Appendix C

Davids Engineering Evapotranspiration and Applied Water Estimates

Technical Memorandum

Technical Memorandum

To: GEI Consultants

From: Davids Engineering

Date: November 30, 2018

Subject: **Kaweah Subbasin Development of Evapotranspiration and Applied Water Estimates Using Remote Sensing**

1 Summary

The purpose of this effort is to develop time series estimates of agricultural water demands for the Kaweah Subbasin from 1999 through 2017. This effort updates a similar analysis previously completed for the Kaweah Delta Water Conservation District (KDWCD) from 1999 through 2016 to include the areas currently not included in the KDWCD area but lying within the Kaweah Subbasin and to extend the estimates through 2017.

The consumptive use of water (i.e., evapotranspiration) is the primary destination of infiltrated precipitation and applied irrigation water within the Kaweah Subbasin. Quantification of consumptive use was achieved by performing daily calculations of evapotranspiration (ET) for individual fields from October 1998 through December 2017. ET was separated into its evaporation (E) and transpiration (T) components. Transpiration was quantified using a remote sensing approach where Landsat satellite images acquired from USGS were used to calculate the Normalized Difference Vegetation Index (NDVI), which was subsequently translated to a basal crop coefficient and combined with referent ET to calculate transpiration over time.

A spatial coverage of field boundaries was developed for the Kaweah Subbasin, and individual field polygons were assigned cropping and irrigation method information over time based on available data. Field boundaries were delineated by combining polygon coverages in GIS format from the United States Department of Agriculture (USDA) and the California Department of Water Resources (DWR). The area encompassed by the field boundary GIS coverage includes the Kaweah Subbasin and the area immediately surrounding but outside of the subbasin.

Crop ET was calculated based on a combination of remote sensing data and simulation of irrigation events in a daily root zone water balance model. Due to the remote sensing approach crop ET estimates are relatively insensitive to crop type and irrigation method so detailed, accurate assignment of crop types and irrigation methods to each field is not critical to developing relatively reliable estimates of crop ET. Crop types and irrigation method were assigned to each field based on a combination of data from DWR and USDA. The amount of green vegetation present over time was estimated for each field polygon based on NDVI, which is calculated using a combination of red and near infrared reflectances as measured using multispectral satellite sensors onboard Landsat satellites. Following the preparation of NDVI imagery spanning the analysis period all images were quality controlled to remove pixels affected by clouds.

Mean daily NDVI values for each field were converted to basal crop coefficients based on cropping information from the 2007 Tulare County crop survey, combined with an analysis of actual evapotranspiration (ET_a) by crop conducted using the Surface Energy Balance Algorithm for Land (SEBAL®) for 2007 (Bastiaanssen et al., 2005; SNA, 2009). Daily precipitation was estimated based on assembly and review of data from the PRISM Climate Group at Oregon State University[1]. Daily reference evapotranspiration (ET_o) was estimated based on information from California Irrigation Management Information System (CIMIS) weather stations. Root zone parameters that influence the amount of available soil moisture storage were estimated based on crops and soils present in the Kaweah Subbasin.

A summary for the 1999 to 2017 analysis period of the annual ET of applied water (ET_{AW}), ET_c (synonymous with ET_a), applied water (AW), deep percolation of applied water (DP_{AW}) and deep percolation of precipitation (DP_{pr}) estimates based on the root zone water balance model is given in the Results section.

Application of remote sensing combined with daily root zone water balance modeling (RS-RZ model) provides an improved methodology for estimation of surface interactions with the groundwater system including net groundwater depletion through estimation of ET of applied water and other fluxes.

2 Introduction

The purpose of this effort is to develop time series estimates of agricultural water demands for the Kaweah Subbasin from 1999 through 2017. Demand was estimated quantitatively at the field scale using a daily root zone water balance model and aggregated to monthly time steps. It is anticipated that these estimates will be used to support development of an integrated hydrologic model for the Kaweah Subbasin and water budget development for one or more Groundwater Sustainability Plans (GSPs). Crop evapotranspiration (ET), the primary driver of agricultural water demand, was estimated based on a combination of remote sensing and simulation of irrigation events using the water balance model.

This effort updates a similar analysis previously completed for the Kaweah Delta Water Conservation District (KDWCD) from 1999 through 2016 to include the areas currently not included in the KDWCD area but lying within the Kaweah Subbasin. In addition to adding the additional areas within the Kaweah subbasin, this analysis extends the estimates through the end of the 2017 calendar year.

3 Methodology

3.1 Daily Root Zone Simulation Model

A conceptual diagram of the various surface layer fluxes of water into and out of the crop root zone is provided in Figure 3.1. The consumptive use of water (i.e., evapotranspiration or ET) is the primary destination of infiltrated precipitation and applied irrigation water within the Kaweah Subbasin. Quantification of consumptive use was achieved by performing daily calculations of ET for individual fields from October 1998 through December 2017. Evapotranspiration was separated into its evaporation (E) and transpiration (T) components. Additionally, each component was separated into the amount of E or T derived from precipitation or applied water.

[1] http://prism.oregonstate.edu/

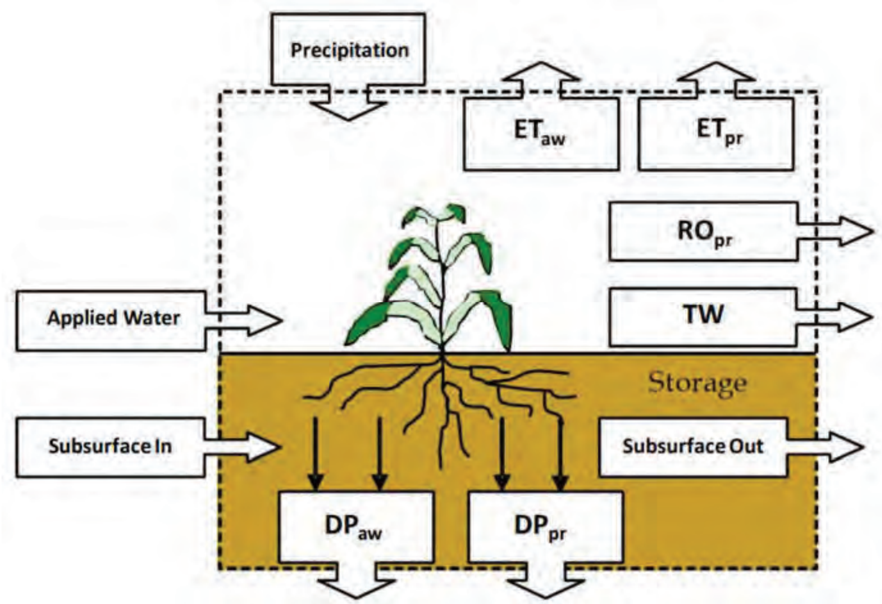

Figure 3.1. Conceptualization of Fluxes of Water Into and Out of the Crop Root Zone

Transpiration was quantified using a remote sensing approach whereby Landsat satellite images acquired from USGS were used to calculate the Normalized Difference Vegetation Index (NDVI), a measure of the amount of green vegetation present. NDVI values were calculated and interpolated for each field over time. NDVI values were then converted to transpiration coefficients that were used to calculate transpiration over time by multiplying daily NDVI by daily reference evapotranspiration (ET_o). Evaporation was quantified by performing a surface layer water balance for the soil based on the dual crop coefficient approach described in FAO Irrigation and Drainage Paper 56 (Allen et al. 1998). On a daily basis, evaporation was calculated based on the most recent wetting event (precipitation or irrigation) and the evaporative demand for the day (ET_o). This methodology is described in greater detail by Davids Engineering (Davids Engineering 2013).

3.2 Development of Field Boundaries

A spatial coverage of field boundaries was developed for the Kaweah Subbasin, and individual field polygons were assigned cropping and irrigation method information. For each field polygon, daily water balance calculations were performed for the 1999 to 2017 analysis period, and irrigation events were simulated to estimate the amount of water applied to meet crop irrigation demands. This section describes the development of the field polygon coverage and assignment of cropping and irrigation method attributes.

3.2.1 Development of Field Boundaries

Field boundaries were delineated by combining publicly available polygon coverages in GIS format from the United States Department of Agriculture (USDA) and the California Department of Water Resources (DWR). For the original KDWCD study area, common land unit (CLU) coverages developed by the USDA Farm Services Administration (FSA) on a county by county basis were combined to develop the base field coverage. Gaps exist in the CLU field coverages for fields not participating in USDA farm programs. These gaps were filled by overlaying the FSA CLU data with field polygons from DWR land use surveys for Kings and Tulare counties.

For the expanded study area encompassing the full Kaweah Subbasin, the original field boundaries were retained, and additional fields were added based on DWR's 2014 statewide spatial cropping dataset.

The area encompassed by the field boundary GIS coverage includes the Kaweah Subbasin and the area immediately surrounding, but outside of, the subbasin. Fields outside of the subbasin were included to provide a more robust dataset for model calibration and validation. Ultimately, results specific to the subbasin as a whole include only those fields with their centroid located within the Kaweah Subbasin.

3.3 Assignment of Cropping and Irrigation Method

As described previously, crop evapotranspiration (ET) was calculated based on a combination of remote sensing data and simulation of irrigation events in a daily root zone water balance model. A result of the remote sensing approach is that crop transpiration was estimated with little influence from the assigned crop type for each field. Additionally, crop transpiration is the dominant component of ET, meaning that ET estimates are likewise largely independent of the assigned crop type.

Crop evapotranspiration is driven to some extent by the characteristics of the irrigation method and its management, including the area wetted during each irrigation event and the frequency of irrigation. Surface irrigation methods typically wet more of the soil surface than micro-irrigation methods; however, surface irrigated fields are typically irrigated less frequently than their micro-irrigated counterparts. As a result, evaporation rates can be similar among surface and micro-irrigated fields and estimates of evaporation are likewise somewhat independent of the assigned irrigation method. Parameters related to irrigation method were assigned based the predominant irrigation method for each crop, as described by recent historical DWR land and water use surveys.

A key result of the relative insensitivity of the crop ET estimates to crop type or irrigation method (due to the remote sensing approach), is that detailed, accurate assignment of crop types and irrigation methods to each field is not critical to developing reliable estimates of crop ET at the field scale and, more importantly, at coarser scales due to the cancellation of errors in individual field estimates as they are aggregated.

Crop types were assigned to each field based on a combination of data from DWR and USDA. DWR data consisted of land use data from 2003 and 2014 for Kings County and from 1999, 2007, and 2014 for Tulare County. USDA data consisted of Cropland Data Layer coverages for 2008 to 2013 and 2015 to 2016. The source of land use data for each year is summarized in Table 3.1.

Table 3.1. Land Use Sources by County and Year.

County	Year(s)	Source
Kings	1999-2007	DWR (2003)
	2008-2013	CDL
	2014	DWR (2014)
	2015-2017	CDL*
Tulare	1999-2002	DWR (1999)
	2003-2007	DWR (2007)
	2008-2013	CDL
	2014	DWR (2014)
	2015-2017	CDL*

* CDL data for 2016 was used for 2017

3.4 NDVI Analysis

The amount of green vegetation present over time was estimated for each field polygon based on the Normalized Difference Vegetation Index (NDVI), which is calculated using a combination of red and near infrared reflectances, as measured using multispectral satellite sensors onboard Landsat satellites. NDVI can vary from -1 to 1 and is typically varies from approximately 0.15 to 0.2 for bare soil to 0.8 for green vegetation with full cover. Negative NDVI values typically represent water surfaces.

3.4.1 Image Selection

Landsat images are preferred due to their relatively high spatial resolution (30-meter pixels, approx. 0.2 acres in size). A total of 682 raw satellite images were selected and converted to NDVI spanning the period from September 1998 to January 2018. Of the images selected, 230 were from the Landsat 5 satellite, 350 were from the Landsat 7 satellite (first available in 2001), and 102 were from the Landsat 8 satellite (first available in 2013). These images were used to process and download surface reflectance (SR) NDVI from the USGS Earth Resources Observation and Science (EROS) Center Science Processing Architecture (ESPA)[2].

An example time series of NDVI imagery for 2010 for the Kaweah Delta Water Conservation District (KDWCD) is shown in Figure 3.1 in Davids Engineering (2013). In the figure, areas with little or no green vegetation present are shown in brown, and areas with green vegetation are shown in green.

There was sufficient cloud-free Landsat imagery available that no cloud gap filling as in Davids Engineering (2013) was necessary. The number of days between image dates ranged from 5 to 56, with an average of 10 days. Generally, there was at least one image selected for each month.

3.4.2 Extraction of NDVI Values by Field and Development of Time Series NDVI Results

Following the preparation of NDVI imagery spanning the analysis period, all images were masked using the Quality Assessment Band (BQA) provided by ESPA to remove pixels affected by clouds. Then, mean NDVI was extracted from the imagery for each field for each image date. These NDVI values were then interpolated across the full analysis period from October 1, 1998 to December 31, 2017 to provide a daily time series of mean NDVI values for each field.

[2] USGS ESPA website: https://espa.cr.usgs.gov/

Top of Atmosphere (TOA) NDVI was calculated for several image dates and compared to SR NDVI on the same image dates to establish the following relationship (R^2=0.99):

$$(\text{TOA NDVI}) = 0.9224*(\text{SR NDVI}) - 0.0171 \quad [3.1]$$

This regression was applied to all image dates to convert from SR to TOA NDVI to provide consistency with the relationship between NDVI and the transpiration coefficient developed by Davids Engineering (2013) Error! Bookmark not defined..

Landsat 8 bandwidth was adjusted to be consistent with bandwidths from Landsat satellites 5 and 7 using the following empirical relationship:

$$(\text{L7 mean NDVI}) = 0.984*(\text{L8 mean NDVI}) - 0.0421 \quad [3.2]$$

An example of time varying NDVI for individual fields over time is found in Section 3 of Davids Engineering (2013). Interpolated NDVI values for selected fields are provided for the period 1999 through 2010 on an annual basis, from January 1 to December 31 of each year. These figures illustrate the ability of the remote sensing approach to account for both changes in cropping over time and the presence of double- and triple-cropping.

3.4.3 Development of Relationships to Estimate Basal Crop Coefficient from NDVI

Basal crop coefficients (K_{cb}) describe the ratio of crop transpiration to reference evapotranspiration (ET_o) as estimated from a ground-based agronomic weather station. By combining K_{cb}, estimated from NDVI, with an evaporation coefficient (K_e), it is possible to calculate a combined crop coefficient ($K_c = K_{cb} + K_e$) over time[3]. By multiplying K_c by ET_o, crop evapotranspiration (ET_c) can be calculated. For this analysis, ET_o, K_{cb}, K_e, and ET_c (synonymous to actual ET, ET_a) were estimated for each field on a daily time step from October 1, 1998 to December 31, 2017.

Mean daily NDVI values for each field were converted to basal crop coefficients based on cropping information from the 2007 Tulare County crop survey conducted by DWR, combined with an analysis of actual evapotranspiration (ET_a) by crop conducted using the Surface Energy Balance Algorithm for Land (SEBAL®) for 2007 (Bastiaanssen et al., 2005; SNA, 2009). Specifically, a relationship between actual basal crop coefficients estimated using SEBAL and field-scale mean NDVI values developed by Davids Engineering (2013) was applied to calculate daily basal crop coefficients for each field over time[4].

3.5 Precipitation

Daily precipitation was estimated based on assembly and review of data from the PRISM Climate Group at Oregon State University[5]. Specifically, each field was assigned estimated precipitation from the 4km PRISM grid cell within which its centroid fell. The update generally results in modest increases in estimated precipitation within the study area, with greater increases moving from west to east due to orographic effects.

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[3] The estimation of Ke is based on a daily 2-stage evaporation model presented in FAO Irrigation and Drainage Paper No. 56 (Allen et al. 1998).

[4] This relationship is developed based on comparison of the combined crop coefficient to NDVI for individual fields, but represents only the transpiration component of ET. Thus, the relationship developed predicts the basal crop coefficient, Kcb.

[5] http://prism.oregonstate.edu/

Annual precipitation totals, averaged over the study area for water years 1999 to 2017, are shown in Figure 3.1. Water year precipitation over the study period varied from 4.1 inches in 2014 to 16.1 inches in 2011, with an annual average of 9.1 inches.

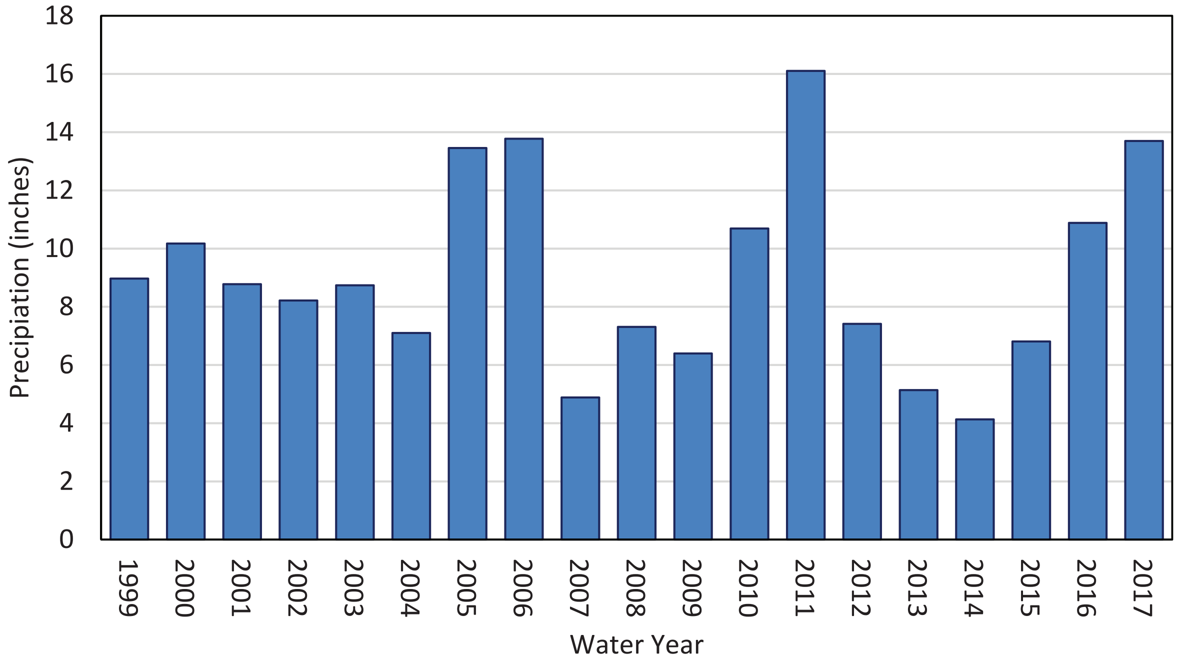


Figure 3.2. Annual Precipitation Totals

3.6 *Estimation of Daily Reference Evapotranspiration*

Daily reference evapotranspiration (ET_o) was estimated based on information from California Irrigation Management Information System (CIMIS) weather stations. ET_o provides a means of estimating actual crop evapotranspiration over time for each field. Based on review of nearby weather stations with data available during the period of analysis, the Porterville station (169) was selected based on it being relatively close to the Kaweah Subbasin, at a similar elevation to the Kaweah Subbasin, having relatively good fetch, and having available data for the majority of the analysis period.

Individual parameters from the available data including incoming solar radiation, air temperature, relative humidity, and wind speed were quality-controlled according to the procedures of Allen et al. (2005). The quality-controlled data were then used to calculate daily ET_o for the available period of record.

CIMIS data for Porterville were not available prior to August 2000. As a result, it was necessary to estimate ET_o for the period from October 1, 1998 to August 1, 2000. ET_o for Porterville was estimated by developing a linear regression to estimate Porterville ET_o using quality-controlled data from the Stratford CIMIS station for the period of overlapping data availability.

3.7 *Estimation of Root Zone Water Balance Parameters*

Root zone parameters that influence the amount of available soil moisture storage were estimated based on crops and soils present in the Kaweah Subbasin. Crop parameters of interest include root depth, NRCS curve number[6], and management allowable depletion (MAD). Root depth was estimated by crop group based on published values and a representative mix of individual crops within each crop group for the Kaweah Subbasin. Curve numbers were estimated based on values published in the NRCS National Engineering Handbook, which provides estimates based on crop type and condition. MAD values by crop were estimated based on values published in FAO Irrigation and Drainage Paper No. 56 (Allen et al., 1998).

Soil hydraulic parameters of interest include field capacity (% by vol.), wilting point (% by vol.), saturated hydraulic conductivity (ft/day), total porosity (% by vol.), and the pore size distribution index (λ, dimensionless). These parameters were estimated by first determining the depth-weighted average soil texture (sand, silt, clay, etc.) based on available NRCS soil surveys. Then, the hydraulic parameters were estimated using hydraulic pedotransfer functions developed by Saxton and Rawls (2006). Next, hydraulic parameters were adjusted within reasonable physical ranges for each soil texture so that the modeled time required for water to drain by gravity from saturation to field capacity agreed with typically accepted agronomic values. Unsaturated hydraulic conductivity (e.g. deep percolation) within the root zone was modeled based on the equation developed by Campbell (1974) for unsaturated flow.

4 Results

4.1 Crop Evapotranspiration

Estimated annual crop evapotranspiration volumes for fields with their centroid within the Kaweah Subbasin are shown in Figure 4.1. Estimated volumes of ET derived from applied water (ETaw) and precipitation (ETpr) are shown in thousands of acre-feet (taf). Annual ETaw ranged from 721 taf to 916 taf, with an average of 817 taf. Annual ETpr ranged from 87 taf to 260 taf, with an average of 174 taf. Total crop ET ranged from 899 taf to 1,056 taf, with an average of 991 taf.

[6] The curve number runoff estimation method developed the Natural Resources Conservation Service (NRCS) was used to estimate runoff from precipitation in the model. For additional information, see NRCS NEH Chapter 2 (NRCS, 1993).

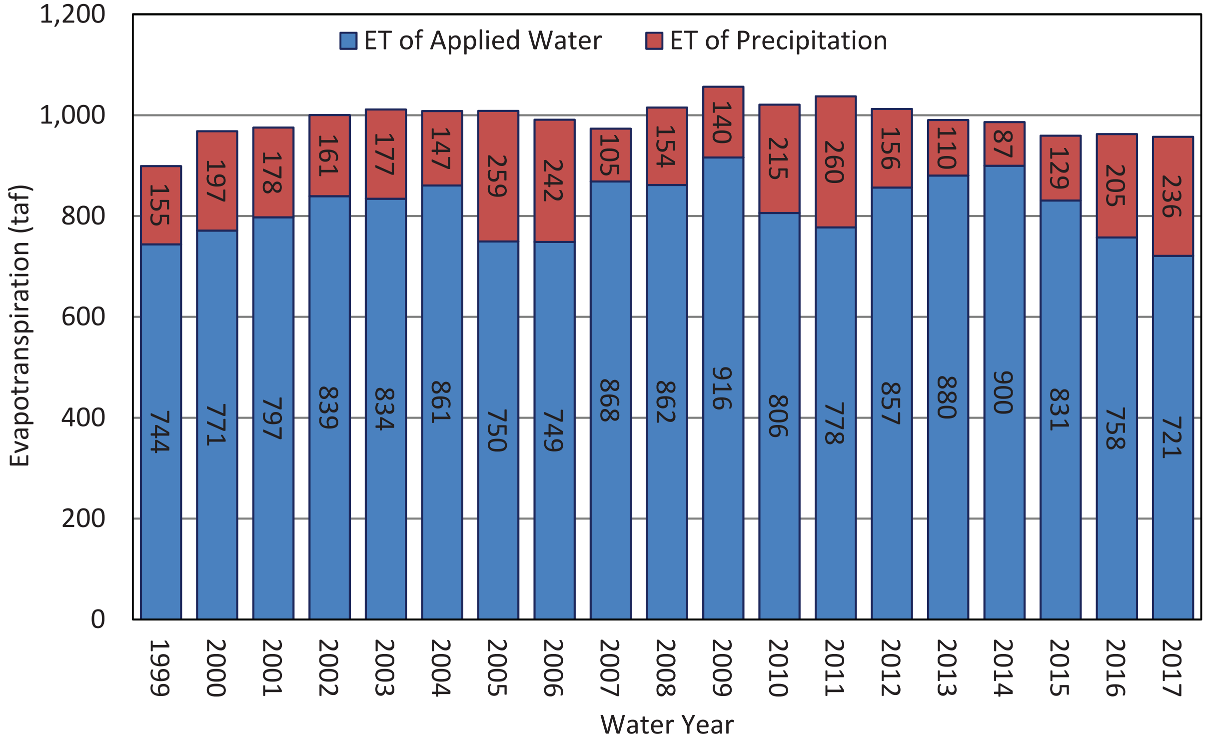


Figure 4.1. Kaweah Subasin Crop ET by Water Year

4.2 Irrigation Demands

Annual estimated irrigation demands for fields with their centroid within the Kaweah Subbasin are shown in Figure 4.2 in thousands of acre feet. Annual demands ranged from 948 taf to 1,149 taf, with an average of 1,042 taf.

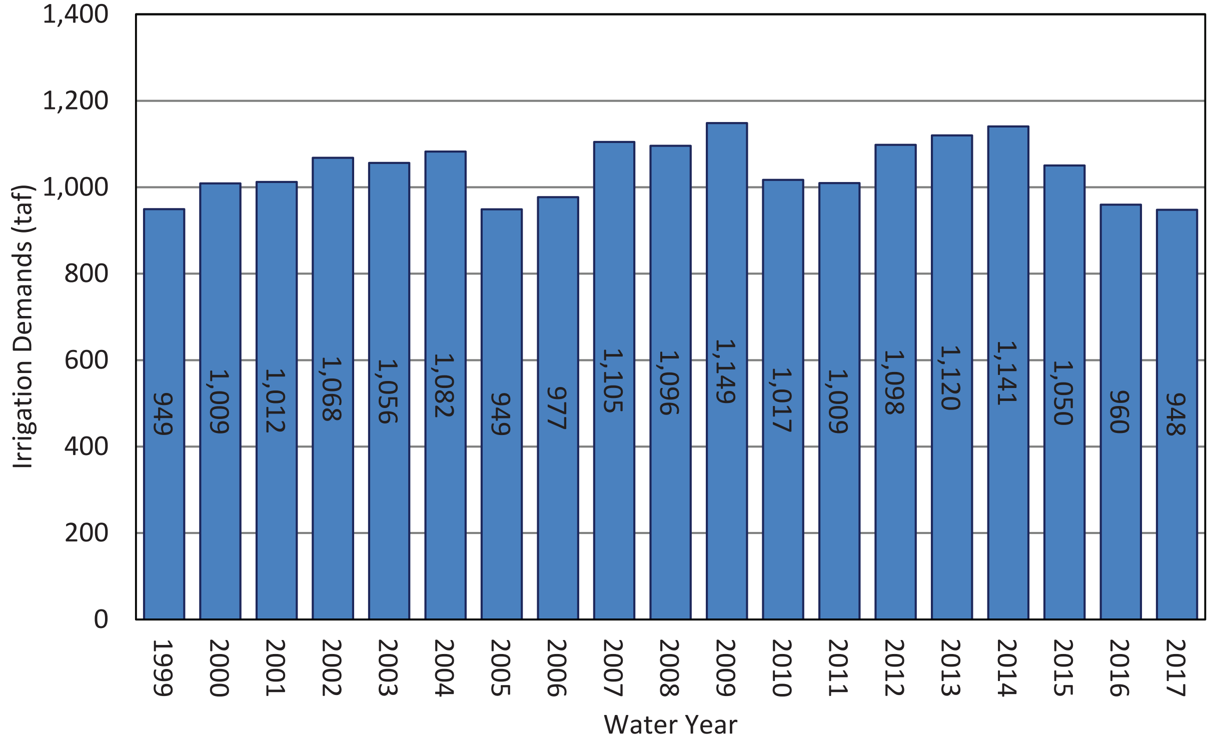


Figure 4.2. Kaweah Subasin Irrigation Demands by Water Year

4.3 Deep Percolation

Estimated annual deep percolation volumes for fields with their centroid within the Kaweah Subbasin are shown in Figure 4.3. Estimated volumes of deep percolation derived from applied water (DPaw) and precipitation (DPpr) are shown in thousands of acre-feet. Annual DPaw ranged from 208 taf to 242 taf, with an average of 227 taf. Annual DPpr ranged from 24 taf to 130 taf, with an average of 60 taf. Total deep percolation ranged from 255 taf to 372 taf, with an average of 287 taf.

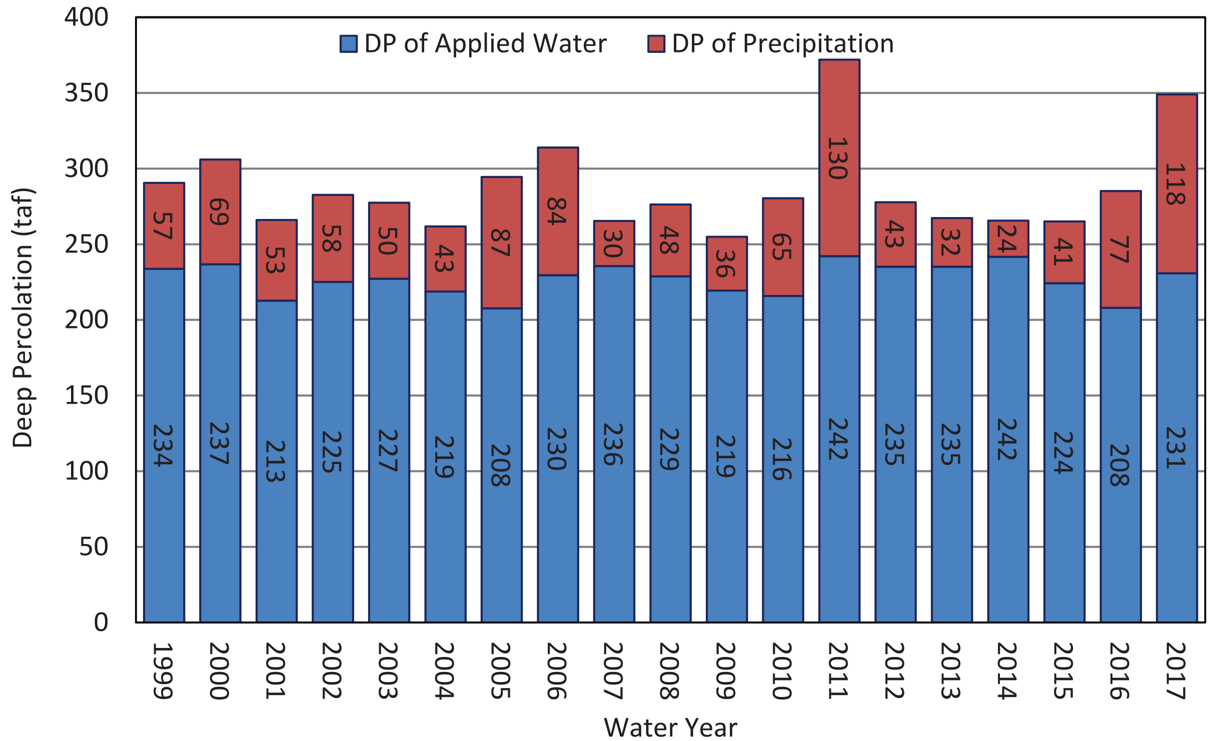


Figure 4.3. Kaweah Subasin Deep Percolation by Water Year

4.4 Annual Evapotranspiration by Crop for 2014

Estimated annual average evapotranspiration by crop is shown in Figure 4.4, along with the estimated acreage for each crop. Figure 4.4 shows the estimated average total ET by crop in inches in 2014. Average ET ranges from 7 inches for miscellaneous grain and hay to 49 inches for walnuts. The primary crops are corn, citrus, alfalfa and walnuts, representing 82, 60,40, and 31 thousand acres, respectively.

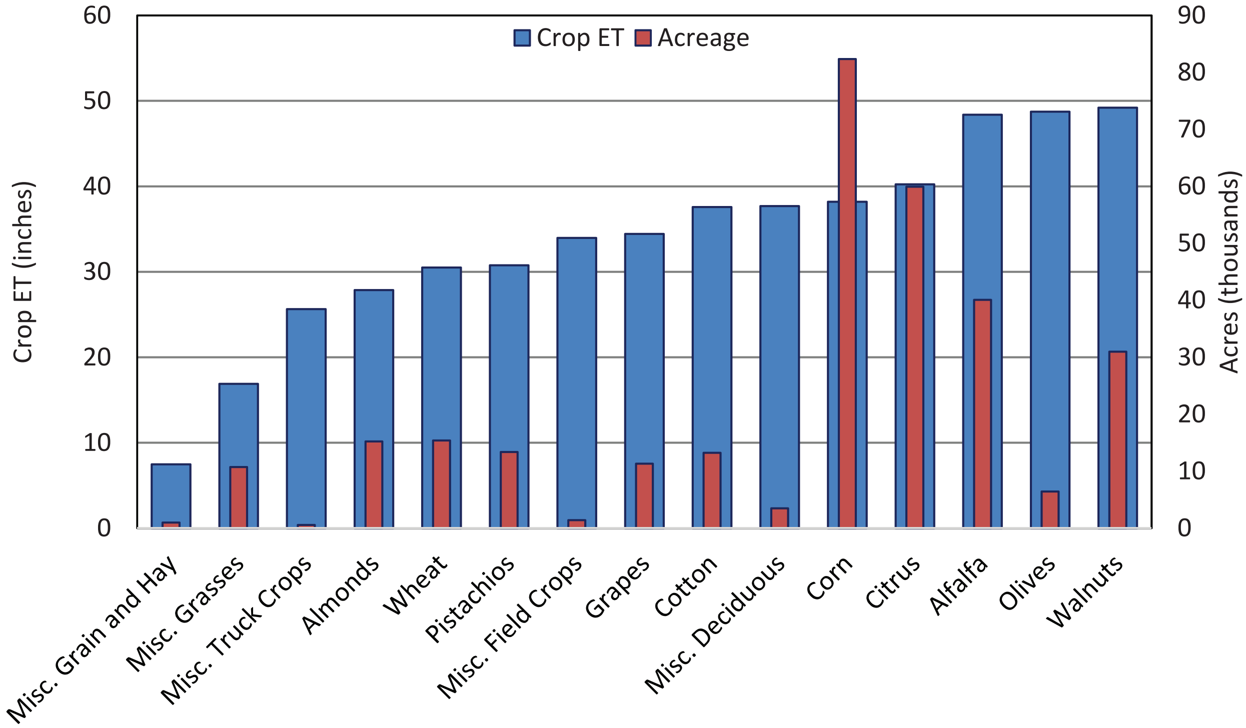


Figure 4.4. Kaweah Subasin 2014 Average ET by Crop and Crop Acreage

Additional monthly plots of ET_{oF}, ET_a and AW by crop for 2014 can be found in the appendix.

5 References

Allen, R.G, L.S. Pereira, D. Raes, and M. Smith. 1998. Crop Evapotranspiration - Guidelines for Computing Crop Water Requirements. FAO Irrigation and Drainage Paper 56. FAO. Rome, Italy.

Davids Engineering. 2013. Time Series Evapotranspiration and Applied Water Estimates from Remote Sensing. Kaweah Delta Water Conservation District. http://www.kdwcd.com/wp-content/uploads/2018/07/KDWCD-NDVI-ET-Analysis-FINAL-REPORT-March-2013.pdf

NRCS. 1993. Chapter 2 - Watershed Project Evaluation Procedures. National Engineering Handbook Part 630, Hydrology.

Saxton, K.E. and W.J. Rawls. 2006. Soil Water Characteristic Estimates by Texture and Organic Matter for Hydrologic Solutions. Soil Sci. Soc. Am. J. 70:1569–1578.

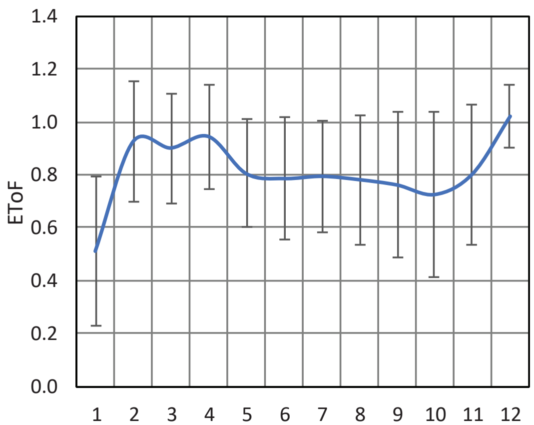
6 Appendix

This appendix includes the following figures:

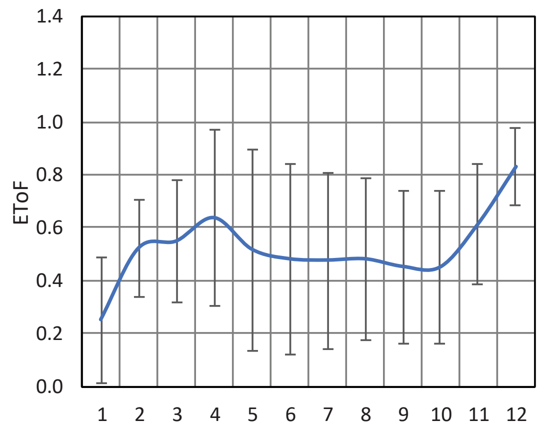
- Average monthly crop water use coefficients or “fraction of reference ET” (EToF) by crop, along with error bars depicting the standard deviation among fields.
- Average monthly crop ET by crop, along with error bars depicting the standard deviation among fields.
- Average monthly applied water by crop, along with error bars depicting the standard deviation among fields.

EToF 2014

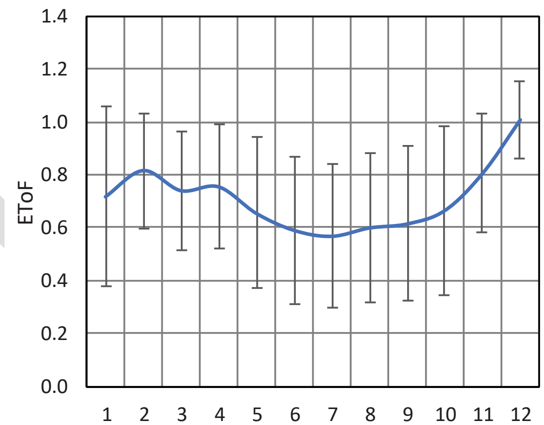
Alfalfa



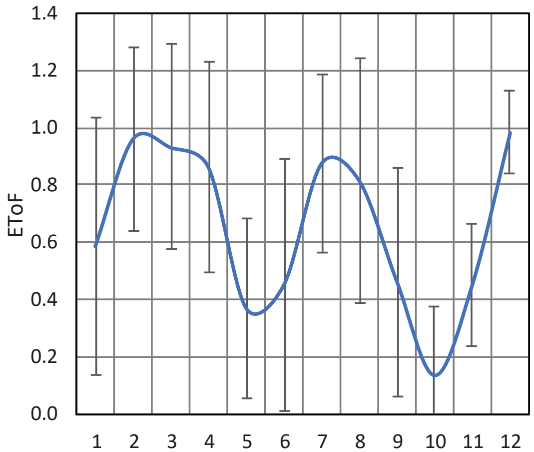
Almonds



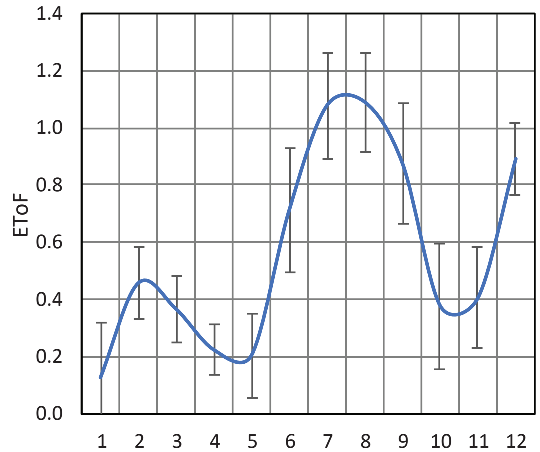
Citrus



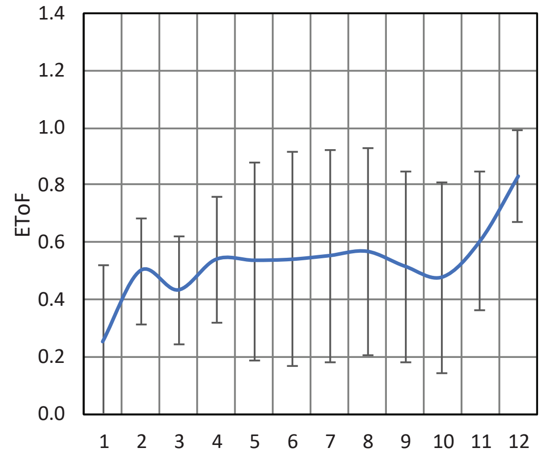
Corn



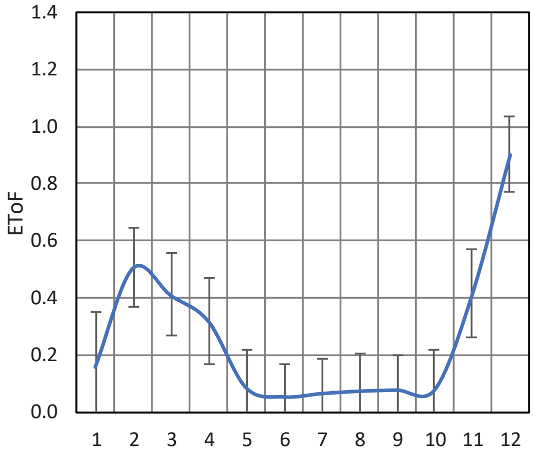
Cotton



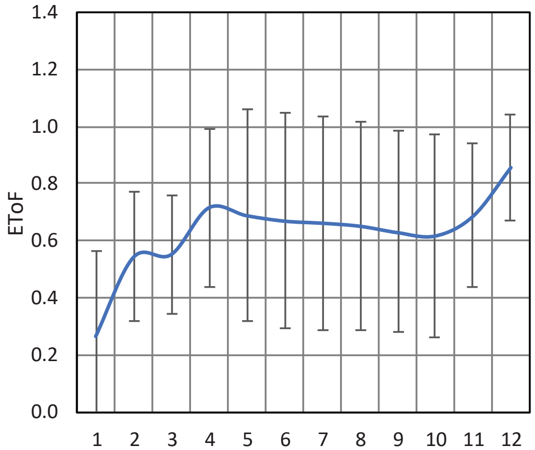
Grapes



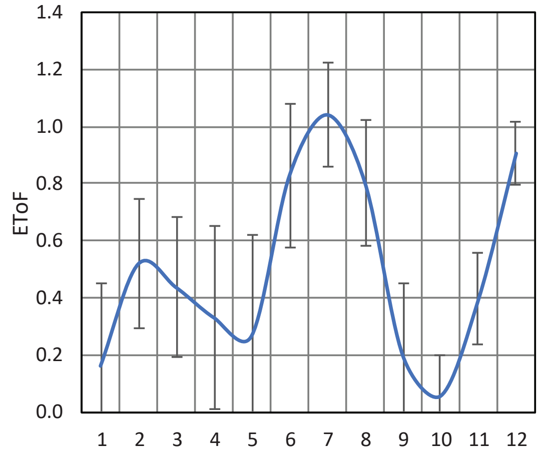
Idle



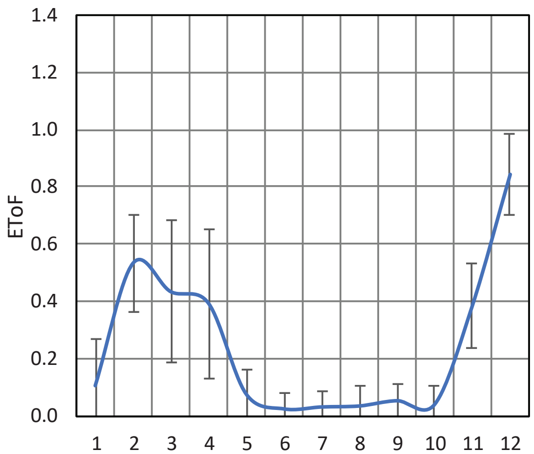
Misc. Deciduous



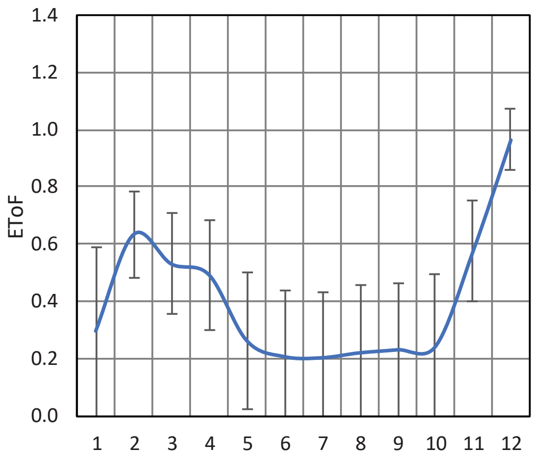
Misc. Field



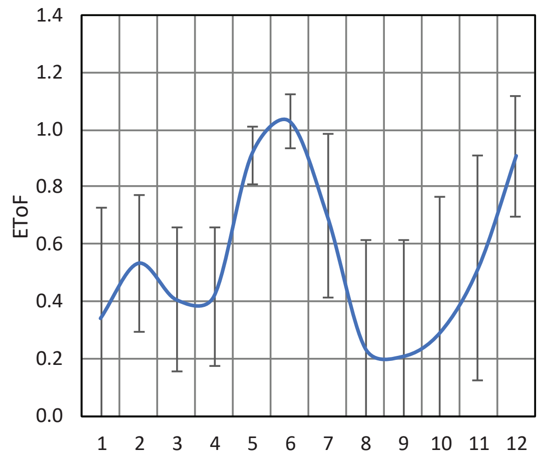
Misc. Grain and Hay



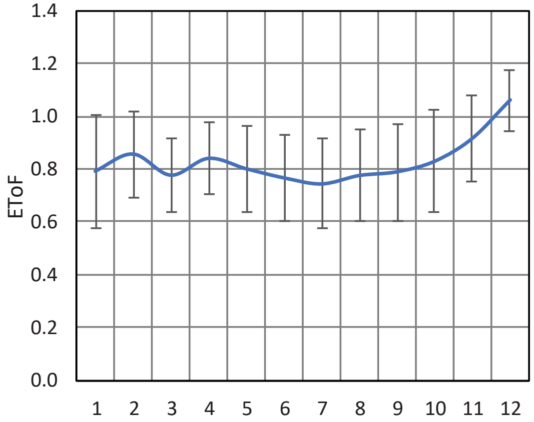
Misc. Grasses



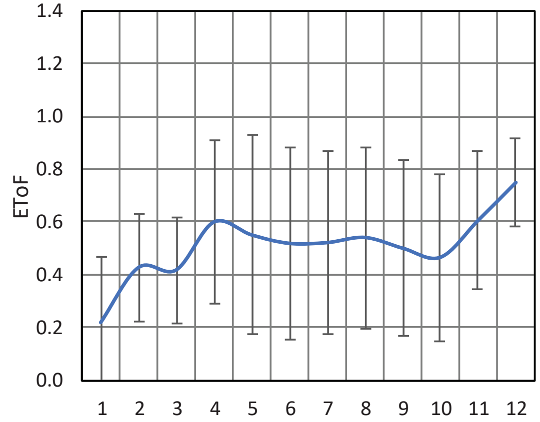
Misc. Truck



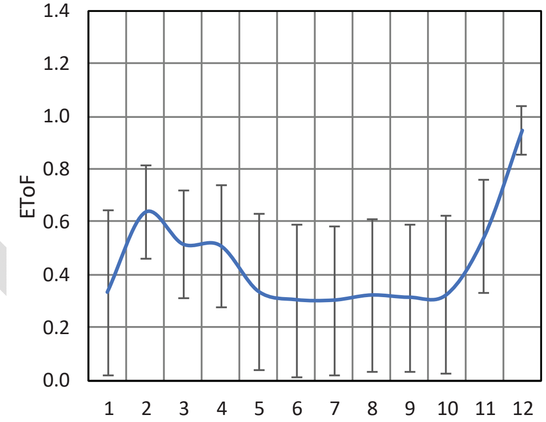
Olives



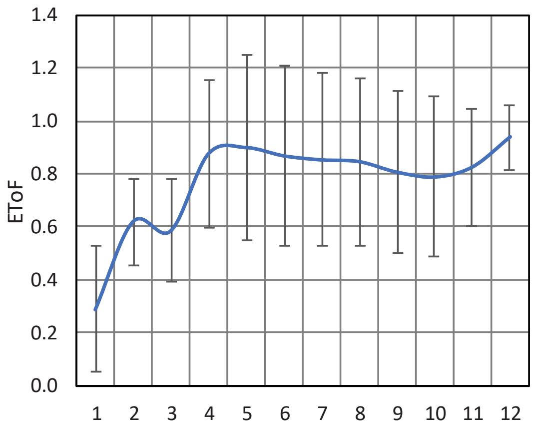
Pistachios



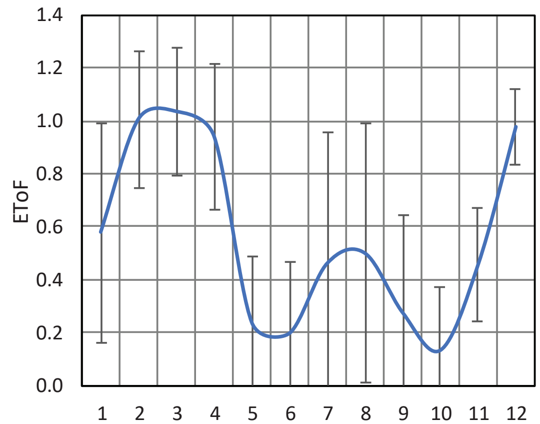
Urban



Walnuts



Wheat



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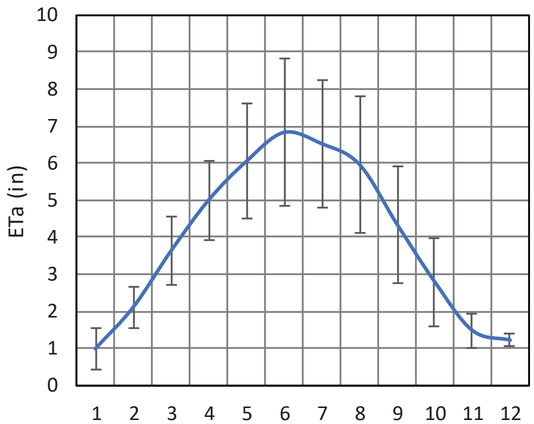
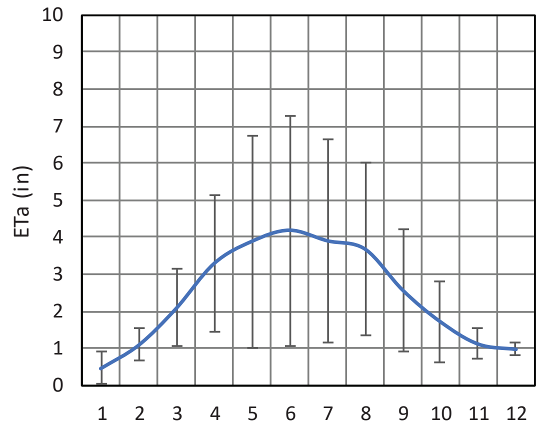
ETc 2014

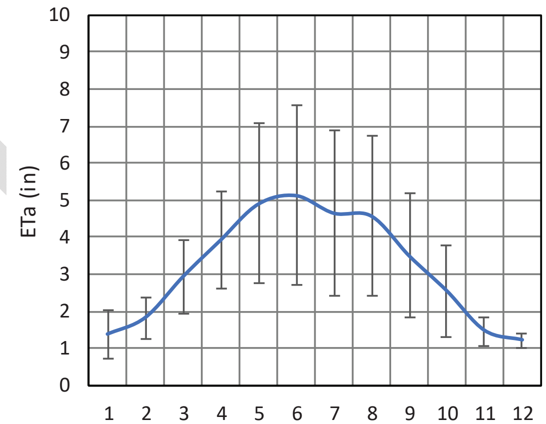
Alfalfa



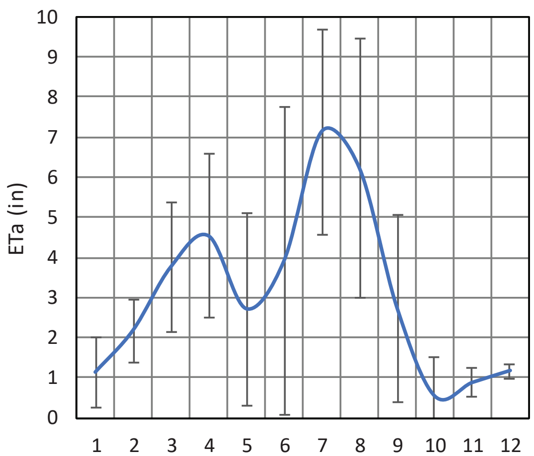
Almonds



Citrus



Corn



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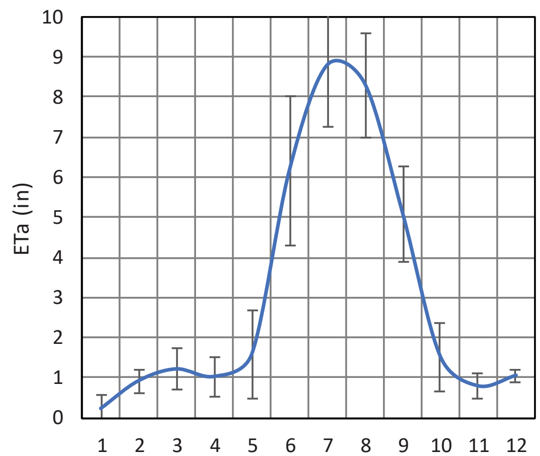

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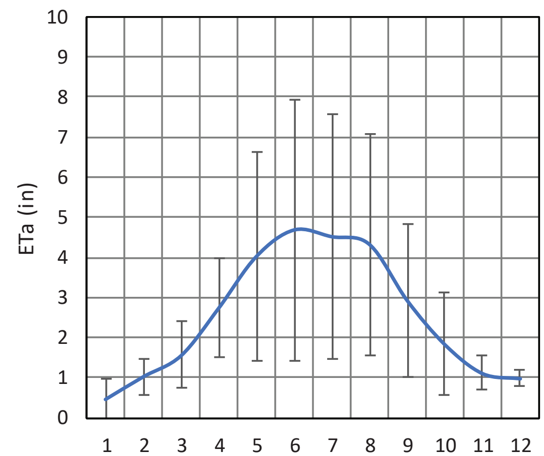

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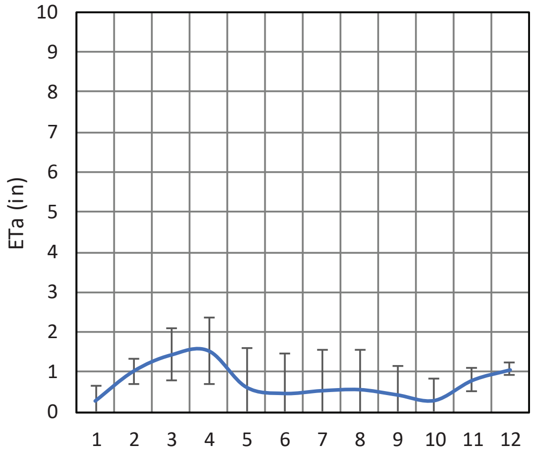

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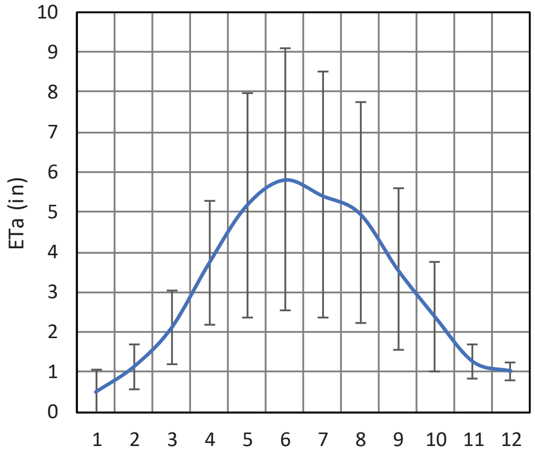

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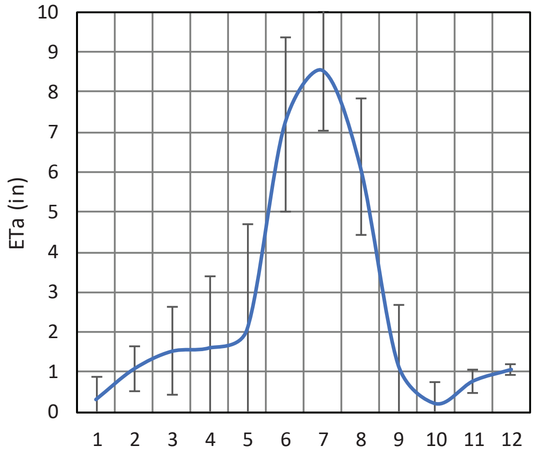

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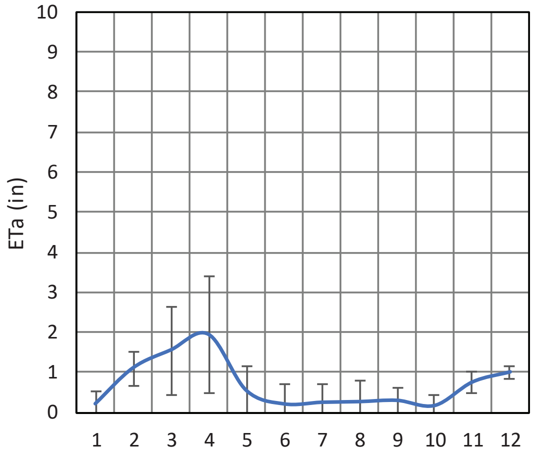

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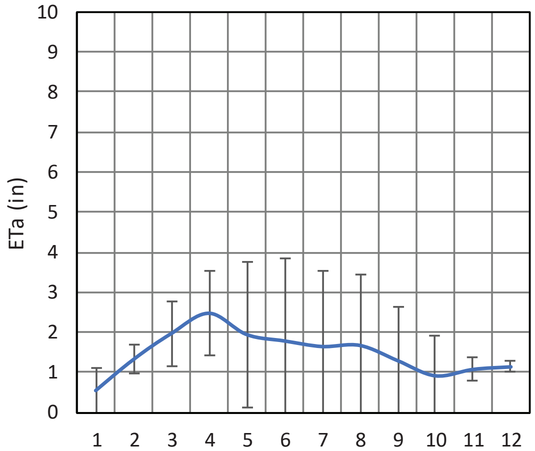

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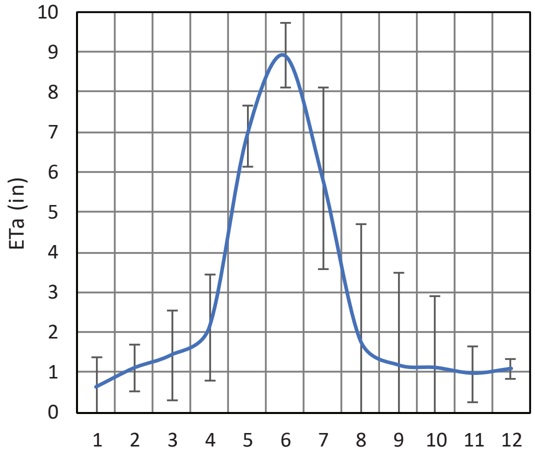

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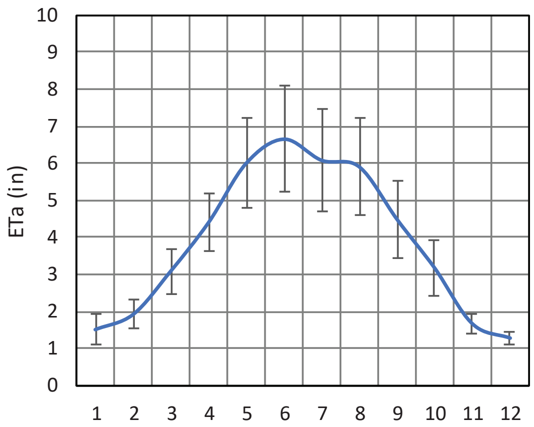

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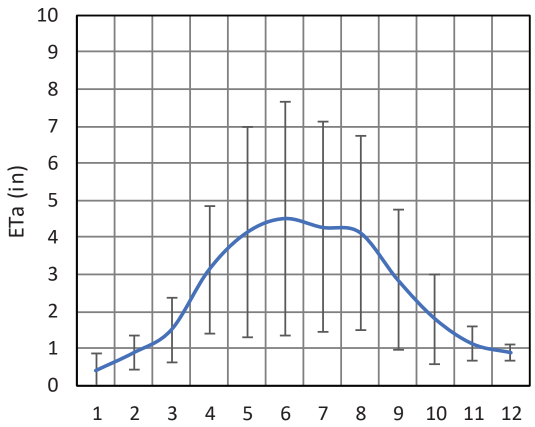

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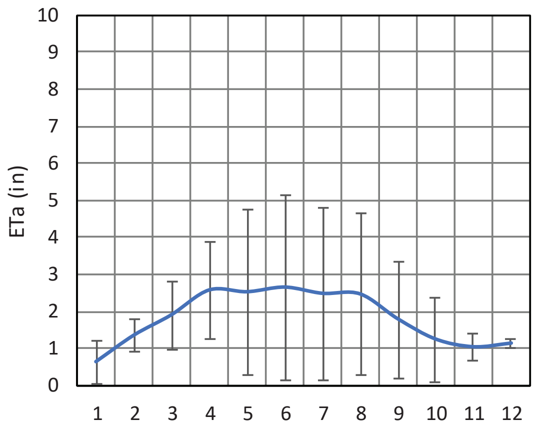

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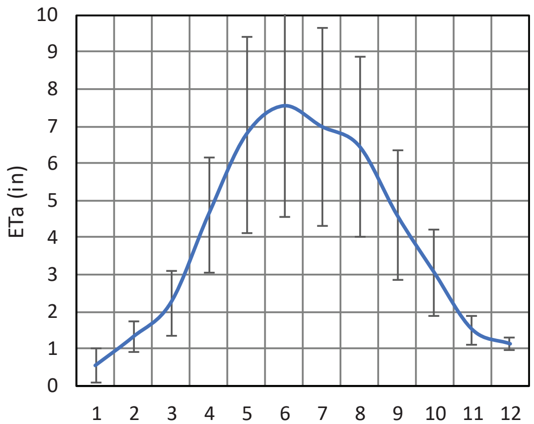

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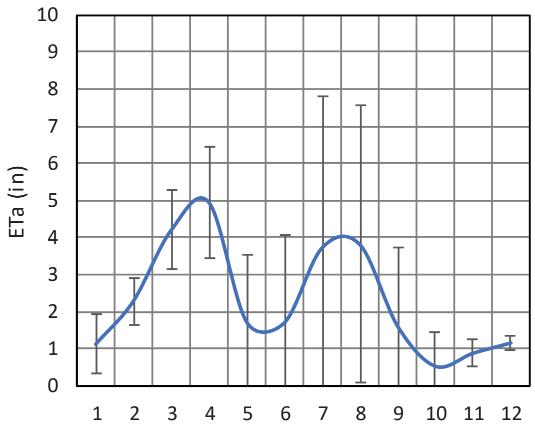

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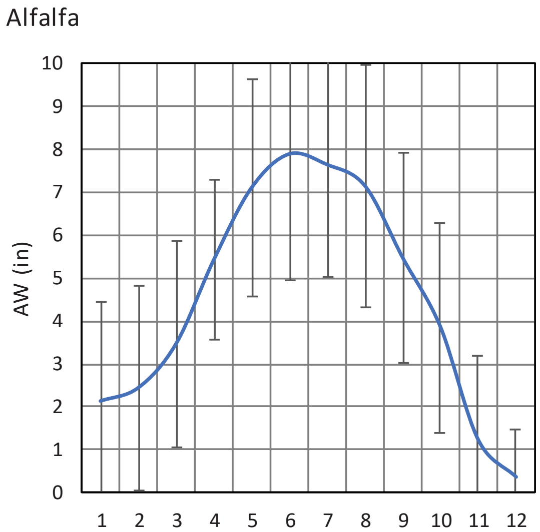
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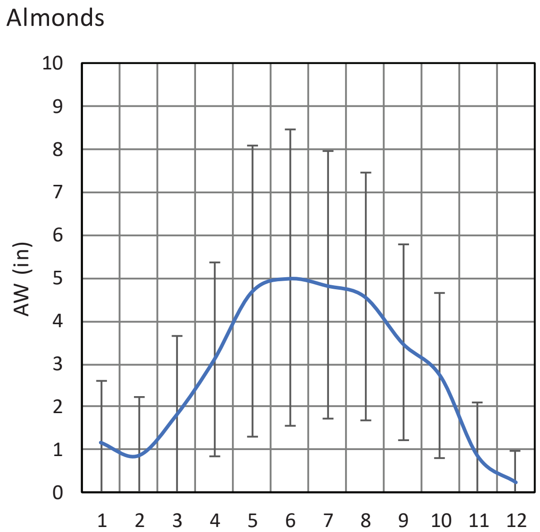
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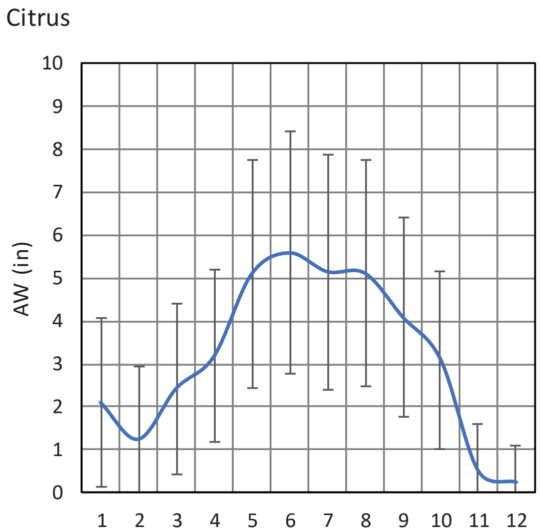
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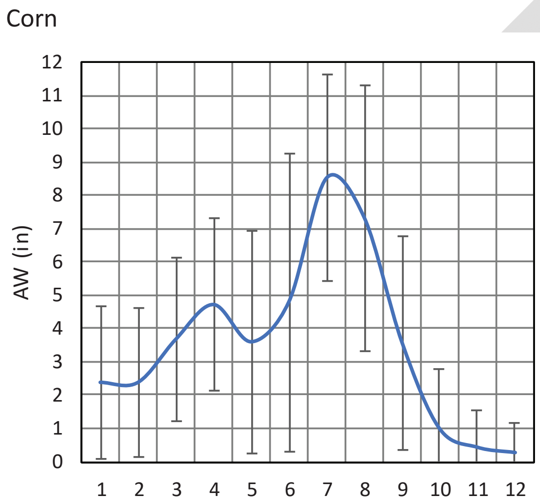
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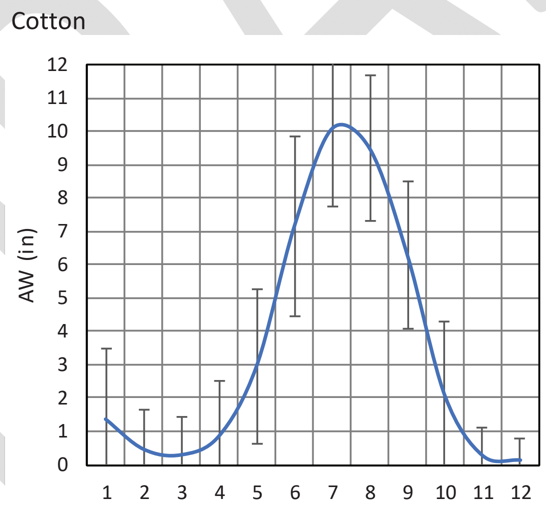
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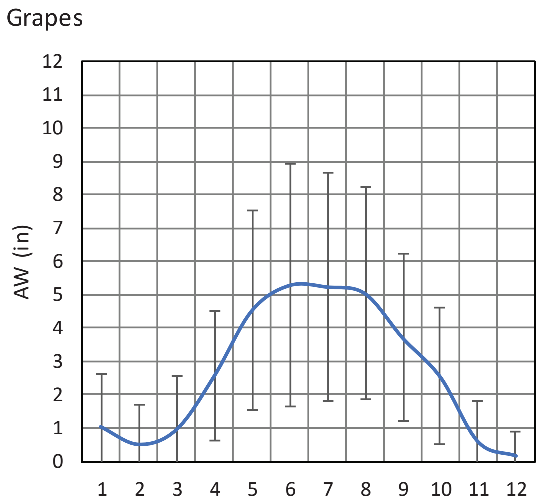
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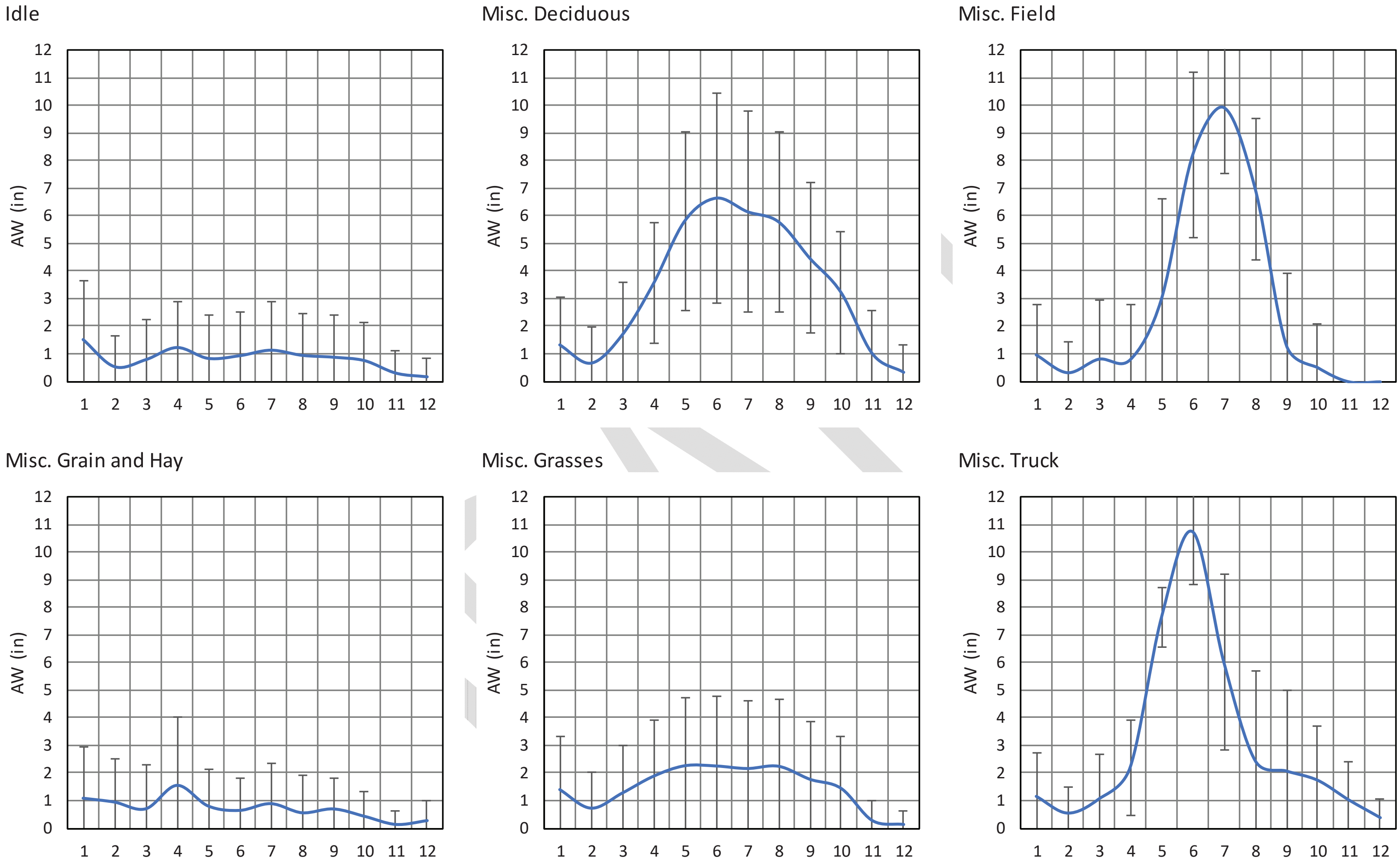
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Misc. Field
Misc. Grain and Hay
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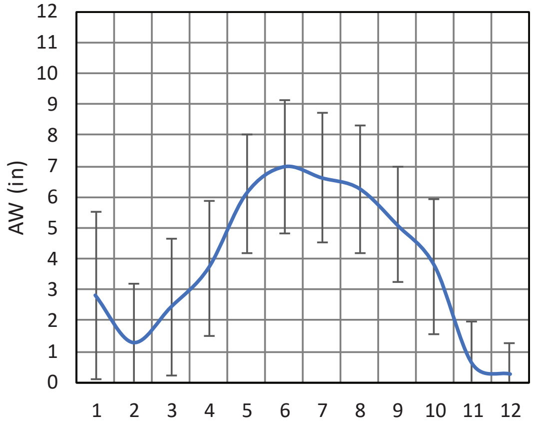

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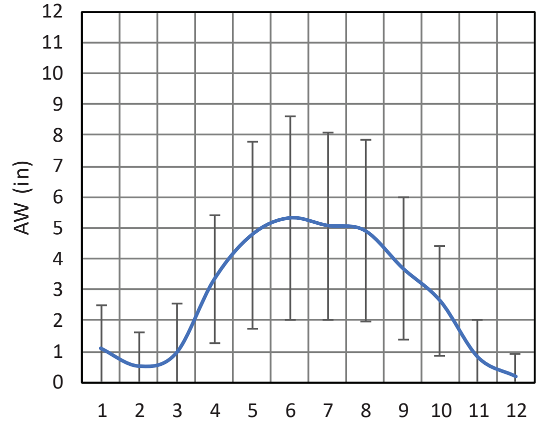

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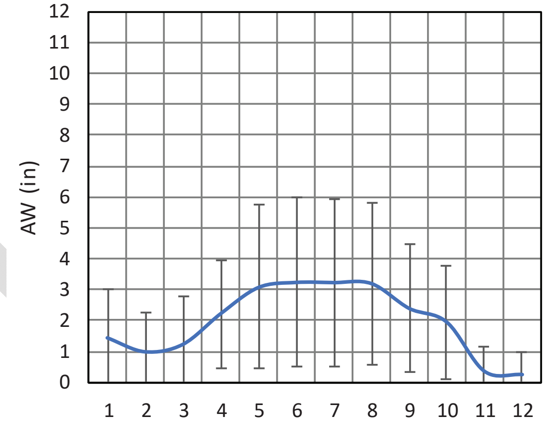

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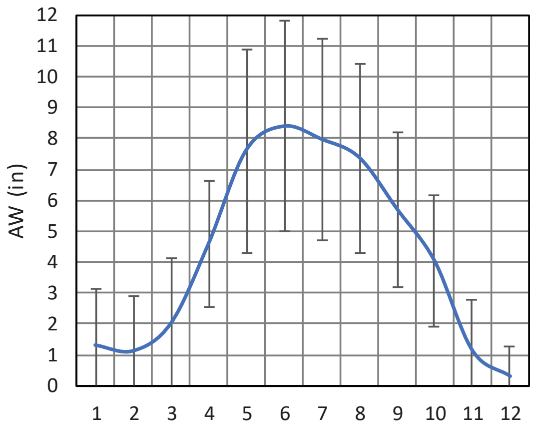

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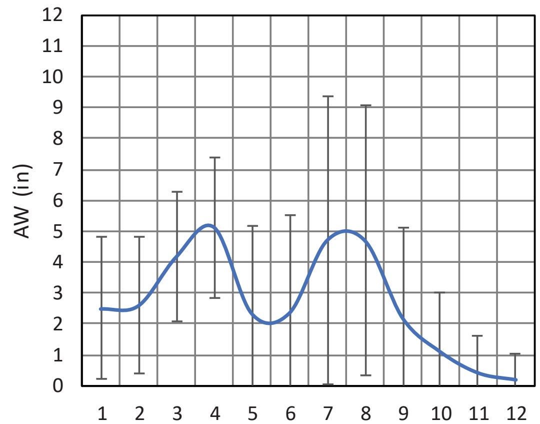

Appendix D

Friant Water Authority

Future Water Supply Study

Friant WATER AUTHORITY

Technical Memorandum

Estimate of Future Friant Division Supplies for use in Groundwater Sustainability Plans, California

CONTENTS

FIGURES

TABLES

ACRONYMS

CFS	cubic feet per second
CVP	Central Valley Project
CWC	California Water Commission
DEW	Drier/Extreme Warming
DWR	California Department of Water Resources
GSA	Groundwater Sustainability Agency
Friant	Friant Water Authority
Friant Contractors	Friant Division long-term contract holders
PEIS/R	Program Environmental Impact Statement/Report
Reclamation	U.S. Department of the Interior, Bureau of Reclamation
RWA	Recovered Water Account
SGMA	Sustainable Groundwater Management Act
SJRRP	San Joaquin River Restoration Program
SJRRS	San Joaquin River Restoration Settlement
SWP	State Water Project
TAF	thousand acre-feet
TM	Technical Memorandum
WMW	Wetter, Moderate Warming
WSIP	Water Supply Investment Program

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BACKGROUND

The Friant Water Authority (Friant) was approached by several Groundwater Sustainability Agencies (GSAs) for information about future water supply availability from the Central Valley Project (CVP) Friant Division. Those GSAs include the following, who were subsequently engaged during the development of analysis to meet their request:

- Mid-Kaweah GSA, represented by Paul Hendrix
- White Wolf Sub-basin GSA, represented by Jeevan Muhar
- Kern Groundwater Authority, represented by Terry Erlewine

This Technical Memorandum (TM) was prepared for use by those GSAs and others, in accordance with the expectations set by the Friant Board of Directors in their 2016 Strategic Plan to provide "accurate and up-to-date data needed to manage water supplies through modeling and data collection."

This TM presents five scenarios that were intended to represent a range of potential water supply conditions for the Friant Division through the end of the century, all of which were assembled from existing studies that were recently conducted using the CalSim-II computer model. These scenarios were assembled from pre-existing model runs and analysis and have been compiled and reviewed by Friant for use or consideration in plans developed by GSAs that receive Friant Contract surface water deliveries. The selected scenarios are summarized below and organized by their identification name in the accompanying "Summary_FutureFriantSupplies_Final" spreadsheet file.

1. **Model Run 2015.c (''2015.c'')** was designed to represent current conditions, where implementation of the San Joaquin River Restoration Settlement (SJRRS) is limited by downstream capacity limitations and the climate and hydrology are assumed to be most similar to historical hydrologic conditions.

2. **''2030.c''** was designed to represent near future climate conditions centered around 2030 and uses California Department of Water Resources (DWR's) central tendency climate projection. This scenario assumes implementation of the SJRRS, as described in the Reclamation's Funding Constrained Framework for Implementing the SJRRS (SJRRP, 2018).

3. **''2070.c''** was designed to represent far-future climate conditions centered around 2070 and uses DWR's central tendency climate projection. This scenario assumes implementation of the SJRRS, as described in the Reclamation's Funding Constrained Framework for Implementing the SJRRS (SJRRP, 2018).

4. **''DEW.c''** was included in this TM for completeness, as it represents an extreme climate condition (being: Drier/Extreme Warming, "DEW") that was produced by DWR for planning studies. The DEW scenario was developed by DWR as a means of bracketing the range of potential future climate conditions by 2070, which are highly uncertain. This scenario was modeled with implementation of the SJRRS, as described in the Reclamation's Funding Constrained Framework for Implementing the SJRRS (SJRRP, 2018).

5. **''WMW.c''** was included in this TM for completeness, as it represents an extreme climate condition (being: Wetter/Moderate Warming, "WMW") that was produced by DWR for planning studies. The WMW scenario was developed by DWR as a means of bracketing the range of potential future climate conditions by 2070, which are highly uncertain. This scenario was modeled with implementation of the SJRRS, as described in the Reclamation's Funding Constrained Framework for Implementing the SJRRS (SJRRP, 2018).

For questions, clarifications, or suggestions that will improve this TM or its application with the implementation of the Sustainable Groundwater Management Act (SGMA) for planning purposes, please contact Jeff Payne, Director of Water Policy at jpayne@friantwater.org

STUDY SETTING

The Friant Division includes storage for waters of the San Joaquin River at Friant Dam (Millerton Lake), as well as conveyance and delivery facilities through the Friant-Kern and Madera canals that deliver water to 32 Friant Division long-term contract holders (Friant Contractors) and other water users. Figure 1 shows the location of the Friant Contractors in the San Joaquin Valley. Friant Contractors all have access to waters of the San Joaquin River through their contracts with Reclamation. However, most Friant Contractors have other supplies that include groundwater and surface water supplies that are local to their geography.

Combined, the facilities of the Friant Division span over 180 miles, crossing seven rivers, and conveying water between 16 GSAs as shown in Figure 2. All the basins connected by the Friant Division and its facilities are considered by DWR to be "critically overdrafted" and therefore are each a "high priority" for the implementation of SGMA. Table 1 lists the Friant Contractors with lands overlapping a GSA and 2014 Friant Contractor irrigated lands. A Friant Contractor may appear in more than one GSA. The 2014 irrigated acreage was obtained from remote sensing from DWR (DWR, 2017). Friant Division M&I contractors were assumed to have no agricultural demand. Kaweah-Delta Water Conservation District agricultural demands were not estimated in this analysis. Any agricultural demand within City of Fresno is represented as part of the Fresno Irrigation District.

Figure 1: Location of Friant Contractors in the San Joaquin Valley

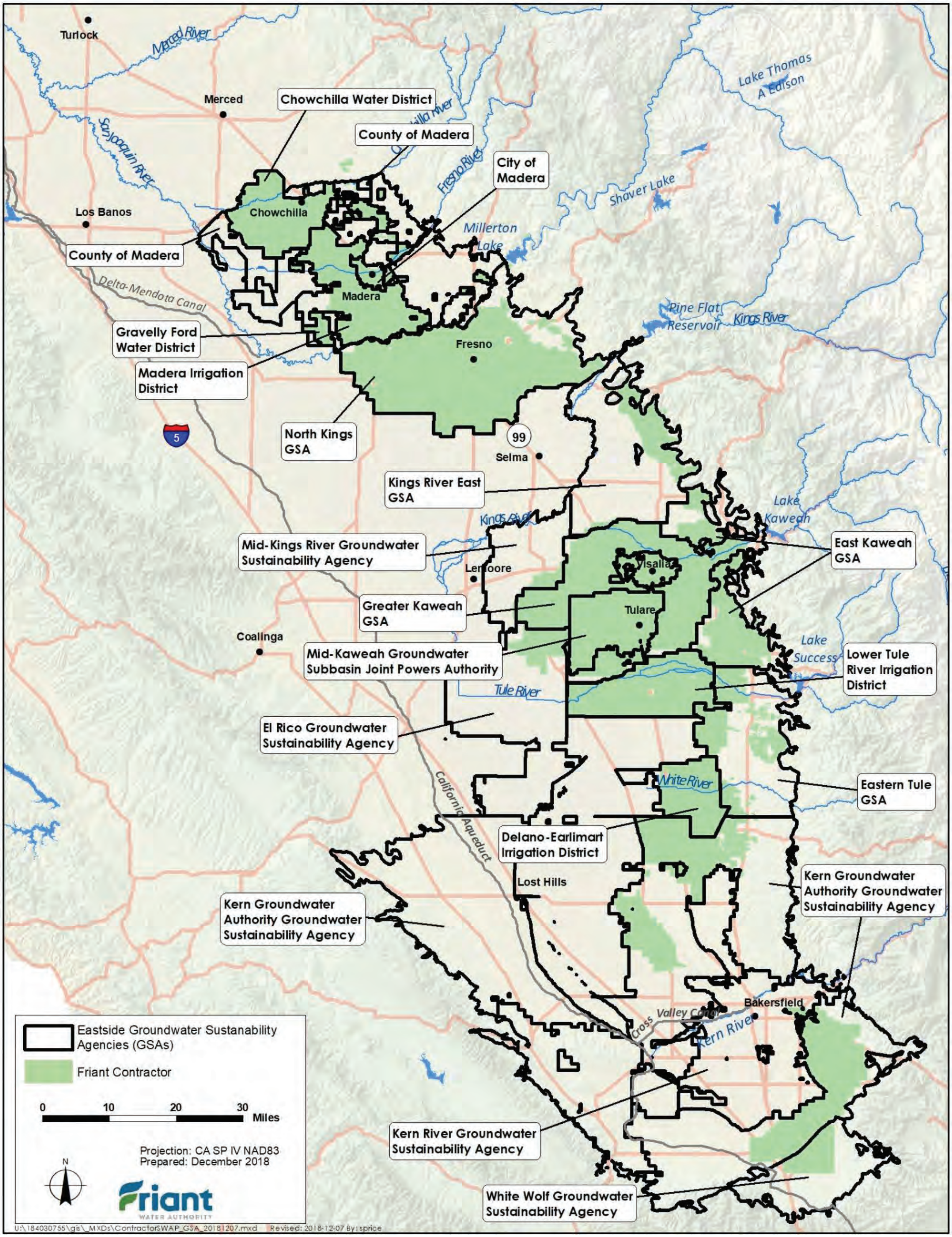

Figure 2: Location of Friant Contractors relative to GSAs

Table 1. Friant Contractors and Estimated Irrigated Acreage relative to GSAs (DWR, 2017)

GROUNDWATER SUSTAINABILITY AGENCY	FRIANT CONTRACTOR[1]	FRIANT CONTRACTOR IRRIGATED LAND[2] (ACRES)
Chowchilla Water District	Chowchilla Water District	67,170
City of Madera	Madera Irrigation District	910
County of Madera	Chowchilla Water District	30
	Madera Irrigation District	90
Gravelly Ford Water District	Gravelly Ford Water District	7,490
Madera Irrigation District	Madera Irrigation District	100,360
North Kings GSA	Fresno Irrigation District[3]	128,330
	Garfield Water District	1,160
	International Water District	540
Kings River East GSA	Hills Valley Irrigation District	2,830
	Orange Cove Irrigation District	24,360
	Tri-Valley Water District	1,040
Mid-Kings River GSA	Kaweah Delta Water Conservation District[2]	NE
East Kaweah GSA	Exeter Irrigation District	10,580
	Ivanhoe Irrigation District	9,630
	Lewis Creek Water District	1,010
	Lindmore Irrigation District	22,760
	Lindsay - Strathmore Irrigation District	10,880
	Lower Tule River Irrigation District	80
	Stone Corral Irrigation District	5,980
Greater Kaweah GSA	Exeter Irrigation District	500
	Ivanhoe Irrigation District	30
	Kaweah Delta Water Conservation District[4]	NE
	Tulare Irrigation District	60
Mid-Kaweah Groundwater Subbasin Joint Powers Authority	Tulare Irrigation District	58,160
El Rico GSA	Kaweah Delta Water Conservation District[4]	NE
Lower Tule River Irrigation District	Lower Tule River Irrigation District	80,480
	Porterville Irrigation District	70
Eastern Tule GSA	Kern - Tulare Water District	8,480
	Porterville Irrigation District	12,470
	Saucelito Irrigation District	18,060
	Tea Pot Dome Water District	3,090
	Terra Bella Irrigation District	9,110
Delano - Earlimart Irrigation District	Delano - Earlimart Irrigation District	49,960
Kern Groundwater Authority GSA	Arvin - Edison Water Storage District	84,280
	Kern-Tulare Water District	14,500
	Shafter - Wasco Irrigation District	30,190
	Southern San Joaquin Municipal Utility District	45,190
Kern River GSA	Arvin - Edison Water Storage District	190
White Wolf GSA	Arvin - Edison Water Storage District	20,830

Key:
GSA = Groundwater Sustainability Agency
NE = Not estimated
Notes:
[1]Only Friant Contractors with agricultural demands shown per GSA, Friant M&I contractors were assumed to have no agricultural demand.
[2] Irrigated lands rounded to nearest 10 acres
[3]Any agricultural lands within City of Fresno is represented as part of the Fresno Irrigation District
[4]Kaweah-Delta Water Conservation District agricultural lands were not estimated

PREVIOUS STUDIES AND REPORTS

The potential range of future Friant Division water supplies from the San Joaquin River have been studied for several recent efforts. This TM relies on computer models, assumptions, and analysis that were initially developed for and reported by the following:

- San Joaquin River Restoration Settlement, and Program (SJRRS and SJRRP)
  - Settlement Agreement (2006)
  - Program Environmental Impact Statement/Report (PEIS/R; Reclamation, 2009)
- Temperance Flat Reservoir studies, including:
  - Federal Feasibility Study (Reclamation, ongoing)
  - Application to California Proposition 1, Water Storage Investment Program (Temperance Flat Reservoir Authority, 2017)

FACTORS AFFECTING FRIANT SUPPLIES THROUGH YEAR 2100

Beyond the natural variability of annual precipitation in the headwaters of the San Joaquin River, several drivers are expected to greatly influence the water supplies of the Friant Division over the coming century. These include:

1. **Changes in the climate and hydrology**: These changes include a warming trend that is expected to reduce winter snow accumulation and hasten spring melt and runoff. Five climate conditions are considered in this report.
2. **Implementation of the SJRRS Restoration Goal:** The SJRRS Restoration Goal is currently limited in its implementation but is expected to be fully implemented by 2030, with the completion of river conveyance enhancements below Friant Dam. When completed, the impact of the SJRRS on Friant Contractor supplies will reach the extent anticipated in the SJRRS.
3. **Implementation of the SJRRS Water Management Goal**: The SJRRS Water Management Goal provides for several mechanisms to reduce or avoid water supply impacts on Friant Contractors. The water supply benefits of two SJRRS provisions are quantified in this analysis, being those described in Paragraphs 16(a) (i.e., recapture and recirculation) and 16(b) (i.e., water sold at $10 per acre foot during wet conditions).
   - Paragraph 16(a) is restricted at this time, being limited to the recapture of flows that can be released from Friant Dam. As implementation of the Restoration Goal progresses, so will recapture and recirculation.
   - Paragraph 16(b) is currently underutilized. At the time of the Settlement, a fixed $10 per acre foot price for wet year supplies was expected to stimulate investments in groundwater infiltration facilities. With subsequent water supply challenges imposed by SGMA on the Eastern San Joaquin Valley, the regional appetite for groundwater infiltration has grown dramatically. At this time, Friant Contractors anticipate considerable interest and ability to divert and infiltrate flows that may have spilled from Friant Dam under historical conditions. The upper end of implementation of 16(b) is expected to occur before 2030.

The technical representations of these conditions were taken from previous studies and reports, in the manner described below.

INVENTORY OF MODEL SIMULATIONS PERFORMED

This report presents simulated operations that account for five climate conditions and the eventual full implementation of SJRRS Restoration and Water Management goals. Table 2 identifies 15 individual modeling runs compiled for this TM, along with the major assumptions for each.

The reader should note that each of the five climate conditions contain three model runs, denoted with a suffix of “a”, “b”, and “c”. To calculate the Restoration Goal for each of these climate conditions, model runs “a” and “b” were conducted to create comparisons that are necessary for explaining effect of SJRRS implementation. Calculation of the Water Management Goal requires a comparison of model runs “a” to model runs “b” and “c” to represent the expected recapture and recirculation for each level of SJRRS implementation. Model runs denoted with “c” are provided for comparative analyses that calculate recapture and recirculation, as well as additional groundwater recharge deliveries during wet conditions.

All simulations were performed using CalSim-II, the State of California’s premiere water supply planning and analysis tool. The primary use of the CalSim model is for estimating water supply exports from the Sacramento-San Joaquin Delta for delivery to CVP and State Water Project (SWP) water users. CalSim-II simulates statewide water supply operations using a continuous 82-year hydrology, traditionally based on the period of historic records beginning October 1921 and running through September 2003.

Table 2. Fifteen model runs simulated for this Report

MODEL RUN	CLIMATE CONDITION	SJRRS SETTLEMENT		BENCHMARK CALSIM-II MODEL USED
		RESTORATION GOAL	WATER MANAGEMENT GOAL	
2015.a	2015 Conditions (historical modified for recent changes)	Pre-SJRRS	Pre-SJRRS	DWR Delivery Capability Report, 2015 climate
2015.b		Limited SJRRS	Limited Access	
2015.c			Full Access	
2030.a	Near-Future (DWR 2030 Central Tendency)	Pre-SJRRS	Pre-SJRRS	Water Commission, 2030 climate
2030.b		Full SJRRS	Limited Access	
2030.c			Full Access	
2070.a	Late-Future (DWR 2070 Central Tendency)	Pre-SJRRS	Pre-SJRRS	Water Commission, 2070 climate
2070.b		Full SJRRS	Limited Access	
2070.c			Full Access	
DEW.a	Late-Future, 2070 Drier/Extreme Warming	Pre-SJRRS	Pre-SJRRS	Water Commission, 2070 DEW climate
DEW.b		Full SJRRS	Limited Access	
DEW.c			Full Access	
WMW.a	Late-Future, 2070 Wetter/Moderate Warming	Pre-SJRRS	Pre-SJRRS	Water Commission, 2070 WMW climate
WMW.b		Full SJRRS	Limited Access	
WMW.c			Full Access	

Key:
DEW = Drier/Extreme Warming
DWR = California Department of Water Resources
SJRRS = San Joaquin River Restoration Settlement
WMW = Wetter/Moderate Warming

CLIMATE CHANGES EVALUATED

The California Water Commission Water Supply Investment Program (CWC WSIP) developed baseline CalSim-II simulations using several levels of potential climate change to modify input hydrology of the entire system, including the San Joaquin River. These scenarios were developed using the 20 combinations of climate change models and representative concentration pathways recommended by DWR Climate Change Technical Advisory Group as being most appropriate for California water resource planning and analysis. Further details on the specific climate change included in each of the simulations is included in the CWC WSIP Technical Reference (CWC, 2016). The resulting climate change conditions used in this analysis include:

1. **2015 Conditions:** This represents a historical hydrology modified to match climate and sea level conditions for a thirty-year period centered at 1995 (reference climate period 1981 – 2010).
2. **Near-Future 2030 Central Tendency:** This represents a 2030 future hydrology with projected climate and sea level conditions for a thirty-year period centered at 2030 (reference climate period 2016 – 2045).
3. **Late-Future 2070 Central Tendency:** This hydrology represents a 2070 future condition with projected climate and sea level conditions for a thirty-year period centered at 2070 (reference climate period 2056 – 2085).
4. **Late-Future 2070 Drier/Extreme Warming Conditions (DEW):** This hydrology represents a 2070 DEW future condition with projected climate and sea level conditions for a thirty-year period centered at 2070 (reference climate period 2056 – 2085).
5. **Late-Future 2070 Wetter/Moderate Warming Conditions (WMW):** This hydrology represents a 2070 WMW future condition with projected climate and sea level conditions for a thirty-year period centered at 2070 (reference climate period 2056 – 2085).

The seasonal timing of inflow to Millerton Lake is projected to change in response to climate change. Historical inflow to Millerton Lake generally peak during the month of June due to the delayed runoff from a large snow pack. The climate change scenarios for 2030 and 2070 are based on warmer conditions that will produce precipitation events with more rainfall and less snowpack than historically occurred, resulting in peak runoff earlier in the year. Peak runoff into Millerton Lake is projected to occur in May for the 2030 scenario, and in April for the 2070 scenario. Figure 3 shows the general trend of Millerton Lake inflow change due to climate change.

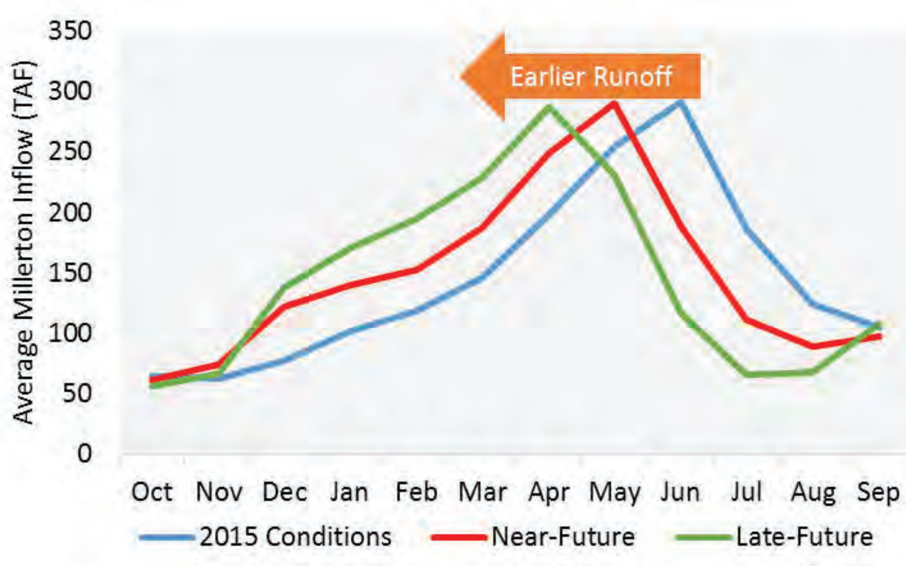

Figure 3. Millerton Lake Inflow Change Due to Climate Change

When analyzing CalSim-II outputs, the results are often summarized by water year type, which classifies groups of years with similar hydrologic characteristics. A water year starts October 1 of the preceding calendar year and ends September 30 of the current year. For example, water year 1922 starts October 1, 1921 and ends September 30, 1922. In this analysis the SJRRS water year type classification was used to summarize the estimated changes in Friant Division supplies. The SJRRS water year types are classified as follows: Wet, Normal-Wet, Normal-Dry, Dry, Critical High and Critical Low. For the CWC WSIP the SJRRP water year type classification remained unchanged between the five climate change conditions. In this TM, the SJRRS water year types were redefined based on Unimpaired Millerton Inflow (consistent with the SJRRS) from the CalSim II SV input files. This was done to update the SJRRS hydrographs to better reflect the anticipated climate change conditions. Table 3 summarizes the SJRRS water year types by climate condition. For reporting purposes, the designation of Critical water year type includes both Critical High and Critical Low SJRRS water year types.

Table 3. SJRRS Water Year Types per Climate Condition by Number of Years and Percentage of Total Years

SJRRS WATER YEAR TYPE	2015 CONDITIONS	NEAR-FUTURE, 2030	LATE-FUTURE, 2070	LATE-FUTURE, 2070 DEW	LATE-FUTURE, 2070 WMW
Wet	16 (20%)	18 (22%)	19 (23%)	21 (26%)	35 (43%)
Normal-Wet	25 (30%)	21 (26%)	20 (24%)	12 (15%)	21 (26%)
Normal-Dry	24 (29%)	25 (30%)	20 (24%)	11 (13%)	15 (18%)
Dry	12 (15%)	11 (13%)	16 (20%)	20 (24%)	9 (11%)
Critical[1]	5 (6%)	7 (9%)	7 (9%)	18 (22%)	2 (2%)
Long-Term[2]	82	82	82	82	82

Key:
DEW = Drier/Extreme Warming
DWR = California Department of Water Resources
SJRRS = San Joaquin River Restoration Settlement
WMW = Wetter/Moderate Warming
Note:
[1]For reporting purposes, the designation of Critical water year type includes both Critical High and Critical Low SJRRP water year types
[2]Long-Term average reflects the 82-year CalSim II simulation period (October 1921 thru September 2003)

SJRRS IMPLEMENTATION

Implementation of the SJRRS includes actions to meet both the Restoration and Water Management Goals. Both goals have a direct effect on Friant Division water supplies, and both are expected to change in implementation over time.

Presently, both goals are implemented in a limited manner because of capacity restrictions in the San Joaquin River below Friant Dam (which constrict releases for the Restoration Goal) and the need for further buildout of groundwater infiltration facilities to take full advantage wet year supplies, when available (for the Water Management Goals). However, Reclamation has plans for implementation that will allow for virtually all SJRRS releases to be made by 2025 (SJRRP, 2018). Further, water users throughout the Friant Division are pursuing a broad array of facilities that will enhance the ability to implement Paragraph 16(b) water supplies, when available.

To represent the current and anticipated future implementation of the SJRRS, the following variations were constructed.

Restoration Goal Implementation

Three levels of Restoration Goal implementation are considered, as follows:

1. **Pre-SJRRS:** This simulation sets the required minimum release from Millerton to the San Joaquin River to the values in the without project baseline conditions (SJRRP, 2009).
2. **Limited SJRRS:** This condition approximates current conditions, which are expected to remain limited until 2025. Simulations of this condition are based on the current channel capacity of 1,300 cubic feet per second (CFS) in Reach 2.
3. **Full SJRRS:** This condition represents the SJRRS hydrograph with capacities identified in the SJRRS Funding Constrained Framework. Under this plan, channel capacity will not exceed the identified 2025 channel capacity of 2,500 CFS in Reach 2. This hydrograph was used in the 2030, 2070, 2070 DEW, and 2070 WMW level of climate change simulations. Flow releases (Flow Schedules) for this condition were approximated with a spreadsheet developed by the SJRRP for the Framework Document (SJRRP, 2018). Table 3 shows the Full SJRRS Implementation hydrograph compared to the Funding Constrained Framework SJRRS hydrograph for the four climate change scenarios. The differences between the four climate change scenarios is due to the different number of years per SJRRS water year type, as shown in Table 3. Table 4 is not the impact of Friant Deliveries, but

represents the SJRRS releases under the Funding Constrained Framework under different climate change conditions.

Table 4 Long-Term Average SJRRS Releases under Full SJRRS Implementation and the Funding Constrained Framework Four Climate Conditions

SJRRS WATER YEAR TYPE	FULL SJRRP IMPLEMENTATION (TAF/YEAR)	FUNDING CONSTRAINED FRAMEWORK			
		NEAR-FUTURE, 2030 (TAF/YEAR)	LATE-FUTURE, 2070 (TAF/YEAR)	LATE-FUTURE, 2070 DEW (TAF/YEAR)	LATE-FUTURE, 2070 WMW (TAF/YEAR)
Wet	674	633	633	628	633
Normal-Wet	474	434	433	428	432
Normal-Dry	365	365	364	363	357
Dry	302	297	296	296	300
Critical High	188	188	188	188	188
Critical Low	117	117	117	117	117
Long-Term[1]	438	417	414	376	483[2]

Key:
DEW = Drier/Extreme Warming
DWR = California Department of Water Resources
SJRRS = San Joaquin River Restoration Settlement
TAF/year = thousand acre-feet per year
WMW = Wetter/Moderate Warming
Note:
[1]Long-Term average reflects the 82-year CalSim II simulation period (October 1921 thru September 2003)
[2] The Long-Term Average SJRRS release for 2070 WMW is higher than the Full SJRRP Implementation because, as Table 3 shows, the number of Wet water years increased from 16 years (20 percent) in the 2015 Condition to 35 years (43 percent) in the 2070 WMW Condition.

The quantification of SJRRS implementation impact is performed by comparing the with and without SJRRS water supplies diverted from Friant Dam.

In the course of compiling these model runs, it was discovered that previous studies had not correctly implemented SJRRS flows under climate change. SJRRS outflow requirements at Friant Dam are determined by the total annual hydrology, which can change enough under climate conditions to alter a given year's release requirements. All scenarios and results in this report have been adjusted to correctly set SJRRS flow requirements, including under climate change.

Water Management Goal Implementation

Three levels of Water Management Goal implementation are considered, as follows:

1. **Pre-SJRRS**: This represents the without SJRRS condition.
2. **Limited Access:** This represents 16(a) supplies available to Friant Contractors as part of the SJRRS that provides for recapture and recirculation of flows released from Friant Dam for the purposes of meeting the Restoration Goal.
3. **Full Access:** This represents supplies anticipated with future ability to divert 16(a) and 16(b) supplies to Friant Contractors. 16(b) stipulates a Recovered Water Account (RWA) that represents water not required to meet SJRRS or other requirements be made available to Friant Contractors who experience a reduction in water deliveries from the implementation of the SJRRS. 16(b) water is made available to those Friant Contractors at $10 per acre-foot during wet condition.

The SJRRS and implementing documents identify several locations for recapture, however modeling conducted for the SJRRP PEIS/R only provided for estimated recapture as the incremental improvement in total Delta Exports that result from the SJRRS. The quantification of water supplies recaptured in the Delta in conformance with 16(a) is performed by comparing simulated Delta exports with and without the implementation of the SJRRS. The net improvement in export is identified as recapturable supply.

The CalSim-II model simulates 16(b) as an additional demand after Class 1 and Class 2 delivery allocations are met and before 215 (“Other”) deliveries are made. The CalSim-II simulated 16(b) delivery via the Friant Kern and Madera canals is based on anticipated development of groundwater infiltration facilities throughout the Friant Division in response to SJRRS implementation. These facilities are not identified and are represented as surrogate water demands in the CalSim-II model. As a result, use of 16(b) water supply availability must be viewed as total opportunity that has not been attributed among individual water users at this time.

The quantification of water supplies diverted from Friant Dam for 16(b) is performed by comparing the with and without SJRRS simulations that allow for added diversions. This required the additional simulation for each scenario, to provide for comparison. The “#.b” scenarios are included in results for reference.

GUIDANCE ON USE OF RESULTS

This TM provides descriptions of potential future water supplies for the Friant Division for five climate change conditions under different levels of SJRRS implementation.

The key outputs of this report are provided in tables by monthly and total volumes by contract year (which begins March 1 of the current calendar year and ends February 28 of the following year), except when noted, and summarized by SJRRS water year type classification and long-term average for each of the following:

- Millerton Lake Inflow
- Total Friant Division deliveries of:
  - Class 1
  - Class 2/Other
  - Paragraph 16(b) water (aka $10 water, or RWA water)
- Friant Dam Spill
- Potential Friant Division Delta Recapture (by year, only), for:
  - Class 1 Delta Recapture
  - Class 2 Delta Recapture
  - Total Delta Recapture

These data are provided in a spreadsheet, entitled: “Summary_FutureFriantSupplies_Final.xlsm”

Table 5 provides a portion of a tabulated output available in the spreadsheet. Tabulated information includes the average monthly and total volumes by SJRRS water year type classification and long-term average. For reporting purposes, the designation of Critical water year type includes both Critical-High and Critical-Low SJRRS water year types. Tabulated information also includes the monthly and total volumes per contract year (Mar-Feb). In the spreadsheet, the tables include the monthly and total volumes per contract year for the entire 82-year CalSim-II simulated period (October 1921 to September 2003).

Table 5. Example Output Table for Class 1 Deliveries

		Class 1 Delivery												
		Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Total
		TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF
	Wet	16.1	28.1	51.6	123.4	189.9	181.5	106.3	48.5	12.2	6.4	6.3	29.8	800.0
	Normal-Wet	26.2	46.3	75.0	149.8	189.3	165.2	84.0	28.9	4.7	4.5	4.5	21.6	800.0
	Normal-Dry	32.9	56.7	92.1	158.6	184.4	152.5	67.9	20.9	3.6	3.6	3.4	19.7	796.3
	Dry	29.7	48.8	81.7	143.9	167.1	130.5	55.8	20.9	4.7	2.3	2.3	17.3	705.1
	Critical	16.7	19.9	36.4	86.6	111.5	65.2	31.0	19.9	6.6	0.0	0.0	9.9	403.8
	Long Term	26.1	44.6	74.1	142.4	179.9	153.4	76.2	28.7	6.0	4.0	3.9	21.3	760.4
2015														
SJRRP	Month	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Total
WY Type	Year	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF
Normal-Wet	1921								0.0	0.0	0.0	0.0	0.0	0.0
Normal-Wet	1922	22.3	37.4	59.8	138.2	189.1	174.0	97.8	36.4	5.5	5.3	5.3	28.9	800.0
Normal-Wet	1923	25.6	42.7	64.4	146.7	187.1	170.7	95.2	33.8	4.9	4.6	4.6	19.7	800.0
Critical	1924	17.9	21.4	39.2	93.2	120.0	72.2	31.6	21.4	7.1	0.0	0.0	10.7	434.7
Normal-Dry	1925	32.8	56.4	89.7	158.4	188.2	152.0	70.7	21.0	3.9	3.9	3.3	19.7	800.0
Normal-Dry	1926	33.2	57.1	98.8	160.4	183.9	151.2	65.6	19.9	3.3	3.3	3.3	19.9	800.0
Normal-Wet	1927	25.7	47.4	80.6	151.2	191.4	163.5	79.8	26.8	4.8	4.6	4.6	19.8	800.0
Normal-Dry	1928	31.6	57.8	92.0	162.4	186.2	153.1	66.4	20.2	3.4	3.4	3.4	20.2	800.0
Dry	1929	26.8	48.2	80.3	132.2	148.5	124.8	53.0	16.1	2.7	2.7	2.7	16.1	654.0
Dry	1930	27.1	48.8	81.1	133.6	150.1	126.2	53.6	16.3	2.7	2.7	2.7	16.3	661.1
Critical	1931	12.9	15.5	28.3	67.4	86.9	52.3	22.9	15.5	5.2	0.0	0.0	7.7	314.5
Normal-Wet	1932	25.6	42.7	64.4	146.7	187.1	170.7	95.2	33.8	4.9	4.6	4.6	19.7	800.0
Normal-Dry	1933	32.8	56.4	89.7	158.4	188.2	152.0	70.7	21.0	3.9	3.9	3.3	19.7	800.0
Dry	1934	24.0	28.7	52.2	124.2	159.9	96.2	42.2	28.5	9.5	0.0	0.0	14.2	579.6
Normal-Wet	1935	28.2	47.3	80.4	150.7	190.7	162.9	79.5	26.7	4.7	4.6	4.6	19.7	800.0
Normal-Wet	1936	28.2	47.2	80.3	150.7	190.7	162.9	79.5	26.7	5.0	4.6	4.6	19.7	800.0
Normal-Wet	1937	28.7	48.0	81.6	159.5	191.1	160.7	74.5	24.0	4.0	4.0	4.0	20.0	800.0
Wet	1938	17.2	28.4	52.1	115.8	193.9	182.0	104.2	49.9	13.0	6.6	6.6	30.4	800.0

CLASS 1 AND CLASS 2 SUPPLY PROJECTIONS

While CalSim-II does produce estimated deliveries of Class 1 water supplies with some confidence, the simulated "Class 2" and "Other" model outputs have always been problematic. This is because CalSim-II approximations of wet year operations were calibrated to mimic total releases – not actual deliveries of Class 2 or (separately) Other supplies. As a result, the modeling outputs provided with this TM do not distinguish between Class 2 and Other modeling categories. These two data outputs have been grouped to describe Class 2 behavior in aggregate. Through previous modeling conducted for SJRRS implementation, Friant Division managers have found the aggregation of Class 2 and Other model outputs performs closer to actual experience with Class 2 deliveries.

CalSim-II does not determine delivery by Friant Contractor, it simulates the annual allocations and then distributes them over the year on a monthly pattern. CalSim- II does approximate the division of flows between the Madera and Friant-Kern canals, but the actual final deliveries simulated in CalSim-II are not to specific Friant contractors or physical locations. Standard practice in interpreting deliveries to Friant Contractors has been to split Class 1 and Class 2/Other deliveries among individual contractors by contract quantity. For example, a district with an 80 thousand acre-feet (TAF) Friant Division Class 1 contract (i.e., 10 percent of total Class 1) and 70 TAF of Class 2 (i.e., five percent of total Class 2), would have access to 10 percent of the Class 1 supplies and five percent of the Class 2/Other supplies in a given year. Table 6 lists the Friant Contractors corresponding Class 1 and Class 2 contract amounts by volume and percentage. These have been incorporated into the spreadsheet to facilitate use.

NOTE: The reader may note that Section 215 water supplies are not discussed. While the factors that produce "215 water" are presumed to exist in the future, the frequency and magnitude of their availability is expected to be greatly diminished by implementation of the SJRRS, which has made available water supplies to Friant Contractors through Paragraph 16(b) of the Settlement. The assumed low availability of 215 water comports with recent experience, even with partial SJRRS implementation. As a result, this analysis makes no attempt to quantify future 215 water supply availability, which may be presumed to be nearly zero for planning purposes. "16(b)" or "RWA" or "$10" water (all the same) is discussed in a later section.

Table 6. Friant Contractor Summary

FRIANT CONTRACTOR	CLASS 1 ACRE-FEET	CLASS 2 ACRE-FEET	CLASS 1 PERCENTAGE	CLASS 2/OTHER PERCENTAGE
Arvin-Edison Water Storage District	40,000	311,675	5.0%	22.2%
Chowchilla Water District	55,000	160,000	6.9%	11.4%
City of Fresno	60,000	0	7.5%	0.0%
City of Lindsay	2,500	0	0.3%	0.0%
City of Orange Cove	1,400	0	0.2%	0.0%
Delano-Earlimart Irrigation District	108,800	74,500	13.6%	5.3%
Exeter Irrigation District	11,100	19,000	1.4%	1.4%
Fresno County Water Works District No. 18	150	0	0.0%	0.0%
Fresno Irrigation District	0	75,000	0.0%	5.4%
Garfield Water District	3,500	0	0.4%	0.0%
Gravelly Ford Water District	0	14,000	0.0%	1.0%
Hills Valley Irrigation District	1,250	0	0.2%	0.0%
International Water District	1,200	0	0.2%	0.0%
Ivanhoe Irrigation District	6,500	500	0.8%	0.0%
Kaweah Delta Water Conservation District	1,200	7,400	0.2%	0.5%
Kern-Tulare Water District	0	5,000	0.0%	0.4%
Lewis Creek Water District	1,200	0	0.2%	0.0%
Lindmore Irrigation District	33,000	22,000	4.1%	1.6%
Lindsay-Strathmore Irrigation District	27,500	0	3.4%	0.0%
Lower Tule River Irrigation District	61,200	238,000	7.7%	17.0%
Madera County	200	0	0.0%	0.0%
Madera Irrigation District	85,000	186,000	10.6%	13.3%
Orange Cove Irrigation District	39,200	0	4.9%	0.0%
Porterville Irrigation District	15,000	30,000	1.9%	2.1%
Saucelito Irrigation District	21,500	32,800	2.7%	2.3%
Shafter-Wasco Irrigation District	50,000	39,600	6.3%	2.8%
Southern San Joaquin Municipal Utility District	97,000	45,000	12.1%	3.2%
Stone Corral Irrigation District	10,000	0	1.3%	0.0%
Tea Pot Dome Water District	7,200	0	0.9%	0.0%
Terra Bella Irrigation District	29,000	0	3.6%	0.0%
Tri-Valley Water District	400	0	0.1%	0.0%
Tulare Irrigation District	30,000	141,000	3.8%	10.1%
Total	800,000	1,401,475	100%	100%

SJRRS WATER SUPPLY PROJECTIONS

The SJRRS Water Management Goal creates two new categories of supplies for Friant Contractors that are described in paragraphs 16(a) and (b) of the Settlement.

Delta recapture (Paragraph 16(a) is quantified in this analysis by taking the difference in Delta Exports between the with and without SJRRS implementation and crediting the net volume of improvement to the SJRRS recapture program. This does not account for the ability to recapture water supplies on the lower San Joaquin River. Delta recapture is reported as an annual quantity to overcome limitations in the simulation of monthly operations, which are not appropriate for use as monthly recapture volumes at this time. This supply represents an upper bound for potential recapture in the Delta. Discussions between Reclamation, DWR, and

Friant are ongoing to establish the availability of this water supply through Delta pumping. At the time of this report, no processes are in place to recapture in the Delta.

In recent practice, recaptured supplies have been split between Class 1 and 2 contractors, using recapture to back-fill for water contract allocations. For this analysis, Delta recapture has been split between Class 1 and Class 2 contractors, based on recent practices by Reclamation. At the request of Friant Contractors, recapture is provided first to Class 1 water users up to the point that the combination of Friant Division deliveries and recapture equal a 100 percent Class 1 allocation. Any volumes in excess are allocated to Class 2 contractors, proportional to their Class 2 contract volumes. The spreadsheet includes summary tables of total Delta recapture, and a breakout of Class 1 and Class 2 recapture by Friant Contractor proportional to their contract amounts as shown in Table 5. Users of this data are encouraged to apply contract quantities (Table 6) to attribute allocations among Friant Contractors.

The second SJRRS water category, Paragraph 16(b) supplies, are quantified in the CalSim II model by assuming a demand for this potential supply and meeting this demand, limited by availability of flood water and channel capacity for delivery. Any remaining flood water is then assumed available for 215/other delivery in the simulation. Specific patterns for the use of this supply do not yet exist and, thus, CalSim-II makes no assertion about anything except for the expectation and potential for these supplies to be delivered.

For consistency with previous efforts to interpret the CalSim II model and its output, 16(b) supplies have been divided among Friant Contractors in proportion to their share of impact from the SJRRS that accumulates to their water supplies. The impact from the SJRRS is estimated by comparison of the total C1 and C2/Other delivery in the Pre-SJRRS and "limited" CalSim II simulations. The allocation to the individual contractors was done based on percentage of impact from the Proposed Implementation Agreement of the Friant Settlement (SJRRP, 2009) and from the percentage impact computed from the new CalSim II simulation performed for this analysis. For example, a Friant Contractor with five percent of reduction in total Class 1 and Class 2/Other is and would have access to five percent of the 16(b) supplies. Table 7 and 8 shows impact of SJRRS under the five climate change conditions and computed impacts from the Mediator's Report for the Friant Contractors.

Table 7. Summary of Friant Contractor Impacts per Climate Change and Mediator's Report (Volume)

FRIANT CONTRACTOR	LONG-TERM AVERAGE CLASS 1 AND CLASS 2/OTHER IMPACTS					
	MEDIATOR'S REPORT	2015 CONDITION	NEAR-FUTURE, 2030	LATE-FUTURE, 2070	LATE-FUTURE, 2070 DEW	LATE-FUTURE, 2070 WMW
	TAF	TAF	TAF	TAF	TAF	TAF
Arvin-Edison Water Storage District	30.342	28.13	28.88	26.54	18.69	28.41
Chowchilla Water District	17.661	15.76	16.58	15.75	12.59	16.04
City of Fresno	3.629	2.30	3.06	3.71	5.22	2.52
City of Lindsay	0.151	0.10	0.13	0.15	0.22	0.11
City of Orange Cove	0.085	0.05	0.07	0.09	0.12	0.06
Delano-Earlimart Irrigation District	13.255	10.53	11.96	12.47	13.10	10.97
Exeter Irrigation District	2.398	2.05	2.20	2.15	1.89	2.10
Fresno County Water Works District No. 18	0.009	0.01	0.01	0.01	0.01	0.01
Fresno Irrigation District	6.719	6.40	6.46	5.79	3.66	6.43
Garfield Water District	0.212	0.13	0.18	0.22	0.30	0.15
Gravelly Ford Water District	1.254	1.19	1.21	1.08	0.68	1.20
Hills Valley Irrigation District[1]	0.000	0.00	0.00	0.00	0.00	0.00
International Water District	0.073	0.05	0.06	0.07	0.10	0.05
Ivanhoe Irrigation District	1.173	0.29	0.37	0.44	0.59	0.32
Kaweah Delta Water Conservation District[1]	0.000	0.000	0.000	0.000	0.000	0.000
Kern-Tulare Water District[1]	0.000	0.000	0.000	0.000	0.000	0.000
Lewis Creek Water District	0.088	0.05	0.06	0.07	0.10	0.05
Lindmore Irrigation District	3.967	3.14	3.58	3.74	3.94	3.28
Lindsay-Strathmore Irrigation District	1.663	1.06	1.40	1.70	2.39	1.16
Lower Tule River Irrigation District	25.024	22.66	23.62	22.16	16.94	22.99
Madera County	0.012	0.01	0.01	0.01	0.02	0.01
Madera Irrigation District	21.805	19.13	20.35	19.61	16.47	19.53
Orange Cove Irrigation District	2.371	1.50	2.00	2.42	3.41	1.65
Porterville Irrigation District	3.655	3.14	3.35	3.24	2.77	3.20
Saucelito Irrigation District	4.221	3.62	3.92	3.86	3.47	3.72
Shafter-Wasco Irrigation District	6.572	5.30	5.96	6.15	6.28	5.50
Southern San Joaquin Municipal Utility District	10.346	7.56	8.82	9.46	10.63	7.94
Stone Corral Irrigation District	0.605	0.38	0.51	0.62	0.87	0.42
Tea Pot Dome Water District	0.454	0.28	0.37	0.44	0.63	0.30
Terra Bella Irrigation District	1.754	1.11	1.48	1.79	2.52	1.22
Tri-Valley Water District[1]	0.000	0.000	0.000	0.000	0.000	0.000
Tulare Irrigation District	14.447	13.18	13.67	12.74	9.49	13.36
Total	**173.945**	**149.13**	**160.26**	**156.49**	**137.14**	**152.67**

Key:
DEW = Drier/Extreme Warming
TAF = thousand acre-feet
WMW = Wetter/Moderate Warming
Note:
[1] Friant Contractor calculated impact as zero because they do not receive a proportion of 16(b) supplies.

Table 8. Summary of Friant Contractor Impacts per Climate Change and Mediator's Report (Percentage)

FRIANT CONTRACTOR	LONG-TERM AVERAGE CLASS 1 AND CLASS 2/OTHER IMPACTS					
	MEDIATOR'S REPORT	2015 CONDITION	NEAR-FUTURE, 2030	LATE-FUTURE, 2070	LATE-FUTURE, 2070 DEW	LATE-FUTURE, 2070 WMW
	%	%	%	%	%	%
Arvin-Edison Water Storage District	17.444%	18.864%	18.020%	16.958%	13.630%	18.611%
Chowchilla Water District	10.153%	10.571%	10.347%	10.066%	9.183%	10.504%
City of Fresno	2.086%	1.544%	1.909%	2.368%	3.806%	1.653%
City of Lindsay	0.087%	0.064%	0.080%	0.099%	0.159%	0.069%
City of Orange Cove	0.049%	0.036%	0.045%	0.055%	0.089%	0.039%
Delano-Earlimart Irrigation District	7.620%	7.063%	7.464%	7.970%	9.553%	7.183%
Exeter Irrigation District	1.378%	1.373%	1.374%	1.376%	1.380%	1.373%
Fresno County Water Works District No. 18	0.005%	0.004%	0.005%	0.006%	0.010%	0.004%
Fresno Irrigation District	3.863%	4.292%	4.030%	3.701%	2.669%	4.213%
Garfield Water District	0.122%	0.090%	0.111%	0.138%	0.222%	0.096%
Gravelly Ford Water District	0.721%	0.801%	0.752%	0.691%	0.498%	0.786%
Hills Valley Irrigation District[1]	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
International Water District	0.042%	0.031%	0.038%	0.047%	0.076%	0.033%
Ivanhoe Irrigation District	0.675%	0.196%	0.234%	0.281%	0.430%	0.207%
Kaweah Delta Water Conservation District[1]	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Kern-Tulare Water District[1]	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Lewis Creek Water District	0.050%	0.031%	0.038%	0.047%	0.076%	0.033%
Lindmore Irrigation District	2.281%	2.108%	2.232%	2.388%	2.876%	2.145%
Lindsay-Strathmore Irrigation District	0.956%	0.708%	0.875%	1.085%	1.744%	0.758%
Lower Tule River Irrigation District	14.386%	15.194%	14.736%	14.159%	12.352%	15.057%
Madera County	0.007%	0.005%	0.006%	0.008%	0.013%	0.006%
Madera Irrigation District	12.536%	12.831%	12.699%	12.532%	12.011%	12.791%
Orange Cove Irrigation District	1.363%	1.009%	1.247%	1.547%	2.486%	1.080%
Porterville Irrigation District	2.101%	2.103%	2.089%	2.072%	2.019%	2.099%
Saucelito Irrigation District	2.427%	2.430%	2.446%	2.467%	2.531%	2.435%
Shafter-Wasco Irrigation District	3.778%	3.553%	3.719%	3.927%	4.581%	3.602%
Southern San Joaquin Municipal Utility District	5.948%	5.071%	5.504%	6.048%	7.754%	5.201%
Stone Corral Irrigation District	0.348%	0.257%	0.318%	0.395%	0.634%	0.276%
Tea Pot Dome Water District	0.261%	0.185%	0.229%	0.284%	0.457%	0.198%
Terra Bella Irrigation District	1.008%	0.746%	0.923%	1.144%	1.839%	0.799%
Tri-Valley Water District[1]	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Tulare Irrigation District	8.305%	8.840%	8.531%	8.141%	6.921%	8.748%
Total	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.000%**

Key:
DEW = Drier/Extreme Warming
WMW = Wetter/Moderate Warming
Note:
[1] Friant Contractor does not receive a proportion of 16(b) supplies.

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California Water Commission, Water Storage Investment Program, Technical Reference, November 2016
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http://www.restoresjr.net/program-releases-framework-to-guide-program-into-next-decade/

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https://www.usbr.gov/mp/nepa/nepa_project_details.php?Project_ID=2940

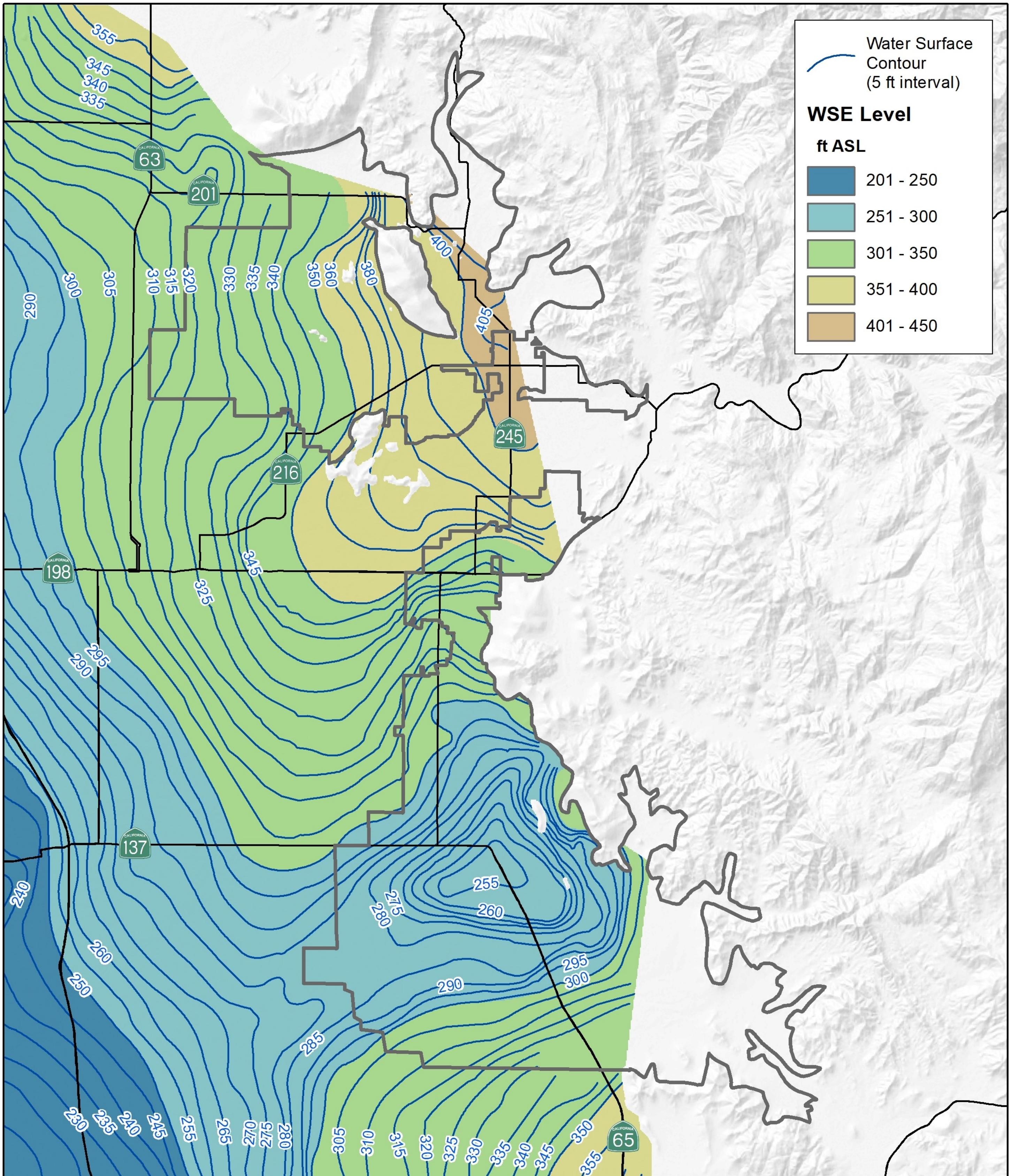
San Joaquin River Restoration Program, Proposed Implementation Agreement of the Friant Settlement, April 2009

San Joaquin River Restoration Program Settlement Agreement, October 2009
http://www.revivethesanjoaquin.org/content/san-joaquin-river-settlement-agreement

SJRRP, *see San Joaquin River Restoration Program*

Appendix 2-B

Historical Groundwater Conditions



EST. 1968
PROVOST& PRITCHARD
CONSULTING GROUP
An Employee Owned Company

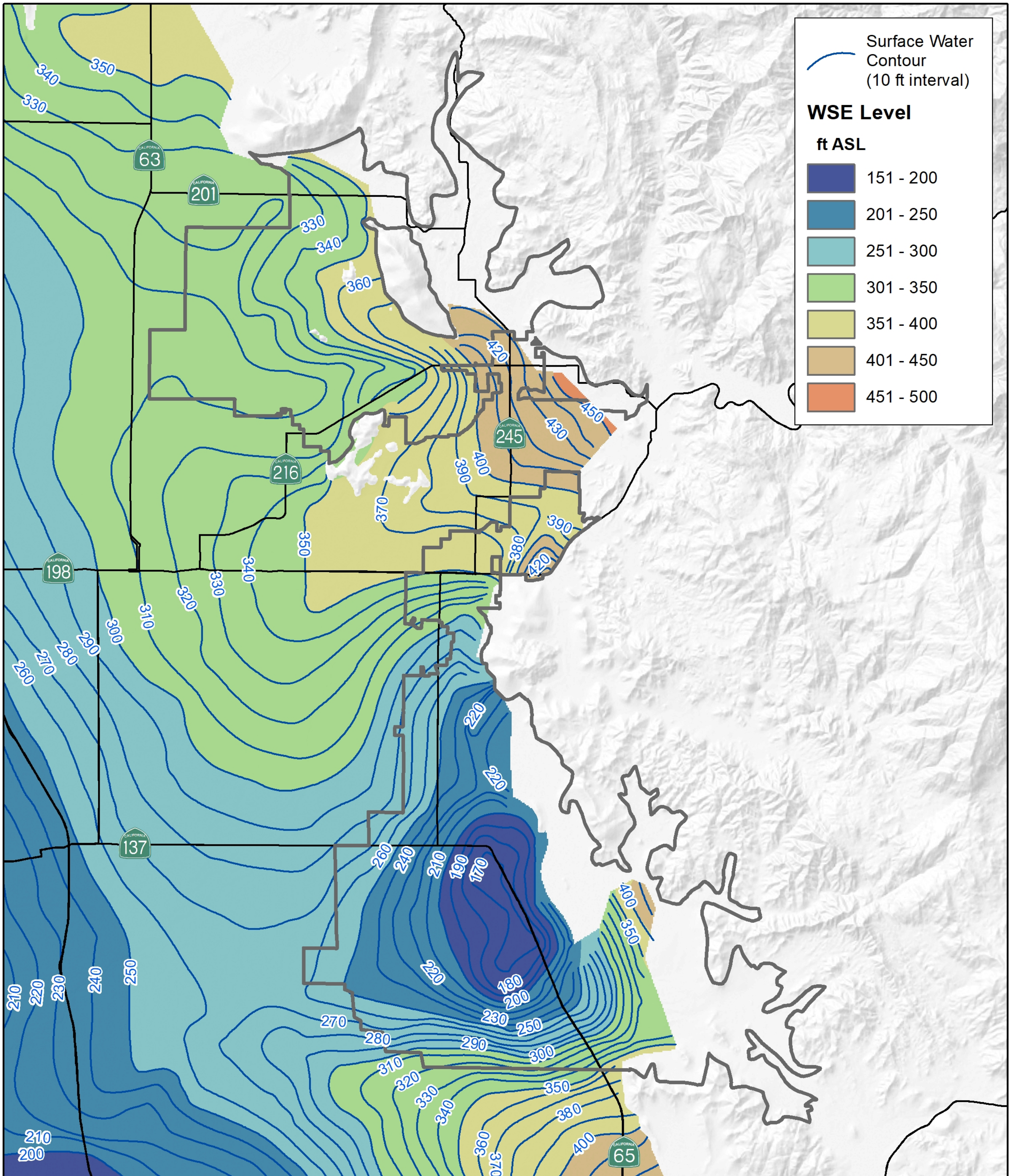
0 2 4
Miles

Ground Water Contours from State of CA Dept. of Public Works, Ground Water Contours as of Oct 1925 in Southern San Joaquin Valley. Contours are in feet above sea level.

Water Surface Elevation October 1925

East Kaweah GSA

12/4/2018 : G:\East Kaweah GSA - 2633\263317001-GSA Support\GIS\Map\GSP\Groundwater Conditions\Groundwater Levels\Historic\1925_gw_contours.mxd



EST. 1968
PROVOST& PRITCHARD
CONSULTING GROUP
An Employee Owned Company

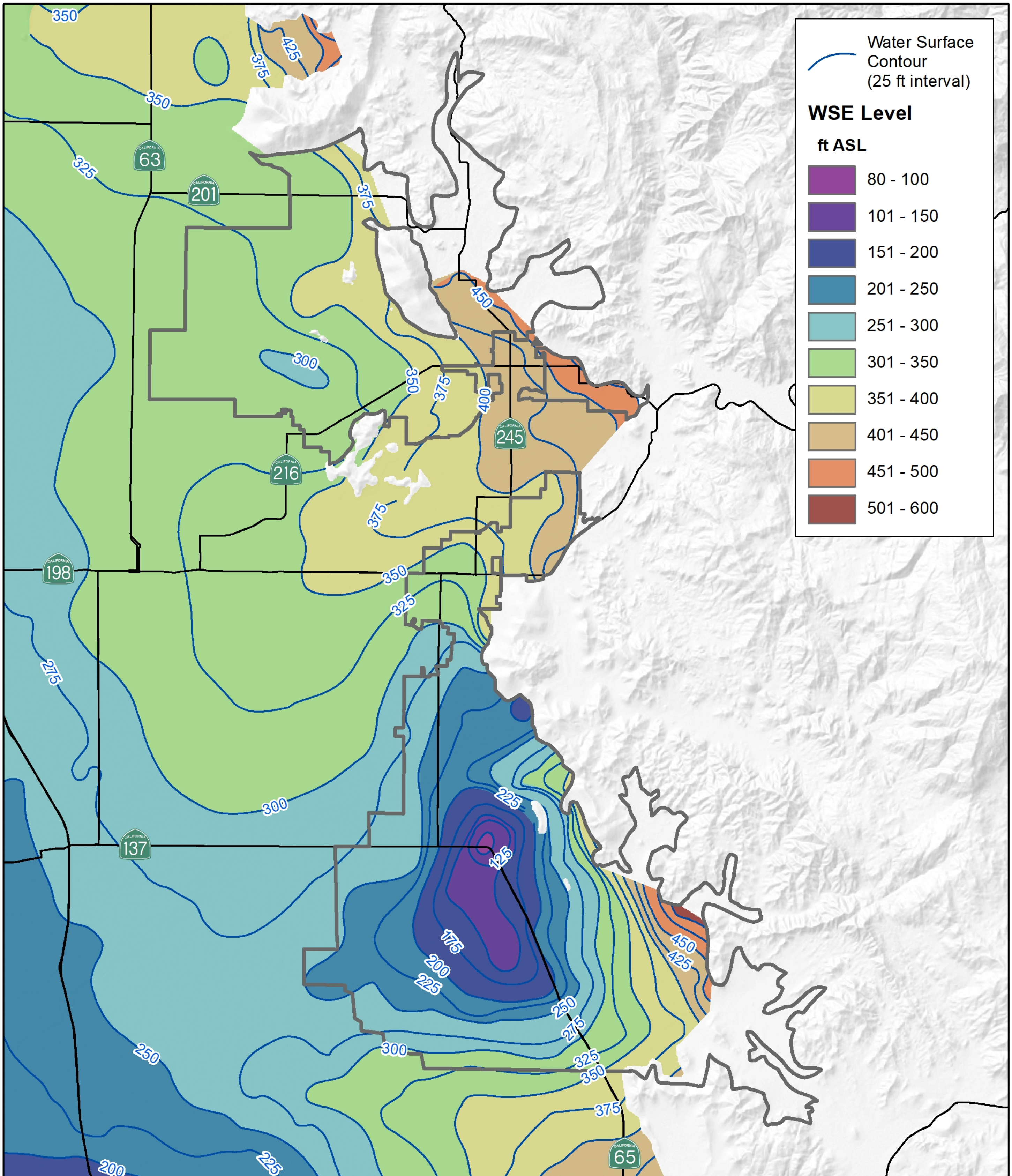
0 2 4
Miles

Contours from CA Dept. of Water Resources, Lines of Equal Elevation of Ground Water Table in Upper San Joaquin Valley, Fall 1939.
Contours are in feet above sea level.

Water Surface Elevation Fall 1939

East Kaweah GSA

12/11/2018 : G:\East Kaweah GSA - 2633\263317001-GSA Support\GIS\Map\GSP\Groundwater Conditions\Groundwater Levels\Historic\1939_WSE_contours.mxd



EST. 1968
PROVOST&
PRITCHARD
CONSULTING GROUP
An Employee Owned Company

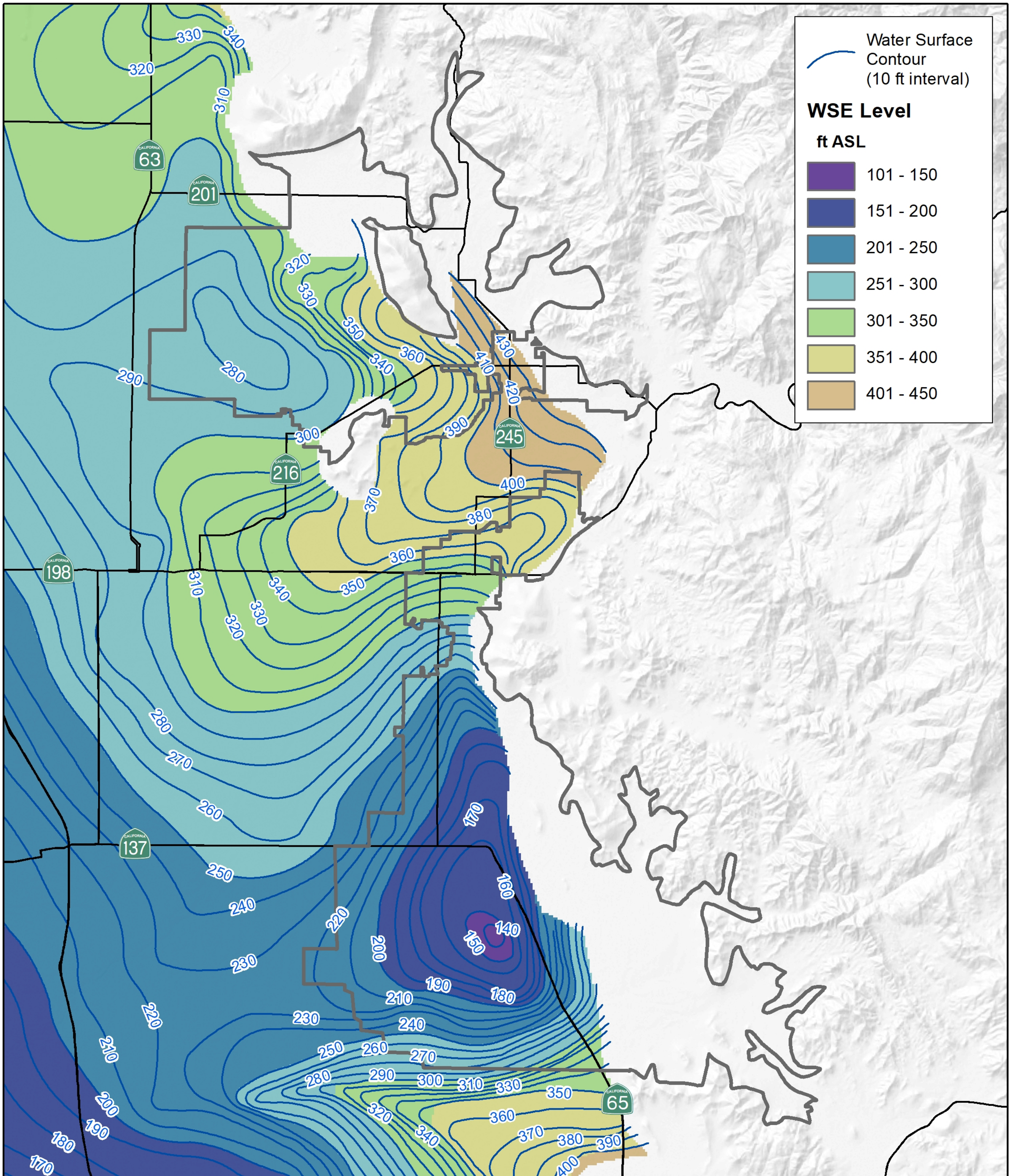
0 2 4
Miles

Contours from CA Dept. of Water Resources, Lines of Equal Elevation of Ground Water Table in Upper San Joaquin Valley, Fall 1945. Contours are in feet above sea level.

Water Surface Elevation
Fall 1945

East Kaweah GSA

12/11/2018 : G:\East Kaweah GSA - 2633\263317001-GSA Support\GIS\Map\GSP\Groundwater Conditions\Groundwater Levels\Historic\1945_WSE_contours.mxd



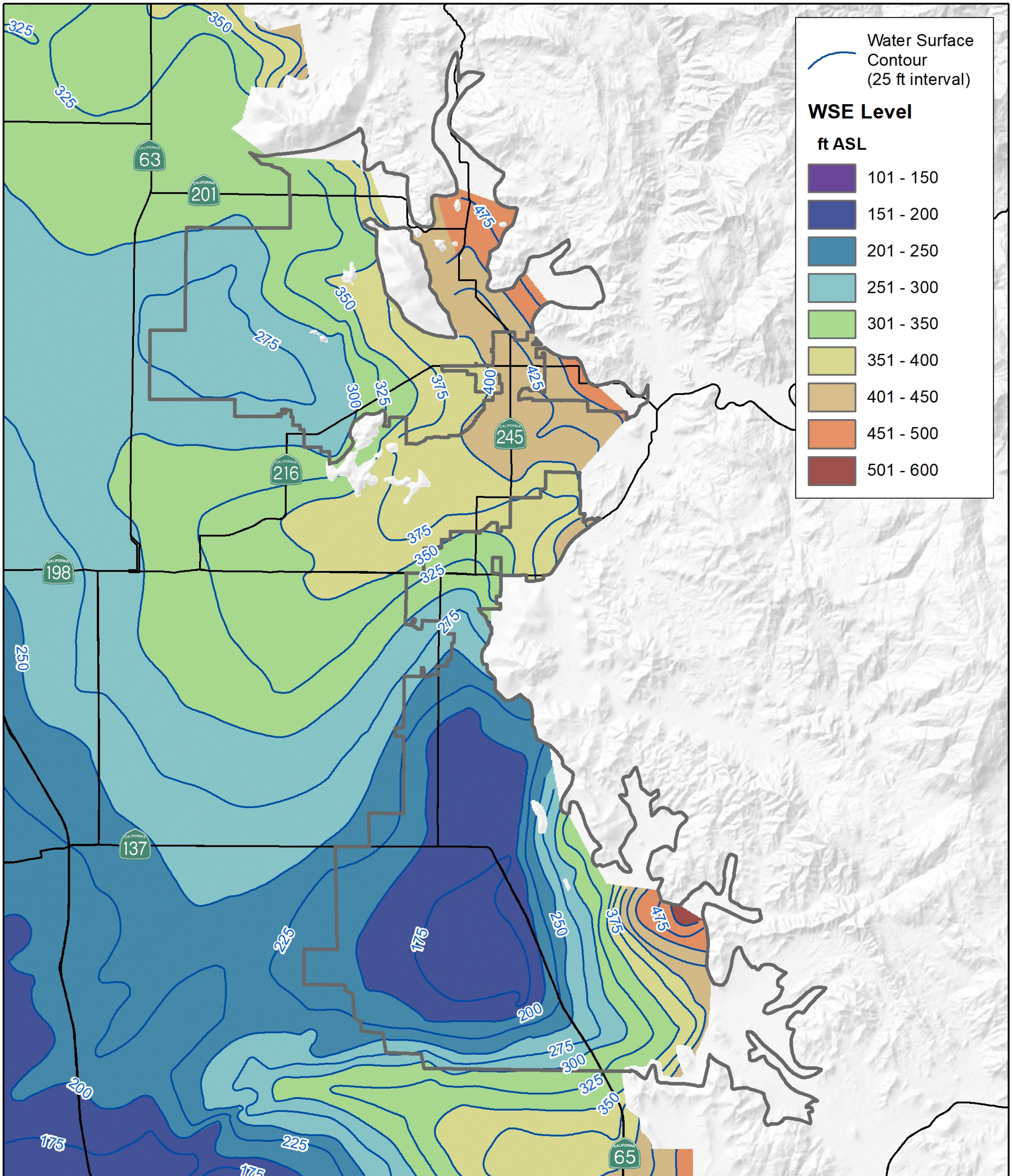
PROVOST& PRITCHARD
EST. 1968
CONSULTING GROUP
An Employee Owned Company

0 2 4
Miles

Water Surface Elevation
Spring 1952

East Kaweah GSA

12/4/2018 : G:\East Kaweah GSA - 2633\263317001-GSA Support\GIS\Map\GSP\Groundwater Conditions\Groundwater Levels\Historic\1952_WSE_contours.mxd



PROVOST& PRITCHARD CONSULTING GROUP
EST. 1968
An Employee Owned Company

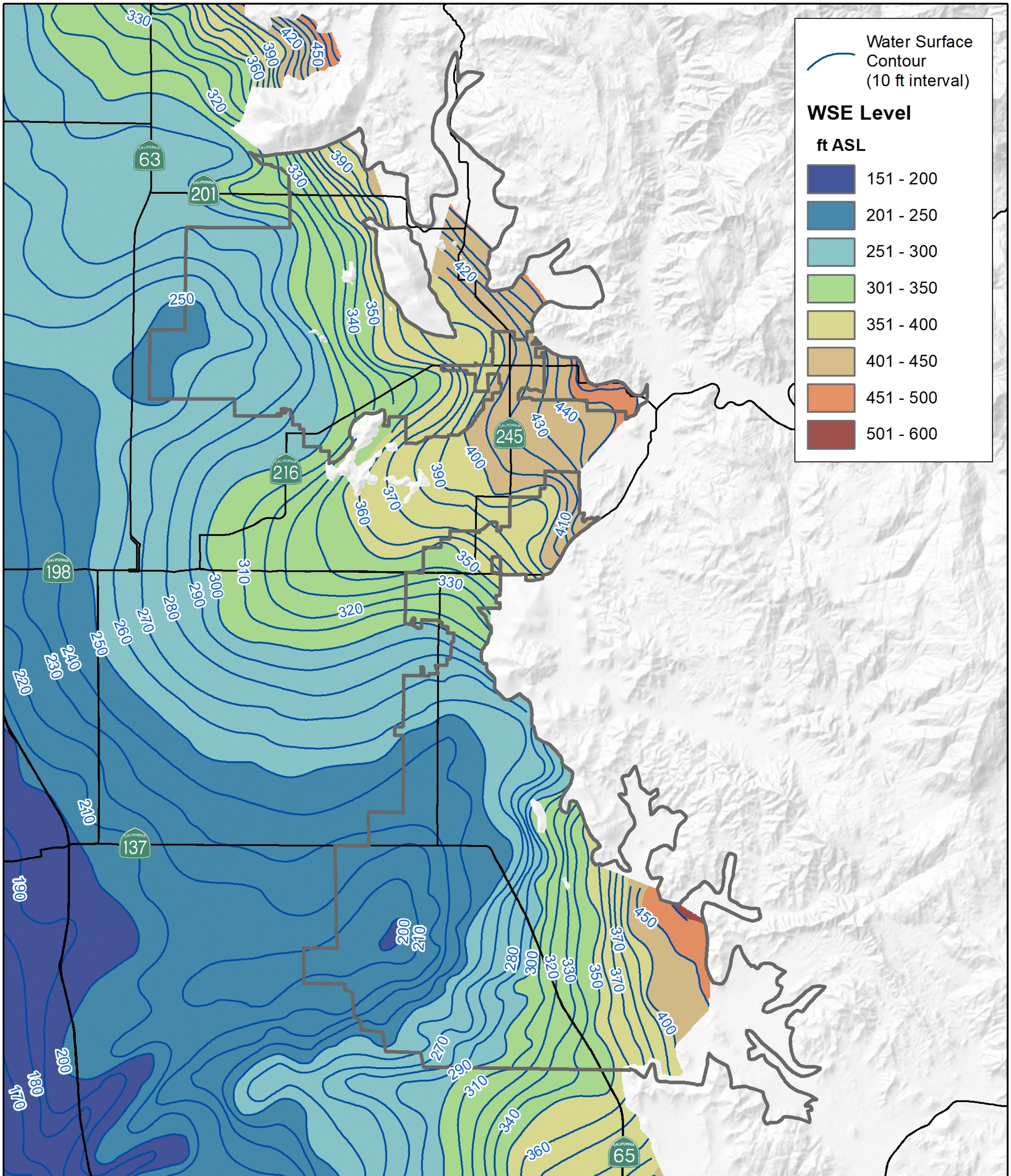
0 2 4
Miles

Ground Water Contours from CA Dept. of Water Resources, Lines of Equal Elevation of Water in Wells, San Joaquin Valley, Fall 1952. Contours are in feet above sea level.

Water Surface Elevation Fall 1952

East Kaweah GSA

12/4/2018 : G:\East Kaweah GSA - 2633\263317001-GSA Support\GIS\Map\GSP\Groundwater Conditions\Groundwater Levels\Historic\1952_WSE_contours_sjv.mxd



PROVOST& PRITCHARD
EST. 1968
CONSULTING GROUP
An Employee Owned Company

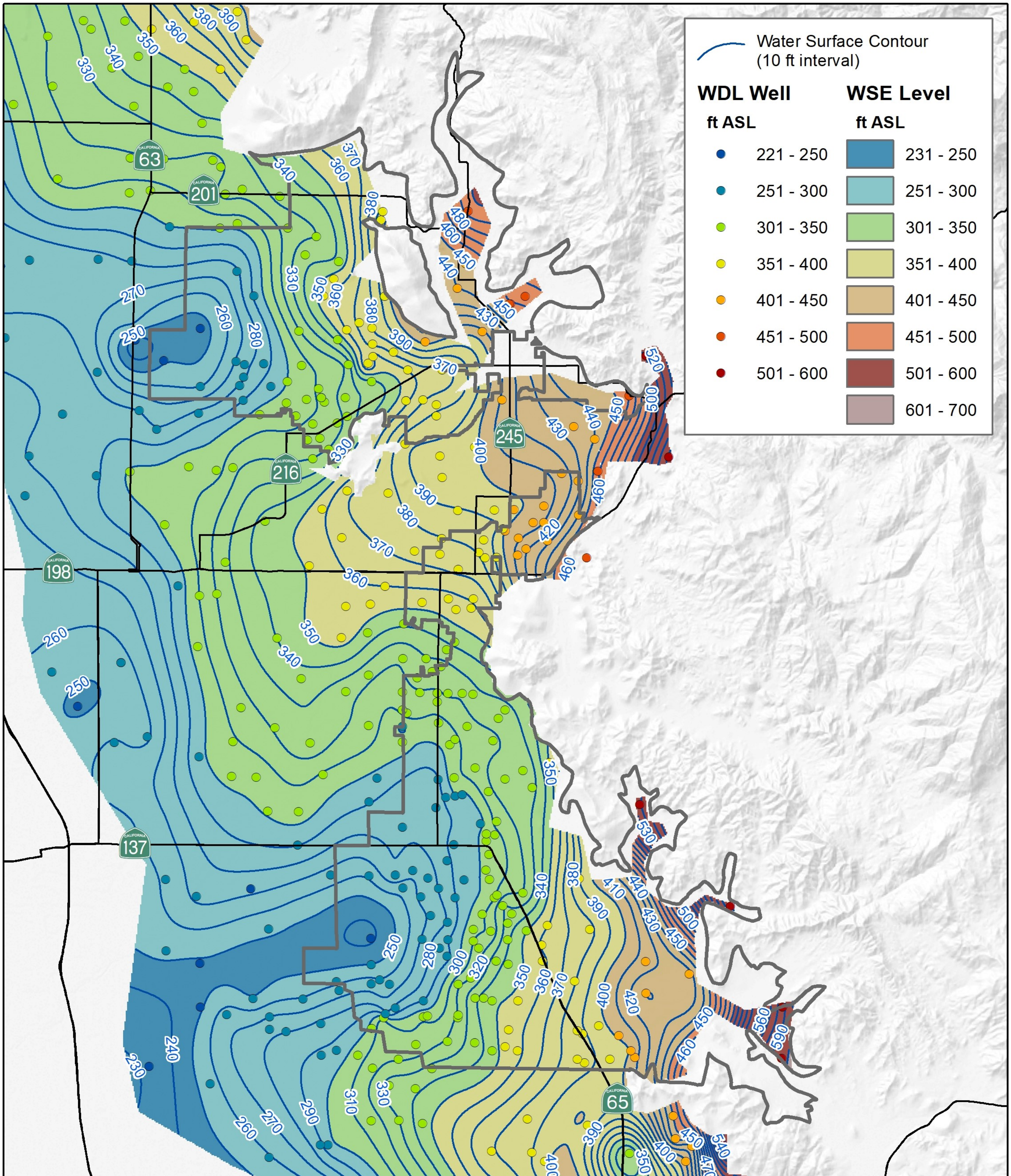
Ground Water Contours from CA Dept. of Water Resources, Lines of Equal Elevation in Wells, San Joaquin Valley, Spring 1962. Contours are in feet above sea level.

Water Surface Elevation Spring 1962

East Kaweah GSA

Appendix 2-C

Current Groundwater Conditions



EST. 1968
PROVOST& PRITCHARD
CONSULTING GROUP
An Employee Owned Company

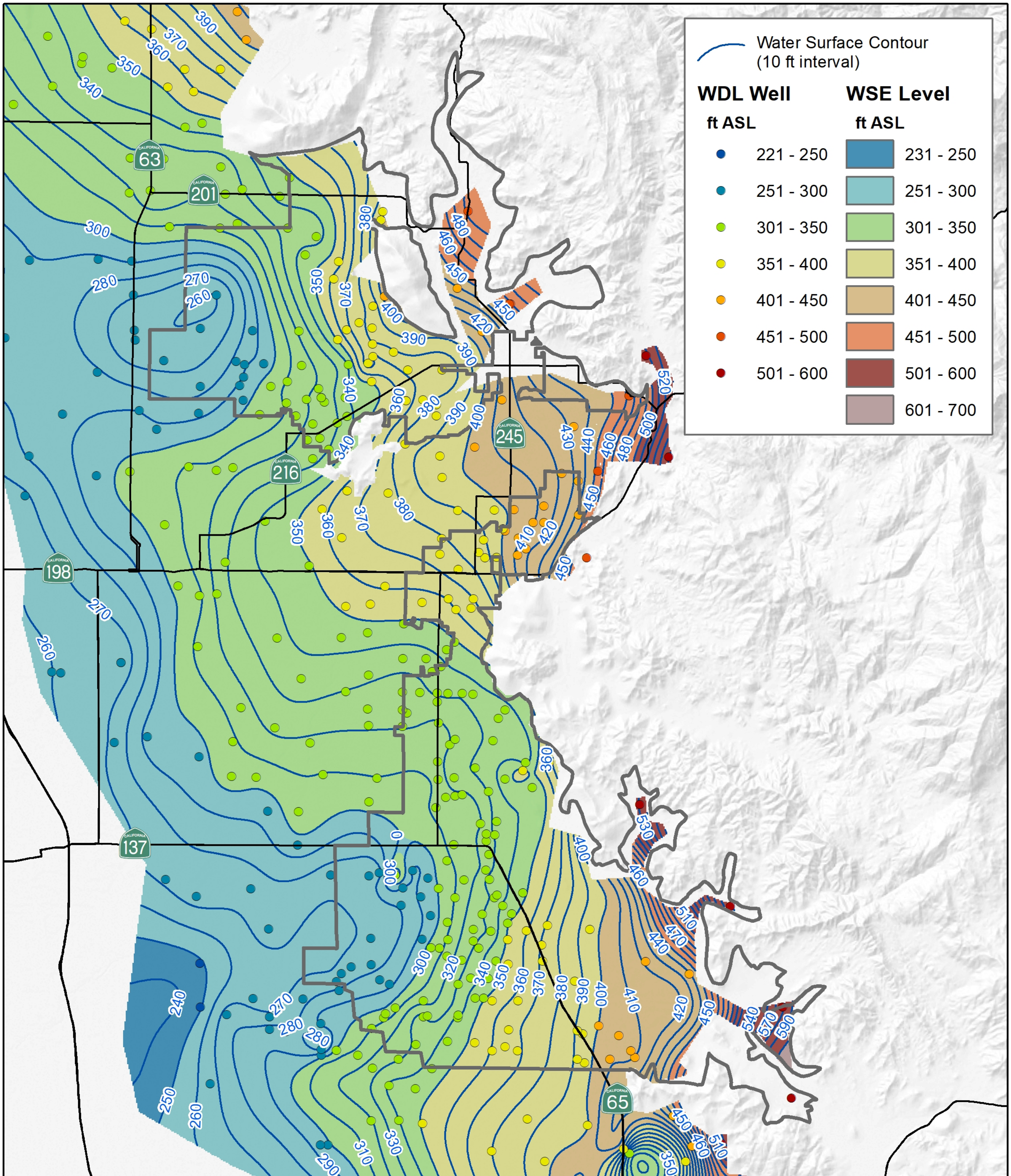
0 2 4
Miles

Well measurements were pulled from the DWR WDL database. Contours are in feet above sea level for the groundwater surface in wells.

Water Surface Elevation
Spring 1981

East Kaweah GSA

12/4/2018 : G:\East Kaweah GSA - 2633\263317001-GSA Support\GIS\Map\GSP\Groundwater Conditions\Groundwater Levels\Historic\1981_WSE_contours.mxd



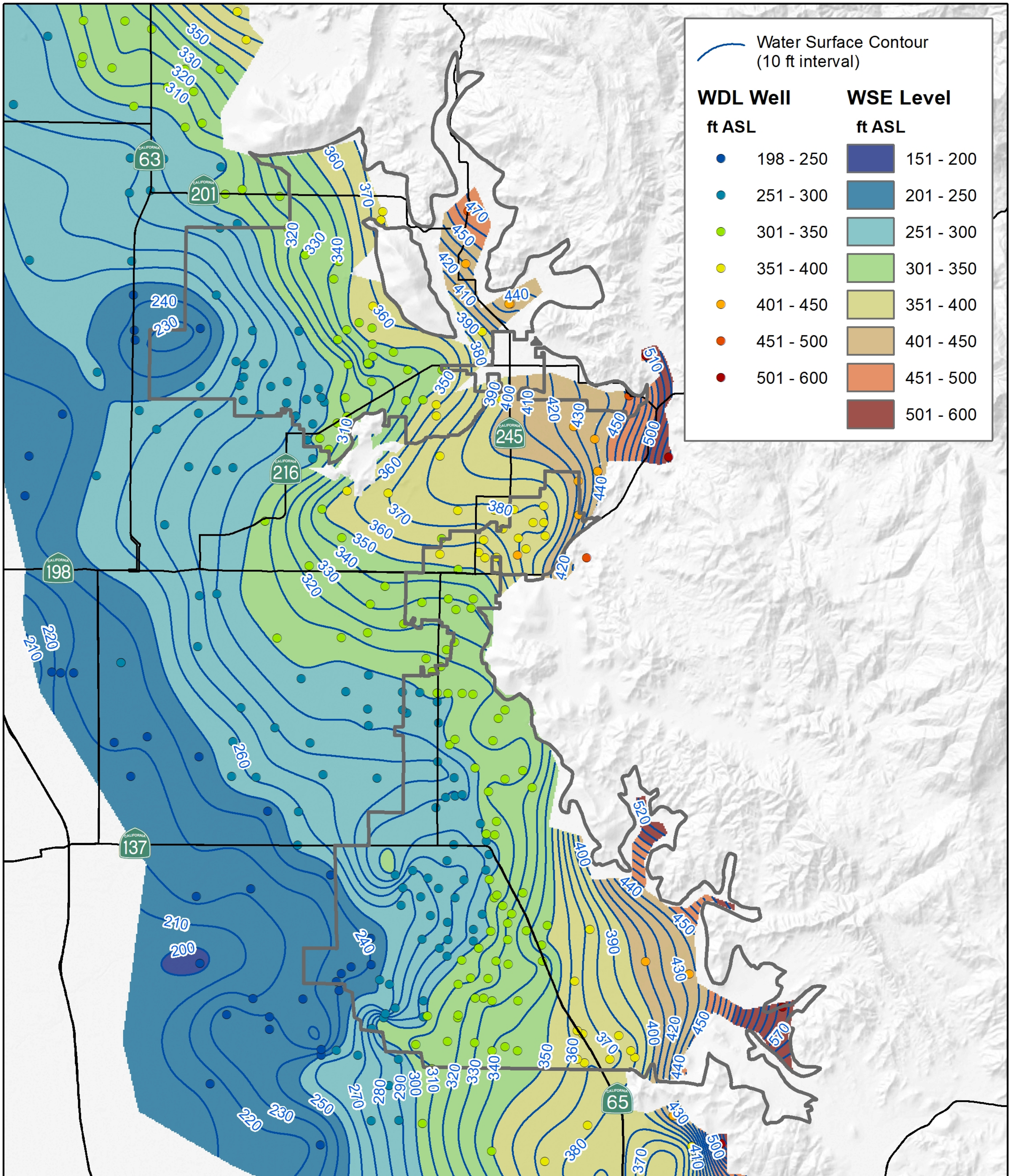
PROVOST& PRITCHARD CONSULTING GROUP EST. 1968
An Employee Owned Company

0 2 4 Miles

Well measurements were pulled from the DWR WDL database. Contours are in feet above sea level for the groundwater surface in wells.

Water Surface Elevation Spring 1986

East Kaweah GSA



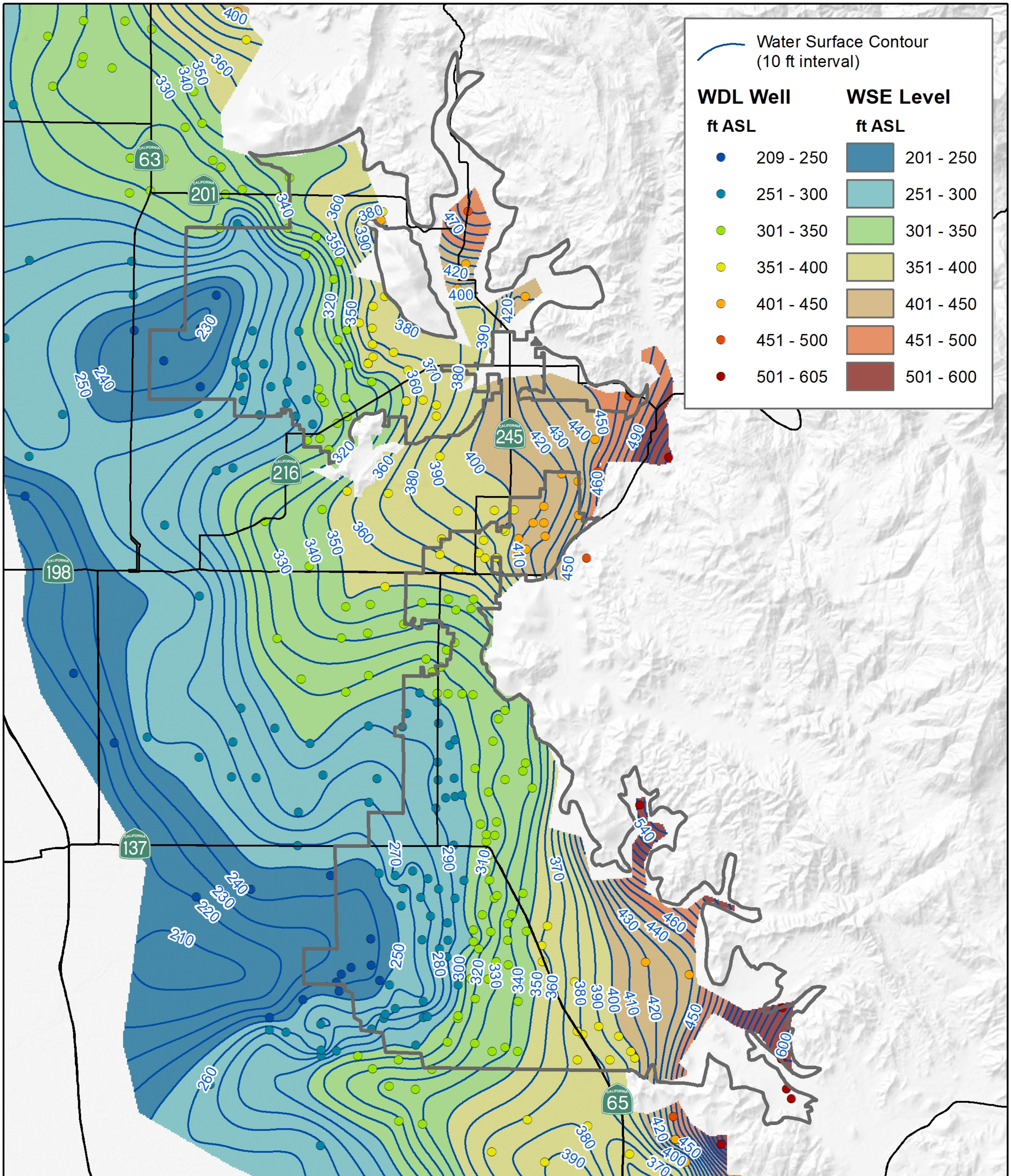
EST. 1968
PROVOST&
PRITCHARD
CONSULTING GROUP
An Employee Owned Company

0 2 4
Miles

Well measurements were pulled from the DWR WDL database. Contours are in feet above sea level for the groundwater surface in wells.

Water Surface Elevation Spring 1991

East Kaweah GSA



PROVOST & PRITCHARD CONSULTING GROUP
EST. 1968
An Employee Owned Company

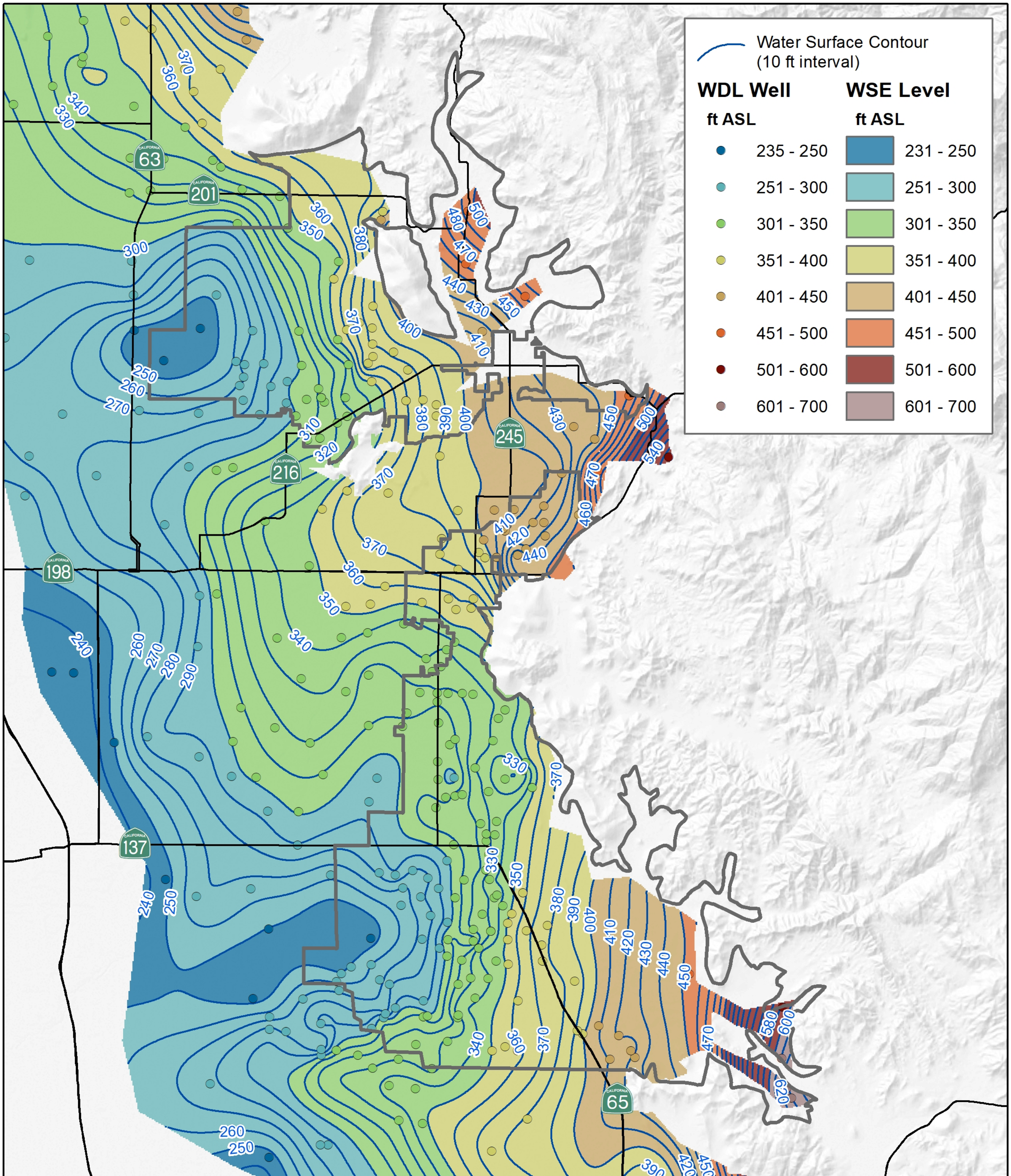
0 2 4
Miles

Well measurements were pulled from the DWR WDL database. Contours are in feet above sea level for the groundwater surface in wells.

Water Surface Elevation Spring 1996

East Kaweah GSA

12/4/2018 : G:\East Kaweah GSA - 2633\263317001-GSA Support\GIS\Map\GSP\Groundwater Conditions\Groundwater Levels\Historic\1996_WSE_contours.mxd



EST. 1968
PROVOST&
PRITCHARD
CONSULTING GROUP
An Employee Owned Company

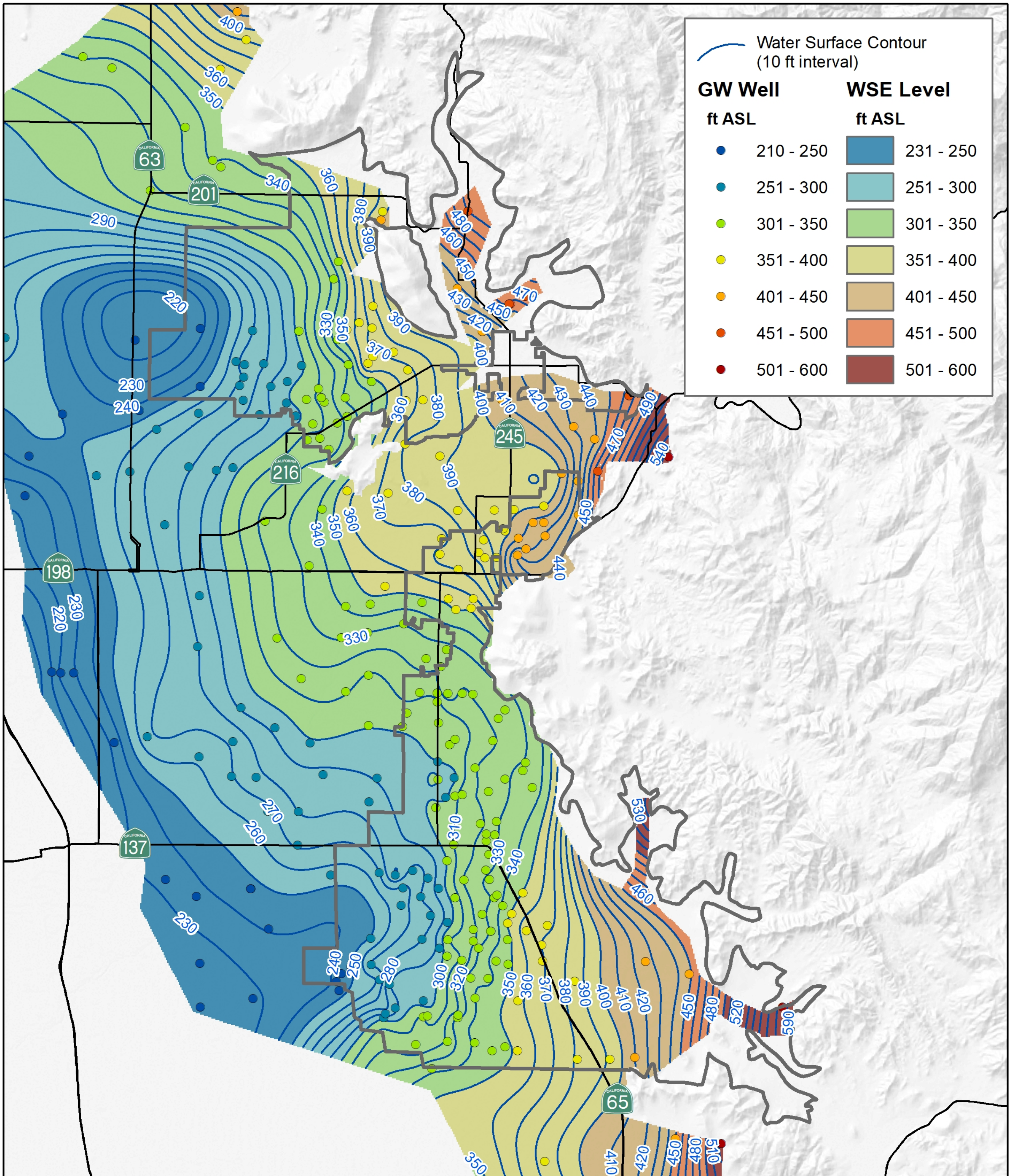
0 2 4
Miles

Well measurements were pulled from the DWR WDL database. Contours are in feet above sea level for the groundwater surface in wells.

Water Surface Elevation
Spring 1999

East Kaweah GSA

12/4/2018 : G:\East Kaweah GSA - 2633\263317001-GSA Support\GIS\Map\GSP\Groundwater Conditions\Groundwater Levels\WSE Maps - Base Period\alt_WSE_1999_Spring.mxd



EST. 1968
PROVOST & PRITCHARD
CONSULTING GROUP
An Employee Owned Company

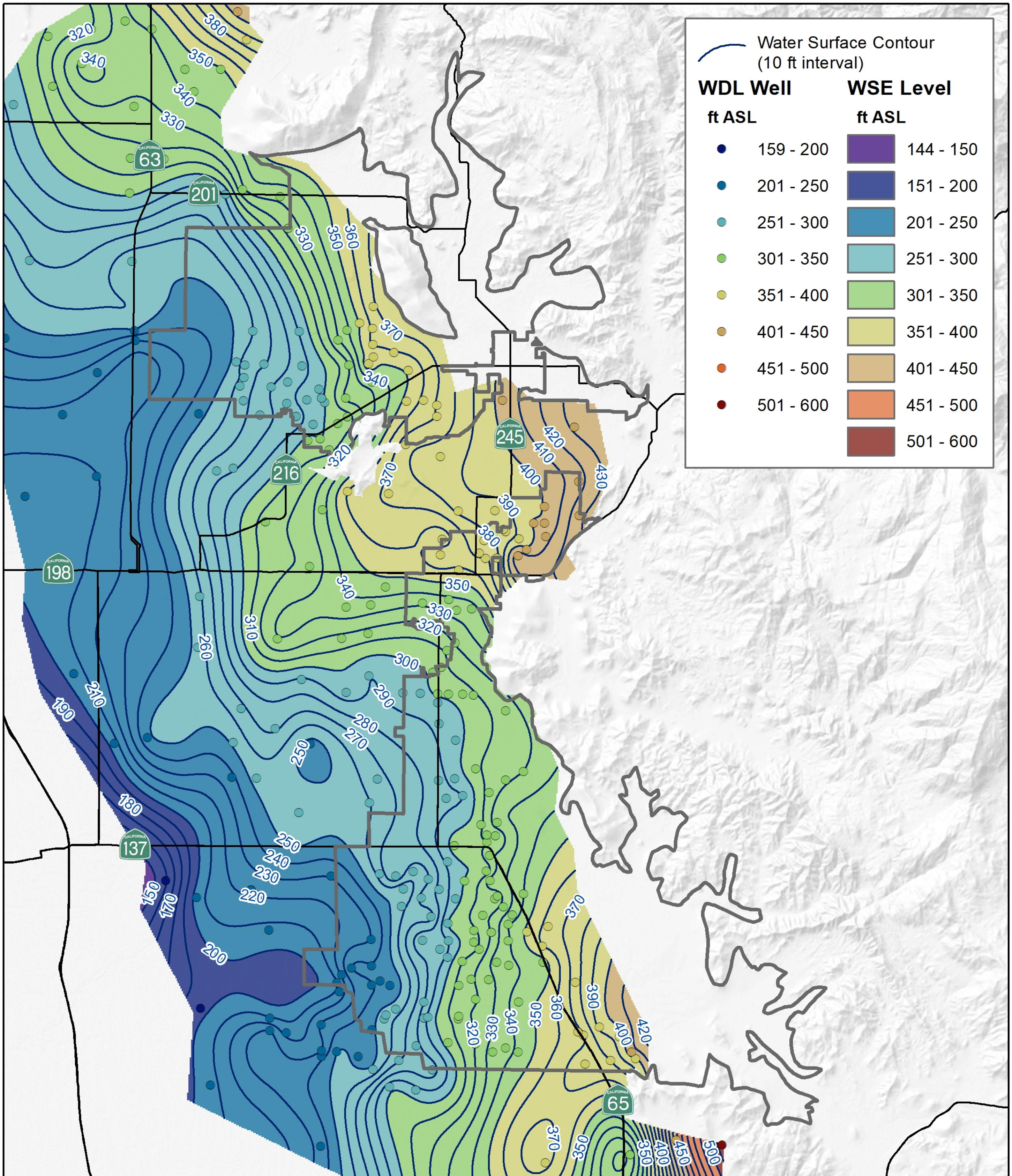
0 2 4
Miles

Well measurements were pulled from the DWR WDL database. Contours are in feet above sea level for the groundwater surface in wells.

Water Surface Elevation Spring 2002

East Kaweah GSA

12/13/2018 : G:\East Kaweah GSA - 2633\263317001-GSA Support\GIS\Map\GSP\Groundwater Conditions\Groundwater Levels\WSE Maps - Base Period\alt_WSE_2002_Spring.mxd



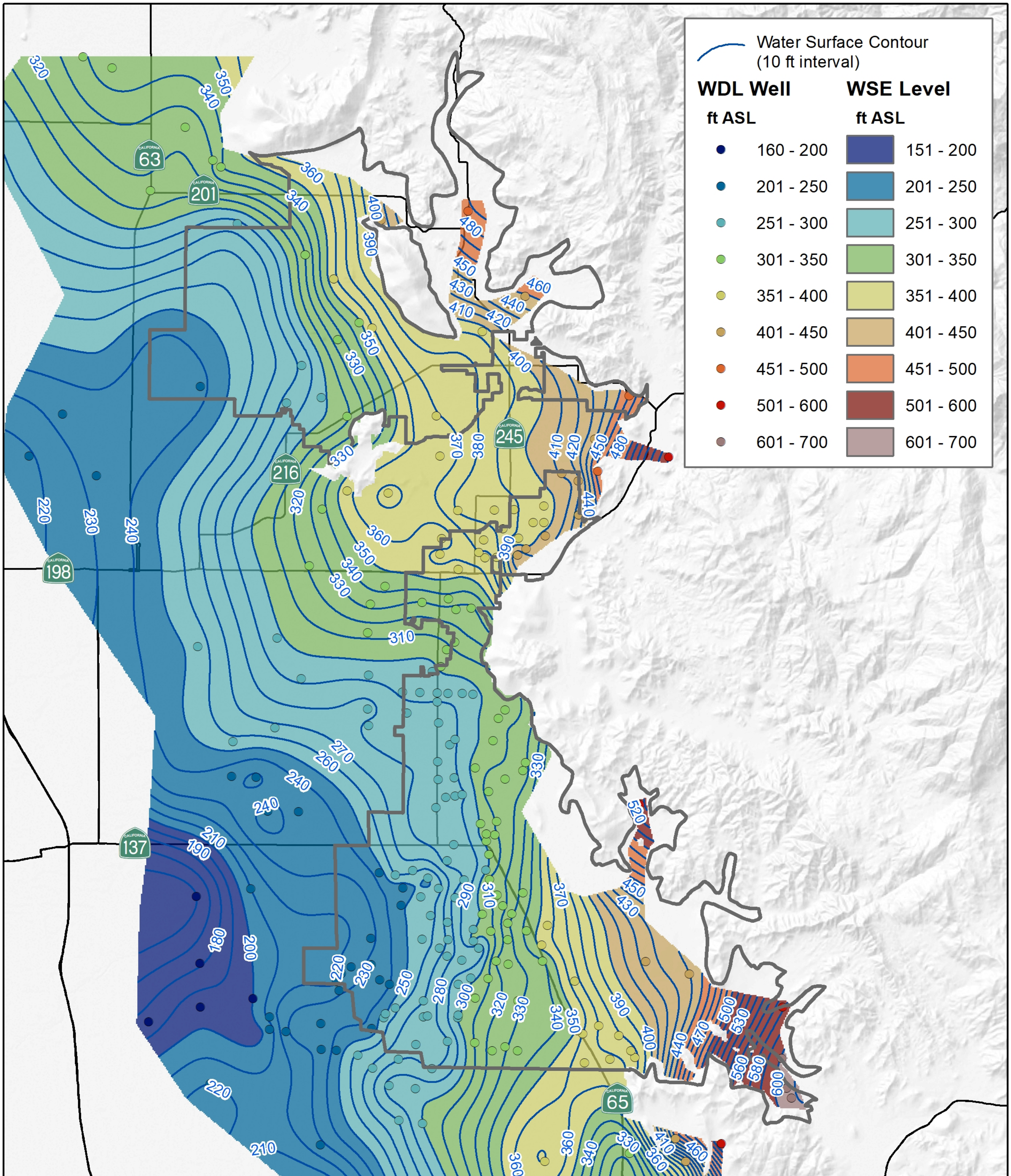
EST. 1968
PROVOST&
PRITCHARD
CONSULTING GROUP
An Employee Owned Company

0 2 4
Miles

Well measurements were pulled from the DWR WDL database. Contours are in feet above sea level for the groundwater surface in wells.

Water Surface Elevation
Spring 2005

East Kaweah GSA



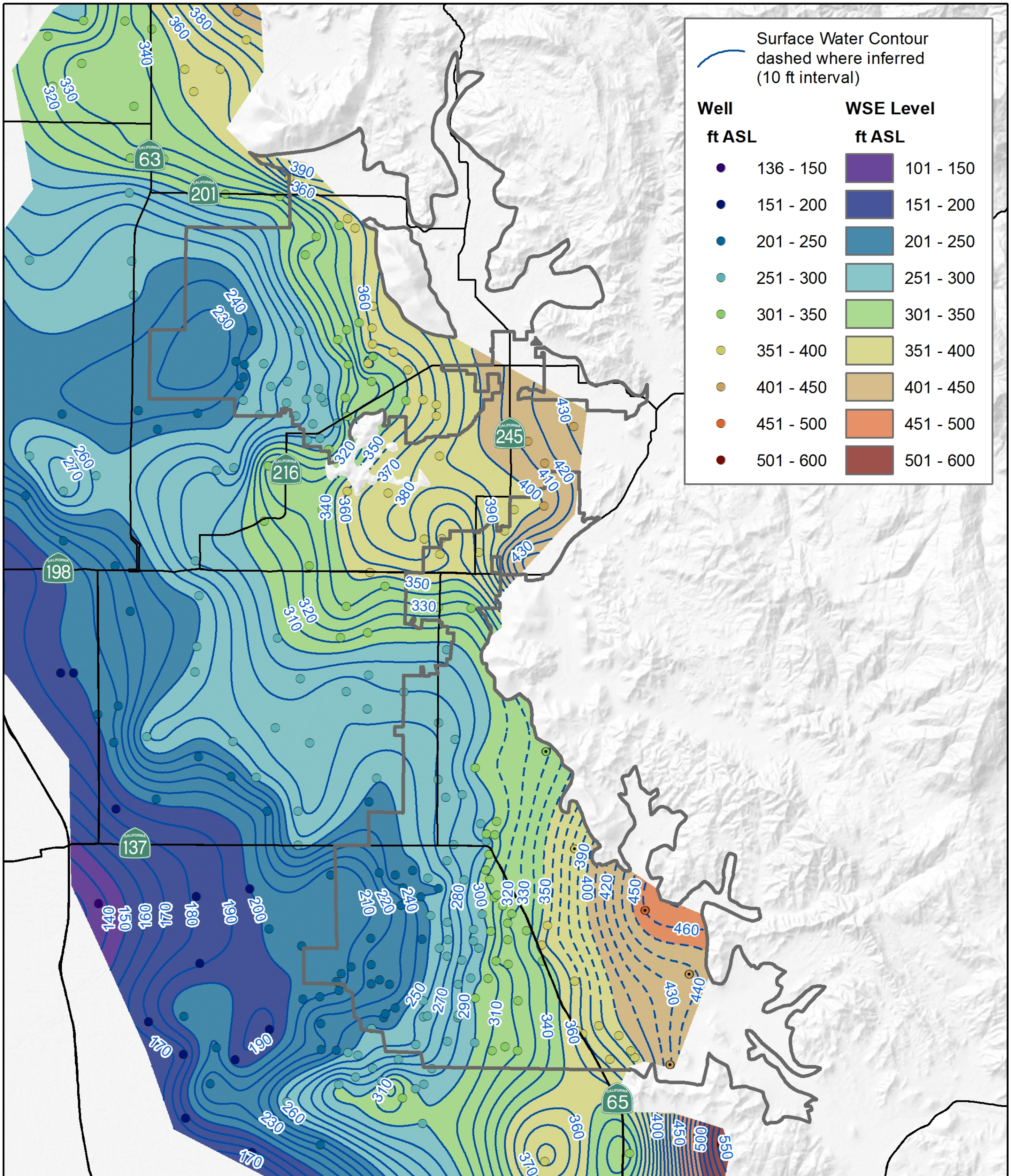
PROVOST& PRITCHARD CONSULTING GROUP
EST. 1968
An Employee Owned Company

Well measurements were pulled from the DWR WDL database. Contours are in feet above sea level for the groundwater surface in wells.

Water Surface Elevation Spring 2008

East Kaweah GSA

12/4/2018 : G:\East Kaweah GSA - 2633\263317001-GSA Support\GIS\Map\GSP\Groundwater Conditions\Groundwater Levels\WSE Maps - Base Period\alt_WSE_2008_Spring.mxd



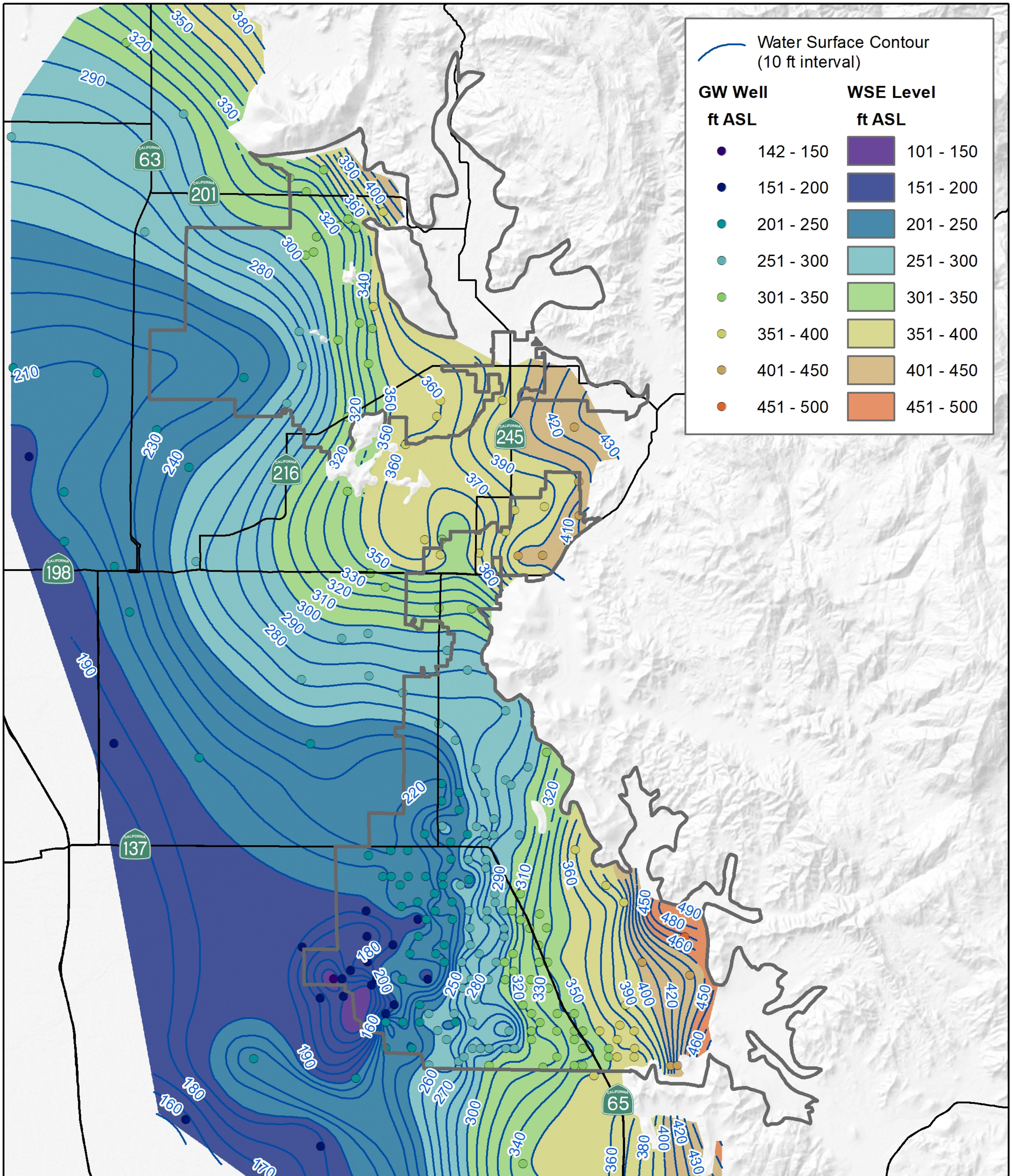
EST. 1968
PROVOST& PRITCHARD
CONSULTING GROUP
An Employee Owned Company

0 2 4
Miles

Well measurements were pulled from the DWR WDL database. Contours are in feet above sea level for the groundwater surface in wells.

Water Surface Elevation Spring 2011

East Kaweah GSA



EST. 1968 PROVOST& PRITCHARD CONSULTING GROUP An Employee Owned Company

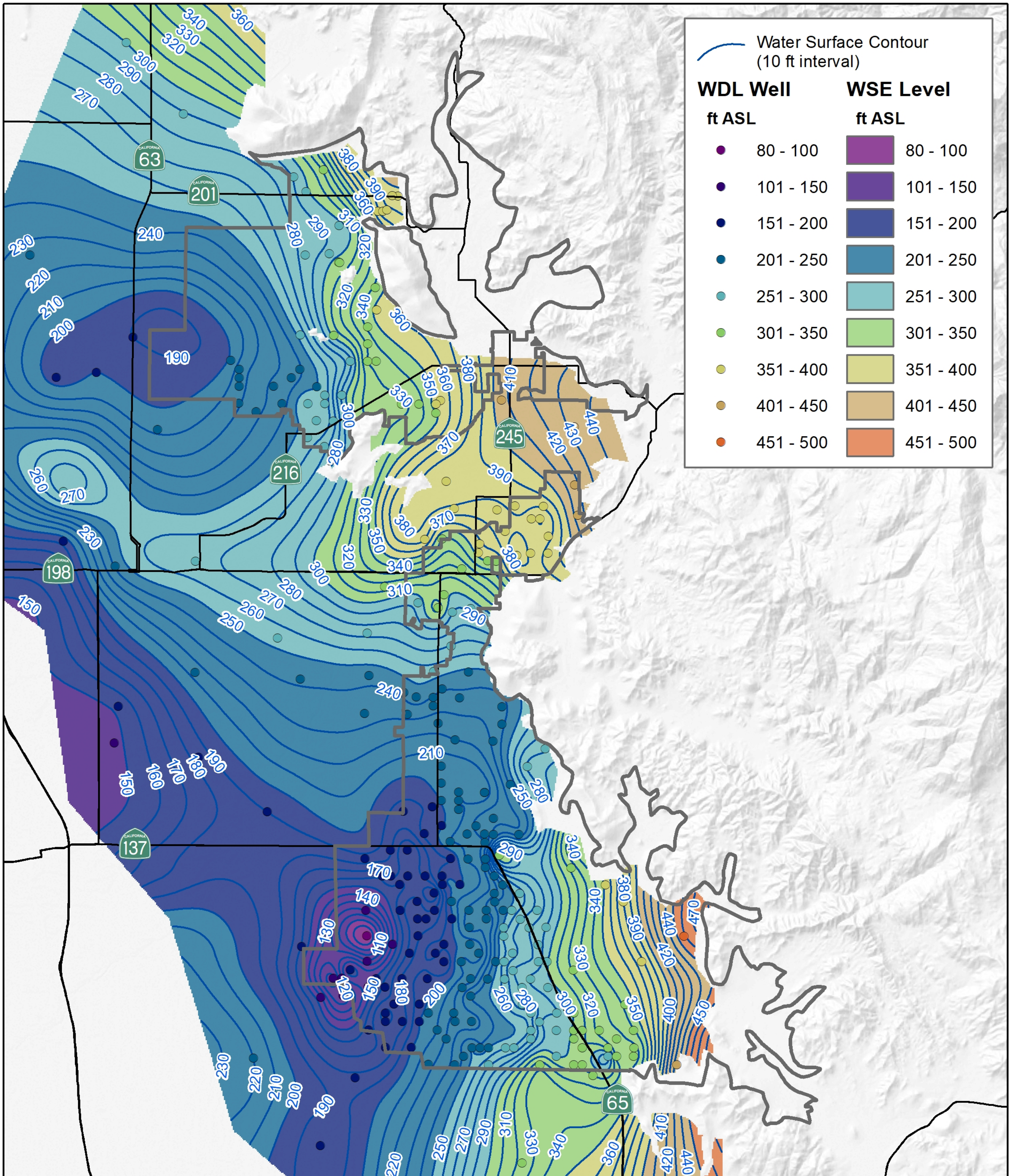
0 2 4 Miles

Well measurements were pulled from the DWR WDL database. Contours are in feet above sea level for the groundwater surface in wells.

Water Surface Elevation Spring 2014

East Kaweah GSA

12/18/2018 : G:\East Kaweah GSA - 2633\263317001-GSA Support\GIS\Map\GSP\GW Conditions\GW Levels\WSE Maps - Base Period\alt_WSE_2014_Spring.mxd



EST. 1968
PROVOST& PRITCHARD
CONSULTING GROUP
An Employee Owned Company

0 2 4
Miles

Well measurements were pulled from the DWR WDL database. Contours are in feet above sea level for the groundwater surface in wells.

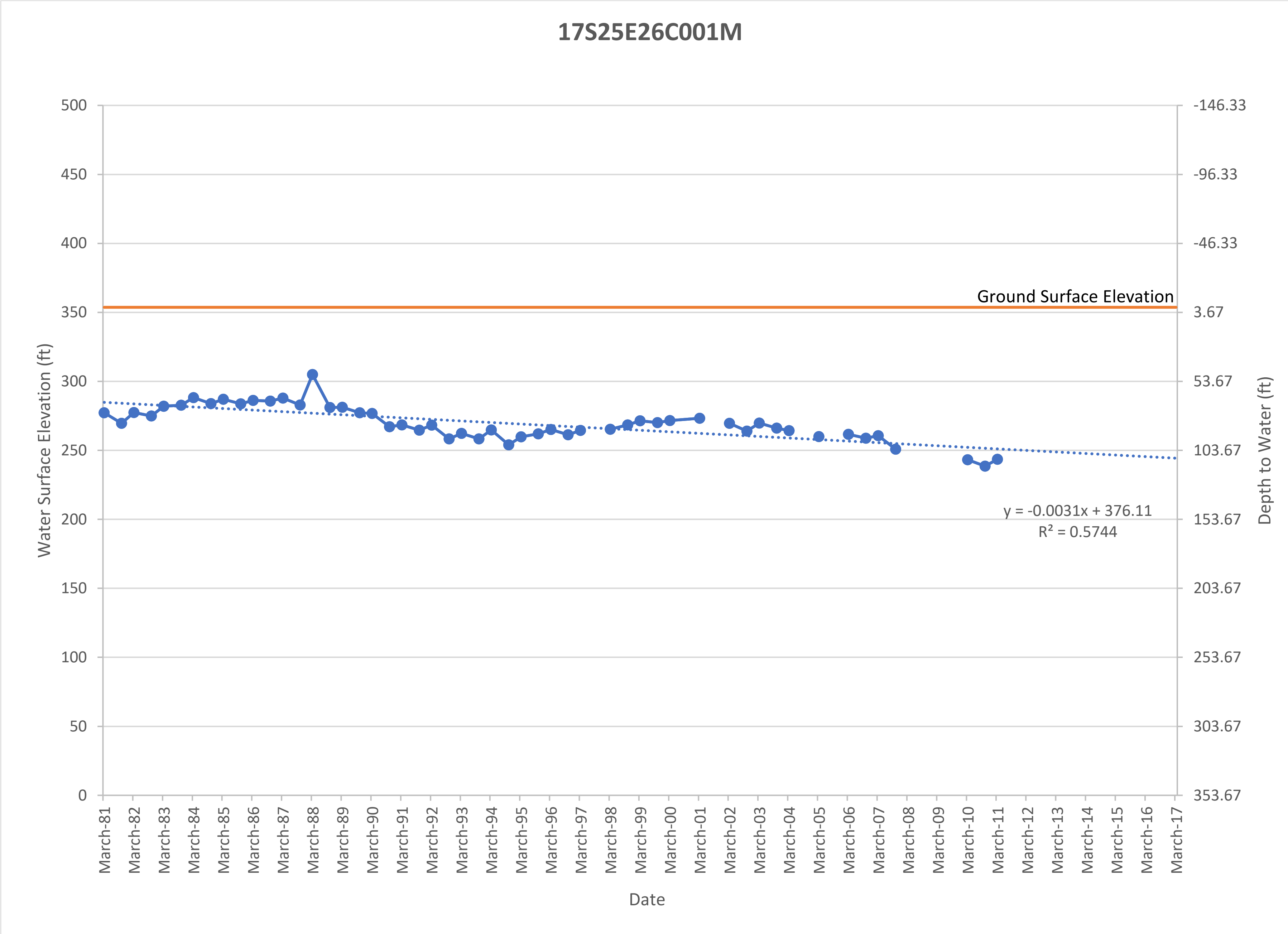
Water Surface Elevation Spring 2017

East Kaweah GSA

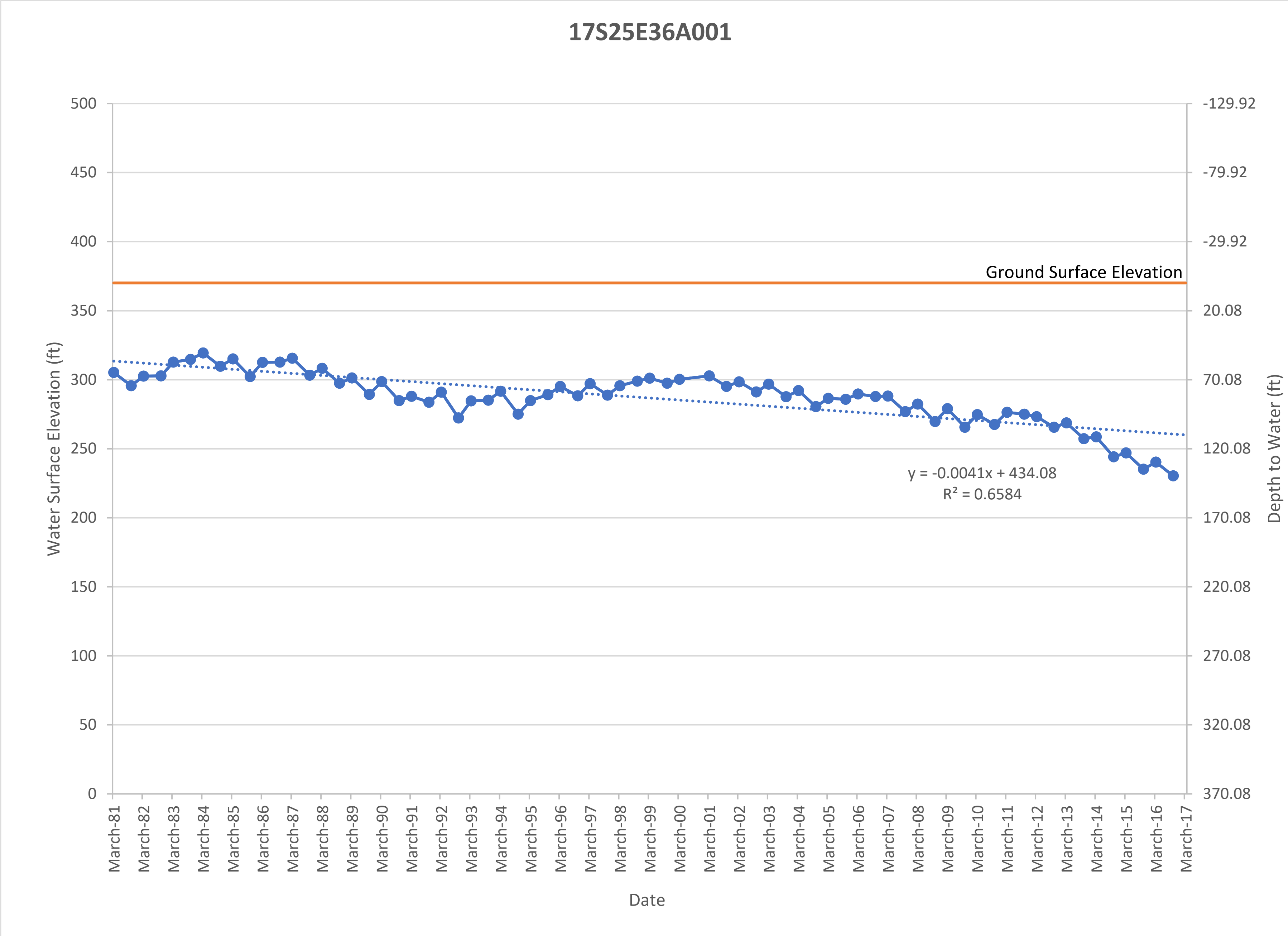
Appendix 2-D

Select Individual Well Hydrographs

Cottonwood Creek Interfan



17S25E26C001M
Water Surface Elevation (ft)
Depth to Water (ft)
Ground Surface Elevation
y = -0.0031x + 376.11
R² = 0.5744
Date
500
450
400
350
300
250
200
150
100
50
0
-146.33
-96.33
-46.33
3.67
53.67
103.67
153.67
203.67
253.67
303.67
353.67
March-81
March-82
March-83
March-84
March-85
March-86
March-87
March-88
March-89
March-90
March-91
March-92
March-93
March-94
March-95
March-96
March-97
March-98
March-99
March-00
March-01
March-02
March-03
March-04
March-05
March-06
March-07
March-08
March-09
March-10
March-11
March-12
March-13
March-14
March-15
March-16
March-17



17S25E36A001
Ground Surface Elevation
Water Surface Elevation (ft)
Depth to Water (ft)
Date
y = -0.0041x + 434.08
R² = 0.6584
500
450
400
350
300
250
200
150
100
50
0
-129.92
-79.92
-29.92
20.08
70.08
120.08
170.08
220.08
270.08
320.08
370.08
March-81
March-82
March-83
March-84
March-85
March-86
March-87
March-88
March-89
March-90
March-91
March-92
March-93
March-94
March-95
March-96
March-97
March-98
March-99
March-00
March-01
March-02
March-03
March-04
March-05
March-06
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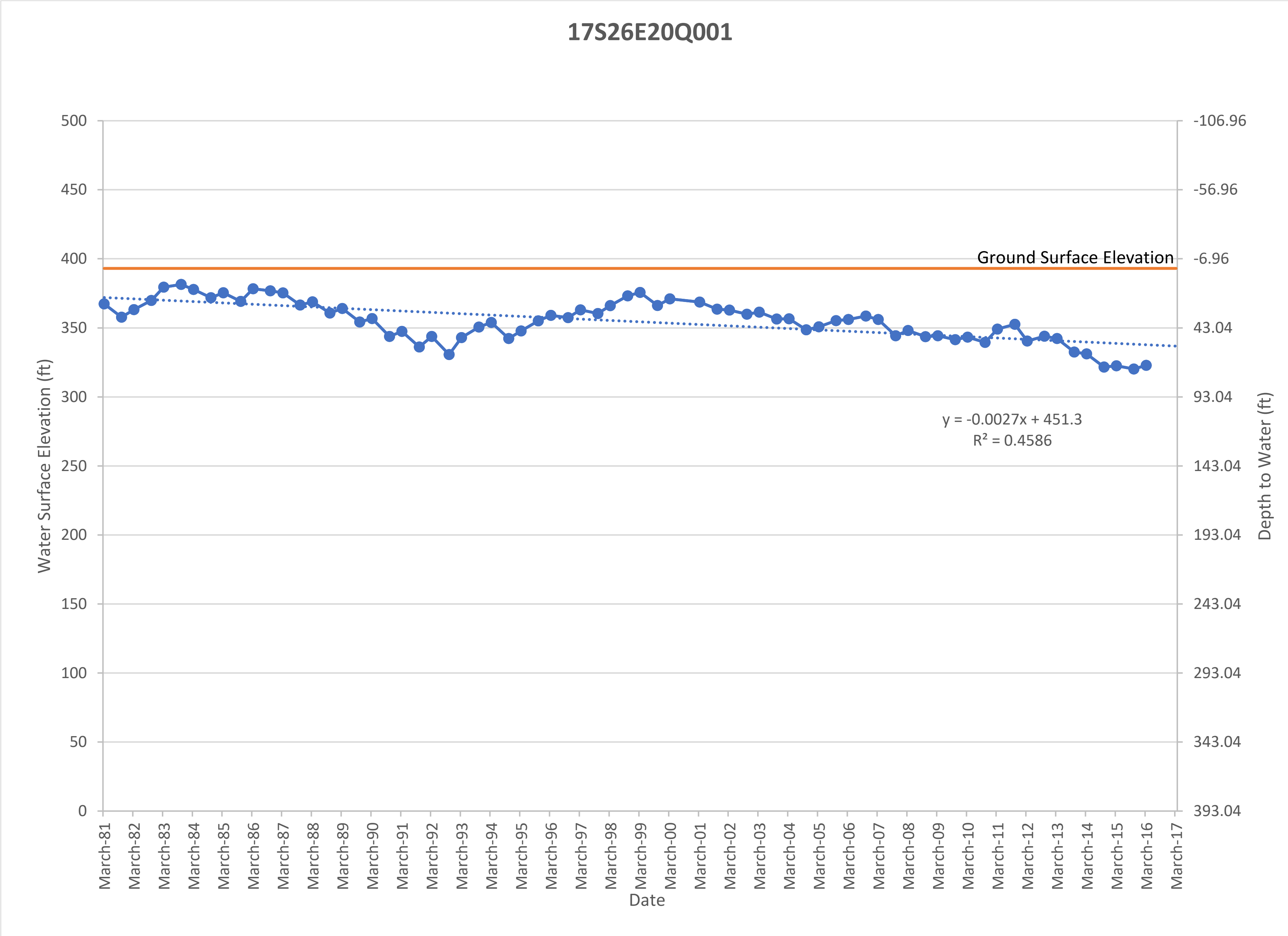
March-11
March-12
March-13
March-14
March-15
March-16
March-17



17S26E20Q001
Ground Surface Elevation
y = -0.0027x + 451.3
R² = 0.4586
Water Surface Elevation (ft)
Depth to Water (ft)
Date
500
450
400
350
300
250
200
150
100
50
0
-106.96
-56.96
-6.96
43.04
93.04
143.04
193.04
243.04
293.04
343.04
393.04
March-81
March-82
March-83
March-84
March-85
March-86
March-87
March-88
March-89
March-90
March-91
March-92
March-93
March-94
March-95
March-96
March-97
March-98
March-99
March-00
March-01
March-02
March-03
March-04
March-05
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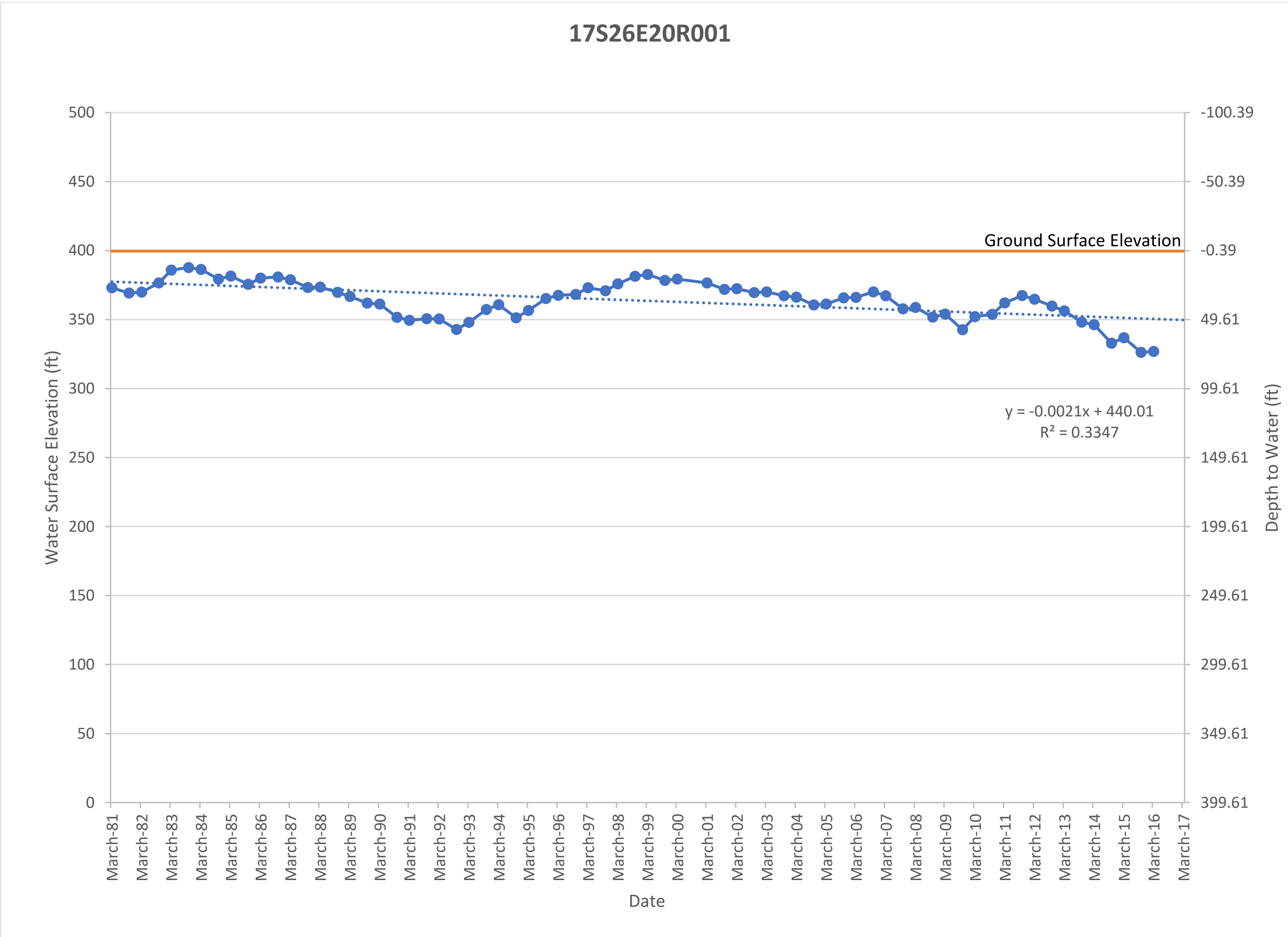
March-15
March-16
March-17



17S26E20R001
Water Surface Elevation (ft)
Depth to Water (ft)
500
450
400
350
300
250
200
150
100
50
0
-100.39
-50.39
-0.39
49.61
99.61
149.61
199.61
249.61
299.61
349.61
399.61
Ground Surface Elevation
y = -0.0021x + 440.01
R² = 0.3347
March-81
March-82
March-83
March-84
March-85
March-86
March-87
March-88
March-89
March-90
March-91
March-92
March-93
March-94
March-95
March-96
March-97
March-98
March-99
March-00
March-01
March-02
March-03
March-04
March-05
March-06
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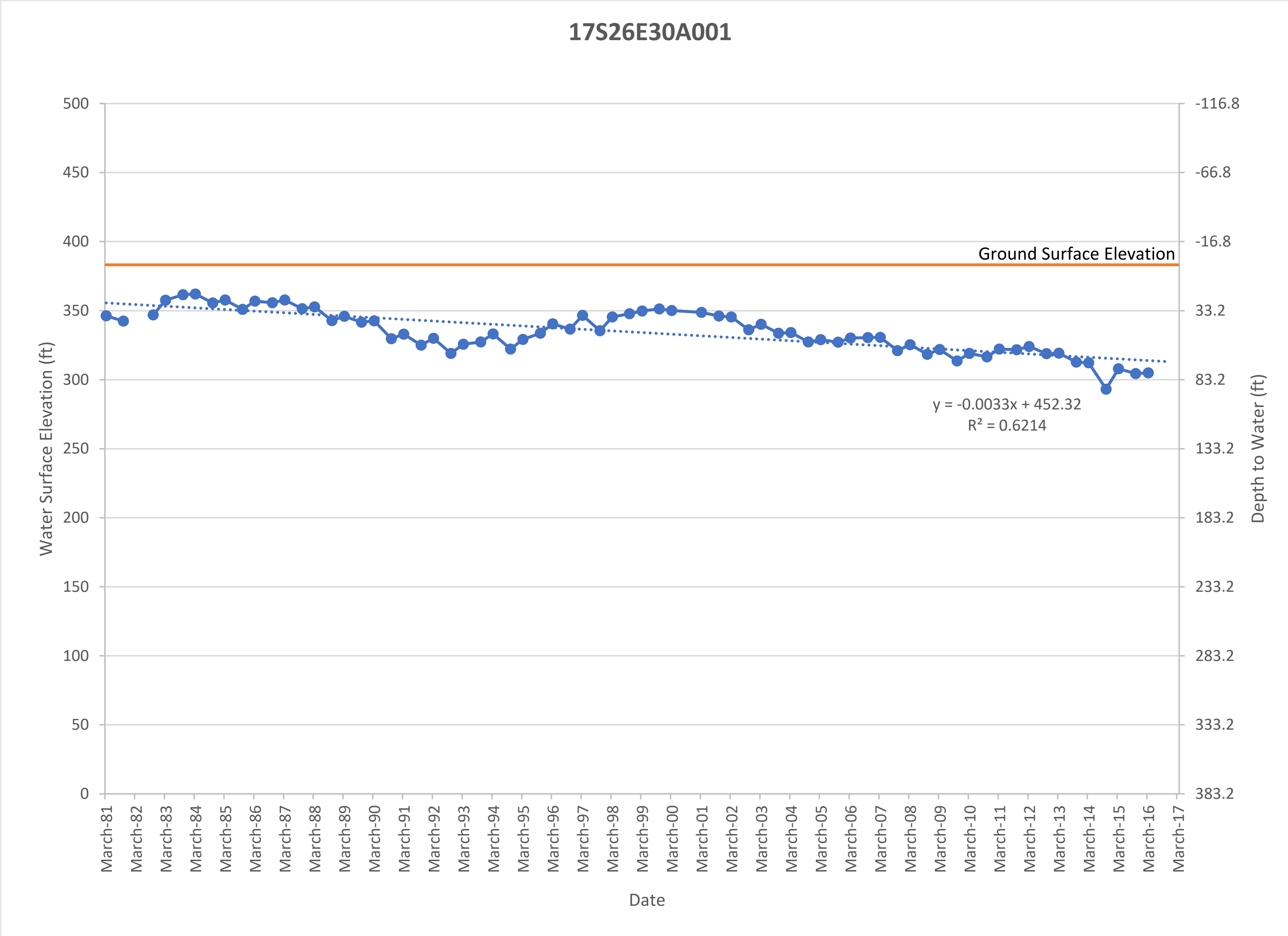
March-11
March-12
March-13
March-14
March-15
March-16
March-17
Date



17S26E30A001
Ground Surface Elevation
y = -0.0033x + 452.32
R^2 = 0.6214
Water Surface Elevation (ft)
Depth to Water (ft)
Date
500
450
400
350
300
250
200
150
100
50
0
-116.8
-66.8
-16.8
33.2
83.2
133.2
183.2
233.2
283.2
333.2
383.2
March-81
March-82
March-83
March-84
March-85
March-86
March-87
March-88
March-89
March-90
March-91
March-92
March-93
March-94
March-95
March-96
March-97
March-98
March-99
March-00
March-01
March-02
March-03
March-04
March-05
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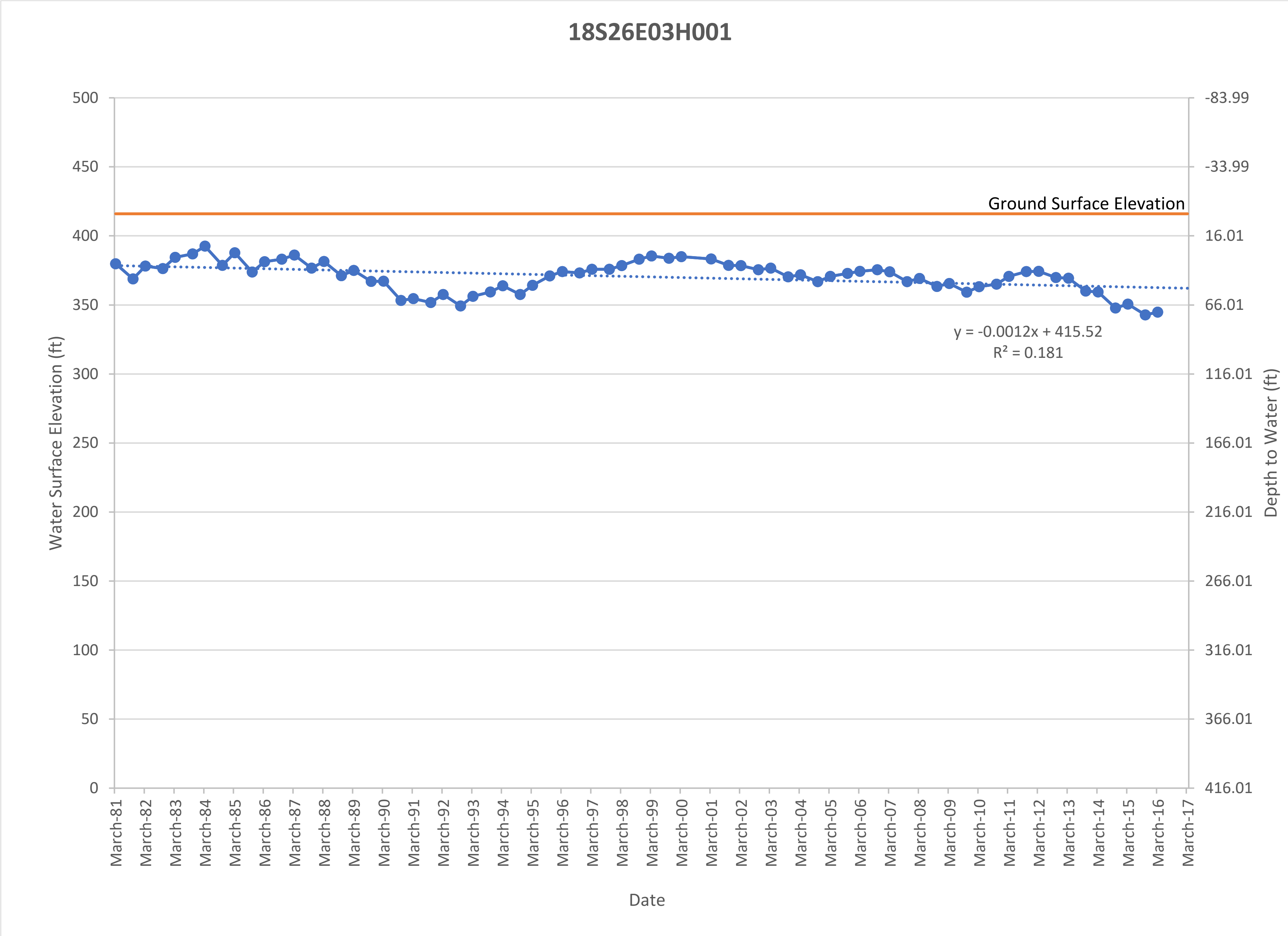
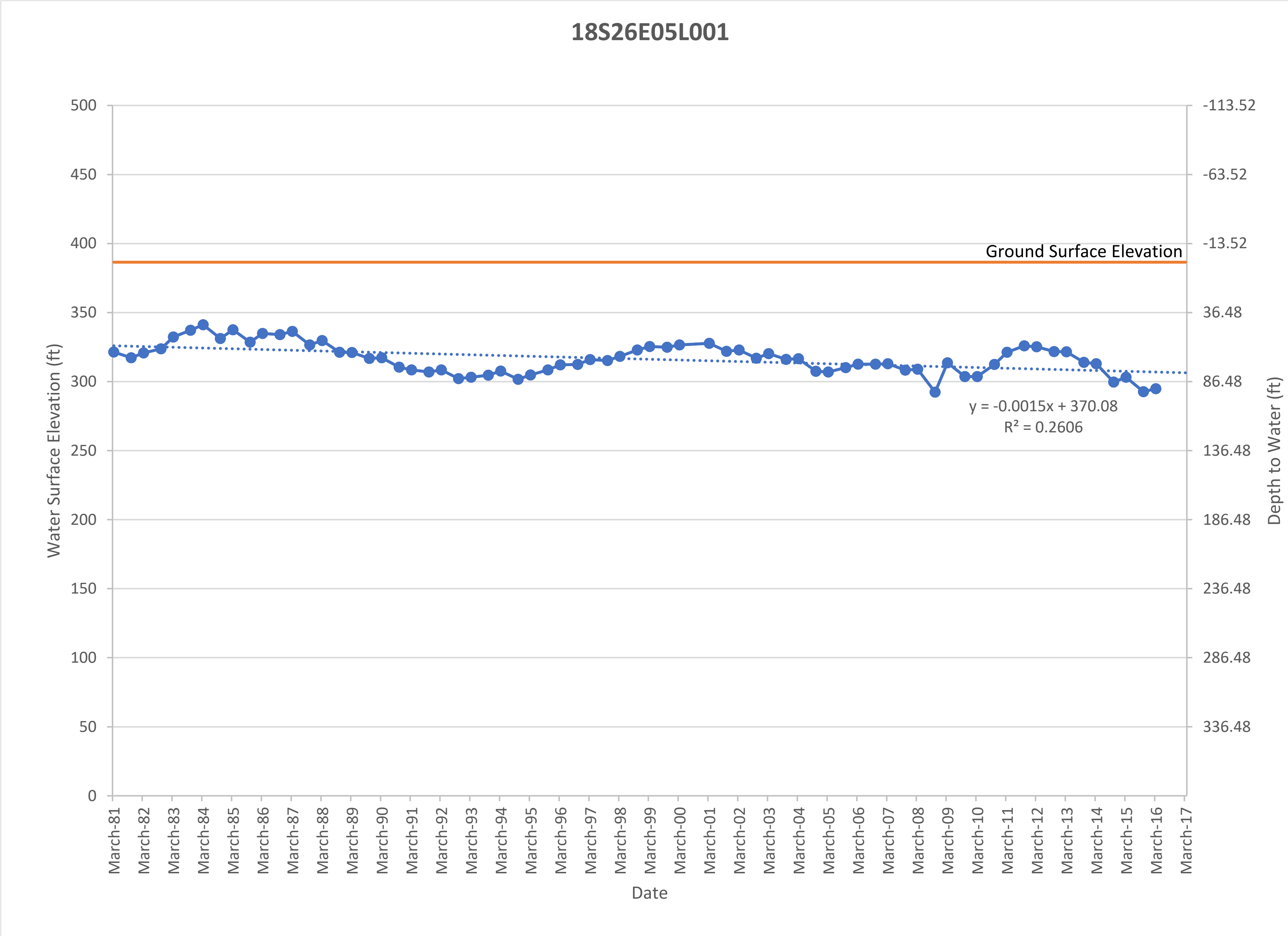
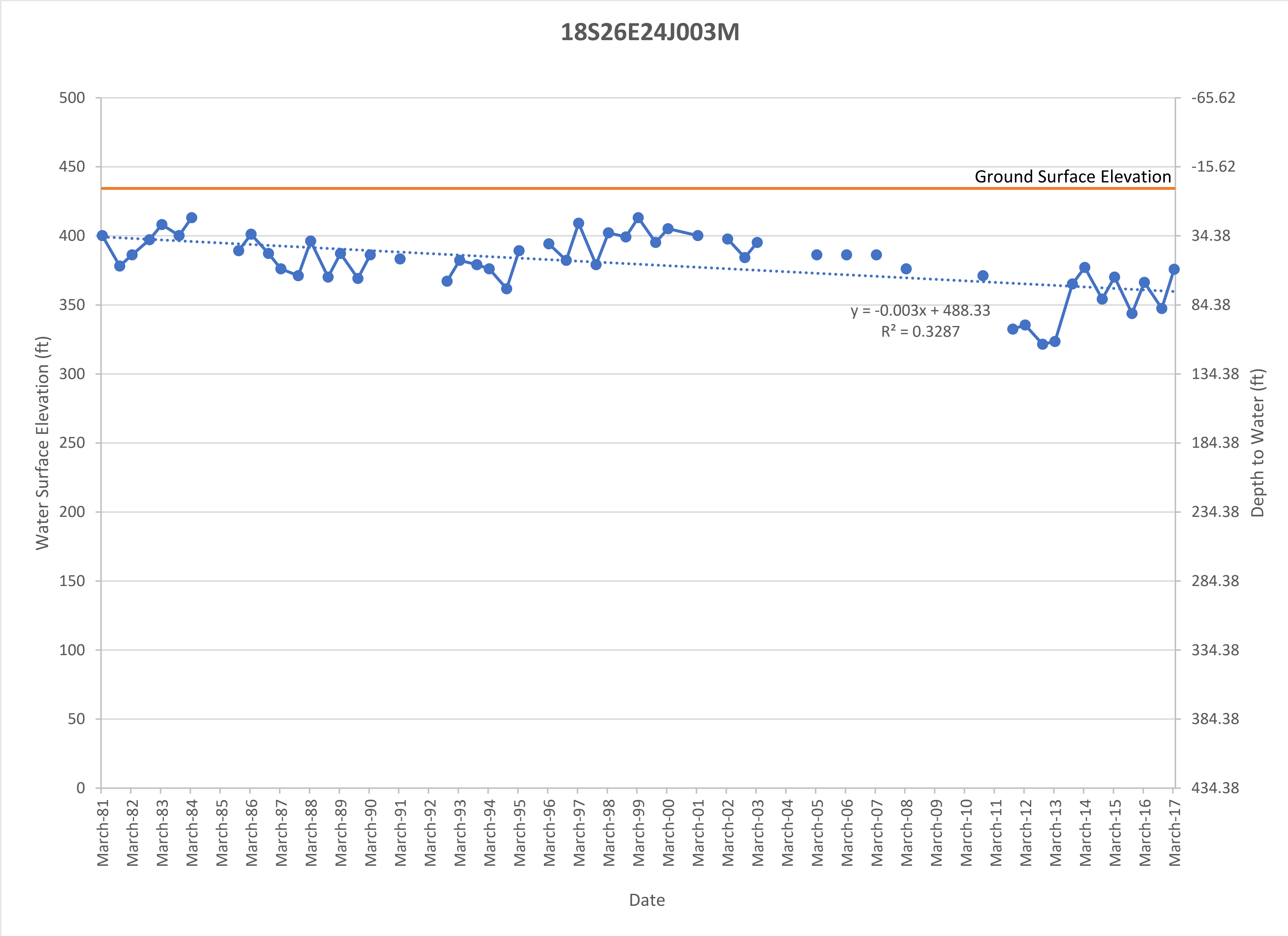
March-15
March-16
March-17



18S26E03H001
Ground Surface Elevation
y = -0.0012x + 415.52
R² = 0.181
Water Surface Elevation (ft)
Depth to Water (ft)
Date
500
450
400
350
300
250
200
150
100
50
0
-83.99
-33.99
16.01
66.01
116.01
166.01
216.01
266.01
316.01
366.01
416.01
March-81 March-82 March-83 March-84 March-85 March-86 March-87 March-88 March-89 March-90 March-91 March-92 March-93 March-94 March-95 March-96 March-97 March-98 March-99 March-00 March-01 March-02 March-03 March-04 March-05 March-06 March-07 March-08 March-09 March-10 March-11 March-12 March-13 March-14 March-15 March-16 March-17


18S26E05L001
Ground Surface Elevation
Water Surface Elevation (ft)
Depth to Water (ft)
y = -0.0015x + 370.08
R² = 0.2606
Date
500
450
400
350
300
250
200
150
100
50
0
-113.52
-63.52
-13.52
36.48
86.48
136.48
186.48
236.48
286.48
336.48
March-81
March-82
March-83
March-84
March-85
March-86
March-87
March-88
March-89
March-90
March-91
March-92
March-93
March-94
March-95
March-96
March-97
March-98
March-99
March-00
March-01
March-02
March-03
March-04
March-05
March-06
March-07
March-08
March-09
March-10
March-11
March-12
March-13
March-14
March-15
March-16
March-17

Kaweah River Alluvial Fan



18S26E24J003M
Water Surface Elevation (ft)
Depth to Water (ft)
Ground Surface Elevation
y = -0.003x + 488.33
R² = 0.3287
Date
500
450
400
350
300
250
200
150
100
50
0
-65.62
-15.62
34.38
84.38
134.38
184.38
234.38
284.38
334.38
384.38
434.38
March-81
March-82
March-83
March-84
March-85
March-86
March-87
March-88
March-89
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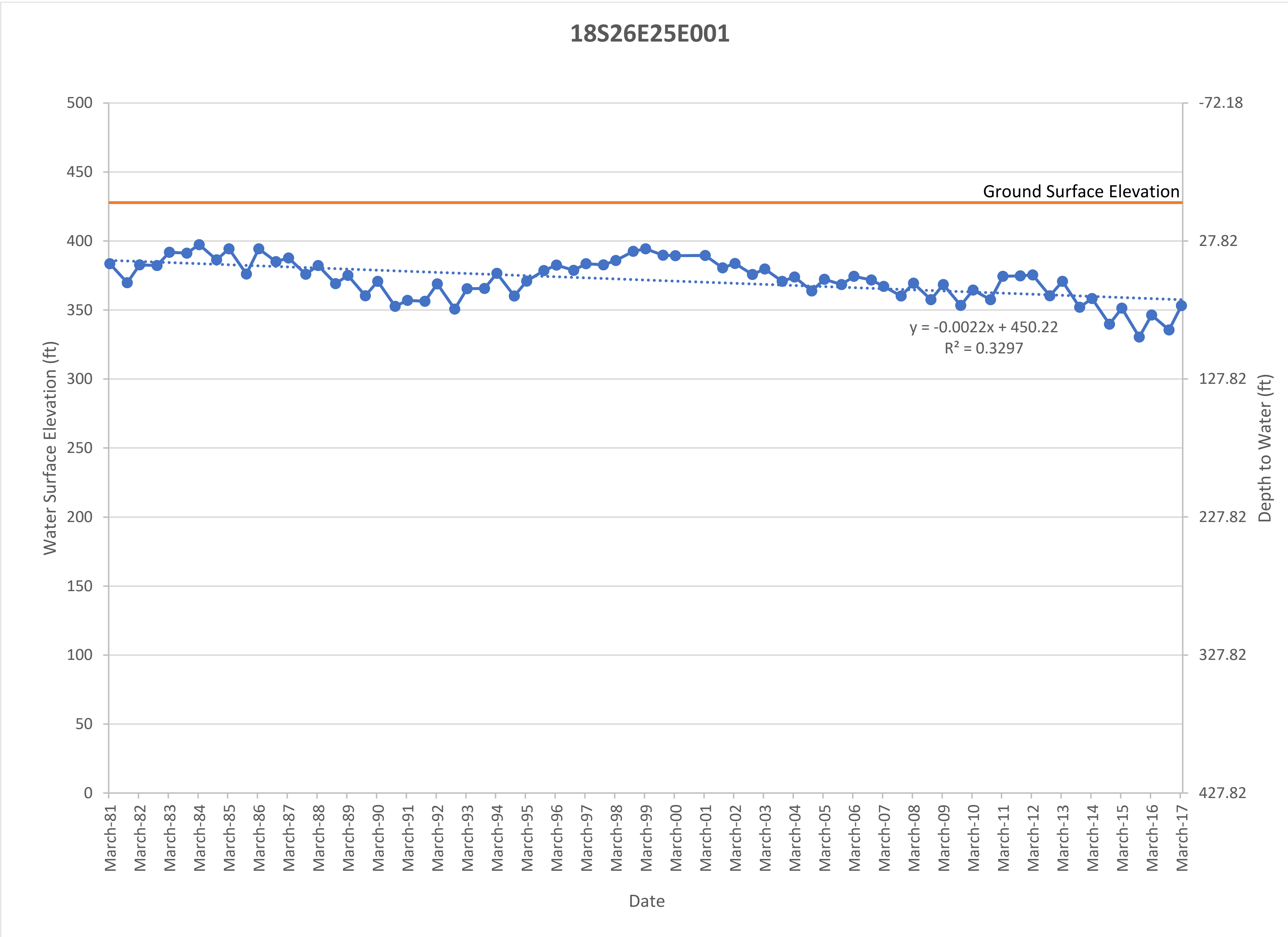
18S26E25E001
Ground Surface Elevation
y = -0.0022x + 450.22
R² = 0.3297
Water Surface Elevation (ft)
Depth to Water (ft)
Date
500
450
400
350
300
250
200
150
100
50
0
-72.18
27.82
127.82
227.82
327.82
427.82
March-81
March-82
March-83
March-84
March-85
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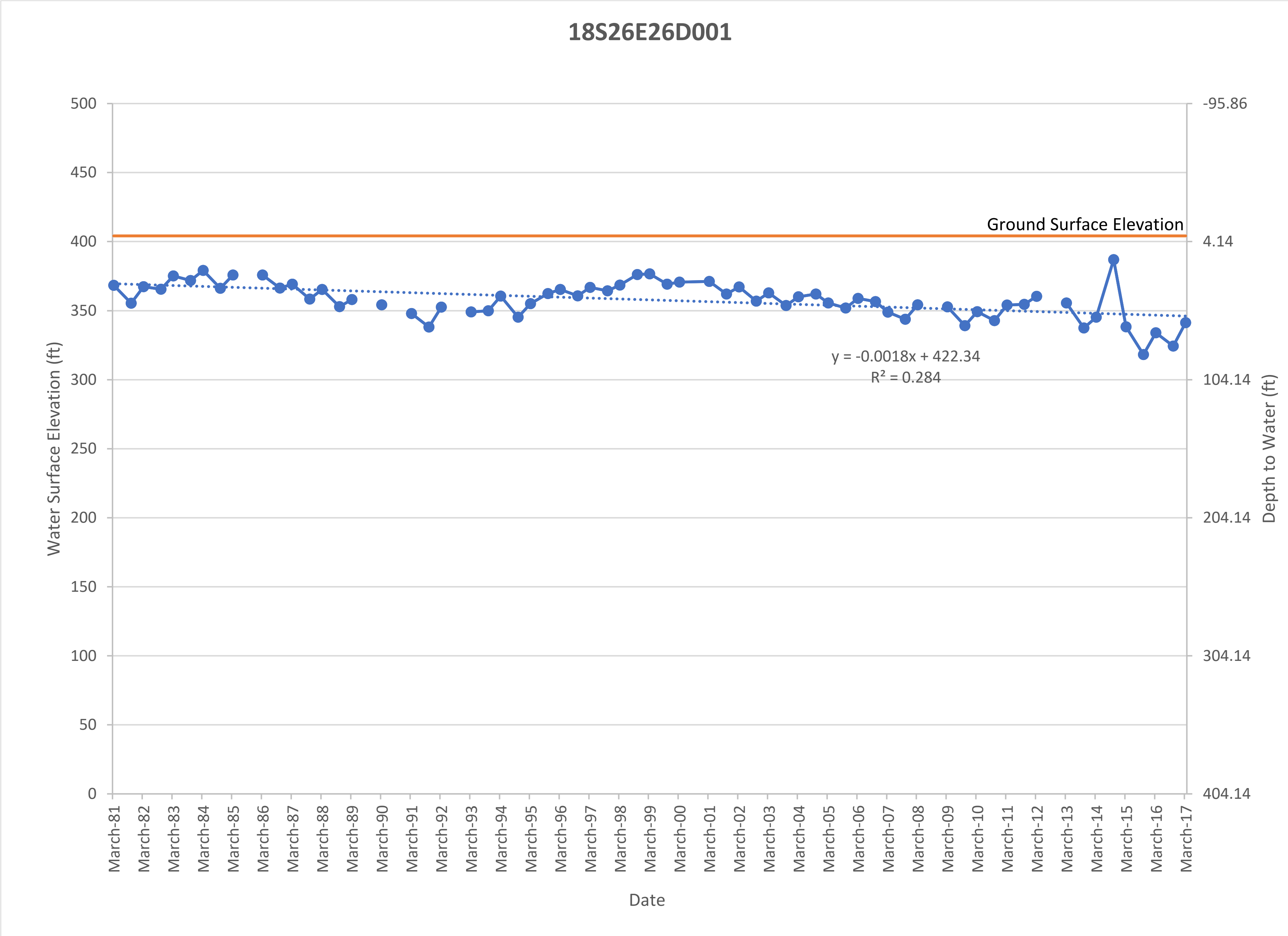

18S26E26D001
Ground Surface Elevation
y = -0.0018x + 422.34
R^2 = 0.284
Water Surface Elevation (ft)
Depth to Water (ft)
Date
500
450
400
350
300
250
200
150
100
50
0
-95.86
4.14
104.14
204.14
304.14
404.14
March-81
March-82
March-83
March-84
March-85
March-86
March-87
March-88
March-89
March-90
March-91
March-92
March-93
March-94
March-95
March-96
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March-00
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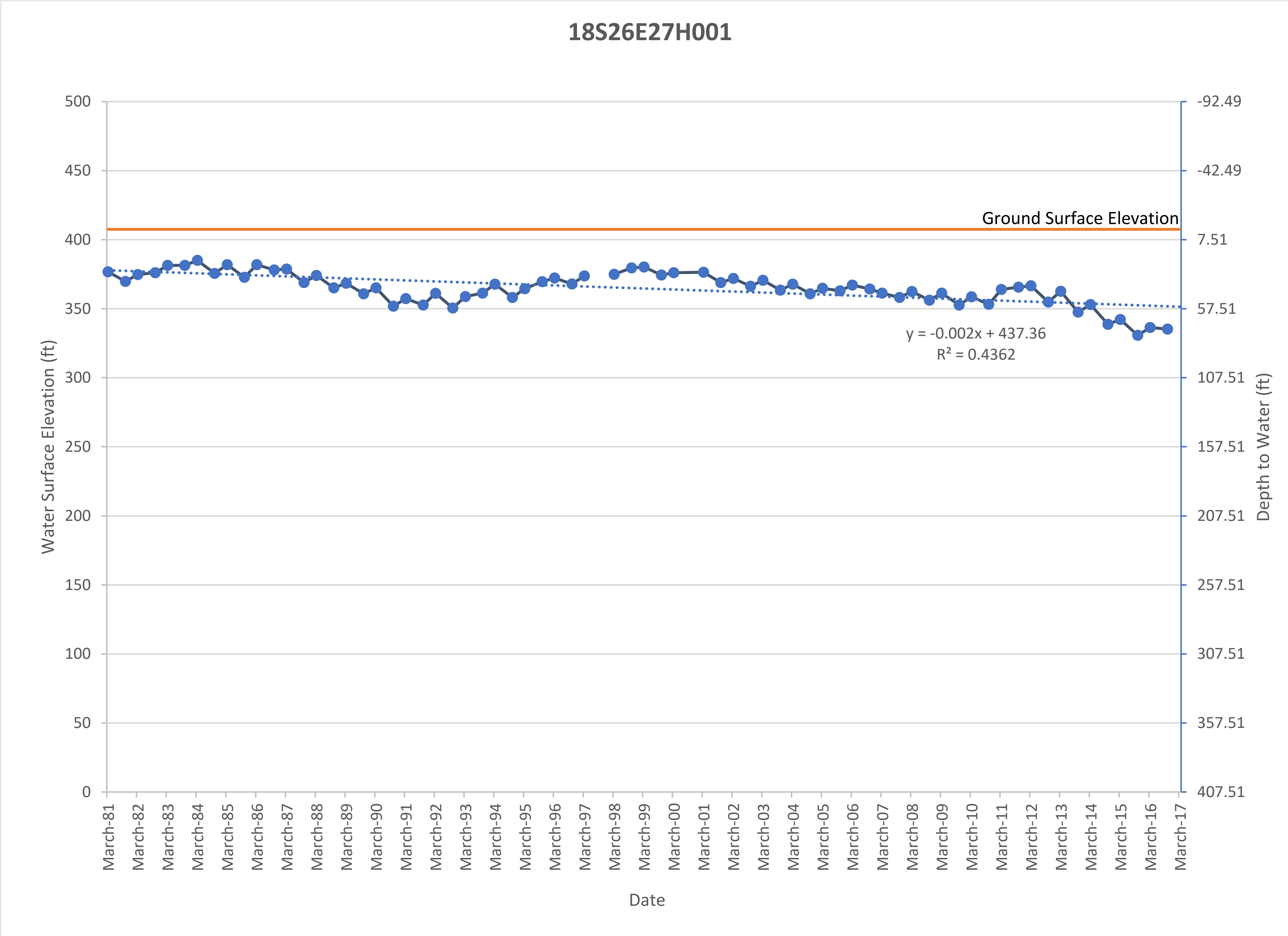

18S26E27H001
Ground Surface Elevation
y = -0.002x + 437.36
R² = 0.4362
Water Surface Elevation (ft)
Depth to Water (ft)
Date
500
450
400
350
300
250
200
150
100
50
0
-92.49
-42.49
7.51
57.51
107.51
157.51
207.51
257.51
307.51
357.51
407.51
March-81
March-82
March-83
March-84
March-85
March-86
March-87
March-88
March-89
March-90
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March-92
March-93
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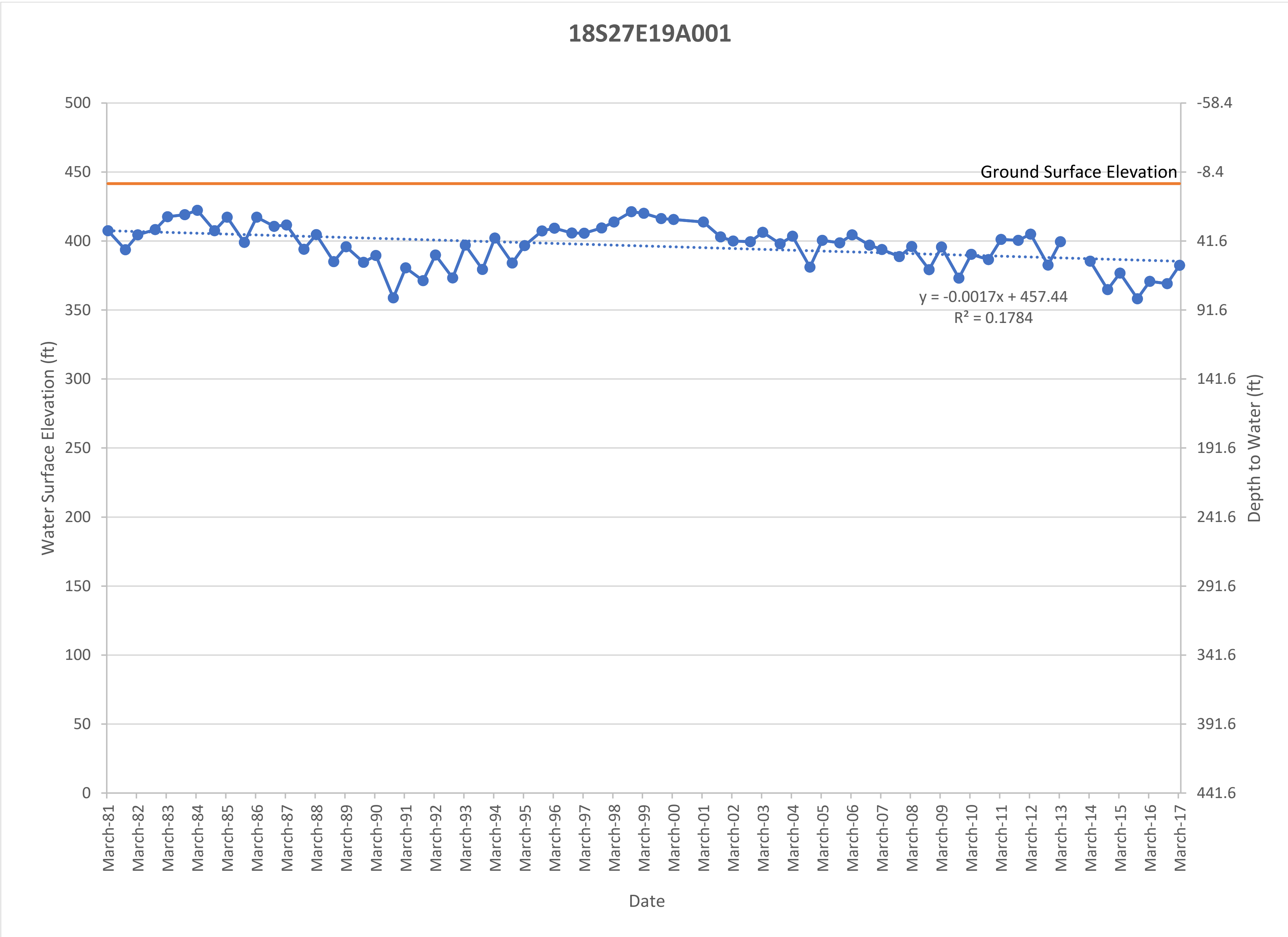

18S27E19A001
Ground Surface Elevation
y = -0.0017x + 457.44
R^2 = 0.1784
Water Surface Elevation (ft)
Depth to Water (ft)
Date
500
450
400
350
300
250
200
150
100
50
0
-58.4
-8.4
41.6
91.6
141.6
191.6
241.6
291.6
341.6
391.6
441.6
March-81
March-82
March-83
March-84
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March-00
March-01
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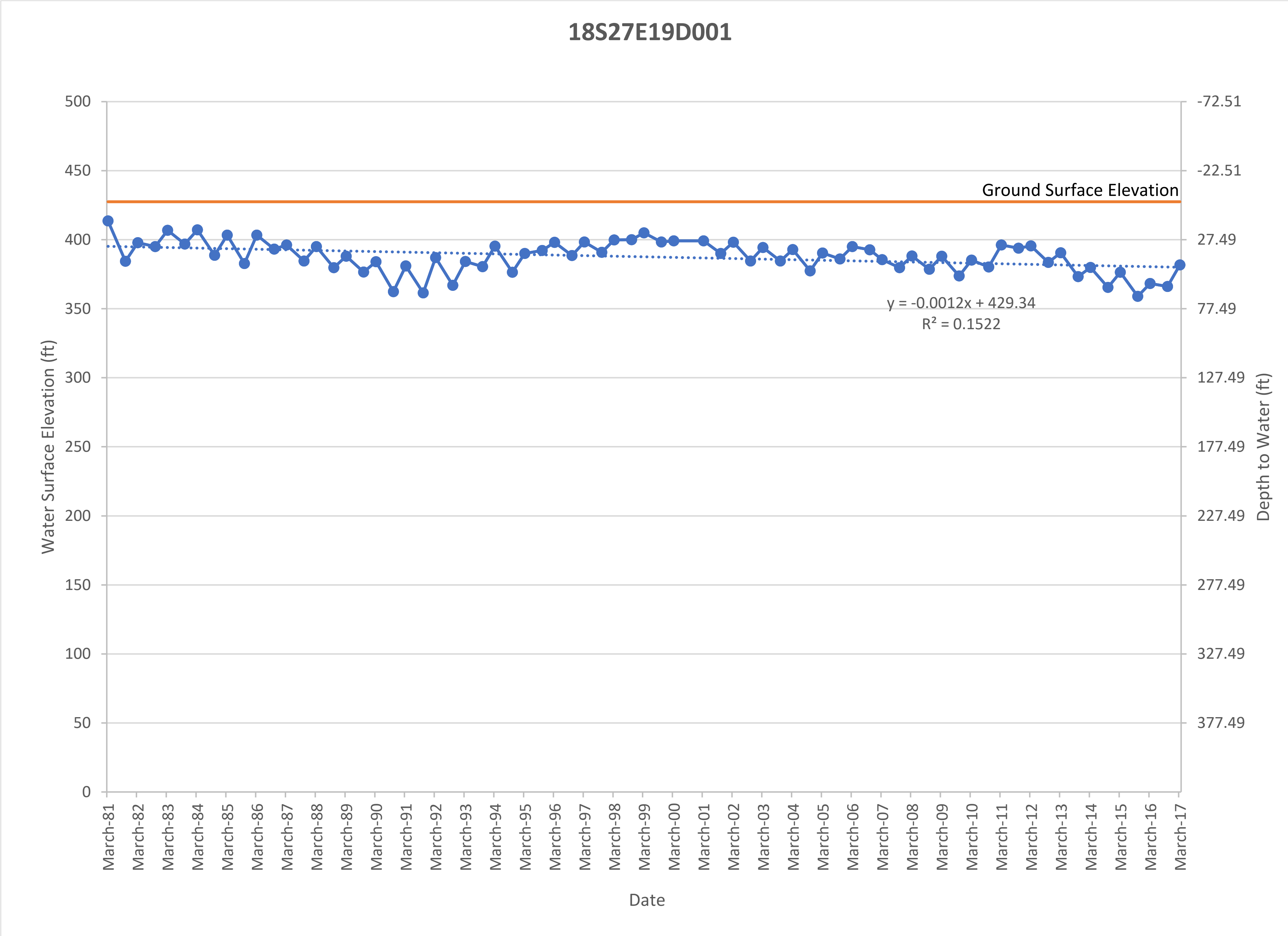
March-16
March-17



18S27E19D001
Ground Surface Elevation
y = -0.0012x + 429.34
R² = 0.1522
Water Surface Elevation (ft)
Depth to Water (ft)
Date
500
450
400
350
300
250
200
150
100
50
0
-72.51
-22.51
27.49
77.49
127.49
177.49
227.49
277.49
327.49
377.49
March-81
March-82
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March-84
March-85
March-86
March-87
March-88
March-89
March-90
March-91
March-92
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March-97
March-98
March-99
March-00
March-01
March-02
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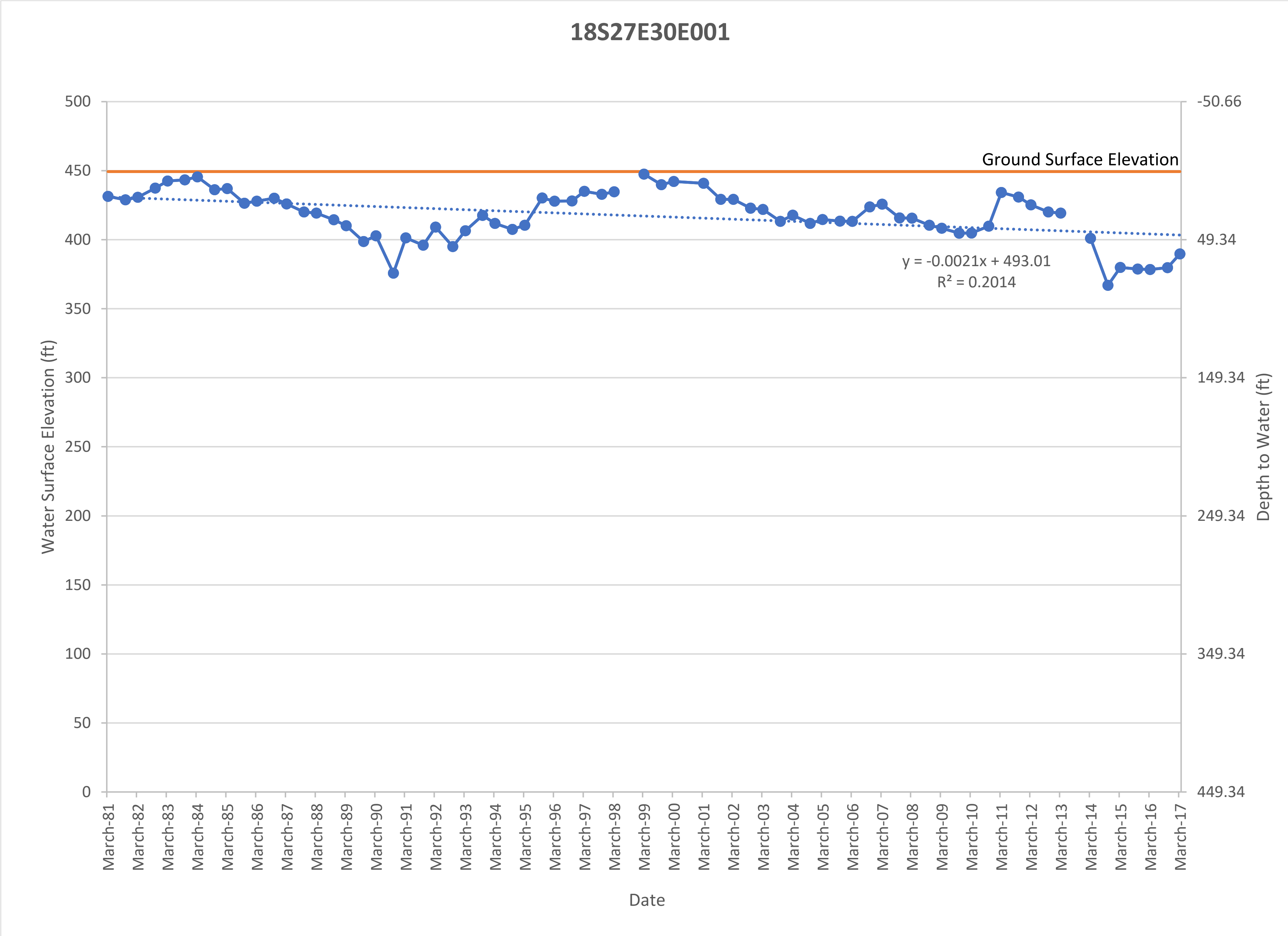

18S27E30E001
Ground Surface Elevation
y = -0.0021x + 493.01
R² = 0.2014
Water Surface Elevation (ft)
Depth to Water (ft)
Date
500
450
400
350
300
250
200
150
100
50
0
-50.66
49.34
149.34
249.34
349.34
449.34
March-81
March-82
March-83
March-84
March-85
March-86
March-87
March-88
March-89
March-90
March-91
March-92
March-93
March-94
March-95
March-96
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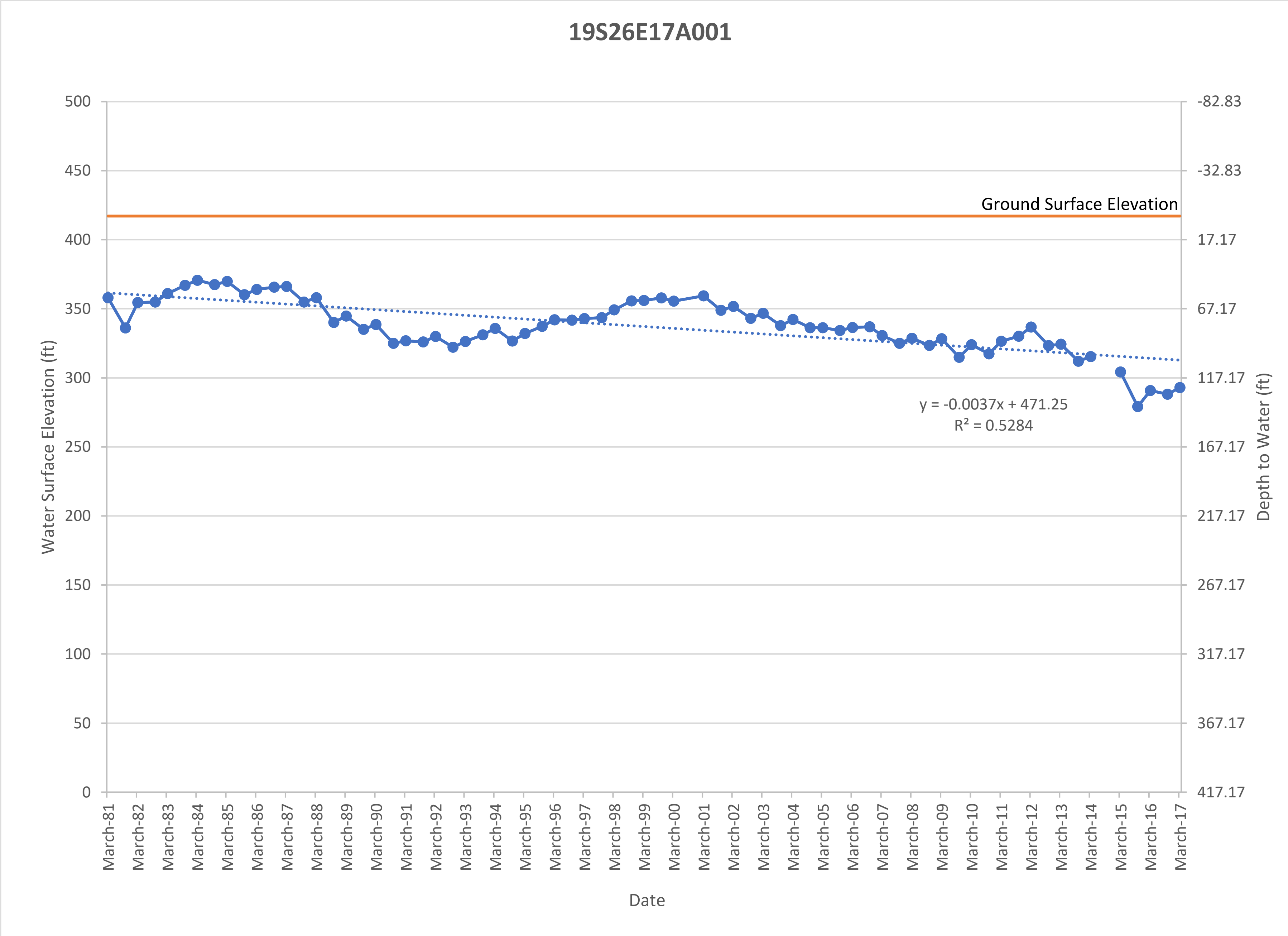
March-16
March-17


19S26E17A001
Ground Surface Elevation
y = -0.0037x + 471.25
R^2 = 0.5284
Water Surface Elevation (ft)
Depth to Water (ft)
Date
500
450
400
350
300
250
200
150
100
50
0
-82.83
-32.83
17.17
67.17
117.17
167.17
217.17
267.17
317.17
367.17
417.17
March-81
March-82
March-83
March-84
March-85
March-86
March-87
March-88
March-89
March-90
March-91
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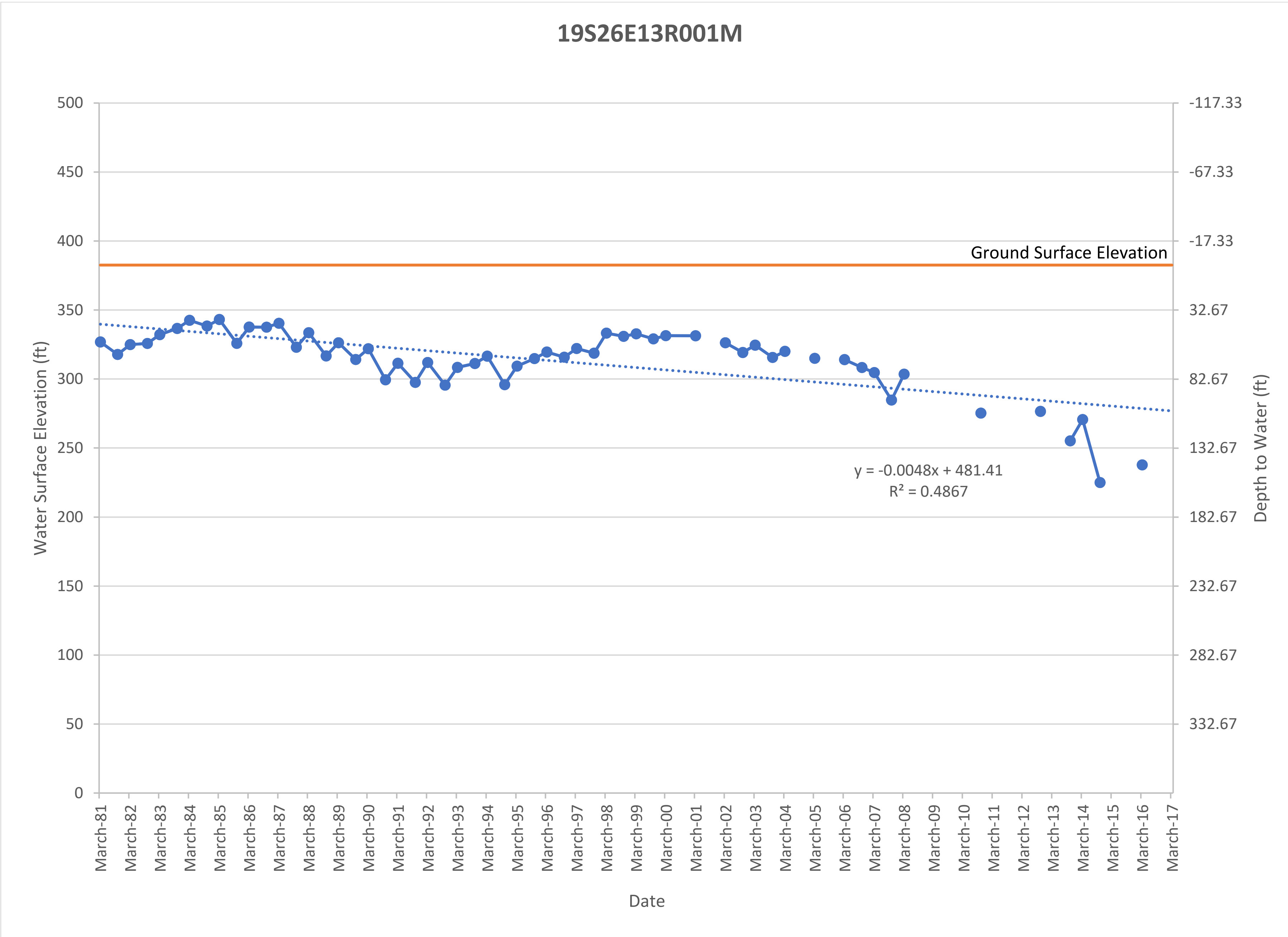
March-17

Lewis Creek Interfan


19S26E13R001M
Water Surface Elevation (ft)
Depth to Water (ft)
500
450
400
350
300
250
200
150
100
50
0
-117.33
-67.33
-17.33
32.67
82.67
132.67
182.67
232.67
282.67
332.67
Ground Surface Elevation
y = -0.0048x + 481.41
R² = 0.4867
March-81
March-82
March-83
March-84
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March-86
March-87
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March-90
March-91
March-92
March-93
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March-06
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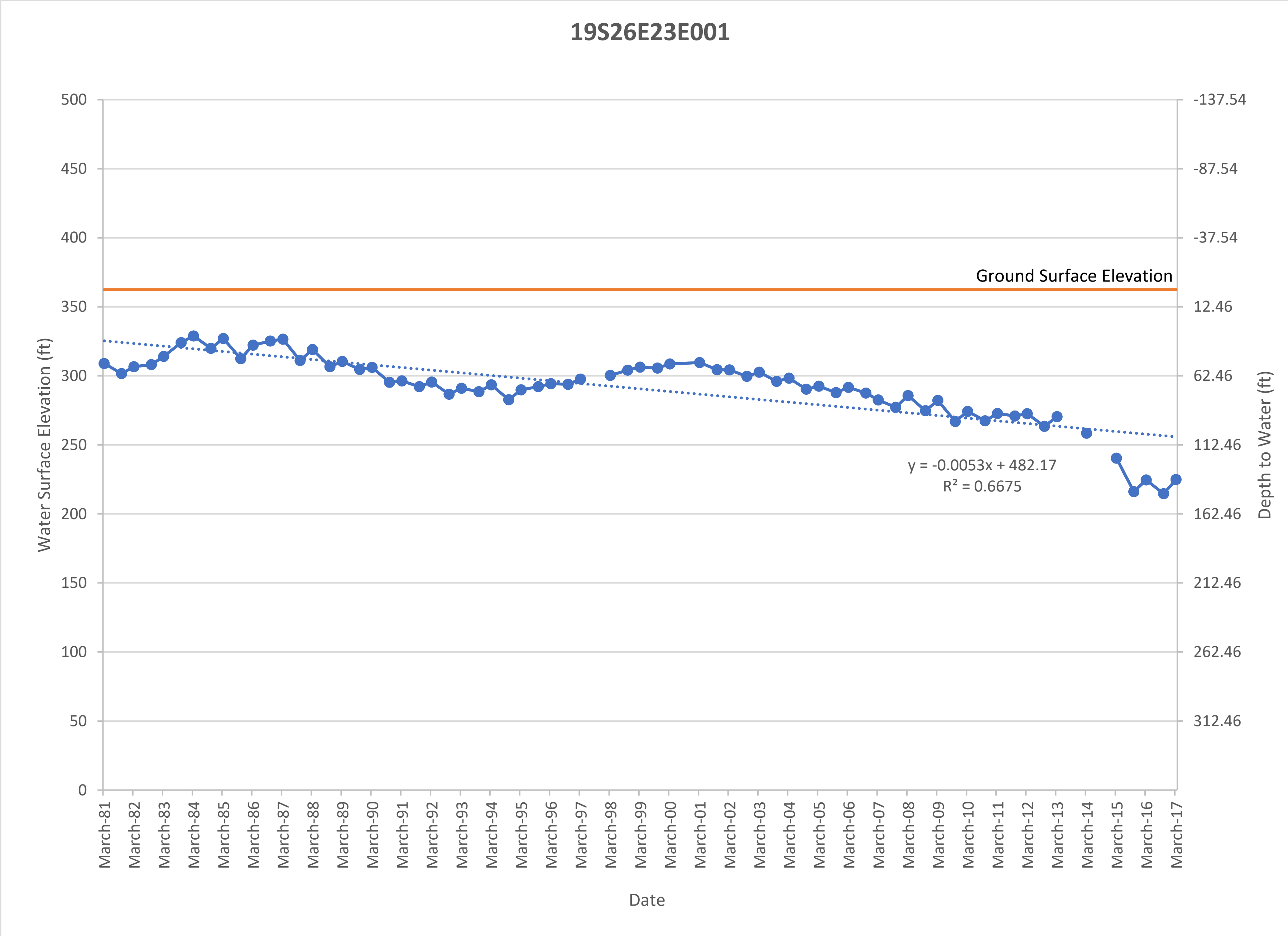
March-14
March-15
March-16
March-17
Date



19S26E23E001
Ground Surface Elevation
y = -0.0053x + 482.17
R² = 0.6675
Water Surface Elevation (ft)
Depth to Water (ft)
Date
500
450
400
350
300
250
200
150
100
50
0
-137.54
-87.54
-37.54
12.46
62.46
112.46
162.46
212.46
262.46
312.46
March-81
March-82
March-83
March-84
March-85
March-86
March-87
March-88
March-89
March-90
March-91
March-92
March-93
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March-00
March-01
March-02
March-03
March-04
March-05
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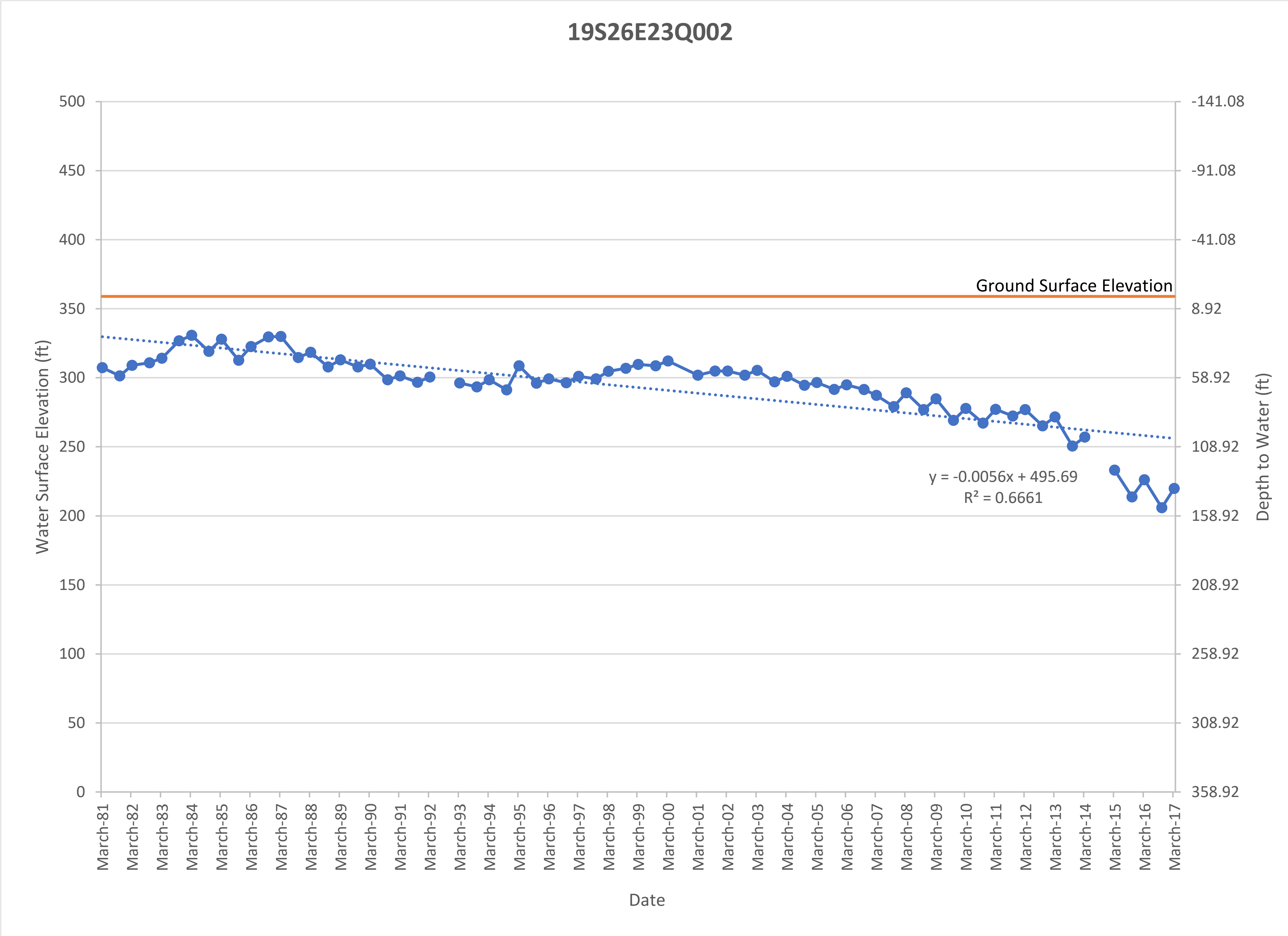
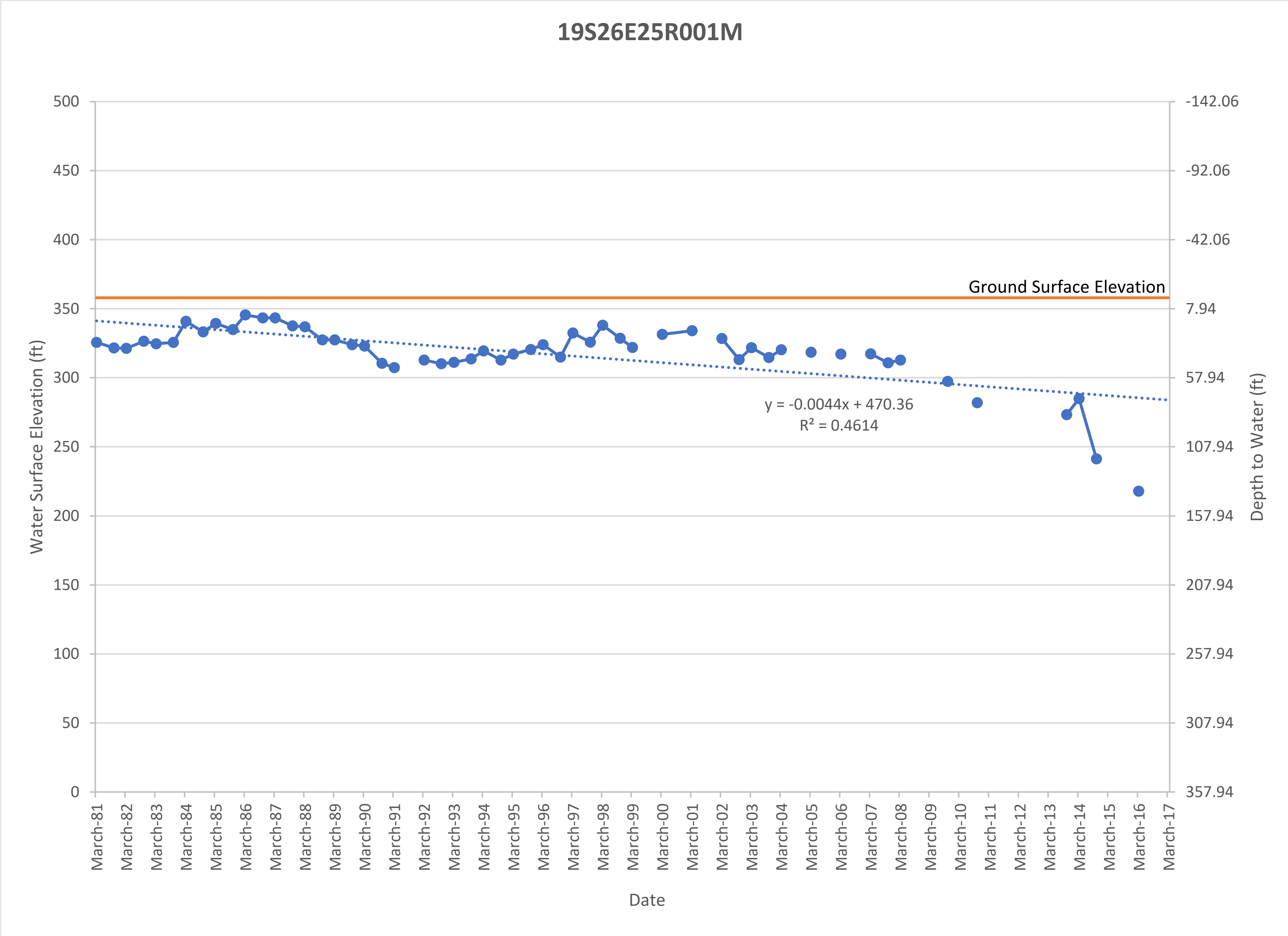
March-15
March-16
March-17


19S26E23Q002
Water Surface Elevation (ft)
Depth to Water (ft)
Date
Ground Surface Elevation
y = -0.0056x + 495.69
R² = 0.6661
500
450
400
350
300
250
200
150
100
50
0
-141.08
-91.08
-41.08
8.92
58.92
108.92
158.92
208.92
258.92
308.92
358.92
March-81 March-82 March-83 March-84 March-85 March-86 March-87 March-88 March-89 March-90 March-91 March-92 March-93 March-94 March-95 March-96 March-97 March-98 March-99 March-00 March-01 March-02 March-03 March-04 March-05 March-06 March-07 March-08 March-09 March-10 March-11 March-12 March-13 March-14 March-15 March-16 March-17


19S26E25R001M
Water Surface Elevation (ft)
Depth to Water (ft)
Date
Ground Surface Elevation
y = -0.0044x + 470.36
R² = 0.4614
500
450
400
350
300
250
200
150
100
50
0
-142.06
-92.06
-42.06
7.94
57.94
107.94
157.94
207.94
257.94
307.94
357.94
March-81
March-82
March-83
March-84
March-85
March-86
March-87
March-88
March-89
March-90
March-91
March-92
March-93
March-94
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March-98
March-99
March-00
March-01
March-02
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March-04
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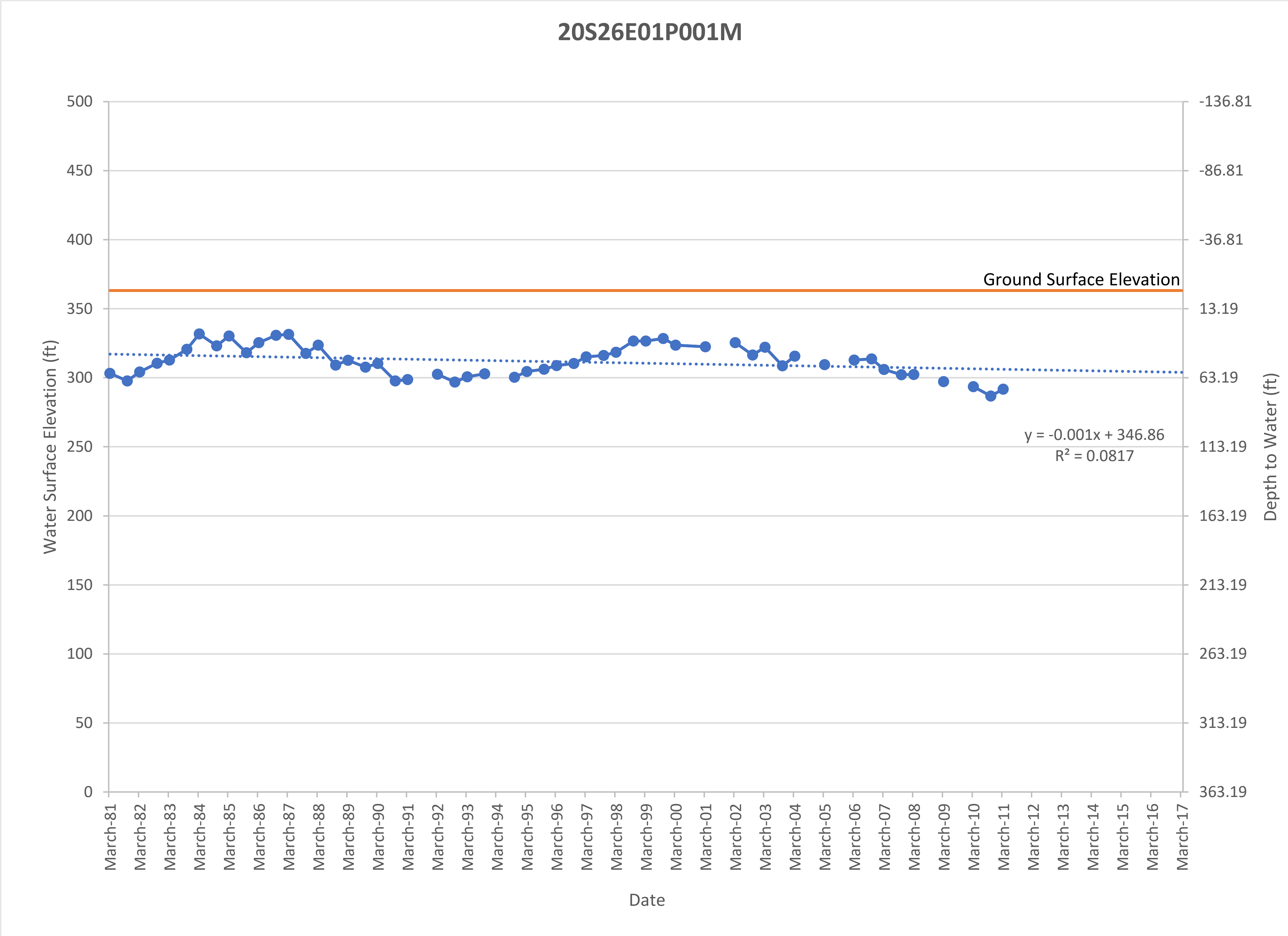
March-16
March-17


20S26E01P001M
Water Surface Elevation (ft)
Depth to Water (ft)
Ground Surface Elevation
y = -0.001x + 346.86
R² = 0.0817
500
450
400
350
300
250
200
150
100
50
0
-136.81
-86.81
-36.81
13.19
63.19
113.19
163.19
213.19
263.19
313.19
363.19
March-81
March-82
March-83
March-84
March-85
March-86
March-87
March-88
March-89
March-90
March-91
March-92
March-93
March-94
March-95
March-96
March-97
March-98
March-99
March-00
March-01
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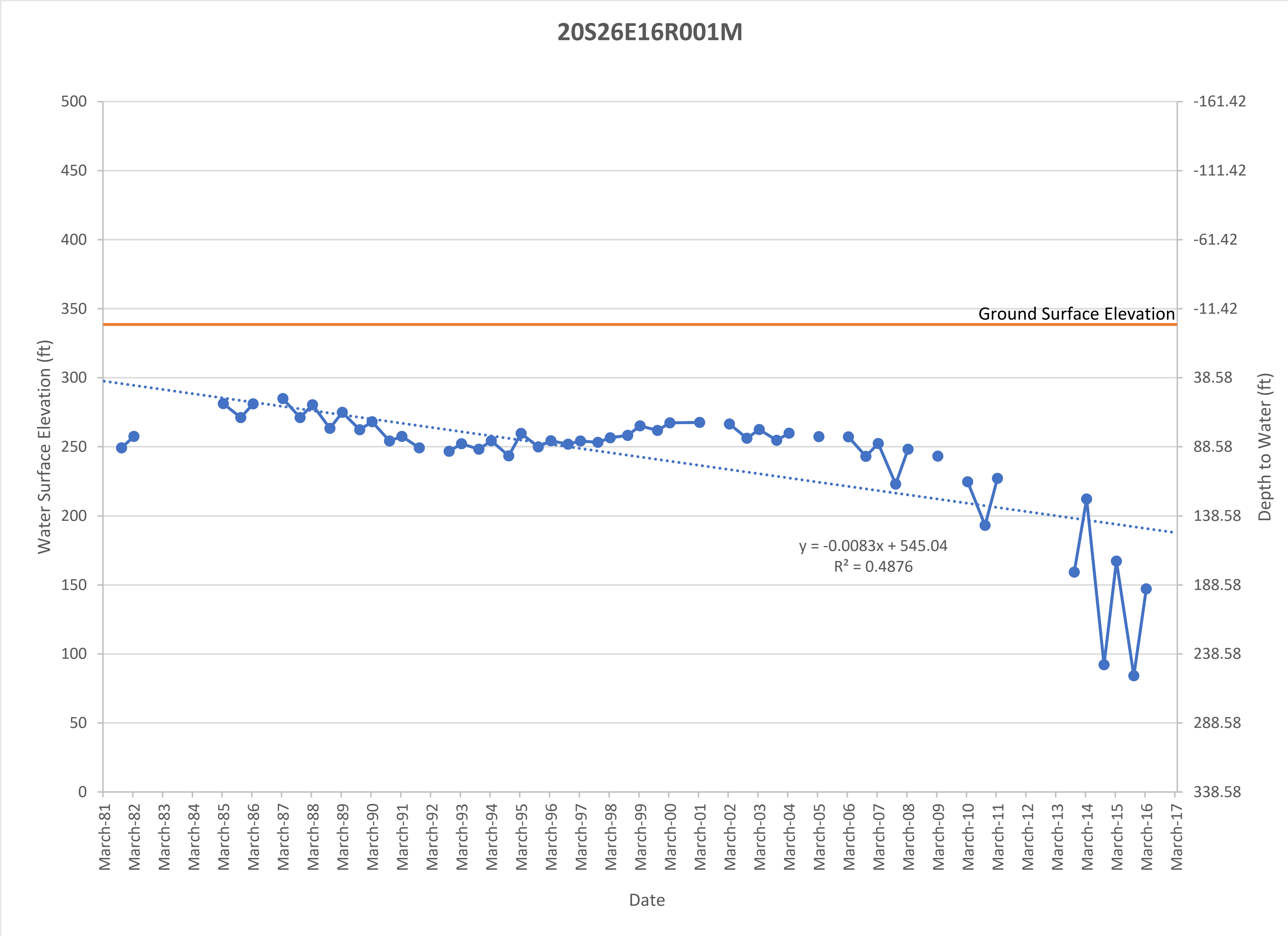
March-15
March-16
March-17
Date


20S26E16R001M
Water Surface Elevation (ft)
Depth to Water (ft)
Ground Surface Elevation
y = -0.0083x + 545.04
R² = 0.4876
Date
500
450
400
350
300
250
200
150
100
50
0
-161.42
-111.42
-61.42
-11.42
38.58
88.58
138.58
188.58
238.58
288.58
338.58
March-81
March-82
March-83
March-84
March-85
March-86
March-87
March-88
March-89
March-90
March-91
March-92
March-93
March-94
March-95
March-96
March-97
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March-02
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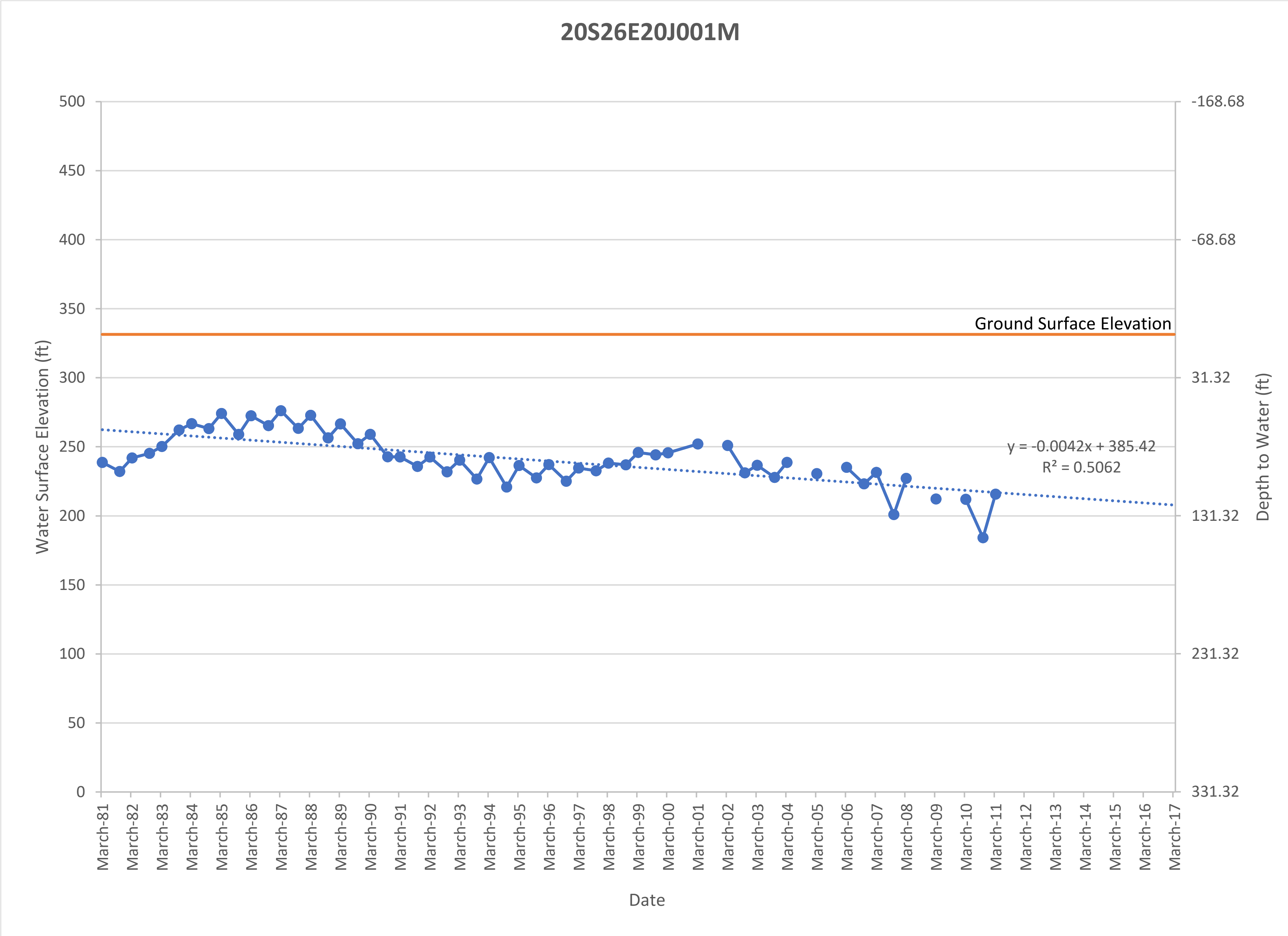
March-15
March-16
March-17



20S26E20J001M
Ground Surface Elevation
y = -0.0042x + 385.42
R^2 = 0.5062
Water Surface Elevation (ft)
Depth to Water (ft)
Date
500
450
400
350
300
250
200
150
100
50
0
-168.68
-68.68
31.32
131.32
231.32
331.32
March-81
March-82
March-83
March-84
March-85
March-86
March-87
March-88
March-89
March-90
March-91
March-92
March-93
March-94
March-95
March-96
March-97
March-98
March-99
March-00
March-01
March-02
March-03
March-04
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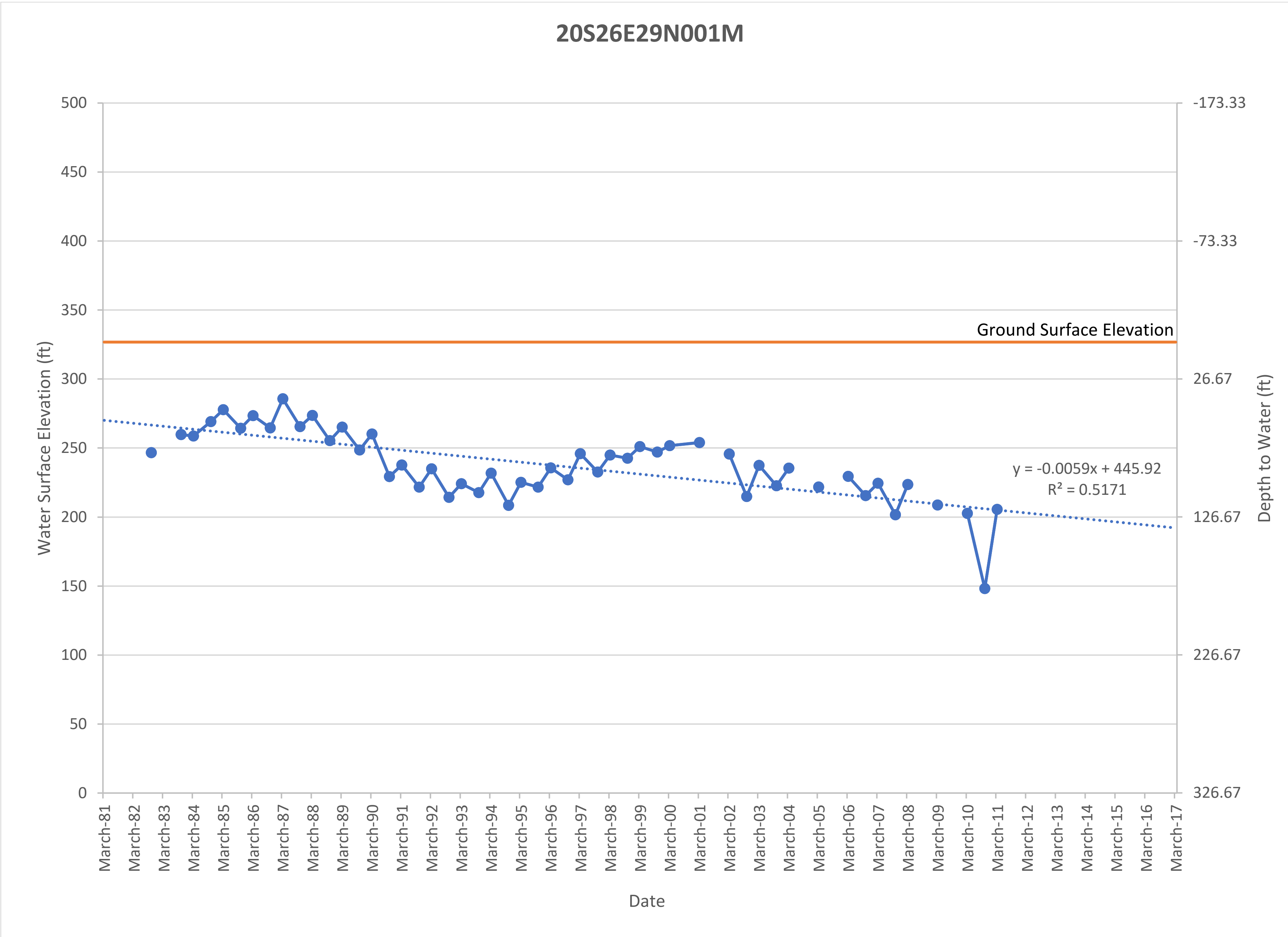

20S26E29N001M
Water Surface Elevation (ft)
Depth to Water (ft)
Ground Surface Elevation
y = -0.0059x + 445.92
R^2 = 0.5171
Date
500
450
400
350
300
250
200
150
100
50
0
-173.33
-73.33
26.67
126.67
226.67
326.67
March-81
March-82
March-83
March-84
March-85
March-86
March-87
March-88
March-89
March-90
March-91
March-92
March-93
March-94
March-95
March-96
March-97
March-98
March-99
March-00
March-01
March-02
March-03
March-04
March-05
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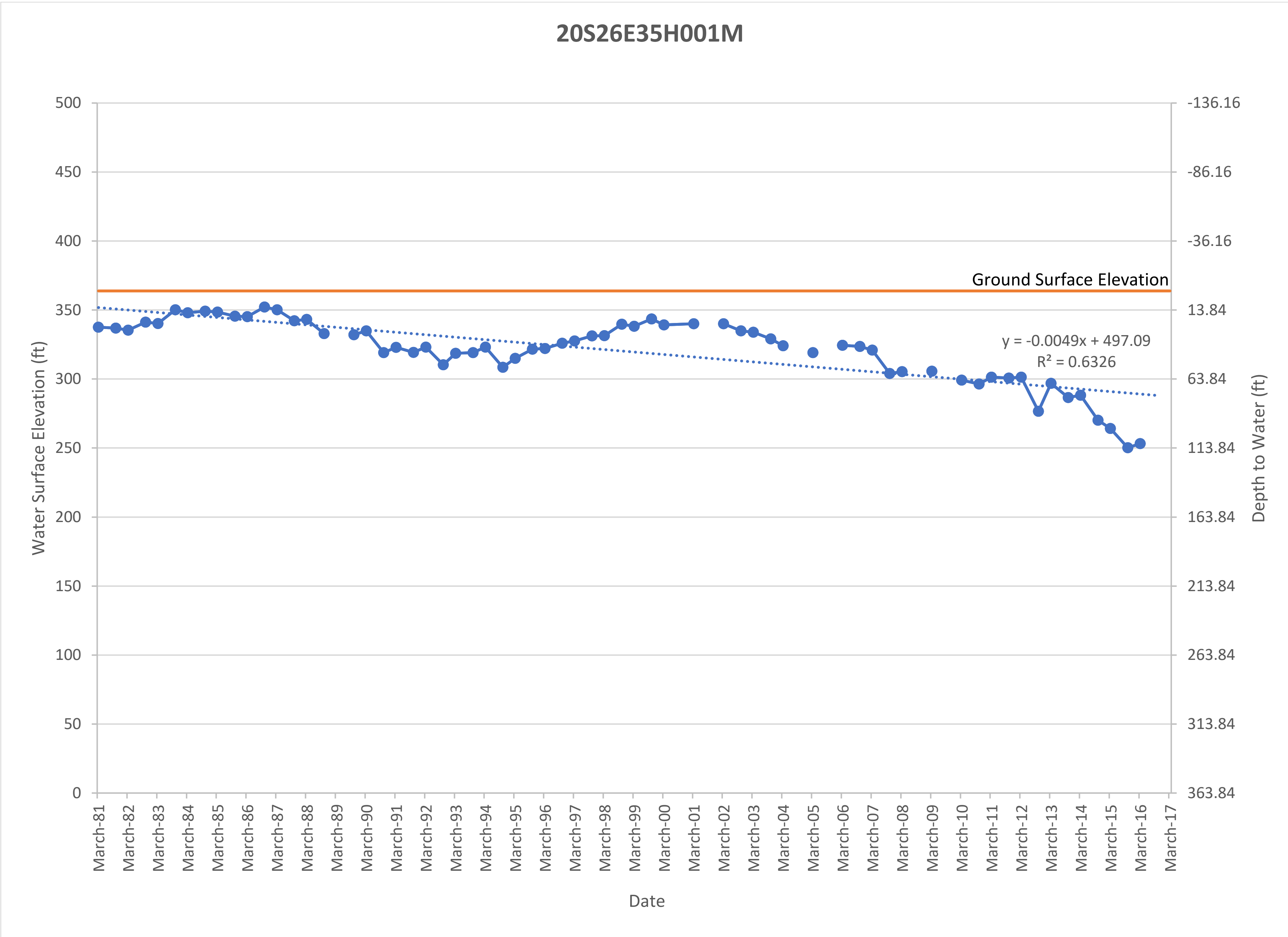
March-15
March-16
March-17


20S26E35H001M
Ground Surface Elevation
y = -0.0049x + 497.09
R^2 = 0.6326
Water Surface Elevation (ft)
Depth to Water (ft)
Date
500
450
400
350
300
250
200
150
100
50
0
-136.16
-86.16
-36.16
13.84
63.84
113.84
163.84
213.84
263.84
313.84
363.84
March-81
March-82
March-83
March-84
March-85
March-86
March-87
March-88
March-89
March-90
March-91
March-92
March-93
March-94
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March-97
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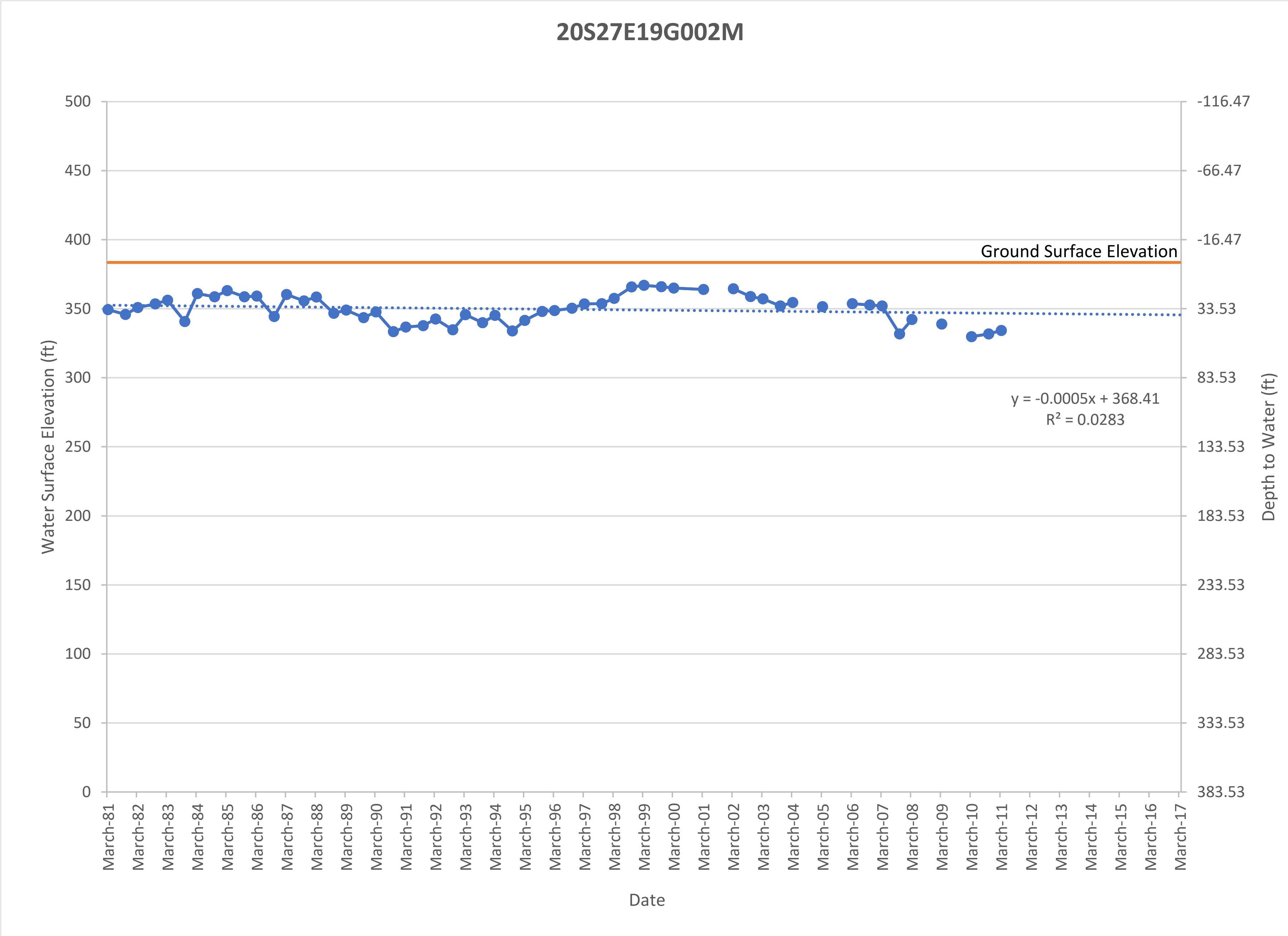

20S27E19G002M
Ground Surface Elevation
y = -0.0005x + 368.41
R² = 0.0283
Water Surface Elevation (ft)
Depth to Water (ft)
Date
500
450
400
350
300
250
200
150
100
50
0
-116.47
-66.47
-16.47
33.53
83.53
133.53
183.53
233.53
283.53
333.53
383.53
March-81
March-82
March-83
March-84
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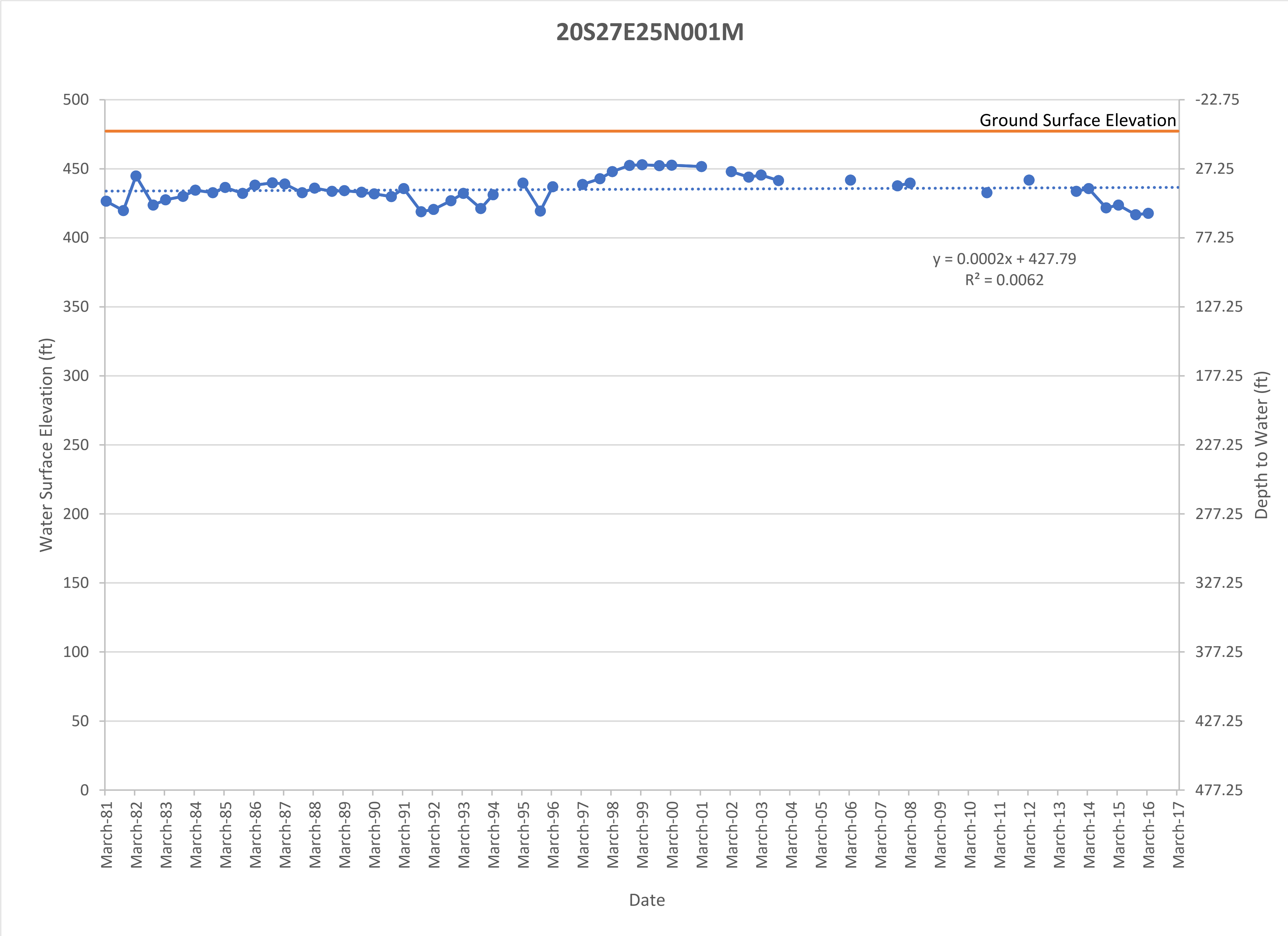

20S27E25N001M
Ground Surface Elevation
y = 0.0002x + 427.79
R² = 0.0062
Water Surface Elevation (ft)
Depth to Water (ft)
Date
500
450
400
350
300
250
200
150
100
50
0
-22.75
27.25
77.25
127.25
177.25
227.25
277.25
327.25
377.25
427.25
477.25
March-81
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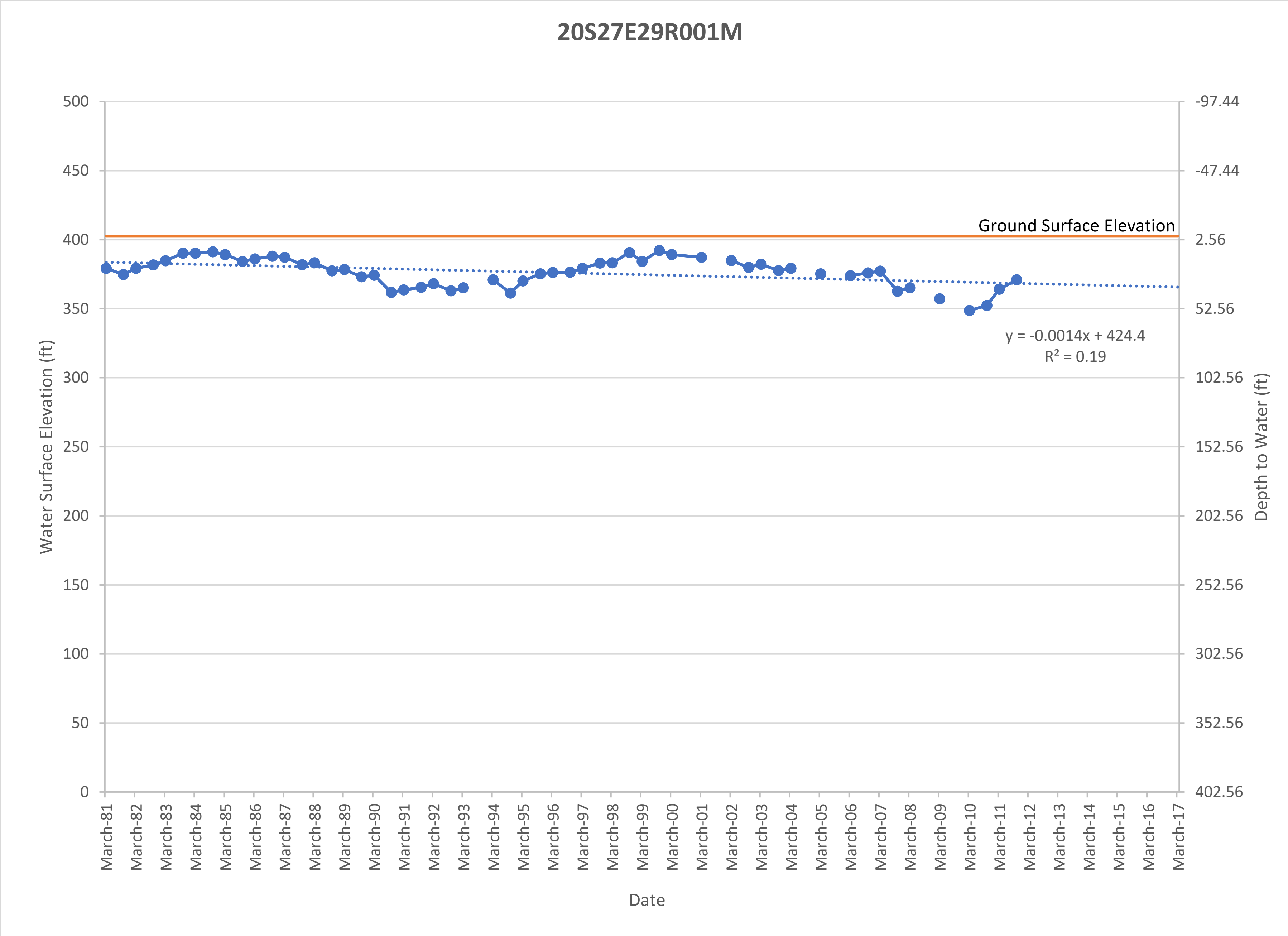

20S27E29R001M
Ground Surface Elevation
y = -0.0014x + 424.4
R^2 = 0.19
Water Surface Elevation (ft)
Depth to Water (ft)
Date
500
450
400
350
300
250
200
150
100
50
0
-97.44
-47.44
2.56
52.56
102.56
152.56
202.56
252.56
302.56
352.56
402.56
March-81
March-82
March-83
March-84
March-85
March-86
March-87
March-88
March-89
March-90
March-91
March-92
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March-97
March-98
March-99
March-00
March-01
March-02
March-03
March-04
March-05
March-06
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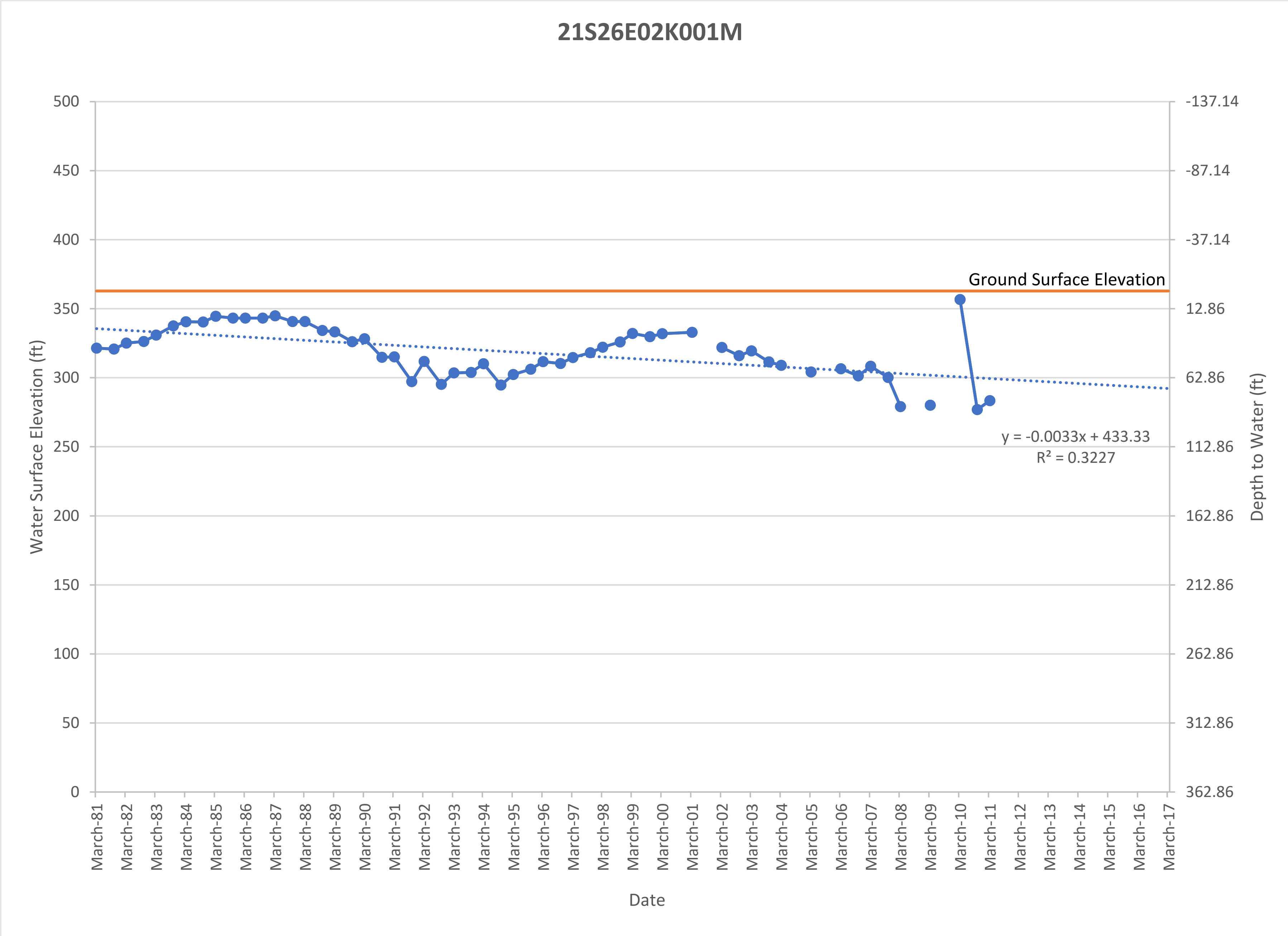
March-10
March-11
March-12
March-13
March-14
March-15
March-16
March-17



21S26E02K001M
Ground Surface Elevation
y = -0.0033x + 433.33
R² = 0.3227
Water Surface Elevation (ft)
Depth to Water (ft)
Date
500
450
400
350
300
250
200
150
100
50
0
-137.14
-87.14
-37.14
12.86
62.86
112.86
162.86
212.86
262.86
312.86
362.86
March-81
March-82
March-83
March-84
March-85
March-86
March-87
March-88
March-89
March-90
March-91
March-92
March-93
March-94
March-95
March-96
March-97
March-98
March-99
March-00
March-01
March-02
March-03
March-04
March-05
March-06
March-07
March-08
March-09
March-10
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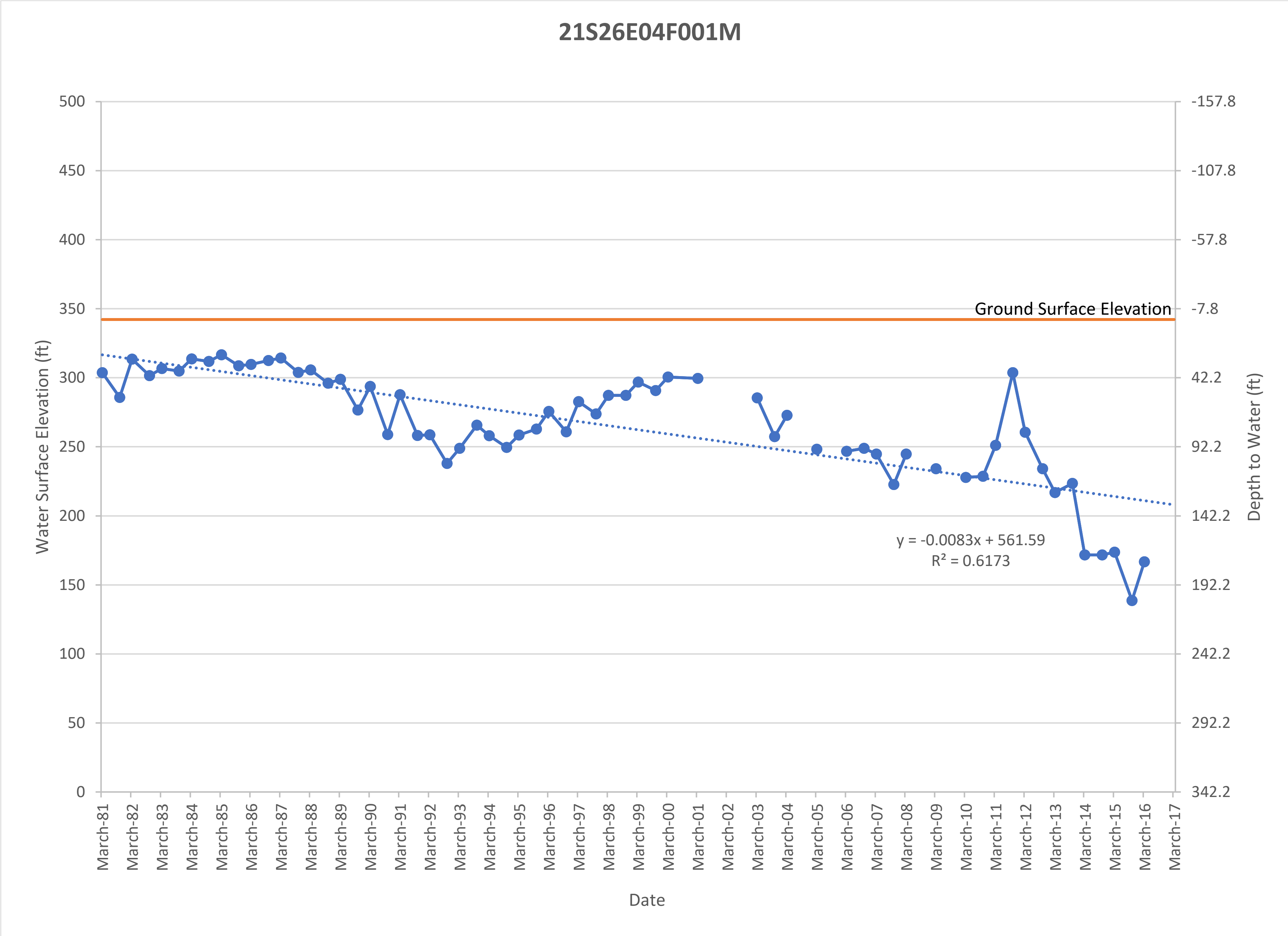
March-12
March-13
March-14
March-15
March-16
March-17



21S26E04F001M
Water Surface Elevation (ft)
Depth to Water (ft)
Ground Surface Elevation
y = -0.0083x + 561.59
R² = 0.6173
500
450
400
350
300
250
200
150
100
50
0
-157.8
-107.8
-57.8
-7.8
42.2
92.2
142.2
192.2
242.2
292.2
342.2
March-81
March-82
March-83
March-84
March-85
March-86
March-87
March-88
March-89
March-90
March-91
March-92
March-93
March-94
March-95
March-96
March-97
March-98
March-99
March-00
March-01
March-02
March-03
March-04
March-05
March-06
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March-11
March-12
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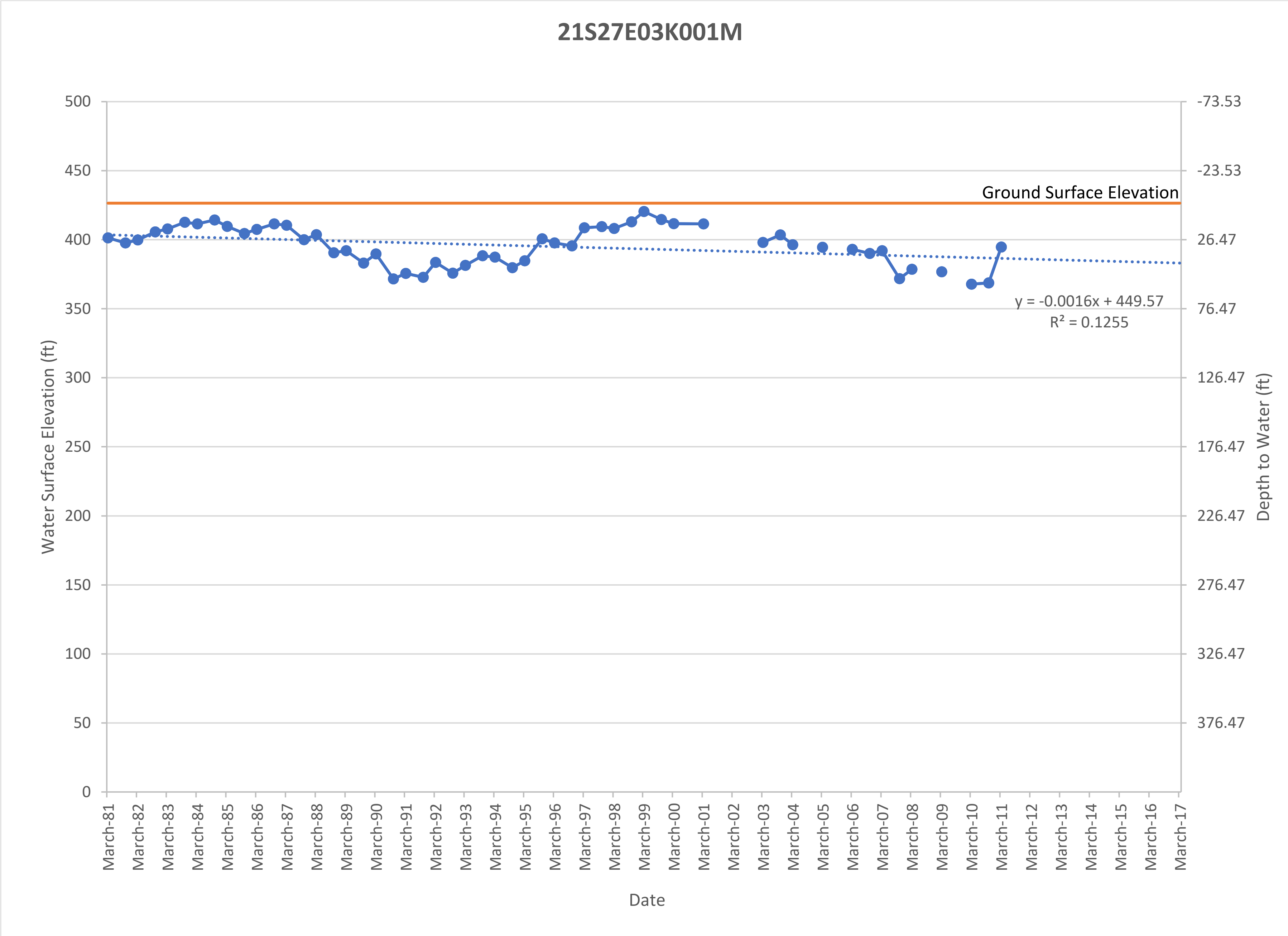
March-14
March-15
March-16
March-17
Date



21S27E03K001M
Water Surface Elevation (ft)
Depth to Water (ft)
Ground Surface Elevation
y = -0.0016x + 449.57
R² = 0.1255
500
450
400
350
300
250
200
150
100
50
0
-73.53
-23.53
26.47
76.47
126.47
176.47
226.47
276.47
326.47
376.47
March-81
March-82
March-83
March-84
March-85
March-86
March-87
March-88
March-89
March-90
March-91
March-92
March-93
March-94
March-95
March-96
March-97
March-98
March-99
March-00
March-01
March-02
March-03
March-04
March-05
March-06
March-07
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March-09
March-10
March-11
March-12
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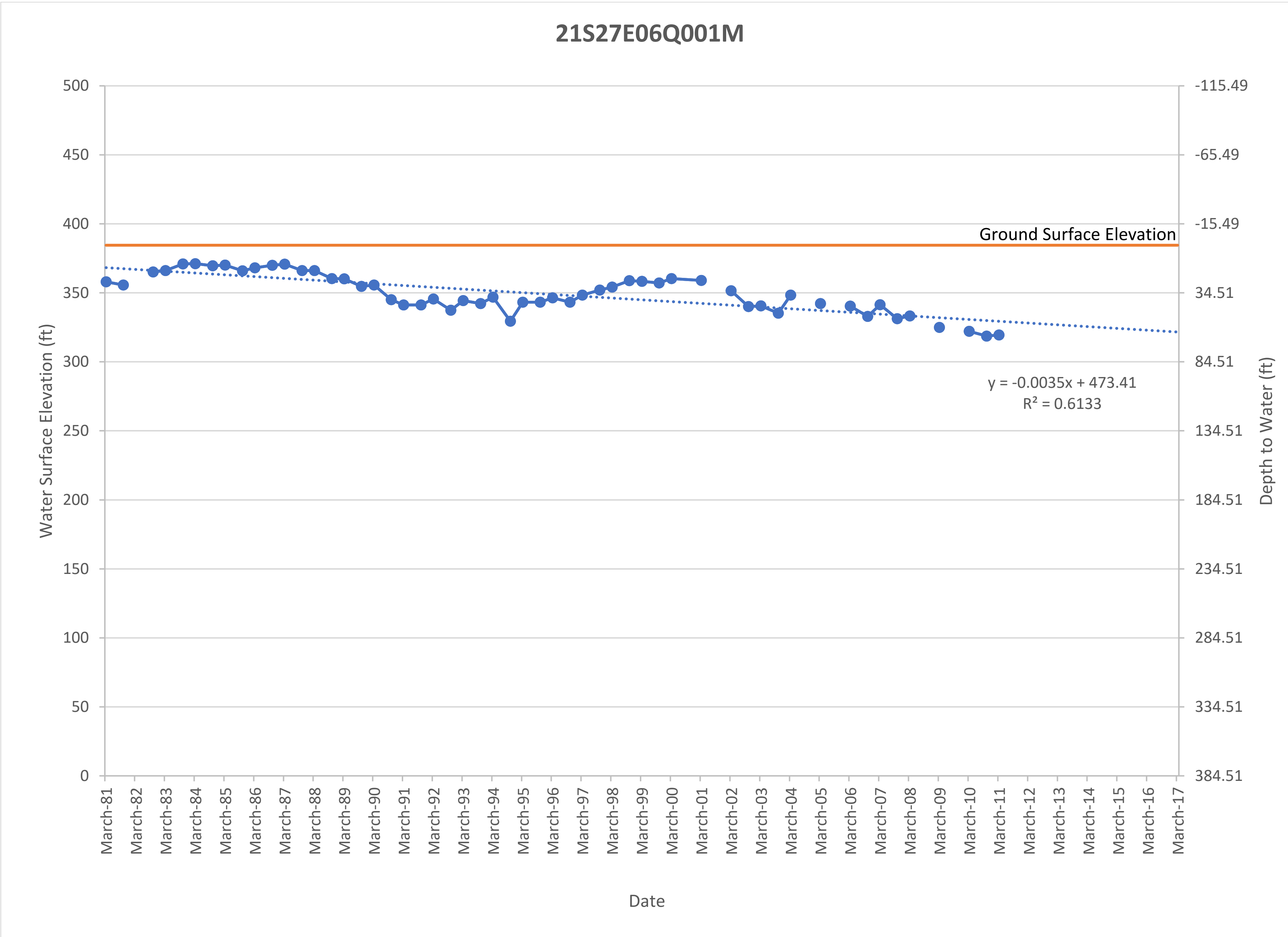
March-14
March-15
March-16
March-17
Date



21S27E06Q001M
Water Surface Elevation (ft)
Depth to Water (ft)
Ground Surface Elevation
y = -0.0035x + 473.41
R² = 0.6133
Date
500
450
400
350
300
250
200
150
100
50
0
-115.49
-65.49
-15.49
34.51
84.51
134.51
184.51
234.51
284.51
334.51
384.51
March-81
March-82
March-83
March-84
March-85
March-86
March-87
March-88
March-89
March-90
March-91
March-92
March-93
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March-95
March-96
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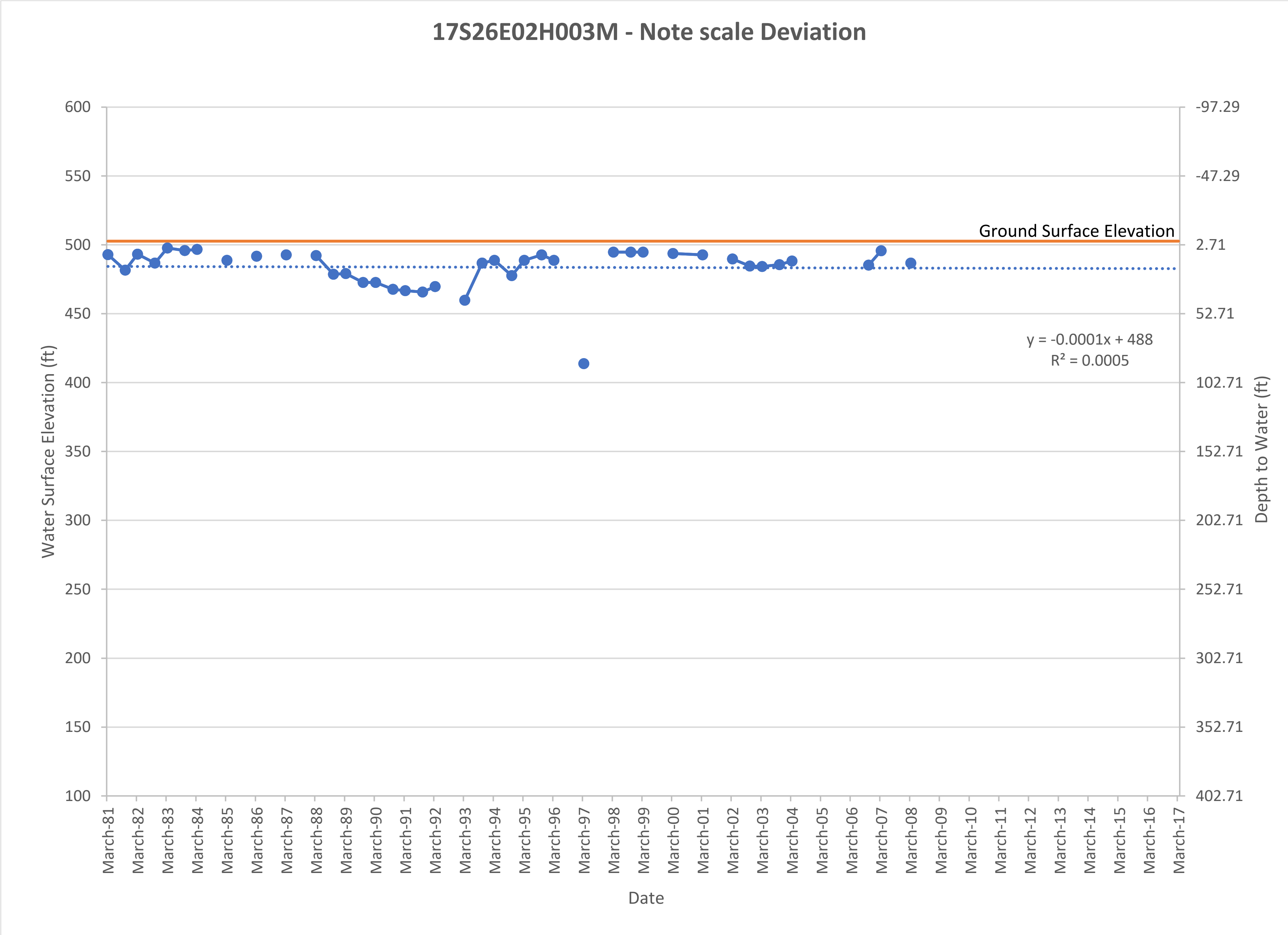
March-15
March-16
March-17

Intermontane Valleys


17S26E02H003M - Note scale Deviation
Ground Surface Elevation
y = -0.0001x + 488
R² = 0.0005
Water Surface Elevation (ft)
Depth to Water (ft)
Date
600
550
500
450
400
350
300
250
200
150
100
-97.29
-47.29
2.71
52.71
102.71
152.71
202.71
252.71
302.71
352.71
402.71
March-81
March-82
March-83
March-84
March-85
March-86
March-87
March-88
March-89
March-90
March-91
March-92
March-93
March-94
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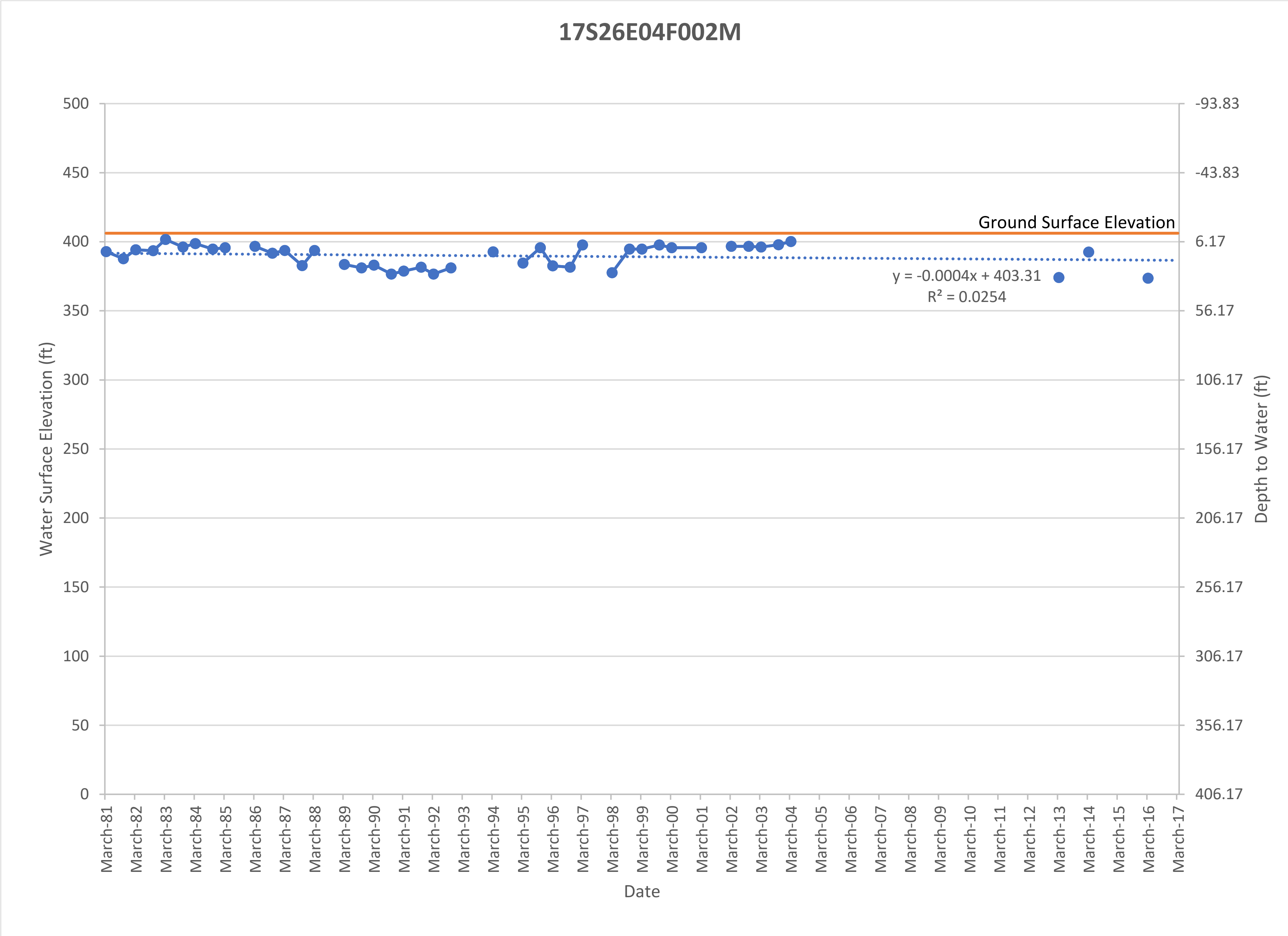

17S26E04F002M
Ground Surface Elevation
y = -0.0004x + 403.31
R² = 0.0254
Water Surface Elevation (ft)
Depth to Water (ft)
Date
500
450
400
350
300
250
200
150
100
50
0
-93.83
-43.83
6.17
56.17
106.17
156.17
206.17
256.17
306.17
356.17
406.17
March-81
March-82
March-83
March-84
March-85
March-86
March-87
March-88
March-89
March-90
March-91
March-92
March-93
March-94
March-95
March-96
March-97
March-98
March-99
March-00
March-01
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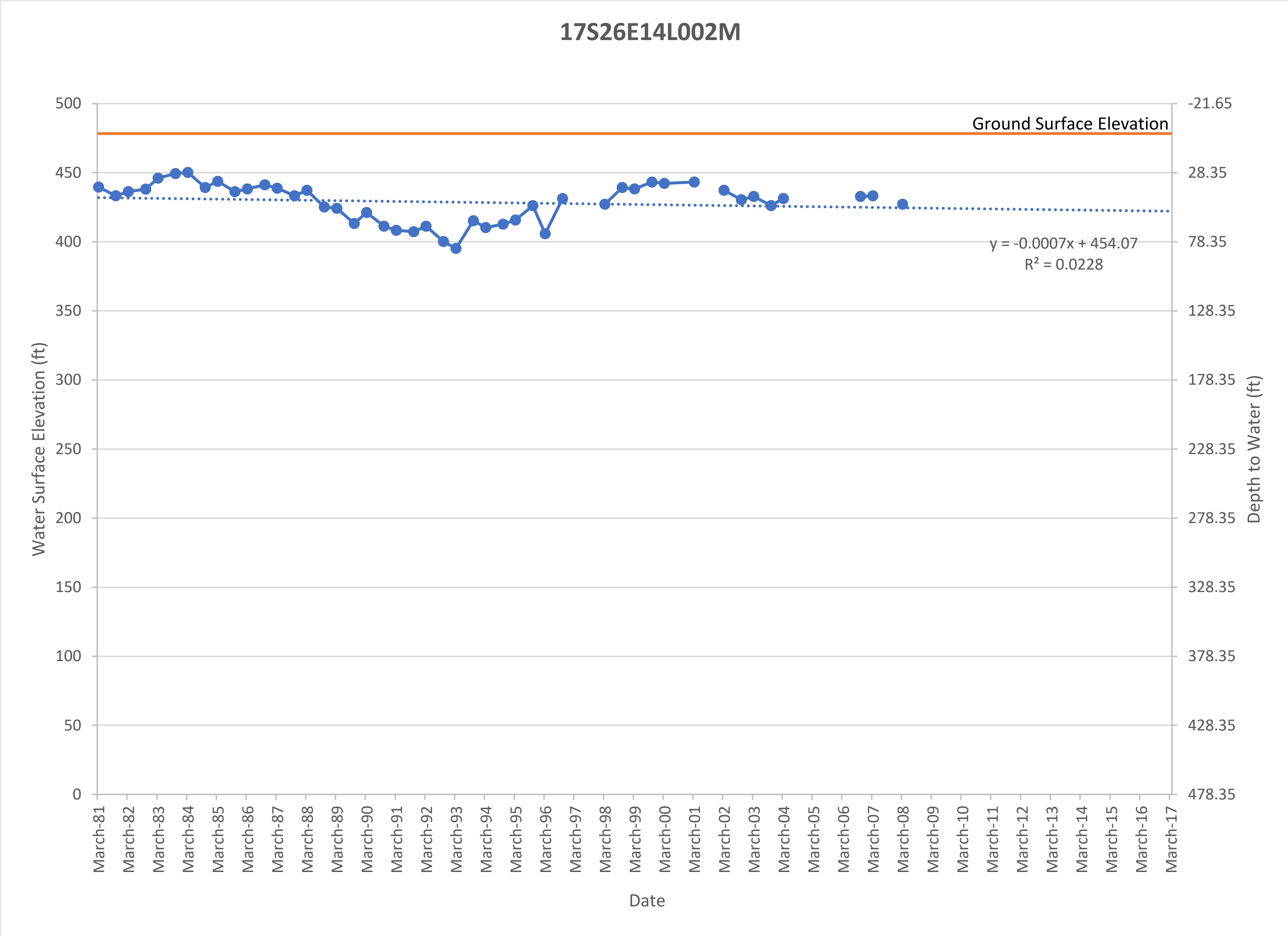
March-16
March-17



17S26E14L002M
Ground Surface Elevation
y = -0.0007x + 454.07
R² = 0.0228
Water Surface Elevation (ft)
Depth to Water (ft)
Date
500
450
400
350
300
250
200
150
100
50
0
-21.65
28.35
78.35
128.35
178.35
228.35
278.35
328.35
378.35
428.35
478.35
March-81
March-82
March-83
March-84
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March-86
March-87
March-88
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March-90
March-91
March-92
March-93
March-94
March-95
March-96
March-97
March-98
March-99
March-00
March-01
March-02
March-03
March-04
March-05
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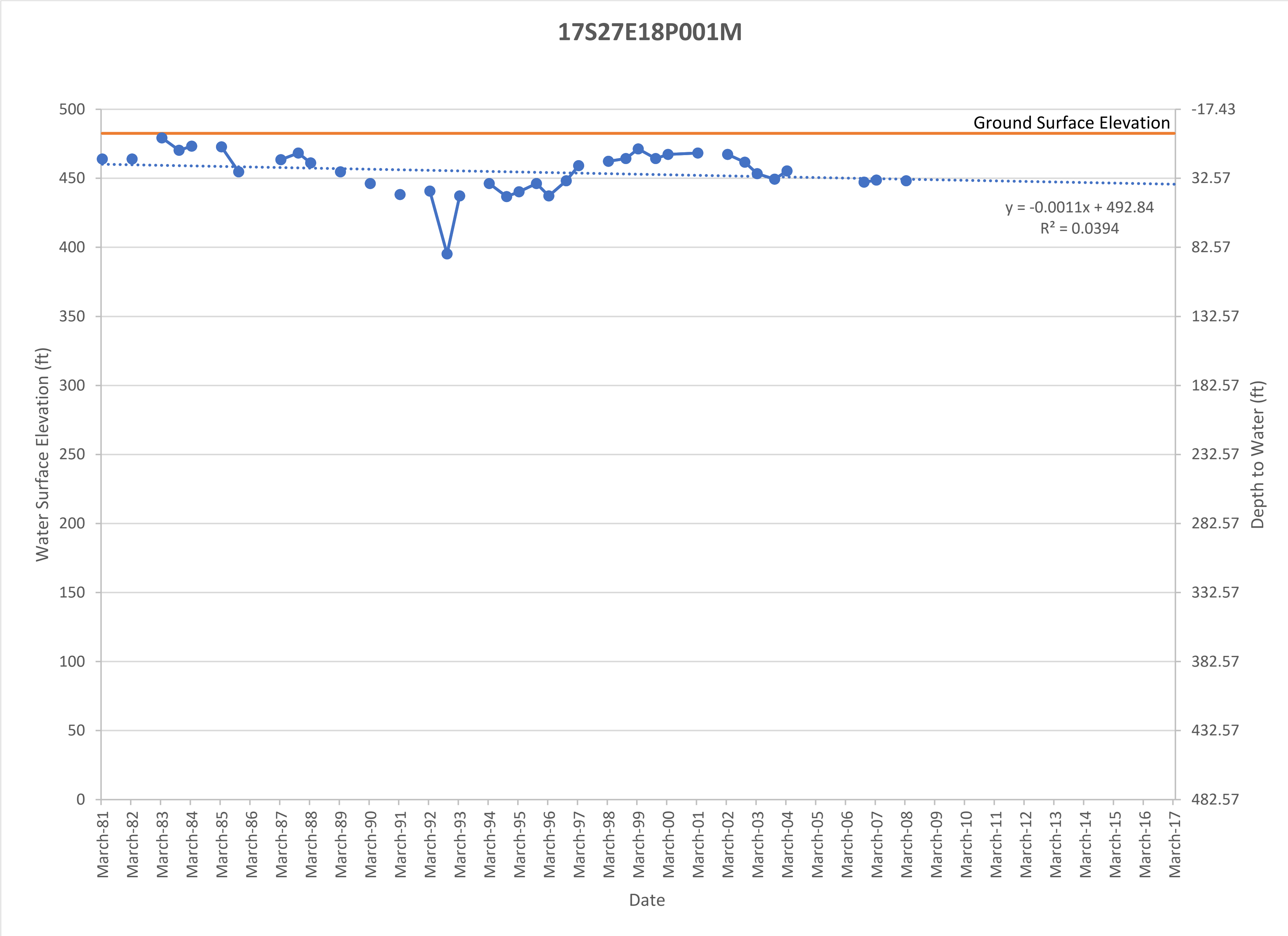
March-15
March-16
March-17


17S27E18P001M
Ground Surface Elevation
y = -0.0011x + 492.84
R² = 0.0394
Water Surface Elevation (ft)
Depth to Water (ft)
Date
500
450
400
350
300
250
200
150
100
50
0
-17.43
32.57
82.57
132.57
182.57
232.57
282.57
332.57
382.57
432.57
482.57
March-81
March-82
March-83
March-84
March-85
March-86
March-87
March-88
March-89
March-90
March-91
March-92
March-93
March-94
March-95
March-96
March-97
March-98
March-99
March-00
March-01
March-02
March-03
March-04
March-05
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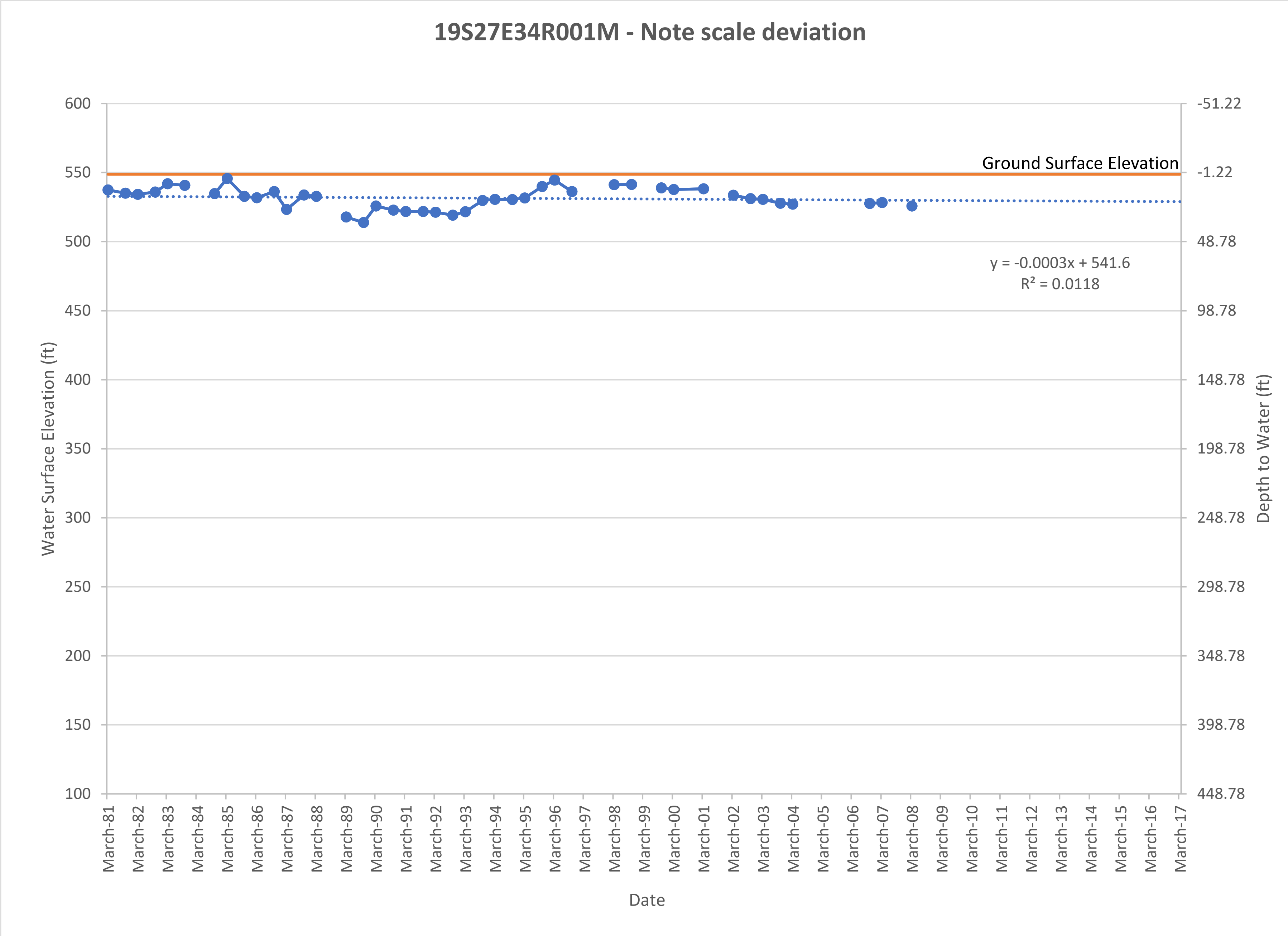
March-15
March-16
March-17


19S27E34R001M - Note scale deviation
Ground Surface Elevation
y = -0.0003x + 541.6
R² = 0.0118
Water Surface Elevation (ft)
Depth to Water (ft)
Date
600
550
500
450
400
350
300
250
200
150
100
-51.22
-1.22
48.78
98.78
148.78
198.78
248.78
298.78
348.78
398.78
448.78
March-81
March-82
March-83
March-84
March-85
March-86
March-87
March-88
March-89
March-90
March-91
March-92
March-93
March-94
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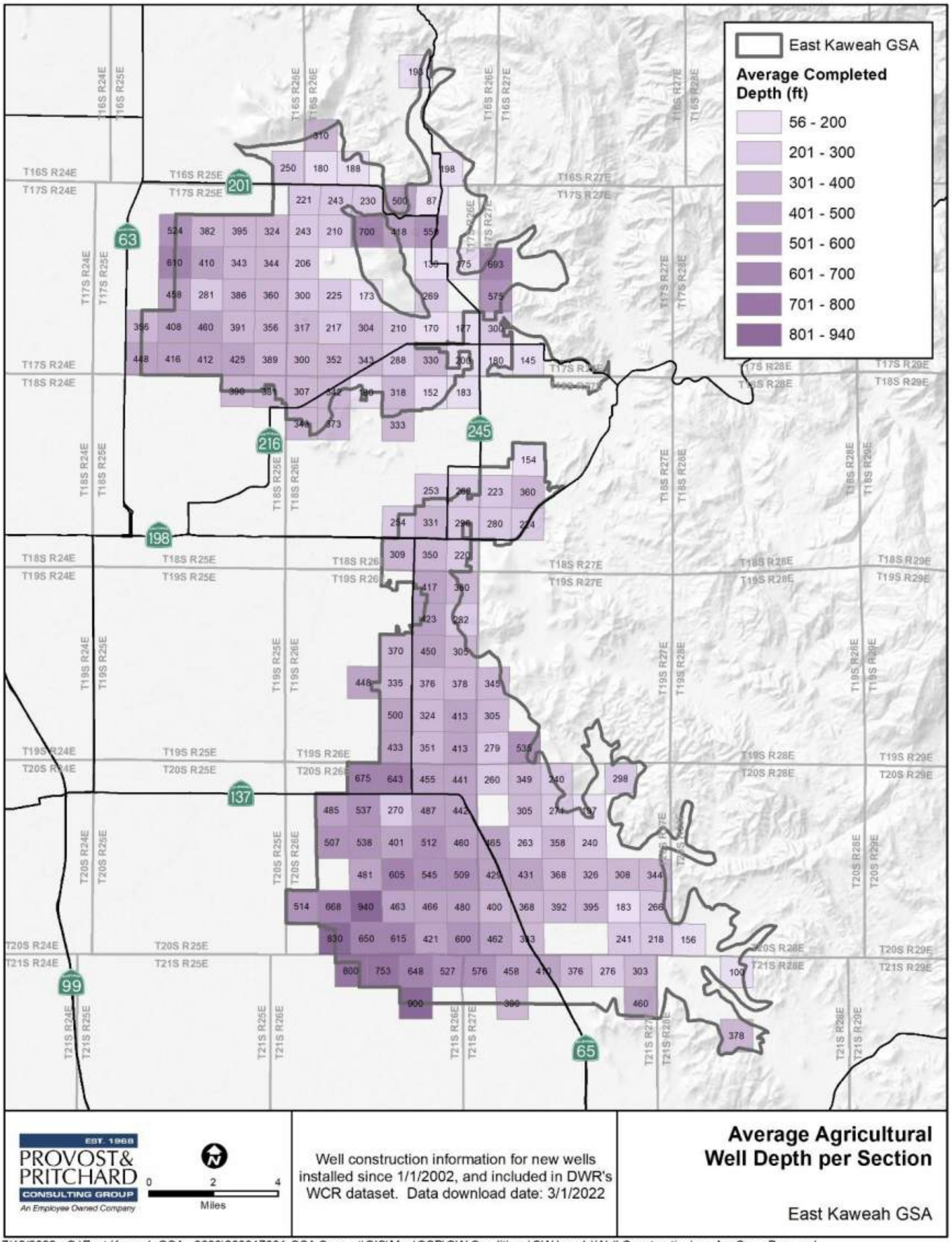
March-17

Appendix 2-E

Well Completion

Average Depth of Agricultural, Domestic, and Public Wells per Section



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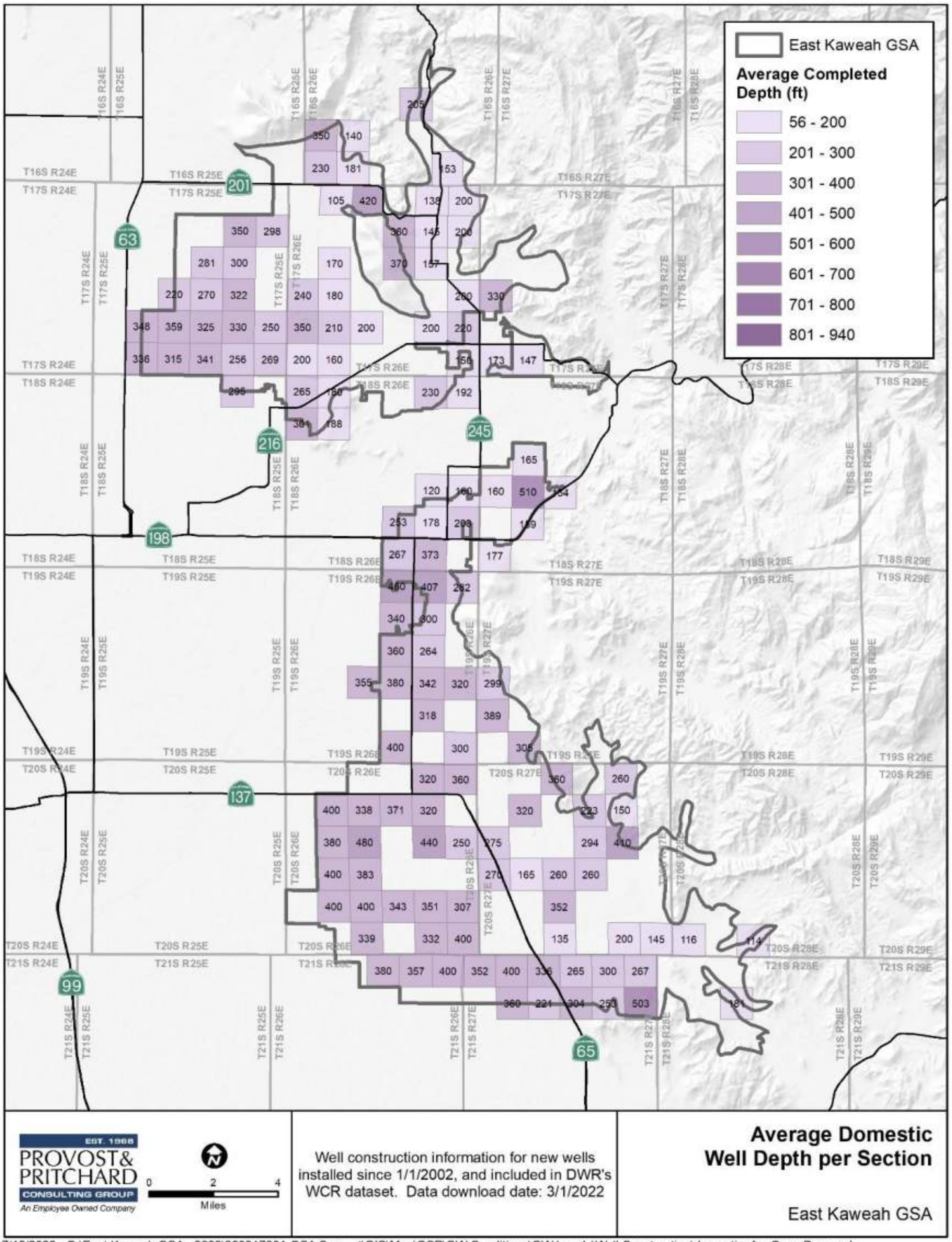
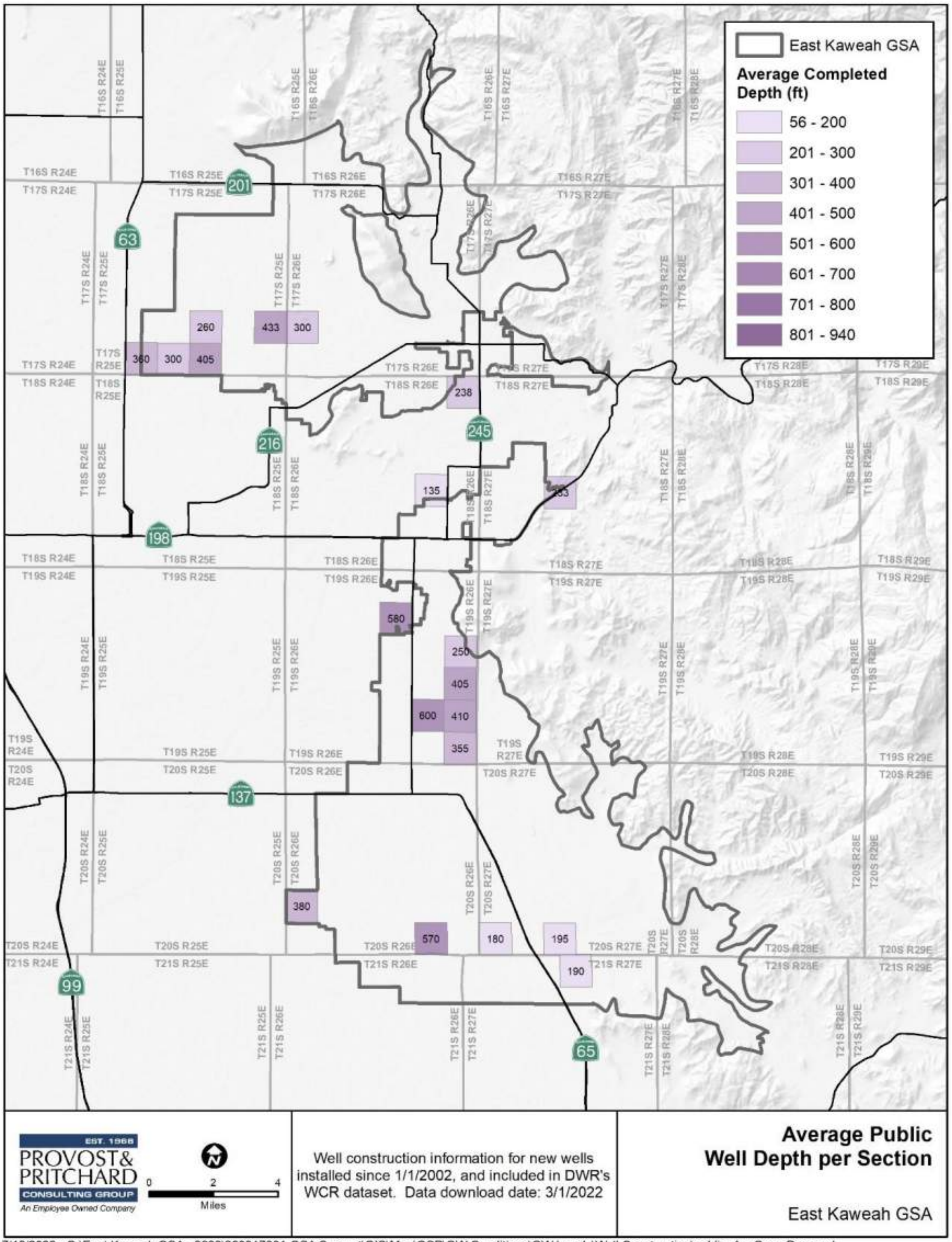
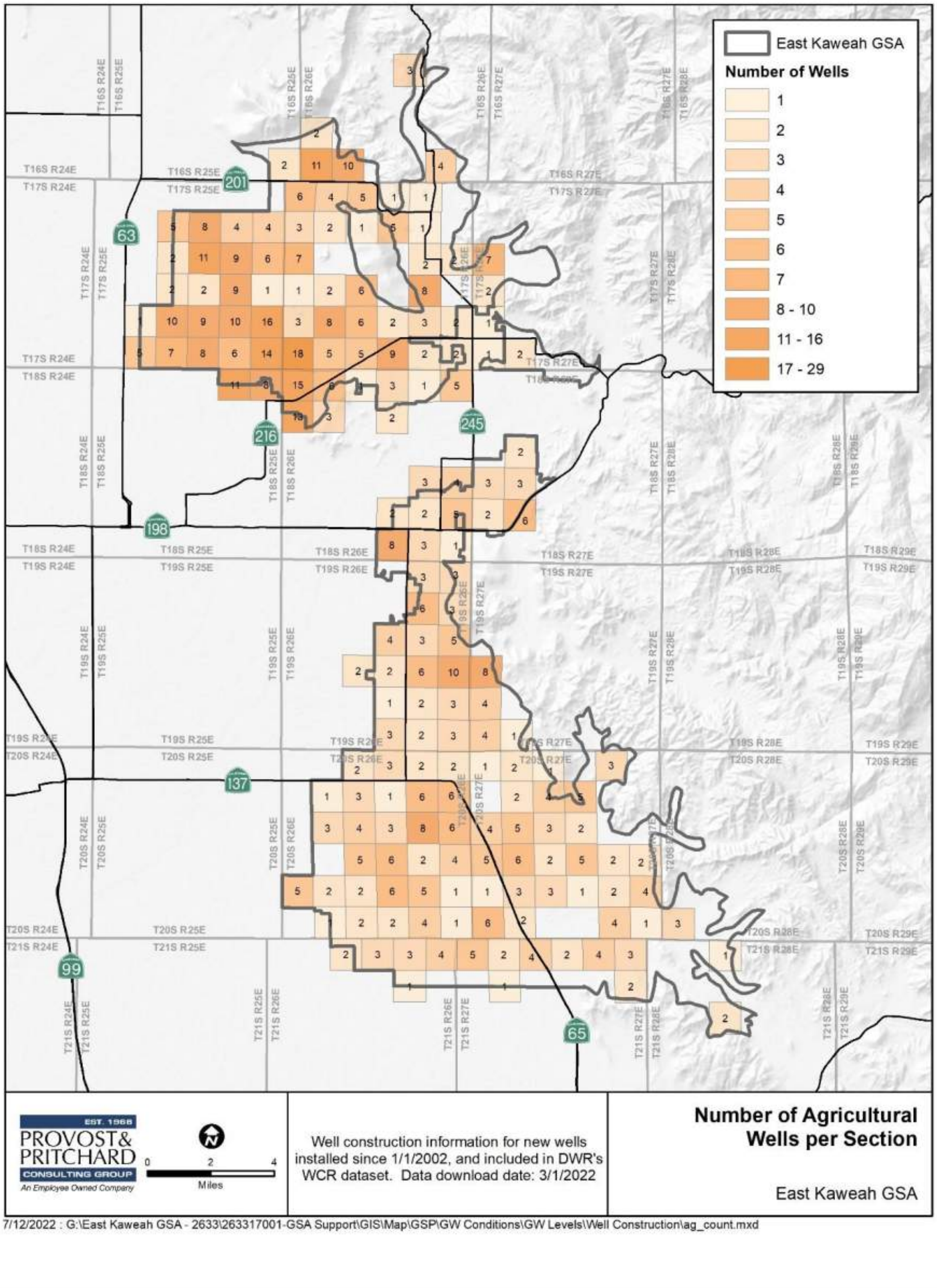


7/12/2022 : G:\East Kaweah GSA - 2633\263317001-GSA Support\GIS\Map\GSP\GW Conditions\GW Levels\Well Construction\domestic_AvgCompDep.mxd

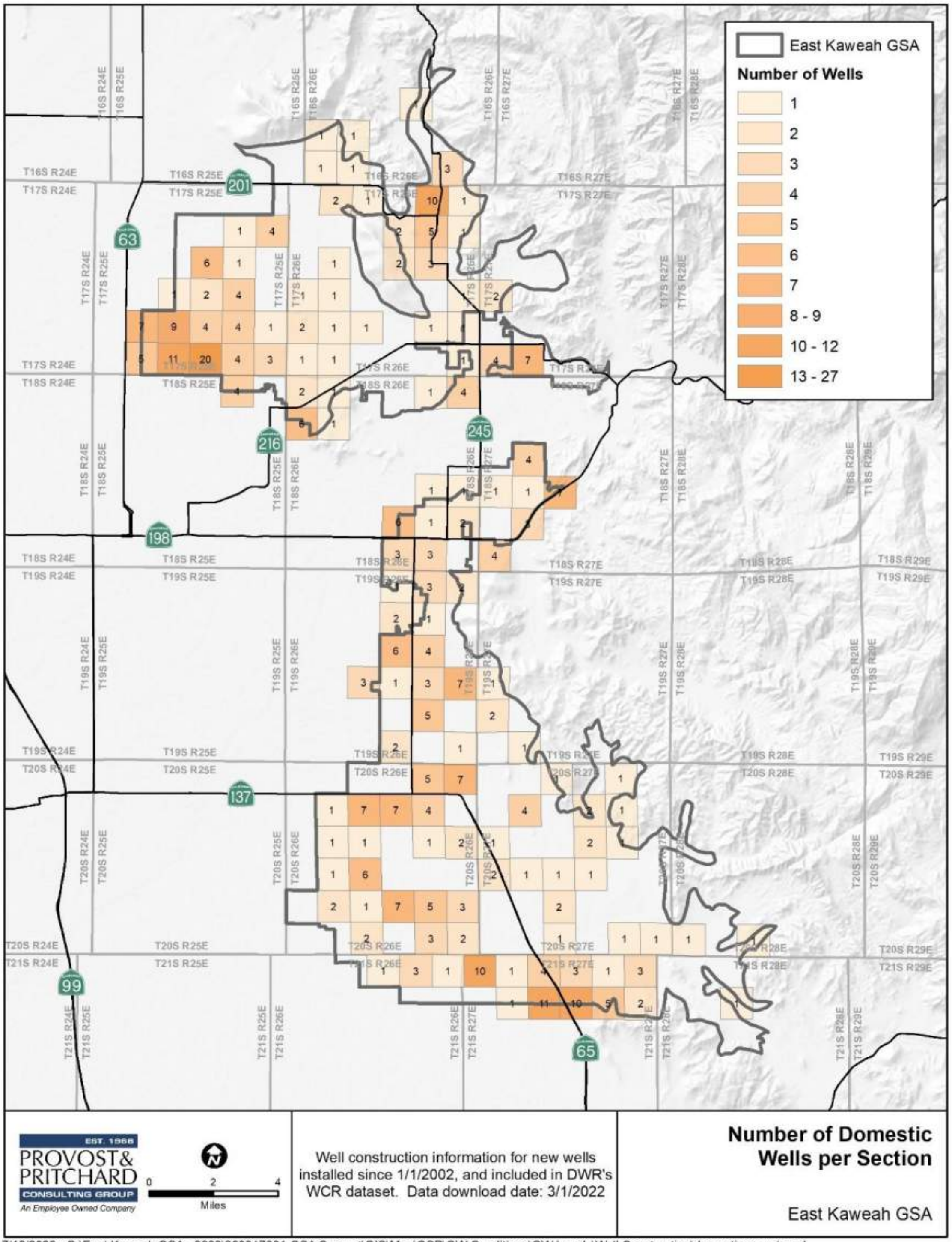


7/12/2022 : G:\East Kaweah GSA - 2633\263317001-GSA Support\GIS\Map\GSP\GW Conditions\GW Levels\Well Construction\public_AvgCompDep.mxd

Total Number of Agricultural, Domestic, and Public Wells per Section



7/12/2022 : G:\East Kaweah GSA - 2633\263317001-GSA Support\GIS\Map\GSP\GW Conditions\GW Levels\Well Construction\ag_count.mxd



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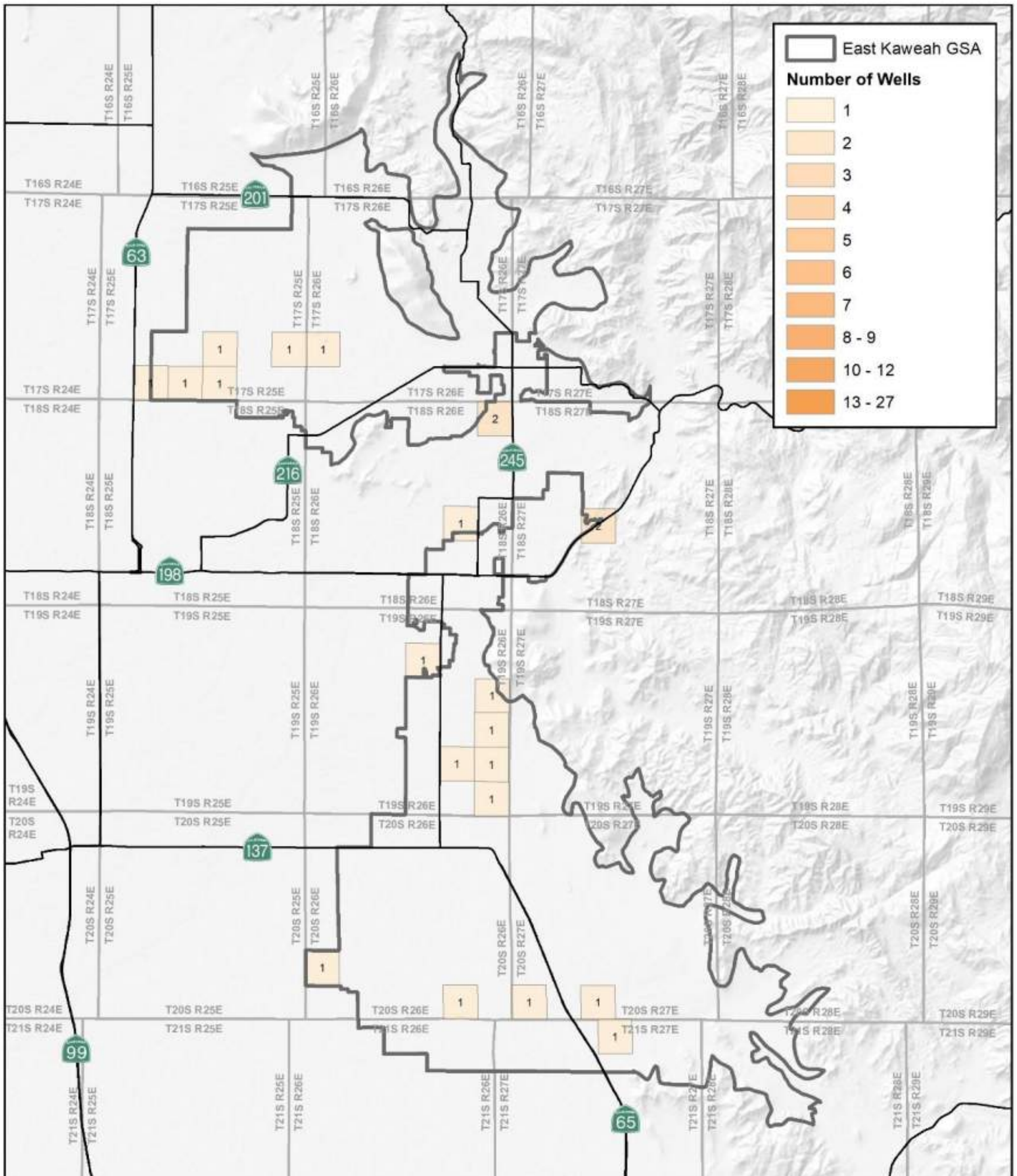


PROVOST& PRITCHARD CONSULTING GROUP
An Employee Owned Company

0 2 4 Miles

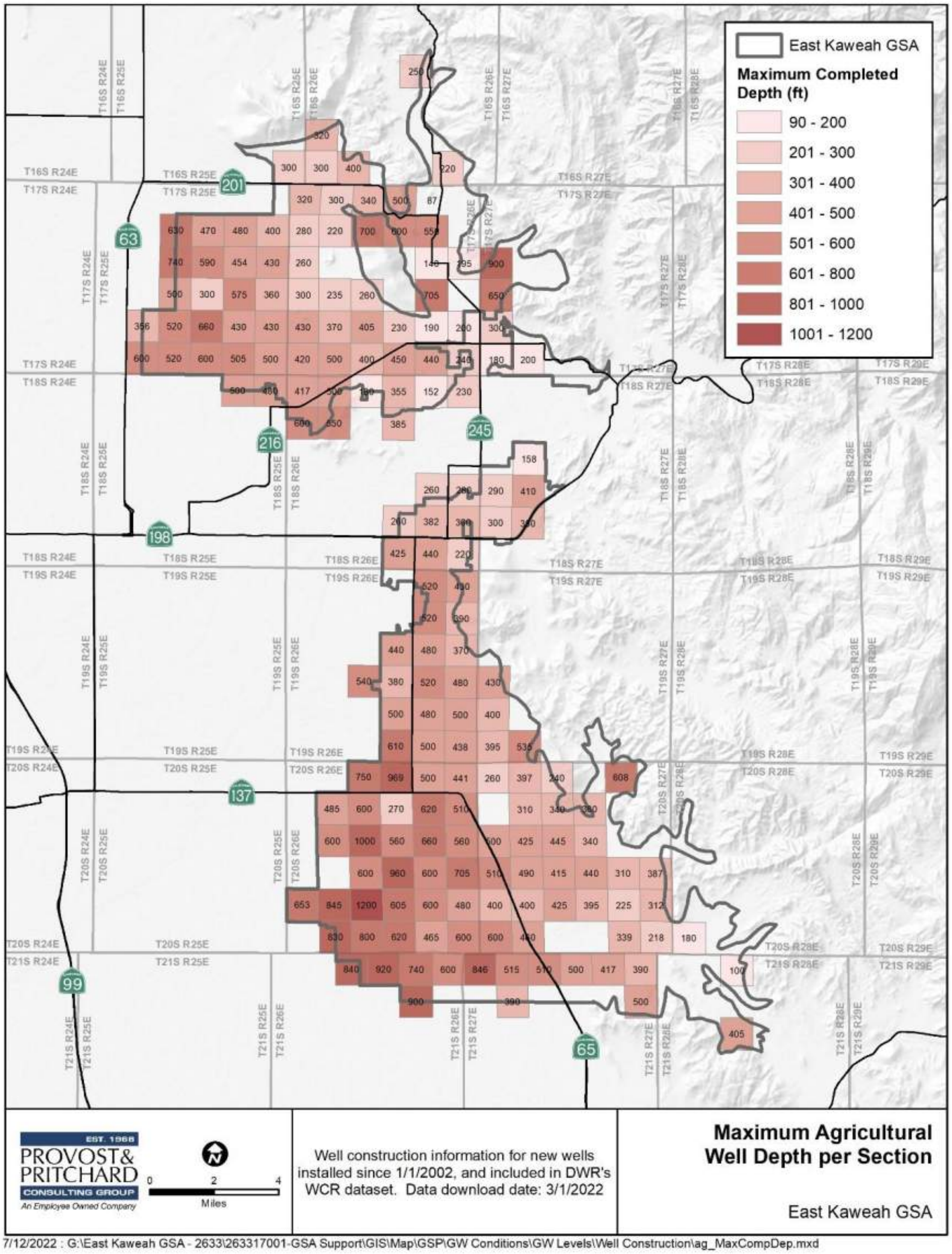
Well construction information for new wells installed since 1/1/2002, and included in DWR's WCR dataset. Data download date: 3/1/2022

Number of Public Wells per Section

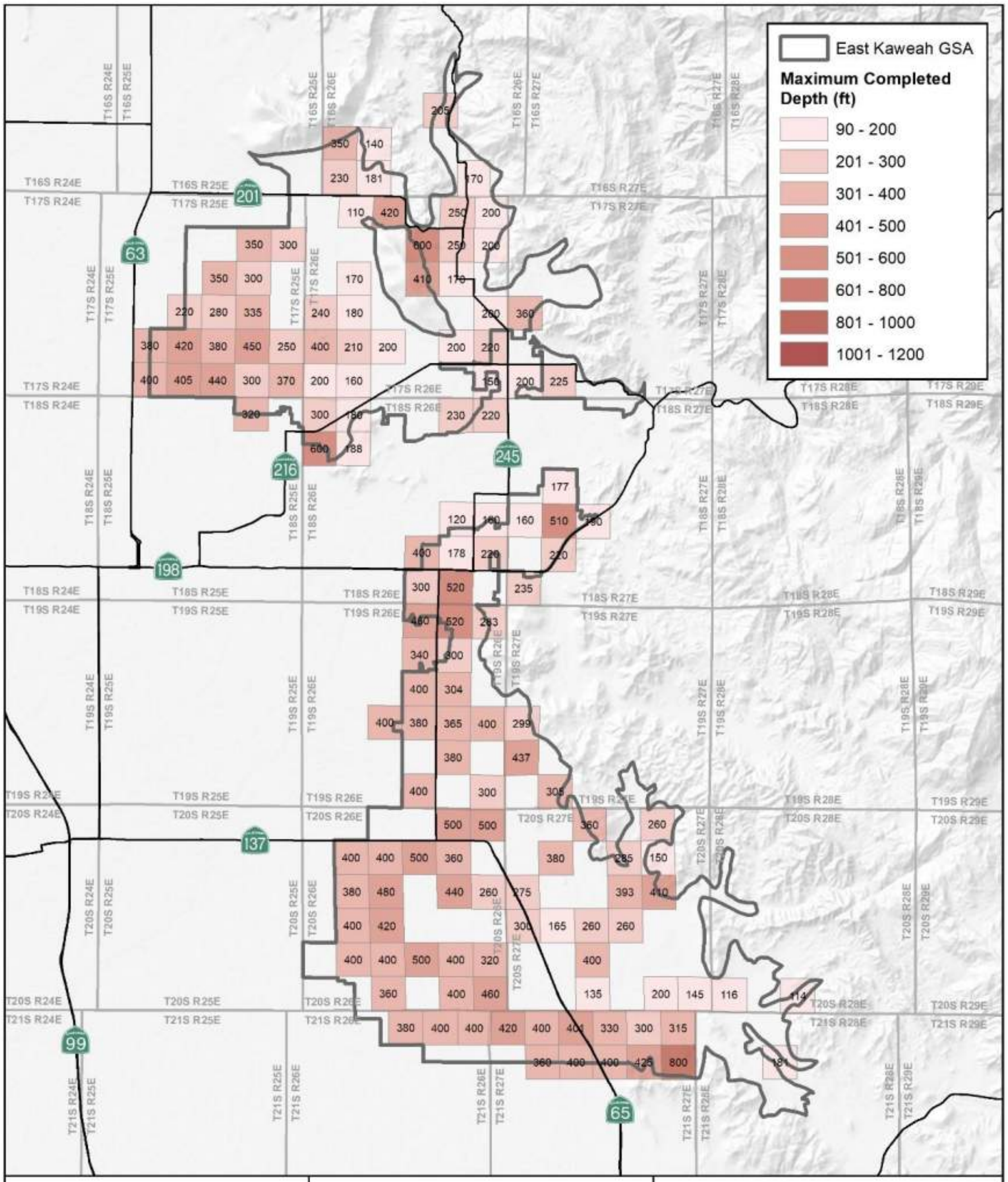
East Kaweah GSA

7/12/2022 : G:\East Kaweah GSA - 2633\263317001-GSA Support\GIS\Map\GSP\GW Conditions\GW Levels\Well Construction\public_count.mxd

Maximum Depth of Agricultural, Domestic, and Public Wells per Section



7/12/2022 : G:\East Kaweah GSA - 2633\263317001-GSA Support\GIS\Map\GSP\GW Conditions\GW Levels\Well Construction\ag_MaxCompDep.mxd



Well construction information for new wells installed since 1/1/2002, and included in DWR's WCR dataset. Data download date: 3/1/2022

Maximum Domestic Well Depth per Section

East Kaweah GSA

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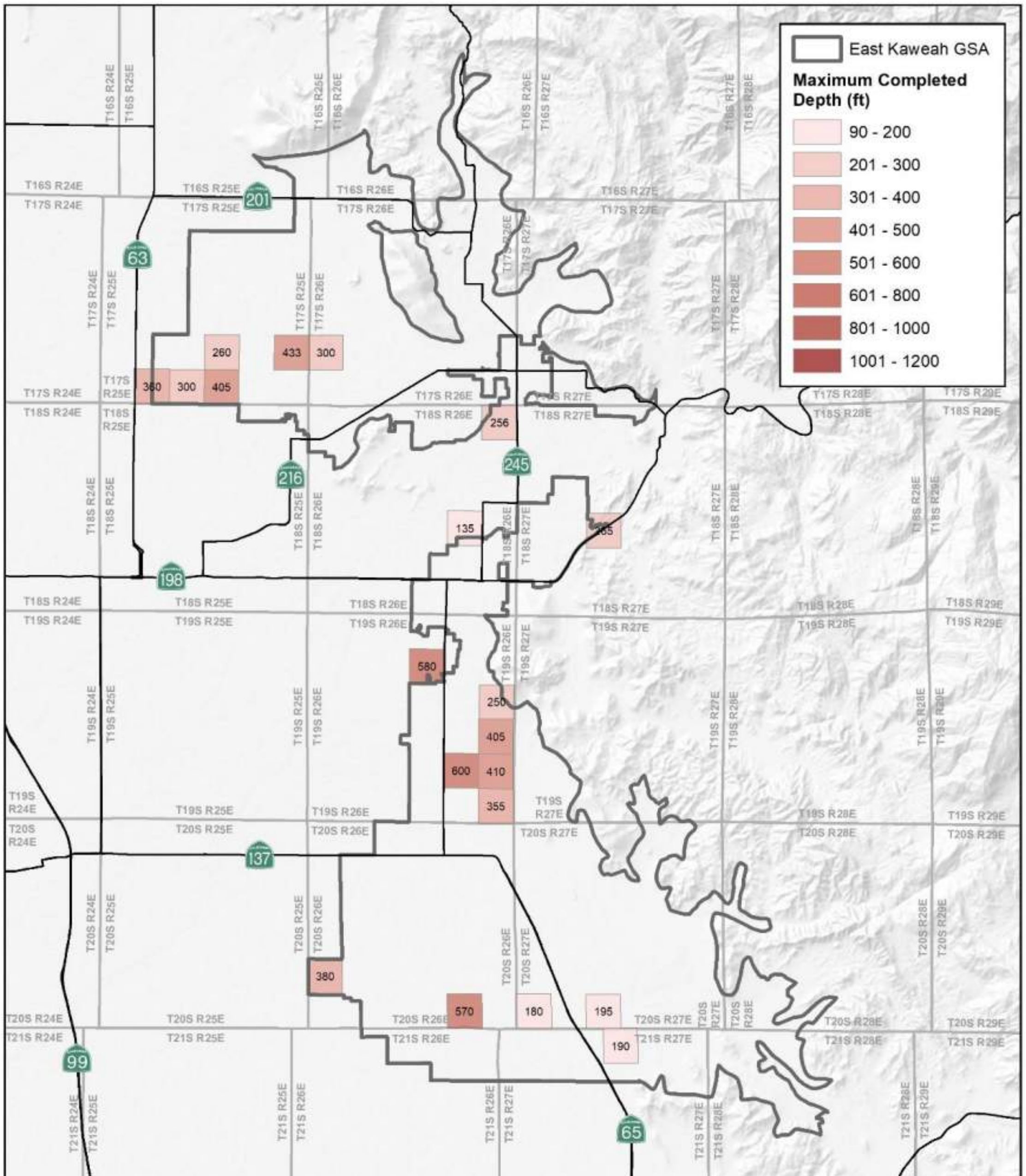
7/12/2022 : G:\East Kaweah GSA - 2633\263317001-GSA Support\GIS\Map\GSP\GW Conditions\GW Levels\Well Construction\domestic_MaxCompDep.mxd



PROVOST& PRITCHARD CONSULTING GROUP EST. 1968 An Employee Owned Company

0 2 4 Miles

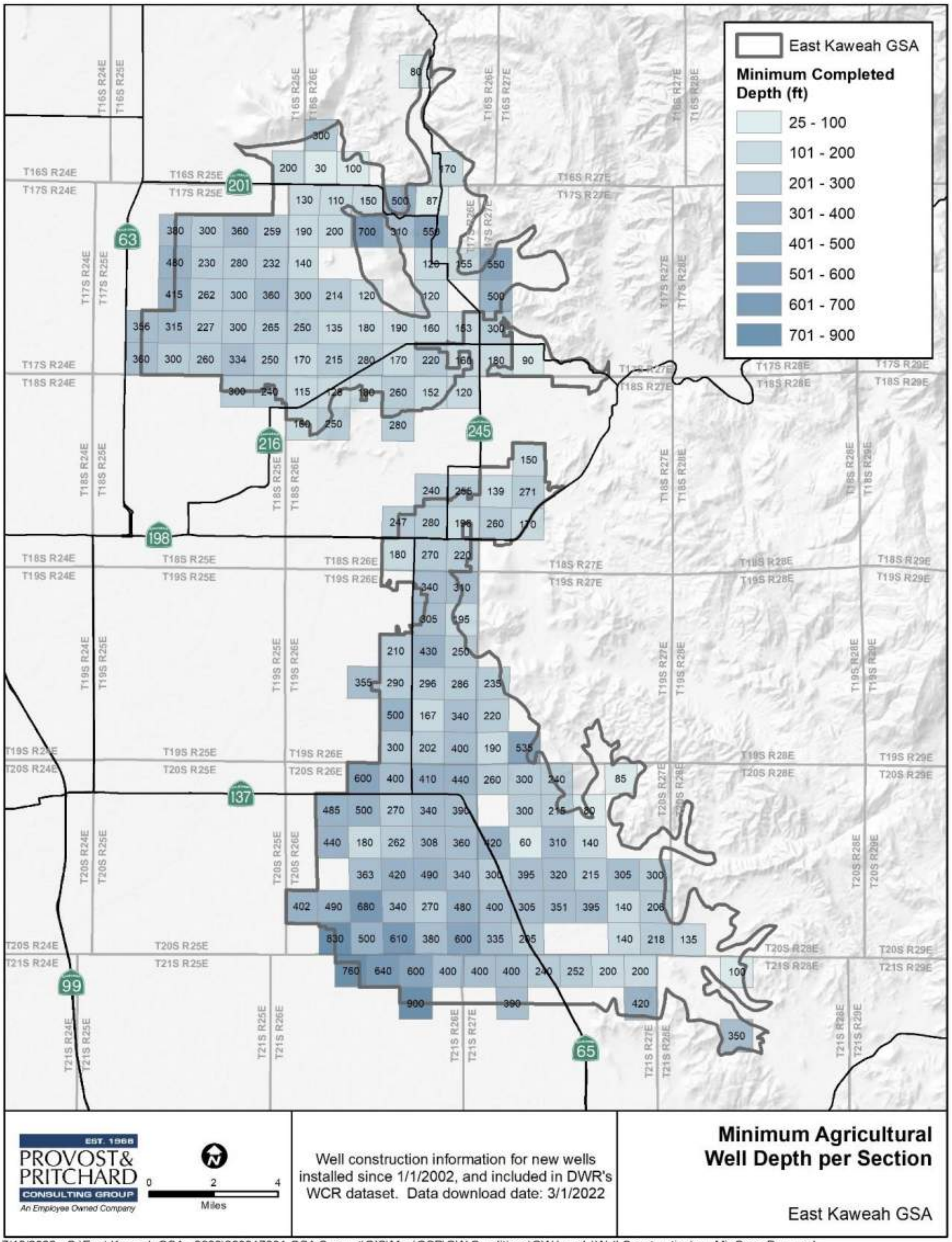
Well construction information for new wells installed since 1/1/2002, and included in DWR's WCR dataset. Data download date: 3/1/2022

Maximum Public Well Depth per Section

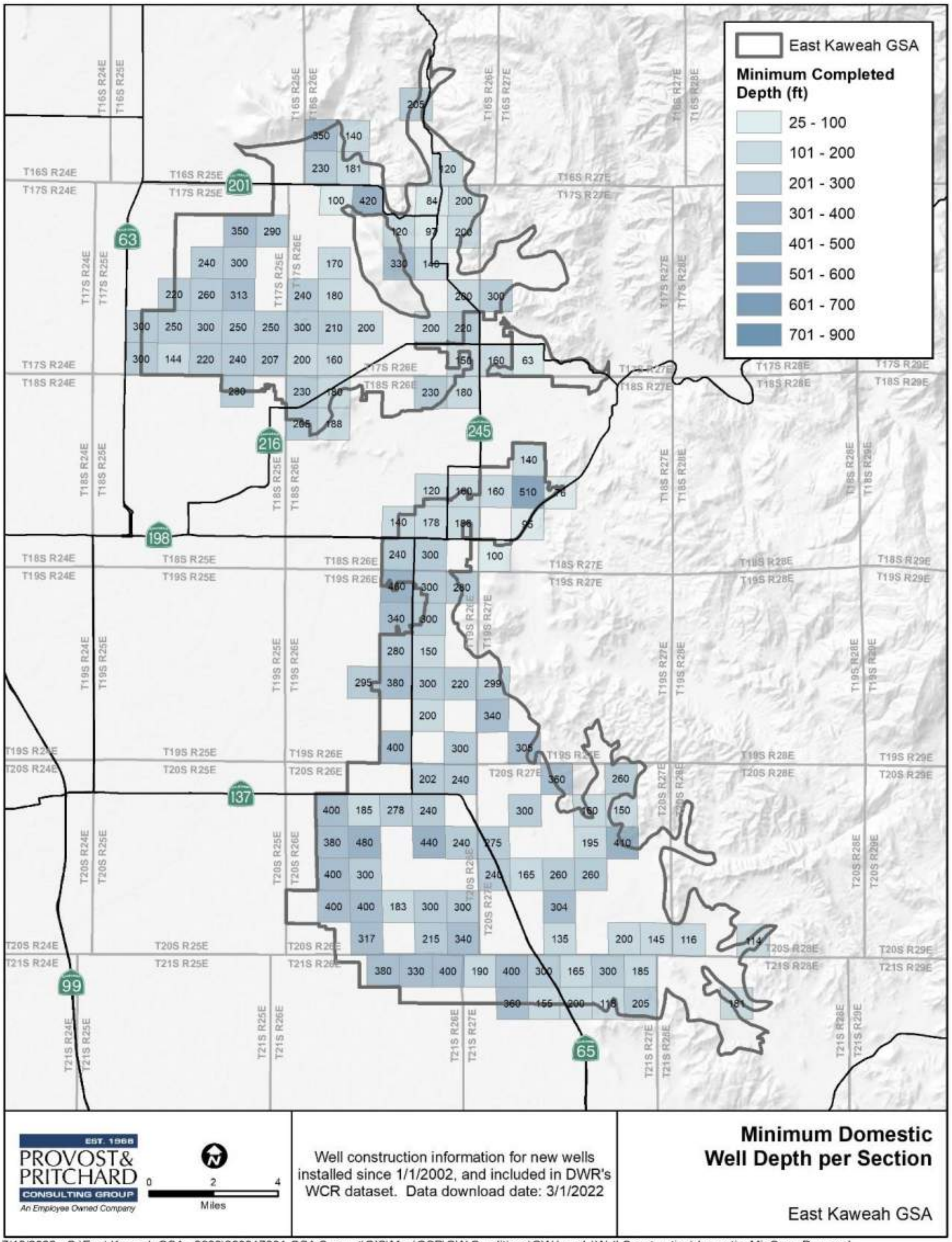
East Kaweah GSA

7/12/2022 : G:\East Kaweah GSA - 2633\263317001-GSA Support\GIS\Map\GSP\GW Conditions\GW Levels\Well Construction\public_MaxCompDep.mxd

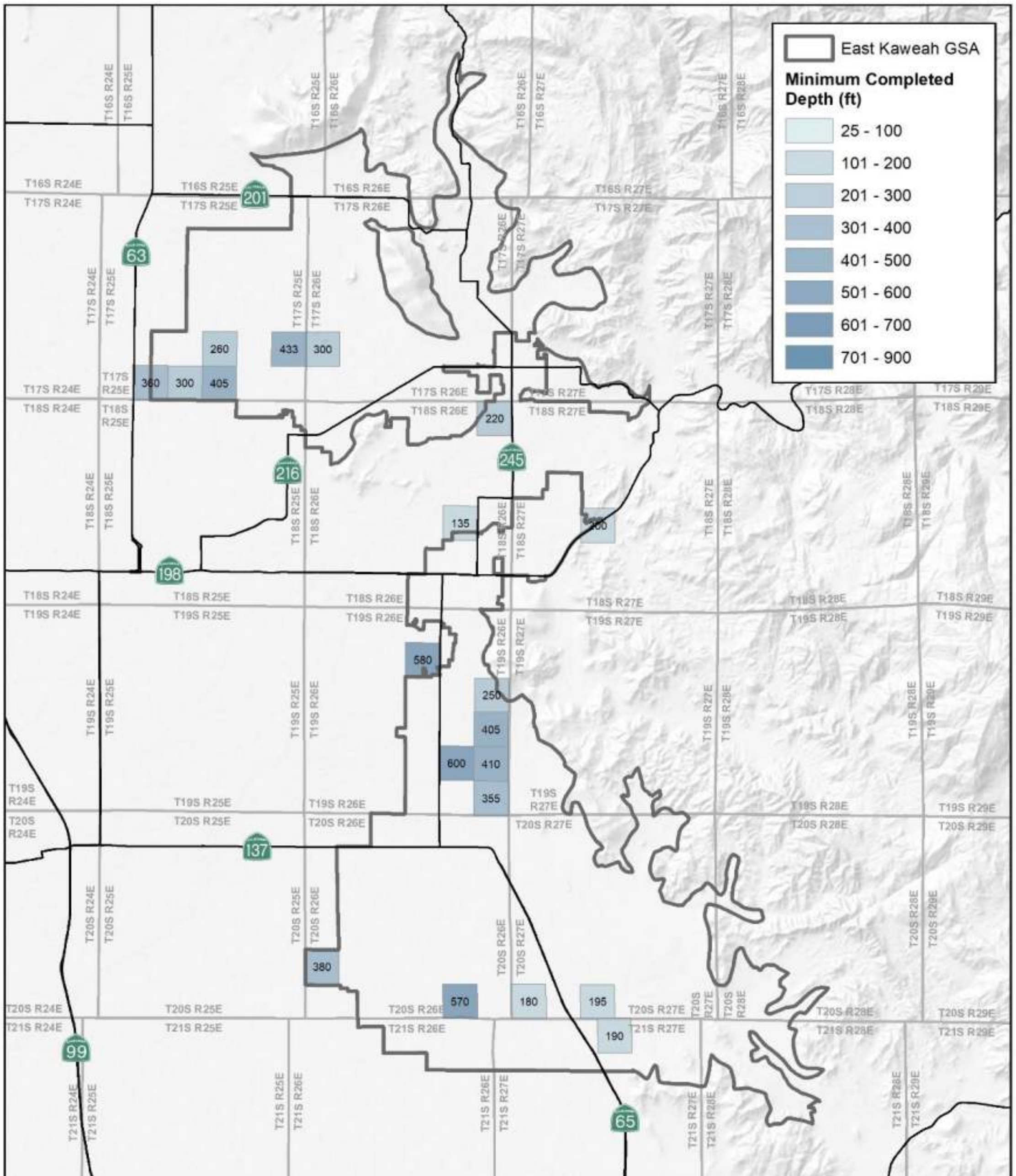
Minimum Depth of Agricultural, Domestic, and Public Well per Section



7/12/2022 : G:\East Kaweah GSA - 2633\263317001-GSA Support\GIS\Map\GSP\GW Conditions\GW Levels\Well Construction\ag_MinCompDep.mxd



7/12/2022 : G:\East Kaweah GSA - 2633\263317001-GSA Support\GIS\Map\GSP\GW Conditions\GW Levels\Well Construction\domestic_MinCompDep.mxd



EST. 1968
PROVOST& PRITCHARD
CONSULTING GROUP
An Employee Owned Company

0 2 4
Miles

Well construction information for new wells installed since 1/1/2002, and included in DWR's WCR dataset. Data download date: 3/1/2022

Minimum Public Well Depth per Section

East Kaweah GSA

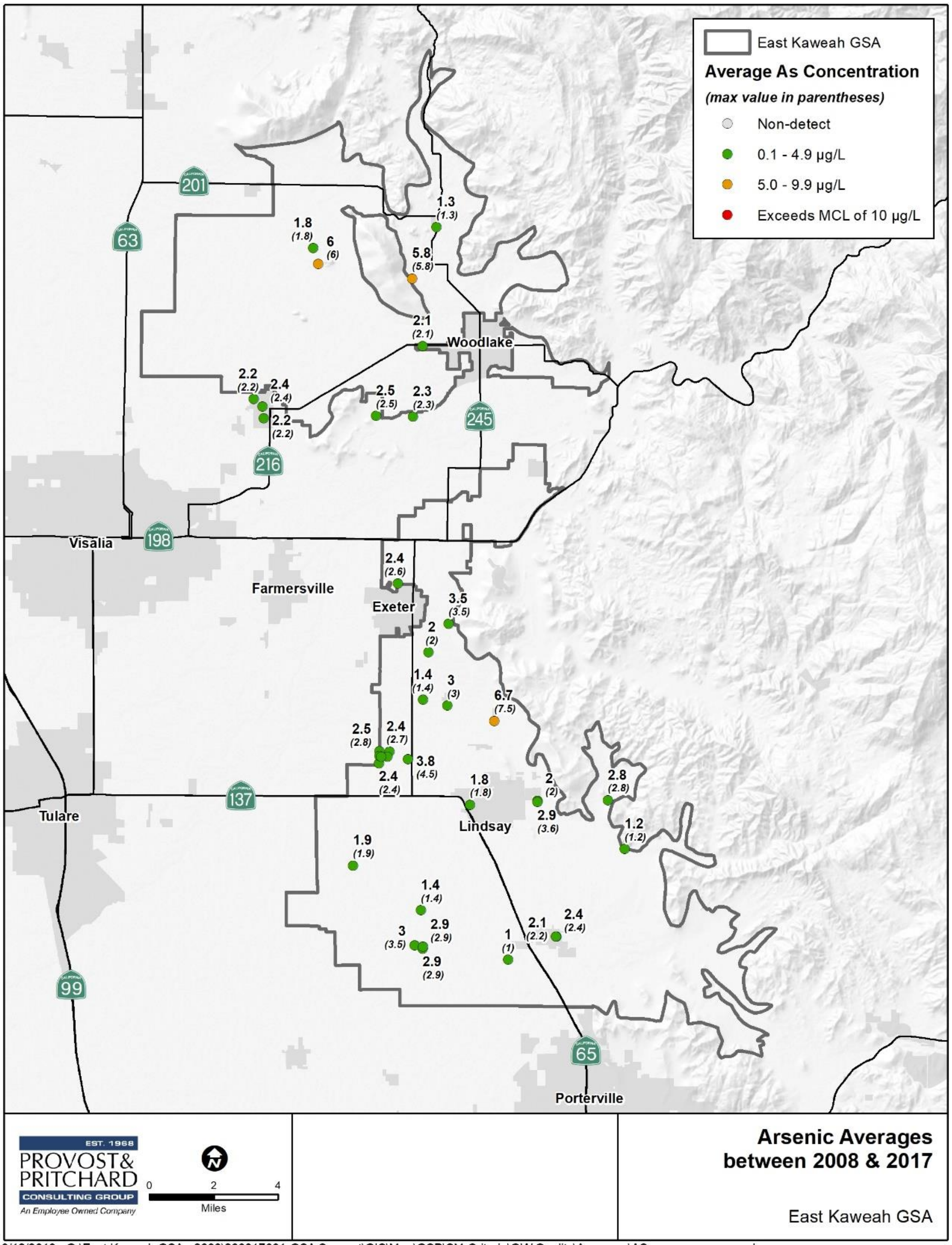
7/12/2022 : G:\East Kaweah GSA - 2633\263317001-GSA Support\GIS\Map\GSP\GW Conditions\GW Levels\Well Construction\public_MinCompDep.mxd

Appendix 2-F

COC Spatial & Temporal Distribution Maps

Groundwater Quality Constituent of Concern Ten-Year Average Concentrations

(2008-2017)



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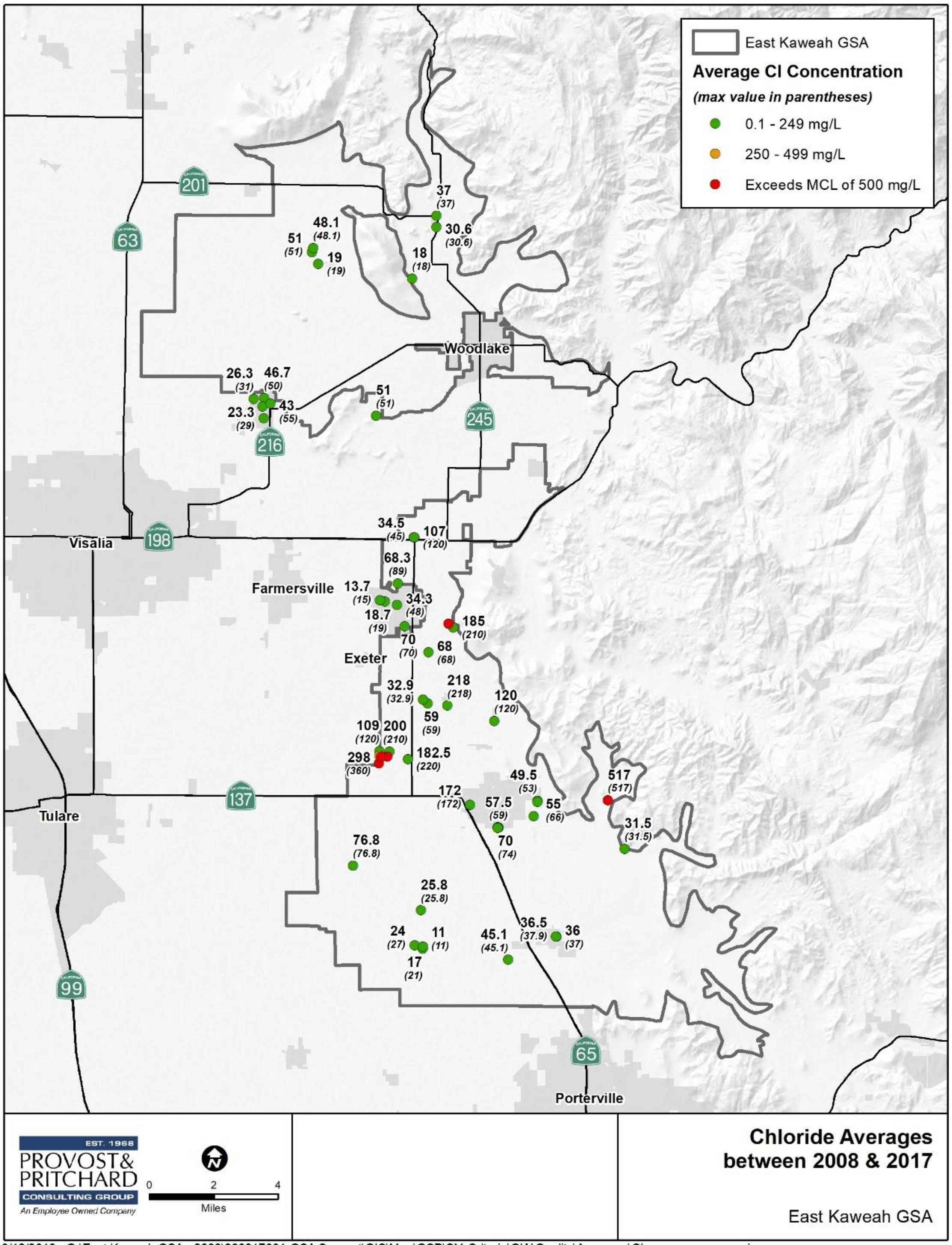
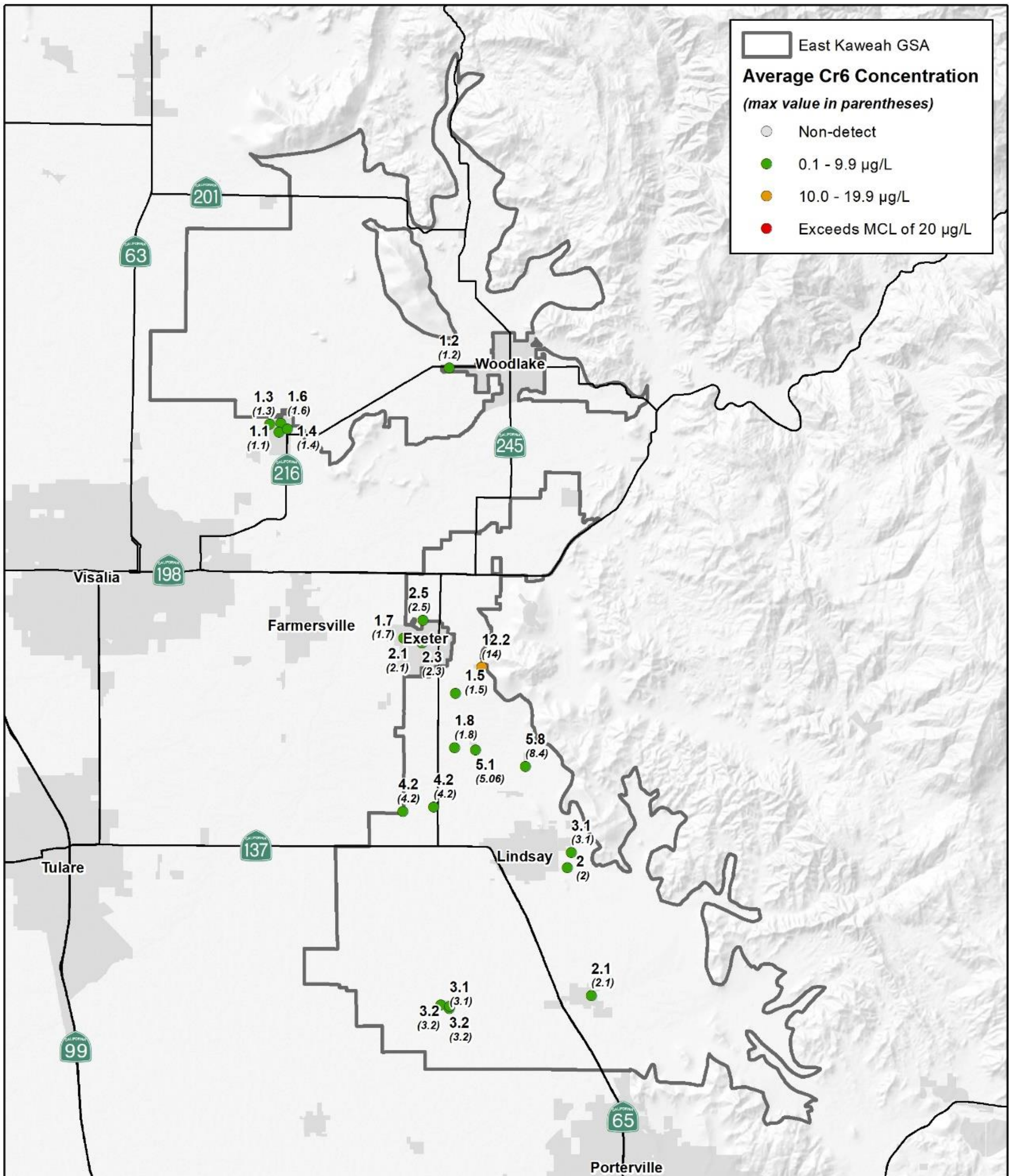


9/12/2019 : G:\East Kaweah GSA - 2633\263317001-GSA Support\GIS\Map\GSP\SM Criteria\GW Quality\Averages\Cl_average_max.mxd



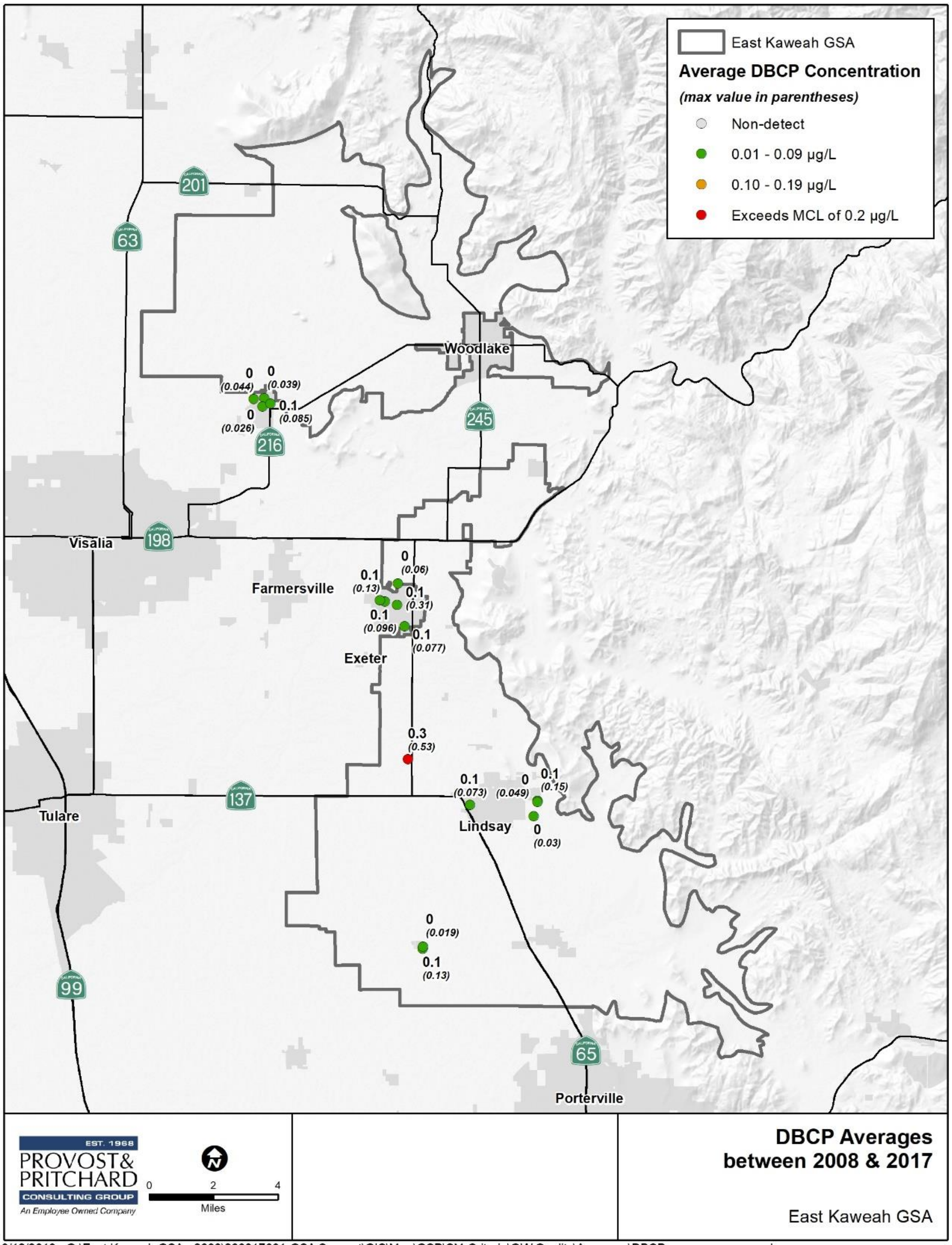
PROVOST& PRITCHARD CONSULTING GROUP, EST. 1968, An Employee Owned Company

0 2 4 Miles

Chromium-6 Averages between 2008 & 2017

East Kaweah GSA

9/12/2019 : G:\East Kaweah GSA - 2633\263317001-GSA Support\GIS\Map\GSP\SM Criteria\GW Quality\Averages\Cr-6_average_max.mxd



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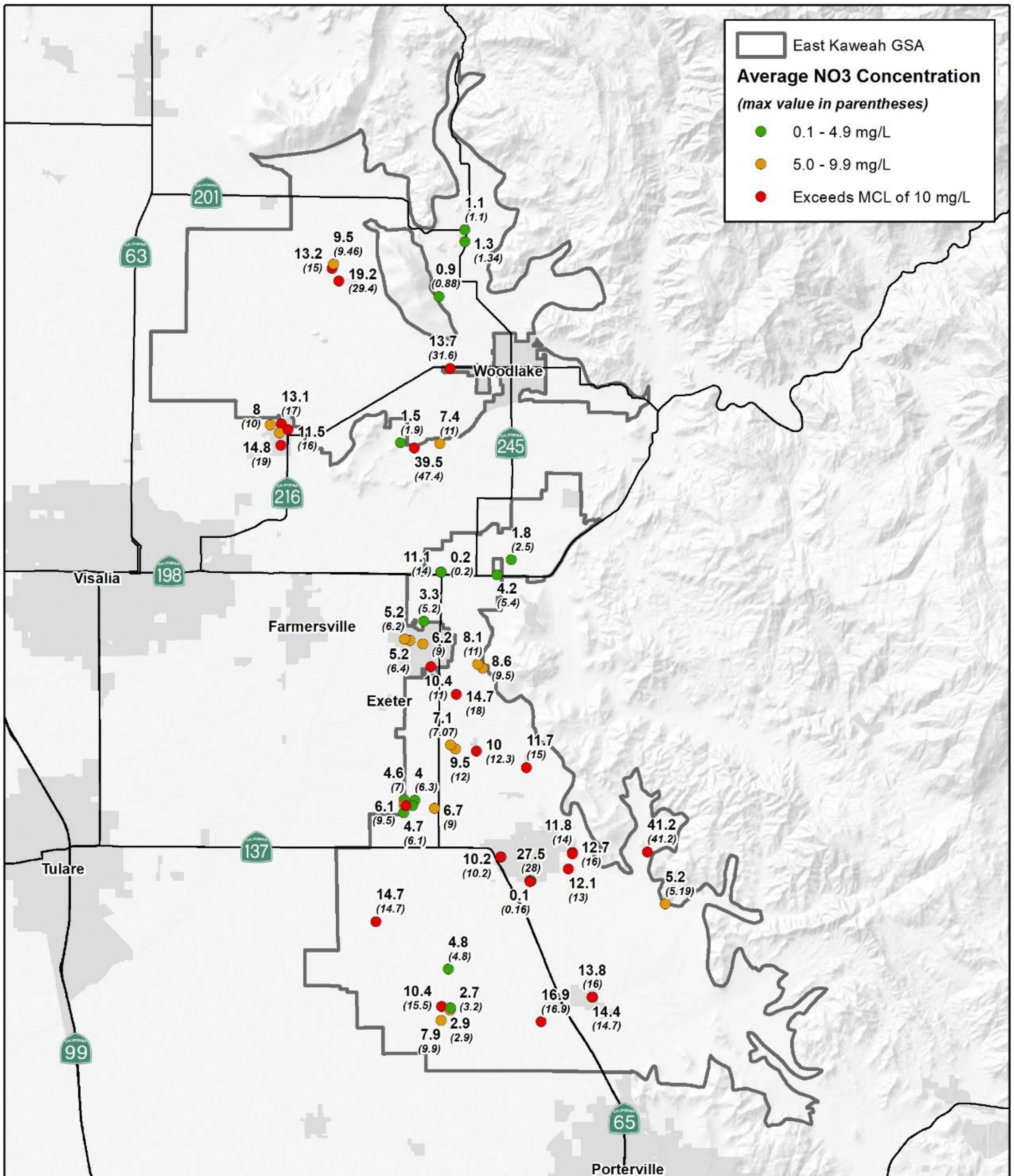

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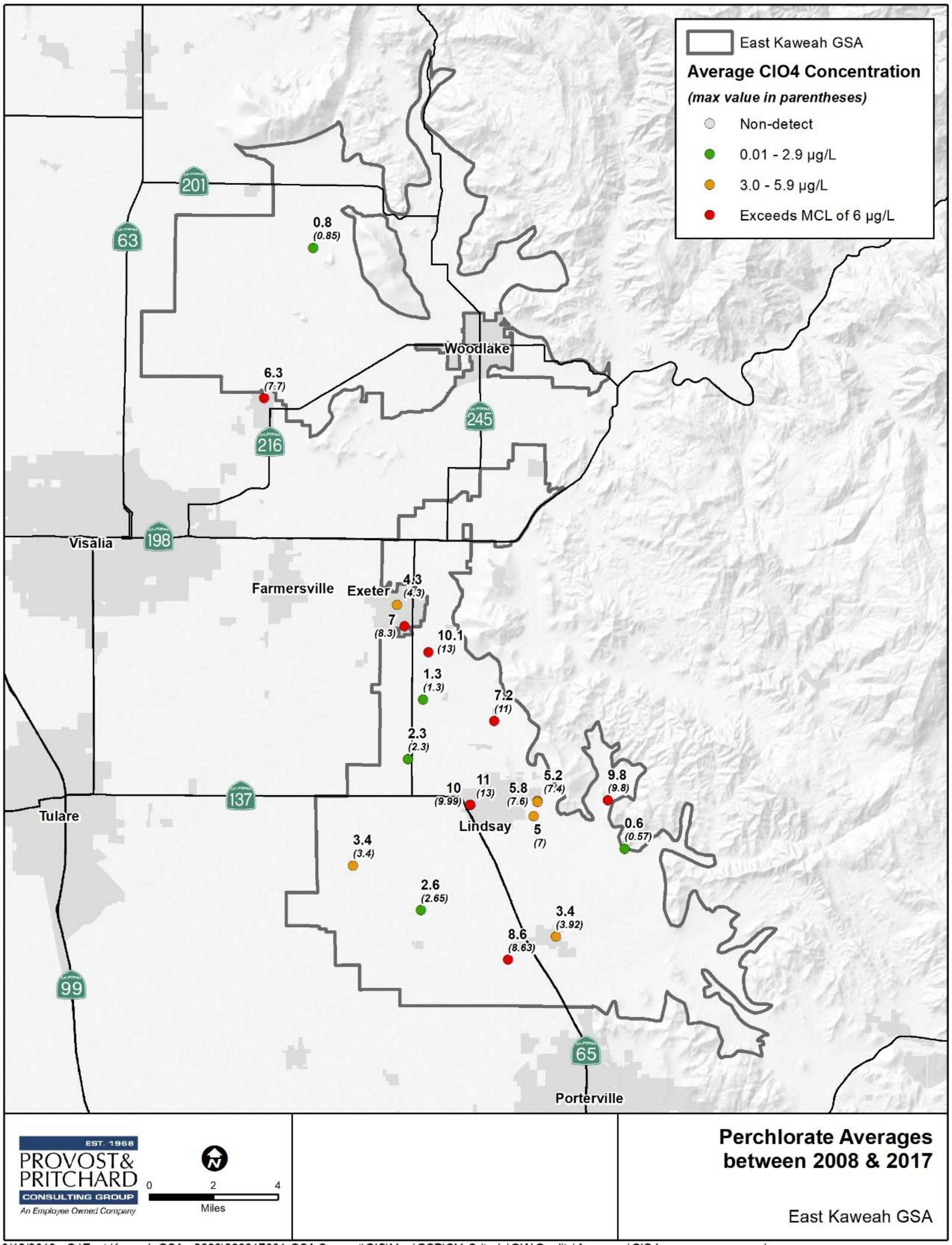
CONSULTING GROUP
An Employee Owned Company

Nitrate Averages between 2008 & 2017

East Kaweah GSA

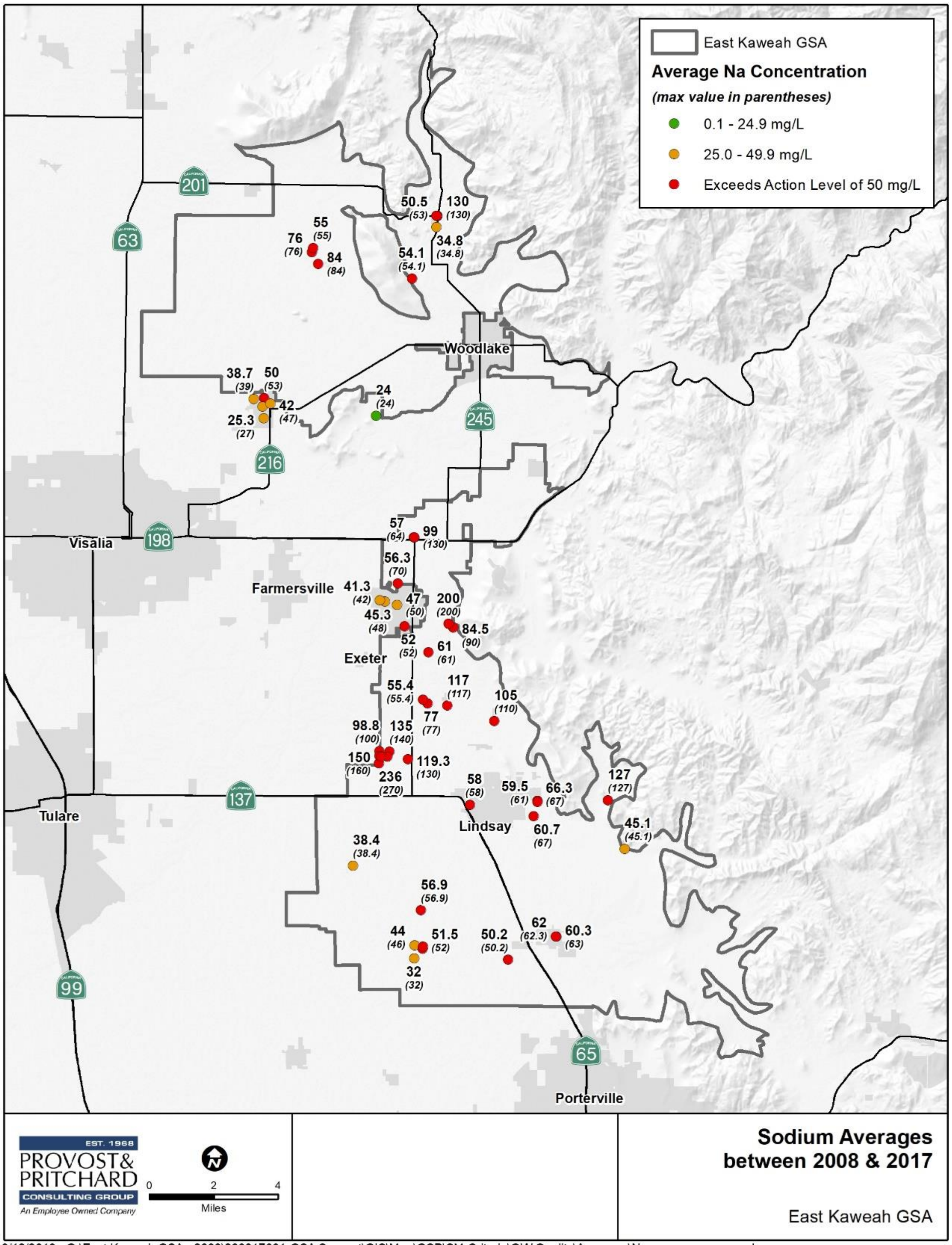
9/12/2019 : G:\East Kaweah GSA - 2633\263317001-GSA Support\GIS\Map\GSP\SM Criteria\GW Quality\Averages\NO3_average_max.mxd



Perchlorate Averages between 2008 & 2017

East Kaweah GSA

9/12/2019 : G:\East Kaweah GSA - 2633\263317001-GSA Support\GIS\Map\GSP\SM Criteria\GW Quality\Averages\ClO4_average_max.mxd



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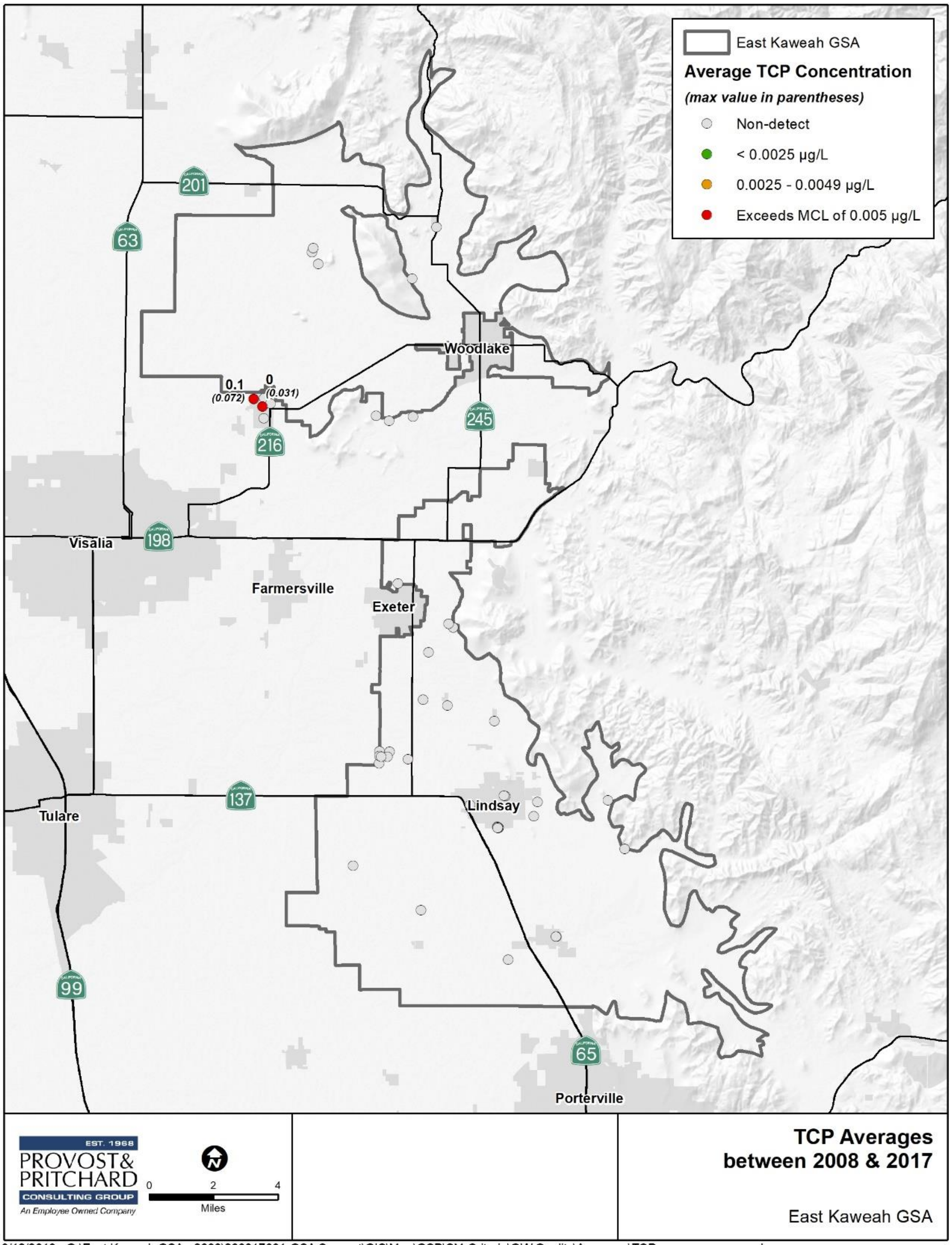
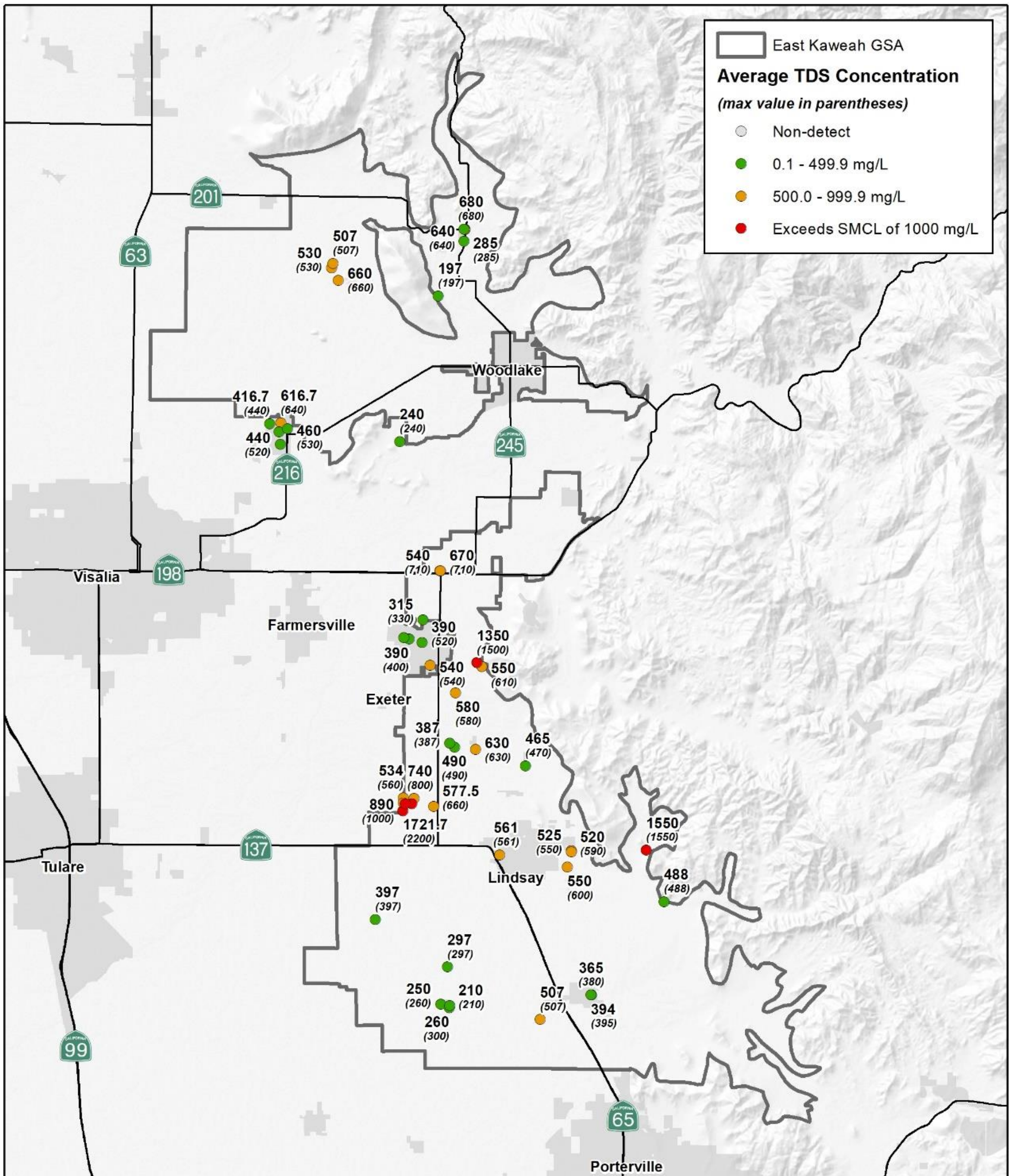


TCP Averages between 2008 & 2017

East Kaweah GSA

9/12/2019 : G:\East Kaweah GSA - 2633\263317001-GSA Support\GIS\Map\GSP\SM Criteria\GW Quality\Averages\TCP_average_max.mxd



EST. 1968 PROVOST& PRITCHARD CONSULTING GROUP
An Employee Owned Company

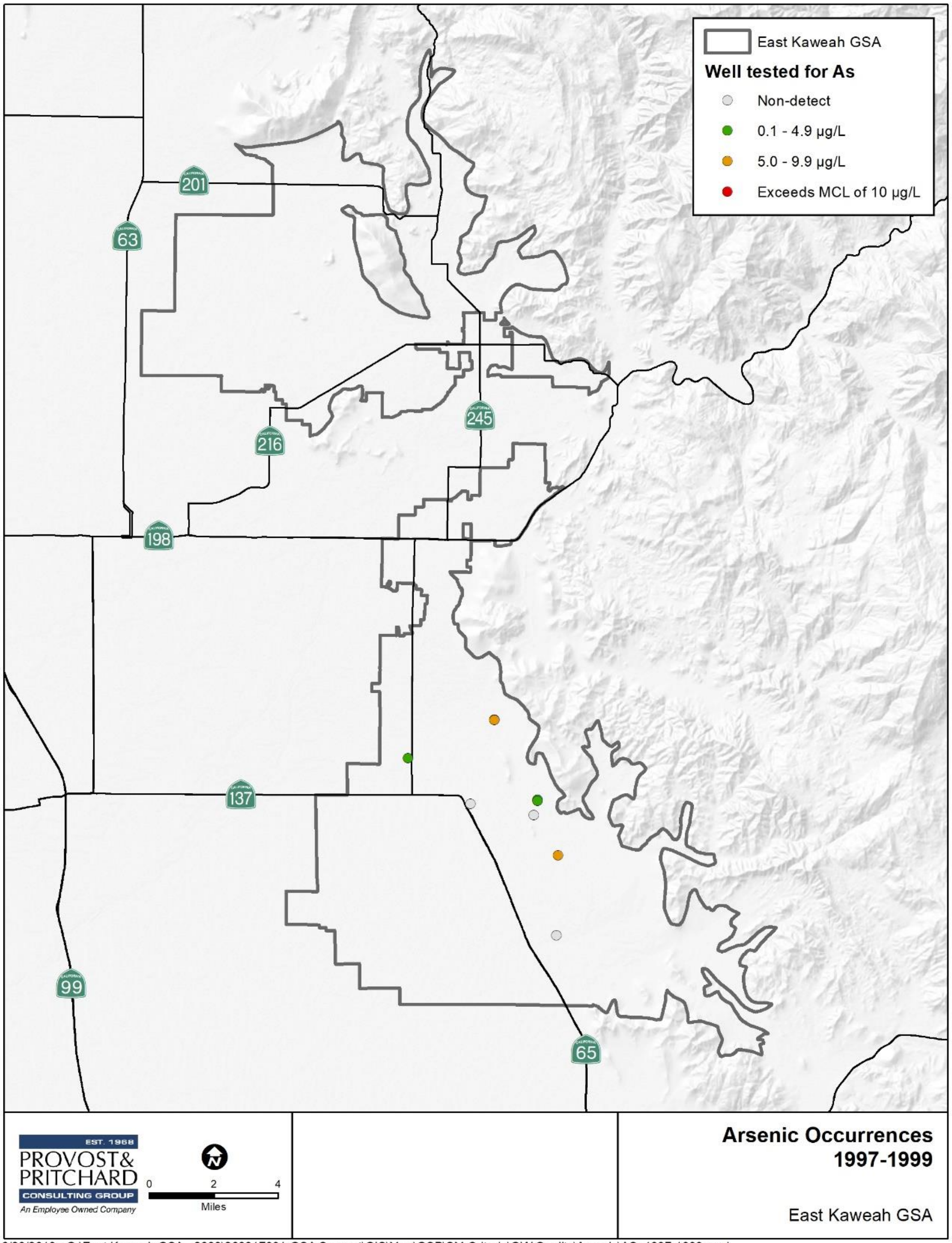
0 2 4
Miles

TDS Averages between 2008 & 2017

East Kaweah GSA

9/12/2019 : G:\East Kaweah GSA - 2633\263317001-GSA Support\GIS\Map\GSP\SM Criteria\GW Quality\Averages\TDS_average_max.mxd

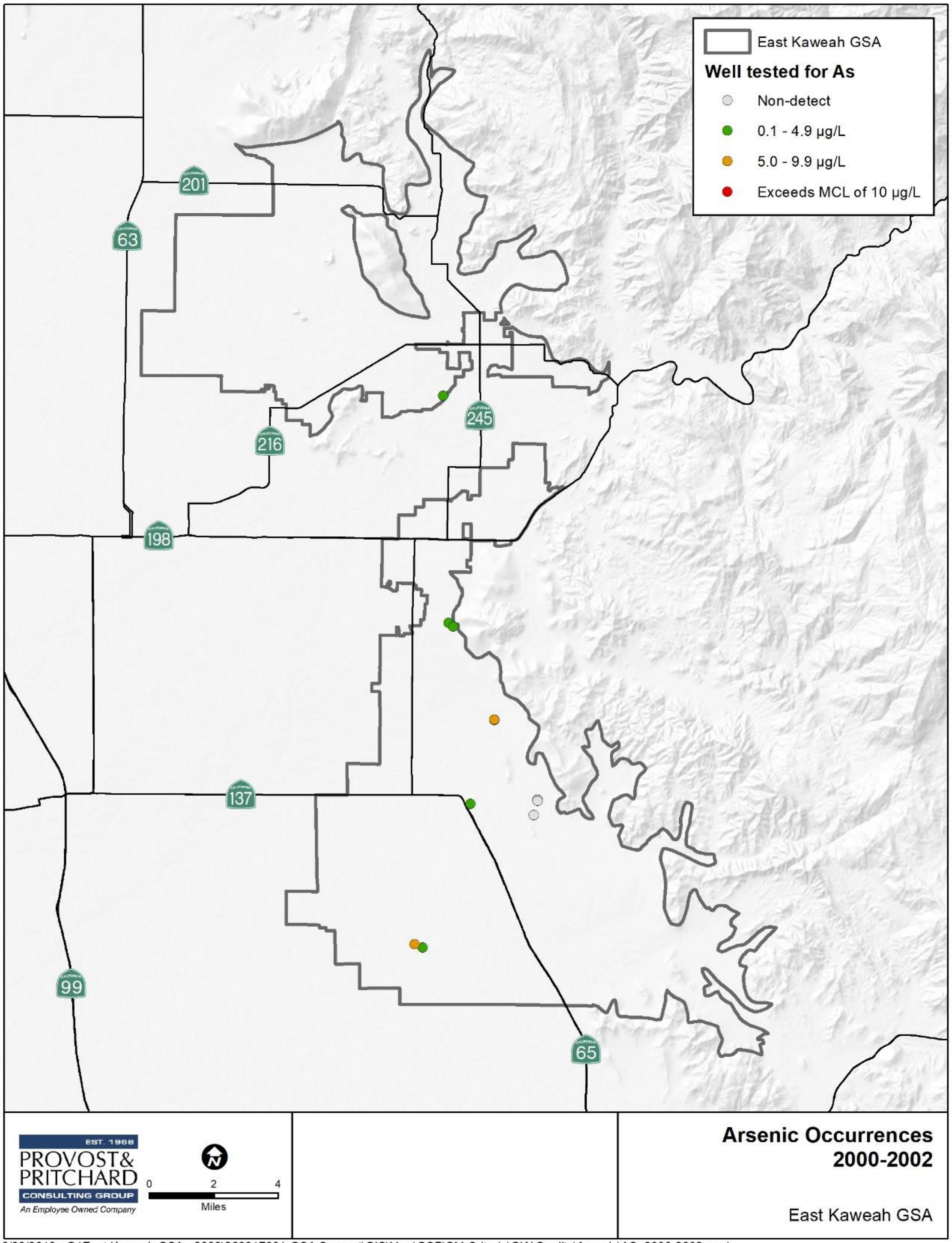
Arsenic Spatial and Temporal Distribution Maps (1997-2017)



Arsenic Occurrences 1997-1999

East Kaweah GSA

6/20/2019 : G:\East Kaweah GSA - 2633\263317001-GSA Support\GIS\Map\GSP\SM Criteria\GW Quality\Arsenic\AS_1997-1999.mxd



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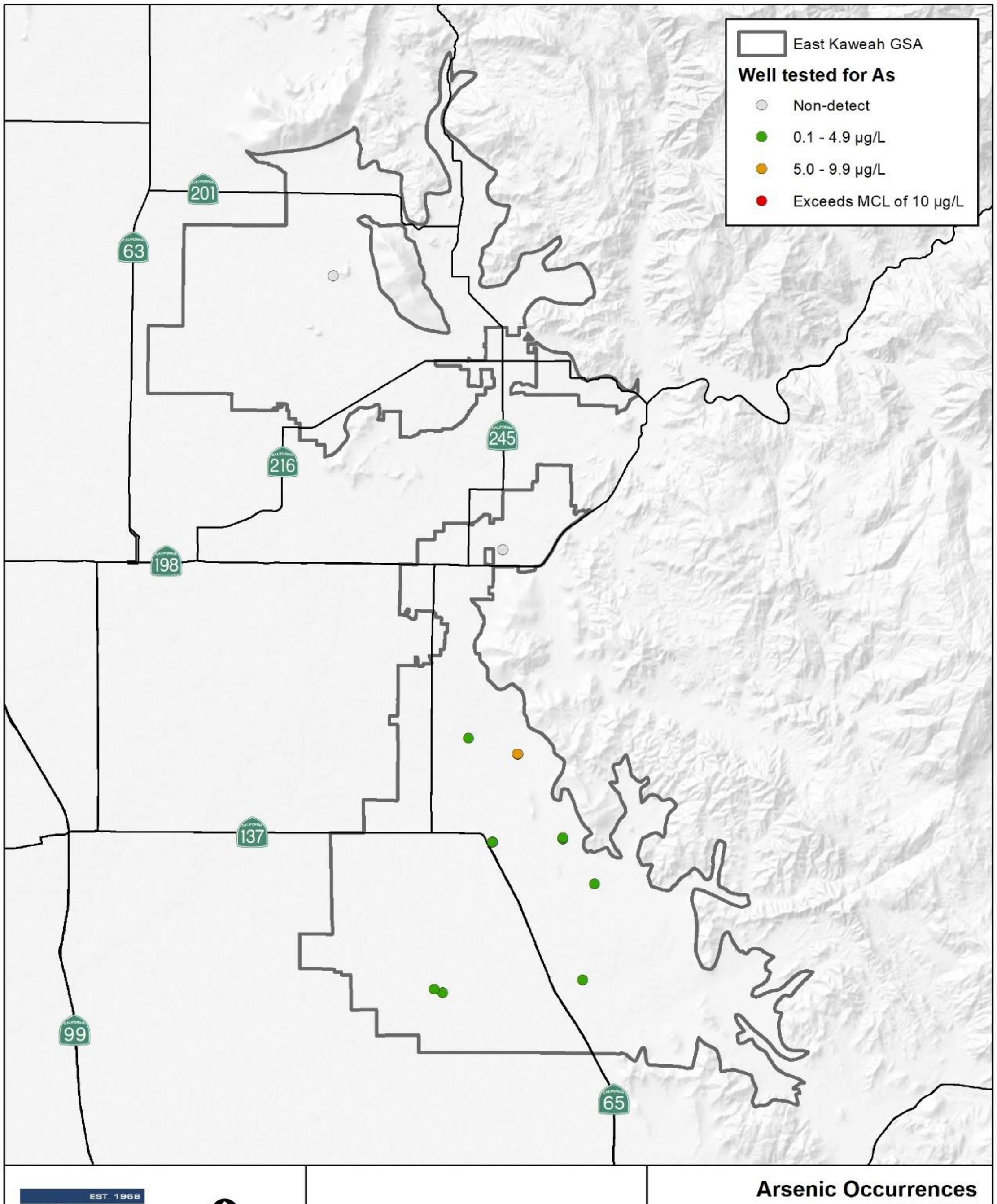

Arsenic Occurrences 2003-2005

East Kaweah GSA

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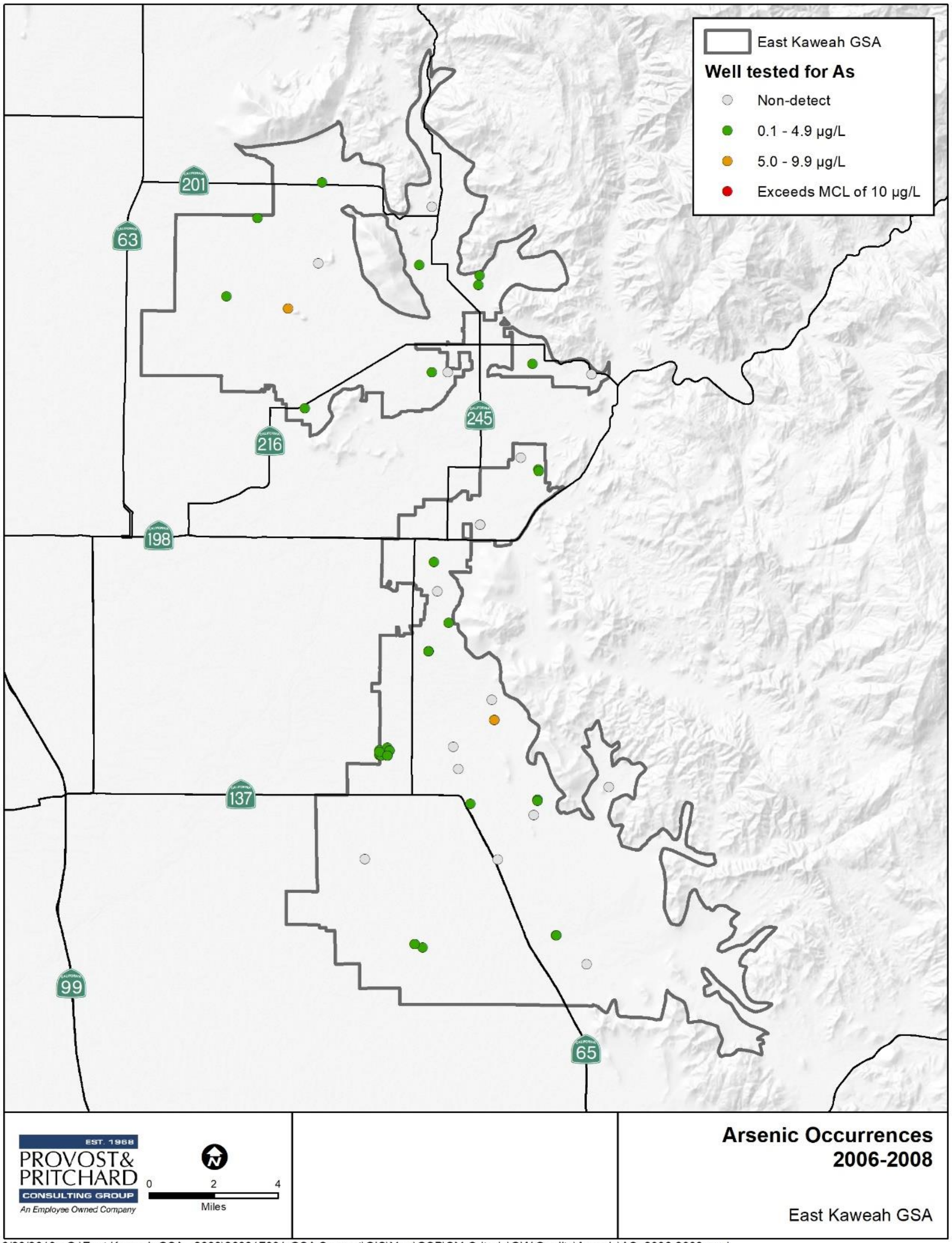

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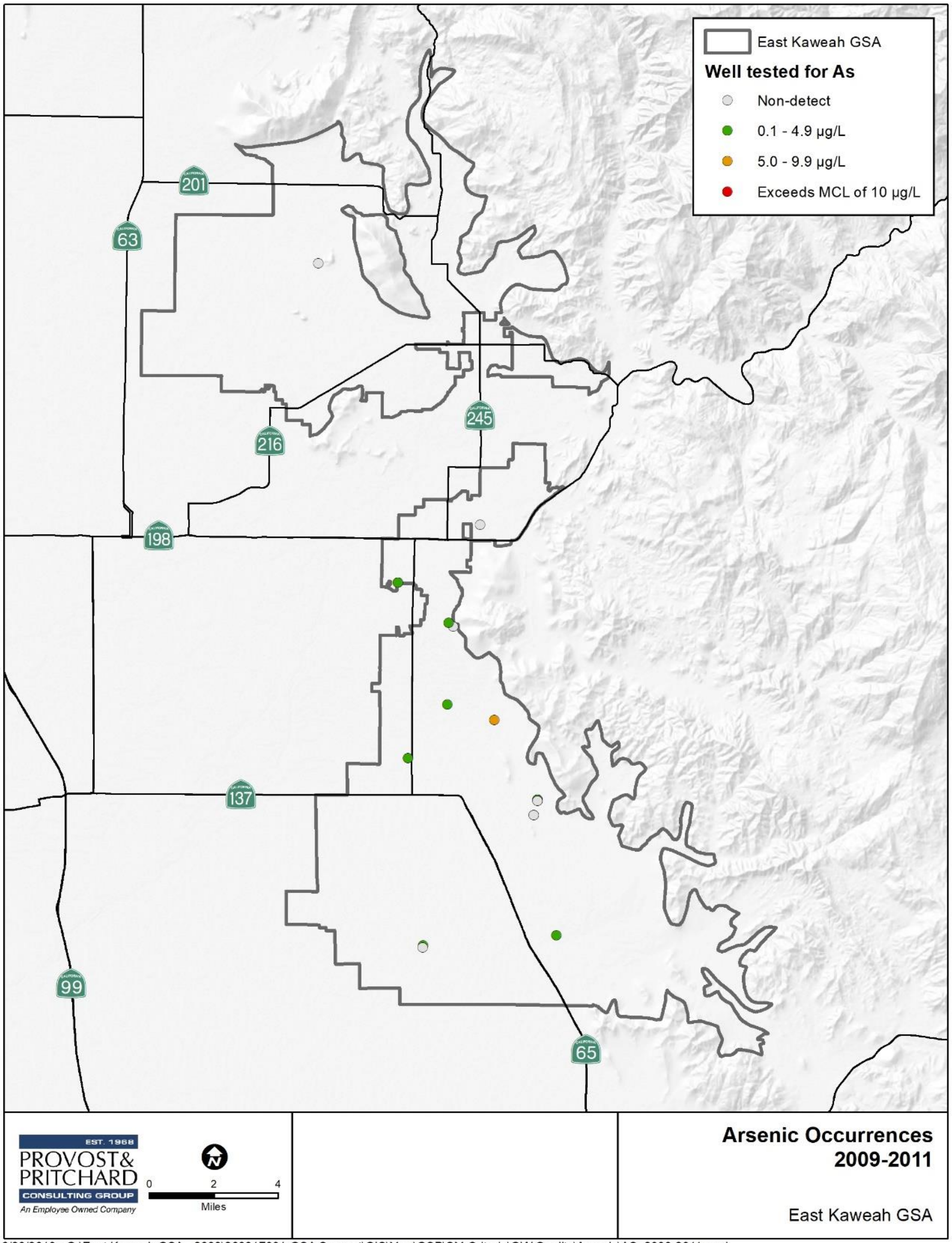

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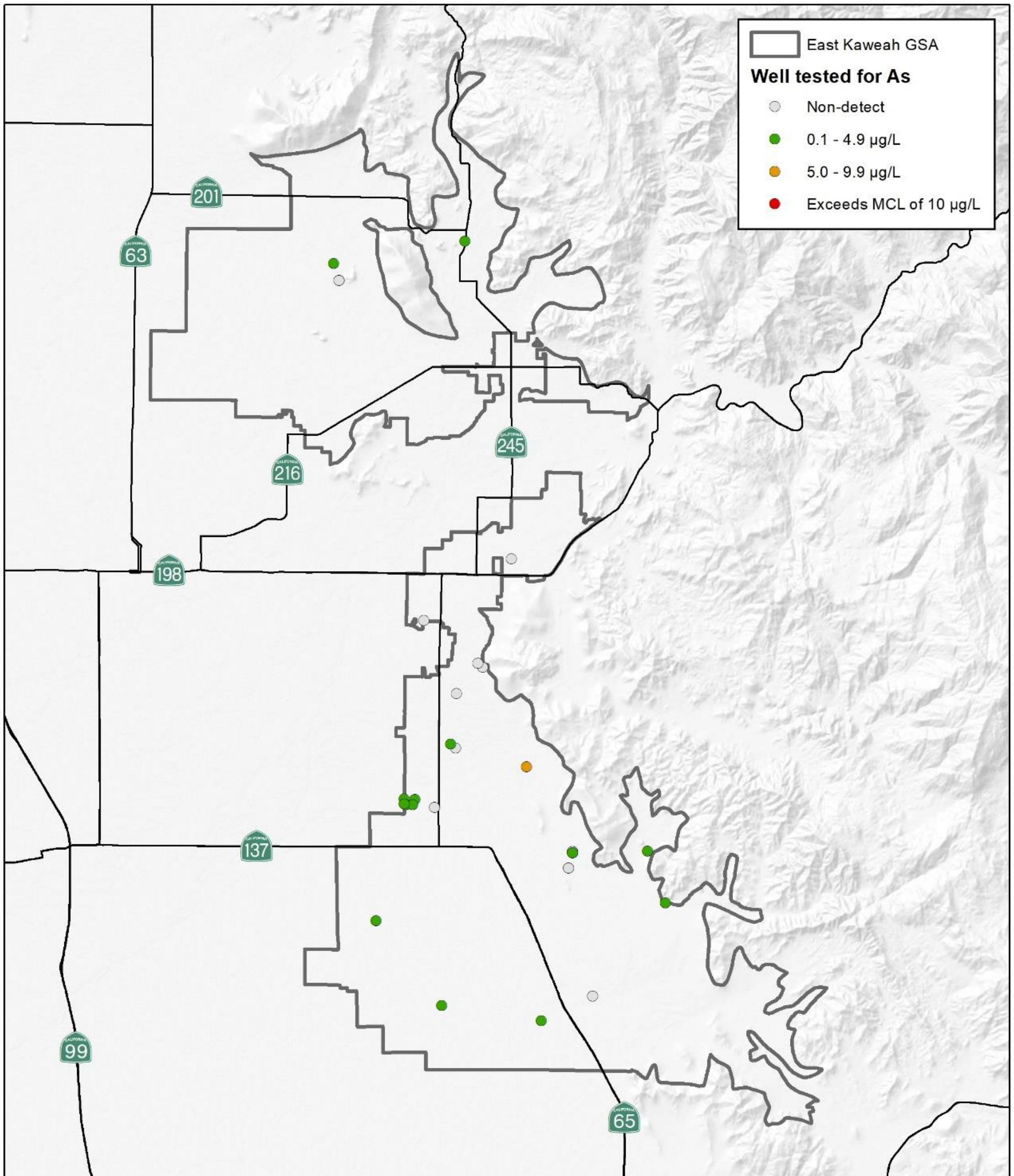

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Arsenic Occurrences 2012-2014

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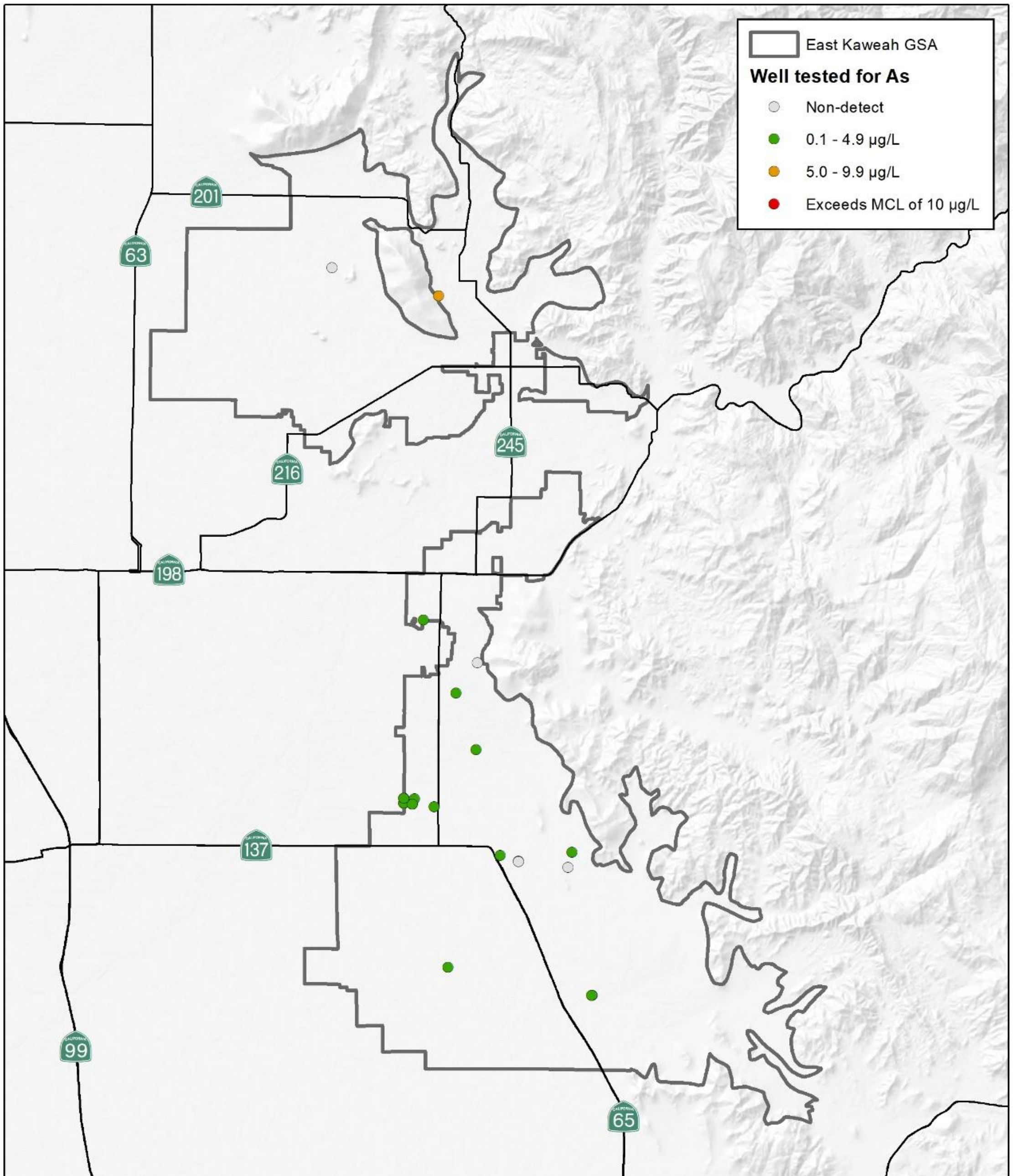

Arsenic Occurrences 2015-2017

East Kaweah GSA

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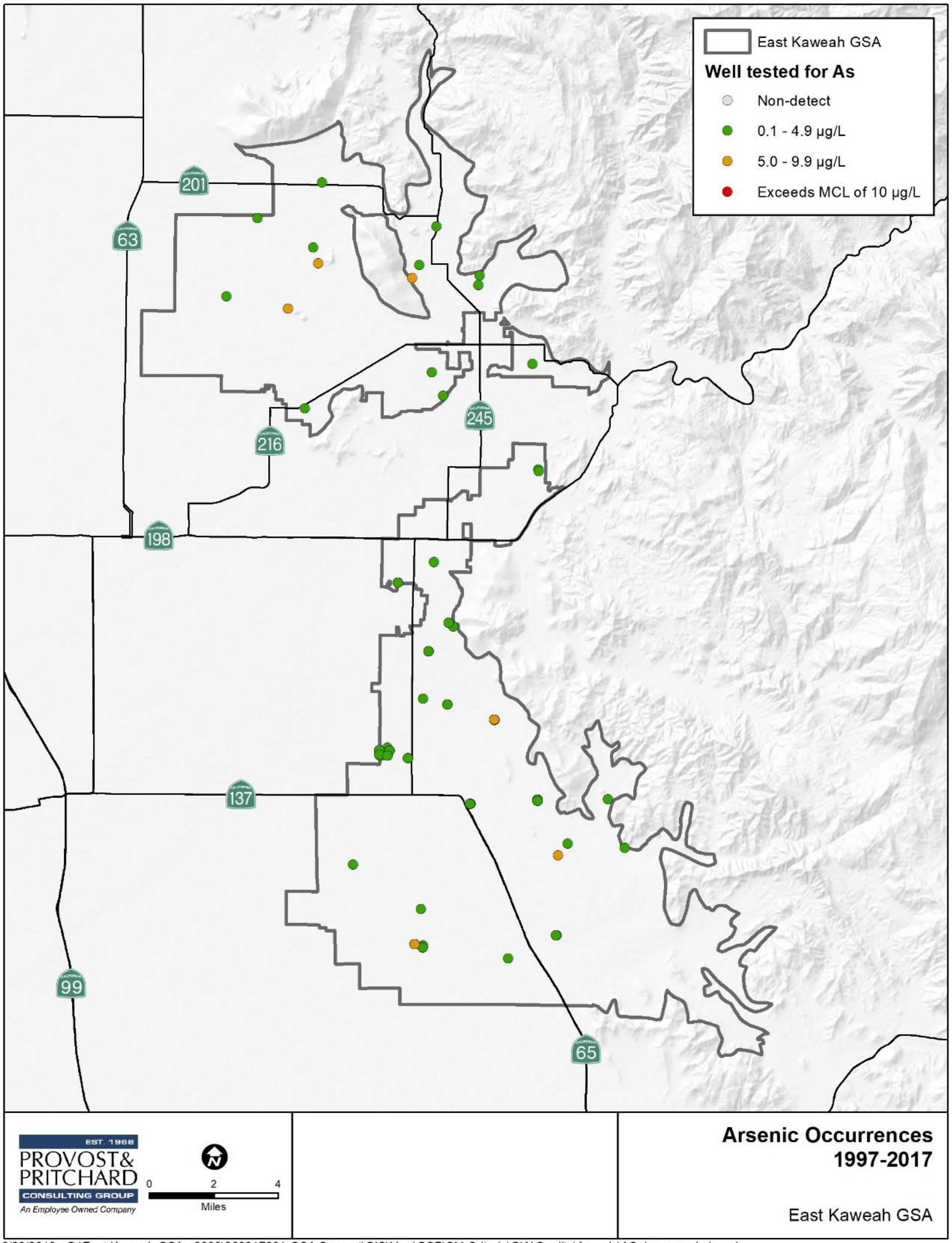

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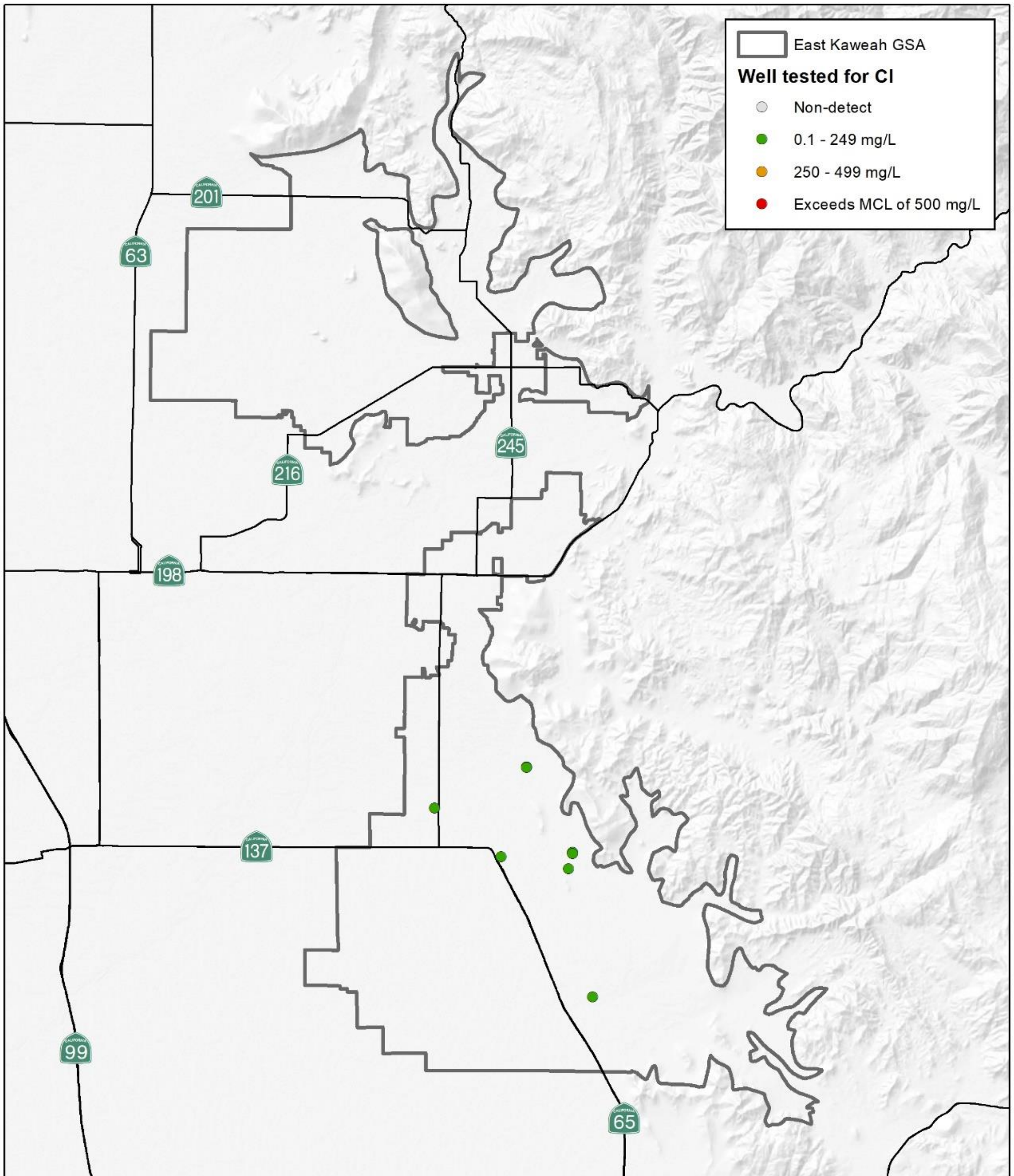
Chloride Spatial and Temporal Distribution Maps (1997-2017)



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Chloride Occurrences 1997-1999

East Kaweah GSA

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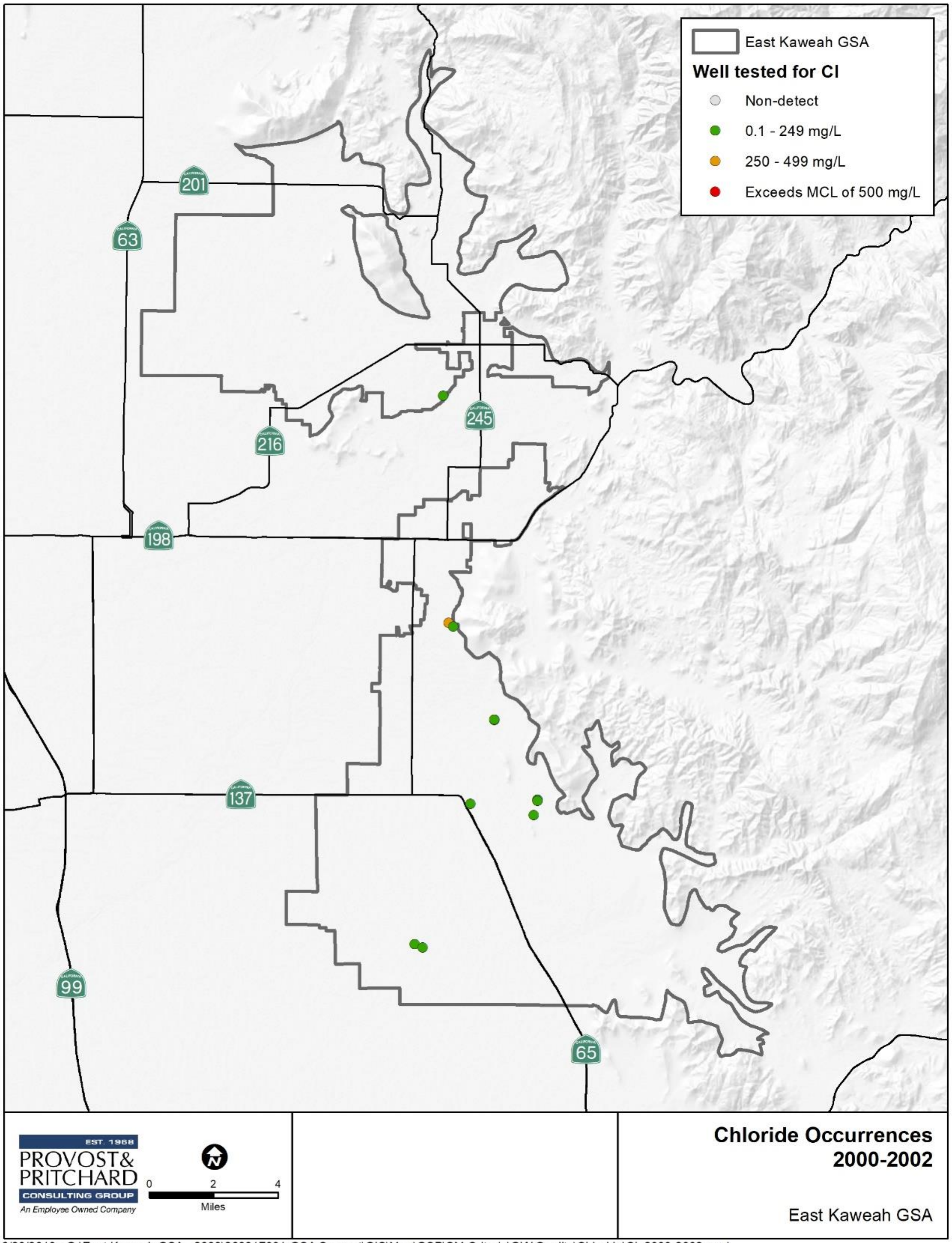

Chloride Occurrences
2000-2002

East Kaweah GSA

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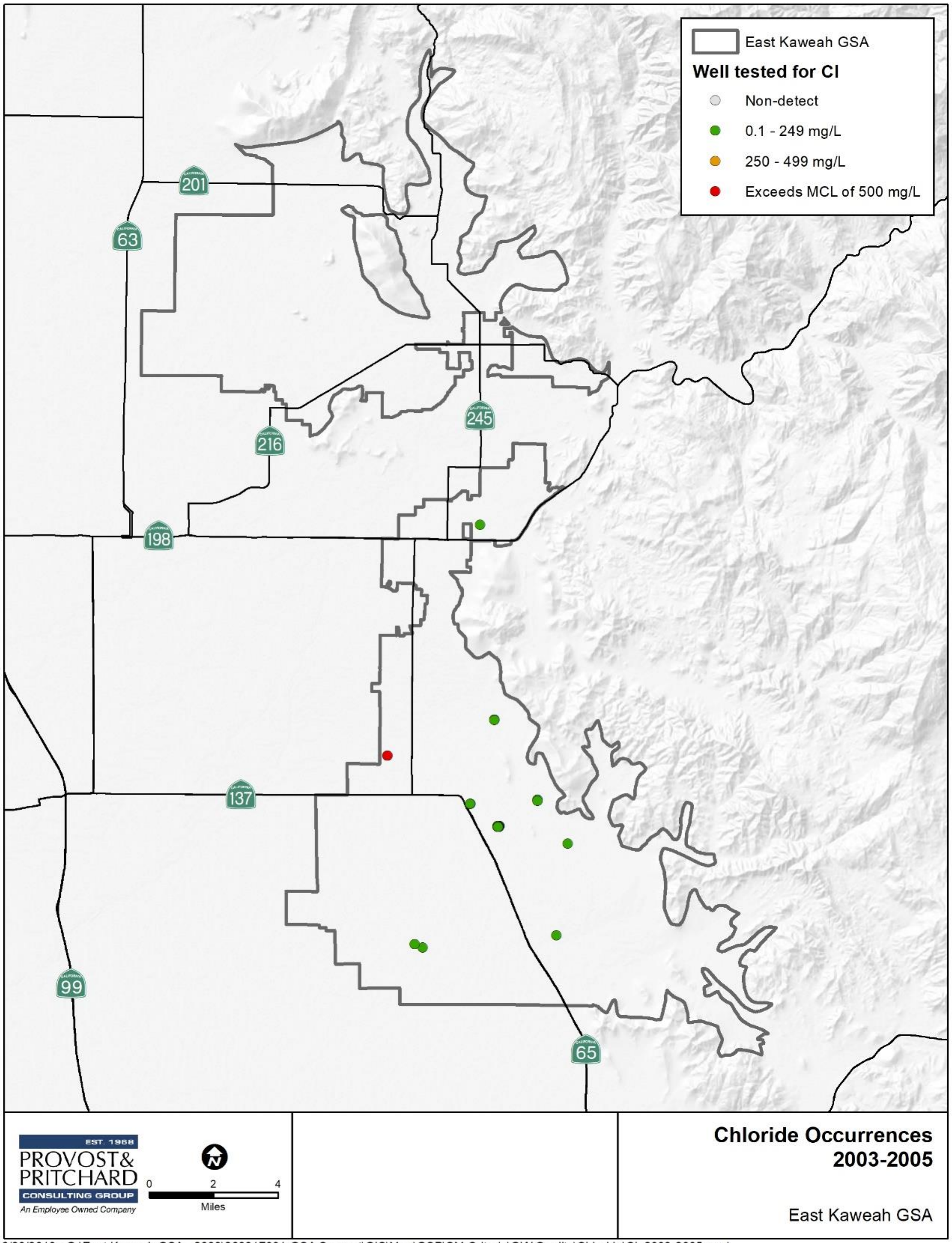

Chloride Occurrences 2003-2005

East Kaweah GSA

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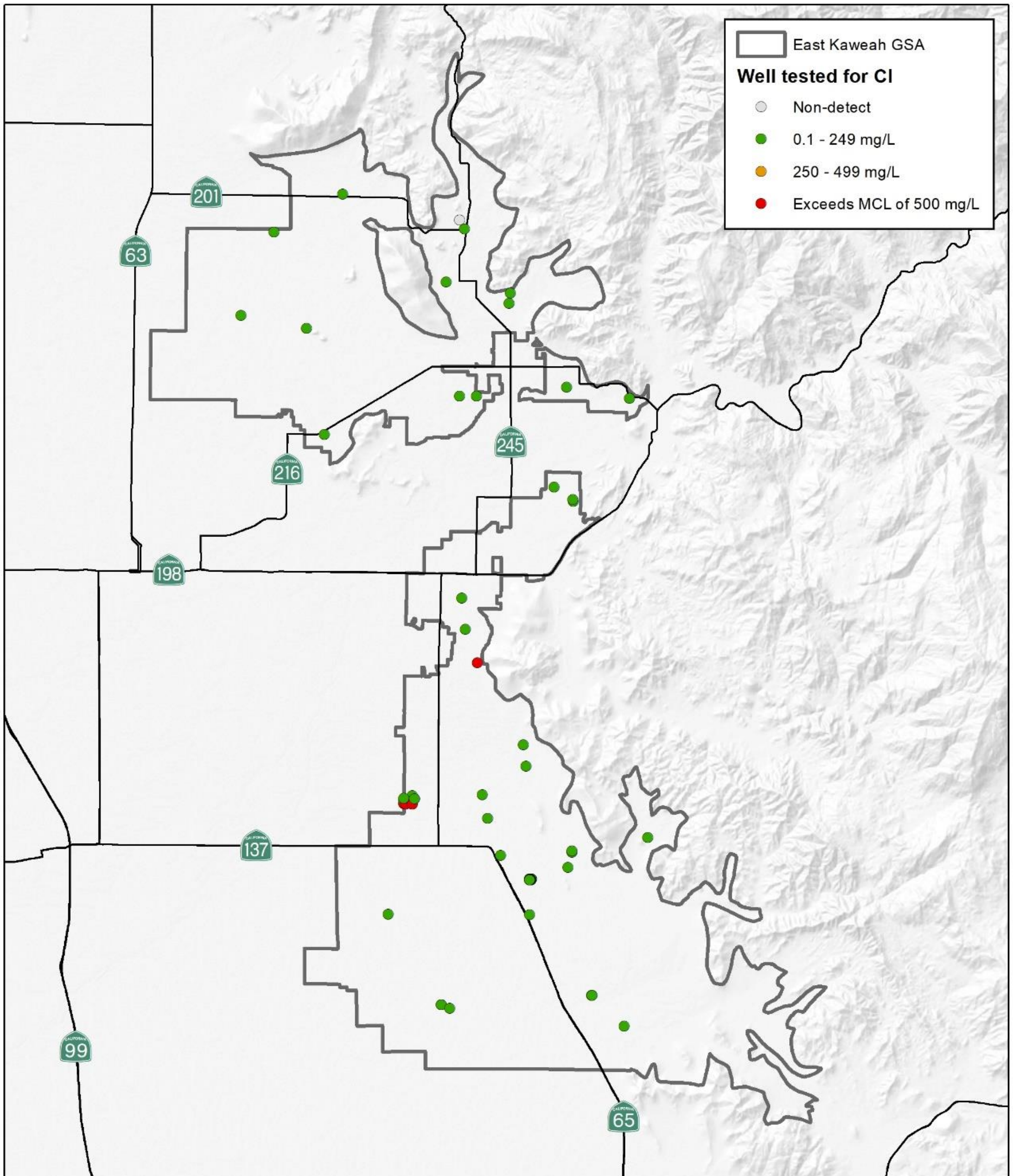

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Chloride Occurrences 2006-2008

East Kaweah GSA

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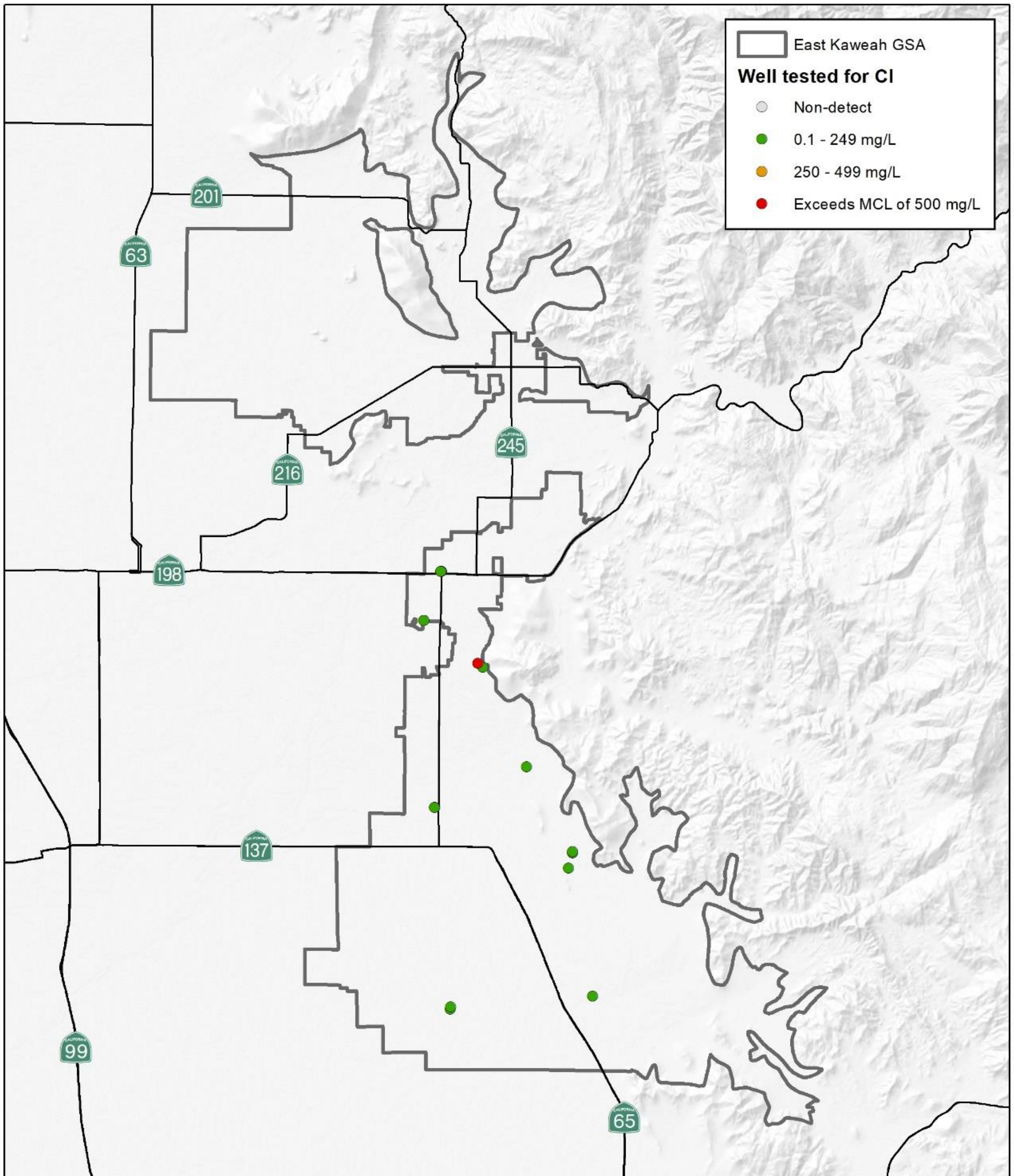

Chloride Occurrences 2009-2011

East Kaweah GSA

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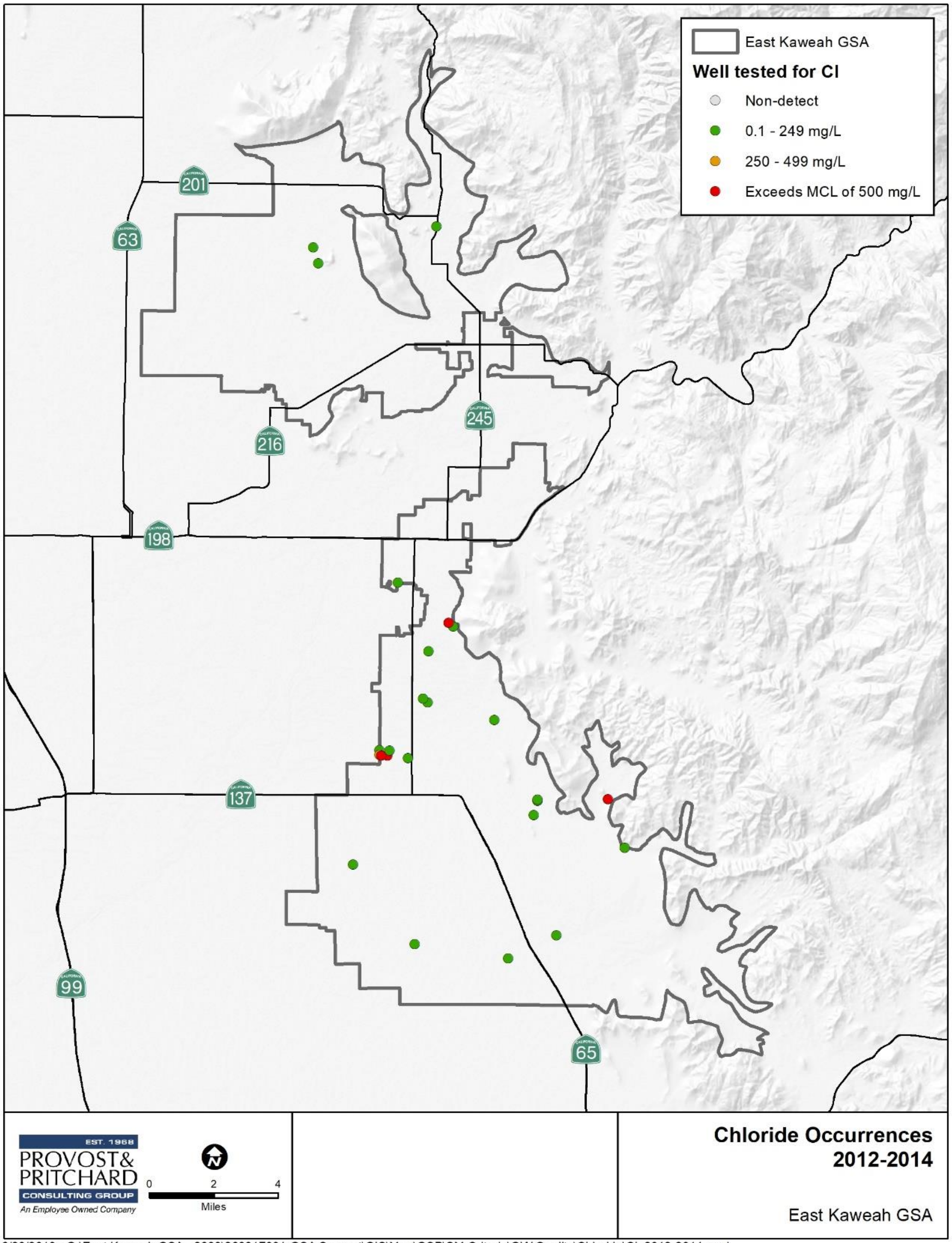

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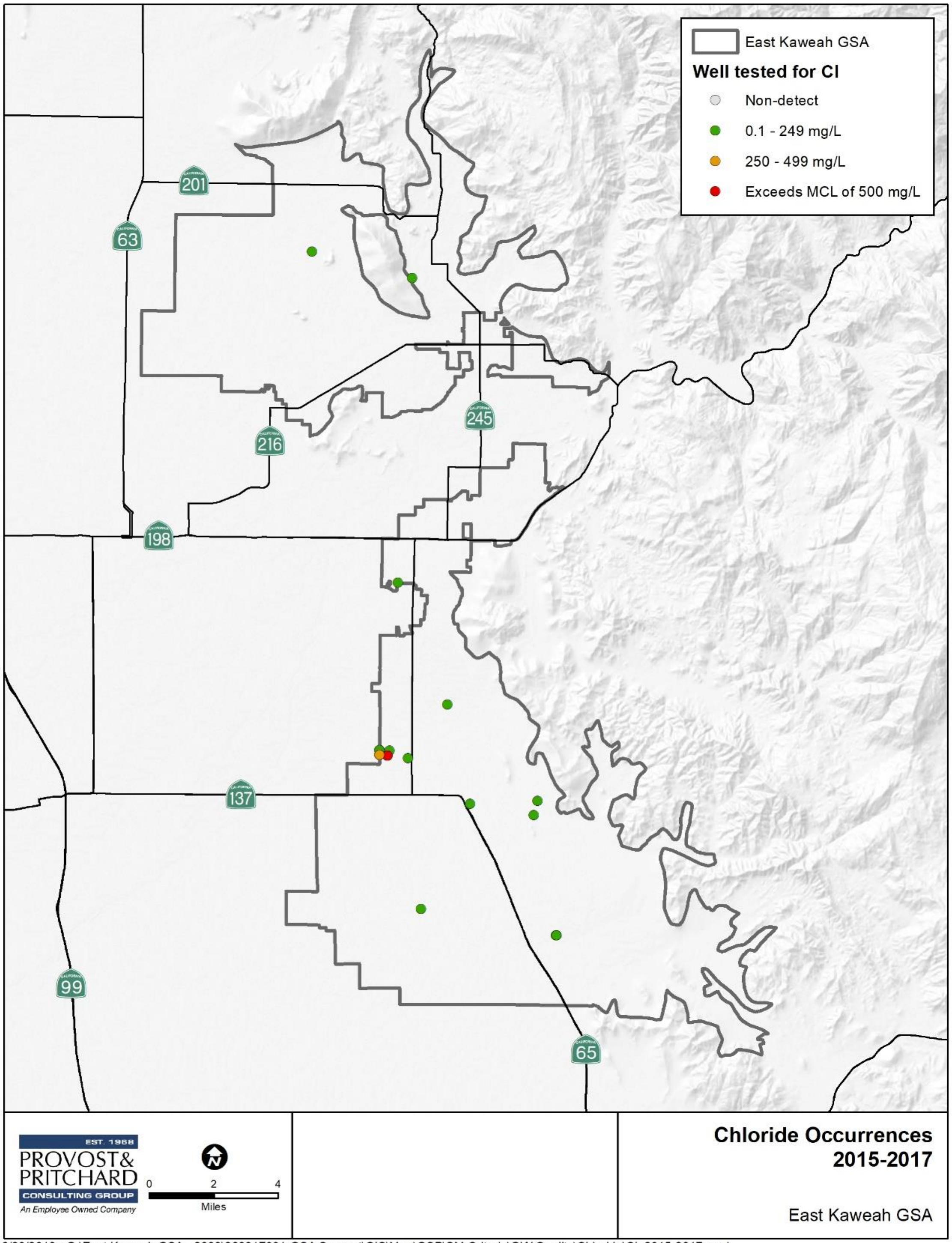

Chloride Occurrences 2015-2017

East Kaweah GSA

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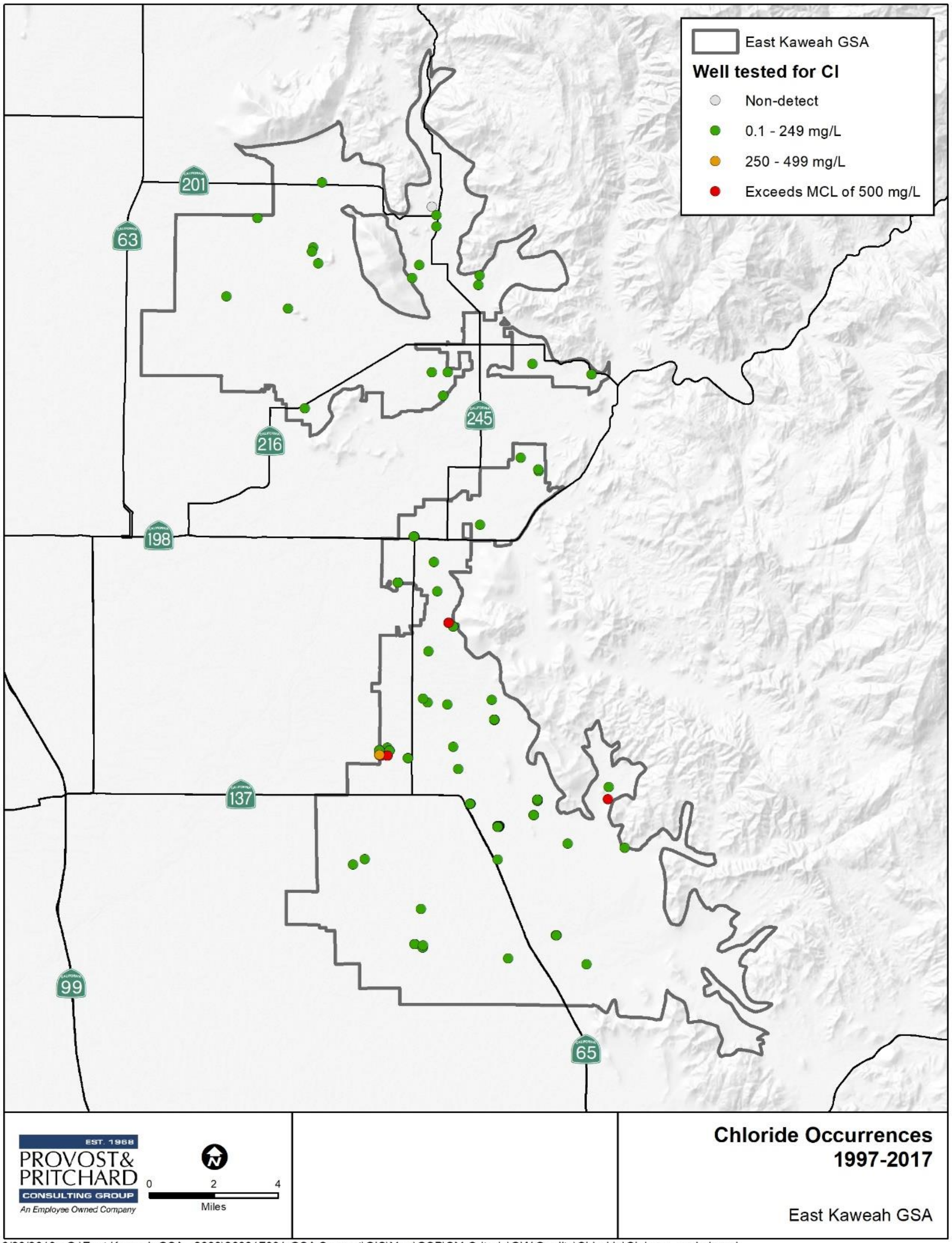

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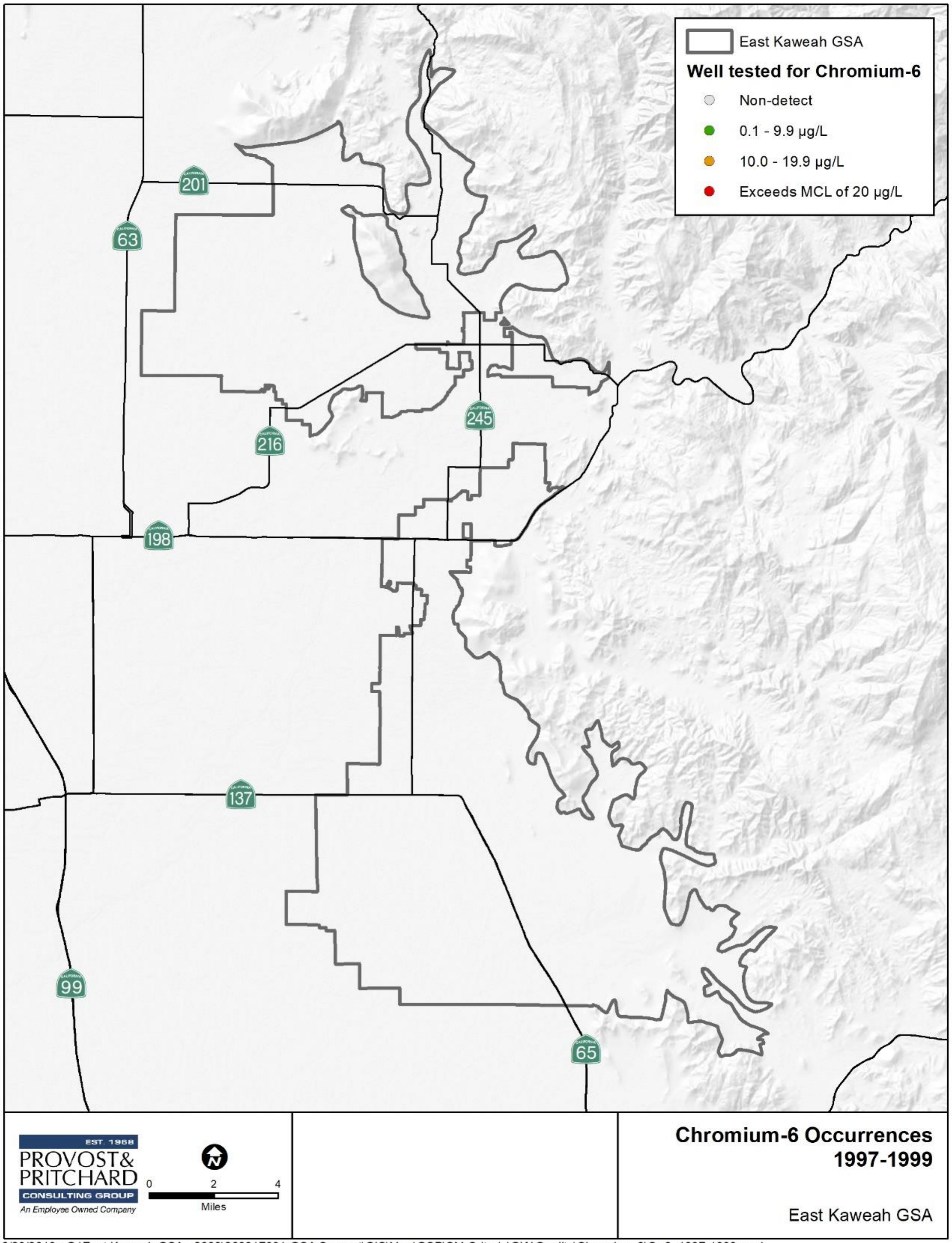
Chromium-6 (Hexavalent) Spatial and Temporal Distribution Maps (1997-2017)



Chromium-6 Occurrences 1997-1999

East Kaweah GSA

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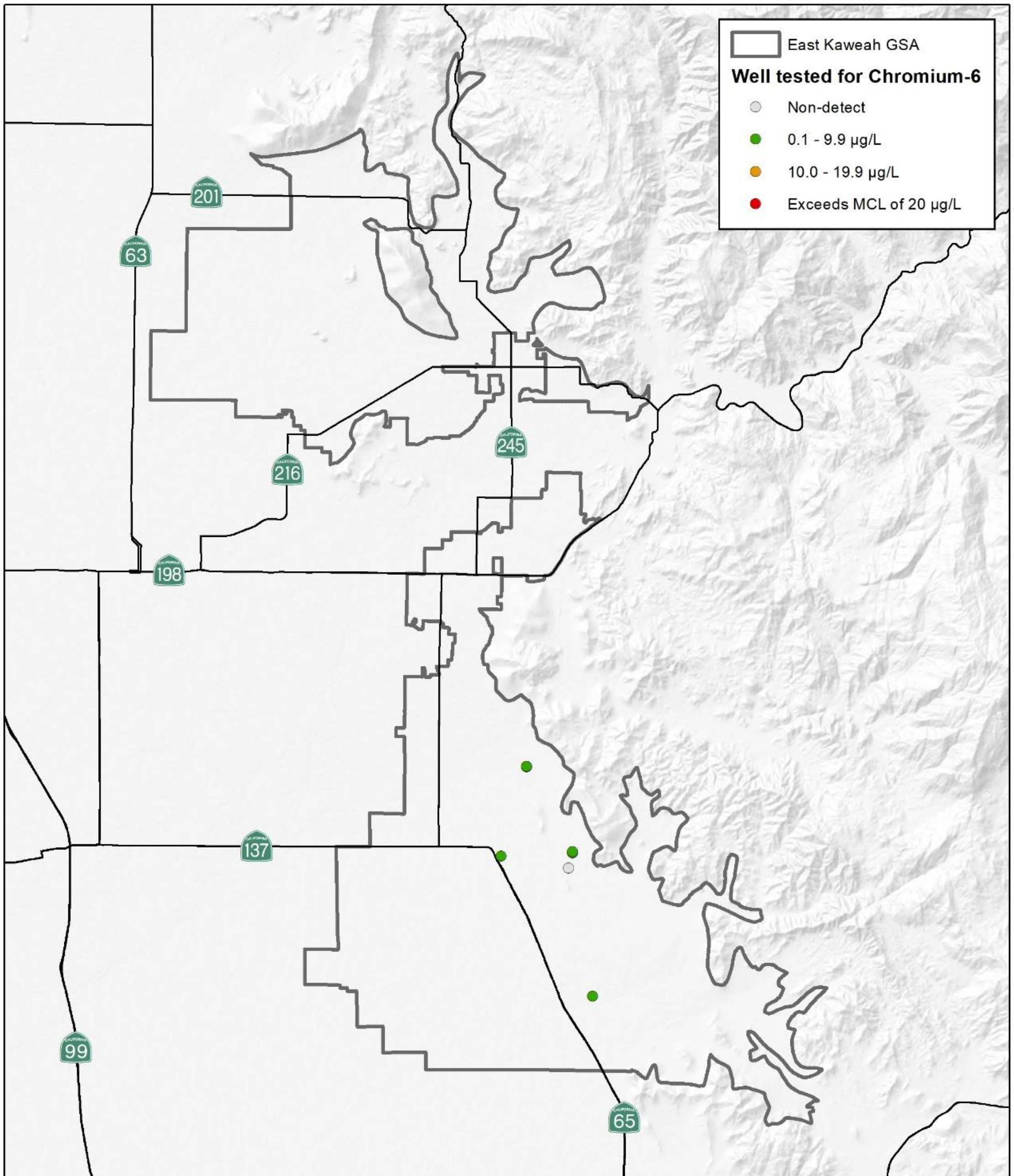

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Chromium-6 Occurrences 2000-2002

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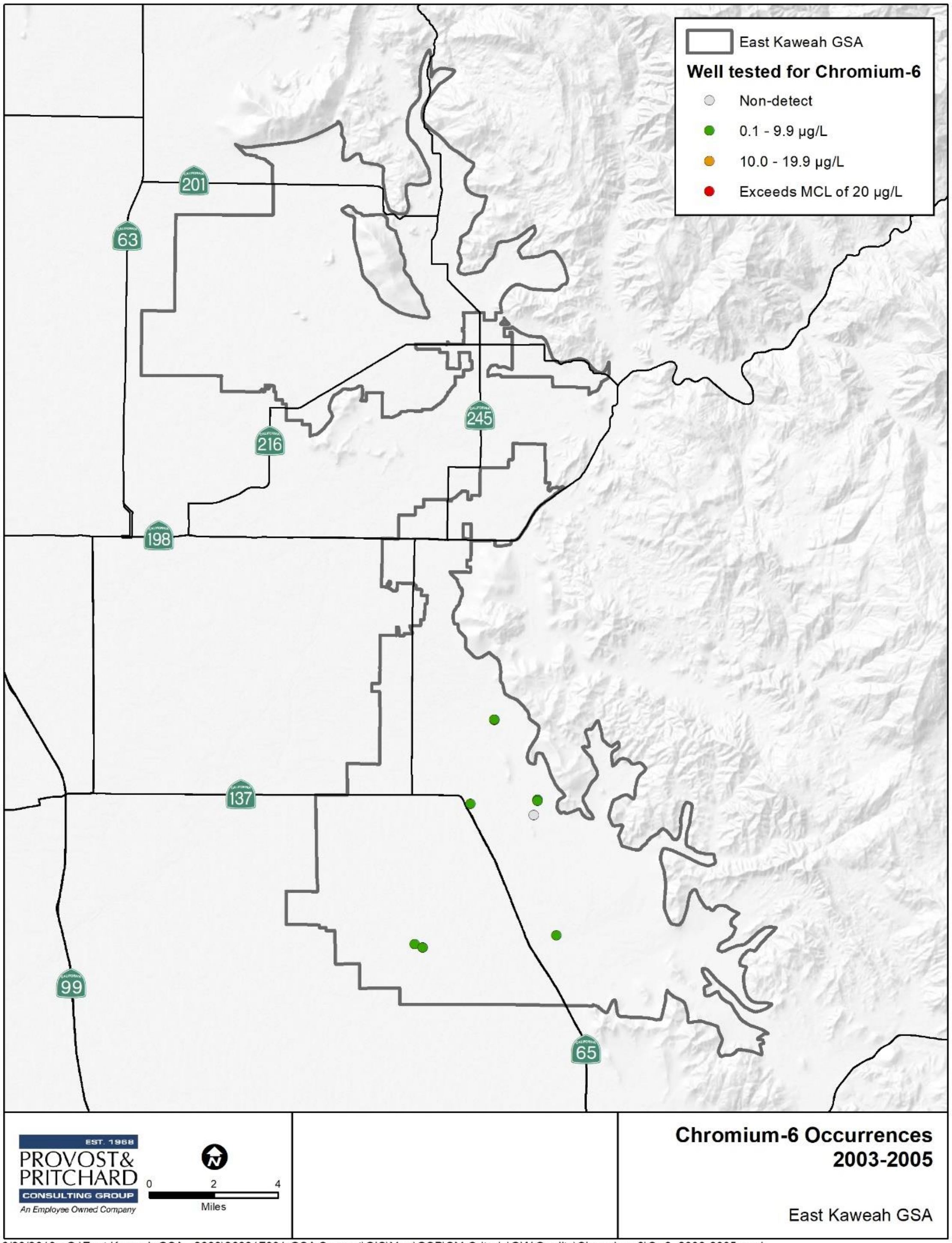

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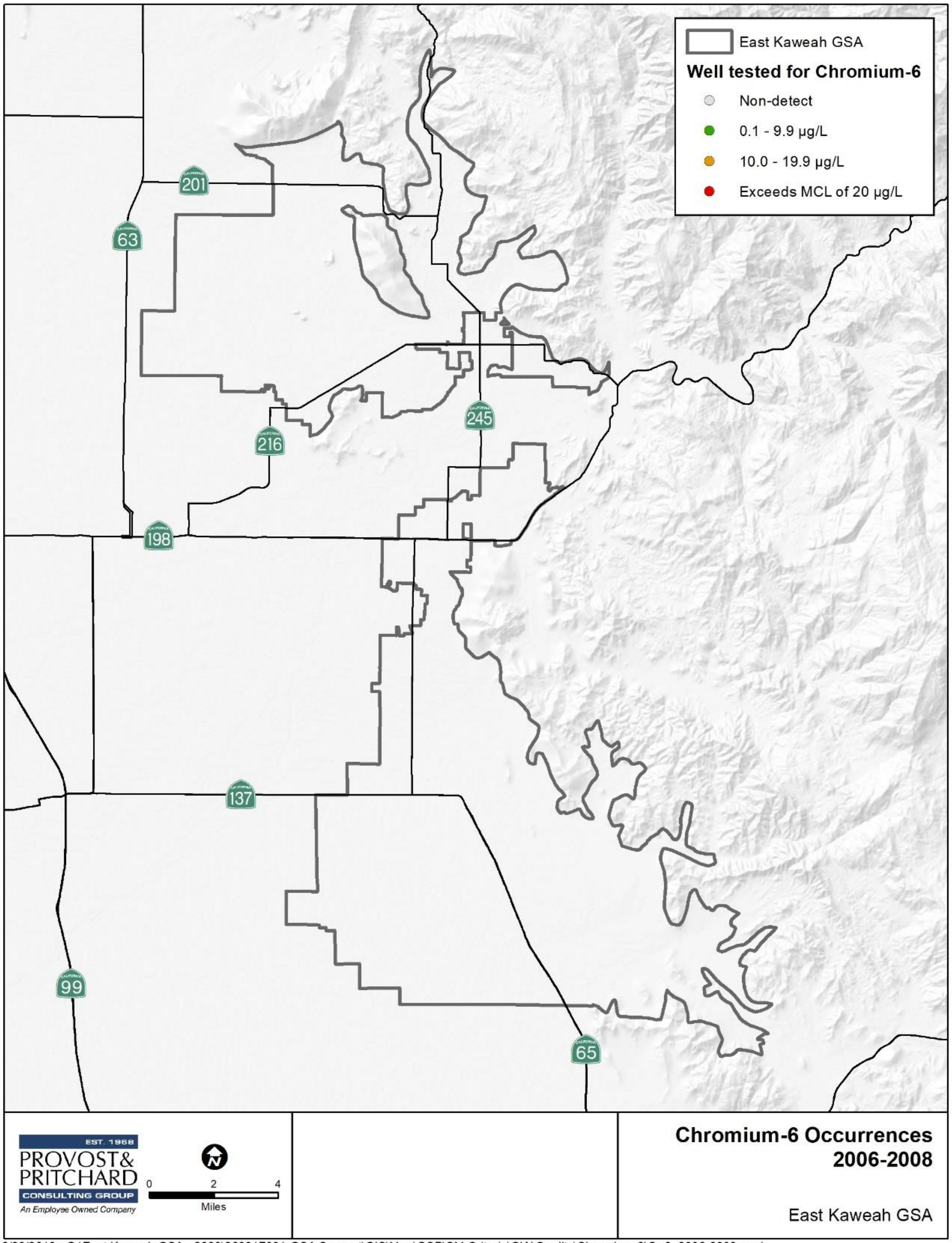

Chromium-6 Occurrences 2006-2008

East Kaweah GSA

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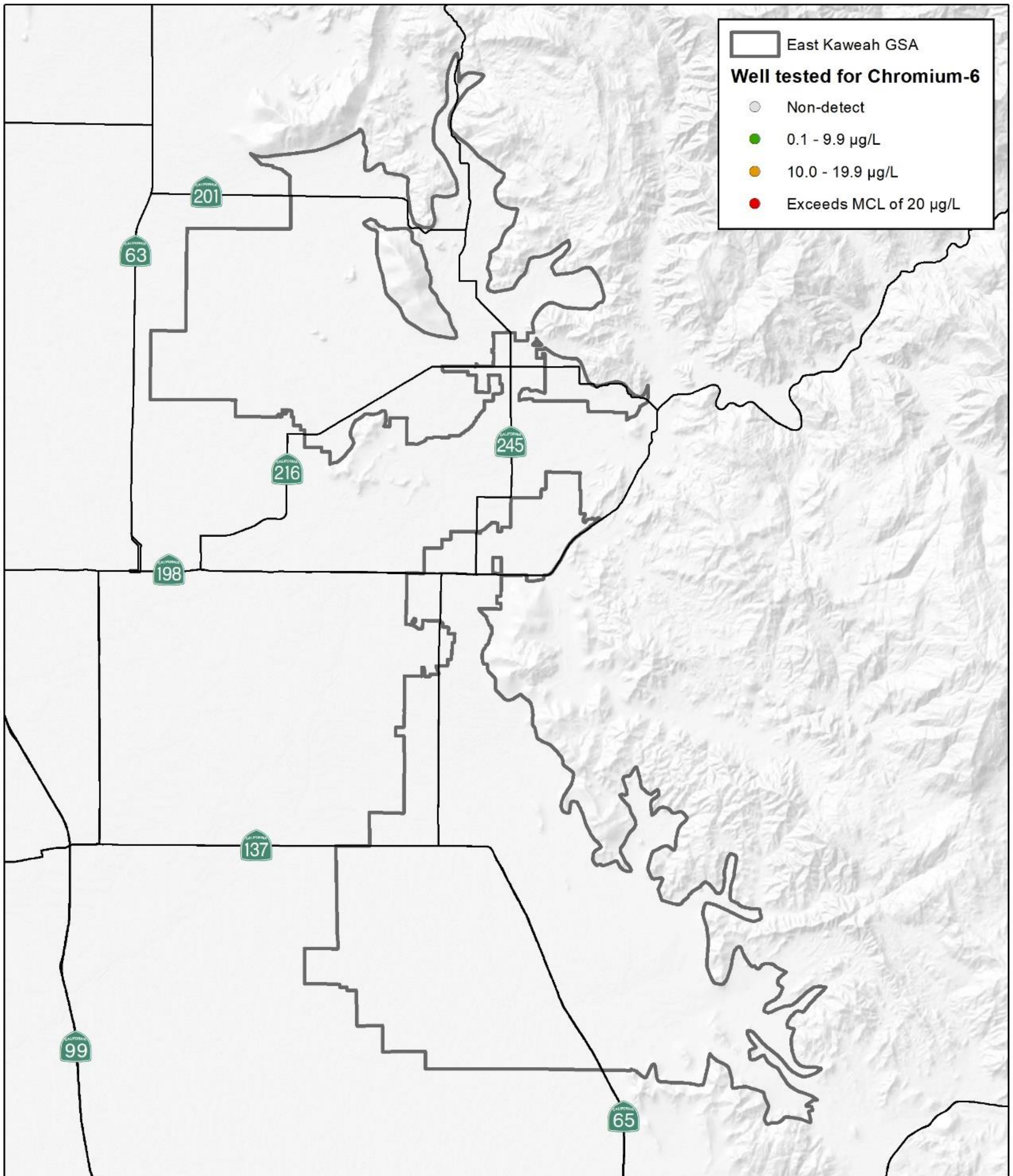

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Chromium-6 Occurrences 2009-2011

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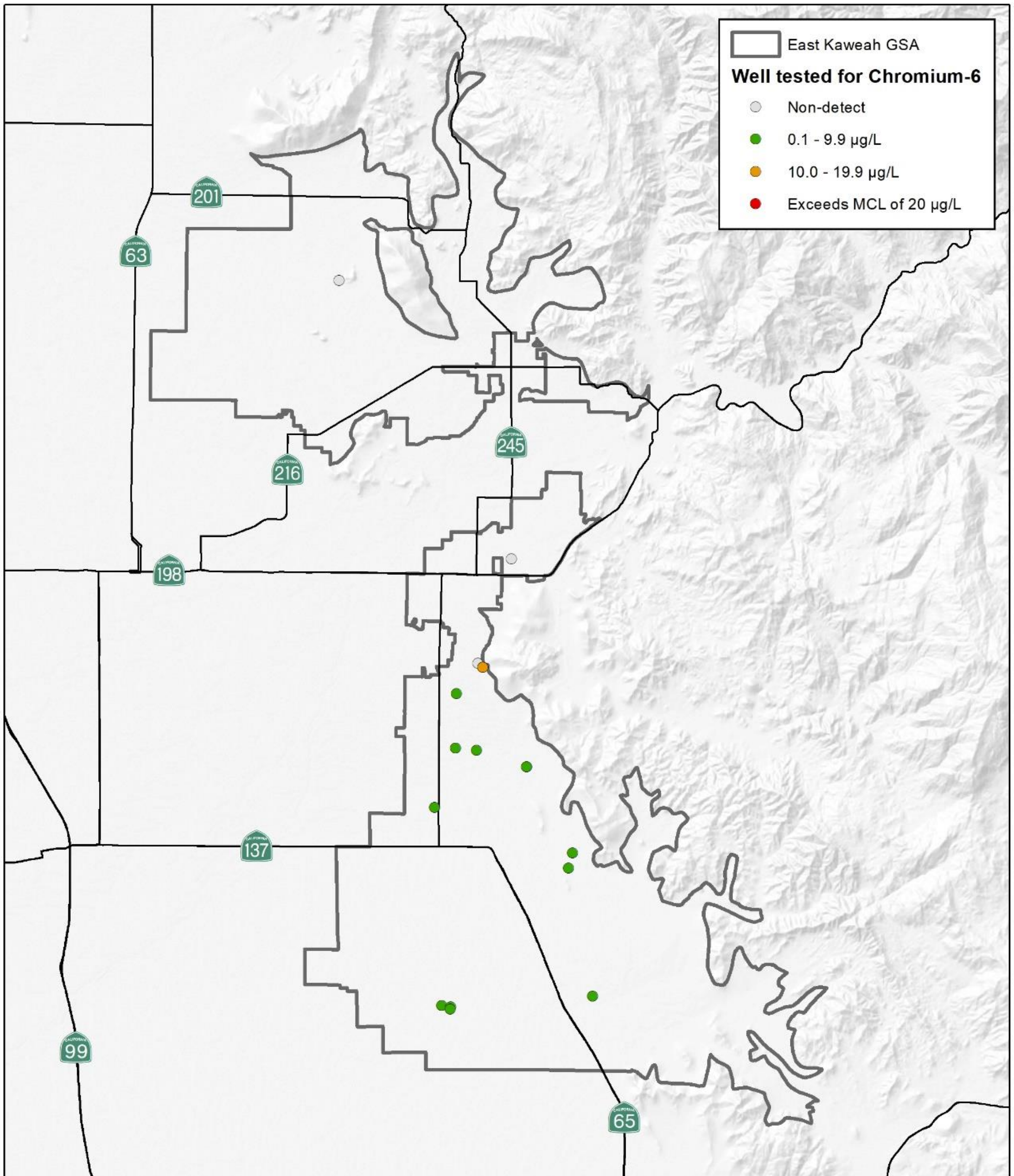

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Chromium-6 Occurrences 2012-2014

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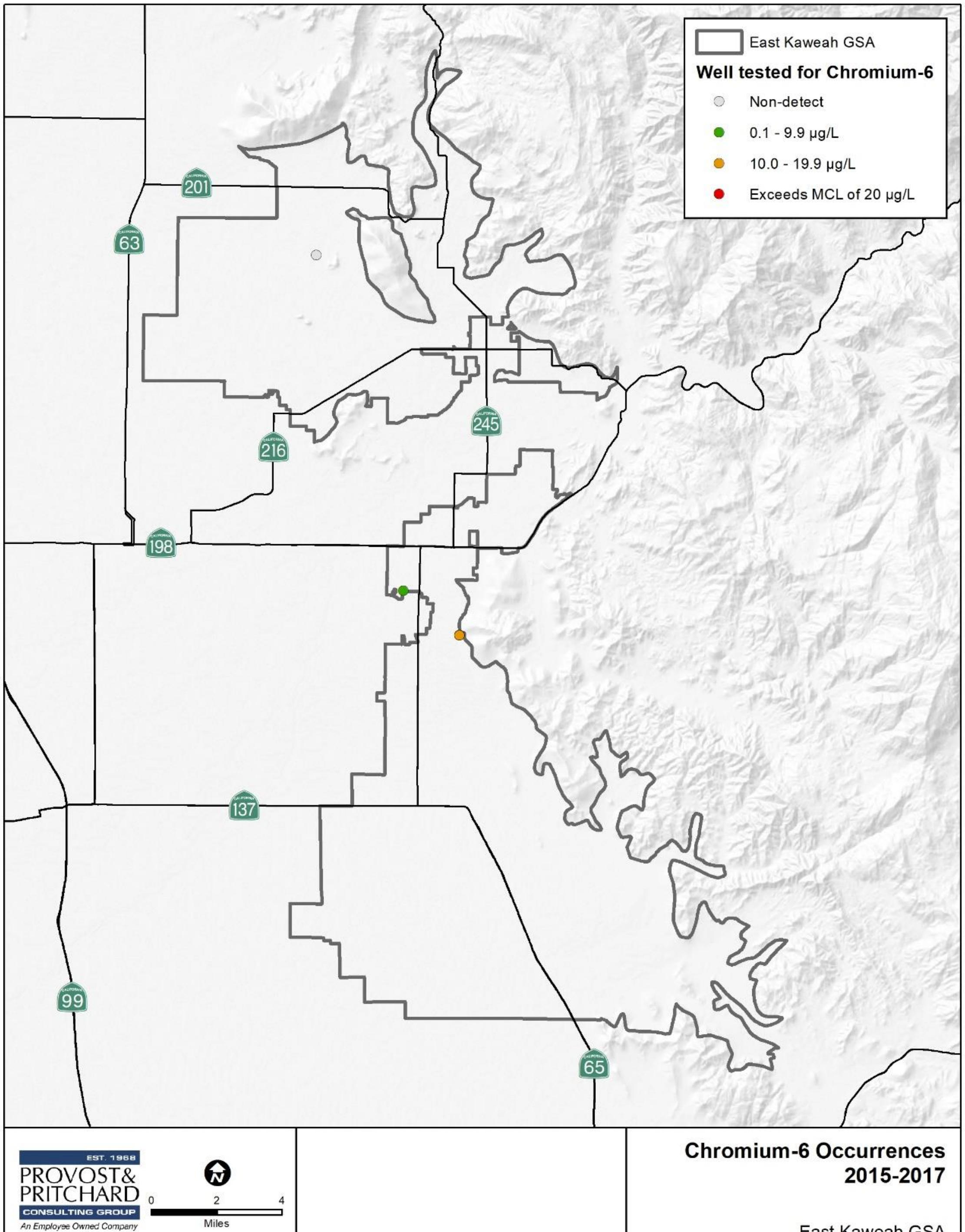

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Chromium-6 Occurrences 2015-2017

East Kaweah GSA

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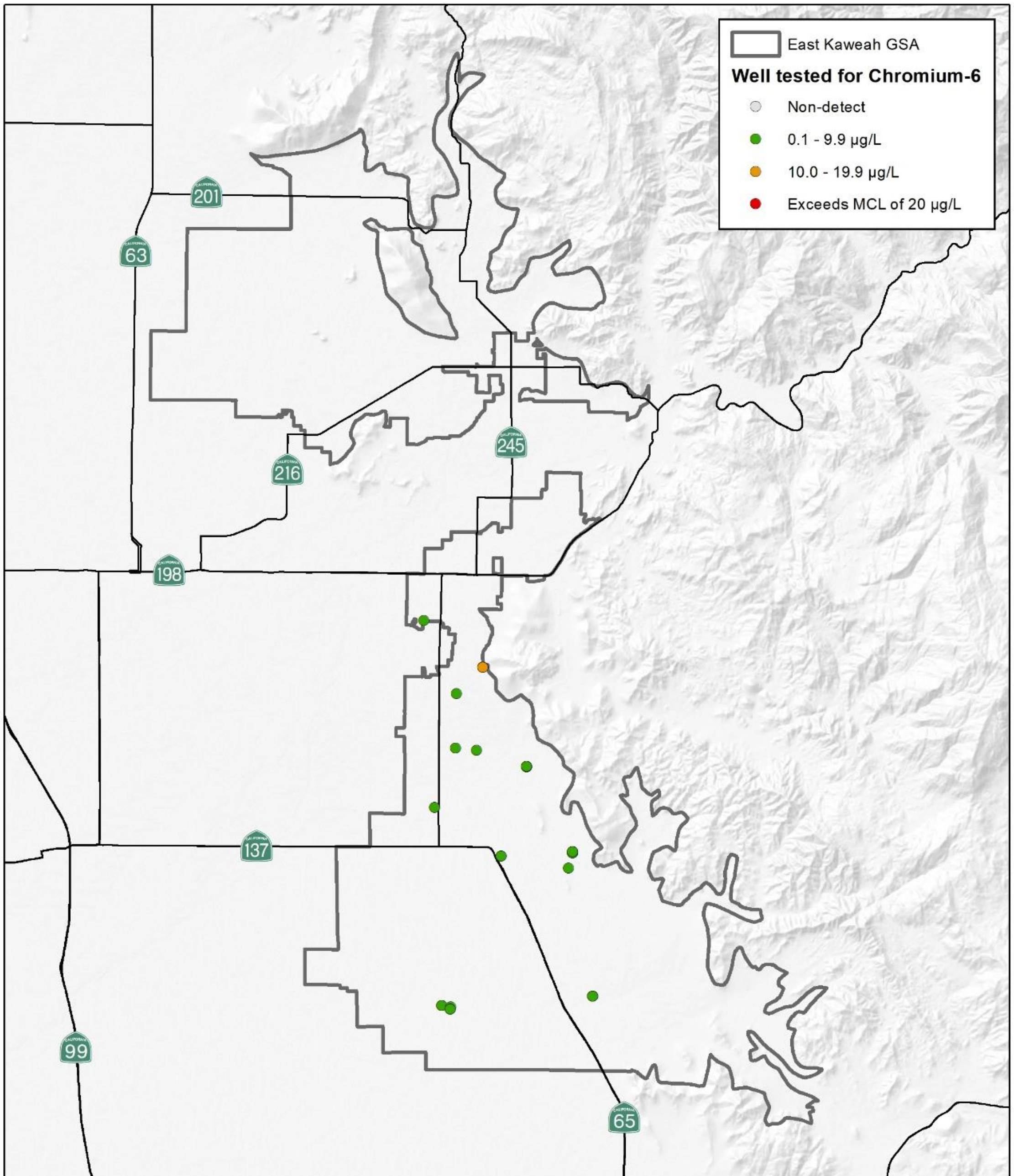

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**Chromium-6 Occurrences
1997-2017**

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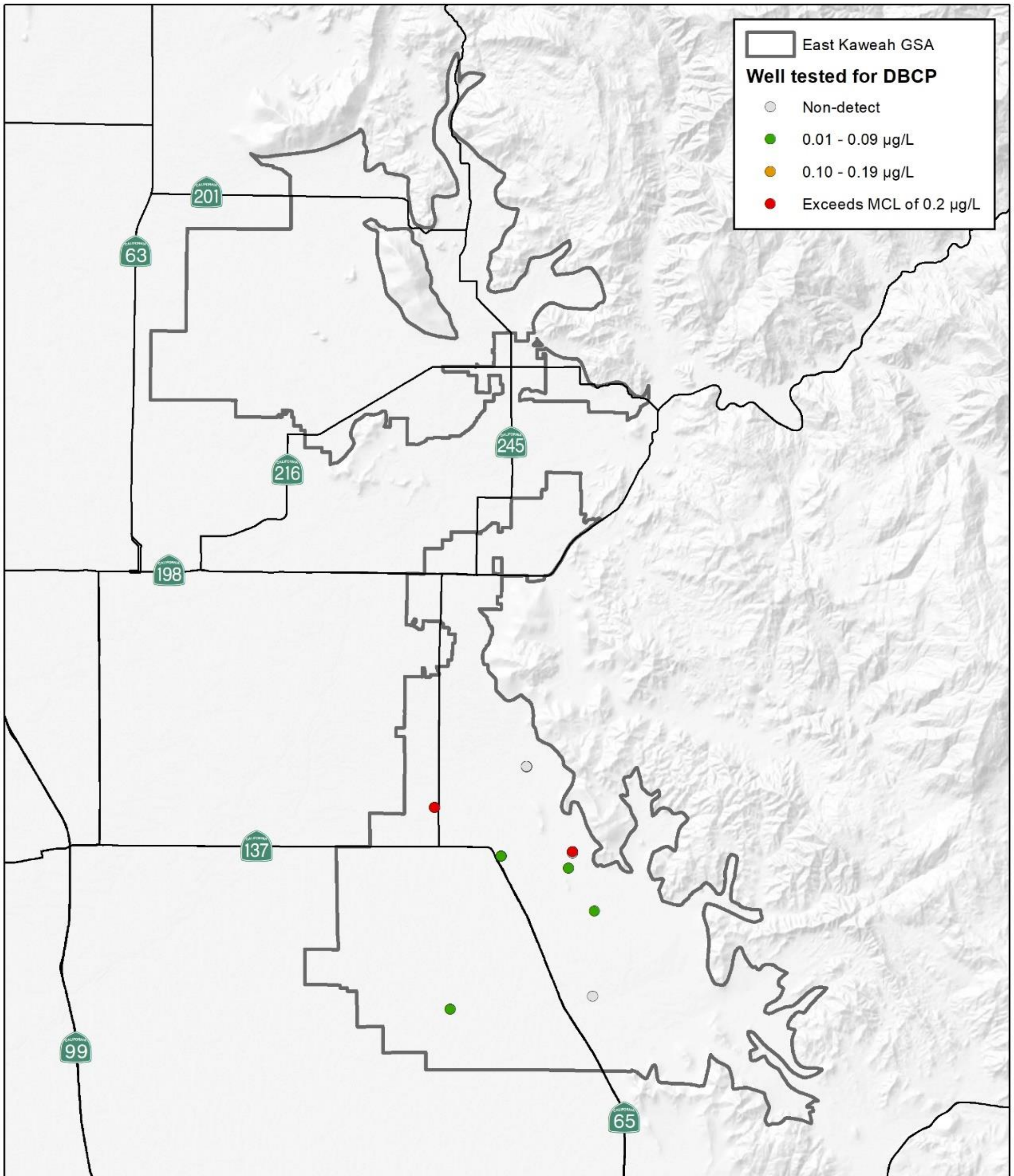
1,2 – Dibromo-3-chloropropane (DBCP) Spatial and Temporal Distribution Maps (1997-2017)



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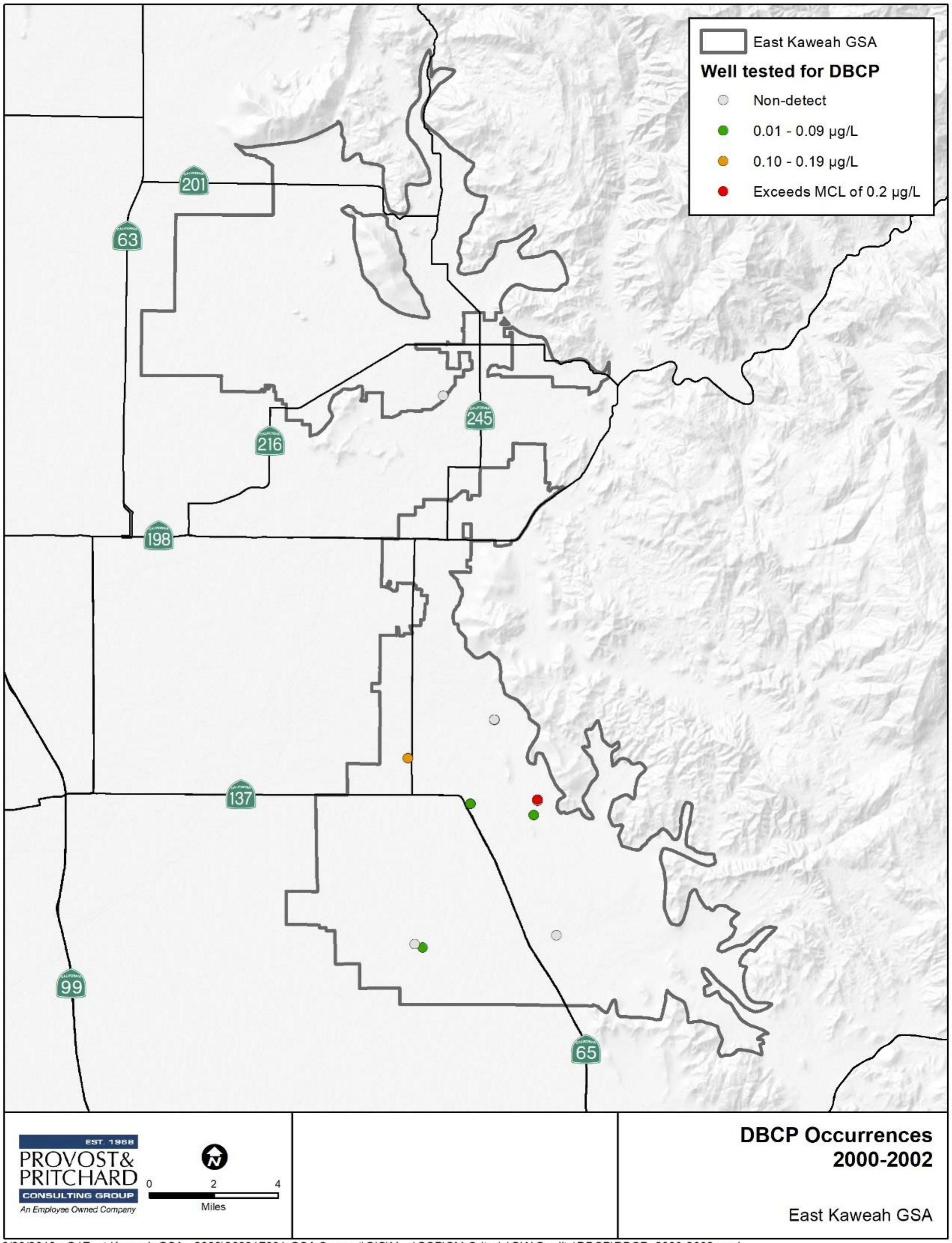
DBCP Occurrences
1997-1999

East Kaweah GSA

6/20/2019 : G:\East Kaweah GSA - 2633\263317001-GSA Support\GIS\Map\GSP\SM Criteria\GW Quality\DBCP\DBCP_1997-1999.mxd



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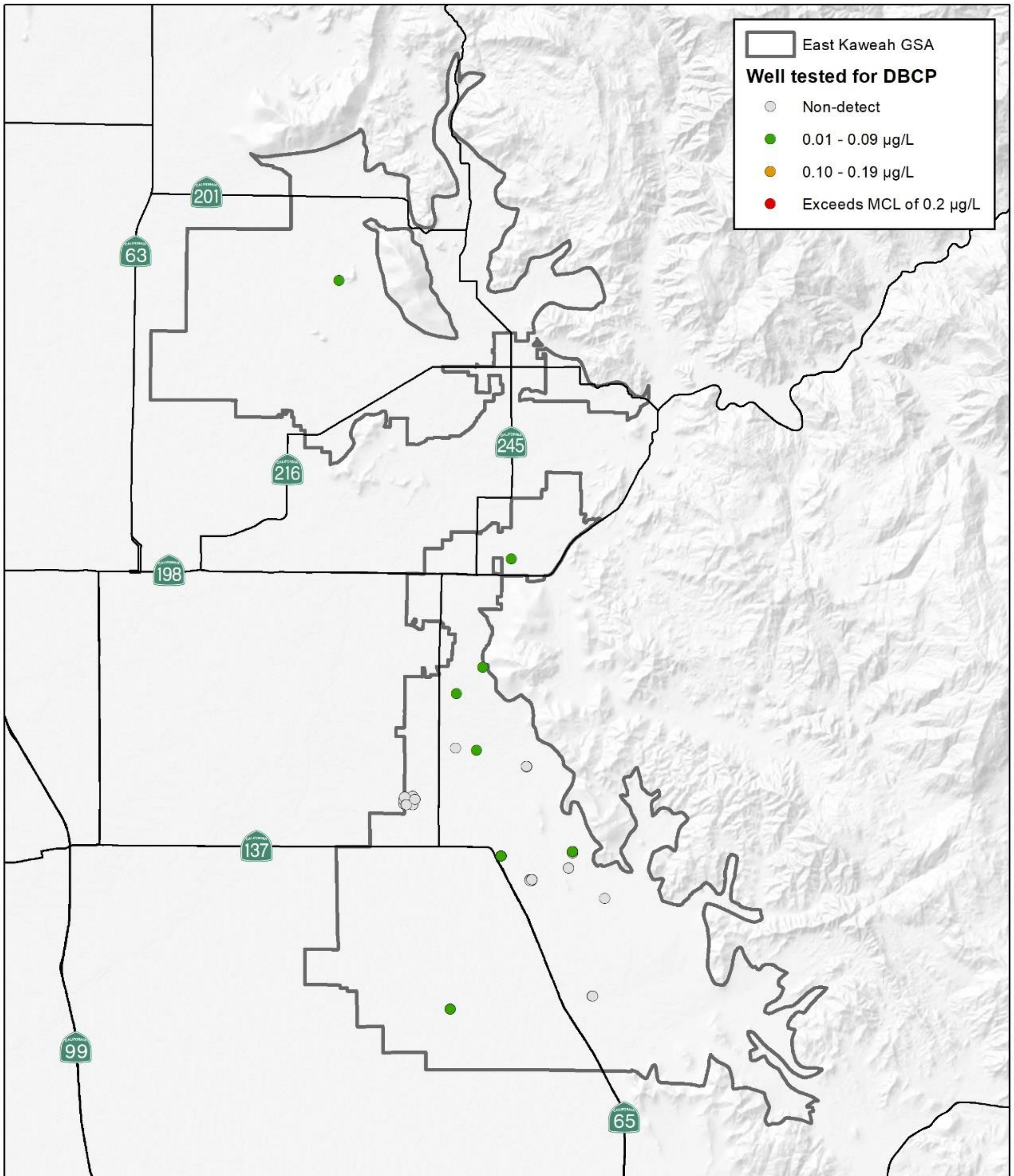

DBCP Occurrences 2003-2005

East Kaweah GSA

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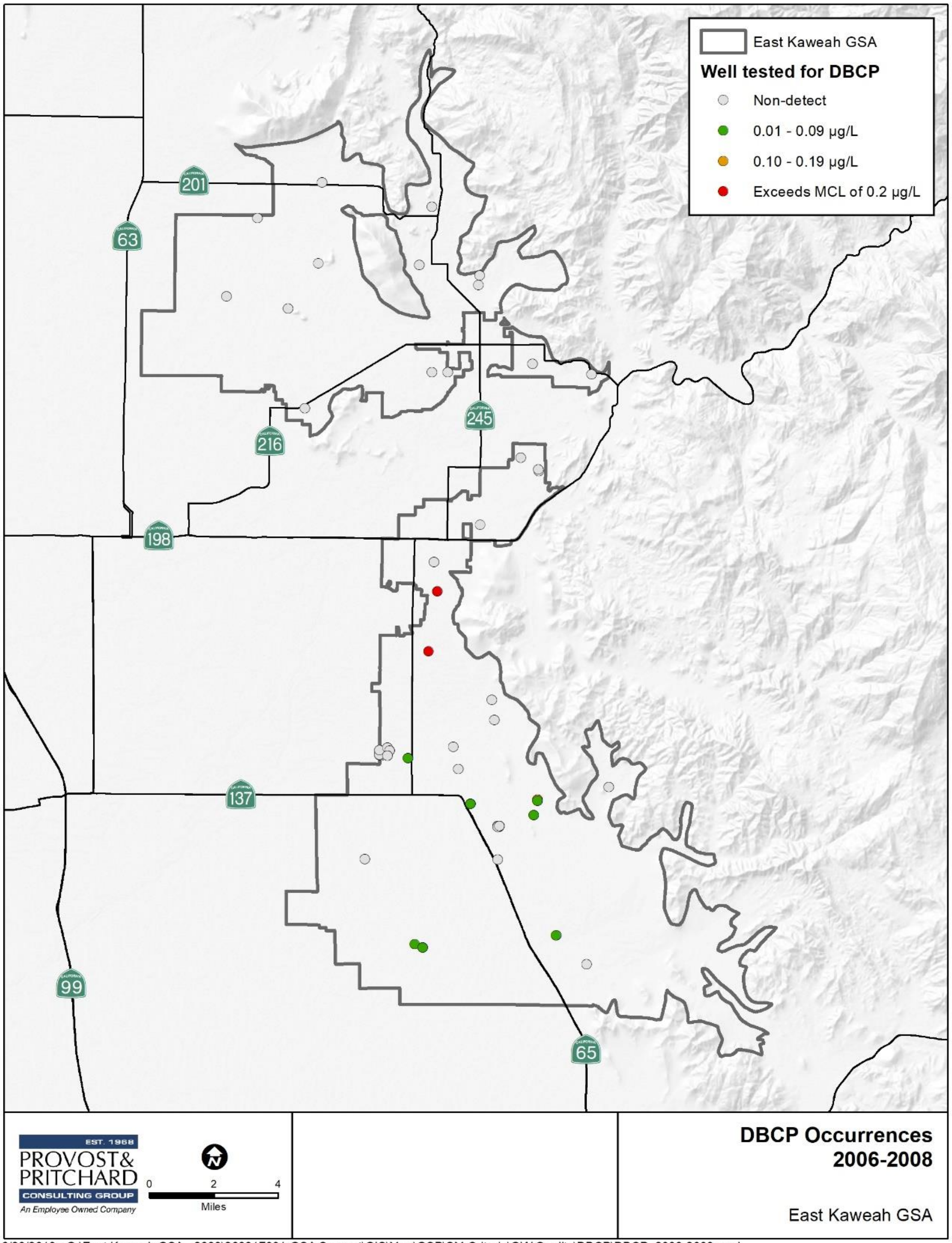

DBCP Occurrences 2006-2008

East Kaweah GSA

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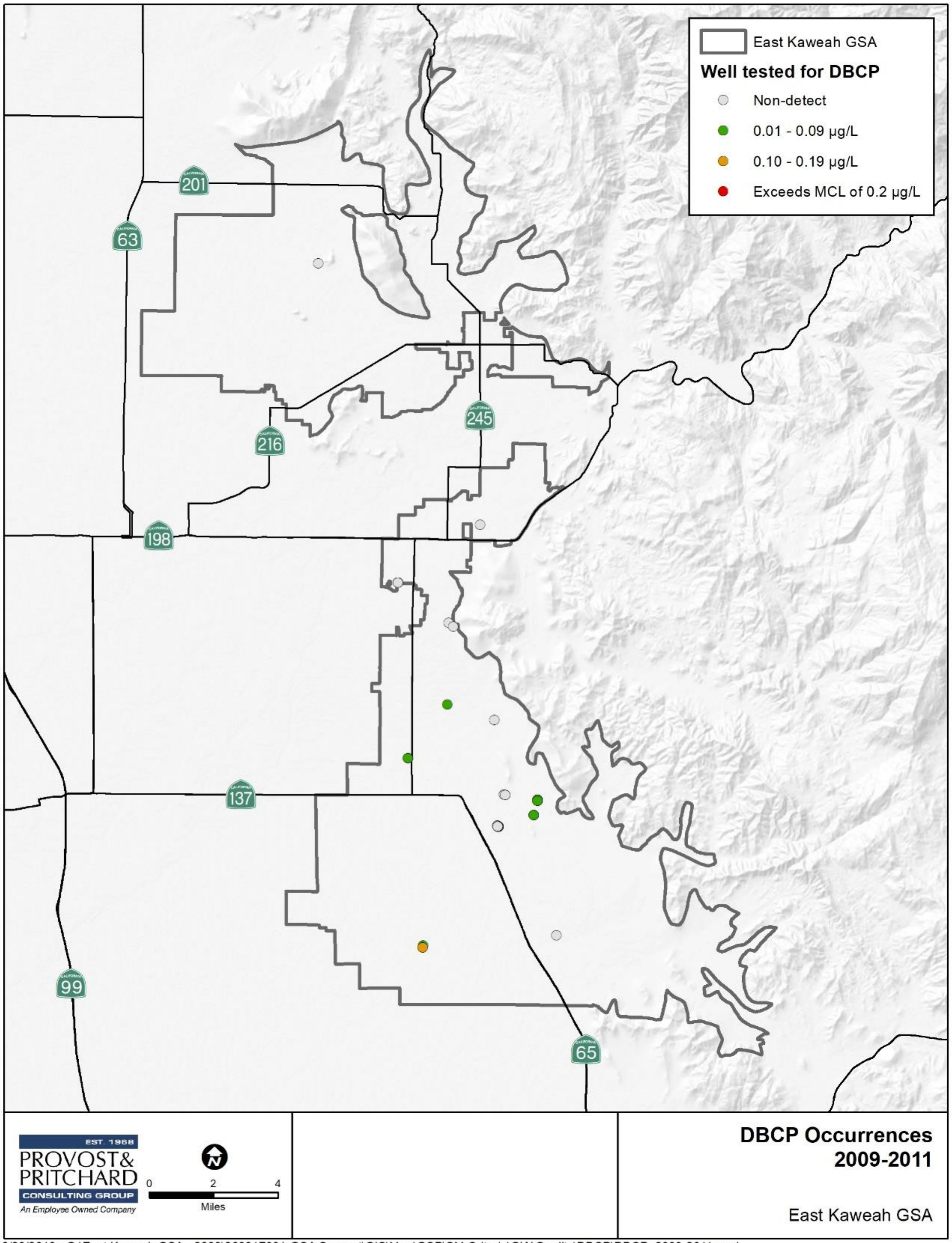

DBCP Occurrences 2009-2011

East Kaweah GSA

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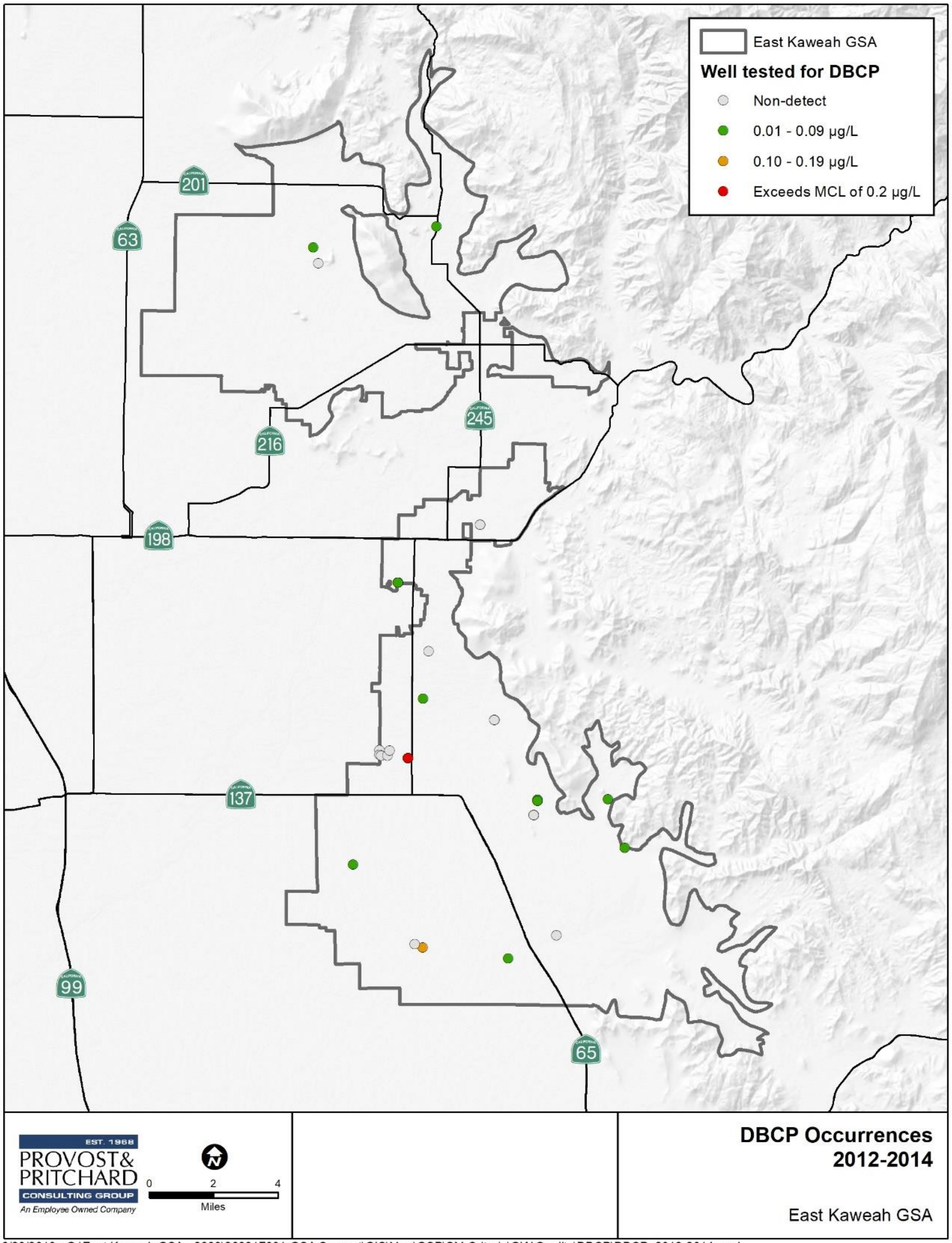

DBCP Occurrences 2012-2014

East Kaweah GSA

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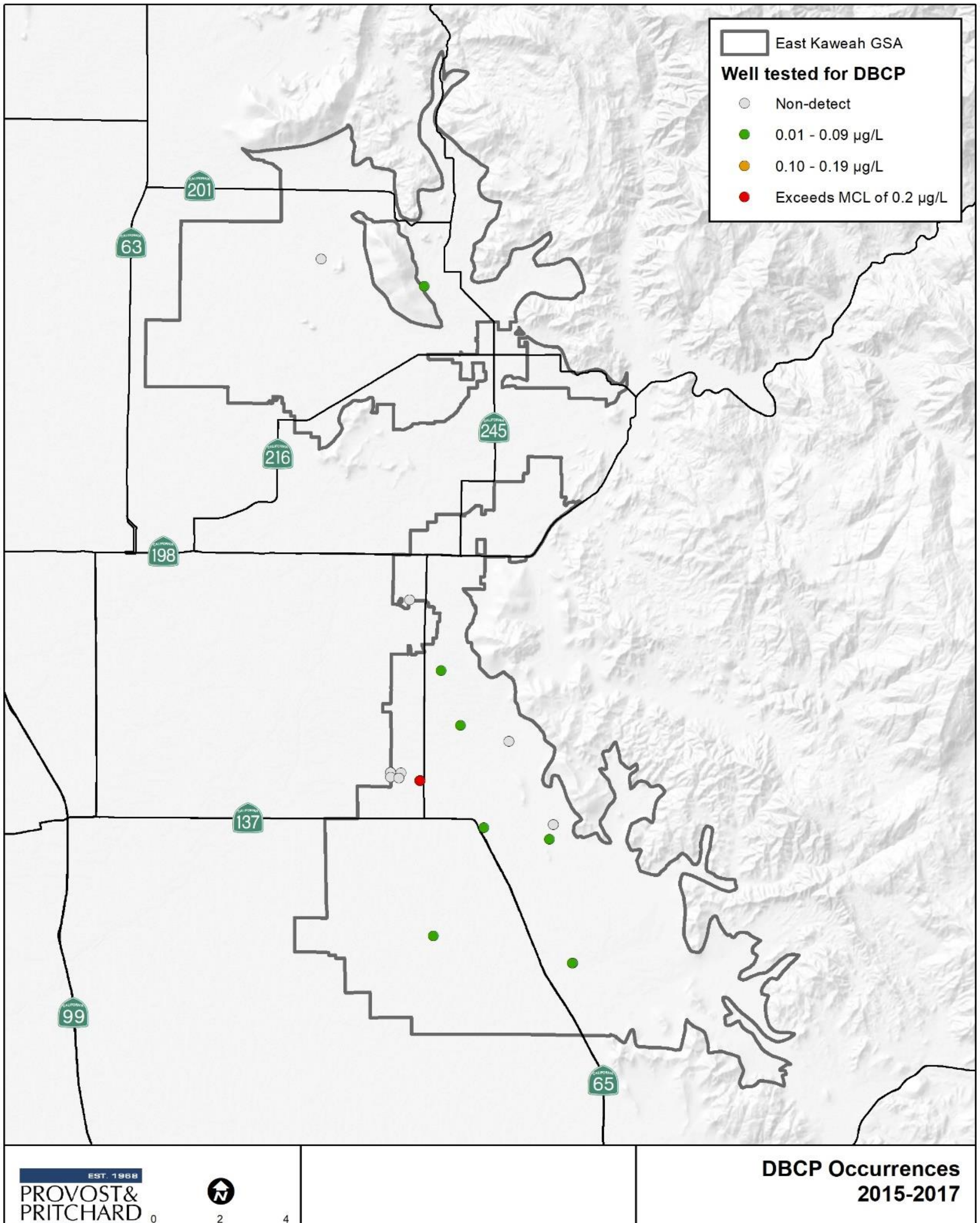

DBCP Occurrences 2015-2017

East Kaweah GSA

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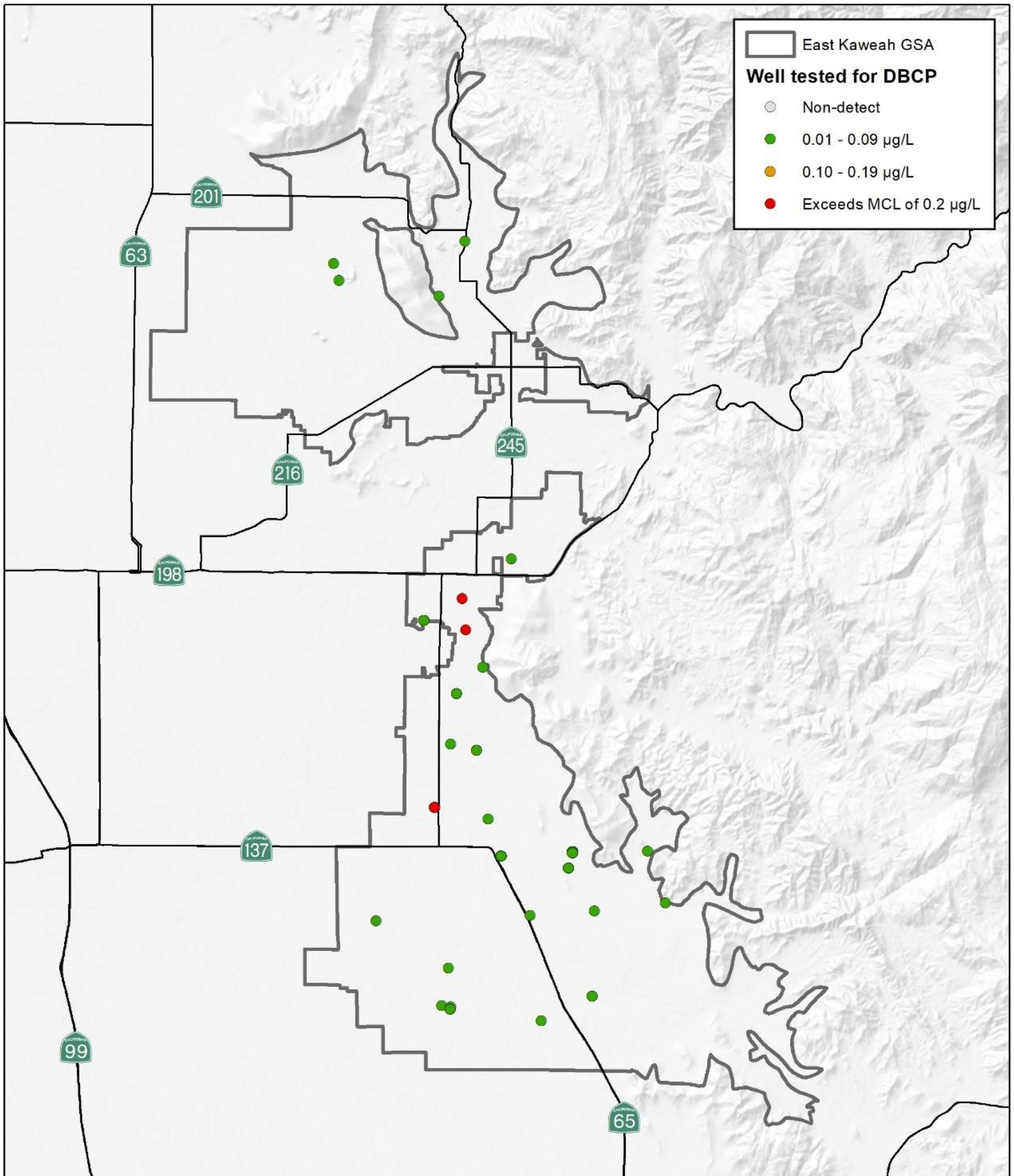

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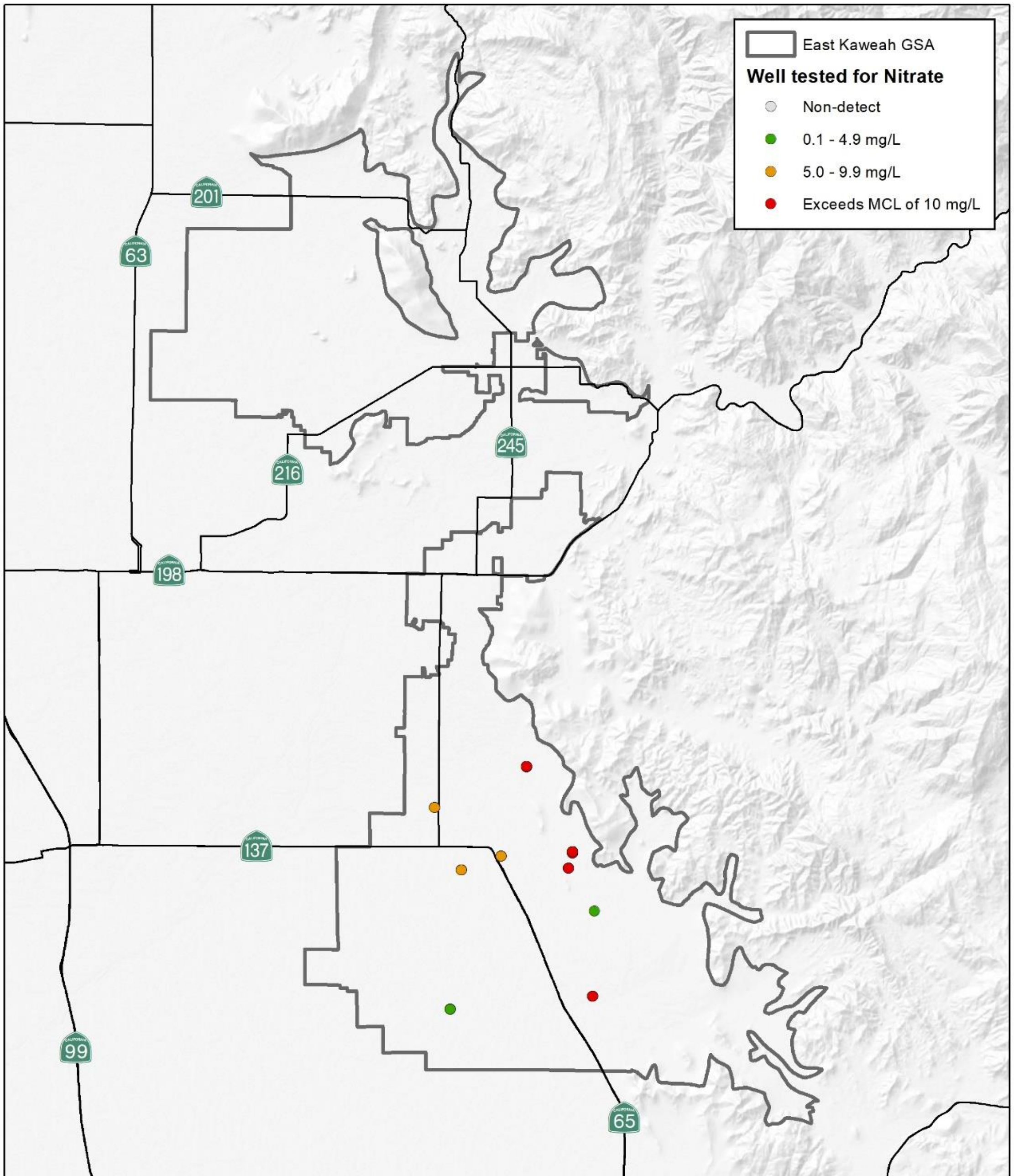
DBCP Occurrences 1997-2017

East Kaweah GSA

6/20/2019 : G:\East Kaweah GSA - 2633\263317001-GSA Support\GIS\Map\GSP\SM Criteria\GW Quality\DBCP\DBCP_base_period.mxd

Nitrate Spatial and Temporal Distribution Maps (1997-2017)



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Nitrate Occurrences
1997-1999

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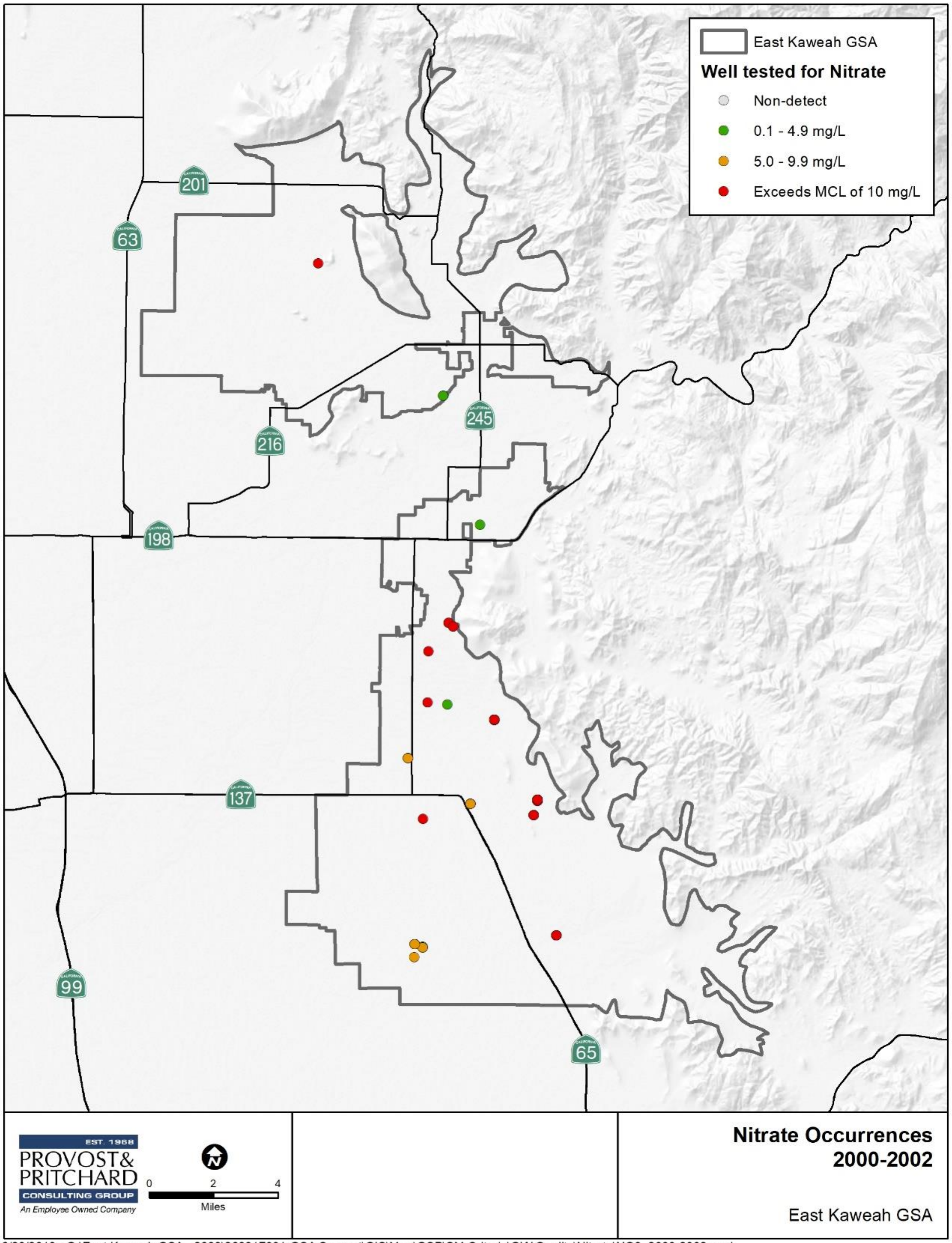

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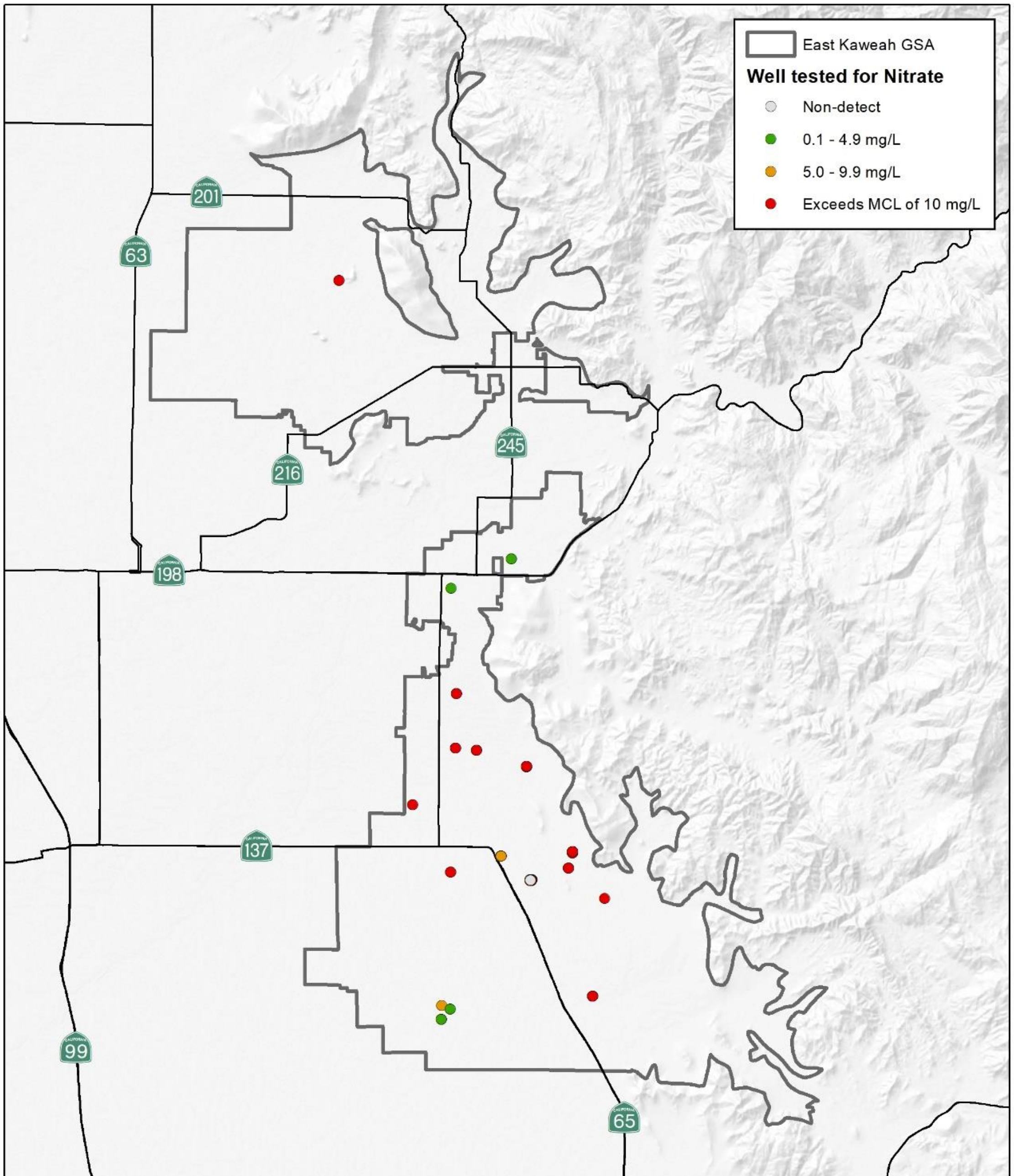

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Nitrate Occurrences 2003-2005

East Kaweah GSA

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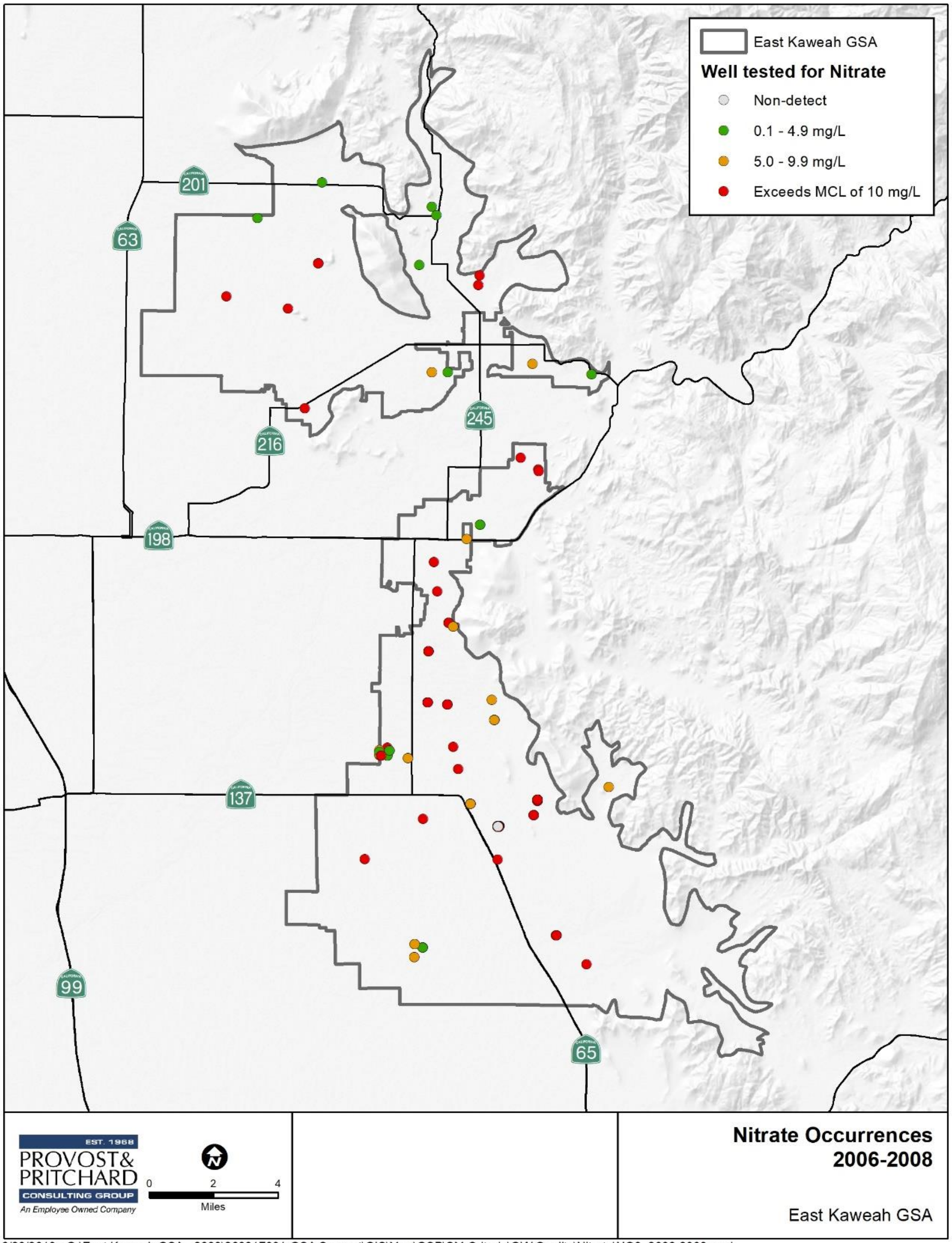

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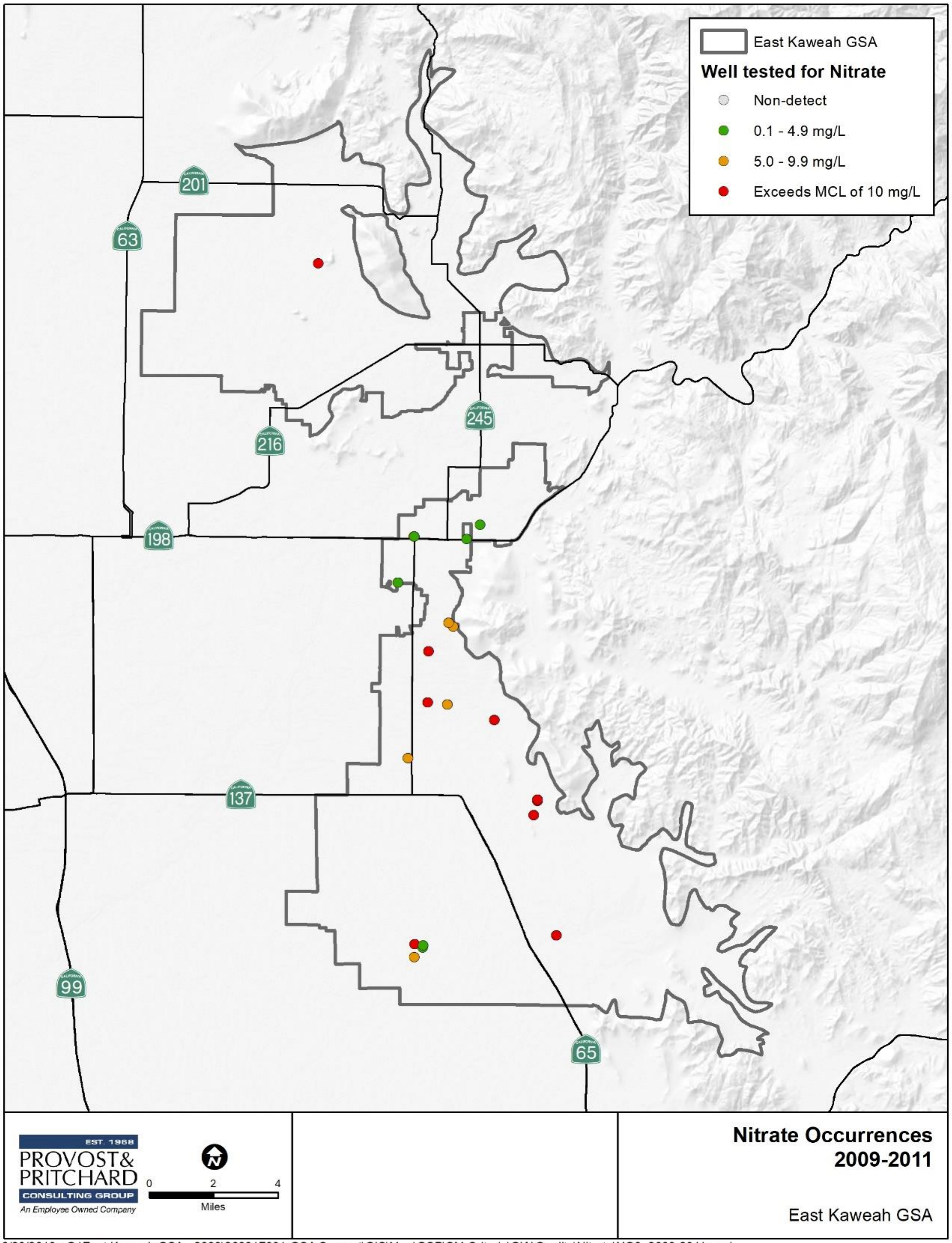

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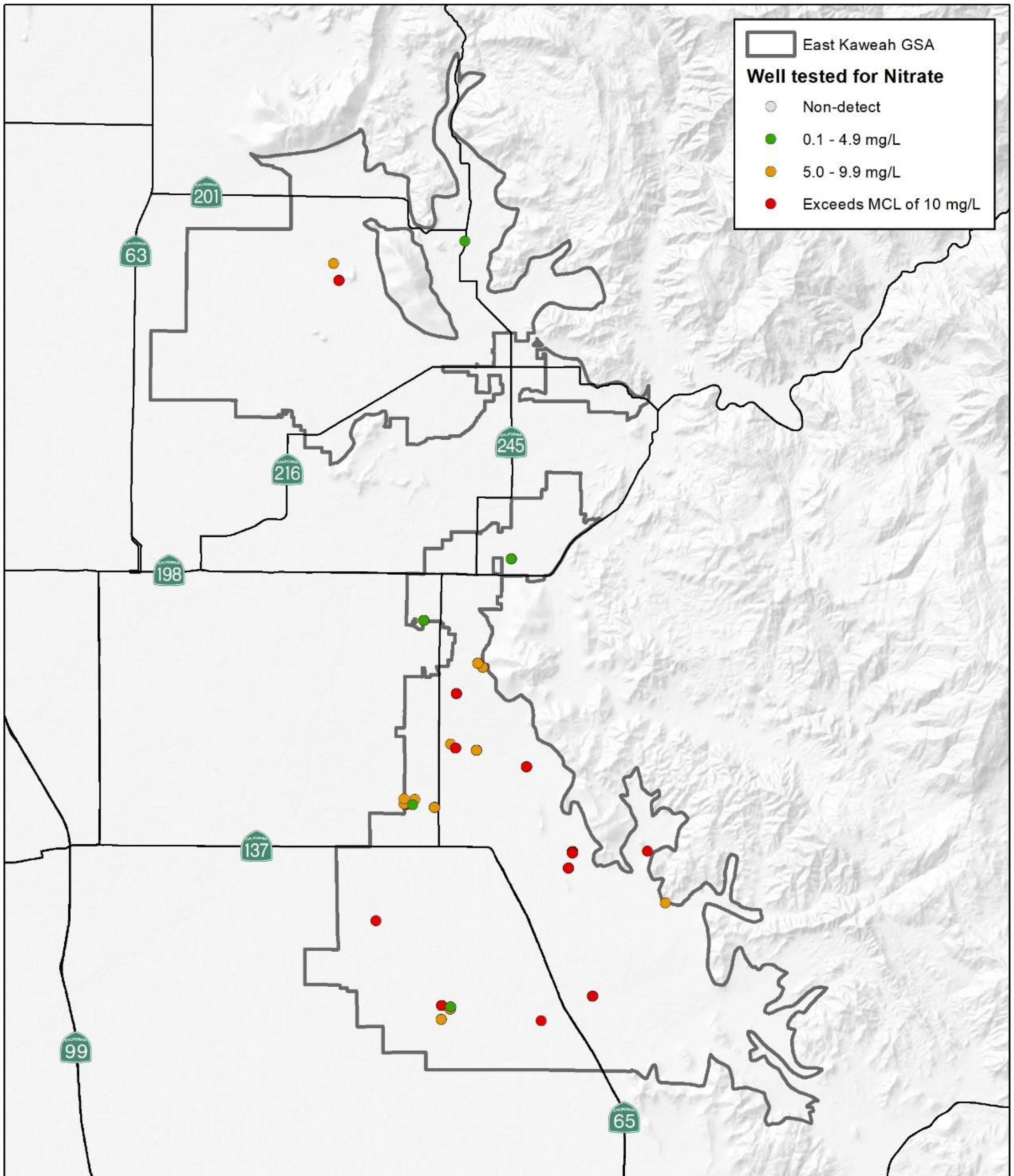

Nitrate Occurrences 2012-2014

East Kaweah GSA

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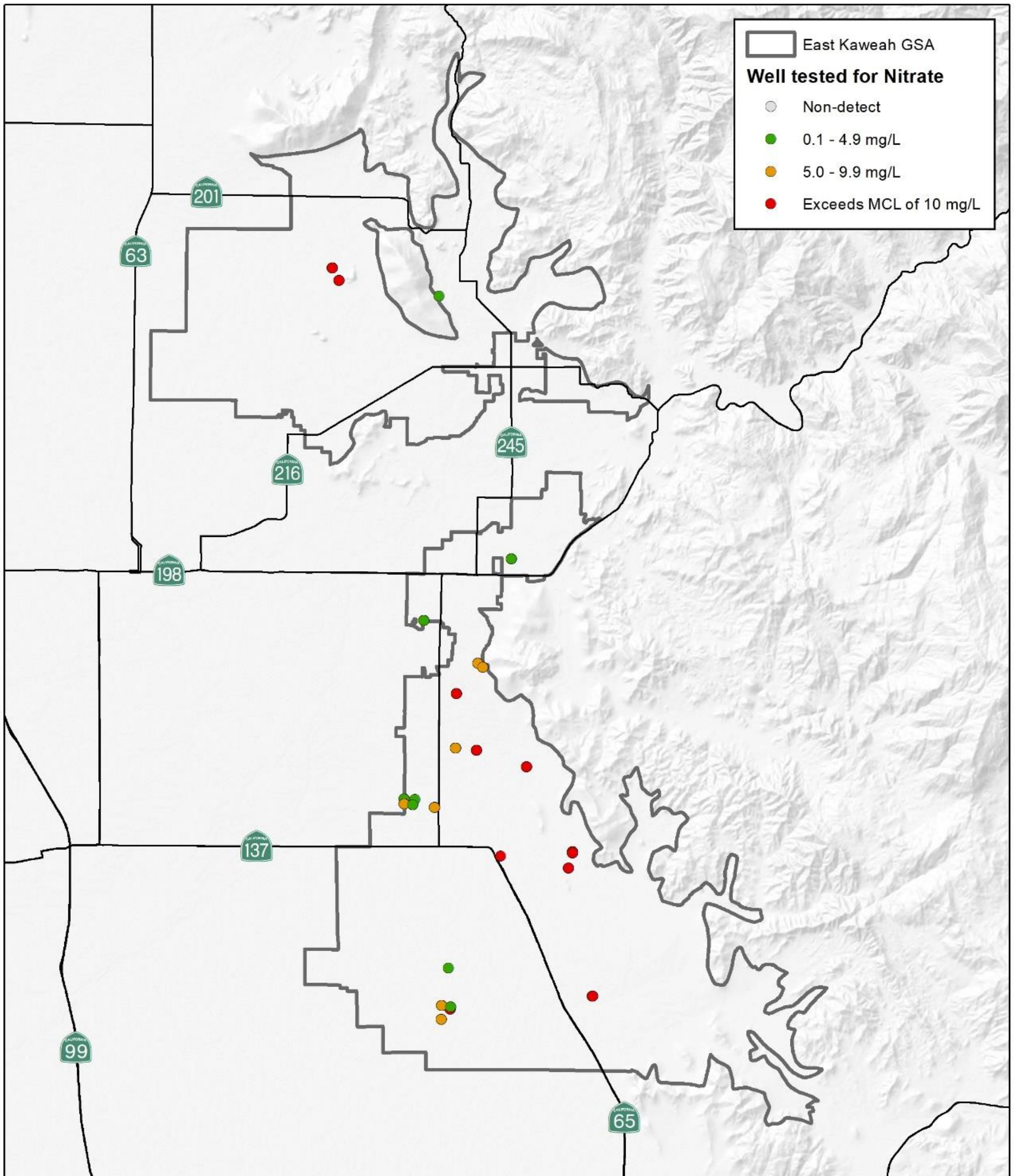

Nitrate Occurrences 2015-2017

East Kaweah GSA

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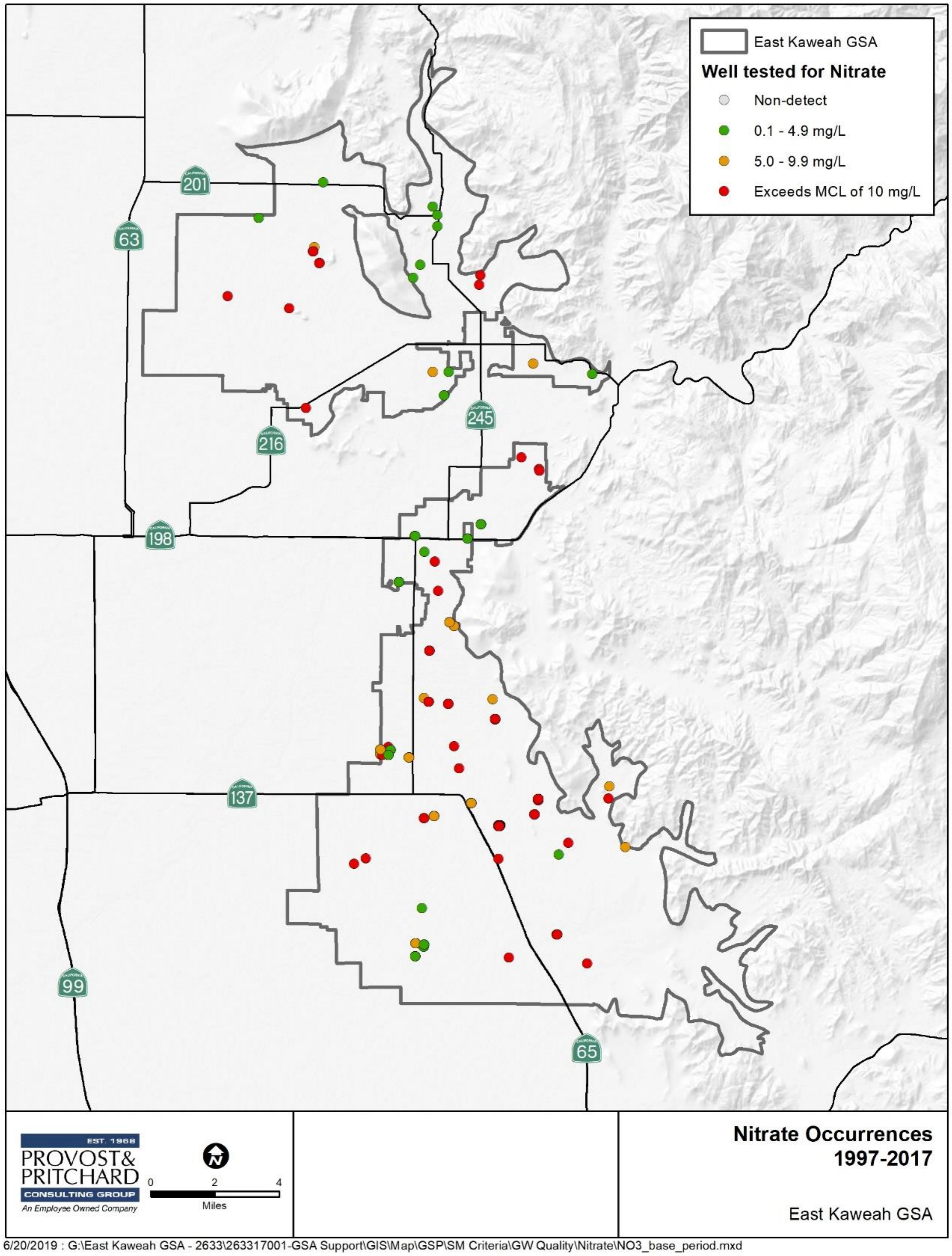
East Kaweah GSA
Well tested for Nitrate
Non-detect
0.1 - 4.9 mg/L
5.0 - 9.9 mg/L
Exceeds MCL of 10 mg/L
201
63
245
216
198
137
99
65
EST. 1968
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0
2
4
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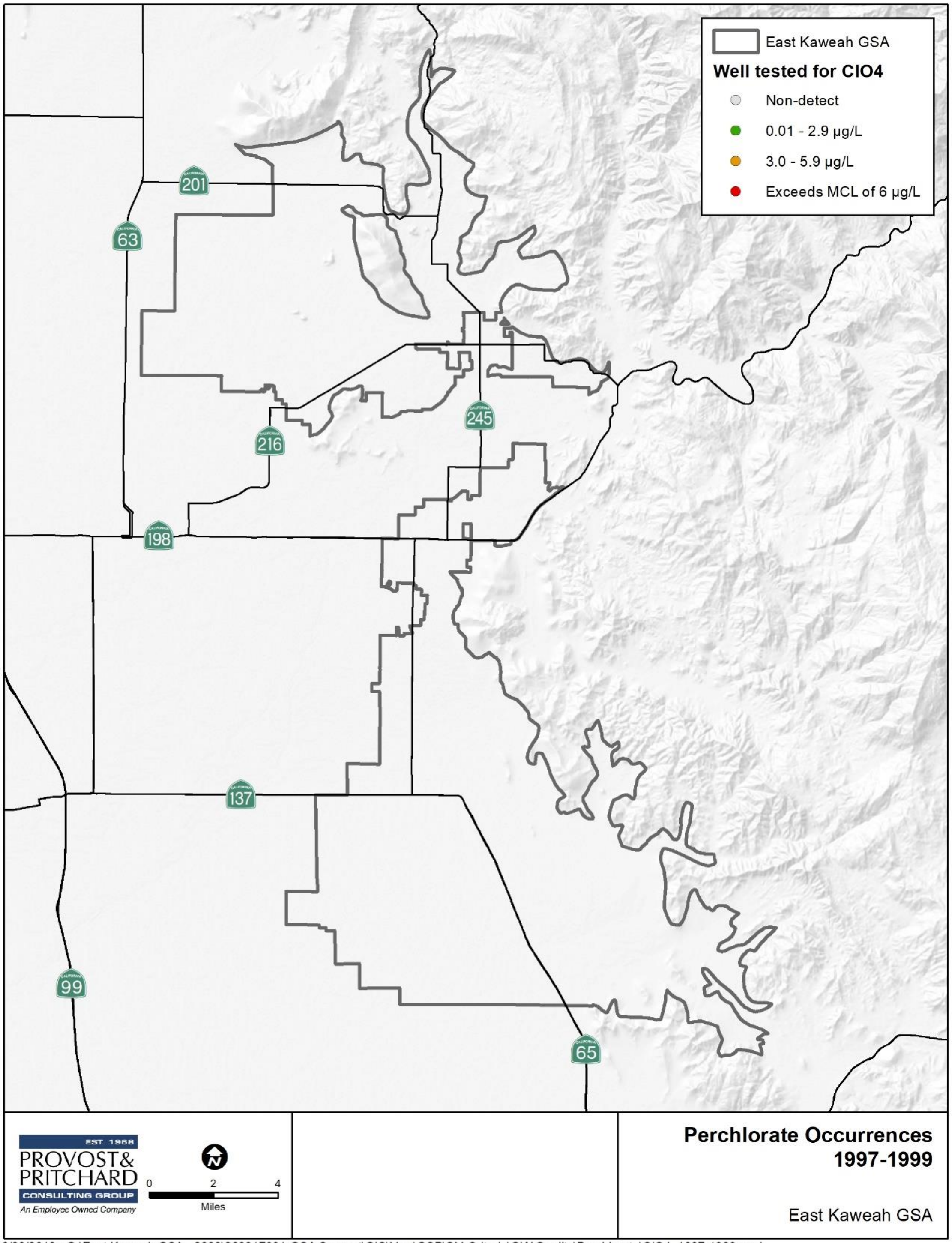
Nitrate Occurrences
1997-2017
East Kaweah GSA
6/20/2019 : G:\East Kaweah GSA - 2633\263317001-GSA Support\GIS\Map\GSP\SM Criteria\GW Quality\Nitrate\NO3_base_period.mxd

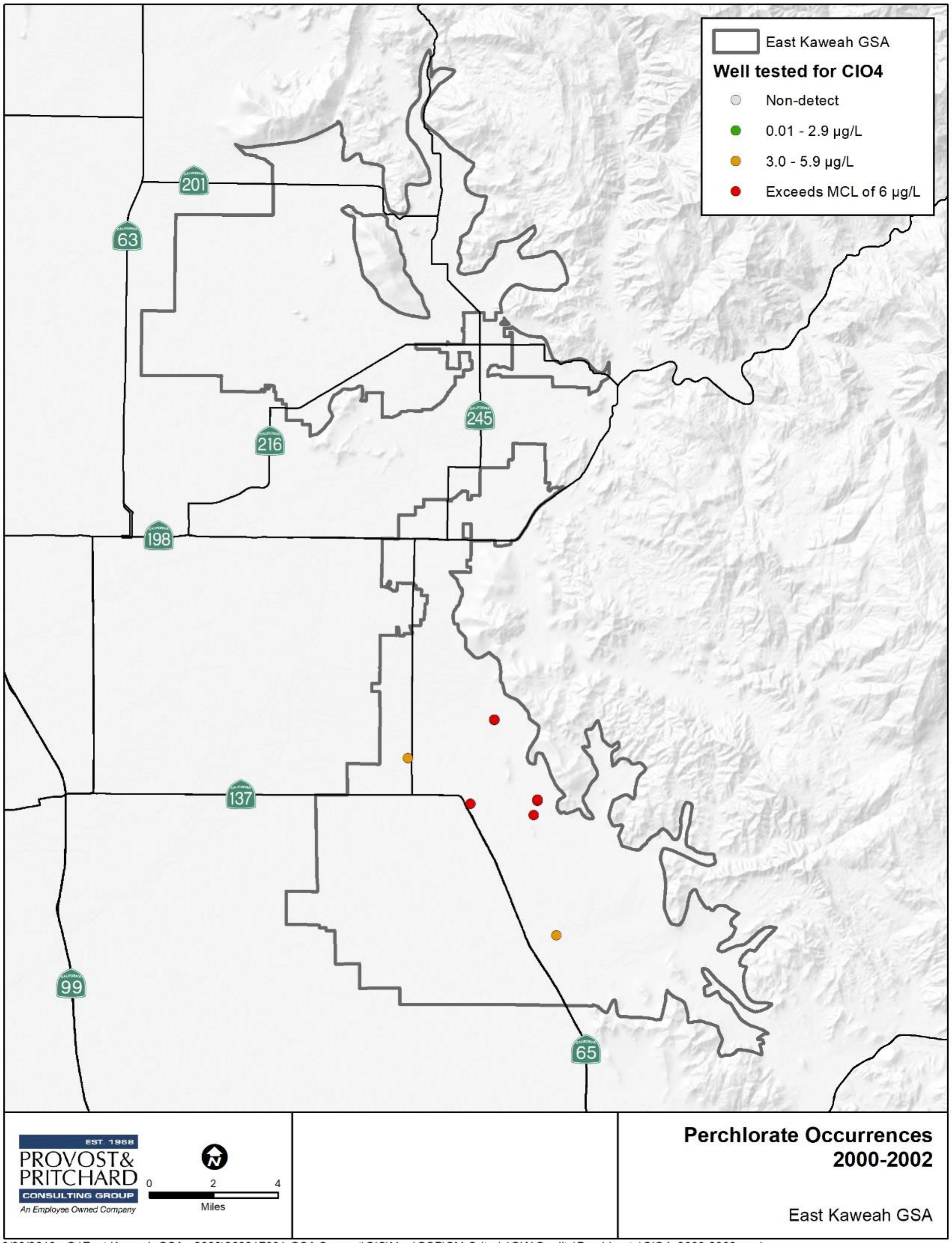
Perchlorate Spatial and Temporal Distribution Maps (1997-2017)



Perchlorate Occurrences 1997-1999

East Kaweah GSA

6/20/2019 : G:\East Kaweah GSA - 2633\263317001-GSA Support\GIS\Map\GSP\SM Criteria\GW Quality\Perchlorate\ClO4_1997-1999.mxd



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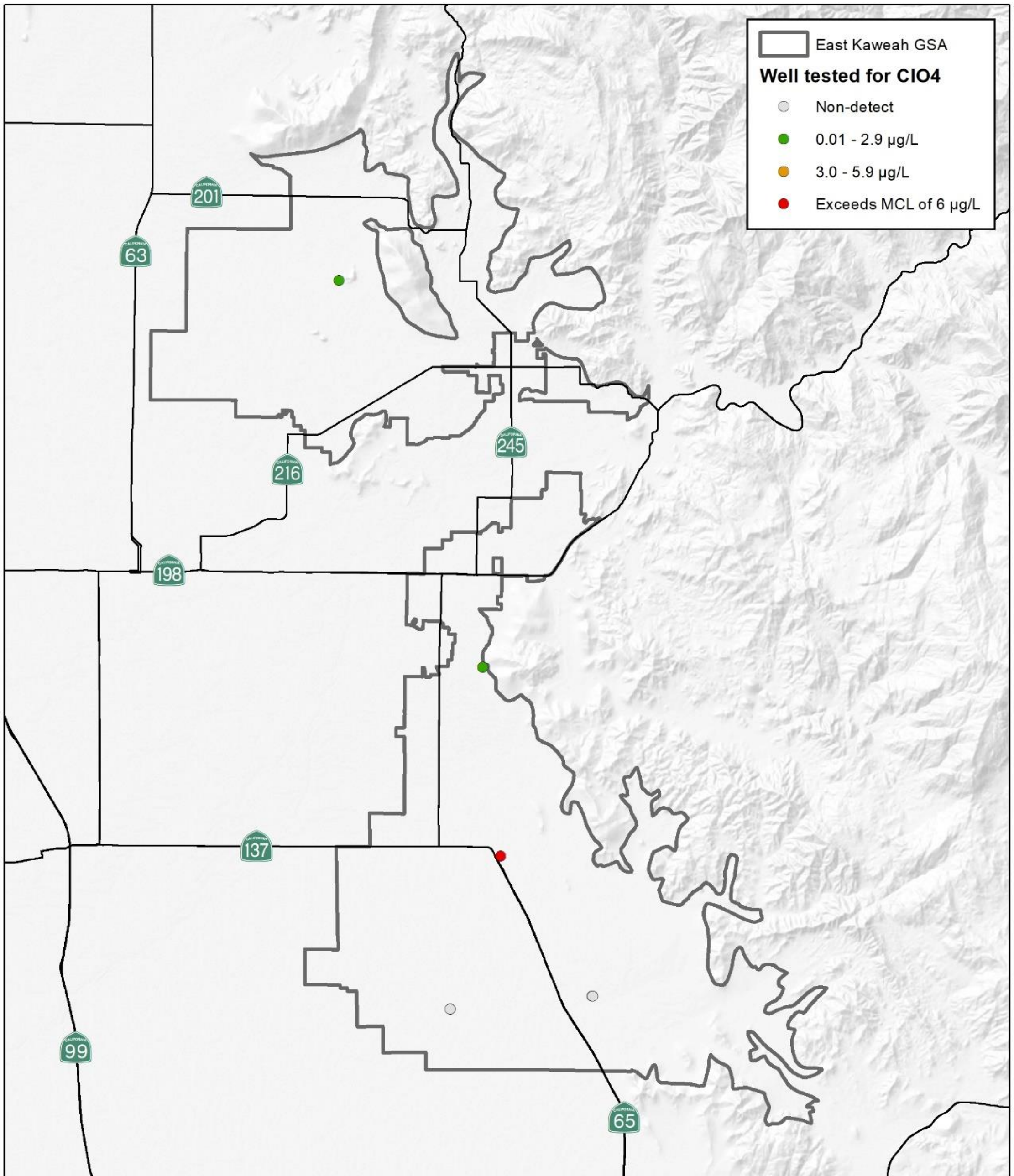

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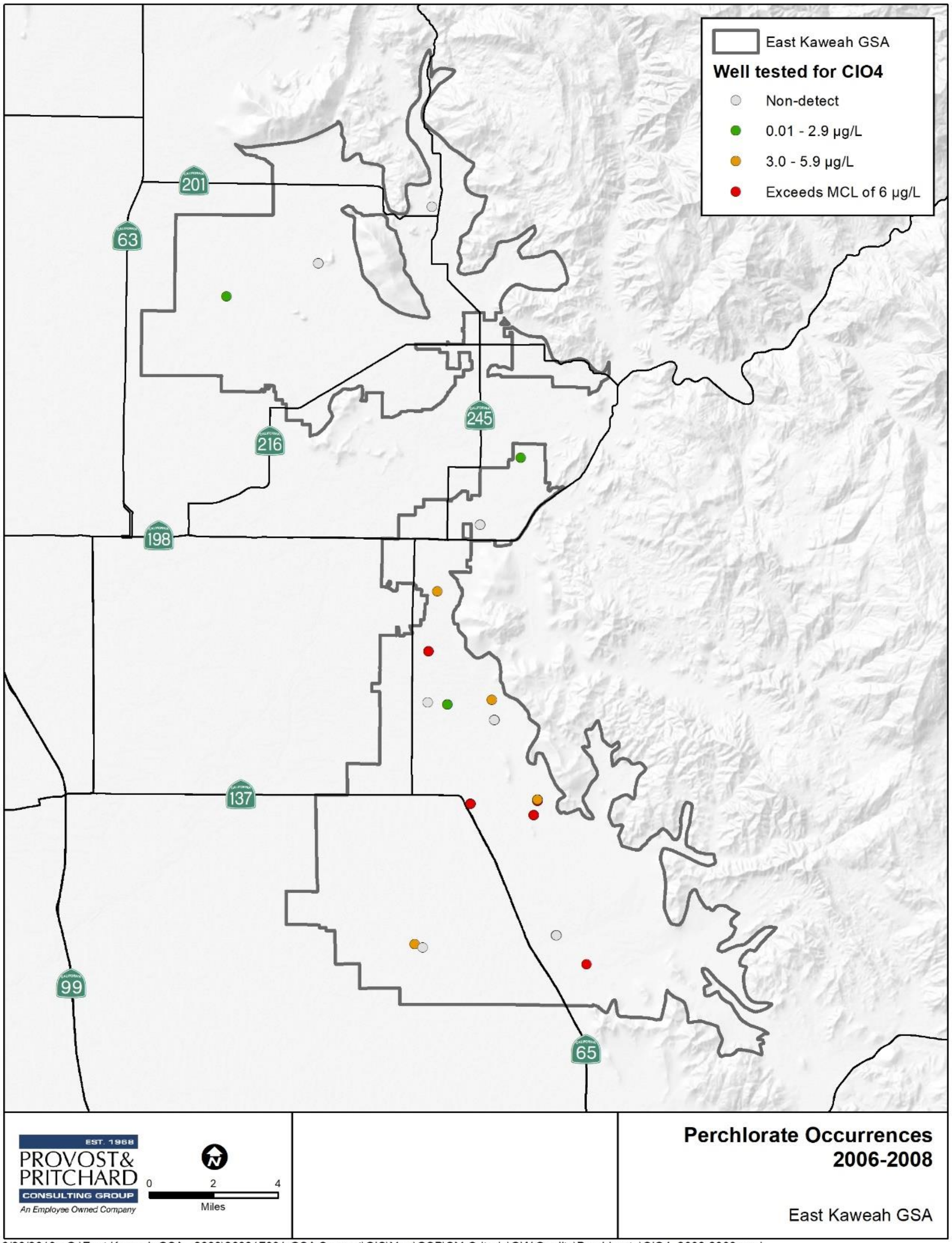
Perchlorate Occurrences
2003-2005

East Kaweah GSA

6/20/2019 : G:\East Kaweah GSA - 2633\263317001-GSA Support\GIS\Map\GSP\SM Criteria\GW Quality\Perchlorate\ClO4_2003-2005.mxd



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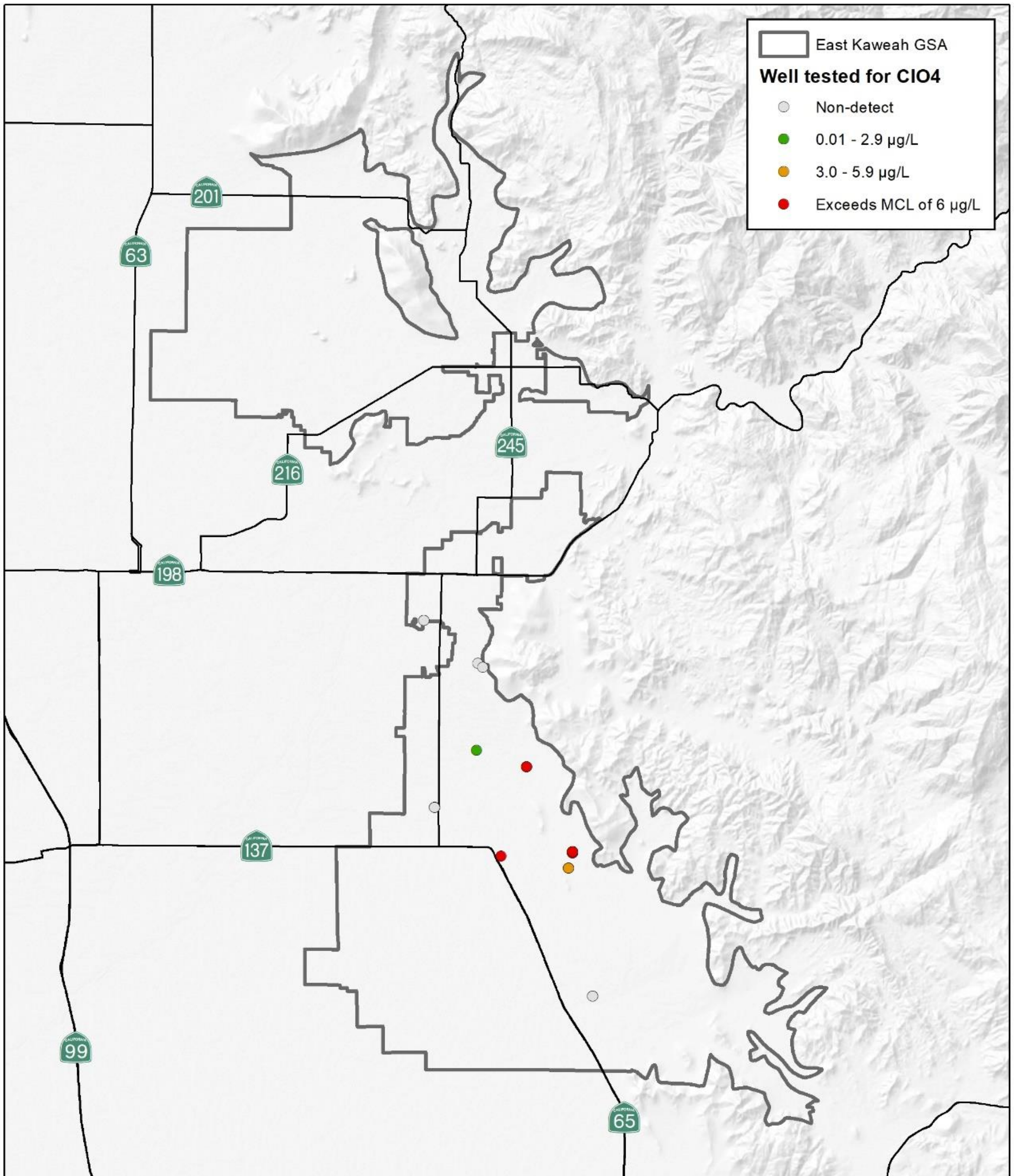

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0 2 4
Miles

Perchlorate Occurrences 2009-2011

East Kaweah GSA

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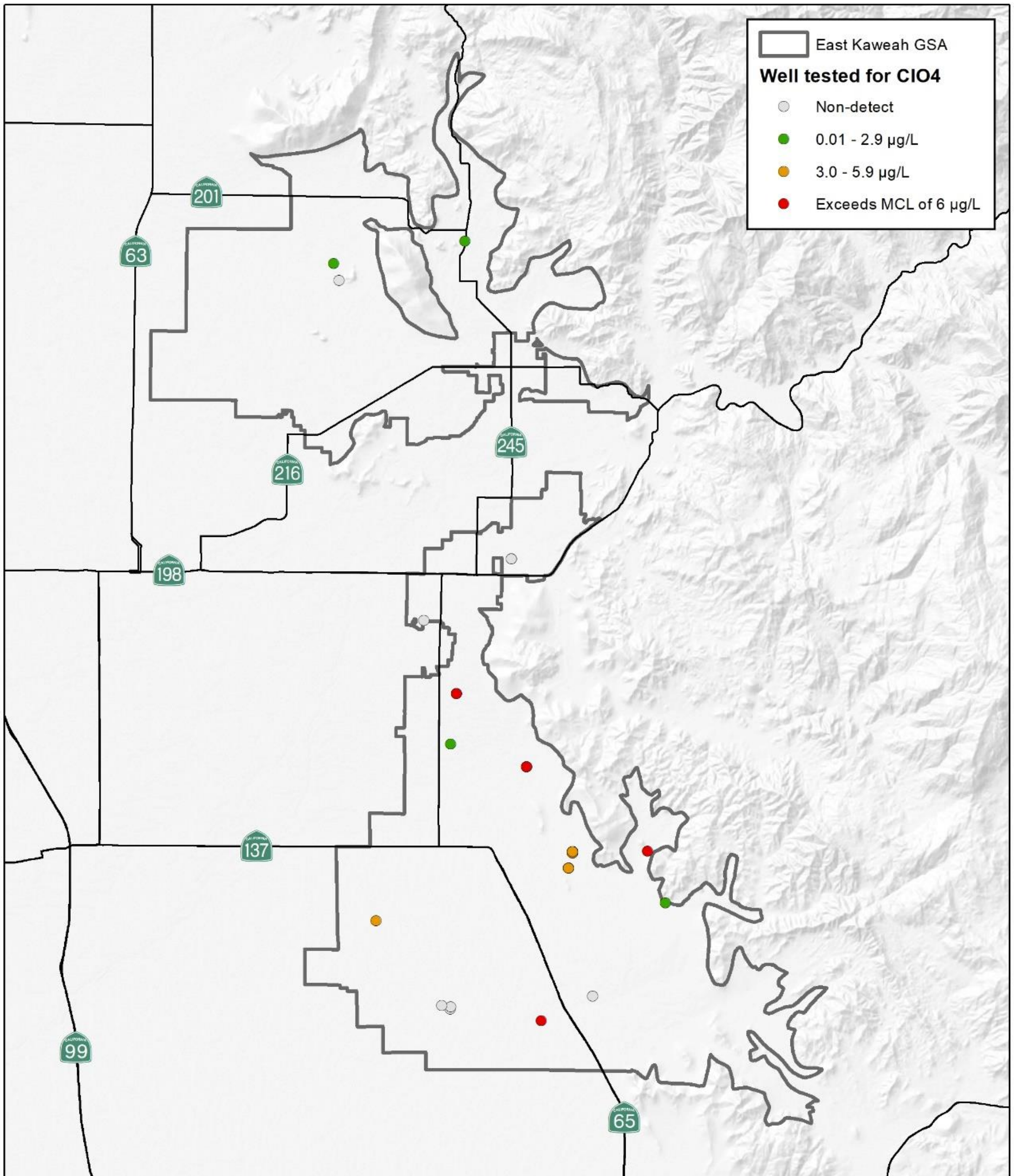

Perchlorate Occurrences 2012-2014

East Kaweah GSA

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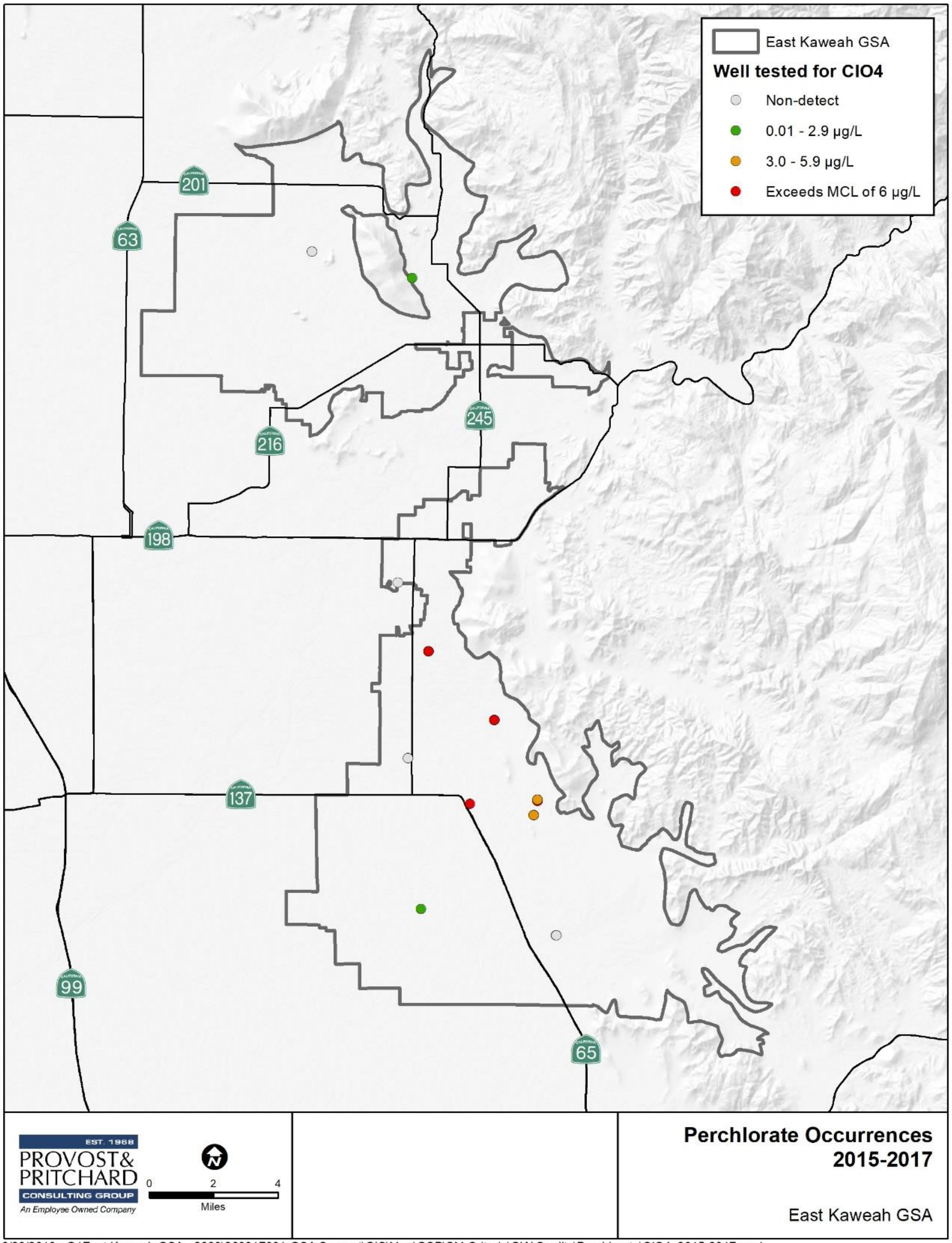

Perchlorate Occurrences 2015-2017

East Kaweah GSA

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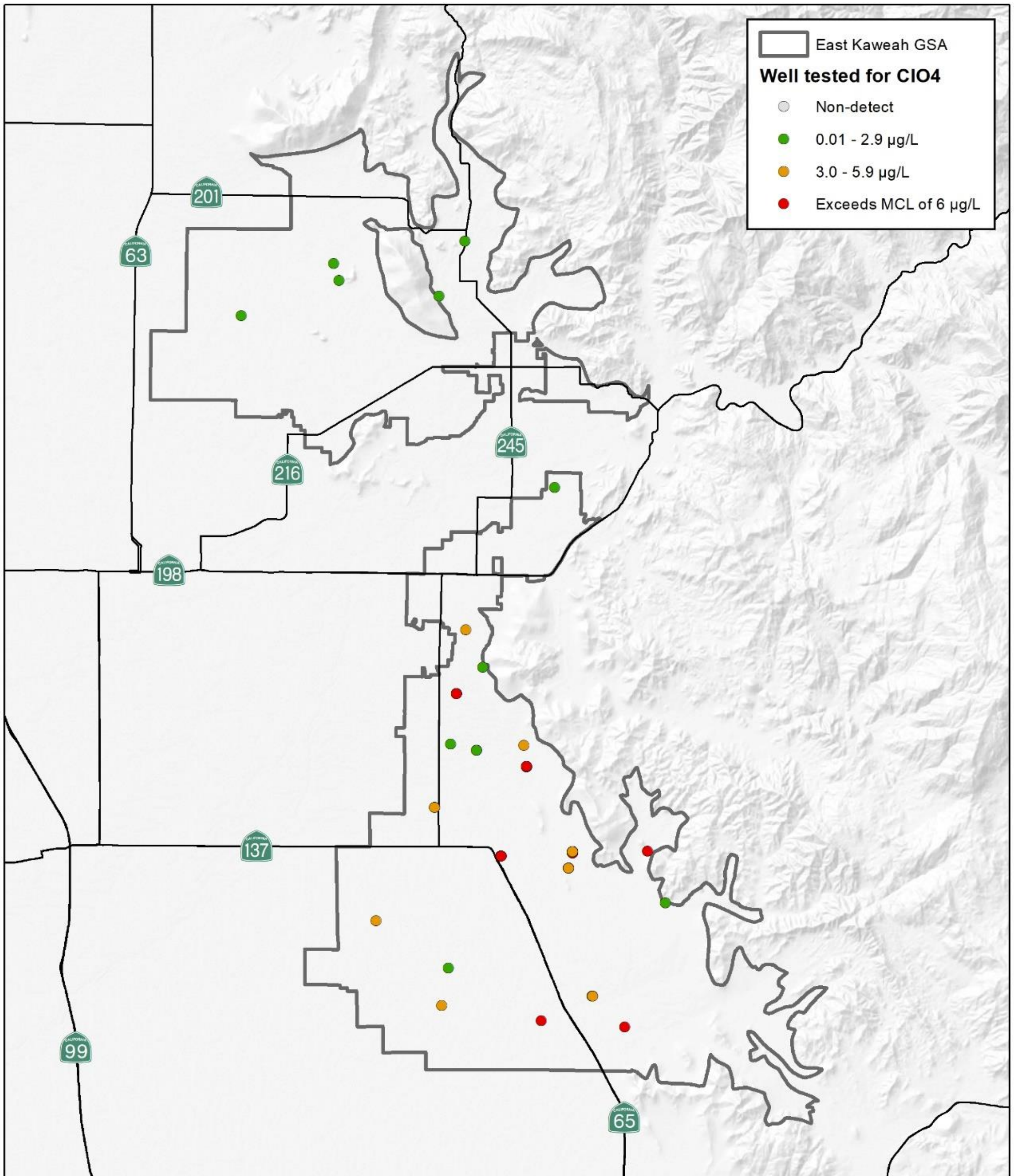

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0 2 4
Miles

Perchlorate Occurrences 1997-2017

East Kaweah GSA

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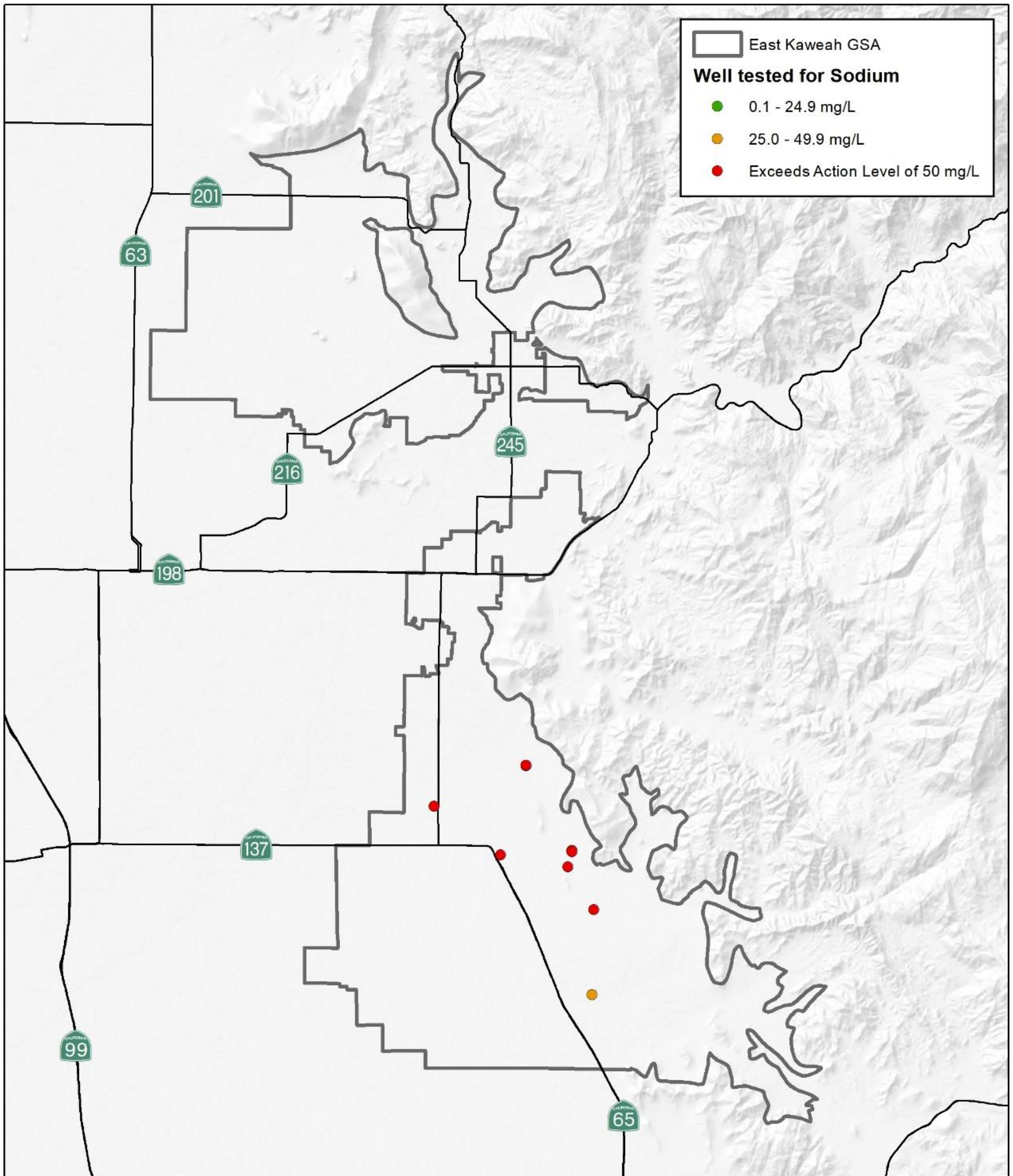
Sodium Spatial and Temporal Distribution Maps (1997-2017)



Sodium Occurrences
1997-1999

East Kaweah GSA

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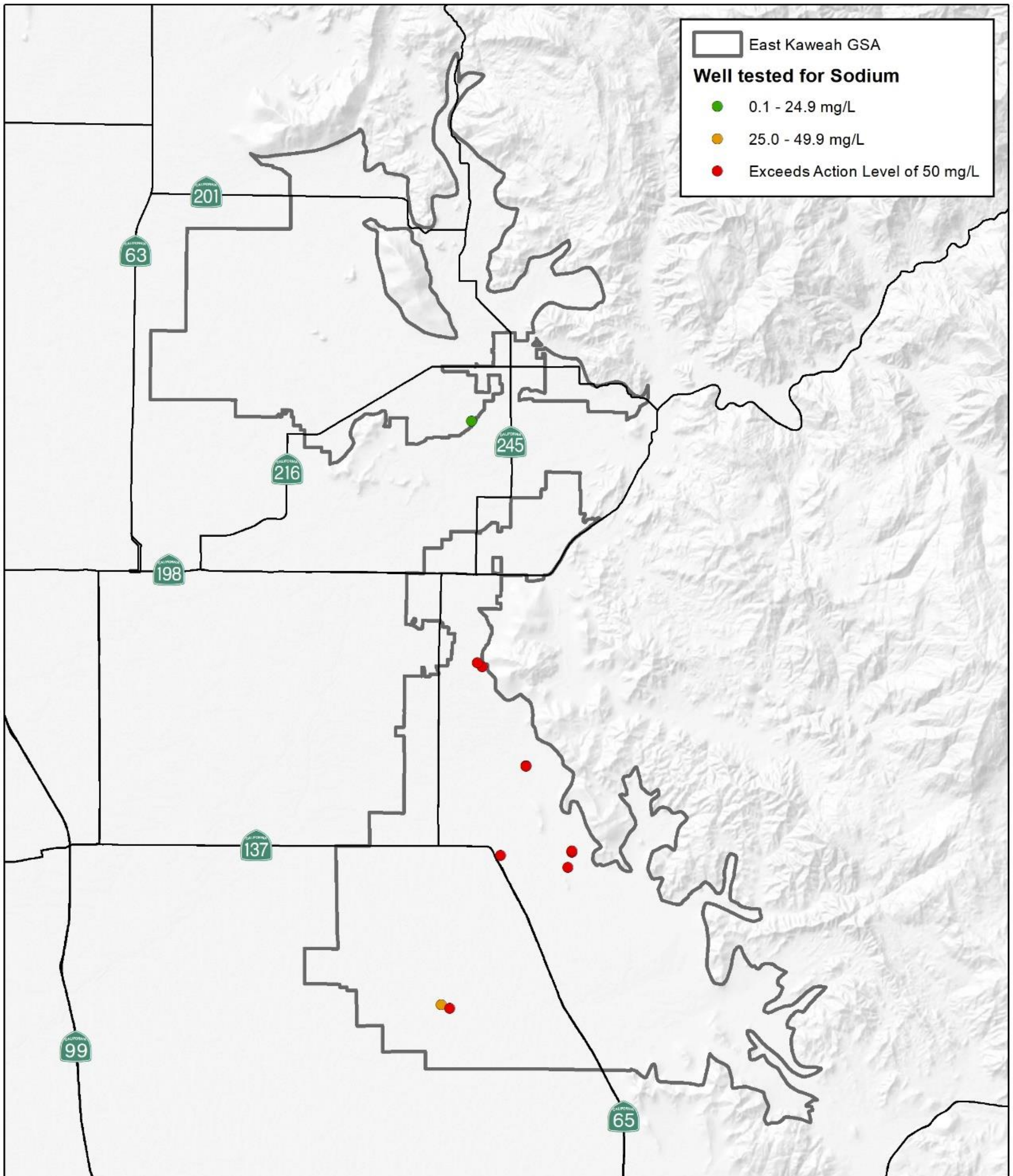

Sodium Occurrences 2000-2002

East Kaweah GSA

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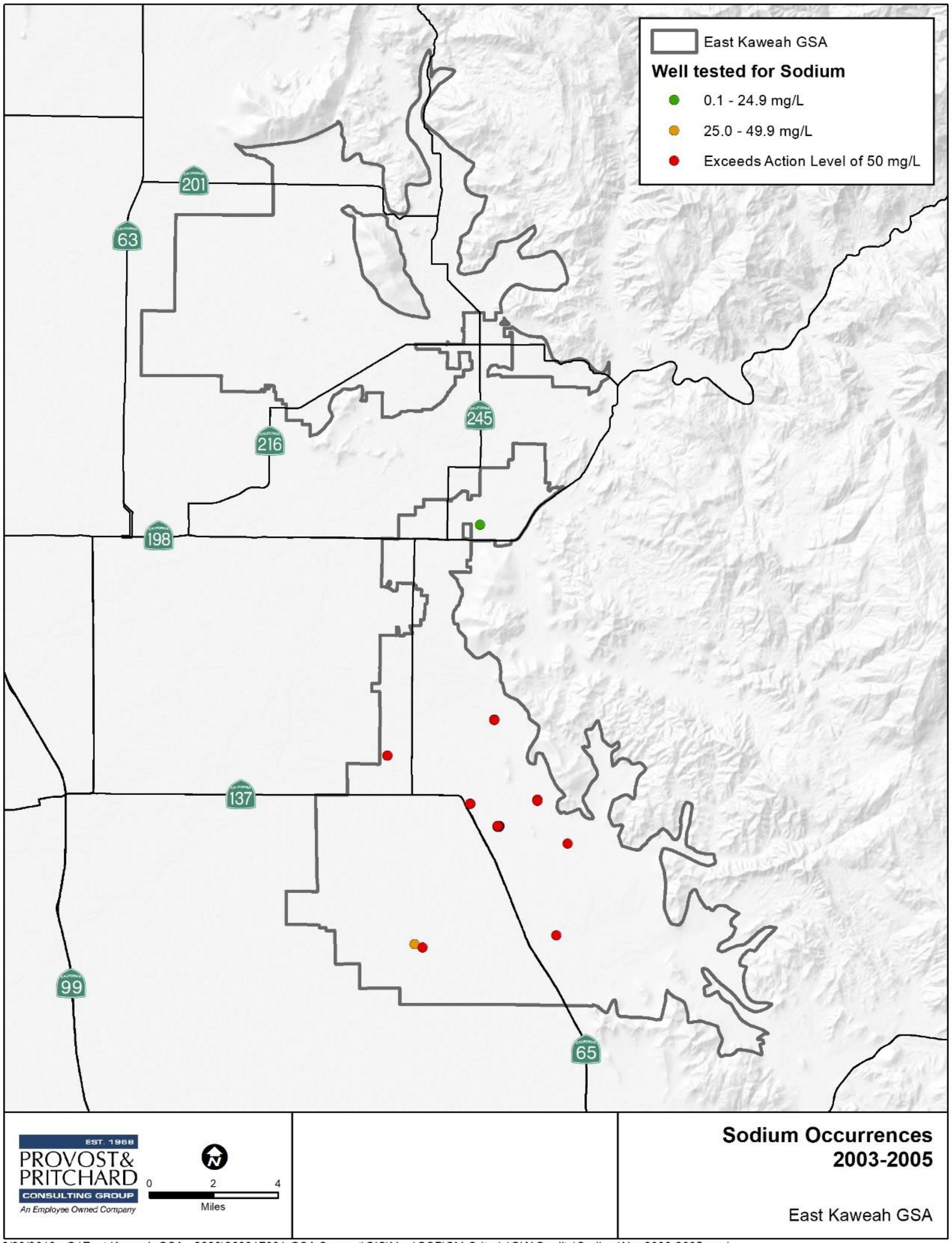

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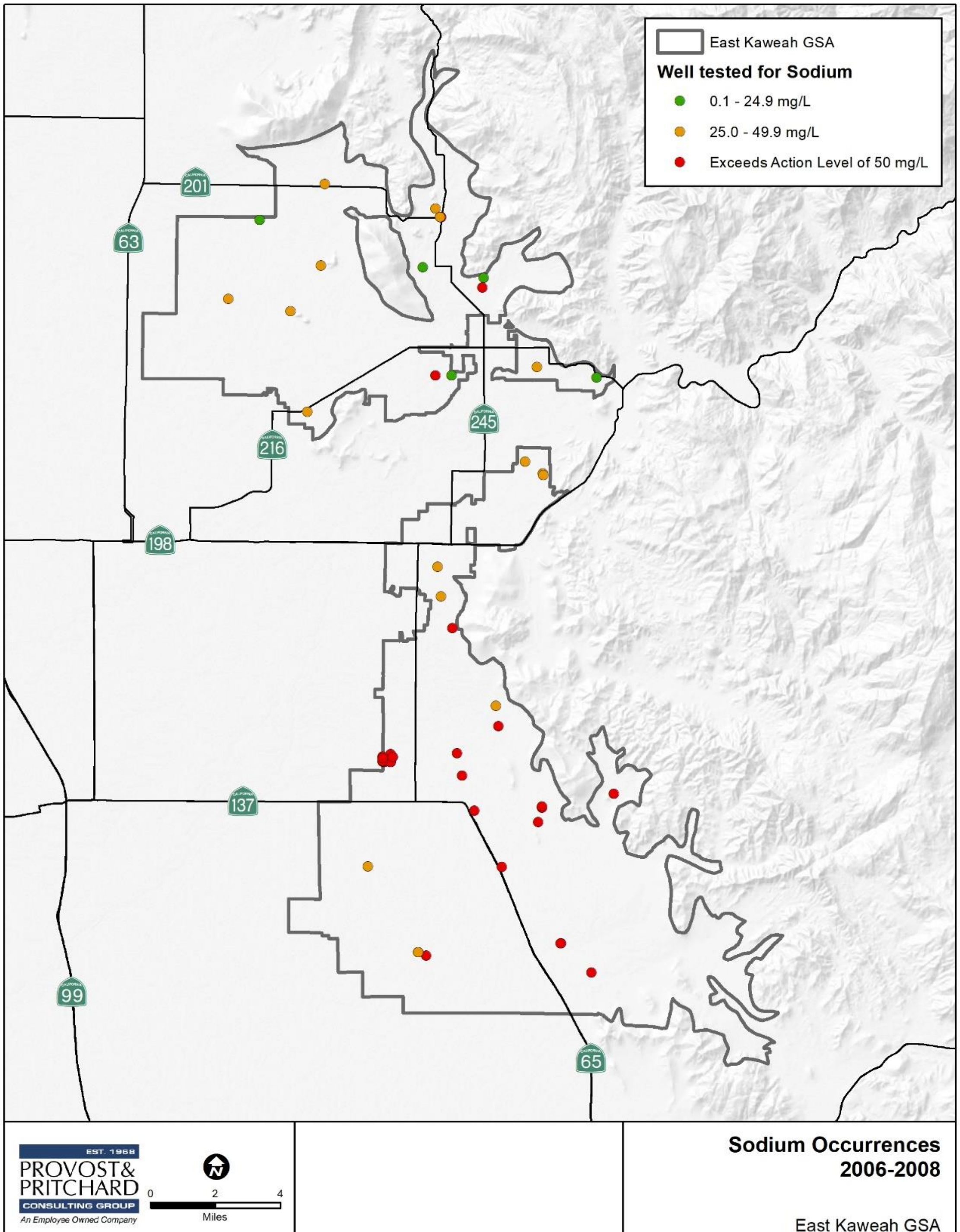

Sodium Occurrences 2006-2008

East Kaweah GSA

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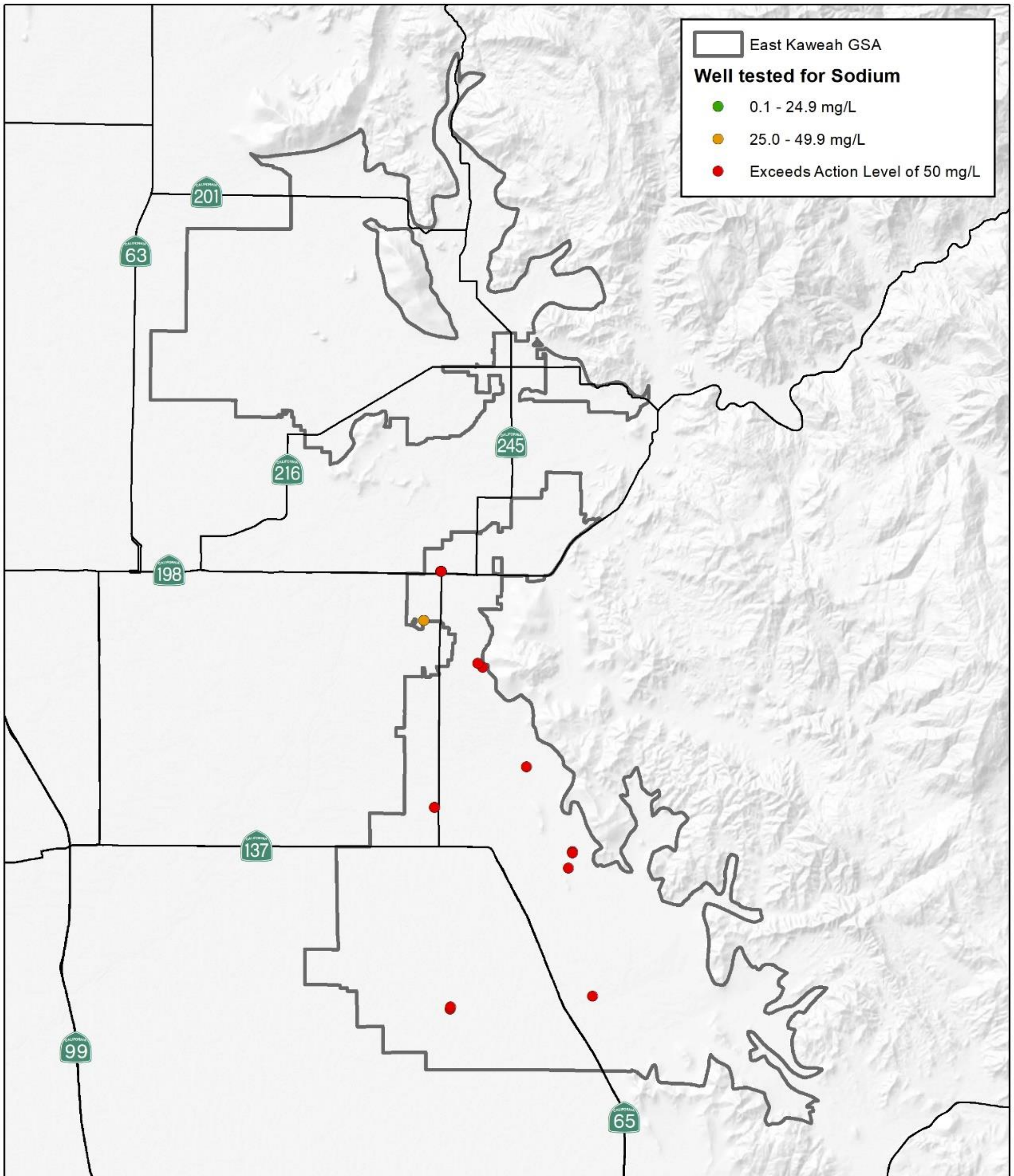

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Sodium Occurrences 2009-2011

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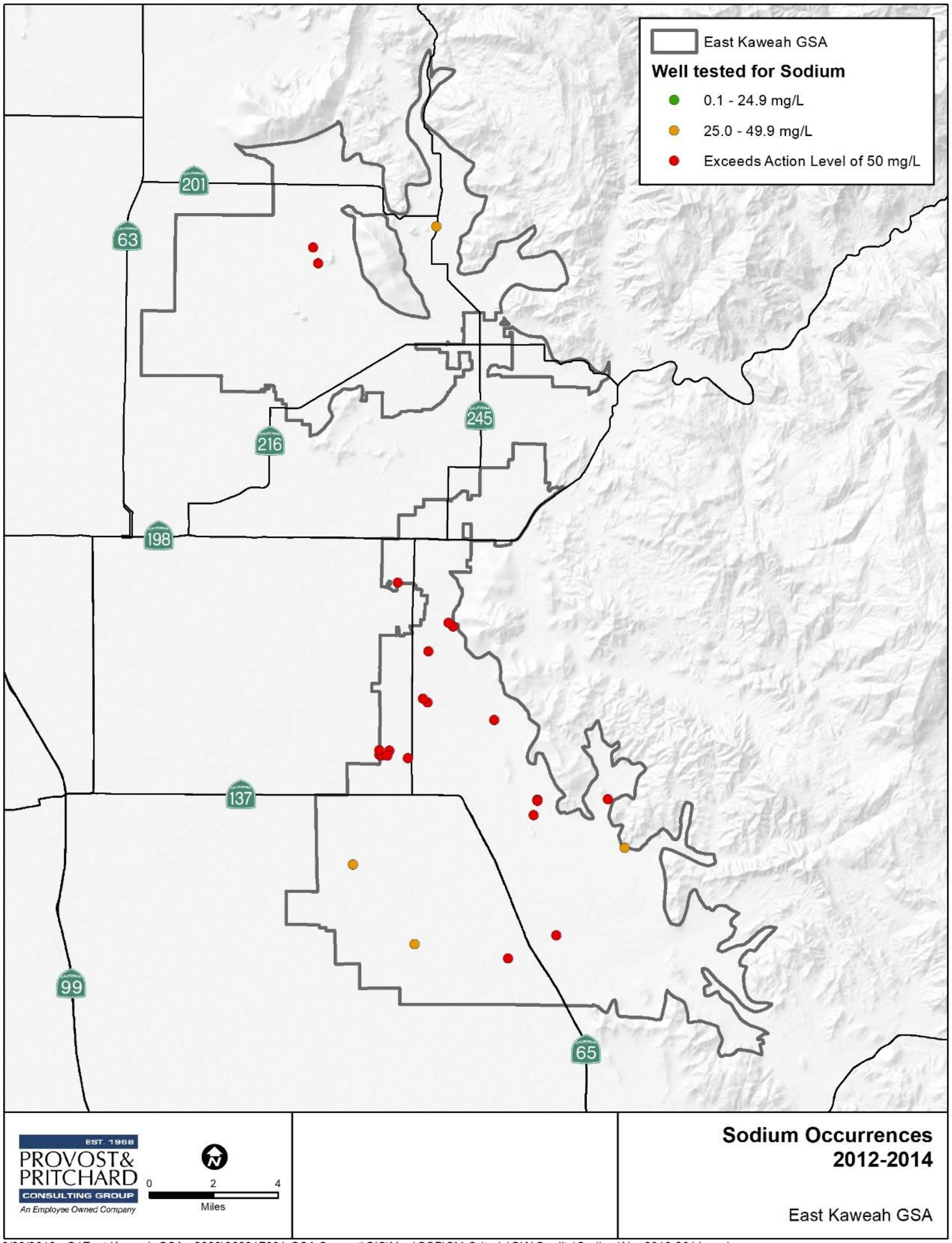

Sodium Occurrences 2012-2014

East Kaweah GSA

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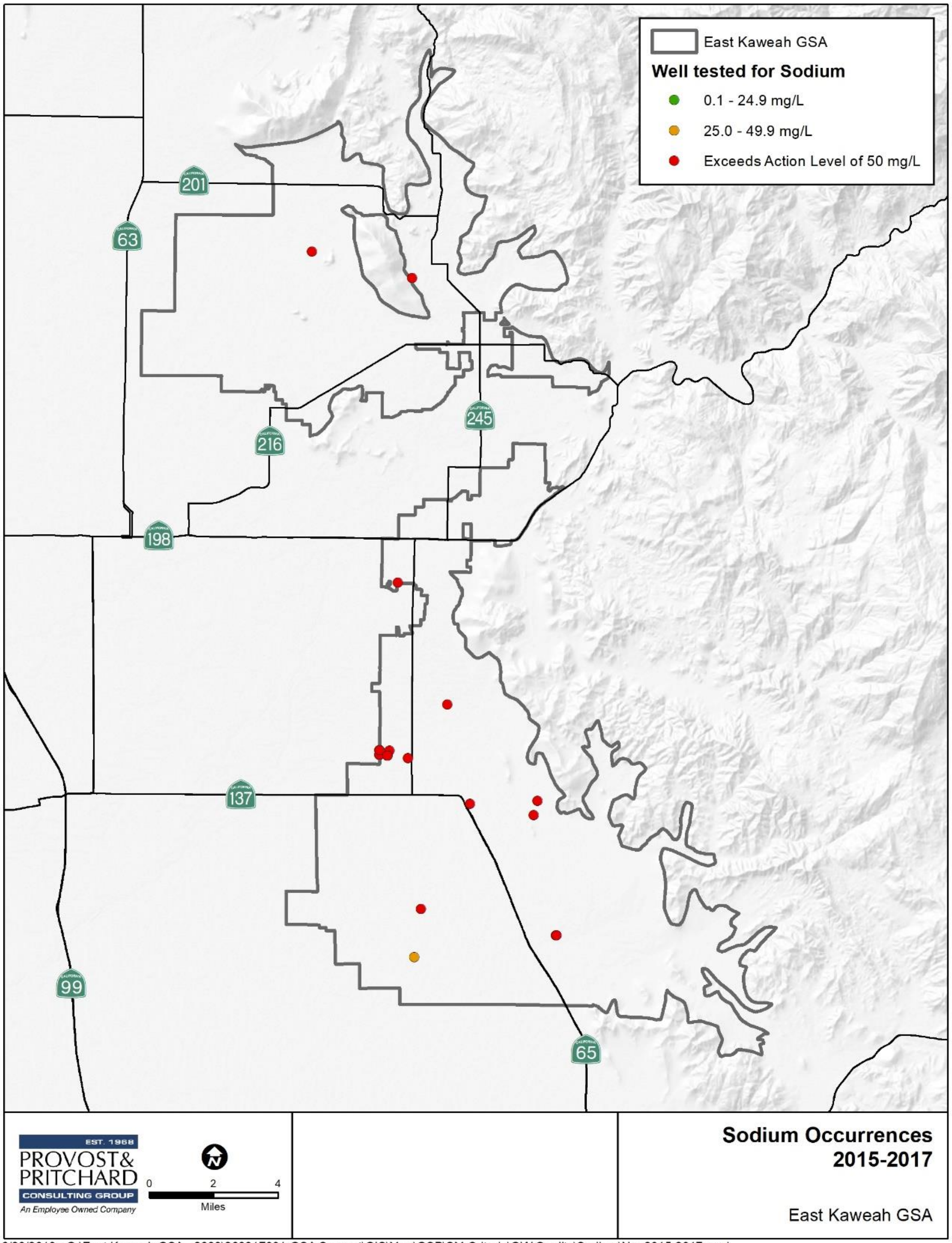

Sodium Occurrences 2015-2017

East Kaweah GSA

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