INTRODUCTION

The Irrigation Training and Research Center (ITRC) at California Polytechnic State University, San Luis Obispo was subcontracted by RMC Water and Environmental to provide actual evapotranspiration (ETc) from vegetation throughout the Merced Area Groundwater Pool Interests (MAGPI) area for a select number of years. This ETc information will be used by RMC as part of a groundwater modeling study for the region that is being funded by MAGPI.

ITRC uses a modified Mapping of EvapoTranspiration with Internal Calibration (METRIC) procedure to compute actual evapotranspiration using LandSAT Thematic Mapper (LandSAT) data. Three LandSAT satellites were used for this study which covered a timeframe starting in 1985-2013 (several years or portions of years were missing in this timeframe). The MAGPI area is shown in Figure 1.

The second objective of this study was to evaluate the net amount of water that was contributed to or taken from the groundwater for crop use in the MAGPI area. ITRC felt that this information would help RMC calibrate the groundwater model for the years examined. This will be discussed in more detail in the body of this report.

ITRC-METRIC MODELING

Satellite Images

LandSAT 5, LandSAT 7, and LandSAT 8 images available from the United States Geological Survey (USGS) on sixteen-day intervals were used for the MAGPI METRIC process. **Table 1** below shows the time frame of available satellite images for each individual satellite.

Table 1. Time frame of available images for LandSAT 5, 7, and 8

LandSAT 5	LandSAT 7**	LandSAT 8
November 1982-October 2011	June 1999-May 2003	April 2013-Present

**After May 2003, LandSAT 7 began producing images with missing data because of a defective sensor

For all three satellites, the LandSAT image that encompassed the area of interest was located in Path 43 and in Row 34. The project area of interest can be seen in **Figure 1** with the July 30th 2013 LandSAT 8 "natural look" image in the background. **Figure 2** shows the infrared background for the same LandSAT 8 image date.

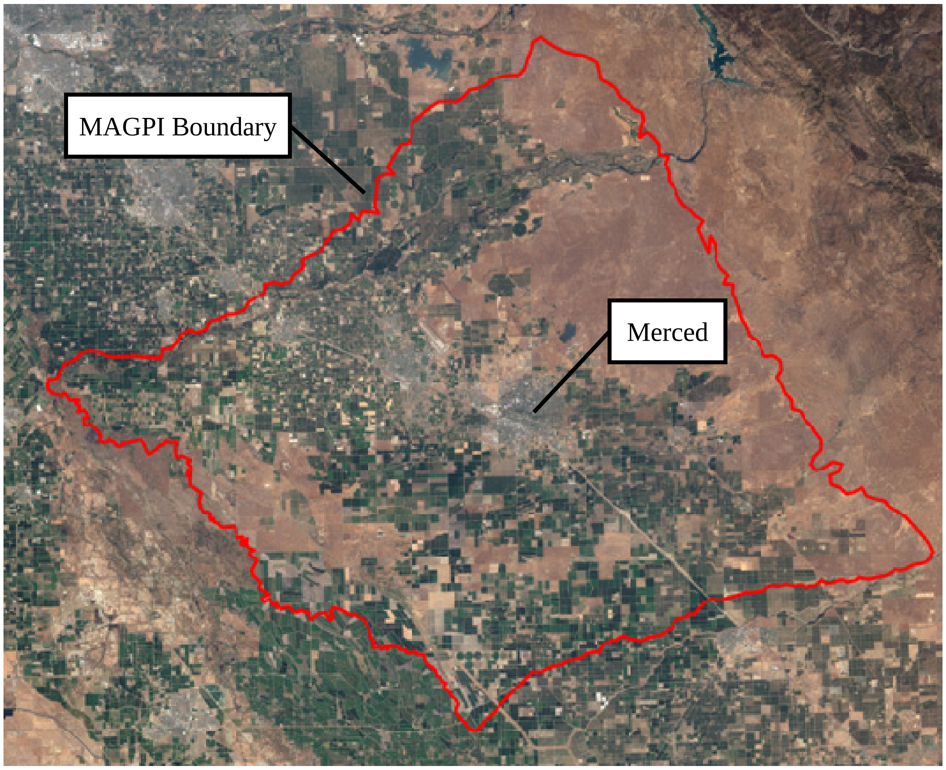


Figure 1. Area of interest with "natural color" image in the background

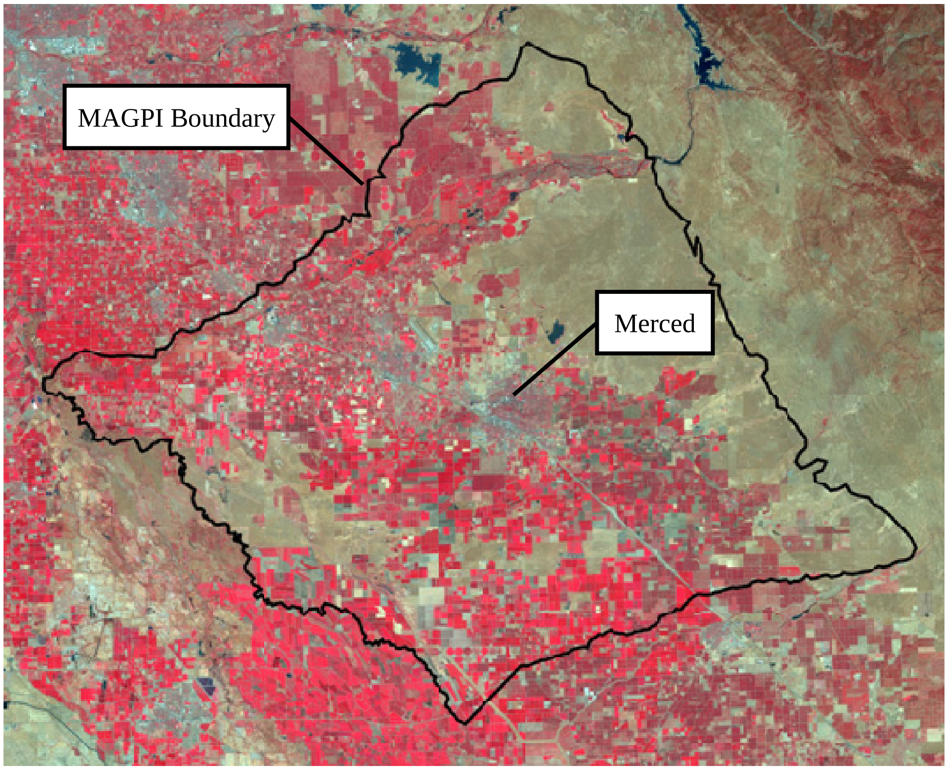


Figure 2. Area of interest with infrared image in the background

A total of nine years were analyzed for the METRIC modeling process. Years were selected so that they covered different precipitation year types (dry, average, or wet water year) and accounted for changes in crop types since the late 1980's. The following years were analyzed for this project:

1. 1989 (Dry water year)
2. 1997 (Average water year)
3. 1998 (Wet water year)
4. 2000 (Average water year)
5. 2001 (Average water year)
6. 2002 (Average/Dry water year)
7. 2008 (Average/Dry water year)
8. 2010 (Wet water year)
9. 2013 (Dry Water Year)

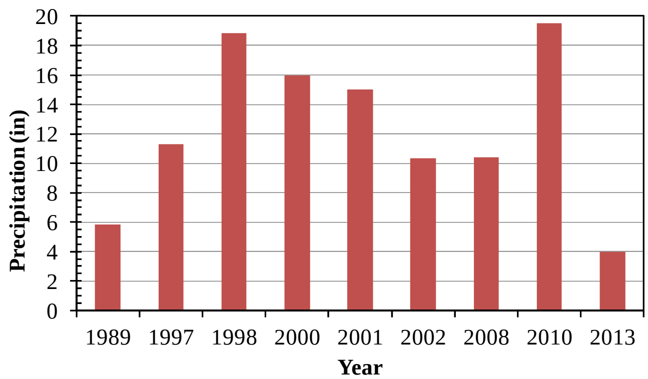
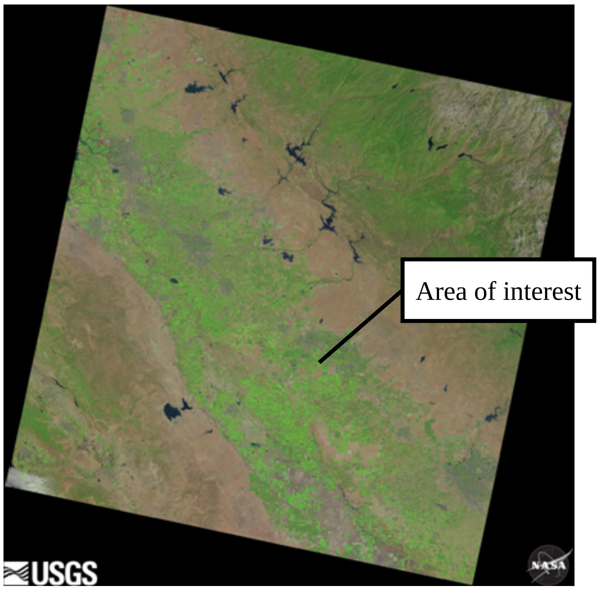


Figure 3. Approximate precipitation amounts in the MAGPI area for the years examined.

In order to obtain reliable results from the METRIC modeling process, daily images need to be free of cloud coverage in the area of interest. **Figure 4** shows the difference between a usable and unusable image for METRIC modeling.



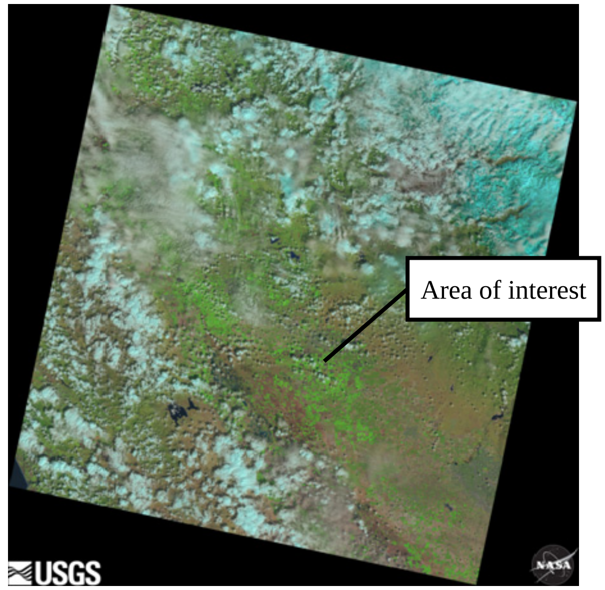


Figure 4. Usable LandSAT image (left image) and an unusable LandSAT image (right image)

All available cloud-free images were used for the modeling process as seen in **Table 2**. A total of 124 images were processed using METRIC.

Table 2. Chosen image dates for MAGPI METRIC Process

Year	1989	1997	1998	2000	2001	2002	2008	2010	2013**
Type	Dry	Average	Wet	Average	Average	Average	Dry	Wet	Dry
Image Dates	1/17 3/22 4/7 5/25 6/10 7/28 8/13 8/29 9/30 10/16 11/1 12/3	1/7 2/24 3/12 3/28 4/13 5/15 5/31 6/16 7/2 7/18 8/3 9/4 9/20 10/22 11/23	2/11 3/15 4/16 5/18 6/19 7/5 7/21 8/6 8/22 9/7 10/9 11/26 12/28	2/1 3/20 4/29* 5/31* 6/16* 6/24 7/2* 7/26 8/11 8/19* 9/20* 9/28 10/14 10/22* 11/17*	1/18 2/3 3/23 4/24 5/10 5/26 6/11 6/19* 7/13 7/29 8/14 8/30 9/15 10/1 11/26* 12/20	3/2* 4/3* 4/19* 5/5* 5/13 6/14 6/30 7/8* 7/24* 8/9* 8/25* 9/10* 9/26* 10/14 10/28*	2/7 3/26 4/11 4/27 5/13 5/29 6/14 6/30 7/16 8/1 8/17 9/2 9/18 10/20	2/12 4/1 5/35 5/19 6/20 7/6 7/22 8/7 8/23 9/24 10/10 11/11	4/25 5/11 6/12 6/28 7/14 7/30 8/15 8/31 9/16 10/18 12/25 12/21
Total	12	15	13	15	16	15	14	12	12

Notes: * indicates LandSAT 7 and ** indicates LandSAT 8

Weather Data

Daily and hourly weather data for the project time frame were collected from the California Irrigation Management Information System (CIMIS) weather stations located near the project area of interest as seen in **Figure 5**.

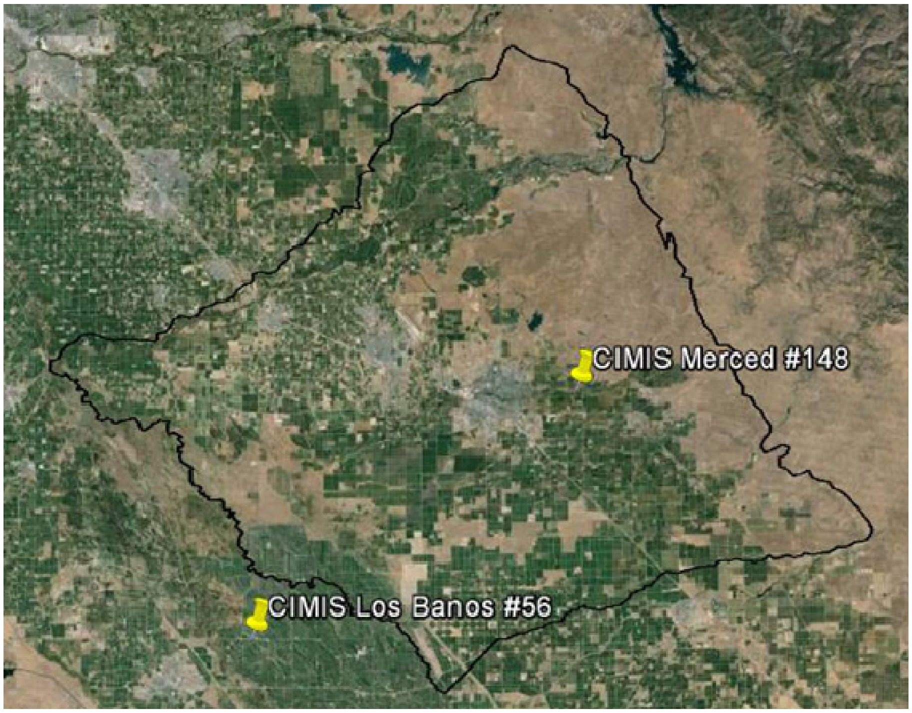


Figure 5. Location of agricultural weather stations considered for historical weather data

Two weather stations were considered for the METRIC modeling process:

1. Merced (Source: CIMIS – Station ID: #148 – Available 1/4/1999 to present)
2. Los Banos (Source: CIMIS – Station ID: #56 – Available 6/28/1988)

The Merced weather station data was used for the modeling years 2000 through 2013 because of its location in respect to the majority of the agricultural area within the MAGPI boundary. The Los Banos weather station data was used for the modeling years prior to the year 2000. The weather component data collected from both weather stations are:

1. Solar radiation (W/m^2)
2. Air temperature (ºC)
3. Wind speed (m/s)
4. Precipitation (mm)
5. Relative humidity (%)
6. Dew point temperature (ºC)

The collected weather data went through a quality control check based FAO procedures. A detailed procedure on the quality control conducted can be found in FAO Irrigation and Drainage paper No. 56 (Allen et al., 1998) along with correction procedures. The main correction needed to compute the hourly *ETo* is to the solar radiation. **Figure 6** contains a graph of the corrected solar radiation over the project time frame.

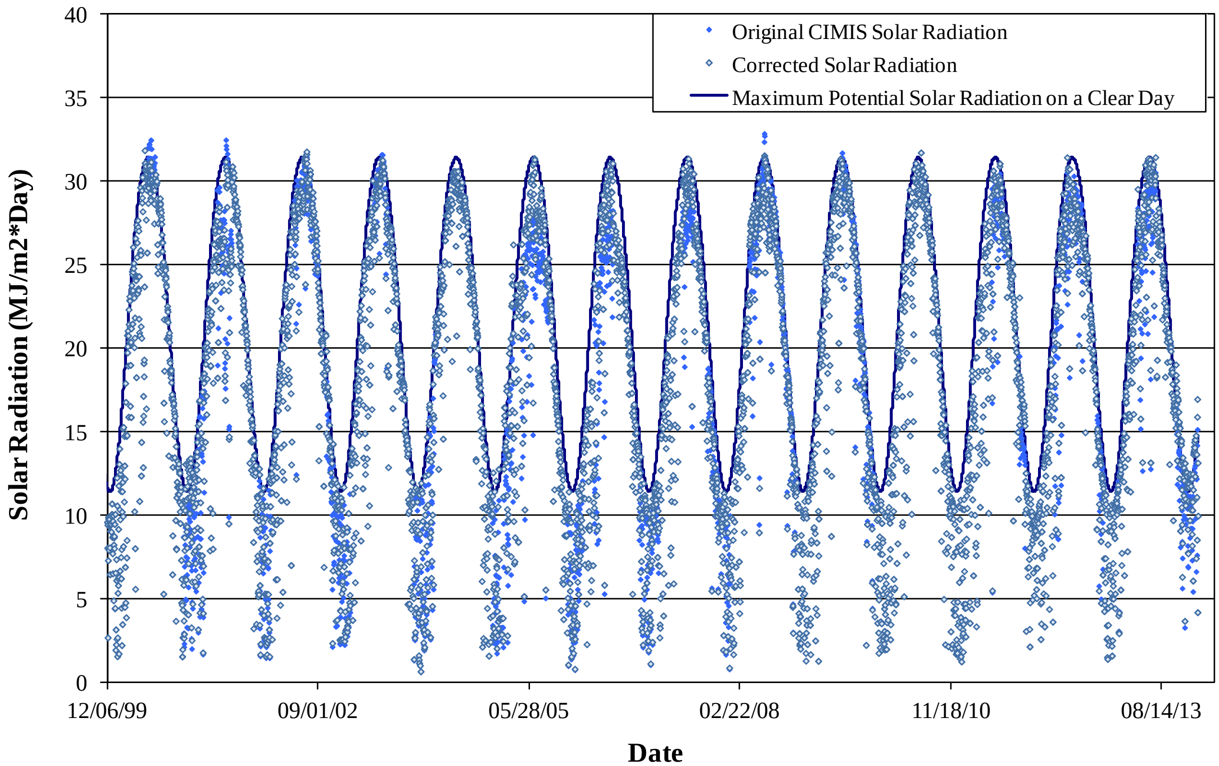


Figure 6. Adjusted solar radiation using FAO 56

Once the solar radiation and any other errors were corrected using the FAO procedures, the *ETo* was computed using the ASCE 2005 Standardized Penman Monteith *ETo* equation. **Figure 7** below shows a monthly comparison of the computed *ETo* for various years of the Merced weather data.

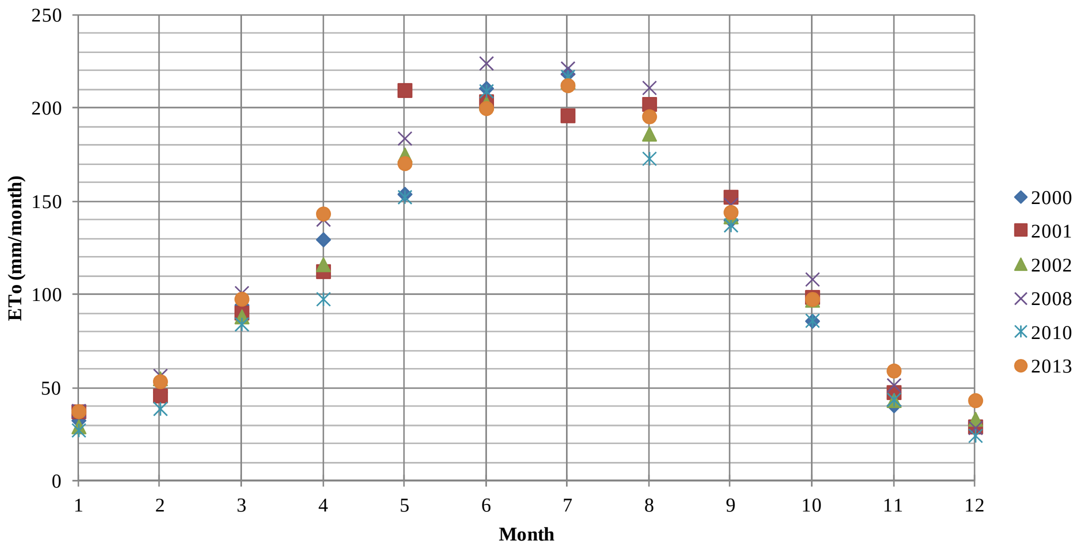


Figure 7. Comparison of monthly ETo computed from the ASCE 2005 Standardized Penman Monteith *ETo* equation using Merced historical weather data

ETo and individual weather data are used within the METRIC process to compute inputs into the software. METRIC computes the instantaneous *ETc* for every pixel within the LandSAT image at the instant the image is taken. Knowing the *ETo* at that instant from the local weather station, a **crop coefficient (*Kc*)** can be computed ($Kc = ETc/ETo$). It has been shown that this instantaneous *Kc* at the time of image acquisition (approximately 11 a.m.) is a very good representation of the *Kc* for that entire day.

Elevation Data

A Digital Elevation Model (DEM) provided by the USGS was used to adjust the model outputs based on the surface elevation through the area of interest. The DEM used had a resolution of 10m (1/3 arc second) which was then re-projected into a 30m x 30m pixel size to match the resolution of the LandSAT images.

Landuse Map

Landuse surveys conducted by the California Department of Water Resources (DWR) on a field by field basis for Merced County in 1995 and 2002 were used as the main source for landuse map in the METRIC modeling process. Additional landuse surveys provided by the DWR for the surrounding counties and annual landuse data provided by the National Agricultural Statistics Service (NASS – an extension of the U.S. Department of Agriculture – USDA) were used to compute the landuse characteristics in the outside areas of Merced County.

All of the landuse maps when through a quality control check to ensure that a single landue value was uniform across an entire field. **Figure 8** shows an example of the Landuse map used for processing the modeling year 2002.

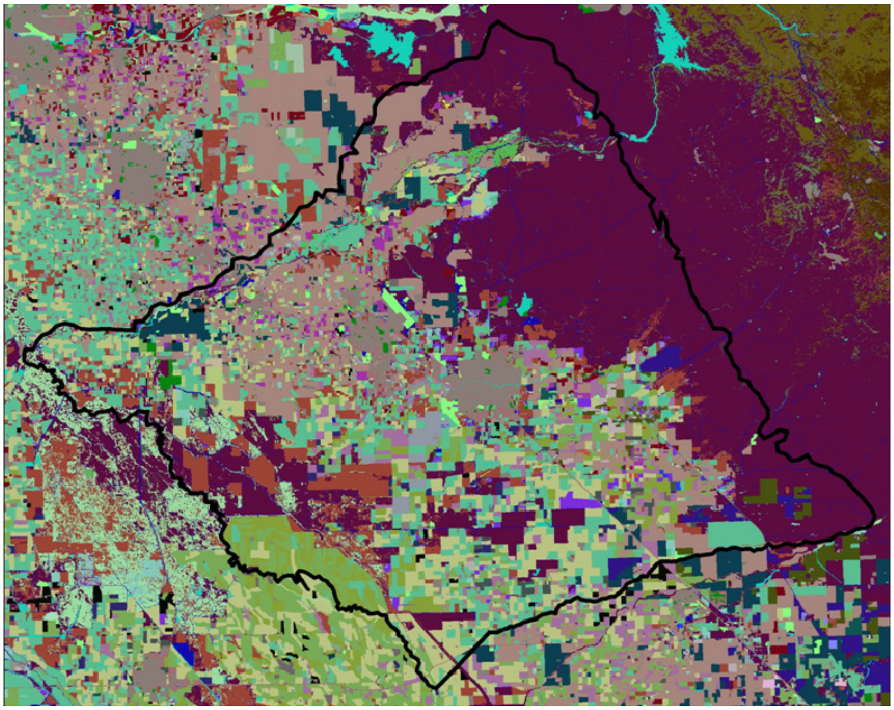


Figure 8. Example of landuse characteristic map used of the METRIC modeling process. Each color identifies a different landuse type (i.e. almonds, alfalfa, developed, etc.)

METRIC Kc Results

Figure 9, **Figure 10**, and **Figure 11** consist of *Kc* results from three different image dates and their ranges of *Kc* values. The lighter the pixel color, such as yellow, the lower the *Kc* value. Conversely, the darker the pixel color, such as blue, the higher the *Kc* value.

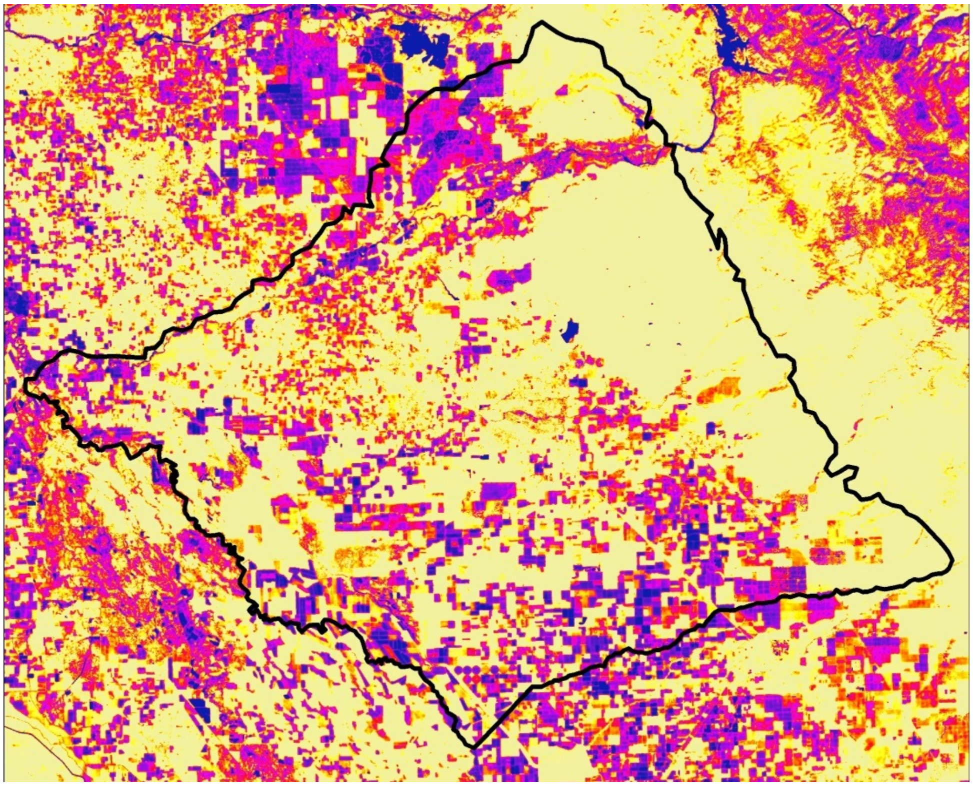


Figure 9. METRIC *Kc* Results for April 25th, 2013

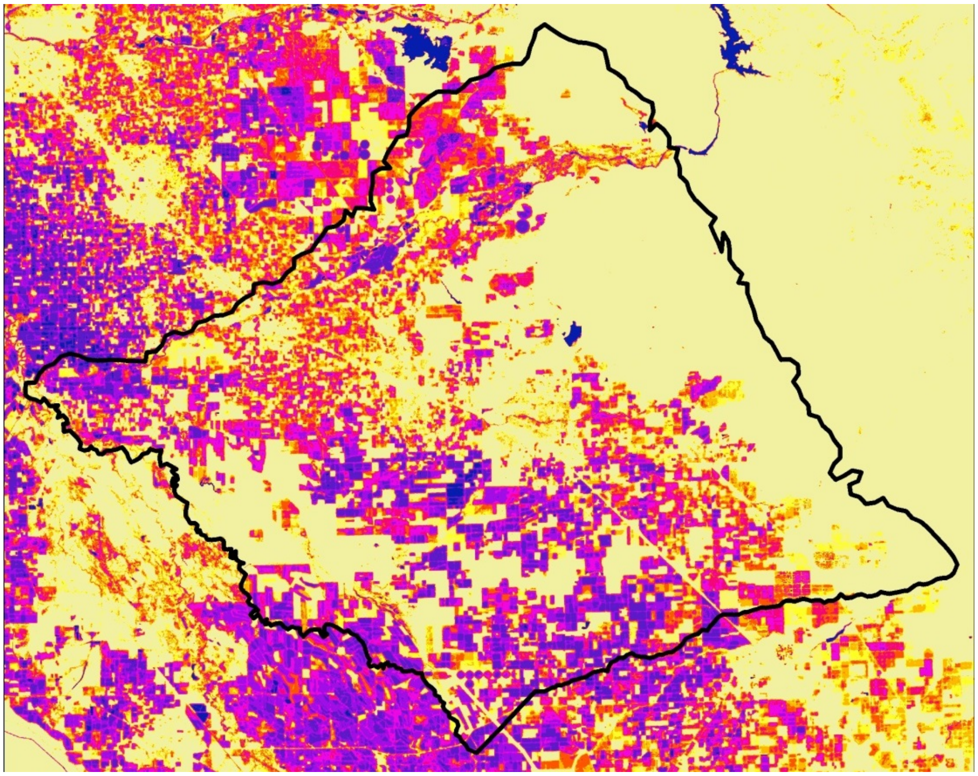


Figure 10. METRIC *Kc* Results for July 30nd, 2013

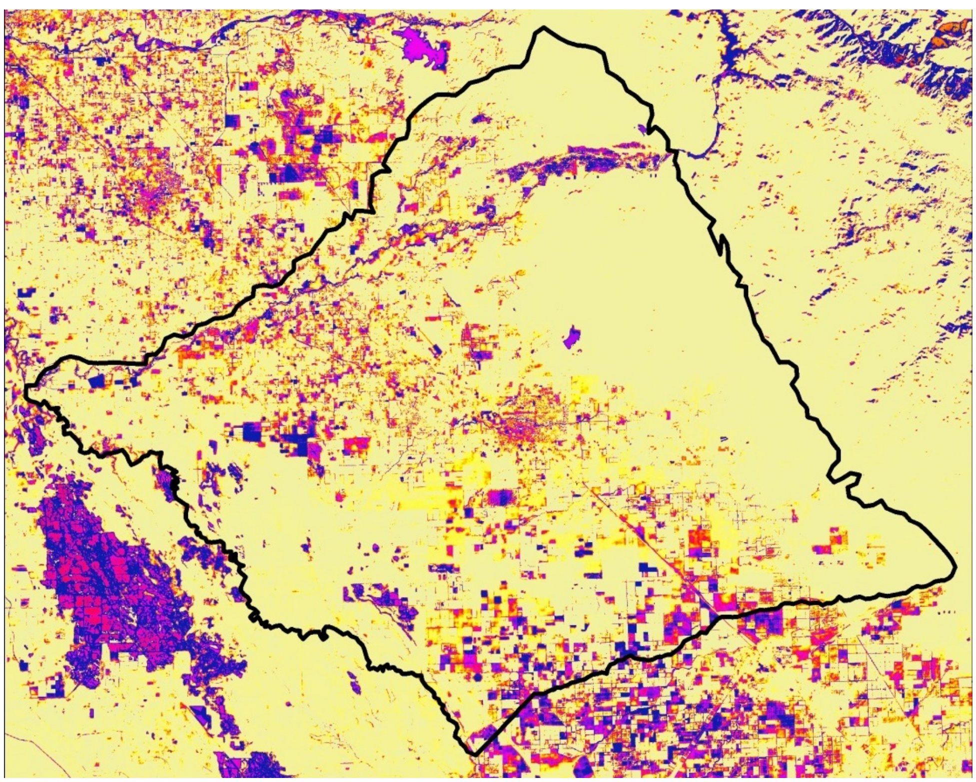


Figure 11. METRIC *Kc* Results for December 21st, 2013

Figure 12 compares the *Kc* values found in individual corn, almond, alfalfa, and peach fields for July 24th, 2002.

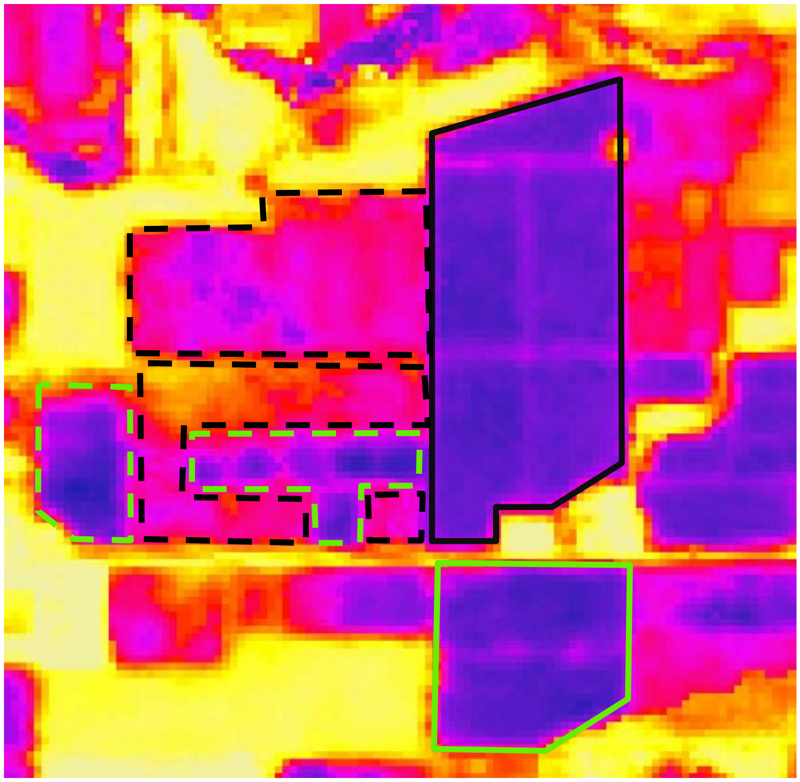


Figure 12. *Kc* color indexing for corn field (solid black border), almond field (dashed black border), alfalfa field (solid green border), and peach field (dashed green boarder) on July 24th, 2002

The *Kc* value ranges for the selected fields in **Figure 12** can be seen in **Table 3** below.

Table 3. Individual Field Kc Values for July 24th, 2002 image (refer to Figure 12)

Individual Field *Kc* Values for July 24th 2002 Image		
Crop	**Border Type/Color**	***Kc* Range**
Corn	Solid Black Line	1.05 – 1.15
Almonds	Dashed Black Line	0.75 – 0.95
Alfalfa	Solid Green Line	1.05 – 1.20
Peaches	Dashed Green Line	1.00 – 1.20

NET TO AND FROM GROUNDWATER MODELING

The other main objective of the ITRC for the MAGPI project besides determining ET for the area of interest was to make monthly estimates of the net amount of water to and from the groundwater for each project year. **Figure 13** shows a simple schematic of the individual components for estimating the *Net To and From Groundwater* (*NTFGW*).

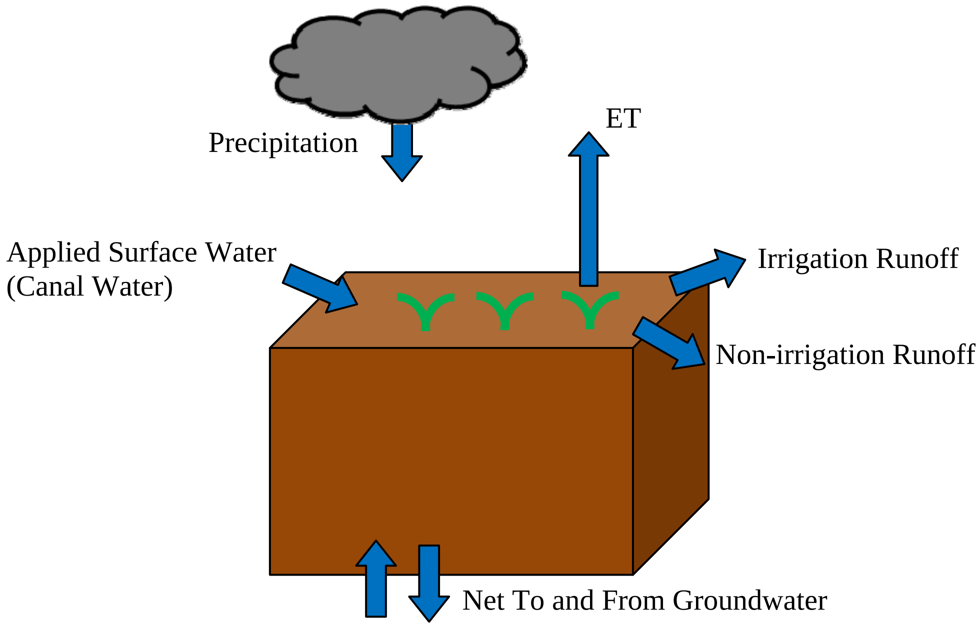


Figure 13. Schematic showing the components for computing the net to and from groundwater

The main components of NTFGW shown in **Figure 13** include:

1. Applied surface water (canal water)
2. Precipitation
3. Evapotranspiration (ET)
4. Irrigation Runoff
5. Non-Irrigation Runoff (precipitation runoff)

The *NTFGW* can be computed using to following equation:

$$NTFGW = Applied\ Water + Precipitation - ET - Irrigation\ Runoff - Non\_Irrigation\ Runoff$$

On a monthly time step, this equation must include the soil moisture depletion (SMD) at the beginning of the month. In order to determine SMD, the soil type and general crop type are needed to determine the soils available water holding capacity in the crops root zone. The initial SMD is estimated based on prior months' (November and December) precipitation amounts. The evaluation of monthly NTFGW requires several checks on Equation 1:

- If Eq. 1NTFGW is positive and is greater than the SMD, the end of the month SMD is assumed to be filled and any additional NTFGW must deep percolate below the root zone (Net to Groundwater).
- If Eq. 1 NTFGW is positive and is less than the SMD, the SMD at the end of the month is equal to the SMD at the beginning plus the Eq 1. NTFGW (no Net to Groundwater).

- If Eq. 1 NTFGW is negative and is less than the water remaining in the soil root zone at the end of the month, SMD at the end of the month is decreased by NTFGW (no Net from Groundwater).
- If Eq. 1 NTFGW is negative and is greater than the water remaining in the soil root zone at the end of the month, the SMD at the end of the month is decreased to the allowable depletion and the remaining NTFGW must be pumped from the groundwater (Net from Groundwater).

The sub-sections below discuss how each parameter of *NTFGW* was computed.

Merced County Parcels

A GIS file containing individual parcel locations in Merced County were obtained from the Merced County website. Output parameters such as ET, applied water, irrigation runoff, etc. were determined on a monthly basis for each individual parcel. **Figure 14** shows all the parcels located in eastern Merced County and within the MAGPI project boundary. **Figure 15** shows an example of an aerial image with individual parcels located just west of Merced.

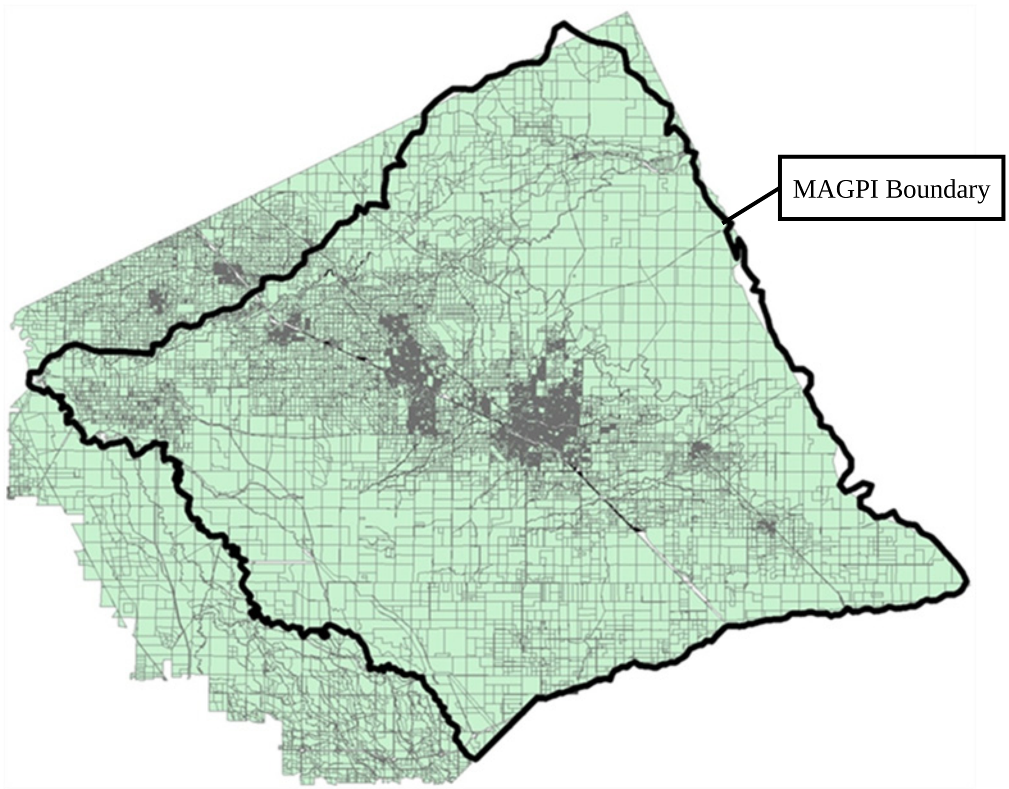


Figure 14. Individual parcels located in eastern Merced County and within the MAGPI project boundary

Figure 15. Aerial image shows individual parcels (outlined with black borders) west of Merced

Applied Surface Water

Surface water delivery events obtained from Merced Irrigation District (MID) from 1992 through 2013 were used to determine the applied water (in acre-feet) for individual water user accounts. The account number for individual surface water users in MID were compared to the known associated parcel numbers. The location of the associated parcel number was compared to the Merced County parcel GIS file to determine the approximate location of the applied water.

With the known approximate acreage of each parcel, the volume of applied water by parcel was converted to applied inches of water on a monthly basis. For simplicity, the applied inches of water were created to be uniform across the entire parcel. Some water accounts had multiple parcels for which the applied water was evenly distributed across all of the parcels under the single account number. A small amount of account numbers did not have an associated parcel number. In this case, the applied water for that account was ignored.

The applied surface water by parcel was averaged over one mile by one mile grid from the Merced County township and sections provided by the Public Land Survey System (PLSS). The reason for averaging the applied water over the quarter mile sub-section was to eliminate field outliers in such cases where small (only a few acres) irrigated fields applying an unrealistic amount of water in a single month. The field outliers were a result of missing parcel numbers for individual accounts that clearly have multiple parcels associated with that account.

An example of the applied water by parcel can be seen in the left image of **Figure 16**. The applied surface water averaged over the one mile grid sections for the same area can be seen in the right image of **Figure 16**. **Figure 17** shows the applied water (one mile resolution) for July 2002 for the entire MAGPI boundary area.

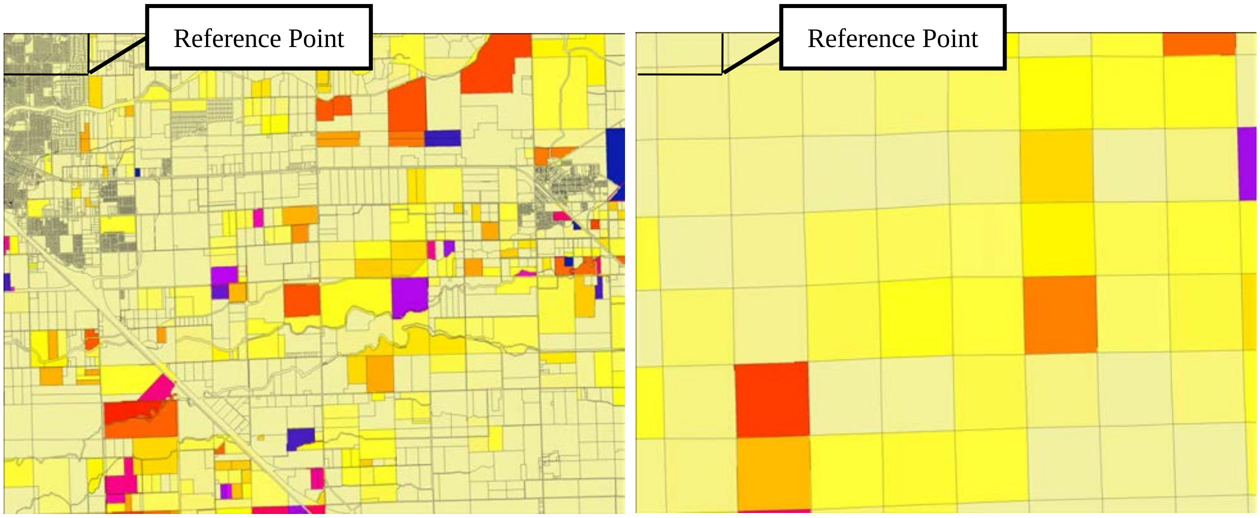


Figure 16. Example of applied water by parcel (left image) compared to applied water over one mile sections (right image) for July 2002. The darker the color the higher the applied surface water.

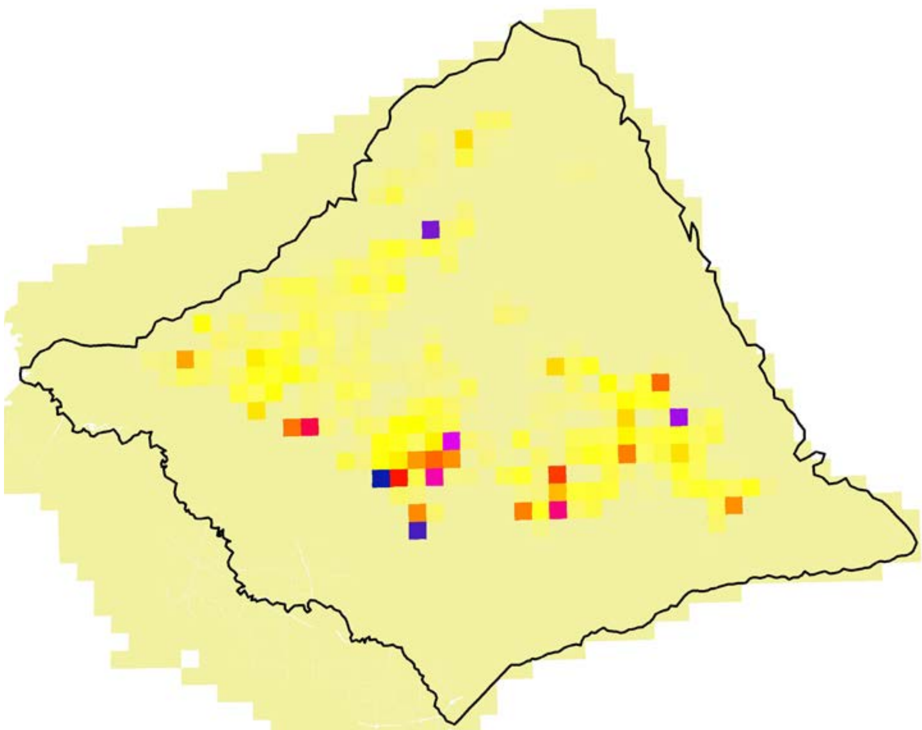


Figure 17. Example of applied surface water on a one mile resolution during July 2002 for the entire MAGPI boundary area

Precipitation

Spatially distributed precipitation maps were downloaded from the PRISM Climate Group of Oregon State University. The raster files displayed monthly precipitation data in millimeters for the entire United States on a 4 km by 4 km resolution.

A sub-set of the original monthly precipitation raster was extracted to be just larger that the project area of interest. The precipitation values of the sub-set precipitation raster were converted from millimeters to inches of precipitation. **Figure 18** shows an example of precipitation raster from PRISM for December 2002. The darker colors indicate a higher monthly total of precipitation.

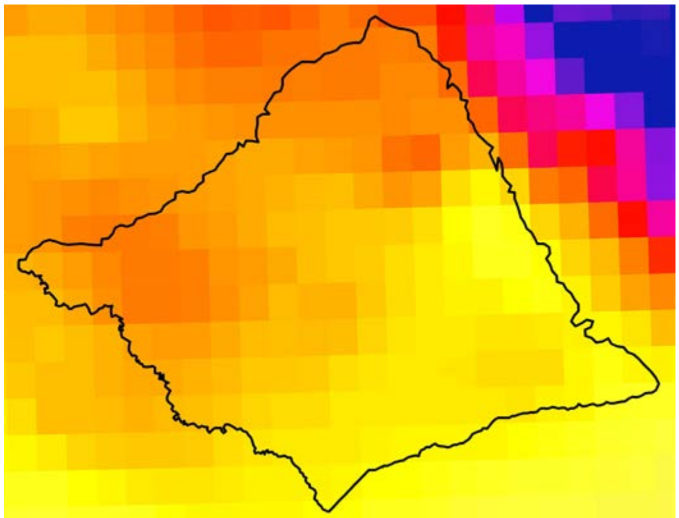


Figure 18. Example of monthly precipitation raster available from PRISM Climate Group for December 2002. The darker colors indicate higher monthly total of precipitation.

ET by Parcel

The average monthly ET per parcel rasters were created from the original 30m by 30 m resolution ET rasters calculated from METRIC. The average monthly ET (in inches) was applied to be uniform across the entire parcel. **Figure 19** shows an example of the average monthly ET by parcel for July 2002 where the dark the colors (blue) indicate a higher the ET value.

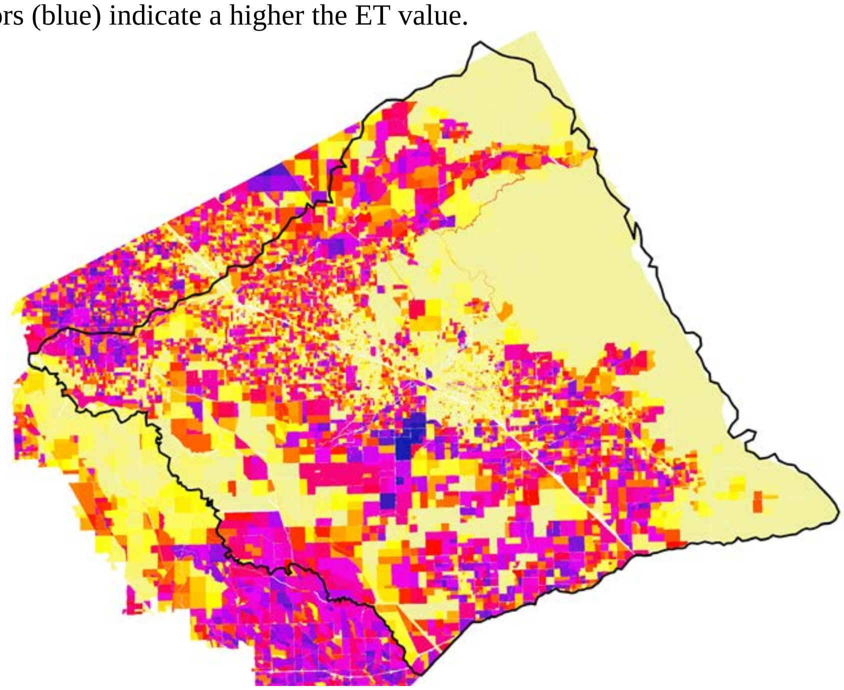


Figure 19. Example of average monthly ET by individual parcel for July 2002. The darker color (blue) indicates a higher ET amount.

Irrigation Runoff

The following process was used to estimate the amount of monthly irrigation runoff from agricultural fields inside the MAGPI project boundary area.

Landuse Type for Determining Irrigation Runoff

Landuse type for each individual parcel was determined using the landuse map created from the DWR land use survey as well as the NASS. Certain crops and landuse types were associated with having no irrigation runoff (refer to **Table 4**). For any orchard or vineyards, it is assumed that drip/microspray irrigation system as used to apply water to the crop and therefore produces no irrigation runoff.

Table 4. Landuse types associated with no irrigation runoff

Landuse Types Associated with No Irrigation Runoff		
Orchards/Vineyards	**Urban**	**Other**
Cherries	Developed – Open Space	Forest
Peaches	Developed – Low Intensity	Shrubland
Apples	Developed – Medium Intensity	Barren
Grapes	Developed – High Intensity	Non-Agriculture
Other Tree Crops		Deciduous Forest
Citrus		Evergreen Forest
Pecans		Mixed Forest
Almonds		Grassland Herbaceous
Walnuts		Fallow/Idle Cropland
Pears		Woody Wetlands
Pistachios		Herbaceous Wetlands
Prunes		
Oranges		
Pomegranates		

Irrigation Method for Determining Irrigation Runoff

The irrigation method for each individual parcel was determined from the DWR land use survey conducted in 2002 for Merced County. The following irrigation methods were assumed to have no irrigation runoff:

- Surface drip irrigation
- Buried drip irrigation (sub-surface drip irrigation)
- Microsprayer irrigation
- Center pivot sprinkler irrigation
- Linear mover sprinkler irrigation
- Non-irrigated fields

Estimated Irrigation Runoff

The following procedure was used to estimate the monthly irrigation runoff for each individual parcel:

1. If a single parcel had either a land use type **or** irrigation method associated with having no irrigation runoff (see previous sections), then it was assumed that no irrigation runoff would occur.

2. If the land use characteristic **<u>or</u>** irrigation method for an individual parcel did not match those stated in the previous sections, then it was assumed that irrigation runoff would occur. For example, a parcel irrigating corn using furrows would be assumed to have some amount of irrigation runoff.
3. For individual parcels assumed to have irrigation runoff occur, the runoff was estimated to be approximately 5% of the average monthly ET computed from METRIC for that specific parcel. For example, if the average monthly ET for a single parcel was 10 inches, the estimated irrigation runoff would be approximately 0.5 inches.

The reasoning behind the 5% of average monthly ET is based on the following reasons:

1. There is not an extensive drainage system throughout the MAGPI boundary to collect tail water runoff.
2. Farmers tend not to have any tail water runoff in their irrigation practices.
3. Some fields throughout the MAGPI boundary utilize tail water recovery systems.

Figure 20 below shows an example of the estimate July 2013 irrigation runoff for each individual parcel. The tan color indicated approximately zero irrigation runoff while the dark colored areas (blue being the darkest) indicating a higher amount of irrigation runoff (up to approximately 0.6 inches for this example).

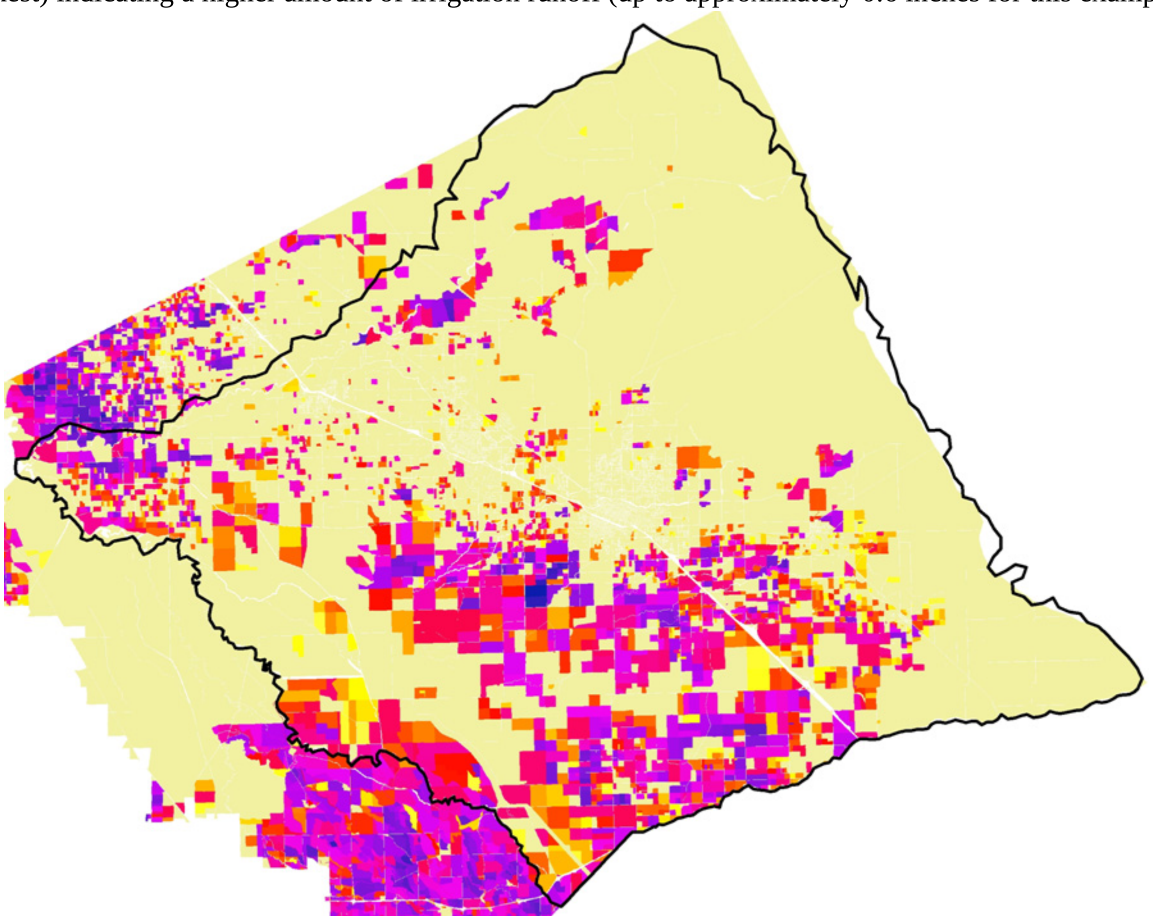


Figure 20. Example of estimate irrigation runoff for individual parcels in July 2013. The darker the color, the higher the irrigation runoff (up to approximately 0.6 inches of irrigation runoff for this example).

Non-Irrigation Runoff

The following procedure was used to estimate the non-irrigation runoff for individual parcels in the agricultural areas within the MAGPI boundary. Precipitation runoff in the urban areas was not considered for this study.

Soil Type Characterization for Individual Parcels

Soil characteristics for Merced County were obtained from the National Resources Conservation Service (NRCS) as seen in **Figure 21**.

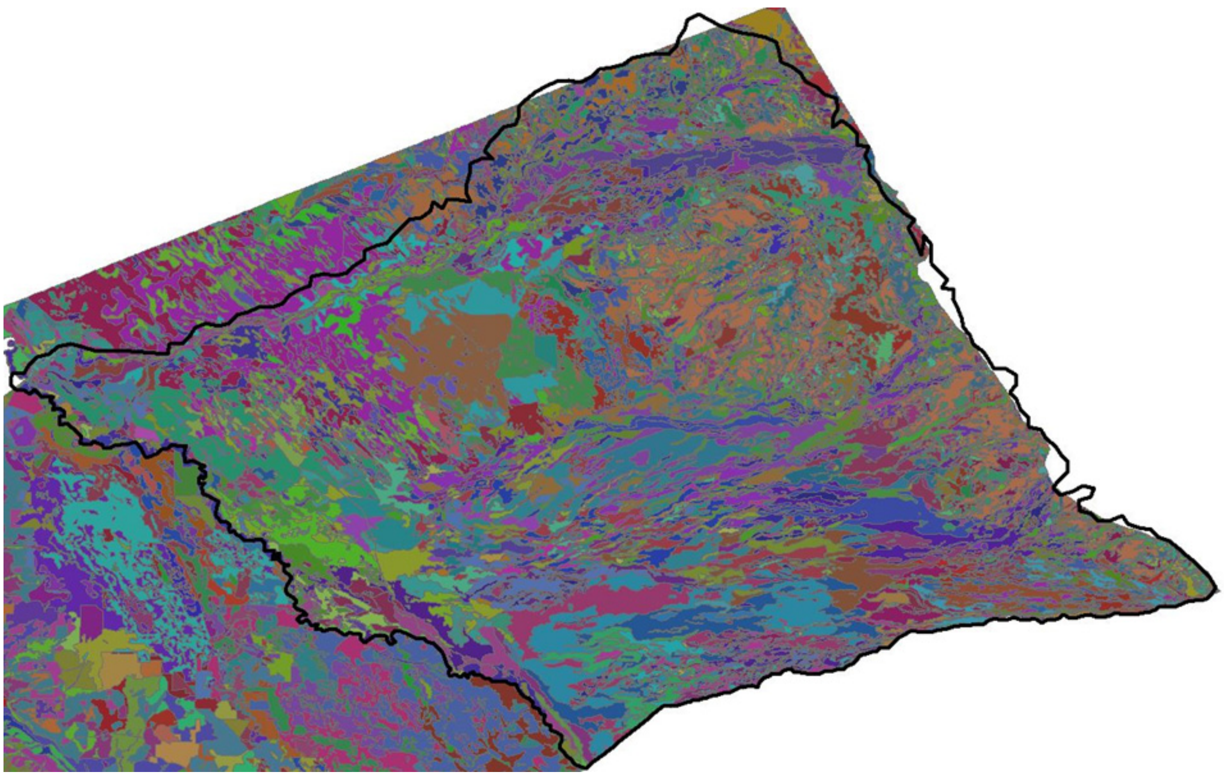


Figure 21. Example of Merced County soil types provided by the NRCS. Each color identifies a separate soil type.

The soil classification provide by the county were assigned a generic soil class types and soil group classification as following:

- Sand – Soil Group A
- Sandy Loam – Soil Group B
- Loam – Soil Group B
- Silt Loam – Soil Group C
- Clay Loam – Soil Group C
- Clay – Soil Group D

The soil types were reclassified for each individual parcel based on the majority of soil type located within each parcel. Each parcel was then assigned a uniform soil type. **Figure 22** shows the uniform soil types reclassified for each parcel to be used for the non-irrigation runoff estimates.

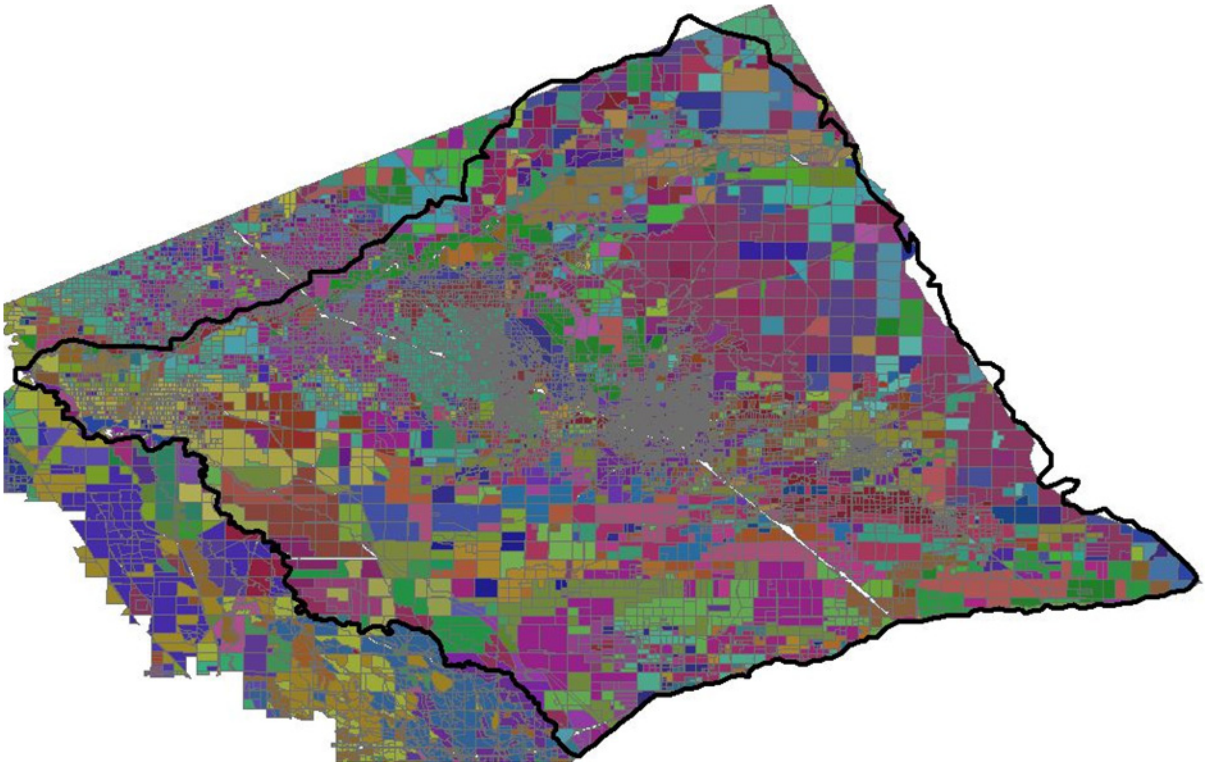


Figure 22. Reclassified soil type by parcel

NRCS (SCS) Rainfall Runoff Procedure for Non-Irrigation Runoff

The NRCS (SCS) rainfall runoff procedure was used to estimate the amount of monthly non-irrigation runoff from agricultural fields inside the MAGPI project boundary area due to precipitation.

Runoff due to precipitation can be estimated using the following equations:

$$P_e = \frac{(P - 0.2S)^2}{(P + 0.8S)}$$

$$S = \frac{1000}{CN} - 10$$

Where: P_e = direct runoff, inches
P = precipitation, inches
S = potential maximum retention
CN = runoff curve number

The precipitation input in the SCS runoff equation was based on daily precipitation totals from the two CIMIS weather stations. It was assumed that the precipitation totals were uniform across the entire project boundary. The curve number for each parcel was determined based on:

1. Assigned land use description (agricultural crop, fallow land, etc).
2. Hydrological soil group.

Table 5 shows the assigned SCS curve numbers used in the estimation of non-irrigation runoff of individual parcels. Runoff from urban areas was not considered in the estimates.

Table 5. Assigned SCS curve numbers for different land use and soil group descriptions

Assigned Curve Numbers for Different Land Use and Soil Group		
Land Use Description**	Soil Group	Curve Number
All agricultural crops – for cultivated agricultural land, row crops, straight rows, in good condition	A	67
	B	78
	C	85
	D	89
Fallow/idle cropland – for non-cultivated agricultural land, pasture or range, no mechanical treatment, in fair condition	A	49
	B	69
	C	79
	D	84
Grassland herbaceous – for non-cultivated agricultural land, forested, grass, in fair condition	A	44
	B	65
	C	76
	D	82
Shrubland – for non-cultivated land, forested, brush, in poor condition	A	48
	B	67
	C	77
	D	83

** Based on SCS Curve Number Descriptions

For small precipitation events, the SCS runoff equation would produce a runoff value greater than the amount of daily precipitation. The reason for this is because of the empirical characteristics for which the SCS runoff equation was produced. Therefore multiple quality control checks were performed on the calculated non-irrigation runoff estimates. The two quality control checks performed were as follows:

1. If the result of $\left[Precipitation - 0.2 \times \left(\frac{1000}{Curve\ No.} - 10\right)\right]$ is negative, then there is no runoff due to precipitation.
2. The amount of computed $Runoff\ must\ be \leq Precipitation.$

Only significant precipitation event with a total daily precipitation of approximately 0.4 inches or greater would produce any runoff amounts. The SCS runoff equation does take into account that a certain amount of precipitation must percolate into the soil before any runoff can occur. That is why only significant precipitation events produce runoff and account for the soil being fully saturated.

The daily runoff estimates were summarized into monthly runoff totals for each model year. **Figure 23** shows an example of the non-irrigation runoff computed for December 2002. The tan color indicated approximately zero non-irrigation runoff while the dark colored areas (blue being the darkest) indicating a higher amount of non-irrigation runoff (up to approximately 0.8 inches for this example).

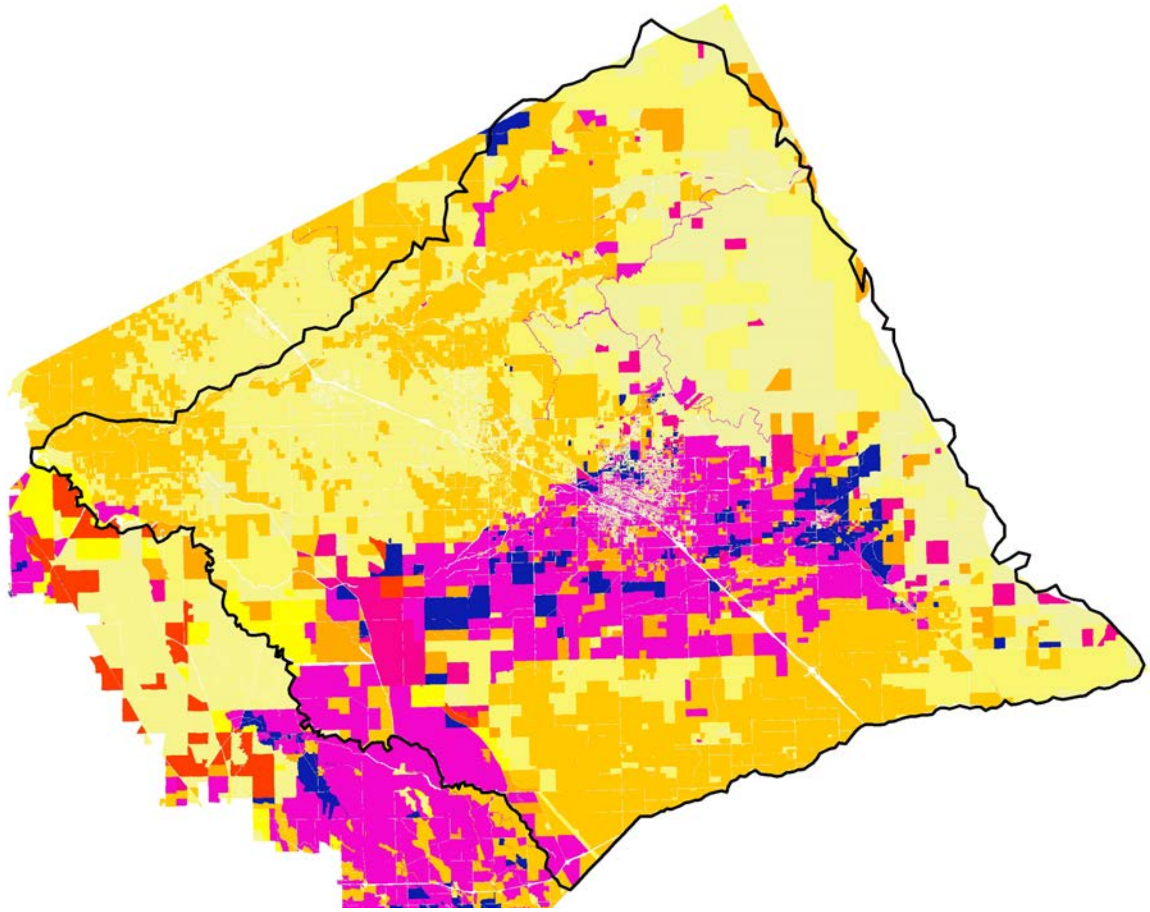


Figure 23. Example of estimate non-irrigation runoff for individual parcels in December 2002. The darker the color, the higher the non-irrigation runoff (up to approximately 0.8 inches of non-irrigation runoff for this example).

Soil Moisture Depletion

The soil's available water holding capacity (AWHC) in the crop root zone is needed to evaluate soil moisture depletion. The NRCS soils map for Merced County provides estimates of AWHC by soil type throughout the area of interest. The AWHC is provided as inches of water held at field capacity per inch of soil (inches/inch) for each soil horizon. A weighted average over the potential root zone was used to determine the root zone AWHC.

Root zones were assumed to be 5 feet for orchards, alfalfa, and vineyards, 3 feet for field crops, and 1.5 feet for natural vegetation. If an orchard or vineyard was irrigated using drip or microspray, the assumed wetted area was 60% of the total area, which reduces the AWHC by 40% for these irrigation methods. There was not a significant amount of buried row crop drip in the region during the analysis period.

The initial soil moisture depletions were estimated based on monthly rainfall in November and December prior to the year being analyzed. ET demand is low during these months and significant precipitation generally occurs in the area between November and February. If there was heavy rainfall during this period the SMD was assumed to be small. If there was little precipitation in the prior month the SMD was assumed to be large (approximately 50%-60% of the root zone AWHC). With average precipitation the SMD was assumed to be 20%-30% of the root zone AWHC.

The soil moisture depletion at the beginning of each month was applied to the procedure for estimating NTFGW as described.

Net To and From Groundwater Results

The resulting monthly *NTFGW* estimates (in inches) were created for each project years. **Figure 24** and **Figure 25** show examples of the computed *NTFGW* for February 2013 and July 2013 respectively.

From summer to fall, the applied water and ET are the driving factors for the *NTFGW* computations. Precipitation, irrigation runoff, and non-irrigation runoff have little to no impact during these months. On the contrary, during late fall through early spring months such as February 2013 (**Figure 24**), the precipitation and non-irrigation runoff become the driving factors. There is very little ET occurring during these months so depending on the monthly precipitation, there should be a slight to a significant contribution to the groundwater.

From the *NTFGW* result for July 2013, there is a apparent withdrawal from the ground water in the outside areas of the MAGPI boundary. No surface water is provided to those outside area and farmers are required to pump groundwater for irrigation. In the same image (**Figure 25**), there also appears to be a slight contribution to the groundwater from agricultural fields located within the MID boundary.

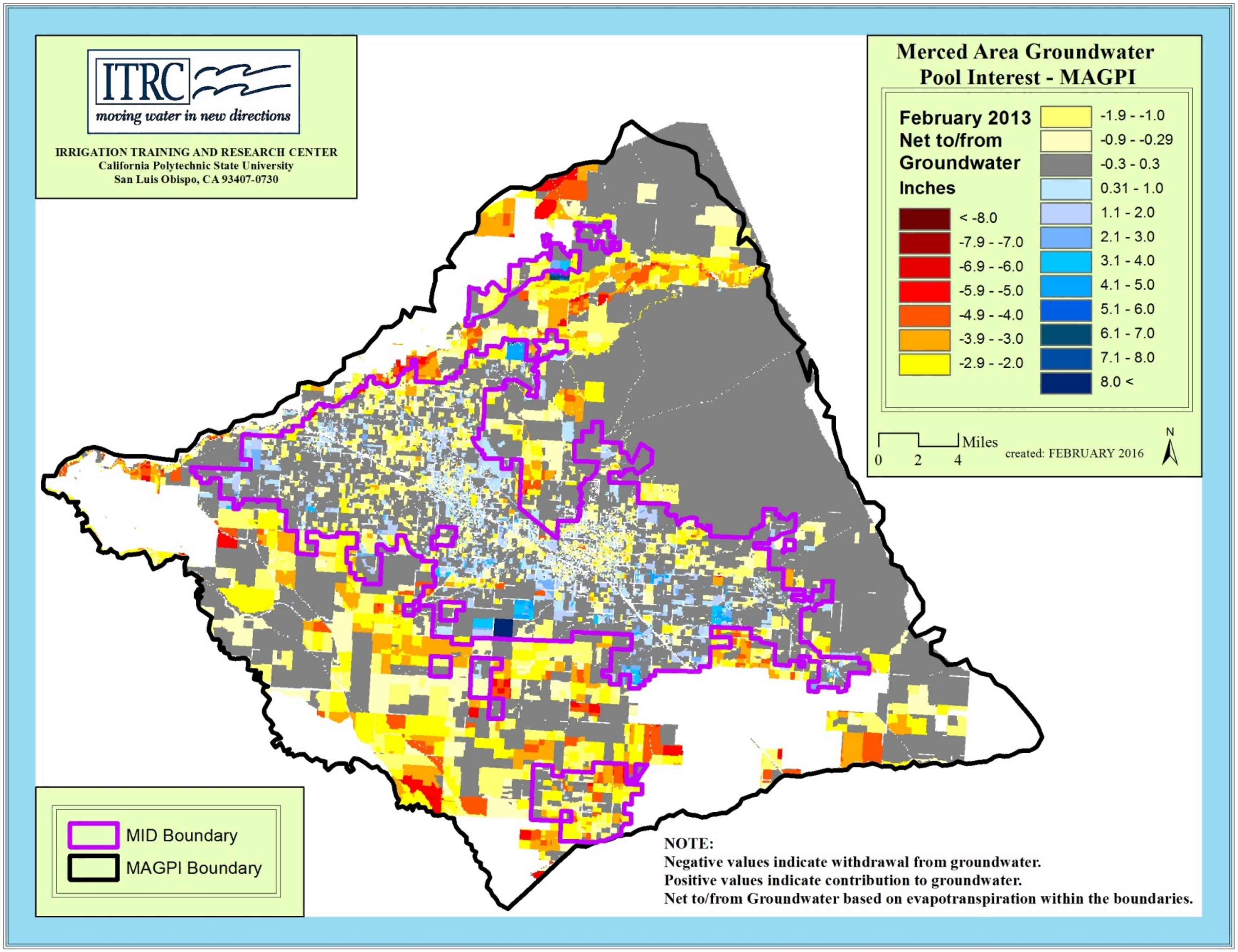


Figure 24. Estimated "Net To and From Groundwater" for February 2013

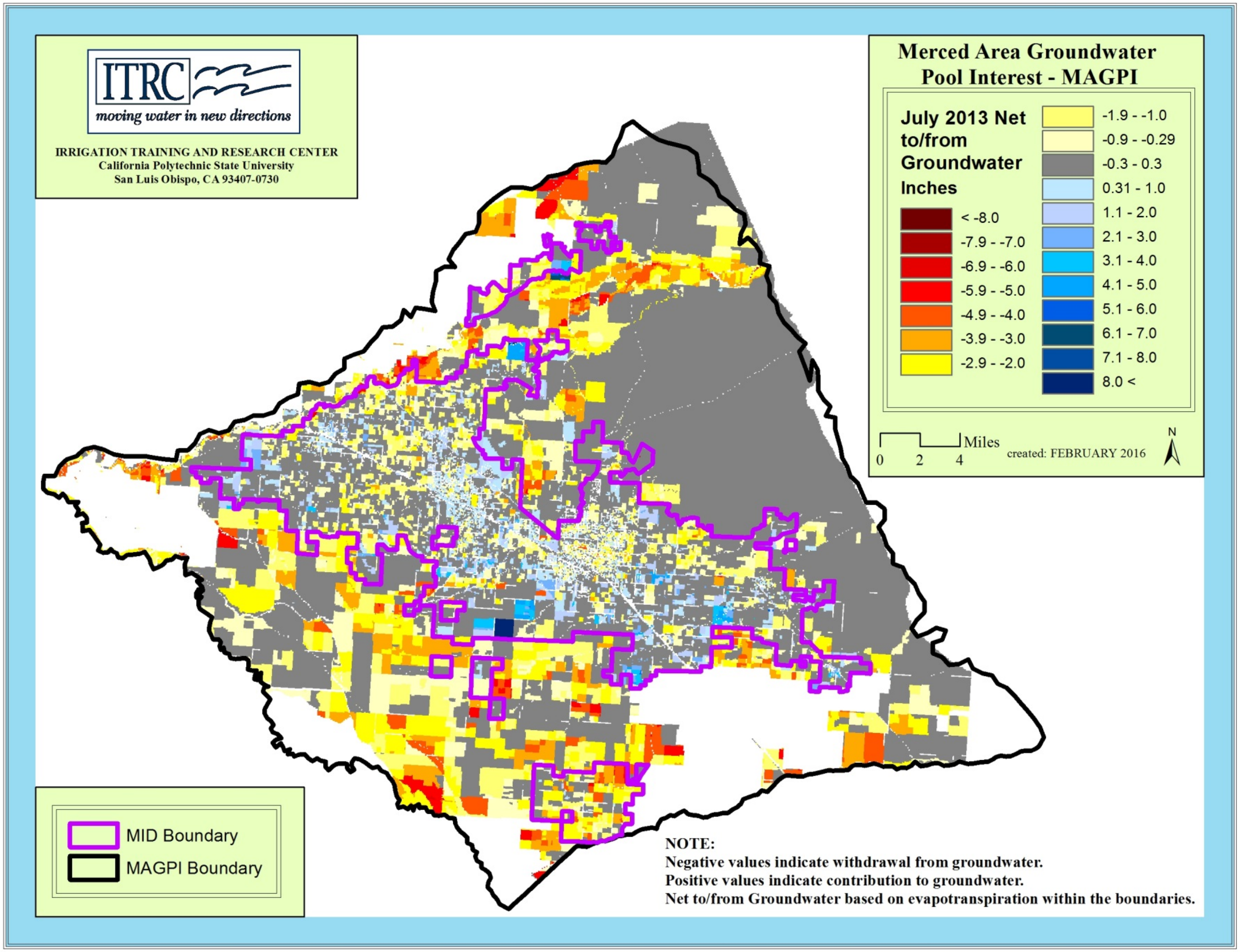


Figure 25. Estimated "Net To and From Groundwater" for July 2013

Missing Surface Water Data for Outside Areas

ITRC was not provided surface water deliveries data made by other irrigation and water districts such as Stevinson Water District or Turner Island Water District. Additionally, ITRC requested but did not receive water diversions from the Merced River north of Merced. Without knowing the amount of applied water in the other water purveyors, the *NTFGW* estimates would be inaccurate. For example, the *NTFGW* estimate would show a significant withdraw in groundwater in those areas when in reality there may only be a small amount of water withdrawn from the groundwater.

Therefore the boundary areas of other water purveyors (see **Figure 26**) were eliminated from the final *NTFGW* estimates.

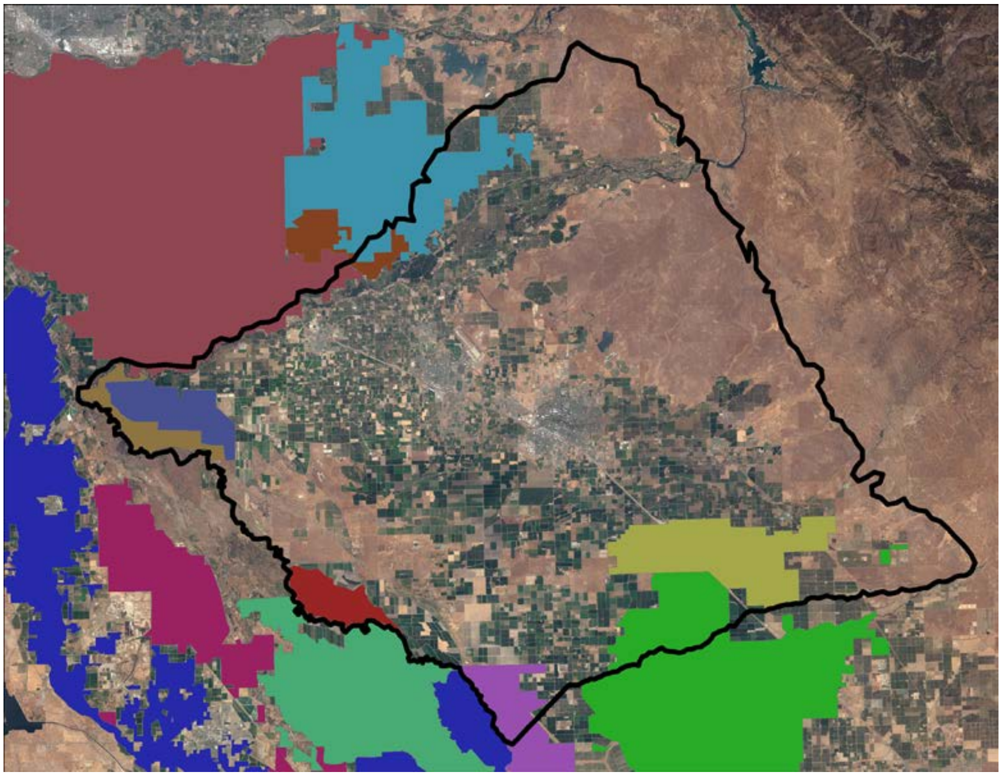
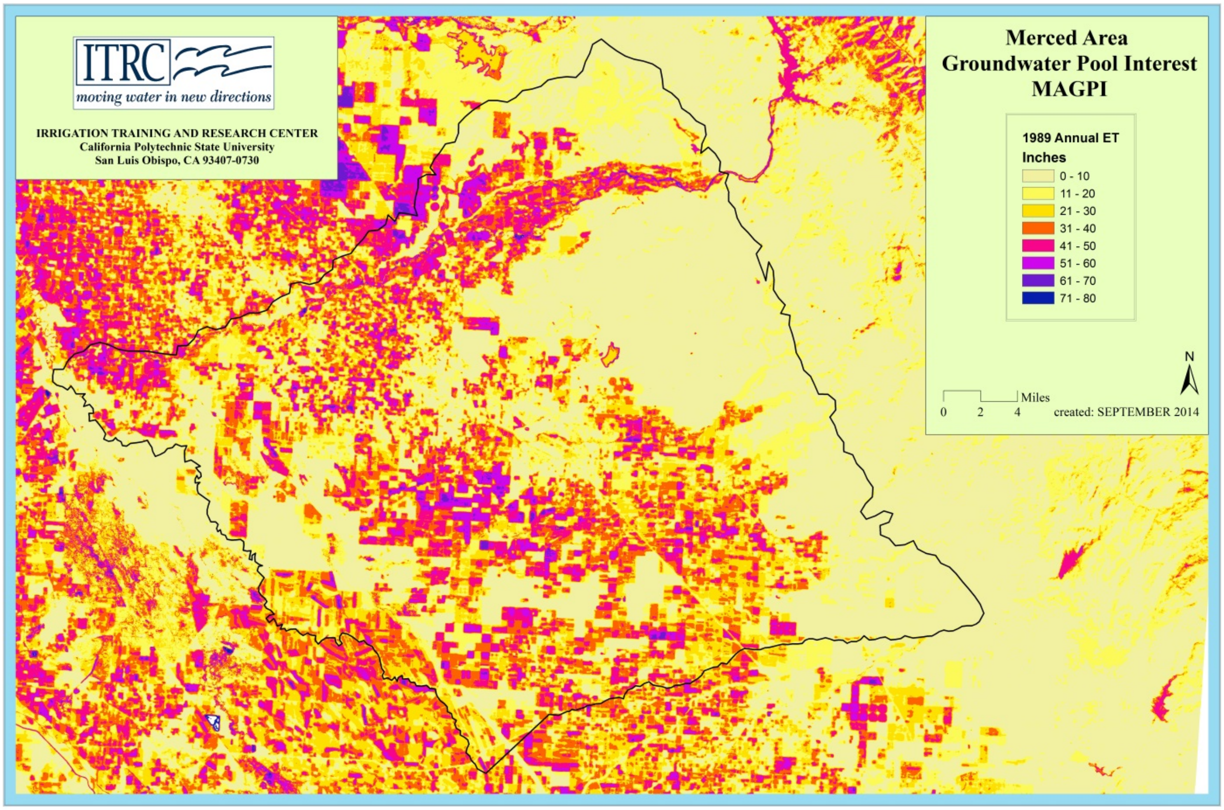
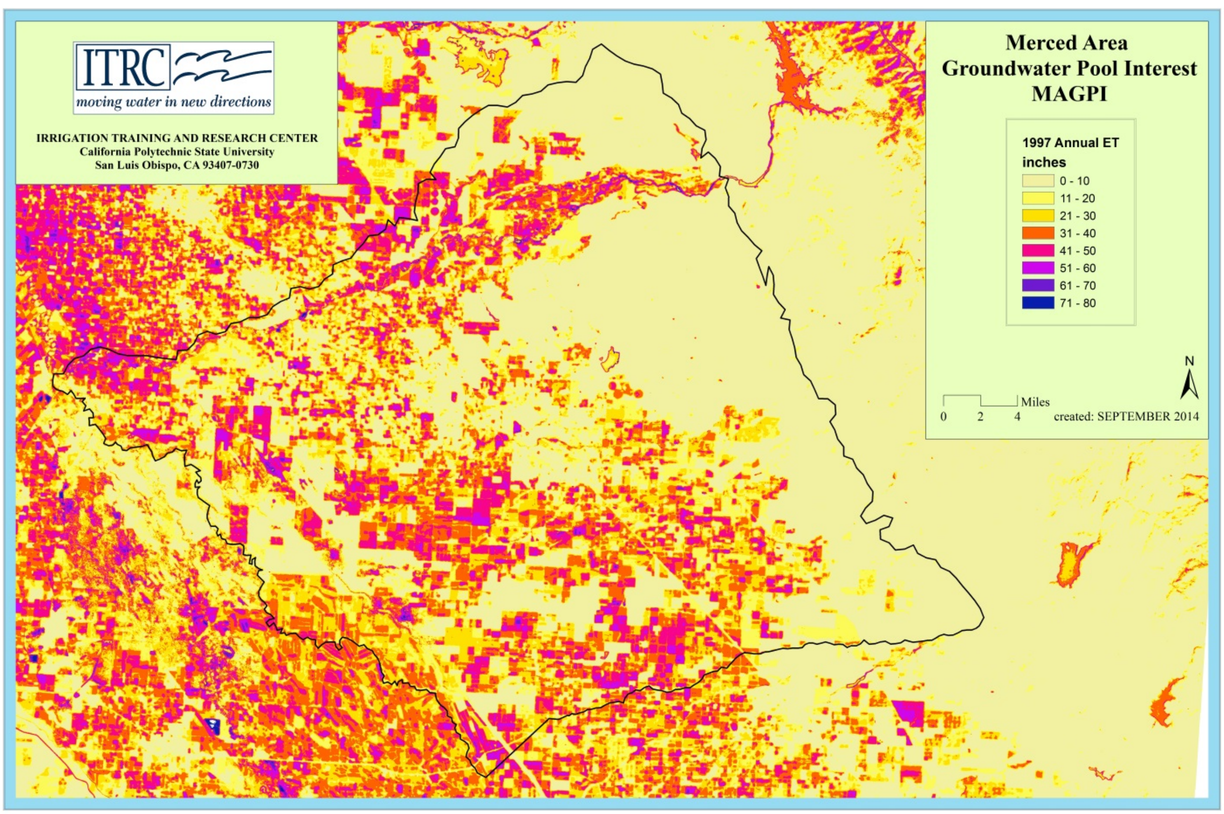
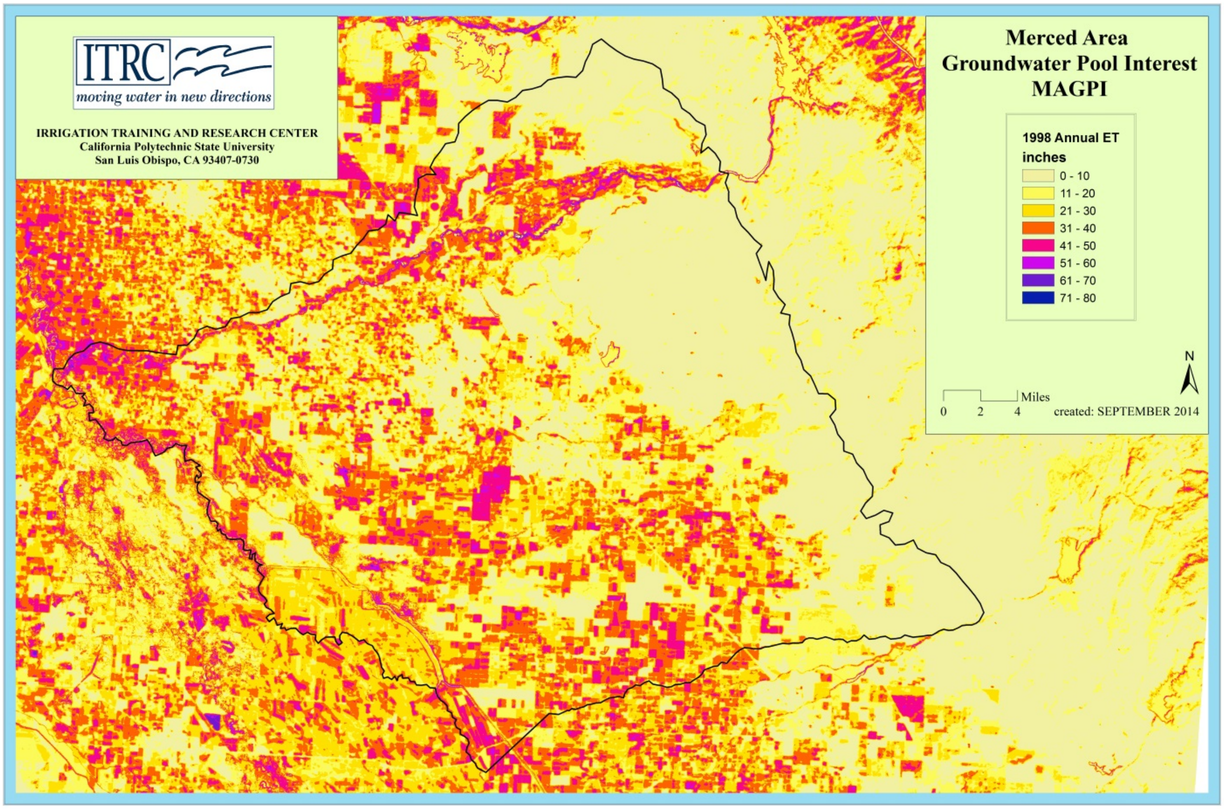


Figure 26. Additional water purveyors in and surrounding the MAGPI boundary for which no surface water data was provided

ATTACHMENT A
ITRC-METRIC Annual ETc Images


ITRC
moving water in new directions
IRRIGATION TRAINING AND RESEARCH CENTER
California Polytechnic State University
San Luis Obispo, CA 93407-0730
Merced Area
Groundwater Pool Interest
MAGPI
1989 Annual ET
Inches
0 - 10
11 - 20
21 - 30
31 - 40
41 - 50
51 - 60
61 - 70
71 - 80
N
Miles
0 2 4
created: SEPTEMBER 2014


ITRC
moving water in new directions
IRRIGATION TRAINING AND RESEARCH CENTER
California Polytechnic State University
San Luis Obispo, CA 93407-0730
Merced Area
Groundwater Pool Interest
MAGPI
1997 Annual ET
inches
0 - 10
11 - 20
21 - 30
31 - 40
41 - 50
51 - 60
61 - 70
71 - 80
N
Miles
0 2 4
created: SEPTEMBER 2014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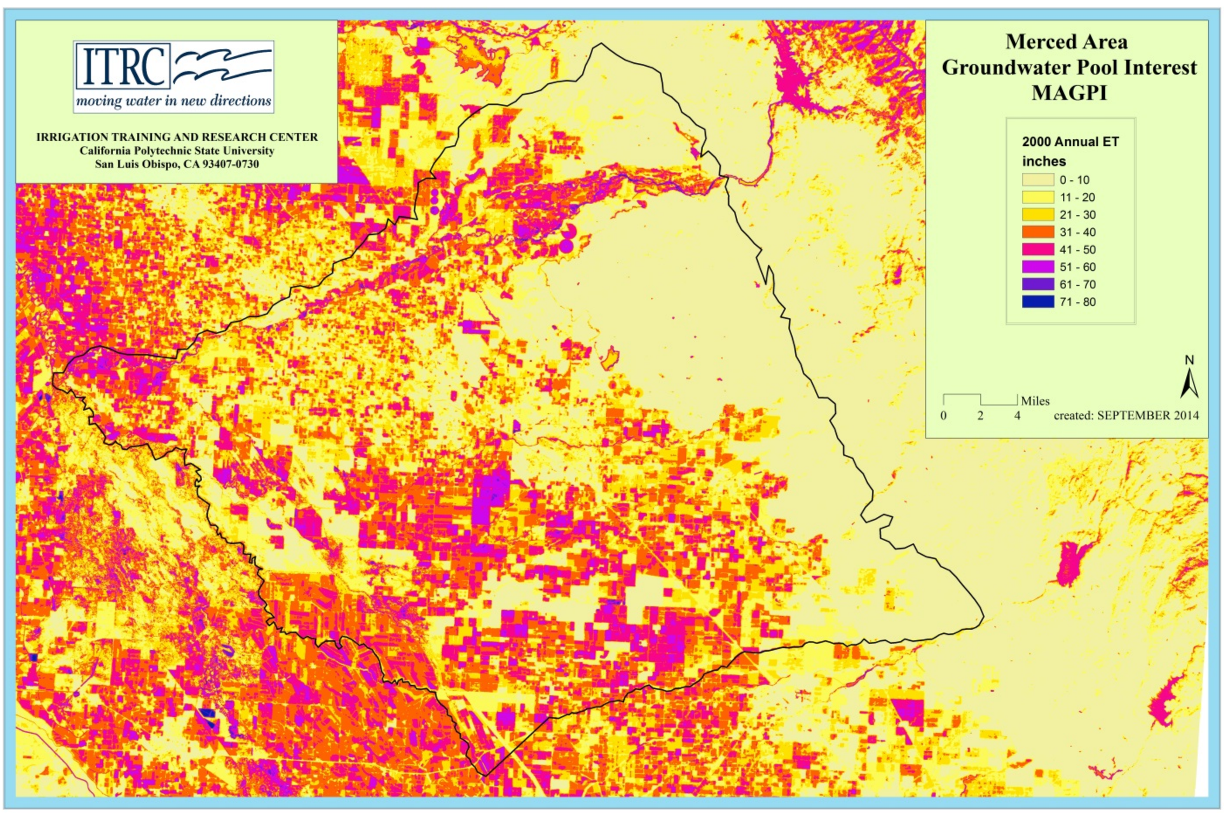
moving water in new directions
IRRIGATION TRAINING AND RESEARCH CENTER
California Polytechnic State University
San Luis Obispo, CA 93407-0730
Merced Area
Groundwater Pool Interest
MAGPI
1998 Annual ET
inches
0 - 10
11 - 20
21 - 30
31 - 40
41 - 50
51 - 60
61 - 70
71 - 80
N
Miles
0 2 4
created: SEPTEMBER 2014


ITRC
moving water in new directions
IRRIGATION TRAINING AND RESEARCH CENTER
California Polytechnic State University
San Luis Obispo, CA 93407-0730
Merced Area
Groundwater Pool Interest
MAGPI
2000 Annual ET
inches
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11 - 20
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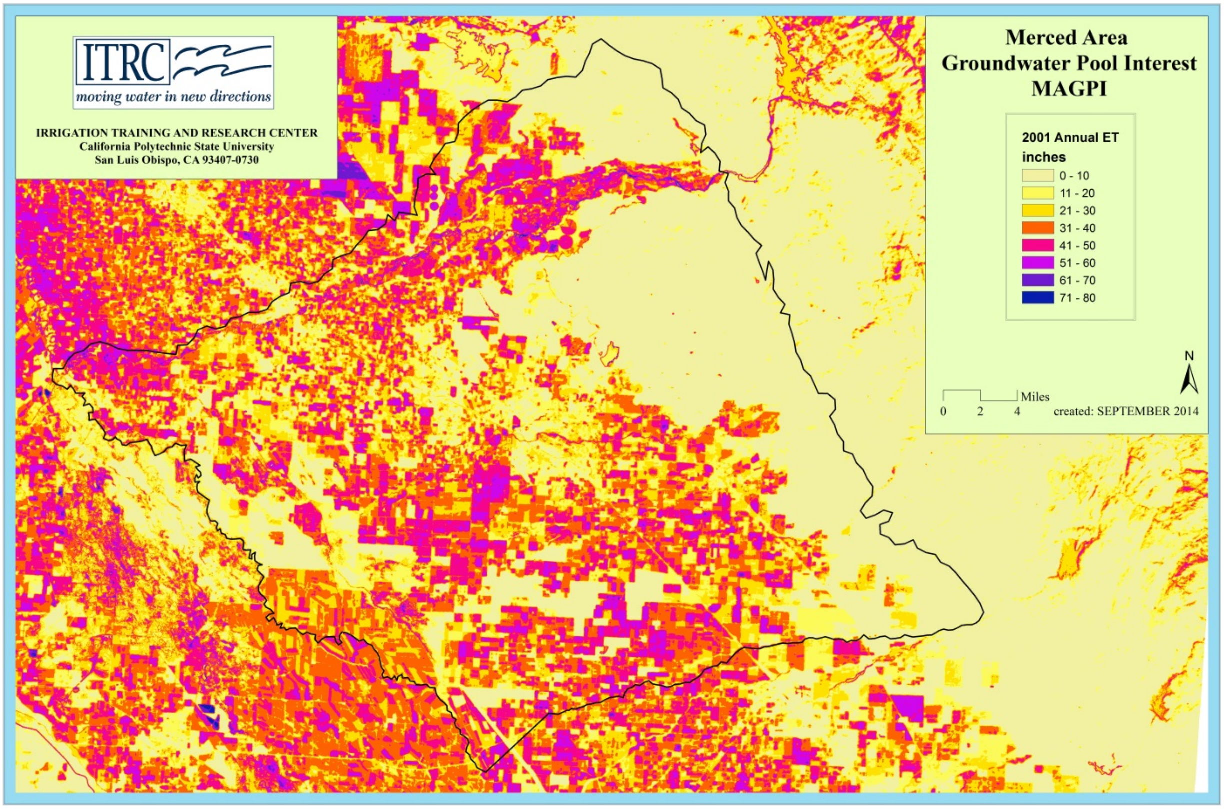
41 - 50
51 - 60
61 - 70
71 - 80
N
Miles
0 2 4
created: SEPTEMBER 2014


ITRC
moving water in new directions
IRRIGATION TRAINING AND RESEARCH CENTER
California Polytechnic State University
San Luis Obispo, CA 93407-0730
Merced Area
Groundwater Pool Interest
MAGPI
2001 Annual ET
inches
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11 - 20
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41 - 50
51 - 60
61 - 70
71 - 80
N
Miles
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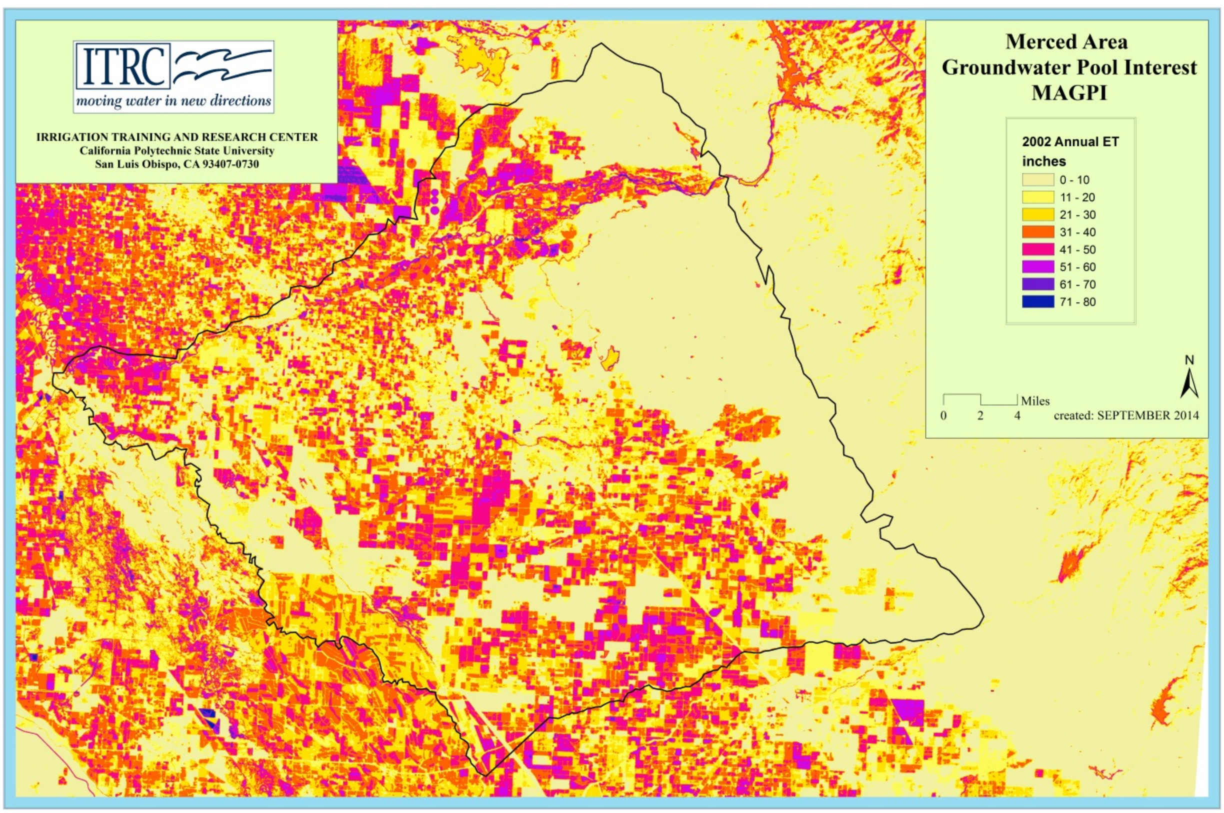
created: SEPTEMBER 2014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IRRIGATION TRAINING AND RESEARCH CENTER
California Polytechnic State University
San Luis Obispo, CA 93407-0730
Merced Area
Groundwater Pool Interest
MAGPI
2002 Annual ET
inches
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41 - 50
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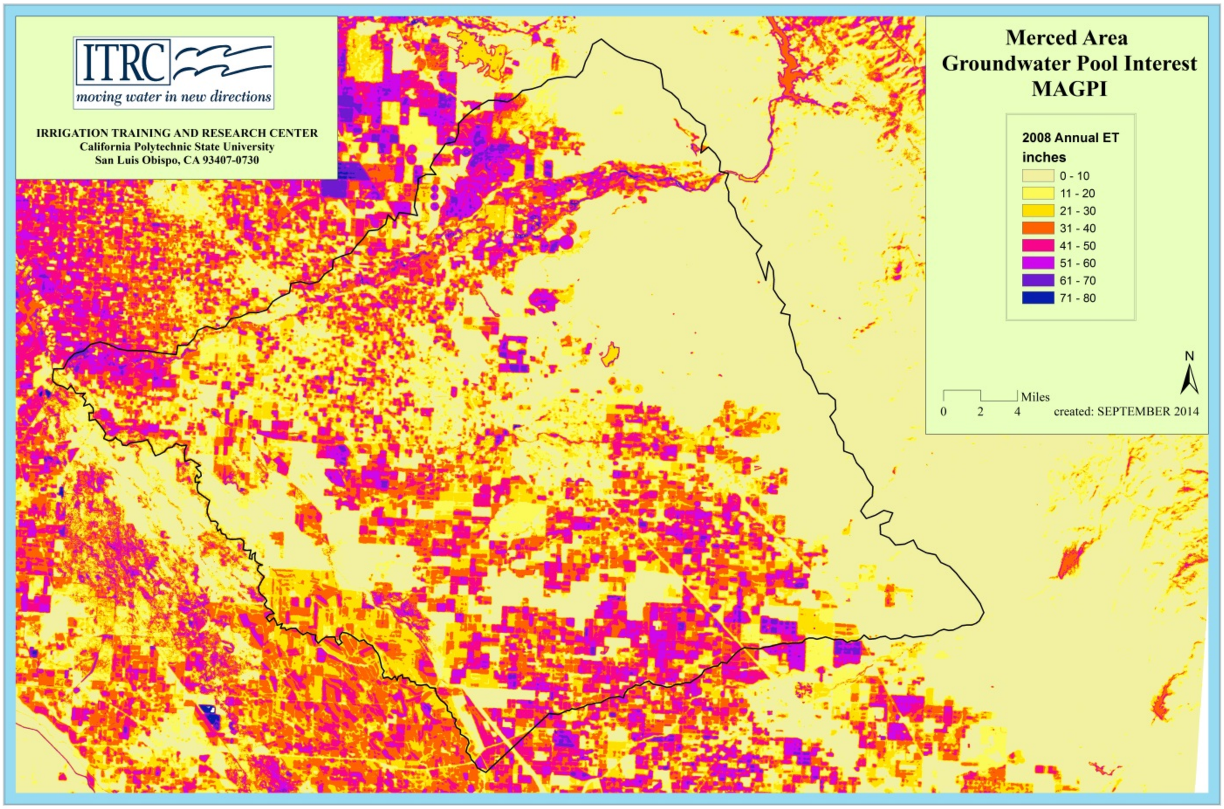
61 - 70
71 - 80
N
Miles
0 2 4
created: SEPTEMBER 2014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moving water in new directions
IRRIGATION TRAINING AND RESEARCH CENTER
California Polytechnic State University
San Luis Obispo, CA 93407-0730
Merced Area
Groundwater Pool Interest
MAGPI
2008 Annual ET
inches
0 - 10
11 - 20
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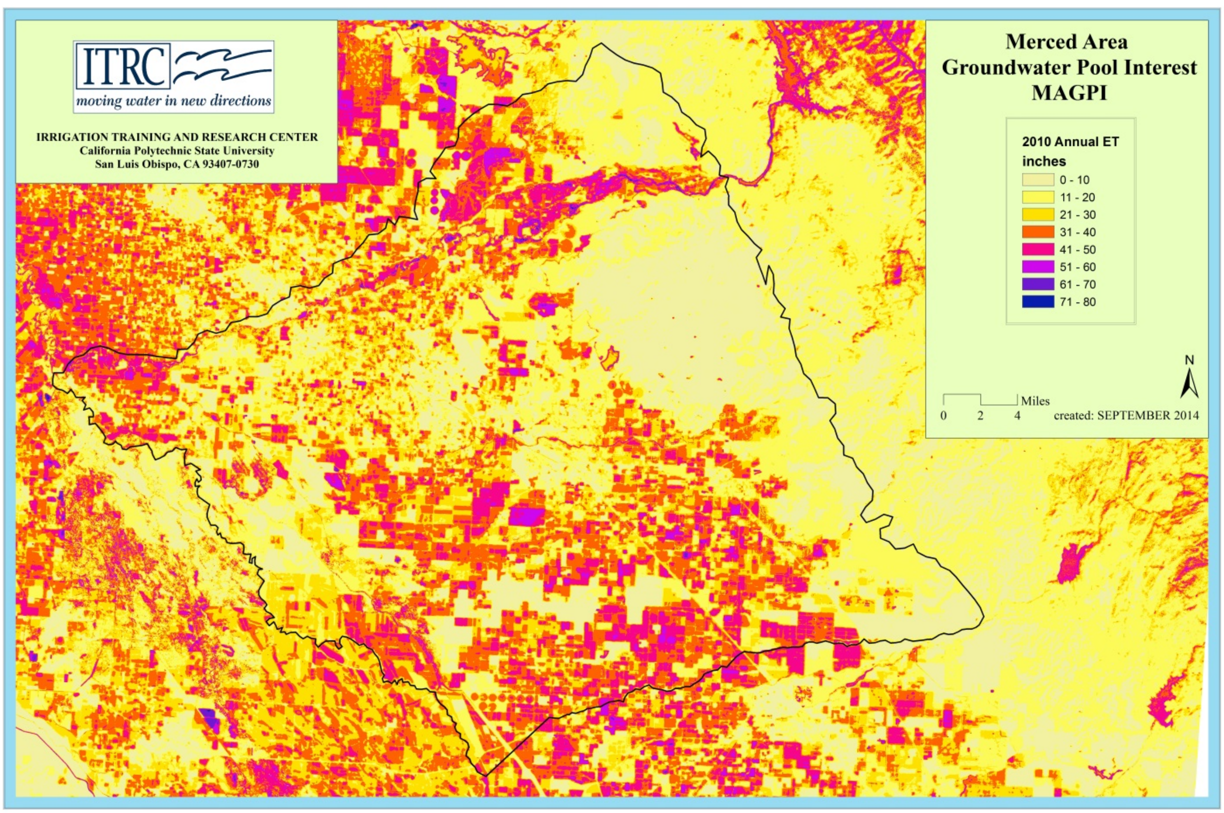
31 - 40
41 - 50
51 - 60
61 - 70
71 - 80
N
Miles
0 2 4
created: SEPTEMBER 2014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moving water in new directions
IRRIGATION TRAINING AND RESEARCH CENTER
California Polytechnic State University
San Luis Obispo, CA 93407-0730
Merced Area
Groundwater Pool Interest
MAGPI
2010 Annual ET
inches
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41 - 50
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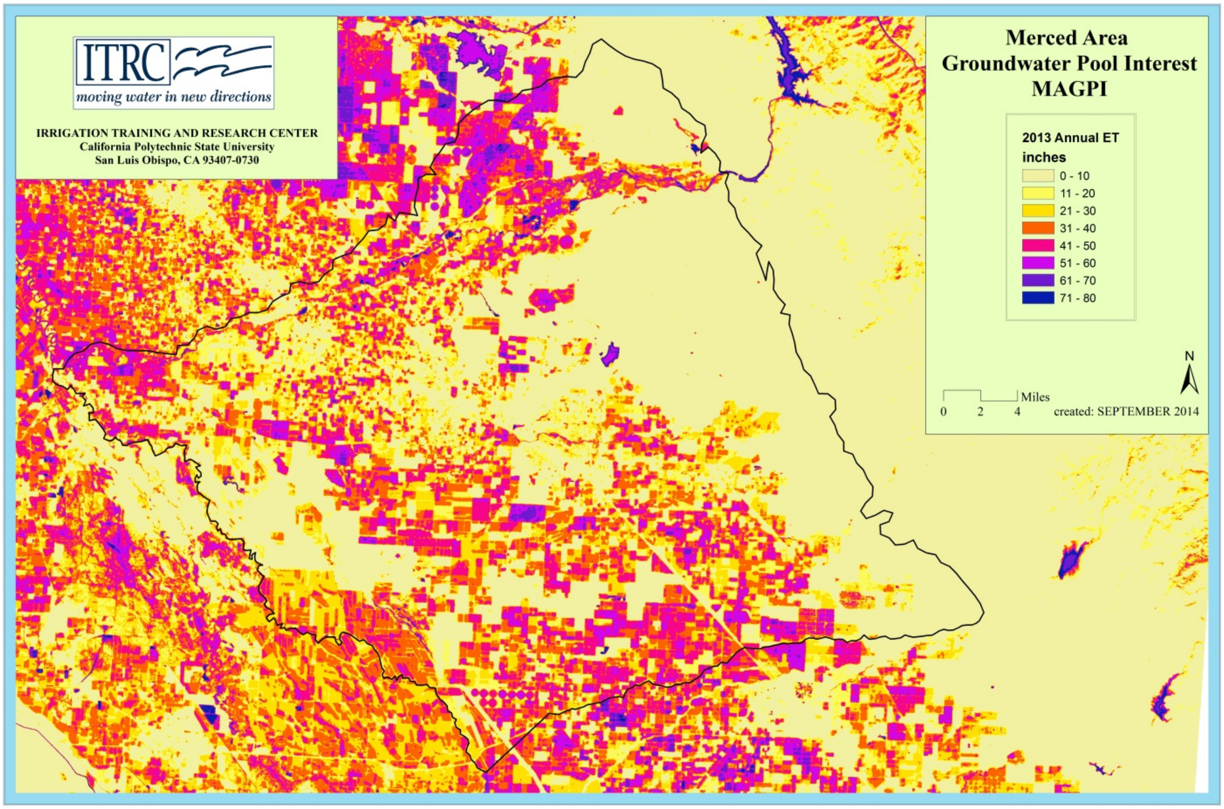
61 - 70
71 - 80
N
Miles
0 2 4
created: SEPTEMBER 2014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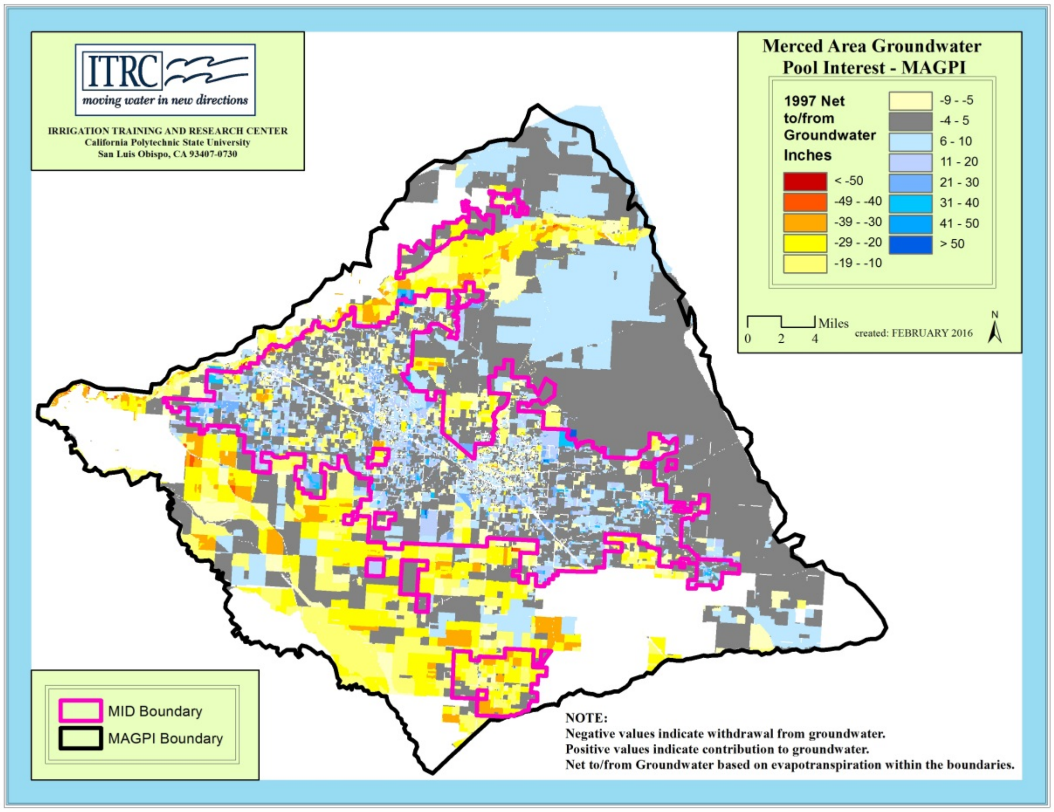
moving water in new directions
IRRIGATION TRAINING AND RESEARCH CENTER
California Polytechnic State University
San Luis Obispo, CA 93407-0730
Merced Area
Groundwater Pool Interest
MAGPI
2013 Annual ET
inches
0 - 10
11 - 20
21 - 30
31 - 40
41 - 50
51 - 60
61 - 70
71 - 80
N
Miles
0 2 4
created: SEPTEMBER 2014

ATTACHMENT B
NTFGW Annual Maps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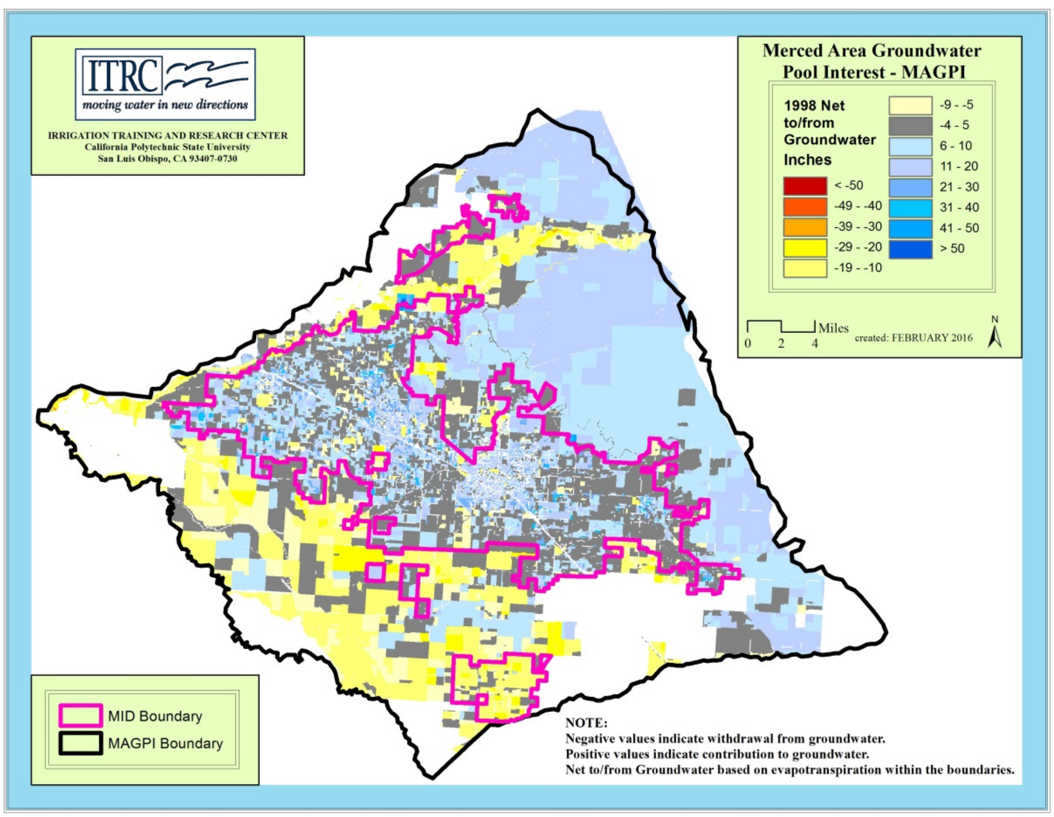
moving water in new directions
IRRIGATION TRAINING AND RESEARCH CENTER
California Polytechnic State University
San Luis Obispo, CA 93407-0730
Merced Area Groundwater Pool Interest - MAGPI
1997 Net to/from Groundwater Inches
< -50
-49 - -40
-39 - -30
-29 - -20
-19 - -10
-9 - -5
-4 - 5
6 - 10
11 - 20
21 - 30
31 - 40
41 - 50
> 50
Miles
0 2 4
created: FEBRUARY 2016
N
MID Boundary
MAGPI Boundary
NOTE:
Negative values indicate withdrawal from groundwater.
Positive values indicate contribution to groundwater.
Net to/from Groundwater based on evapotranspiration within the boundaries.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moving water in new directions
IRRIGATION TRAINING AND RESEARCH CENTER
California Polytechnic State University
San Luis Obispo, CA 93407-0730
Merced Area Groundwater Pool Interest - MAGPI
1998 Net to/from Groundwater Inches
< -50
-49 - -40
-39 - -30
-29 - -20
-19 - -10
-9 - -5
-4 - 5
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21 - 30
31 - 40
41 - 50
> 50
Miles
0 2 4
created: FEBRUARY 2016
N
MID Boundary
MAGPI Boundary
NOTE:
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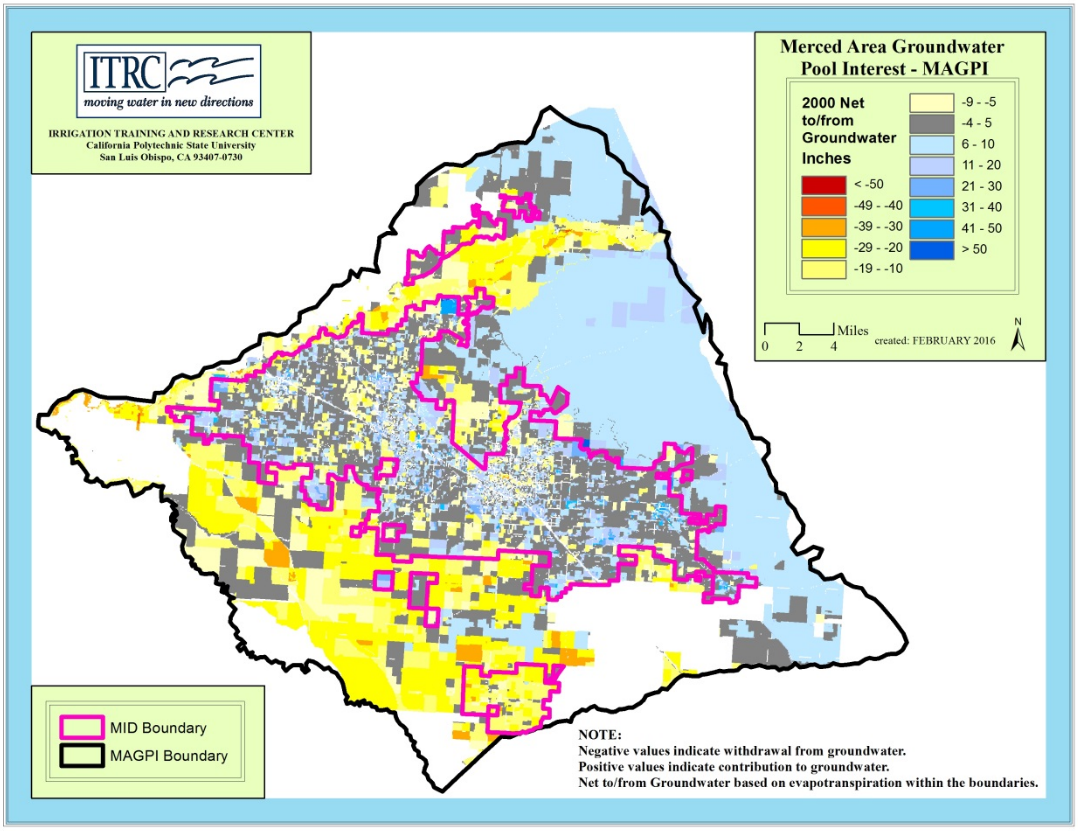
Net to/from Groundwater based on evapotranspiration within the boundaries.


ITRC
moving water in new directions
IRRIGATION TRAINING AND RESEARCH CENTER
California Polytechnic State University
San Luis Obispo, CA 93407-0730
Merced Area Groundwater Pool Interest - MAGPI
2000 Net to/from Groundwater Inches
< -50
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-19 - -10
-9 - -5
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21 - 30
31 - 40
41 - 50
> 50
Miles
0 2 4
created: FEBRUARY 2016
N
MID Boundary
MAGPI Boundary
NOTE:
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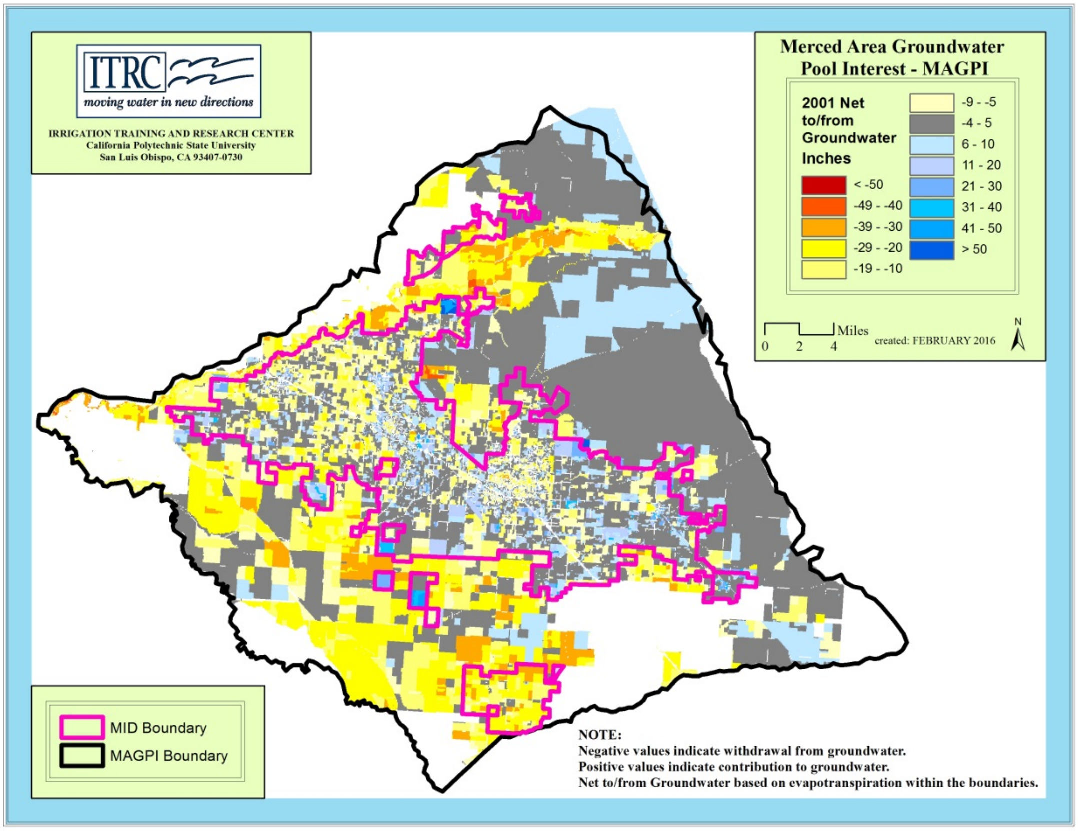
Net to/from Groundwater based on evapotranspiration within the boundaries.


ITRC
moving water in new directions
IRRIGATION TRAINING AND RESEARCH CENTER
California Polytechnic State University
San Luis Obispo, CA 93407-0730
Merced Area Groundwater Pool Interest - MAGPI
2001 Net to/from Groundwater Inches
< -50
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41 - 50
> 50
Miles
0 2 4
created: FEBRUARY 2016
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MAGPI Boundary
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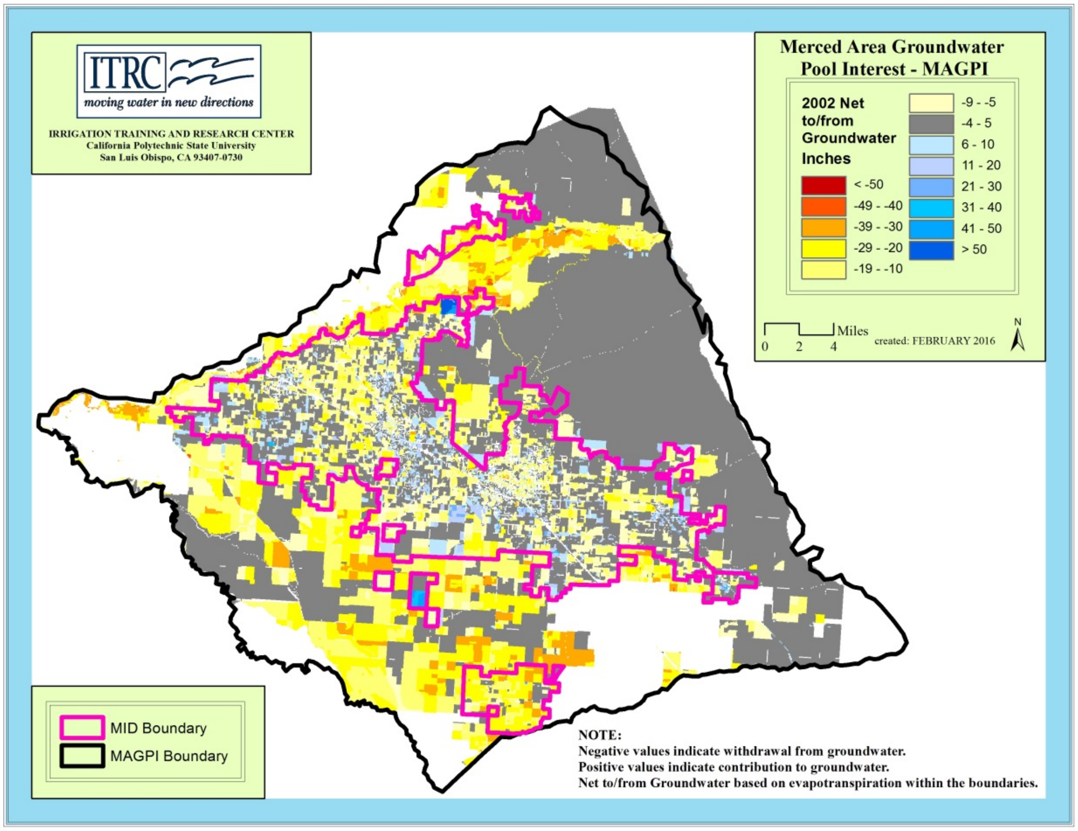
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moving water in new directions
IRRIGATION TRAINING AND RESEARCH CENTER
California Polytechnic State University
San Luis Obispo, CA 93407-0730
Merced Area Groundwater Pool Interest - MAGPI
2002 Net to/from Groundwater Inches
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41 - 50
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Miles
0 2 4
created: FEBRUARY 2016
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MAGPI Boundary
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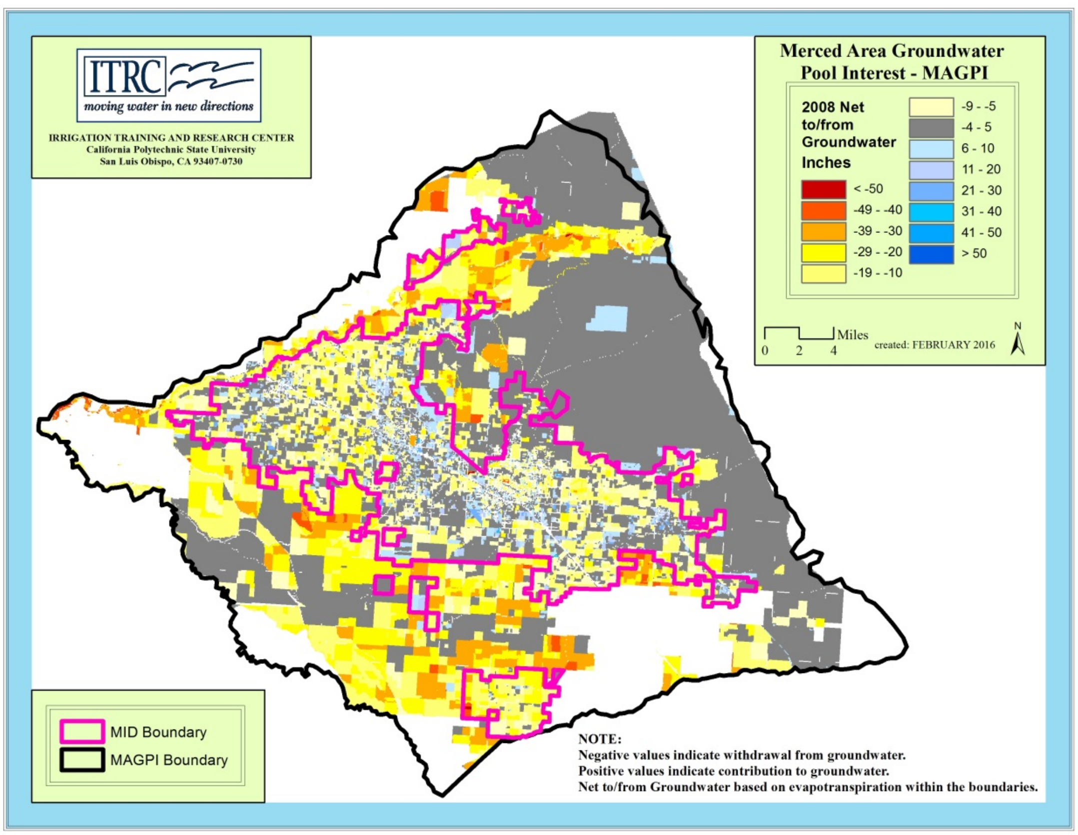
Net to/from Groundwater based on evapotranspiration within the boundaries.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moving water in new directions
IRRIGATION TRAINING AND RESEARCH CENTER
California Polytechnic State University
San Luis Obispo, CA 93407-0730
Merced Area Groundwater Pool Interest - MAGPI
2008 Net to/from Groundwater Inches
< -50
-49 - -40
-39 - -30
-29 - -20
-19 - -10
-9 - -5
-4 - 5
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11 - 20
21 - 30
31 - 40
41 - 50
> 50
Miles
0 2 4
created: FEBRUARY 2016
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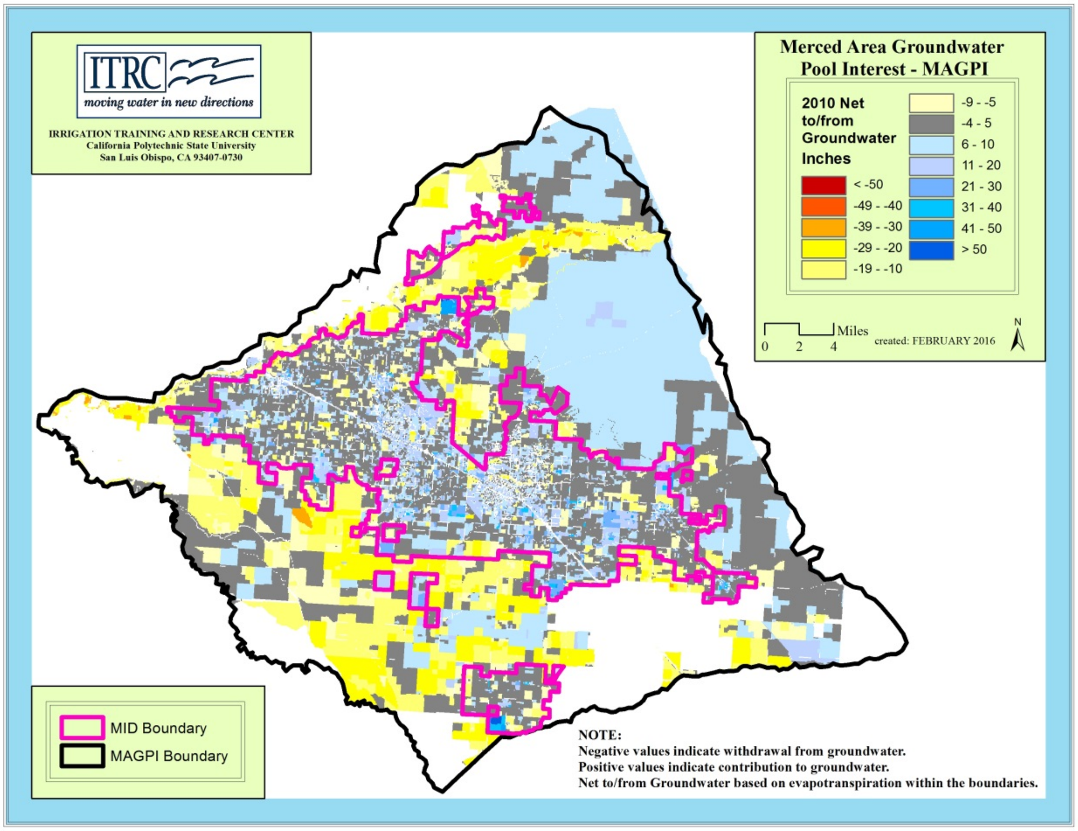
Net to/from Groundwater based on evapotranspiration within the boundaries.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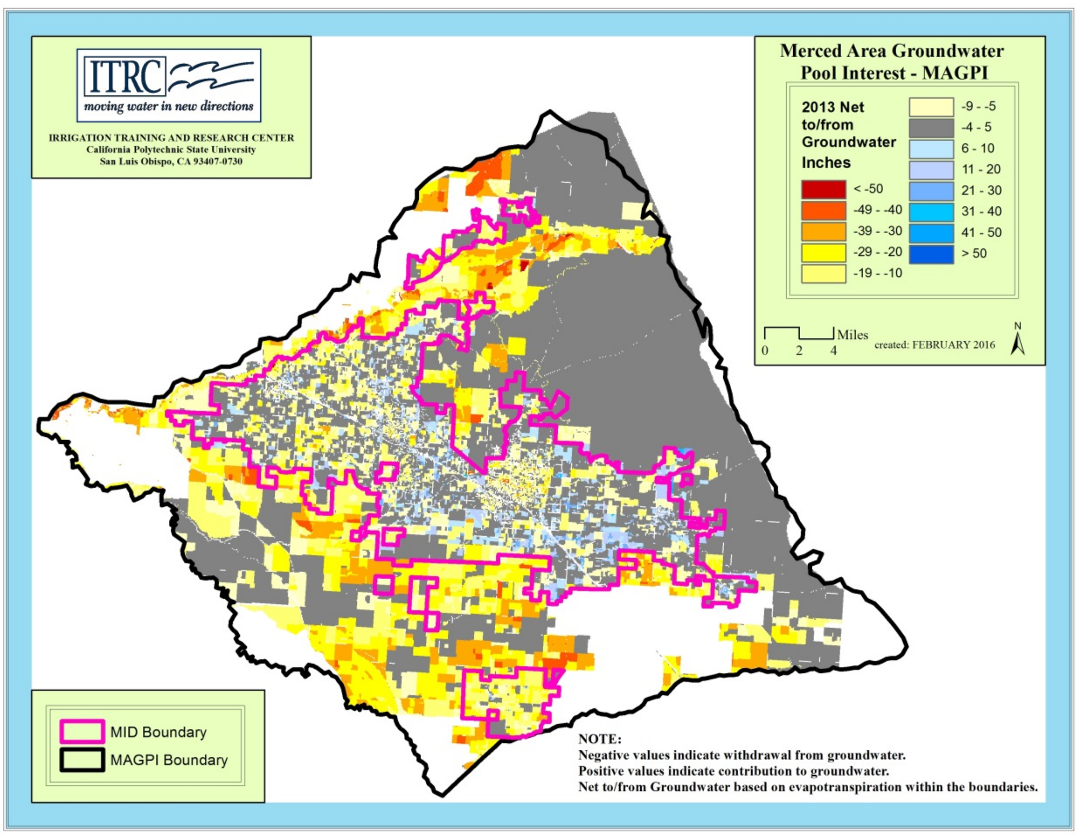
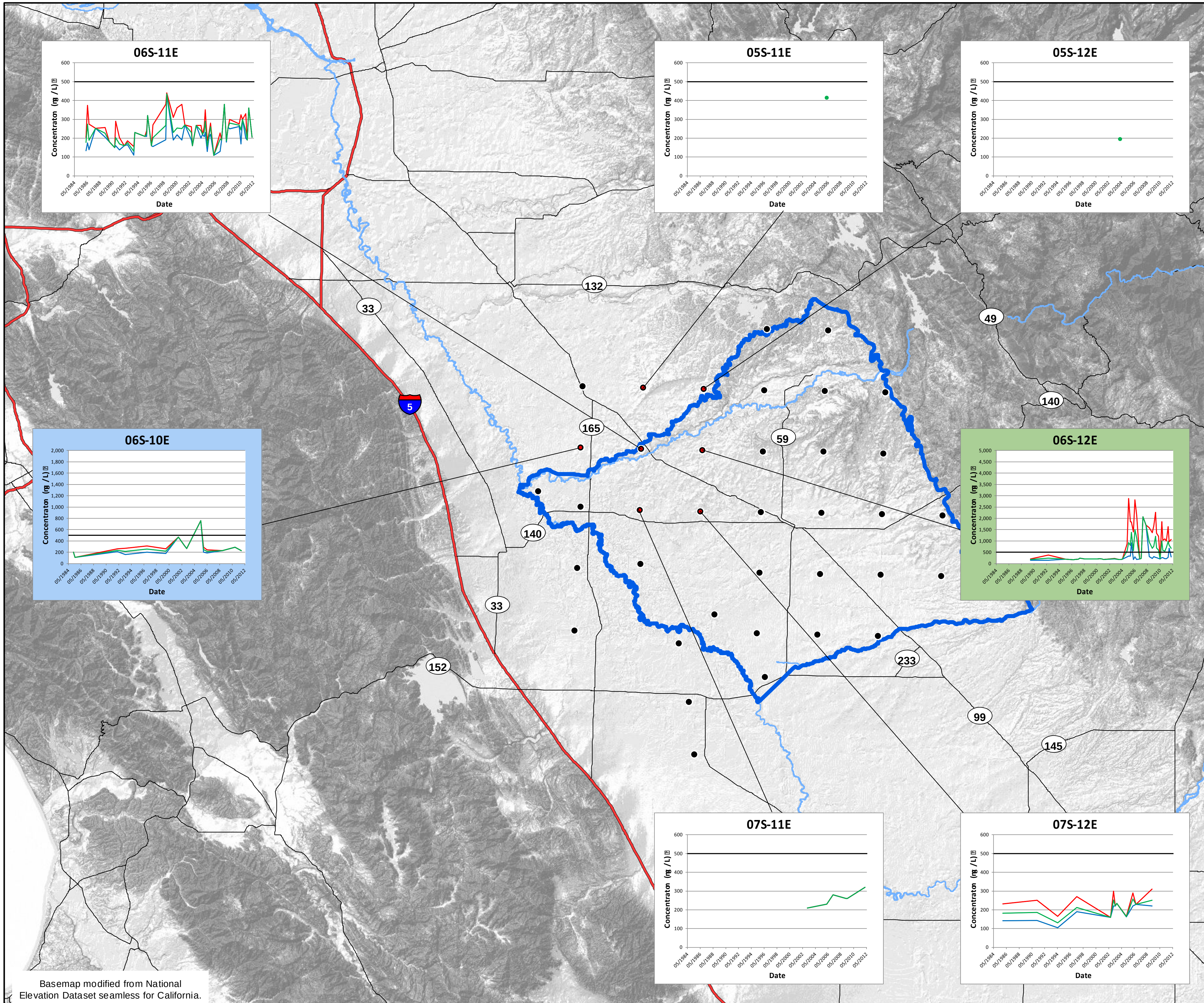
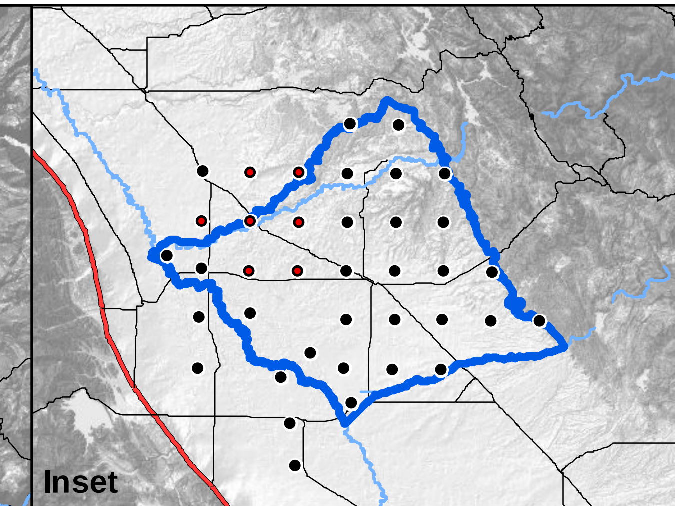
moving water in new directions
IRRIGATION TRAINING AND RESEARCH CENTER
California Polytechnic State University
San Luis Obispo, CA 93407-0730
Merced Area Groundwater Pool Interest - MAGPI
2010 Net to/from Groundwater Inches
< -50
-49 - -40
-39 - -30
-29 - -20
-19 - -10
-9 - -5
-4 - 5
6 - 10
11 - 20
21 - 30
31 - 40
41 - 50
> 50
Miles
0 2 4
created: FEBRUARY 2016
N
MID Boundary
MAGPI Boundary
NOTE:
Negative values indicate withdrawal from groundwater.
Positive values indicate contribution to groundwater.
Net to/from Groundwater based on evapotranspiration within the boundaries.


ITRC
moving water in new directions
IRRIGATION TRAINING AND RESEARCH CENTER
California Polytechnic State University
San Luis Obispo, CA 93407-0730
Merced Area Groundwater Pool Interest - MAGPI
2013 Net to/from Groundwater Inches
< -50
-49 - -40
-39 - -30
-29 - -20
-19 - -10
-9 - -5
-4 - 5
6 - 10
11 - 20
21 - 30
31 - 40
41 - 50
> 50
Miles
0 2 4
created: FEBRUARY 2016
N
MID Boundary
MAGPI Boundary
NOTE:
Negative values indicate withdrawal from groundwater.
Positive values indicate contribution to groundwater.
Net to/from Groundwater based on evapotranspiration within the boundaries.

ATTACHMENT C

APPENDIX E: WATER QUALITY CONSTITUENT CONCENTRATION PLOTS





Explanation:

- Township/Range centroid
- Surface water feature
- Merced IRWM area

Concentration Charts:

- Minimum TDS concentration
- Mean TDS concentration
- Maximum TDS concentration
- Rec. SMCL for TDS (500 mg/l)

Notes:

1. IRWMP = Integrated Regional Water Management Plan
2. Total dissolved solids (TDS) concentrations shown in milligrams per liter (mg/L).
3. Secondary Maximum Contaminant Level (SMCL) as established by the California Department of Public Heath
4. Background color on graphs represent the y-axis range as follows:

White: 0- 600 mg/L
Blue: 0- 2,000 mg/L
Green: 0- 5,000 mg/L

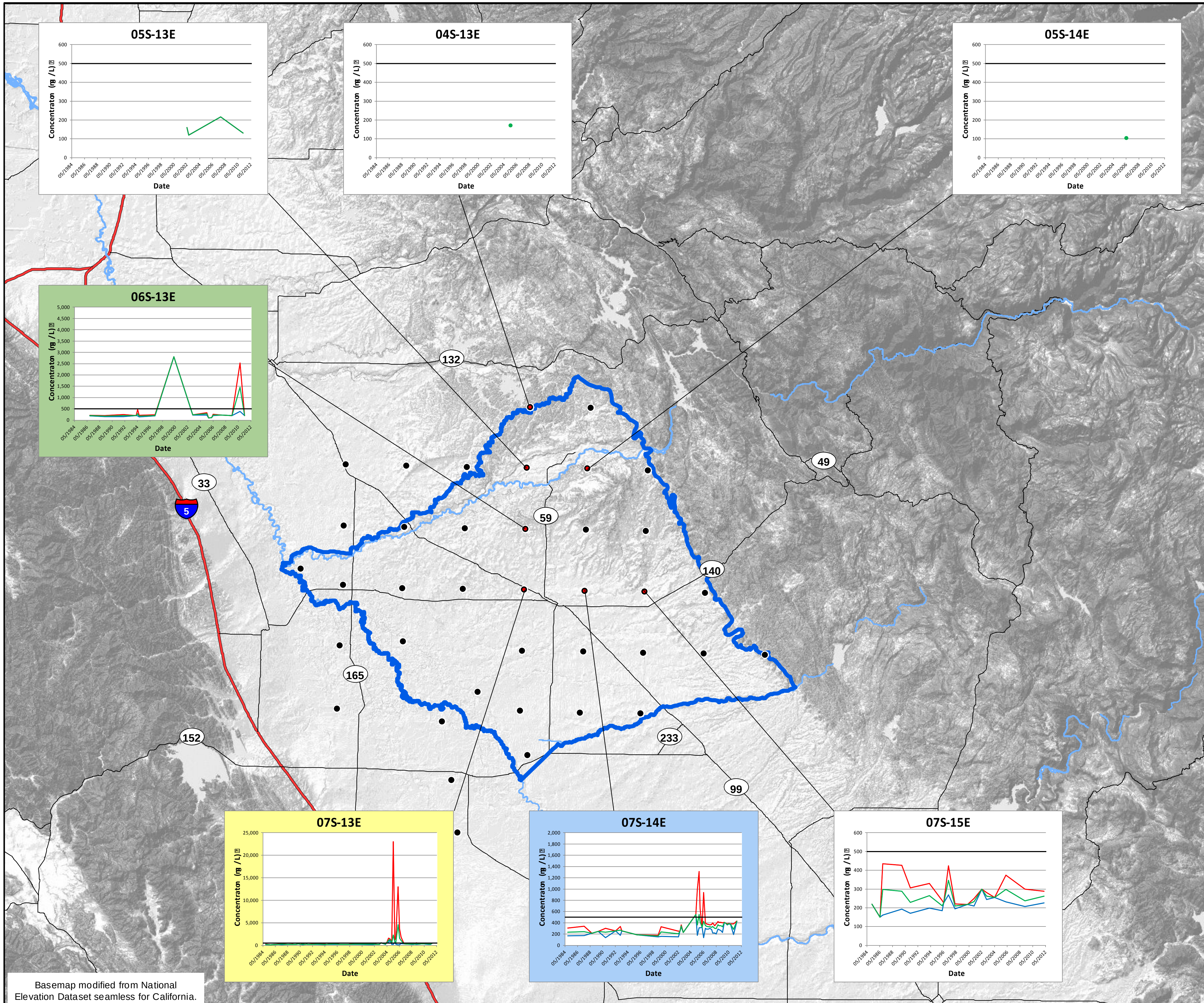
N

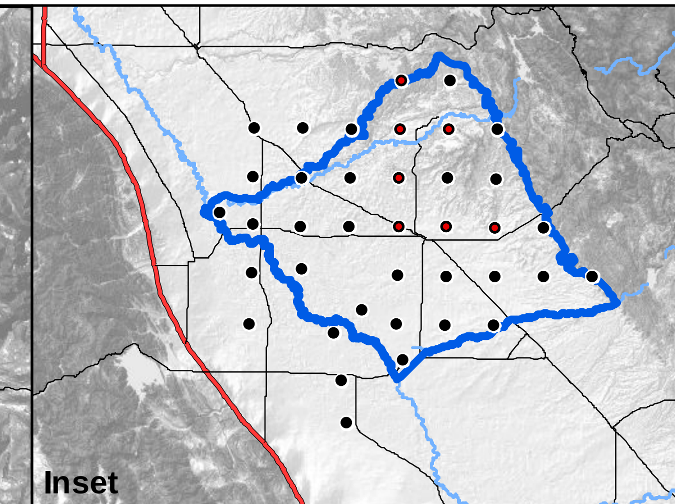
0 5 10
APPROXIMATE SCALE IN MILES

TOTAL DISSOLVED SOLIDS (TDS)
CONCENTRATIONS
1984 THROUGH 2012
Merced IRWMP
Merced County, California

By: DB	Date: 01/08/2013	Project No. FR1216040A
		Figure 1a

N:_FR_projects\FR12s\FR1216040A\gis\maps\2013_01\ConcentrationMaps_fig01a_TDS.mxd





Explanation:

- Township/Range centroid
- Surface water feature
- Merced IRWM area

Concentration Charts:

- Minimum TDS concentration
- Mean TDS concentration
- Maximum TDS concentration
- Rec. SMCL for TDS (500 mg/l)

Notes:

1. IRWMP = Integrated Regional Water Management Plan.
2. Total dissolved solids (TDS) concentrations shown in milligrams per liter (mg/L).
3. Secondary Maximum Contaminant Level (SMCL) as established by the California Department of Public Heath
4. Background color on graphs represent the y-axis range as follows:

White: 0- 600 mg/L
Blue: 0- 2,000 mg/L
Green: 0- 5,000 mg/L
Yellow: 0- 25,000 mg/L

N

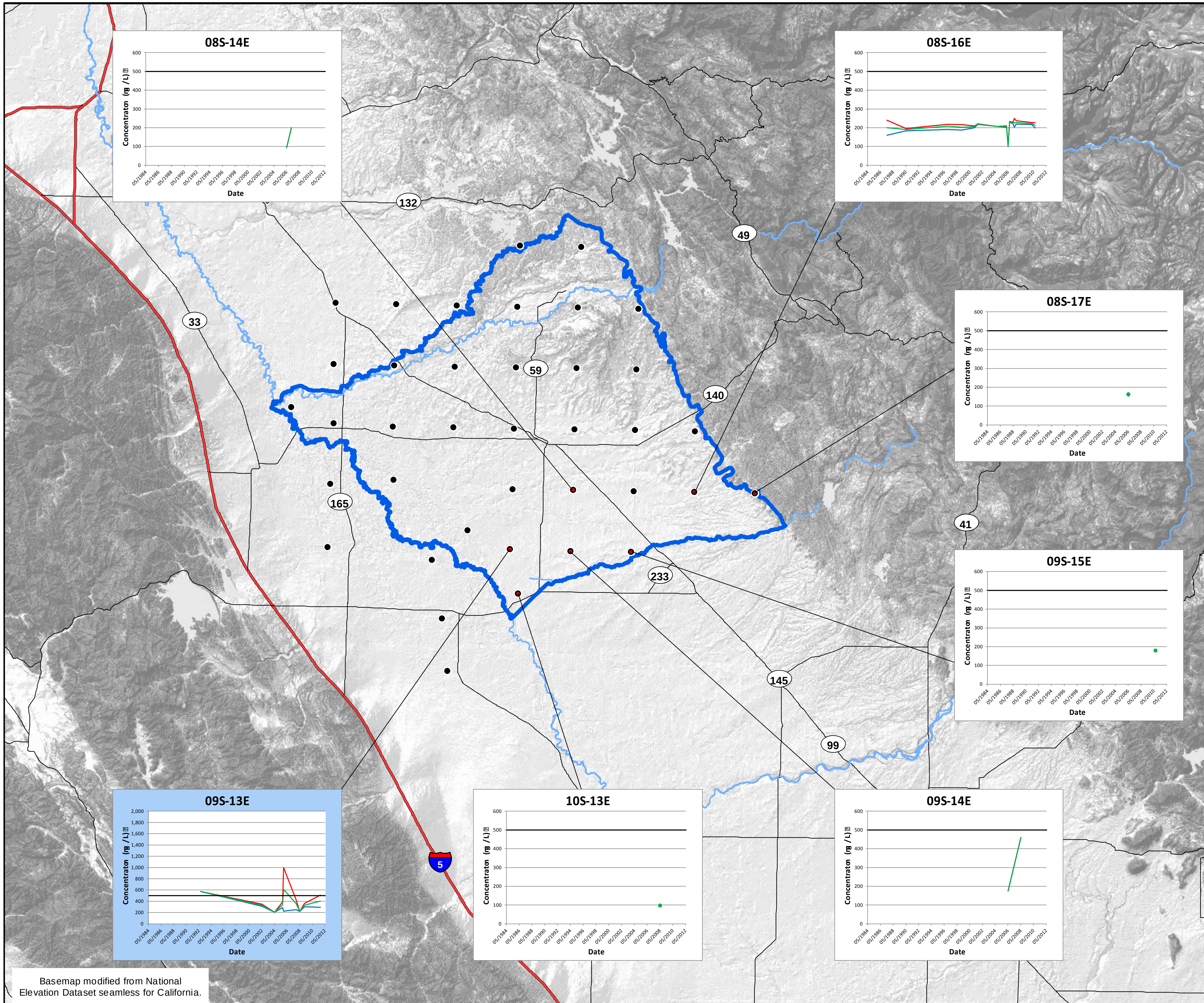
0 5 10

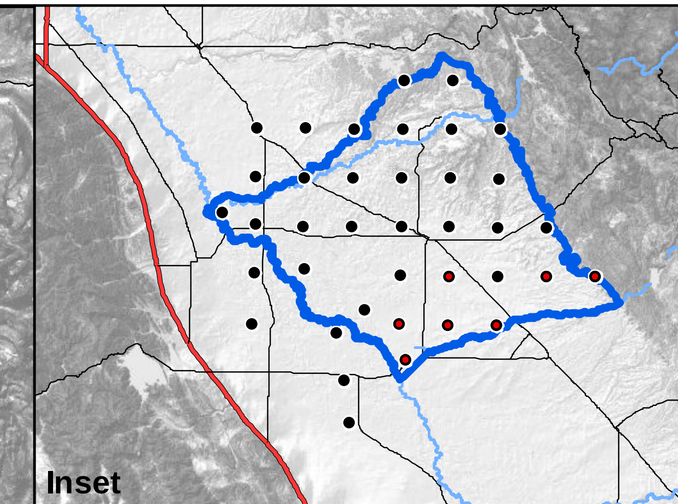
APPROXIMATE SCALE IN MILES

TOTAL DISSOLVED SOLIDS (TDS) CONCENTRATIONS
1984 THROUGH 2012
Merced IRWMP
Merced County, California

By: DB	Date: 01/08/2013	Project No. FR1216040A
		Figure **1b**

N:_FR_projects\FR12s\FR1216040A\gis\maps\2013_01\ConcentrationMaps_fig01b_TDS.mxd





Explanation:

- Township/Range centroid
- Surface water feature
- Merced IRWM area

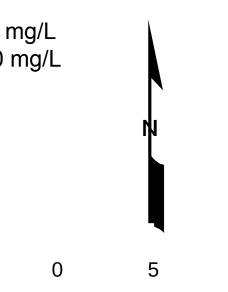
Concentration Charts:

- Minimum TDS concentration
- Mean TDS concentration
- Maximum TDS concentration
- Rec. SMCL for TDS (500 mg/l)

Notes:

1. IRWMP = Integrated Regional Water Management Plan.
2. Total dissolved solids (TDS) concentrations shown in milligrams per liter (mg/L).
3. Secondary Maximum Contaminant Level (SMCL) as established by the California Department of Public Heath
4. Background color on graphs represent the y-axis range as follows:

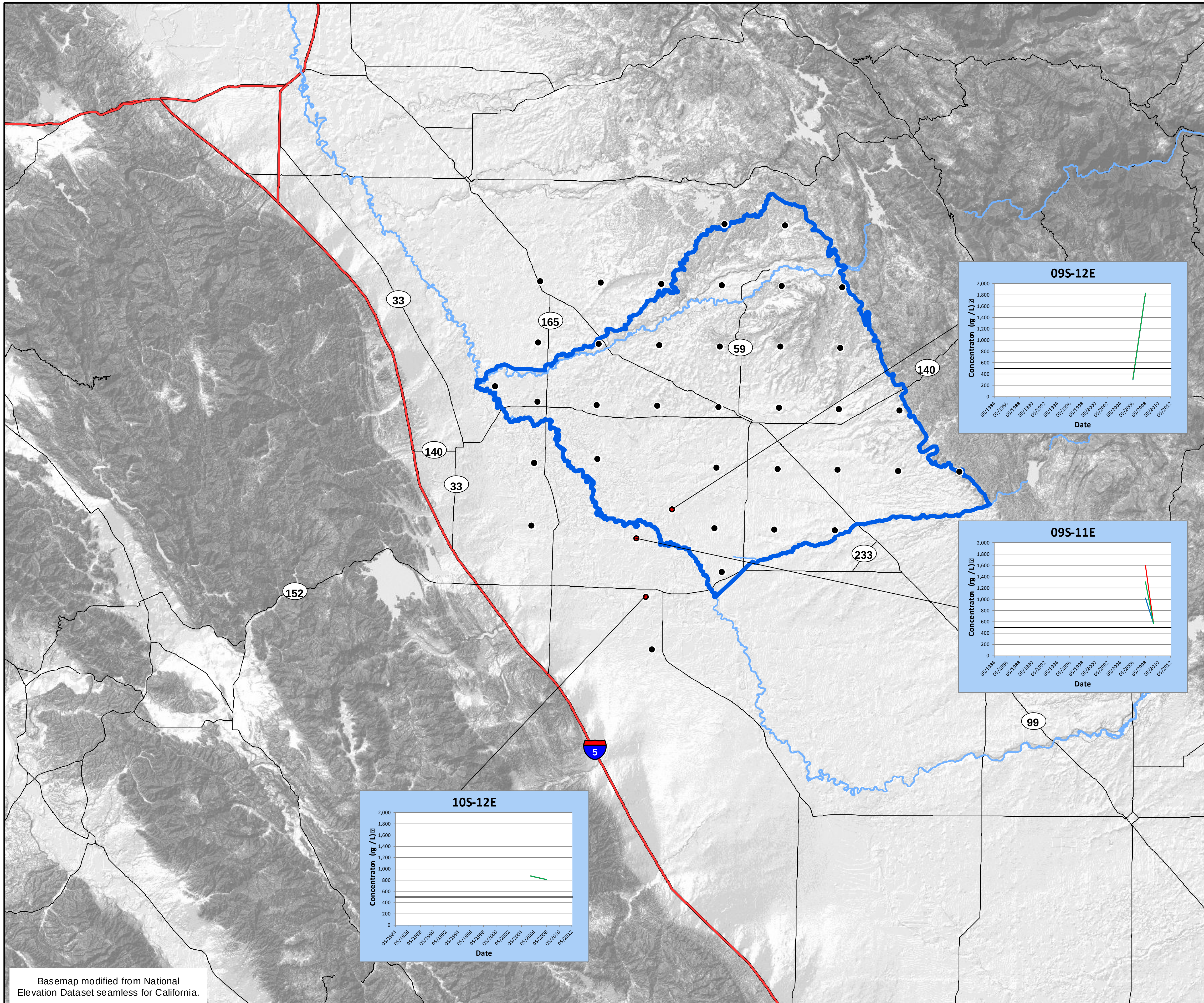
White: 0- 600 mg/L
Blue: 0- 2,000 mg/L

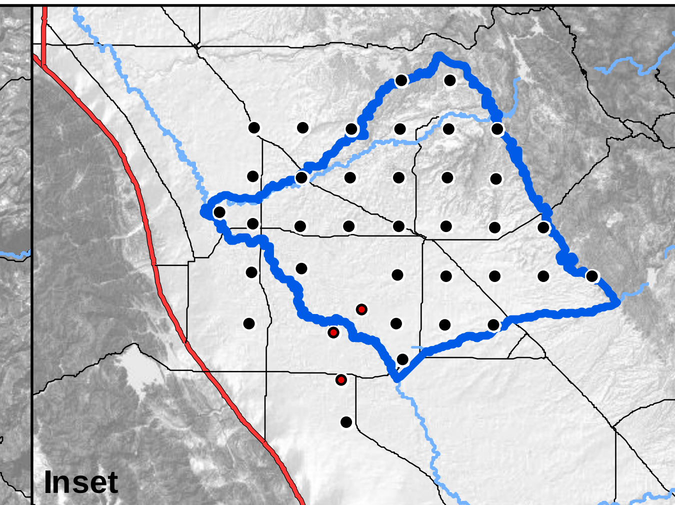


TOTAL DISSOLVED SOLIDS (TDS)
CONCENTRATIONS
1984 THROUGH 2012
Merced IRWMP
Merced County, California

By: DB	Date: 01/08/2013	Project No. FR1216040A
		Figure 1c

N:_FR_projects\FR12s\FR1216040A\gis\maps\2013_01\ConcentrationMaps_fig01c_TDS.mxd





Explanation:

- Township/Range centroid
- Surface water feature
- Merced IRWM area

Concentration Charts:

- Minimum TDS concentration
- Mean TDS concentration
- Maximum TDS concentration
- Rec. SMCL for TDS (500 mg/l)

Notes:

1. IRWMP = Integrated Regional Water Management Plan.
2. Total dissolved solids (TDS) concentrations shown in milligrams per liter (mg/L).
3. Secondary Maximum Contaminant Level (SMCL) as established by the California Department of Public Heath

N

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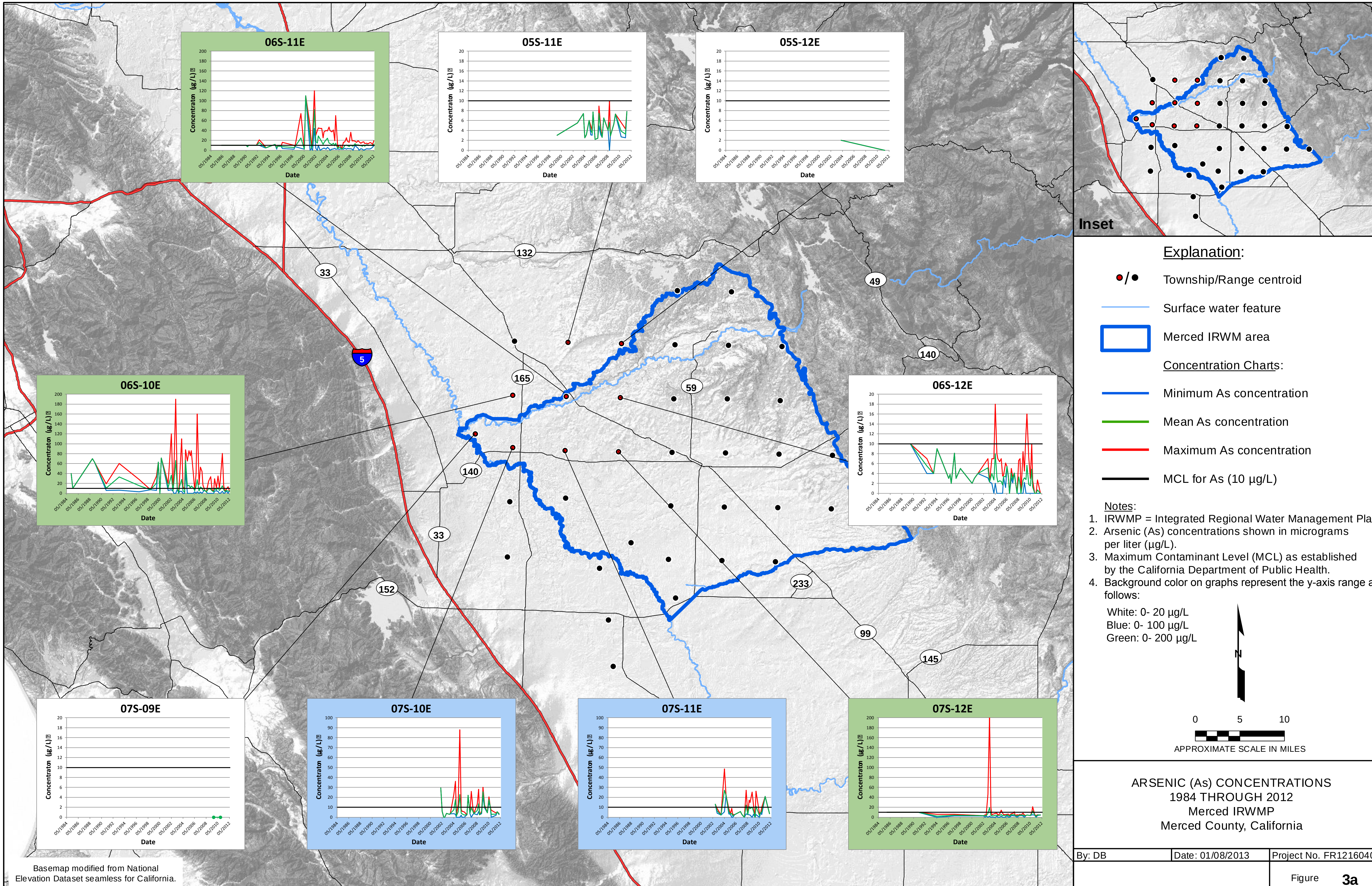
APPROXIMATE SCALE IN MILES

TOTAL DISSOLVED SOLIDS (TDS)
CONCENTRATIONS
1984 THROUGH 2012
Merced IRWMP
Merced County, California

By: DB	Date: 12/05/2012	Project No. FR1216040A
		Figure 1d

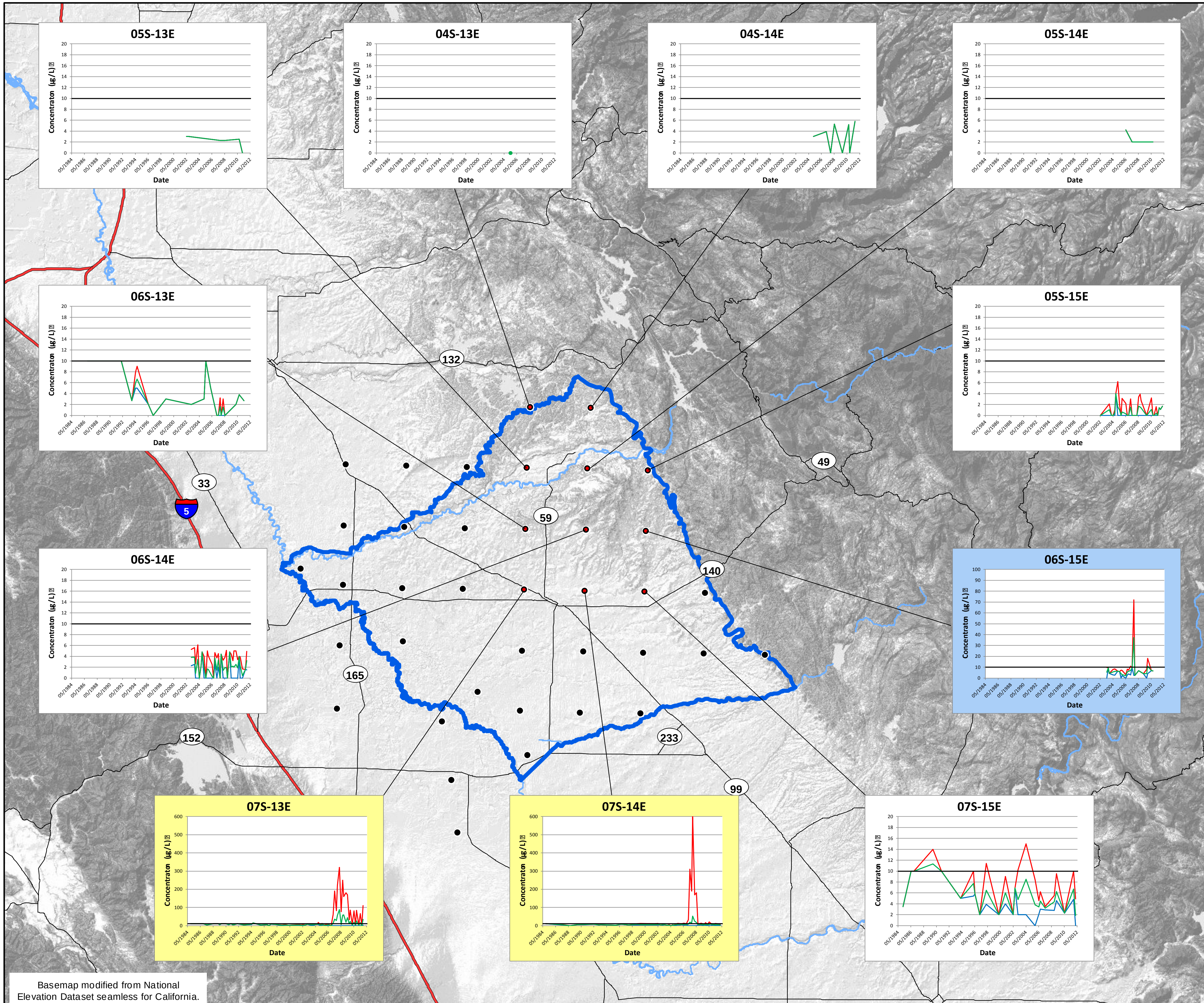
N:_FR_projects\FR12s\FR1216040A\gis\maps\2013_01\ConcentrationMaps_fig01d_TDS.mxd

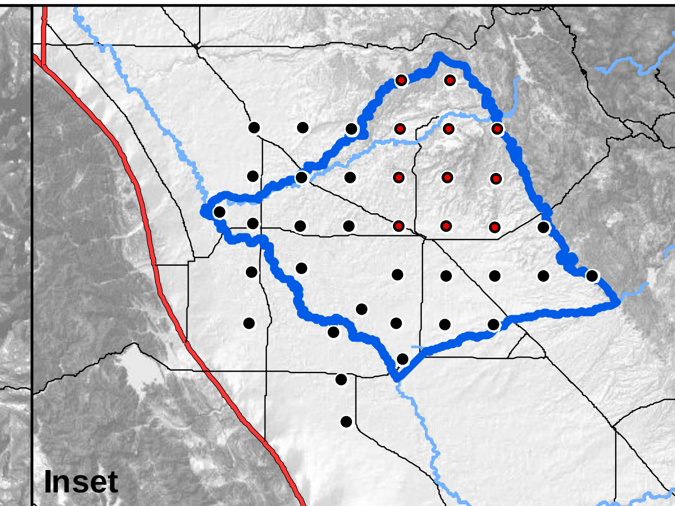


ARSENIC (As) CONCENTRATIONS
1984 THROUGH 2012
Merced IRWMP
Merced County, California

By: DB	Date: 01/08/2013	Project No. FR1216040A
		Figure 3a

N:_FR_projects\FR12s\FR1216040A\gis\maps\2013_01\ConcentrationMaps_fig03a_As.mxd





Explanation:

- Township/Range centroid
- Surface water feature
- Merced IRWM area

Concentration Charts:

- Minimum As concentration
- Mean As concentration
- Maximum As concentration
- MCL for As (10 µg/L)

Notes:

1. IRWMP = Integrated Regional Water Management Plan.
2. Arsenic (As) concentrations shown in micrograms per liter (µg/L).
3. Maximum Contaminant Level (MCL) as established by the California Department of Public Health.
4. Background color on graphs represent the y-axis range as follows:

White: 0- 20 µg/L
Blue: 0- 100 µg/L
Yellow: 0- 600 µg/L

N

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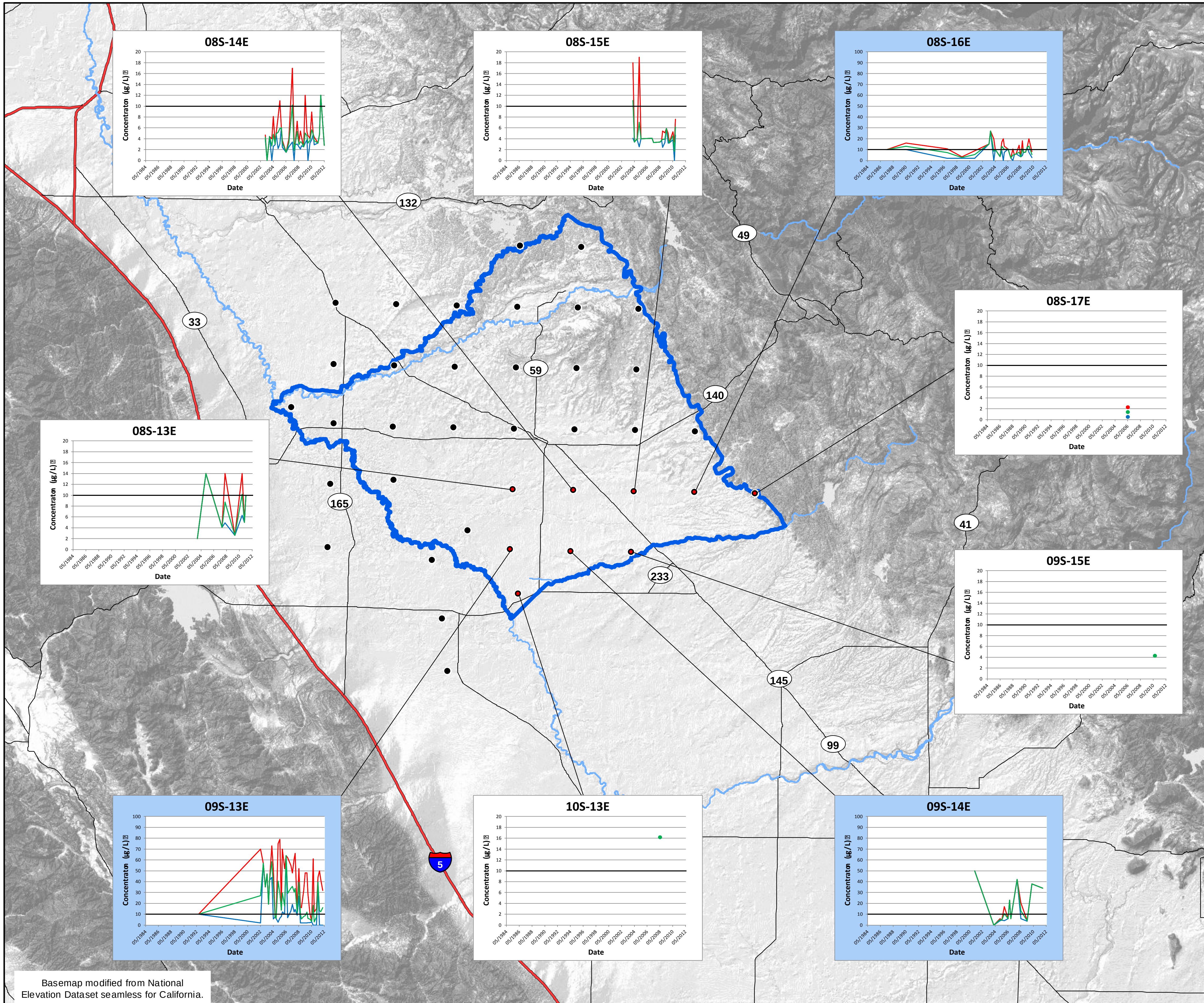
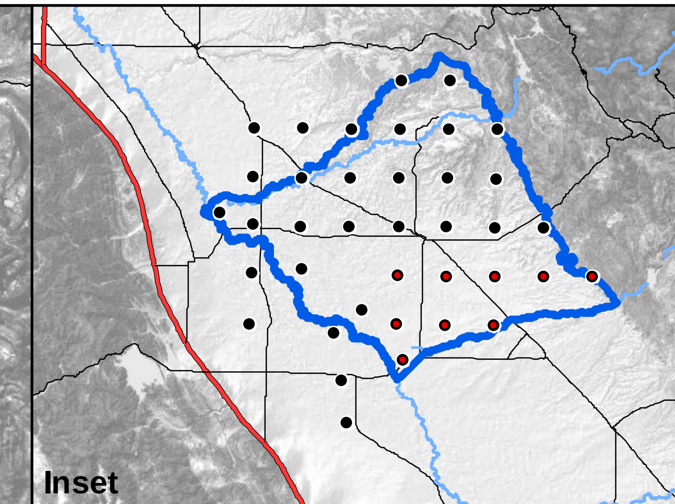
APPROXIMATE SCALE IN MILES

ARSENIC (As) CONCENTRATIONS
1984 THROUGH 2012
Merced IRWMP
Merced County, California

By: DB	Date: 01/08/2013	Project No. FR1216040A
		Figure 3b

N:_FR_projects\FR12s\FR1216040A\gis\maps\2013_01\ConcentrationMaps_fig03b_As.mxd





Explanation:

- ●/● Township/Range centroid
- Surface water feature
- Merced IRWM area

Concentration Charts:

- Minimum As concentration
- Mean As concentration
- Maximum As concentration
- MCL for As (10 µg/L)

Notes:

1. IRWMP = Integrated Regional Water Management Plan.
2. Arsenic (As) concentrations shown in micrograms per liter (µg/L).
3. Maximum Contaminant Level (MCL) as established by the California Department of Public Health.
4. Background color on graphs represent the y-axis range as follows:

White: 0- 20 µg/L
Blue: 0- 100 µg/L

N

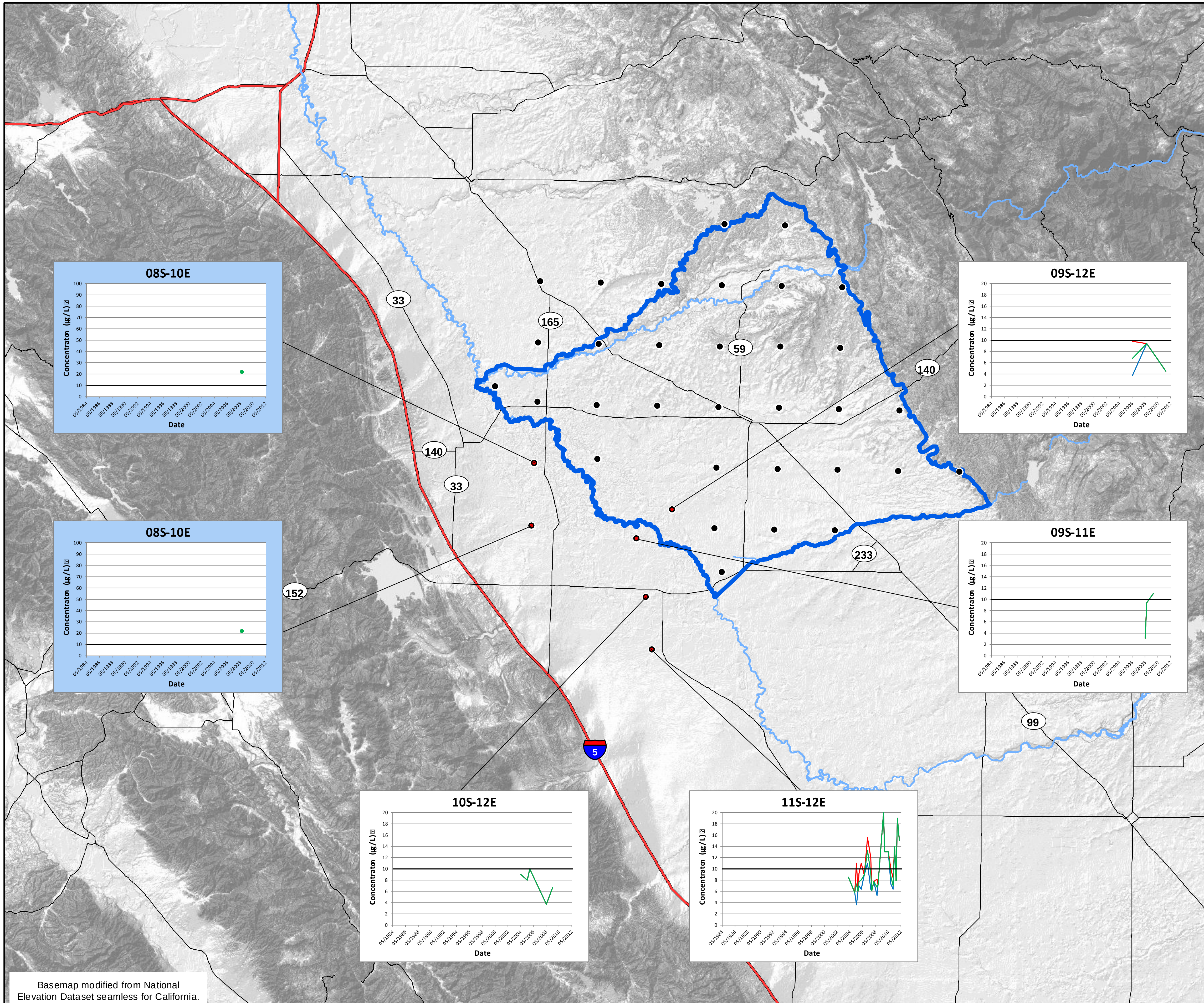
0 5 10

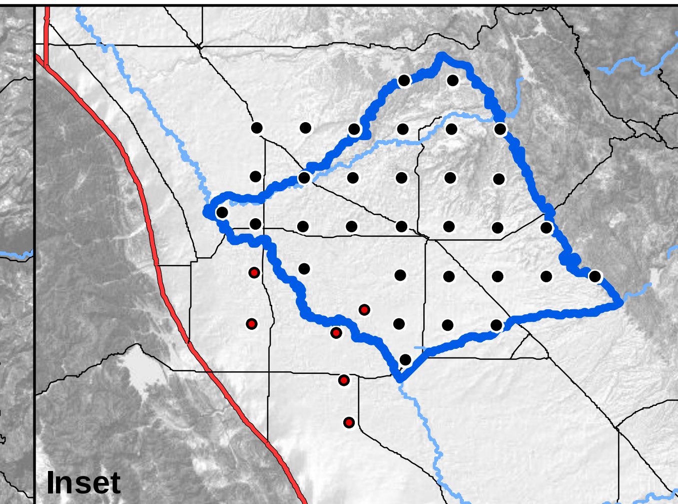
APPROXIMATE SCALE IN MILES

ARSENIC (As) CONCENTRATIONS
1984 THROUGH 2012
Merced IRWMP
Merced County, California

By: DB	Date: 01/08/2013	Project No. FR1216040A
		Figure 3c

N:_FR_projects\FR12s\FR1216040A\gis\maps\2013_01\ConcentrationMaps_fig03c_As.mxd





Explanation:

Township/Range centroid

Surface water feature

Merced IRWM area

Concentration Charts:

Minimum As concentration

Mean As concentration

Maximum As concentration

MCL for As (10 µg/L)

Notes:

1. IRWMP = Integrated Regional Water Management Plan.
2. Arsenic (As) concentrations shown in micrograms per liter (µg/L).
3. Maximum Contaminant Level (MCL) as established by the California Department of Public Health.
4. Background color on graphs represent the y-axis range as follows:

White: 0- 20 µg/L
Blue: 0- 100 µg/L

N

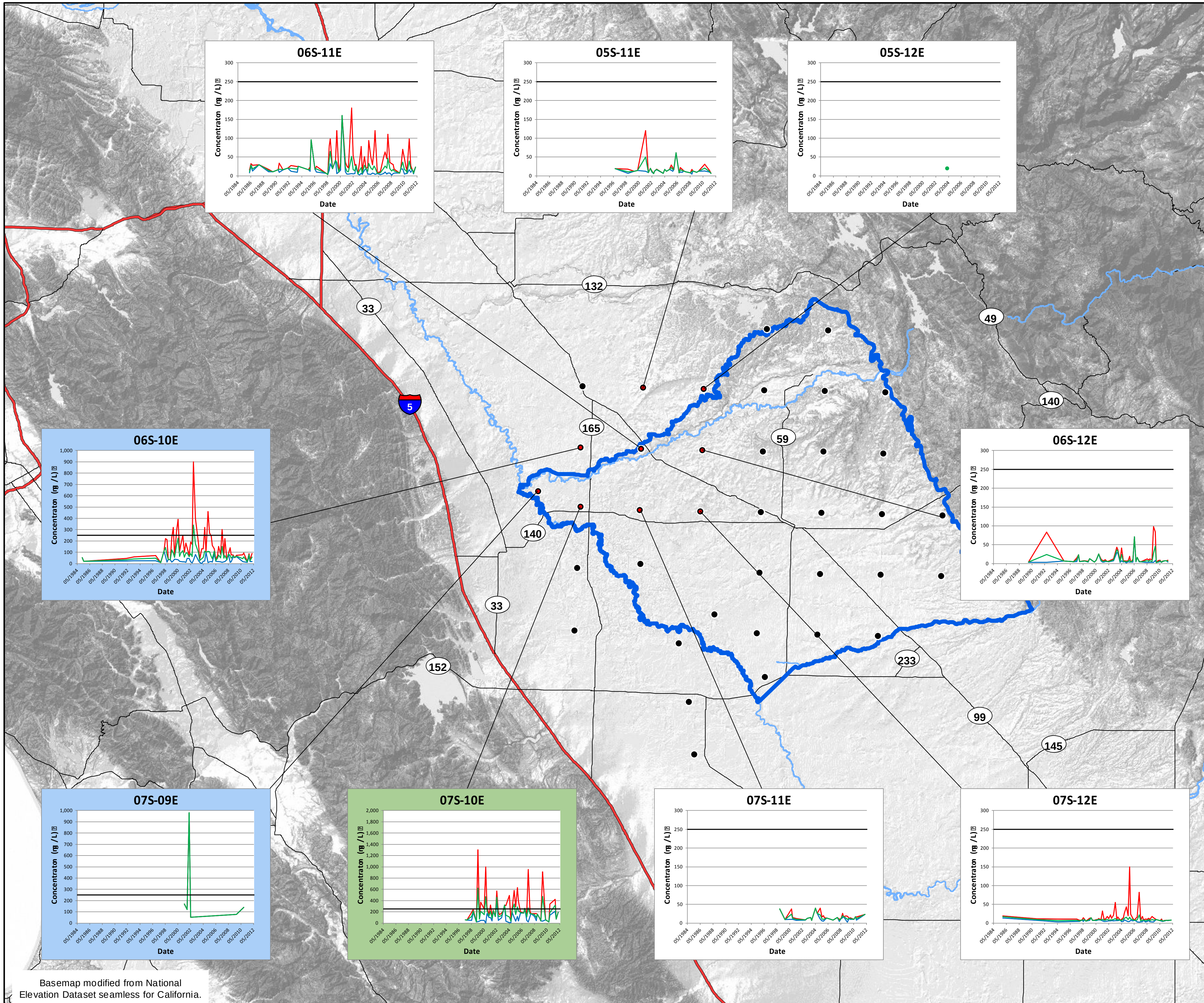
0 5 10

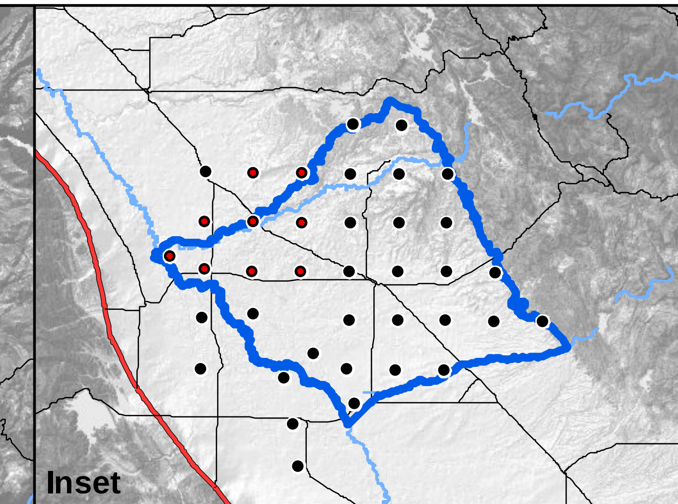
APPROXIMATE SCALE IN MILES

ARSENIC (As) CONCENTRATIONS
1984 THROUGH 2012
Merced IRWMP
Merced County, California

By: DB	Date: 01/08/2013	Project No. FR1216040A
		Figure 3d

N:_FR_projects\FR12s\FR1216040A\gis\maps\2013_01\ConcentrationMaps_fig03d_As.mxd





Explanation:

- Township/Range centroid
- Surface water feature
- Merced IRWM area

Concentration Charts:

- Minimum Cl concentration
- Mean Cl concentration
- Maximum Cl concentration
- Recommended SMCL for Cl (250 mg/L)

Notes:

1. IRWMP = Integrated Regional Water Management Plan.
2. Chloride (Cl) concentrations shown in milligrams per liter (mg/L).
3. Secondary Maximum Contaminant Level (SMCL) as established by the California Department of Public Heath
4. Background color on graphs represent the y-axis range as follows:

White: 0- 300 mg/L
Blue: 0- 1,000 mg/L
Green: 0- 2,000 mg/L

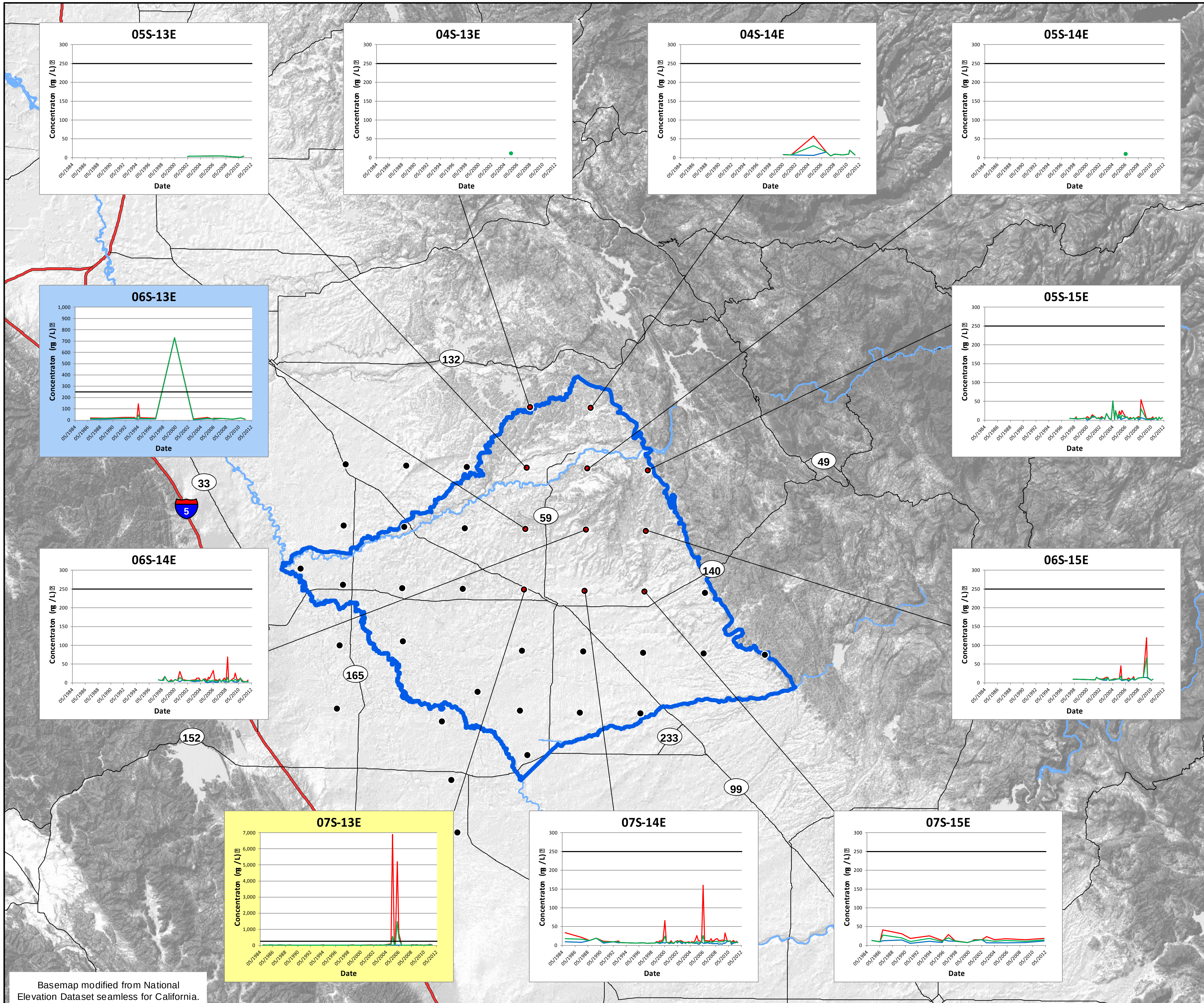
N

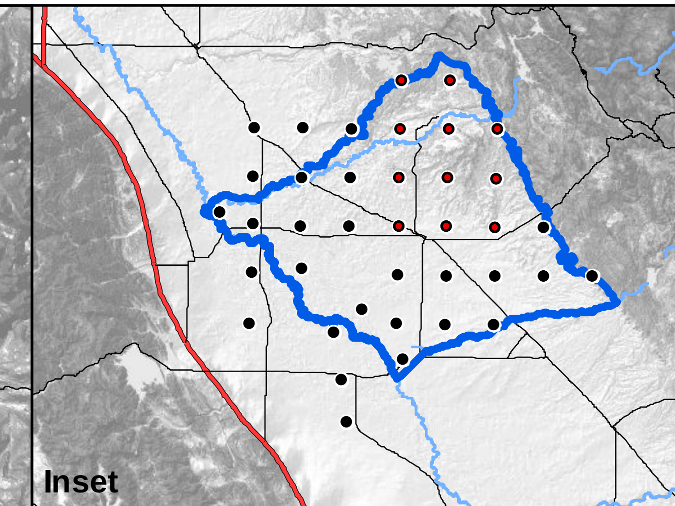
0 5 10
APPROXIMATE SCALE IN MILES

CHLORIDE (Cl) CONCENTRATIONS
1984 THROUGH 2012
Merced IRWMP
Merced County, California

By: DB	Date: 01/08/2013	Project No. FR1216040A
		Figure 4a

N:_FR_projects\FR12s\FR1216040A\gis\maps\2013_01\ConcentrationMaps_fig04a_Cl.mxd





Explanation:

- Township/Range centroid
- Surface water feature
- Merced IRWM area

Concentration Charts:

- Minimum Cl concentration
- Mean Cl concentration
- Maximum Cl concentration
- Recommended SMCL for Cl (250 mg/L)

Notes:

1. IRWMP = Integrated Regional Water Management Plan.
2. Chloride (Cl) concentrations shown in milligrams per liter (mg/L).
3. Secondary Maximum Contaminant Level (SMCL) as established by the California Department of Public Heath
4. Background color on graphs represent the y-axis range as follows:

White: 0- 300 mg/L
Blue: 0- 1,000 mg/L
Yellow: 0- 7,000 mg/L

N

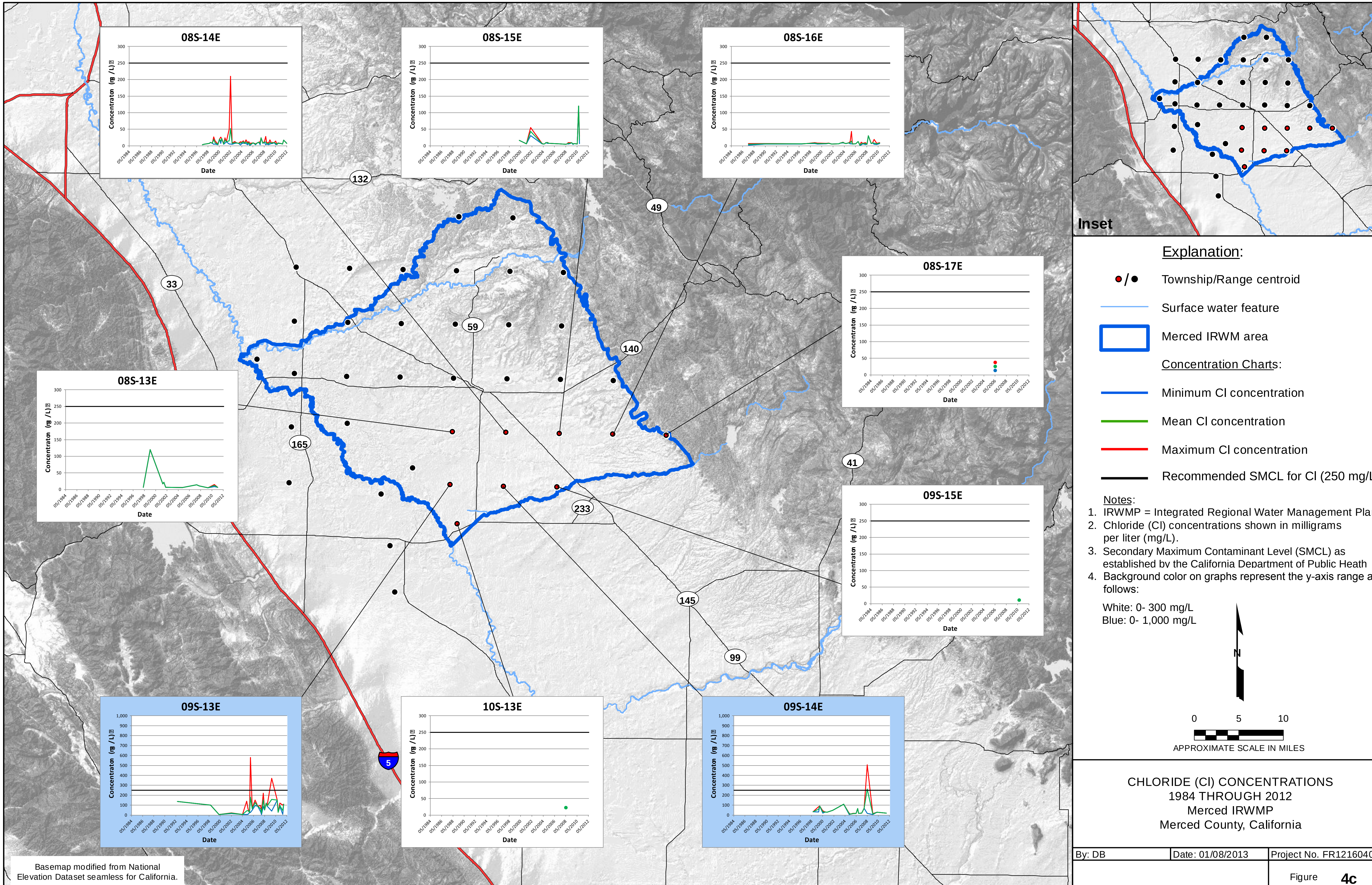
0 5 10

APPROXIMATE SCALE IN MILES

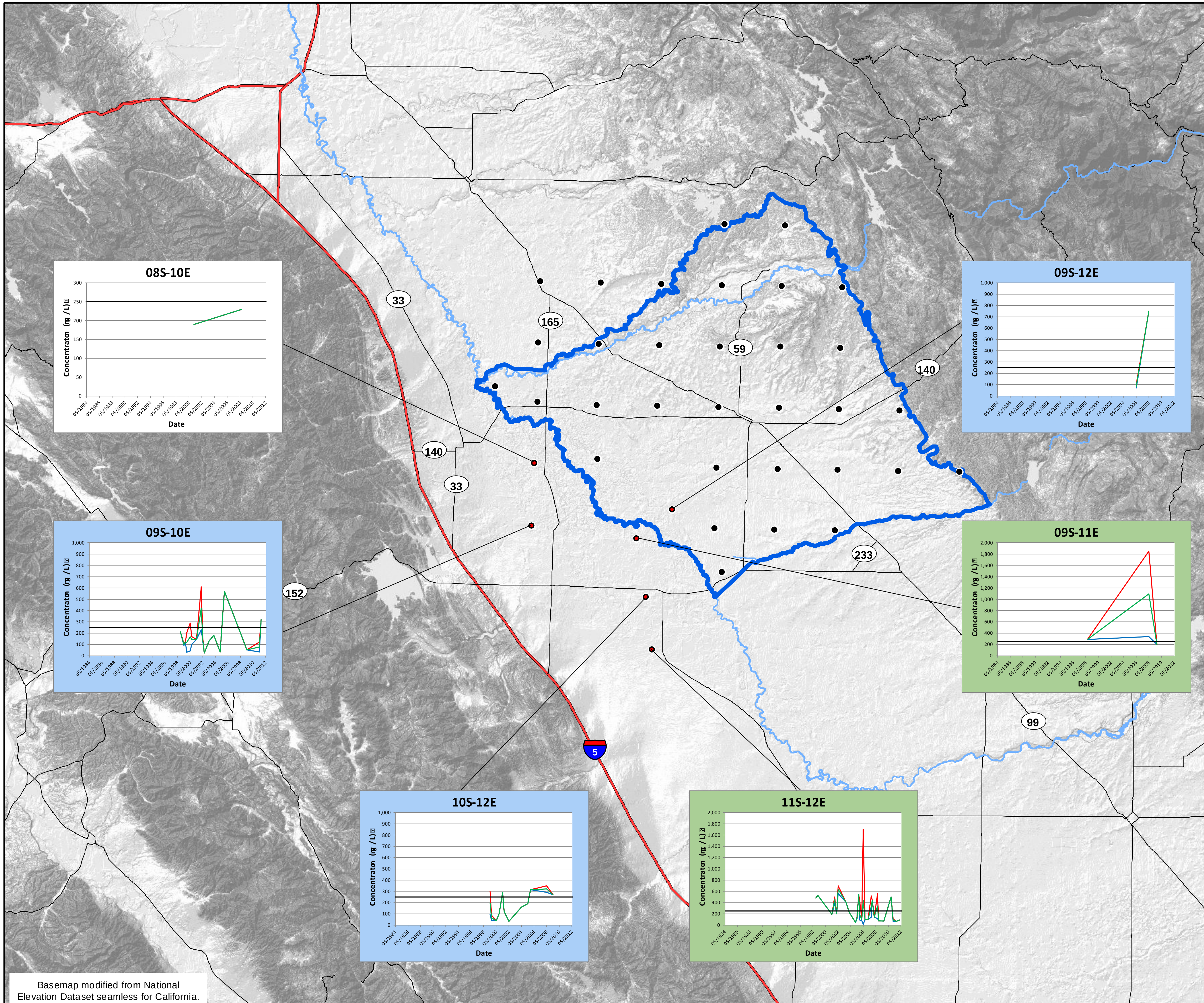
CHLORIDE (Cl) CONCENTRATIONS
1984 THROUGH 2012
Merced IRWMP
Merced County, California

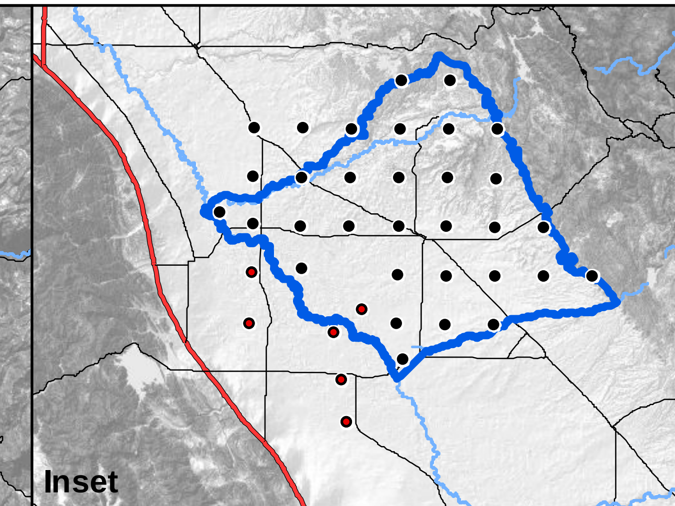
By: DB	Date: 01/08/2013	Project No. FR1216040A
		Figure 4b

N:_FR_projects\FR12s\FR1216040A\gis\maps\2013_01\ConcentrationMaps_fig04b_Cl.mxd



N:_FR_projects\FR12s\FR1216040A\gis\maps\2013_01\ConcentrationMaps_fig04c_Cl.mxd





Explanation:

- ●/● Township/Range centroid
- Surface water feature
- Merced IRWM area

Concentration Charts:

- Minimum Cl concentration
- Mean Cl concentration
- Maximum Cl concentration
- Recommended SMCL for Cl (250 mg/L)

Notes:

1. IRWMP = Integrated Regional Water Management Plan.
2. Chloride (Cl) concentrations shown in milligrams per liter (mg/L).
3. Secondary Maximum Contaminant Level (SMCL) as established by the California Department of Public Heath
4. Background color on graphs represent the y-axis range as follows:

White: 0- 300 mg/L
Blue: 0- 1,000 mg/L
Green: 0- 2,000 mg/L

N

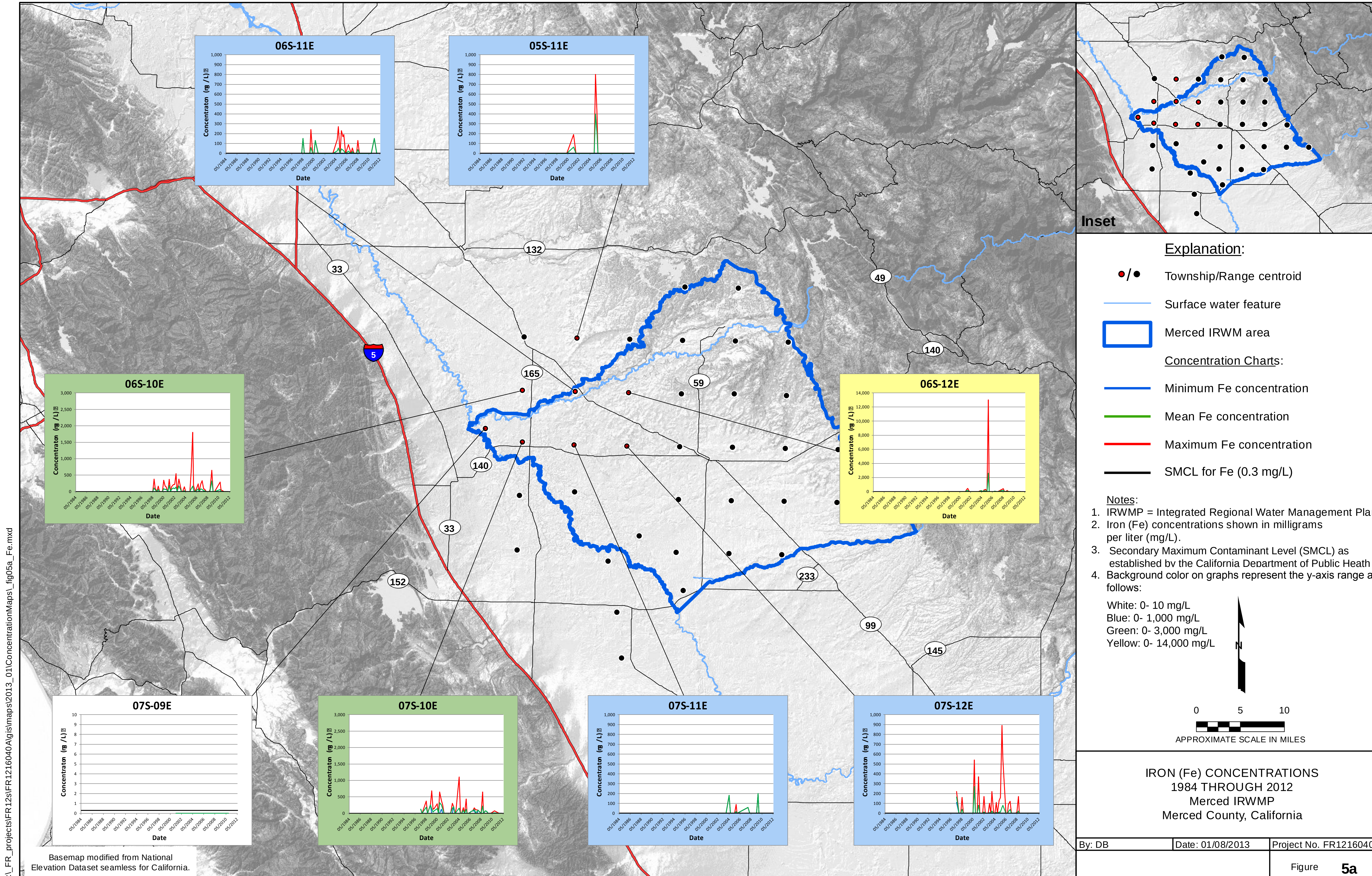
0 5 10

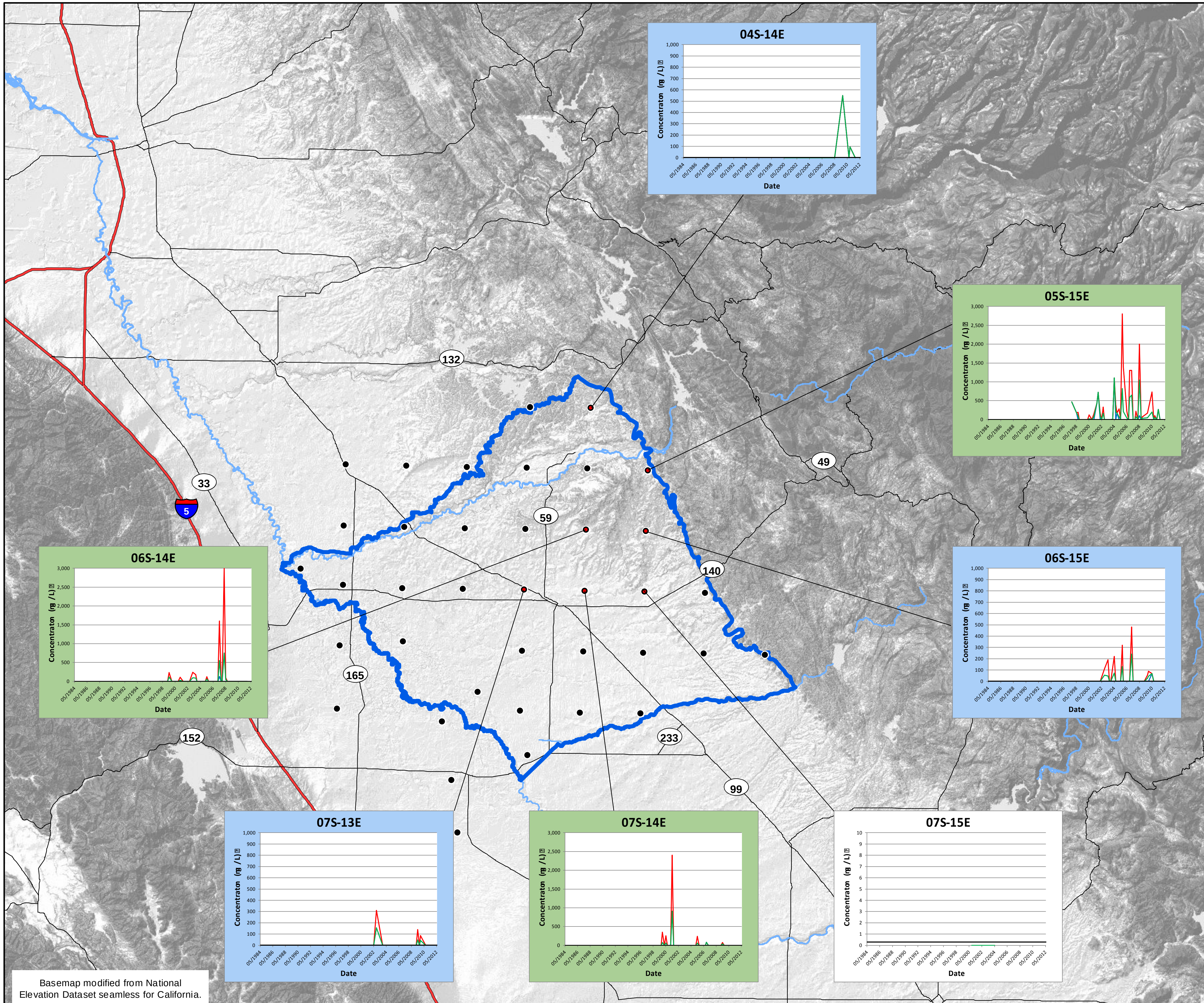
APPROXIMATE SCALE IN MILES

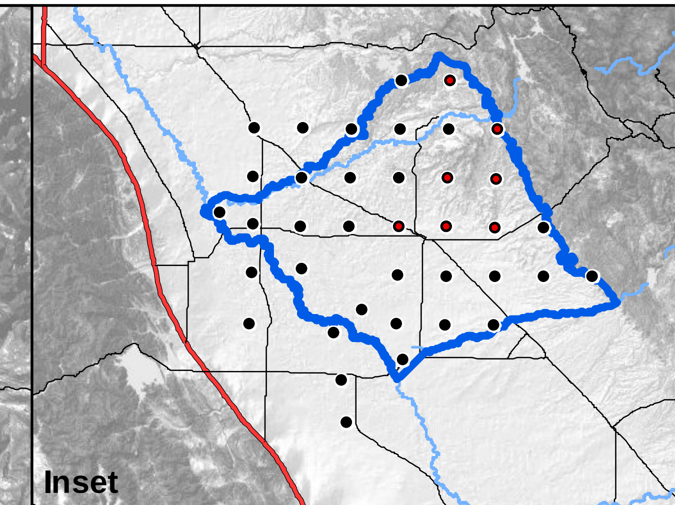
CHLORIDE (Cl) CONCENTRATIONS
1984 THROUGH 2012
Merced IRWMP
Merced County, California

By: DB	Date: 01/08/2013	Project No. FR1216040A
		Figure 4d

N:_FR_projects\FR12s\FR1216040A\gis\maps\2013_01\ConcentrationMaps_fig04d_Cl.mxd


06S-11E
05S-11E
06S-10E
06S-12E
07S-09E
07S-10E
07S-11E
07S-12E
Date
Inset
Explanation:
Township/Range centroid
Surface water feature
Merced IRWM area
Concentration Charts:
Minimum Fe concentration
Mean Fe concentration
Maximum Fe concentration
SMCL for Fe (0.3 mg/L)
Notes:
1. IRWMP = Integrated Regional Water Management Plan.
2. Iron (Fe) concentrations shown in milligrams per liter (mg/L).
3. Secondary Maximum Contaminant Level (SMCL) as established by the California Department of Public Heath
4. Background color on graphs represent the y-axis range as follows:
White: 0- 10 mg/L
Blue: 0- 1,000 mg/L
Green: 0- 3,000 mg/L
Yellow: 0- 14,000 mg/L
N
0 5 10
APPROXIMATE SCALE IN MILES
Basemap modified from National Elevation Dataset seamless for California.
33
132
49
165
59
140
5
33
152
233
99
145
IRON (Fe) CONCENTRATIONS
1984 THROUGH 2012
Merced IRWMP
Merced County, California
By: DB
Date: 01/08/2013
Project No. FR1216040A
Figure 5a
N:_FR_projects\FR12s\FR1216040A\gis\maps\2013_01\ConcentrationMaps_fig05a_Fe.mxd





<u>Explanation</u>:

Township/Range centroid

Surface water feature

Merced IRWM area

<u>Concentration Charts</u>:

Minimum Fe concentration

Mean Fe concentration

Maximum Fe concentration

SMCL for Fe (0.3 mg/L)

<u>Notes</u>:

1. IRWMP = Integrated Regional Water Management Plan.
2. Iron (Fe) concentrations shown in milligrams per liter (mg/L).
3. Secondary Maximum Contaminant Level (SMCL) as established by the California Department of Public Heath
4. Background color on graphs represent the y-axis range as follows:

White: 0- 10 mg/L
Blue: 0- 1,000 mg/L
Green: 0- 3,000 mg/L

N

0 5 10

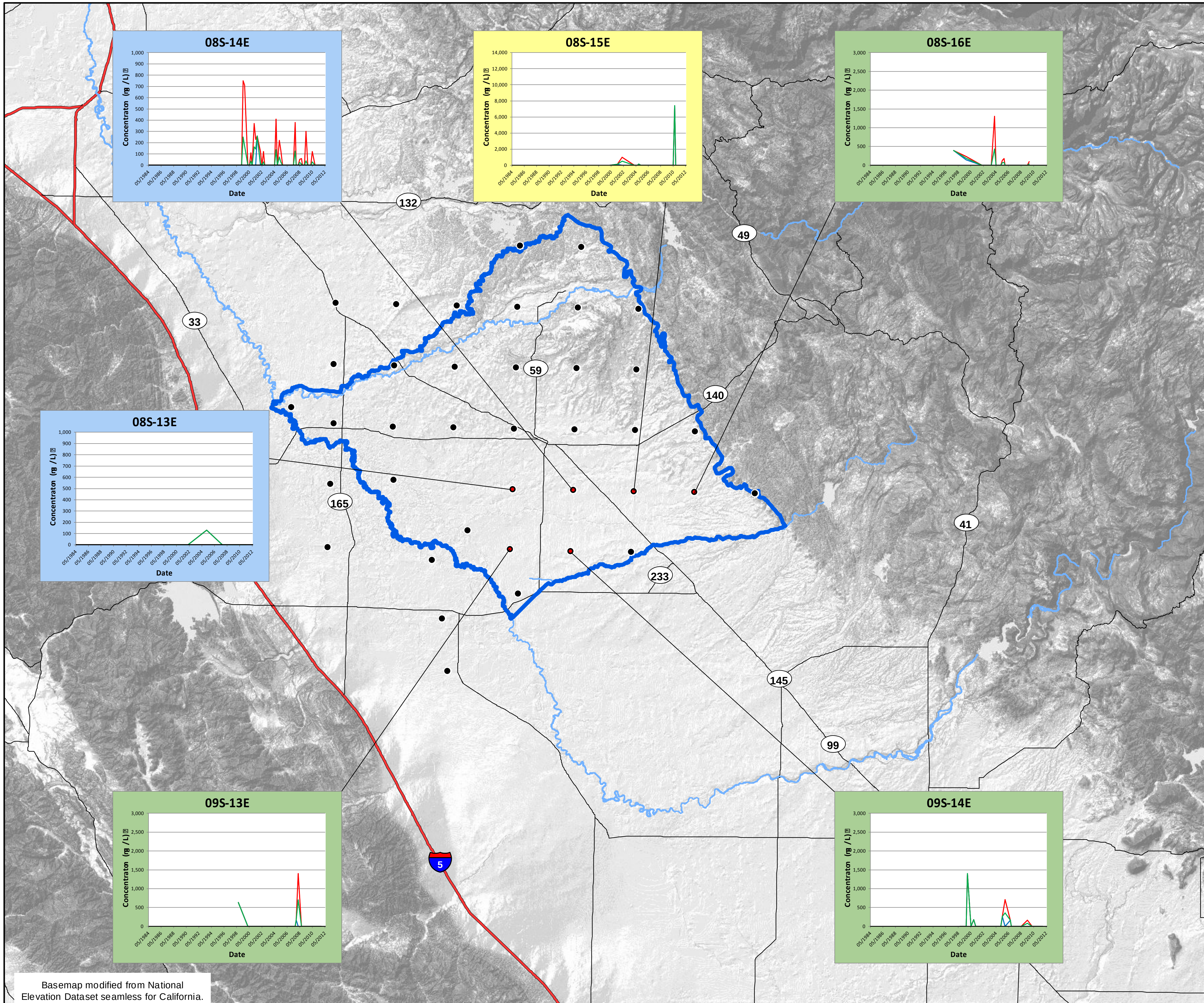
APPROXIMATE SCALE IN MILES

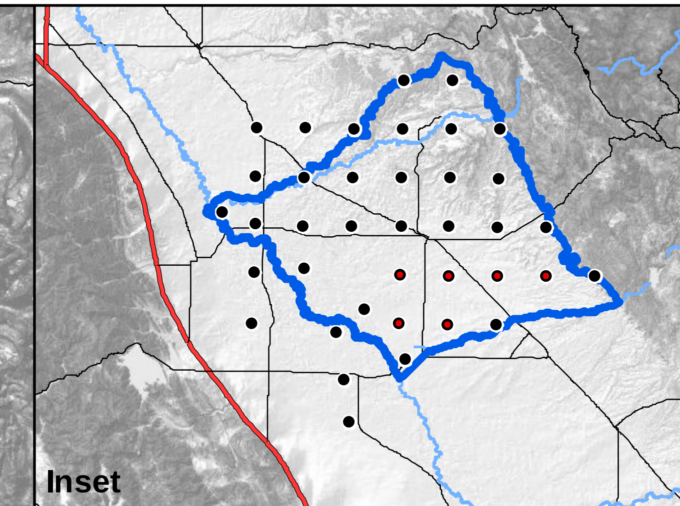
IRON (Fe) CONCENTRATIONS
1984 THROUGH 2012
Merced IRWMP
Merced County, California

By: DB | Date: 01/08/2013 | Project No. FR1216040A

Figure 5b

N:_FR_projects\FR12s\FR1216040A\gis\maps\2013_01\ConcentrationMaps_fig05b_Fe.mxd





Explanation:

- ●/● Township/Range centroid
- Surface water feature
- Merced IRWM area

Concentration Charts:

- Minimum Fe concentration
- Mean Fe concentration
- Maximum Fe concentration
- SMCL for Fe (0.3 mg/L)

Notes:

1. IRWMP = Integrated Regional Water Management Plan.
2. Iron (Fe) concentrations shown in milligrams per liter (mg/L).
3. Secondary Maximum Contaminant Level (SMCL) as established by the California Department of Public Heath
4. Background color on graphs represent the y-axis range as follows:

Blue: 0- 1,000 mg/L
Green: 0- 3,000 mg/L
Yellow: 0- 14,000 mg/L

N

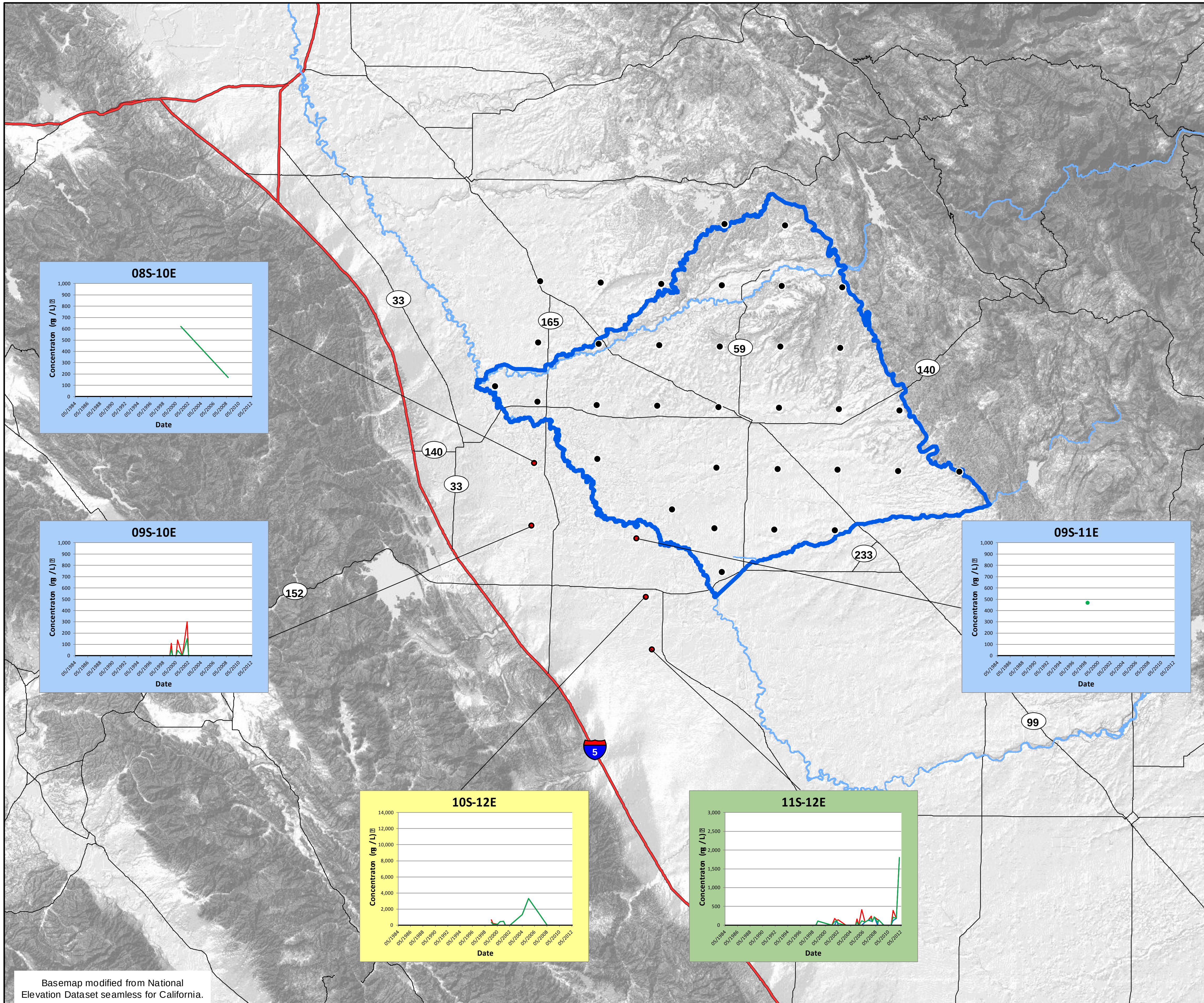
0 5 10

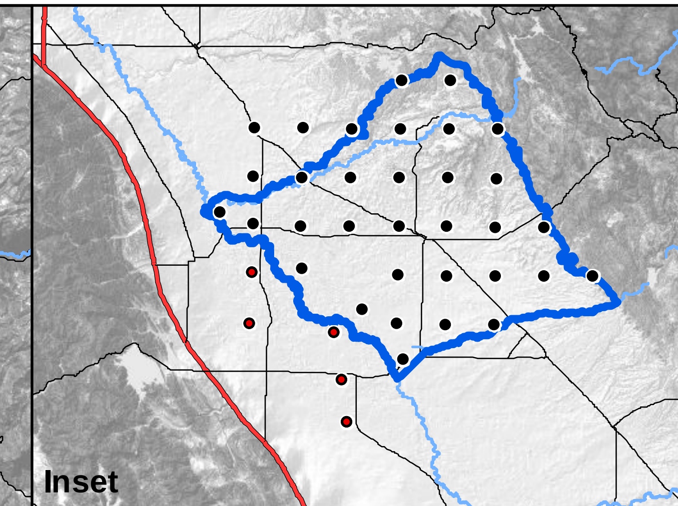
APPROXIMATE SCALE IN MILES

IRON (Fe) CONCENTRATIONS
1984 THROUGH 2012
Merced IRWMP
Merced County, California

By: DB	Date: 01/08/2013	Project No. FR1216040A
		Figure 5c

N:_FR_projects\FR12s\FR1216040A\gis\maps\2013_01\ConcentrationMaps_fig05c_Fe.mxd





Explanation:

- Township/Range centroid
- Surface water feature
- Merced IRWM area

Concentration Charts:

- Minimum Fe concentration
- Mean Fe concentration
- Maximum Fe concentration
- SMCL for Fe (0.3 mg/L)

Notes:

1. IRWMP = Integrated Regional Water Management Plan.
2. Iron (Fe) concentrations shown in milligrams per liter (mg/L).
3. Secondary Maximum Contaminant Level (SMCL) as established by the California Department of Public Heath
4. Background color on graphs represent the y-axis range as follows:

Blue: 0- 1,000 mg/L
Green: 0- 3,000 mg/L
Yellow: 0- 14,000 mg/L

N

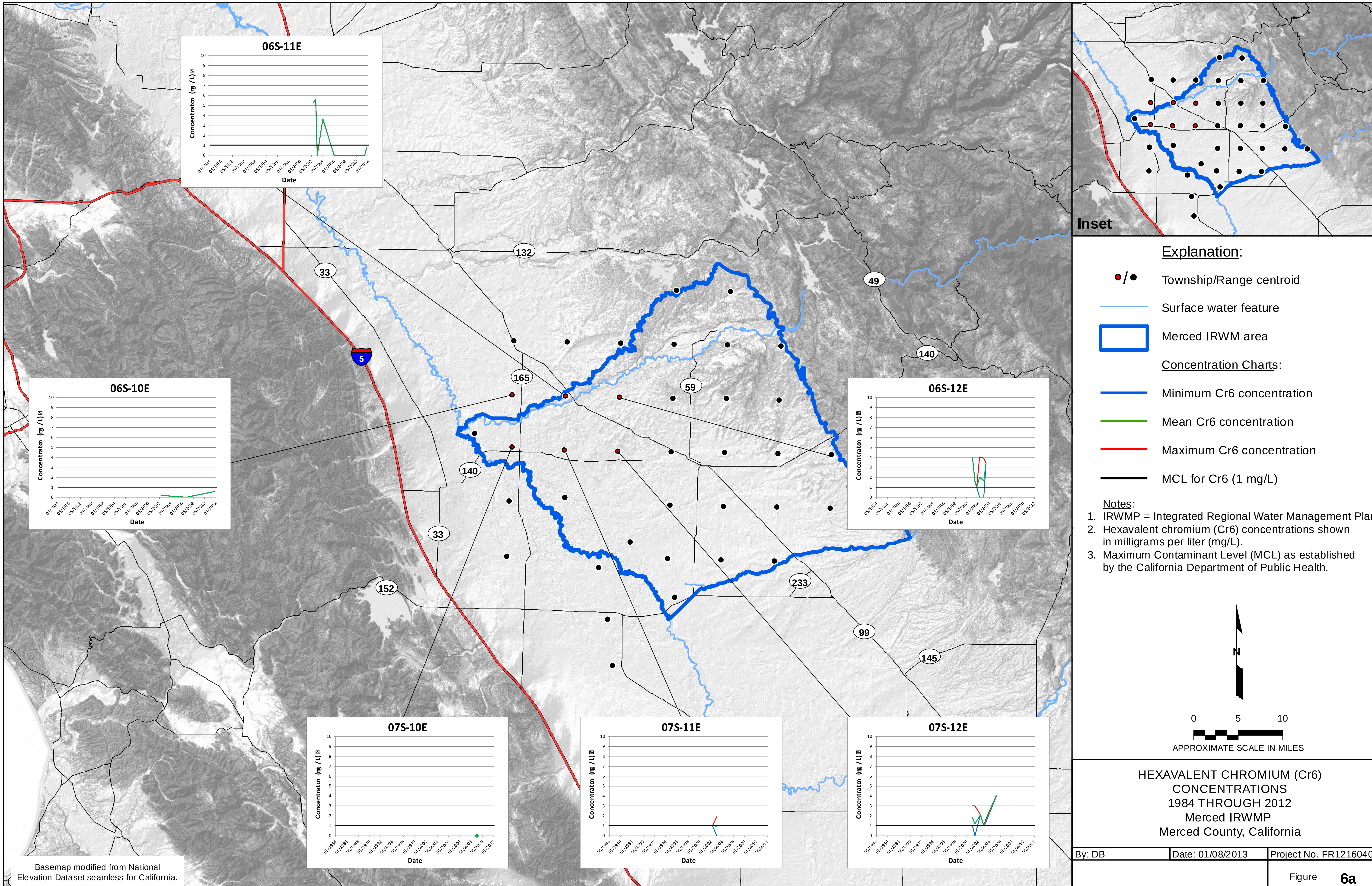
0 5 10

APPROXIMATE SCALE IN MILES

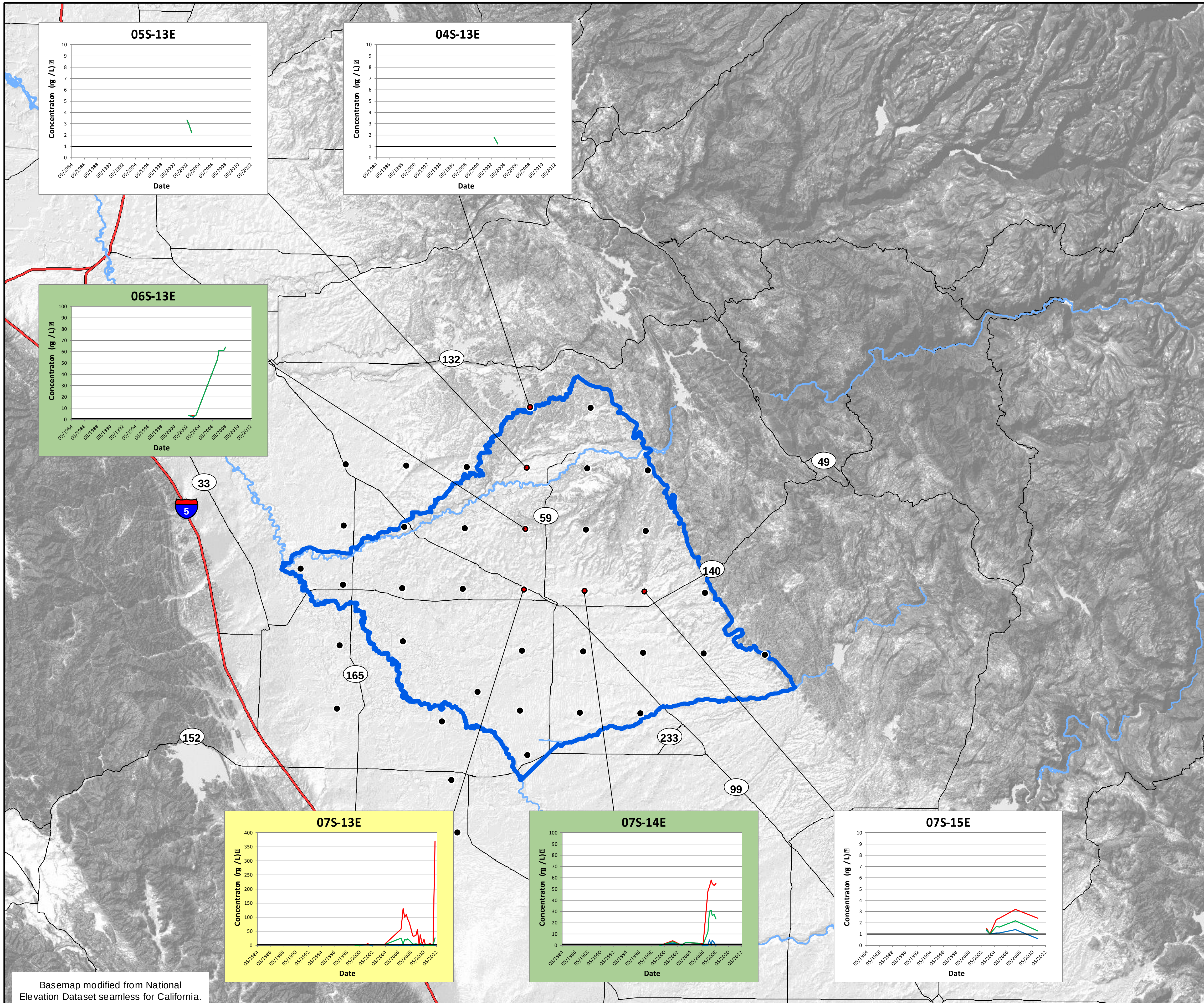
IRON (Fe) CONCENTRATIONS
1984 THROUGH 2012
Merced IRWMP
Merced County, California

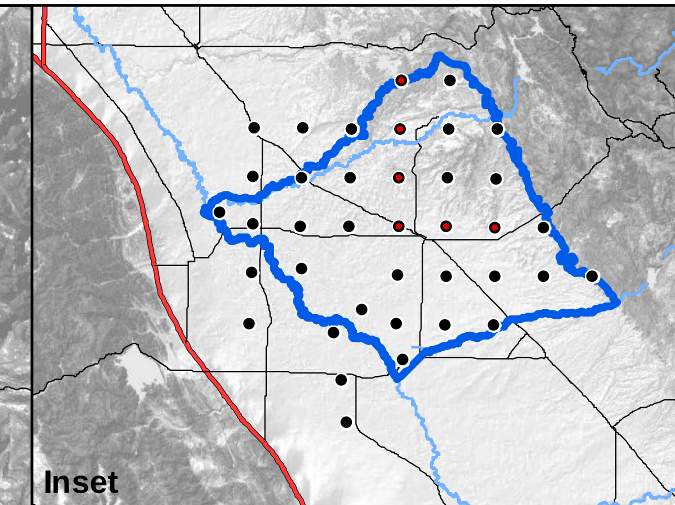
By: DB	Date: 01/08/2013	Project No. FR1216040A
		Figure 5d

N:_FR_projects\FR12s\FR1216040A\gis\maps\2013_01\ConcentrationMaps_fig05d_Fe.mxd



N:_FR_projects\FR12s\FR1216040A\gis\maps\2013_01\ConcentrationMaps_fig06a_Cr6.mxd





Explanation:

●/● Township/Range centroid

Surface water feature

Merced IRWM area

Concentration Charts:

Minimum Cr6 concentration

Mean Cr6 concentration

Maximum Cr6 concentration

MCL for Cr6 (1 mg/L)

Notes:

1. IRWMP = Integrated Regional Water Management Plan.
2. Hexavalent chromium (Cr6) concentrations shown in milligrams per liter (mg/L).
3. Maximum Contaminant Level (MCL) as established by the California Department of Public Health.
4. Background color on graphs represent the y-axis range as follows:

White: 0 - 10 mg/L
Green: 0- 100 mg/L
Yellow: 0- 400 mg/L

N

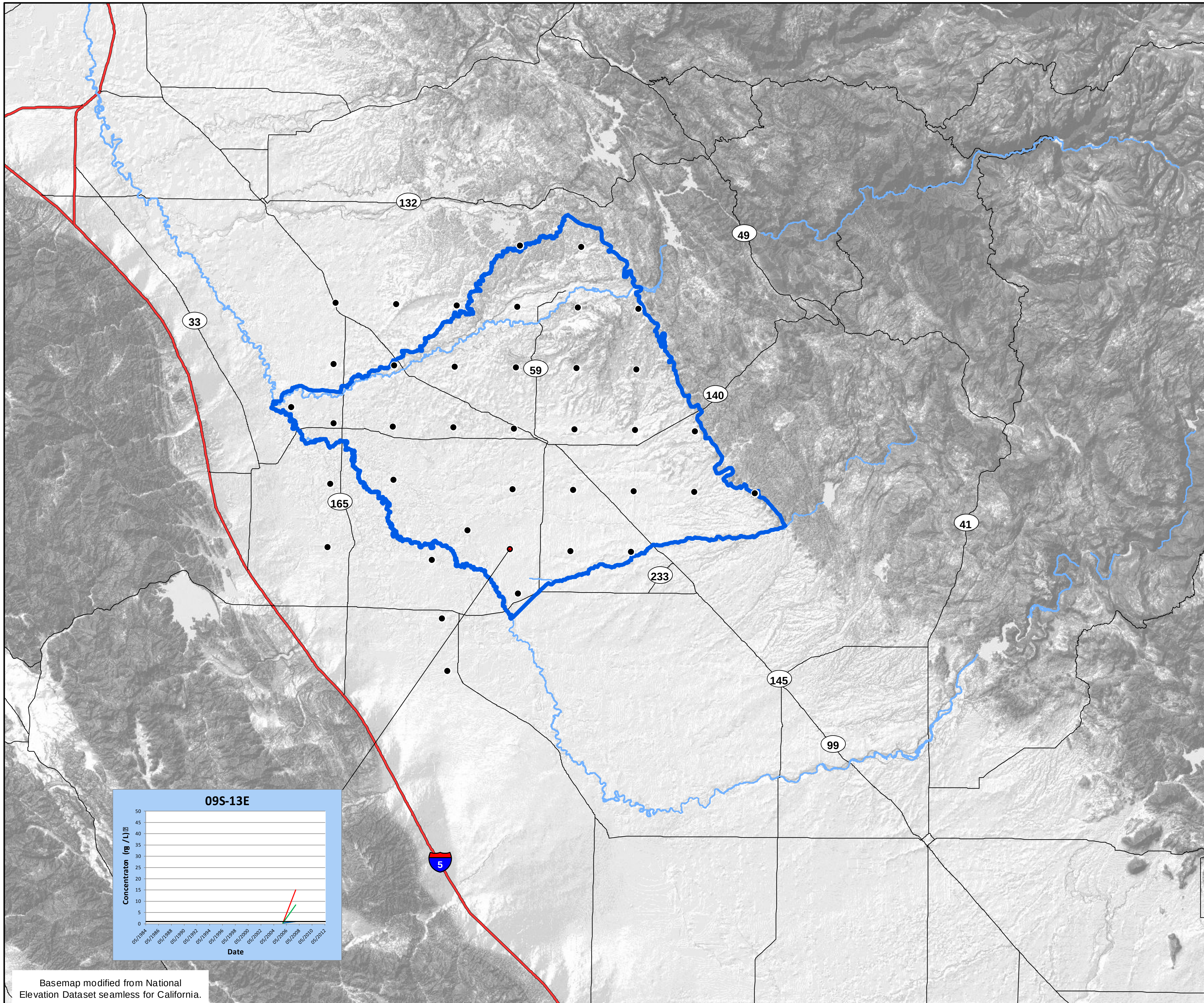
0 5 10

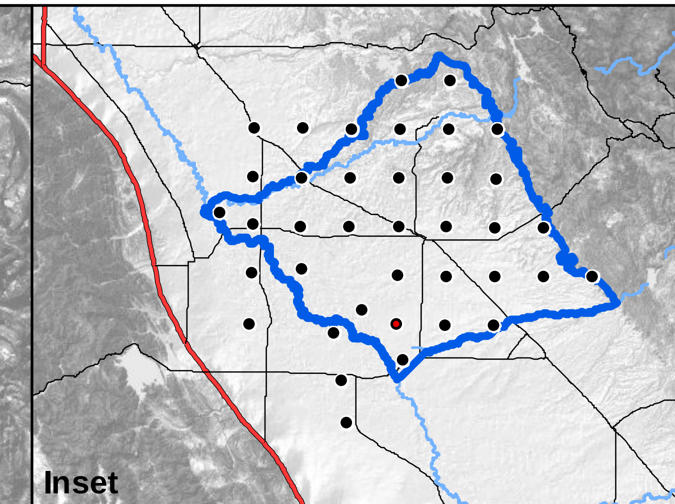
APPROXIMATE SCALE IN MILES

HEXAVALENT CHROMIUM (Cr6) CONCENTRATIONS
1984 THROUGH 2012
Merced IRWMP
Merced County, California

By: DB	Date: 01/08/2013	Project No. FR1216040A
		Figure **6b**

N:_FR_projects\FR12s\FR1216040A\gis\maps\2013_01ConcentrationMaps_fig06b_Cr6.mxd





Explanation:

- Township/Range centroid
- Surface water feature
- Merced IRWM area

Concentration Charts:

- Minimum Cr6 concentration
- Mean Cr6 concentration
- Maximum Cr6 concentration
- MCL for Cr6 (1 mg/L)

Notes:

1. IRWMP = Integrated Regional Water Management Plan.
2. Hexavalent chromium (Cr6) concentrations shown in milligrams per liter (mg/L).
3. Maximum Contaminant Level (MCL) as established by the California Department of Public Health.

N

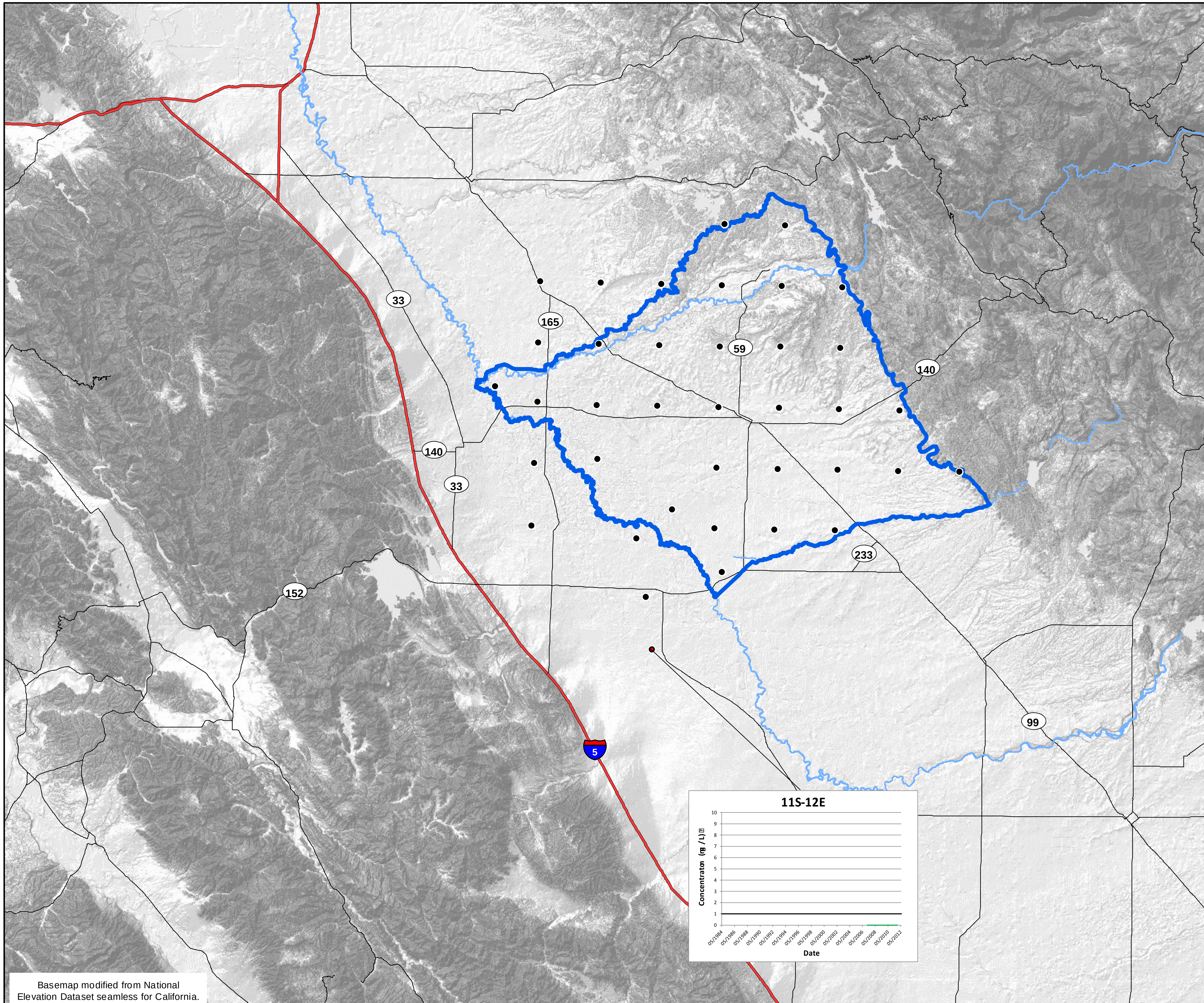
0 5 10

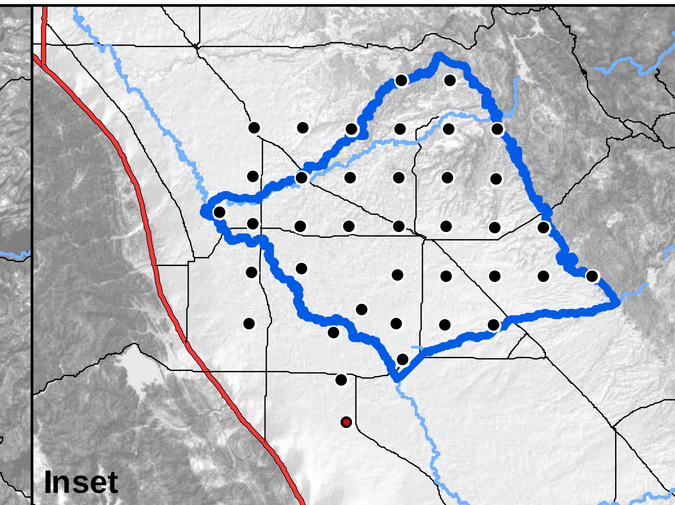
APPROXIMATE SCALE IN MILES

HEXAVALENT CHROMIUM (Cr6)
CONCENTRATIONS
1984 THROUGH 2012
Merced IRWMP
Merced County, California

By: DB	Date: 01/08/2013	Project No. FR1216040A
		Figure 6c

N:_FR_projects\FR12s\FR1216040A\gis\maps\2013_01\ConcentrationMaps_fig06c_Cr6.mxd





Explanation:

- Township/Range centroid
- Surface water feature
- Merced IRWM area

Concentration Charts:

- Minimum Cr6 concentration
- Mean Cr6 concentration
- Maximum Cr6 concentration
- MCL for Cr6 (1 mg/L)

Notes:

1. IRWMP = Integrated Regional Water Management Plan.
2. Hexavalent chromium (Cr6) concentrations shown in milligrams per liter (mg/L).
3. Maximum Contaminant Level (MCL) as established by the California Department of Public Health.

N

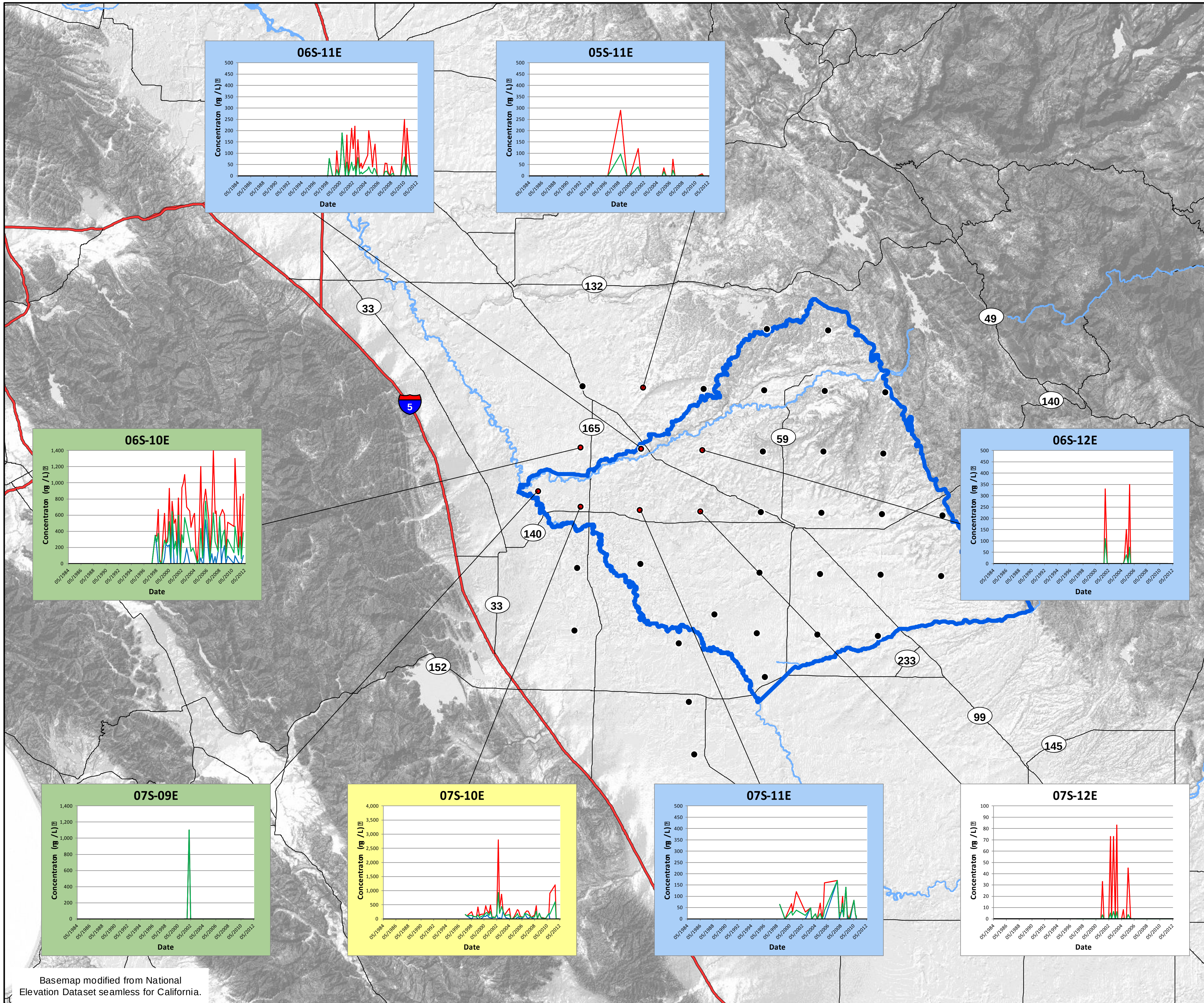
0 5 10

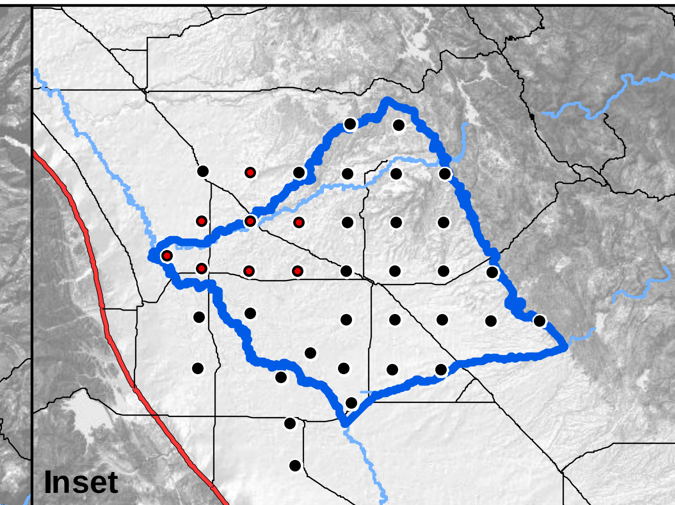
APPROXIMATE SCALE IN MILES

HEXAVALENT CHROMIUM (Cr6)
CONCENTRATIONS
1984 THROUGH 2012
Merced IRWMP
Merced County, California

By: DB	Date: 01/08/2013	Project No. FR1216040A
		Figure 6d

N:_FR_projects\FR12s\FR1216040A\gis\maps\2013_01\ConcentrationMaps_fig06d_Cr6.mxd





Explanation:

- Township/Range centroid
- Surface water feature
- Merced IRWM area

Concentration Charts:

- Minimum Mn concentration
- Mean Mn concentration
- Maximum Mn concentration
- SMCL for Mn (0.05 mg/L)

Notes:

1. IRWMP = Integrated Regional Water Management Plan.
2. Manganese (Mn) concentrations shown in milligrams per liter (mg/L).
3. Secondary Maximum Contaminant Level (SMCL) as established bv the California Department of Public Heath
4. Background color on graphs represent the y-axis range as follows:

White: 0- 100 mg/L
Blue: 0- 500 mg/L
Green: 0- 1,400 mg/L
Yellow: 0- 4,000 mg/L

N

0 5 10

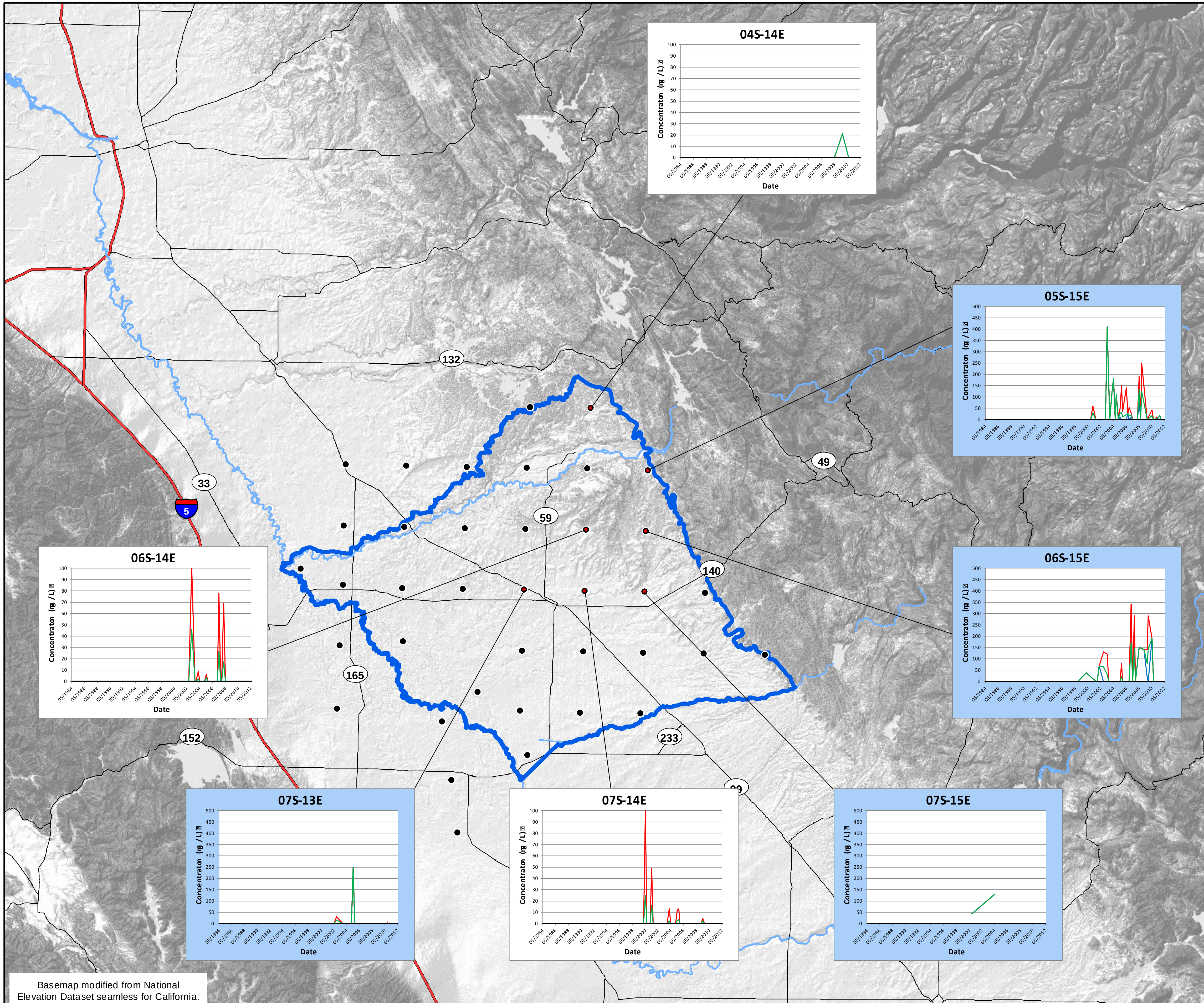
APPROXIMATE SCALE IN MILES

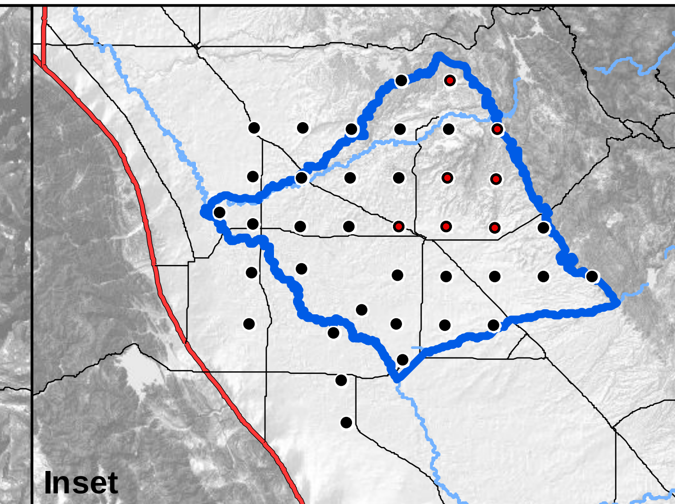
MANGANESE (Mn) CONCENTRATIONS
1984 THROUGH 2012
Merced IRWMP
Merced County, California

By: DB	Date: 01/08/2013	Project No. FR1216040A

Figure 7a

N:_FR_projects\FR12s\FR1216040A\gis\maps\2013_01ConcentrationMaps_fig07a_Mn.mxd





Explanation:

- Township/Range centroid
- Surface water feature
- Merced IRWM area

Concentration Charts:

- Minimum Mn concentration
- Mean Mn concentration
- Maximum Mn concentration
- SMCL for Mn (0.05 mg/L)

Notes:

1. IRWMP = Integrated Regional Water Management Plan.
2. Manganese (Mn) concentrations shown in milligrams per liter (mg/L).
3. Secondary Maximum Contaminant Level (SMCL) as established by the California Department of Public Heath
4. Background color on graphs represent the y-axis range as follows:

White: 0- 100 mg/L
Blue: 0- 500 mg/L

N

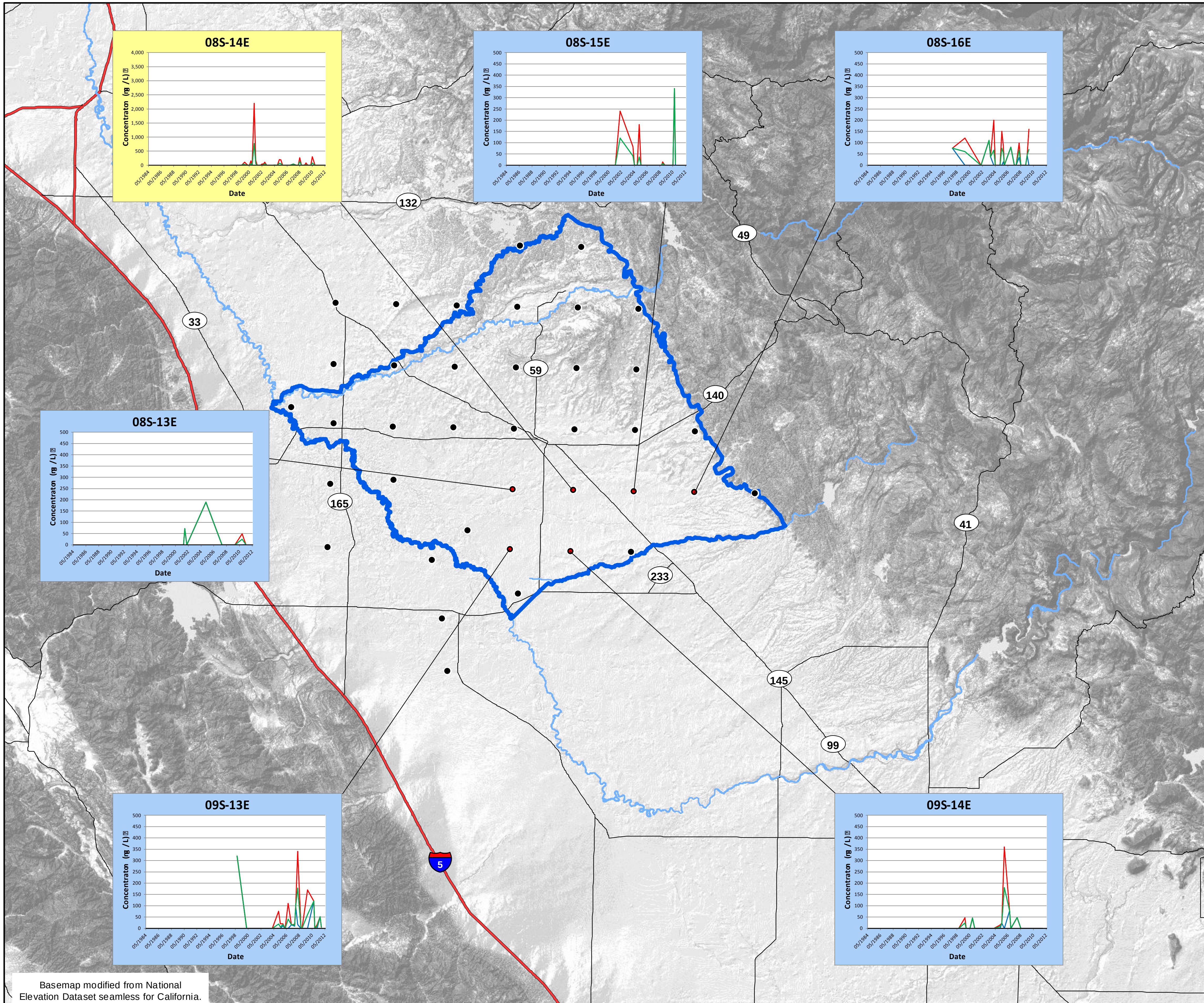
0 5 10

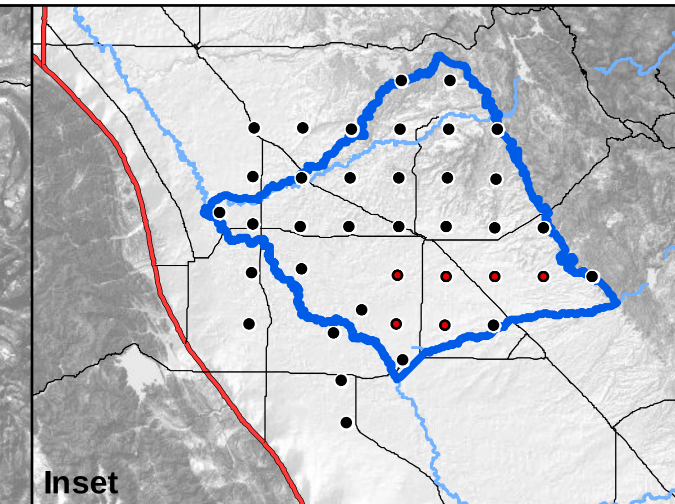
APPROXIMATE SCALE IN MILES

MANGANESE (Mn) CONCENTRATIONS
1984 THROUGH 2012
Merced IRWMP
Merced County, California

By: DB	Date: 01/08/2013	Project No. FR1216040A
		Figure **7b**

N:_FR_projects\FR12s\FR1216040A\gis\maps\2013_01\ConcentrationMaps_fig07b_Mn.mxd





Explanation:

- ●/● Township/Range centroid
- Surface water feature
- Merced IRWM area

Concentration Charts:

- Minimum Mn concentration
- Mean Mn concentration
- Maximum Mn concentration
- SMCL for Mn (0.05 mg/L)

Notes:

1. IRWMP = Integrated Regional Water Management Plan.
2. Manganese (Mn) concentrations shown in milligrams per liter (mg/L).
3. Secondary Maximum Contaminant Level (SMCL) as established by the California Department of Public Heath
4. Background color on graphs represent the y-axis range as follows:

Blue: 0- 500 mg/L
Yellow: 0- 4,000 mg/L

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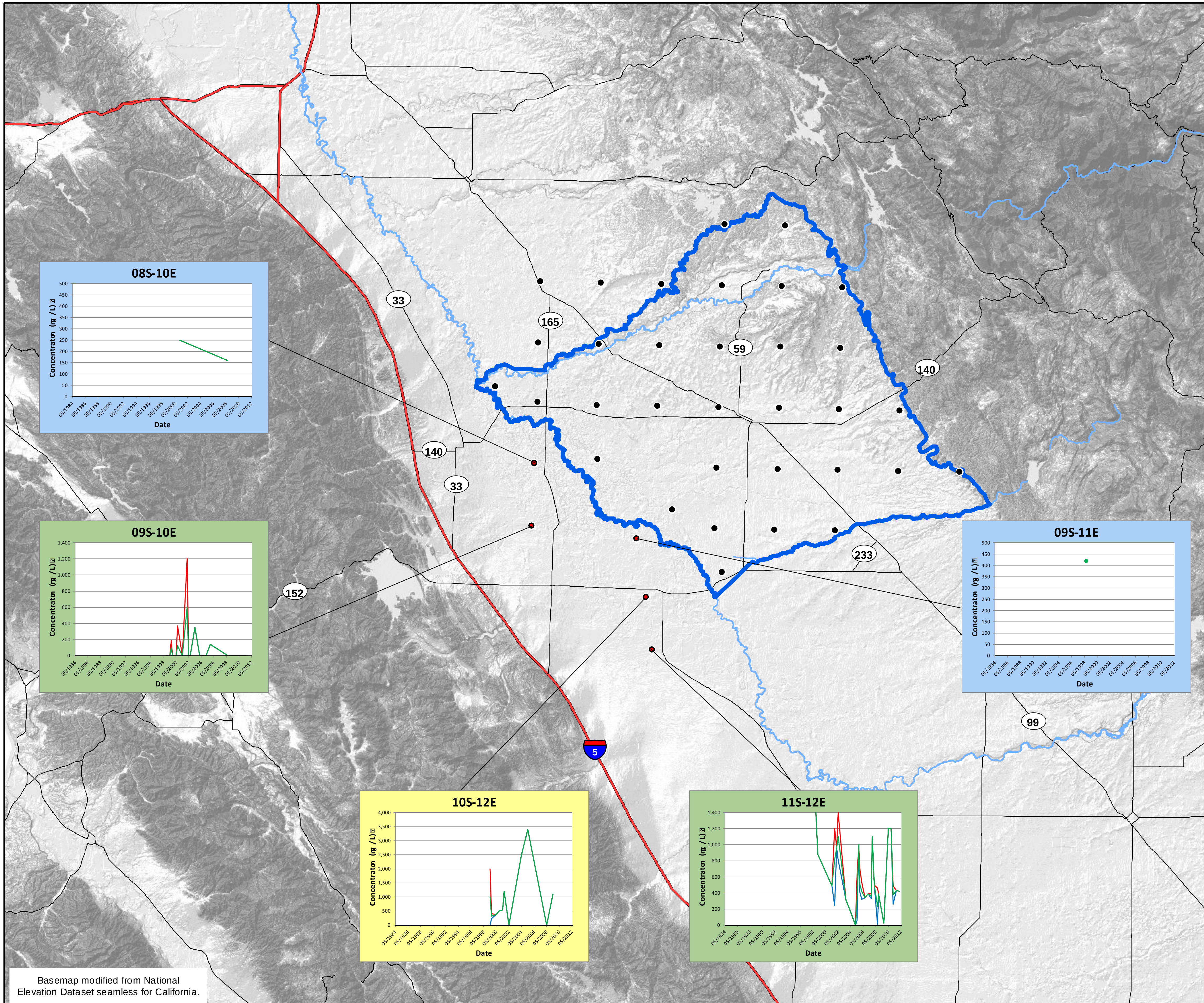
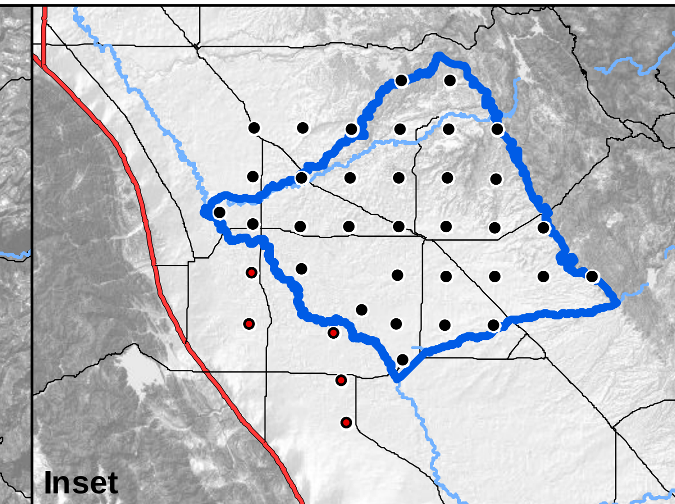
APPROXIMATE SCALE IN MILES

MANGANESE (Mn) CONCENTRATIONS
1984 THROUGH 2012
Merced IRWMP
Merced County, California

By: DB	Date: 01/08/2013	Project No. FR1216040A
		Figure 7c

N:_FR_projects\FR12s\FR1216040A\gis\maps\2013_01\ConcentrationMaps_fig07c_Mn.mxd





Explanation:

- ●/● Township/Range centroid
- Surface water feature
- Merced IRWM area

Concentration Charts:

- Minimum Mn concentration
- Mean Mn concentration
- Maximum Mn concentration
- SMCL for Mn (0.05 mg/L)

Notes:

1. IRWMP = Integrated Regional Water Management Plan.
2. Manganese (Mn) concentrations shown in milligrams per liter (mg/L).
3. Secondary Maximum Contaminant Level (SMCL) as established by the California Department of Public Heath
4. Background color on graphs represent the y-axis range as follows:

Blue: 0- 500 mg/L
Green: 0- 1,400 mg/L
Yellow: 0- 4,000 mg/L

N

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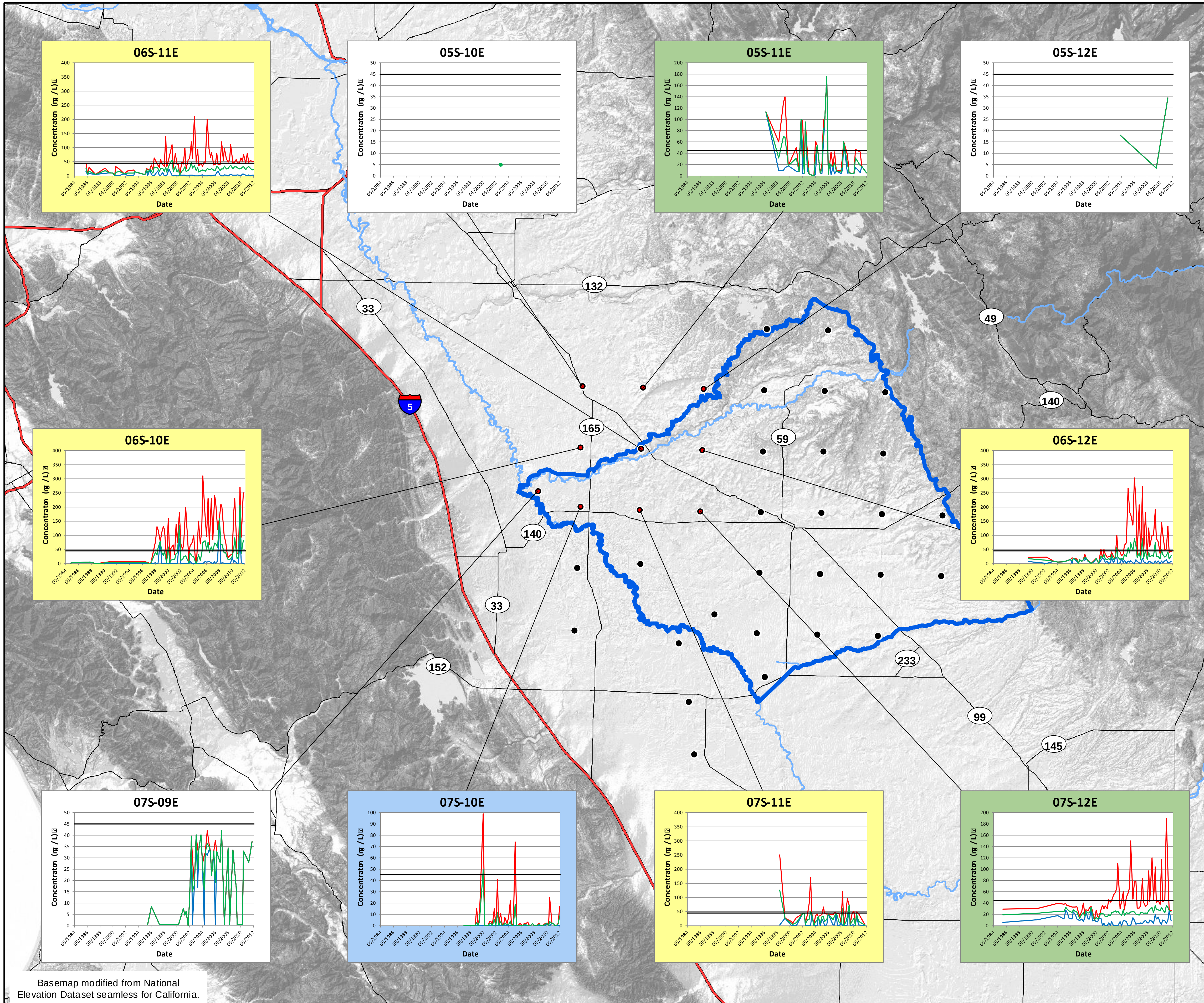
APPROXIMATE SCALE IN MILES

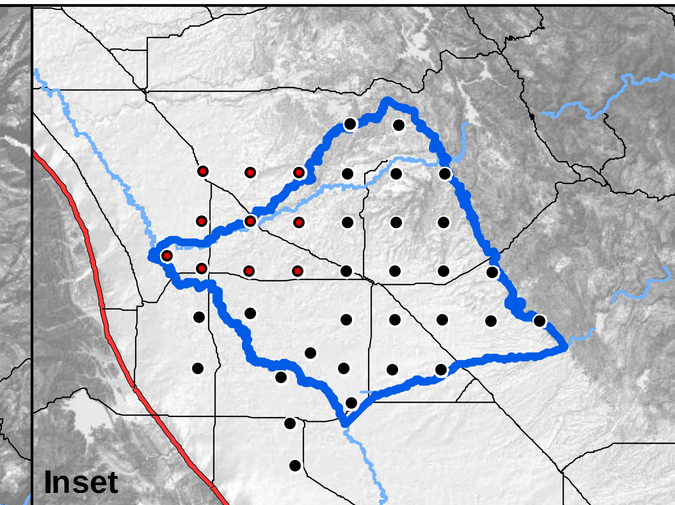
MANGANESE (Mn) CONCENTRATIONS
1984 THROUGH 2012
Merced IRWMP
Merced County, California

By: DB	Date: 01/08/2013	Project No. FR1216040A

Figure **7d**

N:_FR_projects\FR12s\FR1216040A\gis\maps\2013_01\ConcentrationMaps_fig07d_Mn.mxd





Explanation:

- Township/Range centroid
- Surface water feature
- Merced IRWM area

Concentration Charts:

- Minimum NO3 concentration
- Mean NO3 concentration
- Maximum NO3 concentration
- MCL for NO3 (45 mg/L)

Notes:

1. IRWMP = Integrated Regional Water Management Plan.
2. Nitrate (NO3) concentrations shown in milligrams per liter (mg/L).
3. Maximum Contaminant Level (MCL) as established by the California Department of Public Health.
4. Background color on graphs represent the y-axis range as follows:

White: 0- 50 mg/L
Blue: 0- 100 mg/L
Green: 0- 200 mg/L
Yellow: 0- 400 mg/L

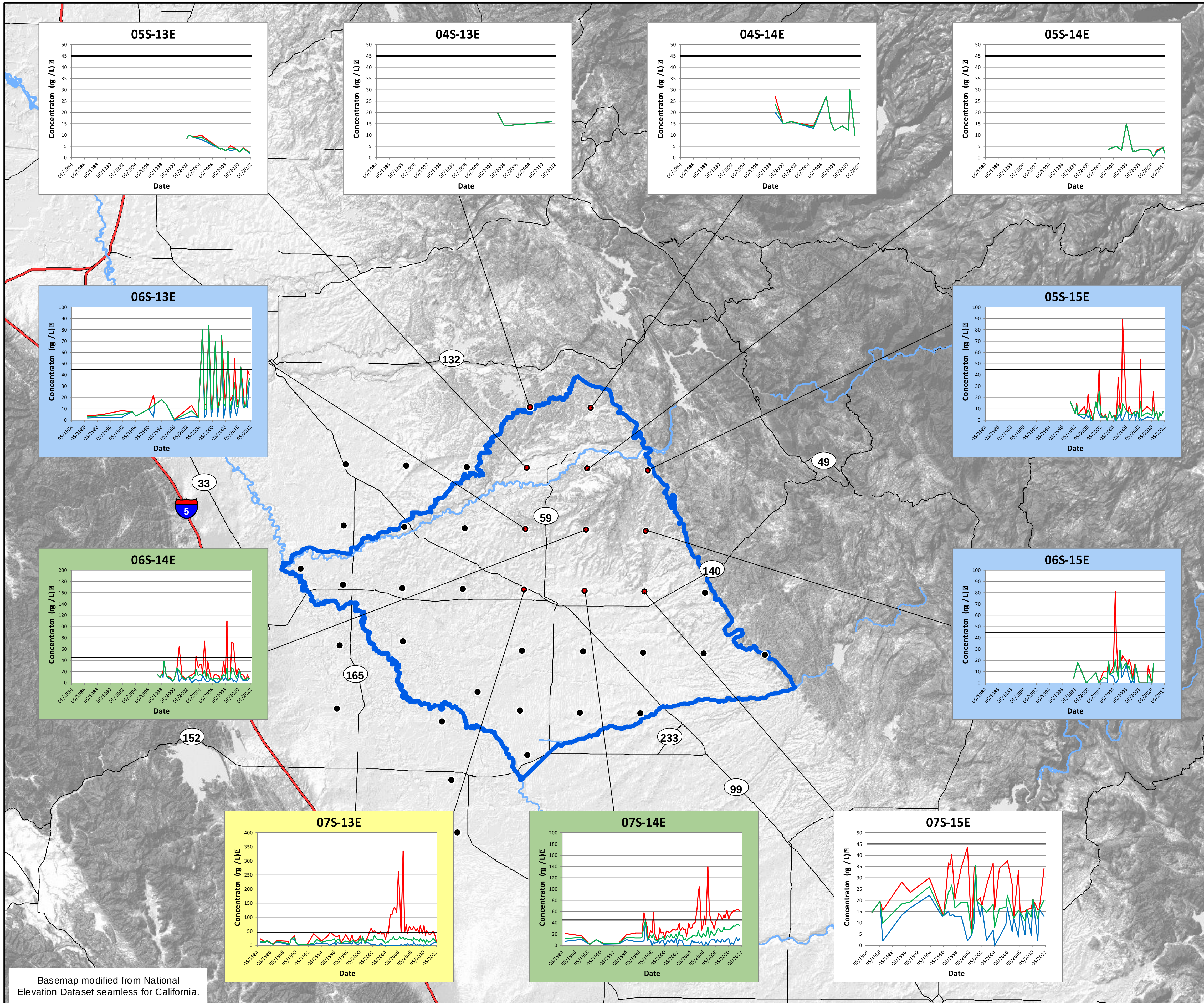
N

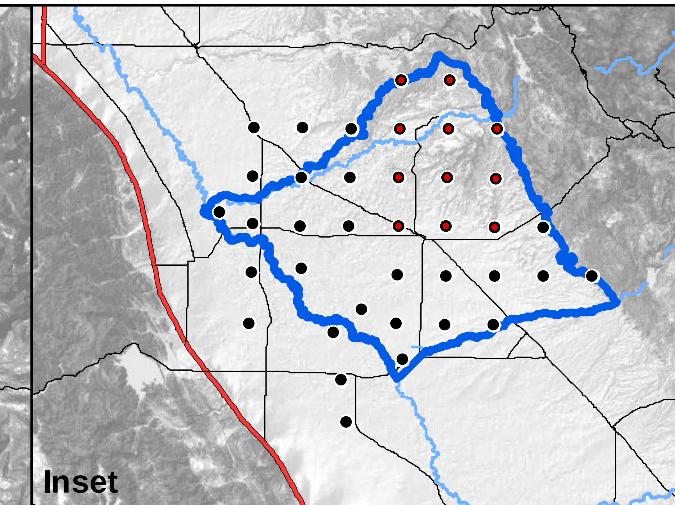
0 5 10
APPROXIMATE SCALE IN MILES

NITRATE (NO3) CONCENTRATIONS
1984 THROUGH 2012
Merced Salt and Nutrient Plan
Merced, California

By: DB	Date: 01/08/2013	Project No. FR1216040A
		Figure 8a

N:_FR_projects\FR12s\FR1216040A\gis\maps\2013_01\ConcentrationMaps_fig08a_NO3.mxd





Explanation:

- Township/Range centroid
- Surface water feature
- Merced IRWM area

Concentration Charts:

- Minimum NO3 concentration
- Mean NO3 concentration
- Maximum NO3 concentration
- MCL for NO3 (45 mg/L)

Notes:

1. IRWMP = Integrated Regional Water Management Plan.
2. Nitrate (NO3) concentrations shown in milligrams per liter (mg/L).
3. Maximum Contaminant Level (MCL) as established by the California Department of Public Health.
4. Background color on graphs represent the y-axis range as follows:

White: 0- 50 mg/L
Blue: 0- 100 mg/L
Green: 0- 200 mg/L
Yellow: 0- 400 mg/L

N

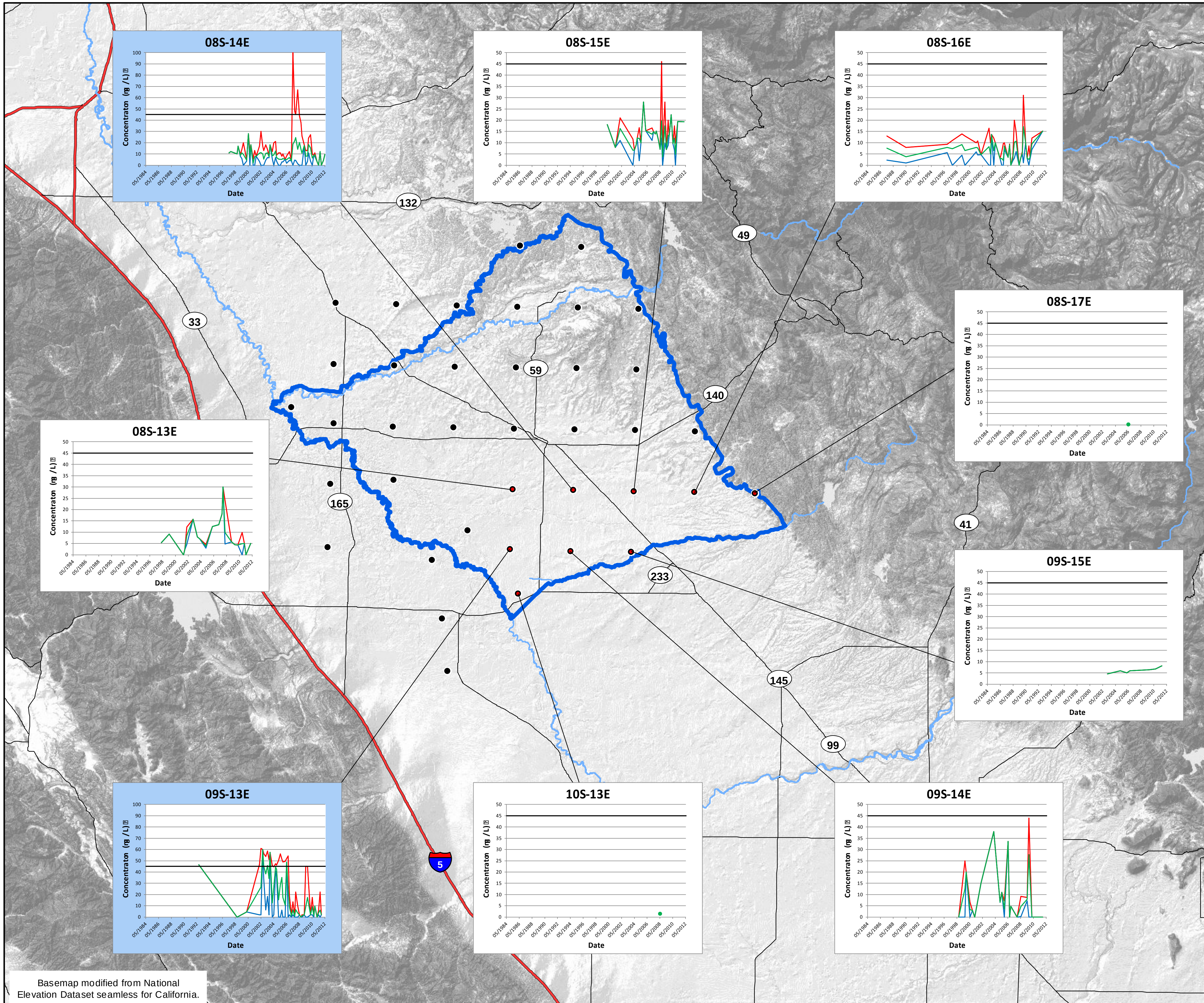
0 5 10

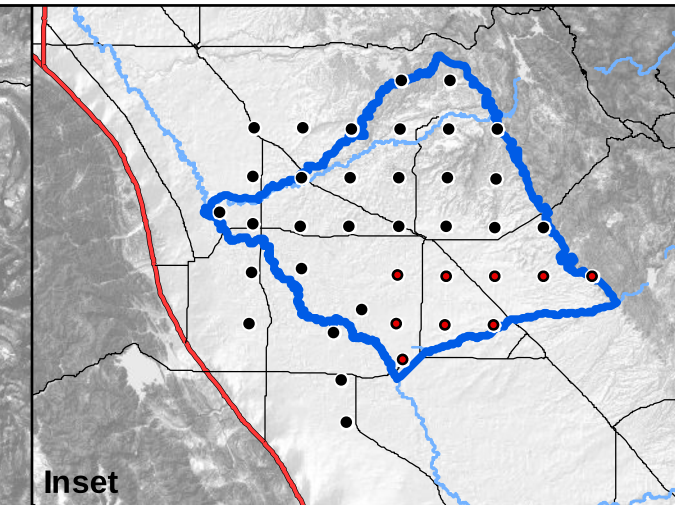
APPROXIMATE SCALE IN MILES

NITRATE (NO3) CONCENTRATIONS
1984 THROUGH 2012
Merced IRWMP
Merced County, California

By: DB	Date: 01/08/2013	Project No. FR1216040A
		Figure 8b

N:_FR_projects\FR12s\FR1216040A\gis\maps\2013_01\ConcentrationMaps_fig08b_NO3.mxd





Explanation:

- Township/Range centroid
- Surface water feature
- Merced IRWM area

Concentration Charts:

- Minimum NO3 concentration
- Mean NO3 concentration
- Maximum NO3 concentration
- MCL for NO3 (45 mg/L)

Notes:

1. IRWMP = Integrated Regional Water Management Plan.
2. Nitrate (NO3) concentrations shown in milligrams per liter (mg/L).
3. Maximum Contaminant Level (MCL) as established by the California Department of Public Health.
4. Background color on graphs represent the y-axis range as follows:

White: 0- 50 mg/L
Blue: 0- 100 mg/L

N

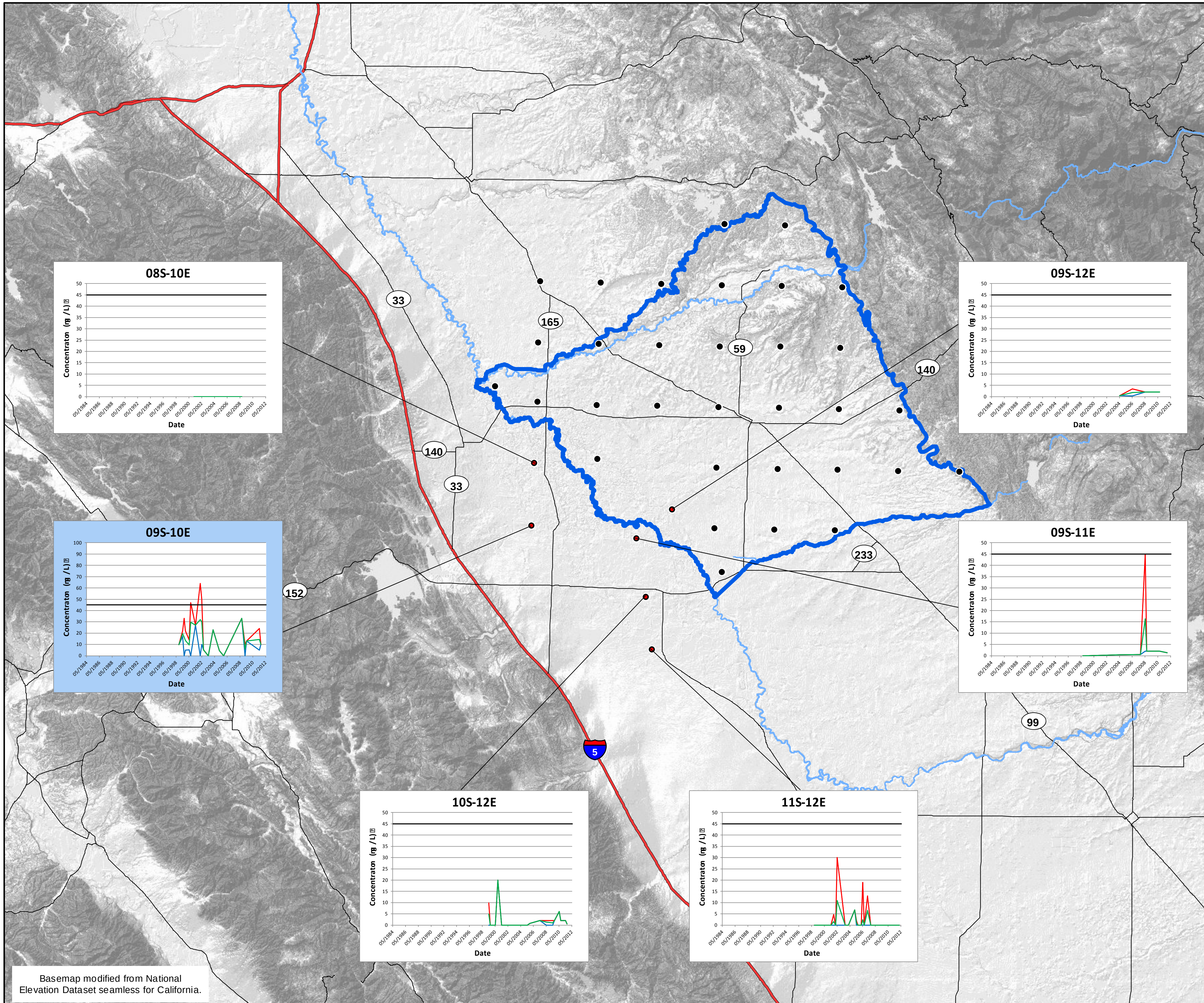
0 5 10

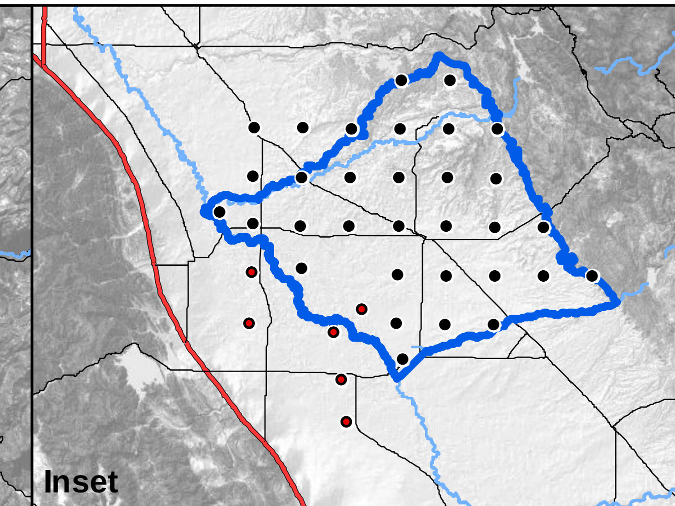
APPROXIMATE SCALE IN MILES

NITRATE (NO3) CONCENTRATIONS
1984 THROUGH 2012
Merced IRWMP
Merced County, California

By: DB	Date: 01/08/2013	Project No. FR1216040A
		Figure 8c

N:_FR_projects\FR12s\FR1216040A\gis\maps\2013_01\ConcentrationMaps_fig08c_NO3.mxd





Explanation:

●/● Township/Range centroid

Surface water feature

Merced IRWM area

Concentration Charts:

Minimum NO3 concentration

Mean NO3 concentration

Maximum NO3 concentration

MCL for NO3 (45 mg/L)

Notes:

1. IRWMP = Integrated Regional Water Management Plan.
2. Nitrate (NO3) concentrations shown in milligrams per liter (mg/L).
3. Maximum Contaminant Level (MCL) as established by the California Department of Public Health.
4. Background color on graphs represent the y-axis range as follows:

White: 0- 50 mg/L
Blue: 0- 100 mg/L

N

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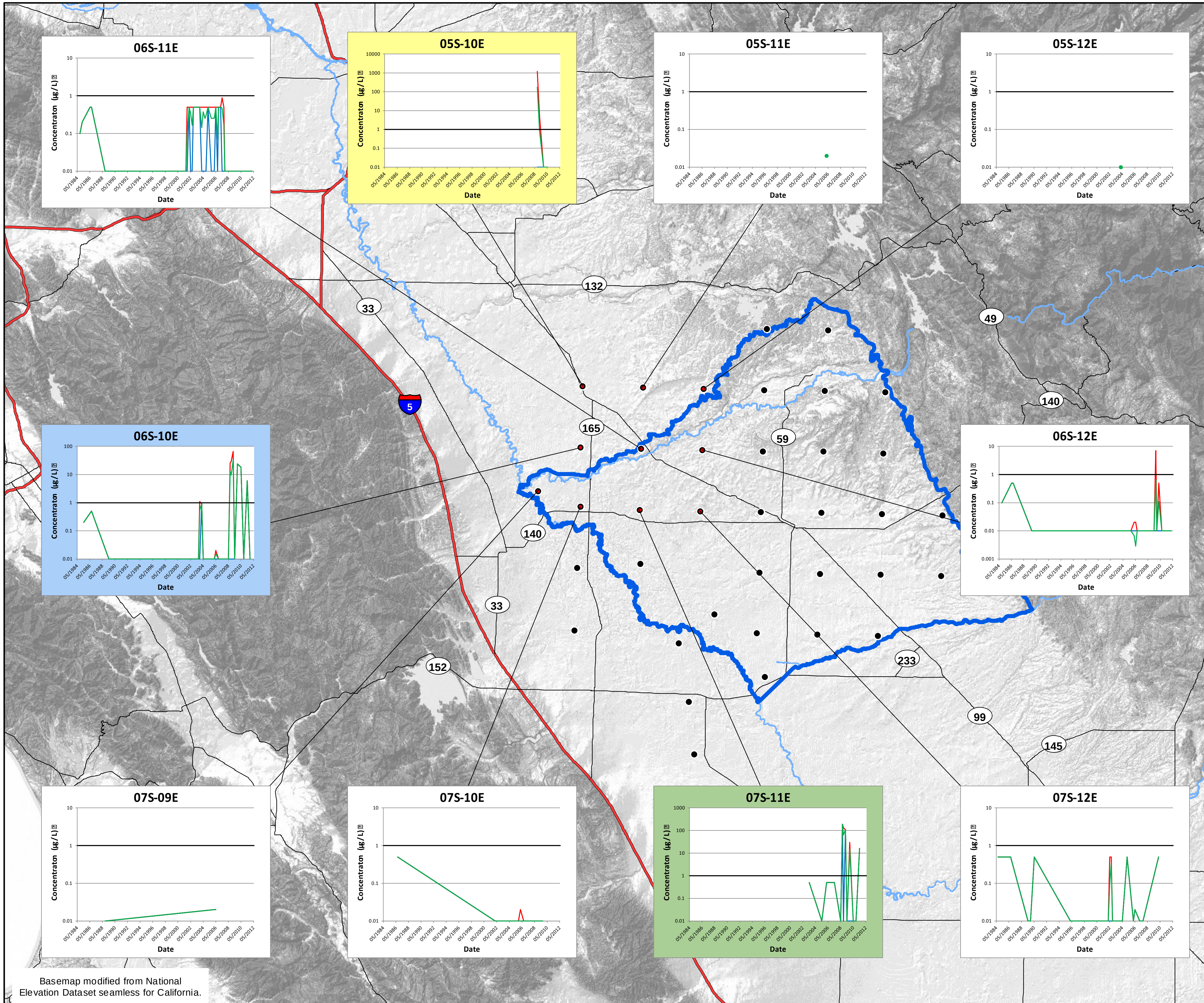
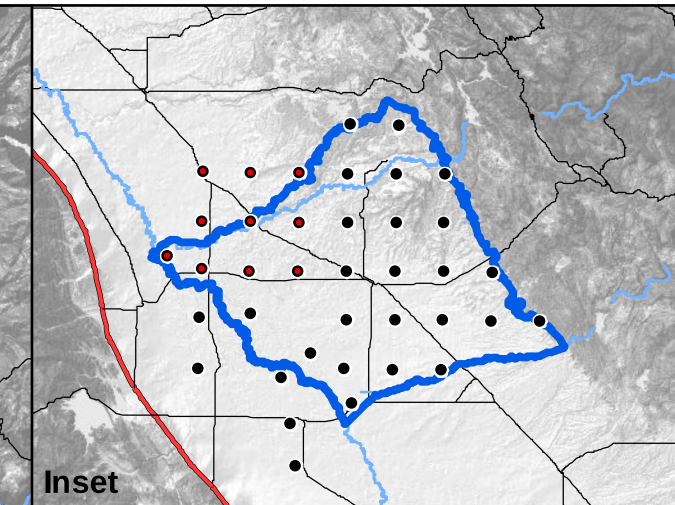
APPROXIMATE SCALE IN MILES

NITRATE (NO3) CONCENTRATIONS
1984 THROUGH 2012
Merced IRWMP
Merced County, California

By: DB	Date: 01/08/2013	Project No. FR1216040A
		Figure 8d

N:_FR_projects\FR12s\FR1216040A\gis\maps\2013_01\ConcentrationMaps_fig08d_NO3.mxd





Explanation:

- Township/Range centroid
- Surface water feature
- Merced IRWM area

Concentration Charts:

- Minimum benzene concentration
- Mean benzene concentration
- Maximum benzene concentration
- MCL for benzene (1 µg/L)

Notes:

1. IRWMP = Integrated Regional Water Management Plan.
2. Benzene concentrations shown in micrograms per liter (µg/L).
3. Maximum Contaminant Level (MCL) as established by the California Department of Public Health.
4. Background color on graphs represent the y-axis range as follows:

White: 0.01- 10 µg/L
Blue: 0.01- 100 µg/L
Green: 0.01- 1,000 µg/L
Yellow: 0.01- 10,000 µg/L

N

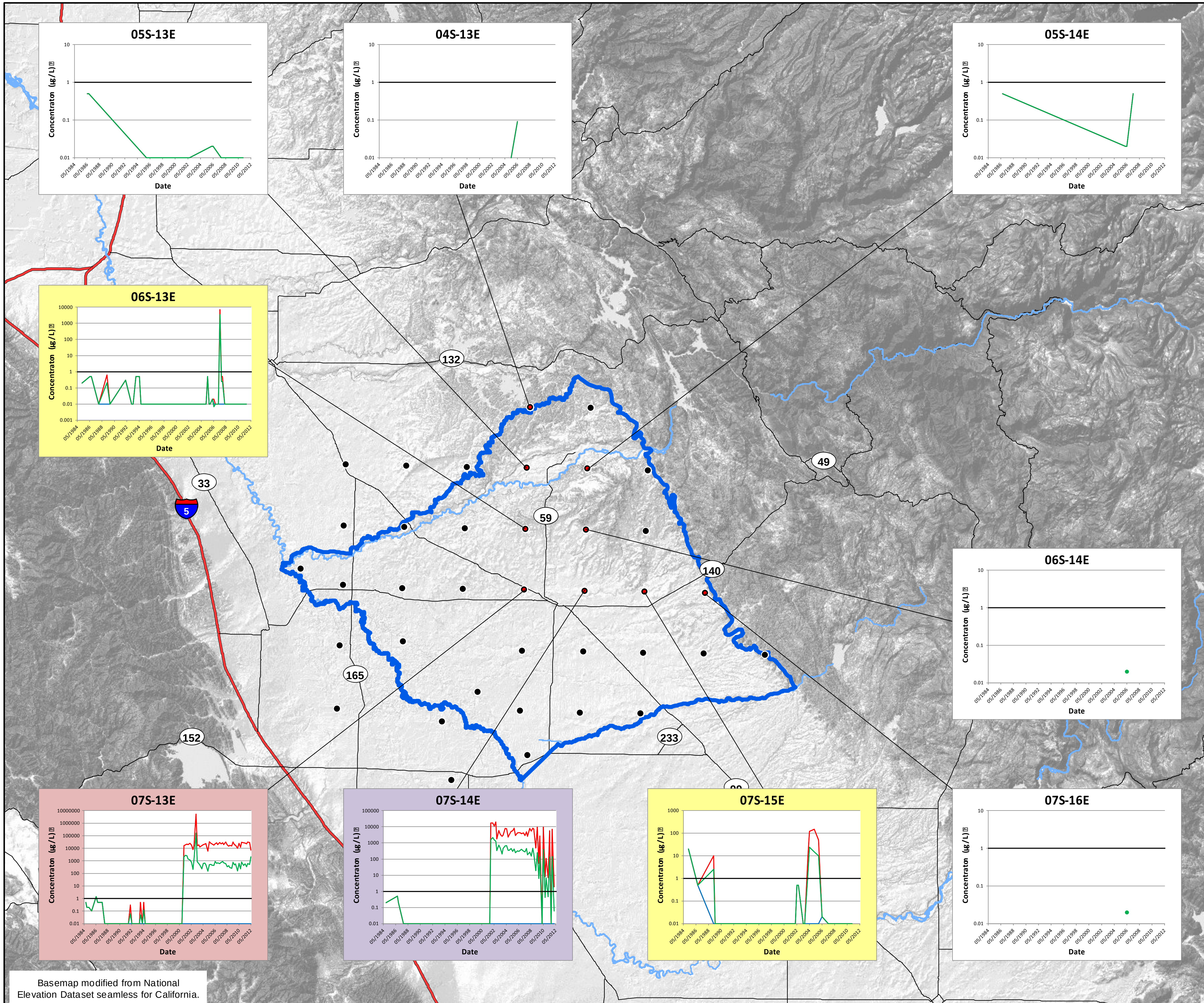
0 5 10

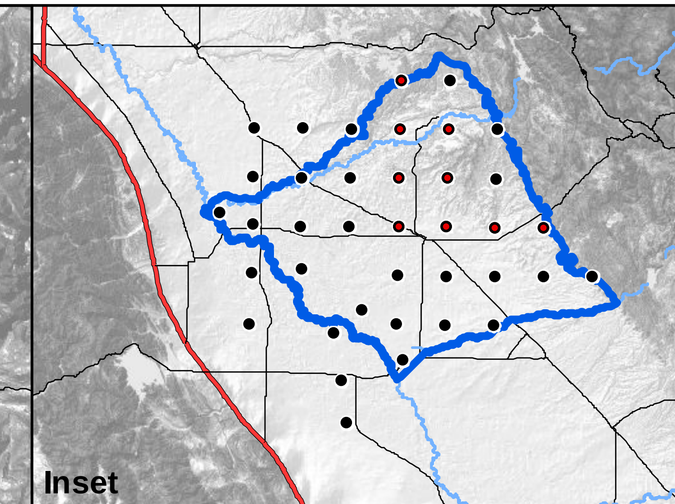
APPROXIMATE SCALE IN MILES

BENZENE CONCENTRATIONS
1984 THROUGH 2012
Merced IRWMP
Merced County, California

By: DB	Date: 01/08/2013	Project No. FR1216040A
		Figure **10a**

N:_FR_projects\FR12s\FR1216040A\gis\maps\2013_01ConcentrationMaps_fig10a_Benzene.mxd





Explanation:

- Township/Range centroid
- Surface water feature
- Merced IRWM area

Concentration Charts:

- Minimum benzene concentration
- Mean benzene concentration
- Maximum benzene concentration
- MCL for benzene (1 µg/L)

Notes:

1. IRWMP = Integrated Regional Water Management Plan.
2. Benzene concentrations shown in micrograms per liter (µg/L).
3. Maximum Contaminant Level (MCL) as established by the California Department of Public Health.
4. Background color on graphs represent the y-axis range as follows:

White: 0.01- 10 µg/L
Yellow: 0.01- 1,000 µg/L
Purple: 0.01- 100,000 µg/L
Pink: 0.01- 10,000,000 µg/L

N

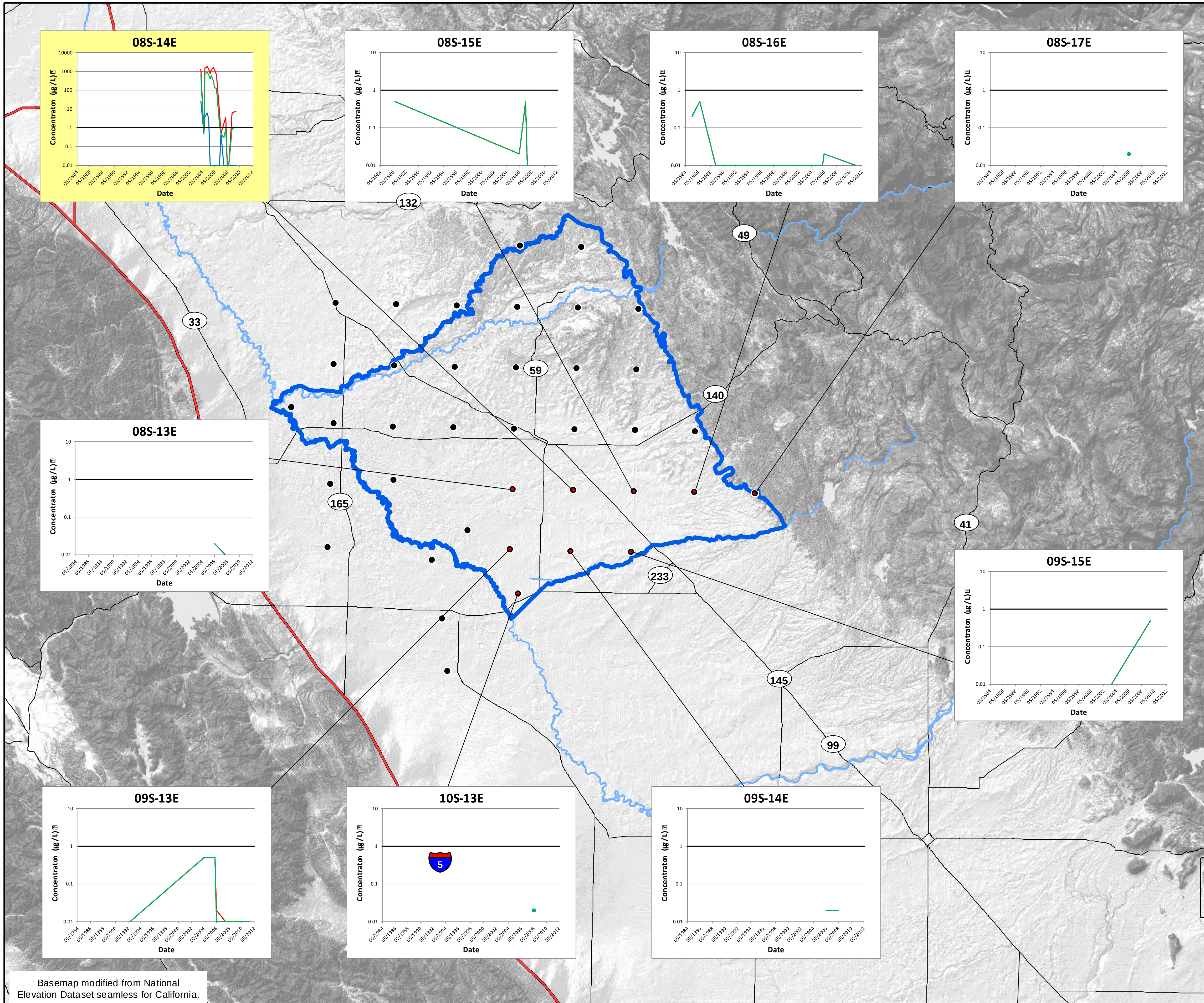
0 5 10

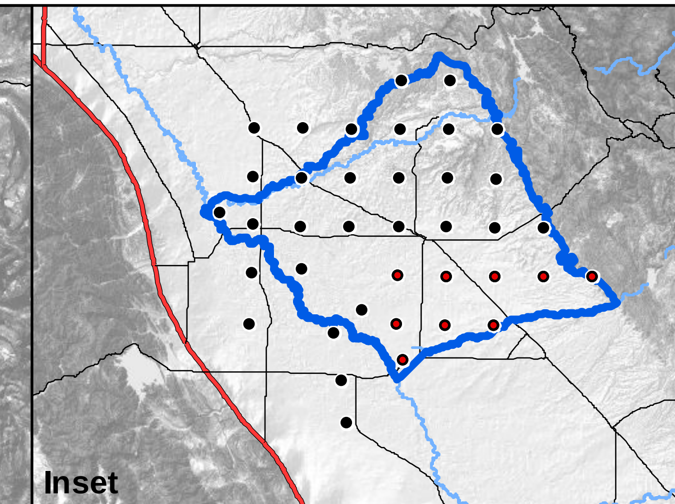
APPROXIMATE SCALE IN MILES

BENZENE CONCENTRATIONS
1984 THROUGH 2012
Merced IRWMP
Merced County, California

By: DB	Date: 12/05/2012	Project No. FR1216040A
		Figure **10b**

N:_FR_projects\FR12s\FR1216040A\gis\maps\2013_01\ConcentrationMaps_fig10b_Benzene.mxd





Explanation:

- Township/Range centroid
- Surface water feature
- Merced IRWM area

Concentration Charts:

- Minimum benzene concentration
- Mean benzene concentration
- Maximum benzene concentration
- MCL for benzene (1 µg/L)

Notes:

1. IRWMP = Integrated Regional Water Management Plan.
2. Benzene concentrations shown in micrograms per liter (µg/L).
3. Maximum Contaminant Level (MCL) as established by the California Department of Public Health.
4. Background color on graphs represent the y-axis range as follows:

White: 0.01- 10 µg/L

Yellow: 0.01- 10,000 µg/L

N

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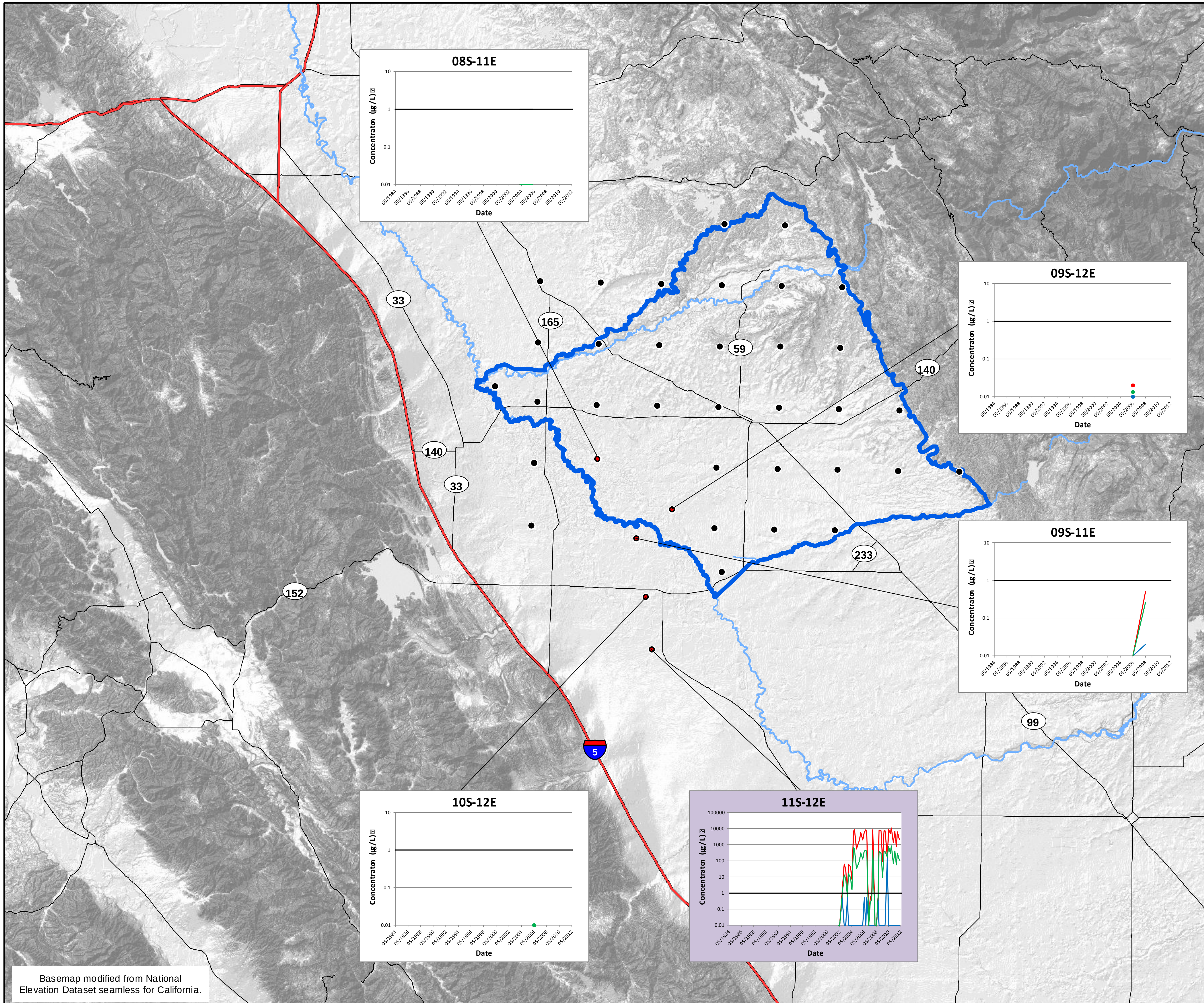
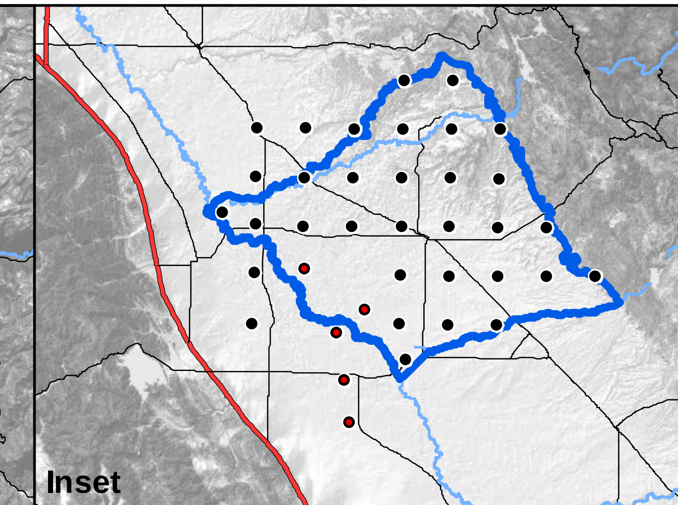
APPROXIMATE SCALE IN MILES

BENZENE CONCENTRATIONS
1984 THROUGH 2012
Merced IRWMP
Merced County, California

By: DB	Date: 01/08/2013	Project No. FR1216040A
		Figure 10c

N:_FR_projects\FR12s\FR1216040A\gis\maps\2013_01\ConcentrationMaps_fig10c_Benzene.mxd





Explanation:

Township/Range centroid

Surface water feature

Merced IRWM area

Concentration Charts:

Minimum benzene concentration

Mean benzene concentration

Maximum benzene concentration

MCL for benzene (1 µg/L)

Notes:

1. IRWMP = Integrated Regional Water Management Plan.
2. Benzene concentrations shown in micrograms per liter (µg/L).
3. Maximum Contaminant Level (MCL) as established by the California Department of Public Health.
4. Background color on graphs represent the y-axis range as follows:
   White: 0.01- 10 µg/L
   Purple: 0.01- 100,000 µg/L

N

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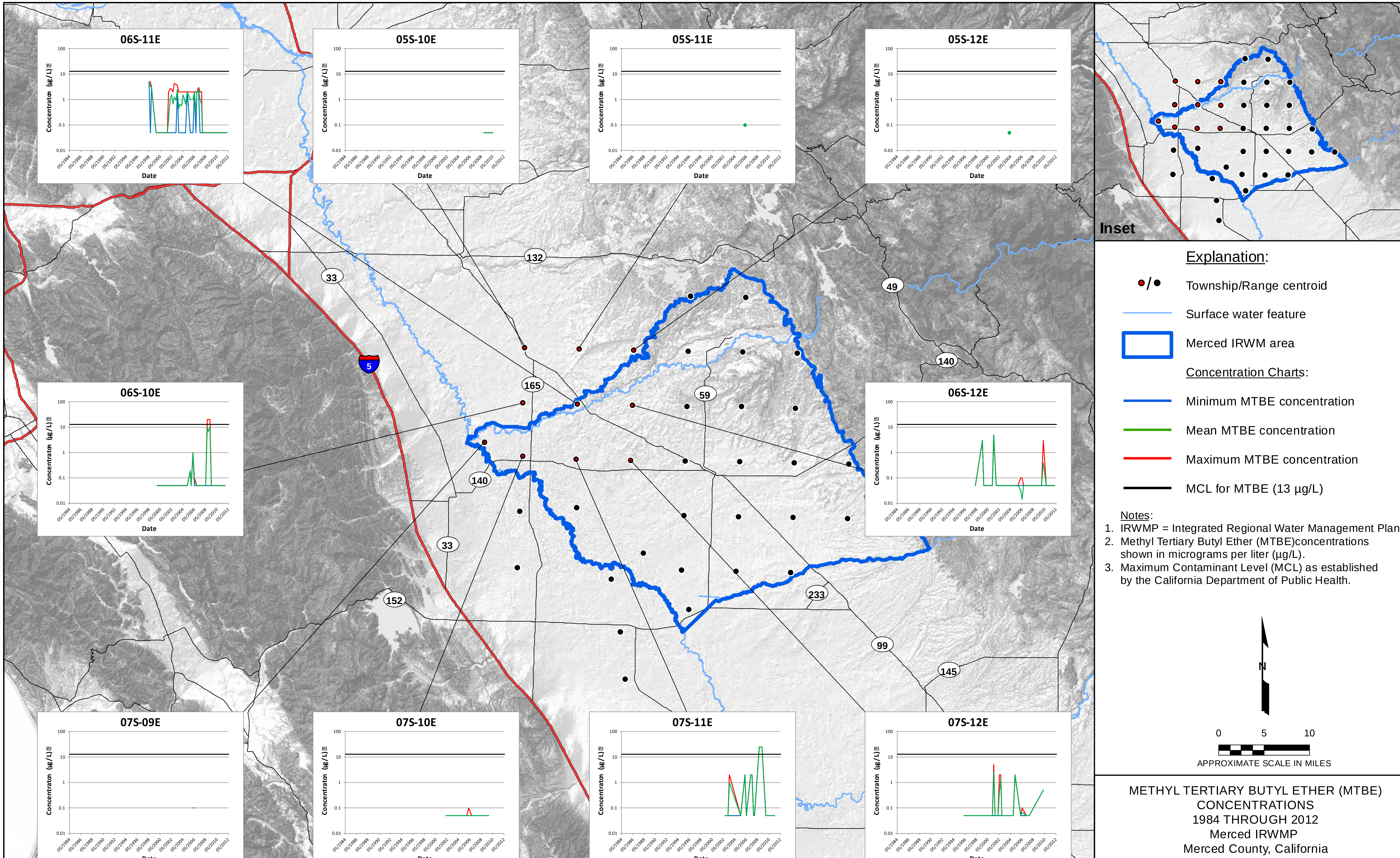
APPROXIMATE SCALE IN MILES

BENZENE CONCENTRATIONS
1984 THROUGH 2012
Merced IRWMP
Merced County, California

By: DB	Date: 01/08/2013	Project No. FR1216040A
		Figure 10d

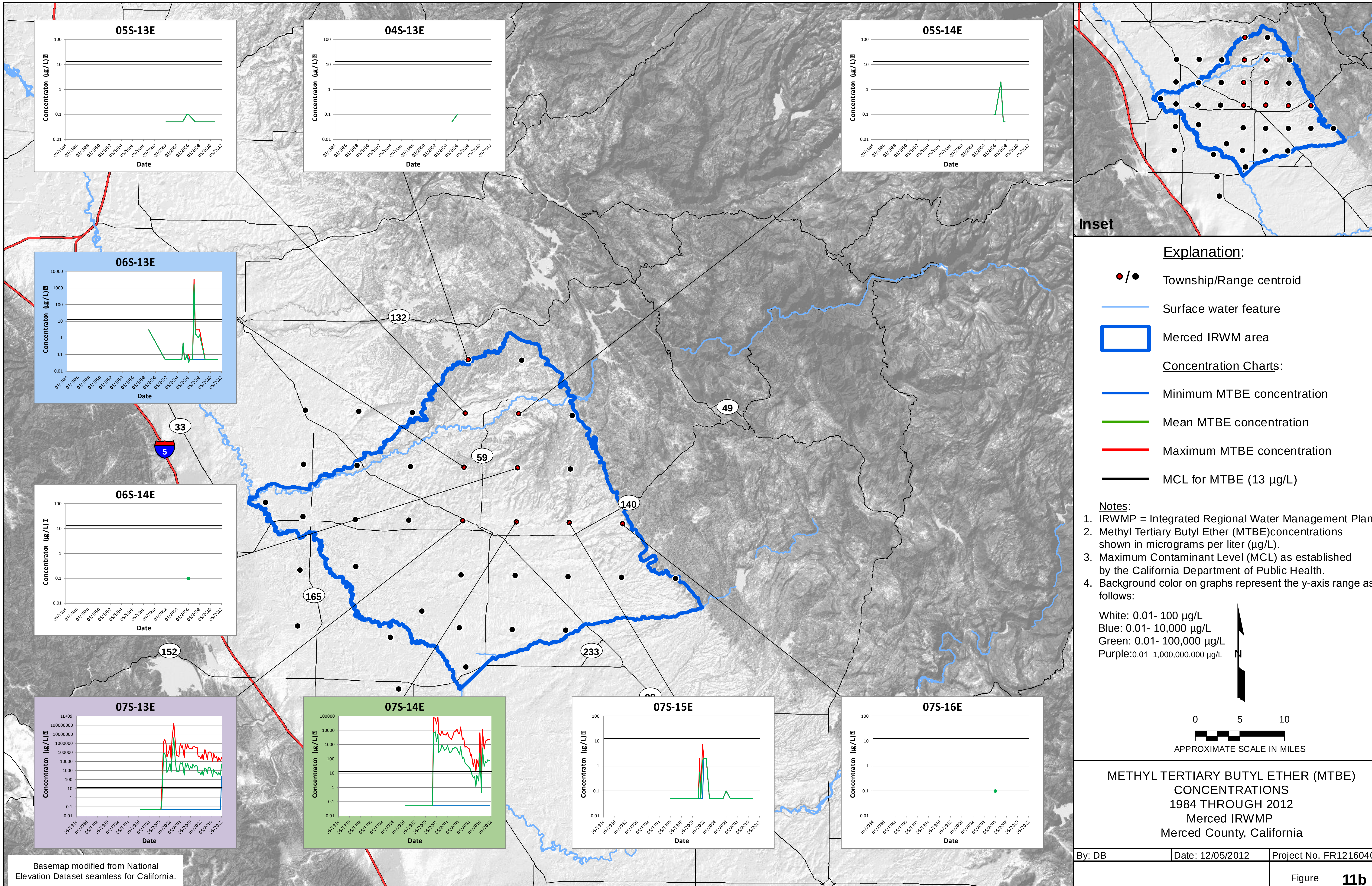
N:_FR_projects\FR12s\FR1216040A\gis\maps\2013_01\ConcentrationMaps_fig10d_Benzene.mxd



METHYL TERTIARY BUTYL ETHER (MTBE) CONCENTRATIONS
1984 THROUGH 2012
Merced IRWMP
Merced County, California

By: DB	Date: 01/08/2013	Project No. FR1216040A
		Figure 11a

N:_FR_projects\FR12s\FR1216040A\gis\maps\2013_01\ConcentrationMaps_fig11a_MTBE.mxd



Explanation:

- Township/Range centroid
- Surface water feature
- Merced IRWM area

Concentration Charts:

- Minimum MTBE concentration
- Mean MTBE concentration
- Maximum MTBE concentration
- MCL for MTBE (13 µg/L)

Notes:

1. IRWMP = Integrated Regional Water Management Plan.
2. Methyl Tertiary Butyl Ether (MTBE)concentrations shown in micrograms per liter (µg/L).
3. Maximum Contaminant Level (MCL) as established by the California Department of Public Health.
4. Background color on graphs represent the y-axis range as follows:

White: 0.01- 100 µg/L
Blue: 0.01- 10,000 µg/L
Green: 0.01- 100,000 µg/L
Purple:0.01- 1,000,000,000 µg/L

N

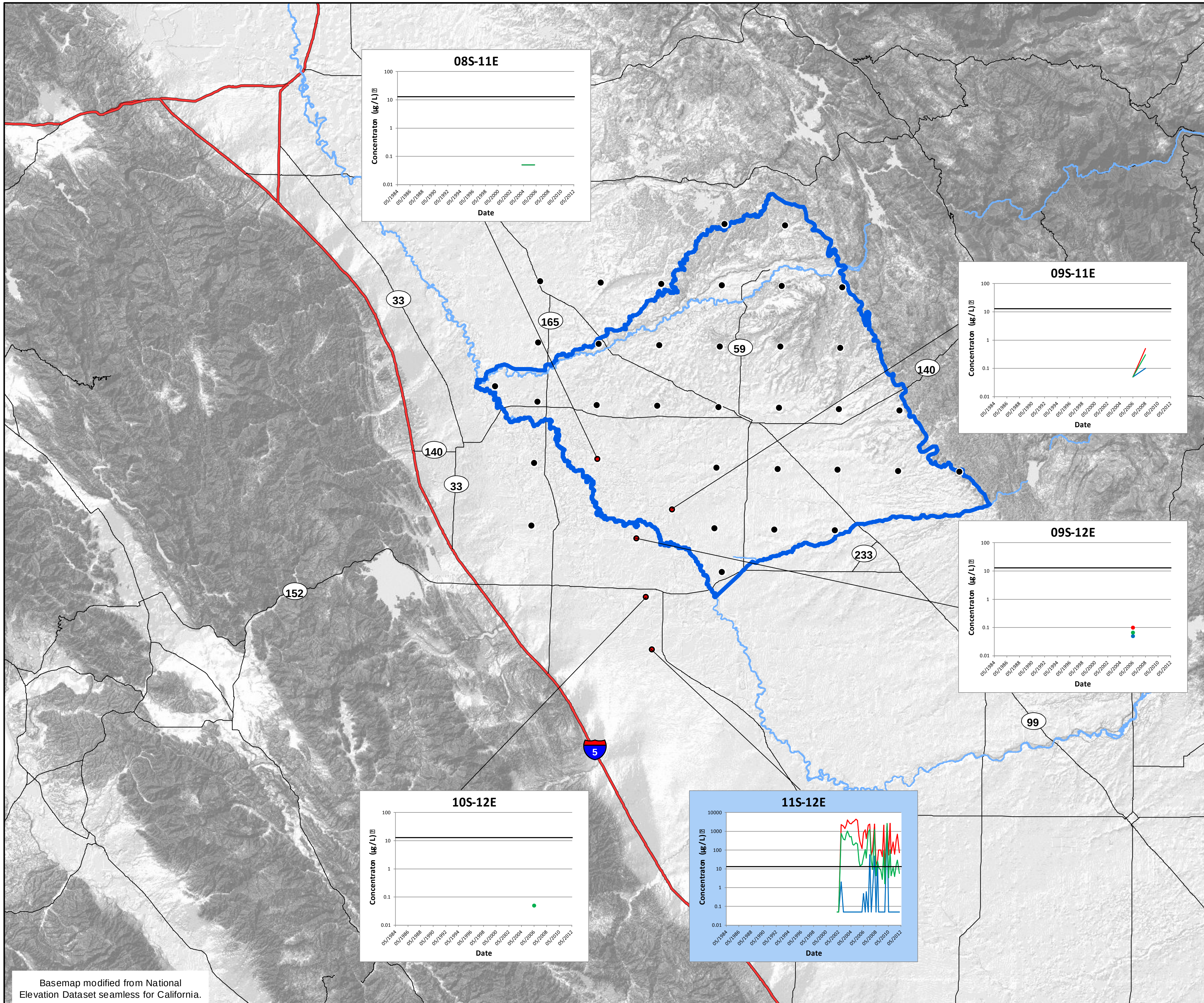
0 5 10

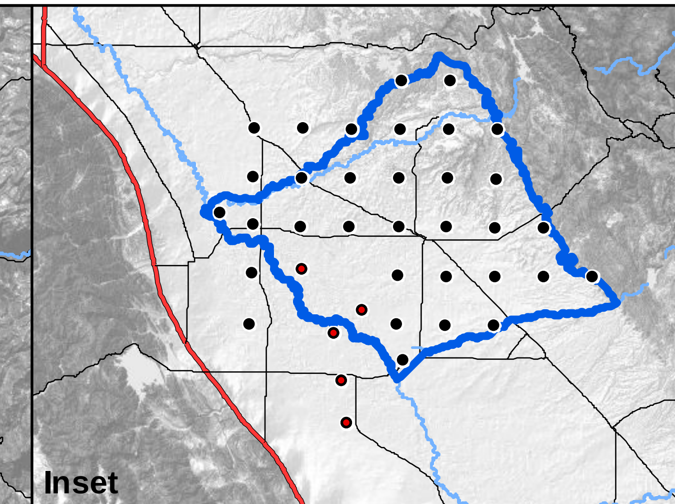
APPROXIMATE SCALE IN MILES

METHYL TERTIARY BUTYL ETHER (MTBE)
CONCENTRATIONS
1984 THROUGH 2012
Merced IRWMP
Merced County, California

By: DB	Date: 12/05/2012	Project No. FR1216040A
		Figure 11b

N:_FR_projects\FR12s\FR1216040A\gis\maps\2013_01\ConcentrationMaps_fig11c_MTBE.mxd





Explanation:

- Township/Range centroid
- Surface water feature
- Merced IRWM area

Concentration Charts:

- Minimum MTBE concentration
- Mean MTBE concentration
- Maximum MTBE concentration
- MCL for MTBE (13 µg/L)

Notes:

1. IRWMP = Integrated Regional Water Management Plan.
2. Methyl Tertiary Butyl Ether (MTBE)concentrations shown in micrograms per liter (µg/L).
3. Maximum Contaminant Level (MCL) as established by the California Department of Public Health.
4. Background color on graphs represents concentration

White: 0.01- 100 µg/L

Blue: 0.01-10,000 µg/L

N

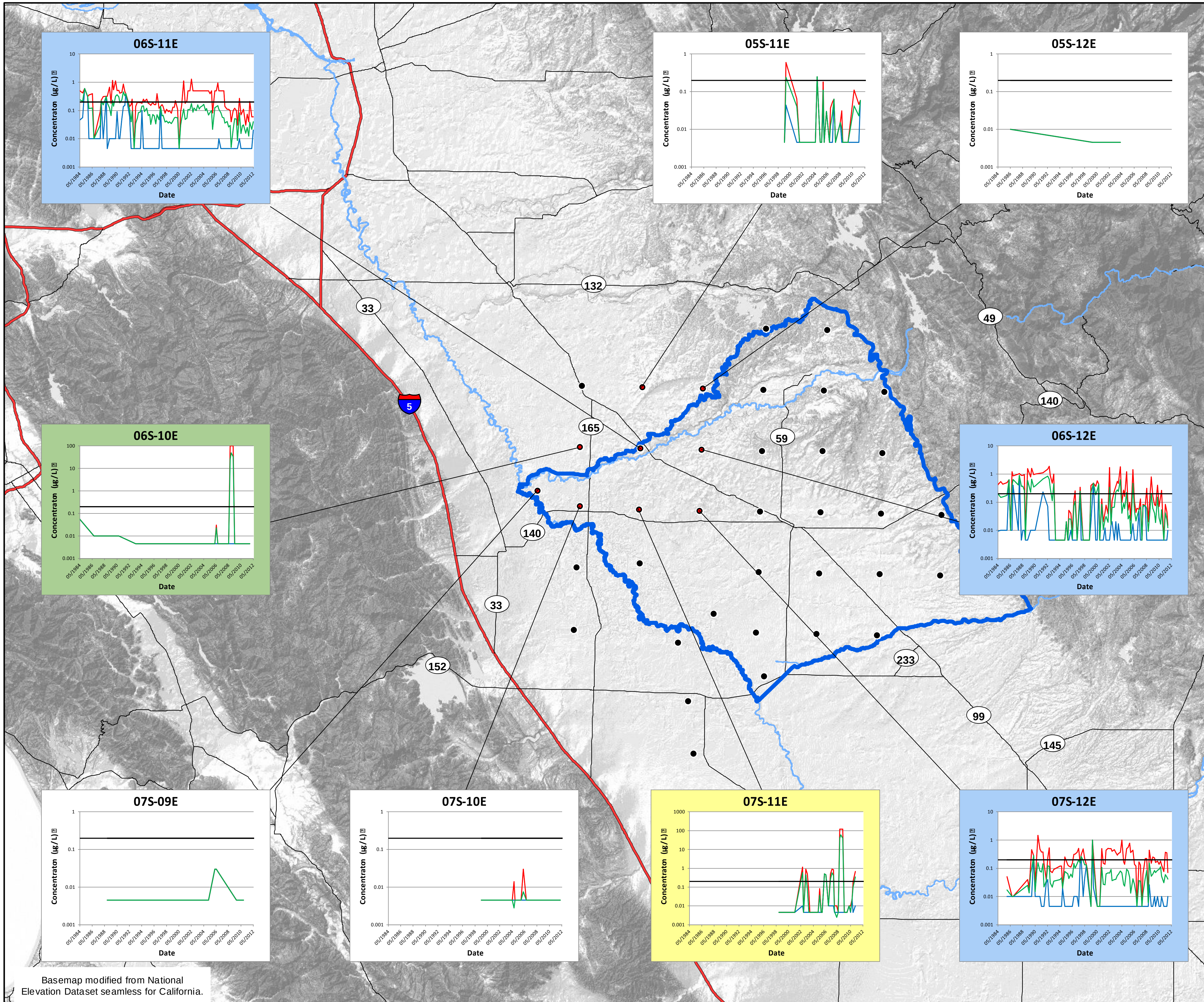
0 5 10

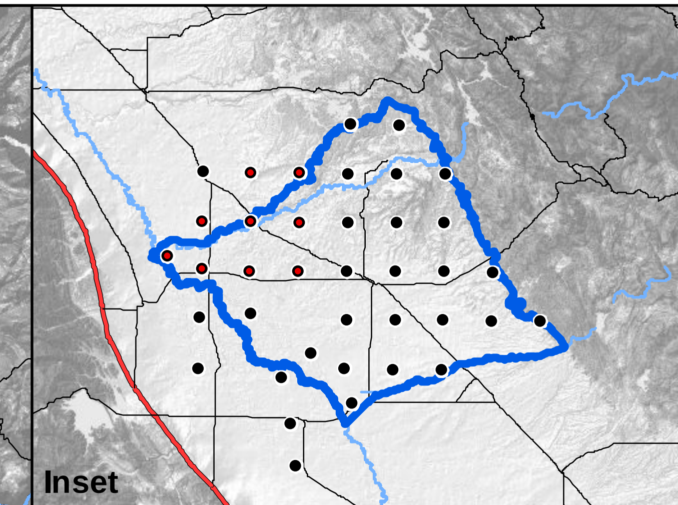
APPROXIMATE SCALE IN MILES

METHYL TERTIARY BUTYL ETHER (MTBE) CONCENTRATIONS
1984 THROUGH 2012
Merced IRWMP
Merced County, California

By: DB	Date: 12/05/2012	Project No. FR1216040A
		Figure 11d

N:_FR_projects\FR12s\FR1216040A\gis\maps\2013_01\ConcentrationMaps_fig11d_MTBE.mxd





Explanation:

Township/Range centroid

Surface water feature

Merced IRWM area

Concentration Charts:

Minimum DBCP concentration

Mean DBCP concentration

Maximum DBCP concentration

MCL for DBCP (0.2 µg/L)

Notes:

1. IRWMP = Integrated Regional Water Management Plan.
2. Dibromochloropropane (DBCP) concentrations shown in micrograms per liter (µg/L).
3. Maximum Contaminant Level (MCL) as established by the California Department of Public Health.
4. Background color on graphs represent the y-axis range as follows:

White 0.001- 1 µg/L
Blue 0.001- 10 µg/L
Green 0.001- 100 µg/L
Yellow 0.001- 1,000 µg/L

N

0 5 10

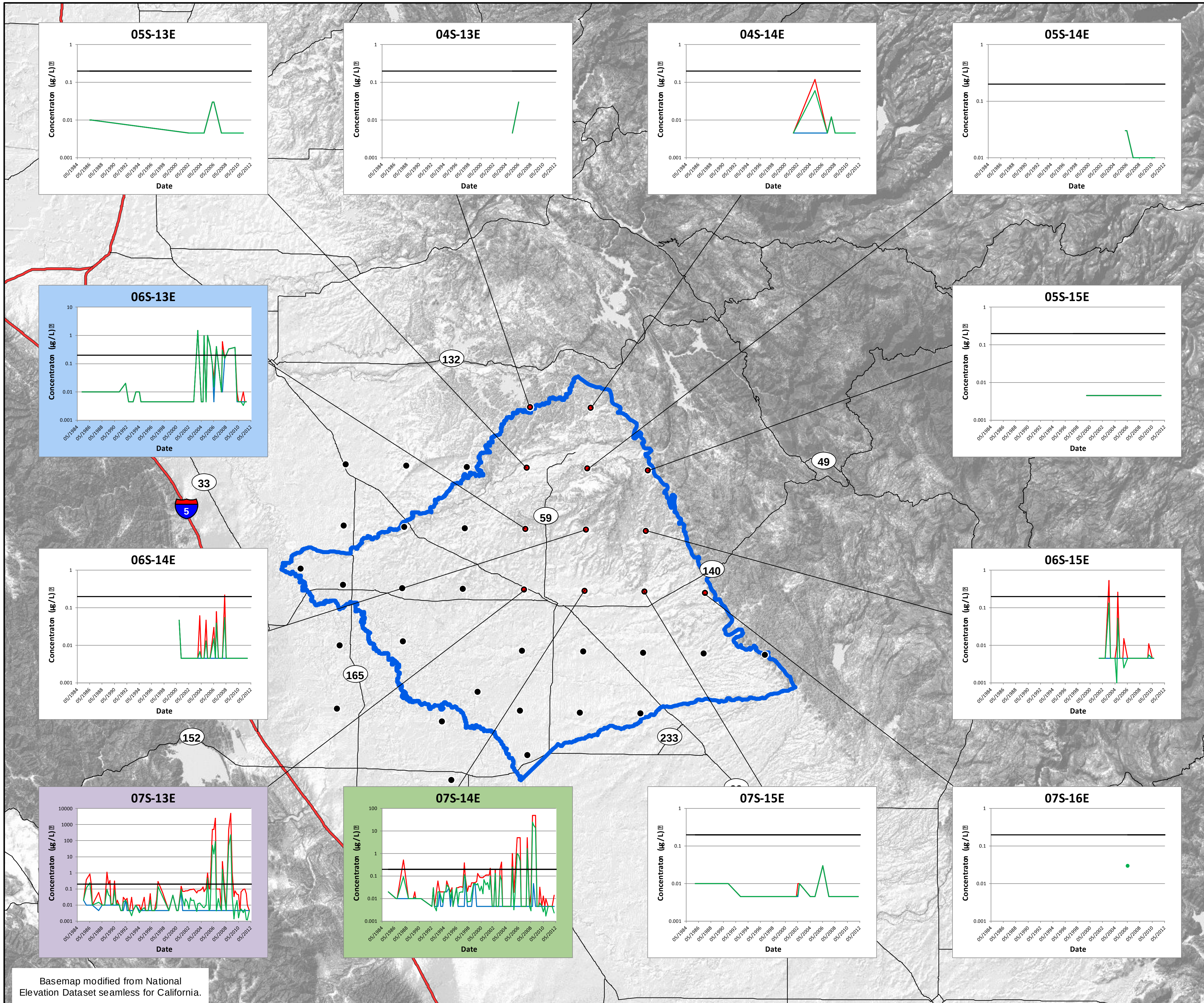
APPROXIMATE SCALE IN MILES

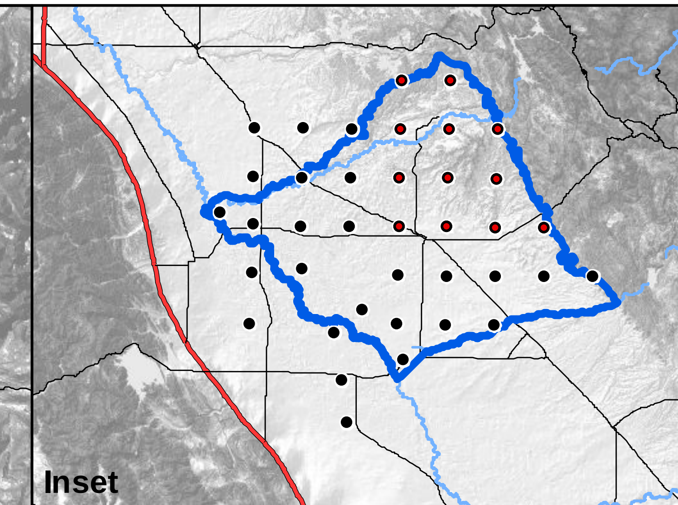
DIBROMOCHLOROPROPANE (DBCP) CONCENTRATIONS
1984 THROUGH 2012
Merced IRWMP
Merced County, California

By: DB | Date: 01/08/2013 | Project No. FR1216040A

Figure 12a

N:_FR_projects\FR12s\FR1216040A\gis\maps\2013_01\ConcentrationMaps_fig12a_DBCP.mxd





Explanation:

- Township/Range centroid
- Surface water feature
- Merced IRWM area

Concentration Charts:

- Minimum DBCP concentration
- Mean DBCP concentration
- Maximum DBCP concentration
- MCL for DBCP (0.2 µg/L)

Notes:

1. IRWMP = Integrated Regional Water Management Plan.
2. Dibromochloropropane (DBCP) concentrations shown in micrograms per liter (µg/L).
3. Maximum Contaminant Level (MCL) as established by the California Department of Public Health.
4. Background color on graphs represent the y-axis range as follows:

White: 0.001- 1 µg/L
Blue: 0.001- 10 µg/L
Green: 0.001- 100 µg/L
Purple: 0.001- 10,000 µg/L

N

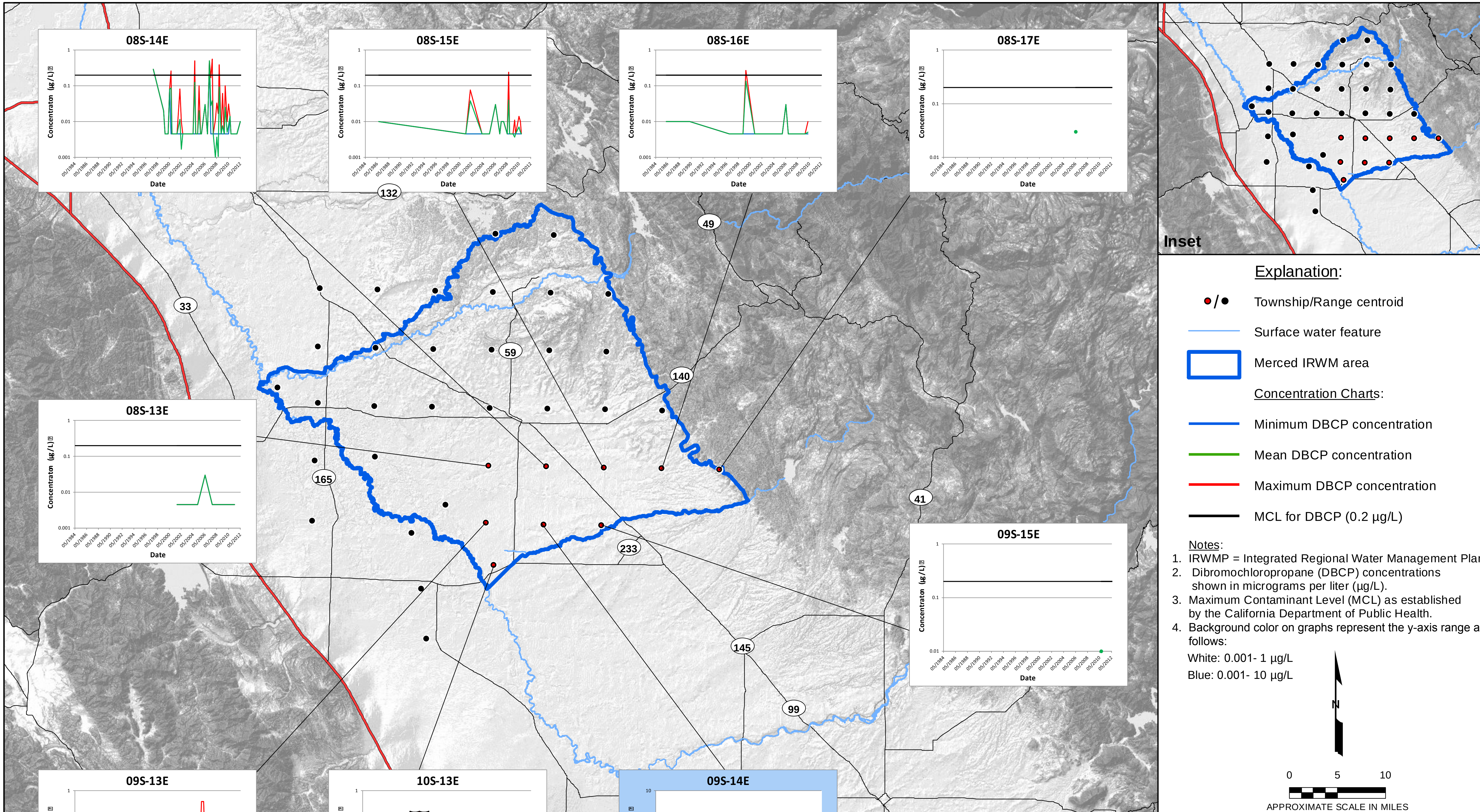
0 5 10

APPROXIMATE SCALE IN MILES

DIBROMOCHLOROPROPANE (DBCP) CONCENTRATIONS
1984 THROUGH 2012
Merced IRWMP
Merced County, California

By: DB	Date: 01/08/2013	Project No. FR1216040A
		Figure 12b

N:_FR_projects\FR12s\FR1216040A\gis\maps\2013_01\ConcentrationMaps_fig12b_DBCP.mxd



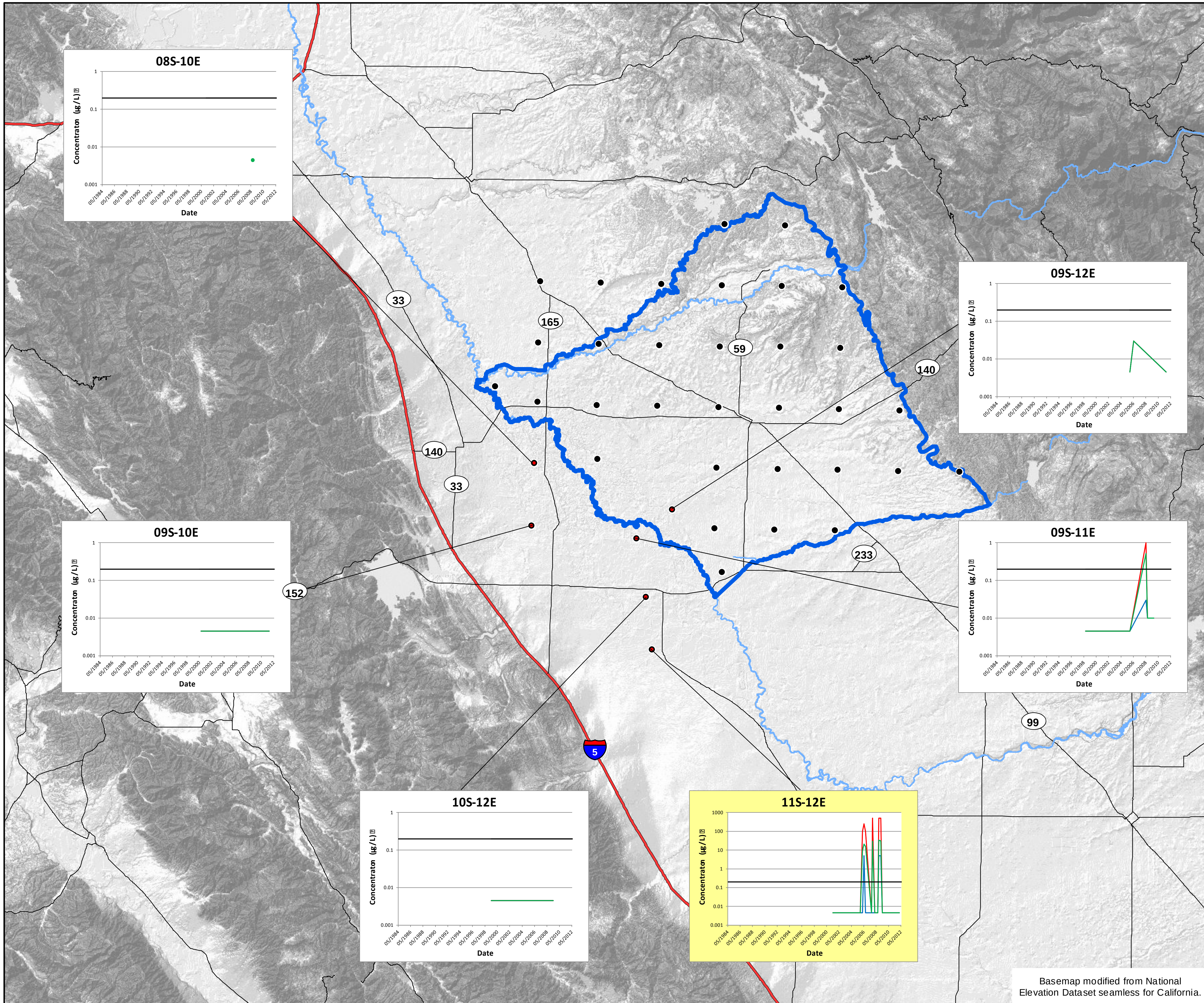
Basemap modified from National Elevation Dataset seamless for California.

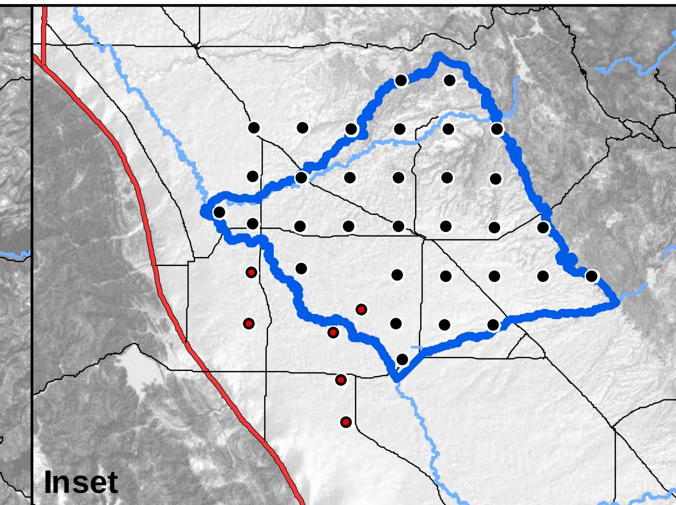
DIBROMOCHLOROPROPANE (DBCP)
CONCENTRATIONS
1984 THROUGH 2012
Merced IRWMP
Merced County, California

By: DB | Date: 01/08/2013 | Project No. FR1216040A

Figure 12c

N:_FR_projects\FR12s\FR1216040A\gis\maps\2013_01\ConcentrationMaps_fig12c_DBCP.mxd





Explanation:

- ●/● Township/Range centroid
- Surface water feature
- Merced IRWM area

Concentration Charts:

- Minimum DBCP concentration
- Mean DBCP concentration
- Maximum DBCP concentration
- MCL for DBCP (0.2 µg/L)

Notes:

1. IRWMP = Integrated Regional Water Management Plan.
2. Dibromochloropropane (DBCP) concentrations shown in micrograms per liter (µg/L).
3. Maximum Contaminant Level (MCL) as established by the California Department of Public Health.
4. Background color on graphs represent the y-axis range as follows:

White: 0.001- 1 µg/L
Yellow: 0.001- 1,000 µg/L

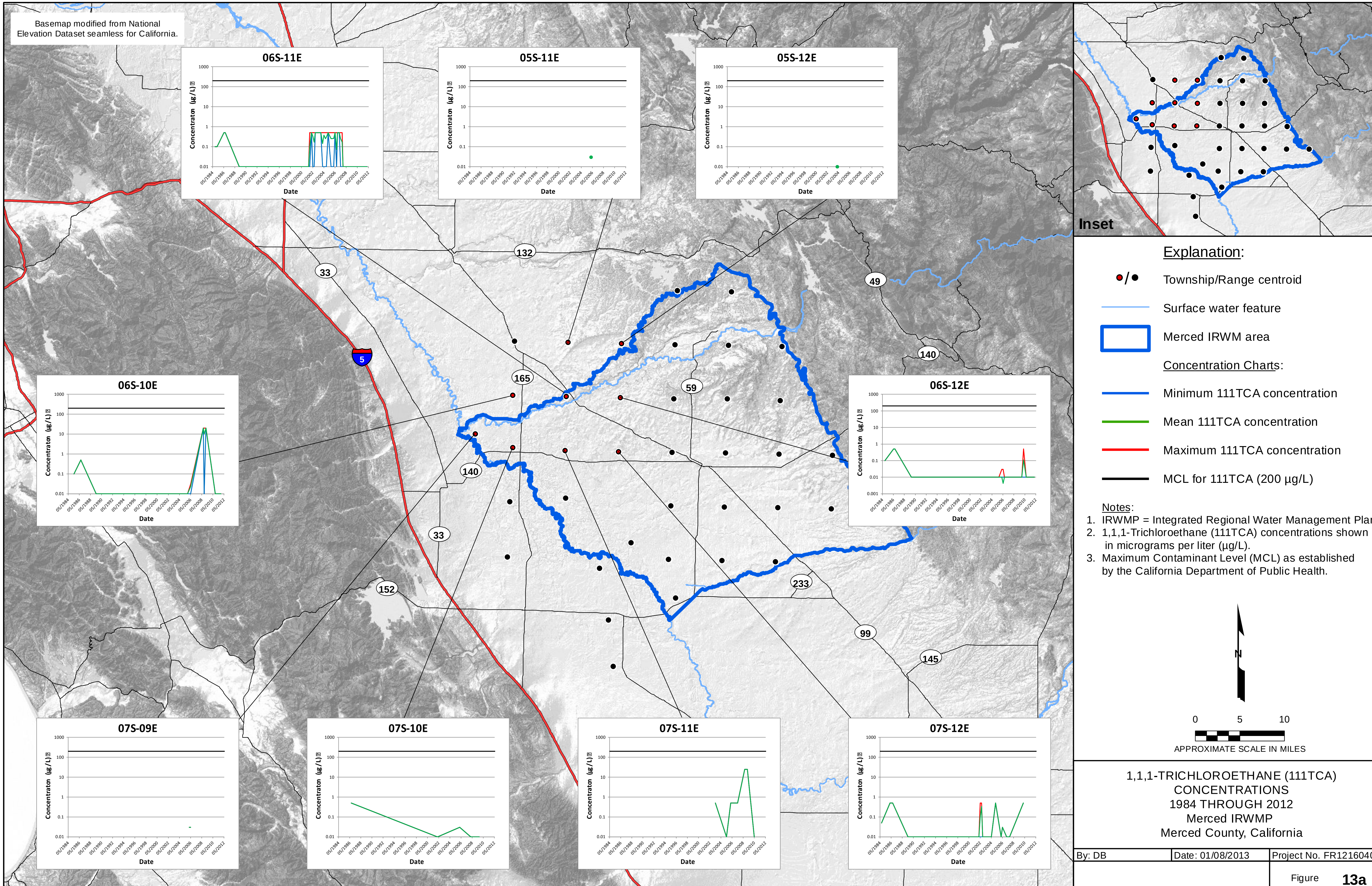
N

0 5 10
APPROXIMATE SCALE IN MILES

DIBROMOCHLOROPROPANE (DBCP)
CONCENTRATIONS
1984 THROUGH 2012
Merced IRWMP
Merced County, California

By: DB	Date: 01/08/2013	Project No. FR1216040A
		Figure **12d**

N:_FR_projects\FR12s\FR1216040A\gis\maps\2013_01\ConcentrationMaps_fig12d_DBCP.mxd



Explanation:

●/● Township/Range centroid

Surface water feature

Merced IRWM area

Concentration Charts:

Minimum 111TCA concentration

Mean 111TCA concentration

Maximum 111TCA concentration

MCL for 111TCA (200 µg/L)

Notes:

1. IRWMP = Integrated Regional Water Management Plan.
2. 1,1,1-Trichloroethane (111TCA) concentrations shown in micrograms per liter (µg/L).
3. Maximum Contaminant Level (MCL) as established by the California Department of Public Health.

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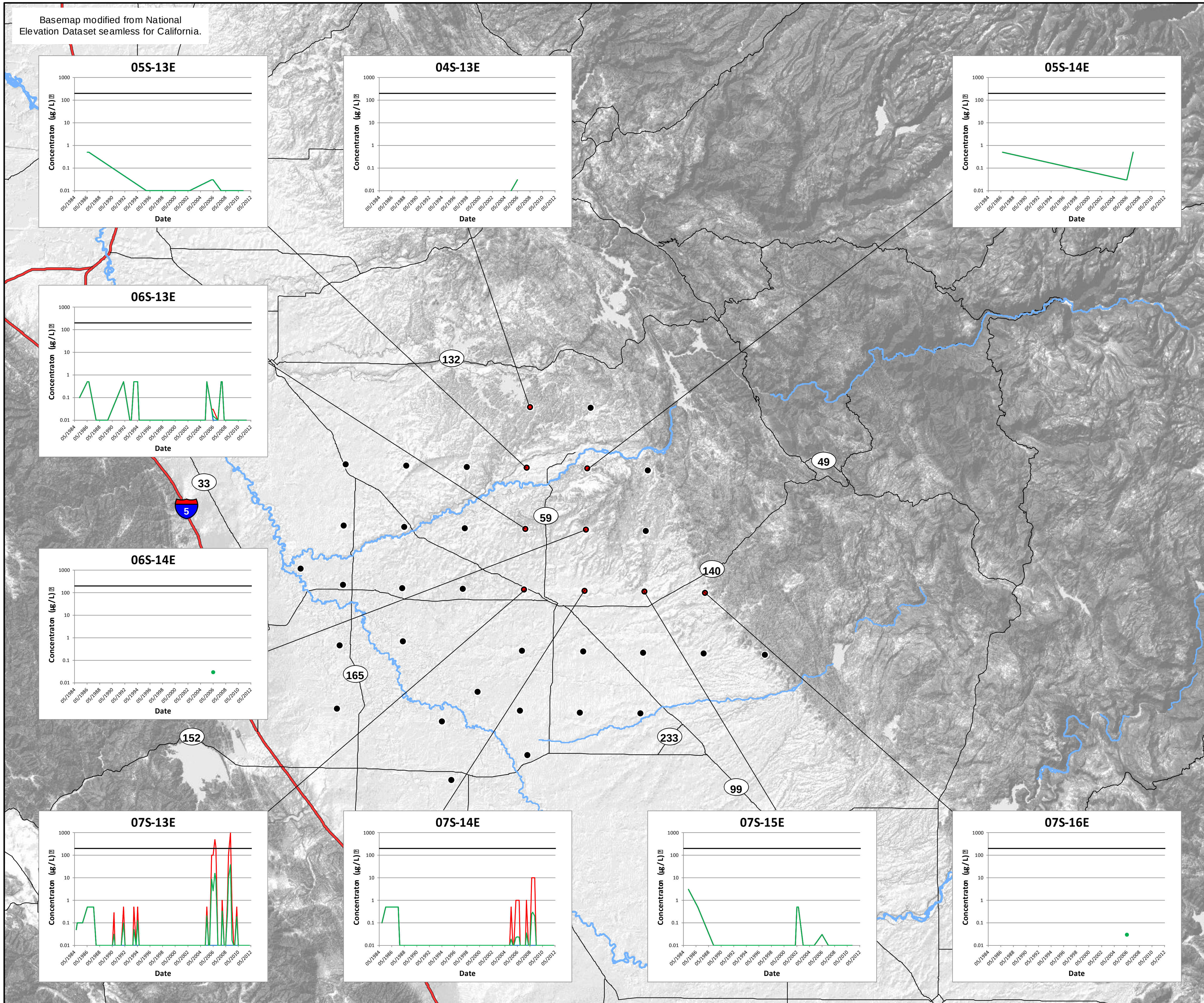
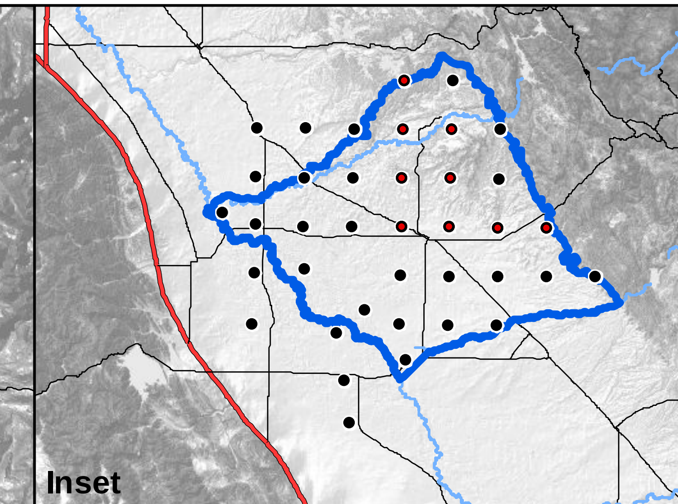
APPROXIMATE SCALE IN MILES

1,1,1-TRICHLOROETHANE (111TCA)
CONCENTRATIONS
1984 THROUGH 2012
Merced IRWMP
Merced County, California

By: DB	Date: 01/08/2013	Project No. FR1216040A
		Figure **13a**

N:_FR_projects\FR12s\FR1216040A\gis\maps\2013_01\ConcentrationMaps_fig13a_111TCA.mxd





Explanation:

- Township/Range centroid
- Surface water feature
- Merced IRWM area

Concentration Charts:

- Minimum 111TCA concentration
- Mean 111TCA concentration
- Maximum 111TCA concentration
- MCL for 111TCA (200 µg/L)

Notes:

1. IRWMP = Integrated Regional Water Management Plan.
2. 1,1,1-Trichloroethane (111TCA) concentrations shown in micrograms per liter (µg/L).
3. Maximum Contaminant Level (MCL) as established by the California Department of Public Health.

N

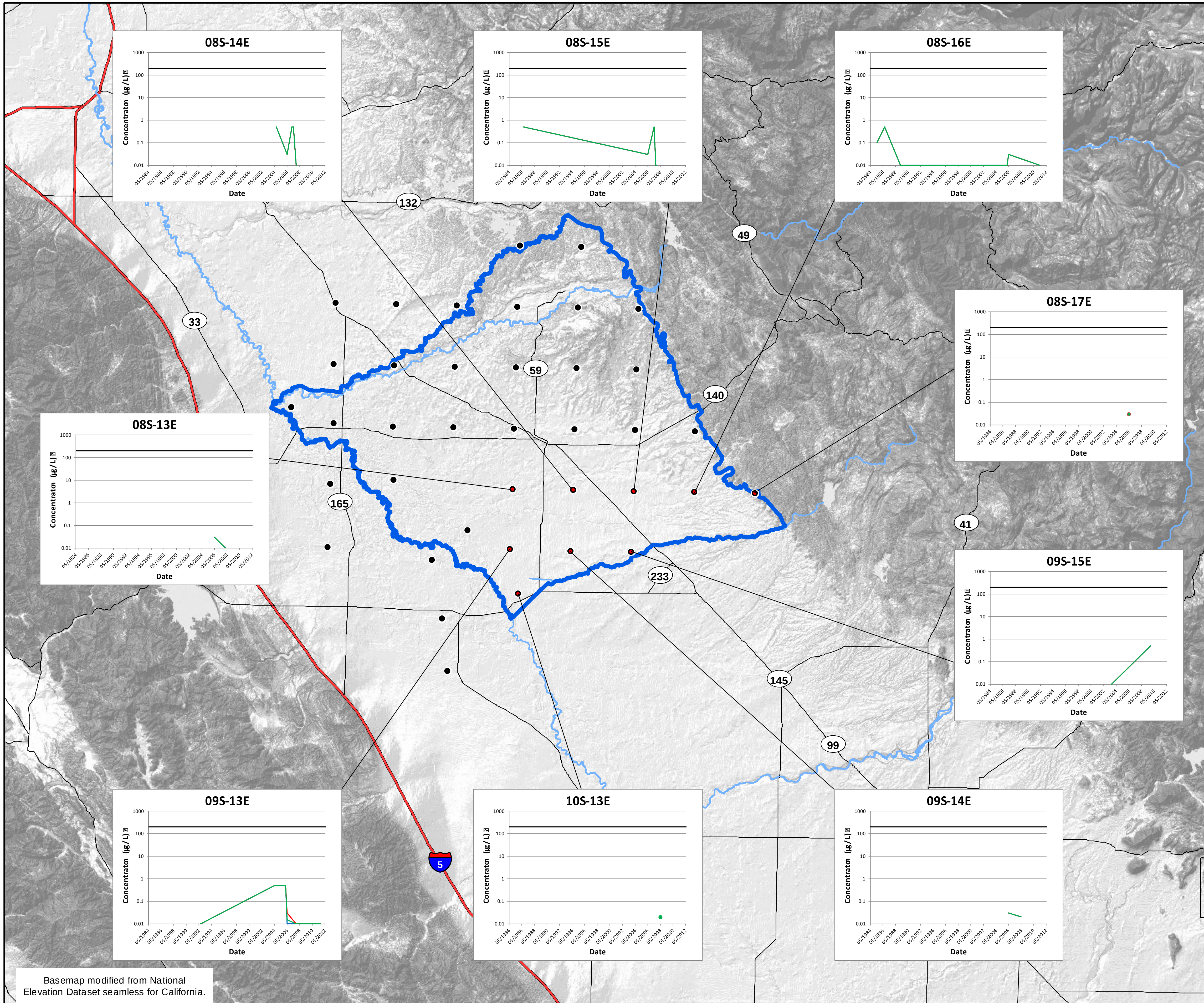
0 5 10

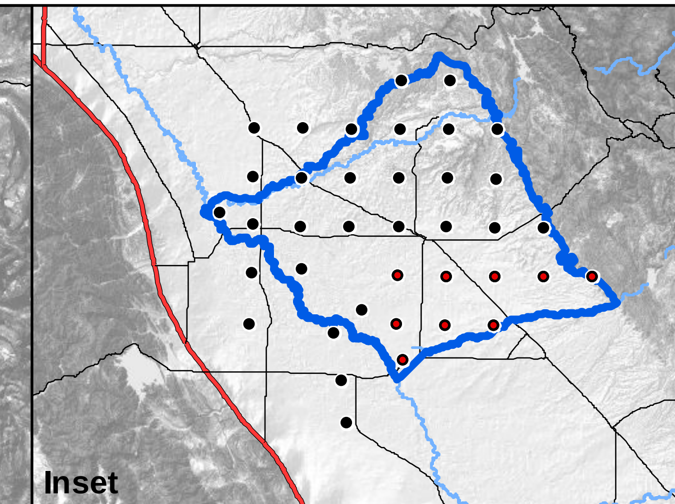
APPROXIMATE SCALE IN MILES

1,1,1-TRICHLOROETHANE (111TCA)
CONCENTRATIONS
1984 THROUGH 2012
Merced IRWMP
Merced County, California

By: DB	Date: 01/08/2013	Project No. FR1216040A
		Figure **13b**

N:_FR_projects\FR12s\FR1216040A\gis\maps\2013_01\ConcentrationMaps_fig13b_111TCA.mxd





Explanation:

- Township/Range centroid
- Surface water feature
- Merced IRWM area

Concentration Charts:

- Minimum 111TCA concentration
- Mean 111TCA concentration
- Maximum 111TCA concentration
- MCL for 111TCA (200 µg/L)

Notes:

1. IRWMP = Integrated Regional Water Management Plan.
2. 1,1,1-Trichloroethane (111TCA) concentrations shown in micrograms per liter (µg/L).
3. Maximum Contaminant Level (MCL) as established by the California Department of Public Health.

N

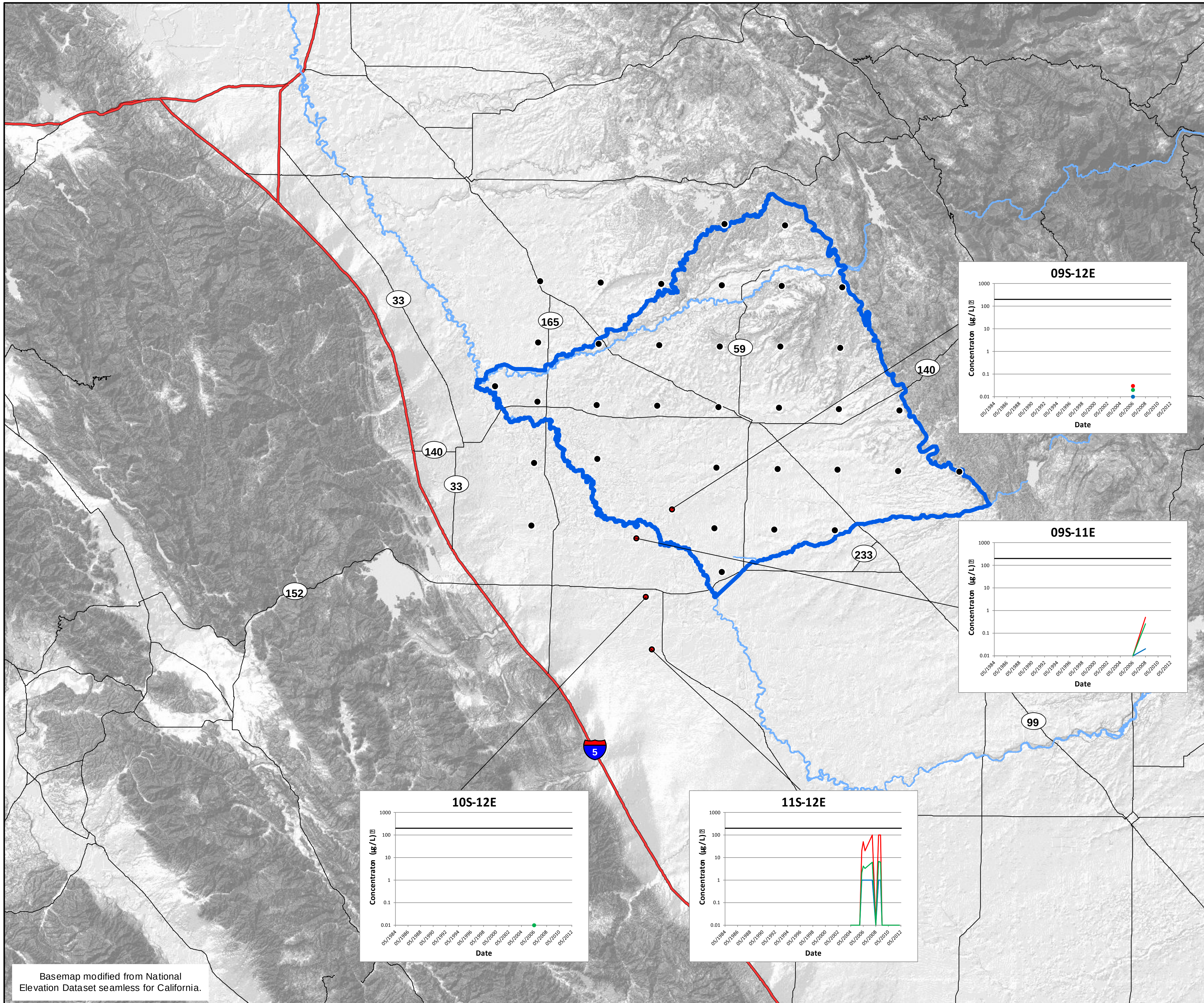
0 5 10

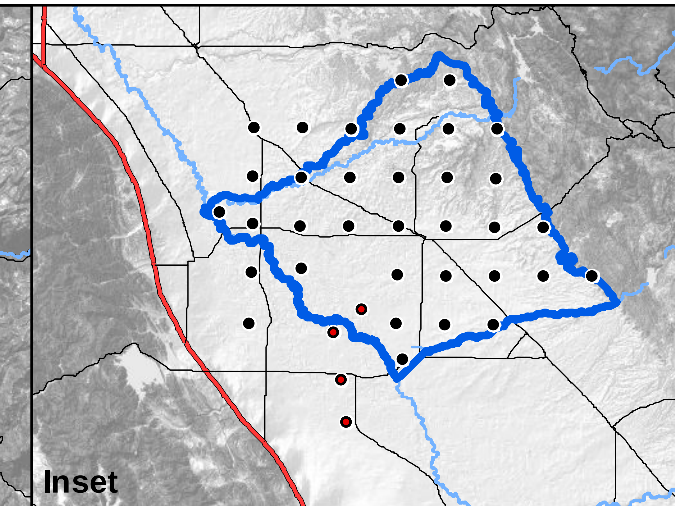
APPROXIMATE SCALE IN MILES

1,1,1-TRICHLOROETHANE (111TCA) CONCENTRATIONS
1984 THROUGH 2012
Merced IRWMP
Merced County, California

By: DB	Date: 01/08/2013	Project No. FR1216040A
		Figure 13c

N:_FR_projects\FR12s\FR1216040A\gis\maps\2013_01ConcentrationMaps_fig13c_111TCA.mxd





Explanation:

- Township/Range centroid
- Surface water feature
- Merced IRWM area

Concentration Charts:

- Minimum 111TCA concentration
- Mean 111TCA concentration
- Maximum 111TCA concentration
- MCL for 111TCA (200 µg/L)

Notes:

1. IRWMP = Integrated Regional Water Management Plan.
2. 1,1,1-Trichloroethane (111TCA) concentrations shown in micrograms per liter (µg/L).
3. Maximum Contaminant Level (MCL) as established by the California Department of Public Health.

N

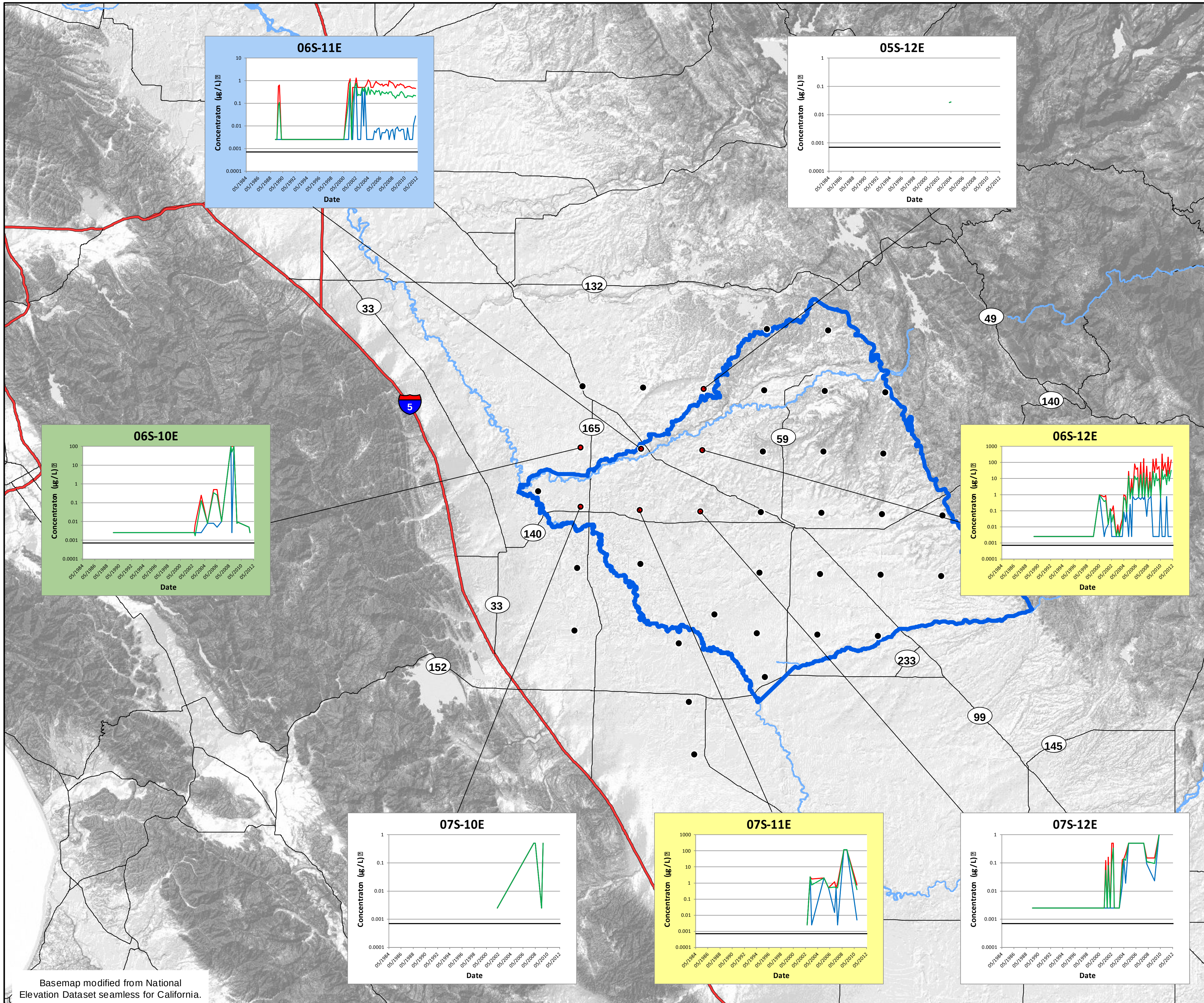
0 5 10

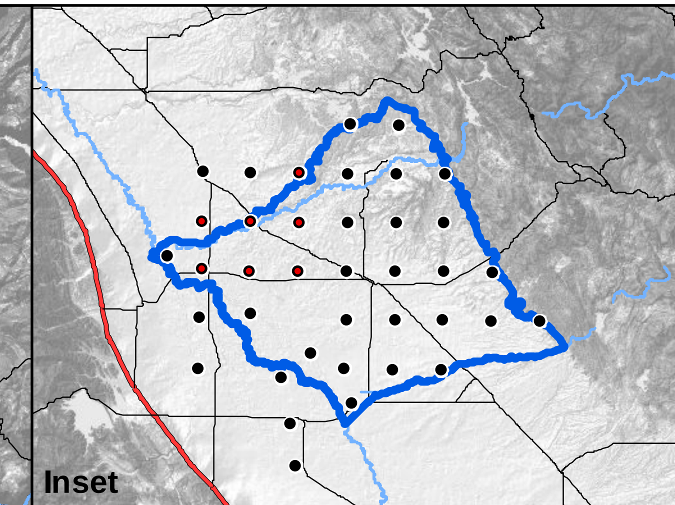
APPROXIMATE SCALE IN MILES

1,1,1-TRICHLOROETHANE (111TCA)
CONCENTRATIONS
1984 THROUGH 2012
Merced IRWMP
Merced County, California

By: DB	Date: 01/08/2013	Project No. FR1216040A
		Figure **13d**

N:_FR_projects\FR12s\FR1216040A\gis\maps\2013_01\ConcentrationMaps_fig13d_111TCA.mxd





Explanation:

Township/Range centroid

Surface water feature

Merced IRWM area

Concentration Charts:

Minimum 123TCP concentration

Mean 123TCP concentration

Maximum 123TCP concentration

PHG for 123TCP (0.0007 ug/L)

Notes:

1. IRWMP = Integrated Regional Water Management Plan.
2. 1,2,3-Trichloropropane (123TCP) concentrations shown in micrograms per liter (µg/L).
3. Public Health Goal (PHG) as established by the California Office of Environmental Health Hazard Assessment
4. Background color on graphs represent the y-axis range as follows:

White: 0.0001- 1 µg/L
Blue: 0.0001- 10 µg/L
Green: 0.0001- 100 µg/L
Yellow: 0.0001- 1,000 µg/L

N

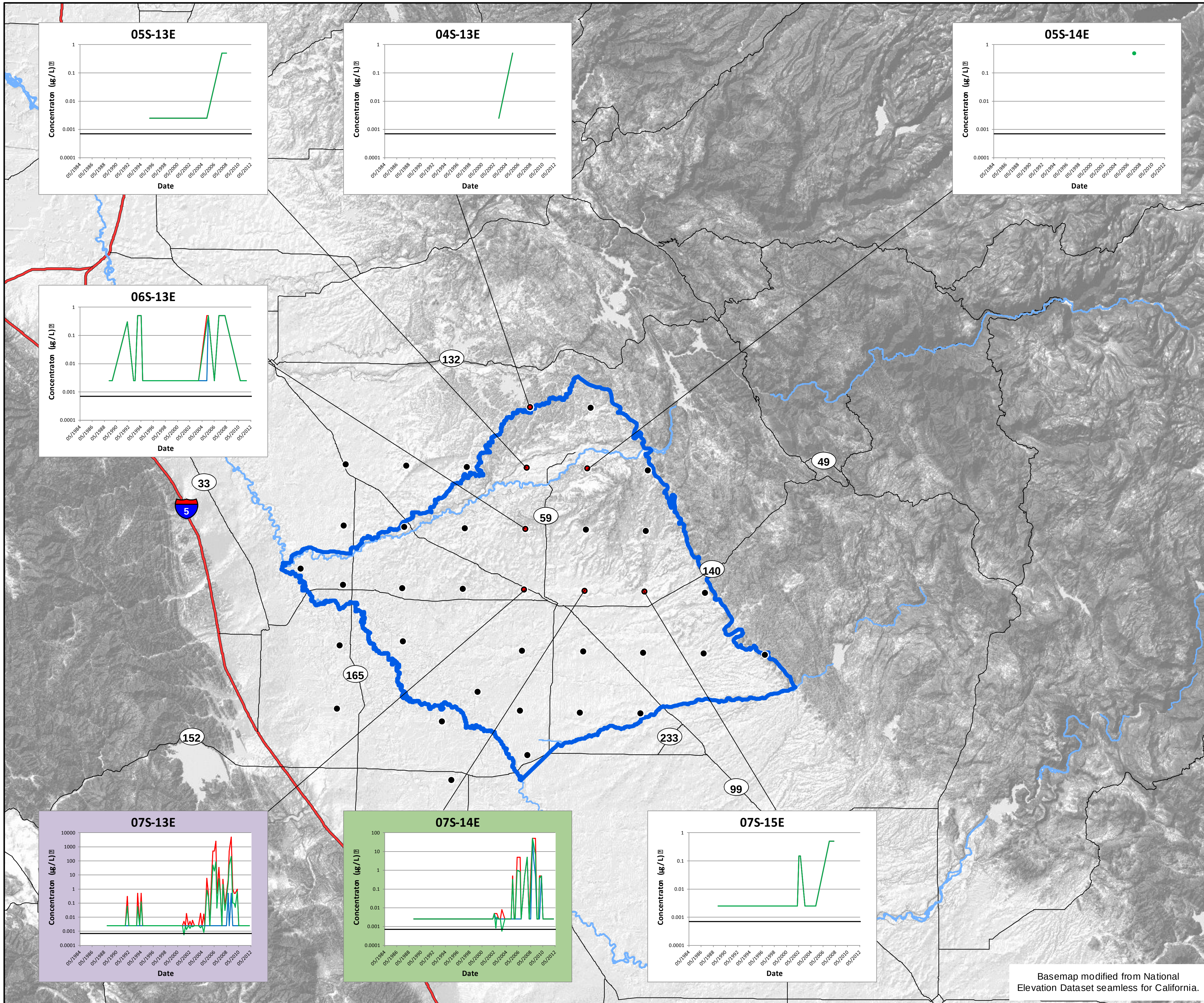
0 5 10

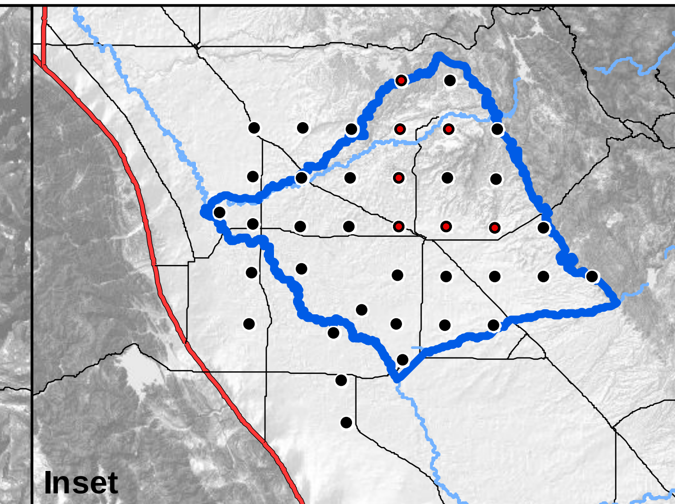
APPROXIMATE SCALE IN MILES

1,2,3-TRICHLOROPROPANE (123TCP)
CONCENTRATIONS
1984 THROUGH 2012
Merced IRWMP
Merced County, California

By: DB	Date: 01/08/2013	Project No. FR1216040A
		Figure **14a**

N:_FR_projects\FR12s\FR1216040A\gis\maps\2013_01ConcentrationMaps_fig14a_123TCP.mxd





Explanation:

- Township/Range centroid
- Surface water feature
- Merced IRWM area

Concentration Charts:

- Minimum 123TCP concentration
- Mean 123TCP concentration
- Maximum 123TCP concentration
- PHG for 123TCP (0.0007 ug/L)

Notes:

1. IRWMP = Integrated Regional Water Management Plan.
2. 1,2,3-Trichloropropane (123TCP) concentrations shown in micrograms per liter (µg/L).
3. Public Health Goal (PHG) as established by the California Office of Environmental Health Hazard Assessment
4. Background color on graphs represent the y-axis range as follows:

White: 0.0001- 1 µg/L
Green 0.0001- 100 µg/L
Purple: 0.0001- 10,000 µg/L

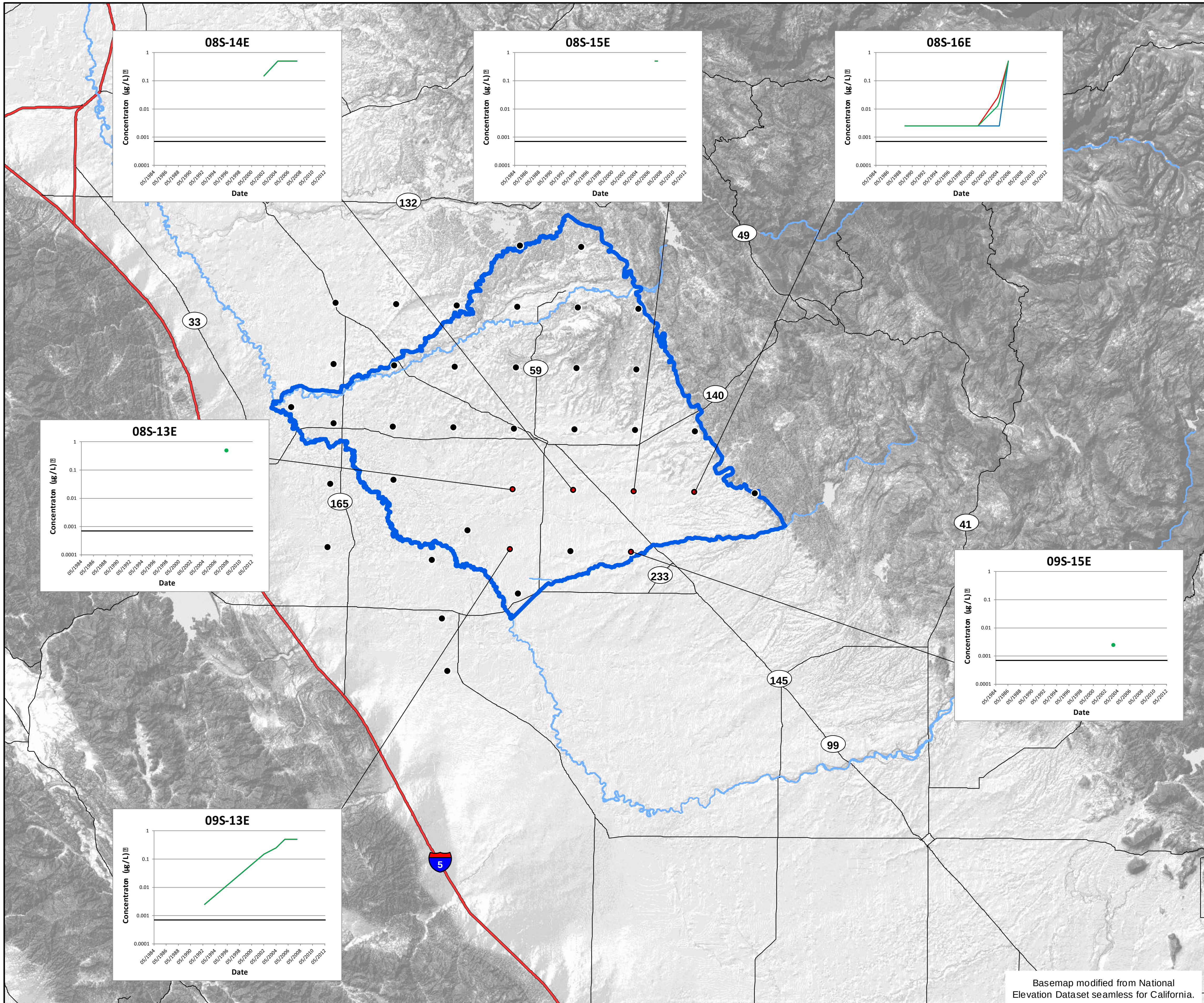
N

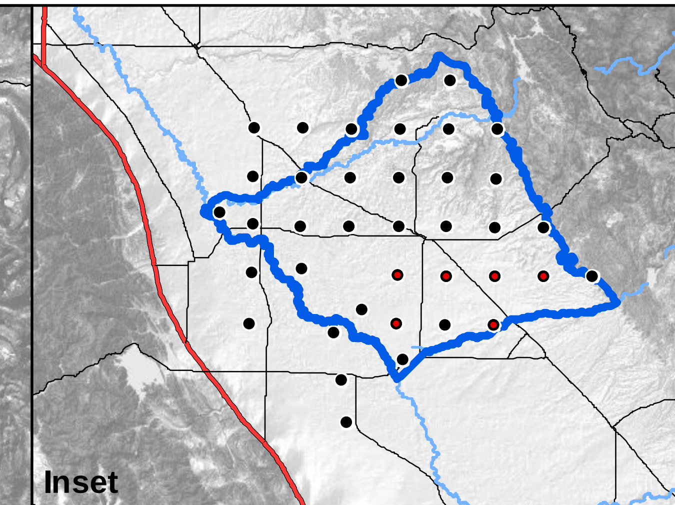
0 5 10
APPROXIMATE SCALE IN MILES

1,2,3-TRICHLOROPROPANE (123TCP)
CONCENTRATIONS
1984 THROUGH 2012
Merced IRWMP
Merced County, California

By: DB	Date: 01/08/2013	Project No. FR1216040A
		Figure **14b**

N:_FR_projects\FR12s\FR1216040A\gis\maps\2013_01\ConcentrationMaps_fig14b_123TCP.mxd





Explanation:

- Township/Range centroid
- Surface water feature
- Merced IRWM area

Concentration Charts:

- Minimum 123TCP concentration
- Mean 123TCP concentration
- Maximum 123TCP concentration
- PHG for 123TCP (0.0007 ug/L)

Notes:

1. IRWMP = Integrated Regional Water Management Plan.
2. 1,2,3-Trichloropropane (123TCP) concentrations shown in micrograms per liter (µg/L).
3. Public Health Goal (PHG) as established by the California Office of Environmental Health Hazard Assessment

N

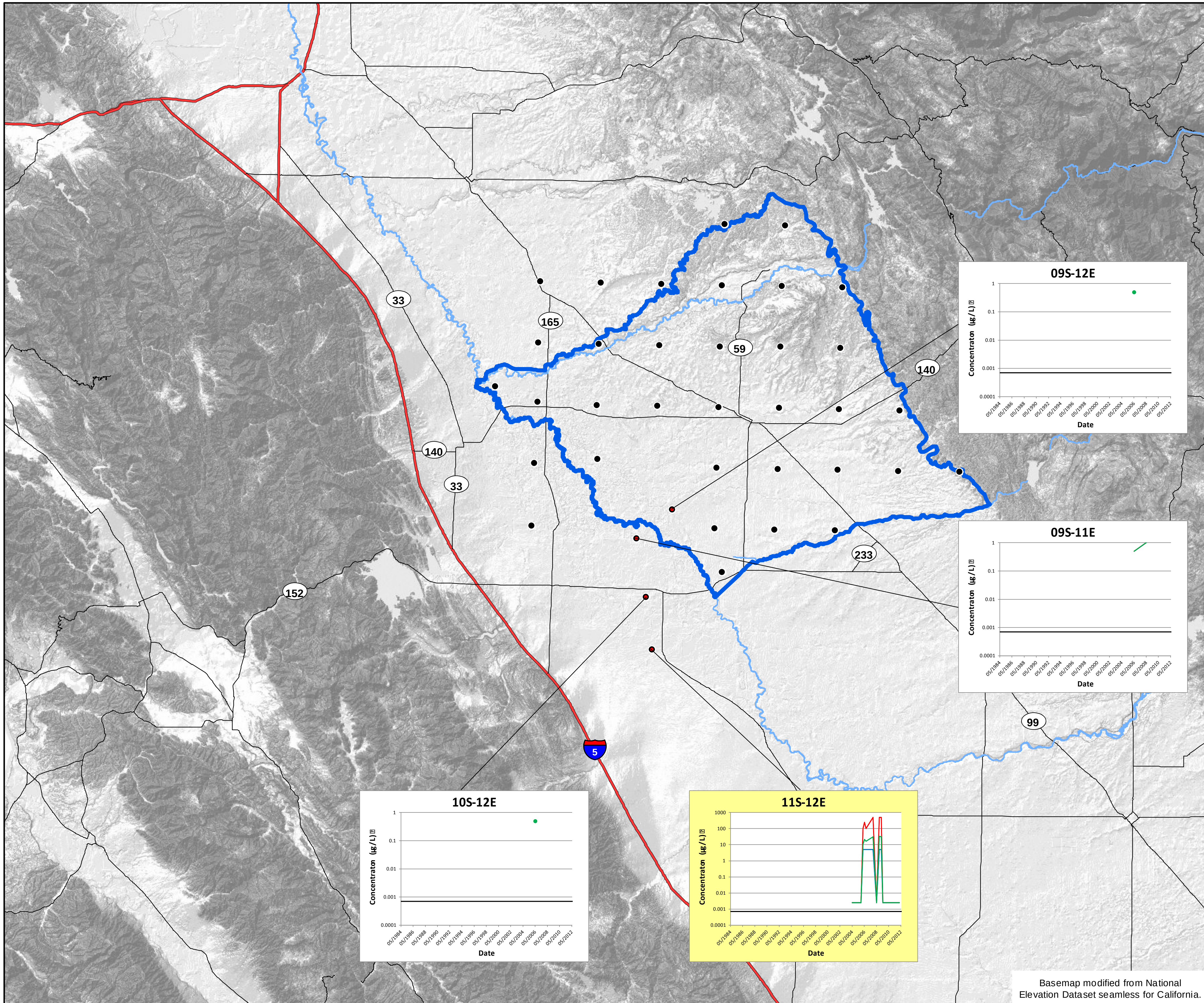
0 5 10

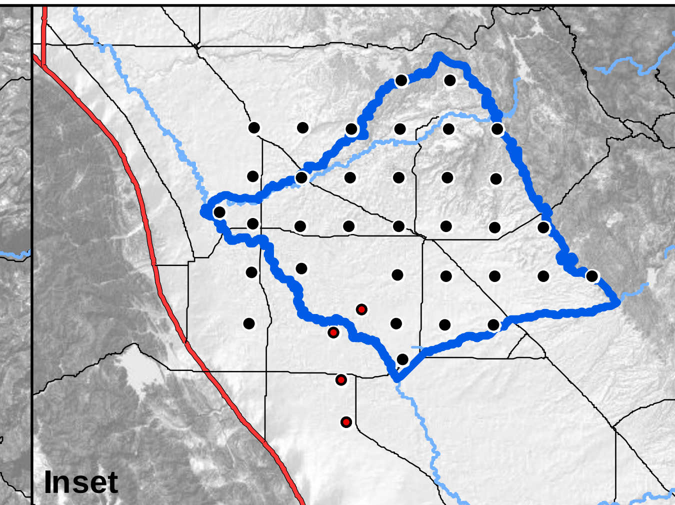
APPROXIMATE SCALE IN MILES

1,2,3-TRICHLOROPROPANE (123TCP) CONCENTRATIONS
1984 THROUGH 2012
Merced IRWMP
Merced County, California

By: DB	Date: 01/08/2013	Project No. FR1216040A
		Figure 14c

N:_FR_projects\FR12s\FR1216040A\gis\maps\2013_01\ConcentrationMaps_fig14c_123TCP.mxd





Explanation:

- ●/● Township/Range centroid
- Surface water feature
- Merced IRWM area

Concentration Charts:

- Minimum 123TCP concentration
- Mean 123TCP concentration
- Maximum 123TCP concentration
- PHG for 123TCP (0.0007 ug/L)

Notes:

1. IRWMP = Integrated Regional Water Management Plan.
2. 1,2,3-Trichloropropane (123TCP) concentrations shown in micrograms per liter (µg/L).
3. Public Health Goal (PHG) as established by the California Office of Environmental Health Hazard Assessment
4. Background color on graphs represent the y-axis range as follows:
   White: 0.0001- 1 µg/L
   Yellow: 0.0001- 1,000 µg/L

N

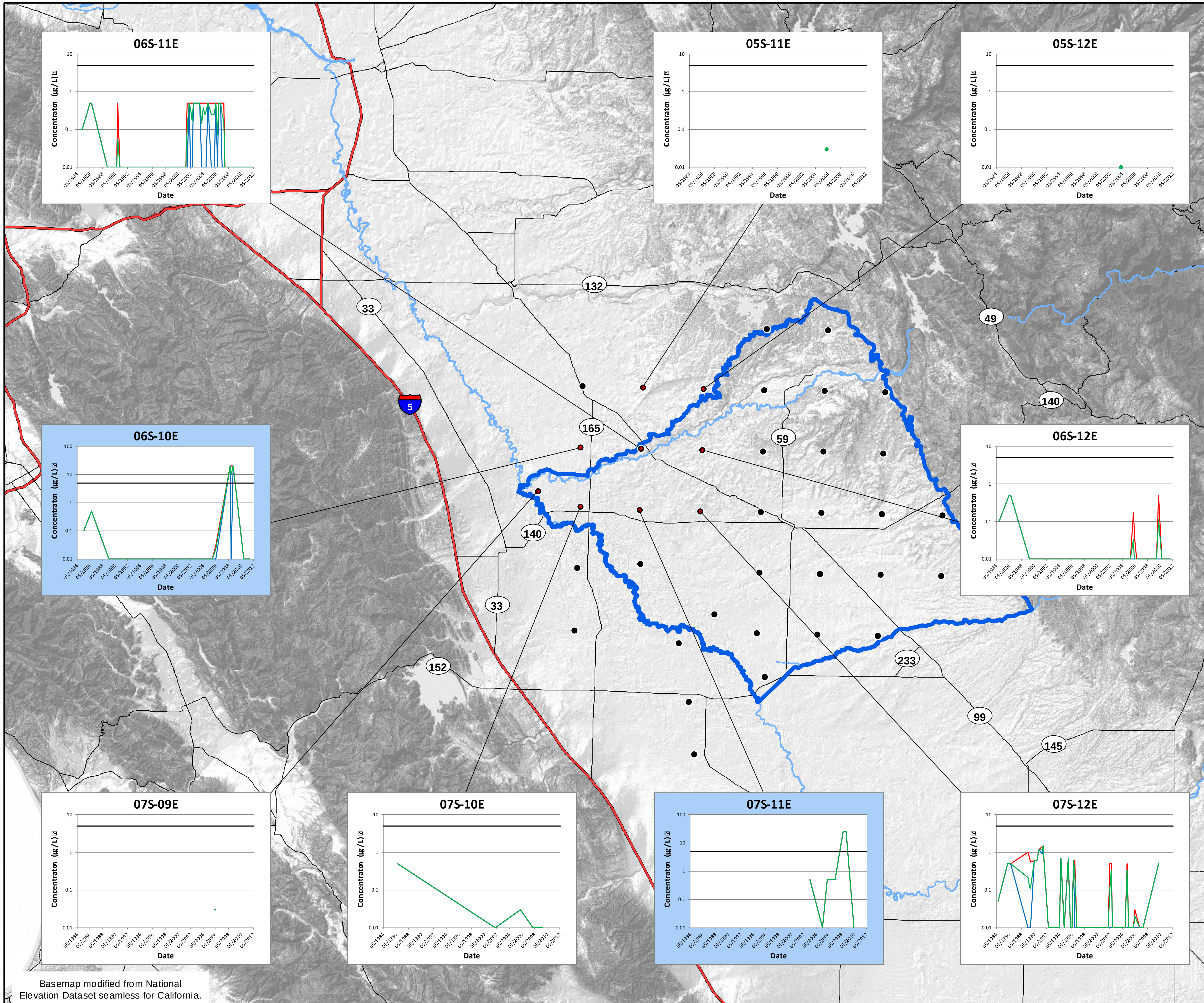
0 5 10

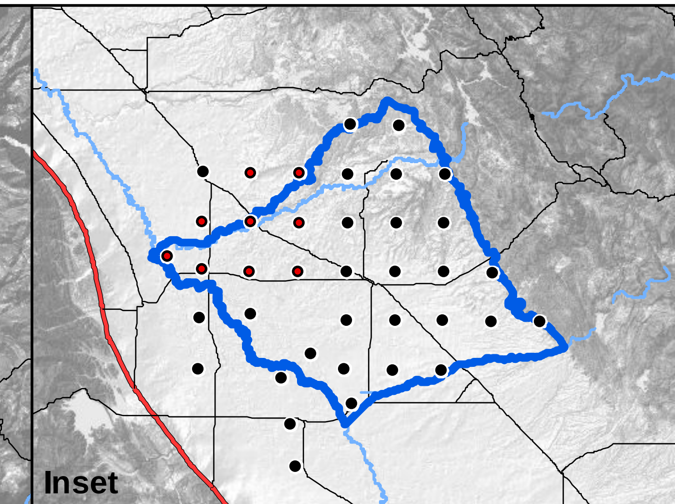
APPROXIMATE SCALE IN MILES

1,2,3-TRICHLOROPROPANE (123TCP) CONCENTRATIONS
1984 THROUGH 2012
Merced IRWMP
Merced County, California

By: DB	Date: 01/08/2013	Project No. FR1216040A
		Figure **14d**

N:_FR_projects\FR12s\FR1216040A\gis\maps\2013_01\ConcentrationMaps_fig14d_123TCP.mxd





Explanation:

- Township/Range centroid
- Surface water feature
- Merced IRWM area

Concentration Charts:

- Minimum PCE concentration
- Mean PCE concentration
- Maximum PCE concentration
- MCL for PCE (5 µg/L)

Notes:

1. IRWMP = Integrated Regional Water Management Plan.
2. Tetrachloroethylene (PCE) concentrations shown in micrograms per liter (µg/L).
3. Maximum Contaminant Level (MCL) as established by the California Department of Public Health.
4. Background color on graphs represent the y-axis range as follows:

White: 0.01- 10 µg/L
Blue: 0.01- 100 µg/L

N

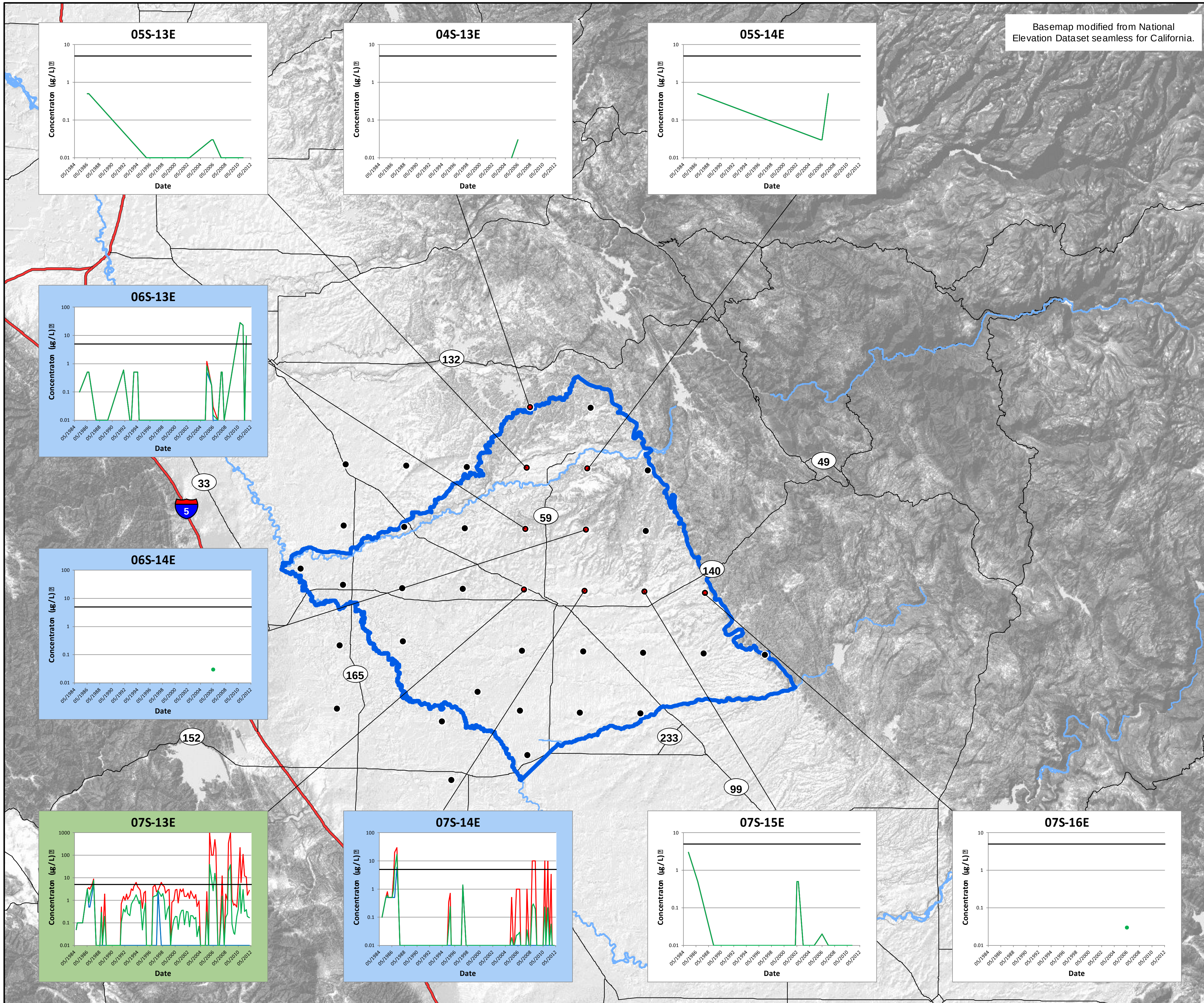
0 5 10
APPROXIMATE SCALE IN MILES

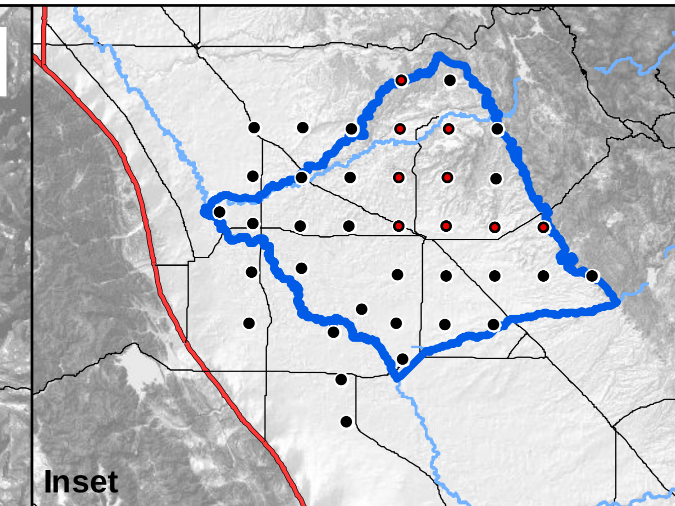
TETRACHLOROETHYLENE (PCE)
CONCENTRATIONS
1984 THROUGH 2012
Merced IRWMP
Merced County, California

By: DB	Date: 01/08/2013	Project No. FR1216040A

Figure 15a

N:_FR_projects\FR12s\FR1216040A\gis\maps\2013_01\ConcentrationMaps_fig15a_PCE.mxd





Explanation:

Township/Range centroid

Surface water feature

Merced IRWM area

Concentration Charts:

Minimum PCE concentration

Mean PCE concentration

Maximum PCE concentration

MCL for PCE (5 µg/L)

Notes:

1. IRWMP = Integrated Regional Water Management Plan.
2. Tetrachloroethylene (PCE) concentrations shown in micrograms per liter (µg/L).
3. Maximum Contaminant Level (MCL) as established by the California Department of Public Health.
4. Background color on graphs represent the y-axis range as follows:

White: 0.01- 10 µg/L
Blue: 0.01- 100 µg/L
Green: 0.01- 1,000 µg/L

N

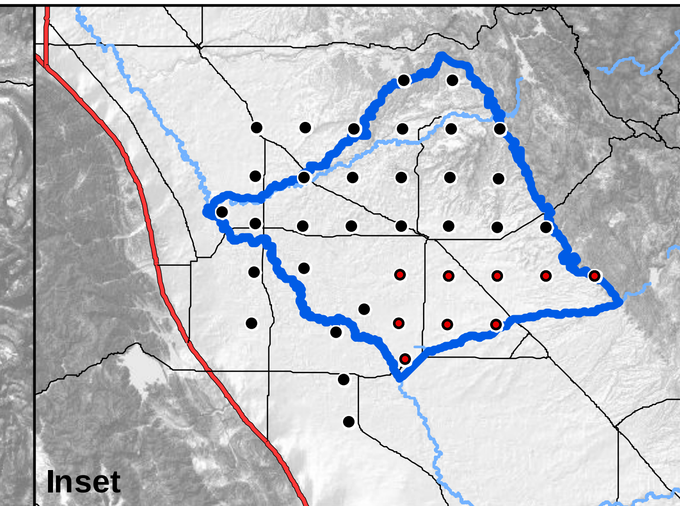
0 5 10

APPROXIMATE SCALE IN MILES

TETRACHLOROETHYLENE (PCE) CONCENTRATIONS 1984 THROUGH 2012 Merced IRWMP Merced County, California

By: DB	Date: 01/08/2013	Project No. FR1216040A
		Figure 15b

N:_FR_projects\FR12s\FR1216040A\gis\maps\2013_01\ConcentrationMaps_fig15b_PCE.mxd



<u>Explanation</u>:

- ●/● Township/Range centroid
- Surface water feature
- Merced IRWM area

<u>Concentration Charts</u>:

- Minimum PCE concentration
- Mean PCE concentration
- Maximum PCE concentration
- MCL for PCE (5 µg/L)

<u>Notes</u>:
1. IRWMP = Integrated Regional Water Management Plan.
2. Tetrachloroethylene (PCE) concentrations shown in micrograms per liter (µg/L).
3. Maximum Contaminant Level (MCL) as established by the California Department of Public Health.

N

0 5 10

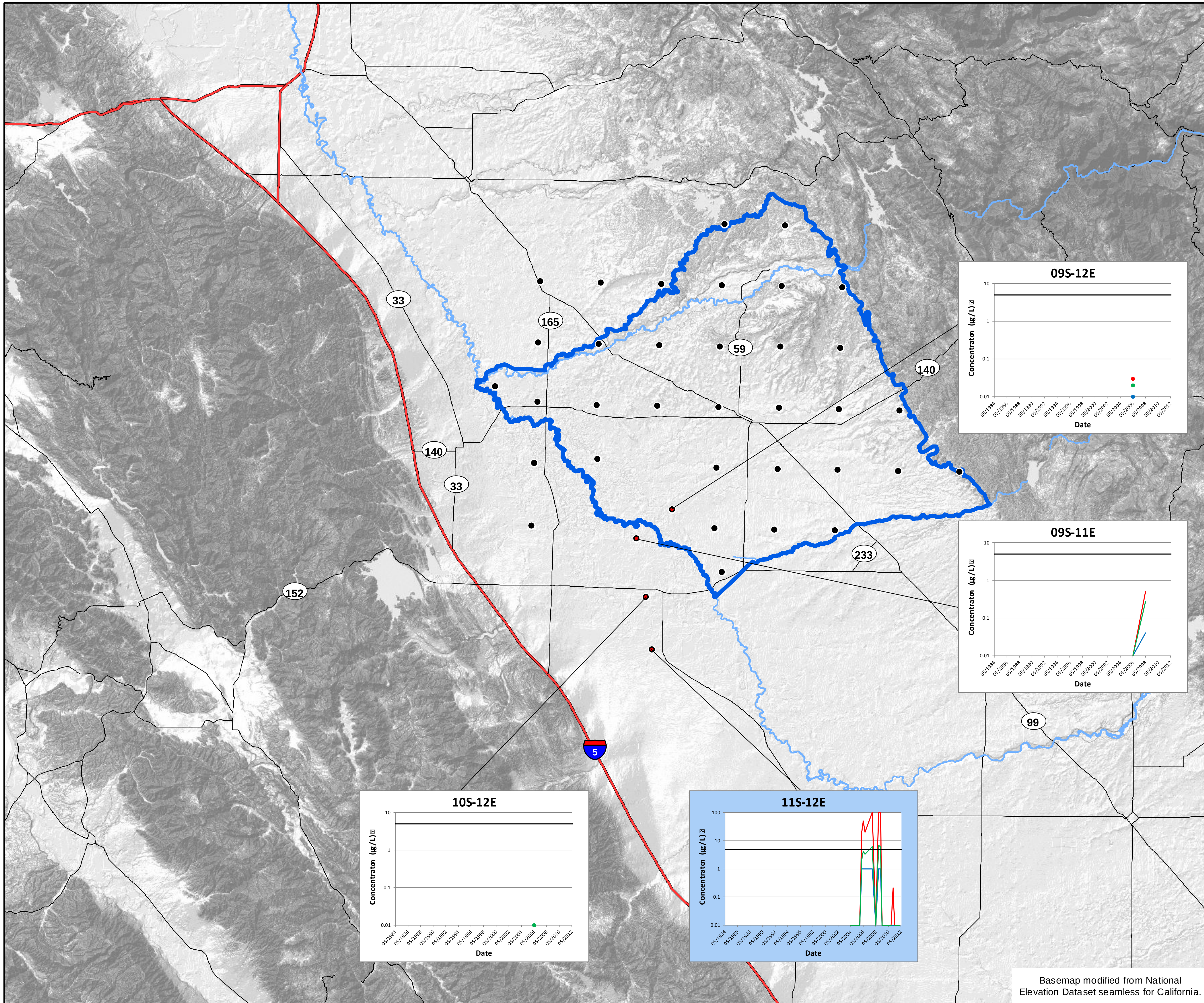
APPROXIMATE SCALE IN MILES

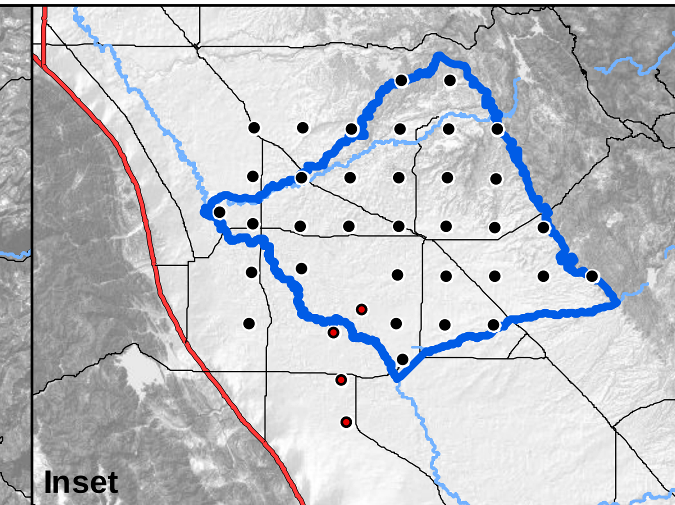
TETRACHLOROETHYLENE (PCE)
CONCENTRATIONS
1984 THROUGH 2012
Merced IRWMP
Merced County, California

By: DB | Date: 01/08/2013 | Project No. FR1216040A

Figure 15c

N:_FR_projects\FR12s\FR1216040A\gis\maps\2013_01\ConcentrationMaps_fig15c_PCE.mxd





Explanation:

Township/Range centroid

Surface water feature

Merced IRWM area

Concentration Charts:

Minimum PCE concentration

Mean PCE concentration

Maximum PCE concentration

MCL for PCE (5 µg/L)

Notes:

1. IRWMP = Integrated Regional Water Management Plan.
2. Tetrachloroethylene (PCE) concentrations shown in micrograms per liter (µg/L).
3. Maximum Contaminant Level (MCL) as established by the California Department of Public Health.
4. Background color on graphs represent the y-axis range as follows:

White: 0.01- 10 µg/L

Blue: 0.01- 100 µg/L

N

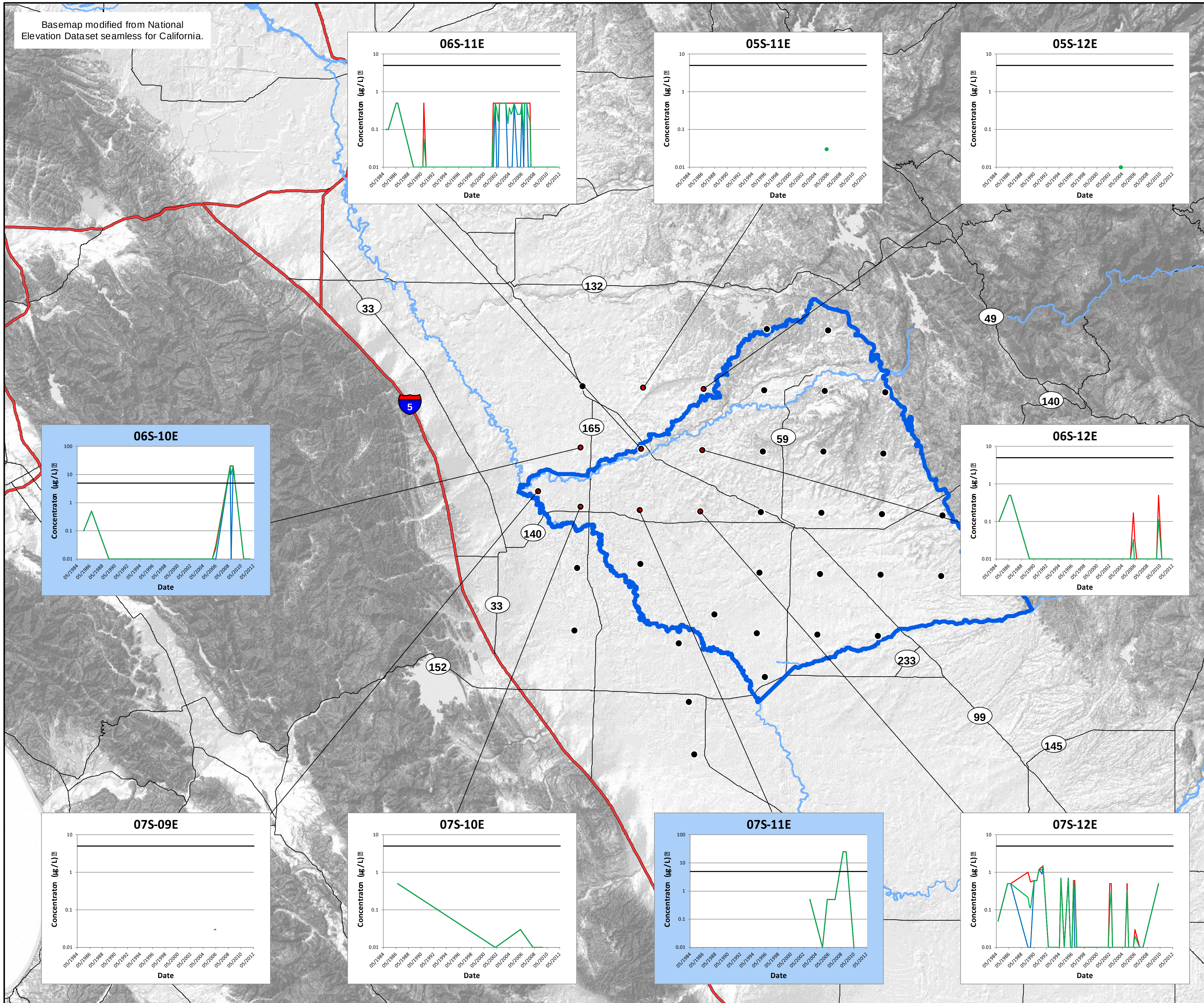
0 5 10

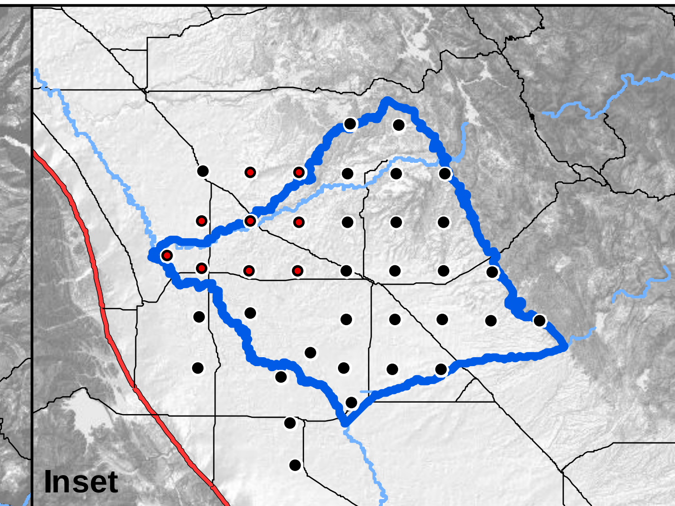
APPROXIMATE SCALE IN MILES

TETRACHLOROETHYLENE (PCE) CONCENTRATIONS 1984 THROUGH 2012
Merced IRWMP
Merced County, California

By: DB	Date: 01/08/2013	Project No. FR1216040A
		Figure 15d

N:_FR_projects\FR12s\FR1216040A\gis\maps\2013_01\ConcentrationMaps_fig15d_PCE.mxd





Explanation:

●/● Township/Range centroid

Surface water feature

Merced IRWM area

Concentration Charts:

Minimum TCE concentration

Mean TCE concentration

Maximum TCE concentration

MCL for TCE (5 µg/L)

Notes:

1. IRWMP = Integrated Regional Water Management Plan.
2. Trichloroethylene (TCE) concentrations shown in micrograms per liter (µg/L).
3. Maximum Contaminant Level (MCL) as established by the California Department of Public Health.
4. Background color on graphs represent the y-axis range as follows:

White: 0.01- 10 µg/L

Blue: 0.01- 100 µg/L

N

0 5 10

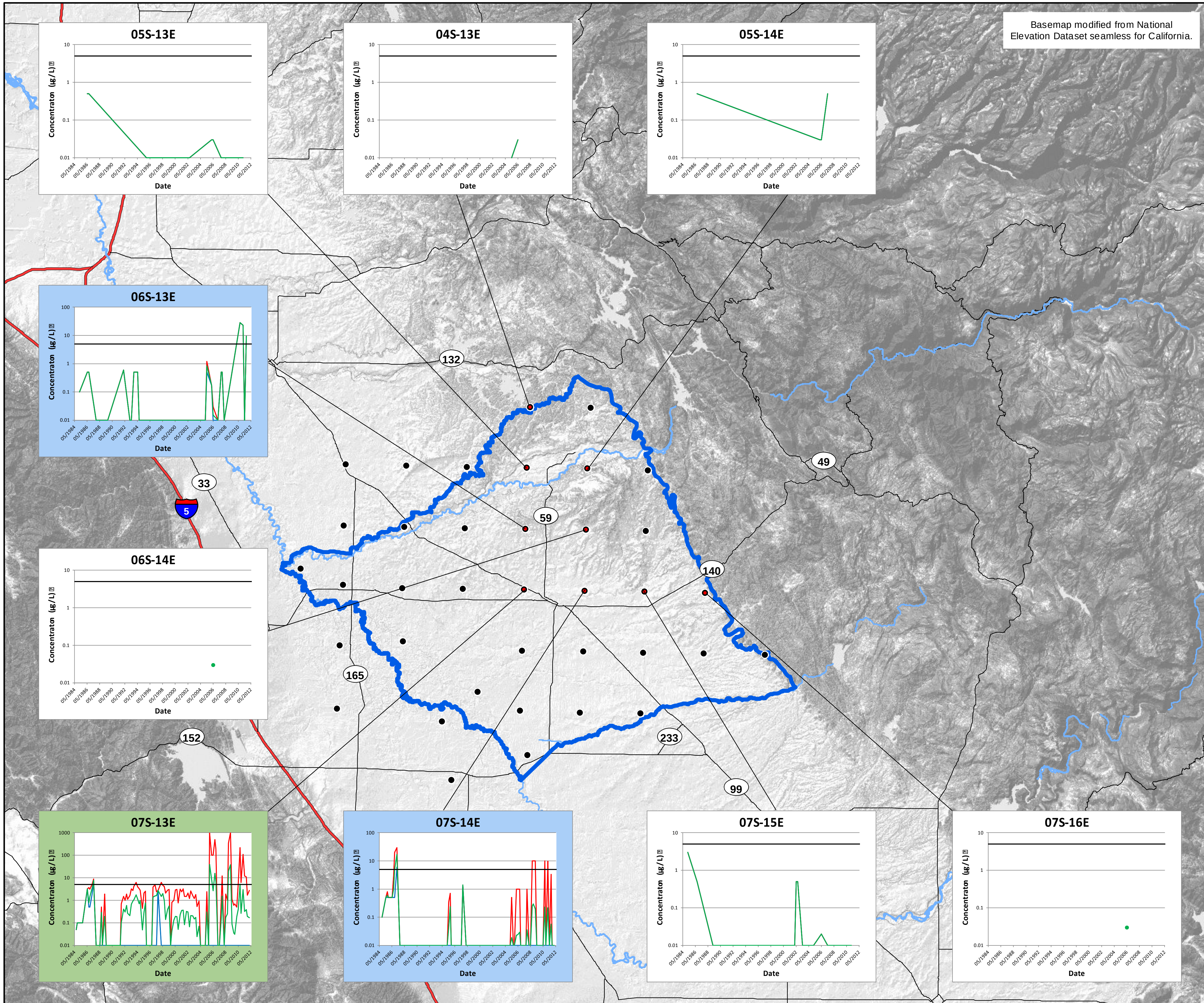
APPROXIMATE SCALE IN MILES

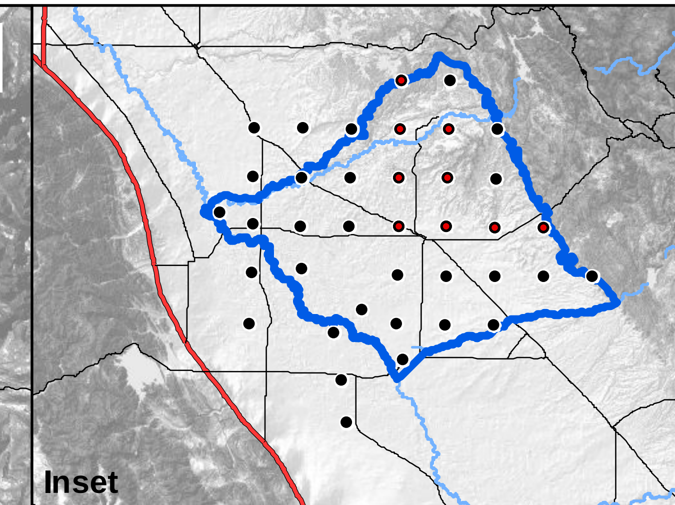
TRICHLOROETHYLENE (TCE)
CONCENTRATIONS
1984 THROUGH 2012
Merced IRWMP
Merced County, California

By: DB	Date: 01/08/2013	Project No. FR1216040A

Figure **16a**

N:_FR_projects\FR12s\FR1216040A\gis\maps\2013_01\ConcentrationMaps_fig16a_TCE.mxd





Explanation:

- ●/● Township/Range centroid
- Surface water feature
- Merced IRWM area

Concentration Charts:

- Minimum TCE concentration
- Mean TCE concentration
- Maximum TCE concentration
- MCL for TCE (5 µg/L)

Notes:

1. IRWMP = Integrated Regional Water Management Plan.
2. Trichloroethylene (TCE) concentrations shown in micrograms per liter (µg/L).
3. Maximum Contaminant Level (MCL) as established by the California Department of Public Health.
4. Background color on graphs represent the y-axis range as follows:

White: 0.01- 10 µg/L
Blue: 0.01- 100 µg/L
Green: 0.01- 1,000 µg/L

N

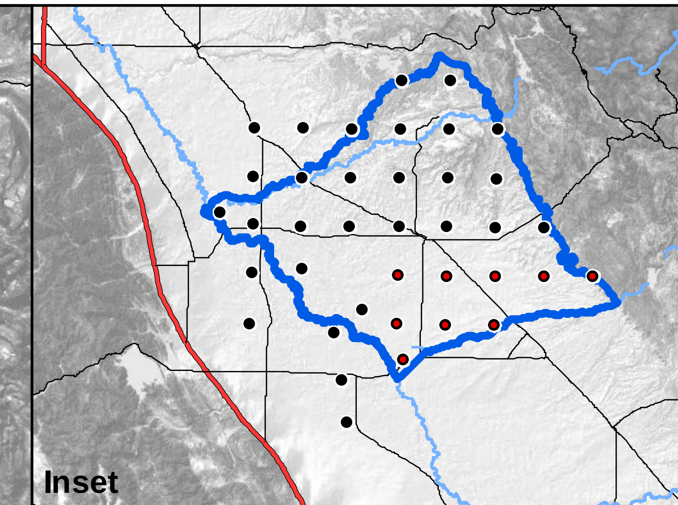
0 5 10

APPROXIMATE SCALE IN MILES

TRICHLOROETHYLENE (TCE)
CONCENTRATIONS
1984 THROUGH 2012
Merced IRWMP
Merced County, California

By: DB	Date: 01/08/2013	Project No. FR1216040A
		Figure 16b

N:_FR_projects\FR12s\FR1216040A\gis\maps\2013_01\ConcentrationMaps_fig16b_TCE.mxd



Explanation:

- Township/Range centroid
- Surface water feature
- Merced IRWM area

Concentration Charts:

- Minimum TCE concentration
- Mean TCE concentration
- Maximum TCE concentration
- MCL for TCE (5 µg/L)

Notes:

1. IRWMP = Integrated Regional Water Management Plan.
2. Trichloroethylene (TCE) concentrations shown in micrograms per liter (µg/L).
3. Maximum Contaminant Level (MCL) as established by the California Department of Public Health.

N

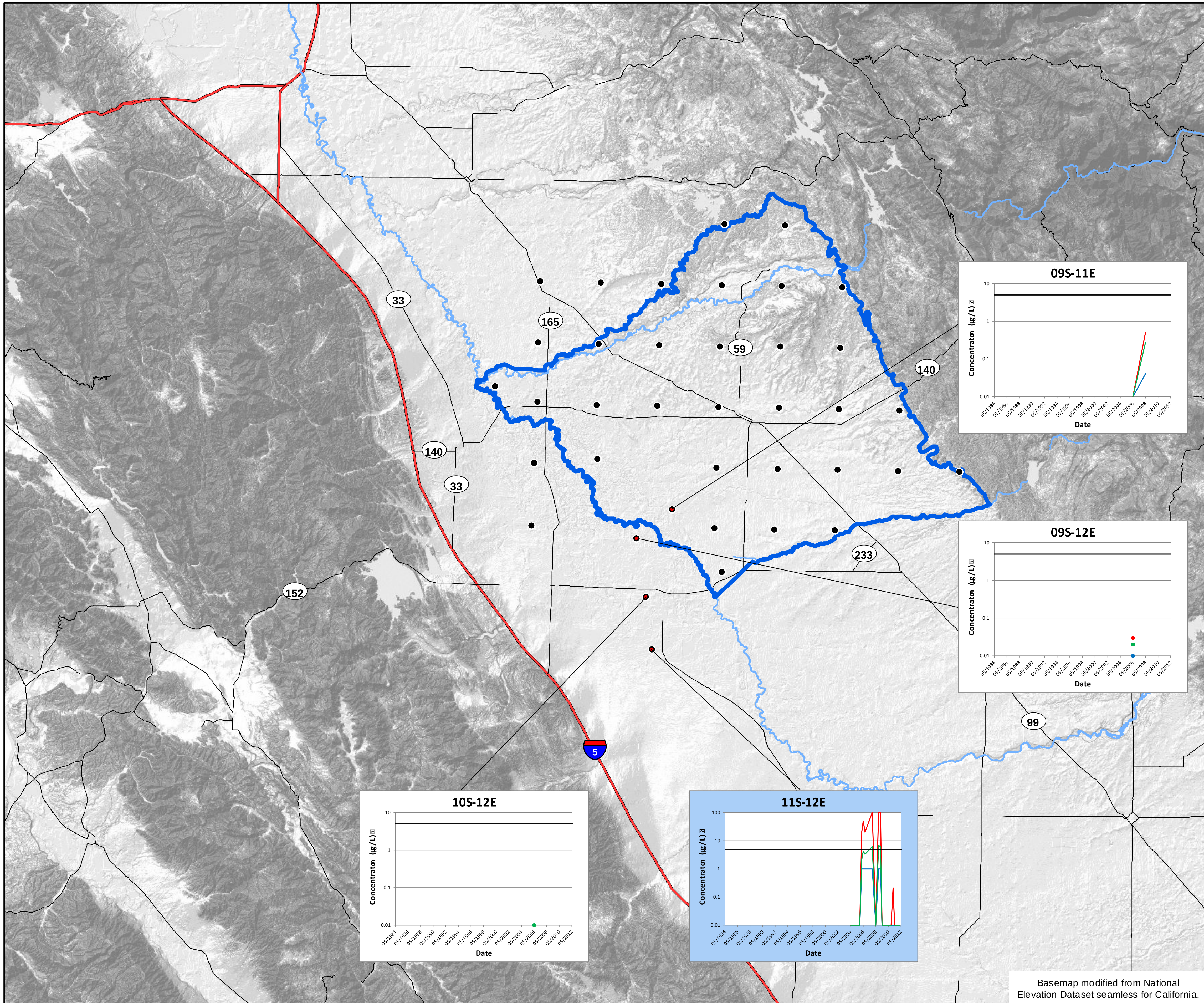
0 5 10

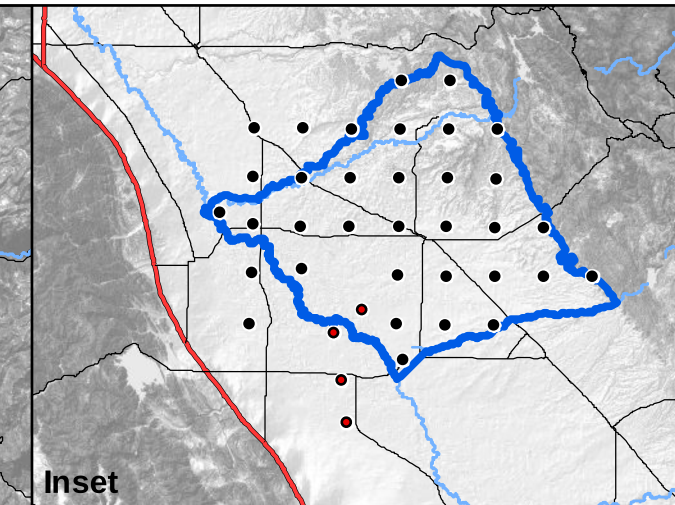
APPROXIMATE SCALE IN MILES

TRICHLOROETHYLENE (TCE)
CONCENTRATIONS
1984 THROUGH 2012
Merced IRWMP
Merced County, California

By: DB	Date: 01/08/2013	Project No. FR1216040A
		Figure **16c**

N:_FR_projects\FR12s\FR1216040A\gis\maps\2013_01\ConcentrationMaps_fig16c_TCE.mxd





Explanation:

- Township/Range centroid
- Surface water feature
- Merced IRWM area

Concentration Charts:

- Minimum TCE concentration
- Mean TCE concentration
- Maximum TCE concentration
- MCL for TCE (5 µg/L)

Notes:

1. IRWMP = Integrated Regional Water Management Plan.
2. Trichloroethylene (TCE) concentrations shown in micrograms per liter (µg/L).
3. Maximum Contaminant Level (MCL) as established by the California Department of Public Health.
4. Background color on graphs represent the y-axis range as follows:

White: 0.01- 10 µg/L

Blue: 0.01- 100 µg/L

N

0 5 10

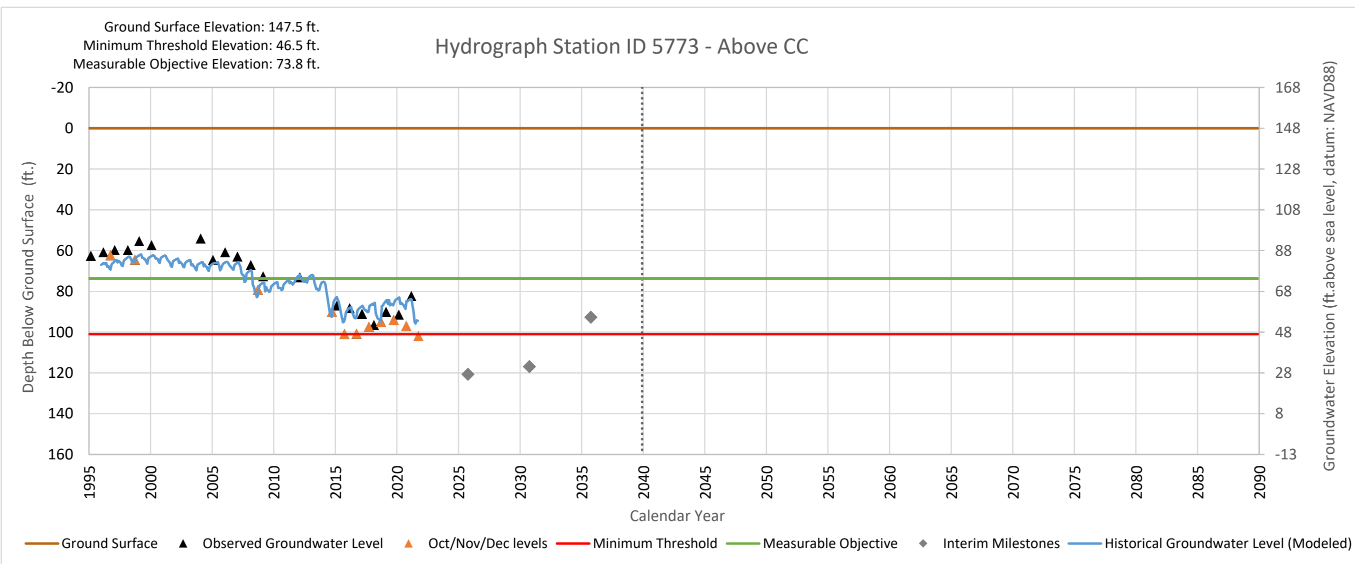
APPROXIMATE SCALE IN MILES

TRICHLOROETHYLENE (TCE)
CONCENTRATIONS
1984 THROUGH 2012
Merced IRWMP
Merced County, California

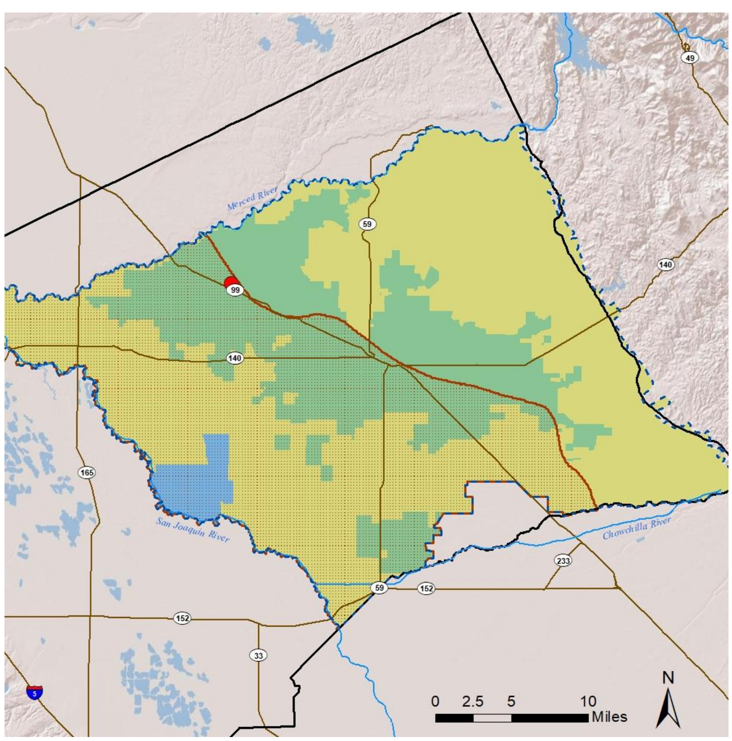
By: DB	Date: 01/08/2013	Project No. FR1216040A
		Figure **16d**

N:_FR_projects\FR12s\FR1216040A\gis\maps\2013_01\ConcentrationMaps_fig16d_TCE.mxd

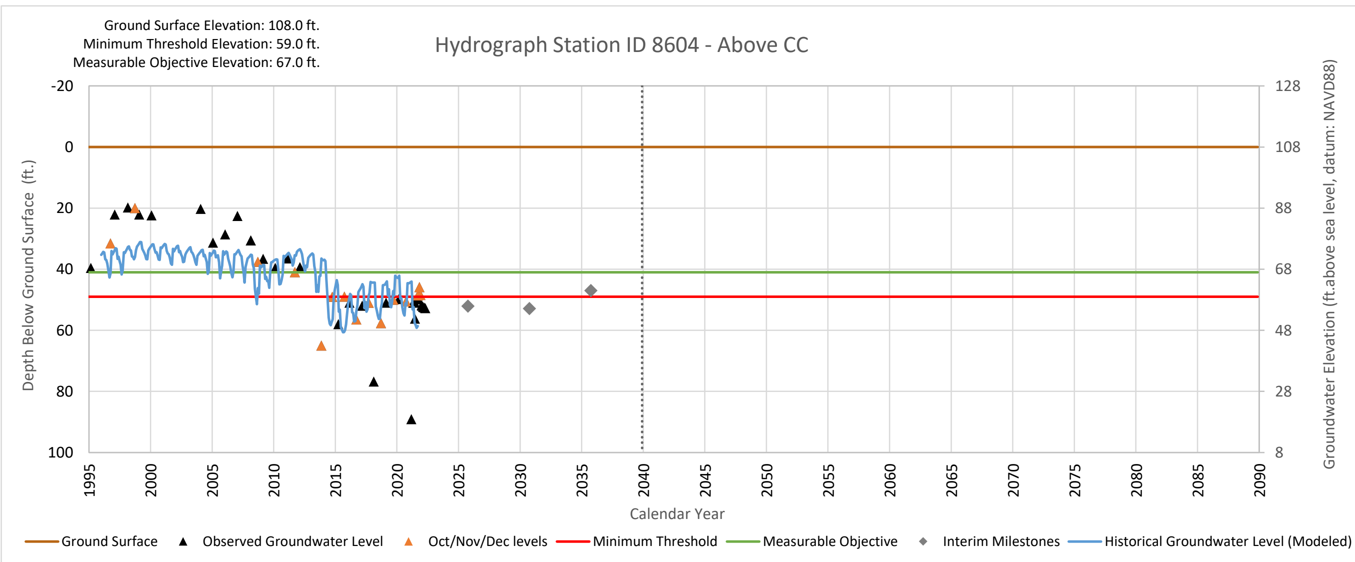
APPENDIX F: SUSTAINABLE MANAGEMENT CRITERIA HYDROGRAPHS FOR DECLINING GROUNDWATER LEVELS



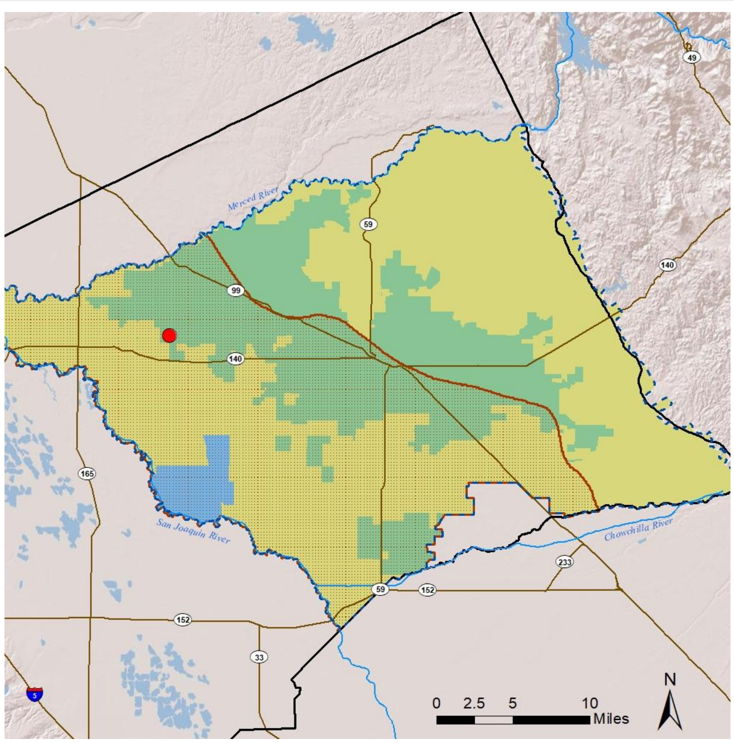
Ground Surface Elevation: 147.5 ft.
Minimum Threshold Elevation: 46.5 ft.
Measurable Objective Elevation: 73.8 ft.
Hydrograph Station ID 5773 - Above CC
Depth Below Ground Surface (ft.)
Groundwater Elevation (ft.above sea level, datum: NAVD88)
-20
0
20
40
60
80
100
120
140
160
168
148
128
108
88
68
48
28
8
-13
1995
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
2055
2060
2065
2070
2075
2080
2085
2090
Calendar Year
Ground Surface
Observed Groundwater Level
Oct/Nov/Dec levels
Minimum Threshold
Measurable Objective
Interim Milestones
Historical Groundwater Level (Modeled)



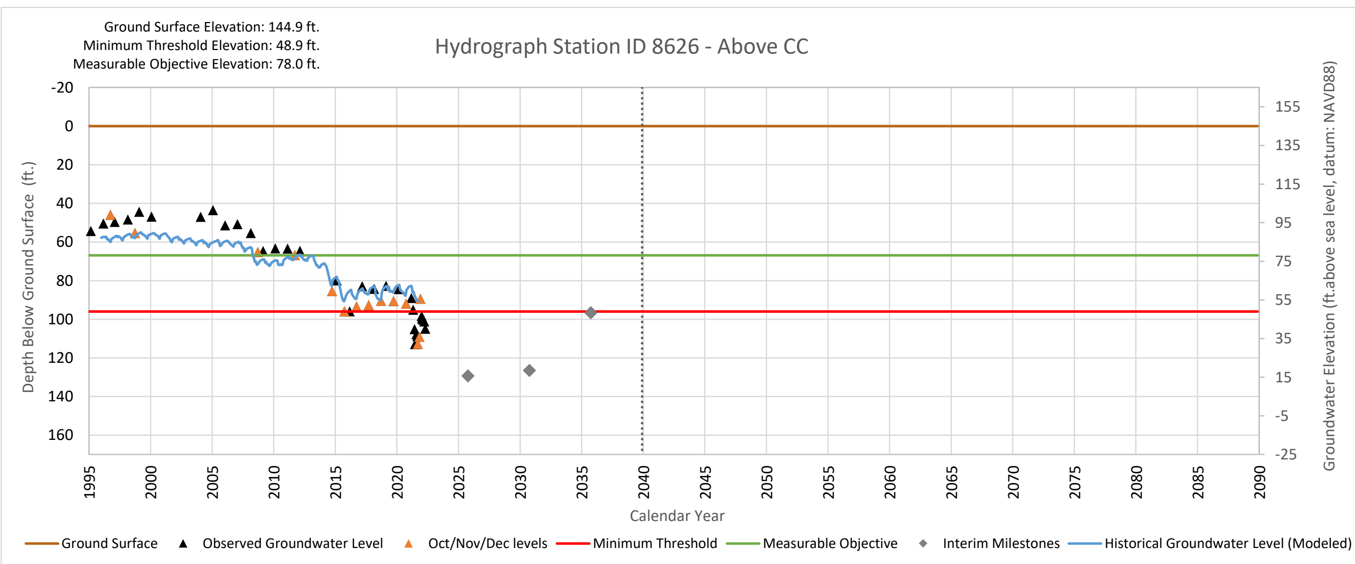
Merced River
San Joaquin River
Chowchilla River
49
59
140
99
165
152
233
33
5
0
2.5
5
10
Miles
N



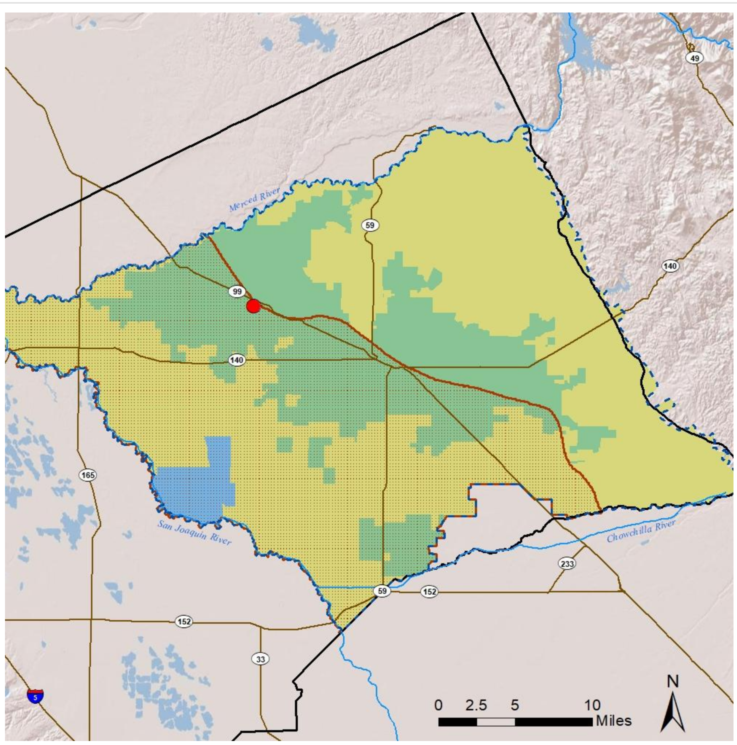
Ground Surface Elevation: 108.0 ft.
Minimum Threshold Elevation: 59.0 ft.
Measurable Objective Elevation: 67.0 ft.
Hydrograph Station ID 8604 - Above CC
Depth Below Ground Surface (ft.)
Groundwater Elevation (ft.above sea level, datum: NAVD88)
Calendar Year
Ground Surface
Observed Groundwater Level
Oct/Nov/Dec levels
Minimum Threshold
Measurable Objective
Interim Milestones
Historical Groundwater Level (Modeled)



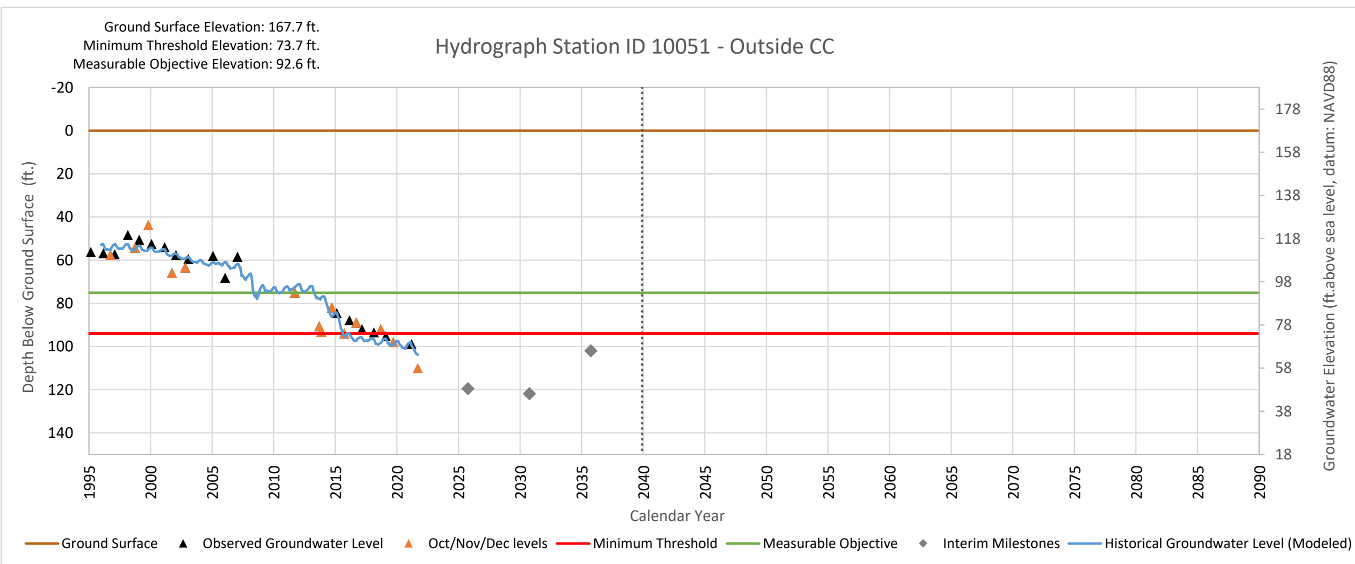
Merced River
San Joaquin River
Chowchilla River
0 2.5 5 10
Miles
N



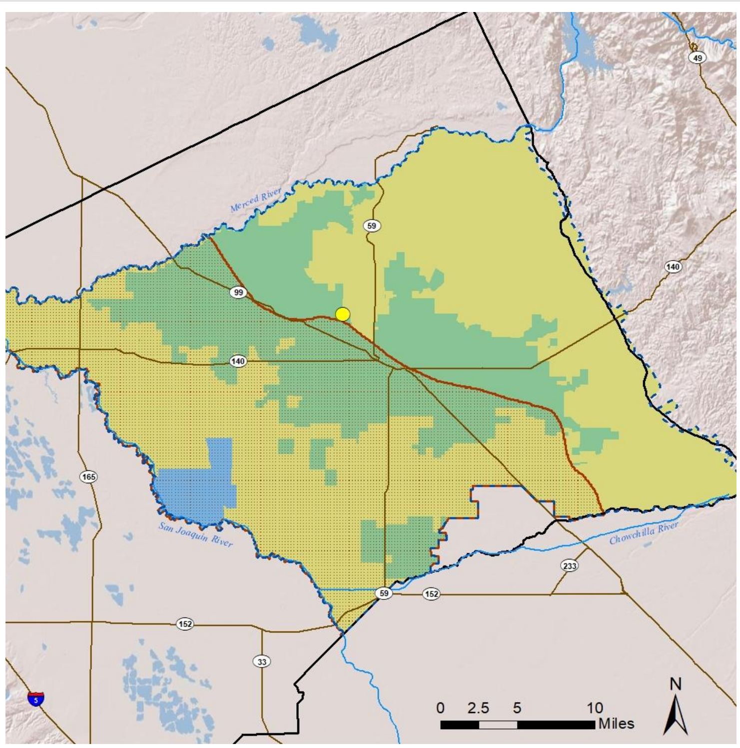
Ground Surface Elevation: 144.9 ft.
Minimum Threshold Elevation: 48.9 ft.
Measurable Objective Elevation: 78.0 ft.
Hydrograph Station ID 8626 - Above CC
Depth Below Ground Surface (ft.)
Groundwater Elevation (ft.above sea level, datum: NAVD88)
Calendar Year
Ground Surface
Observed Groundwater Level
Oct/Nov/Dec levels
Minimum Threshold
Measurable Objective
Interim Milestones
Historical Groundwater Level (Modeled)



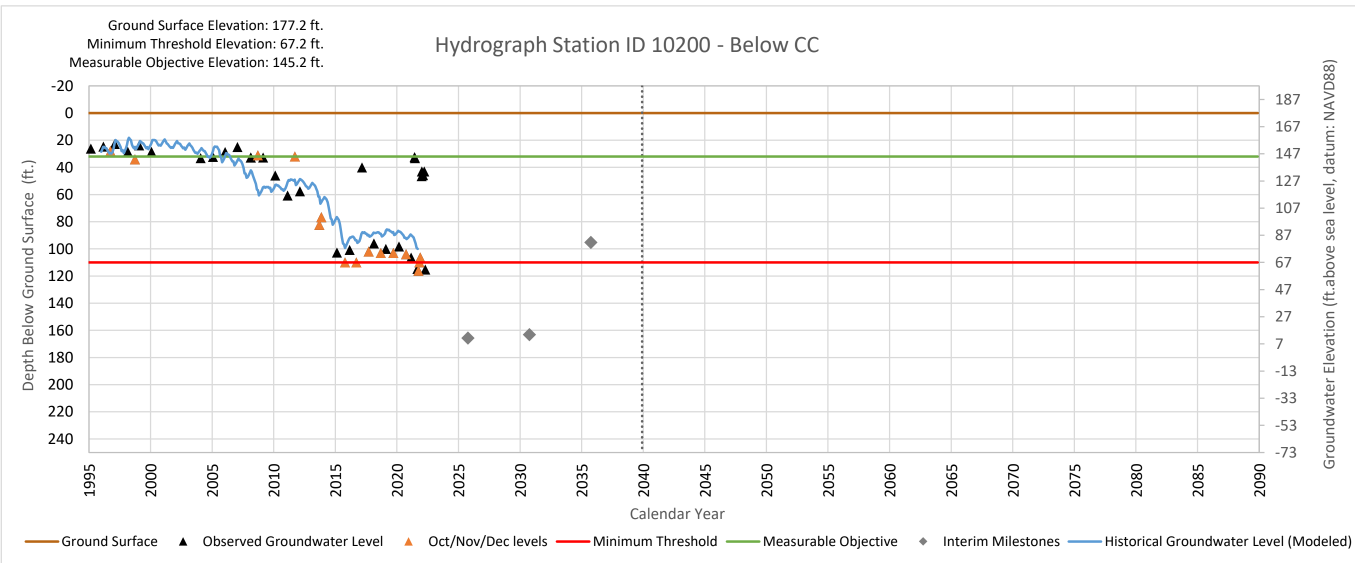
Merced River
San Joaquin River
Chowchilla River
0 2.5 5 10
Miles
N



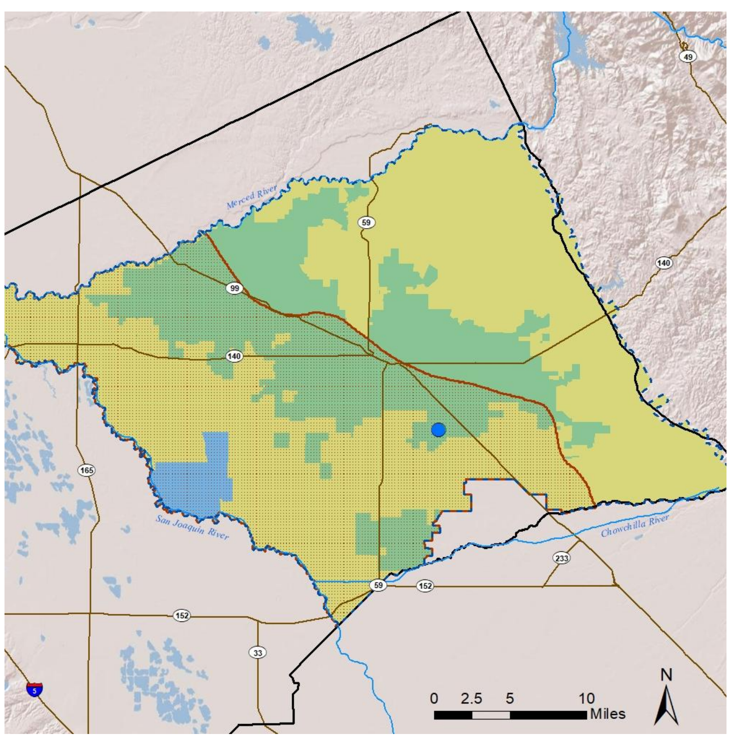
Ground Surface Elevation: 167.7 ft.
Minimum Threshold Elevation: 73.7 ft.
Measurable Objective Elevation: 92.6 ft.
Hydrograph Station ID 10051 - Outside CC
Depth Below Ground Surface (ft.)
Groundwater Elevation (ft.above sea level, datum: NAVD88)
Calendar Year
Ground Surface
Observed Groundwater Level
Oct/Nov/Dec levels
Minimum Threshold
Measurable Objective
Interim Milestones
Historical Groundwater Level (Modeled)



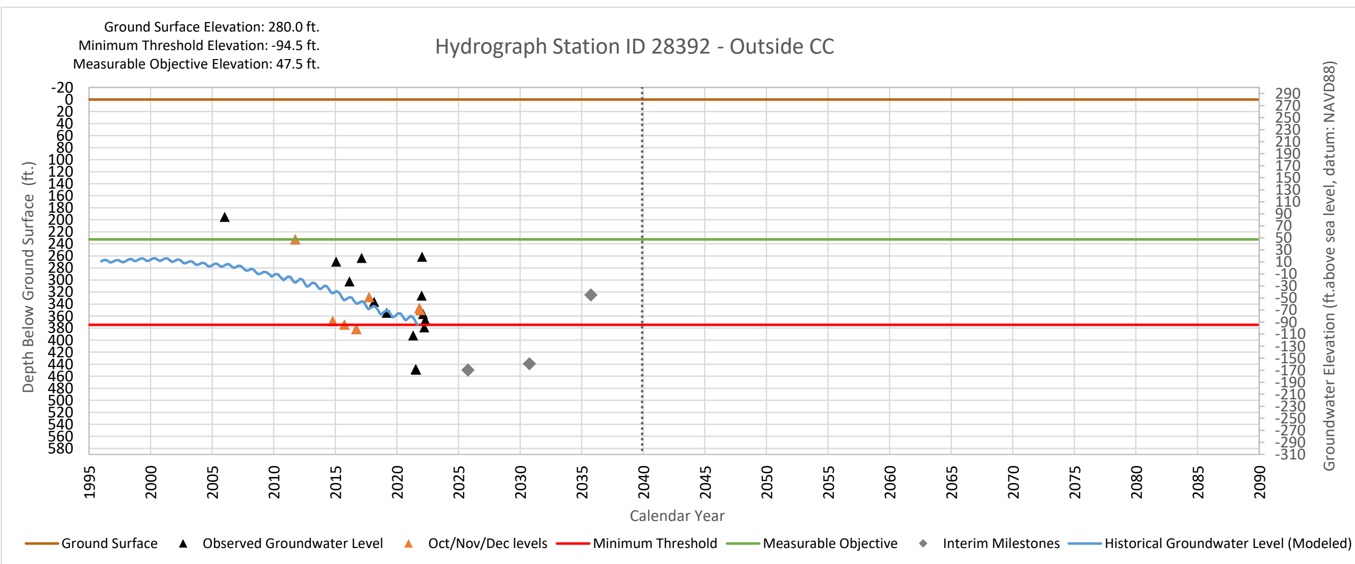
Merced River
San Joaquin River
Chowchilla River
0 2.5 5 10
Miles
N



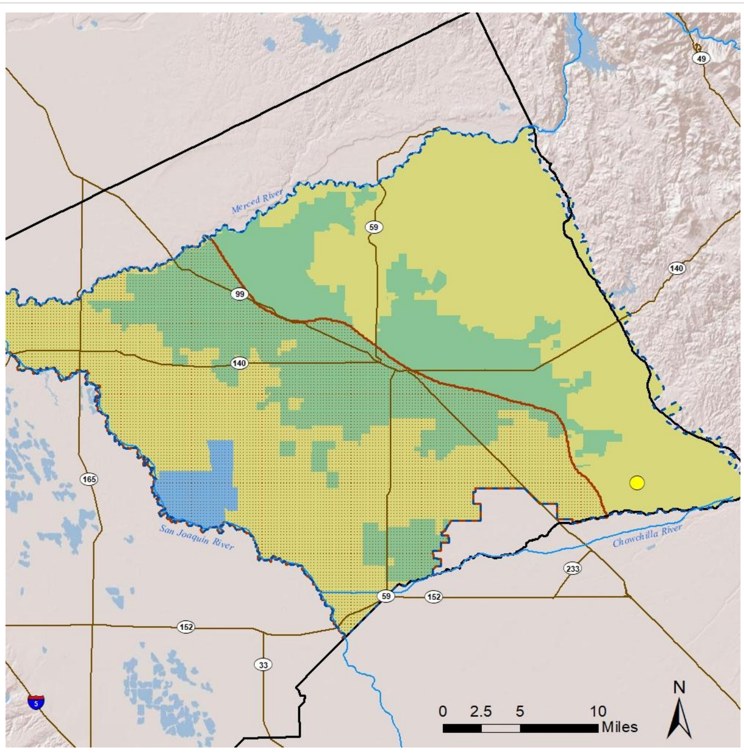
Ground Surface Elevation: 177.2 ft.
Minimum Threshold Elevation: 67.2 ft.
Measurable Objective Elevation: 145.2 ft.
Hydrograph Station ID 10200 - Below CC
Depth Below Ground Surface (ft.)
-20
0
20
40
60
80
100
120
140
160
180
200
220
240
Groundwater Elevation (ft.above sea level, datum: NAVD88)
187
167
147
127
107
87
67
47
27
7
-13
-33
-53
-73
1995
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
2055
2060
2065
2070
2075
2080
2085
2090
Calendar Year
Ground Surface
Observed Groundwater Level
Oct/Nov/Dec levels
Minimum Threshold
Measurable Objective
Interim Milestones
Historical Groundwater Level (Modeled)



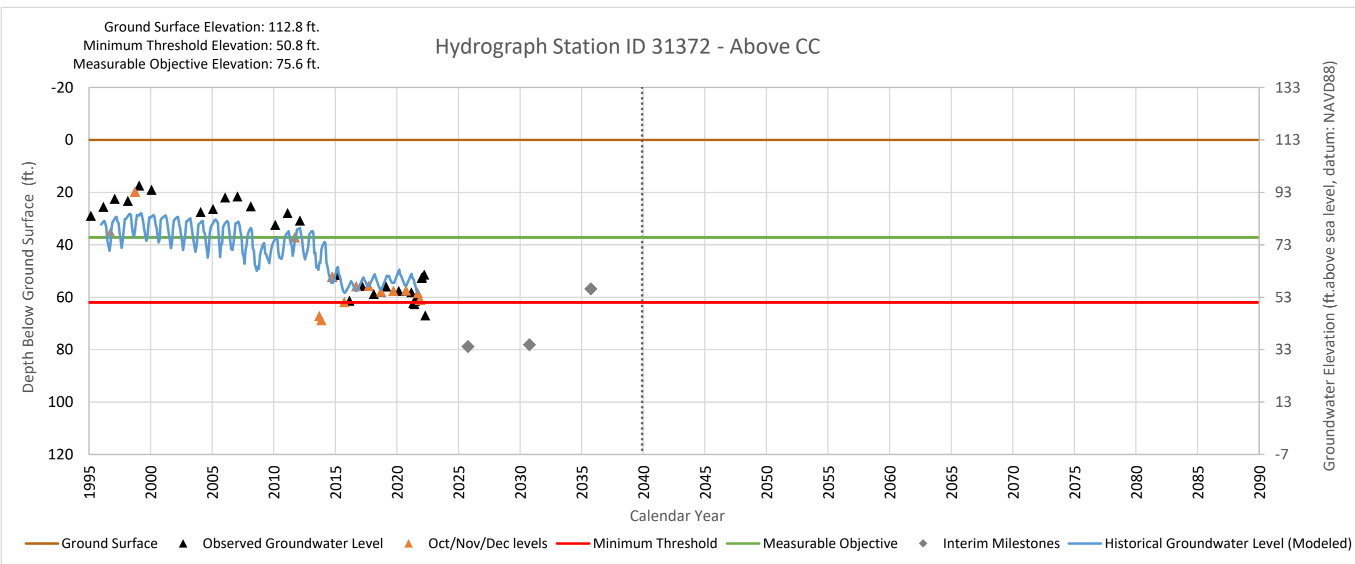
Merced River
San Joaquin River
Chowchilla River
49
59
140
99
165
152
233
33
5
0
2.5
5
10
Miles
N



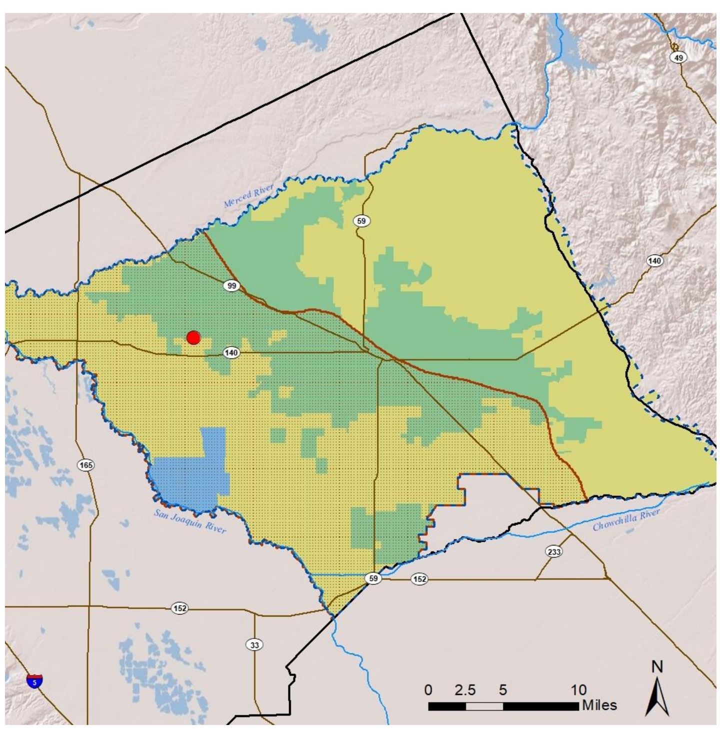
Ground Surface Elevation: 280.0 ft.
Minimum Threshold Elevation: -94.5 ft.
Measurable Objective Elevation: 47.5 ft.
Hydrograph Station ID 28392 - Outside CC
Depth Below Ground Surface (ft.)
Groundwater Elevation (ft.above sea level, datum: NAVD88)
Calendar Year
Ground Surface
Observed Groundwater Level
Oct/Nov/Dec levels
Minimum Threshold
Measurable Objective
Interim Milestones
Historical Groundwater Level (Modeled)



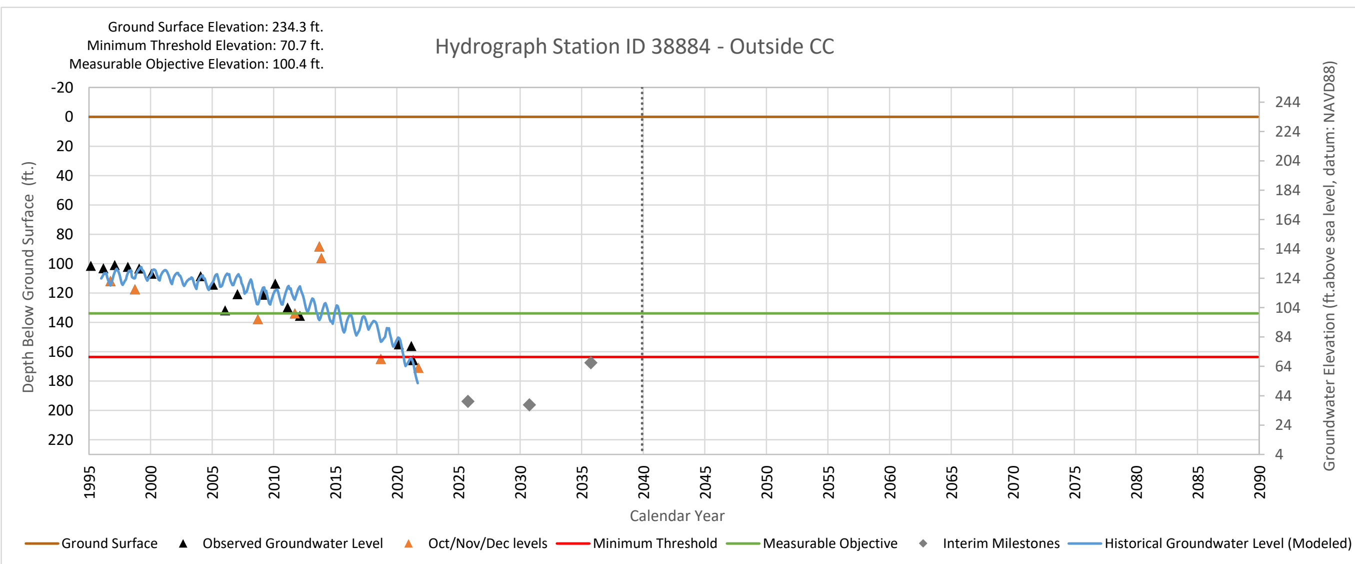
Merced River
San Joaquin River
Chowchilla River
0 2.5 5 10
Miles
N

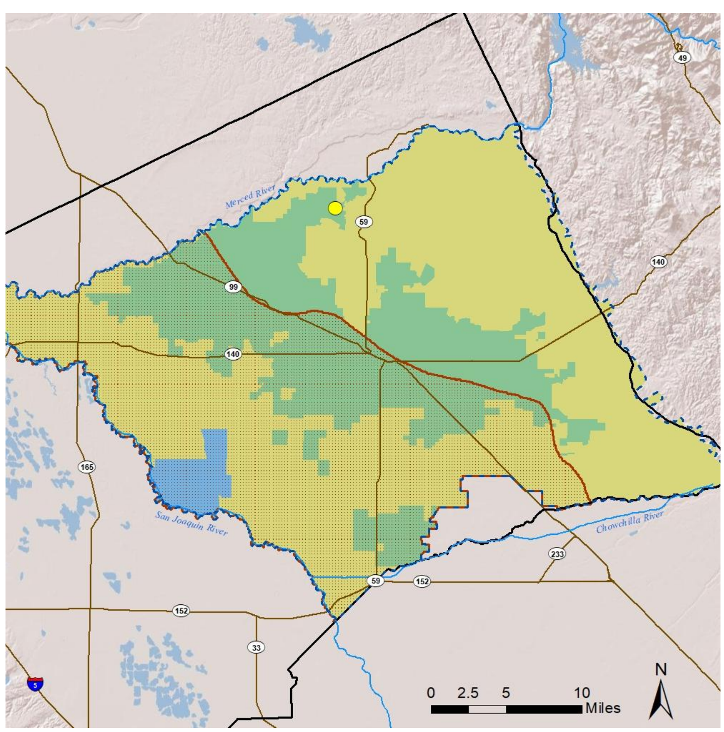


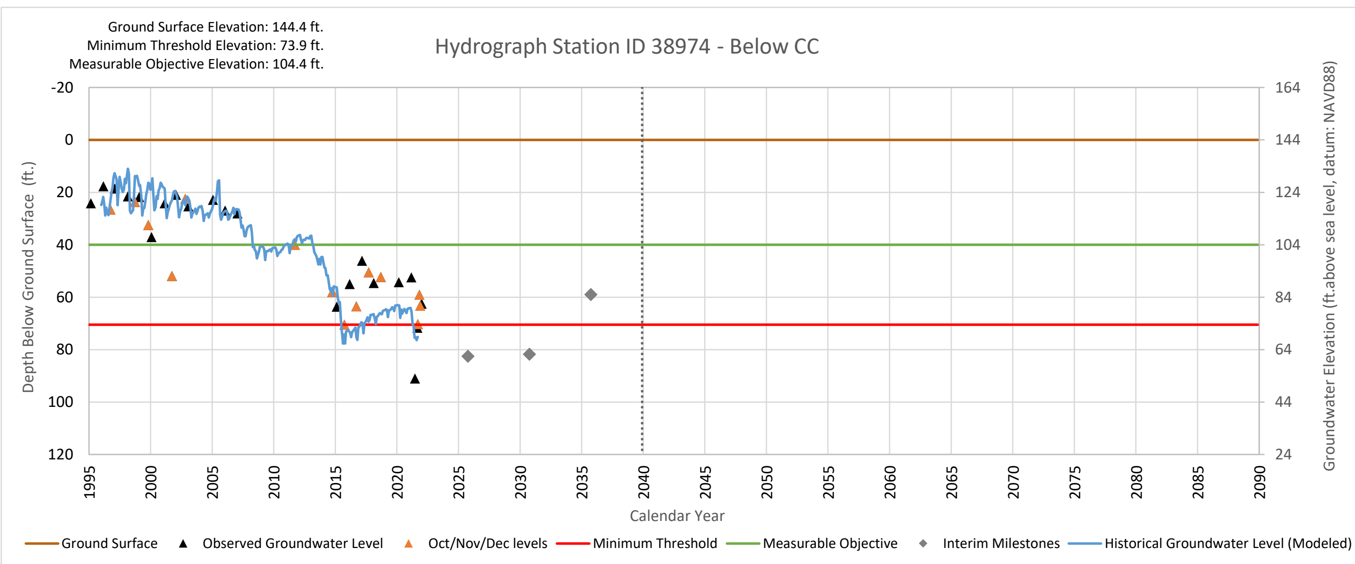
Ground Surface Elevation: 112.8 ft.
Minimum Threshold Elevation: 50.8 ft.
Measurable Objective Elevation: 75.6 ft.
Hydrograph Station ID 31372 - Above CC
Depth Below Ground Surface (ft.)
Groundwater Elevation (ft.above sea level, datum: NAVD88)
Calendar Year
Ground Surface
Observed Groundwater Level
Oct/Nov/Dec levels
Minimum Threshold
Measurable Objective
Interim Milestones
Historical Groundwater Level (Modeled)



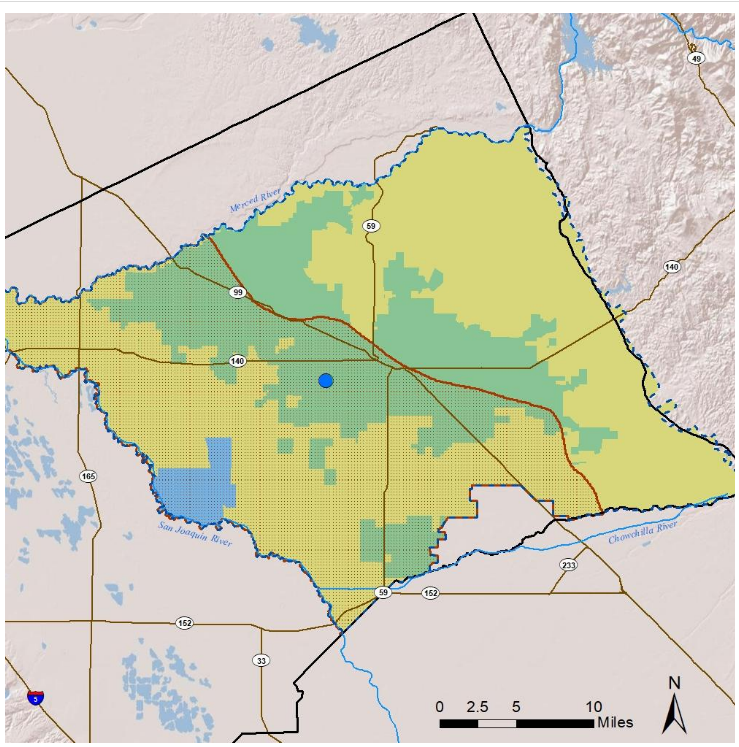
Merced River
San Joaquin River
Chowchilla River
0 2.5 5 10
Miles
N


Ground Surface Elevation: 234.3 ft.
Minimum Threshold Elevation: 70.7 ft.
Measurable Objective Elevation: 100.4 ft.
Hydrograph Station ID 38884 - Outside CC
Depth Below Ground Surface (ft.)
Groundwater Elevation (ft.above sea level, datum: NAVD88)
Calendar Year
Ground Surface
Observed Groundwater Level
Oct/Nov/Dec levels
Minimum Threshold
Measurable Objective
Interim Milestones
Historical Groundwater Level (Modeled)

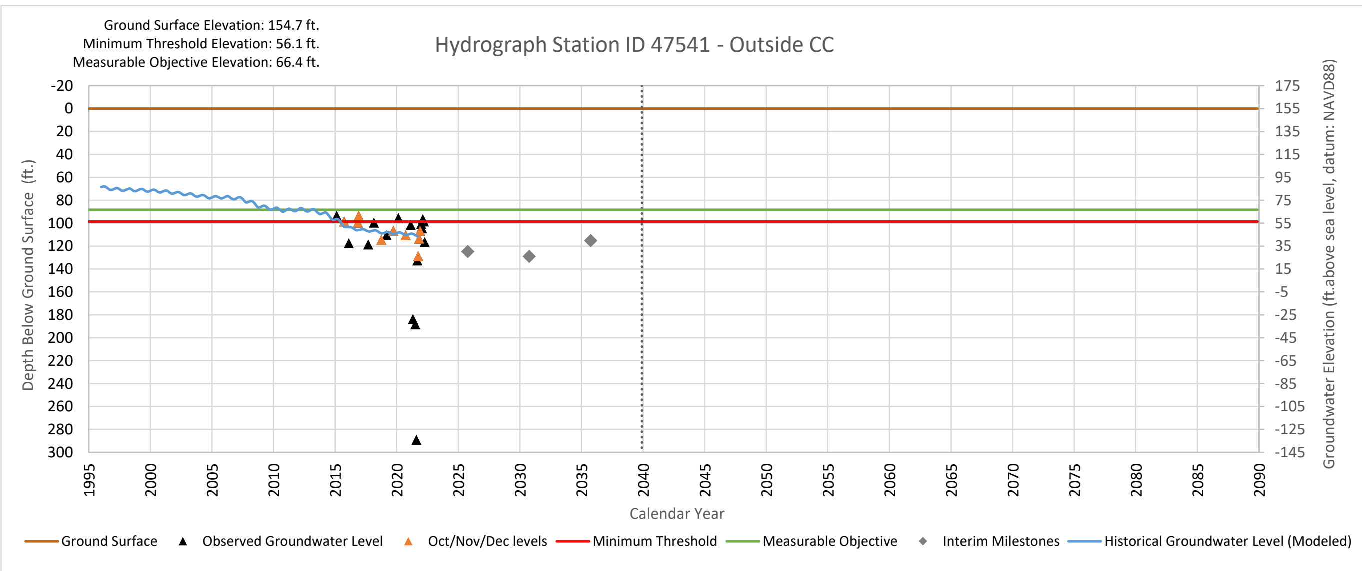

Merced River
San Joaquin River
Chowchilla River
0 2.5 5 10
Miles
N



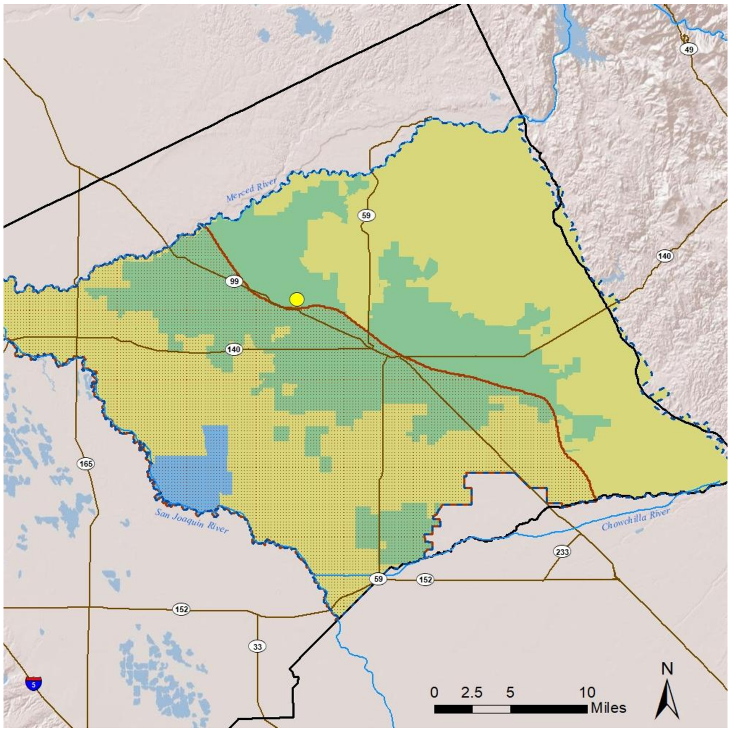
Ground Surface Elevation: 144.4 ft.
Minimum Threshold Elevation: 73.9 ft.
Measurable Objective Elevation: 104.4 ft.
Hydrograph Station ID 38974 - Below CC
Depth Below Ground Surface (ft.)
Groundwater Elevation (ft.above sea level, datum: NAVD88)
-20
0
20
40
60
80
100
120
164
144
124
104
84
64
44
24
1995
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
2055
2060
2065
2070
2075
2080
2085
2090
Calendar Year
Ground Surface
Observed Groundwater Level
Oct/Nov/Dec levels
Minimum Threshold
Measurable Objective
Interim Milestones
Historical Groundwater Level (Modeled)



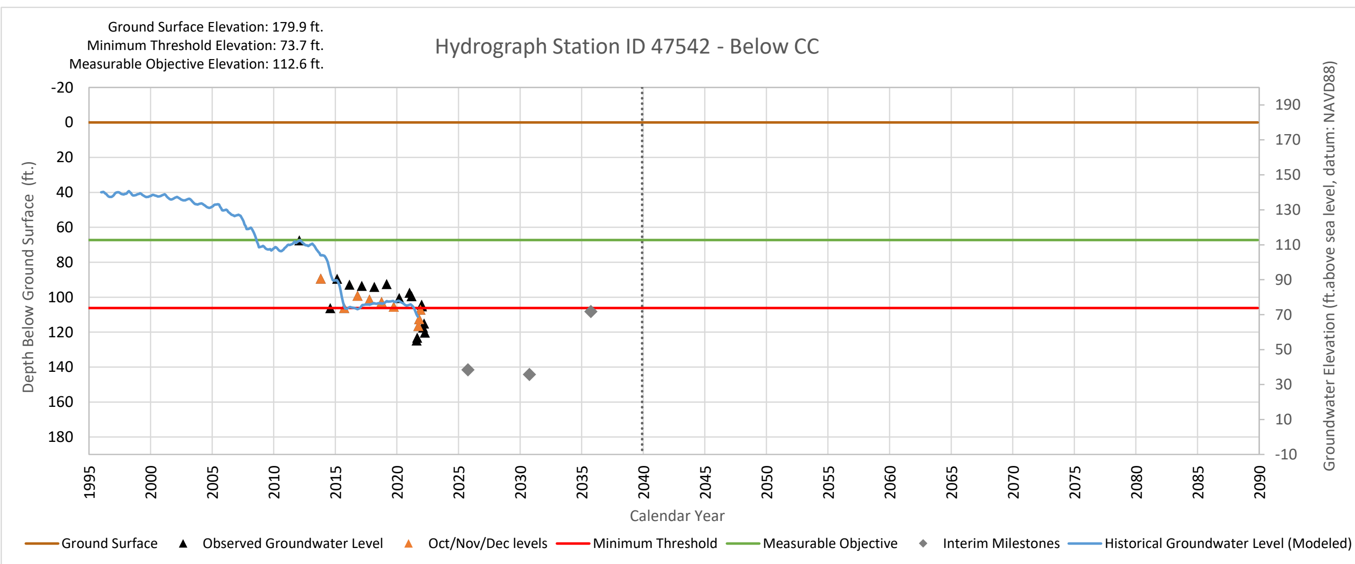
Merced River
San Joaquin River
Chowchilla River
49
59
140
99
165
233
152
33
5
0 2.5 5 10
Miles
N

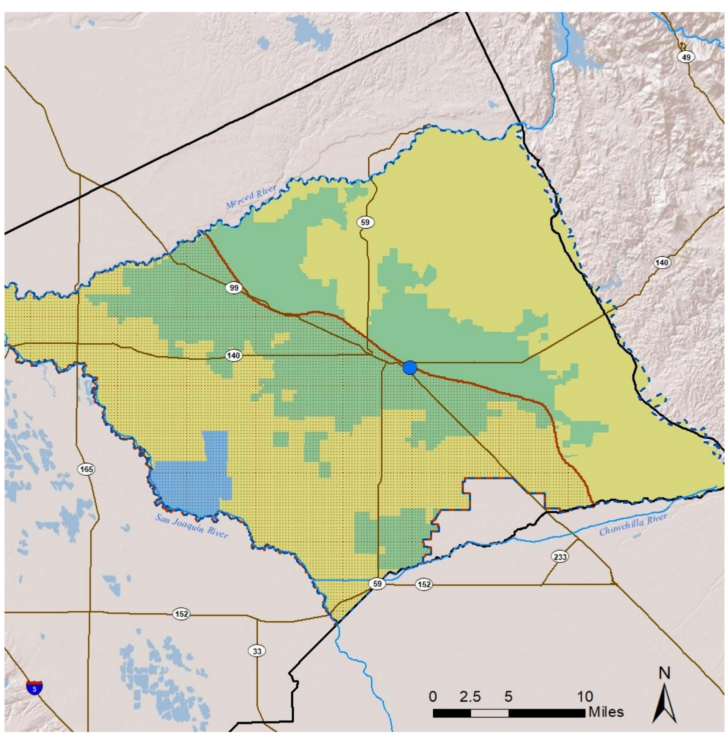


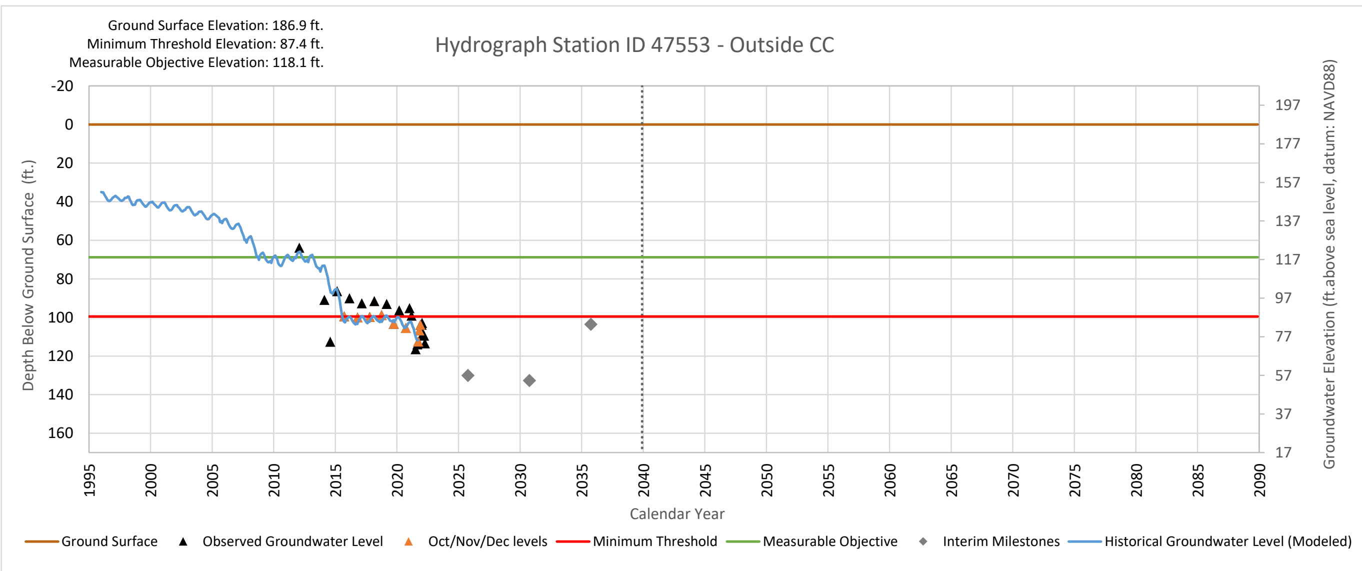
Ground Surface Elevation: 154.7 ft.
Minimum Threshold Elevation: 56.1 ft.
Measurable Objective Elevation: 66.4 ft.
Hydrograph Station ID 47541 - Outside CC
Depth Below Ground Surface (ft.)
Groundwater Elevation (ft.above sea level, datum: NAVD88)
Calendar Year
Ground Surface
Observed Groundwater Level
Oct/Nov/Dec levels
Minimum Threshold
Measurable Objective
Interim Milestones
Historical Groundwater Level (Modeled)



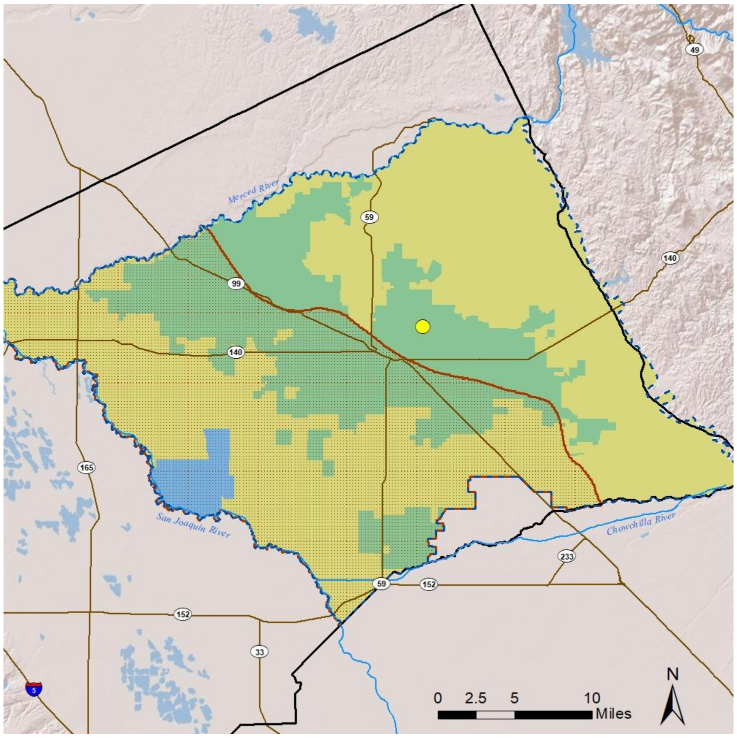
Merced River
San Joaquin River
Chowchilla River
0 2.5 5 10
Miles
N


Ground Surface Elevation: 179.9 ft.
Minimum Threshold Elevation: 73.7 ft.
Measurable Objective Elevation: 112.6 ft.
Hydrograph Station ID 47542 - Below CC
Depth Below Ground Surface (ft.)
Groundwater Elevation (ft.above sea level, datum: NAVD88)
Calendar Year
Ground Surface
Observed Groundwater Level
Oct/Nov/Dec levels
Minimum Threshold
Measurable Objective
Interim Milestones
Historical Groundwater Level (Modeled)

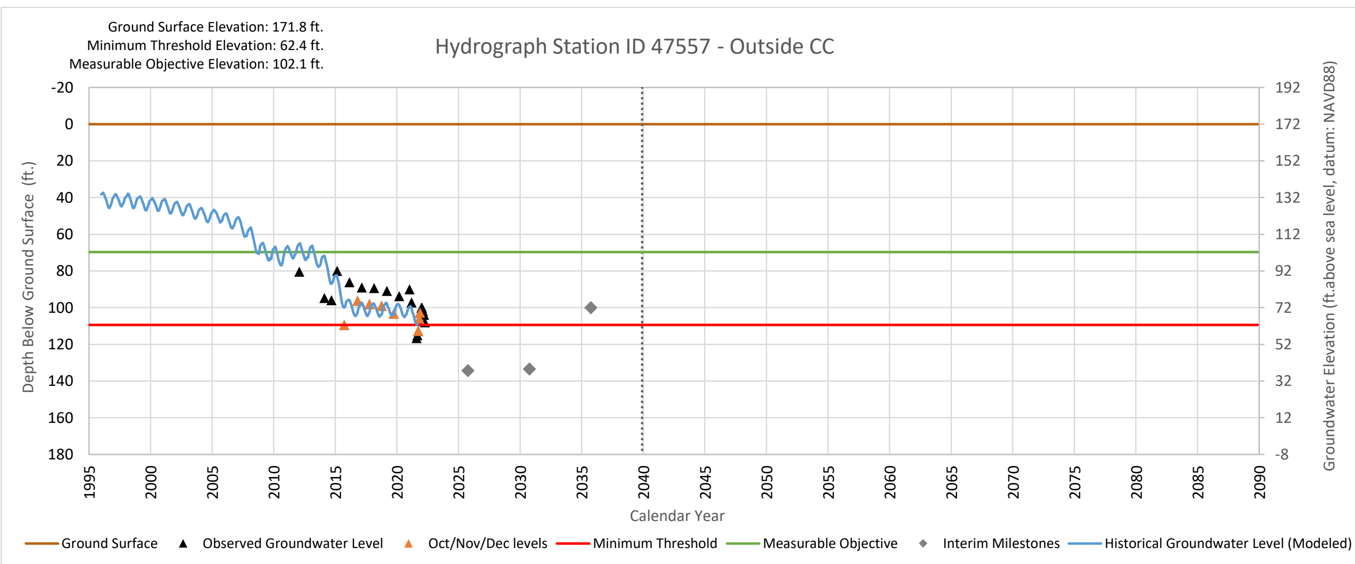

Merced River
San Joaquin River
Chowchilla River
0 2.5 5 10
Miles
N



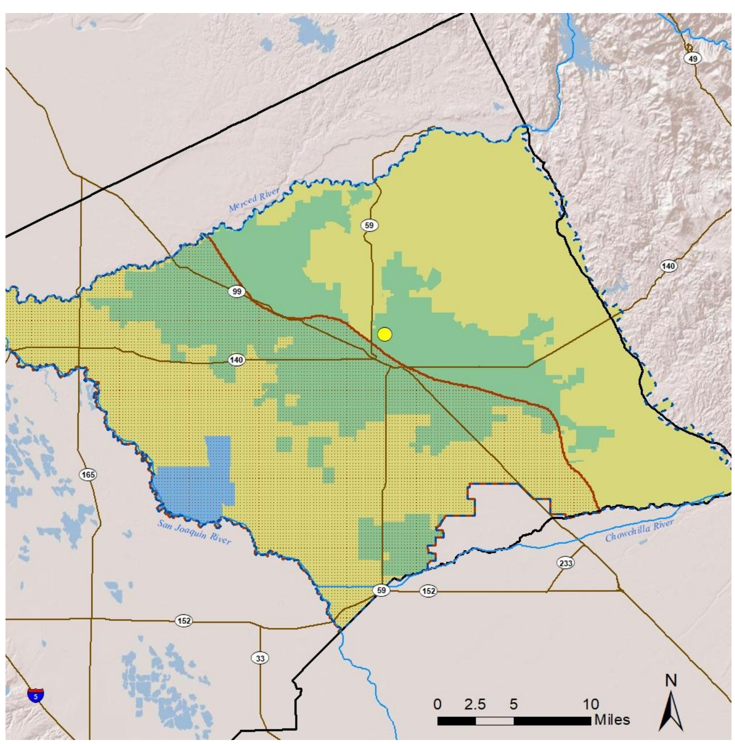
Ground Surface Elevation: 186.9 ft.
Minimum Threshold Elevation: 87.4 ft.
Measurable Objective Elevation: 118.1 ft.
Hydrograph Station ID 47553 - Outside CC
Depth Below Ground Surface (ft.)
Groundwater Elevation (ft.above sea level, datum: NAVD88)
Calendar Year
Ground Surface
Observed Groundwater Level
Oct/Nov/Dec levels
Minimum Threshold
Measurable Objective
Interim Milestones
Historical Groundwater Level (Modeled)



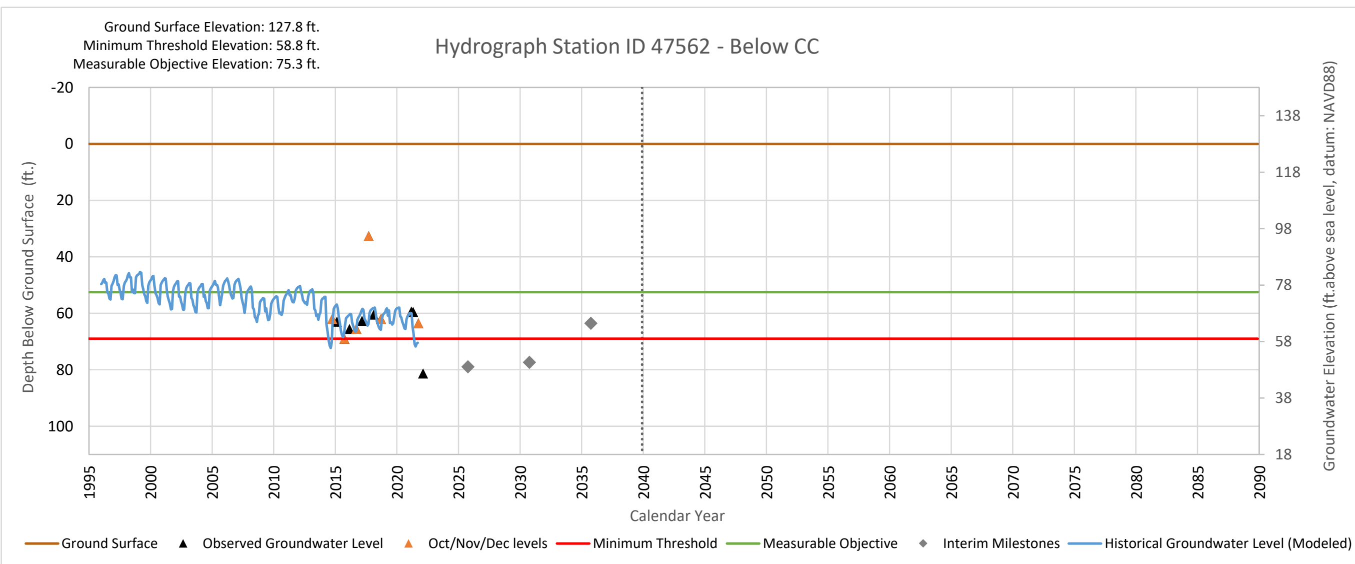
Merced River
San Joaquin River
Chowchilla River
0 2.5 5 10
Miles
N



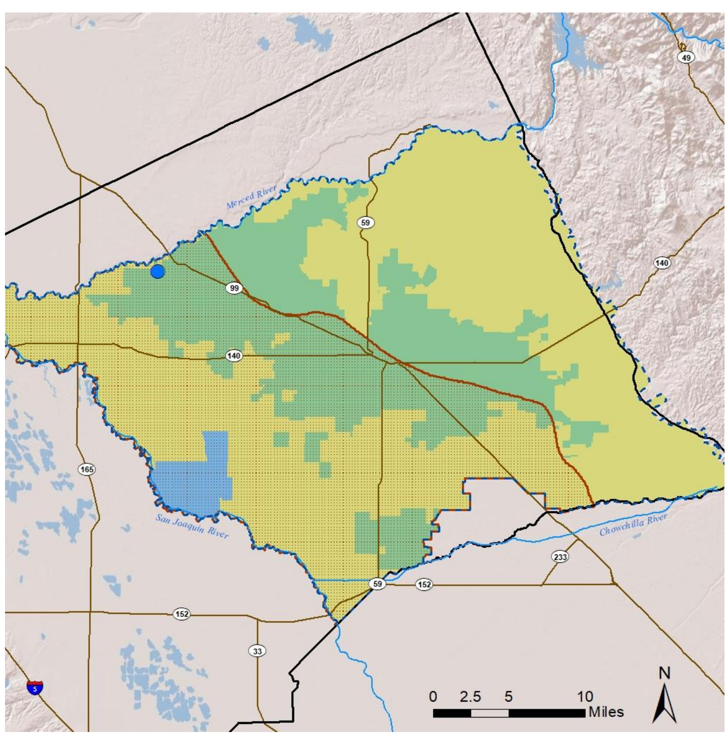
Ground Surface Elevation: 171.8 ft.
Minimum Threshold Elevation: 62.4 ft.
Measurable Objective Elevation: 102.1 ft.
Hydrograph Station ID 47557 - Outside CC
Depth Below Ground Surface (ft.)
Groundwater Elevation (ft.above sea level, datum: NAVD88)
Calendar Year
Ground Surface
Observed Groundwater Level
Oct/Nov/Dec levels
Minimum Threshold
Measurable Objective
Interim Milestones
Historical Groundwater Level (Modeled)



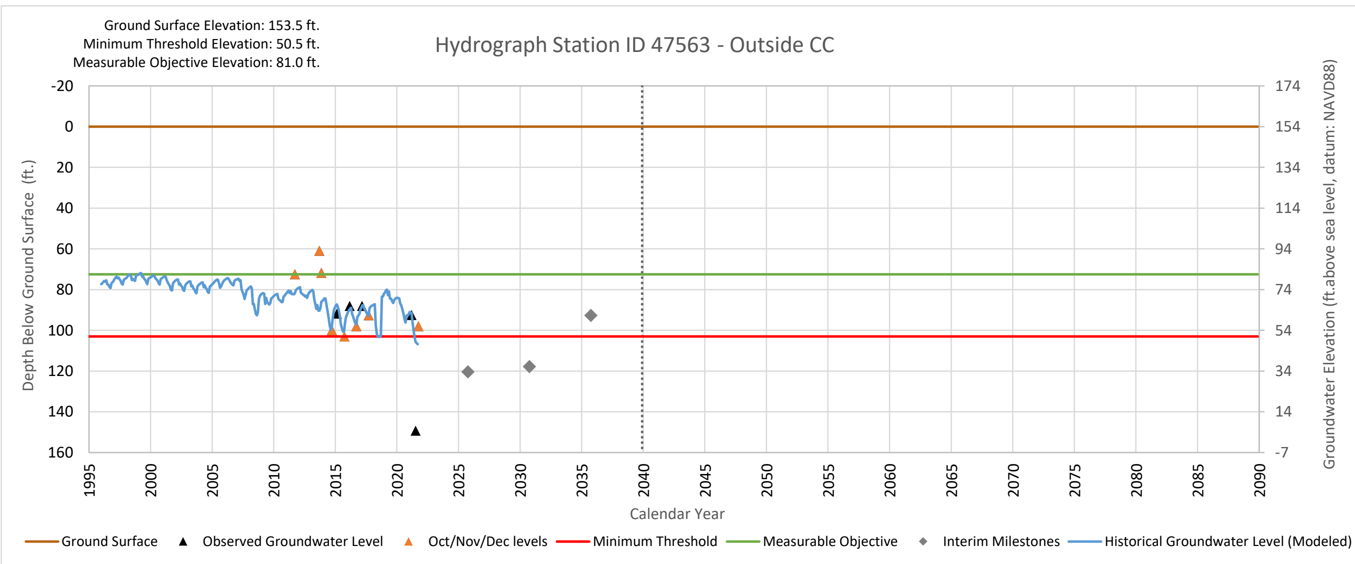
Merced River
Sun Joaquin River
Chowchilla River
0 2.5 5 10
Miles
N

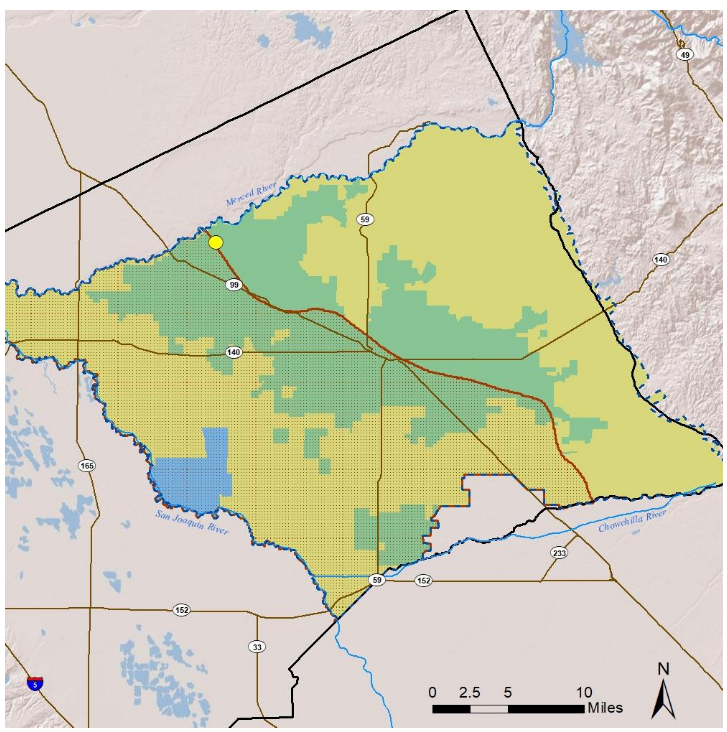


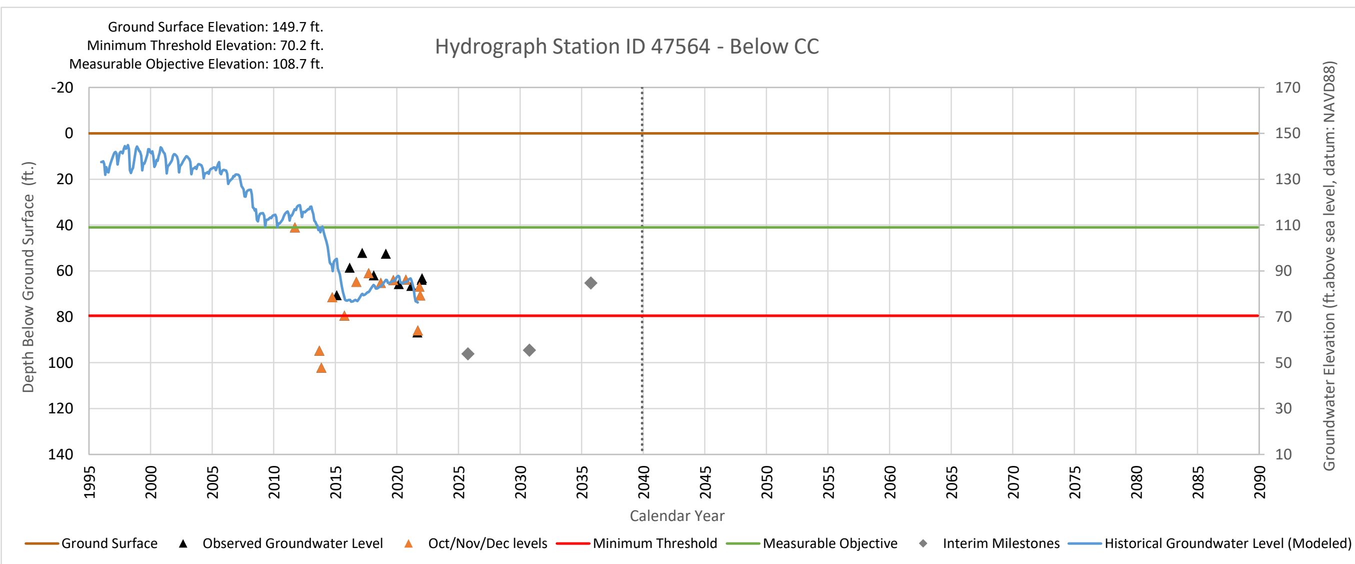
Ground Surface Elevation: 127.8 ft.
Minimum Threshold Elevation: 58.8 ft.
Measurable Objective Elevation: 75.3 ft.
Hydrograph Station ID 47562 - Below CC
Depth Below Ground Surface (ft.)
Groundwater Elevation (ft.above sea level, datum: NAVD88)
Calendar Year
Ground Surface
Observed Groundwater Level
Oct/Nov/Dec levels
Minimum Threshold
Measurable Objective
Interim Milestones
Historical Groundwater Level (Modeled)

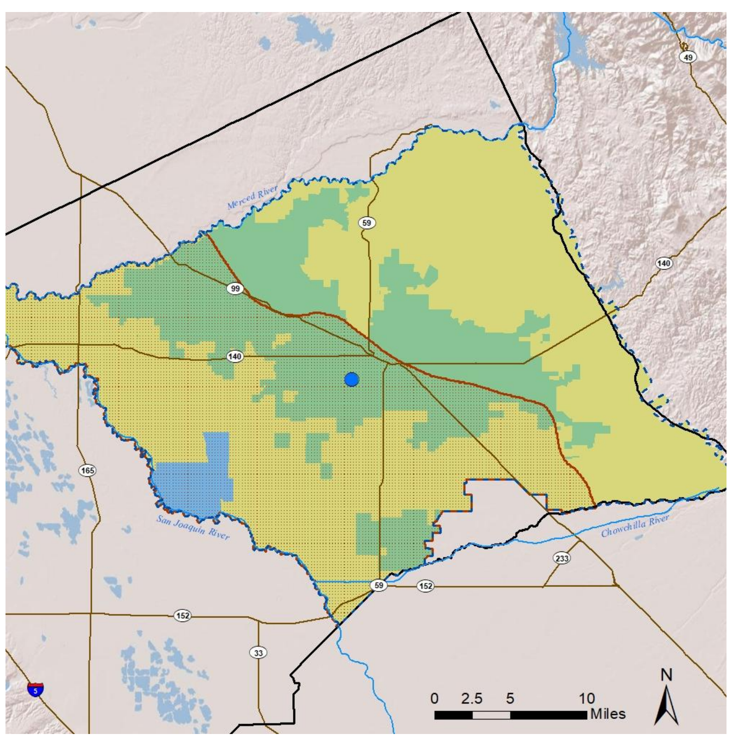


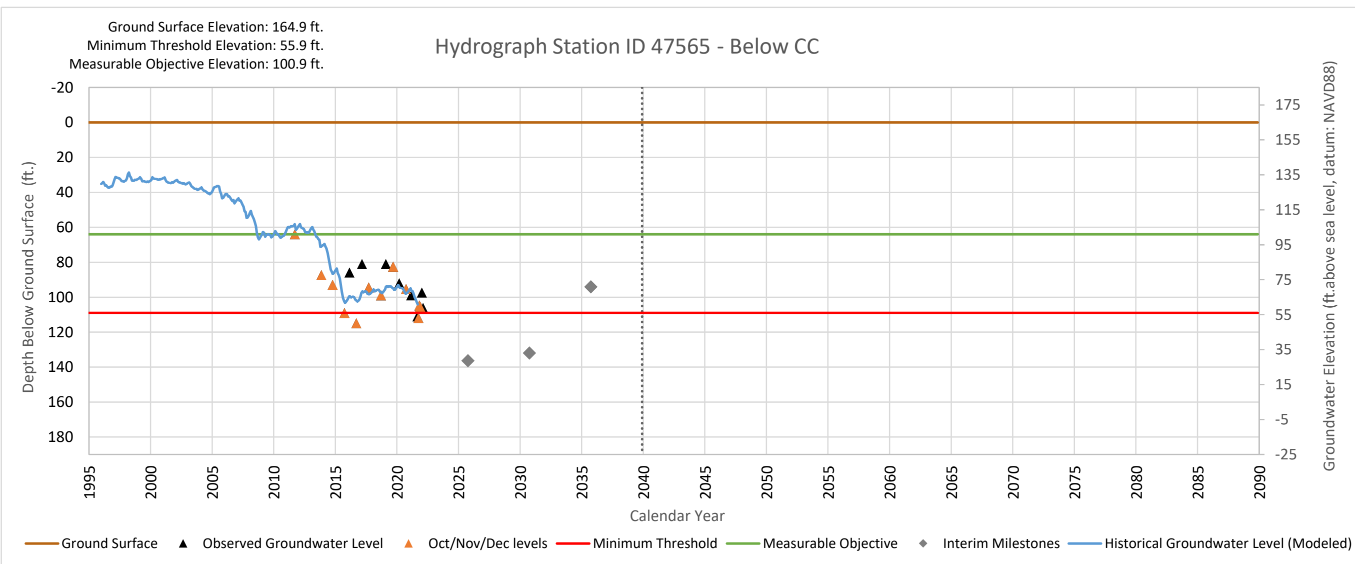
Merced River
San Joaquin River
Chowchilla River
0 2.5 5 10
Miles
N

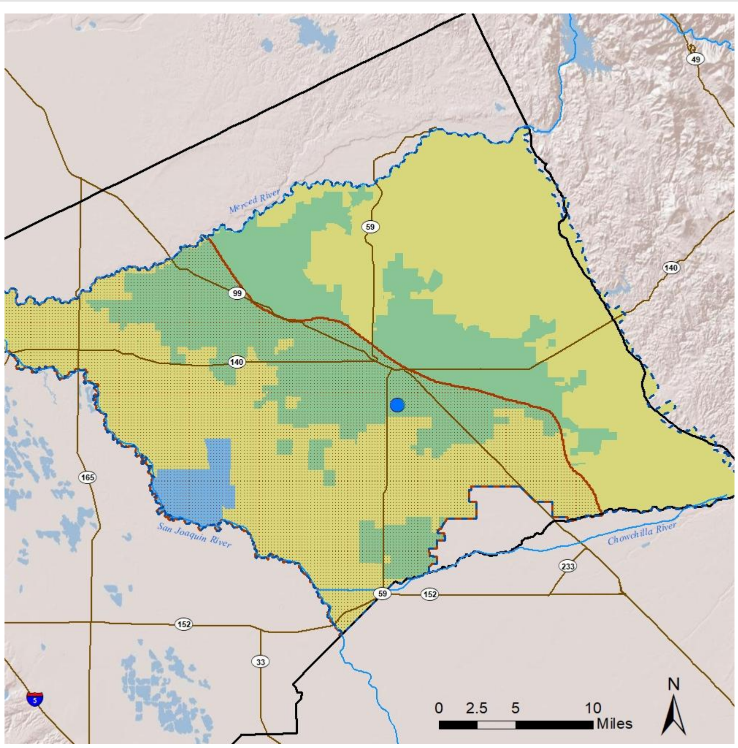

Ground Surface Elevation: 153.5 ft.
Minimum Threshold Elevation: 50.5 ft.
Measurable Objective Elevation: 81.0 ft.
Hydrograph Station ID 47563 - Outside CC
Depth Below Ground Surface (ft.)
Groundwater Elevation (ft.above sea level, datum: NAVD88)
Calendar Year
Ground Surface
Observed Groundwater Level
Oct/Nov/Dec levels
Minimum Threshold
Measurable Objective
Interim Milestones
Historical Groundwater Level (Modeled)

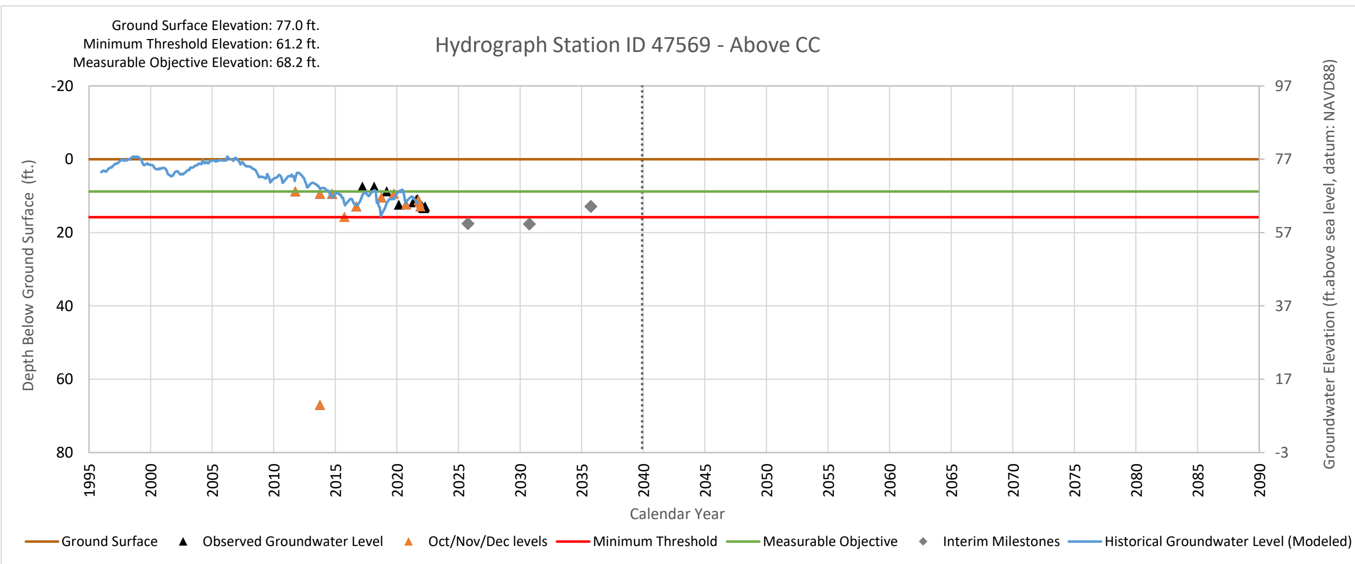

Merced River
San Joaquin River
Chowchilla River
0 2.5 5 10
Miles
N


Ground Surface Elevation: 149.7 ft.
Minimum Threshold Elevation: 70.2 ft.
Measurable Objective Elevation: 108.7 ft.
Hydrograph Station ID 47564 - Below CC
Depth Below Ground Surface (ft.)
Groundwater Elevation (ft.above sea level, datum: NAVD88)
Calendar Year
Ground Surface
Observed Groundwater Level
Oct/Nov/Dec levels
Minimum Threshold
Measurable Objective
Interim Milestones
Historical Groundwater Level (Modeled)

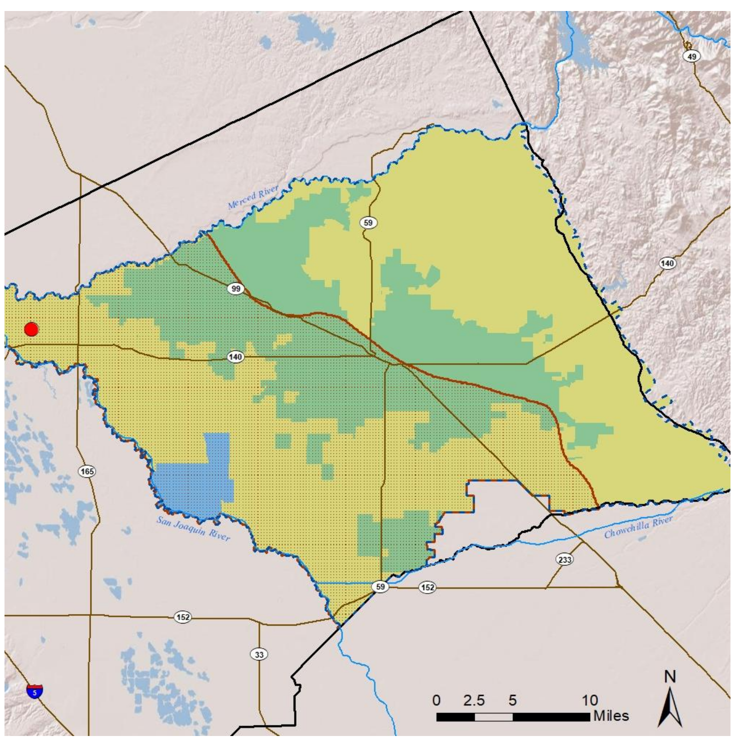

Merced River
San Joaquin River
Chowchilla River
0 2.5 5 10
Miles
N


Ground Surface Elevation: 164.9 ft.
Minimum Threshold Elevation: 55.9 ft.
Measurable Objective Elevation: 100.9 ft.
Hydrograph Station ID 47565 - Below CC
Depth Below Ground Surface (ft.)
Groundwater Elevation (ft.above sea level, datum: NAVD88)
Calendar Year
Ground Surface
Observed Groundwater Level
Oct/Nov/Dec levels
Minimum Threshold
Measurable Objective
Interim Milestones
Historical Groundwater Level (Modeled)

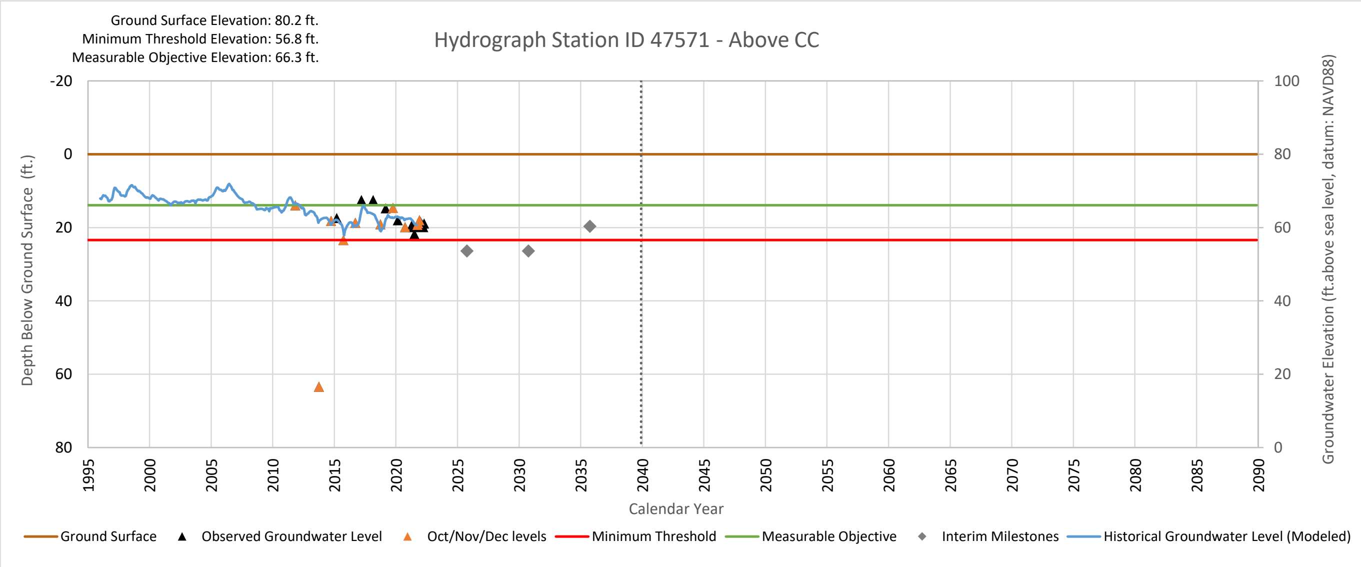

Merced River
San Joaquin River
Chowchilla River
0 2.5 5 10
Miles
N

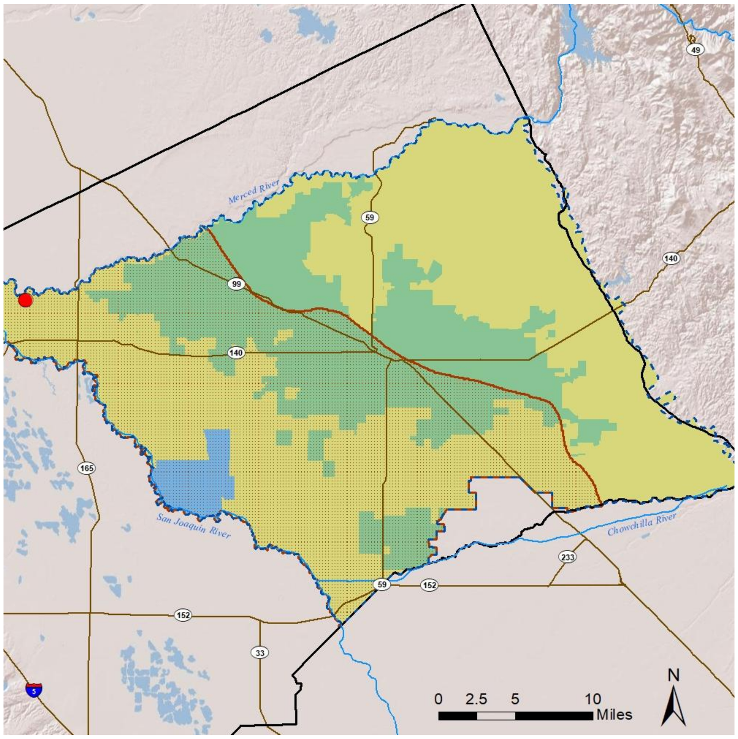


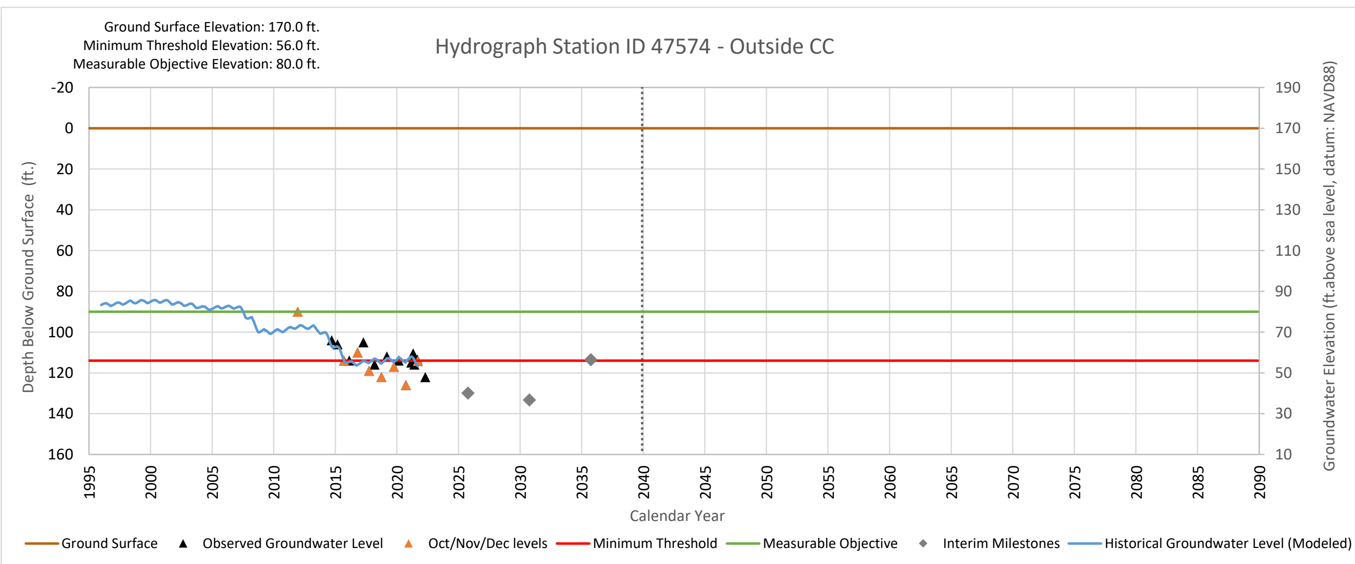
Ground Surface Elevation: 77.0 ft.
Minimum Threshold Elevation: 61.2 ft.
Measurable Objective Elevation: 68.2 ft.
Hydrograph Station ID 47569 - Above CC
Depth Below Ground Surface (ft.)
Groundwater Elevation (ft.above sea level, datum: NAVD88)
Calendar Year
Ground Surface
Observed Groundwater Level
Oct/Nov/Dec levels
Minimum Threshold
Measurable Objective
Interim Milestones
Historical Groundwater Level (Modeled)

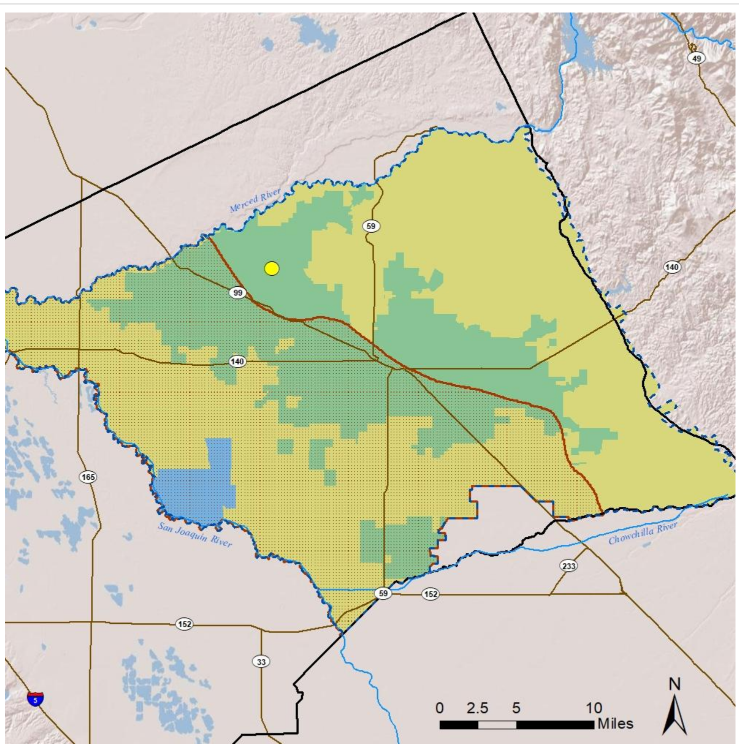


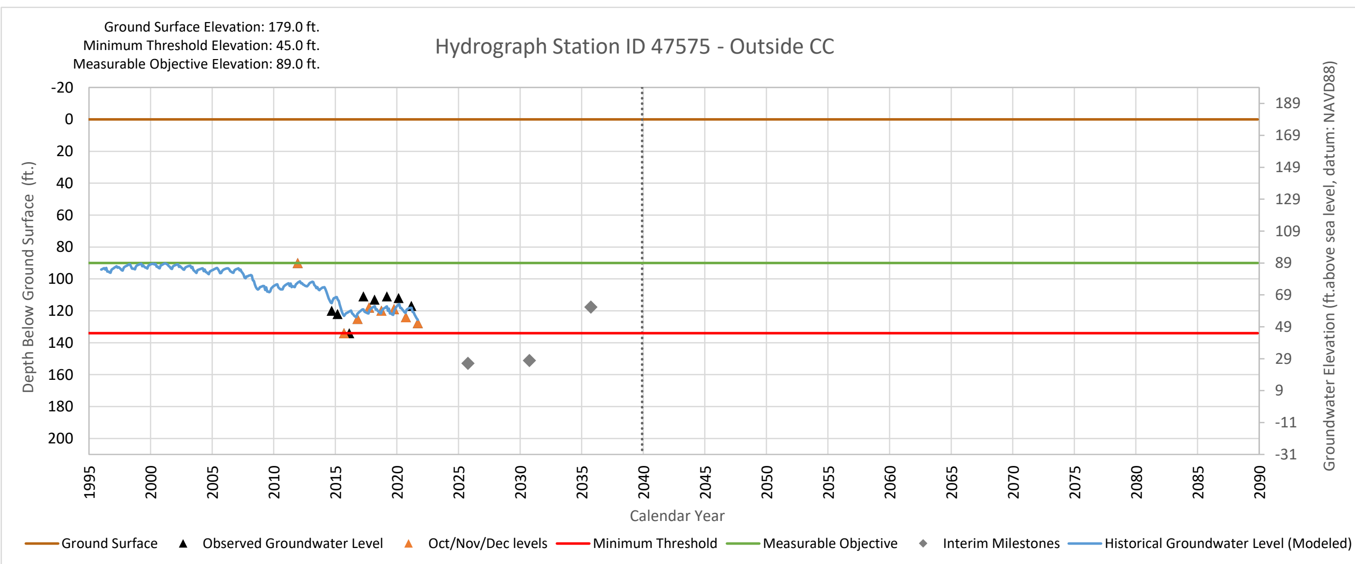
Merced River
San Joaquin River
Chowchilla River
0 2.5 5 10
Miles
N

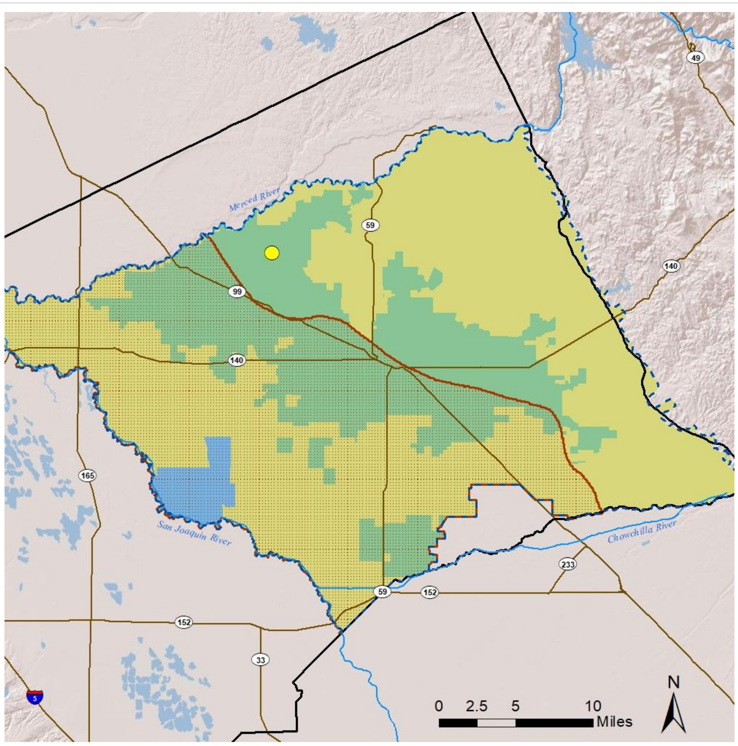

Ground Surface Elevation: 80.2 ft.
Minimum Threshold Elevation: 56.8 ft.
Measurable Objective Elevation: 66.3 ft.
Hydrograph Station ID 47571 - Above CC
Depth Below Ground Surface (ft.)
Groundwater Elevation (ft.above sea level, datum: NAVD88)
Calendar Year
Ground Surface
Observed Groundwater Level
Oct/Nov/Dec levels
Minimum Threshold
Measurable Objective
Interim Milestones
Historical Groundwater Level (Modeled)


Merced River
San Joaquin River
Chowchilla River
0 2.5 5 10
Miles
N


Ground Surface Elevation: 170.0 ft.
Minimum Threshold Elevation: 56.0 ft.
Measurable Objective Elevation: 80.0 ft.
Hydrograph Station ID 47574 - Outside CC
Depth Below Ground Surface (ft.)
Groundwater Elevation (ft.above sea level, datum: NAVD88)
Calendar Year
-20
0
20
40
60
80
100
120
140
160
190
170
150
130
110
90
70
50
30
10
1995
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
2055
2060
2065
2070
2075
2080
2085
2090
Ground Surface
Observed Groundwater Level
Oct/Nov/Dec levels
Minimum Threshold
Measurable Objective
Interim Milestones
Historical Groundwater Level (Modeled)


Merced River
San Joaquin River
Chowchilla River
49
59
99
140
165
152
233
33
5
0
2.5
5
10
Miles
N


Ground Surface Elevation: 179.0 ft.
Minimum Threshold Elevation: 45.0 ft.
Measurable Objective Elevation: 89.0 ft.
Hydrograph Station ID 47575 - Outside CC
Depth Below Ground Surface (ft.)
-20
0
20
40
60
80
100
120
140
160
180
200
Groundwater Elevation (ft.above sea level, datum: NAVD88)
189
169
149
129
109
89
69
49
29
9
-11
-31
1995
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
2055
2060
2065
2070
2075
2080
2085
2090
Calendar Year
Ground Surface
Observed Groundwater Level
Oct/Nov/Dec levels
Minimum Threshold
Measurable Objective
Interim Milestones
Historical Groundwater Level (Modeled)


Merced River
San Joaquin River
Chowchilla River
49
59
99
140
165
233
152
33
5
0
2.5
5
10
Miles
N

APPENDIX G: MERCED CHOWCHILLA INTERBASIN AGREEMENT

INTERBASIN AGREEMENT

MERCED-CHOWCHILLA GROUNDWATER SUBBASINS

This Interbasin Agreement for the Merced-Chowchilla Groundwater Subbasins (this "Agreement") is made and effective as of July 31, 2018 ("Effective Date") by and among **Chowchilla Water District Groundwater Sustainability Agency, Merced Irrigation-Urban Groundwater Sustainability Agency, County of Madera Chowchilla Subbasin Groundwater Sustainability Agency, Merced Subbasin Groundwater Sustainability Agency, Triangle T Water District GSA** and **County of Merced Chowchilla Subbasin Groundwater Sustainability Agency**.

This Agreement is made with reference to the following facts and understandings:

A. On August 29, 2014, the California Legislature passed comprehensive groundwater legislation contained in SB 1168, SB 1319, and AB 1739, collectively known as the "Sustainable Groundwater Management Act" ("SGMA"). SGMA was signed into law on September 16, 2014 and it became effective on January 1, 2015. In adopting SGMA, the Legislature intended to provide local groundwater agencies with the authority and technical and financial assistance necessary to sustainably manage groundwater.

B. Under SGMA, each affected groundwater basin or subbasin will be regulated separately by one or more Groundwater Sustainability Agencies (each, a "GSA"). A local agency or combination of local agencies may elect to be the GSA for a basin or subbasin. Each of the parties to this Agreement ("Party(ies)") is a Groundwater Sustainability Agency (each, as "GSA") established by a local government entity with either water supply, water management, or land use responsibilities within the critically overdrafted Merced and Chowchilla groundwater subbasins of the San Joaquin Valley groundwater basin (the "Subbasins").

C. Groundwater sustainability under SGMA is to be achieved through Groundwater Sustainability Plans (each, a "GSP"). A GSP can be a single plan developed by one or more GSAs, or multiple coordinated plans within a basin or subbasin by multiple GSAs. SGMA requires that the GSPs for critically overdrafted subbasins be adopted by January 31, 2020. The regulations interpreting SGMA allow for GSAs with adjoining jurisdictions to enter into interbasin agreements to establish compatible sustainability goals and understanding regarding fundamental elements of the GSPs of each agency, and thereby promote the compatibility of GSPs where the actions in one subbasin may affect the groundwater of an adjoining subbasin.

D. In March of 2016 the Chowchilla Water District submitted a Basin Boundary Modification request to the California Department of Water Resources ("DWR") proposing that the Chowchilla groundwater subbasin boundary be modified under the Jurisdictional Modification criteria in the DWR Basin Boundary Modification Emergency Regulation, which requested changes do not alter the interactive hydrologic nature of the Subbasins. This Basin Boundary Modification resulted in moving a portion of the Chowchilla Subbasin (as defined by Bulletin 118- 2003) that is within the jurisdiction of Merced Irrigation District and Merced County into the Merced Subbasin. This area in Merced County, mainly around the community of El Nido, has experienced significant land subsidence over the recent years.

E. Merced Irrigation District initially submitted to DWR a letter opposing the Basin Boundary Modification due to concerns regarding inter-basin coordination. Merced County submitted a letter of support for the Basin Boundary Modification contingent upon the adoption of an interbasin agreement. Merced Irrigation District subsequently withdrew its opposition to the Basin Boundary Modification request based on agreement from the Chowchilla Subbasin GSAs to enter into this inter-basin agreement as defined in Section 357.2 of the Groundwater Sustainability Plan Emergency Regulations.

F. The Parties are entering into this Agreement to establish compatible sustainability goals and understandings for the Subbasins, with a focus on the areas where the activities occurring within one Party's jurisdiction may affect groundwater within another Party's jurisdiction, to resolve the comments and concerns of Merced Irrigation District and Merced County regarding the boundary modification request of the Chowchilla Water District, and to coordinate preparation of each agency's respective GSP in order to promote the compatibility thereof. The Parties intend that the GSPs will address the level of cooperation and coordination between the Parties.

G. The intent of the Parties under this Agreement is to provide each Party with the sole right and responsibility to implement SGMA within its respective boundaries, as defined herein, in a manner determined by the Party as a GSA. The Parties expressly intend that neither SGMA, nor this Agreement, nor any GSP shall be construed as authorizing another Party, or the other Parties acting together, or any dispute resolution process contained herein, to:

(i) Determine or alter surface water rights or groundwater rights (California Water Code Section 10720.5 (b));

(ii) Make binding determinations of the water rights of any person or entity (California Water Code Section 10726.8 (b)); or

(iii) Supersede the existing land use authority of cities or counties, including the city or county general plan, within the overlying basin (California Water Code Section 10726.8 (f)).

THEREFORE, in consideration of the mutual promises, covenants and provisions herein set forth, it is agreed by and among the Parties as follows:

1. Recitals Incorporated. The recitals set forth above are hereby incorporated into this Agreement as a statement of the intent and purposes of this Agreement.

2. General Information. Within 120 days from execution of this Agreement, each Party shall develop and share with the other Parties general information regarding the portion of the Subbasins in its jurisdiction, including:

a. Description and general information pertaining to groundwater resources;

b. List of public agencies and other entities with groundwater management responsibilities; and

c. List of groundwater management plans and other water resource management plans.

3. <u>Exchange of Information</u>. The Parties shall exchange relevant available technical information and groundwater data to quantify the level of interconnection between the Subbasins and the areas where the activities occurring within one Party's jurisdiction may affect groundwater within another Party's jurisdiction. The Parties will coordinate shared information and work on adjusting values to the same basis for all data and parameters to the best of their abilities, and within reasonable range of acceptable scientific practices to help all Parties reach sustainability within their respective GSA areas. The information exchanged shall include if feasible:

a. Model aquifer parameter values and other model inputs relevant to calculation of inter-basin groundwater flow (e.g. model layering, grid size vertical pumping distribution, etc.);

b. Model outputs including simulated heads (groundwater elevations) by model layer and model water budget components (including model-estimated flows across the Subbasin boundary);

c. Values for groundwater quality (primarily TDS and nitrate), quantity and land subsidence;

d. An estimate of groundwater flow across basin and jurisdictional boundaries, including consistent and coordinated data, methods and assumptions;

e. An estimate of stream-aquifer interactions at boundaries;

f. A common understanding of the hydrogeology and hydrology as it applies to the determination of groundwater flow across basin and jurisdictional boundaries;

g. Sustainable management criteria, including management goals and thresholds, and a monitoring network that would support confirmation that no adverse impacts result from the implementation of the GSPs;

h. Existing and proposed monitoring locations;

i. Plans, programs, and projects anticipated as options and/or alternatives for sustainable management of respective Subbasins;

j. The following parameters:

i. Groundwater elevation data;
ii. Groundwater extraction data or estimates;
iii. Groundwater quality information;
iv. Surface water supply;
v. Reports of cropping patters on parcels adjacent to the subbasin boundaries, with approximately a 5-mile buffer on both sides of the boundary;
vi. Total water use;
vii. Change in groundwater storage;
viii. Water budget for land surface, stream, and groundwater systems;
ix. Sustainable yield; and
x. Agricultural water demands (consumptive use and extraction).

g. The Parties will work in good faith to complete a preliminary exchange of available information set forth above in Section 3(a)-(j) by August 31, 2018, and a complete exchange of information by June 30, 2019. The Parties shall analyze hydrologic and hydrogeologic conditions, based on the detail and local information available within the Merced Water Resources Model and the model to be developed and used for the Chowchilla Subbasin GSP analyses. The Parties will exchange information for the area of model overlap and analyze hydrologic and hydrogeologic conditions in the area of overlap to the extent relevant to interbasin groundwater flow. Information from items "a" through "j" above will be utilized in the analyses. Field verification and results from GSP monitoring programs will generally be used to validate model results during GSP implementation.

4. Planning for the GSPs. The Parties shall develop compatible sustainability goals, minimum thresholds and measurable objectives for their respective GSPs. Compatible sustainability goals would include, but are not limited to, the following:

a. Targeted 2040 groundwater levels;
b. Measurable objectives and interim milestones; and
c. Volumes of groundwater extraction and managed recharge to ensure coordination of any GSP-established or State-recommended/mandated levels.

"Compatible" in the context of this section means that the sustainability goals developed would not impede the other Party's efforts to achieve sustainability

5. Development of the GSPs. Each Party shall be responsible for development of its own GSP for the lands within its GSA jurisdiction, or for joint development of a GSP for the lands within its GSA jurisdiction and the lands of one or more additional GSA. The contents and adoption of each GSP shall be the decision and responsibility of each Party, subject to the criteria set forth in SGMA and its implementing regulations. However, in developing its GSP, each Party shall utilize the information exchanged under this Agreement, and shall incorporate any agreed sustainability goals, minimum thresholds and measurable objectives into each GSP.

6. Implementation. Each Party, in implementing its GSP and managing its affairs, shall avoid actions that materially and adversely impact or impede the ability to achieve the

sustainability goals of each other Party. Disagreements regarding a Party's implementation of its GSP shall be subject to the dispute resolution process outlined in paragraph 9.

7. Meetings. Commencing within 30 days of execution of this Agreement, the Parties shall meet quarterly while the planning activities described in Paragraph 4 are being performed and while the Parties are developing their GSPs. After all GSPs are approved, the Parties shall meet as agreed to discuss implementation and ongoing issues.

8. Costs. Each Party shall bear its own costs for its direct participation in the activities contemplated by this Agreement, including staff time, administrative and overhead costs, office expenses, legal fees, and consultants that report directly and exclusively to that Party. Contracts for any additional studies, reports, and data development for the matters identified in Paragraphs 3 and 4 must be approved by the unanimous vote of the Parties. The Parties shall select one of their members to be the fiscal agent for implementation of this Agreement, which shall calculate the costs being incurred therefor, assess the Parties for contributions to common costs in a timely manner, and pay invoices for such services. No Party shall be bound, financially or otherwise, by any obligation, contract, or activity undertaken by the other Parties unless and except to the extent agreed upon by the Party.

9. Dispute Resolution. The Parties fully intend to comply with this Agreement in good faith. Should, however, any controversy arise among or between the Parties concerning this Agreement, or the rights and duties of any Party under this Agreement, such a controversy shall be addressed as follows:

a. Any Party may trigger the dispute resolution process by delivering, in writing to all Parties, a notification of a dispute or controversy that contains a specific description of the actions alleged to be contrary to this Agreement and a proposed solution. A dispute resolution group, consisting of one member of the elected or appointed governance of each Party, shall be established by the Parties to resolve disputes and/or controversies relating to this Agreement (the "Dispute Resolution Group"). The Dispute Resolution Group shall meet no later than 30 days following notification of the dispute or controversy. The Party alleged to be in violation shall prepare a written response delivered to all Parties prior to the meeting of the Dispute Resolution Group. Thereafter, the Dispute Resolution Group will have 90 days to issue a written, non-binding opinion on the matter in dispute, including a proposed resolution. Any Party, at its sole expense, may retain outside experts to assist in data development or discussion of the dispute. Upon unanimous approval by the Parties, the Dispute Resolution Group may retain independent experts to assist in mediating the dispute. The Parties shall equally share the cost to retain the experts the Dispute Resolution Group selects. The Dispute Resolution Group may also consult with the Department of Water Resources as necessary. Participation in the process established by the Dispute Resolution Group is mandatory and a condition precedent to resorting to litigation, or referring the dispute to the State Water Resources Control Board or Department of Water Resources for formal action.

b. Should the dispute resolution process described above not provide a final resolution to the controversy raised, any Party may pursue any judicial or administrative remedies otherwise available. However, notwithstanding this Paragraph 9, a Party may seek a preliminary injunction or other interlocutory judicial relief if necessary to avoid irreparable damage or to preserve the status quo.

10. General Provisions.

a. Term of Agreement. This Agreement shall expire on December 31, 2030 unless extended by all of the Parties.

b. Amendment. This Agreement may be amended only by a writing executed by all of the Parties.

c. Withdrawal. Any Party may withdraw from this Agreement starting six (6) months after approval of the GSP for all Parties by the DWR, and upon thirty (30) days prior written notice to all other Parties, provided that the withdrawing Party is cooperating through an approved GSP with other Parties and interests in the Basin, where the approved GSP fully meets and incorporates mutual promises, covenants and provisions 2, 3, 4, 5, and 6 of this agreement; and the written notice provided by the withdrawing party documents the basis for withdrawal and the way(s) in which the mutual promises, covenants and provisions 2, 3, 4, 5 have been addressed in the GSP to which it is a party. A withdrawing Party shall not be obligated for any financial obligations incurred after delivery of notice of its withdrawal, but shall remain liable for and shall pay upon demand all obligations of the Parties approved as provided herein prior to written notice of its withdrawal.

d. Severability. Should the participation of any Party to this Agreement, or any part, term or provision of this Agreement, be decided by any court to be illegal, in excess of that Party's authority, in conflict with any law of the State of California, or otherwise rendered unenforceable or ineffectual, the participation of the other Parties or the validity of the remaining portions, terms or provisions of this Agreement shall not be affected thereby and each Party hereby agrees it would have entered into this Agreement upon the remaining terms and provisions.

e. Counterparts and Facsimile. This Agreement may be executed in counterparts, each counterpart being an exact duplicate of all other counterparts, and all counterparts shall be considered as constituting one complete original and may be attached together when executed by the Parties hereto. Facsimile or electronic signatures shall be binding.

f. Notices. Notices authorized or required to be given pursuant to this Agreement shall be in writing and shall be deemed to have been given when mailed, postage prepaid, or delivered during working hours to the principal offices of the other Parties at the address indicated below, attention to the responsible person at each Party as identified, or to such other changed addresses communicated to the other Parties in writing.

Chowchilla Water District GSA
327 S. Chowchilla Blvd.
Chowchilla, CA 93610

County of Madera Chowchilla Subbasin GSA
Department of Water and Natural Resources
200 W. Fourth Street
Madera, CA 93637

Merced Subbasin Groundwater Sustainability Agency
Community and Economic Development Department
County of Merced
2222 M Street
Merced, CA 95340

County of Merced Chowchilla Subbasin GSA
Community and Economic Development Department
County of Merced
2222 M Street
Merced, CA 95340

Merced Irrigation-Urban Groundwater Sustainability Agency
744 West 20th Street
Merced, CA 95340

Triangle T Water District GSA
4400 Hays Drive
Chowchilla, CA 93610

IN WITNESS WHEREOF, the Parties hereto, pursuant to resolutions duly and regularly adopted by their respective Board of Directors or Board of Supervisors, have caused their names to be affixed by their proper and respective officers as of the day and year first above-written.

CHOWCHILLA WATER DISTRICT GSA,
a California water district

By: ______________________

Name: Kole Upton

Title: Board President

Merced Subbasin Groundwater Sustainability Agency
Community and Economic Development Department
County of Merced
2222 M Street
Merced, CA 95340

County of Merced Chowchilla Subbasin GSA
Community and Economic Development Department
County of Merced
2222 M Street
Merced, CA 95340

Merced Irrigation-Urban Groundwater Sustainability Agency
744 West 20th Street
Merced, CA 95340

Triangle T Water District GSA
4400 Hays Drive
Chowchilla, CA 93610

IN WITNESS WHEREOF, the Parties hereto, pursuant to resolutions duly and regularly adopted by their respective Board of Directors or Board of Supervisors, have caused their names to be affixed by their proper and respective officers as of the day and year first above-written.

CHOWCHILLA WATER DISTRICT GSA,
a California water district

By:______________________________

Name:____________________________

Title:_____________________________

COUNTY OF MADERA CHOWCHILLA SUBBASIN GSA

By: [signature] 7-13-18
Michael R. Linden, Deputy County Counsel

COUNTY OF MADERA

[signature]
Chairman, Board of Supervisors

COUNTY OF MADERA CHOWCHILLA SUBBASIN GSA,

By: ______________________________

Name: ______________________________

Title: ______________________________

COUNTY OF MERCED CHOWCHILLA SUBBASIN GSA,

By: Jerald R. O'Banion JUL 3 1 2018

Name: Jerald R. O'Banion

Title: Chairman, Board of Supervisors

MERCED SUBBASIN GSA

By: ______________________________

Name: ______________________________

Title: ______________________________

APPROVED AS TO LEGAL FORM

JAMES N. FINCHER
MERCED COUNTY COUNSEL

BY: ______________________________
Jeffrey B. Grant

MERCED IRRIGATION-URBAN GSA

By: ______________________________

Name: ______________________________

Title: ______________________________

COUNTY OF MADERA CHOWCHILLA SUBBASIN GSA,

By: ______________________________

Name: ______________________________

Title: ______________________________

COUNTY OF MERCED CHOWCHILLA SUBBASIN GSA,

By: ______________________________

Name: ______________________________

Title: ______________________________

MERCED SUBBASIN GSA

By: [signature]

Name: Robert D Kelley

Title: chairman

MERCED IRRIGATION-URBAN GSA

By: ______________________________

Name: ______________________________

Title: ______________________________

COUNTY OF MADERA CHOWCHILLA SUBBASIN GSA,

By: ______________________________

Name: ______________________________

Title: ______________________________

COUNTY OF MERCED CHOWCHILLA SUBBASIN GSA,

By: ______________________________

Name: ______________________________

Title: ______________________________

MERCED SUBBASIN GSA

By: ______________________________

Name: ______________________________

Title: ______________________________

MERCED IRRIGATION-URBAN GSA

By: [signature]

Name: HICHAM ELTAL

Title: CHAIR

TRIANGLE T WATER DISTRICT GSA

By: ______________________

Name: Mark Hutson

Title: President

Woodard & Curran

APPENDIX H: MERCED TURLOCK INTERBASIN AGREEMENT

MEMORANDUM OF INTENT TO COORDINATE BETWEEN THE MERCED SUBBASIN AND TURLOCK SUBBASIN

WHEREAS, the Turlock Groundwater Subbasin (Subbasin No. 5-22.03) and the Merced Groundwater Subbasin (Subbasin No. 5-22.04) are adjacent subbasins that share a common boundary along the Merced River; and

WHEREAS, the Turlock Subbasin is a high-priority subbasin that is required to submit a Groundwater Sustainability Plan (GSP) to the Department of Water Resources (DWR) by January 31, 2022 and the Merced Subbasin is a high-priority, critically overdraft subbasin that must submit a GSP to DWR by January 31, 2020; and

WHEREAS, the West Turlock Subbasin Groundwater Sustainability Agency (WTSGSA) and the East Turlock Subbasin Groundwater Sustainability Agency (ETSGSA) are working to develop a single GSP in the Turlock Subbasin; and

WHEREAS, the Merced Subbasin Groundwater Sustainability Agency, the Merced Irrigation Urban Groundwater Sustainability Agency, and the Turner Island Water District Groundwater Sustainability Agency-1 are working to develop a single GSP in the Merced Subbasin; and

WHEREAS, the Sustainable Groundwater Management Act (SGMA) prohibits a GSP from adversely affecting an adjacent basin's ability to implement its GSP or impede the ability to achieve its sustainability goal (Water Code, § 10733(c)); and

WHEREAS, the parties to this Memorandum of Intent (MOI) (collectively "Party" or "Parties") desire to establish compatible sustainability goals and understanding regarding fundamental elements of the GSPs of each GSA as they relate to sustainable groundwater management.

NOW, THEREFORE BE IT RESOLVED that the Parties agree to coordinate in the following matter:

1. Each Party desires to comply with SGMA by assuring that its GSP actions do not negatively impact the adjacent GSA in complying with SGMA.

2. To assure this compliance, each Party commits to meeting as necessary to compare GSP development concepts and approaches to identify potential areas of concern that may negatively impact the other.

3. Each Party will commit to sharing data, analysis, methods, results, and any other information that is pertinent to the Parties' compliance with SGMA.

4. The Parties recognize that the development of the respective GSPs have different deadlines and may be developed using different timelines. Coordination is expected to continue, as needed, throughout GSP development and implementation.

5. The Parties recognize there may be data gaps that will need to be filled. Datasets will improve as the Parties develop and implement GSPs over time. The Parties agree to continue to work together to develop and refine understanding of the conditions over time. This common knowledge and understanding will be incorporated into future GSPs as data and information becomes available.

6. The Parties intend to coordinate messaging and outreach along the subbasin borders to maximize stakeholder outreach and understanding between the subbasins.

IN WITNESS WHEREOF, the parties have caused this Memorandum to be executed by and through their respective officers thereunto duly authorized.

WEST TURLOCK SUBBASIN GSA,
a Joint Powers Authority

By: ______________________
Joe Alamo, Chair

Date: 12/18/18

EAST TURLOCK SUBBASIN GSA,
a Joint Powers Authority

By: ______________________
Albert Rossini, Chair

Date: 01-28-19

MERCED IRRIGATION-URBAN GSA

By: ______________________
Chair

Date: 1/19/19

MERCED SUBBASIN GSA,
a Joint Powers Authority

By: ______________________
Chair

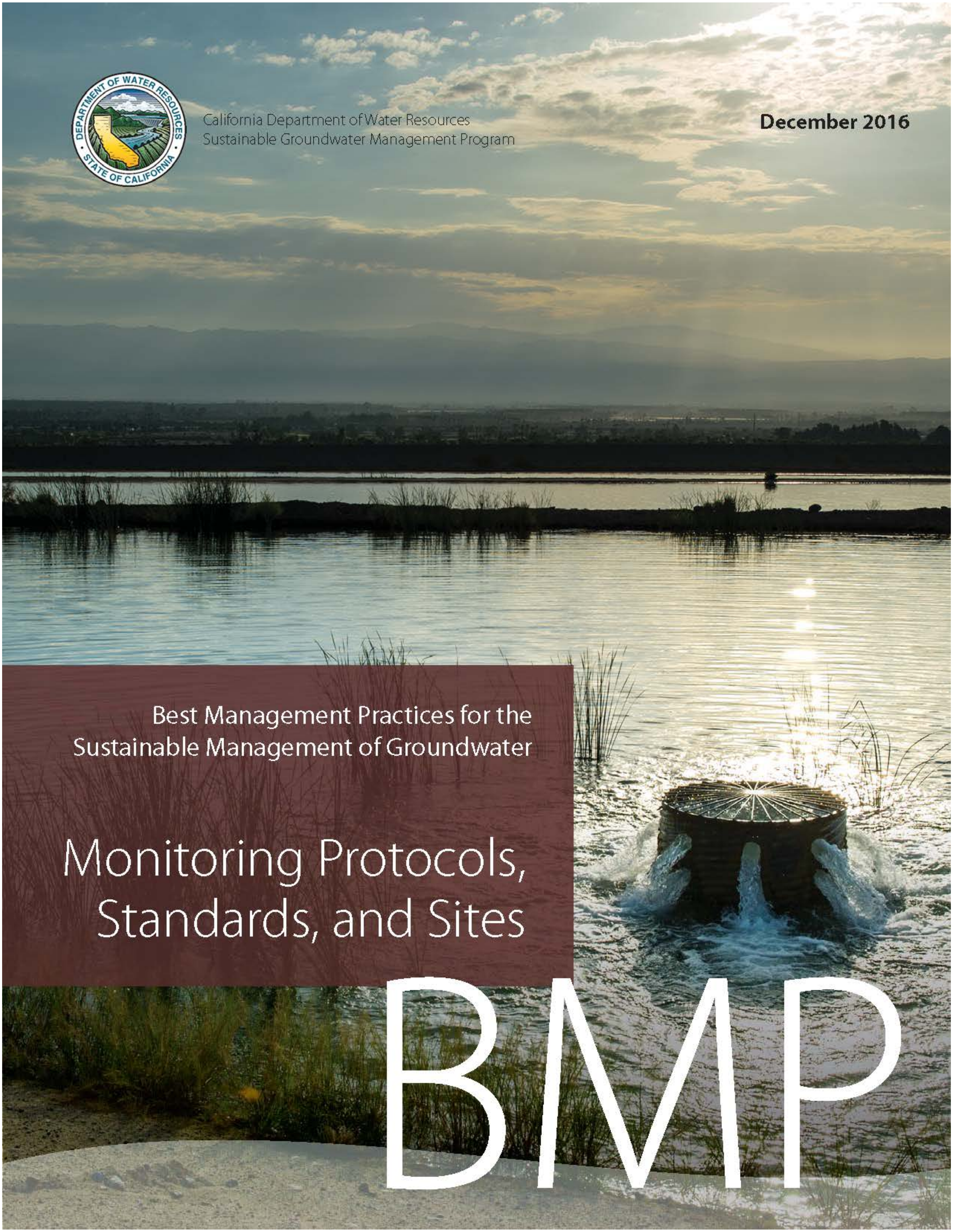
Date: 1/16/19

TURNER ISLAND WATER DISTRICT

By: ______________________
Chair

Date: 2-19-19

APPENDIX I: MONITORING PROTOCOLS – GROUNDWATER LEVELS (DWR BMP)



California Department of Water Resources
Sustainable Groundwater Management Program

December 2016

Best Management Practices for the Sustainable Management of Groundwater

Monitoring Protocols, Standards, and Sites

BMP

State of California
Edmund G. Brown Jr., Governor

California Natural Resources Agency
John Laird, Secretary for Natural Resources

Department of Water Resources
Mark W. Cowin, Director

Carl A. Torgersen, Chief Deputy Director

Office of the Chief Counsel
Spencer Kenner

Public Affairs Office
Ed Wilson

Government and Community Liaison
Anecita S. Agustinez

Office of Workforce Equality
Stephanie Varrelman

Policy Advisor
Waiman Yip

Legislative Affairs Office
Kasey Schimke, Ass't Dir.

Deputy Directors

Gary Bardini	**Integrated Water Management**
William Croyle	**Statewide Emergency Preparedness and Security**
Mark Anderson	**State Water Project**
John Pacheco (Acting)	**California Energy Resources Scheduling**
Kathie Kishaba	**Business Operations**
Taryn Ravazzini	**Special Initiatives**

Division of Integrated Regional Water Management

Arthur Hinojosa Jr., Chief

Prepared under the direction of:

David Gutierrez, Sustainable Groundwater Management Program Manager
Rich Juricich, Sustainable Groundwater Management Branch

Prepared by:

Trevor Joseph, BMP Project Manager

Timothy Godwin
Dan McManus
Mark Nordberg
Heather Shannon
Steven Springhorn

With assistance from:

DWR Region Office Staff

Groundwater Monitoring Protocols, Standards, and Sites Best Management Practice

1. Objective

The objective of this *Best Management Practice* (BMP) is to assist in the development of Monitoring Protocols. The California Department of Water Resources (the Department or DWR) has developed this document as part of the obligation in the Technical Assistance chapter (Chapter 7) of the Sustainable Groundwater Management Act (SGMA) to support the long-term sustainability of California's groundwater *basins*. Information provided in this BMP provides technical assistance to Groundwater Sustainability Agencies (GSAs) and other stakeholders to aid in the establishment of consistent data collection processes and procedures. In addition, this BMP can be used by GSAs to adopt a set of sampling and measuring procedures that will yield similar data regardless of the monitoring personnel. Finally, this BMP identifies available resources to support the development of monitoring protocols.

This BMP includes the following sections:

1. Objective. A brief description of how and where monitoring protocols are required under SGMA and the overall objective of this BMP.
2. Use and Limitations. A brief description of the use and limitations of this BMP.
3. Monitoring Protocol Fundamentals. A description of the general approach and background of groundwater monitoring protocols.
4. Relationship of Monitoring Protocols to other BMPs. A description of how this BMP is connected with other BMPS.
5. Technical Assistance. Technical content providing guidance for regulatory sections.
6. Key Definitions. Descriptions of definitions identified in the GSP Regulations or SGMA.
7. Related Materials. References and other materials that provide supporting information related to the development of Groundwater Monitoring Protocols.

2. USE AND LIMITATIONS

BMPs developed by the Department provide technical guidance to GSAs and other stakeholders. Practices described in these BMPs do not replace the GSP Regulations, nor do they create new requirements or obligations for GSAs or other stakeholders. In addition, using this BMP to develop a GSP does not equate to an approval determination by the Department. All references to GSP Regulations relate to Title 23 of the California Code of Regulations (CCR), Division 2, Chapter 1.5, and Subchapter 2. All references to SGMA relate to California Water Code sections in Division 6, Part 2.74.

3. MONITORING PROTOCOL FUNDAMENTALS

Establishing data collection protocols that are based on best available scientific methods is essential. Protocols that can be applied consistently across all basins will likely yield comparable data. Consistency of data collection methods reduces uncertainty in the comparison of data and facilitates more accurate communication within basins as well as between basins.

Basic minimum technical standards of accuracy lead to quality data that will better support implementation of GSPs.

4. RELATIONSHIP OF MONITORING PROTOCOL TO OTHER BMPS

Groundwater monitoring is a fundamental component of SGMA, as each GSP must include a sufficient network of data that demonstrates measured progress toward the achievement of the sustainability goal for each basin. For this reason, a standard set of protocols need to be developed and utilized.

It is important that data is developed in a manner consistent with the basin setting, planning, and projects/management actions steps identified on **Figure 1** and the GSP Regulations. The inclusion of monitoring protocols in the GSP Regulations also emphasizes the importance of quality empirical data to support GSPs and provide comparable information from basin to basin.

Figure 1 provides a logical progression for the development of a GSP and illustrates how monitoring protocols are linked to other related BMPs. This figure also shows the context of the BMPs as they relate to various steps to sustainability as outlined in the GSP Regulations. The monitoring protocol BMP is part of the Monitoring step identified in **Figure 1**.

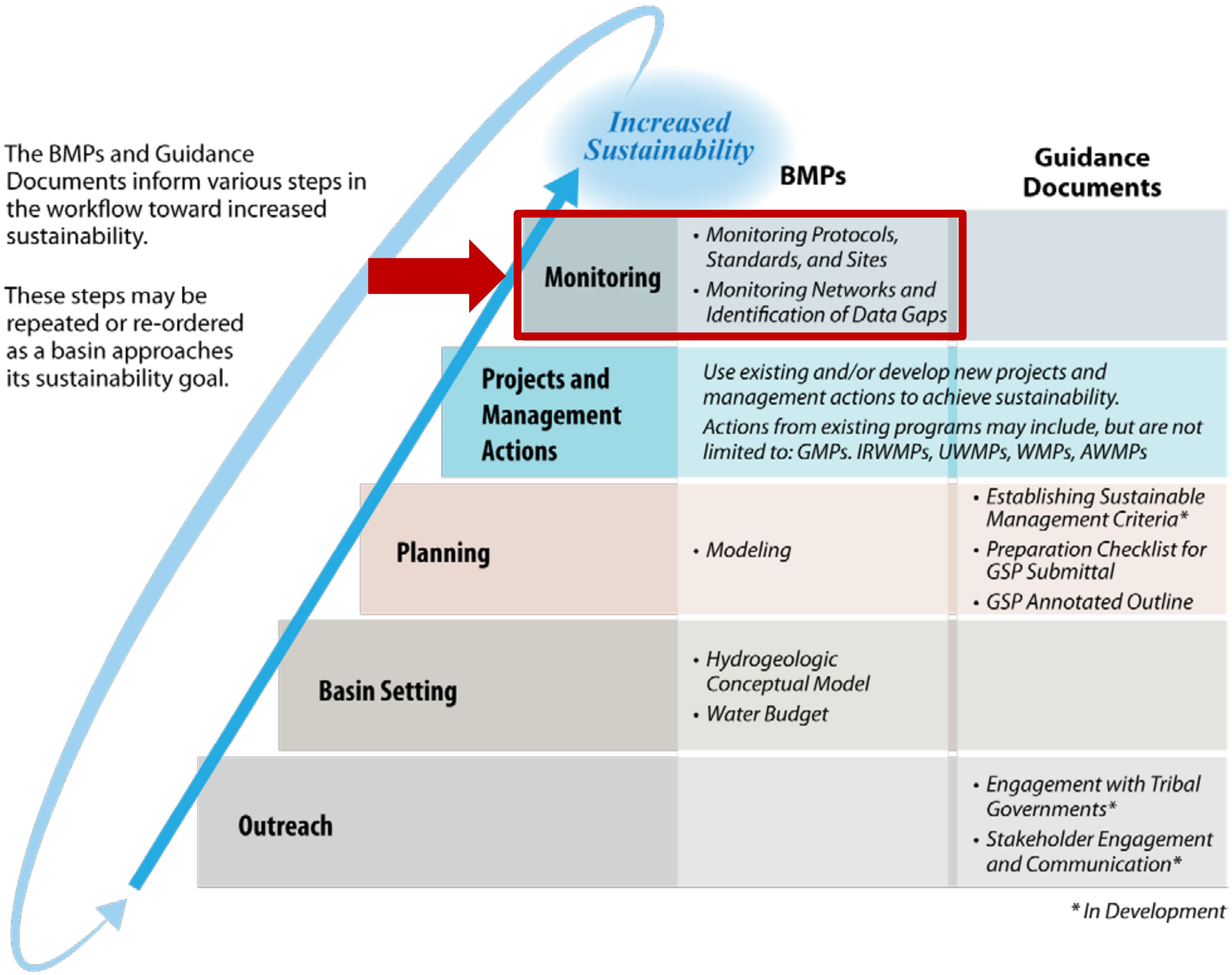


Figure 1 – Logical Progression of Basin Activities Needed to Increase Basin Sustainability

5. TECHNICAL ASSISTANCE

23 CCR §352.2. Monitoring Protocols. Each Plan shall include monitoring protocols adopted by the Agency for data collection and management, as follows:
(a) Monitoring protocols shall be developed according to best management practices.
(b) The Agency may rely on monitoring protocols included as part of the best management practices developed by the Department, or may adopt similar monitoring protocols that will yield comparable data.
(c) Monitoring protocols shall be reviewed at least every five years as part of the periodic evaluation of the Plan, and modified as necessary.

The GSP Regulations specifically call out the need to utilize protocols identified in this BMP, or develop similar protocols. The following technical protocols provide guidance based upon existing professional standards and are commonly adopted in various groundwater-related programs. They provide clear techniques that yield quality data for use in the various components of the GSP. They can be further elaborated on by individual GSAs in the form of standard operating procedures which reflect specific local requirements and conditions. While many methodologies are suggested in this BMP, it should be understood that qualified professional judgment should be used to meet the specific monitoring needs.

The following BMPs may be incorporated into a GSP's monitoring protocols section for collecting groundwater elevation data. A GSP that adopts protocols that deviate from these BMPs must demonstrate that they will yield comparable data.

PROTOCOLS FOR ESTABLISHING A MONITORING PROGRAM

The protocol for establishment of a monitoring program should be evaluated in conjunction with the *Monitoring Network and Identification of Data Gaps* BMP and other BMPs. Monitoring protocols must take into consideration the *Hydrogeologic Conceptual Model, Water Budget, and Modeling* BMPs when considering the data needs to meet GSP objectives and the sustainability goal.

It is suggested that each GSP incorporate the Data Quality Objective (DQO) process following the U.S. EPA *Guidance on Systematic Planning Using the Data Quality Objectives Process* (EPA, 2006). Although strict adherence to this method is not required, it does provide a robust approach to consider and assures that data is collected with a specific purpose in mind, and efforts for monitoring are as efficient as possible to achieve the objectives of the GSP and compliance with the GSP Regulations.

The DQO process presents a method that can be applied directly to the sustainability criteria quantitative requirements through the following steps.

1. State the problem – Define sustainability indicators and planning considerations of the GSP and sustainability goal.
2. Identify the goal – Describe the quantitative measurable objectives and minimum thresholds for each of the sustainability indicators.
3. Identify the inputs – Describe the data necessary to evaluate the sustainability indicators and other GSP requirements (i.e. water budget).
4. Define the boundaries of the study – This is commonly the extent of the Bulletin 118 groundwater basin or subbasin, unless multiple GSPs are prepared for a given basin. In that case, evaluation of the coordination plan and specifically how the monitoring will be comparable and meet the sustainability goals for the entire basin.
5. Develop an analytical approach – Determine how the quantitative sustainability indicators will be evaluated (i.e. are special analytical methods required that have specific data needs).
6. Specify performance or acceptance criteria – Determine what quality the data must have to achieve the objective and provide some assurance that the analysis is accurate and reliable.
7. Develop a plan for obtaining data – Once the objectives are known determine how these data should be collected. Existing data sources should be used to the greatest extent possible.

These steps of the DQO process should be used to guide GSAs to develop the most efficient monitoring process to meet the measurable objectives of the GSP and the sustainability goal. The DQO process is an iterative process and should be evaluated regularly to improve monitoring efficiencies and meet changing planning and project needs. Following the DQO process, GSAs should also include a data quality control and quality assurance plan to guide the collection of data.

Many monitoring programs already exist as part of ongoing groundwater management or other programs. To the extent possible, the use of existing monitoring data and programs should be utilized to meet the needs for characterization, historical record documentation, and continued monitoring for the SGMA program. However, an evaluation of the existing monitoring data should be performed to assure the data being collected meets the DQOs, regulatory requirements, and data collection protocol described in this BMP. While this BMP provides guidance for collection of various regulatory based requirements, there is flexibility among the various methodologies available to meet the DQOs based upon professional judgment (local conditions or project needs).

At a minimum, for each monitoring site, the following information or procedure should be collected and documented:

- Long-term access agreements. Access agreements should include year-round site access to allow for increased monitoring frequency.
- A unique identifier that includes a general written description of the site location, date established, access instructions and point of contact (if necessary), type of information to be collected, latitude, longitude, and elevation. Each monitoring location should also track all modifications to the site in a modification log.

PROTOCOLS FOR MEASURING GROUNDWATER LEVELS

This section presents considerations for the methodology of collection of groundwater level data such that it meets the requirements of the GSP Regulations and the DQOs of the specific GSP. Groundwater levels are a fundamental measure of the status of groundwater conditions within a basin. In many cases, relationships of the sustainability indicators may be able to be correlated with groundwater levels. The quality of this data must consider the specific aquifer being monitored and the methodology for collecting these levels.

The following considerations for groundwater level measuring protocols should ensure the following:

- Groundwater level data are taken from the correct location, well ID, and screen interval depth
- Groundwater level data are accurate and reproducible
- Groundwater level data represent conditions that inform appropriate basin management DQOs
- All salient information is recorded to correct, if necessary, and compare data
- Data are handled in a way that ensures data integrity

General Well Monitoring Information

The following presents considerations for collection of water level data that include regulatory required components as well as those which are recommended.

- Groundwater elevation data will form the basis of basin-wide water-table and piezometric maps, and should approximate conditions at a discrete period in time. Therefore, all groundwater levels in a basin should be collected within as short a time as possible, preferably within a 1 to 2 week period.
- Depth to groundwater must be measured relative to an established Reference Point (RP) on the well casing. The RP is usually identified with a permanent marker, paint spot, or a notch in the lip of the well casing. By convention in open casing monitoring wells, the RP reference point is located on the north side of the well casing. If no mark is apparent, the person performing the measurement should measure the depth to groundwater from the north side of the top of the well casing.
- The elevation of the RP of each well must be surveyed to the North American Vertical Datum of 1988 (NAVD88), or a local datum that can be converted to NAVD88. The elevation of the RP must be accurate to within 0.5 foot. It is preferable for the RP elevation to be accurate to 0.1 foot or less. Survey grade global navigation satellite system (GNSS) global positioning system (GPS) equipment can achieve similar vertical accuracy when corrected. Guidance for use of GPS can be found at USGS http://water.usgs.gov/osw/gps/. Hand-held GPS units likely will not produce reliable vertical elevation measurement accurate enough for the casing elevation consistent with the DQOs and regulatory requirements.
- The sampler should remove the appropriate cap, lid, or plug that covers the monitoring access point listening for pressure release. If a release is observed, the measurement should follow a period of time to allow the water level to equilibrate.
- Depth to groundwater must be measured to an accuracy of 0.1 foot below the RP. It is preferable to measure depth to groundwater to an accuracy of 0.01 foot. Air lines and acoustic sounders may not provide the required accuracy of 0.1 foot.
- The water level meter should be decontaminated after measuring each well.

Where existing wells do not meet the base standard as described in the GSP Regulations or the considerations provided above, new monitoring wells may need to be constructed to meet the DQOs of the GSP. The design, installation, and documentation of new monitoring wells must consider the following:

- Construction consistent with California Well Standards as described in Bulletins 74-81 and 74-90, and local permitting agency standards of practice.
- Logging of borehole cuttings under the supervision of a California Professional Geologist and described consistent with the Unified Soil Classification System methods according to ASTM standard D2487-11.
- Written criteria for logging of borehole cuttings for comparison to known geologic formations, principal aquifers and aquitards/aquicludes, or specific marker beds to aid in consistent stratigraphic correlation within and across basins.
- Geophysical surveys of boreholes to aid in consistency of logging practices. Methodologies should include resistivity, spontaneous potential, spectral gamma, or other methods as appropriate for the conditions. Selection of geophysical methods should be based upon the opinion of a professional geologist or professional engineer, and address the DQOs for the specific borehole and characterization needs.
- Prepare and submit State well completion reports according to the requirements of §13752. Well completion report documentation should include geophysical logs, detailed geologic log, and formation identification as attachments. An example well completion as-built log is illustrated in **Figure 2.** DWR well completion reports can be filed directly at the Online System for Well Completion Reports (OSWCR) http://water.ca.gov/oswcr/index.cfm.

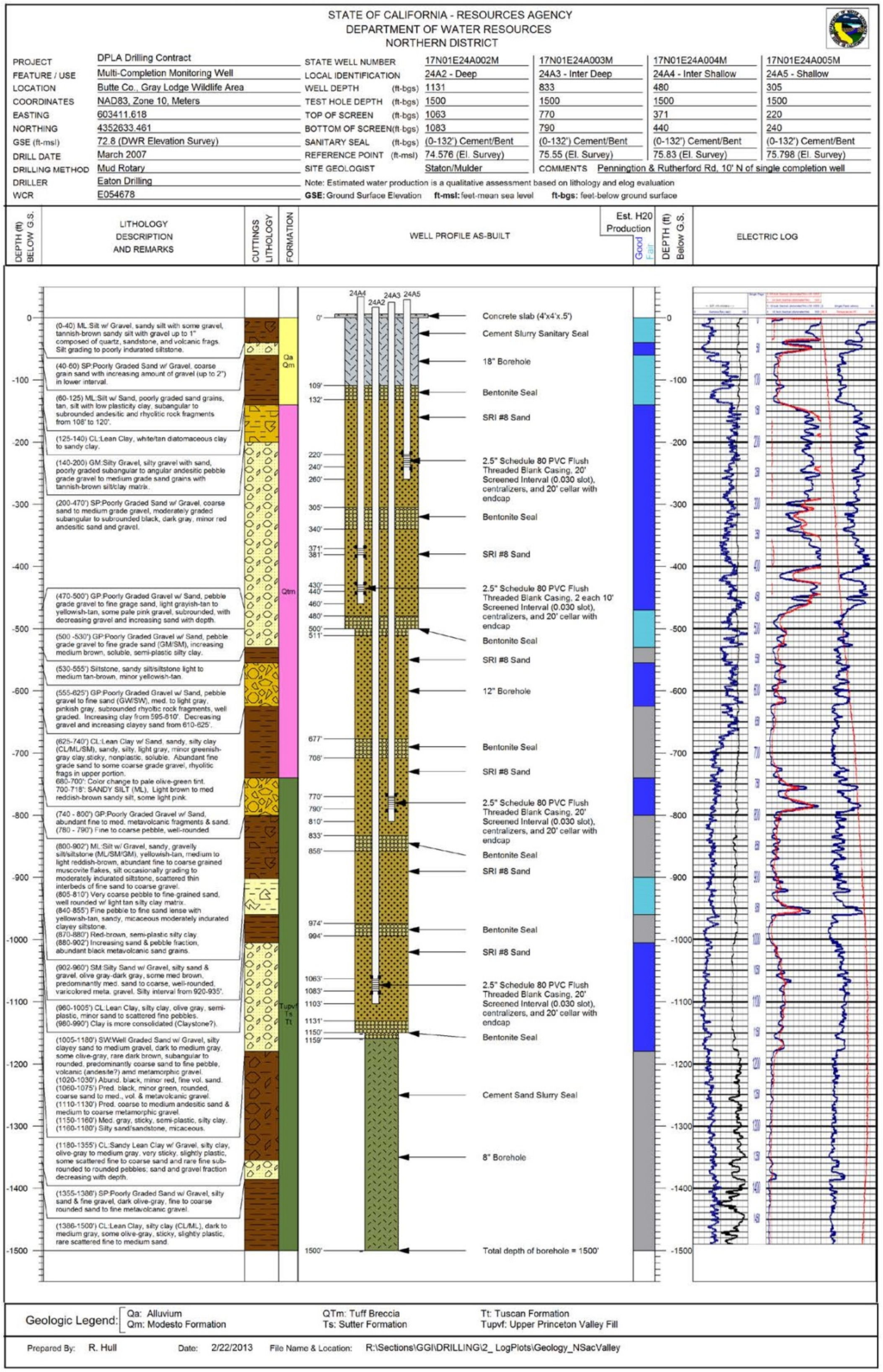


Figure 2 – Example As-Built Multi-Completion Monitoring Well Log

Measuring Groundwater Levels

Well construction, anticipated groundwater level, groundwater level measuring equipment, field conditions, and well operations should be considered prior collection of the groundwater level measurement. The USGS *Groundwater Technical Procedures* (Cunningham and Schalk, 2011) provide a thorough set of procedures which can be used to establish specific Standard Operating Procedures (SOPs) for a local agency. **Figure 3** illustrates a typical groundwater level measuring event and simultaneous pressure transducer download.

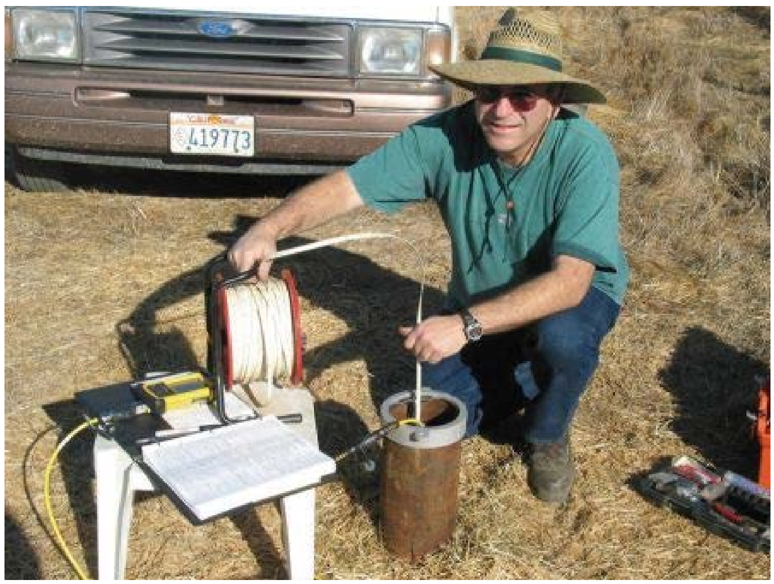


Figure 3 – Collection of Water Level Measurement and Pressure Transducer Download

The following points provide a general approach for collecting groundwater level measurements:

- Measure depth to water in the well using procedures appropriate for the measuring device. Equipment must be operated and maintained in accordance with manufacturer's instructions. Groundwater levels should be measured to the nearest 0.01 foot relative to the RP.
- For measuring wells that are under pressure, allow a period of time for the groundwater levels to stabilize. In these cases, multiple measurements should be collected to ensure the well has reached equilibrium such that no significant changes in water level are observed. Every effort should be made to ensure that a representative stable depth to groundwater is recorded. If a well does not stabilize, the quality of the value should be appropriately qualified as a

questionable measurement. In the event that a well is artesian, site specific procedures should be developed to collect accurate information and be protective of safety conditions associated with a pressurized well. In many cases, an extension pipe may be adequate to stabilize head in the well. Record the dimension of the extension and document measurements and configuration.

- The sampler should calculate the groundwater elevation as:

$$GWE = RPE - DTW$$

Where:

GWE = Groundwater Elevation
RPE = Reference Point Elevation
DTW = Depth to Water

The sampler must ensure that all measurements are in consistent units of feet, tenths of feet, and hundredths of feet. Measurements and RPEs should not be recorded in feet and inches.

Recording Groundwater Levels

- The sampler should record the well identifier, date, time (24-hour format), RPE, height of RP above or below ground surface, DTW, GWE, and comments regarding any factors that may influence the depth to water readings such as weather, nearby irrigation, flooding, potential for tidal influence, or well condition. If there is a questionable measurement or the measurement cannot be obtained, it should be noted. An example of a field sheet with the required information is shown in **Figure 4**. It includes questionable measurement and no measurement codes that should be noted. This field sheet is provided as an example. Standardized field forms should be used for all data collection. The aforementioned USGS *Groundwater Technical Procedures* offers a number of example forms.
- The sampler should replace any well caps or plugs, and lock any well buildings or covers.
- All data should be entered into the GSA data management system (DMS) as soon as possible. Care should be taken to avoid data entry mistakes and the entries should be checked by a second person for compliance with the DQOs.

STATE OF CALIFORNA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES

WELL DATA

STATE WELL NUMBER	COUNTY	REFERENCE POINT ELEV.	MEASURING AGENCY
			DWR

NO MEASUREMENT	QUESTIONABLE MEASUREMENT
0. Measurement discontinued	0. Caved or deepened
1. Pumping	1. Pumping
2. Pump house locked	2. Nearby pump operating
3. Tape hung up	3. Casing leaky or wet
4. Can't get tape in casing	4. Pumped recently
5. Unable to locate well	5. Air or pressure gauge measurement
6. Well has been destroyed	6. Other
7. Special	7. Recharge operation at or nearby well
8. Casing leaky or wet	8. Oil in casing
9. Temporarily inaccessible	

DATE	N M	Q M	TAPE AT RP	TAPE AT WS	RP to WS	OBSR VR	COMMENTS

DWR 1213

Figure 4 – Example of Water Level Well Data Field Collection Form

Pressure Transducers

Groundwater levels and/or calculated groundwater elevations may be recorded using pressure transducers equipped with data loggers installed in monitoring wells. When installing pressure transducers, care must be exercised to ensure that the data recorded by the transducers is confirmed with hand measurements.

The following general protocols must be followed when installing a pressure transducer in a monitoring well:

- The sampler must use an electronic sounder or chalked steel tape and follow the protocols listed above to measure the groundwater level and calculate the groundwater elevation in the monitoring well to properly program and reference the installation. It is recommended that transducers record measured groundwater level to conserve data capacity; groundwater elevations can be calculated at a later time after downloading.
- The sampler must note the well identifier, the associated transducer serial number, transducer range, transducer accuracy, and cable serial number.
- Transducers must be able to record groundwater levels with an accuracy of at least 0.1 foot. Professional judgment should be exercised to ensure that the data being collected is meeting the DQO and that the instrument is capable. Consideration of the battery life, data storage capacity, range of groundwater level fluctuations, and natural pressure drift of the transducers should be included in the evaluation.
- The sampler must note whether the pressure transducer uses a vented or non-vented cable for barometric compensation. Vented cables are preferred, but non-vented units provide accurate data if properly corrected for natural barometric pressure changes. This requires the consistent logging of barometric pressures to coincide with measurement intervals.
- Follow manufacturer specifications for installation, calibration, data logging intervals, battery life, correction procedure (if non-vented cables used), and anticipated life expectancy to assure that DQOs are being met for the GSP.
- Secure the cable to the well head with a well dock or another reliable method. Mark the cable at the elevation of the reference point with tape or an indelible marker. This will allow estimates of future cable slippage.
- The transducer data should periodically be checked against hand measured groundwater levels to monitor electronic drift or cable movement. This should happen during routine site visits, at least annually or as necessary to maintain data integrity.

- The data should be downloaded as necessary to ensure no data is lost and entered into the basin's DMS following the QA/QC program established for the GSP. Data collected with non-vented data logger cables should be corrected for atmospheric barometric pressure changes, as appropriate. After the sampler is confident that the transducer data have been safely downloaded and stored, the data should be deleted from the data logger to ensure that adequate data logger memory remains.

PROTOCOLS FOR SAMPLING GROUNDWATER QUALITY

The following protocols can be incorporated into a GSP's monitoring protocols for collecting groundwater quality data. More detailed sampling procedures and protocols are included in the standards and guidance documents listed at the end of this BMP. A GSP that adopts protocols that deviate from these BMPs must demonstrate that the adopted protocols will yield comparable data.

In general, the use of existing water quality data within the basin should be done to the greatest extent possible if it achieves the DQOs for the GSP. In some cases it may be necessary to collect additional water quality data to support monitoring programs or evaluate specific projects. The USGS *National Field Manual for the Collection of Water Quality Data* (Wilde, 2005) should be used to guide the collection of reliable data. **Figure 5** illustrates a typical groundwater quality sampling setup.

Figure 5 – Typical Groundwater Quality Sampling Event

All analyses should be performed by a laboratory certified under the State Environmental Laboratory Accreditation Program. The specific analytical methods are beyond the scope of this BMP, but should be commiserate with other programs evaluating water quality within the basin for comparative purposes.

Groundwater quality sampling protocols should ensure that:

- Groundwater quality data are taken from the correct location
- Groundwater quality data are accurate and reproducible
- Groundwater quality data represent conditions that inform appropriate basin management and are consistent with the DQOs
- All salient information is recorded to normalize, if necessary, and compare data
- Data are handled in a way that ensures data integrity

The following points are general guidance in addition to the techniques presented in the previously mentioned USGS *National Field Manual for the Collection of Water Quality Data.*

Standardized protocols include the following:

- Prior to sampling, the sampler must contact the laboratory to schedule laboratory time, obtain appropriate sample containers, and clarify any sample holding times or sample preservation requirements.
- Each well used for groundwater quality monitoring must have a unique identifier. This identifier must appear on the well housing or the well casing to avoid confusion.
- In the case of wells with dedicated pumps, samples should be collected at or near the wellhead. Samples should not be collected from storage tanks, at the end of long pipe runs, or after any water treatment.
- The sampler should clean the sampling port and/or sampling equipment and the sampling port and/or sampling equipment must be free of any contaminants. The sampler must decontaminate sampling equipment between sampling locations or wells to avoid cross-contamination between samples.
- The groundwater elevation in the well should be measured following appropriate protocols described above in the groundwater level measuring protocols.
- For any well not equipped with low-flow or passive sampling equipment, an adequate volume of water should be purged from the well to ensure that the groundwater sample is representative of ambient groundwater and not stagnant water in the well casing. Purging three well casing volumes is generally

considered adequate. Professional judgment should be used to determine the proper configuration of the sampling equipment with respect to well construction such that a representative ambient groundwater sample is collected. If pumping causes a well to be evacuated (go dry), document the condition and allow well to recover to within 90% of original level prior to sampling. Professional judgment should be exercised as to whether the sample will meet the DQOs and adjusted as necessary.

- Field parameters of pH, electrical conductivity, and temperature should be collected for each sample. Field parameters should be evaluated during the purging of the well and should stabilize prior to sampling. Measurements of pH should only be measured in the field, lab pH analysis are typically unachievable due to short hold times. Other parameters, such as oxidation-reduction potential (ORP), dissolved oxygen (DO) (in situ measurements preferable), or turbidity, may also be useful for meeting DQOs of GSP and assessing purge conditions. All field instruments should be calibrated daily and evaluated for drift throughout the day.
- Sample containers should be labeled prior to sample collection. The sample label must include: sample ID (often well ID), sample date and time, sample personnel, sample location, preservative used, and analytes and analytical method.
- Samples should be collected under laminar flow conditions. This may require reducing pumping rates prior to sample collection.
- Samples should be collected according to appropriate standards such as those listed in the *Standard Methods for the Examination of Water and Wastewater*, USGS *National Field Manual for the Collection of Water Quality Data,* or other appropriate guidance. The specific sample collection procedure should reflect the type of analysis to be performed and DQOs.
- All samples requiring preservation must be preserved as soon as practically possible, ideally at the time of sample collection. Ensure that samples are appropriately filtered as recommended for the specific analyte. Entrained solids can be dissolved by preservative leading to inconsistent results of dissolve analytes. Specifically, samples to be analyzed for metals should be field-filtered prior to preservation; do not collect an unfiltered sample in a preserved container.
- Samples should be chilled and maintained at 4 °C to prevent degradation of the sample. The laboratory's Quality Assurance Management Plan should detail appropriate chilling and shipping requirements.

- Samples must be shipped under chain of custody documentation to the appropriate laboratory promptly to avoid violating holding time restrictions.
- Instruct the laboratory to use reporting limits that are equal to or less than the applicable DQOs or regional water quality objectives/screening levels.

Special protocols for low-flow sampling equipment

In addition to the protocols listed above, sampling using low-flow sample equipment should adopt the following protocols derived from EPA's *Low-flow (minimal drawdown) ground-water sampling procedures* (Puls and Barcelona, 1996). These protocols apply to low-flow sampling equipment that generally pumps between 0.1 and 0.5 liters per minute. These protocols are not intended for bailers.

Special protocols for passive sampling equipment

In addition to the protocols listed above, passive diffusion samplers should follow protocols set forth in USGS Fact Sheet 088-00.

PROTOCOLS FOR MONITORING SEAWATER INTRUSION

Monitoring seawater intrusion requires analysis of the chloride concentrations within groundwater of each principal aquifer subject to seawater intrusion. While no significant standardized approach exists, the methodologies described above for degraded water quality can be applied for the collection of groundwater samples. In addition to the protocol described above, the following protocols should be followed:

- Water quality samples should be collected and analyzed at least semi-annually. Samples will be analyzed for dissolved chloride at a minimum. It may be beneficial to include analyses of iodide and bromide to aid in determination of salinity source. More frequent sampling may be necessary to meet DQOs of GSP. The development of surrogate measures of chloride concentration may facilitate cost-effective means to monitor more frequently to observe the range of conditions and variability of the flow dynamics controlling seawater intrusion.
- Groundwater levels will be collected at a frequency adequate to characterize changes in head in the vicinity of the leading edge of degraded water quality in each principal aquifer. Frequency may need to be increased in areas of known preferential pathways, groundwater pumping, or efficacy evaluation of mitigation projects.
- The use of geophysical surveys, electrical resistivity, or other methods may provide for identification of preferential pathways and optimize monitoring well placement and evaluation of the seawater intrusion front. Professional judgment

should be exercised to determine the appropriate methodology and whether the DQOs for the GSP would be met.

PROTOCOLS FOR MEASURING STREAMFLOW

Monitoring of streamflow is necessary for incorporation into water budget analysis and for use in evaluation of stream depletions associated with groundwater extractions. The use of existing monitoring locations should be incorporated to the greatest extent possible. Many of these streamflow monitoring locations currently follow the protocol described below.

Establishment of new streamflow discharge sites should consider the existing network and the objectives of the new location. Professional judgment should be used to determine the appropriate permitting that may be necessary for the installation of any monitoring locations along surface water bodies. Regular frequent access will be necessary to these sites for the development of ratings curves and maintenance of equipment.

To establish a new streamflow monitoring station special consideration must be made in the field to select an appropriate location for measuring discharge. Once a site is selected, development of a relationship of stream stage to discharge will be necessary to provide continuous estimates of streamflow. Several measurements of discharge at a variety of stream stages will be necessary to develop the ratings curve correlating stage to discharge. The use of Acoustic Doppler Current Profilers (ADCPs) can provide accurate estimates of discharge in the correct settings. Professional judgment must be exercised to determine the appropriate methodology. Following development of the ratings curve a simple stilling well and pressure transducer with data logger can be used to evaluate stage on a frequent basis. A simple stilling well and staff gage is illustrated in **Figure 6**.

Streamflow measurements should be collected, analyzed, and reported in accordance with the procedures outlined in USGS Water Supply Paper 2175, *Volume 1. – Measurement of Stage Discharge* and *Volume 2. – Computation of Discharge.* This methodology is currently being used by both the USGS and DWR for existing streamflow monitoring throughout the State.

Figure 6 – Simple Stilling Well and Staff Gage Setup

PROTOCOLS FOR MEASURING SUBSIDENCE

Evaluating and monitoring inelastic land subsidence can utilize multiple data sources to evaluate the specific conditions and associated causes. To the extent possible, the use of existing data should be utilized. Subsidence can be estimated from numerous techniques, they include: level surveying tied to known stable benchmarks or benchmarks located outside the area being studied for possible subsidence; installing and tracking changes in borehole extensometers; obtaining data from continuous GPS (CGPS) locations, static GPS surveys or Real-Time-Kinematic (RTK) surveys; or analyzing Interferometric Synthetic Aperture Radar (InSAR) data. No standard procedures exist for collecting data from the potential subsidence monitoring approaches. However, an approach may include:

- Identification of land subsidence conditions.
    - Evaluate existing regional long-term leveling surveys of regional infrastructure, i.e. roadways, railroads, canals, and levees.
    - Inspect existing county and State well records where collapse has been noted for well repairs or replacement.
    - Determine if significant fine-grained layers are present such that the potential for collapse of the units could occur should there be significant depressurization of the aquifer system.

  - Inspect geologic logs and the hydrogeologic conceptual model to aid in identification of specific units of concern.
  - Collect regional remote-sensing information such as InSAR, commonly provided by USGS and NASA. Data availability is currently limited, but future resources are being developed.
- Monitor regions of suspected subsidence where potential exists.
  - Establish CGPS network to evaluate changes in land surface elevation.
  - Establish leveling surveys transects to observe changes in land surface elevation.
  - Establish extensometer network to observe land subsidence. An example of a typical extensometer design is illustrated in **Figure 7**. There are a variety of extensometer designs and they should be selected based on the specific DQOs.

Various standards and guidance documents for collecting data include:

- Leveling surveys must follow surveying standards set out in the California Department of Transportation's Caltrans Surveys Manual.
- GPS surveys must follow surveying standards set out in the California Department of Transportation's Caltrans Surveys Manual.
- USGS has been performing subsidence surveys within several areas of California. These studies are sound examples for appropriate methods and should be utilized to the extent possible and where available:
  - http://ca.water.usgs.gov/land_subsidence/california-subsidence-measuring.html
- Instruments installed in borehole extensometers must follow the manufacturer's instructions for installation, care, and calibration.
- Availability of InSAR data is improving and will increase as programs are developed. This method requires expertise in analysis of the raw data and will likely be made available as an interpretative report for specific regions.

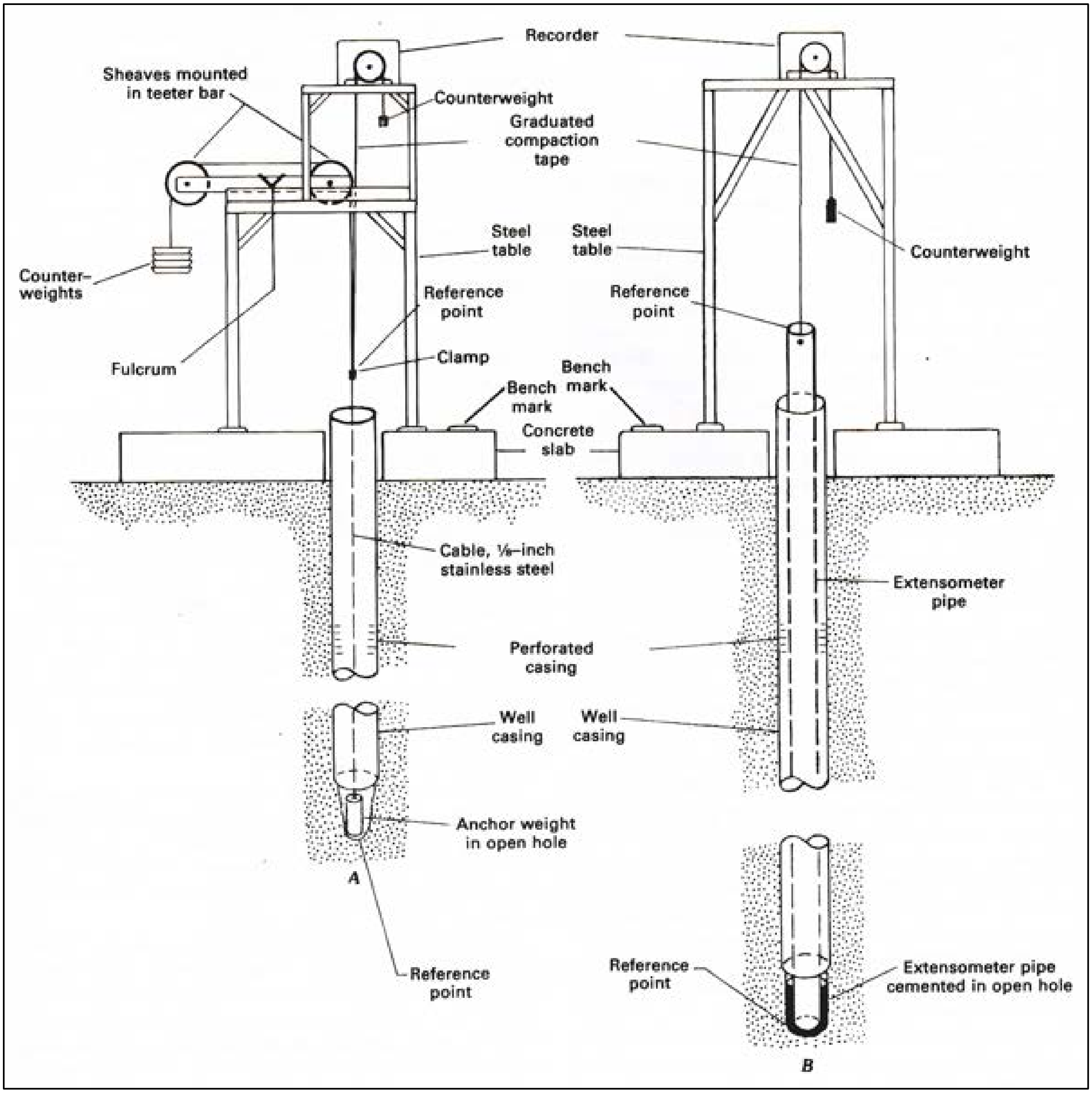


Figure 7 – Simplified Extensometer Diagram

6. KEY DEFINITIONS

The key definitions and sections related to Groundwater Monitoring Protocols, Standards, and Sites outlined in applicable SGMA code and regulations are provided below for reference.

Groundwater Sustainability Plan Regulations (California Code of Regulations §351)

- §351(h) "Best available science" refers to the use of sufficient and credible information and data, specific to the decision being made and the time frame available for making that decision, that is consistent with scientific and engineering professional standards of practice.
- §351(i) "Best management practice" refers to a practice, or combination of practices, that are designed to achieve sustainable groundwater management and have been determined to be technologically and economically effective, practicable, and based on best available science.

Monitoring Protocols Reference

§352.2. Monitoring Protocols

Each Plan shall include monitoring protocols adopted by the Agency for data collection and management, as follows:

(a) Monitoring protocols shall be developed according to best management practices.

(b) The Agency may rely on monitoring protocols included as part of the best management practices developed by the Department, or may adopt similar monitoring protocols that will yield comparable data.

(c) Monitoring protocols shall be reviewed at least every five years as part of the periodic evaluation of the Plan, and modified as necessary.

SGMA Reference

§10727.2. Required Plan Elements

(f) Monitoring protocols that are designed to detect changes in groundwater levels, groundwater quality, inelastic surface subsidence for basins for which subsidence has been identified as a potential problem, and flow and quality of surface water that directly affect groundwater levels or quality or are caused by groundwater extraction in the basin. The monitoring protocols shall be designed to generate information that promotes efficient and effective groundwater management.

7. RELATED MATERIALS

CASE STUDIES

Luhdorff & Scalmanini Consulting Engineers, J.W. Borchers, M. Carpenter. 2014. *Land Subsidence from Groundwater Use in California*. Full Report of Findings prepared for California Water Foundation. April 2014. 151 p. http://ca.water.usgs.gov/land_subsidence/california-subsidence-cause-effect.html

Faunt, C.C., M. Sneed, J. Traum, and J.T. Brandt, 2015. *Water availability and land subsidence in the Central Valley, California, USA*. Hydrogeol J (2016) 24: 675. doi:10.1007/s10040-015-1339-x.
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Poland, J.F., B.E. Lofgren, R.L. Ireland, and R.G. Pugh, 1975. *Land subsidence in the San Joaquin Valley, California, as of 1972*; US Geological Survey Professional Paper 437-H; prepared in cooperation with the California Department of Water Resources, 87 p.
http://pubs.usgs.gov/pp/0437h/report.pdf

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U.S. Environmental Protection Agency, 2006. Guidance on Systematic Planning Using the Data Quality Objectives Process, EPA QA/G-4 https://www.epa.gov/sites/production/files/documents/guidance_systematic_planning_dqo_process.pdf

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ONLINE RESOURCES

Online System for Well Completion Reports (OSWCR). California Department of Water Resources. http://water.ca.gov/oswcr/index.cfm

Measuring Land Subsidence web page. U.S. Geological Survey. http://ca.water.usgs.gov/land_subsidence/california-subsidence-measuring.html

USGS Global Positioning Application and Practice web page. U.S. Geological Survey. http://water.usgs.gov/osw/gps/

APPENDIX J: MONITORING PROTOCOLS – GROUNDWATER QUALITY (CVGM QAPRP & ESJWQC QAPP)

Quality Assurance Program Plan

For Groundwater Monitoring By The

Central Valley Groundwater Monitoring Collaborative

For The

Irrigated Lands Regulatory Program

Central Valley Regional Water Quality Control Board
11020 Sun Center Drive #200
Rancho Cordova, California 95670-6114

Submitted On

April 1, 2019

Prepared By

LUHDORFF & SCALMANINI CONSULTING ENGINEERS

MLJ ENVIRONMENTAL

PROVOST & PRITCHARD CONSULTING GROUP

GROUP A. PROGRAM MANAGEMENT

1. APPROVAL SIGNATURES

Central Valley Regional Water Quality Control Board

Title:	Name:	Signature:	Date:
Senior Environmental Scientist	Susan Fregien		
Senior Engineering Geologist	David Sholes		
Water Resource Control Engineer	Ashley Peters		

State Water Resources Control Board

Title:	Name:	Signature:	Date:
SWRCB QA Officer	Rene Spears		

CVGMC Program Personnel

Title:	Name:	Signature:	Date:
Program Manager	David Cory		
Senior Hydrogeologist	Vicki Kretsinger		
Program QA Officer	Melisa Turner		

Coalition Project Personnel

Title/Project:	Name:	Signature:	Date:
Project Lead, Buena Vista Coalition	Tim Ashlock		
Project Manager, Buena Vista Coalition	Morgan Campbell		
Project QA Officer, Buena Vista Coalition	Sarah Rutherford		
Project Lead, Cawelo Water District Coalition	David Hampton		

Project Manager, Cawelo Water District Coalition	Dennis Pickin		
Project QA Officer, Cawelo Water District Coalition	David Ansolabehere		
Project Lead, East San Joaquin Water Quality Coalition	Parry Klassen		
Project Manager, East San Joaquin Water Quality Coalition	Ally Villalpando		
Project QA Officer, East San Joaquin Water Quality Coalition	Lisa McCrink		
Project Lead, Grassland Drainage Area Coalition	Joe McGahan		
Project Manager, Grassland Drainage Area Coalition	Nick Watterson		
Project QA Officer, Grassland Drainage Area Coalition	Aaron King		
Project Lead, Kaweah Basin Water Quality Association	Donald Ikemiya		
Project Manager, Kaweah Basin Water Quality Association	Jordan Muell		
Project QA Officer, Kaweah Basin Water Quality Association	Sarah Rutherford		
Project Lead, Kern River Watershed Authority	Nicole Bell		
Project Manager, Kern River Watershed Authority	Morgan Campbell		

Project QA Officer, Kern River Watershed Authority	Sarah Rutherford		
Project Lead, Kings River Water Quality Coalition	Charlotte Gallock		
Project Manager, Kings River Water Quality Coalition	Eric Athorp		
Project QA Officer, Kings River Water Quality Coalition	Laura Satterlee		
Project Lead, Westlands Water Quality Coalition	Debra Dunn		
Project Manager, Westlands Water Quality Coalition	Lindsay Nelson		
Project QA Officer, Westlands Water Quality Coalition	Lisa McCrink		
Project Lead, Westside San Joaquin River Watershed	Joe McGahan		
Project Manager, Westside San Joaquin River Watershed	Nick Watterson		
Project QA Officer, Westside San Joaquin River Watershed	Aaron King		
Project Lead, Westside Water Quality Coalition	Phil Nixon		
Project Manager, Westside Water Quality Coalition	Jill Ghelerter		
Project QA Officer, Westside Water Quality Coalition	Josh Spink		

Analytical Laboratory Personnel

Title/Laboratory:	Name:	Signature:	Date:
Laboratory Project Manager, BSK (Kern)	Stephane Maupas		
Laboratory Project Manager, BSK (Kings)	Heather S. White		
Laboratory Project Manager, BSK (Westside)	Adam Trevarrow		
Laboratory QA Officer, BSK	Michael Ng		
Laboratory Project Manager, Caltest	Eli Greenwald		
Laboratory QA Officer, Caltest	Nell Arguelles		
Laboratory Project Manager, Eurofins	Monica Van Natta		
Laboratory QA Officer, Eurofins	Nilda Cox		
Laboratory Project Manager, FGL	Stephanie Herron		
Laboratory QA Officer, FGL	David Terz		

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2.3. List of Appendices

Appendix I. Coalition Specific QAPP Forms

Appendix II. Data Management SOP

Appendix III. Field Sampling SOPs

Appendix IV. Laboratory SOPs

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CVGMC Coalition	QAPP Appendix Reference	Data Management SOP Appendix Reference	Field Sampling SOP Appendix Reference	Laboratory SOPs Appendix Reference
Buena Vista Coalition	Appendix I-A	Appendix II	Appendix III-A	Appendix IV-A
Cawelo Water District Coalition	Appendix I-B	Appendix II	Appendix III-B	Appendix IV-D
East San Joaquin Water Quality Coalition	Appendix I-C	Appendix II	Appendix III-G	Appendix IV-B
Grassland Drainage Area Coalition	Appendix I-D	Appendix II	Appendix III-F	Appendix IV-C
Kaweah Basin Water Quality Association	Appendix I-E	Appendix II	Appendix III-C	Appendix IV-D
Kern River Watershed Coalition Authority	Appendix I-F	Appendix II	Appendix III-D	Appendix IV-A
Kings River Water Quality Coalition	Appendix I-G	Appendix II	Appendix III-E	Appendix IV-A
Westlands Water Quality Coalition	Appendix I-H	Appendix II	Appendix III-G	Appendix IV-B
Westside San Joaquin River Watershed Coalition	Appendix I-I	Appendix II	Appendix III-F	Appendix IV-C
Westside Water Quality Coalition	Appendix I-J	Appendix II	Appendix III-H	Appendix IV-A

2.4. List of Acronyms

AOAC	Association of Official Analytical Chemist
ASTM	American Society of Testing Materials
COC	Chain Of Custody
CRM	Certified Reference Material
CVGMC	Central Valley Groundwater Monitoring Collaborative
CVRWQCB	Central Valley Regional Water Quality Control Board
DDW	Division of Drinking Water
DMS	Data Management System
DO	Dissolved Oxygen
DQI	Data Quality Indicators
E	Environmental sample
EC	Specific Conductance
FB	Field Blank
FD	Field Duplicate
GAR	Groundwater Quality Assessment Report
GQTM	Groundwater Trend Monitoring
ILRP	Irrigated Land and Regulatory Program
LCS	Laboratory Control Spike
LCSD	Laboratory Control Spike Duplicate
MDL	Method Detection Limit
MLJ-LLC	Michael L. Johnson, LLC
MOA	Memorandum of Agreement
MQO	Measurement Quality Objective
MS	Matrix Spike
MSD	Matrix Spike Duplicate
ORP	Oxidation Reduction Potential
PR	Percent Recovery
QA	Quality Assurance
QAPrP	Quality Assurance Project Plan
QC	Quality Control
RL	Reporting Limit
RPD	Relative Percent Difference
RS	Resample
SOP	Standard Operating Procedure
TDS	Total Dissolved Solids
US EPA	United States Environmental Protection Agency
USGS	United States Geological Survey

2.5. List of Units

cm	centimeter
L	liter
mg	milligram
mV	millivolts
NTU	Nephelometric Turbidity Units
pH	Power of Hydrogen
µg	microgram

3. DISTRIBUTION LIST

AFFILIATION	NAME	TITLE:	CONTACT
Central Valley Regional Water Quality Control Board	Susan Fregien	Senior Environmental Scientist	11020 Sun Center Drive, #200 Rancho Cordova, CA 95670
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	Aaron King	Project QA Officer	
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	Lisa McCrink	Project QA Officer	
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	Jill Ghelerter	Project Manager	1281 East Alluvial Avenue, Suite 101, Fresno, CA 93720
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	David Sholes	Senior Engineering Geologist	
	Ashley Peters	Irrigated Lands Water Resource Control Engineer	
State Water Quality Control Board	Rene Spears	State Board QA Officer	1001 I Street Sacramento, CA 95814
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Eurofins Eaton	Nilda Cox	Laboratory QA Officer	750 Royal Oaks Drive, Suite 100 Monrovia, CA 91016
Fruit Growers Laboratories	David Terz	Laboratory QA Officer	9415 W. Goshen Avenue Visalia, CA 93291

4. PROGRAM ROLES AND RESPONSIBILITIES

4.1. Involved Parties and Roles

The Central Valley Groundwater Monitoring Collaborative (CVGMC) is a monitoring program developed by various stakeholders across the Central Valley with the goal of characterizing groundwater quality and the potential impact of waste discharges on groundwater quality. The CVGMC has developed a Technical Workplan for long-term trend monitoring that will be implemented by the participating entities.

Ten Central Valley third-party groups comprise the initial group of Irrigated Lands Regulatory Program (ILRP) Coalitions taking part in the Collaborative. The participating agricultural Coalitions are:

- Buena Vista Coalition
- Cawelo Water District Coalition
- East San Joaquin Water Quality Coalition
- Grassland Drainage Area Coalition
- Kaweah Basin Water Quality Association
- Kern River Watershed Coalition Authority
- Kings River Water Quality Coalition
- Westlands Water Quality Coalition
- Westside San Joaquin River Watershed
- Westside Water Quality Coalition

Each of the participating agricultural Coalitions must meet their own groundwater monitoring requirements, outlined in their individual General Orders. However, each Order allows for the Coalitions to collaborate with other Central Valley third parties to monitor and report on groundwater quality trends on a regional basis. The role of the CVGMC is to establish common monitoring and reporting structure as it applies to the individual groundwater trend monitoring requirements established by each third-party group under their individual General Orders. The third-party groups will participate in a regional effort to collect and share groundwater monitoring data to be used for a broad geographical characterization of the potential effects of agricultural lands on groundwater aquifers, for regulatory compliance and decision making throughout the Central Valley.

The Quality Assurance Program Plan (QAPrP) establishes the quality assurance and quality control standards and requirements for useable data for individual projects contributing to this regional collaboration. It also establishes the requirements for a regional data management system, through which all useable data generated under the CVGMC can be stored and accessed by the participants and regulators.

4.2. Program Administration

The CVGMC participating Coalitions work collaboratively under a Memorandum of Agreement (MOA) signed on October 27, 2017. The Memorandum of Agreement outlines the purpose, organization, roles and responsibilities of the member Coalitions, administrative procedures, length of time the terms of the MOA remain in force, termination procedures, and rules of operation. In addition, there is a cost allocation schedule agreed upon by all member Coalitions.

4.3. Project Management and Coordination

The CVGMC activities are managed by a Coordination Committee which consists of a member from each of the Coalitions including a Chair and Vice Chair. The Coordination Committee is responsible for approving scope of work documents for any contractor and provides oversight for any work performed by outside contractors. The Chair serves as the Program Manager for the purpose of this QAPrP and works directly with the Program QA Officer and the Senior Hydrogeologist to assess data received from the individual Coalitions, compile and assess data, and evaluate data for inclusion in CVGMC analysis and reporting.

4.4. Quality Assurance and Data Management

Quality Assurance Officer Role

The Program QA Officer is responsible for developing the programmatic procedures and QA/QC guidelines for field sampling and analytical procedures conducted as part of the CVGMC Technical Workplan. The Program QA Officer will oversee and manage the assessment of accuracy, completeness and precision for samples collected as part of the CVGMC.

Persons Responsible for the Update and Maintenance of QAPrP

The Program QA Officer in coordination with the Program Manager and Senior Hydrogeologist will be responsible for creating, maintaining and updating the QAPrP including the submission of addendums to reflect updates based on project specific QAPP. The Program QA Officer will be responsible for making changes, submitting drafts for review, preparing a final copy and submitting the final version for signature.

4.5. Field, Laboratory, and Technical Services

Well sampling will be conducted by the member Coalitions as described in their project specific QAPP following quality assurance (QA) requirements found in this QAPrP. The individual entities will maintain and store records of data, field sheets, chain of custody (COC) forms, as well as all other forms of documentation.

Programmatic technical services are overseen by the Senior Hydrogeologist, who is responsible for overseeing the implementation of the Programmatic Workplan and development of five-year trend reports to the CVRWQCB. The Senior Hydrogeologist will review updates to the Workplan and assess how changes to workplans meet the technical requirements of the program.

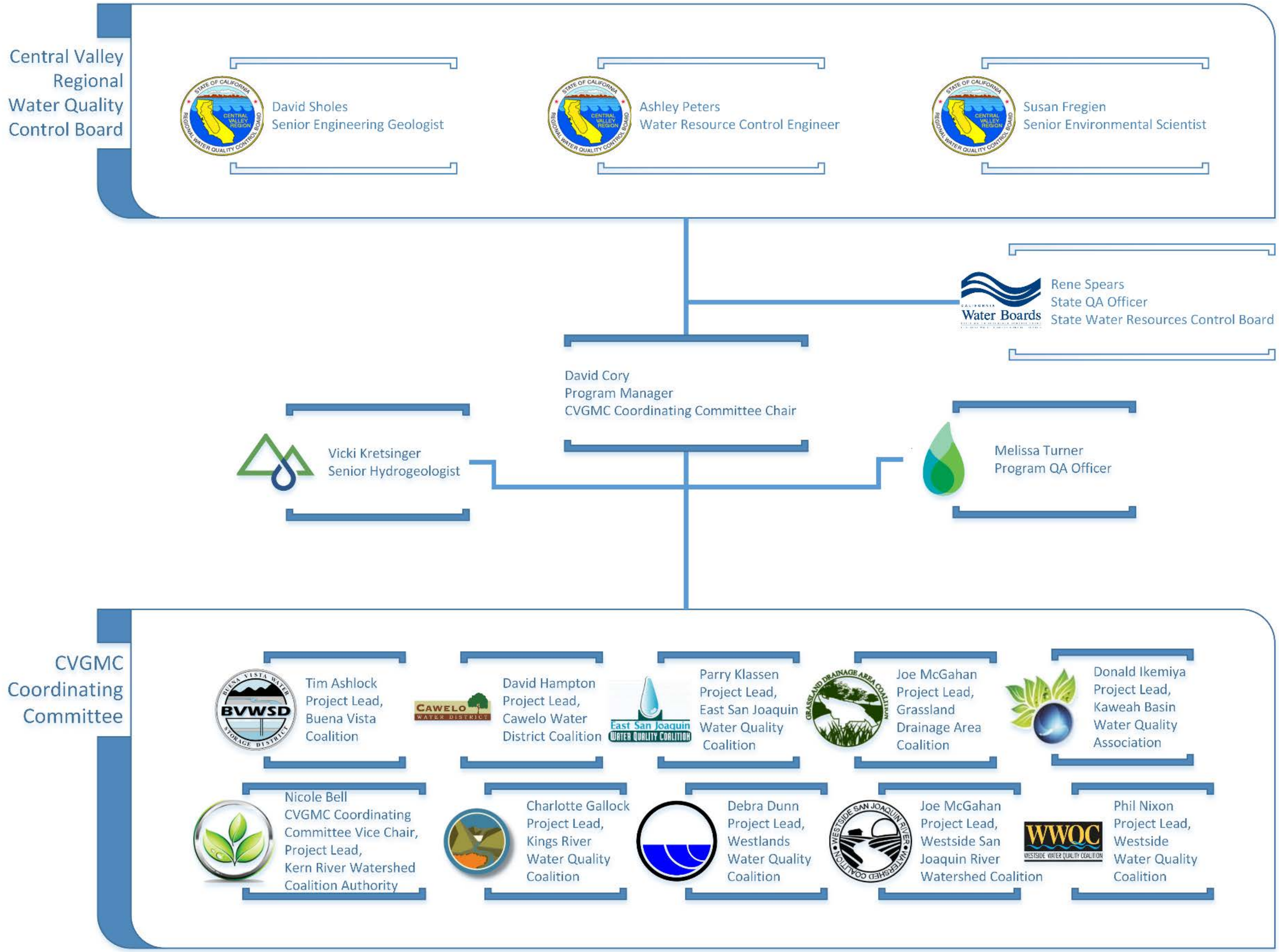
The laboratories contracted to analyze samples collected for the Program studies will provide analytical services for this project in accordance with all method and QA requirements found in this QAPrP. Individual contracts will be maintained by the third-party entities coordinating sampling efforts. All data deliverables generated by contract laboratories will be submitted to the Program Data Management System outlined in this QAPrP in **Section 19.**

All analytical issues will be resolved between the contract entities and covered under individual QAPPs. The laboratories will maintain contact with the individual Project Managers to resolve analytical issues or for notification of laboratory changes.

No individuals outside of the Program Team contribute to the CVGMC in an advisory role.

4.6. Organizational Chart and Responsibilities

Figure 1. Organizational chart - CVGMC.



Individual Project Organizational Charts Attached Below

Figure 2. Project Organizational Chart - Buena Vista Coalition.

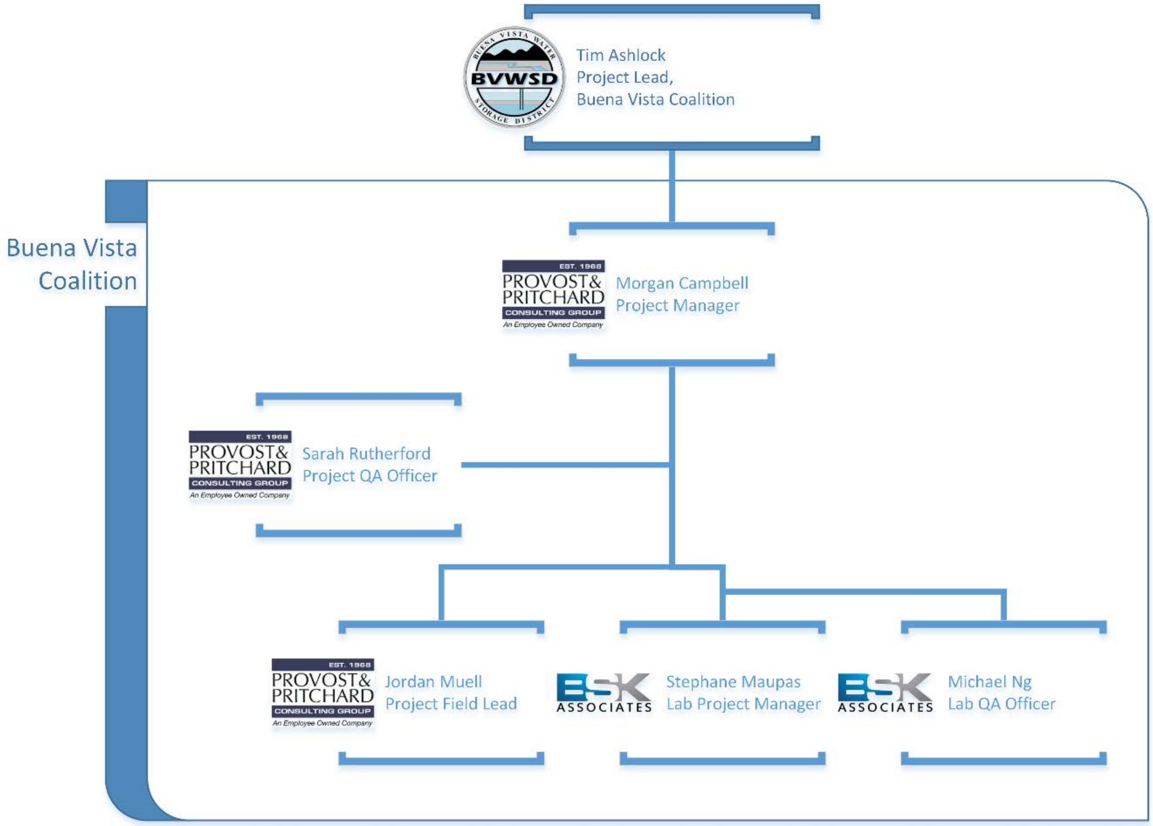


Figure 3. Project Organizational Chart - Cawelo Water District Coalition.

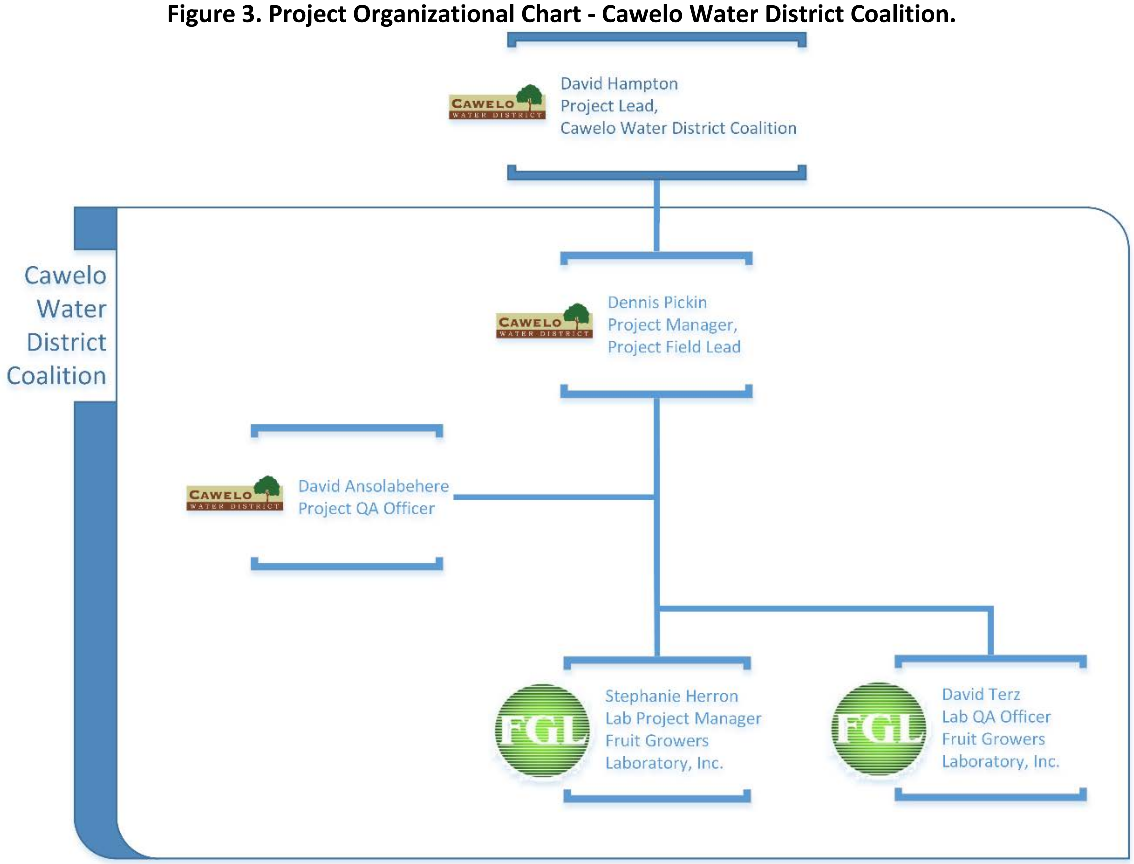


Figure 4. Project Organizational Chart - East San Joaquin Water Quality Coalition.

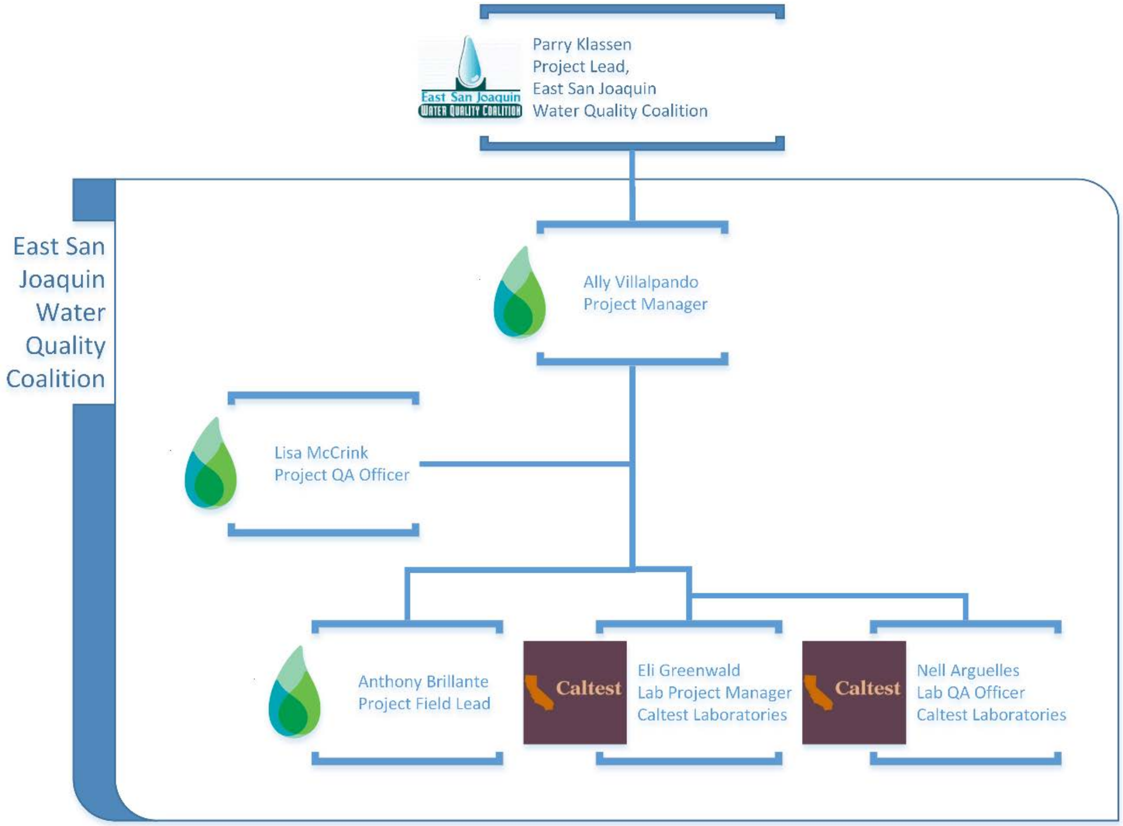


Figure 5. Project Organizational Chart - Grassland Drainage Area Coalition.

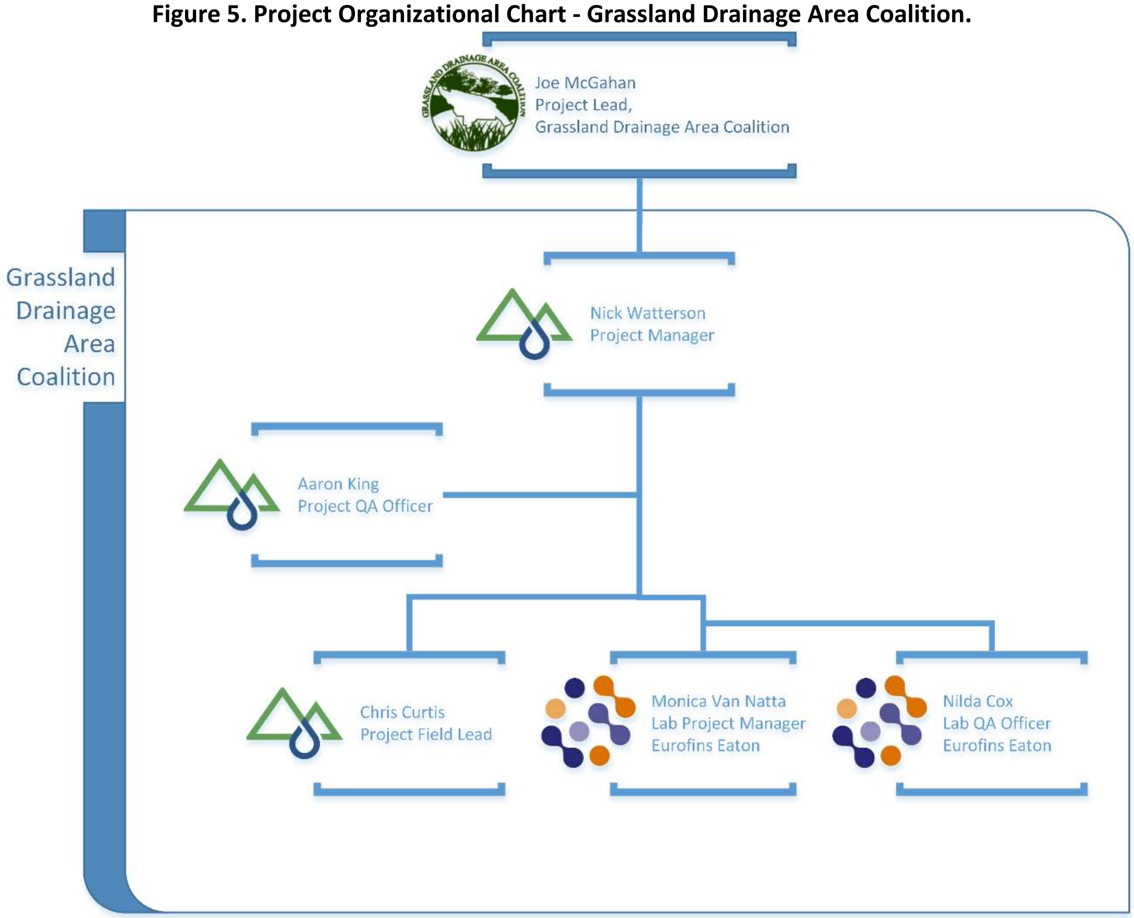


Figure 6. Project Organizational Chart - Kaweah Basin Water Quality Coalition.

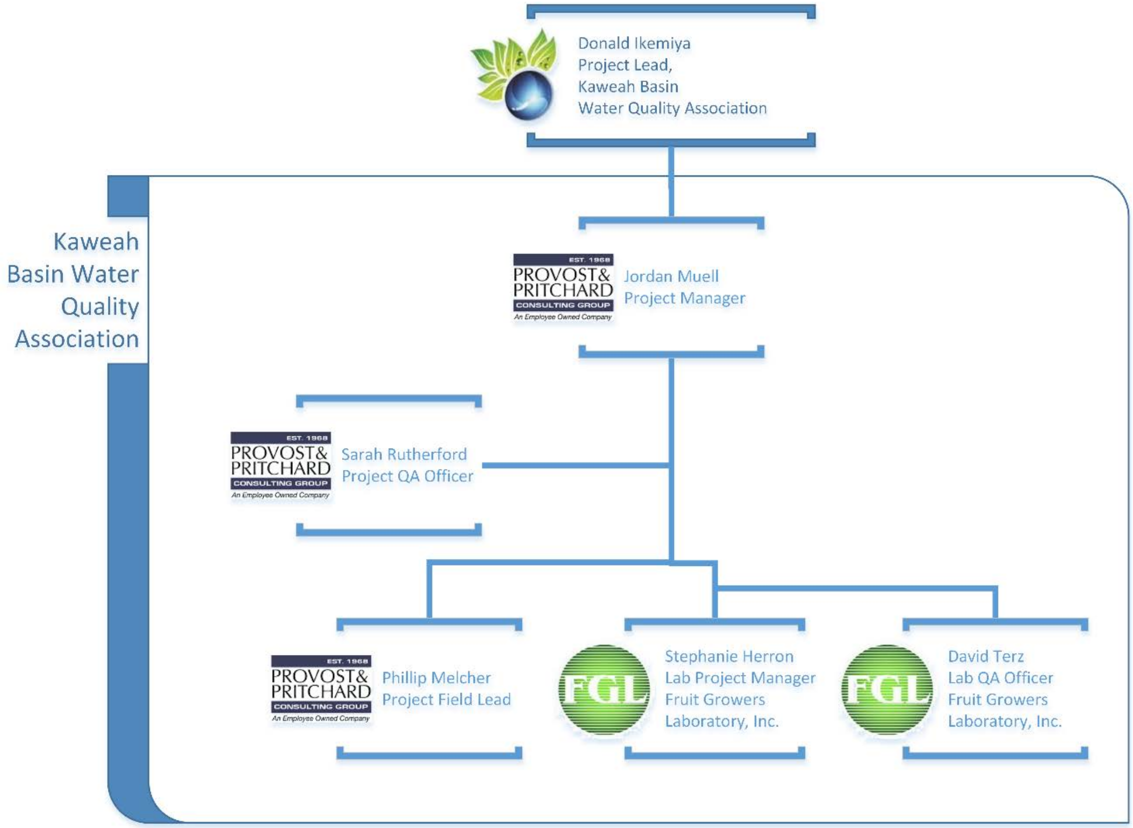


Figure 7. Project Organizational Chart - Kern River Watershed Coalition Authority.

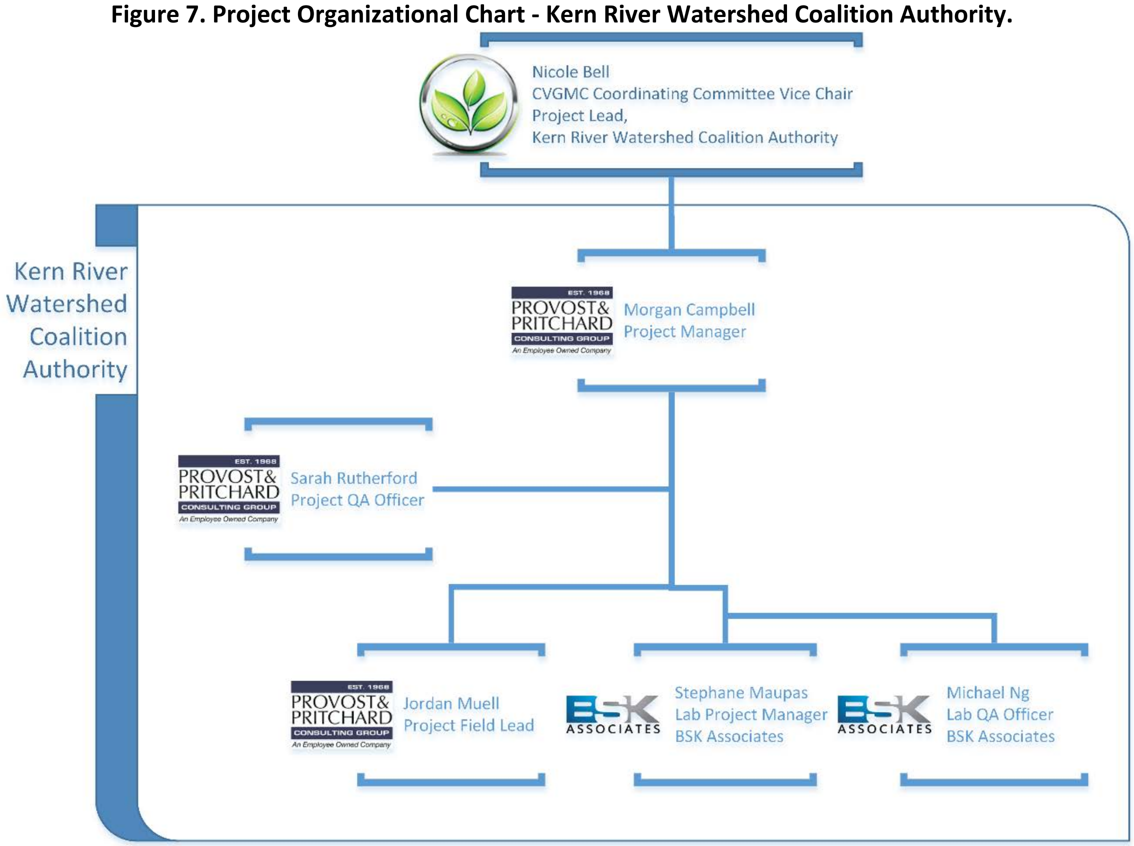


Figure 8. Project Organizational Chart - Kings River Water Quality Coalition.

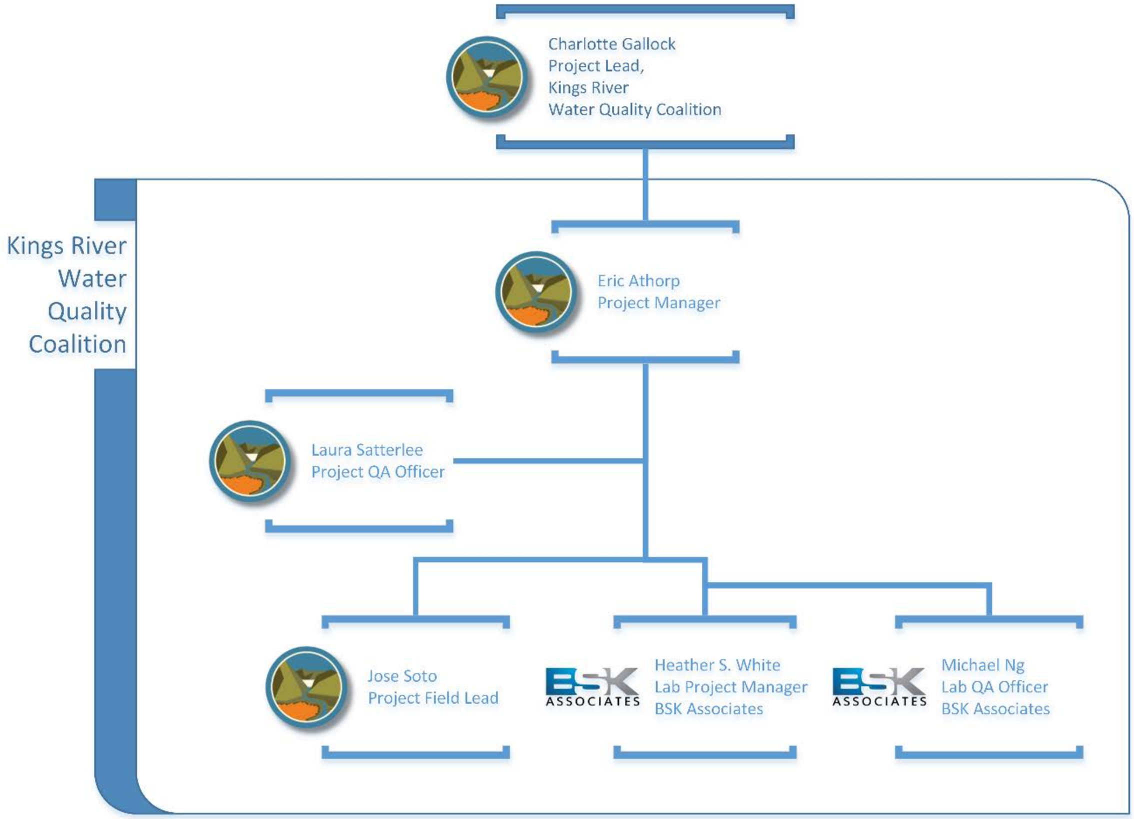


Figure 9. Project Organizational Chart - Westlands Water Quality Coalition.

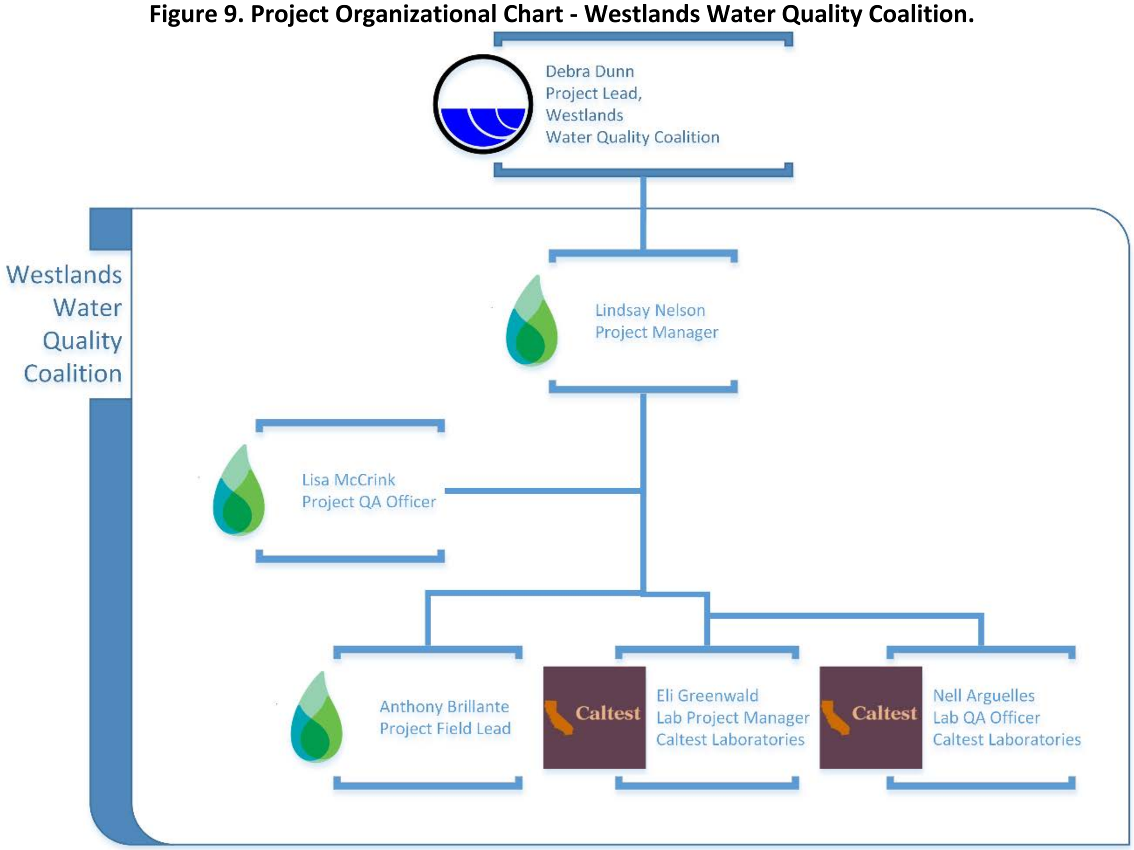


Figure 10. Project Organizational Chart - Westside San Joaquin River Watershed Coalition.

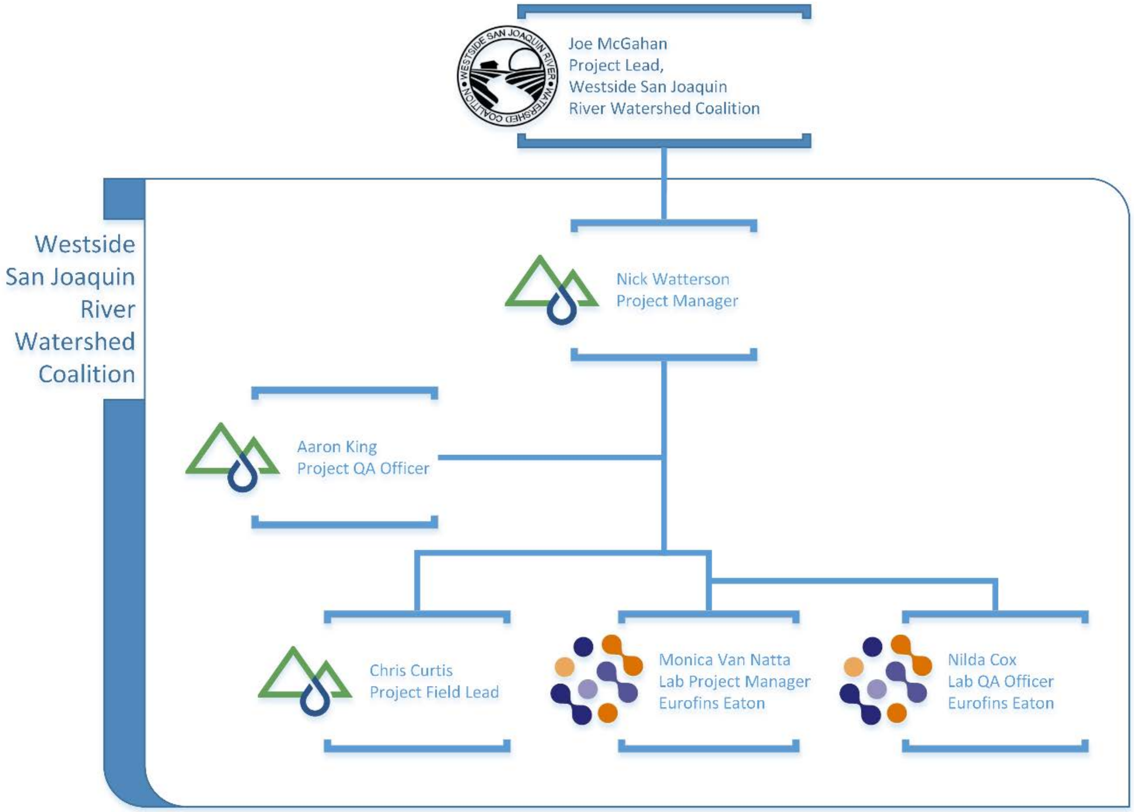
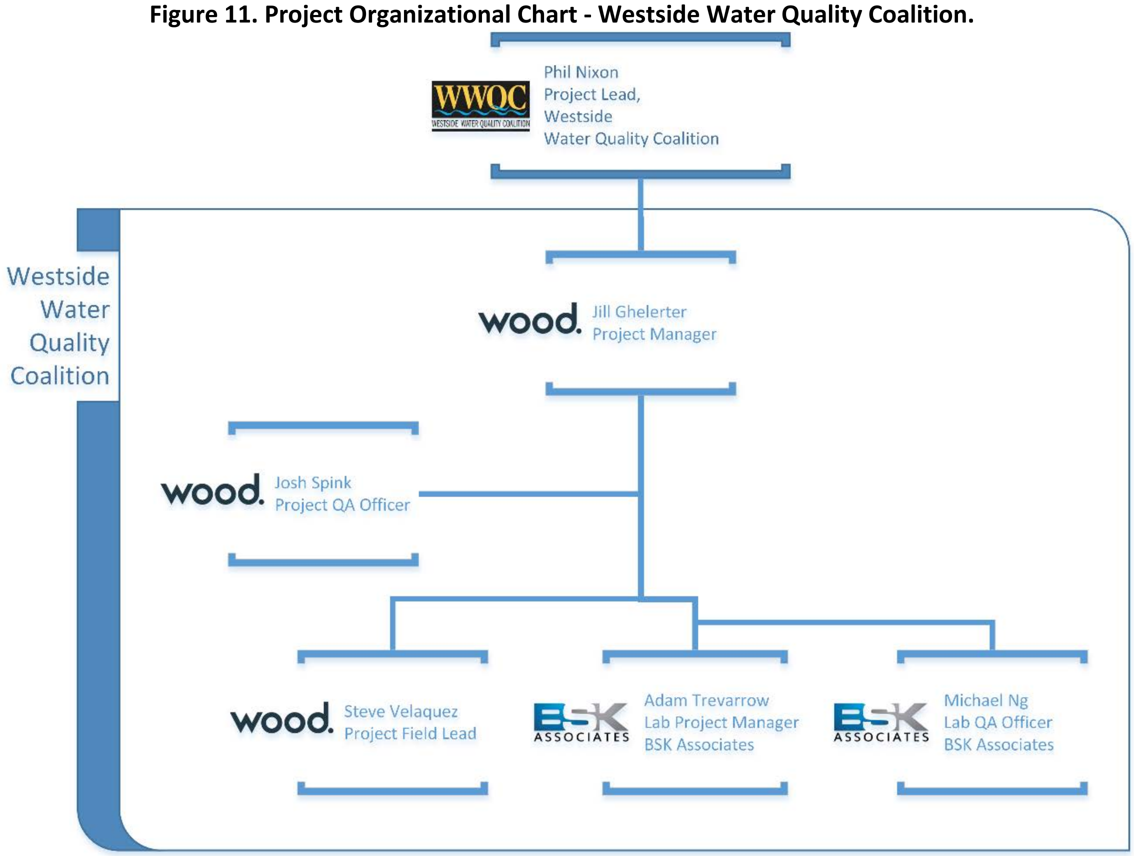


Figure 11. Project Organizational Chart - Westside Water Quality Coalition.



5. PROBLEM DEFINITION/BACKGROUND

The CVGMC was created to comply with the various Waste Discharge Requirements of the participating Central Valley ILRP Coalitions. Given the nature of groundwater trend monitoring and the challenges presented by accurately characterizing groundwater quality on a small geographical scale, groundwater quality trends can be more effectively and efficiently evaluated on a regional level. Furthermore, given the number of state and local regulatory programs with groundwater monitoring requirements, a regional collaboration allows for the individual stakeholders to avoid duplicating costs and effort for the use of the same data.

The Central Valley Regional Water Quality Control Board (CVRWQCB or Regional Board) has allowed the individual Coalitions to opt into a regional effort across the Central Valley to characterize groundwater quality trends and share resources to meet the groundwater monitoring requirements of each third party's individual General Orders. Ten ILRP Coalitions have founded the CVGMC in an effort to meet these requirements. Additionally, the program was created with the understanding that other state and regional programs with groundwater monitoring requirements may also participate in the Collaborative in the future, allowing shared resources across multiple dischargers and stakeholders throughout the Central Valley.

6. PROGRAM DESCRIPTION

6.1. Work Statement and Deliverables

The CVGMC program will be implemented in three phases:

Phase 1. ILRP Technical Workplan;

Phase 2. Coordination Among Existing Groundwater Monitoring Programs;

Phase 3. Future Groundwater Monitoring Coordination

Phase 1 was completed and submitted to the CVRWQCB on May 16, 2018. Upon Executive Officer approval of the Phase 1 Technical Workplan, monitoring of the well network established in the Workplan by the individual participating third parties will begin in Fall 2018.

Individual ILRP Coalitions will report on the data developed in their respective areas annually, in accordance with their individual Orders. All ILRP participants will contribute to a CVGMC 5-Year Report with additional methods to characterize groundwater quality conditions and trends.

Phase 2 and Phase 3 of the program will be implemented once the ILRP Technical Workplan and Data Management System are established.

6.2. Monitoring Projects

Each of the Central Valley ILRP Coalitions have developed a Groundwater Quality Assessment Report (GAR) that characterizes the existing state of groundwater quality within each region. Based on these characterizations, the individual Coalitions have developed, or are currently developing Groundwater

Trend Monitoring Workplans (GQTMs), with the goal of long-term characterization and overall protection and improvement of the groundwater conditions provided by each individual GAR.

By opting into the CVGMC, participating Coalitions will agree to the common approach to monitoring and reporting elements under the Technical Workplan to meet their individual GQTM requirements. The conclusions and existing data developed by each individual GQTM will inform and feed into the regional collaborative Technical Workplan.

Each participating Coalition is responsible for certain Coalition-specific responsibilities. These responsibilities include developing their own individual GQTM to meet specific Order requirements, conducting sampling within their own GQTM network, and preparing Annual Reports in accordance with the CVGMC format.

6.3. Constituents to Be Monitored

Table 1 lists the required constituents associated with CVGMC Technical Workplan and is consistent with the constituents to be monitored by each Coalition. The testing frequency reflects how often a constituent is measured at each well location. The table summarizes the parameter type (whether the result is derived from the field or the laboratory), methods, and analyses used to produce results for each constituent measured at each monitored well.

Table 1. Constituents and parameters.

Constituents and parameters measured are grouped by testing frequency, required or optional and parameter type.

Constituent	Reporting Units	Testing Frequency	Required or Optional	Parameter Type
Nitrate as Nitrogen (NO3-N) or Nitrate + Nitrite as Nitrogen (NO3-N)	mg/L (as N)	Annual	Required	Analytical
Dissolved Oxygen (DO)	mg/L	Annual	Required	Field Measure
Electrical Conductivity (EC) at 25 °C	µS/cm	Annual	Required	Field Measure
pH	pH units	Annual	Required	Field Measure
Temperature	°C	Annual	Required	Field Measure
Depth to standing water (static water level)	ft	Annual	Required[1]	Field Measure
Oxidation-reduction potential (ORP)	mV	Annual	Optional	Field Measure
Turbidity	NTU	Annual	Optional	Field Measure
Anions				
Carbonate	mg/L	Five Years	Required	Analytical
Chloride	mg/L	Five Years	Required	Analytical
Bicarbonate	mg/L	Five Years	Required	Analytical
Sulfate (SO4)	mg/L	Five Years	Required	Analytical
Cations				
Boron	mg/L	Five Years	Required	Analytical
Calcium	mg/L	Five Years	Required	Analytical
Magnesium	mg/L	Five Years	Required	Analytical
Potassium	mg/L	Five Years	Required	Analytical
Sodium	mg/L	Five Years	Required	Analytical
Total Dissolved Solids (TDS)	mg/L	Five Years	Required	Analytical

[1] Collected annually if available/accessible.

6.4. Program Schedule

The program will advance with the deliverable date outlined in **Table 2** below. Wells within the CVGMC network will be monitored starting in Fall 2018, pending Executive Officer approval of the Technical Workplan. Monitoring results will be reported on annually with the expectation that the Workplan will be approved prior to Fall 2018. Annual analysis and reporting of results related to the individual Coalition GQTMs will focus on visual and tabular presentation of data with limited representation of data interpretation. Additional interpretations and conclusions relating to trends and relationships in trends will be conducted as part of reporting every five years.

Table 2. Project deliverable schedule timeline.

Deliverable	Description	Deliverable Due Date
Individual Coalitions Annual Monitoring Reports	Coalition specific analysis and reporting of previous years monitoring results.	November 30, 2019 (Annually)
CVGMC 5-Year Report[1]	Reporting on all CVGMC network monitoring results from the previous 5 years including trends and interpretations.	November 30, 2023 (Every Five Years)

[1]First CVGMC 5-Year Report is shifted to 2023 to have the Coalitions align in their reporting periods coinciding with Groundwater Assessment Reports.

6.5. Geographical Setting

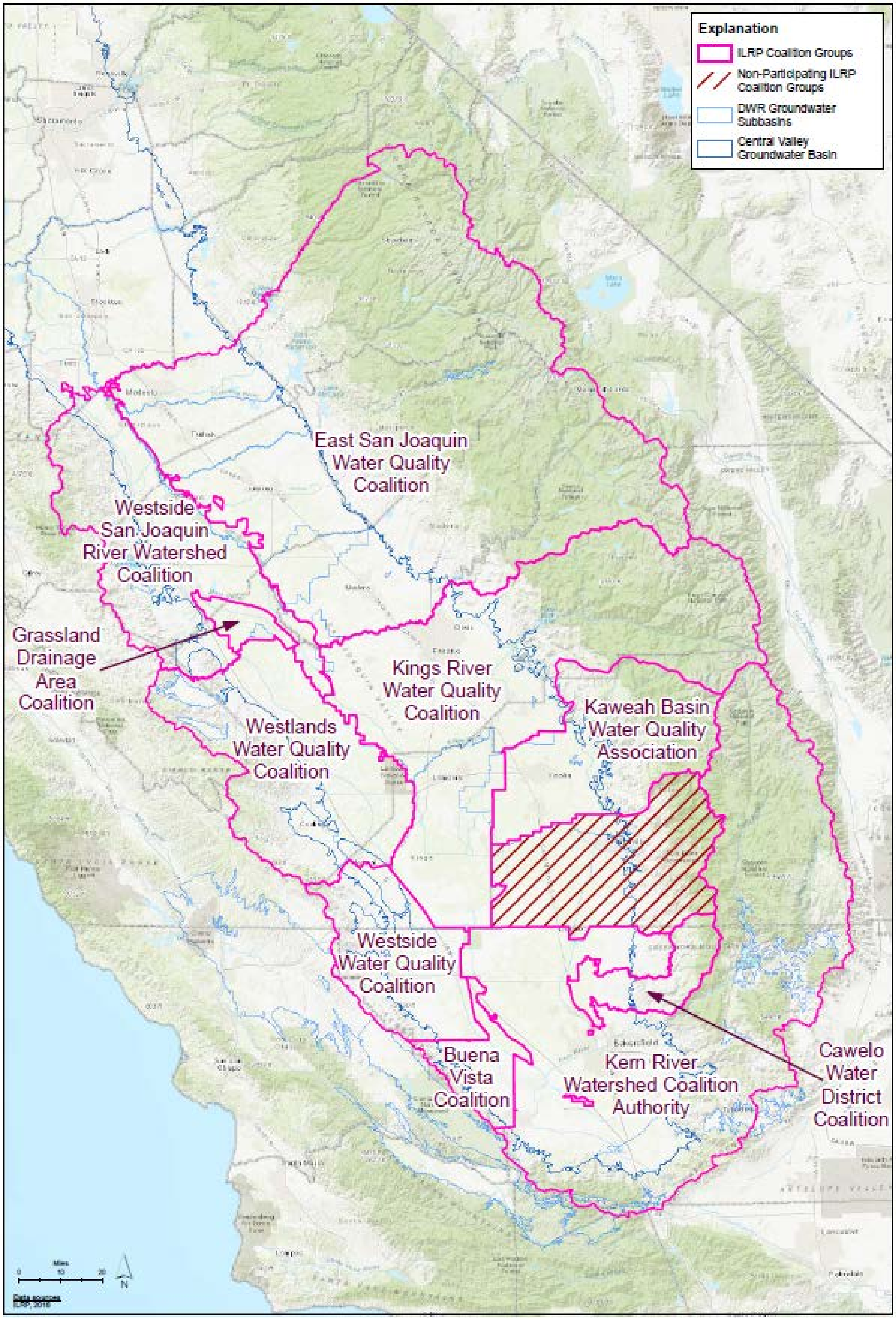
The CVGMC area is made up the groundwater monitoring networks developed by each of the member Coalitions. The area includes the geographic regions of the following Coalitions as part of Phase 1 of the CVGMC: Buena Vista Coalition, Cawelo Water District Coalition, East San Joaquin Water Quality Coalition, Grassland Drainage Area Coalition, Kaweah Basin Water Quality Association, Kern River Watershed Coalition Authority, Kings River Water Quality Coalition, , Westlands Water Quality Coalition, Westside San Joaquin River Watershed Coalition, and Westside Water Quality Coalition (**Figure 12**).

Each Coalition has developed its own network of wells for groundwater quality trend monitoring as described in the individual Coalition GQTMs. These networks include wells spatially distributed across high and low vulnerability areas of each Coalition region in accordance with Coalition-specified prioritization criteria. These well networks will be monitored by the Coalitions and incorporated into the CVGMC network for regional analysis and reporting.

6.6. Constraints

Any constraints that may disrupt the overall goals of the CVGMC are addressed in the Technical Workplan. Constraints associated with individual third-party sampling and data generation should be addressed in individual GQMPs and reported to the CVGMC. It is not anticipated that there will be any constraints that cannot be resolved or which will result in a compliance violation.

Figure 12. Geographical area covered by the CVGMC.



7. PROGRAM QUALITY OBJECTIVES

7.1. Data Quality Indicators

In order to account for the inherent level of uncertainty that can occur from the sampling design process through the result documentation, it is important for the program to have set limits of allowable error to ensure data are useable and supportive of the project goals.

Data Quality Indicators (DQIs) are the quantitative statistics and qualitative descriptors used to interpret the degree of acceptability or utility of data to the user (US EPA QA/G-5, 2002). The principal data quality indicators are precision, accuracy (bias), comparability, completeness, representativeness, and sensitivity.

Limits for error must be established for all applicable DQIs for every measurement conducted under the CVGMC program. Program definitions for each DQI are provided below. For minimum targets associated with each of the following DQIs, see **Section 14.** Project-specific limits for each DQI are provided in Table 5 of the individual QAPP for each participating member of the CVGMC and must at a minimum meet those laid out by this QAPrP.

Precision

Precision measures the agreement among repeated measurements of the same property under identical, or substantially similar, conditions. The closer two values that result from the same measurement under the same conditions are, the higher the degree of precision. The degree of precision can be a result of error and or the limits of the measurement system. A measurement quality objective (MQO) can be set for the allowable amount of variation between multiple measurements to account for limits of the measurement system and the inherent amount of user error associated with the measurement system. Program precision is monitored using duplicate quality control samples, including but not limited to field duplicates, laboratory duplicates, and matrix spike duplicates.

Accuracy (Bias)

Accuracy is a measure of the overall agreement of a measurement to a known value. Accuracy includes a combination of random error (precision) and systematic error (bias) components that are due to sampling and analytical operations.

MQOs can be set to limit bias and to set an amount of error as compared to a true value achieved for a measurement. Contamination, measurement error, and matrix interference are all examples of causes of reduction in accuracy of a measurement.

Contamination that may be introduced during sample handling, preparation, or analysis can be monitored with the use of field blanks and laboratory blanks. If contamination is introduced, blank sample results can provide the degree of bias resulting from the error.

Measurement errors can be monitored through the analysis of a known concentration range and compared to measured results. This can be done using certified reference materials and laboratory control spike samples.

Bias introduced through interfering conditions present in the sample matrix can be monitored by duplicate environmental samples with a known concentration of target analytes prior to analytical process, known as matrix spike samples.

Sensitivity and Resolution

Analytical sensitivity is commonly defined as the lowest value an instrument or method can measure with reasonable degree of certainty. Resolution is the capability of a method or instrument to discriminate between measurement responses representing different levels of a variable of interest. These limits are important to know when evaluating the appropriateness of a method or instrument for the requirements of a given study. Reporting limits represent the level at which a method or instrument can accurately measure a target compound. Reporting limits must be lower than the required project action limit to be appropriate for the project. At a minimum, the data collected under this QAPrP should meet the reporting limits outlined within **Section 13.**

Representativeness

Representativeness is the degree to which data accurately and precisely represent a characteristic of a population, parameter variations at a sampling point, a process condition, or an environmental condition. Representativeness addresses the degree to which the samples collected represent the study and address the program objectives. Though not directly measurable, representativeness depends on appropriate study design and adherence to appropriate standard operating procedures. For groundwater sampling, representativeness can be affected by the measurement of stagnant water in well casings, which are not representative of the chemical conditions of the aquifer. As such, sufficient well purging is required to be addressed in all QAPPs and sampling procedures to ensure representativeness is properly addressed for all project data generated.

Various spatial considerations exist in designing the individual Coalition GQTM well networks and the CVGMC network. These considerations focus on where and how to representatively monitor groundwater quality relative to agricultural activities. Spatial factors relating to the CVGMC and GQTM network design include delineation of areas to monitor and specific sites (wells) suitable for use in monitoring. The approaches used in developing the Coalition GQTM well networks are based on consideration of the GQTM requirements in the WDRs and include consideration of agricultural commodities, conditions discussed/identified in the GARs related to vulnerability prioritization, and areas identified in the GAR as contributing significant recharge to urban and rural communities.

Comparability

Comparability is a measure of the confidence with which one data set or method can be compared to another. Project data are comparable when evaluated against similar quality objectives and when utilizing similar methodology and reporting requirements. Given the nature of the CVGMC requiring data generated from a wide geographical region being used in aggregate to make long term trend evaluations and broad regulatory decisions, comparability of contributing projects is crucial to the efficacy of the Collaborative. All projects contributing to the CVGMC Program must maintain comparability by following the provisions outlined in this QAPrP.

Completeness

Completeness is a measure of the amount of valid data obtained from a measurement system. This assessment is typically expressed as a percentage of measurements reported within the prescribed limits associated with the respective DQOs, compared to those initially planned. Completeness evaluations ensure program requirements for data generation and reporting are met by contributing projects. Program completeness is assessed on three levels: field and transport, analytical, and batch completeness. Field and transport completeness is based on the number of samples successfully collected and transported to the appropriate laboratories. Analytical completeness is based on the number of samples successfully analyzed by the laboratory. Batch completeness is based on whether batches were processed with the appropriate QC samples, as prescribed by the method or defined by the laboratory. Minimum QC sample frequency requirements can be found in **Section 13** of this QAPrP.

8. SPECIAL TRAINING/CERTIFICATION

8.1. Specialized Training or Certifications

Field Crews

Specific training and certifications for field crews are the responsibility of the individual Project Managers and are addressed in Table 2 of the individual GQTM QAPPs. All field staff participating in the program must be properly trained on field collection protocols prior to sample collection. Training includes reviewing all sampling Standard Operating Procedures (SOPs), which detail procedures for collecting groundwater samples and associated QC samples. All personnel will be trained in proper calibration and deployment of equipment, sample handling and hold time requirements, and chain of custody procedures. To further safeguard against sampling error, all sampling by recently trained personnel should be done under the supervision of more experienced personnel who accompany sampling crews at least for the first time that they conduct sampling within the study fields. In addition to training for sampling, all sampling personnel should attend a field safety course.

Laboratories

All CVGMC laboratories must have an internal Quality Assurance Manual that is maintained and actively implemented in the day-to-day operations of the laboratory. Laboratory personnel should maintain current training in all relevant aspects of their role in the sample processing and data generation. Training records will be maintained by the laboratory Quality Assurance Officer and be available upon request.

8.2. Laboratory Certification Requirements

All laboratories processing program data will possess and maintain current Environmental Laboratory Accreditation Program (ELAP) certifications.

Participating laboratories will use the methodology specified by the individual QAPP and performed by qualified personnel in accordance with that accreditation.

9. PROGRAM DOCUMENTATION

9.1. CVGMC Planning Documents

ILRP Technical Workplan

The CVGMC has developed a Technical Workplan that identifies consistent approach(es) for monitoring and reporting among the Coalitions to meet requirements of the General Orders. This document outlines how monitoring and reporting will occur, and how quality assurance will be maintained as part of the CVGMC.

9.2. Quality Assurance Program Plan Distribution

Copies of this QAPrP will be distributed to all personnel and/parties involved in the project as outlined in the distribution list. If any parties associated with CVGMC data generation wish to update parts of the QAPrP, an amendment form should be completed to request an update. A signed amendment form must be submitted to the Program QA Officer for review. Once approved, the Project QA Officer will submit the amendment information to the CVRWQCB for final approval. When an amendment is approved, the QAPrP document will be updated and distributed to the all parties and personnel involved with the project.

Each individual QAPP submitted to the CVRWQCB will include details of when, where and how samples will be collected as well as which constituents will be measured. Field sampling and analytical SOPs will be included with each QAPP. These updates will not require an amendment to the QAPrP if the constituents and methods are already listed within **Table 1.** However, if the GQTM Workplan and associated QAPP requires the analysis of a constituent not already included in this QAPrP, a method not already identified, or proposes different DQOs that are less stringent than those listed, an amendment form must be submitted to the Program QA Officer for review once the GQTM is approved.

An alternative to a Coalition developing their own QAPP is to submit Addendum Forms under this QAPrP that will include information specific to their project for the following sections: 10. Sampling Process and Design, 11. Sampling Methods, 12. Sample Handling and Custody, 13. Analytical Methods, 14. Quality Control, 15. Instrument/Equipment Testing, Inspection and Maintenance, 16. Instrument/Equipment Calibration and Frequency, 17. Inspection/Acceptance of Supplies and Consumables.

If the Coalition chooses this option, all information within this QAPrP applies to their project in addition to the specifics outlined in the Addendum Form.

9.3. Standardized Forms

Field Sheets

Each individual QAPP will include the field sheet that will be used when samples are collected. An example field sheet is included in **Figure 13**. At a minimum field sheets must include the following:

- Project name
- Site name

- Site code
- Physical address of property on which well is situated
- State well number (if available)
- Sampling personnel
- GPS coordinates taken with each sampling event
- Sample type
- QC sample type
- Date and time of sample collection
- Results of field measurements
- Depth to standing water (static water level)
- Sampling conditions
- Constituents sampled
- Sample container
- Sample preservation

Chain of Custody

Each individual QAPP will include a Chain of Custody (COC) form that will be used when samples are collected. An example COC is included in **Figure 14**. At a minimum COC forms must include the following:

- Collection agency name and contact information
- Receipt agency name and contact information
- Sample Identification
- Date and time of sample collection
- Analyses requested
- Sample container type
- Number of sample containers
- Preservation
- Relinquished by name(s)
- Relinquished by date(s)
- Relinquished by signature(s)
- Received by name(s)
- Received by date(s)
- Received by signature(s)

Figure 13. Example field sheet.

Well Purging and Sampling

State Well #: ______ Site Code: ______

Site Name: ______

Property Address: ______

Date: ______

Weather: ______

Personnel: ______

______

Picture #(s): ______

Target Lat/Long: / ______

Field Lat.: ______

Field Long.: ______

Acc.: ______

Unit: ______

QC Site: Yes No

Blank pH: ______

Well Depth: ______

Depth to Water: ______

MP to LSE: ______

Casing Dia.: ______

Sample Point Description:

At the wellhead

After pressure tanks

From a holding tank

Spigot away from wellhead

After filter

Other: ______

Well Type: Domestic Irrigation Domestic/Irrigation

Meter Calibration Log				
	pH	EC	DO	ORP
Standard Used				
Temperature				

Purge start time:				**Purge Log**			
Time	Volume	Temp	EC	DO	pH	ORP	Comments

Purge Method: submersible turbine pump other: ______

Sampling Method: submersible turbine pump other: ______

			Sample Collection Log		**Sample time:**	
Analysis	**Container**	**Volume**	**Quantity**	Filtered Y/N	**Preservative**	**Lab**

Notes:

Figure 14. Example COC form.

REQUEST FOR ANALYSIS AND CHAIN-OF-CUSTODY RECORD

Page ___ of ___

Client Name:	
Address:	
Sampled By:	
Phone:	
Fax:	
Project Manager:	
Project Name:	

	Sample Identification	Sample Date	Sample Time	Sample Matrix	Number Containers	Container Type	Preservative	Analysis Requested						SAMPLE COMMENTS
1														
2														
3														
4														
5														
6														
7														
8														
9														
10														
11														
12														
13														
14														
15														

Comments:

Relinquished By		Relinquished By	
Signature		Signature	
Print Name		Print Name	
Organization		Organization	
Date	Time	Date	Time
Received By		**Received By**	
Signature		Signature	
Print Name		Print Name	
Organization		Organization	
Date	Time	Date	Time

Temperature at Log In: (°C)

9.4. Data Packages and Storage

All projects conducted as part of the CVGMC must maintain electronic records of field sheets, COCs, and laboratory data for all sampling events. Any original hard copy forms should be filed and kept at the Coalition's main office. Hard copies of laboratory reports may be archived as electronic files such as a PDF. Original GeoTracker EDFs must be saved electronically. GeoTracker EDFs must be uploaded to the GeoTracker and submitted to the CVGMC Data Management System (DMS). The CVGMC DMS will be housed on a third-party server with automatic backups performed nightly, at a minimum. Nightly backups will be replicated to at least one independent server to create redundancy and allow for instant replication if a failure occurs. All electronic files will be maintained for a minimum of 10 years.

A complete description of the data management process is described in this QAPrP in **Section 19.**

9.5. Additional Documents and Records

Additional documents may include photographic documentation, summary reports, meeting notes, presentations, and reports. All forms of documentation must be held on file where they are readily available if ever requested.

9.6. Retention of Documents

All data and/or other products created by the program will be retained by the participating entities and contract laboratories for a minimum of 10 years. The documents may be held for 10 years as electronic copies. Servers where the files reside will be backed up nightly.

9.7. Report Documents

Reporting will be accomplished using a common framework among the participating Coalitions. As required by the ILRP General Orders, each Coalition will provide an Annual Report describing groundwater monitoring in their region. The individual Coalition Annual Reports will be consistently formatted to include basic data tables, time series plots (when sufficient data are available), and figures to display the monitoring results of the current year and variation across years. Upon Executive Officer approval of the Phase 1 Technical Workplan, every five years, a coordinated report will be provided to the CVRWQCB that characterizes groundwater quality across the entire Central Valley (or the portions of the Central Valley participating in the CVGMC).

Annual Reports

Annual analysis and reporting of results related to the individual Coalition GQTMs will focus on visual and tabular presentation of data with limited representation of data interpretation. Annual reports will include a map or maps of the wells sampled and monitored as part of the GQTM network. Results from sampling will be provided in a tabulated format consisting of a summary of the results using statistics such as recent, minimum, maximum, and mean result, in addition to a table providing all field and analytical results.

CVGMC Five-Year Assessment Report

Reporting for the CVGMC will include more extensive analysis at five-year intervals. Every five years, a CVGMC Five-Year Assessment Report will be provided to the CVRWQCB that characterizes groundwater quality across the entire Central Valley (or the portions of the Central Valley participating in the CVGMC). The report will include separate chapters reporting on trends in groundwater quality in each Coalition region as well as a chapter(s) that characterizes groundwater quality across all participating regions. Each chapter will be consistently formatted with common maps, figures, and text to facilitate review by Regional Board staff and other interested parties.

GROUP B. DATA GENERATION AND ACQUISITION

10. SAMPLING DESIGN

10.1. Sampling Process Design Program Policy

An overview of the considerations and criteria for the design of the CVGMC trend monitoring network is detailed in the Technical Workplan focusing on the objectives of the program and requirements of the General Orders, including rationale for appropriate monitoring well distribution, encompassing agricultural regions of the Central Valley.

The primary objectives of the CVGMC GQTM are:

1) *Determine current water quality conditions of groundwater relevant to irrigated agriculture;*
2) *Develop long-term groundwater quality information that can be used to evaluate the regional effects of irrigated agricultural practices and changes in agricultural practices;*
3) *Understand long-term temporal trends in regional groundwater quality, particularly as they relate to effects from irrigated agriculture on potential sources of drinking water for communities;*
4) *Evaluate regional groundwater quality conditions in the CVGMC region, particularly in HVAs, and identify differences in groundwater quality laterally and vertically within the CVGMC region;*
5) *Distinguish groundwater quality changes associated with irrigated agriculture compared to other non-agricultural factors.*

For purposes of characterizing the relatively shallower part of the groundwater system, the CVGMC emphasizes monitoring in the Upper Zone within the upper part of the groundwater system. Wells selected for trend monitoring will be sampled and tested at an annual frequency for water quality parameters including nitrate as nitrogen (as N), electrical conductivity at 25 °C (EC), pH, dissolved oxygen (DO), and temperature. Electrical conductivity, pH, DO, and temperature will be measured in the field whereas nitrate concentration will be analyzed by a certified laboratory. In some Coalition regions, public water supply wells represent additional ongoing monitoring wells that are regularly tested. During the first monitoring event, wells selected for inclusion in the CVGMC GQTM will be sampled and tested for additional water quality constituents, including total dissolved solids (TDS), major anions (carbonate, bicarbonate, chloride, sulfate), and major cations (boron, calcium, sodium, magnesium, potassium). Wells will be tested for these additional constituents every 5 years.

Implementation of the CVGMC Technical Workplan will further the understanding of long-term temporal trends in regional groundwater quality. The regional-scale and long-term trend regional monitoring program involves establishing a system through which the groundwater quality within the CVGMC region will be monitored on a long-term basis to evaluate temporal trends and their relationship with irrigated agriculture. The approach to monitoring for long-term regional groundwater quality trends in the GQTM emphasizes evaluation of trends in wells that are believed to provide a representation of regional trends in areas dominated by irrigated agriculture. The spatial distribution of the monitoring network across the CVGMC region will be variable based on the prioritization of monitoring applied by individual Coalitions. Areas of generally higher priority, most commonly in the HVAs identified in the Coalition GARs, are a greater emphasis for long-term trend monitoring locations than areas of relatively lower priority, especially in lower vulnerability areas because hydrogeologic conditions suggest these areas are less vulnerable to contamination.

10.2. Deferral of Sampling Design Description

This QAPrP does not dictate the exact spatial distribution or prioritization of GQTM wells; the details of prioritization and final well selection are included in each Coalition's GQTM. Specific sample types, matrices, and volumes are outlined in Table 5 of the individual project QAPPs. Project activity schedule and the logistics of submitting samples to contract laboratories are outlined in individual field sampling SOPs. As part of individual Coalition GQTMs, a network of proposed wells exists for each Coalition region recognizing the applied prioritization and any associated delineation of targeted monitoring areas. A variety of factors were considered by individual Coalitions in prioritizing monitoring areas within their respective regions and these are summarized in the CVGMC Technical Workplan including high vulnerability areas, irrigated agriculture and commodities, groundwater quality trends, nitrate MCL exceedances, communities, and recharge areas relative to communities (including non ag sources).

11. SAMPLING METHODS

11.1. Sampling Method Program Policy

All samples collected for inclusion in the CVGMC GQTM analysis will be collected according to detailed SOPs included in the individual QAPPs. The SOPs contain instructions for collecting samples and cleaning equipment between samples. Below is a brief description of the minimal sampling method requirements.

Upon arrival at the well, an attempt will be made to measure the depth to water. Water levels can be measured using an electronic sounder or an air line; air lines have been installed on some agricultural supply wells and can be used to determine depth to water. When possible, it is preferred to use an electronic sounder and record the depth to water to the nearest 0.01 feet. Typically, all depth measurements should be made from the top (the highest point) of the inner well casing. The measuring point location is recorded on the field sheet and used in all subsequent measurements. If there is no measuring point or access to the inside of the well a note will made on the field data sheet.

Field parameters (pH, water temperature, EC, ORP and DO) are measured using field meters specified in the individual QAPPs. The meters will be calibrated for pH, ORP, and DO once in the morning prior to beginning sampling. For pH, a single 3-point calibration with be done using pH 4, 7, and 10 standards; exceptions are if the pH range is known and a calibration is conducted within that range. Conductivity will be calibrated in the morning prior to sampling, and then recalibrated to the nearest calibration solution whenever the conductivity of the well changes substantially. Calibration standards will be maintained at temperatures close to the temperature of the well water.

Except as noted below, purging should be performed for all groundwater monitoring wells prior to sample collection in order to remove stagnant water from within the well casing and ensure that a representative sample is obtained. In general, purging should be done to remove three casing volumes prior to sampling. The field sheet should include details for tracking the amount of volume purged relative to the depth of the well and well casing diameter. It may not be possible to purge three volume casings of water due to the volume of the casing which would result in considerable time and effort. In addition, it may not be necessary to purge three casing volumes for wells that are used daily and are not likely to have stagnant water in the well casing. Other methods for ensuring that the water collected is an adequate representation of the water quality in the groundwater is to monitor field parameters with a flow through system and wait to collect a sample until the measurements are steady, or to use a no-purge sampler such as a Hydrasleeve.

After samples are collected, they must be kept away from sunlight and kept at ≤ 6°C until extraction or analysis. Field personnel collect ten percent of the total samples for quality assurance purposes (5% field duplicate and 5% blank samples). Duplicate field parameter measurements are not necessary. The duplicate samples are submitted to the laboratory as semi-blind samples. Field QC samples are stored at ≤ 6°C alongside environmental samples until extraction or analysis. Field blank samples are processed in the field identically as the other samples using deionized water as sample water. The blank samples are submitted to the laboratory as semi-blind samples.

Any deviation from the written SOP requires notification of the Project QA Officer. All deviations or problems will be noted on the field sheet and corrective actions should be determined by the Project QA Officer. Deviations will also be reviewed by the CVGMC Program QA Officer to determine acceptability of data.

11.2. Deferral of Sampling Method Information

Individual QAPPs include the details for sample collection, including field calibration and sampling SOPs, and purging details. The QAPPs must give enough information to ensure that sampling methods will result in a sample that is void of contamination, representative of the groundwater, and is reproducible. Sample container, volume, and preservative requirements are specified in Table 5 of each individual QAPP. Project-level corrective actions in response to problems that occur during sample collection are the responsibility of the individual Project QA Officers. The Program QA Officer may be included, if necessary.

12. SAMPLE HANDLING AND CUSTODY

12.1. Sample Handling and Custody Program Policy

All sample containers should be clearly labeled with sample ID, collection date and time, collector, and requested analyses. All sampling SOPs must be followed while collecting samples. Custody of all samples is documented and traceable from collection time to submittal for analysis on a Chain of Custody (COC) form. COCs must be with samples during transport to the laboratory. The samples are considered in custody if:

- They are in actual possession;
- They are in view after being in physical possession;
- They are placed in a secure area (accessible by or under the scrutiny of authorized personnel only after in possession).

All samples and accompanying COCs are signed by the sampler in charge and submitted to analyzing laboratories by the samplers, by private overnight courier, or by overnight common parcel service. Once the laboratory has received the samples and COCs, they are responsible for maintaining custody logs sufficient to track each sample submitted and to analyze or preserve each sample within specified holding times.

Enough sample quantity should be collected to permit more than one analysis in case samples need to be re-analyzed. The contract laboratories may recommend sample quantities as well as types of containers for sample collection; most laboratories offer containers to use for analysis. All samples collected for use in the CVGMC GQTM must at a minimum follow program-defined QA requirements for sampling containers, holding time, and sample custody outlined in **Table 3** below. Holding times refer to the maximum time limit at which a laboratory must analyze a sample for the constituent listed. Any sample handling and custody information that deviates from the program sampling handling requirements will be described within the individual GQTMP QAPP and submitted to the CVGMC QA Officer as an amendment to the CVGMC QAPrP.

Table 3. Sample handling and custody.

Analyte	Recommended Container	Initial Preservation/Holding Requirements	Maximum Holding Time
Nitrate (as N)	Polyethylene	Cool to ≤ 6°C	48 hours
Nitrate + Nitrite (as N)	Polyethylene	Cool to ≤ 6°C; H_2SO_4 to pH ≤ 2	28 days
Carbonate	Polyethylene	Store at ≤ 6°C	14 days
Bicarbonate	Polyethylene	Store at ≤ 6°C	14 days
Chloride	Polyethylene	Store at ≤ 6°C	28 days
Sulfate (SO_4)	Polyethylene	Store at ≤ 6°C	28 days
Boron	Polyethylene	Preserve HNO_3 pH ≤2, store at ≤ 6°C	6 months
Calcium	Polyethylene	Preserve HNO_3 pH ≤2, store at ≤ 6°C	6 months

Analyte	Recommended Container	Initial Preservation/Holding Requirements	Maximum Holding Time
Magnesium	Polyethylene	Preserve HNO_3 pH ≤2, store at ≤ 6°C	6 months
Potassium	Polyethylene	Preserve HNO_3 pH ≤2, store at ≤ 6°C	6 months
Sodium	Polyethylene	Preserve HNO_3 pH ≤2, store at ≤ 6°C	6 months
Total Dissolved Solids	Polyethylene	Store at ≤ 6°C	7 days

13. ANALYTICAL METHODS

13.1. Analytical Methods Policy

Table 5 of the individual GQTM QAPPs identifies the specific analytical methods to be used. All analytical methods employed by a project must be identified within this QAPrP and will be subject to the requirements below.

13.2. QA Program-Defined Analytical Method Requirements

Standard Methodology

For the purposes of this QAPrP, standard methodology is defined as methods that follow a procedure approved by the US EPA or provided in *Standard Methods for the Examination of Water and Wastewater.* Additionally, methods developed or published by the US Geological Survey (USGS), American Society of Testing Materials (ASTM), and Association of Official Analytical Chemist (AOAC) may be used by accredited laboratories.

If a field crew or laboratory uses a method that is not listed in **Table 4**, the Project QA Officer must review the validity and comparability of the data generated following that method. The data validation process should consist of determining the sensitivity level (MDL and RL), accuracy of QC samples and standards, precision of duplicate data, and analytical bias associated with the new method. This information should be compared to the same components associated with the method in this QAPrP. If the Project QA Officer determines the achievability of the new method is comparable to the method listed in this QAPrP, justification for the new method and a copy of the method should be submitted as an amendment to this document and approved by the State Board QA Officer.

The Project QA Officer should be in communication with the Laboratory Project Manager to resolve analytical issues, when they arise. It is the responsibility of the Project QA Officer to determine the most appropriate course of action to resolve any problems and/or accept data. All corrective actions are overseen by the Project QA Officer and should be reported in the annual reports.

Laboratory Turnaround Time

Laboratory reports and electronic deliverables will be submitted to the individual Project Managers within 60 days of samples being submitted to the laboratory. The Program QA Officer will be notified when all samples have been collected and if the laboratory turnaround time has been exceeded.

Table 4. List of acceptable analytical methods for constituents and maximum sensitivity requirements.

Field equipment and laboratories must be able to achieve reporting limits that are equal to or less than those listed.

Constituent	Acceptable Methods	Reporting Limit	Reporting Unit
Field Parameters			
Dissolved Oxygen (DO)	EPA 360.1, EPA 360.2, SM 4500-O	0.1	mg/L
Electrical Conductivity (EC) at 25 °C	EPA 120.1, SM 2510B	2.5	µS/cm
pH	EPA 150.1, EPA 150.2, SM 4500-H+B	0.1	pH units
Temperature	SM 2550	0.1	°C
Turbidity	EPA 180.1, SM 2130B	1	NTU
Nutrients			
Nitrate (as N)	EPA 300.0, EPA 300.1, EPA 351.3, EPA 353.2, SM 4500-NO3, SM 4110 B,	0.1	mg/L (as N)
Nitrate + Nitrite (as N)		0.1	mg/L (as N)
Anions			
Carbonate	EPA 310.1. EPA 310.2, SM 2320B	10	mg/L
Bicarbonate		10	mg/L
Chloride	EPA 300.0, EPA 300.1, EPA 325.2, EPA 325.3, SM 4110B, SM 4110C, SM 4500-Cl	0.25	mg/L
Sulfate (SO4)	EPA 300.0, EPA 300.1, EPA 375.1, EPA 375.2, EPA 375.3, EPA 375.4, SM 4110B, SM 4110C, SM 4500-SO42-C	1	mg/L
Cations			
Boron	EPA 200.5, EPA 200.7, EPA 212.3, SM 3120 B, SM4500-B-B	0.1	mg/L
Calcium	EPA 200.5, EPA 200.7, EPA 215.1, EPA 215.2, SM 3111B, SM 3120 B, SM 3500-Ca B	0.5	mg/L
Magnesium	EPA 200.5, EPA 200.7, EPA 242.1, SM 3111B, SM 3120 B	0.06	mg/L
Potassium	EPA 200.7, EPA 258.1, SM 3111B, SM 3120 B, SM 3500-K B	1	mg/L
Sodium	EPA 200.5, EPA 200.7, EPA 273.1, SM 3111B, SM 3120 B, SM 3500-Na B	0.01	mg/L
Solids			
Total Dissolved Solids	EPA 160.1, SM 2540C	10	mg/L

14. QUALITY CONTROL

14.1. Program Policy

Samples analyzed as part of the CVGMC will be subjected to laboratory and method-specific guidelines to maintain comparability across multiple projects. All projects must utilize the minimum analytical QC outlined below to address the DQIs outlined in this QAPrP within **Section 7.1.**

14.2. CVGMC Programmatic MQOs

Measurement quality objectives are the individual performance or acceptance goals for the individual DQIs. All projects must adhere to the minimum QAPrP MQOs; approved QAPPs may have more stringent MQOs.

Field Quality Control

Field QC results must adhere to the limits of error and frequency requirements detailed in **Table 5**. Field QC frequencies are calculated to ensure that a minimum of 5% of all analyses are for QC purposes (both field duplicate and field blanks).

Table 5. Field Sampling QC.

Sample Type	Frequency	Acceptable Limits	Corrective Action
Field Duplicate	5% annual total	RPD ≤ 25%	Determine cause, take appropriate corrective action.
Field Blank	5% annual total	Detectable substance contamination <RL or < sample/5	Determine cause of problem, remove sources of contamination.

Analytical Quality Control

Analytical QC results must adhere to the minimum limits of error and frequency requirements detailed in **Table 6**. All analytical QCs must be analyzed at a frequency of 1 every 20 samples, minimum of 1 per batch.

Table 6. Analytical measurement quality objectives.

Sample Type	Frequency	Acceptable Limits	Corrective Action
Nutrients			
Lab Blanks (method, reagent, instrument)	1 per 20 samples, minimum 1 per batch	Detectable substance contamination <RL	Determine cause of problem, remove sources of contamination, reanalyze suspect samples or flag all suspect data.
Lab Duplicate*	1 per 20 samples, minimum 1 per batch	RPD < 25%	Determine cause, take appropriate corrective action. Recalibrate and reanalyze all suspect samples or flag all suspect data.
Matrix Spike	1 per 20 samples, minimum 1 per batch	80-120%	Determine cause, take appropriate corrective action. Recalibrate and reanalyze all suspect samples or flag all suspect data.
Lab Control Spike, CRM, or SRM	1 per 20 samples, minimum 1 per batch	90-110%	Determine cause, take appropriate corrective action. Recalibrate and reanalyze all suspect samples or flag all suspect data.
Anions			
Lab Blanks (method, reagent, instrument)	1 per 20 samples, minimum 1 per batch	Detectable substance contamination <RL	Determine cause of problem, remove sources of contamination, reanalyze suspect samples or flag all suspect data.
Lab Duplicate*	1 per 20 samples, minimum 1 per batch	RPD < 25%	Determine cause, take appropriate corrective action. Recalibrate and reanalyze all suspect samples or flag all suspect data.
Lab Control Spike, CRM, or SRM	1 per 20 samples, minimum 1 per batch	75-125%	Determine cause, take appropriate corrective action. Recalibrate and reanalyze all suspect samples or flag all suspect data.
Cations			
Lab Blanks (method, reagent, instrument)	1 per 20 samples, minimum 1 per batch	Detectable substance contamination <RL	Determine cause of problem, remove sources of contamination, reanalyze suspect samples or flag all suspect data.
Lab Duplicate*	1 per 20 samples, minimum 1 per batch	RPD < 25%	Determine cause, take appropriate corrective action. Recalibrate and reanalyze all suspect samples or flag all suspect data.
Matrix Spike*	1 per 20 samples, minimum 1 per batch	75-125%	Determine cause, take appropriate corrective action. Recalibrate and reanalyze all suspect samples or flag all suspect data.

SAMPLE TYPE	FREQUENCY	ACCEPTABLE LIMITS	CORRECTIVE ACTION
Lab Control Spike, CRM, or SRM	1 per 20 samples, minimum 1 per batch	75-125%	Determine cause, take appropriate corrective action. Recalibrate and reanalyze all suspect samples or flag all suspect data.
Total Dissolved Solids			
Lab Blanks (method, reagent, instrument)	1 per 20 samples, minimum 1 per batch	Detectable substance contamination <RL	Determine cause, take appropriate corrective action. Recalibrate and reanalyze all suspect samples or flag all suspect data.
Lab Duplicate*	1 per 20 samples, minimum 1 per batch	RPD < 25%	Determine cause, take appropriate corrective action. Recalibrate and reanalyze all suspect samples or flag all suspect data.
Lab Control Spike, CRM, or SRM	1 per 20 samples, minimum 1 per batch	80-120%	Determine cause, take appropriate corrective action. Recalibrate and reanalyze all suspect samples or flag all suspect data.

*For the purposes of this program it is acceptable for the matrix spike duplicate or the laboratory control duplicate to stand in for the lab duplicate as a measure of the precision of the analytical method.

Precision will be assessed through a combination of field duplicate samples and laboratory duplicate samples. Precision of a pair of samples is measured as the relative percent difference (RPD) between a sample and its duplicate—a laboratory control sample (LCS) and its duplicate (LCSD), a matrix spike (MS) and matrix spike duplicate (MSD), an environmental sample (E) and field duplicate (FD), or an environmental sample and its associated lab duplicate. It is calculated as follows:

$$RPD\ (\%) = \left| \frac{2(V_i - V_D)}{V_i + V_D} \right| \times 100$$

V_i = The measured concentration of the initial sample
V_D = The measured concentration of the sample duplicate

For precision assessment purposes, any lab duplicate, including a matrix spike duplicate or a lab control spike duplicate, may function as the lab duplicate in any batch.

Accuracy is assessed using either an LCS or MS. For an LCS, lab water is spiked with a known concentration of a target analyte and the percent recovery (PR) is reported. PR in an LCS is calculated as follows:

$$\%\ Recovery = \left(\frac{V_{LCS}}{V_{Spike}} \right) \times 100$$

V_{LCS} = The measured concentration of the spiked control sample
V_{Spike} = The expected spike concentration

A MS can also be used to assess accuracy. For a MS, environmental water is spiked with a known concentration of a target analyte and the PR is reported. PR in and MS is calculated as follows:

$$\% \, Recovery = \left(\frac{V_{MS} - V_E}{V_{Spike}} \right) x \, 100$$

V_{MS} = The measured concentration of the spiked matrix sample
V_{Spike} = The concentration of the spike added
V_E = The measured concentration of the original (unspiked) matrix sample

The MS should not be used solely to assess accuracy due to the likelihood of matrix interference; however, if an LCS does not fall within acceptance criteria an MS may be used to validate a batch if the MS is within acceptance criteria. Some constituents are difficult to spike (e.g., Total Dissolved Solids); therefore, a laboratory may choose to analyze a certified reference material (CRM). A CRM analysis may be used in place of an LCS analysis.

14.3. Field and Laboratory Corrective Actions

Batches should be reanalyzed if a single QC sample did not meet an MQO due to an identifiable laboratory error and/or MQOs are not met for more than 50% of analytes analyzed in a QC sample. When batches are reanalyzed, the laboratory should provide both results to the third party. If DQOs fail, but neither of the above scenarios is applicable, the laboratory should follow the corrective actions prescribed in **Table 5** and **Table 6**. Overall, all data failing to meet MQOs should be flagged; re-analysis may occur to confirm improvements in accuracy, precision or contamination measures. The laboratory Project Manager and the Project QA Officer may further discuss additional corrective actions on a case by case basis.

Field crews and contract laboratories are responsible for responding to failures in their measurement systems. If sampling or analytical equipment fails, personnel must record the problem according to their documentation protocols.

15. INSTRUMENT/EQUIPMENT TESTING, INSPECTION, AND MAINTENANCE

15.1. Programmatic Policies

Field Equipment

All field equipment must be inspected and repaired as necessary prior to each sampling event. Routine maintenance and repair of field equipment should follow manufacturer instructions and guidelines. Records of field equipment maintenance and repairs should be maintained for each instrument and are summarized in Table 8 of the individual project QAPPs and outlined in attached sampling SOPs. Project Field Leads are responsible for ensuring that inspection and maintenance activities are completed in accordance with project requirements. Project QA officers oversee all maintenance records generated by project personnel. These records will be available to the Program Manager upon request.

Laboratory Equipment

Routine laboratory instrument testing, inspection, and maintenance should be carried out by a qualified technician. Laboratories are responsible for testing, inspecting, and maintaining all laboratory equipment according to manufacturer specifications. Frequency and procedures for maintenance of analytical equipment used by each laboratory are documented in the Quality Assurance Manual for each laboratory, which will be available to Program Managers from any contract laboratory on request. Laboratory instrument inspection and maintenance activities are outlined in Table 8 of the individual project QAPPs. Any instrument deficiencies that are not resolved prior to data generation will be reviewed by the Project QA Officer. Corrective actions for any deficiencies are the responsibility of the Project QA Officer.