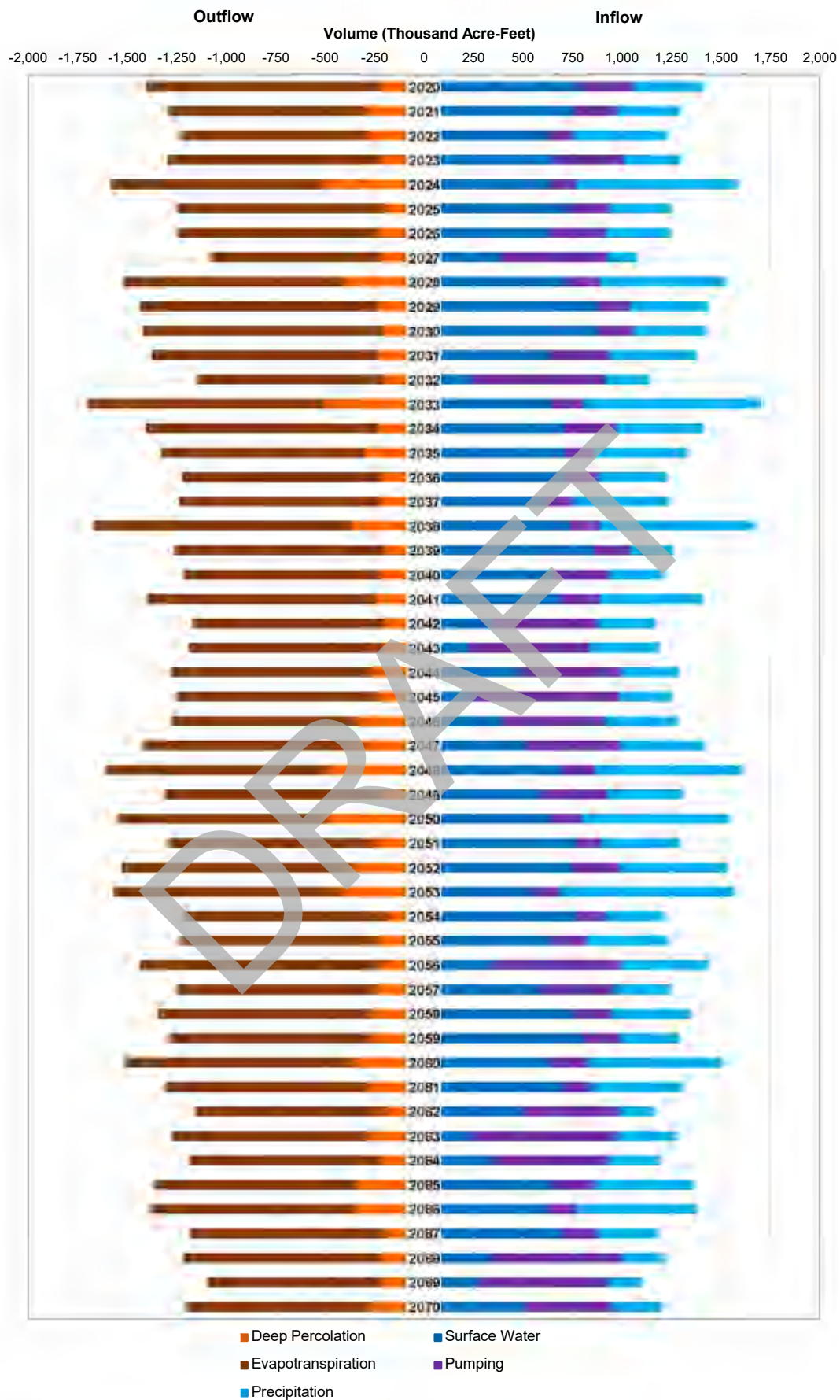




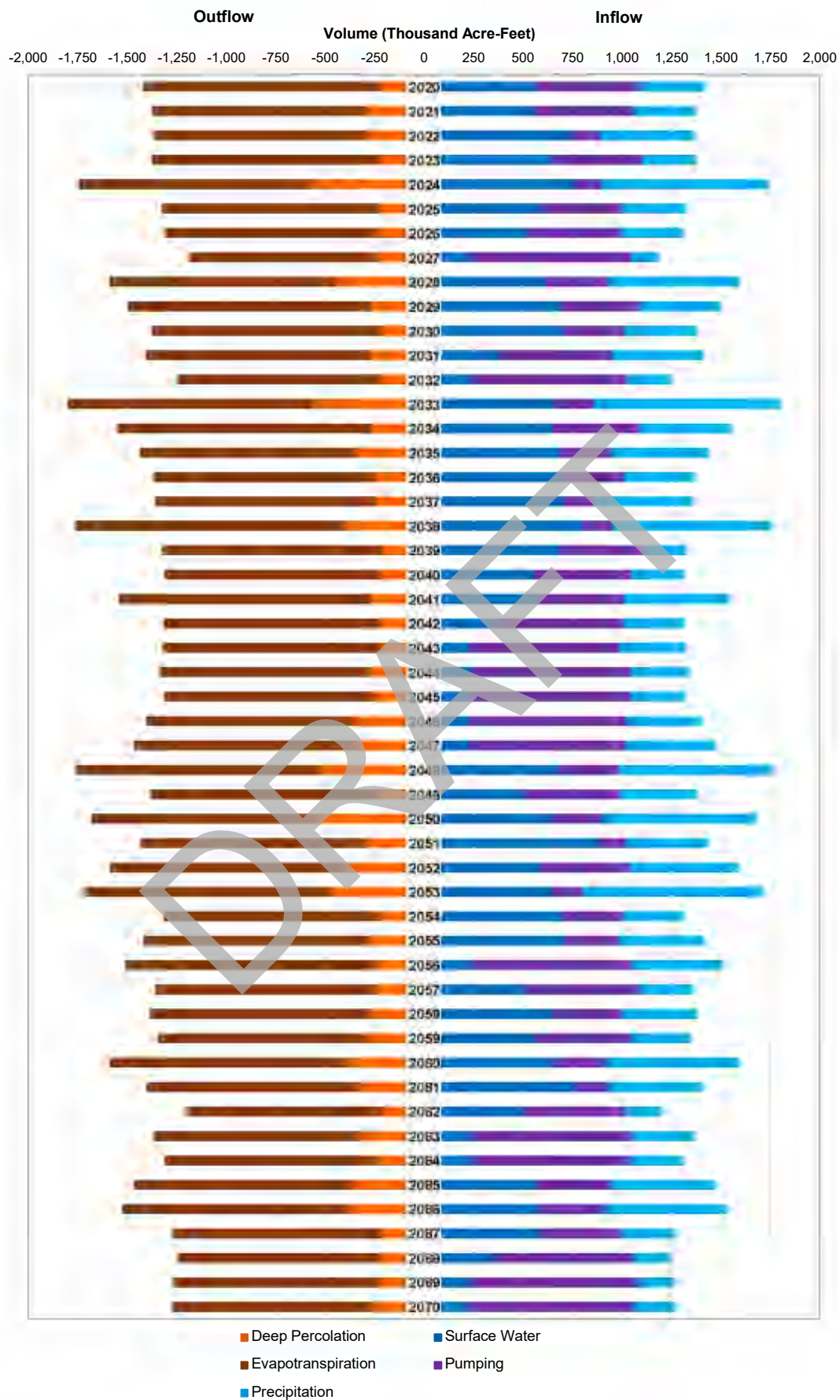
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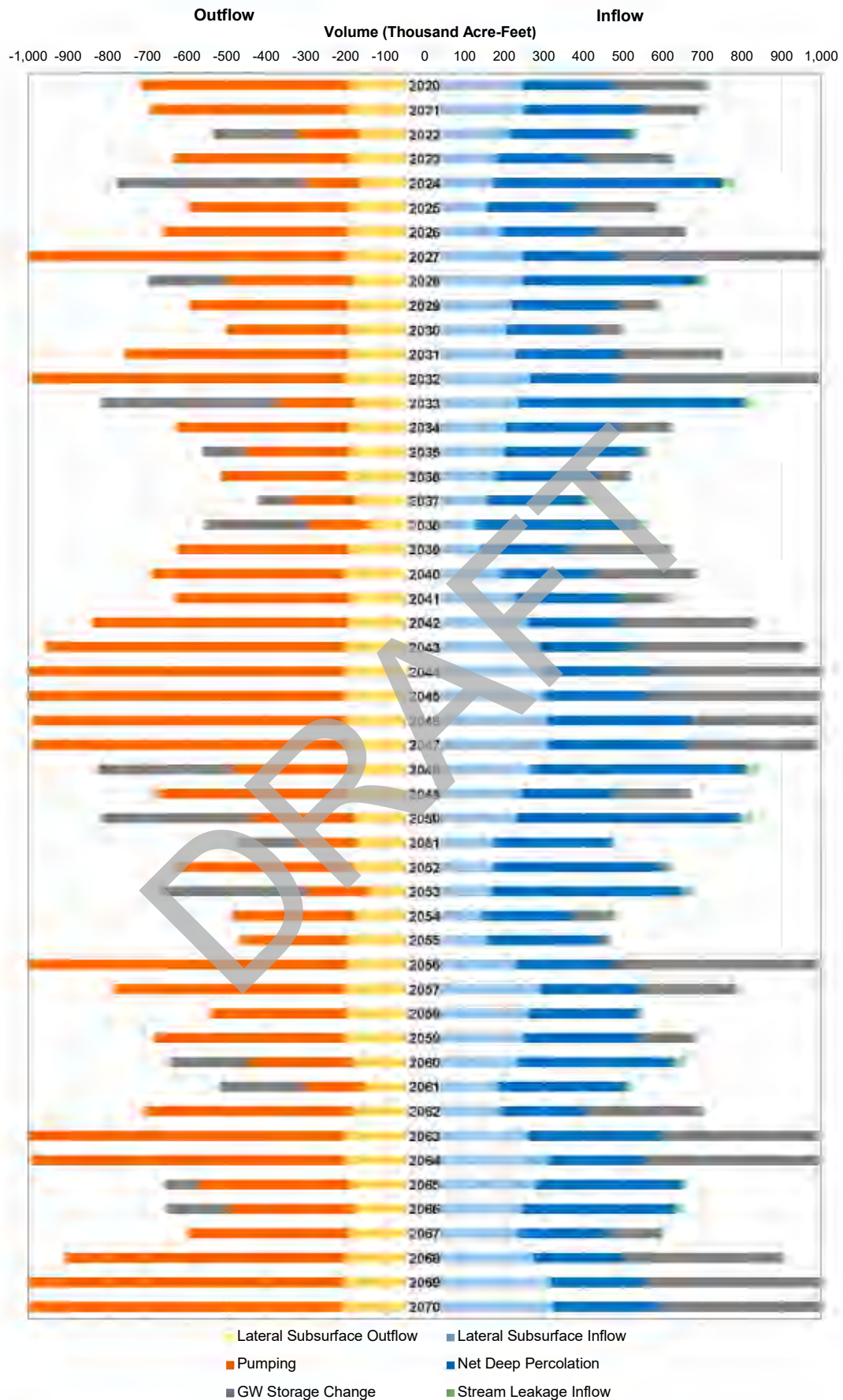


Table 2-8. Historic Water Budget San Joaquin Valley and Sacramento Valley Water Year Type

Water Year	Water Year Type San Joaquin Valley	Water Year Type Sacramento Valley
1989	C	D
1990	C	C
1991	C	C
1992	C	C
1993	W	AN
1994	C	C
1995	W	W
1996	W	W
1997	W	W
1998	W	W
1999	AN	W
2000	AN	AN
2001	D	D
2002	D	D
2003	BN	AN
2004	D	BN
2005	W	AN
2006	W	W
2007	C	D
2008	C	C
2009	BN	D
2010	AN	BN
2011	W	W
2012	D	BN
2013	C	D
2014	C	C
2015	C	C

Table 2-9. Projected Water Budget San Joaquin Valley and Sacramento Valley Water Year Type

Historic Water Year	Projected Water Year	Water Year Type San Joaquin Valley	Water Year Type Sacramento Valley	Historic Water Year	Projected Water Year	Water Year Type San Joaquin Valley	Water Year Type Sacramento Valley
2017	2017 ¹	W	W	1989	2044	C	D
1963	2018 ²	AN	W	1990	2045	C	C
1964	2019 ²	D	D	1991	2046	C	C
1965	2020	W	W	1992	2047	C	C
1966	2021	BN	BN	1993	2048	W	AN
1967	2022	W	W	1994	2049	C	C
1968	2023	D	BN	1995	2050	W	W
1969	2024	W	W	1996	2051	W	W
1970	2025	AN	W	1997	2052	W	W
1971	2026	BN	W	1998	2053	W	W
1972	2027	D	BN	1999	2054	AN	W
1973	2028	AN	AN	2000	2055	AN	AN
1974	2029	W	W	2001	2056	D	D
1975	2030	W	W	2002	2057	D	D
1976	2031	C	C	2003	2058	BN	AN
1977	2032	C	C	2004	2059	D	BN
1978	2033	W	AN	2005	2060	W	AN
1979	2034	AN	BN	2006	2061	W	W
1980	2035	W	AN	2007	2062	C	D
1981	2036	D	D	2008	2063	C	C
1982	2037	W	W	2009	2064	BN	D
1983	2038	W	W	2010	2065	AN	BN
1984	2039	AN	W	2011	2066	W	W
1985	2040	D	D	2012	2067	D	BN
1986	2041	W	W	2013	2068	C	D
1987	2042	C	D	2014	2069	C	C
1988	2043	C	C	2015	2070	C	C

1. 2017 Climate and Streamflow. Reported Surface Water through February 2017.

2. Included in Numerical Model. Not Included in Analysis of Projected Period.

Table 2-10: Historic Land Surface Water Budget - Westside Subbasin (1989-2015)

Water Year	Water Year Type	Precipitation (af)	Imported Surface Water ¹ (af)	Utilized Surface Water ² (af)	Groundwater Pumping (af)	Total Inflow (af)	Evapo-transpiration (af)	Net Deep Percolation ³ (af)	Total Outflow (af)
1989	C	269,000	1,135,000	1,069,000	328,000	1,667,000	1,183,000	483,000	1,667,000
1990	C	243,000	924,000	902,000	484,000	1,629,000	1,200,000	429,000	1,629,000
1991	C	336,000	421,000	418,000	697,000	1,452,000	1,138,000	315,000	1,452,000
1992	C	402,000	457,000	455,000	665,000	1,521,000	1,221,000	300,000	1,521,000
1993	W	706,000	760,000	752,000	318,000	1,776,000	1,327,000	448,000	1,776,000
1994	C	362,000	891,000	881,000	439,000	1,682,000	1,286,000	396,000	1,682,000
1995	W	715,000	951,000	883,000	170,000	1,767,000	1,240,000	528,000	1,767,000
1996	W	364,000	1,373,000	1,227,000	177,000	1,769,000	1,269,000	500,000	1,769,000
1997	W	506,000	1,319,000	1,111,000	178,000	1,795,000	1,295,000	499,000	1,795,000
1998	W	847,000	993,000	881,000	116,000	1,845,000	1,370,000	474,000	1,845,000
1999	AN	290,000	1,279,000	1,158,000	208,000	1,655,000	1,304,000	351,000	1,655,000
2000	AN	388,000	949,000	902,000	304,000	1,595,000	1,319,000	275,000	1,595,000
2001	D	412,000	907,000	884,000	409,000	1,705,000	1,399,000	306,000	1,705,000
2002	D	265,000	892,000	864,000	412,000	1,541,000	1,254,000	287,000	1,541,000
2003	BN	380,000	997,000	963,000	227,000	1,571,000	1,254,000	317,000	1,571,000
2004	D	272,000	1,044,000	974,000	233,000	1,479,000	1,151,000	328,000	1,479,000
2005	W	633,000	992,000	909,000	79,000	1,621,000	1,266,000	356,000	1,621,000
2006	W	453,000	1,121,000	1,023,000	90,000	1,565,000	1,197,000	369,000	1,566,000
2007	C	163,000	1,025,000	963,000	241,000	1,368,000	1,126,000	242,000	1,368,000
2008	C	302,000	574,000	554,000	329,000	1,185,000	1,054,000	132,000	1,185,000
2009	BN	257,000	357,000	348,000	377,000	982,000	952,000	30,000	982,000
2010	AN	474,000	603,000	593,000	181,000	1,248,000	1,041,000	207,000	1,248,000
2011	W	587,000	1,011,000	928,000	93,000	1,609,000	1,160,000	449,000	1,609,000
2012	D	271,000	829,000	796,000	304,000	1,371,000	1,115,000	256,000	1,371,000
2013	C	196,000	508,000	493,000	454,000	1,143,000	1,021,000	121,000	1,143,000
2014	C	160,000	223,000	220,000	614,000	993,000	947,000	46,000	993,000
2015	C	250,000	179,000	178,000	608,000	1,035,000	920,000	115,000	1,035,000
Average		389,000	841,000	790,000	324,000	1,503,000	1,185,000	317,000	1,503,000

1. Reported surface water imports from WWD records

2. Simulated surface water imports (imports not utilized by model rejected and not included in FMP water budget)

3. Difference between deep percolation and groundwater uptake from plants and direct evaporation

Table 2-12: Historic Groundwater Budget - Westside Subbasin (1989-2015)

Water Year	Water Year Type	Net Deep Percolation (af)	Stream Leakage (af)	Lateral Subsurface Inflow (af)	Total Inflow (af)	Groundwater Pumping (af)	Lateral Subsurface Outflow (af)	Total Outflow (af)	Change In Groundwater Storage (af)
1989	C	485,000	0	205,000	691,000	326,000	178,000	503,000	182,000
1990	C	430,000	1,000	202,000	633,000	483,000	180,000	663,000	-36,000
1991	C	316,000	5,000	235,000	556,000	697,000	168,000	865,000	-315,000
1992	C	301,000	8,000	245,000	554,000	667,000	167,000	834,000	-286,000
1993	W	451,000	30,000	223,000	705,000	317,000	153,000	470,000	231,000
1994	C	398,000	3,000	206,000	607,000	436,000	162,000	598,000	2,000
1995	W	530,000	32,000	185,000	747,000	169,000	144,000	313,000	427,000
1996	W	500,000	10,000	141,000	651,000	176,000	152,000	329,000	320,000
1997	W	500,000	18,000	119,000	637,000	177,000	164,000	341,000	294,000
1998	W	476,000	33,000	102,000	611,000	116,000	163,000	279,000	329,000
1999	AN	349,000	6,000	98,000	453,000	209,000	171,000	380,000	73,000
2000	AN	275,000	6,000	114,000	394,000	304,000	163,000	467,000	-73,000
2001	D	306,000	10,000	142,000	458,000	408,000	170,000	578,000	-121,000
2002	D	287,000	1,000	167,000	455,000	413,000	173,000	587,000	-133,000
2003	BN	318,000	3,000	157,000	478,000	230,000	180,000	410,000	59,000
2004	D	328,000	2,000	133,000	462,000	236,000	192,000	428,000	31,000
2005	W	356,000	26,000	117,000	499,000	91,000	155,000	246,000	244,000
2006	W	368,000	14,000	88,000	470,000	101,000	153,000	254,000	211,000
2007	C	239,000	1,000	88,000	328,000	253,000	171,000	424,000	-98,000
2008	C	125,000	7,000	105,000	238,000	326,000	188,000	514,000	-281,000
2009	BN	28,000	1,000	130,000	159,000	373,000	186,000	559,000	-401,000
2010	AN	209,000	12,000	131,000	352,000	179,000	162,000	341,000	9,000
2011	W	451,000	24,000	96,000	572,000	92,000	148,000	240,000	327,000
2012	D	249,000	2,000	97,000	348,000	302,000	160,000	462,000	-112,000
2013	C	118,000	1,000	130,000	249,000	450,000	183,000	633,000	-383,000
2014	C	43,000	1,000	186,000	231,000	608,000	188,000	796,000	-568,000
2015	C	115,000	0	225,000	340,000	603,000	184,000	787,000	-449,000
Average		317,000	10,000	151,000	477,000	324,000	169,000	493,000	-19,000

Table 2-15: Projected Land Surface Water Budget - Westside Subbasin (2017-2070)

Water Year	Water Year Type	Precipitation (af)	Imported Surface Water ¹ (af)	Utilized Surface Water ² (af)	Groundwater Pumping (af)	Total (af)	Evapo-transpiration (af)	Net Deep Percolation ³ (af)	Total Outflow (af)
2017*	W	577,000	1,296,000	853,000	111,000	1,540,000	1,069,000	471,000	1,540,000
2018	AN	344,000	805,000	720,000	156,000	1,220,000	63,000	63,000	63,000
2019	D	255,000	457,000	456,000	498,000	1,209,000	57,000	57,000	57,000
2020	W	333,000	791,000	791,000	232,000	1,356,000	53,000	53,000	53,000
2021	BN	322,000	862,000	842,000	155,000	1,319,000	65,000	65,000	65,000
2022	W	462,000	1,282,000	689,000	143,000	1,295,000	71,000	71,000	71,000
2023	D	279,000	712,000	693,000	334,000	1,306,000	67,000	67,000	67,000
2024	W	775,000	1,310,000	716,000	131,000	1,622,000	133,000	133,000	133,000
2025	AN	297,000	755,000	742,000	206,000	1,245,000	91,000	91,000	91,000
2026	BN	328,000	626,000	626,000	293,000	1,247,000	81,000	81,000	81,000
2027	D	146,000	386,000	386,000	596,000	1,128,000	69,000	69,000	69,000
2028	AN	622,000	853,000	722,000	155,000	1,499,000	108,000	108,000	108,000
2029	W	391,000	981,000	878,000	144,000	1,413,000	91,000	91,000	91,000
2030	W	353,000	884,000	867,000	155,000	1,375,000	72,000	72,000	72,000
2031	C	402,000	665,000	665,000	235,000	1,301,000	64,000	64,000	64,000
2032	C	231,000	238,000	238,000	721,000	1,189,000	55,000	55,000	55,000
2033	W	851,000	822,000	642,000	173,000	1,666,000	123,000	123,000	123,000
2034	AN	424,000	753,000	749,000	279,000	1,452,000	98,000	98,000	98,000
2035	W	460,000	955,000	740,000	146,000	1,346,000	85,000	85,000	85,000
2036	D	338,000	772,000	766,000	178,000	1,282,000	80,000	80,000	80,000
2037	W	484,000	1,179,000	658,000	148,000	1,289,000	73,000	73,000	73,000
2038	W	757,000	1,325,000	741,000	148,000	1,645,000	125,000	125,000	125,000
2039	AN	214,000	897,000	886,000	165,000	1,265,000	93,000	93,000	93,000
2040	D	270,000	662,000	662,000	320,000	1,251,000	75,000	75,000	75,000
2041	W	503,000	740,000	740,000	210,000	1,453,000	78,000	78,000	78,000
2042	C	284,000	345,000	345,000	595,000	1,223,000	62,000	62,000	62,000
2043	C	338,000	227,000	227,000	694,000	1,260,000	51,000	51,000	51,000
2044	C	275,000	482,000	482,000	508,000	1,265,000	49,000	49,000	49,000
2045	C	249,000	235,000	235,000	747,000	1,231,000	41,000	41,000	41,000
2046	C	343,000	397,000	397,000	572,000	1,311,000	52,000	52,000	52,000
2047	C	409,000	511,000	511,000	457,000	1,377,000	54,000	54,000	54,000
2048	W	719,000	974,000	772,000	150,000	1,640,000	96,000	96,000	96,000
2049	C	369,000	602,000	597,000	336,000	1,302,000	60,000	60,000	60,000
2050	W	728,000	977,000	694,000	151,000	1,573,000	111,000	111,000	111,000
2051	W	374,000	1,194,000	826,000	138,000	1,338,000	94,000	94,000	94,000
2052	W	517,000	747,000	745,000	232,000	1,493,000	131,000	131,000	131,000
2053	W	865,000	1,304,000	592,000	147,000	1,604,000	158,000	158,000	158,000
2054	AN	296,000	906,000	795,000	144,000	1,234,000	110,000	110,000	110,000
2055	AN	397,000	722,000	720,000	199,000	1,315,000	106,000	106,000	106,000
2056	D	420,000	354,000	354,000	640,000	1,415,000	87,000	87,000	87,000
2057	D	271,000	603,000	603,000	423,000	1,298,000	71,000	71,000	71,000
2058	BN	388,000	760,000	758,000	171,000	1,318,000	63,000	63,000	63,000
2059	D	277,000	827,000	822,000	159,000	1,259,000	67,000	67,000	67,000
2060	W	645,000	657,000	657,000	189,000	1,491,000	92,000	92,000	92,000
2061	W	462,000	1,316,000	709,000	147,000	1,318,000	89,000	89,000	89,000
2062	C	167,000	513,000	498,000	466,000	1,131,000	68,000	68,000	68,000
2063	C	308,000	234,000	234,000	743,000	1,285,000	70,000	70,000	70,000
2064	BN	263,000	353,000	353,000	623,000	1,239,000	52,000	52,000	52,000
2065	AN	484,000	680,000	680,000	207,000	1,371,000	62,000	62,000	62,000
2066	W	599,000	735,000	686,000	156,000	1,441,000	89,000	89,000	89,000
2067	D	276,000	781,000	774,000	162,000	1,212,000	62,000	62,000	62,000
2068	C	200,000	342,000	341,000	659,000	1,201,000	54,000	54,000	54,000
2069	C	163,000	281,000	281,000	742,000	1,186,000	42,000	42,000	42,000
2070	C	254,000	505,000	505,000	482,000	1,241,000	43,000	43,000	43,000
Average (2020 - 2040)		416,000	843,000	700,000	241,000	1,357,000	84,000	84,000	1,357,000
Average (2020 - 2070)		404,000	726,000	620,000	320,000	1,343,000	79,000	79,000	1,343,000

* Actual water year type for 2017 (all other years derived from historic record)
1. Reported surface water imports from WWD records
2. Simulated surface water imports (imports not utilized by model rejected and not included in FMP water budget)
3. Difference between deep percolation and groundwater uptake from plants and direct evaporation

Table 2-16: Projected Groundwater Budget - Westside Subbasin (2017-2070)

Water Year	Water Year Type	Net Deep Percolation (af)	Stream Leakage (af)	Lateral Subsurface Inflow (af)	Total Inflow (af)	Pumping (af)	Lateral Subsurface Outflow (af)	Total Outflow (af)	Change In Groundwater Storage (af)
2017*	W	401,000	15,000	204,000	620,000	110,000	160,000	269,000	341,000
2018	AN	245,000	11,000	139,000	396,000	155,000	172,000	326,000	63,000
2019	D	210,000	1,000	152,000	363,000	494,000	188,000	681,000	-317,000
2020	W	218,000	12,000	173,000	403,000	230,000	194,000	424,000	-28,000
2021	BN	311,000	1,000	137,000	449,000	153,000	200,000	354,000	91,000
2022	W	288,000	23,000	111,000	421,000	142,000	155,000	297,000	120,000
2023	D	218,000	10,000	114,000	343,000	330,000	187,000	517,000	-172,000
2024	W	515,000	32,000	116,000	663,000	130,000	148,000	278,000	380,000
2025	AN	199,000	5,000	97,000	302,000	204,000	187,000	391,000	-92,000
2026	BN	246,000	2,000	110,000	359,000	290,000	201,000	491,000	-134,000
2027	D	226,000	1,000	172,000	399,000	591,000	198,000	789,000	-388,000
2028	AN	415,000	13,000	182,000	611,000	154,000	171,000	324,000	277,000
2029	W	236,000	11,000	124,000	372,000	143,000	190,000	332,000	35,000
2030	W	208,000	11,000	107,000	327,000	154,000	203,000	357,000	-35,000
2031	C	230,000	8,000	107,000	345,000	233,000	204,000	436,000	-91,000
2032	C	203,000	0	175,000	378,000	714,000	200,000	914,000	-532,000
2033	W	506,000	21,000	197,000	725,000	171,000	162,000	333,000	383,000
2034	AN	241,000	4,000	150,000	394,000	276,000	185,000	461,000	-69,000
2035	W	301,000	21,000	133,000	455,000	145,000	177,000	322,000	127,000
2036	D	222,000	1,000	110,000	333,000	176,000	200,000	376,000	-46,000
2037	W	236,000	23,000	99,000	358,000	146,000	162,000	308,000	48,000
2038	W	373,000	22,000	92,000	487,000	146,000	137,000	283,000	199,000
2039	AN	203,000	4,000	84,000	291,000	163,000	193,000	356,000	-68,000
2040	D	222,000	1,000	101,000	324,000	317,000	210,000	527,000	-200,000
2041	W	253,000	30,000	121,000	405,000	208,000	194,000	402,000	-2,000
2042	C	204,000	6,000	168,000	377,000	589,000	194,000	782,000	-402,000
2043	C	218,000	2,000	242,000	462,000	687,000	191,000	879,000	-417,000
2044	C	261,000	0	260,000	521,000	503,000	192,000	695,000	-177,000
2045	C	230,000	1,000	272,000	503,000	740,000	196,000	936,000	-433,000
2046	C	332,000	5,000	280,000	617,000	566,000	191,000	758,000	-146,000
2047	C	318,000	8,000	267,000	592,000	453,000	191,000	644,000	-58,000
2048	W	487,000	30,000	219,000	736,000	149,000	168,000	317,000	409,000
2049	C	211,000	3,000	170,000	383,000	333,000	185,000	518,000	-134,000
2050	W	493,000	31,000	155,000	679,000	150,000	162,000	312,000	362,000
2051	W	264,000	10,000	119,000	393,000	137,000	158,000	295,000	91,000
2052	W	380,000	17,000	110,000	507,000	229,000	178,000	407,000	96,000
2053	W	427,000	32,000	103,000	562,000	146,000	140,000	286,000	269,000
2054	AN	196,000	6,000	91,000	293,000	142,000	172,000	314,000	-23,000
2055	AN	241,000	5,000	92,000	338,000	197,000	190,000	387,000	-51,000
2056	D	216,000	10,000	161,000	387,000	634,000	195,000	829,000	-438,000
2057	D	244,000	1,000	215,000	460,000	419,000	198,000	617,000	-159,000
2058	BN	264,000	3,000	182,000	449,000	169,000	194,000	363,000	78,000
2059	D	268,000	1,000	138,000	406,000	158,000	201,000	359,000	43,000
2060	W	359,000	26,000	121,000	505,000	187,000	187,000	373,000	128,000
2061	W	292,000	12,000	114,000	418,000	146,000	150,000	296,000	118,000
2062	C	192,000	0	142,000	334,000	462,000	183,000	645,000	-304,000
2063	C	304,000	6,000	214,000	524,000	736,000	199,000	935,000	-411,000
2064	BN	224,000	0	266,000	491,000	617,000	195,000	812,000	-324,000
2065	AN	333,000	12,000	229,000	574,000	205,000	186,000	391,000	173,000
2066	W	361,000	23,000	170,000	554,000	154,000	171,000	325,000	221,000
2067	D	201,000	1,000	142,000	344,000	160,000	185,000	345,000	-2,000
2068	C	223,000	0	182,000	406,000	653,000	201,000	854,000	-442,000
2069	C	222,000	0	262,000	485,000	735,000	203,000	937,000	-456,000
2070	C	286,000	0	271,000	557,000	477,000	198,000	675,000	-123,000
Average (2020 - 2040)		277,000	11,000	128,000	416,000	238,000	184,000	422,000	-9,000
Average (2020 - 2070)		281,000	10,000	160,000	451,000	317,000	185,000	501,000	-53,000

* Actual water year type for 2017 (all other years derived from historic record)

Table 2-17: Projected Land Surface Water Budget (2030 Climate Change Factors)- Westside Subbasin (2017-2070)

Water Year	Water Year Type	Precipitation (af)	Imported Surface Water1 (af)	Utilized Surface Water2 (af)	Groundwater Pumping (af)	Total (af)	Evapo-transpiration (af)	Net Deep Percolation3 (af)	Total Outflow (af)
2017*	W	579,000	1,296,000	804,000	112,000	1,495,000	1,069,000	471,000	1,495,000
2018	AN	347,000	805,000	652,000	185,000	1,184,000	63,000	63,000	1,184,000
2019	D	267,000	457,000	456,000	460,000	1,183,000	57,000	57,000	1,183,000
2020	W	345,000	791,000	791,000	271,000	1,406,000	53,000	53,000	1,406,000
2021	BN	317,000	862,000	758,000	218,000	1,293,000	65,000	65,000	1,293,000
2022	W	471,000	1,282,000	614,000	144,000	1,229,000	71,000	71,000	1,229,000
2023	D	283,000	712,000	662,000	349,000	1,295,000	67,000	67,000	1,295,000
2024	W	810,000	1,310,000	641,000	134,000	1,585,000	133,000	133,000	1,585,000
2025	AN	306,000	755,000	726,000	213,000	1,246,000	91,000	91,000	1,246,000
2026	BN	333,000	626,000	625,000	287,000	1,245,000	81,000	81,000	1,245,000
2027	D	151,000	386,000	385,000	545,000	1,081,000	69,000	69,000	1,081,000
2028	AN	628,000	853,000	719,000	175,000	1,522,000	108,000	108,000	1,522,000
2029	W	401,000	981,000	886,000	151,000	1,438,000	91,000	91,000	1,438,000
2030	W	367,000	884,000	875,000	182,000	1,423,000	72,000	72,000	1,423,000
2031	C	442,000	665,000	636,000	301,000	1,379,000	64,000	64,000	1,379,000
2032	C	233,000	238,000	238,000	674,000	1,145,000	55,000	55,000	1,145,000
2033	W	895,000	822,000	642,000	166,000	1,703,000	123,000	123,000	1,703,000
2034	AN	436,000	753,000	706,000	267,000	1,409,000	98,000	98,000	1,409,000
2035	W	471,000	955,000	714,000	145,000	1,330,000	85,000	85,000	1,330,000
2036	D	342,000	772,000	715,000	167,000	1,224,000	80,000	80,000	1,224,000
2037	W	482,000	1,179,000	608,000	148,000	1,238,000	73,000	73,000	1,238,000
2038	W	779,000	1,325,000	742,000	148,000	1,669,000	125,000	125,000	1,669,000
2039	AN	222,000	897,000	853,000	186,000	1,261,000	93,000	93,000	1,261,000
2040	D	278,000	662,000	653,000	282,000	1,214,000	75,000	75,000	1,214,000
2041	W	515,000	740,000	690,000	199,000	1,404,000	78,000	78,000	1,404,000
2042	C	291,000	345,000	345,000	534,000	1,169,000	62,000	62,000	1,169,000
2043	C	348,000	227,000	227,000	614,000	1,189,000	51,000	51,000	1,189,000
2044	C	286,000	482,000	482,000	515,000	1,283,000	49,000	49,000	1,283,000
2045	C	266,000	235,000	235,000	751,000	1,252,000	41,000	41,000	1,252,000
2046	C	368,000	397,000	397,000	514,000	1,279,000	52,000	52,000	1,279,000
2047	C	425,000	511,000	511,000	483,000	1,419,000	54,000	54,000	1,419,000
2048	W	739,000	974,000	689,000	178,000	1,606,000	96,000	96,000	1,606,000
2049	C	380,000	602,000	593,000	335,000	1,307,000	60,000	60,000	1,307,000
2050	W	749,000	977,000	643,000	151,000	1,543,000	111,000	111,000	1,543,000
2051	W	389,000	1,194,000	765,000	138,000	1,292,000	94,000	94,000	1,292,000
2052	W	543,000	747,000	745,000	242,000	1,529,000	131,000	131,000	1,529,000
2053	W	879,000	1,304,000	543,000	146,000	1,568,000	158,000	158,000	1,568,000
2054	AN	302,000	906,000	769,000	142,000	1,214,000	110,000	110,000	1,214,000
2055	AN	407,000	722,000	644,000	179,000	1,230,000	106,000	106,000	1,230,000
2056	D	440,000	354,000	354,000	642,000	1,437,000	87,000	87,000	1,437,000
2057	D	281,000	603,000	599,000	367,000	1,247,000	71,000	71,000	1,247,000
2058	BN	399,000	760,000	758,000	190,000	1,347,000	63,000	63,000	1,347,000
2059	D	297,000	827,000	800,000	191,000	1,287,000	67,000	67,000	1,287,000
2060	W	675,000	657,000	641,000	195,000	1,510,000	92,000	92,000	1,510,000
2061	W	461,000	1,316,000	698,000	147,000	1,306,000	89,000	89,000	1,306,000
2062	C	174,000	513,000	495,000	491,000	1,160,000	68,000	68,000	1,160,000
2063	C	305,000	234,000	234,000	736,000	1,275,000	70,000	70,000	1,275,000
2064	BN	268,000	353,000	353,000	568,000	1,189,000	52,000	52,000	1,189,000
2065	AN	505,000	680,000	657,000	200,000	1,362,000	62,000	62,000	1,362,000
2066	W	606,000	735,000	612,000	166,000	1,383,000	89,000	89,000	1,383,000
2067	D	301,000	781,000	698,000	183,000	1,182,000	62,000	62,000	1,182,000
2068	C	212,000	342,000	342,000	664,000	1,217,000	54,000	54,000	1,217,000
2069	C	176,000	281,000	281,000	641,000	1,099,000	42,000	42,000	1,099,000
2070	C	250,000	505,000	505,000	448,000	1,204,000	43,000	43,000	1,204,000
Average (2020 - 2040)		428,000	843,000	676,000	245,000	1,349,000	84,000	84,000	1,349,000
Average (2020 - 2070)		416,000	726,000	598,000	316,000	1,330,000	79,000	79,000	1,330,000

* Actual water year type for 2017 (all other years derived from historic record)
1. Reported surface water imports from WWD records
2. Simulated surface water imports (imports not utilized by model rejected and not included in FMP water budget)
3. Difference between deep percolation and groundwater uptake from plants and direct evaporation

Table 2-18: Projected Groundwater Budget (2030 Climate Change Factors) - Westside Subbasin (2017-2070)

Water Year	Water Year Type	Net Deep Percolation (af)	Stream Leakage (af)	Lateral Subsurface Inflow (af)	Total Inflow (af)	Pumping (af)	Lateral Subsurface Outflow (af)	Total Outflow (af)	Change In Groundwater Storage (af)
2017*	W	398,000	15,000	204,000	618,000	111,000	158,000	269,000	338,000
2018	AN	246,000	12,000	141,000	399,000	184,000	169,000	353,000	42,000
2019	D	207,000	1,000	149,000	357,000	455,000	189,000	644,000	-286,000
2020	W	220,000	12,000	175,000	407,000	268,000	201,000	469,000	-67,000
2021	BN	305,000	1,000	152,000	458,000	216,000	193,000	409,000	46,000
2022	W	292,000	23,000	123,000	438,000	142,000	147,000	289,000	144,000
2023	D	219,000	10,000	118,000	348,000	346,000	186,000	532,000	-182,000
2024	W	528,000	32,000	126,000	685,000	132,000	149,000	281,000	398,000
2025	AN	200,000	5,000	103,000	308,000	211,000	185,000	396,000	-89,000
2026	BN	246,000	3,000	112,000	361,000	284,000	202,000	486,000	-126,000
2027	D	225,000	1,000	163,000	389,000	539,000	198,000	738,000	-347,000
2028	AN	419,000	13,000	180,000	613,000	173,000	169,000	343,000	259,000
2029	W	239,000	12,000	126,000	377,000	149,000	195,000	344,000	27,000
2030	W	212,000	11,000	111,000	334,000	180,000	206,000	386,000	-55,000
2031	C	237,000	8,000	118,000	363,000	298,000	202,000	499,000	-134,000
2032	C	201,000	0	187,000	388,000	667,000	198,000	866,000	-475,000
2033	W	524,000	22,000	196,000	742,000	165,000	159,000	323,000	410,000
2034	AN	240,000	4,000	149,000	393,000	264,000	189,000	453,000	-64,000
2035	W	305,000	22,000	132,000	458,000	143,000	176,000	319,000	132,000
2036	D	220,000	1,000	107,000	328,000	166,000	191,000	357,000	-32,000
2037	W	232,000	22,000	97,000	351,000	146,000	159,000	306,000	42,000
2038	W	376,000	22,000	91,000	489,000	146,000	141,000	288,000	196,000
2039	AN	201,000	4,000	87,000	292,000	185,000	195,000	379,000	-90,000
2040	D	220,000	1,000	100,000	321,000	280,000	211,000	491,000	-165,000
2041	W	249,000	30,000	115,000	395,000	197,000	191,000	388,000	1,000
2042	C	199,000	6,000	154,000	359,000	529,000	193,000	722,000	-358,000
2043	C	212,000	2,000	224,000	437,000	608,000	190,000	798,000	-360,000
2044	C	263,000	0	252,000	516,000	510,000	192,000	702,000	-190,000
2045	C	231,000	1,000	267,000	499,000	744,000	198,000	943,000	-443,000
2046	C	336,000	6,000	271,000	613,000	509,000	193,000	702,000	-96,000
2047	C	324,000	8,000	267,000	599,000	478,000	194,000	672,000	-78,000
2048	W	491,000	30,000	224,000	745,000	176,000	161,000	337,000	397,000
2049	C	209,000	3,000	174,000	386,000	331,000	183,000	514,000	-129,000
2050	W	500,000	31,000	156,000	687,000	149,000	159,000	308,000	370,000
2051	W	262,000	10,000	119,000	392,000	136,000	150,000	287,000	101,000
2052	W	383,000	18,000	111,000	512,000	240,000	175,000	415,000	93,000
2053	W	434,000	32,000	103,000	570,000	144,000	137,000	281,000	282,000
2054	AN	195,000	6,000	90,000	291,000	141,000	173,000	314,000	-23,000
2055	AN	237,000	6,000	88,000	331,000	177,000	185,000	362,000	-31,000
2056	D	213,000	10,000	157,000	380,000	636,000	196,000	832,000	-446,000
2057	D	239,000	1,000	203,000	442,000	363,000	196,000	559,000	-118,000
2058	BN	265,000	3,000	170,000	438,000	189,000	198,000	387,000	46,000
2059	D	271,000	1,000	142,000	414,000	189,000	199,000	388,000	22,000
2060	W	368,000	27,000	124,000	518,000	193,000	184,000	377,000	135,000
2061	W	288,000	13,000	117,000	418,000	145,000	149,000	294,000	119,000
2062	C	192,000	0	142,000	335,000	486,000	181,000	667,000	-325,000
2063	C	300,000	6,000	221,000	527,000	729,000	197,000	926,000	-399,000
2064	BN	220,000	0	260,000	480,000	562,000	193,000	756,000	-276,000
2065	AN	336,000	12,000	226,000	574,000	198,000	185,000	382,000	181,000
2066	W	360,000	24,000	168,000	552,000	164,000	166,000	330,000	213,000
2067	D	195,000	1,000	143,000	339,000	182,000	179,000	360,000	-24,000
2068	C	224,000	8,000	185,000	417,000	657,000	202,000	859,000	-437,000
2069	C	213,000	2,000	260,000	475,000	635,000	198,000	833,000	-360,000
2070	C	278,000	0	263,000	542,000	444,000	200,000	644,000	-108,000
Average (2020 - 2040)		279,000	11,000	131,000	421,000	243,000	183,000	426,000	-8,000
Average (2020 - 2070)		281,000	10,000	160,000	451,000	313,000	183,000	496,000	-47,000

* Actual water year type for 2017 (all other years derived from historic record)

Table 2-19: Projected Land Surface Water Budget (2070 Climate Change Factors) - Westside Subbasin (2017-2070)

Water Year	Water Year Type	Precipitation (af)	Imported Surface Water1 (af)	Utilized Surface Water2 (af)	Groundwater Pumping (af)	Total (af)	Evapo-transpiration (af)	Net Deep Percolation3 (af)	Total Outflow (af)
2017*	W	578,000	1,295,000	907,000	111,000	1,596,000	1,069,000	471,000	1,596,000
2018	AN	355,000	759,000	750,000	190,000	1,294,000	63,000	63,000	1,294,000
2019	D	248,000	210,000	210,000	804,000	1,262,000	57,000	57,000	1,262,000
2020	W	327,000	560,000	560,000	532,000	1,419,000	53,000	53,000	1,419,000
2021	BN	315,000	553,000	553,000	506,000	1,375,000	65,000	65,000	1,375,000
2022	W	472,000	1,105,000	731,000	162,000	1,365,000	71,000	71,000	1,365,000
2023	D	275,000	665,000	653,000	449,000	1,377,000	67,000	67,000	1,377,000
2024	W	840,000	1,057,000	763,000	141,000	1,744,000	133,000	133,000	1,744,000
2025	AN	320,000	606,000	601,000	404,000	1,325,000	91,000	91,000	1,325,000
2026	BN	313,000	525,000	525,000	469,000	1,308,000	81,000	81,000	1,308,000
2027	D	142,000	233,000	233,000	813,000	1,188,000	69,000	69,000	1,188,000
2028	AN	658,000	611,000	611,000	323,000	1,592,000	108,000	108,000	1,592,000
2029	W	405,000	691,000	691,000	402,000	1,497,000	91,000	91,000	1,497,000
2030	W	364,000	715,000	707,000	308,000	1,379,000	72,000	72,000	1,379,000
2031	C	458,000	380,000	380,000	570,000	1,408,000	64,000	64,000	1,408,000
2032	C	217,000	231,000	231,000	798,000	1,246,000	55,000	55,000	1,246,000
2033	W	942,000	665,000	659,000	200,000	1,801,000	123,000	123,000	1,801,000
2034	AN	461,000	651,000	651,000	439,000	1,551,000	98,000	98,000	1,551,000
2035	W	490,000	683,000	683,000	263,000	1,437,000	85,000	85,000	1,437,000
2036	D	358,000	690,000	690,000	318,000	1,366,000	80,000	80,000	1,366,000
2037	W	492,000	881,000	704,000	163,000	1,359,000	73,000	73,000	1,359,000
2038	W	810,000	1,320,000	803,000	148,000	1,760,000	125,000	125,000	1,760,000
2039	AN	206,000	692,000	683,000	435,000	1,324,000	93,000	93,000	1,324,000
2040	D	265,000	558,000	558,000	488,000	1,312,000	75,000	75,000	1,312,000
2041	W	531,000	569,000	569,000	444,000	1,544,000	78,000	78,000	1,544,000
2042	C	311,000	356,000	356,000	649,000	1,316,000	62,000	62,000	1,316,000
2043	C	334,000	227,000	227,000	761,000	1,322,000	51,000	51,000	1,322,000
2044	C	290,000	238,000	238,000	809,000	1,337,000	49,000	49,000	1,337,000
2045	C	271,000	227,000	227,000	816,000	1,315,000	41,000	41,000	1,315,000
2046	C	381,000	230,000	230,000	793,000	1,403,000	52,000	52,000	1,403,000
2047	C	446,000	230,000	230,000	793,000	1,469,000	54,000	54,000	1,469,000
2048	W	780,000	679,000	679,000	303,000	1,762,000	96,000	96,000	1,762,000
2049	C	389,000	506,000	506,000	486,000	1,382,000	60,000	60,000	1,382,000
2050	W	776,000	645,000	645,000	259,000	1,681,000	111,000	111,000	1,681,000
2051	W	406,000	1,109,000	882,000	144,000	1,432,000	94,000	94,000	1,432,000
2052	W	550,000	589,000	588,000	449,000	1,587,000	131,000	131,000	1,587,000
2053	W	914,000	1,301,000	649,000	153,000	1,717,000	158,000	158,000	1,717,000
2054	AN	306,000	714,000	695,000	310,000	1,312,000	110,000	110,000	1,312,000
2055	AN	430,000	710,000	710,000	276,000	1,416,000	106,000	106,000	1,416,000
2056	D	461,000	243,000	243,000	809,000	1,512,000	87,000	87,000	1,512,000
2057	D	267,000	507,000	507,000	586,000	1,360,000	71,000	71,000	1,360,000
2058	BN	385,000	655,000	655,000	345,000	1,385,000	63,000	63,000	1,385,000
2059	D	305,000	556,000	556,000	485,000	1,346,000	67,000	67,000	1,346,000
2060	W	677,000	656,000	656,000	258,000	1,590,000	92,000	92,000	1,590,000
2061	W	481,000	1,316,000	772,000	150,000	1,402,000	89,000	89,000	1,402,000
2062	C	178,000	510,000	497,000	526,000	1,201,000	68,000	68,000	1,201,000
2063	C	326,000	234,000	234,000	806,000	1,367,000	70,000	70,000	1,367,000
2064	BN	274,000	240,000	240,000	795,000	1,310,000	52,000	52,000	1,310,000
2065	AN	519,000	568,000	568,000	382,000	1,469,000	62,000	62,000	1,469,000
2066	W	618,000	590,000	590,000	318,000	1,526,000	89,000	89,000	1,526,000
2067	D	272,000	589,000	589,000	410,000	1,271,000	62,000	62,000	1,271,000
2068	C	181,000	353,000	353,000	711,000	1,245,000	54,000	54,000	1,245,000
2069	C	180,000	232,000	232,000	855,000	1,266,000	42,000	42,000	1,266,000
2070	C	218,000	229,000	229,000	824,000	1,270,000	43,000	43,000	1,270,000
Average (2020 - 2040)		435,000	670,000	603,000	397,000	1,435,000	84,000	84,000	1,435,000
Average (2020 - 2070)		423,000	586,000	530,000	471,000	1,424,000	79,000	79,000	1,424,000

* Actual water year type for 2017 (all other years derived from historic record)
1. Reported surface water imports from WWD records
2. Simulated surface water imports (imports not utilized by model rejected and not included in FMP water budget)
3. Difference between deep percolation and groundwater uptake from plants and direct evaporation

Table 2-20: Projected Groundwater Budget (2070 Climate Change Factors) - Westside Subbasin (2017-2070)

Water Year	Water Year Type	Net Deep Percolation (af)	Stream Leakage (af)	Lateral Subsurface Inflow (af)	Total Inflow (af)	Pumping (af)	Lateral Subsurface Outflow (af)	Total Outflow (af)	Change In Groundwater Storage (af)
2017	W	405,000	15,000	204,000	624,000	110,000	165,000	275,000	339,000
2018	AN	260,000	12,000	145,000	416,000	188,000	184,000	371,000	38,000
2019	D	209,000	1,000	195,000	405,000	797,000	191,000	988,000	-582,000
2020	W	223,000	11,000	256,000	491,000	527,000	190,000	717,000	-231,000
2021	BN	297,000	1,000	256,000	554,000	502,000	191,000	693,000	-140,000
2022	W	307,000	23,000	214,000	543,000	160,000	162,000	323,000	214,000
2023	D	225,000	10,000	183,000	418,000	444,000	191,000	635,000	-215,000
2024	W	579,000	32,000	175,000	786,000	140,000	162,000	302,000	477,000
2025	AN	231,000	6,000	155,000	392,000	400,000	191,000	591,000	-198,000
2026	BN	245,000	2,000	195,000	442,000	464,000	196,000	660,000	-220,000
2027	D	238,000	1,000	249,000	489,000	806,000	200,000	1,006,000	-518,000
2028	AN	449,000	14,000	248,000	711,000	320,000	181,000	501,000	199,000
2029	W	269,000	12,000	220,000	501,000	398,000	195,000	593,000	-94,000
2030	W	218,000	12,000	207,000	438,000	305,000	195,000	500,000	-65,000
2031	C	275,000	10,000	227,000	512,000	564,000	192,000	756,000	-244,000
2032	C	220,000	0	269,000	489,000	790,000	200,000	991,000	-504,000
2033	W	568,000	23,000	239,000	831,000	198,000	175,000	373,000	445,000
2034	AN	271,000	4,000	204,000	479,000	435,000	192,000	627,000	-147,000
2035	W	346,000	23,000	203,000	572,000	261,000	190,000	451,000	112,000
2036	D	253,000	1,000	180,000	434,000	315,000	199,000	514,000	-85,000
2037	W	244,000	22,000	161,000	427,000	161,000	176,000	337,000	83,000
2038	W	408,000	23,000	130,000	561,000	146,000	142,000	289,000	266,000
2039	AN	215,000	4,000	142,000	361,000	431,000	192,000	623,000	-261,000
2040	D	230,000	1,000	193,000	423,000	484,000	205,000	689,000	-264,000
2041	W	277,000	30,000	228,000	535,000	439,000	190,000	630,000	-99,000
2042	C	226,000	6,000	259,000	492,000	643,000	195,000	837,000	-346,000
2043	C	226,000	2,000	289,000	517,000	754,000	200,000	954,000	-440,000
2044	C	272,000	0	302,000	574,000	802,000	203,000	1,005,000	-434,000
2045	C	258,000	1,000	304,000	562,000	809,000	204,000	1,013,000	-451,000
2046	C	365,000	6,000	308,000	680,000	785,000	201,000	987,000	-313,000
2047	C	348,000	9,000	313,000	669,000	786,000	200,000	986,000	-322,000
2048	W	538,000	31,000	270,000	840,000	300,000	183,000	483,000	344,000
2049	C	227,000	3,000	243,000	473,000	482,000	193,000	675,000	-201,000
2050	W	563,000	32,000	232,000	828,000	257,000	175,000	432,000	383,000
2051	W	297,000	11,000	176,000	485,000	143,000	173,000	316,000	160,000
2052	W	413,000	18,000	175,000	606,000	445,000	184,000	629,000	-24,000
2053	W	479,000	32,000	171,000	682,000	152,000	141,000	293,000	380,000
2054	AN	223,000	6,000	147,000	376,000	307,000	177,000	484,000	-107,000
2055	AN	286,000	7,000	157,000	449,000	273,000	191,000	464,000	-20,000
2056	D	244,000	11,000	230,000	486,000	801,000	197,000	999,000	-511,000
2057	D	246,000	1,000	293,000	540,000	581,000	201,000	782,000	-246,000
2058	BN	270,000	3,000	263,000	536,000	342,000	198,000	540,000	-11,000
2059	D	294,000	1,000	251,000	546,000	480,000	201,000	681,000	-137,000
2060	W	393,000	27,000	237,000	657,000	255,000	183,000	439,000	206,000
2061	W	327,000	14,000	184,000	524,000	148,000	152,000	300,000	217,000
2062	C	209,000	0	194,000	403,000	521,000	186,000	707,000	-297,000
2063	C	332,000	7,000	264,000	604,000	799,000	203,000	1,002,000	-399,000
2064	BN	238,000	0	313,000	552,000	788,000	203,000	991,000	-443,000
2065	AN	367,000	13,000	281,000	662,000	379,000	190,000	568,000	87,000
2066	W	386,000	23,000	245,000	654,000	315,000	177,000	492,000	155,000
2067	D	217,000	1,000	238,000	457,000	406,000	190,000	596,000	-143,000
2068	C	230,000	10,000	274,000	514,000	704,000	204,000	908,000	-395,000
2069	C	236,000	2,000	318,000	556,000	847,000	207,000	1,054,000	-501,000
2070	C	265,000	0	324,000	589,000	816,000	208,000	1,024,000	-438,000
Average (2020 - 2040)		301,000	11,000	205,000	517,000	393,000	187,000	579,000	-66,000
Average (2020 - 2070)		305,000	11,000	231,000	547,000	467,000	189,000	656,000	-112,000

* Actual water year type for 2017 (all other years derived from historic record)

3 SUSTAINABLE MANAGEMENT CRITERIA

This chapter of the Groundwater Sustainability Plan (GSP or Plan) provides a discussion of the sustainability goals, measurable objectives, interim milestones, minimum thresholds, undesirable results, and the monitoring network for each sustainability indicator within the Plan area encompassed by the WWD GSP.

This chapter defines sustainability in the Plan area. The Measurable Objectives (MO), Minimum Thresholds (MT), and undesirable results presented in this chapter describe the future sustainable conditions in the Plan area and commit the GSA to actions that will achieve these future conditions.

This chapter presentsutilizes data and information provided in Chapter 2 and describes the data and methods used to develop the Sustainable Management Criteria (SMC) and demonstrates their influence on beneficial uses and users. The SMC presented in this chapter are based on current available data and applications of the best available science.

As noted in this GSP, data gaps and uncertainty exist in the characterization of the hydrogeologic conceptual model and groundwater conditions. The uncertainty was considered when developing the SMC and because of these uncertainties, the SMC presented herein are considered initial criteria. The GSAs will periodically evaluate this GSP, assess changing conditions in the Plan area that may warrant modifications of the GSP or management objectives, and may adjust components accordingly. The GSA will focus theirs evaluation on determining whether the actions under the GSP are meeting the Plan's management objectives and whether those objectives are meeting the sustainability goal of the Plan area.

This chapter is organized to address all the GSP regulations regarding SMC and is organized in accordance with DWR's GSP annotated outline. This chapter includes a description of:

- Development of locally defined significant and unreasonable conditionconditions related to the sustainability indicators that exist in the Subbasin.
- How minimum thresholds were developed, including:
 - The information and methodology used to develop minimum thresholds,
 - The relationship between minimum thresholds and significant and unreasonable undesirable results,
 - The relationship of these minimum thresholds to other sustainability indicators,
 - The effect of minimum thresholds on neighboring basins,
 - The effect of minimum thresholds on beneficial uses and users,
 - The relationship of minimum thresholds to relevant Federal, State or local standards and
 - The method for quantifying measurable minimum thresholds.
- How measurable objectives were developed, including:

- The methodology for setting measurable objectives
- ~~Interim milestones~~
- The quantification of Interim milestones that represent the estimated pathway to sustainable management of groundwater resources in the Subbasin by 2040.
- How undesirable results were developed, including:
 - The criteria defining when and where the effect of the groundwater conditions cause undesirable results based on a quantitative description of ~~the combination of~~ minimum threshold exceedances
 - The potential causes of undesirable results
 - The effect of these undesirable results on the beneficial use and users.

The SMC presented in this chapter were developed using information from interested parties and public input and correspondence with the GSAs, public meetings, hydrogeologic analysis, groundwater dependent ecosystem (GDE) analysis, and meetings with GSA technical representatives. The general process for establishing SMC included:

- GSA public meetings that outlined the GSP development process and introduced interested parties to the SMC
- Conducting GSP public meetings to present proposed methodologies to establish minimum thresholds and measurable objectives and receive additional public input.
- Reviewing public input on preliminary SMC methodologies with GSA staff/technical representatives
- Providing a Draft GSP for public review and comment
- Establishing and modifying minimum thresholds, measurable objectives, and undesirable results based on feedback from public meetings, public/interested party review of the Draft GSP, and input from GSA staff/technical representatives.

To ensure the Plan area ~~meets~~shows progress in meeting its sustainable goal by 2040, the GSA ~~proposed~~proposes projects and management actions (PMAs) described in **Chapter 4**, to address undesirable results. The ~~projects and PMAs~~ proposed PMAs include augmentation projects and management actions that optimize groundwater use in the Subbasin. The sustainability goals will be maintained through proactive monitoring and management by the GSA as described in this chapter and throughout the GSP. ~~Table 3-1 presents a summary of the six undesirable results and whether each has occurred, is occurring or is expected to occur in the future in the Subbasin without GSP implementation. The table also presents the proposed PMAs that have been developed to address each of the undesirable results that may be presently occurring or have historically occurred in the Subbasin. Locations of all sustainability indicator wells are shown in Figure 3-1.~~

Conditions within the Subbasin will be considered sustainable when all of the following goals are met:

1. Long-term aggregate groundwater use is equal to the Subbasin's estimated sustainable yield.

2. The average annual ~~rate~~volume of groundwater storage changes within the Subbasin, ~~—~~averaged across ~~indicator wells—the Subbasin—~~is approximately zero, representing generally stable ~~when conditions coincident with the achievement of sustainable groundwater storage is equivalent to 2015 baseline conditions~~levels at measurable objective groundwater elevations.
3. Groundwater levels are maintained at ~~elevations necessary to the set~~ measurable objectives. The measurable objectives represent water levels present during sustainable conditions, including a margin of operational flexibility, and will avoid undesirable results, ~~such as~~ lowering groundwater levels ~~potentially leading to that result in~~ significant and unreasonable depletions of available water supply for beneficial ~~use could occur if groundwater levels decline to levels that result in the loss of water availability for uses available to~~ well users.
- ~~4. Groundwater quality will exhibit trends consistent with historical background concentrations along with the allowable increases in groundwater quality from human activities as described in the existing Basin Plan and proposed Basin Plan Amendment.~~
4. Groundwater quality will be maintained at constituent concentrations in those areas of the Subbasin where degraded water quality does not already exist prior to the 2015 baseline period. Groundwater extractions will be managed to ensure that beneficial users of groundwater can utilize groundwater that meets drinking water standards for urban and domestic users and agricultural guidelines for agricultural beneficial users without the implementation of PMAs.
5. Subsidence is maintained at levels that do not significantly impact the operations of critical infrastructure such as the ~~California Aqueduct/SLC~~ within the Subbasin.
6. Sustainability goals for interconnected surface water and seawater intrusion are not provided as a result of the absence of these sustainability ~~indictors~~indicators in the Subbasin.

Table 3-1: Summary of Undesirable Results Applicable to the Plan Area

Sustainability Indicator	Historical Period	Existing Condition	Future Conditions Without GSP Implementation	PMAs Implemented to meet the GSP Sustainability Goal
Chronic Lowering of Groundwater Levels	Yes	Yes	Yes	Voluntary Fallowing of Agricultural Land; Intra-Subbasin Water Transfers; imported surface water supplies; aquifer storage and recovery projects; groundwater recharge projects; allocation of groundwater per acre of land.
Reduction of Groundwater Storage	Yes	Yes	Yes	Voluntary Fallowing of Agricultural Land; Intra-Subbasin Water; Transfers; imported water supplies; aquifer storage and recovery projects; groundwater recharge projects; allocation of groundwater per acre of land.
Seawater Intrusion	Not Applicable	Not Applicable	Not Applicable	Not Applicable

Degraded Water Quality	Yes	Yes	Yes	Intra-Subbasin Water Transfers; imported water supplies.
Land Subsidence	Yes	Yes	Yes	Voluntary Fallowing of Agricultural Land; Intra-Subbasin Water Transfers; imported water supplies to replace groundwater pumping in “subsidence sensitive areas”; incentives to shift pumping from Lower Aquifer to Upper Aquifer; groundwater recharge projects; allocation of groundwater per acre of land.
Depletion of Interconnected Surface Water	Not Applicable	Not Applicable	Not Applicable	Not Applicable

3.1 Sustainability Goal (Reg §354.24)

The sustainability goal for the Subbasin has three sections:

1. A description of the sustainability goal; ~~7.2~~
2. A discussion of the measures that will be implemented to ensure the Subbasin will operate within the sustainable yield; ~~7.2~~ and
3. An explanation of the Subbasin’s pathway to achieve the sustainability goal within 20 years of GSP implementation and maintained through the planning and implementation horizon.

3.1.1 Goal Description

The goal of this GSP is to develop projects and management actions that result in the sustainable management of the groundwater resources of the Subbasin for long-term community, financial, and environmental benefits of residents and business in the Subbasin. This GSP outlines the approach to achieve sustainable management of groundwater resources within 20 years, while maintaining the unique cultural, community, and agricultural business aspects of the Subbasin. The GSA’s sustainability goal is to ensure that by 2040, and thereafter within the planning and implementation horizon of this GSP (50 years to 2070), the Subbasin is operated within its sustainable yield and does not exhibit undesirable results.

3.1.2 Description of Measures

Meeting this goal requires achieving a balance of water demand with available water supply for all beneficial users in the Subbasin, while protecting/monitoring groundwater quality and working with beneficial users to ensure sustainable groundwater supplies, by the end of the GSP implementation timeframe, carrying through the SGMA planning and implementation horizon.

3.1.3 Description of Measures and Explanation of How the Goal Will Be Achieved in 20 Years

To ensure the Subbasin meets its sustainability goal by 2040, the GSA proposed several Projects and Management Actions (PMAs), described in Chapter 4, to address conditions that would lead to undesirable results. The PMAs, listed below, were developed to ensure the Subbasin Goal was achieved by 2040.

1. Surface Water Deliveries described in PMA 1 provide in-lieu recharge through the direct delivery of surface water in the Subbasin coupled with a reduction in groundwater pumping.
2. Groundwater Allocation Program described in PMA 2 promotes conjunctive use in the Subbasin to ensure groundwater resources are used in sustainable quantities.
3. Aquifer Storage and Recovery (ASR) described in PMA 3 increases groundwater storage and groundwater levels, minimizes the potential for subsidence and improves water quality in the ASR well.
4. Targeted Pumping Reductions described in PMA 4 ensure that an alternative water supply is provided to subsidence prone areas of the Subbasin.
5. Recharge Projects described in PMA 5 enable the GSA and landowners to develop recharge projects throughout the Subbasin to augment groundwater storage, quality, and groundwater levels.

The sustainability goal as well as the absence of undesirable results are expected to be achieved by 2040 through implementation of the PMAs. The sustainability goals will be tracked and maintained through monitoring and management by the GSA as described in this GSP.

3.2 Measurable Objectives and Interim Milestones (GSP Reg. § 354.30)

Measurable objectives, as well as interim milestones, that represent the path to sustainability in 5-year increments, are detailed below. Measurable objectives represent the quantified metric at each representative monitoring site for each sustainability indicator that is expected to occur under sustainable groundwater extraction operating pumping conditions for the Subbasin. If the GSA successfully manages groundwater extraction that pumping which results in the achievement of the measurable objectives described, the Subbasin will be operating sustainably. Measurable objectives and interim milestones are detailed below. A description of the measurable objectives and how they were established are provided, along with recognition of the anticipated fluctuations in basin conditions around the established measurable objectives. In addition, this section describes how the GSP helps to meet each measurable objective, how each measurable objective is intended to achieve the sustainability goal for the Plan area for the long-term beneficial uses, and how the interim milestones are intended to reflect the anticipated progress toward the measurable objectives during the 2020 to 2040 implementation period.

The GSP regulations define measurable objectives as specific, quantifiable goals for the maintenance or improvement of specific groundwater conditions that have been included in an adopted Plan to achieve the sustainability goal for the basin.

Per GSP Regulations (GSP Reg. § 354.30):

1. Measurable objectives shall be established, "...including interim milestones in increments of five years, to achieve the sustainability goal for the basin within 20 years of Plan implementation and to continue to sustainably manage the groundwater basin over the planning and implementation horizon." (GSP Reg. § 354.30(a).)
2. "Measurable objectives shall be established for each sustainability indicator, based on quantitative values using the same metric and monitoring sites as are used to define the minimum thresholds." (GSP Reg. § 354.30(b).)
3. "Measurable objectives shall provide a reasonable margin of operational flexibility under adverse conditions which shall take into consideration components such as historical water budgets, seasonal and long-term trends, and periods of drought, and be commensurate with levels of uncertainty." (GSP Reg. § 354.30(c).)
4. "...a representative measurable objective for groundwater elevation to serve as the value for multiple sustainability indicators..." may be established where "...the Agency can demonstrate that the representative value is a reasonable proxy for multiple individual measurable objectives as supported by adequate evidence." (GSP Reg. § 354.30(d).)
5. "Each Plan shall describe a reasonable path to achieve the sustainability goal for the basin within 20 years of Plan implementation, including a description of interim milestones for each relevant sustainability indicator, using the same metric as the measurable objective, in increments of five years." (GSP Reg. § 354.30(e).)

The measurable objectives developed for each applicable sustainability indicator in this GSP are based on the current understanding of the Plan Area and Basin Setting as discussed in detail in Chapter 2. Representative Monitoring Sites (RMS) are identified for monitoring of interim milestones, measurable objectives, and minimum thresholds for each sustainability indicator, and are also ~~known~~ referred to as sustainability indicator wells.

3.2.1 Measurable Objectives for Chronic Lowering of Water Levels

Measurable objectives and interim milestones for chronic lowering of groundwater levels are described below.

3.2.1.1 Description of Measurable Objectives

Measurable objectives for groundwater levels were established by analyzing historical groundwater level data, ~~estimating during the historic~~ historical water budget period when the Subbasin was pumping groundwater level variability in wells, consistent with the sustainable yield and forecasting future changes in groundwater levels avoiding undesirable results. As discussed in Section 2.3.7.4, the sustainable yield of the Subbasin was estimated utilizing the numerical ~~groundwater flow model.~~ flow model simulation of projected conditions in the Subbasin. The estimation of sustainable yield also accounted for the effects of climate change and on groundwater levels in the future. This analysis ~~provided estimates~~ of the ~~expected~~ sustainable yield formed the basis for determining the MOs.

The MOs were established using a multi-step process. The first step was to identify a time period from the model where pumping occurred within the range of the sustainable yield. This time frame would provide groundwater level conditions present in a sustainable condition. This process identified 2006 through 2012 as a time frame where annual pumping was within the range of the sustainable yield. This time frame was also favorable as it encompassed a year (2007) when groundwater levels were high enough that subsidence did not occur. Therefore, 2006 through 2012 was chosen as the time frame on which to base the MOs. Specifically, MOs were set to the average Spring water levels from 2006 through 2012.

In order to establish these MOs, observed water levels from 2006 through 2012 were analyzed at the representative monitoring wells. This analysis revealed that most wells only contained data for Fall water levels as opposed to spring. In order to extrapolate spring water level variability due to climatic and operational variability in the future. Both annual (variability from year to year) and seasonal variability were considered in the development of measurable objectives. Groundwater elevation SMC were developed averages for the wells, model data were used. Average fall water levels for 2006 through 2012 were calculated at each site based on historic measurements and a sustainability goal of preventing a long-term trend of declining groundwater levels. observed values. Fall water level averages were also calculated at each of the wells using modeled data for 2006 through 2012. The magnitude of difference between these two datasets was then used to extrapolate the spring observed average water levels from the spring modeled average water levels at each site. Wherever historical data was not available for this extrapolation, recent (2017 through 2020) Spring averages were used as the MOs.

MOs were set at each of the monitoring sites (Table 3-1 and 3-2 and Figure 3-1 and 3-2). These sites were selected in order to provide an even distribution of coverage over the GSP and based on each Subbasin. The individual wells were selected based on the well's ability to capture the general groundwater trend for other wells in their vicinity. The GSA will evaluate whether further monitoring wells or refinement to these measurable objectives are needed to historical record, location within each hexagon, and viability for continued monitoring boundary conditions with adjacent basins. The construction information for the selected wells was also analyzed to ensure subsurface inflow and outflow conditions remain consistent with water budget and model results.

Specifically, in order to determine measurable objectives, historical water elevations and model generated water elevation data were combined and analyzed. The modeled data was utilized to determine water levels at which sustainability would be achieved in different areas of the Subbasin. The methodology for estimating measurable objectives at each well in the GSP monitoring network involved a multi-step process. The initial step was to utilize the numerical model to identify a recent period which experienced sustainable groundwater levels in comparison to the projected water budget period. This evaluation identified 2017 as a year that represented long-term sustainable groundwater levels. The next step was to select a measurable objective groundwater level for each well in the monitoring network by adjusting the measured 2016 (water budget year) water levels by the relative amount of water level change the numerical model simulated between 2016 and 2017 water levels. The relative amount of

~~change was added to the measured 2016 groundwater level to produce an equivalent 2017 groundwater level/measurable objective. they were screened in the appropriate aquifer for monitoring.~~

Groundwater level hydrographs showing measurable objectives for each groundwater level sustainable indicator well are provided in **Appendix 3-A3A**. Measurable objectives for each groundwater level monitoring ~~wellswell~~ in the upper and lower aquifers are summarized in **Tables 3-21 and 3-32**.

3.2.1.2 Interim Milestones (Operational Flexibility)

Interim milestones at 5, 10, and 15 years are summarized in **Table 3-21 and Table 3-3 above2**. Interim milestones convey a series of milestones that demonstrate progress towards achieving sustainability as represented by the measurable objective values. The starting point in the development of interim milestones ~~were~~~~was~~ assumed to be the minimum threshold value at each monitored well in the GSP network. The interim milestones ~~were set to split~~~~are~~ the difference between the measurable objectives and minimum thresholds equally distributed over four interim milestones.

3.2.1.3 Path to Achieve and Maintain the Sustainability Goal

Historic trends and planned groundwater extraction and management actions provide a reasonable path to maintain the sustainability goal with stable groundwater elevation. Recent water levels remain above the MO and the recovery of groundwater elevation is not required to reach the sustainability goal. The interim milestones served to maintain the existing sustainable conditions. The sustainability goal for groundwater elevation is to prevent a trend of declining water levels. Planned management actions in conjunction with coordination of SMC with adjacent GSAs will ensure the ~~MO~~~~MOs~~ for groundwater elevation are met. However, preliminary reviews of draft GSPs from the Kings and Tulare Lake subbasins indicate that MOs and MTs in these adjacent subbasins are lower than 2015 baseline conditions in the Westside Subbasin and could impact GSP implementation and sustainability goals in the Westside Subbasin, especially in areas of the Subbasin adjacent to the Kings and Tulare Lake subbasins. If the District determines activities in Kings and Tulare Lake subbasins are affecting sustainability in the Westside Subbasin, the District will engage in inter-basin outreach efforts with neighboring GSAs to minimize the potential impact to the achievement of sustainability in the Subbasin.

The combination of interim milestones and measurable objectives reflect how the basin anticipates achieving and maintaining sustainability. It should be noted that future projections require assumptions about future hydrologic conditions, including the sequence of wet, average, and dry climatic years. The future climatic assumptions for the Implementation Period (through 2040) used in this GSP incorporate sequences of wet, average, and dry years that represent overall long-term average historical climatic conditions over the Implementation Period. Under these climatic assumptions, the Implementation Period is expected to experience annual variations in groundwater levels, with an overall stable trend through 2040 during which time, the GSA is implementing projects and management actions to ensure sustainable conditions are maintained through 2070.

3.2.1.4 Impact of Selected Measurable Objectives on Adjacent Basins

The measurable objectives established for the Subbasin provide a good basis for evaluation of anticipated impacts on adjacent subbasins from implementation of the GSP. This is because MOs are set to reflect the average groundwater levels to be maintained during the Sustainability Period. Ultimately, the potential for impacts on adjacent subbasins will be primarily a function of average water levels in the Subbasin during the Sustainability Period, average water levels in adjacent subbasins during the Sustainability Period, and natural groundwater flow conditions that would be expected to occur at Plan area boundaries. The average groundwater levels expected for the Plan area are reflected in the Measurable Objectives **Table 3-21** and **Table 3-32**. Groundwater model results indicate that the average groundwater levels reflected in the **MOMOs** will result in greatly reduced net subsurface inflow to the Plan area from surrounding subbasins compared to historic net subsurface inflow. Therefore, the projects and management actions implemented for this GSP are expected to benefit adjacent subbasins and not hinder the ability of adjacent subbasins to be sustainable.

3.2.2 Measurable Objectives for Reduction in Groundwater Storage

Measurable objectives and interim milestones for reduction in groundwater storage are described below.

3.2.2.1 Description of Measurable Objectives

The measurable objective, reduction of groundwater in storage, was developed using the same methodology as chronic lowering of groundwater levels. The estimated reduction of groundwater in storage simulated using the District's Model to establish the interim milestones and measurable objective. The measurable objective of the reduction of groundwater storage is zero once the measurable objective of chronic lowering of groundwater levels is achieved.

3.2.2.2 Interim Milestones (Operational Flexibility)

Interim milestones at 5, 10, and 15 years are summarized in **Table 3-21** and **Table 3-32** for groundwater levels and when multiplied by the aquifer storage coefficient and areal extent of the Subbasin, will provide the interim milestones for change in groundwater storage (**Table 3-3a3**).

Table 3-3: Measurable Objectives and Interim Milestones for the Change in Groundwater Storage, Upper and Lower Aquifers, (acre-feet)

Aquifer	Interim Milestone 5 Years	Interim Milestone 10 Years	Interim Milestone 15 Years	Measurable Objective
Upper	1,700,000	1,700,000	1,700,000	0
Lower	13,000	13,000	13,000	0

3.2.2.3 Path to Achieve and Maintain the Sustainability Goal

The combination of interim milestones and measurable objectives reflect how the Subbasin will achieve and maintain sustainability. Since groundwater levels serve as a practical proxy for evaluating reduction in groundwater storage, achieving and maintaining sustainability relative to this indicator is similar to the groundwater level section.

3.2.2.4 Impact of Selected Measurable Objectives on Adjacent Basins

Groundwater modeling results indicate the average groundwater levels reflected in the MO will result in reduced net subsurface inflow to the Subbasin from surrounding basins compared to historic net subsurface inflow. This will serve to allow more groundwater to remain in storage in adjacent basins. Therefore, the projects and management actions implemented for this GSP will not hinder the ability of adjacent basins to be sustainable with regards to groundwater storage.

3.2.3 Measurable Objectives for Subsidence

Measurable objectives and interim milestones for reduction in land subsidence are described below.

3.2.3.1 Description of Measurable Objectives

The measurable objectives for subsidence represent target subsidence rates in the Subbasin along the San Luis Canal (SLC). Discussions with GSA staff indicate that subsidence occurred in other areas of the Subbasin historically. However, during the last drought the District did not experience any significant impacts to the District's infrastructure, other than impacts to DWR's SLC. DWR prepared a report in 2017 (DWR, 2017) that identified impacts on the California Aqueduct/SLC that resulted from subsidence. The impacts on the SLC reduced the design freeboard of three feet down to almost zero feet of freeboard in some isolated areas. This reduction in freeboard impacts the storage capacity of Pools, ability to convey Pools impacted by subsidence (Pools 17, 18 and 21). Since construction of the SLC, subsidence impacts have required DWR to raise the freeboard on the SLC to maintain the minimum design freeboard of three feet. The measurable objectives were set to account for a small amount of subsidence that will continue to occur as a result of residual subsidence. Residual subsidence is a result of historical groundwater pumping that occurred in the region prior to the construction of the SLC and prior to development of the GSP. As conditions in the Subbasin improve, it is expected that residual subsidence will reduce overtime. Once the Subbasin is no longer experiencing current rates of residual subsidence, the GSA will evaluate whether it is feasible to lower the measurable objectives for subsidence during subsequent updates to the GSP.

The measurable objective for subsidence is based on DWR's historical design investigations of the SLC that estimated residual or lag subsidence would continue regardless of groundwater level recovery at a rate that was approximately 10 percent of the historical rates of active subsidence (subsidence that occurs as a direct result of groundwater level declines and associated decreases in pore water pressure in fine-grained materials) (DWR, 2017). Recently, extensometer measured subsidence along the SLC during the last drought was up to one foot per year in some locations within the Subbasin. Thus, residual subsidence

is expected to continue to occur at a rate of approximately 0.1 feet per year which is the measurable objective for subsidence along the SLC. Since recent subsidence has not reportedly resulted in significant damage to infrastructure in other parts of the Subbasin, the extensometer-measured measurable objective in those areas was assigned a value of 0.25 feet per year.

In some areas, groundwater levels will be utilized as a proxy for subsidence measurements. The measurable objectives for subsidence that utilize groundwater levels were set at elevations that are not expected to cause active subsidence to occur in the subsidence-prone areas and allow an equivalent amount of subsidence as the 0.25 feet per year described above. Historical groundwater levels in the vicinity of the SLC were analyzed and compared to subsidence trends in order to correlate the occurrence of active subsidence to groundwater levels. Groundwater level measurable objectives in areas outside subsidence-prone areas underlying the SLC will be evaluated during the implementation period in coordination with evaluation of subsidence benchmark locations. As discussed in Section 3.4.1.3, some annual land surface elevation from elastic subsidence results in temporary fluctuations, but these seasonal fluctuations do not necessarily translate into long-term inelastic subsidence.

Because the measurable objective of subsidence on an annual basis is the best achievable outcome, the measurable objectives were set lower than the minimum threshold annual values. The current subsidence monitoring well network, SLC global positioning system (gps) benchmarks, and extensometers are shown on **Figure 3-4**. Based on the existing monitoring system, the subsidence measurable objectives are shown in **Table 3-4** for the extensometers and groundwater levels.

The MOs for subsidence and subsurface compaction were established based on (1) assessment of the susceptibility of critical infrastructure to future subsidence and coordination with beneficial users described in **Section 2.2.8.6**, (2) analysis of historical and current rates and total amounts of subsidence described in **Section 2.2.8.4**, and (3) anticipated benefits from Projects and Management Actions described in **Chapter 4**.

MOs are specified at the RMS within the GSA and described in **Section 3.5.1.3**. These include GPS locations measuring land surface displacement (subsidence), extensometers measuring subsurface compaction and wells measuring water levels as a proxy where more direct measurements of subsidence are not currently in place (**Figure 3-3**). At sites measuring vertical displacement or compaction, MOs are defined using an annual rate of subsidence or compaction which may occur in a given year measured between the winter of consecutive years coupled with a total cumulative amount measured during GSP implementation. Annual rates and total amounts of subsidence apply solely to inelastic (irreversible) subsidence described in **Section 2.2.8.1.2**. As a result, annual rates, total amounts of subsidence and groundwater elevations are evaluated from measurements taken after groundwater levels have recovered from pumping during the irrigation season to estimate inelastic subsidence.

MOs specified in sites selected adjacent to SLC establish the objective of a maximum annual rate of 0.0 feet of subsidence or compaction and a cumulative total of 0.0 feet of subsidence at GPS locations and

extensometers (Table 3-4, Appendix 3B). Water level proxies are not used in evaluating subsidence adjacent to the SLC. The selection of subsidence criteria is targeted to address the threat of unreasonable subsidence along the California Aqueduct and the request from the DWR California Aqueduct Subsidence Program (CASP) to fully abate subsidence along the SLC particularly near Checks 16, 17 and 20.

MOs in other portions of the Subbasin allow for a maximum annual rate of 0.1 feet of subsidence and a total cumulative amount of 0.5 feet of subsidence or compaction at GPS sites and extensometers (Table 3-4, Appendix 3B). Where water level proxies are used, MOs are specified to be consistent with MOs defined for chronic lowering of water levels defined in Section 3.2.1.1. Some additional subsidence is expected in less sensitive portions of the Subbasin as a result of the implementation of Projects and Management Actions during GSP implementation from 2020-2040 and possibly beyond. PMAs targeted towards the management of groundwater pumping through allocations, aquifer storage and recovery and pumping reductions may lead to changes in the spatial distribution and amounts of groundwater pumping. As a result, it is anticipated that implementation of the PMAs in some areas may lead to (1) local relative increases in groundwater pumping and (2) groundwater extraction from previously undeveloped portions of the aquifer system. Both instances might lead to local short-term increases in inelastic subsidence. Consequently, the District will continue active monitoring and data collection efforts to identify special areas of concern and develop potential conditions and as well as further refinements of management measures designed to avoid undesirable results to critical infrastructure and minimize these impacts. Furthermore, GSPs submitted in adjacent groundwater basins suggest groundwater levels may continue to decline (leading to possibly commensurate rates of subsidence) within those basins which could propagate across shared jurisdictional boundaries. These external hydraulic influences and variable localized conditions could lead to impacts within the District that cannot be managed without inter-basin coordination.

3.2.3.2 Interim Milestones (Operational Flexibility)

Interim milestones at 5, 10, and 15 years are summarized in Table 3-4.

Interim Milestones at 5, 10, 15 and 20 years are summarized in Table 3-4. Interim milestones in sites adjacent to the SLC are defined as an annual rate of 0.0 feet of subsidence and total amount of 0.0 feet in extensometers and GPS sites. In other portions of the Subbasin, Interim Milestones allow for up to 0.1 feet of subsidence annually and up to 0.5 feet of subsidence through the 2040 GSP implementation period for extensometers and GPS sites. In cases where measured groundwater levels are used as a proxy for subsidence, Interim Milestones are consistent with those for chronic lowering of water levels described in Section 3.2.1.2.

3.2.3.3 Path to Achieve and Maintain the Sustainability Goal

Historical trends and planned groundwater extraction and management actions provide a reasonable path to maintain the sustainability goal with reduced levels of subsidence to levels that will not impact to a significant and unreasonable degree the operation of the SLC in Checks 16, 17, and 20. Groundwater levels measured after the recent drought are higher which is a positive indication that subsidence has abated.

~~Implementation of PMAs early in the Implementation Period will prevent the occurrence of significant and unreasonable levels of subsidence in areas overlain by critical infrastructure. The interim milestones served to maintain the existing sustainable conditions. The sustainability goal for subsidence is to prevent a trend of increasing rates of active subsidence. Planned management actions will ensure the MOs for subsidence are met.~~

~~The path to achieve and maintain the sustainability goal will be accomplished through implementation of planned PMAs aimed at augmenting groundwater supply and demand described in Chapter 4. Historically, subsidence has largely resulted due to high amounts of groundwater extraction which coincide with dry years and periods of prolonged drought. PMA No. 2 was developed to allocate groundwater extraction based on the sustainable yield of the Subbasin in order to reduce regional impacts of groundwater overdraft on subsidence. PMA No. 4 was developed to reduce the acute impacts of groundwater extraction subsidence through targeted reductions in groundwater pumping in subsidence-prone portions of the SLC, which impacts the freeboard required to maintain operational flexibility for the CVP and SWP. These demand-driven PMAs are coupled PMA No. 3 and 5 intended to augment water supply through Aquifer Storage and Recovery and targeted recharge through percolation basins. Supply-driven PMAs are designed to increase the volume of stored groundwater during wet periods mitigating pumping impacts during subsequent droughts. In conjunction, planned management actions will ensure the measurable objective for subsidence is met.~~

3.2.3.4 Impact of Selected Measurable Objective on Adjacent Basins

The anticipated effect of the subsidence measurable objectives on each of the neighboring subbasins is not expected to be significant as a result of the following factors:

- The District retired approximately 9094,000 acres of land primarily located adjacent to neighboring subbasins. As a result, groundwater pumping from the Lower Aquifer within the Subbasin is not expected to result in significant amounts of subsidence that may occur miles away in adjacent subbasins.
- Neighboring basins such as the Kings and Tulare Lake Subbasins are expected to continue to have declining groundwater levels below historic lows as part of those basins' implementation of their GSPs, in contrast to ~~the~~this GSA which is planning on minimizing the exceedance of historic lows. As a result, it is unlikely that GSP implementation actions by the GSA will result in a proportion of subsidence in the adjacent basins.

3.2.4 Measurable Objectives for Degraded Water Quality

3.2.4.1 Description of Measurable Objectives

~~The Regional Board sets water quality objectives for the Westside Subbasin through a Basin Plan and any subsequent Basin Plan Amendments. The measurable objectives for minimizing the degradation of groundwater quality from human activities is based on groundwater sample concentrations not exceeding the historic trends in background groundwater quality along with a degradation rate attributed to human activities and beneficial uses that does not exceed the existing or planned Basin Plan Amendments. Based~~

on the review of groundwater quality in Chapter 2, the constituents evaluated for all beneficial users are TDS. The basis for establishing the measurable objective is to minimize the additional contribution of TDS from human activities that would degrade water quality, rather than attempt to improve naturally-occurring, background water quality that in some areas is impacted by marine sediments from the Coast Range. Measurable objectives, as represented by relative increase in TDS concentrations per year, for wells in the Upper and Lower Aquifers are summarized in **Table 3-5** and **Table 3-6** and shown on **Figure 3-5** and **Figure 3-6**. These figures indicate which wells will be used in both the water level and water quality monitoring network, and those that will just be used for the water quality monitoring network.

The measurable objectives for groundwater quality represent the expected trends in background TDS concentrations along with acceptable annual increases in TDS concentrations from human activities that are generally representative of the Basin Plan Amendment allowances. The minimum threshold is a deviation from the TDS concentration anticipated based on the measurable objectives and baseline concentration. The deviation is based on an analysis of annual variations in TDS concentrations in historical groundwater quality data. Future observations of TDS concentrations will be compared to the expected minimum threshold concentrations for that year (during the planning and implementation horizon). Water quality impacts from human activities will be addressed through stakeholder outreach, communication and voluntary efforts at reducing the over application of fertilizers and other chemical applications that may result in the exceedance of allowable degradation of groundwater from human activities as allowed by the Basin Plan Amendment.

Based on the review of groundwater quality in **Chapter 2**, TDS was selected as a proxy for constituents of concern to the beneficial users that primarily exist in the Subbasin. Constituents of concern for domestic and urban beneficial users are those constituents that are regulated under the State of California's drinking water standards. As described in **Section 2.2.7**, TDS was shown to be a proxy for constituents that may exceed drinking water standards in the Subbasin where domestic and urban beneficial users of groundwater for drinking water purposes exist. As presented in Chapter 2, there was either a correlation between TDS and other constituents or TDS was shown as being conservative in relation to trace elements in the sense that where trace elements were observed, the concentrations of trace elements were mostly below MCLs while TDS concentrations were above the drinking water standards. In addition, the District coordinated with Fresno County on its approach to use TDS as a proxy for other constituents in monitoring groundwater quality in the Subbasin and the influence groundwater pumping activities have on groundwater quality. Fresno County supports the District's approach to use TDS as a proxy for other constituents.

In order to select representative monitoring wells and set measurable objectives, all available TDS data was evaluated on a hexagon basis. Hexagons where TDS measurements exceeded 1,000 mg/L were not assigned sustainable management criteria, however, these areas will continue to be monitored under the groundwater quality monitoring program. As explained in **Chapter 2, Sections 2.2.7.1** and **2.2.7.2**, these areas with elevated TDS concentrations represent baseline conditions. These areas with elevated

concentrations are the result of marine sediments. As a result, those areas with historical exceedances of TDS above the MCL are not assigned a MO, however, those areas of the Subbasin that are below the 1,000 mg/L TDS concentration are assigned a MO of 500 mg/L TDS for municipal and domestic beneficial users and 800 mg/L TDS for agricultural beneficial users. The MO for agricultural beneficial users was based on outreach and discussions with the District that conveyed that the MO for agricultural beneficial users was a concentration that, without any management action, could be sustainably applied for agricultural beneficial users in the Subbasin.

As mentioned above, because the goal of the MOs is to minimize groundwater quality degradation resulting from groundwater pumping activities that are not sustainable, the areas of the Subbasin that have naturally degraded groundwater quality were excluded from being assigned MOs. Instead, the GSP focused on setting MOs at wells in hexagons that had less than two exceedances of 1,000 mg/L TDS (Figures 3-4 and 3-5) for municipal and domestic beneficial users of groundwater. This concentration was also utilized for agricultural beneficial users of groundwater. The 1,000mg/L threshold was utilized as an upper limit based on the published drinking water MCL. If a well's groundwater quality is above this threshold, management to mitigate a potential undesirable result is required. In the Westside Subbasin, mitigation could include blending with surface water, treatment and/or applying groundwater to salt tolerant crops.

Different MOs were set for hexagons where domestic and urban users were present compared to hexagons where only agricultural users were present. In hexagons with domestic or urban users, MOs were set to 500 mg/L. This value reflects the drinking water standards for TDS. For hexagons where only agricultural users are present, MOs were set to 800 mg/L. This value ensures that the TDS concentration in groundwater will be at a level that is not harmful to the crops and other vegetation that generally exist in the Subbasin (UCANR, 2016).

All available water quality data was plotted by hexagon and analyzed to determine where MOs and MTs would be set based on the criteria described above. In the Upper Aquifer, this analysis yielded two (2) hexagons. One well per hexagon was chosen to be included in the RMS network with MOs and MTs set. Because one hexagon had domestic and urban users present within it, the MO at the representative well was set to 500 mg/L. The other hexagon only had agricultural users present so the MO was set to 800 mg/L. Both wells were chosen due to their locations within their respective hexagons and are irrigation wells.

The same analysis was done for the Lower Aquifer and four (4) hexagons met the criteria for establishing MOs and MTs. One (1) well per hexagon was chosen to be included in the RMS network. Each well was chosen based on its location, length of record when available, and for also serving as a groundwater level monitoring site. MOs at three (3) of the sites were set to 500 mg/L due to the presence of a domestic users within the hexagon. The remaining site had an MO of 800 mg/L because only agricultural users were present within that hexagon. All four (4) RMS wells are irrigation wells.

The wells to be utilized for monitoring in the Upper and Lower Aquifers are summarized in **Table 3-5** and **Table 3-6** and show on **Figure 3-4** and **Figure 3-5**.

3.2.4.2 Interim Milestones (Operational Flexibility)

Interim Milestones are summarized on **Table 3-5** and **Table 3-6**. ~~Since the measurable objectives are related to maintaining historical trends in TDS concentrations along with allowable degradation due to human activities, the interim milestones represent a path that is similar to the measurable objectives for each monitoring location. Interim milestones were set based on the MOs and current TDS concentrations at the representative monitoring wells. The interim milestones are a progression towards sustainability. Therefore, the difference between the current conditions and the MOs was equally distributed amongst each five-year period to reach the MOs. The interim milestones focus on agricultural beneficial users since the occurrence of drinking water wells for domestic and municipal beneficial users are already under the oversight of the Regional Water Quality Control Board and the Department of Drinking Water.~~

3.2.4.3 Path to Achieve and Maintain the Sustainability Goal

Planned groundwater extraction, imported water supplies, blending, retired lands, and management actions provide a reasonable path to achieve the groundwater quality objectives. The GSP monitoring program for groundwater quality will provide the GSA with a more comprehensive understanding of groundwater quality and trends in the Subbasin. As the GSP monitoring program progresses and data gaps in groundwater quality are filled, the Measurable Objectives and Minimum Thresholds may be adjusted to accurately represent trends in groundwater quality.

3.2.4.4 Impact of Selected Measurable Objectives on Adjacent Basins

There are no known areas of degraded water quality from human activities within the Subbasin's primary aquifer systems that are known to have migrated to adjacent subbasins north, east, and south of the Westside Subbasin; therefore, there is not any impact from the Measurable Objectives and Minimum Thresholds on adjacent subbasins. ~~In addition, planned compliance with Basin Plan Amendment degradation allowances that are incorporated into the Measurable Objectives and Minimum Thresholds are not expected to impact adjacent subbasins.~~

3.2.5 Measurable Objectives for Interconnected Surface Waters

3.2.5.1 Description of Measurable Objectives

As described in Chapter 2, interconnected surface water likely ~~does~~ not exist in the Subbasin and is currently designated as a data gap due to a lack of monitoring facilities in some areas of the Subbasin and historical data. In addition, streams in the Subbasin are ephemeral in nature and have historically not had sufficient flows to maintain GDEs. Therefore, no minimum measurable objectives were developed for this sustainability indicator. If in the future, data from ~~a~~ groundwater level monitoring indicate that surface water from the ephemeral streams in the Subbasin and groundwater are interconnected, the GSA will develop minimum thresholds, undesirable results and measurable objectives. Since minimum thresholds/sustainable management criteria were not developed for the GSP, information about the

methods used to develop minimum thresholds, the quantitative metrics to track compliance with minimum thresholds, and their impacts on other sustainability indicators, other Subbasins, and beneficial use and users of groundwater is not presented in this ~~section~~Chapter.

3.2.5.2 Interim Milestones (Operational Flexibility)

Not currently applicable for this sustainability indicator.

3.2.5.3 Path to Achieve and Maintain the Sustainability Goal

Not currently applicable for this sustainability indicator.

3.2.5.4 Impact of Selected Measurable Objectives on Adjacent Basins

Not currently applicable for this sustainability indicator.

3.3 Minimum Thresholds (GSP Reg. § 354.28)

The GSP Regulations define undesirable results as occurring when significant and unreasonable effects are caused by groundwater conditions occurring throughout the Plan area for a given sustainability indicator. (GSP Reg. § 354.26.) Significant and unreasonable effects occur when Minimum Thresholds (MTs) are exceeded for one or more sustainability indicators. Minimum thresholds refer to a numeric value for each sustainability indicator used to define undesirable results. A GSP must establish minimum thresholds that quantify groundwater conditions for each applicable sustainability indicator at each monitoring site or representative monitoring site. The numeric value used to define the minimum threshold shall represent a point for conditions in the Subbasin that, if exceeded may cause significant and unreasonable undesirable results. A GSA may establish a representative minimum ~~threshold~~threshold, such as groundwater elevation (GWE) to serve as the value for multiple sustainability indicators, if the GSA can demonstrate the representative value is a reasonable proxy for multiple individual minimum thresholds, as supported by adequate evidence. Minimum thresholds are not required for sustainability indicators that are not present and not likely to occur in the Subbasin.

The description of minimum thresholds shall include the following:

1. The information and criteria relied upon to establish and justify the minimum threshold for each sustainability indicator. The justification for the minimum threshold shall be supported by information provided in the basin setting, and other data or models as appropriate and qualified by uncertainty in the understanding of basin setting. (GSP Reg. § 354.28(b)(1).)
2. The relationship between the minimum thresholds for each sustainability indicator, including an explanation of how the Agency determined that basin conditions at each minimum threshold will avoid undesirable results from each sustainability indicator. (GSP Reg. § 354.28(b)(2).)
3. How minimum thresholds have been selected to avoid causing undesirable results in adjacent basins or affecting adjacent ~~basins~~basin's ability to achieve sustainability goals. (GSP Reg. § 354.28(b)(3).)

4. How minimum thresholds may affect the interests of beneficial users and users of groundwater or land uses and property interests. (GSP Reg. § 354.28(b)(4).)
5. How state, federal, or local standards relate to the relevant sustainability indicator. If the minimum threshold differs from other regulatory standards, the Agency shall explain the nature of and basis for the difference. (GSP Reg. § 354.28(b)(5).)
6. How each minimum threshold will be quantitatively measured, consistent with the monitoring network requirements. (GSP Reg. § 354.28(b)(6)).

3.3.1 Minimum Thresholds for Chronic Lowering of Groundwater Levels

3.3.1.1 Description of Minimum Threshold

Groundwater levels will be measured at existing or new monitoring wells to gauge if minimum thresholds are being met. The groundwater level monitoring will be conducted in accordance with the monitoring plan outlined in **Section 3.75.2.1**. Furthermore, the groundwater level monitoring will meet the requirements of the technical and reporting standards included in the GSP regulations. As noted in **Section 3.65.1.1**, the current groundwater monitoring network includes ~~3422~~ wells in the Upper Aquifer and ~~4144~~ wells in the Lower Aquifer (**Figure 3-21** and **Figure 3-3, 2**). The GSA also installed five nested monitoring wells in 2019 which will augment the existing wells in the network (**Figure 3-7**). The GSA will evaluate whether further monitoring wells or refinement to these minimum thresholds are needed to monitoring boundary conditions with adjacent basins to ensure subsurface inflow and outflow conditions remain consistent with water budget and model results.

The GSP regulations provide that “[t]he minimum thresholds for chronic lowering of groundwater levels shall be the groundwater level indicating a depletion of supply at a given location that may lead to undesirable results.” (GSP Reg. § 354.28(c)(1).) Chronic lowering of groundwater levels in the Subbasin cause significant and unreasonable declines if they are sufficient in magnitude to lower the rate of production of pre-existing groundwater wells below that necessary to meet the minimum required to support beneficial use(s) where alternative means of obtaining sufficient water resources are not technically or financially feasible. In addition, GWEs will be managed at levels above the minimum thresholds to ensure the major aquifers in the Subbasin are not depleted in a manner to cause significant and unreasonable impacts to other sustainability indicators. At the same time, the GSA is mindful that groundwater levels may decline on a short-term basis below 2015 levels before they are stabilized by the end of the GSP implementation period. Thus, the minimum thresholds have been designated with that circumstance in mind.

The minimum thresholds are intended to protect against significant and unreasonable levels of chronic groundwater storage declines, water quality degradation from human activities and subsidence in areas where critical infrastructure is located. The development of minimum thresholds for chronic lowering of groundwater levels included a review of the magnitude of historical groundwater level declines during extended drought periods. ~~The magnitude of the groundwater level declines over the 2020 through 2040 period were superimposed on historic groundwater level lows to establish the minimum thresholds. The minimum thresholds~~ Hydrographs were generated for all representative monitoring wells and analyzed

for seasonal fluctuations and changes in water levels during drought periods. The baseline measurements were established using the lowest water levels encountered during the 2012-2016 drought period. However, these water level measurements (including those captured in 2015) were measured in the fall and are not representative of the seasonal low that would have been measured in the summer. To account for this discrepancy, the seasonal low water level was estimated using available data. The largest fluctuation in water levels was utilized to establish the MTs. MTs were calculated by subtracting this number (40 feet) from the baseline water level elevation at each well. Forty feet represents the projected average seasonal low.

In the Lower Aquifer, the MTs were calculated differently for seven wells located in subsidence prone areas near the SLC and highlighted in Table 3-8. In the cases of these seven wells, the 40 feet was not subtracted from the baseline value. Instead, the MTs were set to the measured low water level elevation in 2015 which reflects a groundwater level that is above the preconsolidation head. The MT is specified to maintain groundwater levels above the preconsolidation head to prevent further subsidence in subsidence prone areas.

The MTs for chronic lowering of groundwater levels are based on documented screen intervals of key wells located both in the upper and lower aquifers in the Subbasin. Key indicator wells and the subsequent minimum thresholds are listed in **Table 3-7** and **Table 3-8**. Groundwater level hydrographs from which the minimum thresholds were developed are provided in **Appendix 3-A3A**

3.3.1.2 Quantitative Measurement

Groundwater elevations will be determined by collecting depth to groundwater measurements from a known reference point and converted to an elevation relative to mean sea level. Measured values will be compared to the established minimum threshold value set at each individual well.

3.3.1.3 Existing Local, State, or Federal Standards

No Federal, State, or local standards exist for chronic lowering of groundwater elevations. Similarly, subsidence minimum thresholds on the San Luis Canal system do not exist, however, the GSA and DWR are communicating on efforts to minimize impacts from subsidence on the San Luis Canal within the Subbasin.

3.3.1.4 Avoidance of Undesirable Results

A prolonged period of extracting groundwater in excess of the sustainable yield has historically caused chronic lowering of groundwater levels in some areas of the Subbasin and could cause an undesirable result in the future. Conditions that may lead to an undesirable result include the following:

- Localized over pumping of groundwater. Even if regional pumping is maintained within the sustainable yield, a cluster (or pumping centers) of high capacity wells may cause excessive localized drawdowns that lead to undesirable results in specific areas.

- Extensive, unanticipated drought and associated drastic curtailments of imported surface water supplies. Minimum thresholds were established based on historical groundwater elevation and reasonable estimates of future groundwater elevations. Extensive, unanticipated droughts and associated curtailment of imported water supplies will likely lead to excessively low groundwater elevations and undesirable results.

As described in Chapter 4, PMA 1 (Surface Water Deliveries), PMA 3 (ASR), and PMA 5 (Recharge Project) were included to avoid undesirable results and increase groundwater levels in the Subbasin. Additionally, PMA 2 (Groundwater Allocation Program) and PMA 4 (Target Pumping Reductions) are physical solutions that when implemented protect groundwater levels, MTs, and avoid undesirable results. The efficacy of these PMAs in avoiding Undesirable Results is demonstrated through numerical modeling documented in Chapter 7 of Appendix I.

3.3.1.5 Effects of the Beneficial Uses and Users of Groundwater

The primary detrimental effects to beneficial users from water levels falling below the minimum threshold ~~area~~ are loss of significant well capacity, increased costs due to higher pumping lifts, lack of groundwater extraction due to groundwater levels declining below the pump setting depth or the bottom of the well, or subsidence impacts on well structures and above ground infrastructure, especially if the pumping is concentrated in a small geographic area.

The beneficial users with the shallowest wells that would be impacted are domestic well owners. To ensure these beneficial users would not be impacted by the established MTs, all active domestic wells within the Subbasin were plotted on the hexagonal grid. Figure 3-8 and Figure 3-9 compare the screen intervals of the domestic wells and the established water level MTs for Upper Aquifer and Lower Aquifer monitoring wells for each hexagon, respectively. This comparison resulted in no domestic wells where the water level at the MT would potentially drop below the screen interval. One Upper Aquifer well located in the northern portion of the Subbasin had insufficient information to adequately evaluate the impact of MTs on well capacity. Since no agricultural groundwater pumping occurs in this portion of the Subbasin and groundwater conditions are relatively stable, impacts to this well are not anticipated.

Similarly, the District plotted all the municipal and industrial wells within the Subbasin by hexagonal grid to ensure the established MTs would not deplete access to groundwater. Figure 3-8 and Figure 3-9 compare the screen intervals of the municipal and industrial wells and the established water level MTs for Upper Aquifer and Lower Aquifer monitoring wells for each hexagon, respectively. This comparison resulted in all municipal and industrial wells with screen intervals below the MTs.

Other beneficial users of groundwater in the Subbasin are agricultural well owners. However, all of these wells are screened deeper than the domestic monitoring wells. Therefore, if the MTs do not adversely affect the domestic wells, the municipal, industrial, and agricultural well owners will also not be impacted.

3.3.2 Minimum Thresholds for Reduction in Groundwater Storage

3.3.2.1 Description of Minimum Threshold

GSP Regulation § 354.28(c)(2) states that “[t]he minimum threshold for reduction of groundwater storage shall be a total volume of groundwater that can be withdrawn from the basin without causing conditions that may lead to undesirable results.” Minimum thresholds for reduction of groundwater storage shall be calculated based on historical trends, water year type and projected water use in the Subbasin. Reduction in groundwater storage is not a parameter that can be directly measured; rather, change in storage is calculated from change in groundwater levels and aquifer material storage coefficients. Change in groundwater storage will be regularly estimated based on monitoring results derived from analysis of groundwater elevations and aquifer properties. Periodically, during periods that correspond with GSP updates, an analysis of groundwater storage change using the water budget information from the numerical flow model will be used to verify changes in groundwater storage estimates from analysis of groundwater level monitoring data.

The minimum threshold for decline in groundwater storage will be equivalent to the maximum decline in groundwater levels between 2017 levels and groundwater level minimum thresholds. This will be calculated by developing a spatially weighted average of the difference between 2017 groundwater levels and minimum thresholds for groundwater levels at each well. For the Subbasin, the minimum threshold is estimated to be a decline in storage of 240,000 AFY using an average storage coefficient of 0.15 for the Upper Aquifer and a storage coefficient of 0.001 for the Lower Aquifer. The storage coefficients are average values obtained from the numerical flow model of the Subbasin and are consistent with literature values (Freeze and Cherry, 1971).

3.3.2.2 Quantitative Measurement

The minimum thresholds for reduction in groundwater storage is a single value of average groundwater elevation over the entire Subbasin. Therefore, the potential conflict between minimum thresholds at different locations in the Subbasin is not applicable. The reduction in groundwater storage minimum threshold was selected to avoid undesirable results for other sustainability indicators as outlined below:

1. Chronic lowering of groundwater levels. Since groundwater elevation will be used for estimating changes in groundwater storage, the reduction in groundwater storage would not cause undesirable results for this sustainability indicator.
2. Degraded water quality. Exceedances of the minimum threshold for declines in groundwater storage is not expected to lead to a degradation of groundwater quality.
3. Subsidence. Future average groundwater levels and changes in long-term aquifer storage will be stable and will not induce any additional subsidence in areas where additional subsidence will adversely impact the operations of the San Luis Canal near checks 16, 17, and 20.

The minimum thresholds for reducing groundwater storage are based on groundwater levels set at a minimum water level over the historical period. Most representative wells use the groundwater elevation to avoid reduction in groundwater storage. Groundwater levels will be measured at existing and new

monitoring wells. The groundwater level monitoring will be conducted in accordance with the monitoring plan outlined in Section 3.7.2. Furthermore, the groundwater level monitoring will meet the requirements of the technical and reporting standards included in the GSP Regulations. The change in groundwater elevations from year to year will be determined and multiplied by the storage coefficients associated with the specific aquifer being measured and multiplied by the areal extent of the Subbasin to derive the annual change in storage.

3.3.2.3 Existing Local, State, or Federal Standards

No Federal, State or local standards exist for reduction in groundwater storage.

3.3.2.4 Avoidance of Undesirable Results

A prolonged period of extracting groundwater in excess of the sustainable yield has historically caused groundwater storage declines, which when coupled with reductions in imported water supplies in some areas of the Subbasin, could cause an undesirable result in the future. Conditions that may lead to an undesirable result include the following:

- Localized over pumping of groundwater. Even if regional pumping is maintained within the sustainable yield, a cluster (or pumping centers) of high capacity wells may cause excessive localized drawdowns that lead to undesirable results in specific areas.
- Extensive, unanticipated drought and associated drastic curtailments of imported surface water supplies. Minimum thresholds were established based on historical groundwater elevation and reasonable estimates of future groundwater elevations. Extensive, unanticipated droughts and associated curtailment of imported water supplies will likely lead to excessively low groundwater elevations and undesirable results.

3.3.2.5 Effects of the Beneficial Uses and Users of Groundwater

The practical effect of implementing this management criteria is that it encourages no net change in groundwater elevation and storage during average, long-term hydrologic conditions. Therefore, during average, long-term hydrologic conditions, beneficial uses and users will have access to the same amount of groundwater in storage that currently exists, and the undesirable result will not have a negative effect on the beneficial users and uses of groundwater. Pumping during dry years will temporarily lower groundwater elevations, reduce the amount of groundwater in storage and could result in short-term impacts from a reduction in groundwater in storage on all beneficial users and users of groundwater. However, the GSP is designed to promote conjunctive use in the Subbasin and acknowledges the sustainable yield as an average value that can experience annual variations in storage.

3.3.3 Minimum Thresholds for Subsidence

3.3.3.1 Description of Minimum Threshold

GSP Regulations state that “[t]he minimum thresholds for land subsidence shall be the rate and extent of subsidence that substantially interferes with surface land uses and may lead to undesirable results.” (GSP Reg. § 354.28(c)(5)). ~~Information used to establish the land subsidence minimum thresholds include:).~~

The MT for subsidence and subsurface compaction were established based on (1) assessment of the susceptibility of critical infrastructure to future subsidence and coordination with beneficial users of groundwater and other interested parties, (2) analysis of historical and current rates and total amounts of subsidence described in **Section 2.2.8.4**, and (3) anticipated impacts of Projects and Management Actions described in **Chapter 4**.

- Historical land surface elevation data from GPS locations in the Subbasin and satellite imagery of subsidence.
- Technical reports and correspondence about significant and unreasonable subsidence conditions along the San Luis Canal from GSA and DWR staff and interested parties.

Subsidence monitoring in and adjacent to the Subbasin includes several different data collection programs. WWD obtains or collects subsidence data from 98 GPS survey locations. USBR collects subsidence data from 25 field GPS locations along the SLC. The USGS collects subsidence data from 12 extensometer locations (three of which are currently active within the Subbasin) and also obtains continuous GPS subsidence data from UNAVCO which maintains and monitors three GPS subsidence stations.

In addition, satellite imagery, used to estimate subsidence over large areas, is collected and processed by the USGS and DWR. However, this spatial subsidence data does not encompass the entire Subbasin and covers short periods of time.

Figure 3-4 depicts the distribution of the subsidence monitoring locations within the Subbasin. The majority of the stations from all agencies are concentrated in the central area of the Subbasin; specifically, near the SLC.

Public comments at GSA meetings indicated that while people were generally in agreement with the goal of minimal to zero subsidence in areas of the SLC that have been impacted the most by subsidence, there was concern about being held accountable for small amounts of subsidence of agricultural land that would not harm infrastructure. This concern was expressed to the GSA at the April 3rd, 2019 Groundwater Modeling Workshop.

Substantial rates of subsidence, if maintained over a long period of time, could lead to significant and unreasonable conditions. Therefore, the minimum threshold is a rate of subsidence for the three extensometers and gps benchmark survey locations near Checks 16, 17, and 20 of 0.3 feet per year. However, in other areas of the Subbasin, some amount of subsidence is acceptable and not significant and unreasonable if the subsidence does not substantially impact the operation or function of the infrastructure or land use. Since there have not been recent documented occurrences of subsidence impacts to infrastructure in the Subbasin other than the SLC, setting a rate of subsidence for minimum threshold is related to 2015 baseline groundwater elevations and associated rates of subsidence that occurred when groundwater levels in the Subbasin were at those levels. If groundwater levels fluctuate

above the 2015 groundwater elevations, then subsidence rates will decrease over time until aquitard pore pressures stabilize.

Key indicator wells and the subsequent Minimum Thresholds are listed in **Table 3-9**. Key well construction and monitoring history are

MTs are specified at the RMS within the GSA and described in **Section 3.5.1.3** and shown in **Figure 3-3**. These include GPS locations measuring land surface displacement (subsidence), extensometers measuring subsurface compaction and wells measuring water levels as a proxy where more direct measurements of subsidence are not currently in place (**Figure 3-3**). In sites measuring vertical displacement or compaction, MTs are defined using an annual rate of subsidence or compaction which may occur in a given year measured between the winter of consecutive years coupled with a total cumulative allowable amount measured during GSP implementation. The winter to winter comparison was selected because there is less ground disturbance activity (e.g., agricultural grading) to interfere with the vertical displacement measurements, and provides accurate inelastic subsidence measurements, if any. As is the case in evaluating MOs, annual rates and total amounts of subsidence apply solely to inelastic (irreversible) subsidence. As a result, annual rates, total amounts of subsidence and groundwater elevations are evaluated from measurements taken after groundwater levels have recovered from pumping during the irrigation season.

MTs specified in monitoring sites selected adjacent to SLC allow for a maximum annual rate of 0.3 feet of subsidence or compaction and a cumulative total of 1.5 feet of subsidence (**Table 3-9, Appendix 3B**). The annual rate of 0.3 feet per year of subsidence was determined based on the approximate rates of subsidence which occurred during droughts in the early 1990's and between 2012-2016 described in **Section 2.2.8.4**. Cumulative total amounts of subsidence were determined based on recent rates of groundwater pumping, subsidence, and the timeline for implementation of PMAs. Cumulative total amounts were also compared to estimates of freeboard in the SLC to evaluate how MTs would impact the conveyance capacity in the canal and coordination meetings with the DWR CASP (**Appendix 3C**). PMAs are intended to substantially reduce and ultimately abate subsidence by 2040. However, it is anticipated that some subsidence will occur during the GSP implementation period as PMAs are employed and refined to reach this goal. It is also recognized that some subsidence may occur locally due to future groundwater management (e.g., pumping rates, distribution of pumping, ASR), which is tolerable provided subsidence does not exceed the cumulative MT. The DWR CASP expressed a willingness to support proposed MTs presented during a follow up GSA engagement meeting citing that although the MT will allow for some additional subsidence, the plan illustrates a pathway to arrest subsidence along the SLC (DWR CASP, personal comm., May 25, 2022).

MTs in other portions of the Subbasin allow for a maximum annual rate of 0.3 feet of subsidence and a total cumulative amount of 2.5 feet of subsidence or compaction at GPS sites and extensometers. Where water level proxies are used, MTs for subsidence are consistent with MTs for chronic lowering of water levels defined in **Section 3.3.1.1**. The annual rate of 0.3 feet per year of subsidence was determined based on the approximate rates of subsidence which occurred during droughts in the early 1990's and between

2012 and 2016 described in [Section 2.2.8.4](#). Cumulative total amounts of subsidence were determined based on recent rates of groundwater pumping and subsidence and the timeline for implementation of PMAs. As described in [Section 3.3.3.5](#) and [3.4.3.3](#), infrastructure in other portions of the Subbasin have been less impacted by past subsidence and are likely less prone to interference and repairs due to future subsidence. Based on coordination with the District's Supervisor of Field Engineering and input from Caltrans, the total cumulative subsidence MT was set at an amount that is unlikely to produce substantial impacts to surface land uses which may lead to undesirable results. Historical subsidence caused limited impacts to District infrastructure and no reported impacts to roads and bridges. Future subsidence will be constrained by the MT which allows for substantially less subsidence than has occurred historically. As a result, it can be qualitatively inferred that it is unlikely that future subsidence will significantly interfere with surface land uses.

3.3.3.2 [Quantitative Measurement](#)

~~Two separate methodologies were employed to determine the minimum thresholds depending on site type. Where water level monitoring wells were used for monitoring, the Minimum Thresholds, Measurable Objectives, and Interim Milestones were established based on the water level monitoring objectives and thresholds.~~

~~The extensometer sites minimum threshold was established by calculating the compaction level from July 2013 to March 2015 and rounding down to the nearest tenth of a foot.~~

~~The quantitative metric for assessing compliance will be to continue to use groundwater level data and future GPS benchmark survey locations near the 14 identified wells ([Table 3-9](#)) which will be downloaded annually. Groundwater level data will be converted to average monthly data and plotted. Both quantitative and qualitative assessments of the data will be performed to assess if any trends are apparent, and if the annual subsidence is greater than the minimum thresholds.~~

[MTs for annual rates of subsidence or compaction and cumulative total subsidence or compaction measured at GPS and extensometer sites will be evaluated based on measurements taken in the winter of each year. Cumulative total amounts of subsidence and compaction will be calculated in each given year based on a baseline January 2020. January 2020 serves as a meaningful benchmark for inelastic subsidence as this period coincides with the GSAs' adoption of the GSP and GSP implementation activities to address undesirable results from subsidence that may occur as a result of unsustainable groundwater pumping in the Subbasin. Unlike other sustainability indicators, inelastic subsidence \(or compaction\) is irreversible. As a result, the SMCs do not include prior inelastic subsidence because the GSAs cannot address irreversible subsidence occurring before the GSAs had the authority to implement the projects and management actions to mitigate subsidence described in the GSP. The January 2020 benchmark was established from direct measurement at USBR and UNAVCO GPS sites and USGS extensometer sites. The baseline was established indirectly using TREA InSAR where January 2020 measurements were unavailable at DWR and WWD GPS sites.](#)

Quantitative measurements of MTs in GPS and extensometer sites varies depending on the monitoring agency. Subsidence at GPS sites operated by DWR is calculated based on measurements of land surface elevation taken by static GPS benchmarks in January and February of each year and provided to the GSA following internal QA/QC. Subsidence at the UNAVCO PBO site (P302) is collected as relative vertical displacement and uploaded continuously to the UNAVCO webpage. Subsidence is calculated using a 10-day moving average and evaluated in the winter of each year. Subsidence at USBR sites is calculated based on measurements of land surface elevation from static GPS benchmarks taken in December of each year and published to the USBR San Joaquin Restoration Project (SJRRP) webpage. Subsidence at GPS sites monitored by WWD is calculated based on measurements of land surface elevation taken at static GPS benchmarks in March of each year by the District consultant (Blair, Church & Flynn) and provided to the GSA after internal QA/QC. Compaction at USGS extensometer sites is measured and provided continuously through the USGS NWIS webpage. Compaction is evaluated in the winter of each year.

Quantitative measurement in sites where groundwater levels will be used as a proxy for subsidence are described in the methodology for chronic lowering of groundwater levels presented in **Section 3.3.1.2**.

3.3.3.3 Existing Local, State, or Federal Standards

Specific standards for subsidence minimum thresholds do not exist on the San Luis Canal system, however, the GSA and DWR are communicating on efforts to minimize impacts from subsidence on the San Luis Canal within the Subbasin.

3.3.3.4 Avoidance of Undesirable Results

~~Conditions that may lead to an undesirable result of a significant and unreasonable amount for land subsidence has historically occurred during periods with surface water supply curtailments coupled with groundwater pumping in excess of sustainable yield in areas where critical infrastructure exists. Conditions that may lead to an undesirable result include the following:~~

- ~~• Localized pumping. Even if regional pumping is maintained within the sustainable yield, cluster (or pumping centers) of high capacity wells may cause excessive localized drawdowns that lead to undesirable results in specific areas.~~
- ~~• Extensive, unanticipated drought. Minimum thresholds were established based on historical groundwater elevation and reasonable estimates of future groundwater elevations. Extensive, unanticipated droughts may lead to excessively low groundwater elevations and subsidence.~~

~~Groundwater storage MT's were developed based on the groundwater elevation MT's. The established MT values for groundwater storage will avoid undesirable results for the same reasons described in section 4.3.1.4.~~

Avoidance of undesirable results will be accomplished through implementation of planned projects and management actions aimed at augmenting groundwater supply and demand described in **Section 4**. PMA No. 2 was developed to allocate groundwater extraction based on the sustainable yield of the Subbasin in order to reduce regional impacts of groundwater overdraft on subsidence. PMA No. 4 was developed to

reduce the acute impacts of groundwater extraction subsidence through targeted reductions in groundwater pumping in subsidence-prone portions of the SLC, which impacts the freeboard required to maintain operational flexibility for the CVP and SWP. These demand-driven PMAs are coupled PMA No. 3 and 5 intended to augment water supply through ASR and targeted recharge through percolation basins. Supply-driven PMAs are designed to increase the volume of stored groundwater during wet periods mitigating pumping impacts during subsequent droughts. In conjunction with the proposed monitoring network, planned management actions are targeted to avoid and respond to undesirable results and emergent impacts on surface land uses.

3.3.3.5 Effects on the Beneficial Uses and Users of Groundwater

~~The subsidence minimum thresholds are set to prevent subsidence that could significantly impact the operations of the SLC or other critical infrastructure without sizable financial investments to fix impacts resulting from subsidence. Significant amounts of subsidence on critical infrastructure such as the SLC impacts primarily agriculture and urban beneficial users, not just within the Subbasin but in any area of the State that relies on water being delivered by the SLC/California Aqueduct. In addition, the amount of water being conveyed may be reduced if certain sections of the SLC have subsided, thereby reducing the amount of water that can be conveyed from a reduction in freeboard from subsidence. These impacts effect agricultural and urban beneficial users as it may impact water deliveries and costs to operate the CVP and SWP.~~

The effects of MTs may affect beneficial uses and users of groundwater, land uses and other infrastructure. Potential effects on entities with infrastructure sensitive to subsidence are described below:

- MTs specified at sites along the SLC may further impact the short operational flexibility due to subsidence in pools 17, 18 and 20 until liner raises are completed. Impacts are less likely to impact operations in other pools. Specific thresholds with relation to MTs from monitoring sites are shown in **Appendix 3C; Figure 3-10.**
- Pipelines and turnout structures operated by the District may be impacted by MTs which allow for between 1.5 and 2.5 feet of additional subsidence. While specific thresholds are not available, given the relatively limited existing impacts relative magnitude of past subsidence, it is unlikely that subsidence allowed under the MTs will lead to substantial impacts to WWD operations. Pipelines which could be potentially impacted by subsidence are shown in **Figure 3-11.**
- The impact of subsidence on well casings for agricultural wells owned and operated by landowners has been known to occur but is not well documented. It is anticipated that the subsidence MTs may lead to additional well retrofits, but this is challenging to predict.
- It is the District's understanding the impact of subsidence on roads and bridges maintained by Caltrans is not identified as a design factor. When designing roadways and structures, Caltrans focus its design on the soil five feet below groundwater surface, strength of the soil, and potential to collapse given an assumed vehicle miles traveled. Roadway repairs are usually due to rain migrating into the aggregate, roadways lifespan and/or the collapse due to the weight of the aggregate. Further, Caltrans does not identify subsidence as a design factor because impacts from

subsidence on roadways are repaired as result of normal maintenance and structures, such as bridges, are designed to withstand vertical displacement associated with subsidence. The District confirmed its understanding of how subsidence affects, if any, Caltrans infrastructure through personal communication with the Caltrans Maintenance Engineering Chief from Region 6 on June 10, 2022. It is anticipated that the subsidence MTs may lead to impacts to roads and bridges, but since specific thresholds are unavailable, specific impacts cannot be predicted. Roads and bridges which could be potentially impacted by subsidence are shown in **Figure 3-12**. Historically Caltrans has not attributed roadway repairs to land subsidence and during the implementation of the GSP land subsidence is not projected to impact the beneficial use of infrastructure within the Subbasin.

3.3.4 Minimum Thresholds for Groundwater Quality

3.3.4.1 Description of Minimum Threshold

The minimum threshold for degraded water quality from human activity is protective of existing and potential beneficial uses and users in the Subbasin. SGMA's water quality objective focuses on a constituent's contribution due to activities at the land surface rather than on the presence of naturally occurring constituents. Based on the review of groundwater quality in Chapter 2, the constituents of concern for beneficial users in the Subbasin are TDS. Nitrate and other constituents that may be of interest are not at concentrations, based on available data, that impact beneficial users. The bases for establishing minimum thresholds is to account for short term increases in TDS concentrations that, if continued for an extended period of time, would not be consistent with regulatory requirements such as the upcoming Basin Plan Amendment for salinity. The minimum threshold was based on an analysis of readily available historical data that shows short term variations of groundwater quality. The availability of site specific groundwater quality data that spans multiple years is scarce in the Subbasin. The data available exhibits a wide range of short term variability. Relative changes in TDS concentrations are only available for a few GSP monitoring locations. In order to determine whether a TDS concentration obtained from GSP monitoring efforts exceed the minimum threshold, the following process will be conducted:

1. Calculate the expected concentration of TDS utilizing the trend in annual change in concentrations for the well using the Measurable Objectives and Minimum Thresholds identified in **Tables 3-10 and 3-11** and add to the baseline concentration value.
$$\text{Expected Concentration} = \text{Initial Concentration} + (\text{Trend Concentration} \times \text{Number of years since Initial Concentration})$$
2. Compare the expected concentration value (Step 1) to the TDS concentration from the monitoring program. If the analyzed concentration is lower than the expected concentration, then the analyzed concentration is better than the expected concentration for that particular year that represents the Measurable Objective.
3. If the analyzed TDS concentration is higher than the expected concentration, then add the minimum threshold relative change in concentration value to the expected concentration to obtain a TDS concentration that, if exceeded, would exceed the expected Minimum Threshold concentration. Compare the analyzed TDS concentration to the expected Minimum Threshold concentration and if the analyzed concentration is lower, than the minimum threshold would not be exceeded.

Minimum thresholds that represent relative change in TDS concentrations for wells in the Upper and Lower Aquifers are summarized in [Table 3-10](#) and [Table 3-11](#).

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The MT for degraded water quality for beneficial uses and users in the Subbasin are based on drinking water standards for domestic and municipal beneficial users and outreach to interested parties, and discussions with the Advisory Committee and Technical Advisory Committees for agricultural beneficial users. As mentioned in the discussion for MOs, TDS is being used as a proxy for other main constituents of concern for agricultural users and constituents monitored for drinking water standards are of primary concern for municipal and domestic users. However, TDS will be used as a proxy for these additional drinking water constituents because of the correlation between TDS and the presence of these additional constituents. In addition, other water quality constituents are being monitored by other water quality programs (e.g., CV-SALTS and ILRP). The District will monitor these other programs to ensure water quality constituents impacted by the implementation of the Westside Subbasin GSP are sustainably managed.

4.1. Minimum thresholds for all representative monitoring wells were set at the same concentration. All minimum thresholds were set to 1,000 mg/L. This concentration is the short-term MCL for drinking water. Also, this concentration of TDS is tolerable for crops and vegetation for the short-term. Any TDS concentrations exceeding 1,000 mg/L may be considered undesirable and use of such water quality would need to be treated, blended with other better quality water supplies, or used on salt tolerant crops. However, if this threshold is exceeded, the GSA has defined a process to prevent undesirable results from occurring (described further in **Section 3.3.4.4.**). These measures include investigating the causes of TDS exceedances, development of appropriate management actions to address the exceedances with effected beneficial users. These measures may include blending, changes in land use, changes in groundwater pumping patterns, treatment, and other options

Minimum thresholds that for TDS concentrations for wells in the Upper and Lower Aquifers in those areas of the Subbasin that have not already been degraded prior to the 2015 baseline are presented are summarized in **Table 3-10 and Table 3-11** along with wells used for groundwater quality monitoring in the degraded areas that are not assigned a minimum threshold.

3.3.4.2 Quantitative Measurement

Groundwater quality will be monitored on an annual basis at key, representative monitoring and production wells (~~shown in Table 3-10 and 3-11~~). All measurements will comply with the Sampling and Analysis Plan and Quality Project Plan and be recorded in the GSA's data management system. The monitoring network and monitoring protocols are described in **Section 3.6 and 3.75** (Monitoring Network and Monitoring Protocols for Data Collection). **Tables 3-10 and 3-11** include each well being monitored in the GSP monitoring program for groundwater quality in the Upper and Lower Aquifers, along with the 2015 baseline TDS concentration (if available), ~~minimum threshold, measurable objective~~ MT, MO, and interim milestones. Generally, ~~minimum thresholds~~ MTs were set at 21,000 milligrams per liter (mg/L) TDS in the Upper and Lower Aquifers.

The ~~measurable objectives~~ MOs for groundwater quality are concentrations of TDS that are generally representative of secondary drinking water standards and tolerable for most crops grown in the Subbasin without blending with surface water supplies. ~~The minimum threshold is established at 2,000 mg/L which~~

~~represents the upper limit of freshwater as defined by the USGS. Groundwater quality in the Subbasin is influenced in some areas of the upper aquifer by naturally occurring marine sediments from the Coast Range. These marine sediments naturally result in groundwater quality that exceeds drinking water standards in some areas of the upper aquifer. This is mitigated by utilizing surface water supplies or blending groundwater and surface water for desired water quality for domestic/urban use and irrigation for crops, due to the salt tolerance of most crops.~~

3.3.4.3 Existing Local, State, or Federal Standards

The minimum threshold for TDS is based on the Regional Water Quality Control Board Basin Plan Amendment that is currently being updated and developed. The minimum thresholds, if exceeded for a prolonged period, may indicate impacts from human activities at the land surface that will be addressed in coordination with Regional Water Quality Control Board direction.

3.3.4.4 Avoidance of Undesirable Results

~~In order to prevent undesirable results from occurring, if the minimum thresholds are exceeded at any representative monitoring well, the GSA will conduct additional sampling in the impacted wells and any domestic or urban use wells within the hexagon. This sampling will confirm whether the wells are exceeding the MT of 1,000 mg/L. If exceedances are present, the GSA will work with well owners to mitigate these concentrations and bring them back to levels below the minimum threshold. The same approach will be utilized in the case of agricultural wells exceeding the threshold. In that case, the GSA will work with well owners to implement management actions such as changing crops or blending water to mitigate impacts.~~

3.3.4.5 Effects of the Beneficial Uses and Users of Groundwater

~~The effect of degraded groundwater quality from human activities on agricultural beneficial users is manifested in crop damage and reduced yields, and a reduction in the use of land for irrigated agriculture if the sole water supply is groundwater.~~

Urban and domestic beneficial uses are impacted if water/groundwater of degraded quality is the only source of water for potable use. The impacts include the need to utilize alternative sources of water that may be more expensive than groundwater and potential requirement to treat prior to use. The effect of degraded groundwater quality from SGMA activities on agricultural beneficial users is manifested in crop damage and reduced yields, and a reduction in the use of land for irrigated agriculture if the sole water supply is groundwater.

3.3.5 Minimum Thresholds for Interconnected Surface Waters

3.3.5.1 Description of Minimum Threshold

As described in Chapter 2, interconnected surface waters are currently designated as a data gap due to a lack of historical data and monitoring facilities, ~~therefore.~~ Therefore, no minimum thresholds were developed for this sustainability indicator. If in the future, data from a groundwater level monitoring

indicate that surface water from the ephemeral streams in the Subbasin and groundwater are interconnected, minimum thresholds and measurable objectives will be developed. Since minimum thresholds were not developed for the GSP, information about the methods used to develop minimum thresholds, the quantitative metrics to track compliance with minimum thresholds, and their impacts on other sustainability indicators, other Subbasins, and beneficial use and users of groundwater is not presented in this section.

3.3.5.2 Quantitative Measurement

Not currently applicable for this sustainability indicator.

3.3.5.3 Existing Local, State, or Federal Standards

Not currently applicable for this sustainability indicator.

3.3.5.4 Avoidance of Undesirable Results

Not currently applicable for this sustainability indicator.

3.3.5.5 Effects of the Beneficial Uses and Users of Groundwater

Not currently applicable for this sustainability indicator.

3.3.6 Relationship Between the Established Minimum Threshold and Sustainability Indicator(s)

The wells described in **Tables 3-21** through **Table 3-11** ~~are in locations that were selected to~~ reflect a diverse and wide cross section of ~~Subbasin~~ the Subbasin's groundwater conditions. These locations are representative of the overall Subbasin conditions because the monitoring sites are spatially distributed throughout the Subbasin both vertically (across the Upper and Lower Aquifers) and laterally. The GSA determined that use of the minimum elevation thresholds at each of the listed wells will help avoid the undesirable results of chronic lowering of groundwater levels because it should preserve access to adequate water resources for beneficial users within the Subbasin.

Groundwater elevation minimum thresholds can influence other sustainability indicators. The groundwater elevation minimum thresholds were selected to avoid undesirable results for other sustainability indicators.

1. Change in groundwater storage. A significant and unreasonable condition for change in groundwater storage is pumping groundwater in excess of the sustainable yield that would result in groundwater levels to decline below minimum thresholds for an extended period of years. Pumping at or less than the sustainable yield will maintain or raise average groundwater elevations in the Subbasin. The groundwater elevation minimum thresholds are set ~~below 2015~~ consistent with 2012-2015 drought baseline groundwater elevations, consistent with the potential action of pumping in excess of the sustainable yield during a drought type period that spans multiple years. Therefore, the exceedance of the groundwater elevation minimum threshold will not result in long-term significant or unreasonable change in groundwater storage.

2. Degraded water quality. Preserving groundwater quality is important to the groundwater resource. A significant and unreasonable condition of degraded water quality from human activities management of groundwater resources is exceeding concentrations of constituents of concern in groundwater due to actions proposed in the GSP. Water quality could be affected through two processes:
 - a. Low groundwater elevations in an area could cause deeper, poor-quality groundwater (saline groundwater located below the base of freshwater) to flow upward into existing wells. Groundwater elevation minimum thresholds are set at, or above historic low levels, experienced in the 1950s and 1960s, preventing a return to changes to those historical vertical flow gradients, thereby avoiding upward flow of deep, poor quality groundwater that would not otherwise occur. The groundwater elevation minimum threshold will avoid poor-quality water from impacting existing wells and beneficial users.
 - b. Declines in groundwater elevations east of the Subbasin as a result of adjacent subbasin's measurable objectives and minimum thresholds that change historical groundwater gradients, which could cause changes in flow patterns of poor-quality groundwater towards wells that would not have otherwise been impacted.
3. Subsidence. A significant and unreasonable condition for subsidence is any measurable permanent subsidence that results in severe impacts to the operations of existing infrastructure to a degree that would require design and construction projects to mitigate the impact. Subsidence is caused by dewatering and compaction of clay-rich sediments in response to lowering groundwater levels. The groundwater elevation minimum thresholds are set at or above groundwater elevations that will induce additional subsidence in areas that currently have minimum tolerances for additional subsidence along the San Luis Canal.
4. Depletion of interconnected surface waters. Due to a lack of monitoring facilities and historical data of shallow zone groundwater conditions, this sustainability indicator has been designated as a data gap. Existing streams in the Subbasin are ephemeral in nature and flow infrequently. Therefore, interconnected surface water that sustains GDEs and is affected by groundwater pumping historically has not occurred. In addition, in many parts of the Subbasin where the ephemeral streams are located, Upper Aquifer groundwater quality is degraded and, as a result, groundwater pumping in the Upper Aquifer that could influence surface water flows directly and potential GDEs does not likely occur from examination of Upper Aquifer groundwater pumping distribution and analysis of streamflow occurrence. These conditions have led to a lack of monitoring facilities and historical data based on these observations of groundwater pumping and ephemeral streamflow patterns along with analysis of shallow zone groundwater conditions. Therefore, there are no current minimum thresholds or undesirable results that could be affected by the groundwater elevation minimum thresholds.
5. Seawater Intrusion. The location of the Subbasin in the San Joaquin Valley and physically separated from the Pacific Ocean precludes the existence or presence of seawater intrusion. Therefore, there are no minimum thresholds or undesirable results for this sustainability indicator.

3.3.7 Minimum Thresholds Impacts to Adjacent Basins

Four neighboring groundwater basins (Delta-Mendota, Kings, Tulare Lake, and Pleasant Valley) are required to develop a GSP. The implementation of the Westside Subbasin GSP's anticipated effect of the groundwater elevation minimum thresholds on each of the four subbasins is not expected to impact adjacent basins GSP implementation efforts. In fact, preliminary review of draft GSPs from adjacent basins indicate that Westside Subbasin efforts to achieve sustainability will be beneficial to adjacent basins. This is due to the fact that the Subbasin is not planning on minimum thresholds being below historic lows and 2015 baseline levels for a significant amount of time. In contrast, adjacent basins (with the exception of Pleasant Valley as that basin has not developed information that is reviewable at the time of the preparation of this GSP), Kings and Tulare Lake are planning on measurable objectives and minimum thresholds that are lower than historic lows and 2015 baseline levels. As a result, those basins may impact the ability of the Westside Subbasin to become sustainable in some areas of the Subbasin. It is anticipated that ongoing outreach efforts will be conducted with adjacent basins to mitigate impacts to the Subbasins implementation of the Westside Subbasin's sustainability goal. The Pleasant Valley Subbasin is planning on developing MTs that are higher than the Westside Subbasin, however it is not anticipated that the groundwater elevation MTs in the Westside Subbasin will impact the ability of the Pleasant Valley Subbasin to be sustainable due to the presence of geologic features such as an anticline (see discussion in Section 2.2.3.7) located between the two subbasins which impedes groundwater flow between the two subbasins.

3.3.8 Minimum Thresholds Impacts on Beneficial Users

The minimum thresholds established for the sustainability indicators that are present in the Subbasin may have several effects on beneficial users and land use in the Subbasin. Since the minimum thresholds are set at levels that are equivalent to historic lows or 2015 levels in most areas of the Subbasin, agricultural beneficial uses may be impacted in a way that would limit or prevent an expansion of groundwater use to the extent that minimum thresholds are continuously exceeded. In subsidence prone areas near Checks 16, 17, and 20, the minimum thresholds for groundwater levels and subsidence will result in reductions in groundwater use during drought periods.

Urban beneficial users should not be impacted since urban water supplies are primarily met with imported water supplies rather than groundwater. Groundwater use for urban beneficial users is limited in nature and primarily used to supplement imported water supplies. As described in Sections 2.1.1.1 and 3.3.1.5, domestic users of groundwater are not expected to be impacted by the minimum thresholds since those thresholds have already been experienced historical lows without documented impacts to domestic users. Lack of groundwater availability for domestic water uses in the Subbasin during the last drought as a result of declining groundwater levels was not reported. Additionally, DWR's Dry Wells Reporting System has not reported dry wells in the Westside Subbasin.

3.4 Undesirable Results (GSP Reg. § 354.26)

According to GSP Regulations, the GSP's description of undesirable results is to include the following:

1. The cause of groundwater conditions occurring throughout the basin that would lead to or has led to the undesirable results based on information described in the basin setting, and other data or models as appropriate. (GSP Reg. § 354.26(b)(1).)
2. The criteria used to define when and where the effects of the groundwater conditions cause undesirable results for each applicable sustainability indicator. The criteria shall be based on a quantitative description of the combination of minimum threshold exceedances that cause significant and unreasonable effects in the basin. (GSP Reg. § 354.26(b)(2).)
3. Potential effects on the beneficial uses and users of groundwater, on land uses and property interests, and other potential effects that may occur or are occurring from undesirable results. (GSP Reg. § 354.26(b)(3).)

Under SGMA, undesirable results occur when significant and unreasonable effects for any of the six sustainability indicators are caused by groundwater conditions occurring throughout the basin. These sustainability indicators are:

1. Chronic lowering of groundwater levels,
2. Reduction of groundwater storage,
3. Seawater intrusion,
4. Degraded water quality,
5. Land subsidence, and
6. Depletion of interconnected surface water.

A summary of criteria used to define undesirable results is provided below in **Table 3-12**, and detailed discussion of each sustainability indicator is provided in subsequent sections of this Chapter.

3.4.1.1 Chronic Lowering of Groundwater Levels

Significant and unreasonable levels of the chronic lowering of groundwater elevations is defined as a fraction of the groundwater elevations measured in the GSP monitoring well network that are less than the minimum threshold values. For the Subbasin, this fraction is estimated as 25 percent or more of the groundwater elevations for two consecutive years will result significant and undesirable levels of chronic lowering of groundwater levels.

3.4.1.2 Reduction of Groundwater Storage

Significant and unreasonable levels of groundwater storage declines is defined as an exceedance of the groundwater storage decline minimum threshold for two consecutive years values. For the Subbasin, this exceedance for two consecutive years will result significant and undesirable levels of groundwater level declines that could impact the use of existing wells and beneficial users of groundwater. The significant and unreasonable decline in storage would result in limiting the volume of groundwater available for agriculture, municipal, industrial and domestic uses without any management actions or projects to mitigate the impact through the use of new and deeper wells.

3.4.1.3 Land Subsidence

The GSP Regulations state that the subsidence undesirable result is a quantitative combination of subsidence minimum threshold exceedances. For the Westside Subbasin, significant subsidence that impacts infrastructure such as the SLC to a degree that conveyance operations are severely impacted is unacceptable. However, available continuous subsidence data shows annual land subsidence that does not necessarily indicate long-term subsidence is occurring when annual groundwater level declines are consistent with the long-term trend. To address the inherent data uncertainty, one minimum threshold exceedance is allowed each year. Therefore, the subsidence undesirable result occurs when two or more subsidence minimum thresholds are exceeded during any one year. An individual continuous GPS sites may not exceed minimum thresholds for more than two consecutive years.

Locally defined significant and unreasonable conditions for land subsidence were assessed based on public meetings and discussions with DWR and GSA staff. The amount of subsidence in the Subbasin that is considered significant and unreasonable depends on the geographic location within the Subbasin. In areas located near Checks 16, 17, and 20 of the San Luis Canal minimal amounts of additional subsidence are considered significant and unreasonable. In those areas, additional subsidence will result in the San Luis Canal to need repairs to operate as it was originally designed. (DWR, 2017) However, in other areas of the Subbasin land subsidence of a certain amount and extent is tolerable due to a lack of critical infrastructure or infrastructure that can account for some subsidence.

3.4.1.4 Degraded Groundwater Quality

3.4.1 Chronic Lowering of Groundwater Levels

3.4.1.1 Criteria Defining an Undesirable Result

The District will compare the measured water levels at the representative monitoring wells to the established MTs. If water levels fall below the established MTs, domestic beneficial users may be impacted as those are the shallowest wells. Modeling described in **Section 7.2.3.1** in **Appendix I** suggests that through implementation of PMAs, groundwater levels will stabilize during the GSP planning and implementation period. However, if an exceedance of the MT is observed, the District will communicate with domestic well users within the hexagon to determine whether those wells have been impacted and the District will attempt to mitigate the impact at a local level.

An undesirable result will occur if water levels fall below 50% of the screen interval of a domestic well within a hexagon due to an MT exceedance during the fall measurement of a non-drought year. If no domestic wells are present in a hexagon, an undesirable result will occur if 10% of agricultural wells within a hexagon go dry due to an MT exceedance during the fall measurement of a non-drought year. These triggers for undesirable results were established based on the existence of both well types within the Subbasin.

Due to the small number of domestic wells present, 50% of the screen interval of a single domestic well going dry is an undesirable result as the production from the well may be impacted. Although sparse, domestic wells are located throughout the Subbasin. This definition of an undesirable result ensures that each well is protected from going dry as the criteria is based on each individual well instead of a percentage of the total number of domestic wells.

Similarly, the threshold of 10% or more of agricultural wells within a hexagon going dry was considered an undesirable result because that threshold would reduce the available water supply capacity to a degree that may impact agricultural beneficial uses in the impacted hexagon and may cause long-term reductions in the viability of agricultural wells.

A prolonged period of extracting groundwater in excess of the sustainable yield has historically caused chronic lowering of groundwater levels in some areas of the Subbasin and could cause an undesirable result in the future. Conditions that may lead to an undesirable result include the following:

- Localized over pumping of groundwater. Even if regional pumping is maintained within the sustainable yield, a cluster (or pumping centers) of high capacity wells may cause excessive localized drawdowns that lead to undesirable results in specific areas.
- Extensive, unanticipated drought and associated drastic curtailments of imported surface water supplies. Minimum thresholds were established based on historical groundwater elevation and reasonable estimates of future groundwater elevations. Extensive, unanticipated droughts and associated curtailment of imported water supplies will likely lead to excessively low groundwater elevations and undesirable results.

3.4.1.2 Potential Effects on Beneficial Users

The primary detrimental effects to beneficial users from water levels falling below the minimum threshold area loss of significant well capacity, increased costs due to higher pumping lifts, lack of groundwater extraction due to groundwater levels declining below the pump setting depth or the bottom of the well, or subsidence impacts on well structures and above ground infrastructure, especially if the pumping is concentrated in a small geographic area. The undesirable results are set to avoid significant and unreasonable depletions of groundwater supply at existing domestic, M&I and agricultural wells within the Subbasin.

3.4.2 Reduction in Groundwater Storage

3.4.2.1 Criteria Defining an Undesirable Result

A significant and unreasonable condition for change in groundwater storage is pumping groundwater in excess of the sustainable yield that would result in groundwater levels to decline below minimum thresholds and lead to a decrease in groundwater storage. An undesirable result will have occurred and trigger management actions if the MT for groundwater storage has been exceeded for two (2) consecutive non-drought years.

3.4.2.2 Cause of Undesirable Result

The causes of undesirable results for groundwater storage are tied to those for groundwater levels at the representative monitoring wells. Drought conditions and water extraction in excess of the sustainable yield range would lead to undesirable results.

3.4.2.3 Potential Effects on Beneficial Users

An undesirable result for reduction of groundwater storage would decrease the sustainable yield for the Subbasin. The practical effect of implementing the undesirable result for reduction of groundwater storage is that it encourages no net change in groundwater elevation and storage during average, long-term hydrologic conditions. Therefore, during average, long-term hydrologic conditions, beneficial uses and users will have access to the same amount of groundwater in storage that currently exists, and the undesirable result will not have a negative effect on the beneficial users and uses of groundwater. Pumping during dry years will temporarily lower groundwater elevations, reduce the amount of groundwater in storage and could result in short-term impacts from a reduction in groundwater in storage on all beneficial users and users of groundwater. In addition, the GSP is designed to promote conjunctive use in the Subbasin and acknowledges the sustainable yield as an average value that can experience annual variations in storage.

3.4.3 Subsidence

3.4.3.1 Criteria Defining an Undesirable Result

An undesirable result for subsidence occurs when there are significant and unreasonable land subsidence that substantially interferes with surface land uses (DWR, 2017). Subsidence impacts vary depending on

the magnitude of subsidence and location of critical infrastructure and other land uses. As described in [Section 3.4.3.3](#) below, impacts to the SLC are of heightened concern due to the existing subsidence and potential consequences of additional subsidence to SLC conveyance capacity and operational flexibility. The remainder of the Subbasin has fewer documented cases of subsidence impacts to surface land uses and is considered less susceptible to interference from subsidence. Accordingly, separate criteria are defined for monitoring sites located adjacent to the SLC and sites located in other portions of the Subbasin.

In the monitoring sites located adjacent to the SLC and listed on [Table 3-4](#), an undesirable result is defined when:

- The annual rate of subsidence or compaction at three (3) GPS benchmarks or extensometers is exceeded the annual rate MT for two (2) or more consecutive years. This condition is indicative of a regional or systemic increase in the rates of subsidence based on review of subsidence rates which occurred during past droughts where surface uses were impacted. Based on engagement meeting with DWR CASP, such a condition is considered significant and unreasonable (DWR CASP, personal comm., May 25, 2022). Such a condition would be mitigated through implementation or modification of PMA No. 2, PMA No. 3 and PMA No. 4 as described in [Sections 3.3.3.4](#) and [4.2](#).
- The cumulative total amount of subsidence or compaction at any GPS benchmark or extensometer exceeds the cumulative MT. As shown in [Appendix 3C](#), subsidence exceeding the cumulative total MT at any of the 15 monitoring site adjacent to the SLC would likely impact conveyance capacity and operational flexibility in the SLC. This condition is considered significant and unreasonable. Such a condition would require implementation of PMA No. 2, PMA No. 3 and PMA No. 4 as described in [Sections 3.3.3.4](#) and [4.4](#).

In the monitoring sites located in other portions of the Subbasin and listed on [Table 3-4](#), and Undesirable Result is defined when:

- The annual rate of subsidence or compaction or water level at three (3) GPS benchmarks, extensometers, or groundwater wells exceed the annual rate or water level MT for two (2) or more consecutive years. This condition is indicative of a regional or systemic increase in the rates of subsidence or groundwater level declines and is considered significant and unreasonable based on review of subsidence rates which occurred during past droughts where surface uses were impacted. Such a condition would be mitigated through implementation or modification of PMA No. 2 and PMA No. 3 as described in [Section 3.3.3.4](#) and [Section 4.2](#).

The cumulative total amount of subsidence or compaction at three (3) GPS benchmarks or extensometers exceeds the cumulative MT. While surface land uses in other portions of the Subbasin are less susceptible to interference due to subsidence, this condition is indicative of a regional or systemic increase in the total amount of subsidence or groundwater level declines and is considered significant and unreasonable based on review of subsidence which occurred during past droughts where surface uses were impacted. Such a condition would be mitigated through implementation or modification of PMA No. 2 and PMA No. 3 as described in [Section 3.3.3.4](#) and [Section 4.2](#).

3.4.3.2 Cause of Undesirable Result

Conditions that may lead to an Undesirable Result of a significant and unreasonable amount for land subsidence have historically occurred during periods with surface water supply curtailments coupled with groundwater pumping in excess of sustainable yield in areas where critical infrastructure exists. Conditions that may lead to an Undesirable Result include the following:

- Prolonged drought conditions. Drought conditions result in curtailments of CVP and other supplemental surface water imports resulting in increases in groundwater demand causing regional groundwater level declines. Reduction in aquitard pore pressure beyond the preconsolidation head results in inelastic subsidence which can impact surficial land uses and damage or otherwise negatively impact critical infrastructure.
- Localized groundwater extraction. Even if regional pumping is maintained within the sustainable yield, cluster (or pumping centers) of high capacity wells may cause localized reduction in aquitard pore pressure and subsidence causing Undesirable Results in specific areas.

3.4.3.3 Potential Effects on Beneficial Users

Undesirable Results may affect beneficial uses and users of groundwater, land uses and other infrastructure. Potential effects on entities with infrastructure sensitive to subsidence are described below:

- Freeboard has been reduced due to subsidence impacting conveyance capacity and operational flexibility of the SLC (California Aqueduct) owned and operated by the USBR and DWR. Impacts to the SLC are unique in that downstream beneficial users who hold CVP and SWP contracts may also be affected by reduction in SLC conveyance. DWR CASP has indicated that the most severe impacts have occurred in Pools 17, 18 and 20. Comparisons of the design water level to the liner elevation in 2022 illustrate areas which are most impacted by subsidence and most sensitive to future subsidence (**Figure 3-10**). Continued subsidence along the SLC has the potential to impact the operational flexibility due to subsidence in Pools 17, 18 and 20. Impacts are less likely to impact operations in other pools. DWR CASP is in the process of completing environmental documentation and acquiring funding for liner raises in areas most impacted by subsidence (DWR, 2022). As a result, impacts to conveyance capacity and operational flexibility are considered relatively short-term. Specific thresholds with relation to MTs from monitoring sites are shown in **Appendix 3C**, and expected to avoid significant and unreasonable subsidence to the SLC near Pools 17, 18 and 20.
- Existing impacts to pipelines and turnout structures due to subsidence from groundwater are limited to sealing of the Lateral 1L headworks due to a canal raise in the area (**Figure 3-11**). Undesirable results to pipelines and turnout structures operated by WWD are likely to be small, but could impact the efficiency of this infrastructure. While specific thresholds are not known, given the relatively limited existing impacts relative magnitude of past subsidence, it is unlikely that the amount subsidence allowed by the defined undesirable result will lead to substantial impacts to the District's operations.

- The impact of subsidence on well casings for agricultural wells owned and operated by landowners has been known to occur but is not well documented. It is anticipated that the subsidence MTs may lead to additional well retrofits but specific thresholds or number of wells which are susceptible to impacts are unknown. However, based on the total amount of pumping that occurred during the last drought period, modeling projections when groundwater levels exceed the MTs for two consecutive years shown in **Section 7.2.3.2 of Appendix I**, and the fact that well casing operational impacts were not reported to the District, the Undesirable Results are defined such that the District does not expect impacts to well owners.
- As described in Section 3.3.3.5, it is the District's understanding that Caltrans does not identify subsidence as a design factor and does not attribute repairs to its infrastructure as a result of subsidence. Instead repairs to Caltrans infrastructure are typically due to heavy loads and vehicle miles traveled using the roadways. The District confirmed its understanding of how subsidence affects, if any, Caltrans infrastructure through personal communication with the Caltrans Maintenance Engineering Chief from Region 6 (Caltrans, personal comm., June 10, 2022). While specific thresholds are not known, given the relatively limited existing impacts relative magnitude of past subsidence, it is unlikely that the amount subsidence allowed by the minimum threshold will lead to substantial impacts to Caltrans operations. Roads and bridges which could be potentially impacted by subsidence are shown in **Figure 3-12**.

3.4.4 Degraded Groundwater Quality

3.4.4.1 Criteria Defining an Undesirable Result

The undesirable result for degradation of groundwater quality is avoiding groundwater degradation due to actions directly resulting from GSP implementation on the beneficial users of groundwater.

The GSA will evaluate the annual TDS data collected from the monitoring network and compare the TDS concentrations at the representative monitoring wells to the established MTs. An undesirable result will have occurred if a well exceeds its MT for two (2) consecutive measurements. Based on the available groundwater data in the Westside Subbasin, one year of an exceedance generally does not result in degraded groundwater quality because a single measurement may not represent groundwater quality conditions due to uncertainty in groundwater quality analyses, aquifer groundwater quality variability and other factors. Two consecutive years of exceeded measurements are consistent with groundwater quality QA/QC approaches used by State Boards recommendation when determining a potential degraded groundwater quality trend. Whenever an MT exceedance is reported, the District will conduct additional sampling and implement mitigation procedures to prevent undesirable results.

3.4.4.2 Cause of Undesirable Result

Degraded water quality in the Subbasin is generally naturally occurring as a result of marine sediments from the Coast Range impacting groundwater quality in some areas of the Upper Aquifer and Lower Aquifers. Undesirable results from the naturally occurring degraded water quality is present in some geographic locations in the Subbasin that limit the beneficial use of the groundwater without blending with better quality water or treatment in order to serve certain beneficial uses. ~~The degraded water~~

quality is considered significant and unreasonable if the magnitude of degradation at pre-existing groundwater wells is not usable without taking management actions to improve the quality of the water to concentrations less than the minimum threshold. Groundwater quality degradation is considered an undesirable result when 25 percent of wells are above the MT for the same constituent, based on the average of the most recent three year period. Groundwater quality changes are expected to occur but are not expected to be directly correlated to the implementation of the Westside Subbasin GSP. However, drought conditions and local extraction could cause a lowering of groundwater levels resulting in degraded water quality.

3.4.4.3 Potential Effects on Beneficial Users

Urban and domestic beneficial uses are impacted if water of degraded quality is the only source of water for potable use. The mitigation of impacts to potable supplies of groundwater include the need to utilize alternative sources of water that may be more expensive than groundwater and potential requirement to treat prior to use or use of bottled water for potable purposes. The effect of degraded groundwater quality from SGMA activities on agricultural beneficial users is manifested in crop damage, reduced yields, increased costs, and a reduction in the use of land for irrigated agriculture if the sole water supply is groundwater. Mitigation measures for agricultural beneficial users may involve blending with other water supplies, shift in crop mix, or fallowing. The undesirable results for degradation of groundwater quality are defined to identify and engage in adaptive management prior to domestic and agricultural users experiencing significant and unreasonable impacts from poor water quality supplies.

3.4.23.4.5 Depletion of Interconnected Surface Waters

Undesirable Results for depletion of interconnected surface water were not developed for this GSP. Impacts to beneficial uses and users of groundwater, related to interconnected surface water and groundwater are not expected. If in the future, data from a more comprehensive monitoring program indicate that surface water and groundwater are interconnected, undesirable results related to interconnected surface water and groundwater will be assessed.

3.4.33.4.6 Potential Effects on the Beneficial Users of Groundwater

For agricultural beneficial users of groundwater, the most significant undesirable results are groundwater levels, groundwater storage, groundwater quality, and subsidence. The undesirable results for interconnected surface waters will not have a direct impact on agriculture. Undesirable results for any of the sustainability indicators of concern will limit the ability of agricultural users ~~of~~ to extract groundwater and irrigate crops.

For domestic beneficial users of groundwater, the most significant undesirable results are groundwater levels, groundwater storage, and groundwater quality. Undesirables results for any of these three sustainability indicators could potentially restrict the ability of households to use water for domestic purposes. Subsidence and interconnected surface waters will not have direct impact on domestic users.

For environmental beneficial uses of groundwater in the Subbasin, the most significant undesirable result is subsidence. Continued subsidence in the WWD area will restrict the ability to flood areas in the [MWA-Mendota Wildlife Area \(MWA\)](#).

3.4.43.4.7 Management Areas

Management areas have not been established in the Subbasin.

3.5 Monitoring Network

This section describes the proposed monitoring network, including GSA monitoring objectives monitoring protocols, and data reporting requirements. This section was prepared in accordance with GSP Regulations. The monitoring network was developed to collect a sufficient amount of data to characterize groundwater and related surface water conditions in the Subbasin and to evaluate changing conditions and GSP implementation. The monitoring network was designed to collect data to allow for the analysis of short- and long-term trends, seasonal variations and estimate annual changes in aquifer storage. The monitoring sites have been distributed across the Subbasin to provide a comprehensive analysis of current and ongoing conditions within the GSA. This widespread distribution coupled with the monitoring frequency will allow the GSA to chart its progress towards the established sustainability goals and also ensure real time tracking of any impacts on beneficial users. Specifically, the monitoring program will allow the GSA to quantify changes in groundwater storage and quality and assess the efficacy of any implemented management programs. ~~This~~These data will facilitate changes to management programs to maintain continued progress towards the GSA's sustainability objectives.

The GSP Regulations require monitoring networks to be developed to promote the collection of a data set of enough quality, frequency, and spatial distribution to characterize groundwater and related surface water conditions in the Subbasin and to evaluate changing conditions that occur through implementation of the GSP. (GSP Reg. § 354.34(b).) The monitoring network should accomplish the following:

- Demonstrate progress towards achieving measurable objectives described in the GSP;
- Monitor impacts to the beneficial uses and users of groundwater;
- Monitor changes in groundwater conditions relative to measurable objectives and minimum thresholds; and
- Quantify annual changes in water budget components. (GSP Reg. § 354.34(b)(1)-(4).)

The minimum thresholds and measurable objectives for the network are described above.

The GSP Regulations require that if management areas are established, the quantity and density of monitoring sites in those areas shall be sufficient to evaluate conditions of the Subbasin setting sustainable management criteria specific to that area. (GSP Reg. § 354.34(c).) At this time, management areas have not been defined for the Subbasin. If management areas are developed in the future, the monitoring network will be reevaluated to ensure that there is sufficient monitoring to evaluate conditions.

3.5.1 Description of Monitoring Network (GSP Reg. § 354.34)

The GSP monitoring network is composed of aquifer specific wells that are screened in the Upper or Lower Aquifers. The network will not include composite wells that span both the Upper and Lower Aquifers. The network will enable the collection of data to assess sustainability indicators, the effectiveness of management actions and projects to achieve sustainability and evaluate the measurable objectives of each applicable sustainability indicator (i.e., chronic lowering of groundwater levels, reduction in groundwater storage, degraded water quality, land subsidence). ~~The Subbasin is isolated from the Pacific Ocean; therefore, this GSP does not provide monitoring for seawater intrusion sustainability indicators.~~

For depletion of interconnected surface waters, there is little data to indicate the ephemeral streams in the Subbasin have direct connections to groundwater. ~~The proposed GSP groundwater level monitoring program will address data gaps in Upper Aquifer groundwater levels in the western portions of the Subbasin where the ephemeral streams exist. As discussed in Chapter 2, the Subbasin is located in an area of the San Joaquin Valley where there is an absence of perennial natural streams and rivers. The three minor ephemeral streams that are located in the western area of the Subbasin primarily only flow under local wet conditions. These periods of flow often correspond with periods when WWD does not pump much groundwater from the Upper Aquifer due to the availability of imported surface water supplies. During these periods, flow in the ephemeral streams naturally discharge to the subsurface. During years when pumping from the Upper Aquifer occurs, there is little to no flow in these ephemeral streams to recharge groundwater, therefore, no interconnection is believed to exist.~~ The Subbasin is isolated from the Pacific Ocean; therefore, this GSP does not provide monitoring for seawater intrusion sustainability indicators.

3.5.1.1 Groundwater Elevation Monitoring Network

The District currently has over 1,200 wells that were actively monitored for water level data in 2018. However, for the purposes of the GSP monitoring program, a subset of these wells was identified that represent geographical variation along with a historical data record. (GSP Reg. § 354.36.) This effort resulted in the selection of ~~4122~~ wells in the Upper Aquifer and ~~5544~~ wells in the Lower Aquifer as documented in ~~Table~~Tables 3-13 and 3-14 (the selection process is described further below). The GSA has ~~complete~~ well construction information for these wells, which allows the GSA to determine the aquifer being monitored with certainty. Furthermore, composite wells that span both the Upper and Lower Aquifers were not selected for this GSP monitoring program in order to provide aquifer specific data.

Figures 3-1 illustrates and 3-2 illustrate the wells are distributed throughout the Westside Subbasin providing full coverage of the Subbasin. This coverage allows for the collection of data to evaluate groundwater gradients and flow directions over time and the annual change in storage. Furthermore, the monitoring frequency of the wells will allow for the monitoring of seasonal highs and lows. Because wells were chosen with the existing length of historical data record in mind, future groundwater data will be able to be compared to historical data.

The minimum thresholds and measurable objectives for the chronic lowering of groundwater levels sustainability indicator are evaluated by monitoring groundwater levels. The GSP Regulations require a network of monitoring wells to demonstrate groundwater occurrence, flow direction and hydraulic gradients between principal aquifer and surface water features. (GSP Reg. § 354.32.)

The objectives of the groundwater level monitoring program include the following:

- Improve the understanding of the occurrence and movement of groundwater; monitor local and regional groundwater levels including seasonal and long-term trends; and identify vertical hydraulic head differences in the aquifer system and aquifer-specific groundwater conditions, especially in areas where short-term and long-term development of groundwater resources are planned;
- Detect the occurrence of, and factors attributable to, natural recharge (e.g., direct infiltration of precipitation), irrigation, and surface water seepage to groundwater or recharge projects and management actions (recharge basins, aquifer storage and recovery) that affect groundwater levels and trends;
- Identify appropriate monitoring sites to further evaluate groundwater-surface water interaction, and recharge/discharge mechanisms, including whether groundwater utilization is affecting surface water flows;
- Establish a monitoring network to aid in the assessment of changes in groundwater storage; and
- Generate data to better estimate groundwater basin conditions and assess local current and future water supply availability and reliability; update analyses, including the groundwater model and water budget, as additional data become available.

Figures 3-21 and **3-32** illustrate the locations of the wells selected for monitoring of groundwater levels in the upper and lower aquifers, respectively. **Tables 3-1413** and **3-1514** list the well identification, location, monitoring frequency, well construction data (which includes well depth, perforation intervals, and ground surface elevation (GSE)), and measurement years, and number of measurements for the Upper and Lower Aquifer, respectively.

In order to assist local agencies with the preparation of their GSP's, DWR released a series of best management practices (BMPs). The BMPs document for monitoring networks provides guidance on determining an appropriate number of monitoring wells. The method developed by Hopkins (1984) was applied to the Westside Subbasin. This methodology states that for districts pumping more than 10,000 ac-ft/yr per 100 square miles, they should have four monitoring wells for every 100 square miles. The Westside Subbasin is approximately 927 square miles, yielding 37 monitoring wells minimum. Additional wells were added based on informational needs resulting from management actions and historical trends in groundwater levels.

After computing the appropriate number of monitoring wells for the Subbasin based on the Hopkins method, a hexagonal tessellation was generated over the basin area in ArcPro. All available wells with complete construction data and aquifer assignment were then mapped onto this grid. Wells were

weighted based on their length of record in the following manner: (1) 0-9 years received a weight of 0, (2) 10-19 years of data were weighted 1, 20-29 were weighted 2, (3) 30-39 were weighted 3, (4) 40-49 were weighted 4, and (5) 50-59 were weighted 5, consistent with the Hopkins method.

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Once the wells were plotted against the hexagons, each hexagon (numbered 1 through 37) was examined separately for both the Upper Aquifer and Lower Aquifer. Within a hexagon, wells were selected on both their proximity to the center of the hexagon and the length of record. A minimum length of record weight of two was required for well selection. From the wells with a weight of two or more, the location was examined, and a well was selected. After the initial selection of wells, the resulting network was examined for distribution across the basin. In cases where no well fulfilled the length requirement, the well was chosen solely for its location within the hexagon.

After selecting the first round of wells for each aquifer, the hexagon grid was overlain with a layer representing the areas of concern for subsidence. This layer highlighted data gaps in two specific areas; one in the northern and one in the southern portion of the Subbasin. Additional wells were added to these areas (based on availability) in order to obtain a higher resolution of monitoring in these two regions. The selection rationale for all water level monitoring wells is summarized in [Table 3-16](#) and [Table 3-14](#).

Table 3-16: Summary of Rationale for Selection for Wells Utilizing Groundwater Levels

Site	Aquifer	Basis for Selection
14S/13E-23E02	Upper	well location and number of records
13S/14E-32K01	Upper	GQTM well
14S/15E-20Q01	Upper	well location and number of records
15S/13E-05F04	Upper	GQTM well
15S/13E-22A01	Upper	GQTM well
15S/14E-10A06	Upper	well location and number of records
15S/15E-16K01	Upper	well location and number of records
15S/14E-14R01	Upper	number of records
16S/15E-10M01	Upper	well location
16S/16E-09Q01	Upper	number of records
16S/16E-33G01	Upper	well location and number of records
17S/14E-13A01	Upper	number of records
17S/15E-08G02	Upper	well location and number of records
17S/17E-16C01	Upper	well location and number of records
17S/17E-31N03	Upper	number of records
17S/15E-29D01	Upper	well location and number of records
18S/15E-22B02	Upper	well location
18S/16E-22Q03	Upper	well location and number of records
18S/17E-11Q01	Upper	well location and number of records
18S/18E-05K01	Upper	well location and number of records
18S/18E-28N04	Upper	well location and number of records
18S/19E-20F01	Upper	well location and number of records

Site	Aquifer	Basis for Selection
19S/16E-35N01	Upper	well location and number of records
19S/17E-20B01	Upper	well location and number of records
19S/18E-34N04	Upper	well location and number of records
19S/19E-08N04	Upper	well location and number of records
19S/19E-26D02	Upper	number of records
20S/16E-21R01	Upper	well location and number of records
20S/17E-09N03	Upper	well location and number of records
20S/19E-07G02	Upper	well location
21S/17E-11N01	Upper	well location and number of records
21S/18E-05C01	Upper	well location and number of records
21S/18E-28Q02	Upper	well location and number of records
21S/19E-07H01	Upper	well location
13S/13E-24E02	Lower	well location and number of records
14S/12E-35J01	Lower	well location and number of records
14S/13E-06P02	Lower	number of records
14S/13E-12P01	Lower	well location and number of records
14S/15E-32N02	Lower	well location
15S/12E-13D01	Lower	well location
15S/13E-02P01	Lower	GQTM-well
15S/13E-22P01	Lower	added for subsidence; well location and number of records
15S/14E-19Q01	Lower	added for subsidence; well location and number of records
15S/14E-26N02	Lower	well location and number of records
15S/14E-31N03	Lower	well location and number of records
15S/15E-04A03	Lower	well location
15S/15E-29K01	Lower	well location
16S/14E-03H01	Lower	added for subsidence; well location and number of records
16S/14E-14F01	Lower	added for subsidence; well location and number of records
16S/14E-17A01	Lower	added for subsidence; well location and number of records
16S/14E-36E01	Lower	well location and number of records
16S/15E-16E01	Lower	number of records
16S/15E-32A06	Lower	added for subsidence; well location and number of records
16S/16E-10Q01	Lower	well location and number of records
16S/16E-29E01	Lower	number of records
17S/15E-09N02	Lower	added for subsidence; well location and number of records
17S/15E-23D01	Lower	well location and number of records
18S/16E-04N02	Lower	well location and number of records
17S/17E-09Q01	Lower	well location

Site	Aquifer	Basis for Selection
17S/18E-33H02	Lower	well location
18S/15E-15D01	Lower	well location and number of records
18S/16E-34N02	Lower	well location and number of records
18S/17E-09P01	Lower	well location and number of records
18S/18E-01R02	Lower	well location
19S/17E-28P01	Lower	number of records
20S/18E-04G01	Lower	number of records
19S/18E-04C01	Lower	well location and number of records
19S/19E-29A01	Lower	number of records
20S/19E-02A01	Lower	well location and number of records
20S/19E-17M01	Lower	well location and number of records
20S/18E-35D02	Lower	well location and number of records
21S/18E-22E01	Lower	added for subsidence; well location
21S/18E-35Q02	Lower	well location
21S/19E-20D02	Lower	well location

The GSA will evaluate whether further monitoring wells or refinement to these measurable objectives are needed to monitoring boundary conditions with adjacent basins to ensure subsurface inflow and outflow conditions remain consistent with water budget and model results.

3.5.1.43.5.1.2 Groundwater Storage Monitoring Network

The objective of the monitoring program is to utilize groundwater level data and knowledge of aquifer storage coefficients to calculate changes in groundwater storage. The goal includes the following:

- Improve the understanding of the occurrence and movement of groundwater; monitor local and regional groundwater levels including seasonal and long-term trends in the aquifer system to calculate changes in groundwater storage on an annual basis and in areas where management actions and projects are planned;

Changes in groundwater storage cannot be measured directly, therefore this GSP adopts groundwater levels as a proxy for assessing change in storage, as described previously in Chapter 3. The wells selected for monitoring changes in groundwater storage will be the same wells used for groundwater level monitoring. **Figures 3-21** and **3-32** illustrate the locations of the wells selected for monitoring of groundwater levels for the Upper Aquifer and Lower Aquifer, respectively. **Tables 3-1713** and **3-1814** list the well identification, location, monitoring frequency, well construction data, and measurement years, and number of measurements for the Upper Aquifer and Lower Aquifer wells, respectively. The same wells for water level monitoring are proposed for groundwater storage monitoring and the selection process and rationale for selection is consistent with **Section 3.6 and 3.75.1.1 (Table 3-1913 and 3-14)**.

3.5.1.23.5.1.3 Subsidence Monitoring Network

The sustainability indicator for land subsidence is evaluated by monitoring land surface elevation ~~at a network of~~ from various agencies within the Subbasin. In areas where land surface elevation data are not available, groundwater levels from the Groundwater Elevation Monitoring Network (**Section 3.5.1.1**) are used as a proxy for subsidence monitoring. The monitoring network includes data from various agencies at 46 locations shown in **Figure 3-3**:

- Aquifer system compaction collected continuously by the USGS from three (3) extensometers described in **Section 2.2.8.3.2**;
- Land surface elevation collected annually by the DWR CASP in the winter from ten (10) GPS benchmarks adjacent to the SLC described in **Section 2.2.8.3.3**;
- Land surface displacement collected continuously by UNAVCO from one (1) GPS benchmark as part of the GPS PBO and described in **Section 2.2.8.3.4**;
- Land surface elevation collected bi-annually by USBR in the summer and winter from four (4) GPS benchmarks described in **Section 2.2.8.3.5**;
- Land surface elevation collected bi-annually by the District in the summer and winter from sixteen (16) GPS benchmarks described in **Section 2.2.8.3.6**; and
- Groundwater elevation collected bi-annually by the District in the summer and winter from twelve (12) Lower Aquifer monitoring wells used as a proxy for subsidence measurements described in **Section 3.5.1.1**.

InSAR data collected from Sentinel-1 made available by DWR will also be evaluated periodically where direct measurement of land subsidence or aquifer system compaction is not currently available. InSAR will be used to identify emerging areas of concern within the Subbasin and inform future monitoring.

The objectives and rationale for selection of sites included in the subsidence monitoring network are described in **Table 3-15**:

- Monitor and inform management of areas have previously or are currently experiencing high rates of subsidence. Monitoring density is increased near SLC checks 16, 17 and 20 which showed both high rates of subsidence and substantial impacts on SLC conveyance.
- Ensuring accuracy and reliability of measurements to effectively quantify and managing land surface subsidence. These goals are achieved by incorporating measurements from numerous entities (USGS, USBR, UNAVCO, DWR and WWD).
- The subsidence monitoring network is designed to provide robust information for the GSA to successfully measure and manage ~~subsidence monitoring programs in the Subbasin. The robust monitoring network includes the following~~ impacts along the SLC. Sites were prioritized to provide a sufficient number of sides adjacent to the SLC which measure subsidence or compaction.
- The subsidence monitoring network is designed to provide sufficient spatial coverage to adequately monitor both existing and future areas which are experiencing high rates of subsidence. Sites are selected to provide sufficient horizontal coverage in all areas of the Subbasin

that have the potential for subsidence. Where groundwater levels are used as a proxy, monitoring targets wells completed in the Lower Aquifer where the majority of subsidence is believed to occur.

- The frequency of data collection programs should provide sufficient information to quantify inelastic subsidence. Selected sites include measurements taken in the winter or spring. To better disaggregate inelastic subsidence from elastic subsidence, all sites include winter or spring measurements. Since historical subsidence may also play a role in future management, sites with a long period of record were also prioritized.
- The DWR collects subsidence data from 98 GPS survey locations, of which a subset will be utilized for GSP monitoring purposes to augment extensometer and groundwater level monitoring identified in **Tables 3-20 and 3-21**;
- USBR and DWR collects subsidence data from field GPS locations along the SLC; and
- The USGS collects subsidence data from 12 extensometer locations in the region, three of which are located in the Subbasin.
- UNAVCO collects continuous GSP subsidence data from 3 GPS subsidence stations in the Subbasin. In addition, satellite imagery used to estimate subsidence over large areas is collected and processed by the USGS. However, this spatial subsidence data does not encompass the entire Subbasin and covers short periods of time.

For GSP subsidence monitoring purposes, DWR GPS survey benchmark locations, the three extensometers located within the Subbasin, GPS monitoring by Reclamation and DWR along the SLC, and groundwater level data from will be used for monitoring subsidence in the Subbasin. The extensometers and wells for land subsidence level monitoring and the selection process and rationale for selection are presented in **Table 3-20 and Table 3-21**.

In order to make progress towards achieving Measurable Objectives defined in Section 3.2.3.1 and implement projects and management to avoid Undesirable Results defined in Section 3.4.1.1, measurements from the monitoring network will be evaluated annually.

3.5.1.33.5.1.4 Groundwater Quality Monitoring Network

The sustainability indicator for degraded water quality is evaluated by monitoring groundwater quality at a network of existing supply wells.

The objectives of the groundwater quality monitoring program for the Subbasin include the following:

- Evaluate groundwater quality conditions in the various areas of the basin, and identify differences in water quality spatially between areas and vertically in the aquifer system;
- Detect the occurrence of and factors attributable to natural (e.g., general minerals and trace metals) constituents of concern as represented by ~~total dissolved solids (TDS);~~ TDS;
- Assess the changes and trends in groundwater quality (seasonal, short- and long-term trends); and
- Identify the natural and human factors that affect changes in water quality.

Figures 3-56 and **3-67** illustrate the locations of the wells selected for monitoring of groundwater quality in the Upper and Lower Aquifers, respectively. The methodology to determine the minimum thresholds and measurable objectives is described in **Section 3.3.54.1**. **Tables 3-2216** and **3-2317** list the well identification, location, monitoring frequency, well construction data, and measurement years, and number of measurements for the upper and lower aquifer, respectively.

As indicated by the number of water level monitoring wells utilized for the groundwater quality monitoring network, data collection for groundwater quality has been limited in recent years in the Subbasin. ~~The monitoring networks designated for the Upper and Lower Aquifers are designed to address this data gap. Similar to the approach for groundwater level monitoring above, monitoring wells were distributed across the Subbasin using the Hopkins method to provide thorough coverage.~~ Although spatial and temporal data gaps exist in groundwater quality data, this network will allow for a comprehensive mapping of TDS trends. Data collection in both spring and fall will allow for the analysis of seasonal trends. ~~Furthermore~~ Further, continuous monitoring at the sites selected will establish a temporal record moving forward and assist in evaluating management actions implemented moving forward. The distribution of wells ~~across the Subbasin will not only help delineate spatial differences in TDS concentration but~~ will also highlight areas in need of management actions in the future. Subsequent updating of the groundwater quality constituents will be developed in future GSP updates based on annual evaluation of TDS concentrations.

The first step involved in constructing the water quality monitoring network and well selection was to map all wells with available TDS data onto the hexagonal tessellation grid for the Subbasin by aquifer. Wells were then examined for their number of records, years with data, and location within each hexagon. In the Upper Aquifer, most of the wells only had one to two data points dating back to the mid-1990s. In addition to wells with TDS data, wells selected for the regional Groundwater Quality Trend Monitoring program (GQTM) classified as being in the Upper Aquifer also were considered. ~~One of these wells was incorporated into the GSP monitoring program. However, due to lack of groundwater quality data, most of the wells selected for the GSP monitoring program for the Upper Aquifer are the same as the wells being utilized for groundwater level monitoring. In contrast, the Lower Aquifer provided a larger selection of wells with TDS data.~~

~~In contrast, Data within each hexagon was analyzed for TDS concentrations over time. Hexagons were evaluated for the number of exceedances above 1,000 mg/L. Based on this analysis, all hexagons in the Upper and Lower Aquifer provided a larger selection of aquifers with two or more exceedances were excluded from the monitoring network. The rationale behind this exclusion relates to pre-existing elevated TDS concentrations due to marine sediments. The objective of this monitoring program is to monitor water quality degradation caused by human activities and therefore, these hexagons with high TDS concentrations were not included in the monitoring program. Data in the remaining hexagons was reviewed to ensure that each hexagon had at least two wells with TDS data. For all hexagons data points. Any hexagons without two wells with measurements were classified as areas with data gaps and excluded. This analysis resulted in two monitoring wells being selected in the Upper Aquifer, and four wells in the Lower Aquifer.~~

~~Wells available for monitoring within the hexagons were analyzed for historical records and well location and selected based on these criteria. In cases where wells with substantial TDS data was available, wells were chosen based on the criteria described above. Any spatial gaps were then supplemented with wells used for water quality data were unavailable, groundwater level monitoring- wells were selected.~~ The

selection rationale for groundwater quality monitoring wells is summarized in [TableTables 3-24-16 and 3-17](#). Each site will comply with the data and reporting standards that are described in [Section 3.85.2.4](#).

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~~3.5.1.4~~ 3.5.1.5 Interconnected Surface Water Monitoring Network

Not currently applicable; however, the GSA will continue to evaluate whether interconnected surface water exists within the Subbasin based, in part, on data available from wells screened in the Shallow Zone. If appropriate, the GSA will develop a monitoring network and sustainability indicators for interconnected surface waters in a subsequent update to this GSP.

3.5.2 Description of Monitoring Protocols (GSP Reg. § 354.34)

~~3.5.3~~ Protocols for Monitoring Sites

The monitoring protocols that will be used by the GSA as part of implementing this Groundwater Sustainability Plan are largely based on the *Best Management Practices for the Sustainable Management of Groundwater: Monitoring Protocols, Standards, and Sites* produced by the DWR. The recommended monitoring protocols were adjusted and added to fit the specific monitoring needs of the Subbasin to achieve sustainability. Monitoring protocols for seawater intrusion were not necessary as the Subbasin is not connected to the coast. ~~Monitoring protocols for measuring groundwater pumping amounts also are included.~~ Monitoring protocols regarding groundwater pumping were not described in the BMP document and accounting for groundwater pumping will be an integral part of achieving sustainability in Subbasin. The monitoring protocols that are described in this document will provide the necessary data to track the minimum thresholds and measurable objectives for each of the sustainability indicators. The monitoring protocols established herein will be reviewed every five years as a part of periodic GSP updates. The following protocols will be applied to all monitoring sites:

- A unique identifier that includes a written description of the site location, date established, access instructions, type(s) of data to be collected, latitude, longitude, and elevation.
- A modification log is to be kept in order to track all modifications to the monitoring site.
- Geographic locations shall be reported in GSP coordinates to a minimum accuracy of 30 feet or relative to NAD83.
- Reference point elevations shall be measured in feet to an accuracy of at least 0.5 feet relative to NAVD88

~~3.5.3.1~~ 3.5.2.1 Groundwater Level Elevation

~~3.5.3.2~~ Protocols for measuring groundwater levels

~~Protocols for measuring groundwater levels~~ including the following:

- Measure depth to water in the well using procedures appropriate for the measuring device. Equipment must be operated and maintained in accordance with manufacturer's instructions. Groundwater levels should be measured to the nearest 0.1 foot relative to the Reference Point (RP).
- For measuring wells that are under pressure, allow a period of time for the groundwater levels to stabilize. In these cases, multiple measurements should be collected to ensure the well reached equilibrium such that no significant changes in water level are observed. Every effort should be

made to ensure that a representative stable depth to groundwater is recorded. If a well does not stabilize, the quality of the value should be appropriately qualified as a questionable measurement.

- The groundwater elevation should be calculated using the following equation.

$$\text{GWE} = \text{RPE} - \text{DTW}$$

Where: GWE is the groundwater elevation in NAVD88 datum

RPE = Reference Point (RP) is the reference point elevation in NAVD88 datum

DTW is the depth to water

- ~~The measurements of depth to water should be consistent in units of feet, to an accuracy of tenths of feet or hundredths of feet.~~
- The well caps or plugs should be secured following depth to water measurement.
- Groundwater level measurements are to be made on a semi-annual basis at a minimum during periods which will capture seasonal highs and lows.

~~3.5.3.2.13.5.2.1.1~~ Recording Groundwater Level Measurements

- The sampler should record the well identifier, date, time (24-hour format), RPE, height of RP above or below ground surface, DTW, GWE, and comments regarding any factors that may influence the depth to water readings such as weather, nearby irrigation, flooding, potential for tidal influence, or well condition. If there is a questionable measurement or the measurement cannot be obtained, it should be noted. Standardized field forms should be used for all data collection.
- All data should be entered into the GSA data management system (DMS) as soon as possible. Care should be taken to avoid data entry mistakes and the entries should be checked by ~~a second person, the QA/QC Officer.~~

~~3.5.3.2.23.5.2.1.2~~ Installing Pressure Transducers and Downloading Data

The following procedures will be followed in the installation of a pressure transducer and periodic data downloads:

- The sampler must use an electronic sounder or chalked steel tape and follow the protocols listed above to measure the groundwater level and calculate the groundwater elevation in the monitoring well to properly program and reference the installation. It is recommended that transducers record measured groundwater level to conserve data capacity; groundwater elevations can be calculated at a later time after downloading.
- The sampler must note the well identifier, the associated transducer serial number, transducer range, transducer accuracy, and cable serial number.
- Transducers must be able to record groundwater levels with an accuracy of at least 0.1 foot. Professional judgment will be exercised to ensure that the data being collected is meeting the Data Quality Objectives (DQO) and that the instrument is capable. Consideration of the battery life, data storage capacity, range of groundwater level fluctuations, and natural pressure drift of the transducers should be included in the evaluation.

- The sampler must note whether the pressure transducer uses a vented or non-vented cable for barometric compensation. Vented cables are preferred, but non-vented units provide accurate data if properly corrected for natural barometric pressure changes. This requires the consistent logging of barometric pressures to coincide with measurement intervals.
- Follow manufacturer specifications for installation, calibration, data logging intervals, battery life, correction procedure (if non-vented cables used), and anticipated life expectancy to assure that DQOs are being met for the GSP.
- Secure the cable to the well head with a well dock or another reliable method. Mark the cable at the elevation of the reference point with tape or an indelible marker. This will allow estimates of future cable slippage.
- The transducer data should periodically be checked against hand measured groundwater levels to monitor electronic drift or cable movement. This should happen during routine site visits, at least annually to maintain data integrity.
- The data should be downloaded as necessary to ensure no data is lost and entered into the basin's DMS following the quality assurance/quality control (QA/QC) program established for the GSP. Data collected with non-vented data logger cables should be corrected for atmospheric barometric pressure changes, as appropriate. After the sampler is confident that the transducer data have been safely downloaded and stored, the data should be deleted from the data logger to ensure that adequate data logger memory remains.

~~3.5.3.33~~ 3.5.2.2 Groundwater Storage Measurements

The monitoring protocols for evaluating change in groundwater storage are the same as the protocols described above for groundwater levels.

3.5.2.3 Subsidence Measurements

Monitoring sites included in the subsidence monitoring network are managed by multiple entities. Additional information regarding monitoring sites is described in **Section 2.2.8.3**.

- Aquifer system compaction is measured continuously (daily) from three (3) extensometers in the Subbasin by the USGS. Compaction data are published continuously to the USGS NWIS webpage (<https://waterdata.usgs.gov/ca/nwis/>). Compaction measurements will be downloaded and used to estimate compaction annually. Protocols and measurement error for data collected by the USGS are published on the NWIS webpage (USGS, 2022).
- Vertical displacement is acquired from one (1) high-precision continuous GPS PBO site operated by UNAVCO. Daily measurements of vertical displacement are published to the UNAVCO website (<https://www.unavco.org/data/gps-gnss/gps-gnss.html>). Daily measurements will be downloaded annually and filtered using a 10-day moving average to estimate subsidence.
- Land surface elevation is acquired from ten (10) benchmarks along the SLC by GPS in January and February and are supplied annually to the GSA from the DWR CASP office through an informal agreement. Land surface elevation provided in NGVD29 will be used to calculate vertical displacement (subsidence) annually. Specific data collection protocols and quantification of measurement error are not currently available from the CASP.

- Land surface elevation is acquired by GPS by USBR from four (4) benchmarks bi-annually in July and December. Land surface elevation data are published to the SJRRP subsidence monitoring webpage following QA/QC (<https://www.restoresjr.net/science/subsidence-monitoring/>). Land surface elevation provided in NAVD88 will be used to calculate vertical displacement (subsidence) annually. Protocols and measurement error for data collected by USBR are published on the SJRRP webpage (USBR, 2011).
- Land surface elevation is acquired by GPS from the District's consultant for WWD from sixteen (16) benchmarks bi-annually in October and March. Land surface elevation provided to the GSA in NAVD88 will be used to calculate vertical displacement (subsidence) annually. GPS measurements are tied to Continuously Operating Reference Stations (CORS) to calculate precise location information (Blair, Church & Flynn, 2021).
- Groundwater level data collected as part of the subsidence monitoring program will follow protocols for groundwater level monitoring described in **Section 3.5.2.1**.

3.5.3.43.5.2.4 Groundwater Quality Measurements

Annual monitoring of groundwater quality will include sampling and laboratory analysis of TDS. Additional constituents will be considered in the future as additional information becomes available. Additional information will be made available through the Groundwater Quality Trend Monitoring program. These wells will also be sampled for nitrate as nitrogen (as N) on a bi-annual basis. Furthermore, during the first sampling event, these wells will also be tested for major anions (carbonate, bicarbonate, chloride, sulfate) and major cations (boron, calcium, sodium, magnesium, potassium). Following the first sampling event, these anions and cations will be tested for every five years. During sampling events, measurement of select water quality parameters will take place in the field. These field parameters should be measured at an annual frequency and include electrical conductivity at 25 °C (EC) in $\mu\text{S}/\text{cm}$, pH, temperature (in °C), and dissolved oxygen (DO) in mg/L. The annual testing is summarized in **Table 3-25-18**.

The GSP monitoring program will utilize the following protocols for collecting groundwater quality samples:

- Prior to sampling, the analytical laboratory will be contacted to schedule laboratory time, obtain appropriate sample containers, and clarify any sample holding times or sample preservation requirements.
- Each well used for groundwater quality monitoring will have a unique identifier. This identifier will appear on the well housing or the well casing to verify well identification.
- In the case of wells with dedicated pumps, samples should be collected at or near the wellhead following purging.
- Prior to sampling, the sampling port and sampling equipment will be cleaned of any contaminants. The equipment will be decontaminated between each sampling locations or wells to avoid cross-contamination.
- The groundwater elevation in the well should be measured following appropriate protocols described above in the groundwater level measuring protocols.

- For any well not equipped with low-flow or passive sampling equipment, an adequate volume of water should be purged from the well to ensure that the groundwater sample is representative of ambient groundwater and not stagnant water in the well casing. Purging three well casing volumes is generally considered adequate. Professional judgment should be used to determine the proper configuration of the sampling equipment with respect to well construction such that a representative ambient groundwater sample is collected. If pumping causes a well to be evacuated (go dry), document the condition and allow well to recover to within 90% of original level prior to sampling.
- Field parameters of pH, electrical conductivity and temperature should be collected during purging and prior to the collection of each sample. Field parameters should be evaluated during the purging of the well and should stabilize prior to sampling. Measurements of pH should only be measured in the field; lab pH analysis are typically unachievable due to short hold times. Other parameters, such as Oxidation-Reduction Potential (ORP), Dissolved Oxygen (DO) (in situ measurements preferable), or turbidity, may also be useful for assessing purge conditions. All field instruments will be calibrated daily and evaluated for drift throughout the day.
- Sample containers should be labeled prior to sample collection. The sample label must include sample ID (often well ID), sample date and time, sample personnel, sample location, preservative used, and analytes and analytical method.
- Samples should be collected under laminar flow conditions. This may require reducing pumping rates prior to sample collection.
- All samples requiring preservation must be preserved as soon as practically possible, ideally at the time of sample collection. Ensure that samples are appropriately filtered as recommended for the specific analyte. Entrained solids can be dissolved by preservative leading to inconsistent results of dissolve analytes. Specifically, samples to be analyzed for metals should be field filtered prior to preservation; do not collect an unfiltered sample in a preserved container.
- Samples should be chilled and maintained at 4 °C to prevent degradation of the sample. The laboratory's Quality Assurance Management Plan should detail appropriate chilling and shipping requirements.
- Samples must be shipped under chain of custody documentation to the appropriate laboratory promptly to avoid violating holding time restrictions.
- Groundwater quality samples shall be collected annually.
- All data will be entered into the GSA data management system (DMS) as soon as possible. Data entries should be checked by a second person to avoid incorrect data.

3.5.3.5.2.5 Groundwater Pumping Measurements

Measurements of groundwater extractions are conducted in the Subbasin in the vast majority of wells. Measurement devices utilized by the GSA consist of totalizer meters that record extractions. The few remaining active wells will be fitted with meters within the GSP implementation period. The meters will be periodically checked for accuracy utilizing manufacturers recommendations. If necessary, meters will be periodically calibrated according to manufacturer specifications. The meters will be read on a quarterly basis and the data collected will be recorded in gallons and converted to acre feet.

~~3.5.4 Subsidence Measurements~~

~~Subsidence monitoring for WWD will include the following protocols:~~

- ~~• Download and review subsidence data collected by the USGS at the operational extensometers, the DWR monitoring of subsidence along the SLC, and the UNAVCO PBO stations located within the Subbasin. Downloaded data will be stored in the DMS following QA/QC.~~
- ~~• Subsidence data will be downloaded when available from the various agencies and uploaded to the GSA's DMS.~~
- ~~• Groundwater level data collected as part of the subsidence monitoring program will follow the same protocols as described above for groundwater level monitoring.~~

~~3.5.4.13.5.2.6~~ Interconnected Surface Water Measurements

No monitoring protocols are included since this sustainability indicator is not present in the Subbasin. However, as noted, the GSA will develop monitoring protocols for interconnected surface waters if areas are identified within the Subbasin.

~~3.5.53.5.3~~ Representative Monitoring (GSP Reg. § 354.36)

Representative Monitoring Sites (RMS) are defined in the GSP Regulations as a subset of monitoring sites that are representative of conditions in the Subbasin. All the monitoring sites in this section are considered RMS utilizing methods of selection consistent with best management practices described above under the groundwater level protocols. Groundwater level monitoring will be used to determine changes in groundwater storage and to assist in monitoring subsidence near existing subsidence monitoring locations. As previously stated in Chapter 3, reduction in groundwater storage cannot be directly measured. However, groundwater level data will be used in conjunction with aquifer parameters and the groundwater model to compute changes in groundwater storage Subbasin wide. In the case of subsidence, ~~there are several stations~~ representative monitoring for compaction throughout using the Subbasin. ~~However, the GSA highlighted areas that are highly susceptible to subsidence. In these areas, water approach used for selecting groundwater level monitoring wells are being utilized to supplement subsidence sites is conducted. In areas experiencing high rates of subsidence or co-located with critical infrastructure, more detailed monitoring stations. Changes in water levels can be used as an early detection method for compaction. is implemented.~~

~~3.5.63.5.4~~ Assessment and Improvement of Monitoring Network (GSP Reg. § 354.38)

The GSA does not anticipate that the data gaps will impact the Subbasin's ability to achieve sustainability and is committed to fill in data gaps as described in **Section 3.8.9.7.5.4.3.**

As described in section 354.38 of the GSP Regulations, each agency is required to analyze the monitoring network for improvements as follows:

- Each GSA shall review the monitoring network and include an evaluation in the Plan and each five-year assessment, including a determination of uncertainty and whether there are data gaps that could affect the ability of the Plan to achieve the sustainability goal for the basin.
- Each GSA shall identify data gaps wherever the basin does not contain enough monitoring sites, does not monitor sites at a sufficient frequency, or utilizes monitoring sites that are unreliable, including those that do not satisfy minimum standards of the monitoring network adopted by the GSA.
- If the monitoring network contains data gaps, the Plan shall include a description of the following:
 - The location and reason for data gaps in the monitoring network
 - Local issues and circumstances that limit or prevent monitoring
- Each GSA shall describe steps that will be taken to fill data gaps before the next five-year assessment, including the location and purpose of newly added or installed monitoring sites.
- Each GSA shall adjust the monitoring frequency and distribution of monitoring sites to provide an adequate level of detail about site-specific surface water and groundwater conditions and to assess the effectiveness of management actions under circumstances that include the following:
 - Minimum threshold exceedances
 - Highly variable spatial or temporal conditions
 - Adverse impacts to beneficial uses and users of groundwater
 - The potential to adversely affect the ability of an adjacent basin to implement its Plan or impede achievement of sustainability goals in an adjacent basin

3.5.6.13.5.4.1 Review and Evaluation of the Monitoring Network

The monitoring networks described above for each of the applicable sustainability indicators will be evaluated on a yearly basis. This evaluation will involve a review of the described minimum thresholds and measurable objectives and their comparison to observed trends in the networks. Furthermore, a more comprehensive review of the monitoring networks will be conducted every five years as part of the GSP update. During this review, management actions and projects will be evaluated, and the monitoring networks will be assessed for their efficacy in tracking progress based on the actions and projects. These evaluations and assessments also will highlight any additional data gaps and recommended changes to the monitoring networks.

3.5.6.23.5.4.2 Identification and Description of Data Gaps

Identification and description of data gaps for the monitoring networks ~~described above~~ for each of the applicable sustainability indicators are described below.

3.5.6.2.13.5.4.2.1 Groundwater Elevation

3.5.4.2.2 Groundwater Storage

3.5.4.2.3 Subsidence

The subsidence monitoring network provides robust spatial coverage and sufficient frequency to measure vertical displacement, compaction and groundwater levels. The primary data gap results from locations where subsidence is quantified indirectly through measurement of groundwater levels as a proxy. These sites fall generally along the western boundary of the Subbasin and east of the Huron where the Corcoran clay is not present.

Portions of the Upper Aquifer may be susceptible to significant compaction depending on local conditions as described in Section 2.2.8.4.4. Local geology, groundwater conditions and compaction in the Upper Aquifer may require further monitoring and study in portions of the Subbasin prior to the GSA considering a substantial shift in the vertical distribution of pumping from the Lower Aquifer to the Upper Aquifer as part of an aquifer-specific allocation contemplated as part of the PMA for the Groundwater Allocation Program. (See Section 4.2.1.2.)

3.5.6.2-23.5.4.2.4 Groundwater Quality

Groundwater quality data had the most pronounced data gaps of all the assessed sustainability indicators and these gaps spanned both spatial and temporal spectrums. Historical data related to TDS was sparse and not continuously collected for a long period of time at any monitoring wells. Most data collected was part of stand-alone programs. The Upper Aquifer wells exhibited higher levels of data gaps than the Lower Aquifer wells. This fact is reflected in the wells selected for the monitoring network. During analysis of the TDS data, 12 hexagons in the Upper Aquifer were found to have insufficient data to determine if they met the criteria for water quality monitoring.

The Upper Aquifer utilizes mainly water level monitoring wells whereas the Lower Aquifer contains more wells with historical TDS data. Due to the lack of historical data, measurable objectives, minimum thresholds, and interim milestones were difficult to set based on a 2015 baseline date. These data gaps will be addressed by the GSA early in the Implementation Period and will influence how the groundwater quality monitoring program will evolve over time between 2020 and 2040.

3.5.6.3 Groundwater Storage

Groundwater storage data gaps are described in the groundwater elevation section as water levels are being used as a proxy for groundwater storage.

3.5.6.4 Subsidence

The GSA highlighted two specific areas within the Subbasin that are highly susceptible to subsidence. In addition, the area along the SLC has experienced subsidence. Subsidence along the SLC is monitored by numerous stations and no data gaps are currently evident in this area. The two independent regions identified by the GSA were considered when designing the subsidence monitoring program. Although no extensometers were present in these areas, additional water level monitoring wells were selected to provide extensive coverage. No data gaps are presently evident in the Subbasin for subsidence monitoring; however, the network will be reevaluated on a yearly basis for any emerging data gaps.

~~3.5.6.53.5.4.3~~ Description of Steps to Remedy Data Gaps

Data gaps have been presented in the groundwater elevation, groundwater quality, and groundwater storage monitoring networks. The GSA will take the following steps, prior to the first five-year GSP update in 2025 to address these data gaps:

- The GSA installed five new aquifer-specific nested monitoring wells within the Subbasin in areas where data gaps historically existed. These new wells will address the data gaps described in the Upper and Lower Aquifers for groundwater elevation data (**Figure 3-713**). Furthermore, these new wells will also be added to the groundwater quality monitoring networks in both aquifers to fill spatial coverage gaps. Also represented in this figure are the proposed locations for additional shallow zone monitoring wells. For the purposes of identifying interconnected surface waters and groundwater dependent ecosystems, these shallow wells will be screened in the upper 40 feet. In an effort to fill this data gap, the GSA applied for the DWR Technical Support Services program in January 2021 to drill wells to acquire data and is coordinating with DWR to drill the shallow wells in late 2023/early 2024.
- The GSA will install sampling ~~taps~~ spickets on groundwater level wells designated for groundwater quality monitoring. These wells will then be sampled simultaneously for groundwater elevation data and groundwater quality data.
- Sampling events will be coordinated with well owners to prevent pumping and access issues.
- The GSA will evaluate conditions in the twelve (12) hexagons with insufficient water quality information in the Upper Aquifer. Groundwater conditions will be investigated to determine if areas identified as data gaps contain usable groundwater (i.e., are saturated above the Corcoran clay). The GSA will also evaluate data collected from the ILRP GQTM network to determine if that data can help bridge this data gap. Where appropriate, the GSA will conduct sampling to determine if any of these hexagons require management or further monitoring as part of the GSP monitoring network.
- Although no monitoring network is currently in place for interconnected surface water (ISW), due to the fact the streams in the Subbasin are ephemeral, the GSA will look at the data gaps brought forth in the GDE assessment and reevaluate this indicator in the future. If present, the GSA will establish a monitoring network to address the ISW data gap and incorporate depletion of interconnected surface water as an undesirable result, including establishing minimum thresholds and measurable objectives, in subsequent updates to the GSP.
- The GSA also will continue to evaluate whether groundwater conditions in adjacent basins may affect Westside Subbasin subsurface inflows and outflows and supplement the monitoring network in these areas to ensure changes are monitored and, as needed, address concerns about groundwater management in neighboring basins.
- The GSA installed ten (10) additional GPS benchmarks in 2022 to monitor land surface elevation and subsidence. This total twenty-five (25) benchmarks throughout the Subbasin. New GPS benchmarks were installed in portions of the Subbasin where the exiting monitoring network is reliant on measurement groundwater levels as a proxy for subsidence. The additional sites are co-located with multi-completion wells installed by WWD and/or target areas where interferograms

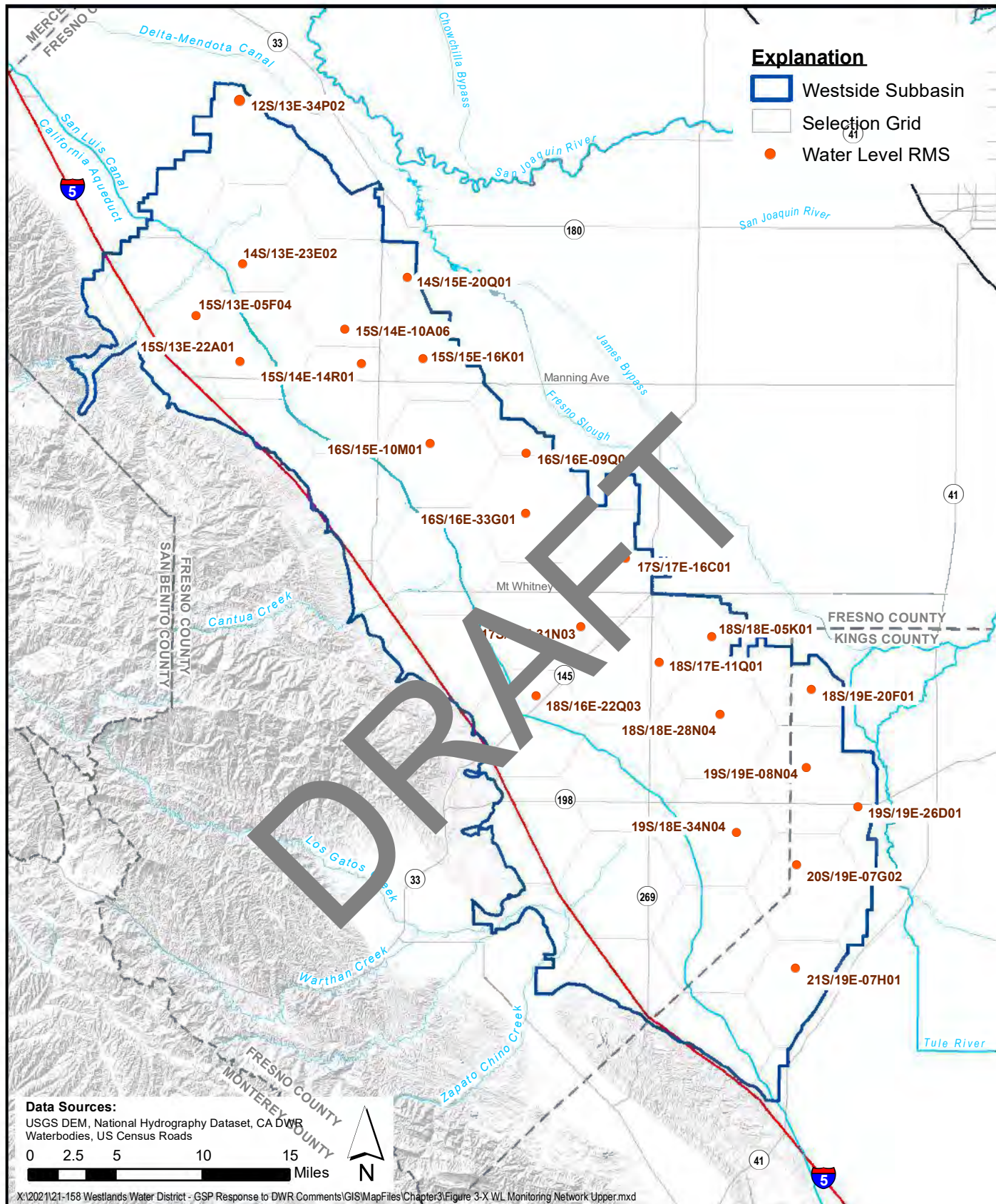
provided by DWR indicate high rates of subsidence. The monitoring network will be revised to include new benchmarks prior to the 2025 GSP update.

- The GSA will evaluate the susceptibility of the Upper Aquifer to compaction in areas where groundwater pumping in the Upper Aquifer is promoted during PMA implementation. Local geologic conditions will be evaluated through review of textural and electric resistivity logs to identify compressible geologic materials. This analysis will be coupled with review of available groundwater level, subsidence, InSAR or compaction data. Any additional data gaps will be identified and remedied through supplemental data collection and monitoring as appropriate.

In addition to these steps, the monitoring networks will be evaluated on a yearly and five-year basis. If additional data gaps arise, the GSA will consider the implications of these gaps, associated costs, and importance to the continued implementation of the GSP and take appropriate actions to address the gaps.

~~3.5.6~~3.5.4.4 Description of Monitoring Frequency and Density of Sites

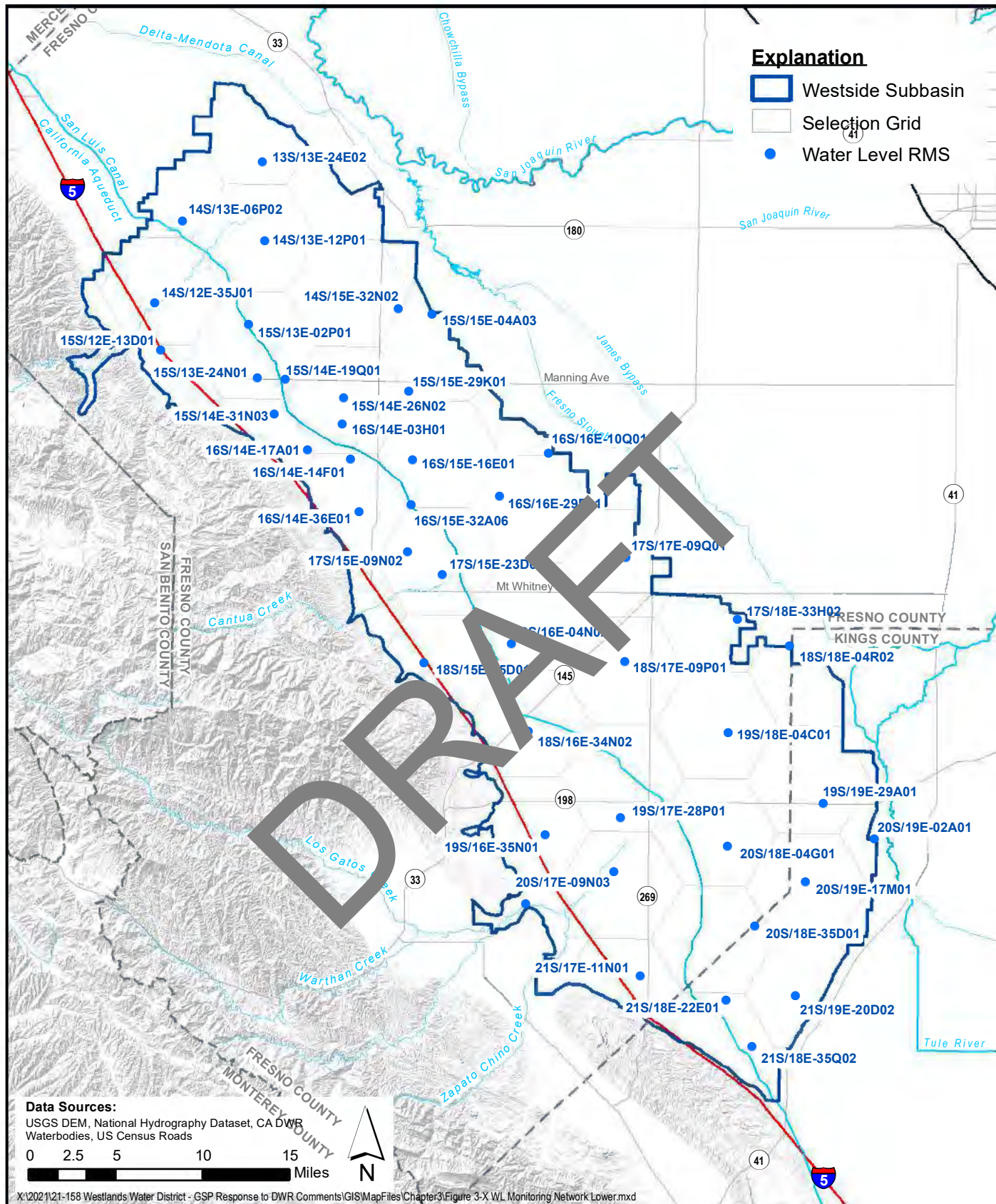
Monitoring frequency and density of sites for all sustainability indicators are described in previous sections in Chapter 3 of this report.



Representative Monitoring Sites for Groundwater Levels (Upper Aquifer)

SGMA Sustainability Analyses
 Westside Subbasin

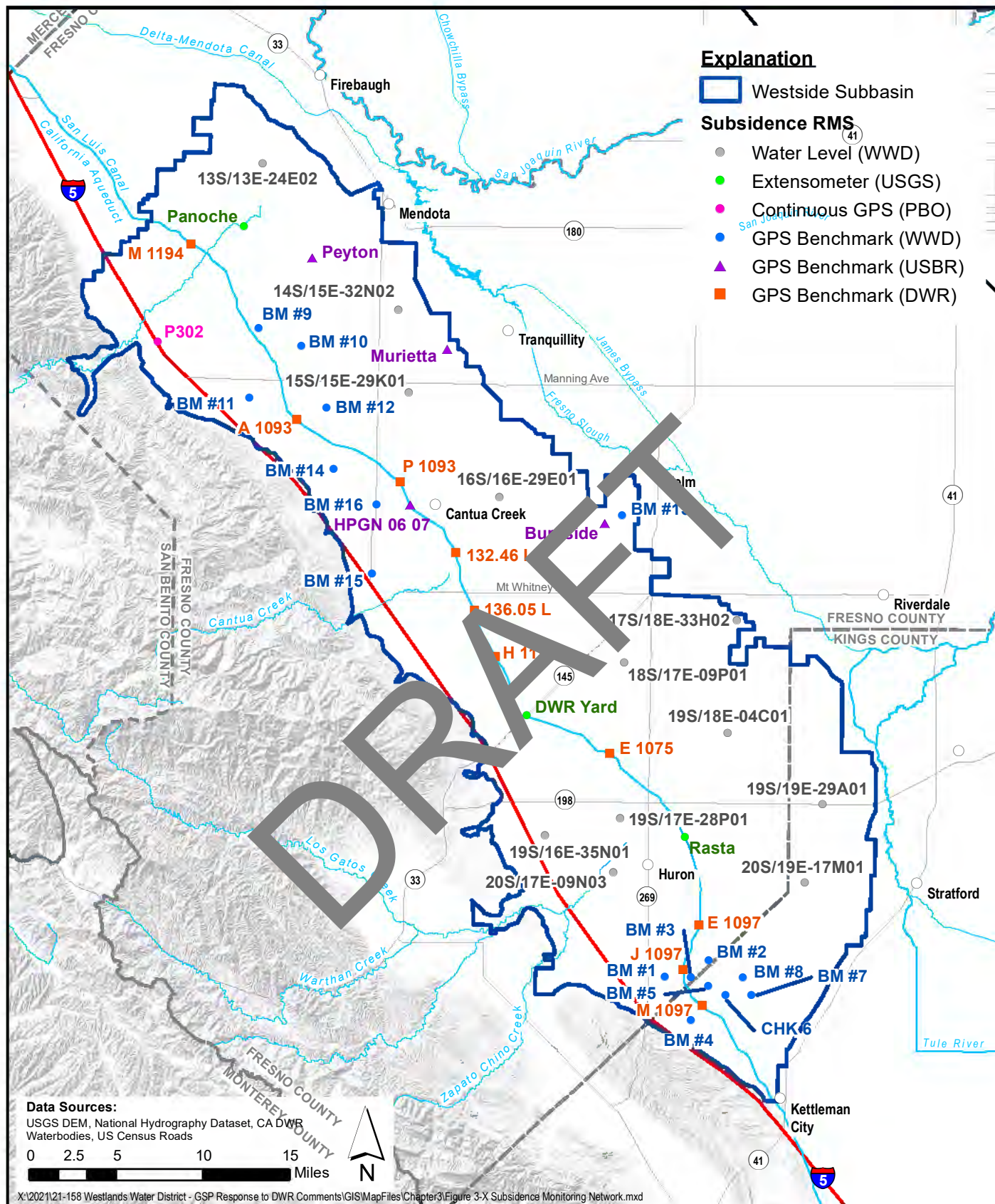
Figure 3-1



Representative Monitoring Sites for Groundwater Levels (Lower Aquifer)

SGMA Sustainability Analyses
Westside Subbasin

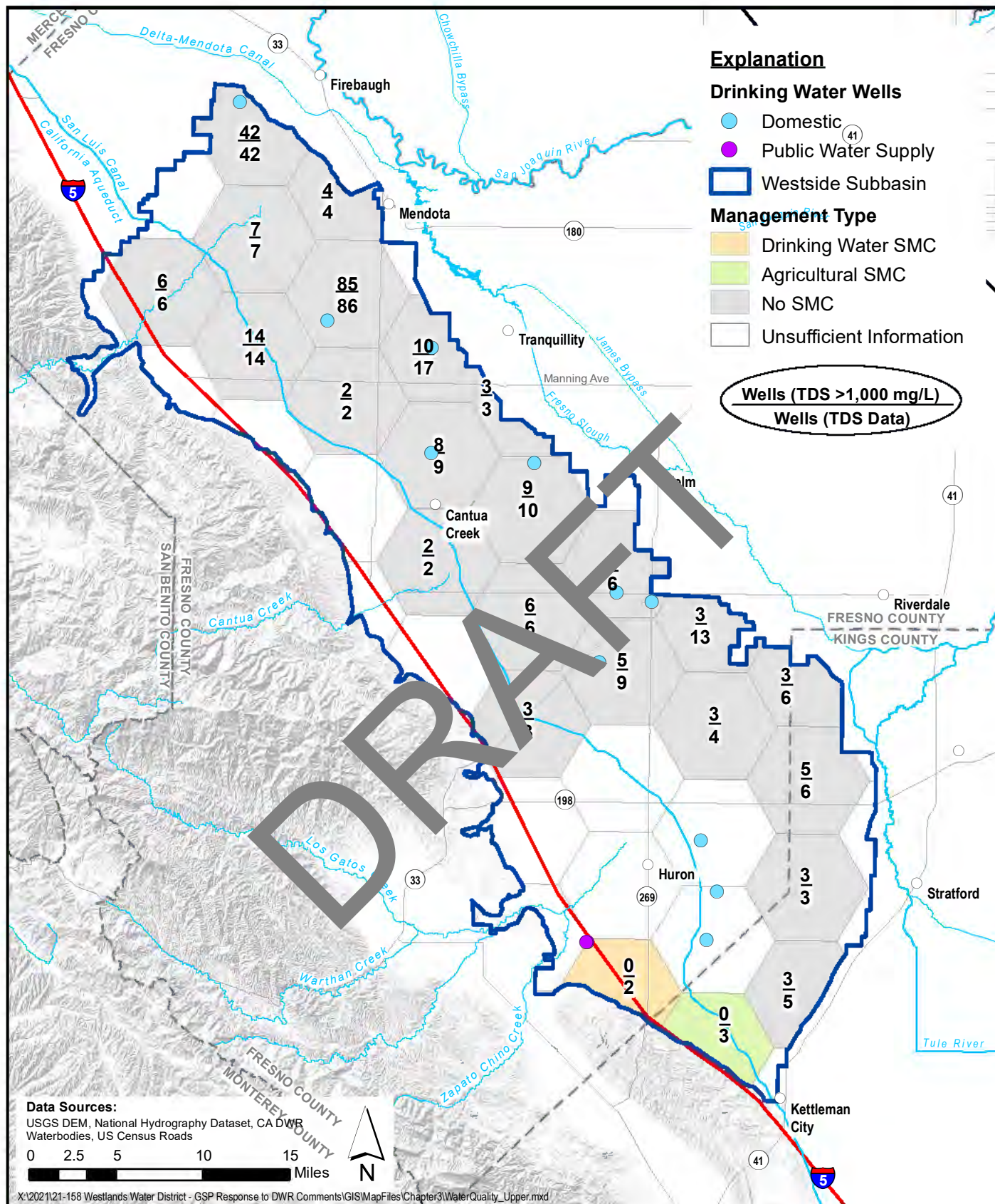
Figure 3-2



Representative Monitoring Sites for Land Surface Subsidence

SGMA Sustainability Analyses
Westside Subbasin

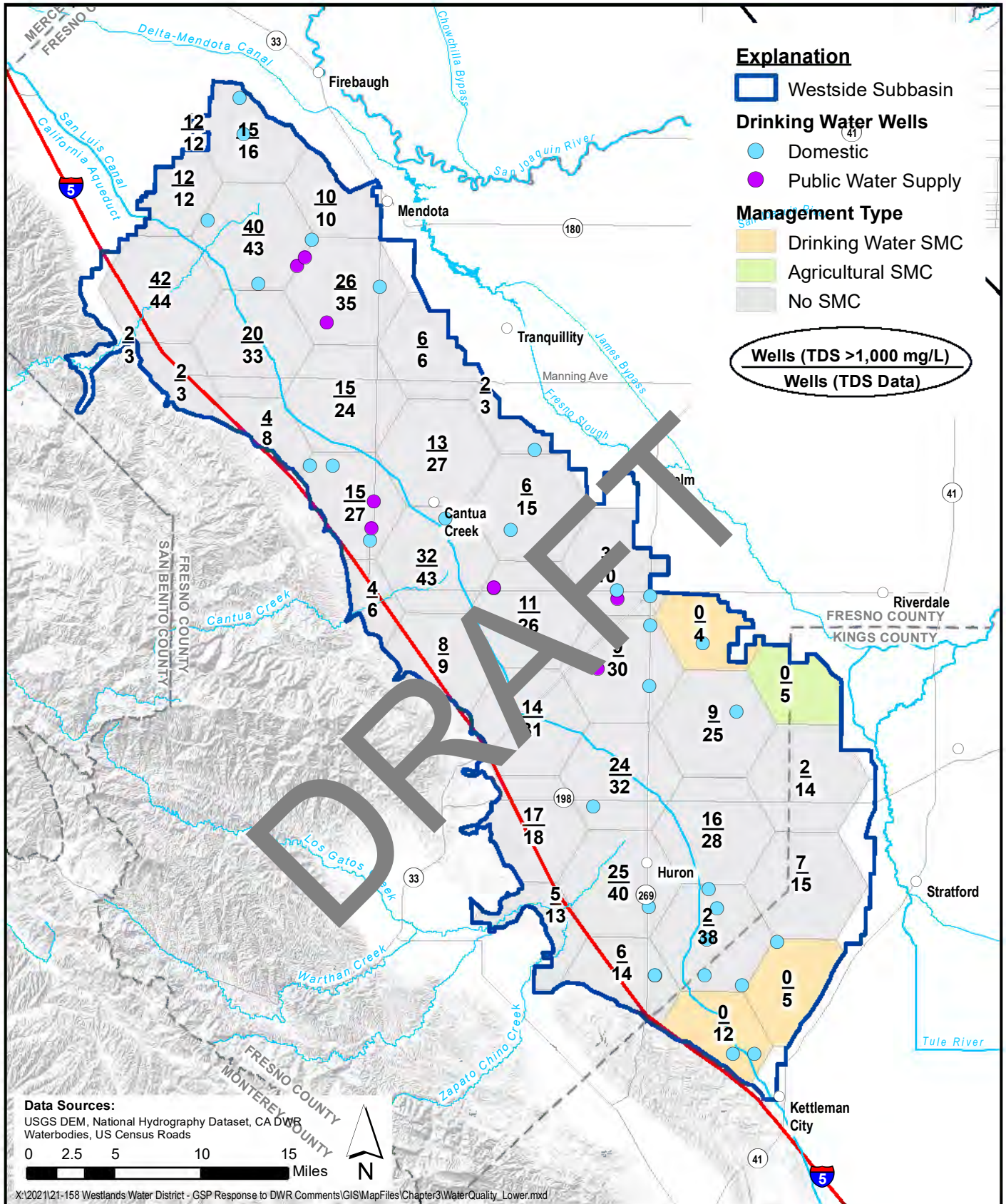
Figure 3-3



Summary of Measured TDS in Groundwater Wells (Upper Aquifer)

SGMA Sustainability Analyses
Westside Subbasin

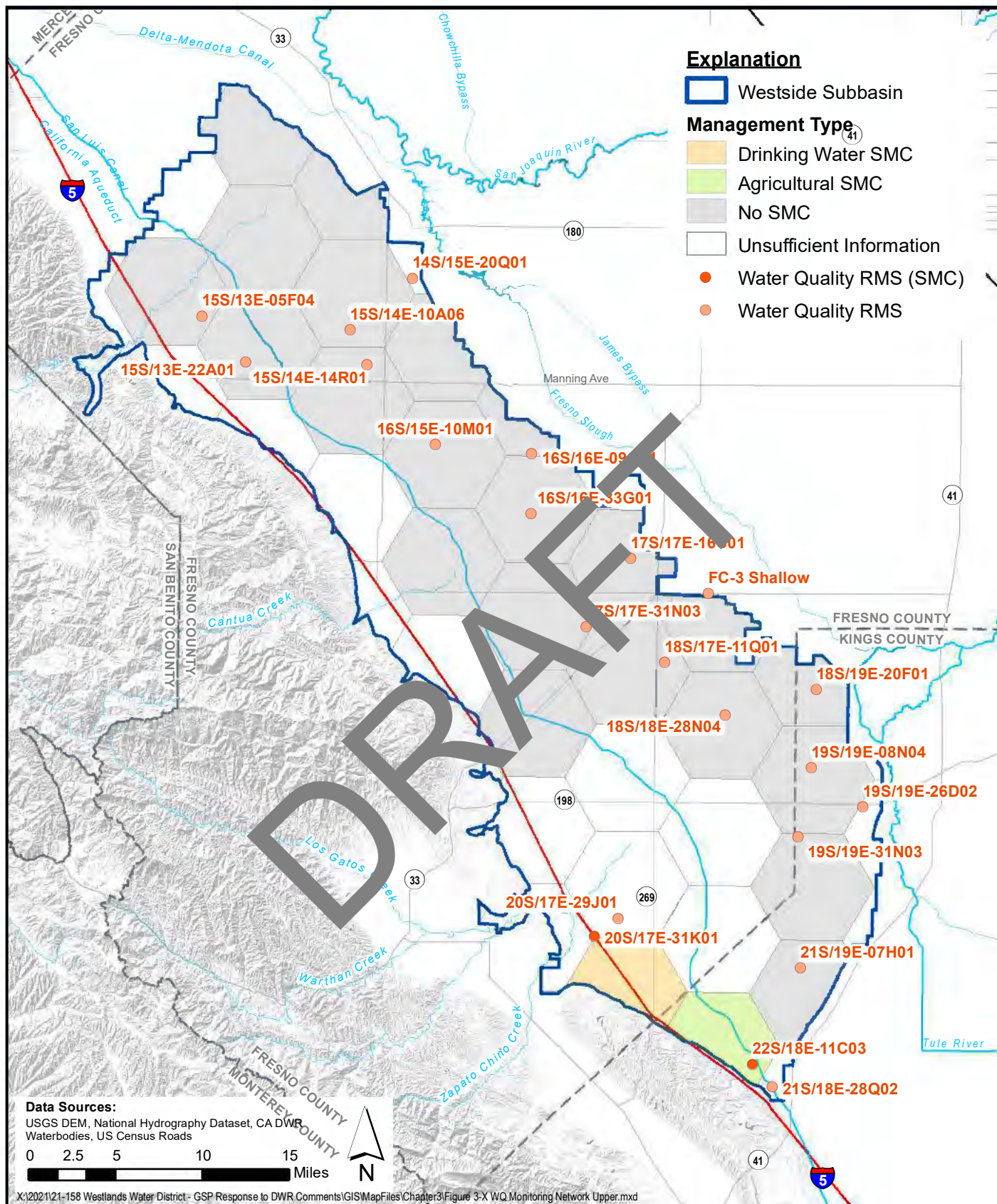
Figure 3-4



Summary of Measured TDS in Groundwater Wells (Lower Aquifer)

SGMA Sustainability Analyses
Westside Subbasin

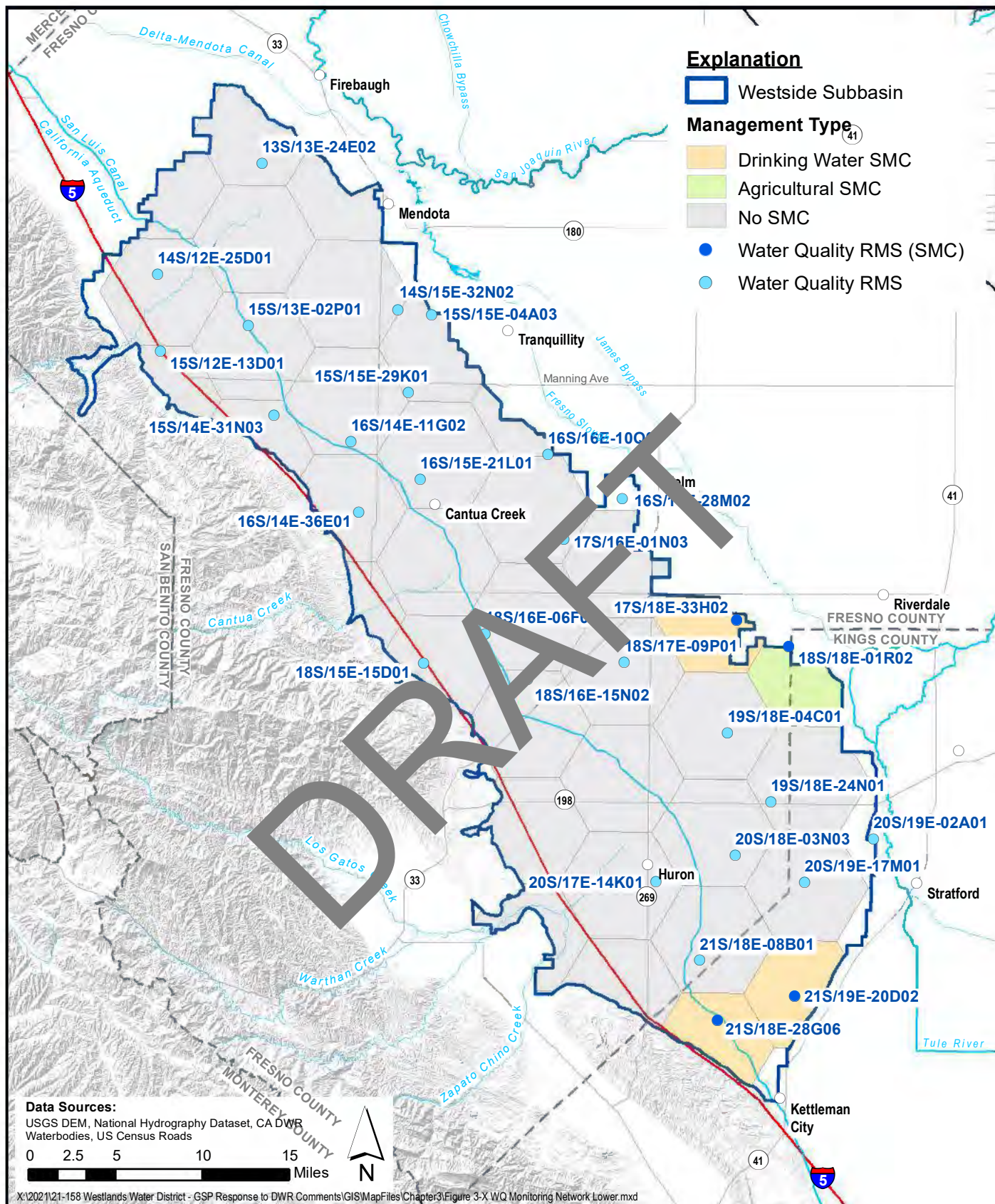
Figure 3-5



Representative Monitoring Sites for Groundwater Quality (Upper Aquifer)

SGMA Sustainability Analyses
Westside Subbasin

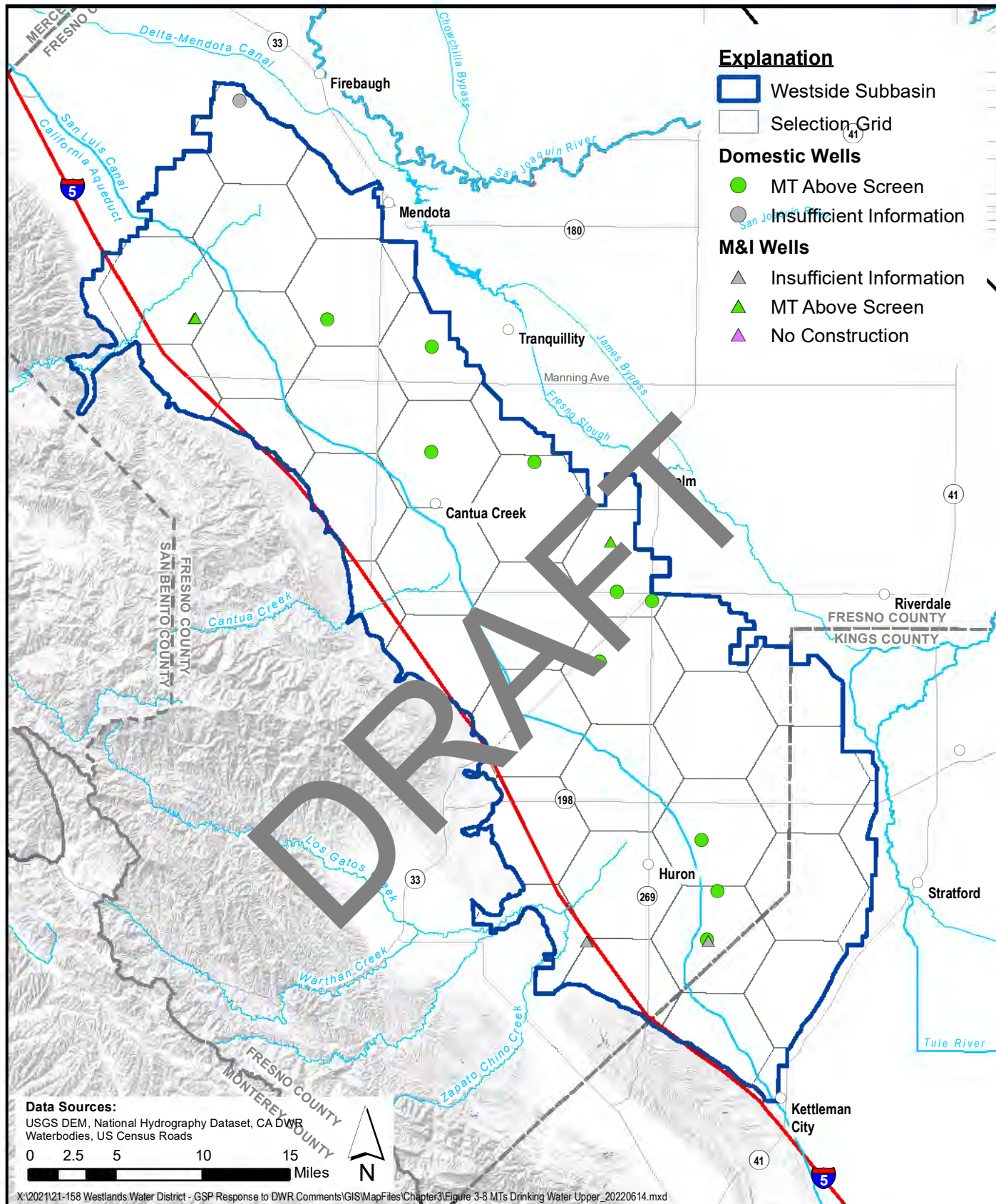
Figure 3-6



Representative Monitoring Sites for Groundwater Quality (Lower Aquifer)

SGMA Sustainability Analyses
Westside Subbasin

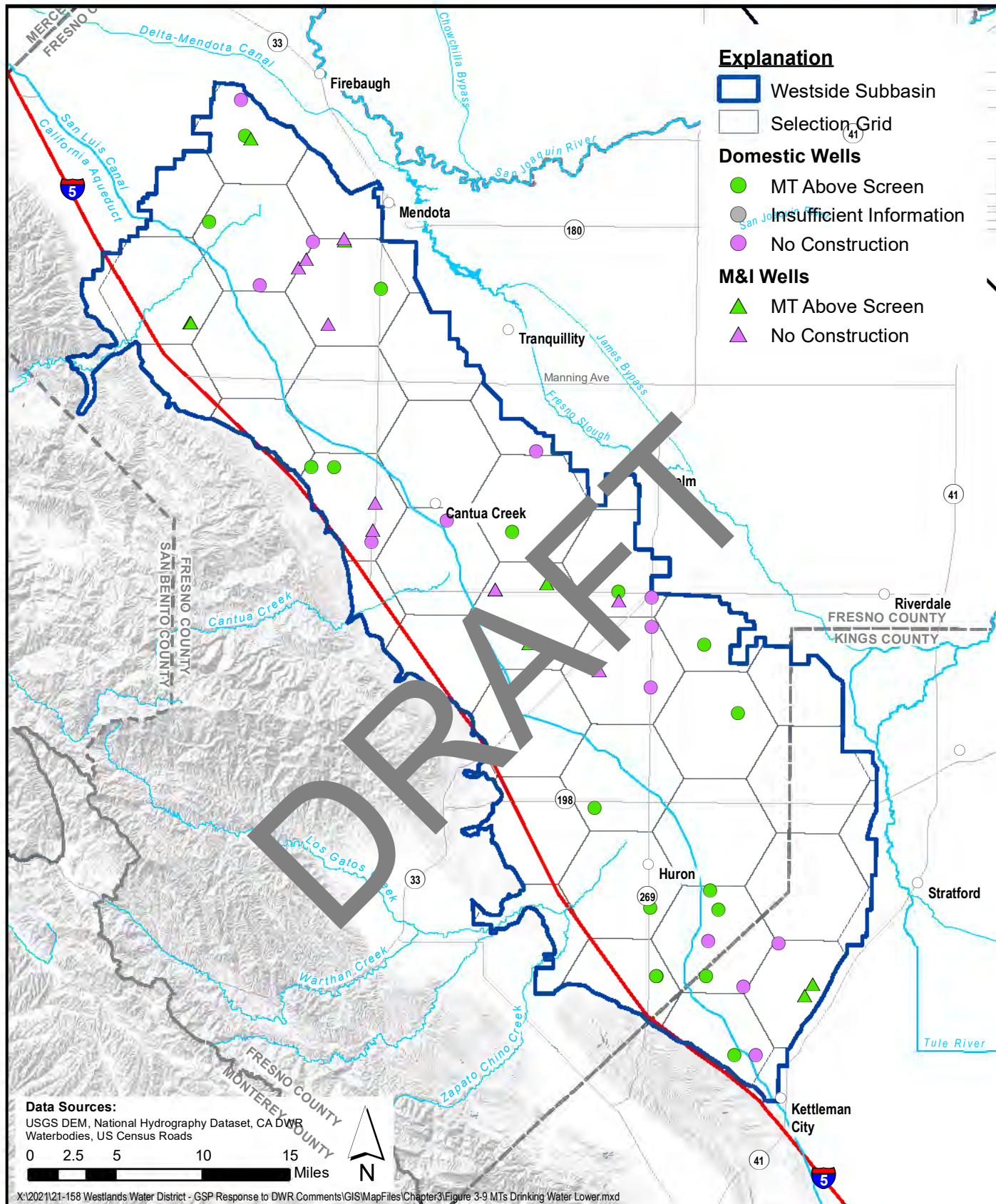
Figure 3-7



Comparison of Domestic and M&I Well Construction to Minimum Thresholds (Upper Aquifer)

Figure 3-8

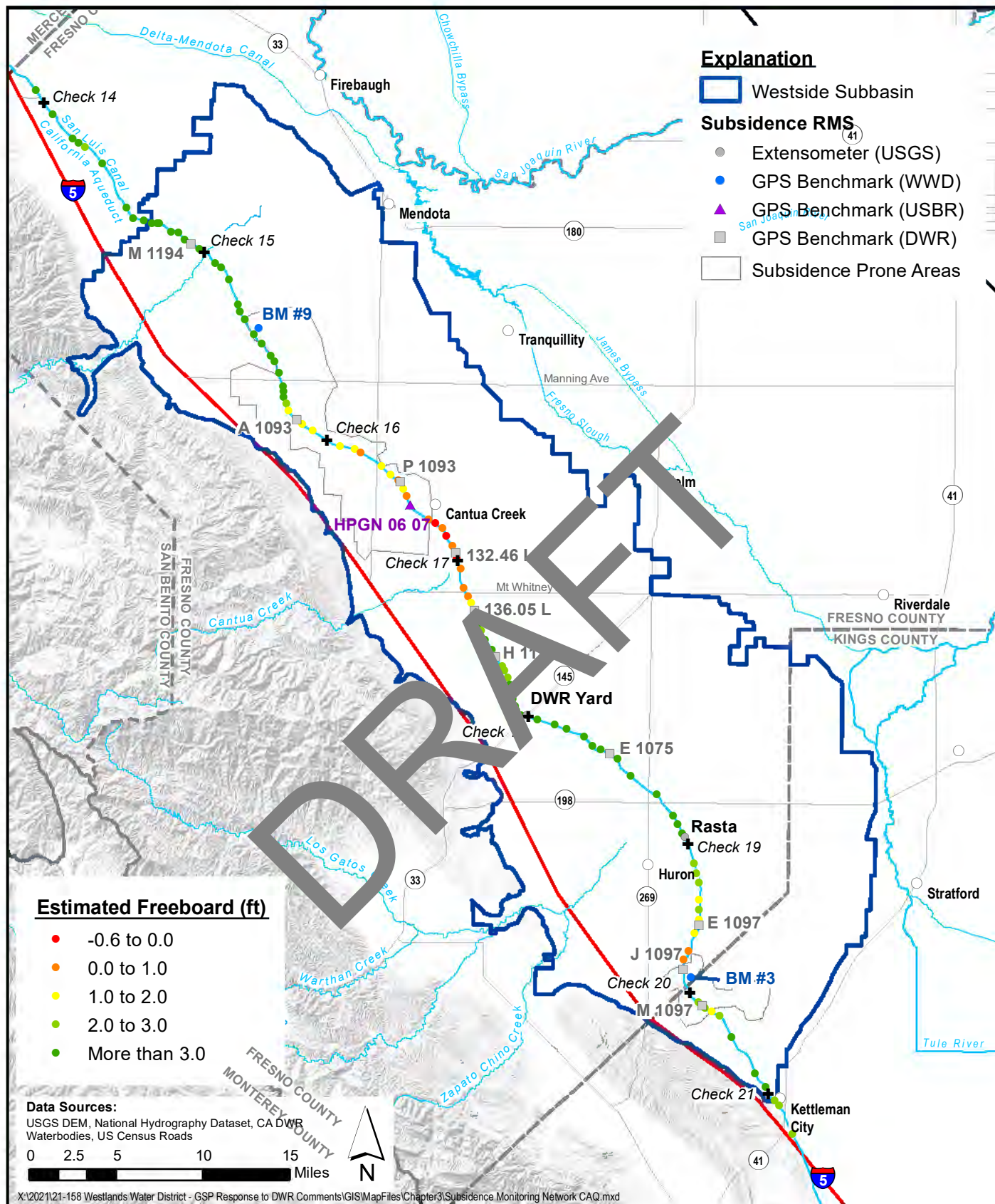
SGMA Sustainability Analyses
 Westside Subbasin



Comparison of Domestic and M&I Well Construction to Specified Minimum Thresholds (Lower Aquifer)

Figure 3-9

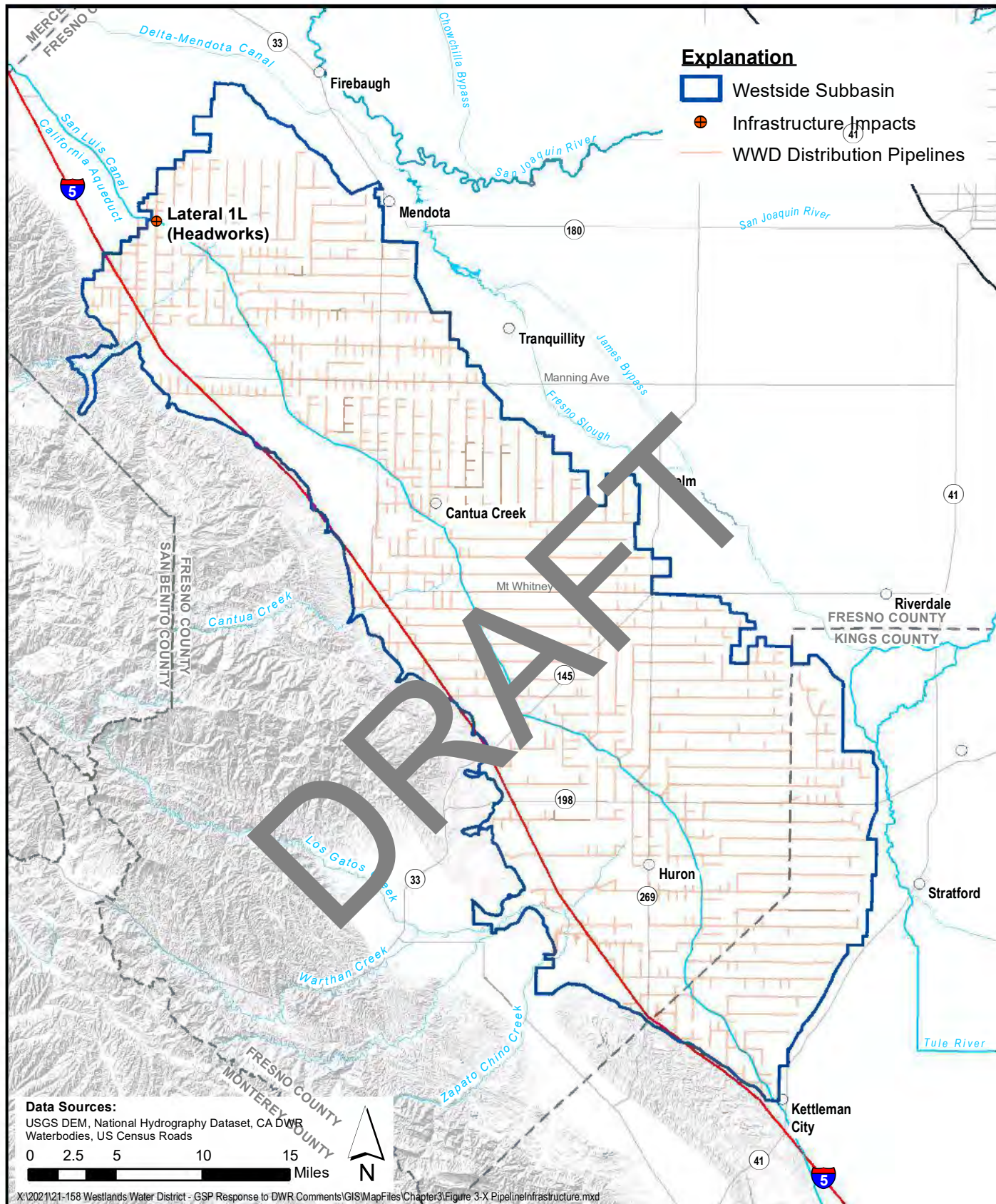
SGMA Sustainability Analyses
 Westside Subbasin



Available Freeboard in the San Luis Canal Design Water Surface Elevation (2022)

SGMA Sustainability Analyses
Westside Subbasin

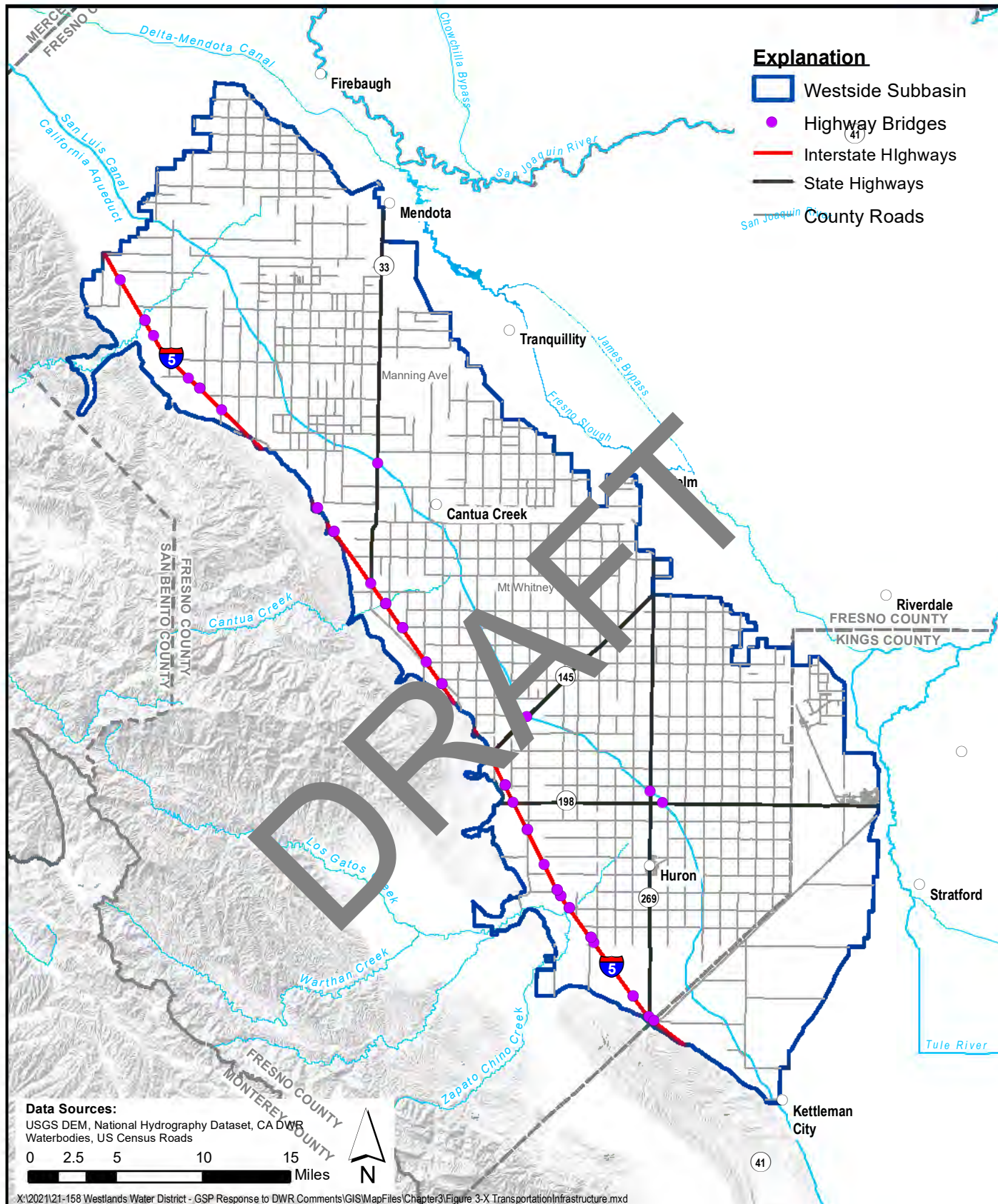
Figure 3-10



Subsidence Impacts to Pipelines and Turnout Structures

SGMA Sustainability Analyses
 Westside Subbasin

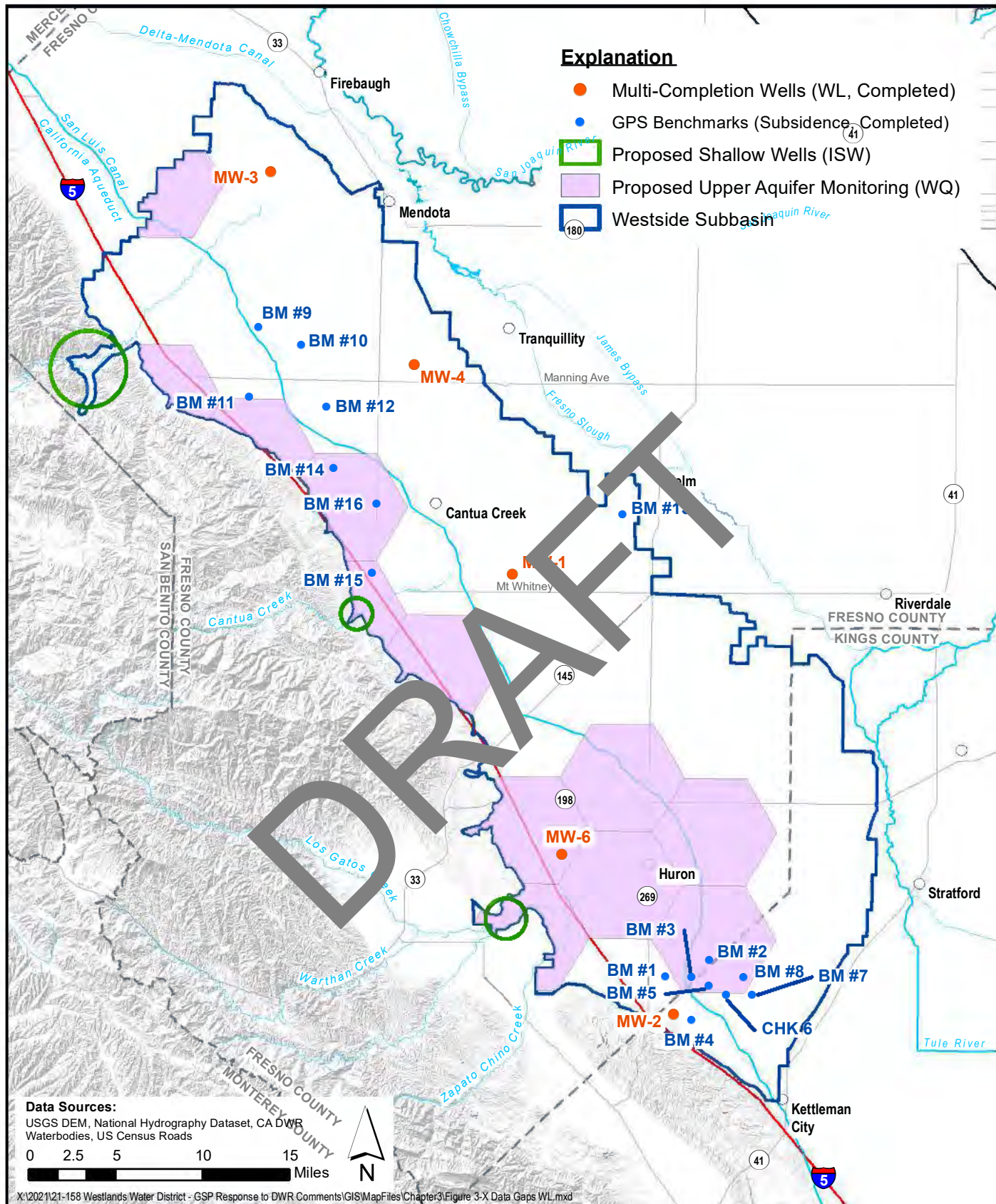
Figure 3-11



Transportation Infrastructure that May be Potentially Impacted by Subsidence

SGMA Sustainability Analyses
 Westside Subbasin

Figure 3-12



Sites and Areas to Remedy Monitoring Data Gaps

SGMA Sustainability Analyses
Westside Subbasin

Figure 3-13

**Table 3-1: Measurable Objectives and Interim Milestones for the
Chronic Lowering of Water Elevations – Upper Aquifer**

Well Name	Date of Baseline	Baseline	Interim Milestone 5 Years	Interim Milestone 10 Years	Interim Milestone 15 Years	Measurable Objective
		Water Surface Elevation (feet NAVD88)				
14S/13E-23E02	11/27/2012 ¹	-29.0	-2.1	24.9	51.9	78.8
14S/15E-20Q01	12/18/2015	116.5	114.2	112.0	109.7	107.4
15S/13E-05F04	11/18/2015	251.4	253.3	255.3	257.2	259.2
15S/13E-22A01	11/18/2015	153.6	158.0	162.4	166.8	171.2
15S/14E-10A06	12/10/2015	169.5	161.2	152.9	144.7	136.4
15S/15E-16K01	1/6/2015 ¹	116.6	115.8	115.0	114.2	113.5
15S/14E-14R01	11/25/2014 ¹	-11.4	21.1	53.5	86.0	118.5
16S/15E-10M01	1/1/2015 ¹	1.6	24.1	46.5	69.0	91.5
16S/16E-09Q01	1/7/2014 ¹	86.7	87.9	89.1	90.3	91.5
16S/16E-33G01	11/17/2016 ¹	25.8	38.2	50.5	62.9	75.2
17S/17E-16C01	5/25/2016	-1.1	10.7	22.4	34.2	46.0
17S/17E-31N03	12/2/2015	-83.0	-68.4	-53.7	-39.1	-24.5
18S/16E-22Q03	12/1/2015	-12.9	1.0	14.8	28.7	42.6
18S/17E-11Q01	11/17/2015	11.0	29.6	48.1	66.7	85.2
18S/18E-05K01	1/8/2015 ¹	27.9	27.4	27.0	26.5	26.0
18S/18E-28N04	1/9/2015 ¹	62.9	70.7	78.6	86.4	94.2
18S/19E-20F01	1/23/2015	5.9	21.3	36.8	52.2	67.6
19S/18E-34N04	12/3/2015	-144.1	-106.1	-68.1	-30.0	8.0
19S/19E-08N04	1/1/2015 ¹	96.4	111.8	127.2	142.6	158.0
19S/19E-26D02	1/1/2016 ¹	3.2	3.4	3.7	3.9	4.1
20S/19E-07G02	12/7/2016 ¹	49.5	57.5	65.5	73.5	81.5
21S/19E-07H01	12/12/2016 ¹	34.2	38.6	42.9	47.3	51.6

1. Value interpolated for recent historical low (2015) using available data

**Table 3-2: Measurable Objectives and Interim Milestones for the
Chronic Lowering of Water Elevations - Lower Aquifer**

Monitoring Site	Date of Baseline	Baseline	Interim Milestone 5 Years	Interim Milestone 10 Years	Interim Milestone 15 Years	Measurable Objective
		Water Surface Elevation (feet NAVD88)				
13S/13E-24E02	9/30/2015	-10.7	2.8	16.4	29.9	43.4
14S/12E-35J01	1/5/2015 ¹	-70.2	-37.8	-5.5	26.9	59.3
14S/13E-06P02	10/29/2015	-48.5	-22.3	3.9	30.0	56.2
14S/13E-12P01	1/6/2015 ¹	-61.5	-31.7	-1.8	28.1	57.9
14S/15E-32N02	12/4/2015	-97.5	-49.7	-1.8	46.1	93.9
15S/12E-13D01	12/3/2015	-58.2	-44.5	-30.8	-17.1	-3.4
15S/13E-02P01	1/1/2015 ¹	-132.0	-102.7	-73.5	-44.2	-14.9
15S/13E-24N01	9/28/2015	-95.3	-54.0	-12.6	28.8	70.2
15S/14E-19Q01	12/6/2016 ¹	-169.4	-123.1	-76.8	-30.4	15.9
15S/14E-26N02	10/23/2015	-225.3	-180.4	-135.6	-90.7	-45.8
15S/14E-31N03	10/28/2015	-183.2	-123.2	-63.3	-3.3	56.7
15S/15E-04A03	12/21/2015	-70.5	-66.8	-63.0	-59.3	-55.5
15S/15E-29K01	10/28/2015	-178.4	-143.4	-108.4	-73.4	-38.4
16S/14E-03H01	10/28/2015	-42.3	-9.5	23.3	56.0	88.8
16S/14E-14F01	12/22/2014 ¹	-120.2	-89.0	-57.8	-26.6	4.6
16S/14E-17A01	12/22/2014 ¹	-152.1	-106.7	-61.2	-15.8	29.7
16S/14E-36E01	12/22/2014 ¹	-156.1	-92.1	-28.1	36.0	100.0
16S/15E-16E01	10/23/2015	-233.3	-183.3	-133.3	-83.3	-33.3
16S/15E-32A06	1/1/2015 ¹	-17.4	-9.8	-2.2	5.4	13.0
16S/16E-10Q01	5/31/2016	-136.3	-98.5	-60.7	-22.8	15.0
16S/16E-29E01	11/5/2015	-181.2	-139.4	-97.6	-55.8	-14.0
17S/15E-09N02	10/26/2015	-166.1	-104.1	-42.0	20.1	82.1
17S/15E-23D01	10/26/2015	-239.1	-177.0	-115.0	-52.9	9.2
17S/17E-09Q01	9/28/2015	-150.1	-118.3	-86.5	-54.7	-22.9
17S/18E-33H02	10/20/2015	-88.1	-59.9	-31.8	-3.6	24.6
18S/15E-15D01	11/9/2015	-23.6	5.4	34.4	63.4	92.4
18S/16E-04N02	10/30/2015	-188.9	-152.3	-115.7	-79.0	-42.4
18S/16E-34N02	11/19/2015	-52.9	-24.5	3.9	32.2	60.6
18S/17E-09P01	10/20/2015	-194.0	-142.9	-91.8	-40.6	10.5
18S/18E-01R02	11/17/2015	-41.2	-5.5	30.3	66.1	101.8
19S/16E-35N01	10/15/2015	77.9	82.2	86.5	90.7	95.0
19S/17E-28P01	10/20/2015	-87.0	-48.0	-9.0	30.1	69.1
19S/18E-04C01	1/1/2015 ¹	-103.6	-72.4	-41.2	-10.0	21.2
19S/19E-29A01	11/19/2014 ¹	-112.1	-83.5	-54.8	-26.2	2.5
20S/16E-21R01	10/21/2015	-23.0	41.6	106.2	170.8	235.4
20S/17E-09N03	12/29/2016 ¹	-39.8	-8.1	23.7	55.5	87.2
20S/18E-04G01	5/5/2016 ¹	-185.1	-111.6	-38.1	35.4	108.9
20S/18E-35D02	12/20/2016 ¹	-126.0	-105.9	-85.9	-65.8	-45.7
20S/19E-02A01	1/1/2015 ¹	-28.3	-8.2	12.0	32.1	52.2
20S/19E-17M01	10/2/2015	-107.1	-84.8	-62.6	-40.3	-18.0
21S/17E-11N01	1/21/2015	-58.1	-23.8	10.5	44.8	79.1
21S/18E-22E01	1/27/2015	-142.1	-104.2	-66.2	-28.3	9.7
21S/18E-35Q02	1/1/2015 ¹	-42.9	-41.1	-39.3	-37.5	-35.7
21S/19E-20D02	12/12/2016 ¹	-147.4	-130.6	-113.8	-97.0	-80.3

1. Value interpolated for recent historical low (2015) using available data

Table 3-4: Measurable Objectives and Interim Milestones for Subsidence

Monitoring Site	Monitoring Type	Monitoring Entity	Interim Milestone 5 Years	Interim Milestone 10 Years	Interim Milestone 15 Years	Interim Milestone 20 Years	Measurable Objective	
			Subsidence (ft)					
			Annual Rate (Cumulative Total ¹)					
DWR Yard ²	Extensometer	USGS	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	
Panoche	Extensometer	USGS	0.1 (0.2)	0.1 (0.3)	0.1 (0.4)	0.1 (0.5)	0.1 (0.5)	
Rasta ²	Extensometer	USGS	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	
P302	CGPS	UNAVCO	0.1 (0.2)	0.1 (0.3)	0.1 (0.4)	0.1 (0.5)	0.1 (0.5)	
BM #1	GPS	WWD	0.1 (0.2)	0.1 (0.3)	0.1 (0.4)	0.1 (0.5)	0.1 (0.5)	
BM #2	GPS	WWD	0.1 (0.2)	0.1 (0.3)	0.1 (0.4)	0.1 (0.5)	0.1 (0.5)	
BM #3 ²	GPS	WWD	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	
BM #4	GPS	WWD	0.1 (0.2)	0.1 (0.3)	0.1 (0.4)	0.1 (0.5)	0.1 (0.5)	
BM #5	GPS	WWD	0.1 (0.2)	0.1 (0.3)	0.1 (0.4)	0.1 (0.5)	0.1 (0.5)	
CHK 6	GPS	WWD	0.1 (0.2)	0.1 (0.3)	0.1 (0.4)	0.1 (0.5)	0.1 (0.5)	
BM #7	GPS	WWD	0.1 (0.2)	0.1 (0.3)	0.1 (0.4)	0.1 (0.5)	0.1 (0.5)	
BM #8	GPS	WWD	0.1 (0.2)	0.1 (0.3)	0.1 (0.4)	0.1 (0.5)	0.1 (0.5)	
BM #9 ²	GPS	WWD	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	
BM #10	GPS	WWD	0.1 (0.2)	0.1 (0.3)	0.1 (0.4)	0.1 (0.5)	0.1 (0.5)	
BM #11	GPS	WWD	0.1 (0.2)	0.1 (0.3)	0.1 (0.4)	0.1 (0.5)	0.1 (0.5)	
BM #12	GPS	WWD	0.1 (0.2)	0.1 (0.3)	0.1 (0.4)	0.1 (0.5)	0.1 (0.5)	
BM #13	GPS	WWD	0.1 (0.2)	0.1 (0.3)	0.1 (0.4)	0.1 (0.5)	0.1 (0.5)	
BM #14	GPS	WWD	0.1 (0.2)	0.1 (0.3)	0.1 (0.4)	0.1 (0.5)	0.1 (0.5)	
BM #15	GPS	WWD	0.1 (0.2)	0.1 (0.3)	0.1 (0.4)	0.1 (0.5)	0.1 (0.5)	
BM #16	GPS	WWD	0.1 (0.2)	0.1 (0.3)	0.1 (0.4)	0.1 (0.5)	0.1 (0.5)	
Burnside	GPS	USBR	0.1 (0.2)	0.1 (0.3)	0.1 (0.4)	0.1 (0.5)	0.1 (0.5)	
HPGN 06 07 ²	GPS	USBR	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	
Murietta	GPS	USBR	0.1 (0.2)	0.1 (0.3)	0.1 (0.4)	0.1 (0.5)	0.1 (0.5)	
Peyton	GPS	USBR	0.1 (0.2)	0.1 (0.3)	0.1 (0.4)	0.1 (0.5)	0.1 (0.5)	
M 1194 ²	GPS	DWR	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	
A 1093 ²	GPS	DWR	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	
P 1093 RESET 1983 ²	GPS	DWR	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	
132.46 L ²	GPS	DWR	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	
136.05 L RESET 1984 ²	GPS	DWR	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	
H 1195 ²	GPS	DWR	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	
E 1075 ²	GPS	DWR	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	
E 1097 ²	GPS	DWR	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	
J 1097 ²	GPS	DWR	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	
M 1097 ²	GPS	DWR	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	
13S/13E-24E02	Water Level ³	WWD	2.8	16.4	29.9	43.4	43.4	
14S/15E-32N02	Water Level ³	WWD	-49.7	-1.8	46.1	93.9	93.9	
15S/15E-29K01	Water Level ³	WWD	-143.4	-108.4	-73.4	-38.4	-38.4	
16S/16E-29E01	Water Level ³	WWD	-139.4	-97.6	-55.8	-14.0	-14.0	
17S/18E-33H02	Water Level ³	WWD	-59.9	-31.8	-3.6	24.6	24.6	
18S/17E-09P01	Water Level ³	WWD	-142.9	-91.8	-40.6	10.5	10.5	
19S/16E-35N01	Water Level ³	WWD	82.2	86.5	90.7	95.0	95.0	
19S/17E-28P01	Water Level ³	WWD	-48.0	-9.0	30.1	69.1	69.1	
19S/18E-04C01	Water Level ³	WWD	-72.4	-41.2	-10.0	21.2	21.2	
19S/19E-29A01	Water Level ³	WWD	-83.5	-54.8	-26.2	2.5	2.5	
20S/17E-09N03	Water Level ³	WWD	-8.1	23.7	55.5	87.2	87.2	
20S/19E-17M01	Water Level ³	WWD	-84.8	-62.6	-40.3	-18.0	-18.0	

1. Total cumulative land subsidence since January 2020

2. Site adjacent San Luis Canal (California Aqueduct)

3. Water Surface Elevation - Measured in feet above mean sea level (NAVD88)

Table 3-5: Measurable Objectives
Groundwater Quality – Upper Aquifer

Well Name	Measurable Objective TDS (mg/L)
22S/18E-11C03	800
20S/17E-31K01	500
14S/15E-20Q01	N/A
15S/13E-05F04	N/A
15S/13E-22A01	N/A
15S/14E-10A06	N/A
15S/14E-14R01	N/A
16S/15E-10M01	N/A
16S/16E-09Q01	N/A
16S/16E-33G01	N/A
17S/17E-16C01	N/A
17S/17E-31N03	N/A
18S/17E-11Q01	N/A
18S/18E-28N04	N/A
18S/19E-20F01	N/A
19S/19E-08N04	N/A
19S/19E-26D02	N/A
19S/19E-31N03	N/A
20S/17E-29J01	N/A
21S/18E-28Q02	N/A
21S/19E-07H01	N/A
FC-3 Shallow	N/A

**Table 3-6: Measurable Objectives for
Groundwater Quality – Lower Aquifer**

Well Name	Measurable Objective TDS (mg/L)
17S/18E-33H02	500
18S/18E-01R02	800
21S/18E-28G06	500
21S/19E-20D02	500
13S/13E-24E02	N/A
14S/15E-32N02	N/A
15S/12E-13D01	N/A
15S/13E-02P01	N/A
15S/14E-31N03	N/A
15S/15E-04A03	N/A
15S/15E-29K01	N/A
16S/14E-36E01	N/A
16S/16E-10Q01	N/A
18S/15E-15D01	N/A
18S/17E-09P01	N/A
19S/18E-04C01	N/A
20S/19E-02A01	N/A
20S/19E-17M01	N/A
14S/12E-25D01	N/A
16S/14E-11G02	N/A
16S/15E-21L01	N/A
16S/17E-28M02	N/A
17S/16E-01N03	N/A
18S/16E-06F01	N/A
18S/16E-15N02	N/A
19S/18E-24N01	N/A
20S/17E-14K01	N/A
20S/18E-03N03	N/A
21S/18E-08B01	N/A

**Table 3-7: Minimum Thresholds for the
Chronic Lowering of Water Elevations – Upper Aquifer**

Well Name	Date of Baseline	Baseline	Minimum Threshold
		Water Surface Elevation (feet NAVD88)	
14S/13E-23E02	11/27/2012 ¹	-29.0	-69.0
14S/15E-20Q01	12/18/2015	30.0	-10.0
15S/13E-05F04	11/18/2015	251.4	211.4
15S/13E-22A01	11/18/2015	153.6	113.6
15S/14E-10A06	12/10/2015	169.5	129.5
15S/15E-16K01	1/6/2015 ¹	116.6	76.6
15S/14E-14R01	11/25/2014 ¹	-11.4	-51.4
16S/15E-10M01	1/1/2015 ¹	1.6	-38.4
16S/16E-09Q01	1/7/2014 ¹	86.7	46.7
16S/16E-33G01	11/17/2016 ¹	25.8	-14.2
17S/17E-16C01	5/25/2016	-1.1	-41.1
17S/17E-31N03	12/2/2015	-83.0	-123.0
18S/16E-22Q03	12/1/2015	-12.9	-52.9
18S/17E-11Q01	11/17/2015	11.0	-29.0
18S/18E-05K01	1/8/2015 ¹	27.9	-12.1
18S/18E-28N04	1/9/2015 ¹	62.9	22.9
18S/19E-20F01	1/23/2015	5.9	-34.1
19S/18E-34N04	12/3/2015	-144.1	-184.1
19S/19E-08N04	1/1/2015 ¹	96.4	56.4
19S/19E-26D02	1/1/2016 ¹	3.2	-36.8
20S/19E-07G02	12/7/2016 ¹	49.5	9.5
21S/19E-07H01	12/12/2016 ¹	34.2	-5.8

1. Value interpolated for recent historical low (2015) using available data

**Table 3-8: Minimum Thresholds for the
Chronic Lowering of Water Elevations – Lower Aquifer**

Well Name	Date of Baseline	Baseline	Minimum Threshold
		Water Surface Elevation (feet NAVD88)	
13S/13E-24E02	9/30/2015	-10.7	-50.7
14S/12E-35J01	1/5/2015 ¹	-70.2	-110.2
14S/13E-06P02	10/29/2015	-48.5	-88.5
14S/13E-12P01	1/6/2015 ¹	-61.5	-101.5
14S/15E-32N02	12/4/2015	-97.5	-137.5
15S/12E-13D01	12/3/2015	-58.2	-98.2
15S/13E-02P01	1/1/2015 ¹	-132.0	-172.0
15S/13E-24N01	9/28/2015	-95.3	-135.3
15S/14E-19Q01 ²	12/6/2016 ¹	-169.4	-169.4
15S/14E-26N02	10/23/2015	-225.3	-265.3
15S/14E-31N03 ²	10/28/2015	-183.2	-183.2
15S/15E-04A03	12/21/2015	-70.5	-110.5
15S/15E-29K01	10/28/2015	-178.4	-218.4
16S/14E-03H01	10/28/2015	-42.3	-82.3
16S/14E-14F01 ²	12/22/2014 ¹	-120.2	-120.2
16S/14E-17A01 ²	12/22/2014 ¹	-152.1	-152.1
16S/14E-36E01 ²	12/22/2014 ¹	-156.1	-156.1
16S/15E-16E01	10/23/2015	-233.3	-273.3
16S/15E-32A06	1/1/2015 ¹	-17.4	-57.4
16S/16E-10Q01	5/31/2016	-136.3	-176.3
16S/16E-29E01	11/5/2015	-181.2	-221.2
17S/15E-09N02 ²	10/26/2015	-166.1	-166.1
17S/15E-23D01	10/26/2015	-239.1	-279.1
17S/17E-09Q01	9/28/2015	-150.1	-190.1
17S/18E-33H02	10/20/2015	-88.1	-128.1
18S/15E-15D01	11/9/2015	-23.6	-63.6
18S/16E-04N02	10/30/2015	-188.9	-228.9
18S/16E-34N02	11/19/2015	-52.9	-92.9
18S/17E-09P01	10/20/2015	-194.0	-234.0
18S/18E-01R02	11/17/2015	-41.2	-81.2
19S/16E-35N01	10/15/2015	77.9	37.9
19S/17E-28P01	10/20/2015	-87.0	-127.0
19S/18E-04C01	1/1/2015 ¹	-103.6	-143.6
19S/19E-29A01	11/19/2014 ¹	-112.1	-152.1
20S/16E-21R01	10/21/2015	-23.0	-63.0
20S/17E-09N03	12/29/2016 ¹	-39.8	-79.8
20S/18E-04G01	5/5/2016 ¹	-185.1	-225.1
20S/18E-35D02	12/20/2016 ¹	-126.0	-166.0
20S/19E-02A01	1/1/2015 ¹	-28.3	-68.3
20S/19E-17M01	10/2/2015	-107.1	-147.1
21S/17E-11N01	1/21/2015	-58.1	-98.1
21S/18E-22E01 ²	1/27/2015	-142.1	-142.1
21S/18E-35Q02	1/1/2015 ¹	-42.9	-82.9
21S/19E-20D02	12/12/2016 ¹	-147.4	-187.4

1. Value interpolated for recent historical low (2015) using available data

2. MT is historical low value in subsidence prone area

Table 3-9: Minimum Thresholds for Subsidence

Monitoring Site	Monitoring Type	Monitoring Entity	Minimum Threshold (ft)
DWR Yard ²	Extensometer	USGS	0.3 (1.5)
Panoche	Extensometer	USGS	0.3 (2.5)
Rasta ²	Extensometer	USGS	0.3 (1.5)
P302	CGPS	UNAVCO	0.3 (2.5)
BM #1	GPS	WWD	0.3 (2.5)
BM #2	GPS	WWD	0.3 (2.5)
BM #3 ²	GPS	WWD	0.3 (1.5)
BM #4	GPS	WWD	0.3 (2.5)
BM #5	GPS	WWD	0.3 (2.5)
CHK 6	GPS	WWD	0.3 (2.5)
BM #7	GPS	WWD	0.3 (2.5)
BM #8	GPS	WWD	0.3 (2.5)
BM #9 ²	GPS	WWD	0.3 (1.5)
BM #10	GPS	WWD	0.3 (2.5)
BM #11	GPS	WWD	0.3 (2.5)
BM #12	GPS	WWD	0.3 (2.5)
BM #13	GPS	WWD	0.3 (2.5)
BM #14	GPS	WWD	0.3 (2.5)
BM #15	GPS	WWD	0.3 (2.5)
BM #16	GPS	WWD	0.3 (2.5)
Burnside	GPS	USBR	0.3 (2.5)
HPGN 06 07 ²	GPS	USBR	0.3 (1.5)
Murietta	GPS	USBR	0.3 (2.5)
Peyton	GPS	USBR	0.3 (2.5)
M 1194 ²	GPS	DWR	0.3 (1.5)
A 1093 ²	GPS	DWR	0.3 (1.5)
P 1093 RESET 1983 ²	GPS	DWR	0.3 (1.5)
132.46 L ²	GPS	DWR	0.3 (1.5)
136.05 L RESET 1984 ²	GPS	DWR	0.3 (1.5)
H 1195 ²	GPS	DWR	0.3 (1.5)
E 1075 ²	GPS	DWR	0.3 (1.5)
E 1097 ²	GPS	DWR	0.3 (1.5)
J 1097 ²	GPS	DWR	0.3 (1.5)
M 1097 ²	GPS	DWR	0.3 (1.5)
13S/13E-24E02	Water Level ³	WWD	-50.7
14S/15E-32N02	Water Level ³	WWD	-137.5
15S/15E-29K01	Water Level ³	WWD	-218.4
16S/16E-29E01	Water Level ³	WWD	-221.2
17S/18E-33H02	Water Level ³	WWD	-128.1
18S/17E-09P01	Water Level ³	WWD	-234
19S/16E-35N01	Water Level ³	WWD	37.9
19S/17E-28P01	Water Level ³	WWD	-127
19S/18E-04C01	Water Level ³	WWD	-143.6
19S/19E-29A01	Water Level ³	WWD	-152.1
20S/17E-09N03	Water Level ³	WWD	-79.8
20S/19E-17M01	Water Level ³	WWD	-147.1

1. Total cumulative land subsidence since January 2020

2. Site adjacent San Luis Canal (California Aqueduct)

3. Water Surface Elevation - Measured in feet above mean sea level

**Table 3-10: Minimum Thresholds
Groundwater Quality – Upper Aquifer**

Well Name	Minimum Threshold TDS (mg/L)
22S/18E-11C03	1000
20S/17E-31K01	1000
14S/15E-20Q01	N/A
15S/13E-05F04	N/A
15S/13E-22A01	N/A
15S/14E-10A06	N/A
15S/14E-14R01	N/A
16S/15E-10M01	N/A
16S/16E-09Q01	N/A
16S/16E-33G01	N/A
17S/17E-16C01	N/A
17S/17E-31N03	N/A
18S/17E-11Q01	N/A
18S/18E-28N04	N/A
18S/19E-20F01	N/A
19S/19E-08N04	N/A
19S/19E-26D02	N/A
19S/19E-31N03	N/A
20S/17E-29J01	N/A
21S/18E-28Q02	N/A
21S/19E-07H01	N/A
FC-3 Shallow	N/A

**Table 3-11: Minimum Thresholds for
Groundwater Quality – Lower Aquifer**

Well Name	Minimum Threshold TDS (mg/L)
17S/18E-33H02	1000
18S/18E-01R02	1000
21S/18E-28G06	1000
21S/19E-20D02	1000
13S/13E-24E02	N/A
14S/15E-32N02	N/A
15S/12E-13D01	N/A
15S/13E-02P01	N/A
15S/14E-31N03	N/A
15S/15E-04A03	N/A
15S/15E-29K01	N/A
16S/14E-36E01	N/A
16S/16E-10Q01	N/A
18S/15E-15D01	N/A
18S/17E-09P01	N/A
19S/18E-04C01	N/A
20S/19E-02A01	N/A
20S/19E-17M01	N/A
14S/12E-25D01	N/A
16S/14E-11G02	N/A
16S/15E-21L01	N/A
16S/17E-28M02	N/A
17S/16E-01N03	N/A
18S/16E-06F01	N/A
18S/16E-15N02	N/A
19S/18E-24N01	N/A
20S/17E-14K01	N/A
20S/18E-03N03	N/A
21S/18E-08B01	N/A

Table 3-12: Summary of Undesirable Results Applicable to the Plan Area

Sustainability Indicator	Historical Period	Existing Condition	Future Conditions Without GSP Implementation	PMAs Implemented to meet the GSP Sustainability Goal
Chronic Lowering of Groundwater Levels	Yes	Yes	Yes	- Voluntary fallowing of agricultural land; - Intra-Subbasin water transfers; - Imported surface water supplies; - Aquifer storage and recovery projects; - Groundwater recharge projects; - Allocation of groundwater.
Reduction of Groundwater Storage	Yes	Yes	Yes	- Voluntary fallowing of agricultural land; - Intra-Subbasin water transfers; - Imported surface water supplies; - Aquifer storage and recovery projects; - Groundwater recharge projects; - Allocation of groundwater.
Seawater Intrusion	Not Applicable	Not Applicable	Not Applicable	Not Applicable
Degraded Water Quality	Yes	Yes	Yes	- Intra-Subbasin water transfers; - Imported surface water supplies; - Aquifer storage and recovery projects; - Groundwater recharge projects.
Land Subsidence	Yes	Yes	Yes	- Voluntary fallowing of agricultural land; - Intra-Subbasin water transfers; - Imported surface water supplies; - Aquifer storage and recovery projects; - Groundwater recharge projects; - Allocation of groundwater; - Upper Aquifer pumping incentives; - Targeted pumping reductions.
Depletion of Interconnected Surface Water	Not Applicable	Not Applicable	Not Applicable	Not Applicable

**Table 3-13: Proposed Monitoring Network for Water Levels and Storage
Upper Aquifer**

Well Name	Latitude (NAD83)	Longitude (NAD83)	Monitoring Frequency	Depth (ft bgs)	Perforations (ft bgs)	Ground-Surface Elevation (ft NAVD88)	Period of Record	Number of Measurements	Rationale ^{1,2,3}
14S/13E-23E02	36.70013	-120.53161	Bi-Annual	716	326-716	319.6	1977-2018	44	1,2
14S/15E-20Q01	36.69083	-120.36034	Bi-Annual	205	115-205	170.5	1991-2018	30	1,2
15S/13E-05F04	36.65638	-120.57873	Bi-Annual	215	199-209	408.64	2010-2018	16	1
15S/13E-22A01	36.61850	-120.53256	Bi-Annual	379	363-373	434.64	2010-2018	16	1
15S/14E-10A06	36.64697	-120.42445	Bi-Annual	582	150-582	224.5	1990-2018	33	1,2
15S/14E-14R01	36.61810	-120.40669	Bi-Annual	600	400-600	206.6	1991-2018	30	2
15S/15E-16K01	36.62312	-120.34270	Bi-Annual	500	300-500	174.6	1979-2019	44	1,2
16S/15E-10M01	36.55198	-120.33427	Bi-Annual	560	320-540	238.7	2007-2018	14	1
16S/16E-09Q01	36.54519	-120.23450	Bi-Annual	580	280-560	194.7	1992-2018	29	2
16S/16E-33G01	36.49476	-120.23433	Bi-Annual	520	300-520	233.8	1992-2018	29	1,2
17S/17E-16C01	36.45839	-120.13030	Bi-Annual	480	270-480	210.9	1988-2018	34	1,2
17S/17E-31N03	36.40062	-120.17558	Bi-Annual	780	498-738	253	1990-2018	30	2
18S/16E-22Q03	36.34233	-120.22092	Bi-Annual	400	280-400	300.1	1990-2018	30	1,2
18S/17E-11Q01	36.37182	-120.09403	Bi-Annual	630	350-630	257	1988-2018	33	1,2
18S/18E-05K01	36.39366	-120.04000	Bi-Annual	652	342-643	233.9	1978-2019	47	1,2
18S/18E-28N04	36.32833	-120.03050	Bi-Annual	670	300-660	262.9	1991-2018	30	1,2
18S/19E-20F01	36.35013	-119.93664	Bi-Annual	604	244-604	225.9	1988-2018	32	1,2
19S/18E-34N04 ³	36.22992	-120.01246	Bi-Annual	733	400-700	288.9	1994-2018	25	1,2
19S/19E-08N04	36.28475	-119.94090	Bi-Annual	620	300-620	236.9	1993-2018	27	1,2
19S/19E-26D02	36.25259	-119.88725	Bi-Annual	580	300-580	220.9	1992-2018	28	2
20S/19E-07G02	36.20367	-119.94992	Bi-Annual	690	175-670	250.9	2010-2018	12	1
21S/19E-07H01	36.11684	-119.95004	Bi-Annual	790	286-770	231.8	2016-2018	5	1

1. Location of Well

2. Number of Records

3. Well Construction Estimated

**Table 3-14: Proposed Monitoring Network for Water Levels and Storage
Lower Aquifer**

Well Name	Latitude (NAD83)	Longitude (NAD83)	Monitoring Frequency	Depth (ft bgs)	Perforations (ft bgs)	Ground-Surface Elevation (ft NAVD88)	Period of Record	Number of Measurements	Rationale ^{1,2,3}
13S/13E-24E02	36.78538	-120.51260	Bi-Annual	860	560-780	223	2015-2018	7	1,2,3
14S/12E-35J01	36.66652	-120.62223	Bi-Annual	1035	654-1035	435.8	1979-2018	44	1,2
14S/13E-06P02	36.73504	-120.59483	Bi-Annual	1214	702-1214	323.5	1979-2018	44	2
14S/13E-12P01	36.72006	-120.50911	Bi-Annual	1520	700-1400	275.5	1977-2018	44	1,2
14S/15E-32N02	36.66479	-120.36908	Bi-Annual	986	544-986	180.5	1977-2018	43	1,3
15S/12E-13D01	36.62694	-120.61508	Bi-Annual	998	698-998	552.8	1990-2018	23	1
15S/13E-02P01	36.64960	-120.52410	Bi-Annual	1244	884-1244	337.5	2009-2018	11	1
15S/13E-24N01a	36.60481	-120.51445	Bi-Annual	1849	917-1849	400.7	1963-2021	47	1
15S/14E-19Q01	36.60403	-120.48540	Bi-Annual	1265	865-1265	332.6	1994-2018	27	1,2
15S/14E-26N02	36.58913	-120.42465	Bi-Annual	1500	700-1500	230.7	1979-2018	44	1,2
15S/14E-31N03	36.57501	-120.49656	Bi-Annual	1918	915-1800	372.8	1965-2018	52	1,2
15S/15E-04A03	36.66072	-120.33393	Bi-Annual	1000	600-1000	164.5	2008-2019	15	1
15S/15E-29K01	36.59583	-120.35703	Bi-Annual	1162	600-1162	190.6	2013-2019	9	1,3
16S/14E-03H01	36.56752	-120.42545	Bi-Annual	2018	718-2018	275.7	1958-2018	57	1,2
16S/14E-14F01	36.53837	-120.41662	Bi-Annual	2803	1000-2803	358.8	1960-2019	55	1,2
16S/14E-17A01	36.54510	-120.46143	Bi-Annual	2230	930-2210	437.9	2003-2018	18	1,2
16S/14E-36E01	36.49438	-120.40687	Bi-Annual	2200	841-2104	477.9	1987-2019	34	1,2
16S/15E-16E01	36.53801	-120.35214	Bi-Annual	1200	840-1200	267.7	1992-2018	29	2
16S/15E-32A06	36.50061	-120.35328	Bi-Annual	1218	618-1218	328.8	1993-2019	29	1,2
16S/16E-10Q01	36.54539	-120.21163	Bi-Annual	965	645-945	187.7	1993-2018	30	1,2
16S/16E-29E01	36.50897	-120.26163	Bi-Annual	995	675-995	244.8	1992-2018	28	2,3
17S/15E-09N02	36.46126	-120.35602	Bi-Annual	2529	861-2529	392.9	1978-2019	35	1,2
17S/15E-23D01	36.44281	-120.32009	Bi-Annual	1500	842-1500	362.9	1978-2018	34	1,2
17S/17E-09Q01	36.45883	-120.12969	Bi-Annual	1002	602-1002	209.9	2009-2018	14	1
17S/18E-33H02	36.40831	-120.01361	Bi-Annual	1340	600-1310	216.9	2014-2019	8	1,3
18S/15E-15D01	36.36883	-120.33744	Bi-Annual	2583	1788-2488	541.4	1988-2018	23	1,2
18S/16E-04N02	36.38563	-120.24702	Bi-Annual	1760	942-1720	287.1	1989-2019	32	1,2
18S/16E-34N02	36.31265	-120.22875	Bi-Annual	2000	800-2000	337.1	1992-2018	29	1,2
18S/17E-09P01	36.37167	-120.13000	Bi-Annual	1187	700-1150	268	1991-2018	31	1,2,3
18S/18E-01R02	36.38645	-119.95955	Bi-Annual	1281	598-1281	217.8	2010-2018	10	1
19S/16E-35N01	36.22638	-120.20998	Bi-Annual	2035	719-2035	432.9	1978-2018	35	1,2,3
19S/17E-28P01	36.24105	-120.13212	Bi-Annual	2018	716-2005	368	1987-2018	35	2,3
19S/18E-04C01	36.31356	-120.02182	Bi-Annual	1620	866-1600	266.9	2008-2018	15	1,2,3
19S/19E-29A01	36.25485	-119.92323	Bi-Annual	1423	718-1423	237.9	1990-2018	31	2,3
20S/16E-21R01	36.16830	-120.22907	Bi-Annual	1418	806-1406	504	1978-2018	36	1,2
20S/17E-09N03	36.19597	-120.13880	Bi-Annual	2100	801-2067	413.9	1976-2018	45	1,2,3
20S/18E-04G01	36.21870	-120.02158	Bi-Annual	1040	600-1040	297.9	2000-2018	20	2
20S/18E-35D02	36.15212	-119.99251	Bi-Annual	1700	700-1700	272.8	1989-2018	32	1,2
20S/19E-02A01	36.22586	-119.86996	Bi-Annual	2130	869-2090	210.9	1988-2018	34	1,2
20S/19E-17M01	36.18903	-119.94072	Bi-Annual	1000	700-1000	245.9	1989-2018	34	1,2,3
21S/17E-11N01	36.10895	-120.11015	Bi-Annual	2008	628-1989	440.9	1978-2018	34	1,2
21S/18E-22E01	36.08951	-120.02142	Bi-Annual	1800	720-1780	271.9	2009-2018	13	1
21S/18E-35Q02	36.05101	-119.99421	Bi-Annual	1180	600-1180	278.1	2008-2018	13	1
21S/19E-20D02	36.09394	-119.94984	Bi-Annual	1160	449-1150	225.9	2016-2018	4	1

a. Replaces 15S/13E-22P01

1. Location of Well

2. Number of Records

3. Co-located with Subsidence Monitoring Network

Table 3-15 Subsidence Monitoring Network

Site Name	Site Type	Monitoring Agency	Latitude (NAD83)	Longitude (NAD83)	Monitoring Frequency	Depth (ft bgs)	Perforations (ft bgs)	Ground-Surface Elevation (ft NAVD88) ³	Period of Record	Number of Measurements	Rationale ^{1,2,3}
DWR Yard ²	Extensometer	USGS	36.32639	-120.23028	Continuous	1070	-	323	2011-2022	>1,000	2
Panoche	Extensometer	USGS	36.73278	-120.53139	Continuous	1358	-	288	2012-2022	>1,000	1
Rasta ²	Extensometer	USGS	36.22611	-120.06528	Continuous	1007	-	327	2012-2022	>1,000	2
P302	CGPS	UNAVCO	36.63475	-120.61886	Continuous	-	-	402.3	2004-2022	>1,000	1
BM #1	GPS	WWD	36.10897	-120.08405	Bi-Annual	-	-	350.9	2020-2022	4	1
BM #2	GPS	WWD	36.12310	-120.03944	Bi-Annual	-	-	290.8	2020-2022	4	1
BM #3 ²	GPS	WWD	36.10879	-120.05731	Bi-Annual	-	-	303.5	2020-2022	4	2
BM #4	GPS	WWD	36.07276	-120.05712	Bi-Annual	-	-	408.3	2020-2022	4	1
BM #5	GPS	WWD	36.10145	-120.03939	Bi-Annual	-	-	281.3	2020-2022	4	1
CHK 6	GPS	WWD	36.09428	-120.02153	Bi-Annual	-	-	264.0	2020-2022	4	1
BM #7	GPS	WWD	36.09433	-119.99457	Bi-Annual	-	-	245.4	2020-2022	4	1
BM #8	GPS	WWD	36.10862	-120.00355	Bi-Annual	-	-	258.3	2020-2022	4	1
BM #9 ²	GPS	WWD	36.64744	-120.51424	Bi-Annual	-	-	306.2	2020-2022	4	2
BM #10	GPS	WWD	36.63296	-120.46939	Bi-Annual	-	-	257.2	2020-2022	4	1
BM #11	GPS	WWD	36.58924	-120.52278	Bi-Annual	-	-	437.2	2020-2022	4	1
BM #12	GPS	WWD	36.58187	-120.44273	Bi-Annual	-	-	238.7	2020-2022	4	1
BM #13	GPS	WWD	36.49514	-120.13427	Bi-Annual	-	-	194.2	2020-2022	4	1
BM #14	GPS	WWD	36.53058	-120.43390	Bi-Annual	-	-	398.7	2020-2022	4	1
BM #15	GPS	WWD	36.44331	-120.39279	Bi-Annual	-	-	447.4	2020-2022	4	1
BM #16	GPS	WWD	36.50166	-120.38885	Bi-Annual	-	-	410.2	2020-2022	4	1
Burnside	GPS	USBR	36.48784	-120.15205	Bi-Annual	-	-	196.7	2011-2021	19	1
HPGN 06 07 ²	GPS	USBR	36.50106	-120.35384	Bi-Annual	-	-	330.1	2011-2021	19	2
Murietta	GPS	USBR	36.63206	-120.31784	Bi-Annual	-	-	166.0	2011-2021	19	1
Peyton	GPS	USBR	36.70718	-120.45963	Bi-Annual	-	-	233.8	2012-2021	16	1
M 1194 ²	GPS	DWR	36.71708	-120.58603	Annual	-	-	334.7	1968-2022	26	2
A 1093 ²	GPS	DWR	36.57160	-120.47314	Annual	-	-	331.4	1967-2022	26	2
P 1093 RESET 1983 ²	GPS	DWR	36.52043	-120.36454	Annual	-	-	331.4	1967-2022	26	2
132.46 L ²	GPS	DWR	36.46207	-120.30594	Annual	-	-	327.7	1967-2022	21	2
136.05 L RESET 1984 ²	GPS	DWR	36.41367	-120.28598	Annual	-	-	328.3	1967-2022	27	2
H 1195 ²	GPS	DWR	36.37546	-120.26347	Annual	-	-	325.1	1968-2022	25	2
E 1075 ²	GPS	DWR	36.29531	-120.14409	Annual	-	-	327.4	1967-2022	27	2
E 1097 ²	GPS	DWR	36.15257	-120.04974	Annual	-	-	322.5	1967-2022	24	2
J 1097 ²	GPS	DWR	36.11494	-120.06556	Annual	-	-	322.1	1967-2022	26	2
M 1097 ²	GPS	DWR	36.08494	-120.04511	Annual	-	-	323.8	1967-2022	26	2
13S/13E-24E02	Water Level	WWD	36.78538	-120.51260	Bi-Annual	860	560-780	223.0	2015-2018	7	1
14S/15E-32N02	Water Level	WWD	36.66479	-120.36908	Bi-Annual	986	544-986	180.5	1977-2018	43	1
15S/15E-29K01	Water Level	WWD	36.59583	-120.35703	Bi-Annual	1162	600-1162	190.6	2013-2019	9	1
16S/16E-29E01	Water Level	WWD	36.50897	-120.26163	Bi-Annual	995	675-995	244.8	1992-2018	28	1
17S/18E-33H02	Water Level	WWD	36.40831	-120.01361	Bi-Annual	1340	600-1310	216.9	2014-2019	8	1
18S/17E-09P01	Water Level	WWD	36.37167	-120.13000	Bi-Annual	1187	700-1150	268.0	1991-2018	31	1
19S/16E-35N01	Water Level	WWD	36.22637	-120.20998	Bi-Annual	2035	719-2035	432.9	1978-2018	35	1
19S/17E-28P01	Water Level	WWD	36.24105	-120.13212	Bi-Annual	2018	716-2005	368.0	1987-2018	35	1
19S/18E-04C01	Water Level	WWD	36.31356	-120.02182	Bi-Annual	1620	866-1600	266.9	2008-2018	15	1
19S/19E-29A01	Water Level	WWD	36.25485	-119.92323	Bi-Annual	1423	718-1423	237.9	1990-2018	31	1
20S/17E-09N03	Water Level	WWD	36.19597	-120.13880	Bi-Annual	2100	801-2067	413.9	1976-2018	45	1
20S/19E-17M01	Water Level	WWD	36.18903	-119.94072	Bi-Annual	1000	700-1000	245.9	1989-2018	34	1

1. Location of Site

2. Site adjacent San Luis Canal (California Aqueduct)

3. Elevation at time of installation

Table 3-16: Groundwater Quality Monitoring Network: Upper Aquifer

Well Name	Latitude (NAD83)	Longitude (NAD83)	Monitoring Frequency	Depth (ft bgs)	Perforations (ft bgs)	Ground-Surface Elevation (ft NAVD88)	Period of Record	Number of Measurements	Rationale ^{1,2,3}
22S/18E-11C03 ^a	36.03588	-119.99847	Annual	840	400-840	343	2015-2022	4	1
20S/17E-31K01 ^a	36.14160	-120.16332	Annual	860	200-860	474	-	-	1
14S/15E-20Q01	36.69083	-120.36034	Annual	205	115-205	171	-	-	1,2
15S/13E-05F04	36.65638	-120.57873	Annual	215	199-209	409	1989	1	1,2,3,4
15S/13E-22A01	36.61850	-120.53256	Annual	379	363-373	435	1989	1	1,2,3,4
15S/14E-10A06	36.64697	-120.42445	Annual	582	150-582	225	-	-	1,2
15S/14E-14R01	36.61810	-120.40669	Annual	1055	465-1055	207	-	-	1,2
16S/15E-10M01	36.55198	-120.33427	Annual	560	320-540	239	-	-	1,2
16S/16E-09Q01	36.54519	-120.23450	Annual	580	280-560	195	-	-	1,2
16S/16E-33G01	36.49476	-120.23433	Annual	520	300-520	234	-	-	1,2
17S/17E-16C01	36.45839	-120.13030	Annual	480	270-480	211	-	-	1,2
17S/17E-31N03	36.40062	-120.17558	Annual	780	498-738	253	-	-	1,2
18S/17E-11Q01	36.37182	-120.09403	Annual	630	350-630	257	-	-	1,2,4
18S/18E-28N04	36.32833	-120.03050	Annual	670	300-660	263	-	-	1,2
18S/19E-20F01	36.35013	-119.93664	Annual	604	244-604	226	-	-	1,2
19S/19E-08N04	36.28475	-119.94090	Annual	620	300-620	237	-	-	1,2
19S/19E-26D02	36.25259	-119.88725	Annual	580	300-580	221	-	-	1,2
19S/19E-31N03	36.22663	-119.95370	Annual	N/A	N/A	257	-	-	1,4
20S/17E-29J01	36.15700	-120.13878	Annual	500	350-490	428	-	-	1,4
21S/18E-28Q02	36.01700	-119.97800	Annual	630	400-630	353	1996-2014	14	1,3
21S/19E-07H01	36.11684	-119.95004	Annual	790	286-770	232	-	-	1,2
FC-3 Shallow	36.42991	-120.04924	Annual	665	300-350	214	-	-	1,4

a. SMC is Assigned

1. Well Location

2. Co-located with Groundwater Level Monitoring Site

3. Number of Water Quality Records

4. GQMT Well

Table 3-17: Groundwater Quality Monitoring Network: Lower Aquifer

Well Name	Latitude (NAD83)	Longitude (NAD83)	Monitoring Frequency	Depth (ft bgs)	Perforations (ft bgs)	Ground-Surface Elevation (ft NAVD88)	Period of Record	Number of Measurements	Rationale ^{1,2,3}
17S/18E-33H02 ^a	36.40831	-120.01361	Annual	1340	600-1310	217	-	-	1,2
18S/18E-01R02 ^a	36.38645	-119.95955	Annual	1281	598-1281	218	2018	1	1,2
21S/18E-28G06 ^a	36.07275	-120.02917	Annual	2045	617-2045	335	2015	8	1,3
21S/19E-20D02 ^a	36.09394	-119.94984	Annual	1160	449-1150	226	2021	1	1,2
13S/13E-24E02	36.78538	-120.51260	Annual	860	560-780	223	-	-	1,2
14S/15E-32N02	36.66479	-120.36908	Annual	986	544-986	181	-	-	1,2
15S/12E-13D01	36.62694	-120.61508	Annual	998	698-998	553	-	-	1,2
15S/13E-02P01	36.64960	-120.52410	Annual	1244	884-1244	338	-	-	1,2
15S/14E-31N03	36.57501	-120.49656	Annual	1918	915-1800	373	-	-	1,2
15S/15E-04A03	36.66072	-120.33393	Annual	1000	600-1000	165	-	-	1,2
15S/15E-29K01	36.59583	-120.35703	Annual	1162	600-1162	191	-	-	1,2
16S/14E-36E01	36.49438	-120.40687	Annual	2200	841-2104	478	-	-	1,2
16S/16E-10Q01	36.54539	-120.21163	Annual	965	645-945	188	-	-	1,2
18S/15E-15D01	36.36883	-120.33744	Annual	2583	1788-2488	541	-	-	1,2
18S/17E-09P01	36.37167	-120.13000	Annual	1187	700-1150	268	-	-	1,2
19S/18E-04C01	36.31356	-120.02182	Annual	1620	866-1600	267	-	-	1,2
20S/19E-02A01	36.22586	-119.86996	Annual	2130	869-2090	211	-	-	1,2
20S/19E-17M01	36.18903	-119.94072	Annual	1000	700-1000	246	-	-	1,2
14S/12E-25D01	36.69148	-120.61966	Annual	1001	649-1001	397	1991-2015	7	1,3
16S/14E-11G02	36.55368	-120.41583	Annual	1672	716-1672	312	1992-2009	5	1,3
16S/15E-21L01	36.52295	-120.34341	Annual	1210	670-1190	291	2014-2015	7	1,3
16S/17E-28M02	36.50863	-120.13392	Annual	1040	640-1040	193	2001-2012	4	1,3
17S/16E-01N03	36.47414	-120.19386	Annual	1220	610-1200	217	2014-2015	7	1,3
18S/16E-06F01	36.39410	-120.27433	Annual	2996	1203-2690	323	1992-2015	7	1,3
18S/16E-15N02	36.35657	-120.22958	Annual	2050	763-2009	295	1991-2008	5	1,3
19S/18E-24N01	36.25635	-119.97668	Annual	2114	700-2020	266	1992-2002	4	1,3
20S/17E-14K01	36.18842	-120.09414	Annual	2160	782-2140	367	2013-2015	9	1,3
20S/18E-03N03	36.21153	-120.01250	Annual	1800	800-1800	290	1994-2000	2	1,3
21S/18E-08B01	36.12303	-120.04828	Annual	1570	780-1550	308	2014-2015	7	1,3

a. SMC is Assigned

1. Well Location

2. Co-located with Groundwater Level Monitoring Site

3. Number of Water Quality Records

**Table 3-18: Summary of Groundwater Quality Monitoring
Constituents and Measurement Frequency for
Representative Monitoring Sites**

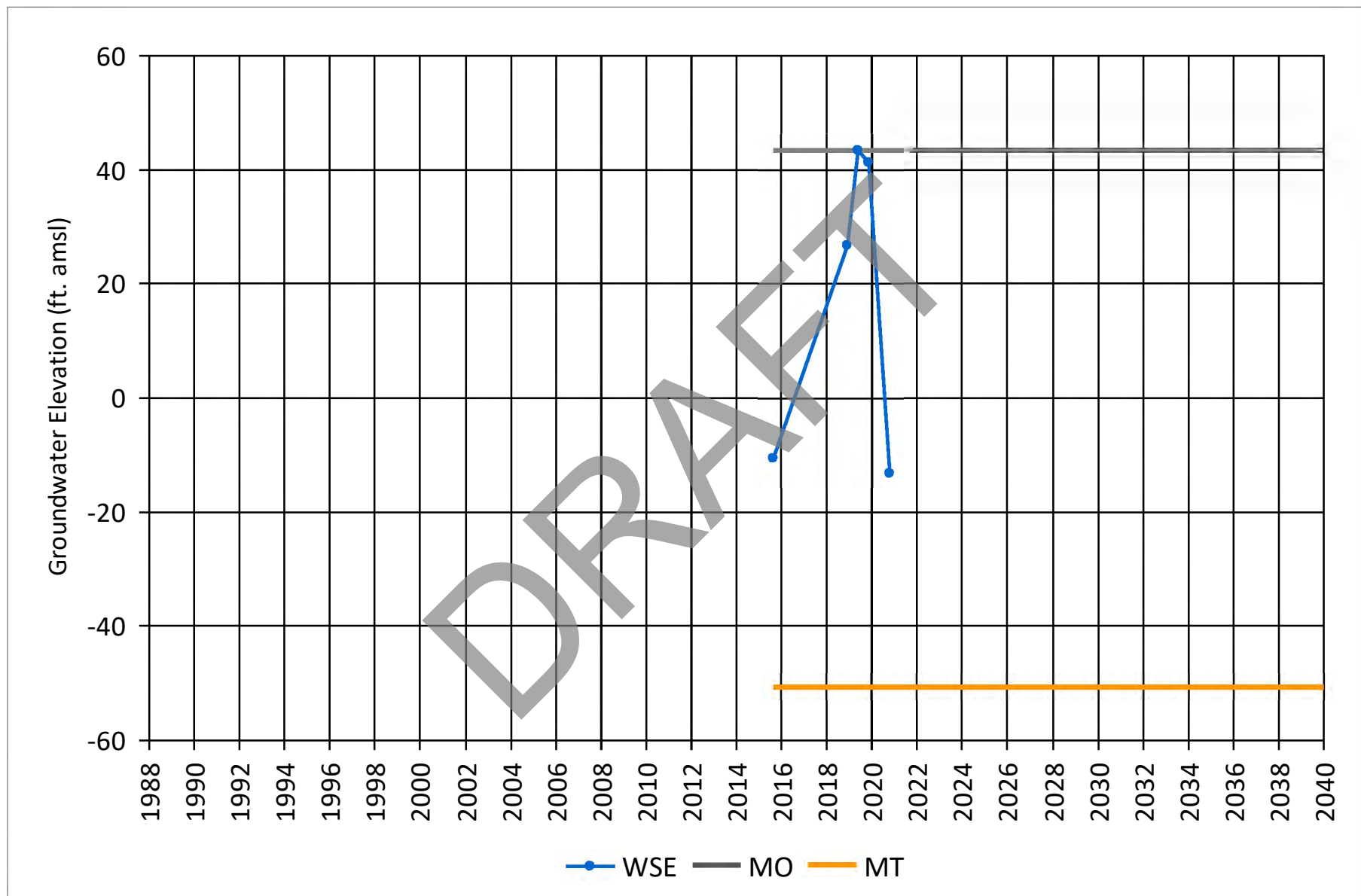
Field Measurements (Annual)	Laboratory Measurements (Annual)	Laboratory Measurements (Five-Year)
Specific Conductance pH Dissolved Oxygen Oxidation-Reduction Potential Temperature	Nitrate TDS	Carbonate Bicarbonate Chloride Sulfate Calcium Sodium Magnesium

DRAFT

Aquifer: Lower
Perforations: 560-780 ft

13S/13E-24E02

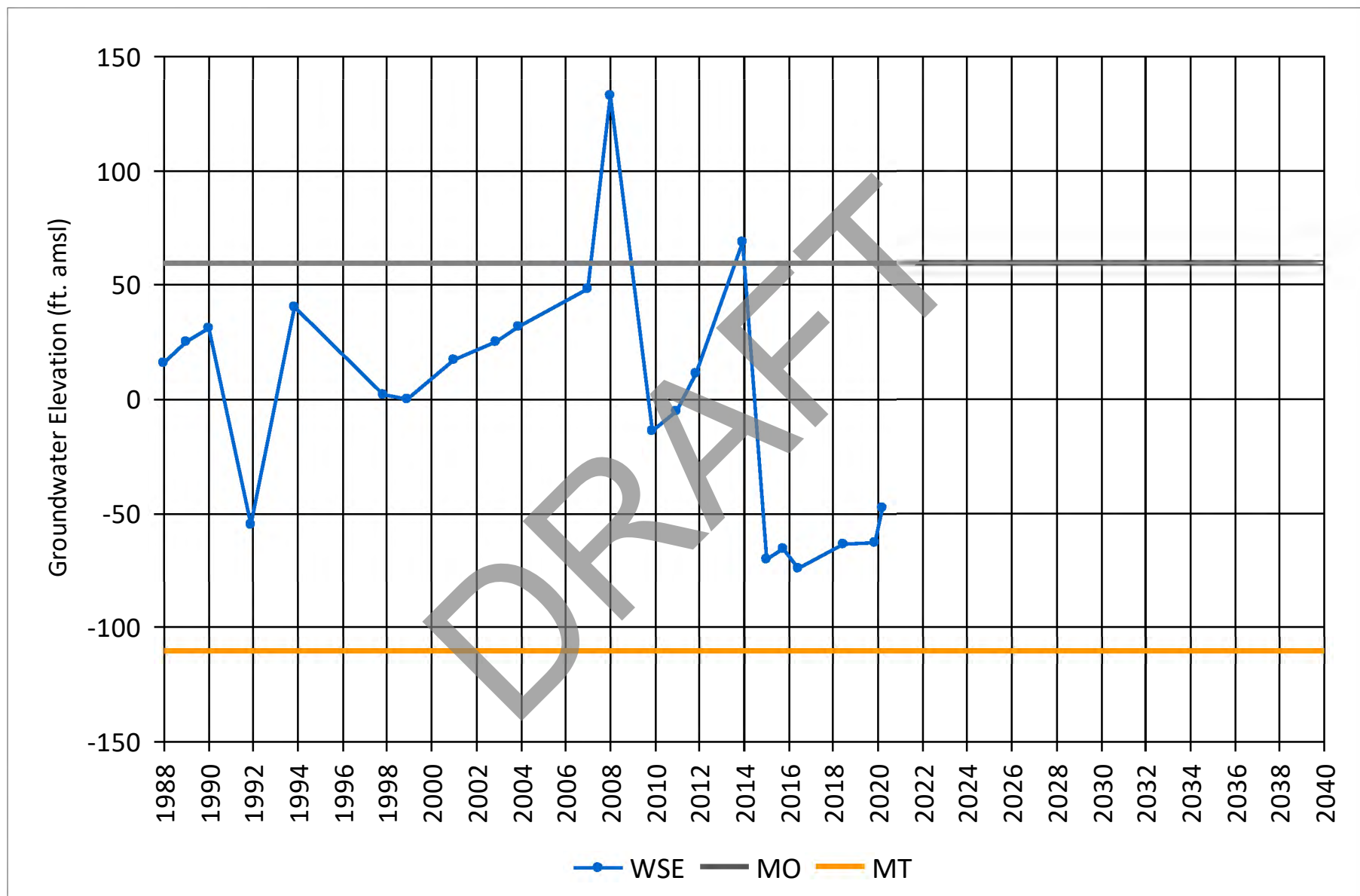
MO: 43.4 MT: -50.7
Depth: 860 ft



Aquifer: Lower
Perforations: 654-1035 ft

14S/12E-35J01

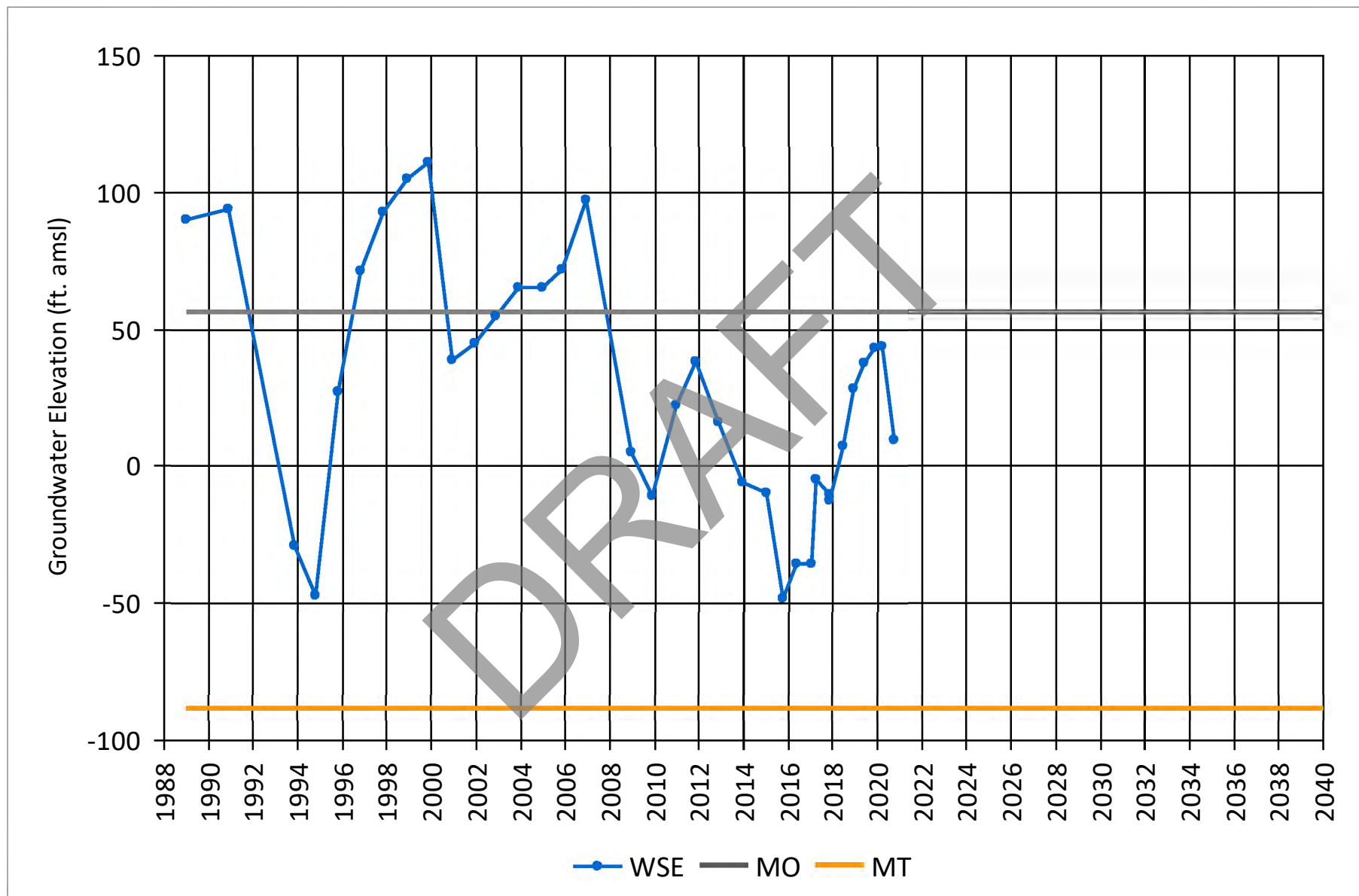
MO: 59.3 MT: -110.2
Depth: 1035 ft



Aquifer: Lower
Perforations: 702-1214 ft

14S/13E-06P02

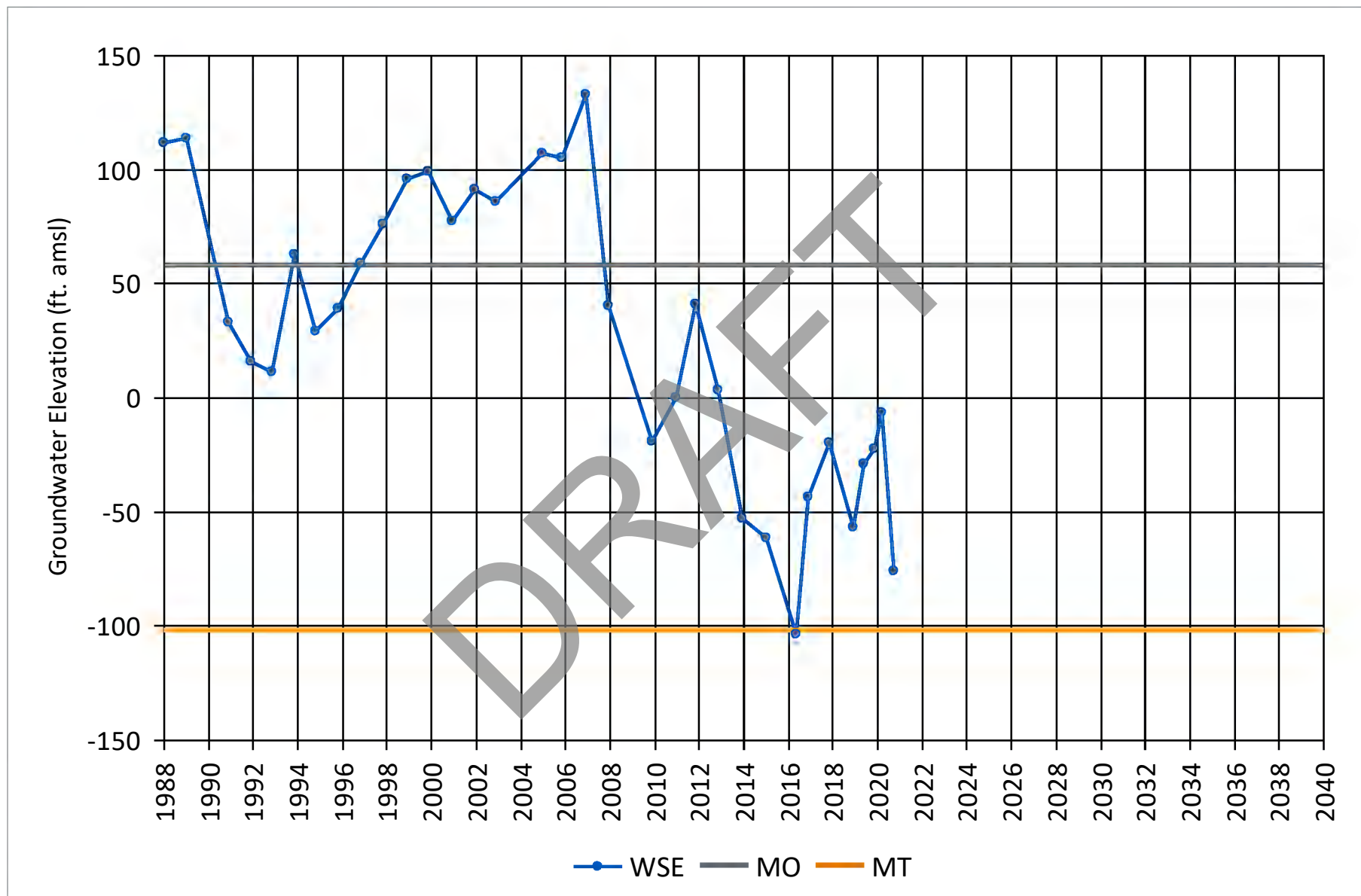
MO: 56.2 MT: -88.5
Depth: 1214 ft



Aquifer: Lower
Perforations: 700-1400 ft

14S/13E-12P01

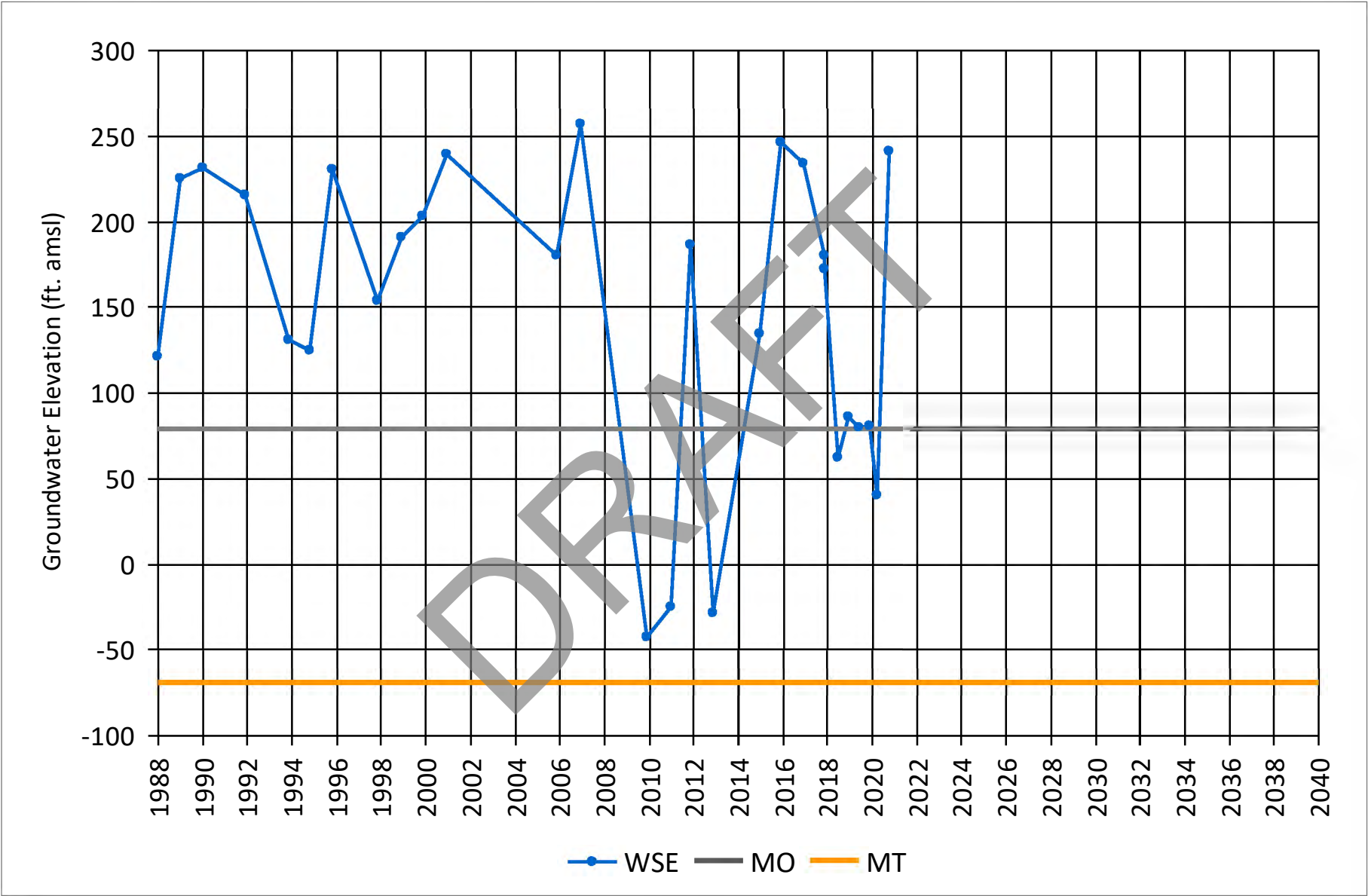
MO: 57.9 MT: -101.5
Depth: 1520 ft



Aquifer: Upper
Perforations: 326-716 ft

14S/13E-23E02

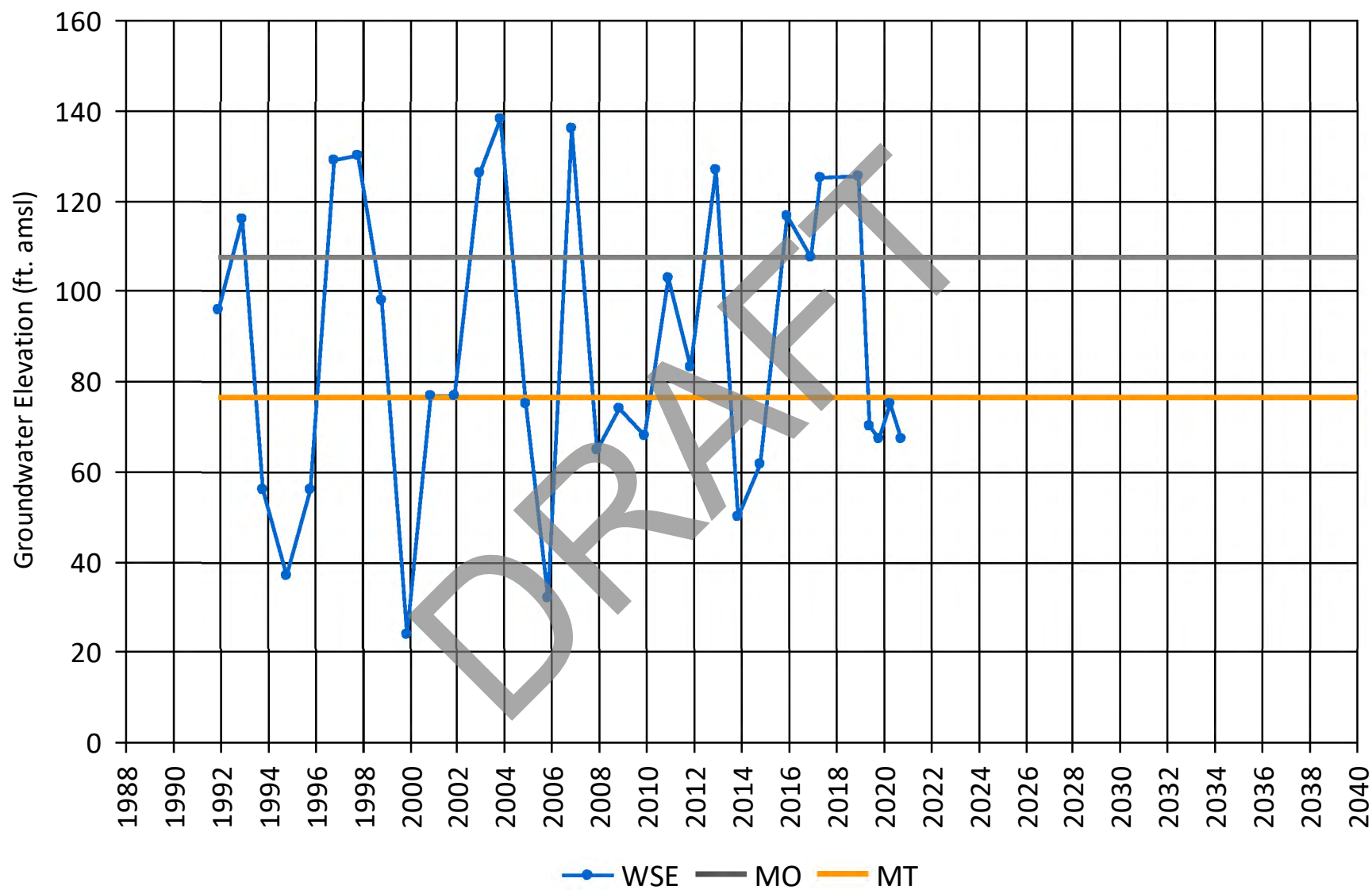
MO: 78.8 MT: -69
Depth: 716 ft



Aquifer: Upper
Perforations: 115-205 ft

14S/15E-20Q01

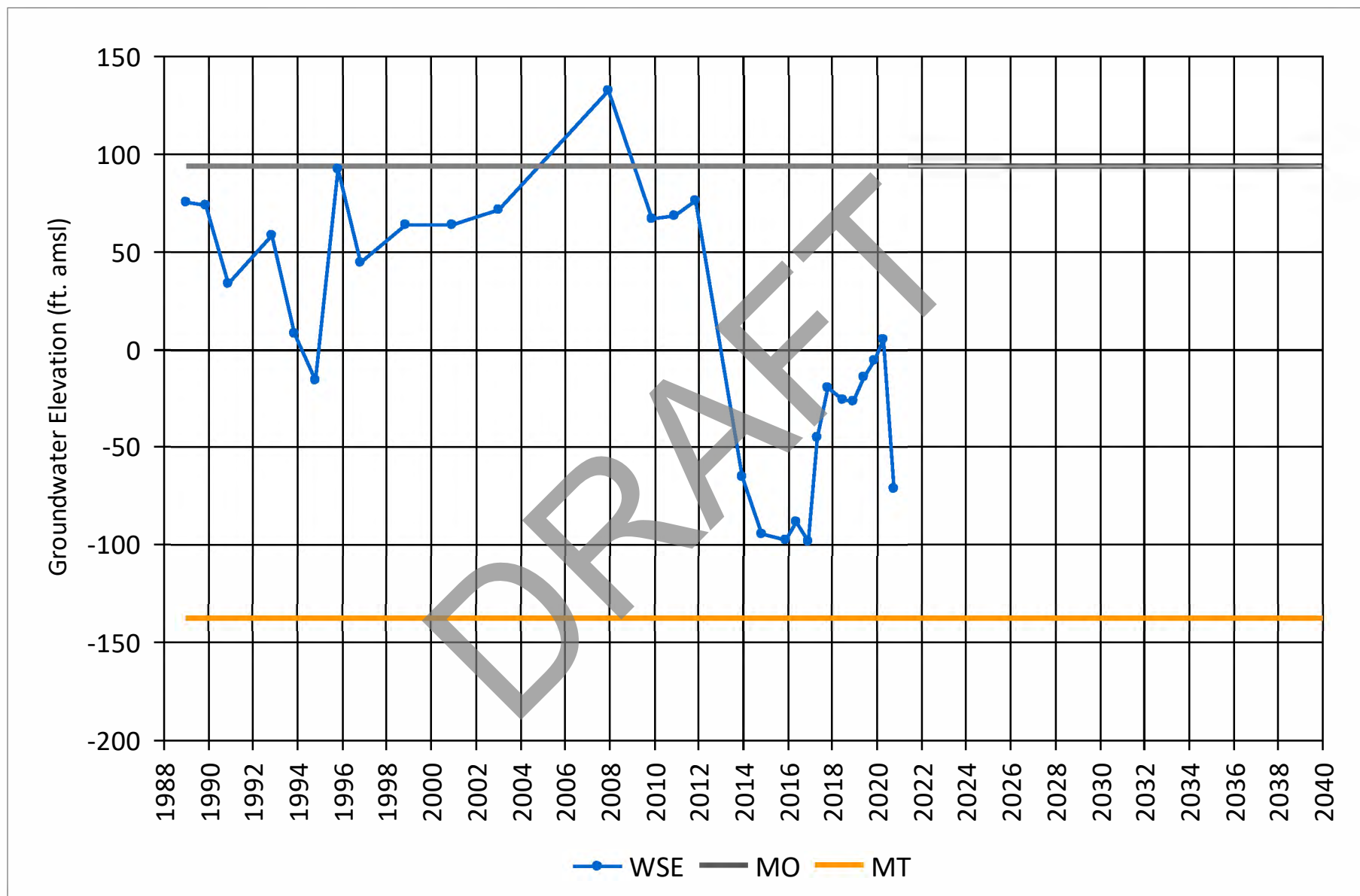
MO: 107.4 MT: 76.5
Depth: 205 ft



Aquifer: Lower
Perforations: 544-986 ft

14S/15E-32N02

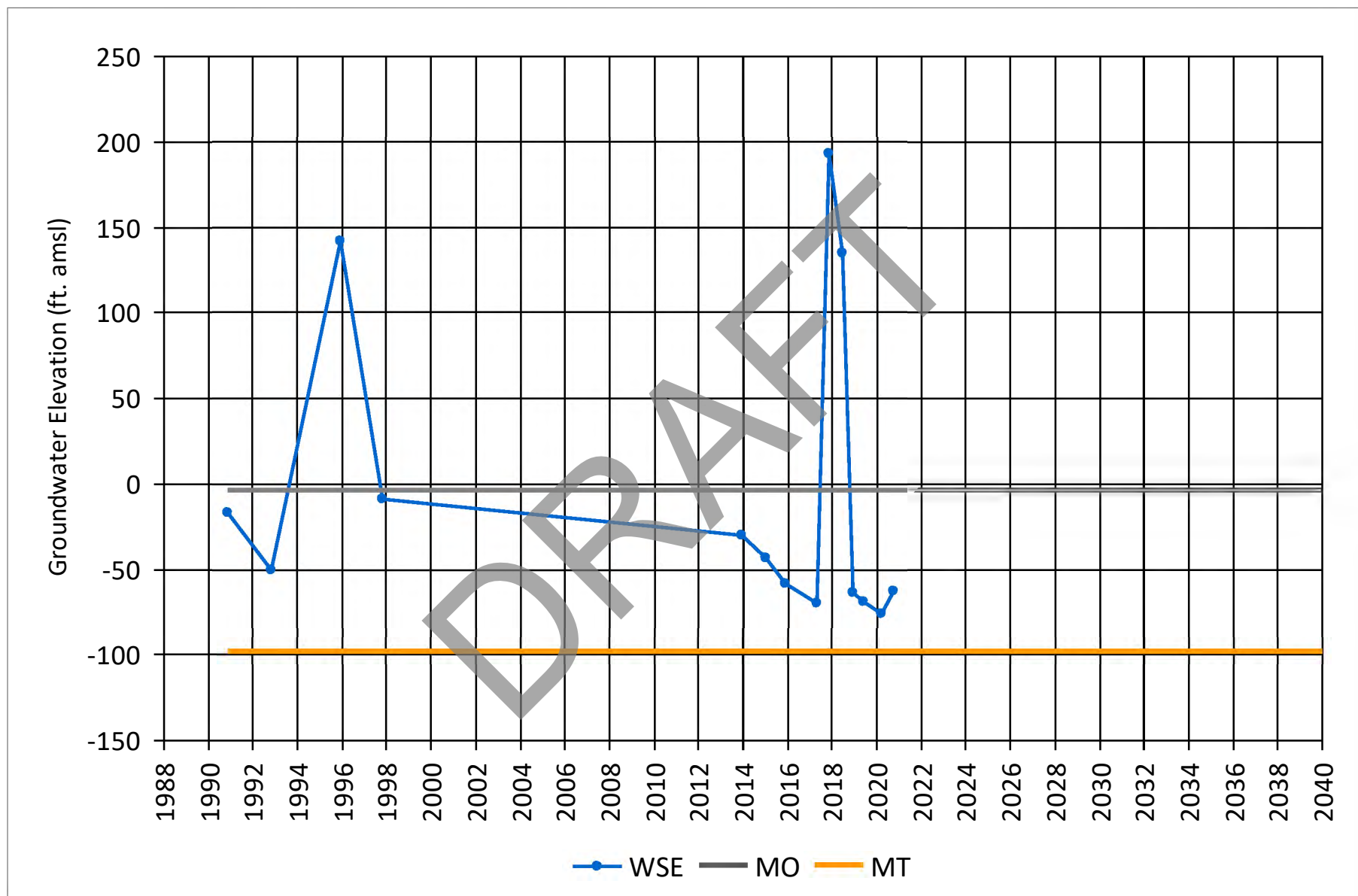
MO: 93.9 MT: -137.5
Depth: 986 ft



Aquifer: Lower
Perforations: 698-998 ft

15S/12E-13D01

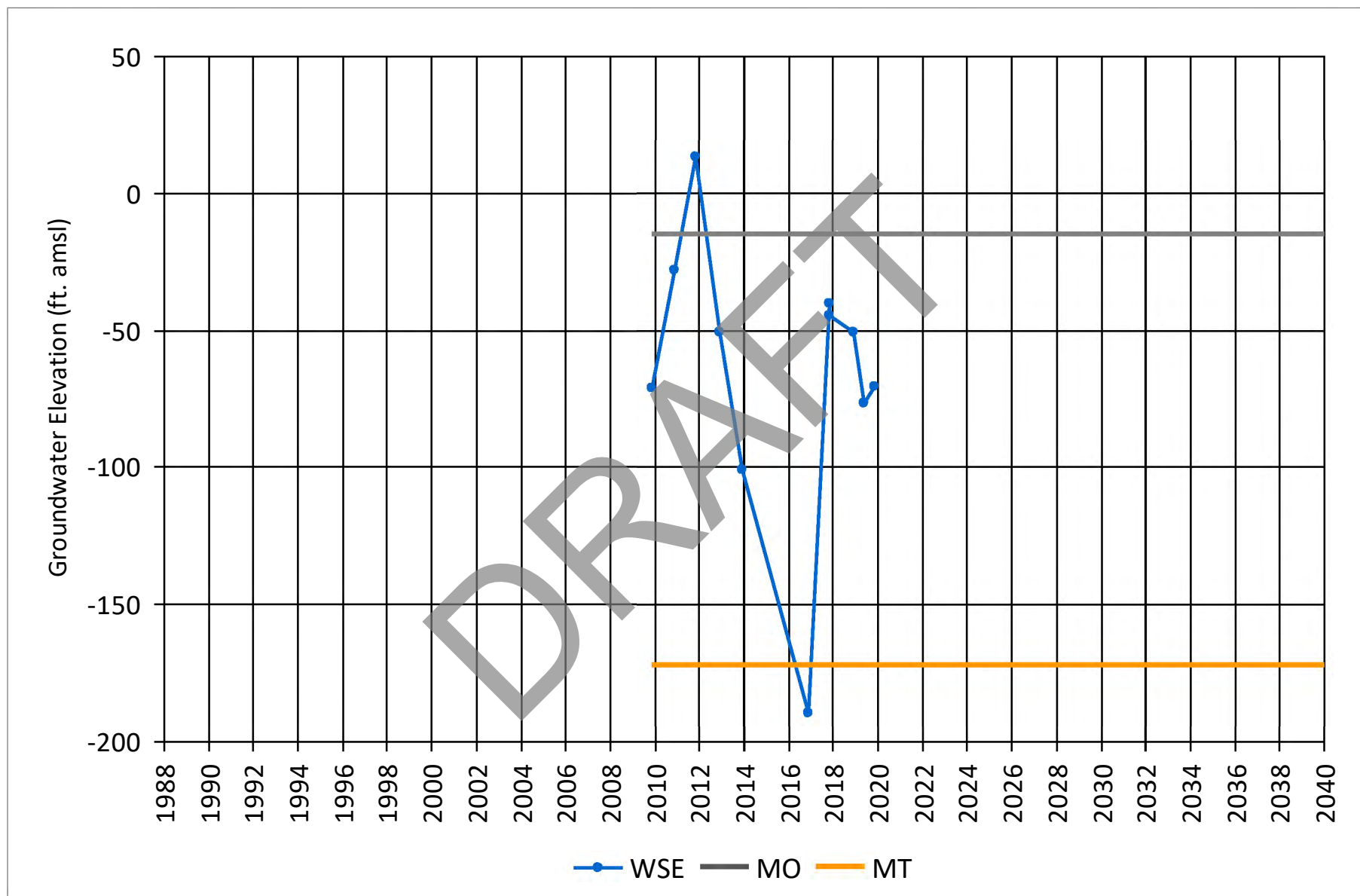
MO: -3.4 MT: -98.2
Depth: 998 ft



Aquifer: Lower
Perforations: 884-1244 ft

15S/13E-02P01

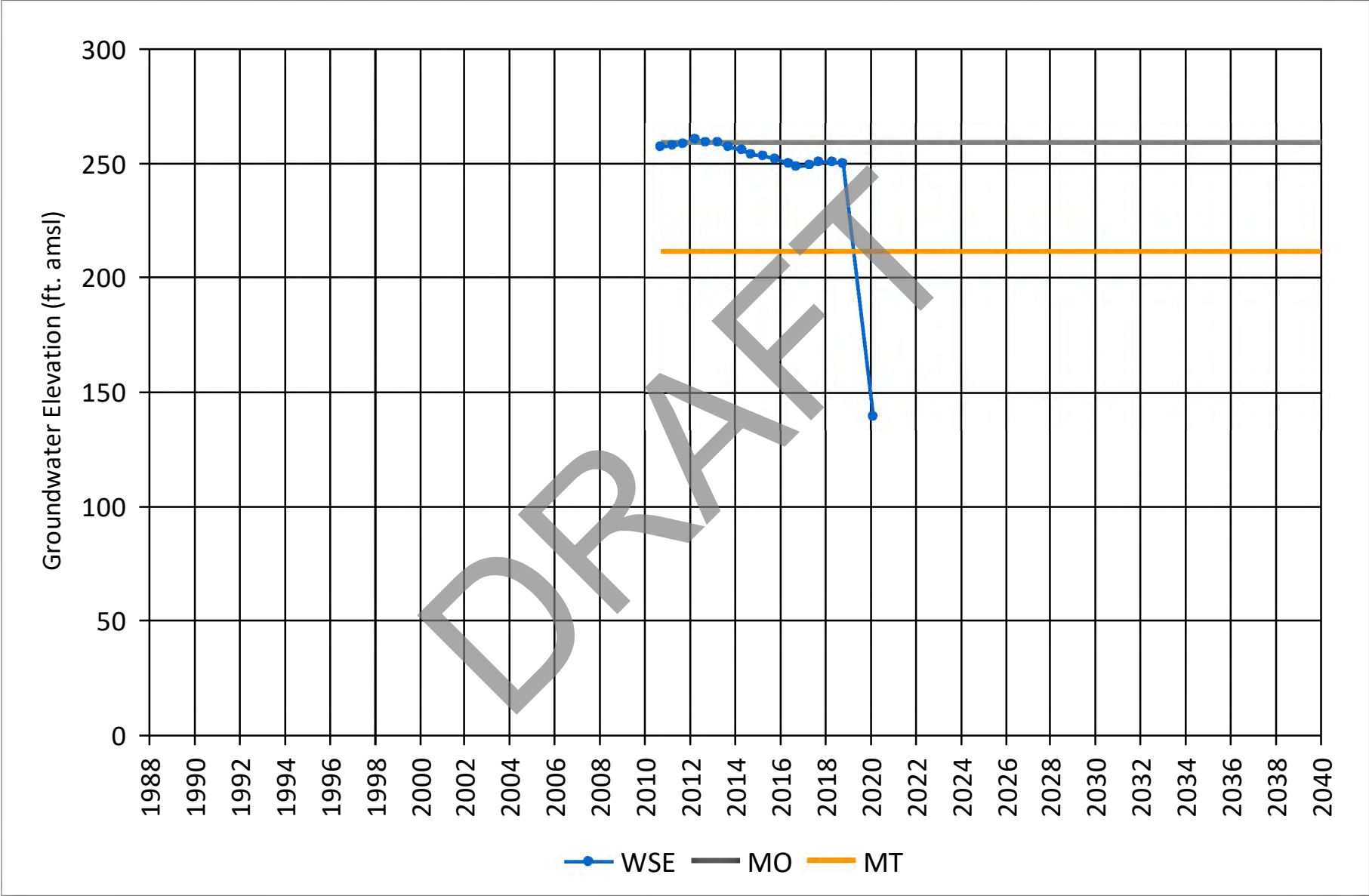
MO: -14.9 MT: -172
Depth: 1244 ft



Aquifer: Upper
Perforations: 199-209 ft

15S/13E-05F04

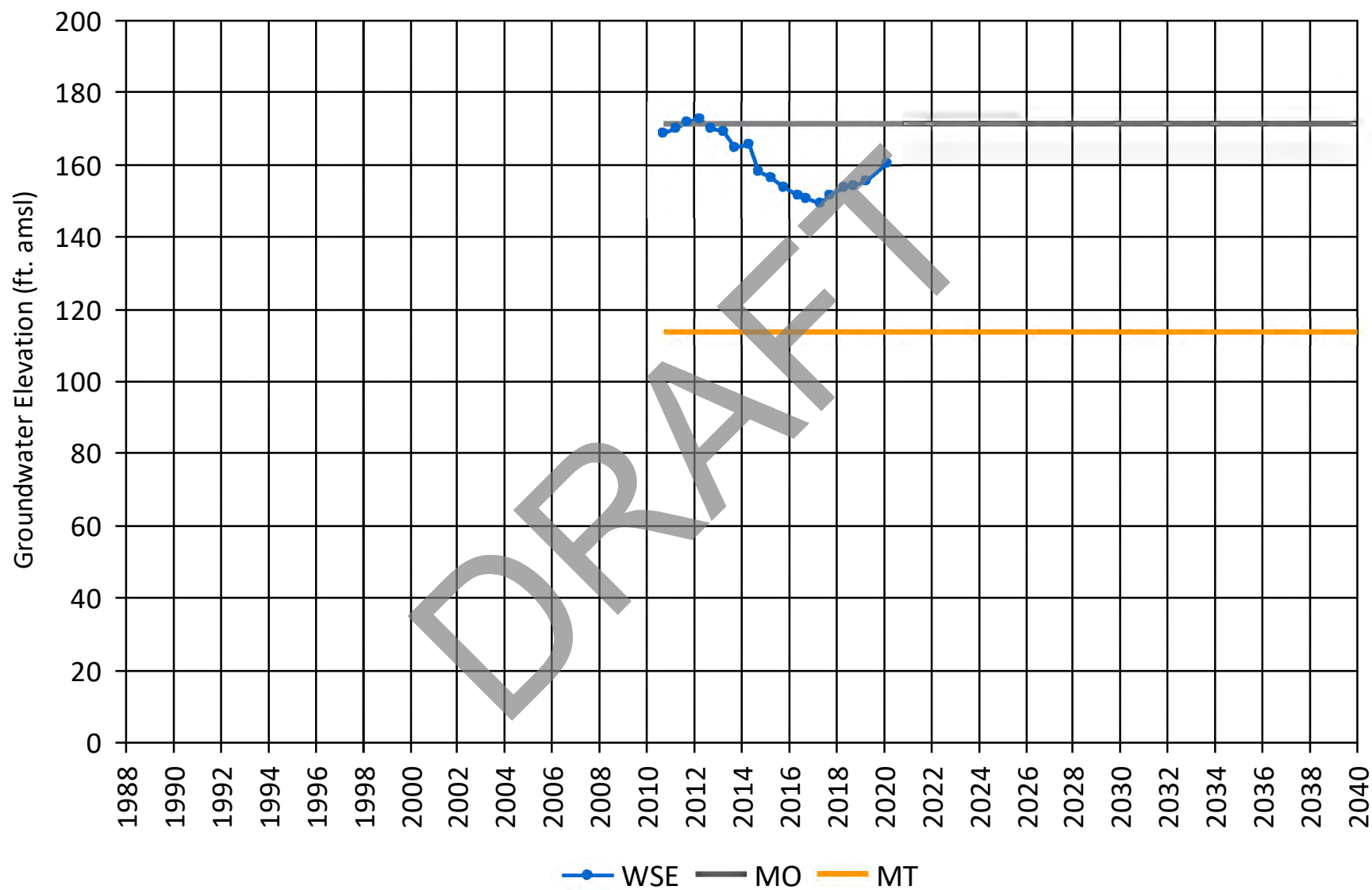
MO: 259.2 MT: 211.4
Depth: 215 ft



Aquifer: Upper
Perforations: 363-373 ft

15S/13E-22A01

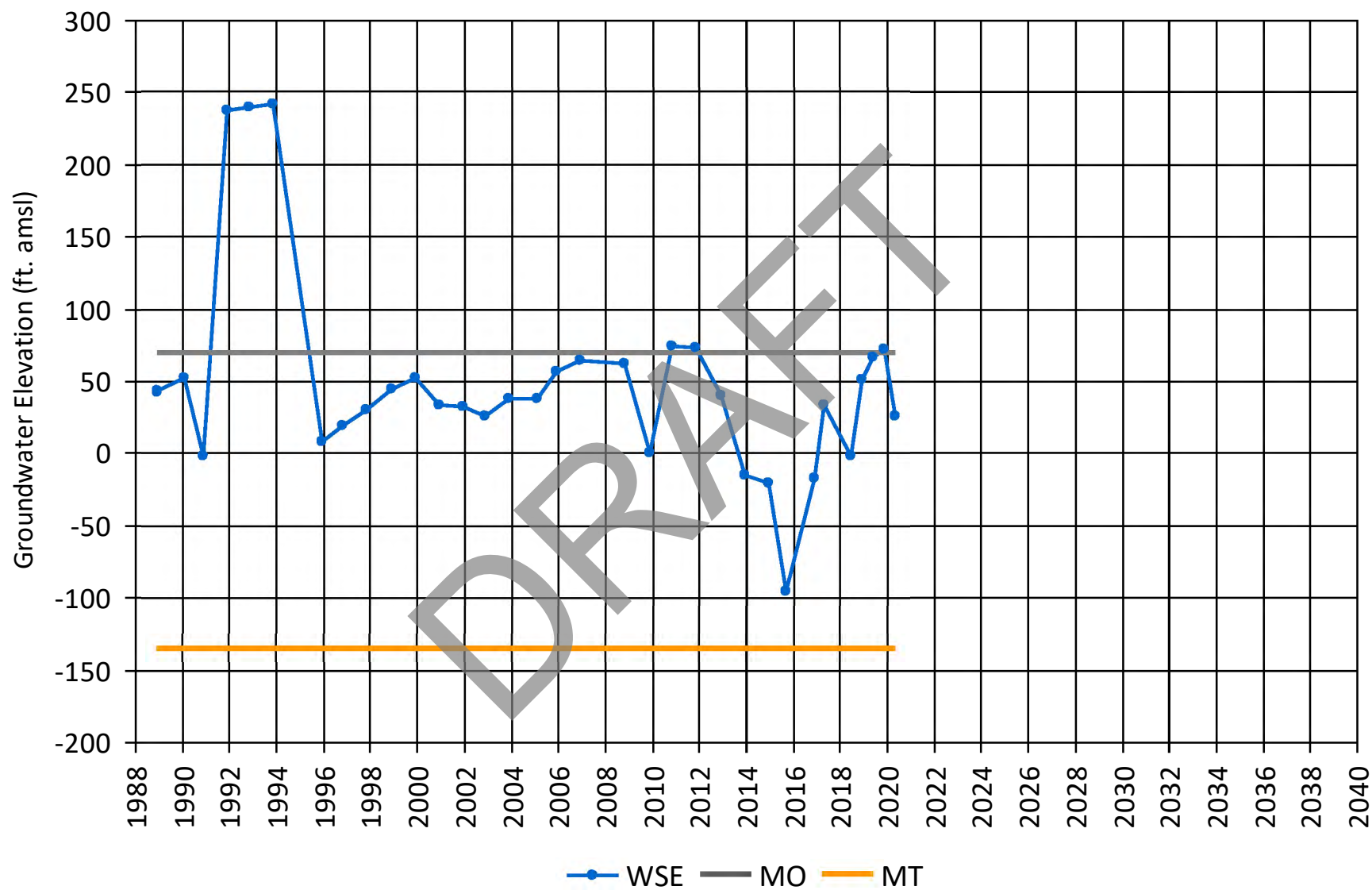
MO: 171.2 MT: 113.6
Depth: 379 ft



Aquifer: Lower
Perforations: 917-1849 ft

15S/13E-24N01

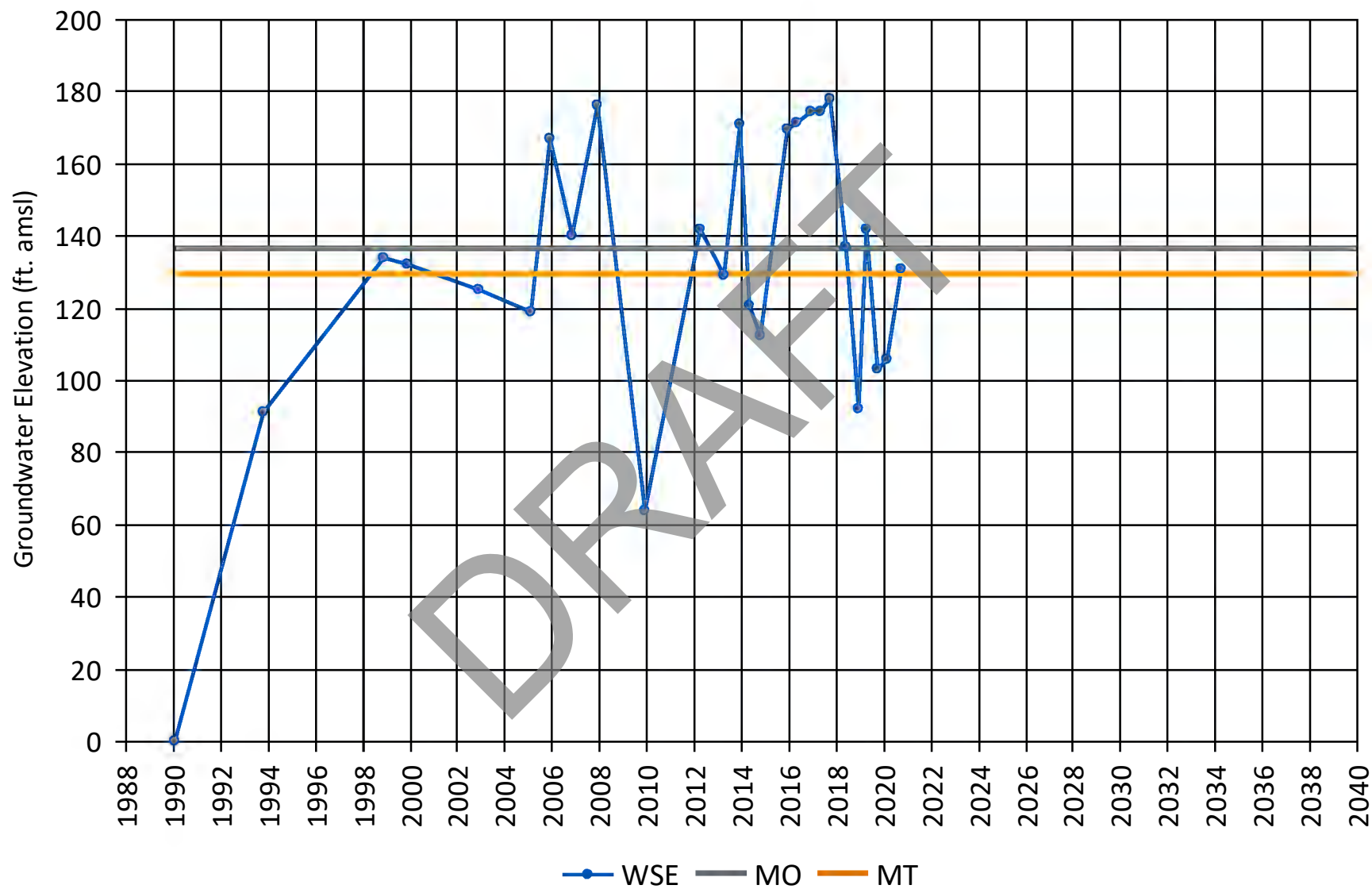
MO: 70.2 MT: -135.3
Depth: 1849 ft



Aquifer: Upper
Perforations: 150-582 ft

15S/14E-10A06

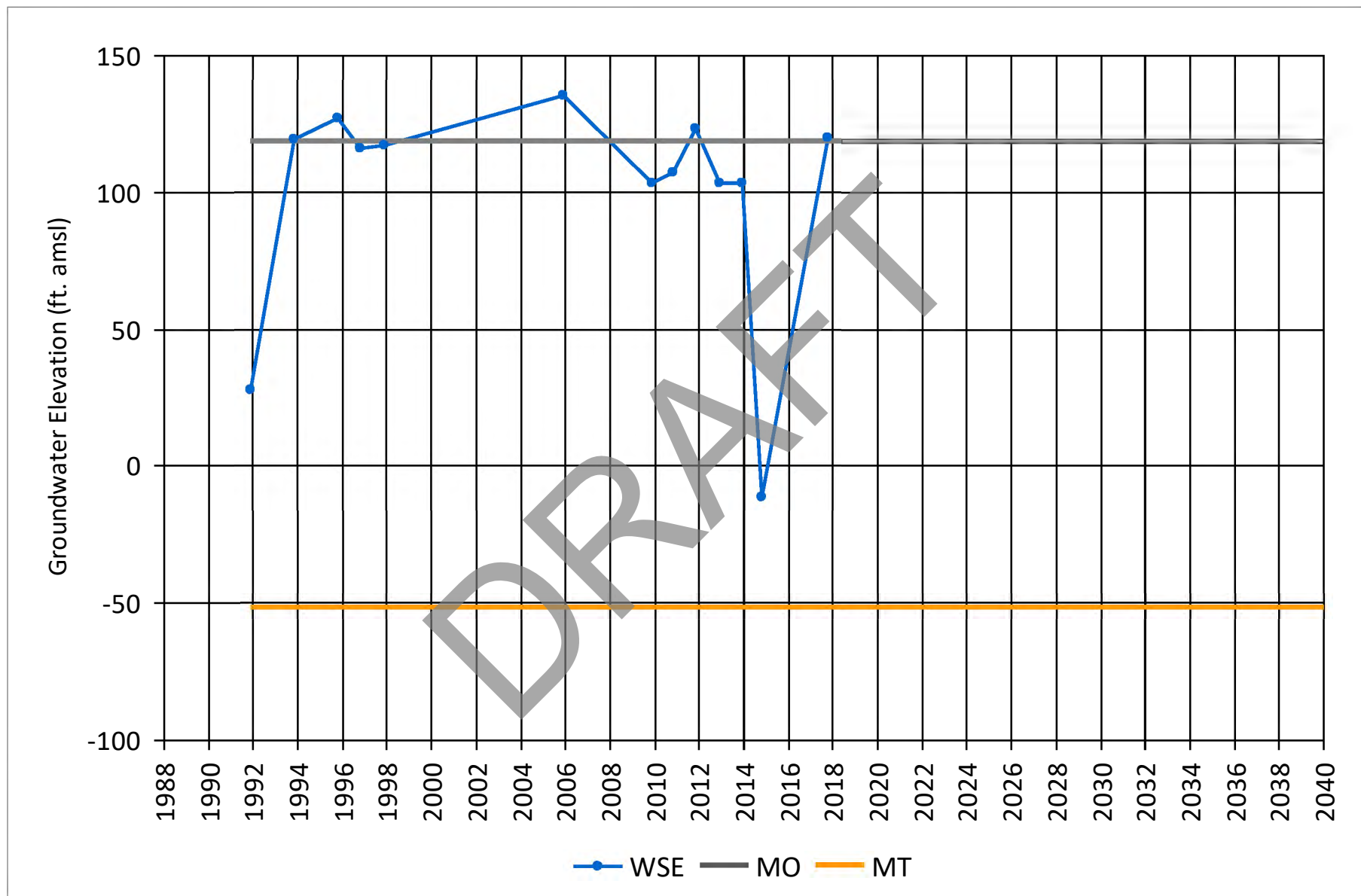
MO: 136.4 MT: 129.5
Depth: 582 ft



Aquifer: Upper
Perforations: 465-1055 ft

15S/14E-14R01

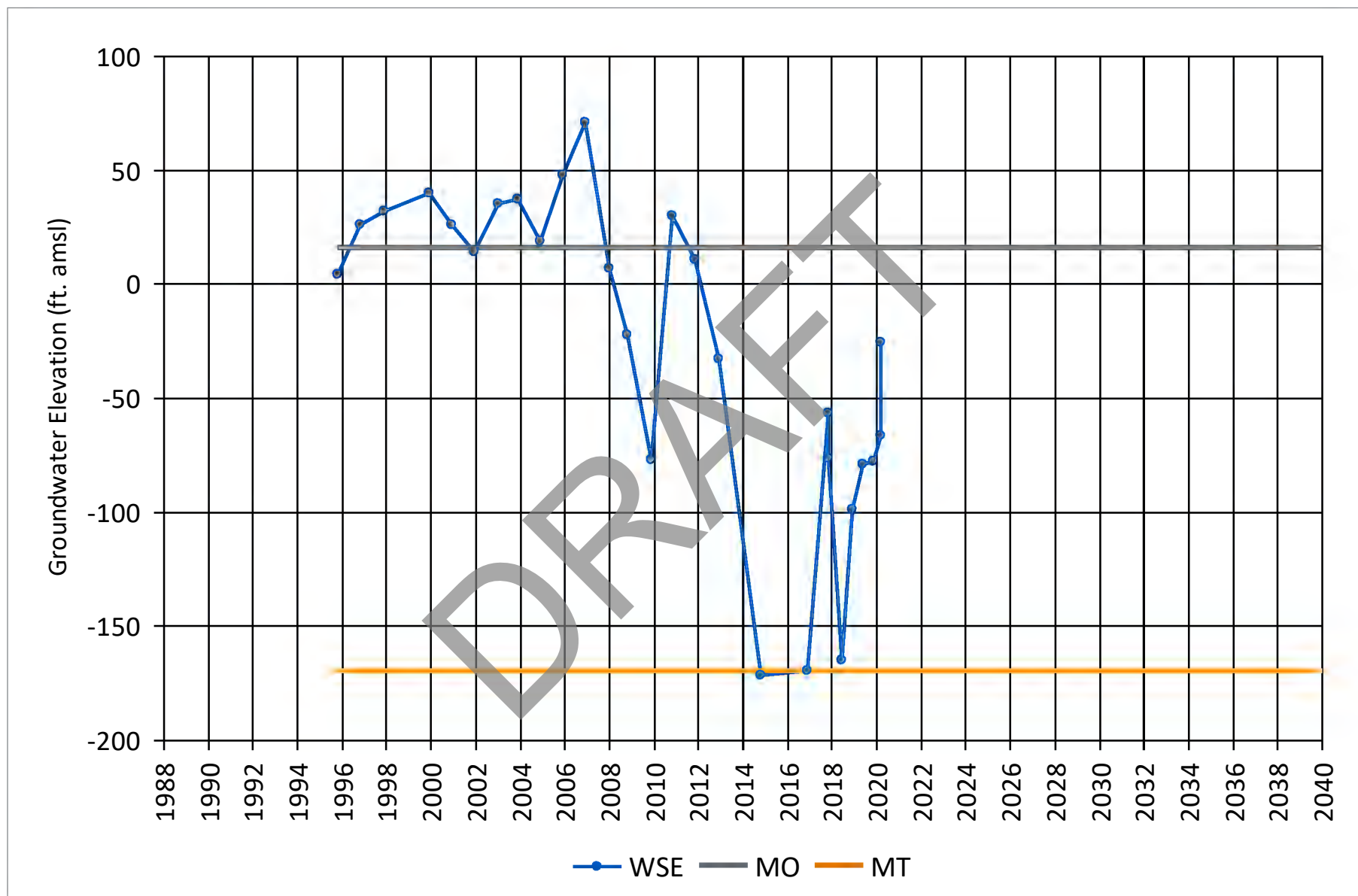
MO: 118.5 MT: -51.4
Depth: 1055 ft



Aquifer: Lower
Perforations: 865-1265 ft

15S/14E-19Q01

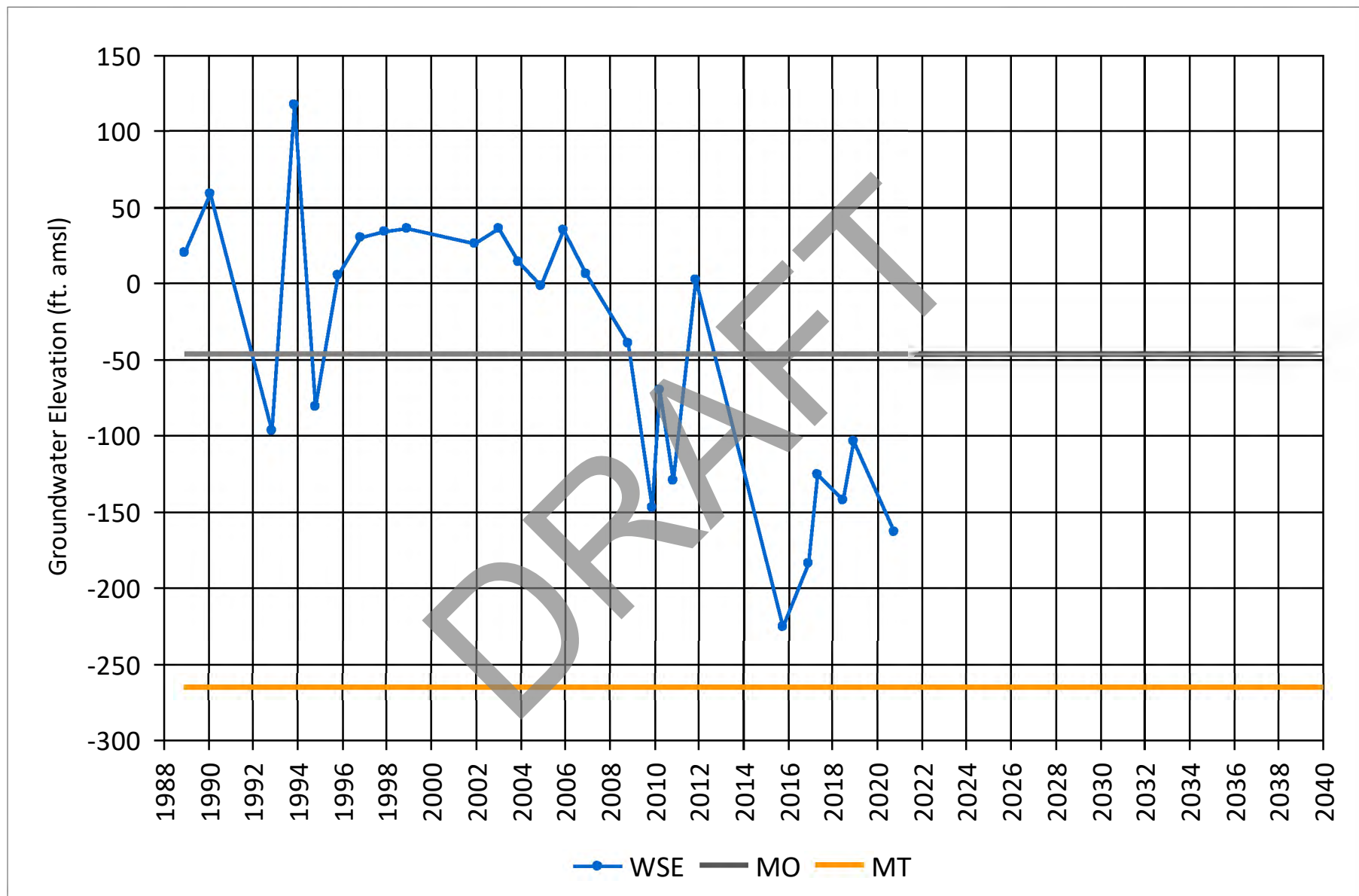
MO: 15.9 MT: -169.4
Depth: 1265 ft



Aquifer: Lower
Perforations: 700-1500 ft

15S/14E-26N02

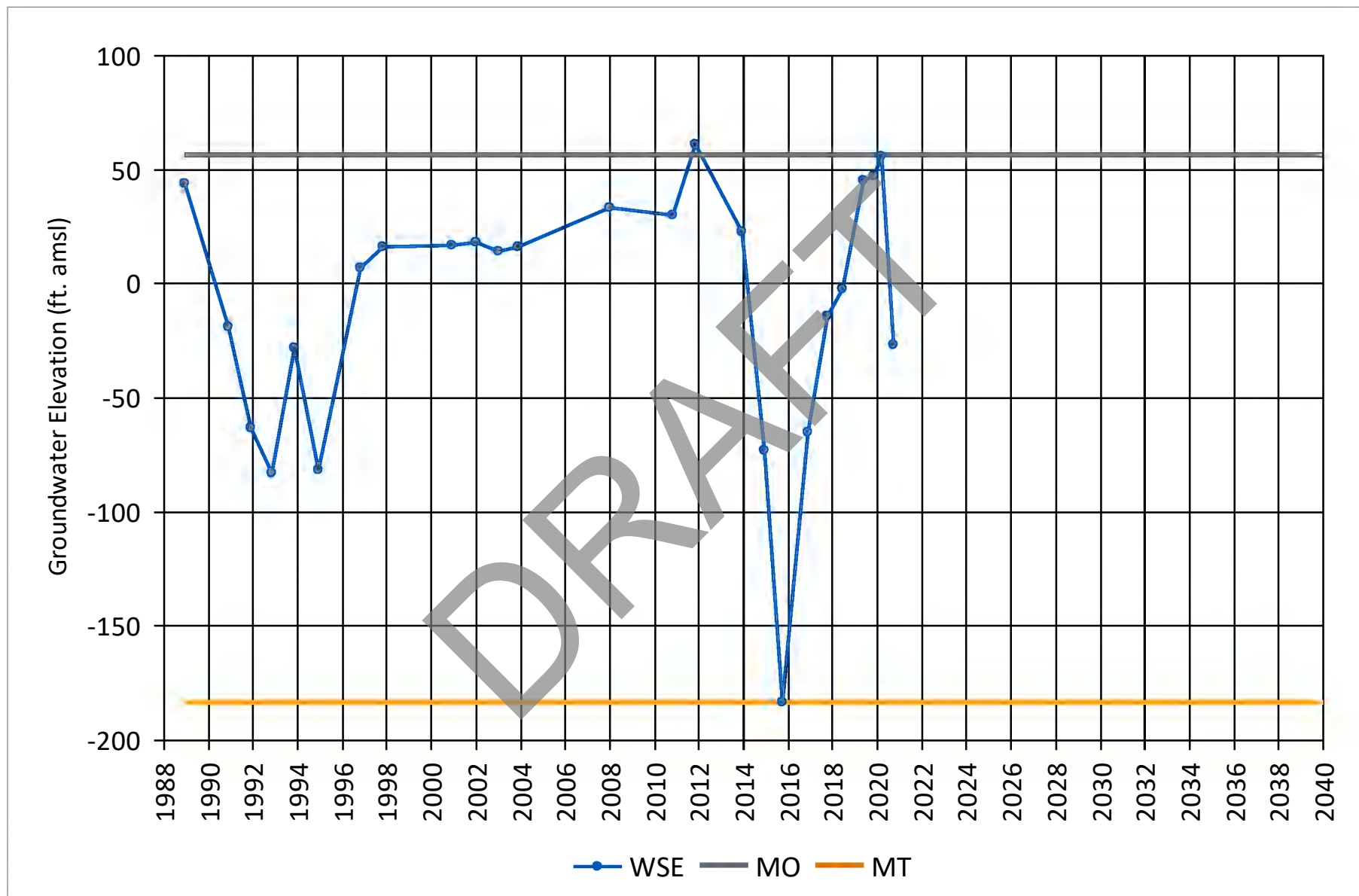
MO: -45.8 MT: -265.3
Depth: 1500 ft



Aquifer: Lower
Perforations: 915-1800 ft

15S/14E-31N03

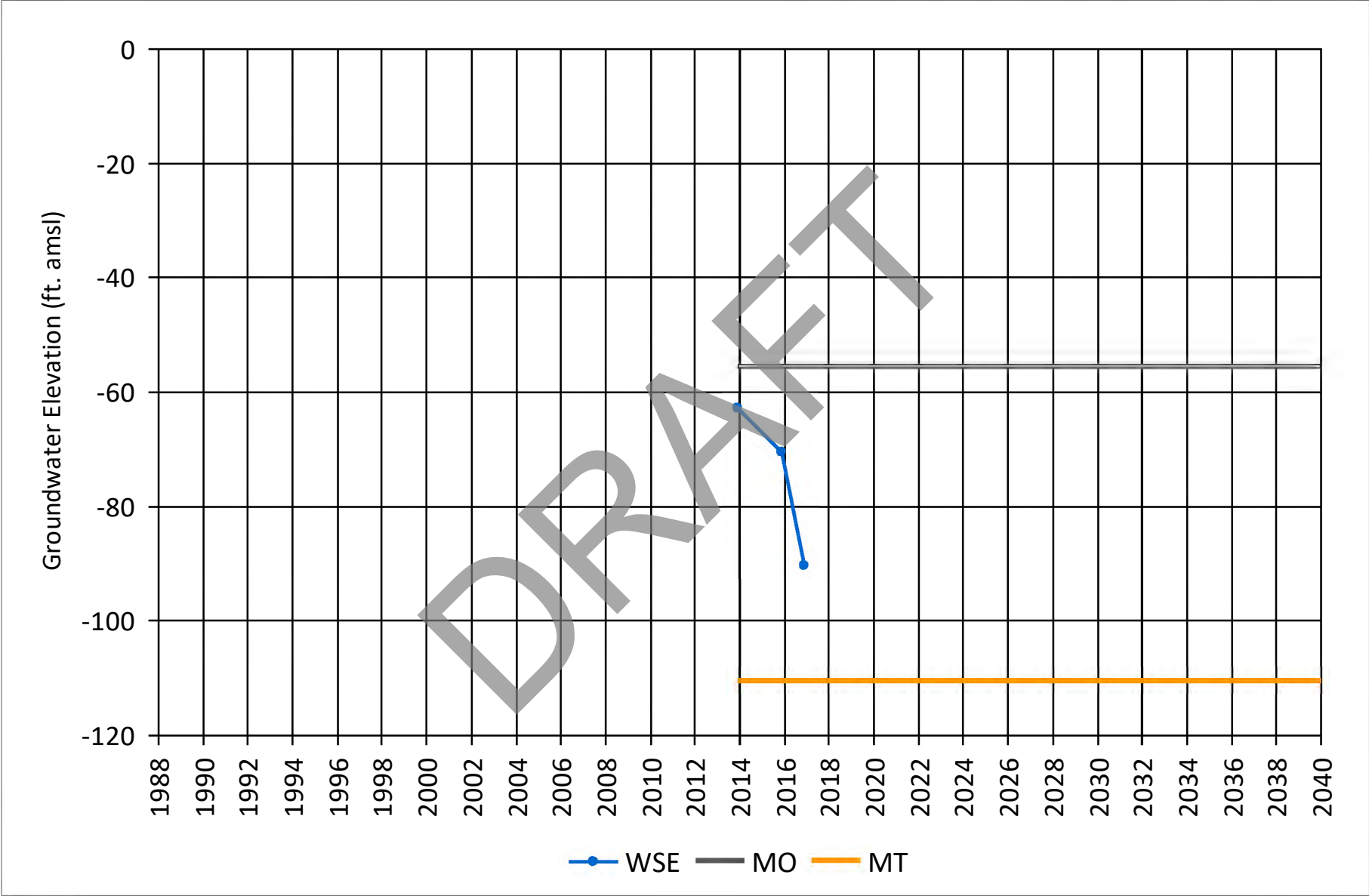
MO: 56.7 MT: -183.2
Depth: 1918 ft



Aquifer: Lower
Perforations: 600-1000 ft

15S/15E-04A03

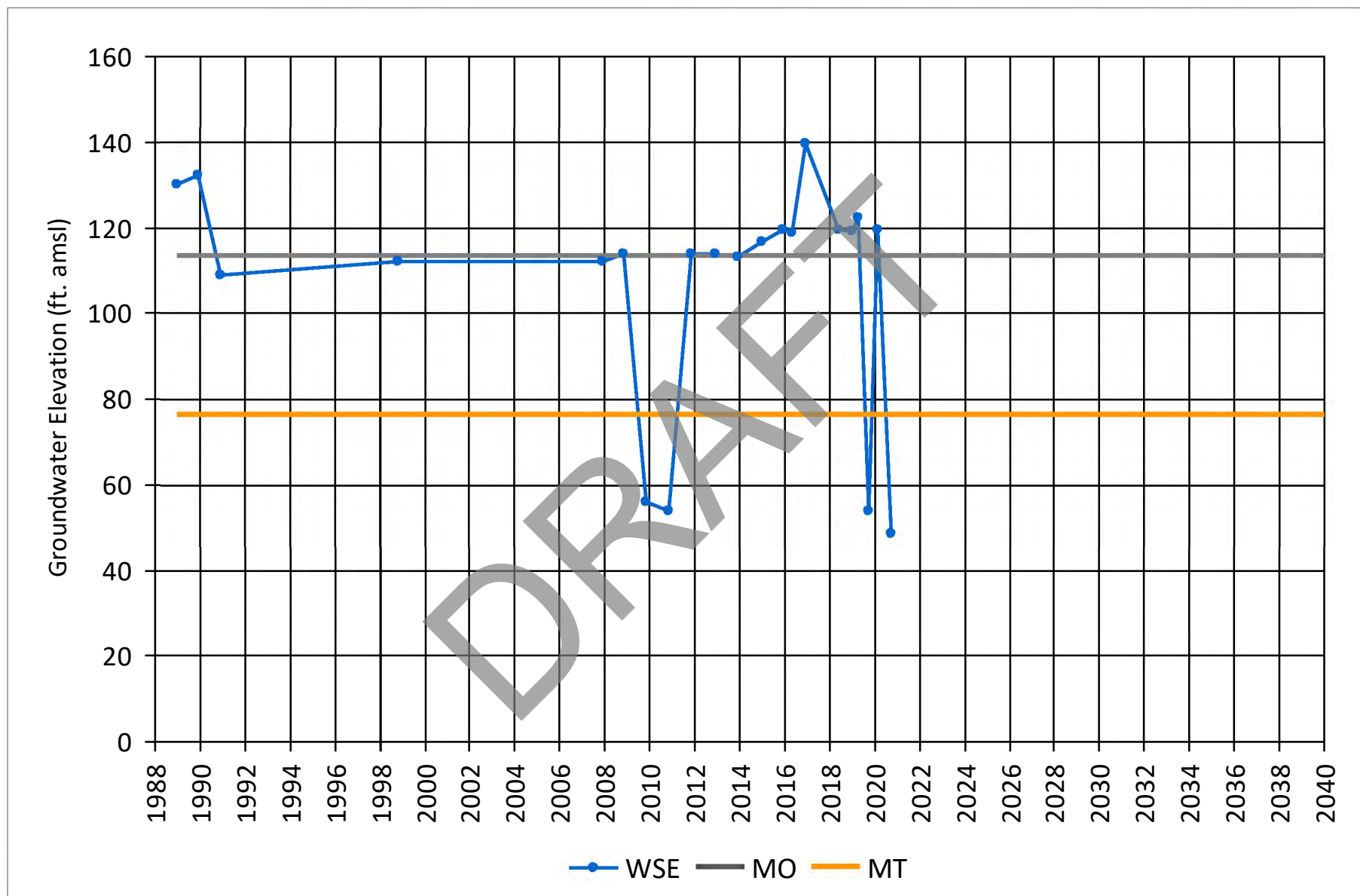
MO: -55.5 MT: -110.5
Depth: 1000 ft



Aquifer: Upper
Perforations: 300-500 ft

15S/15E-16K01

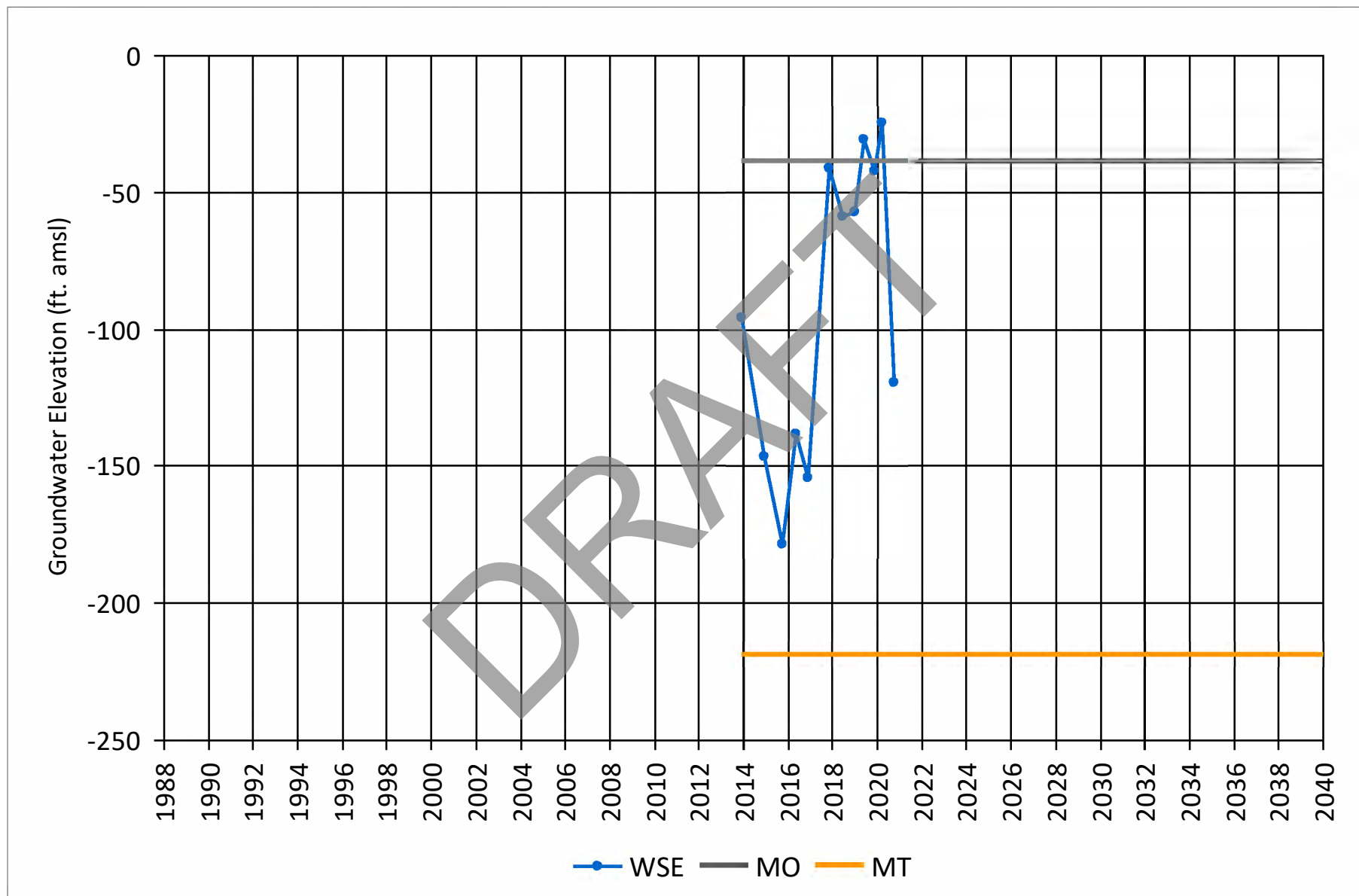
MO: 113.5 MT: 76.6
Depth: 500 ft



Aquifer: Lower
Perforations: 600-1162 ft

15S/15E-29K01

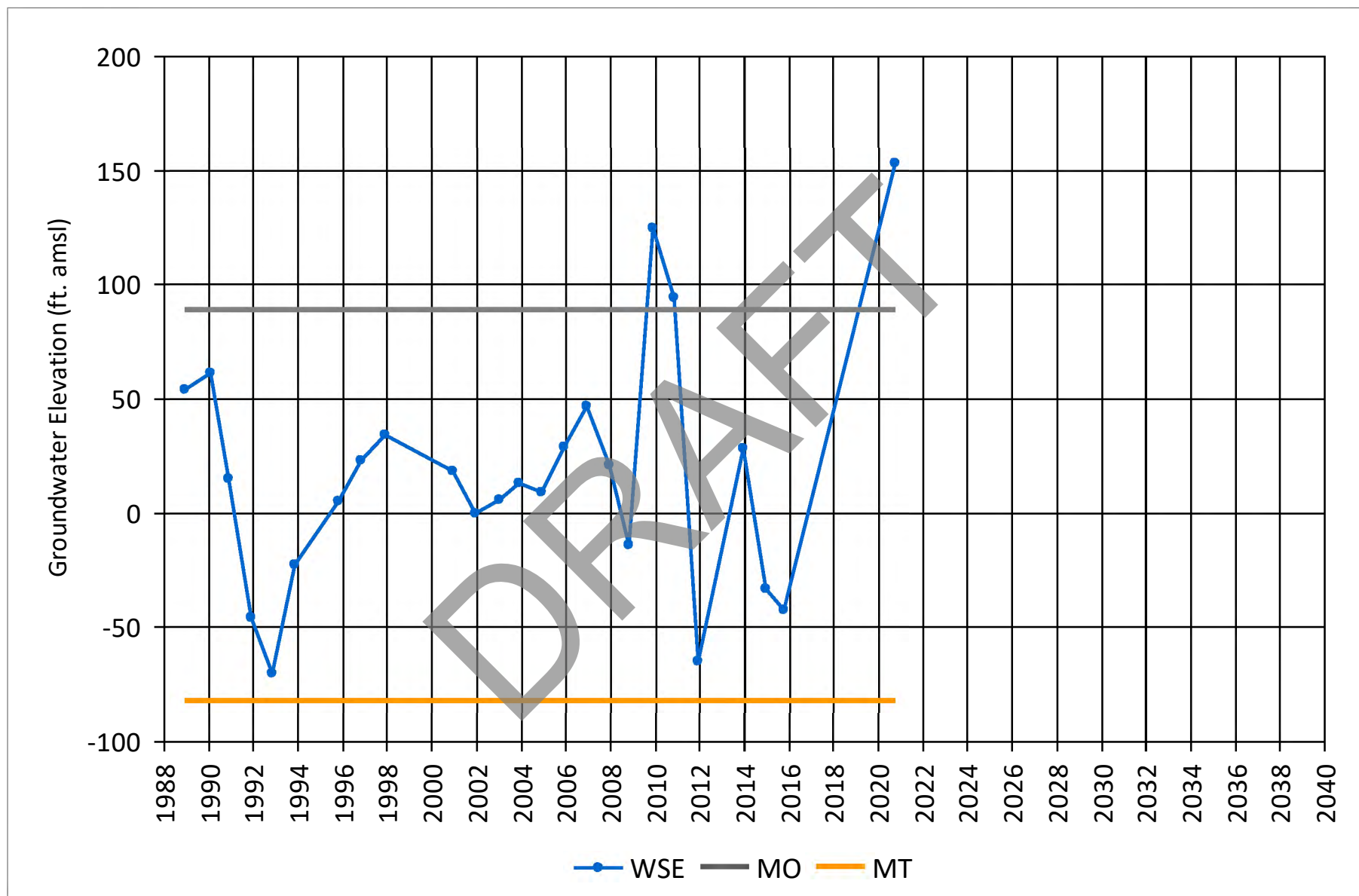
MO: -38.4 MT: -218.4
Depth: 1162 ft



Aquifer: Lower
Perforations: 718-2018 ft

16S/14E-03H01

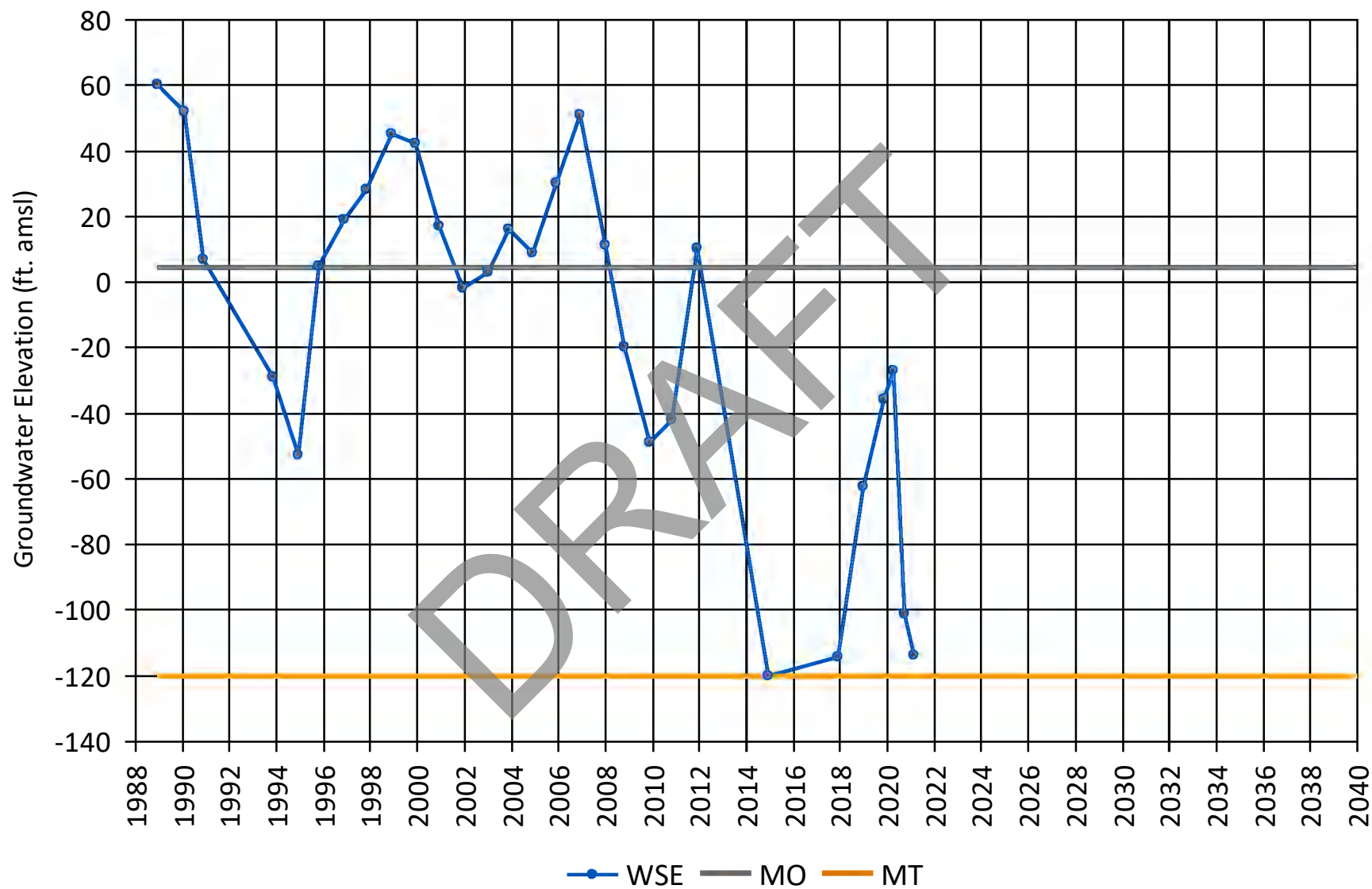
MO: 88.8 MT: -82.3
Depth: 2018 ft



Aquifer: Lower
Perforations: 1000-2803 f

16S/14E-14F01

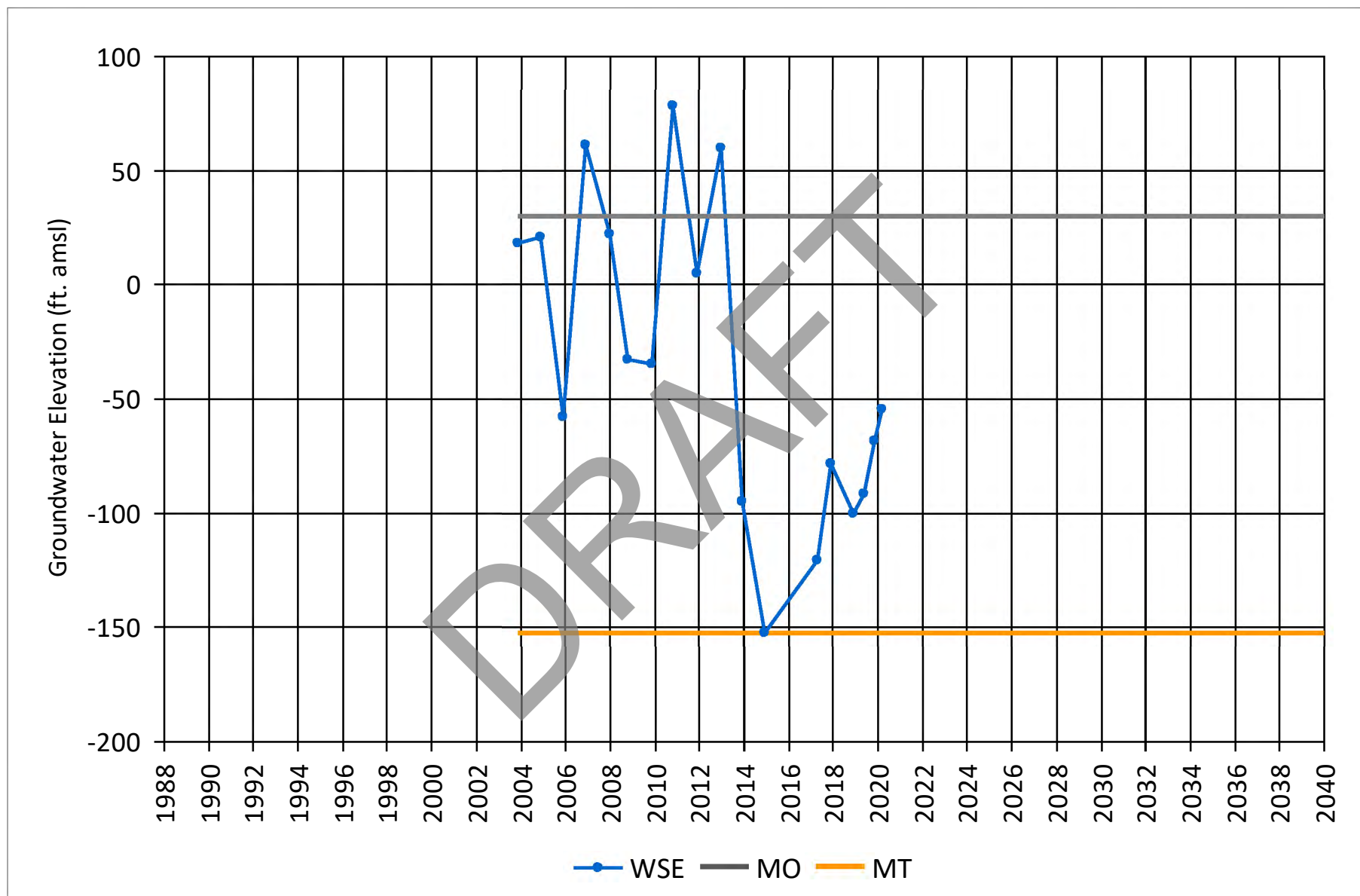
MO: 4.6 MT: -120.2
Depth: 2803 ft



Aquifer: Lower
Perforations: 930-2210 ft

16S/14E-17A01

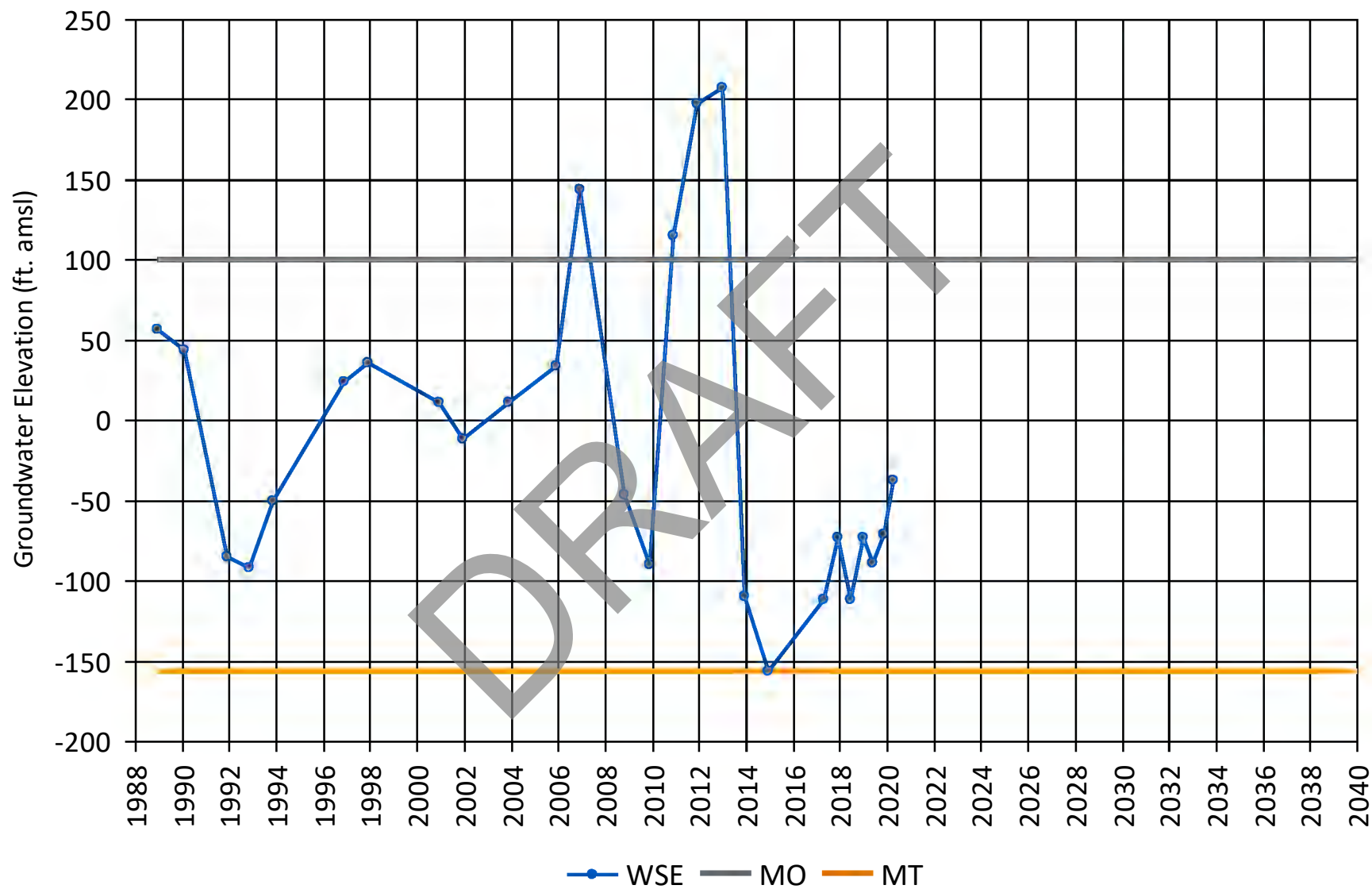
MO: 29.7 MT: -152.1
Depth: 2230 ft



Aquifer: Lower
Perforations: 841-2104 ft

16S/14E-36E01

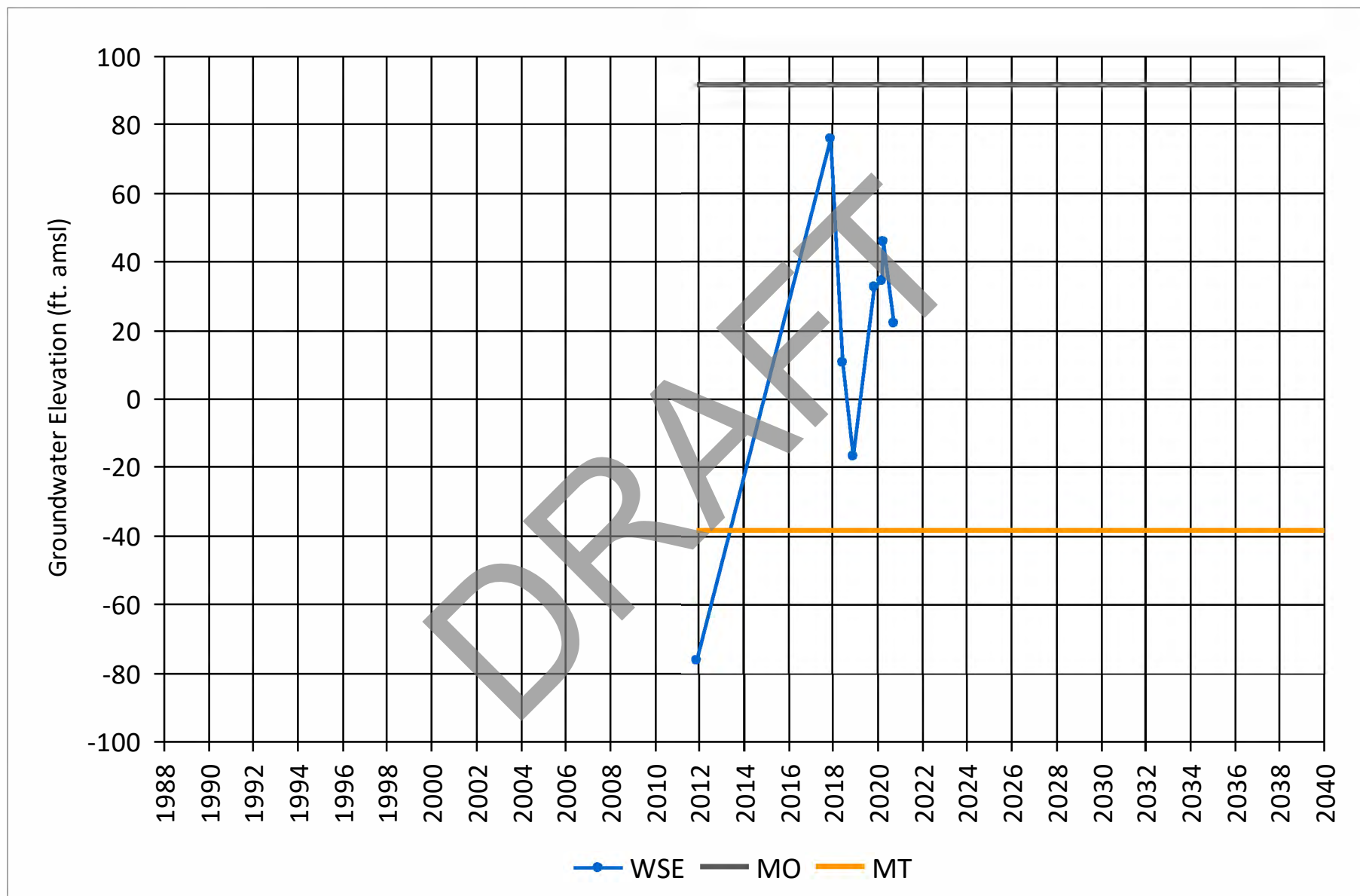
MO: 100 MT: -156.1
Depth: 2200 ft



Aquifer: Upper
Perforations: 320-540 ft

16S/15E-10M01

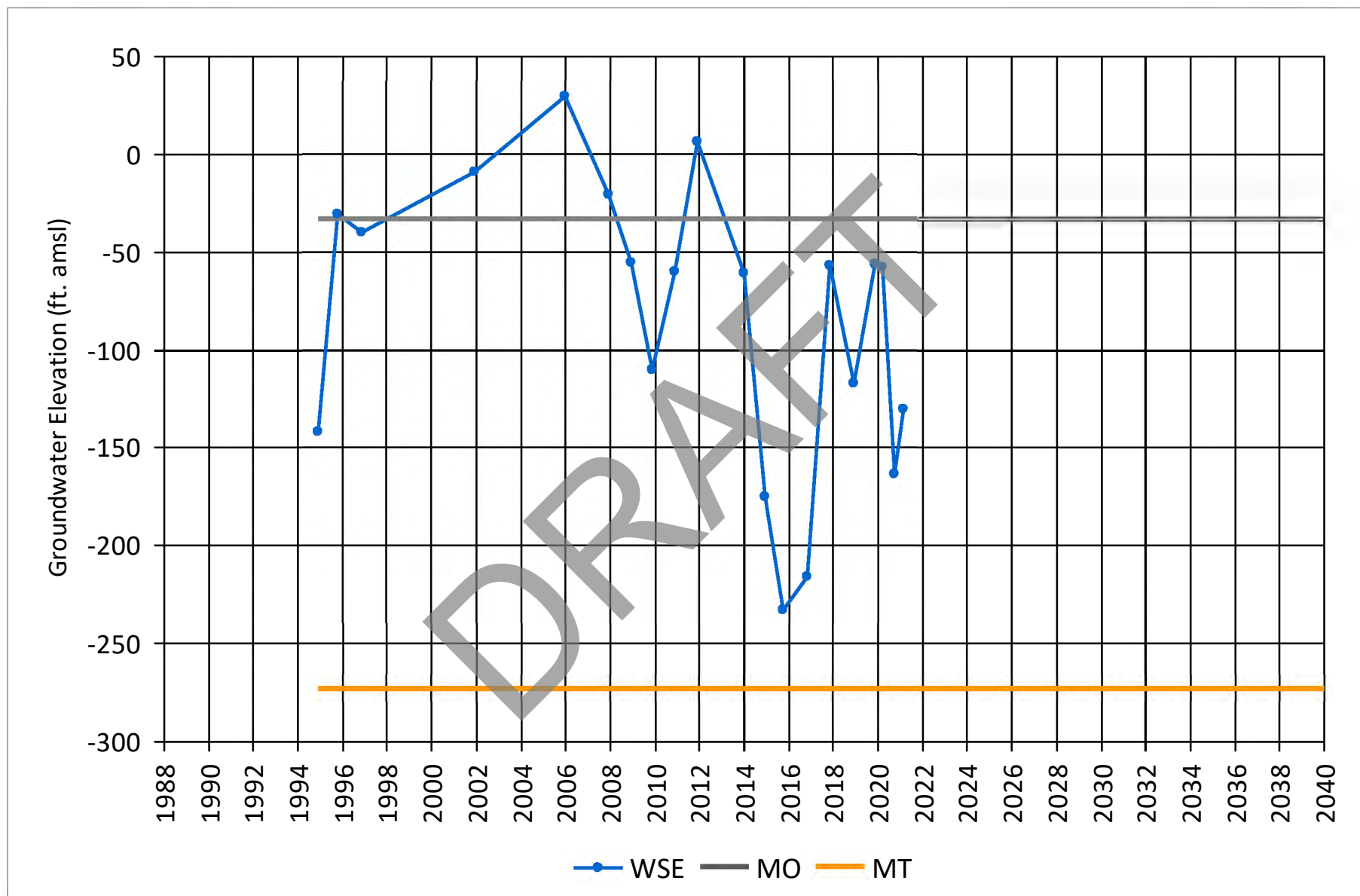
MO: 91.5 MT: -38.4
Depth: 560 ft



Aquifer: Lower
Perforations: 840-1200 ft

16S/15E-16E01

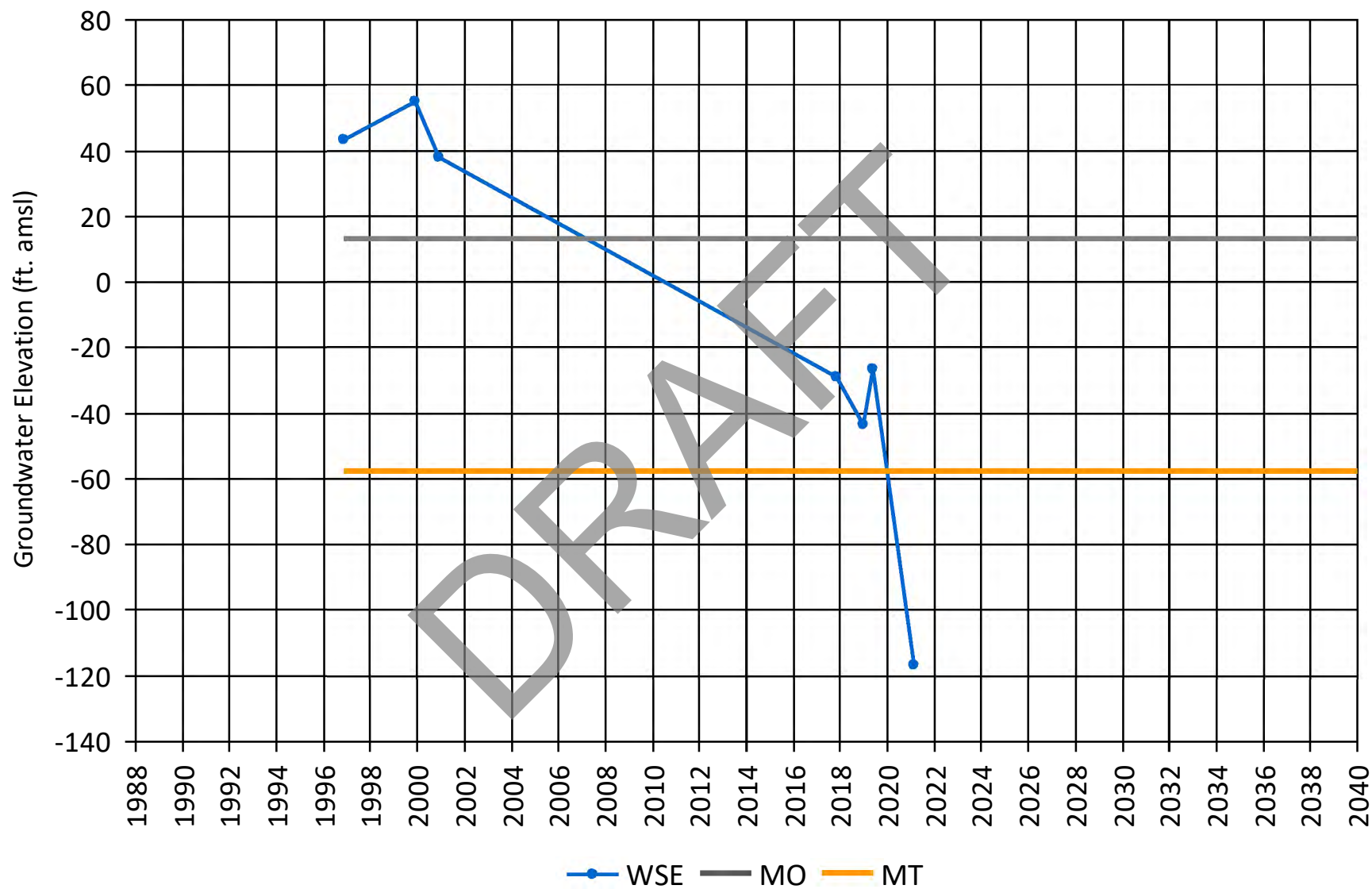
MO: -33.3 MT: -273.3
Depth: 1200 ft



Aquifer: Lower
Perforations: 618-1218 ft

16S/15E-32A06

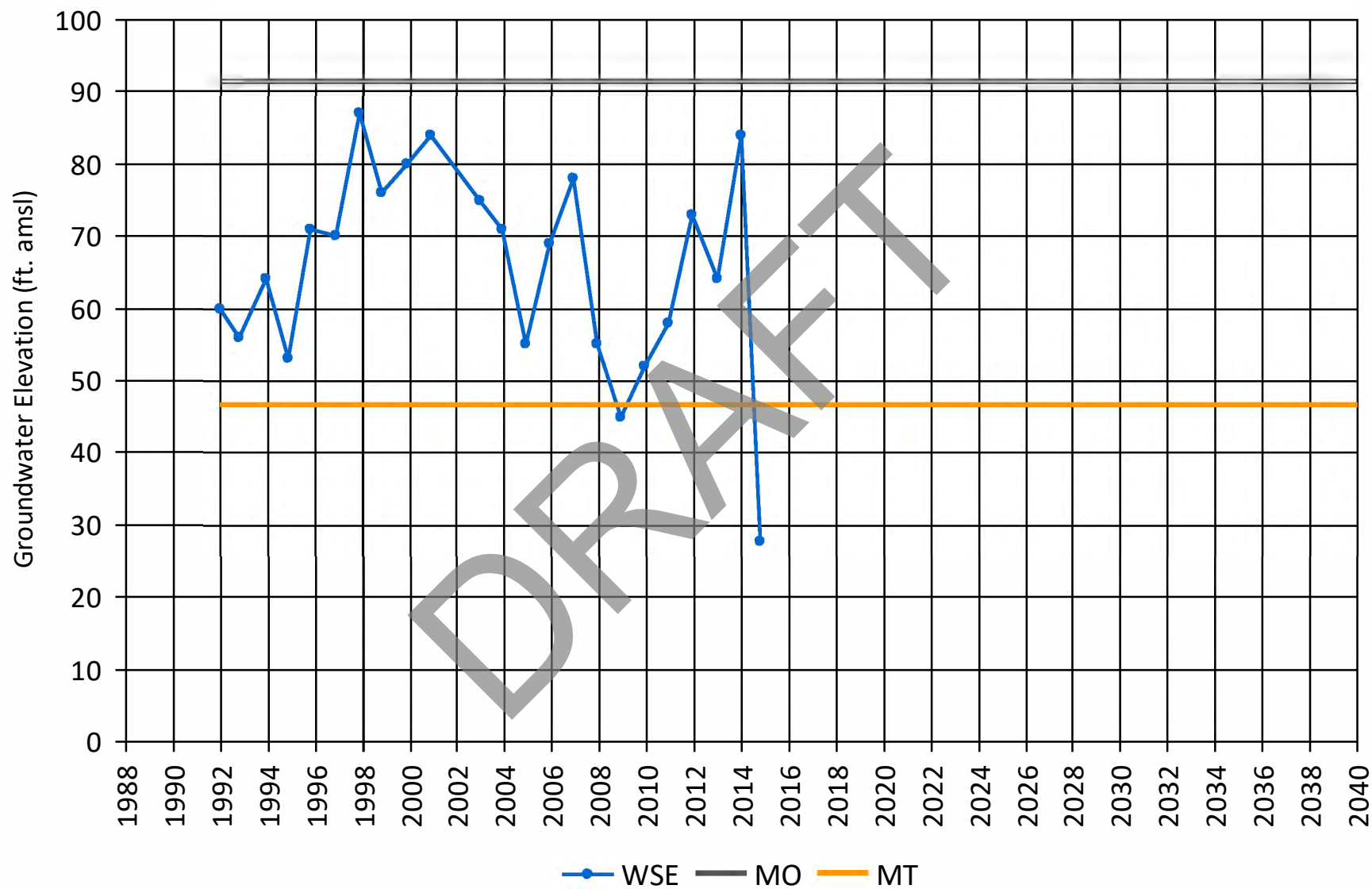
MO: 13 MT: -57.4
Depth: 1218 ft



Aquifer: Upper
Perforations: 280-560 ft

16S/16E-09Q01

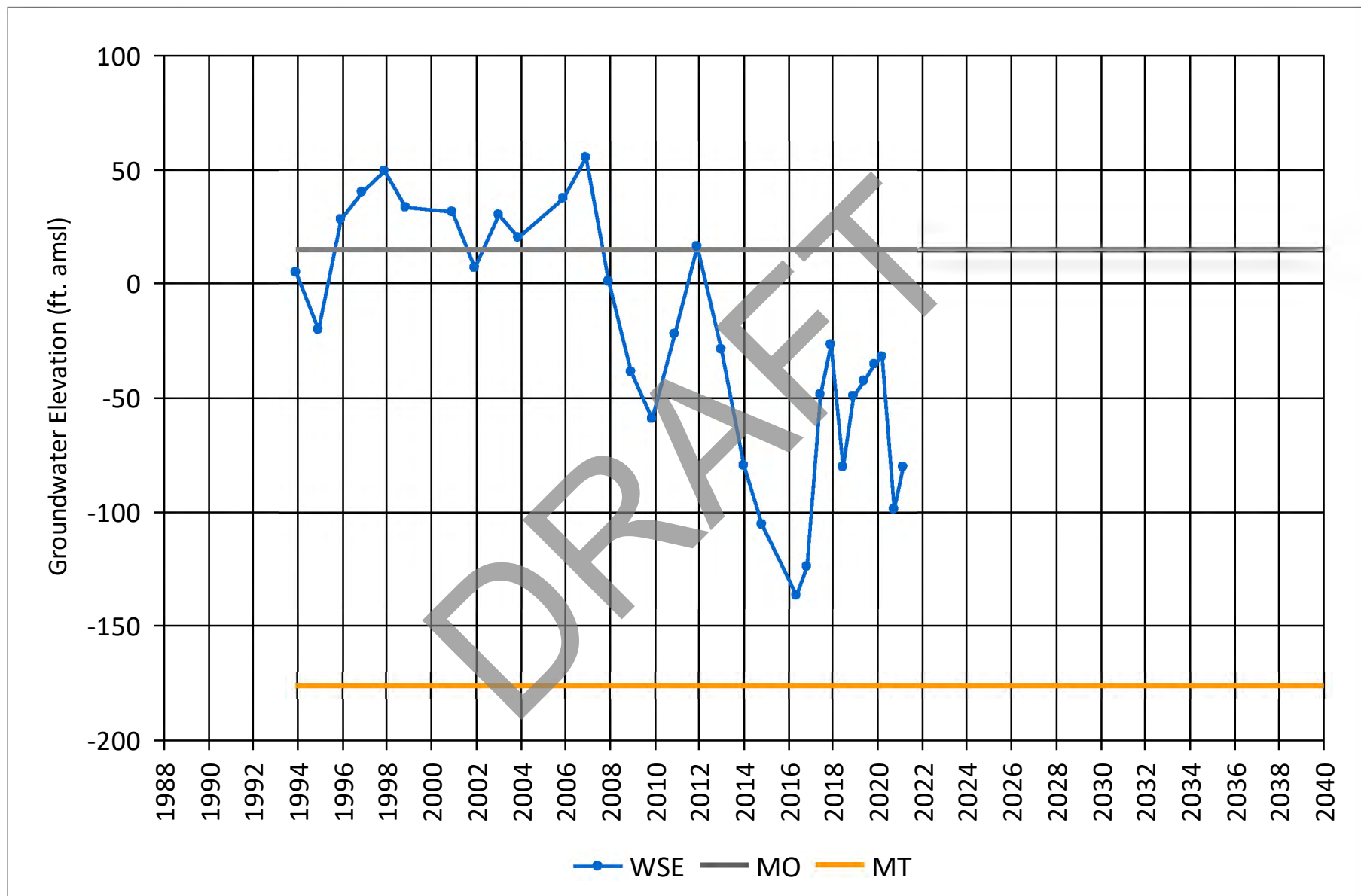
MO: 91.5 MT: 46.7
Depth: 580 ft



Aquifer: Lower
Perforations: 645-945 ft

16S/16E-10Q01

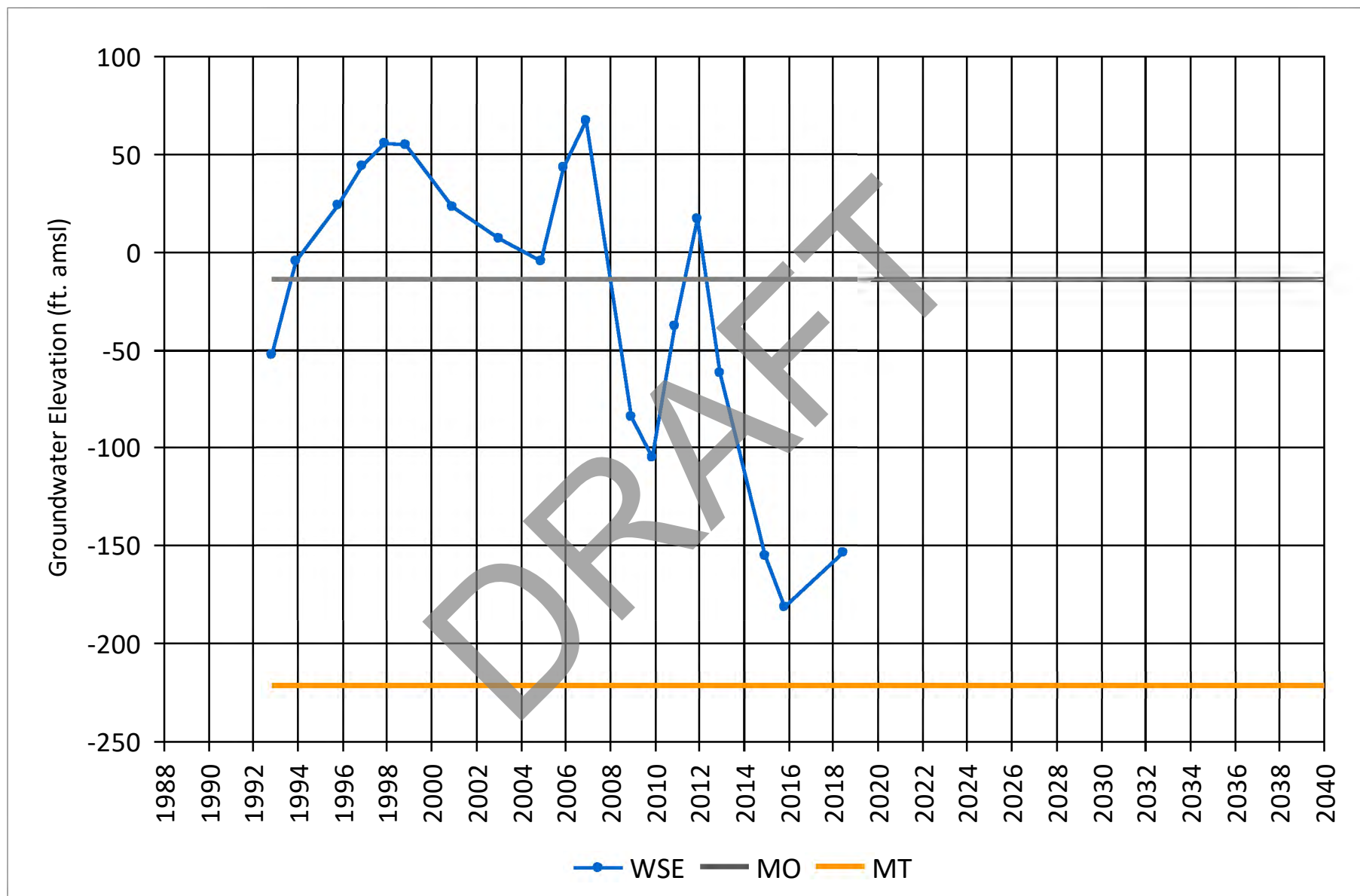
MO: 15 MT: -176.3
Depth: 965 ft



Aquifer: Lower
Perforations: 675-995 ft

16S/16E-29E01

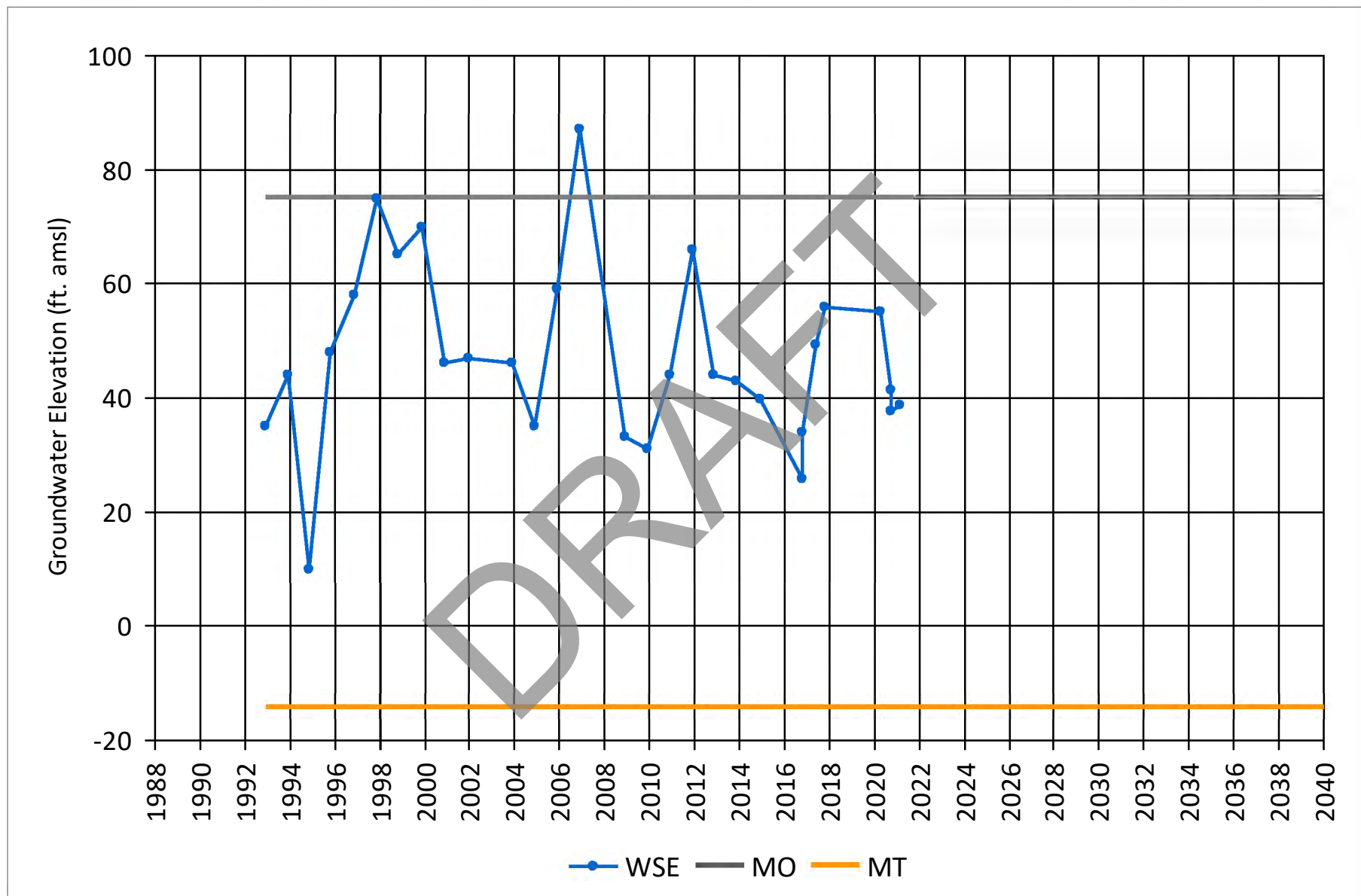
MO: -14 MT: -221.2
Depth: 995 ft



Aquifer: Upper
Perforations: 300-520 ft

16S/16E-33G01

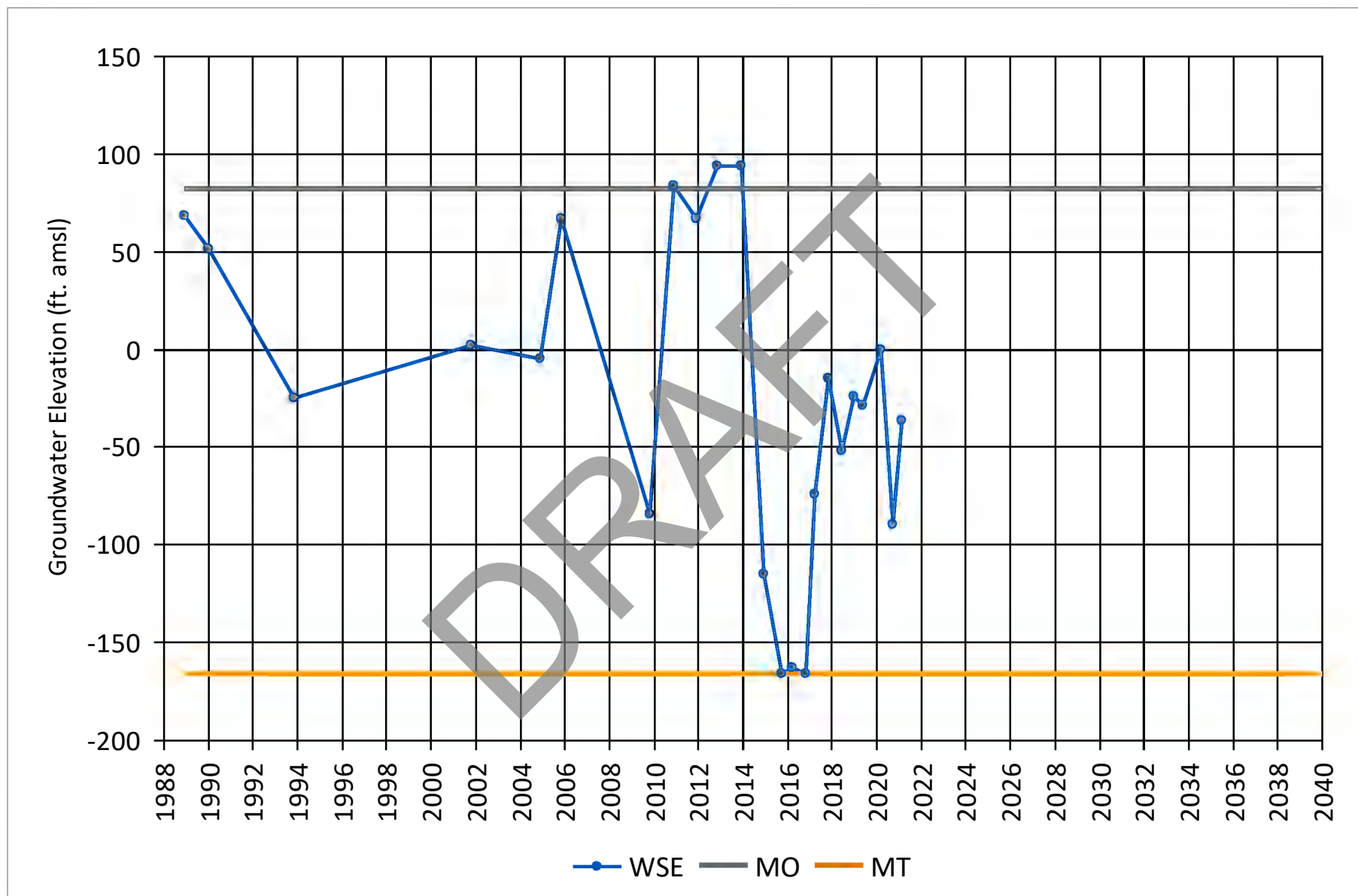
MO: 75.2 MT: -14.2
Depth: 520 ft



Aquifer: Lower
Perforations: 861-2529 ft

17S/15E-09N02

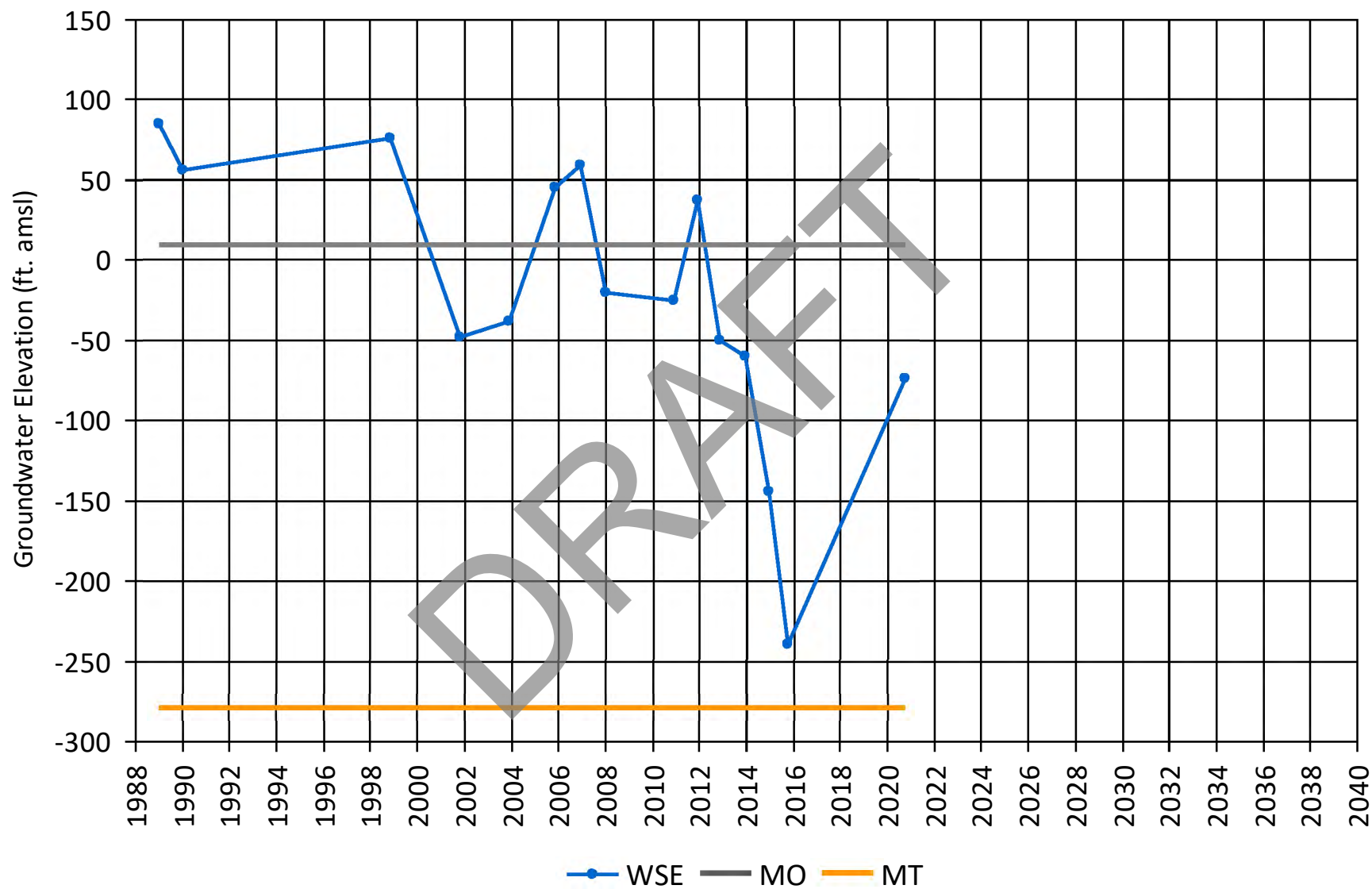
MO: 82.1 MT: -166.1
Depth: 2529 ft



Aquifer: Lower
Perforations: 842-1500 ft

17S/15E-23D01

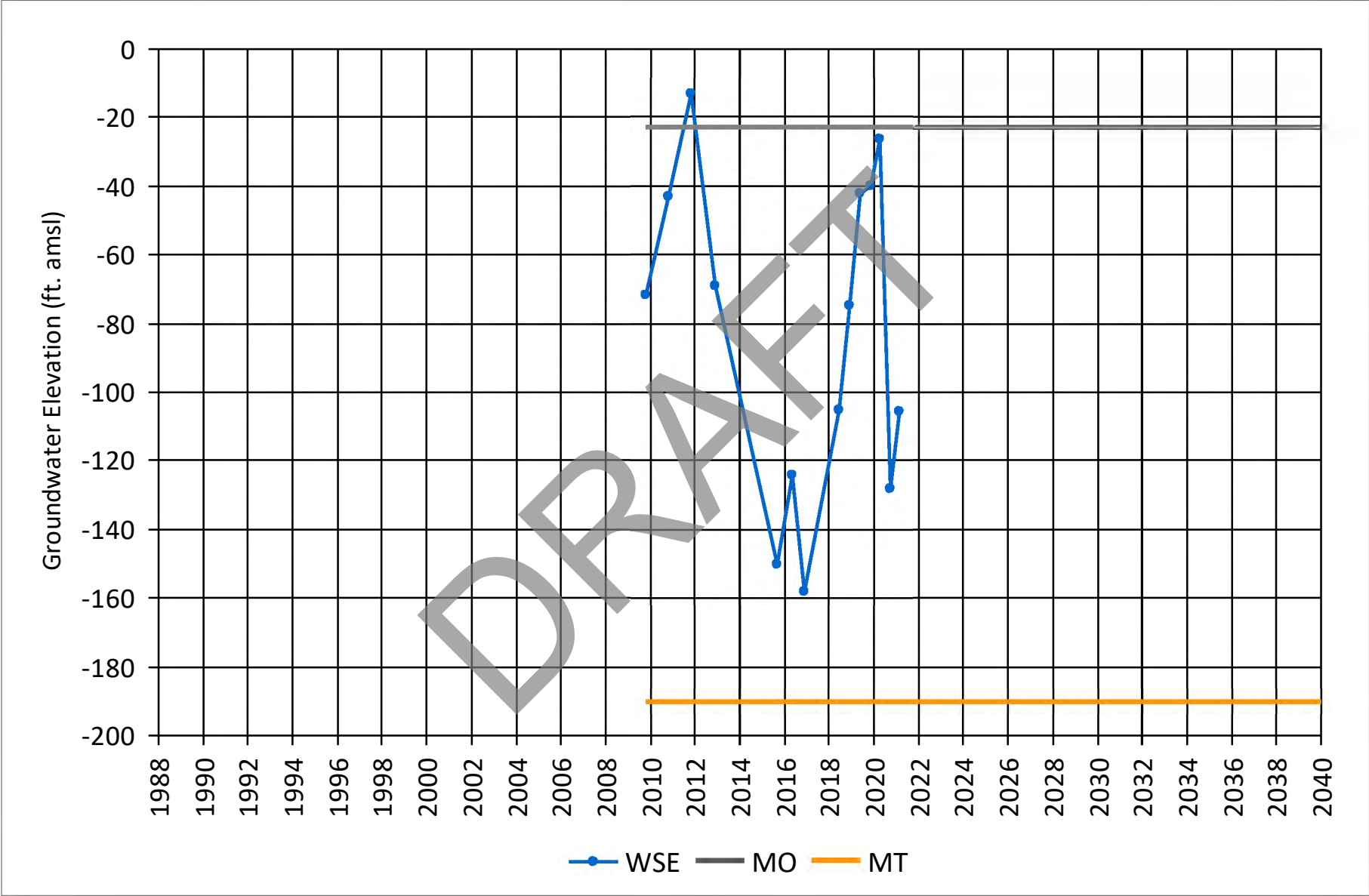
MO: 9.2 MT: -279.1
Depth: 1500 ft



Aquifer: Lower
Perforations: 602-1002 ft

17S/17E-09Q01

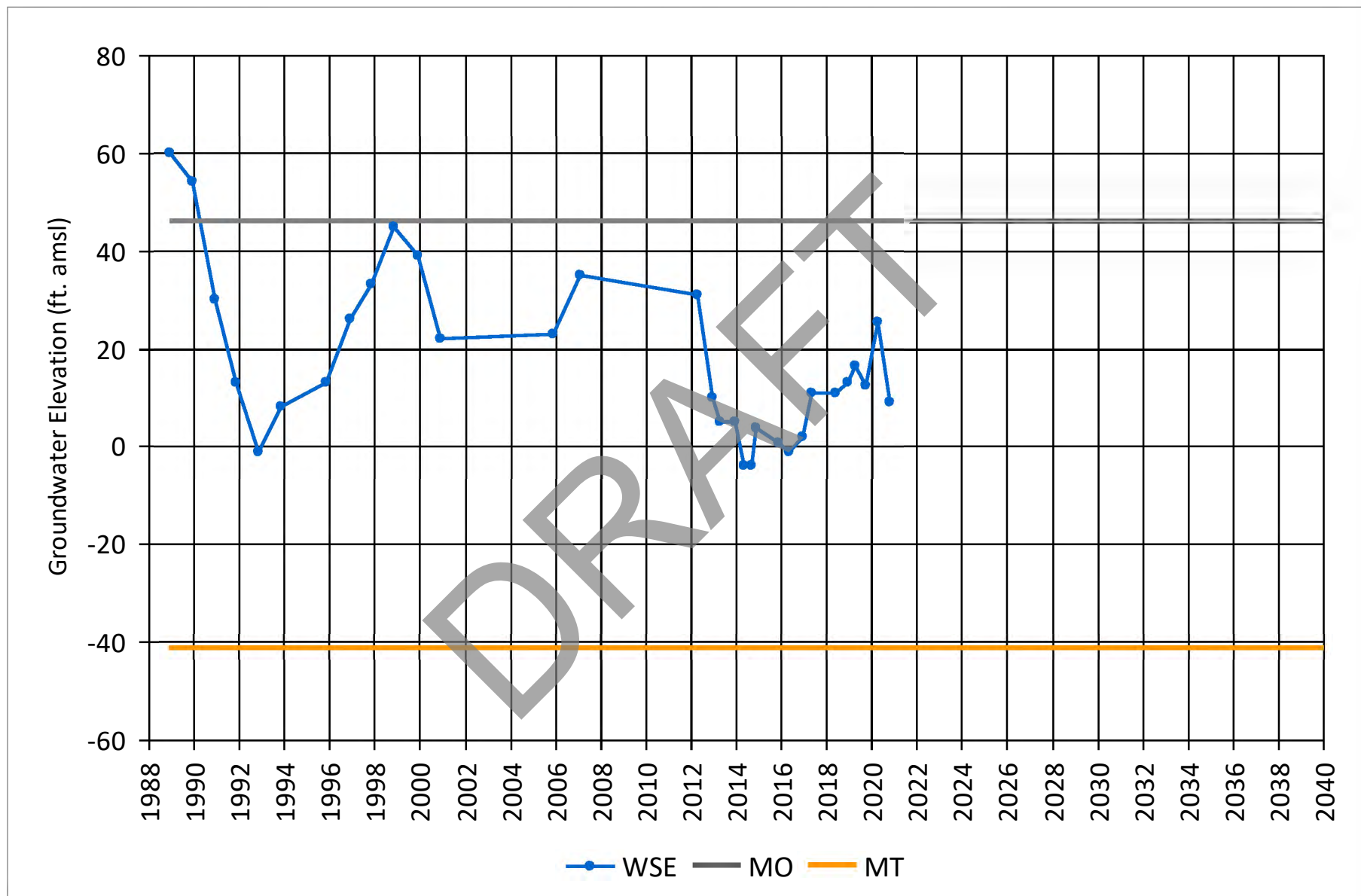
MO: -22.9 MT: -190.1
Depth: 1002 ft



Aquifer: Upper
Perforations: 270-480 ft

17S/17E-16C01

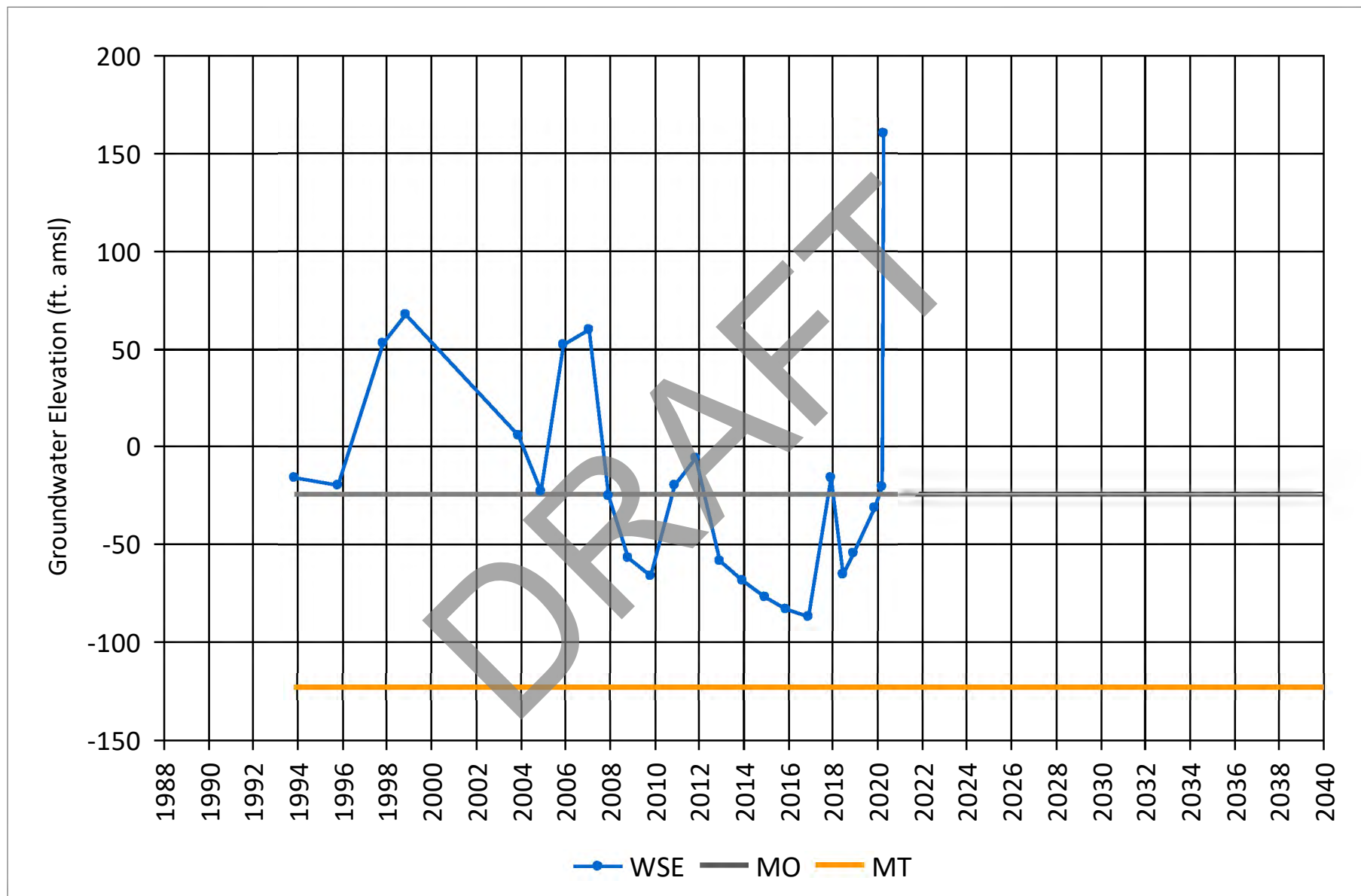
MO: 46 MT: -41.1
Depth: 480 ft



Aquifer: Upper
Perforations: 498-738 ft

17S/17E-31N03

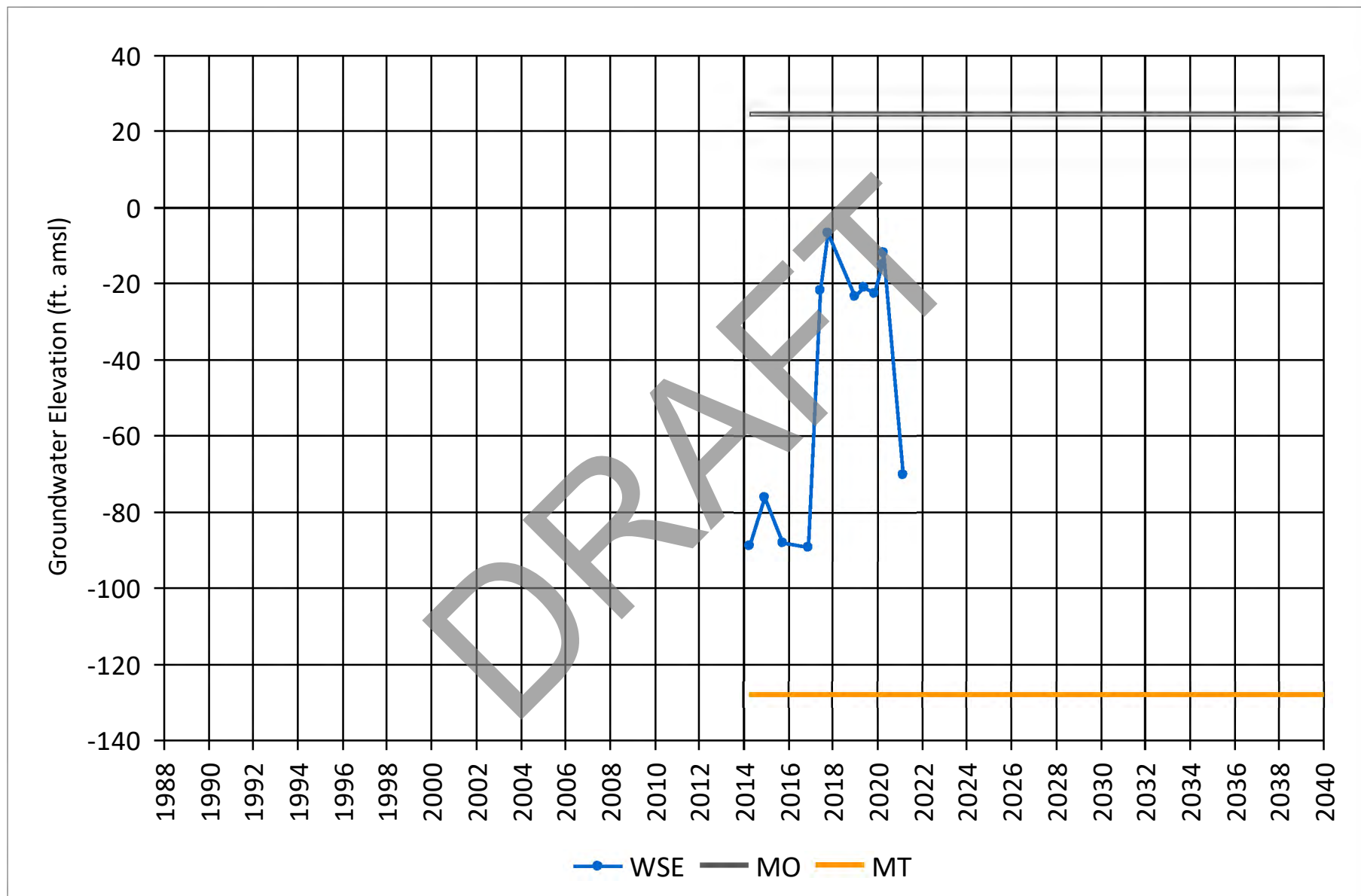
MO: -24.5 MT: -123
Depth: 780 ft



Aquifer: Lower
Perforations: 600-1310 ft

17S/18E-33H02

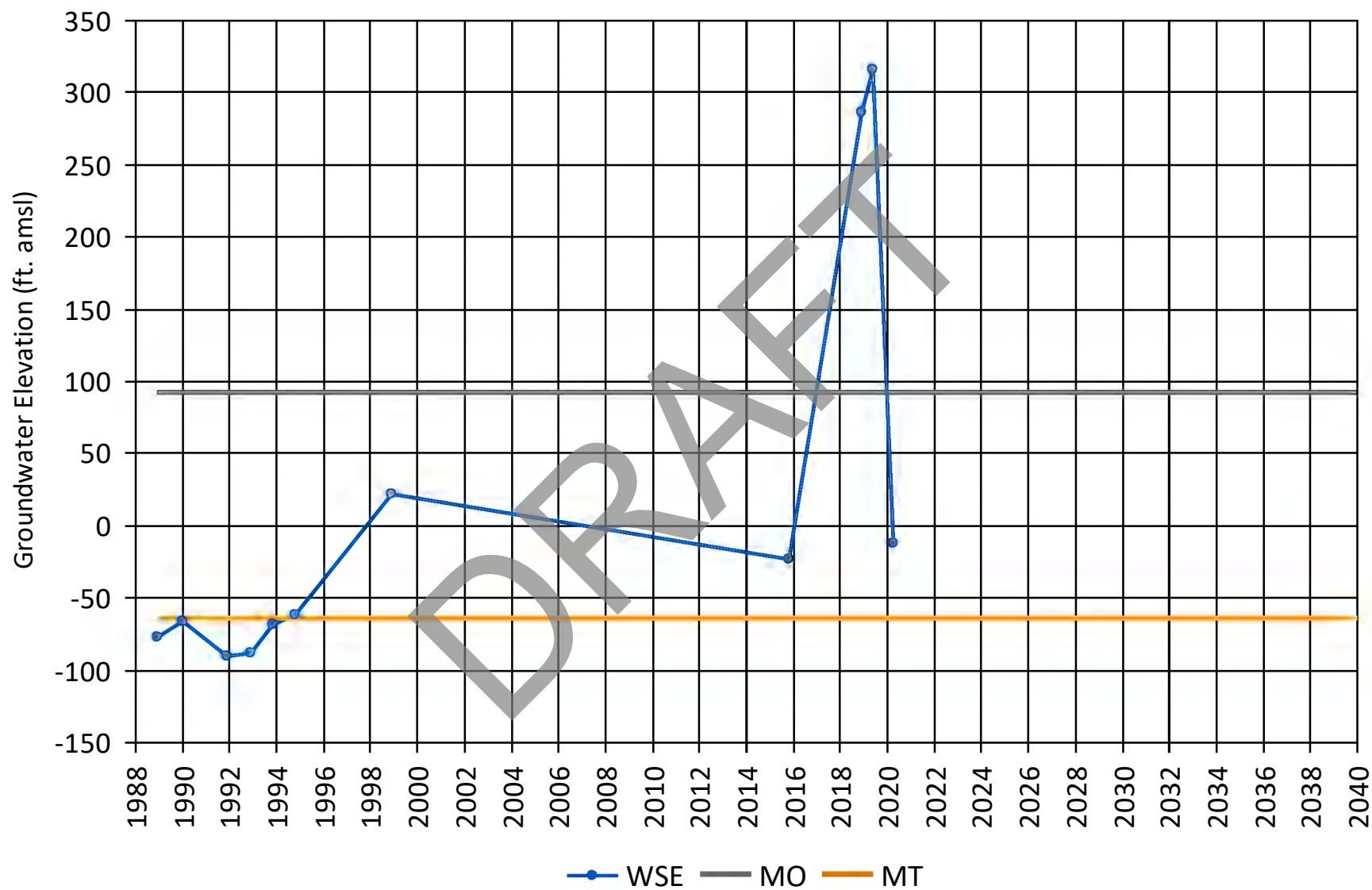
MO: 24.6 MT: -128.1
Depth: 1340 ft



Aquifer: Lower
Perforations: 1788-2488 f

18S/15E-15D01

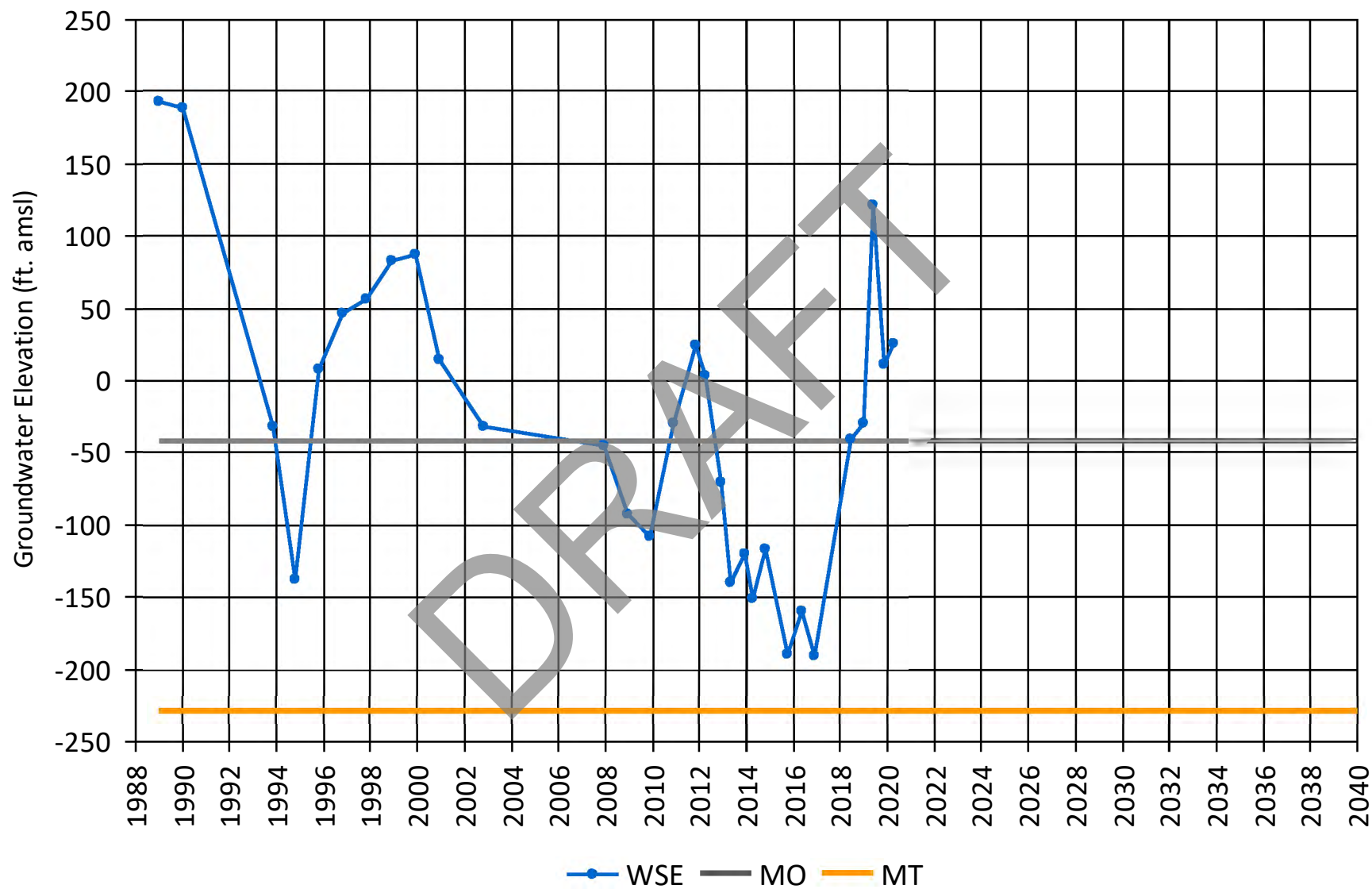
MO: 92.4 MT: -63.6
Depth: 2583 ft



Aquifer: Lower
Perforations: 942-1720 ft

18S/16E-04N02

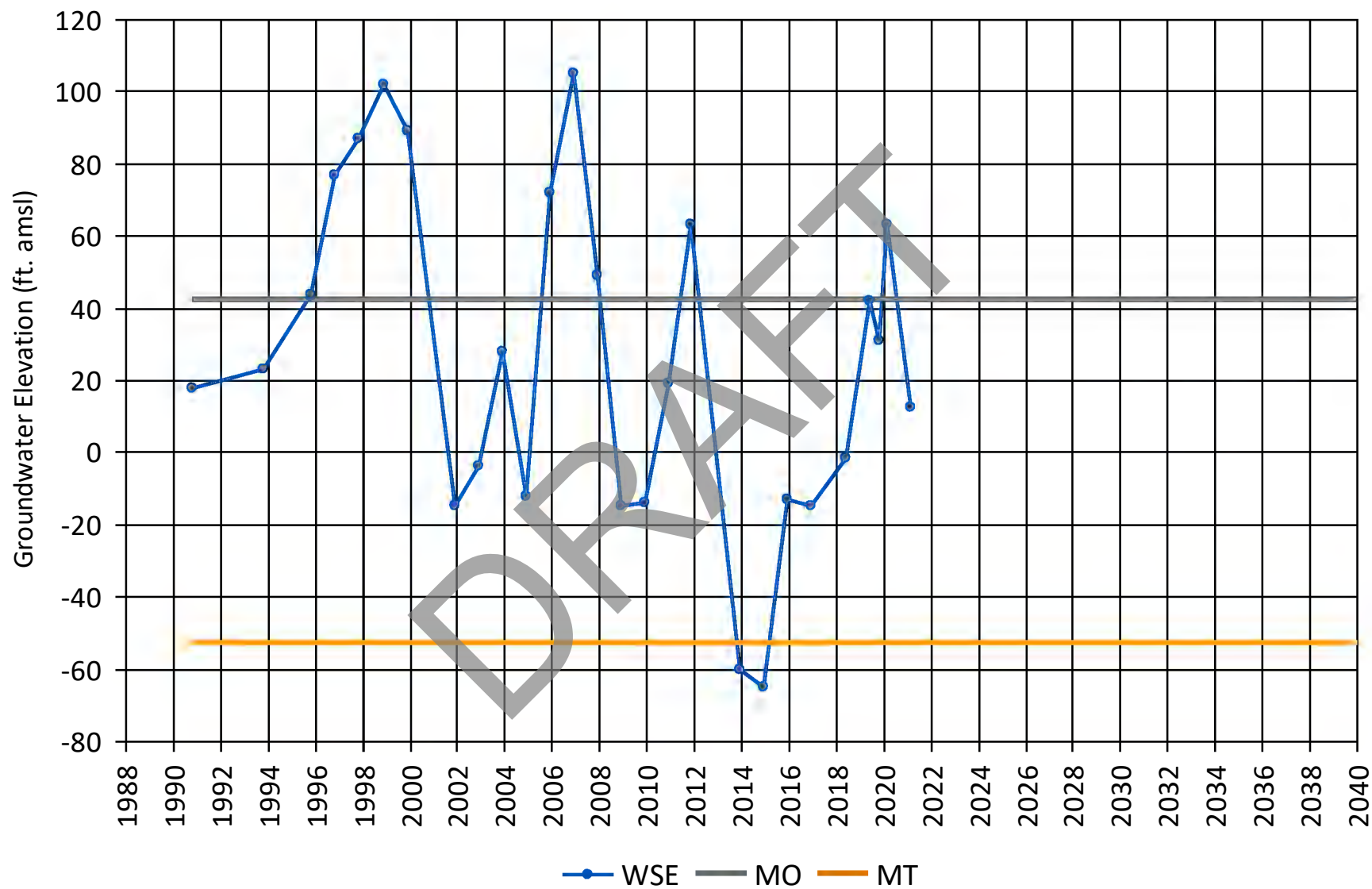
MO: -42.4 MT: -228.9
Depth: 1760 ft



Aquifer: Upper
Perforations: 280-400 ft

18S/16E-22Q03

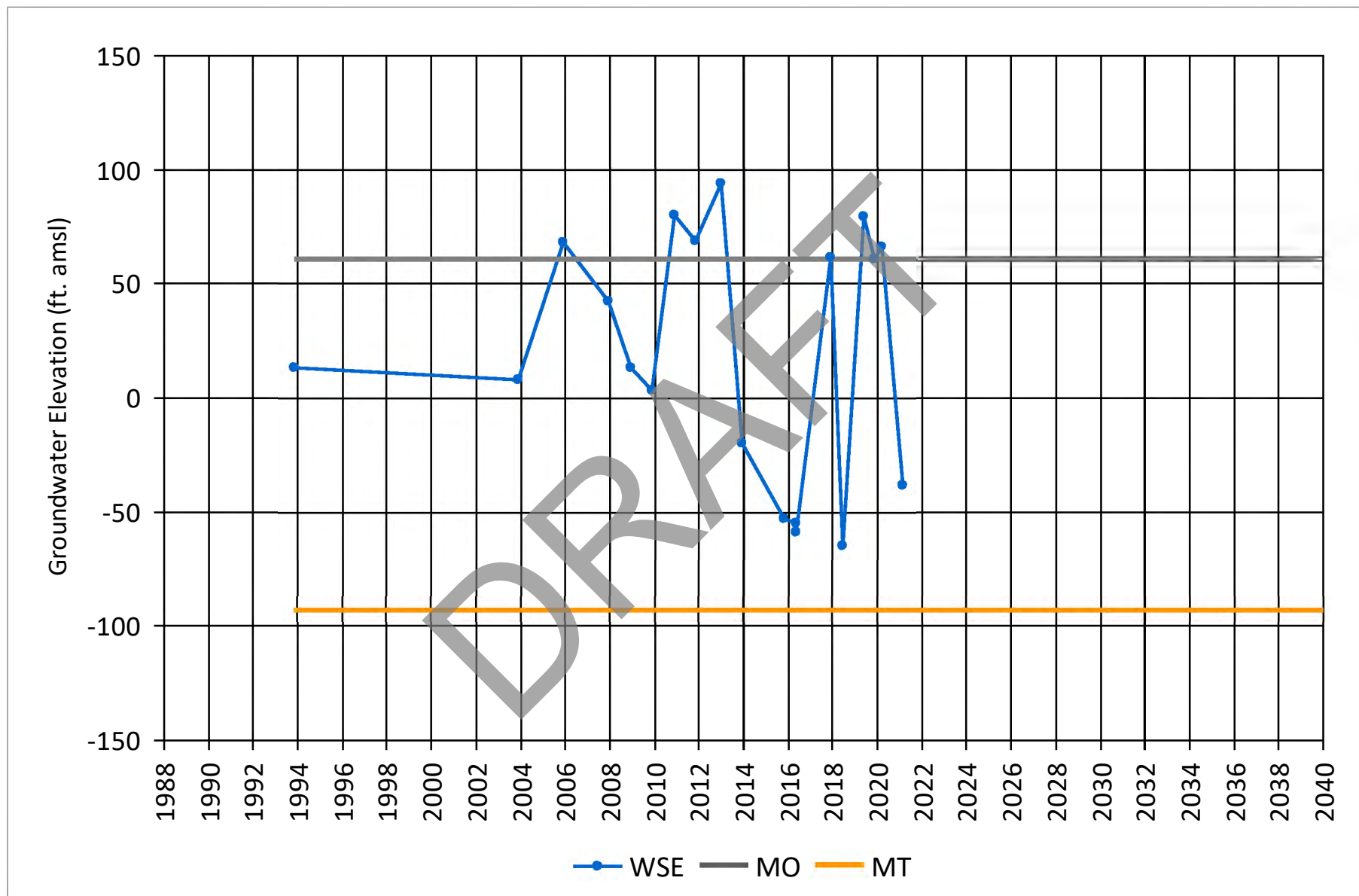
MO: 42.6 MT: -52.9
Depth: 400 ft



Aquifer: Lower
Perforations: 800-2000 ft

18S/16E-34N02

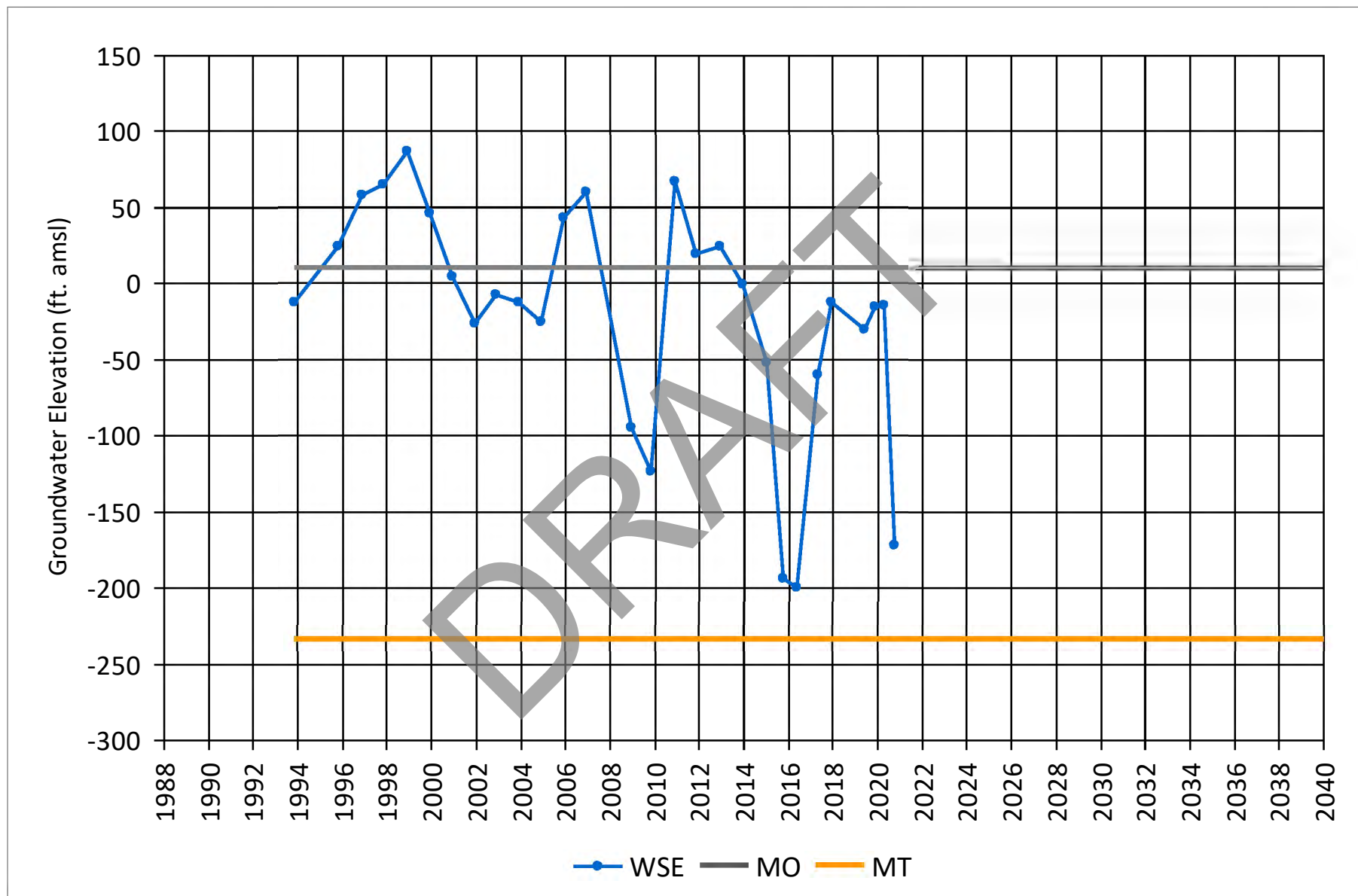
MO: 60.6 MT: -92.9
Depth: 2000 ft



Aquifer: Lower
Perforations: 700-1150 ft

18S/17E-09P01

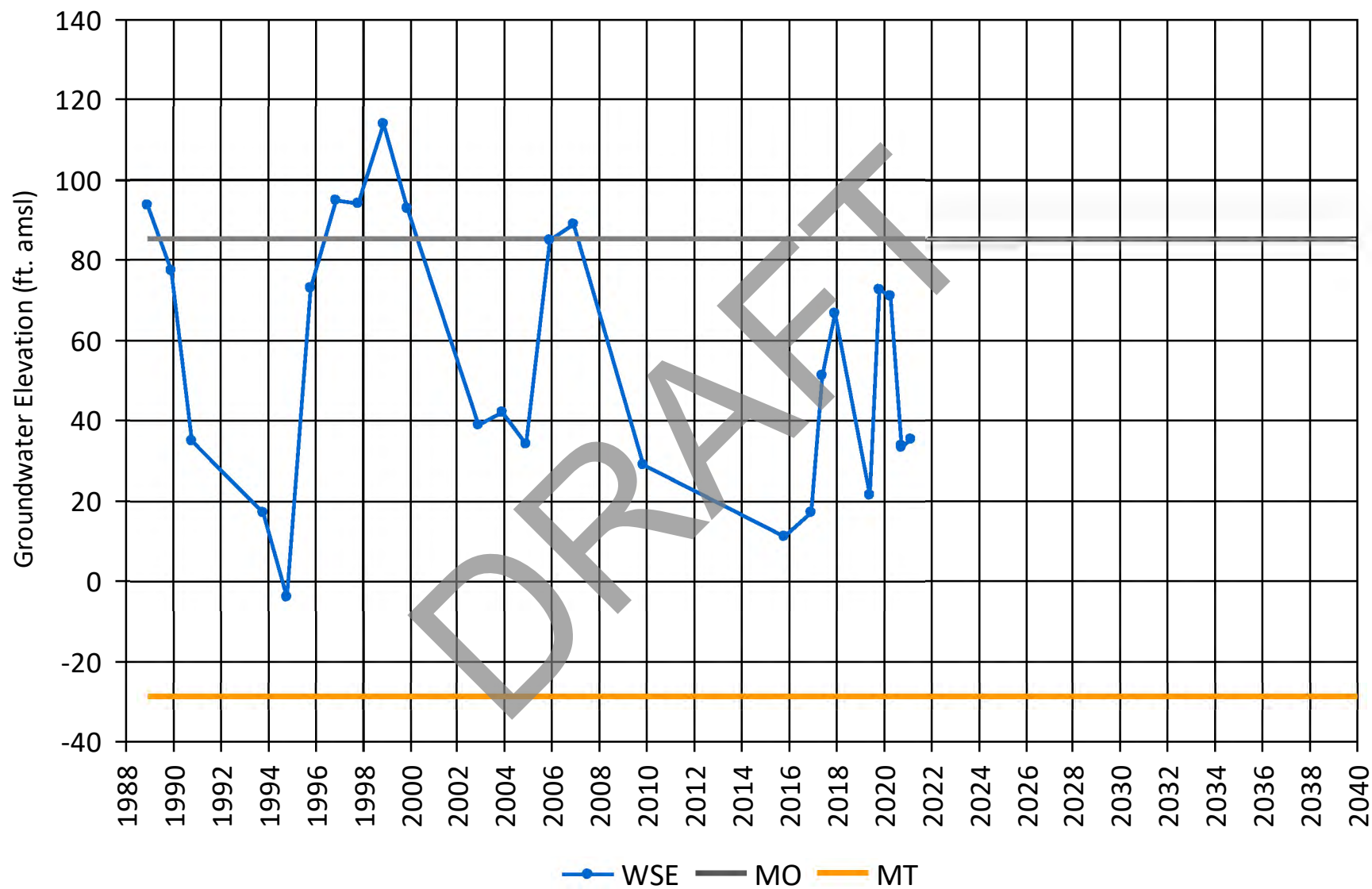
MO: 10.5 MT: -234
Depth: 1187 ft



Aquifer: Upper
Perforations: 350-630 ft

18S/17E-11Q01

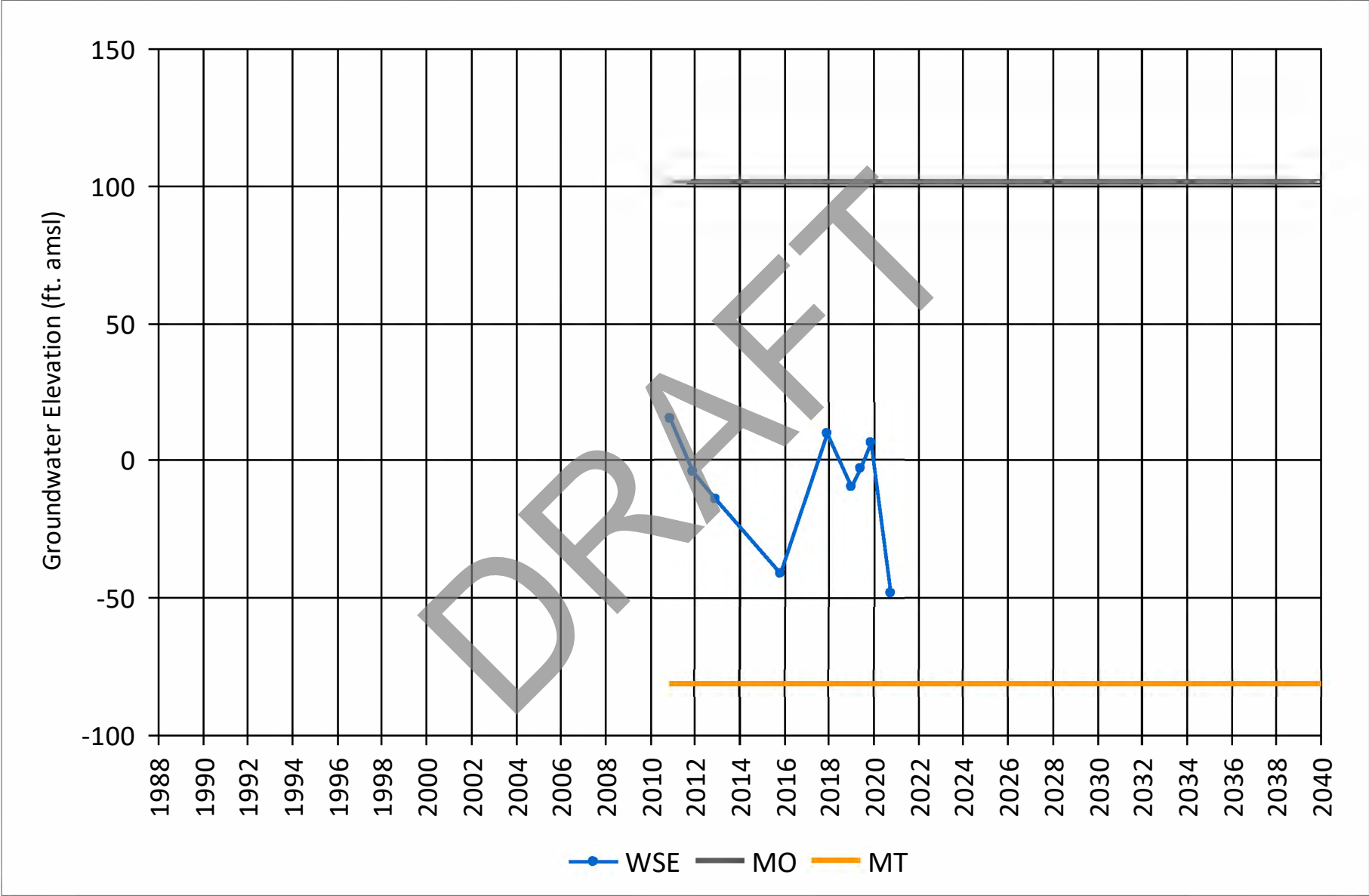
MO: 85.2 MT: -29
Depth: 630 ft



Aquifer: Lower
Perforations: 598 ft

18S/18E-01R02

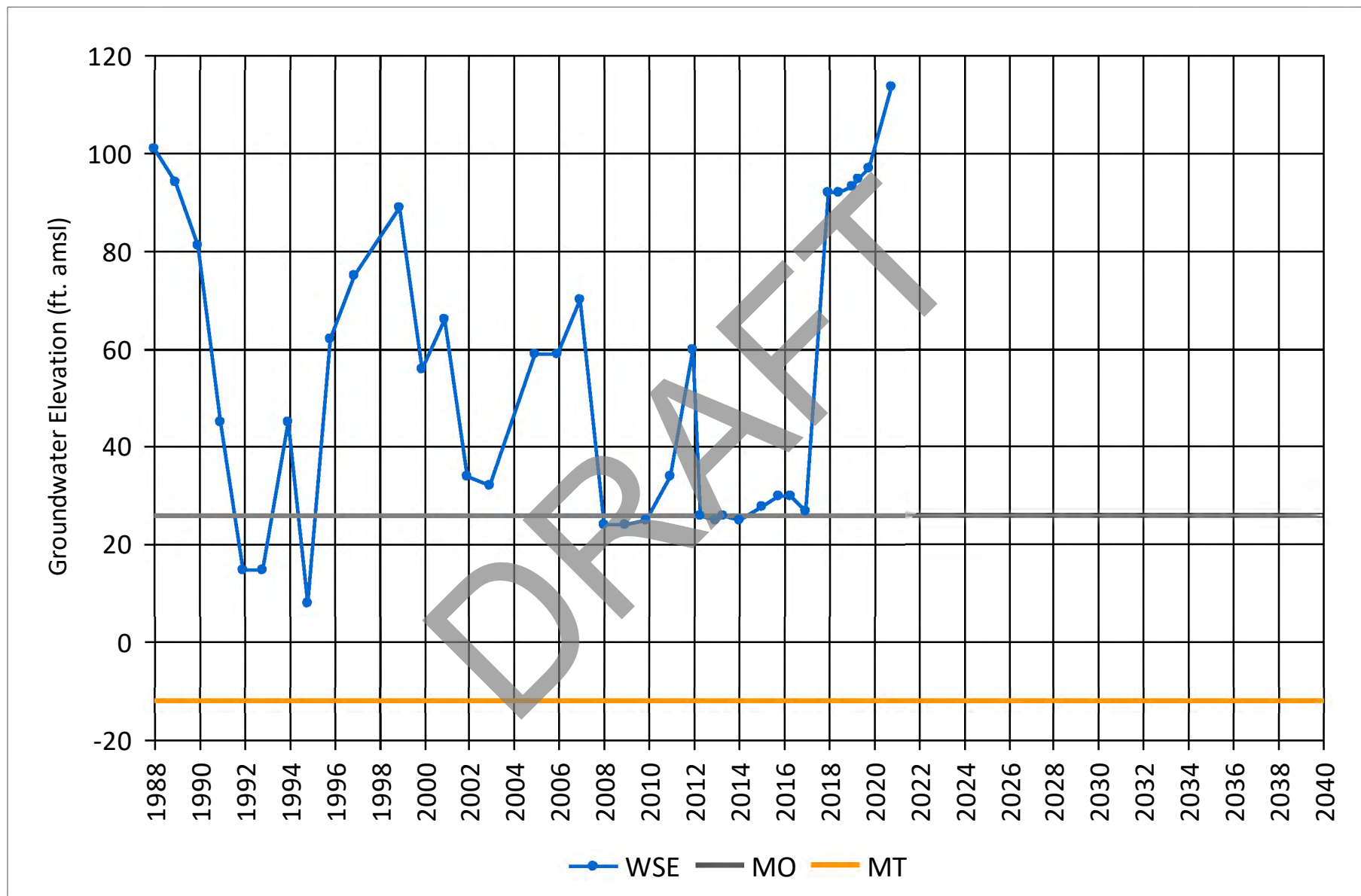
MO: 101.8 MT: -81.2
Depth: 1281 ft



Aquifer: Upper
Perforations: 342-643 ft

18S/18E-05K01

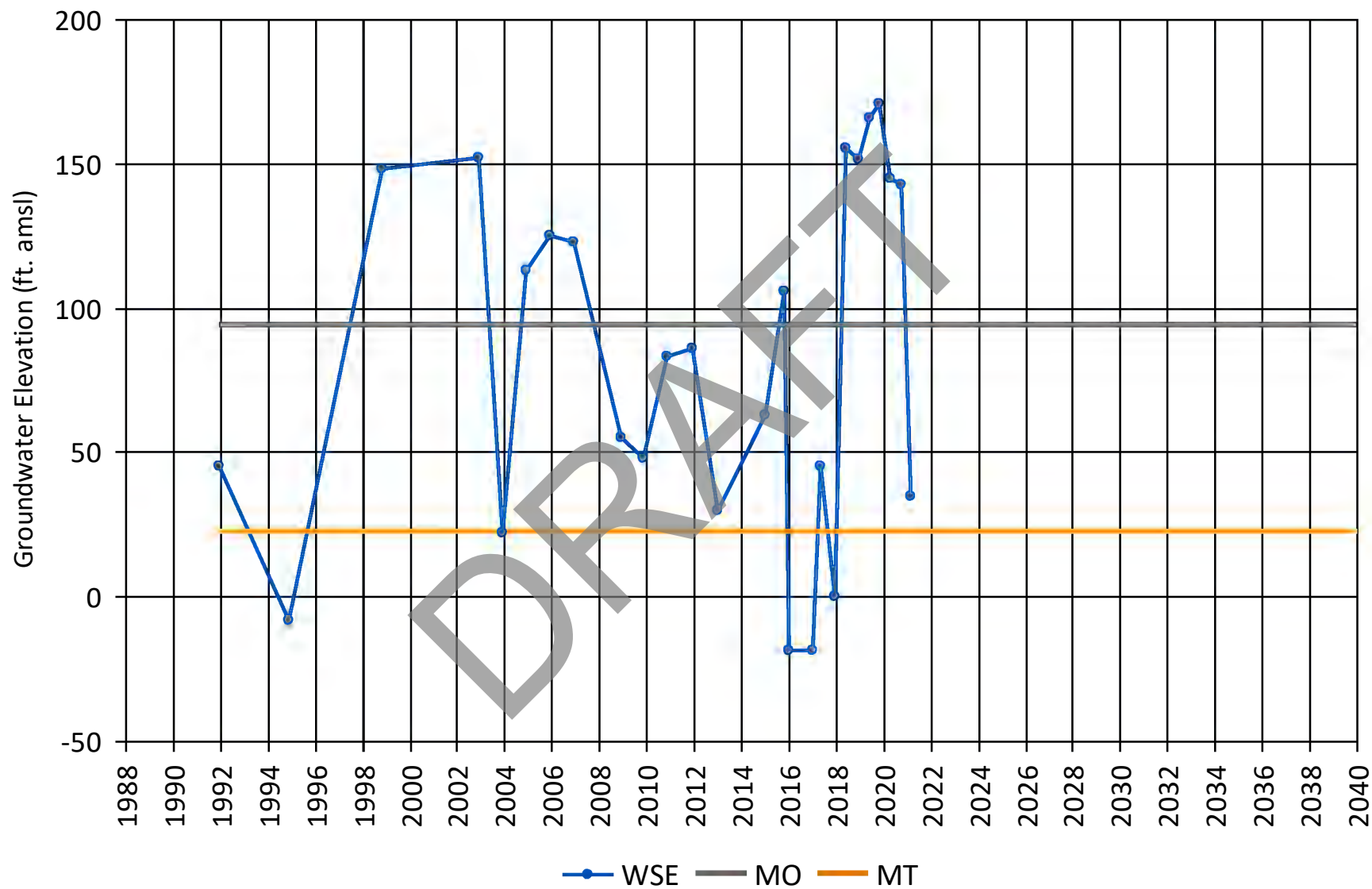
MO: 26 MT: -12.1
Depth: 652 ft



Aquifer: Upper
Perforations: 300-660 ft

18S/18E-28N04

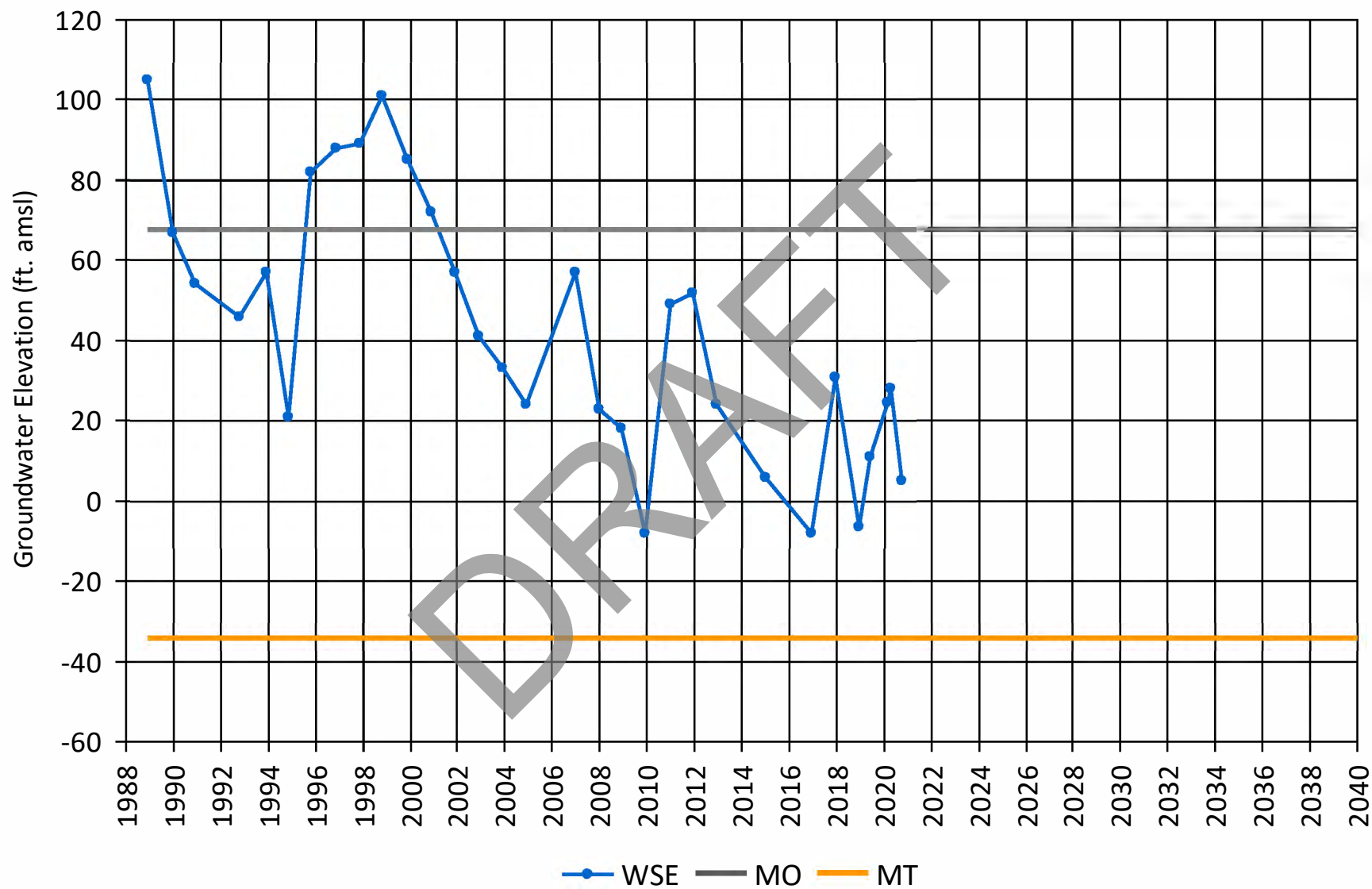
MO: 94.2 MT: 22.9
Depth: 670 ft



Aquifer: Upper
Perforations: 244-604 ft

18S/19E-20F01

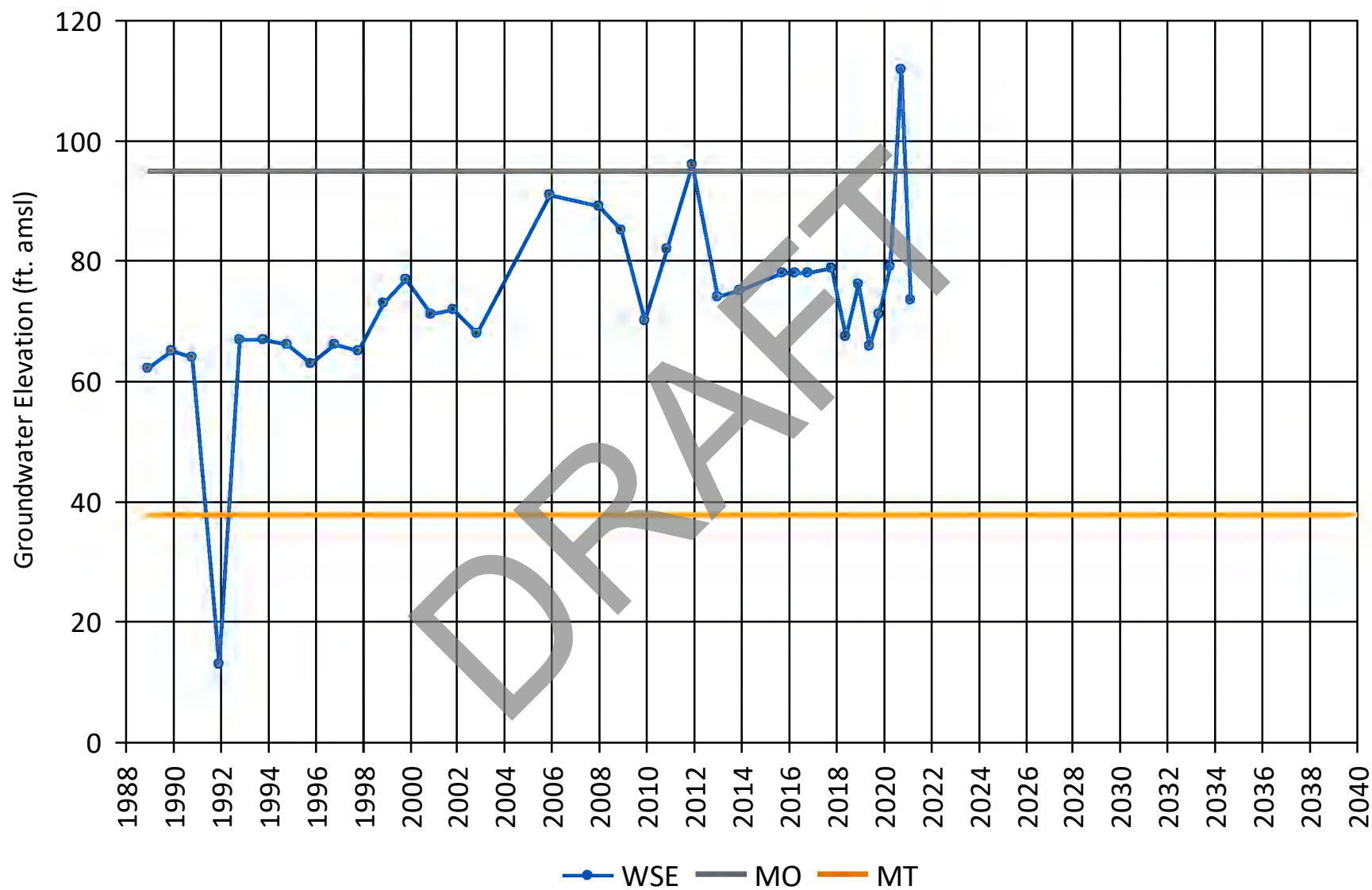
MO: 67.6 MT: -34.1
Depth: 604 ft



Aquifer: Lower
Perforations: 719-2035 ft

19S/16E-35N01

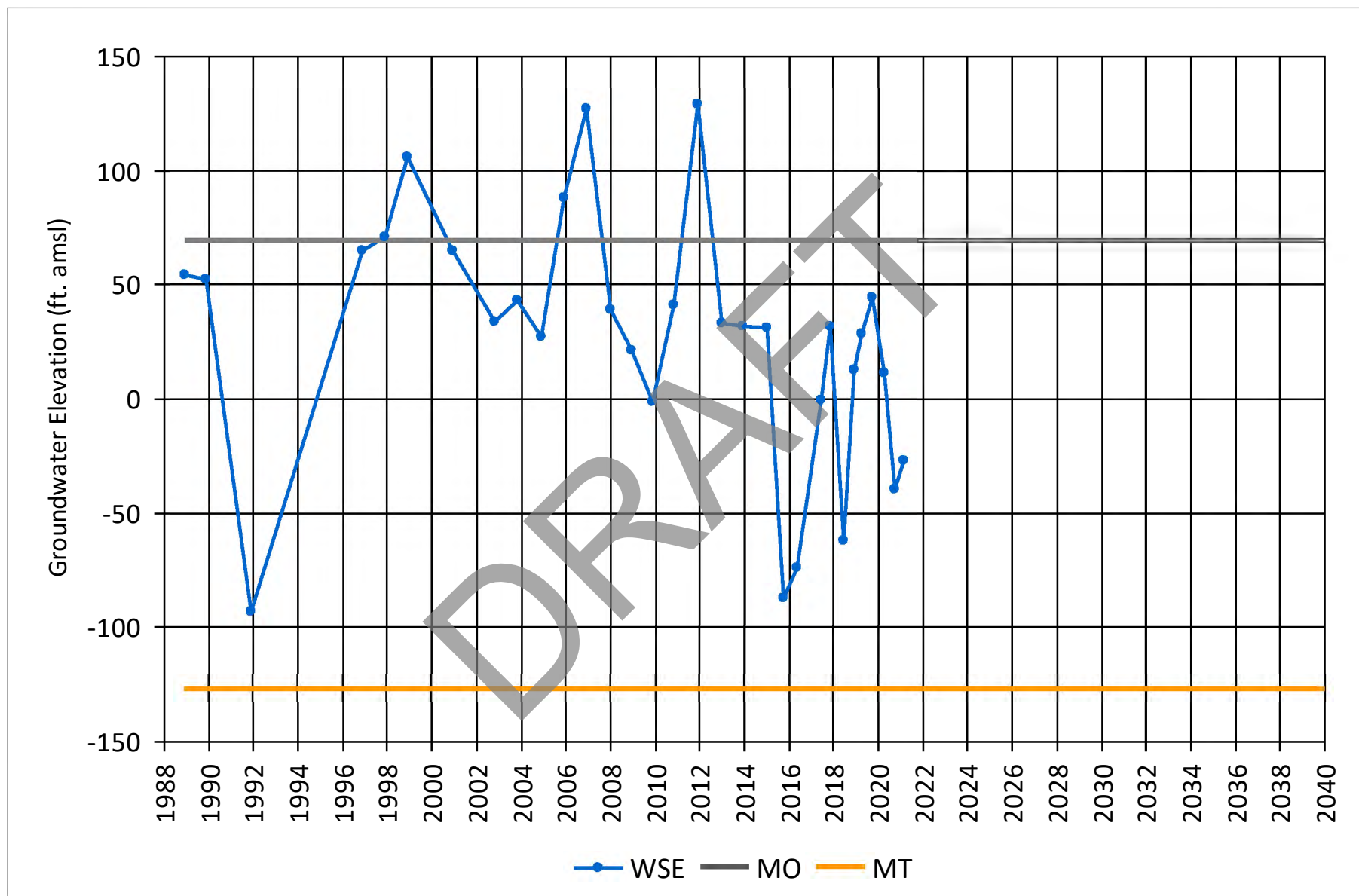
MO: 95 MT: 37.9
Depth: 2035 ft



Aquifer: Lower
Perforations: 716-2005 ft

19S/17E-28P01

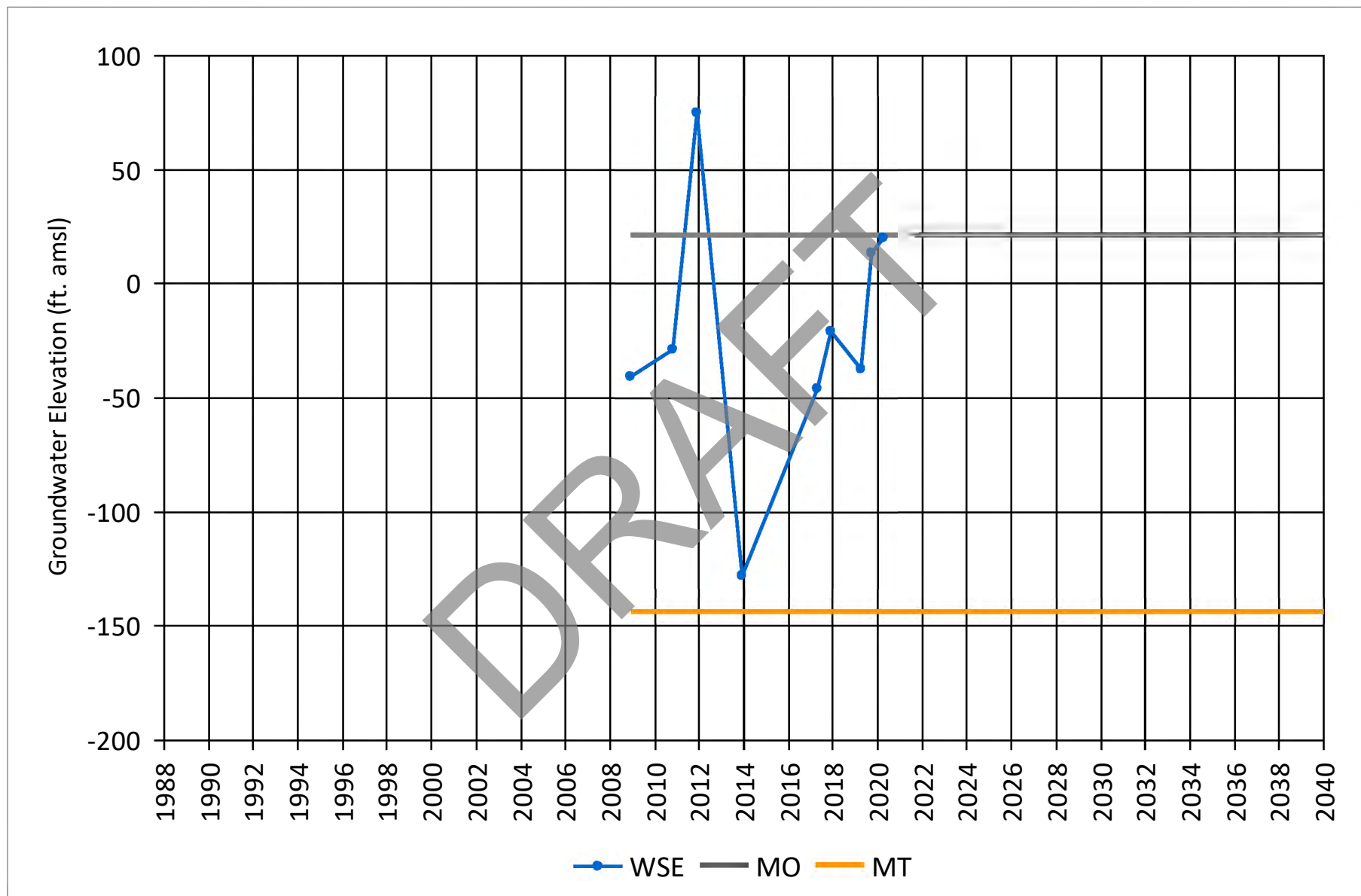
MO: 69.1 MT: -127
Depth: 2018 ft



Aquifer: Lower
Perforations: 866-1600 ft

19S/18E-04C01

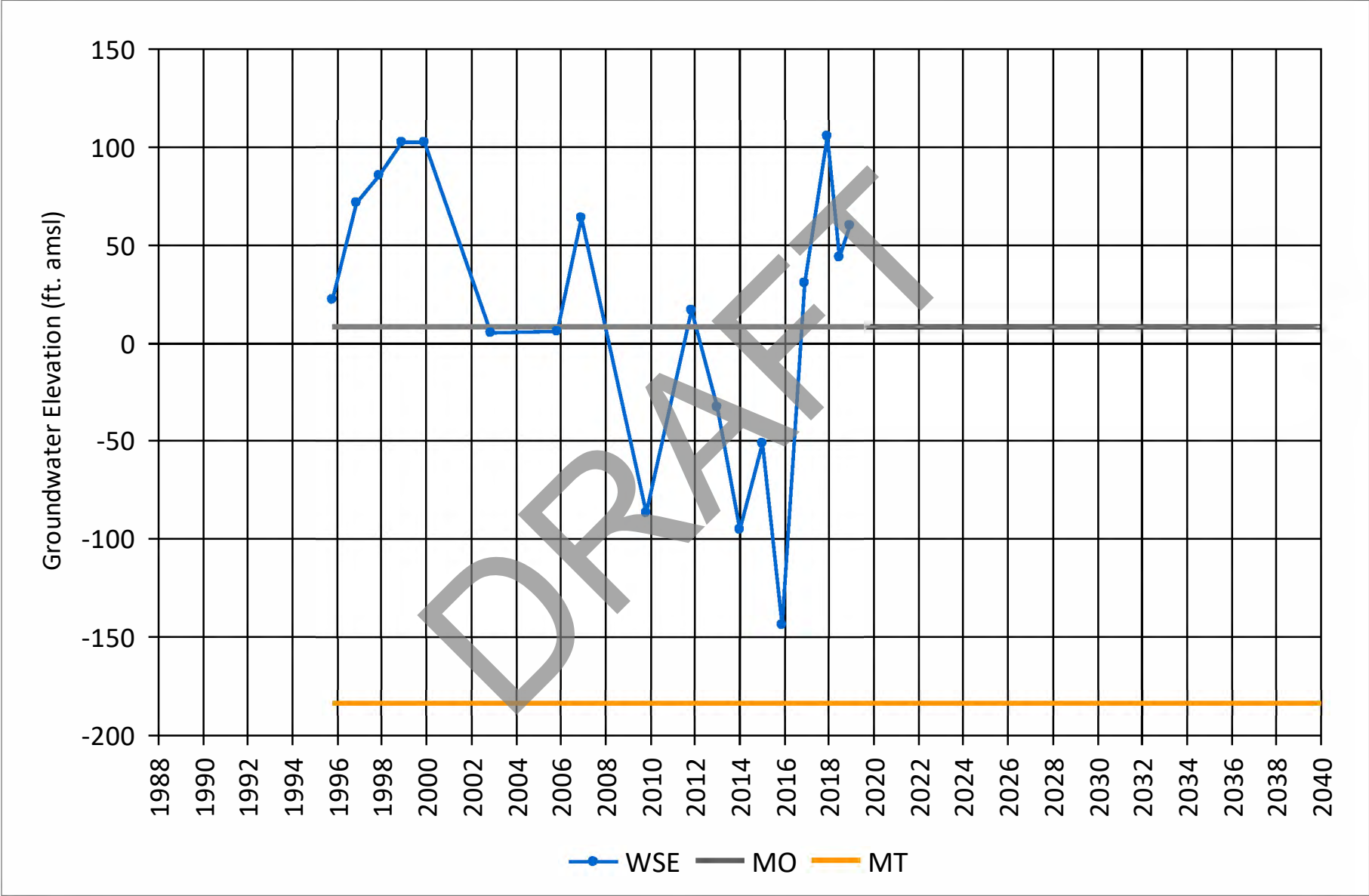
MO: 21.2 MT: -143.6
Depth: 1620 ft



Aquifer: Upper
Perforations: ft

19S/18E-34N04

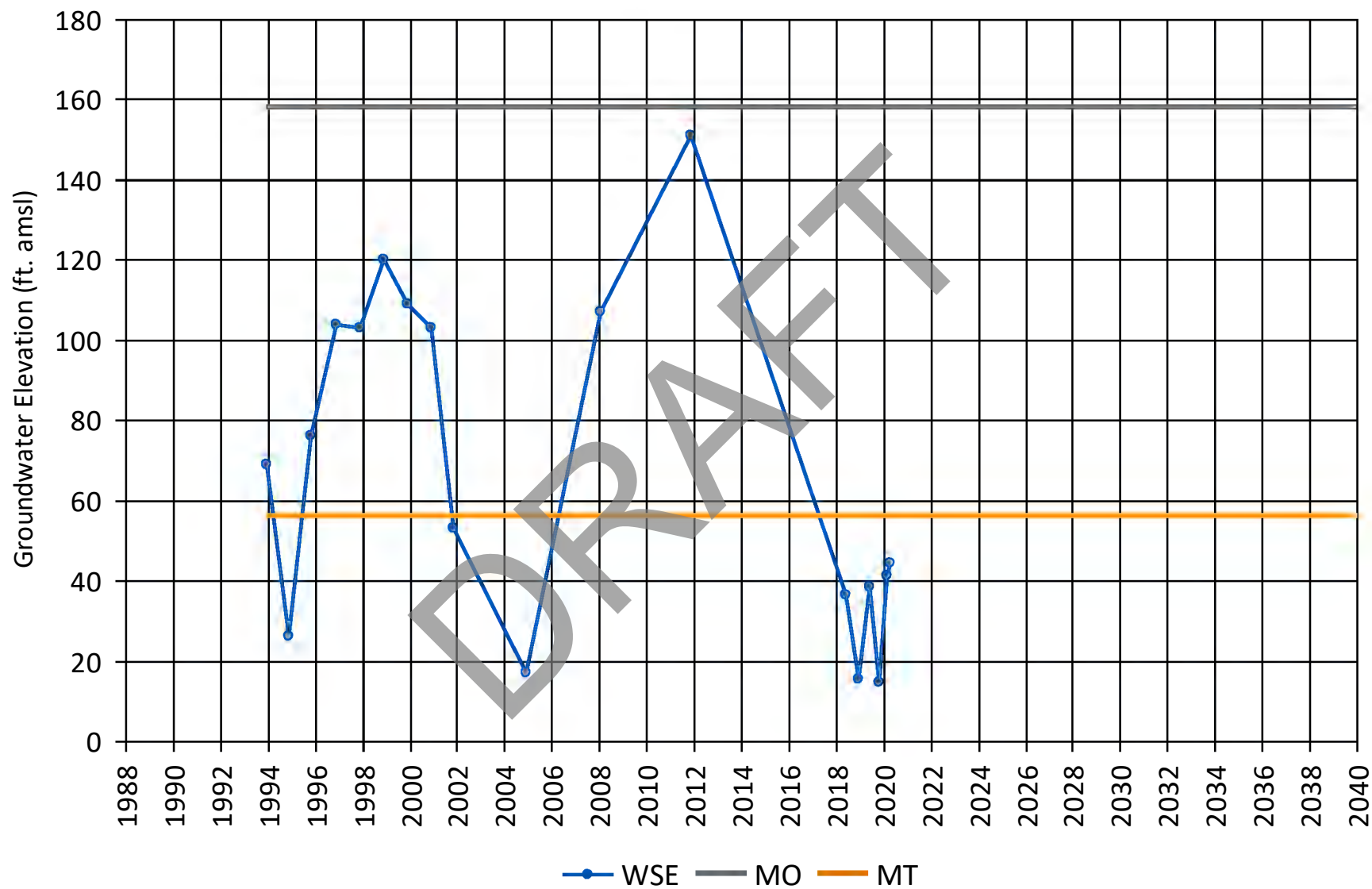
MO: 8
Depth: 0 ft
MT: -184.1



Aquifer: Upper
Perforations: 300-620 ft

19S/19E-08N04

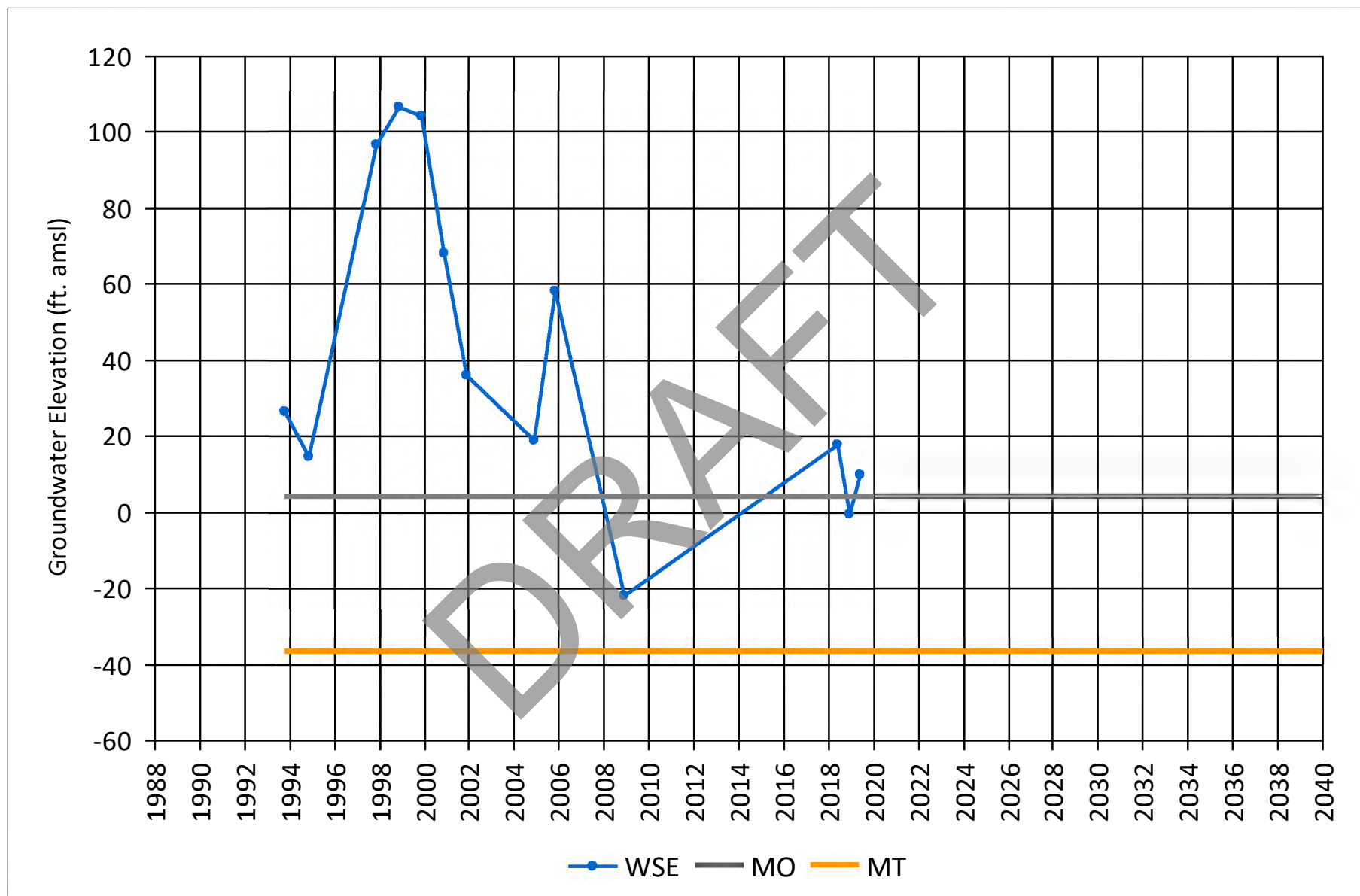
MO: 158
Depth: 620 ft
MT: 56.4



Aquifer: Upper
Perforations: 300-580 ft

19S/19E-26D02

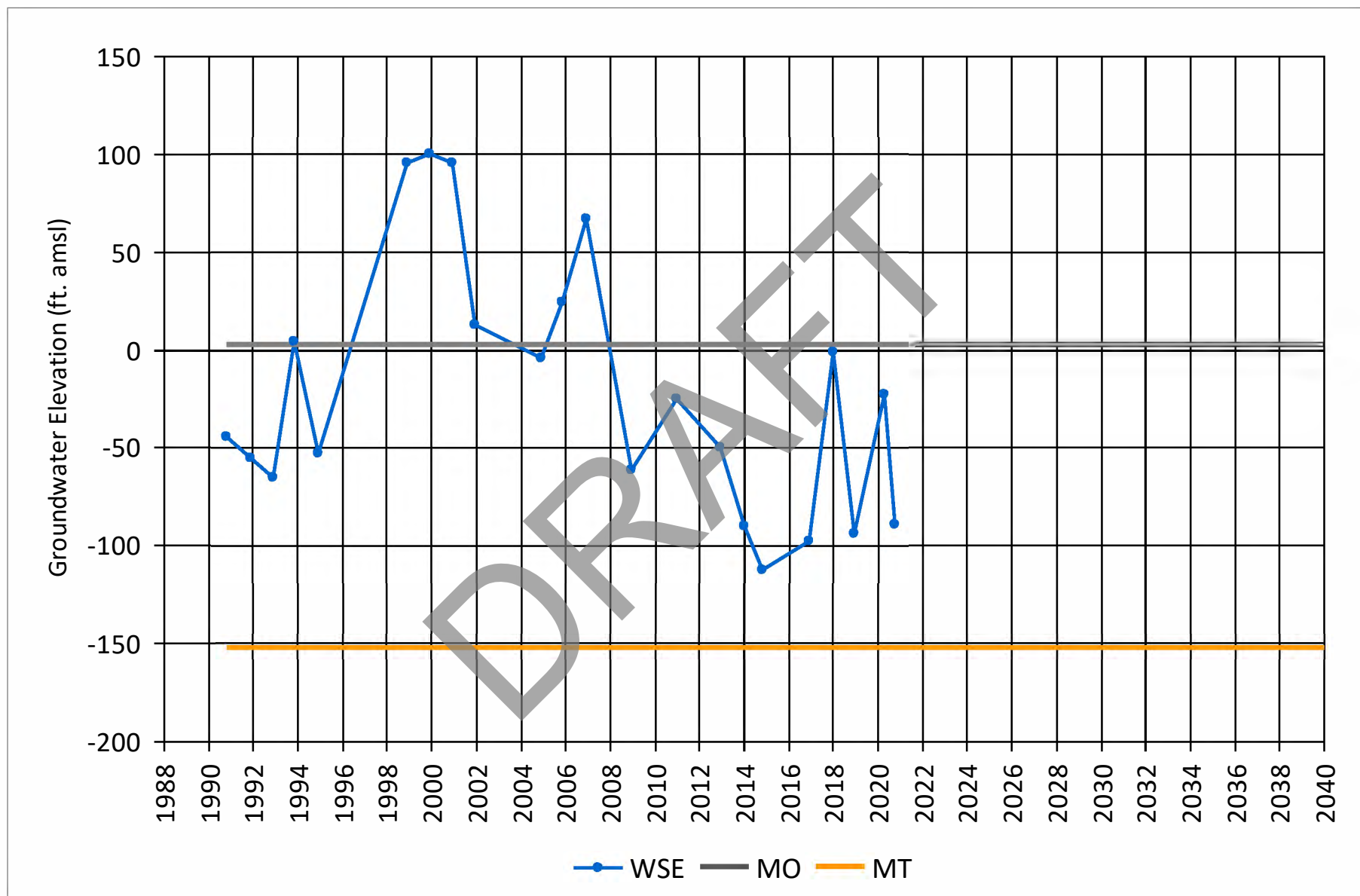
MO: 4.1 MT: -36.8
Depth: 580 ft



Aquifer: Lower
Perforations: 718-1423 ft

19S/19E-29A01

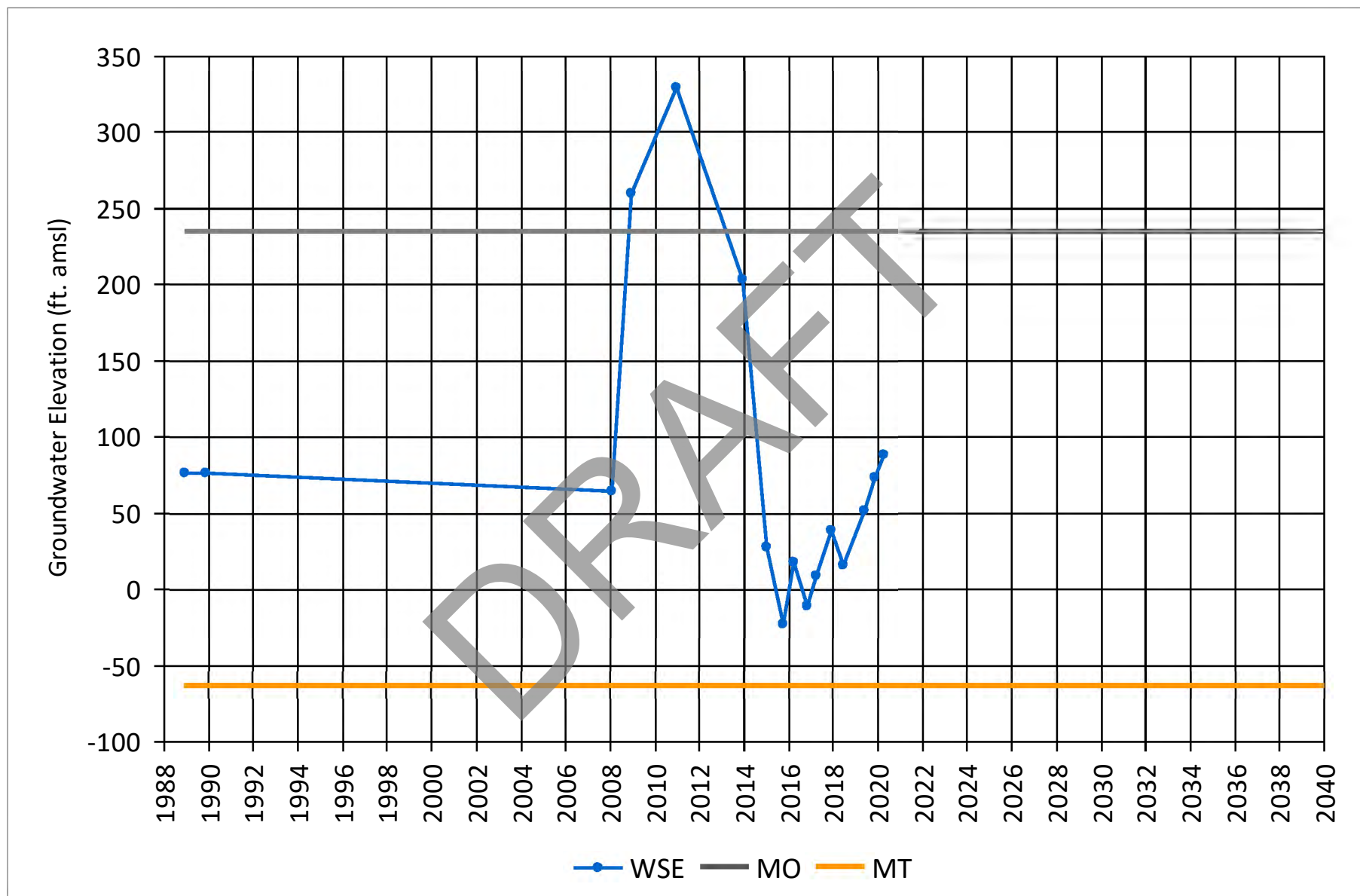
MO: 2.5 MT: -152.1
Depth: 1423 ft



Aquifer: Lower
Perforations: 601-1406 ft

20S/16E-21R01

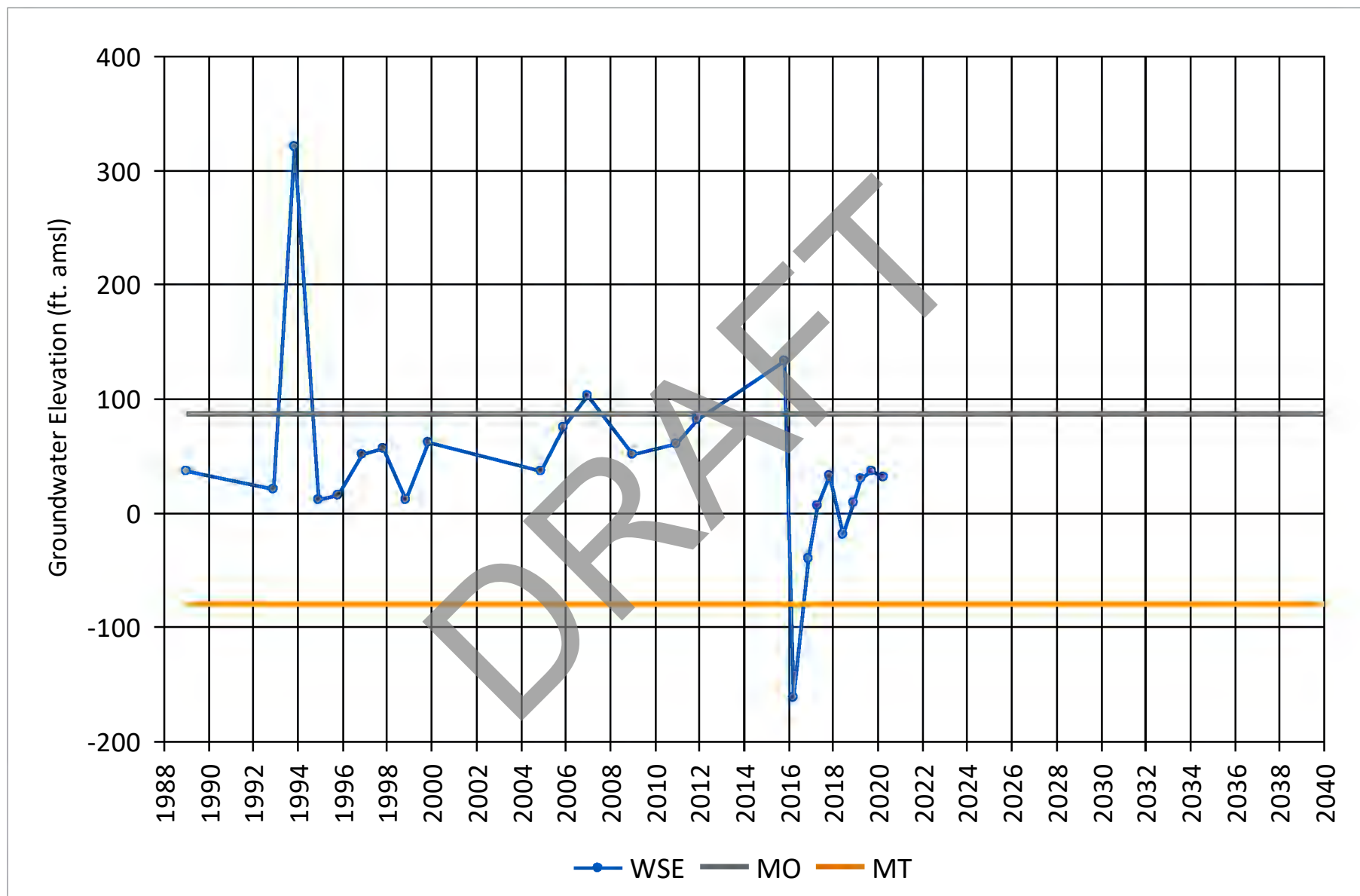
MO: 235.4 MT: -63
Depth: 1418 ft



Aquifer: Lower
Perforations: 801-2067 ft

20S/17E-09N03

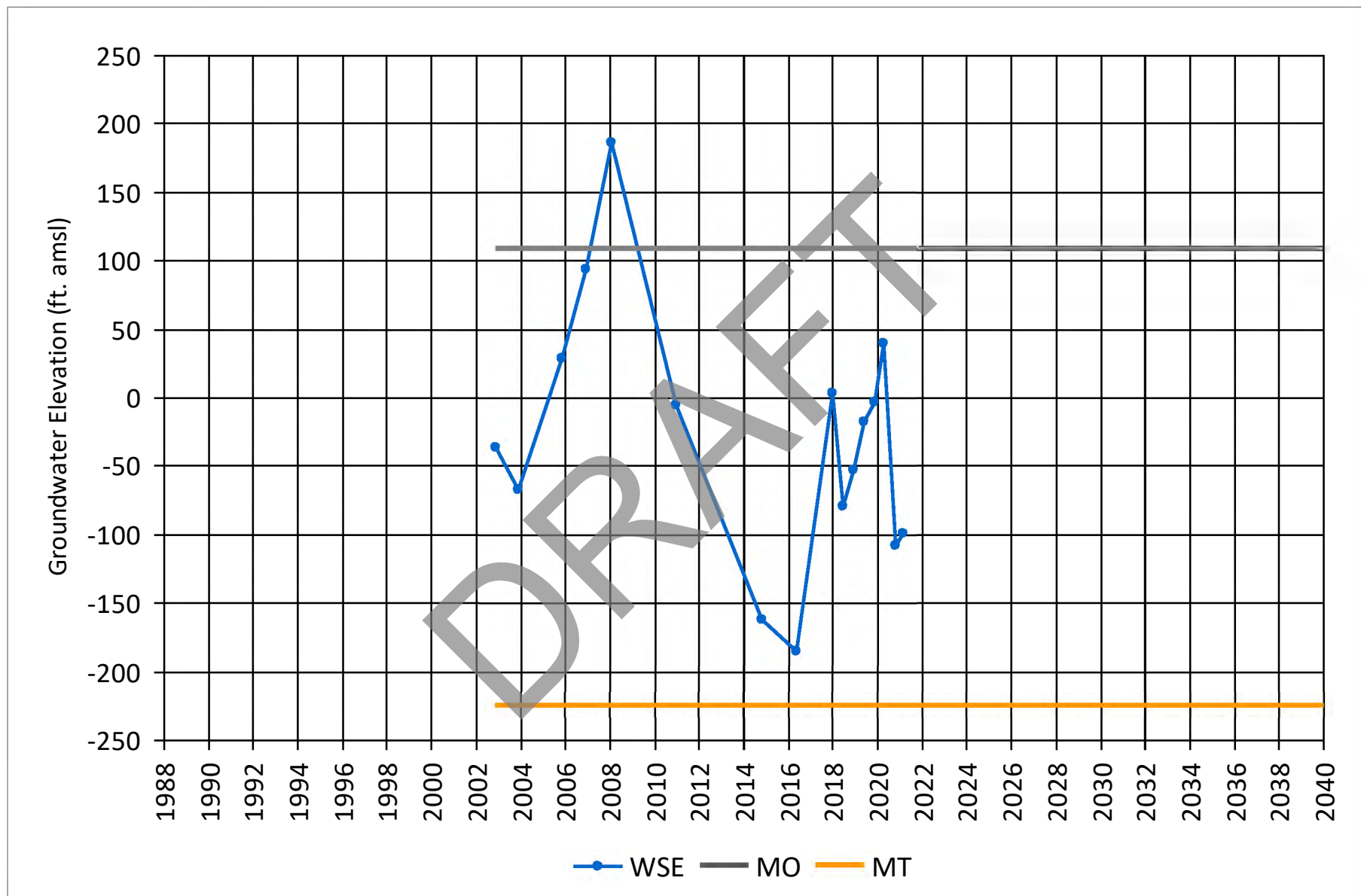
MO: 87.2 MT: -79.8
Depth: 2100 ft



Aquifer: Lower
Perforations: 600-1040 ft

20S/18E-04G01

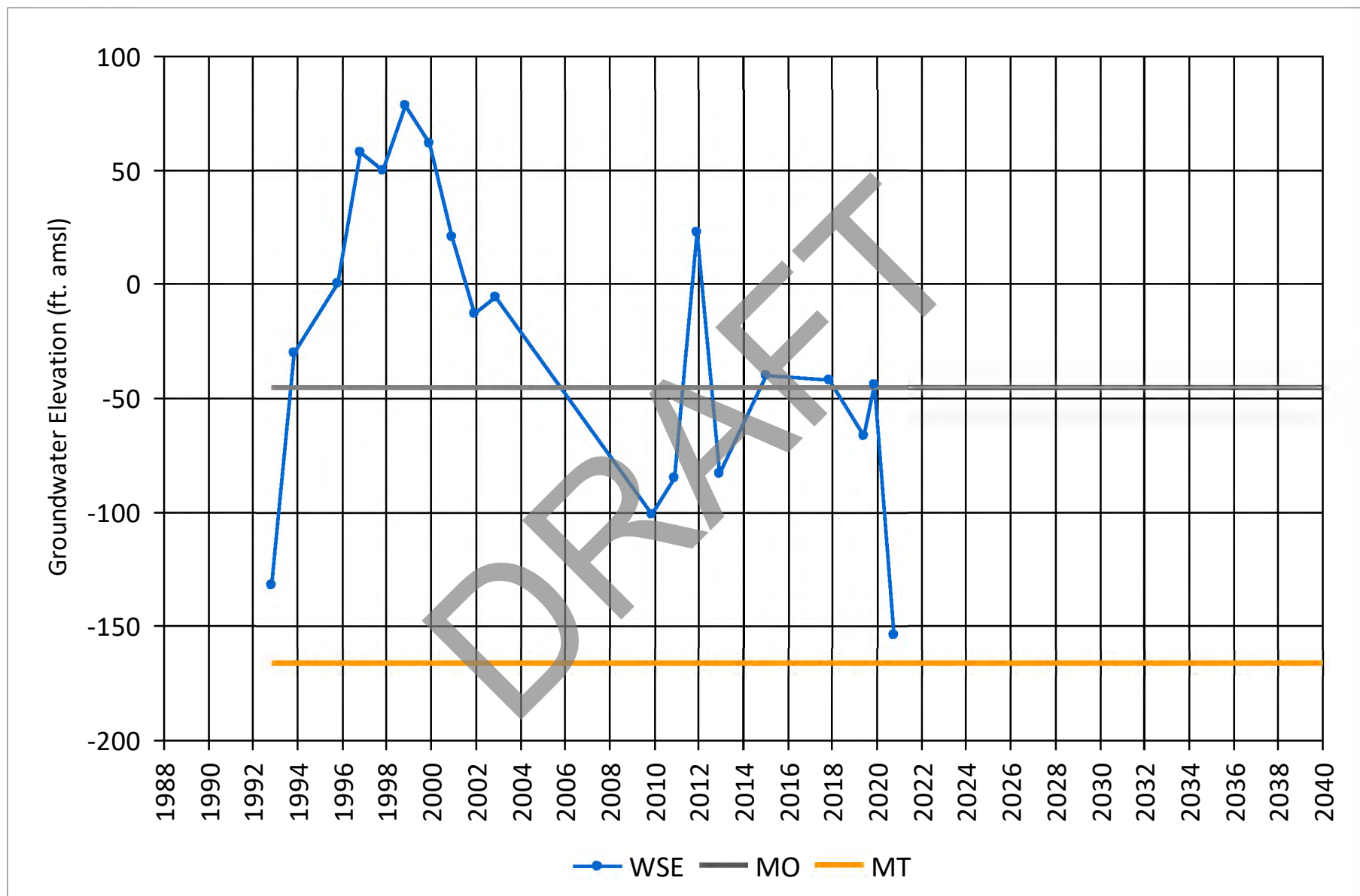
MO: 108.9 MT: -225.1
Depth: 1040 ft



Aquifer: Lower
Perforations: 700-1700 ft

20S/18E-35D02

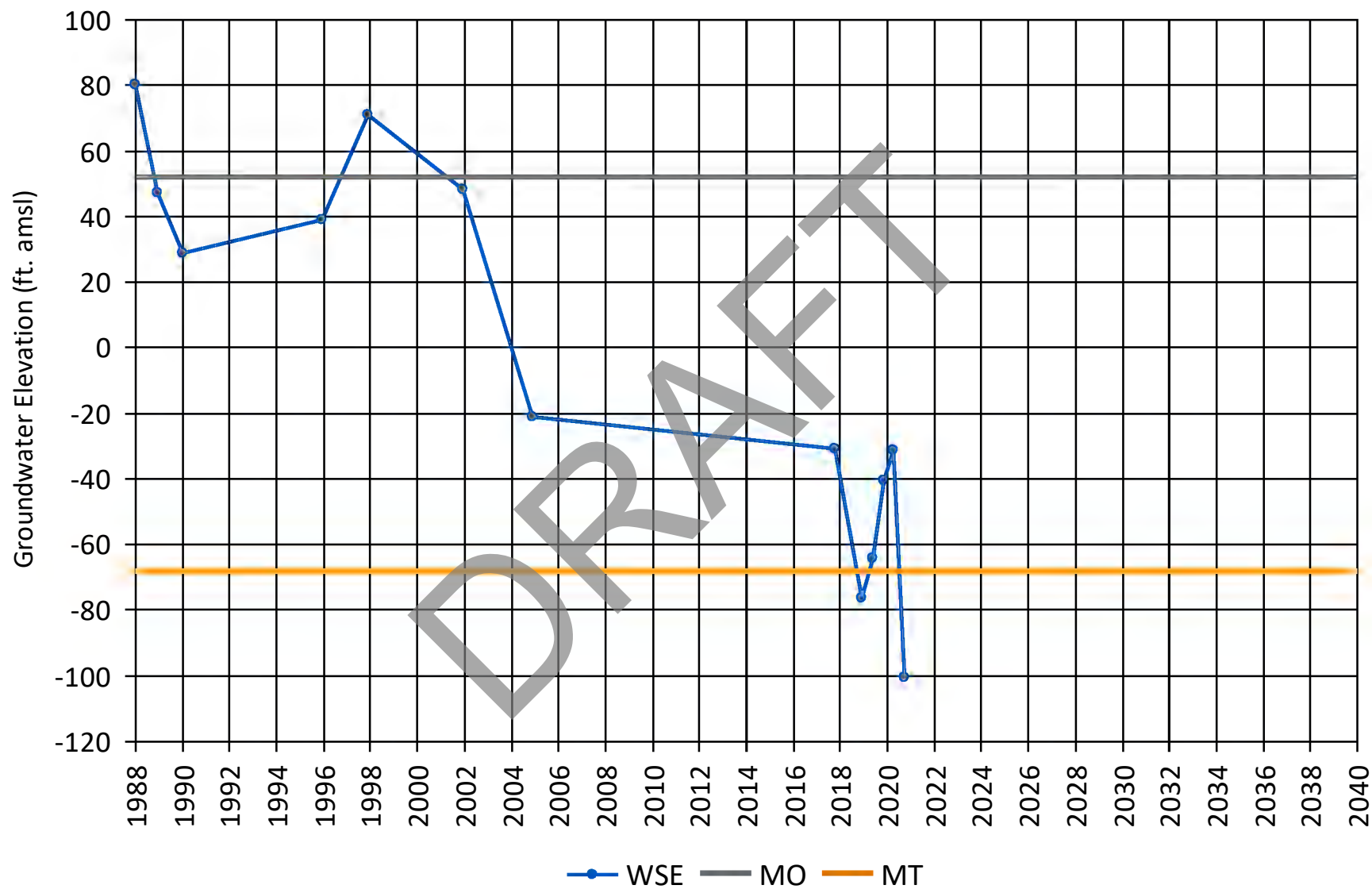
MO: -45.7 MT: -166
Depth: 1700 ft



Aquifer: Lower
Perforations: 869-2090 ft

20S/19E-02A01

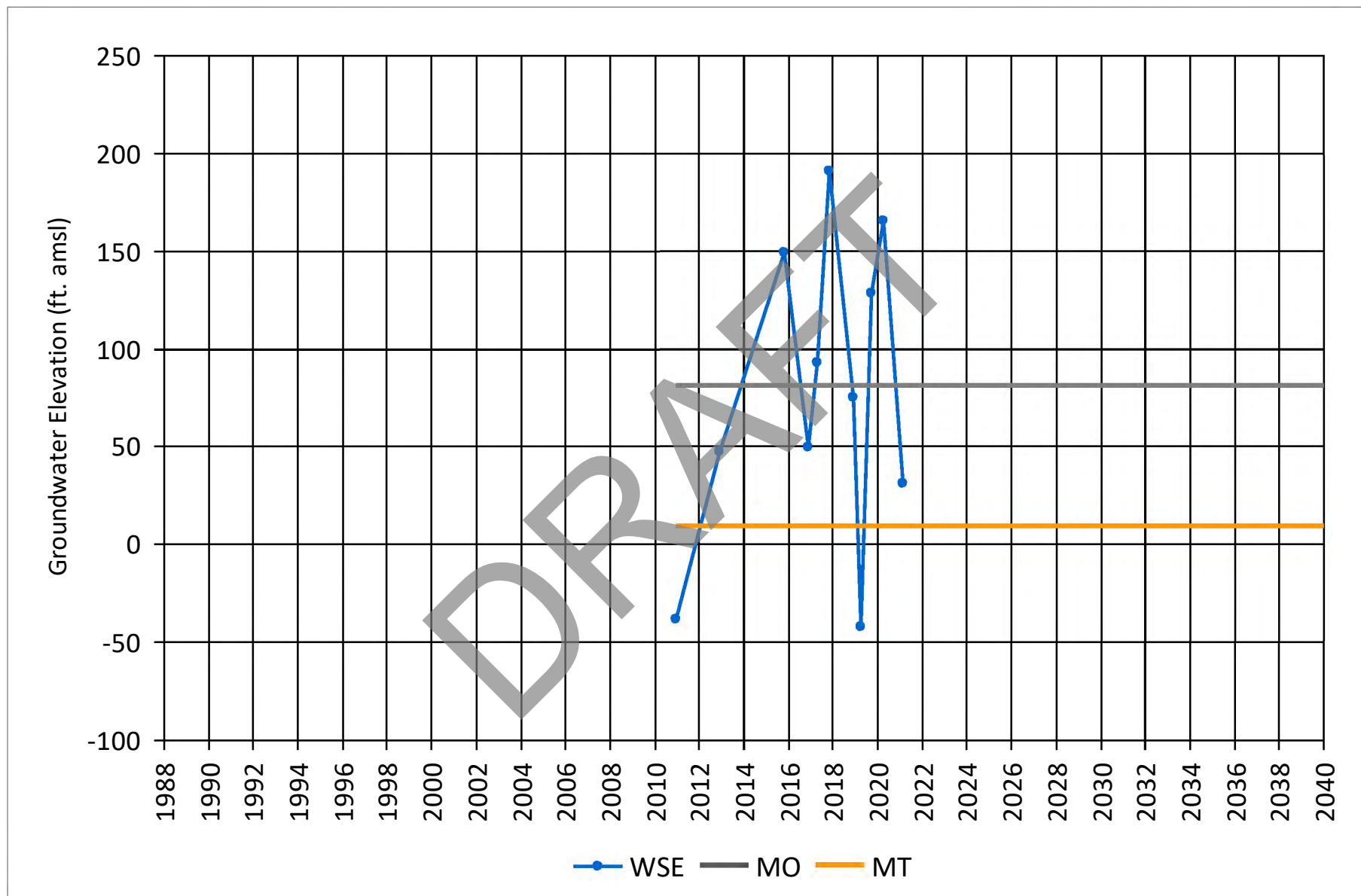
MO: 52.2 MT: -68.3
Depth: 2130 ft



Aquifer: Upper
Perforations: 175-670 ft

20S/19E-07G02

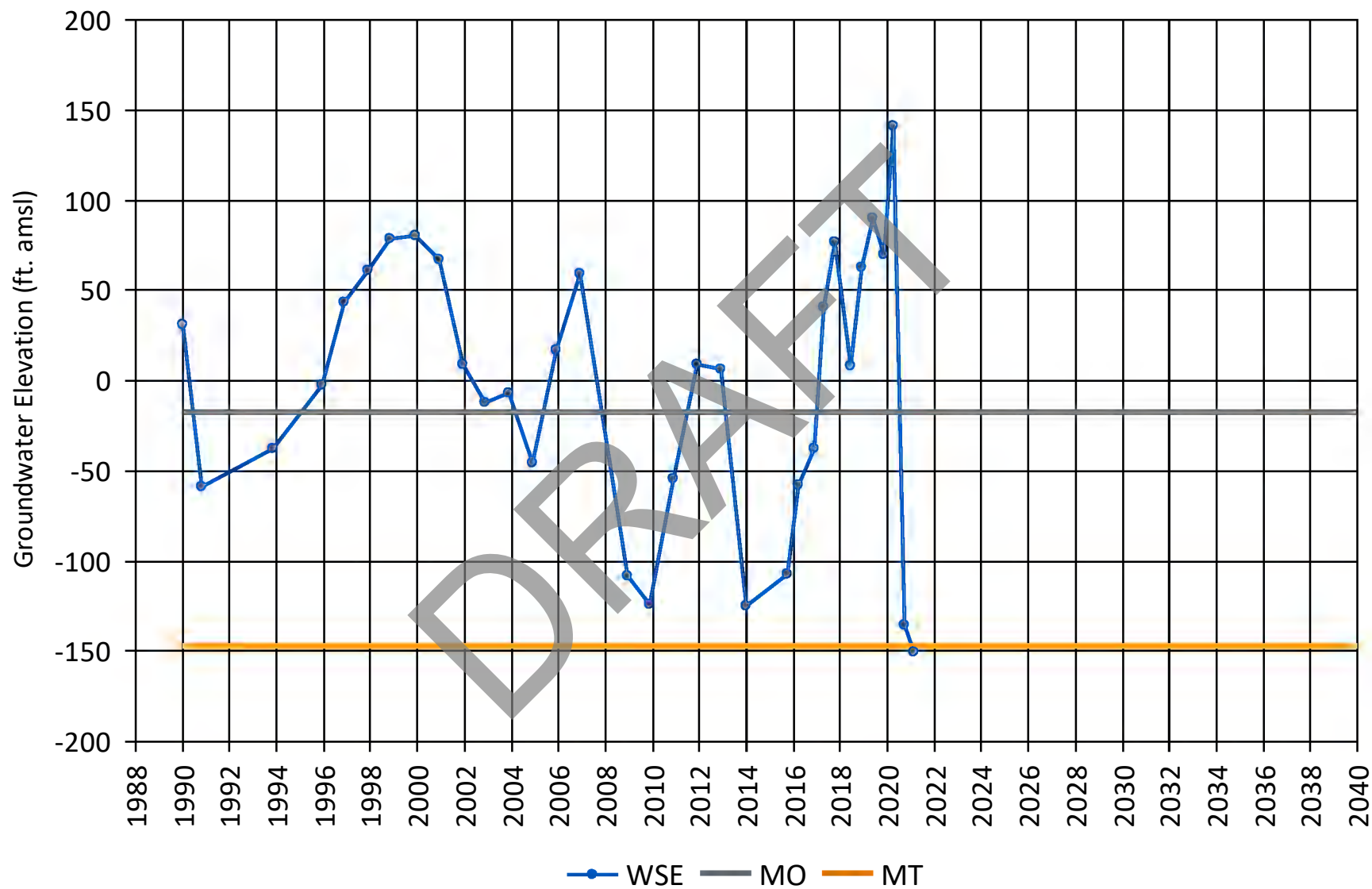
MO: 81.5 MT: 9.5
Depth: 690 ft



Aquifer: Lower
Perforations: 700-1000 ft

20S/19E-17M01

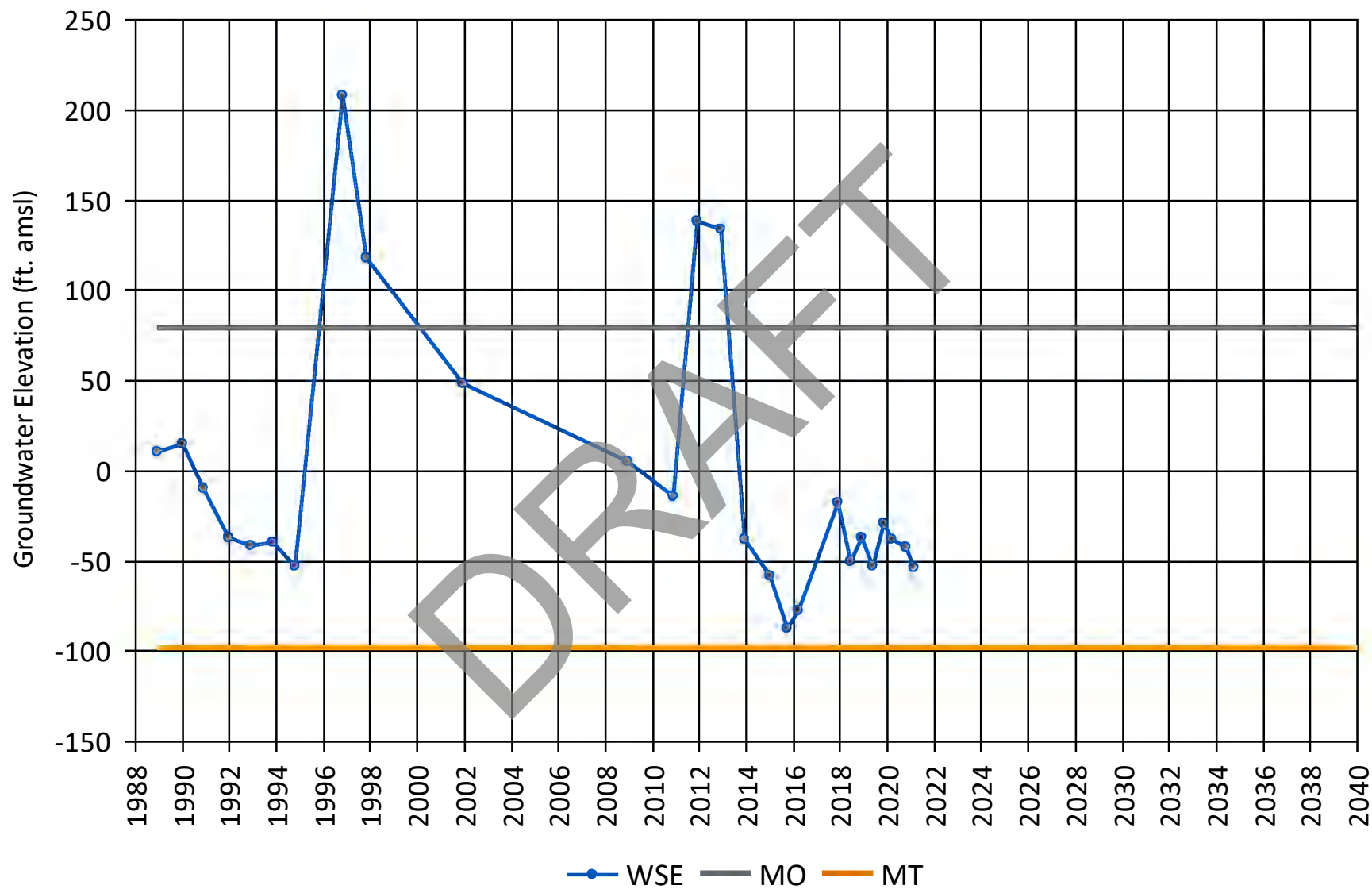
MO: -18 MT: -147.1
Depth: 1000 ft



Aquifer: Lower
Perforations: 628-1989 ft

21S/17E-11N01

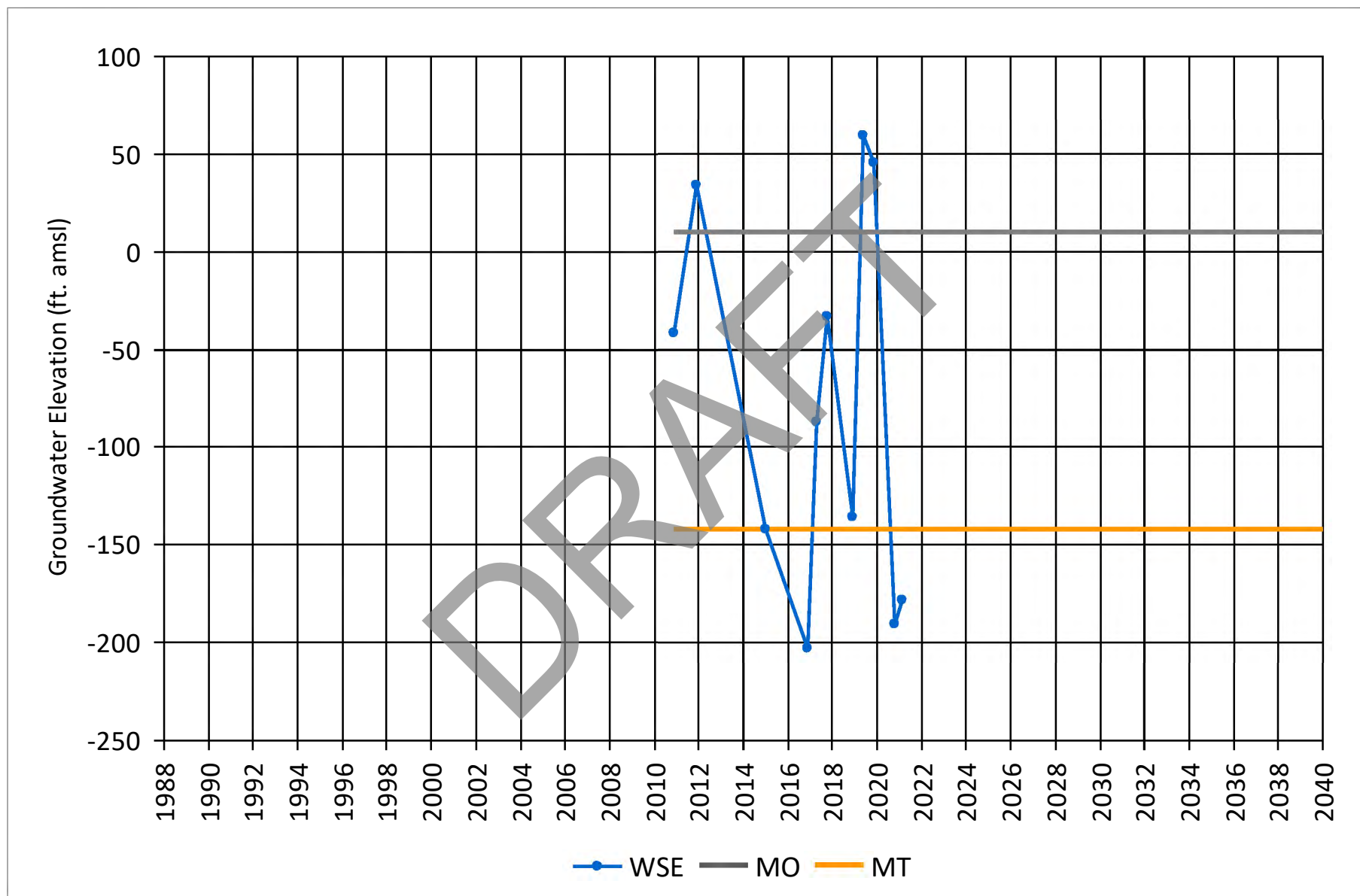
MO: 79.1 MT: -98.1
Depth: 2008 ft



Aquifer: Lower
Perforations: 720-1780 ft

21S/18E-22E01

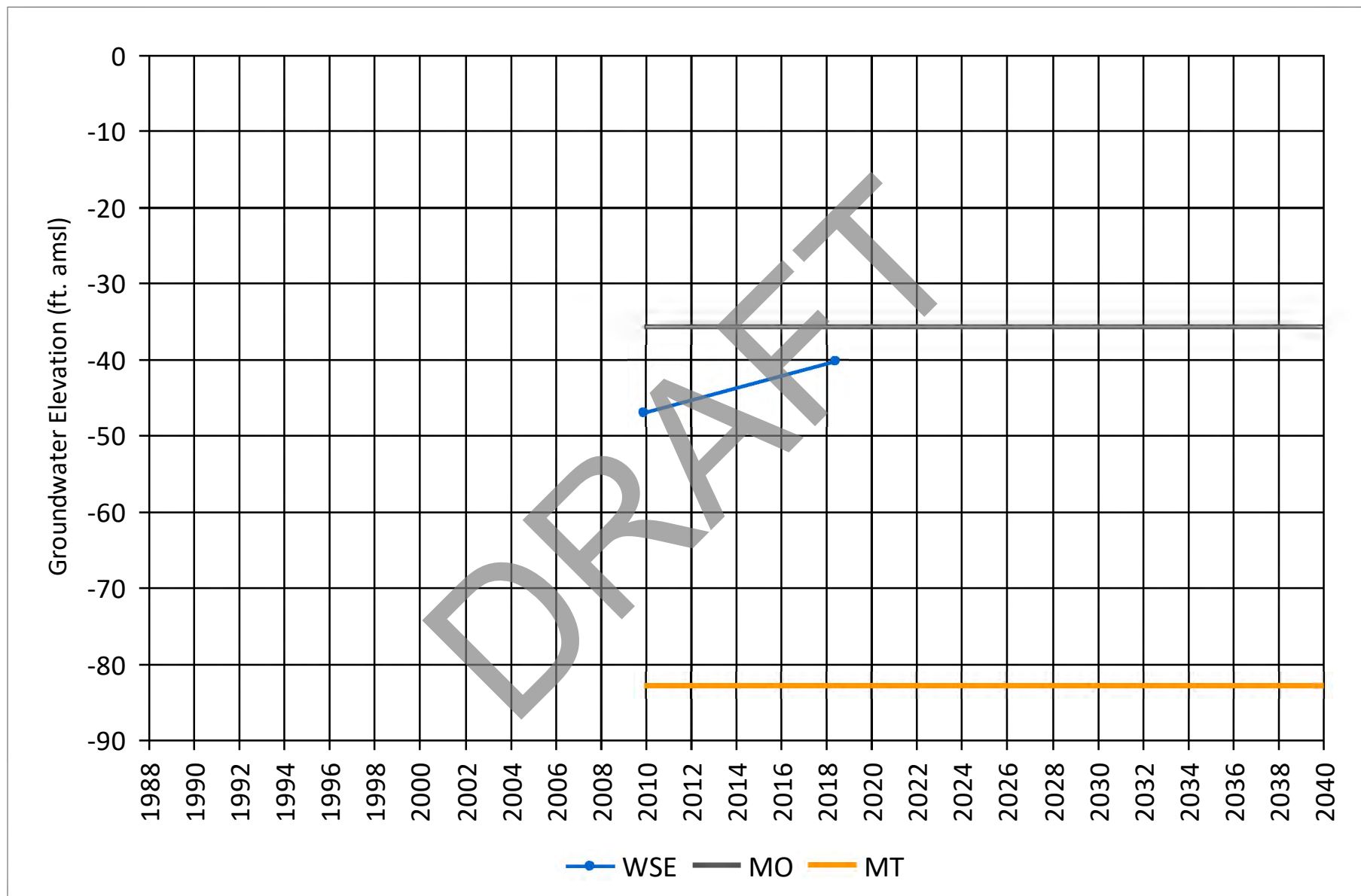
MO: 9.7 MT: -142.1
Depth: 1800 ft



Aquifer: Lower
Perforations: 600-1180 ft

21S/18E-35Q02

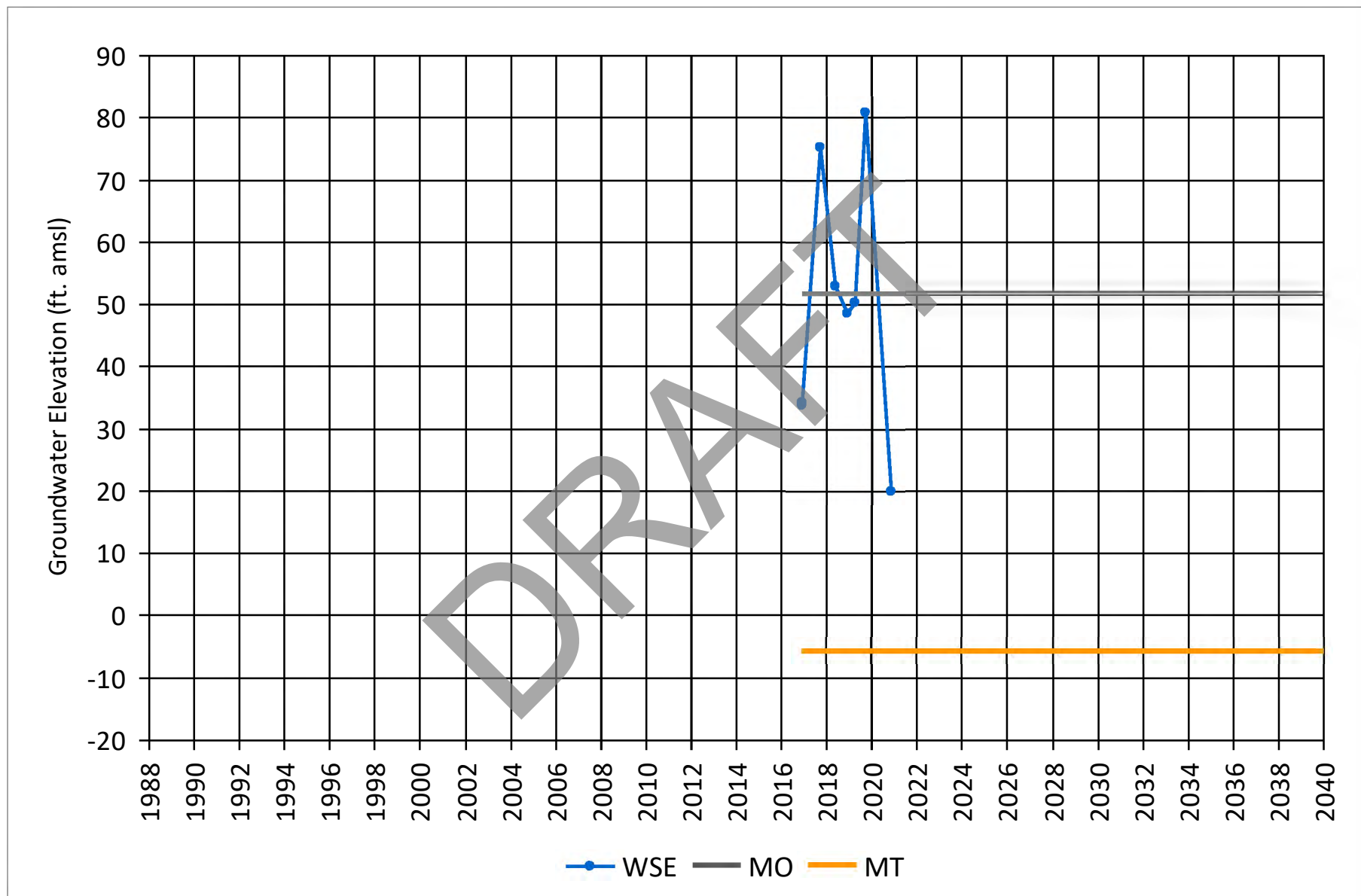
MO: -35.7 MT: -82.9
Depth: 1180 ft



Aquifer: Upper
Perforations: 286-770 ft

21S/19E-07H01

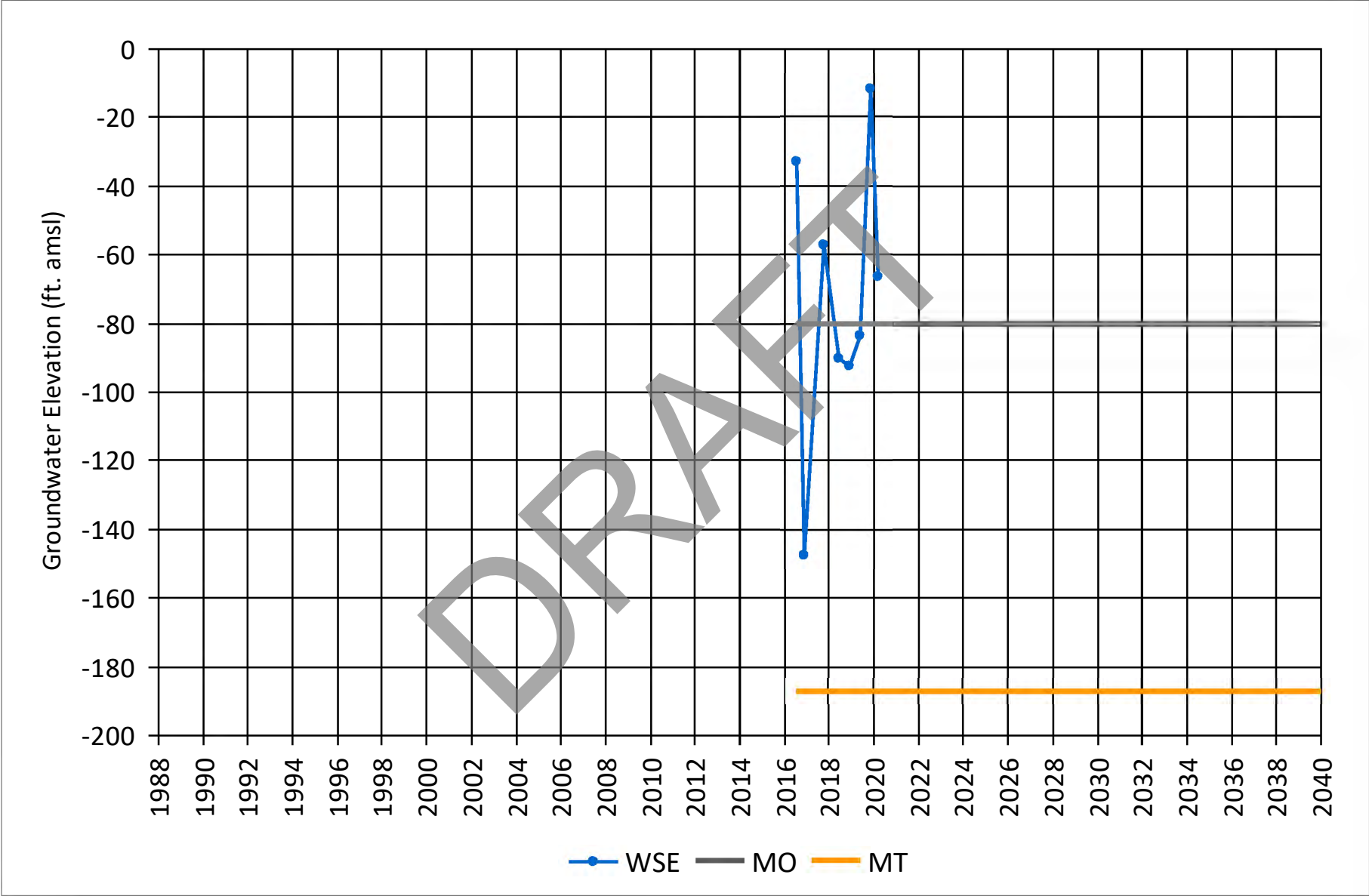
MO: 51.6 MT: -5.8
Depth: 790 ft

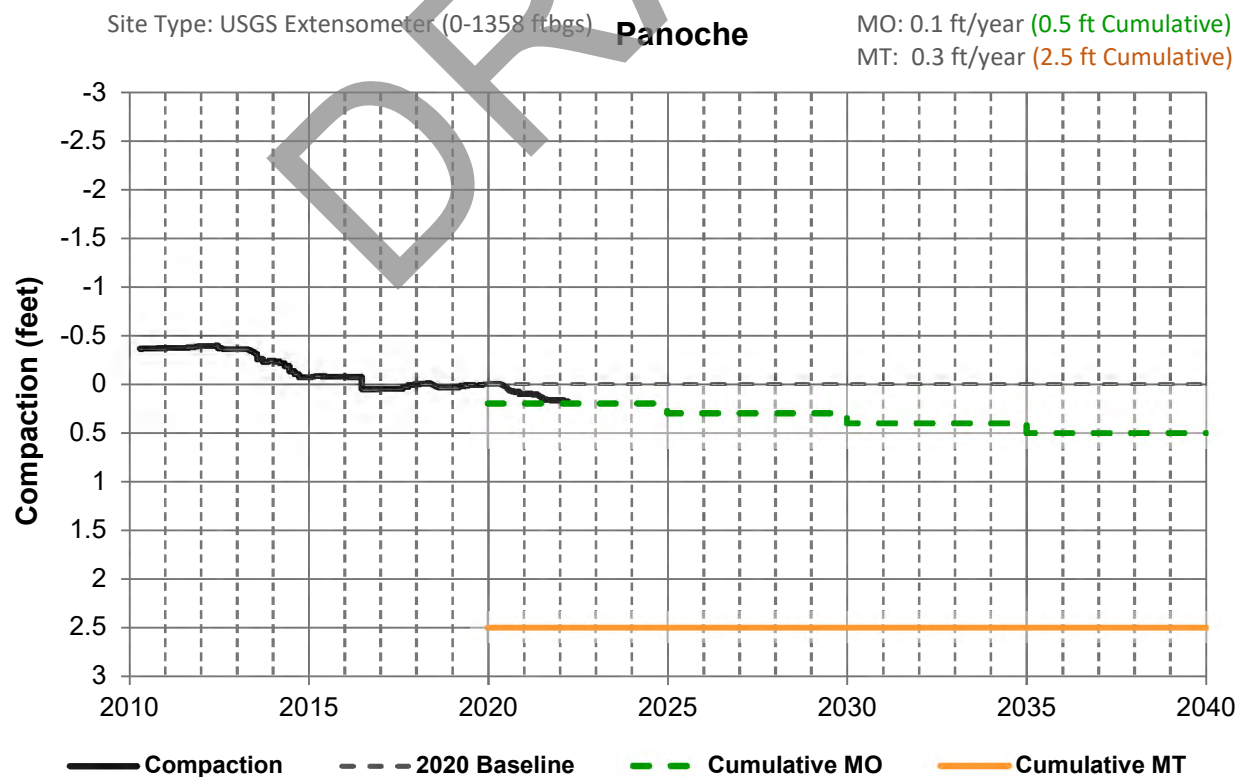
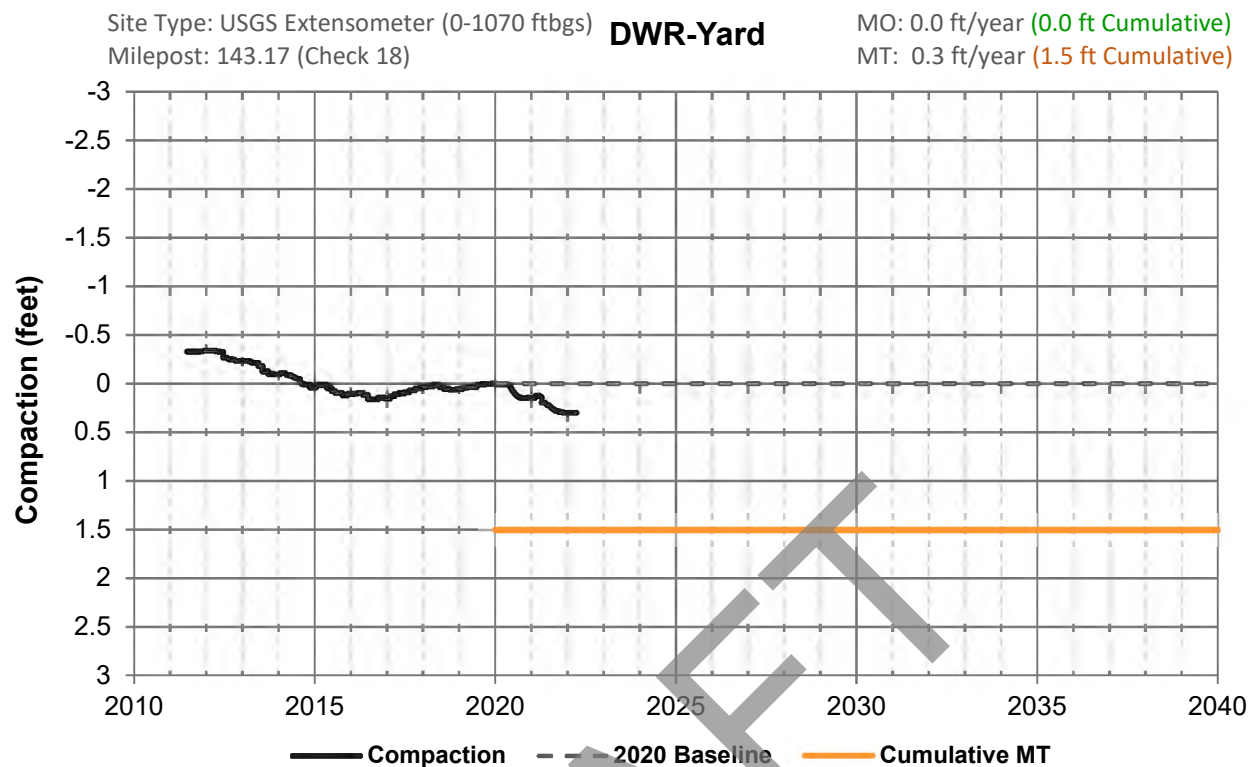


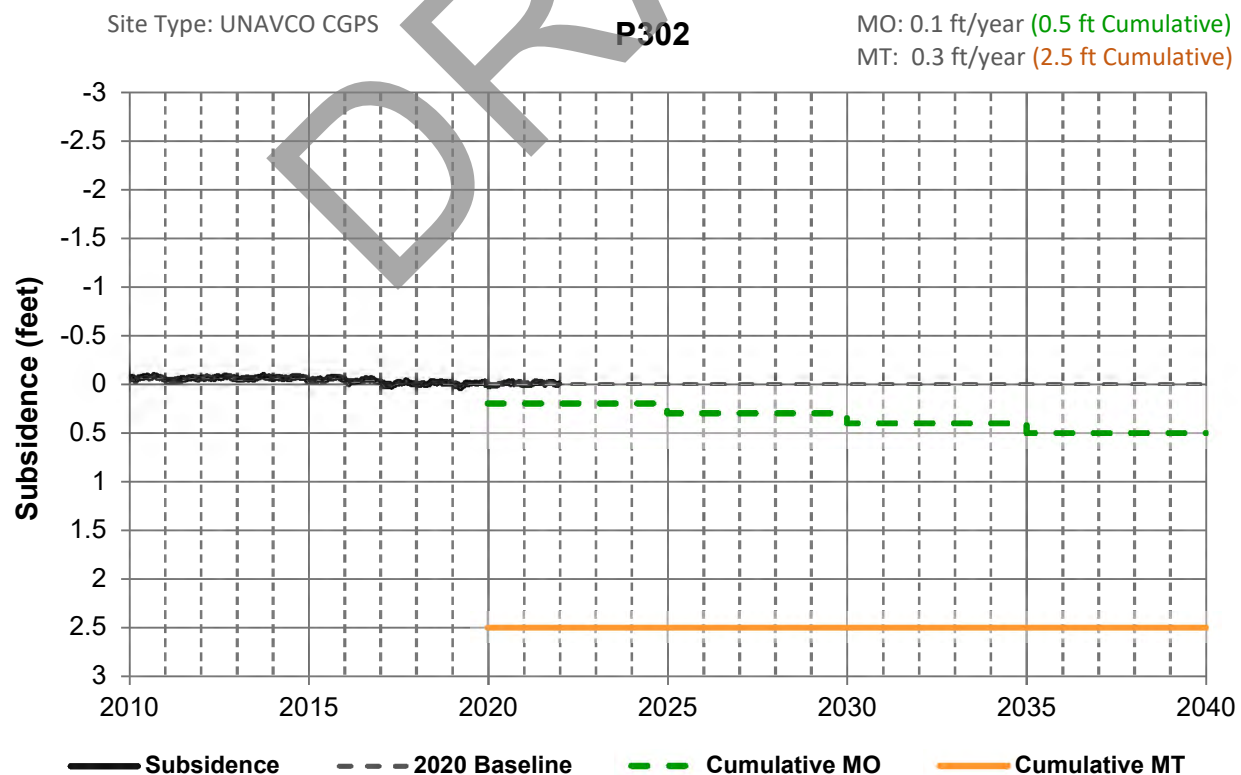
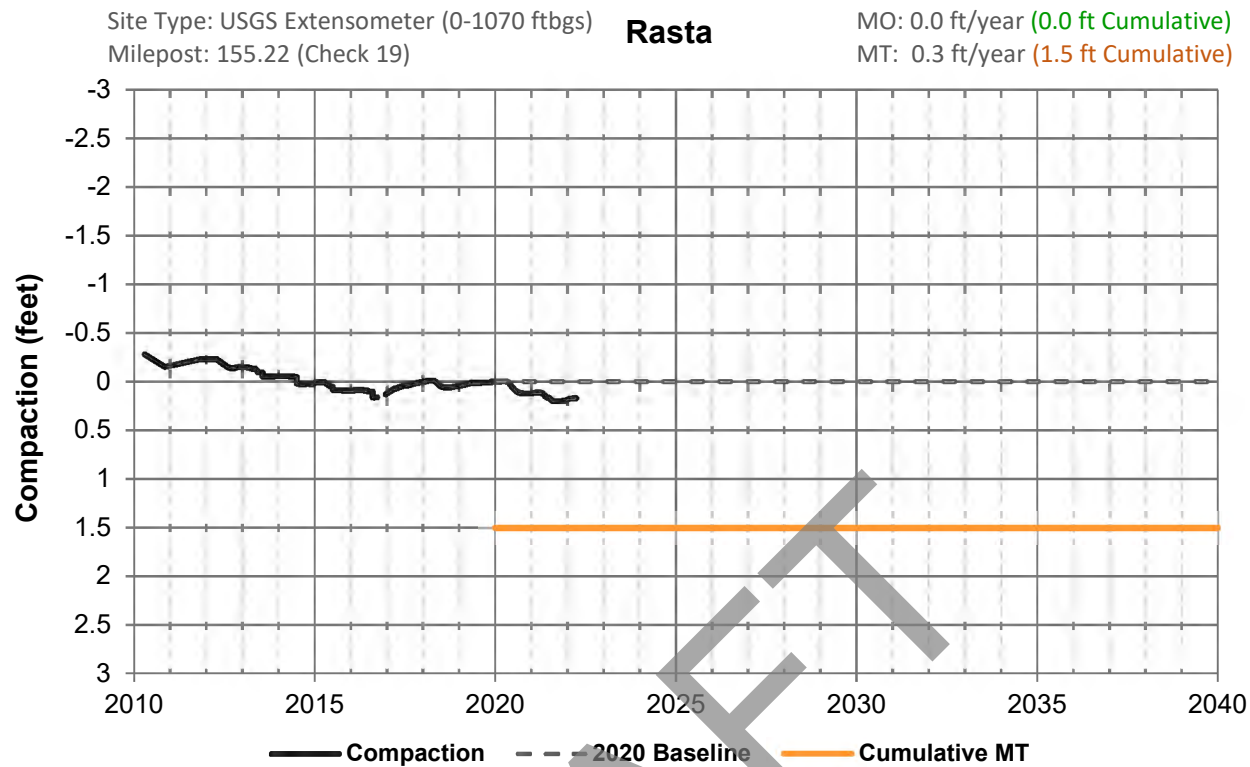
Aquifer: Lower
Perforations: ft

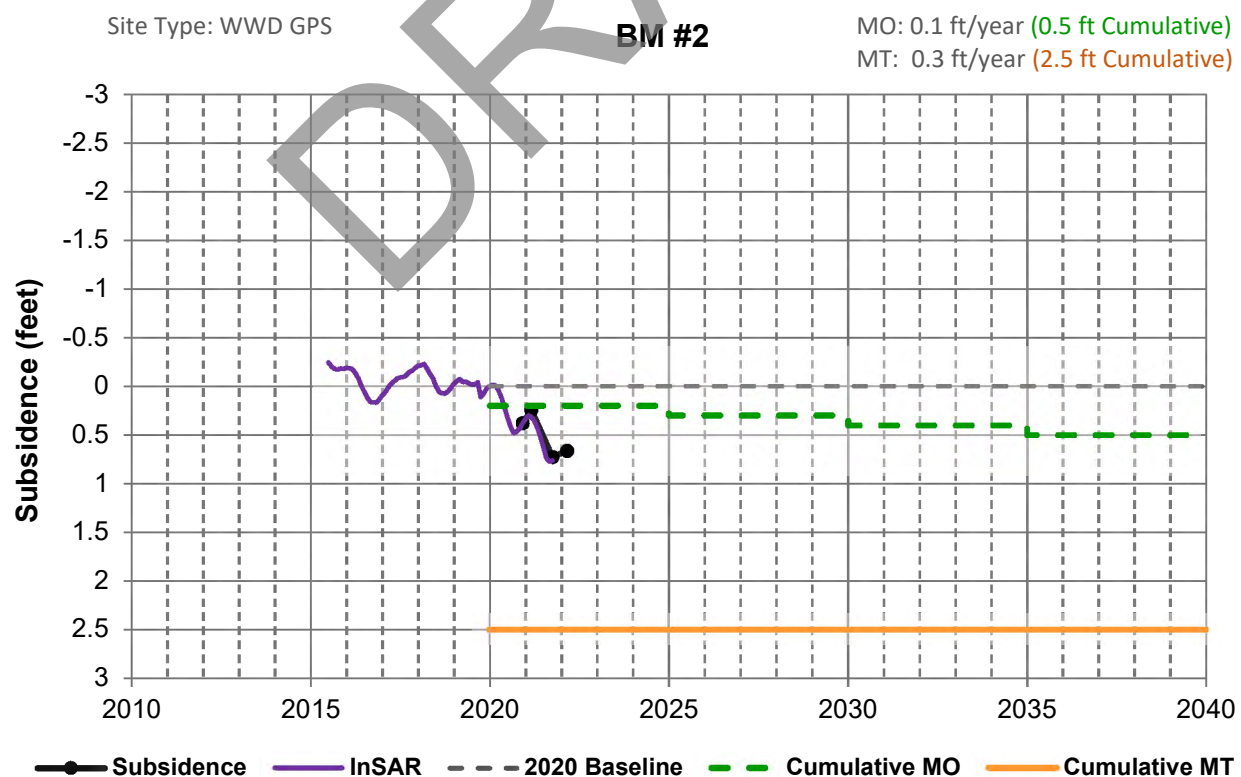
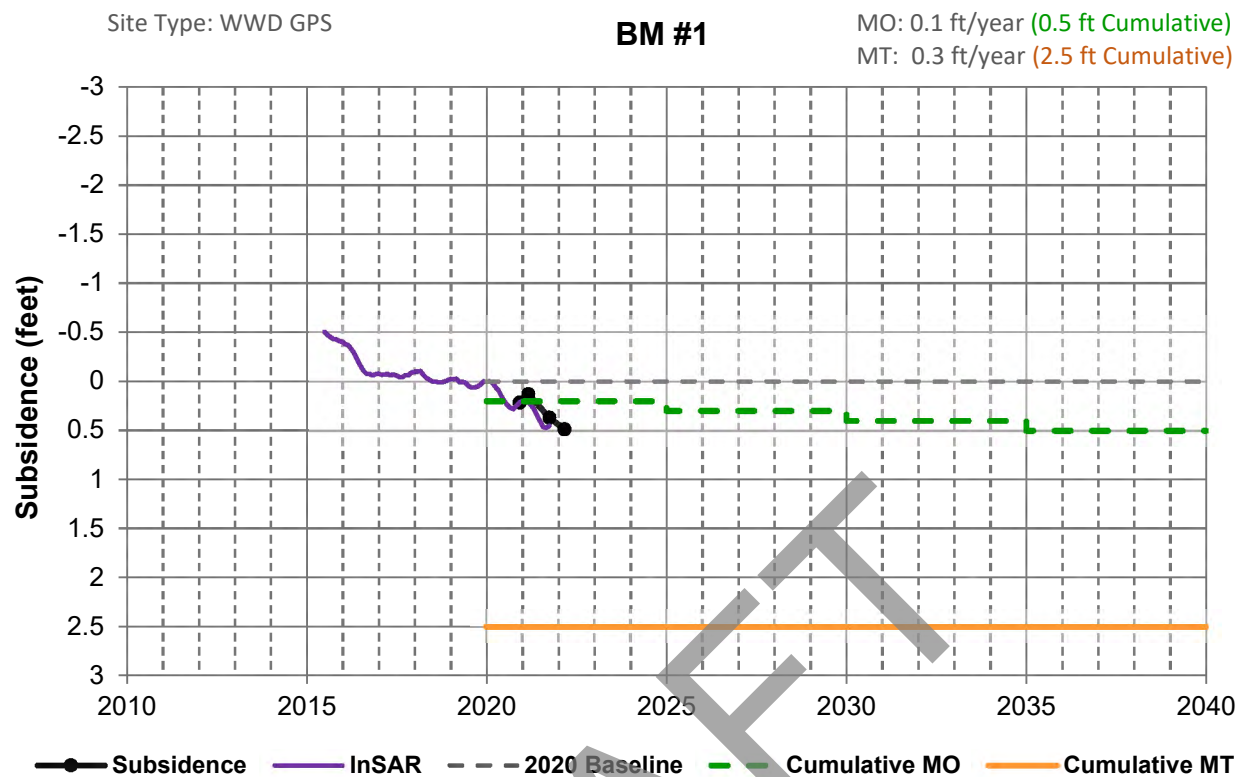
21S/19E-20D02

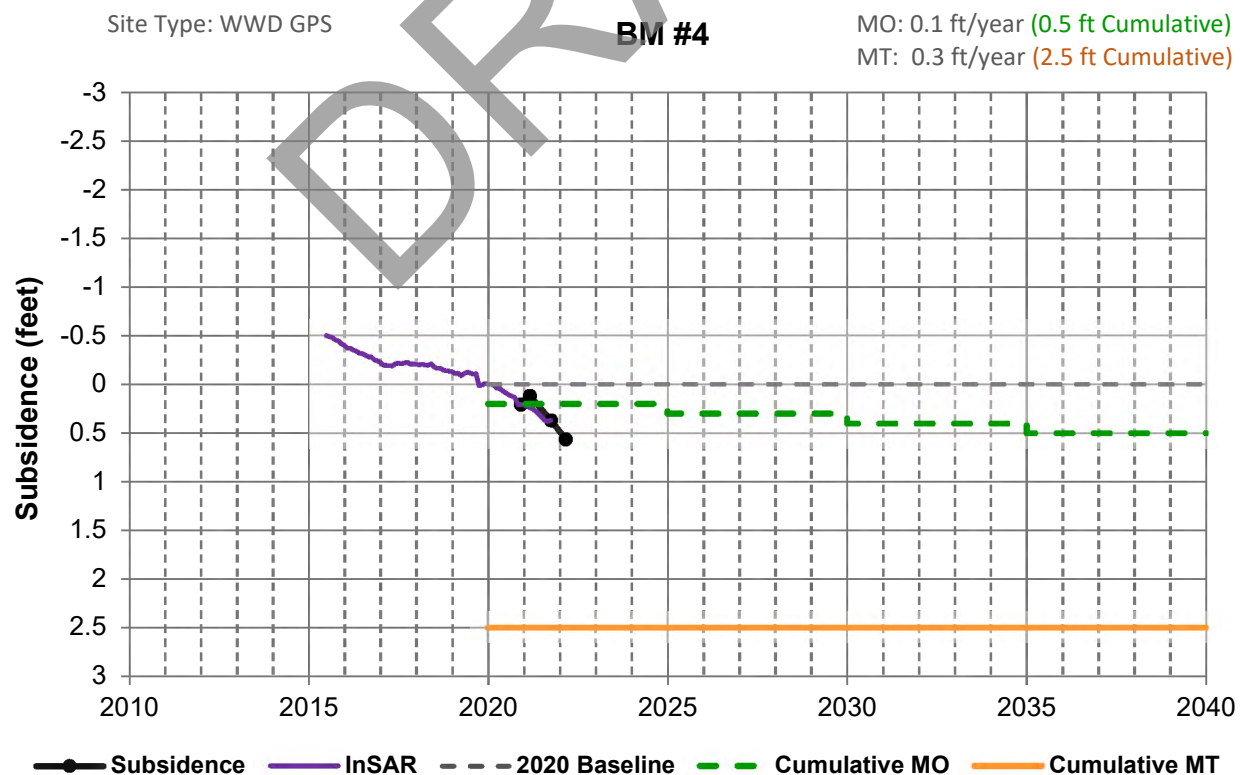
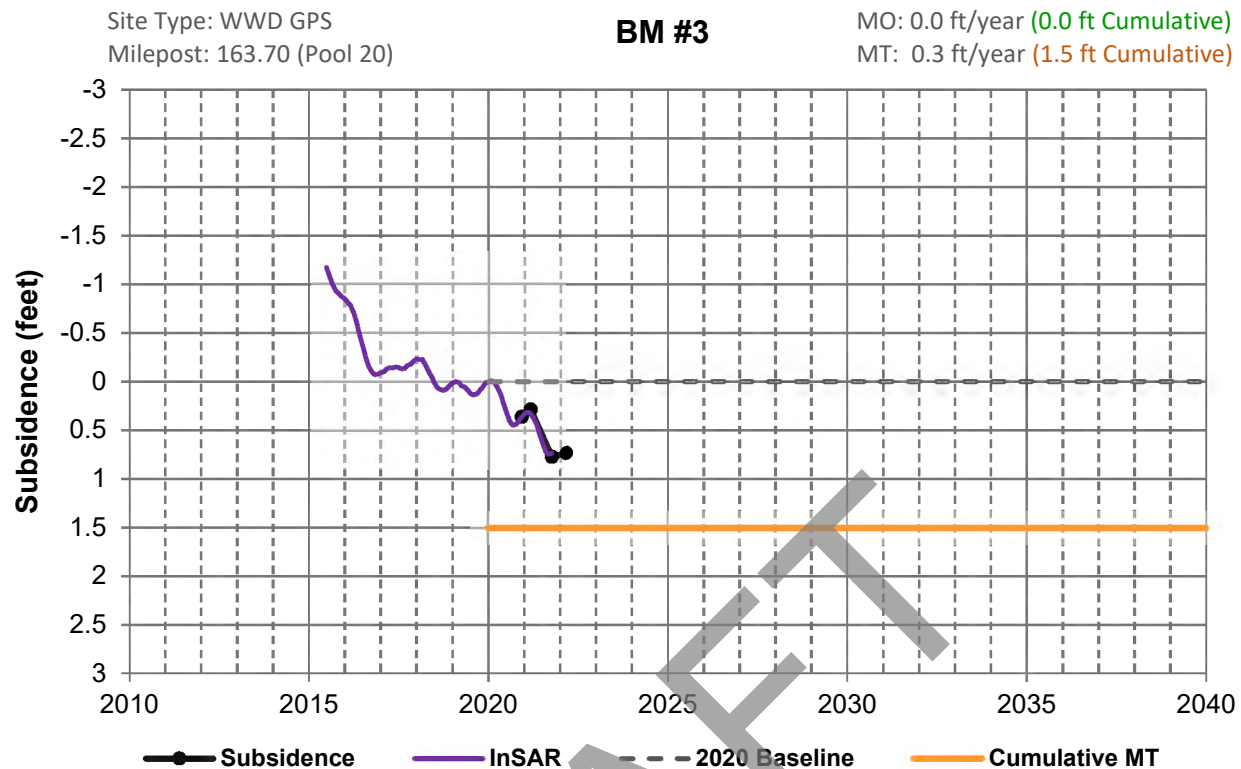
MO: -80.3 MT: -187.4
Depth: ft

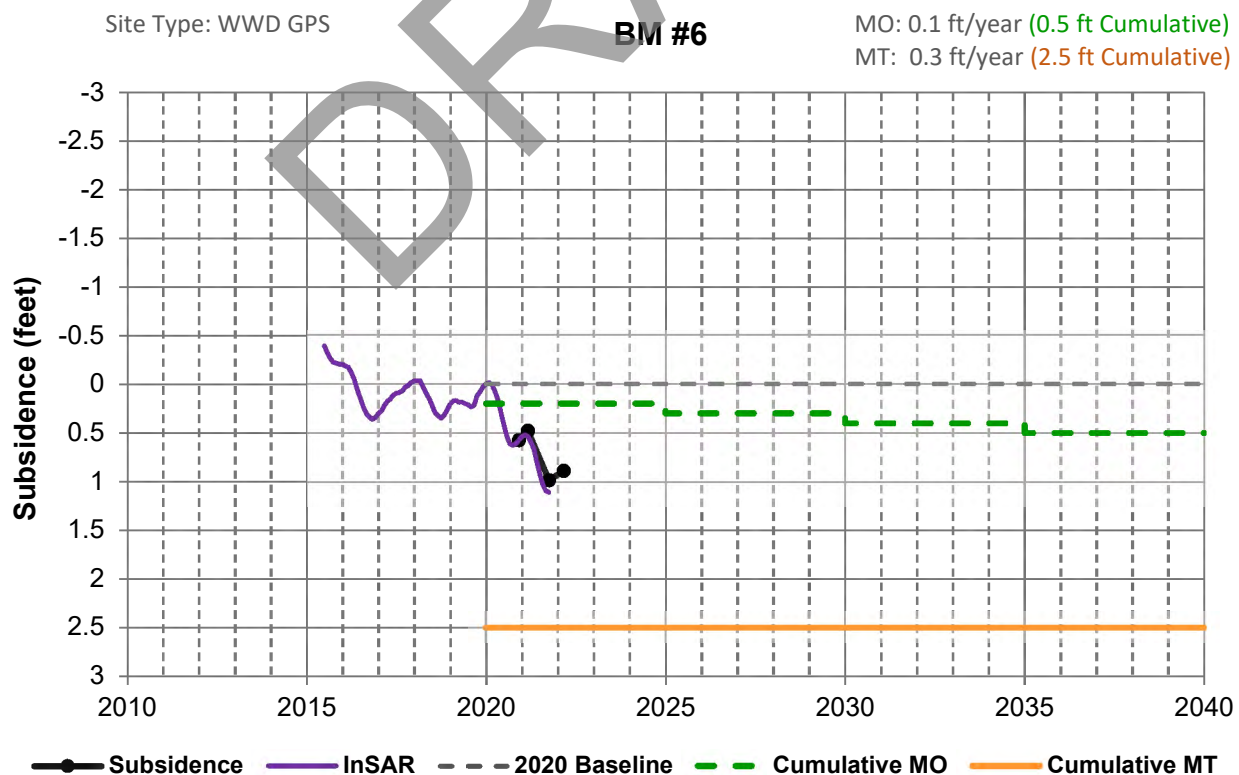
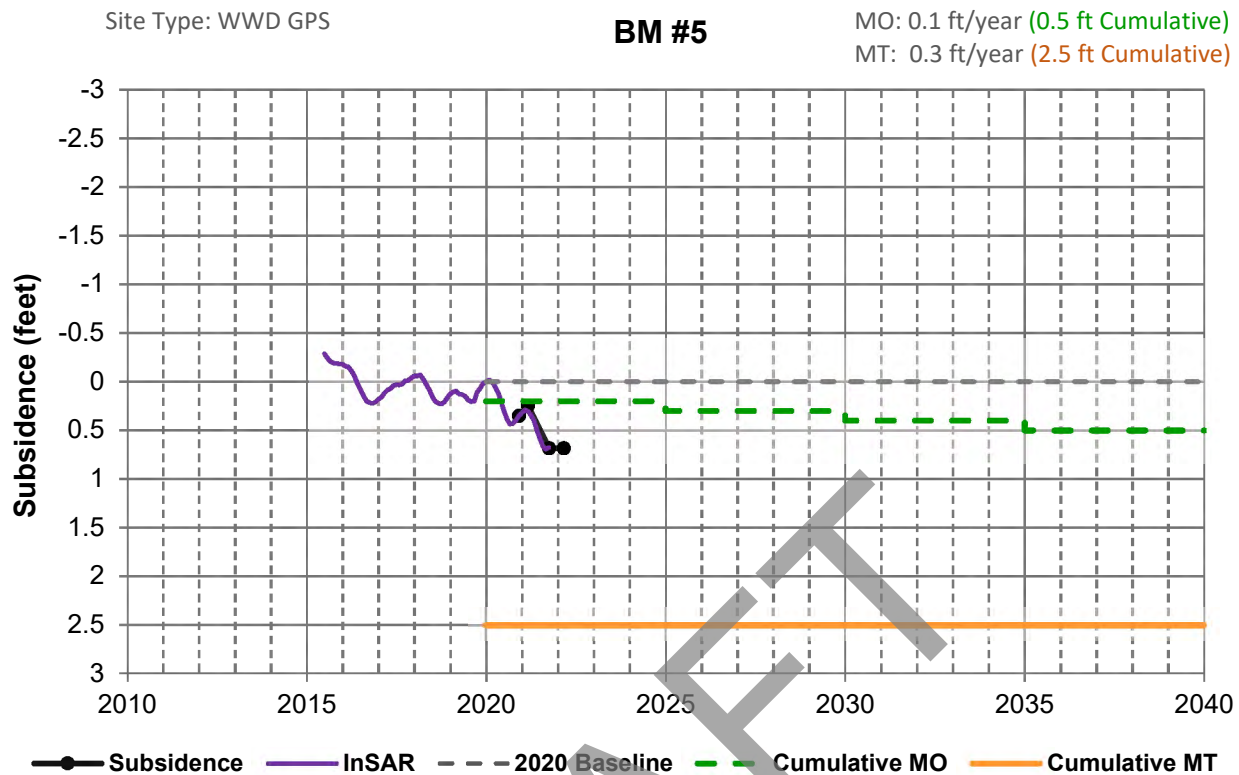


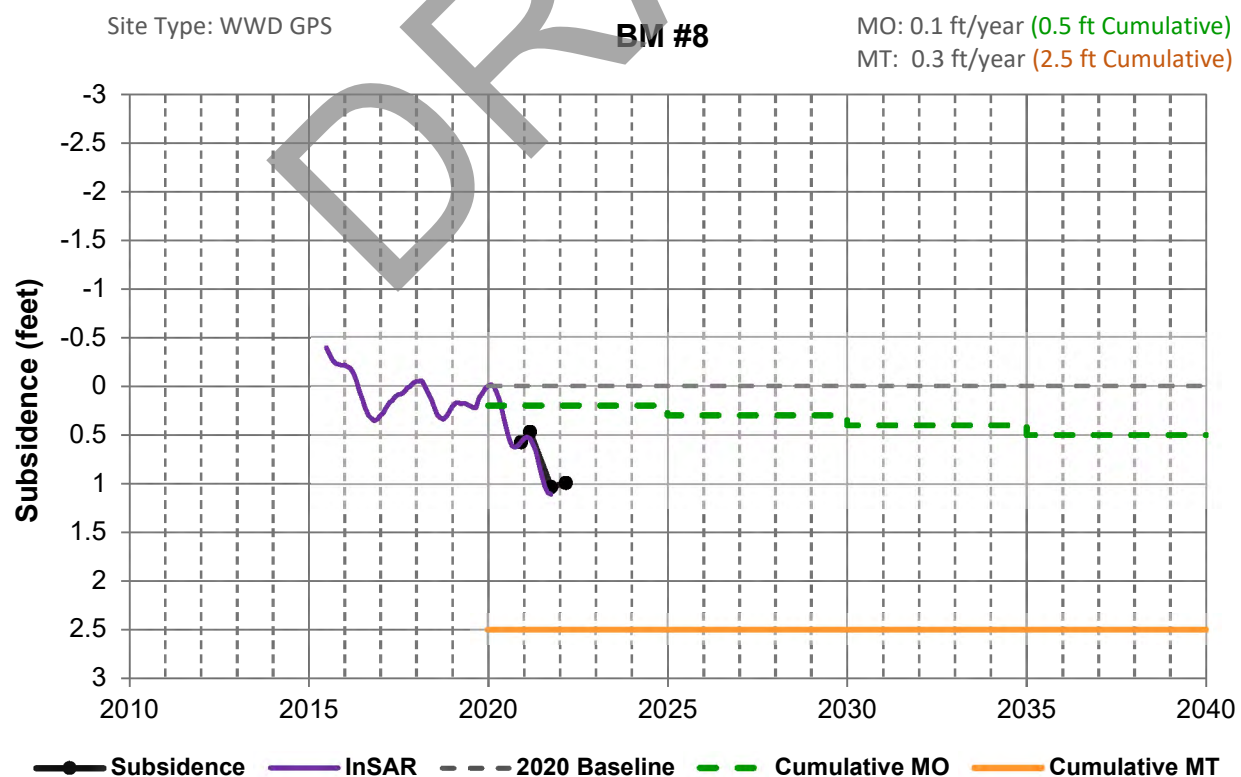
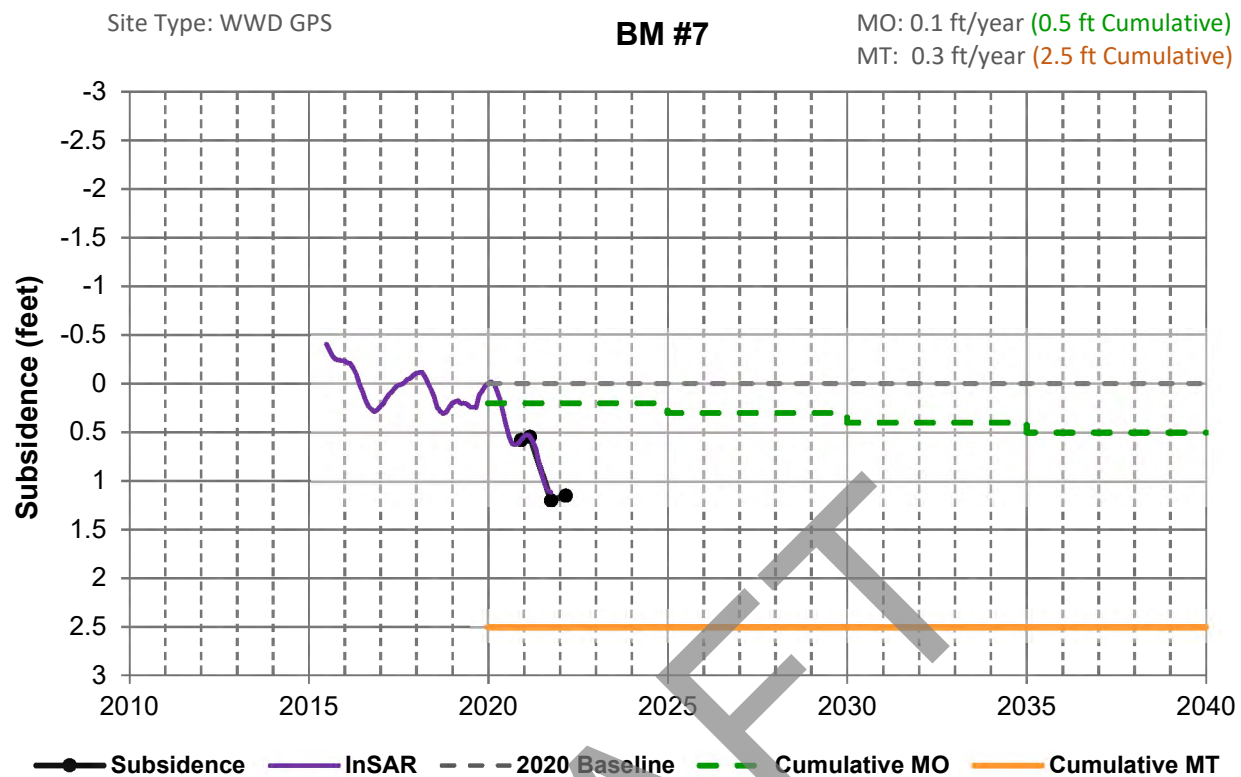


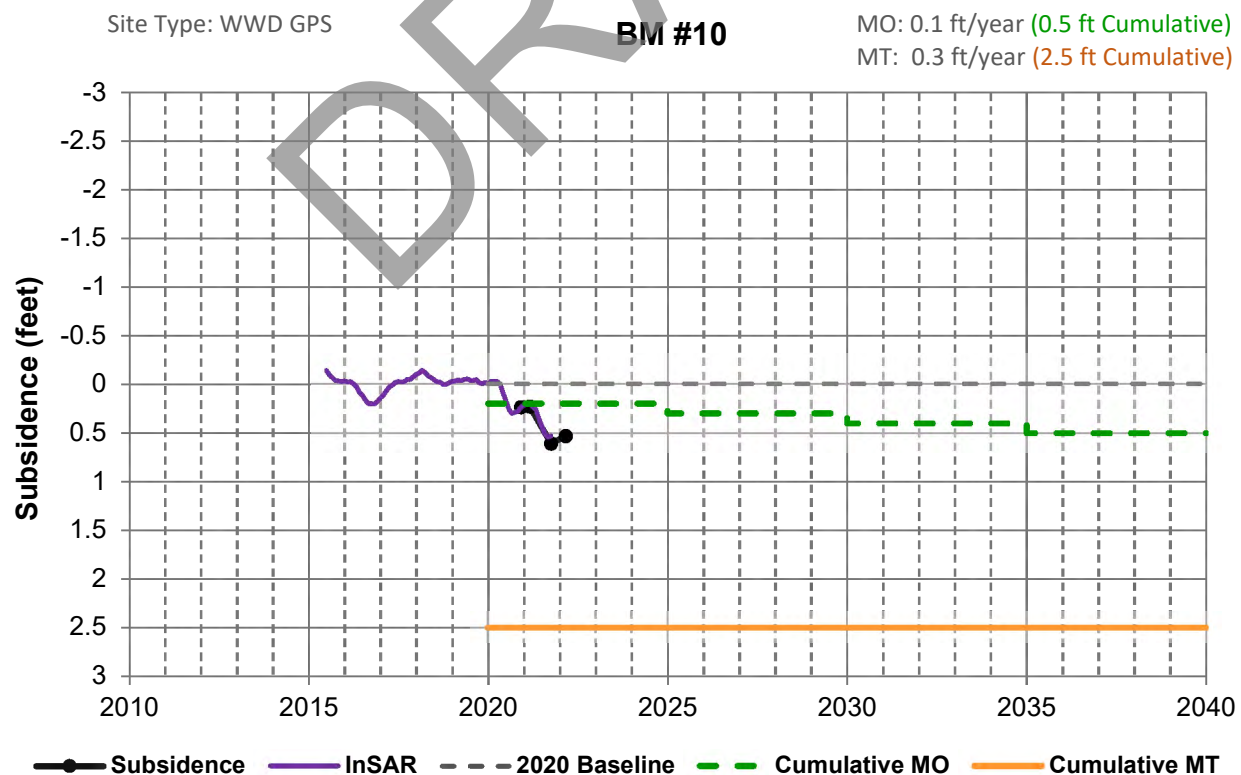
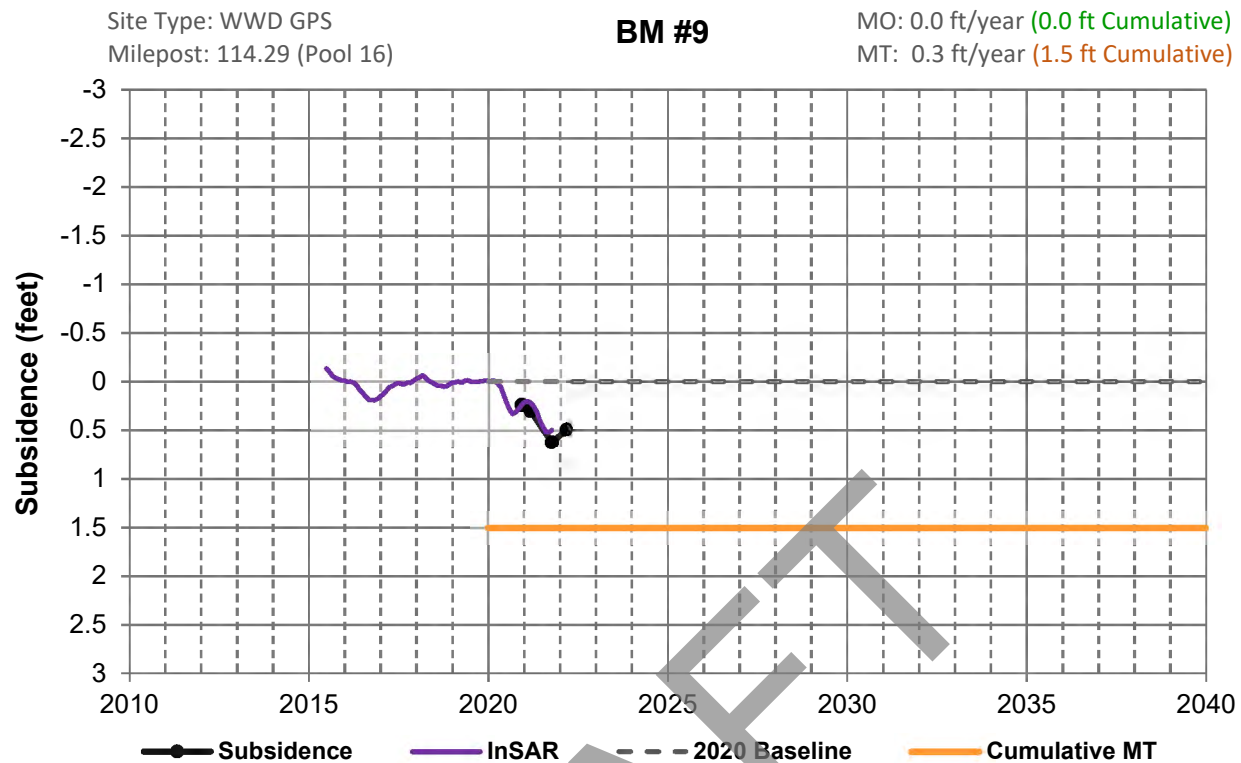


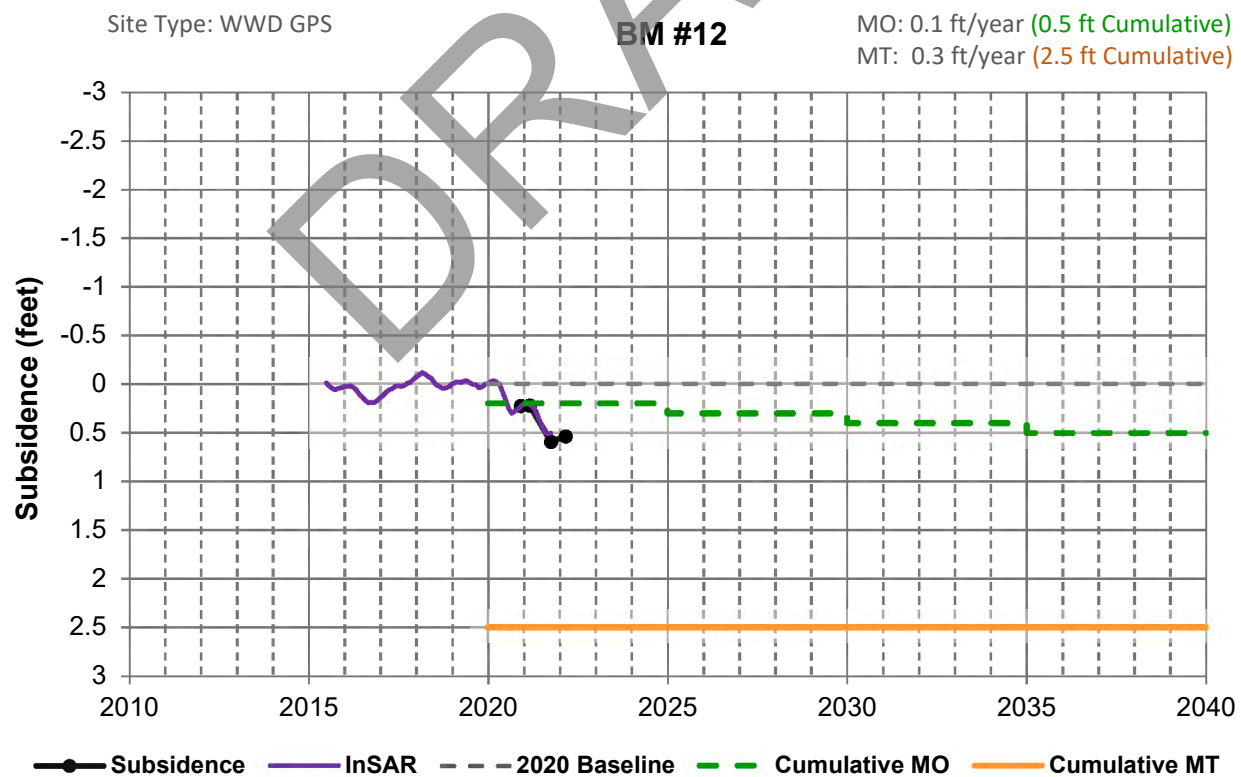
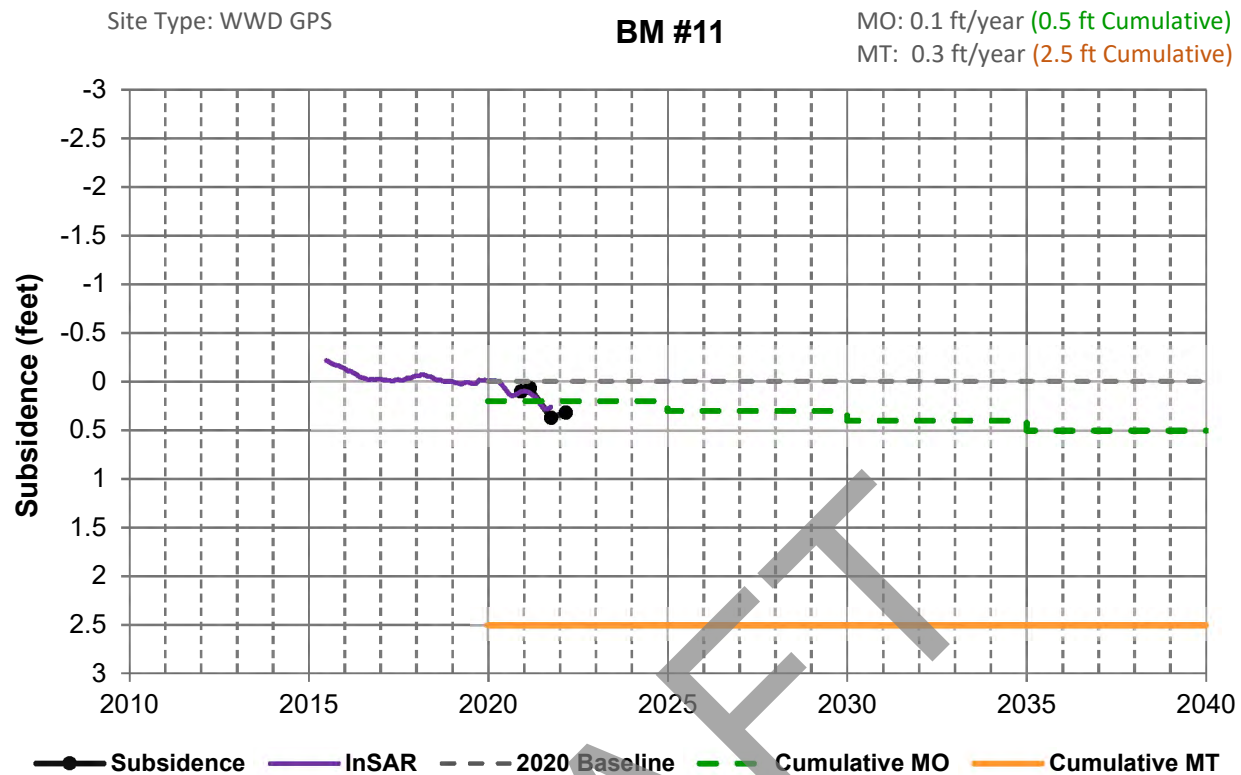


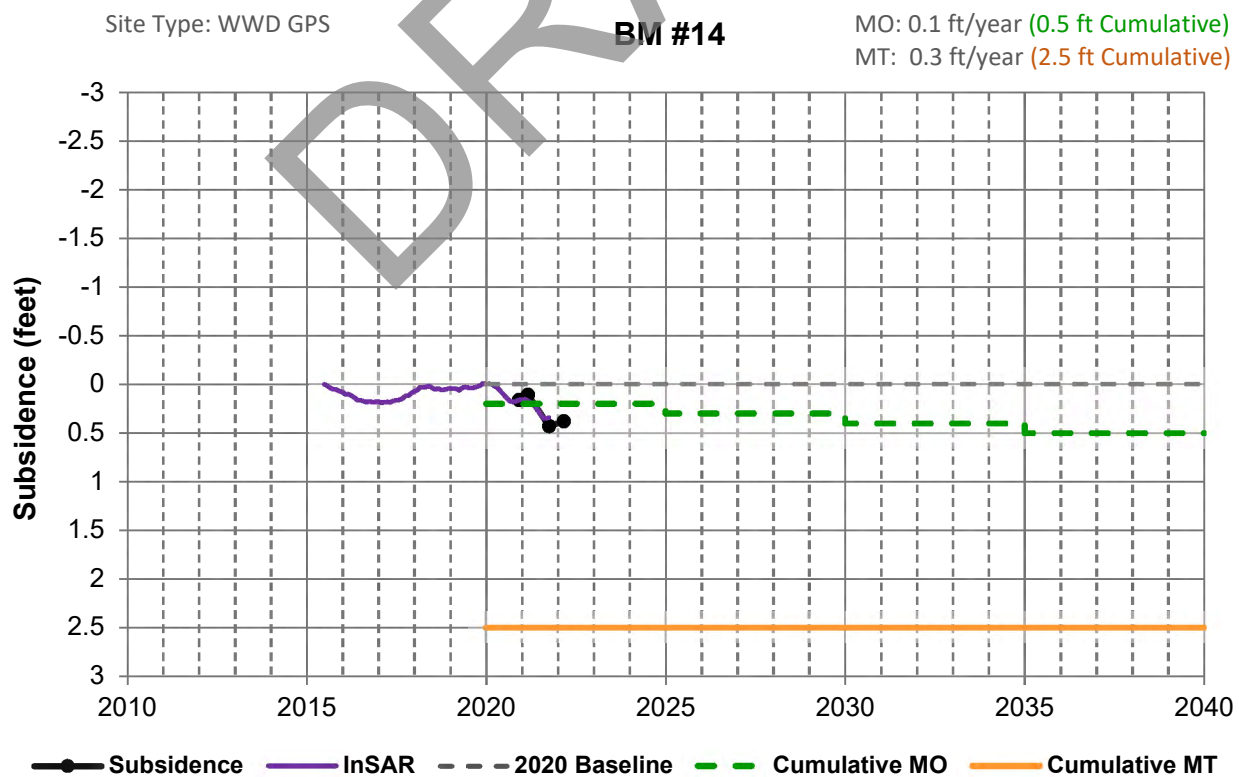
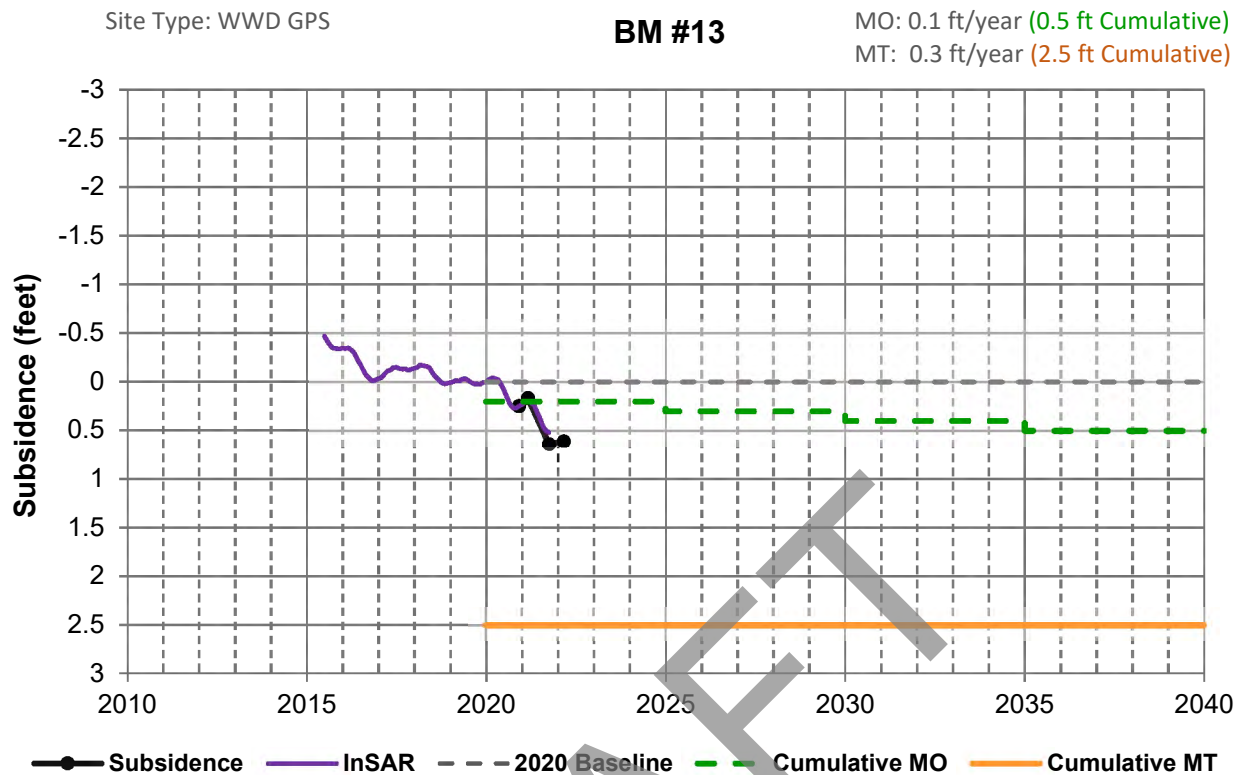


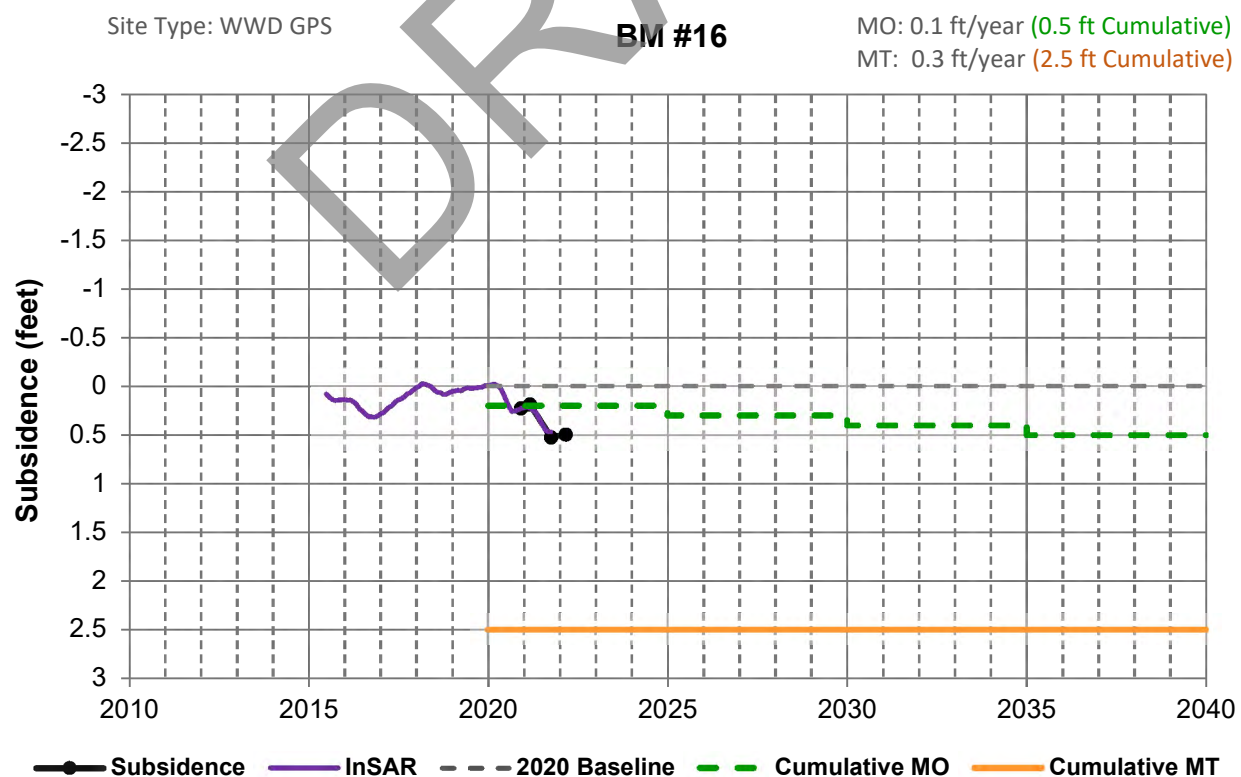
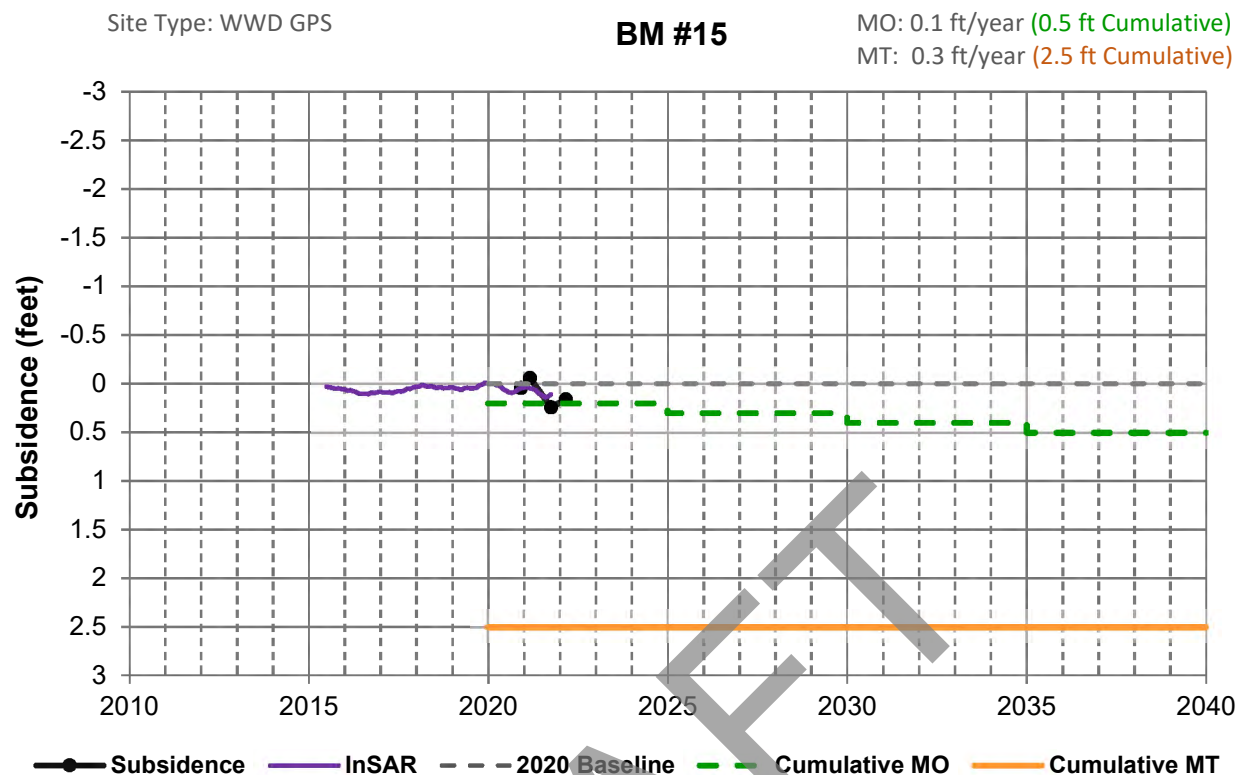


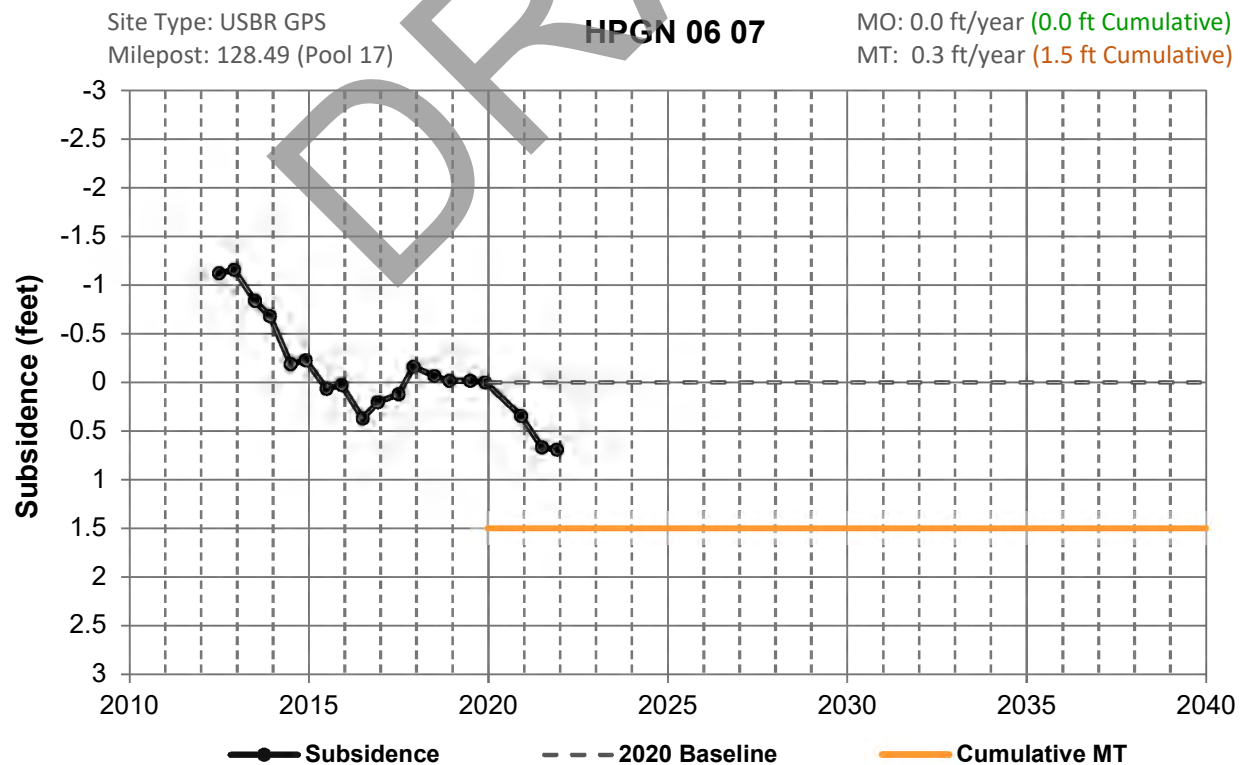
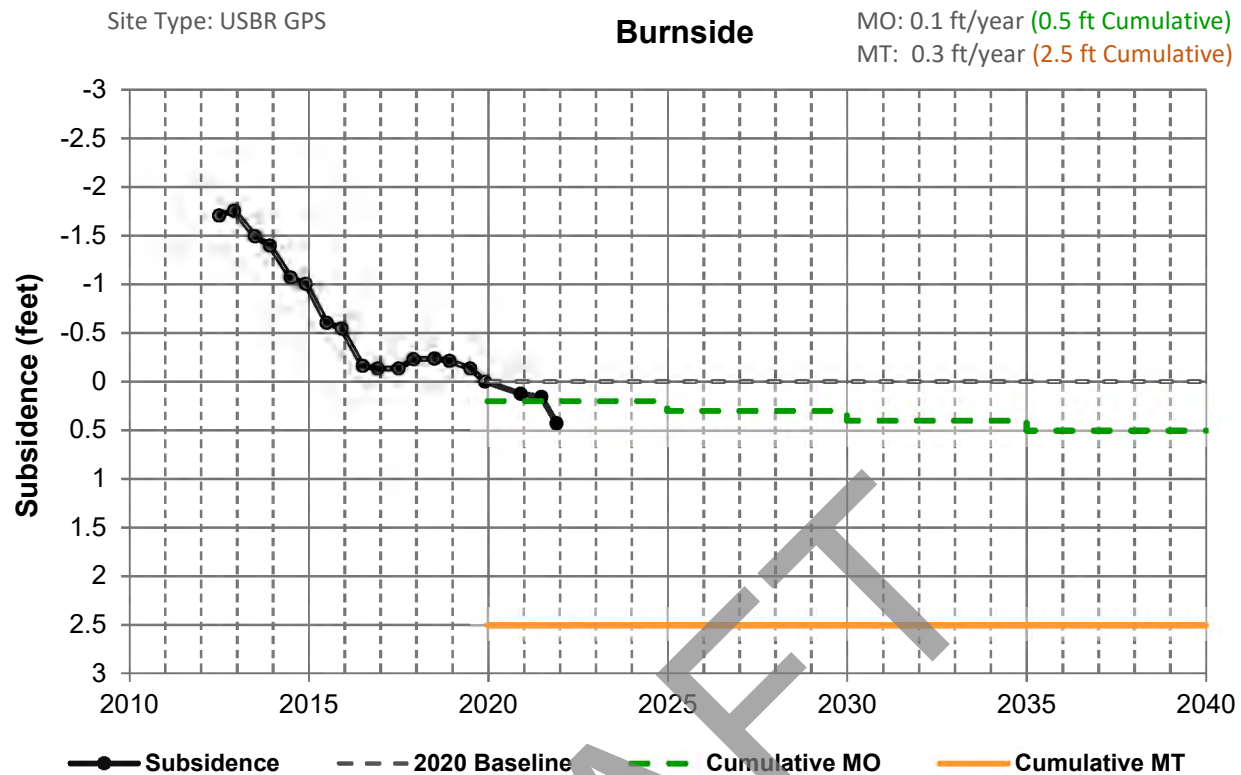


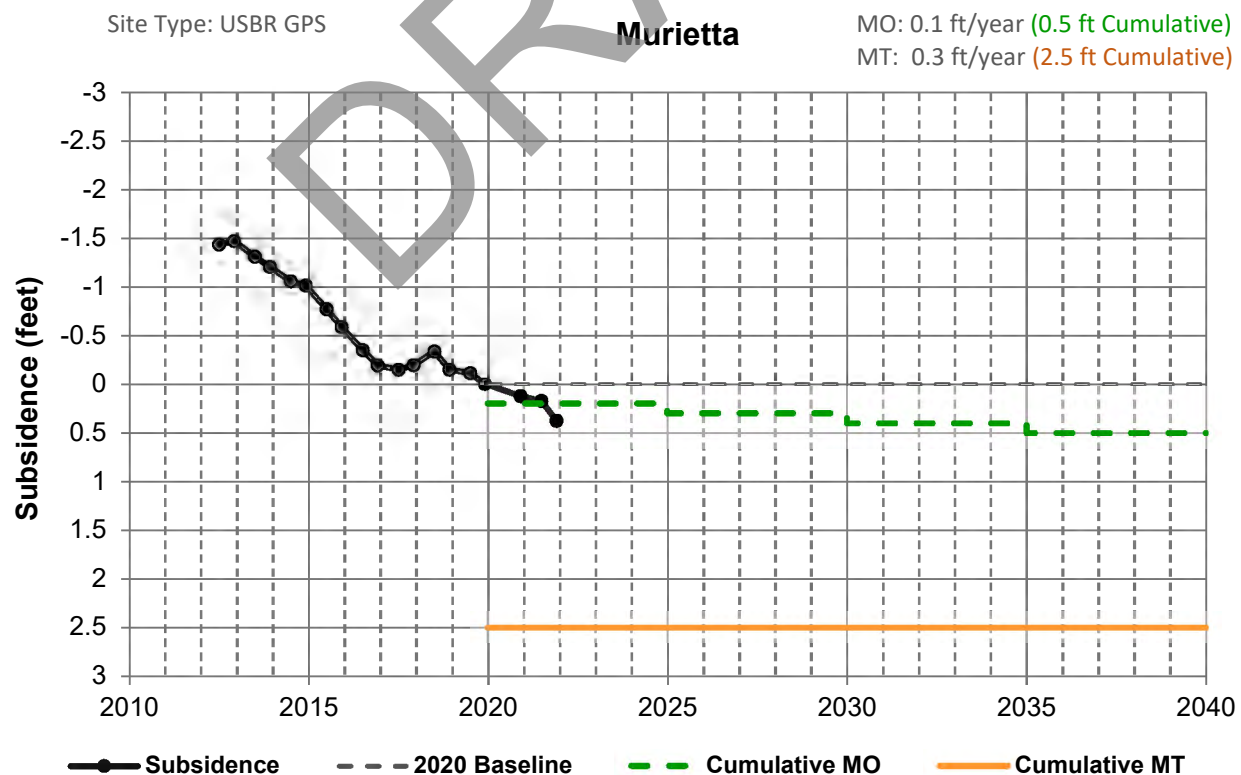
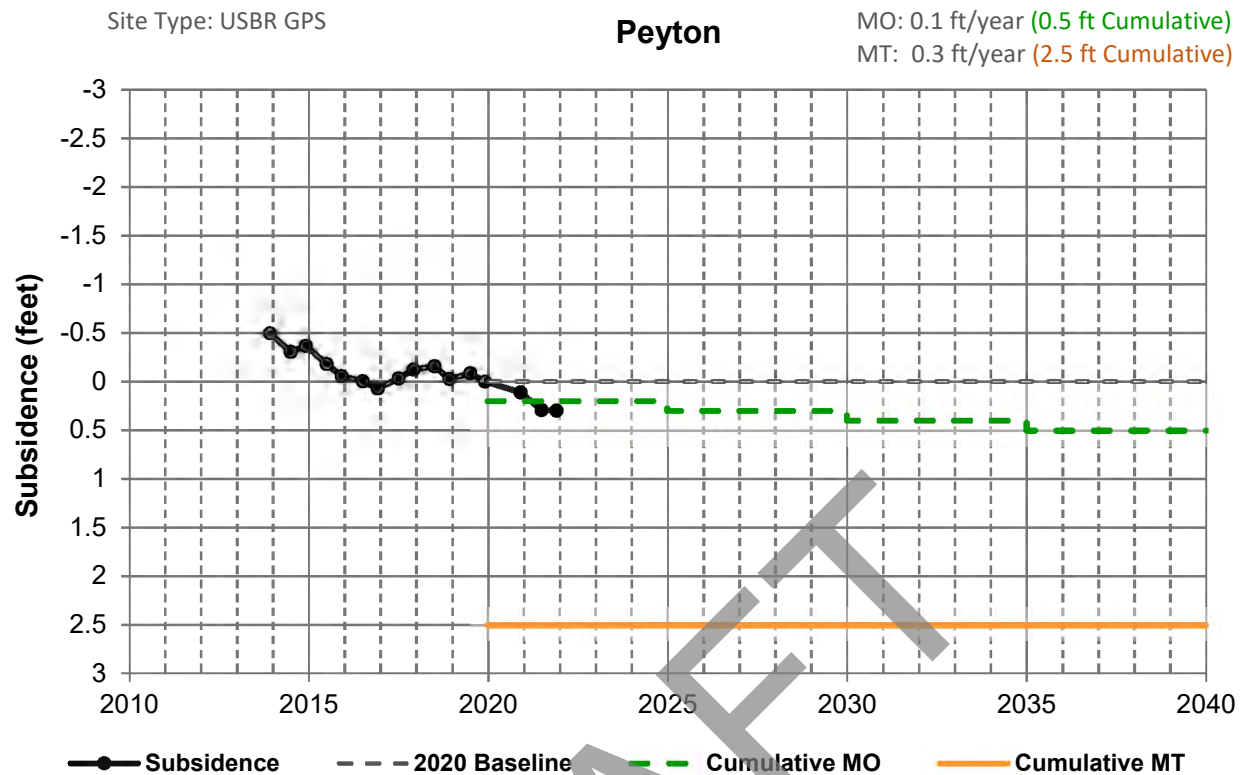


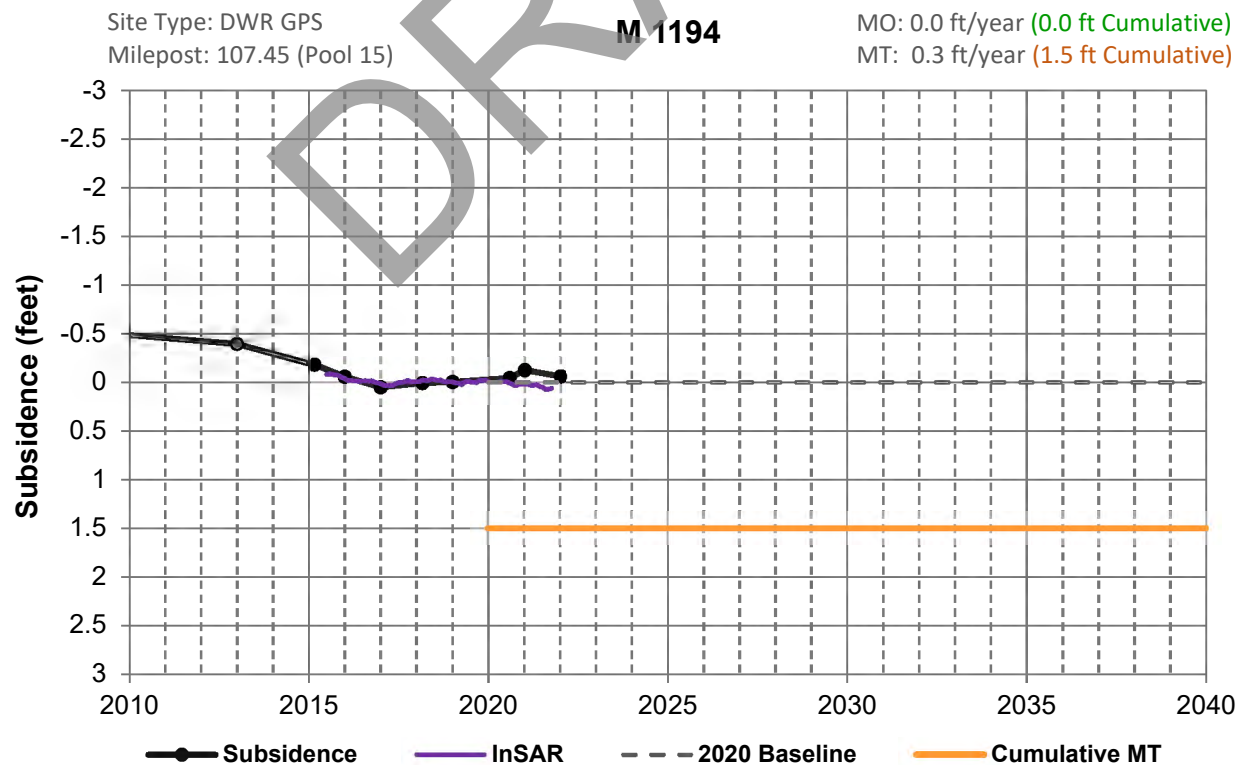
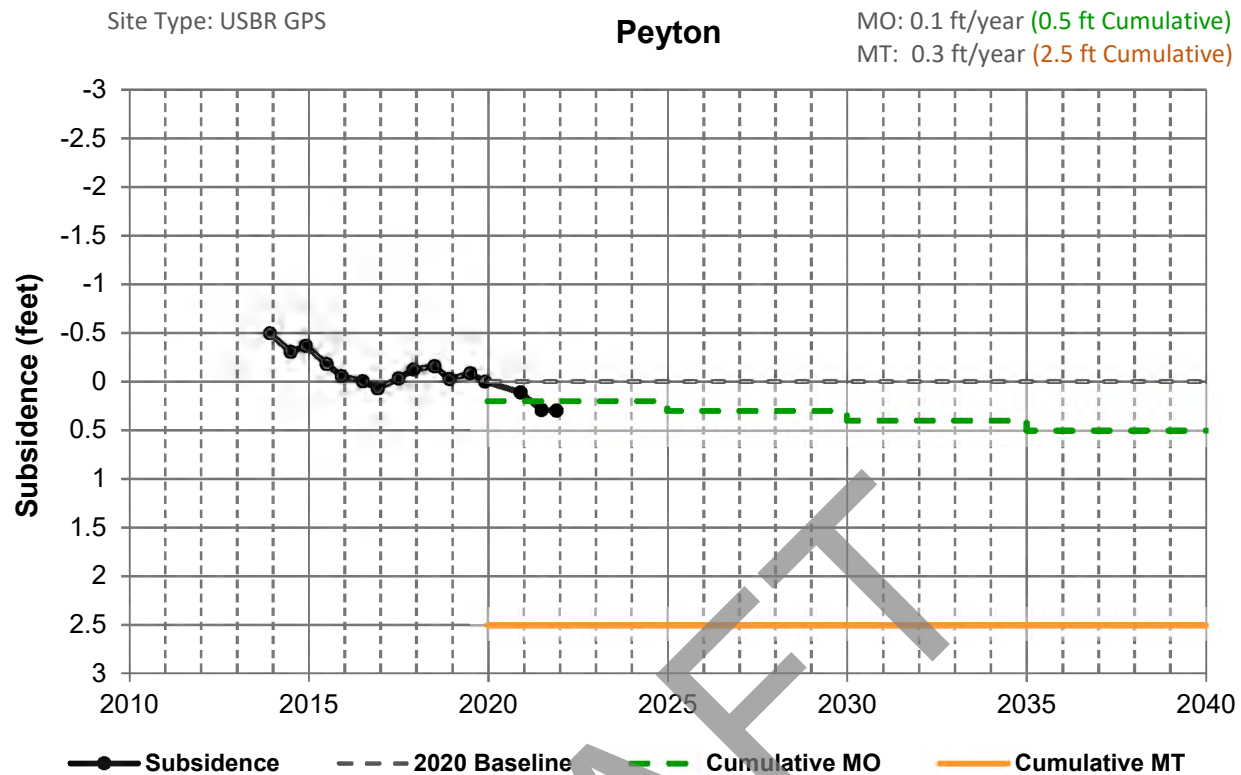


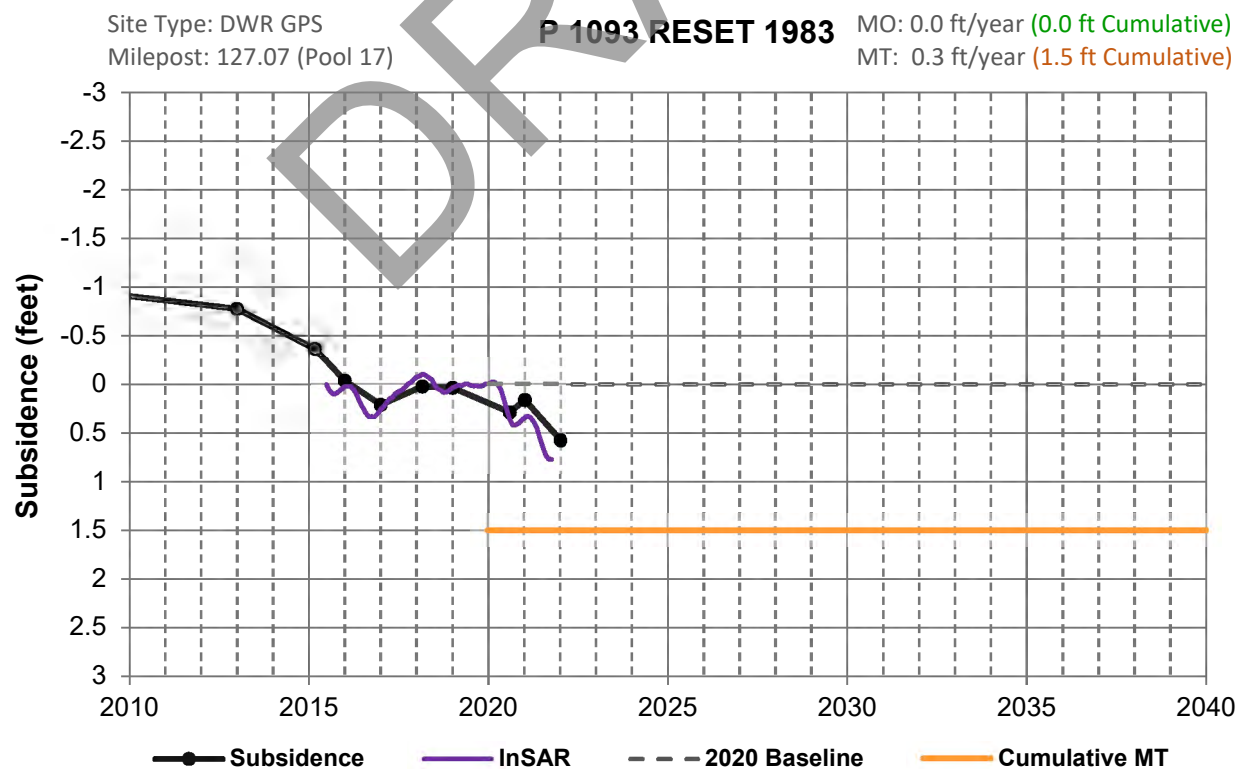
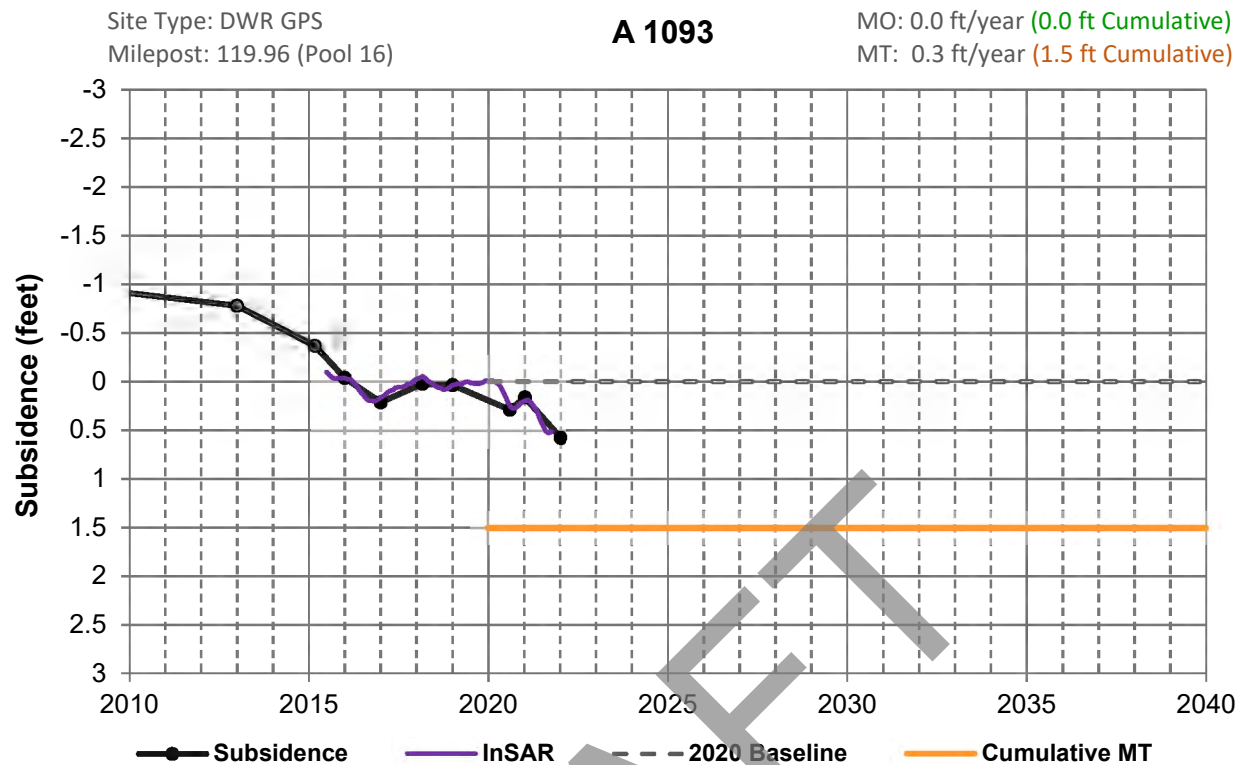


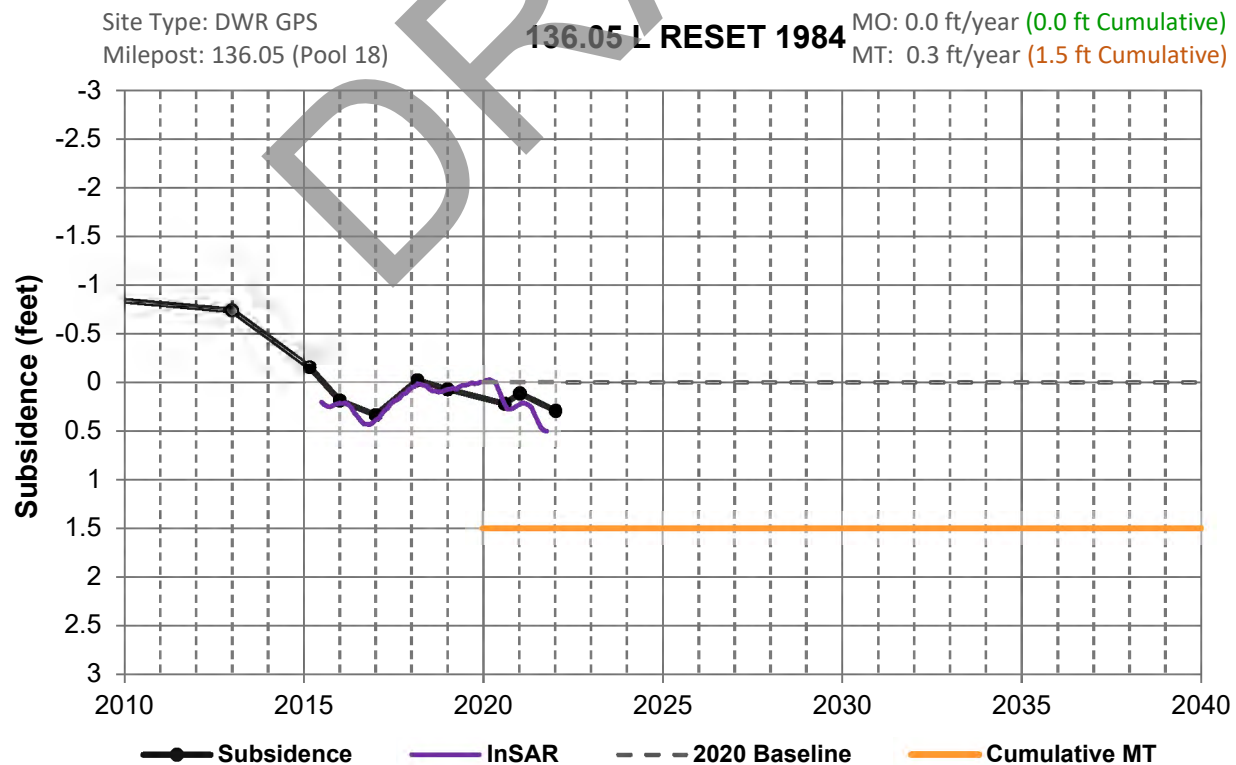
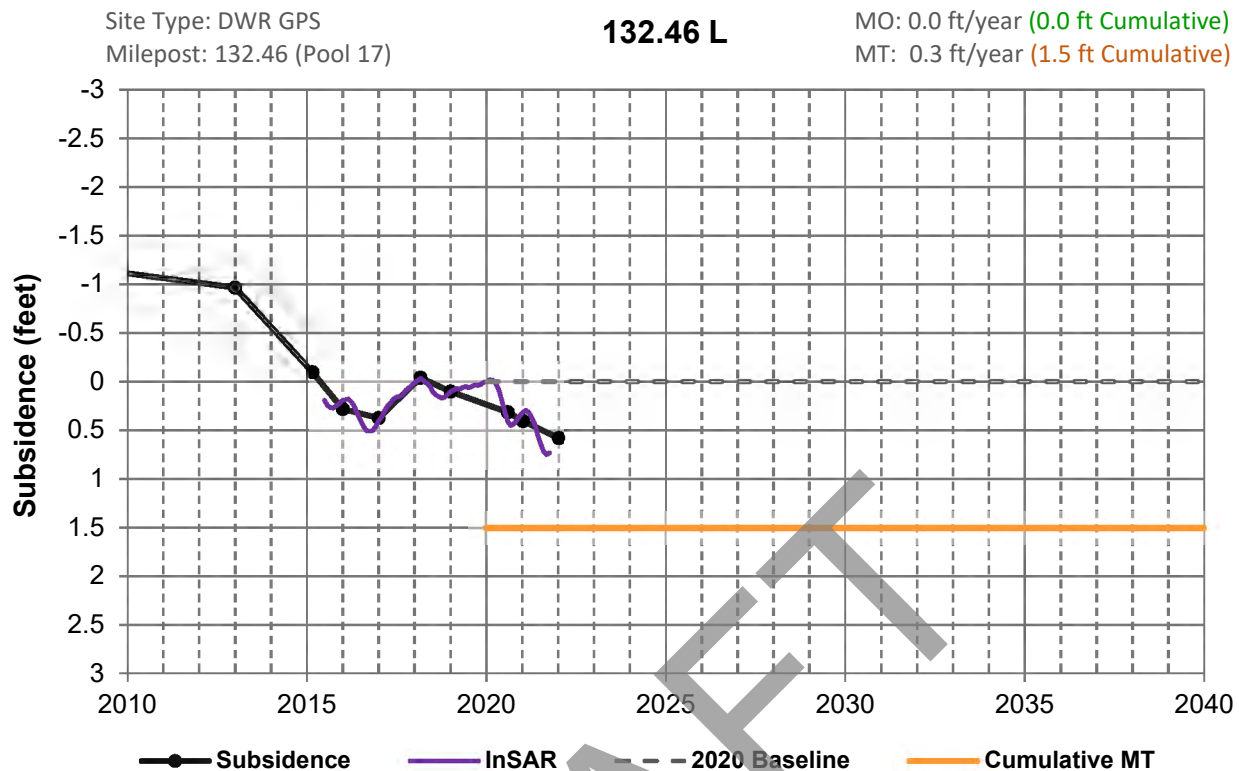


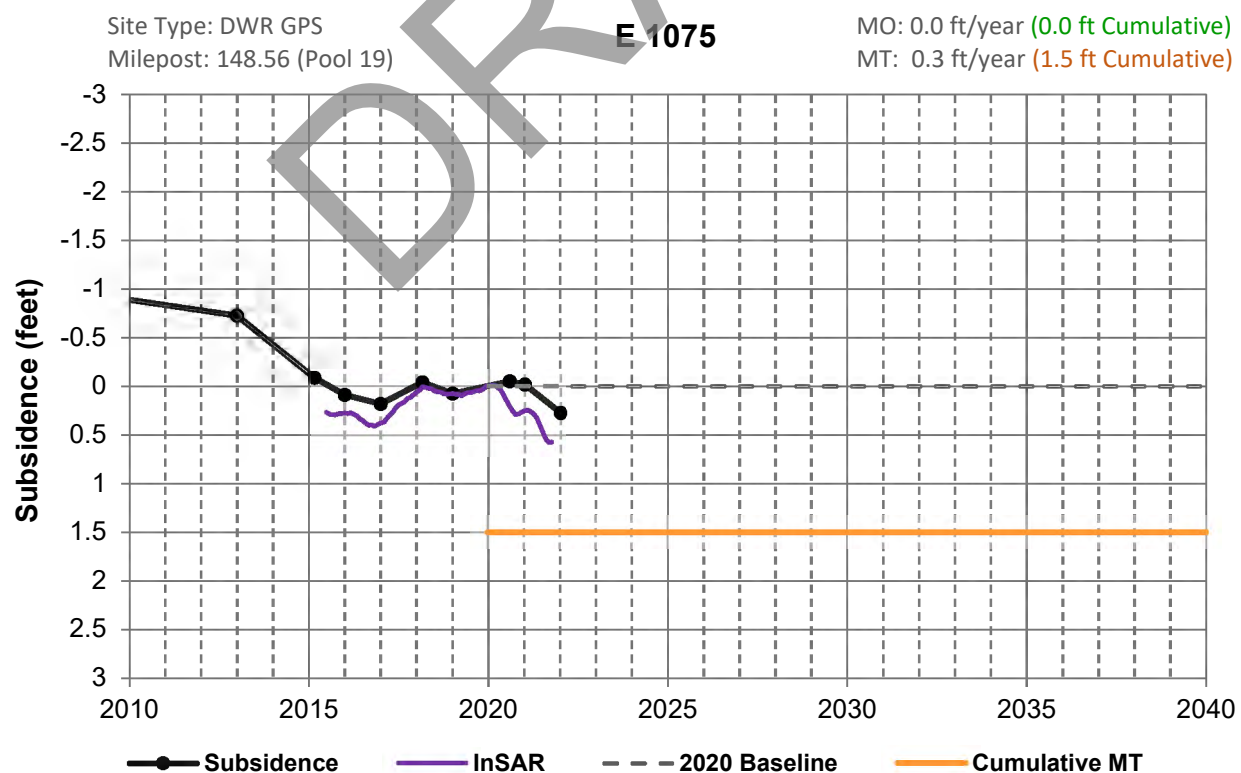
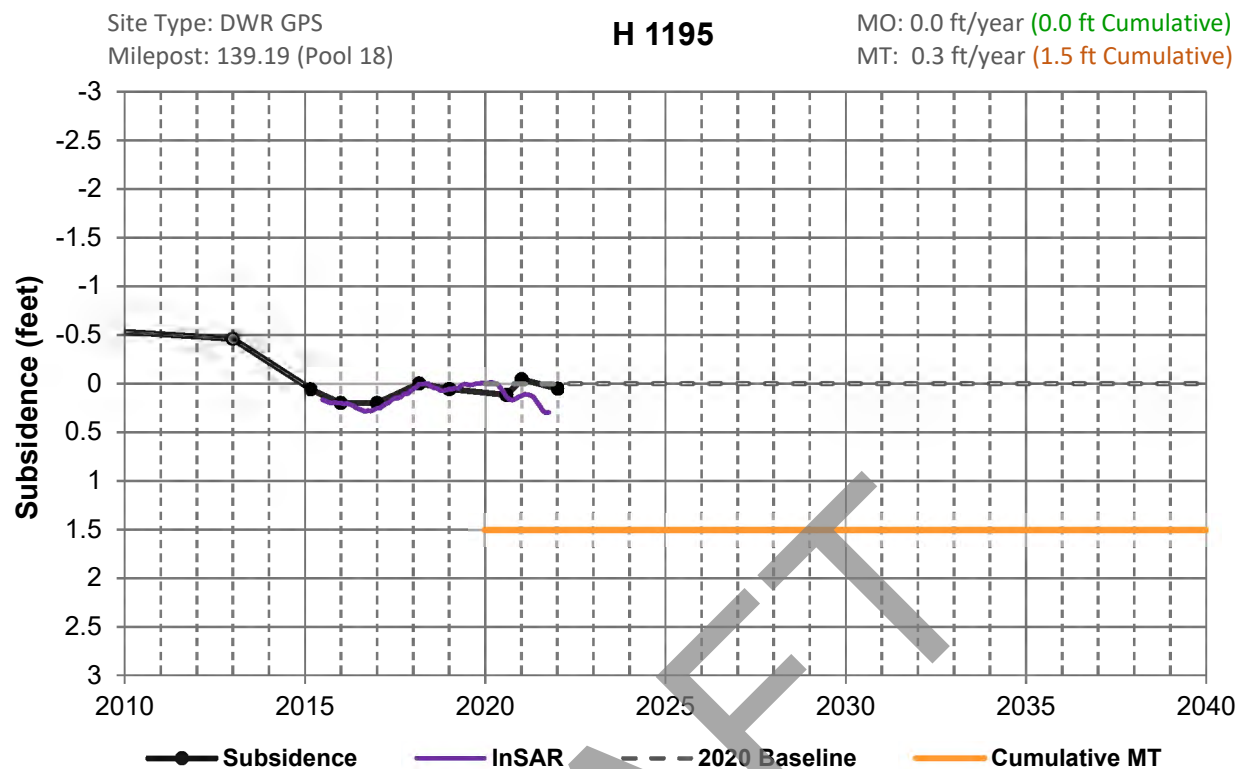


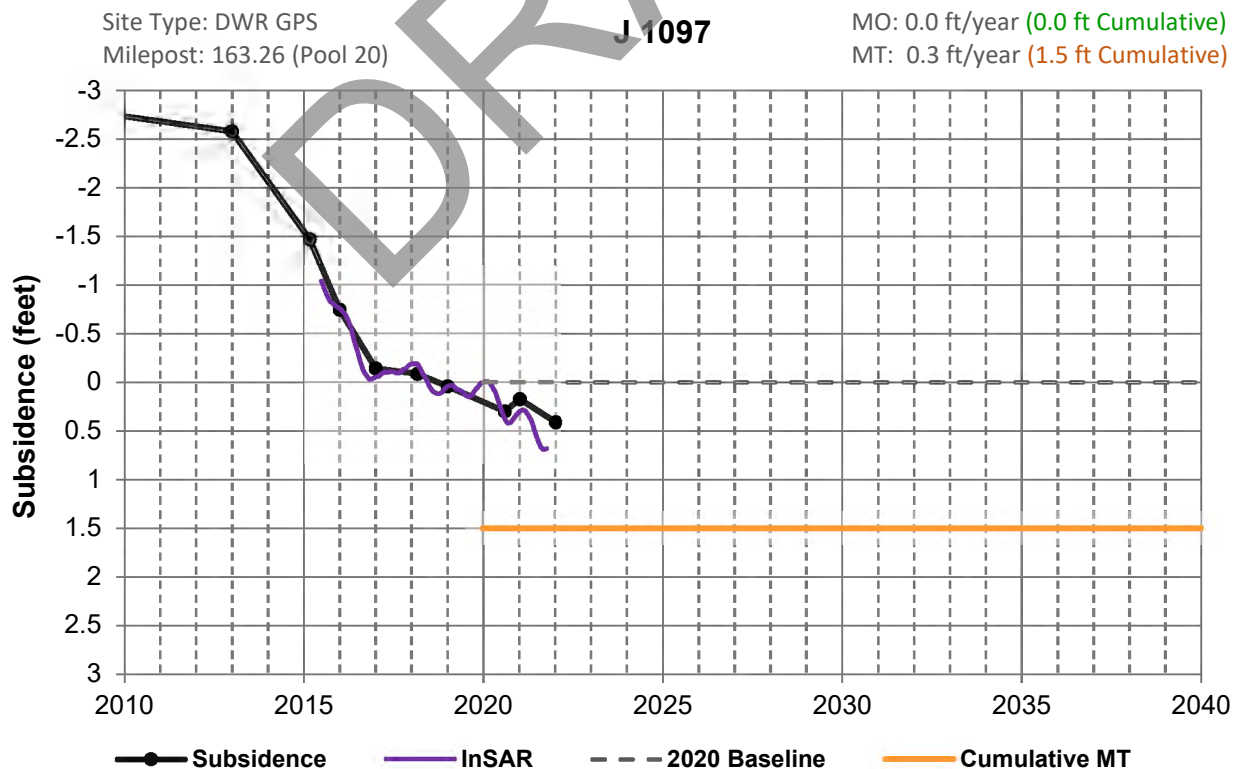
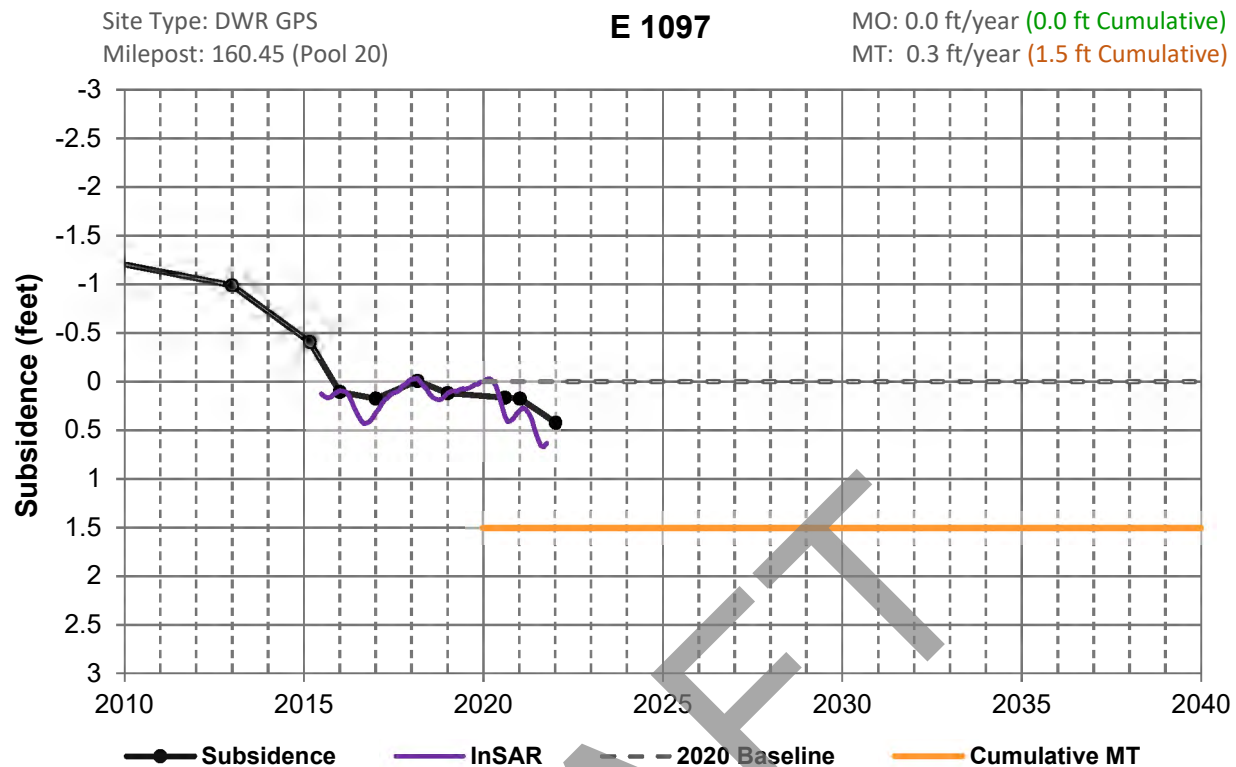


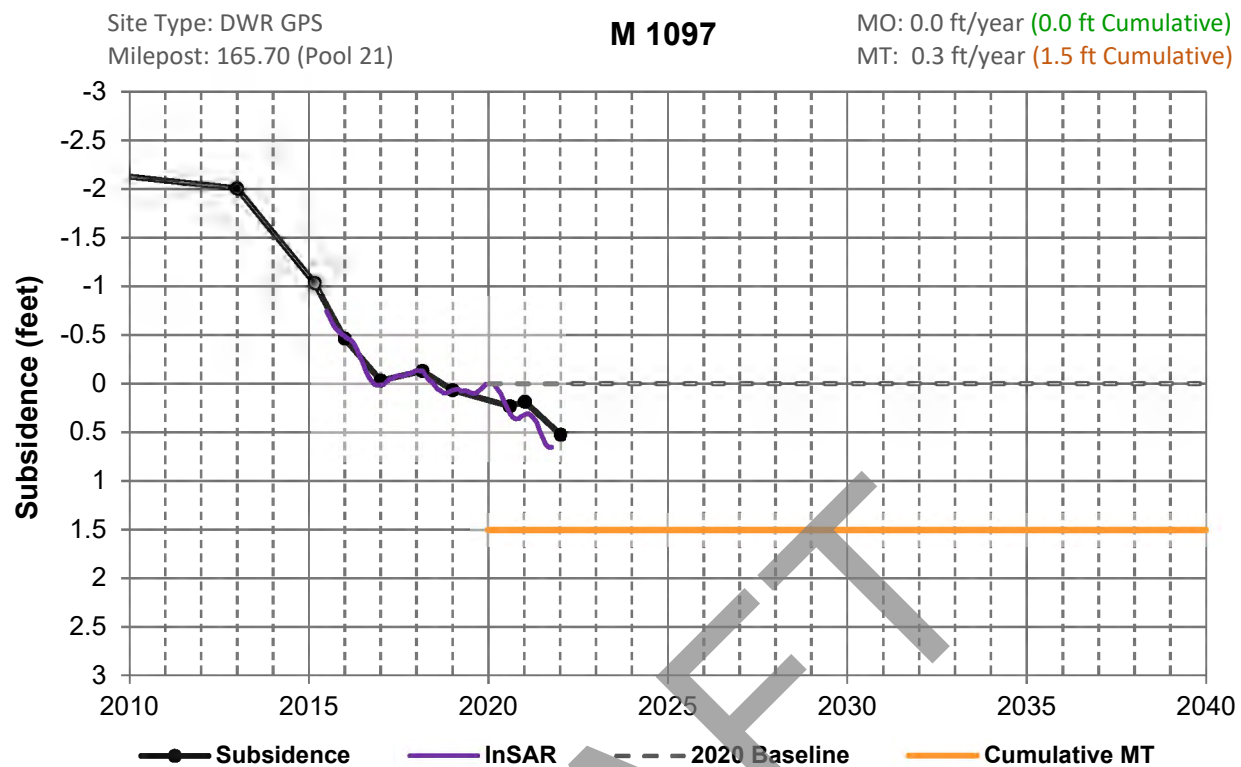


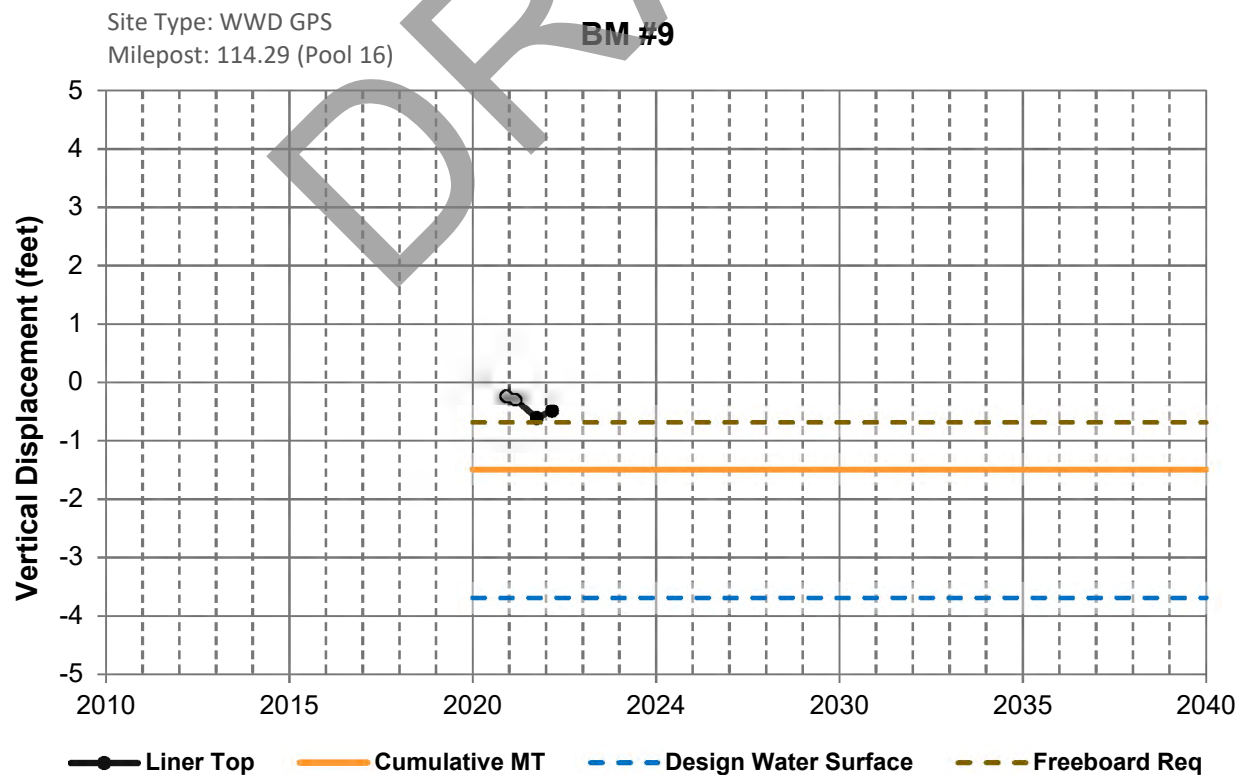
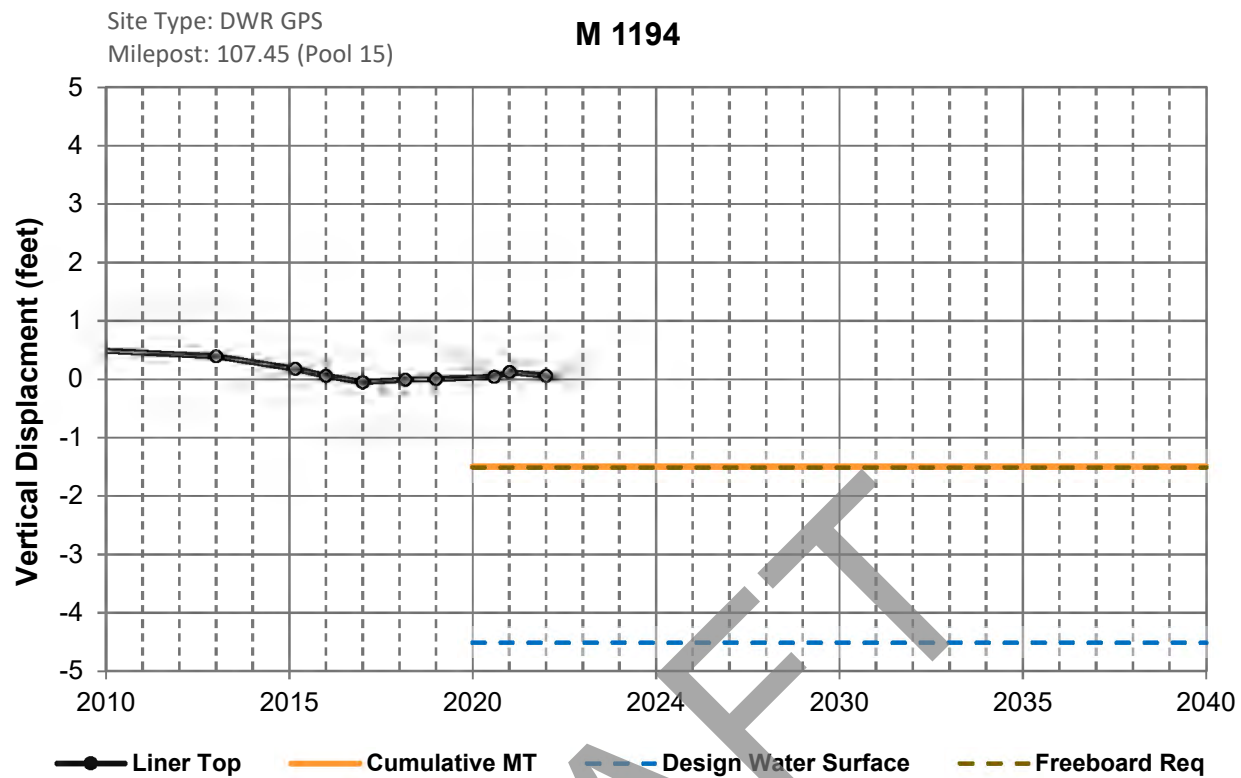


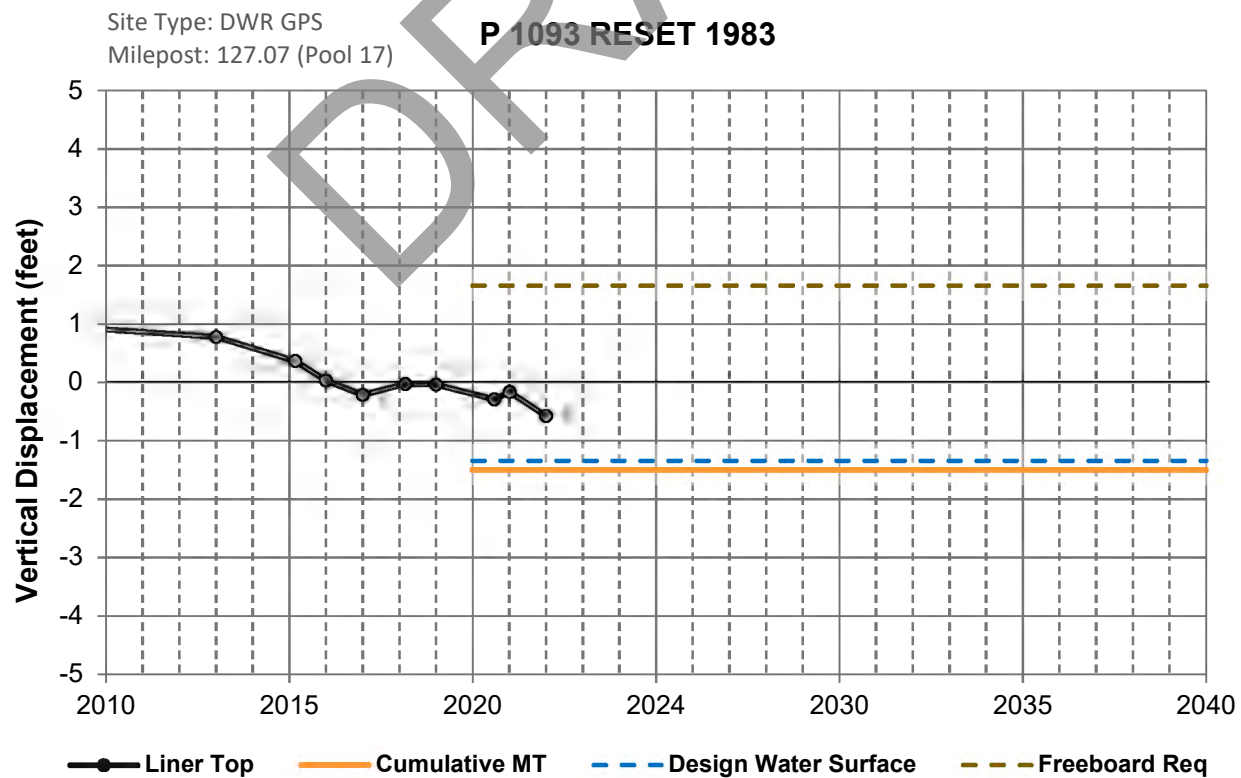
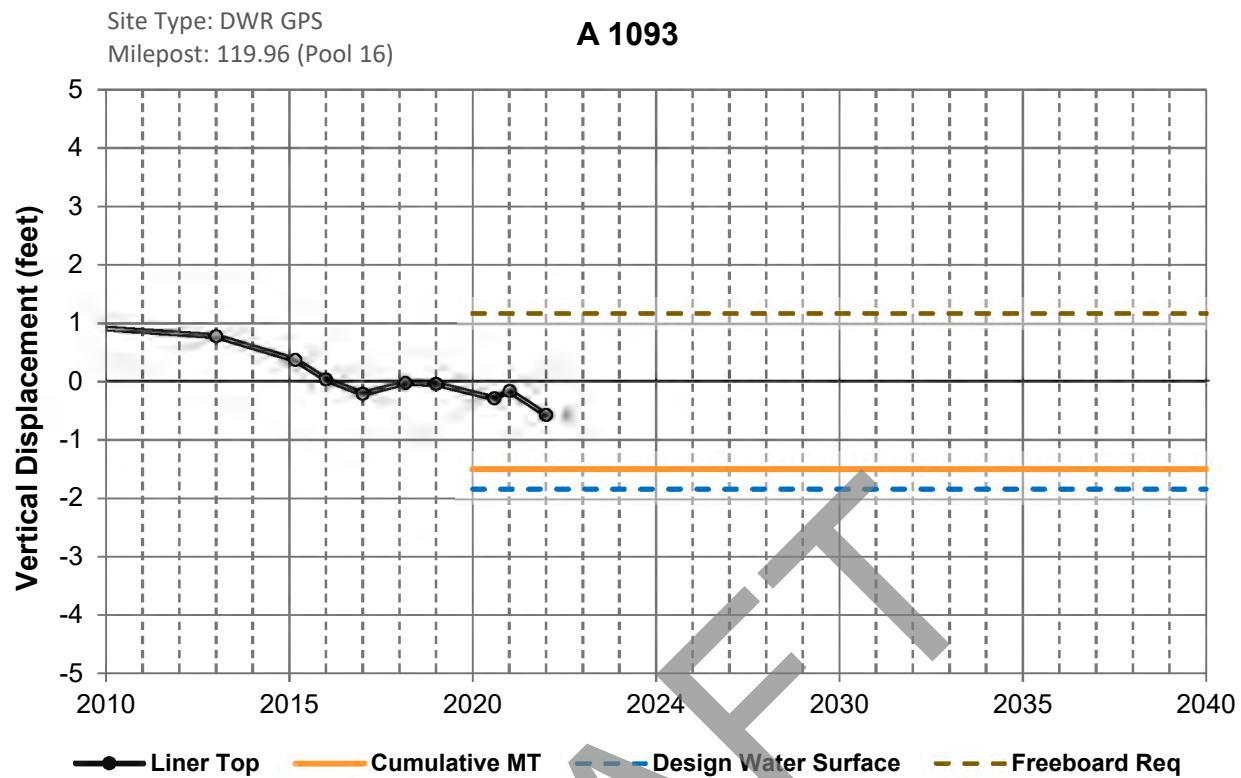


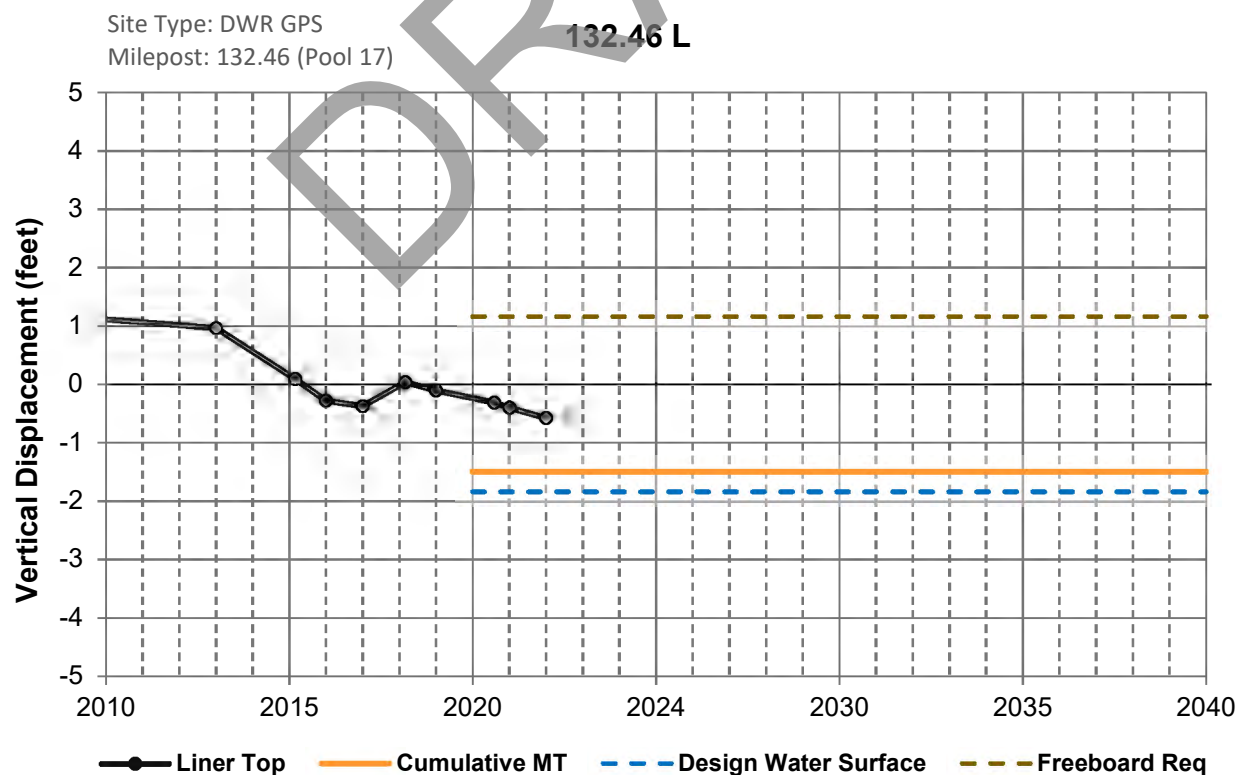
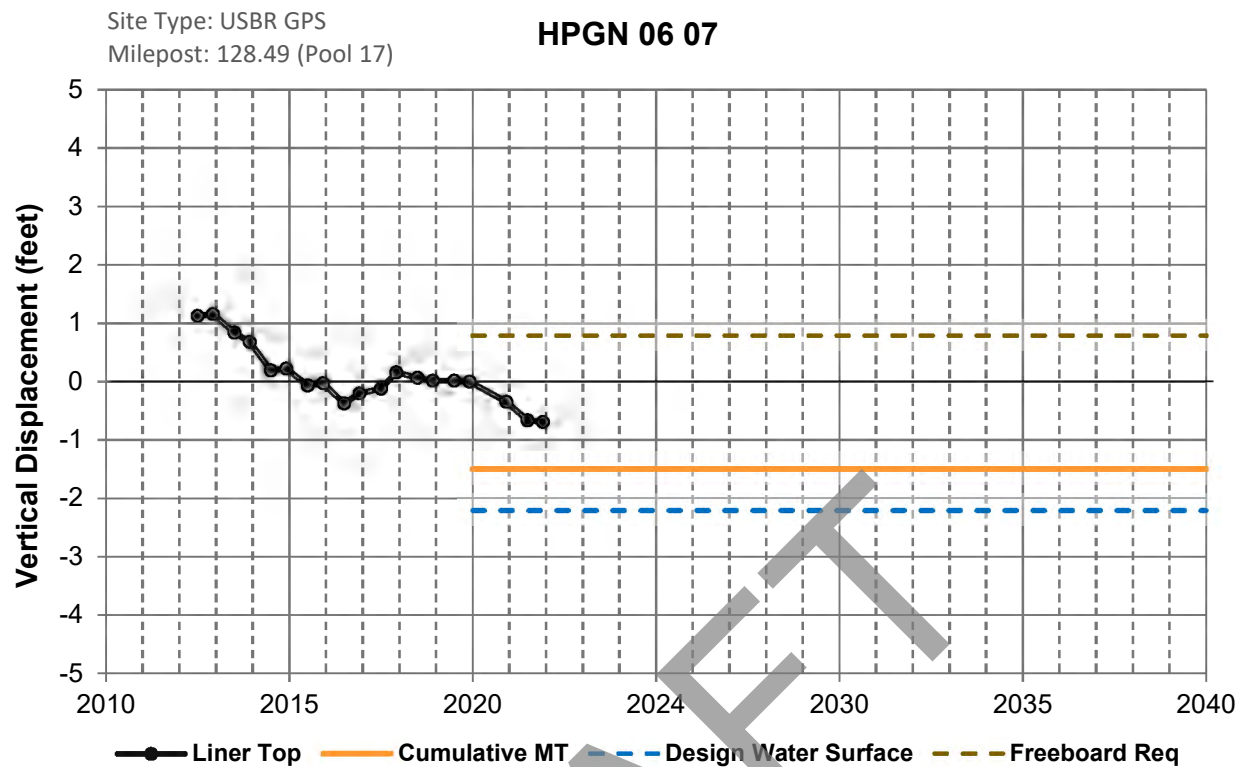


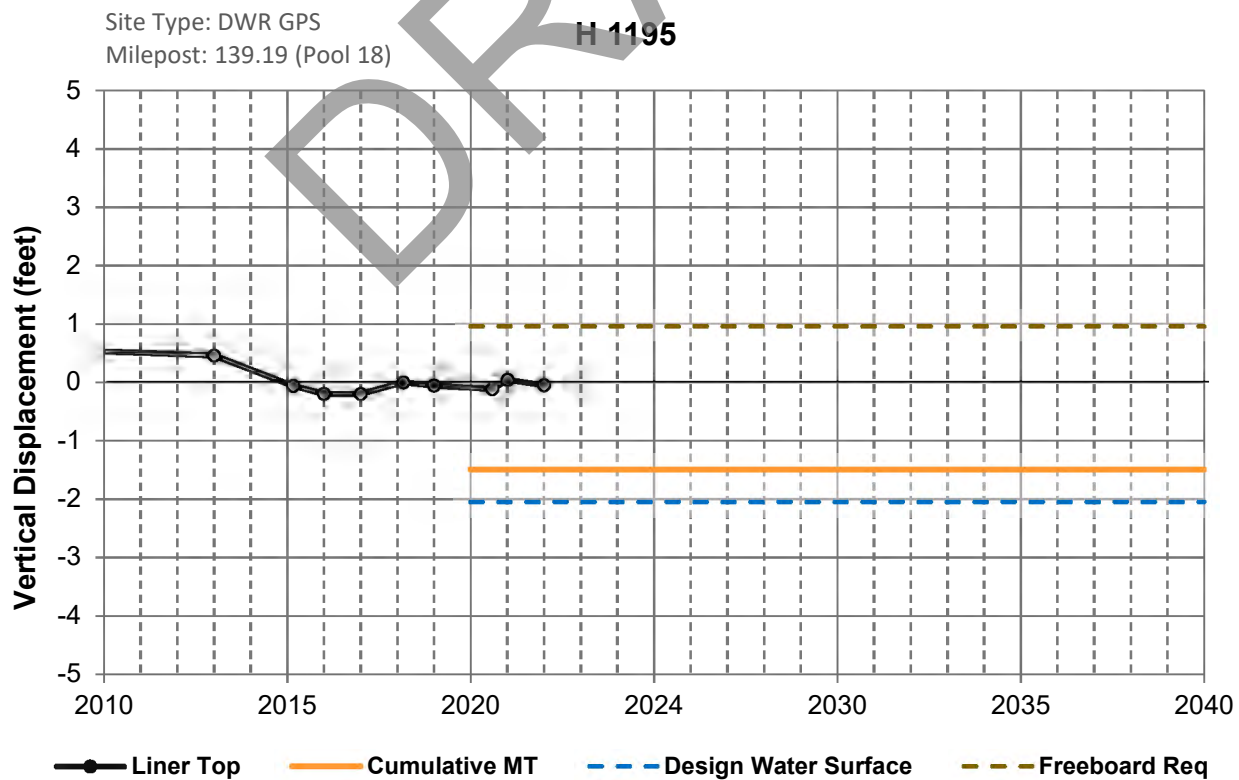
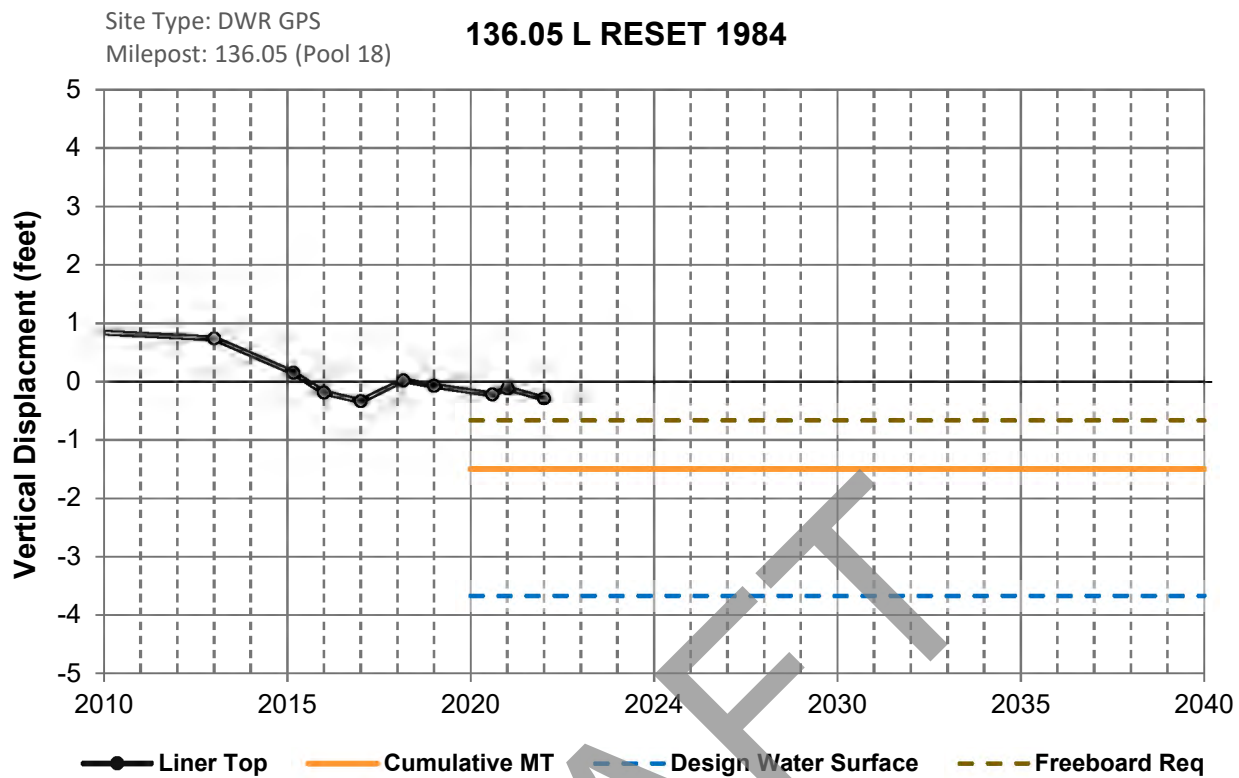


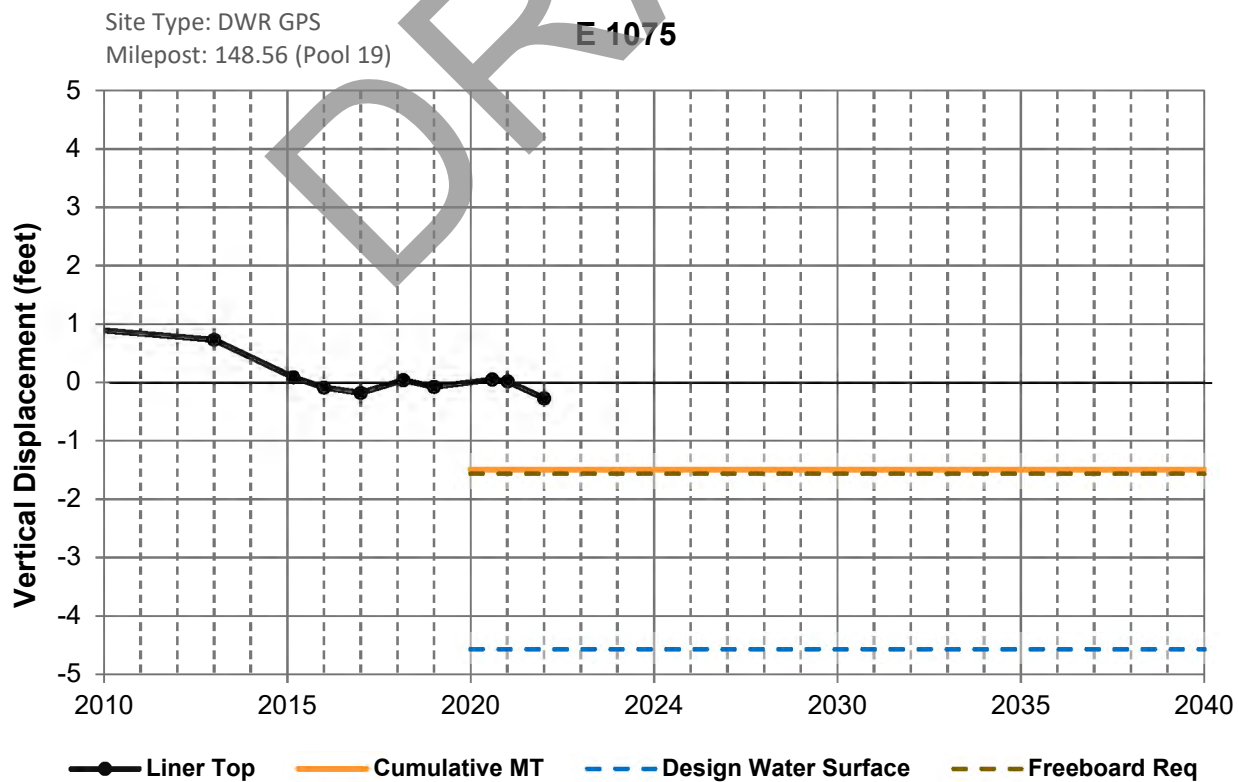
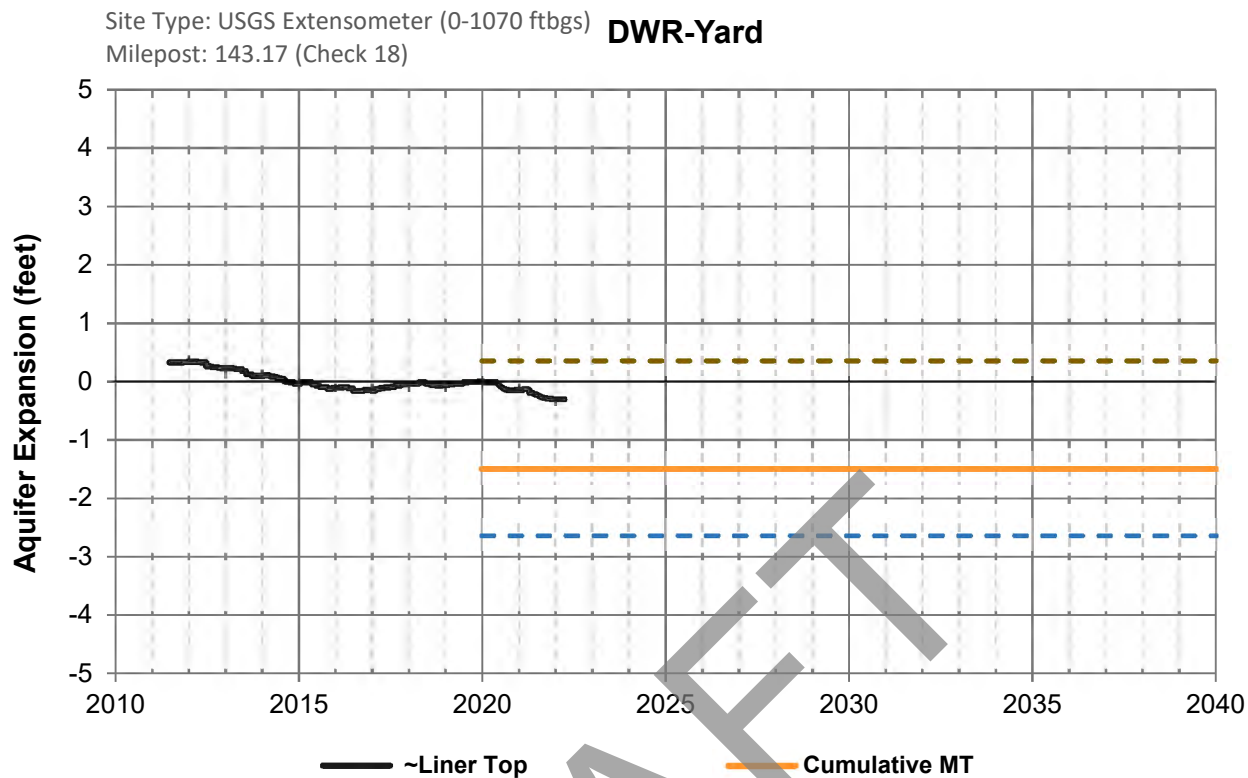


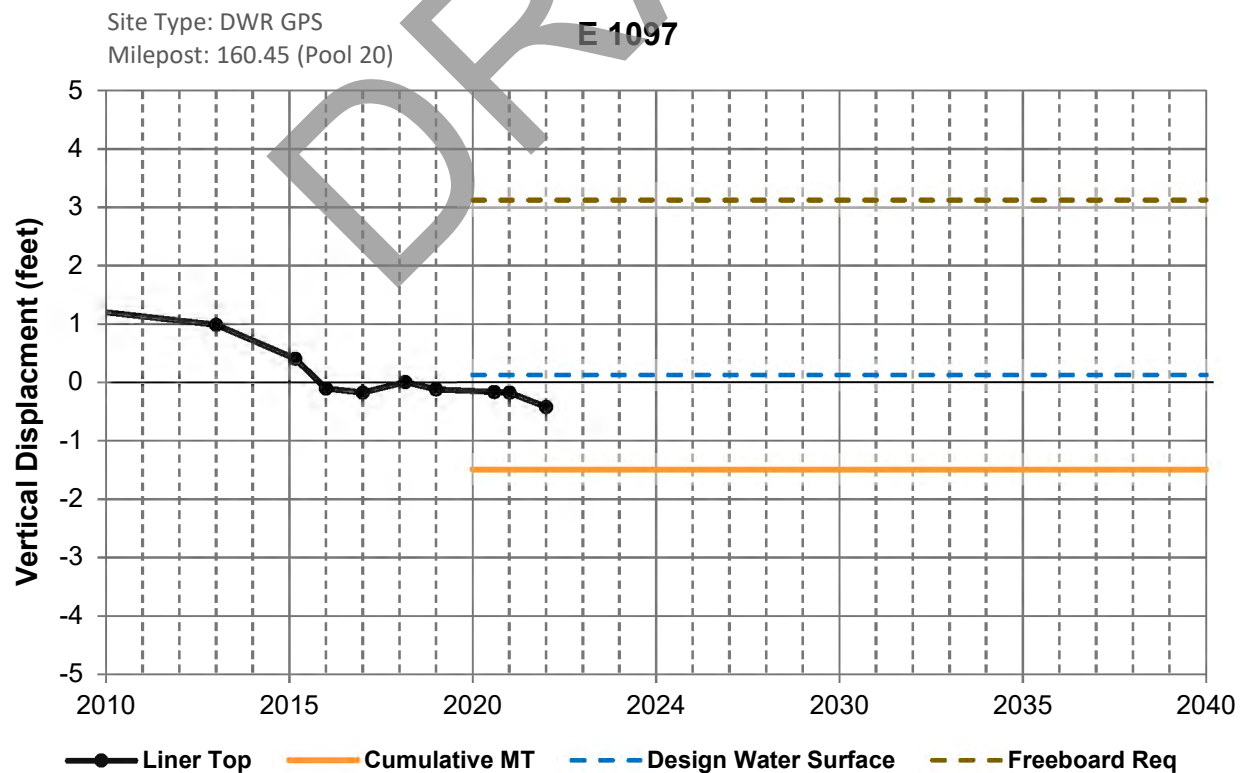
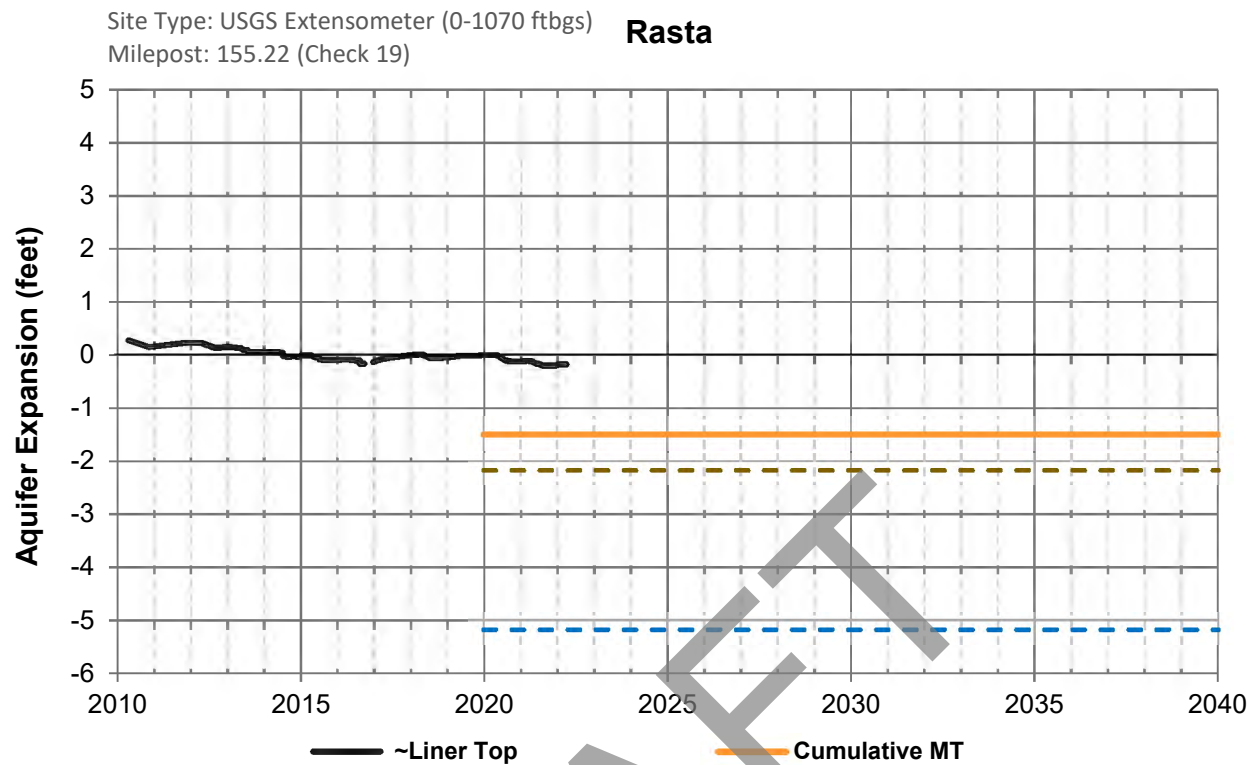


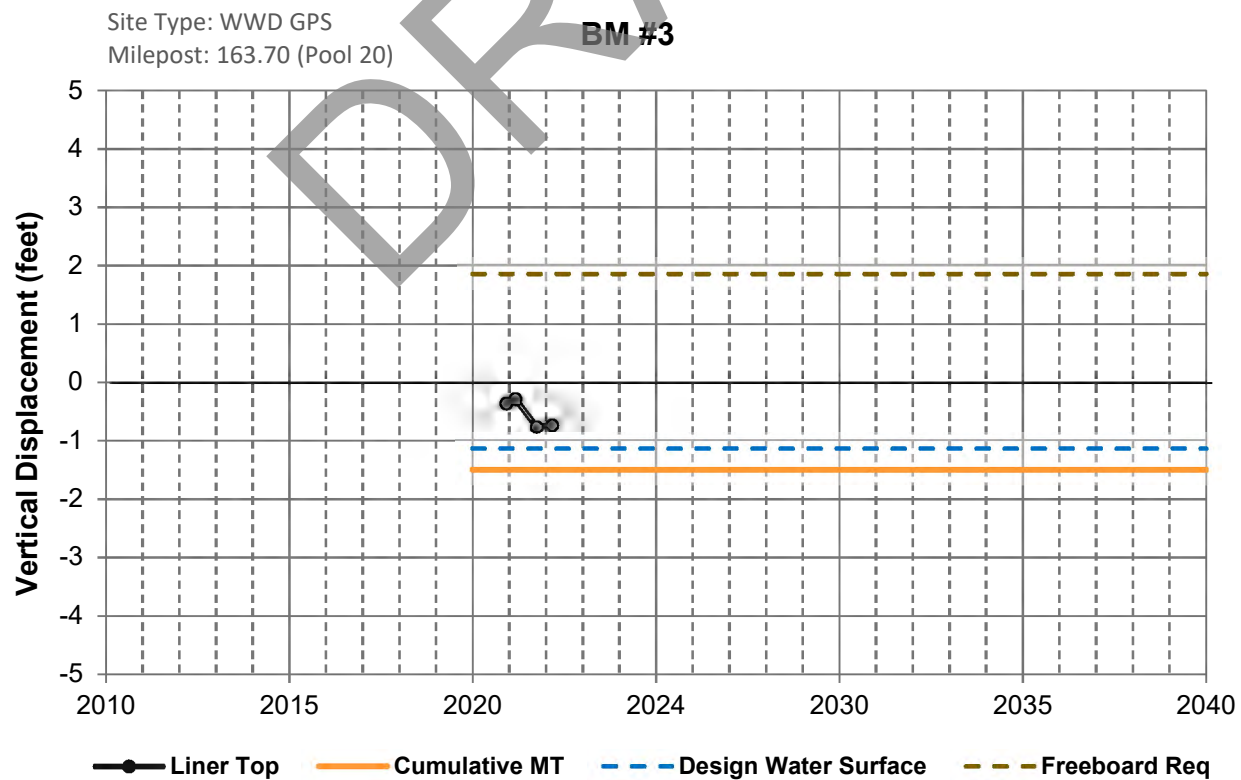
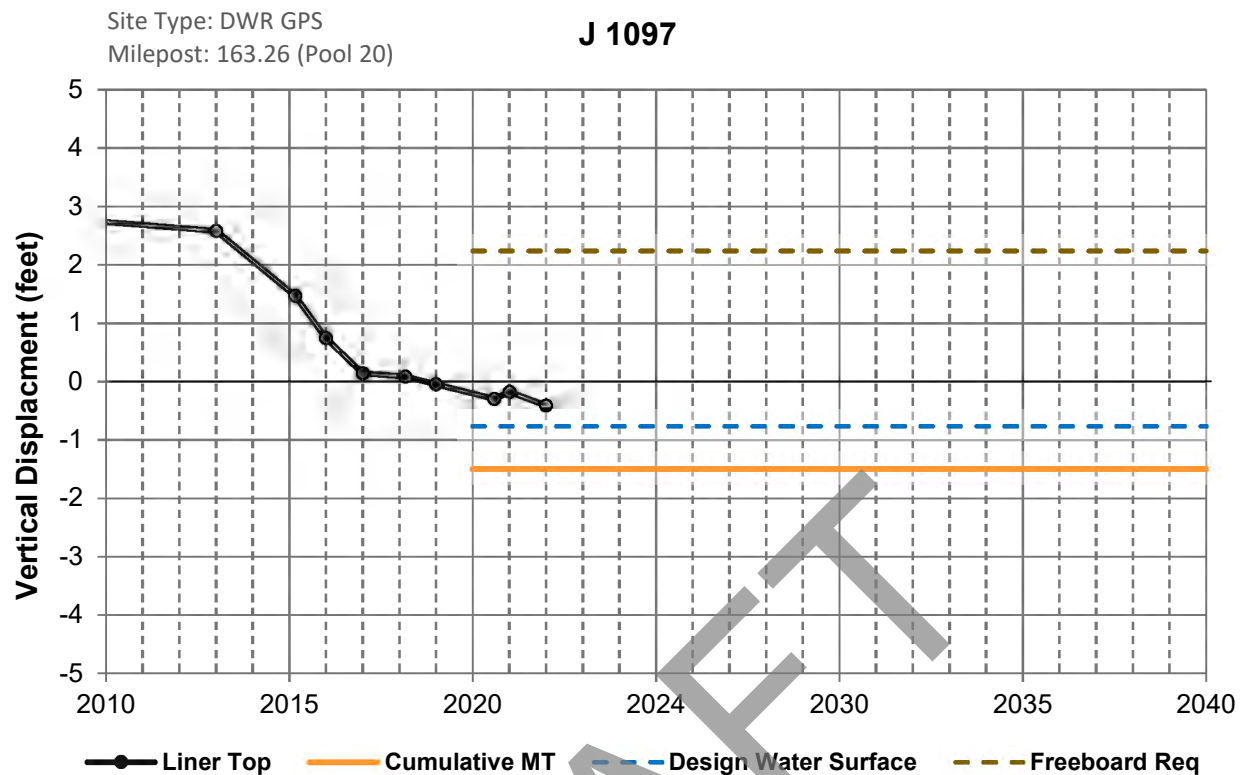


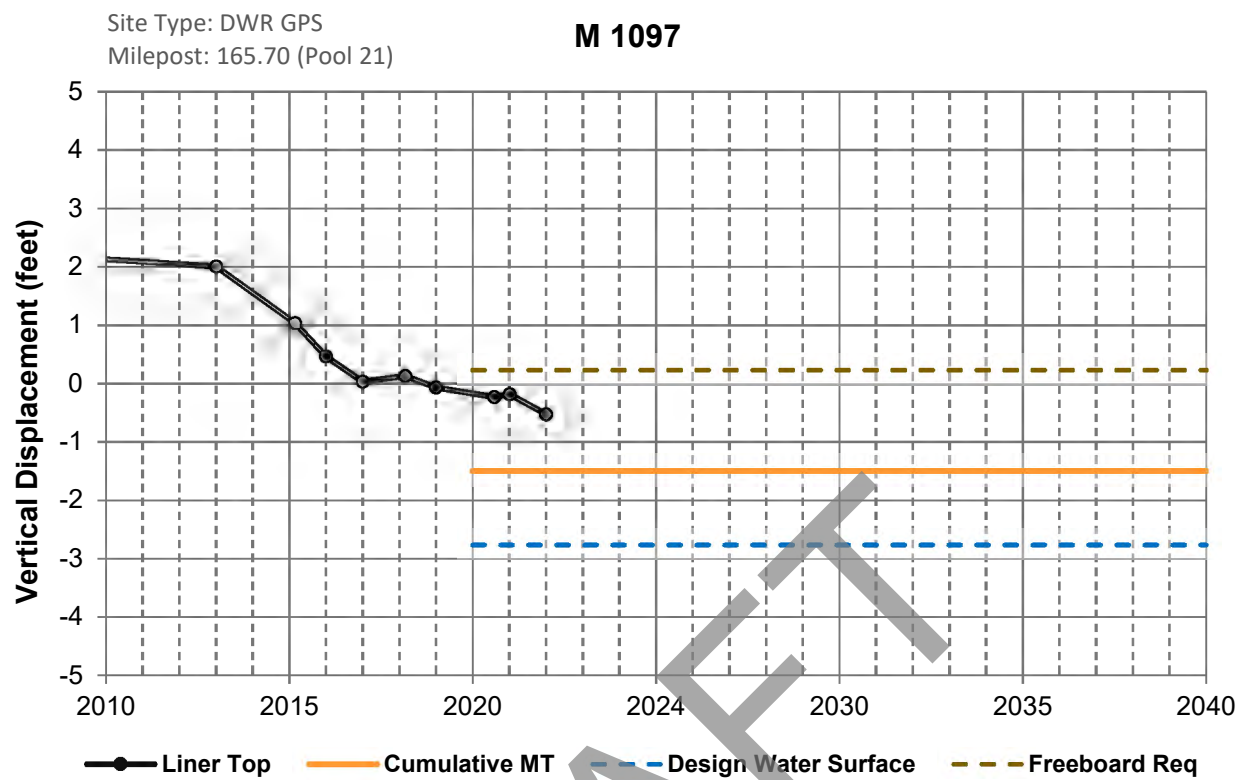












4 PROJECTS AND MANAGEMENT ACTIONS TO ACHIEVE SUSTAINABILITY GOAL

4.2 Project No. 2 – Initial Allocation of Groundwater Extraction

4.2.1.2 Aquifer-Specific Groundwater Allocation

The GSA will also implement an aquifer-specific groundwater pumping allocation to reduce pumping pressure on the Lower Aquifer and increase the optimum use of groundwater resources in the Subbasin. The provisional initial aquifer specific groundwater pumping allocation is 0.60 acre feet per gross acre year and may be subject to change based upon the information developed during the transition period and thereafter as may be reasonably prudent to avoid undesirable results (see Section 4.2.2 below). The aquifer-based allocation will increase the gross groundwater allocation, but require that groundwater pumped from the Lower Aquifer may not exceed a specified fraction of the total groundwater pumped as outlined in the GSA Rules and Regulations. ~~(The GSA Rules and Regulations are forthcoming; when available the GSA Rules and Regulations will be presented to the public and GSA for consideration.)~~ The GSA retains the discretion to defer, condition and/or refrain from some or all elements of an aquifer-specific groundwater allocation in the Subbasin or certain portions of the Subbasin where the Board concludes there is an unreasonable risk that additional Upper Aquifer pumping may cause or contribute to subsidence. For example, in areas where portions of the Upper Aquifer may be susceptible to compaction, the GSA may not implement the aquifer-specific groundwater allocation program until the data gaps identified in Section 3.5.4.2.3 are filled. The collected data should ensure that the program does not cause or contribute to significant and unreasonable subsidence until the GSA can adequately monitor for and mitigate potential subsidence risks (see Section 2.2.8.4.4.). Water users must also coordinate with the GSA to quantify groundwater withdrawals from each aquifer for accounting and reporting processes if they select this option.

Similar to the gross groundwater pumping allocation, aquifer-specific groundwater credits may be banked and reduced in a subsequent year subject to the GSA's Rules and Regulations.

4.2.3 Relation to Groundwater Sustainability

4.2.3.1 Expected Benefits and Metrics

The groundwater pumping allocation will directly contribute to achieving measurable objectives relating to water levels and groundwater storage by promoting groundwater pumping distributions in the Subbasin that minimizes the occurrence of large amounts of groundwater extraction that result in undesirable results. Groundwater allocations are also expected to substantially minimize and prevent undesirable results of chronic lowering of groundwater levels, significant and unreasonable reduction in groundwater storage and significant and unreasonable land subsidence. Under aquifer specific allocations, sustainable utilization of the Upper Aquifer will reduce groundwater user's reliance on the Lower Aquifer to meet their pumping demand and provide additional benefits with respect to subsidence- [within certain areas](#). Pumping allocations may also provide additional indirect benefits to groundwater quality by limiting the migration of poor quality water derived from marine sediments to other portions of the aquifer system due to Upper Aquifer groundwater pumping that results in a reduction in the downward vertical gradient between the Upper and Lower Aquifers. A summary of expected benefits and metrics for evaluating project effectiveness are summarized in **Table 4-5** described and quantified in detail in **Appendix I**.

Table 4-5: Expected Benefits and Metrics for Evaluating Project Effectiveness

PMA No.	PMA Name	Expected Benefit	Evaluation
No. 2	Groundwater Pumping Allocation	1. Stable groundwater levels 2. Reduced depletion in groundwater storage 3. Controlled Avoid and minimize subsidence 4. Maintenance of water quality	1. Direct measurement of groundwater levels and comparative analysis¹ 2. Calculation of annual groundwater storage and comparative analysis¹ 3. Direct measurement of subsidence and compaction and comparative analysis¹ 4. Direct Measurement of water quality constituents and comparative analysis¹

1. Comparative analysis will evaluate project vs. no project annually using a combination of analytical methods and groundwater modeling as part of the 5-year GSP update.

4.4 Project No. 4 – Targeted Pumping Reductions

4.4.2 Implementation

4.4.2.1 Timeline for Implementation and Accrual of Expected Benefits

Depending on water levels, the GSA is prepared to implement a targeted pumping reduction incentive program (Targeted Pumping Reductions Program) in conjunction with in-lieu surface water deliveries as soon as January 31, 2020. All wells used for supplying irrigation water within the Subbasin will be metered by January 2025. Infrastructure required to deliver replacement supplemental surface water in place of groundwater pumping is currently available district-wide via the distribution system and privately-owned temporary divisions. However, participants in the pumping reduction program may elect to offset those reductions by pumping more groundwater from another portion of the Subbasin, from another portion of the Upper Aquifer, or from an unaffected portion of the aquifer in place of receiving supplemental surface water supplies. As a result, implementation of this alternative is dependent on the availability of Upper Aquifer wells with sufficient capacity to meet the additional demand and the installation of groundwater meter- as well as further monitoring of potential impacts associated with increased production from the Upper Aquifer. Otherwise, it is assumed that affected landowners will be able to utilize that option by January 31, 2020.

Pumping reductions are expected to provide an accrued benefit to the aquifer system, substantially mitigating localized undesirable results particularly with respect to groundwater levels and aquifer system compaction and land subsidence. Implementation will only occur when the management action is necessary. Consequently, the timeline for the accrual of expected benefits are specifically tied to avoidance of land subsidence generally and impacts to infrastructure in targeted locations while allowing continued access to groundwater in unaffected areas of the Subbasin.

6 GOVERNANCE

6.1 Overview

In adopting the Sustainable Groundwater Management Act (“SGMA”), the Legislature made clear that nothing in SGMA “determines or alters surface water rights or groundwater rights under common law or any provision of law that determines or grants surface water rights.”¹ In other words, the Legislature intended that actions undertaken in accordance with SGMA respect common law water rights.

Water rights are property rights, protected as such under the California Constitution.² The right to use groundwater, including groundwater from the Westside Subbasin, is limited to the amount that can be beneficially used and not wasted.³ Article X, section 2 of the California Constitution declares that the “general welfare requires that the water resources of the State be put to beneficial use to the fullest extent of which they are capable . . . The right to water or to the use or flow of water . . . shall be limited to such water as shall be reasonably required for the beneficial use to be served”

The groundwater within the Westside Subbasin is overlain by vast acreage with appurtenant, overlying water rights, which allow owners of land overlying a groundwater basin to extract groundwater for use on their overlying land. The groundwater is also subject to appropriations; use of groundwater on non-overlying land, such as for domestic and off-basin uses. Collectively, groundwater withdrawals over the past 50 plus years, within the Subbasin and contiguous adjacent areas, reflect a cycle of depletion and recovery dependent upon the quantity of available surface water supplies. However, recovery in groundwater levels has not been complete and ~~overtime~~over time, undesirable results have occurred, primarily in the form of land subsidence.

Under California common law, groundwater users, neither individually nor collectively, have the right to lower groundwater levels in a manner that causes undesirable results, including land subsidence. Prior to the adoption of SGMA and in the absence of regulatory oversight, where there has been overdraft, the courts have adjudicated water rights, approved and, in some cases, imposed physical solutions ~~providing to provide~~ for the coordinated management of all groundwater rights in a common supply and to avoid undesirable results.⁴ These physical solutions establish management regimes that enable the expression and use of water rights in a manner that enhances the efficient use of water in accordance with the California Constitution.⁵

¹ Wat. Code, § 10720.5(a).

² *State of California v. Riverside Superior Court* (2000) 78 Cal.App.4th 1019, 1025.

³ *Peabody v. City of Vallejo* (1935) 2 Cal.2d 351, 372; *City of Barstow v. Mojave Water Agency* (2000) 23 Cal. 4th 1224, 1242.

⁴ See *City of Santa Maria v. Adam* (2012) 211 Cal.App.4th 266, 287-88.

⁵ The courts have sustained groundwater management strategies that establish physical solutions which concurrently maximize beneficial use, respect common law water rights and avoid causing undesirable results.

While SGMA did not modify common law water rights, it vested the principal responsibility for developing and administering a management plan for groundwater basins to Groundwater Sustainability Agencies (GSA), each of which is either an agency or comprised of agencies local to the subject groundwater basin.⁶

The question of how a GSA's authority is wielded is of critical importance to the efficacy of the GSP. In the end, groundwater management under SGMA must be consistent with Article X, section 2 of the California Constitution and it must be sufficiently adaptive to respond to the challenges and opportunities that may arise over time.

This GSP establishes the objective of maximizing the beneficial use of water within the Westside Subbasin, without causing undesirable results. The powers of a GSA are set forth in SGMA. This GSP meets the requirements of SGMA and vests the management authority in a GSA as provided in this Chapter.

6.2 Powers of the GSAs

1. **In General.** ~~The WWD Board~~ serves as the GSA for the portion of the Westside Subbasin that is within WWD's jurisdictional boundary. The County of Fresno (Fresno County) serves as the GSA for the portion of the Westside Subbasin that is within Fresno County but outside WWD's jurisdictional boundary. Each GSA shall have and may exercise the express powers set forth under SGMA and shall perform the duties as provided in this GSP as it may be amended by the GSA, in accordance with applicable law. It is essential that this GSP allow each GSA the maximum flexibility and adaptability, so that the GSP can be amended and improved to address ~~change~~changes in circumstances and to account for advances in data gathering, analysis, technology, as well as emerging institutional and economic opportunities. Toward this end, each GSA expressly reserves all power and authority to implement and amend the GSP as a physical solution as may be necessary, proper and convenient over time to achieve its objective of maximizing the reasonable and beneficial use of water without causing undesirable results. The enumeration of the powers and authorities set forth herein is not a limitation on any power or authority of each GSA arising under applicable law.
2. **Coordination.** ~~The WWD Board~~ and Fresno County shall coordinate to implement the GSP pursuant to a Memorandum of Understanding (MOU) or as amended in a subsequent Memorandum with respect to implementation of the Sustainable Groundwater Management Act in the Westside Subbasin.
3. **Rules and Regulations.** Each GSA may make, adopt and amend, after public hearing, appropriate rules and regulations for conducting its affairs, including but not limited to, meeting schedules and procedures. Copies shall be maintained on each GSA's website.

⁶ The declared legislative intent in the adoption of SGMA is set forth in Water Code section 10720.1 and includes the directive to provide local management of groundwater.

4. **Committees.** In addition to the formation of the ~~Interested Parties~~Advisory Committee and Technical ~~Committees~~Advisory Committee expressly authorized below, ~~the WWD Board~~ and Fresno County may, periodically and at their discretion, coordinate to establish committees to act solely in an advisory role by providing advice, and recommendations. Any committee established under this GSP shall be chaired by a representative from one of the GSAs.

5. Specific Powers

- (a) Allocation. In close coordination, the GSAs may establish an allocation program and establish terms and conditions on the use of that allocation from time to time, including but not limited to, eligibility, quantity of allocation, method of delivery, banking, transfer, reporting and monitoring.
- (b) Replenishment. Each GSA may arrange for, conduct, authorize and control replenishment by any reasonable means in accordance with applicable law including but not limited to spreading, percolation injection and in-lieu recharge of non-native, imported, foreign and developed water ("supplemental water").
- (c) Groundwater Storage. The Westside Subbasin has a substantial amount of available groundwater storage capacity that may be used for storage and conjunctive use of supplemental water in coordination with native groundwater and return flows from foreign, non-native and imported water. It is essential that the use of this groundwater storage capacity be undertaken only under the control and regulation of a GSA, to protect the integrity of all water held in storage and the sustainable yield of the Westside Subbasin.
- i. Use of Available Groundwater Storage Capacity. No person may make use of the groundwater storage capacity in the Westside Subbasin for the storage and conjunctive use of supplemental water except pursuant to written agreement with a GSA or as may be authorized by a GSA through the adoption of duly authorized rules and regulations.
 - ii. Uniform Rules and Regulations. In close coordination, the GSAs may adopt uniformly applicable rules and a standard form of agreement for storage of supplemental water provided that the performance of any agreement will not cause undesirable results.
 - iii. Abandonment. Any supplemental water recharged or stored in the Westside Subbasin done without a GSA storage agreement or as authorized by adopted rules and regulations, shall be deemed abandoned and not classified as stored water.
 - iv. Priority in allocation. In the allocation of storage capacity, the needs, use and requirements of the lands overlying the Westside Subbasin shall have priority and preference over storage for the purpose of export for use on non-overlying lands.
- (d) Transfers. The right of persons or entities to transfer water, credits, allocations, stored water and any other entitlement authorized by or arising under this GSP, including any rules,

- regulations and conditions thereon, is subject to prior approval of one or both GSA(s) as may be provided under the GSP and adopted rules and regulations.⁷
- (e) Conjunctive Use. In close coordination, the GSAs may adopt specific incentives and mandates, pursuant to ~~the~~ adopted rules and regulations that encourage and, where necessary, require the use of surface water in-lieu of groundwater to avoid undesirable results and to optimize the beneficial use of groundwater.
 - (f) Accounting. WWD shall calculate additions, extractions and losses to the Westside Subbasin and maintain an annual account of all replenished water, stored water, transferred water allocations and produced groundwater. WWD shall provide annually a summary of the annual account information to Fresno County.
 - (g) Federal Reserved Rights. Nothing herein, express or implied, shall be construed as a limitation on the origin, scope or exercise of federal reserved rights to groundwater in the Westside Subbasin, whatever they may be.
6. **VariANCES**. Any person or entity desiring relief (excuse from compliance) from any portion of the GSP, program, policy, rule, regulation or project (collectively "measure") may request a variance from the GSA implementing the GSP for their portion of the Westside Subbasin. In close coordination, the GSAs will prepare a form for the submittal of a request for a variance and make it available to the public following the adoption of the GSP. Any request for variance filed must be submitted in writing to the appropriate GSA and shall (1) identify the specific GSP measure that is the subject of the request, (2) the reason(s) for the requested variance, ~~and~~ (3) whether the requested variance is necessary to avoid substantial physical or economic harm and an explanation thereof, ~~and~~ (4) a statement of the requested relief. Except in the event of an emergency,⁸ any technical request for a variance will be considered by the Technical Advisory Committee ("TAC") prior to consideration by the appropriate GSA. Non-technical requests will be considered directly by the appropriate GSA. Each GSA must consult with the other GSA representative for the Westside Subbasin prior to its consideration of a variance. Either GSA will not grant a variance if it finds that to do so would (1) be a substantial factor in causing or contributing to undesirable results in any portion of the Westside Subbasin, (2) not undermine effective implementation of the GSP, (3) cause material harm to others who have rights to use groundwater within the Westside Subbasin, and (4) only authorize actions that are reasonable necessary and narrowly tailored to avoid unreasonable physical and economic harm to the groundwater user.
7. **~~Complaints~~Appeals**. Any person aggrieved by ~~the implementation an action~~ of WWD staff to implement the GSP and /or pursuant to an implementing measures may submit a written

⁷ Overlying water rights are generally not transferable under common law and overlying owners do not have the right to store unpumped groundwater for use in future years. The allocations arising under this GSP are only as authorized hereunder in furtherance of the physical solution as embodied in the GSP.

⁸ Sudden, unexpected perilous condition.

complaint/appeal to the GSA implementing the GSP/WWD Board for their/its portion of the Westside Subbasin. A Complaint~~An appeal~~ must include each of the following: (i) identification of name and address of the appellant, (ii) Brief description of the project (if applicable), (iii) the specific measure that is decision which appellant appeals, (iv) the date on which the decision was made, (v) the basis or bases for the Complaint, (ii) the harm the complainant believes has or will occur, and (iii) a statement or summary of appeal, (vi) the requested relief-specific action which appellant requests be taken on appeal, and (vii) all information appellant relies upon to support appellant's appeal. Except in the event of an emergency, ~~a Complaint that includes the information required in this section 6(i)-(iii)~~⁹ any technical request for a variance will be considered by the Technical Advisory Committee ("TAC") prior to consideration by the appropriate GSA. Non-technical requests will be considered directly by the appropriate WWD GSA. WWD may reconsider a prior decision, if there is new material information that was not reasonably available to the appellant at the time of the decision. Decision of the WWD Board shall be final.

6.2.1 Advisory Committee

The ~~-WWD GSA~~Board will establish an Advisory Committee ("AC") that in the discretion of the GSA/WWD Board will be comprised of between eight and eleven representatives from stakeholder groups within the Westside Subbasin, which shall include one representative from the County of Fresno Department of Public Works and Planning, as designated by their Director. The purpose of the AC is to increase effective collaboration and communication between and among stakeholders by: (i) providing advice and recommendations to the GSAs, including but not limited to, advice as to methods in which the GSAs may improve the GSP or its implementation. The AC will be chaired by a member of the WWD Board and subject to the Brown Act.

- (a) Appointment. The WWD ~~GSA board~~Board in its discretion will appoint and the AC will maintain from eight to 11 members, with the exception of the County of Fresno appointment, which shall be designated by the Director of the Department of Public Works and Planning
- (b) Qualifications. A minimum of 60 percent of its members shall be active agricultural groundwater producers with at least one each from domestic groundwater users, Fresno County GSA representative, disadvantaged communities and non-governmental organizations.
- (c) Scope and Authority. The AC's duties and authority shall be limited to that expressly set forth in this herein. The AC's recommendations, if any, shall be transmitted to the appropriate GSA(s) for consideration and potential action.

⁹ Sudden, unexpected perilous condition.

- (d) Offices and Records. The AC's records shall be maintained at the ~~WWD GSA office, currently located at 3130 NWWD's~~ Fresno St., Fresno, CA 93703 office. The AC's records shall be available for inspection by any person during regular business hours. ~~Copies of the AC's records may be had upon payment of the costs of the duplication thereof and any preparation costs pertaining thereto.~~
- (e) Meetings. Regular meetings of the AC shall be ~~scheduled no less than once each quarter and held when needed,~~ at a convenient time and location, ~~as may be determined by the chair of the AC or resolution of the GSAs/WWD Board.~~ The Agenda ~~for all regular meetings of the AC shall be posted on the GSAs' website upon the completion of that Agenda and a copy thereof together with all then and all~~ available materials pertaining to agenda items shall be posted and made available in compliance with the Brown Act and WWD standard procedures. ~~The AC members shall be provided to each AC member and each person who has requested a copy of regular meeting agendas and provided an email address to the AC at least 72 hours before the time set for commencement of that meeting. The proposed agenda shall be circulated to all AC members for review opportunity to propose and comment at least three (3) days prior to publication of the final agenda, on agenda items.~~
- (f) Special Meetings. Special meetings of the AC may be called at any time at the discretion of the Chair, by written notice in compliance with the Brown Act. ~~The calling of notice shall specify the time and place of the special meeting and the business to be transacted. No other business shall be considered at any such meeting. The notice shall be provided to each AC member and each person who has requested a copy of special meeting notices at least 24 hours before the time set for the commencement of that meeting.~~
- (g) Adjournment. Any meeting of the AC may be adjourned to a time and place specified in the Order of Adjournment. ~~A copy of the Order or Notice of Adjournment shall be conspicuously posted on or near the door of the place where the meeting was held or to be held, within twenty-four (24) hours after the adoption of the Order of Adjournment.~~
- (h) Open Meetings. All AC meetings shall be open to all members of the public.

6.2.2 Technical Advisory Committee

The WWD Board will establish a TAC. The TAC shall function *solely* in an advisory role. The TAC shall function as an *independent* body of experts that can provide transparent, credible, and timely advice to the GSAs, as the GSAs may deem appropriate, in their discretion, from time to time. The TAC will meet as required to perform the following actions: (i) review of proposed and existing GSP programs and projects; (ii) requests arising from persons seeking specific approvals pursuant to the GSP or relief from its requirements ~~“(i.e., variances”);~~, including the rules and regulations adopted by the GSAs; (c) complaints/appeals regarding WWD staff actions in support of GSP implementation or complaints regarding the actions of third parties authorized thereunder; and (d) evaluating the boundary condition and potential impacts of groundwater use in contiguous basins on inflow into the Westside Subbasin. ~~The TAC is~~ will be chaired by a member of the WWD Board and subject to the Brown Act.

- (a) Appointment. The WWD ~~GSA~~ Board in its discretion will appoint ~~five~~ to ~~nine~~ members to the TAC, including at least one representative from the County of Fresno Department of Public Works and Planning, as designated by their Director.
- (b) Qualifications. Each member shall hold a bachelors or advanced degree or higher in a field related to groundwater, engineering, hydrology and/ or at least five years of relevant professional experience.
- (c) Scope and Authority. The TAC's duties and authority shall be limited to that expressly set forth in this herein. Upon completing its evaluation of any subject matter within the scope of its authority, the TAC's recommendations shall be transmitted to the appropriate GSA(s) for consideration and potential action.
- (d) Offices and Records. The TAC's records shall be maintained at it the WWD's ~~offices, currently located at 3130 N-Fresno St., Fresno, CA 93703-office~~. The TAC's records shall be available for inspection by any person during regular business hours. ~~Copies of the TAC's records may be had upon payment of the costs of duplication thereof and any preparation costs pertaining thereto.~~
- (e) Meetings. Regular meetings of the TAC shall be scheduled ~~no less than once each quarter and held when needed~~, at a convenient time and location, as may be determined by ~~the chair of the TAC or~~ resolution of the WWD ~~GSA-Board~~. The Agenda ~~for all regular meetings of the TAC shall be posted on the GSAs' website upon the completion of that Agenda and a copy thereof together with all then and all~~ available materials pertaining to agenda items shall be ~~provided to each TAC member posted and made available in compliance with the Brown Act and each person who has requested a copy of regular meeting agendas and provided an email address to the TAC at least 72 hours before the time set for commencement of that meeting-WWD standard procedures.~~ The ~~proposed agenda shall be circulated to all TACAC members for review shall be provided an opportunity to propose~~ and comment ~~at least three (3) days prior to publication of the final agenda on agenda items.~~
- (f) Special Meetings. Special meetings of the TAC may be called at any time at the discretion of the Chair, by written notice in compliance with the Brown Act. ~~The calling of notice shall specify the time and place of the special meeting and the business to be transacted. No other business shall be considered at any such meeting. The notice shall be provided to each TAC member and each person who has requested a copy of special meeting notices at least 24 hours before the time set for the commencement of that meeting.~~
- (g) Adjournment. Any meeting of the TAC may be adjourned to a time and place specified in the Order of Adjournment. ~~A copy of the Order or Notice of Adjournment shall be conspicuously posted on or near the door of the place where the meeting was held or to be held, within twenty four (24) hours after the adoption of the Order of Adjournment.~~
- (h) Open Meetings. All TAC meetings shall be open to all members of the public.
- (i) Variance. An application for a variance generally will be reviewed at the first regularly scheduled TAC meeting ~~within sixty (60) if the variance is technical. The Board of Directors will consider the variance within ninety (90)~~ days from the date the appropriate GSA determines the application is complete and provides notice thereof, provided that staff and/or TAC members may for reasonable cause continue consideration of the application to a future date

to ensure a fair evaluation of the application. The TAC's consideration of a variance application is *advisory* only.

- (j) ComplaintsAppeals. Except in the event of an emergency, a-complaintan appeal will be reviewed at the first regularly scheduled TAC meeting and the Board within sixty (60)ninety (90) days from the date of a GSA's receipt of a-complaint, provided that staff and/or TAC members may for reasonable cause continue consideration of the complaint to a future date to ensure a fair evaluation.an appeal. The TAC's consideration of a-complaint-applicationan appeal is *advisory* only.

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