Tulare Lake Subbasin

Sustainable Groundwater Management Act

July 27, 2022

Mr. Paul Gosselin
California Department of Water
Resources715 P Street
Sacramento, CA 95814

Re: Response to Tulare Lake Subbasin GSP Incomplete Determination

Dear Mr. Gosselin:

The Tulare Lake Subbasin has prepared an Updated 2022 GSP in response to the Department of Water Resources (DWR) Incomplete Determination letter for the Tulare Lake Subbasin 2020 Groundwater Sustainability Plans (2020 GSP). In the Incomplete Determination letter dated January 28, 2020, DWR provided recommendations and corrective actions for the Tulare Lake Subbasin GSAs to address deficiencies in the Plan.

The 2022 GSP Addendum has been prepared to specifically address the deficiencies identified in the Incomplete Determination letter from DWR and should be considered a revision of the 2020 GSP. The decision was made by the GSAs to prepare this response as an addendum to the 2020 GSP for the sake of readability. Attached to the Addendum is an edited version of the 2020 GSP that clearly indicates the sections that have been replaced by this Addendum. The modified GSP along with this Addendum together form the complete 2022 Tulare Lake GSP.

To assist DWR in the review of the Appendix, the attached *Summary of Responses to DWR Comments to the Tulare Lake Groundwater Sustainability Plan*, presents a summary of the response to each deficiency and where that response is discussed in the Addendum. The Tulare Lake Subbasin GSAs are confident that the revised 2020 GSP complies with the Determination letter and appropriate SGMA regulations.

We look forward to continuing to work closely with DWR and our stakeholders in further implementing the GSP. If you have any questions regarding the GSP, please contact any of the GSA managers or Amer Hussain at 559.497.2013.

Sincerely,

Amer Hussain, PE
Tulare Lake Subbasin Point of Contact

Attachments:
Summary of Responses to DWR Comments to the Tulare Lake GSP
Tulare Lake Subbasin Groundwater Sustainably Plan - Volume I and II
January 2020 (edited 2022)
Tulare Lake Subbasin Groundwater Sustainably Plan Addendum

Summary of Responses to DWR Comments to the Tulare Lake Subbasin Groundwater Sustainability Plan

DWR Identified Deficiency	DWR Comment	Addendum Section	Summary of Revisions
Chronic Lowering of Groundwater Levels	The GSP does not explain how it considered and addressed potential impacts of dewatering wells in the context of the undesirable result of significant and unreasonable depletion of supply associated with the chronic lowering of groundwater levels. Furthermore, the GSP does not describe how the GSAs determined that significant and unreasonable depletion of supply will be avoided by managing to the established criteria for chronic lowering of groundwater levels.	2.8	The GSAs will implement a well registry of active wells locations and their construction information. The information will provide additional clarification on the amount of pumping in each aquifer zone. Each GSA will prepare a mitigation plan to address impacted wells following the general requirements of the Mitigation Plan Framework. The GSAs are seeking to coordinate these mitigation programs.
	The GSP does not provide supporting information for how it determined that the selected minimum thresholds are consistent with avoiding undesirable results. Without supporting information, Department staff are unable to assess whether the GSAs have established sustainable management criteria based on a commensurate level of understanding of the basin setting or whether the interests of beneficial uses and users have been considered.	2.2	The methodology used to calculate the MT has been updated. The revised approach for developing the SMC is based on a regional analysis of aquifer geometry and well completion depths. This method defines a mapping framework within which the groundwater level SMC is defined. The groundwater infrastructure used to access the groundwater beneficial uses has been statistically analyzed using DWR's OSCWR database of well completions in the Subbasin. The MTs were set to be protective of 90% of wells listed in the database.
Land Subsidence	The GSP does not define undesirable results or set sustainable management criteria for subsidence in the manner consistent with SGMA and the GSP Regulations. Similar to the deficiency described above, the GSP did not define metrics for undesirable results and minimum thresholds based on the level of subsidence that substantially interferes with surface land uses, informed by, and in consideration of, the relevant and applicable beneficial uses and users in the Subbasin.	3.6	Addressed using a risk assessment approach by combining the key elements of subsidence. MTs were set for total subsidence to be protective of infrastructure with "early warning" monitoring based on differential subsidence. Areas where impacts are most likely occurring will be identified through the risk framework. Local-scale minimum thresholds are defined that relate to specific infrastructure tolerances. Additionally, a regional scale risk framework is defined to identify areas that are most prone to undesirable results.

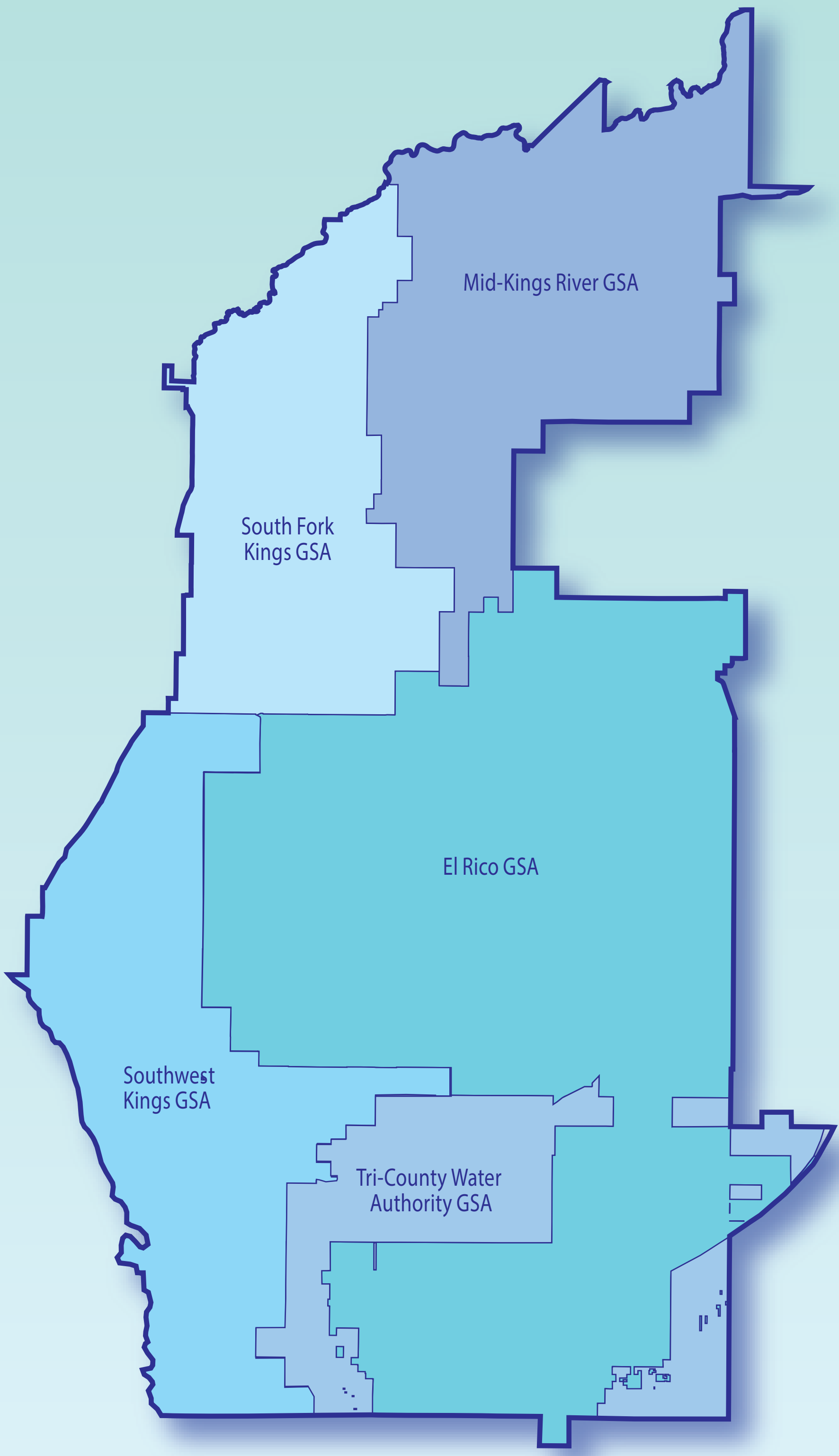
Summary of Responses to DWR Comments to the Tulare Lake Subbasin Groundwater Sustainability Plan

DWR Identified Deficiency	DWR Comment	Section and Addendum	Summary of Revisions
Degraded Water Quality	The GSP does not identify sustainable management criteria for degraded water quality. The reliance on existing regulations and policies to define undesirable results that represent degraded water quality conditions occurring throughout the Subbasin for the purposes of SGMA does not satisfy the requirements of the GSP Regulations.	4.5	The SMCs for each constituent of concern were developed using the most stringent water quality goal. On-going evaluation will be based on utilizing statistical analysis for establishing concentration limits and trend analysis to evaluate COCs annually. Under this approach, an undesirable result for degraded water quality may be triggered and protective efforts will be implemented if the statistical assessment conducted each year indicates an upward trend of one or more COCs.

July 2022

Tulare Lake Subbasin Groundwater Sustainability Plan

Addendum



MID-KINGS RIVER GROUNDWATER SUSTAINABILITY AGENCY | South Fork Kings Groundwater Sustainability Agency | El Rico GSA | SWK Southwest Kings Groundwater Sustainability Agency | TRI-COUNTY WATER AUTHORITY

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µg/L	micrograms per liter
Addendum	2022 Groundwater Sustainability Plan Addendum
AGR	agricultural uses
Amec	Amec Foster Wheeler
BMPs	best management practices
CCR	California Code of Regulations
COC	constituent of concern
CV-SALTS	Central Valley Salinity Alternatives for Long-term Sustainability
DBCP	1,2-dibromo-3-chloropropane
DWR	Department of Water Resources
ESA	European Space Agency
ETc	evapotranspiration
GAMA	Groundwater Ambient Monitoring & Assessment Groundwater Information
gpm	gallons per minute
gpm/ft	gallons per minute per foot
GSAs	Groundwater Sustainability Agencies
GSP	Groundwater Sustainability Plan
ILRP	Irrigated Lands Regulatory Program
InSAR	Interferometric Synthetic Aperture Radar
KRCD	Kings River Conservation District
LMT	local-scale minimum threshold
MCL	secondary maximum contaminant levels
mg/L	milligrams per liter
MO	measurable objective
MSL	above mean sea level
MT	minimum threshold
MUN	municipal uses
N	nitrogen
OSCWR	Online System of Well Completion Reports
pCi/L	picoCuries per liter
RMS	representative monitoring site
RWQCB	Regional Water Quality Control Board
SGMA	Sustainable Groundwater Management Act
SJV	San Joaquin Valley
SMC	Sustainable Management Criteria
SMCL	secondary maximum contaminant levels
Subbasin	Tulare Lake Subbasin
SWRCB-DDW	State Water Resources Control Board, Division of Drinking Water
TCP	1,2,3-trichloropropane
TDS	total dissolved solids
TRE	TRE ALTAMIRA Inc.
TRS	Township-Range-Section
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey (
UTL	upper tolerance limit

1 INTRODUCTION

This Groundwater Sustainability Plan (GSP) Addendum (2022 GSP Addendum) was prepared on behalf of the five Groundwater Sustainability Agencies (GSAs) for the Tulare Lake Subbasin (Subbasin) identified by the Department of Water Resources (DWR) as Basin No. 5-022-12 (Bulletin 118). In compliance with the California Sustainable Groundwater Management Act (SGMA) of 2014, the GSAs adopted the Groundwater Sustainability Plan (GSP) submitted to DWR on January 29, 2020. These five participating GSAs in the Subbasin are the Mid-Kings River, El Rico, South Fork Kings, Southwest Kings, and Tri-County Water Authority. The GSAs remain committed to coordinating and working together to implement the GSP and subsequent updates.

On January 28, 2022, the GSAs received a determination letter from DWR stating the 2020 GSP was considered “incomplete” alongside nine other Subbasins within the San Joaquin Valley. DWR stated that the GSP was considered incomplete as it “does not define undesirable results or set sustainable management criteria for groundwater levels, subsidence, and water quality in the manner consistent with SGMA and the GSP regulations.” Upon receiving the incomplete determination, the Subbasin had 180 days to address the identified deficiencies and submit a revised GSP by July 27, 2022. The GSAs are submitting this 2022 GSP Addendum to address the three deficiencies outlined in the determination letter. The 2022 GSP Addendum has been prepared to specifically address the incomplete determination letter from DWR and should be considered a revision of the 2020 GSP. The decision was made by the GSAs to prepare this response as an addendum to the 2020 GSP for the sake of readability. Attached to the Addendum is a strike-out version of the 2020 GSP that clearly indicates the sections that have been replaced by this Addendum. The modified GSP along with this Addendum together form the complete Tulare Lake GSP.

In preparing this Addendum, the Subbasin management team consisting of the GSA managers communicated with DWR staff to better understand the evaluation criteria utilized by DWR in reviewing the 2020 GSP. While DWR staff were generally helpful, the process was cumbersome considering the tight deadline allowed by the GSP Regulations. As such, we look forward to continued engagement with DWR as we prepare the upcoming five-year Plan update.

The GSAs are committed to remain compliant under SGMA and will continue to gather and report data through the Annual Reports while preparing for the upcoming five-year GSP update. Regular updates to the GSP will continue as more data becomes available and will continue to evolve as changes occur to improve sustainability efforts.

This Introduction section presents a summary of the Addendum and why the decision was made to prepare an Addendum, a summary of the stakeholder outreach efforts conducted during preparation of the Addendum, and a summary of the current basin conditions.

1.1 Addendum Outline

The GSAs decided to submit the response to the determination letter as an addendum to the GSP and not a strikeout version of the 2020 GSP due to the substantial revisions made to the Sustainable Management

Criteria (SMC) chapter of the GSP and additions to the Projects and Management Actions chapter. Chapter 4 of the 2020 GSP presents groundwater levels, subsidence, and water quality SMCs. The 2022 Addendum is influenced by the DWR determination letter and focuses on the undesirable results and how SMCs are established. Deficiencies outlined in the determination letter are covered in Sections 2 through 4 of this Addendum and substantially replace Chapter 4 of the 2020 GSP. In addition, Section 5 of the addendum adds to Chapter 6 of the 2020 GSP which discusses Projects and Management Actions. As noted above, the 2020 GSP is the primary document to reference and is supplemented by this Addendum.

1.2 Stakeholder Communication & Engagement

The stakeholder outreach and engagement efforts started during the preparation of the 2020 GSP were continued subsequent to submittal and during the preparation of this Addendum in general accordance with the existing Stakeholder Communication and Engagement Plan (Tulare Lake Subbasin GSP, 2020 Appendix B). These efforts included considering the interests of all beneficial uses and users of groundwater and including them in the development of the 2022 GSP Addendum. The stakeholder engagement process during the limited time available for preparation of the GSP Addendum specifically included the following:

- Presentation of the Addendum at each GSA Board of Director meetings
- Presentation of the Addendum to GSA member agencies
- Direct outreach to agencies with relevant comments on the 2020 GSP
- Presentations to GSA stakeholder and advisory committees
- Digital communication to interested parties lists
- Direct input from the public

1.2.1 Board of Director Meetings

The GSA Board of Directors have continued to meet in regularly scheduled monthly or bi-monthly meetings. As the GSP Addendum was discussed and prepared by the subbasin management team key decisions were presented and discussed at each of the Board meetings. The Board meetings were noticed to the public and allowed for public comment and input.

1.2.2 Engagement with Interested Parties

Governmental agencies and special districts that submitted comment letters on the 2020 GSP were specifically communicated with to discuss their comments. These communications generally consisted of conference calls to better understand their concerns and how those concerns would be addressed in the GSP Addendum. These agencies included DWR State Water Project, DWR Division of Flood Management, and the Central Valley Flood Protection Board. In addition, other agencies that had input into the original GSP were also contacted including Kings County and the Cross Creek Flood Control District.

1.3 Basin Summary

The Subbasin is located in the south-central portion of the greater San Joaquin Valley, almost entirely within Kings County. The Subbasin covers an area of approximately 535,869 acres (about half the area of Rhode Island) and includes a dry lakebed once occupied by the former Tulare Lake. According to the United States Census Bureau, Kings County has an estimated population of 153,443 people as of July 2021. Approximately 57% of the population is Hispanic or Latino, approximately 30% of the population is white and approximately 20% of the population is foreign born. The area also includes the reservation for the historic Tache Tribe south of Lemoore, as well as the US Navy's largest inland base the Lemoore Naval Air Station. The County has an estimated 1,707 total employer establishments and the median household income is $61,556 which is significantly less than the California average of $78,672. The area is extremely rural, with approximately 46,758 housing units and an average population density of 110 people per square mile.

Land use within the Subbasin and surrounding areas is predominantly agricultural with many families having farmed in the area since the 1850s. There are six localized urban areas with the cities of Hanford, Lemoore, and Corcoran and the communities of Armona, Kettleman City and Stratford. It has been estimated that roughly 5-10% of the County's population lives in the rural areas outside of the cities and communities. The only water generated within the Subbasin is from pumped groundwater which is used for agricultural, municipal/industrial, and domestic needs. The Subbasin receives a significant source of groundwater recharge from surface water received primarily from the Kings, Kaweah, and Tule Rivers as well as imported water from the State Water Project. The Kings River and imported water contribute the most water to the Subbasin while the Kaweah and Tule Rivers only contribute during average to above average rainfall years. Water is imported into the Subbasin through the State Water Project and Central Valley Project as well as operated well fields in the adjacent Tule Subbasin.

Historically, recharge within the Subbasin was dominated by rivers and streams emanating from the Sierra Nevada mountains and lake terrain along the periphery of the Tulare Lake. Over time, development of extensive water supply delivery systems altered recharge, limiting the amount of water received within the Subbasin and offsetting the water balance (inflow versus outflow). The reduction in surface water supply over time has increased reliance on groundwater pumping. The increased reliance on groundwater pumping has also resulted in additional land subsidence.

Land subsidence due to groundwater withdrawals has been well documented and has affected significant areas of the San Joaquin Valley since the 1920s, including in the Subbasin. Natural subsidence has and continues to occur in this area as an effect of the dried Tulare Lake and surface water delivery systems.

The Subbasin is located at the bottom of the valley floor and the historic Lake Bottom where floodwater from the largest flood events collects. As the Subbasin faces longer periods of dry years, the dependency on groundwater pumping increases as agriculture is the Subbasin's primary economic driver outside of government services. The GSAs are committed to achieving sustainability and recognize the challenges ahead.

1.4 Context for SMCs

The groundwater conditions in the Subbasin area developed over many decades and the local GSAs have plans to stabilize the groundwater level declines strategically over the SGMA Implementation Period, while avoiding economic impacts that would destabilize the economy of the predominantly agricultural area. The conditions at the beginning of the Implementation Period are:

1. The area has been developed primarily for agriculture and has been using local surface water since the late 1800s. The primary economy for the area outside of government services is agriculture or is agriculturally linked. This economy sustains the local cities and communities in the Subbasin.
2. The climate of the area experiences regular cycles of drought and flood, but the recovery during the flood periods does not completely offset the decrease in storage developed during the drought years.
3. Long-term groundwater level declines in the portions of the Subbasin prior to SGMA Implementation are about 2 to 3 feet per year on average in the aquifer above the Corcoran Clay (also known as the E-Clay).
4. Historically the area has been known for cotton production. However, through the 1990-2000s, there was a significant transition as dairies moved from the Chino area into the area and as row crops were converted to nut orchards. Now, many farmed acres are linked to dairy facilities that are required to have multiple crops per year to justify the agronomic use of the waste stream from the dairy. Also, the acres planted to permanent crops have significant water demands that cannot be avoided or reduced in drought years.
5. The useful lifespan of existing wells is 15 to 20 years due to persistent groundwater level declines, particularly during critical droughts.
6. Subsidence is a longstanding issue in the area and is a product of local geology (Tulare Lake bed soils) and wells being drilled to deeper zones when they are replaced. Local subsidence issues have been accommodated for many years prior to the enactment of SGMA, but subsidence rates have increased since 2007.

2 REVISED SMC FOR GROUNDWATER LEVEL

This section summarizes the revised approach to defining the SMC for groundwater level. It will be used in conjunction with the SMC thresholds established previously in the initial GSP submitted in January 2020. This addendum therefore describes SMC values that represent "thresholds" that will be in place until the first GSP revision in 2025.

This section specifically addresses the Statement of Findings from DWR regarding determination of incomplete status for the Tulare Lake Subbasin GSP submitted in January 2020, as summarized below:

> *The GSP lacks justification for, and effects associated with, the sustainable management criteria for groundwater levels, particularly the minimum thresholds and undesirable results, and the effects of those criteria on the interests of beneficial uses and users of groundwater.*
>
> *The GSP does not explain how it considered and addressed potential impacts of dewatering wells in the context of the undesirable result of significant and unreasonable depletion of supply associated with the chronic lowering of groundwater levels. Furthermore, the GSP does not describe how the GSAs determined that significant and unreasonable depletion of supply will be avoided by managing to the established criteria for chronic lowering of groundwater levels.*
>
> *The GSP does not provide supporting information for how it determined that the selected minimum thresholds are consistent with avoiding undesirable results. Without supporting information, Department staff are unable to assess whether the GSAs have established sustainable management criteria based on a commensurate level of understanding of the basin setting or whether the interests of beneficial uses and users have been considered.*

More specifically, the corrective actions requested by DWR are addressed:

> *Corrective Action 1*
>
> *a. The GSAs should revise the GSP to describe, with information specific to the Subbasin, the groundwater level conditions that are considered significant and unreasonable and would result in undesirable results. The GSAs may choose to define the conditions in terms of the negative effects they mention in their GSP (e.g., water well problems, subsidence, and deterioration of water quality) or may use other methods to establish a different trigger that would define when an undesirable result would be experienced in the Subbasin. The GSAs should then explain or justify how the quantitative definition of undesirable results is consistent with avoiding the effects the GSAs have determined are undesirable results.*
>
> *b. The GSAs must revise the minimum thresholds for chronic lowering of groundwater level to be consistent with the requirements of SGMA and the GSP Regulations. Rather than relying on a projection of continued groundwater level and storage decline to define the undesirable results and minimum thresholds, the GSAs must determine and document criteria based on a significant and unreasonable depletion of groundwater supply, informed by their understanding of the Subbasin's beneficial uses and users. The GSAs must document the effects of their selected minimum thresholds on beneficial uses and users in the Subbasin. In particular, if the GSP retains minimum thresholds that allow for continued groundwater level decline then the GSP should*

> *explain the anticipated effects of that decline on beneficial uses and users, and should clearly explain whether projects and management actions have been identified to address impacts to those uses and users. If the GSP does not include projects and management actions to address impacts to uses and users that will be impacted by continued declines in groundwater levels, then it should clearly explain the rationale and analysis that led to that decision.*

2.1 Potential Effects to Beneficial Uses and Users

In the Subbasin generally, the effects of water level decline to beneficial uses are related to impacts to water supply wells and subsidence. Subsidence related impacts are discussed in detail in Chapter 3. The impacts of the water level decline are primarily to municipal, industrial, agricultural, and domestic wells. A review of available Kings County well permits indicates that all four types of wells have been installed to deeper depths since the most recent drought. Agriculture is the main economic enterprise in the Subbasin, so effective management of groundwater is critical to the continuation of economic interests of Subbasin communities.

An undesirable result for the water level SMC is defined as a groundwater level that would make a water supply well unusable for supply purposes. Continued groundwater level declines have the potential to cause some wells to become unusable requiring deepening and/or replacement to reach groundwater. Continued groundwater level declines could also force some well owners to lower or replace existing pumps if the existing well pump is not sufficiently deep. Decreases in groundwater levels also increase the energy needed for pumping.

The GSAs recognize that municipal and domestic wells with substantially decreased capacity or that are made unusable due to groundwater level declines are an undesirable result that needs to be avoided. While agricultural users are the key groundwater extractors across the Subbasin, representing more than 90% of the groundwater use, the GSA's efforts are focused on setting water levels to protect municipal and domestic wells.

2.2 Approach

The revised approach for developing the SMC for groundwater level is based on a regional analysis of aquifer geometry and well completion depths. This approach does not rely on trend analysis of water levels or the results of the groundwater modeling. Instead, it defines a mapping framework within which the groundwater level SMC is defined. Within this framework, the groundwater infrastructure (i.e., wells) used to access the groundwater beneficial uses has been statistically analyzed using DWR's OSCWR database of well completions in the Subbasin. The approach is shown schematically on Figure 2-1 and described in further detail below.

Step 1: The first step involved defining depth ranges for each of the aquifer zones that could be used to query the OSCWR database and identify the wells completed in each zone. The depth criteria used were:

- A-zone = Well Completion Depths < 100 ft
- B-zone = Well Completion Depths 100 to 700 ft

- C-zone = Well Completion Depths >700

This aquifer geometry and well completion criteria are used to quantify the minimum threshold (MT) within each aquifer zone.

Step 2: The second step involved defining a grid that could be used to characterize the ground surface elevation and the elevation of the top of the C-zone, which is defined by the E-clay (Corcoran Clay). The grid approach was used because in many cases only the well depth is reported in the OSCWR database, which cannot be translated to an elevation and integrated with a groundwater elevation SMC. The grid provides a more uniform and consistent management framework for evaluating the number of wells and completion characteristics in a given area. The grid was established based on Township-Range-Section (TRS), so each grid cell represents one section (640 acres). Using this grid system, wells without elevation reference points can be described in terms of approximate elevation and subjected to statistical analysis. Similarly wells that do not have exact geographic coordinates can be incorporated into an analysis as long as there is a TRS scale location.

Step 3: This step produced two TRS framework maps for the SMC which are shown on Figure 2-2 (ground surface elevation), and Figure 2-3 (top of E-clay elevation). Each of these figures were derived from figures in Chapter 3 of the 2020 GSP and the line contours from these figures were digitized to calculate the average elevation for each grid cell. The line contours for the E-Clay were based on an original map prepared by Croft (1972) that was also used and modified by the USGS (Faunt et al, 2009). There are nine color-zones for the E-clay generated at 100-foot elevation intervals, so each color zone corresponds to a specific elevation range. For example, the green areas on Figure 2-3 represent areas where the E-clay is at an elevation of between -200 and -300 feet below mean sea level. Table 2-1 summarizes the classification zones of average E-clay elevation shown on Figure 2-3.

Step 4: This step included a query and classification of over 6,000 wells in the OSCWR database that are located in the Subbasin. Each well was classified according to its TRS grid location, the aquifer zone, the year of completion, and the reported Purpose of Use for the well. Only wells with reported Purpose of Use as Domestic, Public, Agriculture, Irrigation, or Industrial were taken to the next step of the analysis. Wells reported as Unknown, Geotechnical, Monitoring, Abandonment, or other similar purposes were not used in the subsequent analysis. Table 2-2 summarizes the well query by aquifer and color zone. There was no ground-truthing of any wells reported in the OSCWR database to verify their status, location, or completion. However, several shallow older wells were removed from the statistical analysis, as described in Section 2.3. A series of maps and tables summarizing Public/Domestic and Agricultural/Industrial wells across the Subbasin was then produced. The maps show the number of wells in each TRS grid section and the purpose of use (Public/Domestic or Agricultural/Industrial). The maps use the elevation of the E-clay as the base-layer, so that each grid cell and number of wells in that cell is associated with an average elevation of the E-clay.

- Figures 2-4a and 2-4b show the number of wells in each TRS grid completed in the A-zone (completion depths of less than 100 feet). Figure 2-4a shows the number of public/domestic wells and Figure 2-4b shows the number of agricultural/industrial wells

- Figures 2-5a and 2-5b show the number of wells in each TRS grid completed in the B-zone (completion depth of 100 to 500 feet). Figure 2-5a shows the number of public/domestic wells and Figure 2-5b shows the number of agricultural/industrial wells
- Figures 2-6a and 2-6b show the number of wells in each TRS grid completed in the C-zone (completion depth greater than 700 feet). Note that these figures include wells that could be completed across the E-clay and also tap into the Lower B-zone. Figure 2-6a shows the number of public/domestic wells and Figure 2-6b shows the number of agricultural/industrial wells

Tables were also produced to summarize the number of wells and completion statistics within each E-clay zone.

- Table 2-3 summarizes the well completion statistics for wells in the C-zone or deeper
- Table 2-4 summarizes the well completion statistics for wells in the B-zone
- Table 2-5 summarizes the well completion statistics for wells in the A-zone

Step 5: A statistical analysis of well completion elevations for B-zone wells was then completed to define MTs across the entire Subbasin for the B-zone. Unlike the original approach to defining the MT in the 2020 GSP, this statistical approach focuses on well completion depths, rather than observed water level trends. In this way, the analysis accounts for all beneficial users, particularly public and domestic uses, and defines an MT throughout the entire Subbasin, regardless of whether there is a designated representative monitoring site (RMS) well. This approach focuses more clearly on broad beneficial use protection and allows quantification of potential impacts to beneficial uses if the MT is reached in each area. A methodology based on a radius around each RMS well was considered, but this would have excluded many wells from the analysis and there would be overlapping areas around individual RMS wells. Because the C-zone is a confined aquifer, well completion elevations were not used to define the MT. Instead, the MT was defined in relation to the elevation of the E-Clay to ensure that water-levels do not decline to the top of the E-clay (see Section 2.3.1). A similar approach was taken for the A-zone and the MT is defined with respect to the elevation of the A-clay, which defines the extent of the A-zone aquifer.

Step 6: The final step was to evaluate observed water levels in RMS locations established in the 2020 GSP as a "reality check" to the statistical analysis and E-clay elevations. As noted in Section 2.3, there are a number of potential uncertainties in well completion data contained in the OSCWR database. Similarly, the average elevation of the E-clay across an entire TRS grid cell does not capture fine-scale influences on the observed groundwater level in any given RMS well. The intent of the approach was to use areas to aggregate well completion data across the entire Subbasin for the MT statistical analysis, while being representative of the groundwater flow pattern and how wells are operated across the Subbasin. However, there were instances where the observed water levels in existing RMS wells were at or below the MT as defined by the statistical analysis, despite no documentation for wells going dry in the vicinity of the RMS well (this is discussed further in Section 2.10). Any methodology based on areas to base MTs on would encounter the same issue, where local influences on the observed groundwater level in each RMS well will not always align with an area-based MT.

2.3 Undesirable Results Lowering of Groundwater Level

23 CCR §354.26(a) *Each Agency shall describe in its Plan the processes and criteria relied upon to define undesirable results applicable to the basin. Undesirable results occur when significant and unreasonable effects for any of the sustainability indicators are caused by groundwater conditions occurring throughout the basin.*

Undesirable results occur when groundwater conditions within the Subbasin result in significant and unreasonable impacts to a sustainability indicator. The revised SMC for groundwater level defines an undesirable result with respect to a numerical threshold (a minimum threshold or MT) which would cause a significant and unreasonable loss of beneficial uses for water supply, particularly for domestic/public supply. The MT for groundwater level that defines the undesirable result is a groundwater level that would make a water supply well unusable for supply purposes.

2.4 Minimum Thresholds for Lowering of Groundwater Level

23 CCR §354.28 (a) *Each Agency in its Plan shall establish minimum thresholds that quantify groundwater conditions for each applicable sustainability indicator at each monitoring site or representative monitoring site established pursuant to Section 354.36. The numeric value used to define minimum thresholds shall represent a point in the basin that, if exceeded, may cause undesirable results as described in Section 354.26.*

This section describes the methodology for quantifying the undesirable result and associated MT for groundwater level for each aquifer (A-, B-, and C-zone). The methodology used to calculate the MT is different than what was used in the 2020 GSP

2.4.1 C-Zone

C-zone wells are completed at depths of greater than 700 feet in a confined aquifer, so the ability to maintain sufficient groundwater supply is not dependent on the completion elevation of the well, but is more related to well performance and whether pumping causes water levels to drop below the top of the confining layer. When pumping in a confined aquifer lowers water levels below the confining layer, the aquifer in the immediate vicinity of the well converts from a confined to unconfined aquifer. There is limited published literature regarding effects of the transition from confined to unconfined aquifer conditions, but a recent white paper prepared to the Southern Trinity Groundwater Conservation District in Texas (Yelderman, 2020) summarized the limited evaluations of this phenomenon and found that, in general, conversion resulted in reduced well yields and reduced rates of drawdown. In the oil and gas industry, casing/well failures resulting from reservoir depletion are not uncommon. A review of historical casing/well failure events in a highly compacting sandstone oil field included a comprehensive geomechanics analysis of various casing-damage mechanisms (tension, axial compression, shear, and bending) related to reservoir depletion (Furui, 2012). Similar geomechanical principles also affect wells when there is ground subsidence. The potential for conversion from confined to unconfined conditions, combined with how mechanical forces act on both the well casing and surrounding formation materials in a confined aquifer, indicates that lowering of groundwater levels below the elevation of the confining layer could make a water supply well unusable for supply purposes (thus producing an undesirable result).

The MT for groundwater level in the C-zone is defined with respect to the elevation of the E-clay, which is the principal regional confining unit in the Subbasin. To quantify the MT, an analysis of the typical specific capacity of wells completed in the C-zone was conducted. Specific capacity is calculated by dividing the pumping rate by the observed drawdown and is reported in units of gpm/ft. A well with a high specific capacity can produce a given flow rate with less drawdown compared to a well with a low specific capacity. By assigning a target flow rate for a well completed in the C-zone, the drawdown (in feet) at that pumping rate can be calculated from the specific capacity. This drawdown (in feet) is then simply added to the elevation of the E-clay to represent the minimum water level elevation that would allow pumping at the target flow rate without lowering groundwater levels below the E-clay during pumping.

There are limited pumping test data available within the Subbasin, but a compilation of 17 aquifer tests by the USGS indicates a median specific capacity of 68 gpm/ft and a 90th-Percentile specific capacity of 20 gpm/ft (McClelland, 1962). These results are similar to a summary of 75 specific capacity tests in the C-zone in the Tule Subbasin (TCWA Tule GSP, 2020). The schematic of Figure 2-7 illustrates the methodology for calculating the C-zone MT.

The MT for groundwater level in the C-zone is defined based on the expected drawdown from a C-zone well at a pumping rate of 1,000 gpm, at a specific capacity of 20 gpm/ft. The value of 1,000 gpm was selected based on discussions with stakeholders for their wells completed in the C-zone. Using this methodology, the expected drawdown is 50 feet (1,000 gpm divided by 20 gpm/ft). This expected drawdown is simply added to the elevation of the E-clay to define a groundwater elevation. If groundwater elevations fall below this level, 10% of wells in the C-zone would not be able to pump at 1,000 gpm without drawing water levels below the E-clay. The quantitative definition of significant and unreasonable lowering of groundwater levels in the C-zone is therefore a groundwater elevation of 50 feet above the elevation of the E-clay.

This methodology has a number of uncertainties associated with the actual depth to the E-clay and how representative the specific capacity data are for wells in the Subbasin. However, it produces TRS-scale management criteria that are representative of actual hydrogeologic conditions, typical pumping rates, and general well performance. It also aligns with minimizing the effects of ground subsidence, since drawdown below the top of the E-clay accelerates compaction of the E-clay and exacerbates ground subsidence. The methodology does not account for situations such as interference drawdown between adjacent pumping wells, or other complicating factors that may have affected the pumping test data used in the analysis.

2.4.2 B-Zone

Minimum thresholds (MT) for the B-zone are defined to insure sufficient access to public/domestic beneficial uses from well extraction. The MT was calculated to represent conditions where water-levels fall below the bottom elevation of wells in the B-zone. The quantitative definition of the MT elevations is based on a statistical percentile for well completion elevations in the B-zone.

The percentile statistic represents the number of wells completed above or below the percentile elevation. For example, an 85th percentile statistic equal to 50 feet means that 85% of the population of wells are completed below an elevation of 50 feet. This means that if the groundwater elevation was 50 feet, 15% of the wells in that well population would be potentially vulnerable to failure because they are completed at or above an elevation of 50 feet. This percentile calculation is made for each population of wells within a given E-clay zone. Figure 2-8 illustrates the percentile approach for calculating the MT for the B-zone.

In order to calculate the MT, the OSCWR database was modified based on a review of the Kings County well permit database and a number of wells from the B-zone were removed from the statistical calculation. In this region, as groundwater levels have declined over time, wells have been drilled deeper and generally the shallower wells are no longer in use. The OWSCR database illustrates that there have been periods when the number of shallow wells installed in the Subbasin has decreased as water levels in the B-zone aquifer have declined over time. Historically, well owners in the Subbasin have adapted to a "typical" lifespan for shallower wells of 30 years or less. As water levels have declined, well owners have become accustomed to having to re-drill or deepen their wells. This is illustrated in Figure 2-9, where the number of wells completed at elevations shallower than 200 feet reaches relative highs in 1977, 1992 and 2003 and then drops significantly. By 2010, the number of well completions shallower than 200 feet was less than five per year, presumably because it became "common knowledge" that water levels had declined below 200 feet and were unlikely to recover. For this reason, wells completed at depths shallower than 200 feet and before the year 2000 have a high likelihood of either being abandoned, deepened, or not used currently for beneficial uses. Therefore, these wells were removed for the percentile statistics calculation. While the OSCWR database shows a total of 2,048 wells in the B-zone, the MT statistics were calculated based on a total of 1,421 wells in the B-zone.

Other MT statistical methods, such as choosing a radius around RMS well locations, were considered but were not used because they would have excluded many wells and created overlapping areas around individual RMS wells. A key objective of the regional approach to defining the MT was to ensure that <u>all</u> wells likely to be actively providing beneficial uses for domestic/public supply were incorporated into the statistical analysis so that an MT could be specified across a broad area and not solely at a single RMS location.

Table 2-6 summarizes the percentile statistics used to establish the MT for wells in the B-zone. The percentile statistic was translated into two additional quantitative values as follows:

- The number of wells that would be potentially vulnerable to failure (Table 2-7). The value is calculated by simply multiplying the number of wells in a given zone by a percentile level. For example, there are 358 public/domestic wells in the Orange zone. The 90th percentile statistic of well records represents a groundwater level where 10% of the well records reflect completion at an elevation shallower than 56 feet MSL (see Table 2-7). Therefore, records indicate 36 wells in the Orange zone (358 x 10%) may be vulnerable to failure if groundwater levels drop below an elevation of 56 feet MSL.
- The available drawdown within the B-zone (Table 2-8). This calculation represents how much saturated thickness remains below a given percentile elevation. It is simply the difference between the percentile elevation and the top of the E-clay. Areas where there is a large saturated thickness below the percentile elevation are more favorable for deepening wells in the B-zone to avoid or mitigate the undesirable result compared to areas with a small saturated thickness.

Table 2-6 also includes separate percentile statistics for areas near the Kings River. This area, designated as the R-zone, is recharged by higher water quality from the Kings River and remains a viable groundwater supply for public/domestic uses. This area is shaded and designated as the R-zone in Figure 2-4. Based on the OSCWR database query, there are 60 public/domestic wells in the R-zone. In these areas, MTs are defined based on percentile statistics for well completion depth, similar to the methodology used for the B-zone.

The SMC approach presented here provides an initial statistical approach to quantifying significant and unreasonable lowering of groundwater level across the large number of wells in the Subbasin. The GSAs selected the 90th percentile groundwater elevation to define the MT associated with significant and unreasonable lowering of groundwater level. This MT is protective of beneficial uses because 90% of the domestic wells completed in the B-zone have completion intervals below this elevation. This MT also implies that the GSAs in the Subbasin are potentially willing to mitigate as many 152 B-zone wells and 25 R-zone wells used for domestic or public supply.

The GSAs believe that the MT will be protective of beneficial uses in the B-zone and, in conjunction with a mitigation program (described in Appendix D), will avoid a significant and unreasonable loss of beneficial uses. The GSAs recognize that mitigation and adaptation to the proposed SMC for groundwater level requires better information on actual well conditions and also will require case-by-case assessments of whether beneficial uses have been impacted at a given point in time. Work is currently underway to develop an improved well database and web-interface that will enable the GSAs to efficiently verify well locations and/or implement registration of well information by individual landowners. This will then link to Kings County's parcel and well permit systems. The Subbasin GSAs are committed to working with landowners to protect beneficial uses and implementing appropriate mitigations to insure continued access to beneficial uses.

2.4.3 A-Zone

A-zone wells are completed at depths of less than 100 feet in a thin unconfined aquifer that relies primarily on recharge from uncontrolled, poor quality, stormwater and agricultural run-off and leakage from irrigation canals. This results in generally poor water quality and significant variability in seasonal water levels and water availability. In essence, the A-zone is poorly suited for public/domestic supply. The GSAs would like to discourage use of the A-zone as a groundwater supply for public/domestic use and encourage landowners to use a more reliable and higher quality source. The A-zone would then offer an opportunity to optimize agricultural uses. Therefore, the MT for the A-zone is simply a water level equal to the elevation of the A-clay or a groundwater level shallower than 5-feet below ground surface (which could cause waterlogged soils or drainage issues).

There are reportedly as many as 377 A-zone wells used for domestic or public supply. As described previously, the number of these wells that are actually used for beneficial use is not known and is likely less. Historically, groundwater levels have routinely dropped to the top of the A-clay (see Appendix A), presumably making many of these wells unsuitable for water supply on a regular basis. These fluctuations in water level are not the result of pumping conditions that the GSA can regulate. They are the result of variations in precipitation, run-off, and delivery of water for irrigation. Wells in the A-zone will be included in the well registration efforts currently in progress and the GSAs will attempt to verify well locations and document beneficial use. The GSAs will also consider appropriate mitigation or management efforts for

A-zone wells (in accordance with the mitigation plan framework described in Appendix D). Mitigation approaches will include consideration of deepening of A-zone wells into the B-zone, restricting agricultural pumping in areas where there are clusters of domestic wells, or filtration requirements that would improve water quality.

2.4.4 Summary and Relationship to Other Sustainability Indicators

The proposed MT for groundwater levels is summarized in Table 2-9 for each aquifer and E-clay zone. The groundwater level MTs are considered “stand-alone” thresholds for groundwater level but are related to SMCs for groundwater storage and subsidence as described below.

DWR’s requested corrective action did not include a request to update the Groundwater Storage SMC, so the original groundwater storage MTs and Measurable Objectives (MOs) from the 2020 GSP have not been changed. However, the groundwater storage SMC will be revisited for the 2025 GSP update through further analysis using a groundwater flow model. The groundwater level MTs specified in this addendum will be factored into the revision of the groundwater flow model, which will then be used to calculate the minimum groundwater storage volume associated with the groundwater level MT. This will then factor into the definition of the groundwater storage MT and thereby tie it to beneficial uses in each aquifer zone.

DWR’s requested corrective action includes a request to update the Ground Subsidence SMC, which is described in Section 3. The subsidence SMC described in Section 3 is focused on DWR’s specific request to *“define metrics for undesirable results and minimum thresholds based on the level of subsidence that substantially interferes with surface land uses.”* In this regard, the SMC is focused on levels of subsidence that would result in impacts to specific types of infrastructure, which are assumed to represent the surface land uses that are being protected by the Subsidence MT. However, groundwater levels in the B-zone and C-zone aquifers generate the relative magnitudes of the effective stresses acting on the clays in the aquifer system and are the underlying physics driving subsidence. This is described in greater detail in Section 3. The MTs for groundwater levels represent one component of what levels of subsidence might occur, but the variables and relationships that cause subsidence are very complex and require modeling to produce quantitative values. The connection between groundwater level and subsidence will be revisited for the 2025 GSP update through a revision of the groundwater flow model, which will be then used to calculate groundwater pumping levels that would minimize subsidence and avoid associated undesirable results. This will more explicitly link groundwater pumping to observed and projected subsidence at different levels of pumping.

2.5 Representative Monitoring Sites (RMS) for Groundwater Level

Table 2-10 presents a revised table of MTs for each RMS well originally identified in the 2020 GSP (Chapter 5) and Figure 2-10 shows the RMS well locations. Table 2-10 includes both the original MO/MT elevations from the 2020 GSP and the revised MTs based on the methodologies described in previous sections. An MT is specified for each RMS well that corresponds to the mid-point between the original MT derived for the specific RMS location in the 2020 GSP and the revised MT based on E-clay zones. These MTs for each RMS well will remain in place until the GSP revision in 2025. The mid-point was selected as being the most representative value for each RMS well since it incorporated both observed trend in water-levels (from the 2020 GSP methodology) and the regional framework based on well completion elevations. Table 2-10 also shows the operating range (MO-MT) for each RMS well. Appendix A contains hydrographs for each RMS well, along with the MT. The rationale for selecting the mid-point between the 2020 GSP MT and the percentile MT is described below.

The E-clay elevation zones were selected as relevant areas to define the general shape and hydrogeologic structure of the groundwater flow system. In the B-zone, groundwater generally flows "on top of" the topography of the E-clay, and flows "beneath" the E-clay in the C-zone, creating a pressure head above the elevation of the E-clay. By using these areas to aggregate well completion data across the entire Subbasin, the MT statistical analysis is representative of both the groundwater flow pattern and how wells are completed and operated across the Subbasin. A more arbitrary methodology for defining the area for calculating well completion statistics (for example a radius around each RMS well) would have excluded many wells from the analysis and there would be overlaps in the areas around each RMS well. While the statistical approach is useful for quantifying beneficial uses in a given area, there are fine-scale influences on the observed groundwater level in a given RMS well that are not related to the elevation of the E-clay or the statistical distribution of wells. Any methodology to calculate areas on which to base statistical well completion analysis will encounter the same issue, where fine-scale influences on the observed groundwater level in a given RMS well will not always align with a statistically generated MT. Therefore, the mid-point method was selected as the most representative method for defining MTs at each RMS site because is reflects a comprehensive aggregation of well completion data in the Subbasin; incorporates the primary hydrogeologic structures in the Subbasin; and includes the observed water-level trend data across the Subbasin at the various RMS locations. The GSAs believe this is the most appropriate management approach to monitor groundwater thresholds and avoid undesirable results. Further investigation of conditions in and around RMS locations where the operating range is less than 20 feet will occur to confirm stratigraphic conditions and influences on observed water levels in these areas. These RMS locations are highlighted on Table 2-10.

It is anticipated that the 2025 update to the GSP will include changes to both the distribution of RMS locations and the numeric values for the MT. During the implementation period, the GSAs will be working to update and verify well locations to improve the accuracy of the well statistics used to derive the MT. The GSAs will also be conducting an analysis of water levels, stratigraphy, and well completion intervals, as well as the relationships between groundwater levels and other SMCs such as groundwater storage and subsidence, as described in the previous section.

2.6 Measurable Objectives for Lowering of Groundwater Level

23 CCR §354.30 *(a) Each Agency shall establish measurable objectives, including interim milestones in increments of five years, to achieve the sustainability goal for the basin with 20 years of Plan implementation and to continue to sustainably manage the groundwater basin over the planning and implementation horizon.*

DWR's corrective action for Groundwater Level SMC did not include a request to update Measurable Objectives (MOs), so the original MOs from the GSP have not been changed. In the interest of clarity, this section outlines the approach currently being considered for the 2025 GSP revision.

The revised SMC methodology for MTs creates clearly defined thresholds derived to be protective of public/domestic beneficial uses and based on the documented infrastructure used for beneficial uses. The proposed MTs are protective of both public/domestic and agricultural/industrial beneficial uses. The MO for groundwater levels will not be derived from well completion data but will rather be tied to the groundwater storage SMC, subsidence SMC and associated projects and management actions that will inform groundwater pumping to avoid undesirable results (including groundwater level and subsidence). This will entail additional analysis of overall groundwater budget, further evaluation of sustainable yield, and groundwater/subsidence modeling under different pumping and recharge scenarios within the Subbasin.

2.7 Data Gaps

Well Registry - The GSAs recognize that there is limited information on the currently active wells across the area. While some GSAs have implemented well registry programs there has not been a consistent requirement across the Subbasin resulting in a significant data gap. A comparison of the OSWR database with Kings County well permit information clearly showed the need for a comprehensive well registry. In particular, the information on active domestic well operations is limited and inconsistent. Working with local agencies and stakeholders, a comprehensive well registry will be prepared.

Updated Groundwater Model – As part of the SGMA Implementation Grant recently awarded to the Subbasin, an updated groundwater model will be prepared utilizing the data that has been collected since the submittal of the 2020 GSP, including updates to well locations, stratigraphy and pumping rates by aquifer zone. The results of the updated model will then be used to conduct a native yield study and to forecast subsidence rates.

Native Yield Study - The SGMA Implementation Grant also included funds for the proposed native yield study. The study will utilize the results of the updated model, with input from stakeholders to further evaluate the sustainable yield available to landowners. The results of the study will help determine the amount of water available to each landowner.

2.8 Protective Efforts

Several on-going and additional protective efforts have been or will be taken by the GSAs to better manage water levels in the area. These efforts will be coordinated with those listed in the subsidence and water quality chapters.

Well Registration – The GSAs will implement a well registry of active wells locations and their construction information. The information will provide additional clarification on the amount of pumping in each aquifer zone.

Mitigation – The GSAs understand that there will likely be impacts to some domestic well users during the implementation period. As such, each GSA will prepare a well mitigation plan following the general requirements of the Mitigation Plan Framework presented in Appendix D. The GSAs are seeking to coordinate these mitigation programs with existing programs administered by local groups and is actively pursuing funding alternatives.

3 REVISED SMC FOR LAND SUBSIDENCE

This section summarizes the revised approach to defining the SMC for ground subsidence. It will be used in conjunction with the SMC thresholds established previously in the 2020 GSP. Again, this addendum describes SMC values that represent the thresholds that will be in place until the GSP update in 2025. The SMCs were developed based on the current level of understanding of the basin setting.

This section specifically addresses the Statement of Findings from DWR regarding determination of incomplete status for the Tulare Lake Subbasin GSP submitted in January 2020, as summarized below:

> *Department staff conclude that the GSP does not define undesirable results, minimum thresholds, and measurable objectives for subsidence in the manner required by SGMA and the GSP Regulations. Specifically, the GSP did not define metrics for undesirable results and minimum thresholds based on the level of subsidence that substantially interferes with surface land uses, informed by, and in consideration of, the relevant and applicable beneficial uses and users in the Subbasin.*
>
> *Department staff conclude that the GSP failed to explain how minimum thresholds, based on maximum simulated subsidence in 2070 under status quo conditions, at the representative monitoring sites are consistent with the requirement to be based on subsidence that represents substantial interference with surface land uses.*
>
> *Department staff are unable to assess whether the GSAs have established sustainable management criteria based on a commensurate level of understanding of the basin setting or whether the interests of beneficial uses and users have been considered.*

More specifically, the corrective actions requested by DWR are addressed:

> *Corrective Action 2*
>
> a. *The GSA should revise their undesirable results to be consistent with SGMA and the GSP Regulations, and to contain sufficient detail to demonstrate that they are reasonable, supported by best available information and science, are commensurate with the level of understanding of the basin, and consider the interests of beneficial users in the Subbasin. If the GSAs are concerned with the functionality of critical infrastructure, then they should clearly describe the critical infrastructure in the Subbasin, and the level of subsidence that would substantially interfere with that infrastructure.*
>
> b. *The GSA should revise their discussions of measurable objectives and minimum thresholds to be consistent with the requirements of SGMA. Rather than basing those criteria on projections of status-quo subsidence, they should be informed by the site-specific consideration of the level of subsidence that would substantially interfere with land surface uses.*
>
> c. *In resolving this discrepancy, the GSAs should demonstrate that their representative monitoring sites, where minimum thresholds and measurable objectives are defined, are commensurate with monitoring for the undesirable results, such as impacts to critical infrastructure, that they are trying to avoid through implementation of the GSP.*

d. *In resolving this discrepancy, Department staff recommend including flood protection infrastructure in the assessment of users susceptible to potential interference from subsidence. Department staff recommend engaging with flood management agencies in the basin and region, as appropriate.*

3.1 Technical Background

3.1.1 Subsidence Overview

Subsidence in the San Joaquin Valley (SJV) and thus in the Subbasin is primarily attributed to compaction[1] of subsurface clay layers (i.e., fine-grained soils) in response to groundwater extraction. The geotechnical mechanisms that contribute to subsidence are described in Appendix B. Groundwater levels and subsidence rates in the SJV have been shown to be tied to one another, with decreasing water levels associated with increasing subsidence, and vice versa (Lees et al. 2021). How closely the water levels are tied to the rate of subsidence is an ongoing area of study. However, there are numerous complexities associated with this relationship, some of which are discussed more in the following sections and in Appendix B. We have assumed herein that as groundwater level declines are decreased and ultimately stabilized over the next 20 years, subsidence is anticipated to mirror this and will likewise decrease and stabilize to a minimum residual “background” level. If subsidence is not directly observed to decrease and stabilize in line with pumping, additional analysis will be required to identify potential mitigation actions required to minimize subsidence.

Since the rate and amount of subsidence in a given area are primarily dependent on groundwater levels, minimizing subsidence itself will be accomplished and managed through MTs and MOs set for groundwater levels. The following sections instead focus on how impacts that result from subsidence will be identified, monitored, and managed, until ultimately such impacts cease with the reduction of subsidence through time.

3.1.2 Subsidence Monitoring

Subsidence monitoring is accomplished through two primary approaches: 1) point monitoring using survey monuments or extensometers, and 2) regional monitoring, using satellite imagery, also known as Interferometric Synthetic Aperture Radar (InSAR). Point monitoring can be useful in that it provides accurate subsidence measurements, but this technique is limited to only a localized area and requires a dense monitoring network to provide information on variations in subsidence for a larger area. Although a network of point locations can provide some information on regional conditions and variations, the resolution of a feasible monitoring network may not be useful for the scales of differential subsidence that are most likely to impact infrastructure. InSAR data provides a more comprehensive dataset that shows variability across the region as well as local variations which can be used to identify areas of

[1] Geotechnical engineers use the term consolidation to describe the process by which a soil layer dissipates (i.e., expels) pore water pressures and decreases in volume. Geologists use the term compaction to describe consolidation. Compaction is known by geotechnical engineers as the densification of soils by the application of mechanical energy (e.g., Holtz and Kovacs, 1981). The term compaction, together with the term consolidation, will be used herein for consistency with literature on the topic of subsidence in the SJV.

differential subsidence that could impact infrastructure.

InSAR data for the subbasin are collected by the European Space Agency (ESA) Sentinel-1A satellite and processed by TRE ALTAMIRA Inc. (TRE). Sentinel-1A InSAR data coverage within the Subbasin began on June 13, 2015. The datasets include point data that represent total vertical displacement values, including GIS rasters files interpolated from the point data showing average total displacement for 100 meter by 100 meter areas. Raster data are available for total vertical displacement relative to 2015, and for annual vertical displacement.

The InSAR data will be used in conjunction with the existing point monitoring program. Since the submittal of the 2020 GSP, the GSAs have worked with the Kings River Conservation District (KRCD) to incorporate their subsidence monitoring program. KRCD began point monitoring for subsidence in 2010 and continues to expand their network as needed. The monitoring program uses existing monuments along the Kings River (levees, bridges, etc.) to measure subsidence near infrastructure. Currently, the subsidence monitoring network has 25 points from KRCD along with the two previously identified for a total of 27 locations. The GSAs have designated these monitoring points as RMS locations for subsidence monitoring. These monitoring points are used to fill data gaps within the InSAR data coverage and are used to ground truth the InSAR data. The monitoring points also provide local coverage near critical infrastructure including near the California Aqueduct and other key canals. In addition, the GSAs utilize subsidence measurements in the Annual Reports which are submitted to DWR. Total versus Differential Subsidence

Total subsidence is measured by the total vertical change in elevation of a point or area relative to some baseline elevation. Figure 3-1 illustrates the total amount of subsidence between 2015 and 2022 within the Subbasin from InSAR data, which shows the general range and distribution of subsidence in recent years across the Subbasin.

Differential subsidence refers to the change in elevation over a given distance over a given time period. Differential subsidence is expressed in terms of slope gradient or angular distortion, where the difference in change in elevation over a given period of time between two contiguous points is divided by the horizontal distance between them. This value is then multiplied by 100 to express it as a percentage. Since differential subsidence numbers are small (i.e., fractions of one percent), another way to express differential subsidence is using fractions. For example, if a 0.1 meter (m) change in elevation difference was measured between two points that are 100 m apart, then 0.1/100 = 0.001 (or 0.1%). The change in slope between the two points can also be expressed as 1/1,000.

If subsidence is uniform (i.e., of equal value) across the extent of a piece of infrastructure, impacts will generally be minimal. If subsidence is variable across a small area, this can result in localized ground disturbance such as cracks and fissures or localized depressions. If subsidence is variable across a larger area, this can result in changes in topographic slopes. Both small-scale and large-scale variations in subsidence are defined as differential subsidence, and this variability in subsidence across the ground surface at various scales is typically the most likely cause for impacts to infrastructure.

3.1.3 Time-Varying Subsidence Issues

It is well documented (e.g., Lees et al. 2021, Borchers and Carpenter 2014, Lofgren and Klausing 1969) that subsidence resulting from groundwater extraction does not all occur instantaneously, but rather some lingering "deferred subsidence" can occur over extended periods of time, well after groundwater extraction has occurred. Appendix B describes more fully the mechanics of subsidence and time rate effects.

It is important to recognize this time lag in evaluating current and projected subsidence, in that current/ongoing subsidence is likely in part related to historical groundwater extraction activities. Subsidence cannot be completely stopped once a stress change has been applied and maintained for a period of time (e.g., groundwater extraction). As such, areas of the SJV that have experienced subsidence will continue to exhibit subsidence for some time, albeit at a lower rate, even if piezometric levels are returned to levels preceding groundwater pumping in the SJV. As such, with reductions in groundwater pumping, subsidence rates and total subsidence values can be minimized and leveled off, but deferred subsidence from historical pumping will persist into the future regardless of current and future activities.

3.1.4 Infrastructure Issues

The impacts of subsidence or other ground disturbances are directly related to the types of land use and infrastructure that are subjected to subsidence and how specific infrastructure is designed. Infrastructure is typically designed to accommodate a certain amount of ground disturbance, along with a multitude of other design criteria such as earthquake magnitude, flood elevations and so on. Some types of infrastructure can tolerate higher amounts of ground subsidence compared to others. The same infrastructure can be designed to withstand different levels of subsidence or ground disturbance. For this reason, the type of infrastructure that could be affected by subsidence is closely tied to how it could be described in terms of an undesirable result under SGMA. Table 3-1 summarizes the types of infrastructure within the Subbasin, the amount of each infrastructure type present inside of and within three miles of the Subbasin, and the geotechnical subsidence issues that can lead to infrastructure impacts. The list of possible impacts highlights how the scale of differential subsidence that impacts each type of infrastructure is variable. For example, for differential subsidence to impact a building, there must be variation in the amount of subsidence within the footprint of the building, which can be quite a small, localized area. In contrast, for differential subsidence to impact a canal, the primary concern is whether the slope of the canal between two points changes, which could be miles apart. Table 3-1 thus illustrates the challenge of developing MTs that capture the range of potentially undesirable results that could occur to this array of infrastructure.

As described previously, differential subsidence is typically the most important expression of subsidence that can cause damage to infrastructure. Areas where there is a uniform amount of subsidence, regardless of magnitude, are less likely to cause infrastructure damage compared to areas where there is high differential subsidence. There are a variety of references and sources of information regarding engineering tolerances to subsidence for various types of infrastructure. A more detailed description of how and why impacts to infrastructure from subsidence occur is provided in Appendix B, along with threshold subsidence values based on engineering design standards and criteria.

3.2 Potential Effects of Subsidence

<u>*Density of Infrastructure*</u> - In the Subbasin, generally the amount of local infrastructure is much denser in

cities and communities than in rural agricultural areas. The corridors along Highways 198, 43 and 41 are considered areas of dense infrastructure because there are significant local highways and facilities that cross them. The corridor along the California Aqueduct is also considered an area of dense infrastructure because of the number of facilities that have been developed that cross over the canal along its alignment. These areas of dense infrastructure were considered in terms of their cumulative risk related to subsidence.

Flood Channels - Rivers and creeks generally begin in watersheds in the coastal hills to the west and the Sierra Nevada Mountains to the east of the Subbasin and flow downhill toward the historic Tulare Lake. Part of the Subbasin's history involves regular floods, and that is why dams were built on local rivers and streams to protect communities and farmlands from flood events. However, even though the dams exist, they only provide protection up to a certain magnitude flooding event. Subsidence has not been observed to diminish the capacity of local flood channels, but it theoretically could impact capacity under the right circumstances. Also, subsidence could cause a change to the amount of sediment that is moved by the system. However, there are parties responsible for the maintenance of these channels and incremental impacts are being addressed through on-going maintenance.

Local Flood Control - Ground surface changes can affect flood zones as well as flood control levees. Local flood control levees are maintained by agencies responsible for maintaining their effectiveness. In 2017, a local flood control levee was raised by several feet to address subsidence concerns, but that was the first such project on that levee in decades and it was completed in just a few months. The planned development of new basin projects and the increased use of wet year surface water should mitigate potential modifications to existing flood zones.

Local Canals - These linear facilities are a critical part of the water management strategy across the Subbasin. Impact to these facilities such as a reduction in capacity is significant and may require GSAs to shift to pumping reductions in the vicinity.

Regional Canals - These linear facilities, like the California Aqueduct, usually have regional significance and have users across large sections of the southern San Joaquin Valley. Due to the significant regional effects, impacts on these facilities need to be minimized and avoided. For that reason, other management strategies like pumping allocations in the vicinity to stabilize groundwater levels may be imposed.

Shallow Wells - Shallow wells that do not have significant exposure to the confined aquifer below the Corcoran Clay do not appear to be at risk from subsidence.

Deep Wells - Wells that have significant exposure to the confined aquifer below the Corcoran-Clay are at risk of collapse due to subsidence that is mostly linked to that zone. Because subsidence has been active in this area for many years, owners and well drillers have been including compression sleeves and thickening well casings to make wells more resilient to subsidence. The area has experienced roughly 4 feet of subsidence in the Corcoran area since 2015. It is believed that a significant percentage of deep wells would experience structural impacts if an additional 10 feet of subsidence occurred.

Railroads - There are several railroads throughout the Subbasin that convey goods along predefined routes and the facilities also have flood control structures, like culverts, along their alignments. The observed grade changes that have occurred from subsidence do not appear to be significant for local railroads and their culverts appear to be staying stable with adjacent properties. However, steep localized subsidence can be a significant issue in terms of the cost of repairs and need to be minimized and avoided.

Property Drainage - Subsidence generally is a phenomenon that occurs over relatively large areas and is gradual enough that it is difficult to identify without a survey. Because of this, many issues that may be related to subsidence are addressed by local parties annually during maintenance efforts. Drainage on very large parcels could be impacted by subsidence, but in discussions with local parties there was almost no evidence of that situation documented by local landowners.

3.3 What Is Important to Protect

3.3.1 Infrastructure of Statewide Importance

California Aqueduct - The California Aqueduct is unique in the Subbasin as it is critical infrastructure that holds statewide importance. Most of the water conveyance facilities in the Subbasin use the natural ground surface slope towards the historic Tulare Lake Bottom to deliver supplies to parties in the Subbasin. However, the Aqueduct was designed to convey supplies from the Sacramento River to San Diego and make deliveries to contractors along its alignment. The Aqueduct is located along the coastal hills, on the far west side of the Subbasin, and on the opposite side of the Subbasin from where the highest rates of subsidence occurred between 2015 and 2020. Again, due to the significant regional effects, impacts to the Aqueduct need to be minimized and avoided. For that reason, other management strategies like pumping allocations or limitations in in the vicinity to stabilize groundwater levels may be imposed.

High Speed Rail – The train is planned to be diesel, so gradual subsidence is not expected to have a significant impact. This is a statewide facility, but it is not fully constructed or operational. Subsidence was evaluated by California High Speed Rail (HSR) and concluded that with the appropriate design considerations, that subsidence was not expected to significantly impact the HSR ride performance (Amec, 2017).

3.3.2 Local Communities

Power systems - These are critical to maintain for the health and human safety of residents of the area, but local parties are not aware of any evidence of subsidence damage.

Municipal water systems - The depth of municipal wells varies across the Subbasin. Based on available information, it appears that municipal wells are completed to deeper depths over time.

Sewer systems – Discussions with local communities indicated that grade dependent sewer systems have not seen significant issues due to subsidence.

Canal Systems – Minimizing the impacts from subsidence to the canal systems are a high priority for the Subbasin. These are necessary to continue to deliver surface water for Management Strategies and projects to be effective.

Deep Wells - The vast majority of deep wells in the area are either agricultural, municipal or industrial. These wells are viewed as being at risk from subsidence, while shallow wells are not. Some rate of impact to these facilities is not significant, given that the mitigation for these same users is likely to be pumping restrictions. However, rates of impact that would affect a significant portion of the users with these facilities would be significant for the Subbasin.

3.4 Data Gaps

Correlation - Subsidence has been compared to many different monitored conditions (groundwater levels, groundwater storage, pumping, well collapse, etc.) and no good correlation has been found given available data.

Subsiding Zone - Although it is understood that the majority of subsidence is being developed below the Corcoran Clay in fine grained sediments that are depressurized, it is not understood whether it is a specific zone (of clay lenses) that is subsiding or a very broad zone (of clay lenses) in that aquifer.

Maintenance – Impacts are difficult to observe because regular maintenance can often address incremental issues.

Well Collapse - No tracking of well collapse in new well permitting process. Also, often there is not just one issue identified when a well collapses.

Flood Zones - Limited data on how subsidence may impact flood zones as the low spot across the Subbasin is moving away from communities, and planned projects are expected to reduce the amount of floodwaters that reach the low spot.

3.5 Subsidence Triggers

Geologic Conditions - The geology of the Subbasin appears to have greater potential for subsidence closer to the Tulare Lake bottom. There is minimal subsidence in the Kettleman City area as it appears that the geology in that area is not susceptible to extensive subsidence. However, it is also important to acknowledge that there is little groundwater pumping in that same area and this could also be contributing to the relatively small amount of subsidence measured in that area.

Deep Pumping - The GSAs understand that deep pumping from pressurized aquifer zones is primarily related to subsidence. In the TLSB, this would generally be below the Corcoran Clay. However, the specific zone below the Corcoran Clay that is subsiding is not currently known. It is also understood that some small component of subsidence is related to water level declines in the upper aquifer.

Groundwater Level Declines & New Deeper Wells - The GSAs understand that the chronic lowering of groundwater levels is related to the triggers for subsidence. As groundwater levels decline, landowners choose to drill deeper wells to restore their access to available groundwater supplies. When new deeper wells are drilled, the geology below the previous well and above the base of the new well is subjected to new impacts from the new well. There are some cases when other wells are already affecting the zone below the old well and above the base of the new one. However, if there are no other wells in the area that are influencing that zone, then pumping from the new well could result in increased subsidence when it begins to reduce the pressure in that zone enough for the fine-grained sediments to depressurize. Generally, the GSAs view the effort to stabilize groundwater levels as critical to future success in dealing with subsidence. As groundwater pumping is reduced across the Subbasin, groundwater level declines will diminish, and fewer wells will be drilled deeper which will reduce the development of subsidence across the Subbasin.

3.6 Undesirable Results

23 CCR §354.26(a) *Each Agency shall describe in its Plan the processes and criteria relied upon to define undesirable results applicable to the basin. Undesirable results occur when significant and unreasonable effects for any of the sustainability indicators are caused by groundwater conditions occurring throughout the basin.*

The undesirable results related to land subsidence are defined as "the significant loss of functionality of a critical infrastructure or facility, so the feature(s) cannot be operated as designed, requiring either retrofitting or replacement to a point that is economically unfeasible." This definition is largely qualitative and subjective, but it is representative of what would generally be construed as "undesirable" by landowners, agencies, and the general public. A significant loss in functionality that could be mitigated through retrofitting but is considered economically feasible would not be considered undesirable. While "significant loss of functionality" is considered a general description, what is an undesirable result must eventually be quantified as an MT.

Defining quantitative metrics for MT and MO that will avoid undesirable results is not a straightforward analysis, since as described previously, there are multiple components related to both the actual amount and type of subsidence (i.e., total versus differential), the general type of infrastructure that is affected (e.g., canals versus roadways), and actual site-specific conditions at and around a given piece of infrastructure (design parameters, soil conditions, etc.). Similarly, the terms "significant loss of functionality" and "economically unfeasible" are difficult to quantify at a subbasin scale and are best addressed using a regional risk assessment approach, where undesirable results are not simply defined as static impacts to infrastructure, but rather combine the key elements of subsidence analysis; specifically:

- the amount and type of subsidence;
- the type of infrastructure that could be affected;
- the engineering design factors that are typically used for each type of infrastructure; and
- the consequence and/or cost of infrastructure failure.

The GSAs have considered these key elements for subsidence in this Addendum by focusing on primary (California Aqueduct) and secondary (outside of aqueduct) infrastructures. The total subsidence undesirable results are as follows:

California Aqueduct – In a recent correspondence with the DWR State Water Project staff, they reiterated their requirements from their May 14, 2020, letter that the rate of subsidence be limited to 0.01 feet per year by 2040 as a reasonable measurable objective with a goal of no subsidence thereafter. This amount of subsidence was estimated by the Department of Water Resources State Water Project as having a significant impact to the capacity of the regionally significant linear surface water conveyance facility. The GSAs agree that the MT for the Aqueduct be set at a rate of 0.01 feet per year until 2040 and limited to residual subsidence thereafter. As such, the GSAs will require all new wells within three miles of the Aqueduct to provide a subsidence evaluation and appropriate coordination with DWR as part of the requirement to obtain a permit. The limited number of existing wells in the area, believed to be approximately six wells, will be limited to historic pumping rates.

Outside of Aqueduct - In the area outside of the California Aqueduct alignment, Undesirable Results were viewed differently. Given that there currently is a limited correlation between subsidence and groundwater levels, groundwater storage, groundwater pumping, or groundwater well collapse in the Subbasin, a general relationship considering multiple factors that developed a protective condition was agreed to by the GSAs. This amount of subsidence was compared with the subsidence experienced since 2007 and the known impacts that have been documented and mitigated in the Subbasin for perspective/reasonableness. Also, there was an acknowledgement that the depth of aquifer across the Subbasin varied significantly, so that less subsidence could be accommodated in shallower aquifers. The general protective condition related to an amount of subsidence that 1) would be protective of local communities' critical facilities, 2) would avoid impacts to a large number of deep wells beyond their current ability to withstand significant structural damage, 3) would avoid requiring significant modification to known flood control levees while still acknowledging reduced floodwater from developing projects, and 4) would avoid the increase in potential for significant capacity impacts to flood control channels and canals with increased subsidence that cannot be economically mitigated.

To address the corrective actions requested by DWR and observe differential subsidence, local-scale minimum thresholds (LMTs) are defined that relate to specific infrastructure tolerances associated with standard engineering design. In addition, a regional scale risk framework is also defined that is derived, in part, from the LMTs and other factors to identify areas (not specific infrastructure) that are most prone to undesirable results. These two approaches will be used together in an iterative process as follows:

1. Areas across the Subbasin where impacts are most likely occurring will be identified through the risk framework;
2. In high-risk areas, more detailed assessments of targeted infrastructure will be used to identify LMT exceedances;
3. Potential impacts from identified exceedances will be verified through visual inspection and field monitoring if necessary in order to quantify actual impacts;
4. Underlying causes for those impacts (including groundwater pumping) will be managed to minimize further impacts; and
5. LMTs and the risk framework will be updated regularly based on identification (or lack thereof) of impacts.

The qualitative definition of undesirable results is not changed from the 2020 GSP.

3.7 Minimum Thresholds

> **23 CCR §354.28** (a) *Each Agency in its Plan shall establish minimum thresholds that quantify groundwater conditions for each applicable sustainability indicator at each monitoring site or representative monitoring site established pursuant to Section 354.36. The numeric value used to define minimum thresholds shall represent a point in the basin that, if exceeded, may cause undesirable results as described in Section 354.26.*

The MT is a marker set by the GSAs to reflect their current view of where, beyond this point, Undesirable Results are expected to occur. In the case of Subsidence, the MT will be conveyed as ground surface or reference point elevations across the Subbasin at Representative Monitoring Sites (RMS). This way when the RMS locations for subsidence are regularly surveyed and the InSAR Data is evaluated at those locations, the monitored data can be compared against the established MT elevation. DWR regulations and published Best Management Practices (BMPs) require that GSAs produce a rate and an extent to avoid or minimize subsidence. The GSAs have set MTs for total subsidence but will monitor differential subsidence as a leading indicator of potential impacts to infrastructure. As discussed in Section 3.1.3, it is viewed that differential subsidence is most concerning for infrastructure.

In considering the MT for total subsidence, the GSA considered the technical evaluation conducted on the critical infrastructure along with discussions of the operators of the infrastructure. The evaluation considered impacts from both local differential subsidence and regional impacts. In addition, the GSAs considered that many of the historic impacts have been mitigated. Based on the results of the evaluation, the GSAs set the MT at values that would be protective of the critical infrastructure.

The vertical extent of subsidence at each RMS location is listed in Table 3-2 where surveyed elevations in 2015 are shown along with the MT elevation at that site, which is understood to be protective against Undesirable Results. The GSAs have also agreed that a rate of 36 inches in three years would indicate an Undesirable Result as this represents the highest rate of subsidence across the Subbasin. Subsidence has been an on-going concern for decades in the area although most areas experience a much slower rate. This rate has allowed the agencies responsible for the infrastructure to adapt and incorporate any impacts into their regular maintenance programs.

The MTs Values for total subsidence were set based on the following approach at each RMS location:

1. The InSAR data from 2016 through 2022 was evaluated to calculate the annual rate of subsidence. This time period was considered to represent current conditions and experienced a wet-dry climate cycle.

2. The rate of subsidence was then repeated at the seven-year cycle through 2040. A cumulative total subsidence was then calculated for each RMS location. This represented the baseline value for total subsidence.

3. Separately, estimates were made on when projects and management actions would be implemented. The implementation of these actions would result in the reduction of the rate of subsidence. This reduction was similar to the values determined by the groundwater model in 2020 GSP. Again, the cumulative total subsidence was calculated for each RMS location and is included in the “GPS Implementation” column in Table 3-2.

The MT was set at the calculated "GSP Implementation" values as exceedance of those values would likely represent undesirable results to critical infrastructure and land use. Impacts to critical infrastructure will be monitored using the methods described in Sections 3.8 and 3.9. This will serve as an "early warning" to areas that experience impacts and allow the GSA to evaluate if other management actions are required.

The GSAs will use management strategies like groundwater pumping limits, following programs and projects like recharge basins to stabilize groundwater levels across the Subbasin and thereby avoid and minimize the triggers of subsidence. Some GSAs have already implemented groundwater pumping allocations and others are evaluating the need for allocations. In addition, several local projects were recently funded by a DWR Implementation Grant and are planned to be completed prior to June 2025.

As discussed in Section 3.6, the MT for the California Aqueduct will be set at a rate of 0.01 feet per year until 2040 and limited to residual subsidence thereafter. As such, the GSAs will require all new wells within three miles of the Aqueduct to provide a subsidence evaluation and appropriate coordination with DWR as part of the requirement to obtain a permit. The limited number of existing wells in the area, believed to be approximately six wells, will be limited to historic pumping rates.

3.8 Local Scale Minimum Threshold

The LMTs for subsidence are defined for each type of applicable infrastructure that could be impacted by subsidence. The focus of the LMTs is on differential subsidence since this is the most damaging expression of subsidence to infrastructure at a local scale. Table 3-3 summarizes the engineering tolerances for differential subsidence for each infrastructure type. These are the LMTs for subsidence and reaching these thresholds at or near specific critical infrastructure could lead to undesirable results (i.e., the significant loss of functionality requiring either retrofitting or replacement to a point that is economically unfeasible).

While these LMTs are specific to the type of infrastructure, they do not address site specific conditions that could cause a specific piece of infrastructure to have a higher or lower threshold to subsidence (e.g., engineering design of a structure; the direction of flow of a canal relative to the direction of topographic slope change, etc.). The LMTs are thus intended to be used to guide GSA managers and stakeholders on focusing subsidence investigations; evaluating the potential for undesirable results; and assessing how groundwater pumping relates to exceedances of these tolerances at specific locations. The LMTs are also used directly in the regional-scale risk framework described in the next section.

Regional-Scale Risk Framework

The regional-scale approach to defining a MT is based on a Township/Range/Section (TRS) geographic framework similar to that used for groundwater level. The regional-scale approach considers infrastructure and subsidence in aggregate, rather than individual infrastructure types and engineering tolerances as used to define the LMTs.

A simple risk assessment formula was applied to each TRS grid cell to define aggregate risk of undesirable results. The aggregate risk in each TRS cell can also be depicted in map format and used to evaluate where the risk of undesirable results is high versus where it is low. The definition of Aggregate Risk is as follows:

Aggregate Risk (R) = Hazard (H) x Vulnerability (V) x C (Consequence), where

- H = the observed subsidence at a point in time or over a given time period for a given TRS grid cell.
- V = the aggregate vulnerability of infrastructure to the hazard (H).
- C = the consequence of damage to a given piece of infrastructure subjected to the hazard.

The consequence was not included in this risk assessment, as the quantitative data (e.g., monetary values for repair or replacement of infrastructure, secondary economic impacts due to impacted infrastructure, etc.) necessary to accurately represent consequence for each type of infrastructure was not available. However, this could be included if such information is developed, to better define high risk areas within the Subbasin.

The first step was to generate maps that summarize the aggregate total subsidence and aggregate differential subsidence (i.e., the hazard, H) for each TRS:

- Figure 3-2 shows average total subsidence values between 2021 and 2022 in each TRS based on InSAR data. This represents the level of hazard posed to infrastructure (i.e., H-Map).
- Figure 3-3 shows average differential subsidence between 2021 and 2022 in each TRS based on InSAR data. Differential subsidence in each TRS was estimated by calculating the slope between each adjacent raster cell from the 100 meter by 100-meter total subsidence InSAR raster, and then taking the average slope value for each TRS. This provides a different representation of the hazard posed to infrastructure (i.e., H-Map), and is the more likely hazard to impact infrastructure, and thus the more useful indicator of potential higher risk areas.

The next step was to generate an infrastructure density map and an infrastructure vulnerability map:

- Figure 3-4 shows the total infrastructure density in the Subbasin. The infrastructure density map shows total infrastructure in each TRS based on the total sum of infrastructure, assuming each point location represents 1 unit of infrastructure (i.e., 1 bridge equals 1 unit of infrastructure), and each 1 mile of linear infrastructure represents 1 unit of infrastructure (i.e., 1 mile of railroad equals 1 unit of infrastructure). The following types of infrastructure are included and counted as noted:
    - Canals and Aqueduct (linear, count is 1 per mile)
    - Levees (linear, count is 1 per mile)
    - Pipelines (linear, count is 1 per mile)
    - Railroads (linear, count is 1 per mile)
    - High Speed Rail (linear, count is 1 per mile)
    - Emergency Facility Buildings (points, count is 1 per building)
    - Airports/Airport runways (points, count is 1 per airport)

- Bridges (points, count is 1 per bridge)
- Roads (linear, count is 1 per mile)

Note that wells are excluded from this list and density maps, as impacts to wells will be addressed separately with well registration and mitigation plans. Subsidence damage to public/domestic supply wells will be evaluated on a case-by-case basis to evaluate the root cause(s) of failure and address those causes.

- Figure 3-5 shows total infrastructure density in the Subbasin, excluding roads. Roads were excluded from the calculation of risk because they are in general considered less critical than other types of infrastructure, have a relatively high tolerance to subsidence, and are routinely maintained as part of normal uses. Including roads in the aggregate was determined to "dilute" the risk of other (higher consequence) infrastructure, and thus was not included in the calculation described below. The infrastructure density map was used to generate an infrastructure vulnerability map (V-Map) as described below.
- Figure 3-6 shows the aggregate infrastructure vulnerability map excluding roads (V-Map), used for differential subsidence risk calculations. The value of V for each TRS was generated using the sum product of the magnitude of each infrastructure type multiplied by its associated LMT for that type of infrastructure. For example, if there are 4 miles of canals and 2 miles of high-speed rail in a given TRS, this value would be calculated as 4 miles of canal multiplied by 1/600 (the canal tolerance LMT on Table 3-3), plus 2 miles of high-speed rail multiplied by 1/80 (the rail tolerance LMT on Table 3-3). A TRS with a high density of infrastructure would have a higher V value compared to one with a low density of infrastructure. Similarly, infrastructure with higher tolerances results in a lower V value compared to infrastructure with lower tolerances for subsidence. Further details on the calculation of V are also provided in Appendix B.
- Figure 3-7 shows the aggregate total subsidence risk map used for total subsidence risk calculations. This map was generated by multiplying the raster map shown in Figure 3-2 (average total subsidence values between 2021 and 2022) by the raster map shown in Figure 3-5 (total infrastructure density in the Subbasin excluding roads).
- Figure 3-8 shows the Aggregate Differential Subsidence Risk Map, which was generated by multiplying the raster map shown in Figure 3-3 (average differential subsidence between 2021 and 2022) by the raster map shown in Figure 3-6 (aggregate infrastructure vulnerability map excluding roads).
- Figures 3-9 and 3-10 are risk series maps, each showing the map inputs (H and V) and final risk map for total (Figure 3-9) and differential subsidence (Figure 3-10). Both risk maps show a general concentration of higher risk areas in the northern and eastern portions of the Subbasin, where both higher subsidence and more concentrated infrastructure areas overlap. Figure 3-10 (differential subsidence) takes into account LMTs by infrastructure type and is thus more fine-tuned in its display of potentially higher risk areas.

The risk framework provides a tool for evaluating where subsidence risks to individual infrastructure are most likely occurring and will be used to focus further investigation or analysis to evaluate whether a specific piece of infrastructure is at risk of experiencing an undesirable result. While the risk map (either total or differential subsidence) does not directly identify undesirable results, it will be used to define actions related to investigations of subsidence that will evaluate the contribution of groundwater pumping to subsidence in "high risk areas." Individual infrastructure within a given TRS is still managed to the LMT for that specific infrastructure type.

3.9 Relationship to Other Sustainability Indicators

The subsidence SMC incorporates multiple levels of management criteria because of the complexity and inter-relationships between subsidence, vulnerable infrastructure, and groundwater levels. The LMTs for subsidence are essentially "stand-alone" thresholds for specific infrastructure types. The regional risk framework integrates actual observed subsidence with the LMTs to identify and prioritize areas of concern. The ultimate goal of minimizing subsidence to the maximum extent practicable is achieved through management of groundwater pumping via the Groundwater Level and Groundwater Storage SMC.

As described previously, DWR's requested corrective action did not include a request to update the Groundwater Storage SMC, but it will be revisited for the 2025 GSP update through further analysis using a groundwater flow model. The groundwater model will also be able to project subsidence based on the MT and MO for groundwater level and groundwater storage, as well as project pumping and managed recharge configurations currently under development. The variables and relationships that cause subsidence are very complex and require modeling to define, analyze and evaluate their relative sensitivity factors (or combination of factors) that can be managed by the GSA to avoid subsidence and associated undesirable results. The connection between groundwater level, groundwater pumping, and subsidence will be revisited for the 2025 GSP revision, which will integrate groundwater pumping into the regional risk framework and LMTs for subsidence.

3.10 Measurable Objectives for Land Subsidence

> **23 CCR §354.30** *(a) Each Agency shall establish measurable objectives, including interim milestones in increments of five years, to achieve the sustainability goal for the basin with 20 years of Plan implementation and to continue to sustainably manage the groundwater basin over the planning and implementation horizon.*

The measurable objective for land subsidence is defined qualitatively as: *"continued operation of critical infrastructure, with economically feasible retrofitting or replacement if necessary."* The measurable objective for subsidence will ultimately be achieved through the MTs and MOs set for groundwater levels and storage, which is expected to result in decreasing subsidence over time. Ongoing monitoring of subsidence through the use of the InSAR data, regional subsidence risk framework, and subsidence LMTs will further define needed adjustments to groundwater level and storage MTs and MOs. The process described below will be followed to regularly implement and update the risk framework, LMTs, and ultimately identify the need to adjust groundwater level and storage MTs and MOs.

The regional-scale risk maps will be updated annually using annual releases of InSAR data to identify changing conditions and to prioritize monitoring and investigation efforts. Based on the regional-scale risk assessment results, high-risk areas (i.e., those in the upper 2 red/orange risk categories shown in Figures

3-7 and 3-8) indicate areas that are potentially approaching MTs and thus require a localized assessment of differential subsidence values relative to thresholds for each type of infrastructure. All high risk TRS locations will be subject to a localized assessment that will have two components:

1. Assess differential subsidence at individual scales most appropriate for each type of potentially impacted infrastructure (e.g., 100s of feet for point locations such as buildings and bridges versus several miles for linear infrastructure such as canals, aqueduct, and rail) using full-scale InSAR data (i.e., not TRS scale), which is available on a quarterly basis. Review will be relative to the specific footprint of potentially impacted infrastructure within high-risk areas to see if the LMT is being exceeded. If values are approaching threshold values for any infrastructure types, a visual inspection of potentially impacted infrastructure will be completed to confirm and characterize potential impacts. LMTs for specific infrastructure may be revised upward or downward based on this initial investigation. In addition, the need for local point monitoring (e.g., survey points or extensometers) will be evaluated.
2. If potential specific impacts to infrastructure are confirmed, an analysis of how groundwater pumping has contributed to the observed local impacts will be conducted and actions will be undertaken to change pumping patterns to minimize further subsidence and associated impacts.

3.11 Representative Monitoring Sites (RMS) for Subsidence

Monitoring of subsidence will occur through InSAR supplemented by site-specific subsidence monitoring. As noted in Section 3.1.2, the RMS locations have already been expanded to more than 95 locations and may be expanded further as needed. InSAR data will be reviewed and used to update the regional risk model annually. In addition, quarterly releases of InSAR data will be reviewed in areas of high risk identified from the risk model. Additionally, site-specific monitoring (e.g., either through existing monitoring locations or through installation of instruments at new locations) will be implemented if site-specific data are needed to better characterize and understand localized occurrences of subsidence. Subsidence RMS locations are presented in Figure 3-11.

3.12 Protective Efforts

Several additional protective efforts will be undertaken by the GSAs to better manage and understand subsidence triggers in the area.

Mitigation - The GSAs want to help protect their landowners from the impacts of subsidence. A mitigation plan needs to be developed with significant local input and a broader understanding of the potential costs for various levels of mitigation. The Subbasin would pursue grant funds for subsidence mitigation and after a mitigation plan is developed, evaluate developing local funding through a Prop 218 process.

Well Registration - The GSAs currently does not have a complete registry of active wells and their construction information. This information will be needed to better evaluate why subsidence is occurring in some areas.

Totalizing Flowmeters - Some GSAs currently require totalizing flowmeters on all deep wells but that is not consistent across the Subbasin. Much of the efforts to date have focused on using Crop evapotranspiration (ETc) to evaluate groundwater use, but for deep wells the better metric is total groundwater extraction. The installation of meters or other measuring methodologies along with the well registration program will help to better evaluate groundwater extraction by location and depth. This information will be needed to better evaluate why subsidence is occurring in some areas.

Local monitoring Network Expansion - The GSA’s Subsidence Monitoring Network will be expanded to regularly observe elevations at key facilities where Undesirable Results need to be avoided. Regular observations from the monitoring network will provide timely information to GSA Board so that Management Strategies can be pursued to avoid Undesirable Results. Since submittal of the 2020 GSP, the GSAs have incorporated the KRCD point monitoring program to evaluate subsidence within the Subbasin that could affect critical infrastructures. The GSAs will continue annual monitoring and reporting at these points.

Data Collection - The GSAs have several monitoring wells that have long periods of record, but do not have construction information. It has been suspected for some time that several of these wells are not categorized in the correct aquifer zone but clarifying this has been challenging. Downhole video surveys for construction information in the wells would definitively answer the question of from which zone(s) is each well pumping.

Pressure Levels - The GSAs plans to increase the number of dedicated monitoring wells that provide information from below the Corcoran Clay. The effort would be to expand the understanding of the pressurized head levels (piezometric levels) in the confined aquifer throughout the year and develop an understanding that could better inform modeling efforts in zones where subsidence is occurring.

Identification of Subsiding Zone - The GSAs require additional information on what particular geologic zone is subsiding. The GSAs would like to partner with DWR and the USGS to develop an extensometer in the Subbasin to collect the data needed to better address subsidence triggers. However, currently the development and maintenance costs for such a facility are considered prohibitive without additional funding sources.

Land Use - The GSAs will make recommendations to land use planning agencies in the Subbasin that grade-sensitive linear facilities that traverse areas where the Corcoran Clay is present not be developed/approved due to its geologic properties and potential for subsidence.

Groundwater-Subsidence Modeling - Given the current lack of data to develop a subsidence model, the modeling effort would have to be pursued after more extensive and higher quality data are collected. The GSAs anticipate that with extensometer records and groundwater logger readings from below the Corcoran Clay in several locations, a groundwater-subsidence model for the Subbasin or region could be developed. The GSAs have been working with consultants toward collecting these data.

4 REVISED SMC GROUNDWATER QUALITY

In the incomplete determination letter DWR noted in Deficiency 3 the absence in the 2020 GSP of identified undesirable results and other sustainable management criteria for degraded groundwater quality, as well as shortcomings with the proposed monitoring network. The corrective action stated in the determination letter indicated the GSP must provide a more thorough discussion of how implementation of SGMA can impact the Subbasin's groundwater quality by the following:

> *The reliance on existing regulations and policies to define undesirable results that represent degraded water quality conditions occurring throughout the Subbasin for the purpose of SGMA does not satisfy the requirements of the GSP Regulations.*

More specifically, the corrective actions requested by DWR are addressed:

> *Corrective Action 3*
>
> *a. Characterize historic and current groundwater quality conditions within the principal aquifers including the primary constituents of concern. Describe how the constituents will be monitored and how the baseline concentrations or federal and state standards will be assessed to evaluate potential degradation. Provide details for constituents which are partially or entirely linked to existing programs, the monitoring and management that those programs implement, and how they align with the requirements of a GSA under SGMA. Describe how the GSAs intend to coordinate and work with existing agencies and programs to evaluate and assess how GSP implementation may impact groundwater quality.*
>
> *Define sustainable management criteria based on the GSAs level of understanding of the historic and current groundwater conditions as required by the GSP Regulations. In defining sustainable management criteria, the GSAs should evaluate and utilize components of existing programs, including federal, state, and agricultural water quality standards. Include a discussion of the methodology used to determine which constituents are included in the sustainable management criteria and describe the potential affects the undesirable results and minimum thresholds may have on groundwater supply and beneficial users.*

The following sections present the revised SMC for groundwater quality developed to address the required Corrective Action.

4.1 Potential Effects to Beneficial Uses and Users

Beneficial uses and users of groundwater in the Subbasin generally include domestic, municipal, agricultural, and environmental uses and users. All identified beneficial uses and users of groundwater, and their associated land uses and property interests, were considered in establishing MTs for degraded water quality. A description of how MTs may affect the interests of beneficial uses and users of groundwater or land uses and property interests is contained herein.

- **Domestic**. Minimum thresholds for degraded water quality are designed to protect groundwater quality accessed by domestic well users in some areas of the Subbasin, ensuring that the groundwater quality is maintained such that treatment is not necessary due to impacts from GSA actions to meet drinking water standards. In areas of the Subbasin where ambient water quality is above drinking water standards, MTs are established to be consistent with California's Antidegradation Policy and not result in additional burden of treatment for domestic well users related to GSP activities.

- **Municipal**. Similar to domestic uses and users, MTs established for degraded water quality are designed to preserve groundwater quality accessed by municipal well users in applicable areas of the Subbasin, ensuring that new or additional treatment will not be needed due to impacts from GSA actions to meet drinking water standards and are consistent with California's Antidegradation Policy.
- **Agricultural.** Drinking water standards tend to require higher quality water than for many agricultural uses, which vary by crop type. Growers in the Subbasin have adapted to current groundwater quality by either blending groundwater with surface water to dilute elevated concentrations of constituents of concern, installing wellhead treatment, or changing crop types. Therefore, although some MTs for degraded water quality based on drinking water standards may results in impacts to specific crop types, overall they are not anticipated to significantly negatively impact agricultural uses and users of groundwater and will preserve the quality of groundwater for agricultural use.
- **Environmental**. Similar to domestic uses and users, where present within the Subbasin, environmental users of groundwater typically rely on shallow groundwater where accumulation of salts from applied water, applied fertilizers, or septic systems are most likely to impact these users. These impacts are from non-GSA activities and GSA projects and actions within the Subbasin occur below this zone. As such, impacts to environmental users are not anticipated to occur within the basin due to GSA projects or actions.

4.2 What's Important to Protect

The GSAs recognize that municipal and domestic wells with substantially decreased water quality are an undesirable result that needs to be minimized and avoided. However, agricultural users are the key groundwater extractors across the Subbasin. As discussed in subsequent sections, sources of degraded water quality or both naturally occurring and from anthropogenic sources that are not related to SGMA activities.

4.3 Approach

The SMCs for each constituent of concern (COC) were developed using a pro-active approach using statistical analysis developed as part of the California Code of Regulations (CCR) Title 27 (Title 27) for establishing concentration limits and trend analysis to evaluate COCs annually. The pro-active approach includes actions that will be taken if upward trends are observed prior to reaching undesirable results. The SMCs are also based on federal and state water quality standards for each of the COCs. Details of this approach are provided in the following Sections.

Characterization of historic and current groundwater quality conditions within the Subbasin were discussed within the 2020 GSP, which included discussions of specific constituents as illustrated on Figures 3-30 through 3-33 of the 2020 GSP. These constituents included salinity as total dissolved solids (TDS), arsenic, nitrate, 1,2,3-trichloropropane (TCP), and 1,2-dibromo-3-chloropropane (DBCP). However, these figures did not present these data in relationship to the principal aquifers. Sections 4.1.1 through 4.1.8 provide a discussion for each of these constituents within each of the primary aquifers that are referred to as A-zone, B-zone, and C-zone (see Section 2). Based on further review of the data since the submittal of 2020 GSP, uranium, sulfate, and chloride were added to the constituents for assessment within the Subbasin. SMCs will be developed for the COCs presented in Section 4.1.9.

Data used for the discussion below is from the Groundwater Ambient Monitoring & Assessment Groundwater Information (GAMA) System available from the California State Water Resources Control Board GeoTracker™ system. Data used from GAMA is included in Appendix C. For the discussion, the constituents are compared to state and federal secondary maximum contaminant levels (SMCL; TDS, sulfate, and chloride) and primary maximum contaminant levels (MCL; arsenic, nitrate, uranium, TCP, and DBCP). Title 22 CCR (Title 22) SMCLs are reported as recommended, upper, and short term SMCLs. Constituent concentrations lower than the recommended SMCL (for example, 500 mg/L for TDS) are desirable for a higher degree of consumer acceptance. Constituent concentrations ranging to the Upper SMCL (for example, 1,000 mg/L for TDS) are acceptable if it is neither reasonable nor feasible to provide water with lower concentrations. Constituent concentrations ranging to the short-term SMCL (for example, 1,500 mg/L for TDS) are acceptable only for existing community water systems on a temporary basis pending construction of treatment facilities or development of acceptable new water sources. For the purposes of the discussions provided below, the Upper SMCLs are used.

It is also noted, as shown on Figure 4-1, that for a large portion of the basin the agricultural uses (AGR) and municipal uses (MUN) of groundwater have been de-designated within the Basin Plan (SWRCB R5-2017-0032) due to salinity and currently are not required to be monitored according to the Regional Water Quality Control Board (RWQCB) and the Tulare Lake Basin Plan Amendment unless projects are proposed that would trigger monitoring in this area. As such, at this time, SMCs for these constituents will not be developed for these areas. If in the future this designation is changed, then the development of SMCs will be prepared accordingly for these areas.

4.3.1 TDS

Figure 4-2 presents the historic Subbasin-wide distribution of TDS in groundwater. Figures 4-2 (a), (b), and (c) show this distribution for the A-zone, B-zone, and C-zone primary aquifers, respectively. Figure 4-2(d) shows the distribution for wells where the screen intervals are unknown. As seen on Figure 4-2(d), the screen interval for the majority of wells within the GAMA system are unknown.

Figure 4-2 (a) shows that only one well with reported screen intervals within A-zone had a reported TDS concentration above the Upper SMCL of 1,000 mg/L. Figure 4-2 (d) shows that numerous wells where the screen intervals are not known have reported TDS concentrations above the Upper SMCL. However, the majority of these wells are located within the de-designated portion of the Subbasin.

Sources of TDS, or salinity, include naturally occurring and anthropogenic sources. Naturally occurring sources include brackish and saline marine connate waters that exist within the de-designated area and at depth beneath the useful aquifers throughout most of the Central Valley. A detailed discussion of these sources is provided in Section 3.2.5 of the 2020 GSP.

4.3.2 Nitrate

Figure 4-3 presents the historic Subbasin-wide distribution of nitrate in groundwater reported as nitrate as nitrogen (N). Figures 4-3 (a), (b), and (c) show this distribution for the A-zone, B-zone, and C-zone primary aquifers, respectively. Figure 4-3 (d) shows the distribution for wells where the screen intervals are unknown. As seen on Figure 4-3 (d), the screen interval for the majority of wells within the GAMA system are unknown.

Figure 4-3 (b) shows that only one well with reported screen intervals within the B-zone had a reported nitrate as N concentration above the MCL of 10 mg/L. Figure 4-3 (d) shows that several wells where the screen interval are not known have reported Nitrate as N concentrations above the MCL. Most of these wells are located outside of the de-designated portion of the Subbasin.

Sources of nitrate are anthropogenic, mostly related to agricultural practices. A discussion of these sources is provided in Section 3.2.5 of the 2020 GSP.

4.3.3 Arsenic

Figure 4-4 presents the historic Subbasin-wide distribution of arsenic in groundwater. Figures 4-4 (a), (b), and (c) show this distribution for the A-zone, B-zone, and C-zone primary aquifers, respectively. Figure 4-4 (d) shows the distribution for wells where the screen intervals are unknown. As seen on Figure 4-4 (d), the screen interval for the majority of wells within the GAMA system is unknown.

Figures 4-4 (a) through (d) show that arsenic has been reported above the MCL of 0.0010 mg/L within the three primary aquifer zones. Figure 4-4 (d) shows that several wells where the screen interval are not known across the Subbasin including the de-designated portion have reported arsenic concentrations above the MCL.

Sources of arsenic are naturally occurring. A discussion of these sources is provided in Section 3.2.5 of the 2020 GSP.

4.3.4 Uranium

Figure 4-5 presents the historic Subbasin-wide distribution of uranium in groundwater. Figures 4.5 (a), (b), and (c) show this distribution for the A-zone, B-zone, and C-zone primary aquifers, respectively. Figure 4-5 (d) shows the distribution for wells where the screen intervals are unknown.

Uranium above the MCL of 20 pCi/L (30 ug/L) was reported in 4 wells completed in northwest portion of the Subbasin for B-zone (Figure 4-5 [b]) and one well in this same area for wells where the screen interval is not known (Figure 4-5 [d]). Sources of uranium are naturally occurring in sediments sourced from the Sierra Nevada.

4.3.5 1,2,3-TCP

Figure 4-6 presents the historic Subbasin-wide distribution of 1,2,3-TCP in groundwater. Figures 4.6 (a), (b), and (c) show this distribution for the A-zone, B-zone, and C-zone primary aquifers, respectively. Figure 4-6 (d) shows the distribution for wells where the screen intervals are unknown. As seen on these figures, 1,2,3-TCP is reported above the MCL of 0.005 µg/L in the three primary aquifer zones. All of the wells listed for B-zone and C-zone had reported concentrations of 1,2,3-TCP above non-detect levels within the Subbasin.

Sources of 1,2,3-TCP are anthropogenic. A discussion of these sources is provided in Section 3.2.5 of the GSP.

4.3.6 DBCP

Figure 4-7 presents the historic Subbasin-wide distribution of DBCP in groundwater. Figures 4.7 (a), (b), and (c) show this distribution for the A-zone, B-zone, and C-zone primary aquifers, respectively. Figure 4-7 (d) shows the distribution for wells where the screen intervals are unknown. As seen on these figures, DBCP has not been reported above the MCL of 0.2 µg/L in any well monitored within the Subbasin.

4.3.7 Sulfate

Figure 4-8 presents the historic Subbasin-wide distribution of sulfate in groundwater. Figures 4.8 (a), (b), and (c) show this distribution for the A-zone, B-zone, and C-zone primary aquifers, respectively. Figure 4-8 (d) shows the distribution for wells where the screen intervals are unknown. As seen on Figure 4-8 (d), the screen interval for the majority of wells within the GAMA system is unknown.

No well with known screen interval information in the Subbasin had reported sulfate concentrations above the Upper SMCL of 500 mg/L (Figure 4-8 (a) through (c)). Figure 4-8 (d) shows that numerous wells where the screen interval are not known have reported sulfate concentrations above the Upper SMCL across the Subbasin including in the de-designated portion.

Sources of sulfate are both naturally occurring and anthropogenic. Naturally occurring sources are related to sulfate rich minerals that occur within the sediments. Anthropogenic sources are mostly related to agricultural practices. A discussion of these sources is provided in Section 3.2.5 of the GSP.

4.3.8 Chloride

Figure 4-9 presents the historic Subbasin-wide distribution of chloride in groundwater. Figures 4.9 (a), (b), and (c) show this distribution for the A-zone, B-zone, and C-zone primary aquifers, respectively. Figure 4-9 (d) shows the distribution for wells where the screen intervals are unknown. As seen on Figure 4-9 (d), the screen interval for the majority of wells within the GAMA system are unknown.

No well with known screen interval information in the Subbasin had reported chloride concentrations above the Upper SMCL of 500 mg/L (Figures 4-8 (a) through (c)). Figure 4-8 (d) shows that numerous wells where the screen interval are not known have reported sulfate concentrations above the Upper SMCL across the Subbasin with the majority of these wells being in the de-designated portion.

Sources of chloride are both naturally occurring similar to those discussed for TDS in Section 4.2.1. A discussion of these sources is provided in Section 3.2.5 of the GSP.

4.3.9 Constituents of Concern

Based on the information presented in Section 4.3.1 through 4.3.8, SMCs are developed for the COCs TDS, nitrate, arsenic, uranium, sulfate, chloride, and 1,2,3-TCP. DBCP is not considered a COC because no concentrations above the MCL have been reported in the Subbasin as discussed in Section 4.3.6. If future data for this constituent or other constituents becomes available that indicate a concern for the GSAs, then SMCs following the approach presented below will be developed.

4.4 Undesirable Results for Degraded Groundwater Quality

23 CCR §354.26(a) *Each Agency shall describe in its Plan the processes and criteria relied upon to define undesirable results applicable to the basin. Undesirable results occur when significant and unreasonable effects for any of the sustainability indicators are caused by groundwater conditions occurring throughout the basin.*

An undesirable result for degraded water quality in the Subbasin would be the result stemming from a causal nexus between groundwater-related GSP activities, such as groundwater extraction or recharge, and a degradation in groundwater quality that causes a significant and unreasonable reduction in long-term viability of domestic, agricultural, municipal, or environmental uses over the planning and implementation horizon of this GSP (see Section 4.5 for potential water quality effects to beneficial uses). The causal nexus reflects that the undesirable results are water quality issues associated with groundwater pumping and other GSP-related activities rather than water quality issues resulting from land use practices, naturally occurring water quality issues, or other issues not associated with groundwater pumping and other groundwater-related activities.

Within applicable areas of the Subbasin, the causal nexus would be related to increases of the following constituents resulting from GSP-related activities:

- Salinity (measured as total dissolved solids [TDS])
- Nitrate (measured as nitrate as N)
- Arsenic
- Uranium
- 1.2.3-TCP
- Sulfate
- Chloride

It should be noted that water quality issues outside of the causal nexus are generally covered by other regulatory frameworks. Impacted sites are regulated by the RWQCB, California Department of Toxic Substances Control, and the U.S. Environmental Protection Agency (EPA). Drinking water quality is regulated by the State Water Resources Control Board, Division of Drinking Water (SWRCB-DDW). Potential impacts by agricultural practices are regulated through Central Valley Salinity Alternatives for Long-term Sustainability (CV-SALTS), Irrigated Lands Regulatory Program (ILRP), and California Department of Pesticide Regulation (DPR).

The GSAs do not have control over the presence of naturally occurring constituents in aquifer materials. Known anthropogenic constituents in groundwater include salinity, nitrate, sulfate, and 1,2,3-TCP. Salinity and sulfate also have naturally occurring sources as discussed in Section 4.2.7. In the event that there is a causal nexus determined between elevated concentrations of constituents of concern and GSP-related activities, the GSAs will consider establishing SMCs for such COCs. Management actions and studies were presented in Chapter 6 of the 2020 GSP with additions presented in Section 5 of this Addendum. Implementation of these projects, management actions, and studies will be implemented pending the availability of grant or other funding, as appropriate research partners are identified and partnerships formed, or as needed for Subbasin management with the goal of further evaluating the fate and transport of COCs.

4.4.1 Identification of Undesirable Results

As discussed above and in Chapter 3 of the 2020 GSP, degraded water quality in the Subbasin occurs from both anthropogenic and natural sources and increases in these constituents not related to GSP-related activities are not considered undesirable results as part of this GSP. However, the GSAs are taking a pro-active approach by developing an "early warning" system to assess groundwater quality trends within the Subbasin. Water quality data will be assessed on an annual basis by aquifer zones. In each annual report, at each representative monitoring well, a trend analysis will be conducted using a statistical method such as the Mann Kendall trend test, for each of the COCs. Trend analysis will not be conducted until at least six samples have been collected for each analyte at each individual RMS well. If the statistical assessment indicates an upward trend as defined by the Mann Kendall test, then an assessment will be conducted to evaluate if there is a relationship between this trend and changing water levels and if these changing water levels are a result of GSP-related activities.

Using the pro-active approach, an undesirable result for degraded water quality is triggered or considered "significant and unreasonable" as follows:

- A representative monitoring well within an individual aquifer zone exceeds the MT for two consecutive measurements when exceedances can be tied to a causal nexus between GSP-related activities and water quality and the individual well has been exhibiting an upward trend.
- When MTs are exceeded with no observable upward trend, when 25% of representative monitoring wells within an individual aquifer zone exceeds the MT for two consecutive measurements at each location where these MT exceedances can be tied to a causal nexus between GSP-related activities and water quality. Twenty-five percent of the representative monitoring wells were selected because no observable upward trend would indicate a non-GSP-related activity at an individual well. Although exceedances of MTs at 25% of the representative monitoring wells with no observable upward trend still indicate non-GSP-related activity, assessing the causal nexus with water quality at this value will provide a factor of safety.

Protective efforts that will be implanted by the GSAs if the statistical assessment conducted each year indicates an upward trend for one or more COCs that can be tied to a causal nexus of GSP-related activities are discussed in Section 4.7.

4.4.2 Potential Causes of Undesirable Results

Water quality degradation has been linked to some anthropogenic activities (see Chapter 3 of the 2020 GSP) and can result from pumping activities. Groundwater pumping may result in water quality degradation due to the migration of contaminant plumes. Additionally, in some areas pumping from deep wells has caused naturally occurring soil contaminants (arsenic, uranium) to leach out and dissolve into groundwater, which may cause undesirable results.

There are no known anthropogenic contaminant plumes within the Subbasin; however, elevated concentrations of salinity in groundwater have been known to exist in some areas of the western Subbasin since the early 1900s. Salinity is considered to have increased over the past 100 years. Additionally, groundwater quality typically varies with depth above and below the Corcoran Clay. In many portions of the Subbasin, salinity is lower beneath the Corcoran Clay. In portions of the Subbasin (Figure 4-1), the agricultural uses (AGR) and municipal uses (MUN) of groundwater have been de-designated within the Basin Plan (SWRCB R5-2017-0032) due to salinity and currently are not required to be monitored according to the RWQCB and the Tulare Lake Basin Plan Amendment unless projects are proposed that would trigger monitoring in this area.

Groundwater quality is currently comprehensively monitored in the Subbasin by regulatory agencies. These agencies rely on existing regulations and policies to define undesirable results related to the deterioration of groundwater quality. The agencies and coalitions include the ILRP, GAMA, RWQCB, CV-SALTS, and cities and communities within the Subbasin.

Conditions that may cause an undesirable result for degraded water quality include changes in the location (both vertically and horizontally) and volume of groundwater pumping or managed groundwater recharge, both resulting in the contribution to and/or potential mobilization of COCs as a result of these activities.

4.4.3 Potential Effects of Undesirable Results

Should undesirable results occur with respect to groundwater quality, the amount of usable groundwater in the Subbasin could be reduced. If treatment is not feasible, this degradation could affect the groundwater supplies for agricultural, municipal, industrial, and domestic needs. Additional costs would be incurred as some treatment could be needed, some supply wells may have to be deepened or their pumps lowered, new wells may have to be drilled, and yields may be reduced. Also, should undesirable results occur with respect to groundwater quality, the amount of usable groundwater in storage may be reduced. A more detailed discussion of potential water quality effects to beneficial uses is presented in Section 4.1.

4.5 Minimum Thresholds for Degraded Groundwater Quality

> **23 CCR §354.28** (a) *Each Agency in its Plan shall establish minimum thresholds that quantify groundwater conditions for each applicable sustainability indicator at each monitoring site or representative monitoring site established pursuant to Section 354.36. The numeric value used to define minimum thresholds shall represent a point in the basin that, if exceeded, may cause undesirable results as described in Section 354.26.*

As discussed in Section 4.3, three of the COCs, TDS, chloride, and sulfate have Title 22 SMCLs reported as recommended, upper, and short term SMCLs. For SMCs only the Recommended SMCL and Upper SMCL are used as discussed in this section and following sections. The other four constituents, nitrate, arsenic, uranium and 1,2,3-TCP have Primary MCLs.

For the Subbasin, the MTs for degraded water quality is established as the higher of: (1) the Upper SMCL for TDS (1,000 mg/L), chloride (500 mg/L) and sulfate (500 mg/L) and Primary MCL for nitrate as N (10 mg/L), arsenic (0.010 mg/L), uranium (20 pCi/L), and 1,2,3-TCP (0.005 µg/L) or (2) current water quality conditions for all constituents defined as data available from 2000 to January 2020 at the representative monitoring well or nearby well within the same aquifer zones described in Section 3.1.8 of the Basin Setting chapter of the 2020 GSP, using the maximum concentration detected for each constituent. For 1,2,3-TCP, limited data has been collected and analytical methods and detection limits have changed. As such MTs have been set at the MCL regardless of past concentrations. Further assessment of the MT for 1,2,3-TCP will be conducted as additional data are collected. Table 4-1 reflects the MTs for degraded water quality at each representative monitoring site. Minimum thresholds for degraded water quality are established consistent with California drinking water standards and California's Antidegradation Policy (State Board Resolution 68-16). The selected MTs for degraded water quality reflect input to the GSAs who conduct regular public meetings and received feedback from local landowners and other stakeholders and are expected to avoid undesirable results in the Subbasin. It should be noted that the concentrations presented for MTs in some cases reflect ambient groundwater quality, where additional treatment may be necessary to meet state and federal MCLs for drinking water.

As discussed above for portions of the Subbasin, the agricultural uses (AGR) and municipal uses (MUN) of groundwater have been de-designated within the Basin Plan due to salinity and currently are not required to be monitored according to the RWQCB and the Tulare Lake Basin Plan Amendment unless projects are proposed that would trigger monitoring in this area. As such, no MTs are set for these areas. If projects are proposed that would trigger monitoring in these areas, then the development of groundwater quality SMCs will be considered.

4.5.1 Relationship to Other Sustainability Indicators

Described below are the relationship between MTs for each sustainability indicator, including an explanation of how it was determined that basin conditions at the MTs for degraded water quality will avoid undesirable results for each of the other applicable sustainability indicators to the Subbasin. Minimum thresholds for degraded water quality are selected to avoid undesirable results for the other applicable sustainability indicators in the Subbasin.

- **Chronic Lowering of Groundwater Levels and Reduction of Groundwater Storage**. There are limited groundwater quality data available in the Subbasin to support a connection between groundwater levels or storage changes and elevated concentrations of COCs. However, the MTs established for degraded water quality could impact direct use of supplemental water supplies for groundwater recharge projects, where ambient water quality may constrain supplies available for recharge or require additional treatment prior to land application or injection, and could thus limit the ability to maintain the measurable objectives established for the chronic lowering of groundwater levels or reduction of groundwater storage sustainability indicator if such projects were to be identified for implementation.

- **Seawater Intrusion**. This sustainability indicator is not applicable to the Subbasin.
- **Land Subsidence**. Based on local knowledge and the best available science, degraded water quality and land subsidence MTs are not related. Therefore, MTs for degraded water quality are not anticipated to cause undesirable results for land subsidence.
- **Depletion of Interconnected Surface Water**. For areas within the Subbasin where interconnected surface water may exist, MTs for degraded water quality are established to be protective of drinking water standards or current water quality (based on available data from 2000 to 2020) where current conditions exceed drinking water standards (the highest beneficial use of water in California), consistent with California's Antidegradation Policy. Additionally, the volume of surface water in the interconnected surface water courses in the Subbasin is much larger than the volume of water that the aquifer is contributing to those streams. As such, while surface water quality is not within the purview of SGMA, the MTs for degraded water quality are not anticipated to degrade the quality of interconnected surface water.

4.6 Representative Monitoring Sites for Degraded Groundwater Quality

Groundwater quality is monitored in the Subbasin by regulatory agencies using existing regulations and policies. Constituents and sample frequencies are determined by existing programs set to drinking water standards and listed with the applicable monitoring agency in Table 4-2. The Subbasin will continue monitoring groundwater quality using the existing monitoring program standards as determined by the SWRCB-DDW. Within the Tulare Lake Subbasin Groundwater Quality Monitoring Network, there are instances where a COC is not monitored at a well location as the constituent is not considered a concern to drinking water and therefore not included in an existing monitoring program. Uranium is the least monitored COC within the GSA's network but is listed as a COC due to higher concentrations found along the northwest portion of the Subbasin where it is monitored.

At this time, the GSAs only monitor the B-zone and C-zone. Water quality monitoring within the A zone is considered a data gap as regulatory programs that observe the perched aquifer do not sample for the constituents discussed in Section 4.1. The GSAs will continue to look for additional monitoring locations for all three aquifers within areas for domestic and environmental uses as well as outside of de-designated areas. Monitoring wells installed by a GSAs to resolve data gaps will be added to the groundwater quality network, such as South Fork Kings GSA's recently installed well "SL-1". These wells will be sampled for COCs annually. The GSAs will search for wells within domestic areas that are screened in the B zone and will commit to sampling these wells on an annual basis. Groundwater quality monitoring locations are shown on Figure 4-10 with well construction included in Table 4-1.

Water quality results will continue to be reported as part of the GSA's Annual Report which is submitted to DWR every year by April 1st. The GSAs will observe statistical analytical trends annually and coordinate with the existing monitoring program managers to receive data prior to public publication and evaluate whether the results are indicative of GSP-related activities and need further assessment. If further assessment is needed, the GSAs will coordinate with the existing monitoring program managers to collect confirmation samples and collectively investigate the cause of groundwater quality issues.

4.7 Measurable Objectives for Water Quality

23 CCR §354.30 *(a) Each Agency shall establish measurable objectives, including interim milestones in increments of five years, to achieve the sustainability goal for the basin with 20 years of Plan implementation and to continue to sustainably manage the groundwater basin over the planning and implementation horizon.*

The measurable objective for degraded water quality for TDS, sulfate, and chloride are as follows:

- Where current conditions are below the recommended SMCL, the measurable objective is the recommended SMCL.
- Where current conditions are above the recommended SMCL, the measurable objective is set as the current water quality conditions based on data available from 2000 to January 2020 at the representative monitoring well or nearby well within the same aquifer zone using the tolerance interval approach. The tolerance interval is one of the approved statistical methods described in Title 27, Division 2, Subdivision 1, Chapter 3, Subchapter 3, Article 1, Section 20415(e)(8)(C) for establishment of concentration limits.
- The purpose of a tolerance interval approach is to define a concentration range, or tolerance interval, from well data within which a large proportion of the monitoring observations should fall with a high probability. The proportion of the population included in the tolerance interval is referred to as the coverage. The probability with which the tolerance interval includes the proportion of the population is referred to as the tolerance coefficient. The upper and lower bounds of the tolerance interval are referred to as the tolerance limits. The upper tolerance limit (UTL) will be used to calculate the MOs for the Subbasin.
- Consistent with USEPA and state recommendations, a 95 percent coverage and 95 percent tolerance coefficient will be used. The upper 95 percent tolerance limit will contain at least 95 percent of the distribution of observations from well data.
- In the event that well-specific data or nearby well data in the same aquifer zone are not present, the measurable objective has been set at the recommended SMCL. As data are collected from these wells, the MO will be reevaluated and if data is over the SMCL the MO will be established as the UTL. A minimum of six samples will be collected prior to calculating the MO using the tolerance interval approach. Prior to collection of six samples, the MO will be the average value of sample collected.

The measurable objective for degraded water quality for nitrate (as N), arsenic, uranium, and 1,2,3-TCP are as follows:

- The current water quality conditions on data available from 2000 to January 2020 at the representative monitoring well or nearby well within the same aquifer zone using the ULT of each constituent.
- In the event that well-specific data or nearby well data in the same aquifer zone are not present, the measurable objective has been set at 70 percent of the MCL per the adaptive management trigger system described in the *Framework for a Drinking Water Well Impact Mitigation Program*

(Self-Help Enterprises et al., n.d.)]. As described above, as data are collected from these wells, the MO will be re-established using the tolerance interval approach.

As discussed in Section 4.3 for MTs, past data for 1,2,3-TCP is questionable due to changes in analytical methods and detection methods. As such, for the COC the MO has been set at 70 percent of the MCL for all RMS wells. As additional data are collected for this COC, additional analysis will be conducted, and the MO modified as appropriate following the approach described in this Section.

4.8 Data Gaps

Data gaps for the degraded groundwater quality include the following:

- Currently, regulatory programs do not sample domestic wells for the COCs within the A-zone.
- B-zone RMS wells do not include domestic wells.

To fill these data gaps, the GSAs will coordinate with other agencies such as the RWQCB and SWRCB-DDW to identify wells that are already monitored within the areas identified as data gaps. For identified wells that are sampled but not for the COCs, the GSAs will request the COCs be added to the sampling list. If wells cannot be identified through these programs, the GSAs will identify existing domestic wells that can be sampled and sample them on an annual basis for the COCs.

4.9 Protective Efforts

Protective efforts that will be employed by the GSAs for degraded groundwater quality if the statistical assessment conducted each year as described in Section 4.3 indicates an increasing concentration trend for one or more COCs that can be tied to a causal nexus of GSP-related activities. These protective efforts will include one or more of the following actions so that the observed increasing trend does not produce an undesirable result:

- Coordinate with agencies and coalitions responsible for groundwater quality concerns by requesting data prior to public publication and notifying agencies of increasing trends.
- Additional geochemical testing to assess potential water/sediment interactions that could result in increases of the COC, specifically for the naturally occurring constituents.
- Aquifer testing to assess transport mechanisms for increases in concentrations.
- Zonal testing of wells to assess if there are specific areas of the aquifer zone where the increases are occurring.
- Restrictions in pumping both laterally and vertically to assess if these changes will reduce or eliminate the increasing trend.

5 PROJECTS AND MANAGEMENT ACTIONS TO ADDRESS POTENTIAL IMPACTS

The GSP identifies five classes of projects that would be implemented to address potential impacts to beneficial uses, including:

- Construction of new and modification of existing conveyance facilities;
- Above-ground surface water storage projects;
- Recharge basins and/or water banking in or out of the Subbasin;
- On-farm flooding; and
- Aquifer Storage and Recovery (ASR).

No substantive changes to these potential project actions are anticipated based on the revisions to the SMC for groundwater level, subsidence, and water quality.

The GSP also identifies a variety of management actions that each GSA would consider for implementation. The management actions listed below are from the GSP submitted in 2020. Additional management action details based on the revised SMC have been added. These additional details are highlighted in ***bold italics***.

Project Policies as needed for Project Implementation

- Construction of new and modification of existing conveyance facilities;
- Above-ground surface water storage projects;
- Recharge basins and/or water banking in or out of the Subbasin;
- On-farm flooding; and
- Aquifer Storage and Recovery (ASR).

Outreach activities

- Education on groundwater use
- ***Education on water budgets***
- ***Education on subsidence***
- ***Education on water quality***
- ***Web-based tools for landowner input and confirmation of well completion details***

Groundwater Allocation

- Development of GSA level groundwater allocation

- Development of landowner groundwater allocation
- Groundwater marketing and trade

Fee Assessments

- Pumping fees for groundwater extractions
- Pumping fees for groundwater allocation exceedances
- Fees for operation and management of groundwater extractions
- ***Voluntary Cost-Share Programs for Well Owners***
- Well efficiency program to improve pumping efficiency in non-de-minimus wells
- Metering program to install meters in non-de-minimus wells
- Water quality monitoring program for domestic well owners

Coordination and Co-management of Kings County Groundwater Regulations

- Annual monitoring and reporting requirements for non-de-minimus wells
- Require new developments (non-de minimis extractors) to prove sustainable water supplies if land use conversion is not a conservation measure
- ***Develop a well registration program for all parcels in Kings County***
- ***Develop overlay maps for a well permit program that can also be used for land use planning***
- ***Fees and/or well construction and monitoring requirements for land development proposals/permits requiring groundwater supply***
- ***Fees and/or siting and monitoring requirements for land development proposals/permits involving critical infrastructure that would be vulnerable to subsidence.***

Mitigation Plan Framework

- See Appendix D for more details

6 REFERENCES

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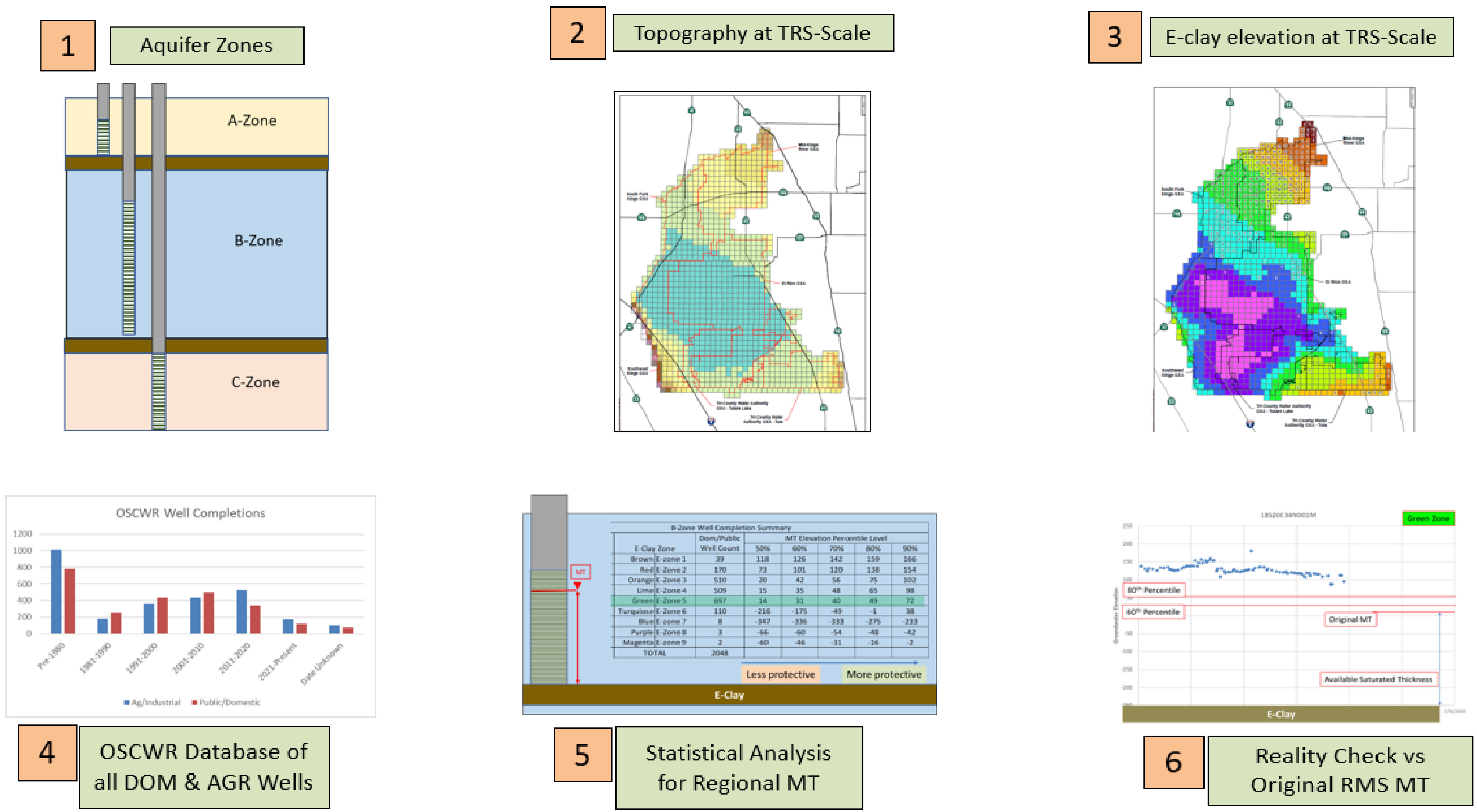
FIGURES



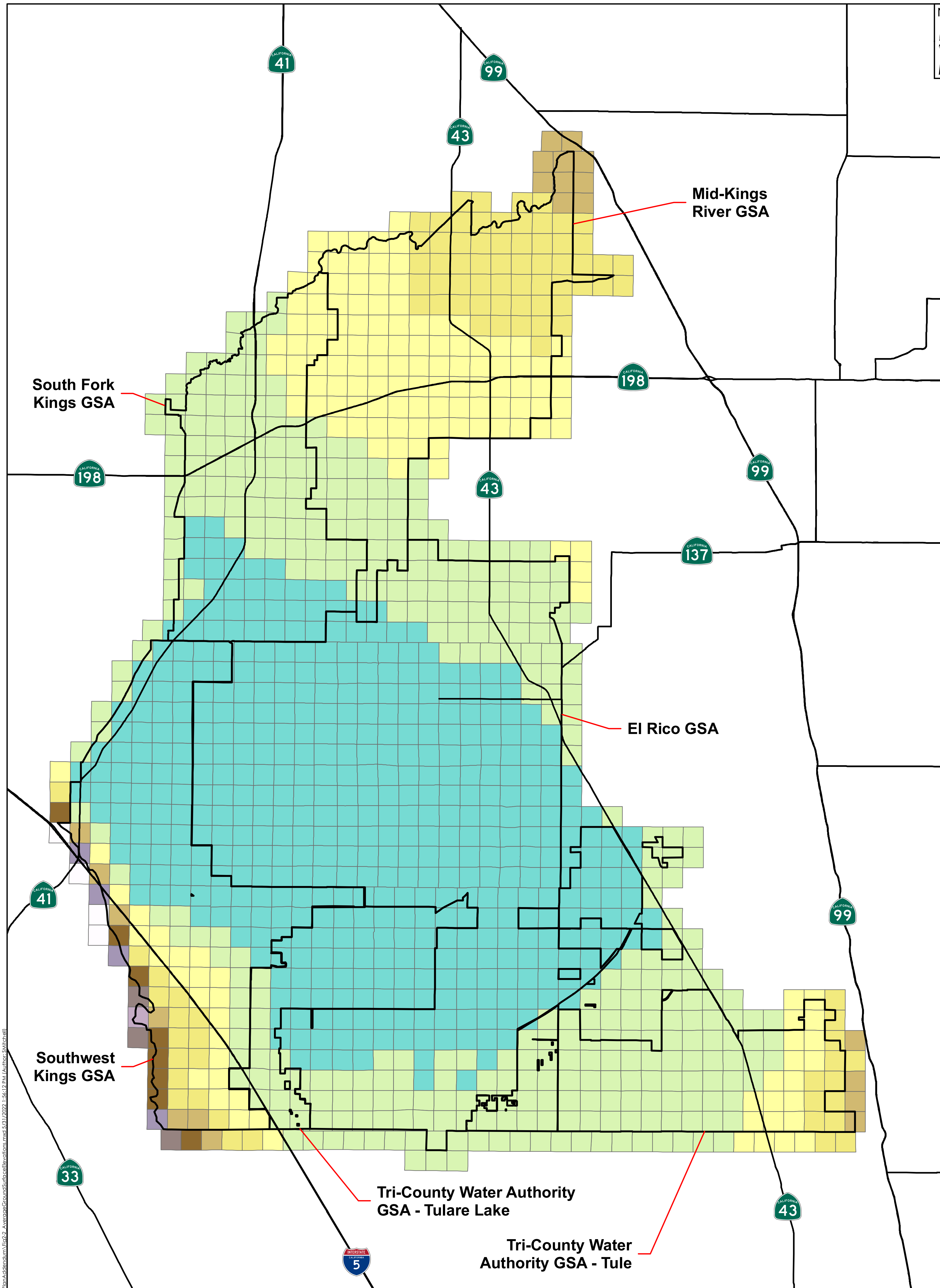
Notes:
AGR = Agricultural
DOM = Domestic
E-Clay = Corcoran Clay
OSCWR = Online System of Well Completion Reports
MT = Minimum Threshold
RMS = Representative Monitoring Site
SMC = Sustainable Management Criteria
TRS = Township, Range, Section

Overview Schematic of Process for Developing SMC for Groundwater Level
Groundwater Sustainability Plan Addendum
Tulare Lake Subbasin, Kings County

Geosyntec consultants

Project No.: SFO138 | June 2022

Figure 2-1



Legend

Mean ground surface elevation (feet msl) [1,2]

181.6 - 206.9	308.1 - 333.2
207.0 - 232.2	333.3 - 358.5
232.3 - 257.4	358.6 - 383.8
257.5 - 282.7	383.9 - 409.0
282.8 - 308.0	409.1 - 434.3

Groundwater Sustainability Agency (GSA) boundary

Note:
1) U.S. Geological Survey (USGS), National Elevation Dataset (NED), 1/3 arc-second Digital Elevation Model (DEM). Accessed 3 March 2022.
2) Mean ground surface elevation per section was calculated using the Zonal Statistics tool in ESRI Spatial Analyst.

5 2½ 0 5 Miles

Map of Average Ground Surface Elevation by Township/Range/Section (TRS)

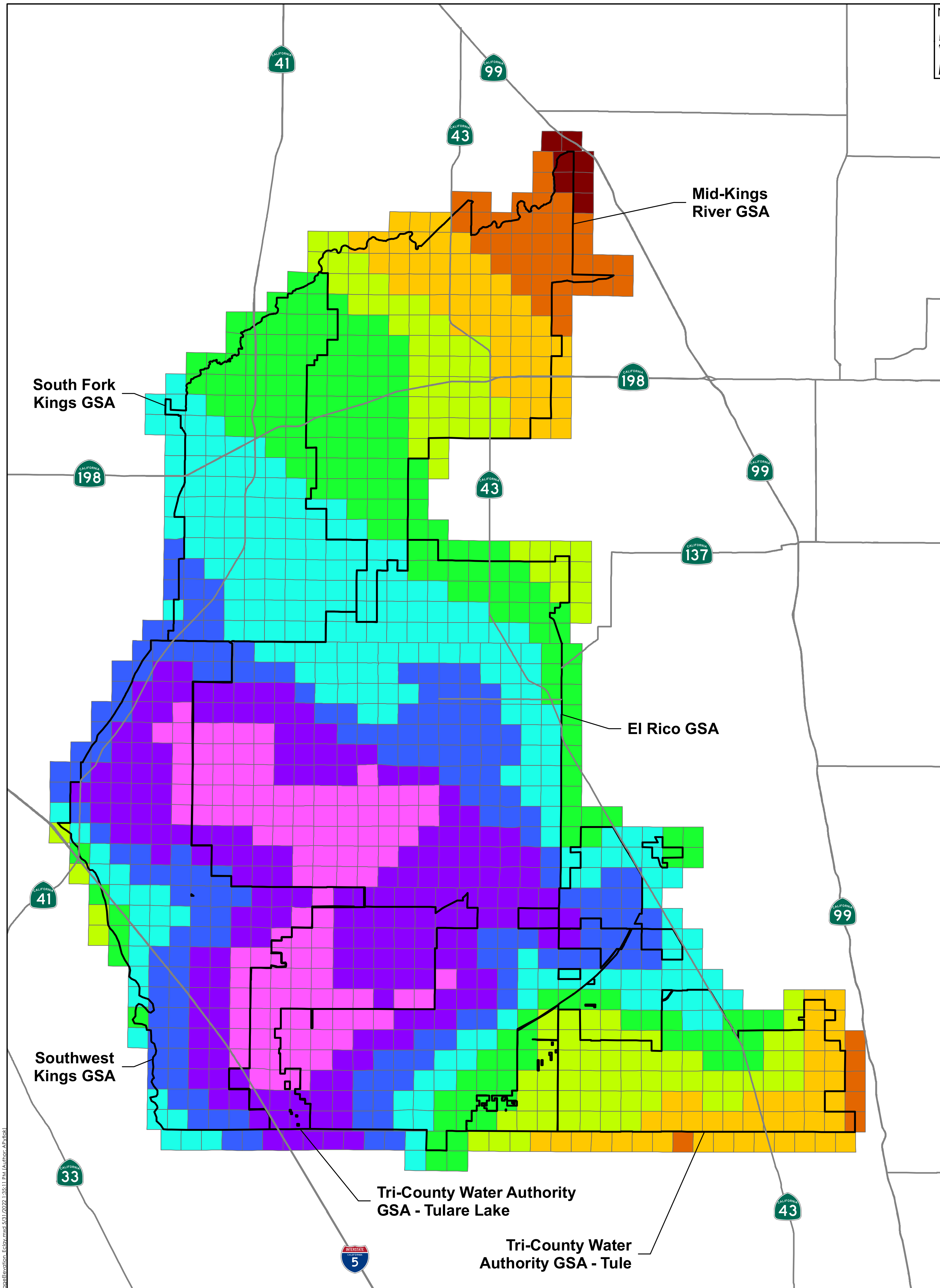
Groundwater Sustainability Plan Addendum
Tulare Lake Subbasin, Kings County

Geosyntec consultants

Figure 2-2

Project No.: SFO138

May 2022



Legend
Average elevation of top of E-clay per section (feet msl)

- < -600
- -599 - -500
- -499 - -400
- -399 - -300
- -299 - -200
- -199 - -100
- -99 - 0
- 1 - 100
- > 100
- Groundwater Sustainability Agency (GSA) boundary

Notes:

Depth to the top of Corcoran Clay (E-clay) was determined using USGS Progessional Paper 1766's Corcoran Clay dataset. The same dataset was used to create Figure 3-19a of the Tulare Lake Subbasin GSP. An elevation raster was created then compared against a ground elevation raster to find the elevation to the top of the E-clay. Mean ground surface elevation per section was calculated using the Zonal Statistics tool in ESRI Spatial Analyst

5 2½ 0 5 Miles

Map of Average Elevation by Township/Range/Section (TRS)

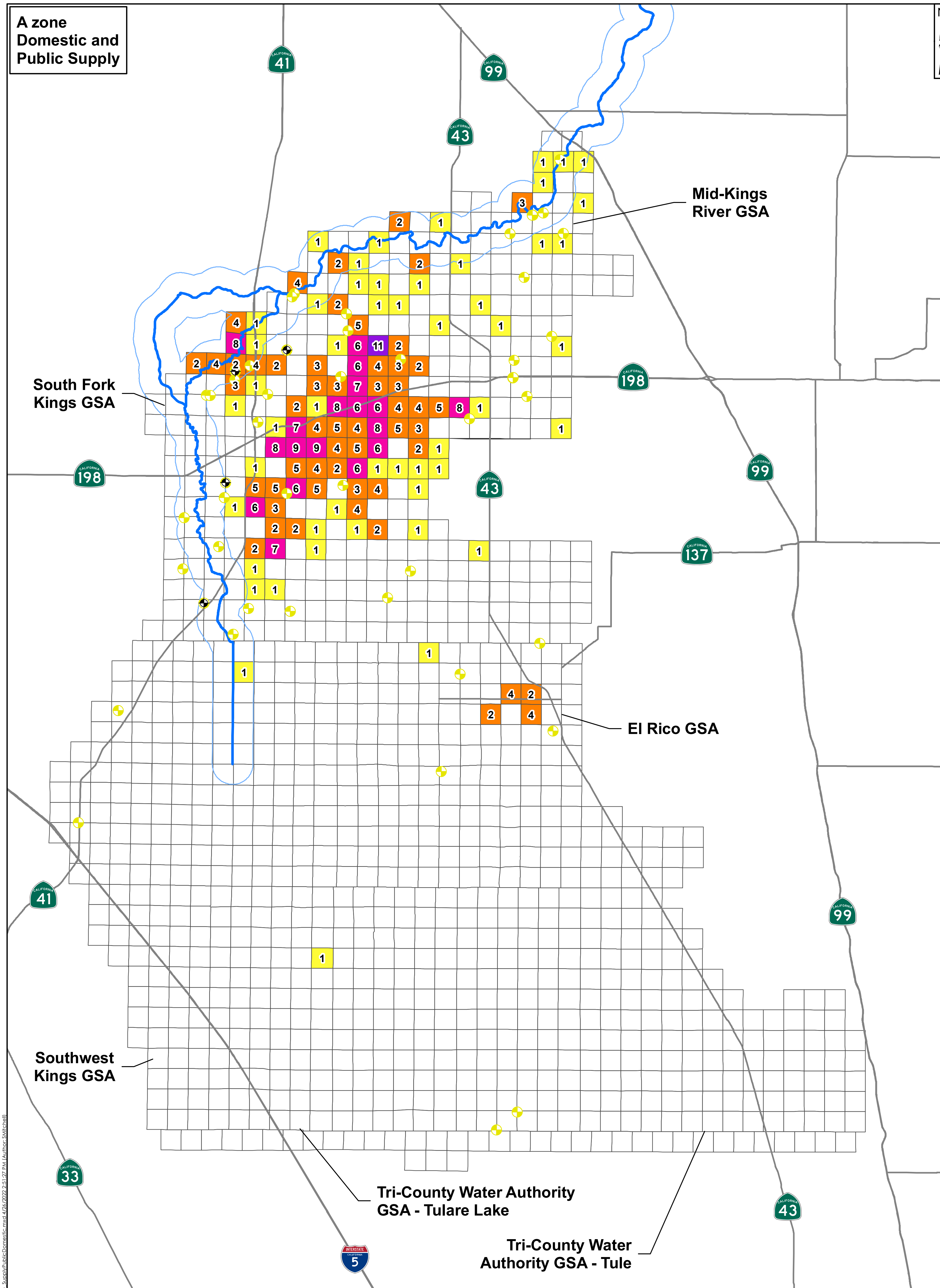
Groundwater Sustainability Plan Agenda
Tulare Lake Subbasin, Kings County

Geosyntec consultants

Figure 2-3

Project No.: SFO138

May 2022



Legend

- RMS Wells
- Groundwater Sustainability Agency (GSA) boundary
- Kings River
- River Zone

Wells per Section

- 0
- 1
- 2 - 5
- 6 - 10
- 11 - 15

5 2½ 0 5 Miles

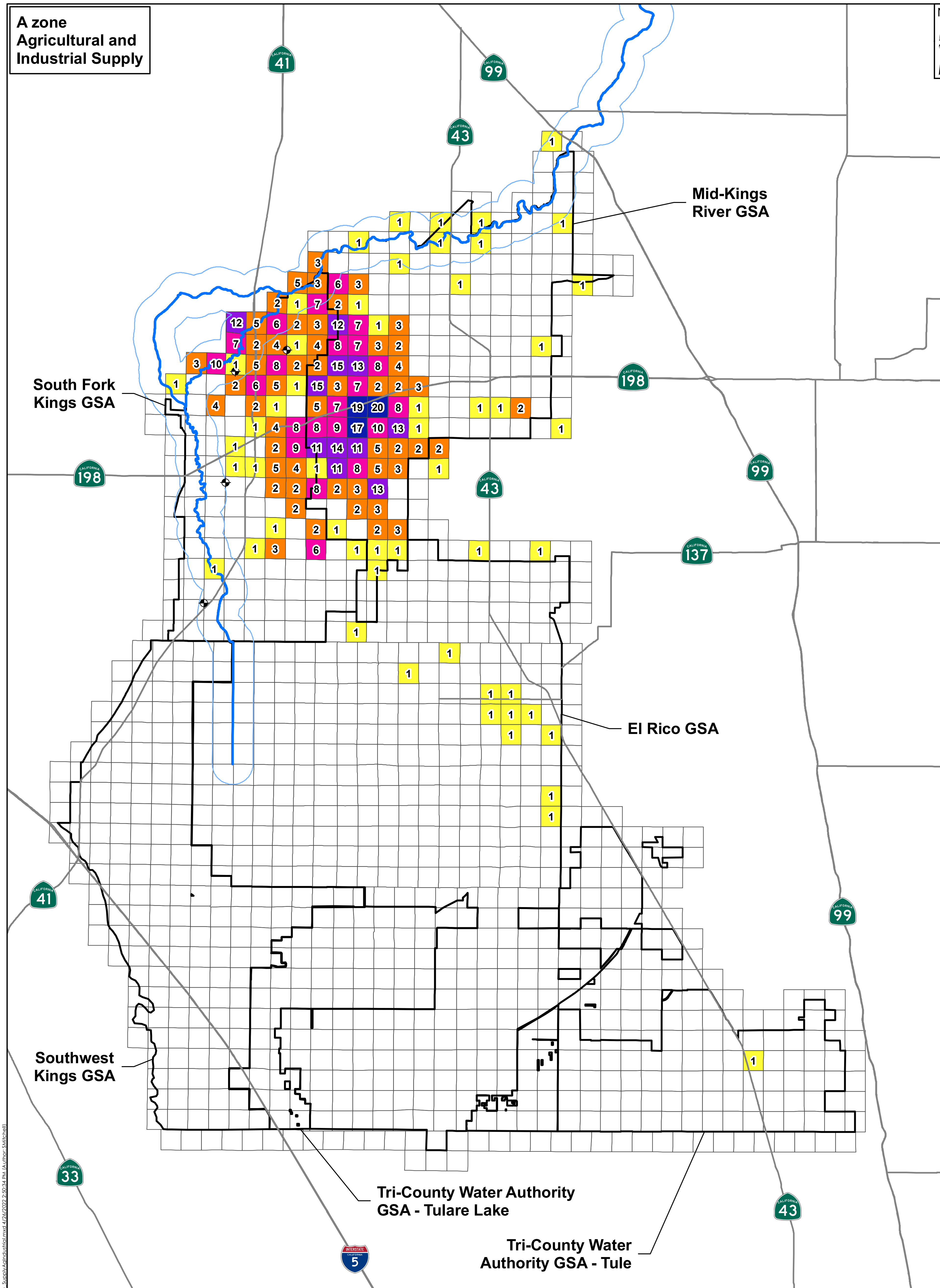
Map of Wells Completed in A-zone for Public/Domestic Purpose of Use

Groundwater Sustainability Plan Addendum
Tulare Lake Subbasin, Kings County

Geosyntec consultants

Figure **2-4a**

Project No.: SFO128 | April 2022



Legend

- RMS Wells
- Groundwater Sustainability Agency (GSA) boundary
- Kings River
- River Zone

Wells per Section

- 0
- 1
- 2 - 5
- 6 - 10
- 11 - 15
- 16 - 20

5 2½ 0 5 Miles

Map of Wells Completed in A-zone for Agricultural/Industrial Purpose of Use

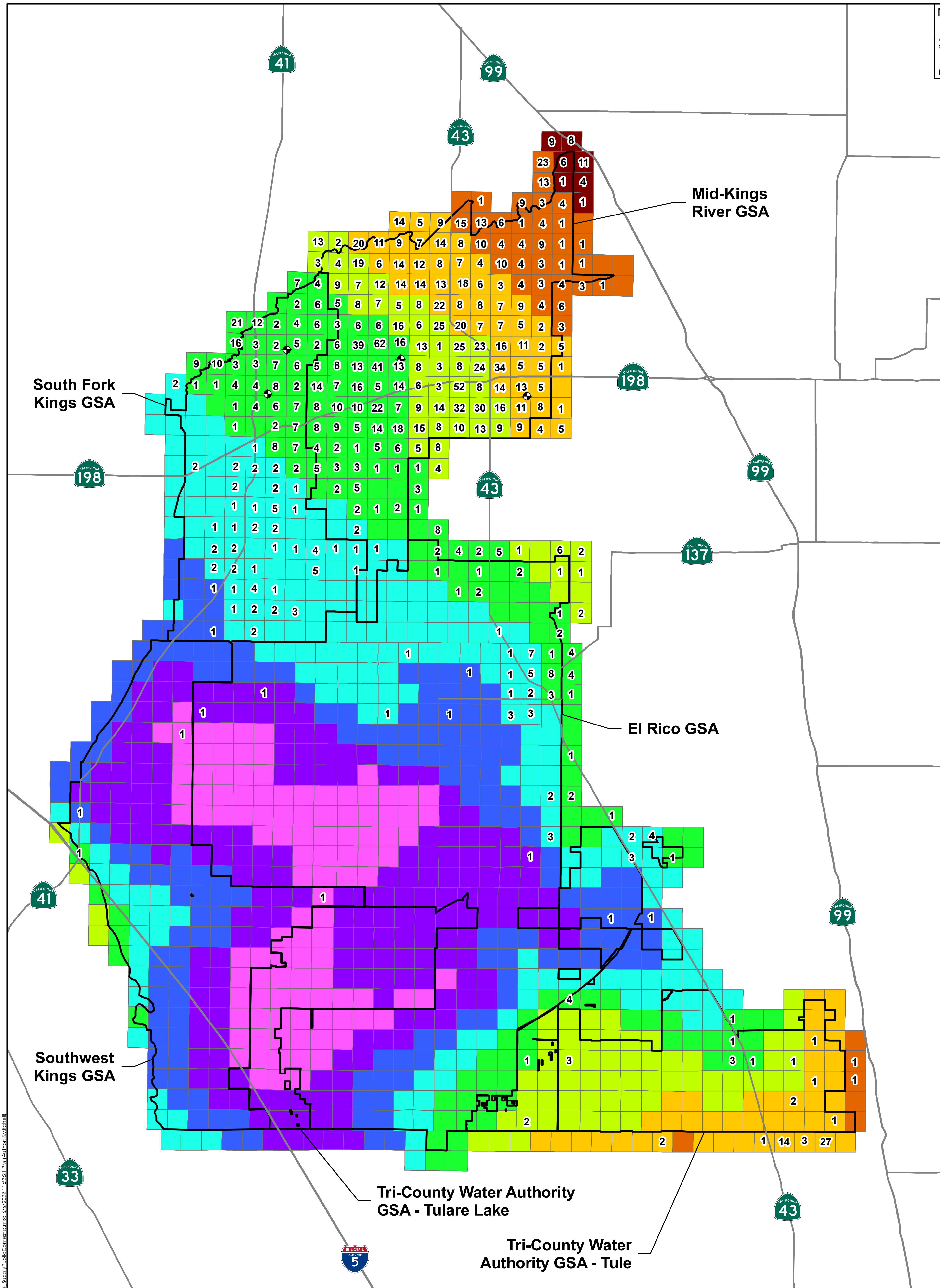
Groundwater Sustainability Plan Addendum
Tulare Lake Subbasin, Kings County

Geosyntec consultants

Project No.: SFO128

April 2022

Figure **2-4b**



Legend

Average elevation of top of E-clay per section (feet msl)

- < -600
- -599 - -500
- -499 - -400
- -399 - -300
- -299 - -200
- -199 - -100
- -99 - 0
- 1 - 100
- > 100
- RMS Wells
- Groundwater Sustainability Agency (GSA) boundary
- Highways

4 2 0 4 Miles

Map of Wells Completed in B-zone for Public/ Domestic Purpose of Use

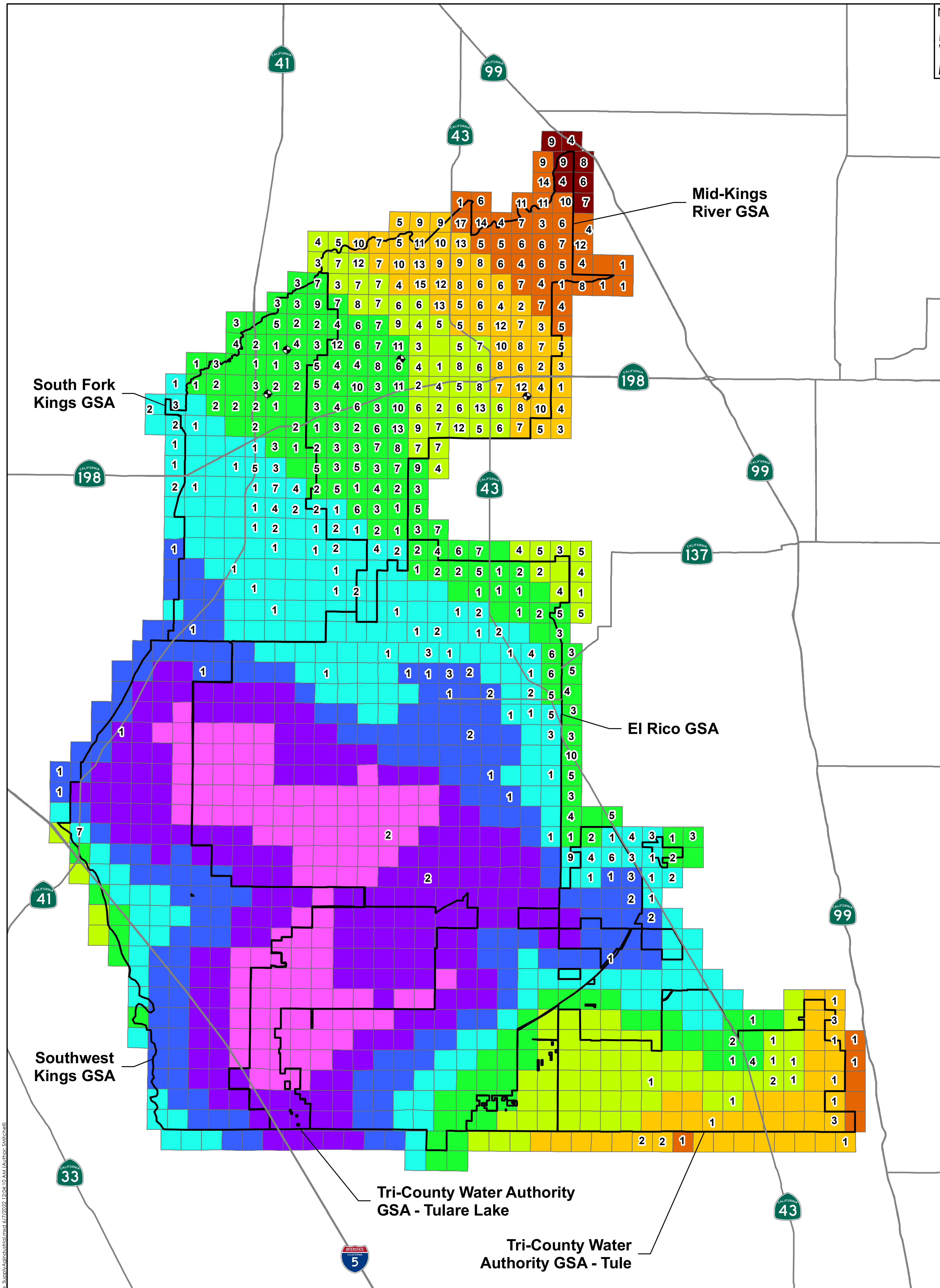
Groundwater Sustainability Plan - Addendum
Tulare Lake Subbasin, Kings County

Geosyntec consultants

Project No.: SFO138

June 2022

Figure **2-5a**



Legend

Average elevation of top of E-clay per section (feet msl)

- < -600
- -599 - -500
- -499 - -400
- -399 - -300
- -299 - -200
- -199 - -100
- -99 - 0
- 1 - 100
- > 100
- RMS Wells
- Groundwater Sustainability Agency (GSA) boundary
- Highways

4 2 0 4 Miles

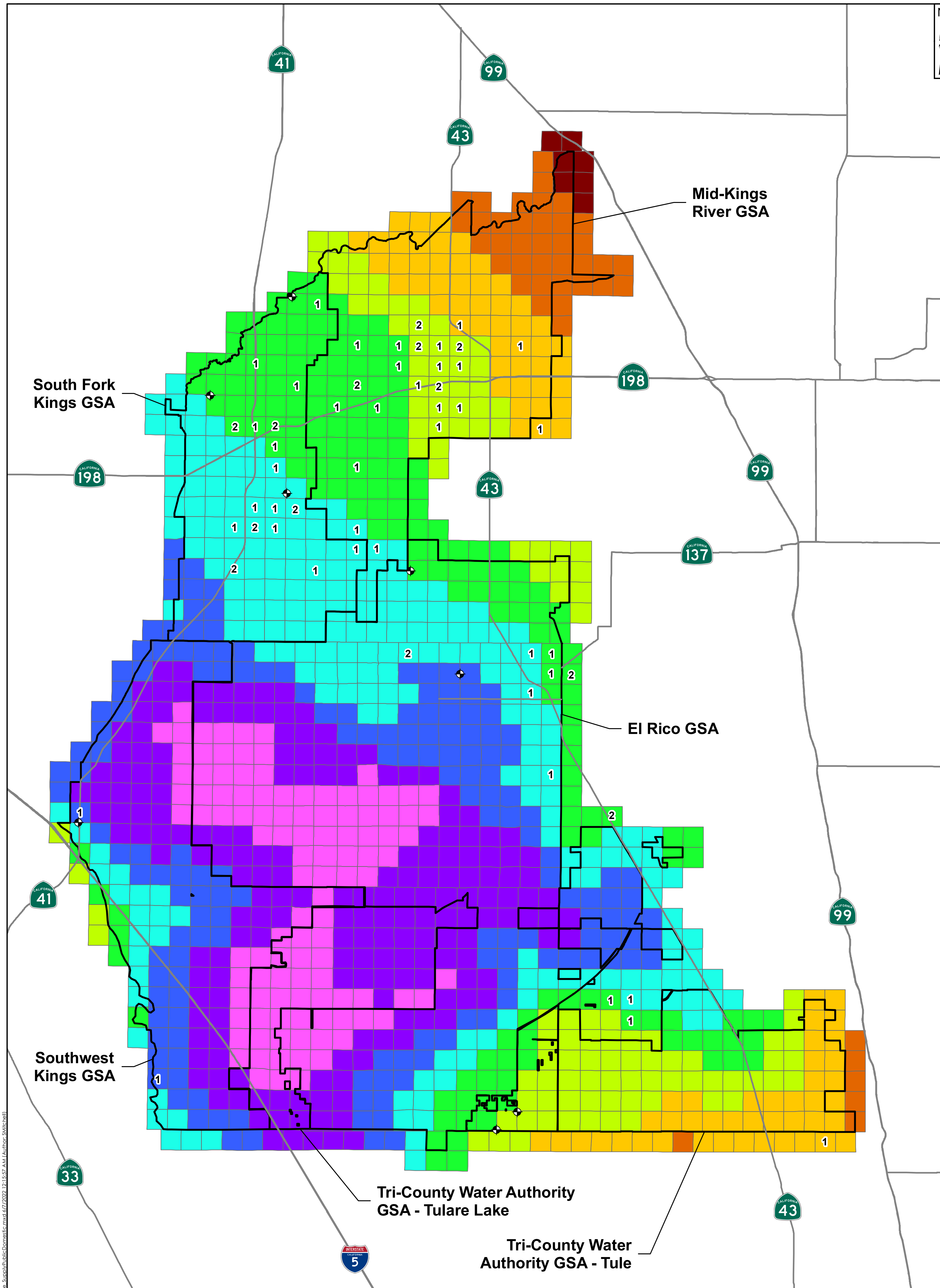
Map of Wells Completed in B-zone for Agricultural/Industrial Purpose of Use

Groundwater Sustainability Plan - Addendum
Tulare Lake Subbasin, Kings County

Geosyntec consultants

Project No.: SFO138 | June 2022

Figure 2-5b



Legend

Average elevation of top of E-clay per section (feet msl)

- < -600
- -599 - -500
- -499 - -400
- -399 - -300
- -299 - -200
- -199 - -100
- -99 - 0
- 1 - 100
- > 100
- RMS Wells
- Groundwater Sustainability Agency (GSA) boundary
- Highways

4 2 0 4 Miles

Map of Wells Completed in C-zone for Public/ Domestic Purpose of Use

Groundwater Sustainability Plan - Addendum

Tulare Lake Subbasin, Kings County

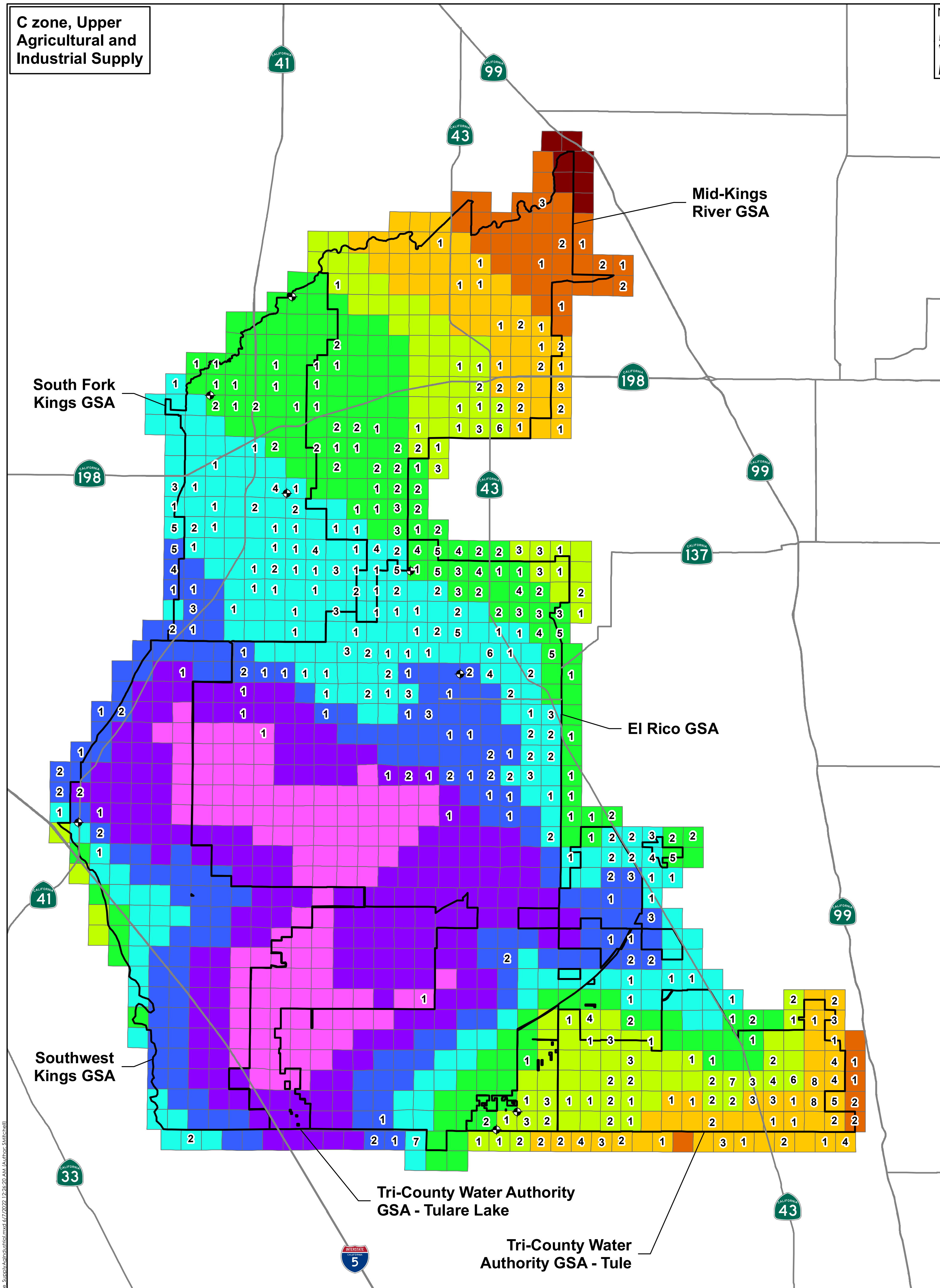
Geosyntec consultants

Project No.: SFO138

June 2022

Figure

2-6a



Legend

Average elevation of top of E-clay per section (feet msl)

- < -600
- -599 - -500
- -499 - -400
- -399 - -300
- -299 - -200
- -199 - -100
- -99 - 0
- 1 - 100
- > 100
- RMS Wells
- Groundwater Sustainability Agency (GSA) boundary
- Highways

4 2 0 4 Miles

Map of Wells Completed in C-zone for Agricultural/Industrial Purpose of Use

Groundwater Sustainability Plan - Addendum
Tulare Lake Subbasin, Kings County

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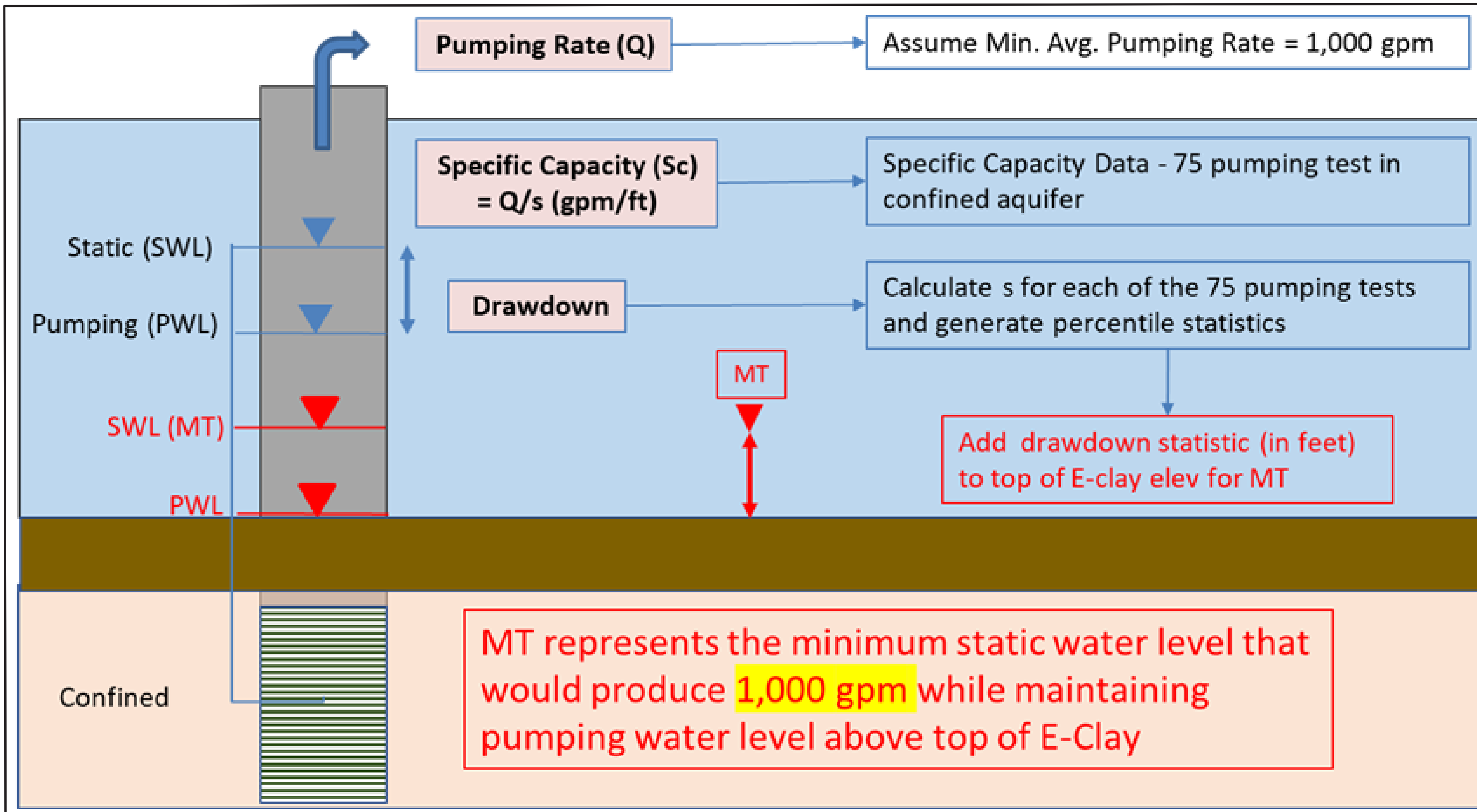
Figure **2-6b**

Project No.: SFO138 | June 2022



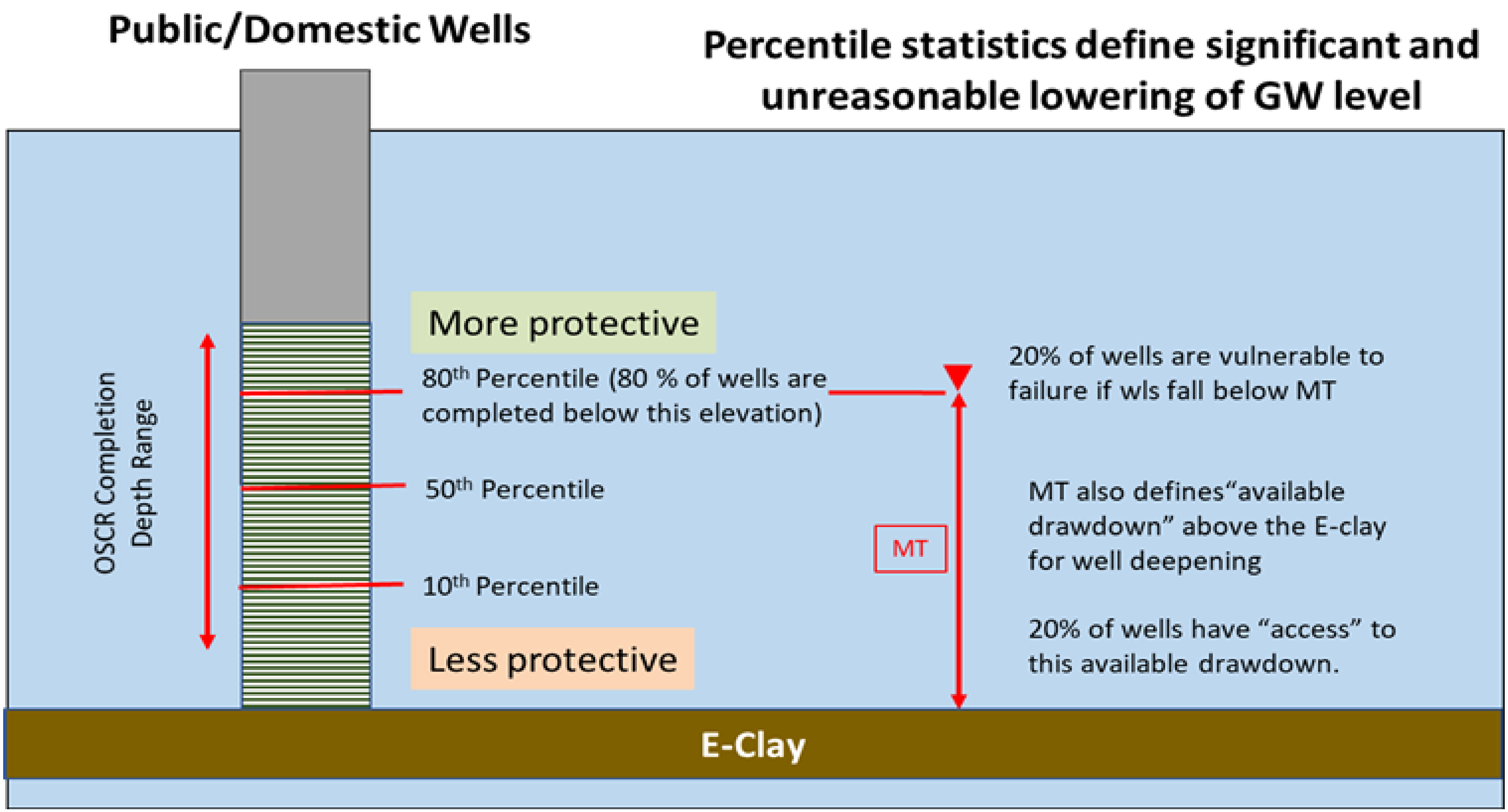
Notes:
Avg. = Average
E-Clay = Corcoran Clay
Gpm = Gallons per minute Min. = Minimum
MT = Minimum Threshold PWL = Pumping Water Level
SWL = Static Water Level

Schematic of Methodology for Calculating MT for Groundwater Level in the C-Zone
Groundwater Sustainability Plan Addendum
Tulare Lake Subbasin, Kings County

Geosyntec consultants

Figure 2-7

SFO138 | May 2022

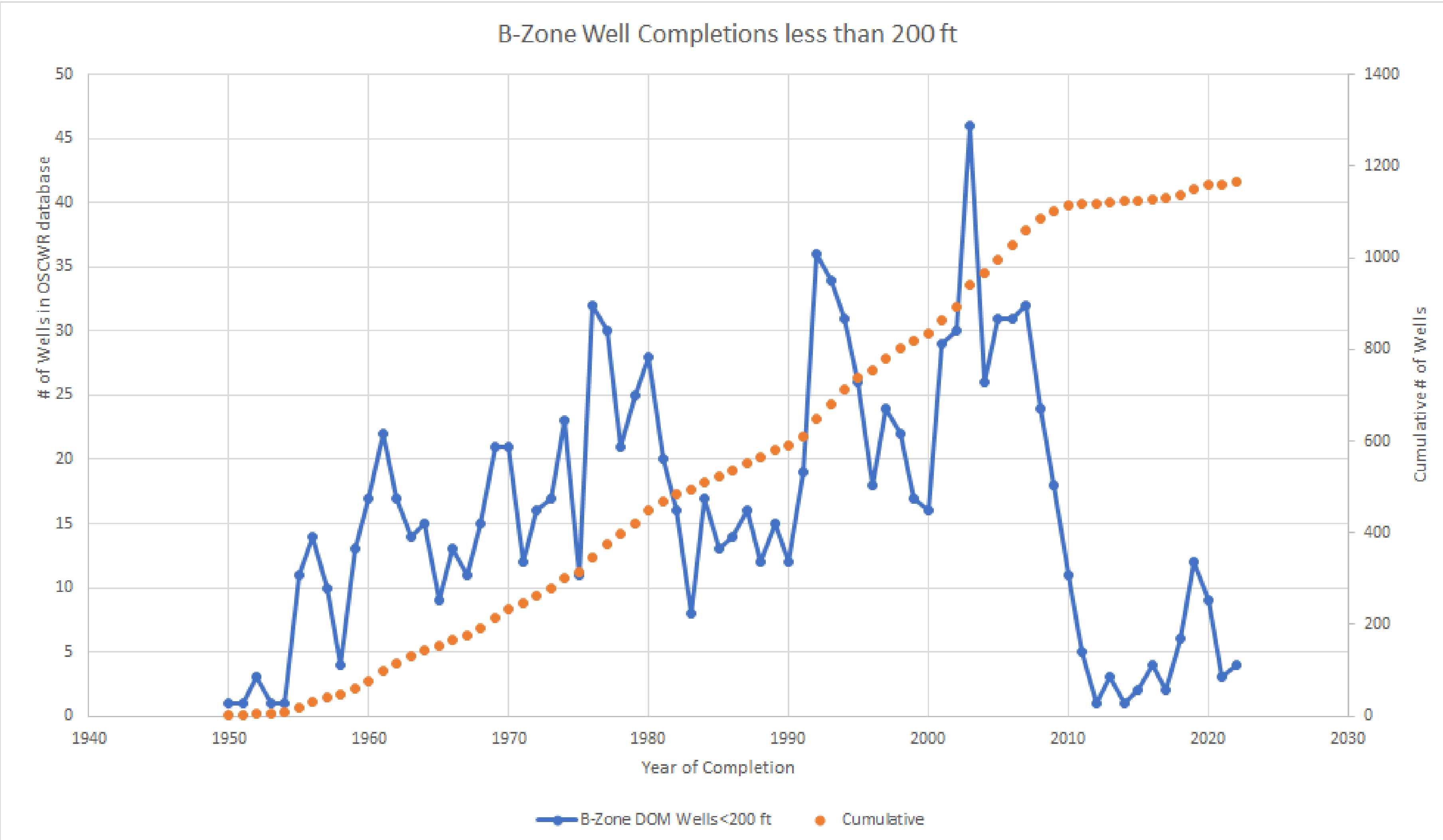


Notes:
E-Clay = Corcoran Clay
GW = Groundwater
MT = Minimum Threshold
OSCWR = Online System of Well Completion Reports
WLs = Water levels

Schematic of Methodology for Calculating MT for Groundwater Level in the B-Zone
Groundwater Sustainability Plan Addendum
Tulare Lake Subbasin, Kings County

Geosyntec consultants

SFO138	May 2022	Figure 2-8



Notes:
DOM = Domestic
OSCWR = Online System of Well Completion

Graph of OSCWR Well Depths Less than 200 feet by Year of Completion
Groundwater Sustainability Plan Addendum
Tulare Lake Subbasin, Kings County

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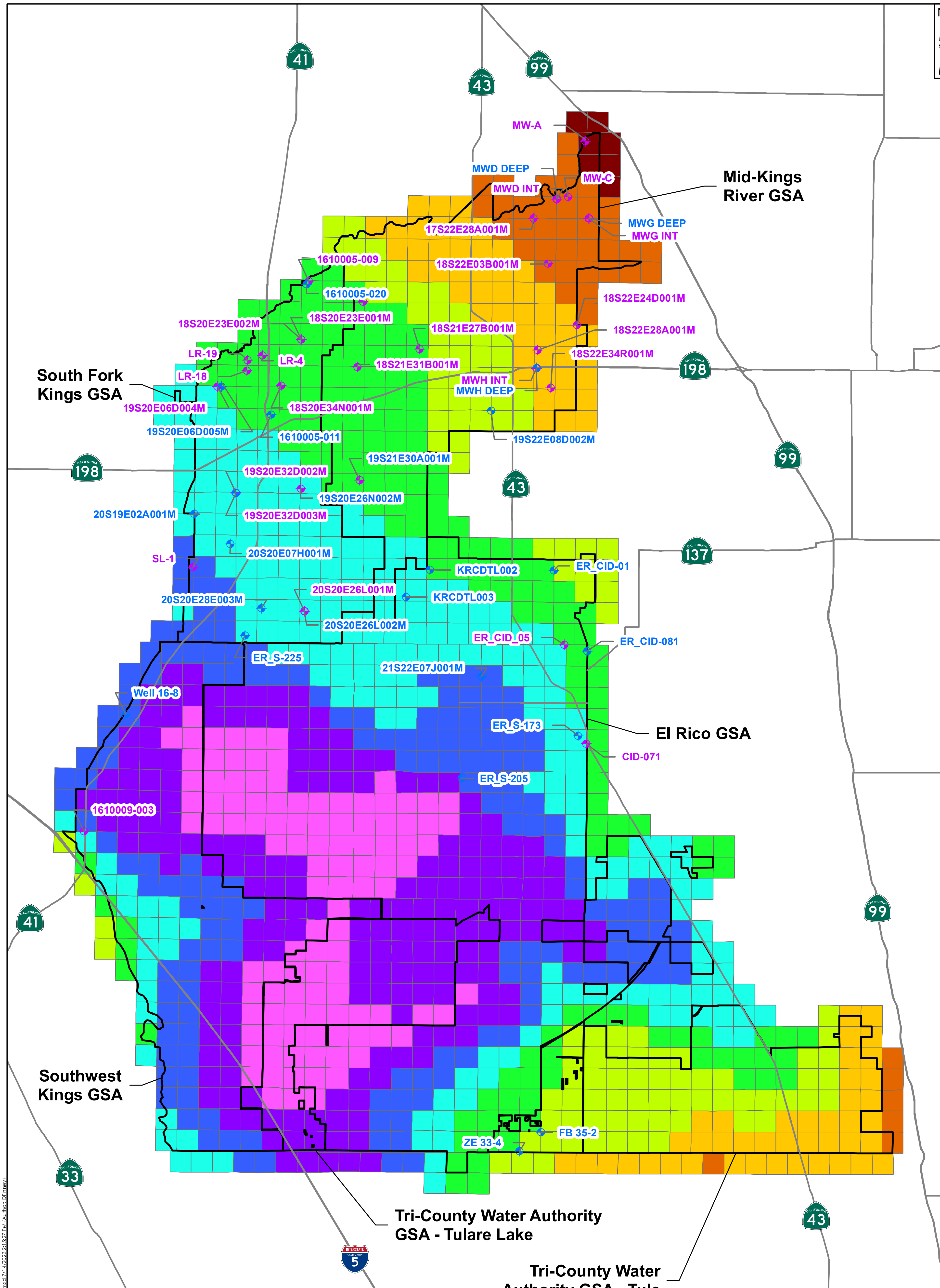
Figure 2-9

Project No.: SFO138 | June 2022



Legend

Average elevation of top of E-clay per section (feet msl)

- < -600
- -599 - -500
- -499 - -400
- -399 - -300
- -299 - -200
- -199 - -100
- -99 - 0
- 1 - 100
- > 100
- Groundwater Sustainability Agency (GSA) boundary

Representative Monitoring Sites

- B-zone
- C-zone

5 2½ 0 5 Miles

RMS Well Locations

Groundwater Sustainability Plan Agenda

Tulare Lake Subbasin, Kings County

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Figure **2-10**

Project No.: SFO138

July 2022

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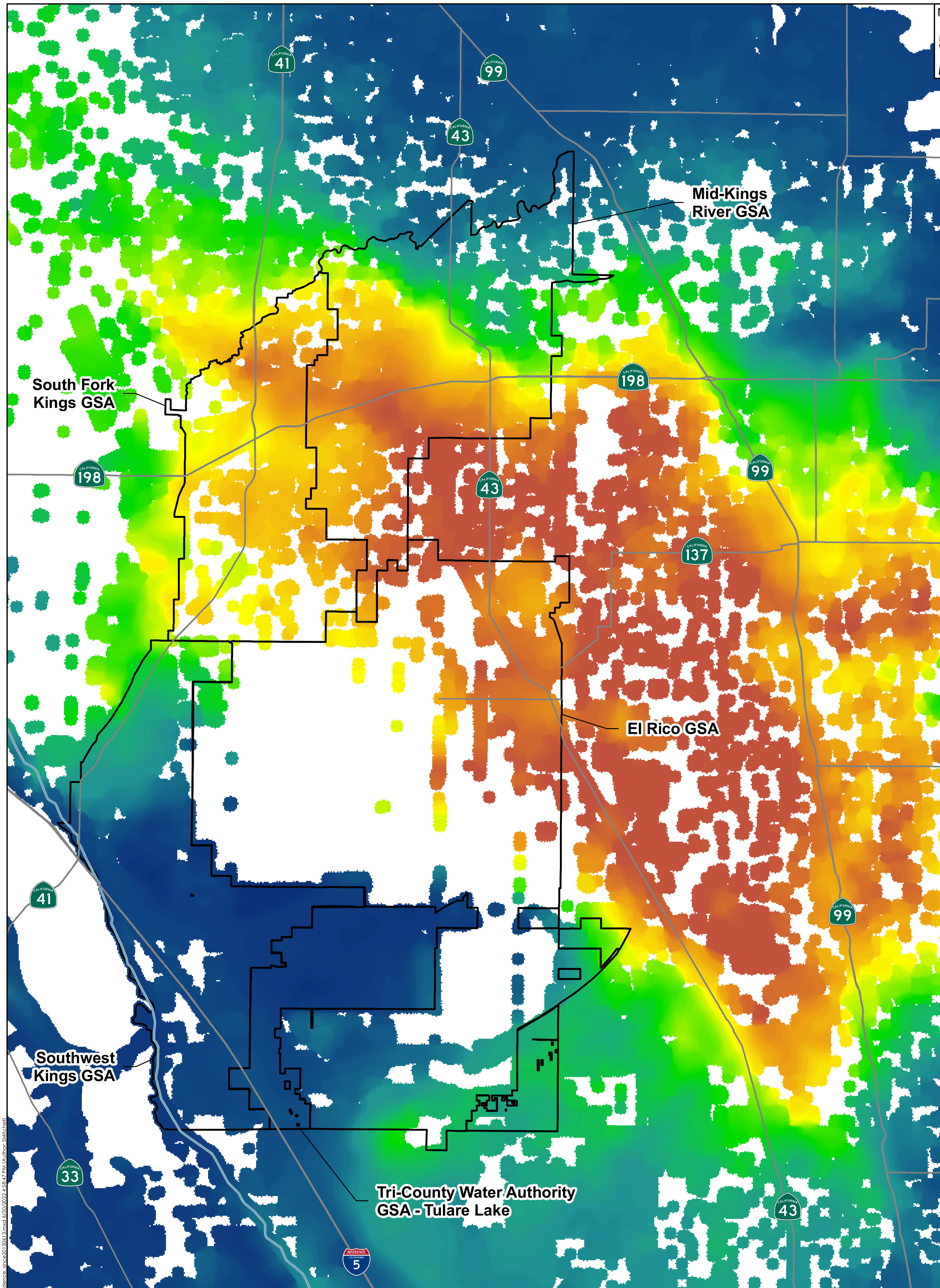


Legend

Mean regional vertical ground displacement (feet)[1]

High : 1.54514

Low : -5.80164

Groundwater Sustainability Agency (GSA) boundary[1]

Highways[2]

California Aqueduct[3]

Notes:
- Total Vertical Ground Displacement between 13 June 2015 and 1 January 2022, from TRE ALTAMIRA InSAR.
- White areas represent areas with no data.

References:
1) California Department of Water Resources.
2) U.S. Census Bureau.
3) U.S. Geological Survey.

4 2 0 4 Miles

Regional (i.e., total) Subsidence Between 2015 and 2022

Tulare Lake Subbasin

Geosyntec consultants

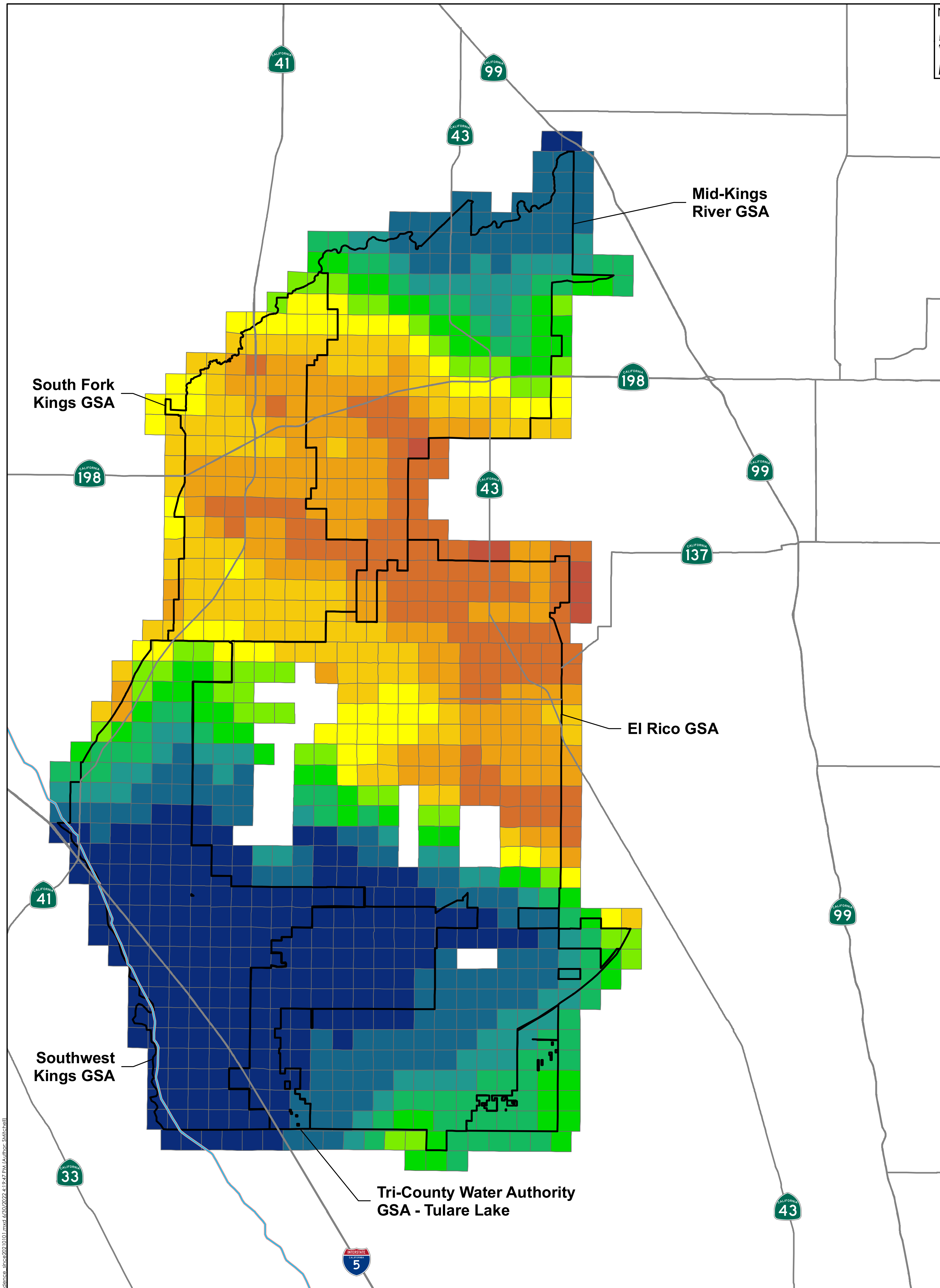
Figure

3-1

Project No.: SFO138

June 2022

P:\GIS\SFO138 - Tulare Lake GSP Update 2022\Projects\202205_Subsidence\Fig3-1_Subsidence_since20150613.mxd 6/30/2022 4:58:47 PM (Author: SMitchell)



Legend

Mean vertical ground displacement per section (feet) [1]

- -0.90 - -0.99
- -0.80 - -0.89
- -0.70 - -0.79
- -0.60 - -0.69
- -0.50 - -0.59
- -0.40 - -0.49
- -0.30 - -0.39
- -0.20 - -0.29
- -0.10 - -0.19
- 0.00 - -0.09
- 0.01 - 0.1

- Groundwater Sustainability Agency (GSA) boundary
- Highways[2]
- California Aqueduct[3]

Notes:
- Mean vertical ground displacement calculated by taking average total vertical ground displacement between 1 January 2021 and 1 January 2022 for each section from TRE ALTAMIRA InSAR.
- White areas represent areas with no data.

References:
1) California Department of Water Resources.
2) U.S. Census Bureau.
3) U.S. Geological Survey.

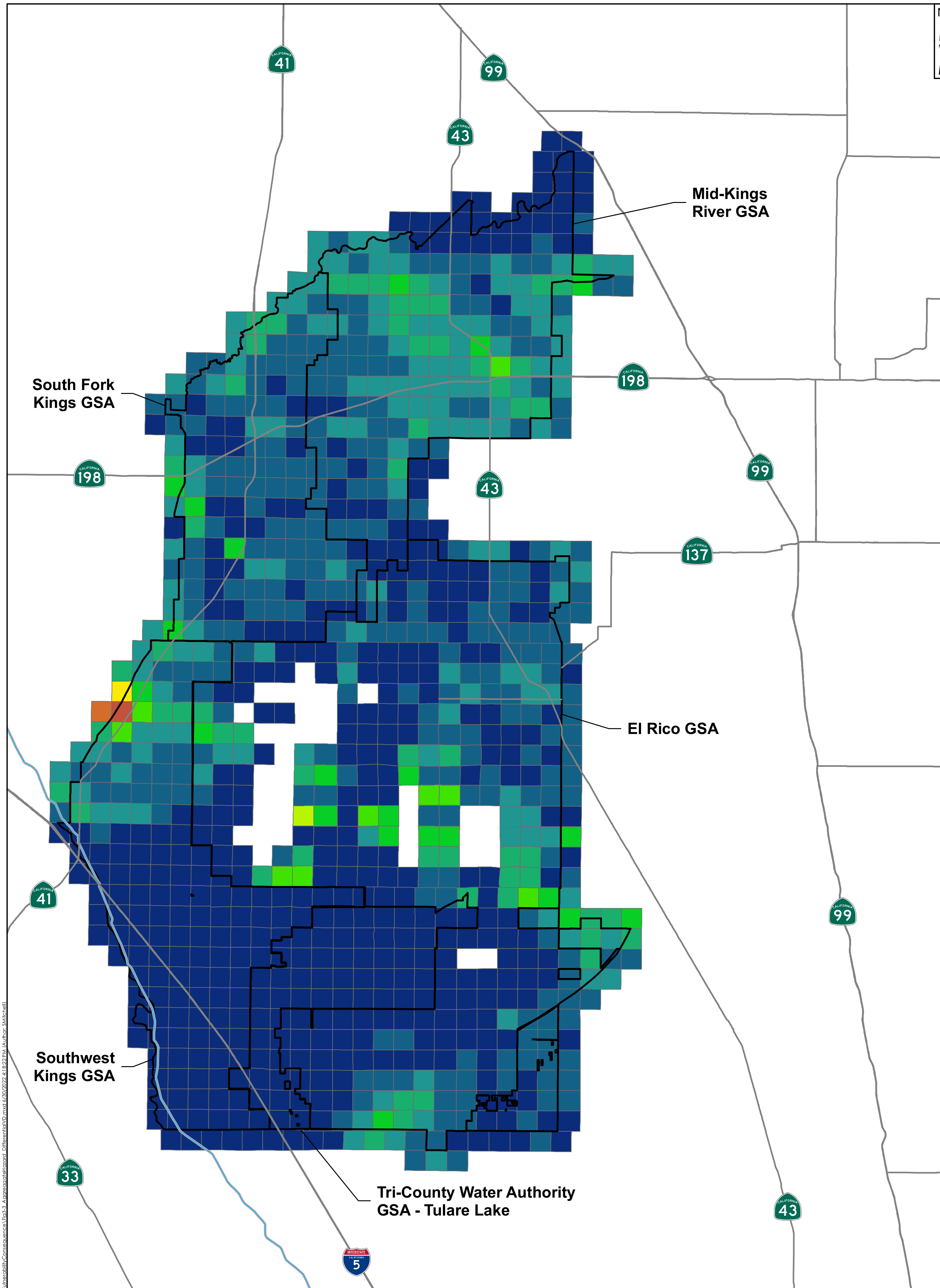
4 2 0 4 Miles

TRS Average Total Subsidence (2021-2022)
H-Map (1)
Tulare Lake Subbasin

Geosyntec consultants

Figure **3-2**

Project No.: SFO138 | June 2022



Legend

Mean differential vertical ground displacement per section (feet) [1]

- 0.0000 - 0.0025
- 0.0026 - 0.0050
- 0.0051 - 0.0075
- 0.0076 - 0.0100
- 0.0101 - 0.0125
- 0.0126 - 0.0150
- 0.0151 - 0.0175
- 0.0176 - 0.0200
- 0.0201 - 0.0225
- 0.0226 - 0.0250
- 0.0251 - 0.0275
- 0.0276 - 0.0300

Groundwater Sustainability Agency (GSA) boundary[1]

Highways[2]

California Aqueduct[3]

Notes:
- Mean differential vertical ground displacement calculated by taking average differential vertical ground displacement between 1 January 2021 and 1 January 2022 for each section from TRE ALTAMIRA InSAR.
- White areas represent areas with no data.

References:
1) California Department of Water Resources.
2) U.S. Census Bureau.
3) U.S. Geological Survey.

4 2 0 4 Miles

TRS Average Differencial Subsidence (2021-2022)
H-Map (2)
Tulare Lake Subbasin

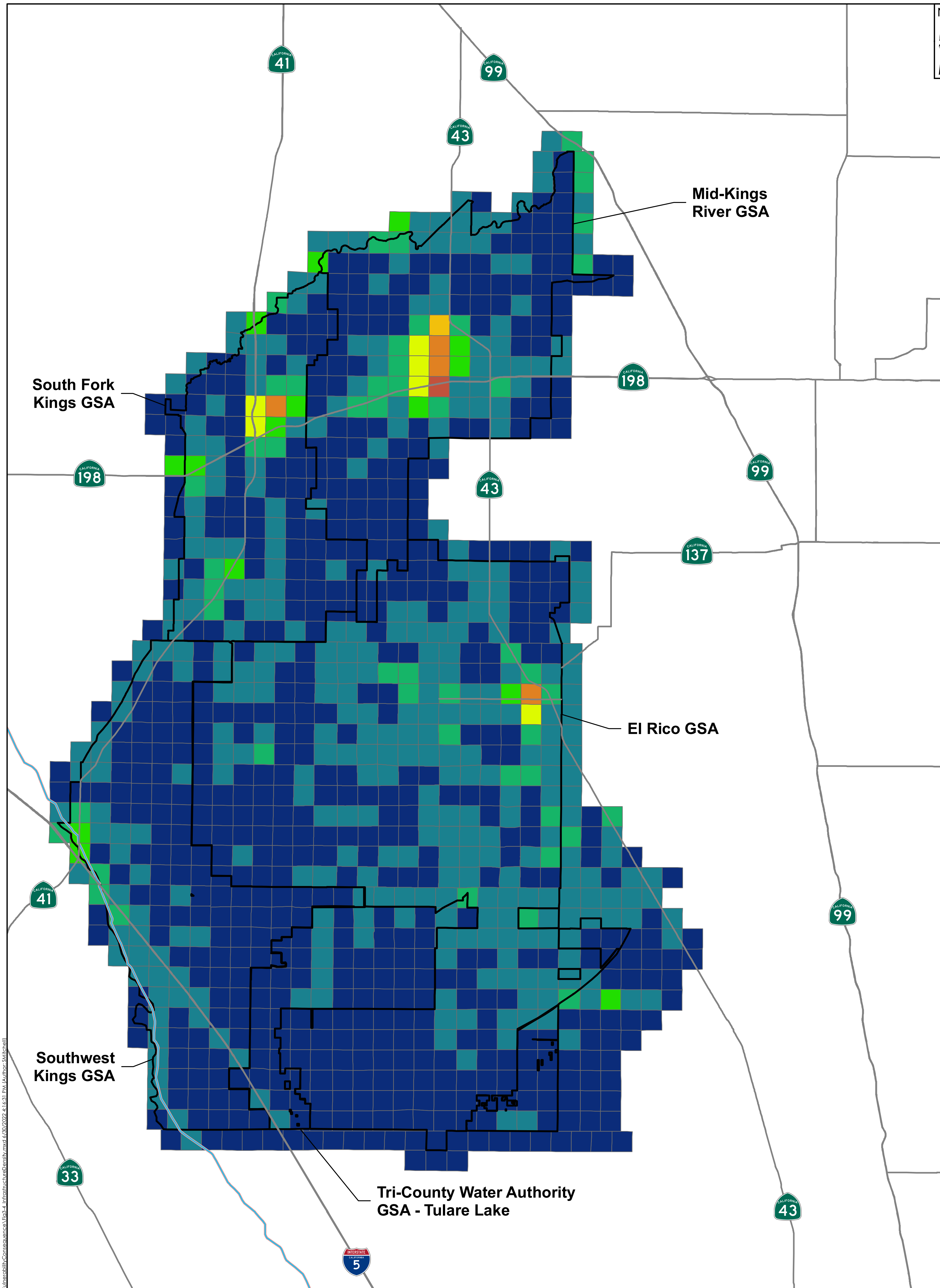
Geosyntec consultants

Project No.: SFO138

June 2022

Figure

3-3



Legend

Infrastructure density score per section

- 0.00 - 5.00
- 5.01 - 10.00
- 10.01 - 15.00
- 15.01 - 20.00
- 20.01 - 25.00
- 25.01 - 30.00
- 30.01 - 35.00
- 35.01 - 40.00
- Groundwater Sustainability Agency (GSA) boundary[1]
- Highways[2]
- California Aqueduct[3]

Notes:
- Density calculated by summing the following infrastructure values within each section:
  - Canals and Aqueducts (linear, 1 per mile)
  - High Speed Rail right-of-way (linear, 1 per mile)
  - Levees (linear, 1 per mile)
  - Pipelines (linear, 1 per mile)
  - Railroads (linear, 1 per mile)
  - Roads (linear, 1 per mile)
  - Airports/Runways (points, 1 per each)
  - Bridges (points, 1 per each)
  - Emergency Facility Buildings (points, 1 per each)

References:
1) California Department of Water Resources.
2) U.S. Census Bureau.
3) U.S. Geological Survey.

4 2 0 4 Miles

TRS Total Infrastructure Density Map
Tulare Lake Subbasin

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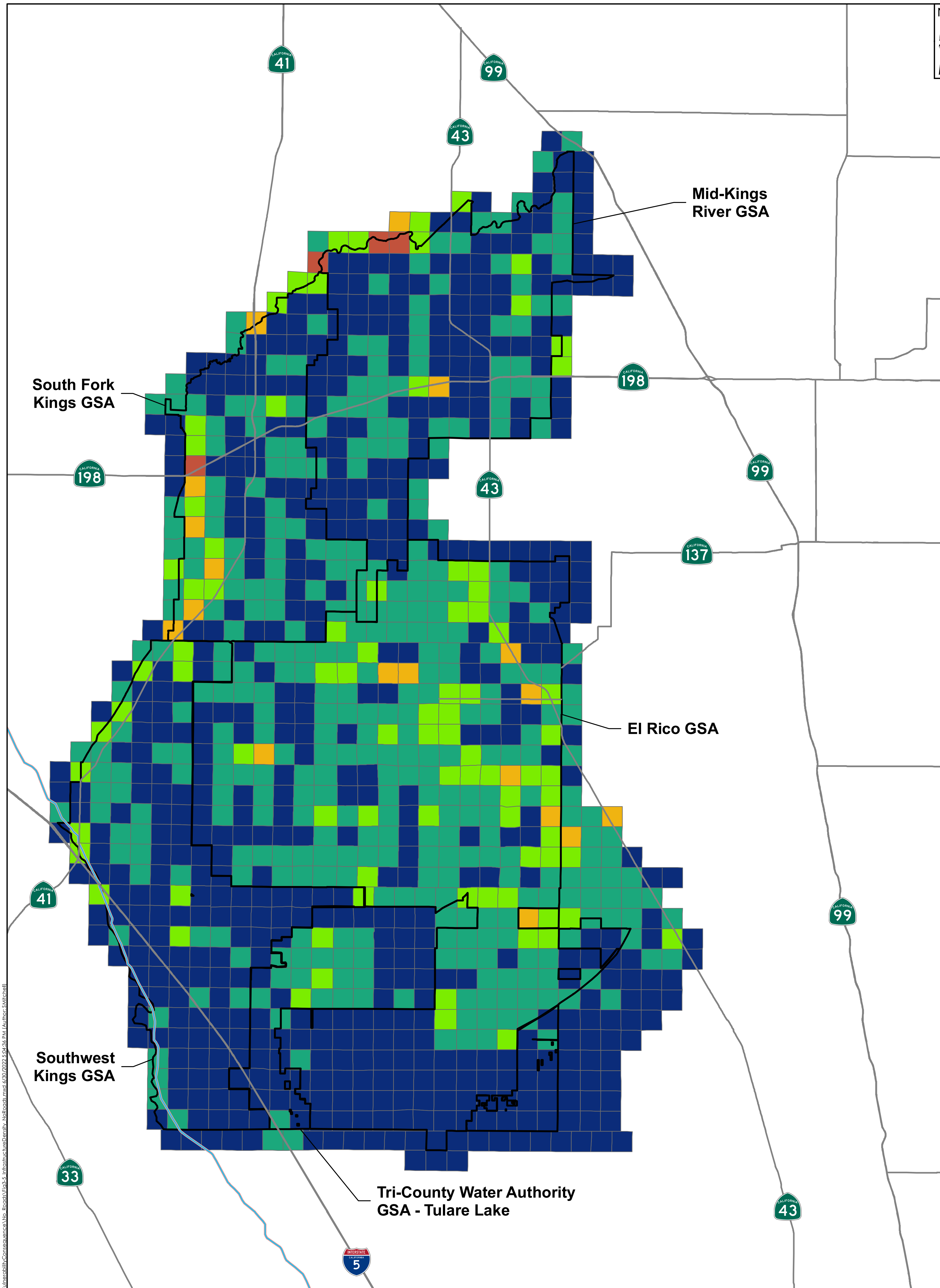
Project No.: SFO138 | June 2022

Figure 3-4

P:\GIS\SFO138 - Tulare Lake GSP Update 2022\Projects\20220531_CriticalInfrastructure_VulnerabilityConsequence\Fig3-4_InfrastructureDensity.mxd 6/30/2022 4:16:31 PM (Author: SMitchell)



Legend

Infrastructure density score per section (no roads)

- 0.00 - 2.00
- 2.01 - 4.00
- 4.01 - 6.00
- 6.01 - 8.00
- 8.01 - 10.00

Groundwater Sustainability Agency (GSA) boundary[1]

Highways[2]

California Aqueduct[3]

Notes:
- Density calculated by summing the following infrastructure values within each section:
  - Canals and Aqueducts (linear, 1 per mile)
  - High Speed Rail right-of-way (linear, 1 per mile)
  - Levees (linear, 1 per mile)
  - Pipelines (linear, 1 per mile)
  - Railroads (linear, 1 per mile)
  - Airports/Runways (points, 1 per each)
  - Bridges (points, 1 per each)
  - Emergency Facility Buildings (points, 1 per each)

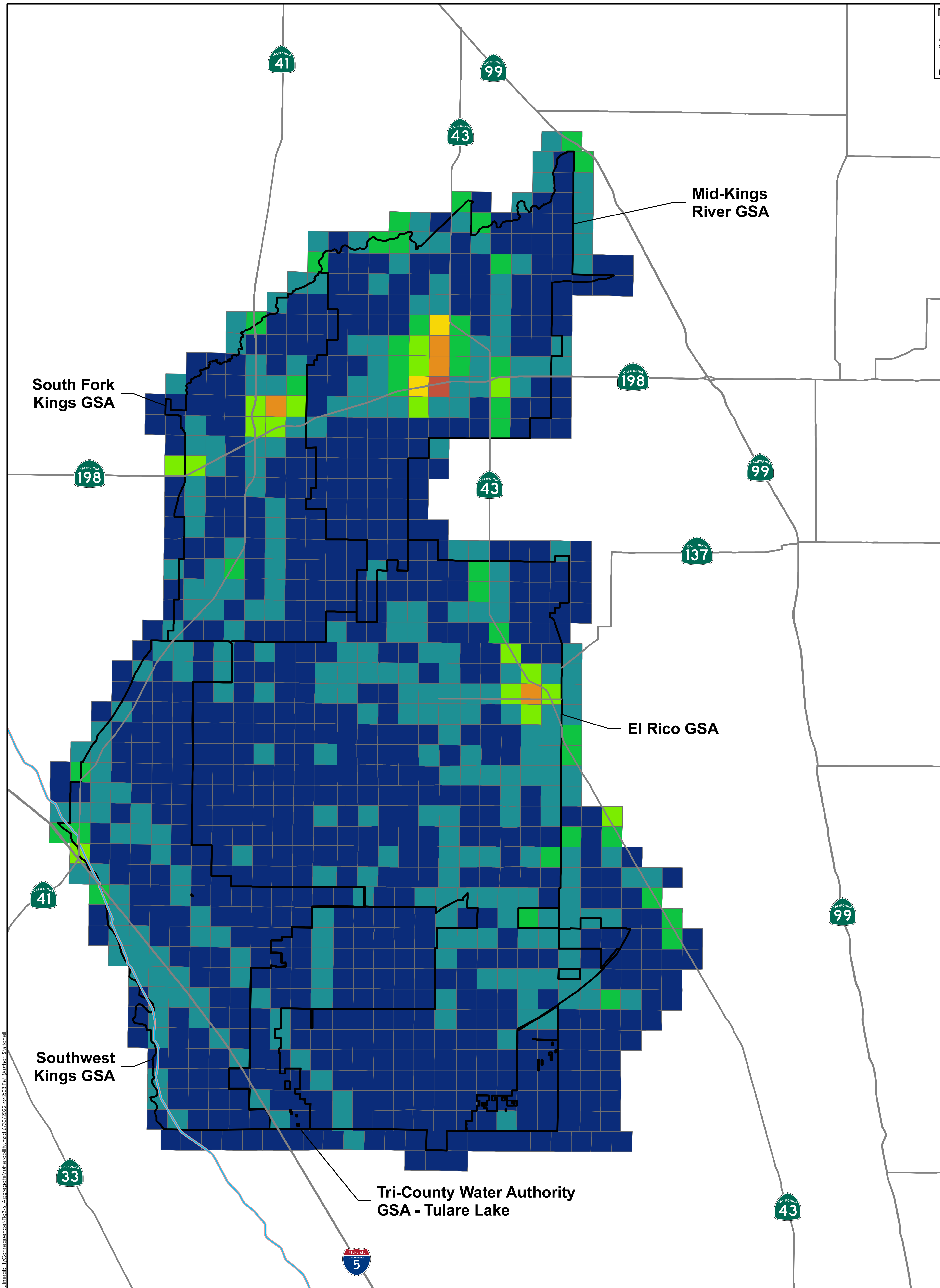
References:
1) California Department of Water Resources.
2) U.S. Census Bureau.
3) U.S. Geological Survey.

TRS Total Infrastructure Density Map, Excluding Roads
V-Map (1)
Tulare Lake Subbasin

Geosyntec consultants

Figure **3-5**

Project No.: SFO138 | June 2022



Legend

Aggregate vulnerability score per section

- 0.000 - 0.010
- 0.011 - 0.020
- 0.021 - 0.030
- 0.031 - 0.040
- 0.041 - 0.050
- 0.051 - 0.060
- 0.061 - 0.070
- Groundwater Sustainability Agency (GSA) boundary[1]
- Highways[2]
- California Aqueduct[3]

Notes:
- The aggregate vulnerability score (V) for each section was calculated by multiplying the density score for each class of infrastructure per section by the associated LMT for that class of infrastructure.
- Infrastructure excludes roads.

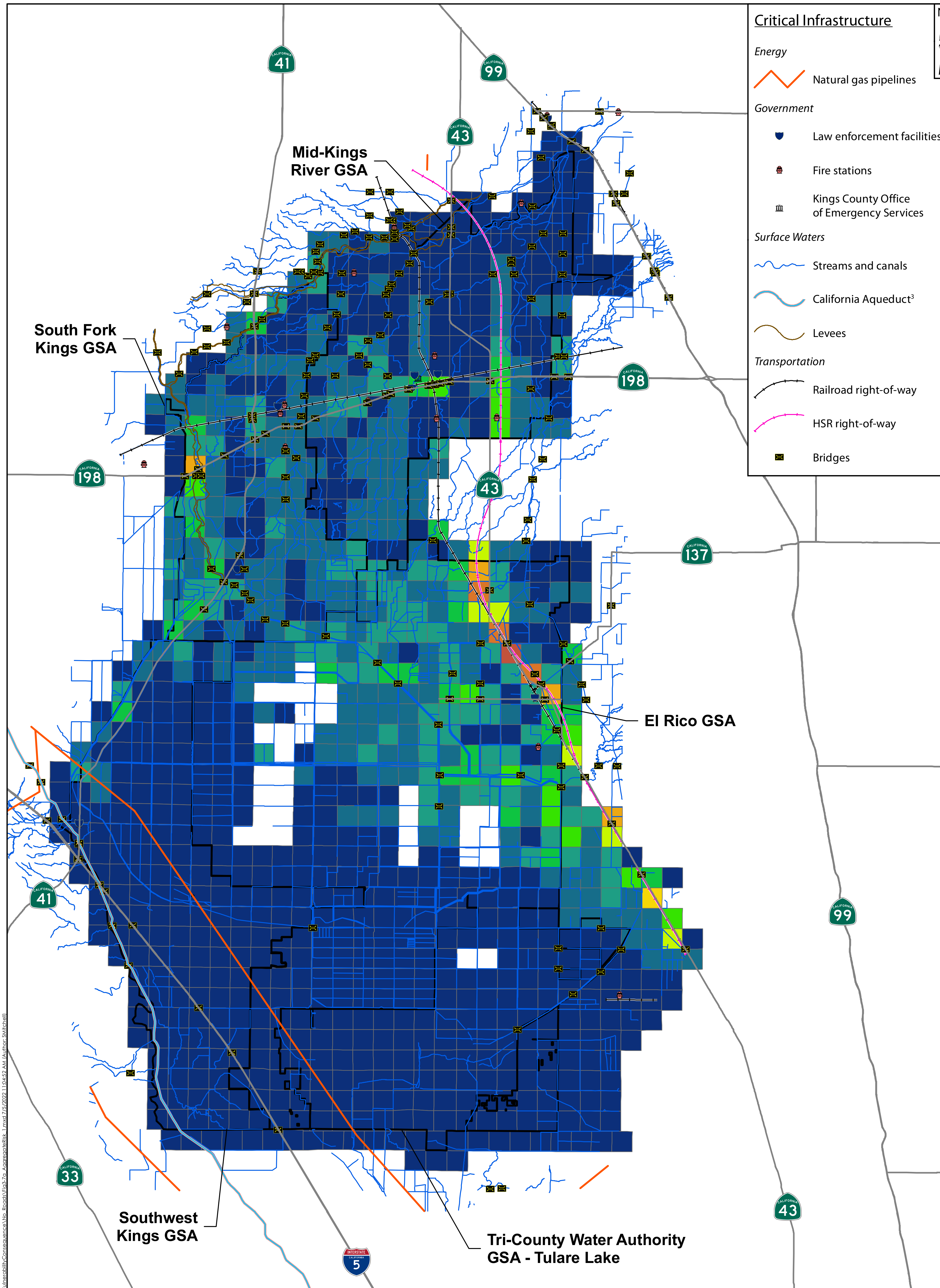
References:
1) California Department of Water Resources.
2) U.S. Census Bureau.
3) U.S. Geological Survey.

TRS Aggregate Infrastructure Vulnerability Map
Differential Subsidence: V-Map (2)
Tulare Lake Subbasin

Geosyntec consultants

Figure **3-6**

Project No.: SFO138 | June 2022



Legend

Aggregate risk score per section

-0.021115 - -0.018942	-0.010246 - -0.008073
-0.018941 - -0.016768	-0.008072 - -0.005900
-0.016767 - -0.014594	-0.005899 - -0.003726
-0.014593 - -0.012421	-0.003725 - -0.001552
-0.012420 - -0.010247	-0.001551 - 0.000622

Groundwater Sustainability Agency (GSA) boundary[1]

Highways[2]

California Aqueduct[3]

Notes:
- Risk score per section calculated as: H-Map (1) x V-Map (1) = R-Map (1)
- White areas represent areas with no data.

References:
1) California Department of Water Resources.
2) U.S. Census Bureau.
3) U.S. Geological Survey.

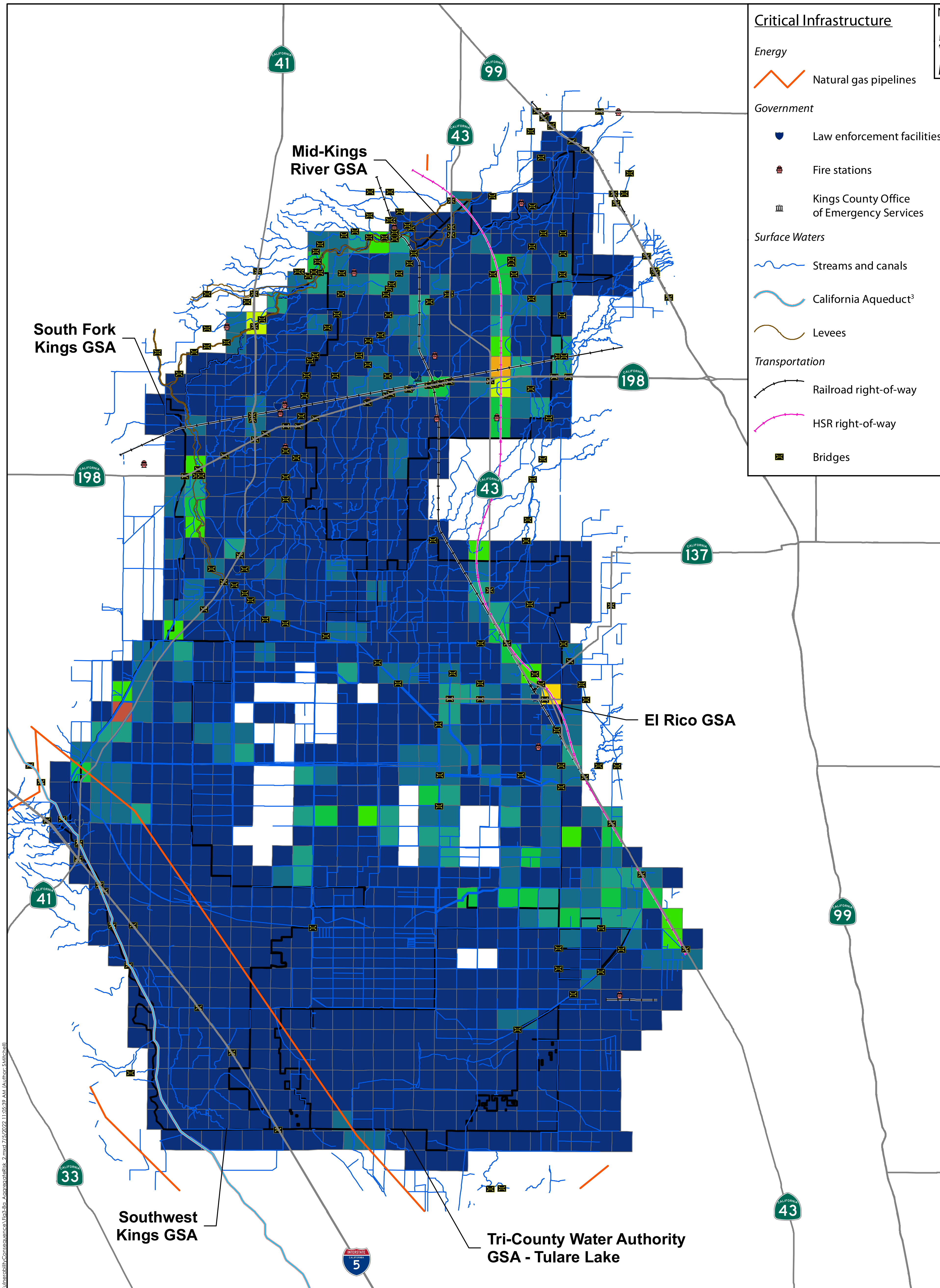
4 2 0 4 Miles

TRS Aggregate Total Subsidence Risk Map
R-Map (1)
Tulare Lake Subbasin

Geosyntec consultants

Figure 3-7

Project No.: SFO138 | July 2022



Legend

Aggregate risk score per section, based on differential ground surface vertical displacement

- 0.00000 - 0.00002
- 0.00003 - 0.00005
- 0.00006 - 0.00007
- 0.00008 - 0.00009
- 0.00010 - 0.00012
- 0.00013 - 0.00014
- 0.00015 - 0.00016
- 0.00017 - 0.00019
- 0.00020 - 0.00021
- 0.00022 - 0.00024

- Groundwater Sustainability Agency (GSA) boundary[1]
- Highways[2]
- California Aqueduct[3]

Notes:
- Risk score per section calculated as: H-Map (2) x V-Map (2) = R-Map (2)
- White areas represent areas with no data.

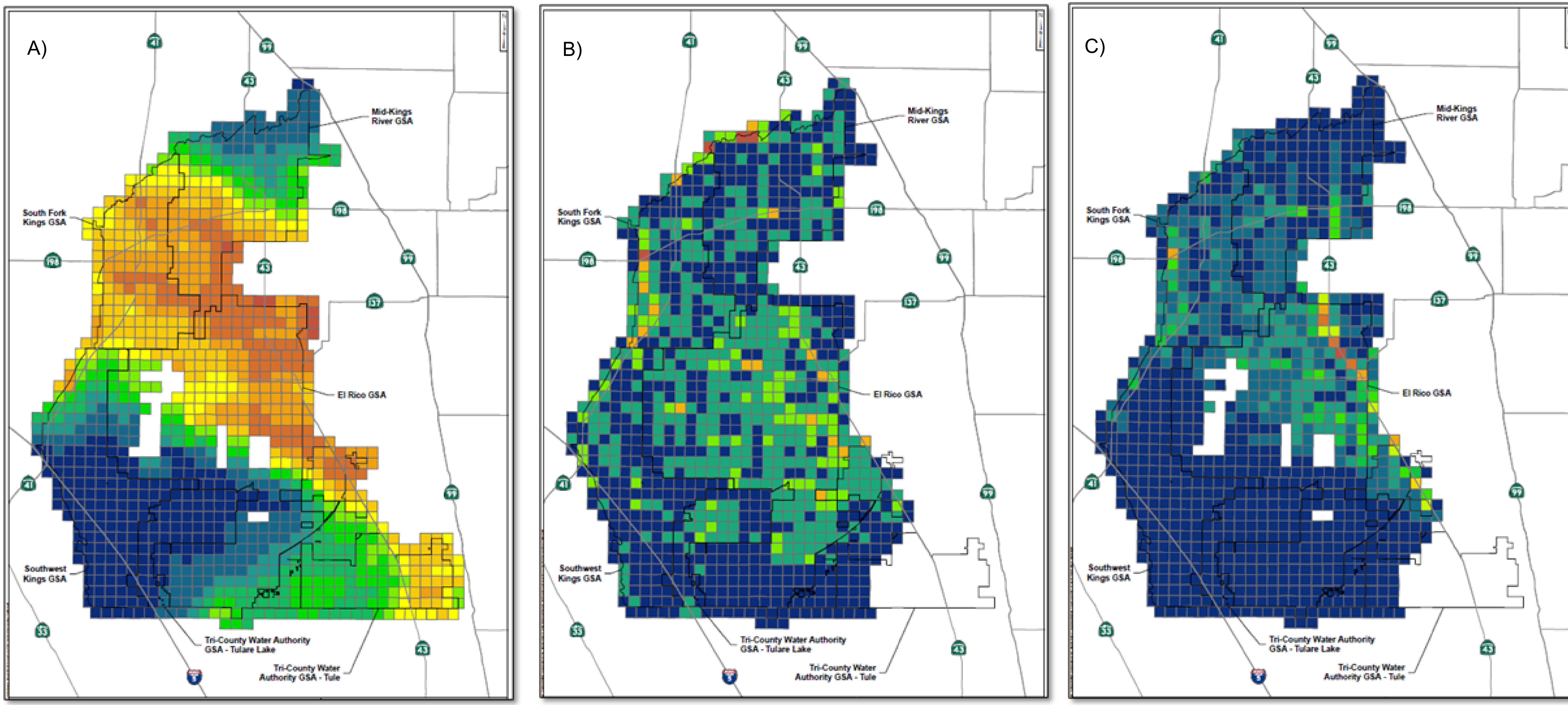
References:
1) California Department of Water Resources.
2) U.S. Census Bureau.
3) U.S. Geological Survey.

TRS Aggregate Differential Subsidence Risk Map R-Map (2)
Tulare Lake Subbasin

Geosyntec consultants

Project No.: SFO138 | July 2022

Figure 3-8



Notes:
Total subsidence risk for the Tulare Lake Subbasin.

H = Hazard
R = Risk
V = Vulnerability

TRS = Township Range Section

Series of maps displayed:

a) Figure 3-2: TRS Average Total Subsidence (2021-2022): H-Map (1)
b) Figure 3-5: TRS Total Infrastructure Density Map Excluding Roads
c) Figure 3-7: TRS H-Map (1) x Total Infrastructure Density Excluding Roads: R-Map (1)

Total Subsidence Risk Series Map: H(1) x V(1) = R(1)
Groundwater Sustainability Plan - Addendum
Tulare Lake Subbasin, Kings County

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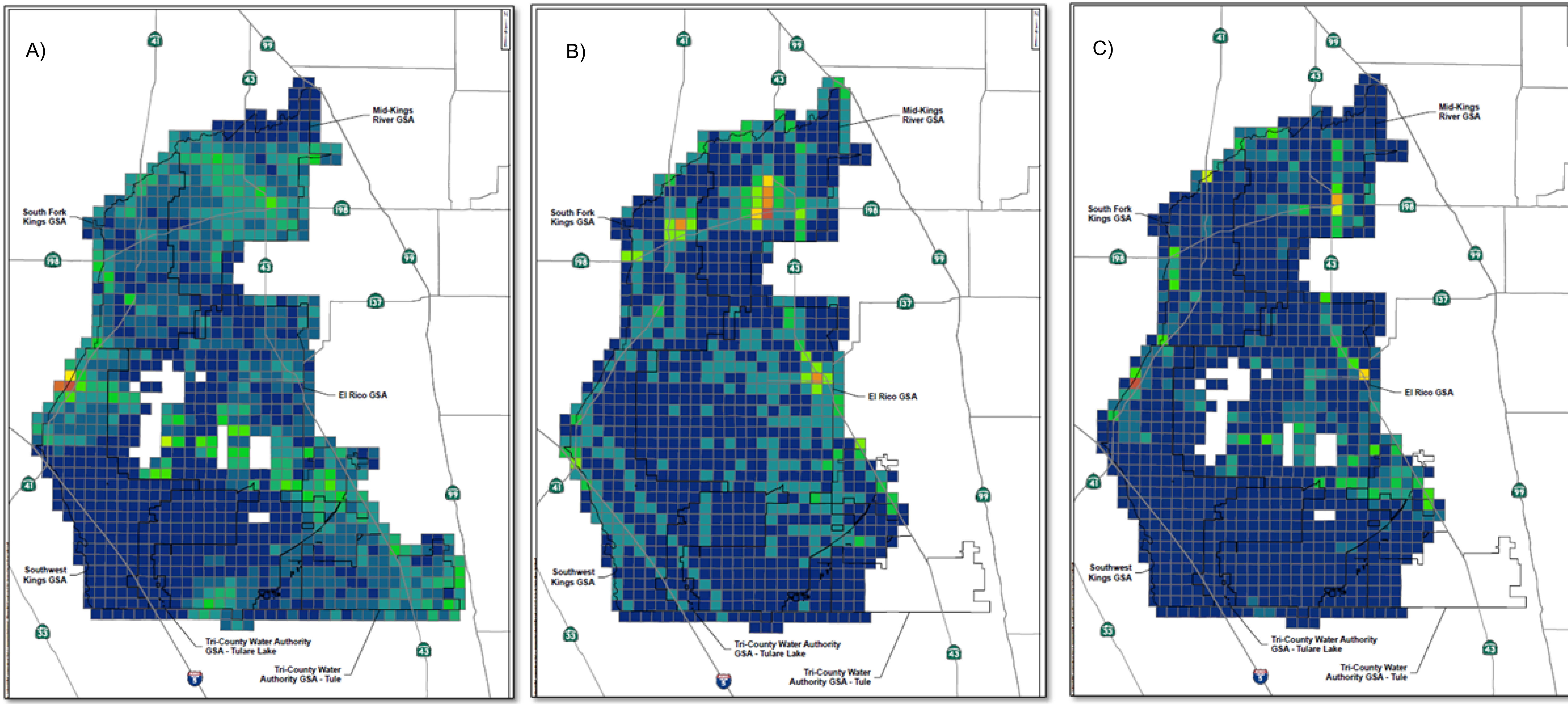
Figure 3-9

Project No.: SFO138 | June 2022



Notes:
Differential Subsidence risk for the Tulare Lake Subbasin. Local Minimum Thresholds (LMT) are considered by infrastructure types.

H = Hazard
R = Risk
V = Vulnerability
TRS = Township Range Section

Series of maps displayed:

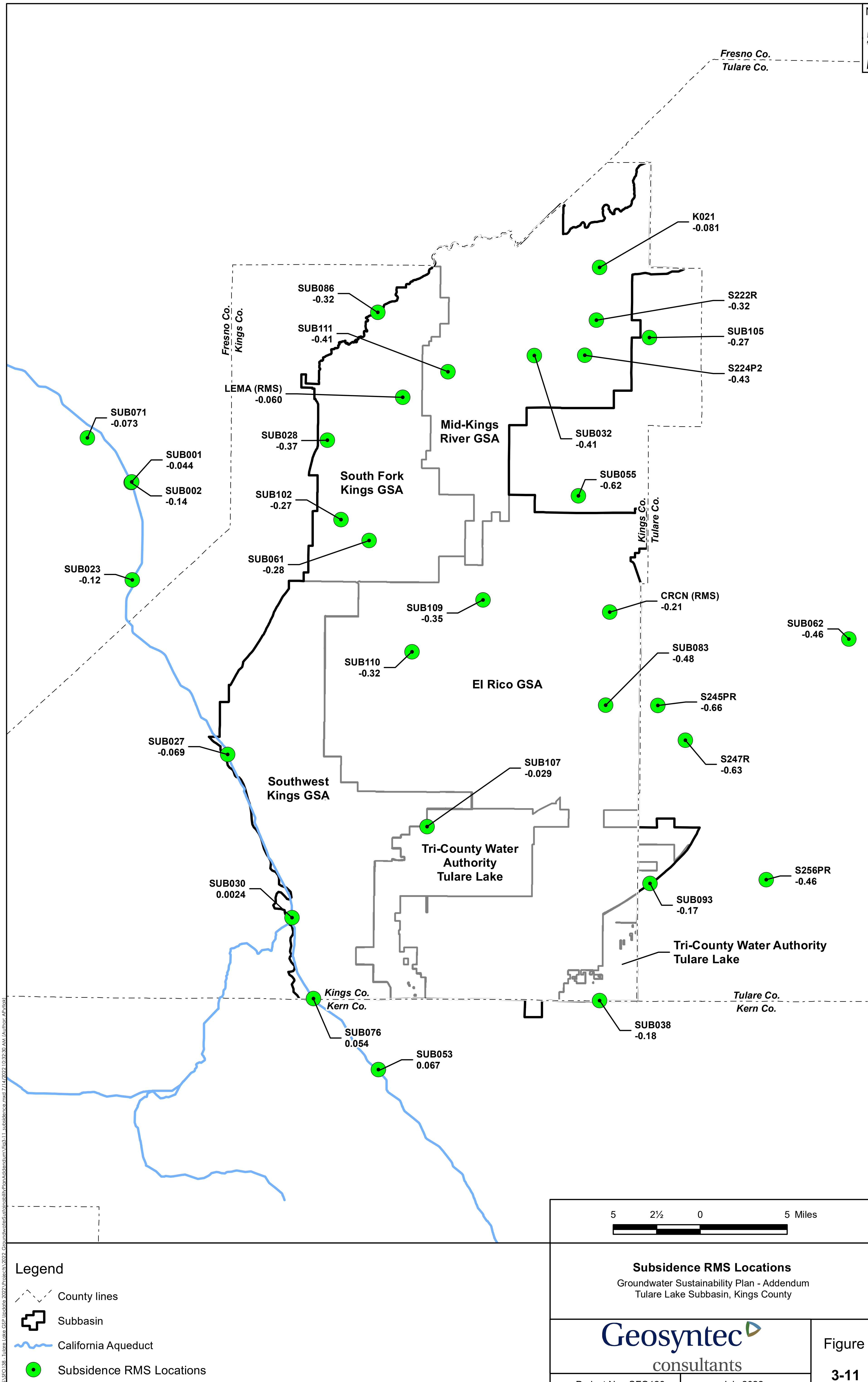
a) Figure 3-3: TRS Average Differential Subsidence (2021-2022): H-Map (2)
b) Figure 3-6: TRS Infrastructure Density x LMT: V-Map
c) Figure 3-8: TRS H-Map (2) x V-Map: R-Map (2)

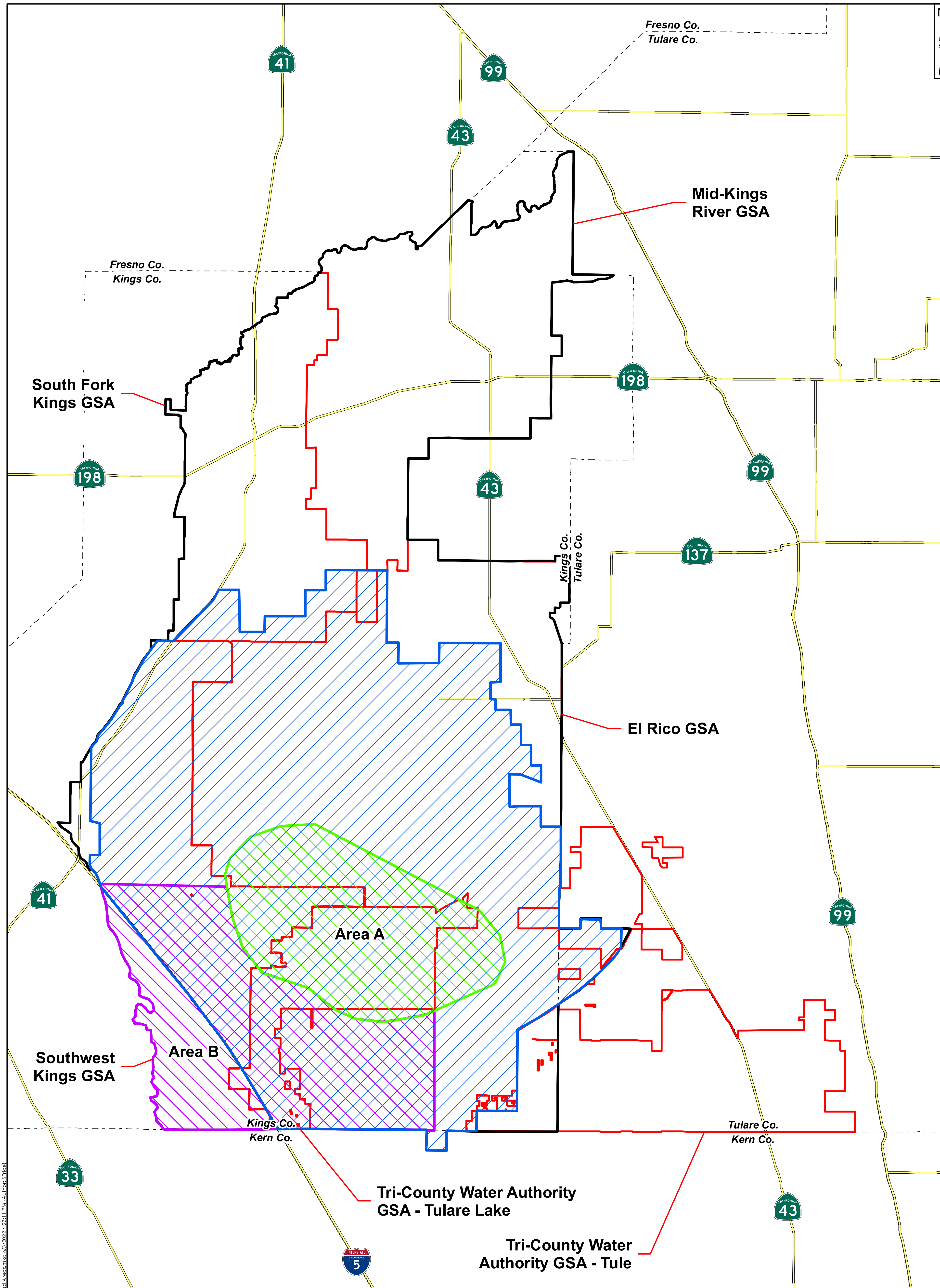
Differential Subsidence Risk Series
Map: H(2) x V(2) = R(2)
Groundwater Sustainability Plan - Addendum
Tulare Lake Subbasin, Kings County

Geosyntec consultants

Project No.: SFO138 | June 2022

Figure **3-10**


N
Fresno Co.
Tulare Co.
Fresno Co.
Kings Co.
Kings Co.
Tulare Co.
Kings Co.
Kern Co.
Tulare Co.
Kern Co.
K021
-0.081
SUB086
-0.32
S222R
-0.32
SUB111
-0.41
SUB105
-0.27
S224P2
-0.43
LEMA (RMS)
-0.060
SUB071
-0.073
Mid-Kings
River GSA
SUB032
-0.41
SUB028
-0.37
SUB001
-0.044
South Fork
Kings GSA
SUB055
-0.62
SUB002
-0.14
SUB102
-0.27
SUB061
-0.28
SUB023
-0.12
CRCN (RMS)
-0.21
SUB109
-0.35
SUB062
-0.46
SUB110
-0.32
SUB083
-0.48
El Rico GSA
S245PR
-0.66
SUB027
-0.069
S247R
-0.63
SUB107
-0.029
Southwest
Kings GSA
Tri-County Water
Authority
Tulare Lake
S256PR
-0.46
SUB030
0.0024
SUB093
-0.17
Tri-County Water Authority
Tulare Lake
SUB076
0.054
SUB038
-0.18
SUB053
0.067
5
2½
0
5 Miles
Legend
County lines
Subbasin
California Aqueduct
Subsidence RMS Locations
Subsidence RMS Locations
Groundwater Sustainability Plan - Addendum
Tulare Lake Subbasin, Kings County
Geosyntec
consultants
Project No.: SFO128
July 2022
Figure
3-11



Legend

- Tulare Lake Subbasin 5-022.12
- Groundwater Sustainability Agency (GSA) boundary
- De-designated Area
- Management Area A
- Management Area B
- Highways
- County lines

Notes:
De-designated and Management Areas are depicted in Figures 5-1, 5-2, and 5-5 of the Tulare Lake Subbasin GSP. The de-designated Area is recognized in the Basin Plan (SWRCB R5-2017-0032).

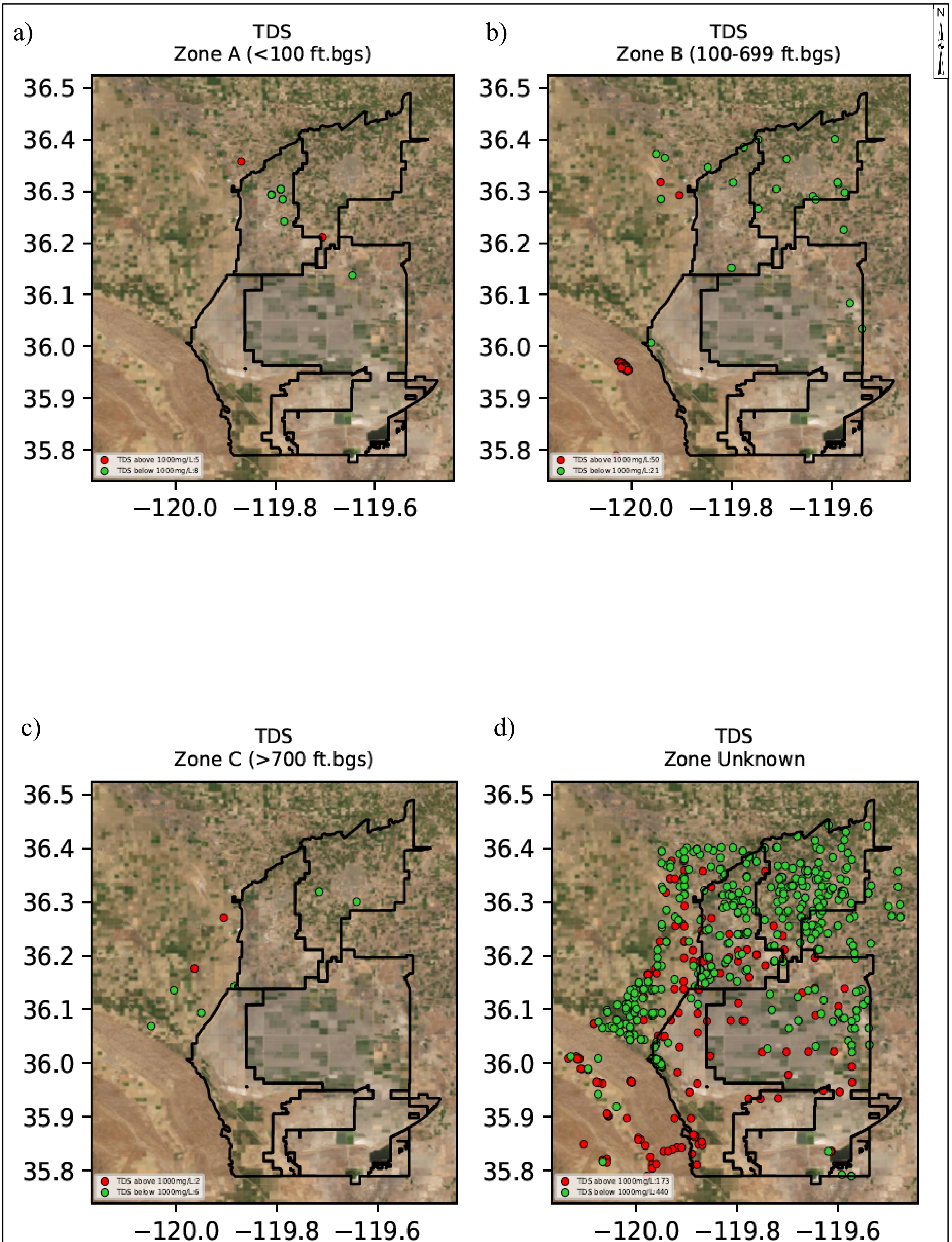
5 2½ 0 5 Miles

Management and De-designated Areas
Groundwater Sustainability Plan Addendum
Tulare Lake Subbasin, Kings County, California

Geosyntec consultants

Project No.: SFO138 | June 2022

Figure 4-1



Legend

- TDS above 1000 mg/L:Well Count
- TDS below 1000 mg/L:Well Count

a) Wells screened above 100 ft bgs
b) Wells screened between 100-699 ft bgs
c) Wells screened below 700 ft bgs
d) Wells with unknown screen interval

Notes

ft. bgs = Feet Below Ground Surface
TDS = Total Dissolved Solids
mg/L = milligrams per liter
Data retrieved from State Water Resources Control Board GAMA database.

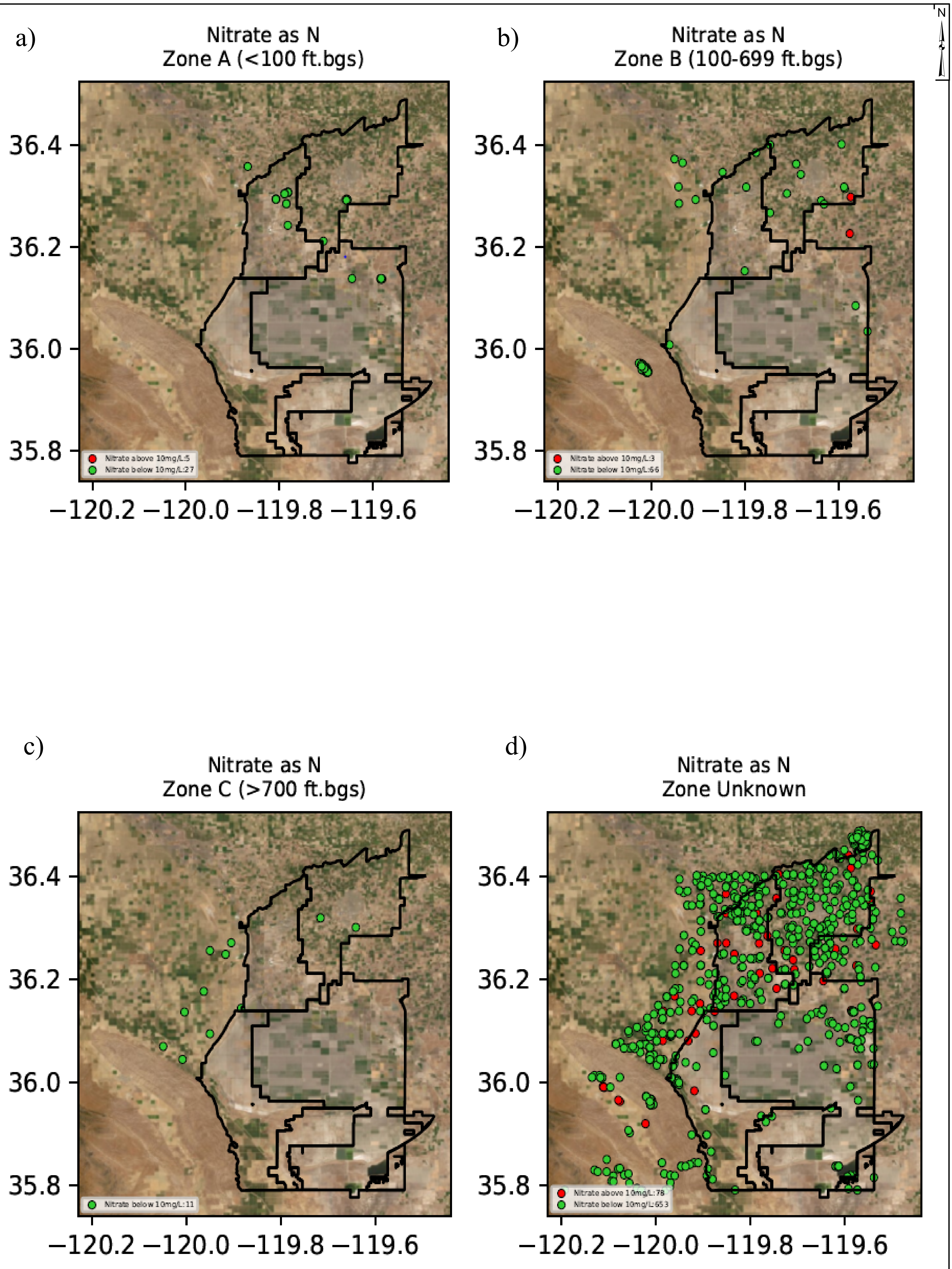
Historic Distribution of TDS Within Tulare Lake Subbasin

Groundwater Sustainability Plan Addendum
Tulare Lake Subbasin, Kings County

Geosyntec consultants

Project No.: SFO138 | June 2022

Figure 4-2



Legend

- Nitrate above 10 mg/L:Well Count
- Nitrate below 10 mg/L:Well Count

a) Wells screened above 100 ft bgs
b) Wells screened between 100-699 ft bgs
c) Wells screened below 700 ft bgs
d) Wells with unknown screen interval

Notes

ft. bgs = Feet Below Ground Surface
N = Nitrogen
mg/L = milligrams per liter
Data retrieved from State Water Resources Control Board GAMA database.

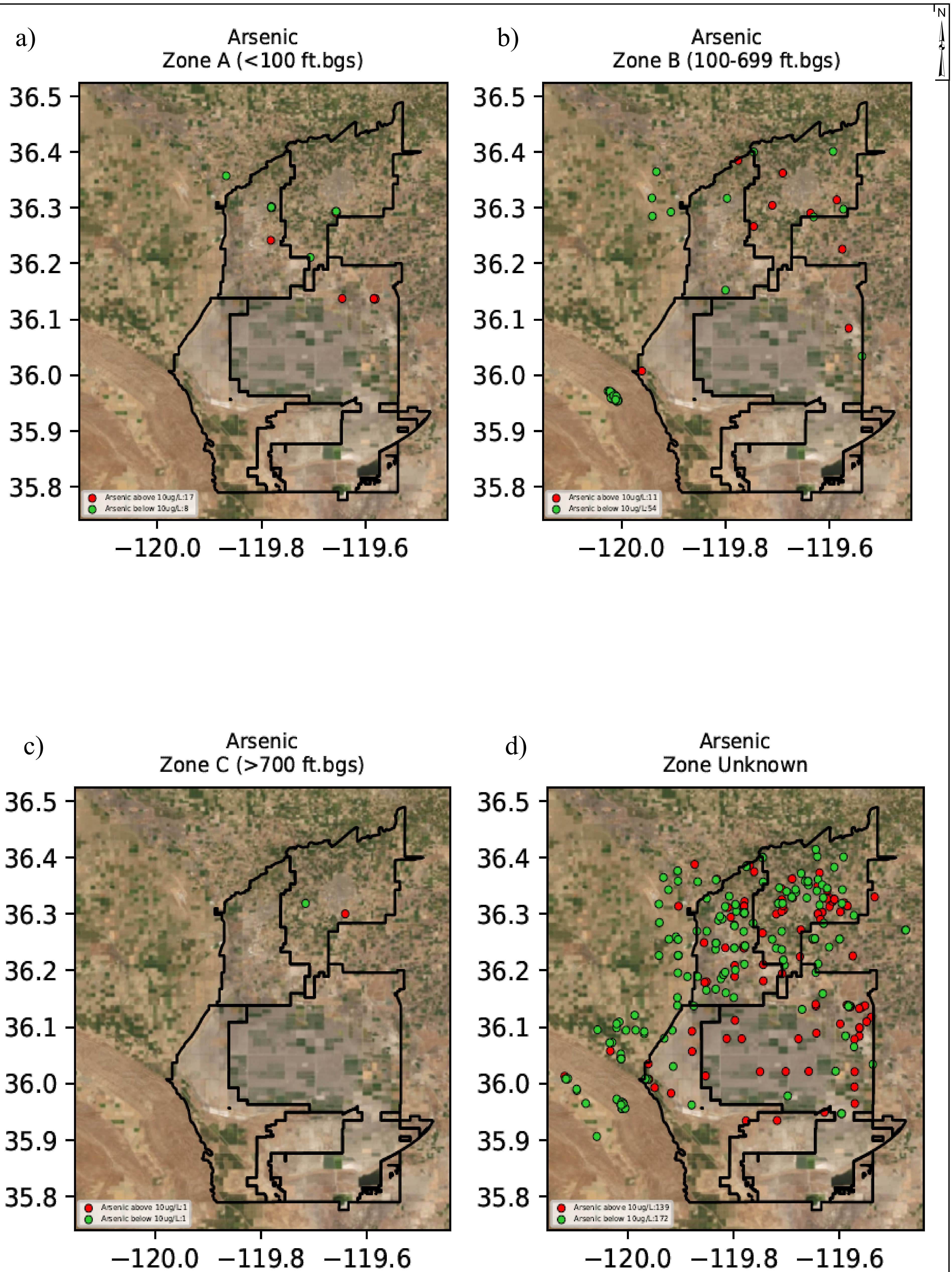
Historic Distribution of Nitrate Within Tulare Lake Subbasin

Groundwater Sustainability Plan Addendum
Tulare Lake Subbasin, Kings County

Geosyntec consultants

Project No.: SFO138 | June 2022

Figure 4-3



Legend

- Arsenic above 10 ug/L:Well Count
- Arsenic below 10 ug/L:Well Count

a) Wells screened above 100 ft bgs
b) Wells screened between 100-699 ft bgs
c) Wells screened below 700 ft bgs
d) Wells with unknown screen interval

Notes

ft. bgs = Feet Below Ground Surface
ug/L = micrograms per liter
Data retrieved from State Water Resources Control Board GAMA database.

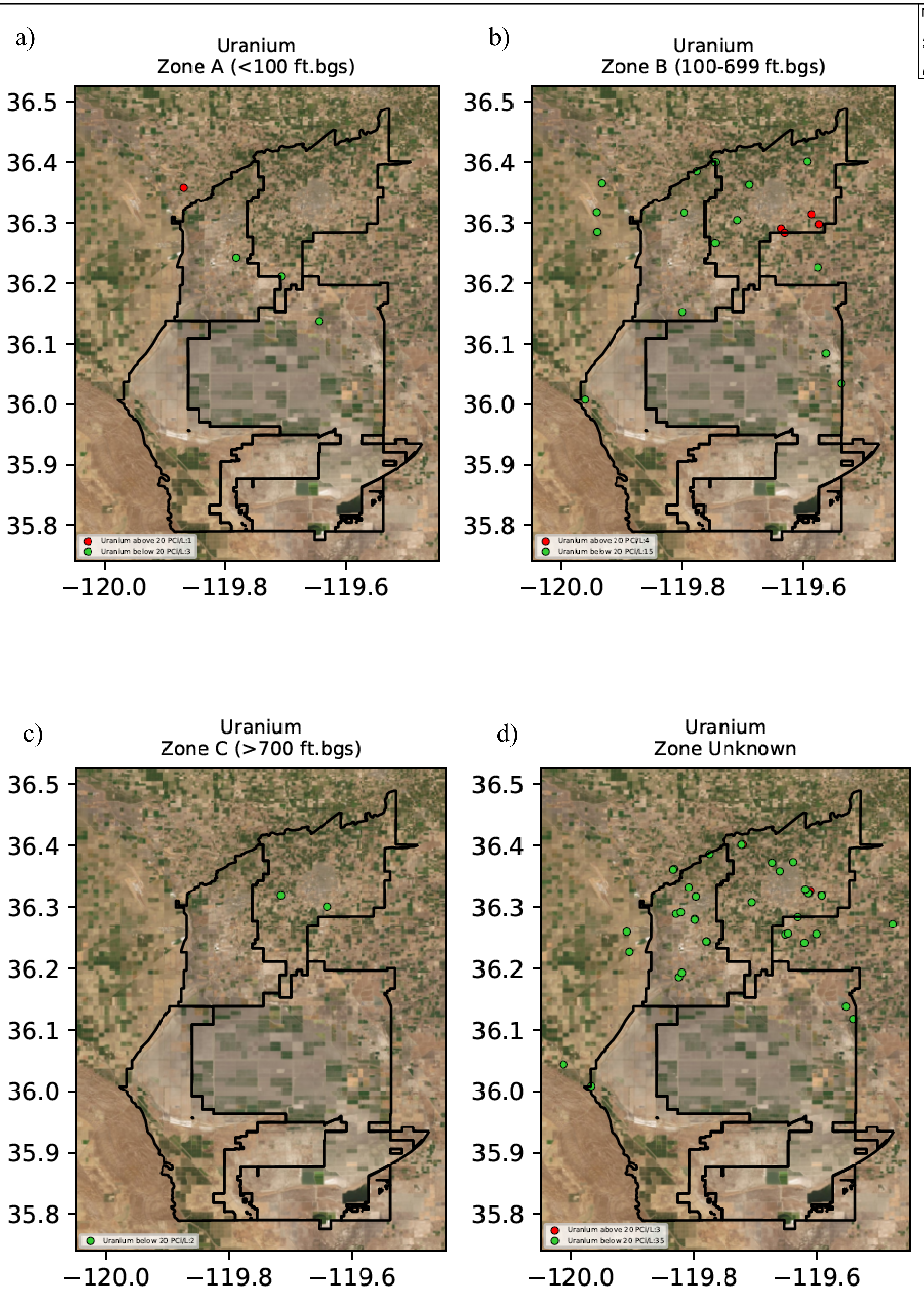
Historic Distribution of Arsenic Within Tulare Lake Subbasin

Groundwater Sustainability Plan Addendum
Tulare Lake Subbasin, Kings County

Geosyntec consultants

Project No.: SFO138 | June 2022

Figure 4-4



Legend

- Uranium above 20 pCi/L:Well Count
- Uranium below 20 pCi/L:Well Count

a) Wells screened above 100 ft bgs
b) Wells screened between 100-699 ft bgs
c) Wells screened below 700 ft bgs
d) Wells with unknown screen interval

Notes

ft. bgs = Feet Below Ground Surface
pCi/L = picocuries per liter
Data retrieved from State Water Resources Control Board GAMA database.

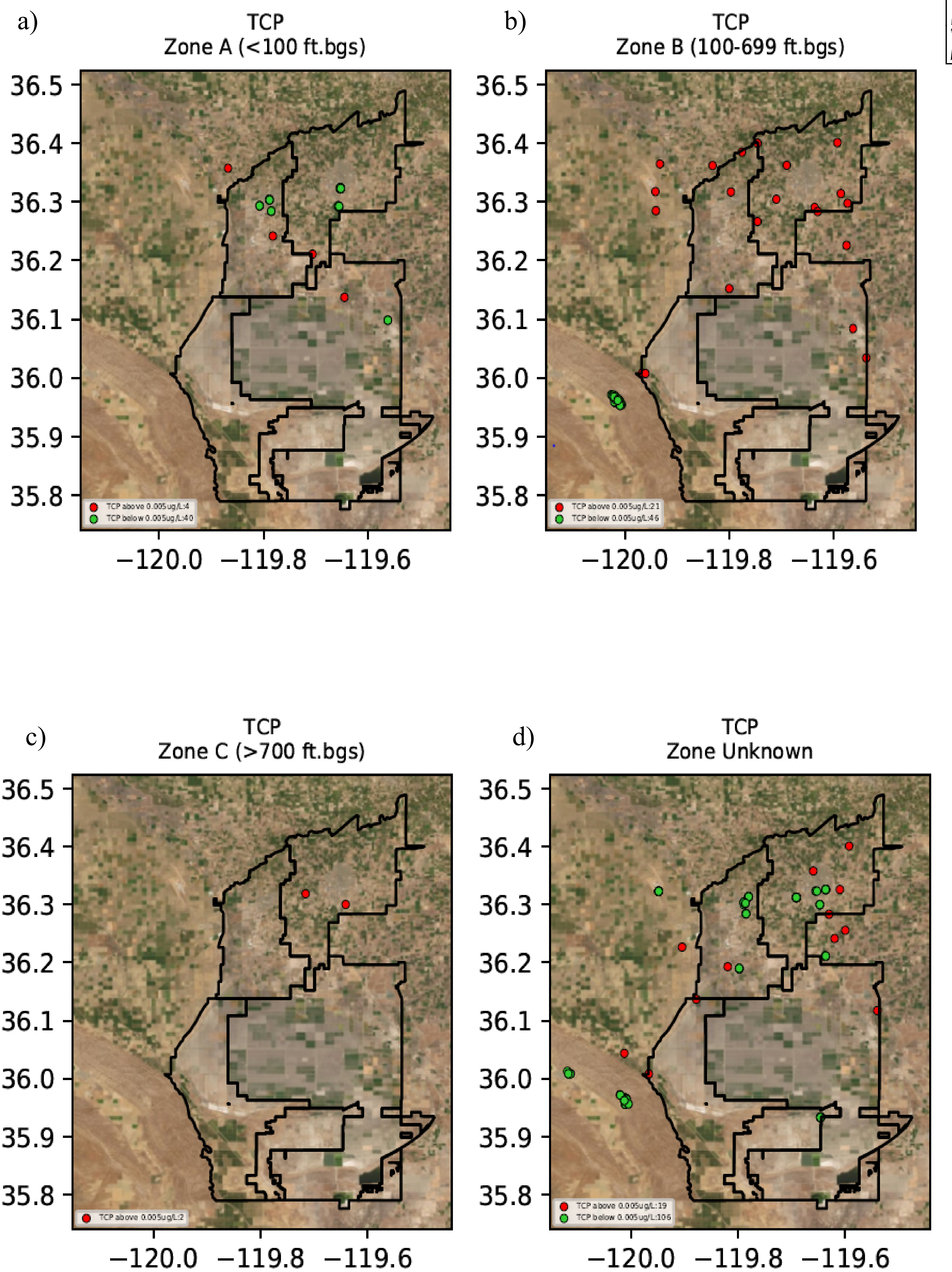
Historic Distribution of Uranium Within Tulare Lake Subbasin

Groundwater Sustainability Plan Addendum
Tulare Lake Subbasin, Kings County

Geosyntec consultants

Project No.: SFO138 | June 2022

Figure 4-5



Legend

- TCP above 0.005 ug/L:Well Count
- TCP below 0.005 ug/L:Well Count

a) Wells screened above 100 ft bgs
b) Wells screened between 100-699 ft bgs
c) Wells screened below 700 ft bgs
d) Wells with unknown screen interval

Notes

ft. bgs = Feet Below Ground Surface
TCP = 1,2,3-Trichloropropane
ug/L = micrograms per liter
Data retrieved from State Water Resources Control Board GAMA database.

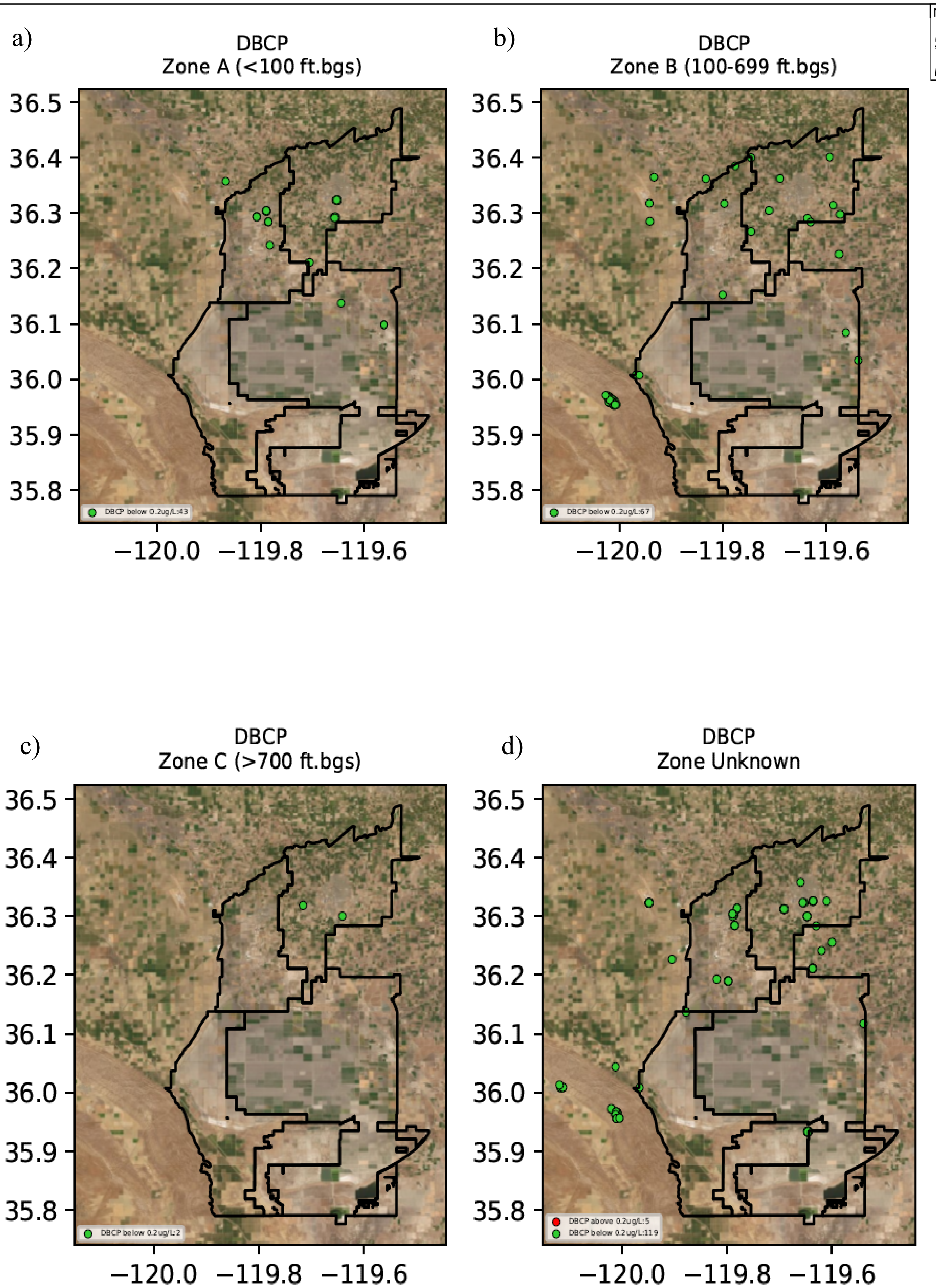
Historic Distribution of TCP Within Tulare Lake Subbasin

Groundwater Sustainability Plan Addendum
Tulare Lake Subbasin, Kings County

Geosyntec consultants

Project No.: SFO138 | June 2022

Figure 4-6



Legend

- DBCP above 0.2 ug/L:Well Count
- DBCP below 0.2 ug/L:Well Count

a) Wells screened above 100 ft bgs
b) Wells screened between 100-699 ft bgs
c) Wells screened below 700 ft bgs
d) Wells with unknown screen interval

Notes

ft. bgs = Feet Below Ground Surface
DBCP = 1,2-Dibromo-3-chloropropane
ug/L = micrograms per liter
Data retrieved from State Water Resources Control Board GAMA database.

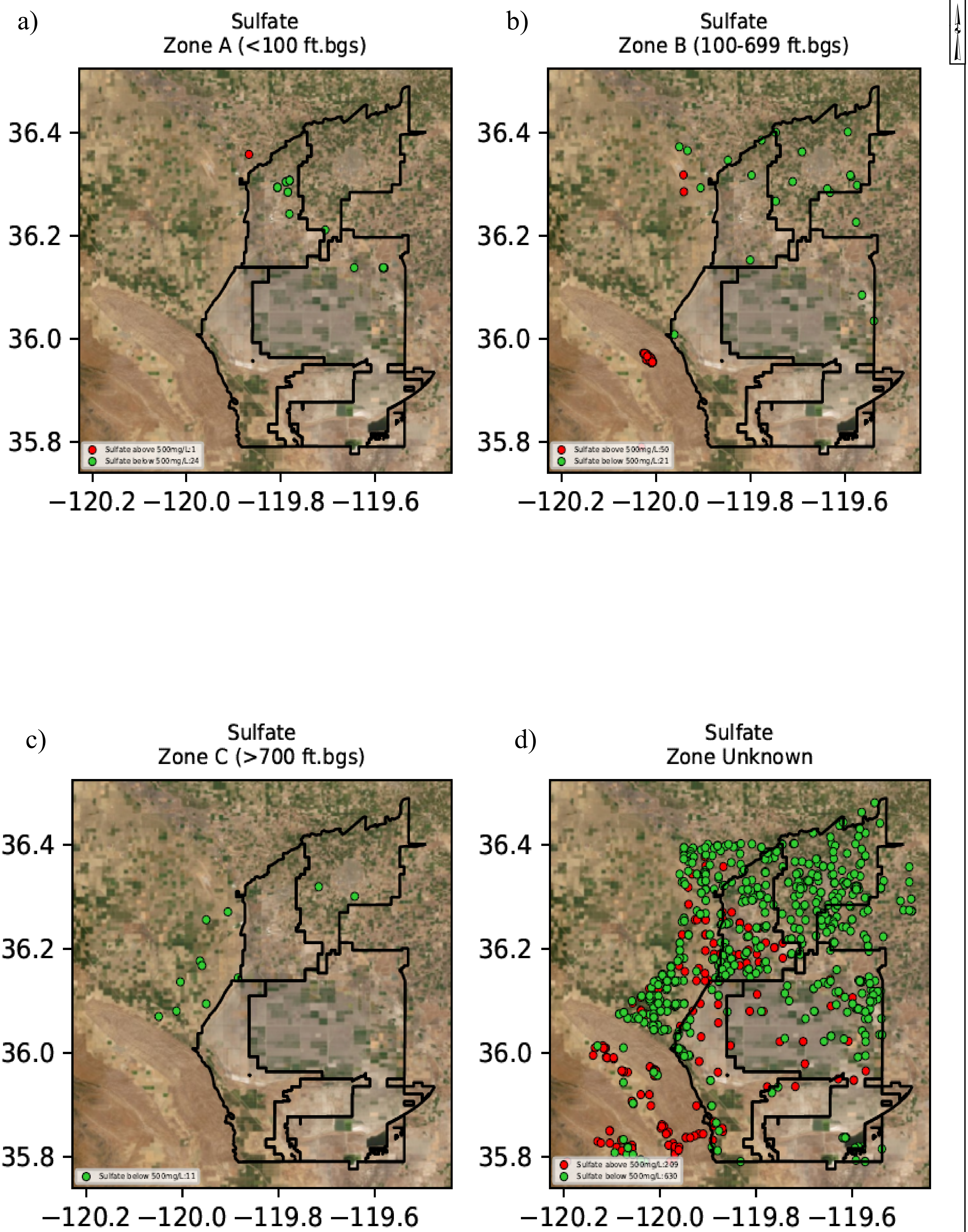
Historic Distribution of DBCP Within Tulare Lake Subbasin

Groundwater Sustainability Plan Addendum
Tulare Lake Subbasin, Kings County

Geosyntec consultants

Project No.: SFO138 | June 2022

Figure 4-7



Legend

- Sulfate above 500 mg/L:Well Count
- Sulfate below 500 mg/L:Well Count

a) Wells screened above 100 ft bgs
b) Wells screened between 100-699 ft bgs
c) Wells screened below 700 ft bgs
d) Wells with unknown screen interval

Notes

ft. bgs = Feet Below Ground Surface
mg/L = milligram per liter
Data retrieved from State Water Resources Control Board GAMA database.

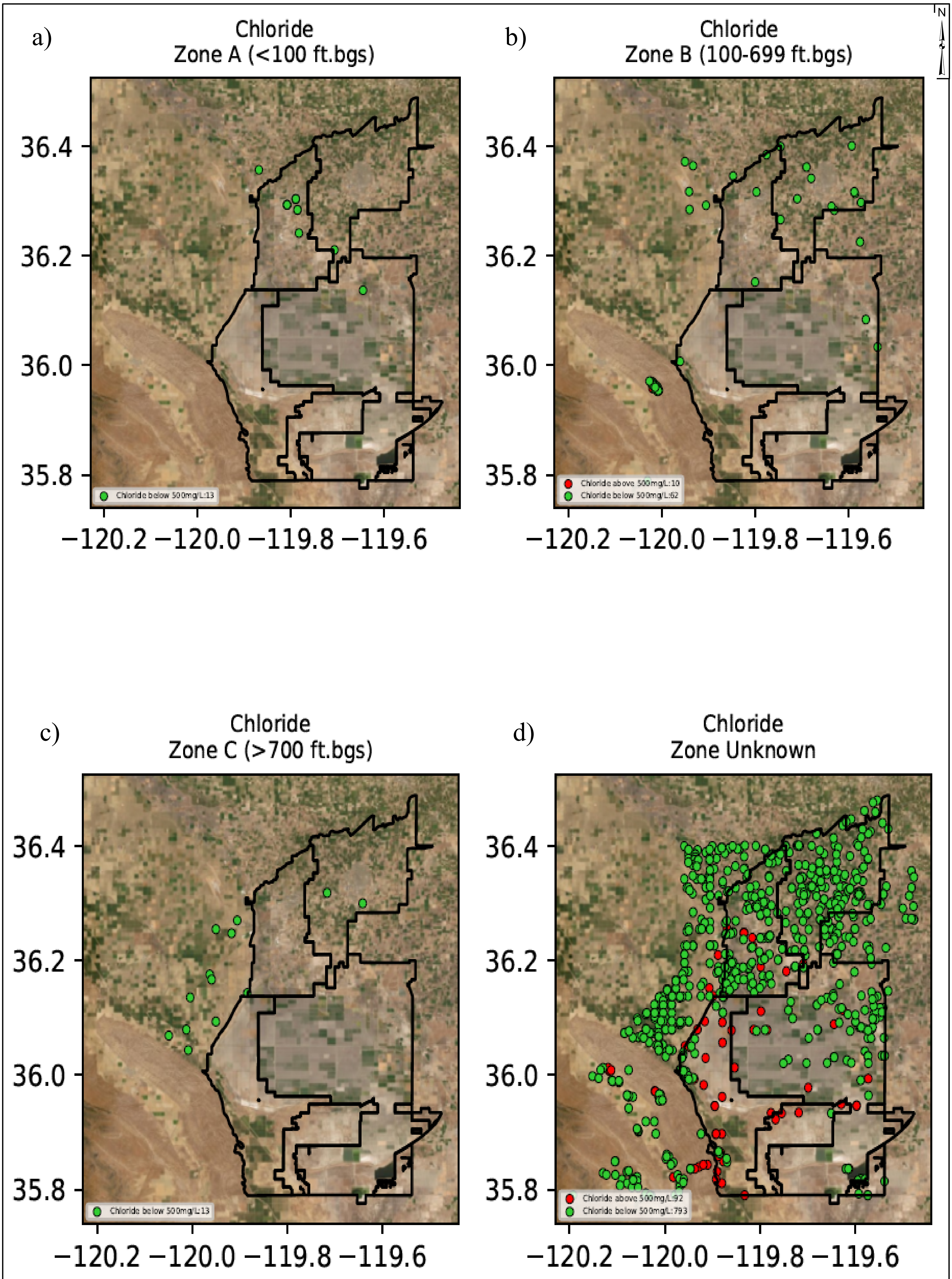
Historic Distribution of Sulfate Within Tulare Lake Subbasin

Groundwater Sustainability Plan Addendum
Tulare Lake Subbasin, Kings County

Geosyntec consultants

Project No.: SFO138 | June 2022

Figure 4-8



Legend

- Chloride above 500 mg/L: Well Count
- Chloride below 500 mg/L:Well Count

a) Wells screened above 100 ft bgs
b) Wells screened between 100-699 ft bgs
c) Wells screened below 700 ft bgs
d) Wells with unknown screen interval

Notes

ft. bgs = Feet Below Ground Surface
mg/L = milligram per liter
Data retrieved from State Water Resources Control Board GAMA database.

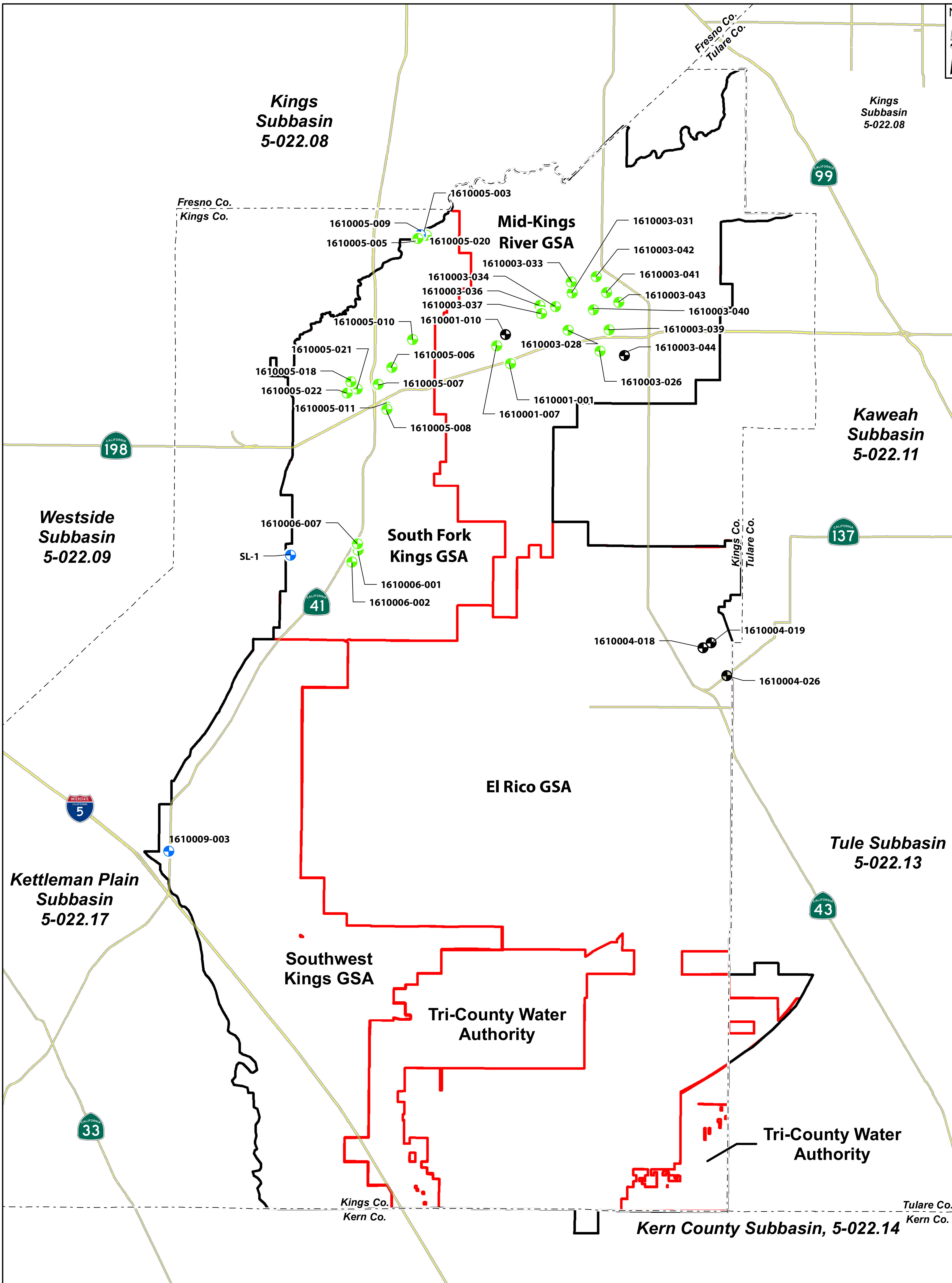
Historic Distribution of Chloride Within Tulare Lake Subbasin

Groundwater Sustainability Plan Addendum
Tulare Lake Subbasin, Kings County

Geosyntec consultants

Figure 4-9

Project No.: SFO138 | June 2022



Legend

- Tulare Lake Subbasin 5-022.12
- GSA_Master
- Highways
- County lines

Aquifer Zone

- Unknown
- B Zone
- C Zone

Groundwater Quality Monitoring Points

Groundwater Sustainability Plan Addendum

Tulare Lake Subbasin, Kings County, California

Geosyntec consultants

Figure 4-10

Project No.: SFO138

June 2022

P:\GIS\SFO138 - Tulare Lake GSP Update 2022\Projects\RMS WQ monitoring points\Fig4-10_RMS WQ Monitoring Points.mxd 6/3/2022 12:18:57 PM (Author: SPrice)

TABLES

Table 2-1
Summary of Map Zones Based on E-Clay Elevation
Tulare Lake Subbasin GSP Addendum

E-Clay Elevation				
Map Color Zone		Upper Elev	Mid Point	Lower Elev
E-zone 1	Brown	100	150	200
E-Zone 2	Red	0	50	100
E-Zone 3	Orange	-100	-50	0
E-Zone 4	Lime	-200	-150	-100
E-Zone 5	Green	-300	-250	-200
E-Zone 6	Turquiose	-400	-350	-300
E-zone 7	Blue	-500	-450	-400
E-Zone 8	Purple	-600	-550	-500
E-zone 9	Magenta	-700	-650	-600

Notes:
E- Clay = Corcoran Clay
Elev = Elevation

Table 2-2

Summary of OSCWR Database Query for Public, Domestic, Agricultural, and Industrial Purpose of Use

Tulare Lake Subbasin GSP Addendum

E-Clay Zone		Domestic/Public Well Count	Ag/Industrial Well Count	Total By E-Zone
Brown	E-zone 1	43	48	91
Red	E-Zone 2	178	248	426
Orange	E-Zone 3	528	488	1016
Lime	E-Zone 4	561	417	978
Green	E-Zone 5	970	1113	2083
Turquiose	E-Zone 6	191	371	562
Blue	E-zone 7	12	107	119
Purple	E-Zone 8	3	14	17
Magenta	E-zone 9	3	4	7
TOTAL		2489	2810	5299
Aquifer		Domestic/Public Well Count	Ag/Industrial Well Count	Total By Aquifer
A-Zone	<100' Depth	377	579	956
B-Zone	100'-700' Depth	2048	1593	3641
C-Zone	> 700' Depth	64	638	702
		2489	2810	5299

Notes:
Ag = Agricultural
E- Clay = Corcoran Clay
OSCWR = Online System of Well Completion Reports

Table 2-3

Summary of Well Completion Depths for Public/Domestic Wells in the C-Zone

Tulare Lake Subbasin GSP Addendum

E-Clay Zone		Dom/Public Well Count	Avg. Completion Elevation	Max Completion Elevation	Min Completion Elevation
Brown	E-zone 1	0	NA	NA	NA
Red	E-Zone 2	0	NA	NA	NA
Orange	E-Zone 3	4	4	-885	-471
Lime	E-Zone 4	15	15	-1223	-564
Green	E-Zone 5	24	24	-1007	-495
Turquiose	E-Zone 6	20	20	-679	-489
Blue	E-zone 7	1	1	-879	-879
Purple	E-Zone 8	0	NA	NA	NA
Magenta	E-zone 9	0	NA	NA	NA
TOTAL		64			

Notes:
Avg = Average
Dom = Domestic
E- Clay = Corcoran Clay
Max = Maximum
Min = Minimum
NA = Not Available

Table 2-4

Summary of Well Completion Depths for Public/Domestic Wells in the B-Zone

Tulare Lake Subbasin GSP Addendum

E-Clay Zone		Dom/Public Well Count	Avg. Completion Elevation	Max Completion Elevation	Min Completion Elevation
Brown	E-zone 1	39	98	187	-115
Red	E-Zone 2	170	56	182	-335
Orange	E-Zone 3	510	6	158	-333
Lime	E-Zone 4	509	-5	150	-434
Green	E-Zone 5	697	-18	142	-473
Turquiose	E-Zone 6	110	-182	120	-491
Blue	E-zone 7	8	-349	-228	-476
Purple	E-Zone 8	3	-106	-37	-216
Magenta	E-zone 9	2	-60	13	-134
TOTAL		2048			

Notes:
Avg = Average
Dom = Domestic
E- Clay = Corcoran Clay
Max = Maximum
Min = Minimum

Table 2-5

Summary of Well Completion Depths for Public/Domestic Wells in the A-Zone

Tulare Lake Subbasin GSP Addendum

E-Clay Zone		Dom/Public Well Count	Avg. Completion Elevation	Max Completion Elevation	Min Completion Elevation
Brown	E-zone 1	4	222	242	195
Red	E-Zone 2	8	211	272	165
Orange	E-Zone 3	14	180	217	157
Lime	E-Zone 4	37	169	200	146
Green	E-Zone 5	249	173	238	125
Turquiose	E-Zone 6	61	169	200	99
Blue	E-zone 7	3	129	147	96
Purple	E-Zone 8	0	NA	NA	NA
Magenta	E-zone 9	1	133	133	133
TOTAL		377			

Notes:

Avg = Average

Dom = Domestic

E- Clay = Corcoran Clay

Max = Maximum

Min = Minimum

NA = Not Available

Table 2-6
Summary of Well Completion Percentiles for Public/Domestic Wells in the B-Zone
Tulare Lake Subbasin GSP Addendum

E-Clay Zone		Dom/Public Well Count	MT Elevation Percentile Level				
			50%	60%	70%	80%	90%
Brown	E-zone 1	16	99	115	118	123	127
Red	E-Zone 2	68	56	67	85	88	104
Orange	E-Zone 3	358	18	34	47	53	56
Lime	E-Zone 4	384	11	28	39	43	48
Green	E-Zone 5	586	15	30	39	44	46
Turquiose	E-Zone 6	98	-210	-109	-37	-16	-1
Blue	E-zone 7	8	-336	-333	-275	-241	-233
Purple	E-Zone 8	3	-60	-54	-48	-45	-42
Magenta	E-zone 9	2	-46	-31	-16	-9	-2
TOTAL		1523					
Kings River Area		Dom/Public Well Count	MT Depth Percentile Level				
			50%	60%	70%	80%	90%
River Zone	R-Zone	61	60	60	70	76.8	85.5

Notes:
Dom = Domestic
E- Clay = Corcoran Clay
MT = Minimum Threshold
R-Zone = River Zone

Table 2-7
Summary of Potential Well Failures in the B-Zone by Percentile
Tulare Lake Subbasin GSP Addendum

E-Clay Zone		Dom/Public Well Count	**MT Elevation Potential Well Fails**				
			50%	60%	70%	80%	90%
Brown	E-zone 1	16	6	5	3	2	2
Red	E-Zone 2	68	27	20	14	10	7
Orange	E-Zone 3	358	143	107	72	54	36
Lime	E-Zone 4	384	154	115	77	58	38
Green	E-Zone 5	586	234	176	117	88	59
Turquiose	E-Zone 6	98	39	29	20	15	10
Blue	E-zone 7	8	3	2	2	1	1
Purple	E-Zone 8	3	1	1	1	0	0
Magenta	E-zone 9	2	1	1	0	0	0
TOTAL		1523	609	457	305	228	152

Notes:
Dom = Domestic
E- Clay = Corcoran Clay
MT = Minimum Threshold

Table 2-8

Summary of Available Saturated Thickness in the B-Zone by Percentile

Tulare Lake Subbasin GSP Addendum

E-Clay Zone		Dom/Public Well Count	MT Elevation Available Drawdown				
			50%	60%	70%	80%	90%
Brown	E-zone 1	16	99	115	118	123	127
Red	E-Zone 2	68	56	67	85	88	104
Orange	E-Zone 3	358	18	34	47	53	56
Lime	E-Zone 4	384	111	128	139	143	148
Green	E-Zone 5	586	215	230	239	244	246
Turquiose	E-Zone 6	98	90	191	263	284	299
Blue	E-zone 7	8	64	67	125	159	167
Purple	E-Zone 8	3	440	446	452	455	458
Magenta	E-zone 9	2	554	569	584	591	598
TOTAL		1523					

Notes:

Dom = Domestic

E- Clay = Corcoran Clay

MT = Minimum Threshold

Table 2-9

Summary of Interim Minimum Thresholds (MT) for All Aquifers

Tulare Lake Subbasin GSP Addendum

E-Clay Zone		Dom/Public Well Count	Interim MT Elevation			
			A Zone	B-Zone Elev (90th Percentile)	C-Zone Elev (E-Clay + 100)	R-Zone (Depth)
Brown	E-zone 1	39	Base of A-Clay	127	200	60
Red	E-Zone 2	170		104	100	
Orange	E-Zone 3	510		56	0	
Lime	E-Zone 4	509		48	-100	
Green	E-Zone 5	697		46	-200	
Turquiose	E-Zone 6	110		-1	-300	
Blue	E-zone 7	8		-233	-400	
Purple	E-Zone 8	3		-42	-500	
Magenta	E-zone 9	2		-2	-600	
TOTAL		2048				

Notes:

Dom = Domestic

E- Clay = Corcoran Clay

MT = Minimum Threshold

R-Zone = River Zone

Table 2-10
Summary of Interim MTs for All RMS Locations
Tulare Lake Subbasin GSP Addendum

Well ID	Alternative Well ID	GSA	GSP (January 2020) GWL SMC Elevations							SMC Addendum (June 2022)								Interim MT (June 2022)		
			MO Elev	MT Elev	2017	2025	2030	2035	2040	Aquifer	E-Clay Elevation Zone		MT Elev (A-Zone)	B-Zone MT Elev (80%)	B-Zone MT Elev (90%)	MT Elev (C-Zone)	# of Public/DomWells in Section	Interim MT (Mid Pt of GSP and 90%) (Elevation)	Difference from 2020 MT (feet)	Operating range (MT-MO) (feet)
18S20E23E003M	KRCDAC1S	SFK	198.4	148.4	199.9	199.81	199.49	199.12	198.78	A							5			
19S20E29E002M		SFK	183.63	133.63	182.08	183.95	184.32	184.86	185.13	A							2			
20S19E25A003M		SFK	199.21	149.21	197.05	200.17	198.83	199.87	200.39	A							0			
AG-1		SFK	--	--	--	--	--	--	--	A							3			
18S21E17N001M		MKR	213.38	163.38	217.33	215.97	214.35	213.67	213.96	A							6			
MW-A		MKR	--	--	--	--	--	--	--	B	E-Zone 1	Brown		84	86		6			
18S22E24D001M		MKR	95.97	45.97	107.86	103.33	98.74	97.17	96.82	B	E-Zone 1	Brown		84	86		3	66	20	30
18S22E03B001M		MKR	134.48	84.48	138.88	139.13	134.6	135.56	135.8	B	E-Zone 1	Brown		84	86		4	85	1	49
17S22E28A001M	KRCDKCWD01	MKR	156.77	106.77	170.05	158.71	151.21	158.75	152.68	B	E-Zone 1	Brown		84	86		6	96	-10	60
MWG INT		MKR	181.23	131.23	184.21	183.5	182.38	184.26	182.74	B	E-Zone 1	Brown		84	86		1	109	-23	73
MWD INT		MKR	191.22	141.22	185.58	191.51	186.29	194.26	188.87	B	E-Zone 1	Brown		84	86		4	114	-28	78
MW-C		MKR	--	--	--	--	--	--	--	B	E-Zone 1	Brown		84	86		3	NA	NA	NA
18S22E34R001M		MKR	144.38	94.38	123.5	151	147.01	145.74	145.1	B	E-Zone 3	Orange		41	53		13	74	-21	71
MWH INT		MKR	110.17	60.17	115.63	117.87	113.63	110.76	109.24	B	E-Zone 3	Orange		41	53		13	57	-4	54
18S22E28A001M	KRCDKCWD08	MKR	95.97	45.97	107.89	103.33	98.74	97.17	96.82	B	E-Zone 3	Orange		41	53		5	49	4	46
1610005-009	18S20E11C002M	SFK	31.3	-18.7	56.38	45.6	33.46	25.94	19	B	E-Zone 5	Green		34	44		2	13	31	19
18S20E23E001M	KRCDAC1D	SFK	26.39	-23.61	51.36	42.78	33.85	25.91	17.82	B	E-Zone 5	Green		34	44		5	10	34	16
18S20E23E002M	KRCDAC1M	SFK	28.42	-21.58	53.89	44.81	35.89	27.95	19.86	B	E-Zone 5	Green		34	44		5	11	33	17
18S20E34N001M		SFK	68.17	18.17	110.82	82.17	75.93	69.21	61.6	B	E-Zone 5	Green		34	44		8	31	13	37
19S20E06D004M		SFK	--	--	--	--	--	--	--	B	E-Zone 5	Green		34	44		0	34	NA	NA
LR-19		SFK	--	--	--	--	--	--	--	B	E-Zone 5	Green		34	44		3	34	NA	NA
LR-18		SFK	--	--	--	--	--	--	--	B	E-Zone 5	Green		34	44		4	34	NA	NA
LR-4		SFK	--	--	--	--	--	--	--	B	E-Zone 5	Green		34	44		3	34	NA	NA
ER_CID_05		El Rico	--	--	--	--	--	--	--	B	E-Zone 5	Green		34	44		0	34	NA	NA
18S21E07R003M		MKR	195.06	145.06	216.92	209.68	200.89	194.34	187.38	B	E-Zone 5	Green		34	44		5	95	-51	101
18S21E31B001M		MKR	67.13	17.13	89.1	81.91	74.48	67.74	59.76	B	E-Zone 5	Green		34	44		7	31	13	37
18S21E27B001M	KRCDKCWD05	MKR	70	20	100.88	87.71	73.98	66.05	59.51	B	E-Zone 5	Green		34	44		13	32	12	38
19S20E32D002M	KRCDAC3M	SFK	-26.91	-76.91	2.94	-15.48	-21.41	-26.36	-32.5	B	E-Zone 6	Turquiose		-41	-5		0	-41	36	14
20S20E26L001M	KRCDAC5M	SFK	45.75	-4.25	52.71	51.59	48.64	46.38	42.63	B	E-Zone 6	Turquiose		-41	-5		3	-5	0	50
CID-071		El Rico	--	--	--	--	--	--	--	B	E-Zone 6	Turquiose		-41	-5		0	-41	NA	NA
SL-1		SFK	--	--	--	--	--	--	--	B	E-Zone 7	Blue		-275	-233		0	-275	NA	NA
1610009-003	Becky Pease Well	SWK	70.58	20.58	78	72.98	72.02	71.04	69.9	B	E-Zone 7	Blue		-275	-233		1	-106	-127	177
MWD DEEP		MKR	158.78	108.78	171.8	175.25	141.09	133.72	146.97	B	E-Zone 3	Orange		41	53		1	54	-54	104
MWG DEEP		MKR	132.82	82.82	151.18	150.45	117.77	108.79	121.59	B	E-Zone 3	Orange		41	53		1	41	-41	91
19S20E26N002M	CU ELEMENTARY SCHOO	SFK	-3.81	-53.81	41.56	18.16	-2.91	-26.38	-14.88	B	E-Zone 6	Turquiose		-41	-5		1	-27	27	23
19S21E30A001M	KRCDKCWD06	MKR	185.18	135.18	202.24	196.33	190.78	185.96	179.82	C	E-Zone 5	Green				-200	2	68	-68	118
19S20E32D003M	KRCDAC3D	SFK	-26.91	-76.91	-7.68	-15.48	-21.41	-26.36	-32.5	C	E-Zone 6	Turquiose				-300	0	-38	38	12
20S20E26L002M	KRCDAC5D	SFK	-19.25	-69.25	-12.95	-13.4	-16.35	-18.61	-22.36	C	E-Zone 6	Turquiose				-300	3	-35	35	15
MWH DEEP		MKR	38.47	-11.53	26.8	67.29	33.5	10.96	22.8	C	E-Zone 3	Orange				0	13	-6	6	44
FB 35-2		TCWA	--	--	--	--	--	--	--	C	E-Zone 4	Lime				-100	0	-100	NA	NA
ER_CID-01		El Rico	--	--	--	--	--	--	--	C	E-Zone 4	Lime				-100	2	-100	NA	NA
19S22E08D002M		MKR	-39.5	-89.5	62.1	-12.1	-42.77	-63.99	-55.37	C	E-Zone 4	Lime				-100	13	-95	-5	55
1610005-020	18S20E11C003M	SFK	7.21	-42.79	43.24	22.11	0.63	-6.76	-9.05	C	E-Zone 5	Green				-200	2	-121	-79	129
19S20E06D005M		SFK	--	--	--	--	--	--	--	C	E-Zone 5	Green				-200	0	-200	NA	NA
1610005-011	1610005-011	SFK	-91.02	-141.02	-42.55	-71.85	-97	-114.74	-112.99	C	E-Zone 5	Green				-200	0	-171	-29	79
ZE 33-4		TCWA	--	--	--	--	--	--	--	C	E-Zone 5	Green				-200	0	-200	NA	NA
ER_CID-081		El Rico	--	--	--	--	--	--	--	C	E-Zone 5	Green				-200	1	-200	NA	NA
KRCDTL002		El Rico	7.43	-42.57	55.1	39.51	20.23	-24.08	15.7	C	E-Zone 5	Green				-200	0	-121	-79	129
20S19E02A001M		SFK	-67.47	-117.47	-30.6	-48.13	-72.04	-91.94	-89.9	C	E-Zone 6	Turquiose				-300	0	-209	-91	141
20S20E07H001M		SFK	-102.74	-152.74	-4.83	-82.67	-100.16	-126.98	-112.22	C	E-Zone 6	Turquiose				-300	2	-226	-74	124
20S20E28E003M		SFK	-41.13	-91.13	-56.13	-23.02	-37.11	-61.17	-43.32	C	E-Zone 6	Turquiose				-300	2	-196	-104	154
ER_S-173		El Rico	-192.36	-242.36	-60.83	-146.83	-153.7	-170.02	-142	C	E-Zone 6	Turquiose				-300	0	-271	-29	79
ER_S-225		El Rico	-208.49	-258.49	-150.47	-184.98	-191.7	-201.67	-167.46	C	E-Zone 6	Turquiose				-300	0	-279	-21	71
KRCDTL003		El Rico	-153.55	-203.55	-106.5	-126.62	-143.64	-174.74	-144.25	C	E-Zone 6	Turquiose				-300	0	-252	-48	98
Well 16-8		SWK	50.96	0.96	63.83	62.42	48.13	47.85	41.71	C	E-Zone 7	Blue				-400	0	-200	-200	250
ER_S-205		El Rico	-280.27	-330.27	-239.05	-226.83	-233.7	-250.02	-222	C	E-Zone 7	Blue				-400	0	-365	-35	85
21S22E07J001M		El Rico	--	--	--	--	--	--	--	C	E-Zone 7	Blue				-400	1	-400	NA	NA

Notes:
E- Clay = Corcoran Clay
GSA = Groundwater Sustainability Agency
GWL = Groundwater Level
ID = Identification
MO = Measurable Objective
MT = Minimum Threshold
SMC = Sustainable Management Criteria

Operating range is less than 20 feet of operating range

Table 3-1
Infrastructure Impacts from Subsidence
Groundwater Sustainability Plan - Addendum
Tulare Lake Subbasin

Type of Infrastructure	Length or Number within 3 miles of TLSB	Possible Impacts to Infrastructure from Subsidence
Canals	1,891 miles	- Decrease in regional or localized slope of the channel that leads to decreased ability to convey flow. - For lined canals, differential vertical movement that causes cracking in lining, which could result in decreased ability to convey flow.
Aqueduct	25.1 miles	
Flood Protection Levees	102 miles	- Decrease in the elevation of the top of the levee with respect to the elevation of the flood water that it is designed to contain
		- Differential vertical movement that causes cracking/break in levee, which could result in decreased ability to contain water.
Pipelines	47 miles	- Differential vertical movement between points that induces axial strain exceeding strain capacity.
High Speed Rail Lines	42 miles	- Differential vertical movement that causes cracking, which could result in unsafe driving conditions.
Buildings (i.e., emergency facilities)	29	- Differential vertical movement between foundation locations that causes distress in structural members or inoperability of equipment housed in the building.
Bridges	222	- Differential vertical movement between piers and abutments that could lead to increased stress in structural members
Roads	4,380 miles	- Differential vertical movement that causes pavement/embankment cracking, which could result in unsafe driving conditions.
Airports	1	
Rail Lines	83 miles	
Water Wells	5,474	- Drag loads that exceed the capacity of the well leading to well failure

Notes:
TLSB = Tulare Lake Subbasin

Table 3-2
Vertical Displacement at RMS Locations
Groundwater Sustainability Plan - Addendum
Tulare Lake Subbasin

Monitoring Station	Baseline	With GSP Implementation
CRCN	11.07	4.34
LEMA	8.98	3.70
SUB001 [2]	Limited data	1.60
SUB002 [2]	Limited data	1.60
SUB023	2.41	1.91
SUB027 [2]	Limited data	0.80
SUB028	8.87	4.38
SUB030 [2]	Limited data	0.70
SUB032	9.49	4.25
SUB036	5.88	2.88
SUB037	3.49	2.27
SUB038	2.61	1.83
SUB053 [2]	Limited data	1.10
SUB055	14.07	6.09
SUB061 [1]	6.35	3.37
SUB062	10.49	4.80
SUB071 [2]	Limited data	1.30
SUB076 [2]	Limited data	0.80
SUB083	12.60	5.58
SUB086	8.63	3.96
SUB093	2.87	1.81
SUB102 [1]	4.55	2.41
SUB105	7.34	3.47
SUB107 [2]	Limited data	0.70
SUB109 [1]	4.32	2.28
SUB110	no data	no data
SUB111	11.62	5.08

Notes:
1. InSAR data was incomplete. Subsidence calculations utilized available data.
2. Values for "With GSP implementation" estimated based on nearby sites due to limited data.

Table 3-3

Local Minimum Thresholds (LMT) for Differential Subsidence

Groundwater Sustainability Plan - Addendum

Tulare Lake Subbasin

Type of Infrastructure	Local Minimum Thresholds (LMT) for Differential Subsidence
Canals and Aqueduct	1/600
Flood Protection Levees	1/600
Pipelines	1/100
High Speed Rail Lines	1/80
Buildings	1/300
Bridges	1/400
Embankments for Roads, Airports, and Rail Lines	1/600

Table 4-1
Upper Tolerance Interval, Measurable Objective, and Minimum Thresholds
Groundwater Sustainability Plan - Addendum
Tulare Lake Subbasin

GSA	Well I.D.	Aquifer Zone	Units	Upper Tolerance Interval						
				TDS	Nitrate as N	Arsenic	Uranium	Sulfate	TCP	Chloride
				mg/L	mg/L	µg/L	pCi/L	mg/L	µg/L	mg/L
MKR	1610001-001	C		-	-	13.9	3.1	-	-	20.1
	1610001-007	C		-	-	51.6	-	-	-	58.8
	1610001-010	unk		-	-	23.9	-	-	-	-
	1610003-031	C		421	5	12	-	-	-	172
	1610003-039	C		487	-	10	-	-	-	223
	1610003-036	C		348	-	7	-	-	-	98
	1610003-041	C		599	-	3	-	-	-	-
	1610003-033	C		422	-	10	-	-	-	167
	1610003-040	C		500	-	5	-	4	-	175
	1610003-026	C		461	-	13	-	10	-	-
	1610003-028	C		425	-	21	-	3	-	-
	1610003-043	C		519	-	10	-	-	-	-
	1610003-042	C		616	-	-	-	-	-	243
	1610003-037	C		331	-	5	-	-	-	79
	1610003-044	unk		474.8	-	12.9	-	-	-	-
	1610003-034	C		386	1	30	-	16	-	126
SFK	1610006-001	C		839	3	7	-	-	-	-
	1610006-002	C		2452	-	-	-	436	-	80
	1610006-007	C		-	-	-	-	-	-	-
	1610005-021	C		420	-	2	-	-	-	92
	1610005-010	C		340	2	11	-	-	-	-
	1610005-003	unk		-	-	20	4	3	-	52
	1610005-022	C		449	-	0	5	1	-	98
	1610005-005	C		309	1	16	3	4	-	51
	1610005-018	C		423	-	2	2	-	-	91
	1610005-008	C		401	-	4	8	-	-	-
	1610005-006	C		382	2	7	3	10	-	77
	1610005-009	B		-	-	29	-	-	-	-
	1610005-020	C		286	-	8	4	-	-	31
	1610005-011	C		451	-	5	-	-	-	84
	SL-1	B		-	2.2	-	-	-	-	-
SWK	1610009-003	B		939	1	17	1	-	-	-
El Rico	1610004-026	unk		269	3	20	-	59	-	43
	1610004-018	unk		-	-	28	-	-	-	-
	1610004-019	unk		174	-	33	11	-	-	-

Notes:

269	Has data from 2000 to 2020
250	Data Pre-2000
-/250	No data avalable
250	New Well, <2 samples collected

Table 4-1
Upper Tolerance Interval, Measurable Objective, and Minimum Thresholds
Groundwater Sustainability Plan - Addendum
Tulare Lake Subbasin

GSA	Well I.D.	Aquifer Zone	Units	Measurable Objective						
				TDS	Nitrate as N	Arsenic	Uranium	Sulfate	TCP	Chloride
				mg/L	mg/L	µg/L	pCi/L	mg/L	µg/L	mg/L
MKR	1610001-001	C		500	7	13.9	3.1	250	0.00025	250
	1610001-007	C		500	7	51.6	14	250	0.00025	250
	1610001-010	unk		500	7	23.9	14	250	0.00025	250
	1610003-031	C		500	5	12	14	250	0.00025	250
	1610003-039	C		500	7	10	14	250	0.00025	250
	1610003-036	C		500	2	7	14	250	0.00025	250
	1610003-041	C		599	7	3	14	250	0.00025	250
	1610003-033	C		500	7	10	14	250	0.00025	250
	1610003-040	C		500	7	5	14	250	0.00025	250
	1610003-026	C		500	7	13	14	250	0.00025	250
	1610003-028	C		500	7	21	14	250	0.00025	250
	1610003-043	C		519	7	10	14	250	0.00025	250
	1610003-042	C		616	7	7	14	250	0.00025	250
	1610003-037	C		500	7	5	14	250	0.00025	250
	1610003-044	unk		474.8	7	12.9	14	250	0.00025	250
	1610003-034	C		500	1	30	14	250	0.00025	250
SFK	1610006-001	C		839	3	7	14	250	0.00025	250
	1610006-002	C		2452	7	7	14	436	0.00025	250
	1610006-007	C		500	7	7	14	250	0.00025	250
	1610005-021	C		500	7	2	14	250	0.00025	250
	1610005-010	C		500	2	11	14	250	0.00025	250
	1610005-003	unk		500	7	20	4	250	0.00025	250
	1610005-022	C		500	7	0.5	5	250	0.00025	250
	1610005-005	C		500	1	16	3	250	0.00025	250
	1610005-018	C		500	7	2	2	250	0.00025	250
	1610005-008	C		500	7	4	8	250	0.00025	250
	1610005-006	C		500	2	7	3	250	0.00025	250
	1610005-009	B		500	7	29	14	250	0.00025	250
	1610005-020	C		500	7	8	4	250	0.00025	250
	1610005-011	C		500	7	5	14	250	0.00025	250
	SL-1	B		1500	2.2	7	14	1000	0.00025	250
SWK	1610009-003	B		939	1	17	1	250	0.00025	250
El Rico	1610004-026	unk		500	3	20	14	250	0.00025	250
	1610004-018	unk		500	7	28	14	250	0.00025	250
	1610004-019	unk		500	7	33	11	250	0.00025	250

Notes:

269	Has data from 2000 to 2020
250	Data Pre-2000
-/250	No data avalable
250	New Well, <2 samples collected

Table 4-1
Upper Tolerance Interval, Measurable Objective, and Minimum Thresholds
Groundwater Sustainability Plan - Addendum
Tulare Lake Subbasin

GSA	Well I.D.	Aquifer Zone	Units	Minimum Threshold						
				TDS	Nitrate as N	Arsenic	Uranium	Sulfate	TCP	Chloride
				mg/L	mg/L	µg/L	pCi/L	mg/L	µg/L	mg/L
MKR	1610001-001	C		1000	10	13.9	20	500	0.0005	500
	1610001-007	C		1000	10	51.6	20	500	0.0005	500
	1610001-010	unk		1000	10	23.9	20	500	0.0005	500
	1610003-031	C		1000	10	56	20	500	0.0005	500
	1610003-039	C		1000	10	10	20	500	0.0005	500
	1610003-036	C		1000	10	10	20	500	0.0005	500
	1610003-041	C		1000	10	10	20	500	0.0005	500
	1610003-033	C		1000	10	69	20	500	0.0005	500
	1610003-040	C		1000	10	10	20	500	0.0005	500
	1610003-026	C		1000	19	23	20	500	0.0005	500
	1610003-028	C		1000	10	35	20	500	0.0005	500
	1610003-043	C		1000	10	10	20	500	0.0005	500
	1610003-042	C		1000	10	10	20	500	0.0005	500
	1610003-037	C		1000	10	10	20	500	0.0005	500
	1610003-044	unk		1000	10	10	20	500	0.0005	500
	1610003-034	C		1000	10	78	20	500	0.0005	500
SFK	1610006-001	C		1000	10	13	20	500	0.0005	500
	1610006-002	C		4500	10	10	20	800	0.0005	500
	1610006-007	C		1000	10	10	20	500	0.0005	500
	1610005-021	C		1000	10	10	20	500	0.0005	500
	1610005-010	C		1000	10	29	20	500	0.0005	500
	1610005-003	unk		1000	10	23	20	500	0.0005	500
	1610005-022	C		1000	10	10	20	500	0.0005	500
	1610005-005	C		1000	10	25	20	500	0.0005	500
	1610005-018	C		1000	10	10	20	500	0.0005	500
	1610005-008	C		1000	10	10	20	500	0.0005	500
	1610005-006	C		1000	10	19	20	500	0.0005	500
	1610005-009	B		1000	10	46	20	500	0.0005	500
	1610005-020	C		1000	10	11	20	500	0.0005	500
	1610005-011	C		1000	10	14	20	500	0.0005	500
	SL-1	B		1500	10	10	20	1000	0.0005	500
SWK	1610009-003	B		1000	10	23	20	500	0.0005	500
El Rico	1610004-026	unk		1000	10	32	20	500	0.0005	500
	1610004-018	unk		1000	10	38	20	500	0.0005	500
	1610004-019	unk		1000	10	33	20	500	0.0005	500

Notes:

269 Has data from 2000 to 2020
250 Data Pre-2000
-/250 No data avalable
250 New Well, <2 samples collected

Table 4-2

Groundwater Quality Network - Sampling Frequency

Groundwater Sustainability Plan - Addendum

Tulare Lake Subbasin

Well Name	GSA	Aquifer Zone	TDS	Nitrate as N	Arsenic	Uranium	Sulfate	TCP	Chloride
1610001-001	MKR	C	NA	9	9	NA	NA	9	NA
1610001-007	MKR	C	NA	9	9	NA	NA	9	NA
1610001-010	MKR	Unk	NA	1	0.25	NA	3	3	3
1610003-031	MKR	C	3	1	3	NA	3	3	3
1610003-039	MKR	C	3	1	3	NA	3	3	3
1610003-036	MKR	C	3	2	3	NA	3	3	3
1610003-041	MKR	C	3	1	3	NA	3	3	3
1610003-033	MKR	C	3	1	3	NA	3	3	3
1610003-040	MKR	C	3	1	3	NA	3	3	3
1610003-026	MKR	C	NA	9	3	NA	NA	9	NA
1610003-028	MKR	C	NA	1	3	NA	3	3	3
1610003-043	MKR	C	3	1	3	NA	3	3	3
1610003-042	MKR	C	3	1	3	NA	3	3	3
1610003-037	MKR	C	3	1	3	NA	3	3	3
1610003-044	MKR	Unk	3	1	3	NA	3	3	3
1610003-034	MKR	C	3	1	3	NA	3	3	3
1610006-001	SFK	C	1	1	3	3	3	3	3
1610006-002	SFK	C	NA	DUE	9	NA	NA	9	NA
1610006-007	SFK	C	1	1	3	NA	3	0.25	3
1610005-021	SFK	C	3	1	0.25	NA	3	3	3
1610005-010	SFK	C	3	1	0.25	NA	3	3	3
1610005-003	SFK	unk	NA	9	9	NA	NA	9	NA
1610005-022	SFK	C	3	1	0.25	NA	3	3	3
1610005-005	SFK	C	3	1	0.25	NA	3	3	3
1610005-018	SFK	C	3	1	0.25	NA	3	3	3
1610005-008	SFK	C	NA	9	0.25	NA	NA	9	NA
1610005-006	SFK	C	3	1	0.25	NA	3	3	3
1610005-009	SFK	B	3	1	0.25	NA	3	3	3
1610005-020	SFK	C	3	1	0.25	NA	3	3	3
1610005-011	SFK	C	3	1	0.25	NA	3	3	3
SL-1	SFK	B	2	2	2	2	2	2	2
1610009-003	SWK	B	NA	9	9	9	NA	9	NA
1610004-026	ELR	Unk	3	1	0.25	NA	3	3	3
1610004-018	ELR	Unk	3	1	0.25	NA	3	3	3
1610004-019	ELR	Unk	3	1	3	NA	3	3	3

Notes:

DUE = Sampling Event due

GSA = Groundwater Sustainability Agency

MKR = Mid-Kings River GSA

NA = Not Available

SFK = South Fork Kings GSA

SWK = Southwest Kings GSA

Unk = Unknown Aquifer Zone.

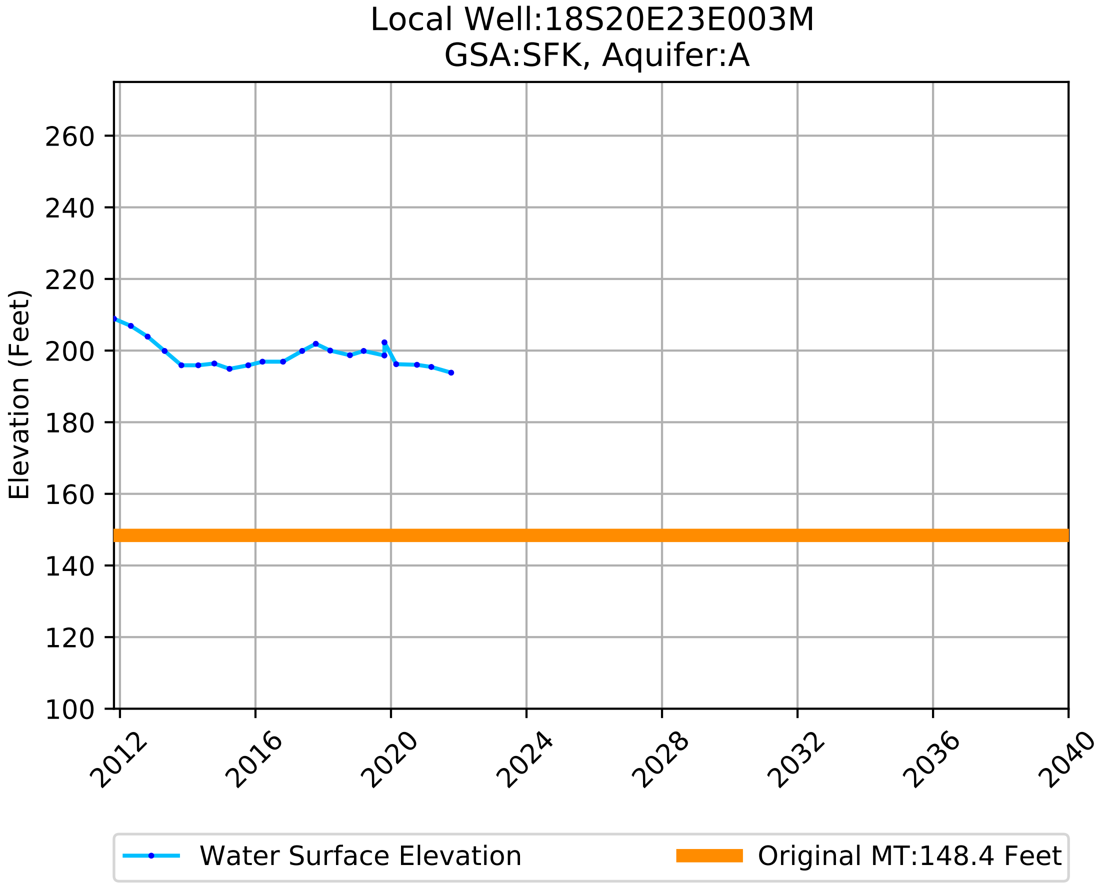
All Numbers are reported in years.

Bold well names are newly added to the Groundwater Quality Monitoring Network.

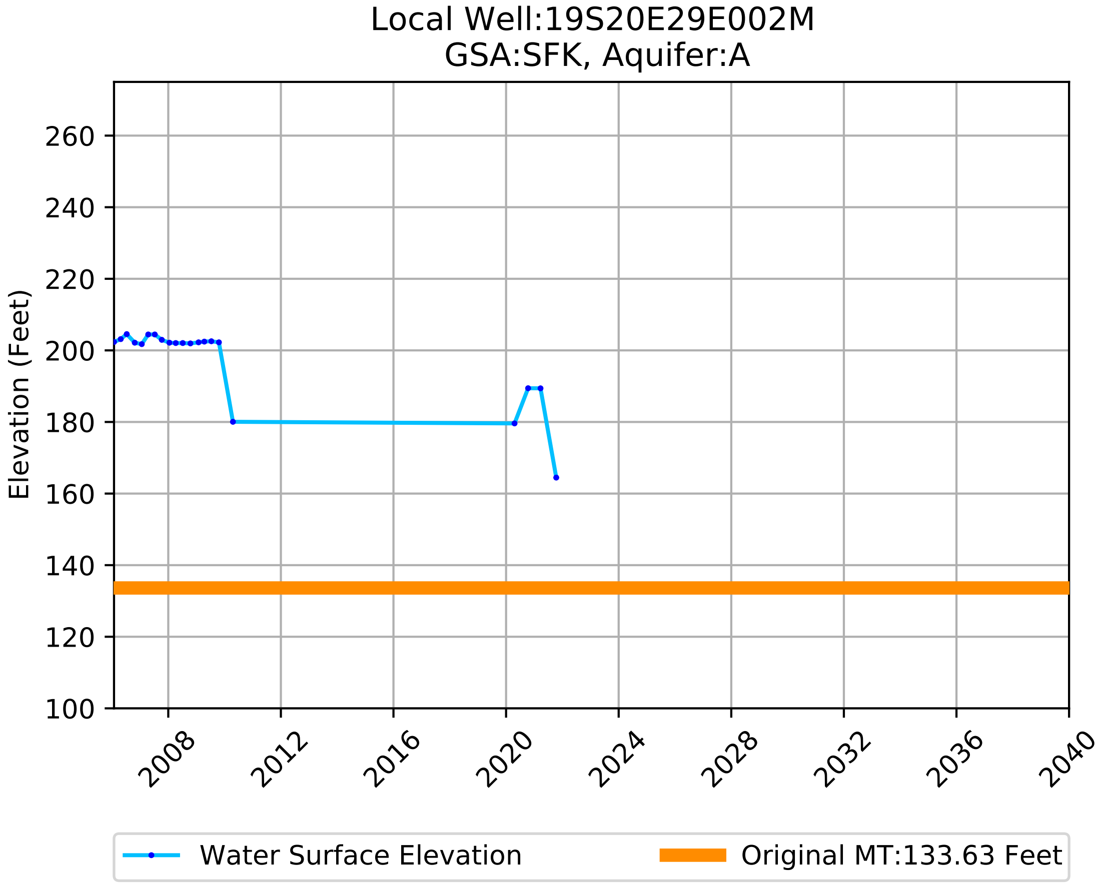
Wells no longer monitored by existing regulatory agencies have been removed from the monitoring network.

APPENDIX A

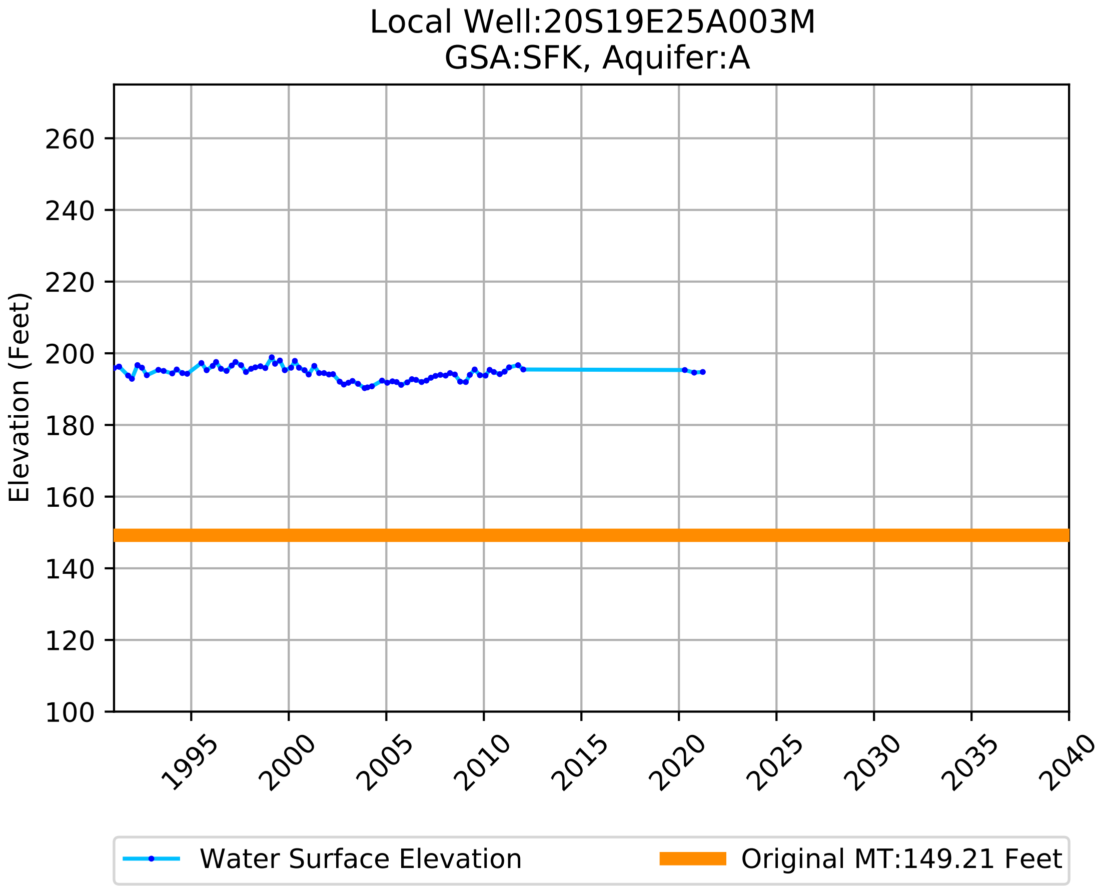
GROUNDWATER LEVEL SMC SUPPORTING INFORMATION

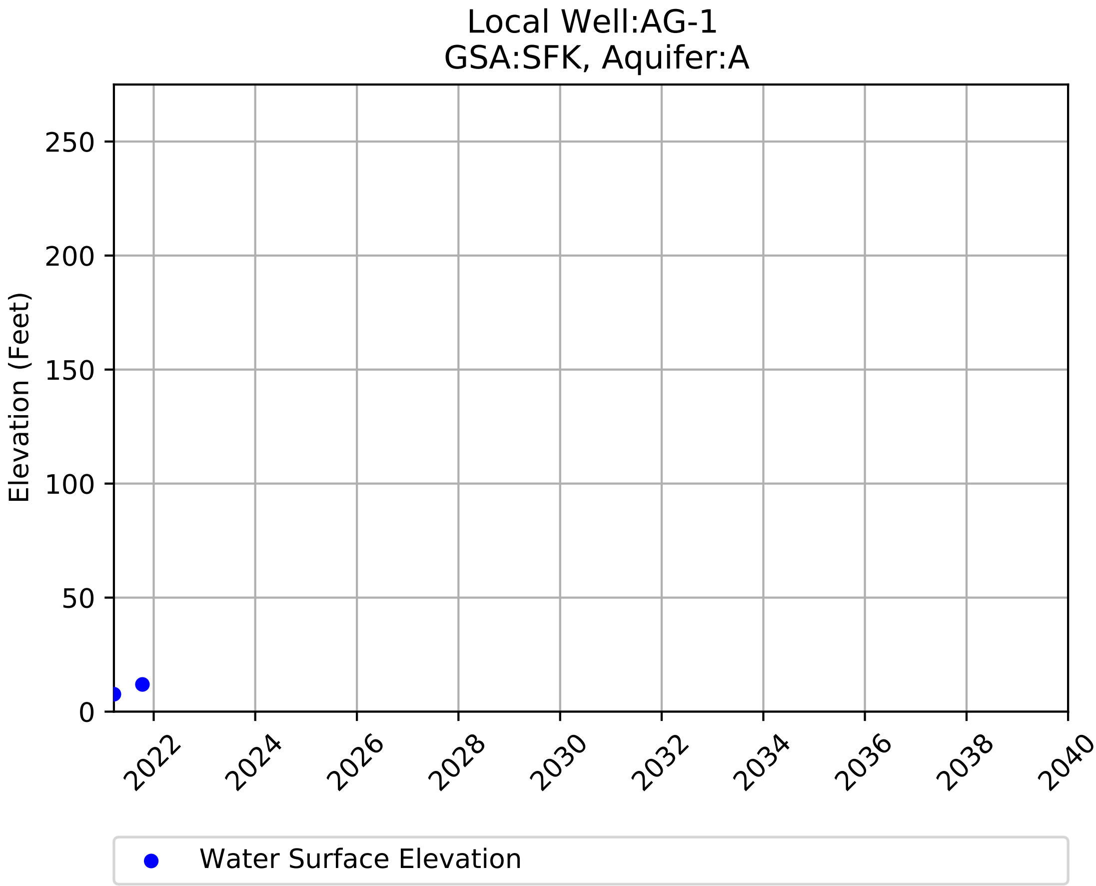


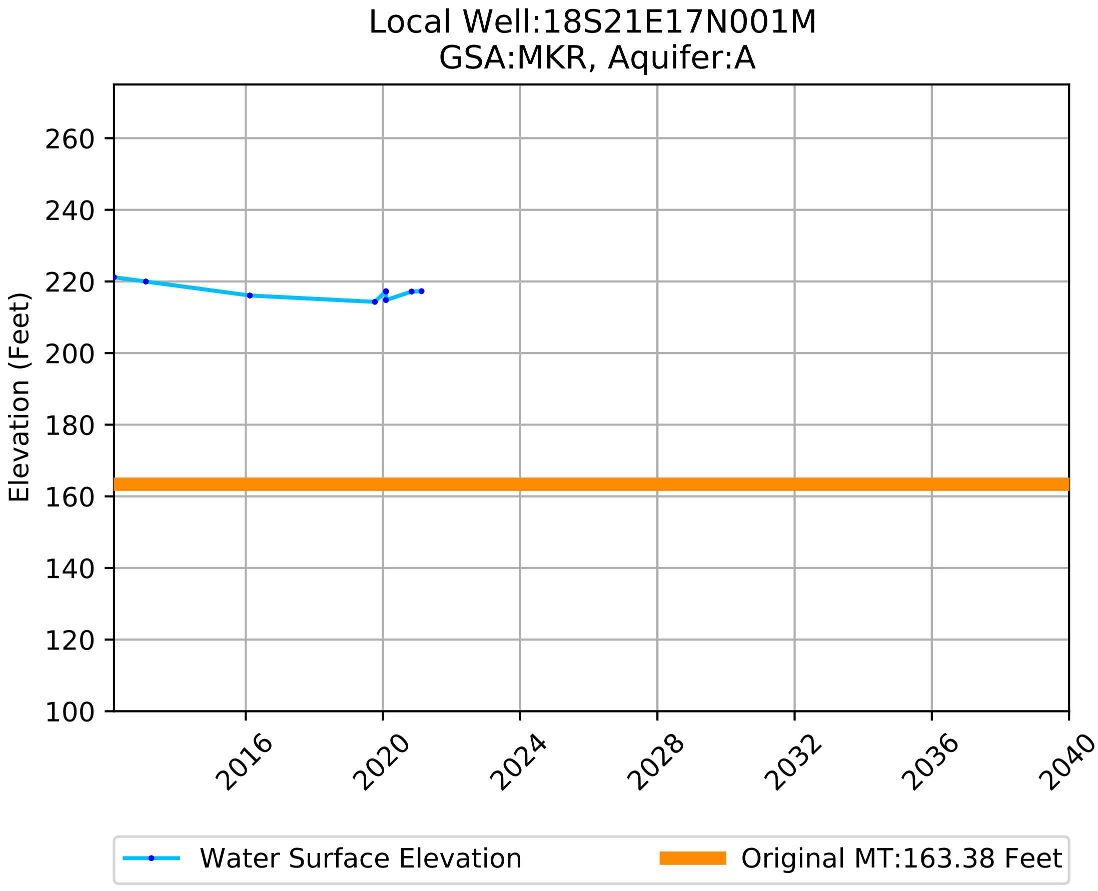
Local Well:18S20E23E003M
GSA:SFK, Aquifer:A
Elevation (Feet)
260
240
220
200
180
160
140
120
100
2012
2016
2020
2024
2028
2032
2036
2040
Water Surface Elevation
Original MT:148.4 Feet



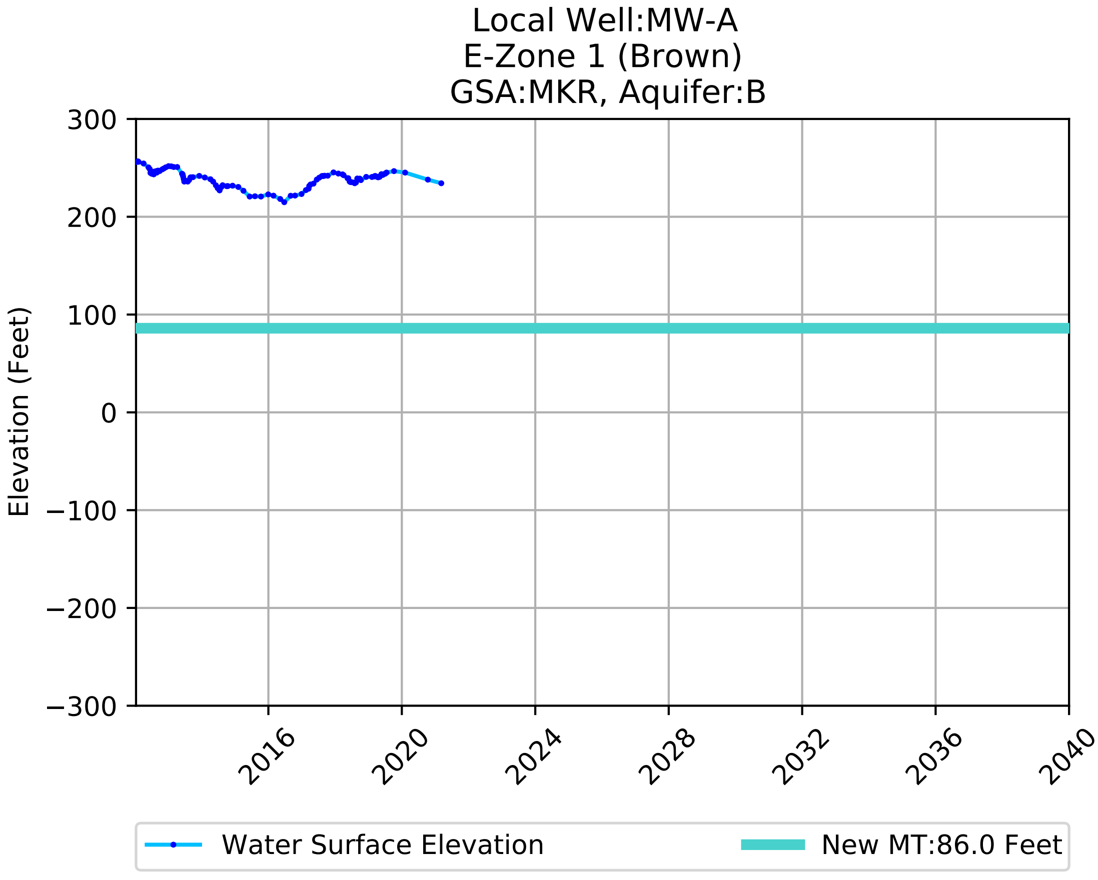
Local Well:19S20E29E002M
GSA:SFK, Aquifer:A
Elevation (Feet)
260
240
220
200
180
160
140
120
100
2008
2012
2016
2020
2024
2028
2032
2036
2040
Water Surface Elevation
Original MT:133.63 Feet


Local Well:20S19E25A003M
GSA:SFK, Aquifer:A
Elevation (Feet)
260
240
220
200
180
160
140
120
100
1995
2000
2005
2010
2015
2020
2025
2030
2035
2040
Water Surface Elevation
Original MT:149.21 Feet

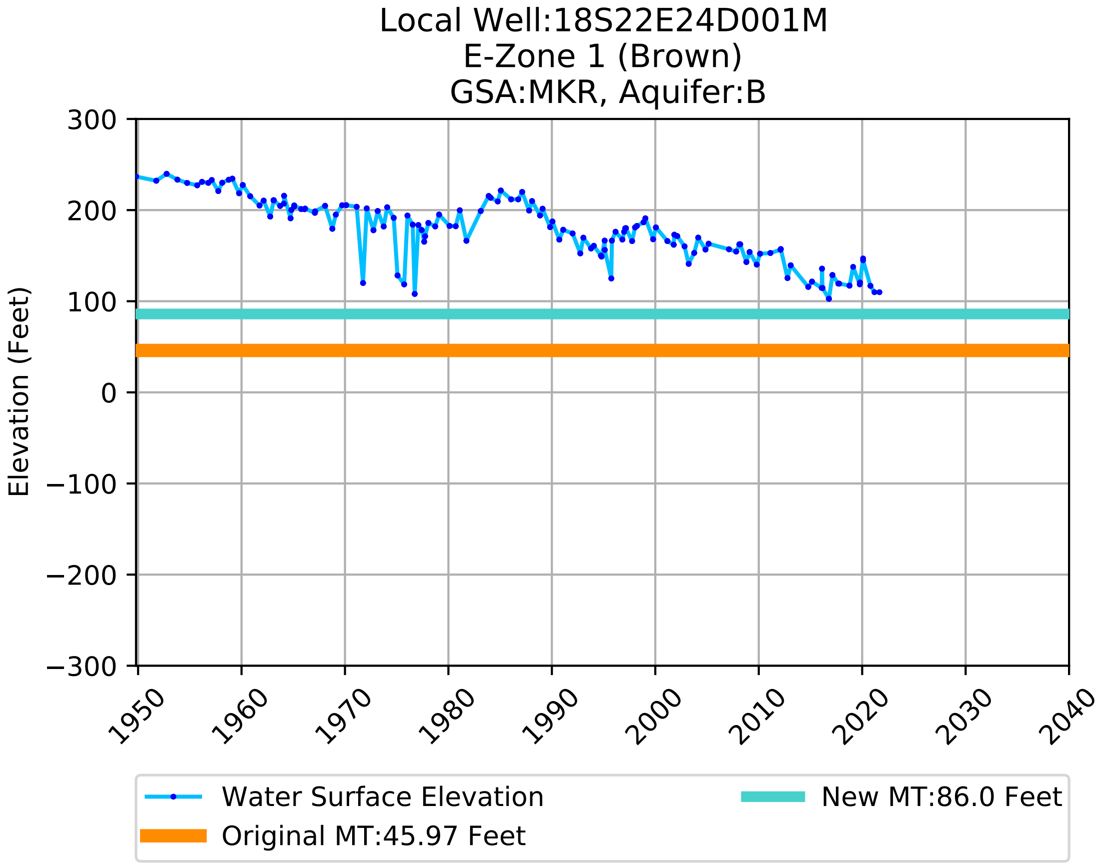

Local Well:AG-1
GSA:SFK, Aquifer:A
Elevation (Feet)
0
50
100
150
200
250
2022
2024
2026
2028
2030
2032
2034
2036
2038
2040
Water Surface Elevation



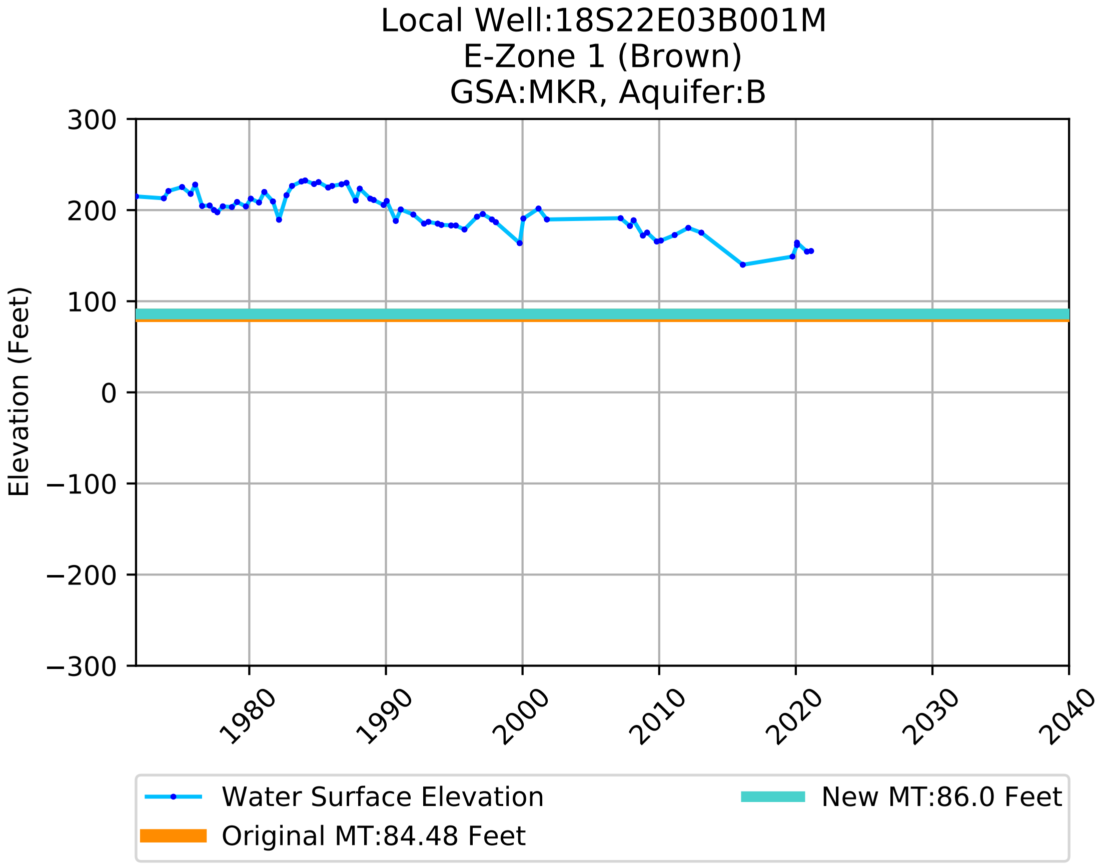
Local Well:18S21E17N001M
GSA:MKR, Aquifer:A
Elevation (Feet)
260
240
220
200
180
160
140
120
100
2016
2020
2024
2028
2032
2036
2040
Water Surface Elevation
Original MT:163.38 Feet

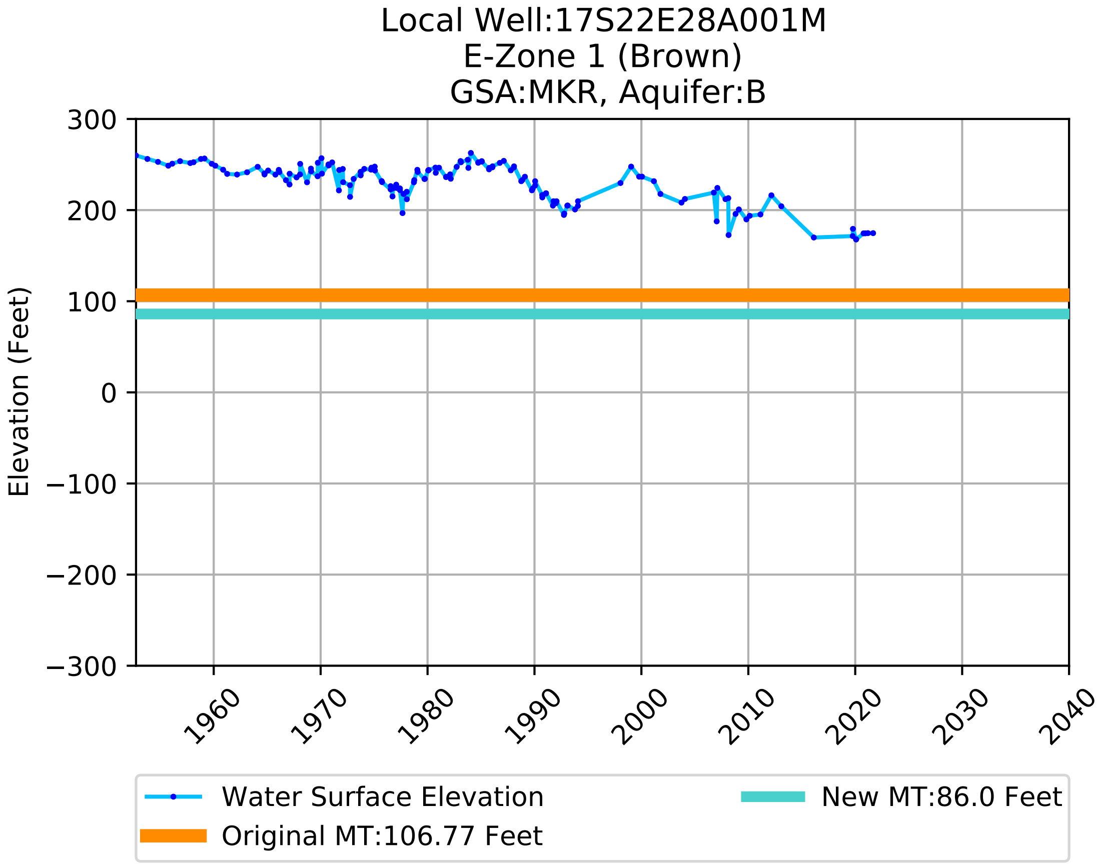


Local Well:MW-A
E-Zone 1 (Brown)
GSA:MKR, Aquifer:B
Elevation (Feet)
300
200
100
0
−100
−200
−300
2016
2020
2024
2028
2032
2036
2040
Water Surface Elevation
New MT:86.0 Feet

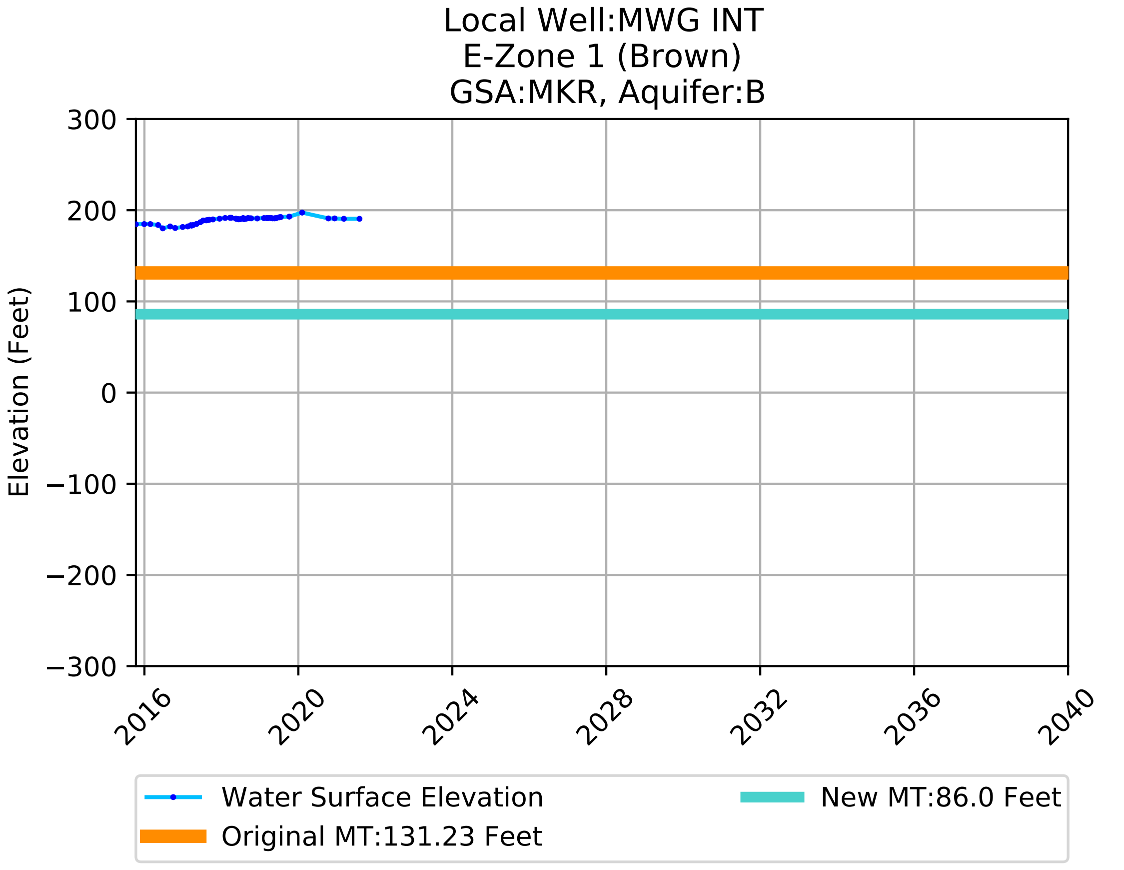


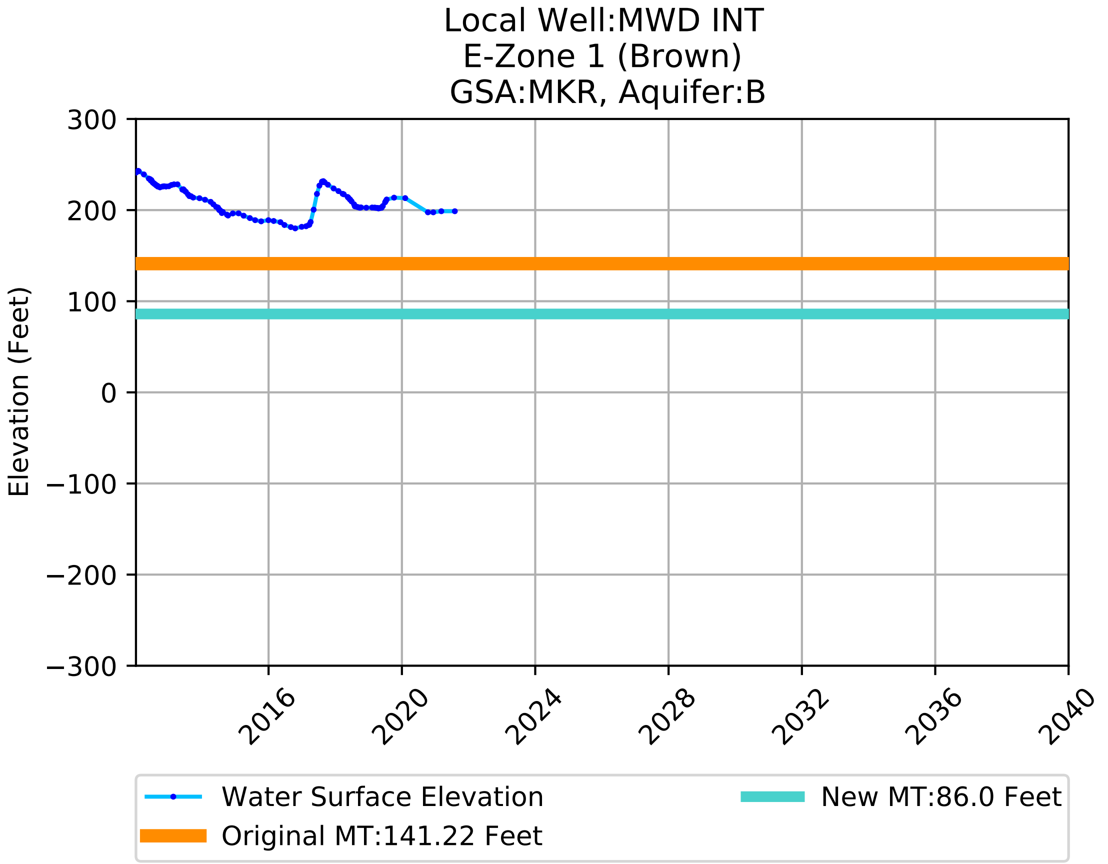
Local Well:18S22E24D001M
E-Zone 1 (Brown)
GSA:MKR, Aquifer:B
Elevation (Feet)
300
200
100
0
−100
−200
−300
1950
1960
1970
1980
1990
2000
2010
2020
2030
2040
Water Surface Elevation
Original MT:45.97 Feet
New MT:86.0 Feet


Local Well:18S22E03B001M
E-Zone 1 (Brown)
GSA:MKR, Aquifer:B
300
200
100
0
−100
−200
−300
Elevation (Feet)
1980
1990
2000
2010
2020
2030
2040
Water Surface Elevation
New MT:86.0 Feet
Original MT:84.48 Feet

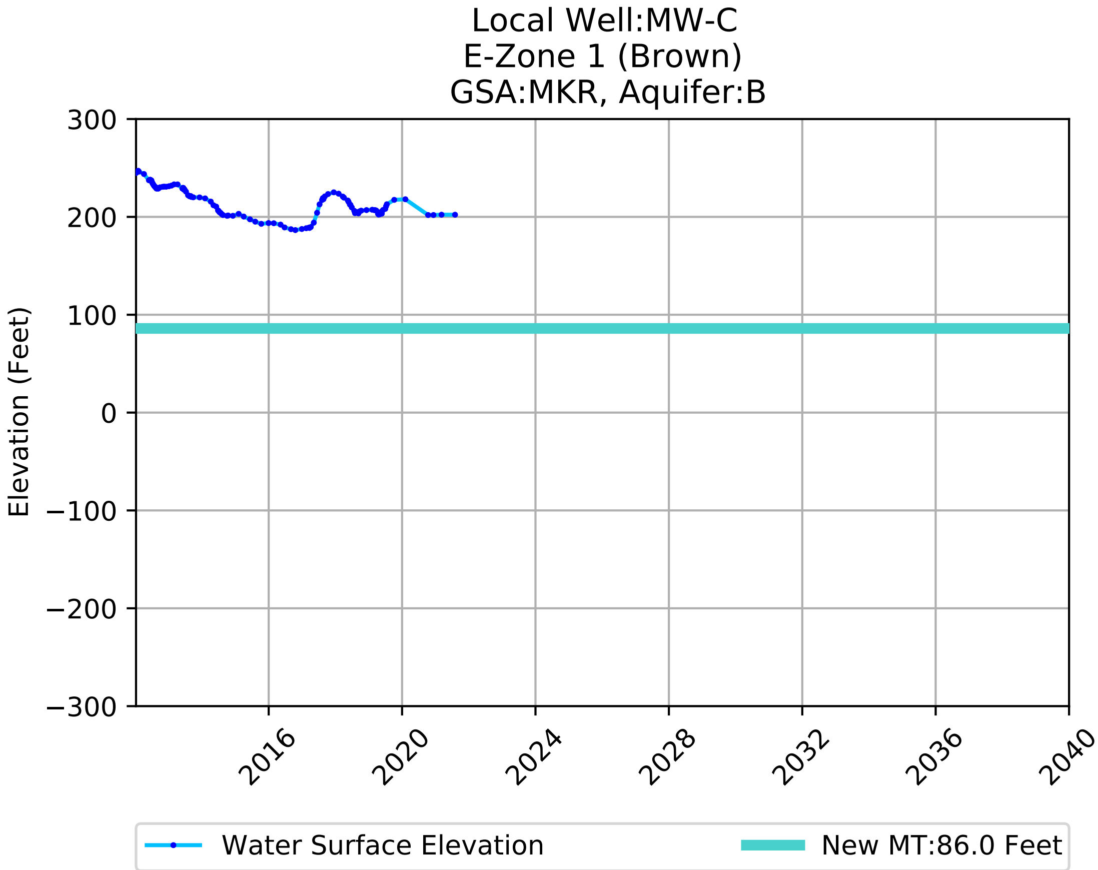


Local Well:17S22E28A001M
E-Zone 1 (Brown)
GSA:MKR, Aquifer:B
Elevation (Feet)
300
200
100
0
−100
−200
−300
1960
1970
1980
1990
2000
2010
2020
2030
2040
Water Surface Elevation
Original MT:106.77 Feet
New MT:86.0 Feet

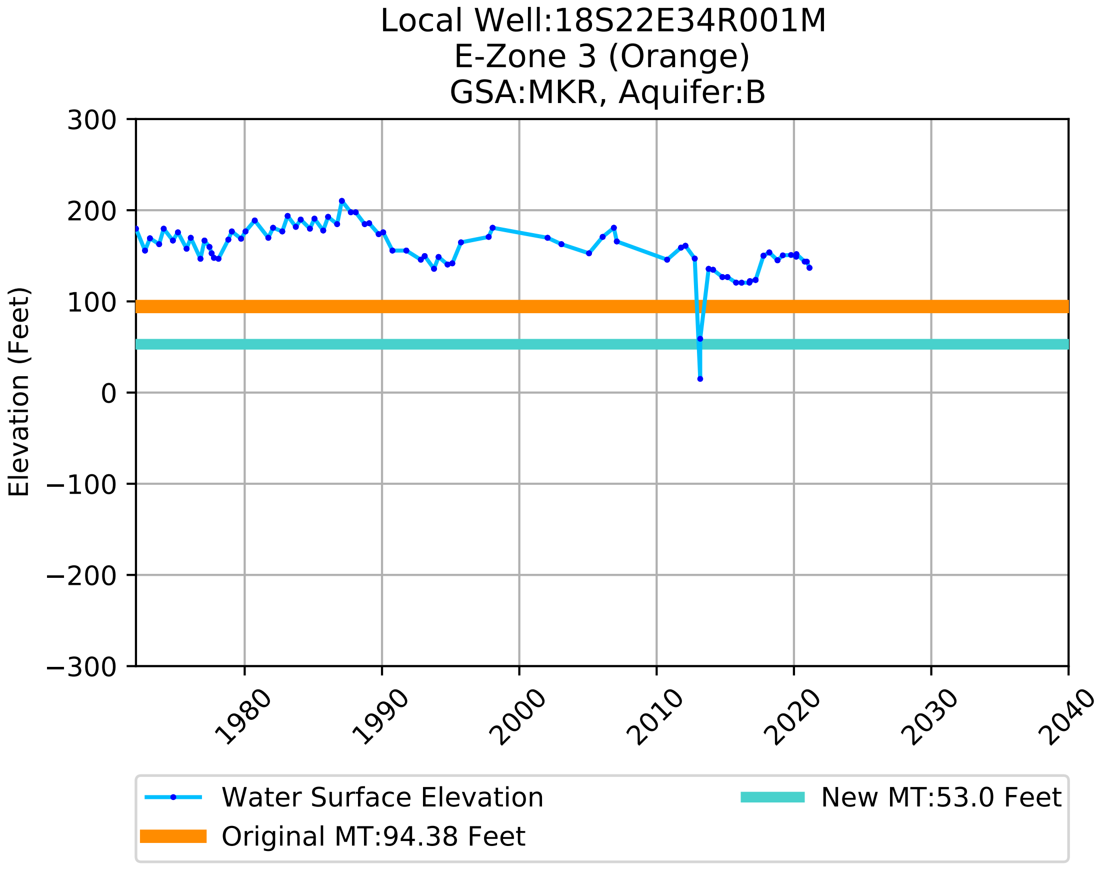

Local Well:MWG INT
E-Zone 1 (Brown)
GSA:MKR, Aquifer:B
Elevation (Feet)
300
200
100
0
−100
−200
−300
2016
2020
2024
2028
2032
2036
2040
Water Surface Elevation
New MT:86.0 Feet
Original MT:131.23 Feet

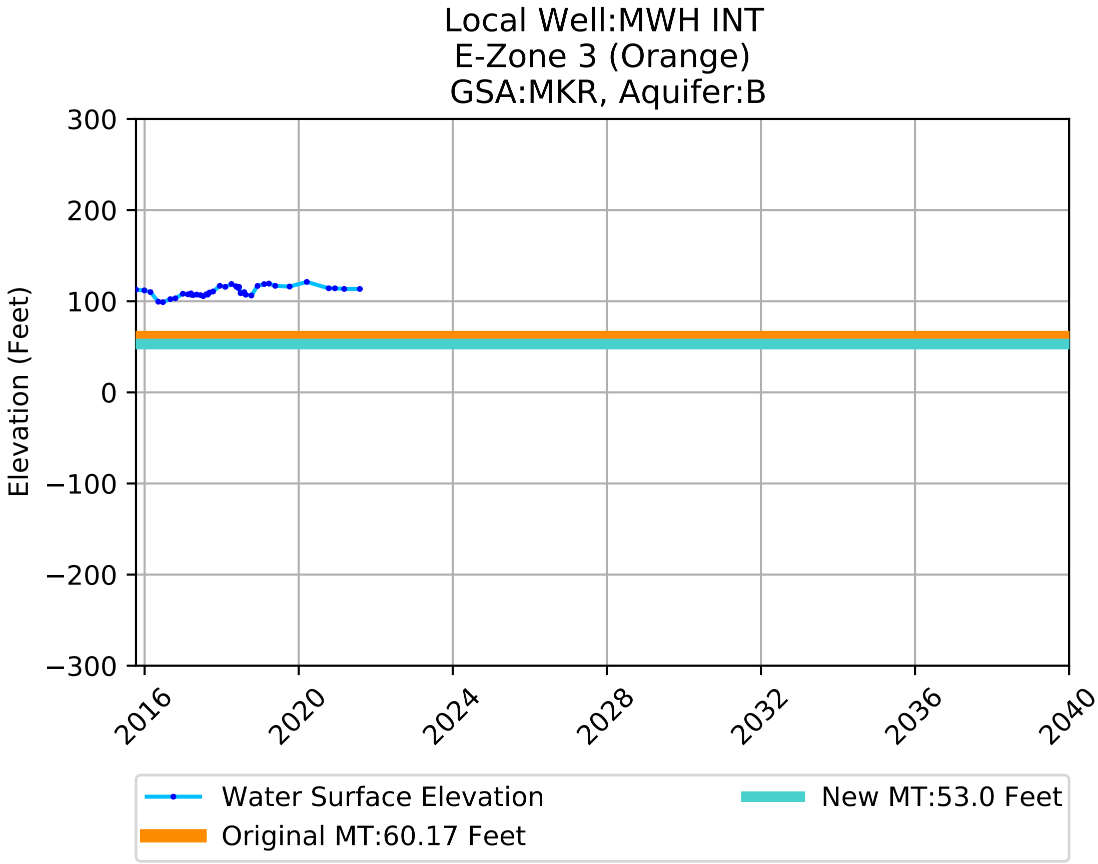


Local Well:MWD INT
E-Zone 1 (Brown)
GSA:MKR, Aquifer:B
Elevation (Feet)
300
200
100
0
−100
−200
−300
2016
2020
2024
2028
2032
2036
2040
Water Surface Elevation
Original MT:141.22 Feet
New MT:86.0 Feet

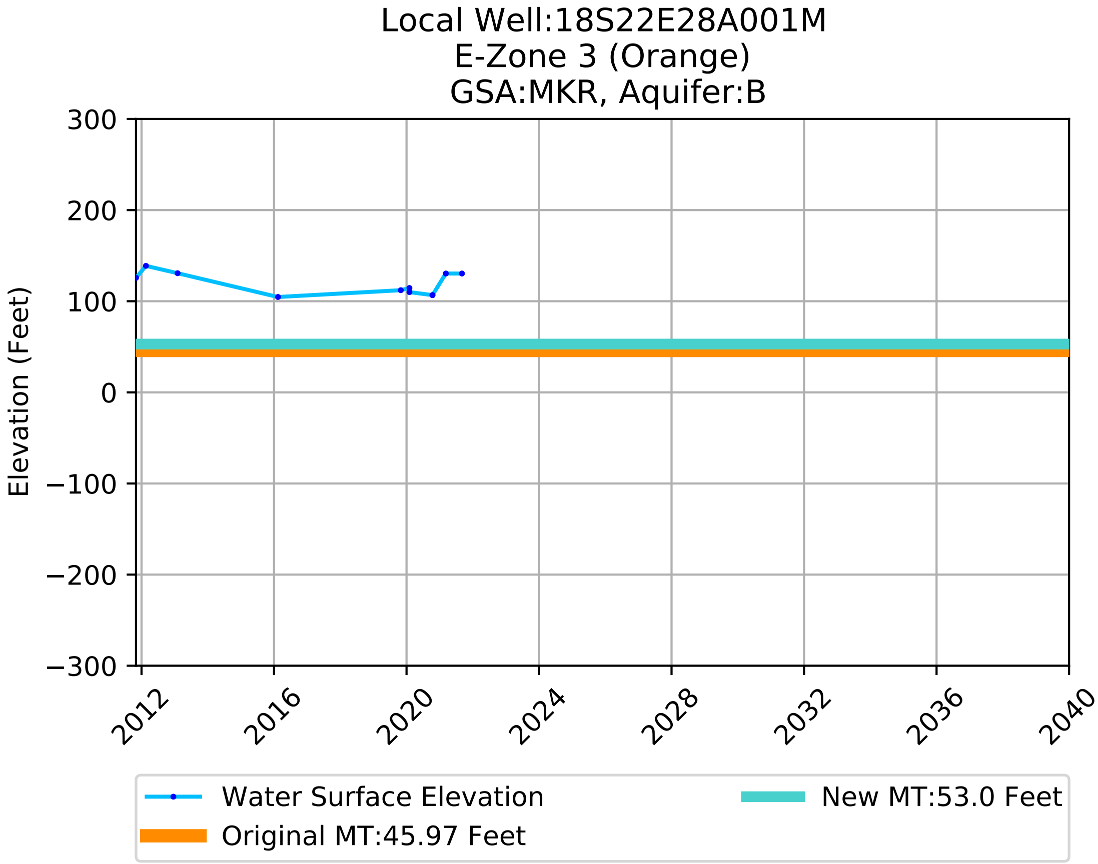


Local Well:MW-C
E-Zone 1 (Brown)
GSA:MKR, Aquifer:B
Elevation (Feet)
300
200
100
0
−100
−200
−300
2016
2020
2024
2028
2032
2036
2040
Water Surface Elevation
New MT:86.0 Feet

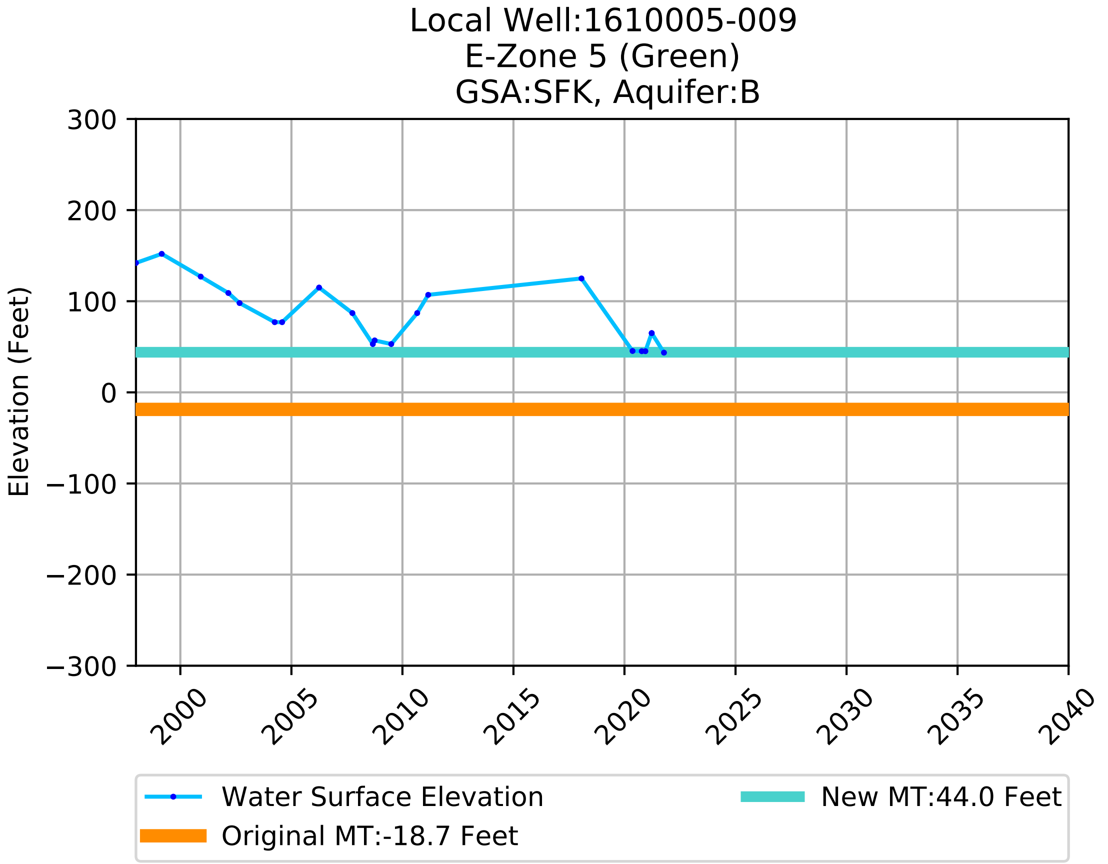

Local Well:18S22E34R001M
E-Zone 3 (Orange)
GSA:MKR, Aquifer:B
Elevation (Feet)
300
200
100
0
−100
−200
−300
1980
1990
2000
2010
2020
2030
2040
Water Surface Elevation
New MT:53.0 Feet
Original MT:94.38 Feet

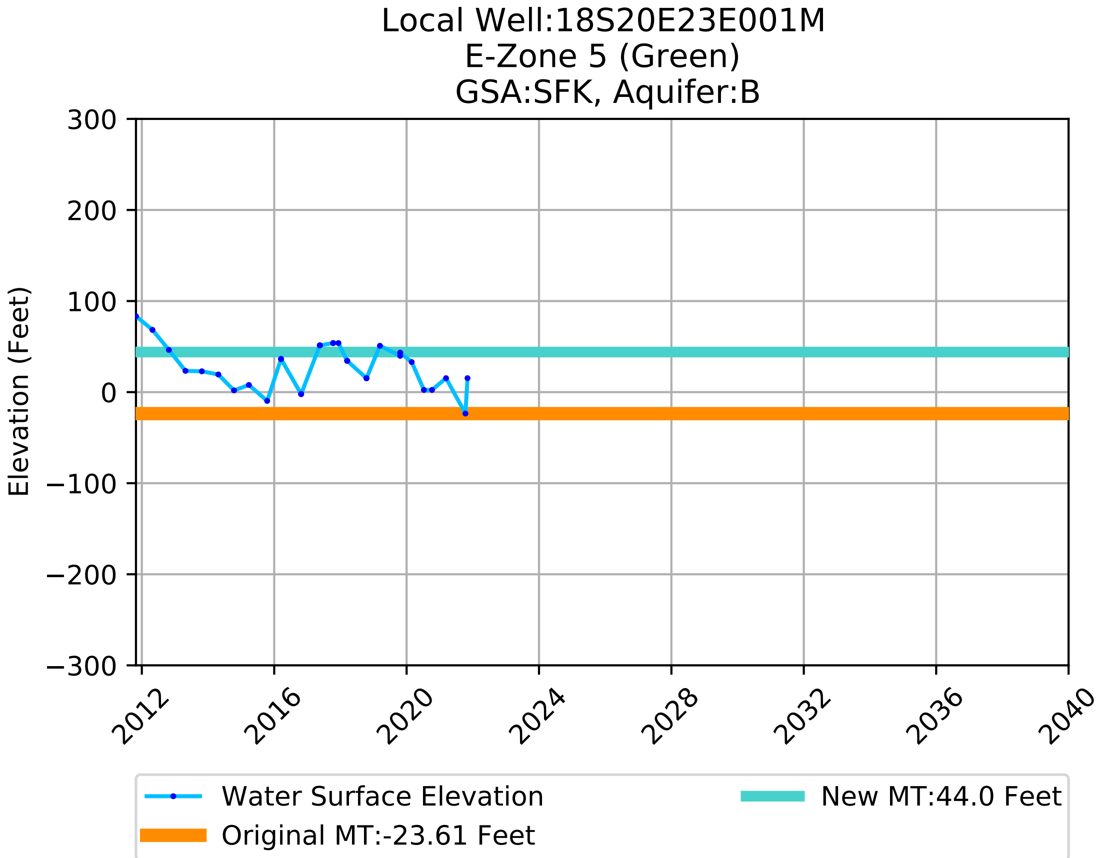


Local Well:MWH INT
E-Zone 3 (Orange)
GSA:MKR, Aquifer:B
300
200
100
0
−100
−200
−300
Elevation (Feet)
2016
2020
2024
2028
2032
2036
2040
Water Surface Elevation
Original MT:60.17 Feet
New MT:53.0 Feet

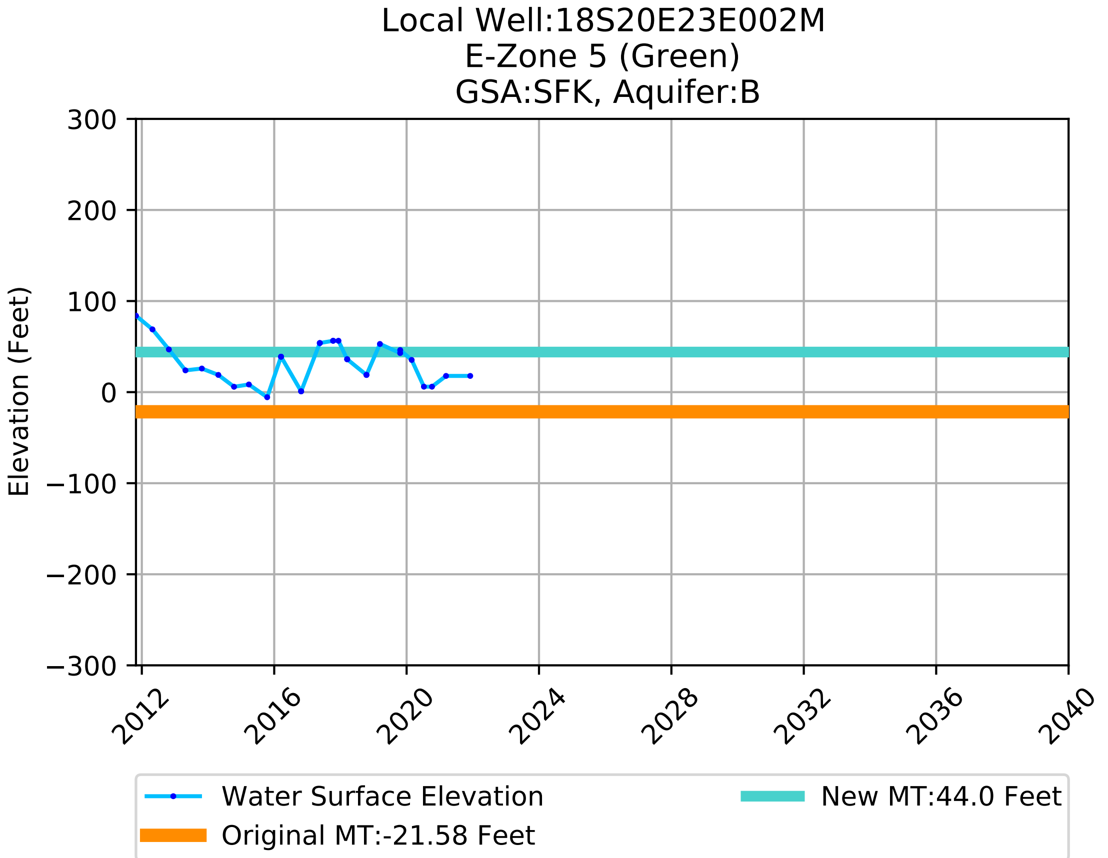


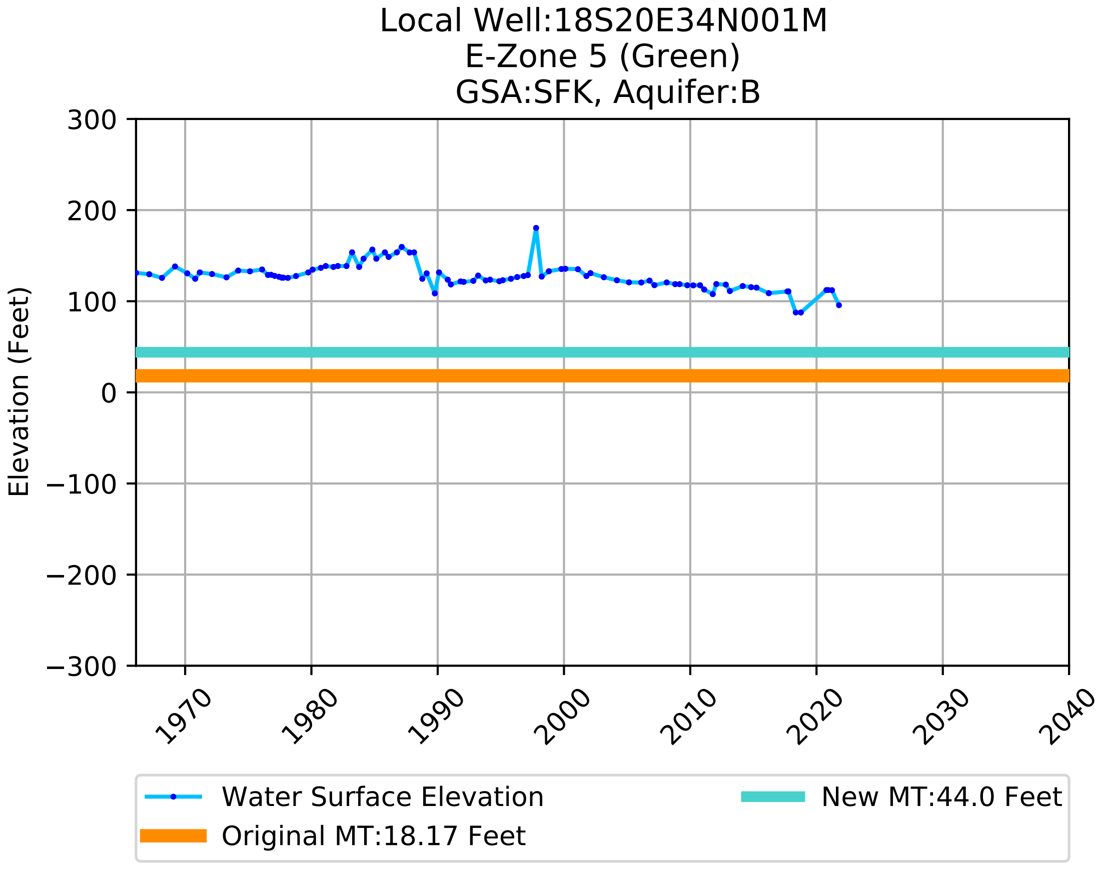
Local Well:18S22E28A001M
E-Zone 3 (Orange)
GSA:MKR, Aquifer:B
Elevation (Feet)
300
200
100
0
−100
−200
−300
2012
2016
2020
2024
2028
2032
2036
2040
Water Surface Elevation
New MT:53.0 Feet
Original MT:45.97 Feet

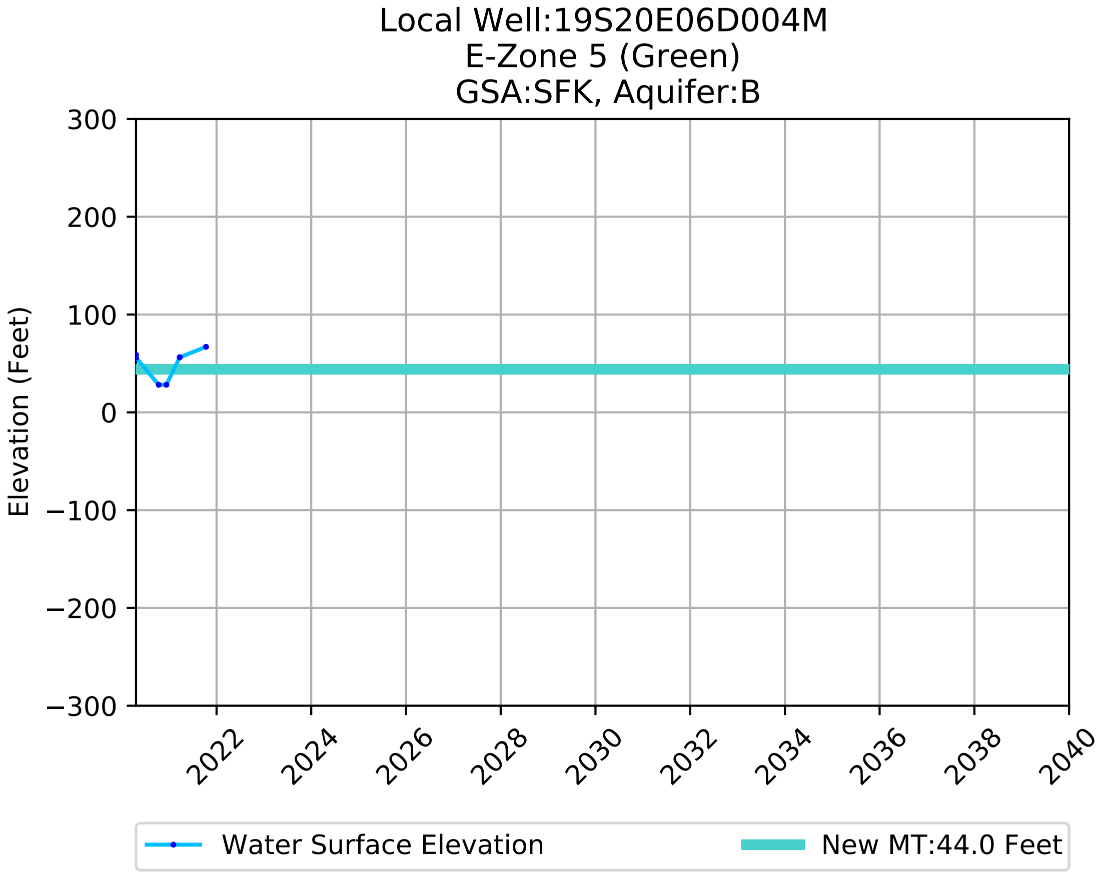

Local Well:1610005-009
E-Zone 5 (Green)
GSA:SFK, Aquifer:B
Elevation (Feet)
300
200
100
0
−100
−200
−300
2000
2005
2010
2015
2020
2025
2030
2035
2040
Water Surface Elevation
New MT:44.0 Feet
Original MT:-18.7 Feet



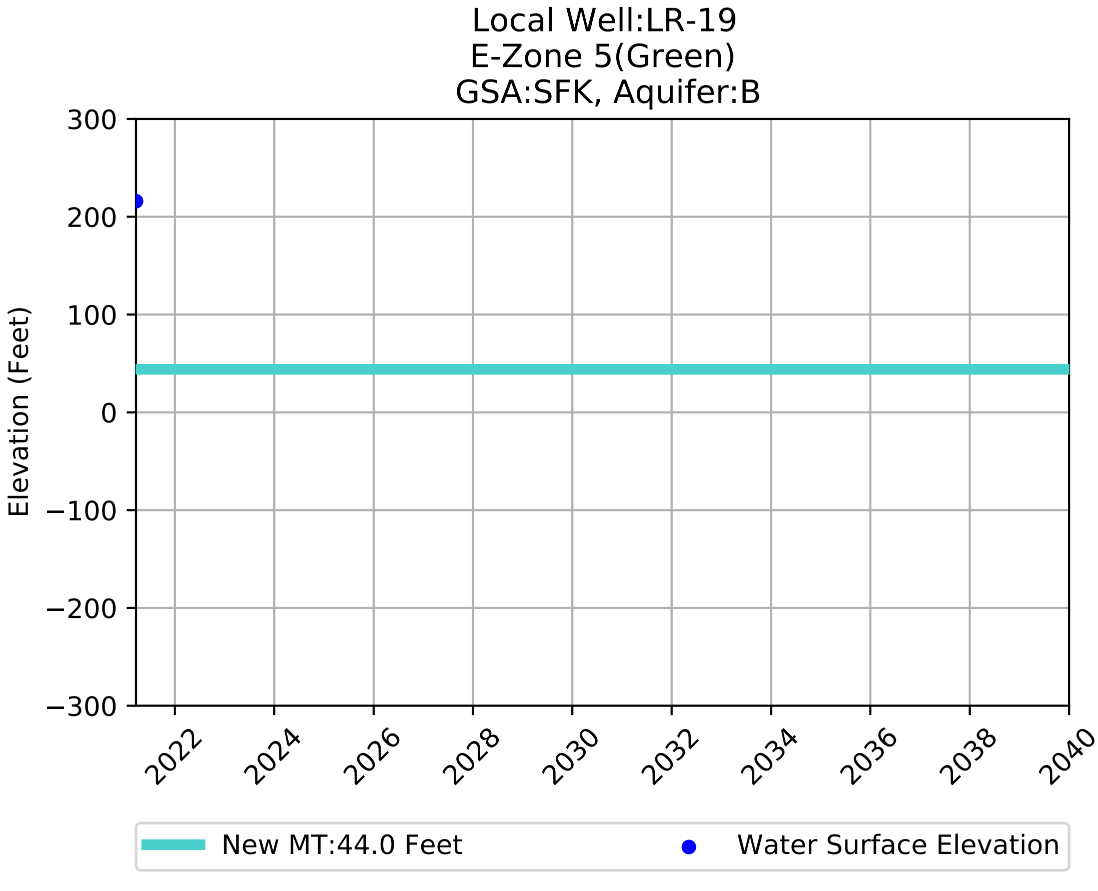
Local Well:18S20E23E001M
E-Zone 5 (Green)
GSA:SFK, Aquifer:B
Elevation (Feet)
300
200
100
0
−100
−200
−300
2012
2016
2020
2024
2028
2032
2036
2040
Water Surface Elevation
New MT:44.0 Feet
Original MT:-23.61 Feet


Local Well:18S20E23E002M
E-Zone 5 (Green)
GSA:SFK, Aquifer:B
Elevation (Feet)
300
200
100
0
−100
−200
−300
2012
2016
2020
2024
2028
2032
2036
2040
Water Surface Elevation
New MT:44.0 Feet
Original MT:-21.58 Feet

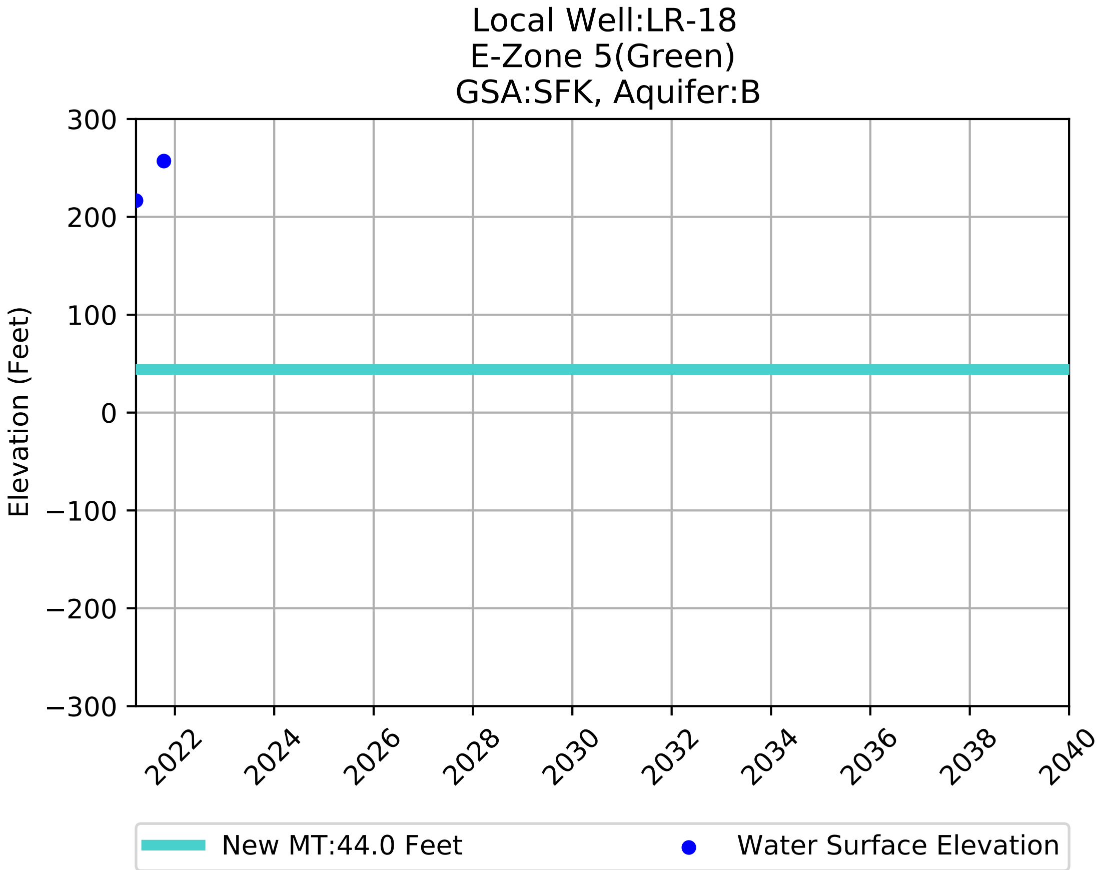

Local Well:18S20E34N001M
E-Zone 5 (Green)
GSA:SFK, Aquifer:B
Elevation (Feet)
300
200
100
0
−100
−200
−300
1970
1980
1990
2000
2010
2020
2030
2040
Water Surface Elevation
New MT:44.0 Feet
Original MT:18.17 Feet

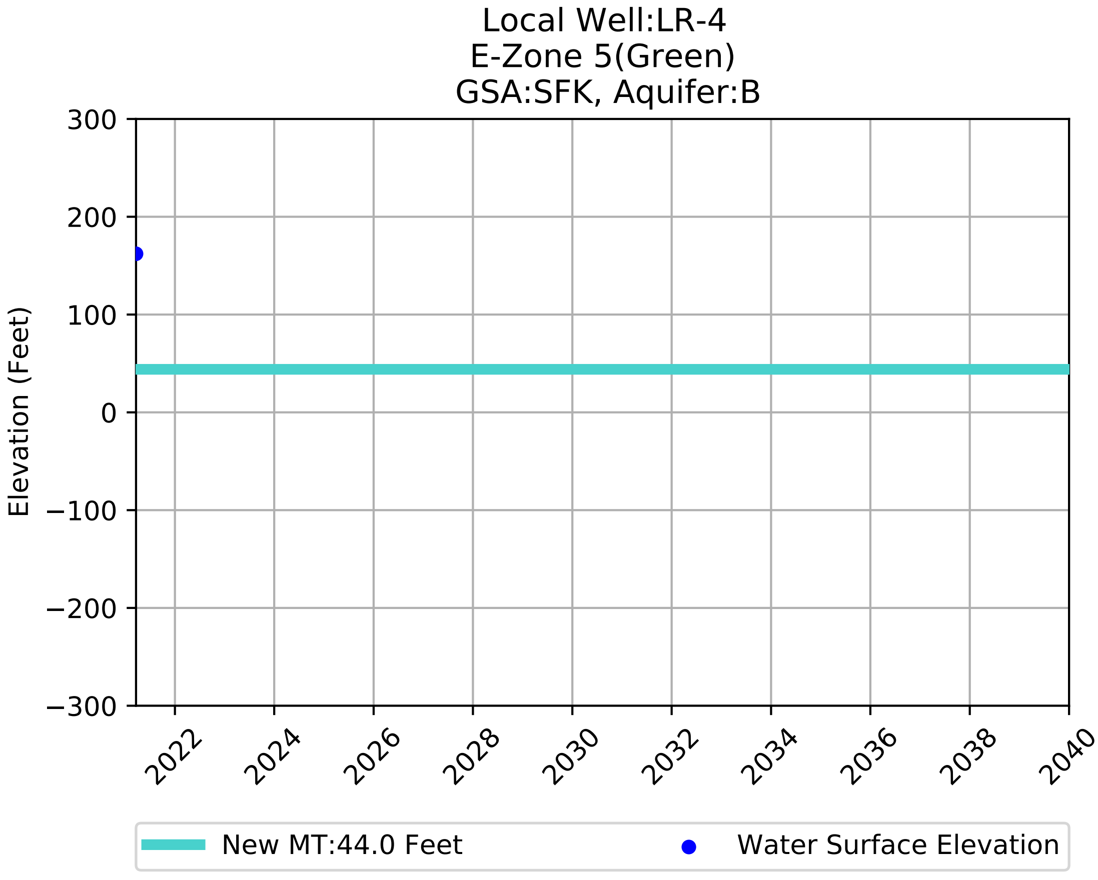


Local Well:19S20E06D004M
E-Zone 5 (Green)
GSA:SFK, Aquifer:B
Elevation (Feet)
300
200
100
0
−100
−200
−300
2022
2024
2026
2028
2030
2032
2034
2036
2038
2040
Water Surface Elevation
New MT:44.0 Feet

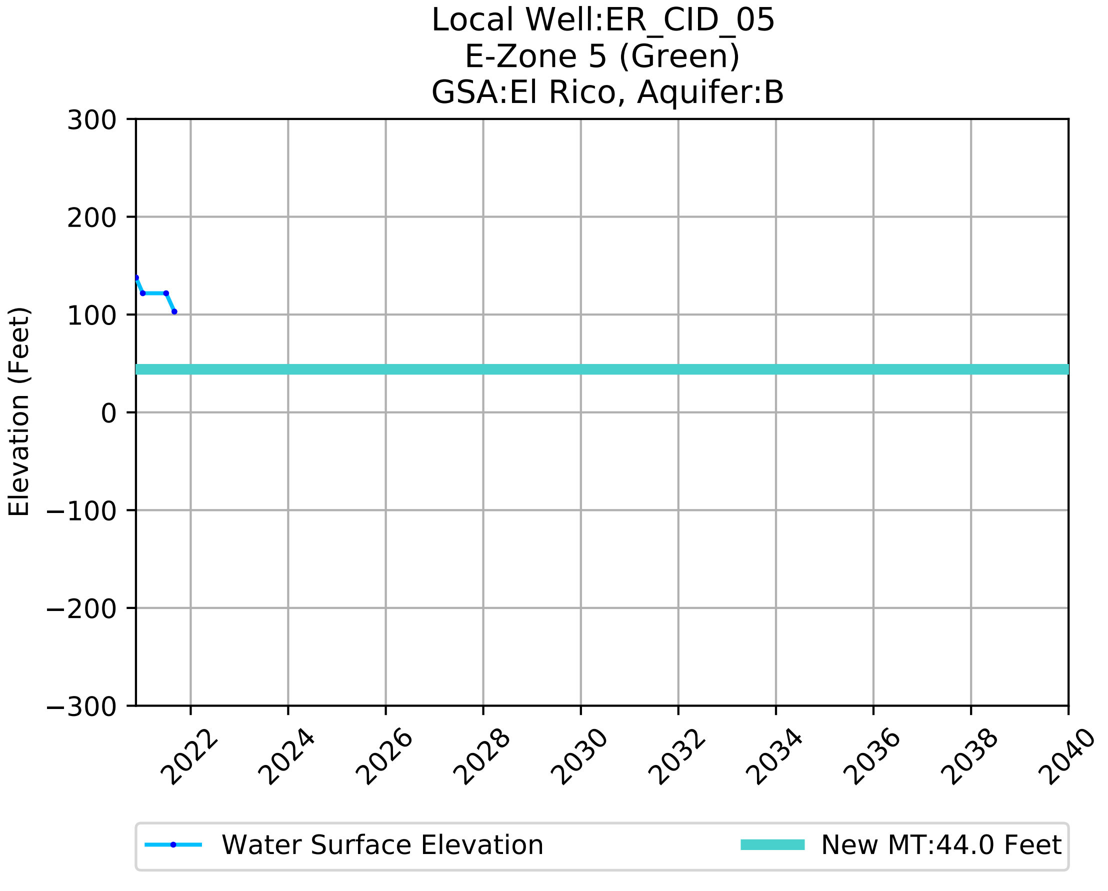


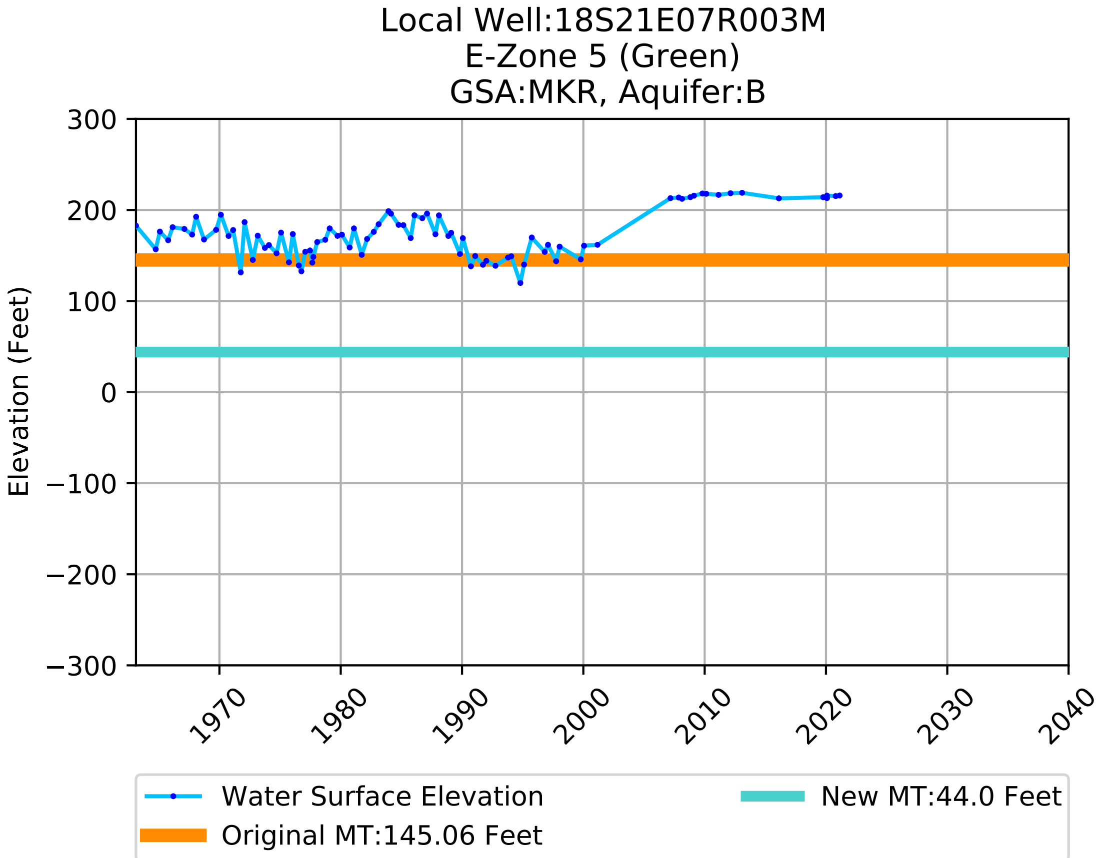
Local Well:LR-19
E-Zone 5(Green)
GSA:SFK, Aquifer:B
Elevation (Feet)
300
200
100
0
−100
−200
−300
2022
2024
2026
2028
2030
2032
2034
2036
2038
2040
New MT:44.0 Feet
Water Surface Elevation


Local Well:LR-18
E-Zone 5(Green)
GSA:SFK, Aquifer:B
Elevation (Feet)
300
200
100
0
−100
−200
−300
2022
2024
2026
2028
2030
2032
2034
2036
2038
2040
New MT:44.0 Feet
Water Surface Elevation

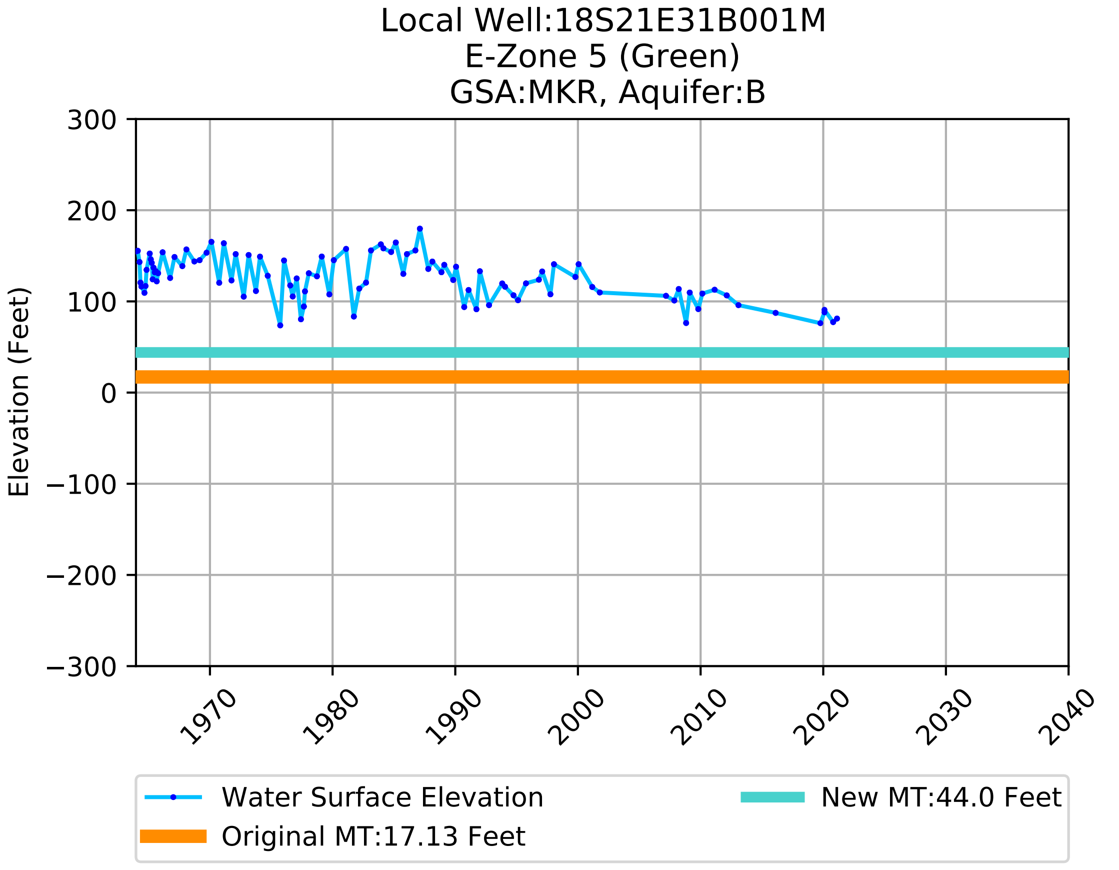


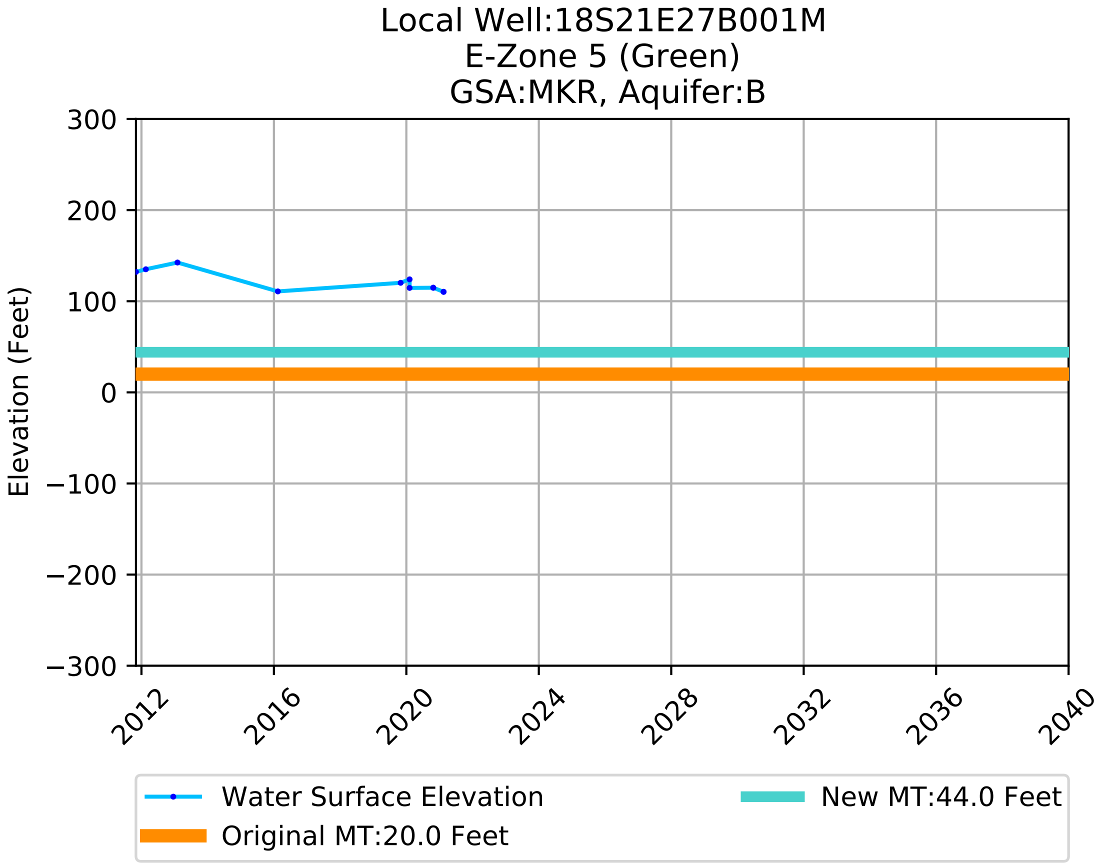
Local Well:LR-4
E-Zone 5(Green)
GSA:SFK, Aquifer:B
Elevation (Feet)
300
200
100
0
−100
−200
−300
2022
2024
2026
2028
2030
2032
2034
2036
2038
2040
New MT:44.0 Feet
Water Surface Elevation


Local Well:ER_CID_05
E-Zone 5 (Green)
GSA:El Rico, Aquifer:B
Elevation (Feet)
300
200
100
0
−100
−200
−300
2022
2024
2026
2028
2030
2032
2034
2036
2038
2040
Water Surface Elevation
New MT:44.0 Feet

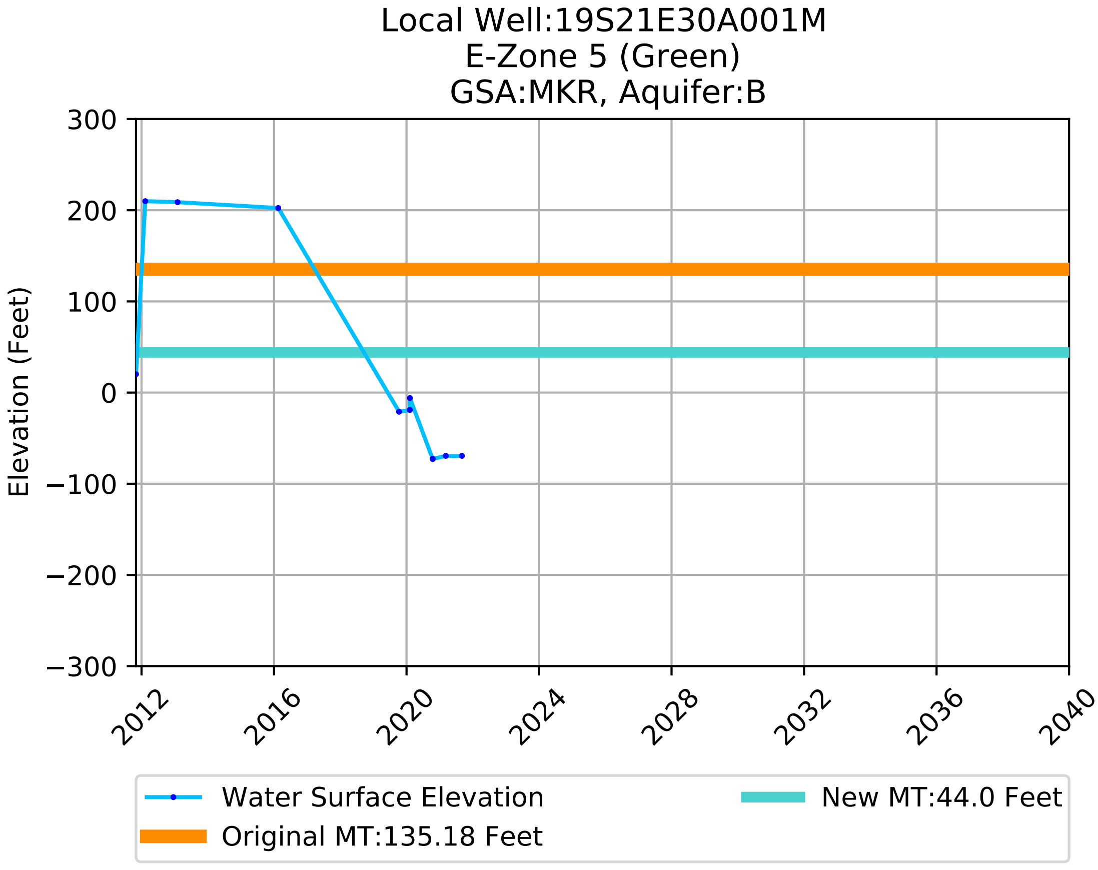


Local Well:18S21E07R003M
E-Zone 5 (Green)
GSA:MKR, Aquifer:B
Elevation (Feet)
300
200
100
0
−100
−200
−300
1970
1980
1990
2000
2010
2020
2030
2040
Water Surface Elevation
Original MT:145.06 Feet
New MT:44.0 Feet

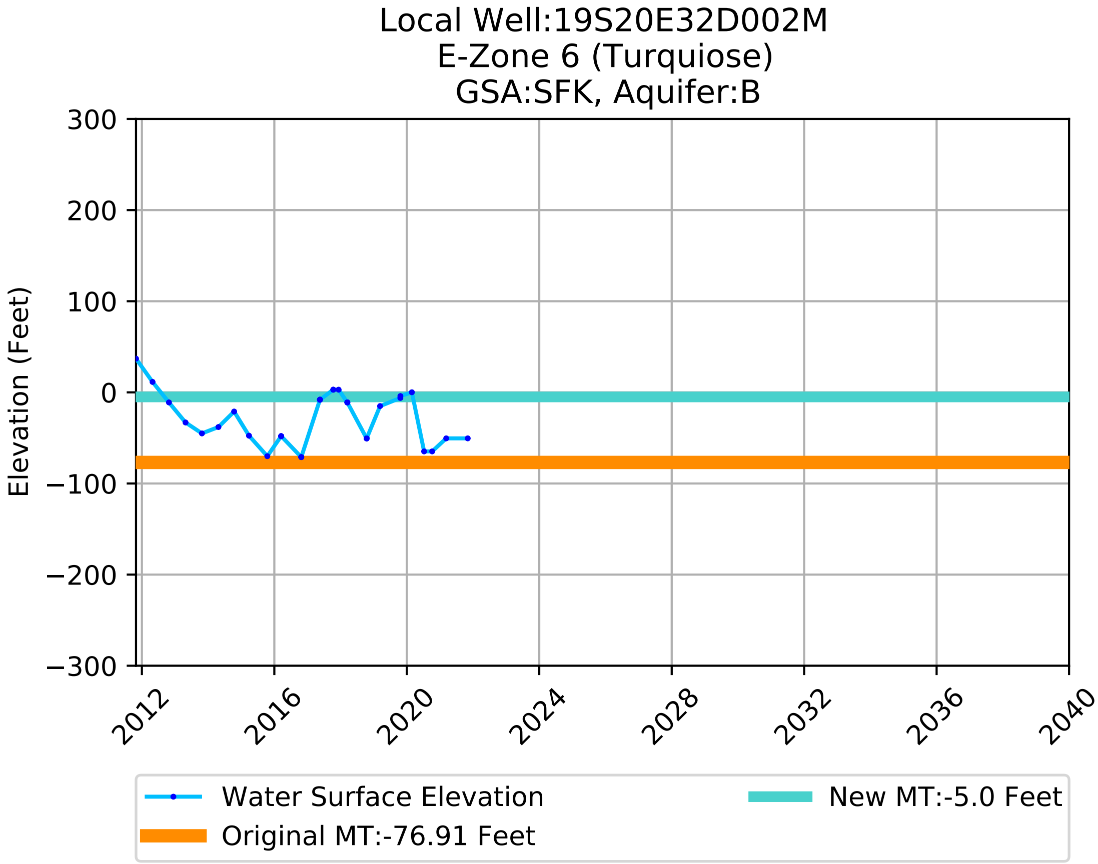

Local Well:18S21E31B001M
E-Zone 5 (Green)
GSA:MKR, Aquifer:B
Elevation (Feet)
300
200
100
0
−100
−200
−300
1970
1980
1990
2000
2010
2020
2030
2040
Water Surface Elevation
New MT:44.0 Feet
Original MT:17.13 Feet

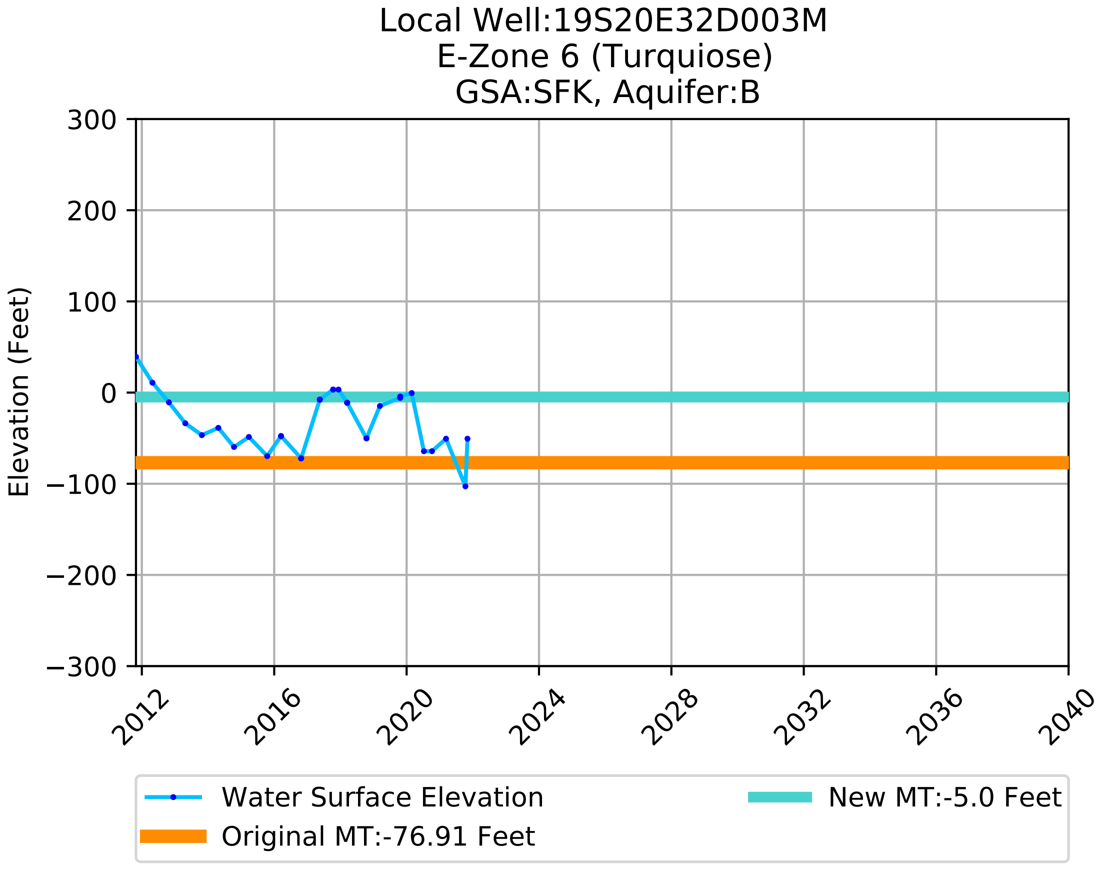


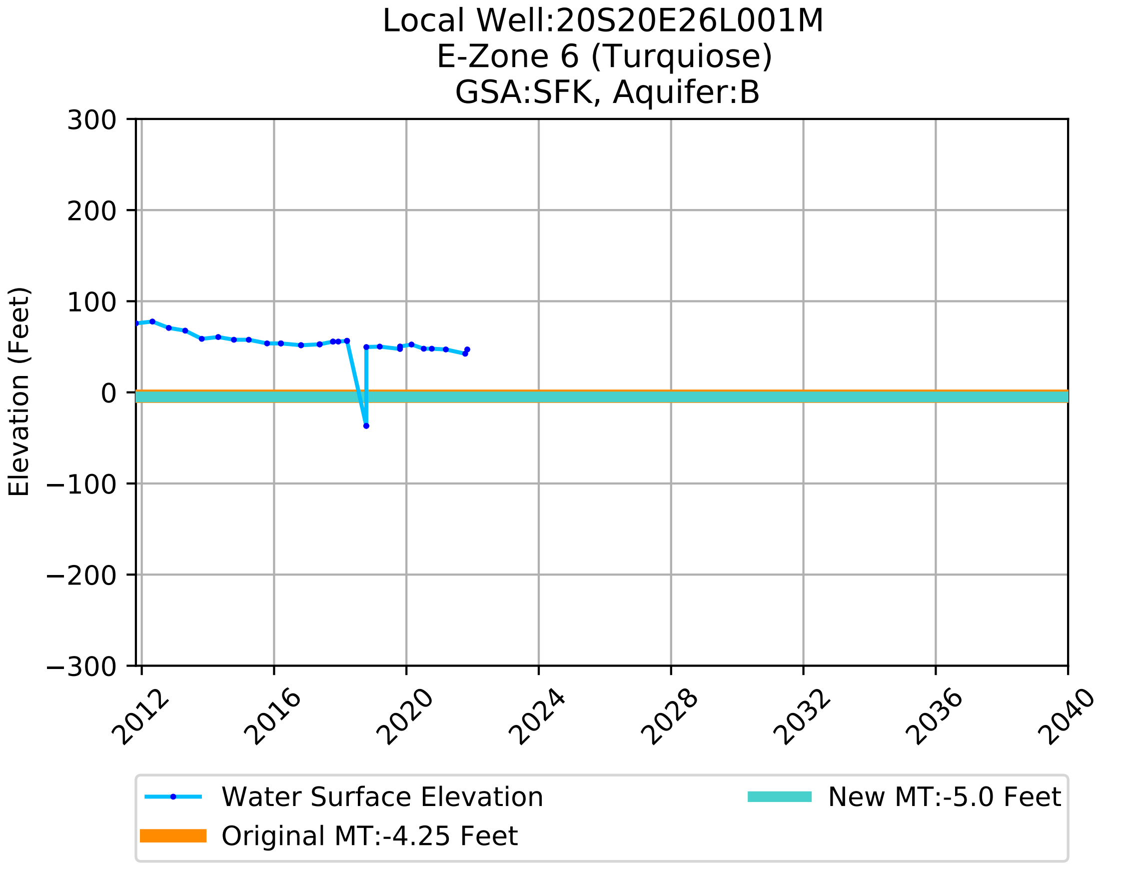
Local Well:18S21E27B001M
E-Zone 5 (Green)
GSA:MKR, Aquifer:B
Elevation (Feet)
300
200
100
0
−100
−200
−300
2012
2016
2020
2024
2028
2032
2036
2040
Water Surface Elevation
New MT:44.0 Feet
Original MT:20.0 Feet



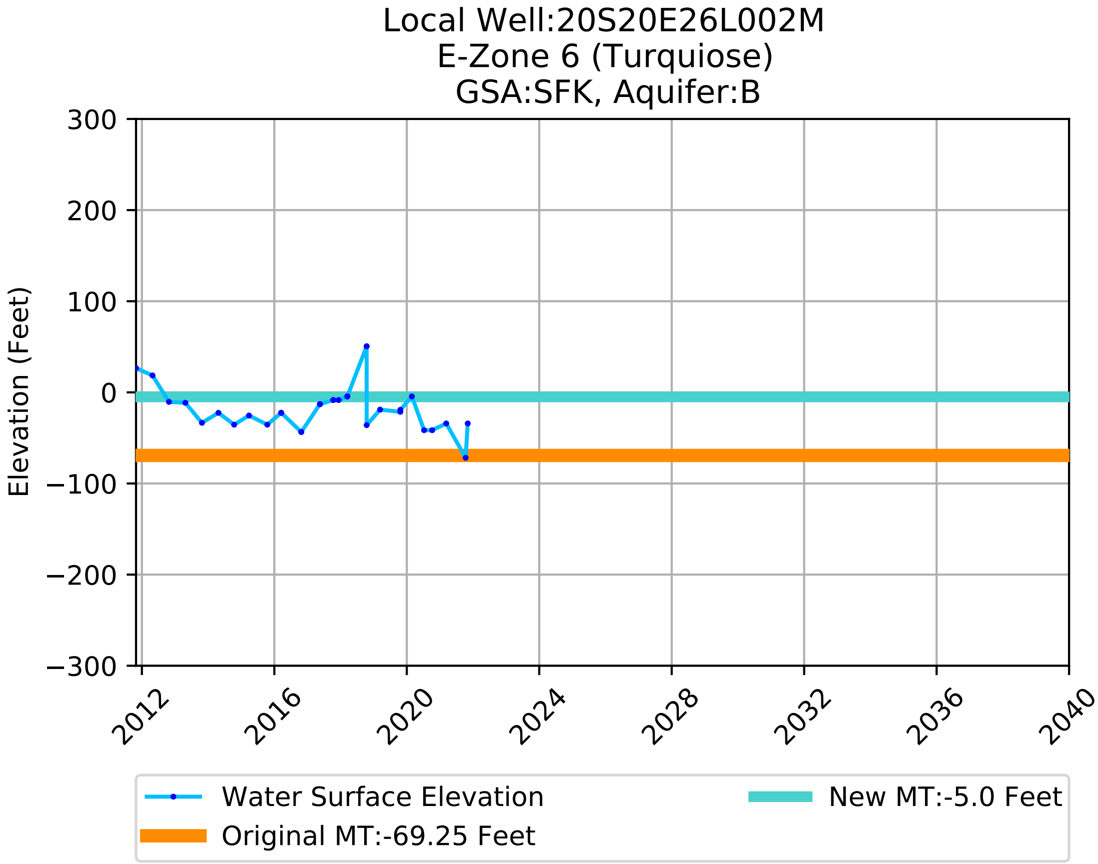
Local Well:19S21E30A001M
E-Zone 5 (Green)
GSA:MKR, Aquifer:B
Elevation (Feet)
300
200
100
0
−100
−200
−300
2012
2016
2020
2024
2028
2032
2036
2040
Water Surface Elevation
Original MT:135.18 Feet
New MT:44.0 Feet


Local Well:19S20E32D002M
E-Zone 6 (Turquiose)
GSA:SFK, Aquifer:B
Elevation (Feet)
300
200
100
0
−100
−200
−300
2012
2016
2020
2024
2028
2032
2036
2040
Water Surface Elevation
New MT:-5.0 Feet
Original MT:-76.91 Feet

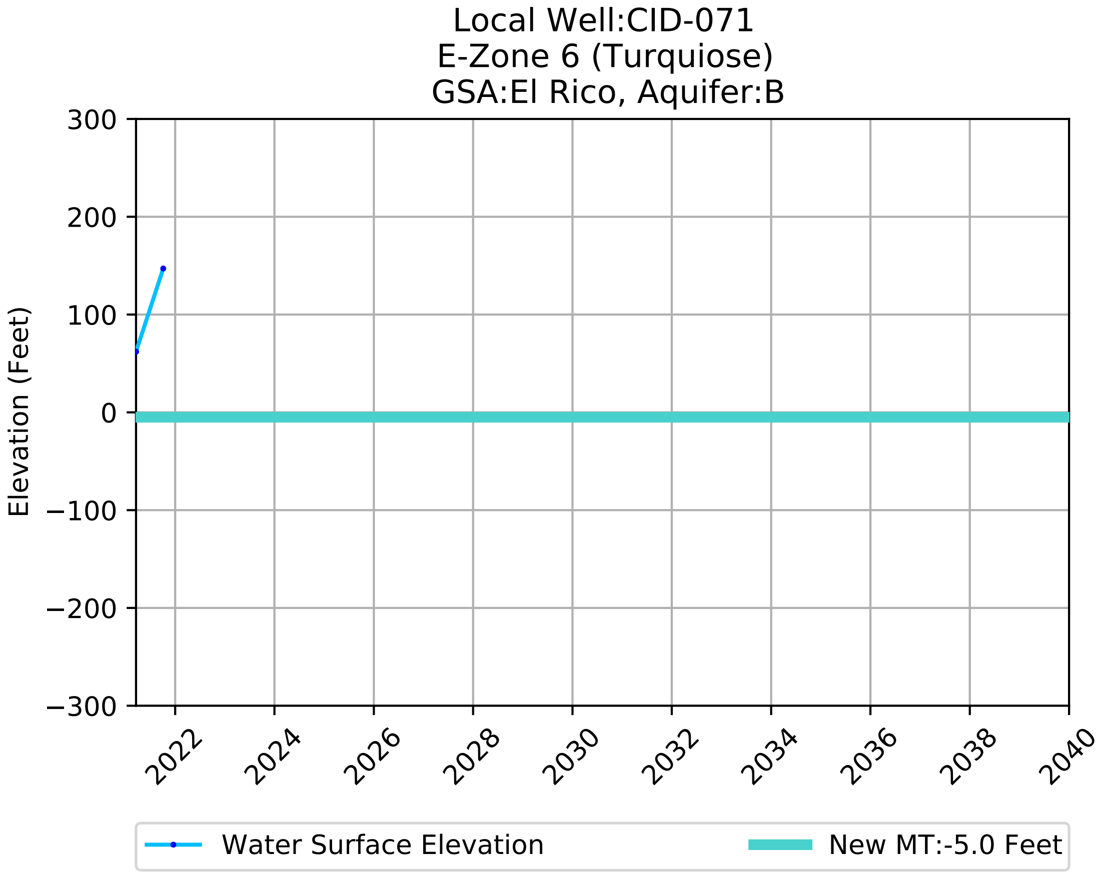

Local Well:19S20E32D003M
E-Zone 6 (Turquiose)
GSA:SFK, Aquifer:B
Elevation (Feet)
300
200
100
0
−100
−200
−300
2012
2016
2020
2024
2028
2032
2036
2040
Water Surface Elevation
New MT:-5.0 Feet
Original MT:-76.91 Feet



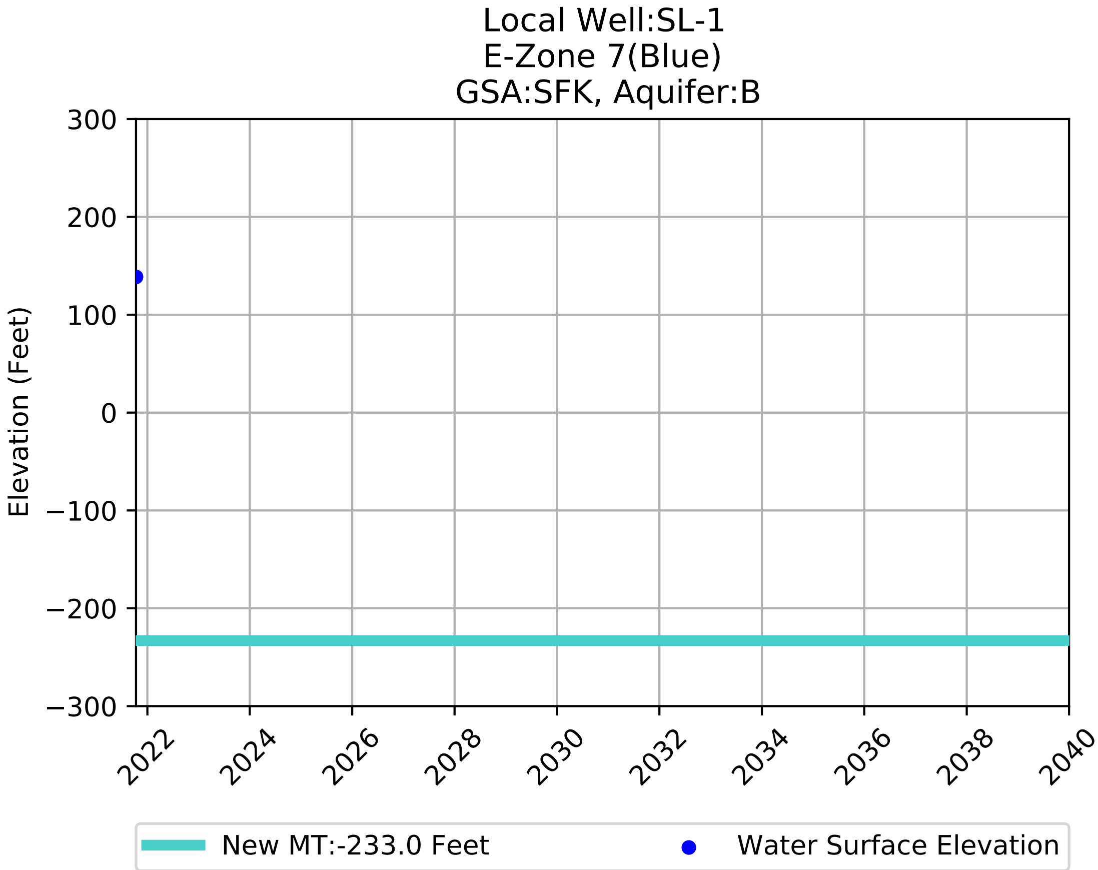
Local Well:20S20E26L001M
E-Zone 6 (Turquiose)
GSA:SFK, Aquifer:B
Elevation (Feet)
300
200
100
0
−100
−200
−300
2012
2016
2020
2024
2028
2032
2036
2040
Water Surface Elevation
Original MT:-4.25 Feet
New MT:-5.0 Feet



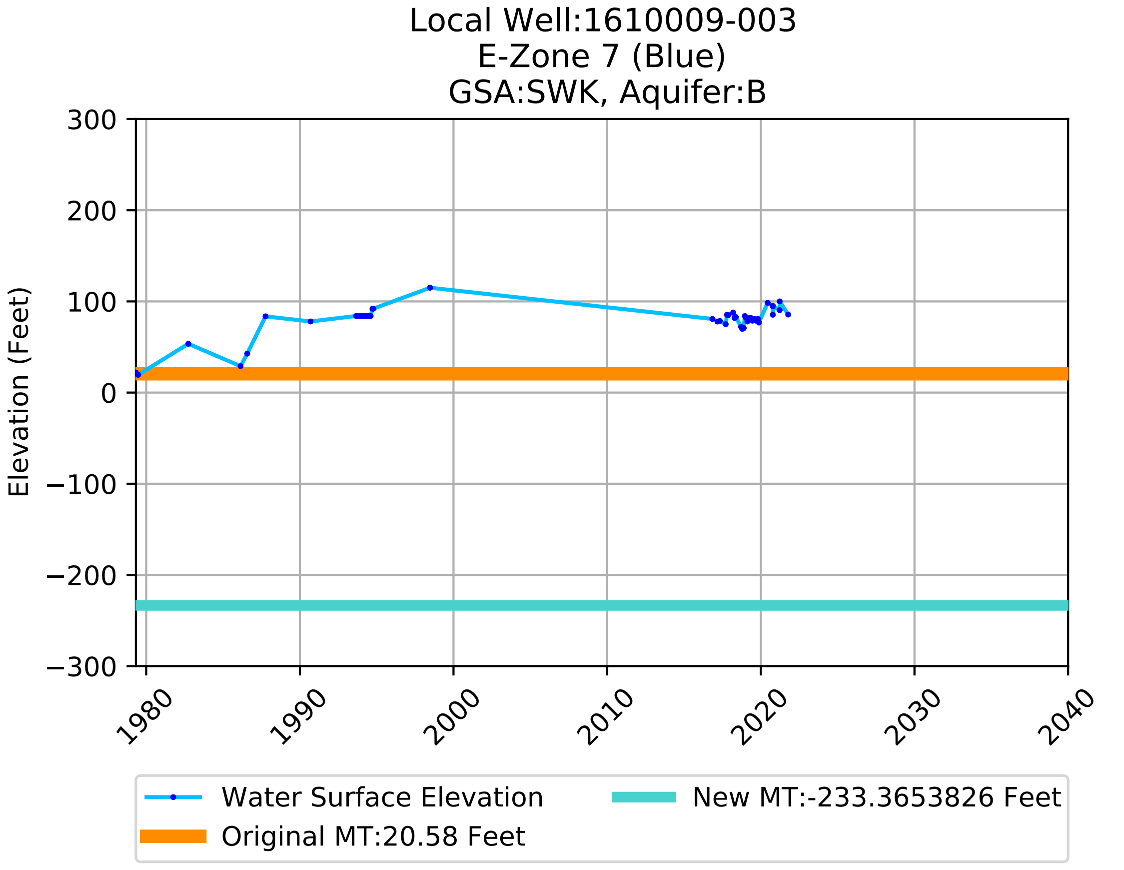
Local Well:20S20E26L002M
E-Zone 6 (Turquiose)
GSA:SFK, Aquifer:B
Elevation (Feet)
300
200
100
0
−100
−200
−300
2012
2016
2020
2024
2028
2032
2036
2040
Water Surface Elevation
New MT:-5.0 Feet
Original MT:-69.25 Feet

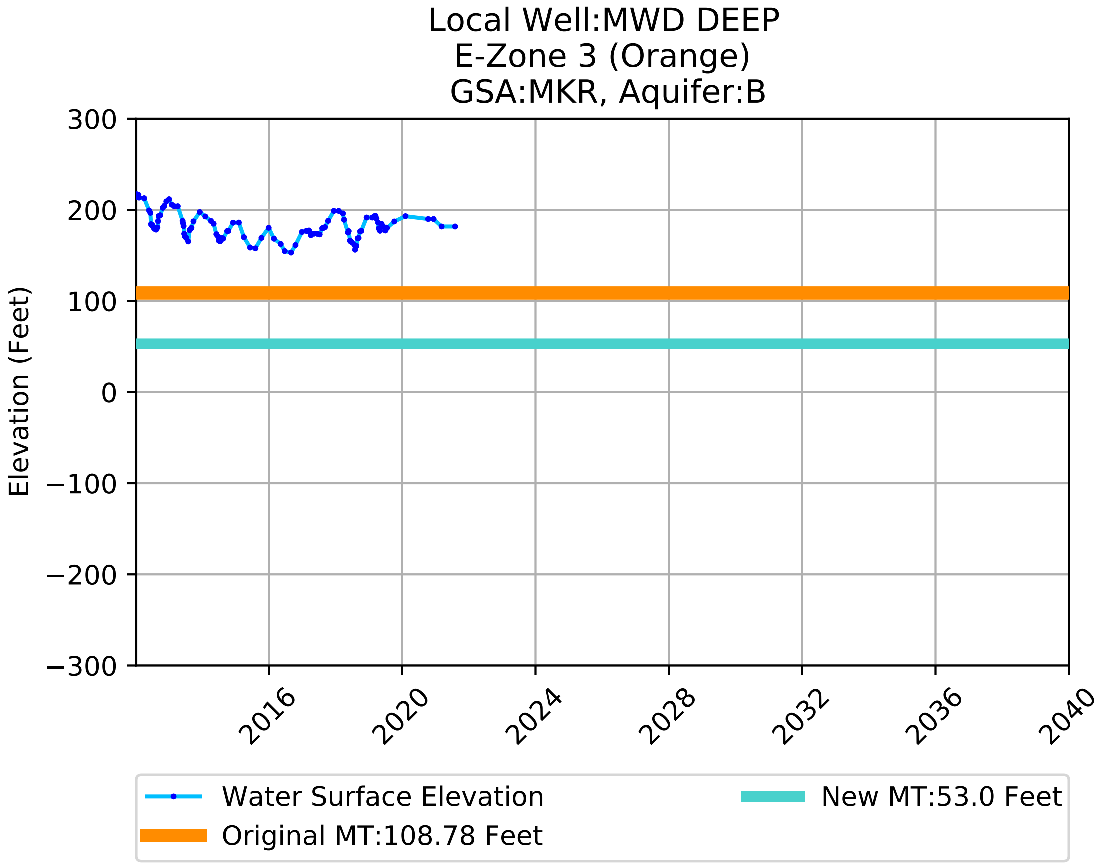


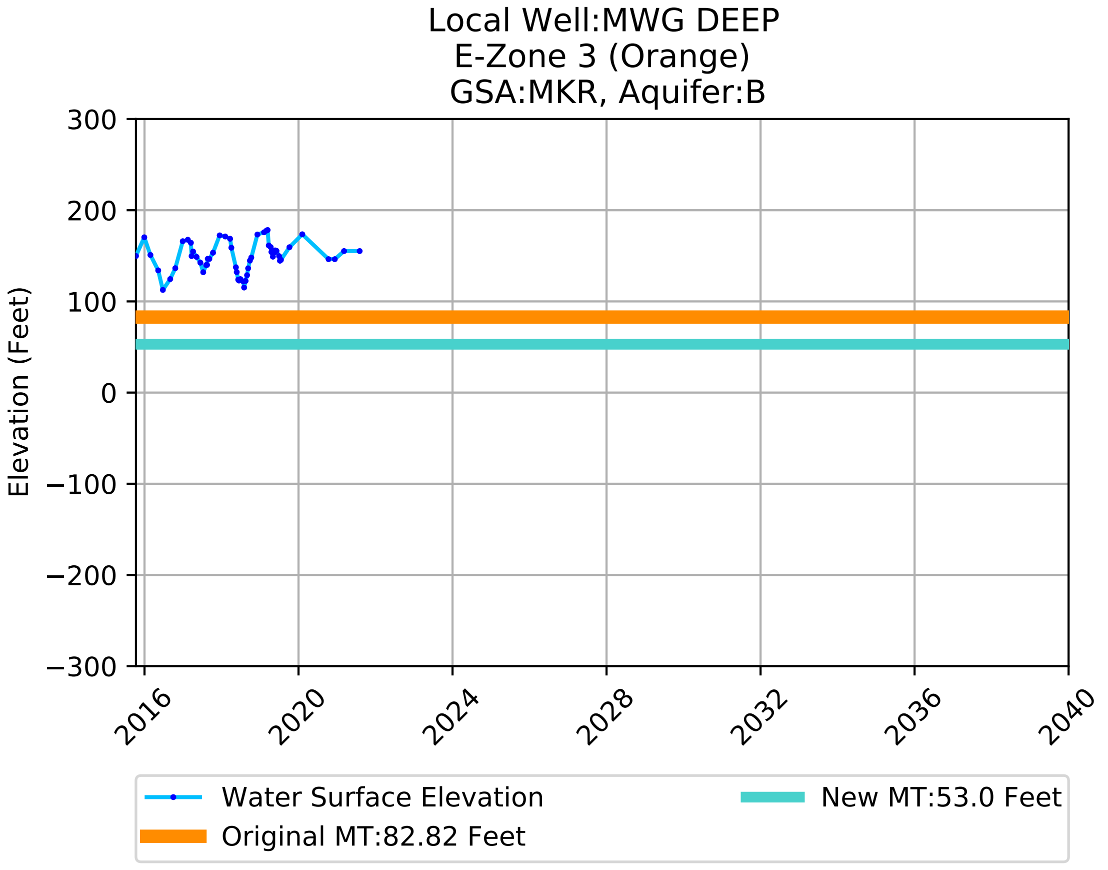
Local Well:CID-071
E-Zone 6 (Turquiose)
GSA:El Rico, Aquifer:B
Elevation (Feet)
300
200
100
0
−100
−200
−300
2022
2024
2026
2028
2030
2032
2034
2036
2038
2040
Water Surface Elevation
New MT:-5.0 Feet



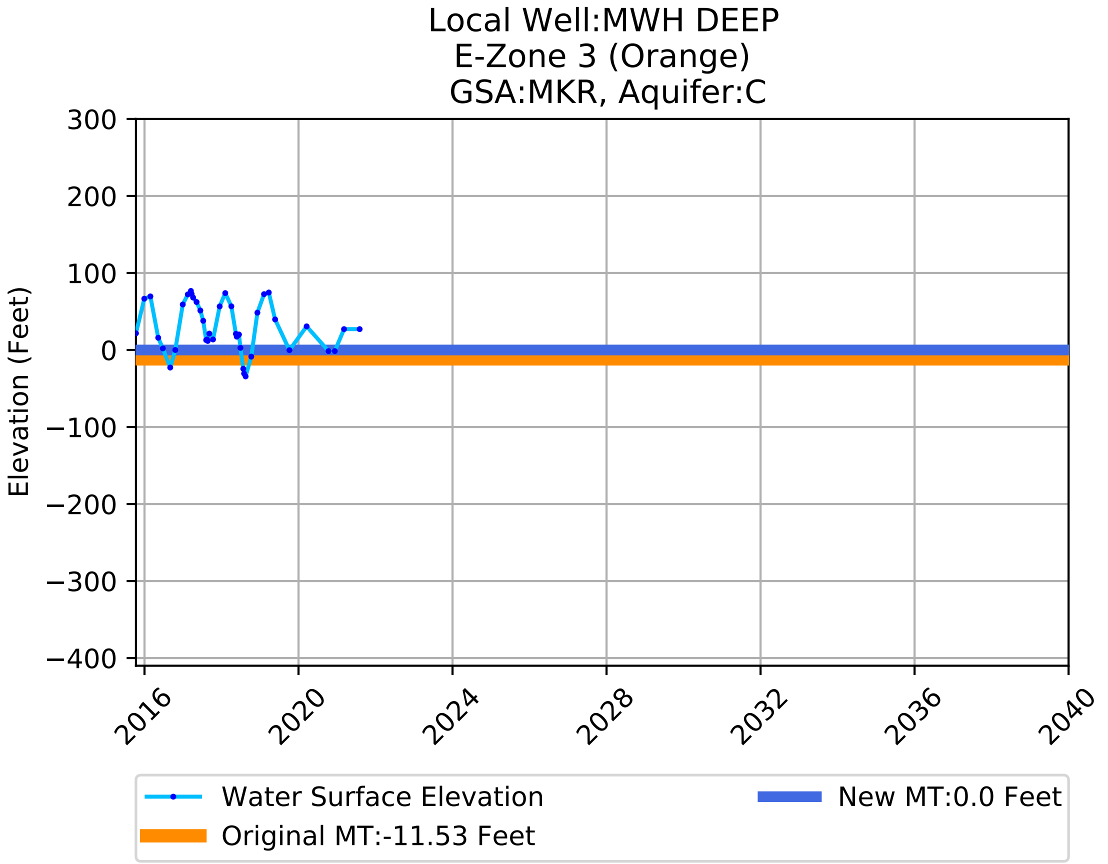
Local Well:SL-1
E-Zone 7(Blue)
GSA:SFK, Aquifer:B
Elevation (Feet)
300
200
100
0
−100
−200
−300
2022
2024
2026
2028
2030
2032
2034
2036
2038
2040
New MT:-233.0 Feet
Water Surface Elevation

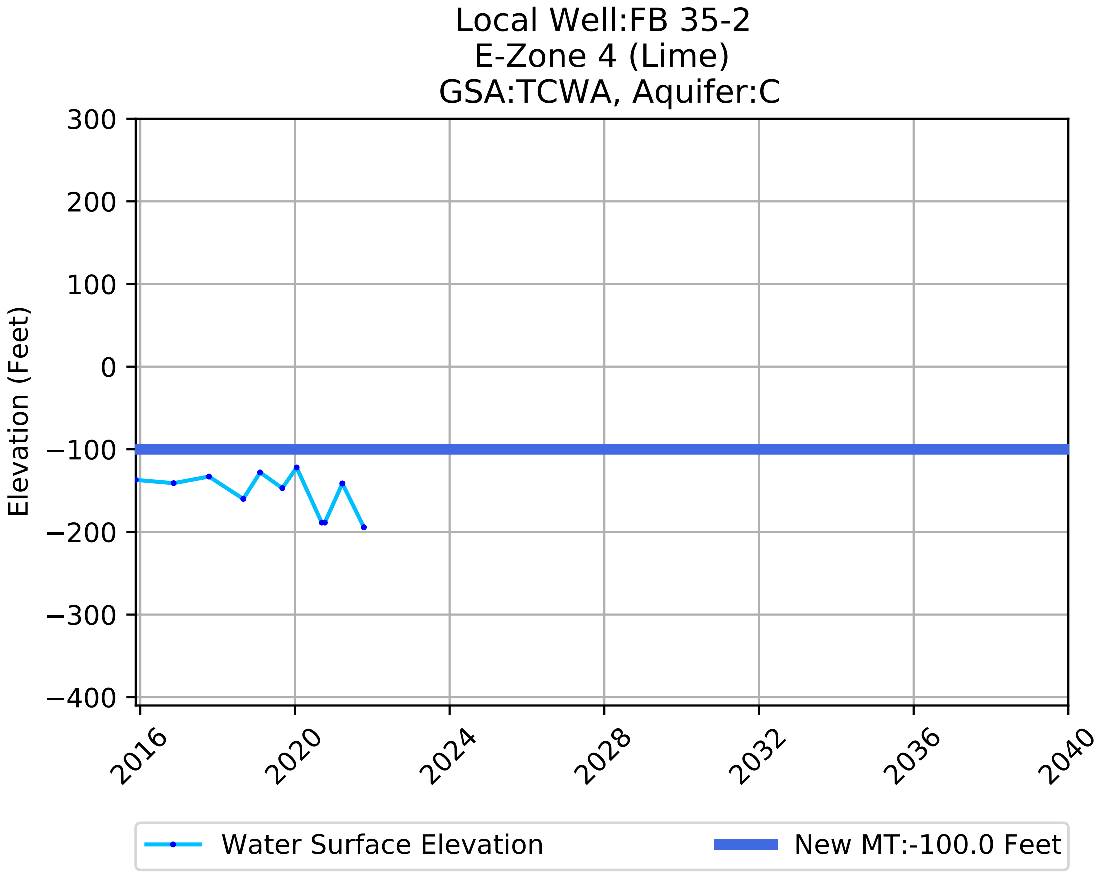

Local Well:1610009-003
E-Zone 7 (Blue)
GSA:SWK, Aquifer:B
Elevation (Feet)
300
200
100
0
−100
−200
−300
1980
1990
2000
2010
2020
2030
2040
Water Surface Elevation
Original MT:20.58 Feet
New MT:-233.3653826 Feet


Local Well:MWD DEEP
E-Zone 3 (Orange)
GSA:MKR, Aquifer:B
Elevation (Feet)
300
200
100
0
−100
−200
−300
2016
2020
2024
2028
2032
2036
2040
Water Surface Elevation
Original MT:108.78 Feet
New MT:53.0 Feet

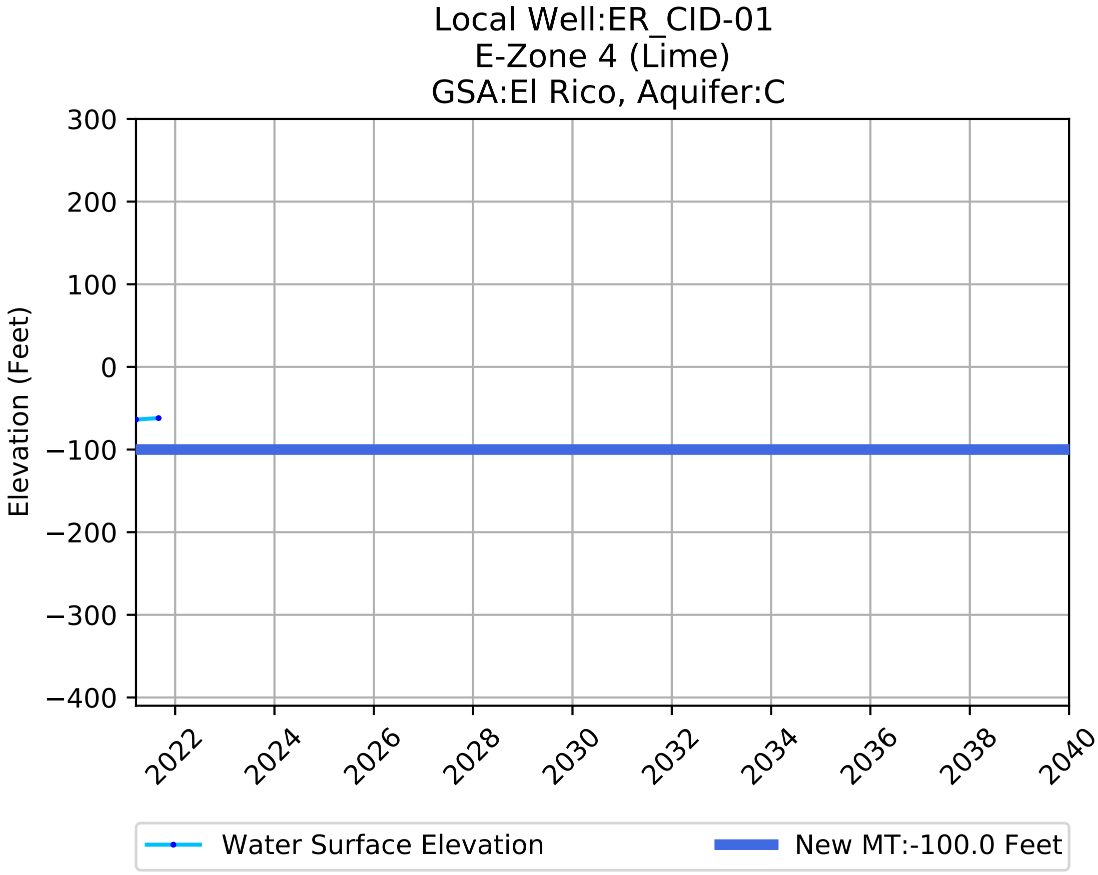


Local Well:MWG DEEP
E-Zone 3 (Orange)
GSA:MKR, Aquifer:B
Elevation (Feet)
300
200
100
0
−100
−200
−300
2016
2020
2024
2028
2032
2036
2040
Water Surface Elevation
New MT:53.0 Feet
Original MT:82.82 Feet

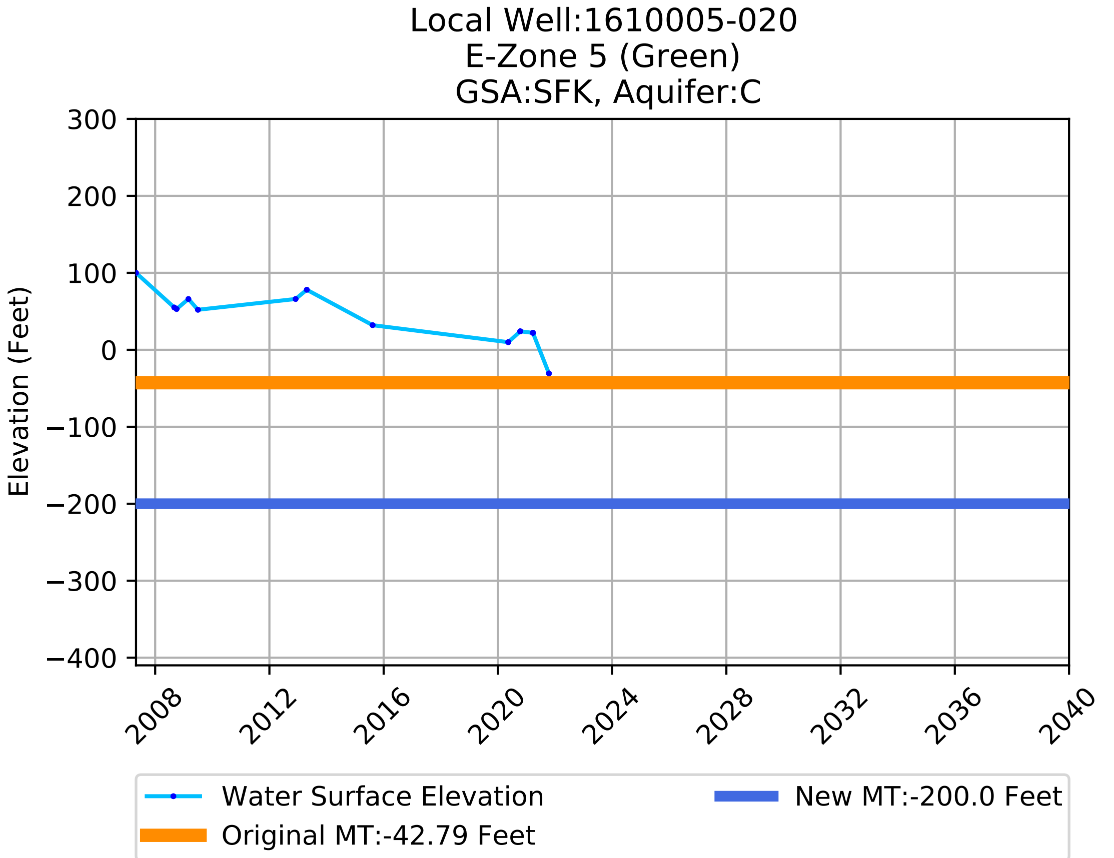

Local Well:MWH DEEP
E-Zone 3 (Orange)
GSA:MKR, Aquifer:C
Elevation (Feet)
300
200
100
0
−100
−200
−300
−400
2016
2020
2024
2028
2032
2036
2040
Water Surface Elevation
New MT:0.0 Feet
Original MT:-11.53 Feet

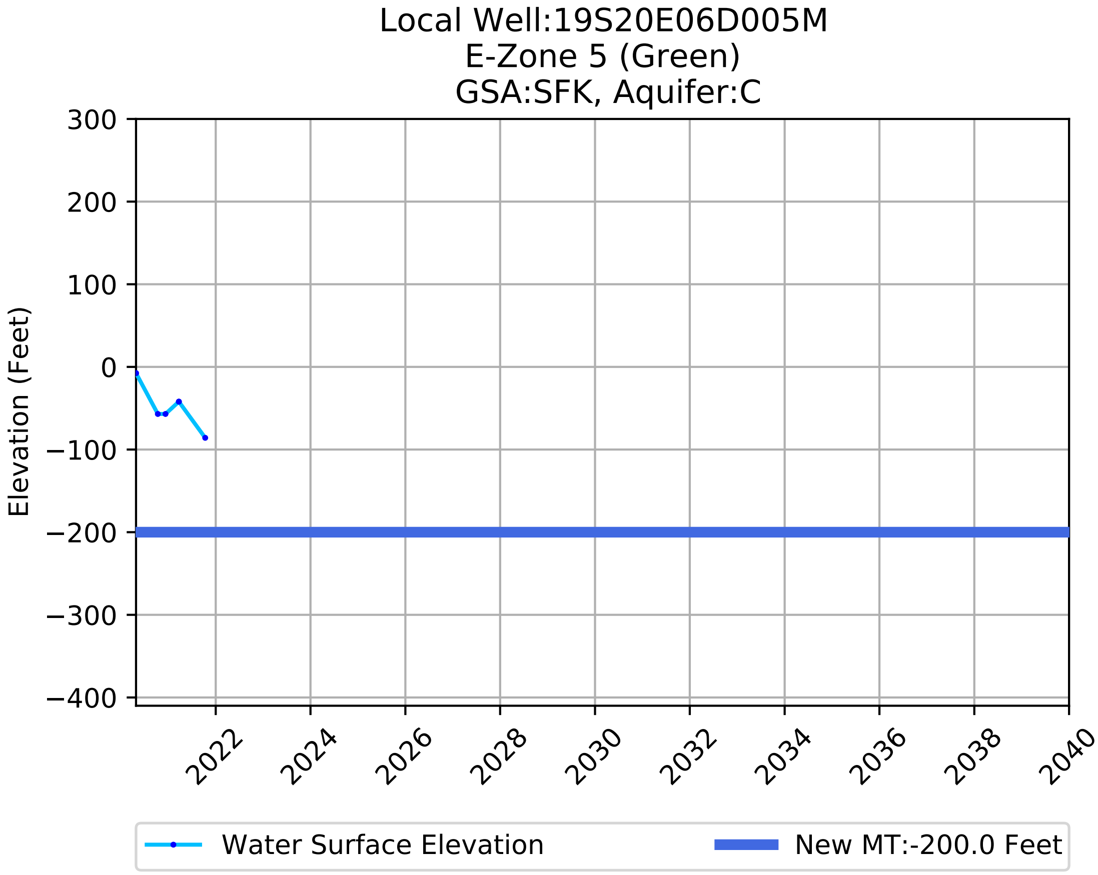


Local Well:FB 35-2
E-Zone 4 (Lime)
GSA:TCWA, Aquifer:C
Elevation (Feet)
300
200
100
0
−100
−200
−300
−400
2016
2020
2024
2028
2032
2036
2040
Water Surface Elevation
New MT:-100.0 Feet

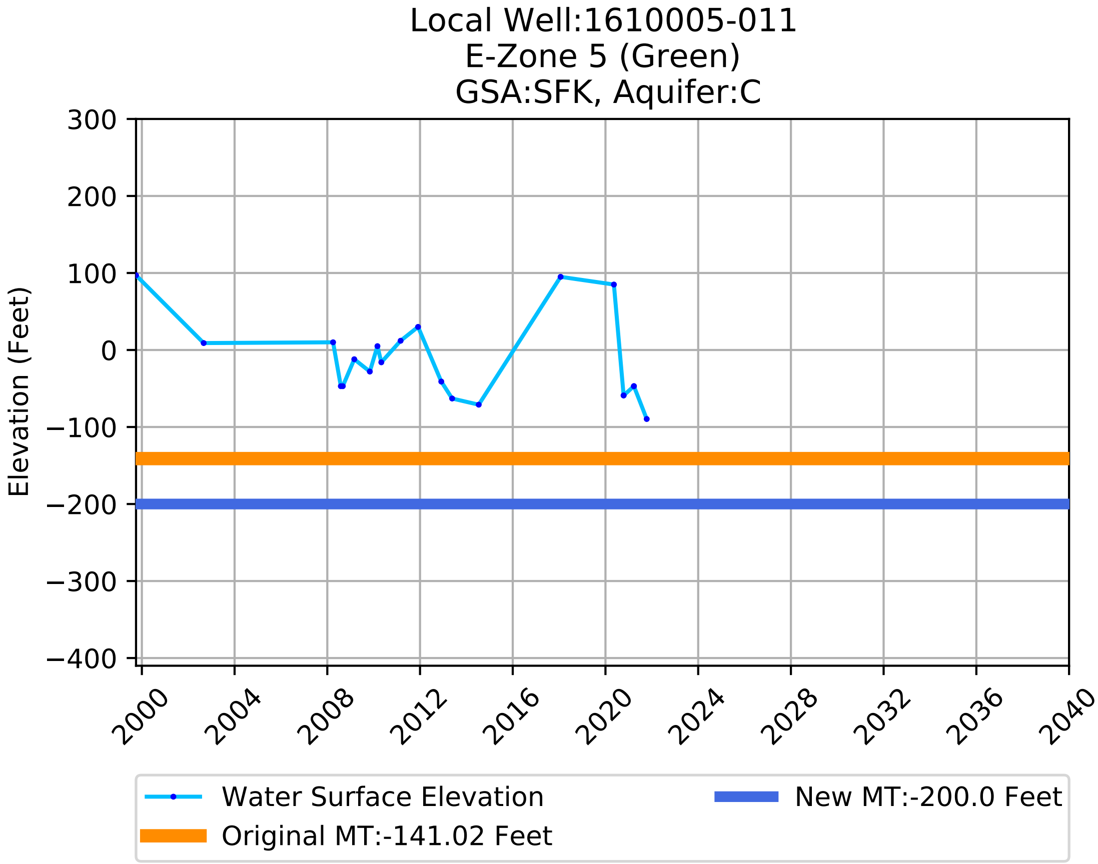


Local Well:ER_CID-01
E-Zone 4 (Lime)
GSA:El Rico, Aquifer:C
Elevation (Feet)
300
200
100
0
−100
−200
−300
−400
2022
2024
2026
2028
2030
2032
2034
2036
2038
2040
Water Surface Elevation
New MT:-100.0 Feet

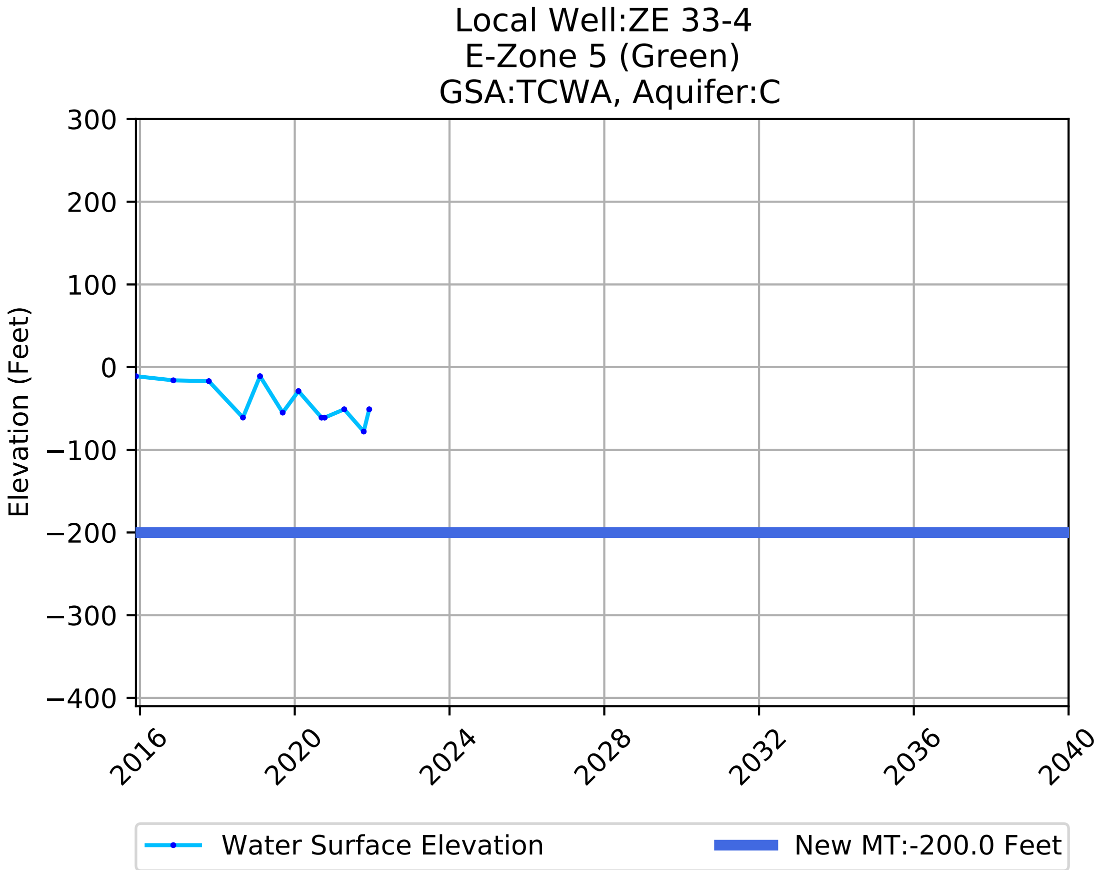

Local Well:1610005-020
E-Zone 5 (Green)
GSA:SFK, Aquifer:C
Elevation (Feet)
300
200
100
0
−100
−200
−300
−400
2008
2012
2016
2020
2024
2028
2032
2036
2040
Water Surface Elevation
Original MT:-42.79 Feet
New MT:-200.0 Feet



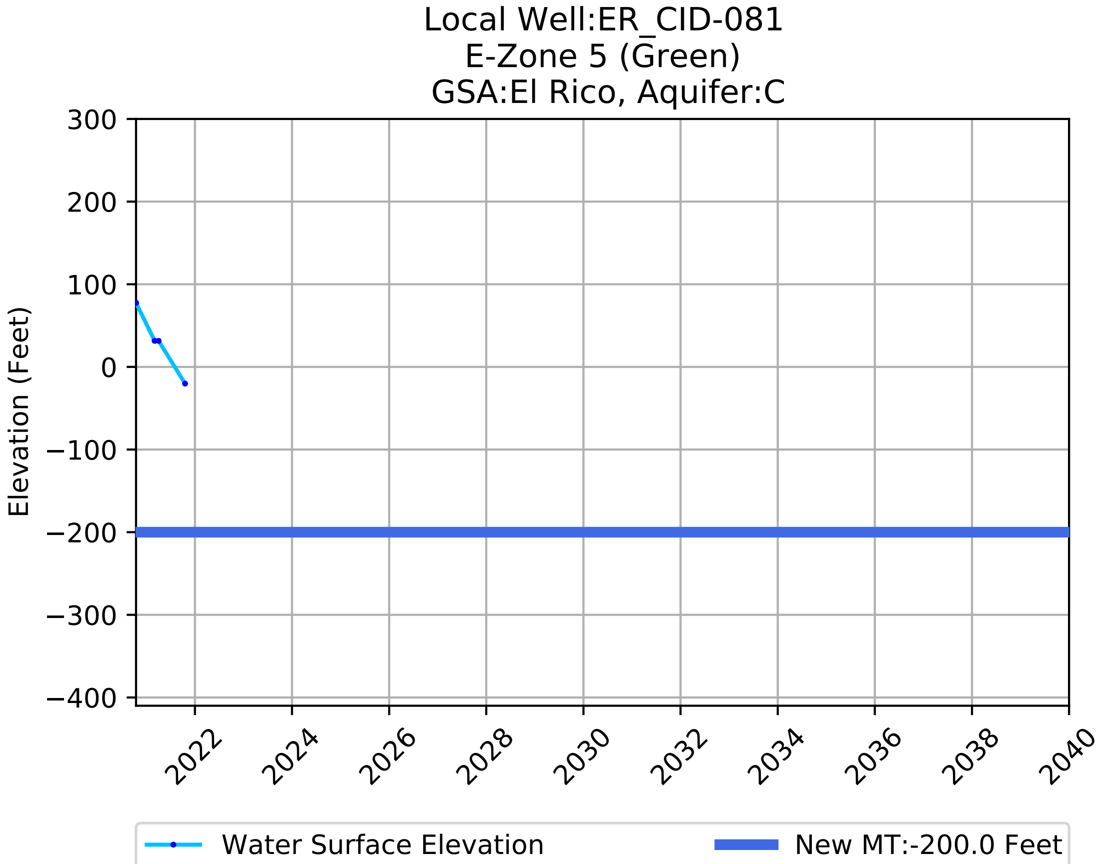
Local Well:19S20E06D005M
E-Zone 5 (Green)
GSA:SFK, Aquifer:C
Elevation (Feet)
300
200
100
0
−100
−200
−300
−400
2022
2024
2026
2028
2030
2032
2034
2036
2038
2040
Water Surface Elevation
New MT:-200.0 Feet



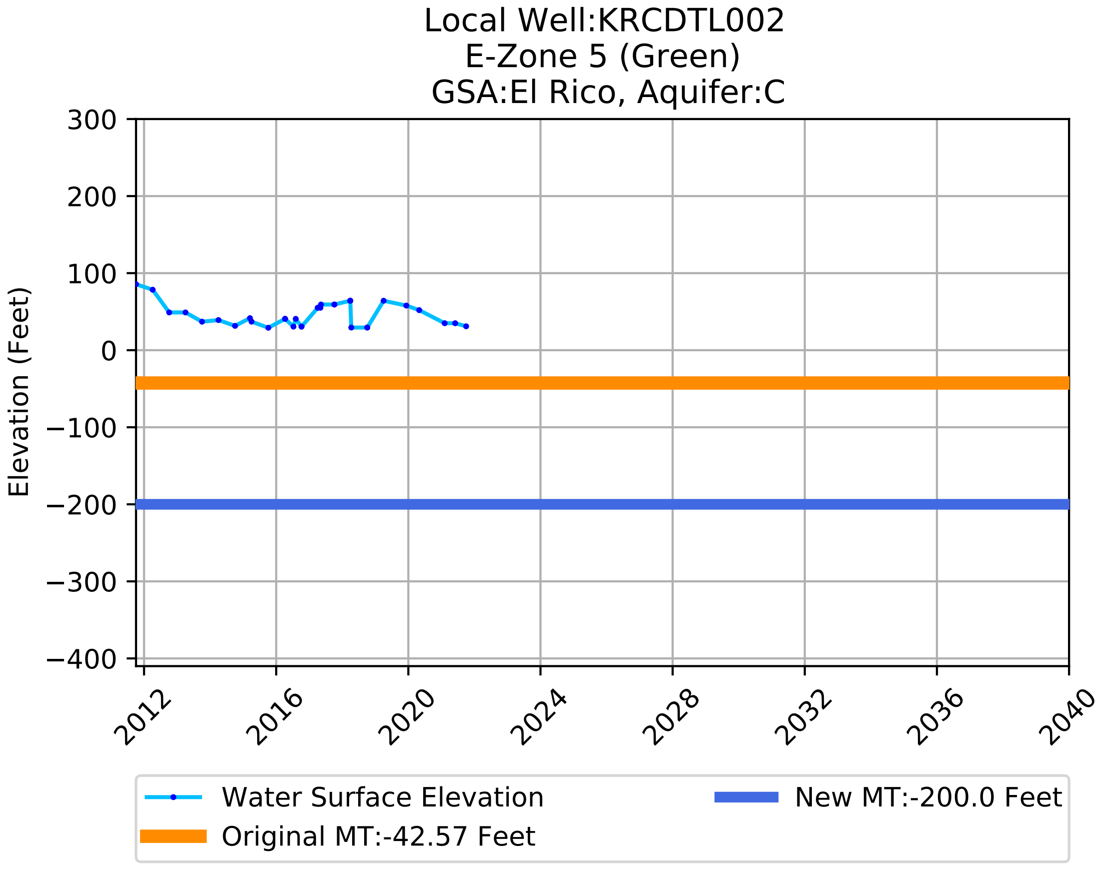
Local Well:1610005-011
E-Zone 5 (Green)
GSA:SFK, Aquifer:C
Elevation (Feet)
300
200
100
0
−100
−200
−300
−400
2000
2004
2008
2012
2016
2020
2024
2028
2032
2036
2040
Water Surface Elevation
New MT:-200.0 Feet
Original MT:-141.02 Feet



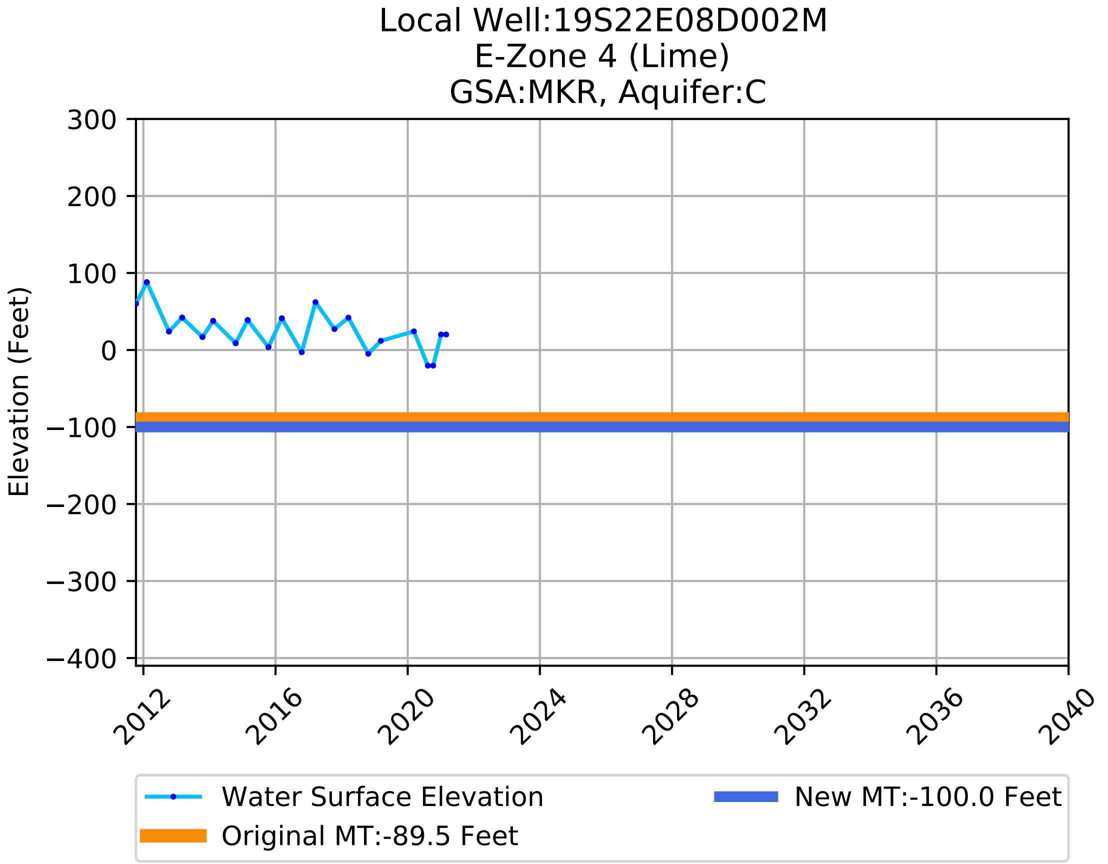
Local Well:ZE 33-4
E-Zone 5 (Green)
GSA:TCWA, Aquifer:C
300
200
100
0
−100
−200
−300
−400
Elevation (Feet)
2016
2020
2024
2028
2032
2036
2040
Water Surface Elevation
New MT:-200.0 Feet

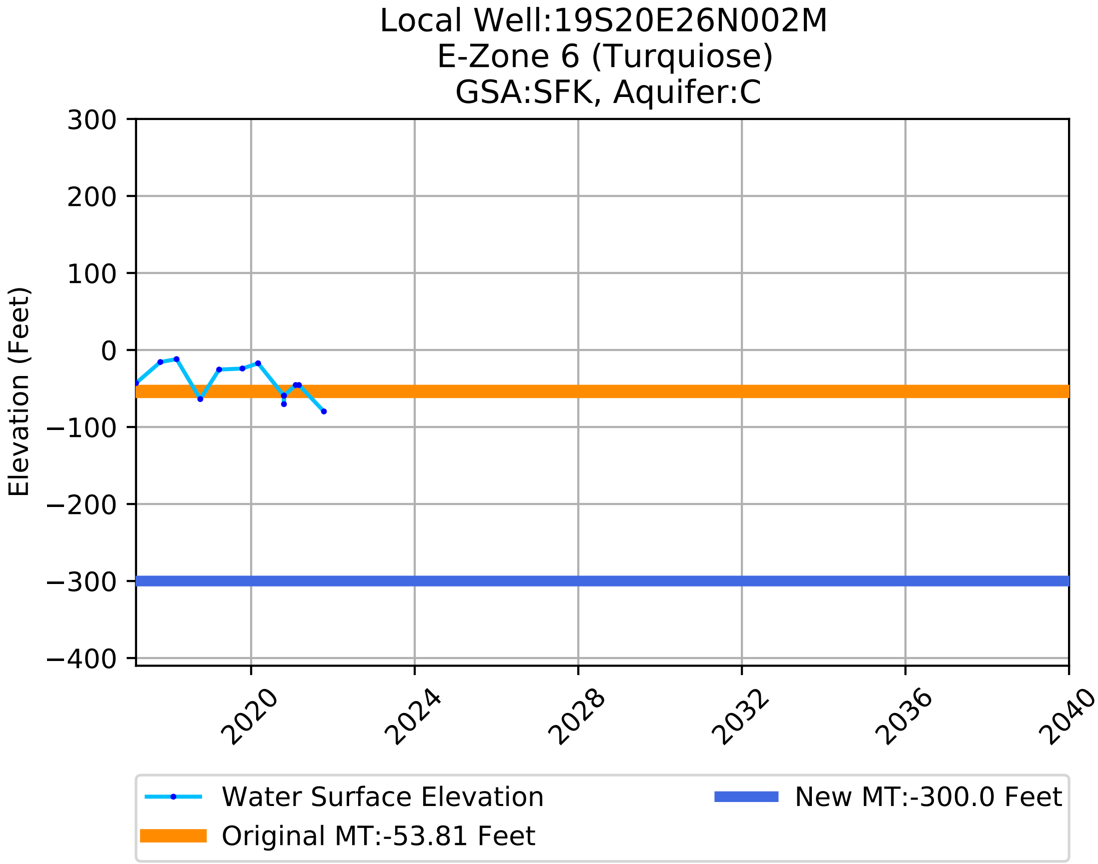


Local Well:ER_CID-081
E-Zone 5 (Green)
GSA:El Rico, Aquifer:C
Elevation (Feet)
300
200
100
0
−100
−200
−300
−400
2022
2024
2026
2028
2030
2032
2034
2036
2038
2040
Water Surface Elevation
New MT:-200.0 Feet

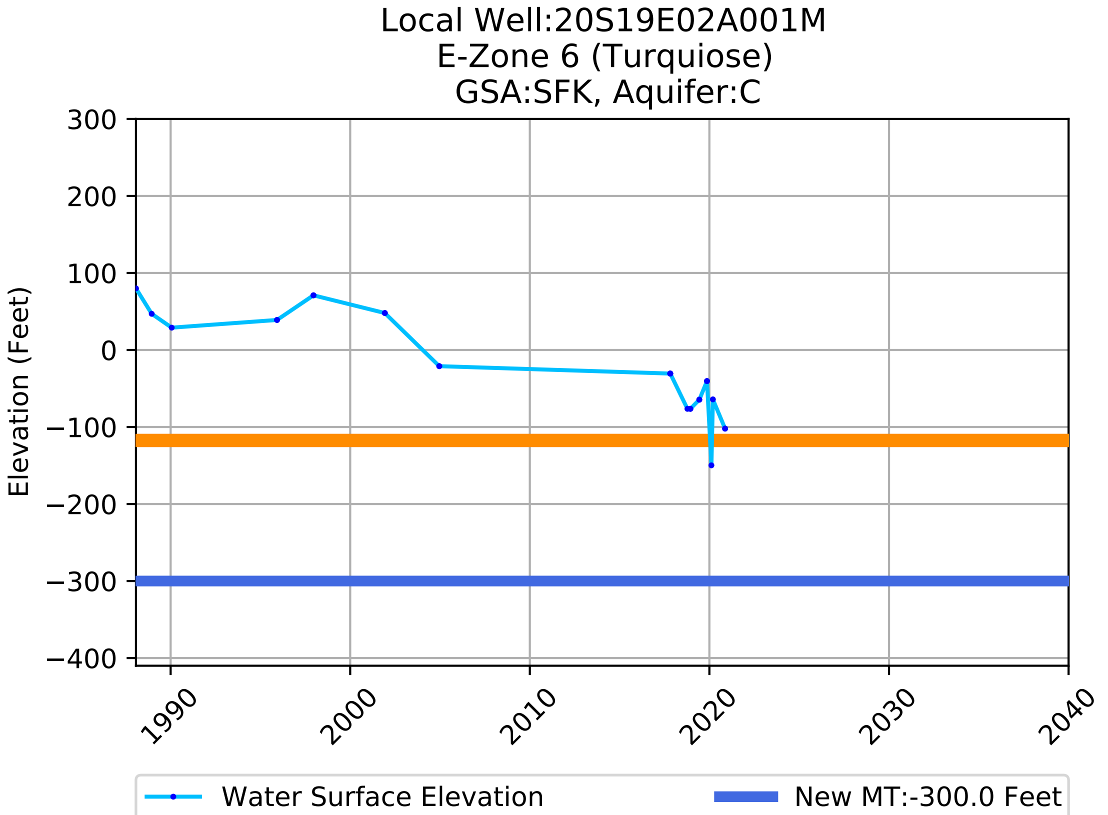


Local Well:KRCDTL002
E-Zone 5 (Green)
GSA:El Rico, Aquifer:C
Elevation (Feet)
300
200
100
0
−100
−200
−300
−400
2012
2016
2020
2024
2028
2032
2036
2040
Water Surface Elevation
New MT:-200.0 Feet
Original MT:-42.57 Feet

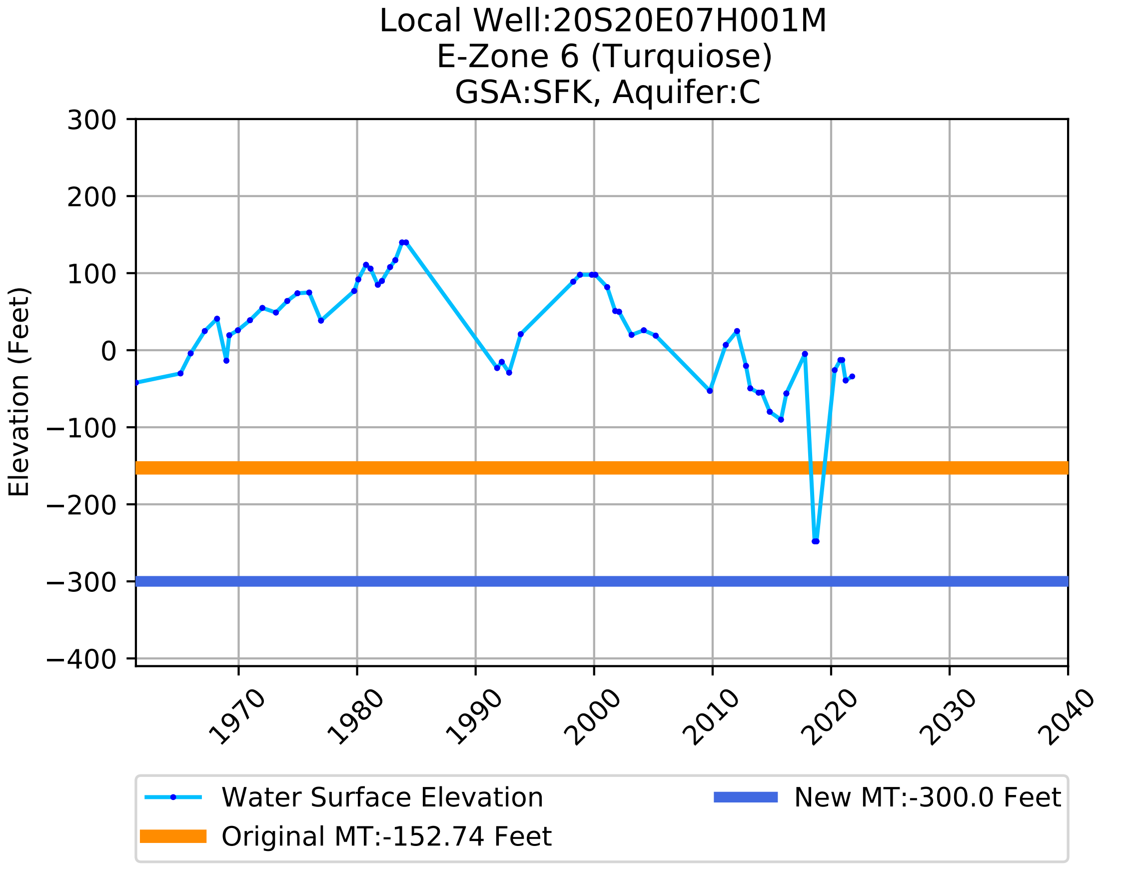

Local Well:19S22E08D002M
E-Zone 4 (Lime)
GSA:MKR, Aquifer:C
Elevation (Feet)
300
200
100
0
−100
−200
−300
−400
2012
2016
2020
2024
2028
2032
2036
2040
Water Surface Elevation
Original MT:-89.5 Feet
New MT:-100.0 Feet



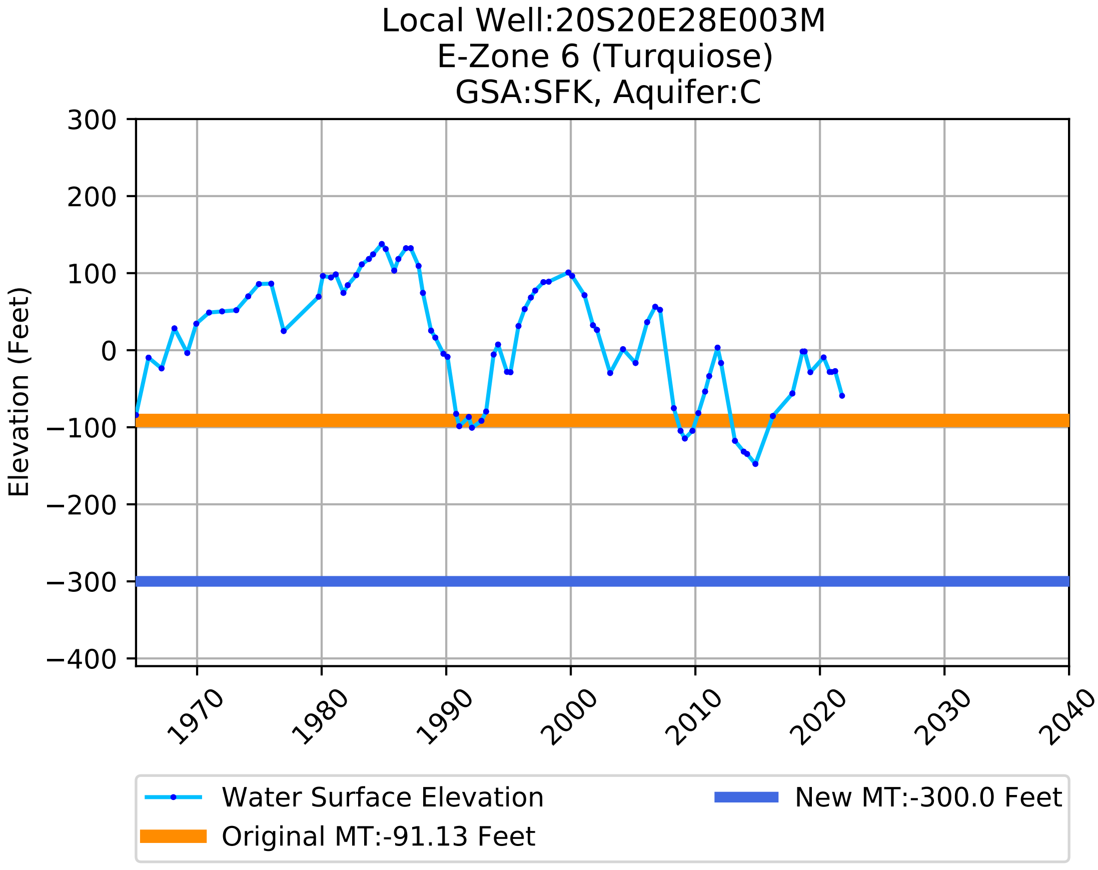
Local Well:19S20E26N002M
E-Zone 6 (Turquiose)
GSA:SFK, Aquifer:C
Elevation (Feet)
300
200
100
0
−100
−200
−300
−400
2020
2024
2028
2032
2036
2040
Water Surface Elevation
New MT:-300.0 Feet
Original MT:-53.81 Feet



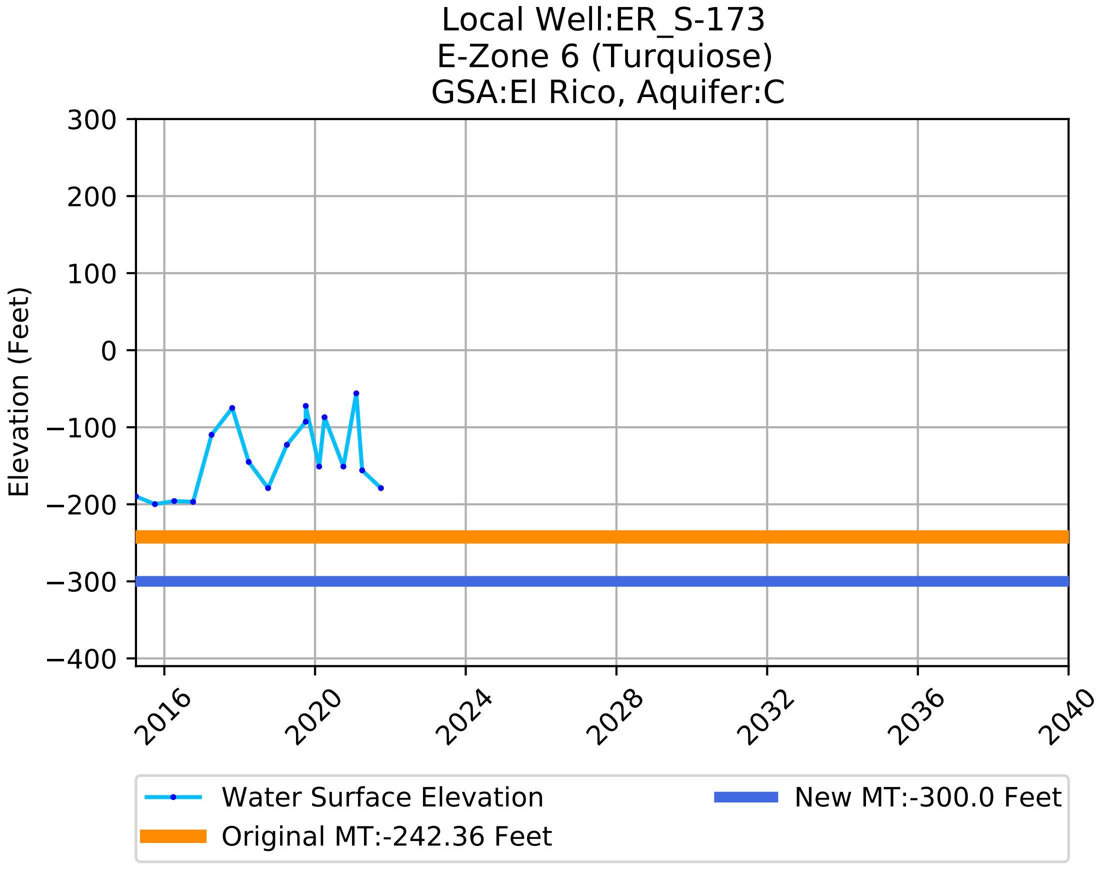
Local Well:20S19E02A001M
E-Zone 6 (Turquiose)
GSA:SFK, Aquifer:C
300
200
100
0
−100
−200
−300
−400
Elevation (Feet)
1990
2000
2010
2020
2030
2040
Water Surface Elevation
Original MT:-117.47 Feet
New MT:-300.0 Feet

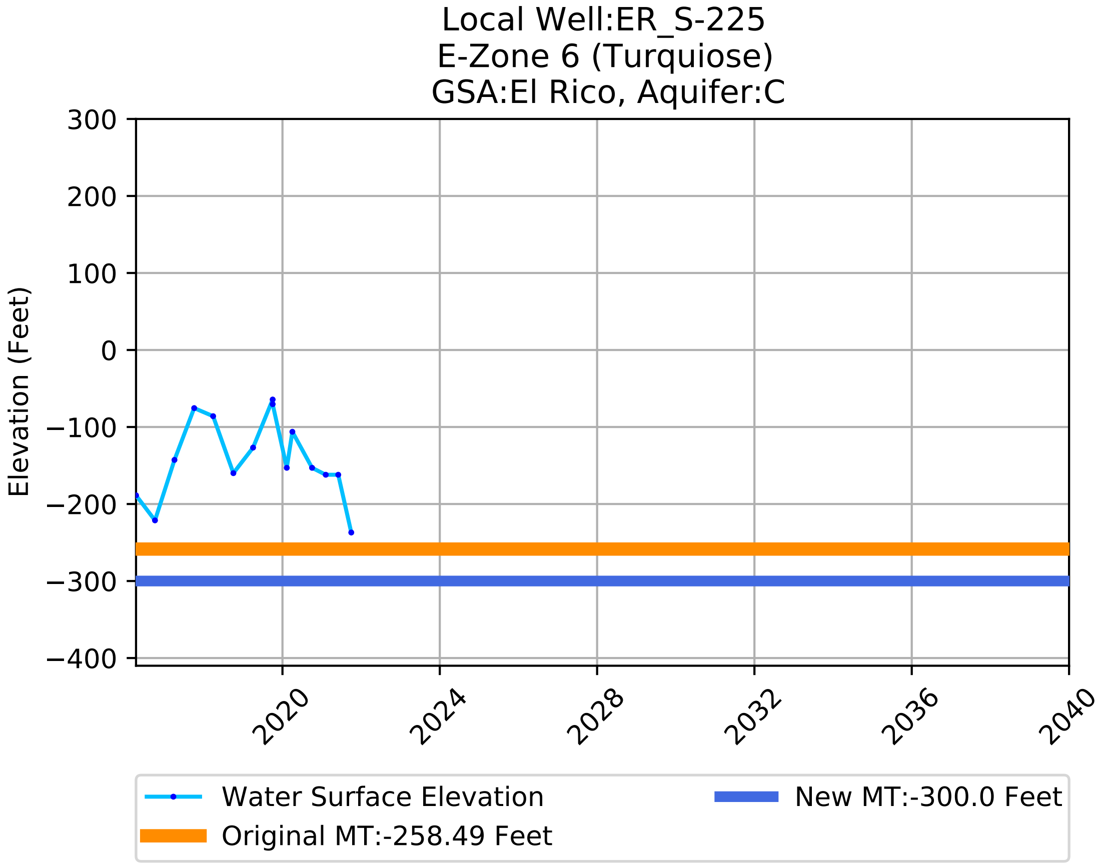


Local Well:20S20E07H001M
E-Zone 6 (Turquiose)
GSA:SFK, Aquifer:C
Elevation (Feet)
300
200
100
0
−100
−200
−300
−400
1970
1980
1990
2000
2010
2020
2030
2040
Water Surface Elevation
New MT:-300.0 Feet
Original MT:-152.74 Feet

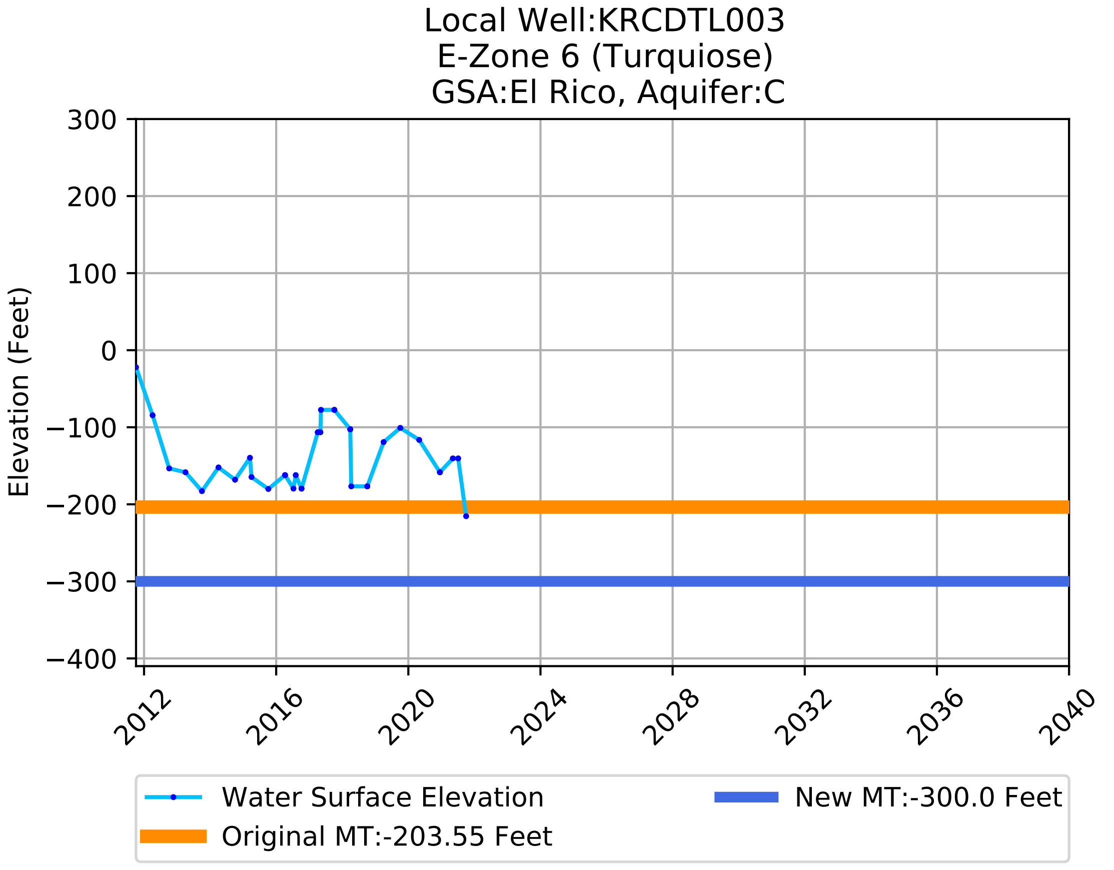


Local Well:20S20E28E003M
E-Zone 6 (Turquiose)
GSA:SFK, Aquifer:C
Elevation (Feet)
300
200
100
0
−100
−200
−300
−400
1970
1980
1990
2000
2010
2020
2030
2040
Water Surface Elevation
New MT:-300.0 Feet
Original MT:-91.13 Feet

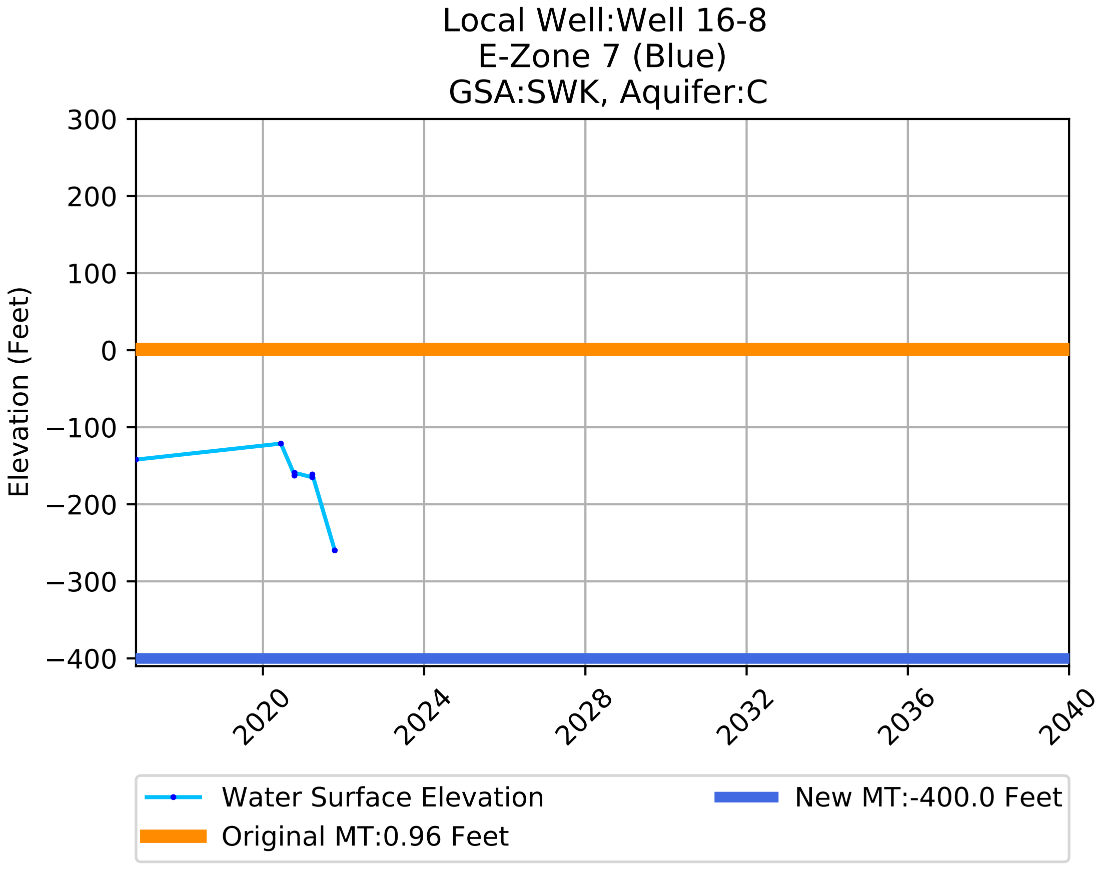

Local Well:ER_S-173
E-Zone 6 (Turquiose)
GSA:El Rico, Aquifer:C
Elevation (Feet)
300
200
100
0
−100
−200
−300
−400
2016
2020
2024
2028
2032
2036
2040
Water Surface Elevation
New MT:-300.0 Feet
Original MT:-242.36 Feet



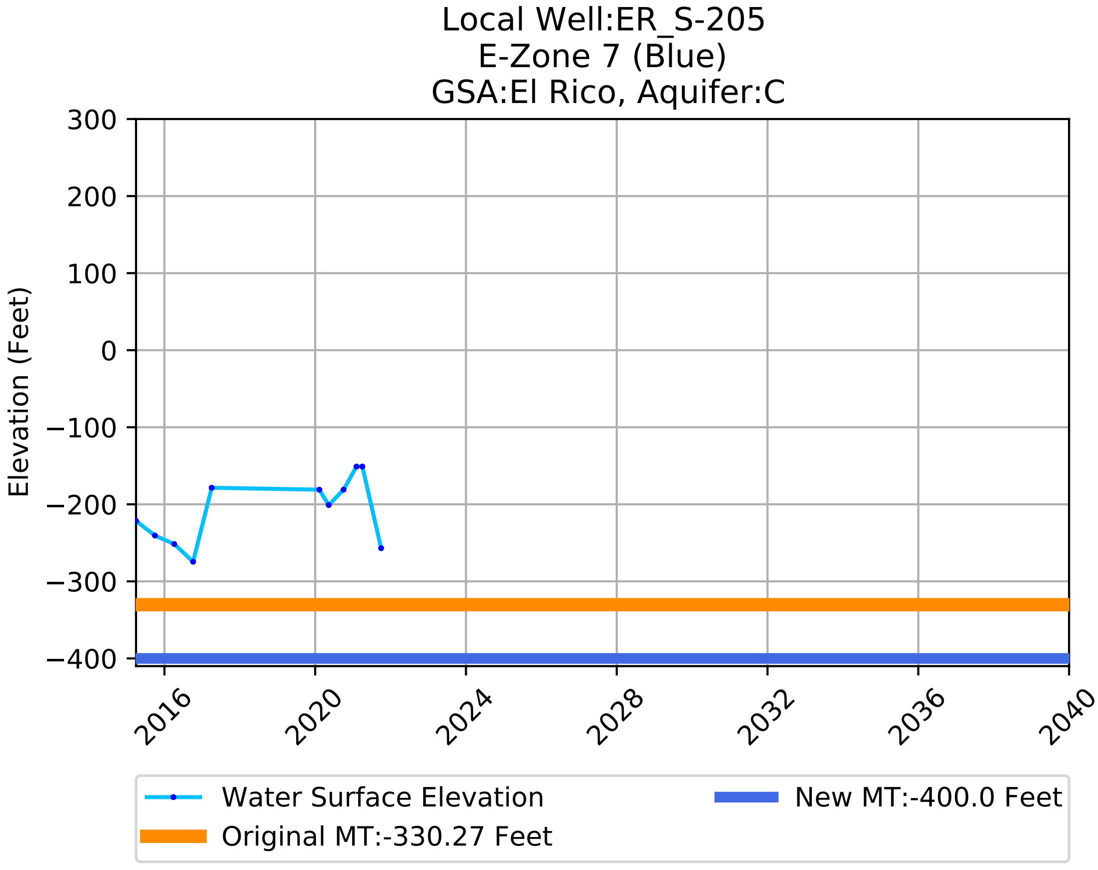
Local Well:ER_S-225
E-Zone 6 (Turquiose)
GSA:El Rico, Aquifer:C
Elevation (Feet)
300
200
100
0
−100
−200
−300
−400
2020
2024
2028
2032
2036
2040
Water Surface Elevation
New MT:-300.0 Feet
Original MT:-258.49 Feet



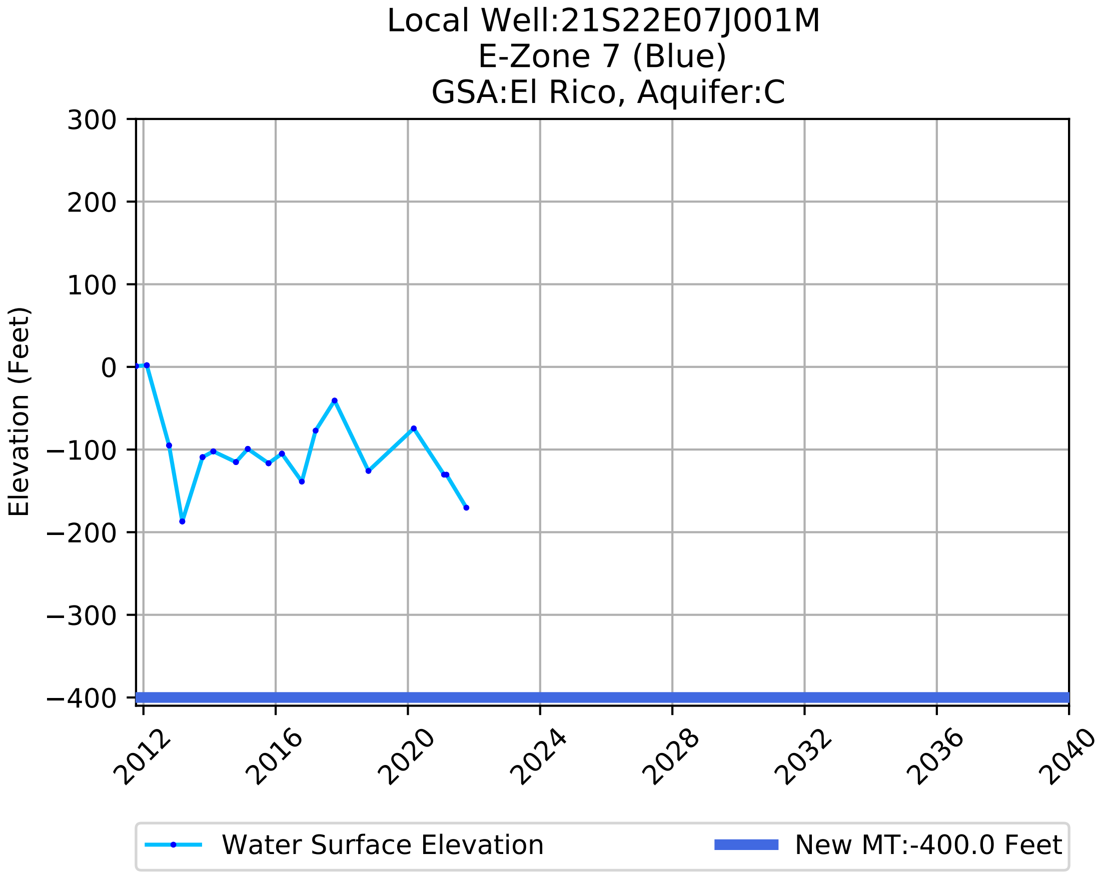
Local Well:KRCDTL003
E-Zone 6 (Turquiose)
GSA:El Rico, Aquifer:C
Elevation (Feet)
300
200
100
0
−100
−200
−300
−400
2012
2016
2020
2024
2028
2032
2036
2040
Water Surface Elevation
New MT:-300.0 Feet
Original MT:-203.55 Feet



Local Well:Well 16-8
E-Zone 7 (Blue)
GSA:SWK, Aquifer:C
Elevation (Feet)
300
200
100
0
−100
−200
−300
−400
2020
2024
2028
2032
2036
2040
Water Surface Elevation
New MT:-400.0 Feet
Original MT:0.96 Feet



Local Well:ER_S-205
E-Zone 7 (Blue)
GSA:El Rico, Aquifer:C
Elevation (Feet)
300
200
100
0
−100
−200
−300
−400
2016
2020
2024
2028
2032
2036
2040
Water Surface Elevation
New MT:-400.0 Feet
Original MT:-330.27 Feet


Local Well:21S22E07J001M
E-Zone 7 (Blue)
GSA:El Rico, Aquifer:C
Elevation (Feet)
300
200
100
0
−100
−200
−300
−400
2012
2016
2020
2024
2028
2032
2036
2040
Water Surface Elevation
New MT:-400.0 Feet

APPENDIX B

GROUND SUBSIDENCE SMC SUPPORTING INFORMATION

MITIGATION PLAN FRAMEWORK

The Tulare Lake GSAs have agreed to prepare and implement mitigation programs to offset impacts. However, it should be understood that the conditions and users in each area vary widely. This framework presents the minimum requirements that would be included in each GSA-specific mitigation program. As the GSAs considered what mitigation might entail in their areas, it became clear that the effort has many facets that will require stakeholder input in each area. In particular, funding for these efforts would need to be developed through a Proposition 218 process and election. Also, most rural residential wells are considered *di minimis* under SGMA, and therefore will need to be investigated more fully to understand their location and construction. Due to the tight deadline allowed in GSP Regulations, insufficient time was available to seek stakeholder input into a complete mitigation program. Instead, the GSAs have agreed to this framework and will prepare individual mitigation programs specific to their stakeholder needs by January 2025 for inclusion into the five-year Plan update.

Purpose

The purpose of the mitigation program is to address local landowner issues to the extent feasible. The plan would be that the mitigation program would address local impacts to beneficial users resulting from GSP implementation. However, care must be taken to establish what portion of the impacts are associated with the choices by the landowner or other nearby landowners, rather than GSA actions to implement the GSP. In this regard, the mitigation plan might be viewed to be similar to efforts put in place around groundwater banks, where benefits and impacts from the banking operations are considered along with all available monitoring information by qualified professionals to develop a view of whether mitigation is warranted. The impacts covered by the program would be limited to domestic wells, critical infrastructure, and land uses that are adversely affected by declining groundwater levels, land subsidence, or changes to groundwater quality. The mitigation plan may be revised or expanded based on groundwater conditions in the future.

Minimum Plan Requirements

Each plan will include the following:

1. Stakeholder outreach
2. Well Registration
3. Eligibility Criteria
4. Application process
5. Evaluation process
6. Identification of suitable mitigation
7. Funding Source

Stakeholder Outreach

The program should present the public outreach and education efforts that will be performed during development of the mitigation program and prior to implementation. Prior to implementation, extensive outreach will be needed to notify stakeholders of the Program requirements and how they can apply for assistance. These efforts should be in general accordance with the existing Stakeholder Communication and Engagement Plan. However, one main difference relative to when the 2020 GSP was developed is that through the Governor's Executive Order N-7-22, GSAs are more directly involved in well permitting. So, for impacted parties, contacting their local GSA about the matter should become routine.

Well Registration

As noted above, the information on domestic wells regarding well construction and operation is limited. The Kings County database provides some information on the existing domestic wells where permits were obtained but is not updated regularly for well operational status. A comprehensive database of the domestic wells with construction details would be complied across the Subbasin.

Eligibility Criteria

The program should present the eligibility requirements to qualify for the program based on stakeholder compliance with the GSP, GSA's Rules & Regulations, and other laws or regulations.

Application Process

The program should clearly present the process by which an affected stakeholder can submit a claim. It is anticipated that this process will include requests for information such as a Well Completion Report on the well, monitored depths to water over time, records on how the well was maintained, information on the amount of water used or power consumption records that could be used as a proxy, water quality records for relevant COCs, and information about existing wells within a radius around the well experiencing the perceived impact.

Evaluation

Once a claim of adverse impact has been made to a GSA, the GSA will investigate the claim to evaluate whether it is associated with GSP Implementation. As was stated before, the mitigation program will be designed to address local impacts to beneficial users resulting from GSP implementation. However, care must be taken to establish what part of the impacts may be associated with choices by the landowner, other nearby landowners, or potentially some other issue with the facility, rather than GSA actions to implement the GSP. In this regard the mitigation plan might be viewed to be similar to efforts put in place around Groundwater Banks, where benefits and impacts from the Banks operations are considered along with all available monitoring information by qualified professionals to come to a view of whether mitigation is warranted.

Mitigation

Once contacted about a potential impact, the GSA will begin working with the local landowner. There are various services available to landowners with well issues, such as County programs to provide temporary water service while a new well is drilled. The GSAs will convey available information on these services and work with the landowner to provide information about the facility and its condition to the GSAs so that an evaluation can be undertaken as quickly as possible. Once a claim of impact has been confirmed to be due to GSP implementation, the GSA will pursue suitable mitigation efforts as described in each GSA specific plan. Various factors may reflect the proper mitigation methods for the specific issue. For example, facility age, location, financial impact to the stakeholder as a result of mitigation.

Funding Source

Funding will be needed for the program through the GSA's implementation of assessments, fees, charges, and penalties. All of these funds will have to be developed consistent with Proposition 218 requirements. Also, much work will have to be done to better understand the sources of the impacts and identify landowners involved in developing the identified impacts, so that funds are collected from the appropriate parties. In addition, the GSAs will explore grant funding as County, state and federal assistance will be needed to successfully implement this program. The State has existing grant programs for community water systems and well construction funding. The GSAs will also work with local NGOs that may be able to provide assistance or seek grant monies to help fund the program.

APPENDIX B – GROUND SUBSIDENCE SMC SUPPORTING INFORMATION

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1 MECHANICS OF SUBSIDENCE

Subsidence in the San Joaquin Valley (SJV) and thus in the subbasin is primarily attributed to compaction[1] of subsurface clay layers (i.e., fine-grained soils) in response to groundwater extraction. As sketched in Figure B1-1, groundwater in the SJV occurs in a shallow unconfined or partially confined aquifer and a deep confined aquifer that comprises fine-grained aquitards interbedded with coarser-grained aquifers. The shallow and deep aquifers are separated by a laterally extensive lacustrine clay layer (aquitard) known as the Corcoran Clay (Galloway et al. 1999). Groundwater in the aquifers is replenished primarily by infiltration through stream channels near the valley margins, and secondarily by precipitation.

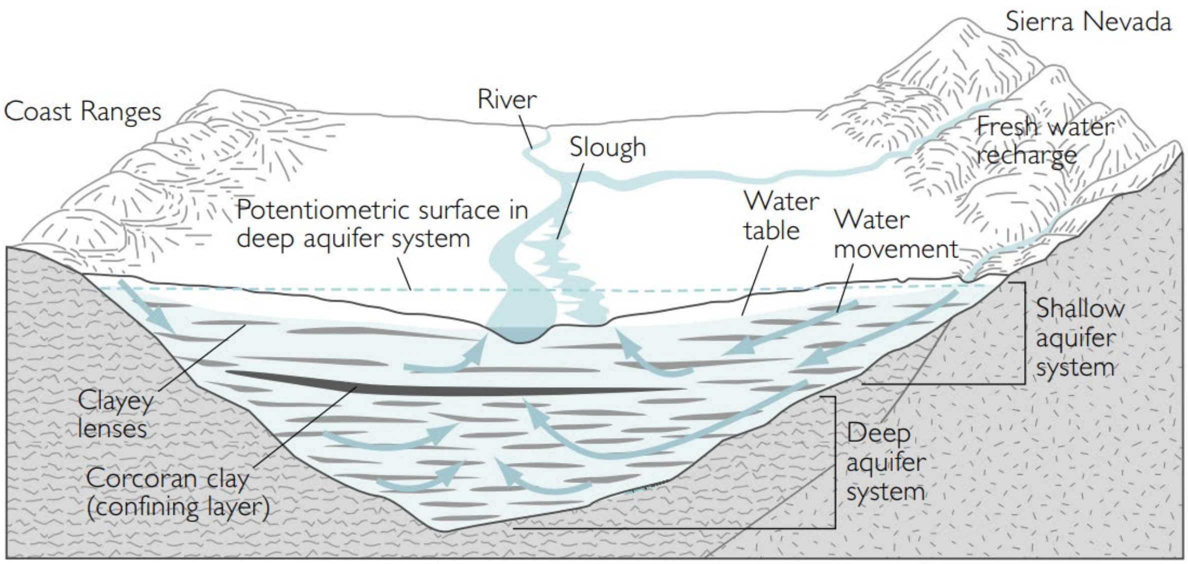

Figure B1-1. Geological sketch of the San Joaquin Valley depicting the shallow and deep aquifer systems separated by the Corcoran Clay layer (figure from Galloway et al. 1999)

Pumping from wells installed in the shallow unconfined aquifer and the deep confined aquifer began over 100 years ago, which led to a decrease in the elevation of the piezometric surface within each aquifer. This led to an increase in the (effective) stress between soil particles, and compression of the soil column which manifested as subsidence at the ground surface.

The concept of effective stress in soil (i.e., the formational material of coarse-grained aquifers and fine-grained aquitards) and the effect of changes in the elevation of the level of the water table (i.e., piezometric surface) is sketched in Figure B1-1. The soil columns are drawn to be somewhat representative of the conditions in the SJV where an upper aquifer is separated from a lower aquifer by a

[1] Geotechnical engineers use the term consolidation to describe the process by which a soil layer dissipates (i.e., expels) pore water pressures and decreases in volume. Geologists use the term compaction to describe consolidation. Compaction is known by geotechnical engineers as the densification of soils by the application of mechanical energy (e.g., Holtz and Kovacs, 1981). The term compaction, together with the term consolidation, will be used herein for consistency with literature on the topic of subsidence in the SJV.

relatively thick aquitard, and the lower aquifer is underlain by bedrock. As shown by Equation B-1, the effective vertical stress (σ'_v) acting between soil particles (or grains) at an arbitrary horizontal plane is equal to the difference between the total stress (σ_t) and the pore-fluid pressure (u).

$$\sigma'_v = \sigma_t - u$$ **Equation B-1**

The total stress is defined as the stress applied by the weight of soil and water above the arbitrary plane, and the pore-fluid pressure is equal to the height of the water column above the arbitrary plane multiplied by the unit weight of water (i.e., 62.4 pounds per cubic foot, pcf). On the column to the left, which is described as the initial condition prior to pumping in the SJV, the pore-fluid pressure at the arbitrary horizontal plane is defined by the height of the water column (z_{w1}). As groundwater is pumped, the elevation of the water table decreases as depicted in the column to the right (final condition) such that the height of the water column above the arbitrary plane decreases and is equal to z_{w2}. The total stress at the arbitrary plane maintains the same value in the initial condition and the final condition, but since the value of the pore-fluid pressure decreases, the effective stress also decreases.

When a soil is loaded, it will compress (i.e., decrease in volume) because of 1) deformation of soil grains, 2) compression of air and water in the voids[2], and/or 3) squeezing out of water and air from the voids between soil particles (Holtz and Kovacs, 1981). At typical loads, the deformation of soil grains is negligible. In soils below the water table, which is most of the soil column in the SJV, water occupies the pore space between soil particles; therefore, compression of the air in the voids is also negligible. Thus, the main component of volume change in the SJV is caused by squeezing of water from the voids.

Changes of the effective stress of the soil lead to changes in the volume that the soil occupies in space. An increase of the effective stress causes a decrease of the volume of the soil and vice-versa. For the columns in Figure B1-2, a change in volume is represented by a change in the elevation of the ground surface, as such an increase in the effective stress causes downward movement of the ground surface (i.e., subsidence). The amount of volume change due to a change in the effective stress depends on the compressibility of the soil material.

In fine-grained soils (i.e., aquitards), volume change is higher than in coarse-grained soils and irreversible when effective stress increases beyond the highest value it has previously experienced[3]. Consequently, a volume reduction is triggered when the piezometric level falls below historically low values.

---

[2] Soils are an assemblage of individual small particles. Voids refers to the space between particles.

[3] Volume change in fine-grained soils is not linearly correlated with an increment in the effective stress. Instead, volume change increases with the logarithm of the increase of effective stress.

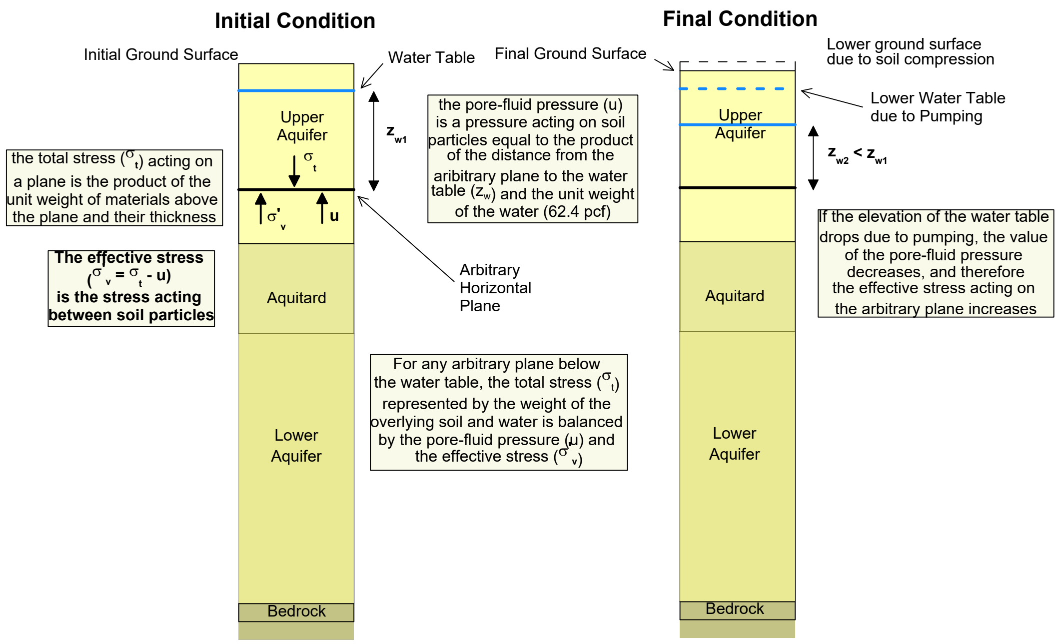

Figure B1-2. The principle of effective stress and the effect of lower water table on effective stress

Subsidence related to groundwater withdrawal generally occurs slowly over a large area, with relatively little differential movement within the subsiding areas. In some instances, scarps, fissures, cracks, and/or sinkholes may form in response to differential movement within subsiding areas, or from rapid surface subsidence.

2 TIME RATE EFFECTS OF SUBSIDENCE

Subsidence in the SJV primarily occurs as water is essentially squeezed out of fine-grained aquitards (i.e., consolidation) due to effective stress increases induced by decreased piezometric levels. The fine-grained nature of the aquitards (i.e., clayey soil units) causes the outflow of water to be relatively slow. As such, subsidence resulting from groundwater extraction does not all occur instantaneously, but rather can occur over extended periods of time (e.g., Lees et al. 2021, Borchers and Carpenter 2014, Lofgren and Klausing 1969). It is important to understand this time lag in evaluating current and projected subsidence, in that current/ongoing subsidence is likely in part related to historical activities. The time-dependent process of subsidence caused by consolidation is as follows:

1. As the piezometric level decreases due to pumping below previous established values, (in Figure B1-1, the previous established value is the water table elevation described as the initial condition), water in the pores of coarse-grained soils drains out relatively quickly causing a change in the pore-fluid pressure and an increase in the vertical effective stress. However, given that fine-grained soils have much lower permeability[4] than coarse-grained soils, the change in the pore-fluid pressure, and thus the change in effective stress, is relatively slow. If the time period during

[4] Herein the term "permeability" is used to describe the coefficient in Darcy's law of flow through porous media, which is also known as "hydraulic conductivity" or "coefficient of permeability".

which the water table is lowered due to pumping is shorter than the time period required for the fine-grained soil to fully drain, and the initial water table elevation is reestablished, then only a portion of the fine-grained layer is affected by the temporarily reduced pore-fluid pressure and the effective stresses only increase in that portion of the soil layer. The portion of the fine-grained layer affected by the increase in effective stress consolidates (compresses and decreases in volume), which is manifested at ground surface as subsidence. The magnitude of subsidence is affected by the portion of the soil layer that drained (or partially drained) and was affected, albeit temporarily, by the higher value of effective stress.

2. If the time period during which the water table is lowered due to pumping is long enough to allow the fine-grained soils to fully drain, then the entire layer is subjected to increased vertical effective stress and the magnitude of subsidence at ground surface is larger. Completion of "primary consolidation" is said to have occurred in the fine-grained layer when the pore-fluid pressure in the entire layer is consistent with the new elevation of the water table and the effective stress at an arbitrary plane is constant over time.
3. After primary consolidation and at constant effective stress, clayey soil units continue to decrease in volume due to a process known as "secondary compression." The magnitude of the decrease in volume over time due to secondary compression is greatest when the applied effective stress is equivalent to the maximum effective stress applied to the soil unit in the past. Using the sketch of Figure B1-1, the magnitude of secondary compression will be highest if the final water elevation condition is maintained. However, secondary compression will decrease if the water elevation rises back to the initial condition and the effective stress in the soil decreases from its maximum value.

The sketch in Figure B2-1 shows how settlement (vertical axis) of a clayey soil unit, which manifests at the ground surface as subsidence, develops over time (horizontal axis in logarithmic units of time). Once a stress change is applied at time = 0, the pore-fluid is slowly squeezed out until primary consolidation is complete and the pore-fluid pressure is stable across the soil unit. Subsequently, secondary compression begins and leads to additional settlement at an approximately constant rate (when plotted against the log of time).

The main purpose of Figure B2-1 is to show that subsidence cannot be completely stopped once a stress change has been applied and maintained for a period of time. Areas of the SJV that have experienced subsidence will continue to exhibit subsidence for some time, albeit at a lower rate, even if piezometric levels are returned to levels preceding groundwater pumping in the SJV.

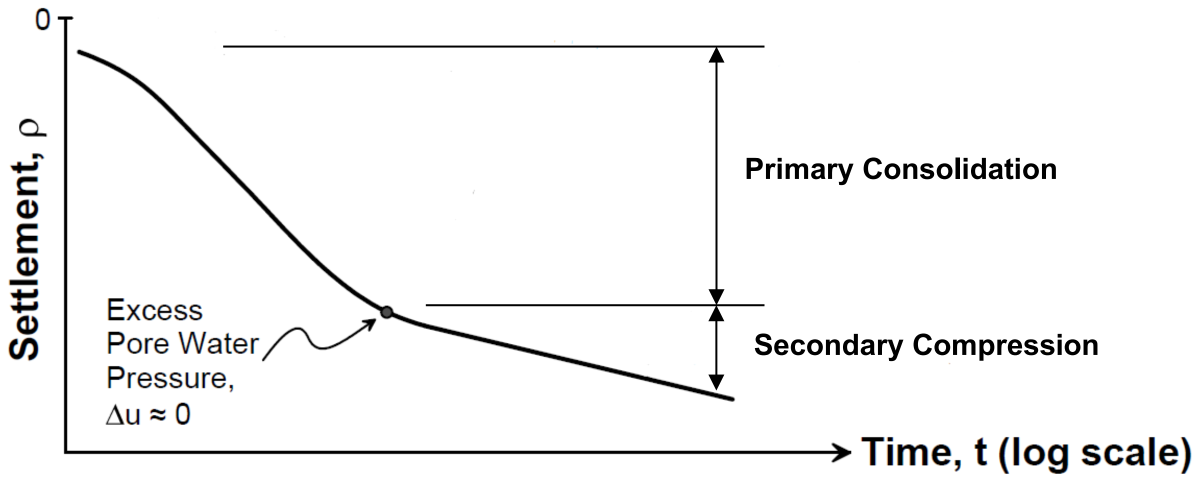

Figure B2-1. Time rate of settlement due to consolidation and compression

3 DEVELOPMENT OF LOCAL MINIMUM THRESHOLDS (LMT)

The following sections describe the ways in which subsidence can damage critical infrastructure. Critical infrastructure includes infrastructure that covers a large area, is intended for multiple beneficial uses and multiple beneficial users (e.g., not localized infrastructure which is maintained locally).

3.1 Overview of Critical Infrastructure

3.1.1 Canals and Aqueducts

Canals are structures with a rectangular or trapezoidal shape that convey water by gravity (i.e., they rely on a positive downward slope from upstream to downstream). Canals can be lined with concrete, as is typical for those that are designed to convey water for distribution purposes (e.g., the California Aqueduct), or they can be unlined and vegetated as is typical for local irrigation canals and drainage ditches.

If subsidence occurs uniformly across the length of the canal, then the total amount of subsidence does not have a significant effect on the performance of the canal because the slope of the canal does not change. However, the performance of the canal (i.e., its ability to convey water in the quantities for which it was designed) will be affected by differential subsidence in two ways:

- Case A: A greater magnitude of subsidence at an upstream point on the canal (Point A) than a downstream point on the canal (Point B) will lead to a reduction of the slope of the canal. This will cause a reduction in the velocity of the water flow and an increase in the depth of water in the canal (and less freeboard) to convey the same volume of water. If subsidence at Point A is significantly higher than at Point B, then the slope of the canal may be reversed leading to a loss of conveyance.

- Case B: A lower magnitude of subsidence at an upstream point on the canal (Point A) than a downstream point on the canal (Point B) will lead to an increase of the slope of the canal. This will cause an increase in the energy gradient of the water flow and a reduction of the depth of water in the canal to convey the same volume of water. If a portion of a canal increases its slope, it is likely that another portion of the canal will experience a decrease in its slope.

Additionally, differential subsidence can damage the concrete lining of the canal.

Subsidence causing a reduction of water conveyance capacity of canals has been reported for the California Aqueduct (Aqueduct) (DWR, 2017), the Delta-Mendota Canal (DMC) (Sneed et al. 2013[5]), and canals of the San Luis Canal Company and the Central California Irrigation District (Amec, 2017). The effect of subsidence on water conveyance in canals can be mitigated if the amount and location of subsidence is incorporated in the design. For example, the Aqueduct was built with extra freeboard ranging from 1 to 9 feet (DWR, 2017) so that the canal could accommodate an increase in water depth due to a reduction of the slope of the canal. If differential subsidence is not incorporated in the design, and the slope of the canal decreases (Case B), then the effect of differential subsidence can be mitigated by raising the freeboard, as was done for the Aqueduct (DWR, 2017) and the DMC, or by installing lift stations, as has been done, for example, to canals owned by the Angiola Water District (AWD) and the Homewood Canal (Amec, 2017). In a letter commenting on the GSP previously delivered by the subbasin, AWD described that the Angiola Ditch, Utica Canal, and Blakely Canal have been negatively affected by subsidence (AWD, 2020).

Canals are perhaps the type of infrastructure most susceptible to subsidence given their significant length within the SJV (e.g., the Aqueduct extends hundreds of miles through the SJV) and the fact that their ability to convey water depends on gravity. As described above, differential subsidence along the length of a canal will have an impact on the flow through the canal; therefore, differential subsidence along the length of the canal should be monitored and its magnitude used to evaluate the effect on performance.

The change in performance of each canal will depend on the canal's design and purpose. Each canal will be affected differently depending on the magnitude of differential subsidence. In lieu of guidance that can be applied to all canals, a maximum differential subsidence threshold of 1/600 (i.e., equivalent to 2 inches of differential settlement over 100 ft) measured anywhere along the canal's alignment as well as between points that are 500 ft, 1,000 ft, and 2,000 ft apart, is suggested herein. Regarding the Aqueduct, DWR (2020) indicated that subsidence along the alignment of the Aqueduct should be limited to less than 0.01 ft per year (i.e., essentially zero) by 2040 and a goal of no subsidence thereafter.

3.1.2 Flood Protection Levees

Flood protection levees are earthen embankments that are built along rivers to protect areas of interest from seasonally high flood water levels. Engineered levees are typically designed following guidance from the US Army Corps of Engineers (USACE, 2000). Accordingly, levees typically fail due to one or more of the

[5] Sneed, M., Brandt, J., and Solt, M. 2013. Land subsidence along the Delta-Mendota Canal in the northern part of the San Joaquin Valley, California, 2003–10: U.S. Geological Survey Scientific Investigations Report 2013–5142, 87 p. A

following conditions:

- Overtopping: flood water elevation exceeds the elevation of the crown of the levee
- Surface erosion: water flowing over the levee erodes the embankment and reduces its section
- Piping: water flowing through the levee develops into a spring which causes internal erosion that in turn causes more flow through the levee and more erosion, eventually leading to a breach of the levee
- Slides: movement within the levee or the foundation soils due to insufficient strength in the soils.

The Urban Levee Design Criteria (DWR, 2012) indicate that levees should be designed to protect against the 200-year return period flood event and that the crown of the levees (i.e., top of levee) should have a minimum 3-foot freeboard. Downward movement (i.e., settlement) of the crown of a levee with respect to the floodplain can reduce the freeboard. This amount of settlement should be incorporated in the design as additional freeboard, or the levee should be topped off as settlement accumulates over time.

The effect of subsidence on the performance of levees is not addressed in USACE (2000) or DWR (2012). The performance of levees is considered to be potentially affected by the regional subsidence in two ways:

- Case 1: By lowering the elevation of the crown of the levee with respect to the elevation of the flood area.
- Case 2: By inducing differential amounts of subsidence along the longitudinal axis of the levee that can lead to longitudinal cracking and other types of distress to the earthen embankment.

When considering Case 1, given that subsidence is a regional phenomenon, the elevation of the flood protection levees and the elevation of the flood-prone areas (i.e., floodplain) generally decrease uniformly. With little or no differential movement between the crown of the levee and the floodplain, the performance of the levee is unaffected.

Regarding Case 2, in general, levees are flexible earthen structures that can tolerate typical differential longitudinal settlement that occurs due to variability of soils in their foundation. As such, there is very little literature on performance limits of levees affected by differential settlement along their longitudinal axis. In their Geotechnical Design Manual, the South Carolina Department of Transportation (SCDOT, 2019) imposes a limit for settlement of paved road embankments, i.e., embankments with a brittle layer on their crown, of 1 inch measured over a distance of 50 ft, which is equivalent to a slope of 1/600. This is considered to be a conservative value for levees given that levees do not typically have paved roads on their crown. Therefore, in lieu of any other applicable guidance, a value of 1/600 should be used to increase awareness by infrastructure managers (i.e., alert level) and trigger actions such as visual inspections to identify cracks that may be detrimental to the performance of the embankments.

3.1.3 Pipelines

Differential subsidence may cause strain on buried hydrocarbon or water pipelines. In regard to steel pipelines carrying hydrocarbons, PRCI (2009) indicates that the lateral component of displacement that may accompany subsidence is responsible for greater potential damage because it can cause large compressive forces in the pipeline and lead to upheaval buckling. General rules cannot be applied to the estimation of the effect of differential subsidence on the integrity of pipelines given that many factors such as pipe material type, diameter, wall thickness, internal operating pressure, weld strength, burial depth, and burial material, need to be considered. Instead, analysis and modeling on a case-by-case basis is required.

As described in Amec (2017), PG&E has not reported any impacts to their pipelines due to subsidence.

3.1.4 Buildings

The performance of individual buildings subjected to differential settlement across supports has been documented with general guidance developed by Bjerrum (1963). Table B3-1 lists threshold and performance criteria for buildings that can be used to evaluate the effect of local differential subsidence. Given the range of performance criteria for buildings listed in Table B3-1 between 1/50 and 1/1000, a value of 1/300 is recommended since it is described as the limit that leads to cracking of panels and thus evident manifestation of the deleterious effect of settlement (subsidence).

Table B3-1. Tolerable settlements for buildings (Bjerrum, 1963 and Fang, 1990)

Threshold Differential Settlement	Performance Criteria
1/1000	Limit where difficulties with machinery sensitive to settlements are to be feared
1/750	Multistory concrete rigid frame on mat foundation 4 ft ± thick
1/600	Limit of danger for frames with diagonals
1/500	Safe limit for buildings where cracking is not permissible. Rigid circular mat or ring footing for tall and slender rigid structures.
1/300	Limit where first cracking in panel walls is to be expected. Limit where difficulties with overhead cranes are to be expected.
1/250	Limit where tilting of high, rigid buildings might become visible.
1/150	Limit where structural damage of buildings is to be feared.

3.1.5 Bridges

In Caltrans (2015), total settlement guidance is provided for bridges supported on footings. Those thresholds are for load-induced settlement and not subsidence. As such, Caltrans does not appear to provide specific guidance on tolerable differential subsidence (or settlement) across a bridge. Instead, a case-by-case approach is suggested in Caltrans (2014) with reference to documents from Washington DOT (WSDOT). In their foundation design manual, WSDOT (2010) provides the settlement criteria reproduced in Table B3-2. If the highest total settlement is selected (i.e., $\Delta H > 4$ inches), then with approval from the State Geotechnical Engineer, a maximum of 3 or more inches (in) can be allowed. Differential settlement of 3 inches over a distance 100 ft, is equivalent to a slope of 0.25%, or 1/400.

Table B3-2. WSDOT settlement criteria for bridges (WSDOT, 2010)

Total Settlement at Pier or Abutment	Differential Settlement over 100 ft within Pier or Abutment, and Differential Settlement between Piers	Action
ΔH ≤ 1 inch (in)	$\Delta H_{100} \leq 0.75$ in	Design and Construct
1 in < ΔH ≤ 4 in	0.75 in < $\Delta H_{100} \leq 3$ in	Ensure structure can tolerate settlement
ΔH > 4 in	$\Delta H_{100} > 3$ in	Obtain approval* prior to proceeding with design and construction

Note: * Approval of WSDOT State Geotechnical Engineer and WSDOT Bridge Design Engineer required

3.1.6 Embankments for Roads, Rail Lines, and Airports

Similar to flood protection levees, embankments for roads, rail lines, and airports are earthen structures that can be affected by subsidence. Perhaps the main difference between embankments for levees and those for roads, rail lines, and airports is that the latter have been typically built with higher engineering standards such as soil placement following specifications and construction quality control. If the amount of differential subsidence along the longitudinal access of the road or runway is excessive, it can cause the development of cracks on the surface pavement or dips and bumps on the road that can pose a hazard to vehicles (cars and planes).

In their Geotechnical Manual, Caltrans (2014) does not limit the amount of differential settlement that can be tolerated by a road embankment. Instead, Caltrans (2014) indicates that applicable design criteria should be determined on a project-by-project basis. In lieu of guidance specific to California, the 1/600 criteria cited by SCDOT and described as a criterion for levees can be applied to road embankments.

Amec (2017) describe that representatives of Burlington Northern-Santa Fe and Union Pacific Railroad were interviewed regarding subsidence impacts to their infrastructure. These representatives indicated that periodic rail track maintenance is carried out as part of the operations and maintenance program and that they have not noticed any increases or changes to maintenance that can be attributed to subsidence. Similarly, Amec (2017) discusses interviews with officers at Caltrans Office of Structure Investigations – North, Caltrans District 6, and Caltrans District 10, which have jurisdiction over areas subjected to subsidence. Accordingly, all Caltrans representatives indicated that they were not aware of any subsidence that has impacted bridges or roadways.

In regard to the proposed high speed rail (HSR) through the area, Amec (2017) indicated that the maximum induced slope change should not exceed 1.25% (1/80).

3.1.7 Water Wells

Subsidence-induced damage to wells is caused by yielding of the well casing under the drag load applied by the soil around the casing. Drag load is a force, typically calculated for the design of foundation piles (e.g., Fellenius, 1989), that develops along the surface area of a well casing when the soil surrounding the casing moves downward relative to the casing.

Drag load is illustrated in B3-1, which shows a relatively shallow well that terminates in the upper aquifer above the Corcoran Clay (Well #1) and a relatively deep well that terminates in the lower aquifer that is confined by the Corcoran Clay (Well #2). Along their length, both wells are in contact with the surrounding soil, which allows friction to develop along the well casing. Reduction of the piezometric surface in the lower aquifer causes an increase in the effective stress within the Corcoran Clay, which induces consolidation (i.e., the process of dissipation of excess pore water pressure in the soil) and leads to settlement of this clay layer, which manifests as subsidence at the ground surface. As the Corcoran Clay settles, the soil above this layer also settles. Well #1, which terminates above the Corcoran Clay, will move downward with the soil above the Corcoran Clay and no significant amount of relative movement is expected between the well and the soil. However, as the Corcoran Clay consolidates and settles, the soil within and above this layer will drag on the casing of Well #2, which is not moving uniformly at the same rate because the lower portion of the well within the lower aquifer is providing resistance due to friction along the casing. If the drag load applied on the casing exceeds the structural capacity of the well casing, then the well casing will yield and fail. Yielding of a well casing is an undesirable effect of subsidence because it renders the well inoperable.

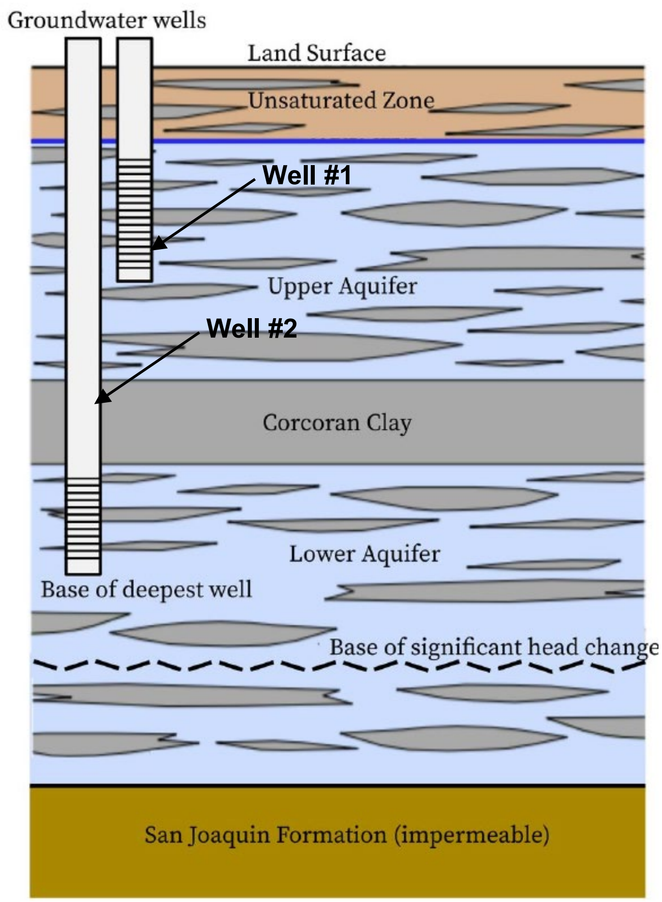

Figure B3-1. Schematic of two typical water wells in the subbasin (background figure from Lees and Knight, 2021)

3.2 Summary of Impacts to Infrastructure from Subsidence

The tables below provide a summary of impacts to infrastructure from subsidence.

Table B3-3. Differential subsidence minimum thresholds for impacts

Type of Infrastructure	Minimum Differential Subsidence for Impacts to Occur	Considerations	Possible Mitigation Measures
Canals (excludes Aqueduct)	Case-by-Case, 1/600	Depends on the construction details of the canal, capacity, water needs, and direction of flow relative to differential subsidence. In general, differential subsidence should be minimized to less than 1/600.	Dredging/filling portions of canals to reestablish desired slopes; repairing concrete cracks; installation of pumps
Aqueduct	Case-by-Case, 1/600	Depends on the local construction details, capacity, water needs, and direction of flow relative to differential subsidence.	Repairing concrete cracks; installation of pumps or lifts
Flood Protection Levees	1/600	Minimum threshold may not lead to cracking. As such, some levees may be subjected to much higher magnitude of differential subsidence without damage.	Fill/cover/repair cracks; top levee off with additional material to increase height
Pipelines	Case-by-Case	Depends on pipe material, diameter, wall thickness, weld capacity, burial depth, type of soil in the pipe trench, etc.	Stress relief excavations; installation of pipe sleeves; replacement of pipe sections
Buildings	1/300	Equal amounts of subsidence typically happen over areas larger than the footprint of a single building.	Releveling building foundations
Bridges	1/400		Releveling bridge foundations
Embankments for Roads, Airports, and Rail Lines	1/600	Minimum threshold may not lead to cracking. As such, some embankments may be subjected to much higher magnitude of differential subsidence without damage.	Repave roads and runways; reset railroad ties
High Speed Rail Lines	1/80		
Water Wells	Case-by-Case Evaluation is Necessary	Depends on well construction details. Wells terminated in the deep aquifer are more likely to be subjected to drag load. New wells should be designed for predicted drag load.	Decrease pumping rates; well repairs; well replacement

Table B3-4. Regional (total) subsidence minimum thresholds for impacts

Type of Infrastructure	Minimum Subsidence for Impacts to Occur	Considerations	Possible Mitigation Measures
Water Wells	N/A	Regional subsidence does not affect the performance of individual wells	N/A
Flood Protection Levees	Change in elevation between the floodplain and the levee > 3 ft	Elevation between the crown of the levee and the floodplain should not change. Given that levees are typically designed with a 3-ft freeboard, a reasonable threshold would be that the change in elevation between the floodplain and the levee does not exceed 3 ft.	Top levee off with additional material to increase height
Embankments for Roads, Airports, and Rail Lines	N/A	The performance of these structures is not affected by a total amount of subsidence	N/A
High Speed Rail Lines	N/A	The performance of these structures is not affected by a total amount of subsidence	N/A
Canals (excludes Aqueduct)	N/A	Regional subsidence does not affect the performance of canals.	N/A
Aqueduct	Case-by-Case	Depends on regional subsidence north and south of TLSB.	Installation of lifts or pumps
Pipelines	N/A	Not applicable because regional subsidence does not affect the performance of pipelines	N/A
Buildings	N/A	Not applicable because regional subsidence does not affect the performance of buildings	N/A
Bridges	N/A	Not applicable because regional subsidence does not affect the performance of bridges	N/A

4 RISK ASSESSMENT INPUTS

The information presented in Section 3 was ultimately used to develop input values for the risk assessment for vulnerability for differential subsidence.

4.1 Definition of Vulnerability (V)

Section 3 describes each type of critical infrastructure in the TLSB, the types and mechanisms of subsidence that can impact each type of infrastructure, and the estimated amount of subsidence necessary for impacts to start to occur. Note that the primary form of subsidence that is a concern for most types of infrastructure is differential subsidence, and thus, these are the primary thresholds used in the risk calculations. Table B3-5 below provides a summary of subsidence values by infrastructure type that may initially result in impacts. The threshold values were multiplied by the amount of respective infrastructure in each TRS (e.g., number of buildings or miles of roads) and then summed to come up with an aggregate V value for each TRS, which was ultimately used in the risk calculations when considering risk related to differential subsidence.

Table B3-5. Thresholds by Infrastructure Type

Type of Infrastructure	Vulnerability (V) Tolerance Factor (i.e., Differential Subsidence Thresholds for Potential Impacts to Occur)
Flood Protection Levees	1/600
Embankments for Roads, Airports, and Rail Lines	1/600
High Speed Rail Lines	1/80
Canals and Aqueduct	1/600
Pipelines	1/100*
Buildings	1/300
Bridges	1/400

Note: *Vulnerability for pipelines is case-by-case; as such, 1/100 is selected as a conservative threshold.

4.2 Definition of Consequence (C)

As described Section 3, subsidence impacts each type of critical infrastructure differently, both in terms of the amount of subsidence necessary to cause impacts, as well as the severity of those impacts and the types of actions required to mitigate each. In many risk assessment, a consequence factor (“C”) is included in the calculation, where R = H x V x C. C represents the consequence of damage to a given piece of infrastructure subjected to the hazard. Subsidence affects some types of infrastructure more severely than others. For example, cracks in a road caused by subsidence are not necessarily a severe or high consequence impact and are already addressed through routine maintenance. Reduction in canal transmission capacity or increases in canal seepage caused by subsidence are more severe or higher consequence impacts. We did not include consequence in this risk assessment, as we did not have the quantitative data (e.g., monetary values for repair or replacement of infrastructure, secondary economic impacts due to impacted infrastructure, etc.) necessary to accurately represent consequence for each type of infrastructure. However, this could be included if such information is developed, to better define high risk areas within the TLSB.

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APPENDIX C

WATER QUALITY SMC SUPPORTING INFORMATION

Appendix C

Upper Tolerance Limit Data

Groundwater Sustainability Plan - Addendum

Tulare Lake Subbasin

Well ID	Analyte	Units	95% Upper Tolerance Limit	Count	Minimum Value	Maximum Value	Mean	Standard Error	Standard Deviation	Date (Minimum)	Date (Maximum)
1610003-031	Arsenic	µg/L	11.575	64	3.0	56.0	9.038	1.270	10.157	10/6/1994	12/18/2018
1610003-039	Arsenic	µg/L	9.637	8	8.4	9.9	9.238	0.169	0.478	7/1/2008	5/9/2019
1610003-036	Arsenic	µg/L	6.610	39	3.9	10.0	6.195	0.205	1.280	1/29/2002	12/20/2018
1610003-041	Arsenic	µg/L	3.125	4	0.0	2.3	1.100	0.636	1.273	5/5/2009	2/9/2010
1610003-033	Arsenic	µg/L	10.339	66	5.7	69.0	8.465	0.938	7.623	11/5/1998	12/18/2018
1610003-040	Arsenic	µg/L	4.698	7	0.0	4.7	3.257	0.589	1.558	4/10/2009	12/20/2018
1610003-026	Arsenic	µg/L	16.014	69	4.7	60.0	13.861	1.079	8.962	2/11/1986	12/15/2015
1610003-038	Arsenic	µg/L	4.972	4	3.4	4.7	4.100	0.274	0.548	5/9/2008	12/14/2015
1610003-028	Arsenic	µg/L	22.943	75	4.9	70.0	20.792	1.079	9.347	7/1/1991	12/20/2018
1610003-043	Arsenic	µg/L	9.889	7	7.4	10.0	8.914	0.398	1.054	3/10/2010	12/18/2018
1610003-042	Arsenic	µg/L	2.879	6	0.0	3.0	1.333	0.601	1.473	3/10/2010	12/18/2018
1610003-037	Arsenic	µg/L	4.678	5	2.2	4.6	3.580	0.395	0.884	5/9/2006	12/20/2018
1610003-034	Arsenic	µg/L	30.348	68	0.0	78.0	25.876	2.240	18.474	5/11/1998	12/20/2018
1610006-001	Arsenic	µg/L	9.796	20	0.0	30.0	6.515	1.568	7.010	3/19/1987	11/6/2017
1610006-002	Arsenic	µg/L	8.584	10	0.0	13.0	5.500	1.363	4.311	1/9/1985	4/10/2019
1610006-005	Arsenic	µg/L	0.883	8	0.0	2.1	0.263	0.263	0.742	12/13/2005	11/11/2011
1610005-021	Arsenic	µg/L	2.078	46	0.0	4.2	1.705	0.185	1.257	1/15/2010	11/5/2019
1610005-007	Arsenic	µg/L	7.695	20	3.0	11.0	6.780	0.437	1.955	10/5/1995	8/13/2013
1610005-010	Arsenic	µg/L	11.043	69	5.2	29.0	9.932	0.557	4.626	8/7/1999	12/20/2019
1610005-003	Arsenic	µg/L	19.863	51	15.0	27.0	19.216	0.322	2.301	3/26/1987	8/25/2015
1610005-022	Arsenic	µg/L	0.348	35	0.0	2.3	0.158	0.093	0.552	5/27/2010	11/5/2019
1610005-005	Arsenic	µg/L	15.795	89	8.2	25.0	14.982	0.409	3.858	3/28/1990	12/20/2019
1610005-018	Arsenic	µg/L	2.174	55	0.0	4.0	1.850	0.162	1.201	12/6/2004	11/5/2019
1610005-008	Arsenic	µg/L	3.632	39	0.0	8.0	3.074	0.276	1.721	10/5/1995	7/2/2019
1610005-006	Arsenic	µg/L	6.424	61	0.0	19.0	5.808	0.308	2.404	10/5/1995	12/4/2018
1610005-009	Arsenic	µg/L	28.770	60	23.0	46.0	27.833	0.468	3.627	2/28/2011	11/5/2019
1610005-020	Arsenic	µg/L	8.200	63	4.0	11.0	7.900	0.150	1.190	4/26/2007	11/5/2019
1610005-011	Arsenic	µg/L	4.541	111	0.0	14.0	3.866	0.341	3.588	2/24/2012	12/10/2019
1610009-003	Arsenic	µg/L	16.651	55	6.8	23.2	15.869	0.390	2.891	11/26/1986	10/2/2019
1610004-026	Arsenic	µg/L	20.289	94	12.0	32.0	19.702	0.296	2.866	7/11/2006	12/11/2019
1610004-018	Arsenic	µg/L	27.545	53	22.0	38.0	26.830	0.356	2.592	3/4/2013	12/23/2019
1610004-019	Arsenic	µg/L	32.634	5	28.0	33.0	30.000	0.949	2.121	12/22/2014	1/8/2019
1610001-001	Arsenic	µg/L	13.935	36	4.1	41.0	11.106	1.394	8.362	2/16/2011	5/1/2019
1610001-007	Arsenic	µg/L	51.609	38	3.0	110.0	37.753	6.839	42.156	2/16/2011	5/1/2019
1610001-010	Arsenic	µg/L	23.917	10	18.0	27.0	21.600	1.024	3.239	8/30/2017	11/6/2019
1610003-039	Arsenic	µg/L	9.877	4	8.4	9.6	9.050	0.260	0.520	8/19/2011	5/9/2019
1610006-001	Arsenic	µg/L	6.606	5	-10.0	3.4	-2.220	3.179	7.108	6/24/2011	11/6/2017
1610005-010	Arsenic	µg/L	11.305	51	5.2	29.0	9.898	0.701	5.003	2/24/2012	12/20/2019
1610005-003	Arsenic	µg/L	22.007	13	17.0	23.0	20.769	0.568	2.048	2/28/2011	8/25/2015

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Upper Tolerance Limit Data
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Well ID	Analyte	Units	95% Upper Tolerance Limit	Count	Minimum Value	Maximum Value	Mean	Standard Error	Standard Deviation	Date (Minimum)	Date (Maximum)
1610005-005	Arsenic	µg/L	16.438	60	8.8	25.0	15.480	0.479	3.709	2/28/2011	12/20/2019
1610005-018	Arsenic	µg/L	0.786	49	-10.0	3.4	-0.818	0.798	5.584	9/20/2011	11/5/2019
1610005-008	Arsenic	µg/L	4.253	16	2.2	5.0	3.750	0.236	0.944	4/15/2013	7/2/2019
1610005-006	Arsenic	µg/L	6.975	38	3.1	19.0	6.129	0.417	2.573	5/11/2012	12/4/2018
1610005-009	Arsenic	µg/L	28.770	60	23.0	46.0	27.833	0.468	3.627	2/28/2011	11/5/2019
1610005-020	Arsenic	µg/L	8.279	55	4.0	11.0	7.949	0.165	1.222	2/28/2011	11/5/2019
1610005-011	Arsenic	µg/L	2.846	115	-10.0	14.0	1.540	0.659	7.069	2/24/2012	12/10/2019
1610009-003	Arsenic	µg/L	15.927	36	6.8	19.0	15.247	0.335	2.010	1/5/2011	10/2/2019
1610004-026	Arsenic	µg/L	20.425	76	12.0	32.0	19.789	0.319	2.782	1/27/2011	12/11/2019
1610004-018	Arsenic	µg/L	27.545	53	22.0	38.0	26.830	0.356	2.592	3/4/2013	12/23/2019
1610004-019	Arsenic	µg/L	32.634	5	28.0	33.0	30.000	0.949	2.121	12/22/2014	1/8/2019
1610003-031	Chloride	mg/L	171.562	7	160.0	180.0	164.286	2.974	7.868	10/6/1994	12/18/2018
1610003-039	Chloride	mg/L	222.801	5	210.0	220.0	216.000	2.449	5.477	7/1/2008	5/9/2019
1610003-036	Chloride	mg/L	97.899	7	83.0	100.0	91.429	2.644	6.997	1/29/2002	12/20/2018
1610003-033	Chloride	mg/L	173.457	8	140.0	190.0	157.500	6.748	19.086	11/5/1998	12/18/2018
1610003-040	Chloride	mg/L	175.456	4	160.0	170.0	167.500	2.500	5.000	4/10/2009	12/20/2018
1610003-026	Chloride	mg/L	141.637	10	60.0	152.0	124.200	7.708	24.376	2/11/1986	12/15/2015
1610003-028	Chloride	mg/L	161.909	9	90.0	170.0	142.778	8.296	24.889	7/1/1991	12/20/2018
1610003-042	Chloride	mg/L	242.992	4	220.0	240.0	230.000	4.082	8.165	3/10/2010	12/18/2018
1610003-037	Chloride	mg/L	79.356	5	72.0	80.0	75.800	1.281	2.864	5/9/2006	12/20/2018
1610003-034	Chloride	mg/L	118.709	8	40.0	120.0	89.625	12.300	34.789	5/11/1998	12/20/2018
1610006-001	Chloride	mg/L	86.701	11	32.0	100.0	71.818	6.679	22.153	3/19/1987	11/6/2017
1610006-002	Chloride	mg/L	80.165	10	28.0	160.0	50.800	12.981	41.050	1/9/1985	4/10/2019
1610006-005	Chloride	mg/L	79.222	5	29.0	83.0	53.000	9.445	21.119	12/13/2005	11/6/2017
1610005-021	Chloride	mg/L	91.792	5	87.0	93.1	88.620	1.142	2.554	1/15/2010	10/30/2018
1610005-007	Chloride	mg/L	40.707	7	8.1	64.0	22.629	7.388	19.548	10/5/1995	4/15/2013
1610005-010	Chloride	mg/L	40.747	7	17.0	40.0	33.429	2.991	7.913	8/7/1999	12/20/2019
1610005-003	Chloride	mg/L	51.619	10	26.0	68.0	42.900	3.854	12.188	3/26/1987	5/14/2013
1610005-022	Chloride	mg/L	98.014	4	92.0	96.7	94.414	1.131	2.263	5/27/2010	2/6/2018
1610005-005	Chloride	mg/L	51.051	12	26.0	58.0	43.167	3.582	12.408	3/28/1990	12/20/2019
1610005-018	Chloride	mg/L	90.662	8	84.0	91.0	88.325	0.988	2.796	12/6/2004	2/6/2018
1610005-008	Chloride	mg/L	32.581	8	9.2	46.0	21.325	4.760	13.464	10/5/1995	4/18/2016
1610005-006	Chloride	mg/L	77.052	7	58.0	81.0	69.429	3.116	8.243	10/5/1995	5/3/2016
1610005-020	Chloride	mg/L	31.009	7	20.0	32.0	27.143	1.580	4.180	4/26/2007	5/14/2019
1610005-011	Chloride	mg/L	84.251	4	13.0	65.0	44.750	12.412	24.824	4/15/2013	5/14/2019
1610009-003	Chloride	mg/L	342.781	8	27.6	450.0	229.512	47.901	135.485	11/26/1986	4/5/2017
1610004-026	Chloride	mg/L	42.662	8	26.0	52.0	35.000	3.240	9.165	7/11/2006	2/8/2017
1610003-039	Chloride	mg/L	224.187	4	210.0	220.0	215.000	2.887	5.774	8/19/2011	5/9/2019
1610005-021	Chloride	mg/L	88.419	4	87.0	88.0	87.500	0.289	0.577	10/18/2011	10/30/2018

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1610005-005	Chloride	mg/L	58.279	4	28.0	51.0	42.000	5.115	10.231	4/15/2013	12/20/2019
1610005-011	Chloride	mg/L	84.251	4	13.0	65.0	44.750	12.412	24.824	4/15/2013	5/14/2019
1610003-031	Nitrate as Nitrogen	mg/L	5.030	4	0.0	4.0	1.750	1.031	2.062	10/6/1994	12/18/2018
1610003-036	Nitrate as Nitrogen	mg/L	2.462	7	0.0	5.0	0.714	0.714	1.890	1/29/2002	7/16/2008
1610003-033	Nitrate as Nitrogen	mg/L	3.939	7	0.0	8.0	1.143	1.143	3.024	11/5/1998	12/12/2019
1610003-026	Nitrate as Nitrogen	mg/L	2.541	10	0.0	7.0	0.960	0.699	2.211	2/11/1986	5/2/2018
1610003-028	Nitrate as Nitrogen	mg/L	0.367	9	0.0	1.0	0.111	0.111	0.333	7/1/1991	12/12/2019
1610003-034	Nitrate as Nitrogen	mg/L	1.013	14	0.0	4.0	0.379	0.294	1.098	5/11/1998	12/11/2019
1610006-001	Nitrate as Nitrogen	mg/L	2.546	39	0.0	25.0	1.154	0.688	4.295	3/19/1987	10/16/2019
1610005-010	Nitrate as Nitrogen	mg/L	2.103	8	0.0	5.0	0.625	0.625	1.768	8/7/1999	5/31/2019
1610005-003	Nitrate as Nitrogen	mg/L	0.020	30	0.0	0.1	0.009	0.005	0.029	3/26/1987	11/29/2018
1610005-005	Nitrate as Nitrogen	mg/L	1.324	14	0.0	4.4	0.533	0.366	1.370	1/28/1993	12/20/2019
1610005-008	Nitrate as Nitrogen	mg/L	1.785	6	0.0	3.0	0.500	0.500	1.225	8/21/2001	8/3/2017
1610005-006	Nitrate as Nitrogen	mg/L	2.042	15	0.0	8.0	0.800	0.579	2.242	10/5/1995	5/1/2018
1610009-003	Nitrate as Nitrogen	mg/L	1.407	37	0.0	8.0	0.902	0.249	1.514	11/26/1986	1/2/2019
1610004-026	Nitrate as Nitrogen	mg/L	2.942	131	0.7	19.0	2.354	0.298	3.407	7/11/2006	12/11/2019
1610004-026	Nitrate as Nitrogen	mg/L	6.151	12	2.7	8.3	5.133	0.462	1.601	12/20/2011	8/10/2015
1610003-040	Sulfate	mg/L	4.182	4	0.0	4.0	1.000	1.000	2.000	4/10/2009	12/20/2018
1610003-026	Sulfate	mg/L	9.769	7	0.0	14.0	5.557	1.721	4.554	2/11/1986	12/15/2015
1610003-028	Sulfate	mg/L	3.478	5	0.0	4.0	1.400	0.748	1.673	7/1/1991	12/15/2015
1610003-034	Sulfate	mg/L	16.362	5	3.7	19.0	8.140	2.961	6.622	5/11/1998	11/9/2009
1610006-001	Sulfate	mg/L	292.323	11	15.0	300.0	231.818	27.155	90.063	3/19/1987	11/6/2017
1610006-002	Sulfate	mg/L	436.010	10	200.0	800.0	305.400	57.737	182.580	1/9/1985	4/10/2019
1610006-005	Sulfate	mg/L	94.036	5	2.0	120.0	31.760	22.430	50.156	12/13/2005	11/6/2017
1610005-003	Sulfate	mg/L	3.045	10	0.0	4.0	1.980	0.471	1.488	3/26/1987	5/14/2013
1610005-022	Sulfate	mg/L	0.823	4	0.0	0.8	0.197	0.197	0.394	5/27/2010	2/6/2018
1610005-005	Sulfate	mg/L	3.735	10	0.0	6.0	2.350	0.612	1.936	3/28/1990	12/20/2019
1610005-018	Sulfate	mg/L	2.848	6	0.0	4.0	1.050	0.699	1.713	12/6/2004	2/6/2018
1610005-006	Sulfate	mg/L	10.226	6	0.0	16.0	3.667	2.552	6.250	10/5/1995	5/3/2016
1610009-003	Sulfate	mg/L	191.946	8	97.0	260.0	148.000	18.585	52.566	11/26/1986	4/5/2017
1610004-026	Sulfate	mg/L	58.780	8	28.0	77.0	44.750	5.933	16.782	7/11/2006	2/8/2017
1610005-005	Sulfate	mg/L	7.252	4	-10.0	2.6	-3.925	3.512	7.024	4/15/2013	12/20/2019
1610005-011	Sulfate	mg/L	11.185	4	-10.0	6.8	-2.625	4.339	8.679	4/15/2013	5/14/2019
1610003-031	TDS	mg/L	421.735	11	370.0	440.0	405.455	7.307	24.234	10/6/1994	12/18/2018
1610003-039	TDS	mg/L	487.016	9	460.0	500.0	477.778	4.006	12.019	7/1/2008	5/9/2019
1610003-036	TDS	mg/L	348.432	9	300.0	360.0	330.000	7.993	23.979	1/29/2002	12/20/2018
1610003-041	TDS	mg/L	598.637	7	560.0	600.0	585.714	5.281	13.973	5/5/2009	12/20/2018
1610003-033	TDS	mg/L	425.003	11	360.0	450.0	404.545	9.181	30.451	11/5/1998	12/18/2018
1610003-040	TDS	mg/L	500.242	7	450.0	520.0	477.143	9.440	24.976	4/10/2009	12/20/2018

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1610003-026	TDS	mg/L	415.825	13	310.0	520.0	372.308	19.973	72.013	2/11/1986	12/15/2015
1610003-038	TDS	mg/L	889.010	4	450.0	870.0	567.500	101.026	202.052	5/9/2008	12/14/2015
1610003-028	TDS	mg/L	417.571	14	310.0	430.0	394.286	10.778	40.328	7/1/1991	12/20/2018
1610003-043	TDS	mg/L	519.229	7	510.0	520.0	514.286	2.020	5.345	3/10/2010	12/18/2018
1610003-042	TDS	mg/L	616.159	7	570.0	630.0	590.000	10.690	28.284	3/10/2010	12/18/2018
1610003-037	TDS	mg/L	331.050	7	300.0	340.0	314.286	6.851	18.127	5/9/2006	12/20/2018
1610003-034	TDS	mg/L	376.121	11	190.0	390.0	330.909	20.291	67.299	5/11/1998	12/20/2018
1610006-001	TDS	mg/L	824.065	14	636.0	860.0	775.429	22.513	84.236	3/19/1987	11/6/2017
1610006-002	TDS	mg/L	2451.918	11	650.0	4500.0	1431.455	457.989	1518.978	1/9/1985	4/10/2019
1610006-005	TDS	mg/L	639.688	5	490.0	640.0	570.000	25.100	56.125	12/13/2005	11/6/2017
1610005-021	TDS	mg/L	420.336	9	390.0	443.0	407.000	5.783	17.349	1/15/2010	10/30/2018
1610005-007	TDS	mg/L	513.138	7	320.0	630.0	412.857	40.983	108.430	10/5/1995	4/15/2013
1610005-010	TDS	mg/L	338.628	9	320.0	340.0	332.222	2.778	8.333	8/7/1999	12/20/2019
1610005-003	TDS	mg/L	259.553	11	220.0	270.0	246.364	5.920	19.633	3/26/1987	5/14/2013
1610005-022	TDS	mg/L	449.086	7	400.0	457.0	425.286	9.727	25.734	5/27/2010	2/6/2018
1610005-005	TDS	mg/L	302.176	12	230.0	330.0	280.000	10.075	34.902	3/28/1990	12/20/2019
1610005-018	TDS	mg/L	422.989	11	410.0	430.0	417.091	2.647	8.780	12/6/2004	2/6/2018
1610005-008	TDS	mg/L	400.503	11	360.0	420.0	388.182	5.530	18.340	8/24/1995	4/18/2016
1610005-006	TDS	mg/L	377.730	10	330.0	400.0	365.000	5.627	17.795	10/5/1995	5/3/2016
1610005-020	TDS	mg/L	285.804	9	250.0	290.0	275.556	4.444	13.333	4/26/2007	5/14/2019
1610005-011	TDS	mg/L	451.368	4	410.0	440.0	427.500	7.500	15.000	4/15/2013	5/14/2019
1610009-003	TDS	mg/L	881.480	12	545.0	1000.0	780.750	45.766	158.537	11/26/1986	4/5/2017
1610004-026	TDS	mg/L	269.001	11	200.0	320.0	243.636	11.384	37.755	7/11/2006	2/8/2017
1610004-018	TDS	mg/L	296.297	6	230.0	300.0	263.333	12.824	31.411	3/4/2013	4/19/2017
1610004-019	TDS	mg/L	174.187	4	160.0	170.0	165.000	2.887	5.774	12/22/2014	12/20/2017
1610003-039	TDS	mg/L	490.912	4	460.0	480.0	475.000	5.000	10.000	8/19/2011	5/9/2019
1610005-021	TDS	mg/L	422.522	4	390.0	420.0	402.500	6.292	12.583	10/18/2011	10/30/2018
1610005-005	TDS	mg/L	329.348	4	250.0	310.0	287.500	13.150	26.300	4/15/2013	12/20/2019
1610005-011	TDS	mg/L	451.368	4	410.0	440.0	427.500	7.500	15.000	4/15/2013	5/14/2019
1610005-021	Uranium	pCi/L	6.833	6	2.6	6.6	4.877	0.761	1.864	10/27/2011	5/16/2012
1610005-007	Uranium	pCi/L	6.312	16	0.5	13.0	4.386	0.904	3.615	12/12/1994	11/22/2011
1610005-003	Uranium	pCi/L	3.632	16	0.0	7.4	2.181	0.681	2.722	3/28/1990	8/29/2005
1610005-022	Uranium	pCi/L	5.275	8	1.9	6.0	3.933	0.568	1.606	1/30/2012	11/27/2012
1610005-005	Uranium	pCi/L	2.786	13	0.0	7.6	1.519	0.581	2.096	12/12/1994	11/19/2002
1610005-018	Uranium	pCi/L	2.419	5	0.0	2.0	1.350	0.385	0.861	8/31/2005	5/9/2007
1610005-008	Uranium	pCi/L	7.774	17	0.9	19.7	5.331	1.152	4.751	12/12/1994	1/30/2015
1610005-006	Uranium	pCi/L	3.320	11	0.0	5.7	1.930	0.624	2.069	4/4/1995	11/19/2002
1610005-020	Uranium	pCi/L	3.632	4	2.5	3.6	2.910	0.227	0.454	2/27/2009	7/30/2010
1610009-003	Uranium	pCi/L	1.161	5	0.0	1.0	0.533	0.226	0.506	9/8/2005	10/7/2015

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1610004-019	Uranium	pCi/L	10.703	4	5.6	9.2	7.405	1.036	2.073	12/22/2014	12/26/2019
1610005-003	Uranium	pCi/L	2.825	17	-10.0	7.4	-0.286	1.468	6.052	3/28/1990	8/29/2005
1610005-022	Uranium	pCi/L	6.693	4	1.9	6.0	3.933	0.868	1.735	1/30/2012	11/27/2012
1610005-005	Uranium	pCi/L	1.692	16	-10.0	7.6	-1.252	1.381	5.524	3/28/1990	11/19/2002
1610005-018	Uranium	pCi/L	5.860	5	-10.0	2.0	-0.650	2.345	5.243	8/31/2005	5/9/2007
1610005-006	Uranium	pCi/L	2.886	14	-10.0	5.7	0.764	0.982	3.676	12/12/1994	11/19/2002
1610005-020	Uranium	pCi/L	3.632	4	2.5	3.6	2.910	0.227	0.454	2/27/2009	7/30/2010
1610005-011	Uranium	pCi/L	8.658	4	3.6	7.9	5.613	0.957	1.914	3/21/2002	11/19/2002

Abbreviations:
µg/L = microgram per liter
mg/L = milligrams per liter
pCi/L = picocuries per liter
TDS = Total Dissolved Solids

APPENDIX D

MITIGATION PLAN FRAMEWORK

MITIGATION PLAN FRAMEWORK

The Tulare Lake GSAs have agreed to prepare and implement mitigation programs to offset impacts. However, it should be understood that the conditions and users in each area vary widely. This framework presents the minimum requirements that would be included in each GSA-specific mitigation program. As the GSAs considered what mitigation might entail in their areas, it became clear that the effort has many facets that will require stakeholder input in each area. In particular, funding for these efforts would need to be developed through a Proposition 218 process and election. Also, most rural residential wells are considered *di minimis* under SGMA, and therefore will need to be investigated more fully to understand their location and construction. Due to the tight deadline allowed in GSP Regulations, insufficient time was available to seek stakeholder input into a complete mitigation program. Instead, the GSAs have agreed to this framework and will prepare individual mitigation programs specific to their stakeholder needs by January 2025 for inclusion into the five-year Plan update.

Purpose

The purpose of the mitigation program is to address local landowner issues to the extent feasible. The plan would be that the mitigation program would address local impacts to beneficial users resulting from GSP implementation. However, care must be taken to establish what portion of the impacts are associated with the choices by the landowner or other nearby landowners, rather than GSA actions to implement the GSP. In this regard, the mitigation plan might be viewed to be similar to efforts put in place around groundwater banks, where benefits and impacts from the banking operations are considered along with all available monitoring information by qualified professionals to develop a view of whether mitigation is warranted. The impacts covered by the program would be limited to domestic wells, critical infrastructure, and land uses that are adversely affected by declining groundwater levels, land subsidence, or changes to groundwater quality. The mitigation plan may be revised or expanded based on groundwater conditions in the future.

Minimum Plan Requirements

Each plan will include the following:

1. Stakeholder outreach
2. Well Registration
3. Eligibility Criteria
4. Application process
5. Evaluation process
6. Identification of suitable mitigation
7. Funding Source

Stakeholder Outreach

The program should present the public outreach and education efforts that will be performed during development of the mitigation program and prior to implementation. Prior to implementation, extensive outreach will be needed to notify stakeholders of the Program requirements and how they can apply for assistance. These efforts should be in general accordance with the existing Stakeholder Communication and Engagement Plan. However, one main difference relative to when the 2020 GSP was developed is that through the Governor's Executive Order N-7-22, GSAs are more directly involved in well permitting. So, for impacted parties, contacting their local GSA about the matter should become routine.

Well Registration

As noted above, the information on domestic wells regarding well construction and operation is limited. The Kings County database provides some information on the existing domestic wells where permits were obtained but is not updated regularly for well operational status. A comprehensive database of the domestic wells with construction details would be complied across the Subbasin.

Eligibility Criteria

The program should present the eligibility requirements to qualify for the program based on stakeholder compliance with the GSP, GSA's Rules & Regulations, and other laws or regulations.

Application Process

The program should clearly present the process by which an affected stakeholder can submit a claim. It is anticipated that this process will include requests for information such as a Well Completion Report on the well, monitored depths to water over time, records on how the well was maintained, information on the amount of water used or power consumption records that could be used as a proxy, water quality records for relevant COCs, and information about existing wells within a radius around the well experiencing the perceived impact.

Evaluation

Once a claim of adverse impact has been made to a GSA, the GSA will investigate the claim to evaluate whether it is associated with GSP Implementation. As was stated before, the mitigation program will be designed to address local impacts to beneficial users resulting from GSP implementation. However, care must be taken to establish what part of the impacts may be associated with choices by the landowner, other nearby landowners, or potentially some other issue with the facility, rather than GSA actions to implement the GSP. In this regard the mitigation plan might be viewed to be similar to efforts put in place around Groundwater Banks, where benefits and impacts from the Banks operations are considered along with all available monitoring information by qualified professionals to come to a view of whether mitigation is warranted.

Mitigation

Once contacted about a potential impact, the GSA will begin working with the local landowner. There are various services available to landowners with well issues, such as County programs to provide temporary water service while a new well is drilled. The GSAs will convey available information on these services and work with the landowner to provide information about the facility and its condition to the GSAs so that an evaluation can be undertaken as quickly as possible. Once a claim of impact has been confirmed to be due to GSP implementation, the GSA will pursue suitable mitigation efforts as described in each GSA specific plan. Various factors may reflect the proper mitigation methods for the specific issue. For example, facility age, location, financial impact to the stakeholder as a result of mitigation.

Funding Source

Funding will be needed for the program through the GSA's implementation of assessments, fees, charges, and penalties. All of these funds will have to be developed consistent with Proposition 218 requirements. Also, much work will have to be done to better understand the sources of the impacts and identify landowners involved in developing the identified impacts, so that funds are collected from the appropriate parties. In addition, the GSAs will explore grant funding as County, state and federal assistance will be needed to successfully implement this program. The State has existing grant programs for community water systems and well construction funding. The GSAs will also work with local NGOs that may be able to provide assistance or seek grant monies to help fund the program.