TECHNICAL MEMORANDUM:

MADERA SUBBASIN

Sustainable Groundwater Management Act (SGMA)

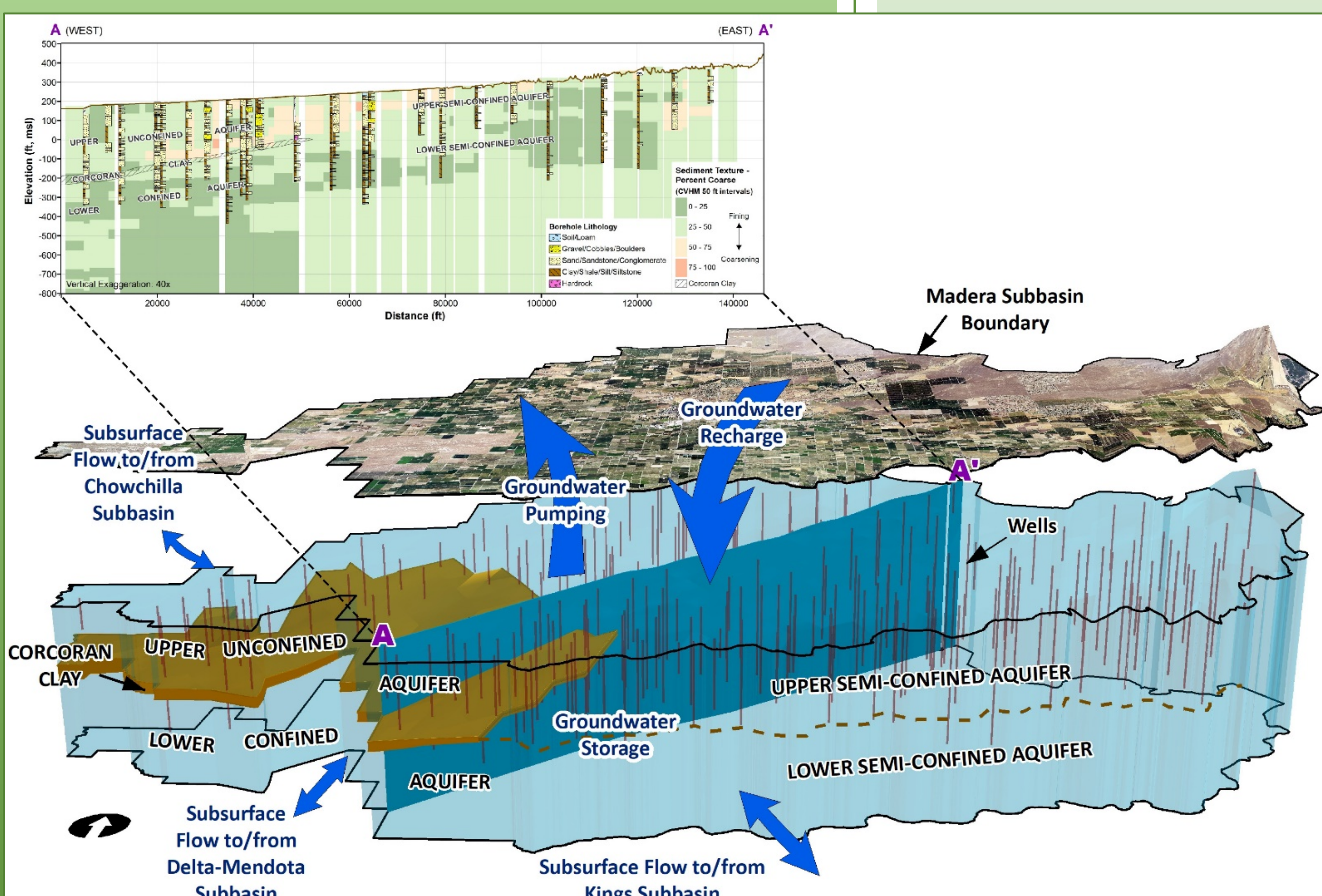
DATA COLLECTION AND ANALYSIS

July 2017

Prepared by

DAVIDS ENGINEERING, INC

LUHDORFF & SCALMANINI CONSULTING ENGINEERS



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Madera Subbasin
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Prepared For

Madera Subbasin Coordinating Committee

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DAVIDS ENGINEERING, INC

and

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ES 1 EXECUTIVE SUMMARY

Agriculture is an important economic driver in the Madera area, and groundwater represents an important water supply for crop irrigation in the Madera Subbasin. Thus, the sustainable management of groundwater is important to the long-term prosperity of the community. The Sustainable Groundwater Management Act of 2014 (SGMA) allows for local control of groundwater resources while requiring sustainable management of these resources.

The Madera Subbasin covers about 347,600 acres in Madera County. Seven Groundwater Sustainability Agencies (GSAs) have formed to cover the subbasin in its entirety (**Figure ES-1**). The objective of this study is to compile available data for the subbasin, identify data gaps, prioritize actions related to development of a Groundwater Sustainability Plan (GSP), and estimate costs to fill the identified data gaps.

This Technical Memorandum (TM) includes a description of the data acquisition process, a preliminary description of the Hydrogeologic Conceptual Model (HCM) (including groundwater conditions), and a description of the conceptual water budget. The TM also summarizes the data gap analysis and provides recommendations for filling high-priority data gaps.

ES 1.1 Data Compilation

Data for the subbasin were received from eight local entities including the City of Madera, Madera County, Madera Irrigation District, Madera Valley Water Company (within Madera County GSA), Madera Water District, New Stone Water District, Root Creek Water District, and Gravelly Ford Water District. Most of the submitted data relate to groundwater levels, water quality, well locations, well construction details, groundwater pumping, water use, and land use. Publicly available data were also compiled and evaluated. Public data were obtained from the U.S. Geological Survey (USGS), the California Data Exchange Center (CDEC), the California Department of Water Resources (DWR), the State Water Resources Control Board (SWRCB), the U.S. Bureau of Reclamation, the U.S. Department of Agriculture (USDA), and several others. Most public data were acquired from online databases. Data compiled from local entities and public data sources, primarily well data, water quality, land use, stream flows, weather and planning documents, are incorporated into the descriptions of the HCM and conceptual water budget.

ES 2.1 Hydrogeologic Conceptual Model

The preliminary HCM described in this TM is based on previous studies and information obtained through the data request for this study. The hydrogeologic conditions for the Madera Subbasin are documented in several reports by USGS and various consultants. The overall geologic setting and subbasin lateral and vertical boundaries are described herein. Several geologic cross-sections were obtained from previous studies, and those cross-sections are compiled and described. The major aquifers and aquitards are delineated using existing geologic cross-sections, and associated data describing aquifer properties were compiled. Additionally, groundwater levels, storage change, and groundwater quality are relatively well documented and included herein, along with available information describing subsidence and groundwater – surface water interaction. The preliminary HCM provides a foundation for developing the HCM required for the GSP.

ES 3.1 Water Budget

The water budget schematics provided in this TM were developed through a process of reviewing historical and current land and water use in the subbasin to identify water use sectors and by reviewing the water sources available for use in the subbasin. After identifying water use sectors and water source types, all inflows and outflows (flow paths) between water use sectors and accounting centers[1] were identified, and the data types and data sources needed to support quantification of each flow path were reviewed to assess data gaps. In addition to defining the required components of the water budget (flow paths), the GSP regulations specify minimum requirements for the water budget time period. The most recent available information is required to characterize current conditions, and information for at least the most recent ten years is required to characterize historical conditions. A longer historical water balance typically provides information that better describes how variability in hydrology, water supplies, and water demands have affected aquifer conditions and better informs the evaluation of sustainability indicators and potential future management actions. Based on the data acquired for the Madera Subbasin, a 27-year base period of 1989 through 2015 is preliminarily recommended.

ES 4.1 Data Gap Assessment

The elements of an HCM (geologic and groundwater conditions) and water budget required for a GSP can generally be prepared based on synthesis of information compiled from existing reports and the data acquired for this study. The following additional efforts are needed prior to GSP development or as a first phase of GSP development: 1) a detailed quality assessment and quality control (QA/QC) check of various data sets, 2) further integration of data collected for this study (e.g., DWR well completion reports), and 3) installation of dedicated monitoring wells. Existing wells to be included in the GSP monitoring network will require known construction details to facilitate an understanding of groundwater elevations and water quality in the upper aquifer versus the lower aquifer. At present, a major data gap is the lack of a sufficient number of water level and water quality monitoring wells with known construction details. A major data gap for the water budget is a lack of surface water outflow stream gages on or near the subbasin boundaries.

For the required water budget analyses, sufficient data exist to complete all of the necessary data types, except that the available record of surface water outflows based on gage data is short. This will require estimates to be prepared from available data and supporting analyses. Also, complete, quality controlled data sets are not available, and all data will require some degree of QA/QC and gap filling for relatively short, intermittent periods.

ES 5.1 Recommendations

Three priority levels of data gaps and related recommendations are presented in this report, with the high and medium priority recommendations summarized in the following sections, respectively. The last section of the report presents data gaps and recommendations in all three priority levels.

ES 5.1.1 High Priority

The high priority recommendations are actions that are key to developing a compliant, high quality, successful GSP and should be initiated immediately. The recommended high priority actions are listed below and summarized in **Tables ES-1** and **ES-2**. The total cost for all high priority recommendations is $1.795 million including $1.65 million for new monitoring wells, $90,000 for the installation of new stream gages, and $55,000 for analyses to associate data from well completion report (WCR) locations with existing wells and to develop a complete surface water outflow record.

[1] Accounting centers represent subareas (volumes) within the larger water budget domain.

- Conduct detailed review of DWR WCRs acquired for this study and associate WCRs with wells with water level data but unknown construction details to further expand the database of wells with known construction details and better characterize groundwater conditions in the upper and lower aquifers.
- Conduct outreach with existing well owners. Identify wells with known construction details that are not currently part of the groundwater monitoring network. If the well owner is willing to participate and has a well that is representative of either the upper or lower aquifer (but not both), consider adding the well to the GSP monitoring network.
- Install new dedicated monitoring wells at locations (**Figure ES-2**) where existing wells with known construction details are lacking to fill data gaps in the existing monitoring network.
- Plan for and install three new gages to measure surface water outflows from the subbasin on Cottonwood Creek, Eastside Bypass, and the Fresno River.
- Review available surface water outflow records and use standard, accepted methods to estimate missing records.

ES 5.1.2 Medium Priority

The medium priority recommendations are actions that are also key to developing a compliant, high quality, successful GSP and need to be initiated soon, but not as soon as the high priority actions. The recommended medium priority actions are listed below and summarized in **Table ES-3**. The total cost for all medium priority recommendations is $145,000 for eight individual analyses.

- Initiate QA/QC and conduct analyses to fill missing record on the following seven time series data sets for flow paths required for the basin boundary water budget:
    1. Meteorological,
    2. Surface Water Inflows,
    3. Land Use,
    4. Water Use (Evapotranspiration),
    5. Surface Water Diversions,
    6. Agricultural Groundwater Pumping, and
    7. Applied Water
- Evaluate potential groundwater dependent ecosystems (GDEs) mapped by The Nature Conservancy (TNC) to determine if the areas truly represent GDEs and, if so, whether they may be adversely impacted by regional pumping.

Table ES-1
High Priority Data Gaps and Cost to Fill

Data Type	Data Use	Required Action/Analysis	Priority*	Estimated Cost
Groundwater Levels	HCM, Groundwater Model, GSP Monitoring Network	Review DWR WCRs to match with existing wells with water level data; identify existing wells to add to monitoring network	High	$30,000-$50,000
		Install new dedicated monitoring wells	High	$95,000-$125,000 per nested well
Groundwater Quality	HCM, Groundwater Model, GSP Monitoring Network	Review DWR WCRs to match with existing wells with water quality data; identify existing wells to add to monitoring network	High	Included in groundwater level cost
		Install new dedicated monitoring wells	High	Included in groundwater level cost
Groundwater Levels and Quality	HCM, Groundwater Model, GSP Monitoring Network	Conduct outreach with existing well owners. Identify wells with known construction details that are not currently part of the groundwater monitoring network. If the well owner is willing to participate and has a well that is representative of either the upper or lower aquifer (but not both), consider adding the well to the GSP monitoring network.	High	$15,000-$25,000
Surface Water Outflows	Fill data gap for future monitoring of surface water outflows	Add and maintain stream gage records on Fresno River, Chowchilla Bypass, and Cottonwood Creek	High	$90,000
Surface Water Outflows	Develop historical data for 50 year period for planning and water budget for 30 years	Review available records and use standard, accepted methods to estimate missing records	High	$15,000

*All identified data gaps will need addressing for the GSP. Data gap priority is assigned based on relative importance and timing sequence.

Table ES-2
Recommended New Monitoring Well Locations, Priority, and Cost

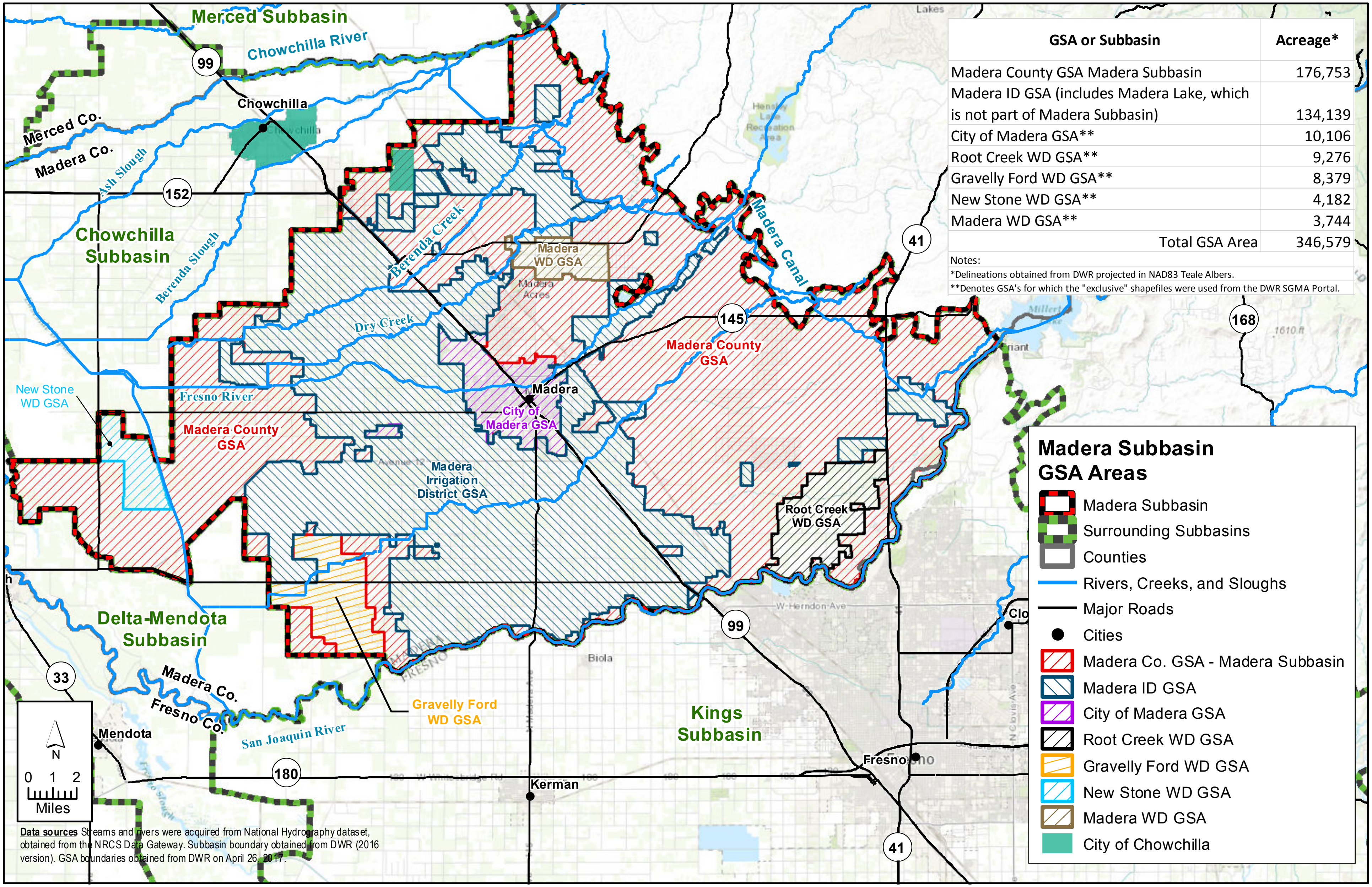
New Monitoring Well*	Approximate Location	Purpose	Priority**	Estimated Cost
4	East of City of Madera	Groundwater Levels/Quality; Upper/Lower Semi-Confined Aquifer; lack of wells in area	High	$95,000-$125,000
5	South central basin boundary	Groundwater Levels/Quality; Upper/Lower Semi-Confined Aquifer; near San Joaquin River; base boundary flow	High	$95,000-$125,000
6	Northeast basin boundary	Groundwater Levels/Quality; Upper/Lower Semi-Confined Aquifer; limited wells in area; basin boundary flows; 2016 groundwater depression	High	$95,000-$125,000
9	Central basin; west of City of Madera	Groundwater Levels/Quality; Upper/Lower Semi-Confined Aquifer; limited wells in area	High	$95,000-$125,000
13	West basin boundary	Groundwater Levels/Quality; Upper Unconfined/Lower Confined Aquifers; lack of wells in area	High	$95,000-$125,000
1	Southeast basin boundary	Groundwater Levels/Quality; Upper/Lower Semi-Confined Aquifer; contours missing in this area due to lack of data	Medium	$95,000-$125,000
2	Southeast basin	Groundwater Levels/Quality; Upper/Lower Semi-Confined Aquifer; limited wells in area	Medium	$95,000-$125,000
3	East basin boundary	Groundwater Levels/Quality; Upper/Lower Semi-Confined Aquifer; contours missing in this area due to lack of data	Medium	$95,000-$125,000
7	Central basin; in City of Madera	Groundwater Levels/Quality; Upper/Lower Semi-Confined Aquifer; lack of upper aquifer wells in area	Medium	$95,000-$125,000
8	North central basin	Groundwater Levels/Quality; Upper/Lower Semi-Confined Aquifer; lack upper aquifer wells in area; basin boundary flows; 2016 groundwater depression	Medium	$95,000-$125,000
10	Northwest basin boundary	Groundwater Levels/Quality; Upper Unconfined/Lower Confined Aquifers; limited wells in area; basin boundary flows; 2016 groundwater depression	Medium	$95,000-$125,000
11	West basin boundary	Groundwater Levels/Quality; Upper Unconfined/Lower Confined Aquifers; limited wells in area	Medium	$95,000-$125,000
12	Southwest basin boundary	Groundwater Levels/Quality; Upper Unconfined/Lower Confined Aquifers; lack of lower aquifer wells in area; basin boundary flows	Medium	$95,000-$125,000

* New monitoring well numbers are identified on Figure 5-5.
** New monitoring well priority is assigned according to existing hydrogeologic data need and importance for future monitoring.

Table ES-3
Medium Priority Data Gaps and Cost to Fill

Data Type	Data Use	Required Action/Analysis	Priority*	Estimated Cost
Meteorological	Develop reference ET by crop and precipitation for 50 year period for planning projections	Use standard, accepted ASCE Manual 70 methods to develop ET_o and precipitation daily time series from available weather data	Medium	$10,000
Surface Water Inflows	Develop water budget for 30 years and 50 year hydrology for planning projections	Review available records and use standard, accepted methods to estimate missing records	Medium	$5,000
Land Use	Assign land use to each water balance area each year for 30 year historical period	Based on available spatial data and crop reports, assign crops to water balance areas	Medium	$15,000
Water Use (Evapotranspiration)	Outflow from subbasin and basis for estimate of agricultural groundwater pumping	Root zone water balance based on meteorological, remotely sensed energy balance ET estimates and land use data to estimate crop water use.	Medium	$20,000
Surface Water Diversions	Develop water budget for 30 years	Review available records and use standard, accepted methods to estimate missing records	Medium	$30,000
Agricultural Groundwater Pumping	Develop water budget for 30 years	Use standard, accepted methods to estimate historical groundwater pumping	Medium	$15,000
Applied Water	Develop water budget for 30 years	Review available records and use standard, accepted methods to estimate missing records	Medium	$15,000
Groundwater Dependent Ecosystems	HCM, Groundwater Model, GSP Monitoring Network	Evaluate potential GDEs mapped by TNC/DWR to determine if could be impacted by regional pumping	Medium	$20,000-$35,000

*All identified data gaps will need addressing for the GSP. Data gap priority is assigned based on relative importance and timing sequence.



GSA or Subbasin	Acreage*
Madera County GSA Madera Subbasin	176,753
Madera ID GSA (includes Madera Lake, which is not part of Madera Subbasin)	134,139
City of Madera GSA**	10,106
Root Creek WD GSA**	9,276
Gravelly Ford WD GSA**	8,379
New Stone WD GSA**	4,182
Madera WD GSA**	3,744
Total GSA Area	346,579

Notes:
*Delineations obtained from DWR projected in NAD83 Teale Albers.
**Denotes GSA's for which the "exclusive" shapefiles were used from the DWR SGMA Portal.

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FIGURE ES-1

Madera Subbasin Map

Madera County - Madera Subbasin
SGMA Data Collection and Analysis

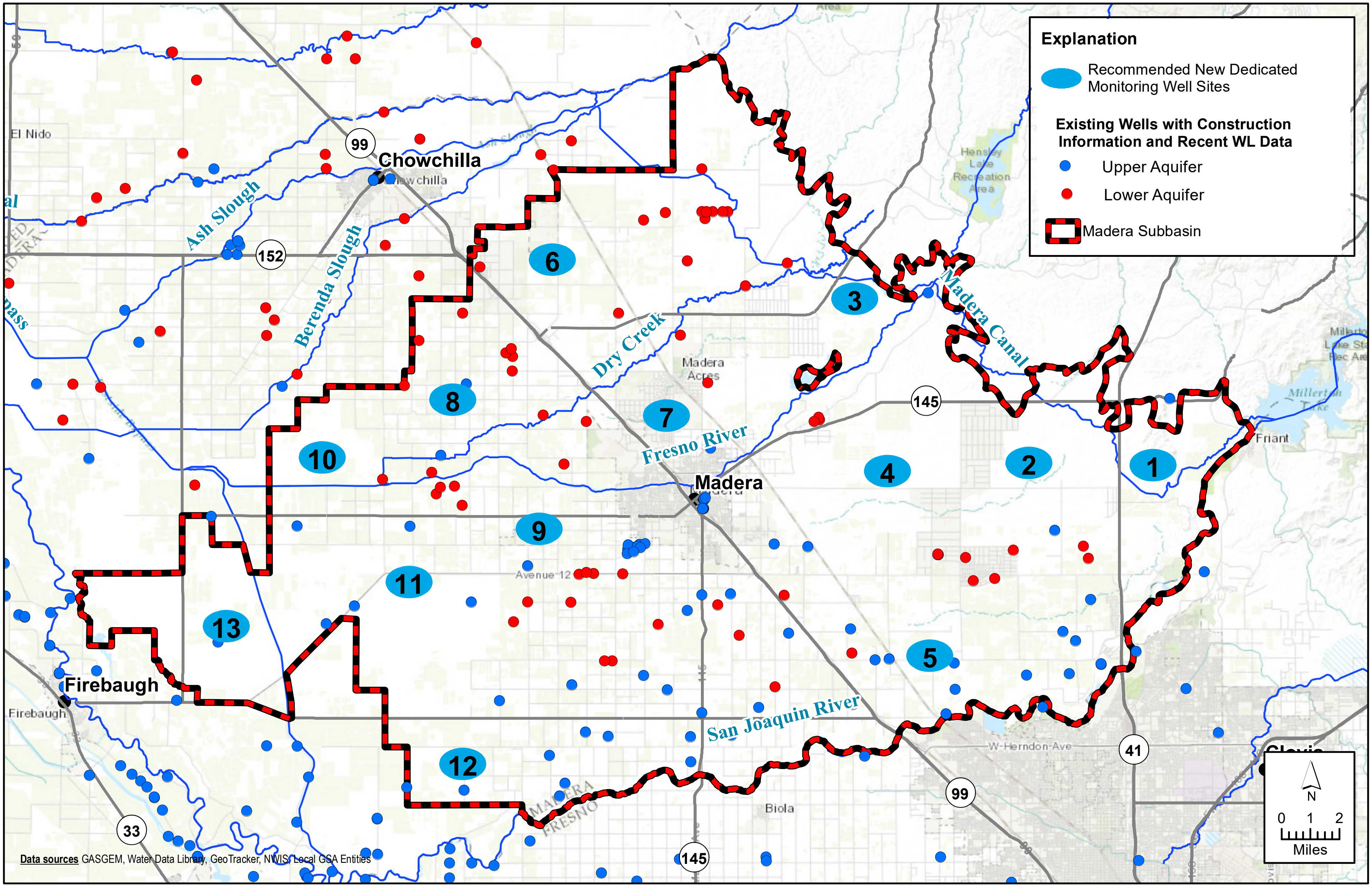

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FIGURE ES-2

Preliminary Recommendations for New Dedicated Monitoring Well Sites

Madera County: Madera Subbasin
SGMA Data Collection and Analysis

1 INTRODUCTION

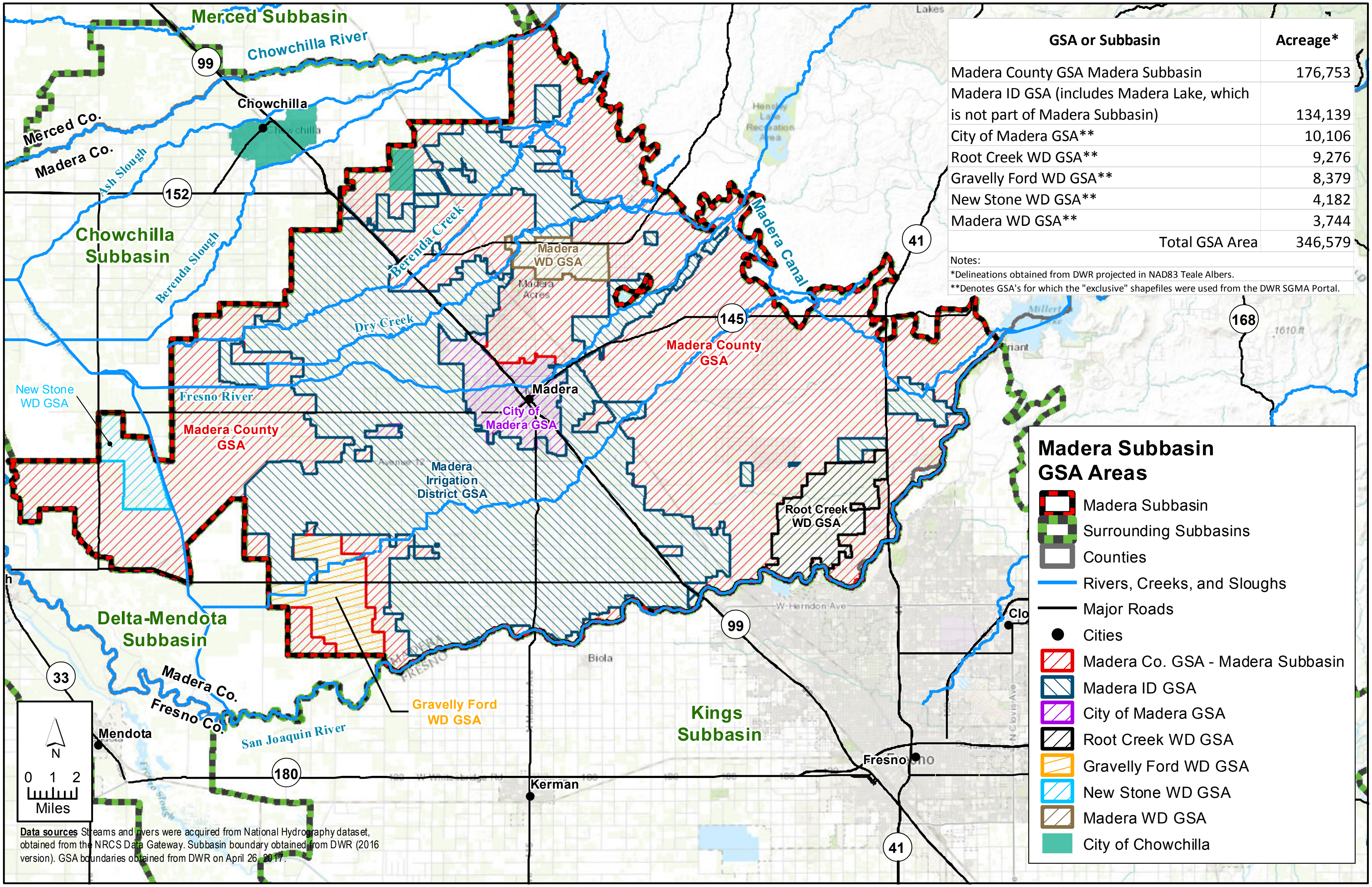
Agriculture is an important economic driver in the Madera area and groundwater represents an important agricultural water supply source in the Madera Subbasin. Thus, the sustainable management of groundwater is important for the long-term prosperity of the community. The Sustainable Groundwater Management Act (SGMA) allows for local control of groundwater resources while requiring sustainable management of these resources.

The Madera Subbasin covers about 347,600 acres all within Madera County. Seven Groundwater Sustainability Agencies (GSA) have formed to cover the subbasin (**Figure 1-1**). The largest of these is the Madera County GSA covering about 176,750 acres. The Madera Irrigation District GSA covers about 134,140 acres in Madera County. The remainder of the subbasin is covered by five additional GSAs including the City of Madera GSA, Root Creek Water District GSA, Gravelly Ford Water District GSA, New Stone Water District GSA, and Madera Water District GSA, each individually covering areas between about 3,700 and 10,000 acres within the subbasin.

The Madera Subbasin has been identified by the California Department of Water Resources (DWR) as a critically overdrafted subbasin and this technical memorandum (TM) documents one of several tasks that have been identified by the Madera Subbasin Coordinating Committee as initial steps towards addressing SGMA requirements and the development of a Groundwater Sustainability Plan (GSP). The objective of this data gap analysis was to collect all the available local and publicly available data pertaining to preparation of GSPs, to review the data for gaps in coverage or other deficiencies, and to develop a plan to fill the most critical data deficiencies.

Specifically, DWR has recently published draft guidance and Best Management Practice (BMP) documents related to the development of GSPs (DWR, 2016). The GSP outline includes four distinct components for the Basin Setting section: HCM, Current and Historical Groundwater Conditions, Water Budget Information, and Management Areas. This TM documents a systematic process to compile and review data needed to prepare these GSP components, and to identify critical data gaps. Special emphasis has been placed on the elements outlined in the GSP regulations, DWR's BMPs, and GSP outline.

This TM includes a description of the data acquisition process preliminary descriptions of the Madera Subbasin HCM (including groundwater conditions) and conceptual water budget, a summary of the gap analysis, and recommendations for next steps.



GSA or Subbasin	Acreage*
Madera County GSA Madera Subbasin	176,753
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New Stone WD GSA**	4,182
Madera WD GSA**	3,744
Total GSA Area	346,579

Notes:
*Delineations obtained from DWR projected in NAD83 Teale Albers.
**Denotes GSA's for which the "exclusive" shapefiles were used from the DWR SGMA Portal.

Data sources Streams and rivers were acquired from National Hydrography dataset, obtained from the NRCS Data Gateway. Subbasin boundary obtained from DWR (2016 version). GSA boundaries obtained from DWR on April 26, 2017.

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FIGURE 1-1

Madera Subbasin GSA Map

Madera County - Madera Subbasin
SGMA Data Collection and Analysis

2 DATA COMPILATION

The SGMA data collection and analysis effort for the Madera Subbasin was conducted to address key requirements for completion of the HCM, water budget, and associated analyses required for the GSP. **Table 2-1** highlights the key data categories related to these GSP requirements, which guided the data compilation.

As an initial step in this data collection and analysis, a meeting was held on February 15, 2017 with representatives of the GSA entities and other local stakeholder entities, to discuss the objectives of the project, types of data required for GSP development, potential data sources, and proposed approaches for acquiring available data and assessing data gaps. Following that meeting, a detailed data request was distributed to local entities within the subbasin outlining the types and forms of local data of interest and the process for local entities to provide these data for incorporation in the data compilation and assessment. The data request was formulated with the intent to acquire as much locally available data as possible, including all data that might be relevant to future GSP HCM and water budget analyses and other GSP development activities, without burdening local entities with collecting data available online from public sources. The request described the interest in a wide variety of data helpful for a broad range of potential analytical tools yet to be determined. The major data content areas in the request included the following:

- General geographic data
- Water planning documents
- District water infrastructure and basemap data
- Hydrogeology
- Groundwater levels
- Groundwater quality
- Land subsidence
- Groundwater pumping
- Surface water diversions and deliveries
- Surface water inflows and outflows
- Land use and water demand
- Climate
- Other data (including available estimates of conveyance losses, groundwater-dependent ecosystems and future conditions).

The complete data request packet is included in **Appendix A**.

Because of the compressed schedule associated with GSP development for critically overdrafted subbasins such as the Madera Subbasin, the timeline for local entities to respond to the data request was short. Data from local entities were requested by April 1, 2017, allowing approximately six weeks to respond to the request. The local entities were very responsive to the data request, and despite the short period in which to provide data, considerable local data were submitted by April 1 for compilation and preliminary analysis.

Data were received from eight local entities within the Madera Subbasin area. Furthermore, local entities also provided data on groundwater conditions such as water levels to DWR and other public entities as part of ongoing monitoring programs (e.g., California Statewide Groundwater Elevation Monitoring [CASGEM]); these data were also acquired from public data sources as discussed below. Those local entities within the subbasin that provided data in response to the data request were the City of Madera, Madera County, Madera Irrigation District, Madera Valley Water Company (within Madera

County GSA), Madera Water District, New Stone Water District, and Root Creek Water District. Most of the submitted data related to groundwater levels, water quality, well locations, well construction details, groundwater pumping, water use, and land use. **Table 2-2** summarizes the basic data types provided by local entities for this project. The types and forms of data submitted vary greatly between different entities as does the temporal period represented by the data. Some of the data files provided were in formats that could be readily evaluated (e.g., Excel spreadsheets, GIS maps), while others were in formats such as Portable Document Format (PDF), which could not be as easily assessed. In select circumstances, well location coordinates and construction information provided in non-tabular formats, were entered into a spreadsheet or other tabular formats for presentation and evaluation on maps. **Figure 2-1** highlights the spatial distribution of groundwater data that were provided for wells that could be readily located. As illustrated in **Table 2-2** and **Figure 2-1**, most of the local entities in the subbasin contributed some data as part of the effort. A complete list of the data provided by local entities is included in **Appendix A. Figure 2-1** also includes data obtained from the DWR CASGEM database for wells monitored by local entities, which includes both formal CASGEM wells and volunteer wells. The formal CASGEM wells have either known screen intervals or known well depths, whereas most of the volunteer wells have unknown well construction details. Additional wells in the CASGEM database that are monitored by DWR or other non-local entities are not shown on **Figure 2-1**, but are incorporated on figures in **Section 5**.

Concurrent with efforts to acquire local data, publicly available data were also compiled and evaluated by the consultant team. Public data sources considered included the U.S. Geological Survey (USGS), DWR, State Water Resources Control Board (SWRCB), U.S. Bureau of Reclamation, U.S. Department of Agriculture (USDA), and many others. Most of the public data were acquired from online databases. As part of the public data acquisition, a Well Completion Report (WCR or well log) request was also submitted to DWR for the entire subbasin area. In response, DWR provided available WCRs for all wells in the subbasin constructed prior to approximately mid-2015. DWR also provided a summary table with approximate well locations, well types, and limited well construction information. Public data sources considered during the data collection effort are listed in the data request packet (**Appendix A**). A summary of public groundwater data compiled for this project is presented in **Table 2-3** and a summary of water budget public data that were acquired is included in **Table 2-4**. A complete list of acquired public data is included in **Appendix A**.

For all data acquired, data quality assessment, quality control, or other processing were conducted to the extent necessary to assess the completeness of data (spatially and temporally). Additionally, groundwater level, groundwater quality, well locations (from WCRs), and other data were preliminarily characterized as part of the data assessment. All data files and related information acquired and generated as part of this data collection and analysis effort are being provided as part of a separate digital data transfer.

The data compiled from local entities and public data sources are incorporated into the descriptions of the Hydrogeologic Conceptual Model (**Section 3**) and Conceptual Water Budget Model (**Section 4**) discussed below, and some of the data are presented in tables and figures associated with these sections. Additional data compiled for this project are presented in summary form in different appendices.

Table 2-1
GSP Data Needs and Sources

Data Type	Relevant GSP Components			Potential Data Sources
	Hydrogeologic Conceptual Model	*Groundwater Conditions*	*Water Budget*	
Topography	●	●	●	USGS
Surficial soils	●		●	NRCS
Geology/hydrogeology	●	●	●	
Aquifer/aquitard properties	●	●	●	DWR, USGS, local/regional studies
Meteorological (e.g., temp, precip, ET)			●	DWR, PRISM, CIMIS, NOAA, USBR, CalSIMETAW, UCCE
Hydrology/streamflow	●		●	DWR, USGS, local entities
Land/water use (e.g., crop, irrig)			●	DWR, USDA, FMMP, AWMPs, UWMPs, UCCE, county Ag Commissioners, General Plans, local entities
Surface water diversions			●	Local entities, SWRCB, DWR, USBR
Groundwater pumping	●	●	●	AWMPs, UWMPs, DWR, USGS, local entities
Groundwater conditions	●	●	●	
Well information	●	●	●	DWR, USGS, local entities
Groundwater levels	●	●	●	DWR, USGS, local entities
Groundwater quality	●	●		DWR, USGS, DPR, local entities
Subsidence	●	●	●	USGS, DWR, NASA
Future conditions (e.g., pop, climate)		●	●	DWR, USGS, USBR, UWMPs, CA Dept. of Finance, Census

Table 2-2
Data Received from Local Entities

Local Entity	Groundwater Levels	Water Quality	Groundwater Pumping	Well/Aquifer Tests	Water Use	Land Use	Well Locations	Well Construction	Subsidence
City of Madera	X	X	X	X	X		X	X	
Madera County	X						X		
Madera ID	X	X			X		X	X	
Madera Valley WC	X				X			X	
Madera WD	X		X		X			X	
New Stone WD				X	X	X			
Root Creek WD	X	X		X	X	X	X	X	
Gravelly Ford WD					X				

Note: Many local entities provide groundwater data to public data sources such as DWR as part of broader groundwater monitoring programs. These data were compiled through public data acquisition.

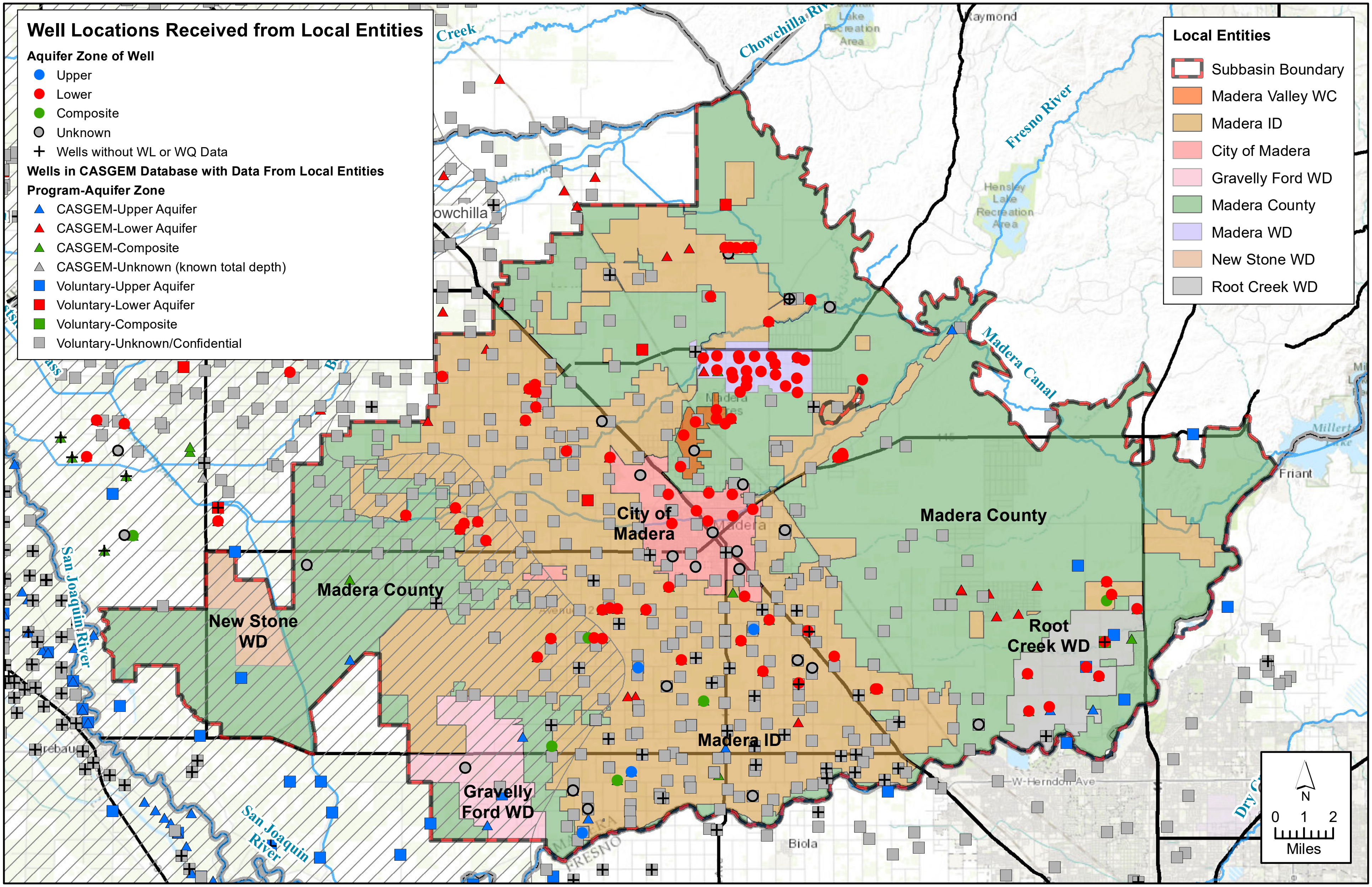
Table 2-3
Summary of Public Well Data

Data Source	Data Type	Description	Period of Record
DWR	Water Level	Data downloaded for Madera, Merced and Fresno Counties. ~8,400 wells with one or more measurement	1920-present
DWR	Well Construction	Well construction data for Madera, Merced, and Fresno Counties. Data includes total depth of well and screen interval. ~1,400 wells with data	n/a
USGS	Water Level	Data downloaded for Madera, Merced, and Fresno Counties. ~5,900 wells with measurements	1901-present
USGS	Well Construction	Well construction data for wells in Madera, Merced, and Fresno Counties. Includes total depth of well. ~5,080 wells with data	n/a
USGS	Water Quality	All surface water and groundwater quality data acquired for Madera, Merced, and Fresno Counties. ~1,700 sites with TDS and nitrate measurements data	1925-present
SWRCB	Water Level	Water level data for Madera, Merced, and Fresno Counties, ~3,200 wells with data (Not all wells surveyed). Water level data from GAMA, >33,000 sites state wide.	1993-present
SWRCB	Well Construction	Well construction data for Madera Merced, and Fresno Counties. Included screen interval. ~1,900 wells. (Very few within Madera Subbasin)	n/a
SWRCB	Water Quality	Surface and groundwater quality data for Madera, Merced, and Fresno Counties. ~1,400 sites with data. Groundwater data from GAMA, ~5,200 sites with data	2000-present
CEDEN	Water Quality	Surface water quality for Madera, Merced and Fresno Counties. ~80 sites with TDS or nitrate measurements.	2002-2014

Table 2-4
Summary of Public Water Budget Data Acquired

Entity	Data Type	Data Description	Period of Record
USGS CIDA	Evapotranspiration Data	Monthly ETa values for Madera Subbasin area and 20-mile buffer	2000-2015
CDFA	Land Use	Contains information for crops in all California counties, including harvested acres, yield, price, production, and value	1980-2015
DWR	Land Use	Land Use surveys for Madera County	1995 and 2011
USDA Cropscape	Land Use	Land usage data with crop delineations and crop-pixel linkages	2007-2016
USGS NLCD	Land Use	California coverage of land usage by crop	2001, 2006, 2011
SSURGO	Soils	Mapped soil characteristics	
STATSGO	Soils	Mapped soil characteristics for California	
DWR	Surface Water Inflows	Streamflow data for station at Cottonwood Creek near Friant	1998-2017
DWR	Surface Water Inflows	Streamflow data for station at Chowchilla Bypass at Head Below Control Structure	1978-1991
DWR	Surface Water Outflows	Streamflow data for station at Fresno River 8 miles West of Madera	1980-1990
DWR	Surface Water Inflows	Streamflow data for station at San Joaquin River Below Friant	1997-2002
DWR	Surface Water Outflows	Streamflow data for station at Delta-Mendota Canal to Mendota Pool	1969-1990
DWR	Surface Water Outflows	Streamflow data for station at San Joaquin River Below Control Structure	1978-1991
DWR	Water Year Type	San Joaquin Valley water year runoff, index, and type	1901-2016
SWRCB	Surface Water Diversion Data	Water rights point of diversions	n/a
USBR	Water Planning Documents	City of Fresno Service Area Water Management Plan	2013
USBR	Water Planning Documents	Madera Water District Water Management Plan	2013
USBR	Water Planning Documents	City of Madera Urban Water Management Plan	2015 and 2017
USBR	Water Planning Documents	Gravelly Ford Water District Water Management Plan	2009 and 2011
USBR	Water Planning Documents	Colombia Canal Company Water Management Plan, some data also located within the Westside San Joaquin Integrated Water Resources Plan	2014
CIMIS	Weather Data	CIMIS station weather data include: ETo, precipitation, solar radiation, average vapor pressure, minimum/maximum/average air temperature, minimum/maximum/average relative humidity, dewpoint, average wind speed, wind run, average soil temperature	1998-2017
NOAA	Weather Data	Daily precipitation and temperature data	1928-2017
PRISM	Weather Data	National values for precipitation, mean/minimum/maximum temperature, mean dewpoint temperature, minimum/maximum vapor pressure deficit, and elevation	1895-2016

CDFA - California Department of Food and Agriculture (CDFA), and County Agricultural Commissioner; SSURGO - Soil Survey Geographic Database; STATSGO - State Soil Geographic Database; CIDA - Center for Integrated Data Analytics; NLCD - National Land Cover Data; SWRCB – State Water Resources Control Board



X:\2016\16-119 Madera Co. - Chowchilla & Madera Subbasins SGMA Support\GIS\Maps\FinalMapsForTM\Madera Subbasin\Figure 2-1 updat.mxd

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LUHDORFF & SCALMANINI CONSULTING ENGINEERS

FIGURE 2-1

Map of Well Data Received from Local Entities

Madera County: Madera Subbasin
SGMA Data Collection and Analysis

3 HYDROGEOLOGIC CONCEPTUAL MODEL

The preliminary HCM provided in this TM is based primarily on previous studies, but it also utilizes some of the information obtained through the data request made for this study. The Data Gaps section of this TM further describes how data obtained for this study may be used to further refine and develop the HCM during the GSP process.

This TM describes the preliminary HCM for the Madera Subbasin with lateral boundaries as defined in **Figure 1-1**. The HCM, as defined in SGMA, focuses primarily on geologic conditions, whereas groundwater conditions are considered as a separate element of the GSP. The term HCM, as used in this TM, incorporates discussion of both geologic and groundwater conditions.

3.1 Geologic Conditions

The geologic conditions portion of the HCM in this TM includes discussion of the regional geologic and structural setting, the subbasin's lateral and vertical boundaries, the major aquifers/aquitards, and aquifer parameters. Geologic cross-sections are described in the discussion of major aquifers and aquitards. Much of the information obtained from previous studies related to geologic conditions is provided in **Appendix B**.

3.1.1 Regional Geologic and Structural Setting

The Madera Subbasin (DWR Subbasin No. 5-22.06) is generally comprised of relatively flat topography that slopes gently downward to the west. Topographic elevations vary from about 350 feet above mean sea level (MSL) in the east to about 150 feet MSL in the west over a distance of about 20 miles (**Figure 3-1**). The major geomorphic features of the subbasin are the alluvial fan and floodplain associated with sediment deposition from the Fresno and San Joaquin Rivers (Mitten et al., 1970). A map of hydrologic soil groups in Madera Subbasin is provided in **Figure 3-2**, and a map of soil saturated hydraulic conductivity (K_{sat}) is provided in **Figure 3-3**. These maps indicate that soils with higher permeability and infiltration rates are present along river channels (Fresno River, Cottonwood Creek, and San Joaquin River) and west/south of the City of Madera (between the Fresno River and Cottonwood Creek). Another zone of higher soil permeability is present in the south central portion of the subbasin between Cottonwood Creek and the San Joaquin River.

Surface geology maps are provided in **Figure 3-4** and in **Appendix B**. The surficial geology of the Madera Subbasin is dominated by Younger and Older Alluvium (generally equivalent to Modesto, Riverbank, and Turlock Lake Formations), which are described in more detail below. Younger Alluvium is most prevalent along the Fresno and San Joaquin Rivers and in an area immediately south and west of the City of Madera. Existing geologic cross-sections are distributed throughout the subbasin, and vary considerably in quality and level of detail as described in the section on Major Aquifers/Aquitards.

The stratigraphy of the Madera Subbasin from the surface down is comprised primarily of Continental Deposits of Quaternary Age (Younger and Older Alluvium), Continental Deposits of Tertiary and Quaternary age, Marine and Continental sedimentary rocks, and crystalline basement rock. The Continental Deposits are unconsolidated, and underlying sedimentary and basement rocks are consolidated. It is uncertain if Mehrten and Ione Formation are present in the Madera Subbasin. Younger Alluvium is generally limited to 50 feet thickness and typically unsaturated. The Older Alluvium consists of up to 1,000 feet of interbedded clay, silt, sand, and gravel. Older Alluvium becomes finer-grained with depth and is underlain by the generally finer-grained Continental deposits of Tertiary and Quaternary age (Mitten et.al., 1970). The primary water bearing unit is Older Alluvium, although recent deeper drilling of agricultural wells is tapping into the underlying Continental Deposits of Tertiary/Quaternary age (Provost & Pritchard, 2014).

The Corcoran Clay occurs in the western portion of Madera Subbasin within the upper portion of Older Alluvium (Mitten et al., 1970). The Corcoran Clay is also considered to be a member of the Turlock Lake Formation (Page, 1986). The depth to top of the Corcoran Clay ranges from about 150 to 400 feet (Provost & Pritchard, 2014). The Corcoran Clay is comprised of clay and silt ranging in thickness from 10 feet at its eastern extent to 80 feet on the western edge of Madera County (Mitten et al., 1970).

3.1.2 Lateral and Vertical Subbasin Boundaries

The Madera Subbasin is bordered by the Sierra Nevada Mountains to the east, Kings Subbasin to south, Chowchilla Subbasin to the north, and Delta-Mendota Subbasin to the west (**Figure 1-1**). Bedrock to the east represents a hydrogeologic boundary, whereas the other three boundaries are political/agency boundaries across which groundwater flow can and does occur. There is a small amount of fractured bedrock groundwater inflow to Madera Subbasin on the east.

The base of fresh water was evaluated by Page (1973), and defined as including water with conductivity up to 3,000 umhos/cm. Overall, the base of freshwater was mapped as ranging from elevation -400 to -1,200 feet msl. In general, the shallowest depths to base of fresh water were along the western boundary of the subbasin, and the greatest depths were areas located just north of the City of Madera in the eastern portion of the subbasin (**Figure 3-5).**

3.1.3 Major Aquifers/Aquitards

Geologic cross-sections are a key element of the HCM required in a GSP under SGMA. This study included review of existing literature to extract the available geologic cross-sections. This section of the TM provides a general description and documents the locations of available geologic cross-sections.

Geologic cross-sections were obtained from Davis et al. (1959), Mitten et al. (1970), Page (1986), KDSA (2001), KDSA (2006), Provost & Pritchard (2014), and LSCE (2017) for the Madera Subbasin. Davis et al. (1959), Mitten et al. (1970), Page (1986), Provost & Pritchard (2014), and LSCE (2017) provide regional coverage, while KDSA (2001 and 2006) contain local project-specific cross-sections in the southeastern portion of the subbasin. The locations of geologic cross-sections extracted from these reports are provided in **Figure 3-6**, and the individual cross-sections are provided in **Appendix B**. A summary of the available geologic cross-sections is provided below.

3.1.3.1 Davis et al. (1959)

Cross-section B-B’ runs from southwest to northeast somewhat diagonally across the center of the Madera Subbasin, and extends to a depth of about 400 feet bgs. The Corcoran Clay is present at depths ranging from about 110 to 225 feet, decreasing in thickness and depth to the northeast. Sediments are typically sand, clay, silt, and silty sand to clay, silty clay, and shale, with intermittent layers of sand and gravel.

Cross-section D-D’ runs from southwest to northeast through the center of the Madera Subbasin, and extends to a depth of about 800 feet bgs. The Corcoran Clay is indicated to be present at an approximate depth of 400 feet bgs at the western edge Madera County, with depth and thickness decreasing towards the northeast (to a depth of about 200 feet at the eastern edge of the clay layer). Sediments consist primarily of sands to sandy clay and silty clay to clay and shale. Layers of gravel are present in the upper 200 feet primarily in the center of Madera County. Mitten et al. (1970)

Cross-section B-B’ runs southwest to northeast across the northern portion of the Madera Subbasin, and extends to an elevation of -1,400 feet msl. The E-Clay (Corcoran Clay) is present in the western portion of the section and tapers off towards the center, with depth decreasing west to east from an approximate depth of 350 feet bgs (elevation of -180 feet msl) to approximately 150 feet bgs (elevation of 100 feet msl). Thin deposits of Quaternary floodplain deposits (Qb) and younger Quaternary alluvium (Qya) are present at the surface in the western and central areas, respectively, and are underlain by older Quaternary alluvium (Qoa). Qoa overlies Tertiary and Quaternary continental deposits (QTc). Pre-Tertiary basement complex (pTb) is present at the surface on the eastern edge of the section.

Cross-section C-C’ runs west to east across the southern portion of the Madera Subbasin, and extends to an elevatiion of -1,400 feet msl. The E-Clay (Corcoran Clay) is present in the western portion of the section at an elevation of about -200 feet msl, tapering out towards the center of the cross-section. The top elevation of the E-Clay depth decreases from west to east, from approximately -200 feet msl to approximately zero feet msl. A thin deposit of Qya is present at the surface in the western portion of the section and are underlain by Qoa. Qoa is underlain by Qtc in the western through central portions of the section.

Cross-section D-D’ runs northwesst to southeast through the western edge of the Madera Subbasin, and extends down to an elevation of -1,400 feet msl. The E-Clay (Corcoran Clay) is present throughout the section and increases in depth from north to south, with the top elevation ranging from approximately -150 feet msl to approximately -200 feet msl in the Madera Subbasin portion of the cross-section. Qoa is present at the surface in the Madera Subbasin and underlain by QTc in this cross-section.

Cross-section E-E’ runs northwest to southeast through the central-eastern portion of the Madera Subbasin, and extends down to an elevation of -1,400 feet msl. The E-Clay (Corcoran Clay) is not present in this section. Qoa over most of the surface is underlain by Qtc throughout the section, and TpTu (i.e., bedrock) underlies QTc in the northern portion of the section at depths of 1,000 to 1,500 feet bgs.

3.1.3.2 Page (1986)

Cross-section B-B’ runs northwest to southeast through the western edge of the Madera Subbasin, and extends down to an elevation of 9,000 feet msl. Within the Madera Subbasin, the Corcoran Clay is present throughout, at an elevation of approximately -100 feet msl. Thin deposits of Quaternary flood-plain deposits (Qb) are present at the surface, underlain by Quaternary continental rocks and deposits (QTcd). A layer of Tertiary marine rocks and deposits interfinger the QTcd layer. A layer of Pre-Tertiary and Tertiary continental and marine rocks and deposits underlies these units.

3.1.3.3 LSCE (2017)

LSCE prepared and presented a geologic cross-section in the team’s proposal for this project that trends southwest to northeast through the central portion of Madera Subbasin. Data presented on the cross-section were obtained from soil texture files for the USGS Central Valley Hydrologic Model (CVHM). The Corcoran Clay is present over one-third of the cross-section line, beginning at a depth of about 350 feet (Elevation -190 feet msl) on the western end and ending at a depth of about 220 feet (10 feet msl) at its easternmost extent. Sediments above the Corcoran Clay are relatively coarse-grained, and sediments below the Corcoran Clay are a mix of fine and coarse-grained materials from the base of the Corcoran Clay to a depth of about 500 feet below the base of the Corcoran Clay (approximate elevation of -700 to -500 feet msl). In the eastern portion of the cross-section where the Corcoran Clay is not present, the semi-confined aquifer consists of a mix of fine- and coarse-grained sediments.

3.1.3.4 KDSA (2001)

Cross-section A-A’ runs southwest to northeast across the southeastern portion of the Madera Subbasin (generally parallel to the San Joaquin River), and extends to a depth of about 1,000 feet bgs (elevation of -700 feet msl). Primarily coarse-grain deposits are present at the surface, with the exception of the northeast edge of the section. Underlying the surface deposits are primarily fine-grained deposits, with thin, discontinuous layers of coarse-grained deposits. The Corcoran Clay is not present within this section.

Cross-section B-B’ runs northwest to southeast across the southeastern portion of the Madera Subbasin (perpendicular to the San Joaquin River), and extends to a depth of about 900 feet bgs (elevation of -600 feet msl). Primarily coarse-grained deposits exist in the upper 150 feet, underlain by discontinuous layers coarse-grained deposits separated by more continuous fine-grained layers. The Corcoran Clay is not present in this section.

3.1.3.5 KDSA (2006)

Cross-section A-A’ runs north to south in the southeastern portion of the Madera Subbasin, and extends to a depth of about 800 feet (elevation of -400 to -450 feet msl). A relatively continuous sequence of coarse-grained deposits are present in the upper 200 feet beneath and adjacent to the San Joaquin River. Layers of coarse-grained sediments alternate with fine-grained sediments to the north of the San Joaquin River.

Cross-section B-B’ runs southwest to northeast in the southeastern portion of the Madera Subbasin, and extends to a depth of up to 950 feet (elevation of -600 feet msl). Overall, fine-grained deposits are more abundant in this cross-section with relatively discontinuous coarse-grained layers.

3.1.3.6 Provost & Pritchard (2014)

Cross-section D-D’ depicted in this report is taken from cross section d-d’ in Davis et al. (1959), which is discussed above.

3.1.3.7 Geologic Cross-Section Summary

The geologic cross-sections provided in Mitten et al. (1970) and Page (1986) illustrate the vertical distribution of major geologic formations, but do not provide any detail on distribution of fine and coarse-grained sediments of the major aquifer units. The LSCE (2017) cross-section focuses more on the general occurrence of fine and coarse-grained sediments in discrete intervals (e.g., every 50 feet) within the two major aquifers. The KDSA (2001, 2006) cross sections provide the greatest detail regarding the specific occurrence intervals of the fine and coarse-grained sediments, albeit on a more local scale than other cross sections.

3.1.3.8 Groundwater System Conceptualization

The Madera Subbasin is underlain by the Corcoran Clay over approximately the western one-third of the subbasin area. The depth to top of Corcoran Clay varies from 100 to 150 feet at its northeastern extent to in excess of 300 feet in the southwestern portion of the subbasin (**Figure 3-7**). Where the Corcoran Clay aquitard exists, the aquifer system is subdivided into an upper unconfined aquifer above the Corcoran Clay and a lower confined aquifer below the Corcoran Clay (**Figure 3-8**). The available cross-sections provided in **Appendix B** generally indicate that approximately the upper 500 feet of the lower confined aquifer are comprised of a greater percentage of coarse-grained sediments as compared to deeper zones within the lower aquifer. Thus, it can be anticipated that most wells will obtain close to their maximum yield within approximately the upper 800 feet of sediments. The vast majority of water wells are constructed within the upper 1,000 feet because sediments generally become finer with depth and towards the center of the valley (Provost and Pritchard, 2014).

In the eastern portions of the subbasin where the Corcoran Clay does not exist, the aquifer system is generally considered to be semi-confined with discontinuous clay layers interspersed with more permeable coarse-grained units (**Figure 3-8**). For discussion purposes, in the eastern part of the subbasin, the semi-confined aquifer can be subdivided into an upper semi-confined aquifer and a lower semi-confined aquifer at a generally arbitrary depth that may range from 200 to 400 feet bgs.

3.1.4 Aquifer Parameters

Aquifer parameter data were compiled from existing reports and the data request for this study, and mapped with regard to general locations (**Figure 3-9**). A summary of the available data is provided in **Table 3-1**. The available data indicate specific capacities (pumping rate divided by drawdown) ranging from 2 to 258 gallons per minute per foot (gpm/ft) for the various wells included in **Table 3-1**. The average specific capacities for City of Madera, Madera Water District, New Stone Water District, and Root Creek Water District wells were 41, 17, 47, and 29 gpm/ft, respectively. Using the rule of 2000 to convert specific capacity data to transmissivity values (Driscoll, 1986) yield, estimated transmissivity values ranged from 34,000 to 94,000 gallons per day per foot (gpd/ft). Combined with transmissivity values obtained from Mitten et al. (1970), the overall range of transmissivity values is 18,000 to 94,000 gpd/ft. Existing available data for Madera Subbasin were limited, but it is anticipated that these data can be supplemented with specific capacity data from DWR well completion reports obtained for this study.

For Madera County as a whole, the recently completed Madera Regional Groundwater Management Plan (year) indicates the Older Alluvium generally has transmissivity values ranging from about 20,000 to 250,000 gpd/ft. Well test data indicate that wells tapping a significant thickness of coarse-grained materials in the upper 500 feet tend to have the highest specific capacities. The underlying Continental Deposits are reported to have transmissivities ranging from 10,000 to 30,000 gpd/ft (Provost and Pritchard, 2014).

Specific yield (Sy) values for Madera County were evaluated in previous studies for use in groundwater storage change calculations (Provost and Pritchard, 2014; Todd, 2002). These county-wide studies used Sy values ranging from 0.10 to 0.13. A study specific to Madera Subbasin (DWR, 2004) cited a specific yield value of 0.104 for use in calculating total groundwater in storage. Given that sediments generally become finer grained with depth, it is possible that the Sy value from DWR (2004) being on the lower end of the county-wide range is due to evaluation of specific yield to a deeper depth than in the other studies.

3.2 Groundwater Conditions

The groundwater conditions portion of the HCM includes discussion of groundwater levels, groundwater quality, subsidence, and surface water-groundwater interaction. The discussion of groundwater levels describes groundwater contour elevation maps, hydrographs, and groundwater level/storage change. Much of the information obtained from previous studies related to groundwater conditions is provided in **Appendices C, D, and E**.

3.2.1 Groundwater Levels

Historical groundwater level data are available from a number of wells in the Madera Subbasin. These data have been used to generate groundwater elevation contour maps, hydrographs, and groundwater level/storage change maps in previous studies. The existing data and maps are described below, along with updated groundwater hydrographs created from data obtained for this study. The discussion of groundwater contour maps focuses on Spring (as opposed to Fall) maps in order to minimize influences from pumping wells. However, Fall groundwater contour maps were compiled and are included in **Appendix C**.

3.2.1.1 Groundwater Elevation Contours

Maps from the early 1900s indicate groundwater flow from northeast to southwest prior to significant development of groundwater in the Madera Subbasin. The western portion of the subbasin was considered part of an "artesian zone" running through the center of the San Joaquin Valley (Mendenhall, 2016). Groundwater elevation contour maps developed by DWR are available for selected years between 1958 and 1989, and annual maps were published from 1989 to 2011 (**Appendix C**). Groundwater elevation data and GIS files of groundwater contours are also available from DWR for 2012 to 2016 (**Appendix C**). Although the DWR maps are developed with water level measurements that include wells with unknown construction details, DWR has categorized these groundwater contour maps as being representative of unconfined and semi-confined aquifer groundwater levels across the Madera Subbasin. The groundwater contour maps referenced in the discussion below are provided in **Appendix C**.

The Spring 1958 DWR groundwater elevation contours run generally north to south. Groundwater elevation ranges from 140 feet msl at the northwestern edge to greater than 240 feet msl towards the eastern edge of the basin. Groundwater elevations are somewhat higher along the Fresno River through the City of Madera and along the San Joaquin River, and a small depression exists towards the bottom of Cottonwood Creek. Near the City of Madera, groundwater elevations range from 190 to 220 feet msl

The Spring 1962 DWR groundwater elevations ranged from 120 feet msl in the northwestern portion of the subbasin to 400 feet msl at the eastern edge of the subbasin. Groundwater elevations are somewhat higher along the Fresno River through the City of Madera and along the San Joaquin River, and a small depression exists towards the bottom of Cottonwood Creek. Another groundwater depression area began to form in the northwest portion of the basin. Near the City of Madera, groundwater elevations range from 180 to 220 feet msl.

Spring 1969 DWR groundwater elevations ranged from 110 feet msl in the northwestern portion of the subbasin to 400 feet msl at the eastern edge of the subbasin. Groundwater elevations are somewhat higher along the San Joaquin River. The groundwater depression in the northwest portion of the basin had started to expand. Near the City of Madera, groundwater elevations ranged from 170 to 220 feet msl.

Spring 1976 DWR groundwater elevations range from 100 feet msl in the western portion of the subbasin to over 200 feet msl east of the City of Madera. Groundwater elevations are somewhat higher along the San Joaquin River. The groundwater depression in the northwest portion of the basin has expanded to cover a larger portion of the west side of the subbasin. Near the City of Madera, groundwater elevations range from 170 to somewhat greater than 200 feet msl.

The Spring 1984 DWR contour map showed groundwater elevations ranging from 90 feet msl in the western portion of the subbasin to over 220 feet msl east of the City of Madera. Groundwater elevations are somewhat higher along the Fresno River through the City of Madera and along the San Joaquin River. The groundwater depression is still present in the western portion of the basin. Near the City of Madera, groundwater elevations range from 170 to 220 feet msl.

Spring 1989 DWR groundwater elevations ranged from 100 feet msl in the western portion of the subbasin to over 200 feet msl east of the City of Madera. Groundwater elevations declined near the City of Madera, where groundwater elevations ranged from 140 to 190 feet msl.

Spring 1993 DWR groundwater elevations ranged from 70 feet msl in the western portion of the subbasin to over 180 feet msl east of the City of Madera. The western groundwater depression has deepened with elevations falling to as low as 70 feet msl. Groundwater elevations declined further near the City of Madera, where groundwater elevations ranged from 120 to 180 feet msl. In addition, a new groundwater depression had formed in the southeast portion of the subbasin. The highest groundwater elevations in the subbasin at this time are along the San Joaquin River at the southeast boundary at 200 feet msl.

Spring 1999 DWR groundwater elevations ranged from 60 feet msl in a newly formed groundwater depression along the north central boundary of the subbasin to 200 feet msl beneath the San Joaquin River along the southeast boundary of the subbasin. Groundwater elevations declined further near the City of Madera, where groundwater elevations ranged from 120 to 160 feet msl. The groundwater depression in the southeast portion of the subbasin has deepened.

Spring 2004 DWR groundwater elevations ranged from 50 feet msl in groundwater depressions to 200 feet msl beneath the San Joaquin River along the southeast boundary of the subbasin. The areas of groundwater depressions in the western and north central portions of the subbasin have continued to deepen (lows of 50 feet msl). There were insufficient data in this year to map the southeastern groundwater depression. Groundwater elevations in the City of Madera were maintained at 120 to 160 feet msl.

Spring 2009 DWR groundwater elevations ranged from 20 feet msl in groundwater depressions to 200 feet msl beneath the San Joaquin River along the southeast boundary of the subbasin. The areas of groundwater depressions in the western and north central portions of the subbasin have continued to deepen. There are insufficient data in this year to map the southeastern groundwater depression. Groundwater elevations in the City of Madera declined considerably and ranged from 20 to 150 feet msl.

Spring 2012 DWR groundwater elevations in the western groundwater depression declined to -40 feet msl. In other areas, groundwater elevations ranged from 10 to 200 feet msl. Groundwater elevations in the City of Madera ranged from 60 to 120 feet msl.

Spring 2016 DWR groundwater contours for Madera Subbasin were based on limited well data for this year, but a broad area of groundwater elevations below 0 feet msl is apparent in the northeastern and north central portion of the subbasin. Groundwater elevations in the City of Madera ranged from 10 to 90 feet msl.

The potential saturated thickness of the upper unconfined aquifer above the Corcoran Clay was evaluated by overlying DWR groundwater elevation contour maps with the map of the top elevation of the Corcoran Clay. **Figure 3-10** provides a map of the difference between DWR groundwater elevation contours and top of Corcoran Clay elevation contours for three different years – 1988, 2012, and 2016. To the extent that DWR groundwater elevation contours may be considered to be representative of the upper unconfined aquifer, this map generally shows the expansion of the unsaturated area of the upper unconfined aquifer over time from 1988 to 2016, corresponding to the long term (and steeper recent) decline in groundwater elevations. However, it should be noted that it is uncertain as to how representative DWR groundwater elevations are for the upper unconfined aquifer, and this will require further evaluation in the future.

Review of available data for groundwater contour mapping indicates it is not possible to map groundwater elevations of the upper unconfined aquifer (or upper semi-confined aquifer to the east) separate from the lower confined aquifer (or lower semi-confined aquifer to the east) because there are an insufficient number of wells with known construction details. In addition, some wells with known construction details are composite wells with screens in both aquifers. Thus, as described in the discussion of data gaps, additional work is needed to expand the water level database to allow for distinct mapping of groundwater levels for the upper and lower aquifers (which is required for the GSP).

3.2.1.2 Groundwater Hydrographs

Groundwater hydrographs with a relatively long period of record and recent data (at least through 2014) were reviewed to evaluate long-term trends (**Appendix C**). Selected hydrographs in different areas of the subbasin are displayed in **Figure 3-11**. Well 3F1 in the northeastern portion of the subbasin shows a sustained long-term decline in groundwater elevations from about 215 feet msl in the late 1950's to -25 feet msl in 2014. Well 16H1 in the middle of the subbasin shows year-to-year climatic fluctuations combined with an overall decline from about 80 feet msl to 0 feet msl from 1955 to 2014. Well 6K1 in the southern portion of the subbasin along the San Joaquin River shows very consistent and stable groundwater elevations from 1955 to 2014 with an overall net decline from about 200 feet msl to 180 feet msl.

Overall, long-term declines and very steep recent declines (between 2012 and 2016) were prevalent in the northwestern and northeastern portions of the subbasin. More stable areas of the subbasin include along the San Joaquin River in the southern portion of the subbasin and an area extending northwest and across the subbasin from the San Joaquin River in the western portion of the subbasin (**Figure 3-12**).

3.2.1.3 Groundwater Storage Change

Previous estimates of groundwater storage change for Madera County include DWR (1992), Todd (2002), and Provost & Pritchard (2014). DWR (1992) estimated groundwater storage decline from 1970 to 1990 to be 74,115 AFY. Todd (2002) calculated a groundwater storage decline of 68,338 AFY for the period from 1990 to 1998.

The most recent evaluation of groundwater level and storage change is included in the 2014 Groundwater Management Plan (Provost & Pritchard, 2014), and covers the time period from 1980 to 2011 (**Figure 3-13**). In general, groundwater levels declined between 30 and 150 feet throughout Madera County, or an average of 1 to 5 feet per year. Groundwater storage change was not quantified by subbasin. For the Madera County area included in the plan (not including areas of Root Creek Water District, Madera Water District, Aliso Water District, or Columbia Canal Company) studied in 2014 (plus the area of Merced County included in Chowchilla Water District), groundwater storage between 1980 and 2011 was estimated to have declined at an average rate of 143,000 AFY, which equates to a total decline of 4.4 million acre-feet over the 31-year period.

As described in the discussion of groundwater contour maps and hydrographs, additional declines in groundwater levels (and hence groundwater storage) have occurred since 2012. Therefore, the groundwater storage change since 2011 is expected to have declined further, although the effects of a very wet 2016-2017 winter season are not yet reflected in the data included in this report.

3.2.2 Groundwater Quality

Several studies and maps of regional groundwater quality have been prepared in recent years, and the various maps are included in **Appendix D**. Regional groundwater quality mapping for the CV-SALTS project was conducted for TDS and nitrates (LSCE and LWA, 2016). TDS mapping for the upper zone (of the upper aquifer) showed generally increasing TDS from east to west across Madera Subbasin. TDS ranged from less than 250 mg/L in the east to greater than 1,000 mg/L in the southwestern corner of the subbasin. Lower zone (of the upper aquifer) TDS mapping showed a similar pattern of increasing TDS from east to west, but with a smaller area of high TDS groundwater. Mapping of nitrate in the upper zone (of the upper aquifer) showed a small area exceeding the MCL in the northwestern part of the subbasin, while nitrate in the lower zone (of the upper aquifer) was indicated to exceed the MCL in similar but somewhat larger area in (compared to upper zone of upper aquifer) the northwest portion of the subbasin.

LSCE (2014) conducted groundwater quality mapping for the San Joaquin Valley for various constituents including TDS, nitrate, arsenic, vanadium, uranium, DBCP/fumigants, herbicides, solvents, and perchlorate. Although the maps were not necessarily aquifer specific (shallow wells were distinguished from deeper wells for this study primarily based upon well use type), they do illustrate general concentrations in wells across the subbasin. For example, TDS concentrations were low to moderate for most shallow and deep wells, with the exception of a couple deep wells, and one well with arsenic exceeding the drinking water Maximum Contaminant Level (MCL) is located in the southeast portion of the subbasin. Uranium showed a pattern of lower concentration in the east and some wells with high concentrations in the western part of the subbasin. Groundwater quality maps for other constituents listed above are provided in **Appendix D**.

Other mapping of regional groundwater quality was included in the Regional Groundwater Management Plan (Provost & Pritchard, 2014). Typically, the major considerations for municipal/domestic and agricultural use with respect to groundwater quality include salinity (specific conductance, TDS), nutrients (nitrate), and metals (arsenic, manganese). For the purposes of this groundwater quality discussion, Provost & Prichard (2014) defined shallow wells (0 to 400 feet), intermediate wells (400 to 600 feet), and deep wells (greater than 600 feet deep). This nomenclature differs slightly from the HCM defined in this TM, and is utilized only for the discussion of groundwater quality in this section of the TM. Overall groundwater quality is generally good for municipal/domestic and agricultural use. Groundwater quality maps from previous reports are provided in **Appendix D**.

Based on limited existing data, specific conductance is generally less than 900 umhos/cm over the eastern and central portions of Madera Subbasin for the shallow wells. The western portion of Madera Subbasin includes one well with specific conductance between 900 and 1,600 umhos/com and one well greater than 1,600 umhos/com. Available data for intermediate zone wells show specific conductance of less than 900 umhos/cm in and around the City of Madera and in the southeast portion of the subbasin. One well in the western portion of the subbasin exceeds 1,600 umhos/cm. Available data for deep wells show specific conductance of less than 900 umhos/cm in and around the City of Madera and in the southeast portion of the subbasin. No deep wells are available in the western portion of the subbasin.

Based on limited existing data, nitrate is generally less than 45 mg/L (as NO3) throughout the subbasin with the exceptions of one shallow well in the western portion and one intermediate depth well in the southeastern portion of the subbasin. Among wells of unknown screen/depth interval, five wells in the central to western portion of the subbasin had nitrate greater than 45 mg/L. However, the five wells with high nitrate was a relatively small proportion of the total wells shown with unknown depths.

Arsenic concentrations for wells less than 400 feet deep and from 400 to 600 feet deep were below the MCL of 10 ug/L. Available data from Provost & Pritchard (2014) for deep wells indicates the majority are at less than the MCL for arsenic, but there were two wells exceeding 10 ug/L in the southeastern portion of the subbasin. The MCL for manganese was exceeded by three shallow wells, but no intermediate or deep wells had manganese in excess of the MCL of 10 ug/L.

3.2.3 Land Subsidence

Recent land subsidence has been a major concern in the northwestern portion of Madera County, primarily impacting the western portion of the adjacent Chowchilla Subbasin. Subsidence mapping using InSAR data for the 2007 to 2011 time period is shown in **Figure 3-14**. The maximum subsidence of about one foot for this time period occurred in the northwest part of the Madera Subbasin.

Other mapping of recent subsidence is included in **Appendix E**. In northwest Madera Subbasin, subsidence from 2008 to 2010 was less than one foot. Mapping by USBR between July 2012 and December 2016 showed total subsidence ranging up to two feet in northwest Madera Subbasin. Various ongoing subsidence monitoring programs are being funded and/or conducted by DWR, USGS, USBR, and NASA-JPL.

3.2.4 Groundwater - Surface Water Interaction

The primary surface water features in Madera Subbasin are the Fresno River, Cottonwood Creek, and San Joaquin River (**Figure 3-15**). Each of these streams is considered to be a natural source of recharge to the subbasin. A review of historical groundwater levels compared to stream thalweg elevations conducted for this study indicate that surface water – groundwater interactions are not a significant issue (i.e., regional groundwater levels are relatively far below creek thalweg (stream bottom) elevations) along the Fresno River and Cottonwood Creek in Madera Subbasin. However, comparison of historical groundwater levels to the stream thalweg (i.e., deepest portion of stream channel) indicate that the San Joaquin River along the southern and western subbasin boundaries was connected with groundwater from 1958 (and likely before) through 1984. Groundwater levels were generally below (and apparently disconnected from) the San Joaquin River by about 10 to 50 feet from 1989 through 2008 except at the extreme northwestern tip of the subbasin where the river may still have been connected to groundwater. The San Joaquin River appeared to be entirely disconnected from groundwater for the entire length of the southern and western subbasin boundaries between 2009 and 2016.

Available data related to wetlands and riparian vegetation are also displayed in **Figure 3-15**. Areas of marsh and wetland were identified in the western portion of Madera Subbasin. Areas of riparian vegetation were mapped along the Fresno River in the east central portion of the subbasin, and along the San Joaquin River at the southern and western boundaries of the subbasin. Wetland and riparian vegetation areas will require more detailed evaluation during GSP preparation.

DWR and The Nature Conservancy are working on mapping of groundwater dependent ecosystems (GDE), but results are not currently available. Our current understanding is that the initial public roll out of the GDE mapping may be available in June 2017. In addition, we understand that The Nature Conservancy will refer to these mapped areas as potential GDEs that will require more detailed assessment by local stakeholders within each groundwater subbasin to determine if vegetation within the mapped areas is dependent on the same groundwater system that is being tapped by local water supply wells.

3.3 HCM Summary and Data Gap Assessment

As described in the previous sections discussing HCM Geologic Conditions and Groundwater Conditions, the hydrogeologic conditions for the Madera Subbasin are relatively well understood and documented. The overall geologic setting and subbasin lateral and vertical boundaries are described in this TM. Several geologic cross-sections were obtained from previous studies, and those geologic cross-sections are compiled and described. The major aquifers and aquitards were able to be delineated from existing geologic cross-sections, and associated aquifer property data were compiled. Additionally, groundwater levels, storage change, and groundwater quality are relatively well documented and available information on subsidence, and groundwater-surface water interaction has also been compiled and described in this TM.

A summary of data gaps for the HCM geologic conditions and groundwater conditions is provided in **Table 3-2**. SGMA requirements for the HCM (geologic conditions) can mostly be met with use of figures, tables, and data from existing reports and data collected for this study. The preliminary HCM provided in this TM provides the first step in the process of compiling and synthesizing all the relevant information for meeting HCM geologic conditions requirements under SGMA. The data gaps identified relative to geologic cross-sections and aquifer parameters are primarily related to potential development of a groundwater model. Recommendations for next steps and additional work to be conducted related to the geologic conditions portion of the HCM during GSP development are provided in **Section 5**.

The data gap assessment for groundwater conditions indicates that some additional work is needed to complete the historical and current groundwater conditions portion of the HCM for the subbasin in the GSP. In particular, identified data gaps for groundwater conditions are primarily related to groundwater levels and quality, for which the data gaps are mostly due to the lack of known construction details (e.g., screen/perforation interval) for many of the wells in the water level and water quality data sets (see additional discussion of monitoring wells below). Additional potential data gaps for groundwater conditions are dependent on further evaluations of surface water – groundwater interaction and groundwater dependent ecosystems. If it is determined that surface water – groundwater interaction along the San Joaquin River needs to be addressed in the GSP, there will be a need for upper unconfined aquifer monitoring wells to evaluate/monitor surface water – groundwater interaction along the San Joaquin River on the western boundary of the subbasin. When groundwater dependent ecosystem mapping becomes available from TNC and DWR, potential GDEs identified in that mapping will require further evaluation to determine if any GDEs need to be addressed in the GSP. The preliminary HCM provided in this TM provides the first step in the process of meeting groundwater conditions requirements under SGMA. Recommendations for additional work to be conducted related to the groundwater conditions portion of the HCM during GSP development are provided in **Section 5**.

This study included review of data gaps related to the existing groundwater monitoring network and what is likely to be required of the monitoring network under SGMA. There are many wells with good records of historical and current water level and/or water quality data, but many existing monitored wells have unknown construction details. Monitoring wells with known screen intervals are necessary to develop a better understanding of groundwater elevations (and quality) in the different aquifers. Therefore, a primary data gap is the need for additional wells with known construction details to include in the GSP groundwater monitoring network. This data gap can be filled by a combination of the following tasks: 1) identify selected wells with good water level datasets but with unknown construction details and try to match them with DWR well completion reports showing screen intervals, 2) identify selected wells with no history of water levels but known construction details (or possibly obtain well videos from well owners to determine construction details) to add to the network for future monitoring, and 3) identify sites for drilling of new monitoring wells for future monitoring. Recommendations for additional work to be conducted to fill data gaps in the monitoring well network are provided in **Section 5**. As discussed above, existing wells may provide information that can be used to fill a portion of the monitoring well data gaps, and maps illustrating the spatial availability of DWR wells logs in the subbasin that may be used for this purpose are presented in **Appendix F**. Additional discussion of the importance and rationale for maximizing use of existing well water level data (via matching of DWR WCRs to existing wells with unknown construction details) is provided in **Section 5.1**.

Table 3-1
Summary of Existing Well/Aquifer Test Data

Entity	Well ID	Total Well Depth (ft)	Perforation Interval (ft, bgs)	Date	Duration (hr)	Static Water Level (ft)	Pumping Water Level (ft)	Pumping Rate (gpm)	Drawdown (ft)	Specific Capacity (gpm/ft)	Efficiency	Transmissivity (gpd/ft)	Step Test No.	Other
City of Madera	15									65				
	16									<15				and falling
	17									22				and rising
	18									44				
	20									90				
	21									70				and falling
	22									45				
	23									37				
	24									32				
	25									40				and falling
	26									40				
	28									15				
	29									25				Variable
	30									35				and falling
	31									43				
	32									65				and rising
	33									20				and falling
	34									12				
Madera WD	1	460		6/27/1994		238.8	281.6	692	42.8	16.2	62.8%			
	1	460		7/8/2003		318.1	357.4	749	39.27	19.1	56.5%			
	2	500	200-500	10/20/1994		248.0	300.0	1,225	52	23.6	67.2%			
	2	500	200-500	7/8/2003		309.9	363.0	982	53.13	18.5	59.4%			
	2	500	200-500	8/14/2014		377	457	499	80	6.2	58%			
	3	500	200-500	10/20/1994		239.5	245.0	1,419	5.5	258.0	58.6%			
	3	500	200-500	7/8/2003		298.4	365.4	1,192	66.99	17.8	74.4%			

Table 3-1 (continued)
Summary of Existing Well/Aquifer Test Data

Entity	Well ID	Total Well Depth (ft)	Perforation Interval (ft, bgs)	Date	Duration (hr)	Static Water Level (ft)	Pumping Water Level (ft)	Pumping Rate (gpm)	Drawdown (ft)	Specific Capacity (gpm/ft)	Efficiency	Transmissivity (gpd/ft)	Step Test No.	Other
Madera WD	4	500	200-500	10/20/1994		265.4	326.0	797	60.6	13.2	60.1%			
	4	500	200-500	7/8/2003		288.8	415.8	627	127.05	4.9	59.8%			
	4	500	200-500	8/15/2014		440	486	219	46	4.8	47%			
	5	500	200-500	10/19/1994		240.5	281.0	933	40.5	23.0	61.9%			
	6	500	200-500	10/19/1994		260.8	266.8	984	6	164.0	62.3%			
	6	500	200-500	7/8/2003		319.6	409.7	998	90.09	11.1	76.3%			
	6	500	200-500	8/15/2014		357	389	307	32	9.6	53%			
	7	500	200-500	10/20/1994		225.0	300.0	772	75	10.3	54.3%			
	7	500	200-500	7/8/2003		268.0	438.9	612	170.94	3.6	52.2%			
	7	500	200-500	8/14/2014		378	460	230	82	2.8	48%			
	8	537	200-537	9/12/2003		276.8	401.6	797	124.77	6.4	64.1%			
	8	537	200-537	8/28/2014		347	500	362	153	2.4	59%			
	9	536	200-536	10/19/1994		255.7	295.0	1,057	39.3	26.9	55.6%			
	9	536	200-536	9/12/2003		302.2	364.6	1,087	62.37	17.4	68.1%			
	9	536	200-536	8/27/2014		361	485	724	124	5.8	58%			
	10	515	200-515	8/15/2014		409	485	204	76	2.7	41%			
	Z	600	180-570	10/19/1994		263.8	300.0	1,661	36.2	45.9	65.1%			
	14	780	300-770	7/8/2003		278.0	380.0	1,006	102	9.9	80.5%			
	15	680	300-670	10/19/1994		243.3	295.0	1,176	51.7	22.7	63.6%			
	15	680	300-670	9/12/2003		306.9	360.0	886	53.13	16.7	58.6%			
	15	680	300-670	8/28/2014		410	579	403	169	2.4	52%			
	16	990	345-970	10/20/1994		299.0	350.0	862	51	16.9	60.4%			
	17	870	250-870	8/14/2014		464	496	684	32	21.4	50%			
	18	840	240-840	8/15/2014		377	387	364	10	36.4	58%			
	19	800	250-800	8/14/2014		426	664	467	238	2.0	44%			
	20	800	380-800	8/15/2014		382	453	1,012	71	14.3	64%			
	21	760	259-759	8/14/2014		418	482	805	64	12.6	62%			
	23	720	460-720	8/14/2014		438	496	741	58	12.8	53%			

Table 3-1 (continued)
Summary of Existing Well/Aquifer Test Data

Entity	Well ID	Total Well Depth (ft)	Perforation Interval (ft, bgs)	Date	Duration (hr)	Static Water Level (ft)	Pumping Water Level (ft)	Pumping Rate (gpm)	Drawdown (ft)	Specific Capacity (gpm/ft)	Efficiency	Transmissivity (gpd/ft)	Step Test No.	Other
New Stone WD	#1			9/28/1998		45.3	57.3	1023	12	85.3				
	#11			9/18/2004		128	138	677.7	10	67.77	69%			
	#13			3/28/2015	1.25	99	138	2200	39	56.41			1	Step test
	#13			3/28/2015	1.5		133	1750					2	Step test
	#13			3/28/2015	1.25		128	1200-					3	Step test
	#13			3/28/2015	1.5		126	1100					4	Step test
	#14			3/7/2011		120.5	148	1139	28	41.4	53%			Run 1
	#14			3/7/2011		120.5	143	1048	23	46.6	58%			Run 2
	#16			4/27/2000		65	83	1272.15	18	70.68				Questio
	#17			5/8/2000	0.25	71	118	1185.95	47	25.23				
	#19			6/15/2013		180	213	1337	33	40.5	64%			
	#2			1/26/2011		135	158	1300						
	#2			6/1/2011		128	148	1300						
	#20			2/16/2011		122	160	1003	38	26.4	70%			Run 1
	#20			2/16/2011		122	170	1287	48	26.8	71%			Run 2
	#21			1/30/2009		121.6	153	913	32	29	53%			
	#23			5/17/2000		73	156	1505	83	18.13				
	#24			1/3/2011		128	144	950						
	#24			6/1/2011		126	139	950						
	#25			7/18/1998		84	100	636.07	16	39.75	24.18%			
	#26			11/21/2015	1	138	175	1000	37	27.03			1	Step test
	#26			11/21/2015	1		194	1250					2	Step test
	#28			4/5/2012		168	211	1134	43	26.4	66%			
	#3			4/27/2000	0.25	54	60	1352.66	6	225.44				
	#34			9/10/2016	2.25	190	202	1300	12	108.33				
	#35			5/2/1997		124.6	188.6	1298	64	20.3	60.80%			

Table 3-1 (continued)
Summary of Existing Well/Aquifer Test Data

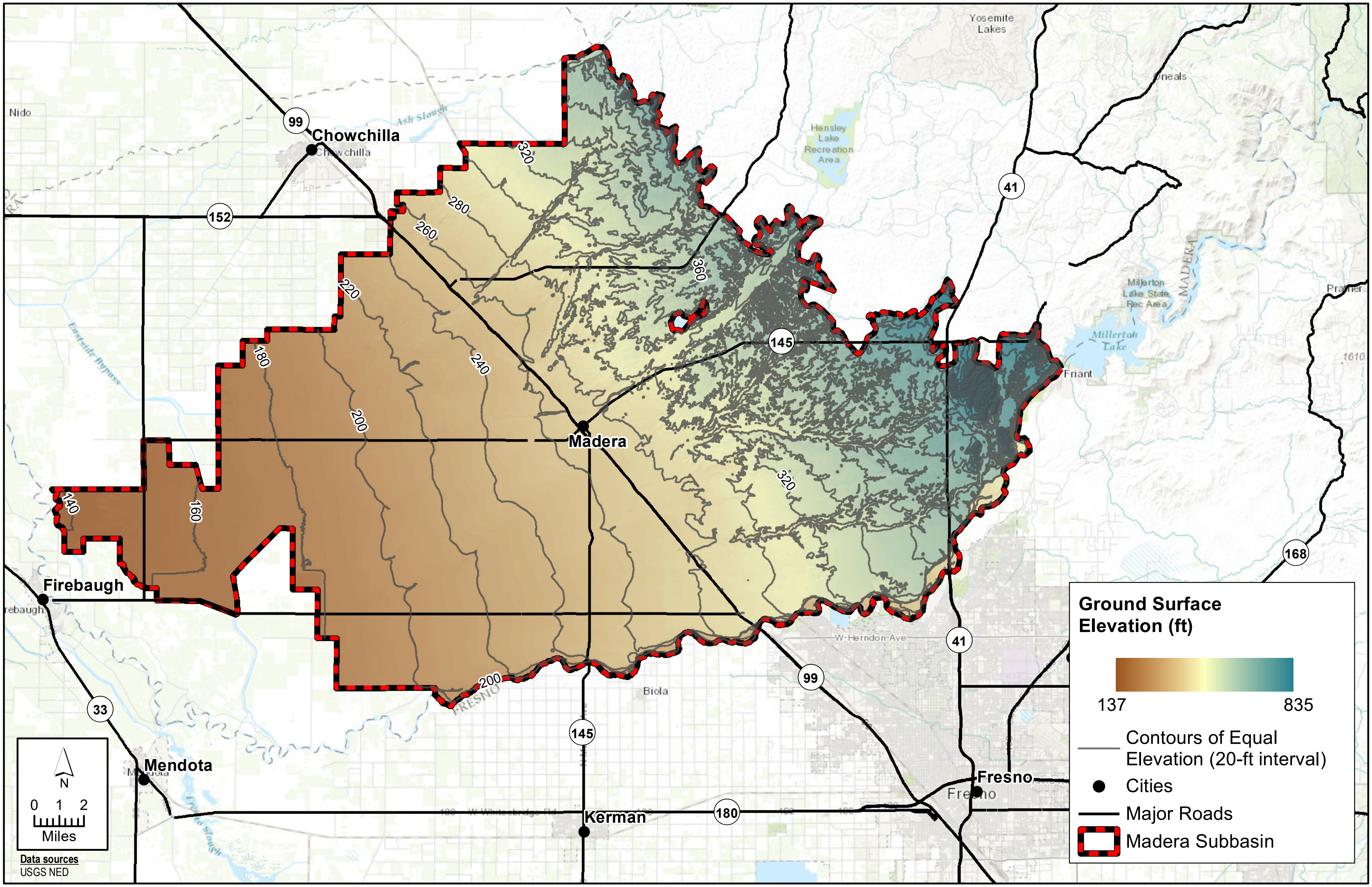
Entity	Well ID	Total Well Depth (ft)	Perforation Interval (ft, bgs)	Date	Duration (hr)	Static Water Level (ft)	Pumping Water Level (ft)	Pumping Rate (gpm)	Drawdown (ft)	Specific Capacity (gpm/ft)	Efficiency	Transmissivity (gpd/ft)	Step Test No.	Other
New Stone WD	#36			7/16/2010		212	266	868	54	13.6	66%			Question-able
	#37			4/6/2011		202.9	284	2175	81	26.9	60%			
	#38			8/17/2013		160	280	2479	56	44.3	67%			
	#39			11/26/2014	2	145	175	1000	30	33.3			1	
	#39			11/26/2014	2		193	1225		26			2	
	#39			11/26/2014	2		207	1500		24.6			3	
	#39			11/26/2014	2		212	1750		26.6			4	
	#39			11/24/2014	6.5	143	242	2600	99	26.26				Development
	#39			11/24/2014	8	145	242	2600	97	26.80				Development
	#41			1/29/2013		143	238	2261	45	23.8	58%			
	#5			9/18/2004		100	123	748.8	23	32.56	68%			
	#7			4/27/2000	0.25	86	118	1280.2	32	40.01				
	New Stone Ranch #12			1/29/2009		119.7	164	961	44	21.7	73%			
	Newstone #10													
	Newstone #9			5/9/2012		120	147	910	27	33.7	48%			
Root Creek WD	Riverstone Well 1	460	340-445; 675-690; 750-880	10/15/2014	4	297.6	325.2	1000	24.6	36.2		48,000	1	Step test
	Riverstone Well 1	460	340-445; 675-690; 750-880	10/15/2014	4		332.8	1195	35.3	33.9			2	Step test
	Riverstone Well 1	460	340-445; 675-690; 750-880	10/15/2014	4		340.1	1400	42.6	32.9			3	Step test
	Riverstone Well 1	460	340-445; 675-690; 750-880	10/16/2014	10	300.2	338.8	1310	38.6	33.9		45,000		Constant rate test
	Well No. 2	930	635-920	1/9/2015	9	292	500	2100	208	10.10				Constant rate test

Table 3-1 (continued)
Summary of Existing Well/Aquifer Test Data

Entity	Well ID	Total Well Depth (ft)	Perforation Interval (ft, bgs)	Date	Duration (hr)	Static Water Level (ft)	Pumping Water Level (ft)	Pumping Rate (gpm)	Drawdown (ft)	Specific Capacity (gpm/ft)	Efficiency	Transmissivity (gpd/ft)	Step Test No.	Other
Mitten et al., 1970 (USGS)	10S/16E-08E01	405	165-272		20.83							30,000		Hantush method (Jacob method, T=59,000)
	10S/16E-24H01	183	136-172		15.83							18,000		Hantush method
	13S/17E-01L01	345	200-250		20.83							50,000		Hantush method (Jacob method, T=99,000)
	9S/17E-30F01	580	136-336		5.83							24,000		Jacob method

Table 3-2
HCM Data Gap Assessment Summary

Data Type	Relevant GSP Regulation	Data Source	Data Use	Data Gap Assessment	Data Gap Assessment- Detailed Comments	Future Needs
Geologic and Structural Setting	§ 354.14.b1	Existing Reports	HCM	No Gaps		
Topography	§ 354.14.4d1	USGS	HCM	No Gaps		
Surface Soil Properties	§ 354.14.4d3	NRCS, SSURGO	HCM	No Gaps		
Surface Geology	§ 354.14.4d2	Existing Reports	HCM	No Gaps		
Lateral Basin Boundaries	§ 354.14.4b2	Existing Reports	HCM, Groundwater Model	No Gaps		
Vertical Basin Boundaries	§ 354.14.4b3	Existing Reports	HCM, Groundwater Model	No Gaps		
Geologic Cross Sections	§ 354.14.c	Existing Reports	HCM, Groundwater Model	More needed for groundwater model	Additional geologic cross-sections will be needed to develop model layering; data necessary for this work has been compiled	Work can be conducted during GSP model preparation
Aquifer Parameters	§ 354.14.b4A	Existing Reports; Local Agencies	HCM, Groundwater Model	More needed for groundwater model	Additional aquifer parameter data will be needed to develop model aquifer property zones; data necessary for this work has been compiled	Work can be conducted during GSP model preparation
Groundwater Levels	§ 354.16.a § 354.16.b	DWR, USGS, Local Agencies	HCM, Groundwater Model	More depth-specific monitoring wells needed	Many wells with water level data lack construction details; need to expand water level database of wells with known construction details	Continue collecting groundwater level data
Groundwater Quality	§ 354.14.b4D § 354.16.d	DWR, USGS, Local Agencies	HCM, Groundwater Model	More depth-specific monitoring wells needed	Many wells with water level data lack construction details; need to expand water quality database of wells with known construction details	Continue collecting groundwater quality data
Land Subsidence	§ 354.16.e	DWR, USGS, USBR	HCM, Groundwater Model	No Gaps	Currently dependent on monitoring being conducted by DWR/USGS/USBR	Verify continued subsidence data collection by DWR/USGS/USBR
Groundwater - Surface Water Interaction	§ 354.16.f		HCM, Groundwater Model	TBD	Requires more detailed assessment to determine if there may be a need for shallow monitoring wells adjacent to San Joaquin River	Work can be conducted during GSP preparation
Groundwater Dependent Ecosystems (GDEs)	§ 354.16.g	TNC/DWR	HCM, Groundwater Model	Data from TNC/DWR pending	Will need to review and incorporate data from TNC/DWR	Data provided by TNC/DWR will represent potential GDEs; additional analysis needed to identify actual GDEs



X:\2016\16-119 Madera Co. - Chowchilla & Madera Subbasins SGMA Support\GIS\Maps\FinalMapsForTM\Madera Subbasin\Figure 3-1 Madera Subbasin Topographic Map.mxd

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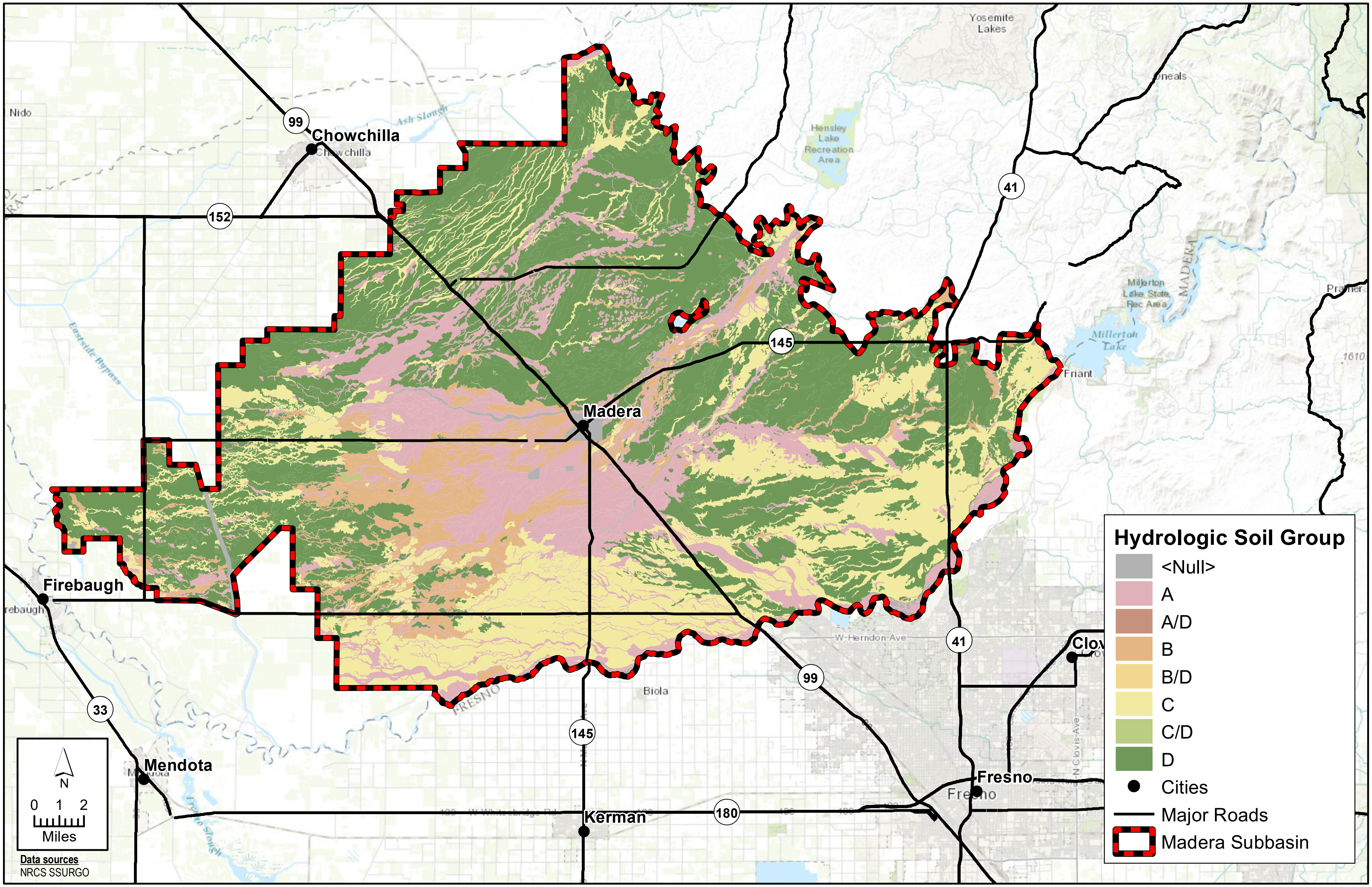
FIGURE 3-1
Topographic Map

Madera County: Madera Subbasin
SGMA Data Collection and Analysis



X:\2016\16-119 Madera Co. - Chowchilla & Madera Subbasins SGMA Support\GIS\Maps\FinalMapsForTM\Madera Subbasin\Figure 3-2 Madera Subbasin Soil Unit Map v2.mxd

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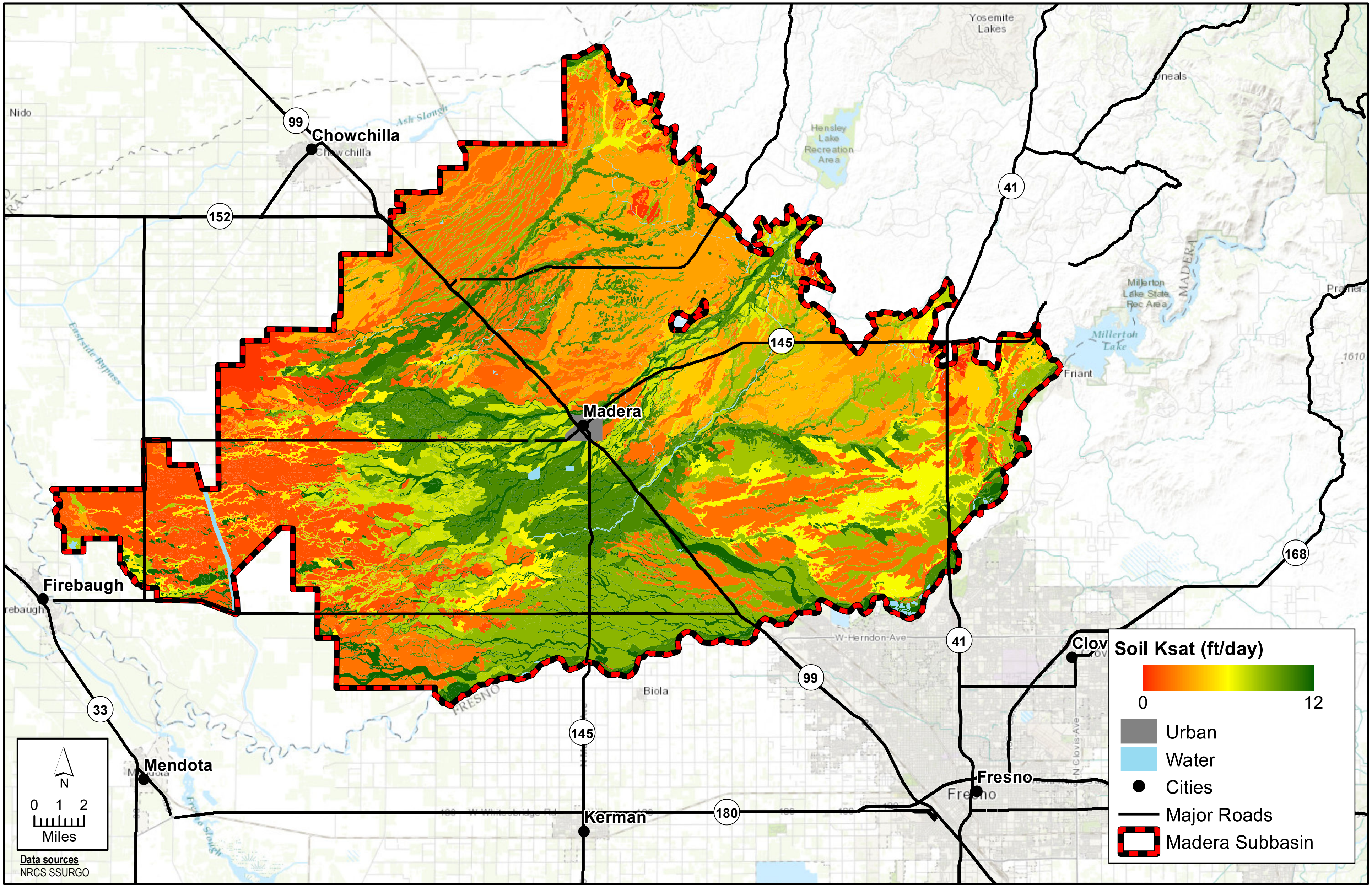
FIGURE 3-2
Soil Unit Map

Madera County: Madera Subbasin
SGMA Data Collection and Analysis



X:\2016\16-119 Madera Co. - Chowchilla & Madera Subbasins SGMA Support\GIS\Maps\FinalMapsForTM\Madera Subbasin\Figure 3-4 Madera Subbasin Soil Saturated K Map.mxd

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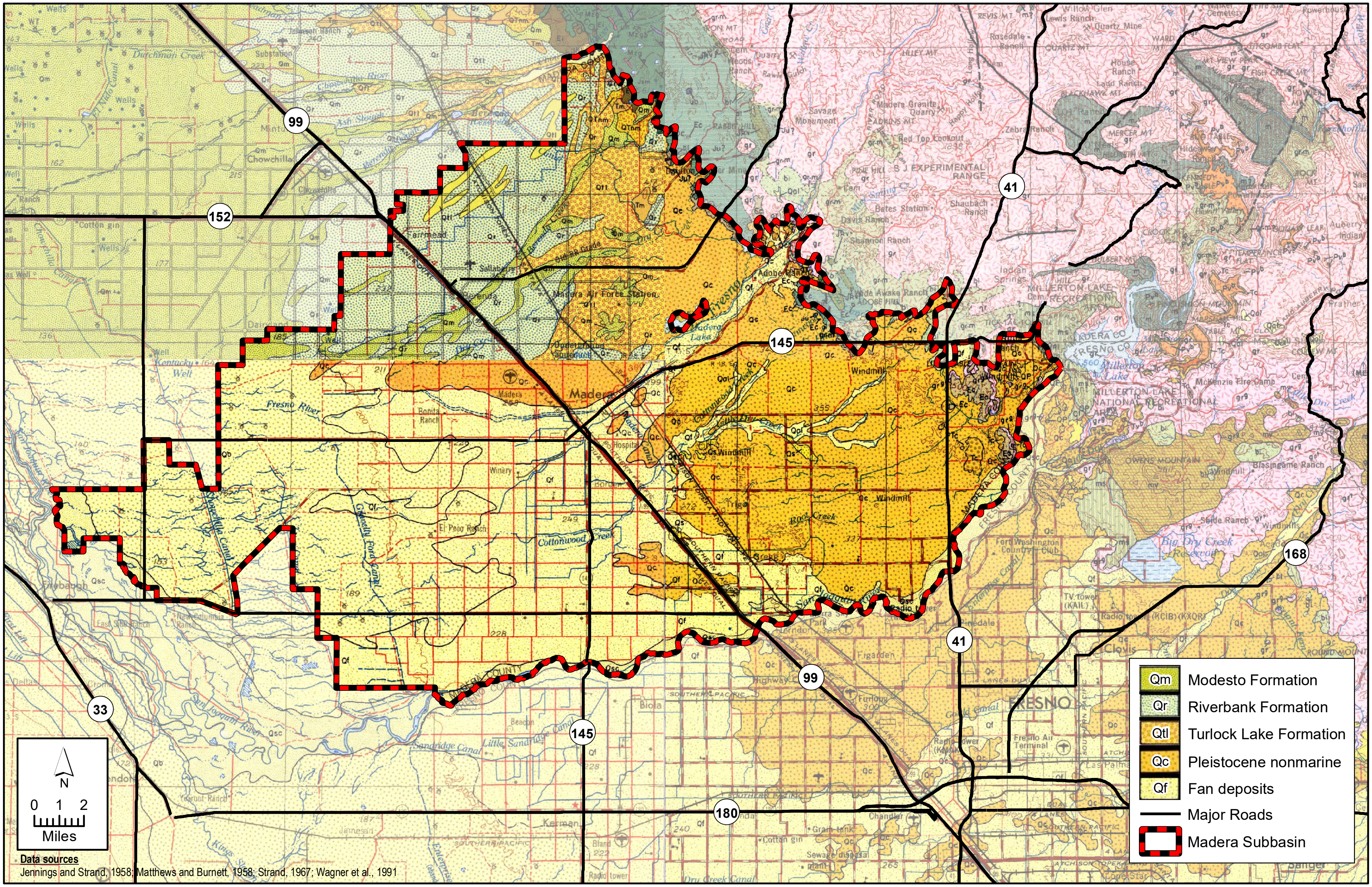
FIGURE 3-3
Soil Saturated Hydraulic Conductivity Map

Madera County: Madera Subbasin
SGMA Data Collection and Analysis



X:\2016\16-119 Madera Co. - Chowchilla & Madera Subbasins SGMA Support\GIS\Maps\FinalMapsForTM\Madera Subbasin\Figure 3-4 Madera Subbasin Surficial Geology Map.mxd

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FIGURE 3-4
Surface Geology Map

Madera County: Madera Subbasin
SGMA Data Collection and Analysis

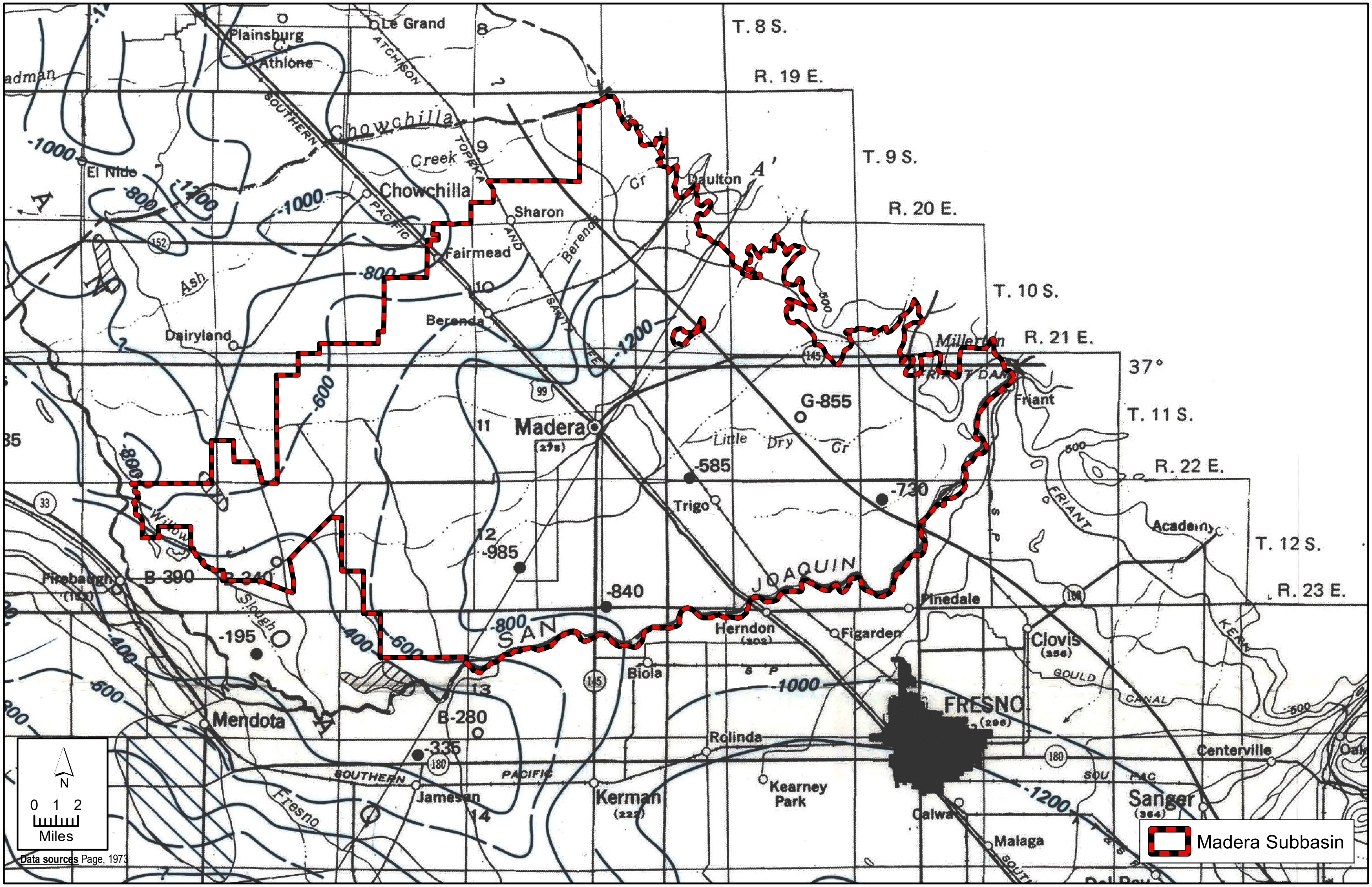

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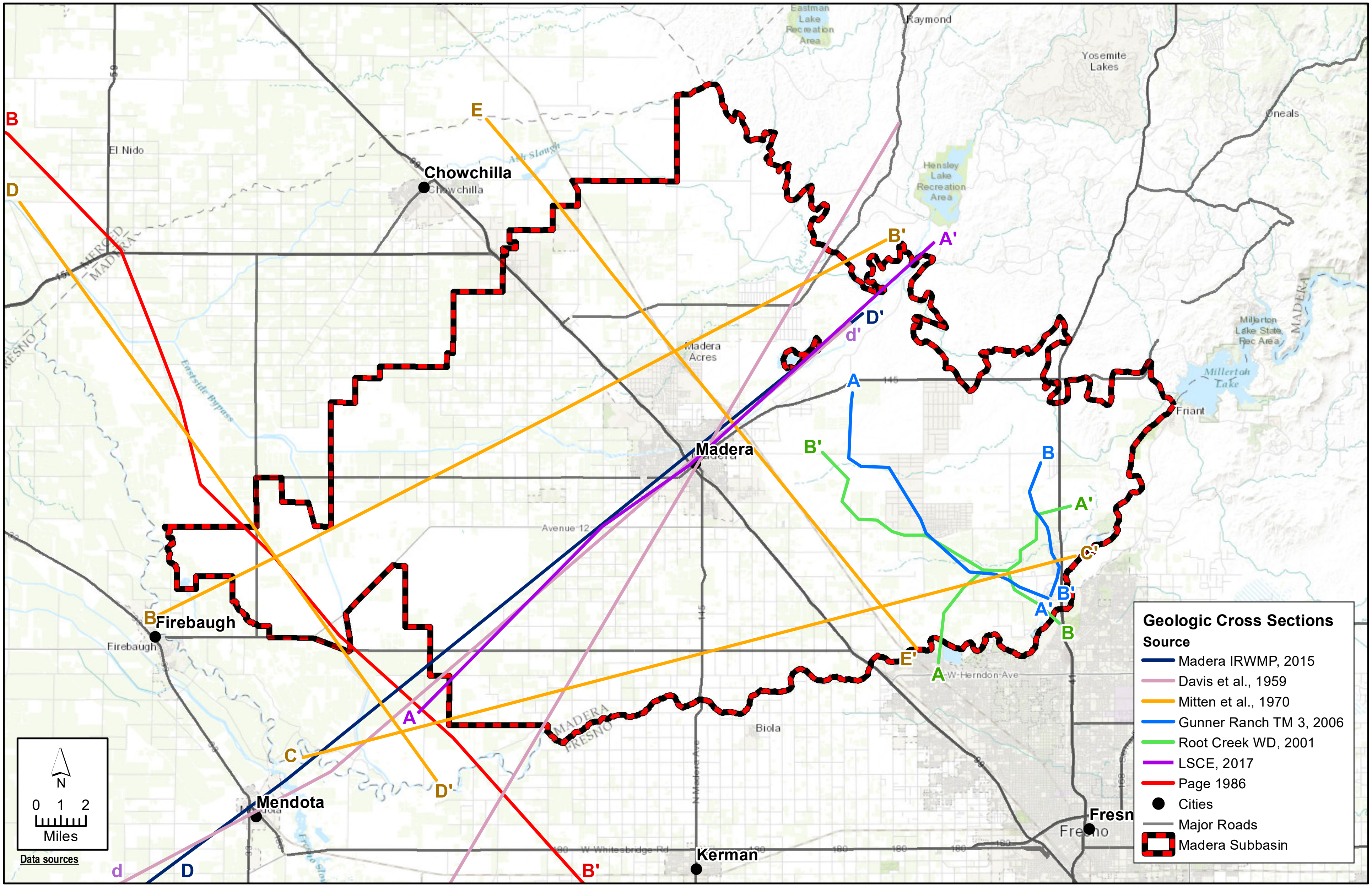
FIGURE 3-5
Base of Freshwater:
Elevation Contours from Page (1973)

Madera County: Madera Subbasin
SGMA Data Collection and Analysis



X:\2016\16-119 Madera Co. - Chowchilla & Madera Subbasins SGMA Support\GIS\Maps\FinalMapsForTM\Madera Subbasin\Figure 3-6 Madera Subbasin Geologic Cross-Sections Location Map.mxd

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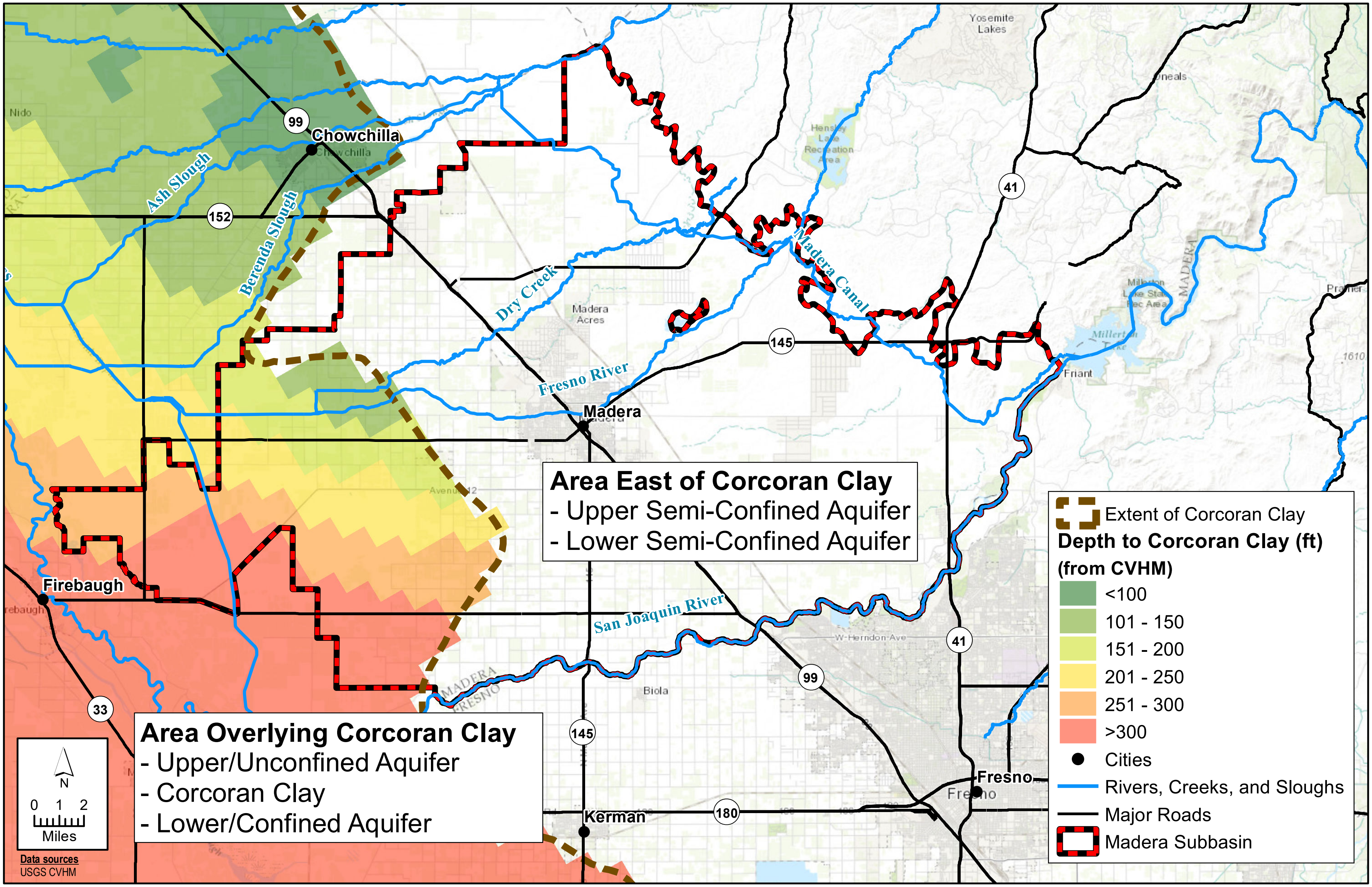
FIGURE 3-6
Geologic Cross-Sections Location Map

Madera County: Madera Subbasin
SGMA Data Collection and Analysis



X:\2016\16-119 Madera Co. - Chowchilla & Madera Subbasins SGMA Support\GIS\Maps\FinalMapsForTM\Madera Subbasin\Figure 3-7 Madera Subbasin Depth to Top of Corcoran Clay.mxd

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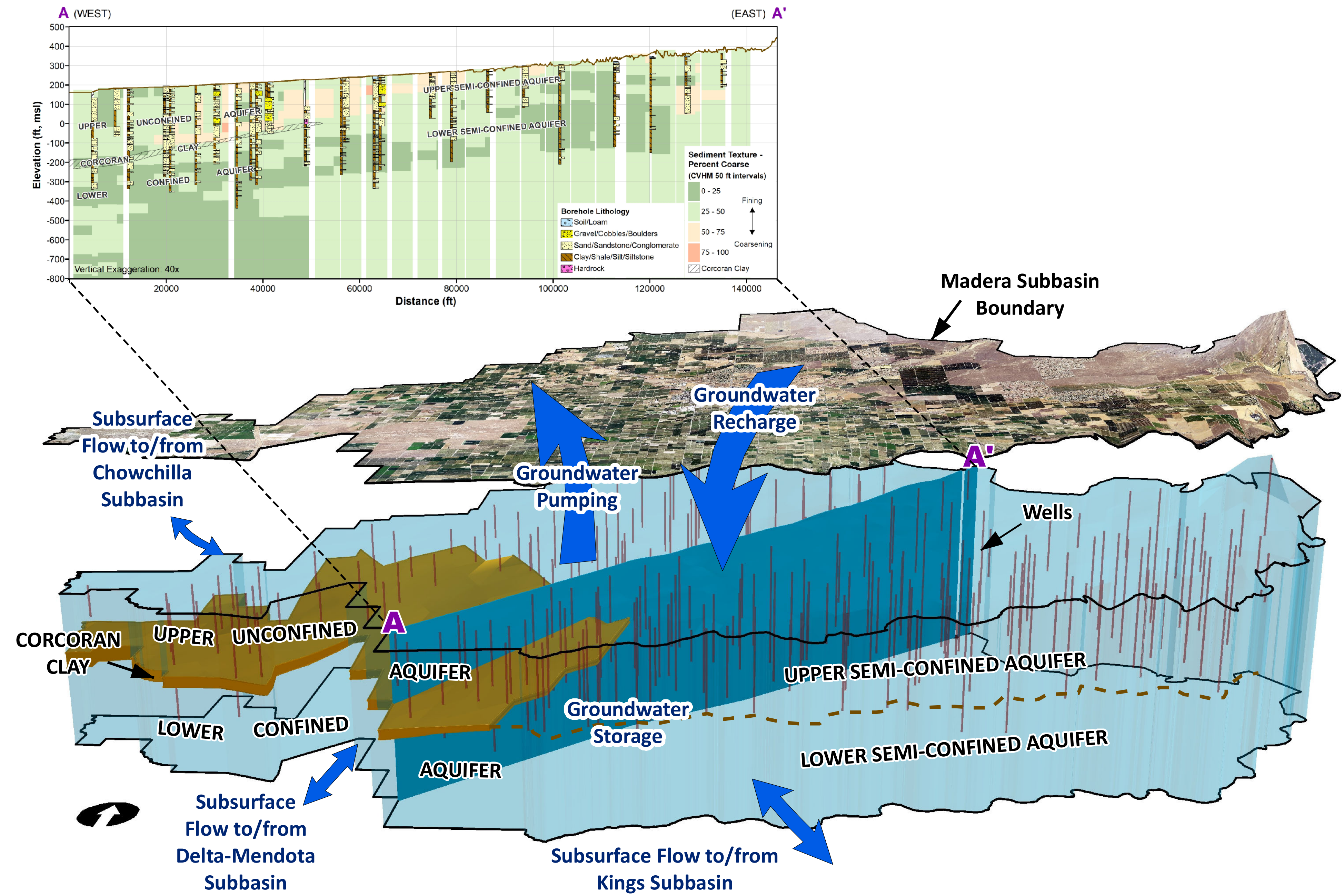
FIGURE 3-7
Depth to Top of Corcoran Clay

Madera County: Madera Subbasin
SGMA Data Collection and Analysis



X:\2016\16-119 Madera Co. - Chowchilla & Madera Subbasins SGMA Support\GIS\Maps\FinalMapsForTM\Madera Subbasin\Figure 3-8 3D Diagram of Hydrogeologic Conceptual Model.mxd

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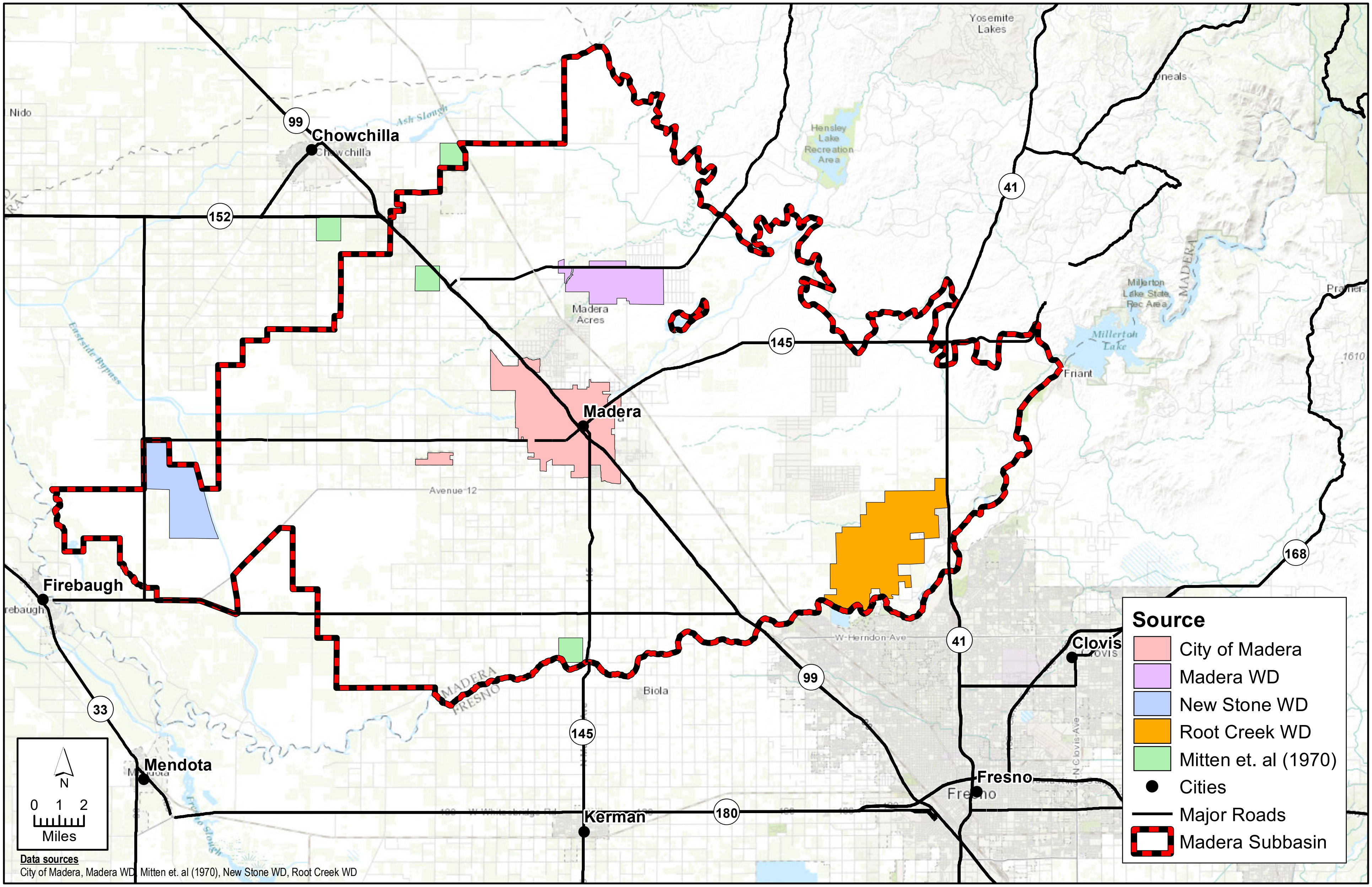
FIGURE 3-8

Madera Subbasin Conceptual Hydrogeologic System

Madera County - Madera Subbasin
SGMA Data Collection and Analysis



X:\2016\16-119 Madera Co. - Chowchilla & Madera Subbasins SGMA Support\GIS\Maps\FinalMapsForTM\Madera Subbasin\Figure 3-9 Madera Subbasin Location Map for Existing Aquifer Test Data.mxd

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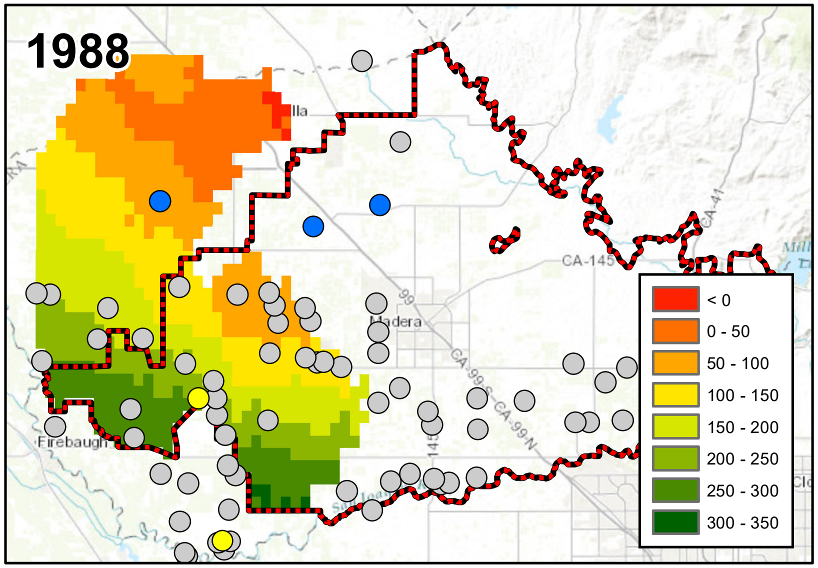
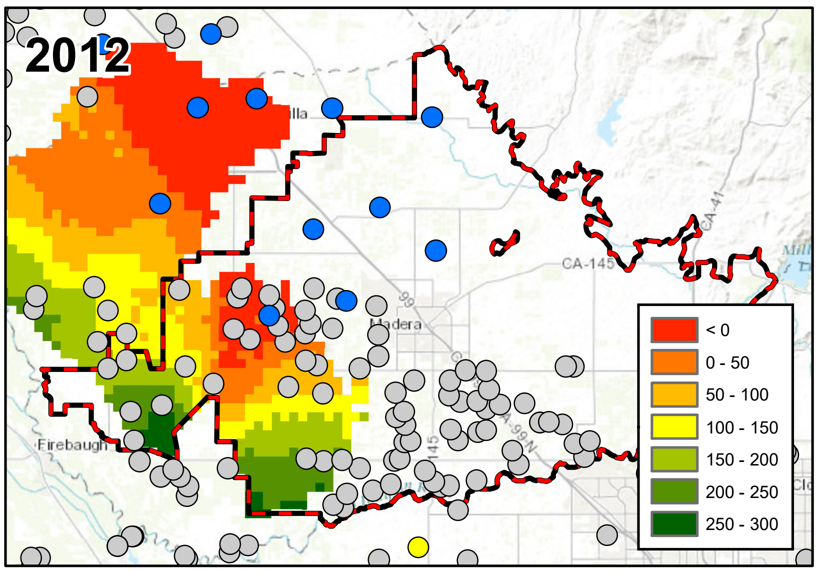
FIGURE 3-9
Location Map for Existing Aquifer Test Data

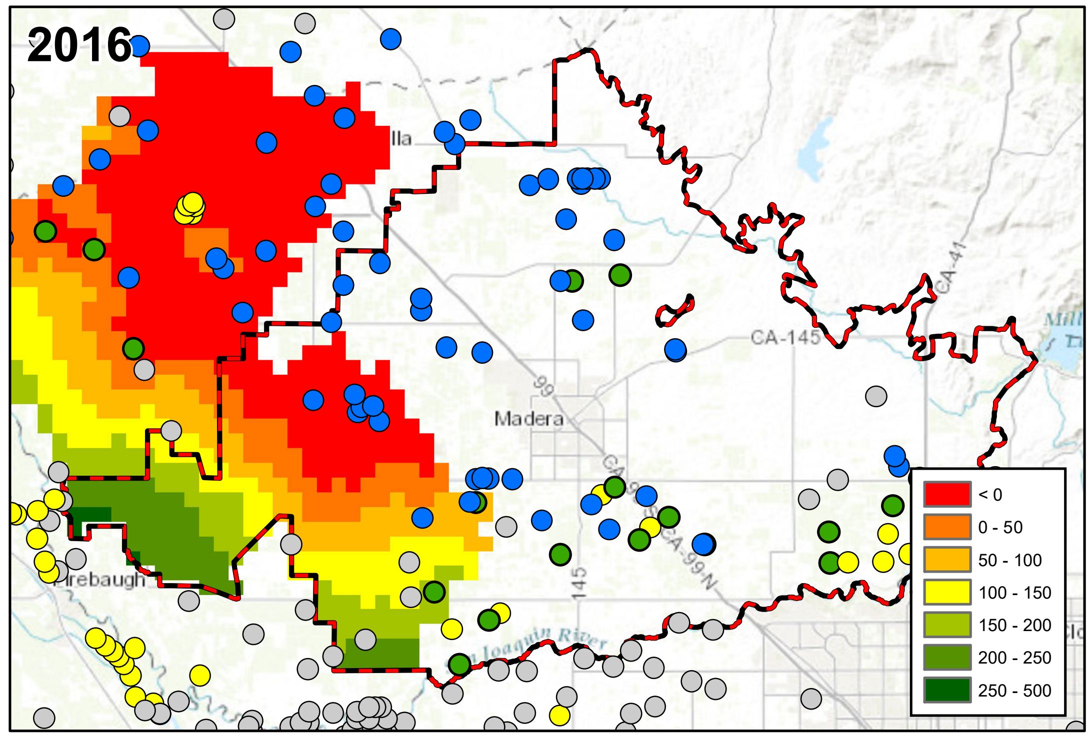
Difference Between Groundwater Elevation Contours and Top of Corcoran Clay

Wells Used for DWR Groundwater Elevation Contour Maps by Aquifer

- Upper
- Lower
- Composite
- Unknown







Note: Values represent groundwater elevations minus top of Corcoran Clay (in feet).

X:\2016\16-119 Madera Co. - Chowchilla & Madera Subbasins SGMA Support\GIS\Maps\FinalMapsForTM\Madera Subbasin\Figure 3-10 Madera Subbasin Comparison of DWR Groundwater Elevation Contours to Top of CC.mxd

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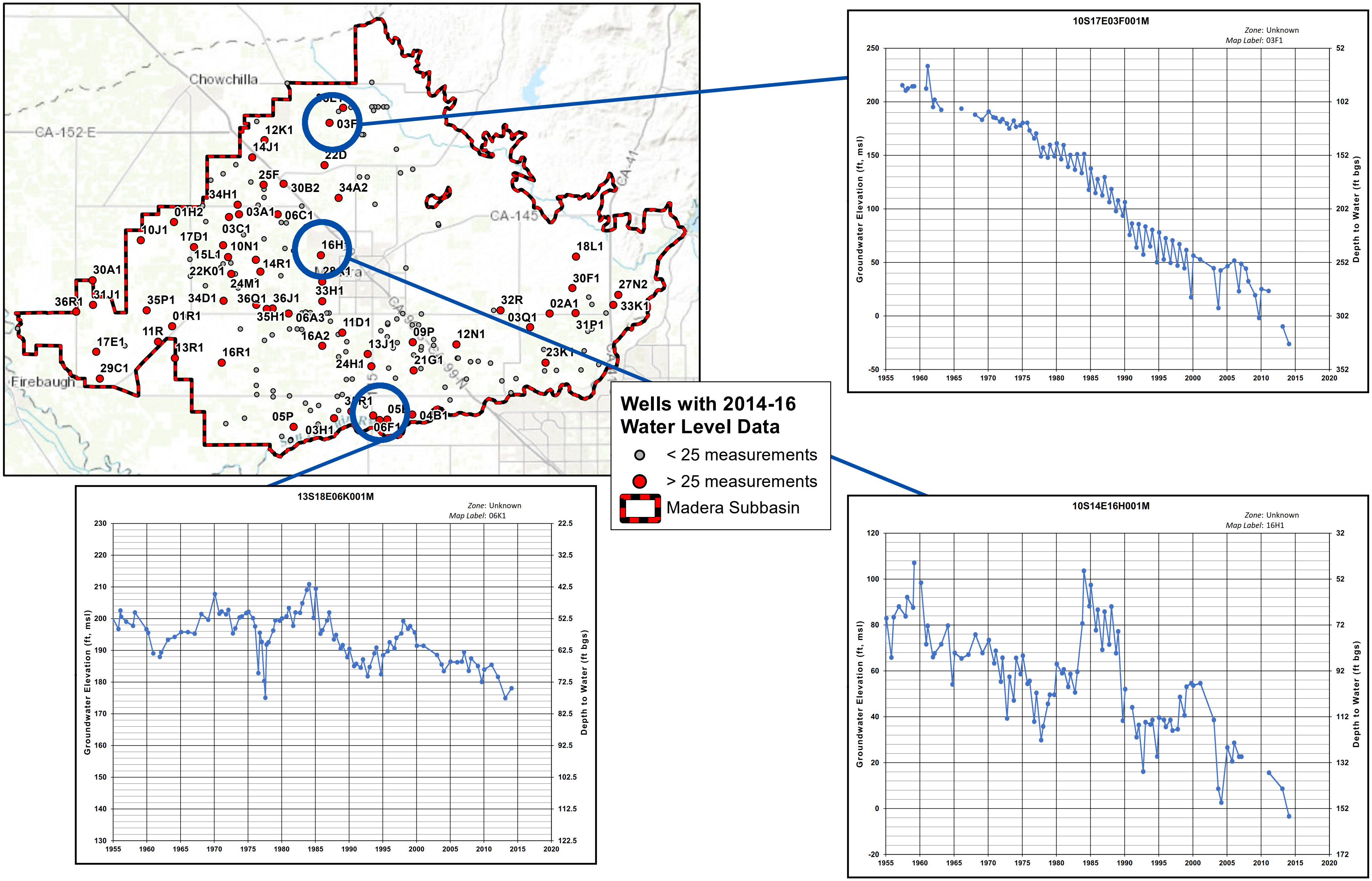
FIGURE 3-10
Comparison of DWR Groundwater Elevation Contours to Top of Corcoran Clay

Madera County - Madera Subbasin
SGMA Data Collection and Analysis



X:\2016\16-119 Madera Co. - Chowchilla & Madera Subbasins SGMA Support\GIS\Maps\FinalMapsForTM\Madera Subbasin\Figure 3-10 Madera Subbasin Selected Groundwater Hydrographs.mxd

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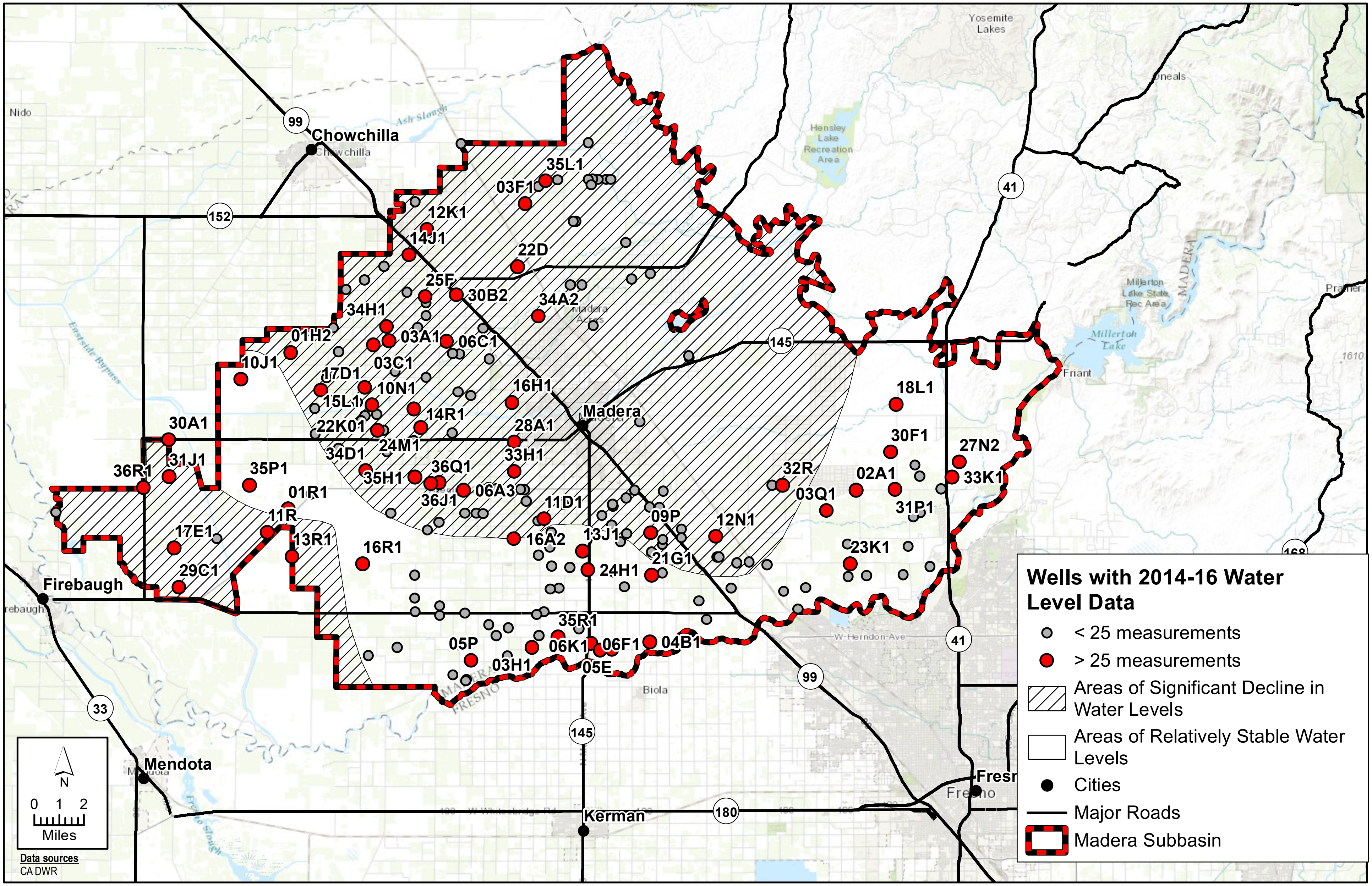
FIGURE 3-11
Selected Groundwater Hydrographs



X:\2016\16-119 Madera Co. - Chowchilla & Madera Subbasins SGMA Support\GIS\Maps\FinalMapsForTM\Madera Subbasin\Figure 3-11 Madera Subbasin General Areas of Declining and Stable Water Levels.mxd

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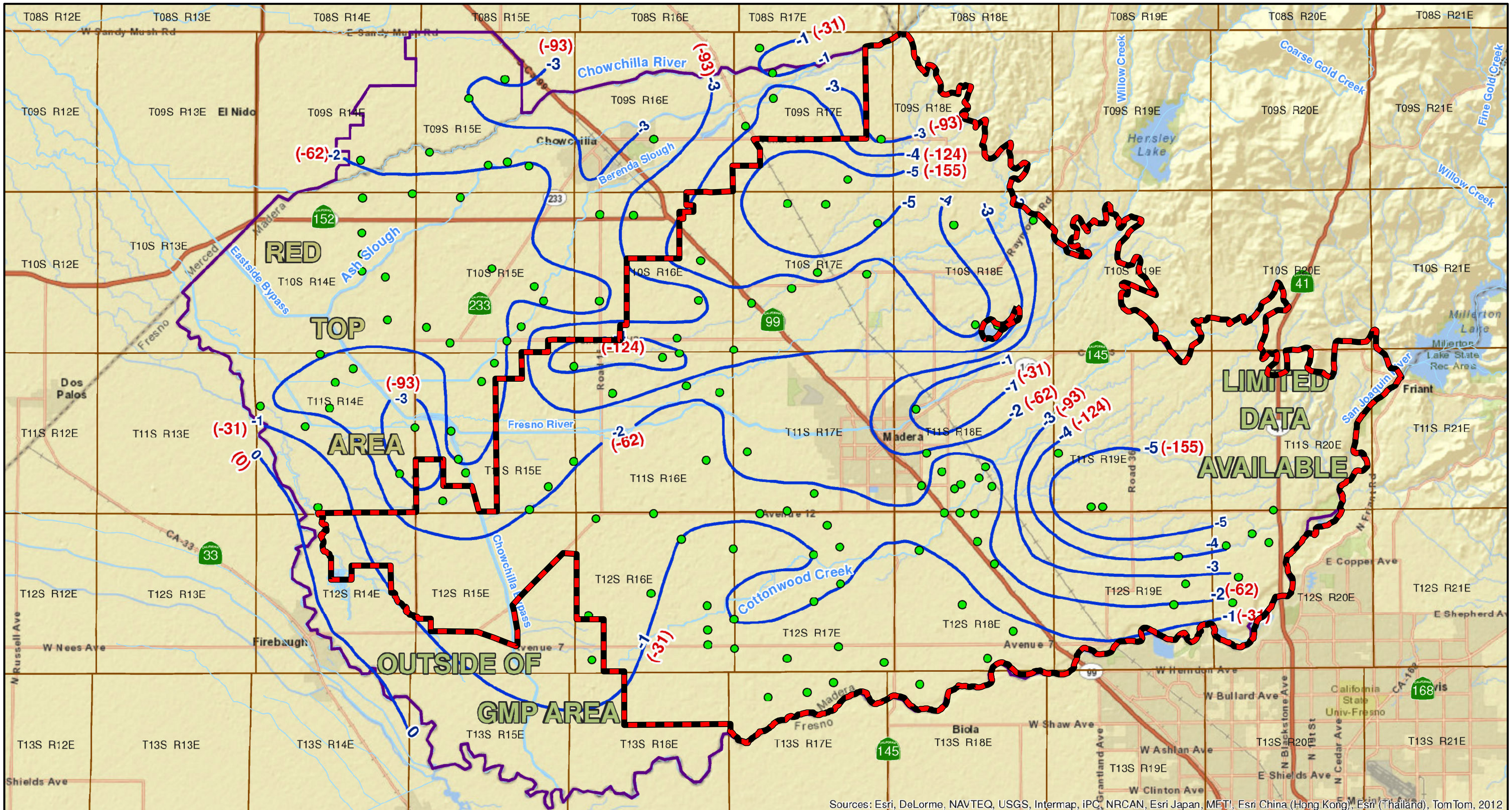
FIGURE 3-12
General Areas of Declining and Stable Water Levels

Madera County: Madera Subbasin
SGMA Data Collection and Analysis



0 2.5 5 Miles

Legend

- Groundwater Management Plan Boundary
- Wells Used for Analysis
- Madera Subbasin
- Average Annual Rates of Water Level Decline (Ft), 1980- 2011
- (-155) Total Groundwater Level Decline, 1980-2011

Source: Madera County AB 3030 Update Report by Ken Schmidt and Associates, December 2013

Madera Regional Groundwater Management Plan

Average Annual Rates and Total Groundwater Level Declines (Ft) from 1980 to 2011

X:\2016\16-119 Madera Co. - Chowchilla & Madera Subbasins SGMA Support\GIS\Maps\FinalMapsForTM\Madera Subbasin\Figure 3-12 Madera Subbasin Groundwater Level Change from 1980 to 2011.mxd

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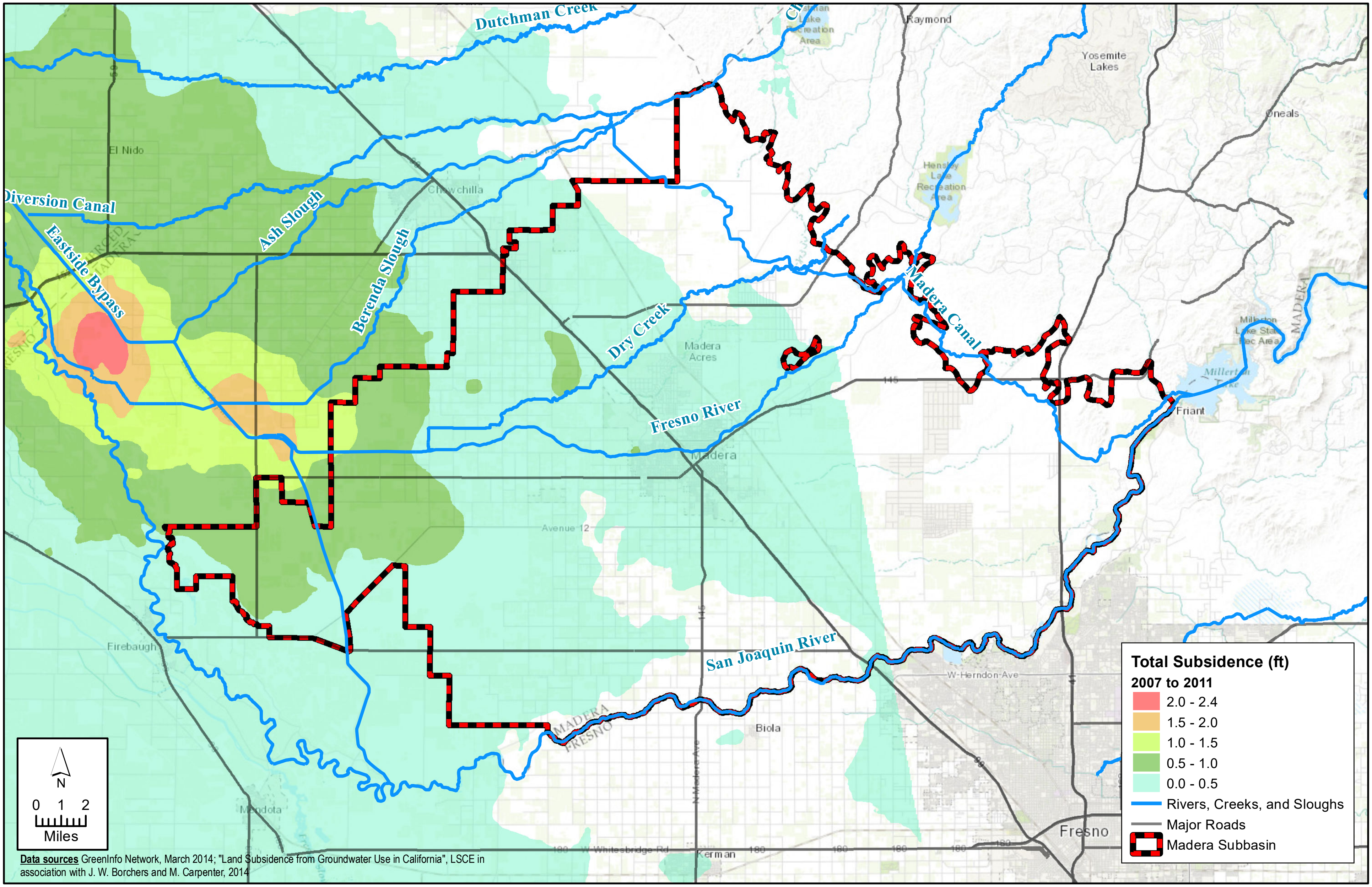
FIGURE 3-13
Groundwater Level Change from 1980 to 2011 (from 2014 Madera Regional GMP)

Madera County: Madera Subbasin
SGMA Data Collection and Analysis



X:\2016\16-119 Madera Co. - Chowchilla & Madera Subbasins SGMA Support\GIS\Maps\FinalMapsForTM\Madera Subbasin\Figure 3-14 Madera Subbasin Map of Land Subsidence.mxd

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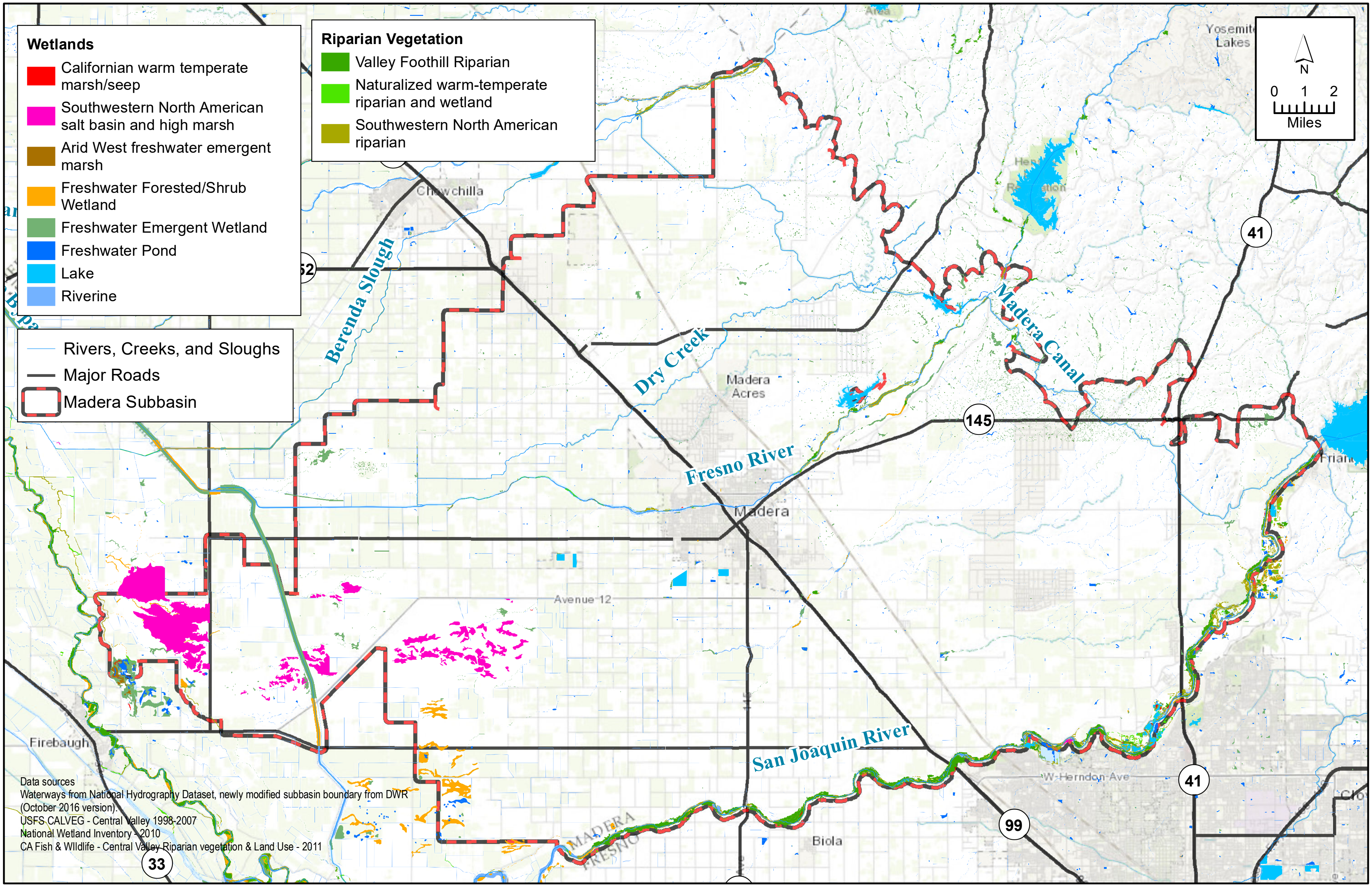
FIGURE 3-14
Map of Land Subsidence: 2007-2011

Madera County: Madera Subbasin
SGMA Data Collection and Analysis



\\lsceexser\Clerical\2016\16-119 Madera Co. - Chowchilla & Madera Subbasins SGMA Support\GIS\Maps\FinalMapsForTM\Madera Subbasin\Figure 3-14 Madera Subbasin Map of Surface Water Features.mxd

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FIGURE 3-15

Map of Surface Water Features and Riparian Vegetation

Madera County: Madera Subbasin
SGMA Data Collection and Analysis

4 CONCEPTUAL WATER BUDGET MODEL

A water budget is defined as a complete accounting of all water flowing into and out of a defined area (e.g., a subbasin) over a specified period of time. The conceptual model for the Madera Subbasin water budget was developed to comply with the GSP Regulations and to adhere to sound water budget principles and practices (BMP, 2016). Additionally, the data required to develop the conceptual model were compared to the existing local and public information obtained through the data acquisition process described previously to identify and evaluate data gaps. Relevant accounting centers (land use categories or water use sectors) and flow paths (inflows and outflows to/from accounting centers) were identified based on the GSP regulations and DWR's water budget BMP (DWR, 2016) (**Figure 4-1**). The conceptual water budget model supports the required accounting and assessment of the total annual volume of groundwater and surface water entering and leaving the basin, and any changes in storage within the subbasin. The same conceptual water budget model (structure) is used for evaluating historical and current subbasin conditions as required by the GSP regulations. The conceptual water budget structure developed here for purposes of assessing data gaps may also be suitable for representing projected future conditions, or may need to be modified to include features associated with future projects or management actions. To the extent that any modifications are made, new data needs and data gaps may be revealed. A schematic representation of all the required water use sectors occurring in the Madera Subbasin was prepared (**Figure 4-2**) to illustrate the full complexity of the subbasin water budget resulting from the GSP regulations, and to serve as a basis for identifying all of the inflows and outflows (by water source type) that need to be quantified for the subbasin water budget. This serves as a comprehensive checklist for identifying data needs.

The lateral extent of the basin is consistent with that defined in **Section 3**, as described under the HCM (§354.14) portion of the GSP regulations. The conceptual model developed conforms to the lateral boundaries of the basin as provided in the recent DWR Bulletin 118 update (DWR, 2016). The vertical basin boundary, or definable bottom of the basin, was also defined in the HCM (**Section 3**). The vertical extent of the basin can be subdivided into a surface water system and groundwater system, with separate water budgets prepared for each; together these represent the overall subbasin water budget.

The surface water system is represented by water at the land surface and within the root zone within the lateral boundaries of the basin. Surface water systems include irrigated lands, lakes, streams, springs, and man-made conveyance systems and near-surface processes such as stream underflow, infiltration from surface water systems or outflow due to evapotranspiration from the root zone. The groundwater system is represented by that portion of the basin from the bottom of the root zone to the definable bottom of the basin and within the lateral boundary of the basin. The following sections focus on the surface water system and describe the basis for identifying accounting centers, flow paths, the preliminarily identified base period and time step and the data gap assessment.

4.1 Accounting Centers

Accounting centers represent subareas (volumes) within the larger water budget domain defined by water use sectors identified in the GSP regulations. In the GSP regulations, water use sectors are defined as: "categories of water demand based on the general land uses to which the water is applied, including urban, industrial, agricultural, managed wetlands, managed recharge, and native vegetation." Thus, comprising the overall water budget for each subbasin are subbudgets representing each water use sector.

Land uses based on the most recent DWR Madera County land use survey (2011) are summarized (**Table 4-1**) to identify which of the water use sectors cited in the GSP regulations occur within the Madera

Subbasin. Agriculture is by far the dominant land use in the Madera Subbasin covering nearly 207,100 acres of the approximately 347,600 acres comprising the subbasin. Native vegetation covers approximately 95,500 acres, followed by urban areas at about 30,900 acres. The semi-agricultural land use category defined by DWR includes dairies, farmsteads, feedlots, poultry farms, and small roads and ditches etc. (**Table 4-2**). These are generally small areas scattered across the subbasin supplied primarily by groundwater. The dairies, feedlots, poultry farms, farmsteads without a residence and small roads and ditches were included in the agricultural water use sector as a semi-agricultural land use type. Farmsteads with a residence were included with the agricultural water use sector as a rural residential land use. The native water surface class includes subclasses for natural streams and lakes and water channels used for conveyance (**Table 4-3**), which provide one estimate of the surface area for the rivers and streams system and conveyance system accounting centers, respectively.

4.2 Management Areas

Subdividing the agricultural land use area into subareas having access to surface water and groundwater versus areas with access only to groundwater is often useful for characterizing groundwater recharge and management. The recent land use surveys described above do not contain sufficient information to map subareas having access to surface water versus groundwater only. However, using the area served by Madera Irrigation District and other Water Districts in the subbasin and available information on water rights from the State Water Resources Control Board (SWRCB) these subareas can be mapped. This subdivision and any additional subdivision by management area should be made in consultation with the County and Coordinating Committee during development of the GSP. More information will be available then to define management areas that will best support characterization of baseline, historical, and current conditions and support the identification and evaluation of potential projects and management actions to achieve sustainability as part of GSP implementation.

4.3 Flow Paths

Subbasin boundary inflows and outflows must be quantified according to Section §354.18(b) of the GSP regulations. These water budget components are often referred to as flow paths. The surface water boundary inflows and outflows and infiltration within the subbasin flowing into the underlying groundwater system (often referred to as deep percolation) must be tracked by water source type.

A water source type is defined in the GSP regulations as: "the source from which water is derived to meet the applied beneficial uses, including groundwater, recycled water, reused water, and surface water sources identified as the Central Valley Project (CVP), the State Water Project (SWP), the Colorado River Project (CRP), local supplies, and local imported supplies." Additionally, recycled water is defined in subdivision (n) of §13050 of the Water Code as "water that, as a result of treatment of waste, is suitable for a direct beneficial use or a controlled use that would not otherwise occur, and is therefore considered a valuable resource." Reused water generally refers to water that has been applied to and subsequently runs off of agricultural fields that is of suitable quality to be reused on the same or other agricultural fields. The Madera Subbasin water budget includes the following water source types: surface water from the CVP (the Madera Canal and Hensley Lake), local supplies (San Joaquin River, Dry Creek, Cottonwood Creek, and Berenda Creek), and local imported supplies (occasional small volumes of water transfers), and groundwater. Reused water is not included because, although there is some reuse of agricultural supplies within the subbasin, there are no reused supplies coming from outside the subbasin. Additionally, based on information received from the City of Madera, all treated wastewater from the city is disposed in percolation ponds as groundwater recharge rather than being used as a recycled water supply.

In some years, winter precipitation exceeds reservoir storage and flood flows are released from Hensley Lake on the Fresno River and Millerton Lake on the San Joaquin River. These flood flows may be available for managed recharged by entities in the subbasin and are included in the water balance as a separate source type.

A total of about 60 flow paths are represented in the Madera Subbasin water budget (**Figure 4-2**) to account for the water use sectors and water source water types required by the GSP regulations. A schematic of the general water budget structure (representing all applicable land uses) is also presented in **Appendix G**, along with more easily readable individual water budget structures for each water use sector included in the GSP regulations and occurring in the subbasin.

4.4 Time Period and Time Step

The GSP regulations require that the most recent available information be used to characterize current conditions and that at least the most recent ten years of information be used to characterize historical (or baseline) conditions. Based on review of the local and public data collected, it is been determined that at least a 27-year historical water budget can be developed for the Madera Subbasin at the subbasin boundary level.

In accordance with GSP regulations, a base period must be selected so that the analysis of sustainable yield is performed for a representative period, with minimal bias that might result from the selection of an overly wet or dry period while recognizing changes in other conditions including land use and water demands. The base period should be selected considering the following criteria: long-term mean annual water supply; inclusion of both wet and dry stress periods, antecedent dry conditions, adequate data availability; and inclusion of current hydrologic, cultural, and water management conditions in the basin. To develop a preliminary base period to be used for sustainability analyses during GSP development, historical precipitation records for the area were evaluated.

Precipitation provides an indication of the long-term mean water supply and potential for natural groundwater recharge. Monthly precipitation records acquired from the Western Regional Climate Center for a station in Madera (Station 045233) were analyzed for the period 1928 through 2015. A plot with annual precipitation, mean annual precipitation, and cumulative departure[2] from mean annual precipitation were developed for the Madera station and is presented in **Figure 4-3**.

Notable on this plot is the long-term overall average period from the late 1920s through the late-1970s (overall flat cumulative departure curve), followed by a somewhat wet period during the late-1970s and early-1980s, dry late-1980s, wet 1990s, overall average from late 1990s to 2011, and recently a dry period from 2012 through 2015. The period of 1989 to 2015 is a relatively balanced climatic period with a similar number of wet and dry years and some prolonged periods of wet, dry, and average conditions and represents a reasonable base period for conducting sustainability analyses. Nevertheless, the net negative slope of the cumulative departure curve over this period suggests that precipitation inputs to the subbasin over the 1989 to 2015 period were on the whole a little below average (relative to the entire 1928-2015 period).

Antecedent (i.e., prior or left-over year) dry conditions minimize differences in groundwater in the unsaturated zone at the beginning and at the end of a study period. Given that the measure of water in

[2] Cumulative departure curves are useful to illustrate long-term rainfall characteristics and trends during drier or wetter periods relative to the mean annual precipitation. Downward slopes of the cumulative departure curve represent drier periods relative to the mean, while upward slopes represent a wetter period relative to the mean.

the unsaturated zone is nearly impossible to determine, particularly at the scale of a groundwater subbasin, selection of a base period with relatively dry conditions antecedent to the beginning and end of the period of record is preferable in that any water stored in the unsaturated zone is minimized. In this case, the proposed base period from 1989 to 2015 begins in a dry year with one additional prior dry year and ends in a dry year with several prior dry years.

The available hydrologic and land and water use data over the period are sufficient to calculate the various parameters used to analyze groundwater conditions as related to the groundwater budget and sustainability (e.g., precipitation, streamflow, land uses, groundwater pumping, groundwater levels, and imported water sources). Lastly, the proposed base period ends near the present time, so that the study period can be used to assess groundwater conditions as they currently exist. Given these criteria, the base period of 1989 to 2015, provides an appropriate base period for assessing groundwater conditions with minimal introduced bias from land use changes or imbalances due to wet or dry conditions. Although the evaluation of the precipitation data at Madera suggest that 1989 through 2015 represents a good base period of 27 years for conducting GSP analyses, additional consideration with respect to the base period should be given during the GSP development as additional data review is conducted. In particular, consideration should be given to the patterns of CVP supplies and to local supplies from Hensley Lake, which may or may not be strongly correlated with local precipitation. Ultimately, the base period may be selected based on some combination of these and/or other factors to define a period that is normal for the subbasin from a water budget perspective.

The GSP regulations require that evaluation of water budgets under projected future conditions utilize 50 years of historical hydrology (precipitation, evapotranspiration and streamflow) information. Review of available data indicates that at least a 75-year hydrologic record can be utilized for such analyses in the Madera Subbasin.

The GSP regulations also specify that sustainability analyses be conducted on at least an annual time step. A monthly time step is recommended to support evaluation of sustainability indicators, and potential projects and management actions. These sustainability evaluations, which may include analyses involving hydrologic modeling, will require data and analyses at a time step sufficient to assess conditions and trends within an annual interval in addition to longer-term trends.

4.5 Water Budget Data Gap Assessment

A data gap is defined in the GSP Regulations as: “a lack of information that significantly affects the understanding of the basin setting or evaluation of the efficacy of Plan implementation, and could limit the ability to assess whether a basin is being sustainably managed.” As described in the previous sections, the data needed to complete the water budget have been identified through the process of reviewing the land use in the subbasin to identify water use sectors, reviewing the source water types available for use in the subbasin, and developing water budget schematics identifying all the relevant flow paths. Once all the flow paths were identified, the data types needed to support quantification of each flow path were reviewed. After compiling all the data collected from local and publicly available sources, the quantity and quality of the data were assessed to identify data gaps.

The primary data types required for the subbasin water budget include: (1) topography and boundaries; (2) surface soil properties; (3) land use; (4) water use; (5) meteorological data (primarily precipitation, air temperature and reference ET); (6) surface water inflows, including streamflows and identified water source types; (7) surface water outflows, including streamflows and identified water source types; (8) agricultural groundwater pumping; (9) applied water; (10) surface water diversions; (11) municipal and industrial pumping; and (12) rural residential pumping. Additional data types needed primarily for the

HCM and groundwater conditions are discussed in the HCM section. Local data and publicly available data for each of these twelve primary data types needed to develop the current, historical, and projected water budgets were reviewed and assessed for data gaps (**Table 4-4**). Generally, sufficient data exist for all of the necessary data types to complete the required water budget analyses. However, some degree of data quality control and data analysis will be required to develop estimates for relatively short, intermittent periods of missing data to produce complete, quality controlled, data sets. Meteorological data, surface water inflows and surface water outflows are discussed in more detail in the following paragraphs.

The locations of streamflow measurements and meteorological stations with respect to subbasin boundaries are shown in **Figure 4-4**. It is evident that the streamflow measurement sites are not always on the subbasin boundary, but they are generally close enough to boundaries to provide sufficiently representative information for the water budget. The Madera station has sufficient records to provide the necessary data for the Madera Subbasin water budget (**Table 4-5**).

The main surface water inflows into the subbasin are the Fresno River, San Joaquin River, and CVP water supplies in the Madera Canal. Local agency records for the last 43 years and 44 years are available for these two sources, respectively (**Table 4-6**). A longer record for the Fresno River has been developed for use in DWR's C2VSim model and is publicly available. A longer record for the CVP water supplies entering the subbasin is also available. The remaining surface water inflows in the table are minor, only flowing occasionally (like Cottonwood Creek), occurring along subbasin boundaries, or crossing only a short distance into the subbasin.

The main surface water outflows from the subbasin are the Fresno River, Chowchilla Bypass, Cottonwood Creek, Berenda Creek, Dry Creek, and San Joaquin River. Limited records of outflow are available in the DWR Water Data Library and California Data Exchange Center (CDEC) (**Table 4-7**). Madera Irrigation District has a recorder just outside the subbasin boundary where the Fresno River joins the Chowchilla Bypass. The outflows are often dry and additional research for flow records and analysis will be required to complete the record.

Table 4-1
DWR Land Use and Corresponding SGMA Water Use Sector and Accounting Center

SGMA Water Use Sector/Accounting Center	DWR Land Use Class	Area, acres
Agriculture	Agriculture*	207,109
Native Vegetation	Native Vegetation	95,482
Urban	Urban	30,906
Agriculture	Semi agricultural	5,639
Conveyance System/River & Stream System	Water Surface**	4,658
Industrial	Industrial	2,285
River & Stream System	Native Riparian	1,608
	Total**	347,686

*Native pasture NOT included
**The total land use area is slightly more than the Madera Subbasin because Madera Lake is included.

Table 4-2
DWR Semi-Agricultural Land Use Subclasses and Assigned Agricultural Land Use Types

CLASS1	SUBCLASS1	DWR Land Use Description	Assigned Land Use Type	Area, acres
S	1	Farmsteads (includes a farm residence)	Rural Residential	2,122
S	6	Miscellaneous semi-ag (small roads, ditches, non-planted areas of cropped fields	Semi-agricultural	1,120
S	3	Dairies	Semi-agricultural	1,071
S	4	Poultry Farms	Semi-agricultural	581
S	5	Farmsteads (without a farm residence)	Semi-agricultural	545
S	2	Livestock feed lot operations	Semi-agricultural	199
			Total:	5,639

Table 4-3
DWR Native Water Surface Subclasses and Assigned Agricultural Land Use Types

CLASS1	SUBCLASS1	DWR Land Use Description	Accounting Center	Area, acres
NW	2	Water channel (all sizes - ditches and canals - delivering water for irrigation and urban use – i.e., State Water Project, CVP, water district canals, etc.)	Conveyance System	2,284
NW	4	Freshwater lake, reservoir, or pond (all sizes, includes ponds for stock, recreation, groundwater recharge, managed wetlands, on-farm storage, etc.)	River & Stream System	1,239
NW	1	River or stream (natural fresh water channels)	River & Stream System	1,011
NW	6	Wastewater pond (dairy, sewage, cannery, winery, etc.)	Agricultural	124
			Total:	4,658

Table 4-4
Water Budget Data Gap Assessment

Data Type	Relevant GSP Regulation	Data Source	Data Use	Data Gap Assessment	Data Gap Assessment-Detailed Comments	Future Needs
Topography*	§ 354.18	USGS	Assign topography characteristics	NO GAPS		
Surface Soil Properties**	§ 354.18	NRCS, SSURGO	Assign soil characteristics	NO GAPS		
Land Use	§ 354.18	USDA, DWR, Counties, Local Agencies	Assign land use to each GW model element each year for 30-year historical run	Sufficient data with analysis	Spatial data available for 1995, 2001 (Madera County), 2007-2016 (Madera and Merced Counties), crops by area available 1980-2015 for use to develop annual spatial coverages for years without spatial data	Continue collecting spatial crop information
Water Use	§ 354.18	DWR, USGS	Estimates of water use	Sufficient data with analysis	Use standard, accepted ASCE Manual 70 methods to develop estimates of ET of applied water	
Meteorological	§ 354.18	CIMIS, NOAA, PRISM	Develop historical ET by crop and precipitation for 30-year historical run	Sufficient data with analysis	Use standard, accepted ASCE Manual 70 methods to develop ET_o and precipitation daily time series from available weather data	Continue support of Madera CIMIS station
Surface Water Inflows	§ 354.18	USGS, CDEC	Develop water budget for 30 years	Sufficient data with analysis	Use standard, accepted methods to estimate missing record	Continue support of stream gaging and water measurement
Surface Water Outflows	§ 354.18	USGS, CDEC	Develop water budget for 30 years	Sufficient data with analysis	Use standard, accepted methods to estimate missing record	Continue support of stream gaging and water measurement
Agricultural Groundwater Pumping	§ 354.18	Analysis and reports	Develop water budget for 30 years	Sufficient data with analysis	Use standard, accepted methods to estimate historical groundwater pumping	Continue to estimate using accepted method
Applied Water	§ 354.18	Local Agencies	Develop water budget for 30 years	Sufficient data with analysis	Use standard, accepted methods to estimate missing record	Continue collecting applied water data
Surface Water Diversions	§ 354.18	Local Agencies	Develop water budget for 30 years	Sufficient data with analysis	Use standard, accepted methods to estimate missing record	Continue collecting surface water diversion data
M&I Groundwater	§ 354.18	Local Agencies	Develop water budget for 30 years	Sufficient data with analysis	Use standard, accepted methods to estimate missing record	Continue collecting groundwater pumping data
Rural Residential Pumping	§ 354.18	DWR, State Dept. of Finance	Develop water budget for 30 years	Sufficient data with analysis	Use standard, accepted methods to estimate rural residential pumping	

*Also required for HCM and groundwater conditions

** Also required for HCM

Table 4-5
Climate Data Summary

Data Source*	Station Name	Station Number	Begin Date	End Date	Time step	Number of Years
CIMIS	Los Banos	56	6/28/1988	2/23/2017	Daily	29
CIMIS	Merced	148	1/4/1999	2/23/2017	Daily	18
CIMIS	Madera	145	5/13/1998	3/27/2013	Daily	15
CIMIS	Madera II**	188	4/2/2013	2/23/2017	Daily	4
NOAA	MADERA CA US	USC00045233	1/1/1928	2/20/2017	Daily	89
NOAA	CHOWCHILLA 0.3 E CA US	US1CAMA0008	1/1/2015	2/22/2017	Daily	2
PRISM	Raster (4 km resolution)		1/1/1981	12/31/2016	Daily	36
PRISM	Raster (4 km resolution)		1/1/1895	12/31/1980	Monthly	85

*CIMIS Includes reference ET, precipitation and required weather measurements to calculate reference ET.

**Madera Station was moved two miles from previous location in the spring of 2013

NOAA includes minimum, maximum and average temperature and precipitation unless noted otherwise.

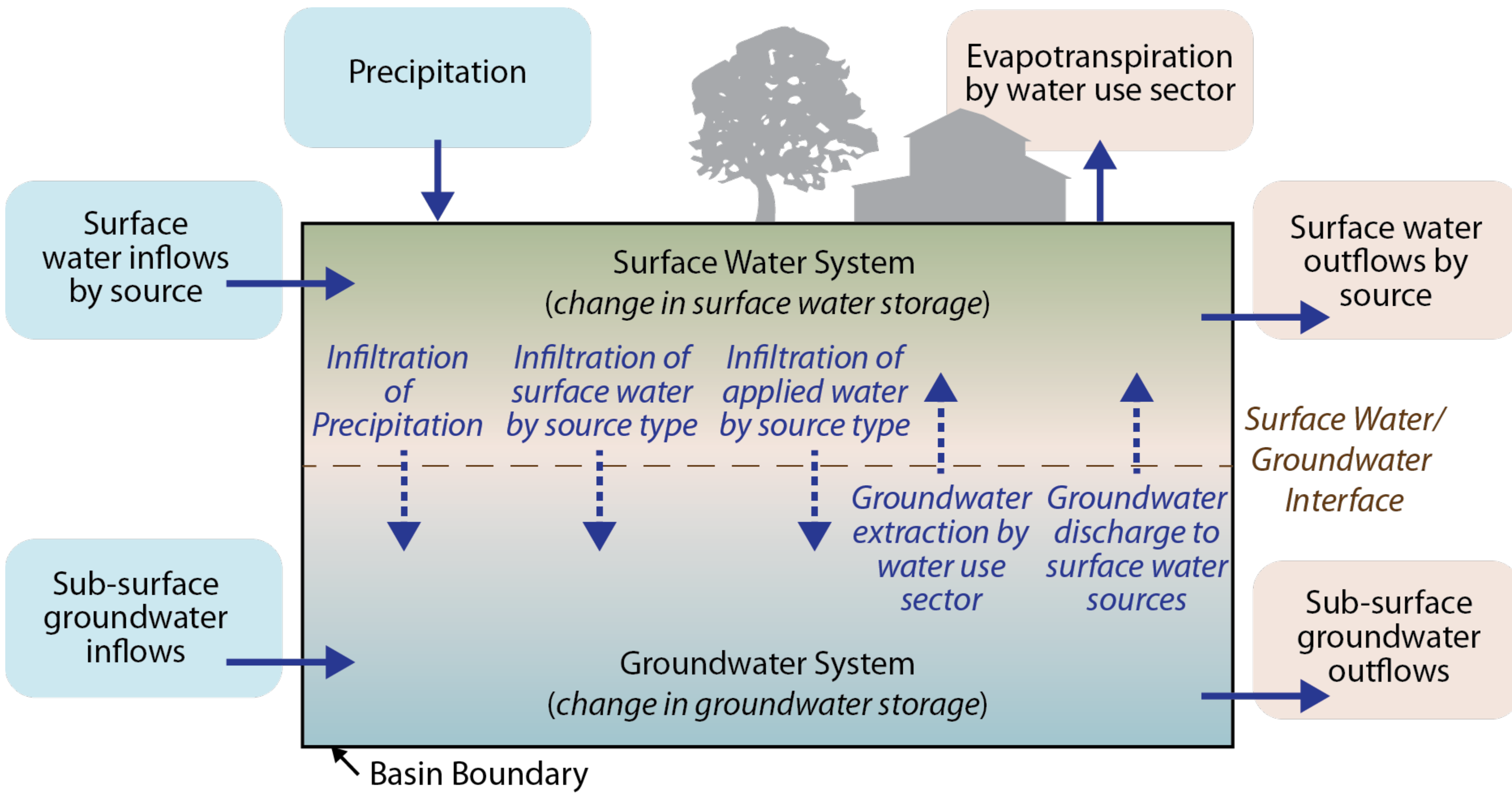
PRISM includes precipitation, minimum, maximum and average temperature, mean dewpoint temp, minimum and maximum vapor pressure deficit, and elevation. Due to use of weather stations in non-agricultural settings, an aridity assessment is required before using this data.

Table 4-6
Surface Water Inflow Summary

Flowpath Name	Station Name	Source	Begin Date	End Date	Number of Years
Madera Canal	MADERA CN A FRIANT CA	USGS	1/1/1970	9/30/2016	47
Cottonwood Creek	Recorder 14: Cottonwood Creek Head	Madera Irrigation District	1/1/1998	2/20/2017	19
Fresno River	Fresno River below Hidden Dam/ Hidden Dam, Hensley Lake	USGS / CDEC	10/1/1941	5/24/2017	76
Dry Creek	Recorder 5: Dry Creek Head Flood Water	Madera Irrigation District	2/1/1966	2/20/2017	51
Chowchilla Bypass	Chowchilla Bypass at Head Below Control Structure (CBP)	DWR Water Data Library	11/14/1982	9/29/1991	9
Chowchilla Bypass	Chowchilla Bypass at Head Below Control Structure (CBP)	CDEC	6/20/1997	6/30/2017	20
Berenda Creek	Recorder 13: Berenda Creek Head	Madera Irrigation District	1/1/1970	12/31/2004	35
San Joaquin River	San Joaquin River Below Friant	USGS	1/1/1920	3/12/2017	97

Table 4-7
Surface Water Outflow Summary

Flowpath Name	Station Name	Data Source	Begin Date	End Date	Num. Years	Notes
Chowchilla Bypass	No Measurement					
Fresno River	Recorder 4 (Fresno River Rd. 16)	Madera Irrigation District	1/1/1951	3/27/2017	66	
Madera Canal	Class 1 and Class 2 Deliveries to Chowchilla Water District	Madera Irrigation District	1973	2016	43	
Berenda Creek	Recorder 2: Berenda Creek Spill	Madera Irrigation District	1/1/1966	7/12/2017	52	
Dry Creek	Recorder 4 (Fresno River Rd. 16)	Madera Irrigation District	1951	2004	53	
San Joaquin River	San Joaquin River at Gravelly Ford (GRF)	CDEC	6/27/1997	7/12/2017	20	
Chowchilla Bypass	Chowchilla Bypass near Subbasin Boundary	Proposed New Site				Improved and more complete information on surface water outflows
Fresno River	Fresno River near Subbasin Boundary	Proposed New Site				Improved and more complete information on surface water outflows
Berenda Creek	Berenda Creek near Subbasin Boundary	Proposed New Site				Improved and more complete information on surface water outflows



(Source: DWR SGMA Water Budget BMP, 2016)

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FIGURE 4-1
Required Water Budget Components

Madera County: Madera Subbasin
SGMA Data Collection and Analysis

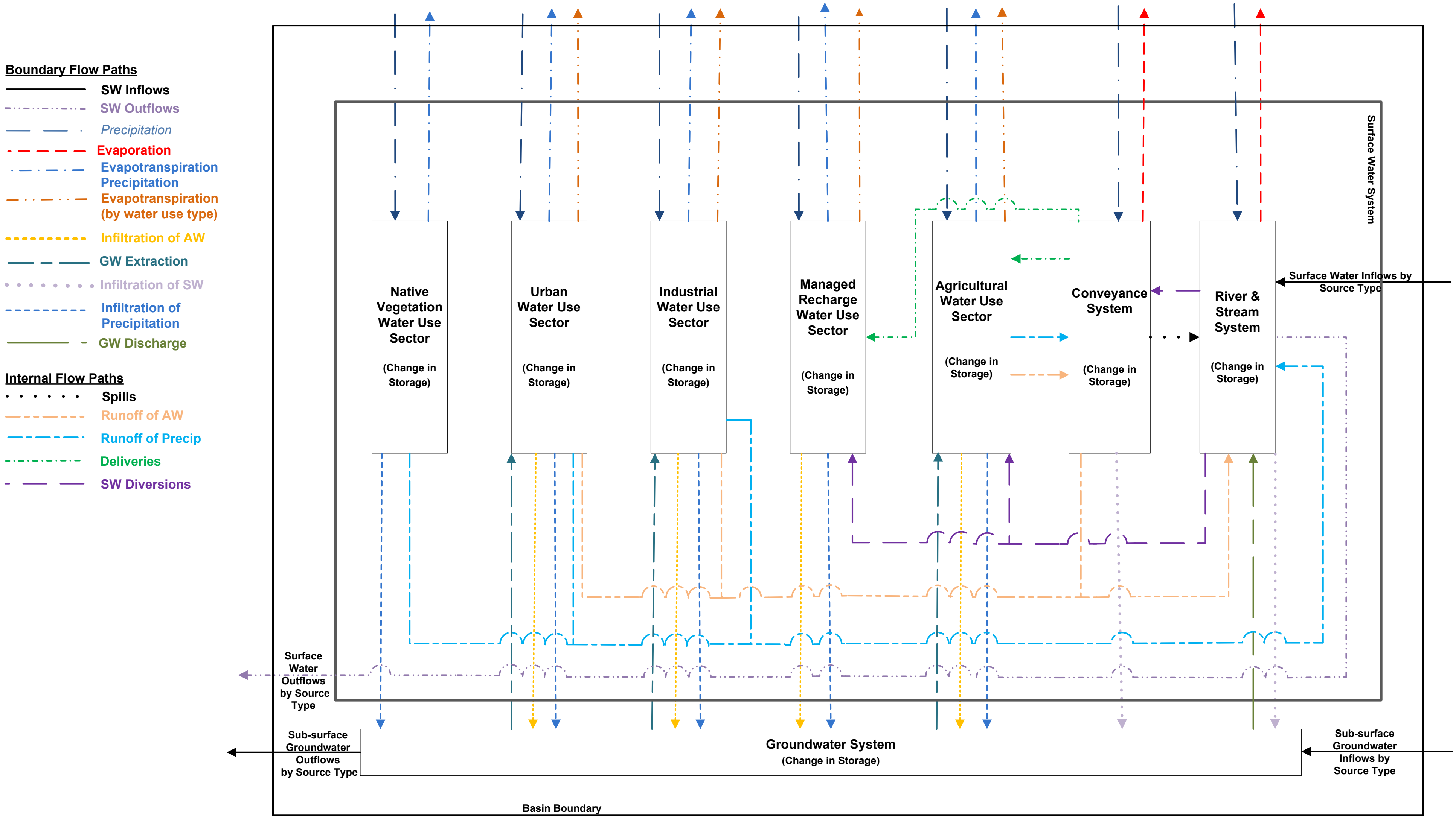

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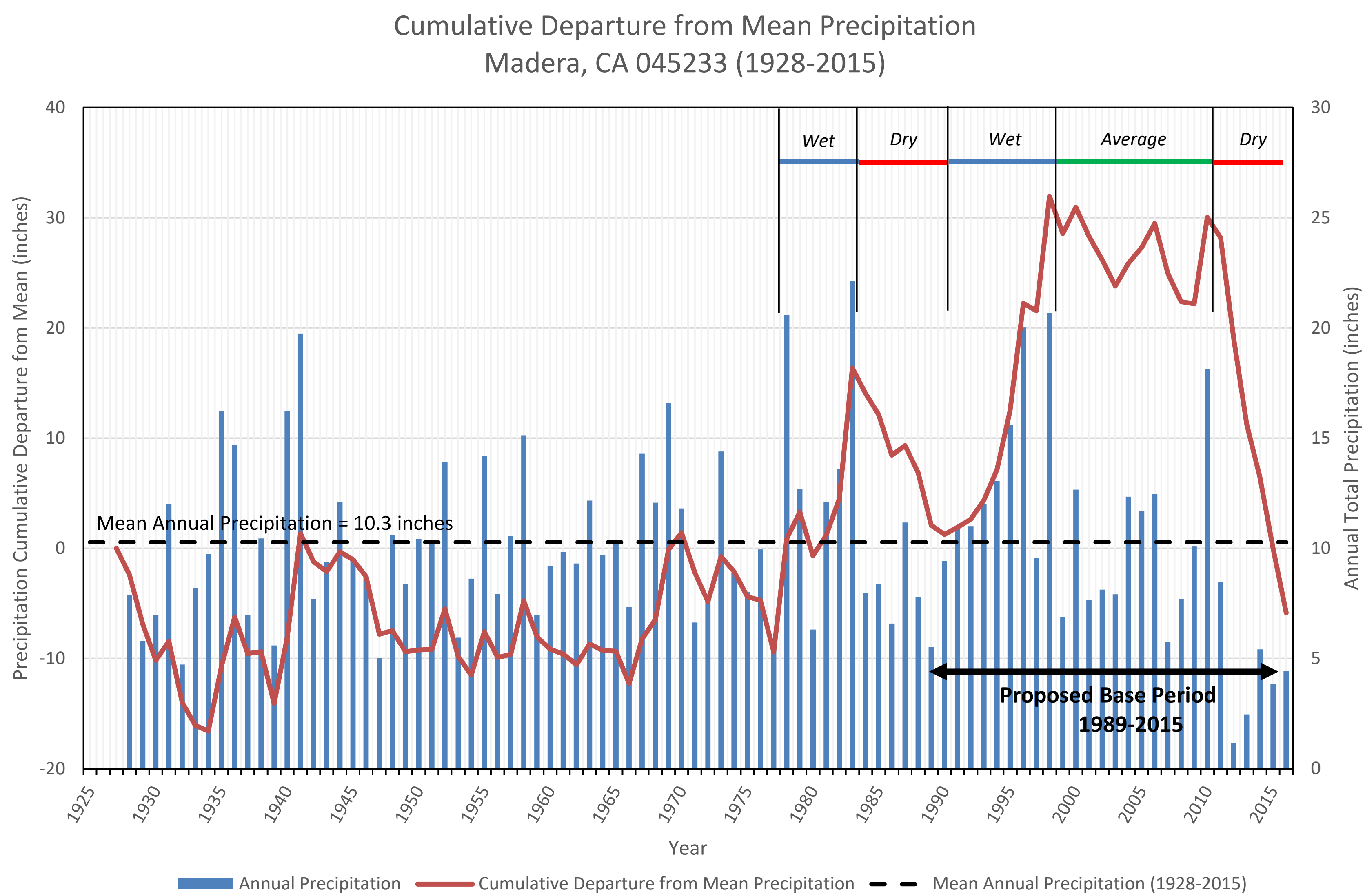
FIGURE 4-2
Complete Water Budget for the Madera Subbasin Including All Water Use Sectors Required by the GSP Regulations
Madera County: Madera Subbasin
SGMA Data Collection and Analysis



(Precipitation data from Western Regional Climate Center, 2017)

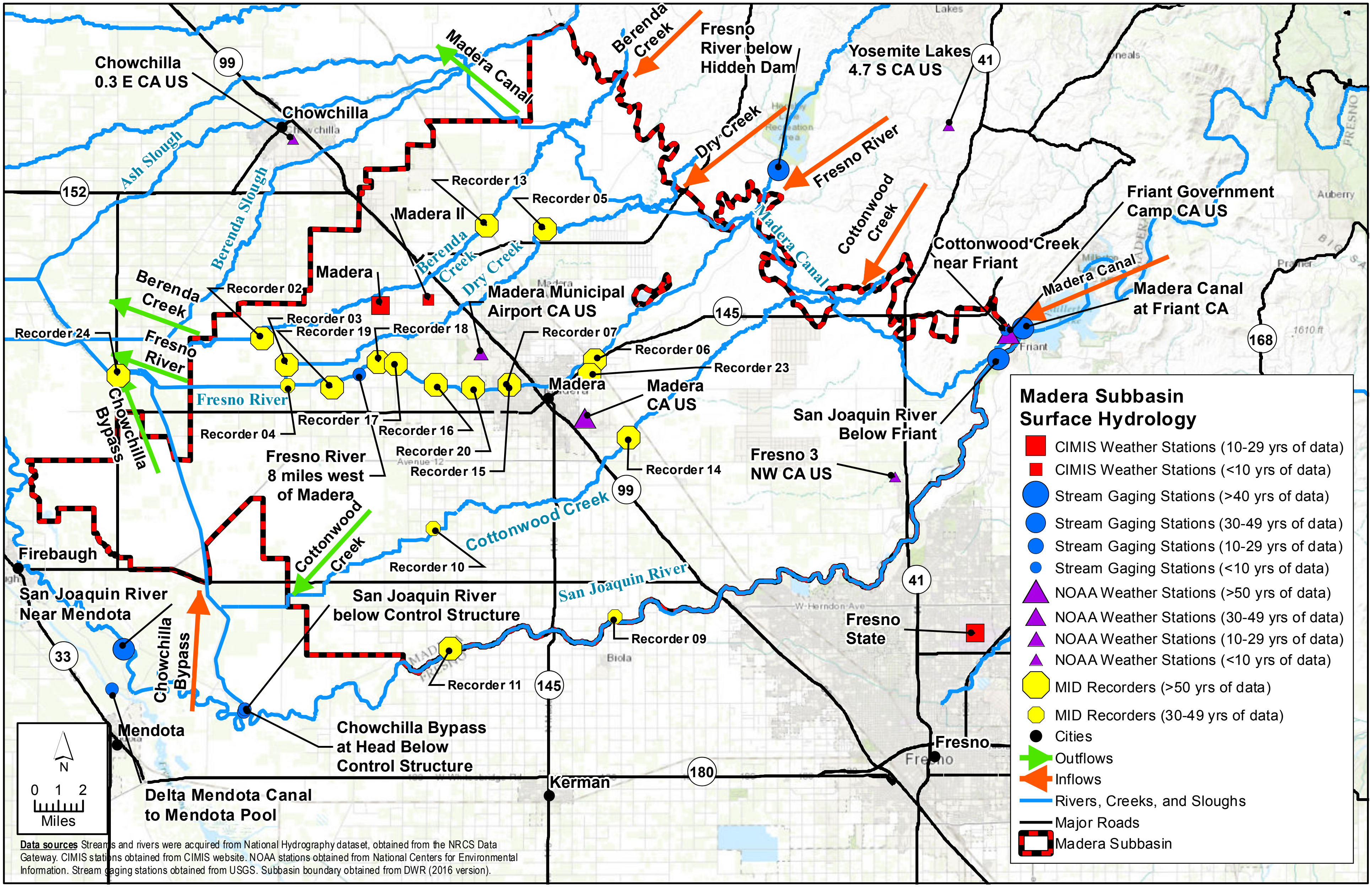


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FIGURE 4-4

Madera Subbasin Surface Hydrology Map

Madera County: Madera Subbasin
SGMA Data Collection and Analysis

5 DATA GAP SUMMARY AND RECOMMENDATIONS

5.1 Hydrogeology Data Gap Summary

Seven data types identified as needing some analysis were evaluated with respect to the importance of the data for developing the HCM (geologic and groundwater conditions) and a reconnaissance level cost estimate was assigned for filling each data gap (**Table 5-1**). These data gaps were identified based, in part, on review of GSP regulations and the GSP element guide for the HCM, groundwater conditions, and water budget (Subarticle 2) provided in **Appendix H**. Although not included in **Appendix H**, our review of GSP regulations and the GSP element guide for data gaps included review of other GSP sections on Sustainable Management Criteria (Subarticle 3) and Monitoring Networks (Subarticle 4), and the required data types for these GSP sections were similar to those required in Subarticle 2.

The actions necessary to fill the data gaps include analyses utilizing data compiled for this study, obtaining and evaluating data that will soon be available, and field work involving drilling and installation of new monitoring wells. Prioritization of data gaps was based on: (1) the overall importance of each identified gap, and (2) the timing sequence and importance of filling the data gap as soon as possible. A simple three level priority system of low, medium, and high was used to rank the data gaps.

As noted in **Table 5-1**, the highest data gap priority was assigned to groundwater levels and quality. Filling data gaps in the network for historical and future groundwater level and quality monitoring for the GSP can be accomplished with a combination of the following:

1) Identifying DWR well completion reports (with construction details) to match existing wells with historical data and unknown construction details that are currently in the monitoring network (this task can be conducted utilizing data in this TM);
2) Existing wells with no historical data and known construction details that can be added to the monitoring network (this task can be conducted utilizing data collected in this TM);
3) New dedicated monitoring wells can be installed to supplement the existing monitoring well network (additional discussion regarding recommendations for locations of potential new monitoring wells is provided below).

A more complete understanding of historical groundwater levels in the two major aquifers requires improvement in the dataset of existing wells with known well construction details. While new dedicated monitoring wells provide important benefits for the future GSP monitoring program, new monitoring wells will not help with characterization of historical groundwater levels. Historic groundwater levels specific to the upper and lower aquifers are critical in development of the hydrogeologic conceptual model and for groundwater flow model calibration. Furthermore, existing wells with historical water level data provide the baseline for comparison with future basin conditions to evaluate effects of changed management practices. In accordance with the above discussion, a combination of matching existing wells with unknown construction details to DWR WCRs and installation of new dedicated monitoring wells to fill gaps in the monitoring well network are essential for the development of the GSP and its future monitoring network. Identification of additional existing wells with known construction details may limit the number of new dedicated monitoring wells that will be needed.

A medium data gap priority was assigned to compilation and assessment of GDE data when it becomes available from The Nature Conservancy/DWR. A low data gap priority was assigned to additional work on geologic cross-sections and aquifer parameters primarily because this work can be accomplished using data compiled for this study during GSP groundwater model development. If groundwater modeling is ultimately to be conducted as part of the GSP process, it is recommended that the following tasks be completed at the beginning of the modeling effort: 1) preparation of additional geologic cross-sections utilizing data compiled for this study (e.g., well completion reports obtained from DWR and any logs provided by local entities) to help define model layering throughout the subbasin, 2) and review of well completion reports to supplement the database for aquifer testing data to help define aquifer parameter zones.

The data gap assessment included review of available groundwater level data with respect to well locations, known well construction details, period of record, and availability of recent measurements. The available historical water level data have been compiled for the work documented in this TM. As indicated in **Figure 5-1** (all wells with measurements), there are many wells throughout the subbasin with historical records of water level measurements. However, a significant portion of these wells have unknown construction details and/or lack recent measurements. A map of wells with recent water level data (i.e., after 2010) and known construction details is provided in **Figure 5-2**. Wells to be included in the GSP monitoring network will require known construction details to facilitate an understanding of groundwater elevations in the upper aquifer versus the lower aquifer. At present, a major data gap is the lack of a sufficient spatial and vertical distribution of water level monitoring wells with known construction details.

Available groundwater quality data were also reviewed with respect to well locations, known well construction details, and period of record – with particular emphasis on TDS and nitrate. The available historical water quality data have been compiled for the work documented in this TM. As indicated in **Figure 5-3** (all wells with water quality data), there are many wells throughout the subbasin with historical records of water quality measurements. However, the majority of these wells have unknown construction details. A map of wells with groundwater quality data (TDS and/or nitrate) and known construction details is provided in **Figure 5-4**. Wells to be included in the GSP monitoring network will require known construction details to facilitate an understanding of groundwater quality in the upper aquifer versus the lower aquifer. At present, a major data gap is the lack of a sufficient spatial and vertical distribution of water quality monitoring wells with known construction details.

Based on this preliminary evaluation, recommended general locations for new monitoring wells are shown in **Figure 5-5** and described in **Table 5-2**. The recommended new dedicated monitoring well locations would fill in spatial and vertical gaps in the existing distribution of wells across the subbasin. The new monitoring wells should be drilled using methods that allow for collection of good geologic information that can be used to enhance the preliminary hydrogeologic conceptual model. A prioritization is provided in **Table 5-2** with consideration of areas lacking monitoring wells, providing better definition of groundwater level depressions, providing data to assess boundary inflows/outflows, and areas of potential groundwater-surface water interaction. Based on these factors, a higher priority was assigned to wells at sites 5, 6, 9, and 13. A medium priority was assigned to other wells.

It is recommended that new dedicated monitoring wells be installed as dual or triple completions to monitor water level differences in upper versus lower aquifer zones. Furthermore, these wells should be installed in accordance with DWR’s BMP guidelines (DWR, 2016) and utilizing detailed engineering specifications that specify drilling methods, geophysical logging, geologic sample collection methods, construction materials, details of the well design, and well development methods. Examples of a typical monitoring well design for this purpose and associated construction specifications are included in **Appendix I**. The drilling contractor should be experienced with deep dual/triple nested monitoring well construction, and field work should be conducted under supervision of a professional geologist or engineer. Anticipated drilling contractor costs for a double or triple completion monitoring well typically range from $80,000 to $100,000, and geologist/engineer costs typically range from $15,000 to $25,000.

5.1.1 Hydrogeology Data Gap Recommendations

In summary, the following steps are recommended to fill existing data gaps:

- Conduct detailed review of DWR well completion reports acquired for this study and comparison of DWR well completion report locations to wells with water level data but unknown construction details to further expand the database of wells with known construction details.
- Conduct outreach with existing well owners that have wells with known construction details but are not currently part of the groundwater monitoring network. If the well owner is willing to participate and has a well that is representative of either the upper or lower aquifer (but not both), the well could be added to the GSP monitoring network.
- The remaining data gaps in the existing monitoring network (of wells with known construction details and recent measurements) could be filled with installation of new dedicated monitoring wells at locations where existing wells with known construction details are lacking.
- When statewide GDE mapping is published by The Nature Conservancy and DWR, compile a map of potential GDEs in the subbasin and conduct further analyses to determine which potential GDEs need to be addressed in the GSP.
- In the preliminary phase of groundwater model development, prepare additional geologic cross-sections as input to model layering.
- In the preliminary phase of groundwater model development, review DWR well completion reports to extract specific capacity data for incorporation in the aquifer parameter database to be used for development of aquifer parameter zones in the model.

5.2 Water Budget Data Gap Summary

This study provides preliminary water budget schematics for use during GSP development and reveals that QA/QC analysis is required for ten of the twelve water budget data types to develop complete, monthly data sets for the historical water budget. Additionally, three new stream gages to measure subbasin outflow are recommended. Prioritization of data gaps was based on: (1) the need for future monitoring, (2) the importance of each identified gap to reduce the uncertainty in the water budget, and (3) the cost of filling the data gap. A simple three level priority system of low, medium, and high was used with priority assigned based primarily on the importance of the data analysis to developing the water budget.

The data gap assessment involved reviewing the data acquired from local agencies and public sources for twelve data types required to complete the water budget and related analyses described in the GSP regulations. The highest priority data gap noted was a lack of surface water outflow stream gages on, or sufficiently close to, the subbasin boundaries. A major reason for this data gap is that these surface water outflow points are dry much of the time. It is recommended to add outflow stream gage sites on or near (depending on site conditions) the subbasin boundary for the Chowchilla Bypass, Fresno River and Cottonwood Creek. The estimated reconnaissance level (+/- 30%) cost is $30,000 per site to install all equipment and set up remote logging of data (USGS, 2017). Site visits are necessary to select locations and refine costs. Additional annual costs including establishing and maintaining a rating curve, site maintenance and logging of data are estimated to be between $15,000 and $18,000 (USGS, 2017).

Ten data types identified as needing QA/QC analysis (data types with no gaps were not evaluated) were evaluated with respect to the importance of the data for developing the water budget and a reconnaissance level cost estimate assigned for each required analysis. The required analysis consists of applying procedures to develop estimates to fill short, intermittent periods of missing data within the overall record.

Groundwater pumping data for agricultural water supply in the Madera Basin are not publicly available. Accepted practice to estimate agricultural groundwater pumping is to estimate total crop irrigation consumptive use based on information describing land use, weather (reference ET and precipitation), agronomic practices (leaching, frost protection, pre-irrigation, etc.), and on-farm irrigation water consumptive use fraction. Then, groundwater pumping is estimated as the total consumptive use, minus measured or estimated surface water deliveries. Sufficient information is available to develop a reasonably accurate estimate of groundwater pumping for purposes of water budget development using this accepted methodology.

To complete the water budget, complete monthly data sets are required for the initial 27-year base period described in **Section 4** (as it may be refined based in further analysis). Initially it is advisable to complete the water budget for the subbasin overall. The basin boundary water budget will provide useful information on the existence and magnitude of historical overdraft, and the types and scales of projects potentially needed to achieve subbasin sustainability.

For each of the ten data types requiring analysis, the data use and required analysis are briefly described in **Table 5-3**. Additionally, a reconnaissance level estimate of cost (+/- 30 percent) to complete the analysis for each data type is provided. It is recommended to assemble all available data related to surface water outflows and complete an analysis to develop a complete, monthly 27-year record including a flood flow analysis to estimate flood flows potentially available for managed recharge. If all of these analyses are completed as recommended, a subbasin boundary water budget can be assembled at an estimated cost of $160,000. This cost includes development of a complete, monthly time step for a 27-year basin boundary balance and includes development of a 50-year precipitation and reference ET time series for use in simulating future subbasin water budgets.

The individual flow path analyses and development of the basin boundary water budget are a medium priority. These analyses provide useful information regarding the water available for recharge and an initial estimate of historical subbasin overdraft. Accordingly, this information should be developed during initial steps of the GSP development.

The quality control and analysis to develop and complete a 27-year record for each data type analysis could be completed individually. From this perspective, developing estimates for surface water outflows should be the highest priority with the objective of developing an improved estimate of water potentially available for recharge. Two methods are considered for developing an improved estimate of the water available for recharge. One method is to collect all available data on inflows and outflows assembling the best possible record and then estimate missing outflows based on the relationship between inflows and outflows when both records are available. The second method is to complete the full water budget at the basin boundary level. The inflow-outflow method is estimated to cost about $15,000 and the water balance method is estimated to cost $160,000. The full water budget method provides additional benefits both in improved confidence in the estimated surface water outflows and provides useful information on sustainability and possible sustainability measures and projects.

5.2.1 Water Budget Data Gap Recommendations

In summary, subject to funding availability and other considerations that the local agencies may elect to apply, the following recommendations are made for addressing identified water budget data gaps:

- Install three additional outflow measurement sites, subject to site visits and additional evaluation, one each at the Chowchilla Bypass, Fresno River and Cottonwood Creek.
- Analyze available surface water outflow records and each of the three subbasin outflow sites, to synthesize a complete record of subbasin outflow to use in the subbasin boundary water budget.
- Once the development of subbasin outflows is complete, develop an initial subbasin boundary water balance.

Table 5-1
HCM Data Gap Evaluation of Importance, Priority, and Cost

Data Type	Data Use	Required Action/Analysis	Priority*	Estimated Cost
Geologic Cross Sections	Groundwater Model	Utilize compiled data (e.g., DWR WCRs) to construct additional geologic cross-sections	Low	$50,000-$70,000
Aquifer Parameters	Groundwater Model	Utilize compiled data (e.g., DWR WCRs) to obtain specific capacity data	Low	$25,000-$35,000
Groundwater Levels	HCM, Groundwater Model, GSP Monitoring Network	Review DWR WCRs to match with existing wells with water level data; identify existing wells to add to monitoring network	High	$30,000-$50,000
		Install new dedicated monitoring wells	High	$95,000-$125,000 per nested well
Groundwater Quality	HCM, Groundwater Model, GSP Monitoring Network	Review DWR WCRs to match with existing wells with water quality data; identify existing wells to add to monitoring network	High	Included in groundwater level cost
		Install new dedicated monitoring wells	High	Included in groundwater level cost
Groundwater Levels and Quality	HCM, Groundwater Model, GSP Monitoring Network	Conduct outreach with existing well owners. Identify wells with known construction details that are not currently part of the groundwater monitoring network. If the well owner is willing to participate and has a well that is representative of either the upper or lower aquifer (but not both), consider adding the well to the GSP monitoring network	High	$15,000-$25,000
Groundwater Dependent Ecosystems	HCM, Groundwater Model, GSP Monitoring Network	Evaluate potential GDEs mapped by TNC/DWR to determine if could be impacted by regional pumping	Medium	$20,000-$35,000

*All identified data gaps will need addressing for the GSP. Data gap priority is assigned based on relative importance and timing sequence.

Table 5-2
Recommended New Monitoring Well Locations, Priority, and Cost

New Monitoring Well*	Approximate Location	Purpose	Priority**	Estimated Cost
1	Southeast basin boundary	Groundwater Levels/Quality; Upper/Lower Semi-Confined Aquifer; contours missing in this area due to lack of data	Medium	$95,000-$125,000
2	Southeast basin	Groundwater Levels/Quality; Upper/Lower Semi-Confined Aquifer; limited wells in area	Medium	$95,000-$125,000
3	East basin boundary	Groundwater Levels/Quality; Upper/Lower Semi-Confined Aquifer; contours missing in this area due to lack of data	Medium	$95,000-$125,000
4	East of City of Madera	Groundwater Levels/Quality; Upper/Lower Semi-Confined Aquifer; lack of wells in area	High	$95,000-$125,000
5	South central basin boundary	Groundwater Levels/Quality; Upper/Lower Semi-Confined Aquifer; near San Joaquin River; base boundary flow	High	$95,000-$125,000
6	Northeast basin boundary	Groundwater Levels/Quality; Upper/Lower Semi-Confined Aquifer; limited wells in area; basin boundary flows; 2016 groundwater depression	High	$95,000-$125,000
7	Central basin; in City of Madera	Groundwater Levels/Quality; Upper/Lower Semi-Confined Aquifer; lack of upper aquifer wells in area	Medium	$95,000-$125,000
8	North central basin	Groundwater Levels/Quality; Upper/Lower Semi-Confined Aquifer; lack upper aquifer wells in area; basin boundary flows; 2016 groundwater depression	Medium	$95,000-$125,000
9	Central basin; west of City of Madera	Groundwater Levels/Quality; Upper/Lower Semi-Confined Aquifer; limited wells in area	High	$95,000-$125,000
10	Northwest basin boundary	Groundwater Levels/Quality; Upper Unconfined/Lower Confined Aquifers; limited wells in area; basin boundary flows; 2016 groundwater depression	Medium	$95,000-$125,000
11	West basin boundary	Groundwater Levels/Quality; Upper Unconfined/Lower Confined Aquifers; limited wells in area	Medium	$95,000-$125,000
12	Southwest basin boundary	Groundwater Levels/Quality; Upper Unconfined/Lower Confined Aquifers; lack of lower aquifer wells in area; basin boundary flows	Medium	$95,000-$125,000
13	West basin boundary	Groundwater Levels/Quality; Upper Unconfined/Lower Confined Aquifers; lack of wells in area	High	$95,000-$125,000

* New monitoring well numbers are identified on Figure 5-5.
** New monitoring well priority is assigned according to existing hydrogeologic data need and importance for future monitoring.

Table 5-3
Water Budget Data Gap Evaluation of Importance, Priority, and Cost

Data Type	Data Use	Required Action/Analysis	Priority	Estimated Cost
Surface Water Outflows	Fill data gap for future monitoring of surface water outflows	Add and maintain stream gage records on Cottonwood Creek, Chowchilla Bypass, and Fresno River (3 separate sites)	High	$90,000
			Subtotal for new stream gages*	$90,000
Surface Water Outflows	Develop historical data for 50 year period for planning and water budget for 30 years	Review available records and use standard, accepted methods to estimate missing records	High	$15,000
Meteorological	Develop reference ET by crop and precipitation for 50 year period for planning projections	Use standard, accepted ASCE Manual 70 methods to develop ET_o and precipitation daily time series from available weather data	Medium	$10,000
Surface Water Inflows	Develop water budget for 30 years and 50 year hydrology for planning projections	Review available records and use standard, accepted methods to estimate missing records	Medium	$5,000
Land Use	Assign land use to each water balance area each year for 30 year historical period	Based on available spatial data and crop reports, assign crops to water balance areas	Medium	$15,000
Water Use (Evapotranspiration)	Outflow from subbasin and basis for estimate of agricultural groundwater pumping	Root zone water balance based on meteorological, remotely-sensed energy balance ET estimates, and land use data to estimate crop water use.	Medium	$20,000
Surface Water Diversions	Develop water budget for 30 years	Review available records and use standard, accepted methods to estimate missing records	Medium	$30,000
Agricultural Groundwater Pumping	Develop water budget for 30 years	Use standard, accepted methods to estimate historical groundwater pumping	Medium	$15,000
Applied Water	Develop water budget for 30 years	Review available records and use standard, accepted methods to estimate missing records	Medium	$15,000
M&I Groundwater Pumping	Develop water budget for 30 years	Review available records and use standard, accepted methods to estimate missing records	Low	$10,000
Rural Residential Pumping	Develop water budget for 30 years	Use standard, accepted methods to estimate historical groundwater pumping	Low	$10,000
		Cost to assemble and document water budget		$15,000
			Subtotal	$160,000
			Total	$250,000

*Estimate of $30,000 per site includes final site selection plus instrumentation. Establishing a rating and continuing annual costs are estimated to be between $15,000 to $20,000.

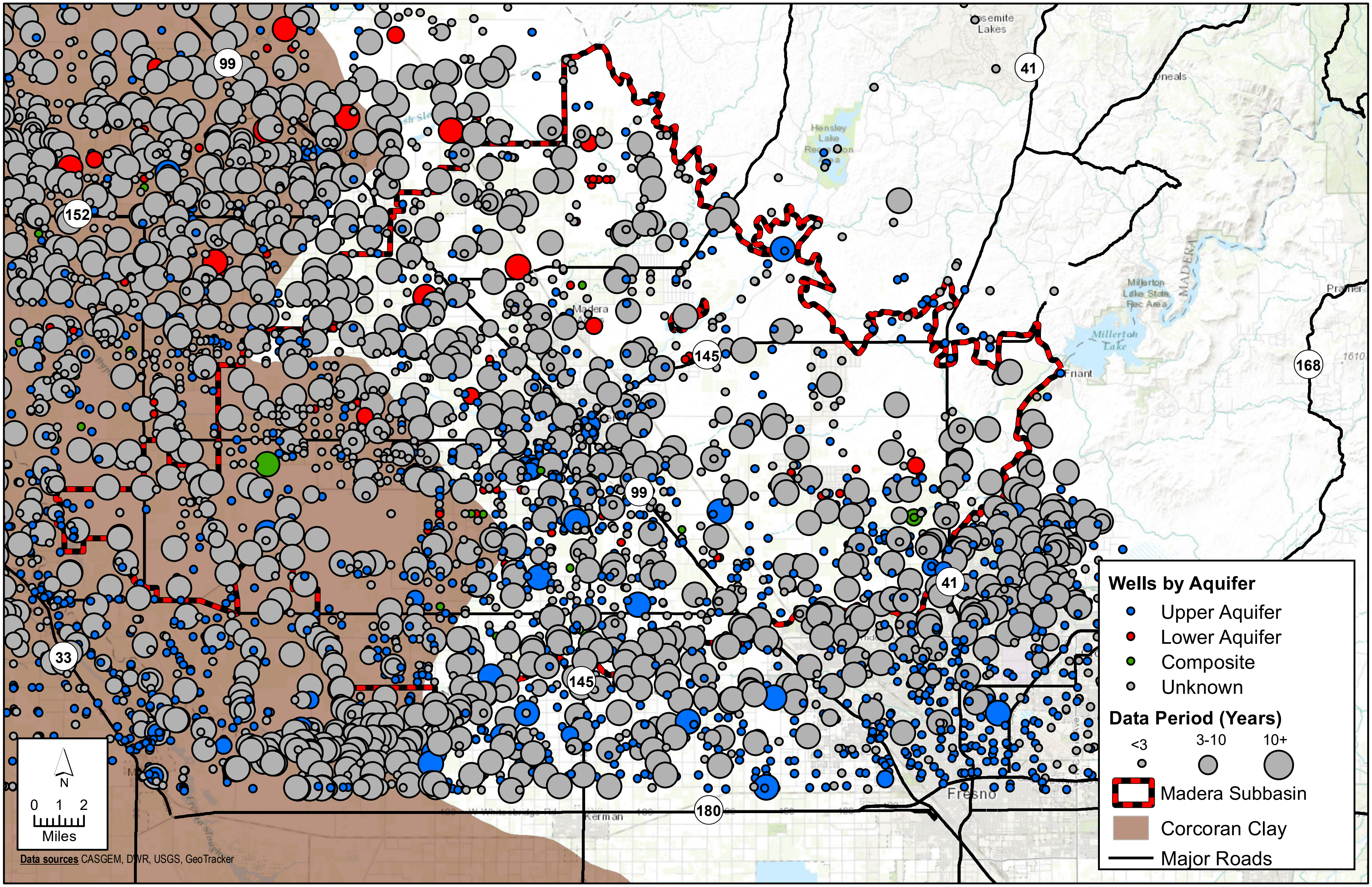

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FIGURE 5-1

Map of Known Wells with Water Level Data

Madera County: Madera Subbasin
SGMA Data Collection and Analysis

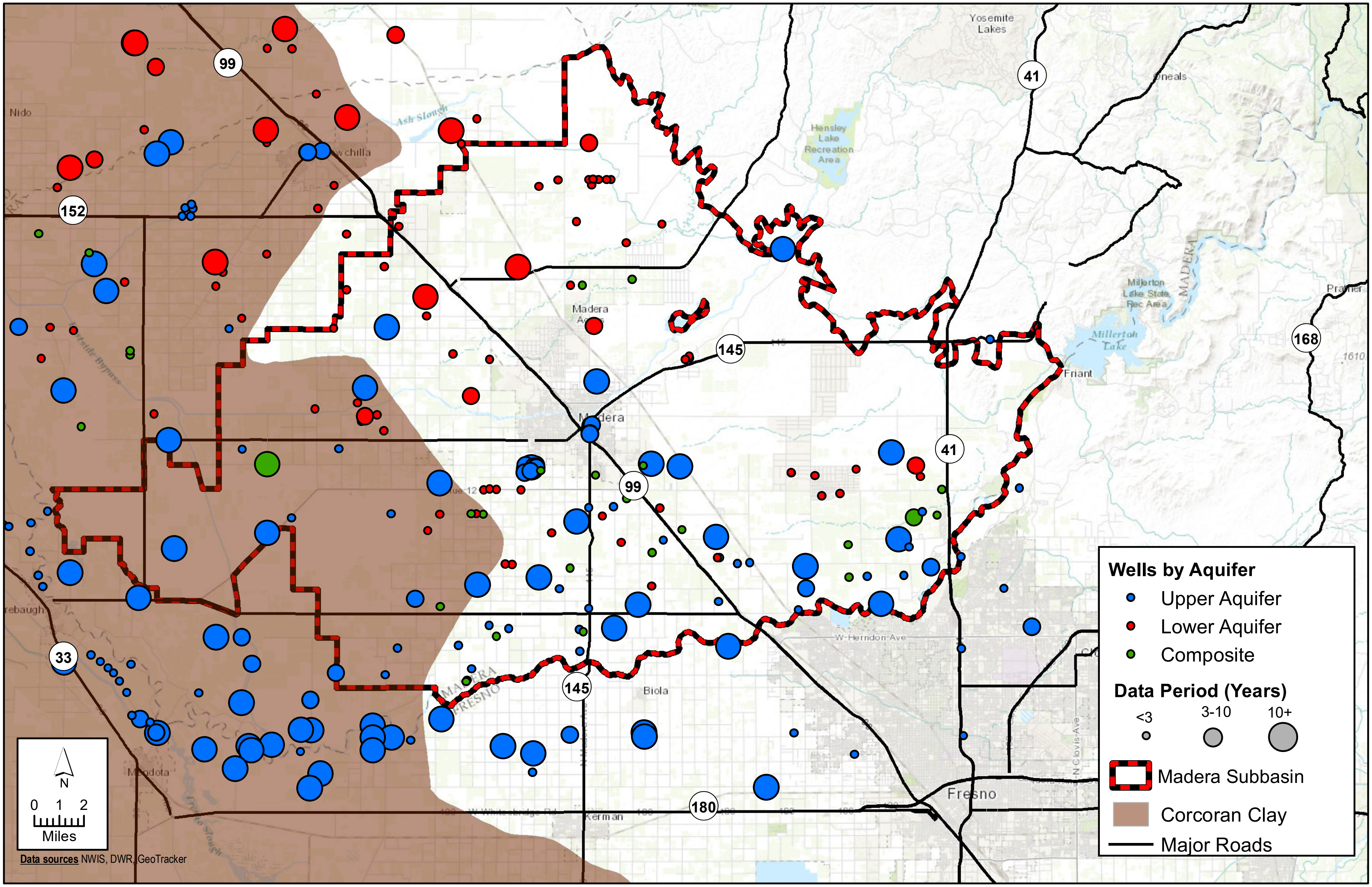

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FIGURE 5-2
Map of Known Wells with Recent Water Level Data and Construction Data

Madera County: Madera Subbasin
SGMA Data Collection and Analysis

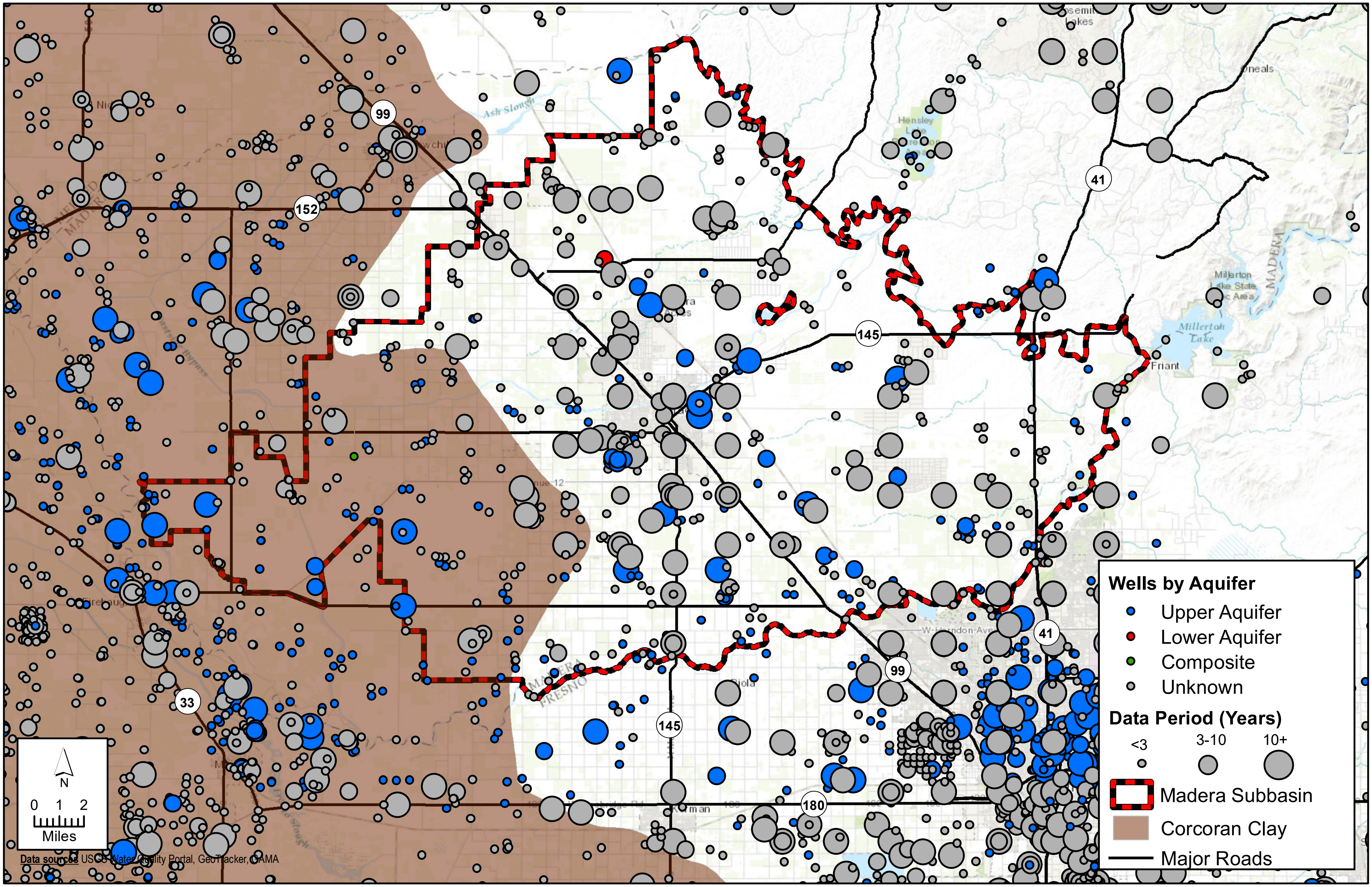

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FIGURE 5-3

Map of Known Wells with Water Quality Data

Madera County: Madera Subbasin
SGMA Data Collection and Analysis

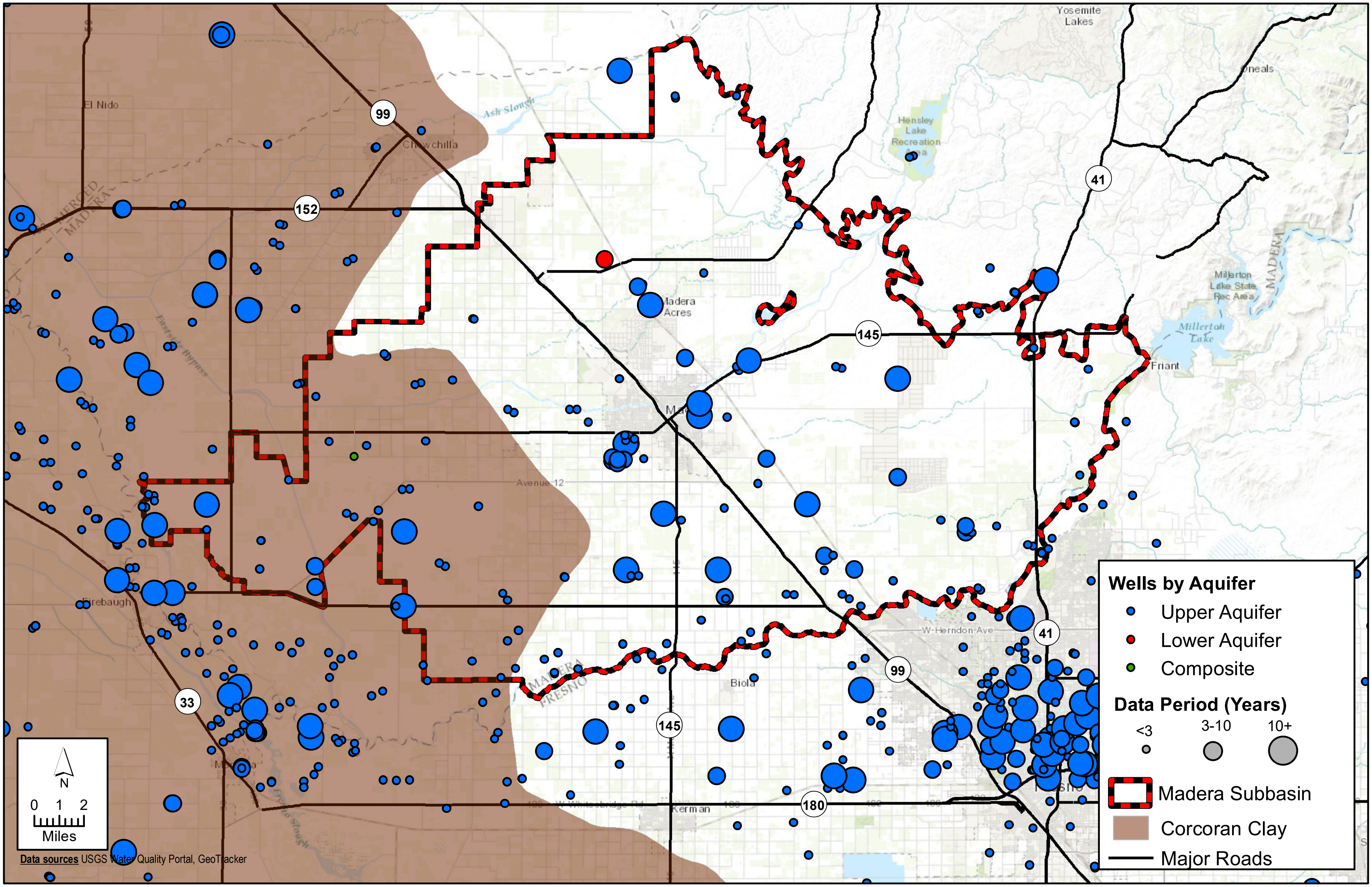

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FIGURE 5-4
Map of Known Wells with Water Quality Data and Construction Data

Madera County: Madera Subbasin
SGMA Data Collection and Analysis

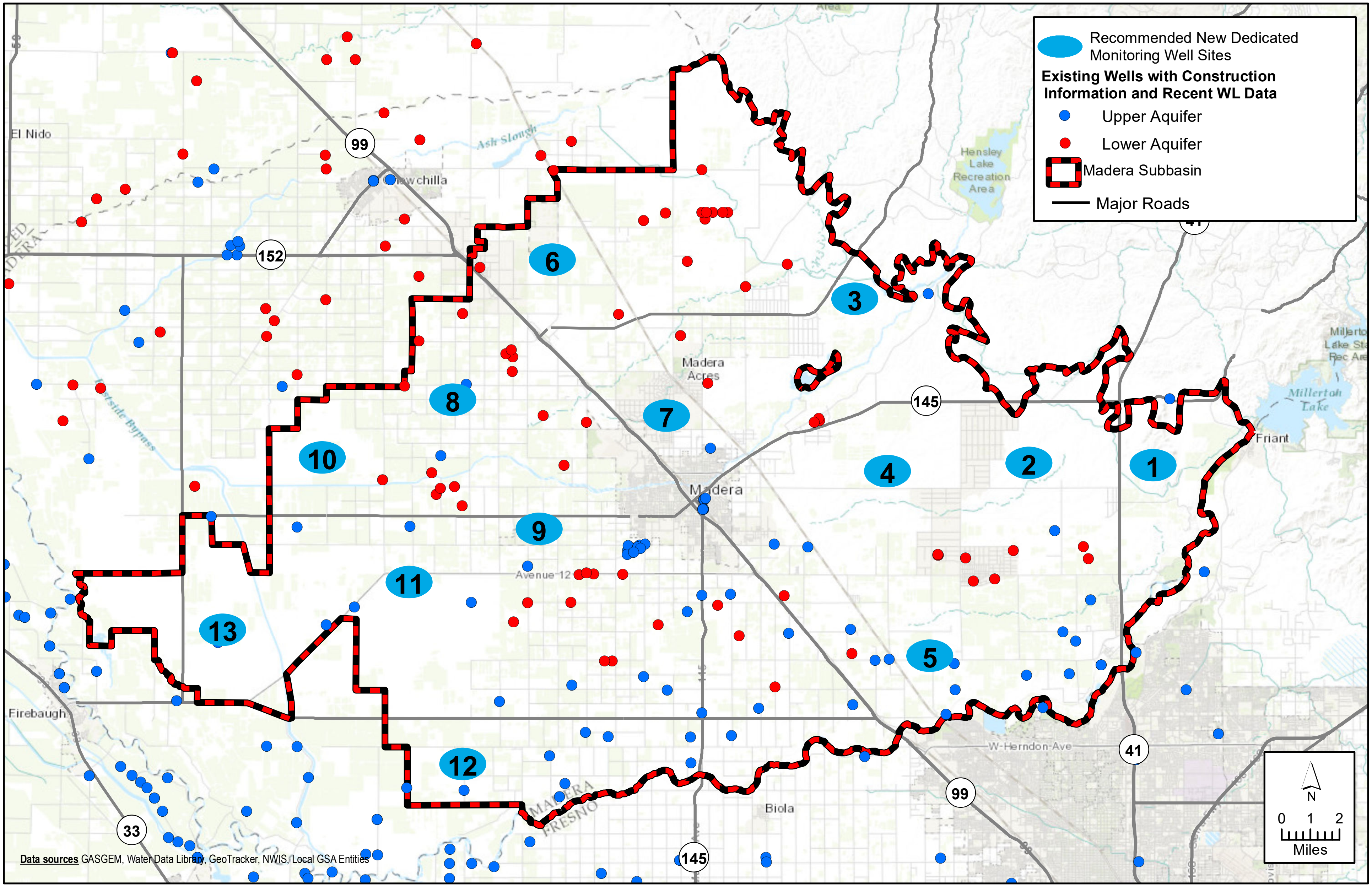

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FIGURE 5-5

Preliminary Recommendations for New Dedicated Monitoring Well Sites

Madera County: Madera Subbasin
SGMA Data Collection and Analysis

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