Appendix E – Hydrogeologic Technical Analysis

Hydrogeologic Technical Analysis
Mendota Pool Group
Exchange Program
EIS/EIR

Prepared For:
Westlands Water District
United States Bureau of Reclamation
Mendota Pool Group

Prepared By:
Luhdorff and Scalmanini, Consulting Engineers

August 2018

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LIST OF ACRONYMS/ABBREVIATIONS

ac	acres
af	acre ft
afy	acre-ft per year
BF	Baker Farms
bgs	below ground surface
BIS	Basic Irrigation Scheduling
CASGEM	California Statewide Groundwater Elevation Monitoring
CCC	Columbia Canal Company
CCID	Central California Irrigation District
CDPH	California Department of Public Health and Safety
CEQA	California Environmental Quality Act
cfd/ft	cubic-ft per day/per foot
cfs	cubic-ft per second
CGH	Coelho-Gardner-Hanson
CIMIS	California Irrigation Management Information System
CVHM	Central Valley Hydrologic Model
CVP	Central Valley Project
DMC	Delta-Mendota Canal
DWR	California Department of Water Resources
EC	Electrical Conductivity
EIR	Environmental Impact Report
EIS	Environmental Impact Statement
ET	evapotranspiration
Exchange Agreement	10-year Exchange Agreement
ft	feet
ft/day	ft per day
FWD	Farmers Water District
GAMA	Groundwater Ambient Monitoring and Assessment Program
GHB	General Head Boundary
GRF	San Joaquin River at Gravelly Ford

GSA	Groundwater Sustainability Agencies
GWL	Groundwater levels
I.D.	Irrigation District
K	hydraulic conductivity
KDSA	Kenneth D. Schmidt & Associates
LAK	Lake Package
LKT	Lake Transport Package
LSCE	Luhdorff and Scalmanini Consulting Engineers
MAE	mean absolute error
ME	mean error
MEN	San Joaquin River at Mendota Dam
mg/L	milligrams per liter
MNW2	Revised Multi-node Well Package
MPG	Mendota Pool Group
msl	mean sea level
MW	Monitoring Well
MWA	Mendota Wildlife Area
NASS	National Agricultural Statistics Service
NAWQA	National Water-Quality Assessment
NCR	New Columbia Ranch
NEPA	National Environmental Policy Act
NRCS	Natural Resources Conservation Service
NRMSE	Normalized Root Mean Squared Error
PFC	Paramount Farming Company
Pool	Mendota Pool
Project	Mendota Pool Exchange Program
PSA	Primary Study Area
RCH	Recharge Package
Reclamation	U.S. Department of Interior's Bureau of Reclamation
RMSE	Root Mean Squared Error
SFR	Streamflow Routing package
SFT	Streamflow Transport package

SGMA	Sustainable Groundwater Management Act
SJB	San Joaquin River at Below Bifurcation
SJR	San Joaquin River
SJREC	San Joaquin River Exchange Contractors Water Authority
SJRRP	San Joaquin River Restoration Program
SLDMWA	San Luis Delta Mendota Water Authority
SLWD	San Luis Water District
SSA	Secondary Study Area
SSM	Sink Mixing Package
SUB	Subsidence and Aquifer-System Compaction Package
SWRCB	State Water Resources Control Board
TDS	Total Dissolved Solids
TLF	Terra Linda Farms
µmhos/cm	micro mhos per centimeter
UPW	Upstream Weighting
USBR	United States Bureau of Reclamation
USGS	United States Geological Survey
Valley	San Joaquin Valley
W.D.	Water District
WEL	Well package
WO	Wonderful Orchards
WWD	Westlands Water District

1 INTRODUCTION

This report presents the results of analyses conducted by Luhdorff and Scalmanini Consulting Engineers (LSCE) on the influence of the Mendota Pool Group's (MPG) proposed extension of the existing Mendota Pool Exchange Program (Project) on groundwater and surface water conditions in the vicinity of the Mendota Pool and in Westlands Water District (WWD). The scope of the analyses focused on providing information for the development of an environmental impact report (EIR) and environmental impact statement (EIS) consistent with the California Environmental Quality Act (CEQA) and National Environmental Policy Act (NEPA) requirements. The technical analysis relies primarily on a numerical groundwater flow model coupled with a solute transport model to assess the impact of pumping groundwater for exchange on groundwater levels, salinity concentrations in groundwater, and subsidence. The influence of pumping for groundwater exchange on projected salinity concentrations in the Mendota Wildlife Area (MWA) and San Joaquin River at the Mendota Dam is evaluated using a surface water quality mixing model.

This first portion of the report contains a summary of the hydrogeologic conceptualization of the groundwater system in the vicinity of the Mendota Pool (Pool) and surrounding area, description of the numerical flow, transport and mixing models, and the results of the calibration of the flow and transport models to historical groundwater elevations and quality. The second portion includes a description of the development and results of predictive model scenarios which simulate the influence of pumping for groundwater exchange on groundwater and surface water conditions.

1.1 Background

The MPG entered into a 10-year Exchange Agreement (Exchange Agreement) in 2005 to allow for the exchange of up to 25,000 acre-ft of water per year (afy) between the MPG and the U.S. Department of Interior's Bureau of Reclamation (Reclamation). The existing Exchange Agreements authorize the MPG to pump water from existing groundwater wells into the Pool and exchange it contractually for Central Valley Project (CVP) water that is delivered to MPG land located in WWD. MPG-owned farmland in WWD is located approximately 10 to 45 miles south of the Pool. The Exchange Agreement expired in February 2015. In 2015, the MPG entered into a three-year agreement with Reclamation with approvals on an annual basis by the parties to the Exchange Agreement. This "bridging" agreement will allow the MPG to complete the EIS/EIR for the extension of the existing Mendota Pool Exchange Program without interruption.

The proposed 20-year extension would allow the MPG to discharge groundwater up to 26,316 afy to the Pool in exchange for 25,000 afy of CVP water delivered to MPG farmland in WWD with a maximum exchange amount of 400,000 acre ft (af) over the 20-year period. This would enable the MPG to maintain agricultural production on historically irrigated farmlands in WWD to offset fluctuations in CVP water deliveries.

1.2 Objectives and Approach

The primary objective of this investigation is to report changes in groundwater and surface water conditions that may occur from the extension of the Exchange Agreement over a 20-year time period. Based on proposed design constraints, four potential Project alternatives have been identified. A brief summary is provided below.

- **No Action Alternative 1A:** This alternative involves no MPG pumping for groundwater exchange and an increase in MPG groundwater pumping for overlying and adjacent use in order to irrigate all MPG-owned land in the vicinity of the Pool. MPG lands in WWD that previously received exchanged water will not be irrigated.
- **No Action Alternative 1B:** This alternative is similar to No Action Alternative 1A except that MPG lands in WWD will be irrigated with groundwater pumped in WWD rather than not being irrigated. The influence of additional groundwater pumping in WWD to offset the loss of exchange water was analyzed empirically without the use of the numerical groundwater flow model.
- **Proposed Action:** This scenario involves MPG pumping for groundwater exchange and adjacent use. Pumping for exchange will be up to 26,316 afy and pumping for adjacent use will be 12,000 afy. In addition, the Proposed Action will utilize existing groundwater recharge facilities in New Columbia Ranch and construction and utilization of a groundwater recharge canal facility west of the Fresno Slough to enhance recharge of groundwater and improve groundwater quality.
- **Alternative 2:** This scenario is similar to the Proposed Action with an additional groundwater recharge facility (River Ranch North) located west of the Fresno Slough and adjacent to the recharge canal described in the Proposed Action.

The approach in conducting the technical analyses was divided into three primary tasks:

The first task involved the development of a conceptual hydrogeologic model which incorporated multiple interconnected parts of the groundwater and surface water system. This phase of the analysis included the characterization of hydrogeologic units (aquifers and aquitards), aquifer properties, spatial and temporal trends in groundwater levels and quality, groundwater flow directions, surface water features, groundwater and surface water interactions, land use and related water use, spatial and temporal trends in precipitation, and historical aquifer response (groundwater elevations and quality) to pumping and other stresses.

In the second task, data used to develop the conceptual model was utilized to refine, develop, and calibrate numerical models of the hydrologic system. This phase involved updating and recalibrating the numerical groundwater flow model through 2012, developing and calibrating a coupled solute transport model to evaluate the fate and transport of salts, and developing and calibrating water quality models for the Pool and Fresno Slough. The aquifer system in the vicinity of the Pool consists of many complex and inter-related processes. For this reason, a numerical modeling approach was selected to simulate the groundwater flow and solute transport within hydrogeologic system and was the foundation of the bulk of the technical analysis. The water quality mixing models developed were shown to more effectively simulate water quality conditions in the Pool and Fresno Slough. Consequently, these models were used to evaluate this portion of the system.

In the third task, the calibrated numerical flow, solute transport, and surface water quality models were utilized to develop predictive scenarios based on the Project alternatives listed above. Results from the predictive scenarios evaluated to determine the projected impacts of project alternatives on groundwater levels, groundwater quality, compaction above the Corcoran clay, and surface water quality.

To investigate potential impacts relating to the extension of the Exchange Agreement, primary and secondary study areas were selected (**Figure 1-1**). The primary study area (PSA) encompasses the area that is, for the most part, included in the numerical flow and transport models and where the primary influences of the proposed project alternatives will occur. The extent of the PSA is based on the area that has been most affected by MPG pumping historically and the boundaries of the ongoing MPG Exchange and Monitoring Program (**Figure 1-2**). The secondary study area (SSA) encompasses the PSA and a larger region in its vicinity with potential regional cumulative and indirect impacts to occur. The SSA includes WWD, including areas where exchanged water is received and pumping increases in the No Action Alternative 1B will occur (**Figure 1-1**).

2 CONCEPTUAL MODEL

The term "groundwater system," as used here, describes a complex configuration of inter-related groundwater sources (recharge) and sinks (discharge) all contained within a physical medium comprised of various geologic and hydrostratigraphic units. Conceptualization of the groundwater system contained within the domain of the numerical flow model, particularly the PSA, included compilation and interpretation of available information and expert opinions relating to:

- Local and regional geology/hydrostratigraphy (aquifer structure)
- Sediment textures and aquifer hydraulic properties
- Spatial and temporal trends in precipitation
- Land use and related water use
- Locations and hydraulic character of surface water features
- Groundwater level trends and flow directions
- Observed groundwater/surface water interactions
- Location and volumes of known and estimated groundwater extraction
- Existing and proposed enhanced groundwater recharge and/or banking operations
- Spatial and temporal trends in groundwater levels and quality
- Observed subsidence

Sources of information for this effort included:

- United States Geological Survey (USGS)
- California Department of Water Resources (DWR)
- California Department of Public Health and Safety (CDPH)
- United States Bureau of Reclamation (USBR)
- Individual water users within the study area and surrounding areas
- PRISM Climate Group at Oregon State University
- University of California Davis crop water-use research
- Local investigations relating to the operation of the existing MPG exchange program
- Previous investigations by LSCE and/or LSCE and Kenneth D. Schmidt & Associates (KDSA)
- Previous modeling investigations by the USGS, USBR, and AMEC
- Consultation with Ken Schmidt of KDSA

Available data, interpretations, and opinions relating to the individual components of the groundwater system were reviewed and analyzed to develop a conceptual model of groundwater flow and fate and transport of salts within the PSA. The process of developing the conceptual model incorporates an understanding of the response of the groundwater and surface water system to historical stresses and recognition of data gaps and uncertainty which exist. The conceptual model is also used in the construction of groundwater flow and transport models and calibration to historical conditions. Once calibrated to historical conditions, the models were used to provide information on the future influence the No Action Alternative 1A and 1B, Proposed Action, and Alternative 2 may have on the ground and surface water system in the PSA. The following subsections describe the individual components of the conceptual model.

2.1 Regional and Local Geology

A brief summary of regional and local geologic conditions within the PSA and surrounding area is described below. For a more complete explanation of regional geologic units and trends see *Subsurface Geology of the Late Tertiary and Quaternary Water-Bearing Deposits of the Southern Part of the San Joaquin Valley, California* (Croft, 1972).

The PSA and model domain are located within the San Joaquin Valley (Valley) near the Cities of Fresno, Mendota, and Firebaugh (**Figure 1-1**). The San Joaquin Valley is a large structural trough bounded by the Sierra Nevada to the east and the Coast Range to the west. The Sierra Nevada are primarily composed of consolidated igneous and metamorphic rocks of pre-Tertiary age, overlain in the foothills by metamorphosed Tertiary age marine and non-marine sedimentary rocks. The Coast Range is composed of complexly folded and faulted, consolidated, marine and non-marine sedimentary rocks of Jurassic, Cretaceous, and Tertiary age. The Valley floor consists primarily of unconsolidated deposits of late Pliocene to Holocene age. This unconsolidated material can be upwards of 4,000 ft (ft)thick near the axis of the Valley and primarily consists of alluvium/fluvium sourced from the Sierra Nevada and Coast Ranges subdivided into informal units by extensive fine-grained lacustrine deposits.

As noted in Croft (1972), the character of sediments which make up the water-bearing units of the model domain is dependent upon a few controlling factors: 1) depositional environment, 2) type of rock in the source area, and 3) competence of the streams that transport sediment to the PSA. Oxidized sediments within the model domain, characterized by red, brown, and yellow coloration, suggest areal deposition, most likely along fluvial systems and continental fans. Coarse-grained incised valley fill deposits, channel sands, and sand splays are common in this environment. Soil formation along the surface of alluvial fans is also common, oftentimes resulting in extensive, relatively impermeable paleosols upon burial and compaction. Reduced sediments, which are typically finer-grained, exhibit characteristic dark green, blue, and gray coloration. These sediments were generally deposited in flood basins, lakes, and marshes with coarser-grained sediments deposited in plains and deltas along the edges of these water features.

Sedimentary deposits derived from the igneous and metamorphic rocks of the Sierra Nevada have been primarily deposited by the major rivers and streams which flow into the valley along the eastern margin. Fluvial deposition from the Sierra Nevada has also been strongly influenced by Plio-Pleistocene cyclical glaciation which produced significantly increased competence and sediment load during periods of glacial melt (Weissmann et. al., 2004). Deposits derived from the marine and non-marine sedimentary units of the Coastal Range are largely deposited by ephemeral streams which have significantly lower flows than those draining the Sierra Nevada. Sediments from these two sources inter-finger west of the axis of the valley and mix with fluvial sediments deposited along the axis of the valley where drainage turns to the north.

Within the model domain, the distribution of sediments is consistent with the general trends described above, with the greatest propensity for coarse-sediments within close vicinity to the current and historical flow path of the San Joaquin River. Additional coarse-grained sediment deposits are found in various locations along the eastern and western boundaries of the model domain, generally consistent with the locations of present surface water features. The distribution of fine-grained sediments is also consistent with patterns expected along fluvial systems and alluvial fans.

Lacustrine deposits consist of impermeable to semi-permeable gypsiferous fine sand, silt and clay. Three such units, identified within the PSA and model domain, are referred to by Croft (1972) and others as the E-, C-, and A-clays. The depth, thickness, and extent of these clays were defined within the model domain based on data from available geophysical logs, DWR Well Completion Reports, and the expert opinion of Ken Schmidt of KDSA.

The E-clay, which underlies the A- and C-clays, is an extensive confining unit identified throughout the San Joaquin Valley and is identified as the Corcoran Clay Member of the Tulare Formation. This unit is a distinct marker bed of Pleistocene age consisting primarily of dark greenish gray-blue diatomaceous silty-clay. The Corcoran Clay generally subdivides the San Joaquin Valley aquifer system into two distinct regional hydrologic units referred to as the “upper water-bearing zone” and the “lower water-bearing zone” described further below. The “lower water-bearing zone” is referred to as the lower aquifer in the PSA and model domain. The lower aquifer is confined and is composed of a series of interbedded sand and clay beds that is hundreds of ft thick. In some localized areas within the model domain the uppermost portion of the lower aquifer has beds of coarse sands and gravels that directly underlie the Corcoran Clay. There are few wells in the model domain that are solely screened in the lower aquifer, however, there are several wells located in the PSA that are screened in both the seep zone and lower aquifer. The depth below ground surface to the top of the Corcoran Clay within the model domain is shown in **Figure 2-1**. The depth to the Corcoran Clay within the PSA ranges from about 300 to 520 fe ft et below ground surface. The depth is greatest in the southern and southwestern portion of the PSA and is the most shallow in the northern and northeastern area of the PSA.

The C-clay overlies the Corcoran Clay and is a fine-grained lacustrine deposit of Pleistocene age consisting primarily of bluish-gray silt and clay. The estimated depth to the top of the C-clay and extent of this unit within the model domain is shown in **Figure 2-2**. The depth to the top of the C-clay ranges from 180 to 230 ft below ground surface (bgs) with the greatest depths in the southern portion of the PSA. The extent of the C-clay or equivalent fine-grained materials extend east toward the eastern extent of the PSA. Within the model domain, the C-clay is not always well defined or described on well logs. This is often the result of either availability of lithologic data within the model domain or the quality of the description of subsurface materials on the wells logs. In some areas vertical variations in groundwater quality (salinity) was used to help identify the location of the C-clay if lithologic data was not adequate or unavailable (KDSA personal communication, 2013).

The A-clay overlies the C-clay and is a fine-grained lacustrine or paludal deposit of Pleistocene and Holocene age consisting of blue or dark greenish-gray, plastic, highly organic clay. The extent and the depth to the top of the A-clay, or its equivalent, is shown in **Figure 2-3**. The depth to the top of the A-clay ranges from about 80 to 120 ft bgs. The A-clay is primarily located in the western portion of the PSA and model domain. In some areas, the A-clay is composed of two or three clay units separated by several ft of sand. In the PSA, the A-clay represents the divide between two water-bearing zones, the shallow and deep zones. The shallow zone overlies the A-clay and the deep zone is located between the A-clay and the Corcoran Clay. The shallow zone is primarily composed of fine to coarse sand and gravel and is considered an unconfined unit. The deep zone is also composed primarily of fine to coarse sand and gravel with some interbedded clays. The vertical hydraulic conductivity of the A-clay can be quite variable throughout the model domain, exhibiting apparent gaps which could be post-depositional erosional features or the result of poorly constructed deep zone wells completed below the A-clay.

The hydraulic conductivity of the aquifer zones (shallow and deep zones and lower aquifer) were derived from an evaluation of lithologic composition of each zone and aquifer along with review of aquifer and pumping test information within the PSA. Hydraulic conductivity values for the aquifer zones in the model domain primarily vary within an order of magnitude (10 to about 500 ft/per day). There was no aquifer test information available for the lower aquifer. In order to estimate aquifer properties in those areas where aquifer test data was not available, lithologic information was reviewed and compared to areas with testing data to estimate aquifer properties as a function of lithologic texture analysis. Storage coefficient values were limited to selected aquifer tests and were not generally available for all areas within the model domain.

2.2 Surface Water Features

The primary surface water features in the model domain and the PSA include the San Joaquin River (SJR), the Fresno Slough, the Pool, and several canals including the Chowchilla Bypass, Delta-Mendota Canal (DMC), the Outside Canal, the Firebaugh Intake Canal, and the Central California Irrigation District (CCID) Main Canal (**Figure 1-2**). There are two locations within the model domain that monitor streamflow on the SJR that have the most comprehensive datasets. These two gages are located at Gravelly Ford and downstream of the Mendota Dam. A third gage is located on the San Joaquin River downstream of the Chowchilla Bypass, however, this location has an incomplete dataset over the time period of interest (1990 through 2012). The major canals have flows recorded near the discharge to the Pool (DMC at Check 21) or at the intakes from the Pool (the Firebaugh Intake Canal, the Outside Canal, the Main Canal, and Columbia Canal).

Discharge from Friant Dam (Millerton Reservoir) flows into the SJR and flows west to the north end of the Pool (the northern SJR branch of the Pool). Prior to the Pool, the SJR is bifurcated at the Chowchilla Bypass. This bypass is used to divert flood flows that are beyond the capacity limits of the San Joaquin River below the Mendota Dam. The SJR continues north of the Dam and flows to the Sacramento-San Joaquin River Delta. Examination of flow data on the SJR indicates recharge to groundwater in the model domain is generally greatest upstream of Gravelly Ford as compared to the portion of the river downstream of Gravelly Ford to the Pool. Historically, the SJR had minimal to no flow between Gravelly Ford and the Pool during the irrigation season until the San Joaquin River Restoration Program (SJRRP) initiated interim flows in the San Joaquin River on October 1, 2009 as stipulated in the Settlement Judgement (Natural Resources Defense Council et al., 2006).

The Pool is a discharge and extraction point for major canals and also receives streamflow from the SJR and flood flows from the Kings River via the Fresno Slough. The primary canals are located at the north end of the Pool (**Figure 1-2**). Groundwater is also discharged into the Pool, by the MPG and others for exchange and for adjacent use when using the Pool as a conveyance for irrigation of lands adjacent to the Pool. The San Luis Delta Mendota Water Authority (SLDMWA) oversees the operations of the Pool along with the Bureau of Reclamation. The SLDMWA monitors the inflows and outflows of the DMC and other major canals, along with groundwater discharged to the Pool.

The DMC is an open, mostly concrete-lined canal that conveys water from the Bill Jones Pumping Plant near Tracy to the Pool, where the water is diverted into several irrigation canals. In addition to the DMC, there are four primary canals at the north end of the Pool: CCID, Main Canal and Outside Canal, the Firebaugh Intake Canal, and the Columbia Canal. There are several parties that divert water from the southern end of the Pool, including the WWD through Laterals 6 and 7.

During flood events on the Kings River, flood flows are directed north into the Fresno Slough portion of the Pool (Fresno Slough or southern branch of the Pool) creating a northerly flow regime. Outside of these flood events, flow in the southern branch of the Pool is generally to the south towards the MWA. The southerly flow is variable with the lowest amount (a few cubic ft per second (cfs)) often occurring in the Spring when demands in the Pool are low and highest (several hundred cfs) in the summer months.

2.3 Land Use

Data on historical land use was obtained from DWR and from the National Agricultural Statistics Service (NASS) of the Natural Resources Conservation Service (NRCS). DWR performs detailed surveys of land use in each county on an irregular basis, usually about every 5 to 10 years. Several of these datasets were available for the counties that overlap the model domain (Fresno and Madera Counties). The NASS of the NRCS has, since 2007, produced land use coverages for California based on remote sensing data (CropScape datasets). The DWR and NASS were the two primary sources used for evaluating historical land use over the model calibration period of 1990 through 2012. Data from each of the two sources were utilized to derive land use coverages for each year of the 23 year simulation. The DWR data is highly accurate for the year of the survey, but it is a snap-shot in time, and these surveys are only produced periodically. It is likely that the data become less accurate as the year of interest deviates from the year of the survey. Fresno County was surveyed in 1986, 1994, 2000, and 2009 (eastern portion of Fresno County); Madera County was surveyed in 1995, 2001, and 2011. The NRCS NASS data is much less accurate than the DWR data at the field scale, but has the advantage of being produced every year since 2007.

Land use in the model domain has primarily consisted of agricultural uses during the study period (1990 to 2012). Over the 23 year study period, the amount of transition from agricultural to urban land uses has been minimal and urban accounts for about five percent of the land use in the model domain. Over the 23-year period, the crop mix has changed significantly with cotton (defined by DWR as a field crop) decreasing from about 13 percent to five percent of the model domain while orchards (primarily almonds) have increased from about eight percent to 23 percent of the model domain. The land use distribution for the beginning of the study period in 1990 used the 1994/1995 DWR land use data (**Figure 2-4**) while the end of the study period in 2012 was represented by the 2009 and 2011 DWR land use data **(Figure 2-5).** These land use maps provide an illustration of the change in land use over the 23-year study period.

2.4 Groundwater Conditions

Groundwater conditions in the form of groundwater levels and quality were evaluated in the PSA and model domain to understand the temporal and spatial trends on an aquifer specific basis. These data were used in the calibration of the numerical flow and solute transport models with a focus on the PSA. Groundwater levels (GWL), Total Dissolved Solids (TDS), and Electrical Conductivity (EC) data were gathered from DWR, CDPH, California State Water Resources Control Board (SWRCB), local sources, and previously collected MPG monitoring program data. These data were also used to provide boundary conditions and initial groundwater level and water quality concentrations for input into both the flow and solute transport models.

2.4.1 Groundwater Levels

The primary source of GWL data was DWR records of 894 monitored wells in and near the model domain. Records of groundwater levels in the model domain began in the 1920s, with the majority occurring during the model study period from 1990 to 2012. LSCE also has groundwater level data from wells in the PSA completed in the shallow and deep zones as part of the existing MPG monitoring program. There is a limited amount of groundwater level data available for the lower aquifer in the PSA. Groundwater levels in the shallow zone in the PSA are generally encountered 5 to 60 ft below ground surface (bgs) during the winter and spring. Shallow zone groundwater levels have declined during historical droughts and recovered during wet periods. In some of the non-MPG shallow zone wells, groundwater levels have shown a slight decline between the late 1990s through the early 2010s while MPG area shallow zone wells have generally shown less declines or stable levels over this time period. This period has been characterized as representing long-term average to dry hydrologic conditions when evaluating cumulative departure from the mean precipitation curve from the Madera C precipitation station **(Figure 2-6)**. Hydrographs of depth to water in shallow zone wells are presented in the Annual Monitoring Reports produced as part of the MPG transfer monitoring program. Two shallow zone hydrographs, one located west of the Fresno Slough (TLF-7s) and one located north of the San Joaquin River (Columbia Canal well USBR-4) represent the historical variability in shallow zone groundwater levels as discussed above (**Figures 2-7 and 2-8**).

Groundwater levels in the deep zone in the model domain are generally under semi-confined to confined conditions. Groundwater levels are encountered at depths ranging from 5 to 150 ft bgs and exhibit greater seasonal variations in groundwater levels than shallow zone wells. Long term trends in deep zone groundwater levels have generally been stable south of the San Joaquin River (**Figure 2-9**) as represented by well BF-2, however, north of the river and east in Madera County, groundwater levels have experienced varying degrees of decline over the past few decades (**Figure 2-10**) as represented by well PFC W-53. Additional hydrographs which illustrate these trends are presented in the Annual Reports prepared on behalf of the signees of the Exchange Agreement.

There are few sites available in the model domain where groundwater levels in the lower aquifer are monitored. The limited data availability in the model domain prevents a thorough understanding of groundwater conditions in the lower aquifer. From the limited data that is available, lower aquifer groundwater levels are lower than groundwater levels in the shallow and deep zones, resulting in a downward hydraulic gradient from the shallow and deep zones to the lower aquifer. Lower aquifer groundwater levels in the model domain appear to be more sensitive to regional variations in pumping as compared to the shallow and deep zones due to the confined nature and associated lower storage coefficient associated with the lower aquifer.

2.4.2 Groundwater Flow Directions

Directions of regional groundwater flow at the end of the study period in the PSA and portions of the model domain (where data is available) in both the shallow and deep zones are generally to the north and northeast (**Figures 2-11 and 2-12**). Groundwater flow is regionally influenced by large groundwater level depressions located in Madera County, east of the Chowchilla Bypass, north and northeast of the PSA as shown on **Figure 2-12**. These pumping depressions have also historically influenced regional groundwater flow directions.

Within the PSA, groundwater flow directions in the shallow zone in the winter of 2012/2013 were affected locally by recharge from the San Joaquin River and by depressed groundwater levels west of the Pool. As shown in **Figure 2-11**, recharge from the San Joaquin River results in a groundwater ridge in the shallow zone. Groundwater flows away from the river to the south and southwest and north and northeast, essentially isolating the effect shallow zone MPG pumping has on groundwater levels to the area west of the Pool.

Within the PSA, groundwater level contours and flow directions in the winter of 2012/2013 in the deep zone are influenced by depressed groundwater levels in Aliso Water District in the northeastern portion of the PSA and east of the Chowchilla Bypass in Madera County (**Figure 2-12**). Locally, groundwater levels are depressed near the Pool and south of the San Joaquin River that influences groundwater flow directions and contours in this area (**Figure 2-12)**. During the irrigation season, groundwater level contours and flow directions generally follow similar patterns as what happens during the winter season with the exception of the influence of more pronounced groundwater level depressions in the Pool Area resulting from MPG and non-MPG pumping. These influences are illustrated in the Annual Monitoring Reports prepared for the MPG transfer program.

2.4.3 Groundwater Quality

One of the primary groundwater quality issues within the PSA and model domain is the fate and transport of salts. Salinity, measured as either total dissolved solids (TDS) or EC, is naturally present in subsurface materials of the western portion of the model domain. Regionally, the major source of saline groundwater is marine sediments which have high levels of naturally occurring salts (Hotchkiss, et al., 1973). Wells completed in both the shallow and deep zones in some locations along the western side of the Pool and Fresno Slough show a gradual increase in salinity in some areas due to the northeasterly movement of a "saline front" of brackish water generated from these sediments (**Figures 2-13 and 2-14**). TDS concentrations can range from approximately 300 to over 6,000 milligrams per liter (mg/L) in the PSA. The regional movement of this saline front is governed primarily by the regional groundwater flow gradient which runs from the southwest to northeast and west to east in the model domain toward Madera County. On a local scale, groundwater pumping may influence the rate of easterly migration of the saline front in the vicinity of the Pool and Fresno Slough north of Whitesbridge Road within the PSA.

Another, local-scale, source of salinity is a plume of saline groundwater, known as the Steffens Plume, located at the former Spreckels Sugar Company processing plant. The Steffens Plume formed from the generation of saline water from processing beets, known as the "Steffens process". The wastewater from the Steffens process was discharged to evaporation ponds and fields east of the Fresno Slough. The salts from the wastewater impact groundwater quality in the shallow and deep zones in the PSA. Salinity concentrations within the PSA vary considerably and are generally good in areas away from the regional saline front and the Steffens Plume. In the southwestern portion of the model domain, measured TDS concentrations in both the shallow and deep zones regularly exceed 5,000 mg/L (**Figures 2-15 and 2-16**). In the central and eastern portions of the model domain, measured salinity concentrations in the form of TDS are generally much lower (less than 1,000 mg/L). In areas where there is recharge from surface water bodies such as the San Joaquin River and the Pool, TDS concentrations are generally lower. Recharge from the San Joaquin River has low concentrations of TDS, leading to generally better groundwater quality with most shallow zone wells exhibiting TDS of less than 250 mg/L in the vicinity of the river (**Figures 2-17 and 2-18**). Water quality in the lower aquifer is also typically better than the shallow and deep zones as the downward vertical migration of salts into the lower aquifer is likely inhibited by the Corcoran Clay.

2.5 Groundwater Recharge

The groundwater system located within the model domain and PSA receives recharge from subsurface inflow, precipitation, infiltration from surface water features, irrigation return flows, the New Columbia Ranch (NCR) recharge ponds, and the Meyers Water Bank. The influence of each source is described below.

2.5.1 Subsurface Inflow

Subsurface inflow primarily enters the PSA from the west in the shallow and deep zones and from the east in the lower aquifer. A portion of the rain and snow which fall in the Coast Range to the west of the model domain and Sierra Nevada to the east percolate into the aquifers of the San Joaquin Valley, especially along the edges of the San Joaquin Valley where coarse-grained materials provide a pathway to the underlying aquifers. The portion of this water which is not captured by up-gradient groundwater pumpers, or discharged to surface water features, flows toward the axis of the valley, turning to the north near the center of the Valley. Additionally, recharge from the San Joaquin River east of the model domain also contribute to subsurface inflow.

2.5.2 Precipitation

Monthly precipitation data for the 1990 through 2012 period was obtained from the PRISM Climate Group at Oregon State University, which compiles climate data from various monitoring networks nationwide to develop spatially continuous climate datasets. The PRISM datasets were used to investigate spatial trends in precipitation across the model domain. Based on the available data, average precipitation in the Mendota area is approximately 12 inches per year, with nearly all rainfall occurring between October and May. The fate of precipitation is often divided among consumption by vegetation through transpiration, evaporation, soil moisture, runoff to surface water features, and deep percolation to groundwater. Evaporation and transpiration often consumes the bulk of precipitation and with only an average of 12 inches of rainfall per year, the amount that percolates and recharges groundwater is likely a small percentage of the total.

2.5.3 Surface Water

Surface water features in the model domain include the SJR, the Fresno Slough (including the Pool), Chowchilla Bypass, and several major irrigation supply canals. These features are sources of recharge in varying degrees. The estimation of recharge is dependent on the availability of data and includes estimates if data is unavailable. Estimating the amount of recharge from the Chowchilla Bypass and irrigation canals was estimated due to a lack of available data on canal losses.

Estimates of recharge from the SJR involved the calculation of losses in streamflow between different reaches on the River utilizing gage data. Several gages exist along the SJR, however the flow data is limited at each gage and none of the gages have a complete record that spans the study period from 1990 through 2012 (USGS, 2013; DWR, 2013). Fortunately, there is enough data at various gages to fill in data gaps. The Millerton Reservoir outflow was available for the entire study period and the recorded outflow from the reservoir was used to fill in data gaps in downstream river gages on the SJR located within the model domain.

The reservoir outflow represents the sum of the flow to the Friant-Kern canal, Madera canal, and the SJR (DWR, 2013). The Friant-Kern canal flow and Madera canal flow were subtracted from the Millerton Reservoir total outflow to calculate the flow that went into the SJR.

The flow calculated for the SJR from the Millerton Reservoir outflow was used to compare with the flow data recorded at the Gravelly Ford gage (DWR, 2013). A comparison of the two datasets was necessary because the data from the Gravelly Ford gage is only available since 1997 and did not span the entire study period. A comparison of the two datasets over common time periods yielded a very good correlation which allowed for the generation of a flow record at Gravelly Ford for the 1990 through 1997 period when comparing the two datasets.

The next gage downstream from Gravelly Ford gage is located at the Bifurcation where flood flows are diverted into the Chowchilla Bypass. The Chowchilla Bypass is operated by the SLDMWA to prevent flooding downstream of the Mendota Dam. The SJR flow at the Bifurcation structure and the James Bypass (Kings River) are monitored, and flow is diverted into the Chowchilla Bypass if the total flow between the SJR and the James Bypass is greater than 4,500 cfs (DWR, 2013). Water from the James Bypass has priority to the SJR downstream of the Pool over water released from Millerton Reservoir because flood flows from the reservoir can be diverted into the Chowchilla Bypass while the Kings River flood flows cannot be diverted. The channel capacity for the SJR downstream of the Mendota Dam is 4,500 cfs (San Joaquin River Restoration Program, 2013). Therefore, the James Bypass and SJR combined flow cannot exceed 4,500 cfs over the Mendota Dam. San Joaquin river flows up to 1,500 cfs are routed into the Pool as long as the James Bypass flow is below 3,000 cfs. Flows in the San Joaquin are reduced at the Bifurcation by diverting water into the Chowchilla Bypass once James Bypass flows exceed 3,000 cfs (San Joaquin Restoration Program, 2013).

Prior to estimating the flow diverted into the Chowchilla Bypass, an estimate of the flow entering the Bifurcation was generated. The SLDMWA supplied the flow data for the SJR below the Bifurcation and the Chowchilla Bypass that was available beginning in 1997 (DWR, 2013). This data was combined to produce the flow above the Bifurcation structure. The flow data above the Bifurcation structure was compared with the flow at Gravelly Ford to generate a linear relationship. The James Bypass and SJR at the Bifurcation were analyzed to generate a diversion flow dataset for the Chowchilla Bypass.

Surface water and groundwater interaction is an important component in evaluating the amount of recharge that may occur to groundwater. Data from the recreated flow datasets at the gage locations were used to determine the amount of water seeping from the river to groundwater between each gage location by evaluating the change in flow assuming there are no direct diversions of water between the gage locations.

The difference in observed flows at the Bifurcation structure and Gravelly Ford were analyzed to determine the minimum flow that would produce a flow at the Bifurcation structure. The San Joaquin River Restoration Study found a minimum of 75 cfs (102 cubic ft per day (cfd/ft)) was needed at Gravelly Ford to overcome losses (including recharge to groundwater) to produce flow at the Bifurcation structure (McBain and Trush, 2002). The study assumed there were minimal seasonal losses (evaporation). These minimum flows were used to determine the riverbed conductance. The riverbed conductance was a model calibration parameter that was adjusted to match the modeled to observed flows.

Since there is not a gage located at the point where the SJR enters the model domain (upstream of the Gravelly Ford gage), the streamflow at the model boundary was estimated by extrapolating the streamflow at Gravelly Ford and Friant Dam.

In 2012, PFC (currently Wonderful Orchards (WO)) performed an extensive investigation of the canal system at NCR, including detailed measurement of unlined canal losses. During this investigation, seepage rates ranged from 0.09 to 0.59 ft per day per linear foot when water was present in the canals (Paramount, 2012). Only limited data on losses to groundwater from other canals within the study area were available, however, it was assumed seepage rates are likely similar to the rates derived from the Paramount investigation.

Recharge from the Pool to groundwater was estimated to be approximately 47 cfs (LSCE and KDSA, 2000). This estimate was based upon measurements of stage decline in the Pool in 1999 prior to drainage of the Pool when DMC flows to the Pool were discontinued over a 44-hour period. It was assumed that this seepage rate is constant whenever the Pool is filled and has a relatively stable stage elevation.

2.5.4 Irrigation

Irrigated agriculture constitutes the primary land use within the model domain, with a variety of crops grown throughout the year and the simulation period. A combination of large crop water demands, irrigation efficiencies, and the need to periodically leach salts from the root zone requires the application of large volumes of irrigation water (4 to 6 af of water per afy is common for the area). Infiltrating irrigation water would primarily supply recharge to the shallow aquifer, with some portion entering the deep aquifer with time and favorable vertical hydraulic properties. While surface water is used to meet the majority of agricultural demand in some areas, groundwater pumping from the shallow and deep zones constitutes the primary source of the water used for irrigation. Recharge from irrigation is primarily from the portion of water applied that does not meet the consumptive use demands of the irrigated crop. This is primarily estimated by evaluating irrigation methods and the assignment of irrigation efficiency values. An estimate of 80 percent for water use efficiency was determined for the model domain based on the large amount of drip and micro-spray irrigation that is utilized and also supported by studies in the model domain (Viers et al., 2012).

2.5.5 Recharge Ponds – New Columbia Ranch

WO has operated four recharge ponds totaling 423 ac at the NCR since March 2008. WO operates these ponds for the benefit of the groundwater system underlying NCR with most of the water coming from SJR flood flows and a surface water right held through Columbia Canal Company (CCC). Between 2008 and 2012, PFC has diverted 39,289 af to their ponds. The ponds are regularly maintained to prevent deterioration of infiltration rates.

2.5.6 Groundwater Banking – Meyers Farming

The Meyers Farm Water Bank located east of the Pool began operation in January 2001. Most of the water recharged by the Bank has been carry-over water rescheduled from Meyers Farm's Central Valley Project allocation from San Luis Water District (SLWD). Carry-over water is delivered to the Pool via the DMC and drawn from the Fresno Slough into the Bank's infiltration ponds. When available, Kings River flood releases and Section 215 temporary water supplies are also used to supplement carry-over water.

From January 2001 through December 2012, Meyers Water Bank has diverted 49,762 af of water to their recharge ponds, while extracting 8,737 af. The Bank's five ponds, totaling 84 acres, undergo regular maintenance to maintain infiltration rates. The Bank recharges the shallow zone and has extraction wells completed in the shallow zone to withdraw banked water. The Bank has a network of monitoring wells to monitor groundwater conditions. During periods of recharge, a groundwater mound develops at the Bank.

2.6 Groundwater Extraction

The vast majority of water pumped from the groundwater system within the PSA and model domain is used for agricultural irrigation. The total volume of water pumped is dependent on the crop type, availability of surface water, precipitation, evapotranspiration (ET), underlying soil types (well drained vs. poorly drained soils), and irrigation efficiency.

Near the Pool and Fresno Slough, irrigation wells are generally completed in the shallow and deep zones (**Figure 2-19**). Groundwater extraction in this area by the MPG, WO (and formerly Newhall Land and Farming), and the Exchange Contractors is well documented on a monthly well by well basis from 1997 through present. From 2008 through 2012, average annual pumping in the PSA by both MPG and non-MPG entities ranged from about 28,000 to 84,000 afy. In the area east of the Chowchilla Bypass, which is generally beyond the extent of the A- and C-clays, wells can be completed entirely above the Corcoran clay (referred to as "unconfined wells" by DWR) or both above and below the Corcoran clay (referred to as "composite" wells). Near Aliso Water District, a relatively thick sand unit deposited on top of the Corcoran clay produces the majority of water to both unconfined and composite wells completed over that interval (Ken Schmidt, 2013). Agricultural demands in this eastern area are typically met entirely with groundwater.

The majority of lands within the PSA west of the City of Mendota and south of the DMC are under agricultural production. Well data in this area are limited. High TDS concentrations are observed in the shallow zone west of the Pool which limits the amount of pumping in this zone in the western portion of the study area. Of the available DWR Well Completion Reports, no wells were found in this area completed in the lower aquifer below the Corcoran clay.

Table 2-1: Annual Mendota Pool Group Pumping (1990 - 2012)

Year	Exchange (af)	Adjacent (af)	Total (af)
1990	17,810	N/A	N/A
1991	50,025	N/A	N/A
1992	52,421	N/A	N/A
1993	18,571	N/A	N/A
1994	40,189	N/A	N/A
1995	0	N/A	N/A
1996	0	N/A	N/A
1997	26,581	9,624	36,205
1998	1,000	6,861	7,861
1999	19,721	13,647	33,368
2000	18,995	16,165	35,160
2001	27,415	13,346	40,761
2002	12,497	15,923	28,420
2003	0	14,239	14,239
2004	0	12,927	12,927
2005	0	10,009	10,009
2006	0	6,364	6,364
2007	22,556	15,463	38,019
2008	24,017	11,792	35,809
2009	26,792	10,087	36,879
2010	11,865	8,071	19,936
2011	0	8,564	8,564
2012	24,872	14,312	39,184
Total	**395,327**	**187,394**	**403,705**

The MPG has extracted groundwater from up to 96 wells located adjacent to the Fresno Slough and within Farmers Water District (FWD) (**Figure 2-20**) during the period of study. This includes 54 wells completed in the shallow zone, 38 wells completed in the deep zone, and 4 wells completed in both the deep zone and lower aquifer (composite wells). Groundwater extracted by the MPG is used for overlying and adjacent use and for exchange to irrigate agricultural lands in WWD. Between 1990 and 2012, 395,327 af of groundwater pumped by MPG was used for groundwater exchange. For the years when pumping for exchange occurred (no pumping for exchange occurred from 1995 to 1996, 2003 to 2006, or in 2011), this equates to an average of 24,708 afy. Between 1997 and 2012, slightly more than half (216,311 af) of the groundwater pumped by MPG was for groundwater exchange while slightly less than half (187,394 af) was for overlying and adjacent use (**Table 2-1**). During this period, the volume of water pumped by the MPG for exchange has been split fairly evenly between the shallow and deep zones **(Table 2-2)**. When accounting for both adjacent and overlying use along with pumping for groundwater exchange, approximately two-thirds of all MPG pumping over this time period was from the deep zone (**Table 2-2**).

Table 2-2: Annual Mendota Pool Group Pumping by Depth Zone (1997 – 2012)

	Deep Wells		Shallow Wells		Total Pumpage		
Year	Exchange (af)	Adjacent (af)	Exchange (af)	Adjacent (af)	Deep (af)	Shallow (af)	Total (af)
1997	16,847	7,831	9,734	1,793	24,678	11,527	36,205
1998	500	5,093	500	1,768	5,593	2,268	7,861
1999	9,765	11,288	9,956	2,359	21,053	12,315	33,368
2000	8,921	10,889	10,074	5,276	19,810	15,350	35,160
2001	15,587	8,770	11,828	4,576	24,357	16,404	40,761
2002	3,668	9,807	8,836	6,109	13,475	14,945	28,420
2003	0	6,797	0	7,442	6,797	7,442	14,239
2004	0	4,941	0	7,986	4,941	7,986	12,927
2005	0	4,664	0	5,345	4,664	5,345	10,009
2006	0	4,791	0	1,573	4,791	1,573	6,364
2007	11,168	6,218	11,387	6,286	20,346	17,673	38,019
2008	13,122	7,138	10,895	4,654	20,260	15,549	35,809
2009	14,476	7,921	12,316	2,166	22,397	14,482	36,879
2010	7,134	5,871	4,731	2,200	13,005	6,931	19,936
2011	0	6,679	0	1,885	6,679	1,885	8,564
2012	10,624	12,102	14,132	2,211	22,725	16,459	39,184
Total	**111,812**	**120,800**	**104,389**	**63,629**	**235,571**	**168,134**	**403,705**

2.7 Subsidence

Compaction is measured at two extensometers in the PSA. The Fordel Extensometer was installed by the MPG in 1999 about 1 mile west of the Fresno Slough (**Figure 2-21**). The Yearout Extensometer was installed by DWR in 1965 and is located about 2 miles east of the Fresno Slough **(Figure 2-21).** These two locations are within the primary groundwater pumping areas of the MPG. Compaction data at the Yearout site was collected by DWR from 1966 to 1982 and by CCID since 1999 through 2012. These extensometers measure compaction of the sediments that overly the Corcoran Clay. Total inelastic compaction between 1999 and 2012 is estimated by comparing long-term winter/spring compaction measurements. Over this period, there has been 0.025 ft at the Fordel Extensometer and an estimated 0.125 ft at the Yearout Extensometer. The Yearout data is estimated as a result of data quality issues encountered during 2012. These cumulative compaction values result in annual average values of about 0.002 ft/per year at the Fordel Extensometer and about 0.01 ft/per year at the Yearout Extensometer.

2.8 Surface Water Quality at Mendota Wildlife Area

Surface water quality in the Fresno Slough at the Mendota Wildlife Area is measured continuously with an electrical conductivity transducer and periodic grab samples approximately one mile south of

Whitesbridge Road (**Figure 2-21**). EC can be used to estimate the TDS concentration through a linear relationship where TDS (mg/L) is about two thirds of EC in units of micro mhos per centimeter (µmhos/cm). In 2012, EC at the MWA ranged from about 500 to 1,500 µmhos/cm **(Figure 2-22).** Generally, EC is highest in the spring and fall and lowest in the summer and winter. The variation in EC is the result of many factors but is mostly affected by the amount and quality of groundwater pumped into the Pool and water quality in the Delta Mendota Canal.

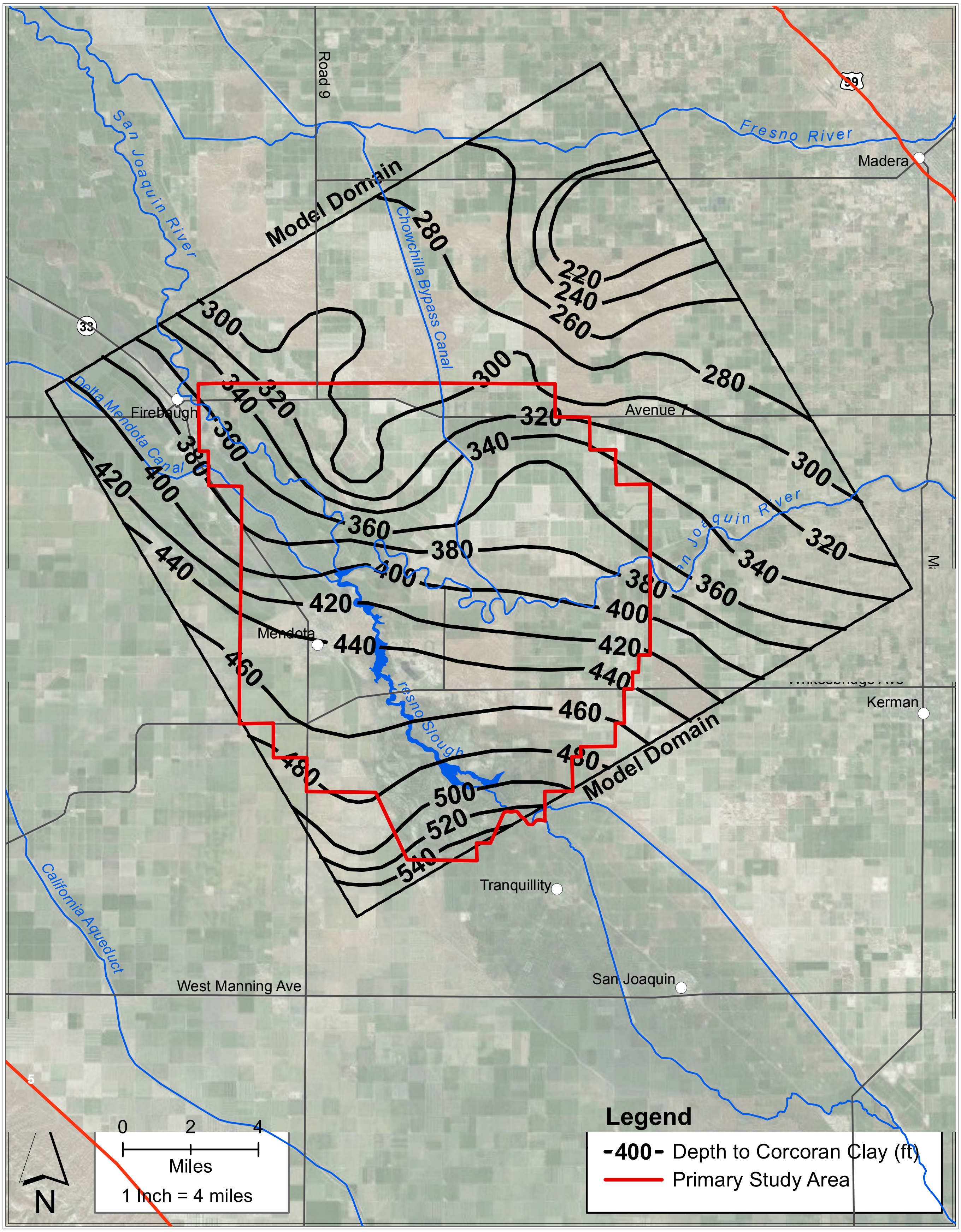

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Figure 2-1
Approximate Extent and Depth of the Corcoran Clay

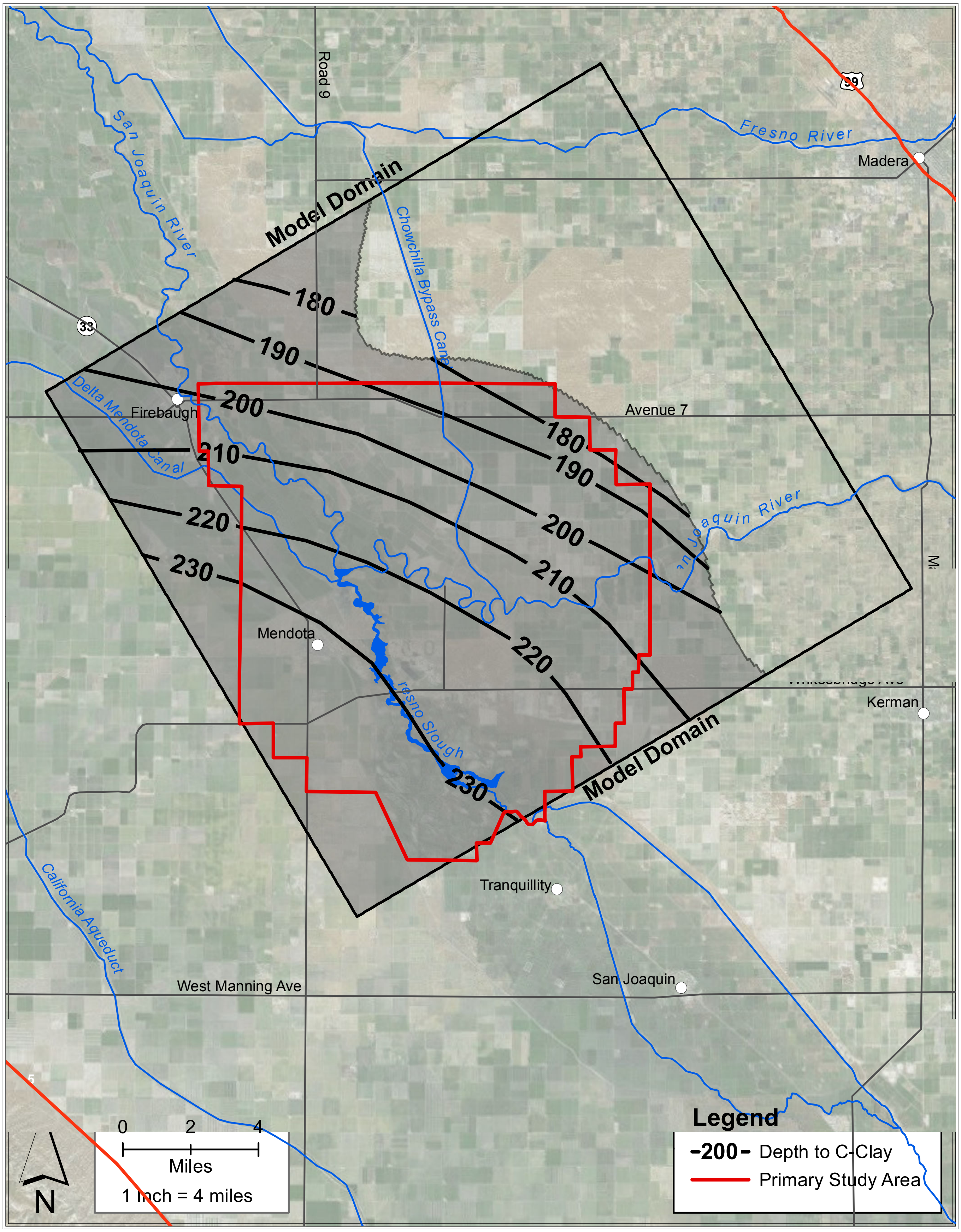

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Figure 2-2
Approximate Extent and Depth of the C-Clay

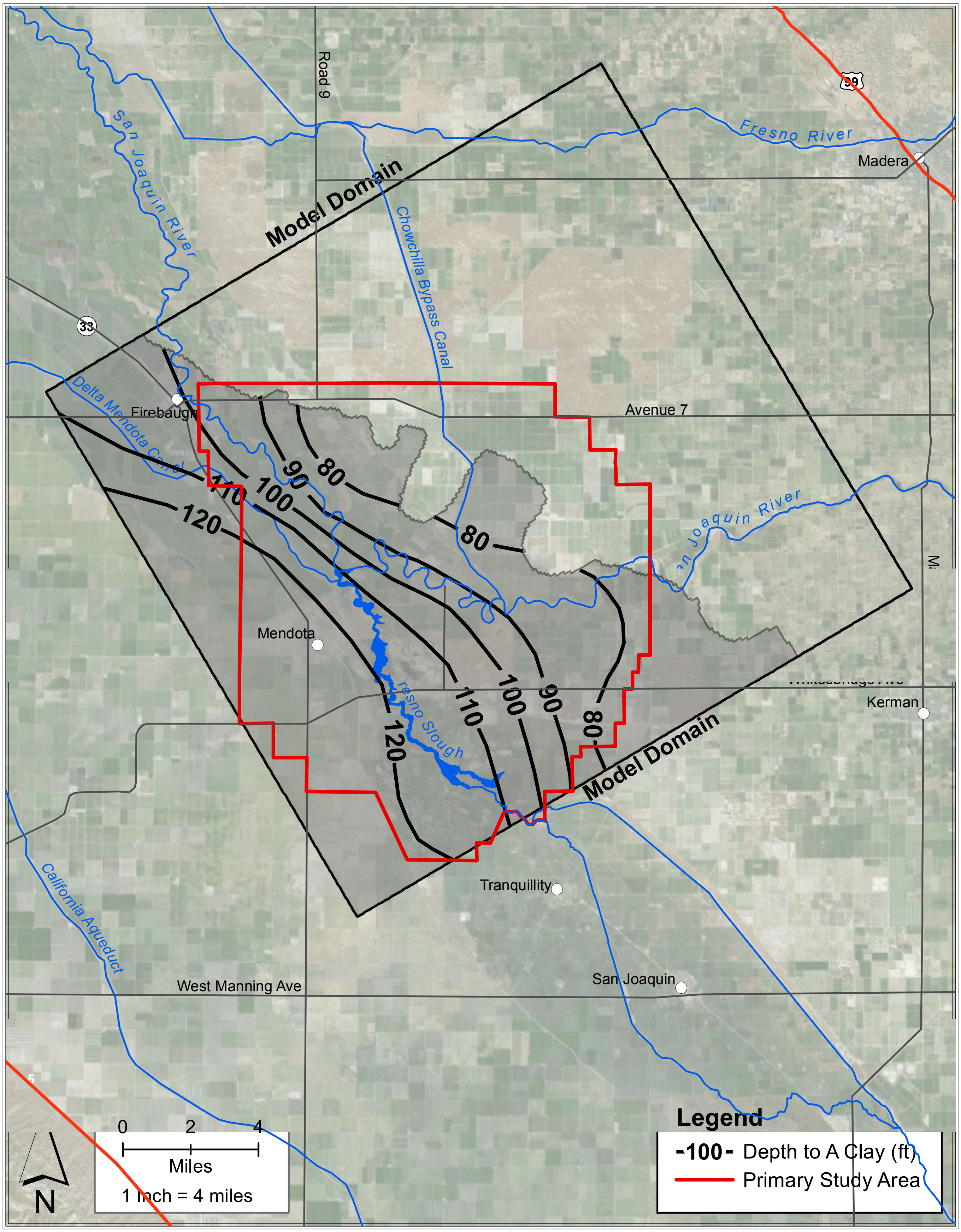

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Figure 2-3
Approximate Extent and Depth of the A-Clay

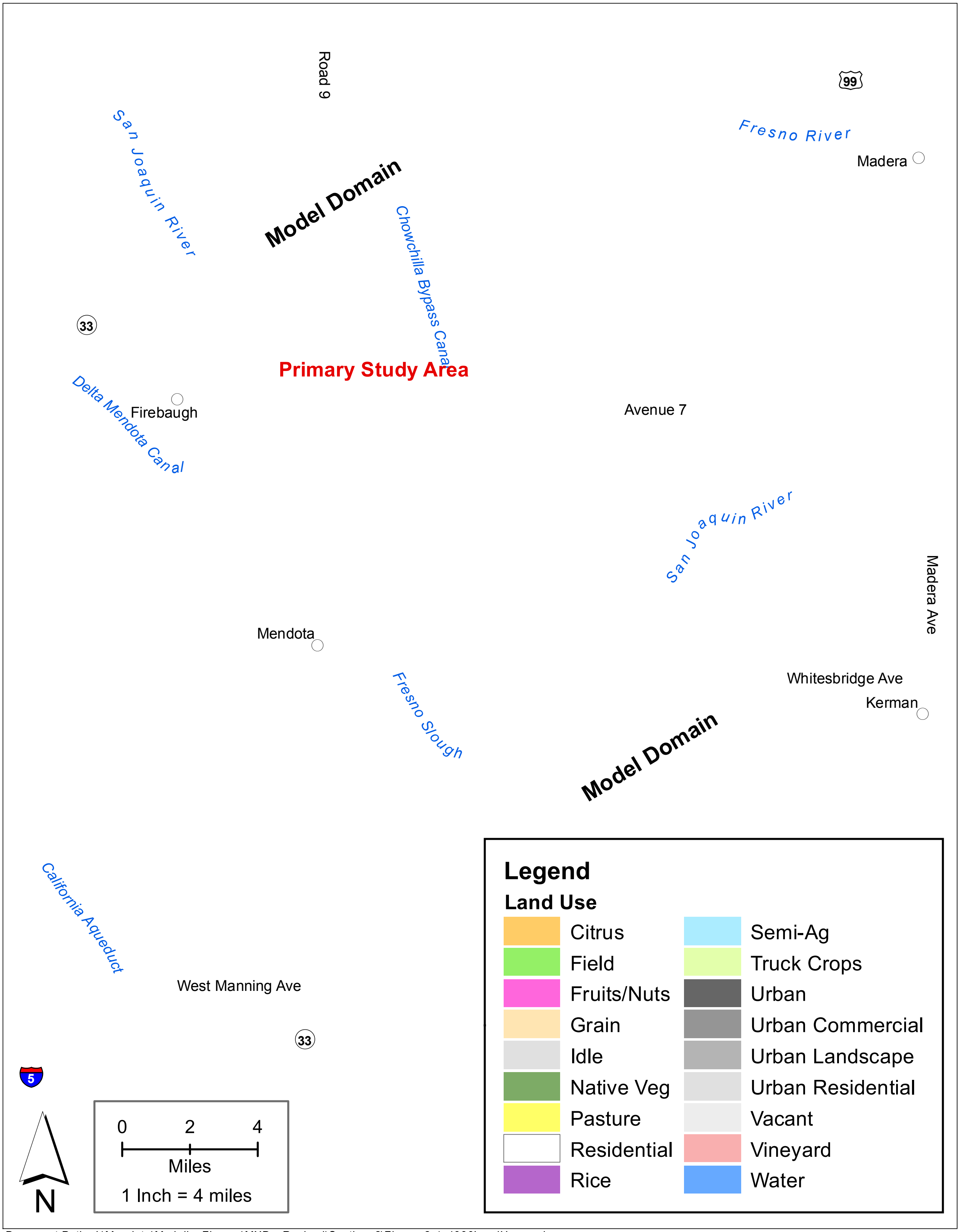

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Figure 2-4
Surveyed Fresno and Madera County Land Use in 1994/1995

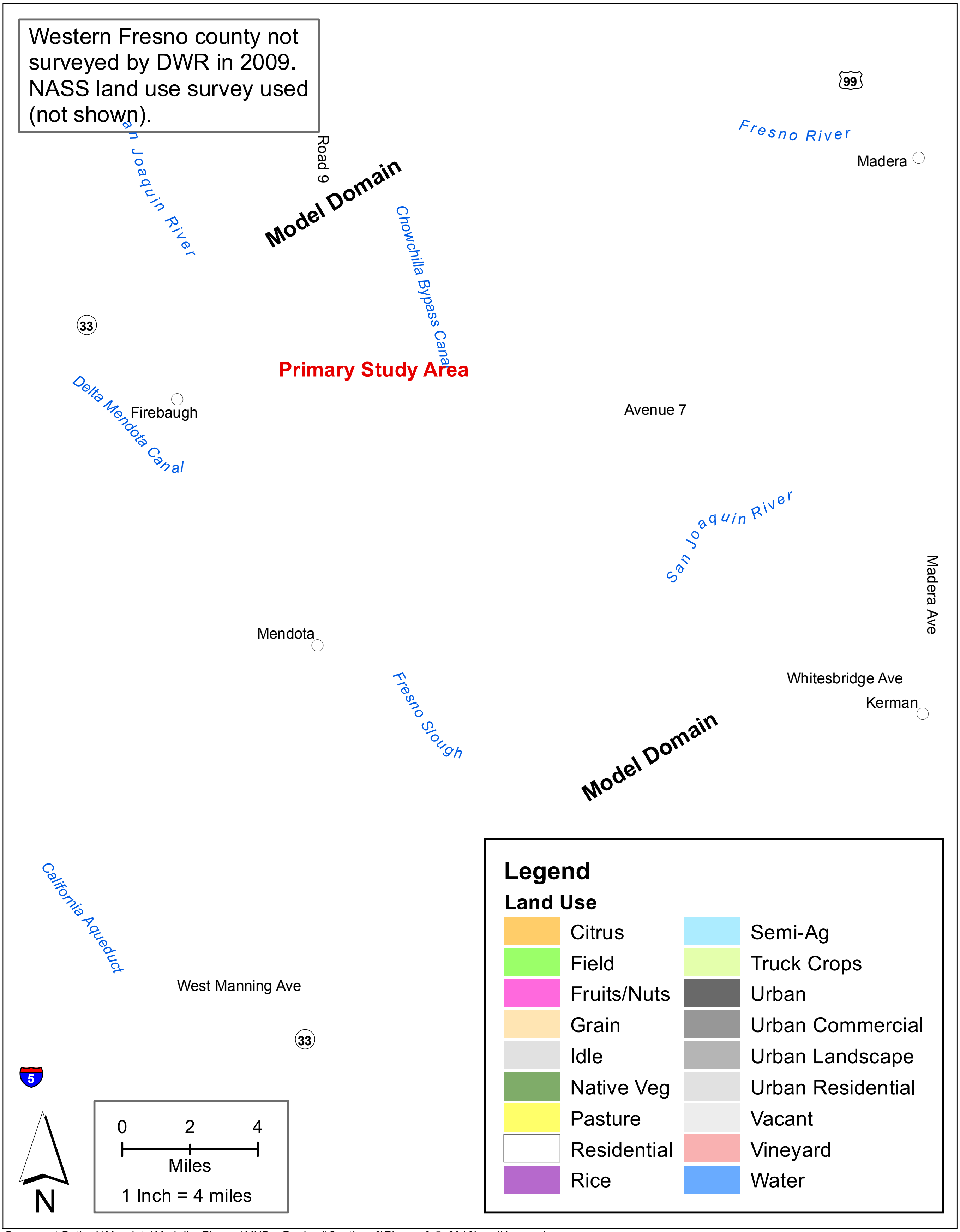

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Figure 2-5
Surveyed Fresno and Madera County Land Use in 2009/2011

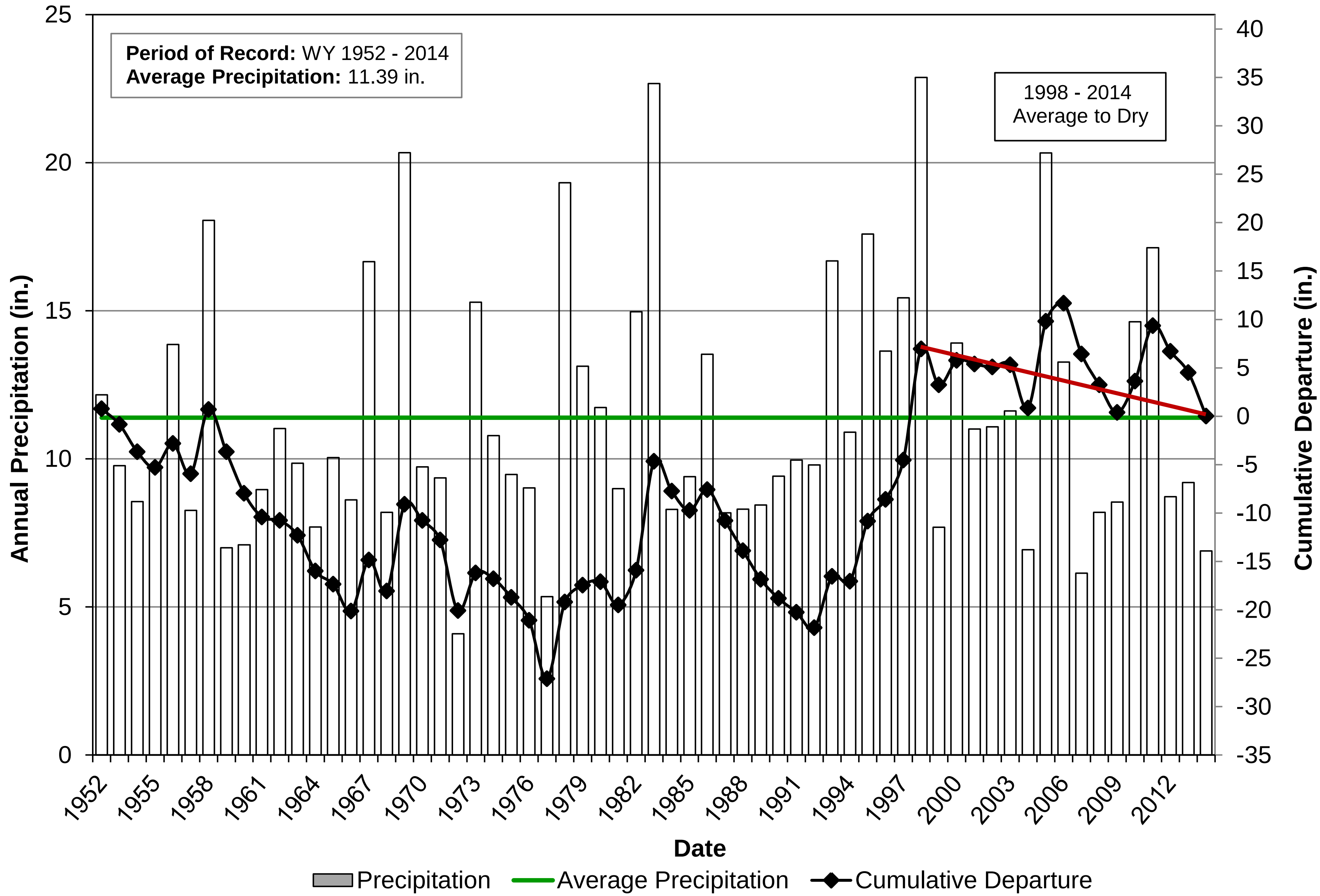

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Figure 2-6
Cumulative Departure from Mean Precipitation
Mendota C. Station

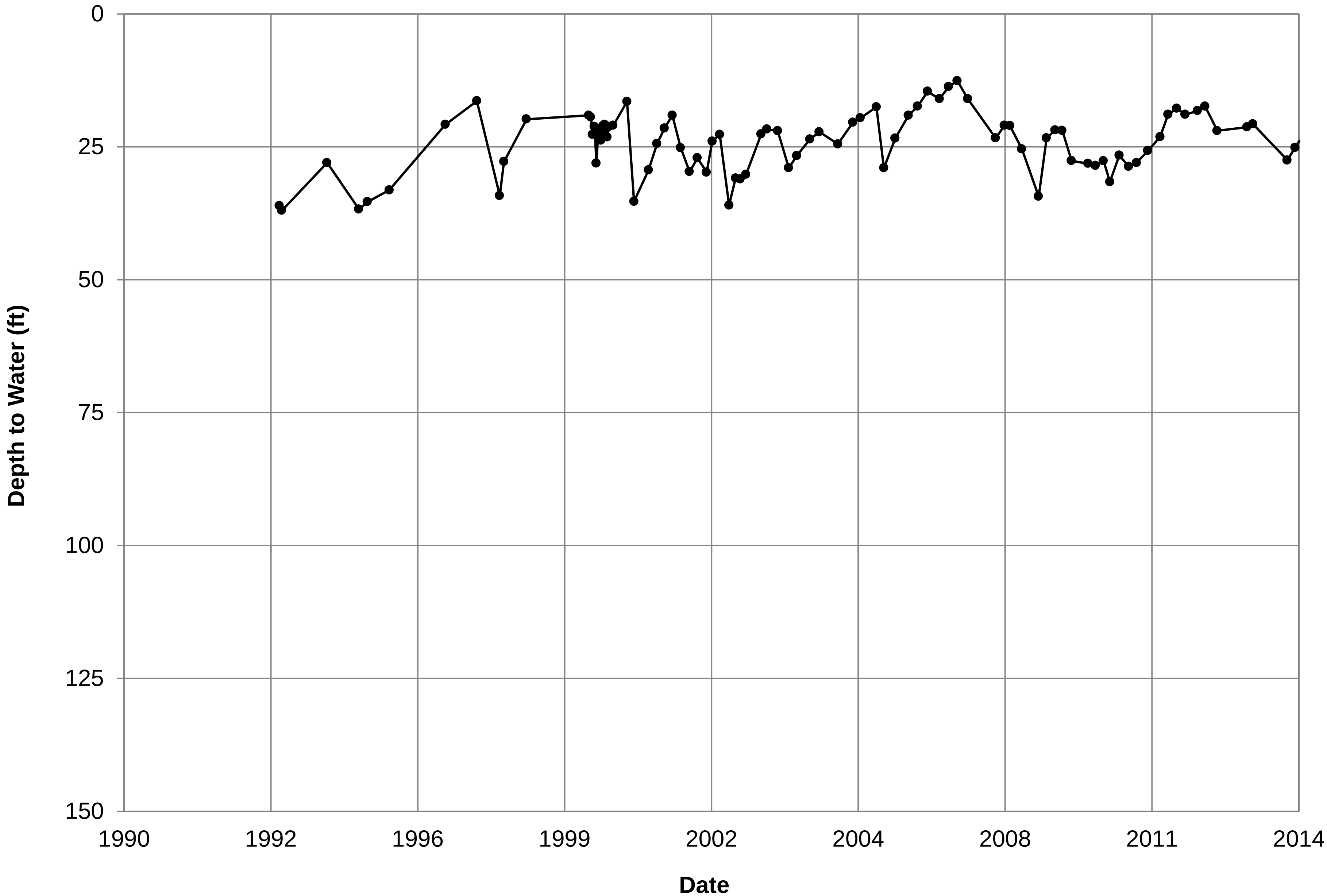

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Figure 2-7
Depth to Groundwater in Shallow Zone
Well TLF-7s

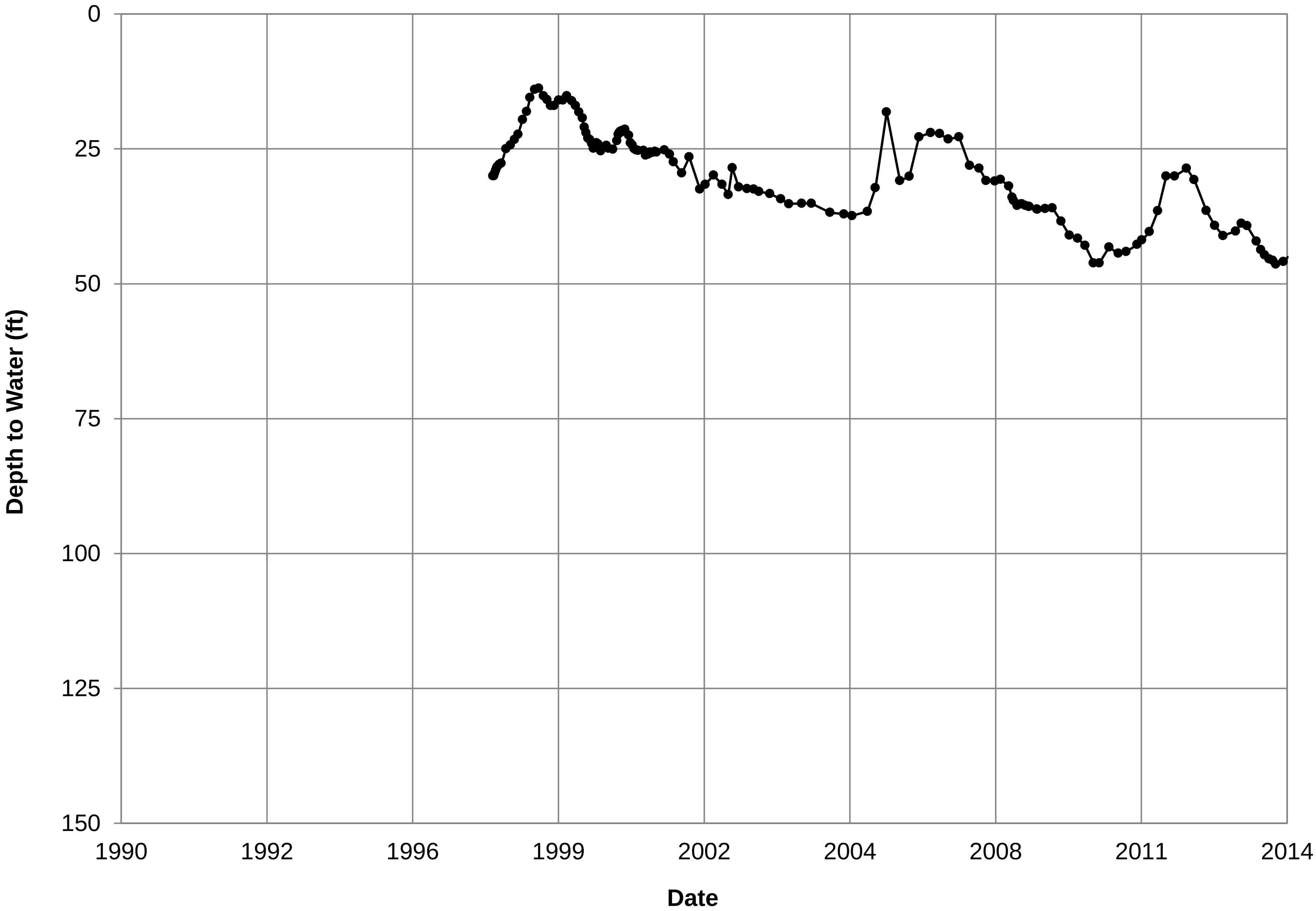

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Figure 2-8
Depth to Groundwater in Shallow Zone Well
CCC-USBR-4

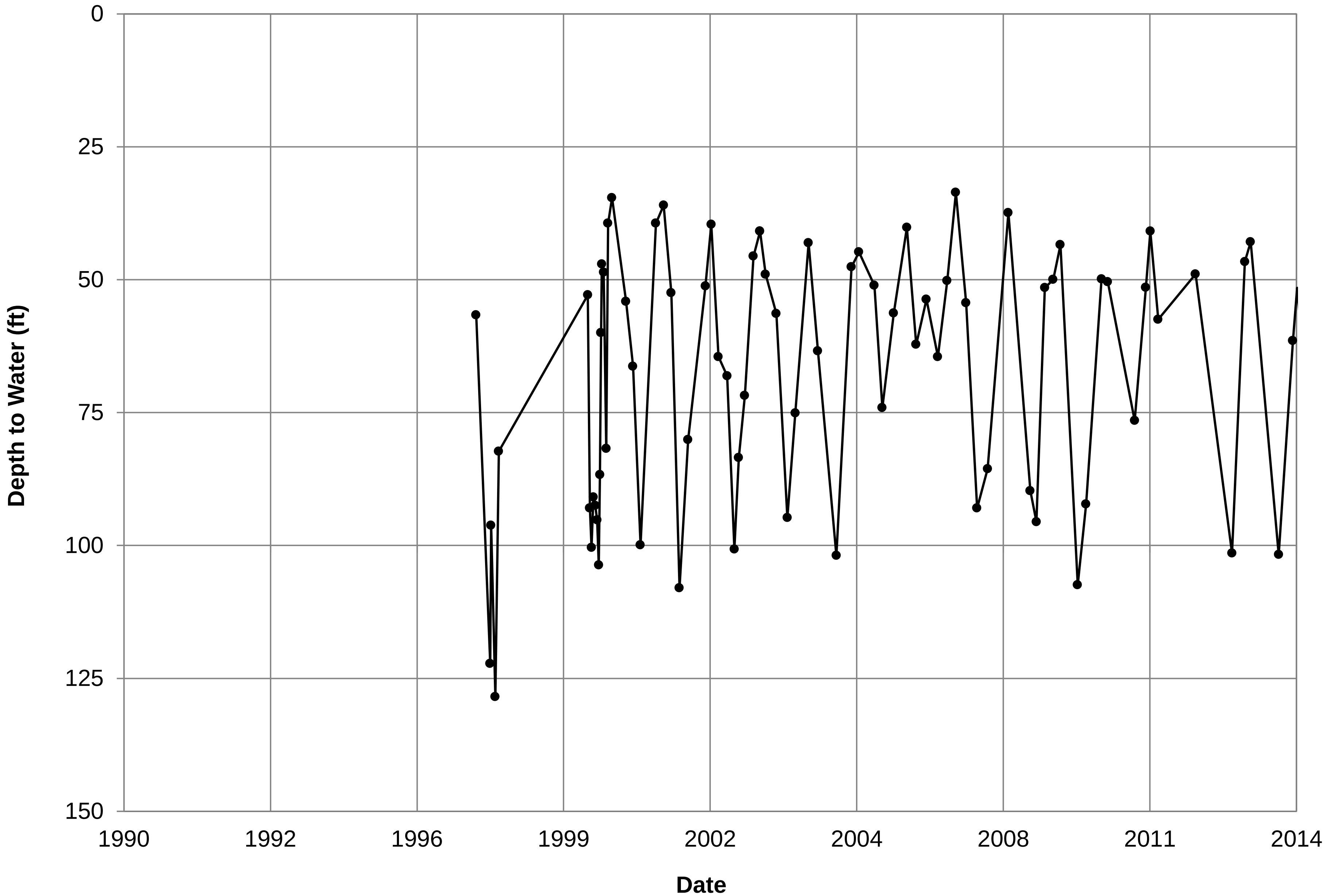

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Figure 2-9
Depth to Groundwater in Deep Zone
Well BF-2

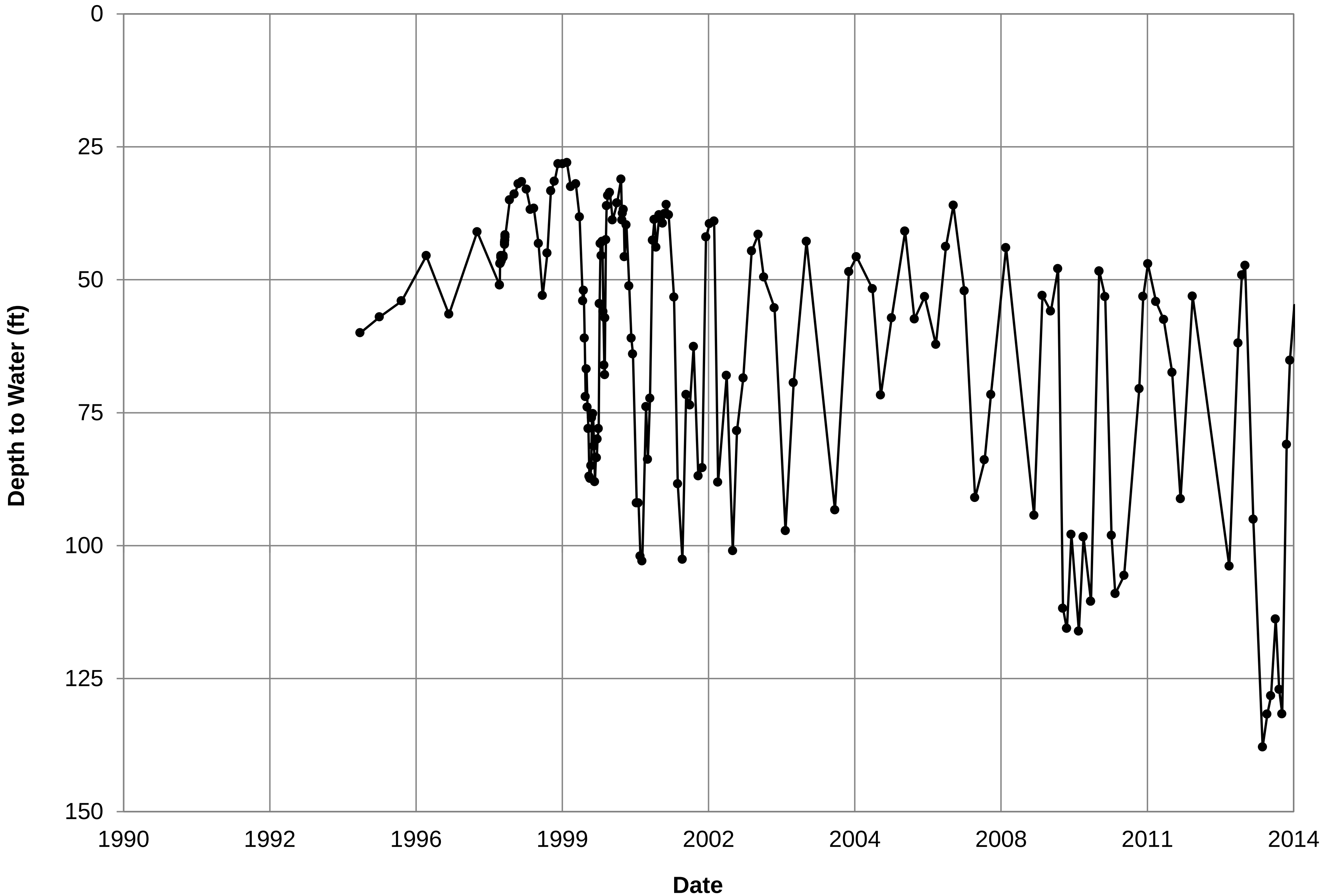

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Figure 2-10
Depth to Groundwater in Deep Zone
Well PFC-W-53

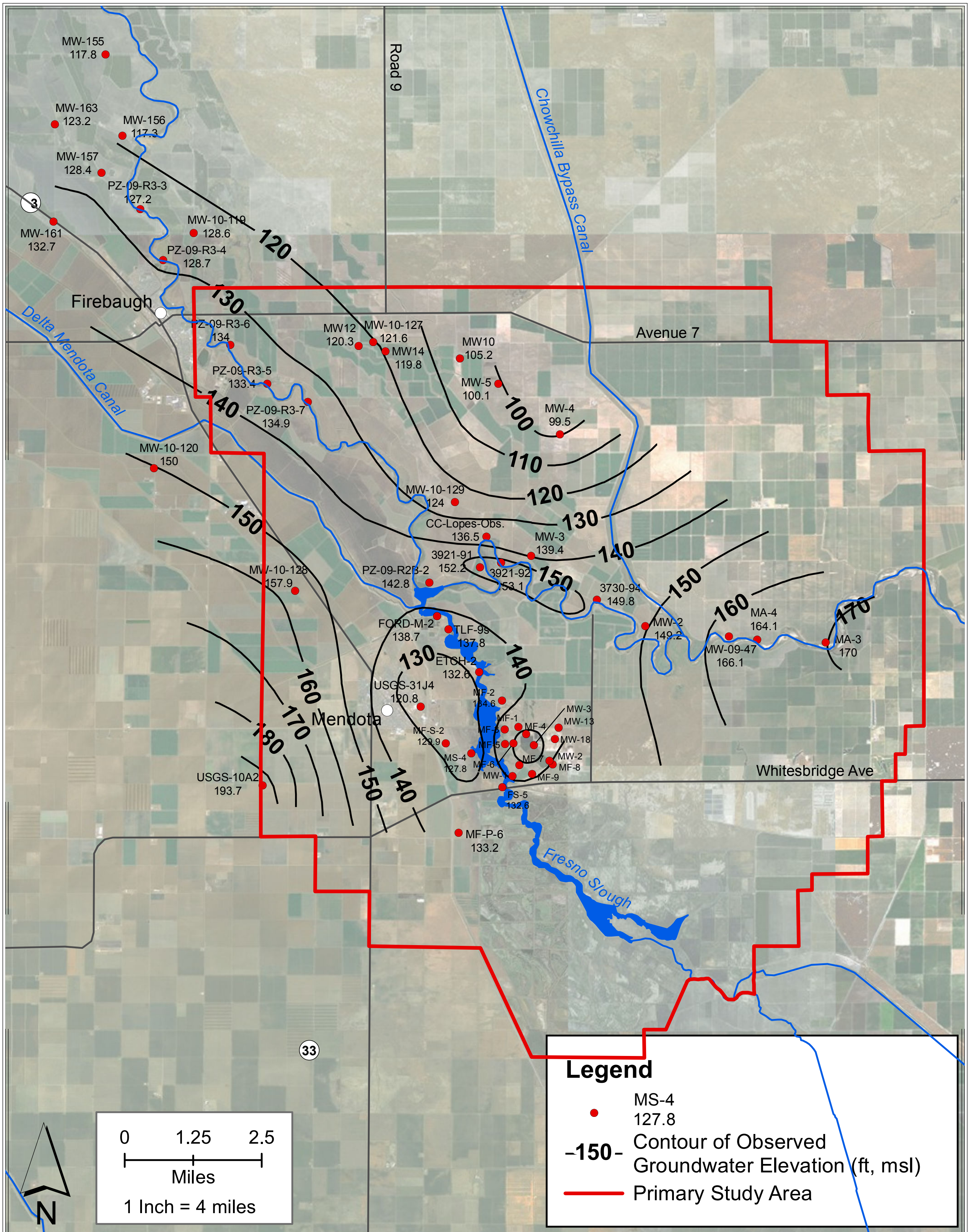

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Figure 2-11
Contours of Equal Observed Groundwater Elevation, Shallow Zone (Winter 2012)

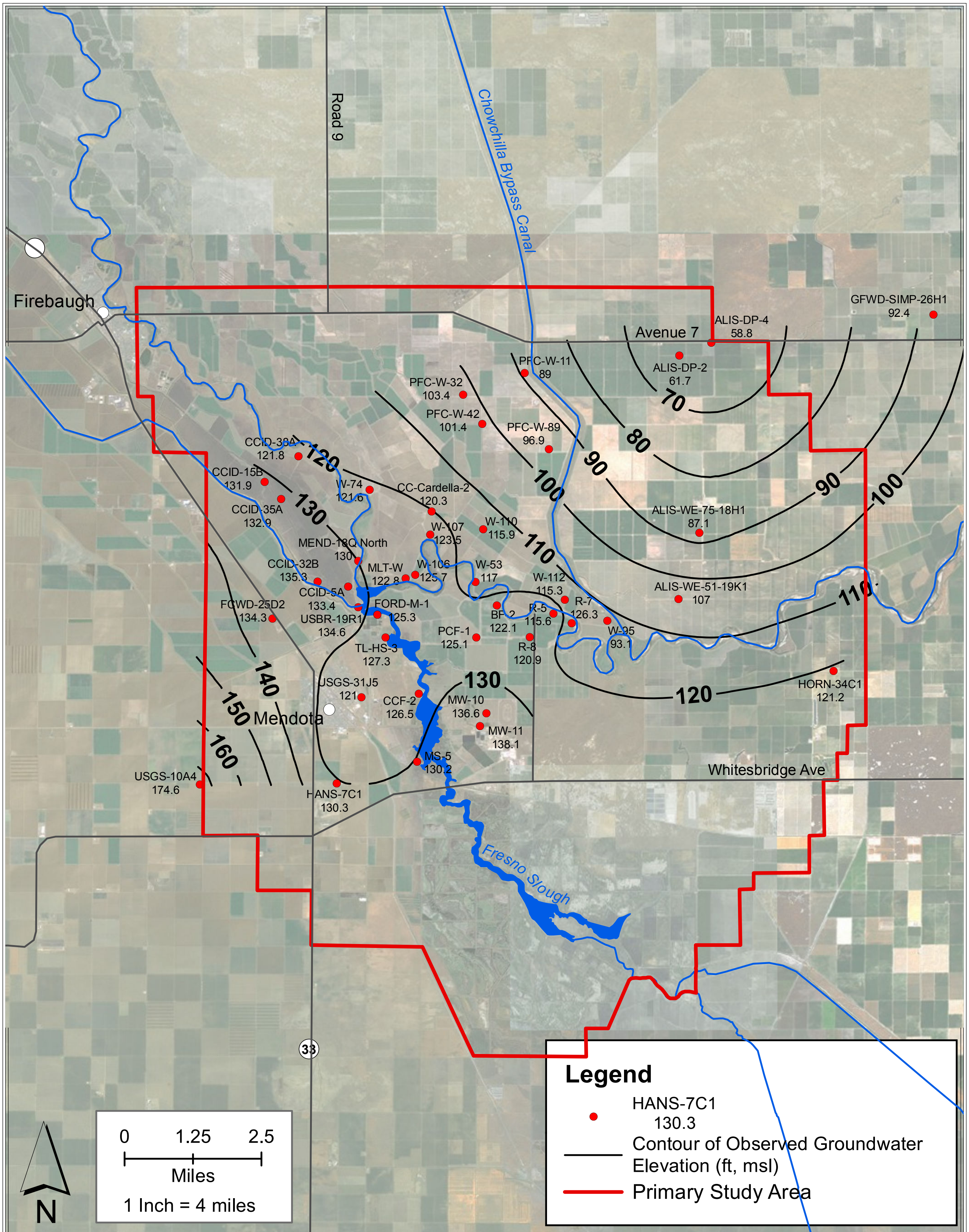

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Figure 2-12
Contours of Equal Observed Groundwater Elevation, Deep Zone (Winter 2012)

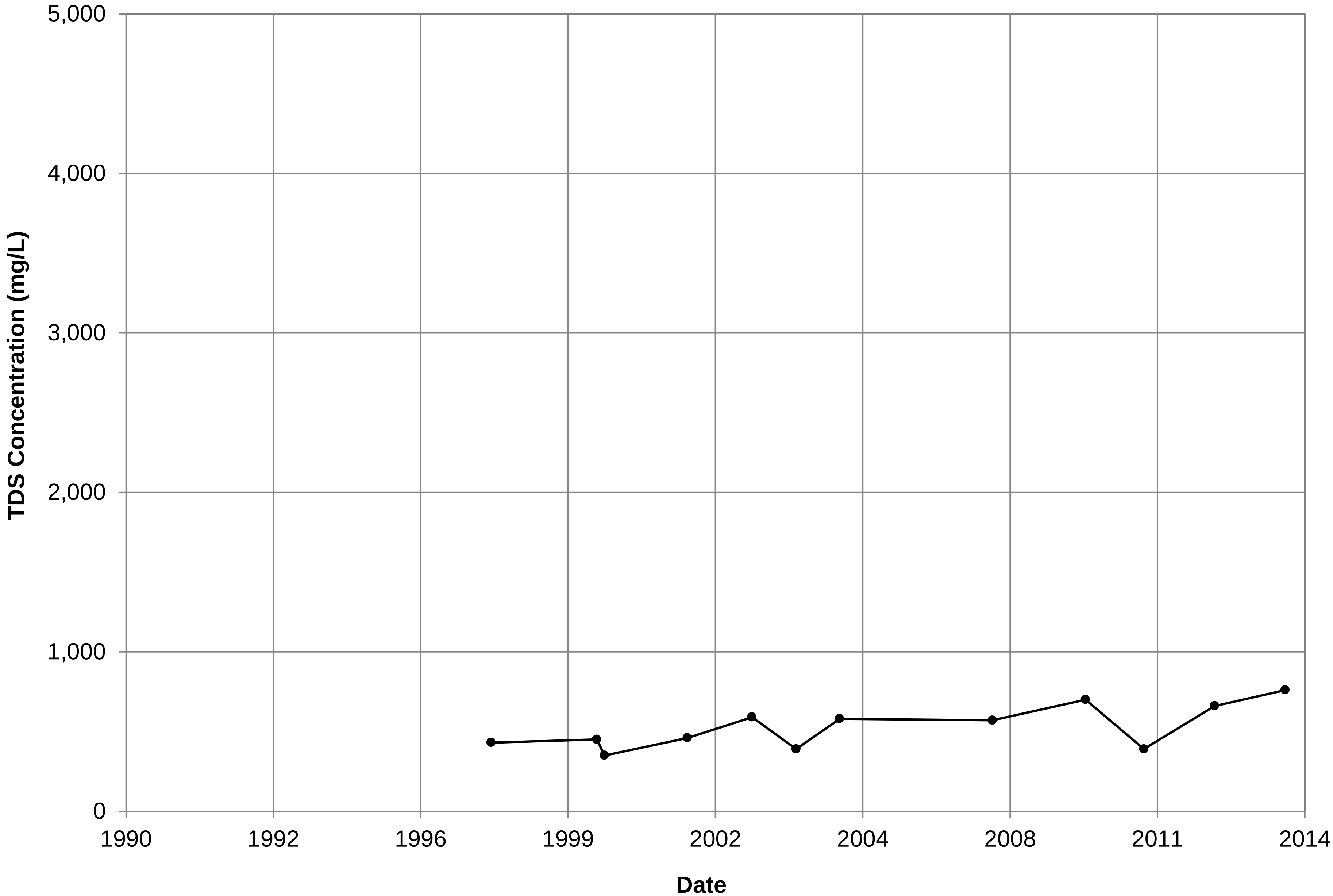

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Figure 2-13
Measured TDS Concentration in Deep Zone
Well CCID-5A

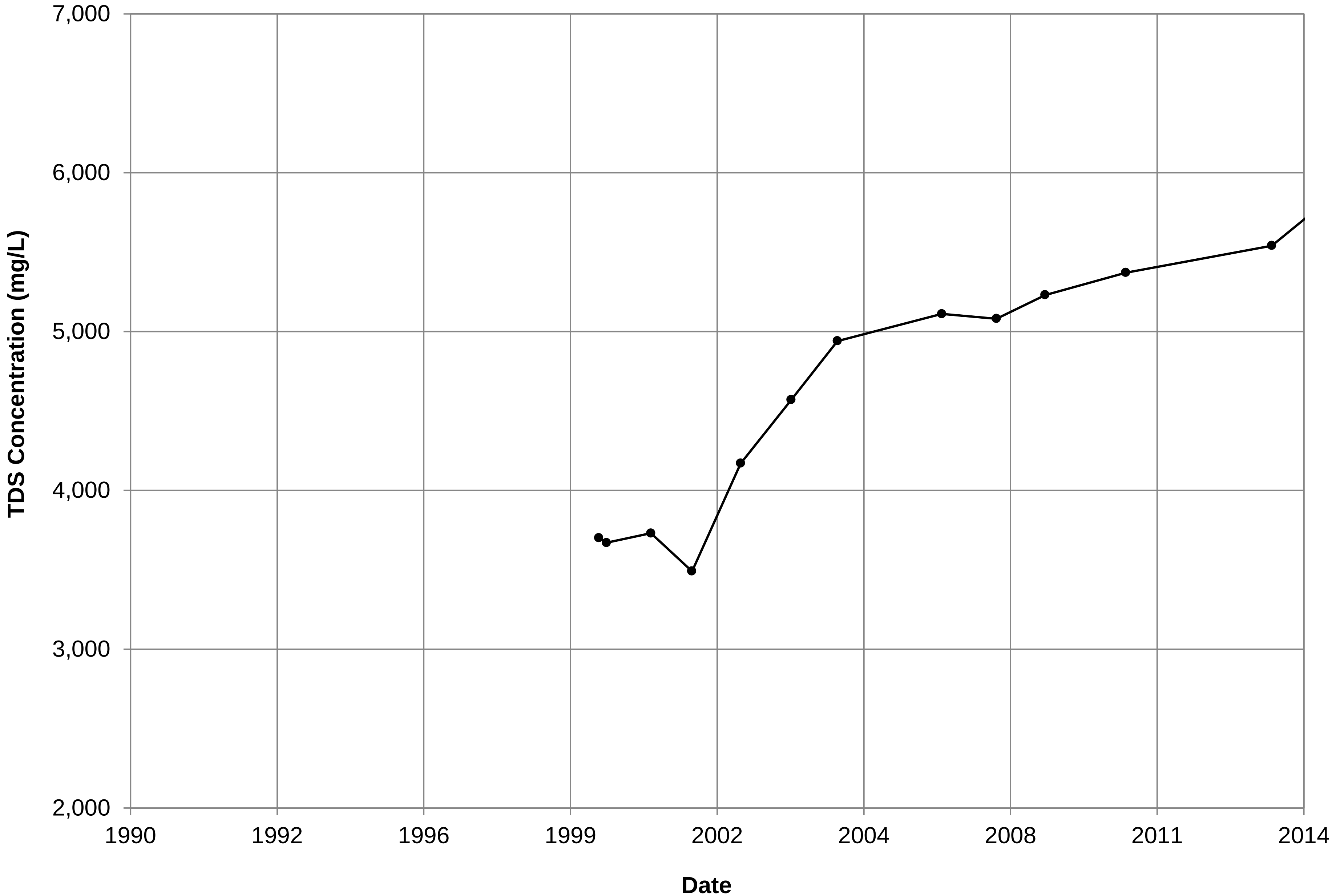

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Figure 2-14
Measured TDS Concentration in Shallow Zone
Well USGS-31J4

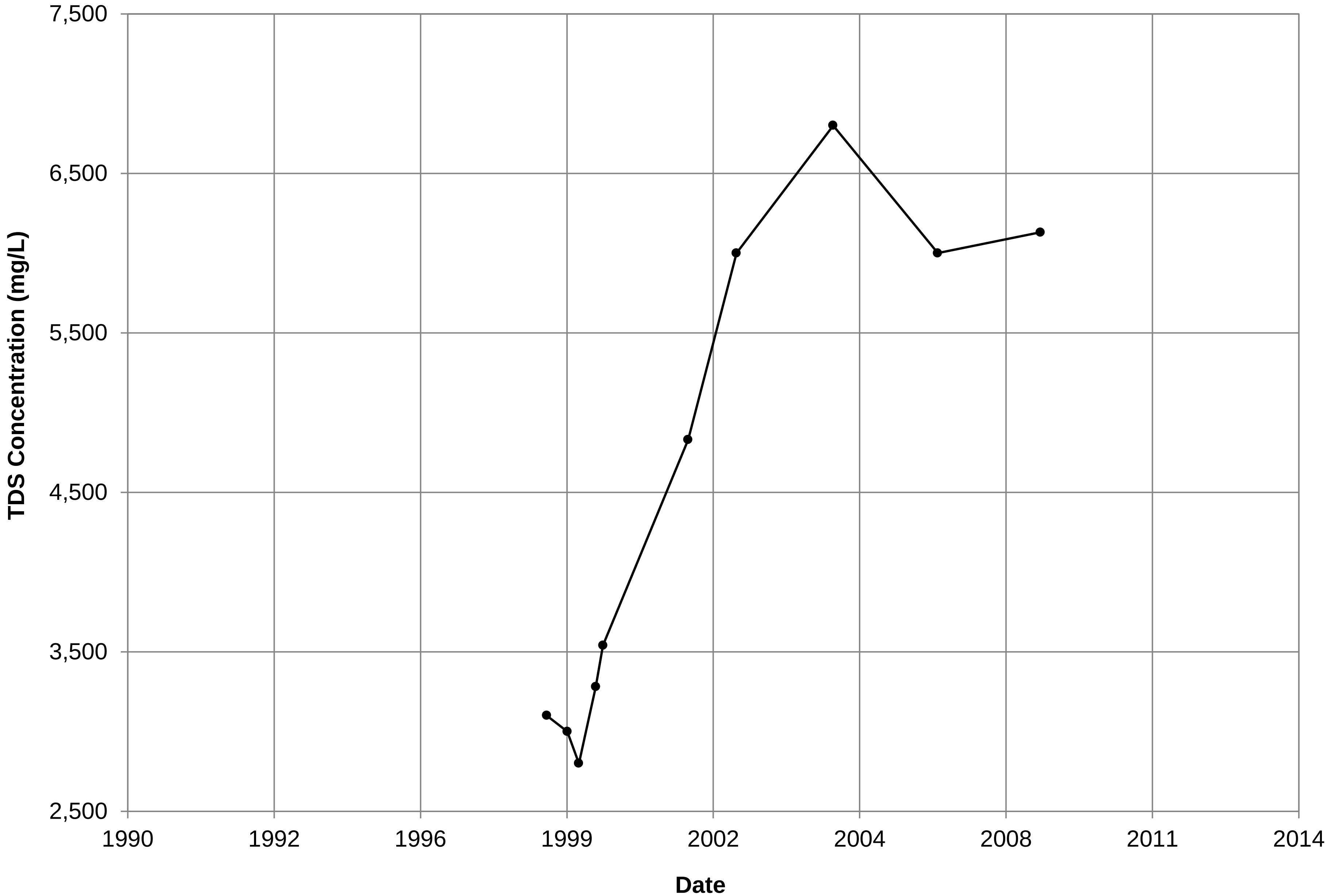

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Figure 2-15
Measured TDS Concentration in Shallow Zone Well MF-S-2

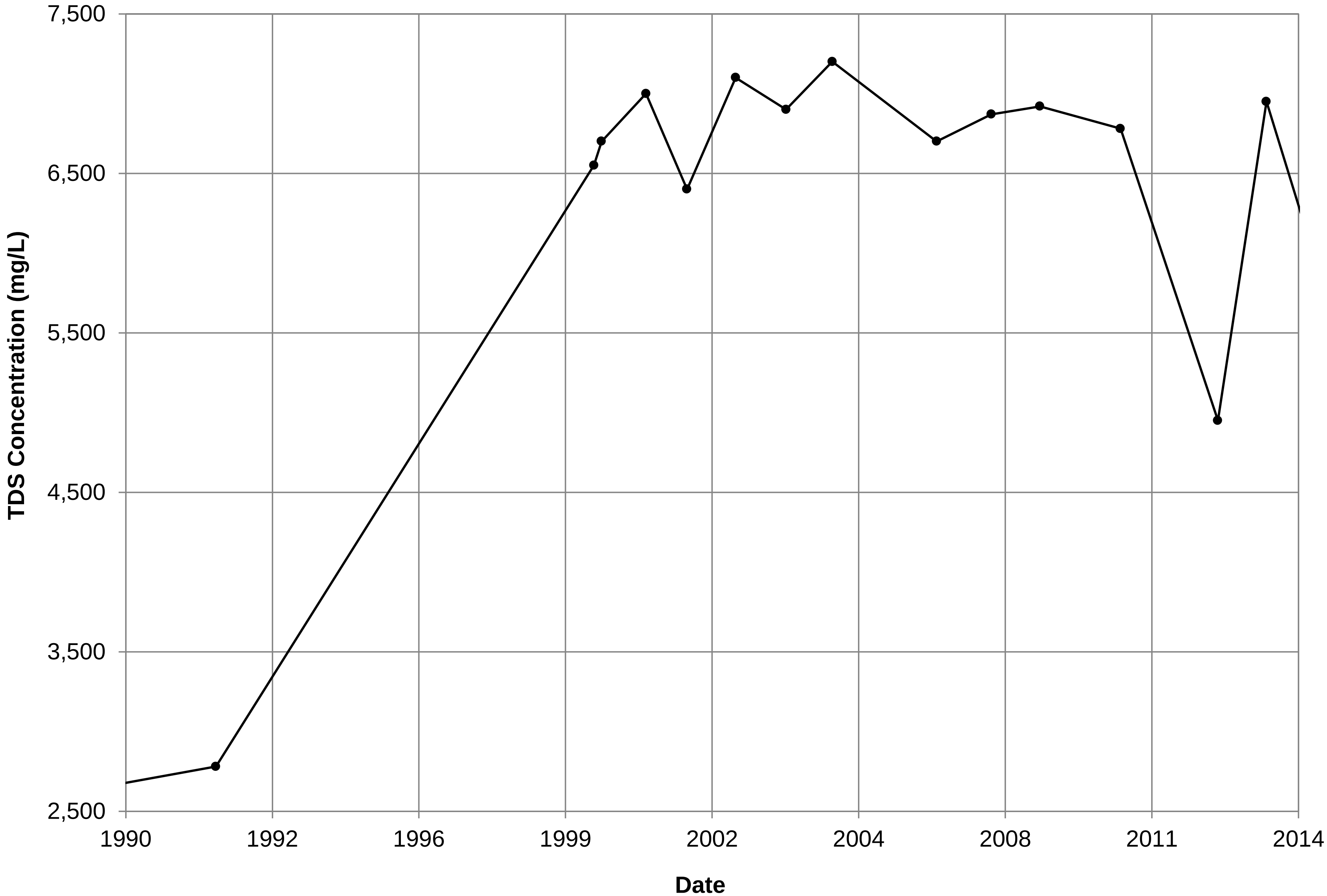

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Figure 2-16
Measured TDS Concentration in Deep Zone
Well USGS-31J5

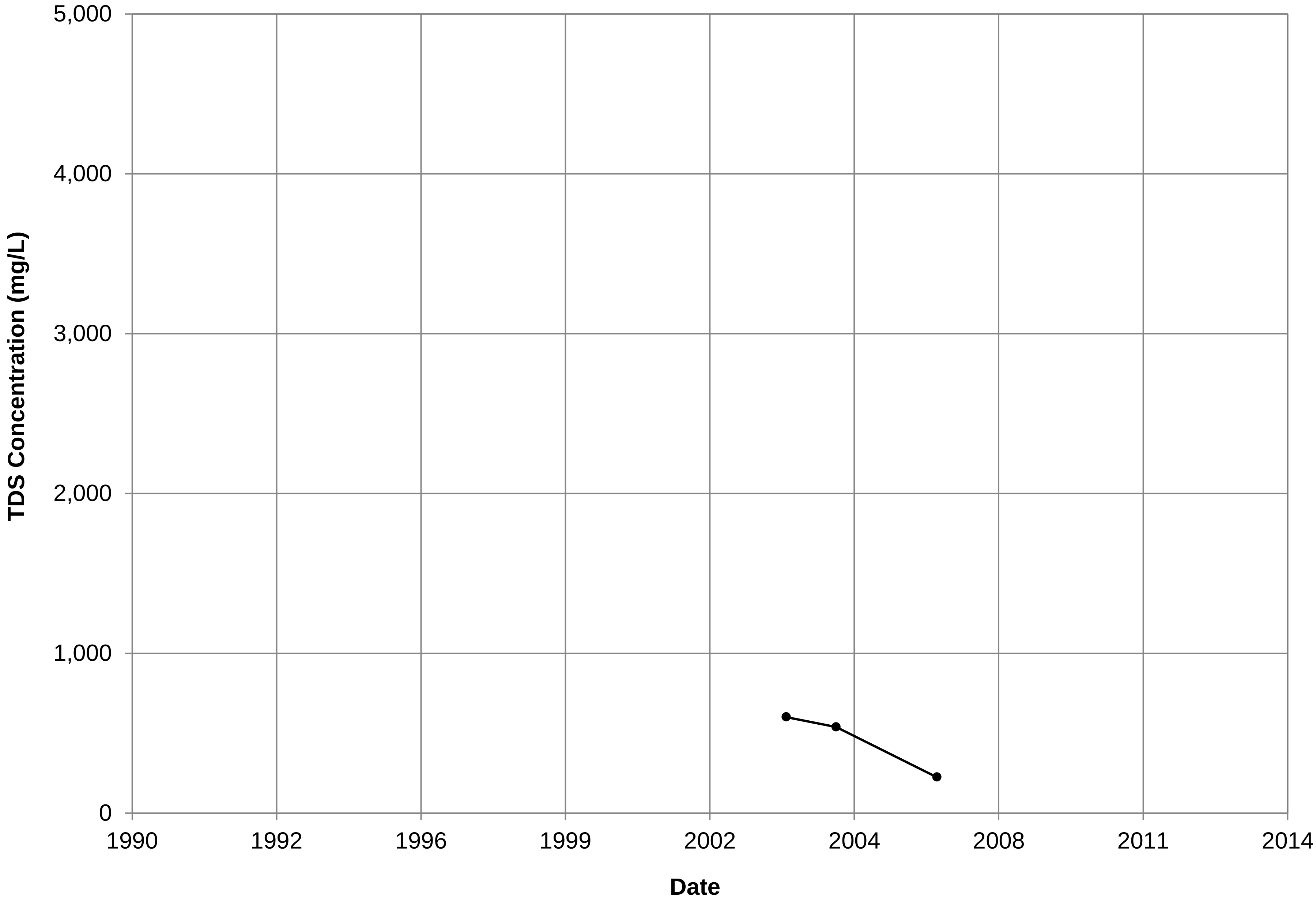

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Figure 2-17
Measured TDS Concentration in Shallow Zone
Well PFC-MW-2

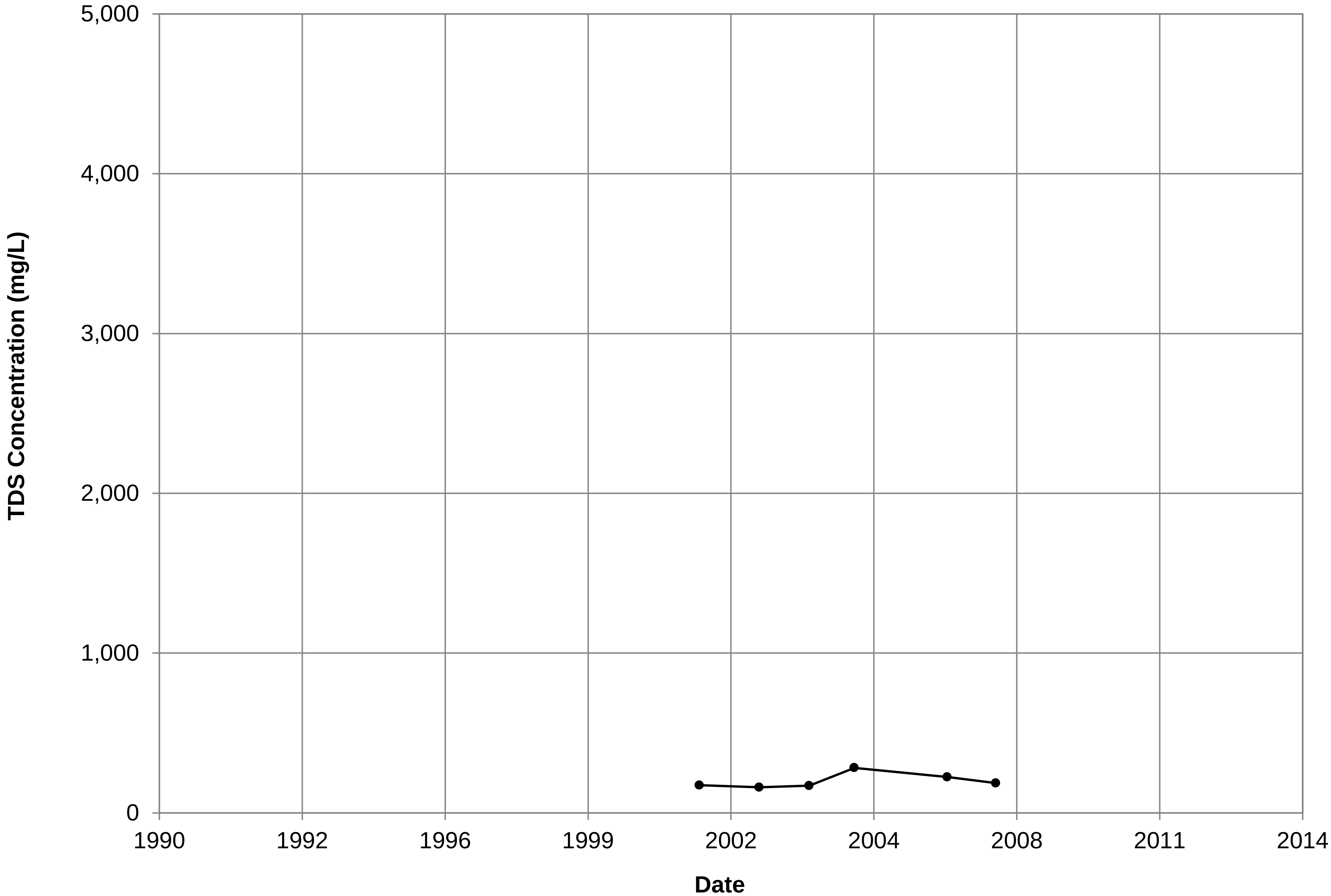

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Figure 2-18
Measured TDS Concentration in Deep Zone Well CC-1

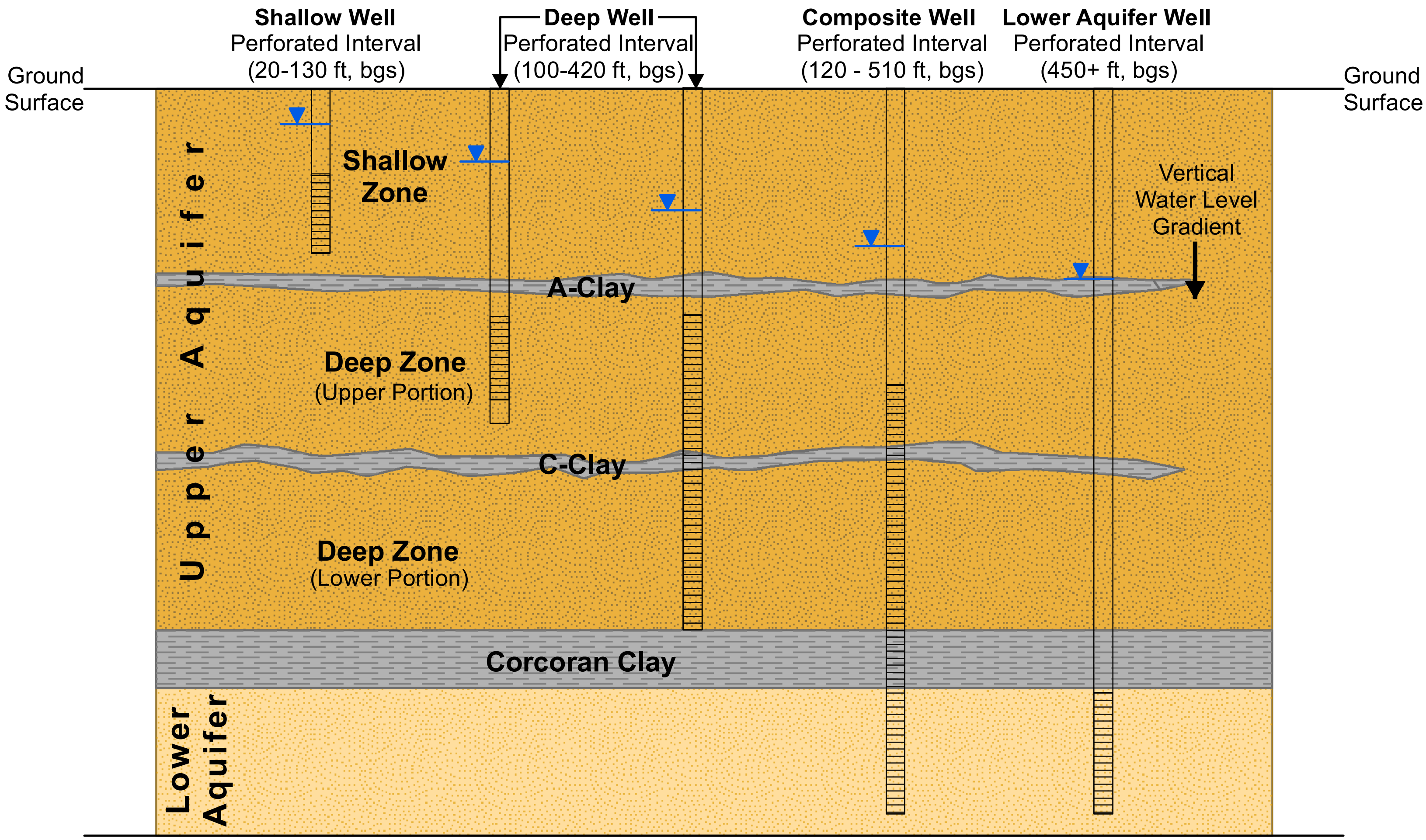

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Figure 2-19
Designation of Aquifer Systems and Well Types
Mendota Pool Group EIS/EIR

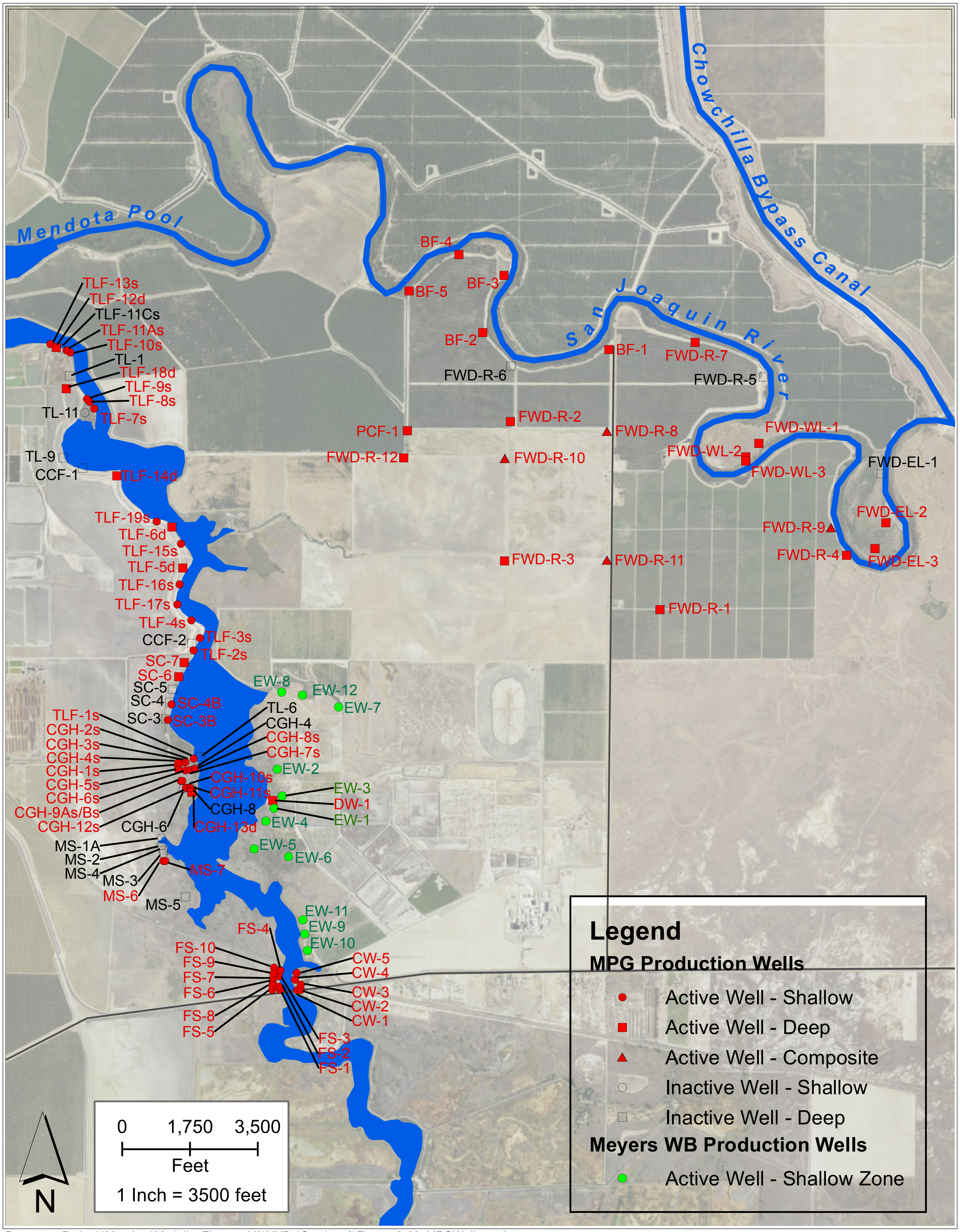

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Figure 2-20
Mendota Pool Group and Meyers Water Bank Production Wells

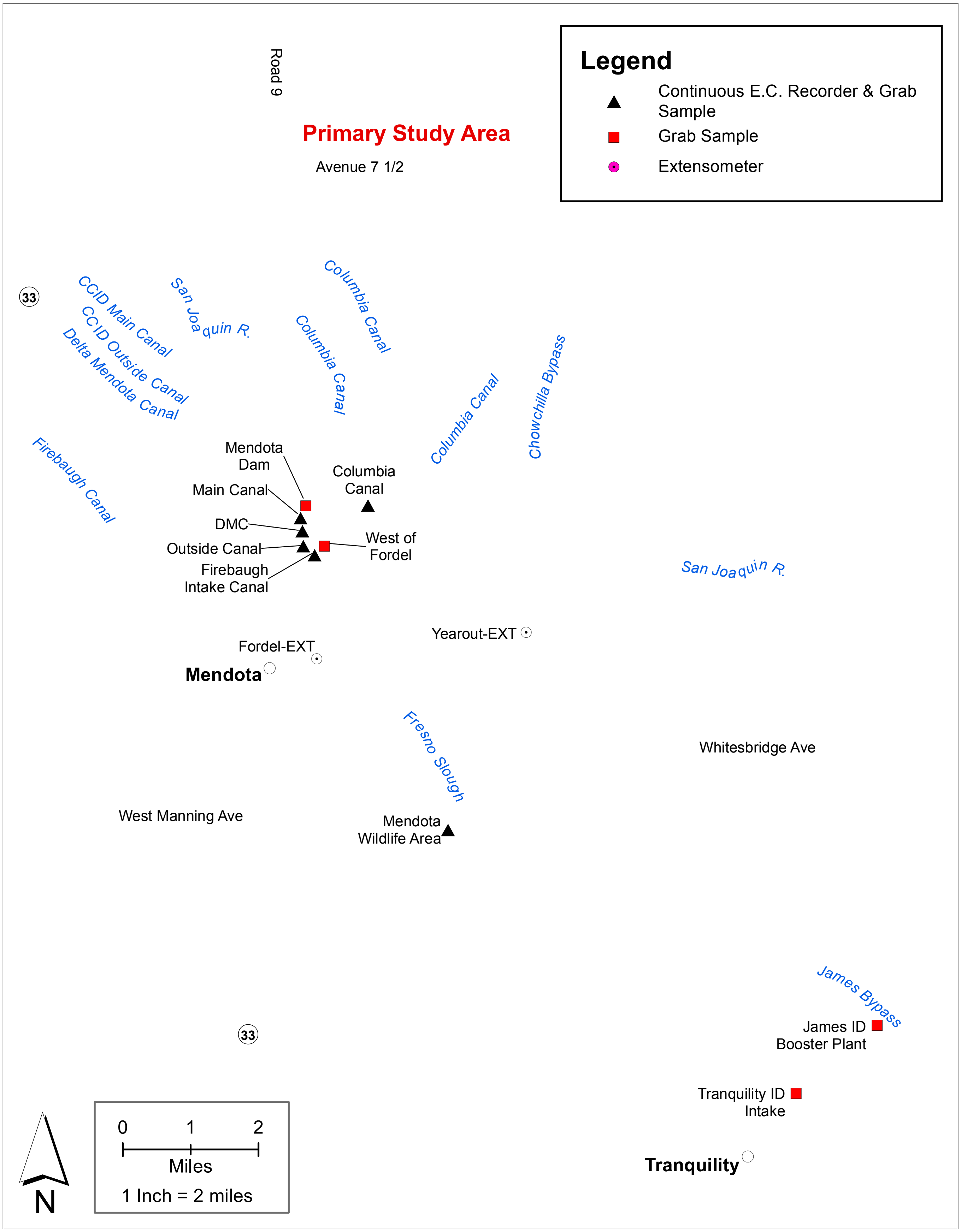

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Figure 2-21
Surface Water Sampling and Extensometer Locations in the Primary Study Area

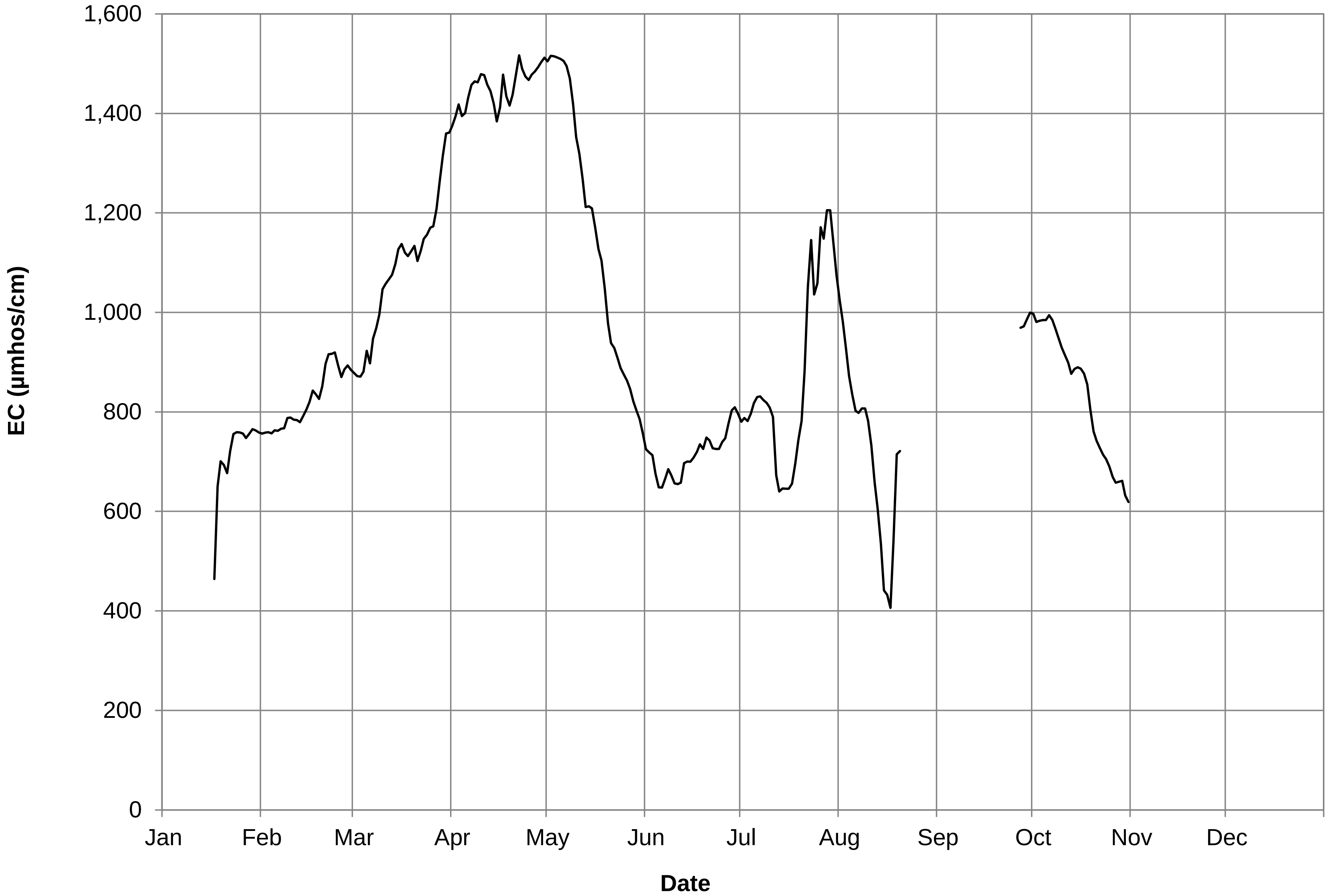

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Figure 2-22
Measured EC at the MWA in 2012

3 GROUNDWATER FLOW MODEL DEVELOPMENT

A numerical model of groundwater flow was developed to investigate the complex interaction of various components of the groundwater and surface water system and quantify the hydrologic response of the proposed Project on groundwater conditions. These include groundwater recharge from irrigation, precipitation, and recharge ponds, groundwater pumping, land use characteristics, groundwater-surface water interaction and subsidence.

3.1 Model Code

The groundwater flow model for this investigation used MODFLOW-NWT, an open source, three-dimensional, finite-difference modeling code developed and maintained by the USGS (Niswonger, 2011). Similar to previous versions of MODFLOW, MODFLOW-NWT utilizes the concept of modularization to represent various aspects of the hydrologic system (McDonald and Harbaugh, 1988). MODFLOW-NWT (Niswonger, 2011), was selected for this problem due to its superior functionality in solving problems involving cell drying and rewetting and nonlinearities arising from surface water boundaries.

3.2 Discretization

3.2.1 Spatial Discretization and Layering

The model domain encompasses a 342 square mile area on an orthogonal finite-difference grid consisting of 216 rows, 228 columns, and 9 layers (**Figure 3-1**). Each cell is 440 x 440 ft square and oriented parallel to the axis of the San Joaquin Valley near Mendota. The areal extent of the model domain was based on consultations with KDSA, the extent of a previous groundwater model developed for the region, and study objectives. The top of the model is the land surface as determined by a 10-meter digital elevation model of the land surface developed by the USGS. The bottom of the model domain was determined by the estimated base of post-Eocene continental deposits and base of fresh water taken from the Central Valley Hydrologic Model (CVHM) model (Faunt, et al., 2009).

The model consists of 9 layers extending from the land surface to below the Corcoran clay (**Figure 3-2**). Layers 1 and 2 represent the unconfined shallow zone overlying the A-clay or A-clay equivalent (where present). Layer 1 is used largely to assign boundary conditions representing streams, canals and the Pool/Fresno Slough. In the majority of the model domain, the thickness of layer 1 ranges from 30 to 40 ft. Over the Pool and Fresno Slough, the thickness of layer 1 was reduced to 12 to 20 ft to better represent the depth of these water bodies that were represented with the Lake (LAK) package. Layer 2 is up to 100 ft thick.

Layer 3 is used to represent the A-clay or A-clay equivalent and is up to 20 ft thick. The top elevation of layer three was estimated based on the top elevation of the A-clay, which generally occurs between 20 and 80 ft, mean sea level (msl) or up to 125 ft bgs as determined by DWR Well Completion Reports, geophysical logs, and land surface elevations (**Figure 3-2**). Beyond the extent of the A-clay, the top of layer 3 follows the slope of the land surface.

The deep zone is represented by model layers 4 through 6. Layers 4 and 6 represent the upper and lower portions of the deep zone, extending from the bottom of the A-clay or A-clay equivalent, to the top of the Corcoran Clay. The thickness of the deep zone as represented by model layers 4 and 6 range from 200 to 435 ft. Layer 5 is about 20 ft thick and is used to represent the C-clay or C-clay equivalent which in some areas of the model domain, bisects the deep zone where this clay is present (**Figure 3-2**).

Layer 7 is used to represent the Corcoran Clay which ranges in thickness from approximately 8 to 90 ft. The thickest portion of the Corcoran Clay is in the northwestern portion of the model domain and it thins to the southeastern portion of the domain (**Figure 3-2**). The thickness of this layer was estimated from available DWR Well Completion Reports and geophysical logs available throughout the model domain. The depth to the top of the Corcorcan Clay in the model domain ranges from 190 to 570 ft, bgs. Layers 8 and 9 are used to represent the lower aquifer that underlies the Corcoran Clay. The top of layer 8 was assigned the same elevation as bottom of the Corcoran clay and the bottom extends to a depth of 215 to 630 ft, bgs (elevation of 700 ft below sea level or the maximum presumed depth of groundwater pumping). Layer 9 is included as a buffer between the bottom of layer 8 and the bottom of the model domain and may intersect the base of fresh water in some areas. Layer 9 ranges from 5 to 460 ft thick (-705 ft to -1160 ft, mean sea level) and dips to the southwest. The bottom elevation of layer 9 corresponds to the bottom of layer 8 in the CVHM (Faunt et al., 2009).

Model layers in MODFLOW-NWT can be assigned as either confined (storage coefficient and transmissivity do not vary) or convertible (storage coefficient dependent on whether confined or unconfined and transmissivity dependent on saturated thickness). Model layers 1 through 6 are designated as convertible while layers 7 through 9 are designated as confined. These designations allowed the model to be flexible in simulating existing unconfined and confined aquifer conditions present in the model domain and PSA.

3.2.2 Temporal Discretization

The groundwater flow model was developed to simulate transient (variable with time) conditions over the January 1, 1990 through December 31, 2012 time period. This time period is divided into 276 monthly stress periods. Specified inflows and outflows, including pumpage, precipitation, ET, and surface-water flow and deliveries are constant within each stress period and vary between stress periods. Each stress period is further subdivided into 4 time steps for which water levels and flows are calculated by the flow model.

3.3 Boundary Conditions

3.3.1 General Head Boundaries

Lateral subsurface flow into and out of the model domain was simulated using the general head boundary (GHB) package (Harbaugh et al, 2000) (**Figure 3-3)**. In the general head boundary, a groundwater elevation is specified at an external reference or "ghost" cell outside of the model domain where the water level is known or extrapolated from known data. The groundwater flux into or out of the domain at the model edges is calculated from the difference in groundwater elevations between the ghost cell and model cell and a conductance value assigned between them.

Assigned groundwater elevations at the model perimeter were varied spatially and temporally, often in response to stresses in the vicinity of the model area boundary. Vertical gradients are present throughout much of the model domain and most especially a downward vertical gradient between the deep zone and the lower aquifer, which was identified in those areas where lower aquifer groundwater level data was available in the model domain. It was assumed that the downward gradient from the deep zone to the lower aquifer exists throughout the model domain. Above the Corcoran Clay, transient groundwater elevations were assigned based on available groundwater elevation monitoring and well construction data. Only aquifer specific elevation data was used in defining the general head boundary condition in the shallow and deep zones. Groundwater elevations and trends were extended between observation locations using linear extrapolation. Observed vertical gradients between the shallow and deep zones were accounted for in the assignment of the general head values.

As mentioned previously, groundwater elevation data is generally sparse in the lower aquifer, both temporally and spatially, making it difficult to define groundwater elevations along the model boundaries in layers 8 and 9 solely based on measured groundwater elevation data. A notable exception is the presence of USGS monitoring well 31J6 completed below the Corcoran clay west of the Pool. USGS 31J6 is part of a cluster of monitoring wells constructed near the Pool east of the William Robert Johnson Municipal Airport. The well has an extensive groundwater elevation record with monthly to quarterly measurements prior to the January 1990 model starting time. Groundwater elevations for the general head boundary condition for the lower aquifer were derived from this well, along with historical USGS groundwater elevation contours, CVHM simulated elevations, and general regional trends based on the professional opinion of Ken Schmidt of KDSA (personal communication, November 2013) and other local groundwater professionals.

The conductance term at each general head cell is held constant throughout the simulation. Assigned groundwater elevations vary with each stress period (monthly) and are consistent with both locally observed well data and regional trends.

3.3.2 Known Groundwater Pumping

Known pumping was simulated using a combination of the Revised Multinode Well (MNW2) package (Konikow et. al., 2010) and the Well (WEL) package (Harbaugh et. al, 2000). The WEL package was used to simulate pumping in wells which are completed in one model layer. In wells completed in multiple aquifers, the MNW2 package was used as it allows for the simulation of pumping from wells perforated in multiple aquifers through accounting for discharge from each aquifer layer to the well based on the perforated interval, aquifer transmissivities, and hydraulic heads.

Known groundwater pumping was assigned to areas where relatively reliable and consistent records of pumping are available. In addition to MPG lands, these areas include portions of the CCID, Columbia Canal Company, New Columbia Ranch, and Meyers Farms (**Figure 3-4**). Monthly metered pumping was assigned to each modeled well for each stress period in the model simulation. During periods where pumping was not reported (1990 -1999), estimates were made based on land use, hydrologic year and the distribution of pumping between wells from known years. Vertically, wells were assigned based on screen elevations provided in well construction information as it was known for the simulation period.

3.3.3 Estimate of Unknown Groundwater Pumping

Pumping that occurs in areas where groundwater withdrawals are not metered were estimated using a water-budget approach (**Figure 3-4**). The water budget incorporates known surface water deliveries, precipitation, irrigation efficiency, and land use characteristics to estimate the unmet crop water demand for each model cell in each stress period. Groundwater pumping is assumed to make up the estimated applied water that is not met by surface water and precipitation. Estimates of pumping were aggregated over an approximately one mile grid of virtual wells simulated using the MNW2 package distributed over areas where measured pumping data are unavailable. In some local areas in the PSA where metered pumping data is incomplete, virtual wells were simulated to augment metered groundwater production. In the Mendota Wildlife Area, no pumping was simulated to address irrigation needs in that area.

The water budget accounts for the fraction of each model cell which is irrigated in each stress period. The distribution of land use was derived from DWR land use survey data for Madera and Fresno Counties and land use data from the NRCS which has, since 2007, produced land use coverages for California based on remote sensing data. These two data sources were the primary sources used for accounting for land use distribution in the model domain. Data were combined from each source to produce data for each year of the model calibration period. Precipitation was estimated based on the simulated monthly spatial distribution of rainfall provided in the PRISM datasets developed by the PRISM Climate Group (PRISM, 2013). Applied surface water was estimated based on reported monthly surface water deliveries for various water purveyors in the area. Since there is no information to determine surface water allocations to particular fields, the total water delivered to each farming entity within each month was distributed to model cells based on the surface water delivered, the fraction of irrigated land in each model cell and the area-weighted cell average evapotranspiration.

The evapotranspiration assigned in each model cell for each stress period was calculated based on the calculated ET for each crop for each stress period weighted by the area of each cell occupied by that crop. ET was estimated from three evapotranspiration stations managed by the California Irrigation Management Information System (CIMIS). These include Station #7 – Firebaugh/Telles, Station #105 – Westlands, and Station #145 – Madera. Crop coefficients and ET were calculated based on the Basic Irrigation Scheduling (BIS) developed by Snyder et al (2000). As mentioned above, the crop irrigation demand was met by precipitation and surface water deliveries first and then remaining applied water demand was met by groundwater pumping.

3.3.4 Areal Recharge

Areal recharge in the model was simulated using the Recharge (RCH) Package. Components of recharge that were simulated included recharge ponds in the NCR, Meyers Water Bank, and recharge from irrigation and precipitation. Estimated monthly pond infiltration rates were used to assign a recharge to each recharge pond when the recharge ponds were operational. Recharge from irrigation was varied in each stress period and was based on the amount of applied water and irrigation efficiency for each crop type.

3.3.5 Groundwater-Surface Water Interaction

Groundwater-surface water interaction was represented using a combination of the Streamflow Routing (SFR) package and LAK (Prudic et al., 2004; Merritt and Konikow, 2000). The SFR package is a module within MODFLOW-NWT used to simulate streamflow and stream-aquifer interaction. Streams and canals were simulated by the SFR package and included the SJR, Delta Mendota Canal, Chowchilla Bypass, and other major canals which divert water from the Pool (**Figure 3-3**). The LAK package is used in conjunction with the SFR package to represent the Pool and Fresno Slough (**Figure 3-3**). Stage and flow within streams and canals are calculated based on known inflow and canal diversion data obtained from the Bureau of Reclamation. Stage in the Pool was based on historical stage levels and assigned during model initialization. Stage in the Pool varied slightly during the model simulation based on inflows from the San Joaquin River, the DMC, groundwater pumping, periodic flood flows from the James Bypass, and diversion to the main canals on the northern end of the Pool along with estimated seepage to the underlying aquifer system. Used together, the SFR and LAK packages simulated groundwater-surface water interaction and accounted for surface water components and variables and the interaction with the groundwater system.

The San Joaquin River upstream of the Pool was divided into three segments based on the location of stream gage data and streambed properties including channel width, slope, and streambed hydraulic conductivity (**Table 3-1**). The first segment represents the upper reach of the SJR from the model boundary to the Gravelly Ford gage. Streamflow into this segment was specified based on measured discharge at the USBR gage at Gravelly Ford and adjusted to compensate for streamflow losses between the gage and the edge of the model domain (**Figure 3-3**). These adjusted flows were used to represent San Joaquin River flow into the model domain upstream of the Gravelly Ford gage. The second segment was assigned on the portion of the San Joaquin River from Gravelly Ford to the bifurcation of the SJR at the Chowchilla Bypass. The third segment represents the SJR from the Bifurcation to the beginning of the SJR branch of the Pool at around San Mateo Avenue. Below the Mendota Dam, the San Joaquin River was simulated with an additional stream segment from the Mendota Dam to the northwestern extent of the model domain. Streamflow at the upper reach of this segment was calculated internally by the groundwater model based on the stage in the Pool and elevation of the Mendota Dam.

Canals represented in the model include the Chowchilla Bypass, Firebaugh Canal, CCID Outside Canal, CCID Main Canal, Columbia Canal, Delta-Mendota Canal, and the primary irrigation canals located in NCR which conveyed water diverted from the Columbia Canal (**Table 3-1, Figure 3-3**). Diversions to the Chowchilla Bypass are defined based on observed data from 2003 to 2012. Prior to 2003, diversions to the Chowchilla Bypass were estimated based on the relationship between flow in the San Joaquin River and known diversion flows. Flows in the Delta-Mendota Canal were specified based on data available from the SLDMWA. Diversions from the Pool to the Firebaugh Canal, CCID Outside Canal, CCID Main Canal, and Columbia Canal were specified based on known monthly diversion volumes provided by the USBR (DWR, 2013; USBR, 2013).

The Pool and Fresno Slough are simulated using one lake boundary condition extending from the Mendota Dam to the southern extent of the model (Fresno Slough) and from the Mendota Dam to the area of the Pool near San Mateo Avenue which covers the northern or SJR branch of the Pool (**Figure 3-3**). Stage in the Pool exhibits little variation, however the stage does fluctuate to some extent during storm events and declines when the Pool is drained periodically for maintenance. Inflows to the Pool simulated by the LAK package include flow from the San Joaquin River, James Bypass, Delta Mendota Canal, some MPG groundwater for adjacent use, MPG groundwater for exchange, along with other non-MPG pumpers. Diversions from the Pool that are simulated include withdrawals by multiple entities or programs including Tranquility Irrigation District, James Irrigation District, MWA, WWD, Meyers Farming, Terra Linda, Coelho-Gardner-Hanson (CGH), Hughes, Wilson, Fresno Slough Water District, Traction Ranch, Warren Act, and Reclamation 1606. Flow data from the Pool over the Mendota Dam into San Joaquin River was obtained from the U.S. Bureau of Reclamation (USBR, 1990 – 2013). Lake bed hydraulic properties (governing exchange between the lake and groundwater) were based on previous estimates of seepage amounts from the Pool (KDSA and LSCE, 2000) as described in Chapter 2. In the northern branch of the Pool, the assigned lake bed conductance was slightly higher than the Fresno Slough portion of the Pool, because lake bed sediments are likely coarser due to influence from the San Joaquin River. In the northern branch of the Pool, the lake bed conductance was 0.02 ft/per day compared to 0.002 ft/per day in the Fresno Slough branch of the Pool.

Table 3-1: Stream Segments in the Streamflow Routing Package

SFR Segment	Water Body
1	San Joaquin River from Model Boundary to Gravelly Ford
2	San Joaquin River from Gravelly Ford to Bifurcation
3	San Joaquin River from Bifurcation to Mendota Pool
4	Chowchilla Bypass
5	San Joaquin River from Mendota Pool to Model Boundary
6	CCID Main Canal
7	Delta Mendota Canal
8	CCID Outside Canal
9	Firebaugh Canal
10	Columbia Canal #1
11	Columbia Canal #2
12	Columbia Canal #3
13	Columbia Canal #4

3.4 Aquifer Properties

The hydraulic properties of an aquifer system govern the movement and storage of groundwater in the system. Hydraulic conductivity, or the rate at which water can flow through a porous medium, is closely related to sediment grain size distribution. Within the model domain, sediments have been largely deposited in a fluvial (riverine) setting subdivided by periods of extensive lacustrine (lake) silt and clay deposition (A and C clays, and Corcoran Clay described above).

The volume of water which an aquifer can release or take into storage given a unit change in hydraulic head is defined as the storativity (for a confined aquifer) or specific yield (for an unconfined aquifer) of that aquifer. While aquifer tests were used (where available) to quantify these parameters, values for these parameters are most often assigned using generally acceptable values for the sediment textures or the type of aquifer that is present, and where possible constrained using what limited aquifer test data may be available. In addition, analysis of seasonal variations in groundwater levels, subsurface geology, and well construction features were used in estimating the type of aquifer and storage coefficient in the absence of aquifer test data. Shallow wells that have minimal seasonal variations likely have high storage coefficients (specific yield). Deep wells that have large variations in seasonal water levels likely have low storage coefficients (storativity or specific storage).

3.4.1 Hydraulic Conductivity

Hydraulic conductivity within the model domain was developed following a three-step process. The first step was to utilize the texture analysis methods and data employed by the USGS in developing the CVHM groundwater model (USGS, 2009) to create a geostatistical representation of textures related to the percent of coarse-grained sediments that are present. The second step was to revise the geostatistical representation to more accurately reflect known and estimated depositional trends in the area of the model domain. Thirdly, textures were converted to hydraulic conductivities based on available aquifer test data (65 total for the shallow and deep zones within the model domain), CVHM values assigned within the model domain, and a review of literature values. This three-step process provided a comprehensive method for producing a reasonable representation of the distribution of hydraulic conductivity which incorporates lithologic data from relatively abundant DWR Well Completion Reports into a regional geologic framework. Hydraulic conductivities were adjusted as part of the calibration process within ranges of values associated with the observed aquifer materials. The calibrated distribution of hydraulic conductivity values are discussed in Chapter 5.

3.4.2 Storage Properties and Aquifer Compaction

Aquifer storage properties and aquifer compaction were simulated using a combination of the Subsidence (SUB) and Upstream Weighting (UPW) packages (Hoffman et al., 2003; Niswonger et al., 2011). The UPW package was used largely to simulate storage changes at the water table. The SUB package was used to simulate aquifer compaction and storage changes occurring in the confined aquifer system.

In an unconfined system, the change in groundwater storage is largely controlled by the specific yield. The specific yield is a dimensionless storage coefficient equal to the ratio of water which an aquifer will yield due to gravity-driven drainage compared to the total bulk aquifer volume. The specific yield is approximately equal to the porosity of a bulk aquifer unit minus some volume of water which remains trapped in the pore spaces due to capillary forces. It is not uncommon for an unconfined aquifer to yield 20 to 30 percent of its total volume in water.

In a confined system, the amount of water a unit volume of aquifer releases or takes up per unit change in hydraulic head is determined by the specific storage (L^{-1}). Since the porous medium in a confined aquifer is always saturated, changes in groundwater storage due to changes in hydraulic head are determined by the compressibility/expandability of the pore spaces leading to deformation of the aquifer skeleton and (to a lesser extent) the compressibility of water. Deformation of the aquifer skeleton can occur either elastically (recoverable) or inelastically (permanent) and is dependent on the composition of the aquifer material and the amount of stress (effective stress) within the aquifer. Inelastic deformation occurs when the effective stress within the fine-grained material in an aquifer system exceeds the maximum effective stress leading to permanent changes in the arrangement of grains and is represented by an inelastic specific storage (L^{-1}). Elastic deformation occurs when the maximum effective stress is not exceeded and is represented using an elastic specific storage (L^{-1}).

The specific yield and compressibility of water were specified in the UPW package (Niswonger, et al., 2011). Values for specific yield were assigned to unconfined layers following a review of the CVHM model values used within the Mendota Model area and adjusted during model calibration. The compressibility of water (L^{-1}, 1.4×10^{-6}) estimated from previous studies (Faunt et al, 2009), was scaled with respect to the porosity of each model layer and assigned to all model layers as a specific storage.

The SUB package solves for changes in compaction and groundwater storage based on changes in the hydraulic head, the preconsolidation stress (or preconsolidation head in the SUB package), and coefficients governing the elastic and inelastic skeletal storage (Hoffman et al., 2003). For this investigation, the delay in subsidence that commonly occurs due to slow groundwater exchange between interbedded fines and coarse-grained aquifer material within a model cell is ignored since historical observations of extensometer data in the PSA indicate there is little delay in inelastic subsidence in the shallow and deep zones.

The elastic and inelastic skeletal storage properties were assigned in the SUB package. The elastic skeletal specific storage coefficients were estimated for fine and coarse grained materials and weighted by the respective coarse and fine grained volume fraction for each model layer. The inelastic skeletal specific storage coefficient for each model layer was calculated based on the volume fraction of fine grained material multiplied by the inelastic specific storage. Initial specific storage values for fine and coarse grained materials were estimated from those reported in Ireland et al. (1984) and Faunt et al. (2009) and adjusted during model calibration to extensometer data collected from the Yearout and Fordel extensometers.

Preconsolidation head input values were assigned to each model cell at the beginning of the model simulation period. These values were determined from the calculated preconsolidation head simulated in CVHM at the end of December 31, 1989. In instances where the initial groundwater head assigned in the MPG model is less than the preconsolidation head simulated in CVHM, the SUB Package assumed the preconsolidation head is equal to the lower of the two values.

3.5 Initial Conditions

Initial conditions define the state of the aquifer system at the beginning of the simulation period. For the Mendota model, the initial condition is representative of groundwater elevations in January 1990. Initial conditions were developed for the shallow and deep zones and the lower aquifer using available zone or aquifer-specific water level data where available. Observed water levels collected between October 1989 and March 1990 were considered in this effort. Regional trends documented by others (DWR, USGS, Kenneth D. Schmidt and Associates) were also considered in developing the initial conditions for each zone or aquifer, with these data sources especially useful where observation data was sparse or non-existent. This condition was especially true below the Corcoran Clay where monitoring data for the lower aquifer within the model domain has only been collected at a few locations. Initial conditions for each zone and aquifer were developed in the form of groundwater contours, which were provided to Kenneth D. Schmidt and Associates for review (personal communication, 2013). The contours were converted to a grid and input to the model.

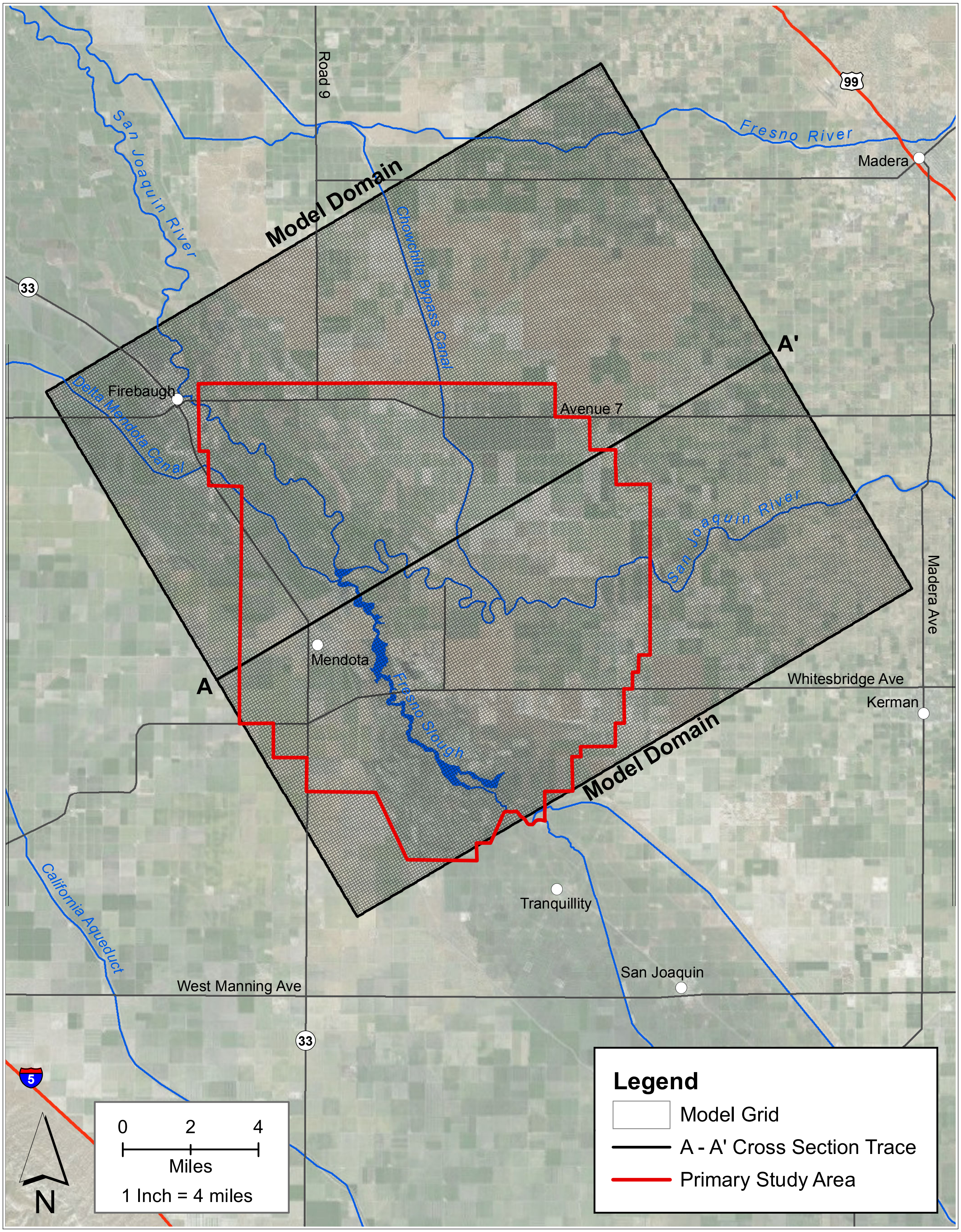

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Figure 3-1
Model Grid and Cross Section Trace
Boundary Conditions

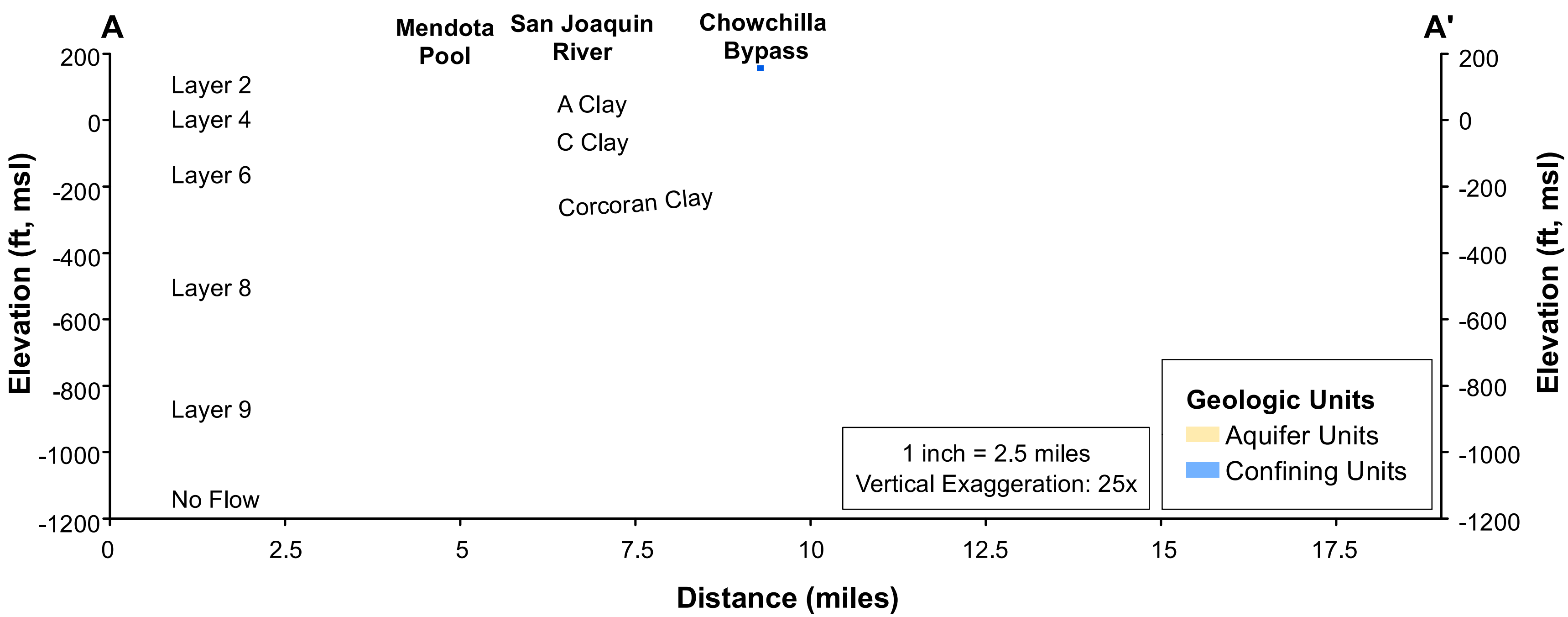

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Figure 3-2
Schematic Cross Section A - A' and Model Layering

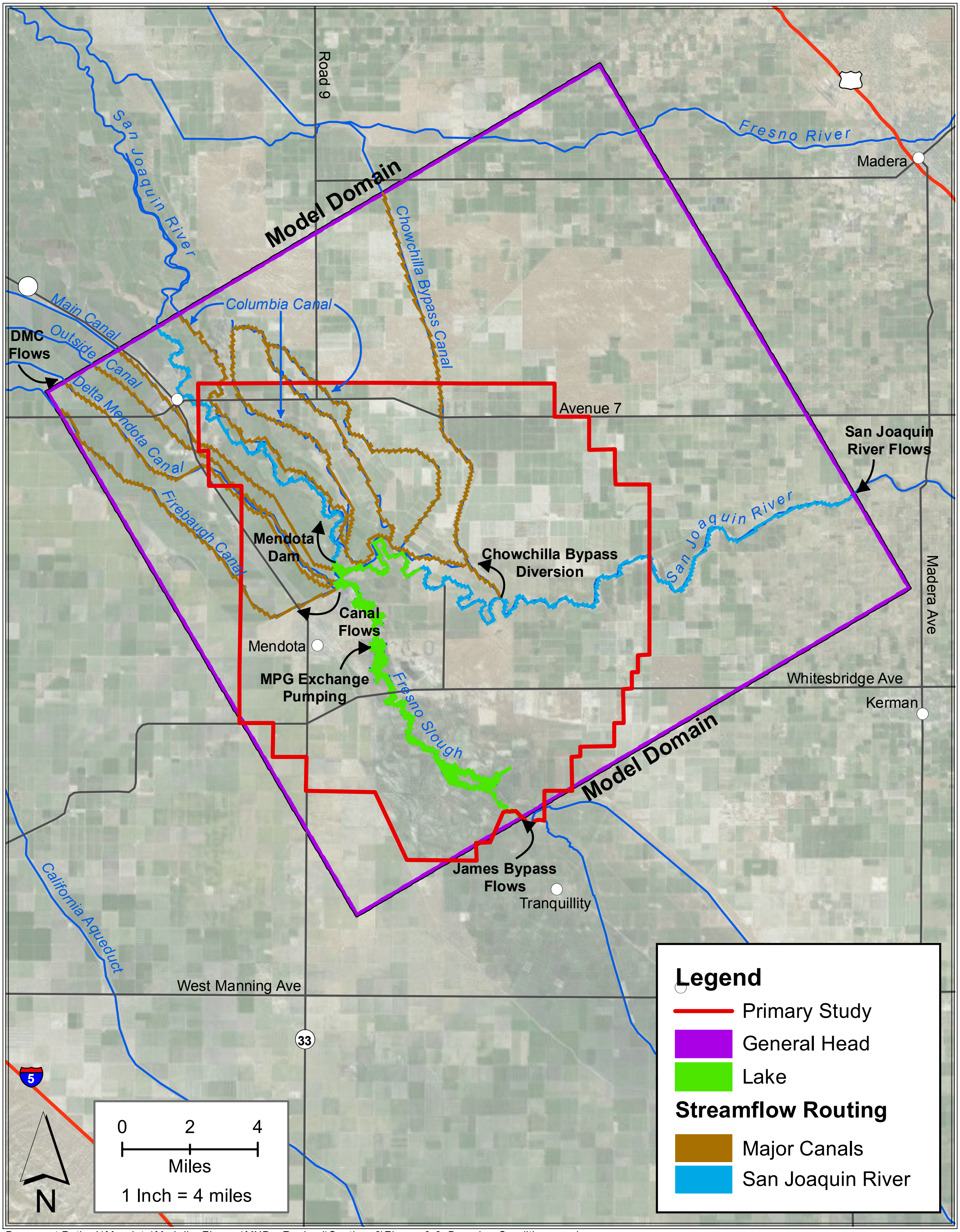

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Figure 3-3
Groundwater Flow Model Boundary Conditions

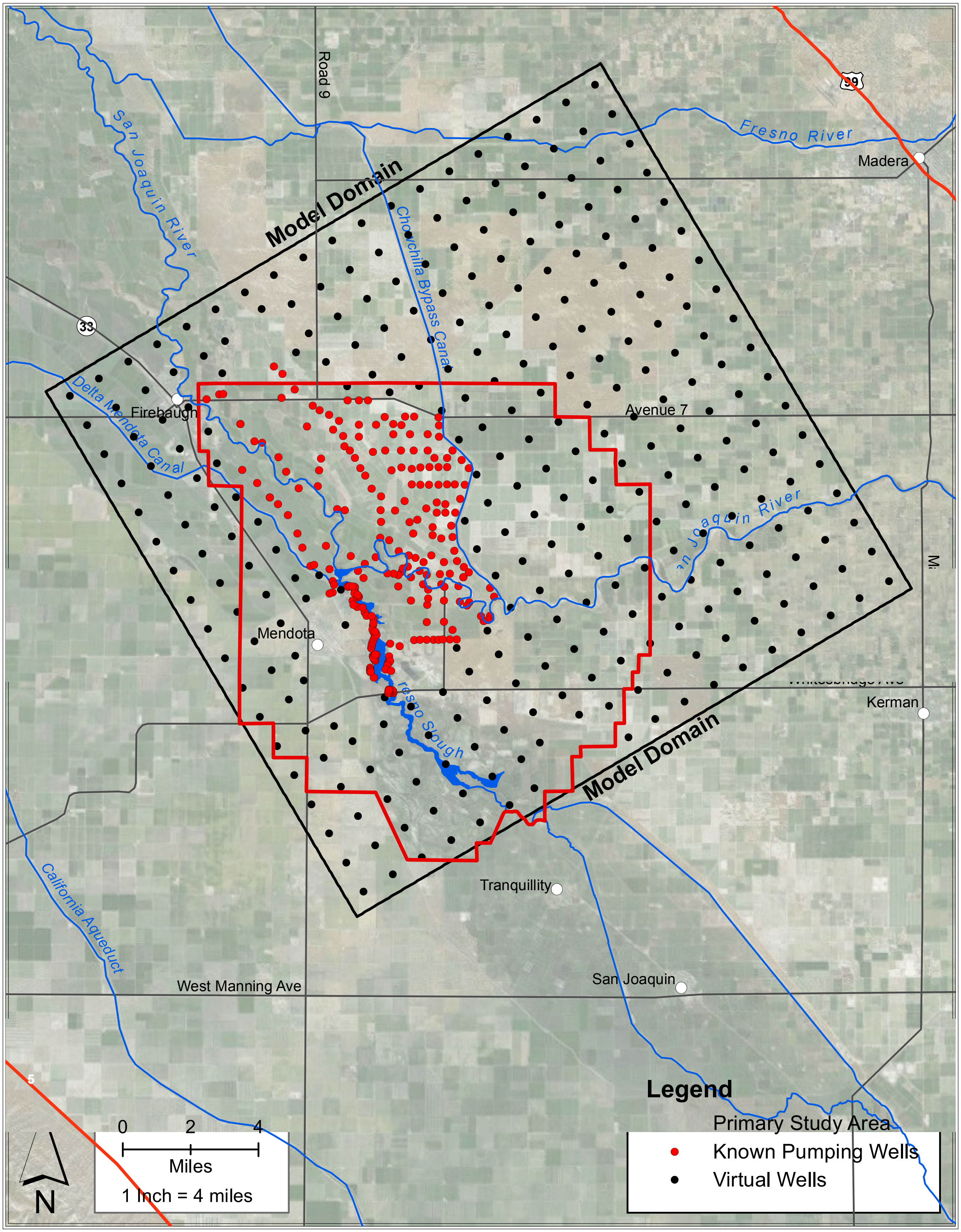

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Figure 3-4
Location of Production Wells within Groundwater Flow Model Domain

4 GROUNDWATER AND SURFACE WATER QUALITY MODEL DEVELOPMENT

Modeling of groundwater and surface water quality was conducted utilizing the two different methods. Groundwater quality was simulated utilized a numerical solute transport model while surface water quality was simulated utilizing an analytical water budget mixing model approach. Both approaches are described below.

4.1 Groundwater Solute Transport Model Code

A solute transport model was developed to simulate the fate and transport of salts in groundwater within the model domain over the calibration period of 1990 through 2012 and to also predict future changes in salinity in groundwater resulting from the Project. Solute transport was simulated using the MT3DUSGS solute transport code. MT3DUSGS is a three-dimensional modeling platform used to simulate advection, dispersion, and reactions of multiple chemical species based on the MT3DMS code (Zheng, 2010). Its modular structure allows it to couple easily with the groundwater flow field generated from MODFLOW simulations. Due to the nature of the technical analysis, the MT3DUSGS version of MT3DMS developed by the USGS (Bedekar, et. al., 2016) was utilized to provide compatibility with the LAK and SFR Packages used in the simulation of groundwater flow (Merritt and Konikow, 2000; Prudic et al., 2004; Zheng, 2010).

4.1.1 Groundwater Solute Transport Model Development

The conceptual model for evaluating fate and transport of salts was developed from review of existing reports, maps, and correspondence in conjunction with more recent analysis of water quality trends in the PSA and model domain. In general, salinity varies considerably over the PSA and is influenced by a number of factors including:

- The northeasterly and easterly movement of the naturally occurring saline groundwater front in response to the regional groundwater flow gradient towards Madera County,
- Applied water (artificial recharge and irrigation) which creates a vertical salt gradient with generally higher TDS in shallower groundwater,
- Generally good water quality in areas where there is sufficient mixing with surface water bodies – San Joaquin River with very low TDS concentrations as well as leakage from the Pool and irrigation canals, and
- MPG pumping which locally influences the hydraulic gradient in the vicinity of the Fresno Slough and is likely contributing to the eastern movement of the saline front in the local area near the Pool area.

4.1.2 Discretization

The solute transport model was discretized spatially on the same spacing and layer elevations used in the finite difference model grid used to generate the groundwater flow field. Temporally, solute migration and concentrations were calculated at 12 hour time steps with each monthly stress period.

4.1.3 Boundary Conditions

Sources and sinks are used within MT3DUSGS to simulate solute mass entering and exiting the model domain from boundary conditions. Salinity sources and sinks in the form of TDS were applied to fluxes from general head, recharge, stream, lake, and well boundary conditions to simulate a variety of processes affecting salinity fate and transport.

Salinity entering and exiting laterally from the edges of the model domain was simulated by assigning a concentration to the general head boundary conditions (**Figure 4-1**). Over the majority of the domain this concentration did not vary throughout the transport simulation and was based on TDS concentrations used to initialize the model. At the model boundary to the west, the TDS concentration was allowed to linearly increase by 1,000 mg/L during the course of the simulation to better capture the trend of generally increasing salinity concentrations in this area of the model where saline groundwater is present. The initial range of TDS concentrations assigned to the general head boundaries in the entire model domain ranged from about 300 to 13,000 mg/L.

Salinity applied through areal recharge of irrigation water and through recharge ponds was assigned using the recharge option in the Source and Sink Mixing Package (SSM). A concentration of 4,500 mg/L was assigned to groundwater recharged over much of the area west of the Fresno Slough (**Figure 4-1**). This value was estimated based on analysis of salinity measurements collected by the DWR from agricultural drains in drainage impaired lands in this area (DWR, 2014). The recharge concentration over the majority of the model domain east of the Fresno Slough and north of the San Joaquin River is largely unknown. Over these lands, a concentration of 1,000 mg/L was assigned during the model calibration process. This estimate was largely based on reasonable values for the concentration of deep percolation from irrigation and precipitation and an estimate of salt mass stored in the vadose zone. These numbers were based on the concentration of applied water, irrigation efficiency and mean precipitation. This value was adjusted within reasonable ranges during calibration to match observed shallow groundwater concentrations. Over wastewater ponds and wastewater irrigated fields near the Spreckels Sugar Company, a recharge concentration of 5,000 mg/L was assigned based on the groundwater quality of shallow zone groundwater in that area.

Mass removed from pumping was simulated as a solute sink assigned from the amount of water removed using the MNW2 package. In wells used for exchange pumping, the water discharged from the wells into the Pool was a source of salinity to the Pool.

Mixing between groundwater and surface water boundary conditions were simulated using the Streamflow Transport package (SFT) and Lake Transport package (LKT). The SFT package computes the salt concentration in each stream node based on a headwater concentration, solute mixing down the stream channel (dispersion), and solute mass lost or accumulated through groundwater-surface water interaction. The SFT Package works in conjunction with the LKT package to calculate the TDS concentration in the Pool/Fresno Slough based on inflow and outflow from streams, canals, and groundwater exchange (**Figure 4-1**). The link between the SFT and LKT packages allows mass stored in surface water boundary conditions to mix between the Pool, San Joaquin River, and major irrigation canals based on flows between them.

In the portion of the San Joaquin River upstream of the Pool, headwater stream concentrations were directly assigned (2004-2012) or estimated from mean monthly EC measured by USBR at Donny Bridge and converted to an equivalent TDS concentration. The EC levels where the Delta Mendota Canal enters the model domain were converted to TDS concentrations and input into the model based on the reported concentration at Check 21. An initial TDS concentration of 400 mg/L was specified for the Pool based on the salinity concentration in the DMC in January of 1990.

The surface runoff process within the LAK/LKT packages was utilized to simulate salinity contributions from exchange pumping and the James Bypass. TDS concentrations assigned to water added to the Pool from exchange pumping was estimated based on the volume weighted TDS concentrations for each month from MPG wells used in the exchange pumping program in 2012. A concentration of 50 mg/L was assumed for flows in the James Bypass. This concentration to the Pool for each stress period was calculated based on the volume weighted concentration of James Bypass and inflows from exchange pumping.

4.1.4 Initial Conditions

Initial groundwater salinity concentrations within the model domain were assigned based on the analysis and distribution of water quality data available from monitoring and production wells. Data sources include the DWR California Statewide Groundwater Elevation Monitoring (CASGEM) database, USGS National Water Quality Assessment (NAQWA) Program, and SWRCB's Geotracker database (GAMA), and TDS concentrations measured by local entities including the MPG, Columbia Canal Company, CCID, and New Columbia Ranch (DWR, 2013; USGS, 2013; SWRCB, 2013).

TDS concentrations in the model layers overlying the Corcoran Clay in the northeastern portion of the model domain were not segregated by layer due to limitations in available data in this region and absence of A and/or C clays which retard vertical migration. In general, water table wells (total depth less than 25ft) with high TDS concentrations were not included for calibration purposes but were used to help understand salt concentrations from recharge from irrigation. Water quality in the lower aquifer below the Corcoran Clay was estimated from limited data from lower aquifer wells. Though analysis focused predominantly on wells screened exclusively below the Corcoran Clay, in many cases salinity concentrations from composite wells (screened above and below the Corcoran clay) were also used to develop initial conditions in the lower aquifer.

In most areas, water quality data were not available for January 1990 initial conditions. In those areas spatial and temporal water quality trends from nearby wells were used to assign representative concentrations used to better constrain salinity concentrations. In general, there is greater uncertainty over the eastern and western portions of the model domain outside the PSA due to sparse data, while data was more available in the PSA.

4.1.5 Transport Properties

Properties controlling solute fate and transport include advection (transport due to the physical movement of groundwater), dispersion (spreading due to aquifer micro and macro heterogeneity and chemical diffusion), sorption (binding to aquifer material), and chemical reactions. For the purposes of this analysis, the transport of salt is conservative, and advection and dispersion are the primary properties influencing the transport of salts. This means that groundwater flow is the primary mechanism controlling the migration of salinity and that chemical reactions do not factor in the occurrence or migration of salinity in the model domain.

Advective transport is derived from the groundwater flow field generated from the numerical flow model. Dispersion is a scale dependent parameter which varies depending on the longitudinal, transverse, and vertical dispersivity assigned as a length within the model. A rule of thumb for longitudinal dispersivity values is a value that is about a tenth of the model cell size which then is adjusted during calibration. An initial value was assigned uniformly throughout the model domain and was refined during model calibration. Vertical and transverse dispersivity were assumed to be one tenth the longitudinal value and adjusted during model calibration. Porosity values from literature references were used to assign estimated porosity values for each model layer based on the geologic materials within the model domain.

4.2 Surface Water Quality Model Development

Impacts of the proposed exchange pumping program on surface water quality in the San Joaquin River at the Mendota Dam and Fresno Slough at the MWA were evaluated using a water budget approach. The water budget incorporates the major inflows and outflows to the Pool to calculate the salinity concentration within the Pool and Fresno Slough. The solute transport model was not used to simulate surface water quality conditions at the MWA or Mendota Dam because the source code of the LKT package does not account for variability in calculated concentrations between lake cells (one concentration is calculated for each lake boundary). Therefore, surface water quality was simulated using the water budget mixing models of the northern and southern branches of the Pool. These mixing models were developed to account for variations in salinity concentrations on an average monthly basis. Since factors affecting salinity concentrations in the northern portion of the Pool differ significantly from factors affecting salinity near the MWA, two surface water budget models were developed, one for the northern branch of the Pool to evaluate salinity concentrations at the Mendota Dam and one for the southern branch of the Pool to evaluate salinity at the MWA.

4.2.1 Northern Branch of the Mendota Pool Mixing Model

The surface water quality in the SJR at the Mendota Dam was estimated on a monthly time period using a water balance approach which incorporates the inflows and outflows in the Pool. The underlying assumption is that the concentration of water flowing out of the Pool at the Mendota Dam can be predicted by computing as a volume weighted average concentration of the contributing sources. In this case, it is assumed that inflow and outflow components south of the A-A cross section located south of the Firebaugh canal will not significantly impact the salinity concentration at the Mendota Dam and are excluded from the water balance. As a result, the flow at the Mendota Dam (Q_{Dam}) can be computed as the sum of the flow entering the Pool from the San Joaquin River (Q_{SJR}), DMC (Q_{DMC}), MPG exchange pumping from FWD (Q_{MPG}), and the Pool itself, minus outflows to the Columbia, CCID Main, CCID Outside, and Firebaugh canals (Q_{Canals}). Respecting the conservation of mass in this approach, the Pool (Q_{Pool}) may be positive or negative depending on whether acts as a source or sink. Assuming complete mixing within the Pool, the concentration of water at the Mendota Dam is predicted by computing a volume weighted average of the concentration of the inflow terms.

The model was validated based on conditions and observed TDS at the Mendota Dam in 2012. Monthly average diversions and flows in the DMC were estimated from the amounts simulated in the groundwater flow and transport model based on amounts reported by USBR and SJREC in 2012. Flows and TDS in the San Joaquin River into and out of the Mendota were estimated based on the calibrated groundwater flow and transport model. Pumping amounts and well concentrations from MPG wells located in FWD were assigned based on reported amounts and water quality measurements taken in, or nearest to 2012.

4.2.2 Southern Branch of the Mendota Pool Mixing Model

Changes in water quality in the Fresno Slough at the MWA due to exchange pumping were also evaluated on a monthly basis using a water balance model based on the amount of flow in the southerly direction in the Pool. The amount of flow depends primarily on the inflow from the DMC and entities pumping groundwater into the Pool and diversions to the San Joaquin River Exchange Contractors (SJREC) in the northern portion of the Pool and to James and Tranquility I.D.s, the MWA, and WWD in the southern portion of the Pool (**Figure 4-2**). North of the A-A’ cross section, the contribution of MPG exchange pumping from FWD into the Pool is ignored. The model calculates the TDS concentration at the MWA based on the net inflow from the DMC and inflows from groundwater pumping and their associated concentrations. Flows from the San Joaquin River are assumed to have very limited influence on the concentration in the southerly branch of the Pool that is simulated with this water budget model and are not incorporated in the model inputs. Groundwater contributions to the Pool include groundwater pumped for exchange, groundwater pumped for adjacent and overlying use by Terra Linda Farms (TLF) and Coelho-Gardner-Hansen, groundwater pumped from the Meyers Water Bank, and the City of Mendota. Contributions from the DMC are calculated based on fraction of total DMC inflow into the Pool which is assumed to reach the MWA; calculated as the flow in the DMC minus the net amount of water diverted from outlet canals located near the DMC.

The model was validated based on conditions and observed TDS at the MWA in 2012. This includes monthly seepage and ET estimates, average flows and concentrations in the DMC, diversions from canals, and available pumping data and well concentrations from the MPG, the City of Mendota, and Meyers Water Bank. Pumping amounts and well concentrations from wells located near the Fresno Slough were assigned based on reported or estimated amounts and water quality measurements taken in, or nearest to 2012.

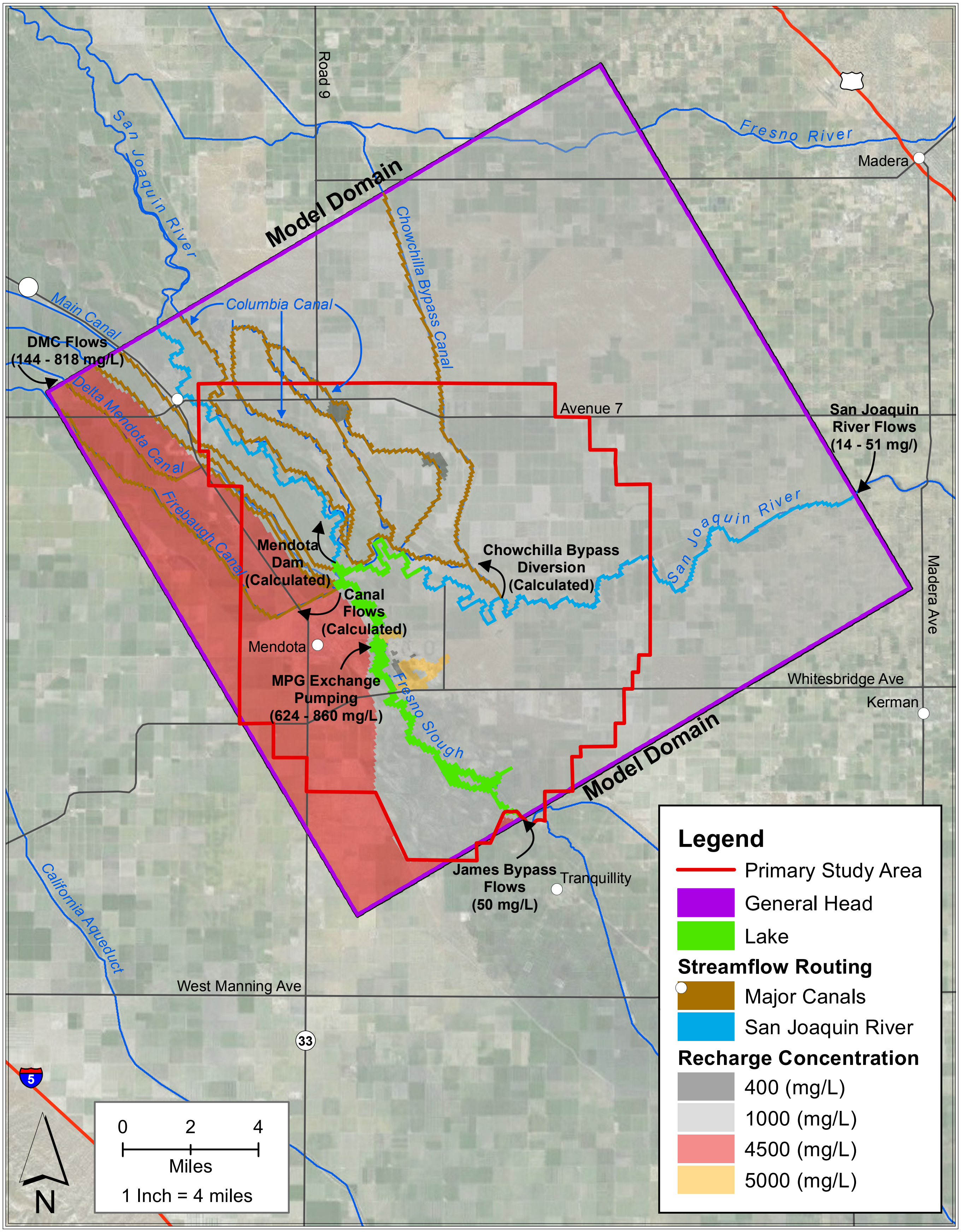

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Figure 4-1
Solute Transport Model Boundary Conditions

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Figure 4-2
Mendota Pool/Fresno Slough Water Budget Components

5 MODEL CALIBRATION

Model calibration involves the adjustment of input parameters within the constraints of the conceptual model to best represent the hydrogeologic system being simulated. The groundwater flow and transport models were calibrated largely by manually adjusting assigned aquifer parameters to achieve an agreeable fit between simulated and observed values. Observations used to calibrate the groundwater models include water level and TDS measurements from wells within the model domain, San Joaquin River streamflow, and compaction measured from the Fordel and Yearout extensometers. Regional trends in simulated groundwater flow direction and salinity were also compared to observed trends to qualitatively evaluate model performance. Both models were calibrated to a 23-year period from 1990 through 2012. This time period was selected because it includes both wet and dry periods which are useful in evaluating how the model performs under varying hydrologic conditions.

The surface water mixing models were not calibrated in the sense that model input values were adjusted, rather, these models were "verified" by comparing the output from the mixing models to measured water quality data at the Mendota Dam and the MWA. This verification exercise would allow for an assessment of the capability of the mixing models to predict Project impacts on surface water quality on an average monthly basis.

5.1 Calibrated Parameter Values

Model calibration focused primarily on adjusting assigned aquifer properties within the model. Parameters modified during model calibration process included:

- Aquifer horizontal and vertical hydraulic conductivity
- Elastic and inelastic skeletal storage and specific yield coefficients
- Streambed and lakebed hydraulic conductivity
- Porosity and dispersivity in the solute transport model

5.1.1 Calibrated Aquifer Hydraulic Conductivity

The horizontal hydraulic conductivity values in the model were adjusted within ranges consistent with observed data and interpretation of aquifer materials. Hydraulic conductivity data from aquifer tests and specific capacity were also used to constrain the range of hydraulic conductivity values. The final calibrated hydraulic conductivity values ranged from 1.7 x 10^{-3} ft per day (ft/day) in the Corcoran clay (model layer 7) to 490 ft/day in layer 3 **(Table 5-1)**. Final calibrated vertical hydraulic conductivity values were from approximately one to two orders of magnitude less than the horizontal hydraulic conductivity and ranged from 2.5 x 10^{-4} ft/day in the Corcoran clay to approximately 50 ft/day in model layers 3, 4, and 6 (**Table 5-1**). Calibrated vertical hydraulic conductivity in the A and C clays was 1.7 x 10^{-3} ft/day (**Table 5-1**). West of the Fresno Slough, the vertical hydraulic conductivity of the A clay was increased to 1.0 x 10^{-2} ft/day to better reflect results from well completion reports which suggest that the A clay is less continuous in this area (**Figure 5-1**). The distribution of final hydraulic conductivity values in the shallow and deep zones and the lower aquifer is presented in **Figures 5-2, 5-3, 5-4,** and **5-5**.

Table 5-1: Calibrated Hydraulic Conductivity

Parameter	Layer	Simulated Value
Horizontal K	1, 2	5.5×10^{-1} to 2.3×10^{2} ft/day
Horizontal K	3	5.4×10^{-1} to 4.9×10^{2} ft/day
Horizontal K	4	4.9×10^{1} to 2.2×10^{2} ft/day
Horizontal K	5	3.8×10^{-1} to 1.0×10^{1} ft/day
Horizontal K	6	2.5×10^{1} to 3.3×10^{2} ft/day
Horizontal K (Corcoran Clay)	7	1.7×10^{-3} ft/day
Horizontal K	8, 9	8.0 to 1.0×10^{2} ft/day
Anisotropy Ratio (HK/VK)	-	5 - 240
Vertical K	1,2	8.4×10^{-2} to 3.5×10^{1} ft/day
Vertical K	3	1.7×10^{-3} to 5.1×10^{1} ft/day
Vertical K	4	1.0×10^{1} to 4.9×10^{1} ft/day
Vertical K	5	1.7×10^{-3} to 1.3 ft/day
Vertical K	6	4.1 to 5.2×10^{1} ft/day
Vertical K (Corcoran Clay)	7	2.5×10^{-4} ft/day
Vertical K	8, 9	1.5 to 1.9×10^{1} ft/day
Vertical K (A and C Clays)	3, 5	1.7×10^{-3} ft/day

5.1.2 Calibrated Storage Coefficients

Storage coefficients assigned to the models included specific yield and inelastic and elastic specific storage. The values for these parameters were adjusted to match observed water levels and compaction above the Corcoran Clay. Calibrated specific yield ranged from 0.28 to 0.31 (**Table 5-2**). Elastic skeletal specific storage assigned to fine-grained material was 1.0×10^{-6} per foot while elastic skeletal specific storage assigned to coarse-grained material was 5.5×10^{-6} per foot (**Table 5-2**). Inelastic skeletal specific storage was 1.6×10^{-4} per foot (**Table 5-2**). Calibrated inelastic specific storage was consistent with values assigned in previous studies (Faunt et al., 2009). Elastic specific storage values were greater than those used in CVHM in order to match observed compaction at extensometer sites, however, water levels in confined layers were not sensitive to this change.

Table 5-2: Calibrated Storage Parameters

Parameter	Simulated Value
Specific Yield	0.28 to 0.31
Elastic Specific Storage (Coarse)	5.5×10^{-6} per ft
Elastic Specific Storage (Fine)	1.0×10^{-5} per ft
Inelastic Specific Storage	1.6×10^{-4} per ft

5.1.3 Calibrated Streambed and Lakebed Hydraulic Conductivity

The hydraulic conductivity of the streambed (K) for the San Joaquin River and large irrigation canals was adjusted within a probable range of values to match observed discharge in the SJR and hydraulic heads in observation wells near the river and canals. Calibrated streambed K was 0.25 ft/day while canal K was a substantially lower 5.0 x 10^{-3} ft/day (**Table 5-3**). Lakebed hydraulic conductivity was estimated by comparing the net seepage from the Pool and Fresno Slough to values estimated by LSCE and KDSA in 2000. A value of 2.0 x 10^{-3} ft/day was used in the Fresno Slough branch of the Pool (**Table 5-3**). The SJR branch of the Pool was assigned a larger value of 2.0 x 10^{-2} ft/day to better match observed water levels in shallow wells in the area and because it is presumed that coarser sediments are present in this portion of Pool as compared to the Fresno Slough branch of the Pool, thereby resulting in a larger value (**Table 5-3**).

Table 5-3: Calibrated Stream and Lakebed Hydraulic Conductivity

Parameter	Simulated Value
San Joaquin River K	2.5 x 10^{-1} ft/d
Canal K	5.0 x 10^{-3} ft/d
Lakebed K	2.0 x 10^{-3} to 2.0 x 10^{-2} ft/d

5.1.4 Calibrated Solute Transport Parameters

Porosity and dispersivity were adjusted during model calibration for observed and simulated TDS concentrations in wells within the model domain. Calibrated porosity ranged from 0.3 to 0.35 (**Table 5-4**). Calibrated longitudinal dispersivity was 20 ft. A calibrated value of 2 ft was used for both horizontal and vertical transverse dispersivity (**Table 5-4**).

Table 5-4: Calibrated Solute Transport Parameters

Parameter	Simulated Value
Porosity	0.3 to 0.35
Longitudinal Dispersivity	20 ft
Transverse Dispersivity	2 ft

5.2 Model Calibration Targets

The groundwater flow model was calibrated to measured groundwater level elevations, streamflow, and compaction above the Corcoran Clay. The solute transport model was calibrated to measured salinity concentrations in groundwater and historical rates of migration of the saline front.

5.2.1 Groundwater Levels

Groundwater levels from 89 dedicated monitoring and production wells (8,905 observations total) were used as the primary source of information used to calibrate the groundwater flow model (**Figures 5-6, 5-7, and 5-8**). Sources of water level data include wells monitored by the MPG and other entities such as the CCID, WO, USGS, DWR and USBR. While an effort was made to rely on observations from wells screened in only discrete intervals in one model layer, wells screened over two or more model layers were used in some cases where available data were limited. Observations are generally concentrated near the Pool and former Spreckels Sugar Company where well construction information and consistent records of water level measurements were available for the calibration period. The water level data was predominantly available for wells constructed in the shallow and deep zones while little data was available for the lower aquifer. This resulted in the model calibration effort focusing on the shallow and deep zones while less focus was provided to the lower aquifer.

5.2.2 Streamflow

Average monthly streamflow was derived from data collected from three stream gage locations on the San Joaquin River and used to calibrate groundwater-surface water interaction in the groundwater flow model. These gage locations were located at the San Joaquin River at Gravelly Ford (GRF) and Below Bifurcation (SJB) monitored by the USBR and the San Joaquin River at Mendota Dam (MEN) monitored by the USGS (**Figure 5-6**). Of these stream gages, the gage at GRF has a relatively consistent streamflow record beginning in 1997, SJB has a sporadic record beginning in 1998, and MEN has a consistent record beginning in 1997.

5.2.3 Subsidence Observations/Rates

Continuous compaction data are collected from two extensometers in the Mendota area to evaluate compliance with the subsidence criterion specified in the original Agreement and Agreement No. 2. The MPG installed the Fordel extensometer west of the Fresno Slough in 1999. The Yearout Ranch extensometer, located east of the Slough, was installed by DWR in 1965 and has been monitored by CCID since 1999 (the USGS took over monitoring the Yearout Ranch Extensometer in 2015). Both extensometers monitor compaction above the Corcoran Clay, the top of which was encountered at depths of 418 and 428 ft at the Fordel and Yearout Ranch sites, respectively (**Figure 5-7**). The compaction data from the extensometers was used as a calibration target for the flow model.

5.2.4 Water Quality

Groundwater quality data are measured by various entities including MPG, WO, CCID, USBR, USGS, and CDPH within the study area. Of the available groundwater quality data, 90 wells with 2,177 data points were selected for model calibration (**Figures 5-9, 5-10, and 5-11**). An effort was made to select only wells which are screened in one model layer. However, as was the case in selecting groundwater level observations, wells screened over multiple model layers were selected in areas where data availability was limited. The number of selected wells with water quality observations decreases with depth and the number of water quality observations below the Corcoran Clay in the lower aquifer is extremely limited in comparison to the amount of data available in the shallow and deep zones. As a result, transport model calibration focused on shallow and deep zone water quality. Within the Pool/Fresno Slough, water quality measurements from grab samples of TDS at four locations were selected for model calibration. These include the Mendota Dam, West of Fordel, Etchegoinberry, and the Mendota Wildlife Area (**Figure 5-9**).

5.2.5 Criteria

Model calibration was evaluated through four common statistics used to characterize model fit. These include the mean error (*ME*), mean absolute error (*MAE*), Root Mean Squared Error (*RMSE*), and the Normalized RMSE (*NRMSE*).

The mean error (*ME*), or model bias, is a measure of the overall tendency of the model to over-predict (**-**) or under-predict (**+**) measured values (Belitz and Phillips, 1993; Anderson and Woessner, 1992). The mean absolute error (*MAE*) is a measure of model accuracy calculated as the average magnitude of the error between observed and simulated values (USGS, 2004; Anderson and Woessner, 1992). The root mean square error (*RMSE*) is also a common measure of model accuracy quantifying the standard error (Anderson and Woessner, 1992). The normalized root mean squared error (*NRMSE)* is calculated to account for the scale dependency of the *RMSE* and is a measure of the *RMSE* divided by the range of observations (Anderson and Woessner, 1992).

In addition to calculated fit statistics, simulated and observed groundwater elevations and TDS concentrations were contoured to compare and evaluate the flow and transport model's ability to represent regional groundwater flow directions and historical migration of the saline front.

5.3 Groundwater Flow Model Calibration Results

Comparison of simulated and observed groundwater elevations over the 1990 through 2012 calibration period show that 66% of simulated groundwater levels are within 10 ft of observed values and 89% of simulated observations are within 20 ft of observed values (**Figure 5-12**). The calculated *RMSE* was 13.24 ft and the *MAE* was 9.46 ft. These values are small compared to the range of observed groundwater levels in the model domain (*NRMSE* = 7.15%) (**Table 5-5**). The calculated *ME* (-3.51) indicates that the model tends to over-predict groundwater levels by an average of about three and a half ft. Model bias is smaller in the shallow zone (-1.37 ft) and slightly larger in the deep zone and in the lower aquifer (-5.20 ft and -7.30 ft, respectively). These results are also shown in a scatter plot of observed and simulated groundwater levels which illustrates that model error is generally smaller in the shallow zone and generally larger in the deep zone (**Figures 5-13, 5-14, and 5-15**). Hydrographs of simulated and observed groundwater elevations (**Appendix A**) show that simulated deep zone water levels during irrigation periods are often over-predicted in many of the production wells. This likely occurs due to errors accrued by averaging water levels over the cell area, water levels affected by head losses in the well which are not able to be simulated, or an overestimated specific storage value. In the lower aquifer, the differences between simulated and measured data may also stem from the inclusion of composite wells used to calibrate groundwater levels and the lack of data available on the lower aquifer.

Table 5-5: Groundwater Flow Model Calibration Statistics

Depth Zone	Number of Wells	Number of Observations	RMSE (ft)	NRMSE	MAE (ft)	ME (ft)
Shallow Zone	41	4190	9.35	7.39%	6.88	-1.37
Deep Zone	43	4067	15.70	9.67%	11.51	-5.20
Lower Aquifer	5	541	17.75	14.23%	13.93	-7.30
Model	89	8798	13.24	7.15%	9.46	-3.51

Comparison between observed and simulated contours of equal groundwater level elevation from the shallow and deep zones indicate that simulated groundwater levels capture observed trends during the calibration period. The groundwater flow direction in the shallow zone in both the winter and summer of 2012, inferred from contours of equal groundwater level elevations, suggests regional groundwater flow is from the southwest to northeast and south to north (**Figures 5-16, 5-17, 5-18, and 5-19**). The model simulates groundwater flow directions in a similar manner as demonstrated by contours of observed groundwater elevations. The model also captures elevated groundwater elevations beneath the San Joaquin River east of the Pool and lower groundwater elevations near the Pool/Fresno Slough during the summer months.

In the deep zone, the model captures the regional groundwater flow gradient from the southwest to the north (**Figures 5-20, 5-21, 5-22, and 5-23**). Modeled groundwater elevations also capture a groundwater depression east of the Chowchilla Bypass during the summer of 2012 (**Figure 5-23**).

The model is generally able to predict observed flows in the San Joaquin River fairly well at Gravelly Ford, below the Chowchilla Bypass, and below the Mendota Dam (**Figures 5-24, 5-25, and 5-26**). Simulated flow in the San Joaquin River below the Mendota Dam is slightly higher than measured flows which may be due to challenges in constraining simulated flows from the Pool using the LAK boundary to the San Joaquin River using the stream routing package. In comparison to the range of observed flows, calculated errors are small with the *NRMSE* ranging from 0.63% at Gravelly Ford to 6.0% below the Mendota Dam.

5.3.1 Subsidence

Simulated compaction in the shallow and deep zones ranged from 0.05 ft higher to 0.09 ft lower than observed compaction. Simulated results generally capture the overall increasing trend in compaction observed at the Yearout Extensometer and generally stable compaction data at the Fordel Extensometer (**Figures 5-27 and 5-28**). The model results show that the model slightly under-predicts compaction at the Yearout Extensometer (*ME* = 0.02 ft) and shows very little bias at the Fordel Extensometer (*ME* = -1.8 x 10^{-3} ft). At the Yearout Extensometer, the model is able to predict inelastic compaction with greater accuracy, but generally under-predicts elastic compaction (**Figure 5-27**).

5.3.2 Water Budget Results

Total groundwater pumping in the calibrated model ranges from 360,000 afy to 556,000 afy (**Figure 5-38**). In general, greater pumping is simulated during drier periods and less pumping occurs in wetter years. Groundwater recharge from dedicated recharge ponds and irrigation ranges from 161,000 afy to 304,000 afy or approximately half of the amount pumped (**Figure 5-39**). Annual subsurface groundwater inflow from general head boundaries are greater than subsurface outflows showing that more groundwater is generally flowing into the model domain than out (**Figure 5-40**). The net amount of recharge from subsurface flows ranges from about 5,000 to 114,000 afy. Another large source of recharge to the system occurs from losses from streams and canals (**Figure 5-41**). In general, greater stream losses coincide with wetter years when streamflow is high. Total net stream loss ranges from approximately 49,000 afy to 133,000 afy. Seepage from the Pool/Fresno Slough is generally the smallest source of groundwater recharge reaching a maximum of 31,000 afy (**Figure 5-42**). Simulated changes in groundwater storage generally track the simulated hydrologic year (**Figure 5-43**). Wetter years tend to show a net increase in stored groundwater, where drier years tend to show decreases in overall storage in the groundwater system. Mass balance error is defined as the calculated difference between inflows, outflows, and change in storage accrued within each model time-step (Anderson and Woessner, 1992). Large mass balance errors generally arise due to instability in the numerical scheme or if the head and flux tolerances in the matrix solvers used to specify model convergence are set too high. The maximum error in mass balance in any time-step in the model run was less than 0.1% of the total mass in or out of the model at that time-step.

5.4 Solute Transport Model Calibration Results

Measured salinity concentrations in the PSA ranges from approximately 300 to over 6,000 mg/L in the form of TDS. This wide range of TDS concentrations over a relatively small region poses challenges to model calibration. Simulated salinity concentrations in the form of TDS generally match observed salinity measured in wells throughout the modeling period. The distribution of model error shows that 55% of simulated values fall within 250 mg/L of observed values (less than 5% of the range in observed TDS concentrations) while 76% of simulated values fall within 500 mg/L of observed values (less than 10% of the range in observed values) (**Figure 5-29**). Over the entire model and in each model layer, simulated TDS is generally slightly less than observed (*ME* = 178 mg/L) (**Table 5-6**). Model errors are largest in the shallow zone (*MAE* = 261 mg/L) and smallest in the deep zone (*MAE* = 92 mg/L) (**Table 5-6**). In the shallow zone and deep zone, the model generally represents measured TDS concentrations fairly well (**Figure 5-30 and Figure 5-31**). The lower aquifer generally shows an agreeable fit, though the availability of calibration data is generally limited (**Figure 5-32**). In areas with high observed TDS (those areas within the high TDS portion of the saline front) in the shallow and deep zones, the model generally underpredicts TDS concentrations (**Figure 5-33**). The simulated TDS concentrations in deep zone wells in FWD closely match observed concentrations (*MAE* = 123.4 mg/L).

Contours of observed and simulated TDS from the shallow and deep zones were prepared to evaluate how the solute transport model captured historical regional groundwater quality over time during the calibration period. The earliest period where there was a comprehensive dataset was 2001. The two time periods that were selected were 2001 and 2012. The contour maps show that the model captures the observed saline front in the form of the 1,000 and 2,000 mg/L contour lines (**Figures 5-34 and 5-35**) for both periods. The comparison of simulated to observed rates of advancement of the saline front is difficult to quantify as observed salinity in 2012 in the shallow zone is sparse. In the vicinity of the Steffens Plume east of the Fresno Slough near the Meyers Water Bank, the model is able to simulate the extent of the plume fairly well. In the shallow zone, the modeled and observed salinity concentrations underlying the former wastewater ponds are similar (**Figures 5-34 and 5-35**). The impact of recharge from ponds used in the Meyers Water Bank is also well represented both in simulated contours of TDS (**Figures 5-34 and 5-35**) and hydrographs from Meyers Farms and Spreckels observation wells **Appendix B**. In the deep zone, contours of equal TDS concentrations show that the simulated concentrations in the Steffens Plume is largely maintained; though the concentrations do begin to spread to some extent by 2012 (**Figures 5-36 and 5-37**).

Table 5-6: Solute Transport Model Calibration Statistics

Depth Zone	Number of Wells	Number of Observations	RMSE (mg/L)	NRMSE	MAE (mg/L)	ME (mg/L)
Shallow Zone	39	1010	918	8.55%	498	261
Deep Zone	45	908	676	9.51%	376	92
Lower Aquifer	6	71	171	18.09%	131	108
Model	90	1989	798	7.44%	429	178

In general, the western portion of the model domain within the saline front and in the vicinity of the former Spreckels Sugar Plant where concentrations are generally high. In both cases, errors can likely be attributed to sharp fronts where the TDS concentration changes considerable over short distances and generally limited data used to constrain the model inputs. Sharp fronts are generally difficult to accurately capture using a regional model with relatively coarse spatial discretization. This is due to the artificial spreading in sharp concentration gradients and errors associated with interpolation of the coarse resolution simulated data. Scarcity in available data led to difficulty in effectively constraining TDS concentrations at the western general head boundary estimating the concentration of deep percolation which reaches the water table. Based on the available data, a uniform recharge concentration was assumed for all areas west of the Fresno Slough which made it difficult to accurately capture and maintain the large variability in TDS concentrations in this area, particularly in the shallow zone. Errors in the shallow zone throughout the model domain, but particularly at the former Spreckels site are likely also exacerbated by a lack of data on soil salinity due to historical surface loading and native soil chemistry.

5.5 Surface Water Quality Model Results

5.5.1 TDS at the Mendota Dam

Results from the 2012 validation show that the northern mixing model predicts TDS at the Mendota Dam with a reasonable amount of accuracy (**Table 5-7, Figure 5-44**). Total groundwater pumping from FWD totaled about 8,700 af and ranged from 0 in most months to about 2,800 af in April. TDS concentrations from these wells averaged 406 mg/L and ranged from 401 mg/L to 419 mg/L. Simulated TDS at the Mendota Dam increases by an annual average of 1 mg/L due to MPG pumping (**Table 5-8**). The simulated maximum impacts from MPG pumping were 4 mg/L which occurred in April. Inflows from the SJR totaled 118,000 af and ranged from 0 to about 42,000 af. TDS in the SJR ranged from 22 mg/L in January to 30 mg/L in July and August. Inflows from the DMC totaled about 850,000 af and ranged from 14,000 af in December to 143,000 af in July. TDS in the DMC ranged from 196 mg/L in July to 570 mg/L in March. Diversions from the Columbia, CCID, and Firebaugh canals totaled about 615,000 af and ranged from about 9,000 af in December to 96,000 af in July (**Table 5-8**).

Table 5-7: Measured vs. Predicted TDS at the Mendota Dam 2012

Month	Measured TDS (mg/L)	Simulated TDS (mg/L)
January	458	422
February	416	407
March	388	427
April	365	343
May	189	256
June	265	249
July	223	190
August	-	240
September	407	373
October	383	327
November	237	251
December	255	283

5.5.2 TDS at the Mendota Wildlife Area

Results from the 2012 validation show that the southern mixing model predicts TDS at the MWA with a reasonable amount of accuracy (**Table 5-9, Figure 5-45**). MPG pumped about 16,000 af of water for groundwater exchange and 8,000 af of groundwater for adjacent use into the Pool in 2012. This caused an average simulated increase of 134 mg/L at MWA due to exchange pumping and 70 mg/L for adjacent pumping (**Table 5-10**). DMC flow to the south totaled about 69,000 af and ranged from 0 af in April when there was northerly flow in the Fresno Slough to 15,000 af in February. TDS in the DMC averaged 353 mg/L. Pumping from the City of Mendota totaled 1,410 af while pumping from Meyers Water Bank totaled 193 af. In total these inputs cause an increase of 8 mg/L in the TDS at the MWA (**Table 5-9**).

Table 5-9: Measured vs. Predicted TDS at the Mendota Wildlife Area 2012

Month	Measured TDS (mg/L)	Simulated TDS (mg/L)
January	458	455
February	525	495
March	692	943
April	927	1,085
May	747	530
June	458	476
July	558	446
August	565	603
September	628	625
October	538	448
November	-	351
December	-	409

5.6 Limitations

Development and calibration of groundwater models are limited by data availability and quality. The numerical flow and transport models developed for the Project have the following limitations which effects the level of uncertainty in model results. Many of the following have been described previously and are summarized below.

- The majority of available groundwater level and quality data is from monitoring locations within the PSA. Data was limited in areas outside the PSA in the model domain.
- The model focused calibration efforts in the primary saturated interval in the shallow zone as a result of the availability of shallow zone wells that represented the interval from a depth of about 30 or 40 ft to 120 ft. Due to a lack of spatial and temporal data, the very shallow depths of the shallow zone (upper 20 ft) were not a focus of model calibration in both the flow and solute transport models.
- Very little data within the model domain and PSA was available for the lower aquifer. Therefore, data from the CVHM was relied upon along with any available data collected as part of ongoing monitoring programs in the PSA. As a result, model calibration results for the lower aquifer have a higher level of uncertainty than the shallow and deep zones.
- The extent and presence of the C-clay is not as well understood as the A-clay and Corcoran Clay from examination of available data. This uncertainty or limitation may influence the model's ability to simulate groundwater levels in the deep zone above and below the C-clay.
- Water level data, especially data collected during the irrigation season within the PSA, may not always be representative of static conditions. This uncertainty results in the model not being able, in some locations, to simulate the large fluctuations in groundwater levels during the

irrigation season because observed data reflects dynamic or partially dynamic conditions (pumping water levels) and effects from variations in well and pump efficiency.

- Observed water quality data in selected wells in the PSA is highly variable which is a condition difficult to simulate by any solute transport model. Highly variable concentrations either in a well or localized area may be a result of sampling procedures or other issues that may influence concentrations but are not able to be represented in the solute transport model.
- Historical land use, wastewater application, and groundwater pumping information for the area near the Spreckels Sugar Plant are limited. As a result, the influence of groundwater pumping at the Plant and residual soil and vadose zone quality is somewhat limited in nature. Additional historical data in this area would improve the ability of the solute transport model to simulate conditions in this area.

	Inflows[1]				Outflows		TDS					
Month	San Joaquin River[2] (af)	DMC[3] (af)	Farmers Water District[4] (af)	Mendota Pool[5] (af)	Diversions[2] (af)	Mendota Dam[2] (af)	San Joaquin River[2] (mg/L)	DMC[6] (mg/L)	Farmers Water District[7] (mg/L)	Mendota Pool[2] (mg/L)	Increase due to FWD (mg/L)	Mendota Dam[8] (mg/L)
January	52	35,785	0	0	10,997	14,379	22	423	0	299	0	422
February	8,227	89,412	0	0	57,443	21,658	25	442	0	389	0	407
March	9,255	25,702	2,427	0	25,759	8,934	26	570	403	434	-2	425
April	13,339	25,705	2,747	0	25,716	13,717	27	502	400	422	4	344
May	41,619	61,118	1,780	0	75,130	18,892	28	408	419	303	3	257
June	6,271	127,817	38	0	86,770	30,655	29	260	403	263	0	249
July	5,650	142,895	0	0	95,562	37,923	30	196	0	214	0	190
August	4,942	132,874	0	0	94,658	33,362	30	248	0	245	0	240
September	0	92,948	880	0	67,014	18,258	31	373	410	354	0	373
October	5,468	74,397	864	0	49,690	19,954	28	348	401	351	1	327
November	15,156	25,468	0	0	18,690	13,992	25	386	0	296	0	251
December	7,701	14,388	0	0	9,187	6,876	28	419	0	274	0	283
Total	**117,679**	**848,509**	**8,736**	**0**	**616,616**	**238,602**						
Annual Mean							**28**	**381**	**406**	**320**	**1**	**314**

1. Based on proposed pumping.
2. Calculated from groundwater model from the calibrated model in 2012.
3. Average monthly flow in the DMC at Check 21 from 2012.
4. 2012 exchange pumping for Farmers Water District (Logoluso, Baker Farms, and Panoche Creek Farms).
5. Assigned to make up the deficit between the calculated inflows (San Joaquin River, DMC, and Farmers Water District) and outflows (canal diversions, flow over the
   Mendota Dam) which is met by flow from the Mendota
Pool
6. Average monthly TDS in the DMC at Check 21 in 2012.
7. Volume weighted TDS calculated from average TDS from each well from 2012 and amount of proposed exchange pumping.
8. Calculated as the volume weighted average TDS of the inflows.

Table 5-8
TDS at the Mendota Dam – 2012

	Flow Contribution at MWA						TDS Increase Due to				
		MPG Wells[1,3]			Meyers	TDS	MPG Pumping			Meyers	TDS
		Exchange	Adjacent	City of	Water	at DMC	Exchange	Adjacent	City of	Water	in Southern Mendota
	DMC[2]	Pumping	Pumping	Mendota[4]	Bank	Check 21[5]	Pumping	Pumping	Mendota	Bank	Pool
Month	(af)	(af)	(af)	(af)	(af)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
January	6,440	0	136	88	0	448	0	4	3	0	455
February	15,315	0	1,490	282	0	424	0	66	5	0	495
March	1,351	2,660	487	269	0	423	392	109	10	0	943
April	0	2,676	674	180	193	394	485	184	19	8	1,085
May	4,671	1,983	697	371	0	335	122	58	8	0	530
June	9,533	1,593	1,248	0	0	309	59	105	12	0	476
July	8,310	1,809	1,445	202	0	204	96	139	4	0	446
August	4,054	1,989	1,138	18	0	272	163	165	21	0	603
September	4,619	2,422	691	0	0	345	205	75	0	0	625
October	5,842	1,002	345	0	0	322	83	43	0	0	448
November	4,501	0	0	0	0	351	0	0	0	0	351
December	4,308	0	0	0	0	409	0	0	0	0	409
Total	**68,945**	**16,135**	**8,350**	**1,410**	**193**						
Annual Mean						**353**	**134**	**79**	**7**	**1**	**572**

1. Including non-MPG pumpage by Don Peracchi in Farmers Water District.
2. Calculated as the difference between the average net demand in the southern portion of the Fresno Slough and the inflow from MPG, Meyers Farm Water Bank wells, and City of Mendota wells along the Fresno Slough.
3. Inflow from MPG wells along the Fresno Slough. Values do not include Farmers Water District pumping (FWD, Baker, and Panoche wells).
4. Based on City's pumpage from Fordel wells in 2010.
5. Monthly average based on reported daily EC in the DMC from 2012.

Table 5-10
TDS at the Mendota Wildlife Area – 2012

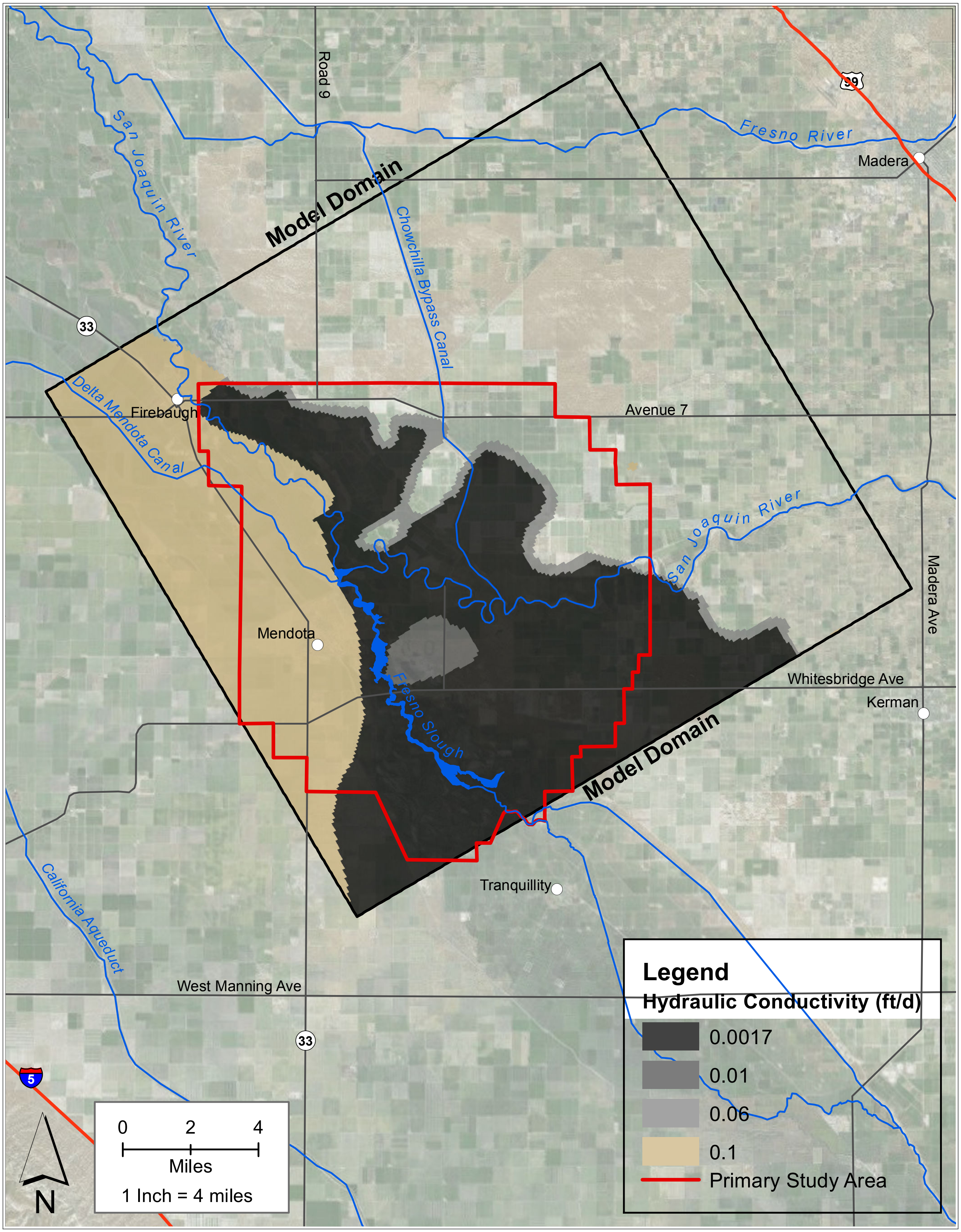

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Figure 5-1
Vertical Hydraulic Conductivity Assigned to the A Clay

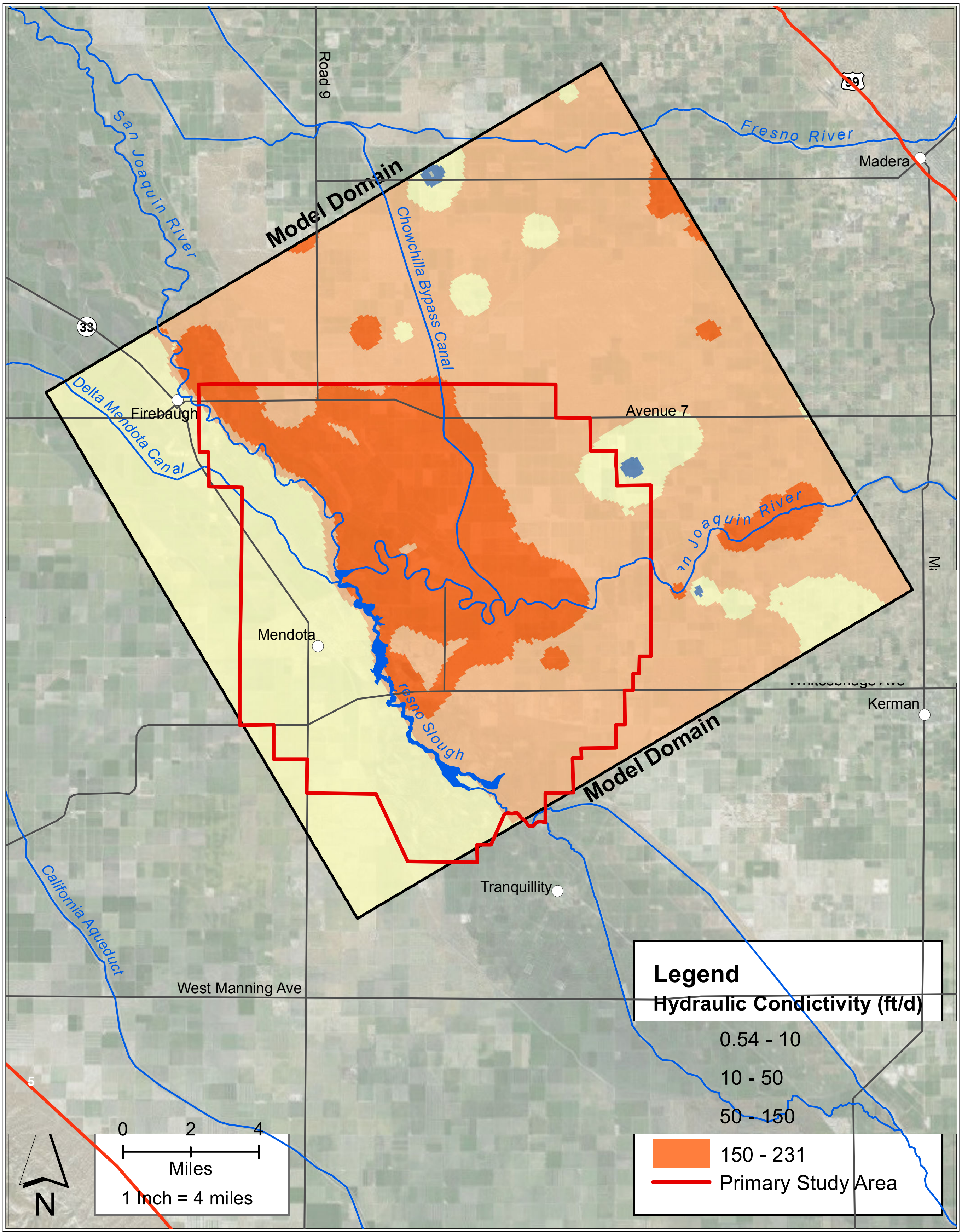

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Figure 5-2
Hydraulic Conductivity Assigned to the Shallow Zone

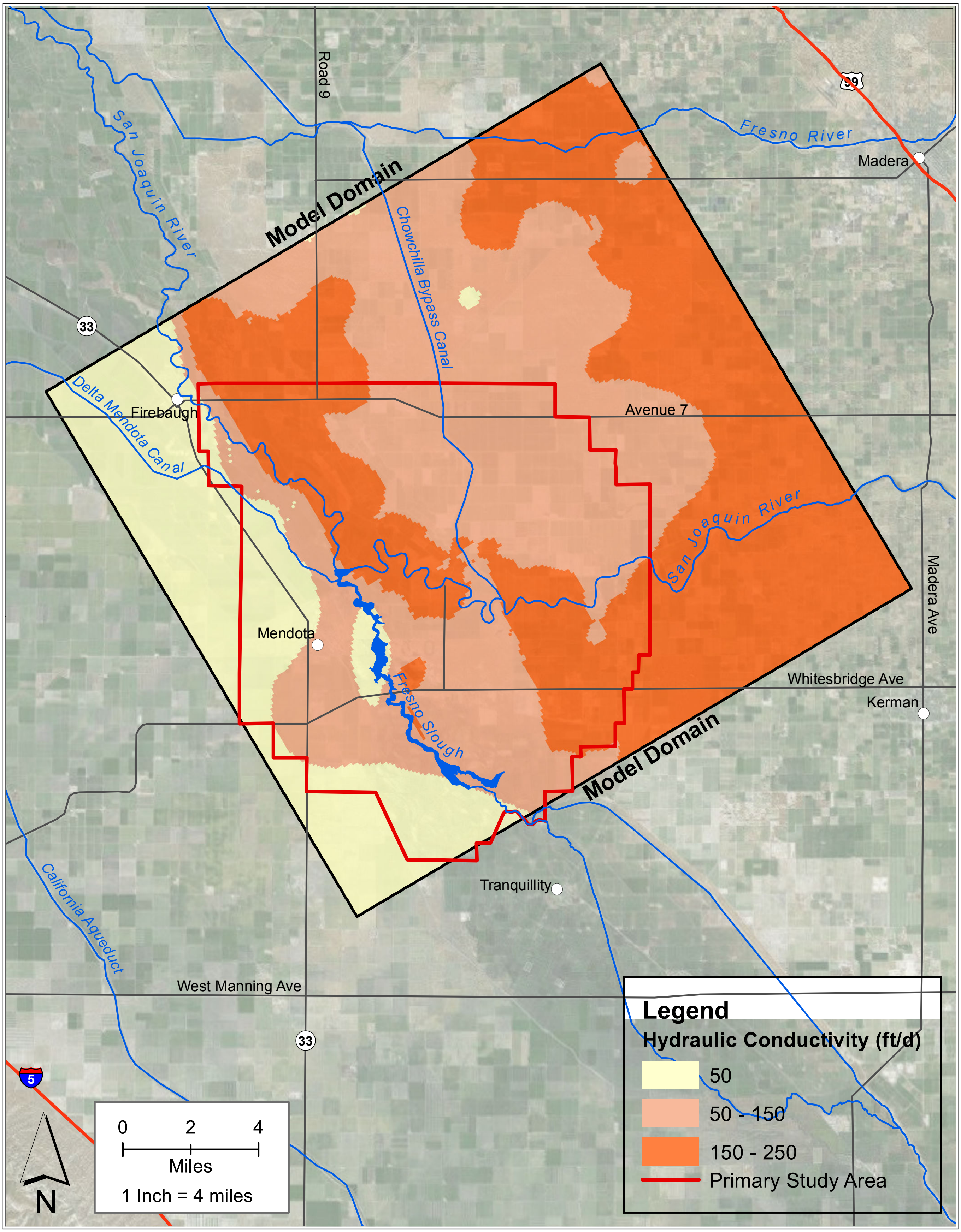

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Figure 5-3
Hydraulic Conductivity Assigned to the Upper Deep Zone

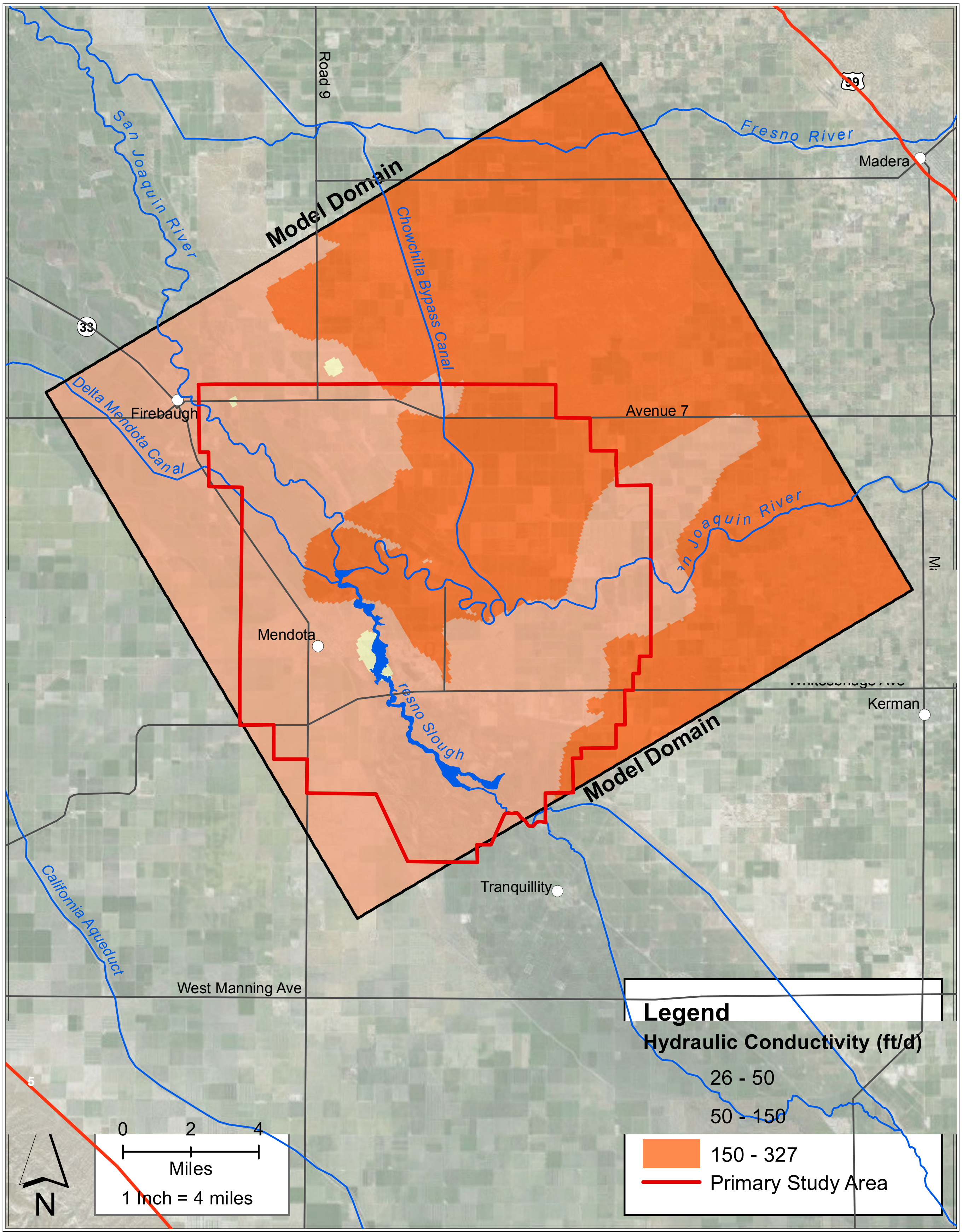

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Figure 5-4
Hydraulic Conductivity Assigned to the Lower Deep Zone

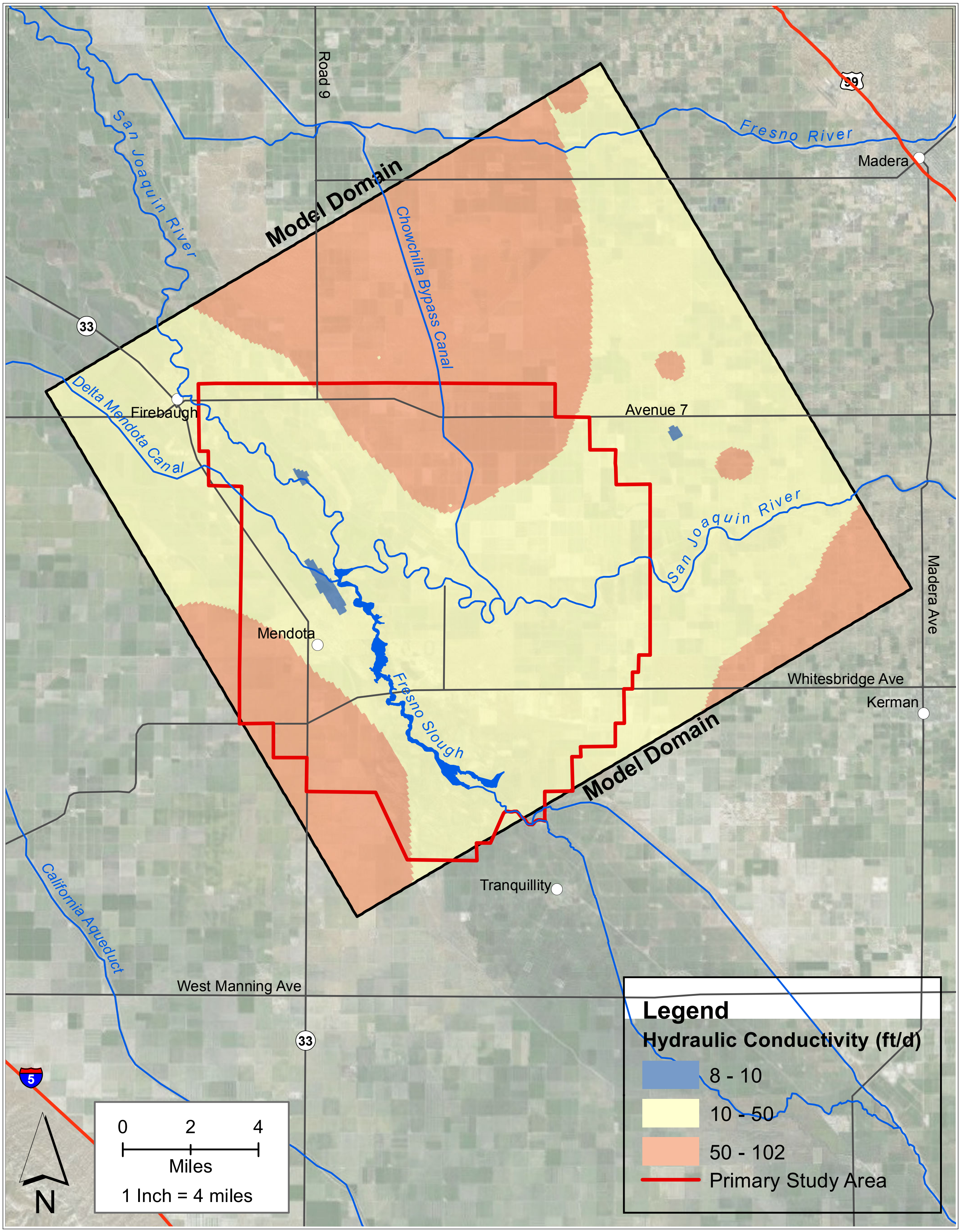

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Figure 5-5
Hydraulic Conductivity Assigned to the Lower Aquifer

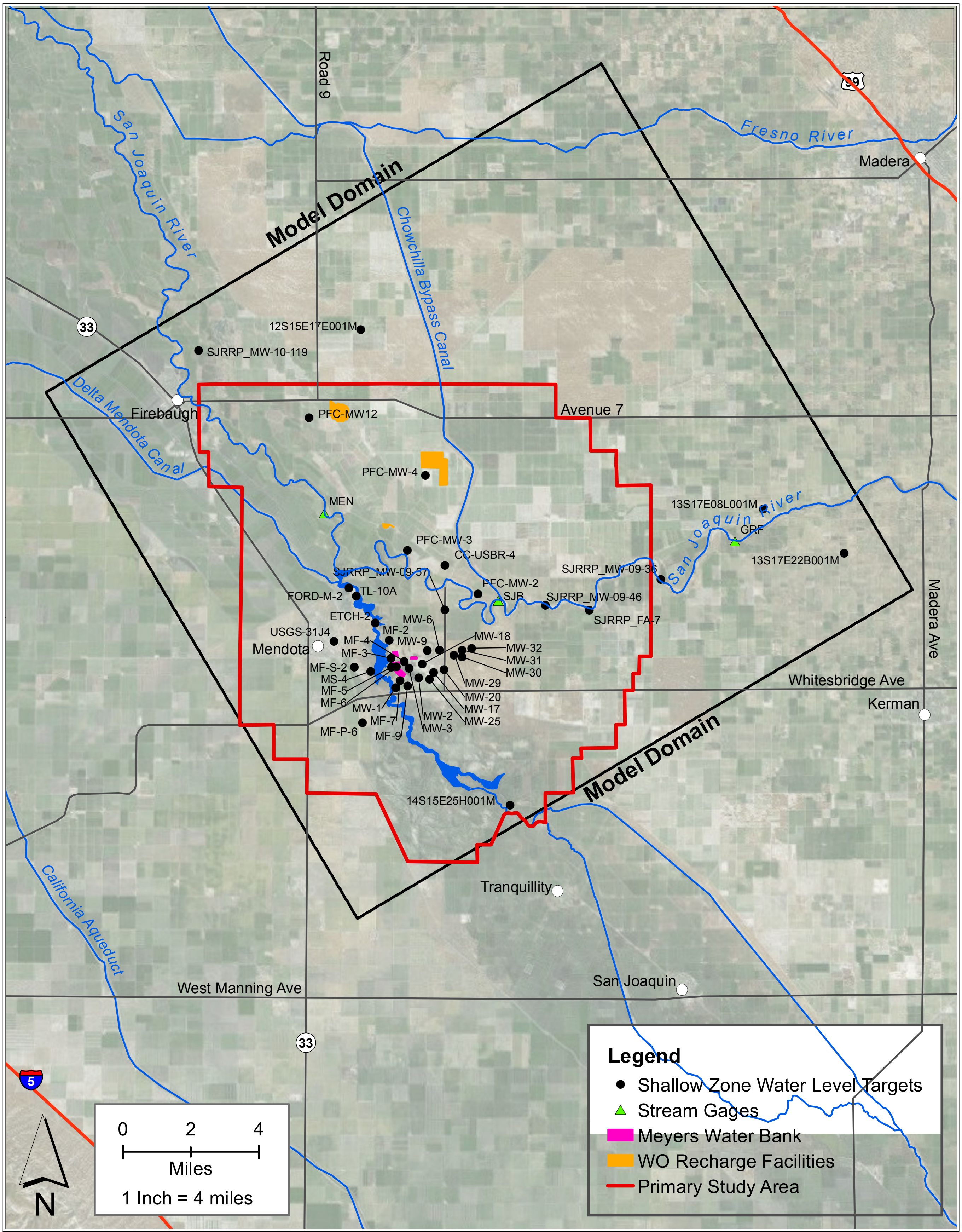

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Figure 5-6
Shallow Zone Groundwater Level And Streamflow Calibration Targets

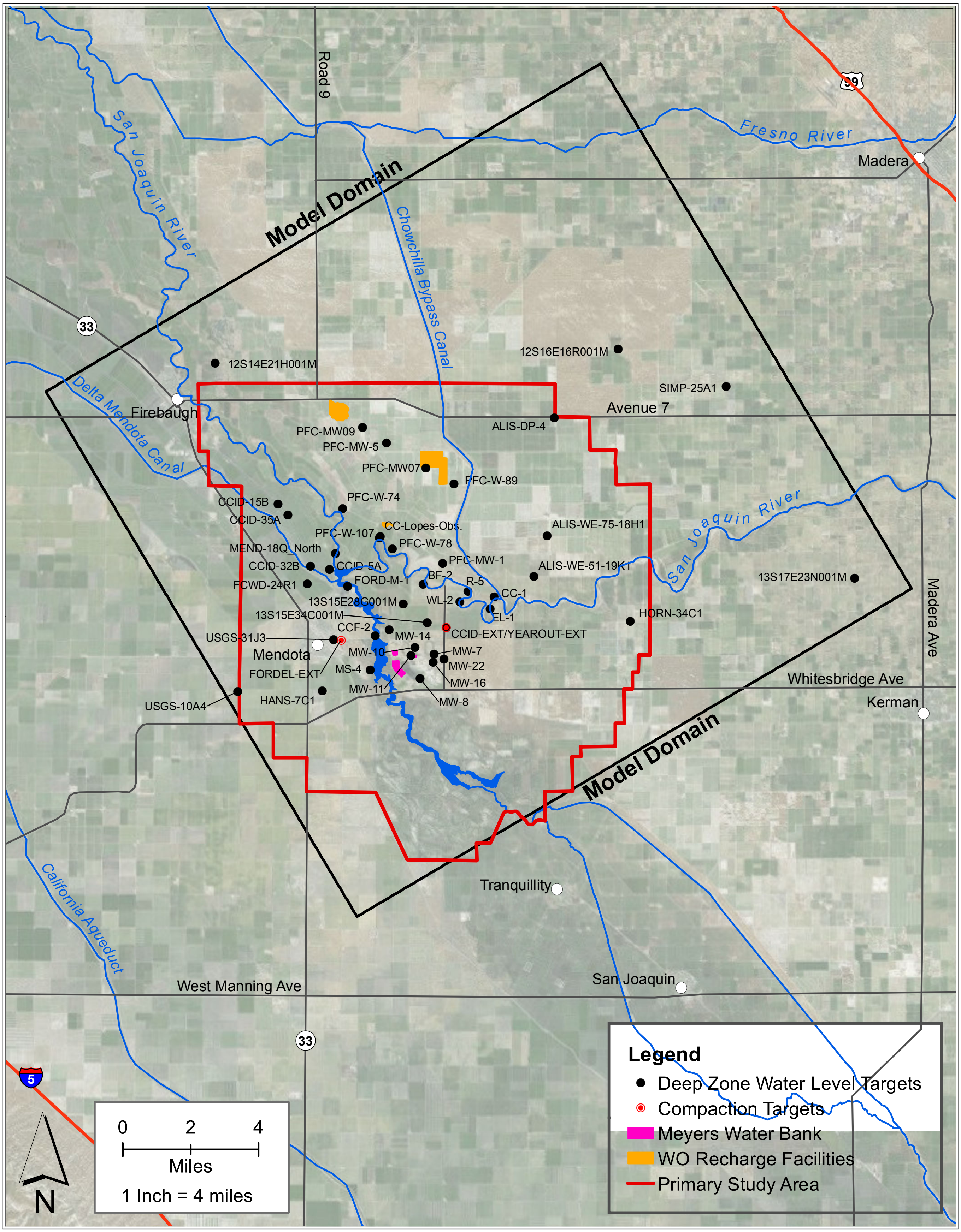

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Figure 5-7
Deep Zone Groundwater Level and Compaction Calibration Targets

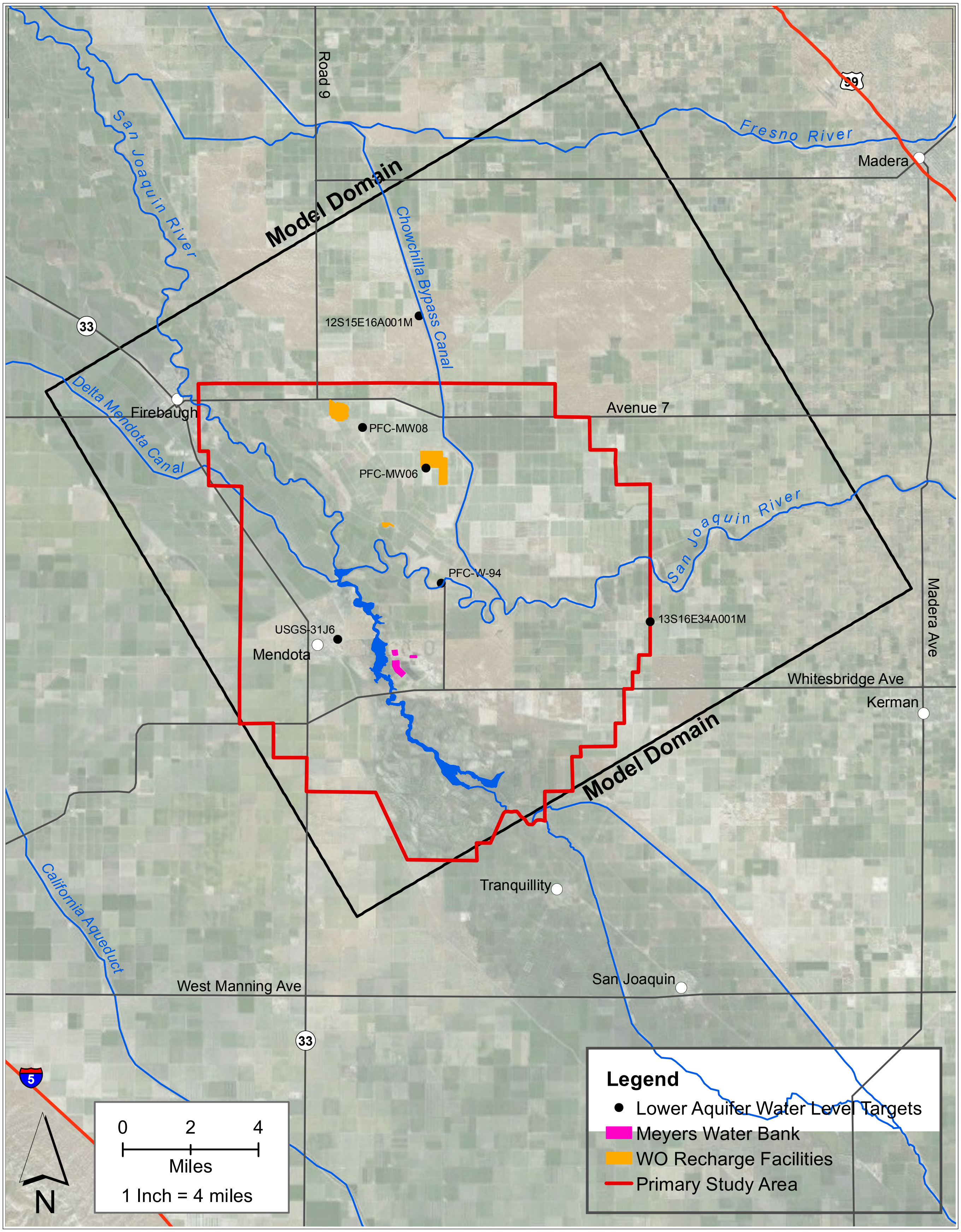

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Figure 5-8
Lower Aquifer Groundwater Level Calibration Targets

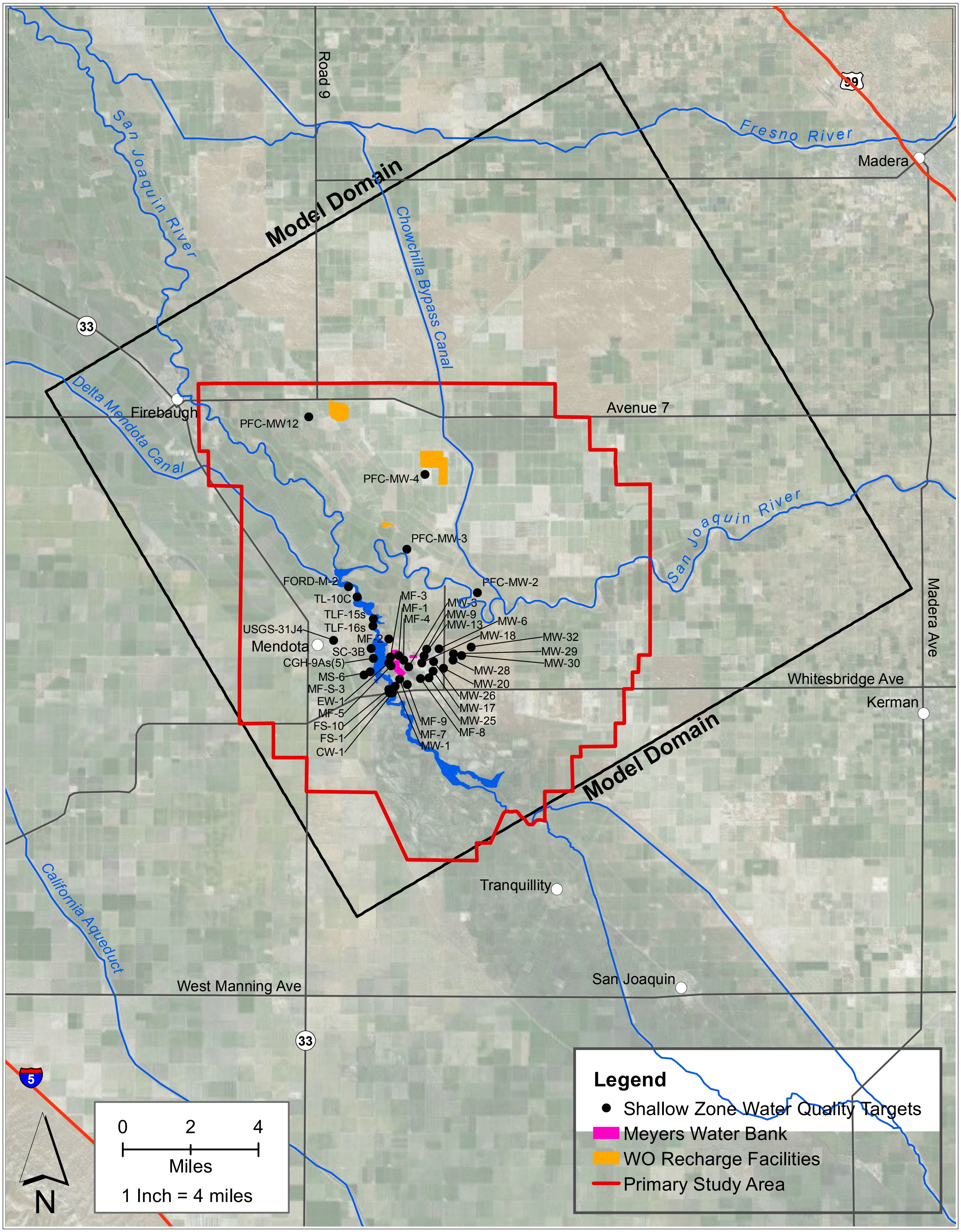

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Figure 5-9
Shallow Zone Groundwater Quality Calibration Targets

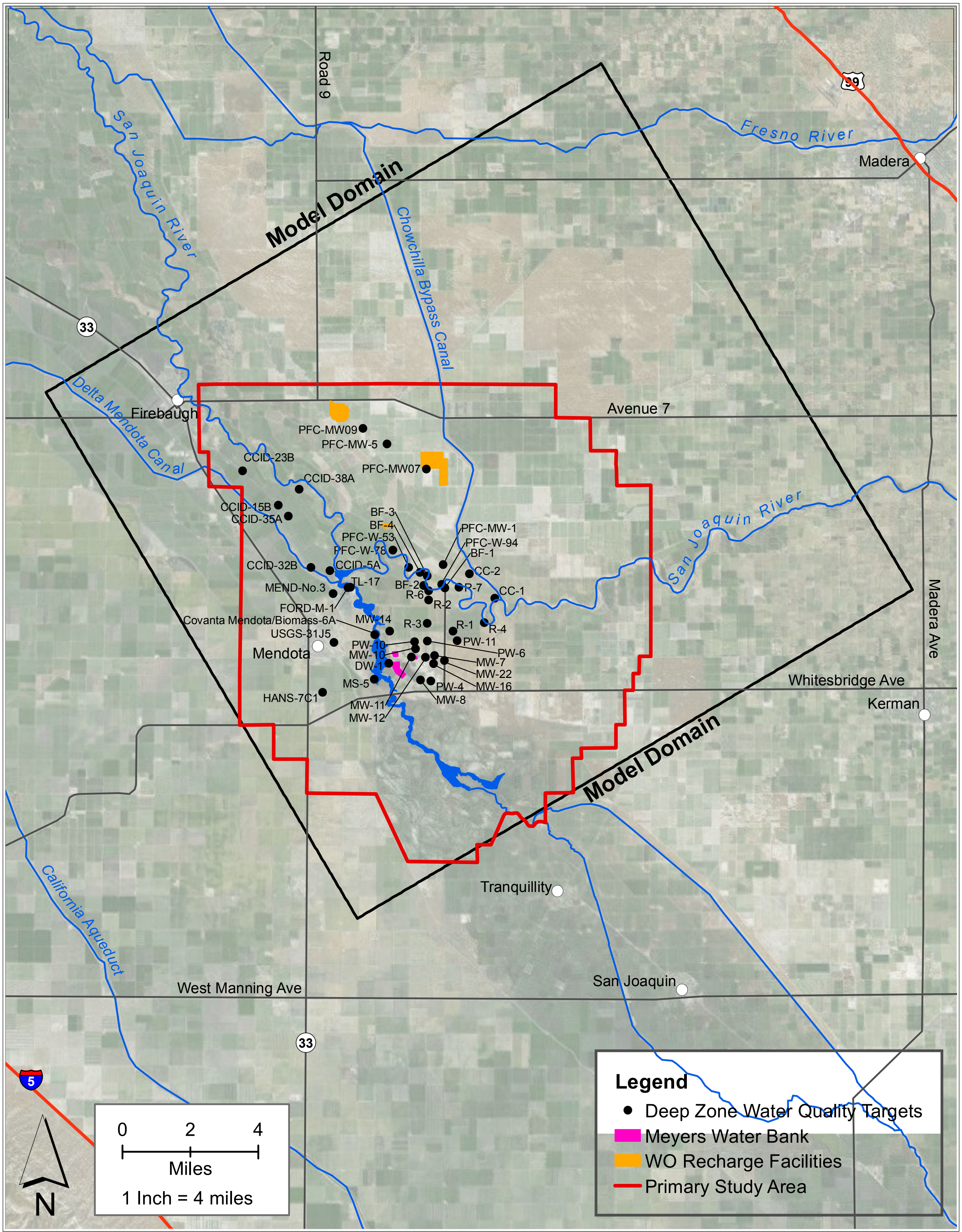

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Figure 5-10
Deep Zone Groundwater Quality Calibration Targets

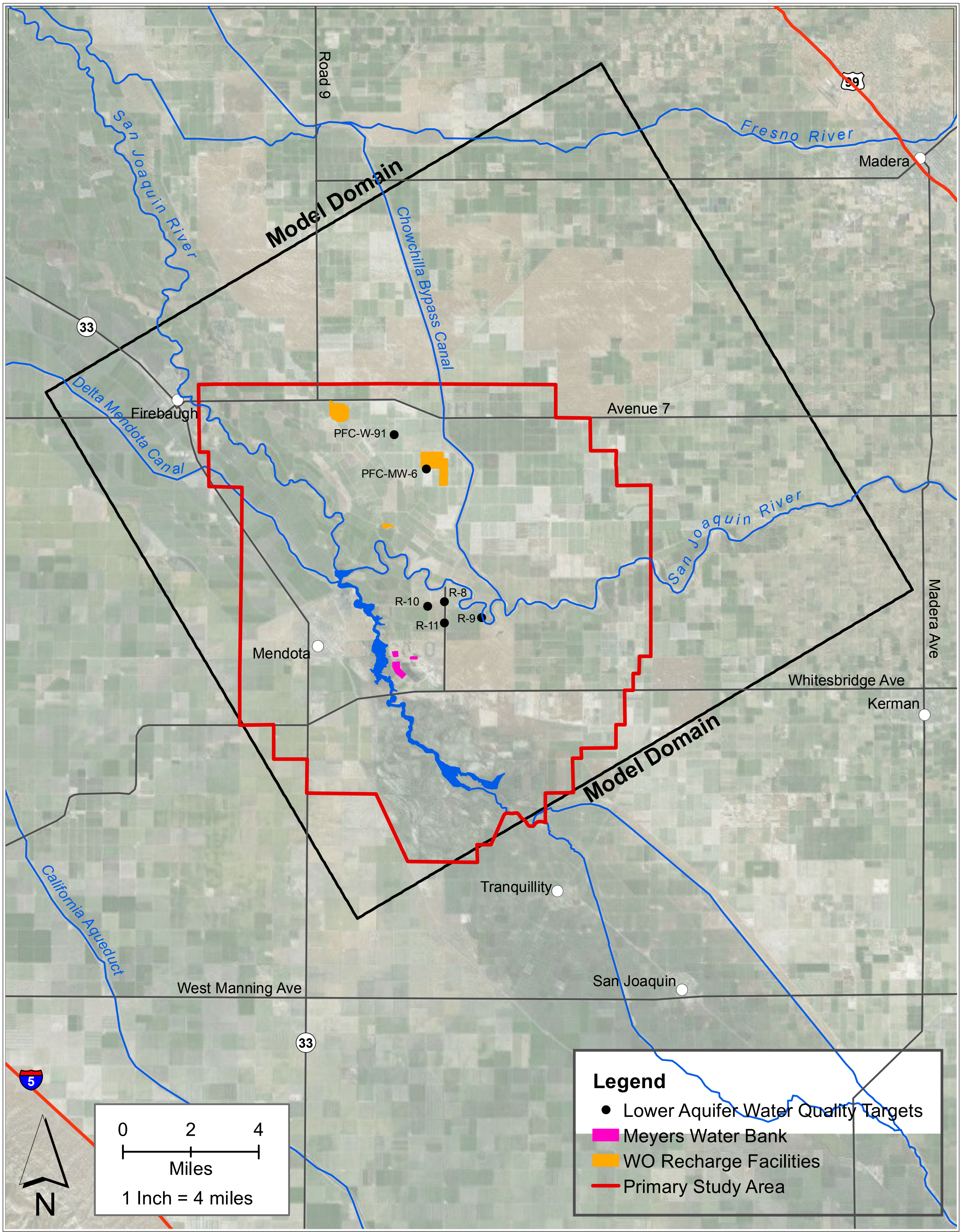

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Figure 5-11
Lower Aquifer Groundwater Quality Calibration Targets

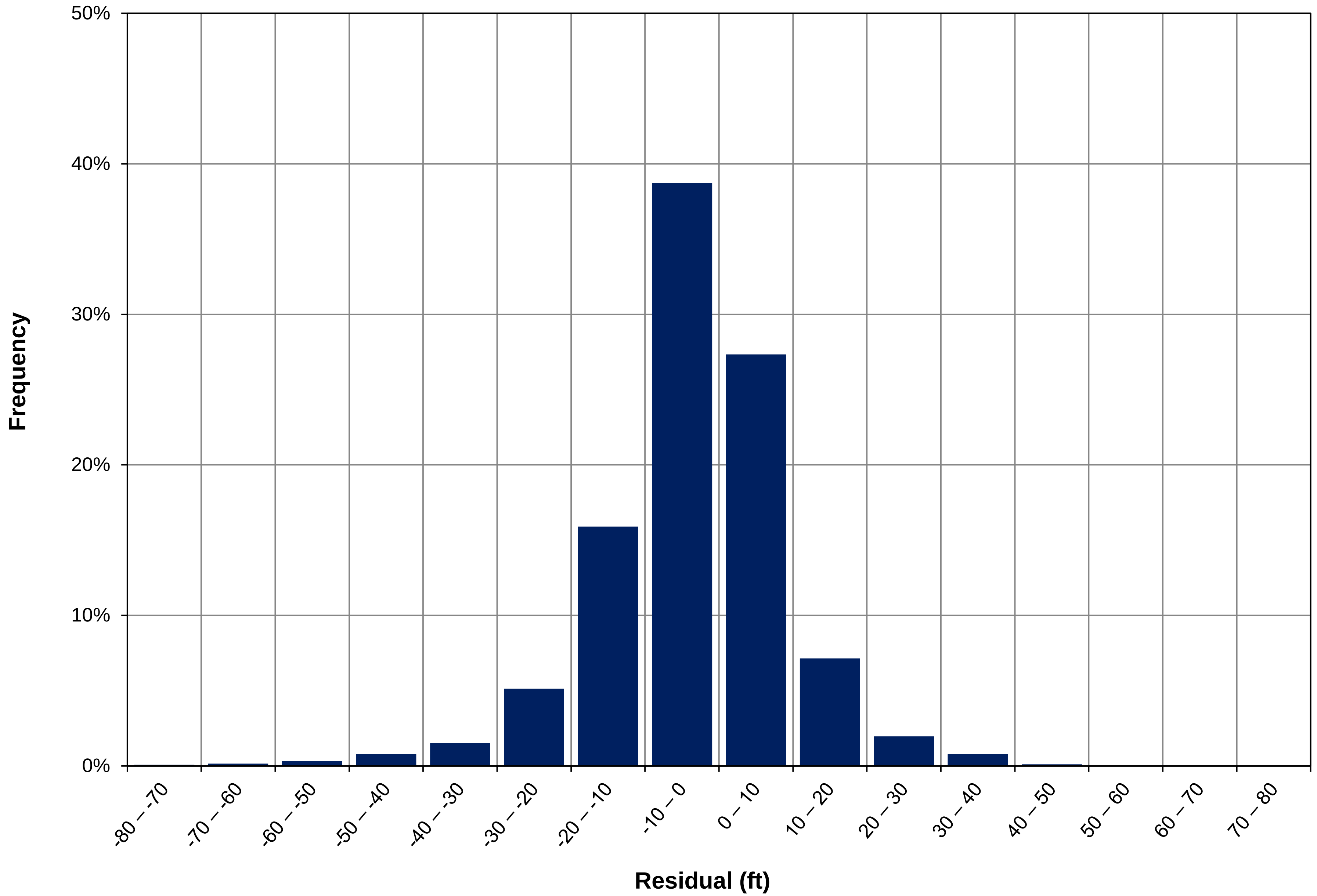

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Figure 5-12
Distribution of Residual Error in Groundwater Level Elevations

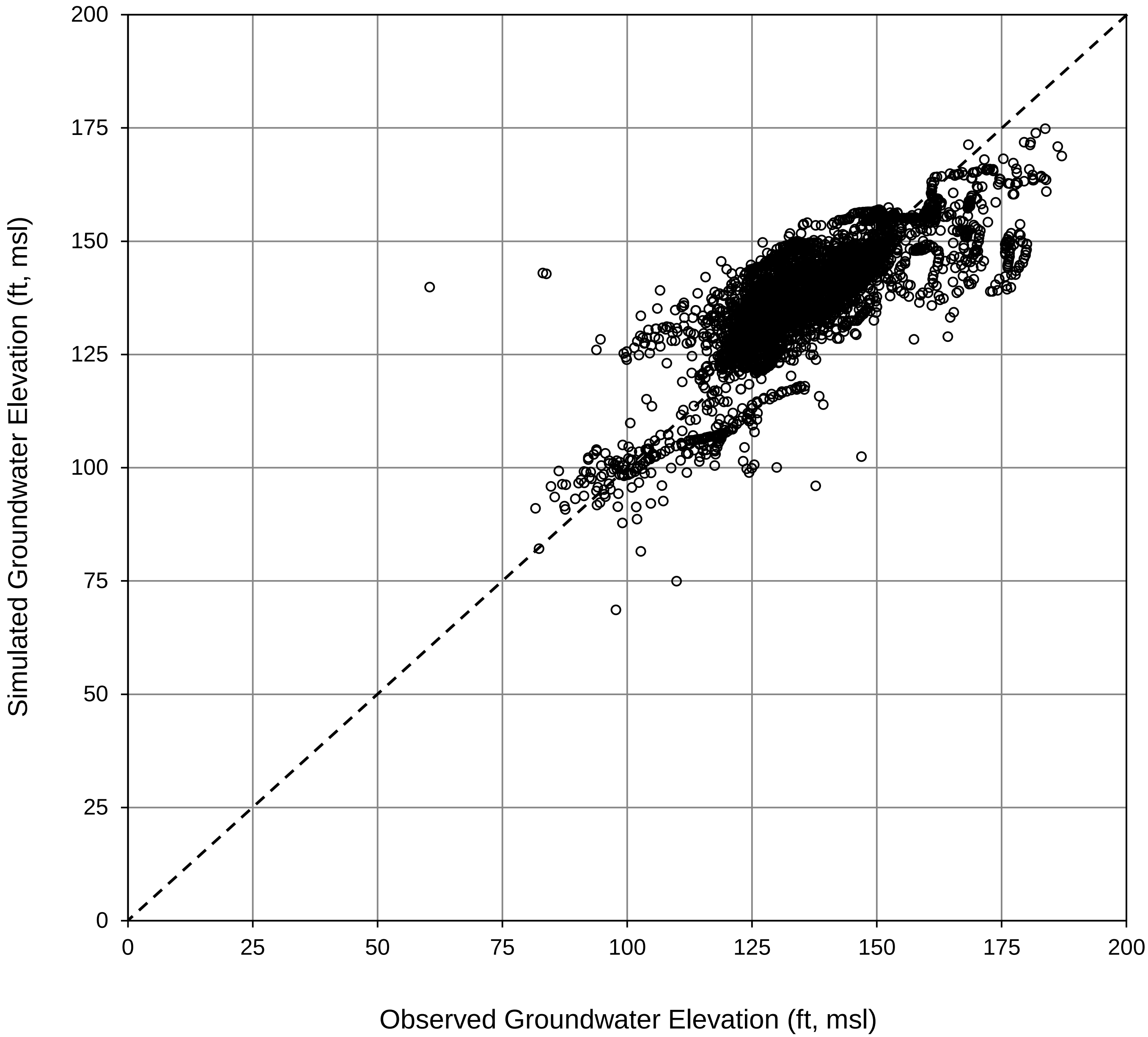

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Figure 5-13
Observed vs. Simulated Groundwater Elevations
Shallow Zone

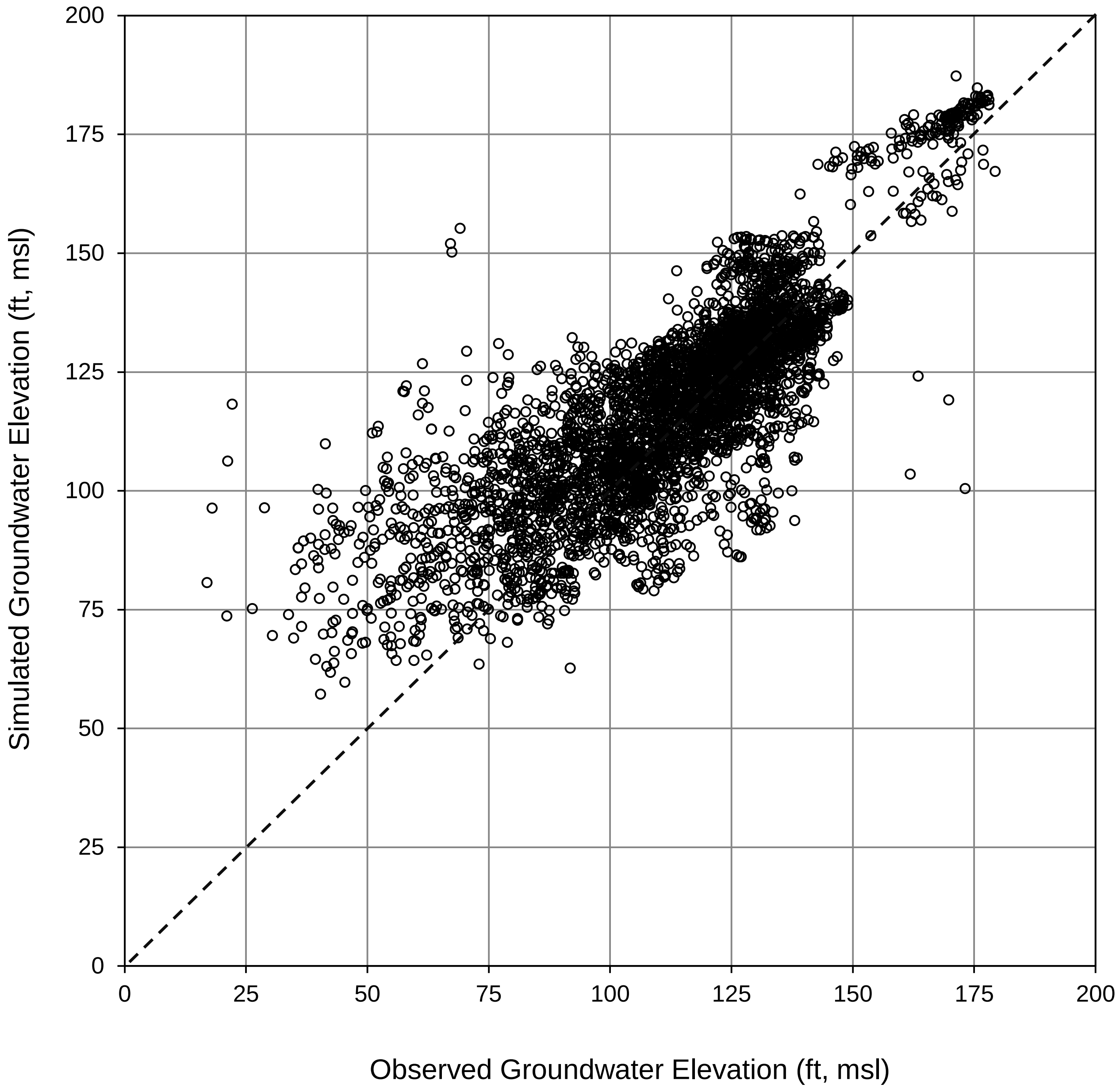

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Figure 5-14
Observed vs. Simulated Groundwater Elevations
Deep Zone

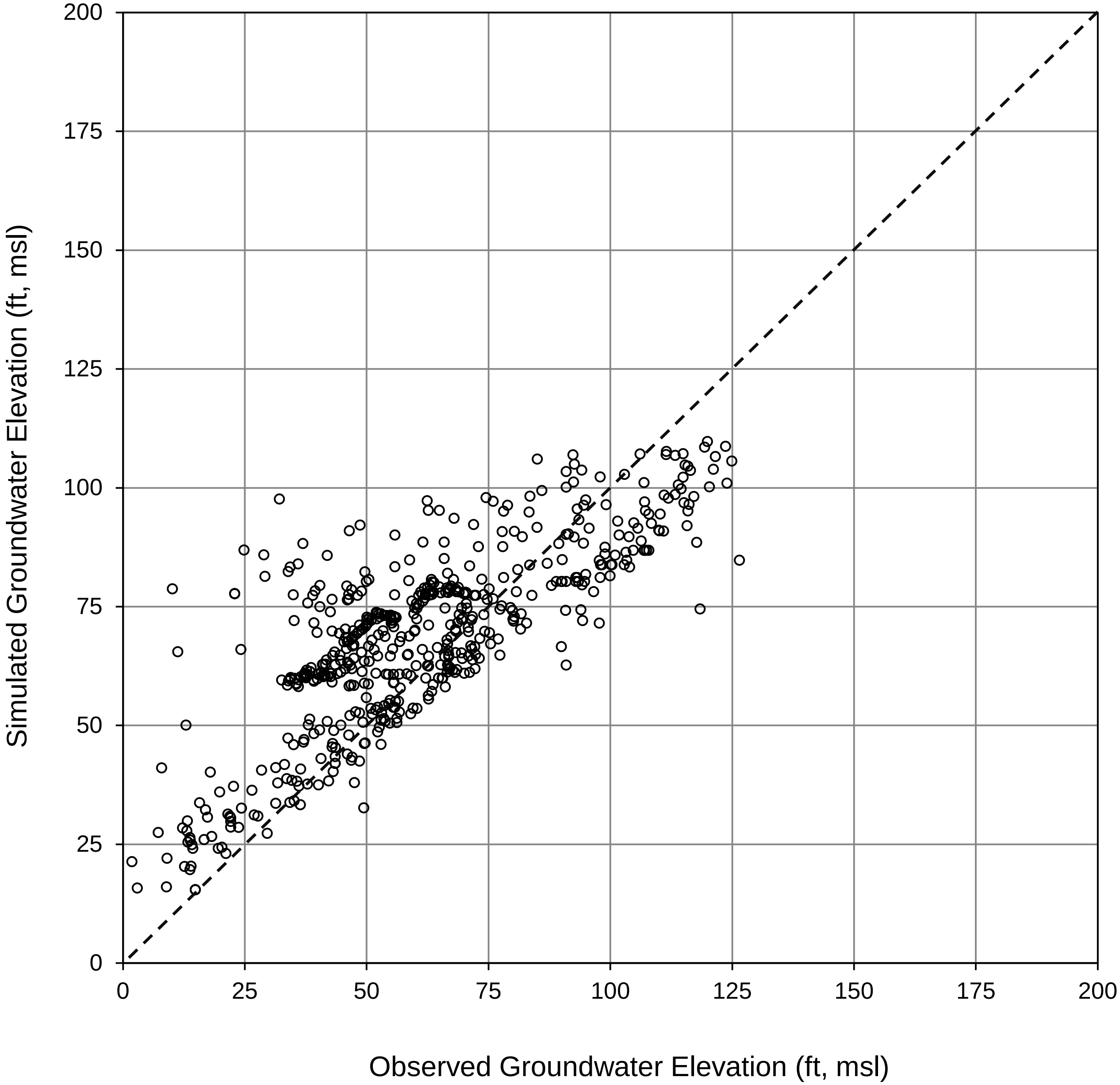

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Figure 5-15
Observed vs. Simulated Groundwater Elevations
Lower Aquifer

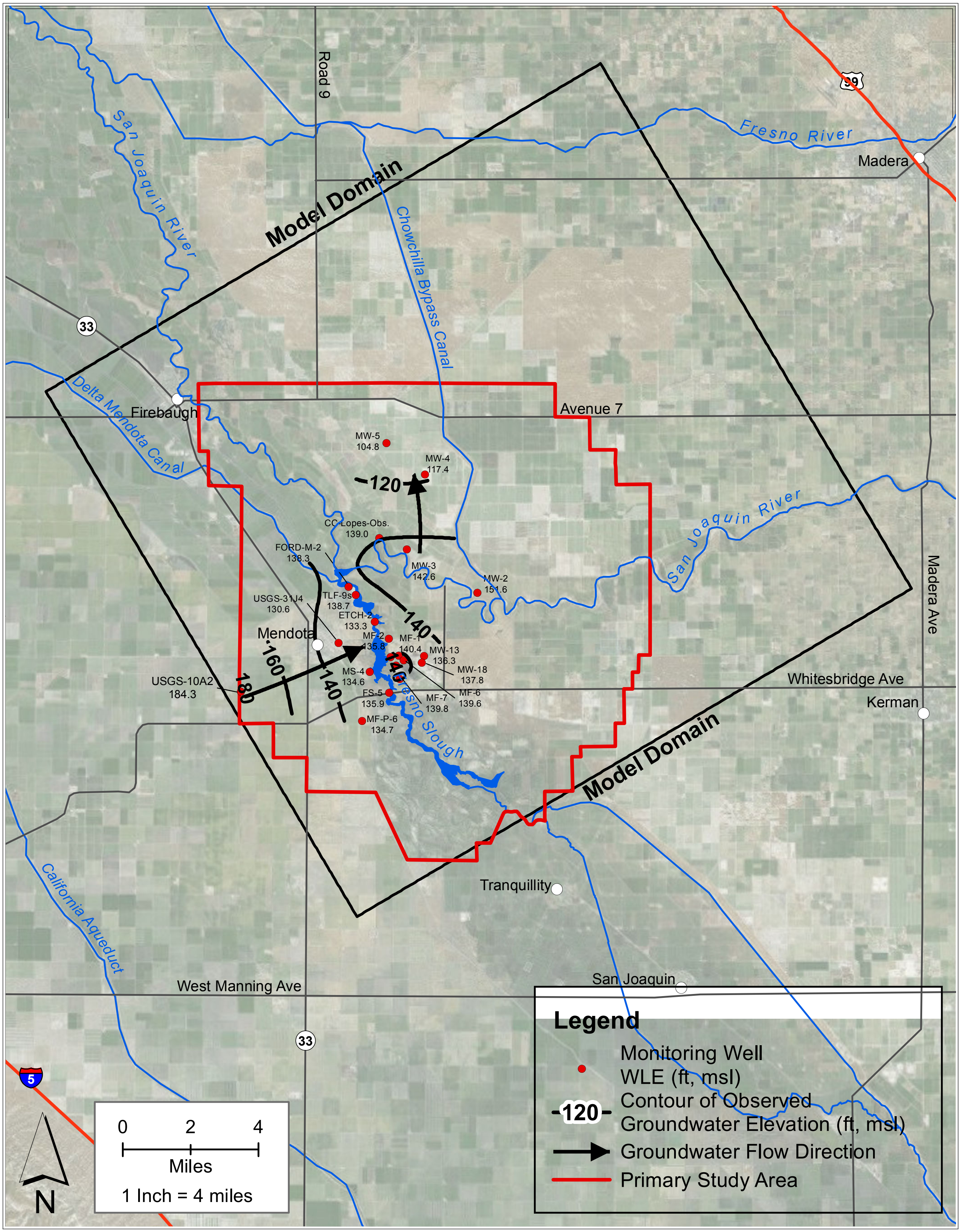

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Figure 5-16
Contours of Equal Observed Groundwater Elevation Shallow Zone, Winter 2012

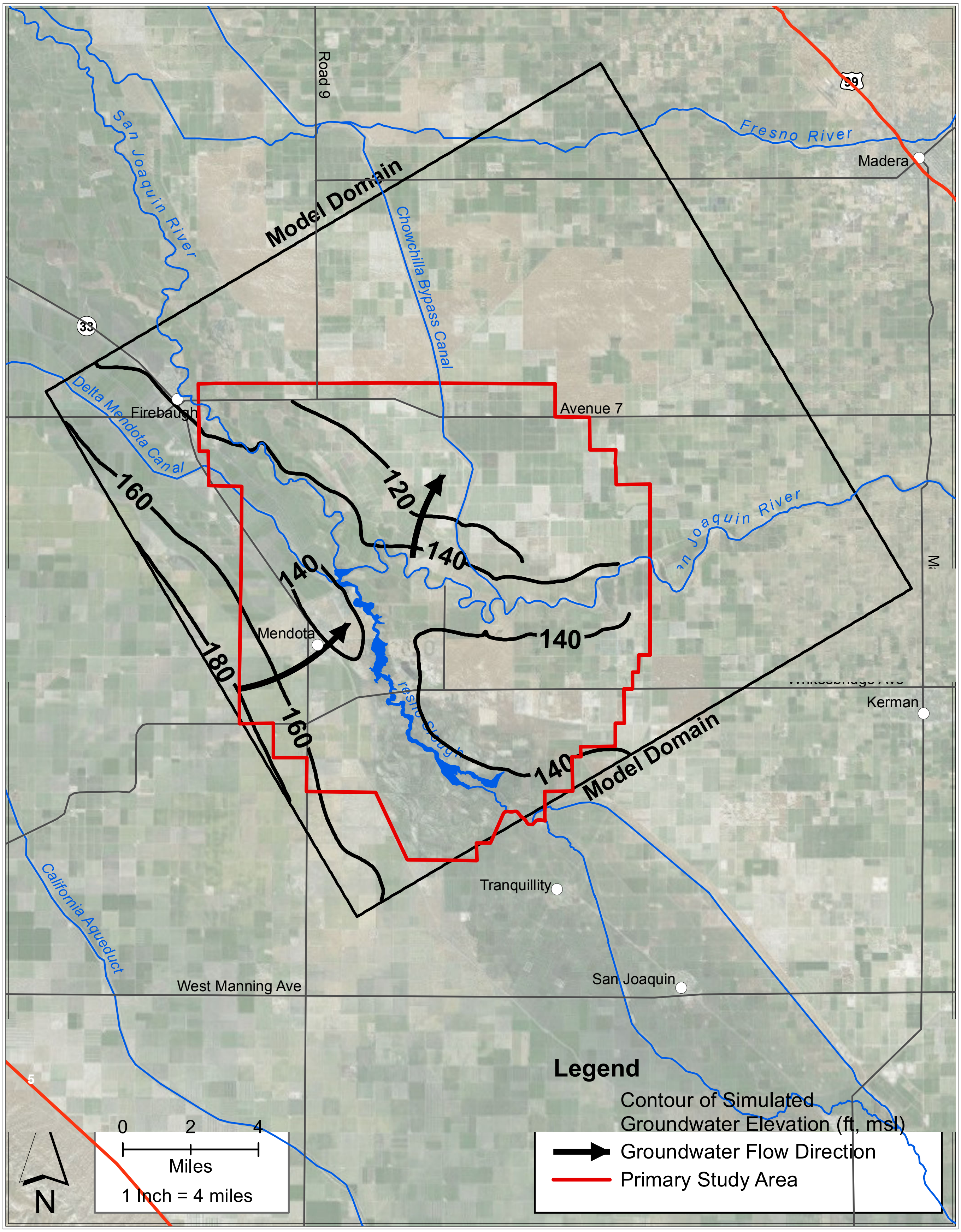

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Figure 5-17
Contours of Equal Simulated Groundwater Elevation Shallow Zone, Winter 2012

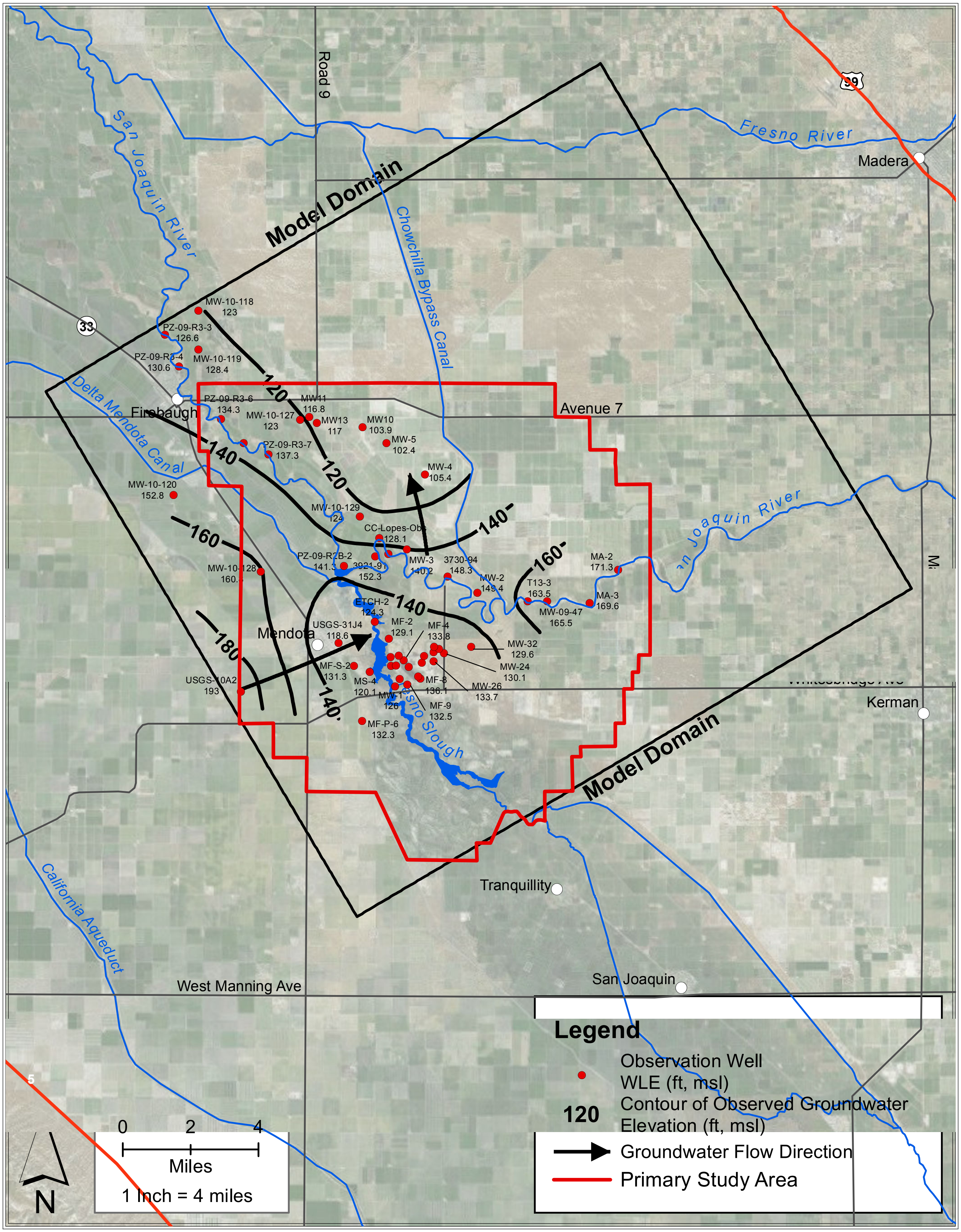

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Figure 5-18
Contours of Equal Observed Groundwater Elevation
Shallow Zone, Summer 2012

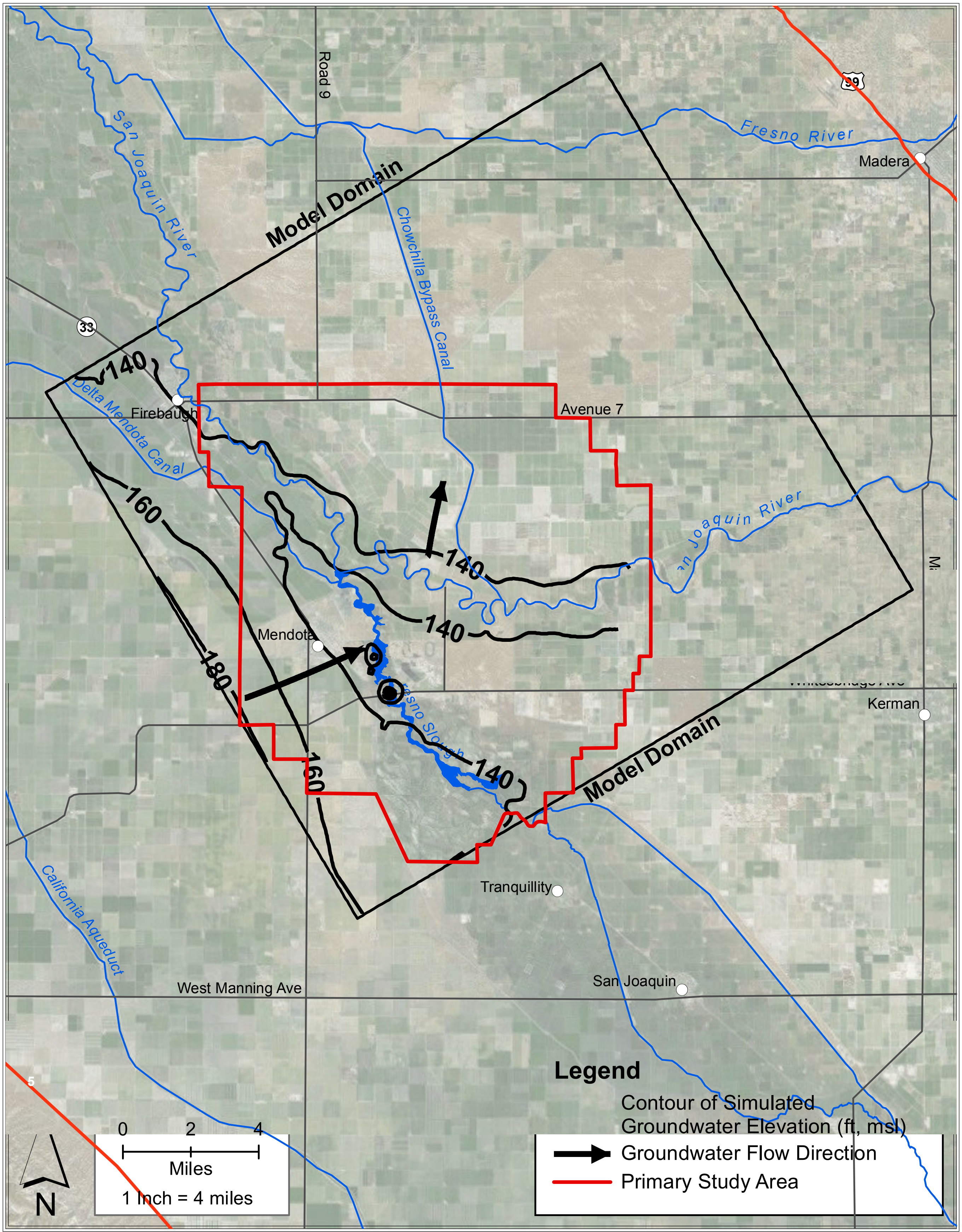

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Figure 5-19
Contours of Equal Simulated Groundwater Elevation
Shallow Zone, Summer 2012

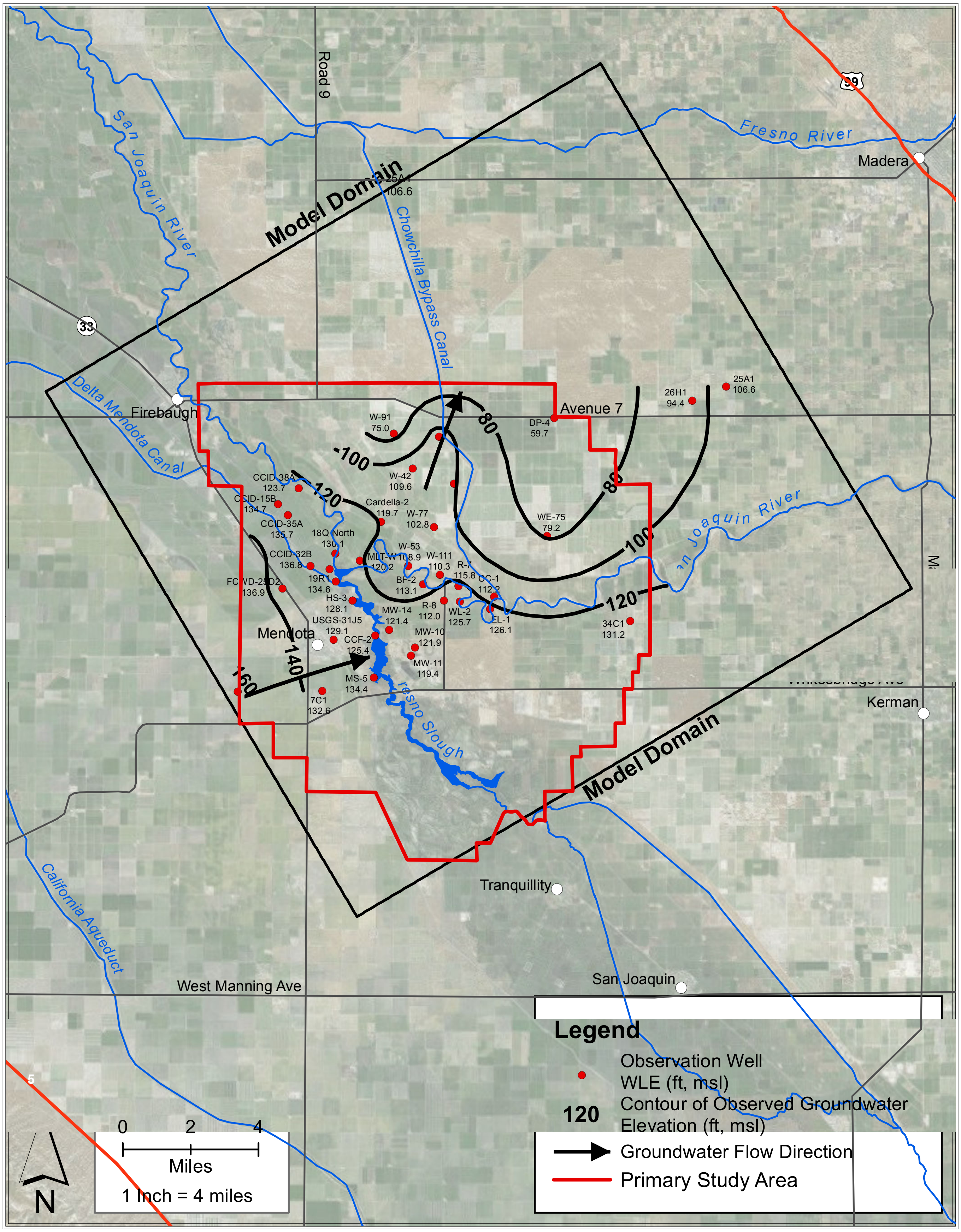

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Figure 5-20
Contours of Equal Observed Groundwater Elevation Deep Zone, Winter 2012

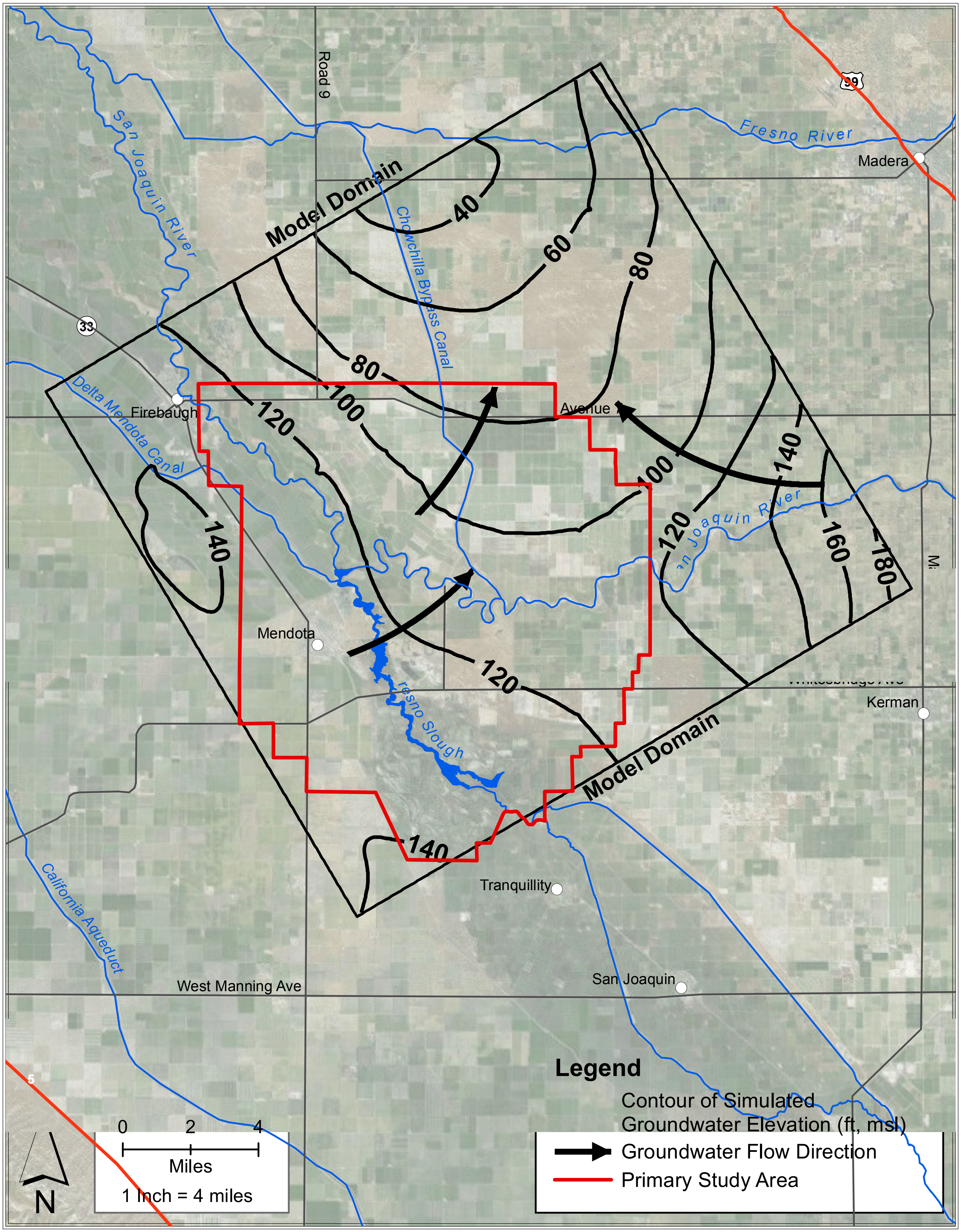

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Figure 5-21
Contours of Equal Simulated Groundwater Elevation Deep Zone, Winter 2012

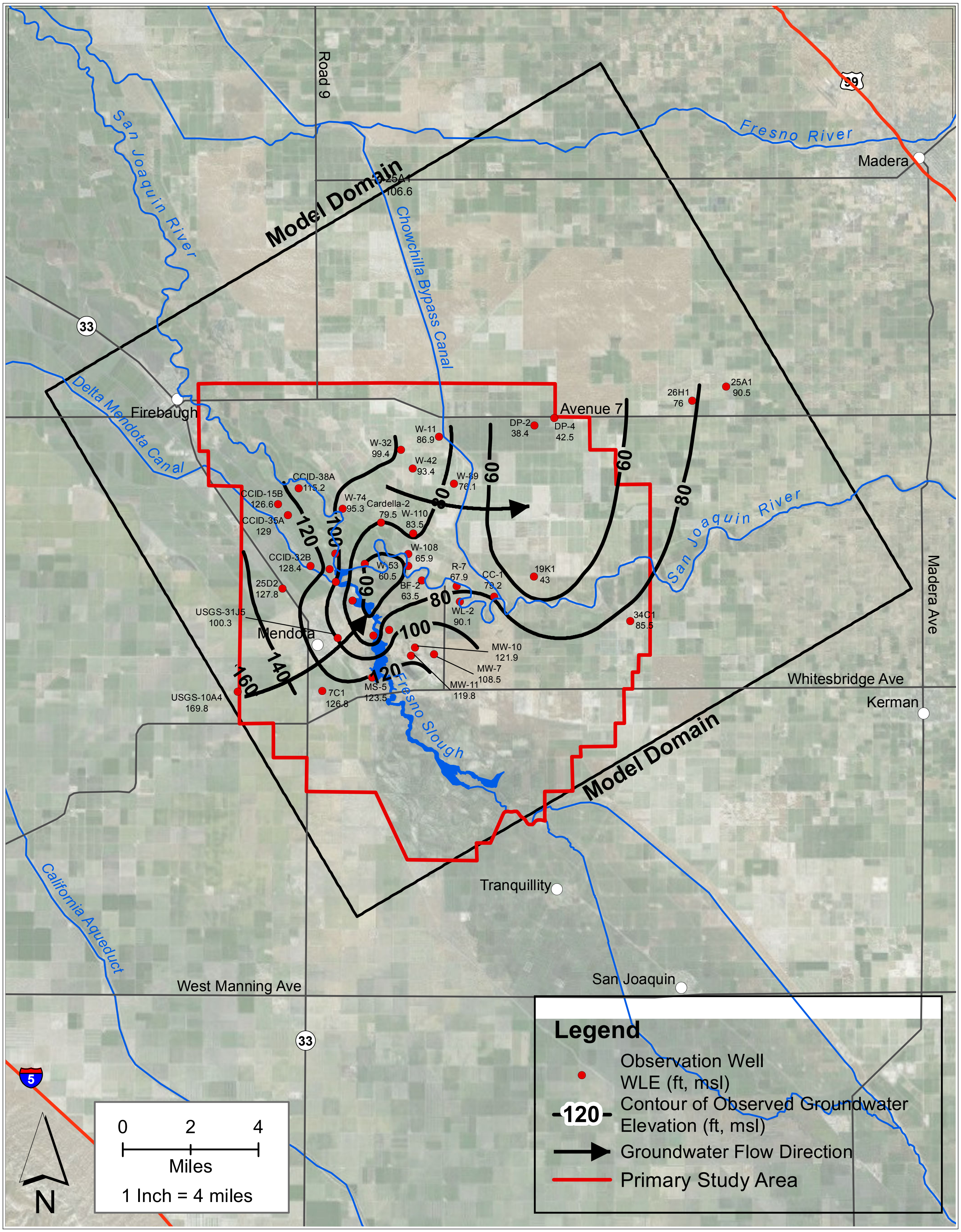

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Figure 5-22
Contours of Equal Observed Groundwater Elevation Deep Zone, Summer 2012

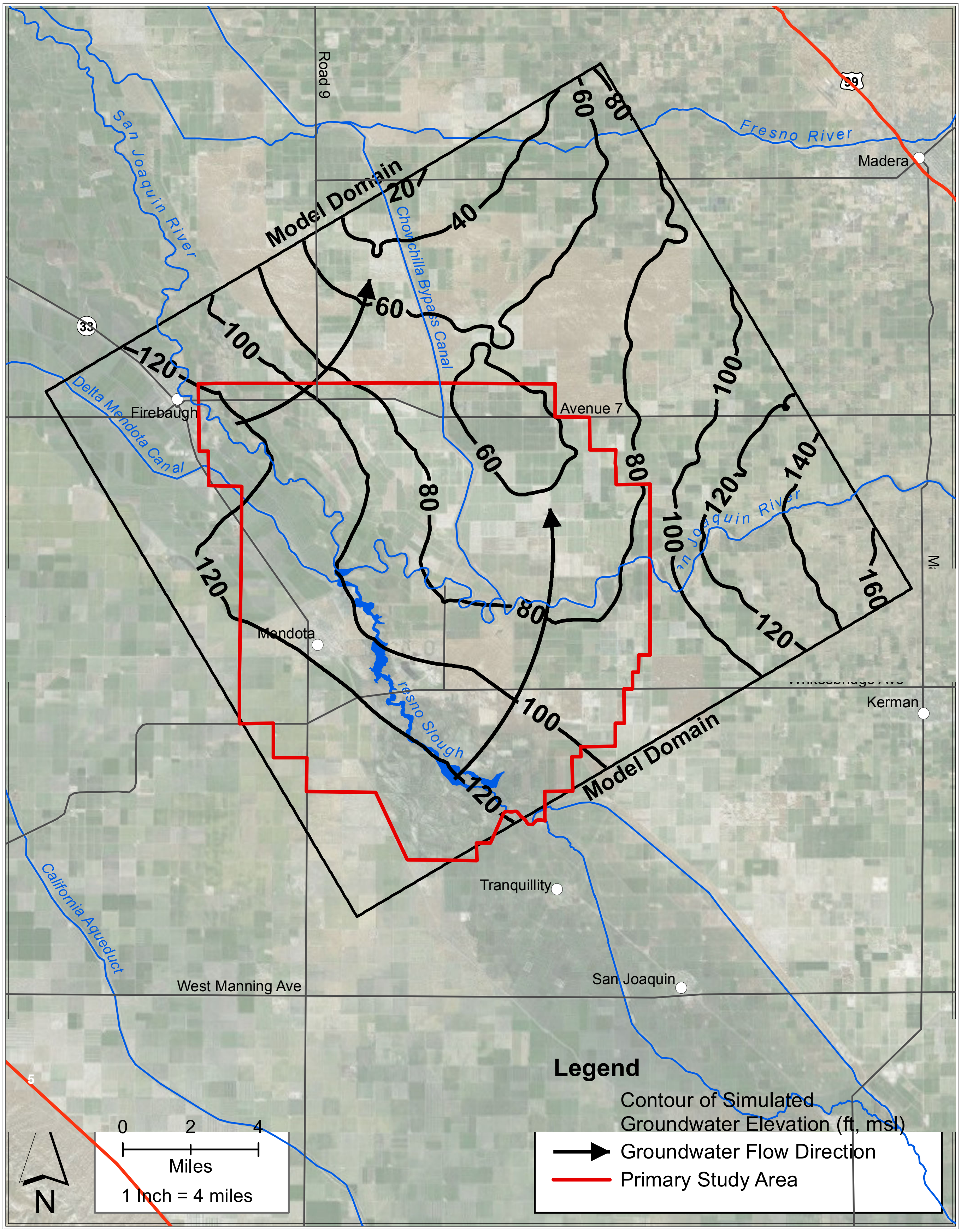

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Figure 5-23
Contours of Equal Simulated Groundwater Elevation Deep Zone, Summer 2012

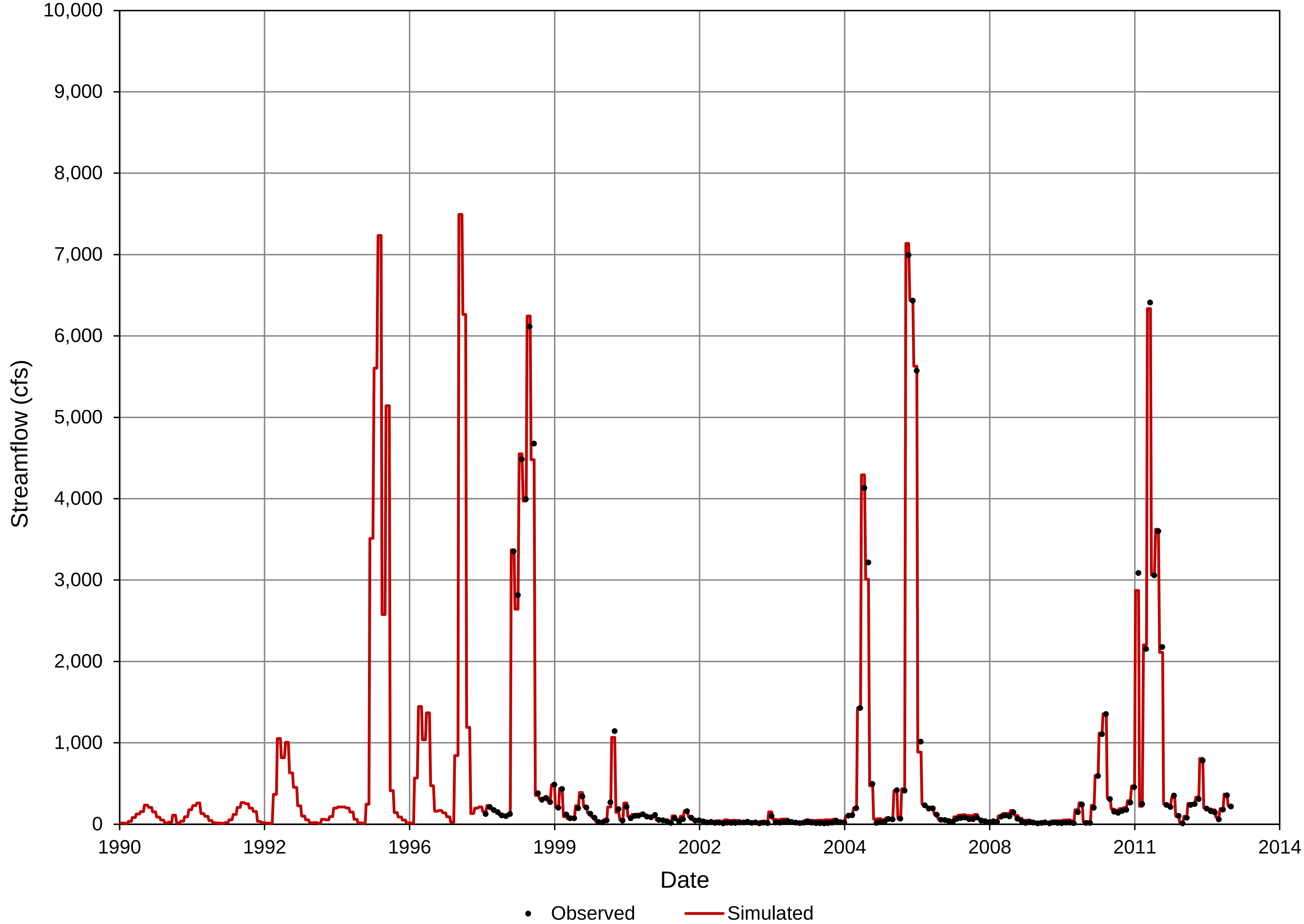

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Figure 5-24
Observed and Simulated Streamflow
San Joaquin River at GRF

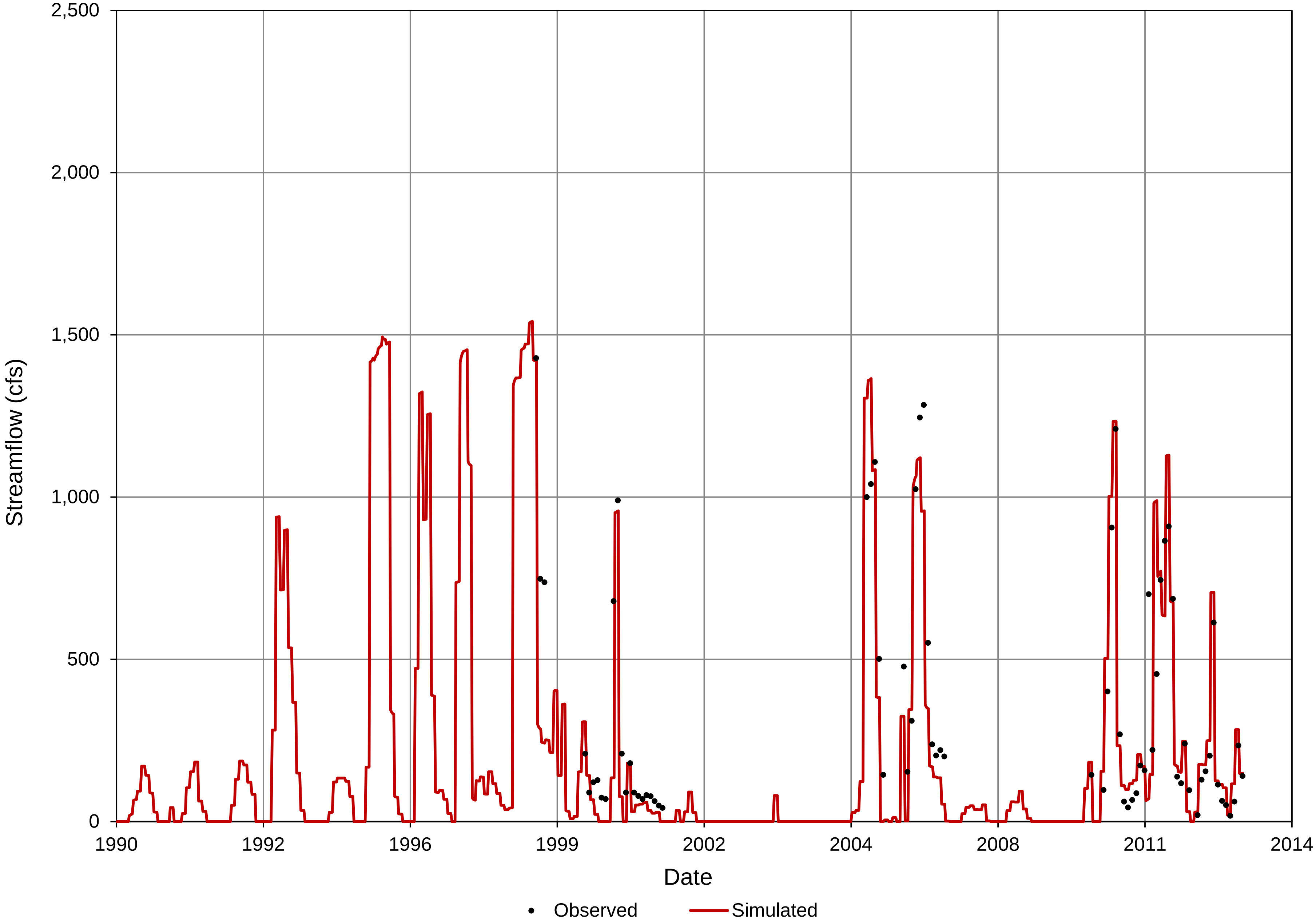

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Figure 5-25
Observed and Simulated Streamflow
San Joaquin River at SJB

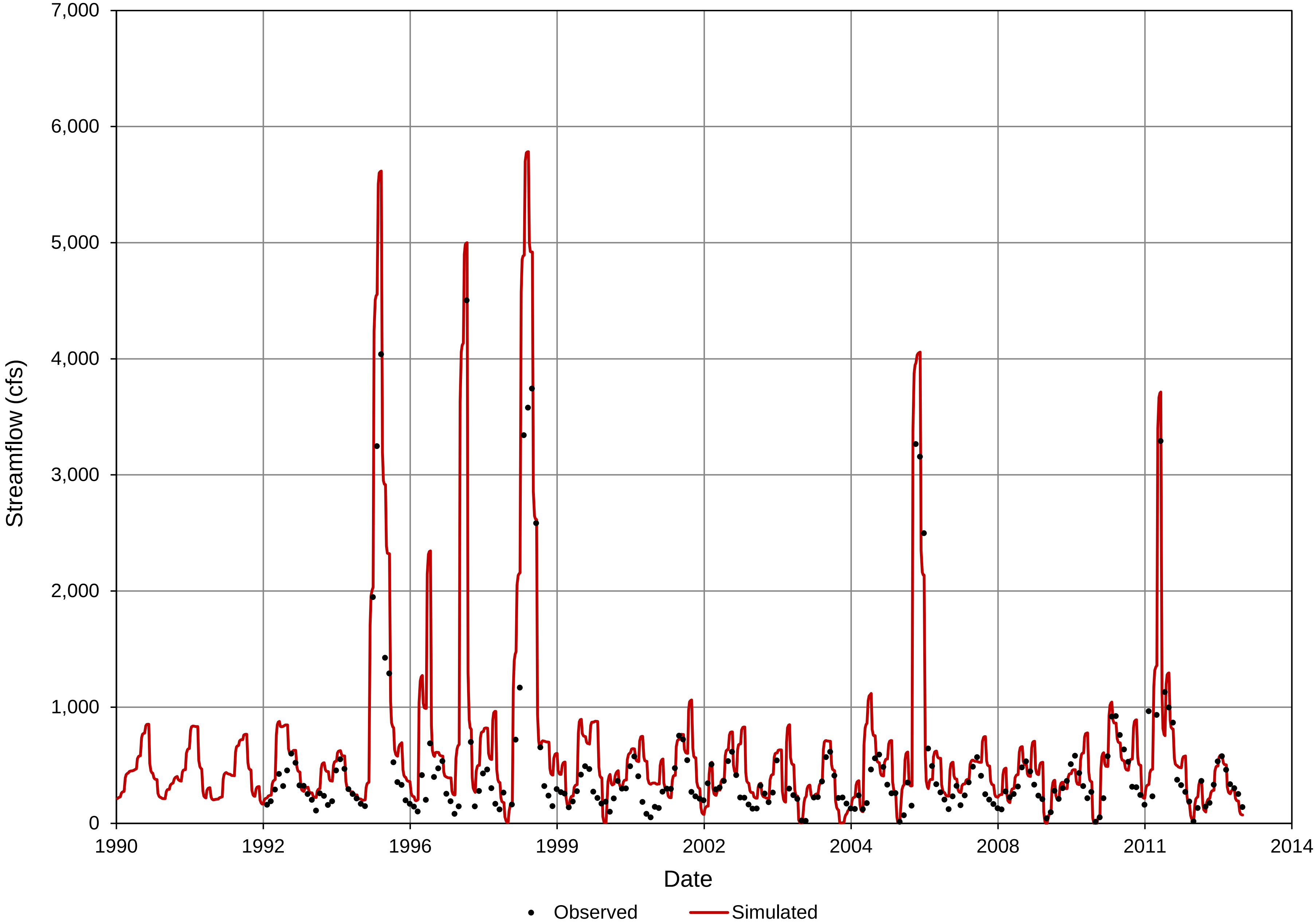

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Figure 5-21
Observed and Simulated Streamflow
San Joaquin River at MEN

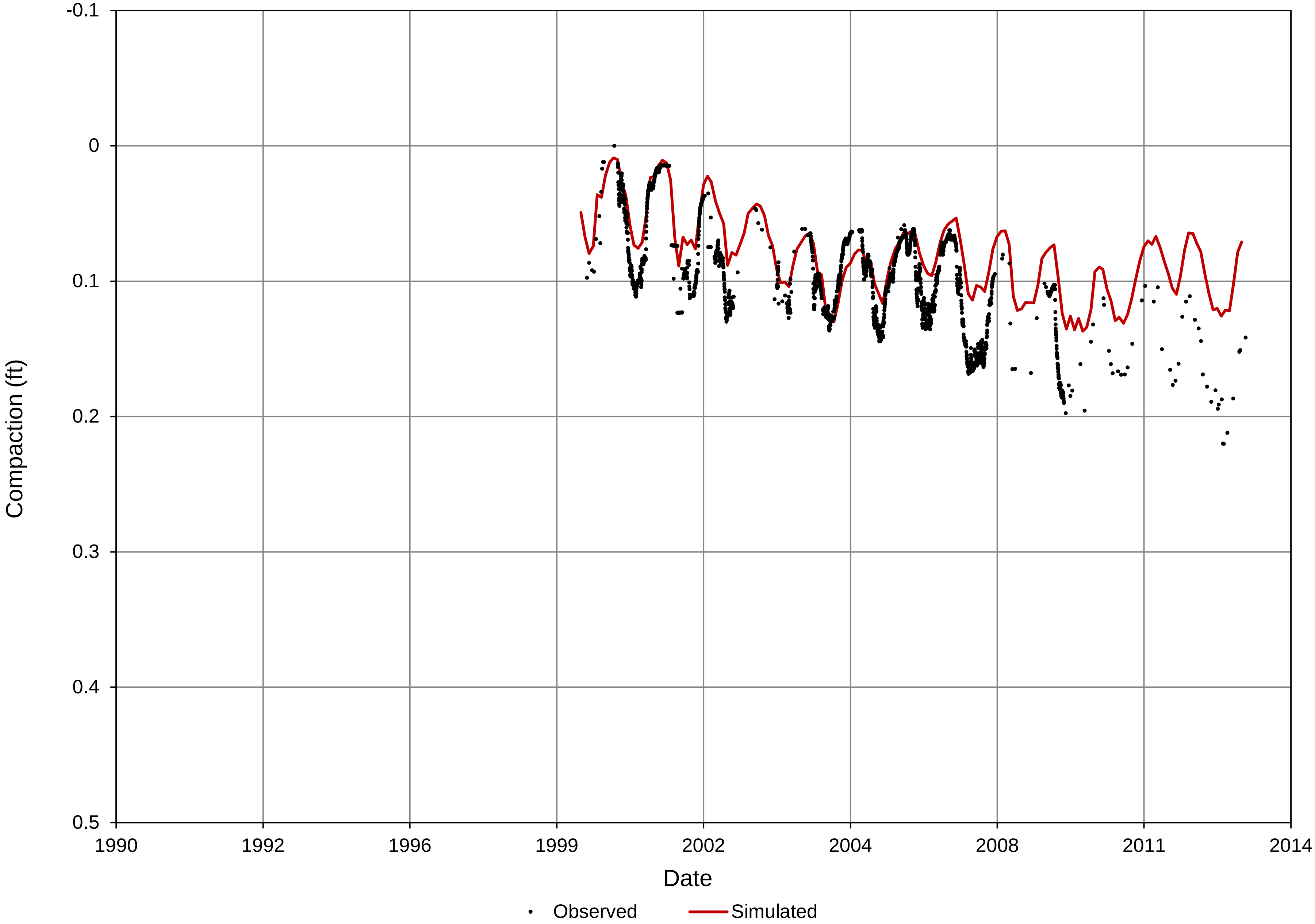

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Figure 5-27
Observed and Simulated Compaction
Yearout Extensometer

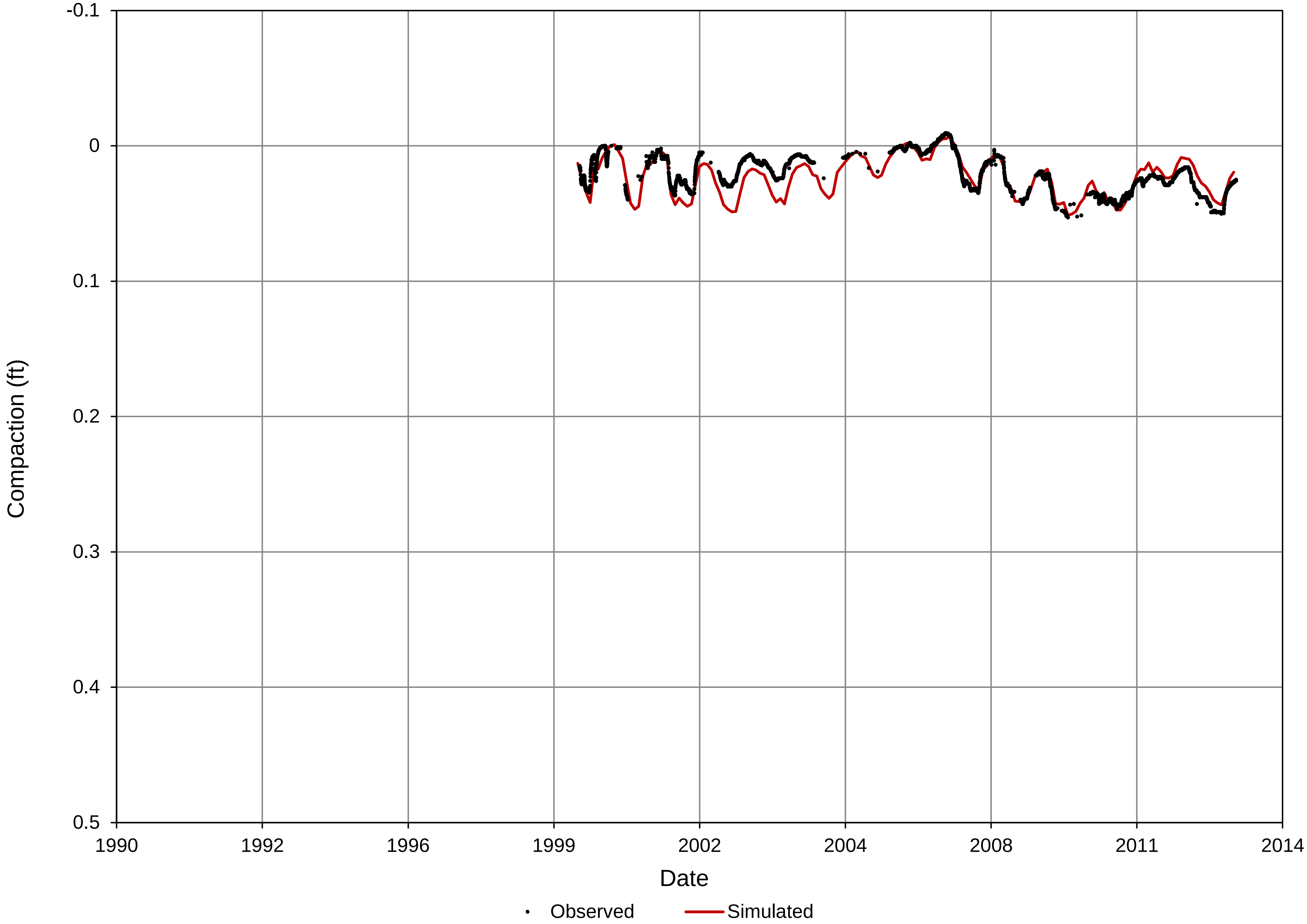

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Figure 5-28
Observed and Simulated Compaction
Fordel Extensometer

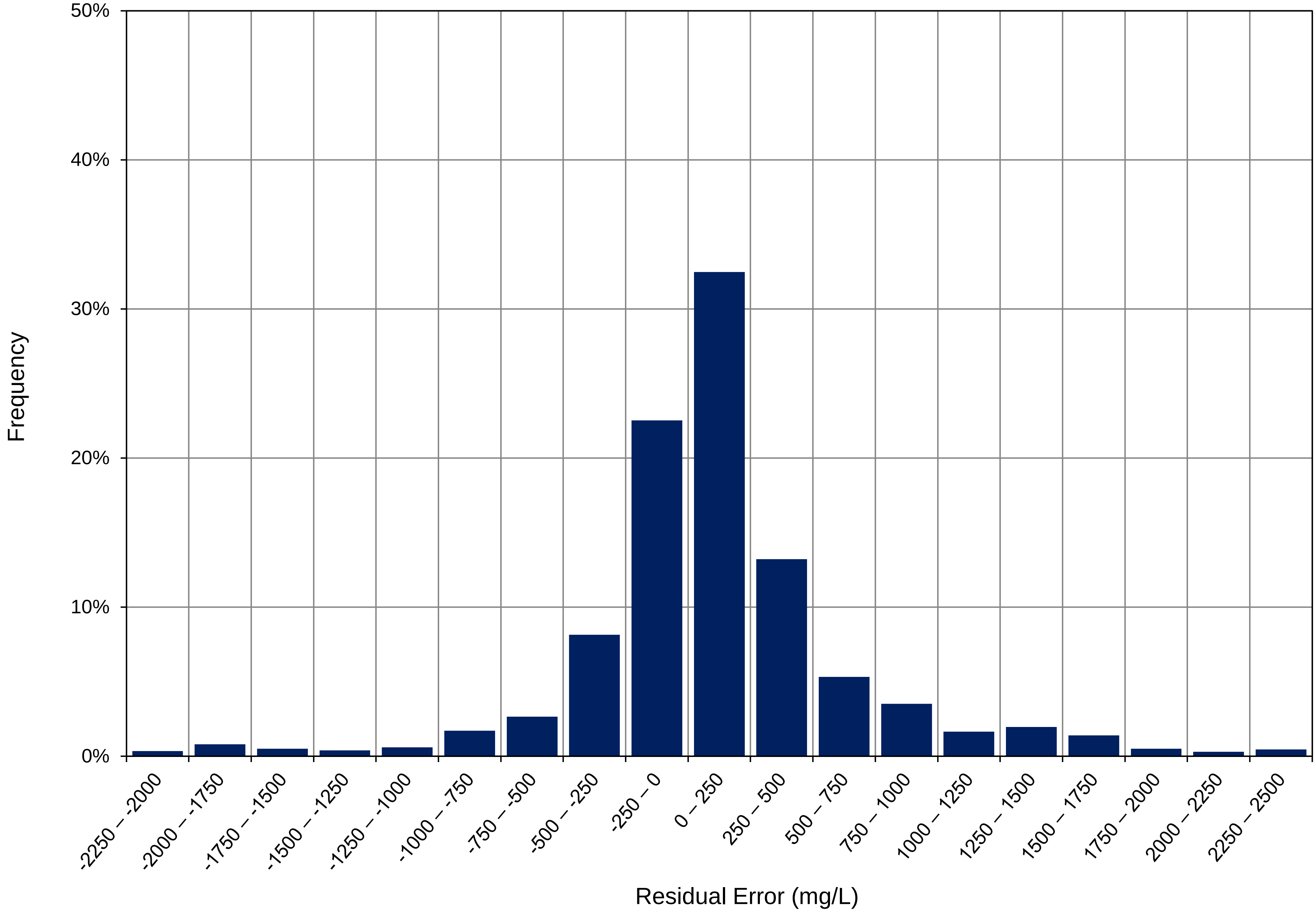

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Figure 5-29
Distribution of Residual Error in TDS Concentrations

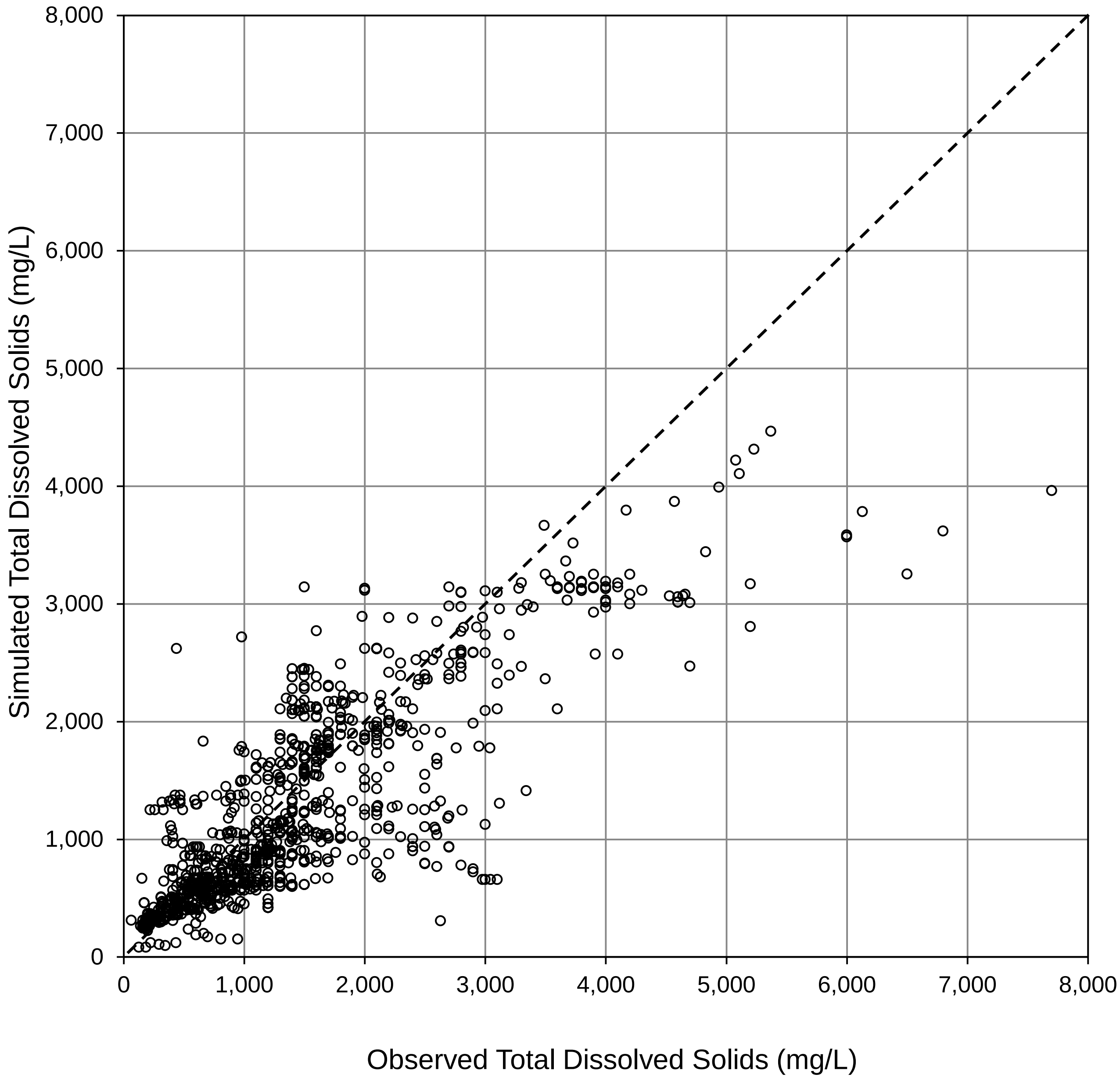

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Figure 5-30
Observed vs. Simulated TDS
Shallow Zone

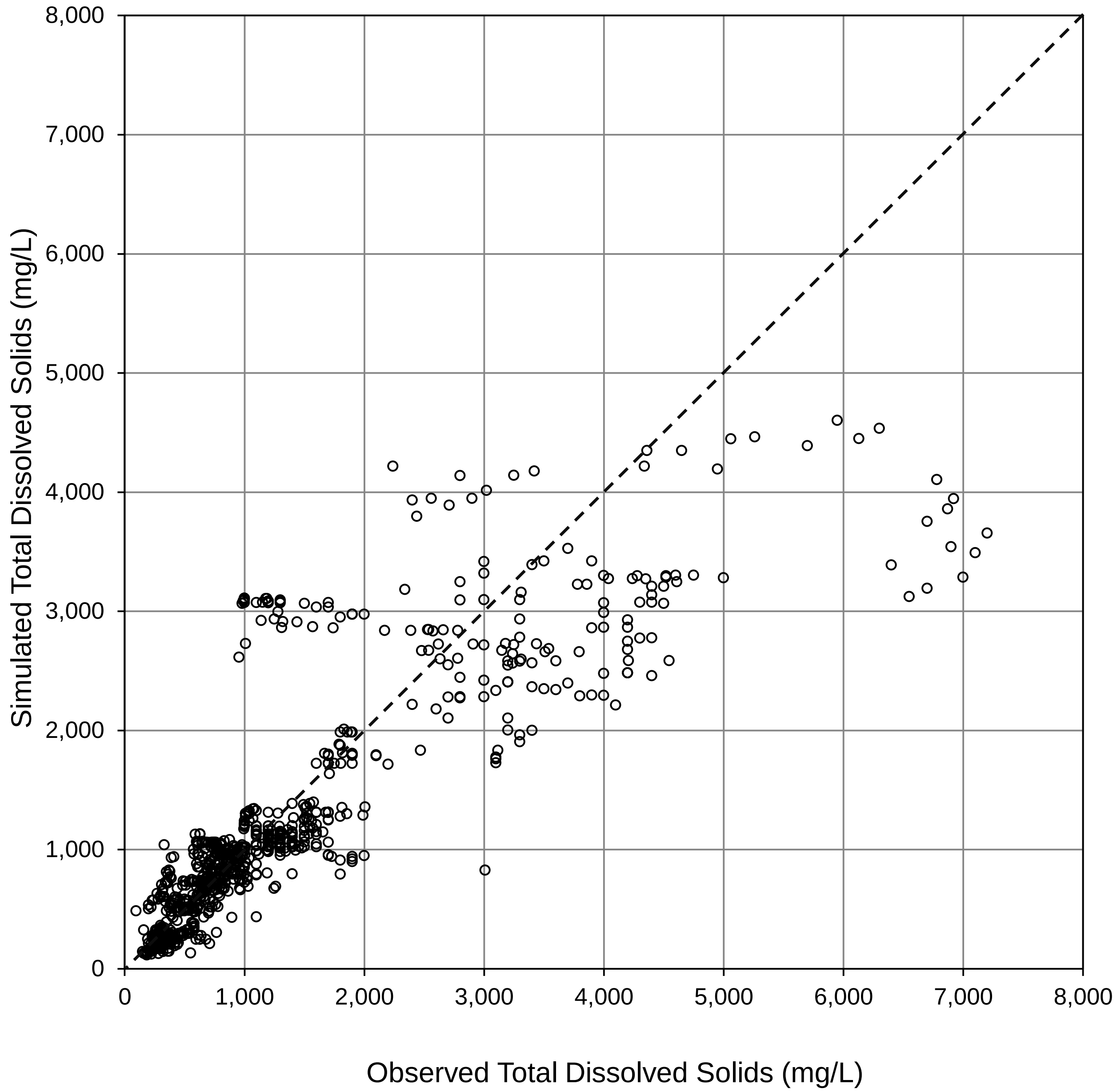

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Figure 5-31
Observed vs. Simulated TDS
Deep Zone

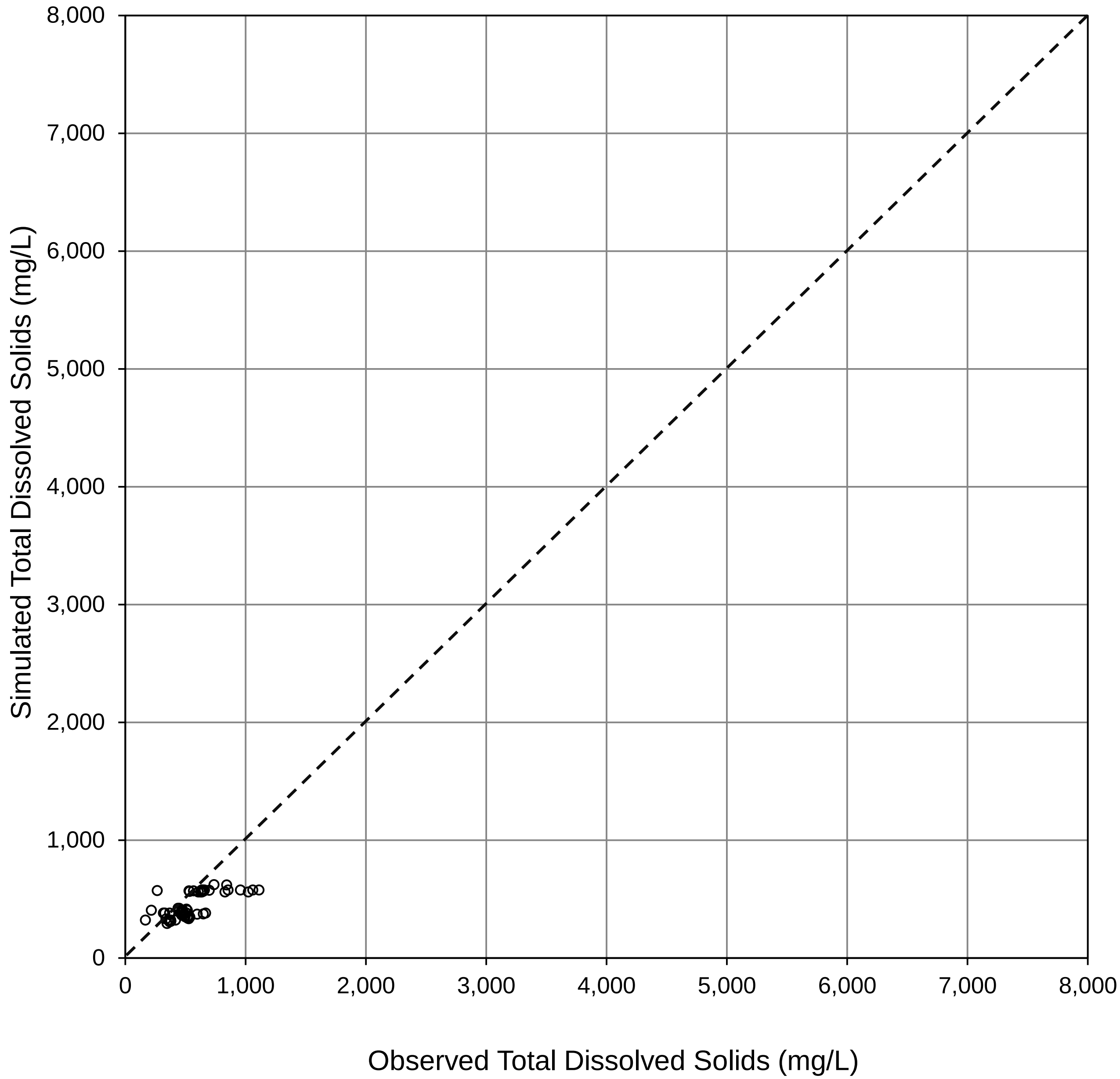

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Figure 5-32
Observed vs. Simulated TDS
Lower Aquifer

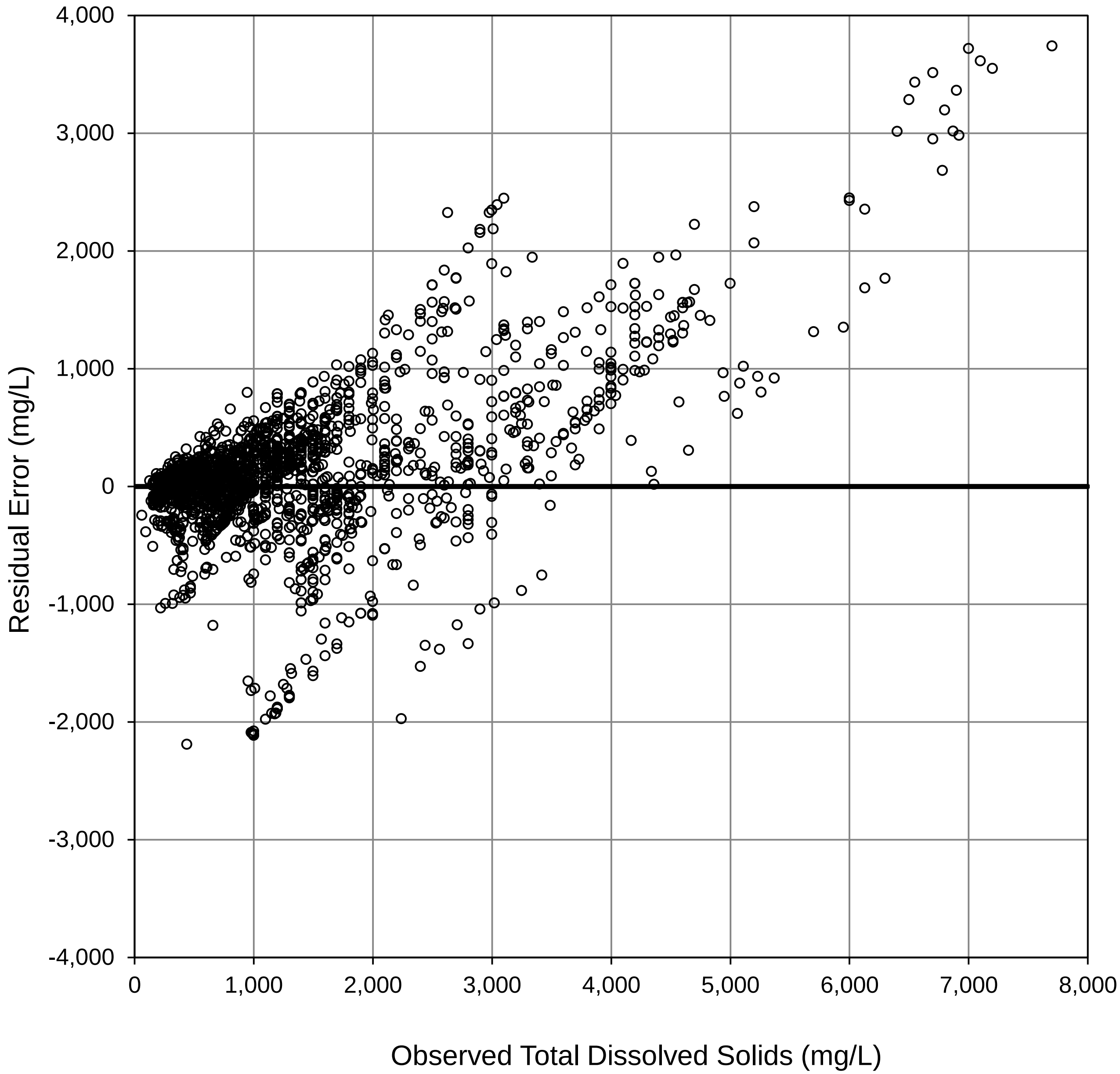

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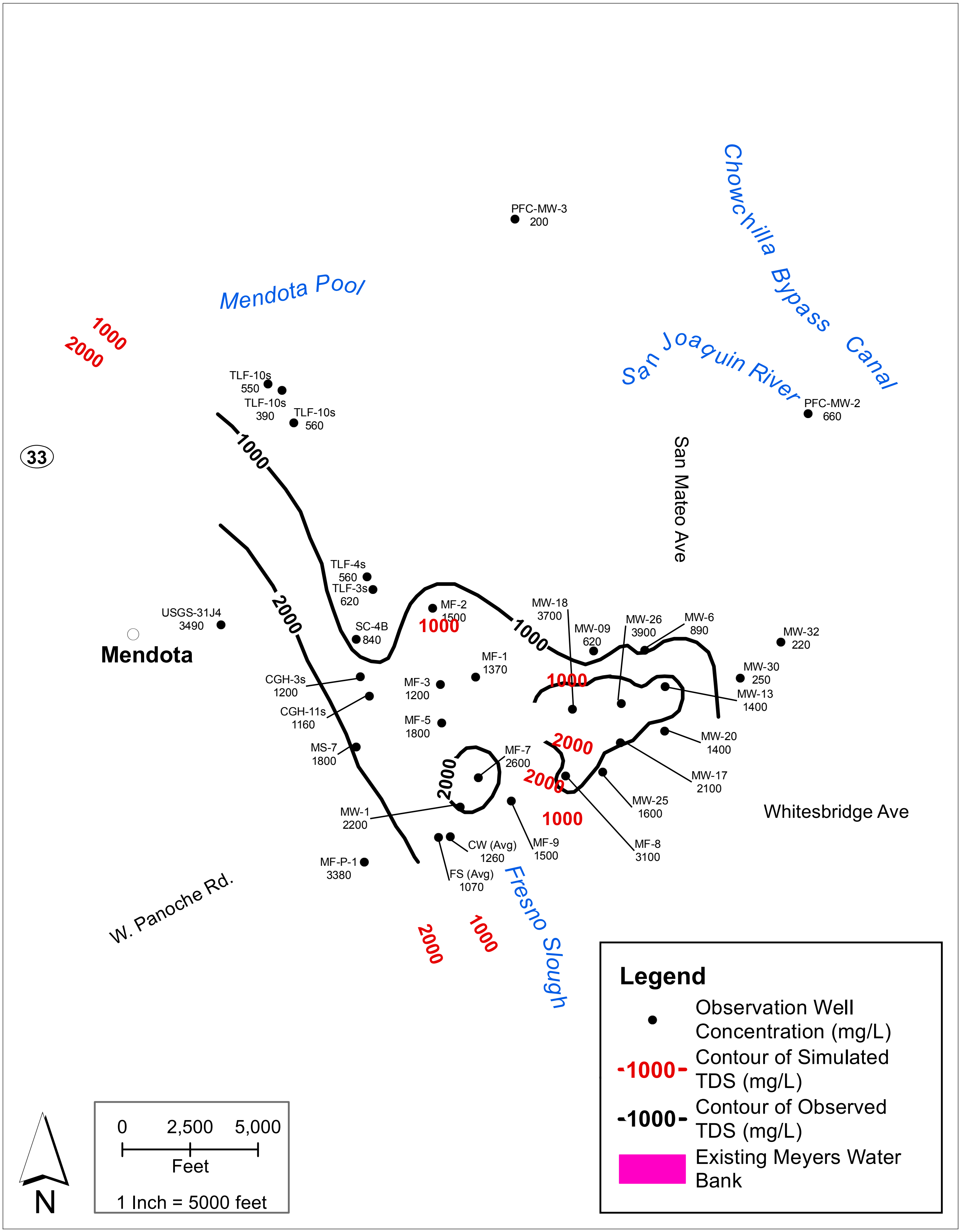
Figure 5-33
Observed TDS Concentration vs. Residual Error



Document Path: J:\Mendota\ModelingFigures_V3\MXDs\Section_5\Figure_5-34_ShallowTDS2001.mxd

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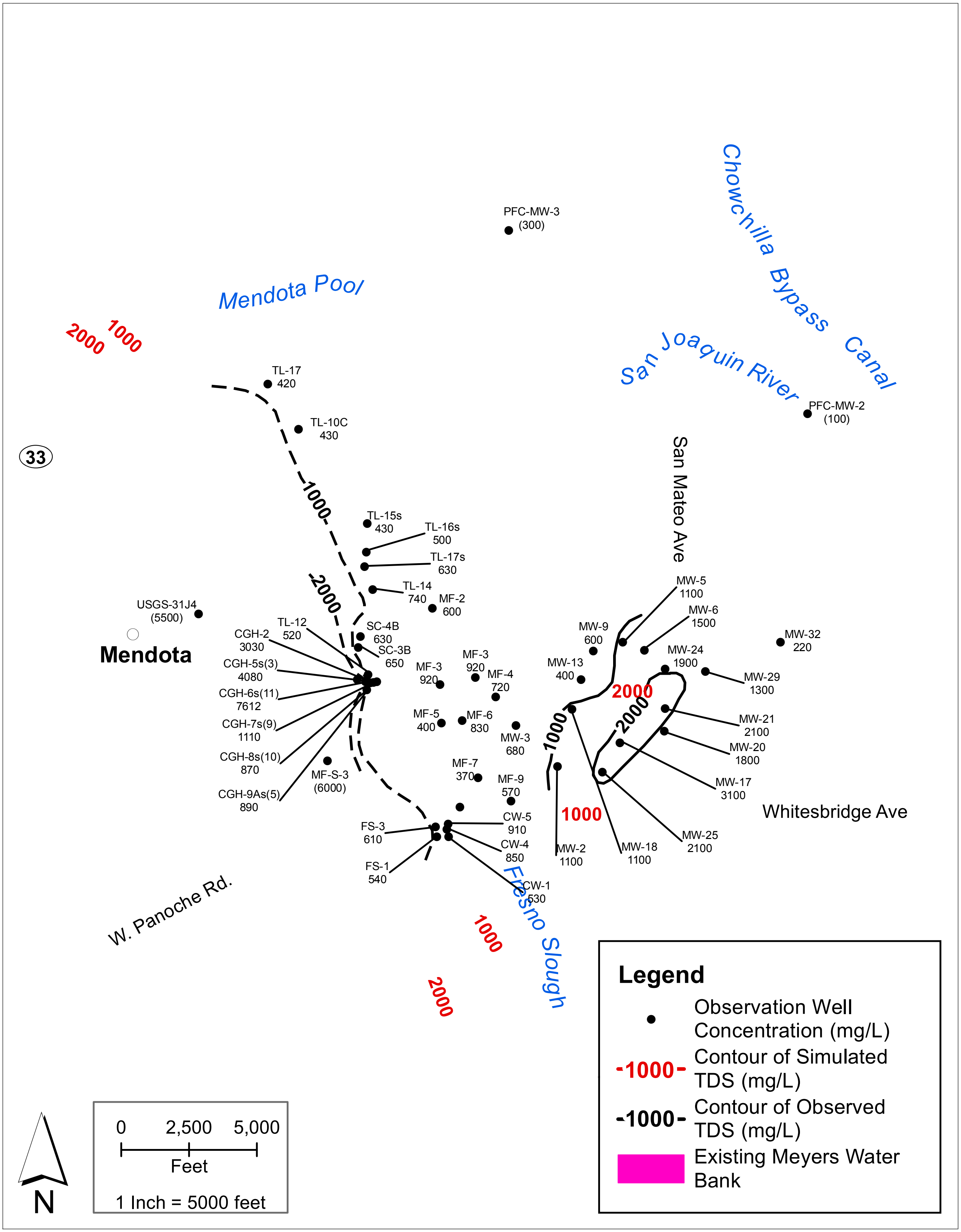
Figure 5-34
Contours of Equal Simulated and Observed TDS
Shallow Zone, Summer 2001



Document Path: J:\Mendota\ModelingFigures_V3\MXDs\Section_5\Figure_5-35_ShallowTDS2012.mxd

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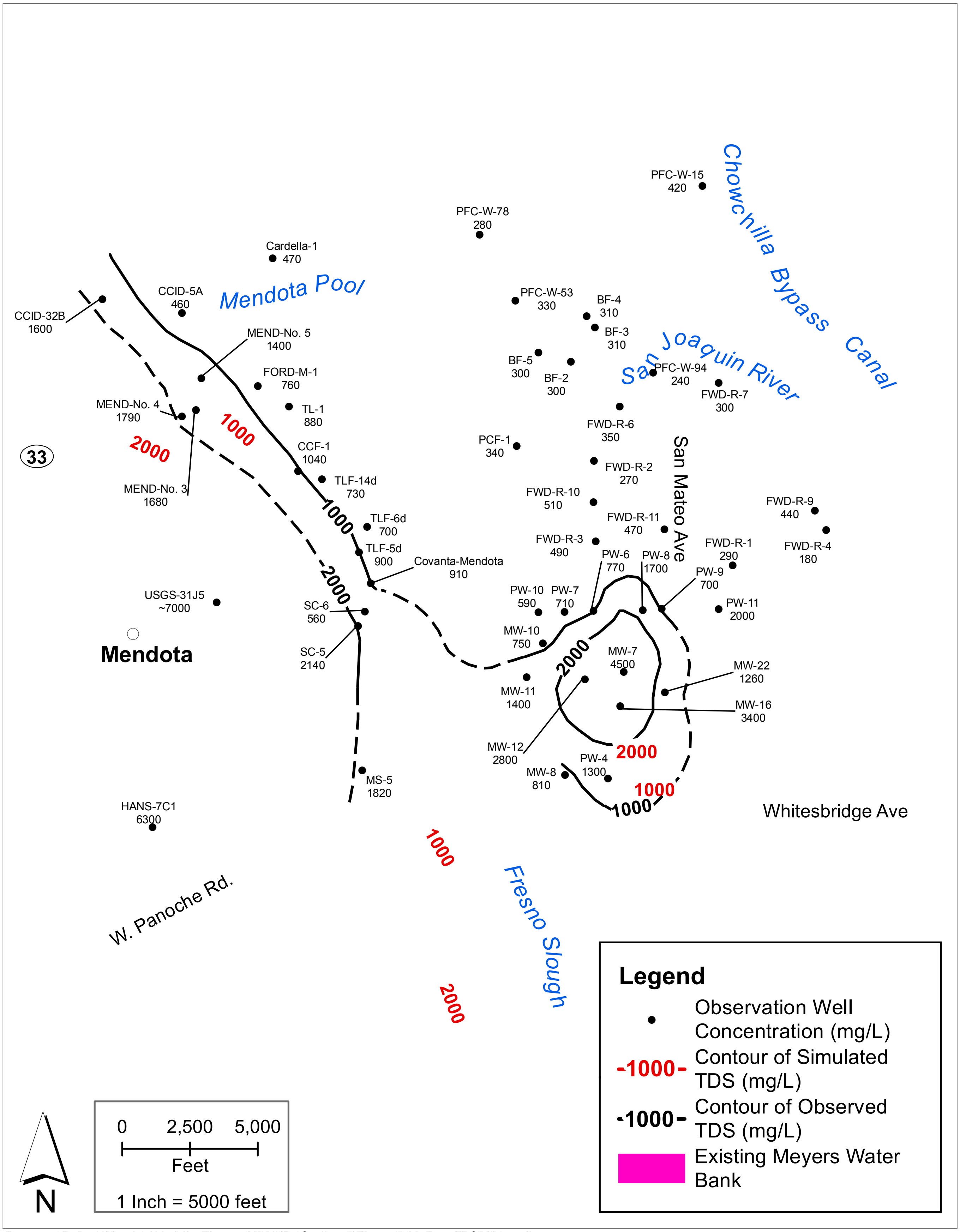
Figure 5-35
Contours of Equal Simulated and Observed TDS
Shallow Zone, Summer 2012



Document Path: J:\Mendota\ModelingFigures_V3\MXDs\Section_5\Figure_5-36_DeepTDS2001.mxd

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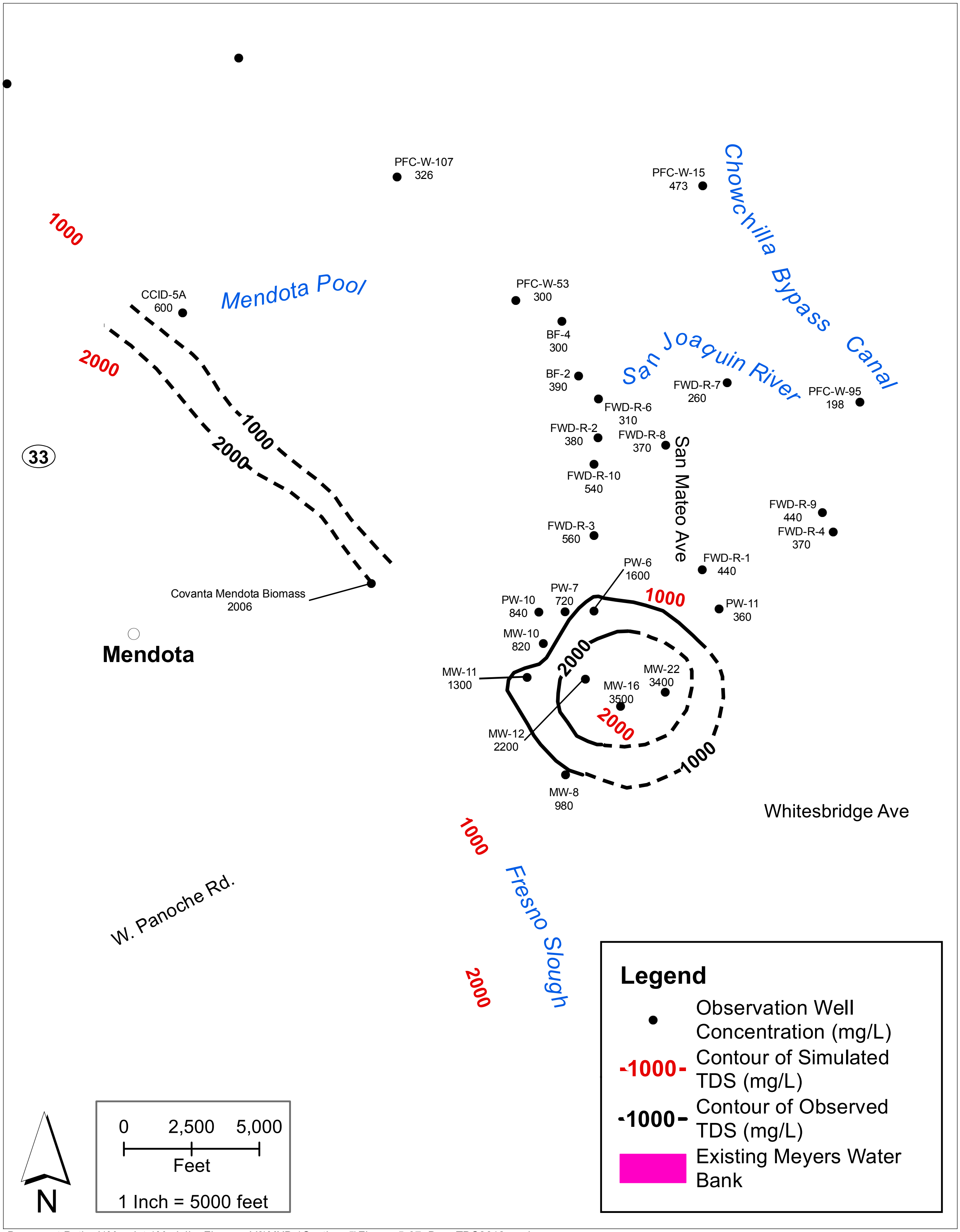
Figure 5-36
Contours of Equal Simulated and Observed TDS Deep Zone, 2001



Document Path: J:\Mendota\ModelingFigures_V3\MXDs\Section_5\Figure_5-37_DeepTDS2012.mxd

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Figure 5-37
Contours of Equal Simulated and Observed TDS
Deep Zone, 2012

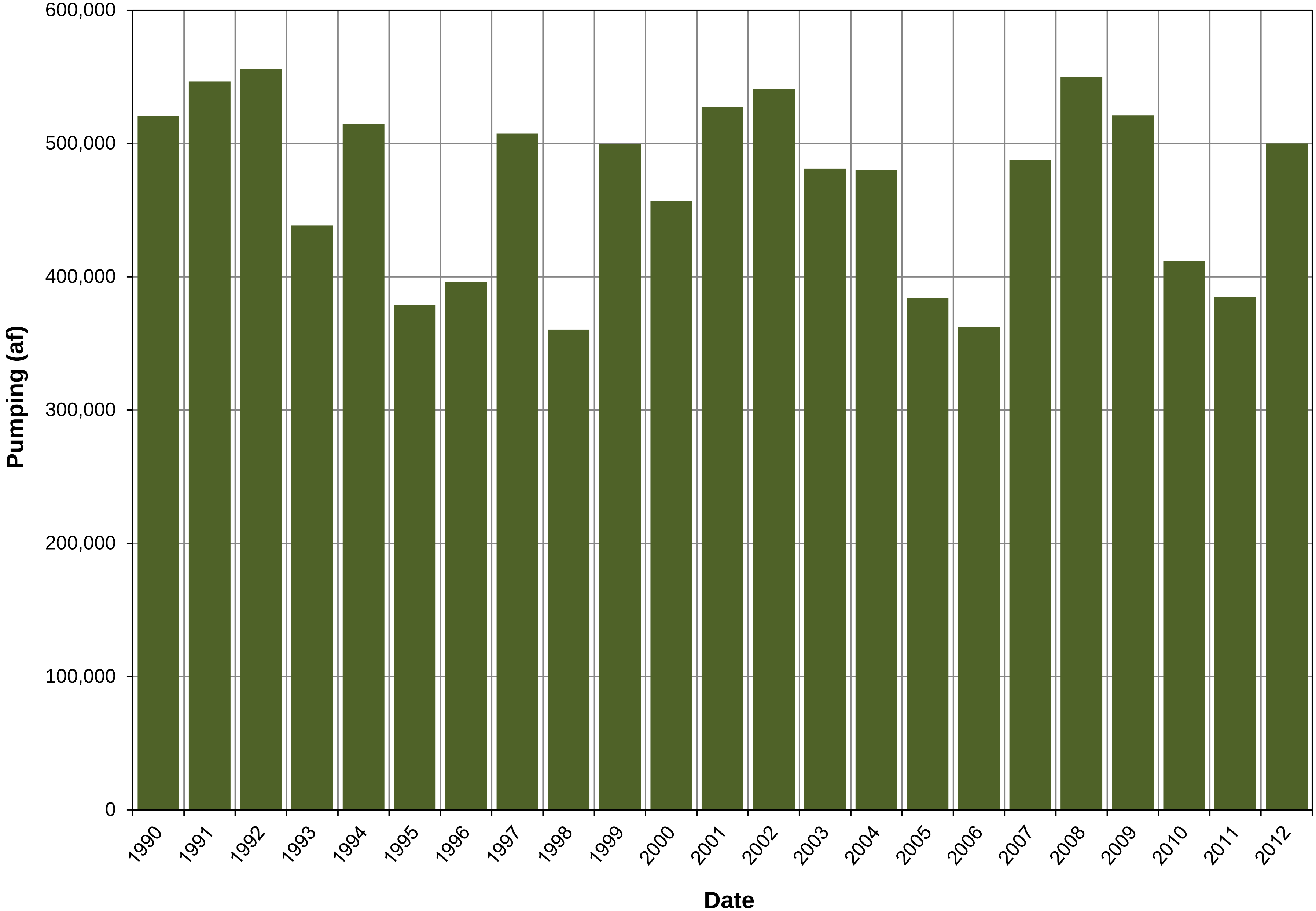

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Figure 5-38
Calibrated Model Simulated Groundwater Pumping

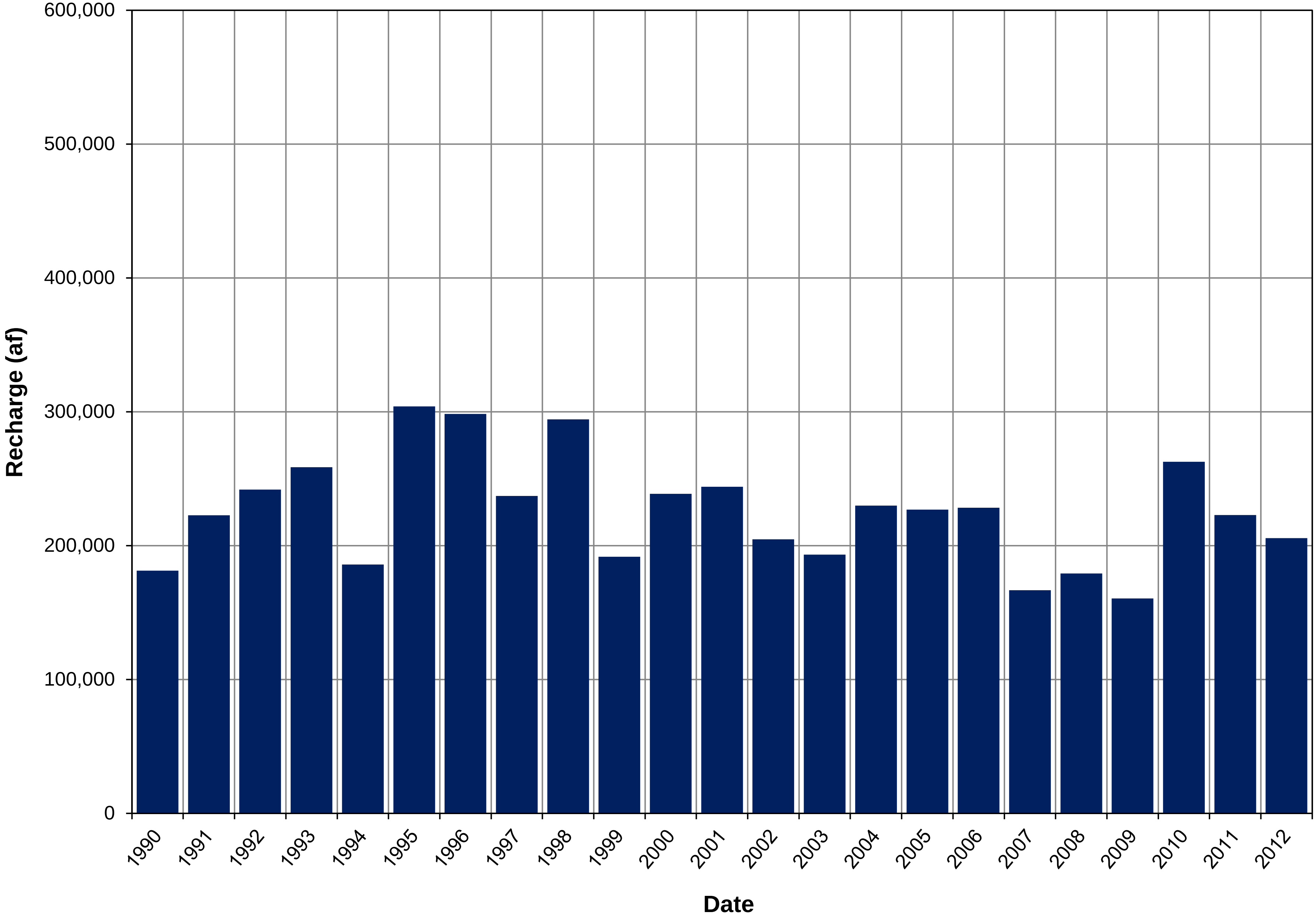

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Figure 5-39
Calibrated Model Simulated Groundwater Recharge

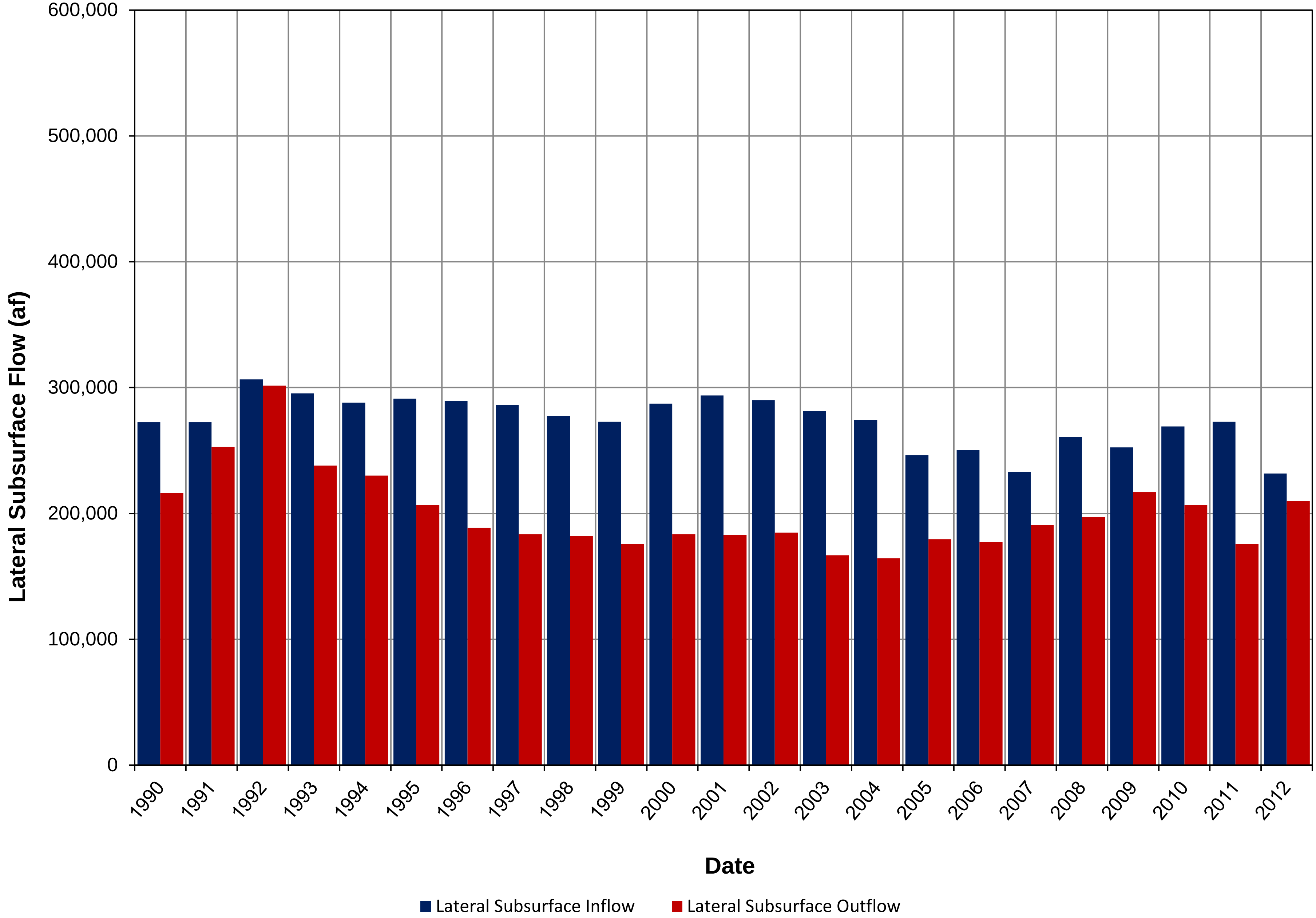

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Figure 5-40
Calibrated Model Simulated General Head Boundary Flux

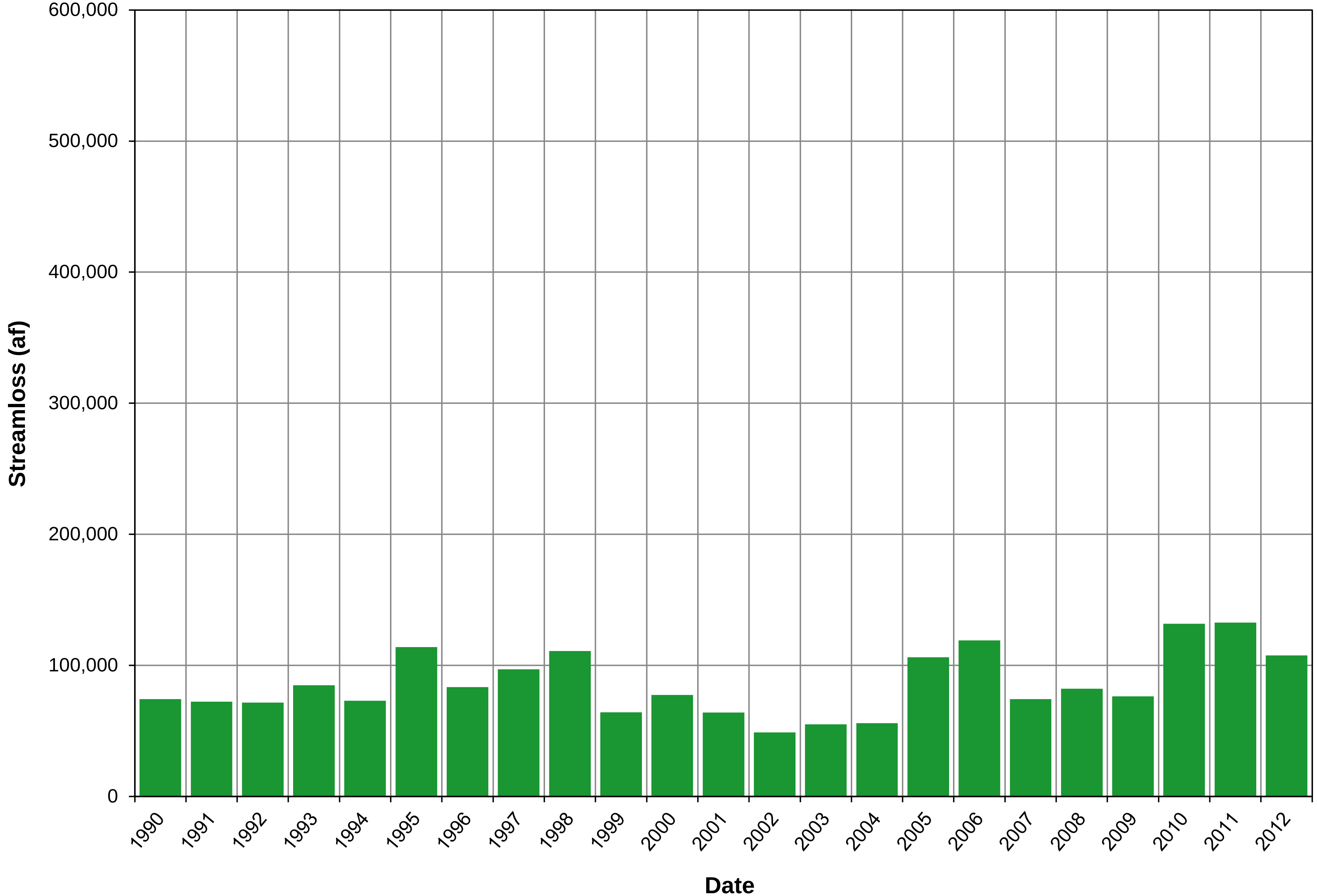

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Figure 5-41
Calibrated Model Simulated Net Streamloss

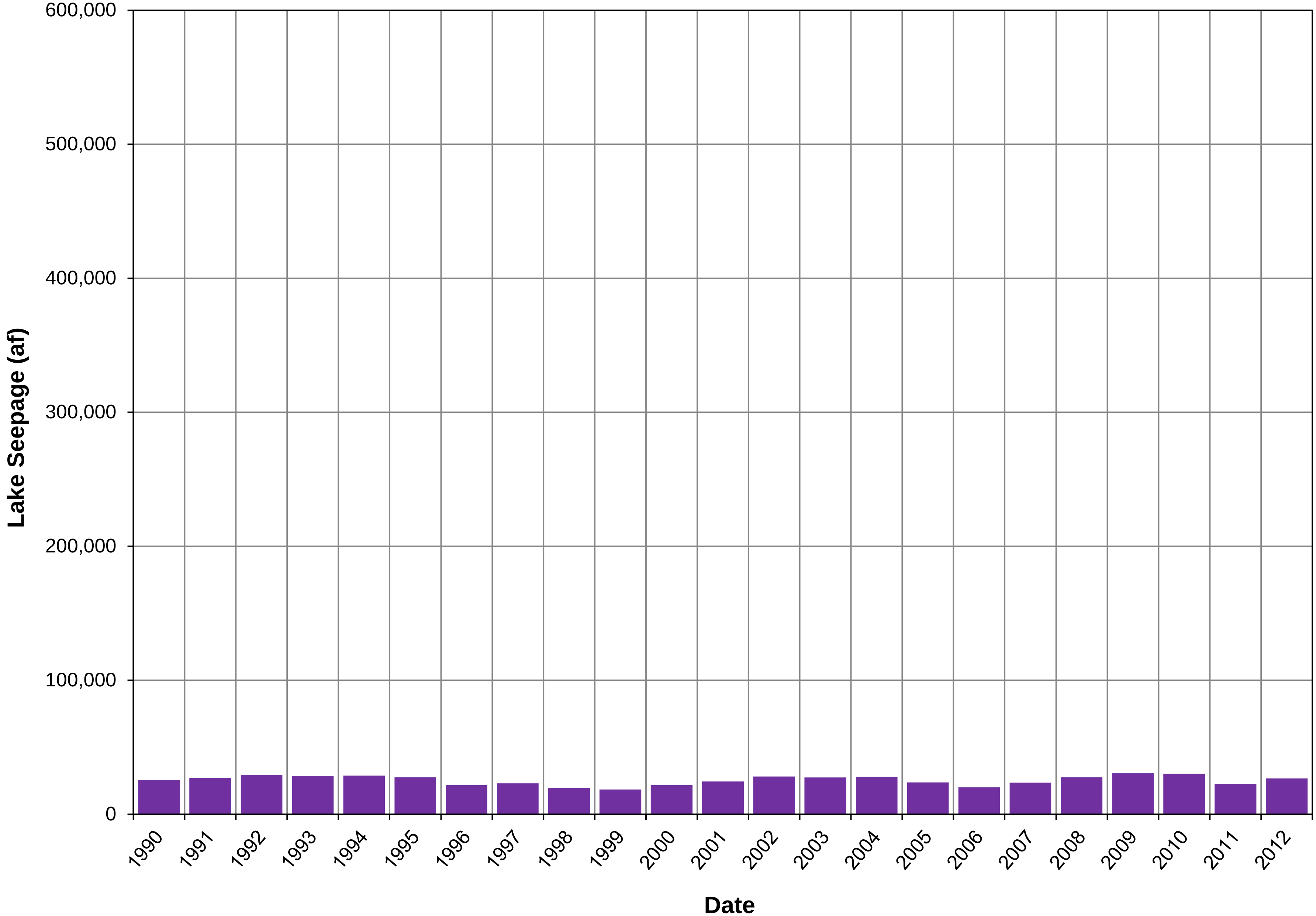

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Figure 5-42
Calibrated Model Simulated Net Lake Seepage

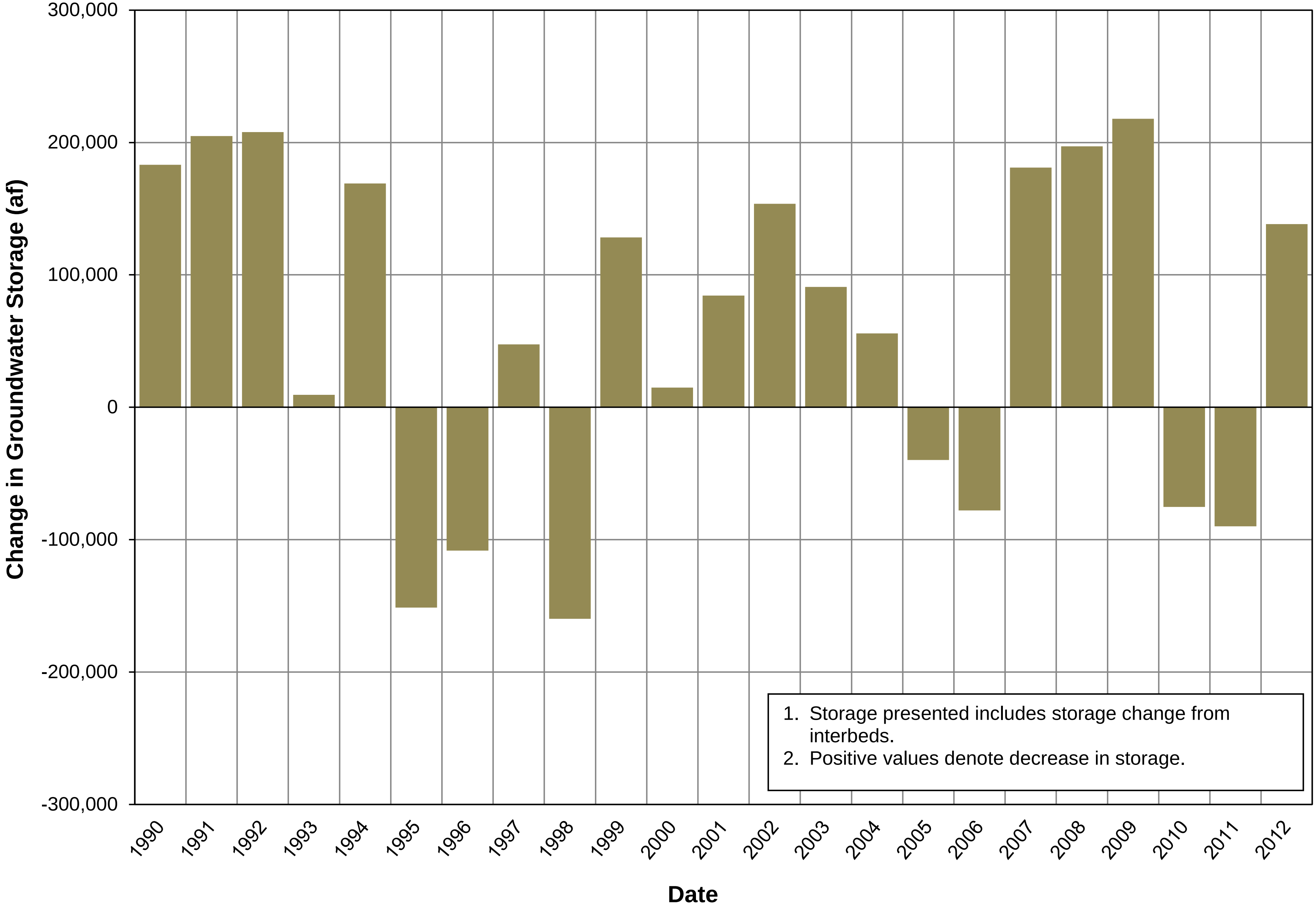

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Figure 5-43
Calibrated Model Simulated Change in Groundwater Storage

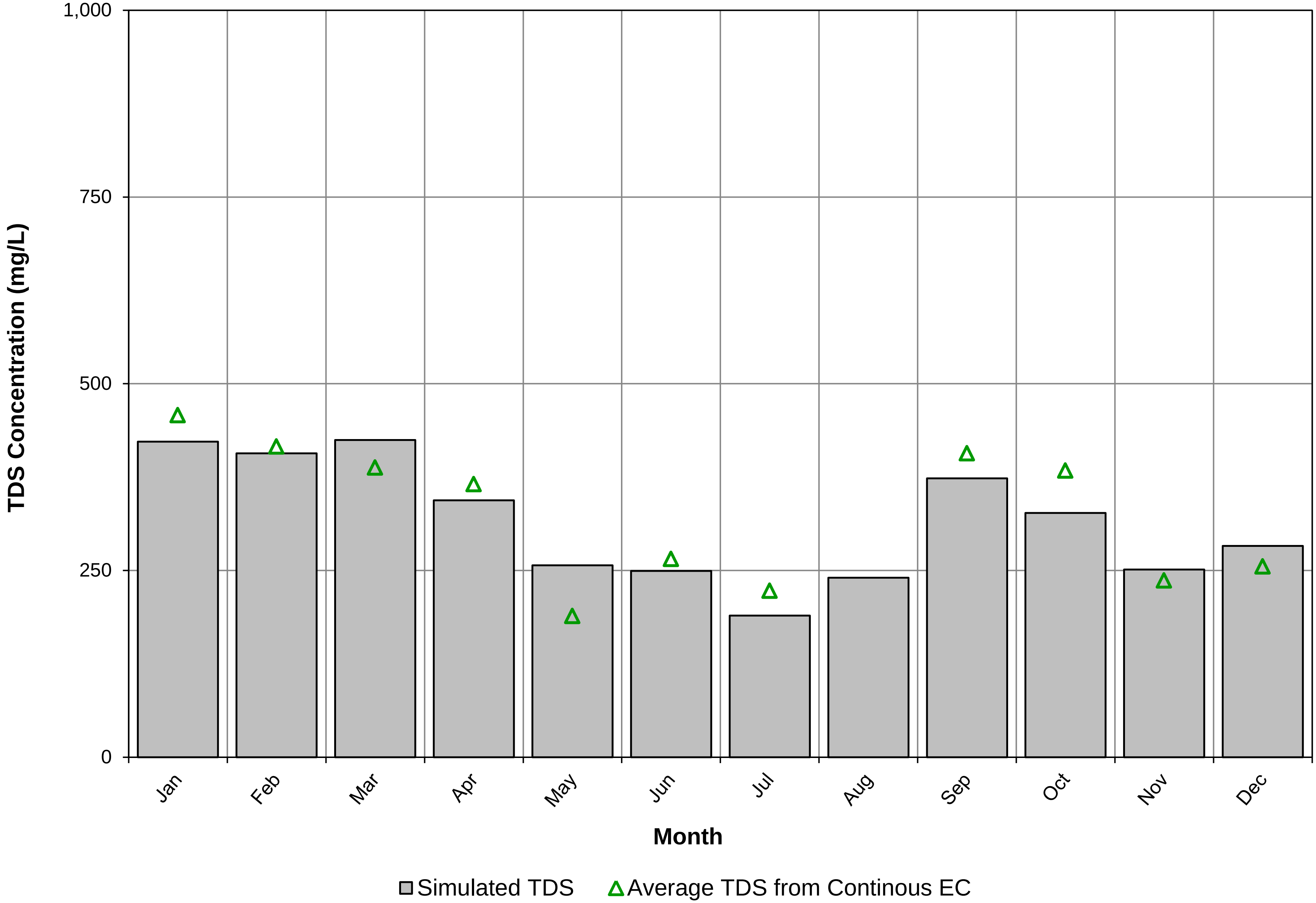

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Figure 5-44
Observed and Simulated TDS at the Mendota Dam - 2012

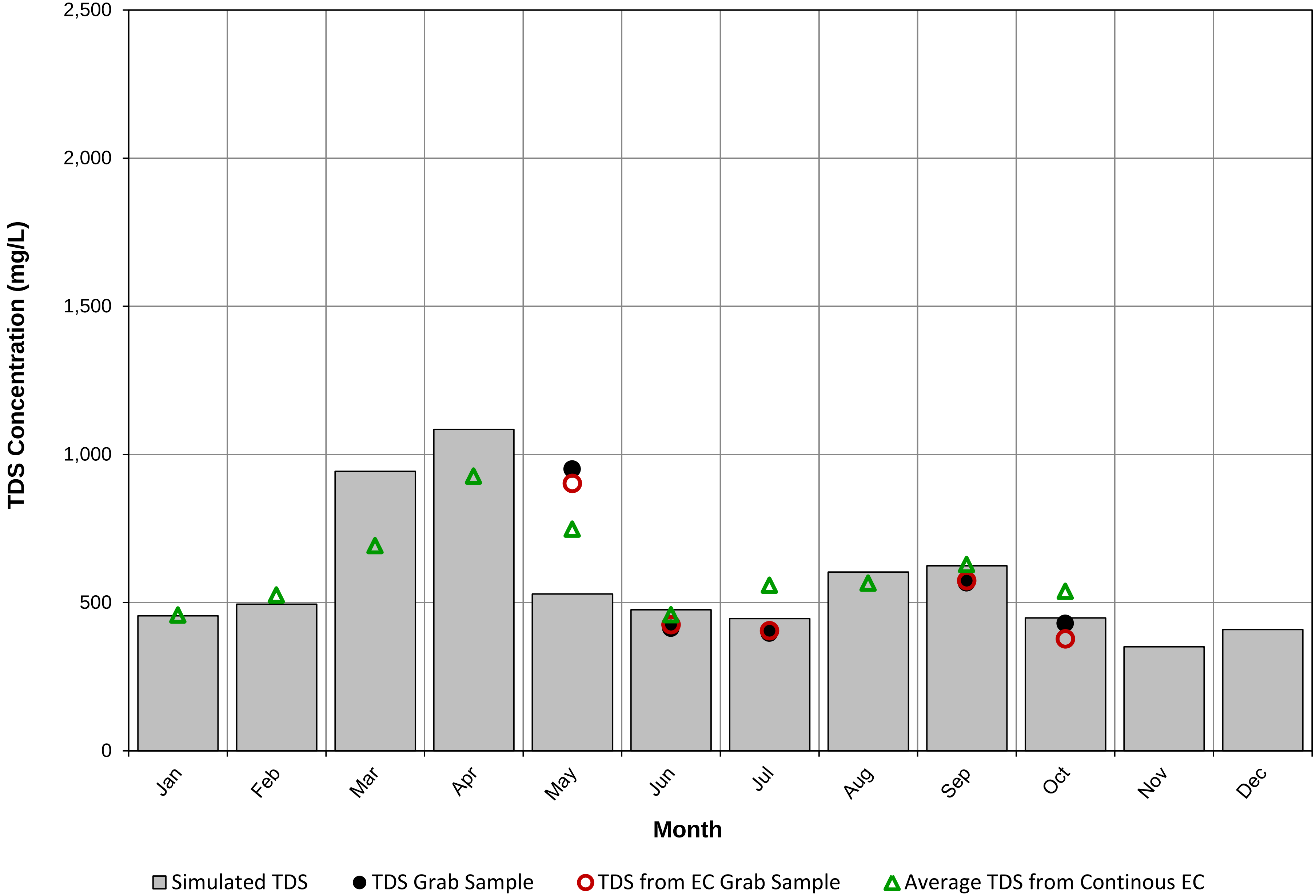

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Figure 5-45
Observed and Simulated TDS at the Mendota Wildlife Area – 2012

6 PREDICTIVE SCENARIOS

The numerical flow and solute transport models were used to evaluate the influence of the Project alternatives on water levels, salinity, and compaction within the PSA and other areas of interest within the model domain. Predictive model scenarios were developed based on the methodology and results obtained from the calibrated groundwater flow and solute transport models.

Predictive scenarios were developed based on the proposed Project design constraints and summarized in **Table 6-1**. These include:

- **No Action Alternative 1A:** No pumping for groundwater exchange, but an increase in groundwater pumping for overlying MPG adjacent use,
- **No-Action Alternative 1B:** No pumping for groundwater exchange, but an increase in groundwater pumping for overlying MPG adjacent use and increased groundwater utilization in MPG lands located outside the model domain in WWD,
- **Proposed Action:** Pumping for groundwater exchange in conjunction with utilization of existing groundwater recharge facilities in New Columbia Ranch and construction and utilization of a groundwater recharge canal west of the Fresno Slough,
- **Alternative 2:** Pumping for groundwater exchange in conjunction with utilization of existing groundwater recharge facilities in New Columbia Ranch, and expanded groundwater recharge facilities west of the Fresno Slough.

In the No-Action Alternative 1A model run, it is assumed that in the absence of an exchange program, MPG members would maximize the utilization of their overlying water rights on land owned in the vicinity of the Pool. The expanded utilization will result in an increase in groundwater pumping over existing levels for irrigation. With No-Action Alternative 1B, expanded utilization of adjacent lands would occur in conjunction with increases in groundwater pumping in WWD to make up for the loss of exchanged water. It is presumed that the impact of the latter constraint would be largely observed within WWD and less directly influence results within the model domain. These impacts were not explicitly evaluated through numerical modeling since the model does not encompass the area in WWD affected by increased pumping. Instead, impacts in WWD were assessed through a more qualitative analysis of water levels to estimate the influence the increased pumping would have on groundwater levels and potential subsidence in WWD. Impacts from both the No-Action Alternative 1A and No Action Alternative 1B are assumed to be the same within the model domain. Consequently, these scenarios are discussed jointly as No Action with respect to the numerical modeling inputs and results reported herein.

These scenarios were simulated under two different sets of background conditions. The first involved existing land and water use conditions while the second incorporated future cumulative effects (those planned to occur within the Project's time frame of 20 years). The existing and Cumulative Impacts conditions that are incorporated in each scenario utilize well construction features for MPG wells that were in existence in 2014 and do not include any modifications subsequently conducted or planned for four MPG wells that have a small portion of the perforated screen interval located below the Corcoran Clay. The description of the scenarios are summarized below in Sections 6.1 and 6.2.

6.1 Existing Conditions

The existing background conditions incorporate the most recent land use maps used in the calibrated model and other conditions described below.

6.1.1 Simulation Period

The simulation period selected for modeling spans a 22-year period that includes the proposed 20-year duration of the Project. The initial two years of the simulation period represent the 2013 and 2014 dry period which allowed the predictive scenario model inputs sufficient time to equilibrate to hydrologic conditions. The next twenty year period (Year 1 through Year 20) was utilized for analysis of predictive scenario results described in Section 7. Initial conditions for the scenarios utilized boundary conditions from the end of the model calibration period and assumed they would be similar to the beginning of the predictive scenario simulation period.

6.1.2 Precipitation and Evapotranspiration

Variations in hydrologic conditions were simulated by repeating the hydrology in the calibrated model. The historical hydrology incorporates both wet and dry periods and the hydrology represents long term average conditions in the region. Climactic variables, such as reference evapotranspiration and precipitation, were assigned such that values used in given stress periods correspond to those used in the calibrated model.

6.1.3 Surface Water

Streamflow in the San Joaquin River specified at the eastern edge of the model domain accounted for the San Joaquin River Restoration Program Interim flows. The timing, occurrence, and magnitude of the Interim flows were based upon historical data. Streamflow was based on the hydrologic year and flow requirement guidelines for the Interim Flows regime on the San Joaquin River (SJRRP, 2013). Deliveries to irrigation canals were assumed to be a repeat of the sequence simulated in the calibrated model. Infiltration at NCR recharge ponds by WO was assigned based on availability of surface water determined from the hydrologic year type. Infiltration volumes assigned in NCR recharge ponds was determined from available flows in the SJR and reviewed by WO (**Table 6-2**).

Table 6-2: Recharge at MPG and NCR Recharge Facilities

Year	NCR Ponds - NCR Recharge (af)	NCR Ponds - MPG Recharge (af)	Terra Linda Canal Recharge (af)	River Ranch North Recharge (af)
-	513	0	0	0
-	0	0	0	0
1	500	0	0	0
2	2,200	0	0	0
3	2,000	0	0	0
4	5,000	3,374	755	3,626
5	3,000	3,374	604	2,360
6	3,000	6,748	453	2,101
7	19,000	5,546	605	2,900
8	3,000	0	0	0
9	3,000	0	0	0
10	2,000	0	0	0
11	2,000	0	0	0
12	2,500	0	0	0
13	2,000	0	0	0
14	4,000	0	402	2,802
15	6,000	0	603	2,802
16	2,500	0	0	0
17	2,700	0	0	0
18	2,300	0	0	0
19	2,200	0	101	466
20	19,000	0	604	2,797

6.1.4 General Head Boundaries

General head boundaries controlling lateral subsurface flow in and out of the model domain were assigned based on values used in the calibrated model. The groundwater elevations assigned to these boundaries were initialized using the last time-step of the calibrated model. Subsequent hydraulic head values were assigned to retain the upward or downward trends historically observed.

6.1.5 Land Use

The distribution of irrigated lands and crop type used to estimate irrigation demand represents the most current conditions in the calibrated model using the most recent crop survey data. The land use pattern and distribution was held constant throughout the simulation period.

In the No Action run, the land use was revised based on the assumption that the MPG will utilize land currently not in production adjacent to the Fresno Slough. In 2012, 5,050 out of 7,240 ac of MPG adjacent lands were in agricultural production (**Figure 6-1**). In the No Action run, it was assumed that approximately 90% (6,510 ac) of MPG lands will be actively farmed in either almonds or pistachios. The remaining 10% (about 730 ac) will remain fallow in the No Action scenario.

6.1.6 Non-MPG Pumpage

Unmetered groundwater pumpage and irrigation was calculated using a water budget model using methodology similar to that employed in the calibrated model. Precipitation, surface water deliveries, and reference ET values used in the calibrated model were assigned to corresponding years in the predictive scenarios. The non-MPG pumpage was adjusted annually depending on the hydrology and associated surface water deliveries for the hydrologic year type.

6.1.7 Meyers Water Bank

Meyers Water Bank operations were estimated based on existing operating capacity and did not incorporate the planned expansion of the Bank. Recharge and recovery operations were developed in consultation with Meyers Water Bank **(Table 6-3).**

6.2 Cumulative Impacts

Besides for the existing background conditions, the predictive scenarios were also simulated utilizing future or cumulative conditions anticipated to occur during the simulation period (**Table 6-1**). The background cumulative conditions utilized in this set of runs are described below.

6.2.1 Simulation Period

The simulation period selected for modeling spans a 22-year period that includes the proposed 20-year duration of the Project. The initial two years of the simulation period represent the 2013 and 2014 dry period which allowed the predictive scenario model inputs sufficient time to equilibrate to hydrologic conditions. The next twenty year period (Year 1 through Year 20) was utilized for analysis of predictive scenario results described in Section 7. Initial conditions for the scenarios utilized boundary conditions from the end of the model calibration period and assumed they would be similar to the beginning of the predictive scenario simulation period.

Table 6-3: Recharge and Extraction at the Meyers Water Bank

Year	Water Year	Existing Land Use[1]			Cumulative Impacts[2]		
		Meyers Recharge (af)	Meyers Extraction (af)	Total Banked (af)	Meyers Recharge (af)	Meyers Extraction (af)	Total Banked (af)
-	C	49	4,889	36,185	49	4,889	36,185
-	C	500	6,200	30,485	500	6,200	30,485
1	C	1,000	6,200	25,285	1,000	6,200	25,285
2	W	5,000	2,500	27,785	10,000	2,500	32,785
3	C	1,000	5,000	23,785	2,000	3,500	31,285

4	W	6,000	2,000	27,785	10,000	2,000	39,285
5	W	6,000	2,500	31,285	9,000	2,500	45,785
6	W	5,000	3,000	33,285	9,000	1,000	53,785
7	W	3,000	2,000	34,285	7,000	1,000	59,785
8	AN	2,500	2,000	34,785	3,000	3,000	59,785
9	AN	3,000	3,000	34,785	3,000	2,500	60,285
10	D	1,400	4,000	32,185	1,500	4,000	57,785
11	D	1,300	2,000	31,485	2,000	5,000	54,785
12	BN	3,000	2,000	32,485	5,000	2,000	57,785
13	D	3,000	6,000	29,485	2,000	5,000	54,785
14	W	6,000	3,000	32,485	5,000	2,000	57,785
15	W	4,000	2,000	34,485	4,000	2,000	59,785
16	C	2,000	2,000	34,485	2,000	4,000	57,785
17	C	2,000	2,500	33,985	2,000	5,000	54,785
18	BN	2,000	3,500	32,485	2,000	5,000	51,785
19	AN	4,000	4,000	32,485	5,000	3,000	53,785
20	W	4,000	2,000	34,485	7,000	1,500	59,285

1. Maximum banked not to exceed 35,000 af. Recharge applied to ponds 1, 2, 3 4, and 5.
2. Maximum banked not to exceed 60,000 af. Recharge applied to ponds 1, 2, 3, 3AE, 4A, 4B.
3. Recharge occurs evenly from September to May.

6.2.2 Precipitation and Evapotranspiration

Variations in hydrologic conditions were simulated by repeating the hydrology in the calibrated model. The historical hydrology incorporates both wet and dry periods and the hydrology represents long term average conditions in the region. Climactic variables, such as reference evapotranspiration and precipitation, were assigned such that values used in given stress periods correspond to those used in the calibrated model.

6.2.3 Surface Water

Flow in the SJR incorporated the restoration flow requirements outlined in the flow requirement guidelines (SJRRP, 2013). Based on the outlined constraints, assigned streamflow in the SJR under these Cumulative Conditions is generally higher than in the Existing conditions runs during low flows and generally lower during spring flows in wet years (**Figure 6-2**) due to differences in SJR flow regimes between the Existing Conditions and Cumulative Impacts. Wet year flood flows are routed through the model domain and subject to groundwater/surface water interaction. Deliveries to irrigation canals were assumed to be a repeat of the sequence simulated in the calibrated model. Infiltration at NCR recharge ponds by WO was assigned based on availability of surface water determined from the hydrologic year type. Infiltration volumes assigned in NCR recharge ponds was determined from available flows in the SJR and reviewed by Paramount Farming Company (PFC) (**Table 6-2**).

6.2.4 General Head Boundaries

General head boundaries controlling lateral subsurface flow in and out of the model domain were assigned based on values used in the calibrated model. The groundwater elevations assigned to these boundaries were initialized using the last time-step of the calibrated model. Subsequent hydraulic head values were assigned to retain the upward or downward trends historically observed.

6.2.5 Land Use

The distribution of irrigated lands and crop type used to estimate irrigation demand represents the most current conditions in the calibrated model using the most recent crop survey data. The land use pattern and distribution was held constant throughout the simulation period.

In the No Action run, the land use was revised based on the assumption that the MPG will utilize land currently not in production adjacent to the Fresno Slough. In 2012, 5,050 out of 7,240 ac of MPG adjacent lands were in agricultural production (**Figure 6-1**). In the No Action run, it was assumed that approximately 90% (6,510 ac) of MPG lands will be actively farmed in either almonds or pistachios. The remaining 10% (about 730 ac) will remain fallow in the No Action scenario.

Land use used to calculate recharge and unknown groundwater pumping in the Cumulative conditions accounted for potential land use changes that may occur in the future. These changes in land use were incorporated into the calibrated model's most recent land use distribution. These changes, described below, also resulted in revisions to water use.

- Land was taken out of agricultural production due to projected seepage impacts from the SJRRP (**Figure 6-3**).
- Land estimated to be impacted by the SJRRP have no recharge from irrigation or associated groundwater pumping. In the No-Action run in the Cumulative Conditions, approximately 1,080 ac of the 6,510 ac of farmed MPG land within FWD is predicted to be fallowed due to seepage from the San Joaquin River.
- Conversion of a portion (50%) of lands surveyed as cotton to tree nuts consistent with recent agricultural trends (**Figure 6-3**). Over these lands, crop water demands were updated to reported values for pistachios and almonds which influenced the amount of water applied for irrigation and percolation to groundwater.
- Land use in the eastern portion of the model domain was revised to incorporate the proposed Madera I.D. Water Supply Enhancement Project (USBR, 2011) which is a groundwater banking project (**Figure 6-3**). This banking project leaves 10 percent of the water that is banked as recharge, while recovering 90 percent of the banked water. On an annual frequency, this banking project may store a maximum of 20,000 af and recover 18,000 af, leaving behind 2,000 af as net recharge. It was assumed for modeling purposes that the maximum storage and recovery amounts were conducted every year (**Figure 6-3**).

6.2.6 Non-MPG Pumpage

Unmetered groundwater pumpage and irrigation was calculated using a water budget model using methodology similar to that employed in the calibrated model. Precipitation, surface water deliveries, and reference ET values used in the calibrated model were assigned to corresponding years in the predictive scenarios. The non-MPG pumpage was adjusted annually depending on the hydrology and associated surface water deliveries for the hydrologic year type.

6.2.7 Meyers Water Bank

Meyers Water Bank operations were estimated based on planned expansion of the Bank's operating capacity to 60,000 af. Based on historical operations, the Bank is expected to focus on recharge operations in the early years of the simulation to maximize the Bank's capacity. Once capacity is reached, recharge operations will only occur only after recovery operations reduce the Bank's capacity. Recharge and recovery operations were developed in consultation with Meyers Water Bank **(Table 6-3).** Additional information on Bank operations are outlined in the *Amendment to the Meyers Groundwater Banking Exchange Agreement* (2012). The extraction capacity of the Meyers Water Bank was increased to 10,526 afy along with expanded pond recharge capacity (**Table 6-3**).

6.3 Predictive Scenarios

6.3.1 No Action –Existing Conditions

The No Action scenario utilizing existing conditions simulated no MPG pumping for transfer purposes and an expansion of groundwater pumping for adjacent and overlying use. The pumping for adjacent and overlying use was estimated to average 33,395 afy. As mentioned previously, this is the result of an expected increase in the utilization of land in the vicinity of the Pool that is currently not in production (**Table 6-4**).

6.3.2 Proposed Action – Existing Conditions

The Proposed Action scenario under Existing Conditions pumps groundwater for exchange and for adjacent and overlying use. This pumping program was derived from project design objectives and existing surface water quality constraints at the MWA. In this scenario, groundwater discharged into the Pool for exchange totals 26,316 af annually in 16 of the 20 years of the Proposed Project exchange program (**Table 6-5**). In the remaining 4 years, which were the wettest years in the simulation period, no pumping for exchange was assigned. This approach was selected rather than assigning an average annual exchange pumping value in order to produce a more conservative analysis of project impacts on groundwater conditions both on an annual and longer term basis. The monthly and well-by-well distribution of exchange pumping was assigned such that water quality constraints in the MWA were met. Consideration of exchange shares among MPG members was not accounted for in the Proposed Action in order to maximize the amount of pumping for exchange.

Adjacent pumping in the Proposed Action totals 14,000 af in every year of the proposed exchange pumping program (**Table 6-6**)**.** Subsequent changes to the Project Description resulted in a reduction in

Adjacent pumping to 12,000 afy, however, the modeling analysis was already completed with the 14,000 afy value. The simulation of 12,000 afy of adjacent pumping rather than 14,000 afy will likely result in less impacts on groundwater and surface water resources compared to the model scenarios simulating 14,000 afy of groundwater pumping for adjacent use. Therefore, the scenarios were not rerun and the impacts presented herein should be considered greater (more conservative) than what would occur with adjacent use pumping of 12,000 afy.

In addition to the differences in transfer and adjacent pumping from the No Action scenario, the Proposed Action also includes an artificial recharge project. In the Proposed Action scenario, the artificial recharge encompasses utilizing the NCR recharge ponds to a greater degree than in the No Action run and also includes a recharge canal facility west of the Pool (**Figure 6-3**). There is available recharge pond capacity at NCR that is utilized by the MPG (**Table 6-2**). Use of the NCR recharge ponds by the MPG occurs when there is available water from Kings River flood flows and when there is not conflicting use by WO. It was determined that available water from flood flows would occur in four years out of the twenty-year Project period. The amount of recharged groundwater at these ponds resulting from the Proposed Action ranges from approximately 3,400 to 6,850 af (**Table 6-2**).

The Proposed Action includes the construction and operation of a recharge canal facility west of the Pool intended to help address concerns related to the migration of the saline front (**Figure 6-3**). Infiltration rates were estimated from infiltration rates at the Meyers Water Bank, NCR recharge ponds, and evaluation of near surface soil and geologic conditions in the vicinity of the recharge canal. Water obtained for the recharge canal was based on the predicted availability of flood flows from the Kings River and was assigned in up to 8 years during the simulation period (**Table 6-2**). The amount of assigned recharge ranges from about 100 to 750 afy that flood flows are available.

6.3.3 Alternative 2 – Existing Conditions

The Alternative 2 scenario under Existing Conditions pumps groundwater for exchange and for adjacent and overlying use. This pumping program was derived from project design objectives and existing surface water quality constraints at the MWA. In this scenario, groundwater discharged into the Pool for exchange totals 26,316 af annually in 16 of the 20 years of the Proposed Project exchange program (**Table 6-5**), similar to the Proposed Action. In the remaining 4 years, which were the wettest years in the simulation period, no pumping for exchange was assigned. This approach was selected rather than assigning an average annual exchange pumping value in order to produce a more conservative analysis of project impacts on groundwater conditions both on an annual and longer term basis. The monthly and well-by-well distribution of exchange pumping was assigned such that water quality constraints in the MWA were met. Consideration of exchange shares among MPG members was not accounted for in the Alternative 2 Project in order to maximize the amount of pumping for exchange.

Adjacent pumping in the Alternative 2 Project totals 14,000 af in every year of the proposed exchange pumping program (**Table 6-6**) even though subsequent changes to the project description will only allow the MPG to pump a total of 12,000 afy for adjacent use.

In addition to the differences in transfer and adjacent pumping from the No Action scenario, Alternative 2 also includes an artificial recharge project which expands upon the one planned for the Proposed Action. In the Alternative 2 scenario, the artificial recharge includes the NCR recharge ponds and recharge canal to the same degree as the Proposed Action run and includes a recharge pond facility west of the Pool (**Figure 6-3**). The recharge pond facility (River Ranch North) will recharge water obtained from Kings River flood flows during the same years flood flows are available for the recharge canal. Recharge at this site is estimated to range from approximately 460 to 3,600 af annually (**Table 6-2**).

6.3.4 No Action – Cumulative Impacts

In the No Action – Cumulative Impacts Analysis scenario, there is no pumping for exchange purposes and pumping for adjacent use was reduced in the FWD area in relation to the No Action – Existing Conditions run to account for seepage impairment from the SJRRP restoration flows. The model does account for the planned widening of the SJR channel in the cumulative scenarios. The MODFLOW SFR package does not rigorously simulate surface water hydraulics, although it does fully account for the routing of flood flows through the domain within the existing channel geometry by increasing the stage if needed.

An estimated 1,080 ac of land in FWD is planned to be impacted by the seepage from the SJRRP. The resulting amount of assigned adjacent pumping in this No Action run for Cumulative Impacts Analysis averages 27,871 afy (**Table 6-7**).

6.3.5 Proposed Action – Cumulative Impacts

The Proposed Action scenario under Cumulative Impacts conditions pumps groundwater for exchange and for adjacent and overlying use. This pumping program was derived from project design objectives and existing surface water quality constraints at the MWA. In this scenario, groundwater discharged into the Pool for exchange totals 26,316 af annually in 16 of the 20 years of the Proposed Project exchange program (**Table 6-5**). In the remaining 4 years, which were the wettest years in the simulation period, no pumping for exchange was assigned. This approach was selected rather than assigning an average annual exchange pumping value in order to produce a more conservative analysis of project impacts on groundwater conditions both on an annual and longer-term basis. The monthly and well-by-well distribution of exchange pumping was assigned such that water quality constraints in the MWA were met. Consideration of exchange shares among MPG members was not accounted for in the Proposed Action in order to maximize the amount of pumping for exchange.

In the Proposed Action, adjacent pumping in FWD was reduced due to a 1,080 ac decrease in irrigated land which are taken out of production due to seepage impairment from the SJRRP (**Table 6-8, Figure 6-2**). Total adjacent pumping was reduced from 14,000 af to about 11,650 af annually.

The Proposed Action also includes an artificial recharge project. In the Proposed Action scenario, the artificial recharge encompasses utilizing the NCR recharge ponds to a greater degree than in the No Action run and includes the recharge canal facility west of the Pool (**Figure 6-3**). Use of the NCR recharge ponds by the MPG occurs when there is available water from Kings River flood flows and when there is not conflicting use by WO. It was determined that available water from flood flows would occur in four years out of the twenty-year Project period. The amount of recharged groundwater at these ponds resulting from the Proposed Action ranges from approximately 3,400 to 6,850 af (**Table 6-2).**

The Proposed Action also includes the operation of the recharge canal facility west of the Pool which is intended to help address concerns related to the migration of the saline front (**Figure 6-3**). Infiltration rates were estimated from infiltration rates at the Meyers Water Bank, NCR recharge ponds, and evaluation of near surface soil and geologic conditions in the vicinity of the recharge canal. Water obtained for the recharge canal was based on the predicted availability of flood flows from the Kings River and was assigned in up to 8 years during the simulation period (**Table 6-2**). The amount of assigned recharge ranges from about 100 to 750 afy that flood flows are available.

6.3.6 Alternative 2 – Cumulative Impacts

The Alternative 2 scenario under Cumulative Impacts Conditions pumps groundwater for exchange and for adjacent and overlying use. This pumping program was derived from project design objectives and existing surface water quality constraints at the MWA. In this scenario, groundwater discharged into the Pool for exchange totals 26,316 af annually in 16 of the 20 years of the Proposed Project exchange program (**Table 6-5**), similar to the Proposed Action. In the remaining 4 years, which were the wettest years in the simulation period, no pumping for exchange was assigned. This approach was selected rather than assigning an average annual exchange pumping value in order to produce a more conservative analysis of project impacts on groundwater conditions both on an annual and longer term basis. The monthly and well-by-well distribution of exchange pumping was assigned such that water quality constraints in the MWA were met. Consideration of exchange shares among MPG members was not accounted for in the Alternative 2 Project in order to maximize the amount of pumping for exchange.

In the Alternative 2 run, adjacent pumping in FWD was reduced due to a 1,080 ac decrease in irrigated land which are taken out of production due to seepage impairment from the SJRRP (**Table 6-8, Figure 6-2**). Total adjacent pumping was reduced from 14,000 af to about 11,650 af annually.

In addition to the differences in transfer and adjacent pumping from the No Action scenario, Alternative 2 also includes an artificial recharge project which expands upon the one planned for the Proposed Action. In the Alternative 2 scenario, the artificial recharge includes the NCR recharge ponds and recharge canal to the same degree as the Proposed Action run and also includes the construction and operation of the River Ranch North recharge pond facility west of the Pool (**Figure 6-3**). The River Ranch North facility will recharge water obtained from Kings River flood flows during the same years flood flows are available for the recharge canal. Recharge at this site ranges from approximately 460 to 3,600 af annually.

6.4 Solute Transport

The solute transport model was developed under similar assumptions as those used in developing the flow model predictive scenarios. At general head boundaries located at the lateral extent of the model, TDS concentrations were fixed at concentration specified at the end of 2012 in the calibrated model for all scenarios. Concentrations from the calibrated model within the DMC and San Joaquin River were repeated in all scenarios. Water entering the Pool which was not specified in the SFR Package was estimated as a volume weighted average of James Bypass flows and the amount of assigned exchange pumping. Recharge concentration over the majority of the model domain was assigned from the concentration used in the calibrated model. A concentration of 400 mg/L was assigned as a recharge concentration in all recharge ponds and facilities within each respective scenario. This assumption was based on the concentration of water in the Fresno Slough/James Bypass during flood flows where the water will likely be sourced. Although likely around 100 mg/L, we assumed a value of 400 mg/L to more conservatively estimate water quality benefits from the ponds.

All other transport properties were assigned from values used in the calibrated model.

6.5 Surface Water Modeling

6.5.1 Southern Branch of the Mendota Pool Mixing Model

The water balance model of the Pool/Fresno Slough was used to evaluate surface water quality at the MWA. Flow to the south in the Fresno Slough was calculated based on the monthly average of inflows and outflows from 2004 through 2013 in years where exchange pumping occurred (2007-2010; 2012, 2013). In the No Action, the Fresno Slough water budget includes about 11,000 af of groundwater delivered to the Traction Ranch based on the calculated irrigation demand at this site (**Figure 6-4**). In the No Action, net flow to the south totaled about 119,000 af per year. In the Proposed Action and Alternative 2, the Fresno Slough water budget includes about 7,000 af which is delivered to Traction Ranch. This amount is based largely on the 14,000 af pumped by MPG for adjacent use which is available for use at Traction Ranch (**Figure 6-5**). In the Proposed Action and Alternative 2, net flow to the south totaled about 114,000 afy. The same years (2007-2010; 2012, 2013) were used to develop an average TDS concentration for each month in the DMC at Check 21 (**Figure 6-6**). Groundwater pumping into the Fresno Slough from MPG was modified such that the total amount of pumping for groundwater exchange, 421,056 af, was divided evenly over the 20 year period such that 21,052 af are assigned annually (**Table 6-9**). The portion of this annual pumping represented by MPG pumping west of the Fresno Slough was simulated in this mixing model. Pumping for adjacent use was maintained at 14,000 af for the Existing Conditions and 11,648 in the Cumulative Impacts (**Table 6-10, Table 6-11**). Pumping from the Meyers Water Bank was assigned based on the extraction amounts in the Existing Condition and Cumulative Impacts amounts summarized in **Table 6-3**. Pumping from the City of Mendota was assigned based on the most recent estimates of city pumping. The TDS in MPG wells, Meyers Water

Bank wells, and City of Mendota Wells was assigned based on the average concentration simulated in the 20-year exchange period.

In addition to the run constructed using average values for the pool budget, a dry year scenario was developed to evaluate more conservative impacts of MPG pumping on TDS at the MWA. In this case, measured flows from 2009, where the total annual flow to the south was the smallest, were used in place of the average. As in the average year models, groundwater pumped into the Fresno Slough delivered to the south were 11,100 af for the No Action and 6,600 af in the Proposed Action and Alternative 2. Total demand in the south was 96,000 af in the No Action (**Figure 6-7**) and 92,000 af in the Proposed Action and Alternative 2 (**Figure 6-8**).

6.5.2 Northern Branch of the Mendota Pool Mixing Model

The water balance model of the Pool was used to evaluate surface water quality at the Mendota Dam. Surface water inflows and concentrations and outflows from the Pool were taken directly from the groundwater flow model over the 20-year exchange period. These include inflows into the Pool from the SJR and DMC and outflows at the Mendota Dam and from the Columbia, CCID, and Firebaugh canals. Groundwater pumping into the Pool from MPG was modified such that the total amount of pumping for groundwater exchange, 421,056 af, was divided evenly over the 20 year period such that 21,052 af are assigned annually (**Table 6-9**). The proportion of pumping associated with FWD was input into the northern branch mixing model. The TDS in each well was assigned based on the average concentration simulated in the 20-year exchange period.

6.6 Climate Change

The effect of climate change was evaluated to assess whether projected changes in occurrence and magnitude of flows in the Kings River would influence MPG utilization of recharge facilities over the 20-year lifespan of the Project. Since MPG is depending on Kings River flood flows as one of the primary sources of water for recharge for their proposed groundwater recharge program, changes in the frequency of flood flows could significantly change the timing of water available for MPG utilization.

Based on the available literature, the influence of climate change focusing on the hydrology of the Kings River watershed (and in turn availability of flood flows) could not be determined. As a result, analysis focused on a 2011 study of the impacts of climate change on stream flow in drainages in the southern Sierra Nevada to infer what may also occur in the Kings River (Das et al., 2011A; Das et al., 2011B). Climate change influences on flood flow frequencies were evaluated for existing conditions (1951-1999), near term conditions (2001-2049), and long term conditions (2050-2099). The study utilized three different climate change models to evaluate the changes in 3-day flood occurrences in the Southern Sierra Nevada. In two out of the three models there was little change (less than 0.3 flood events) in flood occurrences between the existing and near term conditions, while the third model had the annual average frequency of flood events change from 2.7 to 5.1 events. When evaluating the change from existing conditions to long term conditions, two out of the three models showed little change in average annual frequency of flooding while the third model showed a change from 2.7 to 4.0 flood events. Since both comparisons of changes in flood occurrences between existing conditions to either short or long term conditions yielded little change in anticipated flood occurrences in the Southern Sierra Nevada, it was determined that the frequency of available water from Kings River flood flows to the MPG recharge facilities did not need to be adjusted for the analysis of Project impacts.

Scenario	Land Use Overlay	San Joaquin River Stream Flow[1]	Exhange Pumping (af)	Adjacent Pumping (af)[2]	MPG Recharge Facilities	Non-MPG Recharge Facilities[3]
No Action	Existing (2012) Expanded MPG Adjacent	1990 - 2011	0	33,395	None	WO Recharge at NCR Meyers WB
Proposed Action	Existing (2012)	1990 - 2011	26,316	14,000	Terra Linda Canal MPG Recharge at NCR	WO Recharge at NCR Meyers WB
Alternative 2	Existing (2012)	1990 - 2011	26,316	14,000	Terra Linda Canal River Ranch North MPG Recharge at NCR	WO Recharge at NCR Meyers WB
No Action Cumulative Impacts	Fallowing Due to Seepage 50% of Cotton to Tree Nuts Expanded MPG Adjacent	1990 - 2011 Adjusted from SJRRP Flow Requirements	0	27,871	None	WO Recharge at NCR Expanded Meyers WB Madera Ranch
Proposed Action Cumulative Impacts	Fallowing Due to Seepage 50% of Cotton to Tree Nuts	1990 - 2011 Adjusted from SJRRP Flow Requirements	26,316	11,648	Terra Linda Canal MPG Recharge at NCR	WO Recharge at NCR Expanded Meyers WB Madera Ranch
Alternative 2 Cumulative Impacts	Fallowing Due to Seepage 50% of Cotton to Tree Nuts	1990 - 2011 Adjusted from SJRRP Flow Requirements	26,316	11,648	Terra Linda Canal River Ranch North MPG Recharge at NCR	WO Recharge at NCR Expanded Meyers WB Madera Ranch

1. Stream flow assigned to San Joaquin River at the eastern boundary of the model domain. Predictive scenario stream flow based on amount assigned in calibrated model. Within Cumulative Impacts, raw streamflow was adjusted based on constraints outlined in SJRRP flow requirements.
2. Adjacent pumping in Cumulative Impacts is reduced due to seepage impaired lands in Farmers Water District.
3. MPG recharge occurs where there is additional capacity within Wonderful Orchards ponds operated in NCR. Meyers Water Bank recharge ponds described in Table 6-2.

Well	Depth	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
		Pumping (af)												
Terra Linda Farms														
TLF-1s	S	0	0	0	53	96	93	96	96	93	0	0	0	**526**
TLF-2s	S	0	0	16	119	137	133	137	137	133	0	0	0	**812**
TLF-3s	S	0	0	0	35	104	106	110	110	106	0	0	0	**571**
TLF-4s	S	0	0	0	40	79	80	82	82	80	0	0	0	**442**
TLF-5d	D	0	0	0	0	0	19	18	0	0	0	0	0	**37**
TLF-6d	D	0	0	0	0	0	115	162	7	0	0	0	0	**284**
TLF-7s	S	2	7	27	40	41	40	41	41	40	37	11	8	**334**
TLF-8s	S	0	3	26	57	62	60	62	62	60	30	0	0	**420**
TLF-9s	S	0	4	37	73	75	73	75	75	73	51	0	0	**537**
TLF-10s	S	3	8	45	80	82	80	82	82	80	62	0	2	**605**
TLF-11As	S	6	25	67	93	96	93	96	96	93	86	35	19	**806**
TLF-11Cs[1]	S	0	0	0	64	96	93	96	96	93	0	0	0	**538**
TLF-12d	D	0	0	0	0	15	152	170	139	0	0	0	0	**476**
TLF-13s	S	30	49	98	119	123	119	123	123	119	117	70	33	**1,125**
TLF-14d	D	0	0	0	0	34	204	221	220	0	0	0	0	**679**
TLF-15s	S	9	19	104	166	171	166	171	171	166	140	17	19	**1,319**
TLF-16s	S	0	0	52	154	171	166	171	171	166	45	0	0	**1,096**
TLF-17s	S	0	0	3	133	171	166	171	171	166	0	0	0	**981**
TLF-18d	D	0	0	0	44	104	106	110	110	106	0	0	0	**580**
TLF-19s	S	0	0	0	0	1	109	131	53	0	0	0	0	**294**
TL-1[1]	D	0	0	0	22	104	106	110	110	106	0	0	0	**557**
TL-11[1]	S	0	0	0	20	27	27	27	27	27	0	0	0	**155**
TL-9[1]	D	0	0	0	0	0	40	52	0	0	0	0	0	**93**
Coelho/Coelho														
Conejo West[1]	D	0	0	0	0	200	402	415	415	120	0	0	0	**1,552**
Coelho/Coelho/Fordel														
CCF-1[1]	D	0	0	0	19	381	446	461	461	432	0	0	0	**2,199**
Silver Creek Packing														
SC-3B	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
SC-4B	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
SC-6	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
SC-7	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Coelho/Gardner/Hanson														
CGH-1s	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
CGH-2s & 3s	S	0	0	0	51	116	117	121	121	117	0	0	0	**642**
CGH-4s	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
CGH-5s	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
CGH-6s	S	0	0	0	0	0	32	43	1	0	0	0	0	**75**
CGH-7s	S	0	1	25	69	75	73	75	75	73	25	0	0	**491**
CGH-8s	S	10	23	73	106	110	106	110	110	106	94	28	17	**892**
CGH-9As/9Bs	S	0	0	0	0	0	2	2	0	0	0	0	0	**4**
CGH-10s	S	0	0	2	49	62	60	62	62	60	0	0	0	**355**
CGH-11s	S	0	0	0	0	6	54	61	55	0	0	0	0	**176**
CGH-12s	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
CGH-13d	D	0	0	0	4	81	95	98	98	92	0	0	0	**469**
CGH-4[1]	S	0	0	0	0	0	27	33	13	0	0	0	0	**74**
CGH-8[1]	S	0	0	0	0	45	101	105	105	24	0	0	0	**379**
Meyers Farming														
MS-3[1]	S	0	0	0	0	0	5	6	0	0	0	0	0	**11**
MS-4[1]	S	0	0	4	93	154	152	158	158	152	0	0	0	**871**
DW-1	D	0	0	0	4	107	159	164	164	100	0	0	0	**700**
MS-6	S	0	0	0	0	7	96	115	63	0	0	0	0	**280**
MS-7	S	9	20	77	130	137	133	137	137	133	97	23	14	**1,046**
Casaca Vineyards														
FS-1	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
FS-3	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
FS-5	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
FS-6	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
FS-7	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Daddy's Pride Farming														
FS-4	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
FS-9	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
FS-10	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Solo Mio														
FS-2	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
FS-8	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Coelho West														
CW-1	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
CW-2	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
CW-3	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
CW-4	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
CW-5	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Farmers Water District														
R-1	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
R-2	D	0	0	0	149	243	239	247	247	239	0	0	0	**1,363**
R-3	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
R-4	D	0	0	0	0	0	16	17	0	0	0	0	0	**32**
R-12	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
R-7	D	29	67	233	357	370	358	370	370	358	300	78	47	**2,936**
R-8	D	0	0	0	58	270	278	288	288	278	0	0	0	**1,460**
R-9	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
R-10	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
R-11	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
E-Loop-2	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
E-Loop-3	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
W Loop-1	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
W Loop-2	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
W Loop-3	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Baker Farming Co.														
BF-1	D	0	0	0	0	90	258	271	271	22	0	0	0	**913**
BF-2	D	0	0	0	0	0	43	57	0	0	0	0	0	**99**
BF-3	D	0	0	45	211	241	233	241	241	233	31	0	0	**1,476**
BF-4	D	0	0	0	1	154	219	226	226	183	0	0	0	**1,010**
BF-5	D	0	0	0	0	11	214	259	137	0	0	0	0	**622**
Panoche Creek Farms														
PCF-1	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Shallow Pumping		**69**	**160**	**657**	**1,742**	**2,246**	**2,558**	**2,699**	**2,492**	**2,156**	**783**	**184**	**112**	**15,858**
Deep Pumping		**29**	**67**	**277**	**868**	**2,407**	**3,701**	**3,958**	**3,504**	**2,270**	**331**	**78**	**47**	**17,537**
Total Pumping		**98**	**227**	**935**	**2,611**	**4,652**	**6,259**	**6,657**	**5,997**	**4,426**	**1,114**	**261**	**159**	**33,395**

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Table 6-4
Assigned MPG Adjacent Pumping
No Action

		Pumping (af)												
Well	**Depth**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Total**
Terra Linda Farms														
TLF-1s	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
TLF-2s	S	0	0	103	133	137	133	137	137	66	0	0	0	**845**
TLF-3s	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
TLF-4s	S	0	0	0	0	0	0	0	82	80	0	0	0	**162**
TLF-5d	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
TLF-6d	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
TLF-7s	S	0	0	41	40	41	40	41	41	40	0	0	0	**284**
TLF-8s	S	0	0	0	0	0	60	62	62	0	0	0	0	**183**
TLF-9s	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
TLF-10s	S	0	0	82	80	82	80	82	82	80	0	0	0	**567**
TLF-11As	S	0	0	0	93	96	93	96	96	93	96	0	0	**662**
TLF-11Cs[1]	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
TLF-12d	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
TLF-13s	S	0	0	123	119	123	119	123	123	119	0	0	0	**851**
TLF-14d	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
TLF-15s	S	0	0	86	166	171	166	171	171	166	0	0	0	**1,097**
TLF-16s	S	0	0	0	0	0	166	171	171	0	0	0	0	**508**
TLF-17s	S	0	0	128	166	171	166	171	171	166	0	0	0	**1,139**
TLF-18d	D	0	0	0	72	0	0	0	0	0	0	0	0	**72**
TLF-19s	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
TL-1[1]	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
TL-11[1]	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
TL-9[1]	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Coelho/Coelho														
Conejo West[1]	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Coelho/Coelho/Fordel										0				
CCF-1[1]	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Silver Creek Packing														
SC-3B	S	0	0	89	129	134	172	178	89	0	0	0	0	**791**
SC-4B	S	0	0	30	66	68	99	68	41	0	0	0	0	**374**
SC-6	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
SC-7	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Coelho/Gardner/Hanson														
CGH-1s	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
CGH-2s & 3s	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
CGH-4s	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
CGH-5s	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
CGH-6s	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
CGH-7s	S	0	0	0	73	75	73	75	75	36	0	0	0	**408**
CGH-8s	S	0	0	82	106	110	106	110	110	53	110	0	0	**786**
CGH-9As/9Bs	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
CGH-10s	S	0	0	0	0	0	60	62	62	0	0	0	0	**183**
CGH-11s	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
CGH-12s	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
CGH-13d	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
CGH-4[1]	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
CGH-8[1]	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Meyers Farming														
MS-3[1]	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
MS-4[1]	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
DW-1	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
MS-6	S	0	0	0	93	137	133	137	137	0	0	0	0	**636**
MS-7	S	0	0	137	133	137	133	137	137	0	0	0	0	**813**
Casaca Vineyards														
FS-1	S	0	0	51	49	51	49	51	51	49	22	0	0	**372**
FS-3	S	0	0	51	49	51	49	51	51	25	0	0	0	**325**
FS-5	S	0	0	51	49	51	49	51	51	49	0	0	0	**350**
FS-6	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
FS-7	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Daddy's Pride Farming														
FS-4	S	0	0	51	49	51	49	51	51	49	51	0	0	**401**
FS-9	S	0	0	0	0	0	49	51	51	0	0	0	0	**150**
FS-10	S	0	0	0	0	51	49	51	51	0	0	0	0	**201**
Solo Mio														
FS-2	S	0	0	51	49	51	49	51	51	49	51	0	0	**401**
FS-8	S	0	0	0	0	51	49	51	0	0	0	0	0	**150**
Coelho West														
CW-1	S	0	0	0	56	58	56	58	58	56	58	0	0	**402**
CW-2	S	0	0	0	56	58	56	58	58	56	47	0	0	**390**
CW-3	S	0	0	0	0	58	56	58	58	0	0	0	0	**231**
CW-4	S	0	0	0	56	58	56	58	58	0	0	0	0	**287**
CW-5	S	0	0	58	56	44	56	58	58	28	58	0	0	**417**
Farmers Water District														
R-1	D	0	0	151	146	102	0	0	0	0	0	0	0	**399**
R-2	D	0	0	123	175	247	0	0	0	239	247	0	0	**1,031**
R-3	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
R-4	D	0	0	205	199	205	0	0	0	199	205	0	0	**1,014**
R-12	D	0	0	192	186	192	0	0	0	186	192	0	0	**947**
R-7	D	0	0	0	0	0	0	0	0	358	370	0	0	**728**
R-8	D	0	0	288	278	0	0	0	0	0	0	0	0	**566**
R-9	D	0	0	233	225	233	0	0	0	162	116	0	0	**970**
R-10	D	0	0	205	199	205	0	0	0	0	0	0	0	**610**
R-11	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
E-Loop-2	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
E-Loop-3	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
W Loop-1	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
W Loop-2	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
W Loop-3	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Baker Farming Co.		0	0	0	0	0	0	0	0			0	0	**0**
BF-1	D	0	0	0	0	0	0	0	0	262	271	0	0	**534**
BF-2	D	0	0	86	82	113	0	0	0	109	113	0	0	**503**
BF-3	D	0	0	241	233	241	0	0	0	233	241	0	0	**1,190**
BF-4	D	0	0	170	164	226	0	0	0	219	226	0	0	**1,004**
BF-5	D	0	0	284	275	284	0	0	0	275	284	0	0	**1,402**
Panoche Creek Farms														
PCF-1	D	0	0	175	225	233	0	0	0	113	233	0	0	**979**
Shallow Pumping		**0**	**0**	**1,213**	**1,866**	**2,114**	**2,471**	**2,519**	**2,434**	**1,260**	**492**	**0**	**0**	**14,368**
Deep Pumping		**0**	**0**	**2,353**	**2,460**	**2,282**	**0**	**0**	**0**	**2,355**	**2,499**	**0**	**0**	**11,948**
Total Pumping		**0**	**0**	**3,566**	**4,326**	**4,396**	**2,471**	**2,519**	**2,434**	**3,615**	**2,990**	**0**	**0**	**26,316**

1. Well not included for exchange pumping. Added to meet adjacent pumping demand for No Action.

Well	Depth	Pumping (af)												
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Terra Linda Farms														
TLF-1s	S	0	0	96	93	96	93	96	96	93	96	0	0	**758**
TLF-2s	S	0	0	0	0	0	0	0	0	66	137	0	0	**203**
TLF-3s	S	0	0	110	106	110	106	110	110	106	110	0	0	**866**
TLF-4s	S	0	0	82	80	82	80	82	0	0	81	0	0	**487**
TLF-5d	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
TLF-6d	D	0	0	219	0	0	212	219	219	0	0	0	0	**870**
TLF-7s	S	41	0	0	0	0	0	0	0	0	41	0	0	**82**
TLF-8s	S	0	0	62	60	62	0	0	0	60	62	0	0	**304**
TLF-9s	S	0	0	75	73	75	73	75	75	73	75	0	0	**595**
TLF-10s	S	0	0	0	0	0	0	0	0	0	82	0	0	**82**
TLF-11As	S	96	0	96	0	0	0	0	0	0	0	0	0	**192**
TLF-11Cs[1]	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
TLF-12d	D	0	0	0	169	174	169	174	174	124	0	0	0	**983**
TLF-13s	S	123	0	0	0	0	0	0	0	0	123	0	0	**247**
TLF-14d	D	0	0	221	0	0	166	221	221	0	0	0	0	**830**
TLF-15s	S	143	0	0	0	0	0	0	0	0	171	0	0	**314**
TLF-16s	S	0	0	171	166	171	0	0	0	166	171	0	0	**845**
TLF-17s	S	0	0	0	0	0	0	0	0	0	171	0	0	**171**
TLF-18d	D	0	0	0	0	94	106	110	110	77	0	0	0	**496**
TLF-19s	S	S	0	0	96	93	96	93	96	96	93	96	0	**758**
TL-1[1]	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
TL-11[1]	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
TL-9[1]	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Coelho/Coelho														
Conejo West[1]	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Coelho/Coelho/Fordel														
CCF-1[1]	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Silver Creek Packing														
SC-3B	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
SC-4B	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
SC-6	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
SC-7	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Coelho/Gardner/Hanson														
CGH-1s	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
CGH-2s & 3s	S	0	0	30	105	121	117	121	121	98	0	0	0	**711**
CGH-4s	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
CGH-5s	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
CGH-6s	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
CGH-7s	S	0	0	0	0	0	0	0	0	36	36	0	0	**73**
CGH-8s	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
CGH-9As/9Bs	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
CGH-10s	S	0	0	15	30	46	0	0	0	0	0	0	0	**91**
CGH-11s	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
CGH-12s	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
CGH-13d	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
CGH-4[1]	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
CGH-8[1]	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Meyers Farming														
MS-3[1]	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
MS-4[1]	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
DW-1	D	0	0	50	75	150	120	100	100	139	50	0	0	**785**
MS-6	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
MS-7	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Casaca Vineyards														
FS-1	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
FS-3	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
FS-5	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
FS-6	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
FS-7	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Daddy's Pride Farming														
FS-4	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
FS-9	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
FS-10	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Solo Mio														
FS-2	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
FS-8	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Coelho West														
CW-1	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
CW-2	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
CW-3	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
CW-4	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
CW-5	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Farmers Water District														
R-1	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
R-2	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
R-3	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
R-4	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
R-12	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
R-7	D	0	0	129	226	370	193	0	0	0	0	0	0	**918**
R-8	D	0	0	0	0	115	278	288	288	278	144	0	0	**1,391**
R-9	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
R-10	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
R-11	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
E-Loop-2	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
E-Loop-3	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
W Loop-1	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
W Loop-2	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
W Loop-3	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Baker Farming Co.														
BF-1	D	0	0	122	131	163	159	176	176	0	0	0	0	**927**
BF-2	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
BF-3	D	18	0	0	0	0	0	0	0	0	0	0	0	**18**
BF-4	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
BF-5	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Panoche Creek Farms														
PCF-1	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Shallow Pumping		**403**	**0**	**737**	**807**	**856**	**564**	**576**	**497**	**794**	**1,450**	**96**	**0**	**6,781**
Deep Pumping		**18**	**0**	**742**	**600**	**1,066**	**1,403**	**1,289**	**1,289**	**618**	**194**	**0**	**0**	**7,219**
Total Pumping		**421**	**0**	**1,480**	**1,407**	**1,921**	**1,967**	**1,865**	**1,786**	**1,412**	**1,644**	**96**	**0**	**14,000**

1. Well not included for exchange pumping. Added to meet adjacent pumping demand for No Action.

Well	Depth	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
		Pumping (af)												
Terra Linda Farms														
TLF-1s	S	0	0	0	53	96	93	96	96	93	0	0	0	**526**
TLF-2s	S	0	0	16	119	137	133	137	137	133	0	0	0	**812**
TLF-3s	S	0	0	0	35	104	106	110	110	106	0	0	0	**571**
TLF-4s	S	0	0	0	40	79	80	82	82	80	0	0	0	**442**
TLF-5d	D	0	0	0	0	0	19	18	0	0	0	0	0	**37**
TLF-6d	D	0	0	0	0	0	115	162	7	0	0	0	0	**284**
TLF-7s	S	2	7	27	40	41	40	41	41	40	37	11	8	**334**
TLF-8s	S	0	3	26	57	62	60	62	62	60	30	0	0	**420**
TLF-9s	S	0	4	37	73	75	73	75	75	73	51	0	0	**537**
TLF-10s	S	3	8	45	80	82	80	82	82	80	62	0	2	**605**
TLF-11As	S	6	25	67	93	96	93	96	96	93	86	35	19	**806**
TLF-11Cs[1]	S	0	0	0	64	96	93	96	96	93	0	0	0	**538**
TLF-12d	D	0	0	0	0	15	152	170	139	0	0	0	0	**476**
TLF-13s	S	30	49	98	119	123	119	123	123	119	117	70	33	**1,125**
TLF-14d	D	0	0	0	0	34	204	221	220	0	0	0	0	**679**
TLF-15s	S	9	19	104	166	171	166	171	171	166	140	17	19	**1,319**
TLF-16s	S	0	0	52	154	171	166	171	171	166	45	0	0	**1,096**
TLF-17s	S	0	0	3	133	171	166	171	171	166	0	0	0	**981**
TLF-18d	D	0	0	0	44	104	106	110	110	106	0	0	0	**580**
TLF-19s	S	0	0	0	0	1	109	131	53	0	0	0	0	**294**
TL-1[1]	D	0	0	0	22	104	106	110	110	106	0	0	0	**557**
TL-11[1]	S	0	0	0	20	27	27	27	27	27	0	0	0	**155**
TL-9[1]	D	0	0	0	0	0	40	52	0	0	0	0	0	**93**
Coelho/Coelho														
Conejo West[1]	D	0	0	0	0	200	402	415	415	120	0	0	0	**1,552**
Coelho/Coelho/Fordel														
CCF-1[1]	D	0	0	0	19	381	446	461	461	432	0	0	0	**2,199**
Silver Creek Packing														
SC-3B	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
SC-4B	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
SC-6	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
SC-7	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Coelho/Gardner/Hanson														
CGH-1s	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
CGH-2s & 3s	S	0	0	0	51	116	117	121	121	117	0	0	0	**642**
CGH-4s	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
CGH-5s	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
CGH-6s	S	0	0	0	0	0	32	43	1	0	0	0	0	**75**
CGH-7s	S	0	1	25	69	75	73	75	75	73	25	0	0	**491**
CGH-8s	S	10	23	73	106	110	106	110	110	106	94	28	17	**892**
CGH-9As/9Bs	S	0	0	0	0	0	2	2	0	0	0	0	0	**4**
CGH-10s	S	0	0	2	49	62	60	62	62	60	0	0	0	**355**
CGH-11s	S	0	0	0	0	6	54	61	55	0	0	0	0	**176**
CGH-12s	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
CGH-13d	D	0	0	0	4	81	95	98	98	92	0	0	0	**469**
CGH-4[1]	S	0	0	0	0	0	27	33	13	0	0	0	0	**74**
CGH-8[1]	S	0	0	0	0	45	101	105	105	24	0	0	0	**379**
Meyers Farming														
MS-3[1]	S	0	0	0	0	0	5	6	0	0	0	0	0	**11**
MS-4[1]	S	0	0	4	93	154	152	158	158	152	0	0	0	**871**
DW-1	D	0	0	0	4	107	159	164	164	100	0	0	0	**700**
MS-6	S	0	0	0	0	7	96	115	63	0	0	0	0	**280**
MS-7	S	9	20	77	130	137	133	137	137	133	97	23	14	**1,046**
Casaca Vineyards														
FS-1	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
FS-3	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
FS-5	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
FS-6	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
FS-7	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Daddy's Pride Farming														
FS-4	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
FS-9	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
FS-10	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Solo Mio														
FS-2	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
FS-8	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Coelho West														
CW-1	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
CW-2	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
CW-3	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
CW-4	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
CW-5	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Farmers Water District														
R-1	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
R-2	D	0	0	0	0	43	208	234	177	8	0	0	0	**670**
R-3	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
R-4	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
R-12	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
R-7	D	13	30	123	312	369	358	370	370	358	146	34	21	**2,504**
R-8	D	0	0	0	0	0	24	29	0	0	0	0	0	**53**
R-9	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
R-10	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
R-11	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
E-Loop-2	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
E-Loop-3	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
W Loop-1	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
W Loop-2	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
W Loop-3	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Baker Farming Co.														
BF-1	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
BF-2	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
BF-3	D	0	0	0	31	199	233	241	241	216	0	0	0	**1,161**
BF-4	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
BF-5	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Panoche Creek Farms														
PCF-1	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Shallow Pumping		**69**	**160**	**657**	**1,742**	**2,246**	**2,558**	**2,699**	**2,492**	**2,156**	**783**	**184**	**112**	**15,858**
Deep Pumping		**13**	**30**	**123**	**436**	**1,637**	**2,666**	**2,857**	**2,512**	**1,538**	**146**	**34**	**21**	**12,014**
Total Pumping		**82**	**190**	**780**	**2,179**	**3,883**	**5,224**	**5,556**	**5,005**	**3,694**	**930**	**218**	**133**	**27,871**

1. Well not included for exchange pumping. Added to meet adjacent pumping demand for No Action.

Table 6-7
Assigned MPG Adjacent Pumping
No Action
Cumulative Impacts

Well	Depth	Pumping (af) Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Terra Linda Farms														
TLF-1s	S	0	0	96	93	96	93	96	96	93	96	0	0	**758**
TLF-2s	S	0	0	0	0	0	0	0	0	66	137	0	0	**203**
TLF-3s	S	0	0	110	106	110	106	110	110	106	110	0	0	**866**
TLF-4s	S	0	0	82	80	82	80	82	0	0	81	0	0	**487**
TLF-5d	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
TLF-6d	D	0	0	219	0	0	212	219	219	0	0	0	0	**870**
TLF-7s	S	41	0	0	0	0	0	0	0	0	41	0	0	**82**
TLF-8s	S	0	0	62	60	62	0	0	0	60	62	0	0	**304**
TLF-9s	S	0	0	75	73	75	73	75	75	73	75	0	0	**595**
TLF-10s	S	0	0	0	0	0	0	0	0	0	82	0	0	**82**
TLF-11As	S	96	0	96	0	0	0	0	0	0	0	0	0	**192**
TLF-11Cs[1]	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
TLF-12d	D	0	0	0	169	174	169	174	174	124	0	0	0	**983**
TLF-13s	S	123	0	0	0	0	0	0	0	0	123	0	0	**247**
TLF-14d	D	0	0	221	0	0	166	221	221	0	0	0	0	**830**
TLF-15s	S	143	0	0	0	0	0	0	0	0	171	0	0	**314**
TLF-16s	S	0	0	171	166	171	0	0	0	166	171	0	0	**845**
TLF-17s	S	0	0	0	0	0	0	0	0	0	171	0	0	**171**
TLF-18d	D	0	0	0	0	94	106	110	110	77	0	0	0	**496**
TLF-19s	S	0	0	96	93	96	93	96	96	93	96	0	0	**758**
TL-1[1]	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
TL-11[1]	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
TL-9[1]	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Coelho/Coelho														
Conejo West[1]	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Coelho/Coelho/Fordel														
CCF-1[1]	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Silver Creek Packing														
SC-3B	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
SC-4B	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
SC-6	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
SC-7	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Coelho/Gardner/Hanson														
CGH-1s	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
CGH-2s & 3s	S	0	0	30	105	121	117	121	121	98	0	0	0	**711**
CGH-4s	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
CGH-5s	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
CGH-6s	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
CGH-7s	S	0	0	0	0	0	0	0	0	36	36	0	0	**73**
CGH-8s	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
CGH-9As/9Bs	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
CGH-10s	S	0	0	15	30	46	0	0	0	0	0	0	0	**91**
CGH-11s	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
CGH-12s	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
CGH-13d	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
CGH-4[1]	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
CGH-8[1]	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Meyers Farming														
MS-3[1]	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
MS-4[1]	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
DW-1	D	0	0	50	75	150	120	100	100	139	50	0	0	**785**
MS-6	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
MS-7	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Casaca Vineyards														
FS-1	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
FS-3	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
FS-5	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
FS-6	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
FS-7	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Daddy's Pride Farming														
FS-4	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
FS-9	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
FS-10	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Solo Mio														
FS-2	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
FS-8	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Coelho West														
CW-1	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
CW-2	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
CW-3	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
CW-4	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
CW-5	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Farmers Water District														
R-1	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
R-2	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
R-3	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
R-4	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
R-12	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
R-7	D	0	0	36	63	103	54	0	0	0	0	0	0	**255**
R-8	D	0	0	0	0	32	77	80	80	77	40	0	0	**386**
R-9	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
R-10	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
R-11	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
E-Loop-2	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
E-Loop-3	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
W Loop-1	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
W Loop-2	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
W Loop-3	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Baker Farming Co.														
BF-1	D	0	0	34	36	45	44	49	49	0	0	0	0	**257**
BF-2	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
BF-3	D	5	0	0	0	0	0	0	0	0	0	0	0	**5**
BF-4	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
BF-5	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Panoche Creek Farms														
PCF-1	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Shallow Pumping		**403**	**0**	**833**	**804**	**859**	**561**	**579**	**497**	**791**	**1,453**	**0**	**0**	**6,781**
Deep Pumping		**5**	**0**	**560**	**342**	**598**	**948**	**953**	**953**	**417**	**90**	**0**	**0**	**4,867**
Total Pumping		**408**	**0**	**1,394**	**1,147**	**1,457**	**1,509**	**1,533**	**1,451**	**1,208**	**1,543**	**0**	**0**	**11,648**

1. Well not included for exchange pumping. Added to meet adjacent pumping demand for No Action.

Well	Depth	Pumping (af)												
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Terra Linda Farms														
TLF-1s	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
TLF-2s	S	0	0	112	133	137	133	137	137	66	66	137	0	**1,058**
TLF-3s	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
TLF-4s	S	0	0	0	0	0	80	82	82	0	0	0	0	**244**
TLF-5d	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
TLF-6d	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
TLF-7s	S	0	0	41	40	41	40	41	41	20	20	41	0	**325**
TLF-8s	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
TLF-9s	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
TLF-10s	S	0	0	82	80	82	80	82	82	40	40	82	0	**650**
TLF-11As	S	0	0	96	93	96	93	96	96	46	46	96	0	**758**
TLF-11Cs[1]	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
TLF-12d	D	0	0	174	169	174	169	174	174	84	84	174	0	**1,376**
TLF-13s	S	0	0	123	119	123	119	123	123	60	60	123	0	**974**
TLF-14d	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
TLF-15s	S	0	0	171	166	171	166	171	171	83	83	171	0	**1,353**
TLF-16s	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
TLF-17s	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
TLF-18d	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
TLF-19s	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
TL-1[1]	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
TL-11[1]	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
TL-9[1]	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Coelho/Coelho														
Conejo West[1]	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Coelho/Coelho/Fordel														
CCF-1[1]	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Silver Creek Packing														
SC-3B	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
SC-4B	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
SC-6	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
SC-7	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Coelho/Gardner/Hanson														
CGH-1s	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
CGH-2s & 3s	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
CGH-4s	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
CGH-5s	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
CGH-6s	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
CGH-7s	S	0	0	0	18	75	73	75	58	0	0	0	0	**300**
CGH-8s	S	0	0	0	106	110	106	110	110	53	53	110	0	**757**
CGH-9As/9Bs	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
CGH-10s	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
CGH-11s	S	0	0	62	60	62	60	62	62	0	0	0	0	**366**
CGH-12s	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
CGH-13d	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
CGH-4[1]	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
CGH-8[1]	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Meyers Farming														
MS-3[1]	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
MS-4[1]	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
DW-1	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
MS-6	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
MS-7	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Casaca Vineyards														
FS-1	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
FS-3	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
FS-5	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
FS-6	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
FS-7	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Daddy's Pride Farming														
FS-4	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
FS-9	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
FS-10	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Solo Mio														
FS-2	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
FS-8	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Coelho West														
CW-1	S	0	0	58	56	58	56	58	58	28	28	58	0	**460**
CW-2	S	0	0	58	56	58	56	58	58	28	28	47	0	**448**
CW-3	S	0	0	58	56	58	56	58	58	28	28	58	0	**460**
CW-4	S	0	0	58	56	58	56	58	58	25	28	58	0	**457**
CW-5	S	0	0	58	56	58	56	58	58	28	28	58	0	**460**
Farmers Water District														
R-1	D	0	0	75	109	102	0	0	0	119	119	247	0	**772**
R-2	D	0	0	247	239	247	0	0	0	119	119	247	0	**1,217**
R-3	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
R-4	D	0	0	144	199	205	0	0	0	99	99	205	0	**953**
R-12	D	0	0	192	186	192	0	0	0	93	93	192	0	**947**
R-7	D	0	0	0	0	0	0	0	0	179	179	370	0	**728**
R-8	D	0	0	288	278	0	0	0	0	0	0	0	0	**566**
R-9	D	0	0	233	225	233	0	0	0	81	81	116	0	**970**
R-10	D	0	0	103	149	205	0	0	0	0	0	0	0	**457**
R-11	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
E-Loop-2	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
E-Loop-3	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
W Loop-1	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
W Loop-2	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
W Loop-3	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Baker Farming Co.														
BF-1	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
BF-2	D	0	0	113	109	96	0	0	0	55	55	113	0	**541**
BF-3	D	0	0	241	233	241	0	0	0	117	117	241	0	**1,190**
BF-4	D	0	0	226	219	226	0	0	0	109	109	226	0	**1,116**
BF-5	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Panoche Creek Farms														
PCF-1	D	0	0	233	225	233	0	0	0	113	113	233	0	**1,149**
Shallow Pumping		**0**	**0**	**979**	**1,095**	**1,188**	**1,230**	**1,271**	**1,253**	**505**	**509**	**1,040**	**0**	**9,070**
Deep Pumping		**0**	**0**	**2,268**	**2,341**	**2,155**	**169**	**174**	**174**	**1,169**	**1,169**	**2,364**	**0**	**11,982**
Total Pumping		**0**	**0**	**3,247**	**3,436**	**3,343**	**1,398**	**1,445**	**1,427**	**1,674**	**1,677**	**3,404**	**0**	**21,052**

1. Well not included for exchange pumping. Added to meet adjacent pumping demand for No Action.

Table 6-9
Assigned MPG Exchange Pumping for MWA Surface Water Mixing Model – Proposed Action/Alternative 2

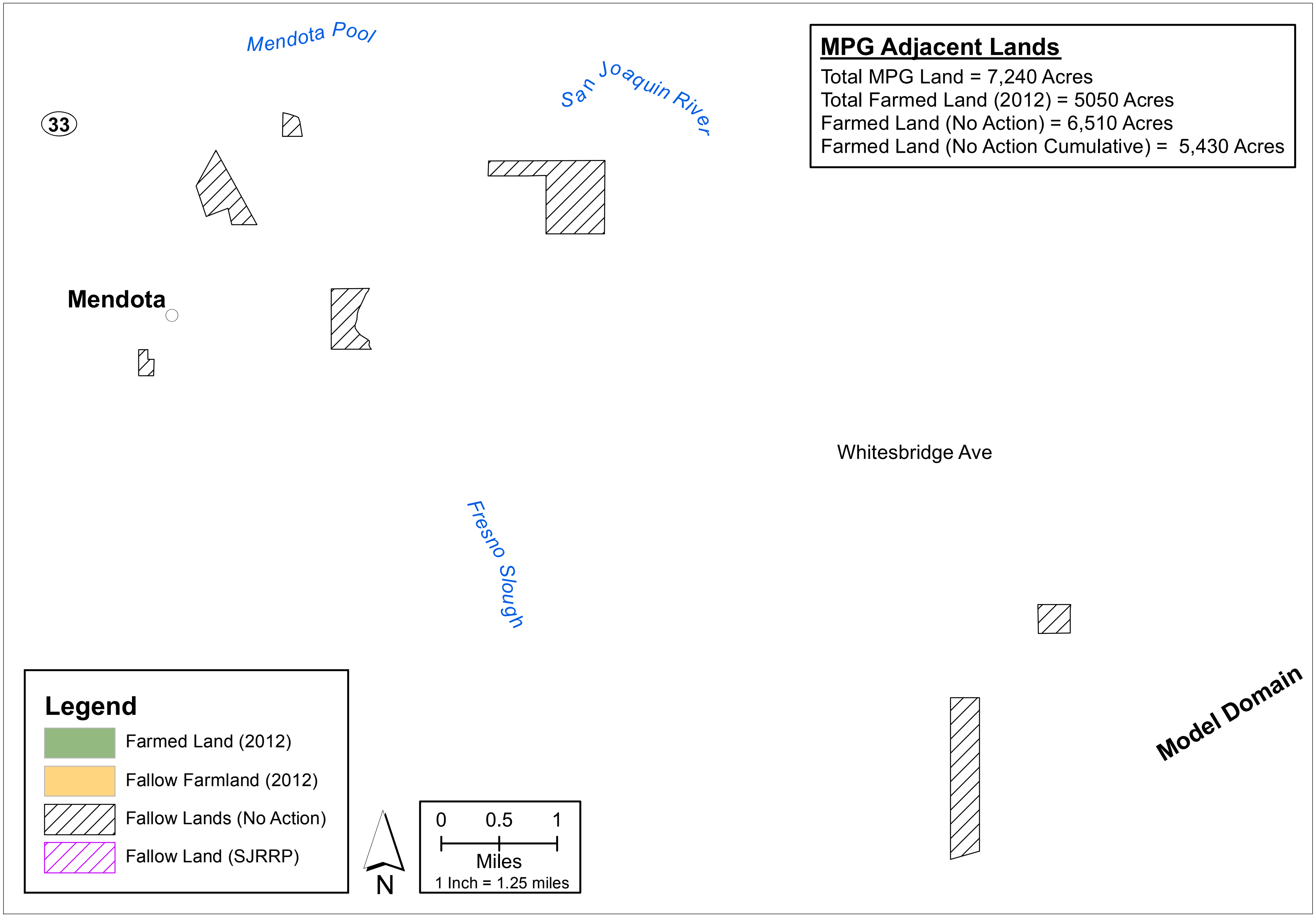
Well	Depth	Pumping (af) Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Terra Linda Farms														
TLF-1s	S	0	0	96	93	96	93	96	96	0	96	0	0	**665**
TLF-2s	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
TLF-3s	S	0	0	110	106	110	106	110	110	106	110	0	0	**866**
TLF-4s	S	0	0	82	80	82	0	0	0	80	81	0	0	**405**
TLF-5d	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
TLF-6d	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
TLF-7s	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
TLF-8s	S	0	0	62	60	62	60	62	62	60	62	0	0	**487**
TLF-9s	S	0	0	75	73	75	73	75	75	73	75	0	0	**595**
TLF-10s	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
TLF-11As	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
TLF-11Cs[1]	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
TLF-12d	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
TLF-13s	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
TLF-14d	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
TLF-15s	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
TLF-16s	S	0	0	171	166	171	166	171	171	166	171	0	0	**1,353**
TLF-17s	S	0	0	0	0	171	166	171	171	0	0	0	0	**679**
TLF-18d	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
TLF-19s	S	0	0	96	93	96	93	96	96	93	96	0	0	**758**
TL-1[1]	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
TL-11[1]	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
TL-9[1]	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Coelho/Coelho														
Conejo West[1]	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Coelho/Coelho/Fordel														
CCF-1[1]	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Silver Creek Packing														
SC-3B	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
SC-4B	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
SC-6	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
SC-7	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Coelho/Gardner/Hanson														
CGH-1s	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
CGH-2s & 3s	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
CGH-4s	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
CGH-5s	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
CGH-6s	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
CGH-7s	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
CGH-8s	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
CGH-9As/9Bs	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
CGH-10s	S	0	0	0	0	62	60	62	62	0	0	0	0	**245**
CGH-11s	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
CGH-12s	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
CGH-13d	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
CGH-4[1]	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
CGH-8[1]	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Meyers Farming														
MS-3[1]	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
MS-4[1]	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
DW-1	D	0	0	0	0	150	120	140	127	0	0	0	0	**537**
MS-6	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
MS-7	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Casaca Vineyards														
FS-1	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
FS-3	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
FS-5	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
FS-6	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
FS-7	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Daddy's Pride Farming														
FS-4	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
FS-9	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
FS-10	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Solo Mio														
FS-2	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
FS-8	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Coelho West		0	0	0	0	0	0	0	0	0	0	0	0	**0**
CW-1	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
CW-2	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
CW-3	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
CW-4	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
CW-5	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Farmers Water District		0	0	0	0	0	0	0	0	0	0	0	0	**0**
R-1	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
R-2	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
R-3	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
R-4	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
R-12	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
R-7	D	0	0	370	358	370	358	370	370	0	0	0	0	**2,195**
R-8	D	0	0	0	0	288	278	288	288	278	288	0	0	**1,708**
R-9	D	0	0	0	0	0	127	116	116	0	0	0	0	**360**
R-10	D	0	0	0	0	0	199	205	205	99	0	0	0	**709**
R-11	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
E-Loop-2	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
E-Loop-3	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
W Loop-1	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
W Loop-2	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
W Loop-3	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Baker Farming Co.		0	0	0	0	0	0	0	0	0	0	0	0	**0**
BF-1	D	0	0	271	262	271	262	271	271	262	271	0	0	**2,144**
BF-2	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
BF-3	D	18	0	0	0	0	0	0	0	0	0	0	0	**18**
BF-4	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
BF-5	D	0	0	0	0	0	275	0	0	0	0	0	0	**275**
Panoche Creek Farms		0	0	0	0	0	0	0	0	0	0	0	0	**0**
PCF-1	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Shallow Pumping		**0**	**0**	**692**	**670**	**925**	**815**	**843**	**843**	**577**	**691**	**0**	**0**	**6,054**
Deep Pumping		**18**	**0**	**641**	**620**	**1,079**	**1,620**	**1,390**	**1,377**	**640**	**559**	**0**	**0**	**7,946**
Total Pumping		**18**	**0**	**1,333**	**1,290**	**2,004**	**2,435**	**2,233**	**2,220**	**1,217**	**1,250**	**0**	**0**	**14,000**

1. Well not included for exchange pumping. Added to meet adjacent pumping demand for No Action.

Table 6-10
Assigned MPG Adjacent Pumping for MWA Surface Water Mixing Model – Proposed Action/Alternative 2

Well	Depth	Pumping (af) Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Terra Linda Farms														
TLF-1s	S	0	0	96	93	96	93	96	96	0	96	0	0	**665**
TLF-2s	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
TLF-3s	S	0	0	110	106	110	106	110	110	106	110	0	0	**866**
TLF-4s	S	0	0	82	80	82	0	0	0	80	81	0	0	**405**
TLF-5d	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
TLF-6d	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
TLF-7s	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
TLF-8s	S	0	0	62	60	62	60	62	62	60	62	0	0	**487**
TLF-9s	S	0	0	75	73	75	73	75	75	73	75	0	0	**595**
TLF-10s	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
TLF-11As	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
TLF-11Cs[1]	S	0	0	96	93	96	93	96	96	93	96	0	0	**758**
TLF-12d	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
TLF-13s	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
TLF-14d	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
TLF-15s	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
TLF-16s	S	0	0	171	166	171	166	171	171	166	171	0	0	**1,353**
TLF-17s	S	0	0	0	0	171	166	171	171	0	0	0	0	**679**
TLF-18d	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
TLF-19s	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
TL-1[1]	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
TL-11[1]	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
TL-9[1]	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Coelho/Coelho														
Conejo West[1]	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Coelho/Coelho/Fordel														
CCF-1[1]	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Silver Creek Packing														
SC-3B	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
SC-4B	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
SC-6	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
SC-7	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Coelho/Gardner/Hanson														
CGH-1s	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
CGH-2s & 3s	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
CGH-4s	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
CGH-5s	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
CGH-6s	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
CGH-7s	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
CGH-8s	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
CGH-9As/9Bs	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
CGH-10s	S	0	0	0	0	62	60	62	62	0	0	0	0	**245**
CGH-11s	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
CGH-12s	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
CGH-13d	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
CGH-4[1]	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
CGH-8[1]	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Meyers Farming														
MS-3[1]	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
MS-4[1]	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
DW-1	D	0	0	0	0	150	120	140	127	0	0	0	0	**537**
MS-6	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
MS-7	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Casaca Vineyards														
FS-1	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
FS-3	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
FS-5	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
FS-6	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
FS-7	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Daddy's Pride Farming														
FS-4	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
FS-9	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
FS-10	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Solo Mio														
FS-2	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
FS-8	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Coelho West														
CW-1	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
CW-2	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
CW-3	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
CW-4	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
CW-5	S	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Farmers Water District														
R-1	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
R-2	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
R-3	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
R-4	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
R-12	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
R-7	D	0	0	370	358	370	358	370	370	0	0	0	0	**2,195**
R-8	D	0	0	0	0	0	0	288	288	278	150	0	0	**1,004**
R-9	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
R-10	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
R-11	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
E-Loop-2	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
E-Loop-3	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
W Loop-1	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
W Loop-2	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
W Loop-3	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Baker Farming Co.														
BF-1	D	0	0	239	262	271	262	271	271	262	0	0	0	**1,840**
BF-2	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
BF-3	D	18	0	0	0	0	0	0	0	0	0	0	0	**18**
BF-4	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
BF-5	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Panoche Creek Farms														
PCF-1	D	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Shallow Pumping		**0**	**0**	**692**	**670**	**925**	**815**	**843**	**843**	**577**	**691**	**0**	**0**	**6,054**
Deep Pumping		**18**	**0**	**609**	**620**	**791**	**741**	**1,069**	**1,055**	**541**	**150**	**0**	**0**	**5,594**
Total Pumping		**18**	**0**	**1,301**	**1,290**	**1,716**	**1,556**	**1,911**	**1,898**	**1,118**	**841**	**0**	**0**	**11,648**

1. Well not included for exchange pumping. Added to meet adjacent pumping demand for No Action.



Document Path: J:\Mendota\ModelingFigures_V3\MXDs\Section_6\Figure_6-1_LandUse_Inset.mxd

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Figure 6-1
MPG Land Use
Assumptions in Predictive Scenarios

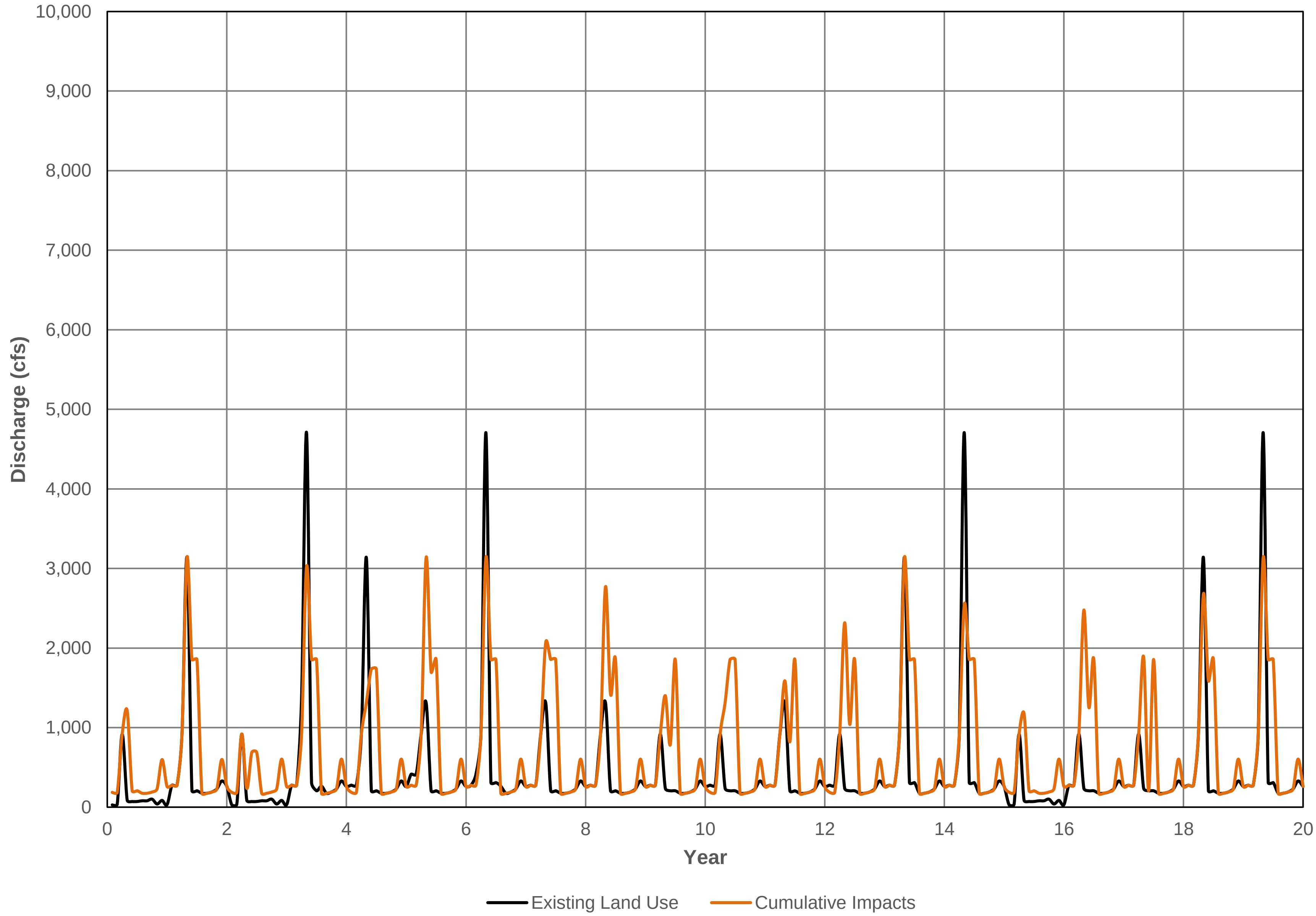

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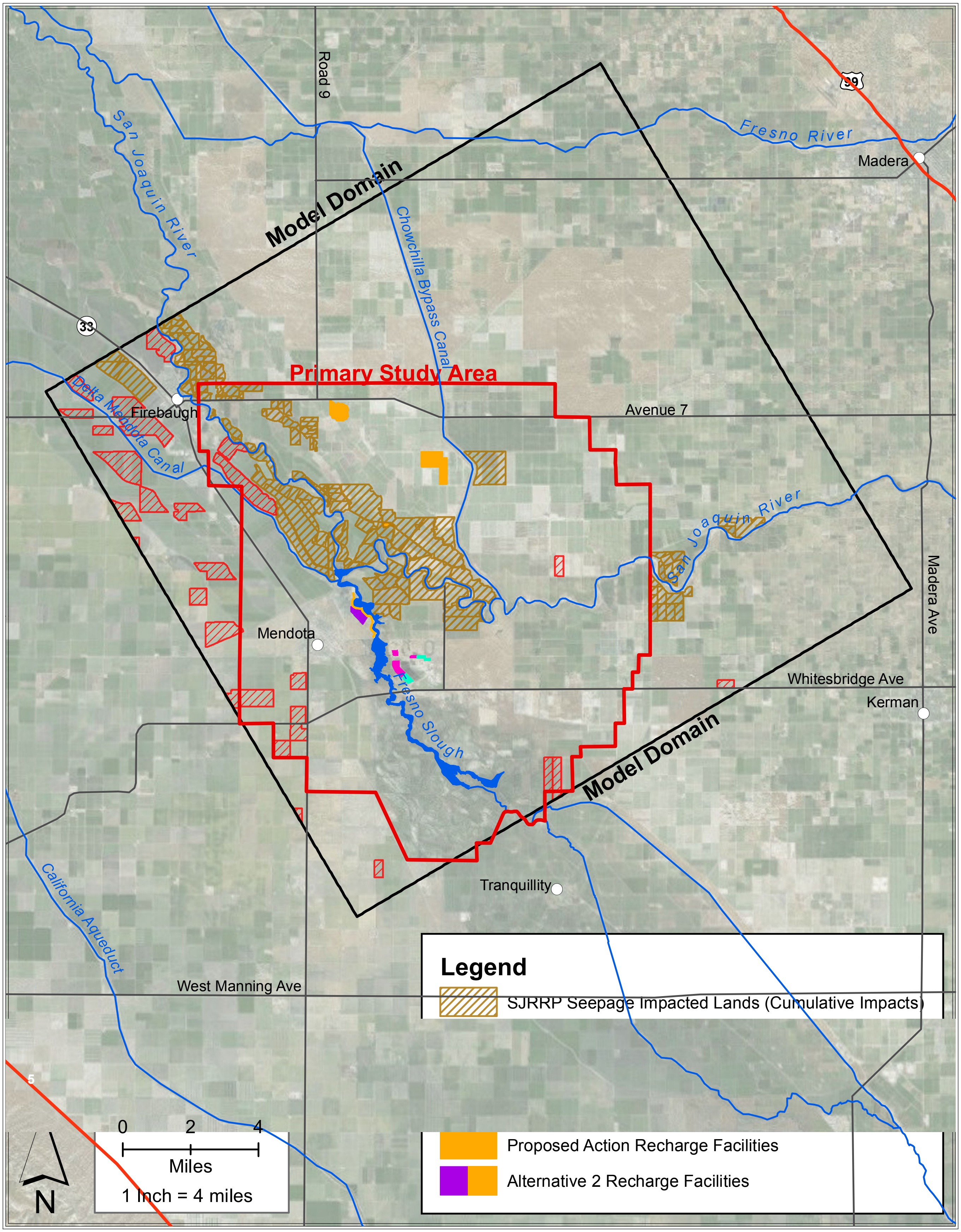
Figure 6-2
Assigned Streamflow in the San Joaquin River



Document Path: J:\Mendota\ModelingFigures_V3\MXDs\Section_6\Figure_6-3_LandUse.mxd

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Figure 6-3
Land Use Assumptions Applied to Predictive Scenarios

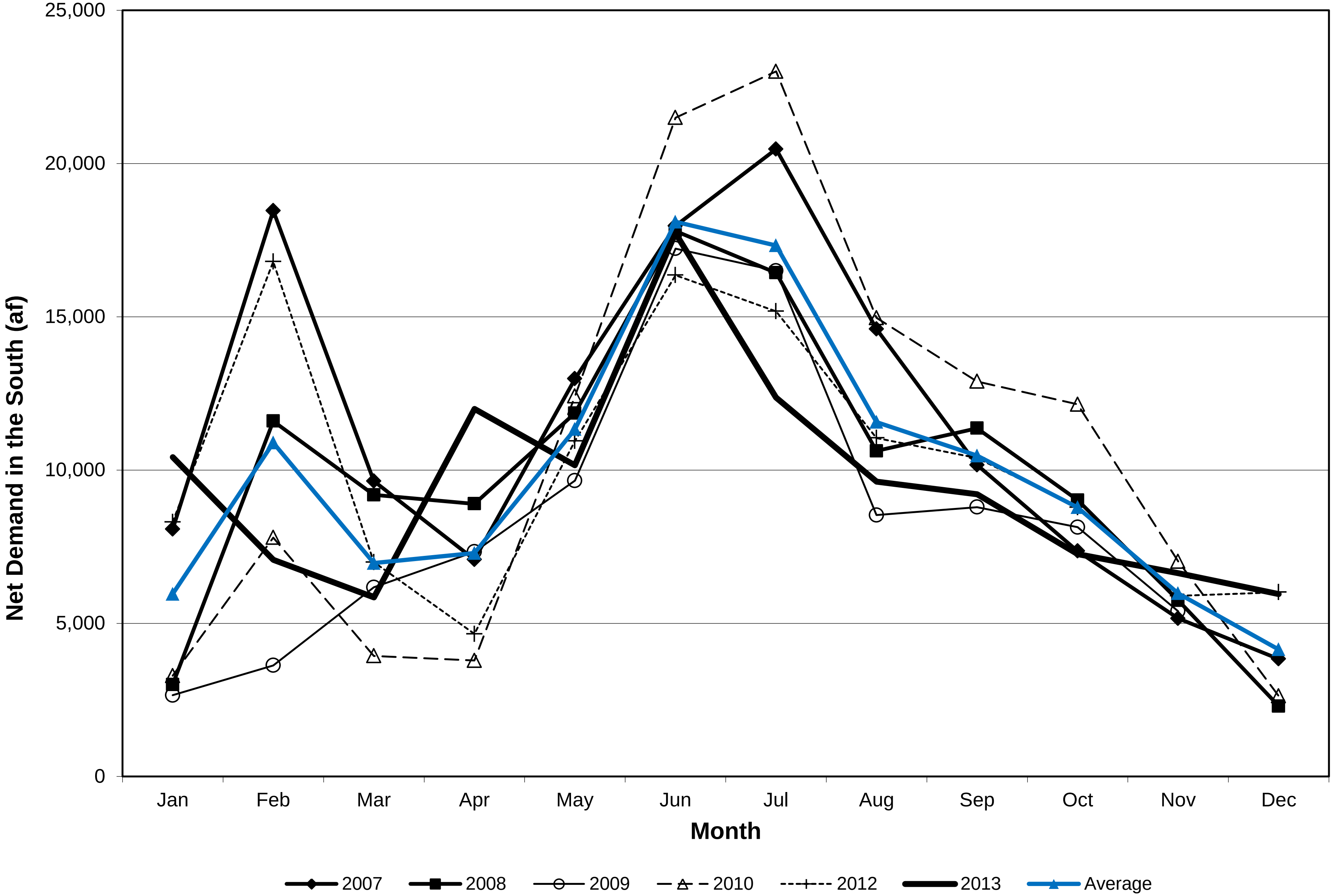

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Figure 6-4
Net Demand at Southern Portion of Fresno Slough
No Action

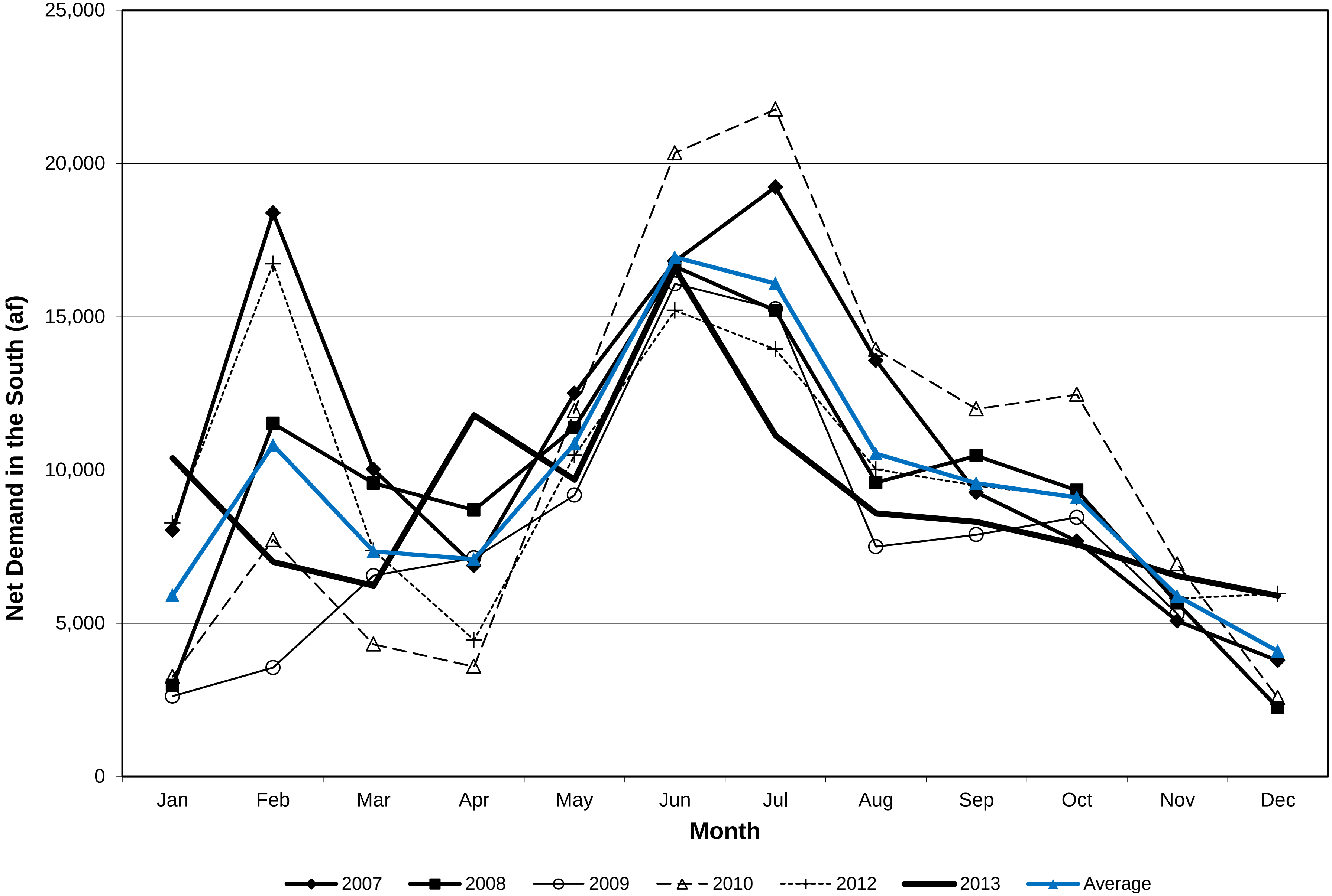

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Figure 6-5
Net Demand at Southern Portion of Fresno Slough
Proposed Action/Alternative 2

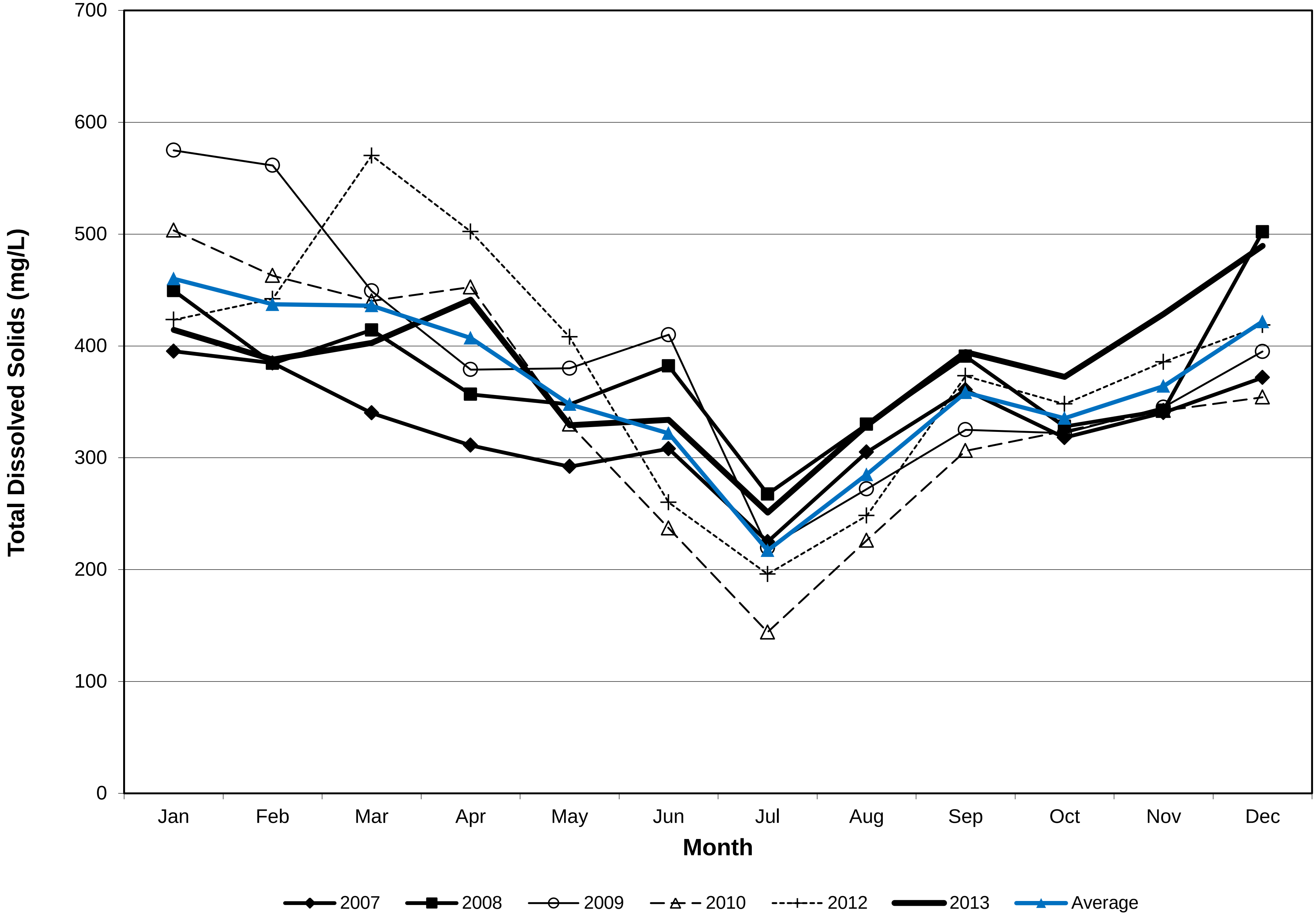

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Figure 6-6
TDS in the Delta Mendota Canal in at Check 21

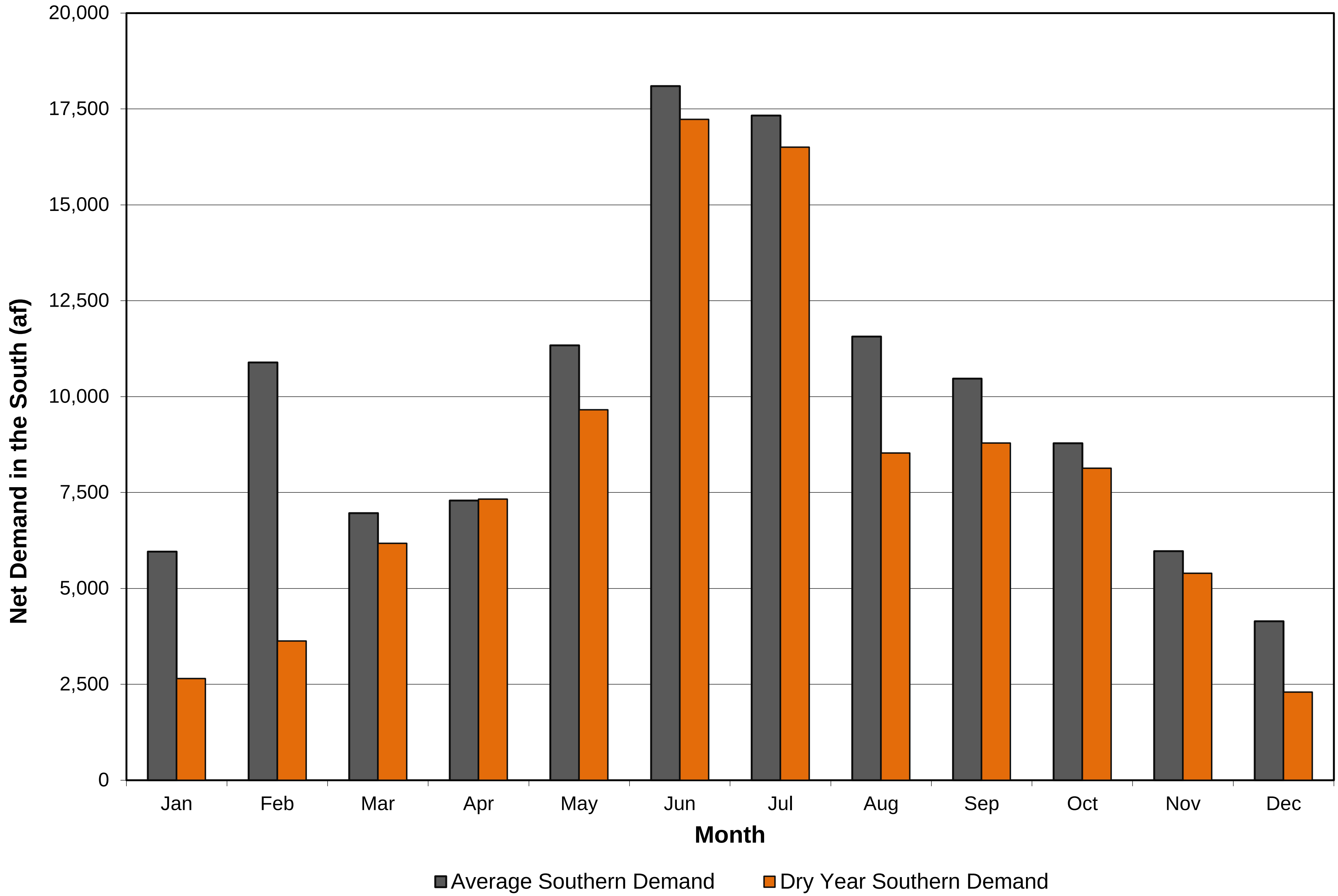

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Figure 6-7
Dry Year Net Demand at Southern Portion of Fresno Slough
No Action

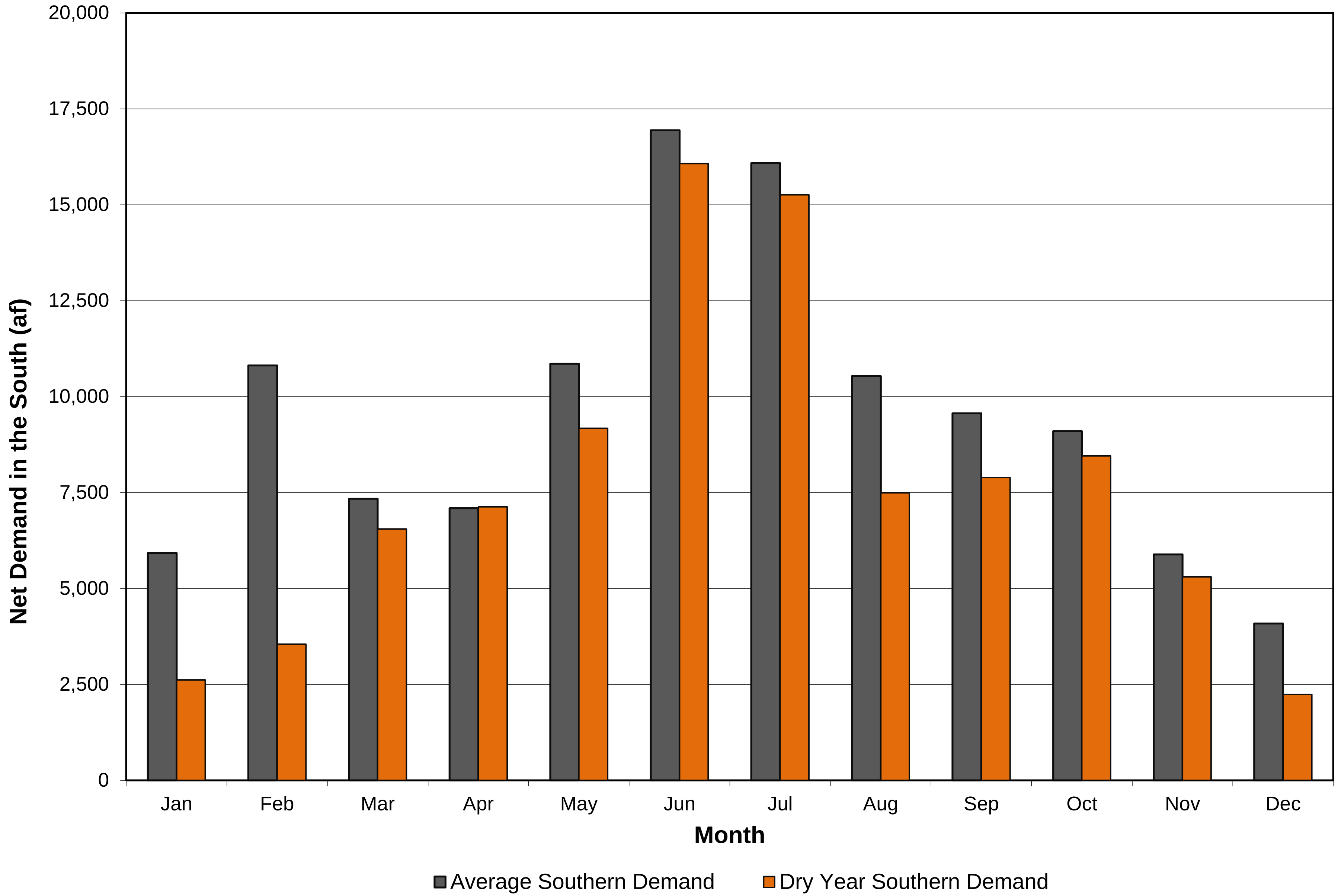


Figure 6-8
Dry Year Net Demand at Southern Portion of Fresno Slough
Proposed Action/Alternative 2

7 ASSESSMENT OF IMPACTS AND INITIAL CONDITIONS

The output generated from the flow and transport models for the six predictive scenarios described in Section 6 was processed to focus on producing information to be utilized in the EIS/EIR. The information produced allowed for the assessment of the influence and levels of significance of Project effects on groundwater levels, groundwater quality, surface water quality, and subsidence. The methodology used to support the assessment of impacts is described below. In addition, a summary of the Year 1 initial conditions that are common to the predictive scenarios is also presented herein.

7.1 Impacts Assessment Methodology

7.1.1 Groundwater Levels

Results from the predictive scenarios were evaluated to determine how proposed pumping for groundwater exchange would impact water levels during the 20-year time frame of the Project. This assessment was made for scenarios developed with both the Existing Conditions land use overlay and those developed for Cumulative Impacts Analysis. Metrics for evaluating project impacts on groundwater levels include:

- The average change in groundwater elevations over the proposed exchange period in the shallow and deep zones in the PSA were tabulated for both winter/spring and summer/fall periods. The average change was calculated for each of the six scenarios to assess the range of changes in groundwater elevations in the different aquifer zones within the PSA over the project period.
- The average change in groundwater levels over the 20-year project period were compared to the pressure head in each aquifer zone at the start of the Project. This information provides a sense of scale to changes in groundwater levels.
- Relative differences in groundwater elevation between the No Action and Proposed Action and between No Action and Alternative 2 model runs were tabulated for six sub-regions in the PSA (**Figure 7-1**). The relative differences were developed for the shallow and deep zones over the 20-year project period. This analysis provides information on the relative change in groundwater elevations over the project period attributed to each scenario and also the relative difference between the No Action and Proposed Action and the No Action and Alternative 2 runs.
- The average drawdown within the PSA attributed to MPG pumping (adjacent and/or exchange) by the end of the project period (Year 20). This provides information on how much drawdown is attributed to any pumping by the MPG by the last year (Year 20) of the project period. These average drawdown values were also compared to the average pressure head in each aquifer zone and reported as a percentage of pressure head estimated in Year 1.
- Hydrographs of average aquifer zone specific groundwater levels over time in the PSA were developed to provide information on project period trends and seasonal variations.
- Several different types of contours of simulated groundwater level data were prepared to evaluate the spatial distribution of scenario results. These contours included groundwater

elevations at the end of the project period, contours of drawdown in the shallow and deep zones by the end of the project period, and contours of relative difference in water levels between Proposed Action and No Action and Alternative 2 and No Action.
- Hydrographs of average groundwater elevations over the project period for the shallow and deep zone within the PSA were prepared to evaluate average groundwater level trends over time for each scenario.
- Differences in average groundwater levels between the Proposed Action and No Action and Alternative 2 and No Action in the shallow and deep zones during the project period were evaluated to analyze the differences over time between these scenarios.

Groundwater level hydrographs over the 20-year project period for wells used in model calibration are provided in **Appendix C** for each Existing Condition scenarios and **Appendix E** for Cumulative Impacts scenarios.

Maps of contoured groundwater elevation, drawdown, and relative differences along with analysis of changes within sub-regions were not developed for the lower aquifer as the bulk of the differences between model runs largely occur in the shallow and deep zones.

7.1.2 Groundwater Quality

The impacts of the No Action, Proposed Action, and Alternative 2 on the fate and transport of salts within the model domain was evaluated by comparing simulated TDS concentrations between the model runs. Emphasis in this analysis is placed on TDS concentrations in the PSA near the Pool/Fresno Slough where the influence of MPG attributed impacts on salinity predominantly occurs.

Metrics for evaluating project impacts on salinity concentrations include:

- TDS concentrations at the end of the proposed exchange agreement (Year 20). Both average TDS in the PSA and the distribution of TDS concentrations in the shallow and deep zones are analyzed to assess changes by the end of the project period.
- Change in TDS concentrations over the project period. This includes color flood maps of the difference in TDS concentrations from Year 1 to Year 20, analysis of changes in TDS concentration within the 6 sub-regions within the PSA (**Figure 7-1**), and quantification of the areal extent of selected TDS concentration ranges at the beginning and end of the project period.
- Relative difference in TDS concentrations between the Proposed Action and No Action and Alternative 2 and No Action. This includes analysis of average TDS concentrations within the PSA in shallow and deep zones, relative changes in TDS concentrations within the 6 sub-regions (**Figure 7-1**), and the relative differences in area which exceeds selected TDS thresholds at the end of Year 20.

TDS concentrations over the 20-year project period from wells used in model calibration are provided in **Appendix D** for Existing Conditions model scenarios and **Appendix F** for the Cumulative Impacts model scenarios.

Analysis of results for the lower aquifer was limited due to the relatively small impact of MPG pumping on lower aquifer TDS concentrations and relatively small differences in TDS concentrations throughout the proposed 20-year project period. TDS concentrations in the vicinity of the former Spreckels Sugar Company are omitted from maps of TDS due to the uncertainty in the predictive capacity of the solute transport model on a local scale.

7.1.3 Surface Water Quality

Surface water quality results generated from the two mixing models focused on average monthly values of TDS concentrations at the MWA and at the Mendota Dam. TDS at the MWA was evaluated for both average and dry-year hydrologic conditions. The latter simulates reduced flow to the south.

7.2 Groundwater Conditions at Start of Year 1

7.2.1 Groundwater Levels

Initial water levels from the beginning of the 20-year project period are variable with depth. In the shallow zone, initial groundwater levels averaged around 135 ft, msl within the PSA. Simulated groundwater levels are higher west of the Fresno Slough and near the SJR and lowest northeast of the SJR near the lateral extent of the A clay (**Figure 7-2**). In the deep zone, average initial water levels were about 115 ft msl within the PSA. Similar to the shallow zone, groundwater levels in the deep zone are higher at the western and eastern (near the San Joaquin River) model boundaries and lowest at the eastern portion of the northern boundary (**Figure 7-3**). Initial simulated groundwater levels in the lower aquifer averaged 43 ft, msl within the PSA. Simulated groundwater levels are greatest in the southeast near the SJR and lowest at the southwestern portion of the model domain (**Figure 7-4**).

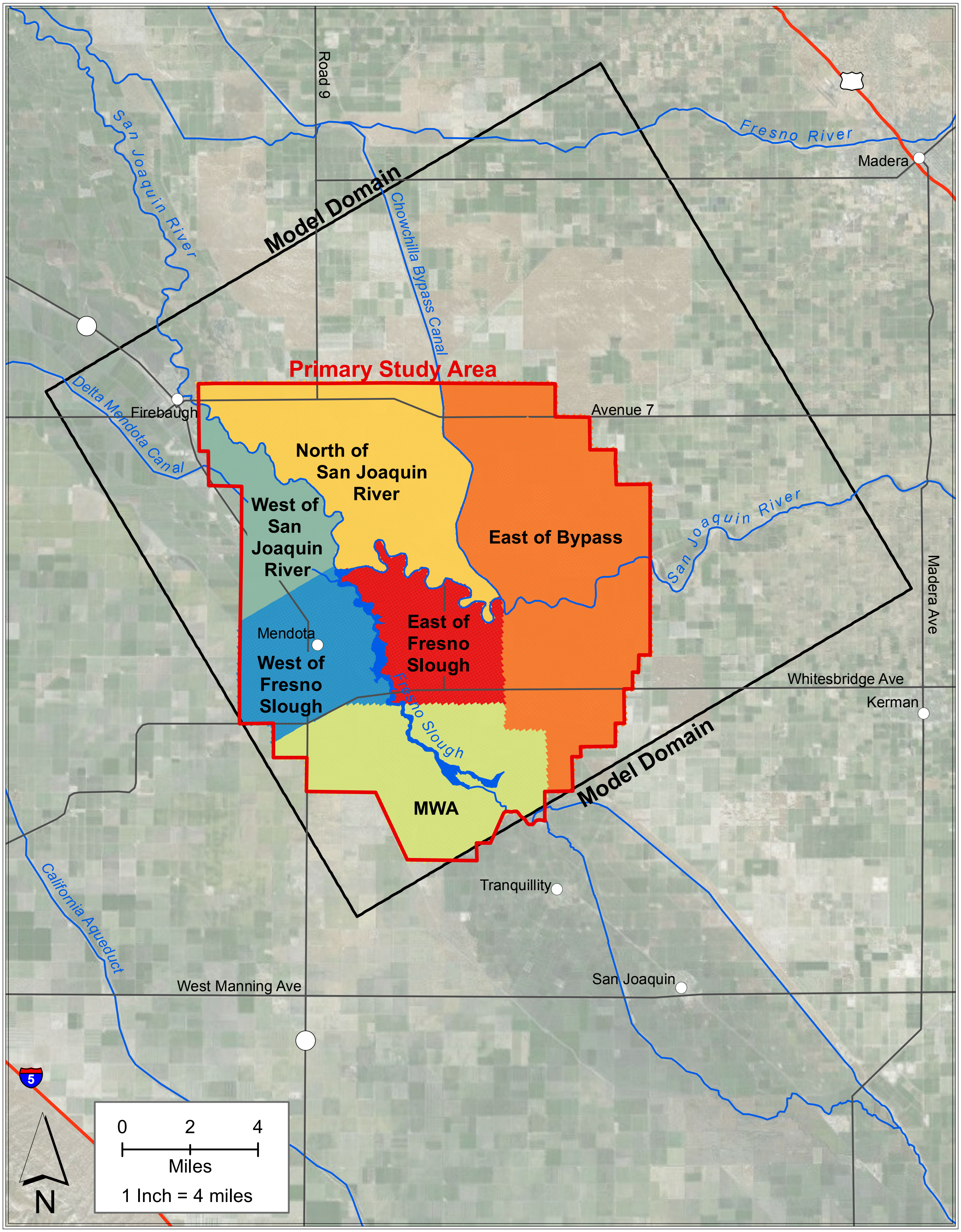
7.2.2 Groundwater Quality

Initial TDS concentrations at the beginning of the proposed 20-year exchange agreement varied throughout the PSA. The TDS concentration in the shallow zone averaged around 1,700 mg/L within the PSA at the beginning of Year 1. The highest TDS concentration occurs west of the Fresno Slough within the “saline front”, while the lowest TDS concentration occurs near the San Joaquin River (**Figure 7-5, Figure 7-6**). At the beginning of Year 1, about 38,000 ac in the shallow zone exceeded a TDS concentration of 800 mg/L, almost 22,000 ac exceeded 1,200 mg/L, and almost 20,000 ac exceeded 2,000 mg/L (**Table 7-1**). In the deep zone, TDS concentrations averaged 1,300 mg/L within the PSA at the beginning of Year 1. Similar to the shallow zone, the highest TDS concentrations occur largely west of the Fresno Slough while the lowest TDS concentrations occur near the SJR (**Figure 7-7, Figure 7-8**). At the beginning of Year 1, almost 44,000 ac in the deep zone exceeded a TDS concentration of 800 mg/L. Of the 44,000 ac, almost 30,000 ac exceeded 1,200 mg/L, and about 20,000 ac exceeded 2,000 mg/L (**Table 7-1**). TDS concentrations in the lower aquifer averaged 670 mg/L.

Table 7-1: Number of Acres Exceeding TDS Threshold in the Primary Study Area Shallow Zone1

Depth Zone	800 (mg/L)[2]	1200 (mg/L)[3]	2000 (mg/L)
	Total (ac)	Total (ac)	Total (ac)
Shallow Zone[1]	38,000	22,000	20,000
Deep Zone[1]	44,000	30,000	20,000

1. Number of acres calculated from simulated TDS concentrations in cells within the Primary Study Area.
2. Number of acres includes acreage that also exceeds 1,200 and 2,000 mg/LTDS.
3. Number of acres includes acreage that exceeds 2,000 mg/LTDS.



Document Path: J:\Mendota\ModelingFigures_V3\MXDs\Section_7\Figure_7-1_AnalysisZones.mxd

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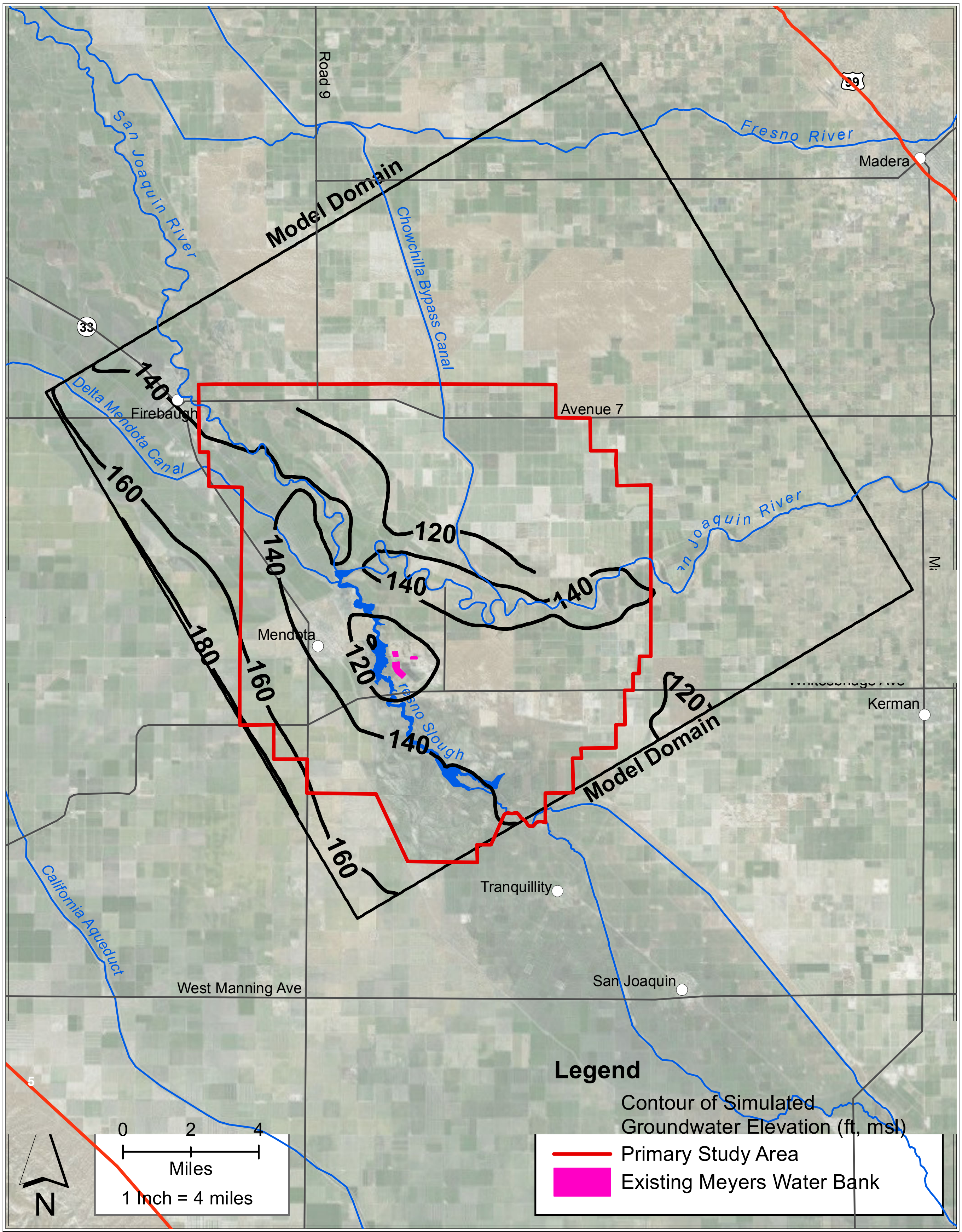
Figure 7-1
Water Level and Water Quality Analysis Sub-Regions



Document Path: J:\Mendota\ModelingFigures_V3\MXDs\Section_7_WL\Figure_7-2_ShallowWL_2015.mxd

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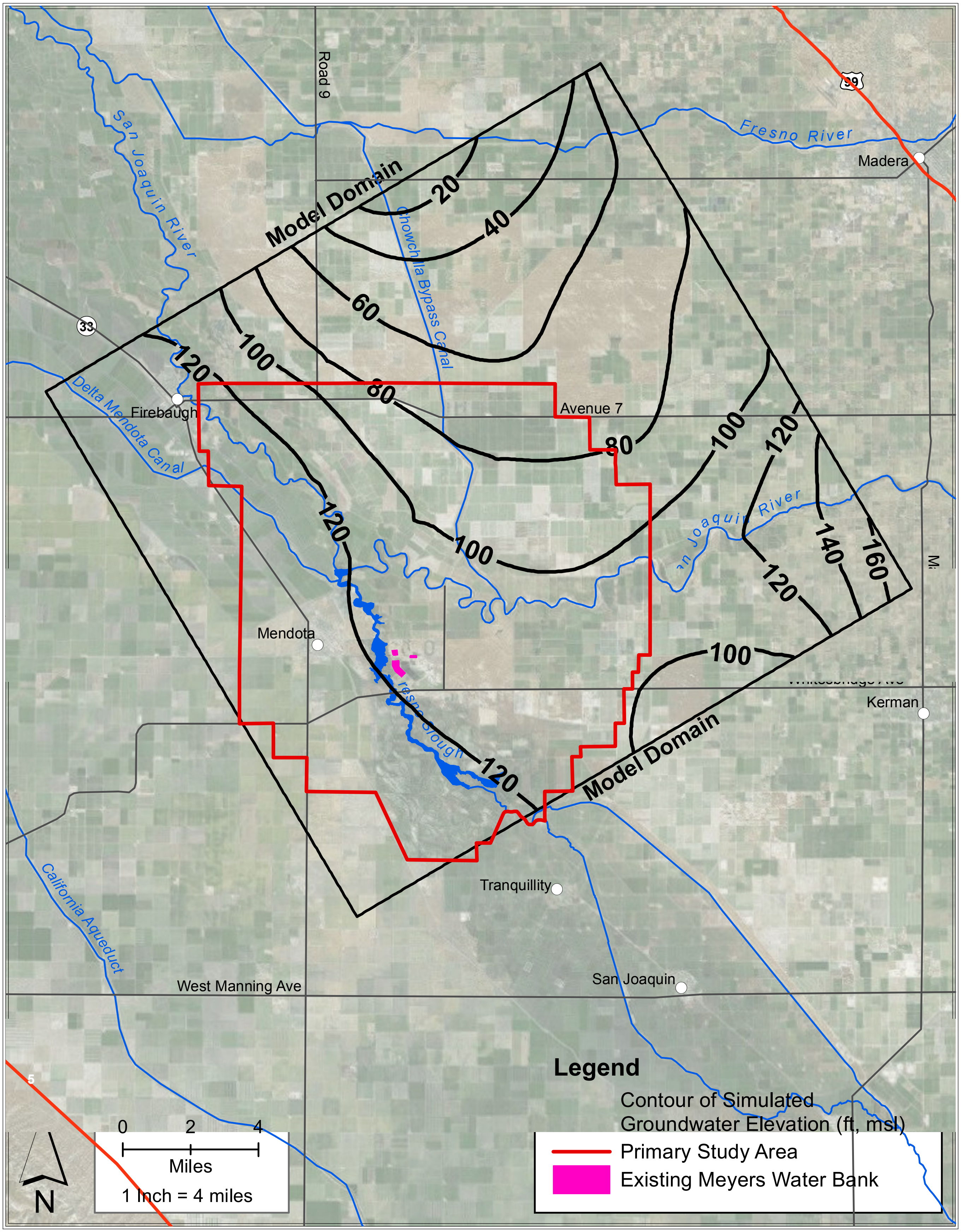
Consulting Engineers

Figure 7-2
Contours of Equal Simulated Groundwater Elevation Shallow Zone, Project Start



Document Path: J:\Mendota\ModelingFigures_V3\MXDs\Section_7_WL\Figure_7-3_DeepWL_2015.mxd

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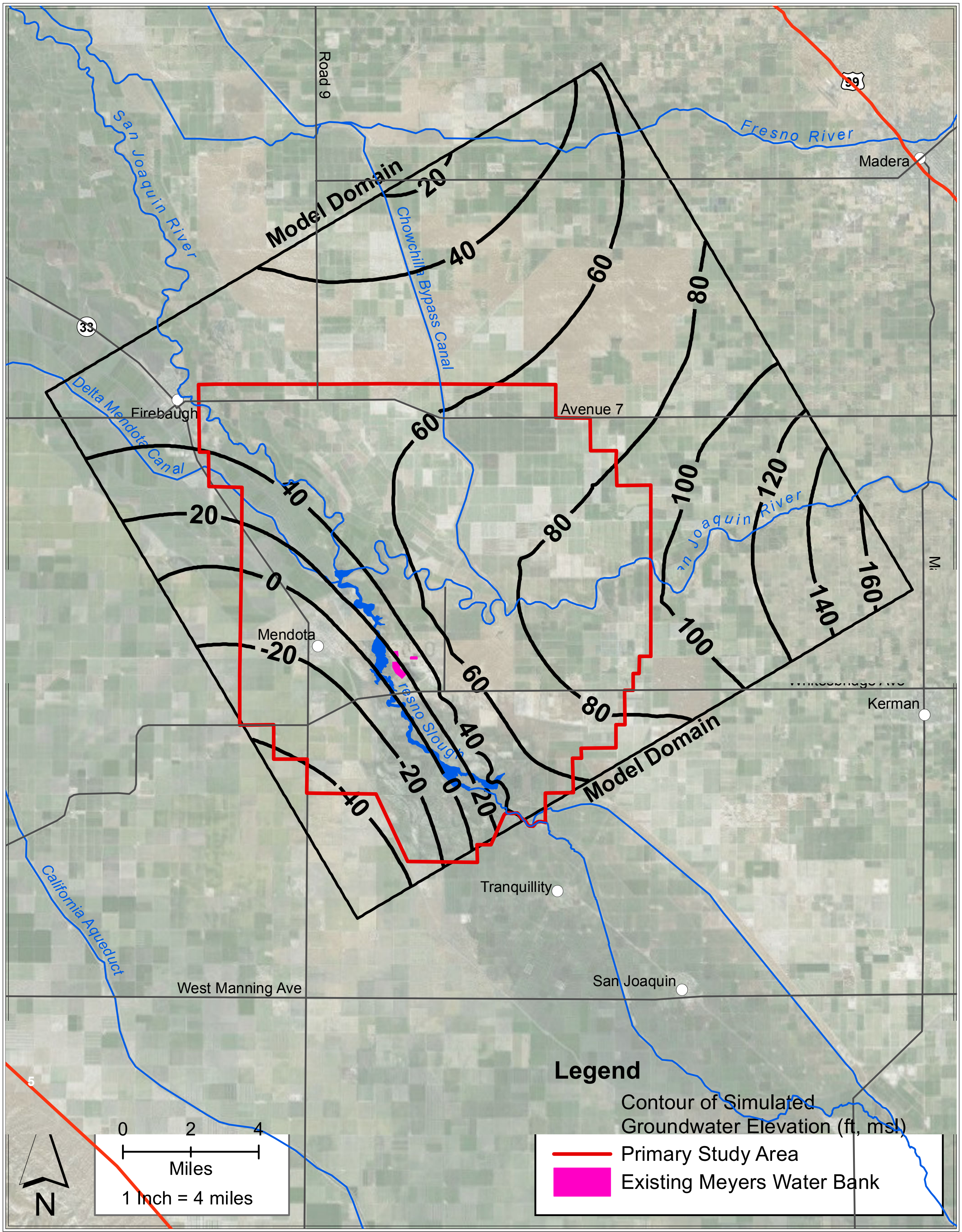
Figure 7-3
Contours of Equal Simulated Groundwater Elevation Deep Zone, Project Start



Document Path: J:\Mendota\ModelingFigures_V3\MXDs\Section_7_WL\Figure_7-4_LowerWL_2015.mxd

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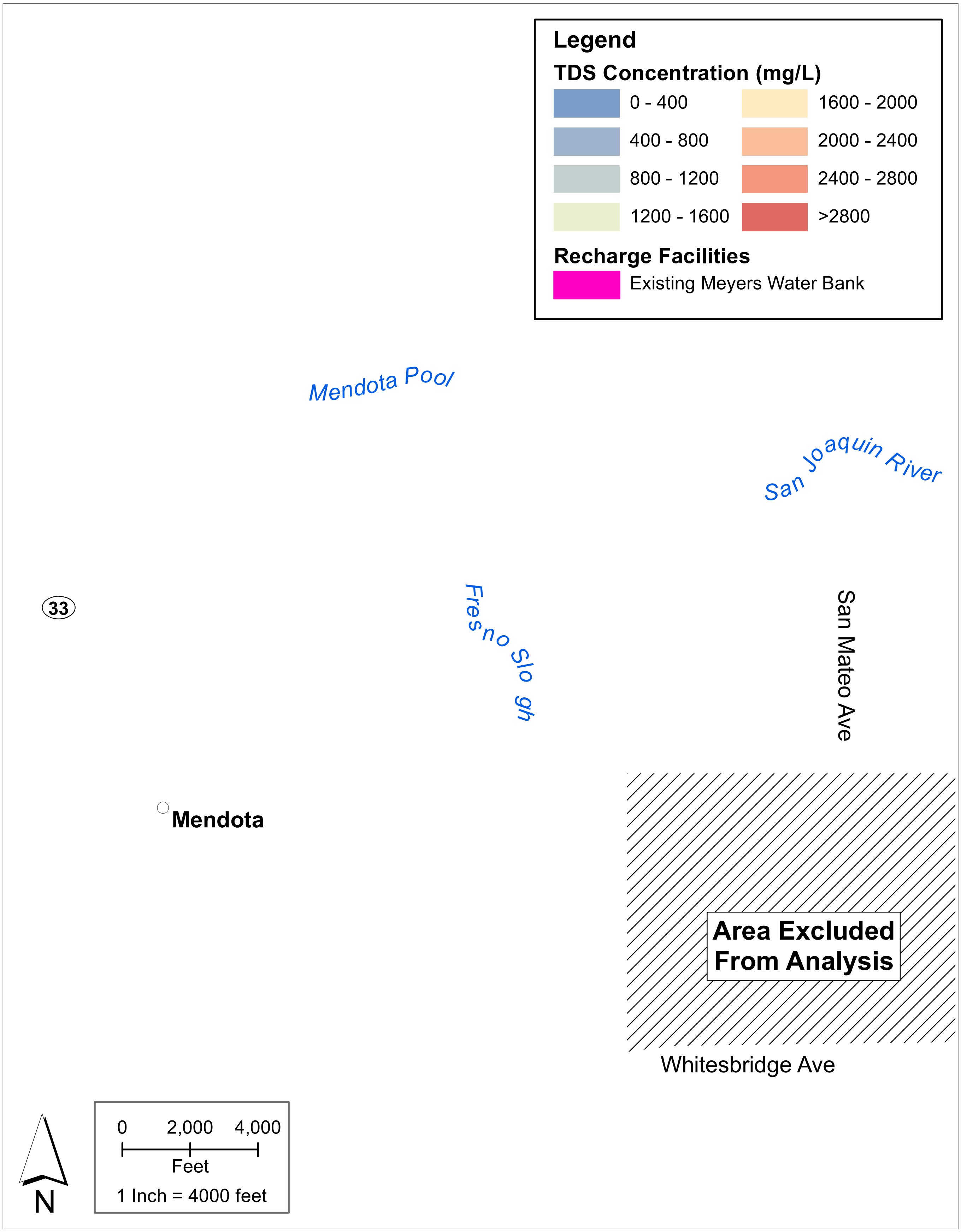
Figure 7-4
Contours of Equal Simulated Groundwater Elevation Lower Aquifer, Project Start



Document Path: J:\Mendota\ModelingFigures_V3\MXDs\Section_7\Figure_7-5_Shallow_Flood_2015.mxd

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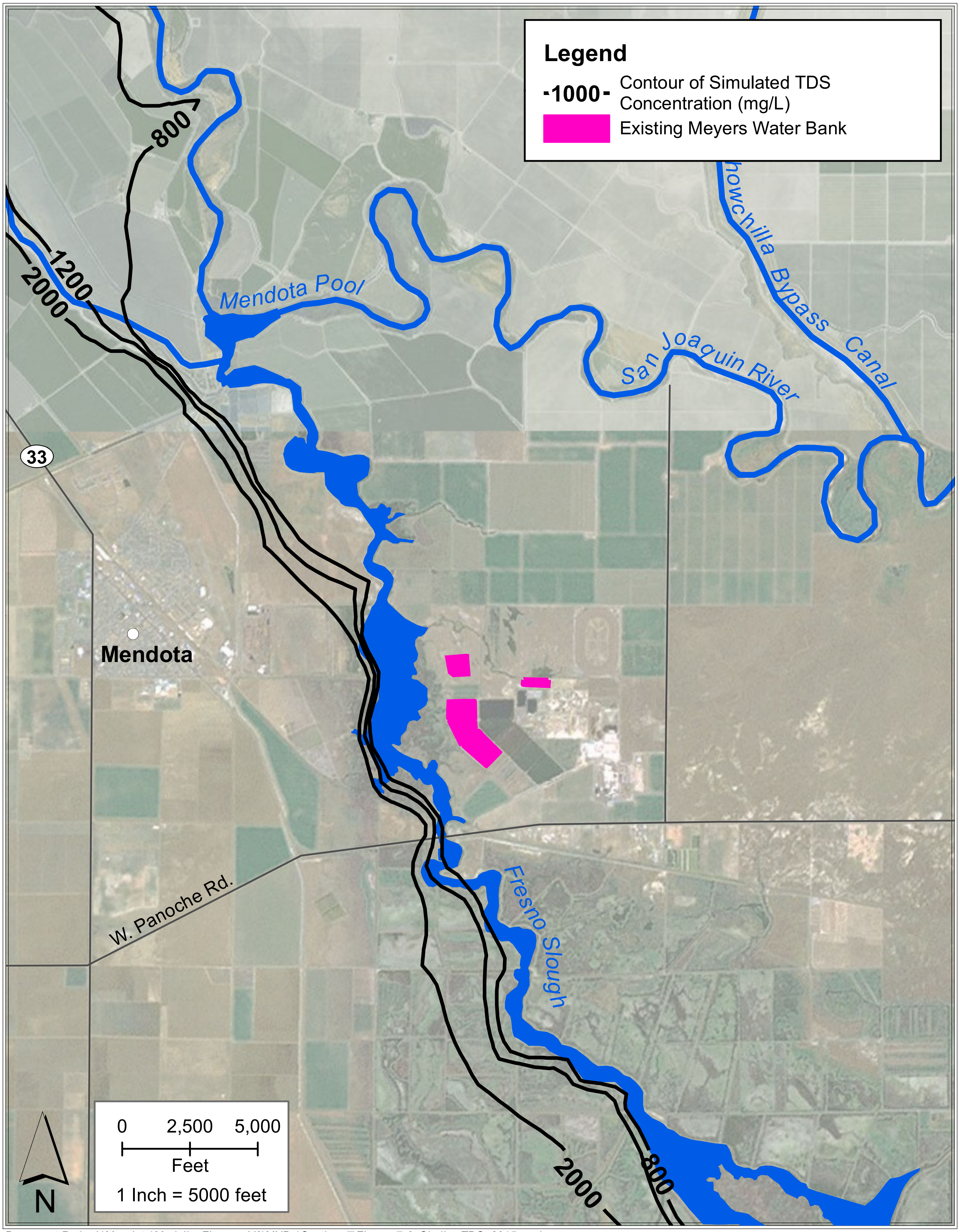
Figure 7-5
Simulated TDS Concentration
Shallow Zone, Project Start



Document Path: J:\Mendota\ModelingFigures_V3\MXDs\Section_7\Figure_7-6_ShallowTDS_2015.mxd

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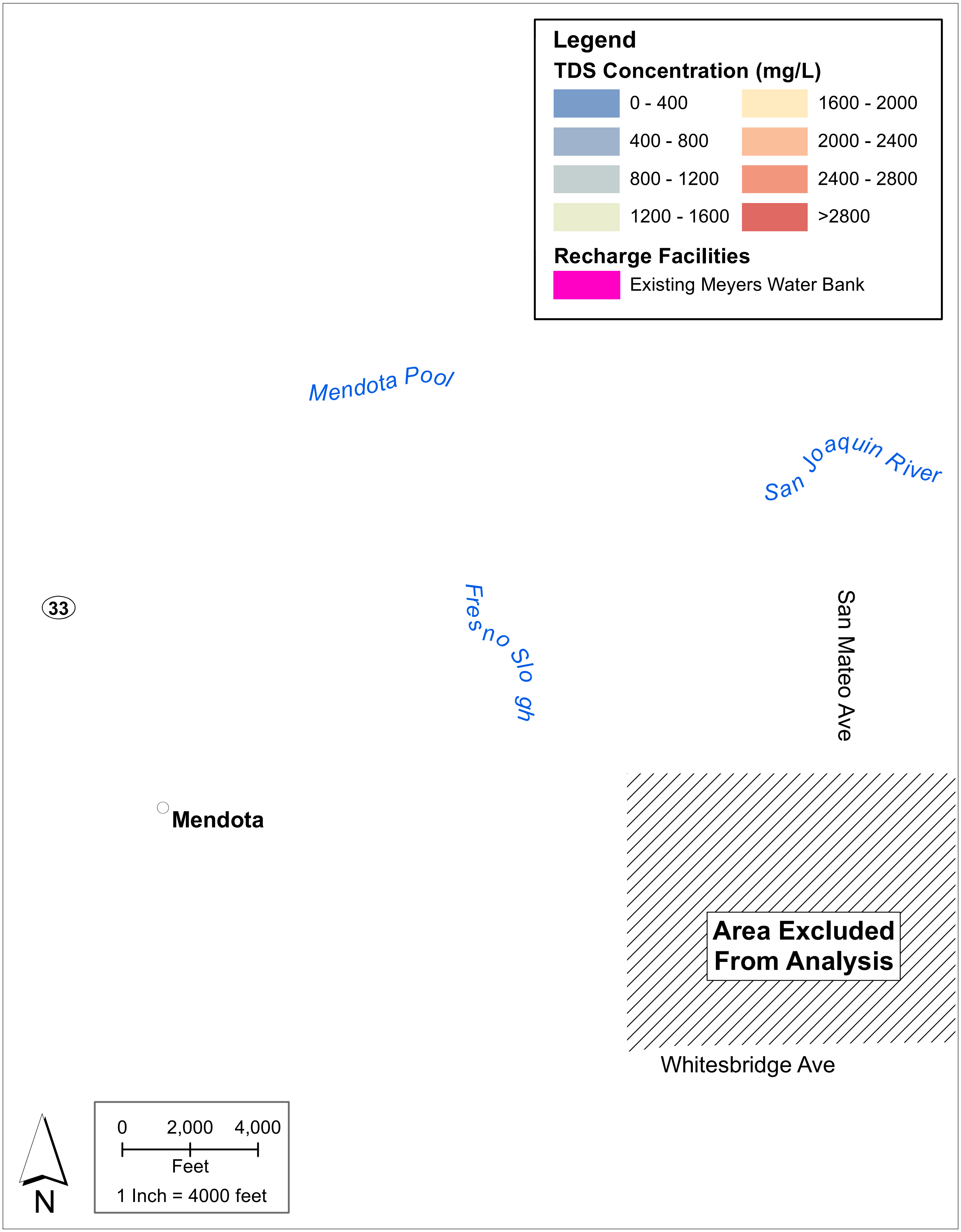
Figure 7-6
Contours of Equal Simulated TDS Concentration Shallow Zone, Project Start



Document Path: J:\Mendota\ModelingFigures_V3\MXDs\Section_7\Figure_7-7_Deep_Flood_2015.mxd

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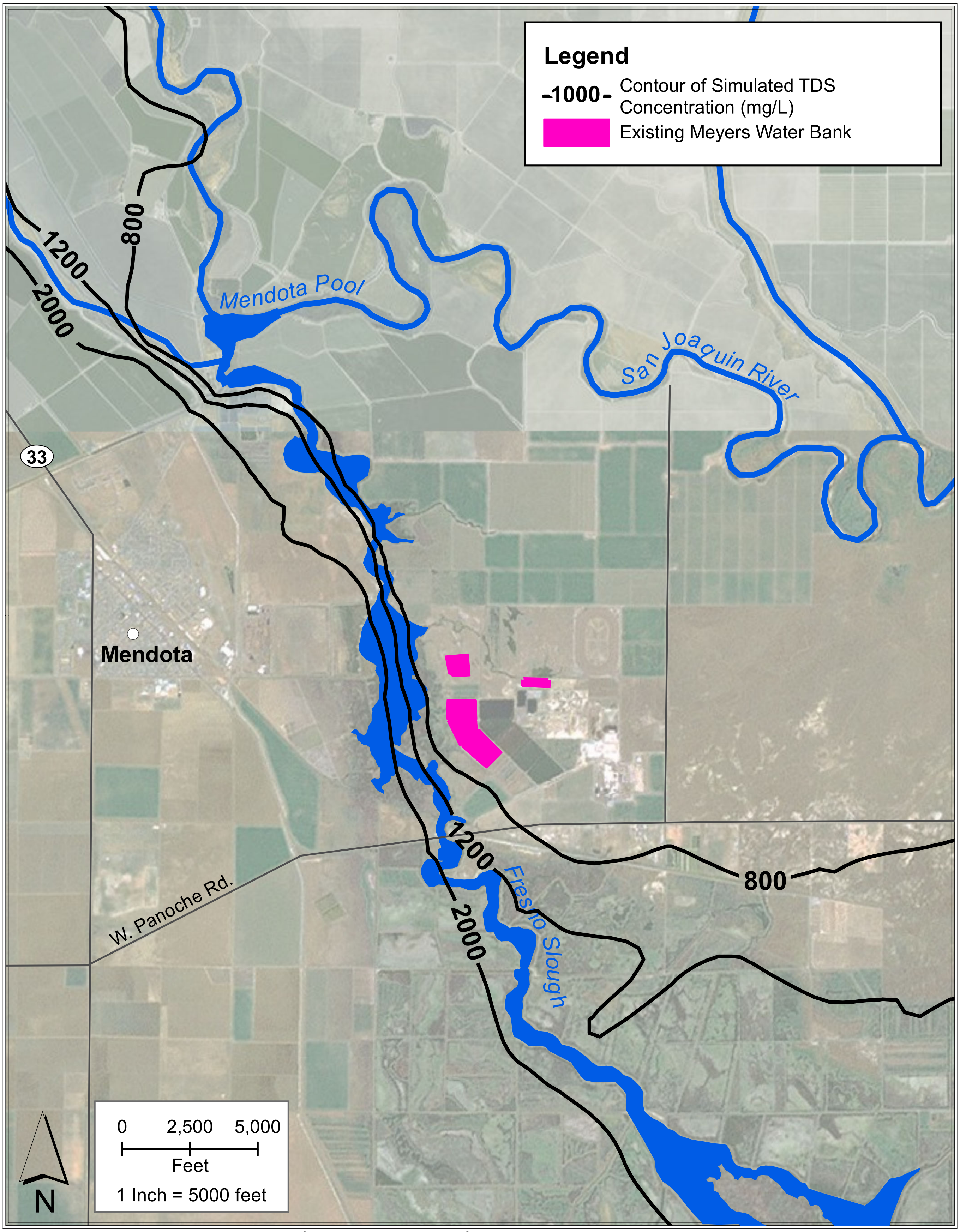
Figure 7-7
Simulated TDS Concentration
Deep Zone, Project Start



Document Path: J:\Mendota\ModelingFigures_V3\MXDs\Section_7\Figure_7-8_DeepTDS_2015.mxd

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Figure 7-8
Contours of Equal Simulated TDS Concentration Deep Zone, Project Start

8 EXISTING LAND USE IMPACTS

The predictive scenarios developed with an existing land use overlay were compared to evaluate the influence of the proposed exchange program on groundwater levels, groundwater and surface water quality, and subsidence in the PSA. As described previously, the No Action scenario includes an increase in adjacent pumping due to expanded production and irrigation on currently fallow/idle lands to an average annual amount of approximately 33,395 afy of groundwater pumping compared to 14,000 afy fixed annual amount assigned in the Proposed Action and Alternative 2 scenarios.

8.1 No Action

8.1.1 Groundwater Levels

8.1.1.1 Shallow Zone

Simulated shallow zone groundwater levels within the PSA at the end of year 20 average approximately 130 ft msl. Contours of simulated groundwater levels in Year 20 are highest on the western edge of the model domain and near the SJR, similar to Year 1 conditions (**Figure 8-1**). Groundwater levels are lowest northeast of the SJR near the lateral extent of the A clay at the end of the project period. Comparison of average Winter/Spring simulated groundwater levels show a decline of about 8 ft within the PSA over the 20-year period. Average Summer/Fall water levels show a decline of almost 5 ft during the same period (**Table 8-1**). As a proportion of the average saturated thickness of the shallow zone within the PSA at the beginning of Year 1, these water level declines represent a decrease of about 6 percent (Winter/Spring) and 11 percent (Summer/Fall) (**Table 8-2**). Average groundwater levels generally show greater declines during dry periods where groundwater is utilized to offset decreases in available surface water and precipitation and tend to recover to some extent during wetter periods (**Figure 8-2**). Spatially, changes in water levels are generally greatest away from the SJR in areas where there is substantial groundwater pumping or increased hydraulic connection with the deep zone near the edge of the A clay, east of Meyers Water Bank, and west of the Pool (**Figure 8-3**). Declines east of the Meyers Water Bank are over 15 ft over the project period, likely due to a combination of distance to surface water features and increased hydraulic connection between the shallow and deep zones (**Figure 8-3**). A groundwater mound forms periodically at the Meyers Water Bank when recharge operations are conducted. The mound occurs at the end of the project period due to recharge occurring at the Water Bank.

Table 8-1: Decrease in Average Simulated Groundwater Levels Over the Proposed 20-Year Exchange Program[1,2]

Depth Zone	No Action (ft)	Proposed Action (ft)	Alternative 2 (ft)
Shallow Zone	8, 5	9, 5	9, 5
Deep Zone	11, 10	13, 9	13, 9
Lower Aquifer	17, 16	18, 16	18, 16

1. Decrease calculated from the average groundwater elevation in the PSA at the beginning of the proposed exchange program minus the average groundwater elevation at the end of proposed exchange program.
2. Comparison made between annually recovered groundwater levels in the winter/spring (first value) and depleted groundwater levels in the fall/summer (second value).

Table 8-2: Decrease in Average Simulated Groundwater Levels Over the Proposed 20-Year Exchange Program As a Fraction of the Pressure Head at the Base of Each Aquifer[1,2,3]

Depth Zone	No Action (Percent)	Proposed Action (Percent)	Alternative 2 (Percent)
Shallow Zone	11, 6	12, 7	12, 7
Deep Zone	3, 3	4, 3	4, 3
Lower Aquifer	2, 2	2, 2	2, 2

1. Decrease calculated from the average groundwater elevation in the PSA at the begining of the proposed exchange program minus the average groundwater elevation at the end of proposed exchange program.
2. Comparison made between annually recovered groundwater levels in the winter/spring (first value) and depleted groundwater levels in the fall/summer (second value).
3. Pressure head at the base of each aquifer is the height of the water column in the aquifer in a model cell. Average pressure head at the base of each aquifer is calculated from the numerical model at the start of the of the proposed groundwater exchange program: **Shallow Aquifer**: 73 ft; **Deep Aquifer**: 352 ft; **Lower Aquifer**: 1070 ft.

Groundwater elevation declines north of the SJR and east of the Chowchilla Bypass average about 6 ft (**Table 8-3**). Changes in groundwater levels are smallest in the MWA and east of the Fresno Slough which decline by approximately 3 ft on average (**Table 8-3**).

Groundwater pumping attributed to the MPG produces an average of approximately 5 ft of drawdown within the PSA in the shallow zone by the end of the project period (**Table 8-4**). This represents a decrease of 7 percent of the average aquifer saturated thickness in the shallow zone (**Table 8-5**).

Table 8-4: Average Drawdown Attributed to MPG Pumping By the End of Proposed 20-Year Exchange Program[1,2]

Depth Zone	No Action (ft)	Proposed Action (ft)	Alternative 2 (ft)
Shallow Zone	5, 5	6, 6	6, 6
Deep Zone	4, 7	6, 5	6, 5
Lower Aquifer	2, 3	2, 3	2, 3

1. Average calculated from the simulated groundwater elevation in model cells within the Primary Study Area at end of the 20-Year program. MPG attributed drawdown calculated from comparison with model run with no assigned MPG pumping.
2. Comparison made between annually recovered groundwater levels in the winter/spring (first value) and depleted groundwater levels in the fall/summer (second value).

Table 8-5: Average Drawdown Attributed to MPG Groundwater Pumping At the End of the Proposed 20-Year Exchange Program As a Fraction of the Pressure Head at the Base of Each Aquifer[1,2,3]

Depth Zone	No Action (Percent)	Proposed Action (Percent)	Alternative 2 (Percent)
Shallow Zone	7, 7	8, 8	8, 8
Deep Zone	1, 2	2, 2	2, 2
Lower Aquifer	<1, <1	<1, <1	<1, <1

1. Average calculated from the simulated groundwater elevation in model cells within the Primary Study Area at end of the 20-Year program. MPG attributed drawdown calculated from comparison with model run with no assigned MPG pumping.
2. Comparison made between annually recovered groundwater levels in the winter/spring (first value) and depleted groundwater levels in the fall/summer (second value).
3. Pressure head at the base of each aquifer is the height of the water column in the aquifer in a model cell. Average pressure head at the base of each aquifer is calculated from the numerical model at the start of the of the proposed groundwater exchange program:
Shallow Aquifer: 73 ft; **Deep Aquifer**: 352 ft; **Lower Aquifer**: 1070 ft.

8.1.1.2 Deep Zone

Simulated deep zone water levels within the PSA average approximately 100 ft msl at the end of the 20-year exchange program. Contours of simulated groundwater levels are greater at the western edge of the model domain and near the SJR, groundwater levels are lowest at the eastern portion of the northern boundary at the end of the project period, similar in nature to Year 1 patterns (**Figure 8-4**). Groundwater levels in the Winter/Spring and Summer/Fall decline about 11 and 10 ft, respectively over the project period (**Table 8-1**). As a proportion of the average pressure head at the base of the deep zone (base of the aquifer is assumed to be the bottom of layer 6) within the PSA, this represents a decrease of about 3 percent (**Table 8-2**). As observed in the shallow zone, average water levels tend to show greater decline during drier periods and recover to some extent during wetter periods (**Figure 8-5**). Seasonal or short-term transient water level declines due to pumping for irrigation average about 20 ft in the Summer/Fall and generally recover during the Winter and Spring (**Figure 8-5**). Spatially, the decline in groundwater elevation over the project period is greatest in the northeastern portion of the model domain and smallest at the southeastern portion of the model domain (**Figure 8-6**).

By subregion, groundwater levels change the most east of the Chowchilla Bypass and north of the SJR which show an average decrease of 16 to 17 ft. The least amount of groundwater level declines occur in the MWA which shows an average project period decrease of approximately 3 ft (**Table 8-3**).

Drawdown over the project period associated with MPG pumping in the deep zone is approximately 4 ft in the Winter/Spring and 7 ft in the Summer/Fall (**Table 8-4**). As a fraction of the saturated thickness, this decline represents a decrease of about 1 and 2 percent, respectively (**Table 8-5**).

8.1.1.3 Lower Aquifer

Average simulated water levels in the lower aquifer within the PSA were approximately 30 ft msl at the end of Year 20. Average groundwater levels within the PSA decline from about 16 ft (Summer/Fall) to 17 ft (Winter/Spring) during the 20-year period (**Table 8-1**). As a fraction of the average pressure head at the base of the lower aquifer (assumed to be the base of fresh water) this represents a decrease of about 2 percent (**Table 8-2**). Seasonally, water levels decline by between 20 to 25 ft in the lower aquifer and generally recover in the Winter/Spring (**Figure 8-7**). Total drawdown resulting from MPG pumping ranges from 2 ft in the Winter/Spring of Year 20 and almost 3 ft in the Summer/Fall (**Table 8-4**).

8.1.2 Groundwater Quality

8.1.2.1 Shallow Zone

TDS concentrations in the shallow zone within the PSA averaged about 1,700 mg/L at the end of the 20-year period. These high average concentration values are skewed due to the occurrence of the saline front over the western portion of the shallow zone. The highest TDS in the PSA occurs west of the Fresno Slough, while the lowest TDS occurs near the SJR due leakage of low TDS water from the river (**Figure 8-8**). Average shallow zone TDS concentrations in the PSA declined by almost 30 mg/L during the 20-year exchange program (**Table 8-6**). Average annual shallow zone TDS within the PSA over the project period does not significantly vary within each year, though individual wells (particularly near the Fresno Slough) show a considerable amount of variability in TDS within each year depending on the amount of groundwater pumping and the amount of inflow from surface water features (**Figure 8-9, Appendix D**). Contours of equal concentrations of TDS concentrations in the shallow zone show that the saline front advances near the northern portion of the Pool and near Whitesbridge Road. All other areas show little advancement (**Figure 8-10**). Over the majority of the PSA, TDS concentrations in the shallow zone show little change over the 20-year period in the No Action (**Figure 8-11**).

Table 8-6: Change in Average Simulated Total Dissolved Solids Concentration Over the Proposed 20-Year Exchange Program

Depth Zone	No Action (mg/L)	Proposed Action (mg/L)	Alternative 2 (mg/L)
Shallow Zone	-30	-20	-20
Deep Zone	200	210	210
Lower Aquifer	3	3	3

1. Average calculated from the simulated TDS concentration in model cells within the Primary Study Area. Increase calculated from the average TDS concentration at the end of the proposed exchange program minus the average TDS concentration at the beginning of proposed exchange program in the PSA.

On a subregion basis, the largest changes in TDS concentrations over the 20-year period occur west of the Fresno Slough (1,200 mg/L decrease to 2,700 mg/L increase), the MWA (1,400 mg/L decrease to 1,000 mg/L increase), and east of the Fresno Slough (1,400 decrease to 280 mg/L increase) and change less than 1,000 mg/L in the other three sub-regions (**Table 8-7**).

Within the PSA, the area exceeding 800 mg/L in Year 20 in the shallow zone decreases by 860 ac while the area exceeding 1,200 and 2,000 mg/L increases by 190 ac and 120 ac, respectively over the 20-year period (**Table 8-8**).

Table 8-8: Number of Acres Exceeding TDS Threshold in the Primary Study Area Shallow Zone in Year 20

Scenario	800 (mg/L)		1200 (mg/L)		2000 (mg/L)	
	Area[1] (ac)	Change[2] (ac)	Area[1] (ac)	Change[2] (ac)	Area[1] (ac)	Change[2] (ac)
No Action	37,400	-860	22,000	190	19,900	120
Proposed Action	37,600	-660	22,200	310	20,000	250
Alternative 2	37,500	-720	22,100	250	20,000	160

1. Area represents the number of acres within the PSA which exceeds given TDS threshold value.
2. Change represents the number of additional acres exceeding given TDS threshold from Year 1 to Year 20.

8.1.2.2 Deep Zone

The average deep zone TDS concentration in the PSA was 1,500 mg/L at the end of Year 20, compared to about 1,300 mg/L at the start of Year 1. TDS concentrations are highest in the deep zone west of the Fresno Slough, while the lowest TDS concentrations occur near the SJR (**Figure 8-12**). Average deep zone TDS concentrations within the PSA increase by about 200 mg/L by the end of Year 20 (**Table 8-6**). Average deep zone concentrations increase relatively linearly throughout the 20-year period and do not vary significantly within each year, though individual wells show some variability (**Figure 8-13, Appendix D**). Contours of simulated deep zone TDS concentrations from Year 1 and Year 20 show saline front migration near MPG wells west of the Fresno Slough and south of Whitesbridge Avenue in the MWA

(**Figure 8-14**). In this areas, deep zone TDS concentrations show the highest increase over the project period (**Figure 8-15**). Away from the saline front, deep zone TDS concentrations show little change.

North of the San Joaquin River and east of the Chowchilla Bypass, deep zone TDS concentrations change by less than 500 mg/L (averages about 40 mg/L and 50 mg/L, respectively) by the end of Year 20 (**Table 8-7**). West of the San Joaquin River, deep zone TDS concentrations are about 300 mg/L lower to almost 1,000 mg/L higher (average almost 400 mg/L increase) in Year 20 compared to the start of Year 1. West of the Fresno Slough, TDS concentrations in Year 20 have ranged between 500 mg/L lower to 2,200 mg/L higher (average about 650 mg/L increase) than Year 1 concentrations. In the MWA, deep zone TDS concentrations are about 650 mg/L lower to about 1,700 mg/L higher (average about 300) at the end of Year 20 compared to Year 1 concentrations. East of the Fresno Slough, deep TDS concentrations are from 1,100 mg/L lower to about 1,800 mg/L higher (average about 250 mg/L higher) at the end of Year 20 compared to Year 1 concentrations (**Table 8-7**). Within the PSA, the area exceeding 800 mg/L and 2,000 mg/L in the deep zone increases by 3,400 acres and 2,100 acres, while the area exceeding 1,200 mg/L decreases by 700 acres (**Table 8-9**).

Table 8-9: Number of Acres Exceeding TDS Threshold in the Primary Study Area Deep Zone

Scenario	800 (mg/L)		1200 (mg/L)		2000 (mg/L)	
	Area[1] (ac)	Change[2] (ac)	Area[1] (ac)	Change[2] (ac)	Area[1] (ac)	Change[2] (ac)
No Action	47,300	3,400	28,800	-720	22,600	2,100
Proposed Action	47,600	3,700	29,100	-440	22,700	2,300
Alternative 2	47,600	3,700	29,100	-430	22,700	2,300

1. Area represents the number of acres within the PSA which exceeds given TDS threshold value.
2. Change represents the number of additional acres exceeding given TDS threshold from Year 1 to Year 20.

8.1.2.3 Lower Aquifer

TDS concentrations in the lower aquifer averaged almost 700 mg/L in the PSA at the end of Year 20, which is similar to Year 1 concentrations (**Table 8-6**). Simulated TDS concentrations in both the PSA as a whole in the lower aquifer and in specific wells were relatively stable from Year 1 to Year 20 (**Figure 8-16, Appendix D**).

8.1.2.4 MPG Well Groundwater Quality

Out of 86 MPG wells used for pumping groundwater in the model (10 of the 86 wells were used for adjacent pumping only while 76 wells were used for both exchange and adjacent use), 19 wells out of the 76 used for exchange pumping were simulated to have TDS concentrations exceed 1,200 mg/L by Year 20 of the project period. In the No Action, 14 of these 19 wells also exceed 2,000 mg/L TDS by Year 20 (**Table 8-10**). Average TDS concentrations in MPG wells over the project period were calculated to assess how many wells had average concentrations that exceed 1,200 and 2,000 mg/L. In the No Action scenario, 19 wells had average TDS concentrations that exceeded 1,200 mg/L and 10 wells exceeded 2,000 mg/L (**Table 8-11**).

8.1.3 Subsidence

Subsidence in the form of compaction was evaluated at the Fordel and Yearout extensometer locations. These extensometers measure compaction that occurs above the Corcoran Clay. In the No Action scenario, compaction by Year 20 ranged from nearly 0.3 ft at Yearout to less than 0.1 ft at the Fordel extensometer (**Table 8-12**). Seasonal variations in elastic compaction occurred at both extensometer locations with the greatest fluctuations at Yearout (about 0.06 ft) as compared to Fordel (0.03 ft) (**Figure 8-17**). The average annual compaction was about 0.015 ft at Yearout (**Table 8-12**) and 0.004 ft at Fordel (**Table 8-13**).

Table 8-12: Compaction Above the Corcoran Clay at the Yearout Extensometer Year 1 to Year 20

Scenario	Compaction (ft)[1]	Difference (ft)[2]	Non-MPG/MPG Adjacent Compaction (ft)[3]	Exchange Compaction (ft)[4]
No Action	0.295 (0.015)	-	-	-
Proposed Action	0.329 (0.016)	0.035 (0.002)	0.230 (0.011)	0.099 (0.005)
Alternative 2	0.327 (0.016)	0.032 (0.002)	0.228 (0.011)	0.099 (0.005)

1. Total simulated inelastic compaction accumulated from Year 1 to Year 20. Annual average shown in parenthesis.
2. Difference between simulated No-Action and Proposed Action/Alternative 2 compaction from Year 1 to Year 20. Annual average shown in parenthesis
3. Simulated inelastic compaction accumulated from Year 1 to Year 20 attributed to non-MPG pumping and MPG adjacent pumping.
4. Total simulated inelastic compaction attributed to MPG exchange pumping. MPG exchange pumping contribution calculated as the difference between total simulated inelastic compaction and compaction attributed to non-MPG and MPG adjacent pumping.

Table 8-13: Compaction Above the Corcoran Clay at the Fordel Extensometer Year 1 to Year 20

Scenario	Compaction (ft)[1]	Difference (ft)[2]	Non-MPG/MPG Adjacent Compaction (ft)[3]	Exchange Compaction (ft)[4]
No Action	0.074 (0.004)	-	-	-
Proposed Action	0.087 (0.004)	0.013 (0.001)	0.029 (0.001)	0.058 (0.003)
Alternative 2	0.081 (0.004)	0.007 (0.000)	0.023 (0.001)	0.058 (0.003)

1. Total simulated inelastic compaction accumulated from Year 1 to Year 20. Annual average shown in parenthesis.
2. Difference between simulated No-Action and Proposed Action/Alternative 2 compaction from Year 1 to Year 20. Annual average shown in parenthesis

3. Simulated inelastic compaction accumulated from Year 1 to Year 20 attributed to non-MPG pumping and
MPG adjacent pumping.
4. Total simulated inelastic compaction attributed to MPG exchange pumping. MPG exchange pumping contribution calculated as the difference between total simulated inelastic compaction and compaction attributed to non-MPG and MPG adjacent pumping.

The total compaction simulated at the end of the project period, and the average annual value derived from the total, is mostly composed of inelastic compaction with a minor proportion that is elastic (reversible). When simulated compaction increases from one spring to the next spring, the simulated amount may not necessarily reflect solely inelastic (or irreversible) compaction because subsequent simulated spring values may show some amount of rebound (such as Years 13 to 14 and Years 18 to 19). For the purposed of this analysis we are considering that total compaction reported over the 20-year period, along with the annual average value represent inelastic (or irreversible) compaction to be conservative.

8.1.4 Surface Water Quality

The mixing model that calculated surface water quality at the Mendota Dam simulated TDS concentrations ranging from 220 mg/L (July) to about 365 mg/L (January) (**Table 8-14**). The inflows to the model from the San Joaquin River ranged from 1,580 to about 27,000 af per month with TDS concentrations ranging from 26 to 37 mg/L. Flows from the DMC ranged from about 12,000 to 130,000 af/per month with TDS concentrations ranging from about 240 to 460 mg/L. Inflows from the Pool were estimated to be 0 to about 35,000 af with TDS concentrations ranging from about 220 to 370 mg/L. Outflows in the mixing model were to the outflow canals (Firebaugh, Main, Outside, and Columbia) and ranged from about 2,000 to 93,000 af/per month. Outflows to the Mendota Dam ranged from about 11,000 to 77,000 af/per month. In the No Action scenario, there was no exchange pumping, therefore there was not any MPG contribution to inflows to the northern mixing model (**Table 8-14**).

The mixing model that calculated surface water quality at the MWA (southern mixing model) simulated TDS concentrations from average MPG pumping conditions over the project period and also MPG pumping during dry year conditions when flow to the south is low (**Tables 8-15 and 8-16**). Given average year conditions, simulated TDS concentrations at the MWA ranged from 317 mg/L in July to about 447 mg/L in January (**Table 8-15**). The inflows to the model from the City of Mendota and Meyers Water Bank totaled about 2,000 to 3,000 afy, respectively, while inflows from adjacent pumping was about 11,000 afy. TDS in the DMC averaged 353 mg/L annually. Adjacent pumping from MPG led to an average annual simulated increase of 36 mg/L at the MWA. TDS contributions from the Meyers Water Bank and the City of Mendota averaged about 9 mg/L annually. The annual mean TDS concentrations at the MWA was 398 mg/L.

Dry year conditions simulated TDS concentrations at the MWA ranging from about 323 mg/L in July to about 447 mg/L in January (**Table 8-16**). The increase in TDS at the MWA due to MPG adjacent pumping averaged 41 mg/L annually. The increase due to City of Mendota and Meyers Water Bank averaged 11 mg/L. The annual mean TDS concentration at the MWA given dry year conditions was about 405 mg/L.

8.1.5 Water Budget

The No Action water budget from the project period and two preceding years is summarized on an annual basis (**Table 8-17**). Water budget terms from the groundwater model include stream and canal seepage, areal recharge, recharge facilities, net subsurface inflow, lake seepage, groundwater pumping, aquifer storage, and interbed storage. Stream and canal seepage ranges from about 76,000 to 140,000 afy with the largest amounts occurring during periods with high streamflow. The annual average amount was about 111,000 afy. Areal recharge ranges from about 166,000 to 320,000 afy with the highest amount of recharge occurring during average and wet years. The annual average amount was about 228,000 afy. Recharge from ponds varies between 1,500 to about 35,000 afy and are dependent on Meyers Water Bank operations and availability of water for NCR recharge ponds. The average annual amount was about 7,700 afy. Net lateral inflow is the net amount of subsurface inflow into the model domain. Positive values indicate there is more subsurface water flowing into the model domain compared to flowing out of the system, while negative numbers indicate more groundwater is flowing out than entering the system. Net lateral inflow ranges from about -48,000 to about 65,000 afy with most years showing more groundwater entering the model domain than leaving. The average annual amount was about 50,000 afy. Seepage from the LAK package shows very little variation and ranges from 29,000 to 37,000 afy. The average annual amount was about 37,000 afy. Groundwater pumping is the largest water budget component and ranges from about 350,000 to about 540,000 afy. The average annual amount was about 481,000 afy. Storage varies annually and negative values in **Table 8-17** indicate an increase in storage while positive values represent a decrease in storage. Over the project period, storage ranges from -142,000 to about 181,000 afy with an annual average amount of about 29,000 afy. Interbed storage ranges from -9,000 to about 69,000 afy. The average annual amount was about 21,000 afy.

8.1.6 No Action Alternative 1B

The influence of increased pumping in WWD encompassed in the No Action Alternative 1B was not directly simulated by the numerical and solute transport models. Instead, a qualitative analysis was conducted to estimate the influence increased pumping would have on groundwater levels and potential subsidence in WWD.

Groundwater pumping in WWD is highly variable and is largely dependent on surface water deliveries. From 1990 through 2012, groundwater pumping in WWD has ranged from 15,000 afy to 600,000 afy, with the greatest amount of pumping occurring when surface water deliveries have been curtailed.

Groundwater levels in WWD have varied considerably over time. From the mid-1950s to mid-1970s, groundwater elevations in WWD have generally been below sea level. By the mid-1960s, groundwater levels declined to about 155 ft bsl. Since the mid-1970s, groundwater elevations have generally increased to levels above sea level. However, in the late 1980s to early 1990s drought, pumping in WWD increased to 600,000 afy which resulted in groundwater levels declining a total of about 125 ft to an average elevation of 62 ft bsl (WWD, 2014). This was the lowest average groundwater elevation that has been experienced in WWD since 1977. During this period, DWR estimated about two ft of subsidence occurred. This amounts to a little less than two percent of the 125 foot groundwater level decline.

Generally, when groundwater levels approach or exceed historic lows, inelastic compaction leading to subsidence is likely to occur if there are fine-grained units present which are still susceptible to compaction. If groundwater levels are kept substantially above historic lows, inelastic compaction is less likely to occur.

It is anticipated that the MPG will need to pump about 25,000 afy of groundwater in WWD to offset the exchange water which is normally pumped into the Pool. During dry periods when surface water deliveries have been reduced, groundwater pumping in WWD has historically ranged from between 250,000 to over 600,000 afy. The addition of about 25,000 afy of groundwater pumping by the MPG to the total pumped in WWD amounts to less than 5 percent to about 10 percent of the total groundwater pumping in WWD. This small incremental increase in pumping may not result in any inelastic subsidence if groundwater levels are maintained well above historic lows. However, during extended drought periods, when total WWD pumping increases significantly, the incremental addition of MPG pumping will likely contribute to inelastic compaction.

Based on subsidence that occurred in the late 1980s to early 1990s when water levels approached historic lows, an annual rate of subsidence of 0.5 ft/per year occurred. If future groundwater levels approach historic lows and WWD pumps between 250,000 and 600,000 afy, it can be assumed that the annual inelastic compaction rate may approach 0.5 ft/per year without the additional MPG pumpage. With the additional 25,000 afy of pumping from MPG, the total amount of groundwater pumping in WWD will increase by about 5 to 10 percent. If it is assumed that annual groundwater pumping is proportional to the annual rate of subsidence, 25,000 afy of additional MPG pumping could produce about 5 to 10 percent additional subsidence in WWD. This would result in the MPG contributing between about 0.025 and 0.05 ft/per year of additional compaction to the 0.5 ft/per year total rate of subsidence attributed to existing WWD groundwater pumping.

Estimation of total subsidence associated with the additional MPG pumping over the project period of 20 years where MPG pumping would occur in 16 out of the 20 years at around 25,000 afy can be highly uncertain and dependent on the occurrence of severe and extended drought conditions which result in historic levels of groundwater pumping to occur in WWD. Although it is presumed that dry climatic conditions will occur during the project period, historic high levels of groundwater pumping and associated subsidence will only occur during periods where there are successive dry years. For this analysis, a single long-term drought condition similar in nature to what is currently occurring in California is conservatively assumed to occur for 7 years during the project period. Assuming that the MPG portion of total subsidence is between 0.025 and 0.05 ft/per year, MPG pumping given these drought conditions could result in 0.175 to 0.35 ft of total compaction in WWD.

8.2 Proposed Action

8.2.1 Groundwater Levels

8.2.1.1 Shallow Zone

Shallow zone groundwater levels within the PSA averaged approximately 130 ft msl at the end of Year 20 compared to 135 ft, msl at the start of Year 1. Simulated water levels are highest near the western boundary and lowest northeast of the SJR near the termination of the A clay (**Figure 8-18**). Shallow zone groundwater levels are also locally higher near the SJR and decline with distance from the riverbed. Simulated shallow zone water levels over the 20-yr period decrease by between 9 ft in the Winter/Spring and 5 ft in the Summer/Fall (**Table 8-1**). As a function of the average saturated thickness at the beginning of the project period, this represents a decrease of between 7 and 12 percent (**Table 8-2**). Average water levels decline by 10 to 15 ft during dry periods to about 125 ft, msl, but largely recover during wet periods (**Figure 8-19**). Similar to the No Action scenario, the distribution of changes in groundwater elevation show larger changes (declines) away from surface water features like the SJR (**Figure 8-20**).

Total change in groundwater elevation in the shallow zone over the 20-year exchange program is greatest north of the SJR and east of the Chowchilla Bypass which shows an average decline of 6 ft, and smallest west of the SJR which declines by an average of 4 ft **(Table 8-3**).

Simulated water levels indicate that MPG groundwater pumping leads to about 6 ft of additional average shallow zone drawdown within the PSA in both the Summer/Fall and Winter/Spring water levels (**Table 8-4**). This represents almost 8 percent of the total saturated thickness of shallow zone at the beginning of Year 1 of the proposed exchange program (**Table 8-5**).

Simulated shallow zone water levels near the MPG recharge facilities show that water levels in the Proposed Action scenario tend to show relative recovery compared to the No Action scenario when recharge is occurring within the Terra Linda Canal (**Appendix C**). However, relative water level increases due to recharge generally coincide with periods when no MPG exchange pumping is occurring. Consequently, recharge benefits from the Terra Linda Canal are difficult to directly quantify. However, since relative recoveries are generally more pronounced in wells near the proposed Terra Linda Canal, it is presumed recharge from the canal is largely concentrated near the recharge facility and do not carry over significantly into subsequent years (**Appendix C**).

When comparing groundwater level response to the No Action scenario, average groundwater levels in the PSA at the end of the 20-year exchange program are about 1 foot or less lower than the No Action water levels in both the Winter/Spring and Summer/Fall (**Table 8-18**). With respect to the average saturated thickness in the shallow zone within the PSA at the beginning of Year 1, the additional drawdown simulated in the Proposed Action represents a 2 percent or less change (**Table 8-19**). Throughout the 20 year project period, the difference in average water levels in the PSA between the Proposed Action and No Action scenarios varies from no difference in years when no transfer pumping occurs to about 2 ft (**Figure 8-21**). The distribution of the difference between the No Action and Proposed Action groundwater shows that the Proposed Action at the end of Year 20 results in an increase in groundwater levels around the Pool and decreases around the Spreckels Sugar Company and MWA areas in the shallow zone (**Figure 8-22**). The increase in groundwater levels around the Pool by Year 20 in the Proposed Action were likely influenced by the lack of exchange pumping during that year of the simulation as a result of wet year hydrology. In the vicinity of the MWA and Spreckels Sugar Company, Proposed Action water levels are lower than the No Action likely because of a delay in the lateral propagation of the relative recovery in the area of the Pool, which is largely controlled by the hydraulic conductivity and aquifer storage coefficients (**Figure 8-22**).

Table 8-18: Difference in Average Groundwater Levels Between No Action and Proposed Action/Alternative 2 At the End of the 20-Year Exchange Program[1,2]

Depth Zone	Proposed Action minus No Action (ft)	Alternative 2 minus No Action (ft)
Shallow Zone	1, <1	<1, <1
Deep Zone	2, -1	1, -1
Lower Aquifer	<1, <-1	<1, <-1

1. Difference calculated from the average groundwater level in the PSA at the end of the proposed
   exchange program in the Proposed Action/Alternative 2 minus the No Action.
2. Comparison made between annually recovered groundwater levels in the winter/spring (first value) and depleted groundwater levels in the fall/summer (second value).

Table 8-19: Difference in Average Groundwater Levels Between No Action and Proposed Action/Alternative 2 At the End of the 20-Year Exchange Program As a Fraction of the Pressure Head at the Base of Each Aquifer

Depth Zone	Proposed Action minus No Action (Percent)	Alternative 2 minus No Action (Percent)
Shallow Zone	2, <1	2, <1
Deep Zone	<1, <-1	<1, <-1
Lower Aquifer	0, 0	0, 0

1. Average calculated from the simulated groundwater elevation in model cells within the Primary
   Study Area. Difference calculated from the average groundwater level at the end of the proposed exchange program in the Proposed Action/Alternative 2 minus the No Action.

2. Comparison made between annually recovered groundwater levels in the winter/spring (first value) and depleted groundwater levels in the fall/summer (second value).
3. Pressure head at the base of each aquifer is the height of the water column in the aquifer in a model cell. Average pressure head at the base of each aquifer is calculated from the numerical model at the start of the of the proposed groundwater exchange program: **Shallow Aquifer**: 73 ft; **Deep Aquifer**: 352 ft; **Lower Aquifer**: 1070 ft.

Average differences in groundwater levels between the No Action and Proposed Action are very small and range from about 2 ft lower to less than a foot higher in the Proposed Action compared to the No Action in the 6 subregions (**Table 8-3**). West of the Fresno Slough, groundwater levels are between 6 ft less and 19 ft higher than the No Action (average less than 1 foot lower than No Action). In the MWA, Proposed Action groundwater levels are up to 6 ft lower than the No Action (average 2 ft lower than No Action). East of the Pool, Proposed Action groundwater levels are between 5 ft lower and 9 ft higher than the No Action (average 2 ft lower than the No Action) (**Table 8-3**). In the other three subregions (North of the SJR, West of the SJR, and East of the Bypass), groundwater levels in the Proposed Action and No Action are within 2 ft at the end of Year 20.

8.2.1.2 <u>Deep Zone</u>

Groundwater levels in the deep zone at the end of the 20-year project period averaged about 100 ft msl within the PSA, compared to about 115 ft msl in Year 1. The groundwater elevations generally show a similar trend to those simulated in the No Action deep zone with higher water levels at the western portion of the model domain and near the SJR, and lower groundwater elevations near the northern model boundary near the Chowchilla Bypass Canal (**Figure 8-23**). Winter/Spring water levels declined by about 13 ft and 9 ft in the Summer/Fall over the project period (**Table 8-1**). As a proportion of the pressure head at the base of deep zone, this represents a decrease of between 3 and 4 percent (**Table 8-2**). Seasonal declines in average deep zone groundwater levels are around 15 to 20 ft during the Summer and Fall with recovery during the Winter and Spring (**Figure 8-24**). The distribution of groundwater level changes in the deep zone is similar to the No Action and generally shows greater declines in the northeastern portion of the model domain and smaller changes near the southern extent of the model domain (**Figure 8-25**). The greatest changes in average deep zone groundwater elevations are north of the SJR and east of the Chowchilla Bypass which show a decline of 16 to 17 ft (**Table 8-3**). Change in average deep zone groundwater elevations are the smallest in the MWA which shows a decline of 3 ft (**Table 8-3**).

Average simulated drawdown attributed to MPG groundwater pumping at the end of the 20-year project period ranges from 5 ft in the Summer/Fall and 6 ft in the Winter/Spring (**Table 8-4**). This represents a decrease of about 2 percent of the pressure head at the base of the deep zone (**Table 8-5**).

Within the PSA, average Proposed Action water levels are between 2 ft lower in the Winter/Spring and about 1 foot higher in the Summer/Fall than the No Action (**Table 8-18**). This amount represents less than 1 percent of the total pressure head at the base of the deep zone at the start of Year 1 (**Table 8-19**). Throughout the 20 year project period, average groundwater levels within the PSA in the Proposed Action are between approximately 2.5 ft lower and 2 ft higher than the No Action (**Figure 8-26**). These differences appear to be attributed largely to discrepancies in the time period during which the majority of groundwater pumping occurs in the deep zone between the No Action and Proposed Action runs. Deep zone groundwater levels in the Proposed Action are generally lower than the No Action during the Spring and Fall when the bulk of exchange pumping from the deep zone occurs and show recovery during the Summer and Winter when there is no exchange pumping from the deep zone. The distribution of deep zone water level differences between the Proposed Action and No Action at the end of Year 20 shows a relative increase in water levels in the northern portion of FWD near the SJR (**Figure 8-27**). Water levels tend to respond more quickly to the lack of exchange pumping in Year 20 in the deep zone than the shallow zone because the deep zone is confined (storage coefficient is several orders of magnitude smaller than the shallow zone).

West of the San Joaquin River and east of the Chowchilla Bypass, the relative difference between the Proposed Action and No Action are no greater than 3 ft (average 0.4 and 0 ft higher) (**Table 8-3**). In the MWA, Proposed Action deep zone water levels are between 0 and 3 ft lower than the No Action (average 0.8 ft lower) at the end of Year 20. North of the San Joaquin River, Proposed Action water levels are between 0 and 4 ft higher than the No Action (average 0.5 ft higher). West of the Fresno Slough, Proposed Action groundwater levels are between 3 ft lower and 2 ft higher than the No Action (average 0.2 ft lower). East of the Fresno Slough, Proposed Action groundwater levels are between 2 ft lower and 8 ft higher than the No Action (average 0.1 ft higher) (**Table 8-3**).

8.2.1.3 Lower Aquifer

Lower aquifer average groundwater levels are approximately 28 ft msl within the PSA at the end of Year 20. Winter/Spring average groundwater levels declined by an average of 18 ft while Summer/Fall water levels declined by about 16 ft (**Table 8-1**). As a fraction of the pressure head at the base of the lower zone this represents a decrease of about 2 percent (**Table 8-2**). During the irrigation season, water levels decline by between 20 to 25 ft in the lower aquifer, however, groundwater levels generally recover in the Winter/Spring (**Figure 8-28**). Drawdown due to groundwater pumping from MPG ranges from between 2 ft in the Winter/Spring and 3 ft in the Summer/Fall (**Table 8-4**). This represents a decrease of less than 1 percent of the pressure head at the base of the lower aquifer at the start of Year 1 (**Table 8-5**).

At the end of Year 20, Proposed Action water levels are between 0.5 ft lower (Winter/Spring) to 0.2 ft higher (Fall/Summer) than the No Action (**Table 8-18**). This amount is less than 0.1 percent of the saturated thickness of the lower aquifer at the beginning of Year 1 (**Table 8-19**). Seasonally, the difference in average water levels in the lower aquifer within the PSA in the Proposed Action are between about 2 ft lower and 1 foot higher than the No Action (**Figure 8-29**).

8.2.2 Groundwater Quality

8.2.2.1 Shallow Zone

Average shallow zone TDS concentrations were 1,700 mg/L within the PSA at the end of Year 20. Simulated shallow zone TDS concentrations are highest west of the Pool in the saline front and generally lowest near the SJR where leakage of low TDS water from the river improves groundwater quality (**Figure 8-30**). Average simulated shallow TDS concentrations in the PSA decrease by almost 20 mg/L from Year 1 to Year 20 (**Table 8-6**). Average TDS concentrations are relatively stable throughout the 20-year simulation and do not vary significantly within each year (**Figure 8-31**). Contours of equal TDS concentrations show that the saline front advances most in the area west of the Terra Linda Canal recharge facility and north of the Pool from Year 1 to Year 20 (**Figure 8-32**). Simulated TDS concentrations in individual wells show both increasing and decreasing TDS concentrations depending on the subarea (**Appendix D**). The largest change in shallow zone TDS concentrations occurs west of the Fresno Slough. The remaining portion of the PSA exhibits little change over the project period (**Figure 8-33**). TDS concentrations increase the most west of the Terra Linda Canal and north of Whitesbridge Road west of the Fresno Slough (**Figure 8-33**).

North of the San Joaquin River and east of the Chowchilla Bypass, shallow zone TDS concentrations change very little (average 30 mg/L decrease to 30 mg/L increase, respectively) from Year 1 to Year 20 (**Table 8-7**). West of the San Joaquin River shallow zone TDS concentrations are about 500 mg/L lower to 960 mg/L higher (average 200 mg/L higher) in Year 20 compared to Year 1 (**Table 8-7**). West of the Fresno Slough, TDS concentrations in Year 20 are about 960 mg/L lower to about 2,600 mg/L higher (average 60 mg/L higher) than in Year 1. In the MWA TDS concentrations are between 1,400 mg/L lower to 1,100 mg/L higher (average 220 mg/L lower) at the end of Year 20. East of the Fresno Slough, TDS concentrations are between 1,600 mg/L lower to almost 500 mg/L higher (average 50 mg/L lower) in Year 20 than Year 1 (**Table 8-7**).

The area in the shallow zone within the PSA which exceeds 800 mg/L decreases by about 660 ac from Year 1 to Year 20, while the area which exceeds 1,200 and 2,000 mg/L increase by about 300 ac and 250 ac, respectively (**Table 8-8**).

Average shallow zone TDS concentrations within the PSA are about 11 mg/L higher than the No Action at the end of Year 20 (**Table 8-20**). Throughout the 20-year simulation, shallow zone TDS concentrations in the Proposed Action tend to increase relative to the No Action in years where exchange pumping is simulated and generally decreases during years where no pumping for groundwater exchange is assigned (**Figure 8-34**). Proposed Action TDS concentrations in the shallow zone are greater than the No Action in areas west of the Fresno Slough by the end of Year 20 (**Figure 8-35**). Over the majority of the PSA, shallow zone Proposed Action TDS concentrations are similar to those simulated in the No Action at the end of Year 20 (**Figure 8-35**).

Table 8-20: Difference in Average TDS Between No Action and Proposed Action/Alternative 2 at the End of the 20-Year Exchange Program

Depth Zone	Proposed Action minus No Action (mg/L)	Alternative 2 minus No Action (mg/L)
Shallow Zone	11	7
Deep Zone	7	6
Lower Aquifer	<1	<1

1. Average calculated from the simulated TDS concentration in model cells within the Primary Study Area. Difference calculated from the average TDS concentration at the end of the proposed exchange program in the Proposed Action/Alternative 2 minus the No Action.

A comparison of water quality results by subarea in Year 20 within the PSA between the Proposed Action and No Action yielded variable results. North of the San Joaquin River, shallow zone Proposed Action TDS concentrations are between 20 mg/L lower to 20 mg/L higher than the No Action and average almost 5 mg/L greater at the end of Year 20 (**Table 8-7**). West of the San Joaquin River, Proposed Action TDS concentrations are between 50 mg/L lower to 30 mg/L higher (average 1 mg/L higher) than the No Action at the end of Year 20 (**Table 8-7**). West of the Fresno Slough, shallow zone Proposed Action TDS concentrations are from about 960 mg/L lower to 2,200 mg/L higher (average 50 mg/L higher) than the No Action at the end of Year 20. In the MWA, Proposed Action shallow zone TDS is from about 80 mg/L lower to almost 800 mg/L higher (average 20 mg/L higher) than the No Action at the end of Year 20 (**Table 8-7**). East of the Fresno Slough, Proposed Action shallow zone TDS concentrations are between 300 mg/L lower to 560 mg/L higher (average 9 mg/L lower) than the No Action at the end of Year 20. East of the Chowchilla Bypass, shallow TDS in the Proposed Action is from 20 mg/L lower to 40 mg/L higher (average 1 mg/L higher) than the No Action (**Table 8-7**).

Simulated results show that the Proposed Action will result in an additional 200 ac over the No Action within the shallow zone which exceed the 800 mg/L (**Table 8-21**). The area in the shallow zone in the Proposed Action which exceeds 1,200 and 2,000 is about 120 ac and 130 ac greater, respectively, than the No Action at the end of Year 20 (**Table 8-21**).

Table 8-21: Difference in Number of Acres Exceeding TDS Thresholds Between the No Action and Proposed Action/Alternative 2 At the End of the 20-Year Exchange Program[1]

Threshold Concentration	Proposed Action minus No Action (ac)		Alternative 2 minus No Action (ac)	
	Shallow	Deep	Shallow	Deep
800 mg/L	200	290	140	310
1,200 mg/L	120	270	60	290
2,000 mg/L	130	170	40	170

8.2.2.2 Deep Zone

The average deep zone TDS concentration in the PSA at the end of Year 20 was 1,500 mg/L. The highest deep zone concentrations in the Proposed Action are simulated west of the Fresno Slough in the saline front (**Figure 8-36**). The lowest simulated deep zone concentrations generally are near the San Joaquin River due to leakage of low TDS surface water from the river and shallow zone (**Figure 8-36**). Average deep zone concentrations in the Proposed Action increase by about 210 mg/L from Year 1 to Year 20 (**Table 8-6**). While average deep zone TDS concentrations in the PSA increase relatively linearly, simulated TDS concentrations in individual wells are more variable throughout the 20-year period (**Figure 8-37, Appendix D**). Contours of equal TDS concentrations show that the saline front advances along the majority of the Fresno Slough, though is less pronounced north of the Terra Linda Recharge canal (**Figure 8-38**). Changes in TDS concentrations are greatest in the saline front near the Fresno Slough, which increases by over 2,000 mg/L in some areas, and are generally less than 500 mg/L throughout the majority of the PSA (**Figure 8-39**).

North and west of the San Joaquin River and east of the Chowchilla Bypass, deep zone TDS concentrations at the end of Year 20 are less than 1,000 mg/L different than in Year 1 (**Table 8-7)**. West of the Fresno Slough, deep zone Year 20 TDS concentrations are between 570 mg/L lower to 2,200 mg/L (average 640 mg/L) higher than Year 1. In the MWA, deep zone simulated TDS concentrations are between 680 mg/L lower to 1,800 mg/L higher in Year 20 than Year 1 (**Table 8-7**). East of the Fresno Slough, Year 20 deep zone TDS concentrations are between 1,200 mg/L lower to 2,100 mg/L higher than Year 1 (**Table 8-7**).

The area in the deep zone which exceeds 800 mg/L and 2,000 mg/L increase by almost 3,700 ac and 2,300 ac, respectively, during the 20-year simulation in the Proposed Action (**Table 8-9**). The area which exceeds 1,200 mg/L decreases by about 450 ac between Year 1 and Year 20 (**Table 8-9**).

Average deep zone TDS concentrations in the PSA are 7 mg/L higher in the Proposed Action than the No Action at the end of Year 20 (**Table 8-20, Figure 8-40**). Between Year 1 and Year 20 the difference between the two runs increases slightly over the project period (**Figure 8-40**). The mapped difference between No Action and Proposed Action TDS concentrations at the end of Year 20 is more modest in the deep zone than in the shallow zone (**Figure 8-41**). The greatest differences occur east of the Fresno Slough, which shows a relative increase of nearly 1,000 mg/L, and west of the Fresno Slough, which shows a relative decrease of more than 1000 mg/L (**Figure 8-41**). Proposed Action TDS concentrations are up to 480 mg/L higher than the No Action south of the San Joaquin River and up to 880 mg/L higher than the No Action near Whitesbridge Avenue at the end of Year 20 in the deep zone. Throughout the majority of the PSA, Proposed Action TDS in the deep zone is within 100 mg/L of the No Action (**Figure 8-41**).

A comparison of water quality results by subarea in Year 20 within the PSA between the Proposed Action and No Action yielded variable results. North of the San Joaquin River, Proposed Action TDS concentrations in the deep zone are between 50 mg/L lower to 150 mg/L greater (average 3 mg/L higher) than the No Action concentrations at the end of Year 20. West of the San Joaquin River, deep zone Proposed Action TDS concentrations are between 50 mg/L lower to about 30 mg/L higher (average 2 mg/L lower) than the No Action concentrations at the end of Year 20 (**Table 8-7**). In the MWA, deep zone Proposed Action TDS concentrations are between 180 mg/L lower to about 300 mg/L higher (average 40 mg/L higher) than the No Action at the end of Year 20. East of the Fresno Slough, Proposed Action TDS concentrations are almost190 mg/L lower to about 1,500 mg/L higher (average 40 mg/L higher) than the No Action at the end of Year 20 (**Table 8-7**). East of the Chowchilla Bypass, Proposed Action TDS concentrations were between 20 mg/L lower to about 30 mg/L higher (average 2 mg/L higher) than the No Action at the end of Year 20 (**Table 8-7**).

Compared to the No Action, an additional 290 ac are simulated to exceed the 800 mg/L threshold in the deep zone in the Proposed Action at the end of Year 20 **(Table 8-21**). An additional 270 ac and 170 ac are simulated to exceed the 1,200 and 2,000 mg/L thresholds in the deep zone in the Proposed Action at the end of Year 20 (**Table 8-21**).

8.2.2.3 Lower Aquifer

The Proposed Action TDS in the lower aquifer at the end of Year 20 averaged 670 mg/L in the PSA. Average TDS in the lower aquifer increased by 3 mg/L during the 20-year proposed project period (**Table 8-6**). Simulated TDS concentrations in the PSA and in specific wells were relatively stable from Year 1 to Year 20 (**Figure 8-42, Appendix D**). At the end of Year 20 the average simulated Proposed Action TDS concentration in the PSA was less than 1 mg/L higher than the No Action (**Table 8-20**). Differences in average TDS in the PSA and in specific wells between the Proposed Action and No Action are relatively minimal throughout the 20-year simulation (**Figure 8-43, Appendix D**).

8.2.2.4 MPG Well Groundwater Quality

Out of 76 MPG wells, 27 included in the exchange program wells were simulated to have TDS concentrations that exceed 1,200 mg/L by Year 20 of the project period. In the Proposed Action, 12 of the 27 wells also exceed 2,000 mg/L TDS by Year 20 (**Table 8-10**). Average TDS concentrations in MPG wells over the project period were calculated to assess how many wells had average concentrations that exceed 1,200 and 2,000 mg/L. For the Proposed Action scenario, 33 wells had average TDS concentrations that exceeded 1,200 mg/L and 12 wells exceeded 2,000 mg/L (**Table 8-11**).

8.2.3 Subsidence

Subsidence in the form of compaction was evaluated at the Fordel and Yearout extensometer locations. These extensometers measure compaction that occurs above the Corcoran Clay. In the Proposed Action scenario, total inelastic compaction by Year 20 ranged from about 0.33 ft at Yearout to about 0.1 ft at the Fordel extensometer (**Tables 8-12 and 8-13**, **Figure 8-44**). Seasonal variations in elastic compaction occurred at both extensometer locations with the greatest fluctuations at Yearout (about 0.06 ft) as compared to Fordel (0.03 ft) (**Figure 8-44**). The average annual inelastic compaction was about 0.016 ft at Yearout (**Table 8-12**) and 0.004 ft at Fordel (**Table 8-13**).

The difference in total inelastic compaction between the Proposed Action and No Action scenarios was about 0.035 ft over the 20 year project period at Yearout and 0.013 ft at Fordel. On an average annual basis, these differences are about 0.002 and less than 0.001 ft, respectively at Yearout and Fordel extensometer locations.

The proportion of total inelastic compaction over the project period associated with MPG pumping for exchange was 0.099 ft and 0.058 ft at the Yearout and Fordel extensometers, respectively (**Tables 8-12 and 8-13**). The remaining portion of total inelastic compaction was associated with non-MPG and MPG pumping for adjacent and overlying use. On an annual basis, MPG pumping for exchange in the Proposed Action resulted in 0.005 and 0.003 ft inelastic compaction at the Yearout and Fordel extensometer locations, respectively.

Compared to the No Action scenario, the Proposed Action resulted in a very small increase in total inelastic compaction (less than 0.05 ft after 20 years at both the Fordel and Yearout extensometer locations (**Figures 8-45 and 8-46**).

8.2.4 Surface Water Quality

The mixing model that calculated surface water quality at the Mendota Dam simulated TDS concentrations ranging from 220 mg/L (July) to about 365 mg/L (January) with an annual average of about 293 mg/L (**Table 8-22**). The inflows to the model from the San Joaquin River ranged from 1,600 to about 27,000 af/per month with TDS concentrations ranging from 26 to 36 mg/L. Flows from the DMC range from about 12,000 to 130,000 afm with TDS concentrations ranging from about 240 to 460 mg/L. Inflows from the Pool were estimated to be 0 to about 37,000 af with TDS concentrations ranging from about 230 to 370 mg/L. Inflows from FWD averaged about 10,000 afy and was limited to the months of March through May and September and October. Outflows in the mixing model were to the outflow canals (Firebaugh, Main, Outside, and Columbia) and ranged from about 2,000 to 93,000 af per month. Outflows to the Mendota Dam ranged from about 11,000 to 80,000 af per month.

The mixing model that calculated surface water quality at the MWA simulated TDS concentrations from average MPG pumping conditions over the project period and also MPG pumping during dry year conditions (**Tables 8-23 and 8-24**). TDS concentrations simulated given average year conditions range from 310 mg/L (July) to about 485 mg/L (April) with an annual mean of about 414 mg/L (**Table 8-23**). The inflows from the City of Mendota and Meyers Water Bank totaled about 2,000 to 3,000 afy, respectively, while inflows from adjacent pumping was about 6,600 afy. The contribution of TDS at the MWA from adjacent pumping and pumping for exchange averaged about 50 mg/L annually (28 mg/L for exchange pumping and 22 mg/L for adjacent pumping). TDS from the DMC had an annual average of 353 mg/L. TDS contributions from the Meyers Water Bank and the City of Mendota averaged about 11 mg/L (**Table 8-23**).

Under dry year conditions, simulated TDS concentrations at the MWA ranged from about 315 mg/L (July) to about 487 mg/L (March and May) with an average annual mean of about 424 mg/L (**Table 8-24**). Assuming dry year conditions, pumping from MPG leads to a total average annual increase of 58 mg/L in TDS at the MWA. Of this, 32 mg/L is attributed to MPG exchange pumping and 26 mg/L is attributed to adjacent pumping.

8.2.5 Water Budget

The Proposed Action water budget from the project period and two preceding years is summarized on an annual basis (**Table 8-25**). Water budget terms from the groundwater model include stream and canal seepage, areal recharge, recharge facilities, net subsurface inflow, lake seepage, groundwater pumping, aquifer storage, and interbed storage. Stream and canal seepage ranges from about 73,000 to 170,000 afy with the largest amounts occurring in years with high streamflow. The annual average is about 111,000 afy. Areal recharge ranges from about 163,000 to 315,000 afy with the highest amount of recharge occurring during average and wet years. The annual average is about 226,000 afy. Recharge from the recharge ponds varies between 1,500 to about 28,000 afy and are dependent on Meyers Water Bank operations and availability of water for NCR recharge ponds. The annual average is about 8,800 afy. Net lateral inflow is the net amount of subsurface inflow into the model domain. Positive values indicate there is more subsurface water flowing into the model domain compared to flowing out of the system, while negative numbers indicate more groundwater is flowing out than entering the system. Net lateral inflow ranges from about -44,000 to about 91,000 afy with most years showing more groundwater entering the model domain than leaving. The annual average is about 52,000 afy. Seepage from the LAK package shows very little variation and ranges from 31,000 to 41,000 afy with an annual average of about 37,000 afy. Groundwater pumping is the largest water budget component and ranges from about 380,000 to about 570,000 afy with an annual average of about 480,000 afy. Storage varies annually and negative values in **Table 8-25** indicate an increase in storage while positive values represent a decrease in storage. Over the project period storage ranges from -166,000 to about 170,000 afy with an annual average of about 30,000 of decrease. Interbed storage ranges from -10,000 to about 78,000 afy with an annual average of 22,000 afy of decrease.

8.3 Alternative 2

8.3.1 Groundwater Levels

8.3.1.1 Shallow Zone

Average shallow zone groundwater levels in the PSA were 130 ft msl at the end of Year 20. Groundwater levels are generally highest at the western edge of the model domain and near the SJR and lowest towards the edge of the A clay in the northeastern portion of the shallow zone (**Figure 8-47**). Average shallow Winter/Spring groundwater levels within the PSA declined by 9 ft between Year 1 and Year 20 while Summer/Fall groundwater levels declined by 5 ft (**Table 8-1**). With respect to the saturated thickness of the shallow zone, this represents a 7 to 12 percent decrease in water levels (**Table 8-2**). Average groundwater levels in the shallow zone tend to fluctuate generally less than 5 ft due to seasonal variations in groundwater pumping and generally show additional decline during dry periods followed by recovery during wetter periods (**Figure 8-48**). Contours of the change in shallow groundwater levels between Year 1 and 20 show increases in water levels in the vicinity of Meyers Water Bank and declines are generally concentrated away from surface water features or where there is increased hydraulic connection between the shallow and deep zones (Spreckels Sugar Company area) (**Figure 8-49**).

By sub-region, groundwater levels change the most north of the San Joaquin River and east of the Chowchilla Bypass which both decline by an average of 6 ft (**Table 8-3**). In all other sub-regions groundwater levels decline between 4 and 5 ft over the project period (**Table 8-3**).

Groundwater pumping from MPG causes simulated water levels to decline by an average of between 6 ft in both the Summer/Fall and Winter/Spring (**Table 8-4**). This represents a decrease in the saturated thickness of the shallow zone at the beginning of Year 1 of about 8 percent (**Table 8-5**).

Relative impacts of the Alternative 2 on shallow zone water levels are similar to those simulated in the Proposed Action run. At the end of the 20-year exchange program, average simulated Alternative 2 shallow zone groundwater levels within the PSA are a foot or less lower than the No Action (**Table 8-18**). This represents a decrease about 1 percent in the simulated saturated thickness of the shallow zone at the beginning of Year 1 (**Table 8-19**). The hydrograph of average simulated water level difference within the PSA shows that Alternative 2 shallow zone groundwater levels are between 2 ft lower than the No Action to l ft higher than the No Action suggesting the relative impacts of Alternative 2 average shallow water levels are not very substantial compared to the No Action (**Figure 8-26**). Shallow zone contours of water level difference between the Alternative 2 and No Action are shown in **Figure 8-50**. Alternative 2 shallow zone groundwater levels are generally higher than the No Action in the vicinity of MPG wells west of the Fresno Slough and lower south of the SJR with distance from MPG wells. This is due in part to the lesser amount of pumping assigned in the shallow zone in the Alternative 2 compared to the No Action in Year 20 and recharge assigned in the River Ranch North recharge facility.

North of the San Joaquin River, Alternative 2 shallow zone water levels up to 2 ft higher than the No Action (average less than 1 foot). West of the San Joaquin River, Alternative 2 shallow zone water levels are up to 3 ft greater than the No Action (average less than 1 foot higher). In the MWA, groundwater levels in the shallow zone are generally lower than the No Action by up 5 ft (average 1 foot lower). East of the Fresno Slough, the results from this scenario are more mixed and are between 5 ft lower to 10 ft higher than the No Action (average 1 foot lower). East of the Bypass, groundwater levels in the "shallow zone" (A-Clay is not present in this area) are up to 2 ft lower than the No Action (average less than 1 foot lower) (**Table 8-3**).

8.3.1.2 Deep Zone

Average deep zone groundwater levels were about 101 ft msl within the PSA at the end of Year 20. Comparisons between Summer/Fall water levels show a decline by about 9 ft over the 20-year project period in the PSA while Winter/Spring water levels decline by 13 ft (**Table 8-1**). As a fraction of the pressure head at the base of the deep zone, this represents a decrease of between 3 and 4 percent (**Table 8-2**). Generally, groundwater levels show a similar distribution to those simulated in the Proposed Action by the end Year 20. The highest water levels are simulated near the western portion of the model domain and near the SJR, and the lowest in the northern portion of the domain (**Figure 8-51**). Groundwater pumping during the irrigation season produce between 15 and 20 ft of seasonal declines in average deep zone groundwater levels within the PSA. Seasonal declines tend to recover when pumping is reduced in the late Fall and Winter (**Figure 8-52**). Contours of simulated groundwater change over the 20-year exchange period generally show that water levels changed minimally along the southern edge of the model domain and declined in the northern portion of the model domain to a maximum of over 45 ft (**Figure 8-53**).

The greatest change in average water levels within the PSA over the project period occurs in the sub-regions located north of the SJR and east of the Chowchilla Bypass which decline by 16 and 17 ft, respectively (**Table 8-3**). Groundwater levels declined by an average of 10 ft east of the Fresno Slough. In all other sub-regions, average water levels exhibited 3 and 6 ft of decline (**Table 8-3**).

Groundwater pumping from the MPG produces an average decline of between 5 ft in Summer/Fall deep groundwater levels and 6 ft in Winter/Spring water levels at the end of Year 20 (**Table 8-4**). This amounts to a decrease of about 2 percent in the average pressure head at the base of the deep aquifer at the start of Year 1 (**Table 8-5**).

Average simulated groundwater levels in the Alternative 2 in the deep zone were about 1 foot higher than the No Action in both the Winter/Spring and Summer/Fall (**Table 8-18**). This amount represents about a 1 percent decrease in the pressure head at the base of the deep aquifer at the start of Year 1 (**Table 8-19**). Average water levels in the Alternative 2 run range from between approximately 3 ft lower and 2 ft higher than the No Action and generally show some recovery during years where no MPG exchange pumping occurs (**Figure 8-26**). Contours of the simulated difference in deep zone water levels in the Alternative 2 scenario are between 1 and 3 ft higher than the No Action at the end of Year 20 (**Figure 8-54**). The distribution and magnitude of deep zone relative water level increases in the

Alternative 2 is generally greater than the Proposed Action suggesting that recharge in the River Ranch north facility does have some impact (albeit small) on water levels in the deep zone (**Figure 8-54**).

North of the San Joaquin River, Alternative 2 deep zone groundwater levels are between 0 and 5 ft greater than the No Action at the end of Year 20 and average water levels are nearly 1 foot higher (**Table 8-3**). West of the San Joaquin River and east of the Chowchilla Bypass, Alternative 2 deep zone groundwater levels are between 1 foot lower and 2 ft higher than the No Action (averages less than 1 foot). West of the Fresno Slough, Alternative 2 deep zone groundwater levels are between 3 ft lower to 2 ft higher than the No Action (average less than 1 foot higher). In the MWA, groundwater levels are between 3 to 0 ft lower than the No Action (average less than 1 foot lower). East of the Fresno Slough, deep zone water levels range from between 2 foot lower to 8 ft higher than No Action (average about 0 ft higher) (**Table 8-3**).

8.3.1.3 Lower Aquifer

Simulated average groundwater levels in the lower aquifer averaged approximately 30 ft msl at the end of Year 20. Winter/Spring average simulated water levels declined by about 18 ft over the 20 year project period, while Summer/Fall water levels declined by about 16 ft (**Table 8-1)**. As a proportion of the pressure head at the base of the lower zone, this represents a decrease of about 2 percent (**Table 8-2)**. Seasonal declines between 20 and 25 ft in average water levels in the lower aquifer occur during the irrigation season (**Figure 8-55**). Simulated drawdown attributed to MPG pumping in the lower aquifer varies between 2 to 3 ft (**Table 8-4**). As a percentage of the pressure head at the base of the lower aquifer this amount represents approximately less than 1 percent (**Table 8-5**).

Alternative 2 water levels in the lower aquifer are between less than 1 foot lower in the Winter/Spring and less than 1 foot higher in the Summer/Fall than the No Action at the end of Year 20 (**Table 8-18**). As a fraction of the pressure head at the base of the lower aquifer, this represents a relative change of less than 1 percent (**Table 8-19**). Average water levels in the PSA in the Alternative 2 are between 2 ft lower and 1 foot higher than the No Action (**Figure 8-29**). The difference in lower aquifer water levels between the Alternative 2 and No Action are relatively indistinguishable from the Proposed Action suggesting that recharge from the River Ranch North recharge facility does not substantially affect lower aquifer water levels.

Over the majority of the model domain, water levels in the Alternative 2 scenario are relatively similar to those simulated in the Proposed Action throughout the predictive simulation. Differences in groundwater levels (>1 foot) between the two model runs are primarily evident in the vicinity of the River Ranch North recharge facility. Water levels, particularly in the shallow zone, tend to increase by an additional 3 to 5 ft due to recharge applied to the River Ranch North recharge facility in Alternative 2. Water levels in deep zone observation wells show a similar, but more dampened (up to 2 to 3 ft), response that is likely reduced due to the presence of confining layers beneath recharge facilities. In general, relative water level increases are largely concentrated in observations near the recharge facilities.

8.3.2 Groundwater Quality

8.3.2.1 Shallow Zone

Shallow zone TDS concentrations in the PSA averaged 1,700 mg/L at the end of Year 20. Simulated shallow zone TDS concentrations are highest west of the Fresno Slough in the saline front and generally lowest adjacent to the San Joaquin River (**Figure 8-56**). Average simulated shallow zone TDS concentrations in the PSA show a decrease of about 20 mg/L over the 20-year project period (**Table 8-6**). Average shallow zone TDS concentrations during the project period are relatively stable throughout the 20-year simulation (**Figure 8-57**). Contours of equal shallow zone TDS concentrations at the beginning and end of the 20-year exchange agreement show some advancement of the saline front largely near the northern portion of the Fresno Slough. However, migration of the saline front is considerably reduced in the vicinity of the River Ranch North recharge facility (**Figure 8-58**). A color flood map depicting areas within the PSA where TDS concentrations have changed from Year 1 to Year 20 indicate the greatest change occurs west of the Pool and the River Ranch North recharge facility in the vicinity of the saline front (**Figure 8-59**). Away from the saline front, TDS concentrations show very little change over the 20-year simulation (**Figure 8-59**).

North of the San Joaquin River, shallow zone TDS concentrations in Year 20 are between 420 mg/L lower to 160 mg/L higher (average 30 mg/L lower) than at the beginning of Year 1 (**Table 8-7**). West of the San Joaquin River, shallow TDS concentrations vary from a decrease of 510 mg/L to an increase of up to 960 mg/L (average about 200 mg/L higher). West of the Fresno Slough, TDS concentrations in the shallow zone are between 980 mg/L lower to 2,600 mg/L higher (average about 60 mg/L higher) at the end of the 20-year project period (**Table 8-7**). In the MWA, TDS is almost 1,400 mg/L lower to about 1,050 mg/L higher (average 220 mg/L lower). East of the Fresno Slough, shallow TDS concentrations are 1,600 mg/L lower to almost 500 mg/L higher (average about 60 mg/L lower) at the end of Year 20 (**Table 8-7**). East of the Chowchilla Bypass, the change in TDS concentrations range from a decrease of about 150 mg/L and increase by up to 160 mg/L (average about 30 mg/L higher) at the end of Year 20 (**Table 8-7**).

When compared to the No Action scenario, the average shallow zone TDS concentration in the PSA in the Alternative 2 is about 6 mg/L greater by the end of Year 20 (**Table 8-20**). Average TDS concentrations show a generally constant relative increase compared to the No Action during the 20-year period in years where there is pumping for groundwater exchange (**Figure 8-34**). However, in years where no exchange pumping is simulated in conjunction with recharge at the River Ranch North and Terra Linda Canal recharge facilities, Alternative 2 average TDS concentrations show a decrease relative to the No Action and is almost 3 mg/L lower than the No Action in Year 7 (**Figure 8-34**). The mapped difference between the Alternative 2 and No Action in the shallow zone shows a considerable relative decrease west of the River Ranch North recharge facility in the Alternative 2 at the end of Year 20 **(Figure 8-60**). Near Whitesbridge Road, Alternative 2 shallow zone TDS concentrations west of the Fresno Slough are substantially higher than the No Action at the end of Year 20. With distance from the Fresno Slough, shallow zone TDS concentrations in the Alternative 2 are similar to the No Action TDS concentrations (**Figure 8-60**).

North of the San Joaquin River, Alternative 2 TDS concentrations in the shallow zone are between 10 mg/L lower to almost 20 mg/L greater (average 4 mg/L higher) than the No Action concentrations at the end of Year 20.TDS concentrations west of the San Joaquin River were between 50 mg/L lower to about 40 mg/L higher at the end of Year 20 compared to the No Action (average 2 mg/L higher). West of the San Joaquin River, Alternative 2 shallow zone TDS concentrations are about 2,200 mg/L lower to 2,100 mg/L higher (average 14 mg/L higher) than the No Action at the end of Year 20 (**Table 8-7**). In the MWA, TDS concentrations are between 80 mg/L lower to 800 mg/L higher (average 20 mg/L higher) than the No Action (**Table 8-7**). East of the Fresno Slough, TDS concentrations in the shallow zone are between 300 mg/L lower to about 600 mg/L higher (average 8 mg/L lower) than the No Action at the end of Year 20 (**Table 8-7**). East of the Chowchilla Bypass, Alternative 2 simulated TDS concentrations are between 20 mg/L lower to 40 mg/L higher (average 1 mg/L higher) than the No Action at the end of Year 20.

The area in the shallow zone within the PSA which exceeds 800 mg/L at the end of Year 20 is about 700 ac less than in Year 1in the Alternative 2 run (**Table 8-8**). The area which exceeds 1,200 and 2,000 mg/L at the end of Year 20 increases by about 250 ac and 170 ac, respectively (**Table 8-8**).

Approximately 140 more ac within the PSA exceed 800 mg/L in the shallow zone in the Alternative 2 than the No Action at the end of Year 20 (**Table 8-21**). The shallow zone area exceeding 1,200 and 2,000 mg/L in the PSA is 60 ac and 40 ac greater in the Alternative 2 than the No Action at the end of Year 20 (**Table 8-21**).

8.3.2.2 Deep Zone

The TDS concentration in the deep zone in the Alternative 2 averaged 1,500 mg/L in the PSA at the end of Year 20. Deep zone TDS concentrations are highest west of the Fresno Slough and generally lowest near the San Joaquin River (**Figure 8-61**). Average simulated deep zone TDS in the Alternative 2 show an increase of about 210 mg/L over the 20-year simulation (**Table 8-6**). The average concentration of TDS in the PSA increases linearly throughout the 20-year period and is minimally impacted by years where exchange pumping does not occur (**Figure 8-62**). Contours of TDS show that the saline front migrates the most near the Fresno Slough and the least west of the San Joaquin River, north of the Pool (**Figure 8-63**). The largest change in TDS concentrations over the 20-year period occur near the Fresno Slough in the area between the River Ranch North recharge facility and about 1 mile south of Whitesbridge Road (**Figure 8-64**).

In the subarea north of the San Joaquin River, Year 20 deep zone TDS concentrations are between 300 mg/L lower to almost 600 mg/L higher (average about 40 mg/L higher) than in Year 1 in the Alternative 2 (**Table 8-7**). West of the San Joaquin River, TDS concentrations are about 300 mg/L lower to 960 mg/L higher (average about 400 mg/L higher) at the end of Year 20. West of the Fresno Slough, TDS concentrations are between 540 mg/L lower to 2,200 mg/L higher (average 630 mg/L higher) at the end of the 20-year simulation (**Table 8-7**). In the MWA, the TDS concentration is lower by almost 700 mg/L and higher by almost 1,800 mg/L (average about 320 mg/L higher) by the end of Year 20. East of the Fresno Slough, TDS concentrations are between 1,200 mg/L lower to about 2,100 mg/L higher (average about 300 mg/L higher) by the end of Year 20. East of the Chowchilla Bypass, TDS concentrations are lower by about 150 mg/L and increase by almost 340 mg/L (average about 50 mg/L higher) between Year 1 and Year 20 (**Table 8-7**).

The area in the deep zone which exceeds the 800 and 2,000 mg/L increases by almost 3,700 ac and 2,300 ac in the PSA between Year 1 and Year 20 (**Table 8-9**). The deep zone area which exceeds 1,200 mg/L decreases by almost 430 ac over the same period (**Table 8-9**).

The average TDS concentration in the deep zone within the PSA is almost 6 mg/L higher in the Alternative 2 than the No Action (**Table 8-20, Figure 8-40**). Between Year 1 and Year 20 the difference between the two runs increase slightly over the project period (**Figure 8-40**). The difference in TDS concentrations between the two runs does not increase or even declines (between Year 4 and Year 8) when exchange pumping either is not simulated or there is recharge in MPG facilities adjacent to the Fresno Slough (**Figure 8-40**). The relative mapped difference in TDS between the Alternative 2 and No Action is generally similar to the Proposed Action (**Figure 8-65**).

West of the San Joaquin River and east of the Chowchilla Bypass, Alternative 2 and No Action TDS concentrations are within 50 mg/L of one another (**Table 8-7**). North of the San Joaquin River, Alternative 2 deep zone TDS concentrations are about 50 mg/L lower to 160 mg/L higher (average 3 mg/L higher) than the No Action (**Table 8-7**). West of the Fresno Slough, Alternative 2 deep zone TDS concentrations are about 1,100 mg/L lower to 1,500 mg/L higher (average 10 mg/L lower) than the No Action at the end of Year 20. In the MWA, Alternative 2 TDS concentrations are about 170 mg/L lower to 320 mg/L higher (average 9 mg/L higher) than the No Action at the end of Year 20. East of the Fresno Slough, deep zone Alternative 2 TDS concentrations are between 170 mg/L lower to about 1,500 mg/L higher (average almost 40 mg/L higher) than the No Action at the end of Year 20 (**Table 8-7**).

Alternative 2 results in a small increase in acreage which exceeds the 800, 1,200, and 2,000 mg/L thresholds compared to the No Action scenario. The number of acreage which exceed the 800, 1,200, and 2,000 mg/L TDS concentration level increases by about 310, 290, and 170 ac, respectively, by the end of Year 20 (**Table 8-21**).

8.3.2.3 Lower Aquifer

TDS concentrations in the lower aquifer in the Alternative 2 scenario averaged 670 mg/L in the PSA at the end of Year 20. The average simulated TDS concentration in the lower aquifer is about 3 mg/L higher at the end of the 20-year exchange agreement (**Table 8-6**). Simulated TDS concentrations in the PSA and wells used in model calibration were relatively stable from Year 1 to Year 20 (**Figure 8-66, Appendix D**). Alternative 2 TDS concentrations in the lower aquifer were generally similar to average concentrations in the No Action scenario in the PSA (**Table 8-20**). The difference in average TDS in the PSA and in wells used for model calibration between the Alternative 2 and No Action are relatively minimal throughout the 20-year simulation (**Figure 8-43, Appendix D**).

8.3.2.4 MPG Well Groundwater Quality

Out of 76 MPG wells, 28 included for exchange wells were simulated to have TDS concentrations that exceed 1,200 mg/L by Year 20 of the project period. In the Alternative 2, 13 of the wells also exceed 2,000 mg/L TDS by Year 20 (**Table 8-10**). Average TDS concentrations in MPG wells over the project period were calculated to assess how many wells had average concentrations that exceed 1,200 and 2,000 mg/L. For the Alternative 2 scenario, 33 wells had average TDS concentrations that exceeded 1,200 mg/L and 12 wells exceeded 2,000 mg/L (**Table 8-11**).

8.3.3 Subsidence

Compaction results at the Fordel and Yearout extensometer sites are used to evaluate the impact of groundwater pumping on aquifer system compaction above the Corcoran clay. Total Alternative 2 compaction accumulated over the 20-year period was 0.327 ft at Yearout and 0.081 ft at Fordel (**Tables 8-12 and 8-13**). On an annual average basis, this results in 0.016 ft at Yearout and 0.004 ft at Fordel (**Table 8-12, Table 8-13**). The seasonal variability in simulated elastic compaction ranged up to 0.1 ft at Yearout and up to 0.05 ft at Fordel (**Figure 8-67**).

The difference in the total accumulated compaction over the 20-year period between the Alternative 2 and No Action scenarios was about 0.032 ft at Yearout and (**Table 8-12, Table 8-13**). The annual average is 0.002 at Yearout and less than 0.001 ft at the Fordel extensometer location (**Table 8-12, Table 8-13**). At both the Yearout and Fordel extensometer locations, the Alternative 2 run shows an increase in elastic compaction compared to the No Action during the Spring and Fall when exchange pumping occurs (**Figure 8-45, Figure 8-46**).

The proportion of total inelastic compaction attributed to MPG exchange pumping was estimated by comparing simulated compaction to an Alternative 2 model run with no assigned MPG exchange pumping. Inelastic compaction is estimated by comparing results from the Winter of each year when water levels recover. Compaction associated with MPG pumping for exchange was 0.099 ft and 0.058 ft at the Yearout and Fordel extensometers, respectively (**Tables 8-12 and 8-13**). The remaining portion of total inelastic compaction was associated with non-MPG and MPG pumping for adjacent and overlying use. On an annual basis, MPG pumping for exchange in the Alternative 2 run resulted in 0.005 and 0.003 ft of inelastic compaction at the Yearout and Fordel extensometer locations, respectively.

8.3.4 Surface Water Quality

The mixing model used to predict surface water quality at the Mendota Dam (northern mixing model) simulated TDS concentrations ranging from 220 mg/L in July to about 365 mg/L in January with an annual average of about 300 mg/L (**Table 8-26**). The inflows to the model from the San Joaquin River ranged from 1,600 to about 27,000 af per month with TDS concentrations ranging from 26 to 36 mg/L. Flows from the DMC ranged from about 13,000 to 130,000 af per month with TDS concentrations ranging from about 240 to 460 mg/L. Simulated inflows from the Pool ranged from 0 af per month in most months to a maximum of about 37,000 af per month with TDS concentrations ranging from about 230 to 370 mg/L. Inflows from FWD occurred during March through May, September and October.

During these months, inflows ranged from around 2,000 to 2,200 af per month with TDS concentrations ranging from around 360 to almost 400 mg/L. Outflows in the mixing model to the irrigation canals (Firebaugh, CCID Main, CCID Outside, and Columbia) ranged from about 2,000 to 93,000 af per month. Outflows to the Mendota Dam ranged from about 11,000 to 80,000 af per month. Pumping for groundwater exchange from FWD into the northern branch of the Pool leads to an average annual increase of approximately 1 mg/L in TDS concentrations in the San Joaquin River at the Mendota Dam (**Table 8-26**).

The mixing model developed to predict surface water quality at the MWA (southern mixing model) simulated TDS concentrations from average and dry year conditions for Alternative 2. Under the assumption of average conditions, simulated TDS concentrations at the MWA averaged 413 mg/L annually, and ranged from about 307 mg/L in July to 485 mg/L in April (**Table 8-27**). Total annual inflows from the DMC were about 92,000 af. MPG adjacent pumping into the Pool was approximately 6,600 af while MPG transfer pumping totaled about 10,500 af. The contribution to the annual average TDS at the MWA from MPG pumping was about 50 mg/L (21 mg/L due to adjacent pumping and 21 mg/L due to exchange pumping). The maximum impacts occur in August (47 mg/L increase) for adjacent pumping and August (58 mg/L increase) for exchange pumping. Pumping into the Pool from the City of Mendota and Meyers Water Bank totaled about 2,000 and 3,000 af leading to a combined increase in TDS of about 11 mg/L at the MWA (**Table 8-27**).

Under the dry year run, simulated TDS at the MWA averaged 422 mg/L and ranged from about 313 mg/L in July to 486 mg/L in March (**Table 8-28**). The relative increase in TDS in the MWA is attributed to a 22,500 af reduction annually in the DMC flows to the MWA during the dry year simulation. In the hypothetical dry year, average annual TDS concentrations increase by 33 mg/L due to exchange pumping and 24 mg/L due to adjacent pumping (**Table 8-28**). The greatest impacts occur in August for exchange (82 mg/L increase) and adjacent pumping (66 mg/L increase). Pumping from the Meyers Water Bank and City of Mendota lead to an average annual increase in TDS concentrations of 13 mg/L at the MWA (**Table 8-28**).

8.3.5 Water Budget

The water budget for the Alternative 2 scenario is tabulated in **Table 8-29**. Water budget results for stream and canal seepage, areal recharge, recharge facilities, net subsurface inflow, lake seepage, groundwater pumping, aquifer storage, and interbed storage are summarized on an annual basis during the project period along with two years that precede the project period that represent drought conditions. Stream and canal seepage ranges from about 68,000 to 170,000 afy with the largest amounts occurring in years with high streamflow. The annual average is 111,000 afy. Areal recharge ranges from about 163,000 to 315,000 afy with the highest amount of recharge occurring during average and wet years. The annual average is 226,000 afy. Recharge from the recharge ponds varies between 1,500 to about 31,000 afy and are dependent on Meyers Water Bank operations and availability of water for NCR recharge ponds. The annual average is 9,800 afy. Net lateral inflow is the net amount of subsurface inflow into the model domain. Positive values indicate there is more subsurface water flowing into the model domain compared to flowing out of the system, while negative numbers indicate more groundwater is flowing out than entering the system. Net lateral inflow ranges from about -44,000 to about 90,000 afy with most years showing more groundwater entering the model domain than leaving. The annual average is 52,000 afy of inflow into the model domain. Seepage from the LAK package shows very little variation and ranges from 31,000 to 41,000 afy. The annual average is 37,000 afy. Groundwater pumping is the largest water budget component and ranges from about 380,000 to about 570,000 afy with an annual average of about 480,000 afy. Storage varies annually and negative values in **Table 8-29** indicate an increase in storage while positive values represent a decrease in storage. Over the project period storage ranges from -167,000 to about 171,000 afy with an annual average storage decline of about 29,600 afy. Interbed storage ranges from -10,000 to about 78,000 afy with an annual average decline of about 21,500 afy.

Geographic Area	Change in Groundwater Elevation by Sub Area[1,2,3,4]		
	No Action (Adjacent Pumping: 33,395 af)	**Proposed Action** (Adjacent Pumping: 14,000 af)	**Alternative 2** (Adjacent Pumping: 14,000 af)
Shallow Zone	Average water level decrease by Year 20: 5 ft	Average water level decrease by Year 20: 5 ft	Average water level decrease by Year 20: 5 ft
North of the SJR	Total: -16 to 4 ft (-6 ft) Variability: 1 to 23 ft (4 ft)	Total: -16 to 4 ft (-6 ft) Relative: -1 to 2 ft (0.1 ft) Variability: 1 to 22 ft (4 ft)	Total: -16 to 4 ft (-6 ft (avg) Relative: 0 to 2 ft (0.2 ft) Variability: 1 to 22 (4 ft)
West of SJR	Total: -10 to -1 ft (- 4 ft) Variability: 1 to 17 ft (4 ft)	Total: -10 to -1 ft (-4 ft) Relative: 0 to 2 ft (0.3 ft) Variability: 1 to 17 ft (4 ft)	Total: - 9 ft to -1 ft (- 4 ft) Relative: 0 to 3 ft (0.5 ft) Variability: 1 to 17 ft (4 ft)
West of Fresno Slough	Total: -16 to 10 ft (-4 ft) Variability: 1 to 73 ft (5 ft)	Total: -10 to 10 ft (-5 ft) Relative: -6 to 19 ft (-0.2 ft) Variability: 2 to 65 ft (5 ft)	Total: - 10 ft to 11 ft (- 4 ft) Relative: - 5 to 19 ft (0.6 ft) Variability: 2 to 65 ft (6 ft)
Mendota Wildlife Area	Total: -12 to 6 ft (- 3 ft) Variability: 0 to 10 ft (2 ft)	Total: -14 to 6 ft (-5 ft) Relative: -6 to 0 ft (-1.5 ft) Variability: 1 to 10 ft (2 ft)	Total: -14 ft to 6 ft (- 5 ft) Relative: -5 ft to 0 ft (- 1.4 ft) Variability: 1 to 10 ft (2 ft)
East of Fresno Slough	Total: -13 to 14 ft (- 3 ft) Variability: 2 to 38 ft (6 ft)	Total: -15 to 13 ft (-5 ft) Relative: -5 to 9 ft (-1.6 ft) Variability: 2 to 45 ft (7 ft)	Total: -15 to 13 ft (-4 ft) Relative: - 5 to 10 ft (-1.0 ft) Variability: 2 to 44 ft (7 ft)
East of Bypass	Total: -14 to 7 ft (-6 ft) Variability: 1 to 18 ft (4 ft)	Total: -15 to 7 ft (-6 ft) Relative: -2 to 0 ft (-0.4 ft) Variability: 1 to 18 ft (4 ft)	Total: -15 to 7 ft (-6 ft) Relative: -2 to 0 ft (-0.4 ft) Variability: 1 to 18 ft (4 ft)
Deep Zone	Average water level decrease by Year 20: 12 ft	Average water level decrease by Year 20: 12 ft	Average water level decrease by Year 20: 12 ft
North of the SJR	Total: -40 to -2 ft (-17ft) Variability: 2 to 76 ft (22 ft)	Total: -40 to -2 ft (-16 ft) Relative: 0 to 4 ft (0.5 ft) Variability: 2 to 70 ft (20: ft)	Total: -40 to -2 ft (-16 ft) Relative: 0 to 5 ft (0.6 ft) Variability: 2 to 70 ft (20: ft)
West of SJR	Total: -12 to - 2 ft (- 7 ft) Variability: 2 to 43 ft (14 ft)	Total: -12 to - 2 ft (- 7 ft) Relative: 0 to 2 ft (0.4 ft) Variability: 2 to 39 ft (13 ft)	Total: -11 to -2 ft (-6 ft) Relative: 0 to 2 ft (0.5 ft) Variability: 2 to 39 ft (13 ft)
West of Fresno Slough	Total:-12 to 20: ft (- 6 ft) Variability: 1 to 77 ft (16 ft)	Total: -11 to 20: ft (-6 ft) Relative: -3 to 2 feet (-0.2 ft) Variability: 2 to 56 ft (14 ft)	Total: -10 to 20: ft (-6 ft) Relative: -3 to 4ft (0.2 ft) Variability: 2 to 56 ft (14 ft)
Mendota Wildlife Area	Total: -7 to 7 ft (-2 ft) Variability: 1 to 23 ft (10 ft)	Total: -8 to 6 ft (-3 ft) Relative: -3 to 0 ft (-0.8 ft) Variability: 2 to 22 ft (10 ft)	Total: -8 to 6 ft (-3 ft) Relative: -3 to 0 ft (-0.7 ft) Variability: 2 to 22 ft (10 ft)
East of Fresno Slough	Total: -27 to 9 ft (-11 ft) Variability: 11 to 71 ft (36 ft)	Total: -22 to 7 ft (-10 ft) Relative: -2 to 8 ft (0.1 ft) Variability: 11 to 68 ft (33 ft)	Total: -22 to 8 ft (-10 ft) Relative: -2 to 8 ft (0.5 ft) Variability: 11 to 68 ft (33 ft)
East of Bypass	Total:-35 to 5 ft (-17 ft) Variability: 4 to 65 ft (27 ft)	Total: -36 to 5 ft (-17 ft) Relative: -1 to 2 ft (0.0 ft) Variability: 4 to 61 ft (27 ft)	Total: -36 to 5 ft (- 17 ft) Relative: -1 to 2 ft (0.1 ft) Variability: 4 to 61 ft (27 ft)

1. Total change defined as the total difference in groundwater elevation accrued from the start of Year 1 to the end of Year 20. Positive numbers indicate net increase in groundwater elevation over the 20-year program.
2. Variability defined as the median amount that groundwater levels change within 1 year.
3. Relative change defined as difference between No Action and Proposed Action/Alternative 2. Positive numbers indicates groundwater elevation in the Proposed Action/Alternative 2 is higher than the No Action.
4. Sub-region averages shown in parenthesis.

Table 8-3
Existing Land Use Simulated Groundwater Levels in PSA Sub-regions Year 1 to Year 20

Geographic Area	Change in TDS by Sub Area[1,2,3]		
	No Action (Adjacent Pumping: 33,395 af)	**Proposed Action** (Adjacent Pumping: 14,000 af)	**Alternative 2** (Adjacent Pumping: 14,000 af)
Shallow Zone	Average change in TDS by Year 20: -30 mg/L	Average change in TDS by Year 20: -20 mg/L	Average change in TDS by Year 20: -20 mg/L
North of the SJR	Total: -430 to 160 mg/L (-30 mg/L)	Total: -420 to 160 mg/L (-30 mg/L) Relative: -20 to 20 mg/L (3 mg/L)	Total: -420 to 160 mg/L (-30 mg/L) Relative: -10 to 20 mg/L (4 mg/L)
West of SJR	Total: -520 to 960 mg/L (200 mg/L)	Total: -510 to 960 mg/L (200 mg/L) Relative: -50 to 30 mg/L (1 mg/L)	Total: -510 to 960 mg/L (200 mg/L) Relative: -50 to 40 mg/L (2 mg/L)
West of Fresno Slough	Total: -1,200 to 2,700 mg/L (40 mg/L)	Total: -980 to 2,900 mg/L (90 mg/L) Relative: -960 to 2,200 mg/L (50 mg/L)	Total: -980 to 2,600 mg/L (60 mg/L) Relative: -2,200 to 2,200 mg/L (20 mg/L)
Mendota Wildlife Area	Total: -1,400 to 1,000 mg/L (-240 mg/L)	Total: -1,400 to 1,000 mg/L(-220 mg/L) Relative: -80 to 800 mg/L (20 mg/L)	Total: -1,400 to 1,000 mg/L (-220 mg/L) Relative: -80 to 800 mg/L (20 mg/L)
East of Fresno Slough	Total: -1,400 to 280 mg/L (-50 mg/L)	Total: -1,600 to 490 mg/L (-50 mg/L) Relative: -300 to 560 mg/L (-9 mg/L)	Total: -1,600 to 490 mg/L (-50 mg/L) Relative: -280 to 580 mg/L (-8 mg/L)
East of Bypass	Total: -150 to 150 mg/L (30 mg/L)	Total: -150 to 160 mg/L (30mg/L) Relative: -20 to 40 mg/L (1 mg/L)	Total: -150 to 160 mg/L (30 mg/L) Relative: -20 to 40 mg/L (1 mg/L)
Deep Zone	Average change in TDS by Year 20: 200 mg/L	Average change in TDS by Year 20: 210 mg/L	Average change in TDS by Year 20: 210 mg/L
North of the SJR	Total: -300 to 420 mg/L (40 mg/L)	Total: -290 to 580 mg/L (40 mg/L) Relative: -50 to 150 mg/L (3 mg/L)	Total: -290 to 590 mg/L (40 mg/L) Relative: -50 to 160 mg/L (3 mg/L)
West of SJR	Total: -290 to 980 mg/L (380 mg/L)	Total: -290 to 960 mg/L (380 mg/L) Relative: -50 to 30 mg/L (-2 mg/L)	Total: -290 to 960 mg/L (380 mg/L) Relative: -50 to 40 mg/L (-1 mg/L)
West of Fresno Slough	Total: -500 to 2,200 mg/L (640 mg/L)	Total: -570 to 2,200 mg/L (640 mg/L) Relative: -570 to 1,500 mg/L (-3 mg/L)	Total: -540 to 2,200 mg/L (630 mg/L) Relative:-1,100 to 1,500 mg/L(-10 mg/L)
Mendota Wildlife Area	Total: -650 to 1,700 mg/L (310 mg/L)	Total: -680 to 1,800 mg/L (320 mg/L) Relative: -180 to 310 mg/L (10 mg/L)	Total: -680 to 1,800 mg/L (320 mg/L) Relative: -170 to 320 mg/L (9 mg/L)
East of Fresno Slough	Total: -1,100to 1,800 mg/L (250 mg/L)	Total: -1,200 to 2,100 mg/L (300 mg/L) Relative: -190 to 1,500 mg/L (40 mg/L)	Total: -1,200 to 2,100 mg/L (300 mg/L) Relative: -170 to 1,500 mg/L (40 mg/L)
East of Bypass	Total: -180 to 330 mg/L (50 mg/L)	Total: -170 to 340 mg/L (50 mg/L) Relative: -20 to 30 mg/L (2 mg/L)	Total: -170 to 340 mg/L (50 mg/L) Relative: -14 to 30 mg/L (2 mg/L)

1. Total change defined as the total difference in TDS accrued from the start of year 1 to the end of year 20. Positive numbers indicate net increase in TDS over the 20-year program.
2. Relative change defined as difference between No Action and Proposed Action/Alternative 2. Positive numbers indicate TDS concentration in the Proposed Action/Alternative 2 is higher than the No Action.
3. Sub-region averages shown in parenthesis.

Table 8-7
Existing Land Use Simulated TDS Concentrations in PSA Sub-regions Year 1 to Year 20

Well	Depth	Total Dissolved Solids Concentration (mg/L) No Action	Proposed Action	Alternative 2
Terra Linda Farms				
TLF-1s	S	749	842	842
TLF-2s	S	777	863	925
TLF-3s	S	735	778	796
TLF-4s	S	918	950	827
TLF-5d	D	2,725	2,916	2,786
TLF-6d	D	2,464	2,626	2,436
TLF-7s	S	425	415	406
TLF-8s	S	428	413	409
TLF-9s	S	430	412	409
TLF-10s	S	388	377	376
TLF-11As	S	383	375	375
TLF-11Cs[1]	S	380	375	375
TLF-12d	D	665	719	774
TLF-13s	S	374	374	374
TLF-14d	D	2,130	2,473	2,098
TLF-15s	S	394	365	358
TLF-16s	S	510	485	446
TLF-17s	S	960	946	709
TLF-18d	D	1,998	1,981	2,042
TLF-19s	S	353	355	358
TL-1[1]	D	1,454	1,509	1,563
TL-11[1]	S	2,062	2,119	2,105
TL-9[1]	D	2,498	2,468	2,346
Coelho/Coelho				
Conejo West[1]	D	3,006	2,893	2,531
Coelho/Coelho/Fordel				
CCF-1[1]	D	2,496	2,495	2,288
Silver Creek Packing				
SC-3B	S	2,131	2,270	2,235
SC-4B	S	1,193	1,198	1,208
SC-6	D	3,568	3,514	3,539
SC-7	D	3,439	3,421	3,448
Coelho/Gardner/Hanson				
CGH-1s	S	3,039	2,536	2,550
CGH-2s & 3s[2]	S	1,774	1,684	1,687
CGH-4s	S	2,718	2,436	2,442
CGH-5s	S	3,068	2,429	2,447
CGH-6s	S	1,792	1,571	1,578
CGH-7s	S	1,115	1,088	1,090
CGH-8s	S	707	759	758
CGH-9As/9Bs[2]	S	2,055	1,792	1,800
CGH-10s	S	1,068	1,080	1,080
CGH-11s	S	954	971	970
CGH-12s	S	1,187	1,195	1,195
CGH-13d	D	4,029	4,042	4,055
CGH-4[1]	S	1,978	1,705	1,713
CGH-8[1]	S	1,848	1,820	1,823
Meyers Farming				
MS-3[1]	S	2,951	2,706	2,701
MS-4[1]	S	3,269	3,547	3,541
DW-1	D	1,298	1,850	1,855
MS-6	S	3,303	3,227	3,223
MS-7	S	3,379	3,636	3,630
Casaca Vineyards				
FS-1	S	427	1,154	1,155
FS-3	S	524	1,258	1,259
FS-5	S	598	1,799	1,802
FS-6	S	669	1,790	1,792
FS-7	S	684	1,748	1,750
Daddy's Pride Farming				
FS-4	S	552	1,251	1,251
FS-9	S	680	1,683	1,685
FS-10	S	708	1,662	1,663
Solo Mio				
FS-2	S	442	1,183	1,185
FS-8	S	646	1,813	1,815
Coelho West				
CW-1	S	333	695	696
CW-2	S	327	650	650
CW-3	S	329	630	630
CW-4	S	339	682	683
CW-5	S	353	662	663
Farmers Water District				
R-1	D	555	491	493
R-2	D	509	482	486
R-3	D	540	484	485
R-4	D	174	165	166
R-12	D	805	1,066	1,084
R-7	D	283	236	237
R-8	D	435	416	417
R-9	D	250	278	278
R-10	D	601	629	633
R-11	D	609	598	599
E-Loop-2	D	34	33	33
E-Loop-3	D	87	85	85
W Loop-1	D	197	172	173
W Loop-2	D	310	281	282
W Loop-3	D	220	194	195
Baker Farming Co.				
BF-1	D	378	358	359
BF-2	D	501	550	558
BF-3	D	442	457	463
BF-4	D	461	471	476
BF-5	D	708	861	870
Panoche Creek Farms				
PCF-1	D	600	583	590
Wells Exceeding 1,200 mg/L[3]		**19**	**27**	**28**
Wells Exceeding 2,000 mg/L[3]		**14**	**12**	**13**

1. Well not included for exchange pumping. Added to meet adjacent pumping demand for No Action.
2. Represent 2 wells manifolded at surface. Concentration is average of wells.
3. Out of 76 wells included in exchange program.

		Total Dissolved Solids Concentration (mg/L)		
Well	**Depth**	**No Action**	**Proposed Action**	**Alternative 2**
Terra Linda Farms				
TLF-1s	S	916	1,031	1,032
TLF-2s	S	793	894	915
TLF-3s	S	792	860	868
TLF-4s	S	955	1,011	947
TLF-5d	D	1,977	2,125	2,093
TLF-6d	D	1,793	1,910	1,848
TLF-7s	S	480	471	467
TLF-8s	S	476	463	463
TLF-9s	S	474	460	461
TLF-10s	S	410	412	417
TLF-11As	S	407	411	415
TLF-11Cs[1]	S	406	410	414
TLF-12d	D	588	626	657
TLF-13s	S	401	406	410
TLF-14d	D	1,642	1,857	1,636
TLF-15s	S	473	480	471
TLF-16s	S	579	589	527
TLF-17s	S	975	1,017	805
TLF-18d	D	1,522	1,526	1,559
TLF-19s	S	419	426	420
TL-1[1]	D	1,122	1,171	1,200
TL-11[1]	S	1,547	1,607	1,602
TL-9[1]	D	1,978	1,949	1,864
Coelho/Coelho				
Conejo West[1]	D	2,264	2,175	2,000
Coelho/Coelho/Fordel				
CCF-1[1]	D	1,953	1,953	1,802
Silver Creek Packing				
SC-3B	S	1,887	2,210	2,199
SC-4B	S	1,103	1,301	1,310
SC-6	D	2,795	2,776	2,792
SC-7	D	2,631	2,635	2,653
Coelho/Gardner/Hanson				
CGH-1s	S	2,898	2,837	2,846
CGH-2s & 3s[2]	S	1,848	1,943	1,946
CGH-4s	S	2,623	2,665	2,669
CGH-5s	S	2,928	2,791	2,803
CGH-6s	S	1,817	1,824	1,830
CGH-7s	S	1,188	1,279	1,281
CGH-8s	S	778	899	899
CGH-9As/9Bs[2]	S	2,121	2,026	2,033
CGH-10s	S	1,199	1,201	1,204
CGH-11s	S	1,059	1,076	1,078
CGH-12s	S	1,347	1,331	1,334
CGH-13d	D	3,385	3,423	3,435
CGH-4[1]	S	1,990	1,982	1,989
CGH-8[1]	S	1,916	1,904	1,910
Meyers Farming				
MS-3[1]	S	2,929	3,072	3,070
MS-4[1]	S	3,223	3,522	3,519
DW-1	D	948	1,251	1,255
MS-6	S	3,264	3,436	3,434
MS-7	S	3,330	3,615	3,613
Casaca Vineyards				
FS-1	S	571	1,278	1,278
FS-3	S	668	1,372	1,369
FS-5	S	792	1,828	1,829
FS-6	S	846	1,837	1,836
FS-7	S	852	1,796	1,793
Daddy's Pride Farming				
FS-4	S	693	1,293	1,289
FS-9	S	843	1,725	1,721
FS-10	S	866	1,641	1,636
Solo Mio				
FS-2	S	593	1,350	1,350
FS-8	S	831	1,853	1,853
Coelho West				
CW-1	S	427	770	770
CW-2	S	416	706	706
CW-3	S	418	703	704
CW-4	S	440	805	806
CW-5	S	449	782	783
Farmers Water District				
R-1	D	495	470	472
R-2	D	418	406	407
R-3	D	487	462	462
R-4	D	150	148	148
R-12	D	555	555	555
R-7	D	213	190	191
R-8	D	372	364	365
R-9	D	233	266	267
R-10	D	454	463	464
R-11	D	535	532	532
E-Loop-2	D	49	48	48
E-Loop-3	D	85	86	86
W Loop-1	D	172	155	155
W Loop-2	D	257	242	243
W Loop-3	D	200	186	187
Baker Farming Co.				
BF-1	D	308	296	296
BF-2	D	406	408	411
BF-3	D	349	346	348
BF-4	D	366	365	367
BF-5	D	450	496	499
Panoche Creek Farms				
PCF-1	D	578	565	568
Wells Exceeding 1,200 mg/L[3]		**19**	**33**	**33**
Wells Exceeding 2,000 mg/L[3]		**10**	**12**	**12**

1. Well not included for exchange pumping. Added to meet adjacent pumping demand for No Action.
2. Represent 2 wells manifolded at surface. Concentration is average of wells.
3. Out of 76 wells included in exchange program.

Table 8-11
Existing Land Use Simulated TDS Concentration in MPG Wells (Year 1 - Year 20 Average)

Month	Inflows[1]				Outflows		TDS					
	San Joaquin River[2] (af)	DMC[3] (af)	Farmers Water District[4] (af)	Mendota Pool[5] (af)	Diversions[2] (af)	Mendota Dam[2] (af)	San Joaquin River[2] (mg/L)	DMC[6] (mg/L)	Farmers Water District[7] (mg/L)	Mendota Pool[2] (mg/L)	Increase due to FWD (mg/L)	Mendota Dam[8] (mg/L)
January	5,521	18,910	0	3,392	2,263	25,560	31	461	0	370	0	364
February	10,747	49,983	0	0	23,702	36,005	36	411	0	364	0	345
March	24,211	46,780	0	1,800	36,997	35,793	37	403	0	314	0	279
April	25,175	45,662	0	30,629	31,827	69,635	32	368	0	269	0	255
May	27,299	69,579	0	35,140	55,197	76,824	30	353	0	253	0	260
June	23,527	102,218	0	12,412	77,087	61,067	28	309	0	246	0	256
July	16,133	130,618	0	0	93,036	45,968	27	244	0	223	0	220
August	5,415	123,623	0	0	83,136	28,842	27	268	0	249	0	257
September	3,228	82,080	0	0	39,952	33,881	27	315	0	288	0	304
October	2,622	66,726	0	0	28,928	30,940	26	312	0	299	0	302
November	1,581	34,868	0	0	12,448	18,655	26	344	0	313	0	330
December	3,660	12,518	0	0	3,428	11,468	27	410	0	326	0	324
Total	**149,119**	**783,565**	**0**	**83,372**	**488,002**	**474,639**						
Annual Mean							**30**	**350**	**0**	**293**	**0**	**291**

1. Total pumping for groundwater exchange: 0 AF. Total pumping for adjacent use: 33,395 AF.
2. Calculated from groundwater model from respective run.
3. Average monthly flow in the DMC at Check 21 from 1992 - 2011 (reflect Year 1 - Year 20 in the predictive scenarios). Years where no exchange pumping occurs excluded.
4. Proposed exchange pumping for Farmers Water District (Logoluso, Baker Farms, and Panoche Creek Farms).
5. Assigned to make up the deficit between the calculated inflows (San Joaquin River, DMC, and Farmers Water District) and outflows (canal diversions, flow over the Mendota Dam) which is met by flow from the Mendota Pool
6. Average monthly TDS in the DMC at Check 21 from 1992 - 2011 (reflect Year 1 to Year 20 in the predictive scenarios). Years where no exchange pumping occurs excluded.
7. Volume weighted TDS calculated from average TDS from each well from Year 1 to Year 20 and amount of proposed exchange pumping.
8. Calculated as the volume weighted average TDS of the inflows.

Table 8-14
TDS at the Mendota Dam – No Action

	Flow Contribution at MWA						TDS Increase Due to				
		MPG Wells[1,3]					MPG Pumping				
Month	DMC[2] (af)	Exchange Pumping (af)	Adjacent Pumping (af)	City of Mendota[4] (af)	Meyers Water Bank (af)	TDS at DMC Check 21[5] (mg/L)	Exchange Pumping (mg/L)	Adjacent Pumping (mg/L)	City of Mendota (mg/L)	Meyers Water Bank (mg/L)	TDS in Southern Mendota Pool (mg/L)
January	5,924	0	33	0	0	448	0	0	0	0	447
February	10,818	0	75	0	0	424	0	0	0	0	425
March	6,651	0	312	0	0	423	0	2	0	0	426
April	5,930	0	871	470	20	394	0	31	13	0	439
May	8,458	0	1,552	615	710	335	0	61	15	14	425
June	14,996	0	2,087	374	640	309	0	70	6	9	394
July	14,218	0	2,220	395	494	204	0	94	9	10	317
August	8,894	0	2,000	204	468	272	0	100	6	12	389
September	8,517	0	1,476	0	476	345	0	60	0	10	415
October	8,161	0	371	0	251	322	0	6	0	7	335
November	5,886	0	87	0	0	351	0	1	0	0	352
December	4,091	0	53	0	0	409	0	0	0	0	409
Total	**102,544**	**0**	**11,137**	**2,058**	**3,060**						
Annual Mean						**353**	**0**	**36**	**4**	**5**	**398**

1. Including non-MPG pumpage by Don Peracchi in Farmers Water District.
2. Calculated as the difference between the average net demand in the southern portion of the Fresno Slough and the inflow from MPG, Meyers Farm Water Bank wells, and City of Mendota wells along the Fresno Slough.
3. Inflow from MPG wells along the Fresno Slough. Values do not include Farmers Water District pumping (FWD, Baker, and Panoche wells).
4. Based on City's pumpage from Fordel wells in 2010.
5. Monthly average based on reported daily EC in the DMC in years with exchange pumping from 2004 - 2013.

Table 8-15
TDS Concentration at MWA – No Action

Month	Flow Contribution at MWA: DMC[2] (af)	Flow Contribution at MWA: MPG Wells[1,3] Exchange Pumping (af)	Flow Contribution at MWA: MPG Wells[1,3] Adjacent Pumping (af)	Flow Contribution at MWA: City of Mendota[4] (af)	Flow Contribution at MWA: Meyers Water Bank (af)	TDS at DMC Check 21[5] (mg/L)	TDS Increase Due to: MPG Pumping Exchange Pumping (mg/L)	TDS Increase Due to: MPG Pumping Adjacent Pumping (mg/L)	TDS Increase Due to: City of Mendota (mg/L)	TDS Increase Due to: Meyers Water Bank (mg/L)	TDS in Southern Mendota Pool (mg/L)
January	2,620	0	33	0	0	448	0	0	0	0	447
February	3,551	0	75	0	0	424	0	0	0	0	425
March	5,863	0	312	0	0	423	0	3	0	0	426
April	5,970	0	871	470	20	394	0	31	13	0	439
May	6,778	0	1,552	615	710	335	0	72	17	16	440
June	14,125	0	2,087	374	640	309	0	74	6	9	398
July	13,392	0	2,220	395	494	204	0	99	10	11	323
August	5,857	0	2,000	204	468	272	0	136	8	16	431
September	6,839	0	1,476	0	476	345	0	71	0	12	428
October	7,512	0	371	0	251	322	0	7	0	7	336
November	5,306	0	87	0	0	351	0	1	0	0	352
December	2,242	0	53	0	0	409	0	1	0	0	410
Total	**80,056**	**0**	**11,137**	**2,058**	**3,060**						
Annual Mean						**353**	**0**	**41**	**5**	**6**	**405**

1. Including non-MPG pumpage by Don Peracchi in Farmers Water District.
2. Calculated as the difference between the average net demand in the southern portion of the Fresno Slough and the inflow from MPG, Meyers Farm Water Bank wells, and City of Mendota wells along the Fresno Slough.
3. Inflow from MPG wells along the Fresno Slough. Values do not include Farmers Water District pumping (FWD, Baker, and Panoche wells).
4. Based on City's pumpage from Fordel wells in 2010.
5. Monthly average based on reported daily EC in the DMC in years with exchange pumping from 2004 - 2013.

Table 8-16
TDS Concentration at MWA – No Action (Dry Year)

Year	Stream and Canal Seepage (af)	Areal Recharge (af)[1]	Recharge Ponds (af)[1]	Net Lateral Inflow (af)	Lake Seepage (af)	Pumping (af)[2]	Storage (af)[3]	Interbed Storage (af)[3]
-	112,000	196,000	560	18,000	31,000	-519,000	117,000	46,000
-	84,000	214,000	500	-25,000	32,000	-512,000	152,000	54,000
Year 1	85,000	239,000	1,500	-45,000	34,000	-515,000	124,000	78,000
Year 2	106,000	262,000	7,200	21,000	35,000	-450,000	-8,700	30,000
Year 3	90,000	180,000	3,000	21,000	36,000	-501,000	127,000	45,000
Year 4	146,000	318,000	11,000	53,000	38,000	-420,000	-142,000	-40
Year 5	111,000	307,000	9,000	71,000	34,000	-423,000	-102,000	-3,500
Year 6	128,000	246,000	8,000	72,000	35,000	-534,000	40,000	7,800
Year 7	148,000	304,000	22,000	59,000	35,000	-393,000	-153,000	-9,300
Year 8	90,000	187,000	5,500	56,000	32,000	-488,000	113,000	7,800
Year 9	104,000	236,000	6,000	60,000	33,000	-441,000	1,600	4,200
Year 10	84,000	237,000	3,400	65,000	34,000	-504,000	70,000	13,000
Year 11	68,000	197,000	3,300	63,000	37,000	-539,000	150,000	23,000
Year 12	73,000	184,000	5,500	73,000	38,000	-485,000	98,000	15,000
Year 13	73,000	225,000	5,000	87,000	39,000	-511,000	60,000	24,000
Year 14	134,000	228,000	10,000	53,000	39,000	-436,000	-33,000	8,400
Year 15	158,000	227,000	10,000	61,000	38,000	-402,000	-87,000	-490
Year 16	97,000	165,000	4,500	34,000	37,000	-538,000	167,000	35,000
Year 17	99,000	181,000	4,700	42,000	39,000	-570,000	152,000	55,000
Year 18	91,000	171,000	4,300	21,000	41,000	-568,000	167,000	76,000
Year 19	156,000	266,000	6,200	50,000	41,000	-457,000	-87,000	28,000
Year 20	169,000	208,000	23,000	89,000	38,000	-437,000	-71,000	-7,100
Annual Average	111,000	228,000	7,700	50,000	37,000	-481,000	29,000	21,000

1. Assigned recharge. An average of approximatley 3,400 AF of assigned recharge is rejected by model anually in areas with high water table.
2. An average of 3,300 AF of assigned pumping rejected by model annually in dry cells.
3. Positive numbers indicate net decrease in storage. Negative numbers indicate net increase in storage.

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Table 8-17
No Action Water Budget

Month	Inflows[1] San Joaquin River[2] (af)	DMC[3] (af)	Farmers Water District[4] (af)	Mendota Pool[5] (af)	Outflows Diversions[2] (af)	Mendota Dam[2] (af)	TDS San Joaquin River[2] (mg/L)	DMC[6] (mg/L)	Farmers Water District[7] (mg/L)	Mendota Pool[2] (mg/L)	Increase due to FWD (mg/L)	Mendota Dam[8] (mg/L)
January	5,504	18,910	0	3,362	2,263	25,512	30	461	0	372	0	365
February	10,729	49,983	0	0	23,702	35,959	35	411	0	364	0	345
March	24,155	46,780	2,094	2,267	36,997	38,299	36	403	392	324	3	283
April	25,114	45,662	2,172	31,796	31,827	72,920	31	368	388	287	3	263
May	27,235	69,579	1,981	36,603	55,197	80,204	30	353	393	266	2	265
June	23,470	102,218	0	14,436	77,087	63,034	28	309	0	254	0	256
July	16,094	130,618	0	0	93,036	47,899	27	244	0	231	0	220
August	5,391	123,623	0	0	83,136	30,728	27	268	0	258	0	258
September	3,204	82,080	2,169	0	39,952	36,671	27	315	362	303	1	306
October	2,601	66,726	2,190	0	28,997	33,204	26	312	364	314	2	304
November	1,568	34,868	0	0	12,448	18,817	26	344	0	321	0	330
December	3,647	12,518	0	0	3,428	11,446	27	410	0	329	0	324
Total	**148,710**	**783,565**	**10,606**	**88,464**	**488,070**	**494,694**						
Annual Mean							**29**	**350**	**380**	**302**	**1**	**293**

1. Total pumping for groundwater exchange: 21,052 AF. Total pumping for adjacent use: 14,000 AF.
2. Calculated from groundwater model from respective run.
3. Average monthly flow in the DMC at Check 21 from 1992 - 2011 (reflect Year 1 - Year 20 in the predictive scenarios). Years where no exchange pumping occurs excluded.
4. Proposed exchange pumping for Farmers Water District (Logoluso, Baker Farms, and Panoche Creek Farms).
5. Assigned to make up the deficit between the calculated inflows (San Joaquin River, DMC, and Farmers Water District) and outflows (canal diversions, flow over the Mendota Dam) which is met by flow from the Mendota Pool
6. Average monthly TDS in the DMC at Check 21 from 1992 - 2011 (reflect Year 1 to Year 20 in the predictive scenarios). Years where no exchange pumping occurs excluded.
7. Volume weighted TDS calculated from average TDS from each well from Year 1 to Year 20 and amount of proposed exchange pumping.
8. Calculated as the volume weighted average TDS of the inflows.

Table 8-22
TDS at the Mendota Dam – Proposed Action

Month	Flow Contribution at MWA: DMC[2] (af)	Flow Contribution at MWA: MPG Wells[1,3] Exchange Pumping (af)	Flow Contribution at MWA: MPG Wells[1,3] Adjacent Pumping (af)	Flow Contribution at MWA: City of Mendota[4] (af)	Flow Contribution at MWA: Meyers Water Bank (af)	TDS at DMC Check 21[5] (mg/L)	TDS Increase Due to: MPG Pumping Exchange Pumping (mg/L)	TDS Increase Due to: MPG Pumping Adjacent Pumping (mg/L)	TDS Increase Due to: City of Mendota (mg/L)	TDS Increase Due to: Meyers Water Bank (mg/L)	TDS in Southern Mendota Pool (mg/L)
January	5,924	0	0	0	0	448	0	0	0	0	448
February	10,818	0	0	0	0	424	0	0	0	0	424
March	5,498	1,153	692	0	0	423	32	25	0	0	480
April	4,666	1,264	670	470	20	394	48	28	15	1	485
May	7,095	1,363	1,075	615	710	335	44	51	16	17	464
June	13,598	1,398	935	374	640	309	33	29	7	11	388
July	12,774	1,445	982	395	494	204	45	39	10	12	310
August	7,466	1,427	969	204	468	272	58	51	7	15	402
September	7,334	1,183	577	0	476	345	35	18	0	13	411
October	6,947	1,214	691	0	251	322	41	28	0	8	399
November	5,886	0	0	0	0	351	0	0	0	0	351
December	4,091	0	0	0	0	409	0	0	0	0	409
Total	**92,098**	**10,446**	**6,591**	**2,058**	**3,060**						
Annual Mean						**353**	**28**	**22**	**5**	**6**	**414**

1. Including non-MPG pumpage by Don Peracchi in Farmers Water District.
2. Calculated as the difference between the average net demand in the southern portion of the Fresno Slough and the inflow from MPG, Meyers Farm Water Bank wells, and City of Mendota wells along the Fresno Slough.
3. Including flow from MPG wells along the Fresno Slough. Values do not include Farmers Water District pumping (FWD, Baker, and Panoche wells).
4. Based on City's pumpage from Fordel wells in 2010.
5. Monthly average based on reported daily EC in the DMC in years with exchange pumping from 2004 - 2013.

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Table 8-23
TDS Concentration at MWA – Proposed Action

Month	Flow Contribution at MWA: DMC[2] (af)	MPG Wells[1,3]: Exchange Pumping (af)	MPG Wells[1,3]: Adjacent Pumping (af)	City of Mendota[4] (af)	Meyers Water Bank (af)	TDS at DMC Check 21[5] (mg/L)	TDS Increase Due to: MPG Pumping: Exchange Pumping (mg/L)	MPG Pumping: Adjacent Pumping (mg/L)	City of Mendota (mg/L)	Meyers Water Bank (mg/L)	TDS in Southern Mendota Pool (mg/L)
January	2,620	0	0	0	0	448	0	0	0	0	448
February	3,551	0	0	0	0	424	0	0	0	0	424
March	4,710	1,153	692	0	0	423	35	28	0	0	487
April	4,706	1,264	670	470	20	394	47	28	15	1	485
May	5,416	1,363	1,075	615	710	335	52	61	19	21	487
June	12,727	1,398	935	374	640	309	35	30	7	12	392
July	11,947	1,445	982	395	494	204	48	41	11	13	315
August	4,430	1,427	969	204	468	272	81	72	9	21	455
September	5,656	1,183	577	0	476	345	43	21	0	15	425
October	6,298	1,214	691	0	251	322	44	30	0	8	405
November	5,306	0	0	0	0	351	0	0	0	0	351
December	2,242	0	0	0	0	409	0	0	0	0	409
Total	**69,609**	**10,446**	**6,591**	**2,058**	**3,060**						
Annual Mean						**353**	**32**	**26**	**5**	**8**	**424**

1. Including non-MPG pumpage by Don Peracchi in Farmers Water District.
2. Calculated as the difference between the average net demand in the southern portion of the Fresno Slough and the inflow from MPG, Meyers Farm Water Bank wells, and City of Mendota wells along the Fresno Slough.
3. Inflow from MPG wells along the Fresno Slough. Values do not include Farmers Water District pumping (FWD, Baker, and Panoche wells).
4. Based on City's pumpage from Fordel wells in 2010.
5. Monthly average based on reported daily EC in the DMC in years with exchange pumping from 2004 - 2013.

Table 8-24
TDS Concentration at MWA – Proposed Action (Dry Year)

Year	Stream and Canal Seepage (af)	Areal Recharge (af)[1]	Recharge Ponds (af)[1]	Net Lateral Inflow (af)	Lake Seepage (af)	Pumping (af)[2]	Storage (af)[3]	Interbed Storage (af)[3]
-	112,000	196,000	560	18,000	31,000	-519,000	117,000	46,000
-	84,000	214,000	500	-25,000	32,000	-512,000	152,000	54,000
Year 1	86,000	237,000	1,500	-44,000	35,000	-523,000	132,000	78,000
Year 2	107,000	260,000	7,200	22,000	36,000	-457,000	-2,100	30,000
Year 3	90,000	178,000	3,000	22,000	37,000	-508,000	132,000	46,000
Year 4	148,000	315,000	15,000	56,000	39,000	-429,000	-138,000	270
Year 5	112,000	304,000	13,000	72,000	34,000	-406,000	-119,000	-4,700
Year 6	128,000	243,000	15,000	74,000	35,000	-536,000	41,000	7,700
Year 7	148,000	301,000	28,000	59,000	34,000	-378,000	-166,000	-9,900
Year 8	89,000	185,000	5,500	57,000	31,000	-494,000	121,000	8,100
Year 9	104,000	233,000	6,000	61,000	33,000	-450,000	10,000	4,300
Year 10	84,000	234,000	3,400	67,000	35,000	-511,000	77,000	13,000
Year 11	68,000	194,000	3,300	65,000	38,000	-542,000	153,000	23,000
Year 12	73,000	182,000	5,500	76,000	39,000	-492,000	103,000	15,000
Year 13	75,000	222,000	5,000	90,000	40,000	-516,000	62,000	25,000
Year 14	134,000	226,000	10,000	57,000	40,000	-443,000	-28,000	8,800
Year 15	159,000	225,000	11,000	63,000	38,000	-386,000	-104,000	-1,200
Year 16	97,000	163,000	4,500	36,000	37,000	-542,000	170,000	36,000
Year 17	100,000	178,000	4,700	45,000	39,000	-573,000	154,000	55,000
Year 18	91,000	168,000	4,300	23,000	41,000	-572,000	169,000	77,000
Year 19	157,000	263,000	6,300	53,000	41,000	-465,000	-81,000	28,000
Year 20	170,000	206,000	24,000	91,000	38,000	-420,000	-89,000	-8,000
Annual Average	111,000	226,000	8,800	52,000	37,000	-482,000	30,000	22,000

1. Assigned recharge. An average of approximately 4,000 AF of assigned recharge is rejected by model annually in areas with high water table.
2. An average of 3,400 AF of assigned pumping rejected by model annually in dry cells.
3. Positive numbers indicate net decrease in storage. Negative numbers indicate net increase in storage.

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Figure 8-25
Proposed Action Water Budget

	Inflows[1]				Outflows		TDS					
Month	San Joaquin River[2] (af)	DMC[3] (af)	Farmers Water District[4] (af)	Mendota Pool[5] (af)	Diversions[2] (af)	Mendota Dam[2] (af)	San Joaquin River[2] (mg/L)	DMC[6] (mg/L)	Farmers Water District[7] (mg/L)	Mendota Pool[2] (mg/L)	Increase due to FWD (mg/L)	Mendota Dam[8] (mg/L)
January	5,507	18,910	0	3,386	2,263	25,541	30	461	0	372	0	365
February	10,732	49,983	0	0	23,702	35,985	35	411	0	364	0	345
March	24,161	46,780	2,094	2,290	36,997	38,328	36	403	393	324	3	283
April	25,119	45,662	2,172	31,815	31,827	72,941	31	368	390	287	3	263
May	27,239	69,579	1,981	36,621	55,197	80,226	30	353	395	266	2	265
June	23,475	102,218	0	14,452	77,087	63,056	28	309	0	254	0	256
July	16,100	130,618	0	0	93,036	47,922	27	244	0	231	0	220
August	5,396	123,623	0	0	83,136	30,750	27	268	0	258	0	257
September	3,209	82,080	2,169	0	39,952	36,693	27	315	363	303	1	306
October	2,604	66,726	2,190	0	28,997	33,225	26	312	366	314	2	304
November	1,571	34,868	0	0	12,448	18,837	26	344	0	321	0	330
December	3,650	12,518	0	0	3,428	11,466	27	410	0	329	0	324
Total	**148,763**	**783,565**	**10,606**	**88,566**	**488,070**	**494,971**						
Annual Mean							**29**	**350**	**381**	**302**	**1**	**293**

1. Total pumping for groundwater exchange: 21,052 AF. Total pumping for adjacent use: 14,000 AF.
2. Calculated from groundwater model from respective run.
3. Average monthly flow in the DMC at Check 21 from 1992 - 2011 (reflect Year 1 - Year 20 in the predictive scenarios). Years where no exchange pumping occurs excluded
4. Proposed exchange pumping for Farmers Water District (Logoluso, Baker Farms, and Panoche Creek Farms).
5. Assigned to make up the deficit between the calculated inflows (San Joaquin River, DMC, and Farmers Water District) and outflows (canal diversions, flow over the Mendota Dam) which is met by flow from the Mendota Pool
6. Average monthly TDS in the DMC at Check 21 from 1992 - 2011 (reflect Year 1 to Year 20 in the predictive scenarios). Years where no exchange pumping occurs excluded
7. Volume weighted TDS calculated from average TDS from each well from Year 1 to Year 20 and amount of proposed exchange pumping.
8. Calculated as the volume weighted average TDS of the inflows.

	Flow Contribution at MWA						TDS Increase Due to				
		MPG Wells[1,3]					MPG Pumping				
Month	DMC[2] (af)	Exchange Pumping (af)	Adjacent Pumping (af)	City of Mendota[4] (af)	Meyers Water Bank (af)	TDS at DMC Check 21[5] (mg/L)	Exchange Pumping (mg/L)	Adjacent Pumping (mg/L)	City of Mendota (mg/L)	Meyers Water Bank (mg/L)	TDS in Southern Mendota Pool (mg/L)
January	5,924	0	0	0	0	448	0	0	0	0	448
February	10,818	0	0	0	0	424	0	0	0	0	424
March	5,498	1,153	692	0	0	423	33	23	0	0	479
April	4,666	1,264	670	470	20	394	49	26	15	1	485
May	7,095	1,363	1,075	615	710	335	45	47	16	17	460
June	13,598	1,398	935	374	640	309	33	26	7	11	386
July	12,774	1,445	982	395	494	204	45	36	10	12	307
August	7,466	1,427	969	204	468	272	58	47	7	15	398
September	7,334	1,183	577	0	476	345	36	16	0	13	410
October	6,947	1,214	691	0	251	322	42	27	0	8	399
November	5,886	0	0	0	0	351	0	0	0	0	351
December	4,091	0	0	0	0	409	0	0	0	0	409
Total	**92,098**	**10,446**	**6,591**	**2,058**	**3,060**						
Annual Mean						**353**	**28**	**21**	**5**	**6**	**413**

1. Including non-MPG pumpage by Don Peracchi in Farmers Water District.
2. Calculated as the difference between the average net demand in the southern portion of the Fresno Slough and the inflow from MPG, Meyers Farm Water Bank wells, and City of Mendota wells along the Fresno Slough.
3. Inflow from MPG wells along the Fresno Slough. Values do not include Farmers Water District pumping (FWD, Baker, and Panoche wells).
4. Based on City's pumpage from Fordel wells in 2010.
5. Monthly average based on reported daily EC in the DMC in years with exchange pumping from 2004 - 2013.

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Table 8-27
TDS Concentration at MWA – Alternative 2

Month	Flow Contribution at MWA					TDS at DMC Check 21[5] (mg/L)	TDS Increase Due to				TDS in Southern Mendota Pool (mg/L)
	DMC[2] (af)	MPG Wells[1,3]		City of Mendota[4] (af)	Meyers Water Bank (af)		MPG Pumping		City of Mendota (mg/L)	Meyers Water Bank (mg/L)	
		Exchange Pumping (af)	Adjacent Pumping (af)				Exchange Pumping (mg/L)	Adjacent Pumping (mg/L)			
January	2,620	0	0	0	0	448	0	0	0	0	448
February	3,551	0	0	0	0	424	0	0	0	0	424
March	4,710	1,153	692	0	0	423	37	26	0	0	486
April	4,706	1,264	670	470	20	394	49	26	15	1	485
May	5,416	1,363	1,075	615	710	335	53	55	19	21	483
June	12,727	1,398	935	374	640	309	35	28	7	12	390
July	11,947	1,445	982	395	494	204	48	38	11	13	313
August	4,430	1,427	969	204	468	272	82	66	10	21	450
September	5,656	1,183	577	0	476	345	44	20	0	15	424
October	6,298	1,214	691	0	251	322	45	29	0	8	404
November	5,306	0	0	0	0	351	0	0	0	0	351
December	2,242	0	0	0	0	409	0	0	0	0	409
Total	**69,609**	**10,446**	**6,591**	**2,058**	**3,060**						
Annual Mean						**353**	**33**	**24**	**5**	**8**	**422**

1. Including non-MPG pumpage by Don Peracchi in Farmers Water District.
2. Calculated as the difference between the average net demand in the southern portion of the Fresno Slough and the inflow from MPG, Meyers Farm Water Bank wells, and City of Mendota wells along the Fresno Slough.
3. Inflow from MPG wells along the Fresno Slough. Values do not include Farmers Water District pumping (FWD, Baker, and Panoche wells).
4. Based on City's pumpage from Fordel wells in 2010.
5. Monthly average based on reported daily EC in the DMC in years with exchange pumping from 2004 - 2013.

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Table 8-28
TDS Concentration at MWA – Alternative 2 (Dry Year)

Year	Stream and Canal Seepage (af)	Areal Recharge (af)[1]	Recharge Ponds (af)[1]	Net Lateral Inflow (af)	Lake Seepage (af)	Pumping (af)[2]	Storage (af)[3]	Interbed Storage (af)[3]
-	112,000	196,000	560	18,000	31,000	-519,000	117,000	46,000
-	84,000	214,000	500	-25,000	32,000	-512,000	152,000	54,000
Year 1	86,000	237,000	1,500	-44,000	35,000	-523,000	132,000	78,000
Year 2	107,000	260,000	7,200	22,000	36,000	-457,000	-2,100	30,000
Year 3	90,000	178,000	3,000	22,000	37,000	-508,000	132,000	46,000
Year 4	148,000	315,000	19,000	56,000	39,000	-429,000	-141,000	210
Year 5	111,000	304,000	15,000	72,000	34,000	-406,000	-120,000	-4,700
Year 6	127,000	243,000	17,000	73,000	34,000	-536,000	41,000	7,600
Year 7	147,000	301,000	31,000	59,000	34,000	-378,000	-167,000	-10,000
Year 8	89,000	185,000	5,500	56,000	31,000	-494,000	122,000	8,200
Year 9	104,000	233,000	6,000	61,000	33,000	-450,000	11,000	4,300
Year 10	84,000	234,000	3,400	67,000	35,000	-511,000	77,000	13,000
Year 11	68,000	194,000	3,300	64,000	38,000	-542,000	153,000	23,000
Year 12	73,000	182,000	5,500	76,000	39,000	-492,000	103,000	15,000
Year 13	74,000	222,000	5,000	89,000	40,000	-516,000	63,000	25,000
Year 14	134,000	226,000	13,000	57,000	40,000	-444,000	-31,000	8,700
Year 15	159,000	225,000	13,000	62,000	38,000	-386,000	-106,000	-1,200
Year 16	97,000	163,000	4,500	36,000	37,000	-542,000	171,000	36,000
Year 17	100,000	178,000	4,700	44,000	39,000	-573,000	155,000	55,000
Year 18	91,000	168,000	4,300	23,000	41,000	-572,000	170,000	76,000
Year 19	157,000	263,000	6,800	53,000	41,000	-465,000	-81,000	28,000
Year 20	170,000	206,000	26,000	91,000	38,000	-420,000	-91,000	-8,100
Annual Average	111,000	226,000	9,800	52,000	37,000	-482,000	30,000	22,000

1. Assigned recharge. An average of approximatley 4,000 AF of assigned recharge is rejected by model anually in areas with high water table.
2. An average of 3,400 AF of assigned pumping rejected by model annually in dry cells.
3. Positive numbers indicate net decrease in storage. Negative numbers indicate net increase in storage.

Figure 8-29
Alternative 2 Water Budget

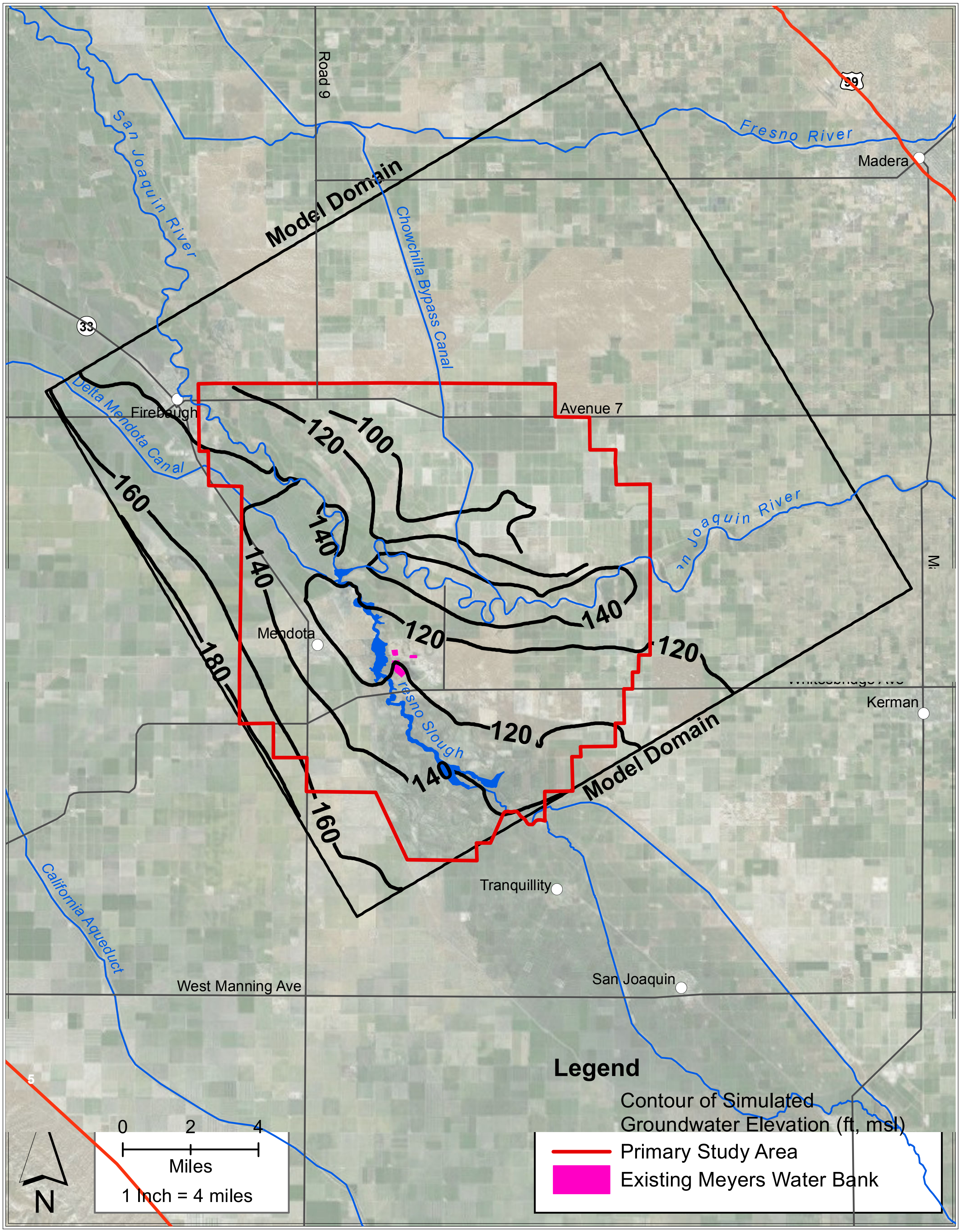

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Figure 8-1
No Action Contours of Equal Simulated Groundwater Elevation Shallow Zone, Year 20

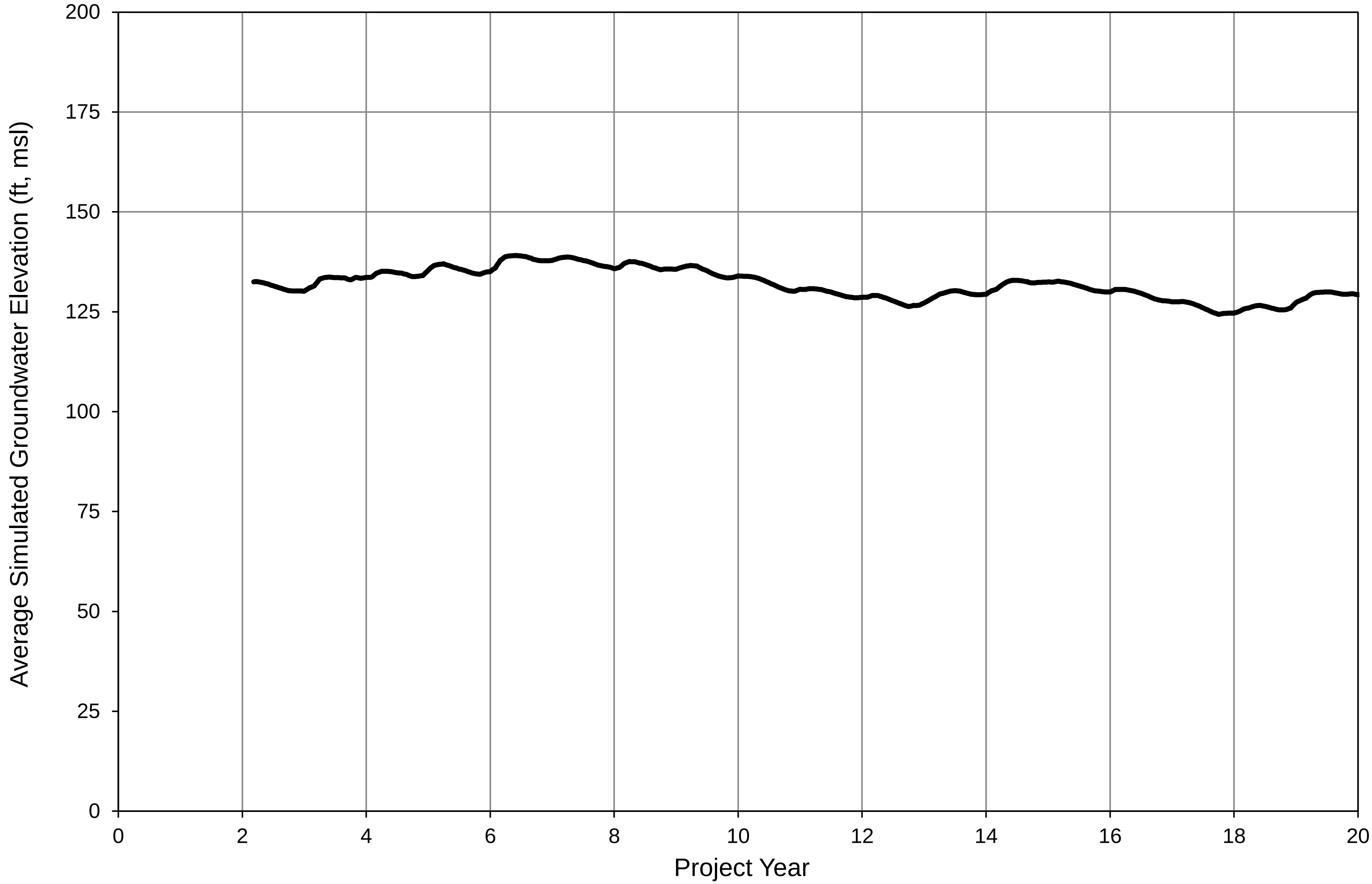

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Figure 8-2
No Action Average Simulated Groundwater Elevation
In the Primary Study Area, Shallow Zone
Mendota Pool Group EIS/EIR

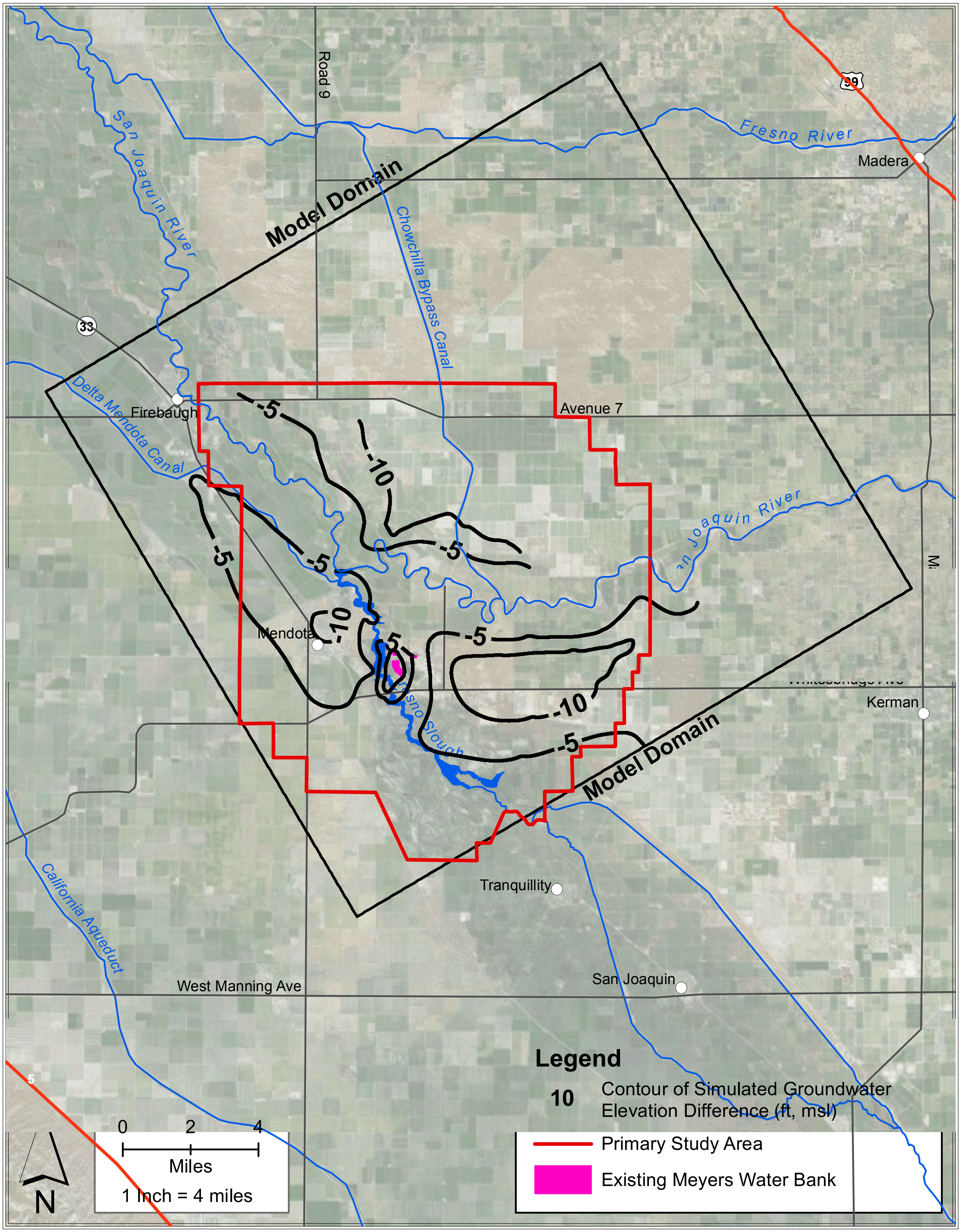

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Figure 8-3
No Action Contours of Equal Simulated Change in Groundwater Elevation Shallow Zone, Year 1 to Year 20

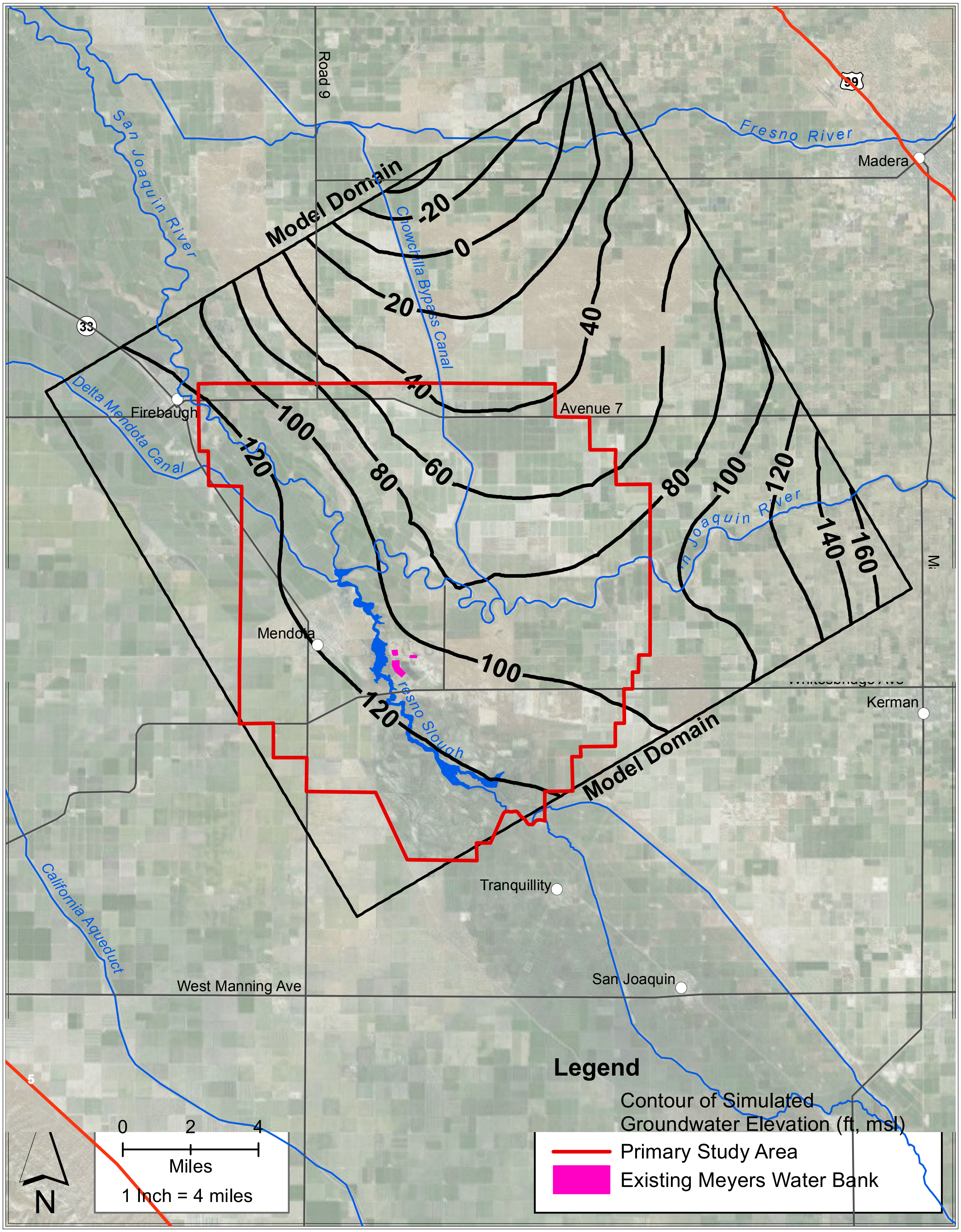

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Figure 8-4
No Action Contours of Equal Simulated Groundwater Elevation Deep Zone, Year 20

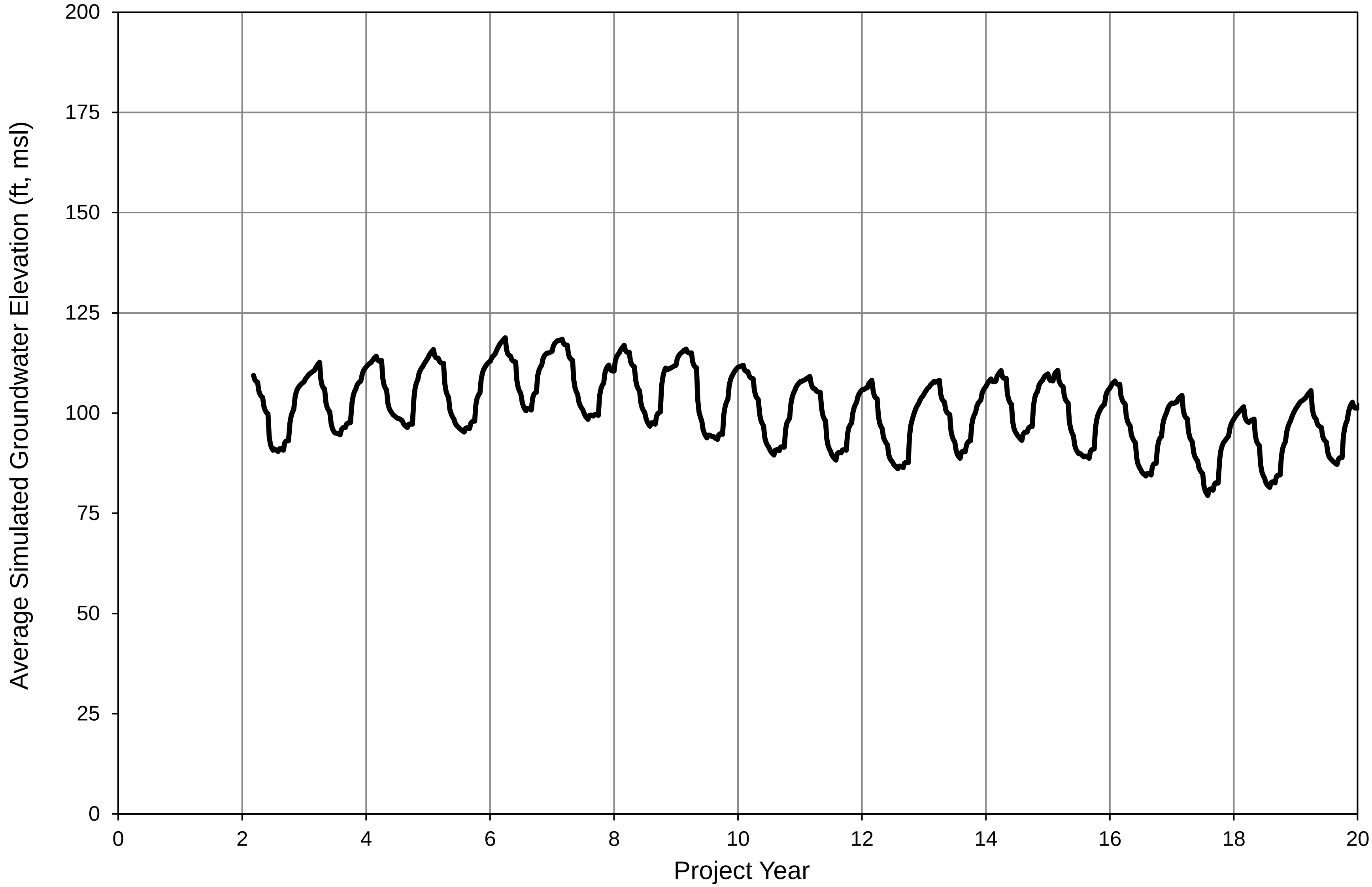

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Figure 8-5
No Action Average Simulated Groundwater Elevation
In the Primary Study Area, Deep Zone
Mendota Pool Group EIS/EIR

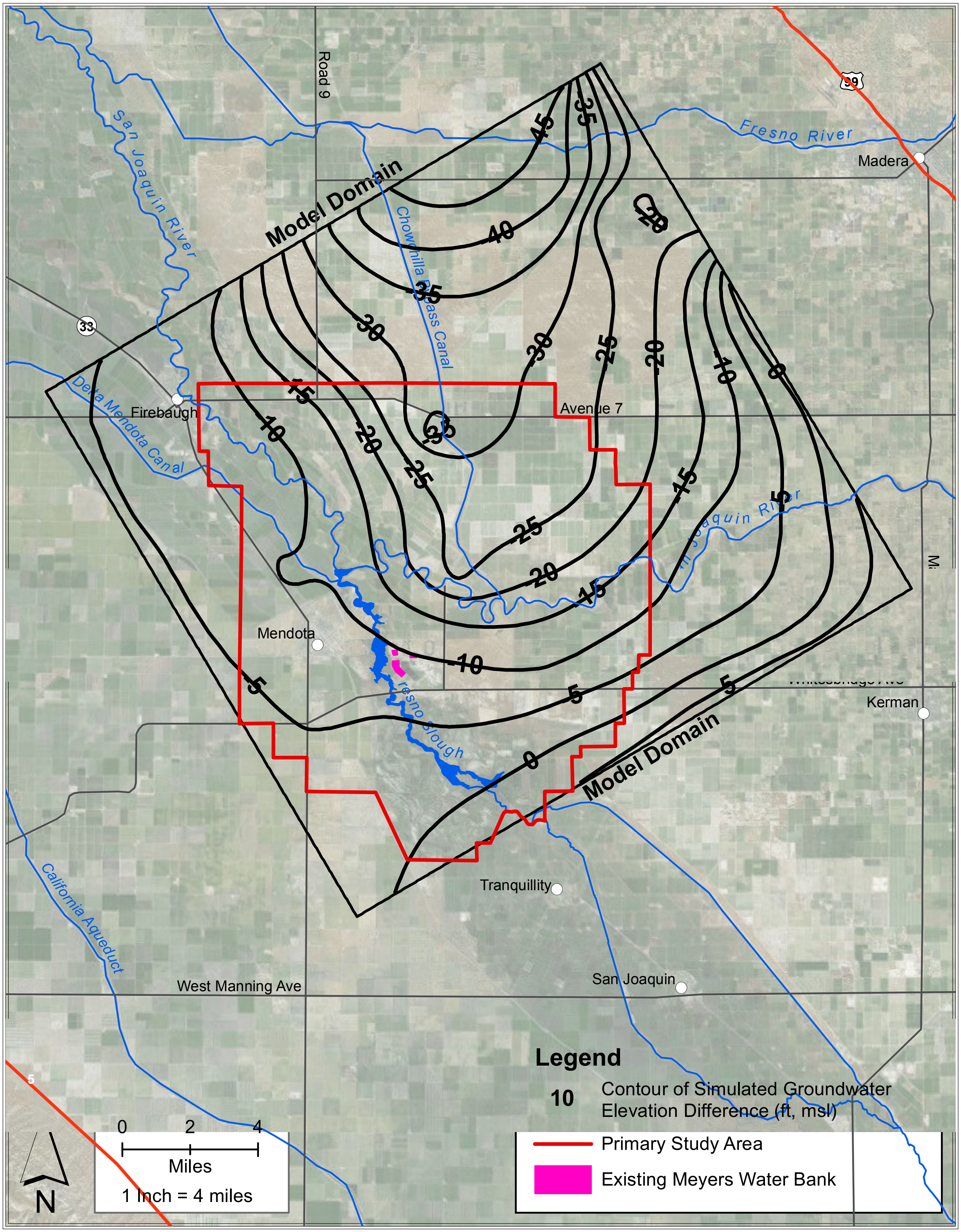

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Figure 8-6
No Action Contours of Equal Simulated Change in Groundwater Elevation Deep Zone, Year 1 to Year 20

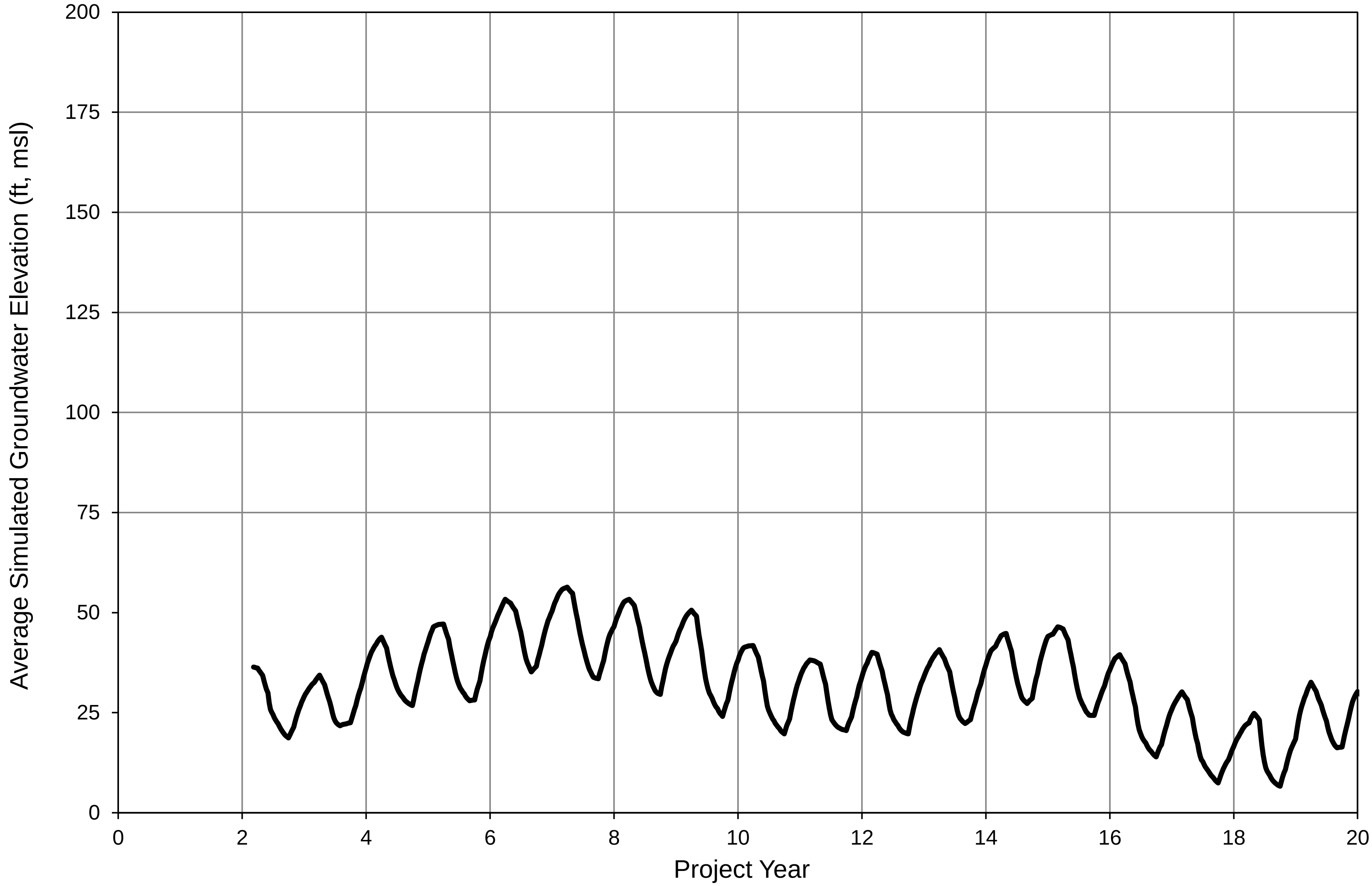

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Figure 8-7
No Action Average Simulated Groundwater Elevation
In the Primary Study Area, Lower Aquifer
Mendota Pool Group EIS/EIR

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Figure 8-8
No Action Simulated TDS Concentration Shallow Zone, Year 20

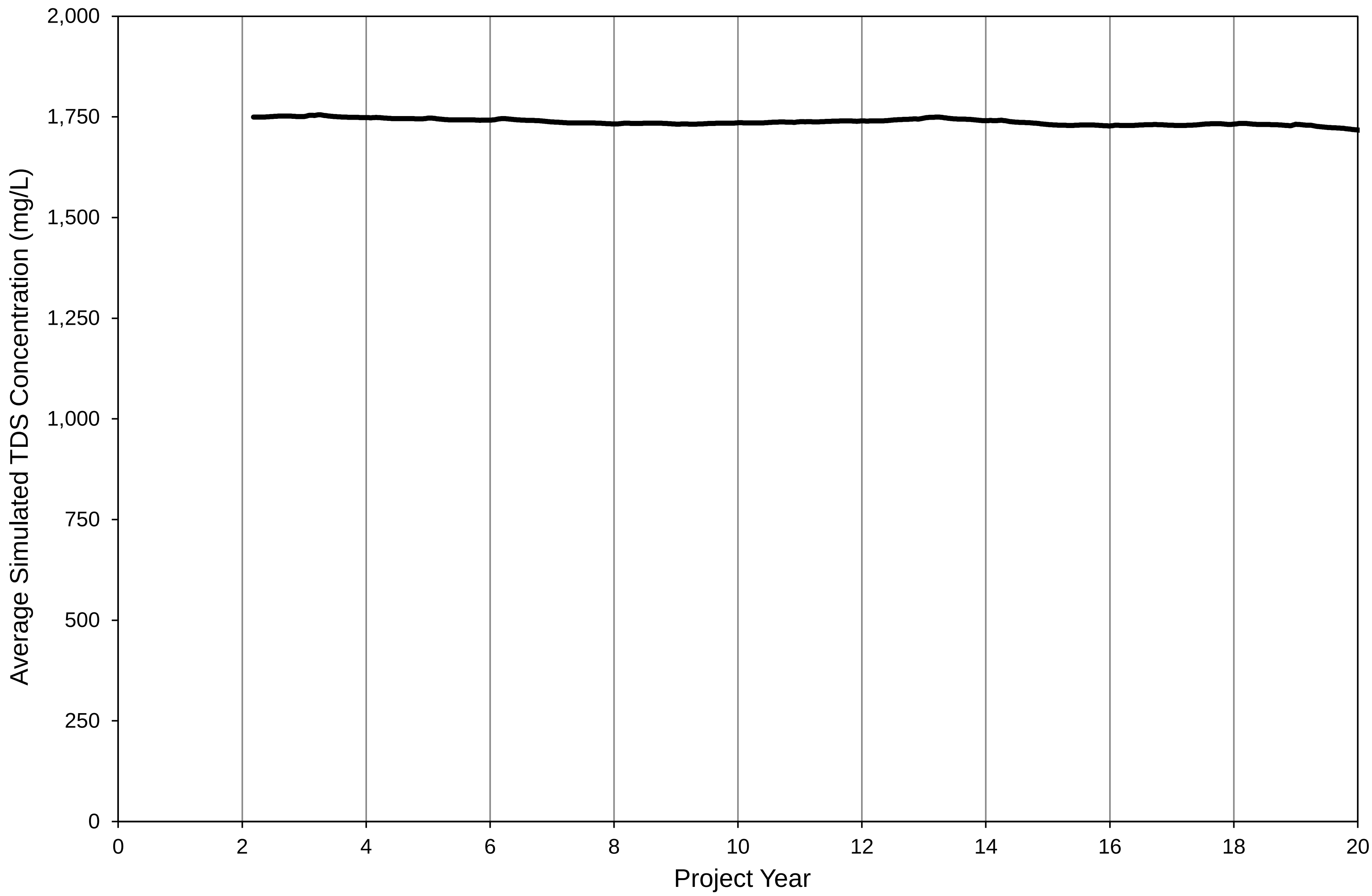

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Figure 8-9
No Action Average Simulated TDS Concentration
In the Primary Study Area, Shallow Zone
Mendota Pool Group EIS/EIR

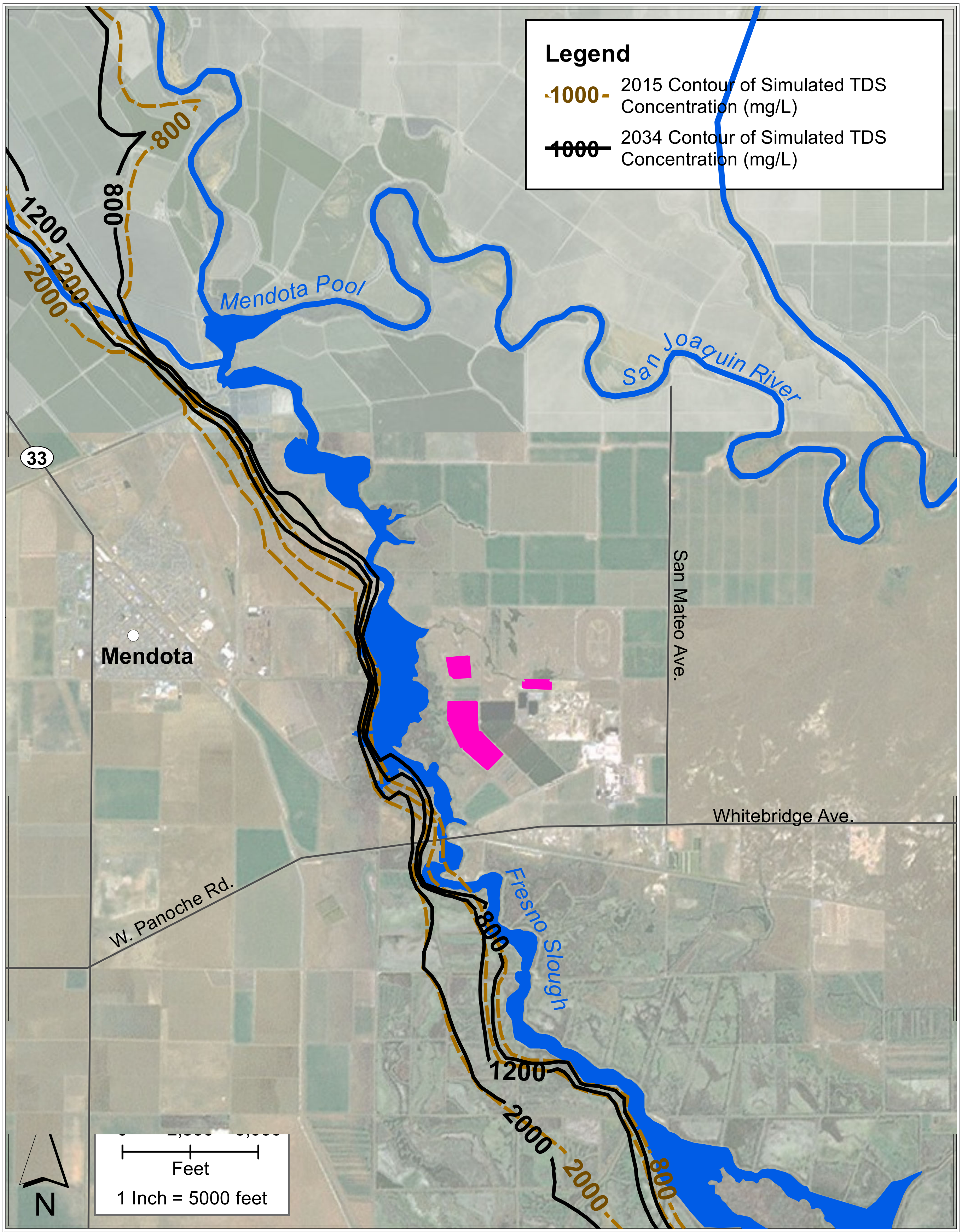

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Figure 8-10
No Action Contours of Equal Simulated TDS Concentration Shallow Zone, Year 20

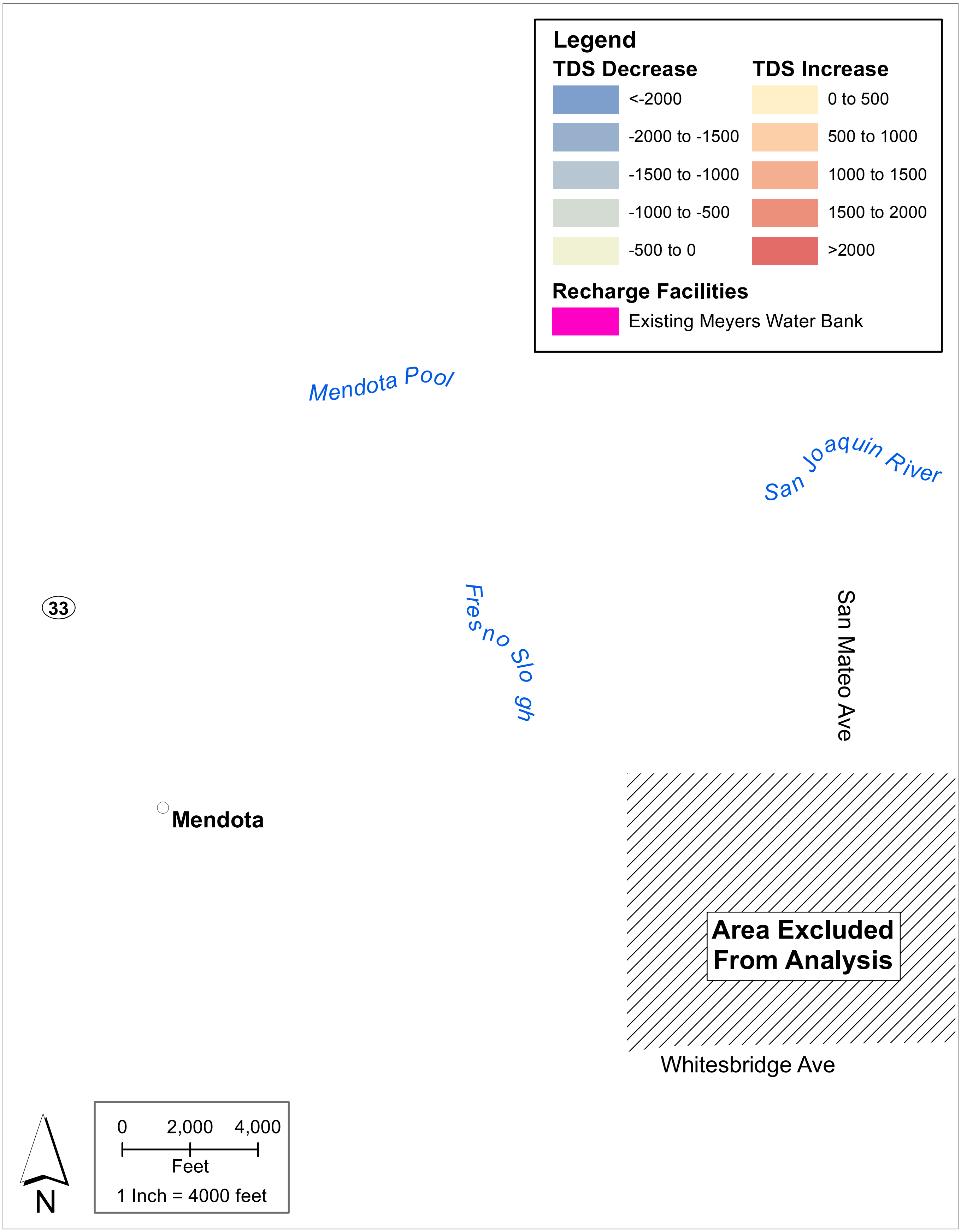

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Figure 8-11
No Action Simulated Change in TDS Concentration from Year 1 to Year 20 Shallow Zone

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Figure 8-12
No Action Simulated TDS Concentration Deep Zone, Year 20

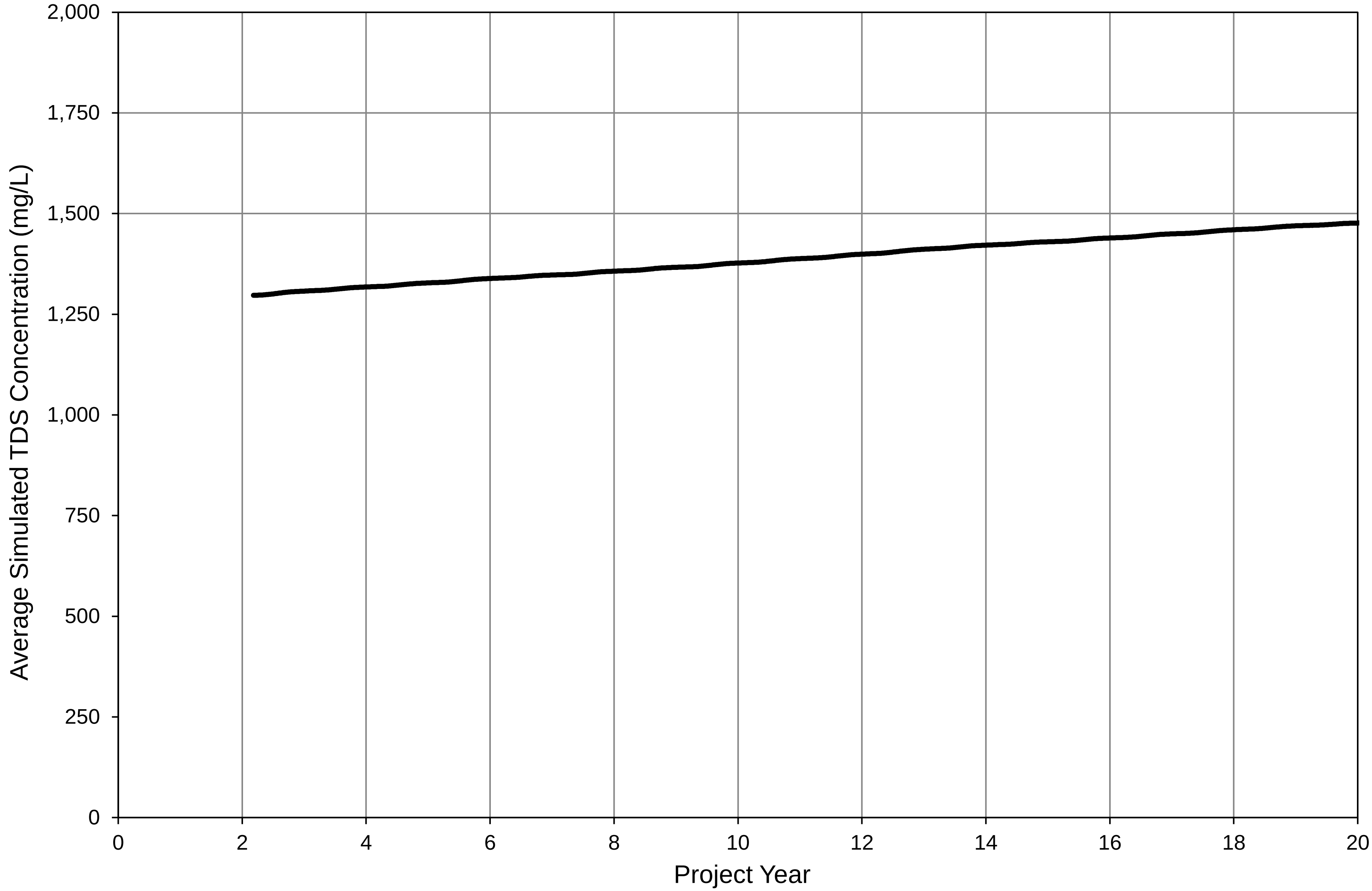

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Figure 8-13
No Action Average Simulated TDS Concentration
In the Primary Study Area, Deep Zone
Mendota Pool Group EIS/EIR

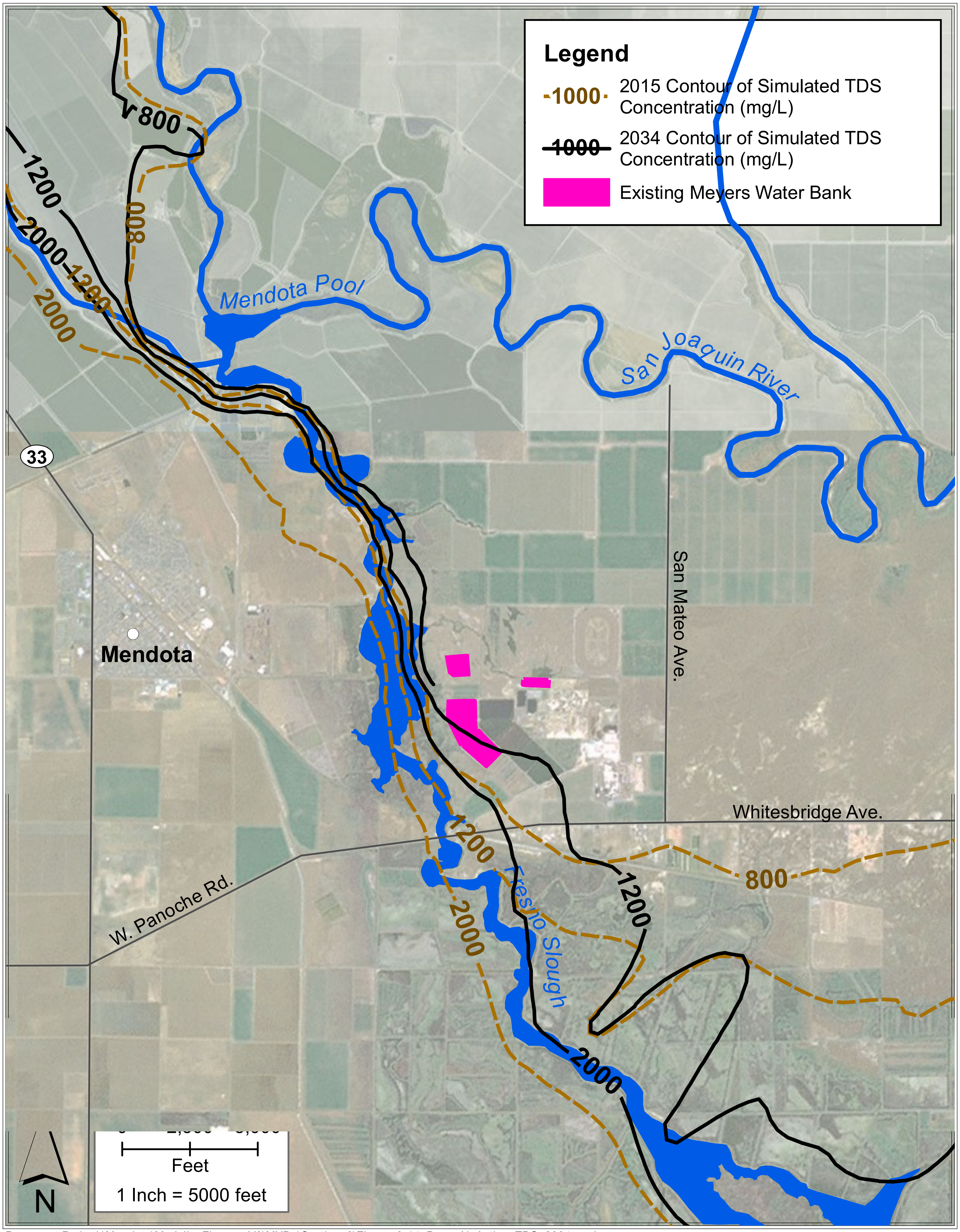

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Figure 8-14
No Action Contours of Equal Simulated TDS Concentration Deep Zone, Year 20

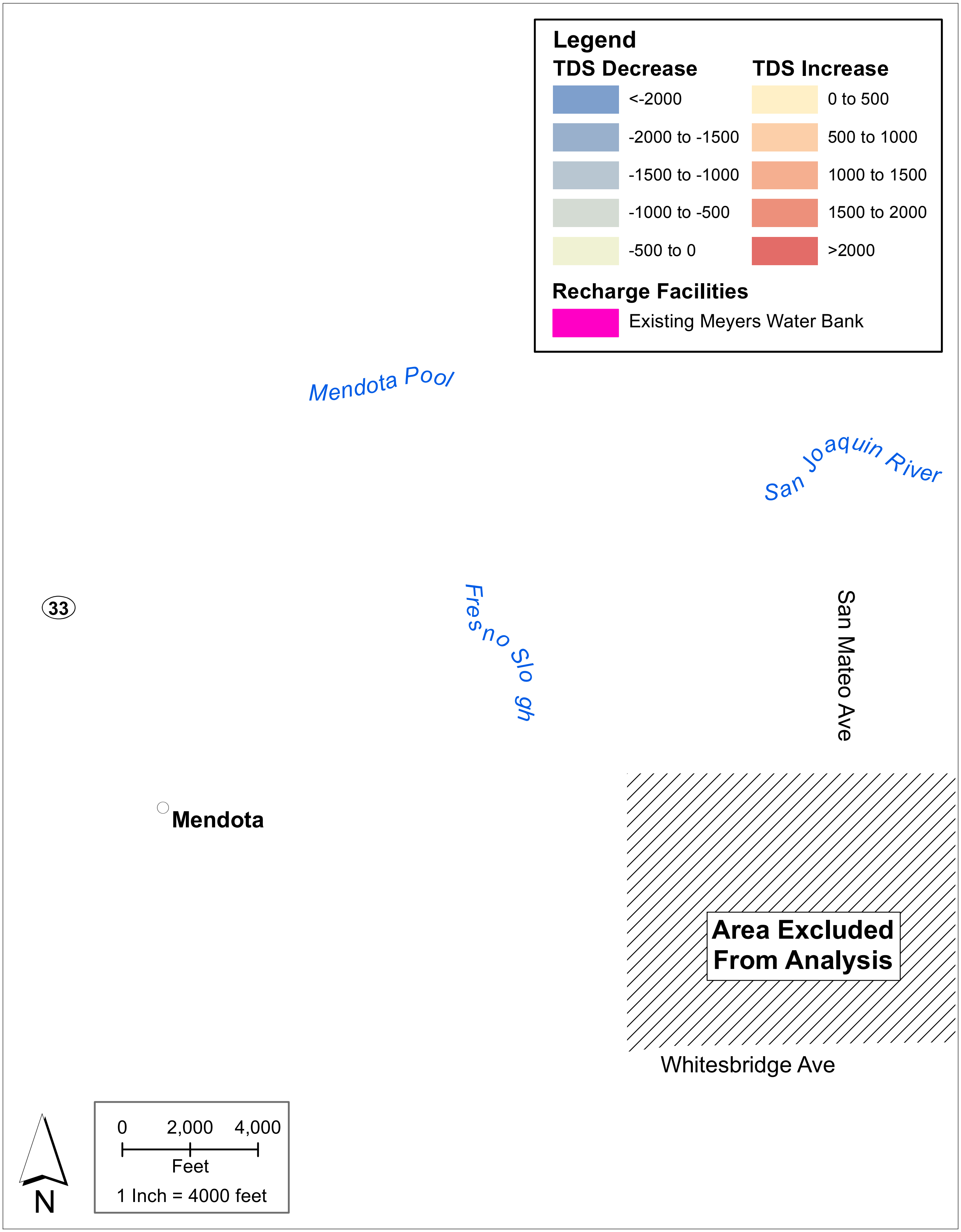

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Figure 8-15
No Action Simulated Change in TDS Concentration from Year 1 to Year 20 Deep Zone

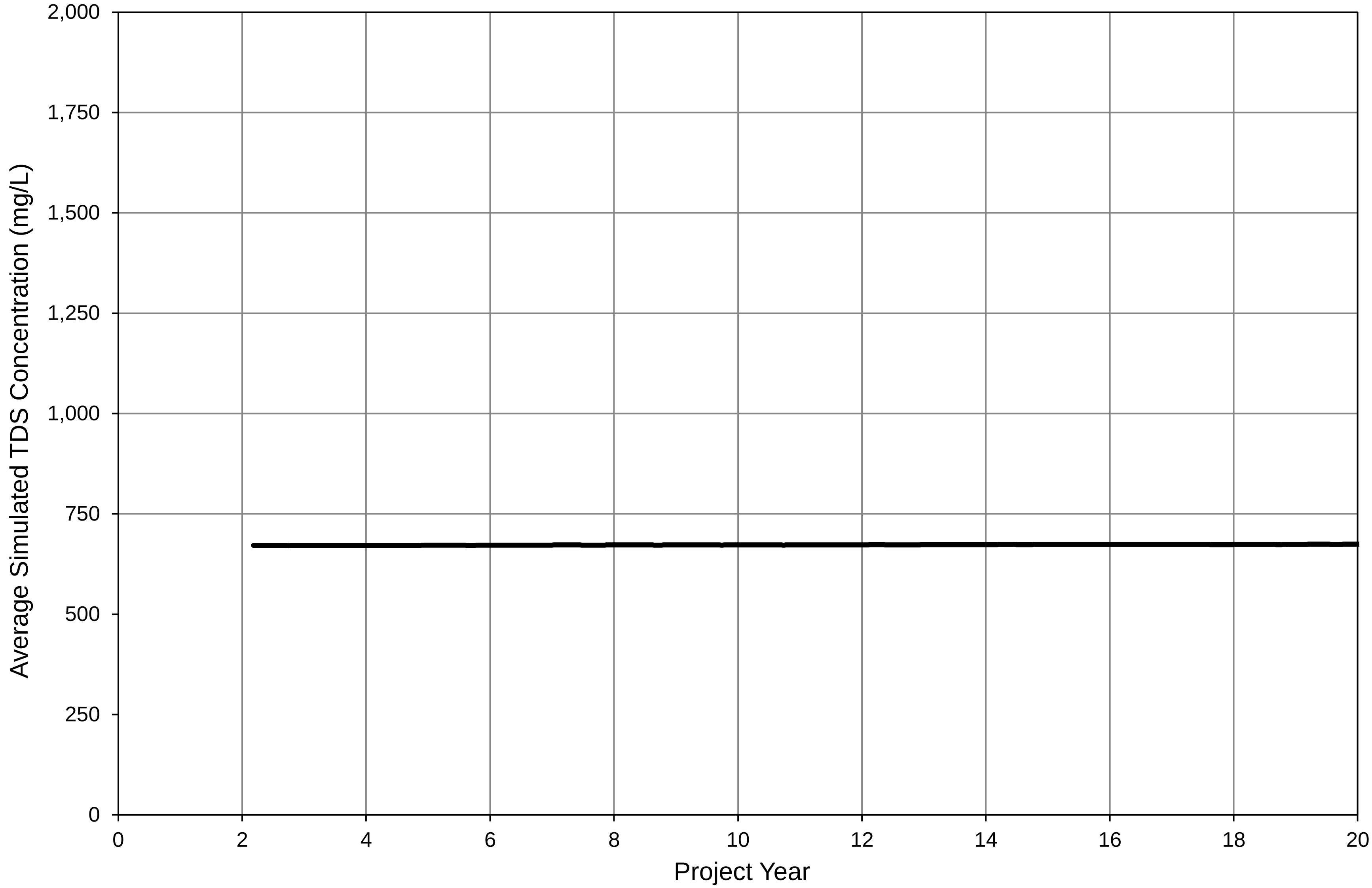

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Figure 8-16
No Action Average Simulated TDS Concentration
In the Primary Study Area, Lower Aquifer
Mendota Pool Group EIS/EIR

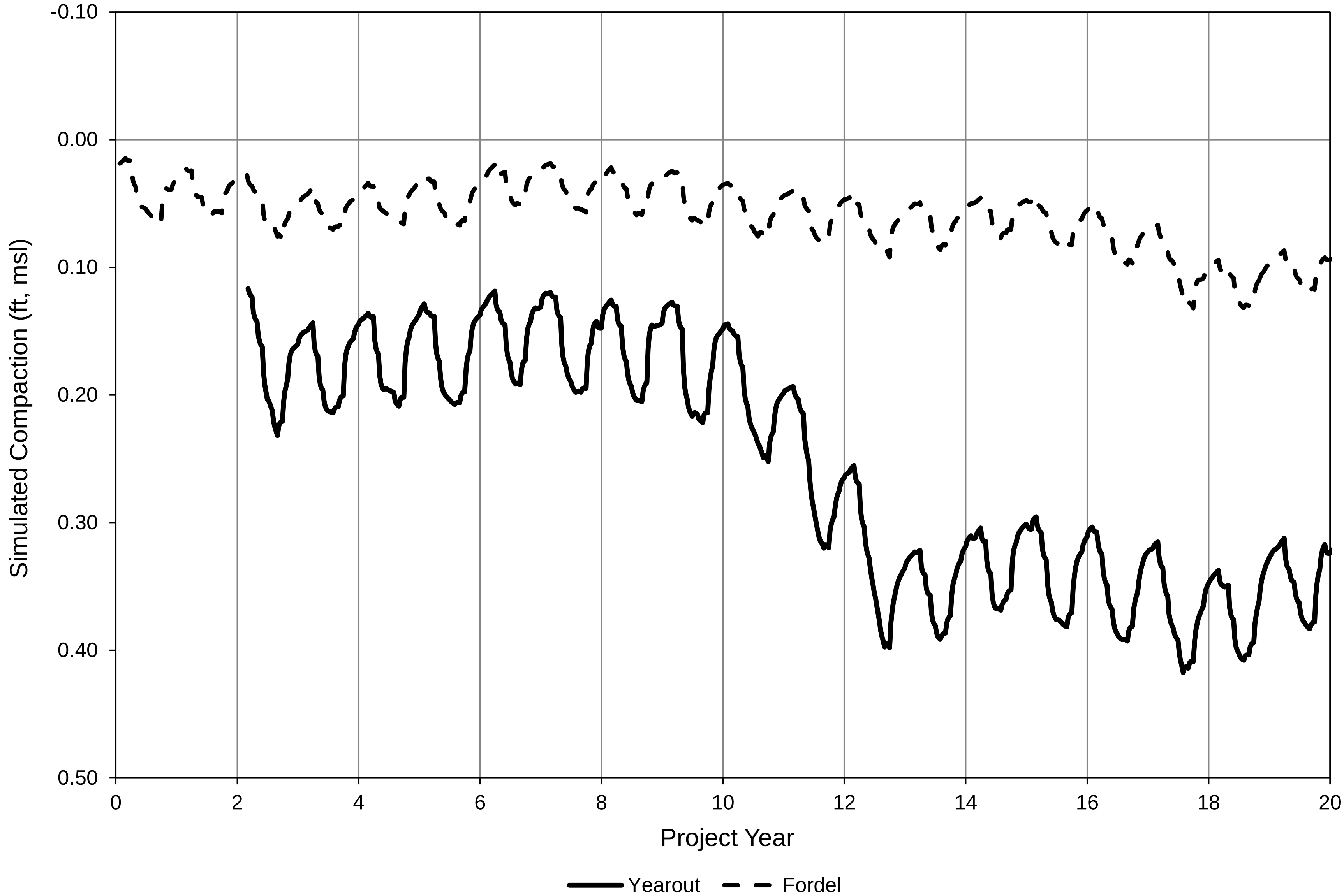

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Figure 8-17
No Action Simulated Compaction Above the Corcoran Clay
Mendota Pool Group EIS/EIR

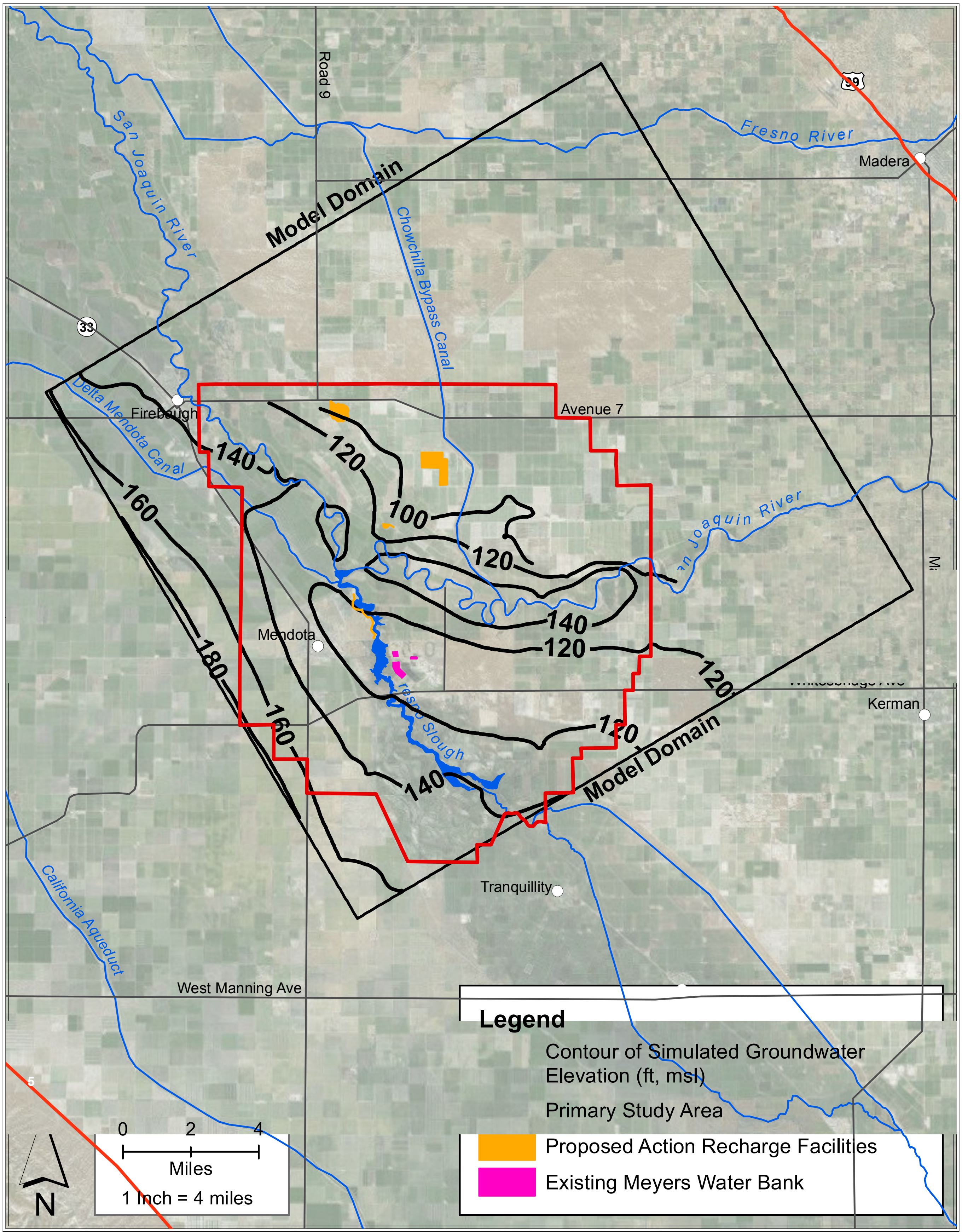

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Figure 8-18
Proposed Action Contours of Equal Simulated Groundwater Elevation Shallow Zone, Year 20

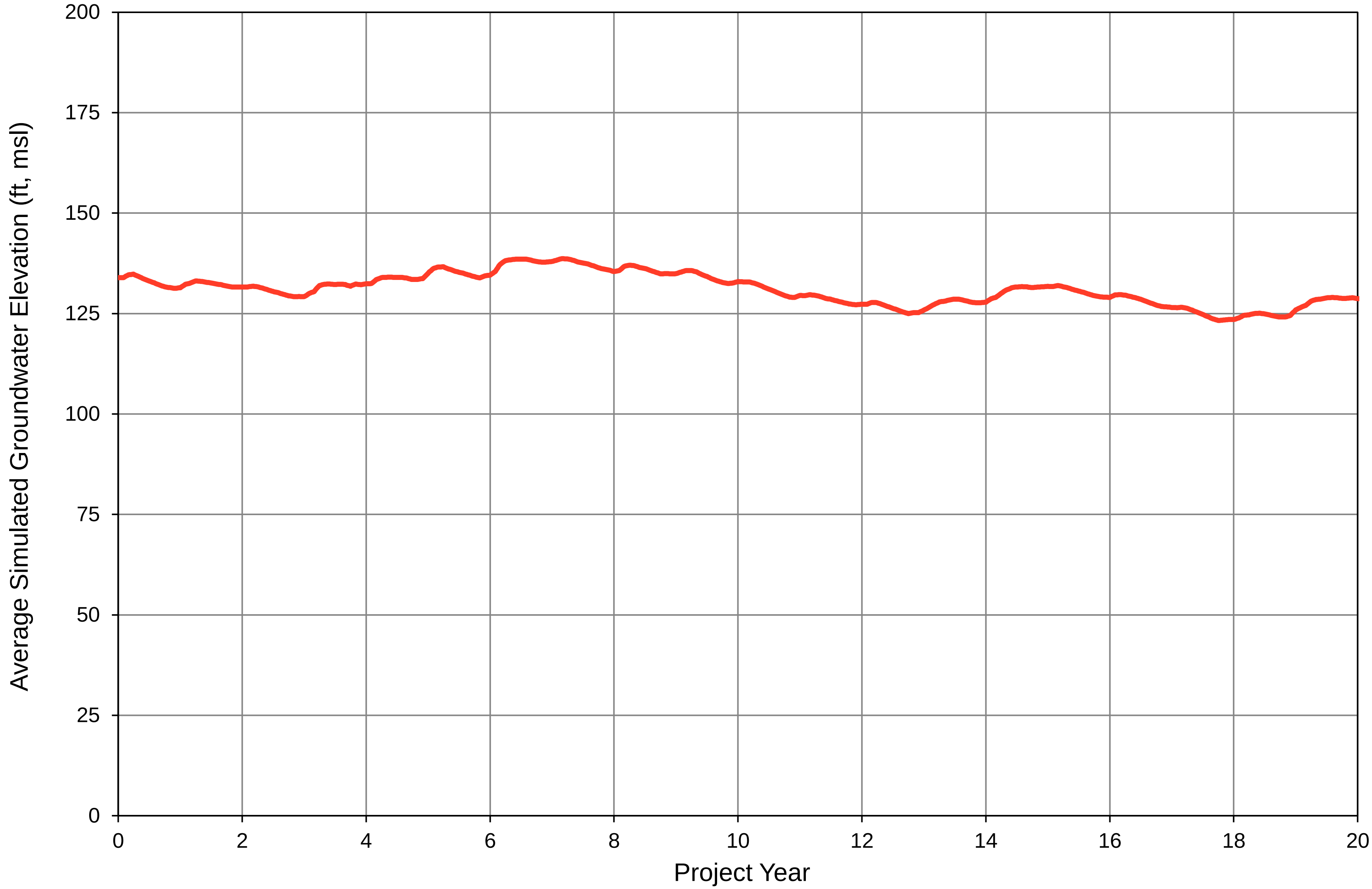

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Figure 8-19
Proposed Action Average Simulated Groundwater Elevation
In the Primary Study Area, Shallow Zone
Mendota Pool Group EIS/EIR

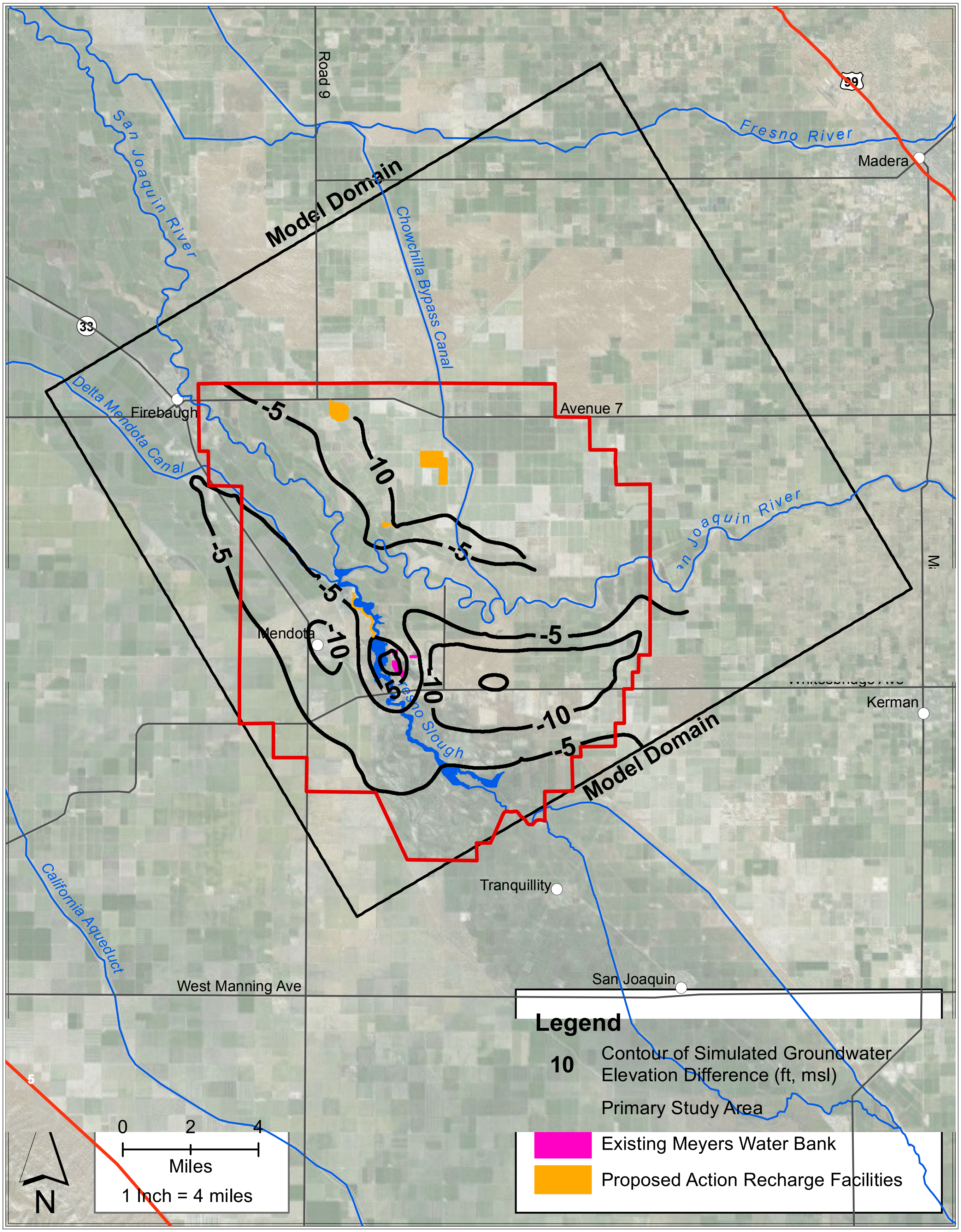

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Figure 8-20
Proposed Action Contours of Equal Simulated Change in Groundwater Elevation Shallow Zone, Year 1 to Year 20

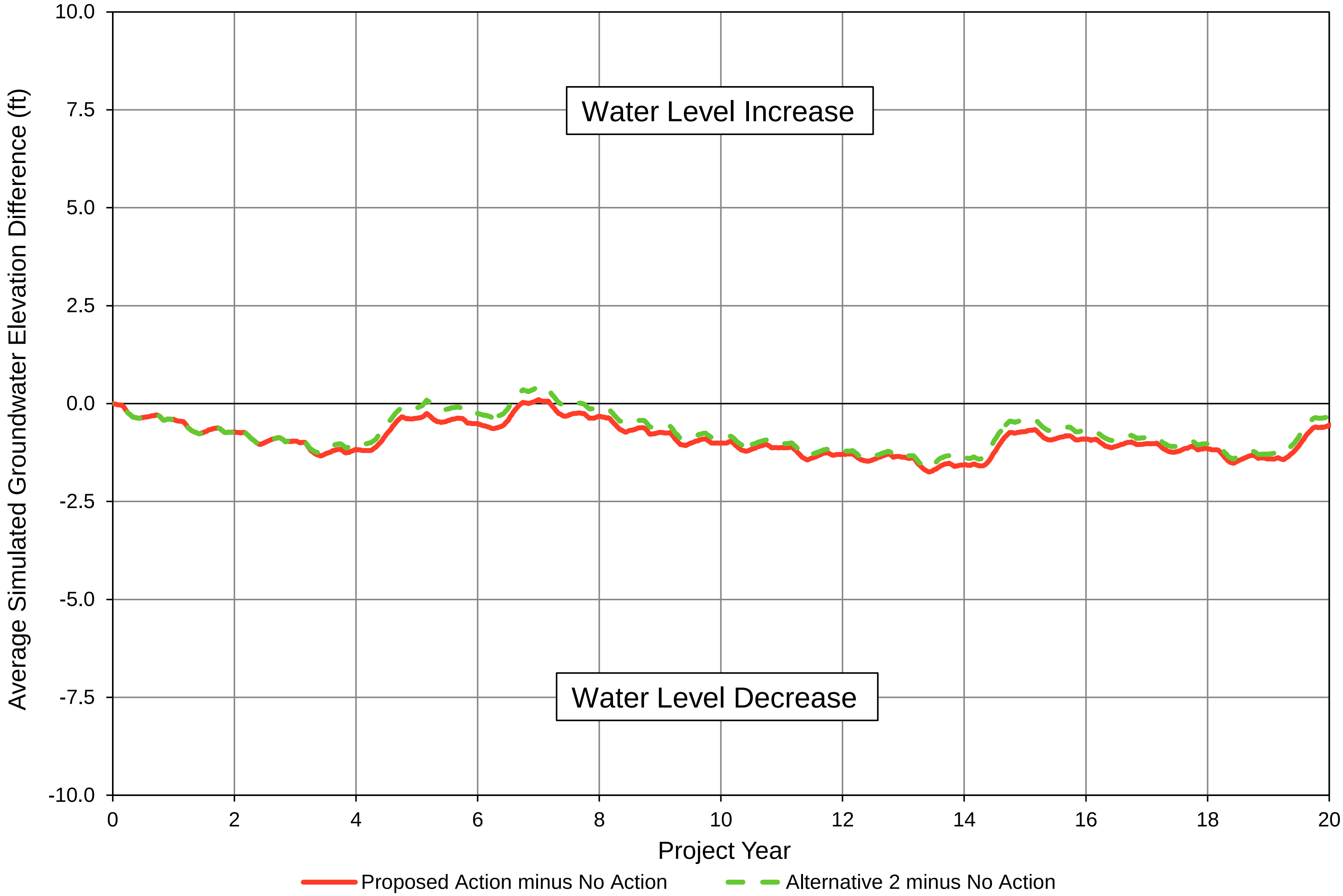

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Figure 8-21
Difference in Average Simulated Groundwater Elevation
In the Primary Study Area, Shallow Zone
Mendota Pool Group EIS/EIR

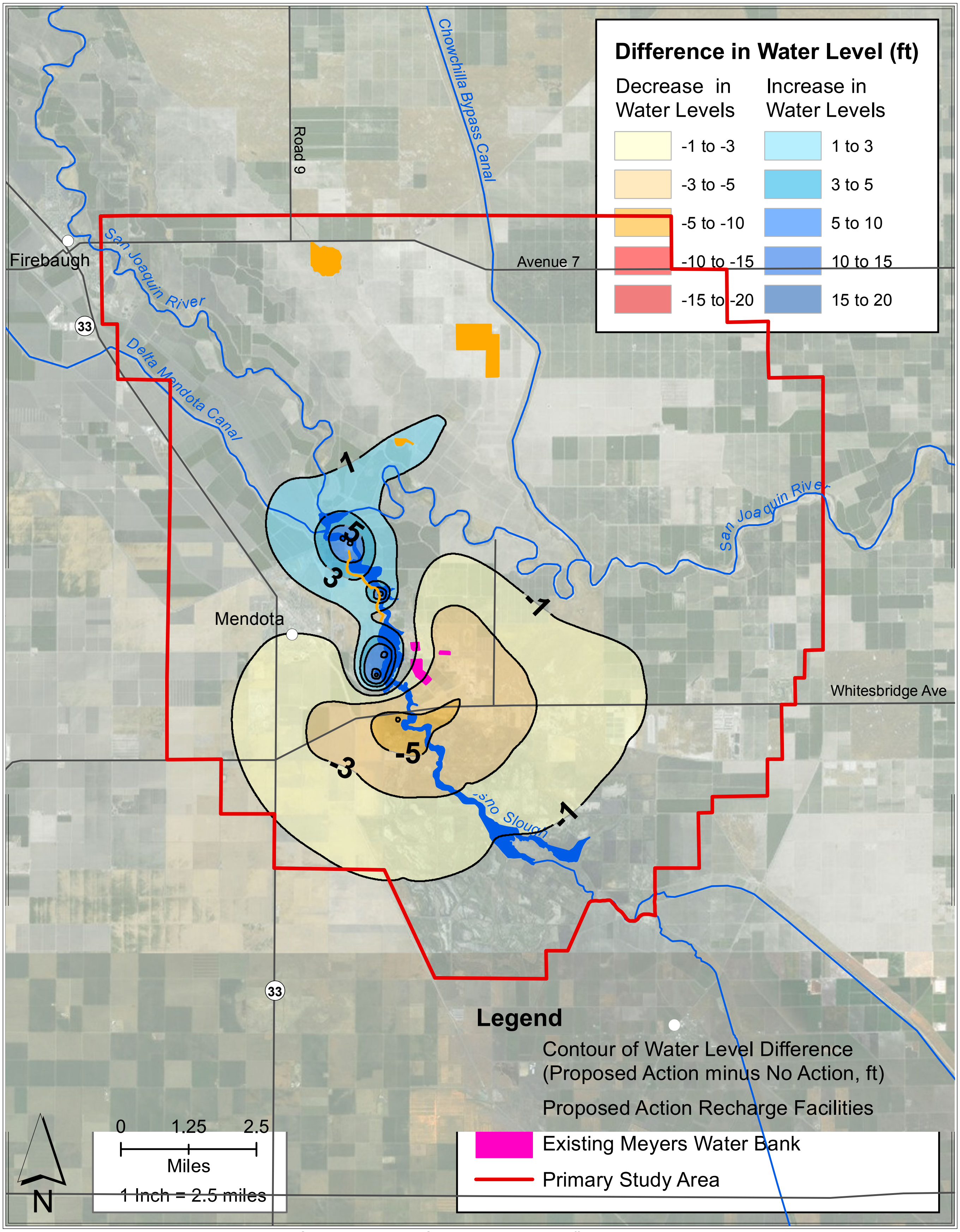

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Figure 8-22
Proposed Action Contours of Equal Simulated Groundwater Elevation Difference Shallow Zone, Year 20

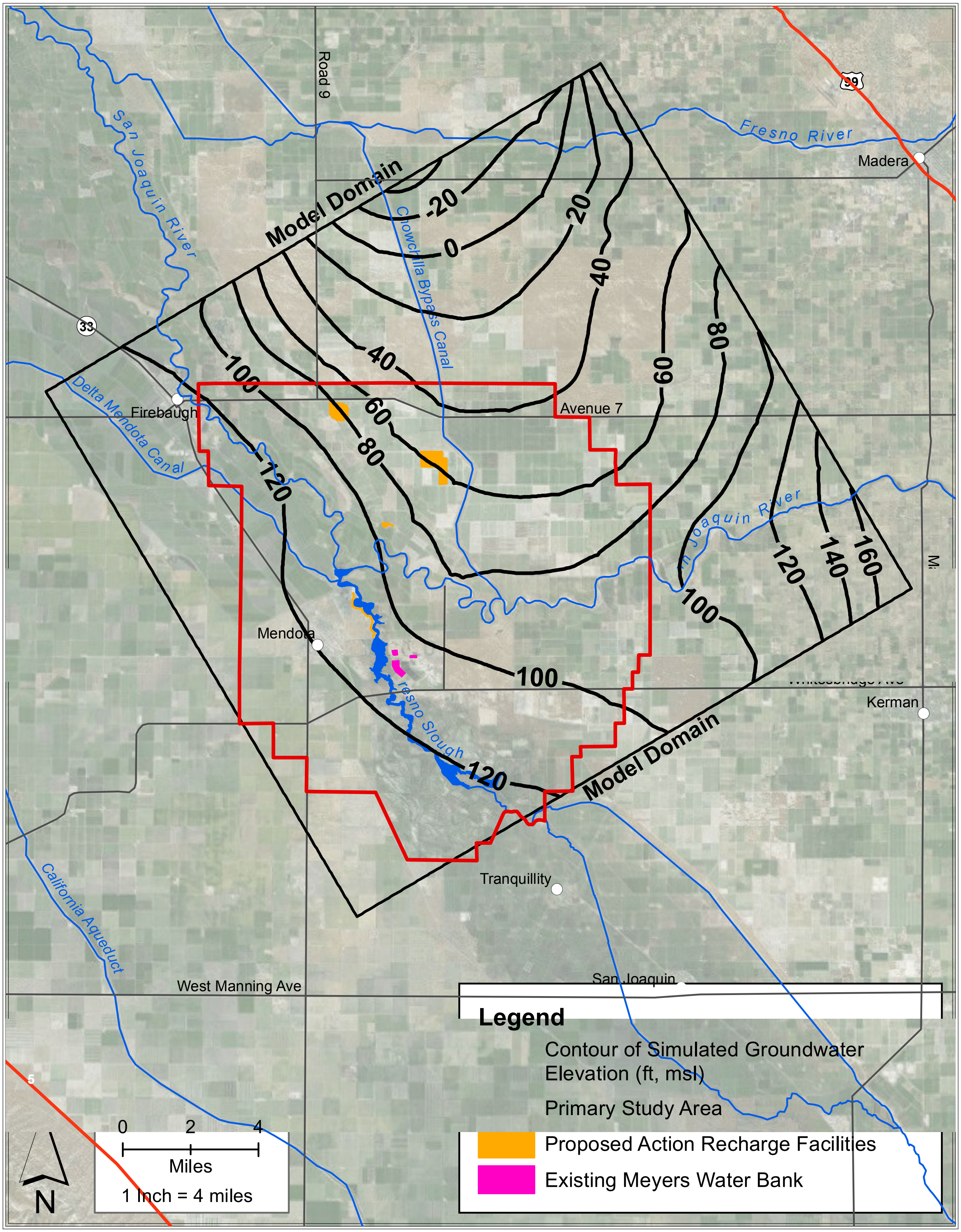

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Figure 8-23
Proposed Action Contours of Equal Simulated Groundwater Elevation Deep Zone, Year 20

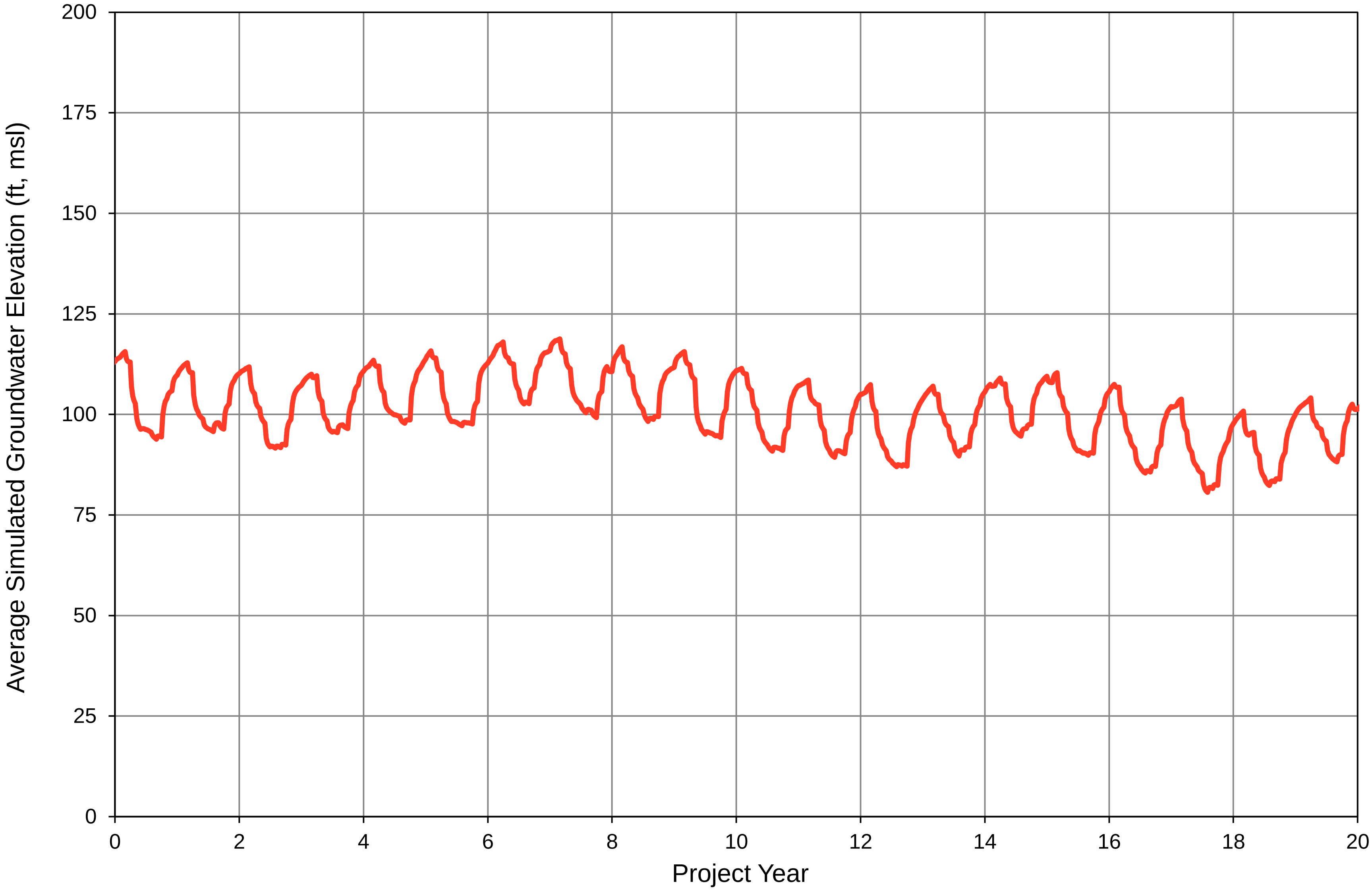

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Figure 8-24
Proposed Action Average Simulated Groundwater Elevation
In the Primary Study Area, Deep Zone
Mendota Pool Group EIS/EIR

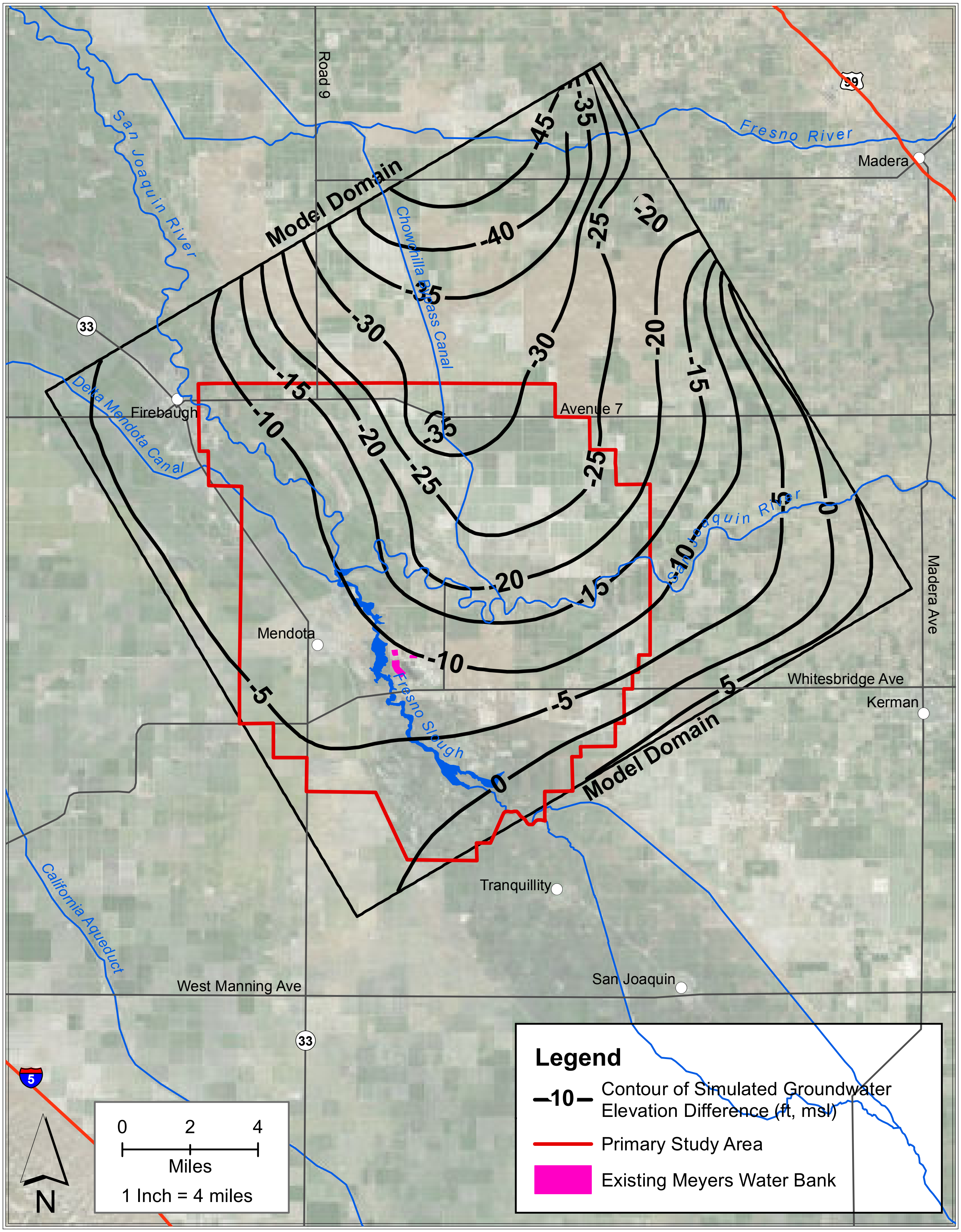

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Figure 8-25
Proposed Action Contours of Equal Simulated Change in Groundwater Elevation Deep Zone, Year 1 to Year 20

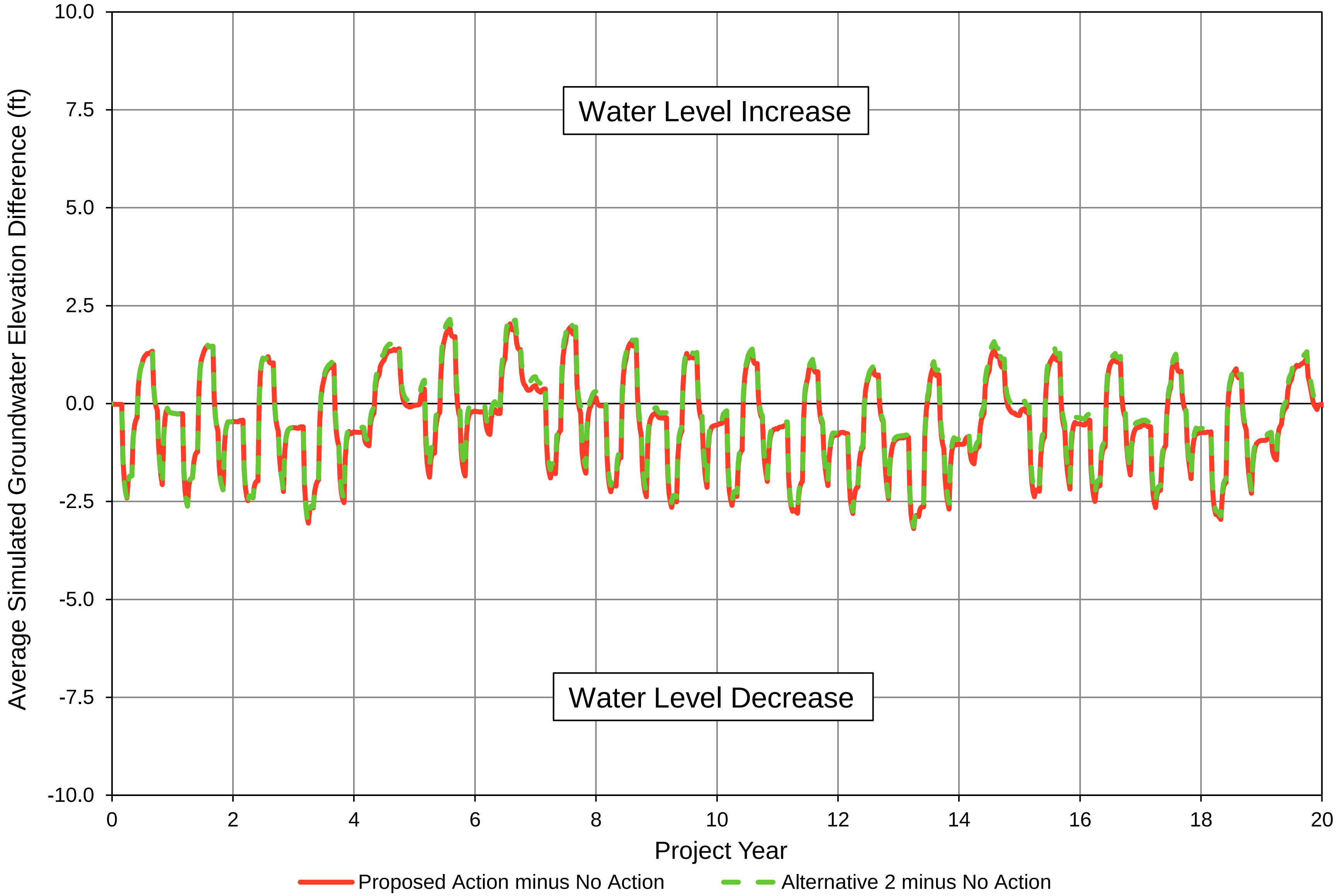

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Figure 8-26
Difference in Average Simulated Groundwater Elevation In the Primary Study Area, Deep Zone
Mendota Pool Group EIS/EIR

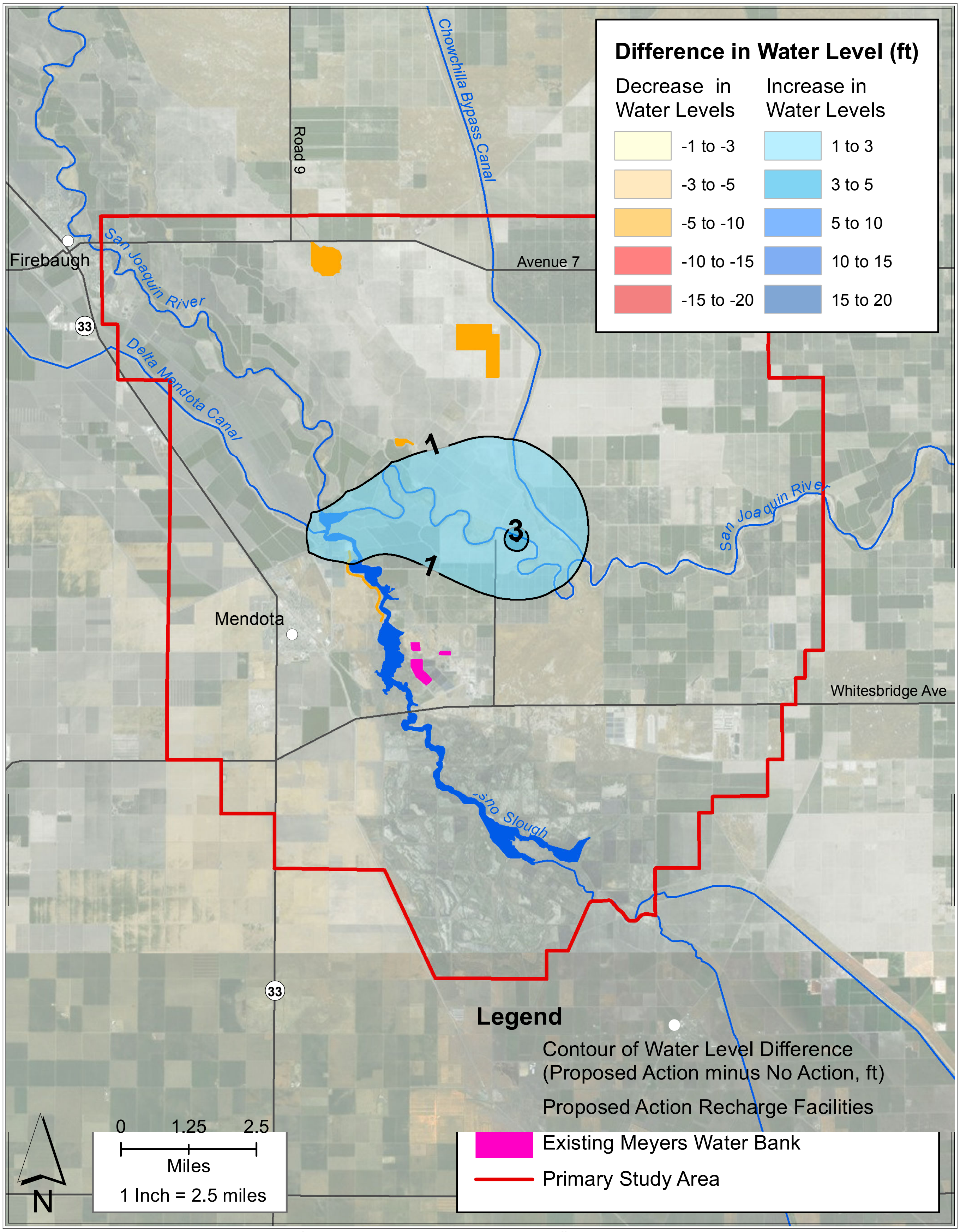

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Figure 8-27
Proposed Action Contours of Equal Simulated Groundwater Elevation Difference Deep Zone, Year 20

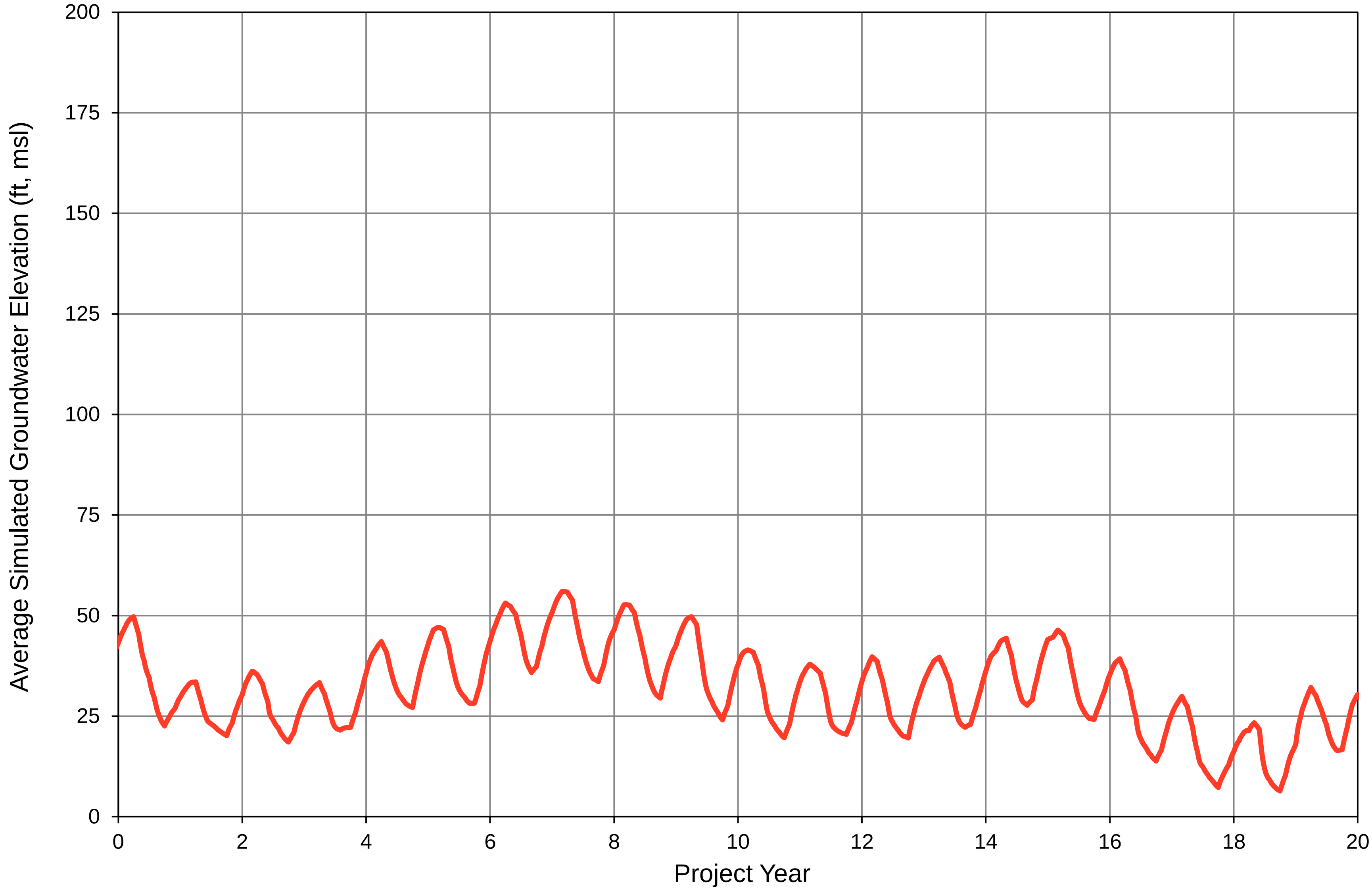

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Figure 8-28
Proposed Action Average Simulated Groundwater Elevation
In the Primary Study Area, Lower Aquifer
Mendota Pool Group EIS/EIR

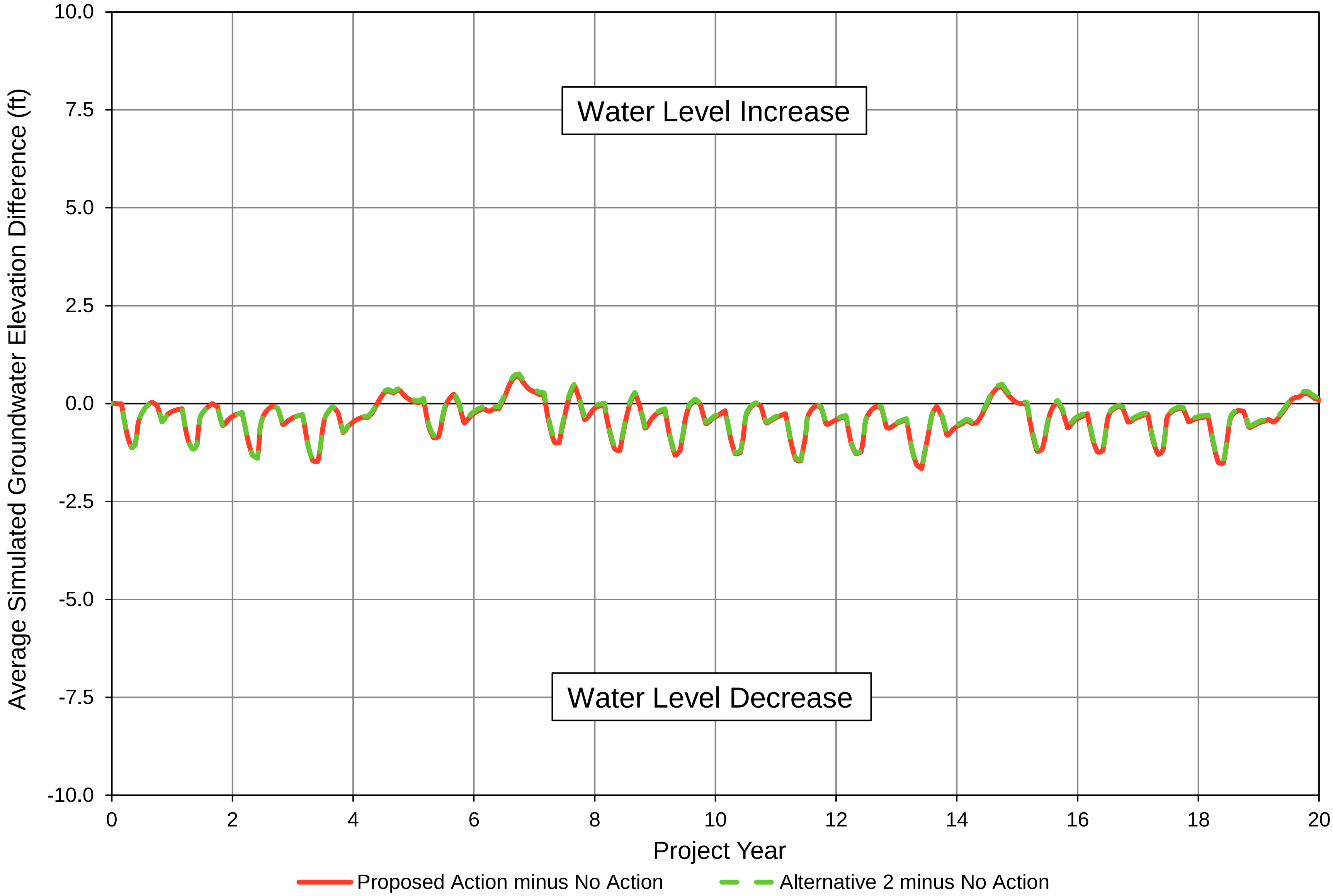

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Figure 8-29
Difference in Average Simulated Groundwater Elevation In the Primary Study Area, Lower Aquifer
Mendota Pool Group EIS/EIR

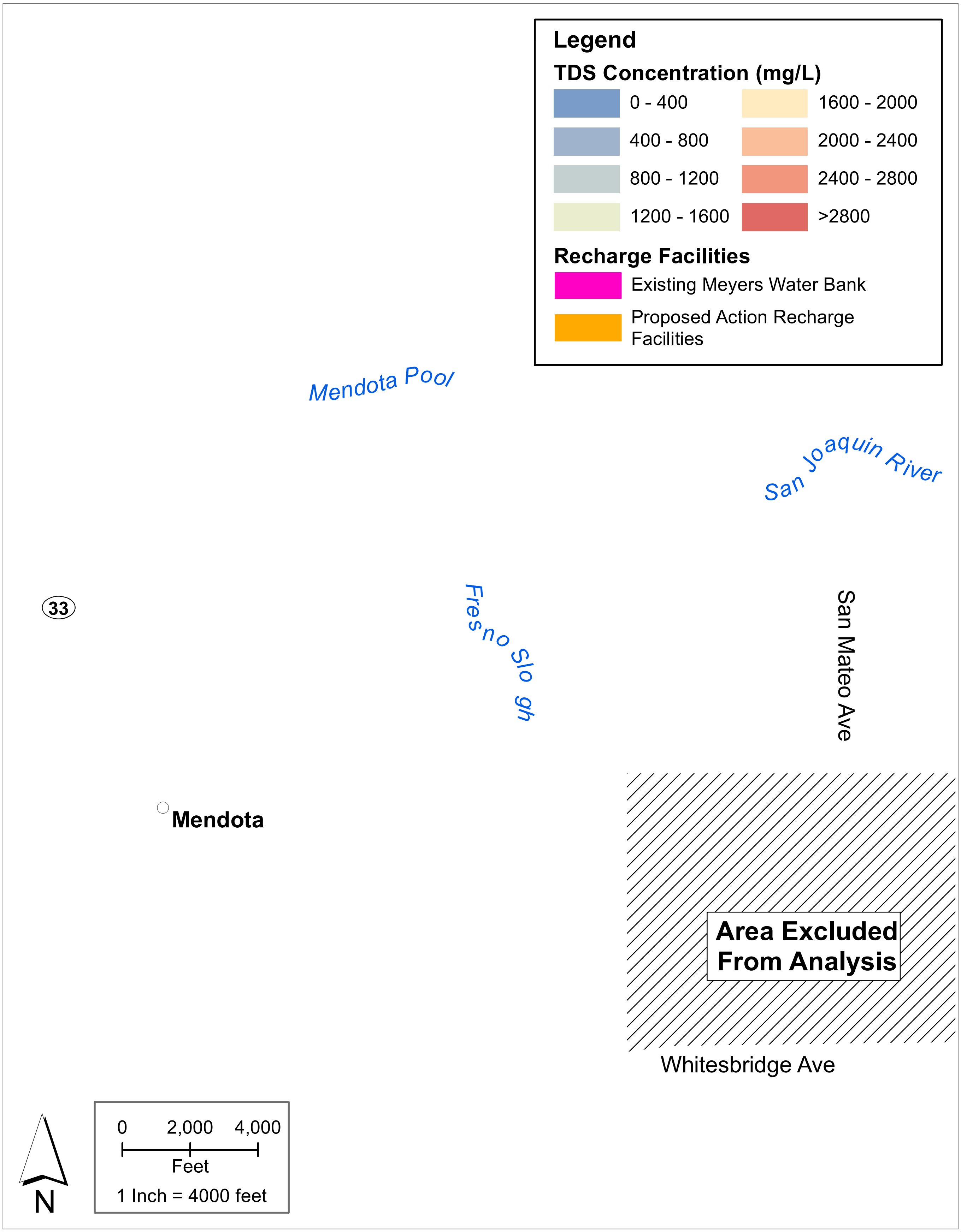

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Figure 8-30
Proposed Action Simulated TDS Concentration Shallow Zone, Year 20

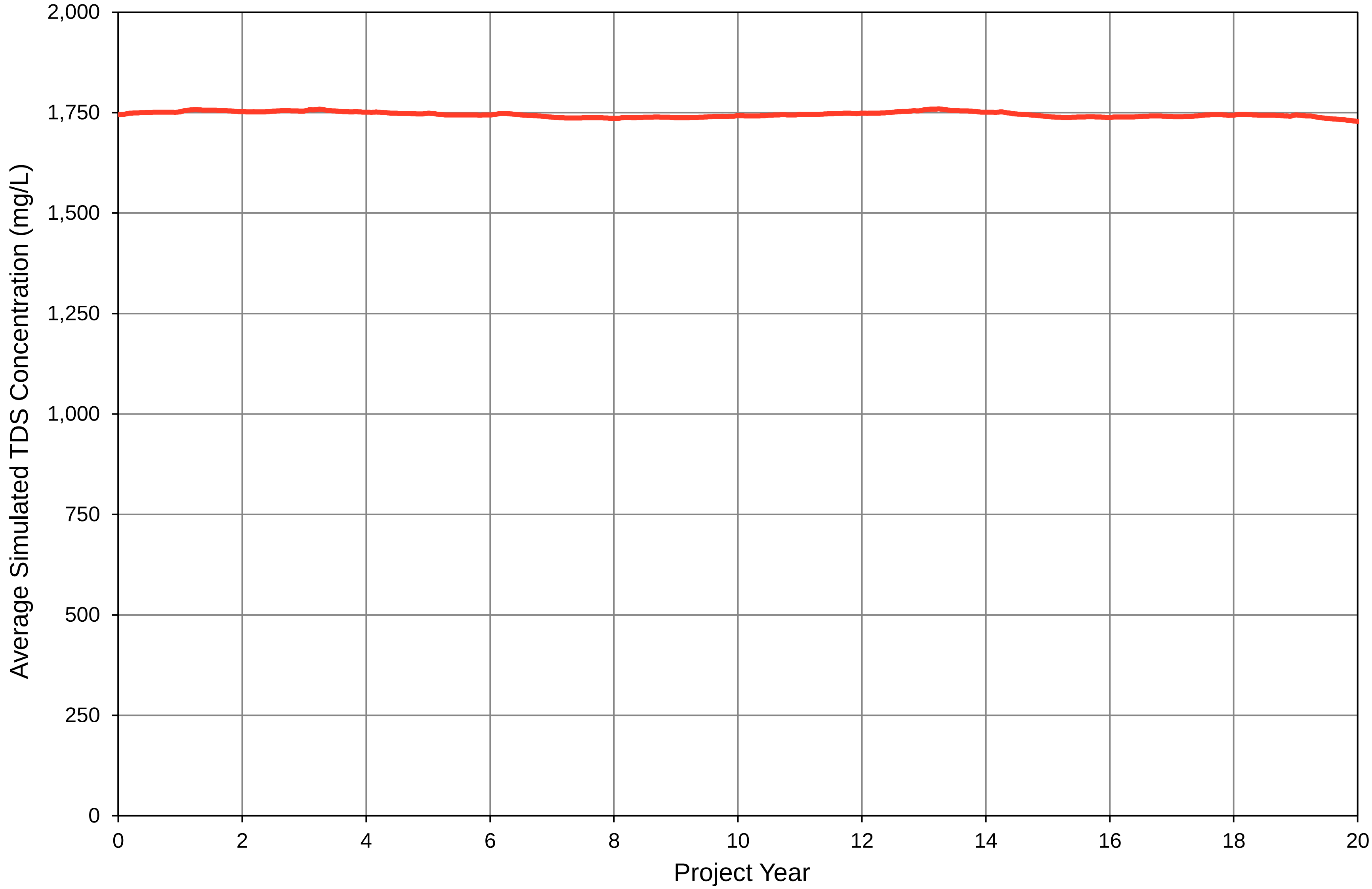

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Figure 8-31
Proposed Action Average Simulated TDS Concentration
In the Primary Study Area, Shallow Zone
Mendota Pool Group EIS/EIR

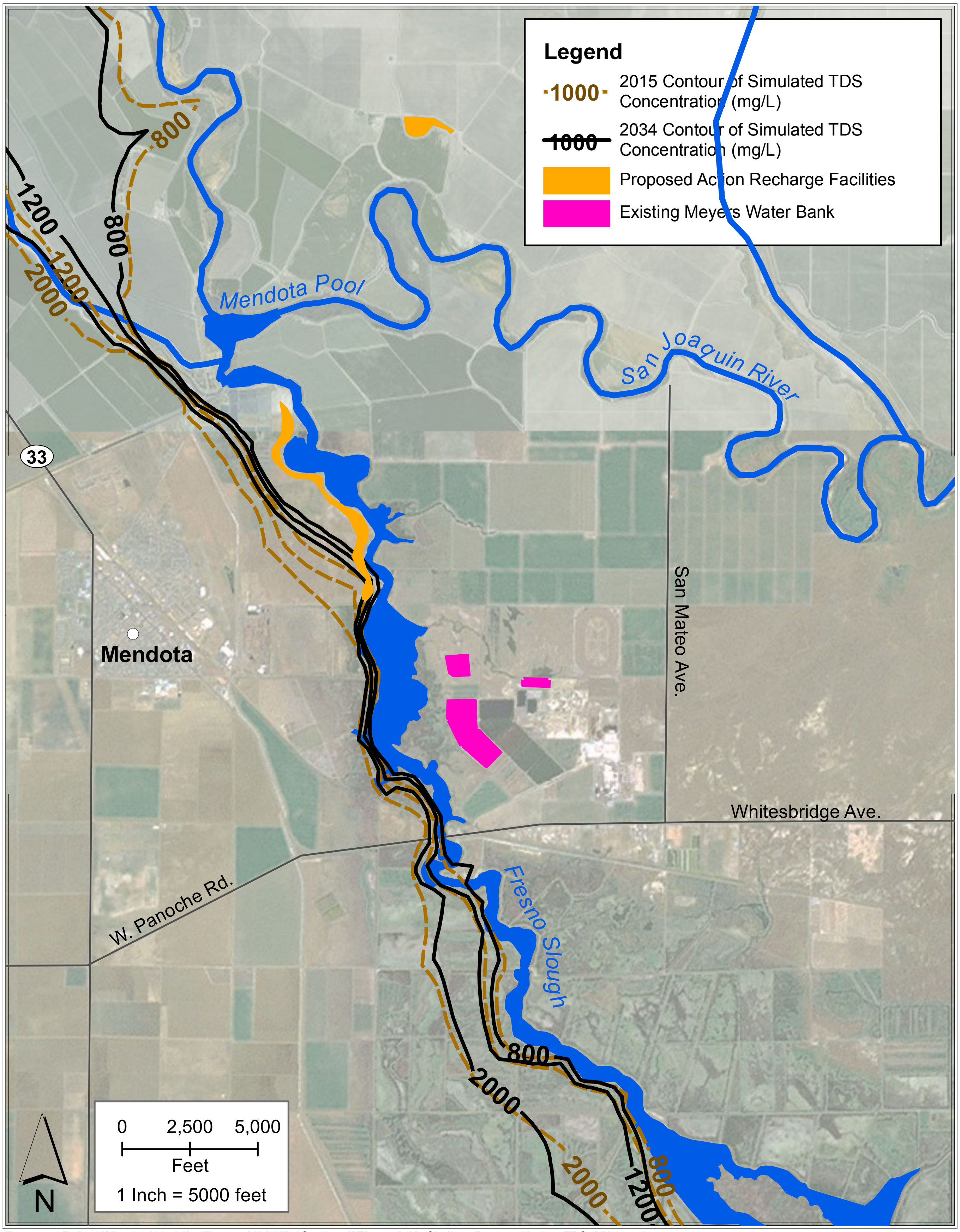

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Figure 8-32
Proposed Action Contours of Equal Simulated TDS Concentration Shallow Zone, Year 20

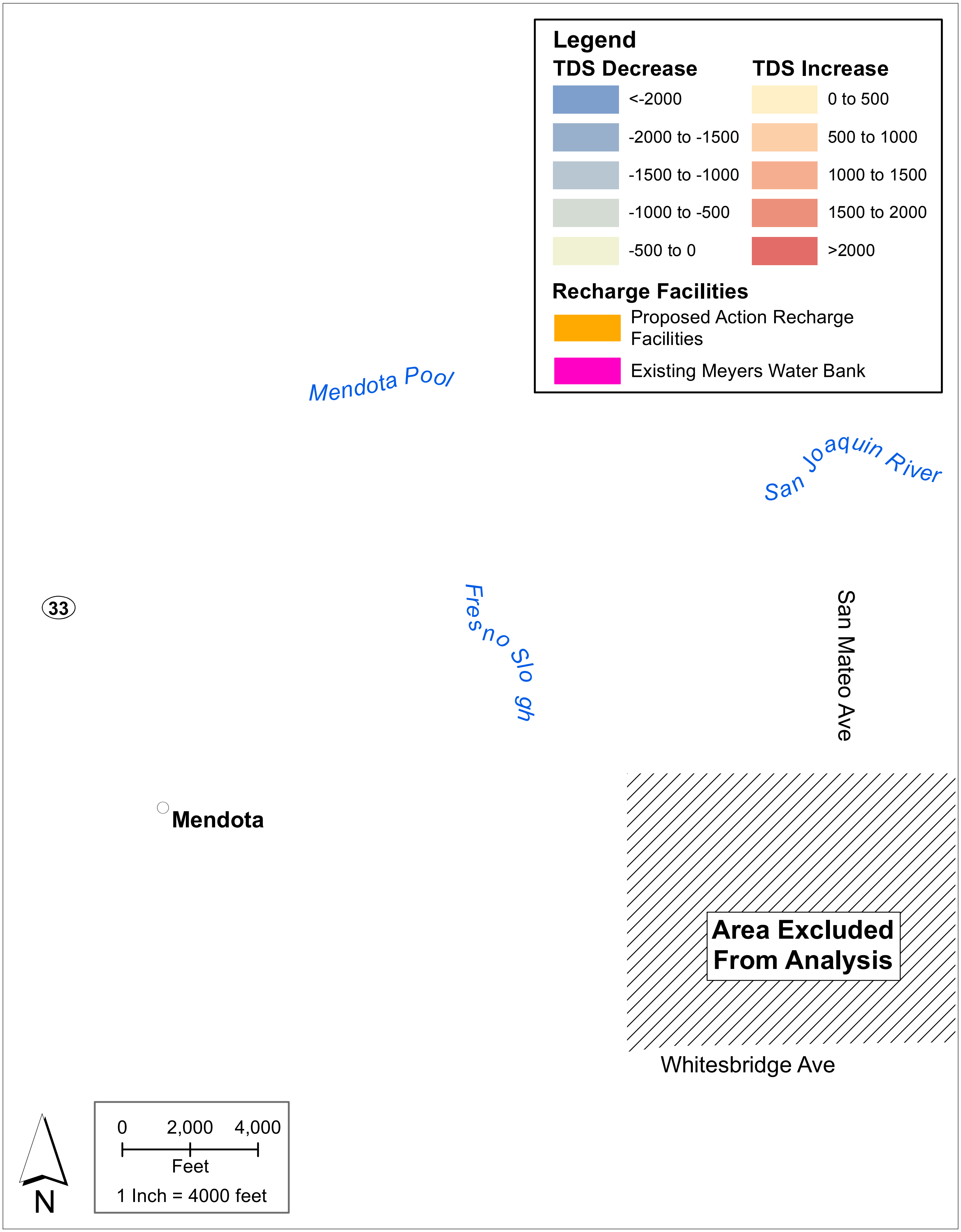

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Figure 8-33
Proposed Action Simulated Change in TDS Concentration from Year 1 to Year 20 Shallow Zone

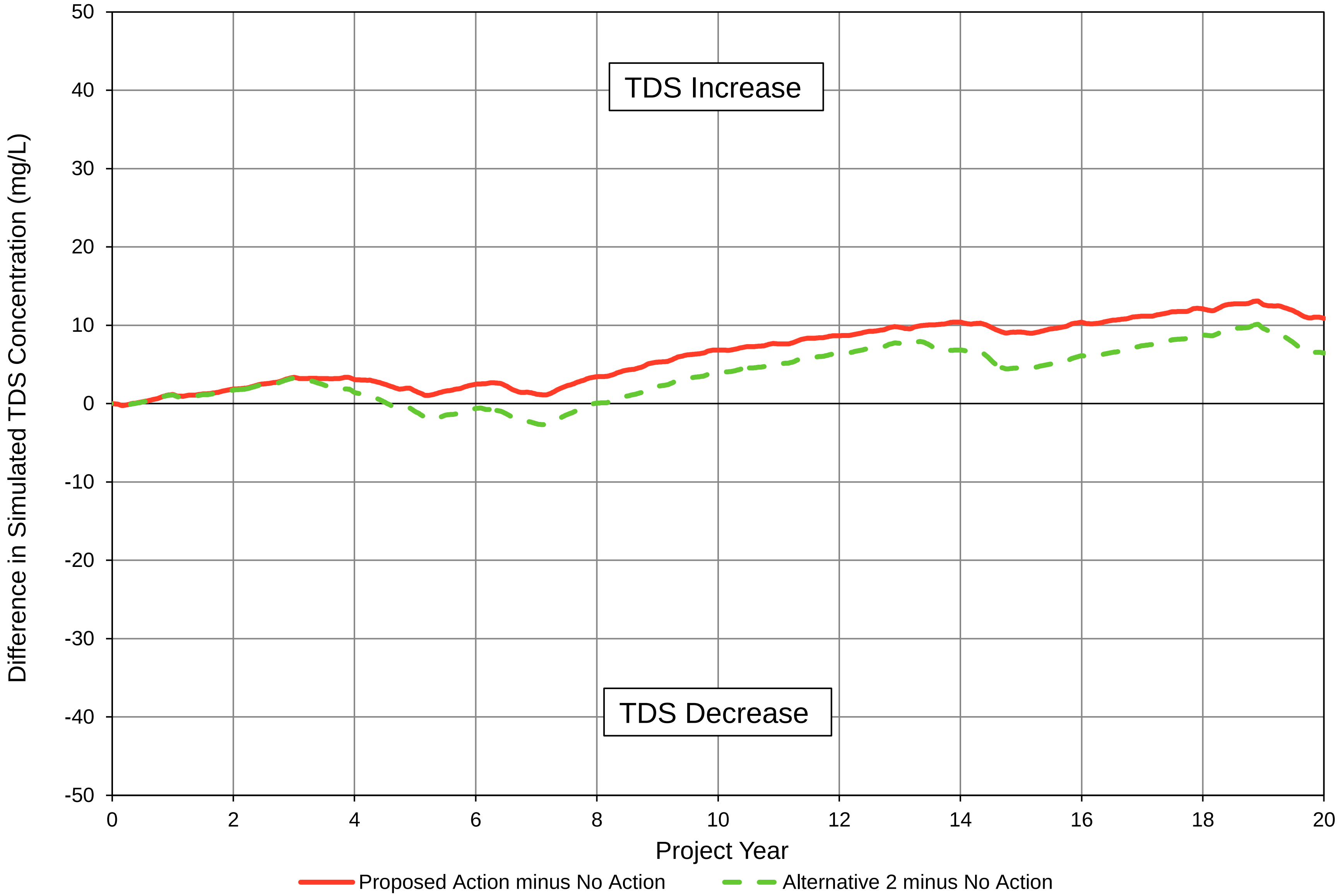

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Figure 8-34
Difference in Average Simulated TDS Concentrations
In the Primary Study Area, Shallow Zone
Mendota Pool Group EIS/EIR

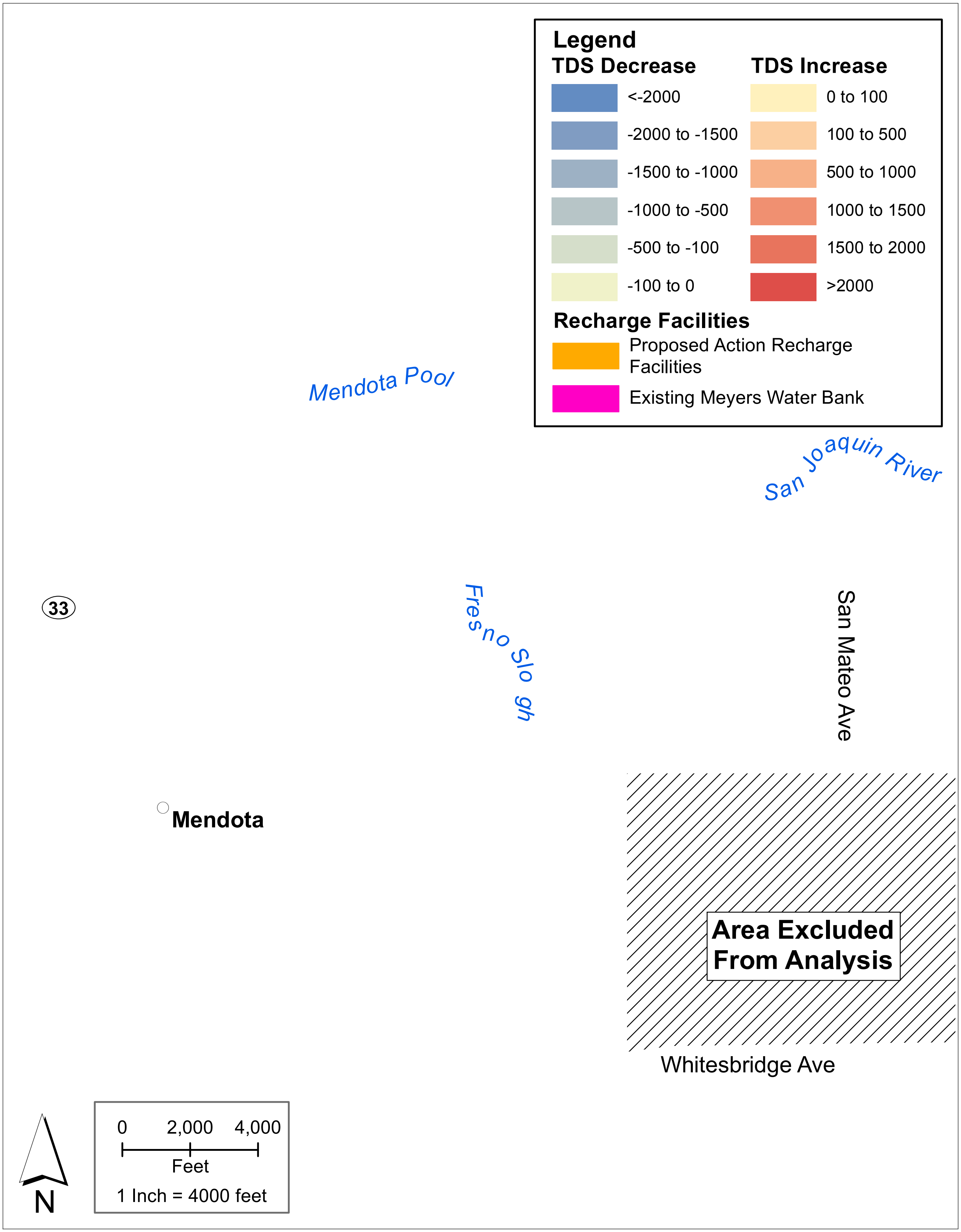

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Figure 8-35
Simulated TDS Difference by Year 20
Proposed Action minus No Action
Shallow Zone

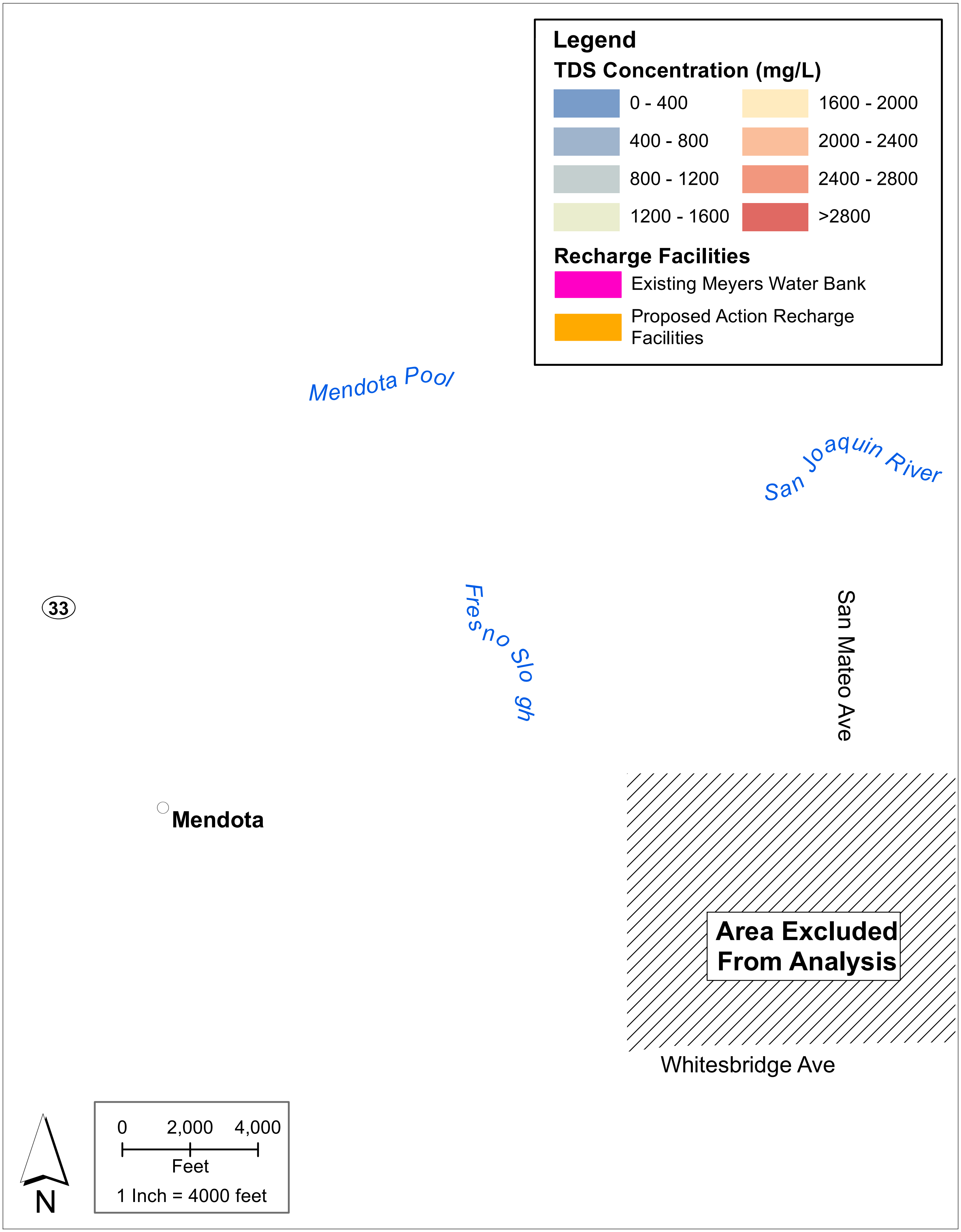

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Figure 8-36
Proposed Action Simulated TDS Concentration Deep Zone, Year 20

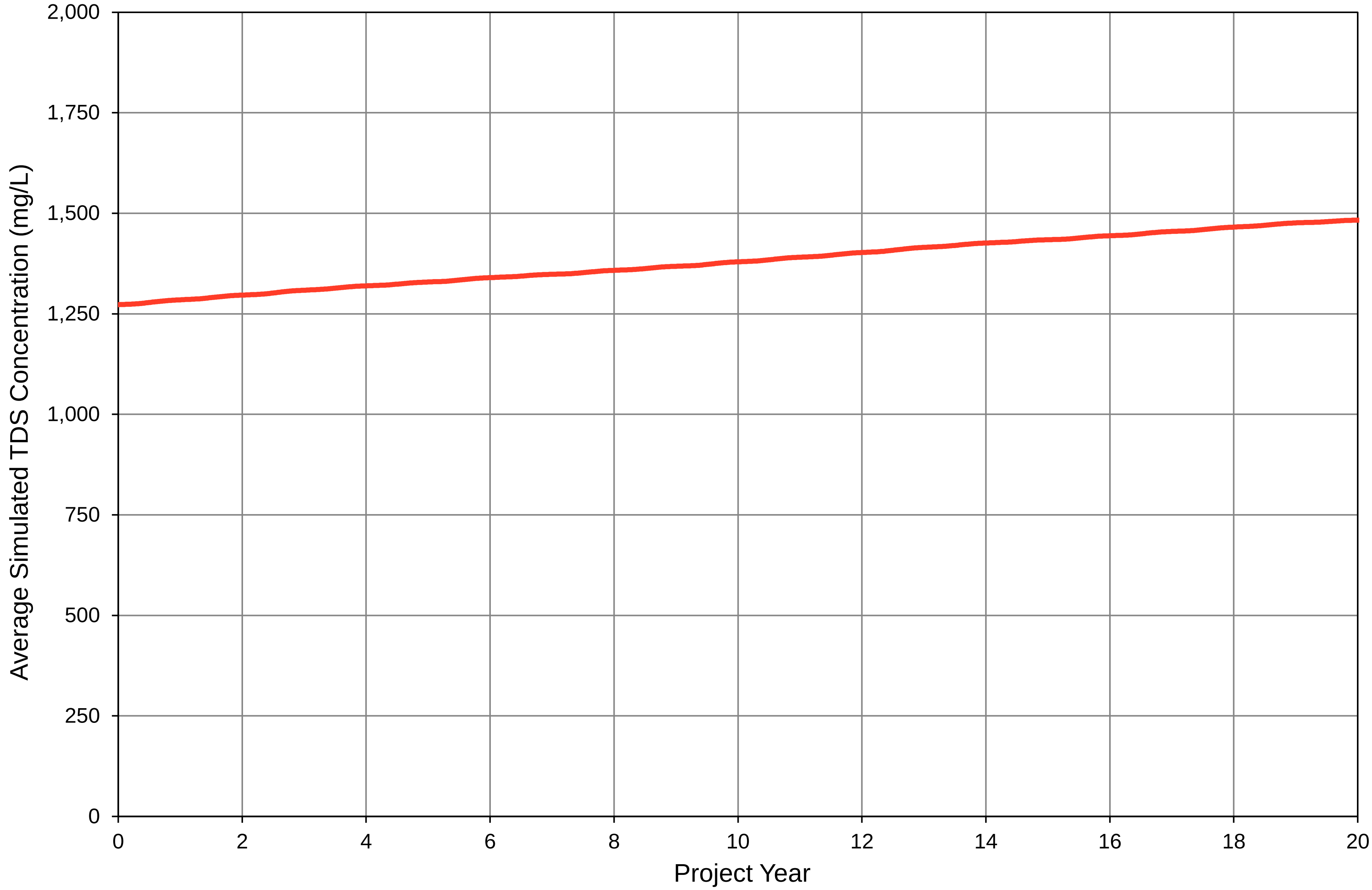

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Figure 8-37
Proposed Action Average Simulated TDS Concentration
In the Primary Study Area, Deep Zone
Mendota Pool Group EIS/EIR

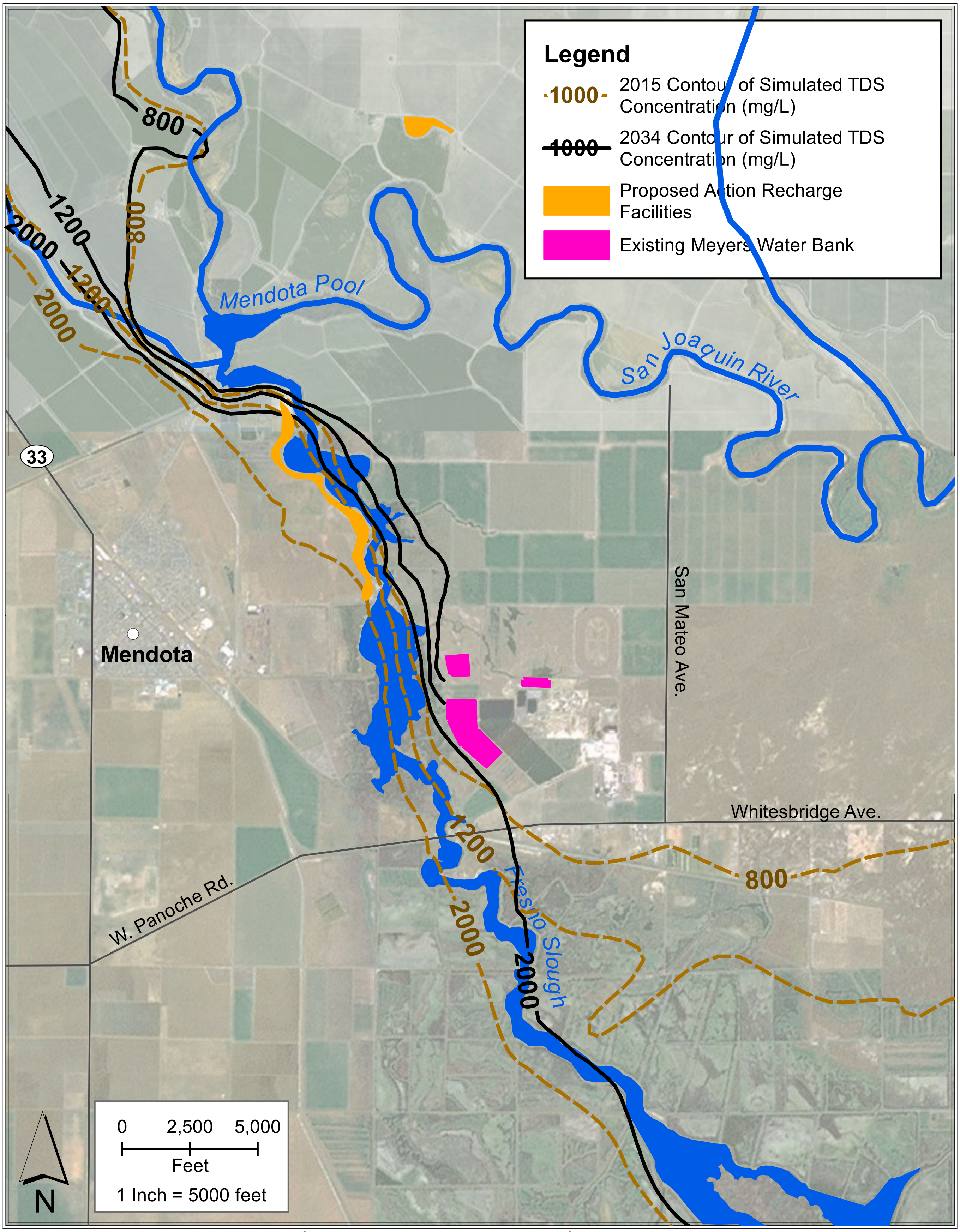

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Figure 8-38
Proposed Action Contours of Equal Simulated TDS Concentration Deep Zone, Year 20

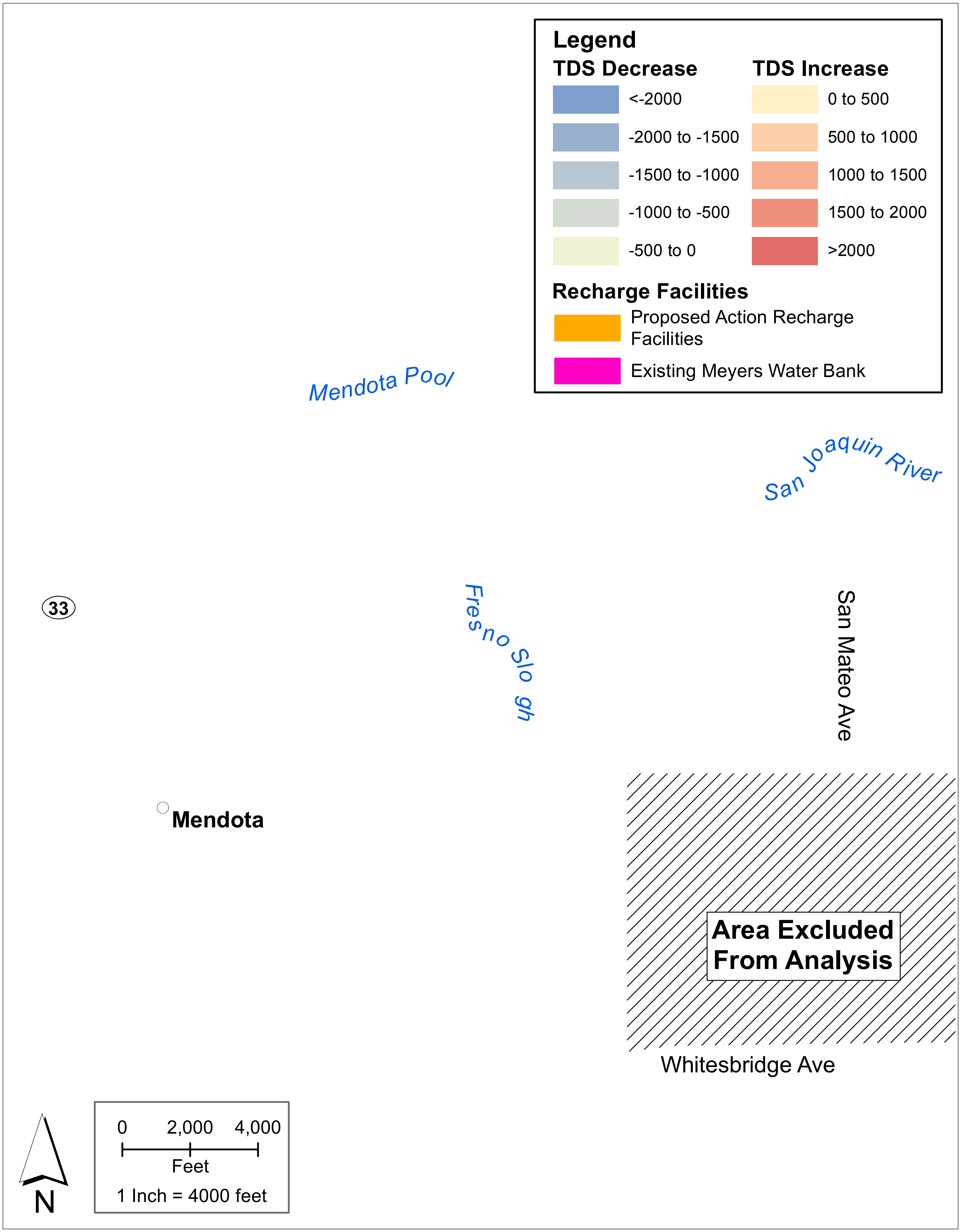

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Figure 8-39
Proposed Action Simulated Change in TDS Concentration from Year 1 to Year 20 Deep Zone

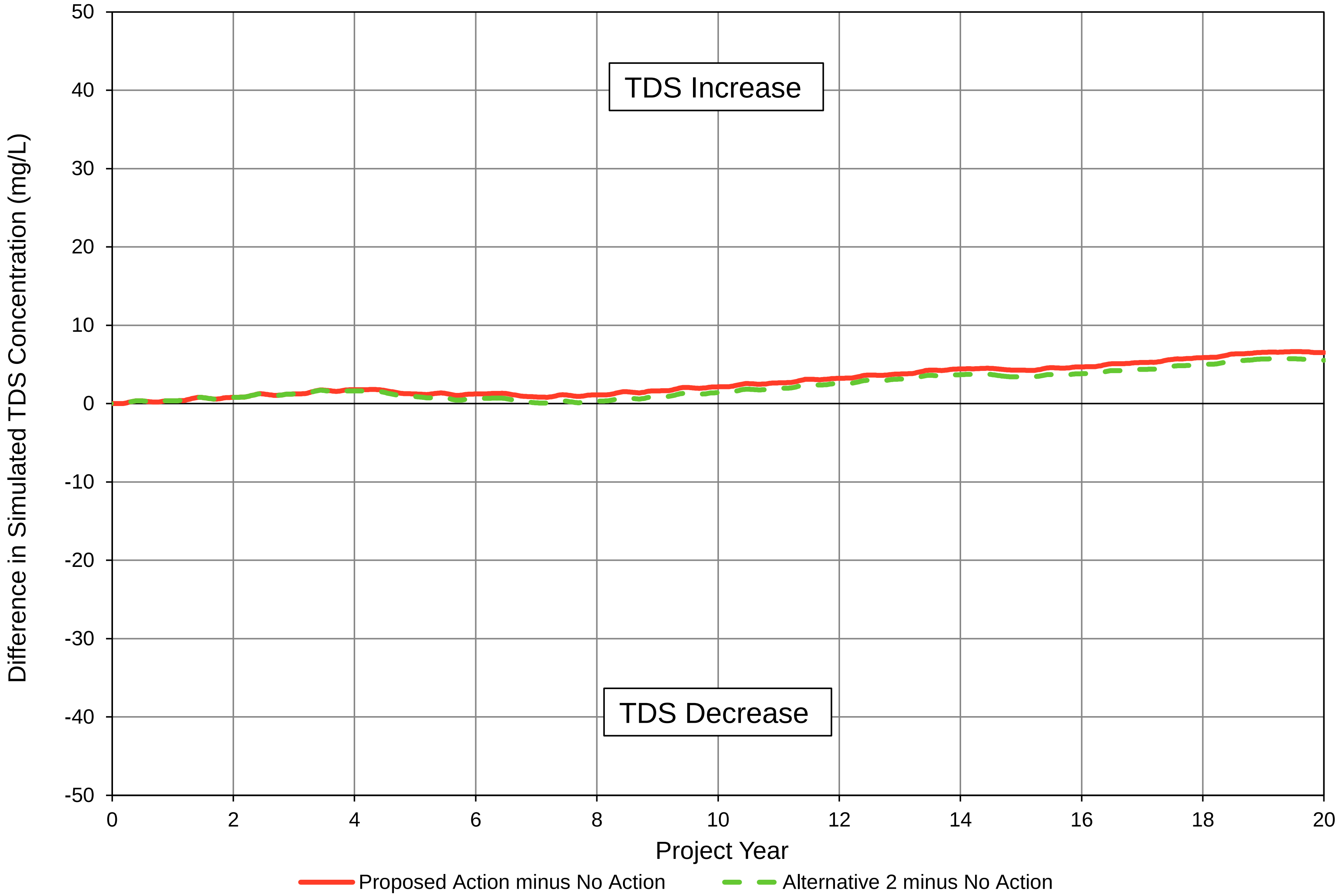

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Figure 8-40
Difference in Average Simulated TDS Concentrations
In the Primary Study Area, Deep Zone
Mendota Pool Group EIS/EIR

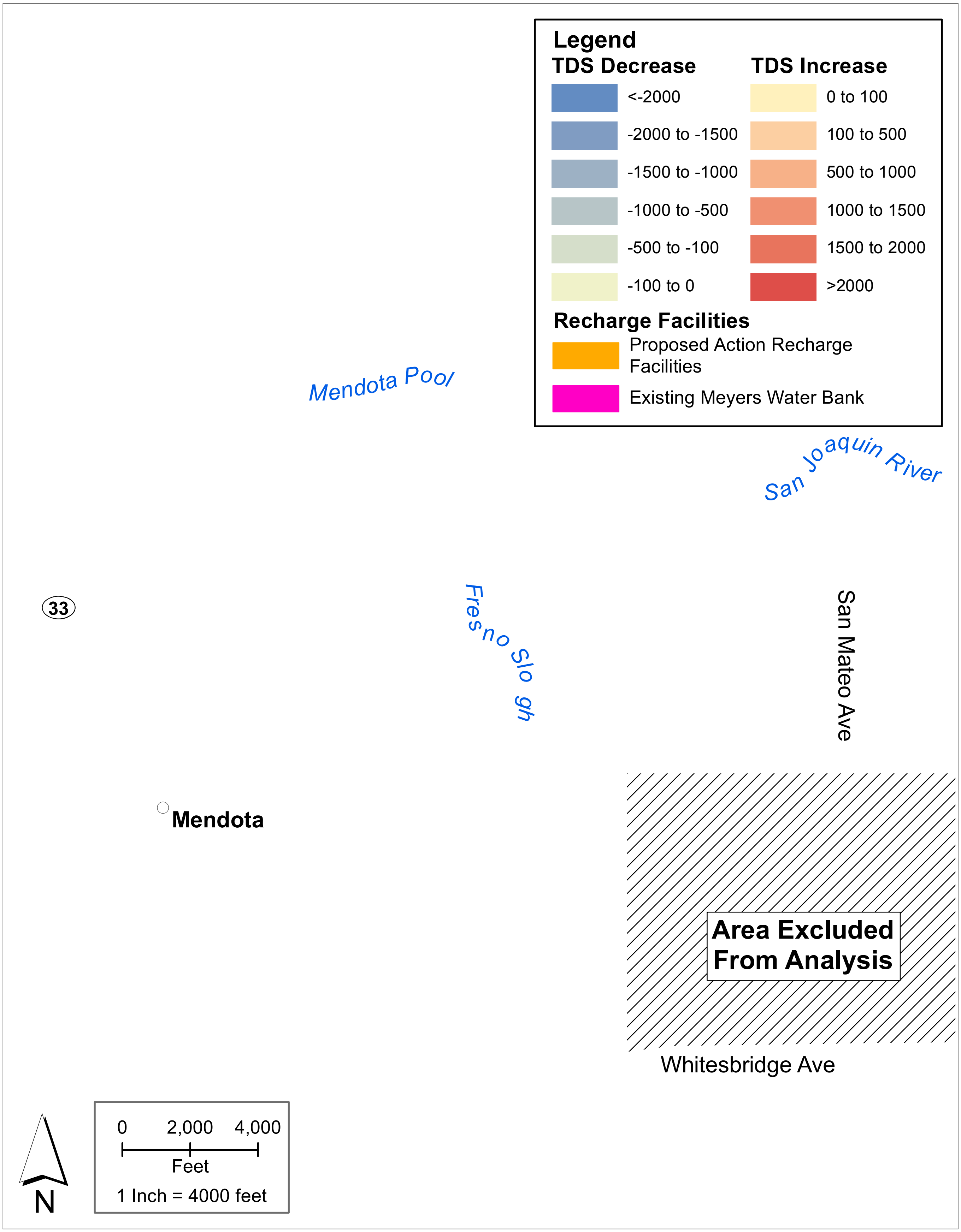

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Figure 8-41
Simulated TDS Difference by Year 20
Proposed Action minus No Action
Deep Zone

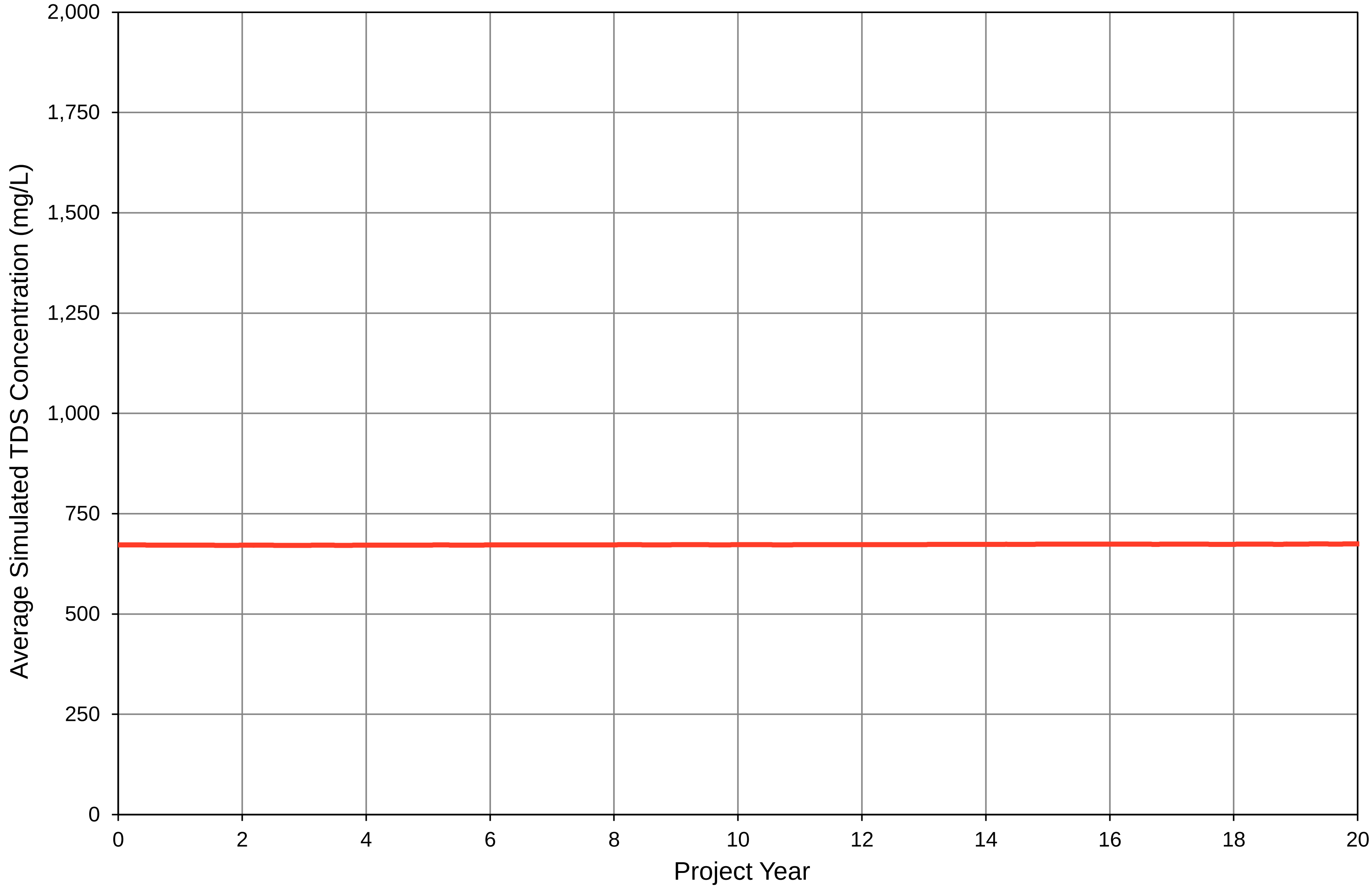

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Figure 8-42
Proposed Action Average Simulated TDS Concentration
In the Primary Study Area, Lower Aquifer
Mendota Pool Group EIS/EIR

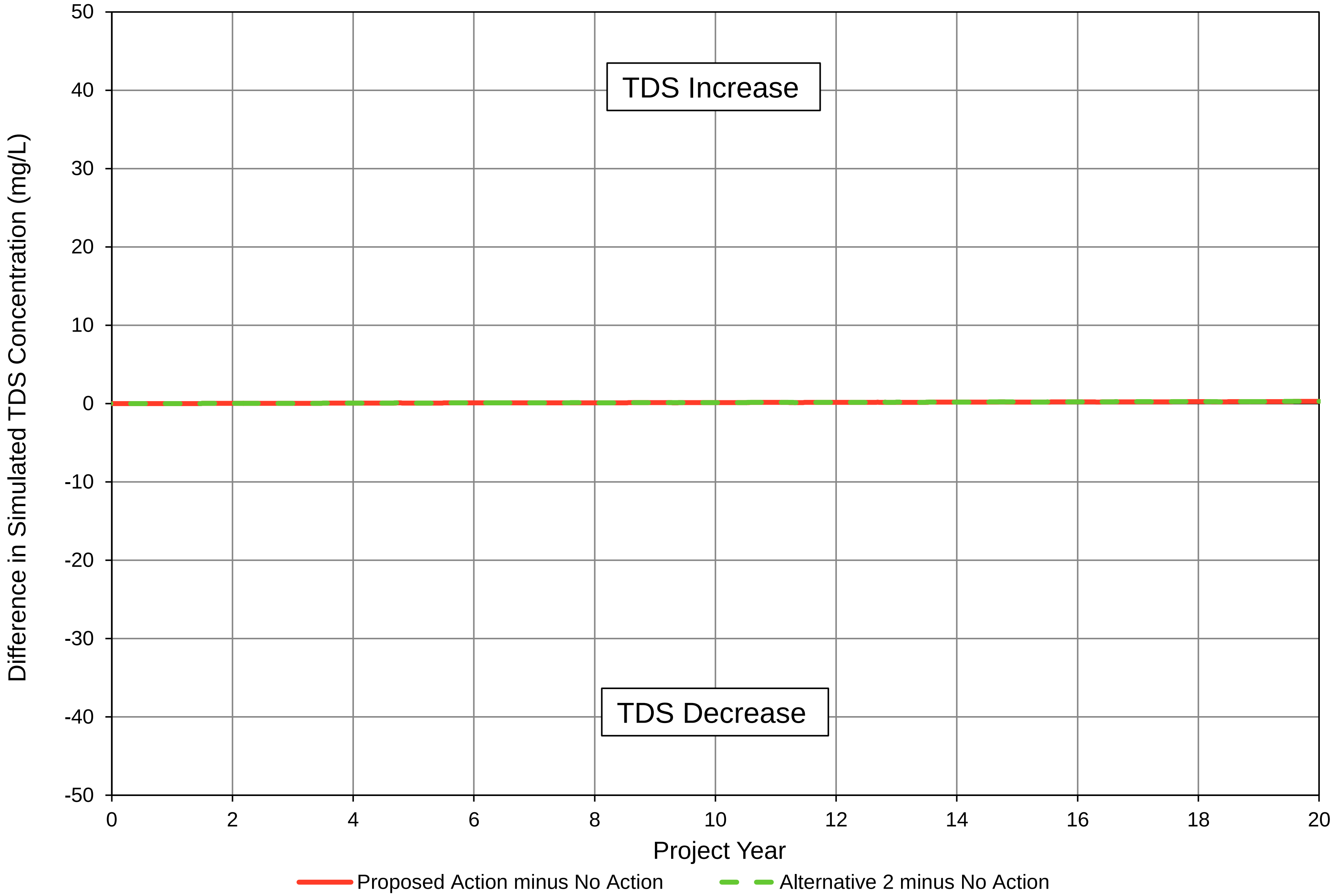

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Figure 8-43
Difference in Average Simulated TDS Concentrations
In the Primary Study Area, Lower Aquifer
Mendota Pool Group EIS/EIR

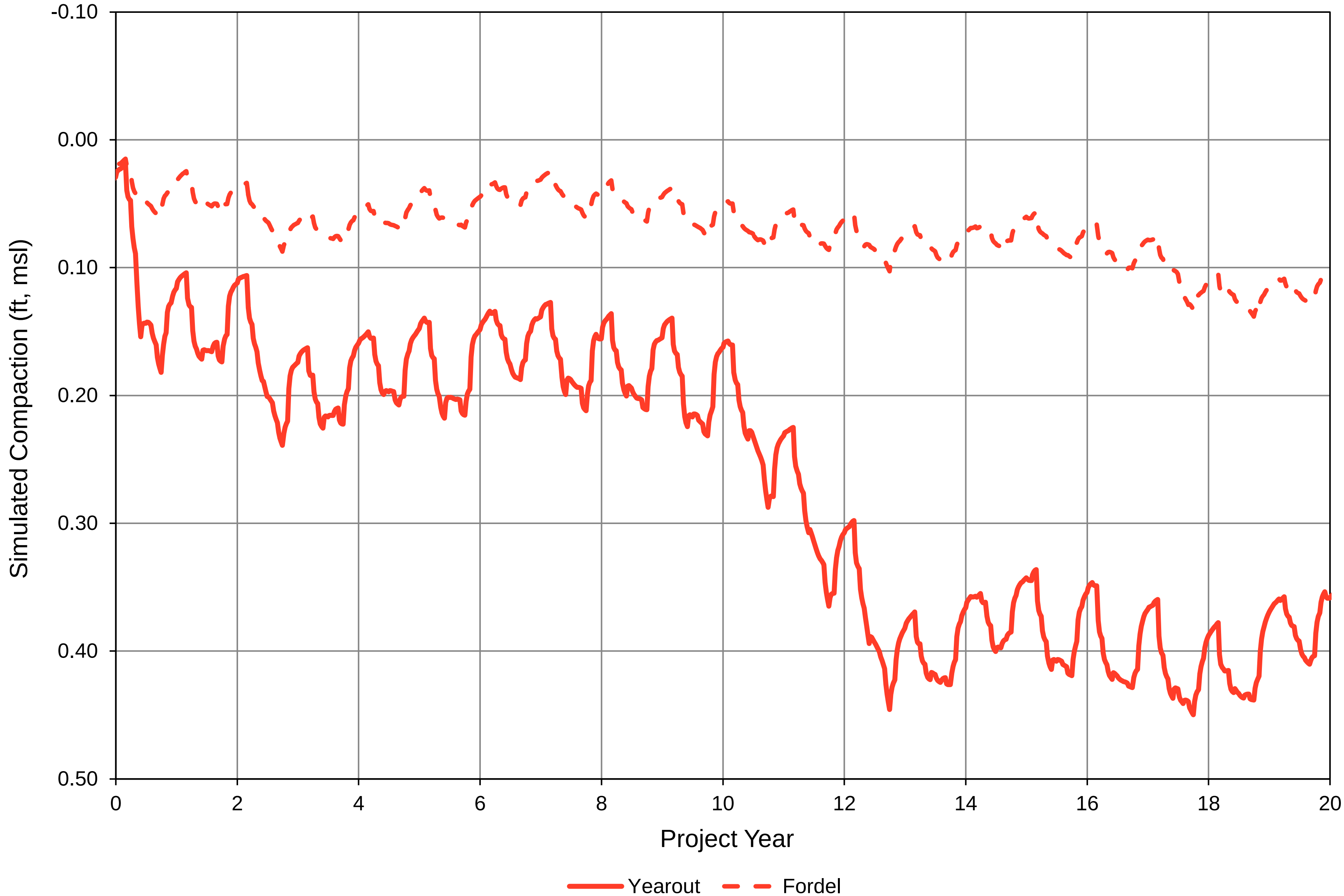

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Figure 8-44
Proposed Action Simulated Compaction Above the Corcoran Clay
Mendota Pool Group EIS/EIR

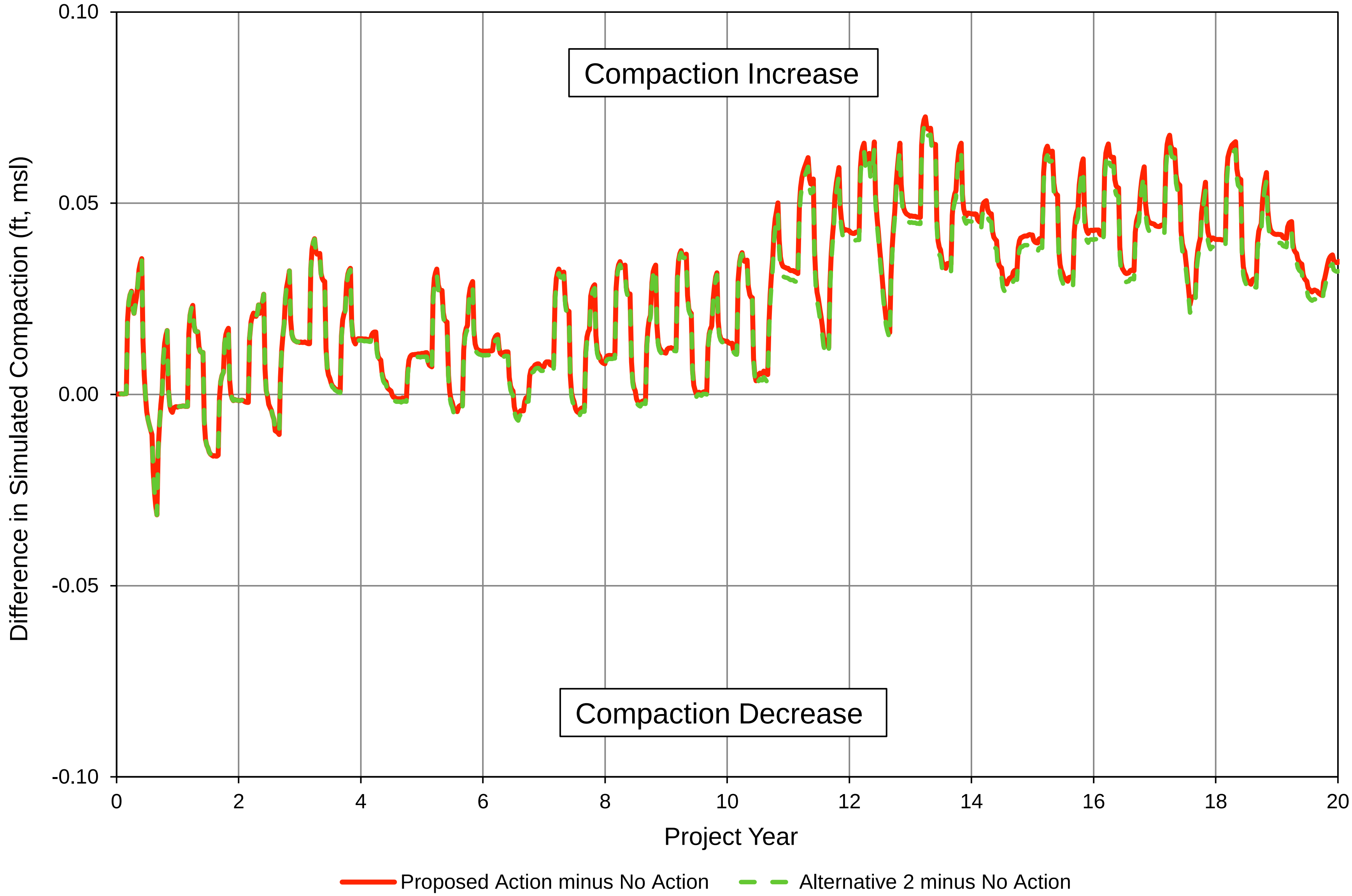

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Figure 8-45
Difference in Simulated Compaction Above the Corcoran Clay at Yearout
Mendota Pool Group EIS/EIR

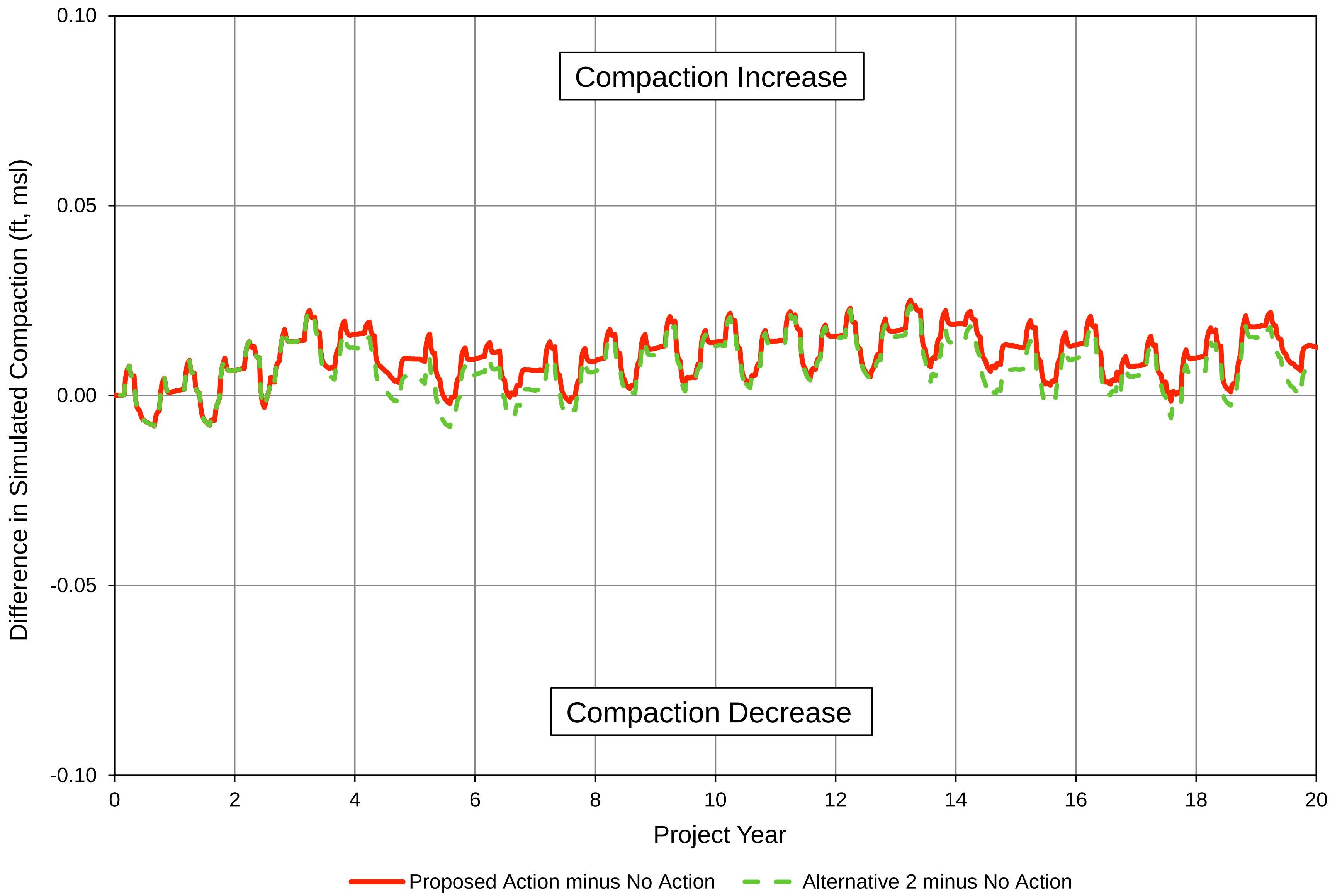

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Figure 8-46
Difference in Simulated Compaction Above the Corcoran Clay at Fordel
Mendota Pool Group EIS/EIR

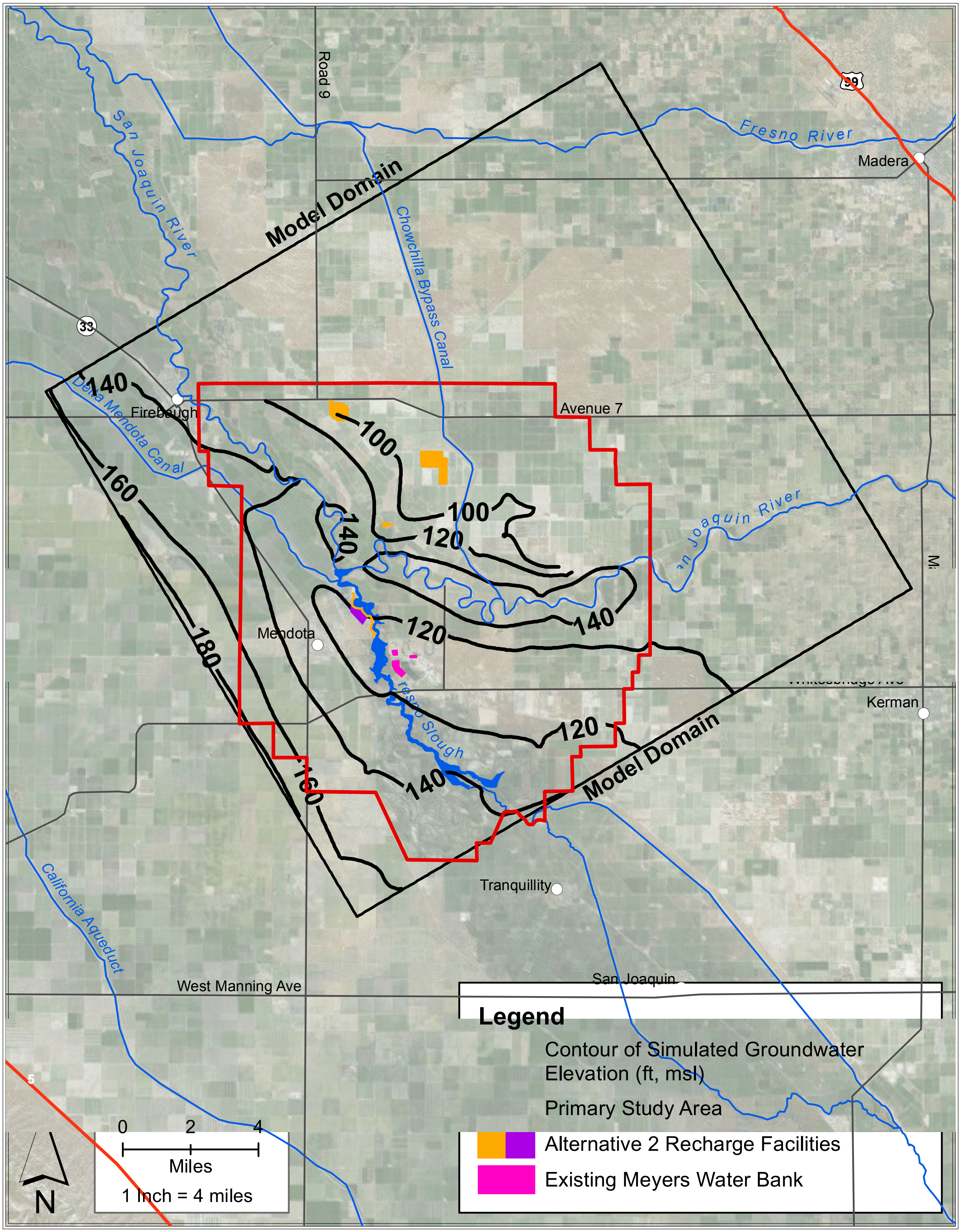

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Figure 8-47
Alternative 2 Contours of Equal Simulated Groundwater Elevation Shallow Zone, Year 20

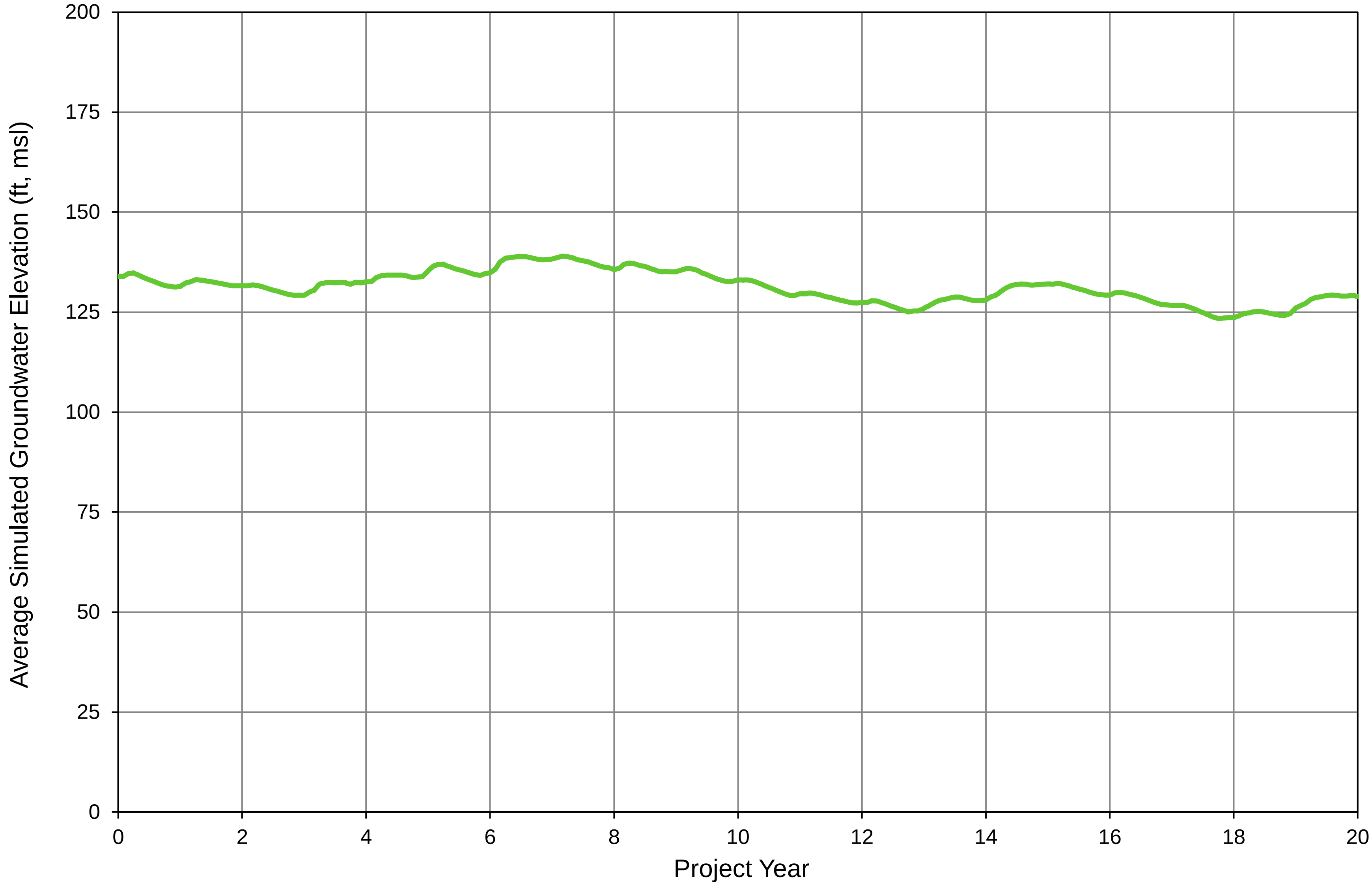

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Figure 8-48
Alternative 2 Average Simulated Groundwater Elevation
In the Primary Study Area, Shallow Zone
Mendota Pool Group EIS/EIR

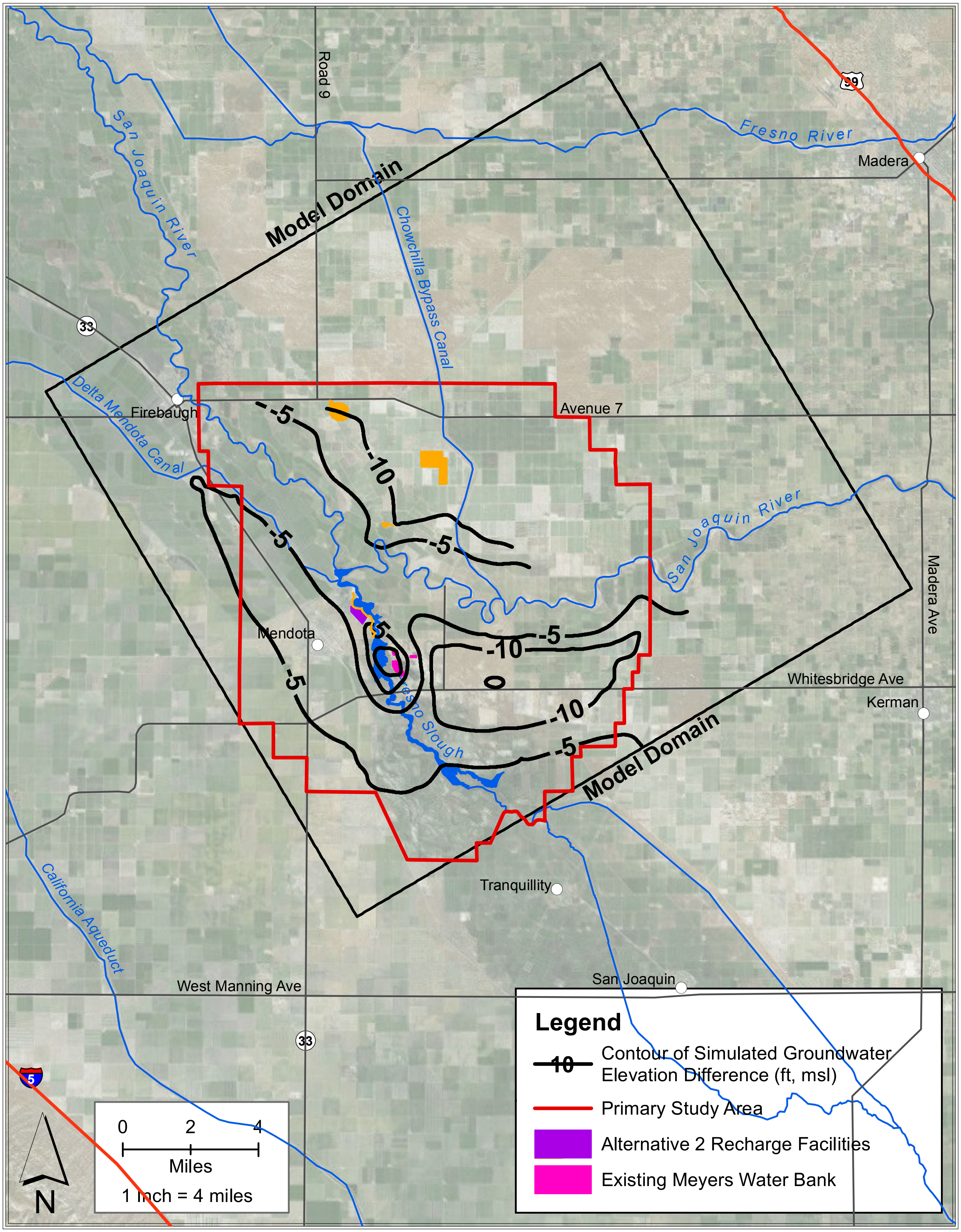

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Figure 8-49
Alternative 2 Contours of Equal Simulated Change in Groundwater Elevation Shallow Zone, Year 1 to Year 20

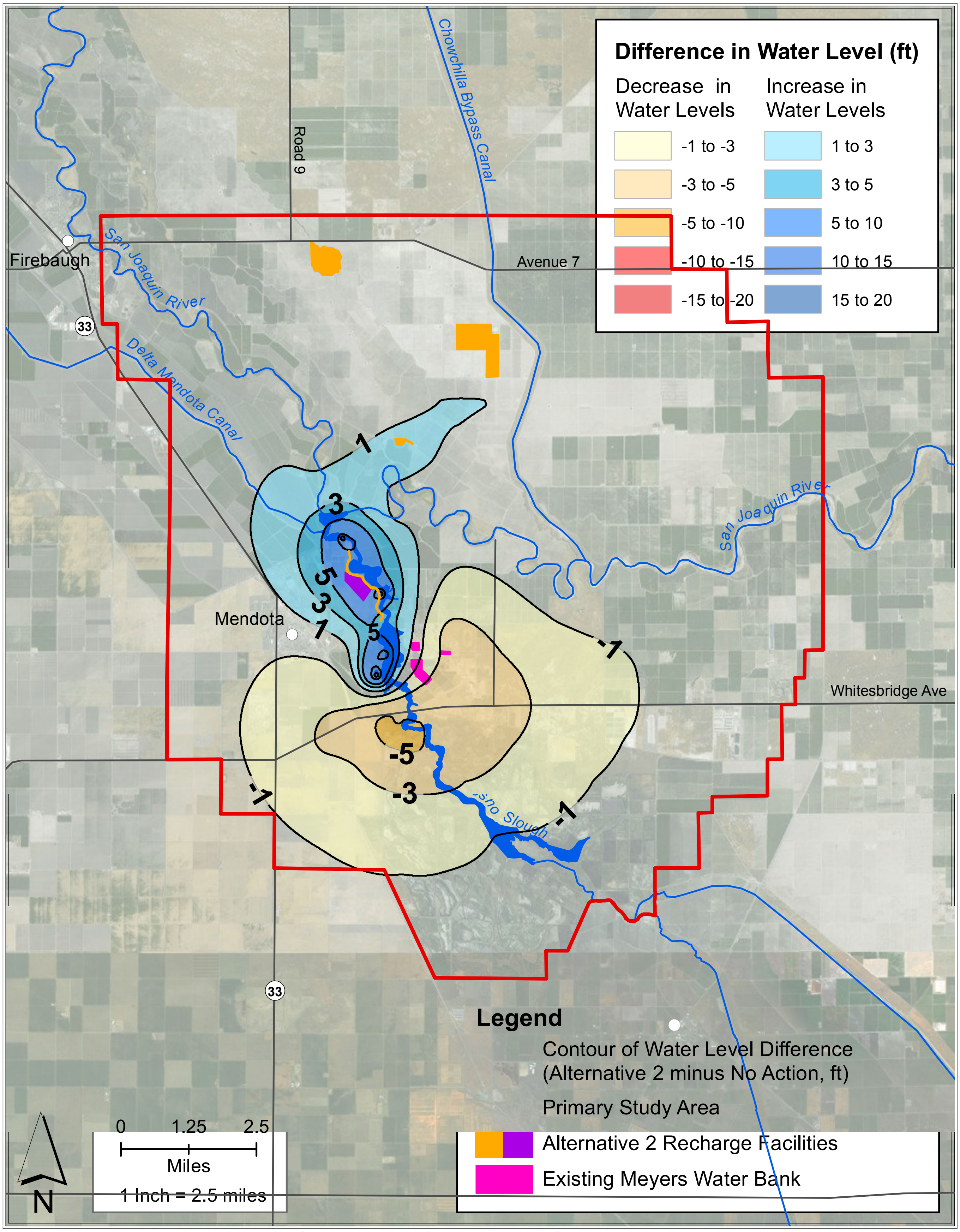

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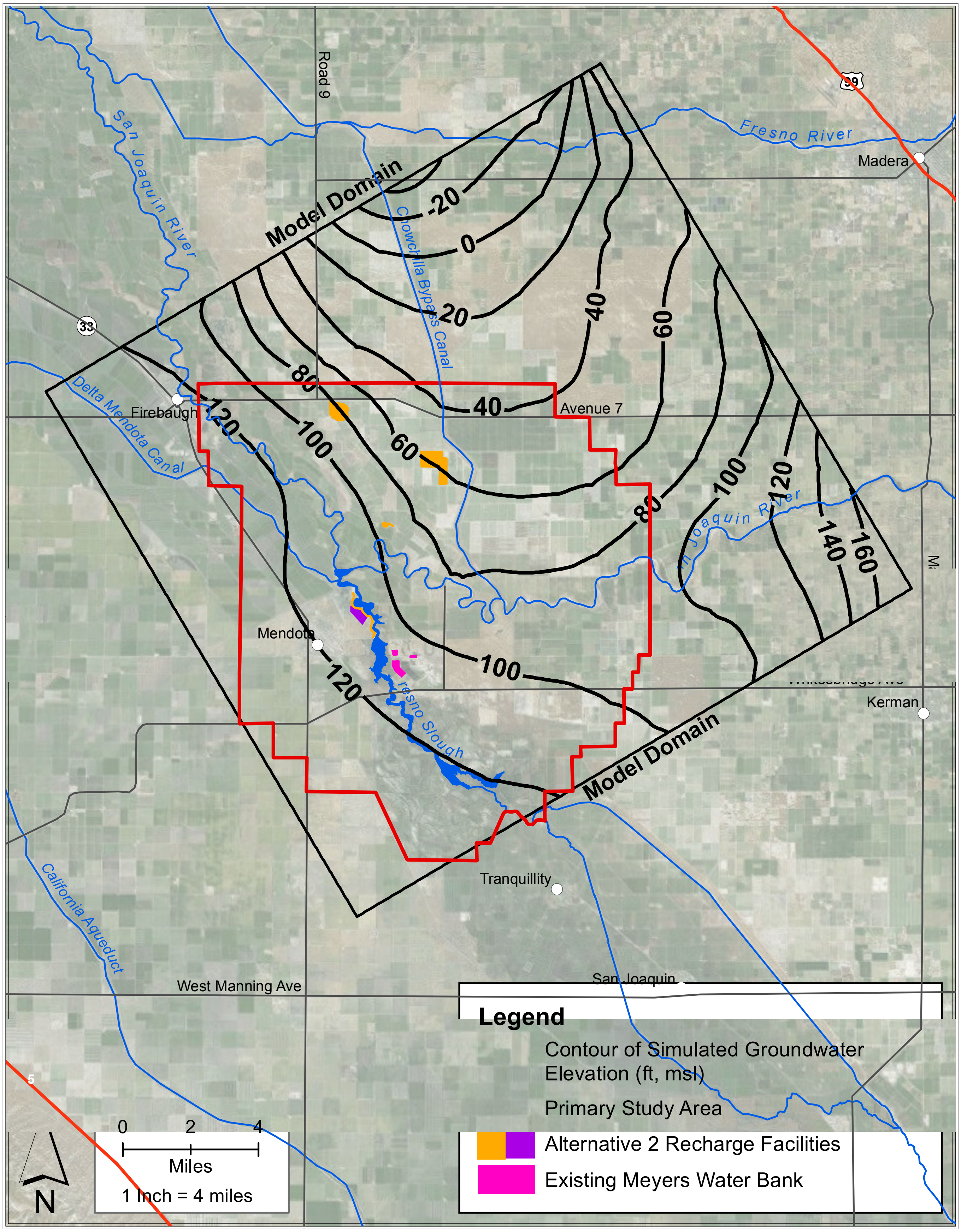
Figure 8-50
Alternative 2 Contours of Equal Simulated Groundwater Elevation Difference Shallow Zone, Year 20



Document Path: J:\Mendota\ModelingFigures_V3\MXDs\Section_8\Figure_8-51_Deep_Alternative2_WL_2034.mxd

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Figure 8-51
Alternative 2 Contours of Equal Simulated Groundwater Elevation Deep Zone, Year 20

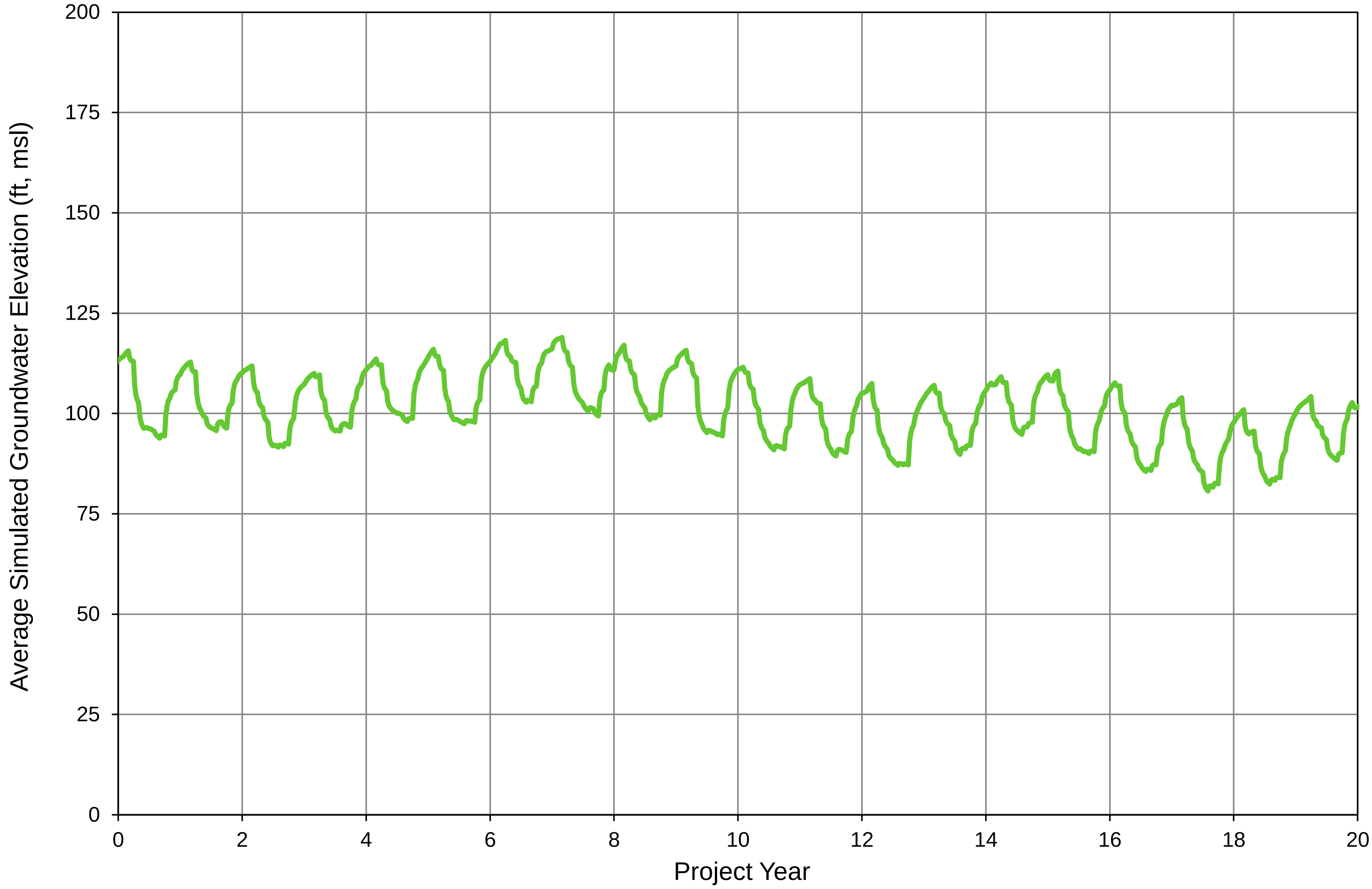

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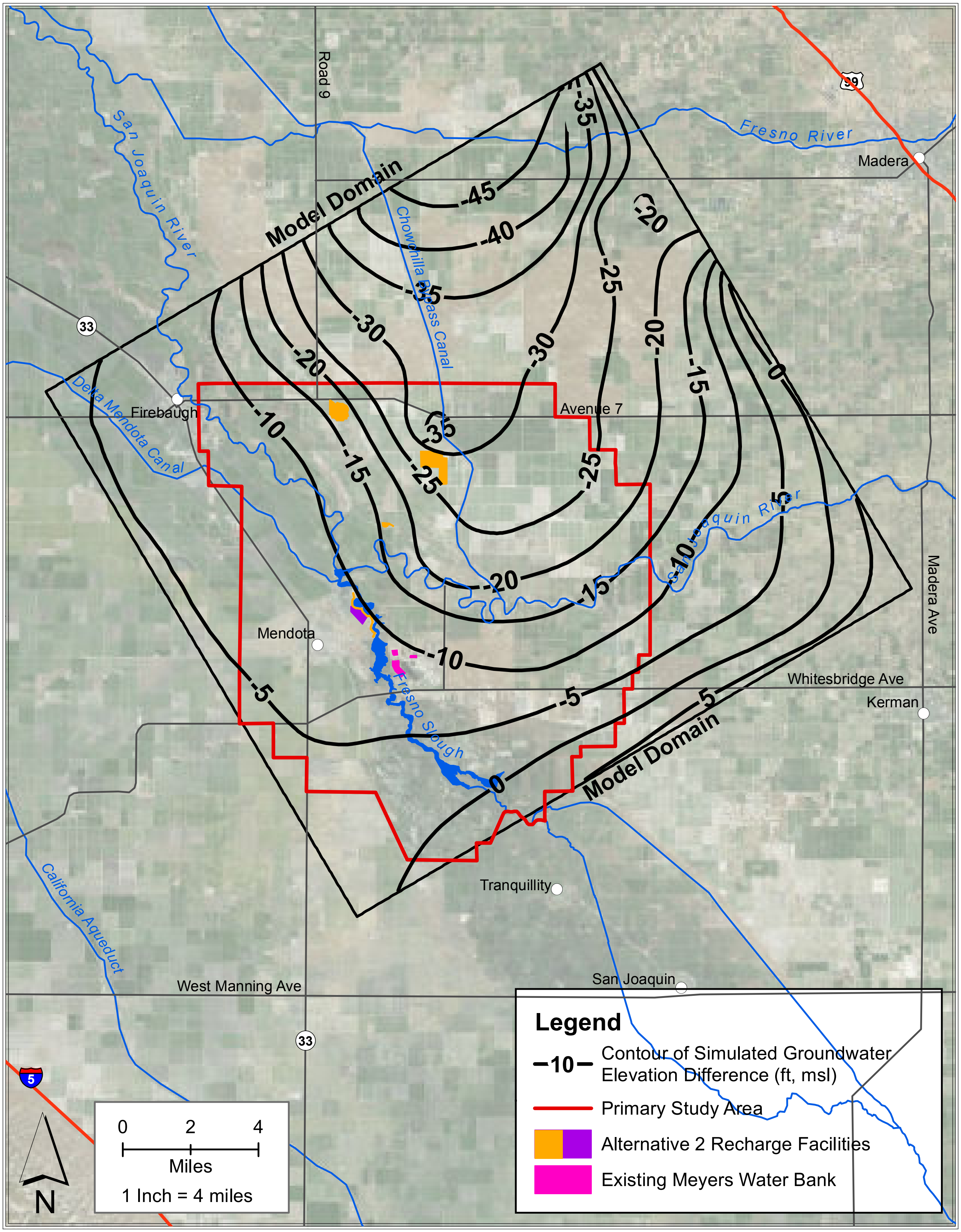
Figure 8-52
Alternative 2 Average Simulated Groundwater Elevation In the Primary Study Area, Deep Zone
Mendota Pool Group EIS/EIR



Document Path: J:\Mendota\ModelingFigures_V3\MXDs\Section_8\Figure_8-53_Deep_Alternative2_WL_Decline.mxd

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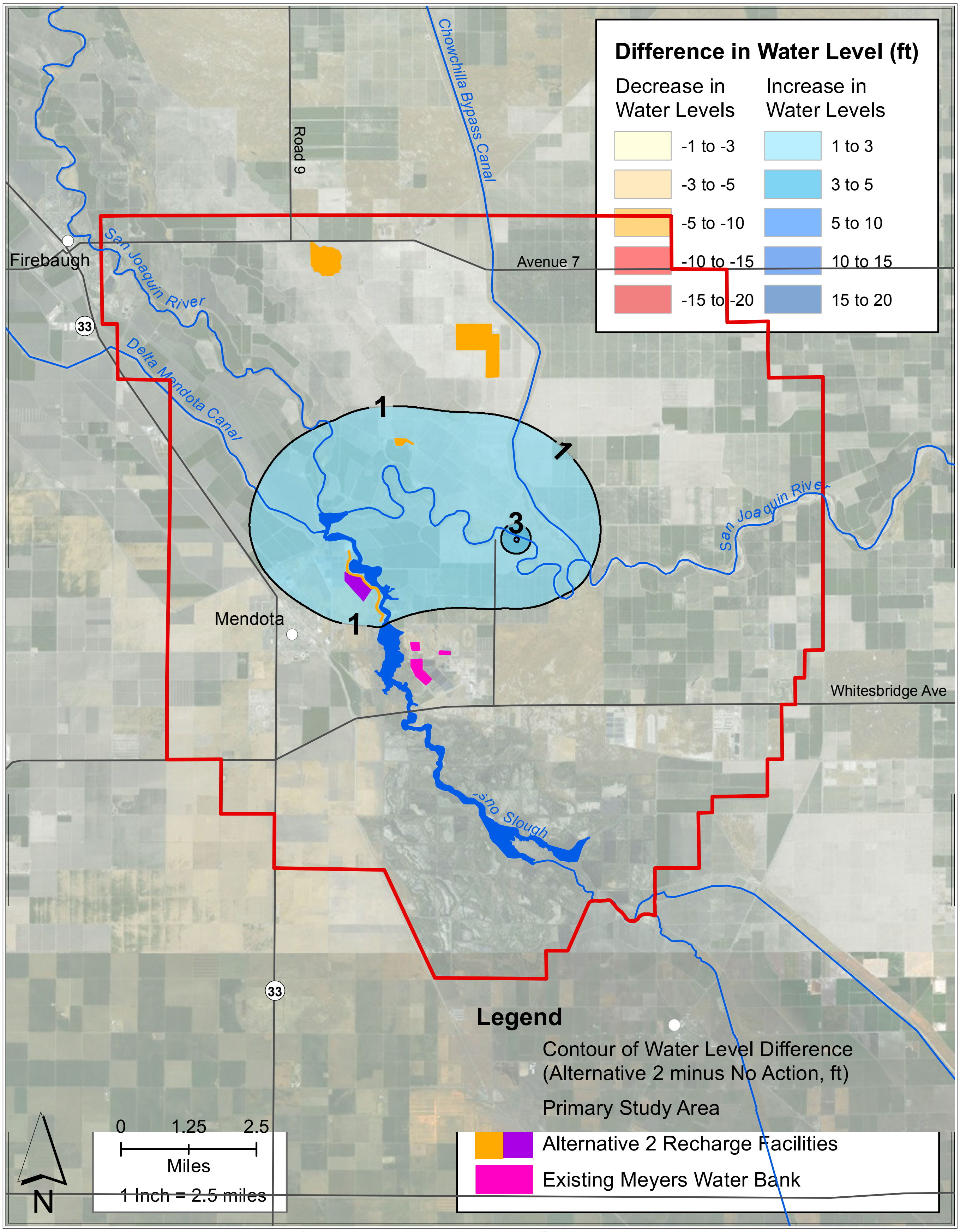
Figure 8-53
Alternative 2 Contours of Equal Simulated Change in Groundwater Elevation Deep Zone, Year 1 to Year 20



Document Path: J:\Mendota\ModelingFigures_V3\MXDs\Section_8\Figure_8-54_Deep_Alternative2_Difference_2034.mxd

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Figure 8-54
Alternative 2 Contours of Equal Simulated Groundwater Elevation Difference Deep Zone, Year 20

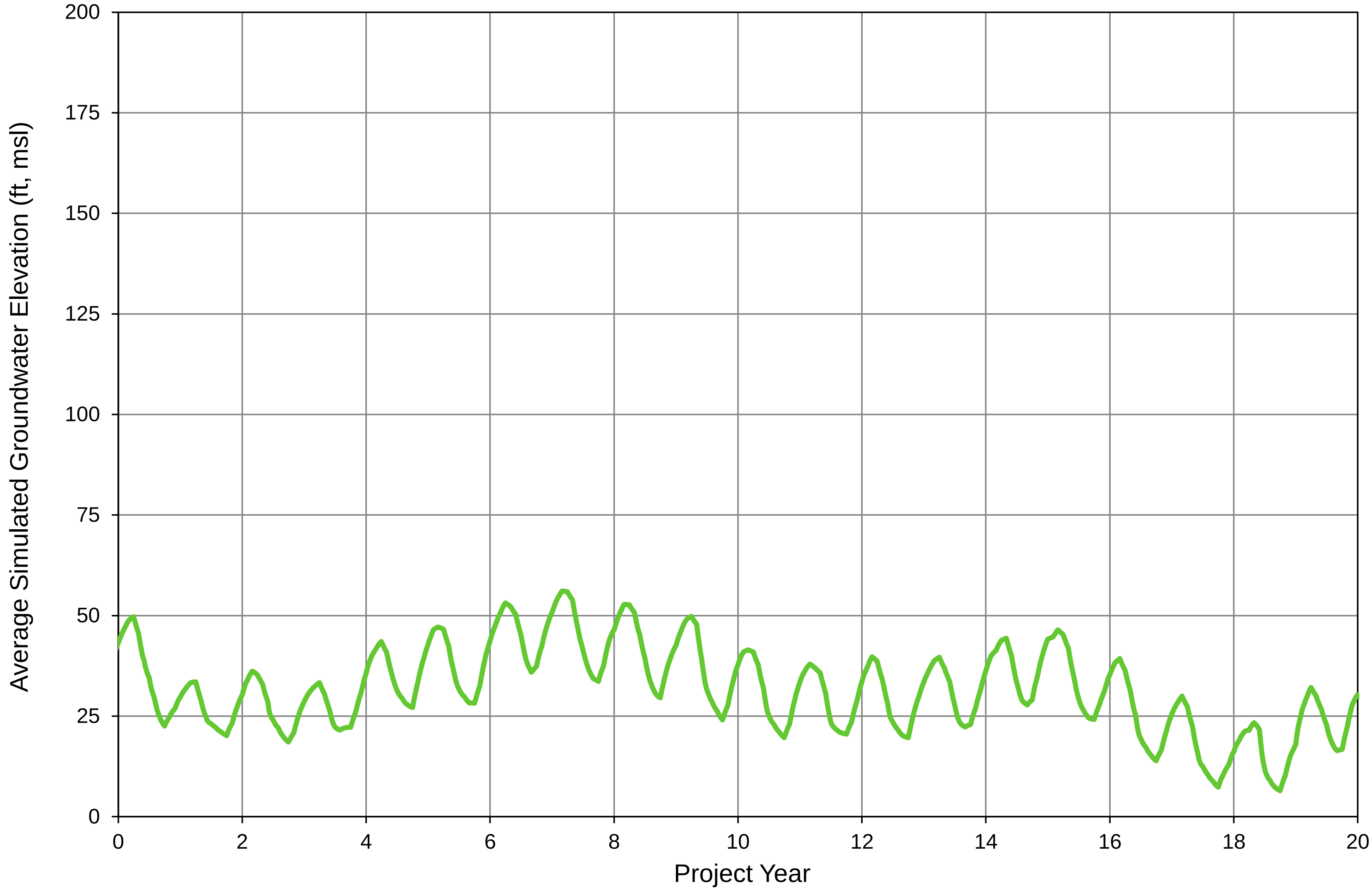

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Figure 8-55
Alternative 2 Average Simulated Groundwater Elevation
In the Primary Study Area, Lower Aquifer
Mendota Pool Group EIS/EIR

Document Path: J:\Mendota\ModelingFigures_V3\MXDs\Section_8\Figure_8-56_Shallow_Flood_Alternative2.mxd

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Figure 8-56
Alternative 2 Simulated TDS Concentration Shallow Zone, Year 20

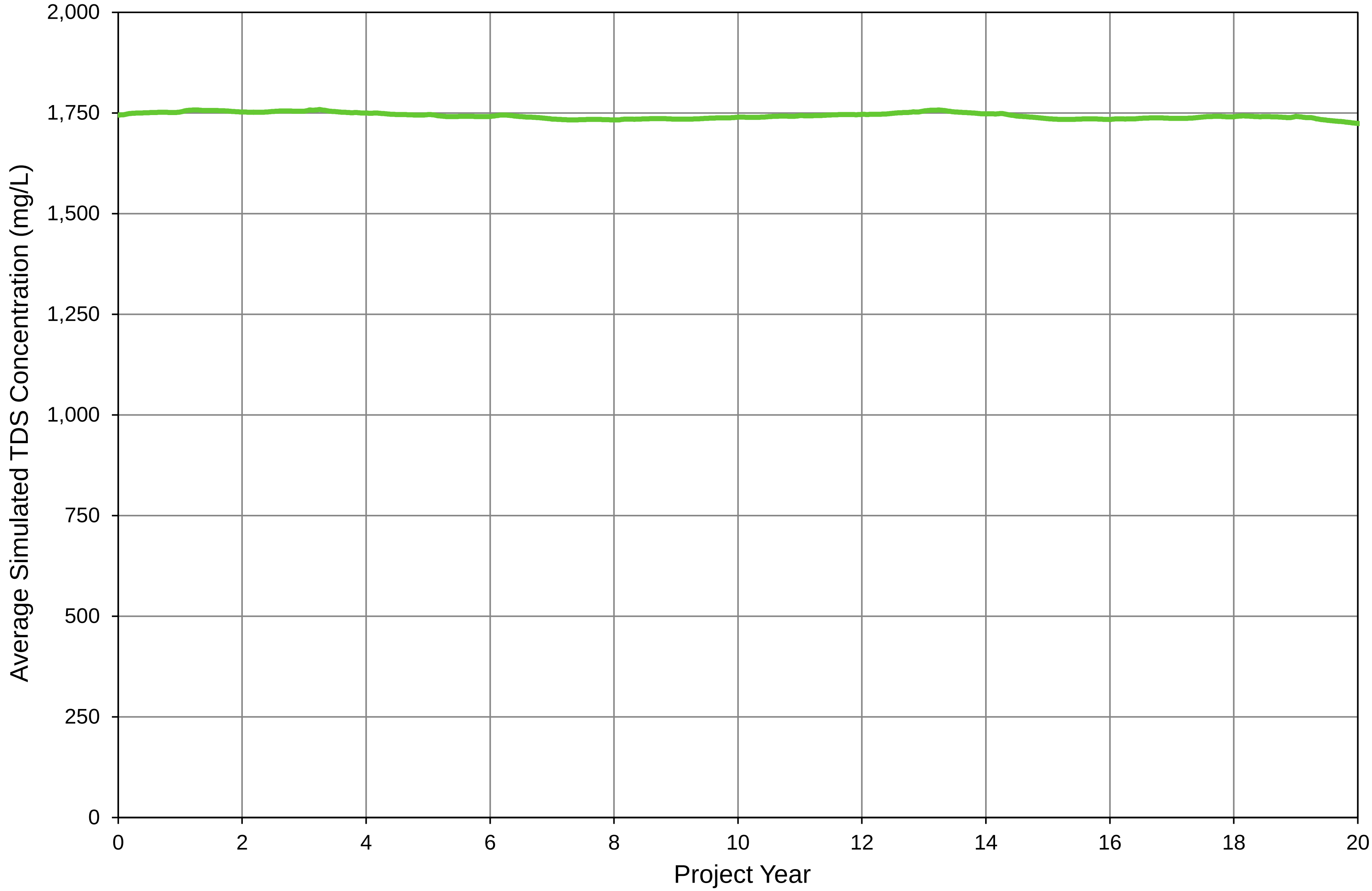

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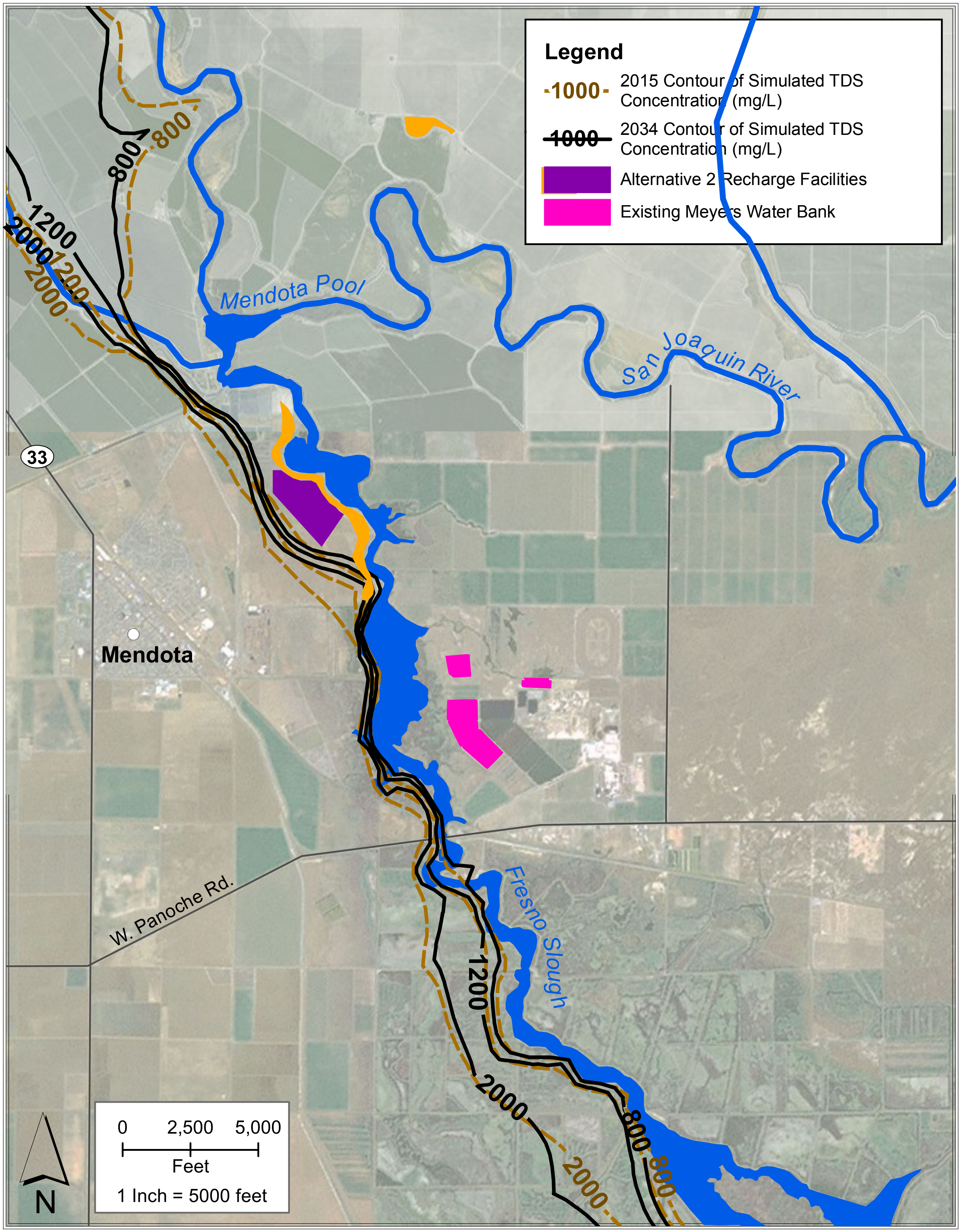
Figure 8-57
Alternative 2 Average Simulated TDS Concentration
In the Primary Study Area, Shallow Zone
Mendota Pool Group EIS/EIR



Document Path: J:\Mendota\ModelingFigures_V3\MXDs\Section_8\Figure_8-58_Shallow_Alternative2_TDS_2034.mxd

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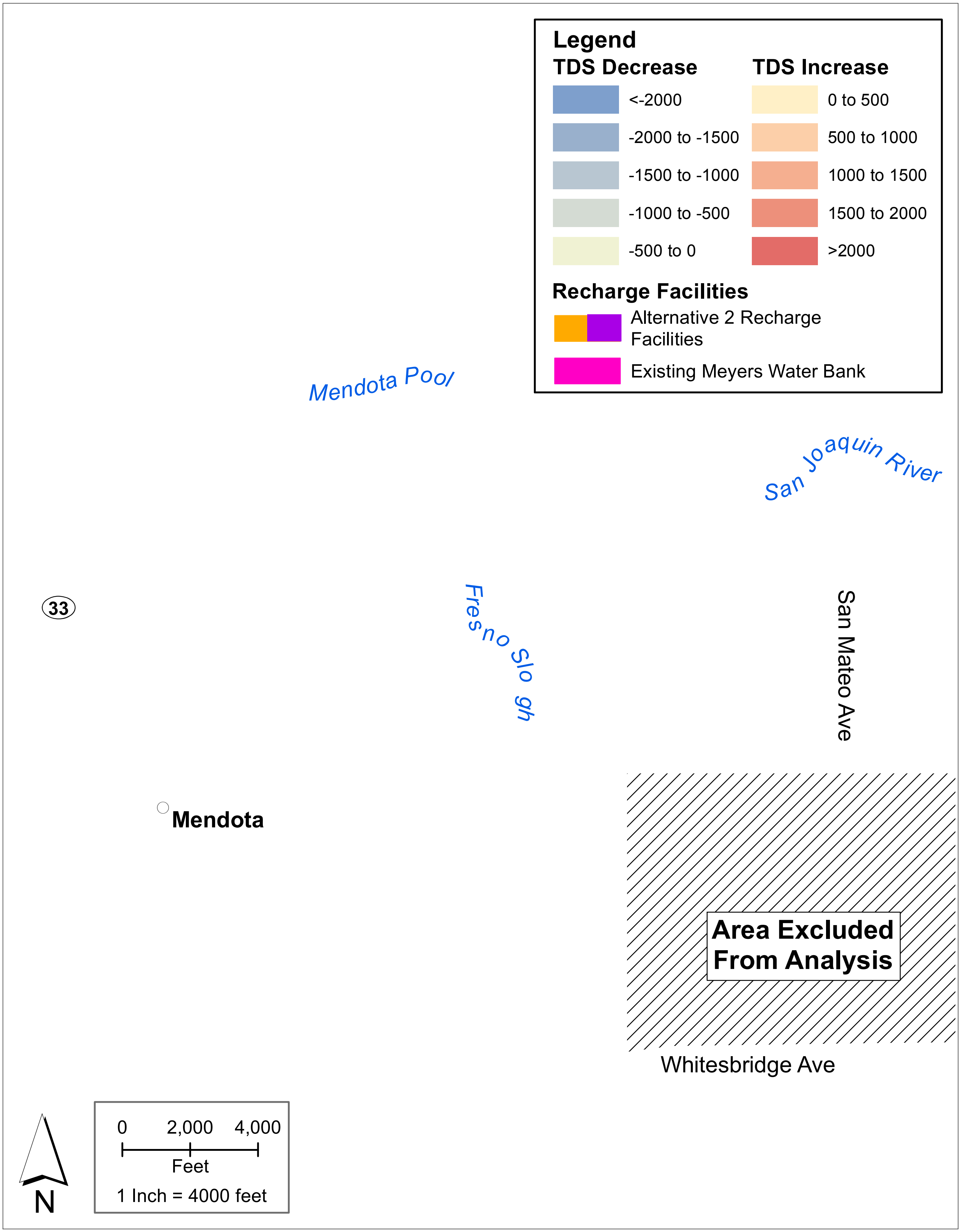
Figure 8-58
Alternative 2 Contours of Equal Simulated TDS Concentration Shallow Zone, Year 20



Document Path: J:\Mendota\ModelingFigures_V3\MXDs\Section_8\Figure_8-59_Shallow_Difference_Flood_Alternative2.mxd

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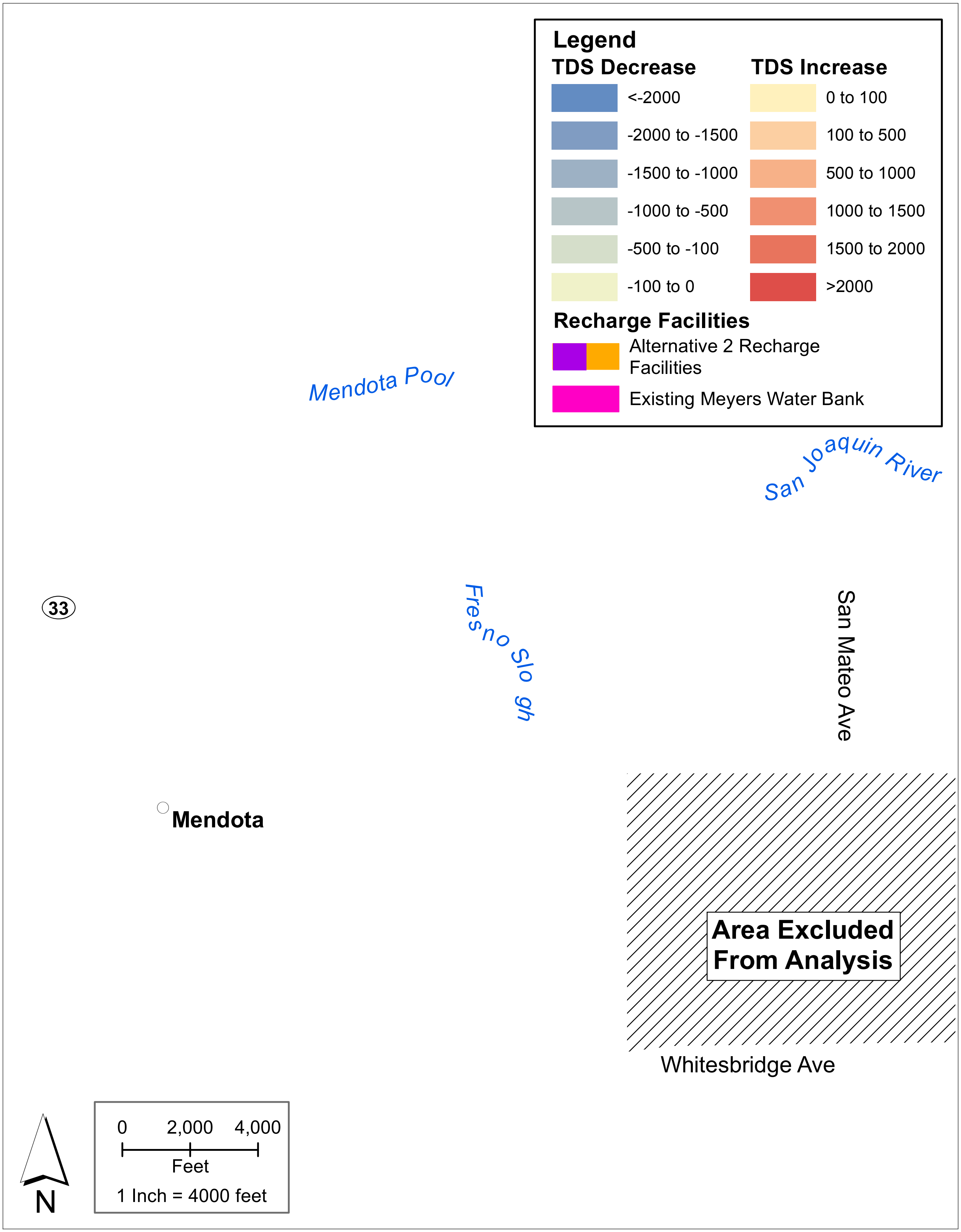
Figure 8-59
Alternative 2 Simulated Change in TDS Concentration from Year 1 to Year 20
Shallow Zone



Document Path: J:\Mendota\ModelingFigures_V3\MXDs\Section_8\Figure_8-60_Shallow_Difference_Flood_Alternative2.mxd

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Figure 8-60
Simulated TDS Difference by Year 20
Alternative 2 minus No Action
Shallow Zone

Document Path: J:\Mendota\ModelingFigures_V3\MXDs\Section_8\Figure_8-61_Deep_Flood_Alternative2.mxd

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Figure 8-61
Alternative 2 Simulated TDS Concentration Deep Zone, Year 20

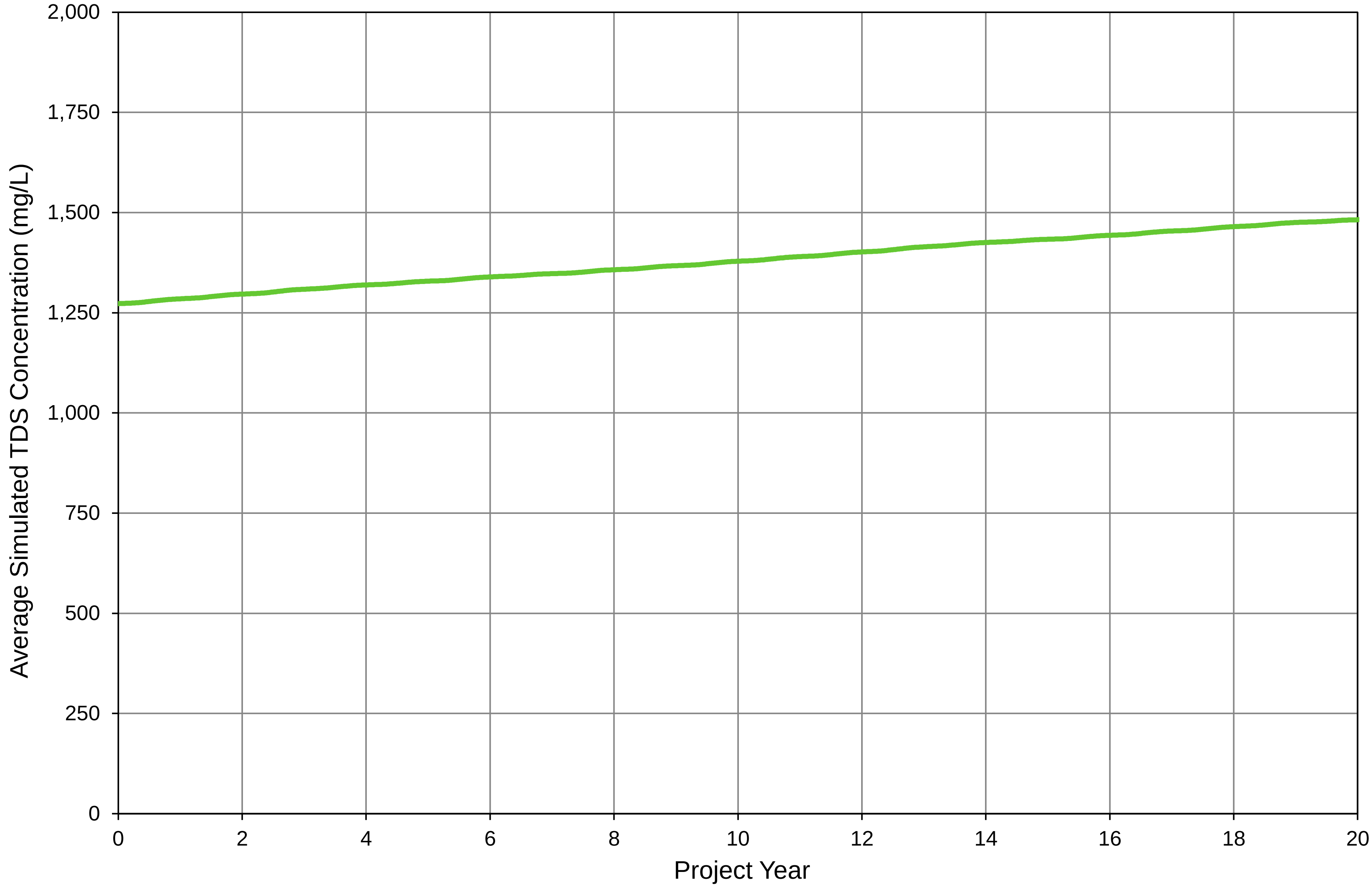

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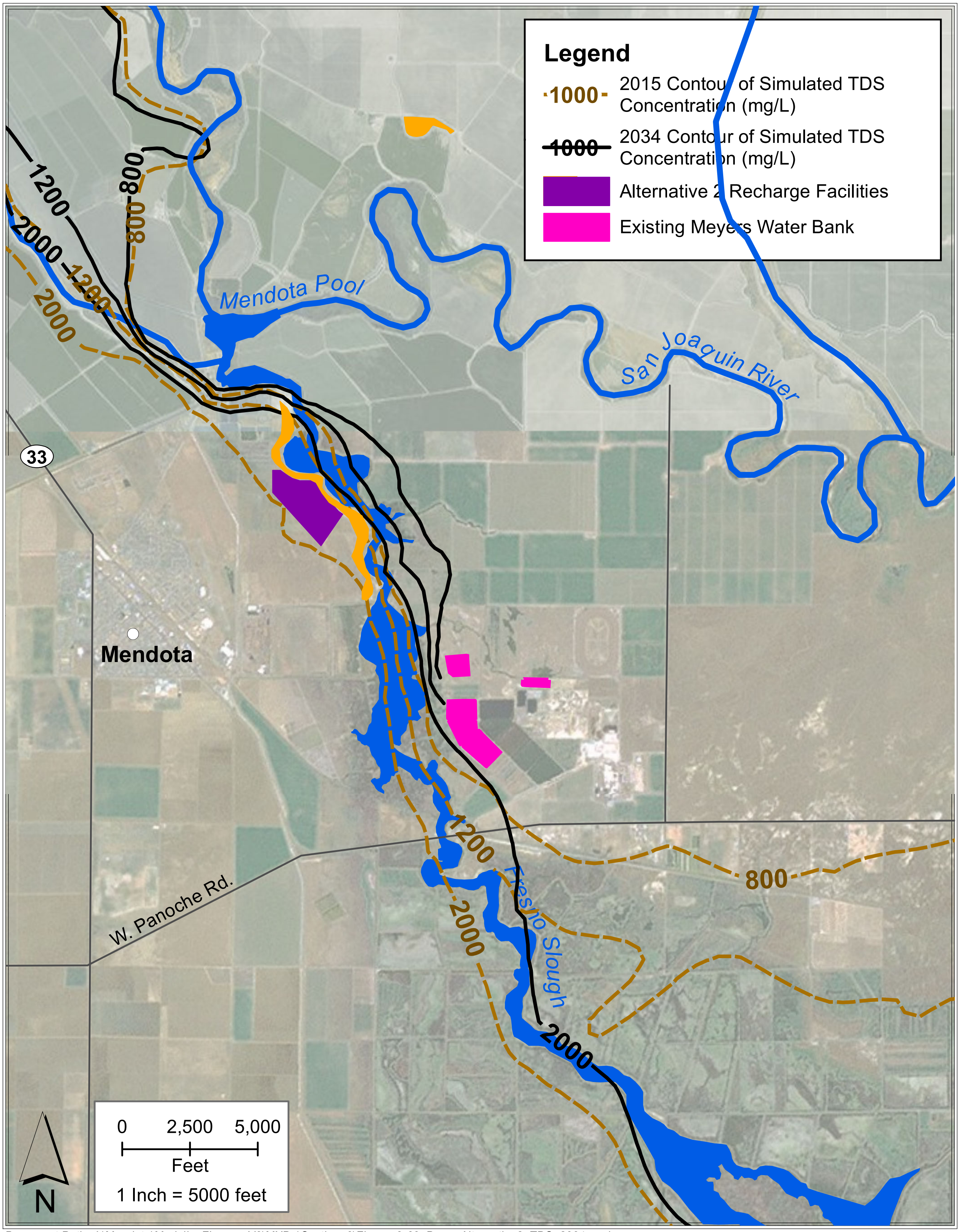
Figure 8-62
Alternative 2 Average Simulated TDS Concentration
In the Primary Study Area, Deep Zone
Mendota Pool Group EIS/EIR



Document Path: J:\Mendota\ModelingFigures_V3\MXDs\Section_8\Figure_8-63_Deep_Alternative2_TDS_2034.mxd

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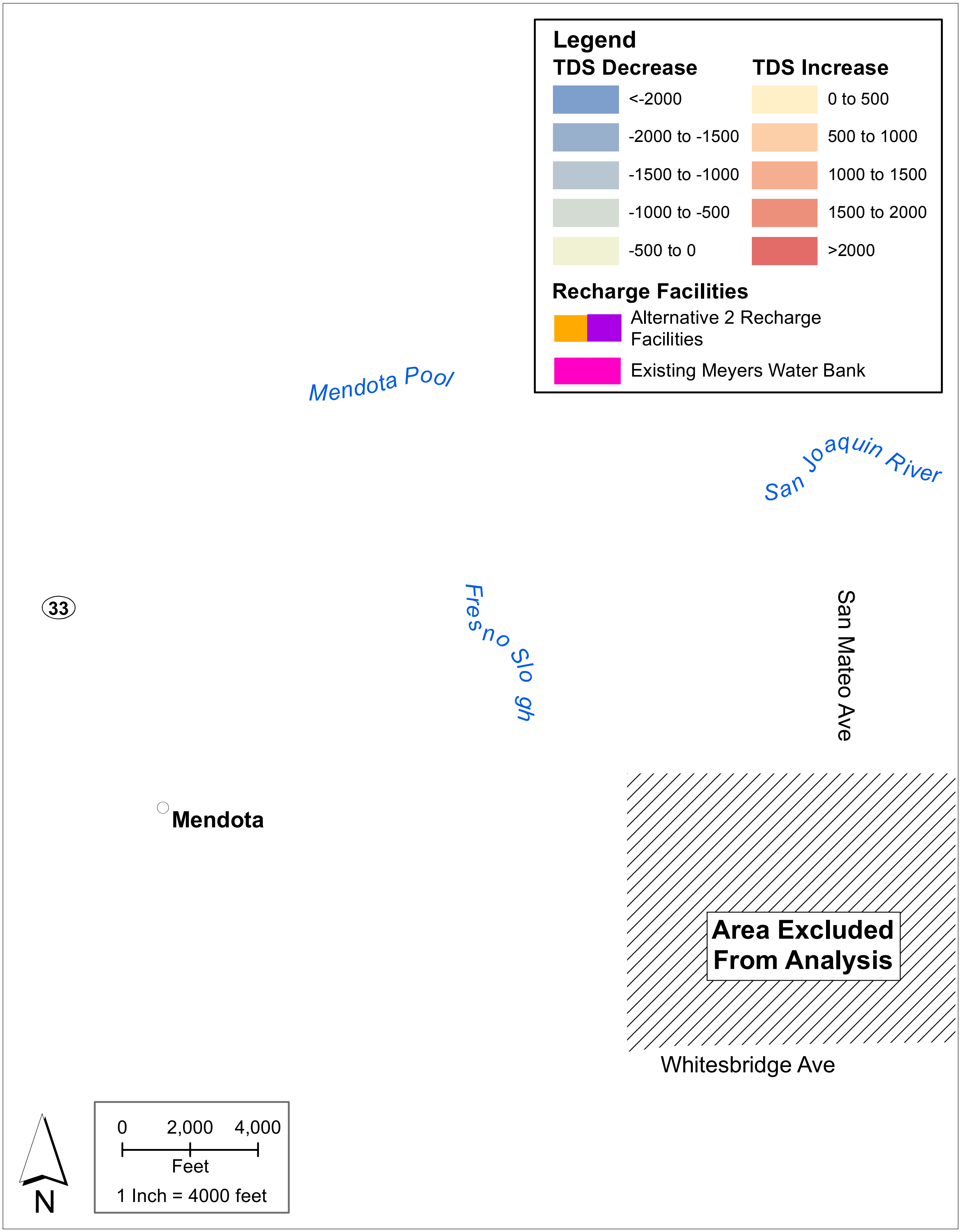
Figure 8-63
Alternative 2 Contours of Equal Simulated TDS Concentration Deep Zone, Year 1 and Year 20



Document Path: J:\Mendota\ModelingFigures_V3\MXDs\Section_8\Figure_8-64_Deep_Difference_Flood_Alternative2.mxd

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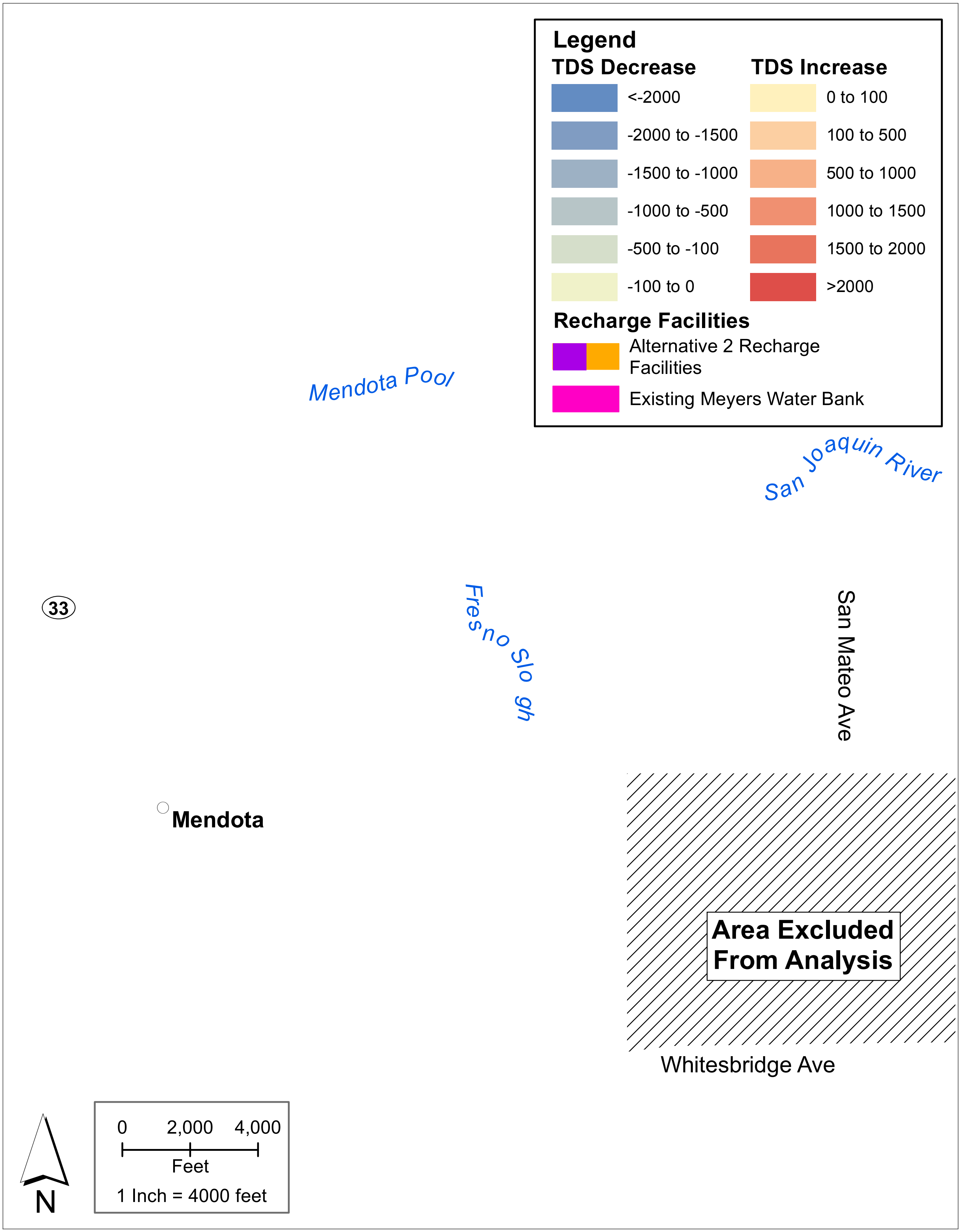
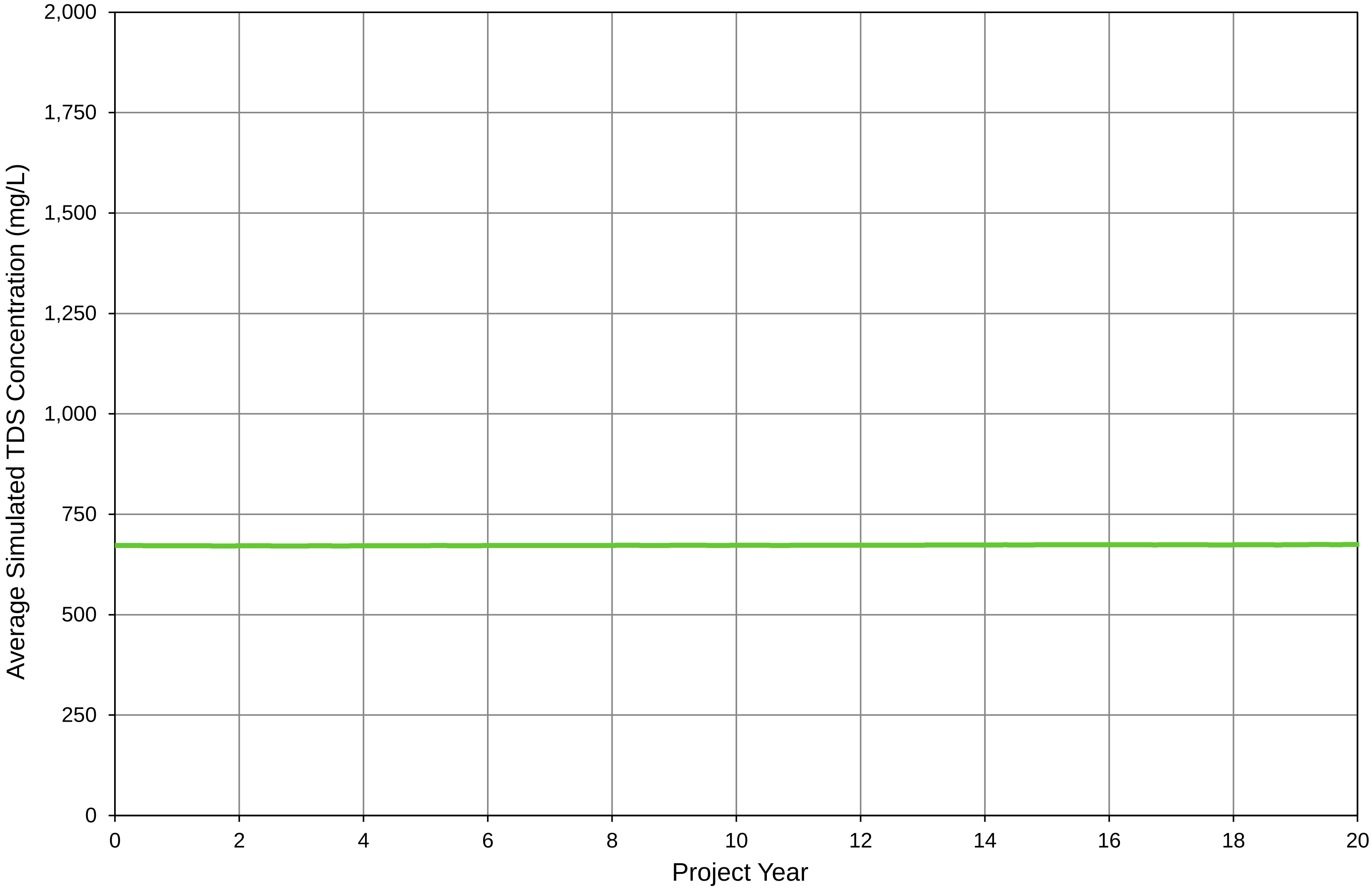
Figure 8-64
Alternative 2 Simulated Change in TDS Concentration from Year 1 to Year 20 Deep Zone



Document Path: J:\Mendota\ModelingFigures_V3\MXDs\Section_8\Figure_8-65_Deep_Difference_Flood_Alternative2.mxd

Luhdorff & Scalmanini Consulting Engineers

Figure 8-65
Simulated TDS Difference by Year 20
Alternative 2 minus No Action
Deep Zone



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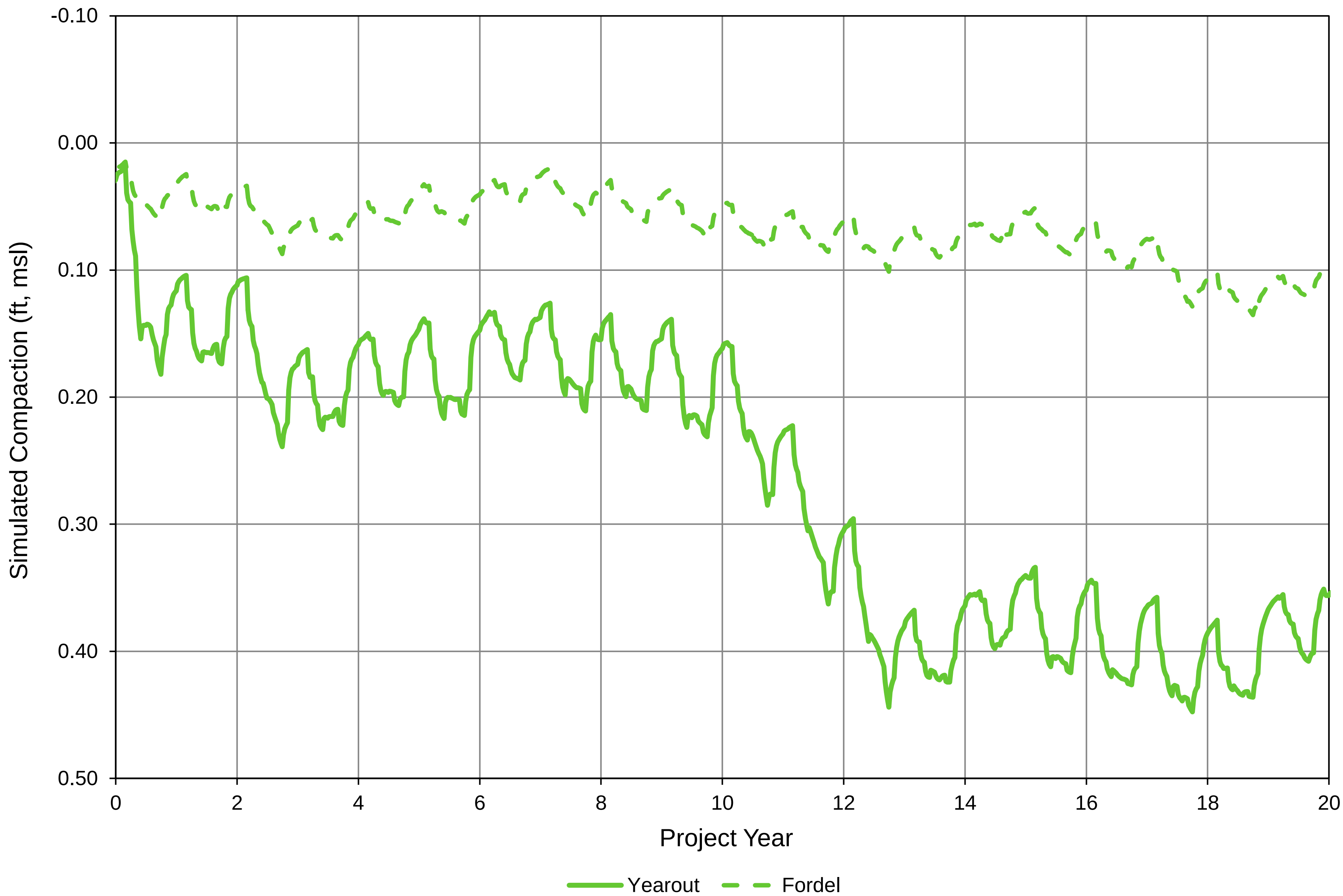
Consulting Engineers

Figure 8-66
Alternative 2 Average Simulated TDS Concentration
In the Primary Study Area, Lower Aquifer
Mendota Pool Group EIS/EIR



Luhdorff & Scalmanini
Consulting Engineers

Figure 8-67
Proposed Action Simulated Compaction Above the Corcoran Clay
Mendota Pool Group EIS/EIR

9 CUMULATIVE IMPACTS

The predictive model runs developed as part of the Cumulative Impacts Analysis were evaluated to quantify the influence of the Proposed Action and Alternative 2 scenarios on water levels and compare these impacts to a No Action scenario. In addition to modifications to underlying assumptions affecting non-MPG lands described in Chapter 7, pumping and recharge over MPG lands were modified for the Cumulative Impacts Analysis to account for a reduction in farmable lands in FWD due to seepage from the SJRRP. These impacts lead to a reduction in No Action adjacent MPG groundwater pumping for overlying adjacent use to an average of about 27,870 afy and a reduction in Proposed Action/Alternative 2 MPG adjacent pumping to approximately 11,650 afy. The water level results from the Cumulative Impacts Analysis are presented below.

9.1 No Action

9.1.1 Water Levels

9.1.1.1 Shallow Zone

Shallow zone simulated water levels within the PSA averaged 133 ft msl at the end of Year 20. Water levels are highest at the western edge of the model domain near the San Joaquin River (**Figure 9-1**). Shallow water levels are lowest near the edge of the A clay and locally between the San Joaquin River and Fresno Slough (**Figure 9-1**). During the 20-year proposed exchange agreement, average simulated groundwater levels decline by between 2 ft in the Summer/Fall and 5 ft in the Winter/Spring comparisons (**Table 9-1**). As a function of the average saturated thickness of the shallow zone within the PSA, this represents a decrease of between 3 and 7 percent (**Table 9-2**). Seasonal fluctuations in average shallow water levels generally are less than 5 ft and are stable throughout the project period (**Figure 9-2**). Contours of simulated changes in shallow zone groundwater levels show approximately 5 ft of decline near the edge of the A clay and south of the San Joaquin River (**Figure 9-3**). Shallow zone water levels are up to 25 ft higher at the end of Year 20 near the Meyers Water Bank recharge ponds (**Figure 9-3**). The mound near the Meyers Water Bank ponds is due to recharge operations during Year 19 and Year 20 (**Table 6-3**).

Average water levels in the shallow zone do not significantly change west of the San Joaquin River, west of the Fresno Slough, in the MWA and east of the Fresno Slough (less than or equal to one foot) at the end of Year 20 (**Table 9-3**). North of the San Joaquin River average shallow zone water levels decline by 3 ft and east of the Chowchilla Bypass water levels decline by 4 ft at the end of Year 20 (**Table 9-3**).

MPG pumping leads to a decrease of about 4 ft in both Winter/Spring and Summer/Fall at the end of year 20 (**Table 9-4**). This decline is about 5 percent of the average saturated thickness in the shallow zone (**Table 9-5**).

Table 9-1: Decrease in Average Simulated Groundwater Levels Over the Proposed 20-Year Exchange Program[1,2] Cumulative Impacts

Depth Zone	No Action (ft)	Proposed Action (ft)	Alternative 2 (ft)
Shallow Zone	5, 2	6, 3	6, 2
Deep Zone	6, 2	7, 2	7, 2
Lower Aquifer	13, 10	14, 10	13, 10

1. Decrease calculated from the average groundwater elevation in the PSA at the beginning of the proposed exchange program minus the average groundwater elevation at the end of proposed exchange program.
2. Comparison made between annually recovered groundwater levels in the Winter/Spring (first value) and groundwater levels in the fall/summer (second value).

Table 9-2: Decrease in Average Simulated Groundwater Levels Over the Proposed 20-Year Exchange Program As a Fraction of the Pressure Head at the Base of Each Aquifer[1,2,3] Cumulative Impacts

Depth Zone	No Action (Percent)	Proposed Action (Percent)	Alternative 2 (Percent)
Shallow Zone	7, 3	8, 4	8, 3
Deep Zone	2, 1	2, 1	2, 1
Lower Aquifer	1, 1	1, 1	1, 1

1. Decrease calculated from the average groundwater elevation in the PSA at the beginning of the proposed exchange program minus the average groundwater elevation at the end of proposed exchange program.
2. Comparison made between annually recovered groundwater levels in the Winter/Spring (first value) and groundwater levels in the fall/summer (second value).
3. Pressure head at the base of each aquifer is the height of the water column in the aquifer in a model cell. Average pressure head at the base of each aquifer is calculated from the numerical model at the start of the of the proposed groundwater exchange program:
   Shallow Aquifer: 73 ft; **Deep Aquifer**: 352 ft; **Lower Aquifer**: 1070 ft.

Table 9-4: Average Drawdown Attributed to MPG Pumping By the End of Proposed 20-Year Exchange Program[1,2] Cumulative Impacts

Depth Zone	No Action (ft)	Proposed Action (ft)	Alternative 2 (ft)
Shallow Zone	4, 4	5, 5	5, 5
Deep Zone	3, 5	4, 4	4, 4
Lower Aquifer	1, 2	2, 2	2, 2

1. Average calculated from the simulated groundwater elevation in model cells within the Primary Study Area at end of the 20-Year program. MPG attributed drawdown calculated from comparison with model run with no assigned MPG pumping.
2. Comparison made between annually recovered groundwater levels in the Winter/Spring (first value) and depleted groundwater levels in the fall/summer (second value).

Table 9-5: Average Drawdown Attributed to MPG Groundwater Pumping At the End of the Proposed 20-Year Exchange Program As a Fraction of the Pressure Head at the Base of Each Aquifer[1,2,3] Cumulative Impacts

Depth Zone	No Action (Percent)	Proposed Action (Percent)	Alternative 2 (Percent)
Shallow Zone	5, 6	7, 6	7, 6
Deep Zone	1, 1	1, 1	1, 1
Lower Aquifer	<1, <1	<1, <1	<1, <1

1. Average calculated from the simulated groundwater elevation in model cells within the Primary Study Area at end of the 20-Year program. MPG attributed drawdown calculated from comparison with model run with no assigned MPG pumping.
2. Comparison made between annually recovered groundwater levels in the Winter/Spring (first value) and depleted groundwater levels in the fall/summer (second value).
3. Pressure head at the base of each aquifer is the height of the water column in the aquifer in a model cell. Average pressure head at the base of each aquifer is calculated from the numerical model at the start of the of the proposed groundwater exchange program: **Shallow Aquifer**: 73 ft; **Deep Aquifer**: 352 ft; **Lower Aquifer**: 1070 ft.

9.1.1.2 Deep Zone

In the deep zone, average simulated water levels within the PSA were approximately 107 ft msl at the end of Year 20. Water level contours in the deep zone are similar to those in the Existing Conditions overlay with the highest water levels observed near the western portion of the model domain and near the San Joaquin River and the lowest observed near the northern model boundary near the Chowchilla Bypass (**Figure 9-4**). Average deep water levels in the PSA decline by between 1 foot in the Summer/Fall and 2 ft in Winter/Spring between Year 1 and 20 (**Table 9-1**). Simulated declines are between 1 and 2 percent of the pressure head at the base of the deep zone at the beginning of Year 1 (**Table 9-2**). Seasonal variations in average deep zone water levels occur due to groundwater pumping. These variations range from 15 to 20 (**Figure 9-5**). Simulated contours of water level changes in the deep zone over the proposed 20-year project period show that water level changes are relatively small along the southern and western model boundaries, but increase to over 45 ft at the northern edge of the model domain near the Chowchilla Bypass (**Figure 9-6**).

North of the San Joaquin River and east of the Chowchilla Bypass, average deep zone water levels decline by approximately 9 ft and 11 ft (**Table 9-3**). East of the Fresno Slough, water levels decline by 4 ft. In the remaining areas, average deep zone groundwater levels decline by between 0 and 3 ft (**Table 9-3**).

MPG related drawdown in average deep zone groundwater levels within the PSA ranges between 3 ft in the Summer/Fall and 5 ft in the Winter/Spring (**Table 9-4**). This amount represents a decline of about 1 percent of the total pressure head at the base of the deep zone (**Table 9-5**).

9.1.1.3 Lower Aquifer

In the lower aquifer, water levels within the PSA averaged about 25 ft msl at the end of Year 20. Average water levels in the lower aquifer within the PSA decline by between 10 ft (Summer/Fall) and 13 ft (Winter/Spring) over the 20-year proposed exchange period (**Table 9-1**). As a fraction of the average pressure head in at the base of the lower aquifer within the PSA, this represents a decrease of about 1 percent (**Table 9-2**). Seasonal variations in average groundwater levels occur and range from 15 to 20 ft (**Figure 9-7**). Drawdown accrued from between Year 1 and Year 20 due to MPG pumping ranges from between 1 foot in the Fall/Summer and 2 ft in the Winter/Spring (**Table 9-4**). As a fraction of the pressure head at the base of the lower aquifer this amounts to less than 1 percent (**Table 9-5**).

9.1.2 Groundwater Quality

9.1.2.1 Shallow Zone

Shallow zone TDS concentrations averaged 1,690 mg/L within the PSA. Similar to simulated results from the Existing Conditions overlay, TDS in the shallow zone is highest west of the Fresno Slough and generally lowest near the San Joaquin River (**Figure 9-8**). The average TDS concentration in the shallow zone decreased by 55 mg/L throughout the 20 year simulation (**Table 9-6**).

Table 9-6: Increase in Average Simulated Total Dissolved Solids Concentration Over the Proposed 20-Year Exchange Program Cumulative Impacts[1]

Depth Zone	No Action (mg/L)	Proposed Action (mg/L)	Alternative 2 (mg/L)
Shallow Zone	-55	-45	-50
Deep Zone	160	170	170
Lower Aquifer	1	1	1

1. Average calculated from the simulated TDS concentration in model cells within the Primary Study Area. Increase calculated from the average TDS concentration at the end of the proposed exchange program minus the average TDS concentration at the beginning of proposed exchange
program in the PSA.

Average shallow TDS concentrations show a relatively slight decline from Year 1 to Year 20 while results from individual wells show both increasing and decreasing salinity and some variability during each year particularly west of the Fresno Slough (**Figure 9-9, Appendix F**). Contours of simulated TDS show that saline front migration is greatest to the northeast of the City of (**Figure 9-10**). In this area, TDS concentrations increase the most due to the migration of the saline front (**Figure 9-11**). In other areas of the PSA, shallow zone TDS exhibits little change over the 20-year project period (**Figure 9-11**).

North of the San Joaquin River and east of the Chowchilla Bypass, shallow zone TDS concentrations change by less than 500 mg/L over the project period (average 8 mg/L and 4 mg/L lower). West of the San Joaquin River, shallow TDS decreases by about 750 mg/L and increases by up to 800 mg/L (average 150 mg/L higher) at the end of Year 20 (**Table 9-7**). West of the Fresno Slough, TDS concentrations are about 1,550 mg/L lower to 2,590 mg/L higher (average 10 mg/L higher) in Year 20 compared to Year 1. In the MWA, TDS concentrations decrease by up to 1,290 mg/L and increase by up to 1,040 mg/L (average 250 mg/L lower) at the end of Year 20 (**Table 9-7**). East of the Fresno Slough, TDS concentrations are between 1,830 mg/L lower to 310 mg/L higher (average 126 mg/L lower) at the end of the 20-year exchange program (**Table 9-7**).

Between Year 1 and Year 20, the area in the shallow zone which exceeds 800 mg/L increases by 495 ac in the No Action (**Table 9-8**). The area which exceeds the 1,200 and 2,000 mg/L thresholds decrease by 95 ac and 150 ac, respectively (**Table 9-8**).

Table 9-8: Number of Acres Exceeding TDS Threshold in the Primary Study Area Shallow Zone Cumulative Impacts

Scenario	800 (mg/L)		1200 (mg/L)		2000 (mg/L)	
	Area[1] (ac)	Change[2] (ac)	Area[1] (ac)	Change[2] (ac)	Area[1] (ac)	Change[2] (ac)
No Action	38,764	495	21,744	-95	19,646	-150
Proposed Action	38,920	651	21,832	-7	19,773	-23
Alternative 2	38,854	585	21,769	-70	19,697	-99

1. Area represents the number of acres within the PSA which exceeds given TDS threshold value.
2. Change represents the number of additional acres exceeding given TDS threshold from Year 1 to Year 20.

9.1.2.2 Deep Zone

The average deep zone TDS concentration is 1,430 mg/L at the end of Year 20. Deep zone TDS is highest west of the Fresno Slough and west of the San Joaquin River and lowest near the San Joaquin River (**Figure 9-12**). Average deep zone TDS concentrations in the PSA increase by about 160 mg/L by Year 20 (**Table 9-6**). Average TDS concentrations increase slightly over the 20 year period while TDS concentrations in wells used in model calibration are more variable (**Figure 9-13, Appendix F**). The 2,000 mg/L contour of deep zone TDS generally advances during the 20-year project period while the 1,200 and 800 contours of TDS both advance and recede along the saline front (**Figure 9-14**). In those areas showing the greatest amount of saline front migration, the annual migration rate is about 125 ft per year (**Figure 9-14**). The greatest changes in TDS concentrations occur in the area west of the Fresno Slough (**Figure 9-15**). West of the City of Mendota and near Whitesbridge Road, TDS concentrations increase the most. Over the majority of the PSA, TDS concentrations exhibit little change (**Figure 9-15**).

North of the San Joaquin River and east of the Chowchilla Bypass, deep zone TDS concentrations change by less than 500 mg/L (average 36 mg/L and 19 mg/L higher, respectively) from Year 1 to Year 20 (**Table 9-7**). West of the San Joaquin River, simulated deep zone TDS decreases by 324 mg/L and increases by up to 908 mg/L (average 314 mg/L increase) between Year 1 and Year 20 (**Table 9-7**). West of the Fresno Slough, TDS is between 278 mg/L lower to 1,986 mg/L higher (average 557 mg/L increase) in Year 20. In the MWA, deep zone TDS concentrations are between 676 mg/L lower to 1,487 mg/L higher (average 280 mg/L higher) in Year 20 than in Year 1. East of the Fresno Slough, deep zone TDS is between 1,233 mg/L lower to 1,475 mg/L higher (average 135 mg/L higher) at the end of Year 20 (**Table 9-7**).

The area in the deep zone which exceeds the 800 and 2,000 mg/L thresholds increases by 3,026 ac and 1,670 ac, respectively, between Year 1 and year 20 (**Table 9-9**). The area which exceeds the 1,200 mg/L threshold decreases by 1,506 ac (**Table 9-9**).

Table 9-9: Number of Acres Exceeding TDS Threshold in the Primary Study Area Deep Zone Cumulative Impacts

Scenario	800 (mg/L)		1200 (mg/L)		2000 (mg/L)	
	Area[1] (ac)	Change[2] (ac)	Area[1] (ac)	Change[2] (ac)	Area[1] (ac)	Change[2] (ac)
No Action	46,960	3,030	28,010	-1510	22,140	1,670
Proposed Action	47,270	3,340	28,170	-1350	22,280	1,810
Alternative 2	47,280	3,350	28,180	-1340	22,270	1,800

1. Area represents the number of acres within the PSA which exceeds given TDS threshold value.
2. Change represents the number of additional acres exceeding given TDS threshold from Year 1 to Year 20.

9.1.2.3 Lower Aquifer

TDS concentrations in the lower aquifer averaged 670 mg/L within the PSA at the end of Year 20. Average lower aquifer TDS concentrations increased by 1 mg/L from Year 1 to Year 20 (**Table 9-6**). Simulated TDS concentrations in both the PSA as a whole and in specific wells were relatively stable from Year 1 to Year 20 (**Figure 9-16, Appendix F**).

9.1.2.4 MPG Well Groundwater Quality

Simulated results from the No Action show that 18 of the 76 MPG active wells exceed 1,200 mg/L and 9 wells exceed 2,000 mg/L at the end of Year 20 (**Table 9-10**). Using average simulated TDS concentrations from Year 1 through Year 20, 19 wells exceed 1,200 mg/L and 10 wells exceed 2,000 mg/L (**Table 9-11**).

9.1.3 Subsidence

Subsidence in the form of compaction was evaluated at the Fordel and Yearout extensometer locations to evaluate the impact of groundwater pumping on aquifer system compaction above the Corcoran clay. Total No Action compaction accumulated over the 20-year period was 0.045 ft at Yearout and 0.014 ft at Fordel. This results in an annual average of 0.002 ft at Yearout and 0.001 ft at Fordel (**Table 9-12, Table 9-13**). The annual variability in simulated elastic compaction ranged from between 0.06 and 0.07 ft at Yearout and between 0.02 and 0.04 ft at Fordel (**Figure 9-17**).

Table 9-12: Compaction Above the Corcoran Clay at the Yearout Extensometer Year 1 to Year 20 Cumulative Impacts

Scenario	Compaction (ft)[1]	Difference (ft)[2]	Non-MPG/MPG Adjacent Compaction (ft)[3]	Exchange Compaction (ft)[4]
No Action	0.045 (0.002)	-	-	-
Proposed Action	0.073 (0.004)	0.027 (0.001)	0.011 (0.001)	0.062 (0.003)
Alternative 2	0.071 (0.004)	0.026 (0.001)	0.010 (0.001)	0.061 (0.003)

1. Total simulated inelastic compaction accumulated from Year 1 to Year 20. Annual average shown in parenthesis.
2. Difference between simulated No-Action and Proposed Action/Alternative 2 compaction from Year 1 to Year 20. Annual average shown in parenthesis
3. Simulated inelastic compaction accumulated from Year 1 to Year 20 attributed to non-MPG pumping and MPG adjacent pumping.
4. Total simulated inelastic compaction attributed to MPG exchange pumping. MPG exchange pumping contribution calculated as the difference between total simulated inelastic compaction and compaction attributed to non-MPG and MPG adjacent pumping.

Table 9-13: Compaction Above the Corcoran Clay at the Fordel Extensometer Year 1 to Year 20 Cumulative Impacts

Scenario	Compaction (ft)[1]	Difference (ft)[2]	Non-MPG/MPG Adjacent Compaction (ft)[3]	Exchange Compaction (ft)[4]
No Action	0.014 (0.001)	-	-	-
Proposed Action	0.028 (0.001)	0.014 (0.001)	-0.003 (0.000)	0.031 (0.002)
Alternative 2	0.022 (0.001)	0.008 (0.000)	-0.007 (0.000)	0.029 (0.001)

1. Total simulated inelastic compaction accumulated from Year 1 to Year 20. Annual average shown in parenthesis.
2. Difference between simulated No-Action and Proposed Action/Alternative 2 compaction from Year 1 to Year 20. Annual average shown in parenthesis
3. Simulated inelastic compaction accumulated from Year 1 to Year 20 attributed to non-MPG pumping and MPG adjacent pumping.
4. Total simulated inelastic compaction attributed to MPG exchange pumping. MPG exchange pumping contribution calculated as the difference between total simulated inelastic compaction and compaction attributed to non-MPG and MPG adjacent pumping.

9.1.4 Surface Water Quality

The mixing model used to predict surface water quality at the Mendota Dam (northern mixing model) simulated TDS concentrations ranging from 156 mg/L in April to about 374 mg/L in February with an annual average of about 259 mg/L (**Table 9-14**). The inflows to the model from the San Joaquin River ranged from about 2,600 to about 83,000 af per month with TDS concentrations ranging from 25 to 43 mg/L. Flows from the DMC ranged from about 13,000 to 130,000 af per month with TDS concentrations ranging from about 240 to 460 mg/L. Simulated inflows from the Pool ranged from 0 af per month in most months to a maximum of about 38,000 af per month with TDS concentrations ranging from about 160 to 320 mg/L. Outflows in the mixing model to the irrigation canals (Firebaugh, CCID Main, CCID Outside, and Columbia) ranged from about 2,000 to 93,000 af per month. Outflows to the Mendota Dam ranged from about 16,000 to 125,000 af per month. In the No Action, FWD groundwater pumping does not affect the water balance or TDS at the Mendota Dam since no groundwater is pumped for adjacent use into the northern branch of the Pool (**Table 9-14**).

The southern mixing model was used to predict water quality at the MWA given both average and dry year conditions. Under the assumption of average conditions, simulated TDS concentrations at the MWA averaged about 390 mg/L annually, and ranged from 306 mg/L in July to almost 450 mg/L in January (**Table 9-15**). Total annual inflows from the DMC were about 102,000 af. MPG adjacent pumping into the Pool was approximately 11,140 af leading to an average increase of about 32 mg/L in simulated TDS at the MWA. Pumping into the Pool from the City of Mendota and Meyers Water Bank totaled about 2,000 and 3,000 af leading to a combined increase in TDS of 8 mg/L at the MWA (**Table 9-15**).

Under dry year assumptions, simulated annual average TDS at the MWA was about 400 mg/L and ranged from 311 mg/L in July to 447 mg/L in January (**Table 9-16**). The relatively small increase in TDS at the MWA is attributed to a 22,000 af reduction annually in the DMC flows to the MWA during the dry year simulation. As a result, TDS concentrations increase by 6 mg/L due to MPG adjacent pumping (5mg/L increase) and 1 mg/L increase from City of Mendota and Meyers Water Bank pumping (**Table 9-16**).

9.1.5 Water Budget

The water budget for the No Action scenario is tabulated in **Table 9-17** for the 20-year project period and two preceding years included in the model simulation. Stream and canal seepage ranges from about 123,000 to 167,000 afy (average 143,000 afy) with the largest amounts coinciding with years with high streamflow. Areal recharge ranges from about 166,000 to 318,000 afy (average 226,000 afy) with the highest amount of recharge occurring during average and wet years. Recharge from ponds varies between 1,000 to about 26,000 afy (average 9,000 afy) and are dependent on Meyers Water Bank operations and availability of water for NCR recharge ponds. Net lateral subsurface inflow ranged from -65,000 to about 109,000 afy (average 5,000 afy of net inflow) with most years showing more groundwater entering the model domain than leaving. Seepage from the Pool and Fresno Slough shows very little variation and ranges from 31,000 to 39,000 afy (average 35,000 afy). Groundwater pumping is the largest water budget component and ranges from about 360,000 to about 535,000 afy (average 446,000 afy). Over the project period, groundwater storage in the model domain increases by as much as 141,000 afy and decreases by as much 163,000 afy (average 16,000 afy decrease). Interbed storage increases by as much as 19,000 afy and decreases by as much as 59,000 afy (average 12,000 afy decrease).

9.2 Proposed Action

9.2.1 Water Levels

9.2.1.1 Shallow Zone

Average shallow zone water levels at the end of Year 20 averaged 132 ft msl within the PSA. Shallow zone water levels at the end of Tear 20 are highest near the western edge of the model domain and near the San Joaquin River and are lowest near the edge of the A clay and south of the San Joaquin River (**Figure 9-18**). Throughout the 20-year project period, average simulated water levels declined by 6 ft in the Winter/Spring and 3 ft in the Summer/Fall (**Table 9-1**). As a fraction of the average saturated thickness at the beginning of the project period, average decline in water levels result in a 4 and 8 percent (**Table 9-2**). Shallow zone groundwater levels exhibit small seasonal variations of 5 to 10 ft depending on hydrologic trends (wet and dry periods) and are generally stable throughout the project period (**Figure 9-19**). Contours of simulated shallow groundwater level differences from Year 1 to Year 20 show that over 5 ft of decline in groundwater elevation occurs in areas west of the Fresno Slough, near the edge of the A clay, and south of the San Joaquin River (**Figure 9-20**). Higher recharge at the Meyers Water Bank recharge ponds during Year 19 and 20 produces a groundwater mound east of the Fresno Slough which exceeds 20 ft.

West of the San Joaquin River and Fresno Slough, and east of the Fresno Slough, average simulated shallow zone groundwater levels change by 1 foot or less over the 20-year project period (**Table 9-3**). North of the San Joaquin River and in the MWA, average shallow water levels decrease by 3 ft. East of the Chowchilla Bypass average water levels decrease by 5 ft (**Table 9-3**).

Groundwater pumping from the MPG produces an average drawdown of about 5 ft in Year 20 **(Table 9-4**). As a percentage of the total saturated thickness of the shallow zone at the beginning of Year 1, this amounts to a decline of about 6 percent (**Table 9-5**).

The relative impacts of the Proposed Action compared to the No Action on shallow zone water levels is similar to those simulated using the existing land use. Average shallow zone water levels are about 1 foot lower than the No Action within the PSA in both Winter/Spring and Summer/Fall (**Table 9-18**). As a fraction of the saturated thickness of the shallow zone at the beginning of Year 1, this amounts to a decrease of about 1percent (**Table 9-19**). Shallow zone water levels range from being similar to the No Action during Year 7 where no exchange pumping is simulated, to about 2 ft lower than the No Action during year 13 (**Figure 9-21**). Contours of relative shallow water level difference at the end of Year 20 show that groundwater levels near MPG wells west of the Fresno Slough are up to 10 ft higher in the Proposed Action than the No Action (**Figure 9-22**). As mentioned above, this can be attributed to the relative recovery of shallow groundwater levels in the Proposed Action run during Year 20 when no exchange pumping is simulated. Drawdown in the Proposed Action is greater than 5 ft with distance from the MPG wells in the MWA, but does not substantially propagate north of the San Joaquin River (**Figure 9-22**).

Table 9-18: Difference in Average Groundwater Levels Between No Action and Proposed Action/Alternative 2 At the End of the 20-Year Exchange Program[1,2] Cumulative Impacts

Depth Zone	Proposed Action minus No Action (ft)	Alternative 2 minus No Action (ft)
Shallow Zone	1, 1	1, 1
Deep Zone	2, -1	1, -1
Lower Aquifer	1, <1	1, <1

1. Difference calculated from the average groundwater level in the PSA at the end of the proposed
exchange program in the Proposed Action/Alternative 2 minus the No Action.
2. Comparison made between annually recovered groundwater levels in the Winter/Spring (first value) and depleted groundwater levels in the fall/summer (second value).

Table 9-19: Difference in Average Groundwater Levels Between No Action and Proposed Action/Alternative 2 At the End of the 20-Year Exchange Program[1,2,3] As a Fraction of the Pressure Head at the Base of Each Aquifer Cumulative Impacts

Depth Zone	Proposed Action minus No Action (Percent)	Alternative 2 minus No Action (Percent)
Shallow Zone	1, 1	1, 1
Deep Zone	<1, <-1	<1, <-1
Lower Aquifer	<1, 0	0, 0

1. Average calculated from the simulated groundwater elevation in model cells within the Primary
Study Area. Difference calculated from the average groundwater level at the end of the proposed exchange program in the Proposed Action/Alternative 2 minus the No Action.
2. Comparison made between annually recovered groundwater levels in the Winter/Spring (first value) and depleted groundwater levels in the fall/summer (second value).
3. Pressure head at the base of each aquifer is the height of the water column in the aquifer in a model cell. Average pressure head at the base of each aquifer is calculated from the numerical model at the start of the of the proposed groundwater exchange program: **Shallow Aquifer**: 73 ft; **Deep Aquifer**: 352 ft; **Lower Aquifer**: 1070 ft.

The drawdown illustrated in areas of the shallow zone where pumping from this zone does not occur is likely the result of the propagation of deep zone pumping effects on shallow zone groundwater levels. North of the San Joaquin River, simulated Proposed Action shallow groundwater levels range from 1 foot lower to 2 ft higher than the No Action (average 0 ft) at the end of Year 20 (**Table 9-3**). Shallow Proposed Action groundwater levels west of the San Joaquin River are up to 2 ft higher than the No

Action (average 0.2 ft) at the end of Year 20. West of the Fresno Slough, simulated shallow zone groundwater levels in the Proposed Action are between 6 ft lower to 17 ft higher than the No Action (average 0.4 ft lower) at the end of the project period. Simulated shallow zone groundwater levels in the MWA are up to 6 ft lower than the No Action (average 1.6 ft lower) at the end of Year 20 (**Table 9-3**). East of the Fresno Slough, groundwater levels are between 5 ft lower to 8 ft higher than the No Action (average 1.9 ft lower). East of the Chowchilla Bypass, Proposed Action groundwater levels are between 0 to 2 ft lower than the No Action (average 0.6 ft lower).

9.2.1.2 Deep Zone

Simulated deep zone groundwater levels averaged 107 ft msl within the PSA. Water levels in the deep zone are generally greatest near the western edge of the model domain and to the east near the San Joaquin River and are generally lowest at the central portion of the northern edge of the model domain (**Figure 9-23**). Simulated Winter/Spring water levels declined by about 2 ft while Summer/ Fall water levels declined by 7 ft (**Table 9-1**). As a fraction of the pressure head at the base of the deep zone in Year 1, these water level declines represent a decrease of between 1 to 2 percent (**Table 9-2**). Simulated average deep zone groundwater levels in the PSA show seasonal variations of 15 to 20 ft with a slight long term downward trend (**Figure 9-24**). Contours of changes in simulated deep zone groundwater levels from Year 1 to Year 20 show that water levels are relatively stable near the southern and western model boundaries and increase to over 45 ft along the northern boundary just east of the Chowchilla Bypass (**Figure 9-25**).

North of the San Joaquin River and east of the Chowchilla Bypass, Proposed Action average deep zone water levels decline by 9 and 11 ft, respectively (**Table 9-3**). In all other sub-regions, average deep zone water levels change by 4 ft or less. MPG pumping in the Proposed Action leads to 4 ft of average deep zone drawdown in the PSA compared to the No Action run with no MPG pumping **(Table 9-4**). As a fraction of the pressure head at the base of the deep zone at the beginning of Year 1, this represents a 1 percent decrease (**Table 9-5**).

Average deep zone water levels within the PSA at the end of Year 20 are about 2 ft higher than the No Action in the Winter/Spring and 1 foot lower than the No Action in the Summer/Fall (**Table 9-18**). This represents less than a 1 percent change in the pressure head at the base of the deep zone (**Table 9-19**). Over the 20-year period, average water levels in the deep zone are between 3 ft lower to 1 foot greater than the No Action depending largely on when the majority of deep zone exchange pumping occurs (**Figure 9-26**). Proposed Action water levels at the end the Year 20 from the deep zone are over 1 foot lower than the No Action south of Whitesbridge Avenue near the Fresno Slough and slightly greater than 1 foot in a small area near the San Joaquin River (**Figure 9-27**). Deep zone drawdown relative to the No Action south of Whitesbridge Avenue can likely be attributed to the reduced leakage from the shallow zone in this area.

At the end of Year 20, water levels north and west of the San Joaquin River and east of the Chowchilla Bypass in the Proposed Action are within 1 foot of the No Action (**Table 9-3**). West of the Fresno Slough, deep zone Proposed Action groundwater levels are 4 ft lower to 2 ft higher than the No Action (average

0.5 ft lower) at the end of Year 20. In the MWA, Proposed Action water levels are up to 4 ft lower than the No Action (average 0.9 ft lower). East of the Fresno Slough, Proposed Action deep zone groundwater levels are 2 ft lower to 3 ft greater than the No Action (average 0.6 ft lower) at the end of Year 20 (**Table 9-3**).

9.2.1.3 Lower Aquifer

Lower aquifer groundwater level elevations averaged approximately 35 ft msl within the PSA. Average water levels declined between 10 to 13 ft between the Summer/Fall and Winter/Spring of Year 1 and Year 20 (**Table 9-1**). As a fraction of the pressure head at the base of the lower aquifer in Year 1, this represents a change of 1 percent (**Table 8-2**). Average lower aquifer water levels exhibit seasonal variations that ranged from approximately 15 to 20 ft (**Figure 9-28**). Lower aquifer drawdown at the end of Year 20 attributed to MPG groundwater pumping is about 2 ft in the Winter/Spring and 2 ft in the Summer/Fall (**Table 9-4**). This represents a decrease of less than 1 percent of the pressure head at the base of the lower aquifer at the start of Year 1 (**Table 9-5**).

Lower aquifer groundwater levels declined up to 1 foot in the Proposed Action compared to the No Action in the Summer/Fall and Winter/Spring (**Table 9-18**). As a fraction of the pressure head at the base of the lower zone in Year 1, this represents a change of less than 1 percent (**Table 9-19**). Average simulated Proposed Action groundwater levels in the lower aquifer within the PSA are up to 2 ft lower to almost 1 foot higher than the No Action during the 20-year project period (**Figure 9-29**). Proposed Action water levels are lower during periods when exchange pumping were higher greatest and generally recover significantly during years where no exchange pumping occurs.

9.2.2 Water Quality

9.2.2.1 Shallow Zone

Shallow zone TDS concentrations at the end of Year 20 occur in the western portion of the PSA, while the lowest were higher generally near the San Joaquin River (**Figure 9-30**). Average shallow zone TDS concentrations generally decline relatively linearly throughout the 20-year simulation, but show considerable variability in specific wells (**Figure 9-31, Appendix F**). Contours of TDS west of the Fresno Slough show that the saline front advances the most near MPG recharge facilities west of the Fresno Slough from Year 1 to Year 20 approximately 40 to 70 ft per year (**Figure 9-32**). The migration of the front in other areas is much less during this period (**Figure 9-32**). Shallow zone TDS concentrations from Year 1 to Year 20 increased by 1,000 to over 2,000 mg/L in localized areas west of the Pool from Year 1 to Year 20 (**Figure 9-33**). Away from the saline front, shallow zone TDS concentrations generally showed little change (**Figure 9-33**).

North of the San Joaquin River and east of the Chowchilla Bypass, shallow TDS concentrations changed very little (average 6 mg/L and 3 mg/L lower) over the 20-year simulation (**Table 9-7**). West of the San Joaquin River, Year 20 shallow TDS concentrations are 750 mg/L lower to 800 mg/L higher (average 150 mg/L higher) than in Year 1. West of the Fresno Slough, shallow TDS concentrations are between 1,000 mg/L lower to 2,800 mg/L higher (average 63 mg/L higher) by the end of Year 20 (**Table 9-7**). In the

MWA, TDS concentrations in the shallow zone are between 1,300 mg/L lower to 1,100 mg/L higher (average 236 mg/L lower) in Year 20 than in Year 1 (**Table 9-7**). East of the Fresno Slough, Year 20 shallow TDS is between 1,900 mg/L lower to 540 mg/L higher (average 135 mg/L lower) than in Year 1 (**Table 9-7**). Within the PSA, the area which exceeds 800 mg/L in the shallow zone increases by 650 ac from Year 1 to Year 20 (**Table 9-8**). The area which exceeds 1,200 and 2,000 mg/L decreases by 7 ac and 23 ac, respectively (**Table 9-8**).

The average shallow TDS concentration in the PSA is 11 mg/L higher than the No Action at the end of Year 20 (**Table 9-20**). Average shallow TDS generally increases relative to the No Action during years where pumping for exchange occurs and is stable or decreases relative to the No Action in years where no exchange pumping occurs (**Figure 9-34**). The mapped difference between shallow TDS concentrations shows that Proposed Action TDS is higher than the No Action in portions west of the Fresno Slough, in particular north of Whitesbridge Road (**Figure 9-35**). In other areas of the PSA, shallow TDS concentrations in the No Action and Proposed Action are generally similar (**Figure 9-35**).

Table 9-20: Difference in Average TDS Between No Action and Proposed Action/Alternative 2 at the End of the 20-Year Exchange Program[1] Cumulative Impacts

Depth Zone	Proposed Action minus No Action (mg/L)	Alternative 2 minus No Action (mg/L)
Shallow Zone	11	7
Deep Zone	7	7
Lower Aquifer	<1	<1

1. Average calculated from the simulated TDS concentration in model cells within the Primary Study Area. Difference calculated from the average TDS concentration at the end of the proposed exchange program in the Proposed Action/Alternative 2 minus the No Action.

North of the San Joaquin River and east of the Chowchilla Bypass, shallow TDS concentrations in the Proposed Action and No Action at the end of Year 20 are less than 50 mg/L different with a long term average difference of less than 5 mg/L (**Table 9-7**). West of the San Joaquin River, Proposed Action TDS is between 90 mg/L lower to 60 mg/L greater (average 1 mg/L higher) than the No Action at the end of Year 20. West of the Fresno Slough, Proposed Action TDS is between 970 mg/L lower to 2,100 mg/L higher (average 50 mg/L higher) than the No Action (**Table 9-7**). In the MWA, shallow TDS is between 140 mg/L lower to 1,000 mg/L higher (average 18 mg/L higher) than the No Action at the end of Year 20. East of the Fresno Slough, TDS concentrations are between 660 mg/L lower to 640 mg/L higher (average 9 mg/L lower) than the No Action at the end of Year 20 (**Table 9-7**).

The area which exceeds the 800, 1,200, and 2,000 mg/L thresholds increase by 156 ac, 88 ac, and 127 ac, respectively, at the end of Year 20 (**Table 9-21**).

9.2.2.2 Deep Zone

TDS concentrations in the deep zone at the end of Year 20 are highest west of the Fresno Slough and lowest generally near the San Joaquin River at the end of the 20-year period (**Figure 9-36**). The average deep zone TDS concentration in the PSA increases relatively linearly though specific wells show considerable variability throughout the simulation (**9-37, Appendix F**). Contours of simulated deep zone TDS shows that the saline front advances over the majority of the Fresno Slough (**Figure 9-38**). TDS concentrations show the greatest increase in the area northwest of the City of Mendota to just south of Whitesbridge Road from Year 1 to Year 20 (**Figure 9-39**). With distance from the saline front, deep zone TDS concentrations generally change by less than 500 mg/L (**Figure 9-39**).

North of the San Joaquin River and east of the Chowchilla Bypass, deep zone TDS concentrations change by less than 500 mg/L (average 40 mg/L and 20 mg/L) between Year 1 and Year 20 (**Table 9-7**). West of the San Joaquin River, deep zone TDS in Year 20 is between 310 mg/L lower to 900 mg/L higher (average 310 mg/L higher) than in Year 1. West of the Fresno Slough, TDS is 280 mg/L lower to 2,100 mg/L higher (average 550 mg/L higher) by the end of Year 20 (**Table 9-7**). In the MWA, Year 20 TDS concentrations are between 680 mg/L lower to 1,600 mg/L higher (average 290 mg/L higher) than Year 1. East of the Fresno Slough, deep zone TDS concentrations are between 1,100 mg/L lower to 2,000 mg/L higher (average 180 mg/L higher) by the end of Year 20 (**Table 9-7**).

The area which exceeds the 800 and 2,000 mg/L thresholds in the deep zone increases by 3,340 ac and 1,807 ac, respectively, between Year 1 and Year 20 (**Table 9-9**). The area which exceeds the 1,200 mg/L threshold decreases by 1,350 ac by the end of Year 20 (**Table 9-9**).

Average deep zone TDS concentrations within the PSA are about 7 mg/L higher than the No Action by the end of Year 20. Relative increase in TDS in the Proposed Action compared to the No Action is greater during years where there is assigned pumping for groundwater exchange and generally smaller during years where there is none (**Figure 9-40**). The mapped relative difference in deep zone TDS concentrations show that the difference between Proposed Action and No Action TDS is greatest east and west of the Fresno Slough and generally less than 100 mg/L throughout the majority of the PSA (**Figure 9-41**).

West of the San Joaquin River and east of the Chowchilla Bypass, the relative difference between the Proposed Action and No Action is less than 100 mg/L (average 3 mg/L in both cases) by the end of Year 20 (**Table 9-7**). North of the San Joaquin River, TDS concentrations are between 230 mg/L lower to 130 mg/L higher (average 3 mg/L higher) than the No Action at the end of Year 20. West of the Fresno Slough, TDS concentrations are between 740 mg/L lower to 1,700 mg/L higher (average 3 mg/L lower) than the No Action (**Table 9-7**). In the MWA, TDS concentrations in the deep zone are between 320 mg/L lower to 390 mg/L higher (average 11 mg/L higher) than the No Action. East of the Fresno Slough, TDS is between 330 mg/L lower to 1,600 mg/L higher (average 46 mg/L higher) than the No Action at the end of Year 20 (**Table 9-7**). The simulated deep zone area within the PSA which exceeds 800, 1,200, and 2,000 mg/L increases by 314 ac, 156 ac, and 137 ac, respectively at the end of Year 20 (**Table 9-21**).

Table 9-21: Difference in Number of Acres Exceeding TDS Thresholds Between the No Action and Proposed Action/Alternative 2 At the End of the 20-Year Exchange Program[1] Cumulative Impacts

Threshold Concentration	Proposed Action minus No Action (ac)		Alternative 2 minus No Action (ac)	
	Shallow	Deep	Shallow	Deep
800 mg/L	156	314	90	327
1,200 mg/L	88	156	25	168
2,000 mg/L	127	137	51	129

9.2.2.3 Lower Aquifer

TDS concentrations in the lower aquifer averaged 670 mg/L within the PSA at the end of Year 20. Lower aquifer TDS concentrations increased by an average of 1 mg/L between Year 1 and Year 20 within the PSA (**Table 9-6**). Both average and well specific TDS concentrations were relatively stable between Year 1 and Year 20 in the PSA (**Figure 9-42**). The average TDS concentration in the PSA in the lower aquifer is less than 1 mg/L higher than the No Action at the end of Year 20 (**Table 9-20**). The relative increase in average TDS in the PSA is generally stable throughout the 20-year period (**Figure 9-43**).

9.2.2.4 MPG Well Groundwater Quality

Simulated results from the Proposed Action show that 25 of the 76 MPG active wells exceed 1,200 mg/L and 12 wells exceed 2,000 mg/L at the end of Year 20 (**Table 9-10**). Using average simulated TDS concentrations from Year 1 through Year 20, 29 wells exceed 1,200 mg/L and 9 wells exceed 2,000 mg/L (**Table 9-11**).

9.2.3 Subsidence

Subsidence in the form of compaction simulated at the Fordel and Yearout extensometers was evaluated to assess the influence of the Proposed Action. Total compaction accumulated over the 20-year period was 0.073 ft at Yearout and 0.028 ft at Fordel. As an annual average, this totals 0.004 ft at Yearout and 0.001 ft at Fordel (**Table 9-12, Table 9-13**). The annual variability in simulated compaction ranged from between 0.04 and 0.1 ft at Yearout and between 0.02 and 0.04 ft at Fordel (**Figure 9-44**).

The difference in the total accumulated compaction over the 20-year period between the Proposed Action and No Action scenarios was about 0.027 ft at Yearout and 0.014 ft at Fordel (**Table 9-12, Table 9-13**). On an average annual basis, these differences are about 0.001 at Yearout and less than 0.001 ft at the Fordel extensometer location (**Table 9-12, Table 9-13**). At both the Yearout and Fordel extensometer locations, the Proposed Action shows an increase in relative compaction compared to the No Action during the spring and fall when exchange pumping occurs (**Figure 9-45, Figure 9-46**). However, the magnitude of this relative increase declines to a large extent during periods where no exchange pumping occurs.

The proportion of total inelastic compaction attributed to MPG exchange pumping was estimated by comparing simulated compaction to a Proposed Action model run with no assigned MPG exchange pumping. Inelastic compaction is estimated by comparing results from the winter of each year when water levels recover. Compaction associated with MPG pumping for exchange was 0.062 ft and 0.031 ft at the Yearout and Fordel extensometers, respectively (**Tables 9-12 and 9-13**). The remaining portion of total inelastic compaction was associated with non-MPG and MPG pumping for adjacent and overlying use. On an annual basis, MPG pumping for exchange in the Proposed Action resulted in 0.003 and 0.002 ft inelastic compaction at the Yearout and Fordel extensometer locations, respectively.

9.2.4 Surface Water Quality

The mixing model used to predict surface water quality at the Mendota Dam (northern mixing model) simulated TDS concentrations ranging from 160 mg/L in April to about 374 mg/L in February with an annual mean of 260 mg/L (**Table 9-22**). The inflows to the model from the San Joaquin River ranged from 2,500 to about 83,000 af per month with TDS concentrations ranging from 25 to 43 mg/L. Flows from the DMC ranged from about 13,000 to 130,000 af per month with TDS concentrations ranging from about 240 to 460 mg/L. Simulated inflows from the Pool ranged from 0 af per month in most months to a maximum of about 40,000 af per month with TDS concentrations ranging from about 170 to 320 mg/L. Outflows in the mixing model to the irrigation canals (Firebaugh, CCID Main, CCID Outside, and Columbia) ranged from about 2,000 to 93,000 af per month. Outflows to the Mendota Dam ranged from about 16,000 to 128,000 af per month. Pumping for groundwater exchange from FWD into the northern branch of the Pool leads to an average annual increase of approximately 1 mg/L in TDS concentrations in the San Joaquin River at the Mendota Dam (**Table 9-22**).

The southern mixing model was used to predict water quality at the MWA given both average and dry year conditions for the Proposed Action. Under the assumption of average conditions, simulated TDS concentrations at the MWA averaged 408 mg/L annually, and ranged from 301 mg/L in July to 473 mg/L in April (**Table 9-23**). Total annual inflows from the DMC were about 92,000 af. MPG adjacent pumping into the Pool was approximately 6,600 af while MPG transfer pumping totaled about 10,500 af. Average annual TDS at the MWA increases by 21 mg/L due to adjacent pumping and 25 mg/L due to exchange pumping. The maximum impacts occur in August (53 mg/L increases for exchange pumping and May 47 mg/L increases for adjacent pumping). Pumping into the Pool from the City of Mendota and Meyers Water Bank totaled about 2,000 and 3,000 af leading to a combined increase in TDS of 10 mg/L at the MWA (**Table 9-23**).

Under dry year assumptions, simulated TDS at the MWA averaged 417 mg/L annually and ranged from 351 mg/L in July to 478 mg/L in March (**Table 9-24**). The relative increase in TDS in the southern portion of the Pool is attributed to a 13,000 af reduction annually in the DMC flows to the MWA during the dry year simulation. In the hypothetical dry year, average annual TDS concentrations increase by 29 mg/L due to exchange pumping and 24 mg/L due to adjacent pumping (**Table 9-24**). The greatest impacts occur in August for both exchange (74 mg/L increase) and adjacent pumping (66 mg/L increase).

Pumping from the Meyers Water Bank and City of Mendota lead to an average annual increase in TDS concentrations of 11 mg/L at the MWA (**Table 9-24**).

9.2.5 Water Budget

The water budget for the Proposed Action scenario is tabulated in **Table 9-25** for the 20-year project period and two preceding years included in the model simulation. Stream and canal seepage ranges from about 125,000 to 167,000 afy (average 143,000 afy) with the largest amounts coinciding with years with high streamflow. Areal recharge ranges from about 164,000 to 316,000 afy (average 223,000 afy) with the highest amount of recharge occurring during average and wet years. Recharge from ponds varies between 2,000 to about 32,000 afy (average 10,000 afy) and are dependent on Meyers Water Bank operations, and availability of water for NCR and MPG recharge facilities. Net lateral subsurface inflow ranged -64,000 to about 112,000 afy (average 8,000 afy) with most years showing more groundwater entering the model domain than leaving. Seepage from the Pool and Fresno Slough shows very little variation and ranges from 31,000 to 40,000 afy (average 36,000 afy). Groundwater pumping is the largest water budget component and ranges from about 350,000 to about 540,000 afy (average 450,000 afy). Over the project period, groundwater storage in the model domain increases by as much as 152,000 afy and decreases by as much 166,000 afy (average 18,000 afy decrease). This decrease in aquifer storage is similar to the No Action scenario. Interbed storage increases by as much as 20,000 afy and decreases by as much as 60,000 afy (average 12,000 afy decrease).

9.3 Alternative 2

9.3.1 Water Levels

9.3.1.1 Shallow Zone

Shallow zone simulated groundwater levels are generally similar between the Alternative 2 and Proposed Action model runs in the Cumulative Impacts Analysis. Shallow zone groundwater levels averaged about 133 ft msl within the PSA at the end of Year 20. The groundwater elevation at the end of Year 20 is generally highest at the western model boundary and near the San Joaquin River, and generally lowest near the edge of the A clay and south of the San Joaquin River (**Figure 9-47)**. Winter/Spring average shallow groundwater levels within the PSA declined by about 6 ft while Summer/Fall water levels declined by 2 ft (**Table 9-1)**. As a fraction of the saturated thickness in the shallow zone in 2014, this represents a decrease of between 3 and 8 percent (**Table 9-2**). Average shallow zone groundwater levels exhibit small seasonal variations of less than 5 ft (**Figure 9-48**). Contours of shallow groundwater level changes from Year 1 to Year 20 show about 5 ft of decline west of the Fresno Slough, south of the San Joaquin River, and near the edge of the A clay (**Figure 9-49**). A groundwater mound forms near recharge ponds in the Meyers Water Bank at the end of Year 20 due to recharge at the Water Bank recharge facilities near the end of the project period (**Figure 9-49**). The 5-foot contour of the groundwater mound also extends over MPG recharge facilities west of the Fresno Slough illustrating the relative impacts MPG recharge ponds have on simulated shallow zone water levels.

West of the San Joaquin River and east and west of the Fresno Slough average shallow zone water levels do not significantly change (**Table 9-3**). North of the San Joaquin River and in the MWA, average shallow water levels in the Alternative 2 decrease by an average of 3 ft. East of the Chowchilla Bypass, average water levels decline by 5 ft (**Table 9-3**).

Simulated groundwater levels show that MPG groundwater pumping produces about 5 ft of additional shallow zone drawdown (**Table 9-4**). This represents an approximate 6 percent decrease in the average saturated thickness of the shallow zone (**Table 9-5**).

Average shallow zone groundwater levels within the PSA during Year 20 range from between 1 foot lower than the No Action in the Summer/Fall and Winter/Spring (**Table 9-18**). This represents about a 1 percent decrease in the saturated thickness of the shallow zone at the beginning of Year 1 (**Table 9-19**). Throughout the 20-year exchange period, average simulated shallow zone groundwater levels range from between 2 ft lower than the No Action in Year 13 to 0.2 ft higher than the No Action in Year 7 when no exchange pumping occurs and there is recharge in the MPG River Ranch North and Terra Linda Canal recharge facilities (**Figure 9-21**). Similar to results in the Proposed Action, Alternative 2 shallow zone groundwater levels at the end of Year 20 are up to 18 ft greater than the No Action near MPG wells west of the Fresno Slough and up to 6 ft lower than the No Action near the Fresno Slough south of Whitesbridge Road (**Figure 9-50**).

West of the San Joaquin River and east of the Chowchilla Bypass, shallow groundwater levels are within 2 ft of those simulated in the No Action (**Table 9-3**). North of the San Joaquin River, simulated Alternative 2 shallow zone water levels are 1 foot lower to 3 ft higher than the No Action (average 0 ft) at the end of Year 20 (**Table 9-3**). West of the Fresno Slough, Alternative 2 shallow groundwater levels are 5 ft lower to 18 ft higher than the No Action (average 0.3 ft). In the MWA, Alternative 2 water levels are 0 to 6 ft lower than the No Action (average -2 ft lower). East of the Fresno Slough, shallow groundwater levels are 5 ft lower to 10 ft higher than the No Action (average -1 ft lower) at the end of Year 20 (**Table 9-3**). In general, simulated Alternative 2 shallow groundwater levels are higher than the Proposed Action at the end of Year 20 due to additional MPG recharge at the River Ranch North recharge facility.

9.3.1.2 Deep Zone

Average simulated groundwater levels in the Alternative 2 run in the deep zone averaged about 107 ft msl at the end of Year 20. Contours of simulated deep zone groundwater levels at the end of Year 20 show that water levels are highest near the western and southeastern boundaries of the model domain and lowest at the northern boundary near the Chowchilla Bypass (**Figure 9-51**). Over the PSA, average deep water levels declined by between 2 and 7 ft in Summer/Fall and the Winter/Spring (**Table 9-1**). As a function of the pressure head at the base of the deep zone, this represents a change of between 1 and 2 percent (**Table 9-2**). Average simulated deep zone groundwater levels show seasonal water level fluctuations of 15 to 20 ft with a slight downward trend (**Figure 9-52**). Contours of groundwater level changes from Year 1 to Year 20 show that deep zone water levels are relatively high near the southern and western model boundaries but decrease towards the northeast to about 45 ft below sea level (**Figure 9-53**).

Average simulated deep zone groundwater levels decrease the most north of the San Joaquin River and east of the Chowchilla Bypass which decline by 9 and 11 ft, respectively (**Table 9-3**). West and east of the Fresno Slough average deep zone water levels decline by 2 and 4 ft, respectively. West of the San Joaquin River, average deep zone groundwater levels decline by 3 ft (**Table 9-3**). In the MWA, deep zone water levels decline by an average of 1 foot (**Table 9-3**).

Both Winter/Spring and Summer/Fall average water levels decline by 4 ft over the 20-year proposed exchange agreement due to MPG pumping (**Table 9-4**). As a fraction of the pressure head at the base of the deep zone, this represents a decrease of about 1 percent (**Table 9-5**).

Average simulated Alternative 2 deep zone groundwater levels within the PSA are 1.4 ft lower to 0.7 ft higher than No Action water levels in the Winter/Spring and Fall/Summer of Year 20 (**Table 9-18**). This represents less than 1 percent change in the pressure head at the base of the deep zone at the beginning of Year 1 (**Table 9-19**). Average Alternative 2 deep zone groundwater levels in the PSA are about 3 ft lower to 1.5 ft higher than the No Action during from Year 1 to Year 20 (**Figure 9-26**). Alternative 2 groundwater levels in the deep zone generally show greater relative drawdown compared to the No Action during the Spring and Fall when pumping for groundwater exchange is occurring and show relative recovery in the Summer when exchange pumping from the deep zone is curtailed (**Figure 9-26**). Contours of deep zone water level differences at the end of Year 20 show that Alternative 2 water levels generally recover relative to the No Action and there is little difference between the two runs (**Figure 9-54**). Contours show some residual drawdown south of Whitesbridge Avenue of 1 to 3, ft likely stemming from reduced leakage from the shallow zone caused by the relative cone of depression in the shallow zone (**Figure 9-54**).

North and west of the San Joaquin River and east of the Chowchilla Bypass simulated deep zone water levels are between 0 and 1 foot lower than No Action at the end of Year 20 (**Table 9-3**). West of the Fresno Slough, Alternative 2 deep zone groundwater levels are 3 ft lower to 4 ft greater than the No Action (average 0 ft) at the end of Year 20. In the MWA, Alternative 2 deep zone groundwater levels are 3 ft lower to 0 ft higher than the No Action (average 0.8 ft lower) at the end of Year 20. East of the Fresno Slough, Alternative 2 water levels are 2 ft lower to 3 ft higher than the No Action at the end of Year 20 (average 0.3 ft lower) (**Table 9-3**).

9.3.1.3 Lower Aquifer

Simulated groundwater levels in the lower aquifer averaged about 35 ft msl over the PSA at the end of Year 20. The average decline in water levels ranged from 10 ft in the Summer/Fall to 13 ft in the Winter/Spring (**Table 9-1**). As a fraction of the pressure head at the base of the lower aquifer in the beginning of Year 1, this decline represents a decrease of about 1 percent (**Table 9-2**). Seasonally, average lower aquifer groundwater levels vary by 20 to 25 ft (**Figure 9-55**). MPG groundwater pumping causes about 2 ft of drawdown in the lower aquifer at the end of Year 20 (**Table 9-4**). As a percentage of the thickness of the lower aquifer, this represents a decrease of less than 1 percent (**Table 9-5**).

Lower aquifer water levels are between 0.1 ft lower than the No Action in the Summer/Fall to 0.5 ft in Winter/Spring (**Table 9-18)**. As a fraction of the pressure head at the base of the lower zone, this represents a decrease of approximately less than 1 percent (**Table 9-19**). Throughout the proposed 20-year project period, lower aquifer water levels range from 2 ft lower than the No Action during the Spring of Year 13 to less than 1 foot higher than the No Action during Year 6 when no exchange pumping is assigned (**Figure 9-29**). Recharge from the River Ranch North recharge facility does not significantly affect water levels below the Corcoran Clay in the lower aquifer.

In general, Alternative 2 simulated groundwater levels are relatively similar to the Proposed Action throughout the simulation. Marked differences between the two scenarios occur primarily in the vicinity of the proposed recharge facilities located west of the Fresno Slough.

9.3.2 Groundwater Quality

9.3.2.1 Shallow Zone

Shallow zone TDS at the end of Year 20 was the highest in the western portion of the PSA west of the Fresno Slough and DMC while the lowest TDS occurs near the San Joaquin River (**Figure 9-56**). Average TDS concentrations in the PSA generally show a steady decline while individual wells, in many cases, show considerable variability throughout the 20-year period (**Figure 9-57, Appendix F**). Alternative 2 contours of TDS show that the saline front advances the most from Year 1 to Year 20 at a rate of about 20 to 60 ft per year (**Figure 9-58**). However, TDS migration is considerably impeded near the River Ranch North recharge facility (**Figure 9-58**). Shallow TDS concentrations increase the most south of the River Ranch North facility to Whitesbridge Avenue (**Figure 9-59**). With distance from the saline front, TDS concentrations generally vary by less than 500 mg/L from Year 1 to Year 20 (**Figure 9-59**).

North of the San Joaquin River and East of the Chowchilla Bypass, TDS concentrations vary by less than 500 mg/L (average 6 mg/L and 3 mg/L, lower respectively) between Year 1 and Year 20 (**Table 9-7**). West of the San Joaquin River, shallow zone TDS concentrations are between 750 mg/L lower to 800 mg/L higher (average 150 mg/L higher) at the end of Year 20. West of the Fresno Slough, Year 20 TDS concentrations are from 1,000 mg/L lower to 2,500 mg/L higher (average 31 mg/L higher) than Year 1 TDS (**Table 9-7**). In the MWA, TDS concentrations are between 1,300 mg/L lower to 1,100 mg/L higher (average 240 mg/L lower) at the end of Year 20. East of the Fresno Slough, shallow zone TDS concentrations are from 1,900 mg/L lower to 550 mg/L higher (average 130 mg/L lower) at the end of Year 20 (**Table 9-7**).

The area in the shallow zone which exceeds 800 mg/L in the Alternative 2 increases by 585 ac by the end of Year 20 (**Table 9-8**). The area which exceeds 1,200 and 2,000 mg/L decreases by 70 ac and 99 ac respectively (**Table 9-8**).

Within the PSA, average simulated shallow zone TDS concentrations in the Alternative 2 were 7 mg/L higher than the No Action (**Table 9-20**). Average TDS concentrations in the Alternative 2 increase relative to the No Action primarily in years where exchange pumping occurs and generally decrease in years where no exchange pumping is simulated and there is recharge in MPG recharge facilities west of the Fresno Slough (**Figure 9-34**). The mapped relative difference between the Alternative 2 and No Action in the shallow zone shows a relative decrease of over 2,000 mg/L west of the River Ranch North recharge facility in the Alternative 2 at the end of Year 20 **(Figure 9-60**). South of MPG recharge facilities west of the Fresno Slough, Alternative 2 shallow TDS concentrations are generally higher than the No Action at the end of Year 20. The greatest relative impact is near Whitesbridge Avenue. With distance from the Fresno Slough, shallow zone TDS in the No Action and Alternative 2 are generally similar to each other (**Figure 9-60**).

North of the San Joaquin River and East of the Bypass the maximum simulated difference between Alternative 2 and No Action TDS is less than 50 mg/L (average 3 mg/L and 1 mg/L higher, respectively) by the end of Year 20 (**Table 9-7**). West of the San Joaquin River, Alternative 2 TDS is between 70 mg/L lower to 80 mg/L higher (average 2 mg/L higher) than the No Action at the end of Year 20. West of the Fresno Slough, shallow Alternative 2 TDS is between 2,100 mg/L lower to 2,100 mg/L higher (average 20 mg/L higher) than the No Action at the end of Year 20 (**Table 9-7**). In the MWA, Alternative 2 shallow TDS is between 140 mg/L lower to 1,000 mg/L higher (average 20 mg/L higher) than the No Action at the end of Year 20. East of the Fresno Slough, Alternative 2 TDS is between 620 mg/L lower to 640 mg/L higher (average 8 mg/L lower) than the No Action by the end of Year 20 (**Table 9-7**).

The area in the shallow zone which exceeds the 800 mg/L threshold in the Alternative 2 is 90 ac greater than the No Action at the end of Year 20 (**Table 9-21**). The area which exceeds the 1,200 and 2,000 mg/L thresholds in the Alternative 2 is 25 ac and 51 ac, respectively, than the No Action (**Table 9-21**).

9.3.2.2 Deep Zone

Deep zone TDS within the PSA at the end of Year 20 are highest west of the Fresno Slough and generally lower near the San Joaquin River (**Figure 9-61**). Average deep TDS in the PSA increased by about 170 mg/L between Year 1 and Year 20 (**Table 9-6**). This increase was relatively uniform over time in average TDS concentrations in the PSA, but more variable in specific wells (**Figure 9-62, Appendix F**). Contours of simulated deep zone TDS shows that the saline front advances over the majority of the Fresno Slough and to a lesser extent from the Pool (**Figure 9-63**). TDS concentrations show the greatest increase from northwest of the City of Mendota to just south of Whitesbridge Road from Year 1 to Year 20 (**Figure 9-64**). With distance from the saline front, deep zone TDS concentrations exhibit little change. (**Figure 9-64**).

North of the San Joaquin River and east of the Chowchilla Bypass, deep zone TDS concentrations change by less than 500 mg/L (average 40 mg/L and 20 mg/L higher) between Year 1 and Year 20 (**Table 9-7**). West of the San Joaquin River, deep zone TDS in Year 20 is between 310 mg/L lower to 900 mg/L higher (average 310 mg/L higher) than in Year 1. West of the Fresno Slough, TDS is 280 mg/L lower to 2,100 mg/L higher (average 540 mg/L higher) by the end of Year 20 (**Table 9-7**). In the MWA, Year 20 TDS concentrations are between 680 mg/L lower to 1,600 mg/L higher (average 290 mg/L higher) than Year 1. East of the Fresno Slough, deep zone TDS concentrations are between 1,100 mg/L lower to 2,000 mg/L higher (average 180 mg/L higher) by the end of Year 20 (**Table 9-7**).

The area which exceeds the 800 and 2,000 mg/L thresholds in the deep zone increases by 3,400 ac and 1,800 ac, respectively, between Year 1 and Year 20 (**Table 9-9**). The area which exceeds the 1,200 mg/L threshold decreases by 1,300 ac by the end of Year 20 (**Table 9-9**).

Average Alternative 2 deep zone TDS within the PSA is about 7 mg/L higher than the No Action by the end of Year 20. Relative increase in TDS in the Alternative 2 compared to the No Action is greater during years where there is assigned pumping for groundwater exchange and generally smaller during years where there is none (**Figure 9-40**). The mapped relative difference in deep zone TDS concentrations show that the difference between Alternative 2 and No Action TDS is greatest east and west of the Fresno Slough and generally less than 100 mg/L throughout the majority of the PSA (**Figure 9-65**).

West of the San Joaquin River and east of the Chowchilla Bypass, the relative difference between the Alternative 2 and No Action is less than 100 mg/L (average 1 mg/L lower and 3 mg/L higher, respectively) by the end of Year 20 (**Table 9-7**). North of the San Joaquin River, TDS concentrations are between 230 mg/L lower to 140 mg/L higher (average 3 mg/L higher) than the No Action at the end of Year 20. West of the Fresno Slough, Alternative 2 TDS concentrations are between 1,100 mg/L lower to 1,700 mg/L higher (average 10 mg/L lower) than the No Action (**Table 9-7**). In the MWA, Alternative 2 TDS concentrations in the deep zone are between 3005 mg/L lower to 390 mg/L higher (average 10 mg/L higher) than the No Action. East of the Fresno Slough, deep Alternative 2 TDS is between 300 mg/L lower to 1,600 mg/L higher (average 50 mg/L higher) than the No Action at the end of Year 20 (**Table 9-7**).

The simulated deep zone area in the Alternative 2 within the PSA which exceeds 800 1,200, and 2,000 mg/L increases by 330 ac, 170 ac, and 130 ac, respectively at the end of Year 20 (**Table 9-21**).

9.3.2.3 Lower Aquifer

Alternative 2 TDS concentrations in the lower aquifer averaged 670 mg/L within the PSA at the end of Year 20. Lower aquifer TDS concentrations increased by an average of 1 mg/L between Year 1 and Year 20 within the PSA (**Table 9-6**). Both average and well specific TDS concentrations were relatively stable between Year 1 and Year 20 in the PSA (**Figure 9-66**). The average TDS concentration in the PSA in the lower aquifer is less than 1 mg/L higher than the No Action at the end of Year 20 (**Table 9-20**). The relative increase in average TDS in the PSA generally remain unchanged throughout the 20-year Project period (**Figure 9-43**).

9.3.2.4 MPG Well Groundwater Quality

Simulated results from the Alternative 2 show that 25 of the 76 MPG active wells exceed 1,200 mg/L and 11 wells exceed 2,000 mg/L at the end of Year 20 (**Table 9-10**). Using average simulated TDS concentrations Year 1 through Year 20, 29 wells exceed 1,200 mg/L and 9 wells exceed 2,000 mg/L (**Table 9-11**).

9.3.3 Subsidence

Subsidence in the form of compaction occurring above the Corcoran clay was evaluated at the Fordel and Yearout extensometer sites to assess the impact of groundwater pumping on aquifer system compaction. Total Alternative 2 compaction accumulated over the 20-year period was 0.071 ft at Yearout and 0.022 ft at Fordel. As an annual average, this totals 0.004 ft at Yearout and 0.001 ft at Fordel (**Table 9-12, Table 9-13**). The annual variability in simulated compaction ranged from between 0.04 and 0.1 ft at Yearout and between 0.02 and 0.04 ft at Fordel (**Figure 9-67**).

The difference in the total accumulated compaction over the 20-year period between the Alternative 2 and No Action scenarios was about 0.026 ft at Yearout and 0.008 ft at Fordel (**Table 9-12, Table 9-13**). On an average annual basis, these differences are about 0.001 at Yearout and less than 0.001 ft at the Fordel extensometer location (**Table 9-12, Table 9-13**). At both the Yearout and Fordel extensometer locations, the Alternative 2 shows an increase in relative compaction compared to the No Action during the spring and fall when exchange pumping occurs (**Figure 9-45, Figure 9-46**). However, the magnitude of this relative increase declines to a large extent during periods where no exchange pumping occurs.

The proportion of total inelastic compaction attributed to MPG exchange pumping was estimated by comparing simulated compaction to an Alternative 2 model run with no assigned MPG exchange pumping. Inelastic compaction is estimated by comparing results from the winter of each year when water levels recover. Compaction associated with MPG pumping for exchange was 0.061 ft and 0.029 ft at the Yearout and Fordel extensometers, respectively (**Tables 9-12 and 9-13**). The remaining portion of total inelastic compaction was associated with non-MPG and MPG pumping for adjacent and overlying use. On an annual basis, MPG pumping for exchange in the Proposed Action resulted in 0.003 and 0.001 ft inelastic compaction at the Yearout and Fordel extensometer locations, respectively.

9.3.4 Surface Water Quality

The mixing model used to predict surface water quality at the Mendota Dam (northern mixing model) simulated TDS concentrations ranging from 160 mg/L in April to about 374 mg/L in February (**Table 9-26**). The inflows to the model from the San Joaquin River ranged from 2,500 to about 83,000 af per month with TDS concentrations ranging from 25 to 43 mg/L. Flows from the DMC ranged from about 13,000 to 130,000 af per month with TDS concentrations ranging from about 240 to 460 mg/L. Simulated inflows from the Pool ranged from 0 af per month in most months to a maximum of about 40,000 af per month with TDS concentrations ranging from about 170 to 320 mg/L. Outflows in the mixing model to the irrigation canals (Firebaugh, CCID Main, CCID Outside, and Columbia) ranged from about 2,000 to 93,000 af per month. Outflows to the Mendota Dam ranged from about 16,000 to 128,000 af per month. Pumping for groundwater exchange from FWD into the northern branch of the Pool leads to an average annual increase of approximately 1 mg/L in TDS concentrations in the San Joaquin River at the Mendota Dam (**Table 9-26**).

The southern mixing model was used to predict water quality at the MWA given both average and dry year conditions for the Alternative 2. Under the assumption of average conditions, simulated TDS concentrations at the MWA averaged 407 mg/L annually, and ranged from 299 mg/L in July to 413 mg/L in April (**Table 9-27**). Total annual inflows from the DMC were about 92,000 af. MPG adjacent pumping into the Pool was approximately 6,600 af while MPG transfer pumping totaled about 10,500 af. Average annual TDS at the MWA increases by 19 mg/L due to adjacent pumping and 25 mg/L due to exchange pumping. The maximum impacts occur in August (43 mg/L increase) for adjacent pumping and (53 mg/L increase) for exchange pumping. Pumping into the Pool from the City of Mendota and Meyers Water Bank totaled about 2,000 and 3,000 af leading to a combined increase in TDS of 10 mg/L at the MWA (**Table 9-27**). Under dry year assumptions, simulated TDS at the MWA averaged 415 mg/L and ranged from 304 mg/L in November to 478 mg/L in March (**Table 9-28**). The relative increase in TDS in the southern portion of the Pool is attributed to a 13,000 af reduction annually in the DMC flows to the MWA during the dry year simulation. In the hypothetical dry year, average annual TDS concentrations increase by 29 mg/L due to exchange pumping and 22 mg/L due to adjacent pumping (**Table 9-28**). The greatest impacts occur in August for exchange (75 mg/L increase) and adjacent pumping (61 mg/L increase). Pumping from the Meyers Water Bank and City of Mendota lead to an average annual increase in TDS concentrations of 11 mg/L at the MWA (**Table 9-28**).

9.3.5 Water Budget

The water budget for the Alternative 2 scenario is tabulated in **Table 9-29** for the 20-year project period and two preceding years included in the model simulation. Stream and canal seepage ranges from about 123,000 to 167,000 afy (average 143,000 afy) with the largest amounts coinciding with years with high streamflow. Areal recharge ranges from about 164,000 to 312,000 afy (average 223,000 afy) with the highest amount of recharge occurring during average and wet years. Recharge from ponds varies between 1,500 to about 35,000 afy (average 11,000 afy) and are dependent on Meyers Water Bank operations, and availability of water for NCR and MPG recharge facilities. Net lateral subsurface inflow ranged -64,000 to about 112,000 afy (average 8,000 afy) with most years showing more groundwater entering the model domain than leaving. Seepage from the Pool and Fresno Slough shows very little variation and ranges from 31,000 to 39,000 afy (average 36,000 afy). Groundwater pumping is the largest water budget component and ranges from about 350,000 to about 540,000 afy (average 450,000 afy). Over the project period, groundwater storage in the model domain increases by as much as 153,000 afy and decreases by as much 167,000 afy (average 17,000 afy decrease). Interbed storage increases by as much as 20,000 afy and decreases by as much as 60,000 afy (average 12,000 afy decrease).

Geographic Area	Change in Groundwater Elevation by Sub Area[1,2,3,4]		
	No Action (Adjacent Pumping: 27,871 af)	**Proposed Action** (Adjacent Pumping: 11,648 af)	**Alternative 2** (Adjacent Pumping: 11,648 af)
Shallow Zone	Average water level decrease by Year 20: 2 ft	Average water level decrease by Year 20: 2 ft	Average water level decrease by Year 20: 2 ft
North of the SJR	Total: - 10 to 1 ft (-3 ft) Variability: 1 to 15 ft (3 ft)	Total: -10 to 2 ft (-3 ft) Relative: -1 to 2 ft (0 ft) Variability: 1 to 14 ft (3 ft)	Total: -10 to 3 ft (-3 ft) Relative:-1 to 3 ft (0 ft) Variability: 1 to 14 ft (3 ft)
West of SJR	Total: - 4 tp 3 ft (0 ft) Variability: 2 to 26 ft (6 ft)	Total: -4 to 3 ft (0 ft) Relative: 0 to 2 ft (0.2 ft) Variability: 2 to 27 ft (6 ft)	Total: -3 ft to 3 ft (0 ft) Relative: 0 to 2 ft (0.3 ft) Variability: 2 to 27 ft (6 ft)
West of Fresno Slough	Total: -8 to 21 ft (0 ft) Variability: 1.4 to 76 ft (5 ft)	Total: - 6 to 20: ft (0 ft) Relative: -6 to 17 ft (-0.4 ft) Variability: 2 to 66 ft (5 ft)	Total: -5 to 21 ft (0 ft) Relative:-5 to 18 ft (0.3 ft) Variability: 2 to 66 ft (5 ft)
Mendota Wildlife Area	Total: - 5 to 10 ft (-1 ft) Variability: 1 to 10 ft (2 ft)	Total: - 7 to 6 ft (-3 ft) Relative: -6 to 0 ft (-1.6 ft) Variability: 1 to 10 ft (2 ft)	Total: -7 to 6 ft (-3 ft) Relative: -6 to 0 ft (-1.5 ft) Variability: 1 to 10 ft (2 ft)
East of Fresno Slough	Total: -6 to 26 ft (1 ft) Variability: 1 to 36 ft (5 ft)	Total: -8 to 24 ft (-1 ft) Relative: -5 to 8 ft (-1.9 ft) Variability: 2 to 42 ft (6 ft)	Total: -8 to 24 ft (0 ft) Relative: -5 to 10 ft (-1.3 ft) Variability: 2 to 42 ft (6 ft)
East of Bypass	Total: -10 to 8 ft (-4 ft) Variability: 0 to 15 ft (3 ft)	Total: -10 t0 8 ft (-5 ft) Relative: -2 to 0 ft (-0.6 ft) Variability: 1 to 15 ft (3 ft)	Total: -10 to 8 ft (-5 ft) Relative:-2 to ft (-0.5 ft) Variability: 1 to 15 ft (3 ft)
Deep Zone	Average water level decrease by Year 20: 6 ft	Average water level decrease by Year 20: 7 ft	Average water level decrease by Year 20: 7 ft
North of the SJR	Total: -27 to 0 ft (- 9 ft) Variability: 1 to 56 ft (16 ft)	Total: -27 to 0 ft (-9 ft) Relative: -1 to 1 ft (0.0 ft) Variability: 1 to 54 ft (16 ft)	Total: -27 to 0 ft (-9 ft) Relative: 0 to 2 ft (0.1 ft) Variability: 1 to 54 ft (16 ft)
West of SJR	Total: -8 to 2 ft (-3 ft) Variability: 2 to 35 ft (13 ft)	Total: -8 to 2 ft (-3 ft) Relative: 0 to 1 ft (0.2 ft) Variability: 2 to 34 ft (13 ft)	Total: -8 to 2 ft (-3 ft) Relative: 0 to 2 ft (0.3 ft) Variability: 2 to 34 ft (13 ft)
West of Fresno Slough	Total: -6 to 20: ft (-2 ft) Variability: 1 to 68 ft (14 ft)	Total: -6 to 20: ft (-3 ft) Relative: -4 to 2 ft (-0.5 ft) Variability: 2 to 50 ft (13 ft)	Total: -6 to 20: ft (-2 ft) Relative: -3 to 4 ft (0.0 ft) Variability: 2 to 50 ft (13 ft)
Mendota Wildlife Area	Total: -4 to 7 ft (0 ft) Variability: 1 to 23 ft (10 ft)	Total: -5 to 7 ft (-1 ft) Relative: -4 to 0 ft (-0.9 ft) Variability: 2 to 23 ft (10 ft)	Total: -5 to 7 ft (-1 ft) Relative: -3 to 0 ft (-0.8 ft) Variability: 2 to 23 ft (10 ft)
East of Fresno Slough	Total: -15 to 16 ft (-4 ft) Variability: 9 to 53 ft (28 ft)	Total: -13 to 14 ft (-4 ft) Relative: -2 to 3 ft (-0.6 ft) Variability: 10 to 54 ft (27 ft)	Total: -13 to 14 ft (-4 ft) Relative: -2 to 3 ft (-0.3 ft) Variability: 10 to 54 ft (27 ft)
East of Bypass	Total: -24 to 6 ft (-11 ft) Variability: 3 to 51 ft (25 ft)	Total: -25 to 6 ft (-11 ft) Relative: -1 to 0 ft (-0.5 ft) Variability:3 to 48 ft (24 ft)	Total: -25 to 6 ft (-11 ft) Relative: -1 to 0 ft (-0.4 ft) Variability: 3 to 48 ft (24 ft)

1. Total change defined as the total difference in groundwater elevation accrued from the start of year 1 to the end of Year 20. Positive numbers indicate net increase in groundwater elevation over the 20-year program.
2. Variability defined as the median amount that groundwater levels change within 1 year.
3. Relative change defined as difference between No Action and Proposed Action/Alternative 2. Positive numbers indicates groundwater elevation in the Proposed Action/Alternative 2 is higher than the No Action.
4. Sub-region averages shown in parenthesis.

Table 9-3
Cumulative Impacts Simulated Groundwater Levels in PSA Sub-regions Year 1 to Year 20

Geographic Area	Change in TDS by Sub Area[1,2,3]		
	No Action (Adjacent Pumping: 27,871 af)	**Proposed Action** (Adjacent Pumping: 11,648 af)	**Alternative 2** (Adjacent Pumping: 11,648 af)
Shallow Zone	Average change in TDS by Year 20: -55 mg/L	Average change in TDS by Year 20: -44 mg/L	Average change in TDS by Year 20: -48 mg/L
North of the SJR	Total: -296 to 344 mg/L (-8 mg/L)	Total: -296 to 345 mg/L (-6 mg/L) Relative: -19 to 22 mg/L (2 mg/L)	Total: -296 to 345 mg/L (-6 mg/L) Relative: -23 to 22 mg/L (3 mg/L)
West of SJR	Total: -754 to 800 mg/L (150 mg/L)	Total: -750 to 799 mg/L (151 mg/L) Relative: -87 to 56 mg/L (1 mg/L)	Total: -746 to 799 mg/L (152 mg/L) Relative: -73 to 81 mg/L (2 mg/L)
West of Fresno Slough	Total: -1553 to 2590 mg/L (10 mg/L)	Total: -1001 to 2772 mg/L (63 mg/L) Relative: -967 to 2145 mg/L (53 mg/L)	Total: -1001 to 2504 mg/L (31 mg/L) Relative: -2051 to 2149 mg/L (20 mg/L)
Mendota Wildlife Area	Total: -1292 to 1037 mg/L (-254 mg/L)	Total: -1297 to 1066 mg/L (-236 mg/L) Relative: -143 to 1012 mg/L (18 mg/L)	Total: -1297 to 1064 mg/L (-236 mg/L) Relative: -139 to 1015 mg/L (18 mg/L)
East of Fresno Slough	Total: -1827 to 312 mg/L (-126 mg/L)	Total: -1913 to 543 mg/L (-135 mg/L) Relative: -655 to 636 mg/L (-9 mg/L)	Total: -1916 to 550 mg/L (-134 mg/L) Relative: -623 to 644 mg/L (-8 mg/L)
East of Bypass	Total: -265 to 147 mg/L (-4 mg/L)	Total: -267 to 145 mg/L (-3 mg/L) Relative: -20 to 34 mg/L (2 mg/L)	Total: -267 to 145 mg/L (-3 mg/L) Relative: -20 to 34 mg/L (1 mg/L)
Deep Zone	Average change in TDS by Year 20: 161 mg/L	Average change in TDS by Year 20: 169 mg/L	Average change in TDS by Year 20: 168 mg/L
North of the SJR	Total: -208 to 312 mg/L (36 mg/L)	Total: -202 to 327 mg/L (39 mg/L) Relative: -231 to 128 mg/L (3 mg/L)	Total: -202 to 328 mg/L (39 mg/L) Relative: -234 to 136 mg/L (3 mg/L)
West of SJR	Total: -324 to 908mg/L (314 mg/L)	Total: -314 to 904 mg/L (313 mg/L) Relative: -90 to 33 mg/L (-2 mg/L)	Total: -313 to 902 mg/L (313 mg/L) Relative: -84 to 45 mg/L (-1 mg/L)
West of Fresno Slough	Total: -278 to 1986 mg/L (557 mg/L)	Total: -281 to 2056 mg/L (554 mg/L) Relative: -739 to 1699 mg/L (-3 mg/L)	Total: -279 to 2080 mg/L (544 mg/L) Relative:-1084 to1724 mg/L(-12 mg/L)
Mendota Wildlife Area	Total: -676 to 1487 mg/L (280 mg/L)	Total: -676 to 1600 mg/L (291 mg/L) Relative: -322 to 386 mg/L (11 mg/L)	Total: -676 to 1602 mg/L (291 mg/L) Relative: -305 to 390 mg/L (11 mg/L)
East of Fresno Slough	Total: -1233 to 1475 mg/L (135 mg/L)	Total: -1085 to 1955 mg/L (180 mg/L) Relative: -327 to 1556 mg/L (46 mg/L)	Total: -1109 to 1978 mg/L (183 mg/L) Relative: -302 to 1586 mg/L (48 mg/L)
East of Bypass	Total: -183 to 249 mg/L (19 mg/L)	Total: -182 to 263 mg/L (22 mg/L) Relative: -19 to 49 mg/L (3 mg/L)	Total: -182 to 262 mg/L (22 mg/L) Relative: -18 to 46 mg/L (3 mg/L)

1. Total change defined as the total difference in TDS accrued from the start of year 1 to the end of year 20. Positive numbers indicate net increase in TDS over the 20-year program.
2. Relative change defined as difference between No Action and Proposed Action/Alternative 2. Positive numbers indicates TDS concentration in the Proposed Action/Alternative 2 is higher than the No Action.
3. Sub-region averages shown in parenthesis.

Luhdorff & Scalmanini
Consulting Engineers

Table 9-7
Cumulative Impacts Simulated TDS Concentrations in PSA Sub-regions Year 1 to Year 20

		Total Dissolved Solids Concentration (mg/L)		
Well	Depth	No Action	Proposed Action	Alternative 2
Terra Linda Farms				
TLF-1s	S	722	779	779
TLF-2s	S	738	772	824
TLF-3s	S	653	633	651
TLF-4s	S	812	798	696
TLF-5d	D	2,261	2,600	2,508
TLF-6d	D	1,949	2,204	2,073
TLF-7s	S	438	439	423
TLF-8s	S	445	442	430
TLF-9s	S	451	444	435
TLF-10s	S	462	440	438
TLF-11As	S	458	438	436
TLF-11Cs[1]	S	451	433	431
TLF-12d	D	514	537	581
TLF-13s	S	434	423	424
TLF-14d	D	1,740	2,164	1,863
TLF-15s	S	295	284	294
TLF-16s	S	433	406	384
TLF-17s	S	896	845	635
TLF-18d	D	1,723	1,687	1,777
TLF-19s	S	292	309	326
TL-1[1]	D	1,139	1,182	1,239
TL-11[1]	S	1,705	1,859	1,870
TL-9[1]	D	2,255	2,229	2,133
Coelho/Coelho				
Conejo West[1]	D	2,685	2,546	2,229
Coelho/Coelho/Fordel				
CCF-1[1]	D	2,211	2,254	2,083
Silver Creek Packing				
SC-3B	S	1,942	2,033	2,008
SC-4B	S	1,119	1,153	1,160
SC-6	D	3,334	3,287	3,318
SC-7	D	3,156	3,168	3,202
Coelho/Gardner/Hanson				
CGH-1s	S	2,862	2,345	2,362
CGH-2s & 3s[2]	S	1,670	1,541	1,546
CGH-4s	S	2,560	2,261	2,270
CGH-5s	S	2,886	2,228	2,249
CGH-6s	S	1,677	1,426	1,434
CGH-7s	S	1,043	984	986
CGH-8s	S	668	692	691
CGH-9As/9Bs[2]	S	1,880	1,590	1,598
CGH-10s	S	956	934	933
CGH-11s	S	859	844	842
CGH-12s	S	1,058	1,030	1,028
CGH-13d	D	3,845	3,901	3,919
CGH-4[1]	S	1,854	1,552	1,562
CGH-8[1]	S	1,669	1,639	1,641
Meyers Farming				
MS-3[1]	S	2,743	2,614	2,610
MS-4[1]	S	3,116	3,423	3,419
DW-1	D	1,030	1,548	1,556
MS-6	S	3,142	3,140	3,136
MS-7	S	3,239	3,522	3,519
Casaca Vineyards				
FS-1	S	344	982	983
FS-3	S	400	1,028	1,030
FS-5	S	458	1,534	1,536
FS-6	S	507	1,518	1,521
FS-7	S	513	1,457	1,459
Daddy's Pride Farming				
FS-4	S	418	1,011	1,012
FS-9	S	502	1,362	1,365
FS-10	S	517	1,317	1,320
Solo Mio				
FS-2	S	351	1,006	1,008
FS-8	S	493	1,548	1,550
Coelho West				
CW-1	S	286	585	585
CW-2	S	284	544	544
CW-3	S	285	533	534
CW-4	S	290	588	589
CW-5	S	299	579	580
Farmers Water District				
R-1	D	352	347	349
R-2	D	396	384	387
R-3	D	435	388	389
R-4	D	128	123	124
R-12	D	536	865	883
R-7	D	237	178	179
R-8	D	326	326	327
R-9	D	213	243	244
R-10	D	507	552	555
R-11	D	584	584	584
E-Loop-2	D	41	41	41
E-Loop-3	D	64	65	65
W Loop-1	D	145	127	128
W Loop-2	D	243	229	230
W Loop-3	D	156	146	147
Baker Farming Co.				
BF-1	D	285	277	279
BF-2	D	378	405	410
BF-3	D	333	334	338
BF-4	D	341	357	360
BF-5	D	453	577	584
Panoche Creek Farms				
PCF-1	D	488	464	470
Wells Exceeding 1,200 mg/L[3]		**18**	**25**	**25**
Wells Exceeding 2,000 mg/L[3]		**9**	**12**	**11**

1. Well not included for exchange pumping. Added to meet adjacent pumping demand for No Action.
2. Represent 2 wells manifolded at surface. Concentration is average of wells.
3. Out of 76 wells included in exchange program.

Table 9-10
Cumulative Impacts Simulated TDS Concentration in MPG Wells (Year 20)

		Total Dissolved Solids Concentration (mg/L)		
Well	**Depth**	**No Action**	**Proposed Action**	**Alternative 2**
Terra Linda Farms				
TLF-1s	S	880	997	998
TLF-2s	S	764	857	878
TLF-3s	S	762	804	814
TLF-4s	S	911	948	888
TLF-5d	D	1,742	1,969	1,957
TLF-6d	D	1,519	1,695	1,661
TLF-7s	S	478	480	475
TLF-8s	S	480	478	475
TLF-9s	S	482	479	478
TLF-10s	S	468	469	475
TLF-11As	S	465	466	472
TLF-11Cs[1]	S	459	460	465
TLF-12d	D	510	532	555
TLF-13s	S	444	445	450
TLF-14d	D	1,426	1,696	1,520
TLF-15s	S	407	410	409
TLF-16s	S	533	529	478
TLF-17s	S	936	964	760
TLF-18d	D	1,360	1,366	1,412
TLF-19s	S	368	381	383
TL-1[1]	D	954	1,004	1,033
TL-11[1]	S	1,357	1,474	1,481
TL-9[1]	D	1,843	1,824	1,752
Coelho/Coelho				
Conejo West[1]	D	2,065	1,998	1,849
Coelho/Coelho/Fordel				
CCF-1[1]	D	1,794	1,827	1,697
Silver Creek Packing				
SC-3B	S	1,776	2,151	2,139
SC-4B	S	1,042	1,284	1,292
SC-6	D	2,658	2,652	2,671
SC-7	D	2,470	2,498	2,520
Coelho/Gardner/Hanson				
CGH-1s	S	2,817	2,742	2,753
CGH-2s & 3s[2]	S	1,786	1,878	1,883
CGH-4s	S	2,544	2,581	2,588
CGH-5s	S	2,849	2,689	2,703
CGH-6s	S	1,759	1,753	1,761
CGH-7s	S	1,145	1,229	1,233
CGH-8s	S	747	864	866
CGH-9As/9Bs[2]	S	2,046	1,929	1,939
CGH-10s	S	1,141	1,132	1,136
CGH-11s	S	1,007	1,015	1,018
CGH-12s	S	1,283	1,254	1,259
CGH-13d	D	3,255	3,328	3,342
CGH-4[1]	S	1,928	1,907	1,915
CGH-8[1]	S	1,833	1,800	1,807
Meyers Farming				
MS-3[1]	S	2,805	2,939	2,939
MS-4[1]	S	3,093	3,373	3,371
DW-1	D	822	1,107	1,113
MS-6	S	3,153	3,312	3,312
MS-7	S	3,207	3,473	3,472
Casaca Vineyards				
FS-1	S	506	1,138	1,139
FS-3	S	574	1,204	1,202
FS-5	S	685	1,650	1,652
FS-6	S	724	1,647	1,647
FS-7	S	725	1,595	1,593
Daddy's Pride Farming				
FS-4	S	591	1,130	1,127
FS-9	S	711	1,510	1,507
FS-10	S	724	1,424	1,419
Solo Mio				
FS-2	S	521	1,204	1,205
FS-8	S	715	1,669	1,670
Coelho West				
CW-1	S	391	698	699
CW-2	S	381	648	649
CW-3	S	382	649	649
CW-4	S	399	732	732
CW-5	S	407	710	709
Farmers Water District				
R-1	D	403	414	416
R-2	D	376	367	368
R-3	D	451	429	430
R-4	D	129	127	127
R-12	D	401	508	513
R-7	D	203	168	169
R-8	D	326	320	321
R-9	D	221	252	253
R-10	D	409	429	430
R-11	D	513	517	517
E-Loop-2	D	45	44	44
E-Loop-3	D	65	67	67
W Loop-1	D	157	140	141
W Loop-2	D	230	216	216
W Loop-3	D	178	167	167
Baker Farming Co.				
BF-1	D	272	259	260
BF-2	D	364	361	363
BF-3	D	315	305	306
BF-4	D	328	329	330
BF-5	D	363	403	405
Panoche Creek Farms				
PCF-1	D	541	518	521
Wells Exceeding 1,200 mg/L[3]		**19**	**29**	**29**
Wells Exceeding 2,000 mg/L[3]		**10**	**9**	**9**

1. Well not included for exchange pumping. Added to meet adjacent pumping demand for No Action.
2. Represent 2 wells manifolded at surface. Concentration is average of wells.
3. Out of 76 wells included in exchange program.

Table 9-11
Cumulative Impacts Simulated TDS Concentration in MPG Wells (Year 1 - Year 20 Average)

Month	Inflows[1] San Joaquin River[2] (af)	Inflows[1] DMC[3] (af)	Inflows[1] Farmers Water District[4] (af)	Inflows[1] Mendota Pool[5] (af)	Outflows Diversions[2] (af)	Outflows Mendota Dam[2] (af)	TDS San Joaquin River[2] (mg/L)	TDS DMC[6] (mg/L)	TDS Farmers Water District[7] (mg/L)	TDS Mendota Pool[2] (mg/L)	TDS Increase due to FWD (mg/L)	TDS Mendota Dam[8] (mg/L)
January	7122	18910	0	4225	2263	27994	37	461	0	301	0	339
February	6409	49983	0	0	23635	32660	40	411	0	327	0	369
March	39371	46780	0	649	36997	49804	42	403	0	254	0	238
April	55675	45662	0	30337	31827	99848	36	368	0	202	0	189
May	3580	69579	0	38402	54626	56936	34	353	0	244	0	305
June	3296	102218	0	12751	76178	42085	33	309	0	259	0	296
July	2495	130618	0	0	92964	32473	32	244	0	235	0	240
August	3120	123623	0	0	83136	26188	27	268	0	255	0	262
September	3715	82080	0	0	39952	34477	27	315	0	290	0	303
October	5697	66726	0	0	28997	33978	26	312	0	295	0	290
November	10177	34868	0	0	12448	27070	26	344	0	286	0	272
December	6973	12518	0	0	3466	14748	28	410	0	277	0	274
Total	**147,631**	**783,565**	**0**	**86,364**	**486,490**	**478,261**						
Annual Mean							**32**	**350**	**0**	**269**	**0**	**281**

1. Total pumping for groundwater exchange: 0 AF. Total pumping for adjacent use: 27,871 AF.
2. Calculated from groundwater model from respective run.
3. Average monthly flow in the DMC at Check 21 from 1992 - 2011 (reflect Year 1 - Year 20 in the predictive scenarios). Years where no exchange pumping occurs excluded.
4. Proposed exchange pumping for Farmers Water District (Logoluso, Baker Farms, and Panoche Creek Farms).
5. Assigned to make up the deficit between the calculated inflows (San Joaquin River, DMC, and Farmers Water District) and outflows (canal diversions, flow over the Mendota Dam) which is met by flow from the Mendota Pool
6. Average monthly TDS in the DMC at Check 21 from 1992 - 2011 (reflect Year 1 to Year 20 in the predictive scenarios). Years where no exchange pumping occurs excluded.
7. Volume weighted TDS calculated from average TDS from each well from Year 1 to Year 20 and amount of proposed exchange pumping.
8. Calculated as the volume weighted average TDS of the inflows.

Month	Flow Contribution at MWA					TDS at DMC Check 21[5] (mg/L)	TDS Increase Due to				TDS in Southern Mendota Pool (mg/L)
	DMC[2] (af)	MPG Wells[1,3]		City of Mendota[4] (af)	Meyers Water Bank (af)		MPG Pumping		City of Mendota (mg/L)	Meyers Water Bank (mg/L)	
		Exchange Pumping (af)	Adjacent Pumping (af)				Exchange Pumping (mg/L)	Adjacent Pumping (mg/L)			
January	5,924	0	33	0	0	448	0	0	0	0	448
February	10,818	0	75	0	0	424	0	0	0	0	425
March	6,651	0	312	0	0	423	0	2	0	0	425
April	5,930	0	871	470	21	394	0	27	11	0	433
May	8,440	0	1,552	615	728	335	0	55	12	14	416
June	14,981	0	2,087	374	656	309	0	61	5	9	384
July	14,206	0	2,220	395	506	204	0	84	8	10	306
August	8,882	0	2,000	204	480	272	0	89	5	12	377
September	8,505	0	1,476	0	488	345	0	54	0	10	409
October	8,155	0	371	0	257	322	0	6	0	7	335
November	5,886	0	87	0	0	351	0	1	0	0	353
December	4,091	0	53	0	0	409	0	0	0	0	409
Total	**102,469**	**0**	**11,137**	**2,058**	**3,135**						
Annual Mean						**353**	**0**	**32**	**3**	**5**	**393**

1. Including non-MPG pumpage by Don Peracchi in Farmers Water District.
2. Calculated as the difference between the average net demand in the southern portion of the Fresno Slough and the inflow from MPG, Meyers Farm Water Bank wells, and City of M endota wells along the Fresno Slough.
3. Inflow from MPG wells along the Fresno Slough. Values do not include Farmers Water District pumping (FWD, Baker, and Panoche wells).
4. Based on City's pumpage from Fordel wells in 2010.
5. Monthly average based on reported daily EC in the DMC in years with exchange pumping from 2004 - 2013.

Table 9-15
TDS Concentration at MWA – No Action Cumulative Impacts

Month	Flow Contribution at MWA					TDS at DMC Check 21[5] (mg/L)	TDS Increase Due to				TDS in Southern Mendota Pool (mg/L)
	DMC[2] (af)	MPG Wells[1,3]		City of Mendota[4] (af)	Meyers Water Bank (af)		MPG Pumping		City of Mendota (mg/L)	Meyers Water Bank (mg/L)	
		Exchange Pumping (af)	Adjacent Pumping (af)				Exchange Pumping (mg/L)	Adjacent Pumping (mg/L)			
January	2,620	0	33	0	0	448	0	0	0	0	447
February	3,551	0	75	0	0	424	0	1	0	0	425
March	5,863	0	312	0	0	423	0	2	0	0	425
April	5,969	0	871	470	21	394	0	27	11	0	432
May	6,761	0	1,552	615	728	335	0	64	14	17	430
June	14,109	0	2,087	374	656	309	0	65	5	9	388
July	13,380	0	2,220	395	506	204	0	88	9	11	311
August	5,845	0	2,000	204	480	272	0	120	7	16	415
September	6,827	0	1,476	0	488	345	0	64	0	12	421
October	7,506	0	371	0	257	322	0	6	0	7	336
November	5,306	0	87	0	0	351	0	2	0	0	353
December	2,242	0	53	0	0	409	0	1	0	0	410
Total	**79,981**	**0**	**11,137**	**2,058**	**3,135**						
Annual Mean						**353**	**0**	**37**	**4**	**6**	**399**

1. Including non-MPG pumpage by Don Peracchi in Farmers Water District.
2. Calculated as the difference between the average net demand in the southern portion of the Fresno Slough and the inflow from MPG, Meyers Farm Water Bank wells, and City of Mendota wells along the Fresno Slough.
3. Inflow from MPG wells along the Fresno Slough. Values do not include Farmers Water District pumping (FWD, Baker, and Panoche wells).
4. Based on City's pumpage from Fordel wells in 2010.
5. Monthly average based on reported daily EC in the DMC in years with exchange pumping from 2004 - 2013.

Table 9-16
TDS Concentration at MWA – No Action (Dry Year)
Cumulative Impacts

Year	Stream and Canal Seepage (af)	Areal Recharge (af)[1]	Recharge Ponds (af)[1]	Net Lateral Inflow (af)	Lake Seepage (af)	Pumping (af)[2]	Storage (af)[3]	Interbed Storage (af)[3]
-	112,000	196,000	560	18,000	31,000	-519,000	117,000	46,000
-	111,000	214,000	500	-26,000	32,000	-512,000	128,000	53,000
Year 1	77,000	241,000	1,500	-48,000	34,000	-481,000	110,000	67,000
Year 2	117,000	266,000	12,000	14,000	34,000	-417,000	-44,000	21,000
Year 3	75,000	182,000	4,000	11,000	35,000	-465,000	122,000	37,000
Year 4	115,000	323,000	15,000	44,000	36,000	-390,000	-135,000	-2,900
Year 5	103,000	309,000	12,000	60,000	32,000	-390,000	-115,000	-6,600
Year 6	102,000	249,000	12,000	62,000	32,000	-493,000	34,000	4,800
Year 7	101,000	305,000	26,000	51,000	30,000	-362,000	-128,000	-8,800
Year 8	100,000	190,000	6,000	45,000	29,000	-454,000	80,000	6,400
Year 9	100,000	238,000	6,000	44,000	30,000	-408,000	-10,000	3,000
Year 10	102,000	239,000	3,500	47,000	31,000	-470,000	40,000	8,400
Year 11	108,000	200,000	4,000	40,000	33,000	-503,000	105,000	15,000
Year 12	115,000	185,000	7,500	46,000	33,000	-448,000	57,000	7,000
Year 13	113,000	228,000	4,000	56,000	34,000	-474,000	26,000	15,000
Year 14	111,000	228,000	9,000	21,000	33,000	-402,000	-2,000	5,900
Year 15	112,000	224,000	10,000	33,000	33,000	-371,000	-37,000	-110
Year 16	80,000	168,000	4,500	8,100	34,000	-501,000	176,000	33,000
Year 17	132,000	179,000	4,700	16,000	36,000	-534,000	119,000	51,000
Year 18	134,000	171,000	4,300	-8,800	36,000	-532,000	129,000	69,000
Year 19	138,000	266,000	7,200	18,000	36,000	-423,000	-63,000	24,000
Year 20	123,000	211,000	26,000	62,000	35,000	-406,000	-32,000	-6,700
Annual Average	108,000	230,000	9,000	31,000	33,000	-446,000	22,000	17,000

1. Assigned recharge. An average of approximately 3,500 AF of assigned recharge is rejected by model annually in areas with high water table.
2. An average of 3,200 AF of assigned pumping rejected by model annually in dry cells.
3. Positive numbers indicate net decrease in storage. Negative numbers indicate net increase in storage.

Table 9-17
No Action Water Budget
Cumulative Impacts

Month	Inflows[1]				Outflows		TDS					
	San Joaquin River[2] (af)	DMC[3] (af)	Farmers Water District[4] (af)	Mendota Pool[5] (af)	Diversions[2] (af)	Mendota Dam[2] (af)	San Joaquin River[2] (mg/L)	DMC[6] (mg/L)	Farmers Water District[7] (mg/L)	Mendota Pool[2] (mg/L)	Increase due to FWD (mg/L)	Mendota Dam[8] (mg/L)
January	7048	18910	0	4169	2263	27864	37	461	0	303	0	340
February	6348	49983	0	0	23625	32556	40	411	0	327	0	369
March	39252	46780	2094	1151	36997	52280	42	403	359	265	3	241
April	55546	45662	2172	31448	31827	103003	36	368	355	218	3	196
May	3507	69579	1981	39742	54907	59903	34	353	361	257	1	310
June	3244	102218	0	14741	76315	43886	33	309	0	268	0	296
July	2458	130618	0	0	92964	34380	32	244	0	242	0	240
August	3088	123623	0	0	83136	28058	27	268	0	264	0	262
September	3670	82080	2169	0	39952	37225	27	315	330	305	1	303
October	5623	66726	2190	0	28997	36266	26	312	332	310	1	291
November	10083	34868	0	0	12448	27092	26	344	0	293	0	273
December	6883	12518	0	0	3466	14618	28	410	0	280	0	275
Total	**146,749**	**783,565**	**10,606**	**91,251**	**486,899**	**497,129**						
Annual Mean							**32**	**350**	**347**	**278**	**1**	**283**

1. Total pumping for groundwater exchange: 21,052 AF. Total pumping for adjacent use: 11,648 AF.
2. Calculated from groundwater model from respective run.
3. Average monthly flow in the DMC at Check 21 from 1992 - 2011 (reflect Year 1 - Year 20 in the predictive scenarios). Years where no exchange pumping occurs excluded.
4. Proposed exchange pumping for Farmers Water District (Logoluso, Baker Farms, and Panoche Creek Farms).
5. Assigned to make up the deficit between the calculated inflows (San Joaquin River, DMC, and Farmers Water District) and outflows (canal diversions, flow over the Mendota Dam) which is met by flow from the Mendota Pool
6. Average monthly TDS in the DMC at Check 21 from 1992 - 2011 (reflect Year 1 to Year 20 in the predictive scenarios). Years where no exchange pumping occurs excluded.
7. Volume weighted TDS calculated from average TDS from each well from Year 1 to Year 20 and amount of proposed exchange pumping.
8. Calculated as the volume weighted average TDS of the inflows.

Month	Flow Contribution at MWA					TDS at DMC Check 21[5] (mg/L)	TDS Increase Due to				TDS in Southern Mendota Pool (mg/L)
	DMC[2] (af)	MPG Wells[1,3]		City of Mendota[4] (af)	Meyers Water Bank (af)		MPG Pumping		City of Mendota (mg/L)	Meyers Water Bank (mg/L)	
		Exchange Pumping (af)	Adjacent Pumping (af)				Exchange Pumping (mg/L)	Adjacent Pumping (mg/L)			
January	5,924	0	0	0	0	448	0	0	0	0	448
February	10,818	0	0	0	0	424	0	0	0	0	424
March	5,498	1,153	692	0	0	423	26	23	0	0	472
April	4,666	1,264	670	470	21	394	41	26	11	1	473
May	7,078	1,363	1,075	615	728	335	40	46	13	16	450
June	13,582	1,398	935	374	656	309	30	26	6	10	380
July	12,761	1,445	982	395	506	204	42	36	9	12	301
August	7,455	1,427	969	204	480	272	53	47	6	14	391
September	7,322	1,183	577	0	488	345	31	16	0	11	404
October	6,941	1,214	691	0	257	322	37	26	0	7	392
November	5,886	0	0	0	0	351	0	0	0	0	351
December	4,091	0	0	0	0	409	0	0	0	0	409
Total	**92,023**	**10,446**	**6,591**	**2,058**	**3,135**						
Annual Mean						**353**	**25**	**21**	**4**	**6**	**408**

1. Including non-MPG pumpage by Don Peracchi in Farmers Water District.
2. Calculated as the difference between the average net demand in the southern portion of the Fresno Slough and the inflow from MPG, Meyers Farm Water Bank wells, and City of Mendota wells along the Fresno Slough.
3. Inflow from MPG wells along the Fresno Slough. Values do not include Farmers Water District pumping (FWD, Baker, and Panoche wells).
4. Based on City's pumpage from Fordel wells in 2010.
5. Monthly average based on reported daily EC in the DMC in years with exchange pumping from 2004 - 2013.

Table 9-23
TDS Concentration at MWA – Proposed Action Cumulative Impacts

Month	Flow Contribution at MWA					TDS at DMC Check 21[5] (mg/L)	TDS Increase Due to				TDS in Southern Mendota Pool (mg/L)
	DMC[2] (af)	MPG Wells[1,3]		City of Mendota[4] (af)	Meyers Water Bank (af)		MPG Pumping		City of Mendota (mg/L)	Meyers Water Bank (mg/L)	
		Exchange Pumping (af)	Adjacent Pumping (af)				Exchange Pumping (mg/L)	Adjacent Pumping (mg/L)			
January	2,620	0	0	0	0	448	0	0	0	0	448
February	3,551	0	0	0	0	424	0	0	0	0	424
March	4,710	1,153	692	0	0	423	29	26	0	0	478
April	4,705	1,264	670	470	21	394	41	26	11	1	473
May	5,398	1,363	1,075	615	728	335	47	55	15	19	471
June	12,711	1,398	935	374	656	309	31	28	6	11	384
July	11,935	1,445	982	395	506	204	44	38	9	12	307
August	4,418	1,427	969	204	480	272	74	66	8	19	439
September	5,644	1,183	577	0	488	345	38	20	0	14	417
October	6,292	1,214	691	0	257	322	40	28	0	8	398
November	5,306	0	0	0	0	351	0	0	0	0	351
December	2,242	0	0	0	0	409	0	0	0	0	409
Total	**69,534**	**10,446**	**6,591**	**2,058**	**3,135**						
Annual Mean						**353**	**29**	**24**	**4**	**7**	**417**

1. Including non-MPG pumpage by Don Peracchi in Farmers Water District.
2. Calculated as the difference between the average net demand in the southern portion of the Fresno Slough and the inflow from MPG, Meyers Farm Water Bank wells, and City of Mendota wells along the Fresno Slough.
3. Inflow from MPG wells along the Fresno Slough. Values do not include Farmers Water District pumping (FWD, Baker, and Panoche wells).
4. Based on City's pumpage from Fordel wells in 2010.
5. Monthly average based on reported daily EC in the DMC in years with exchange pumping from 2004 - 2013.

Table 9-24
TDS Concentration at MWA – Proposed Action (Dry Year) Cumulative Impacts

Year	Stream and Canal Seepage (af)	Areal Recharge (af)[1]	Recharge Ponds (af)[1]	Net Lateral Inflow (af)	Lake Seepage (af)	Pumping (af)[2]	Storage (af)[3]	Interbed Storage (af)[3]
-	112,000	196,000	560	18,000	31,000	-519,000	117,000	46,000
-	111,000	214,000	500	-26,000	32,000	-512,000	128,000	53,000
Year 1	78,000	239,000	1,500	-48,000	35,000	-490,000	119,000	68,000
Year 2	119,000	263,000	12,000	15,000	35,000	-426,000	-37,000	22,000
Year 3	76,000	180,000	4,000	13,000	36,000	-473,000	128,000	38,000
Year 4	116,000	320,000	19,000	47,000	38,000	-401,000	-129,000	-2,300
Year 5	104,000	306,000	16,000	61,000	32,000	-374,000	-132,000	-7,400
Year 6	103,000	246,000	19,000	64,000	33,000	-499,000	36,000	5,100
Year 7	101,000	302,000	32,000	52,000	30,000	-350,000	-141,000	-9,400
Year 8	100,000	188,000	6,000	47,000	29,000	-462,000	88,000	6,900
Year 9	101,000	236,000	6,000	46,000	31,000	-419,000	-1,900	3,200
Year 10	104,000	237,000	3,500	50,000	33,000	-478,000	46,000	8,700
Year 11	110,000	198,000	4,000	43,000	34,000	-510,000	107,000	15,000
Year 12	116,000	183,000	7,500	50,000	35,000	-458,000	61,000	7,400
Year 13	115,000	226,000	4,000	60,000	35,000	-482,000	29,000	15,000
Year 14	114,000	226,000	9,400	26,000	34,000	-413,000	2,300	6,200
Year 15	113,000	223,000	11,000	36,000	34,000	-357,000	-53,000	-770
Year 16	80,000	166,000	4,500	12,000	35,000	-508,000	180,000	33,000
Year 17	133,000	177,000	4,700	20,000	36,000	-540,000	121,000	51,000
Year 18	136,000	169,000	4,300	-5,200	37,000	-540,000	132,000	69,000
Year 19	140,000	262,000	7,300	22,000	37,000	-433,000	-57,000	25,000
Year 20	123,000	210,000	27,000	65,000	35,000	-391,000	-48,000	-7,500
Annual Average	109,000	228,000	10,000	34,000	34,000	-450,000	23,000	17,000

1. Assigned recharge. An average of approximately 4,200 AF of assigned recharge is rejected by model annually in areas with high water table.
2. An average of 3,200 AF of assigned pumping rejected by model annually in dry cells.
3. Positive numbers indicate net decrease in storage. Negative numbers indicate net increase in storage.

Table 9-25
Proposed Action Water Budget
Cumulative Impacts

	Inflows[1]				Outflows		TDS					
Month	San Joaquin River[2] (af)	DMC[3] (af)	Farmers Water District[4] (af)	Mendota Pool[5] (af)	Diversions[2] (af)	Mendota Dam[2] (af)	San Joaquin River[2] (mg/L)	DMC[6] (mg/L)	Farmers Water District[7] (mg/L)	Mendota Pool[2] (mg/L)	Increase due to FWD (mg/L)	Mendota Dam[8] (mg/L)
January	7054	18910	0	4196	2263	27896	37	461	0	303	0	340
February	6352	49983	0	0	23626	32586	40	411	0	327	0	369
March	39261	46780	2094	1179	36997	52317	42	403	360	265	3	241
April	55555	45662	2172	31472	31827	103030	36	368	356	218	3	196
May	3512	69579	1981	39763	54907	59928	34	353	362	257	1	310
June	3249	102218	0	14762	76315	43911	33	309	0	268	0	296
July	2462	130618	0	0	92964	34404	32	244	0	242	0	240
August	3092	123623	0	0	83136	28084	28	268	0	264	0	262
September	3675	82080	2169	0	39952	37250	27	315	331	305	1	303
October	5630	66726	2190	0	28997	36293	26	312	333	310	1	291
November	10092	34868	0	0	12448	27121	26	344	0	293	0	273
December	6891	12518	0	0	3466	14650	28	410	0	280	0	275
Total	**146,825**	**783,565**	**10,606**	**91,372**	**486,900**	**497,471**						
Annual Mean							**32**	**350**	**348**	**278**	**1**	**283**

1. Total pumping for groundwater exchange: 21,052 AF. Total pumping for adjacent use: 11,648 AF.
2. Calculated from groundwater model from respective run.
3. Average monthly flow in the DMC at Check 21 from 1992 - 2011 (reflect Year 1 - Year 20 in the predictive scenarios). Years where no exchange pumping occurs excluded.
4. Proposed exchange pumping for Farmers Water District (Logoluso, Baker Farms, and Panoche Creek Farms).
5. Assigned to make up the deficit between the calculated inflows (San Joaquin River, DMC, and Farmers Water District) and outflows (canal diversions, flow over the Mendota Dam) which is met by flow from the Mendota Pool
6. Average monthly TDS in the DMC at Check 21 from 1992 - 2011 (reflect Year 1 to Year 20 in the predictive scenarios). Years where no exchange pumping occurs excluded.
7. Volume weighted TDS calculated from average TDS from each well from Year 1 to Year 20 and amount of proposed exchange pumping.
8. Calculated as the volume weighted average TDS of the inflows.

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Table 9-26
TDS at the Mendota Dam – Alternative 2
Cumulative Impacts

	Flow Contribution at MWA						TDS Increase Due to				
		MPG Wells[1,3]					MPG Pumping				
Month	DMC[2] (af)	Exchange Pumping (af)	Adjacent Pumping (af)	City of Mendota[4] (af)	Meyers Water Bank (af)	TDS at DMC Check 21[5] (mg/L)	Exchange Pumping (mg/L)	Adjacent Pumping (mg/L)	City of Mendota (mg/L)	Meyers Water Bank (mg/L)	TDS in Southern Mendota Pool (mg/L)
January	5,924	0	0	0	0	448	0	0	0	0	448
February	10,818	0	0	0	0	424	0	0	0	0	424
March	5,498	1,153	692	0	0	423	27	21	0	0	472
April	4,666	1,264	670	470	21	394	43	24	12	1	473
May	7,078	1,363	1,075	615	728	335	41	42	13	16	447
June	13,582	1,398	935	374	656	309	30	24	6	10	378
July	12,761	1,445	982	395	506	204	42	33	9	12	299
August	7,455	1,427	969	204	480	272	53	43	6	14	388
September	7,322	1,183	577	0	488	345	32	15	0	12	404
October	6,941	1,214	691	0	257	322	38	25	0	7	392
November	5,886	0	0	0	0	351	0	0	0	0	351
December	4,091	0	0	0	0	409	0	0	0	0	409
Total	**92,023**	**10,446**	**6,591**	**2,058**	**3,135**						
Annual Mean						**353**	**25**	**19**	**4**	**6**	**407**

1. Including non-MPG pumpage by Don Peracchi in Farmers Water District.
2. Calculated as the difference between the average net demand in the southern portion of the Fresno Slough and the inflow from MPG, Meyers Farm Water Bank wells, and City of Mendota wells along the Fresno Slough.
3. Inflow from MPG wells along the Fresno Slough. Values do not include Farmers Water District pumping (FWD, Baker, and Panoche wells).
4. Based on City's pumpage from Fordel wells in 2010.
5. Monthly average based on reported daily EC in the DMC in years with exchange pumping from 2004 - 2013.

Table 9-27
TDS Concentration at MWA – Alternative 2
Cumulative Impacts

	Flow Contribution at MWA						TDS Increase Due to				
		MPG Wells[1,3]					MPG Pumping				
Month	DMC[2] (af)	Exchange Pumping (af)	Adjacent Pumping (af)	City of Mendota[4] (af)	Meyers Water Bank (af)	TDS at DMC Check 21[5] (mg/L)	Exchange Pumping (mg/L)	Adjacent Pumping (mg/L)	City of Mendota (mg/L)	Meyers Water Bank (mg/L)	TDS in Southern Mendota Pool (mg/L)
January	2,620	0	0	0	0	448	0	0	0	0	448
February	3,551	0	0	0	0	424	0	0	0	0	424
March	4,710	1,153	692	0	0	423	30	24	0	0	478
April	4,705	1,264	670	470	21	394	42	24	12	1	473
May	5,398	1,363	1,075	615	728	335	48	50	16	19	467
June	12,711	1,398	935	374	656	309	32	25	6	11	382
July	11,935	1,445	982	395	506	204	44	35	10	12	304
August	4,418	1,427	969	204	480	272	75	61	8	19	434
September	5,644	1,183	577	0	488	345	39	18	0	14	416
October	6,292	1,214	691	0	257	322	41	27	0	8	397
November	5,306	0	0	0	0	351	0	0	0	0	351
December	2,242	0	0	0	0	409	0	0	0	0	409
Total	**69,534**	**10,446**	**6,591**	**2,058**	**3,135**						
Annual Mean						**353**	**29**	**22**	**4**	**7**	**415**

1. Including non-MPG pumpage by Don Peracchi in Farmers Water District.
2. Calculated as the difference between the average net demand in the southern portion of the Fresno Slough and the inflow from MPG, Meyers Farm Water Bank wells, and City of Mendota wells along the Fresno Slough.
3. Inflow from MPG wells along the Fresno Slough. Values do not include Farmers Water District pumping (FWD, Baker, and Panoche wells).
4. Based on City's pumpage from Fordel wells in 2010.
5. Monthly average based on reported daily EC in the DMC in years with exchange pumping from 2004 - 2013.

Table 9-28
TDS Concentration at MWA – Alternative 2 (Dry Year)
Cumulative Impacts

Year	Stream and Canal Seepage (af)	Areal Recharge (af)[1]	Recharge Ponds (af)[1]	Net Lateral Inflow (af)	Lake Seepage (af)	Pumping (af)[2]	Storage (af)[3]	Interbed Storage (af)[3]
-	112,000	196,000	560	18,000	31,000	-519,000	117,000	46,000
-	111,000	214,000	500	-26,000	32,000	-512,000	128,000	53,000
Year 1	78,000	239,000	1,500	-48,000	35,000	-490,000	119,000	68,000
Year 2	119,000	263,000	12,000	15,000	35,000	-426,000	-37,000	22,000
Year 3	76,000	180,000	4,000	13,000	36,000	-473,000	128,000	38,000
Year 4	116,000	320,000	23,000	47,000	37,000	-401,000	-132,000	-2,300
Year 5	104,000	306,000	18,000	61,000	32,000	-374,000	-133,000	-7,500
Year 6	102,000	246,000	21,000	64,000	32,000	-499,000	36,000	5,000
Year 7	101,000	302,000	35,000	51,000	29,000	-350,000	-142,000	-9,400
Year 8	99,000	188,000	6,000	46,000	29,000	-462,000	89,000	6,900
Year 9	101,000	236,000	6,000	46,000	31,000	-419,000	-980	3,200
Year 10	103,000	237,000	3,500	49,000	33,000	-478,000	47,000	8,600
Year 11	110,000	198,000	4,000	43,000	34,000	-510,000	108,000	15,000
Year 12	116,000	183,000	7,500	49,000	35,000	-458,000	61,000	7,400
Year 13	115,000	226,000	4,000	60,000	35,000	-482,000	29,000	15,000
Year 14	113,000	226,000	12,000	26,000	34,000	-413,000	70	6,100
Year 15	113,000	223,000	13,000	36,000	34,000	-357,000	-54,000	-800
Year 16	80,000	166,000	4,500	11,000	34,000	-508,000	181,000	33,000
Year 17	133,000	177,000	4,700	19,000	36,000	-540,000	122,000	51,000
Year 18	135,000	169,000	4,300	-5,500	37,000	-540,000	132,000	69,000
Year 19	140,000	262,000	7,800	22,000	37,000	-433,000	-57,000	25,000
Year 20	123,000	210,000	29,000	65,000	35,000	-391,000	-50,000	-7,500
Annual Average	109,000	228,000	11,000	33,000	34,000	-450,000	22,000	17,000

1. Assigned recharge. An average of approximately 4,200 AF of assigned recharge is rejected by model annually in areas with high water table.
2. An average of 3,200 AF of assigned pumping rejected by model annually in dry cells.
3. Positive numbers indicate net decrease in storage. Negative numbers indicate net increase in storage.

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Table 9-29
Alternative 2 Water Budget
Cumulative Impacts

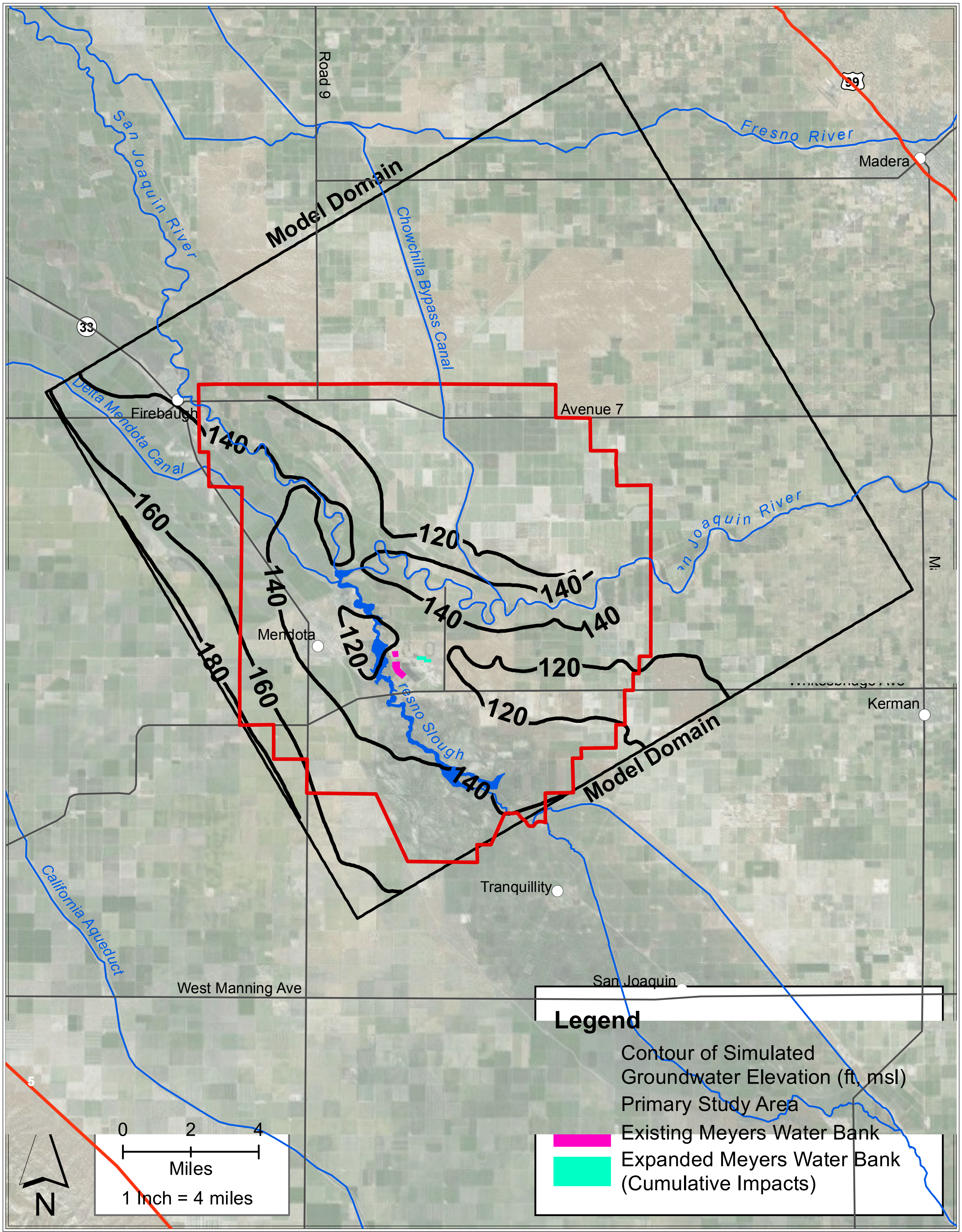

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Figure 9-1
No Action Contours of Equal Simulated Groundwater Elevation Shallow Zone, Year 20 (Cumulative Impacts)

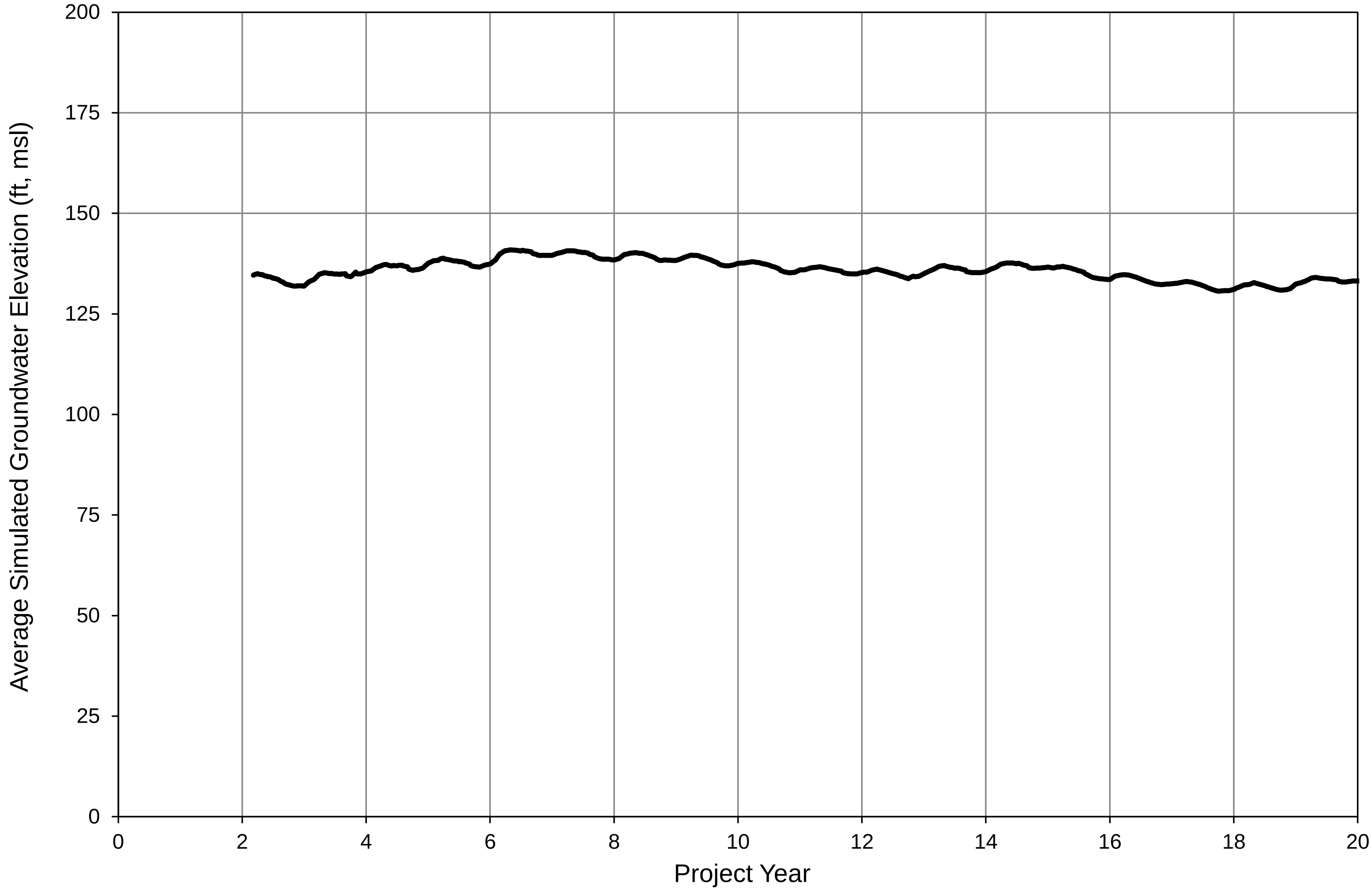

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Figure 9-2
No Action Average Simulated Groundwater Elevation
In the Primary Study Area, Shallow Zone (Cumulative Impacts)
Mendota Pool Group EIS/EIR

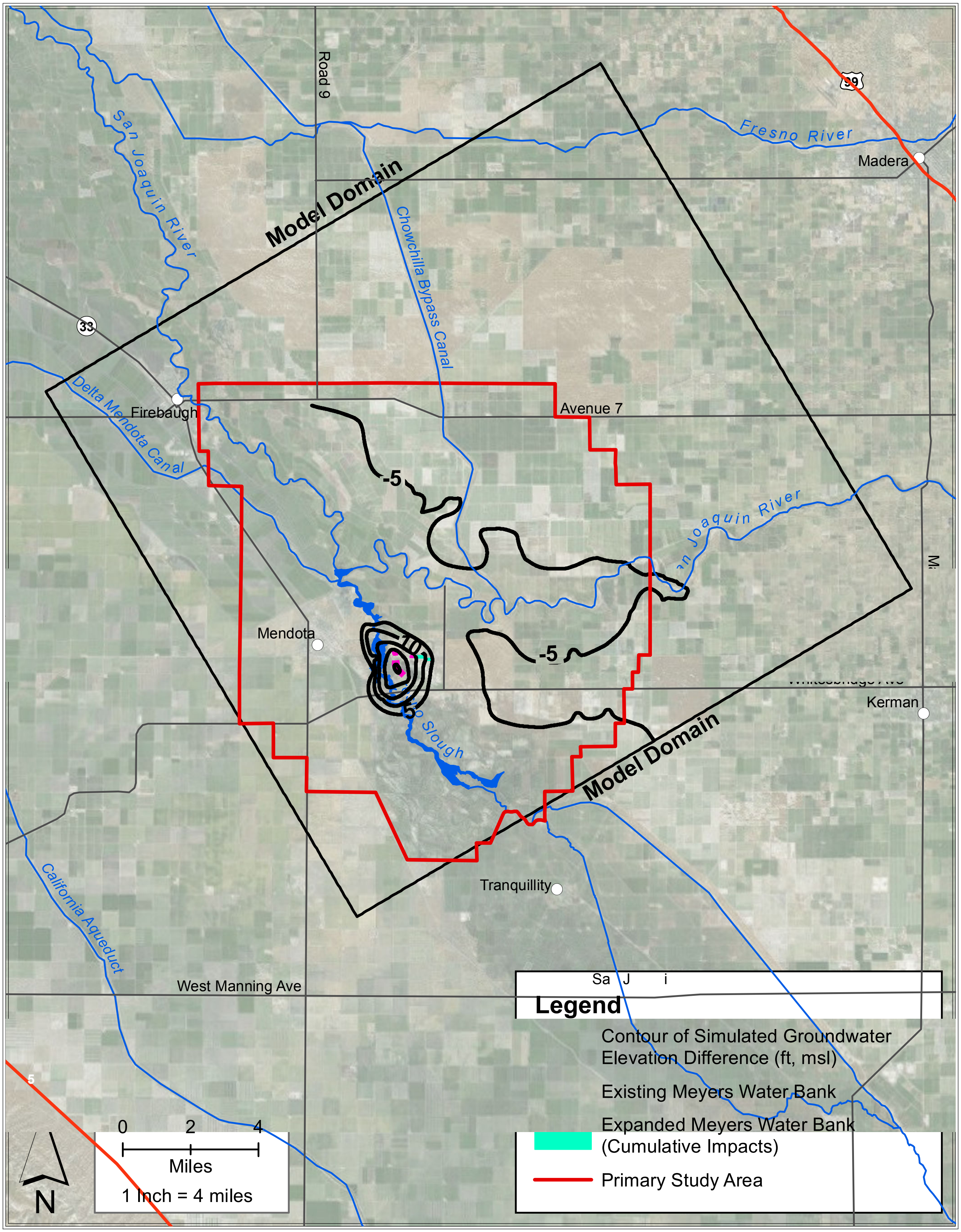

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Figure 9-3
No Action Contours of Equal Simulated Change in Groundwater Elevation Shallow Zone, Year 1 to Year 20 (Cumulative Impacts)

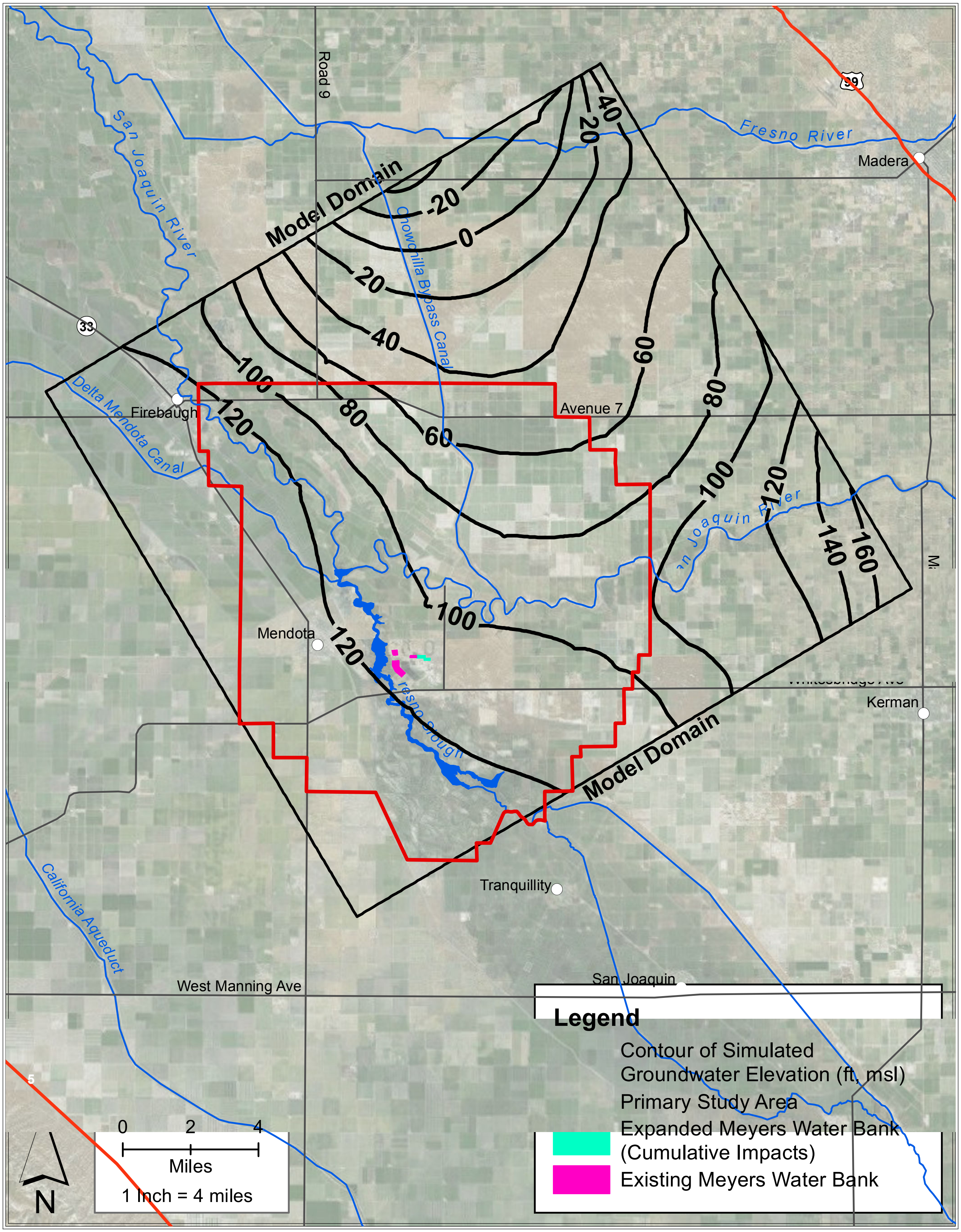

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Figure 9-4
No Action Contours of Equal Simulated Groundwater Elevation Deep Zone, Year 20 (Cumulative Impacts)

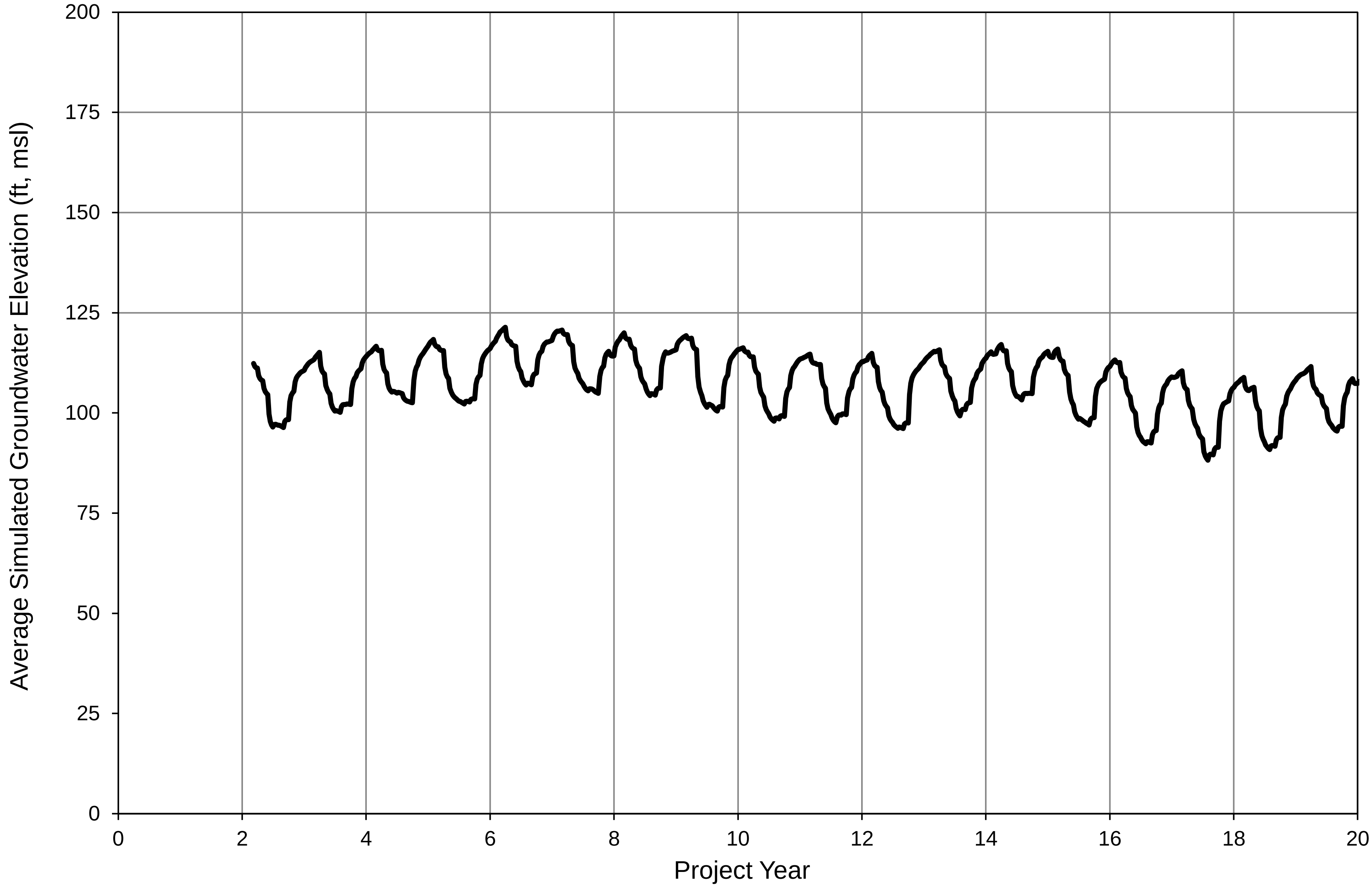

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Figure 9-5
No Action Average Simulated Groundwater Elevation
In the Primary Study Area, Deep Zone (Cumulative Impacts)
Mendota Pool Group EIS/EIR

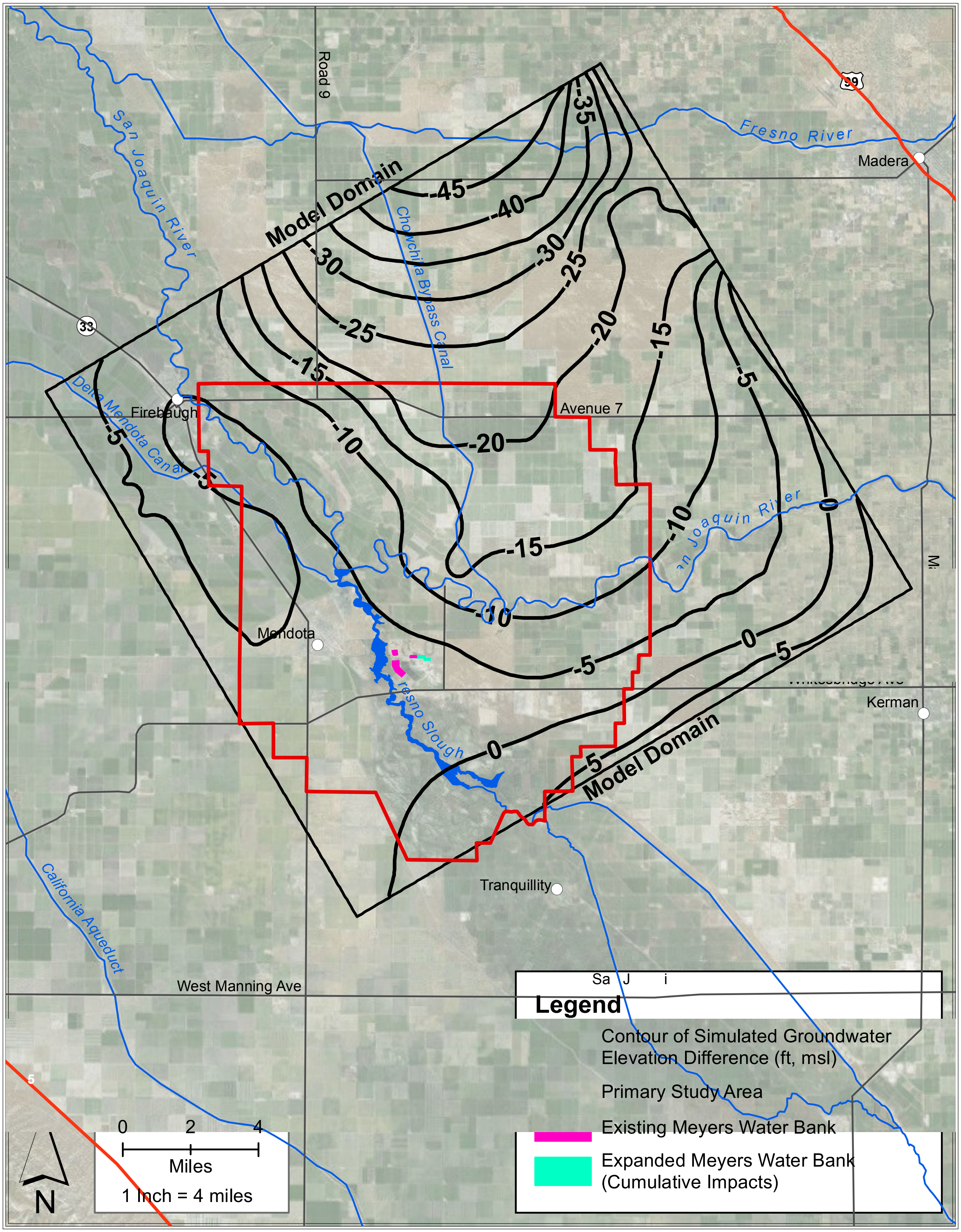

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Figure 9-6
No Action Contours of Equal Simulated Change in Groundwater Elevation Deep Zone, Year 1 to Year 20 (Cumulative Impacts)

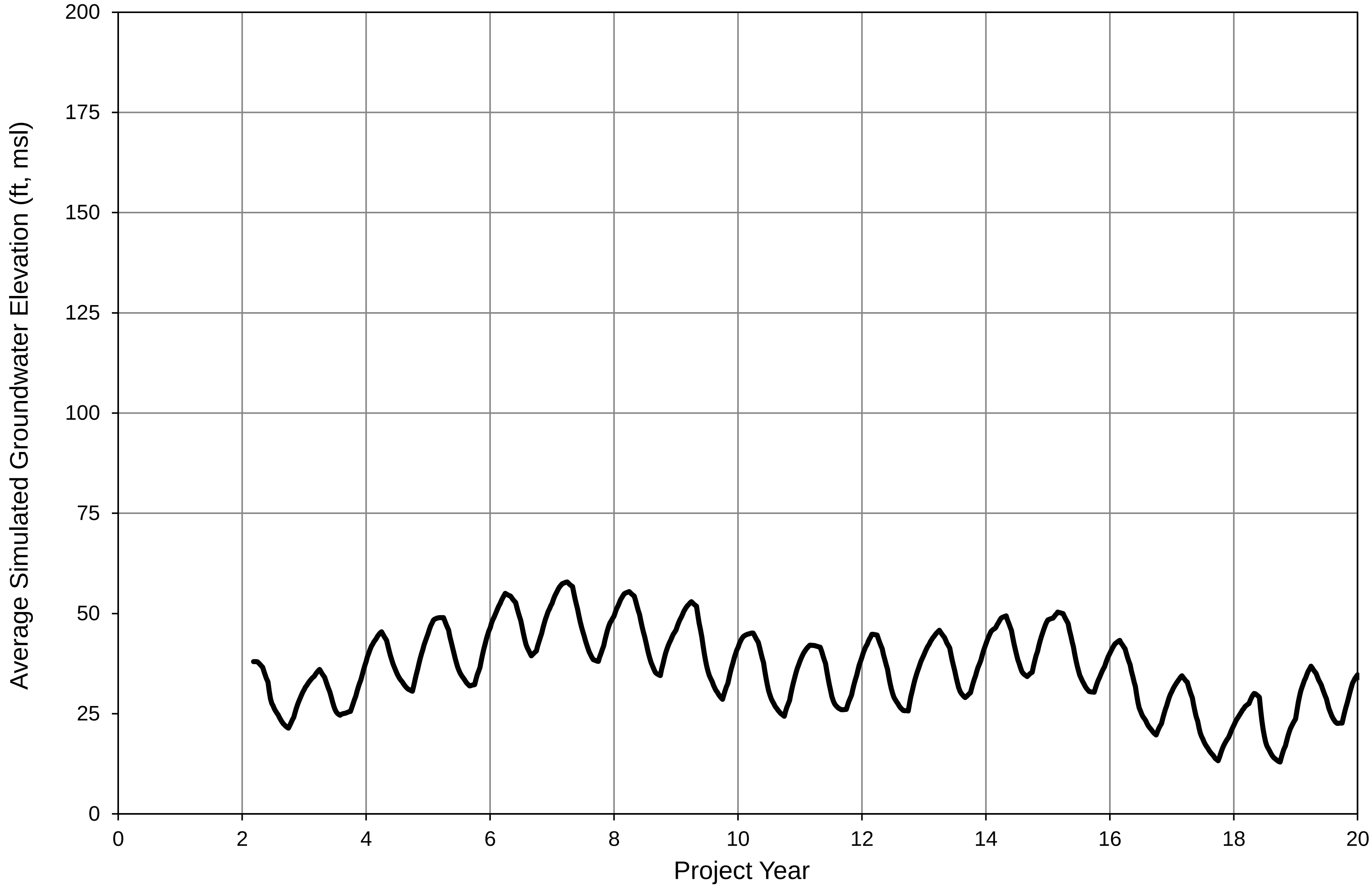

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Figure 9-7
No Action Average Simulated Groundwater Elevation
In the Primary Study Area, Lower Aquifer (Cumulative Impacts)
Mendota Pool Group EIS/EIR

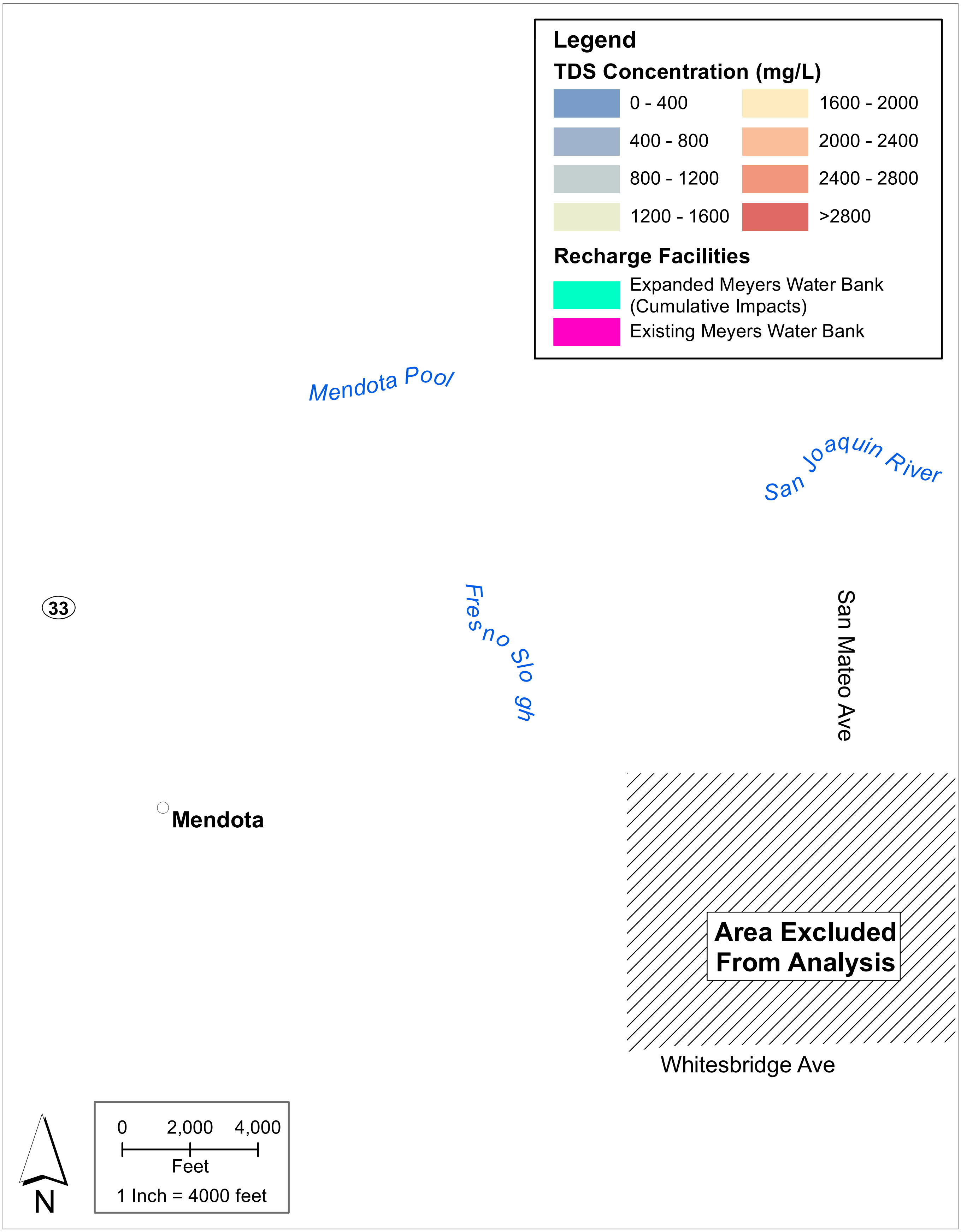

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Figure 9-8
No Action Simulated
TDS Concentration
Shallow Zone, Year 20 (Cumulative Impacts)

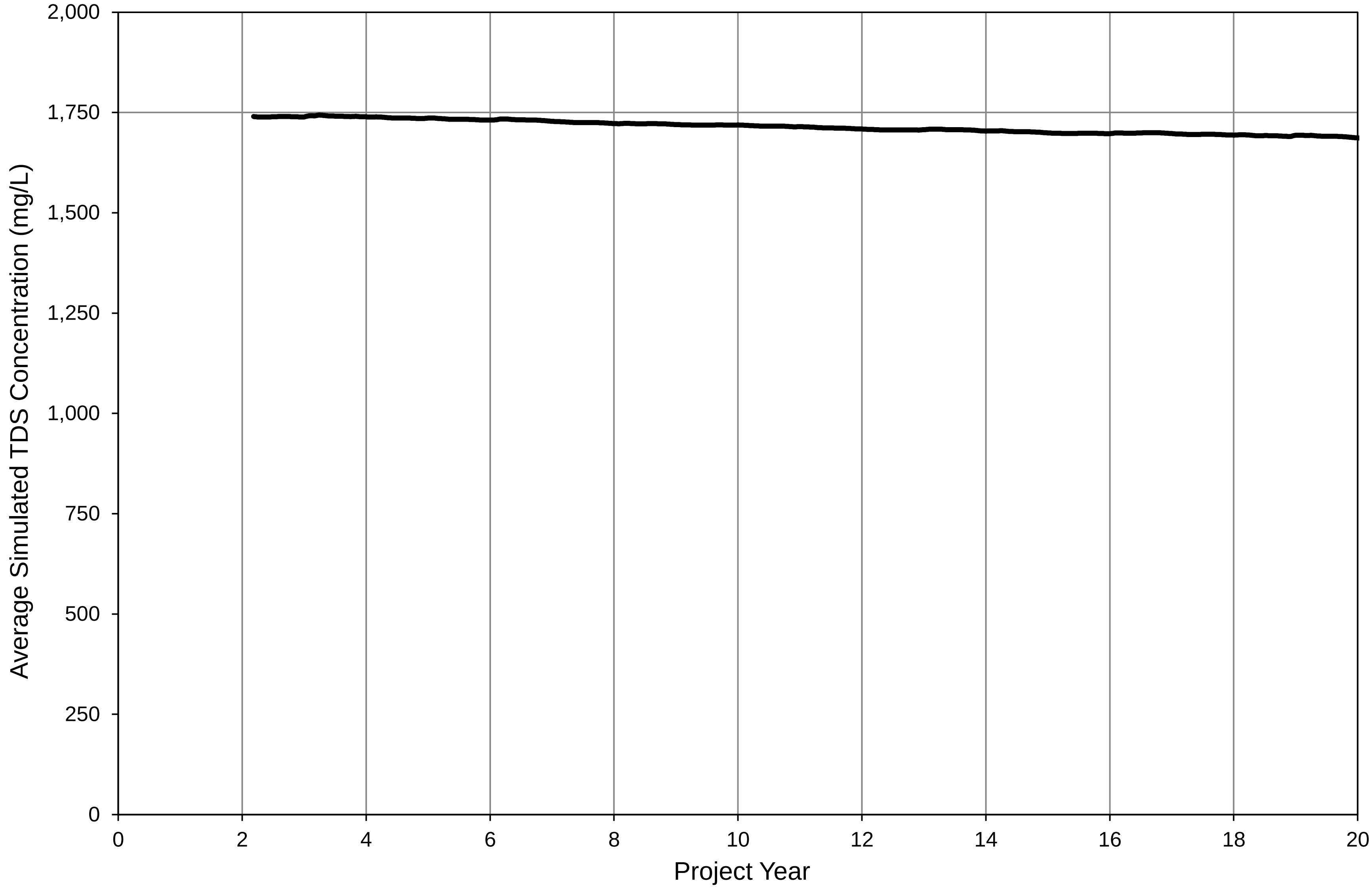

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Figure 9-9
No Action Average Simulated TDS Concentration
In the Primary Study Area, Shallow Zone (Cumulative Impacts)
Mendota Pool Group EIS/EIR

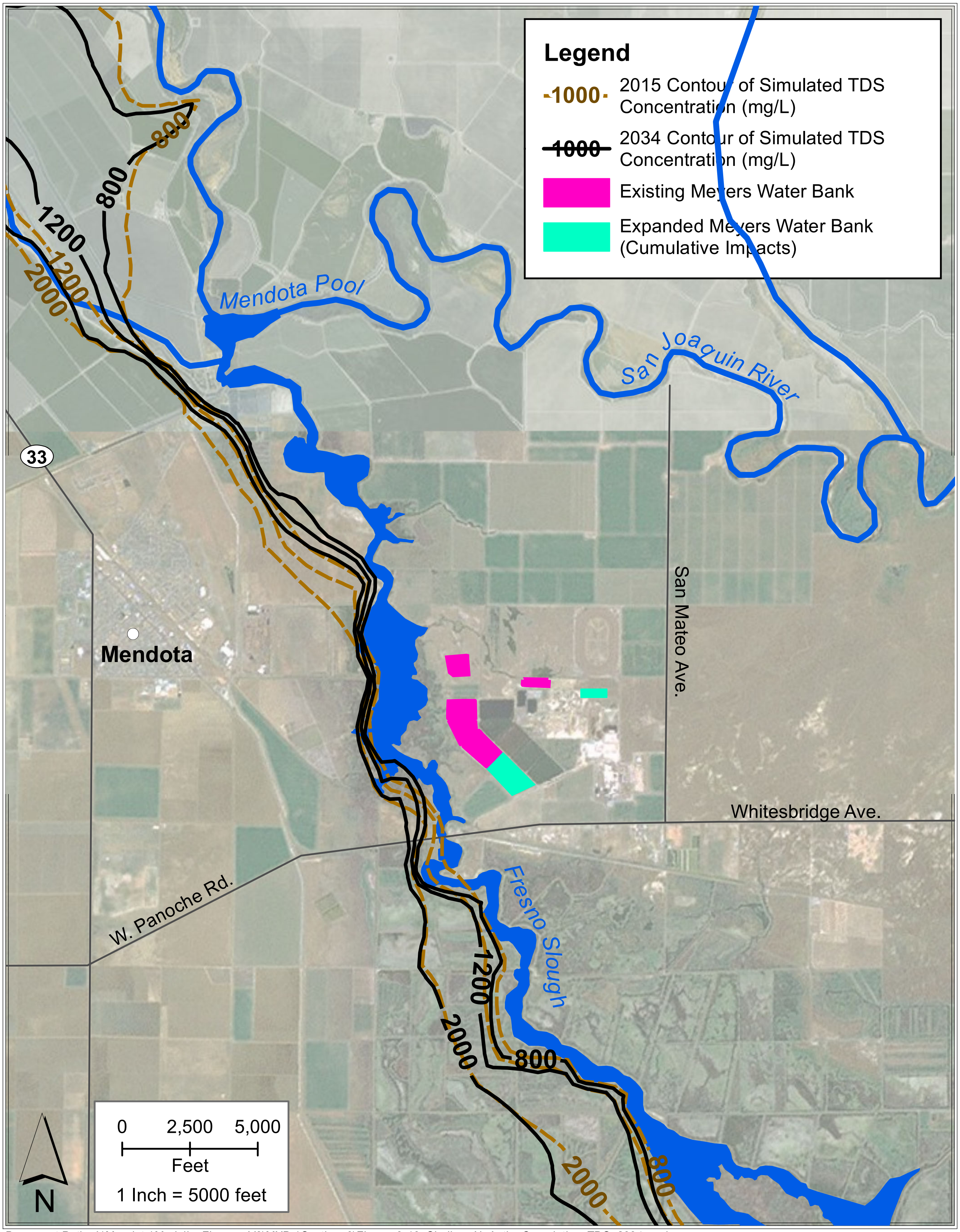

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Figure 9-10
No Action Contours of Equal Simulated TDS Concentration Shallow Zone, Year 20 (Cumulative Impacts)

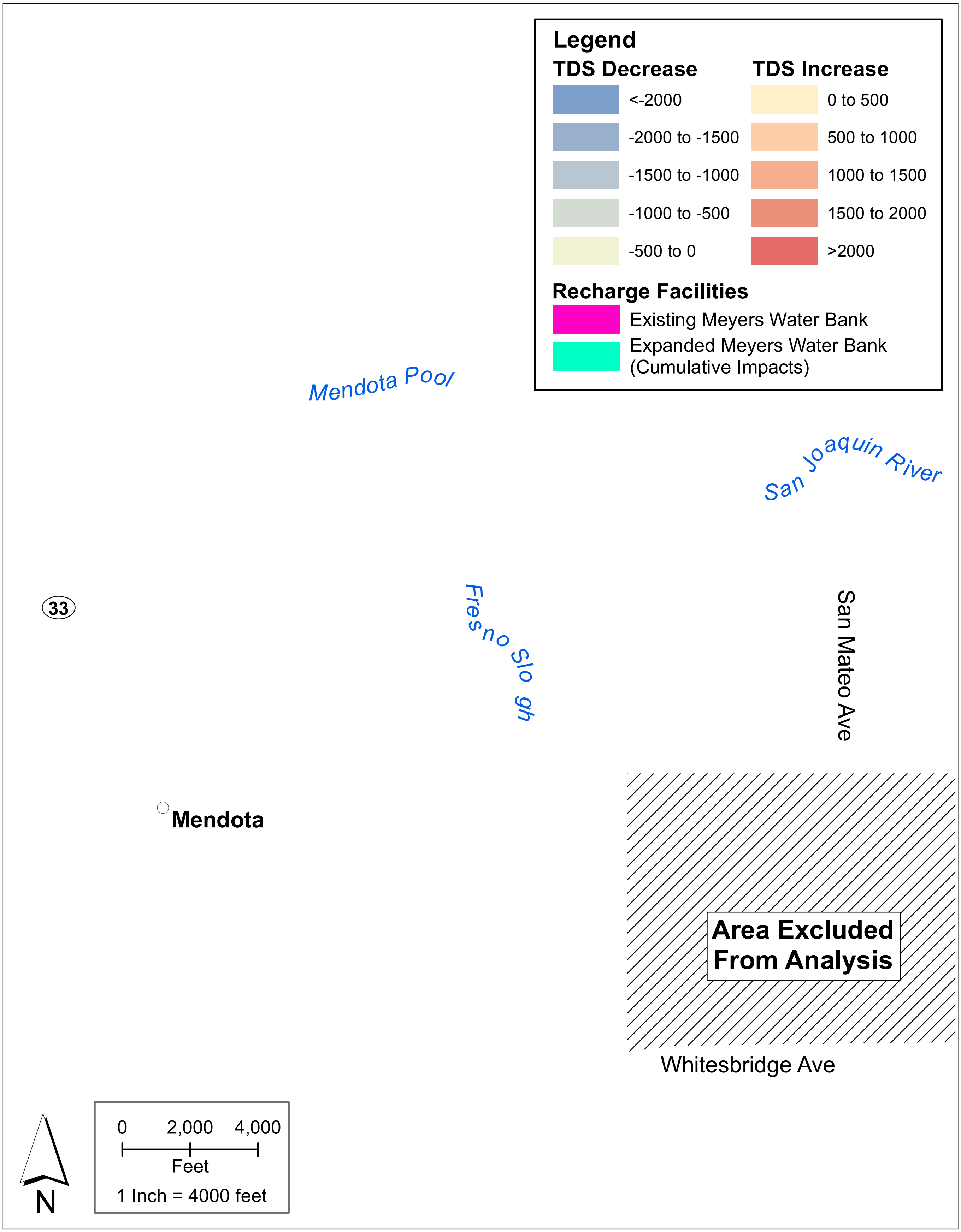

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Figure 9-11
No Action Simulated Change in TDS Concentration from Year 1 to Year 20 Shallow Zone (Cumulative Impacts)

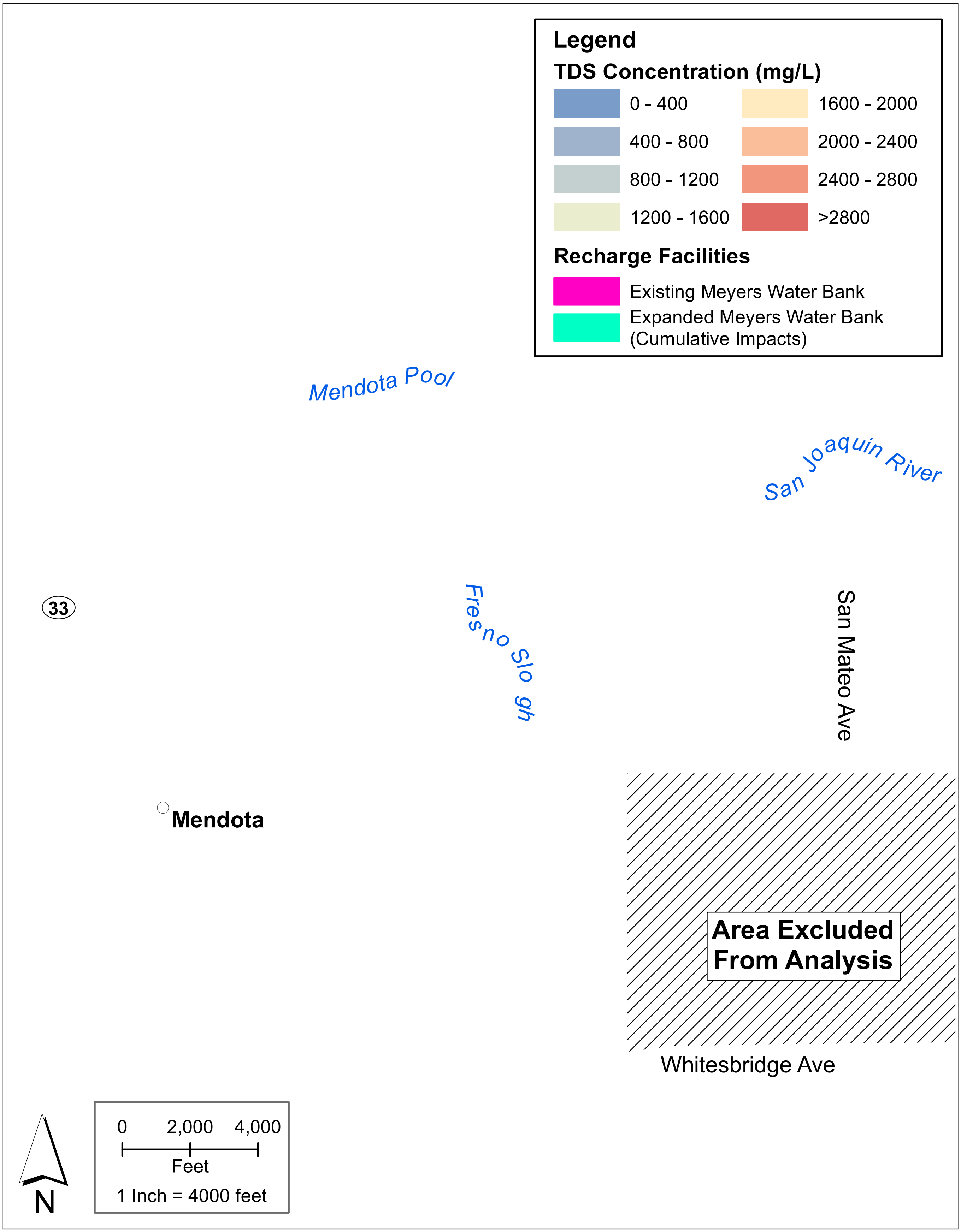

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Figure 9-12
No Action Simulated
TDS Concentration
Deep Zone, Year 20 (Cumulative Impacts)

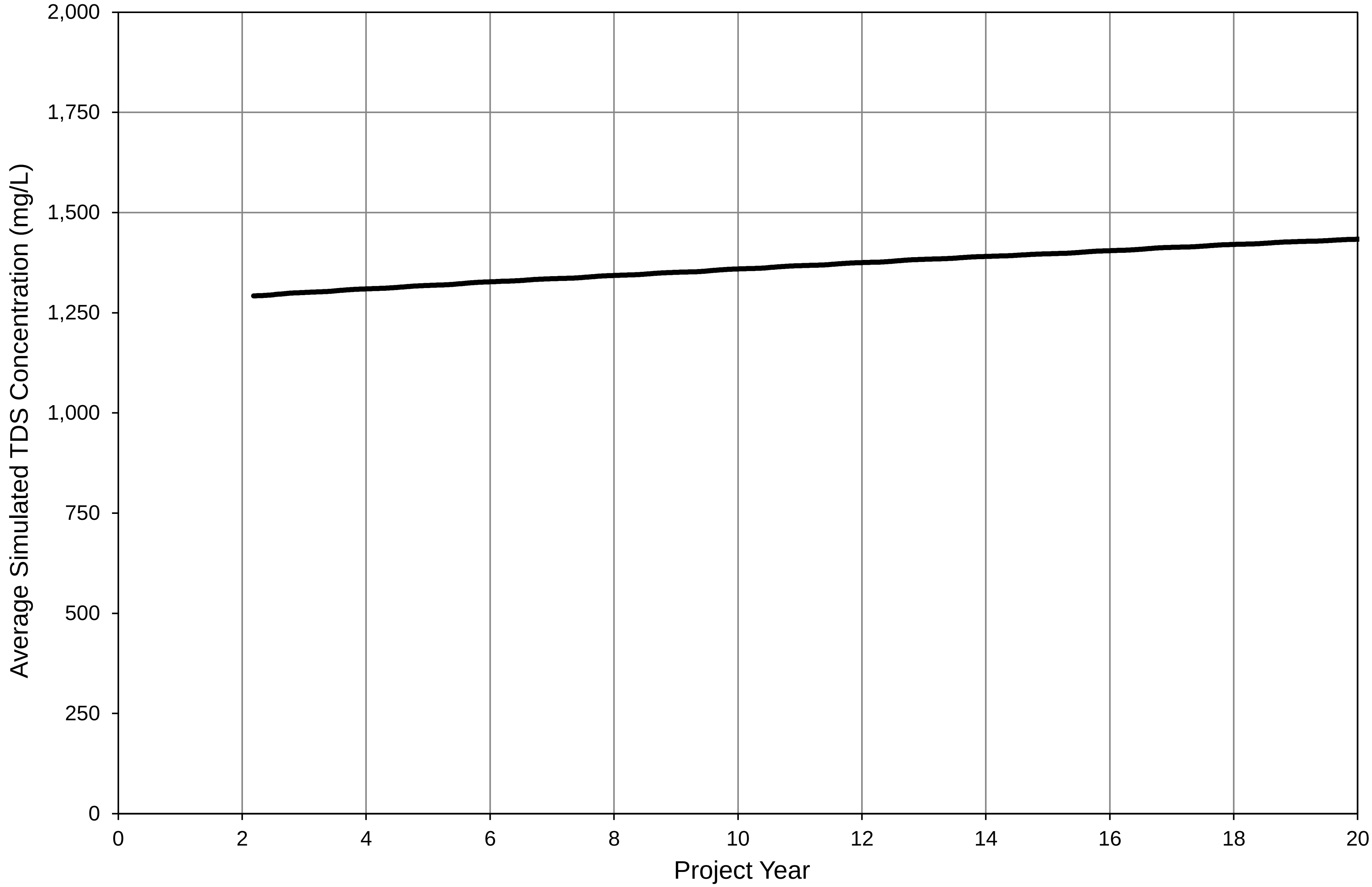

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Figure 9-13
No Action Average Simulated TDS Concentration
In the Primary Study Area, Deep Zone (Cumulative Impacts)
Mendota Pool Group EIS/EIR

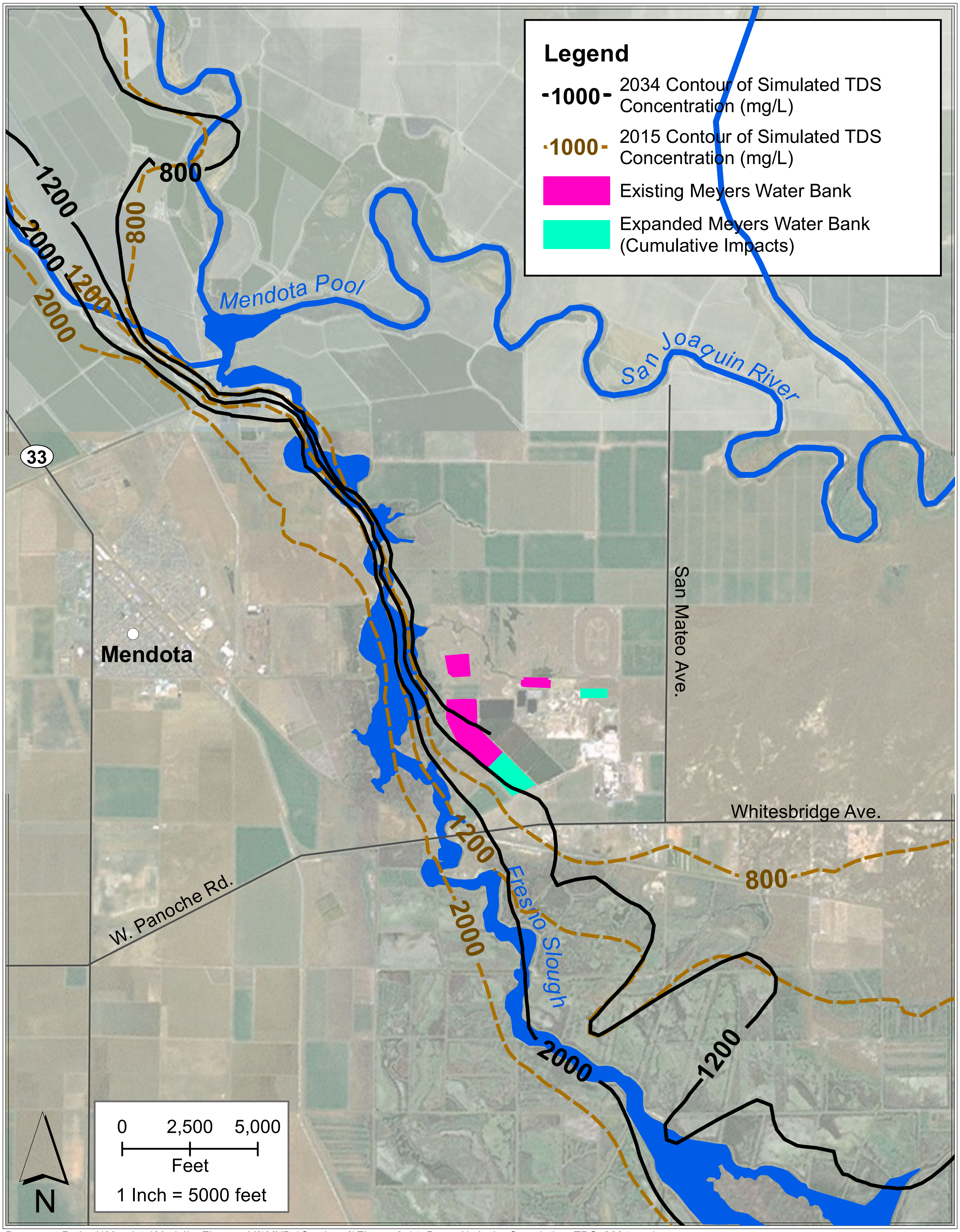

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Figure 9-14
No Action Contours of Equal Simulated TDS Concentration Deep Zone, Year 20 (Cumulative Impacts)

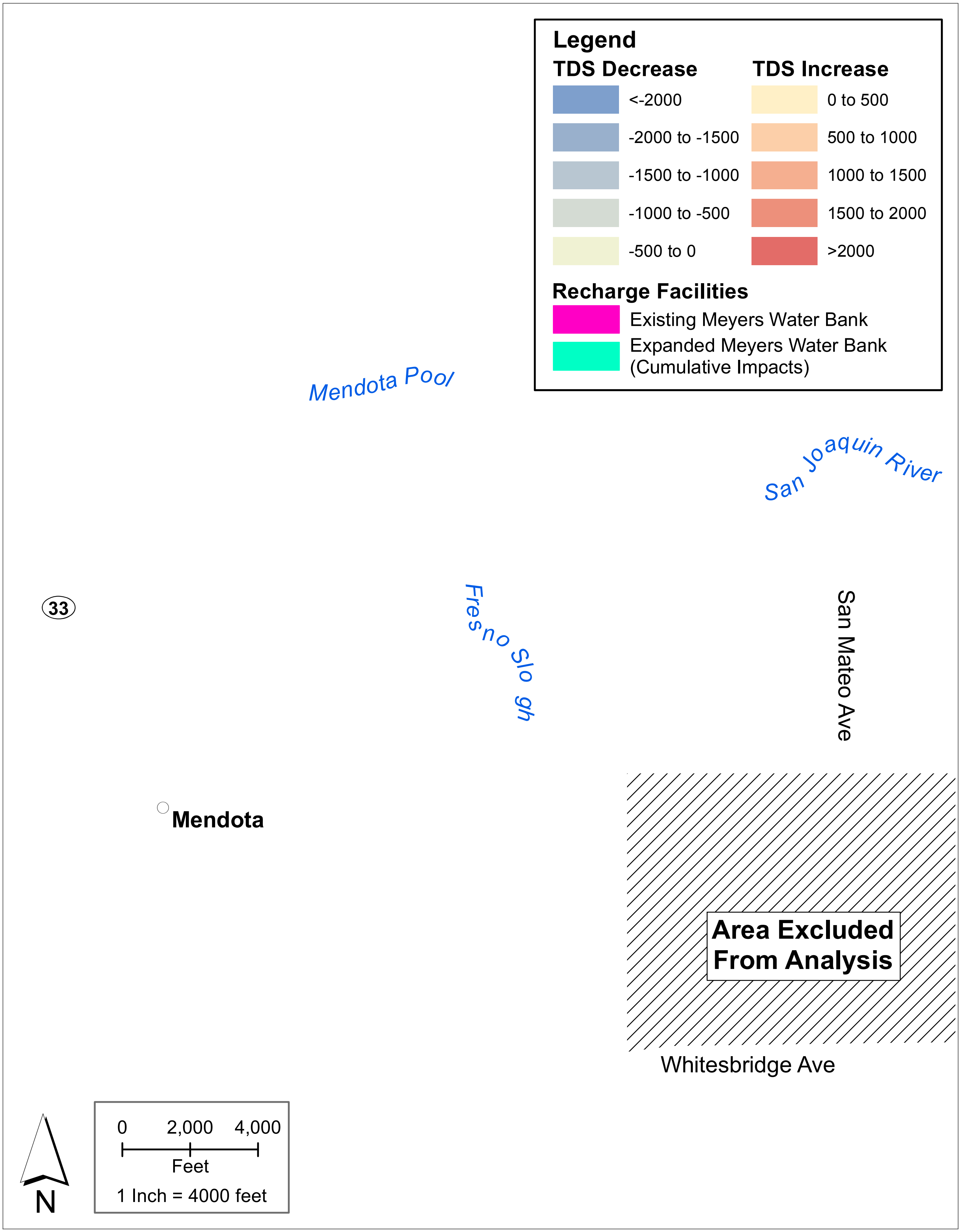

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Figure 9-15
No Action Simulated Change in TDS Concentration from Year 1 to Year 20 Deep Zone (Cumulative Impacts)

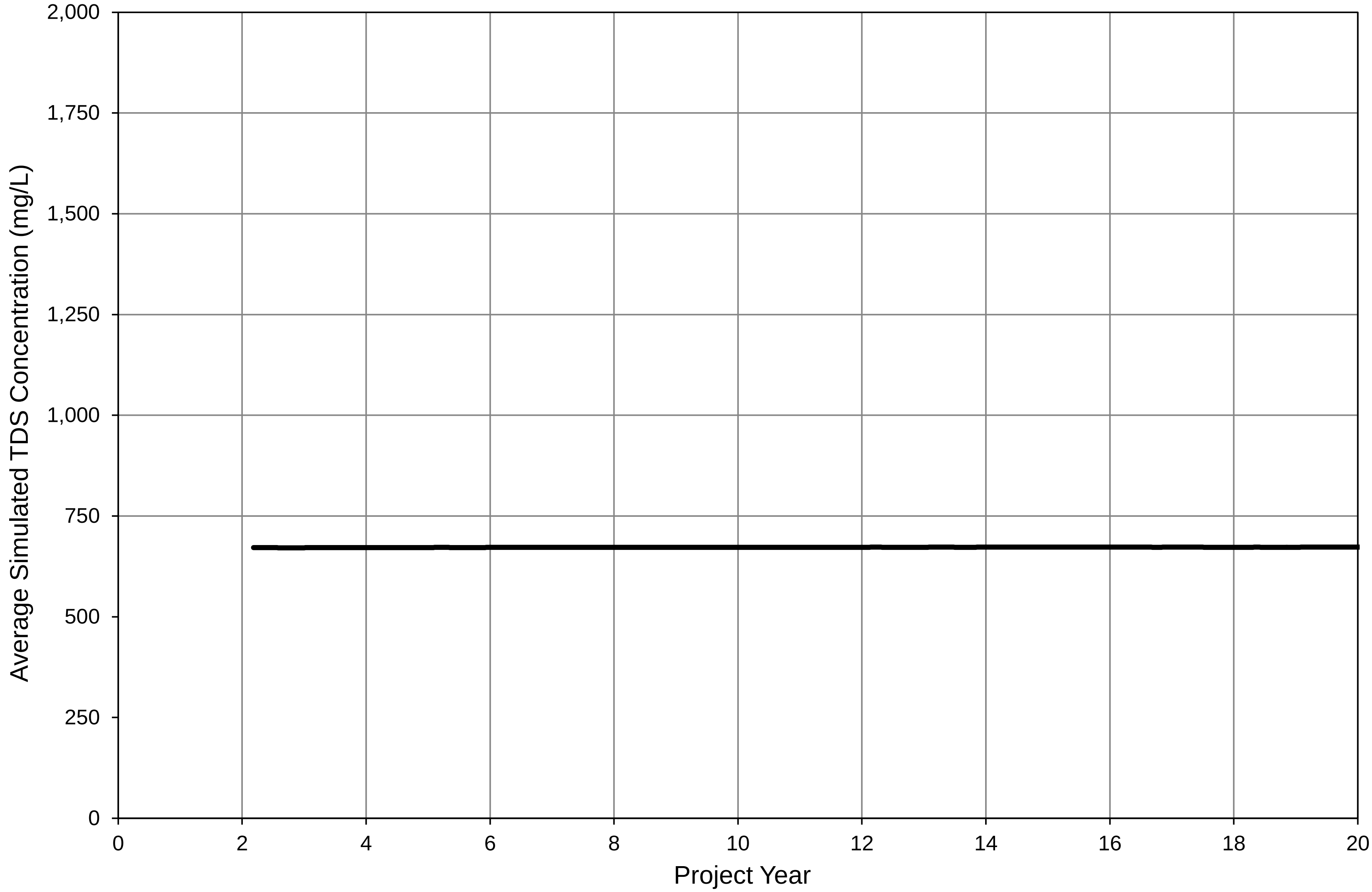

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Figure 9-16
No Action Average Simulated TDS Concentration
In the Primary Study Area, Lower Aquifer (Cumulative Impacts
Mendota Pool Group EIS/EIR

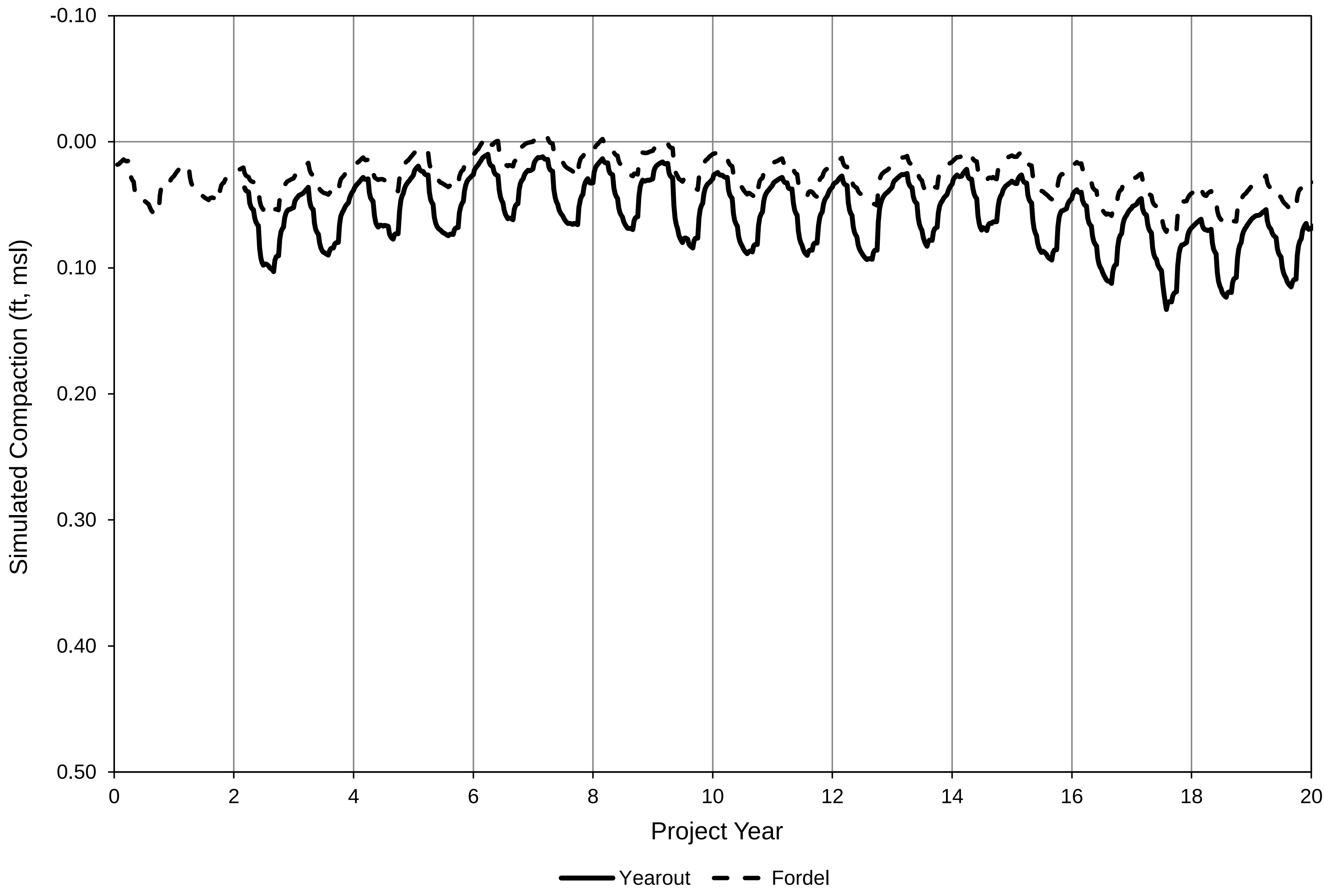

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Figure 9-17
No Action Simulated Compaction Above the Corcoran Clay (Cumulative Impacts)
Mendota Pool Group EIS/EIR

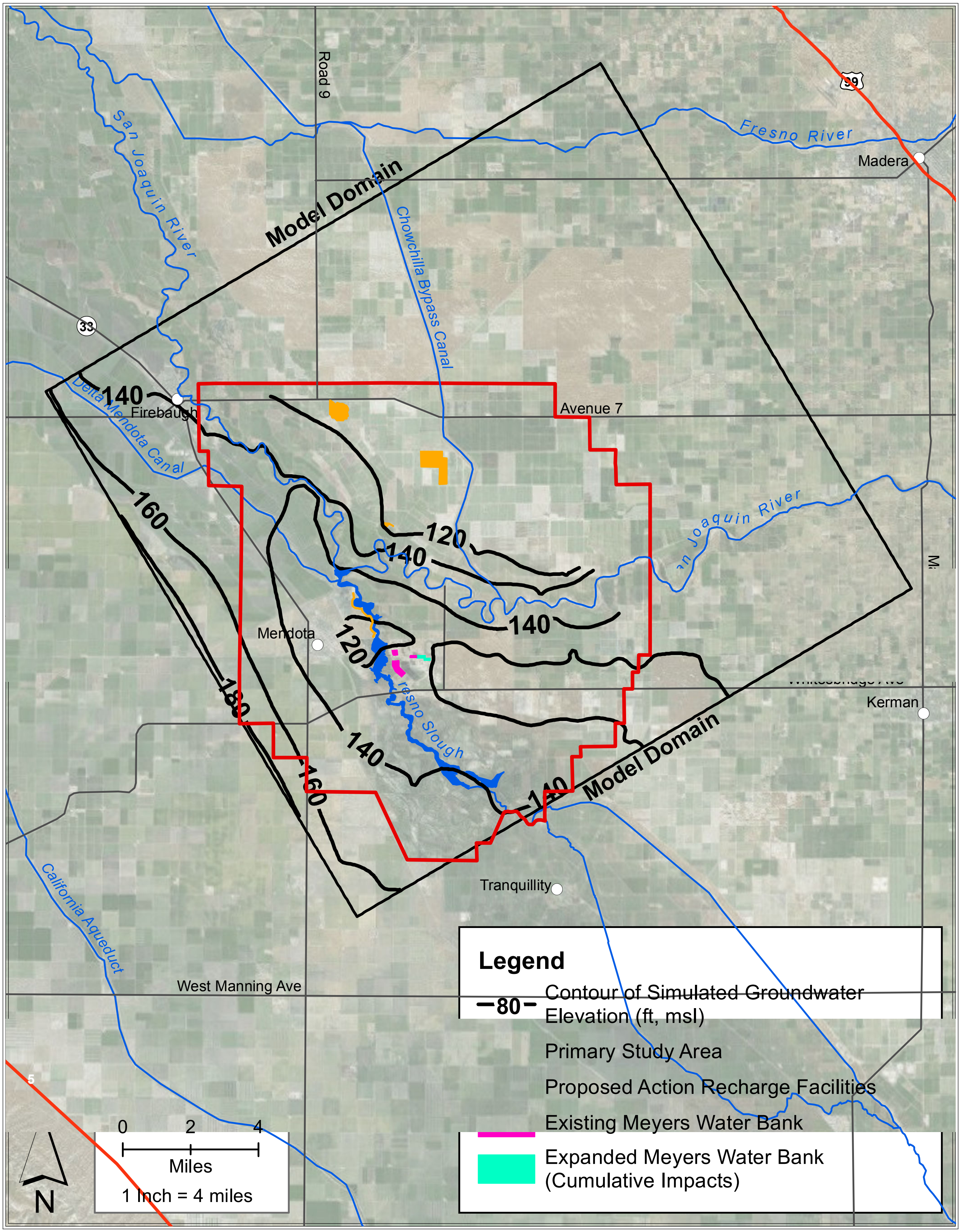

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Figure 9-18
Proposed Action Contours of Equal Simulated Groundwater Elevation Shallow Zone, Year 20 (Cumulative Impacts)

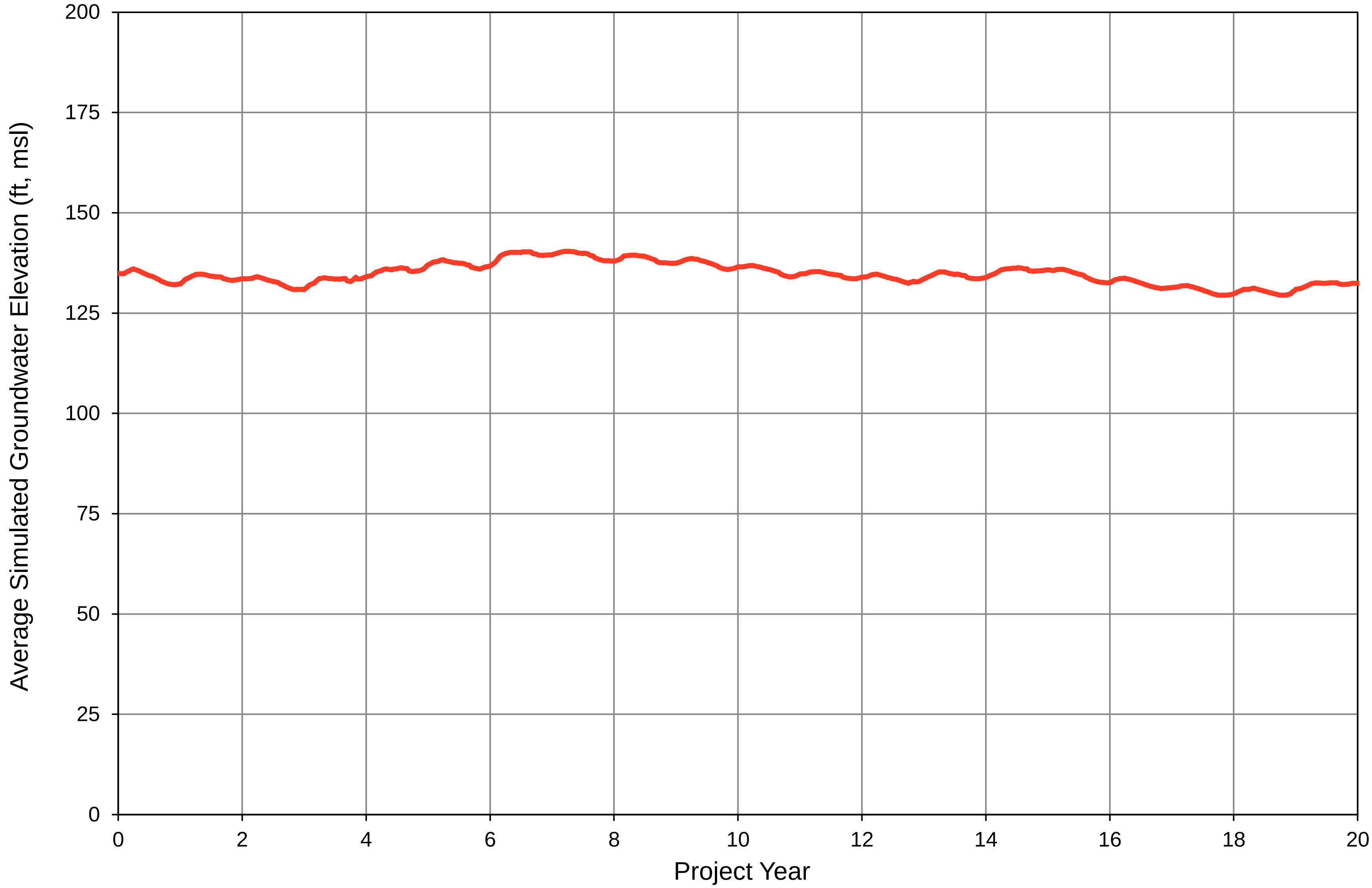

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Figure 9-19
Proposed Action Average Simulated Groundwater Elevation
In the Primary Study Area, Shallow Zone (Cumulative Impacts)
Mendota Pool Group EIS/EIR

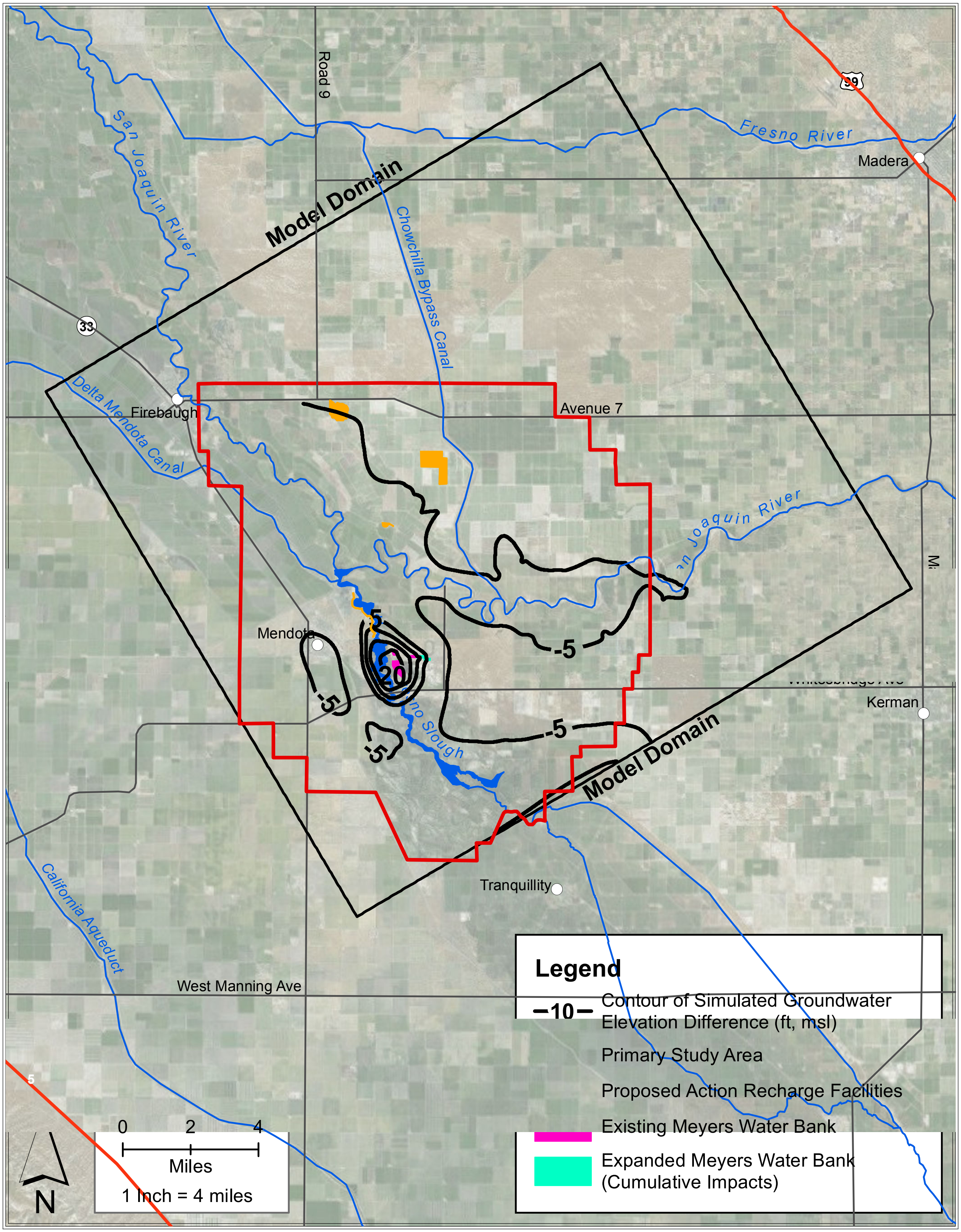

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Figure 9-20
Proposed Action Contours of Equal Simulated Change in Groundwater Elevation Shallow Zone, Year 1 to Year 20 (Cumulative Impacts)

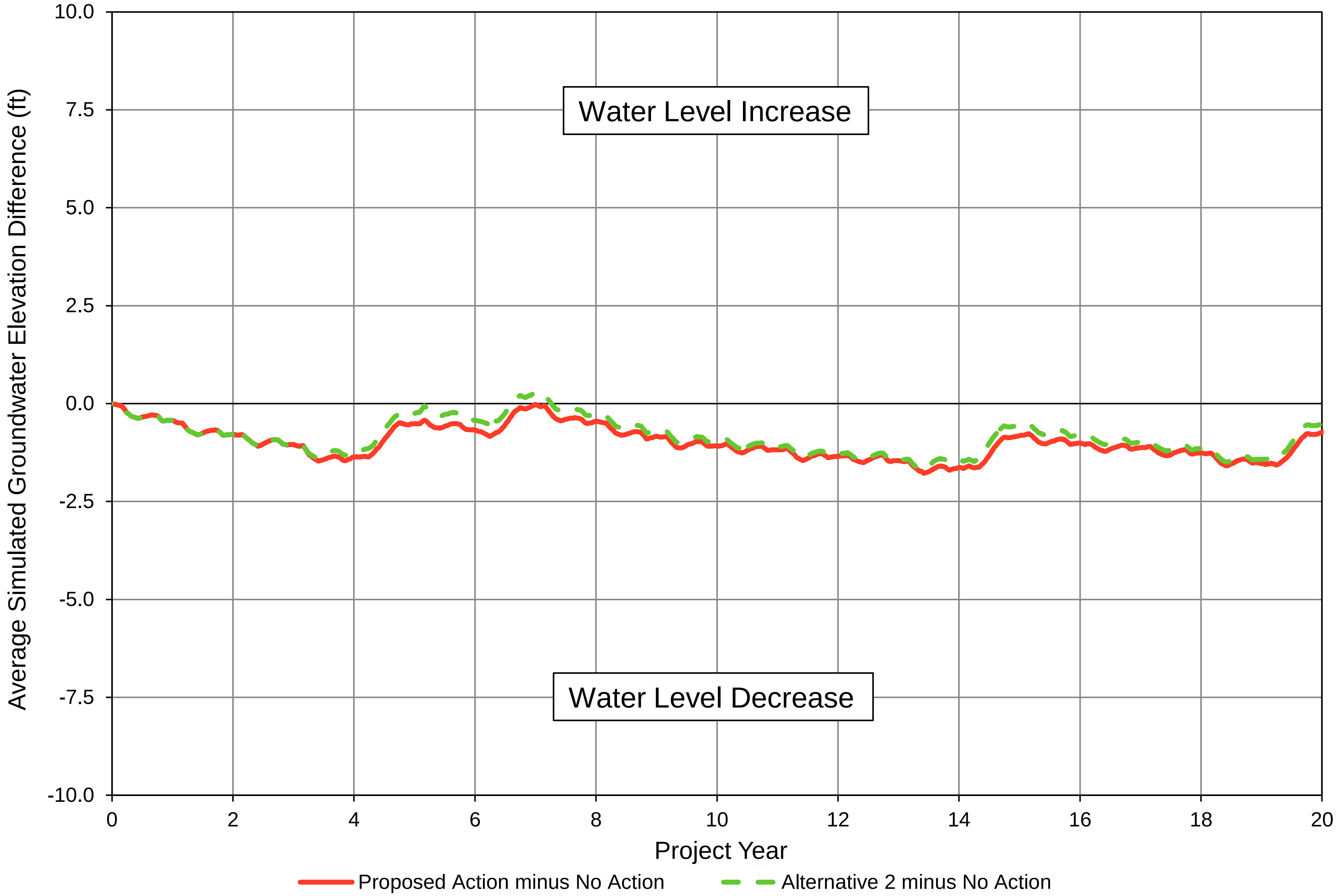

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Figure 9-21
Difference in Average Simulated Groundwater Elevation
In the Primary Study Area, Shallow Zone (Cumulative Impacts)
Mendota Pool Group EIS/EIR

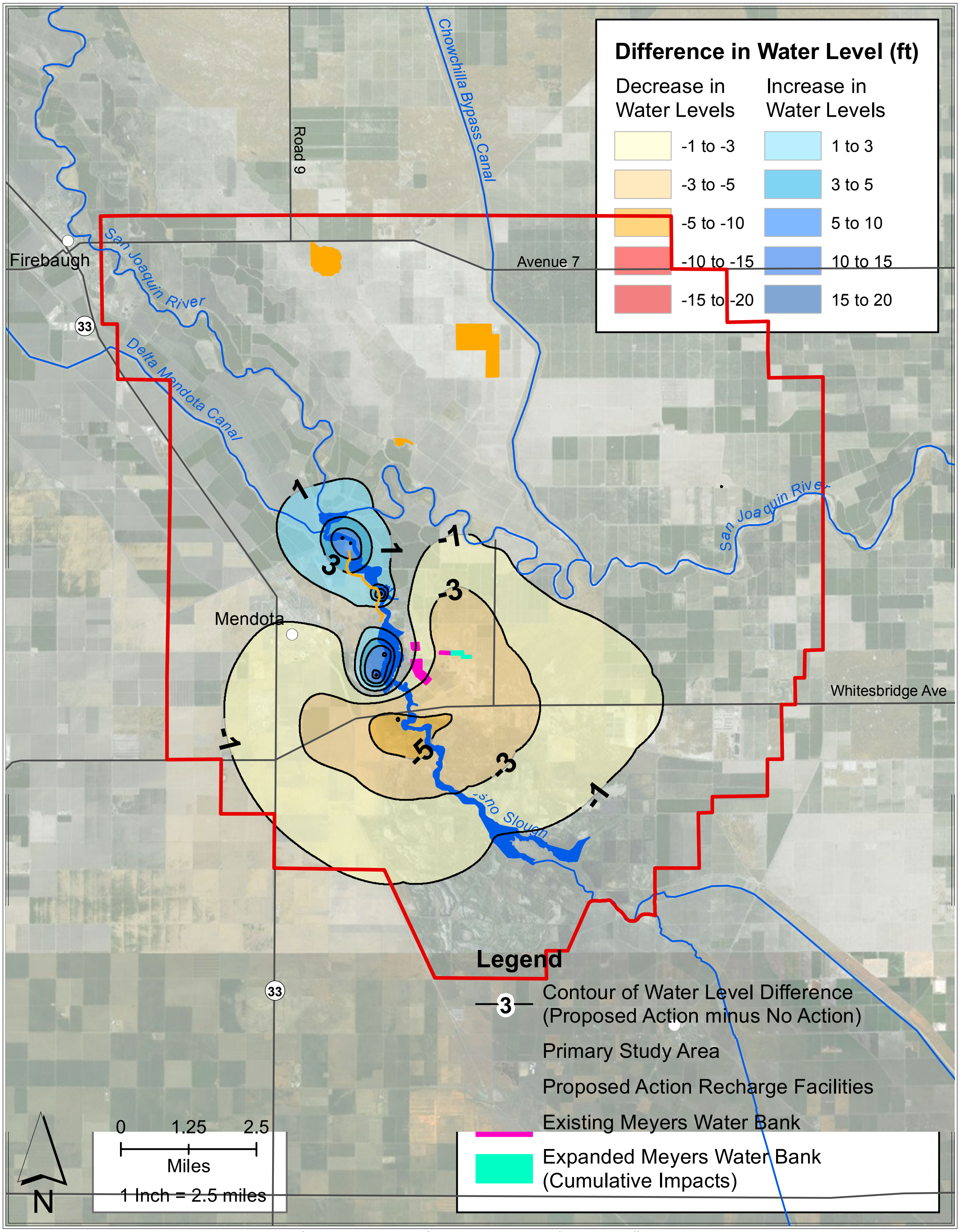

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Figure 9-22
Proposed Action Contours of Equal Simulated Groundwater Elevation Difference Shallow Zone, Year 20 (Cumulative Impacts)

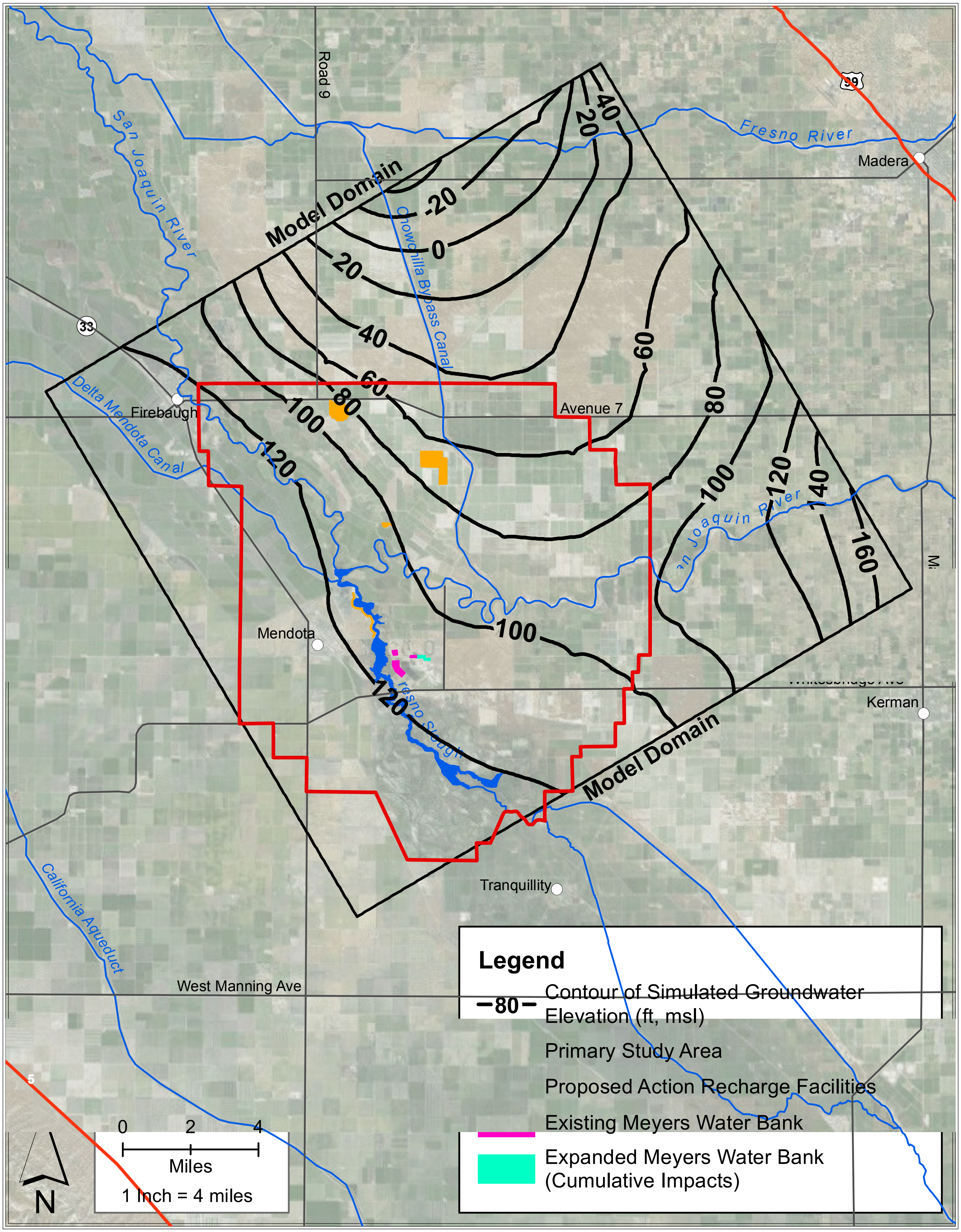

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Figure 9-23
Proposed Action Contours of Equal Simulated Groundwater Elevation Deep Zone, Year 20 (Cumulative Impacts)

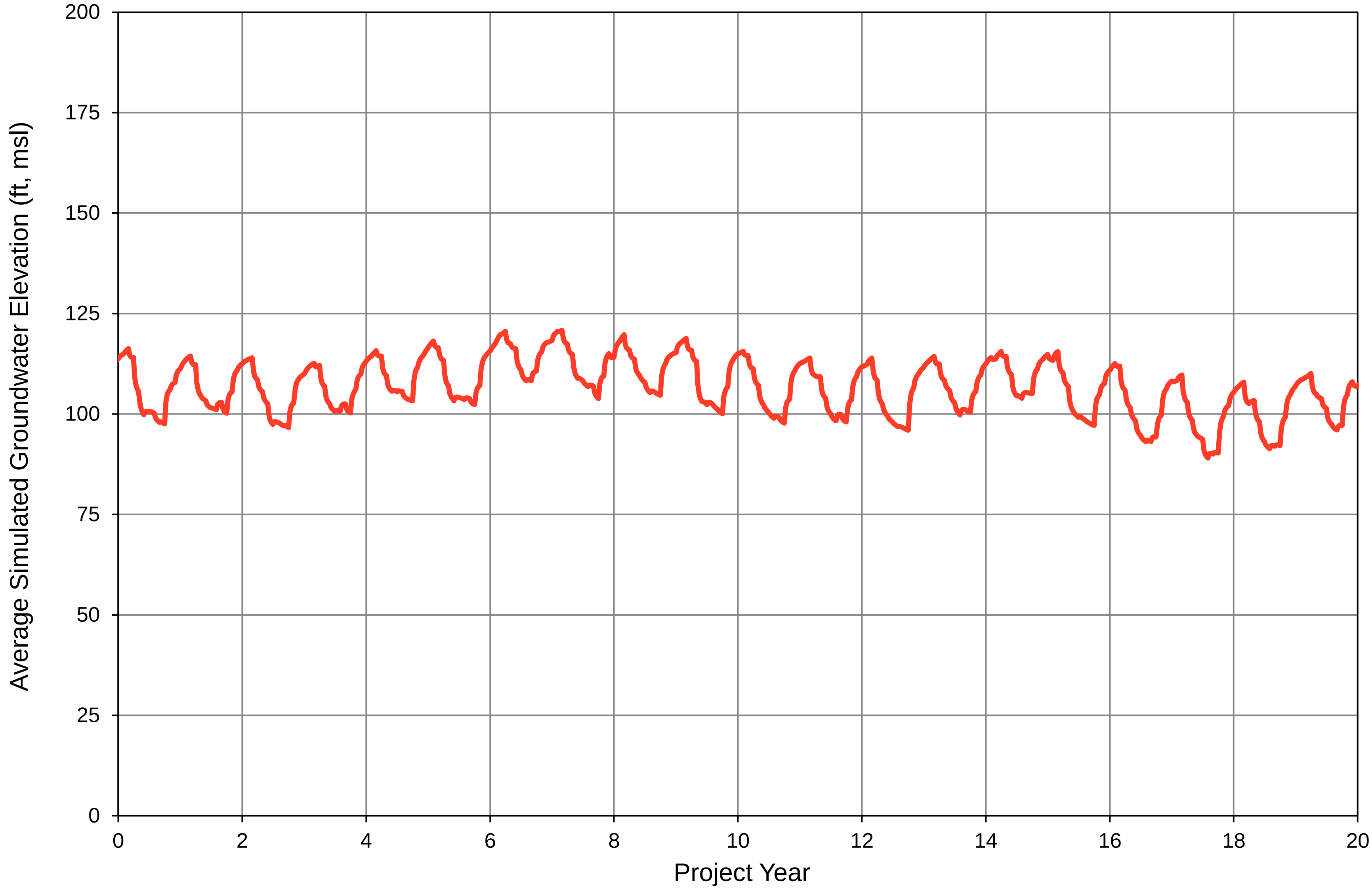

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Figure 9-24
Proposed Action Average Simulated Groundwater Elevation
In the Primary Study Area, Deep Zone (Cumulative Impacts)
Mendota Pool Group EIS/EIR

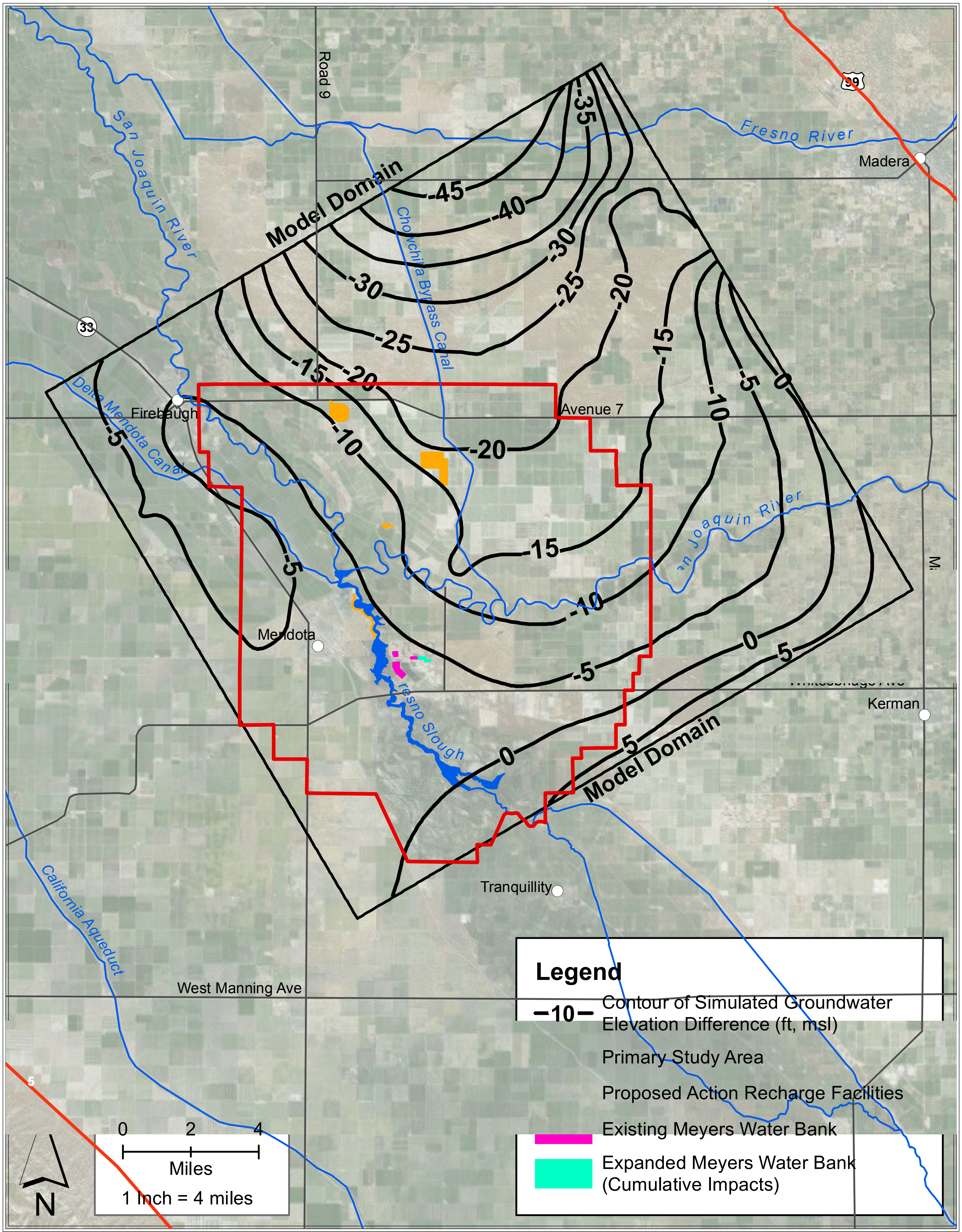

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Figure 9-25
Proposed Action Contours of Equal Simulated Change in Groundwater Elevation Deep Zone, Year 1 to Year 20 (Cumulative Impacts)

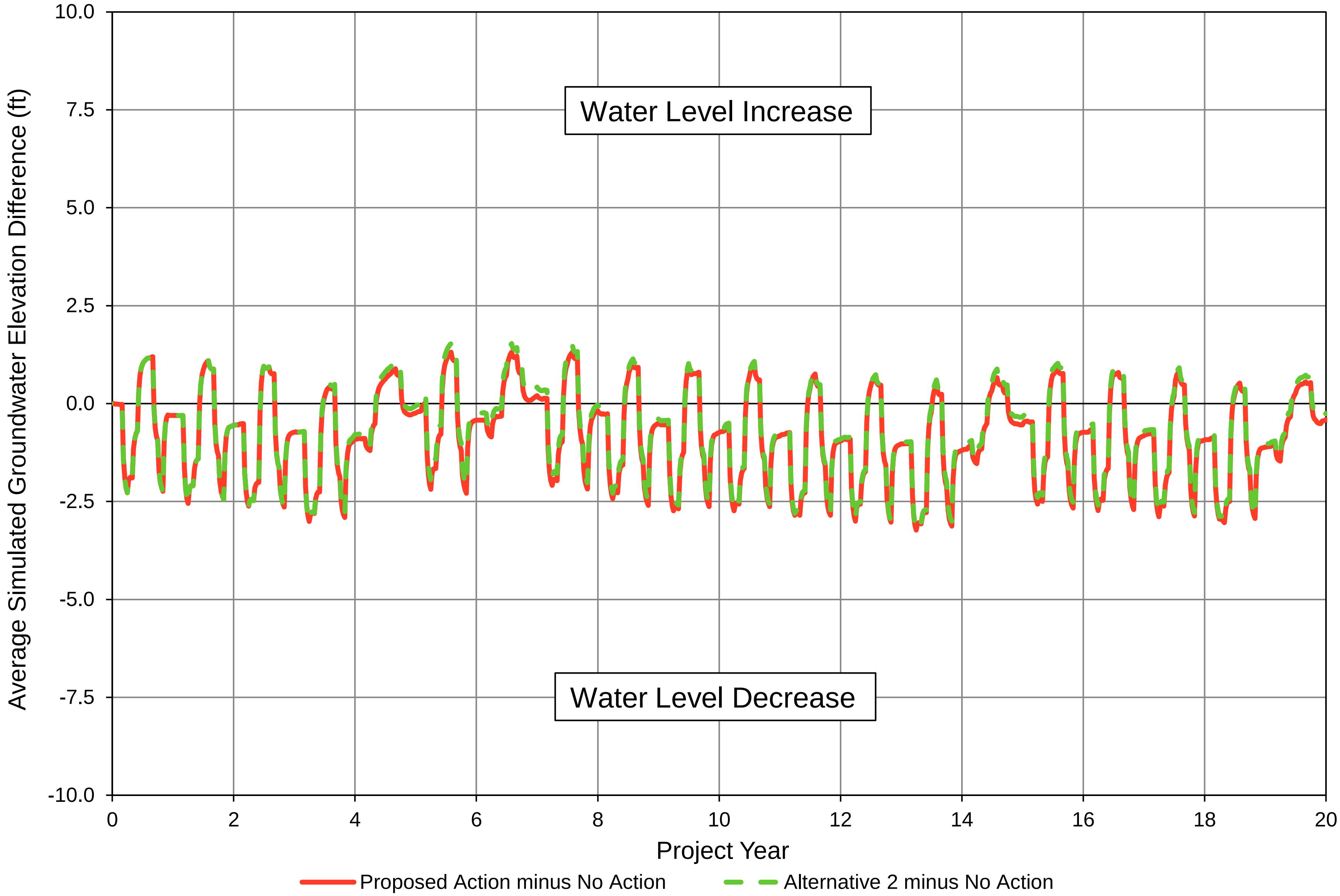

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Figure 9-26
Difference in Average Simulated Groundwater Elevation
In the Primary Study Area, Deep Zone (Cumulative Impacts)
Mendota Pool Group EIS/EIR

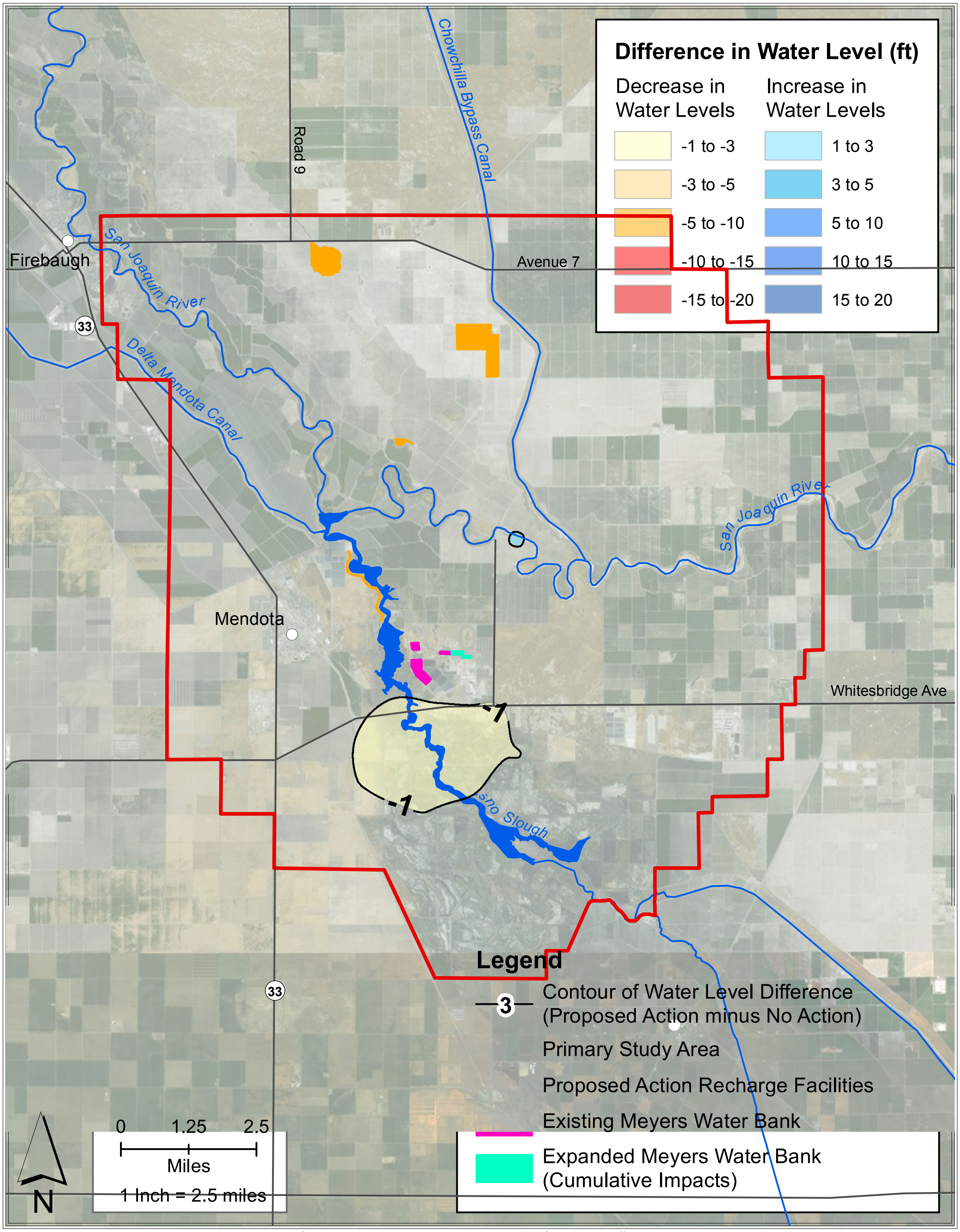

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Figure 9-27
Proposed Action Contours of Equal Simulated Groundwater Elevation Difference Deep Zone, Year 20 (Cumulative Impacts)

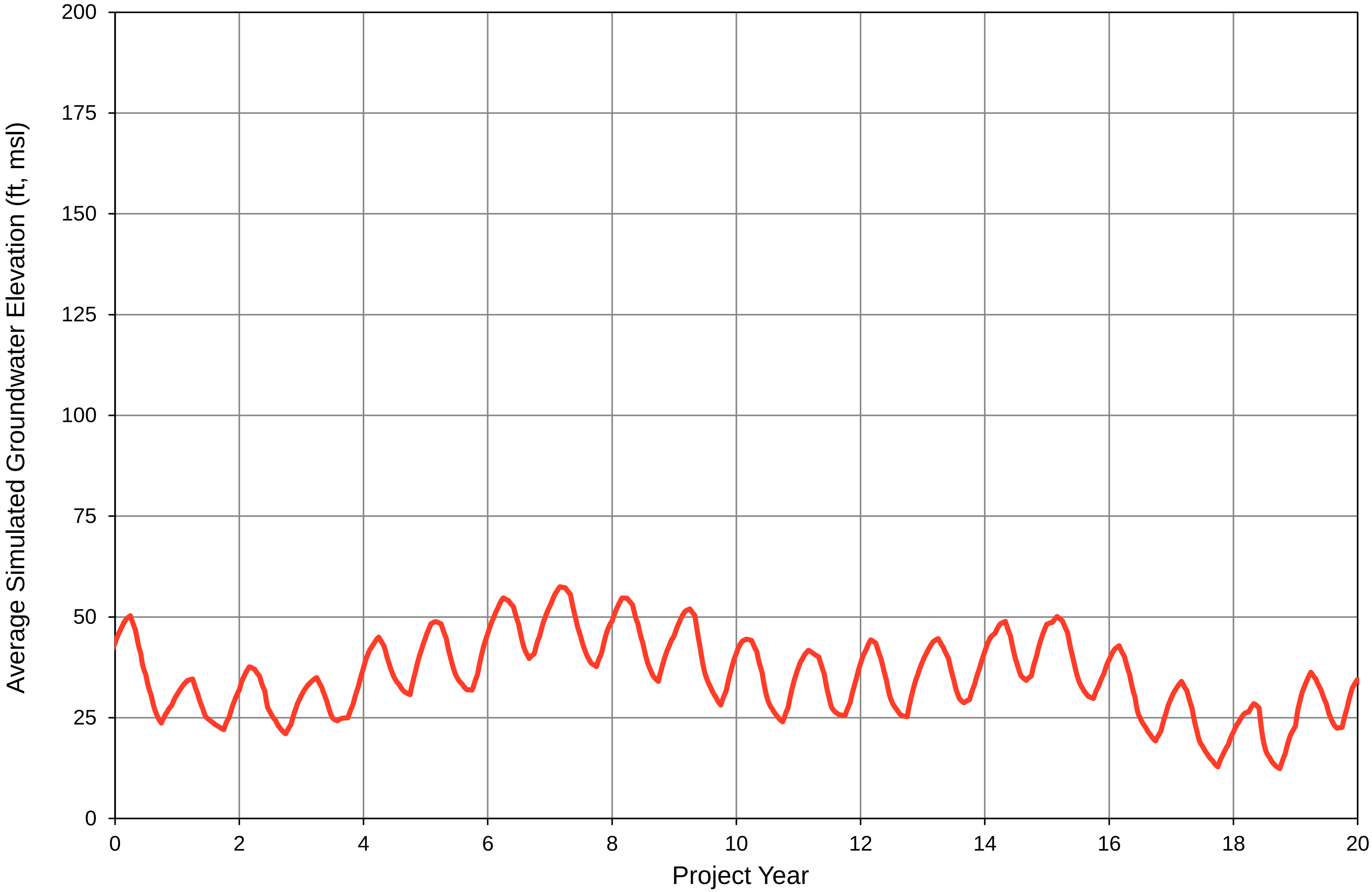

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Figure 9-28
Proposed Action Average Simulated Groundwater Elevation
In the Primary Study Area, Lower Aquifer (Cumulative Impacts)
Mendota Pool Group EIS/EIR

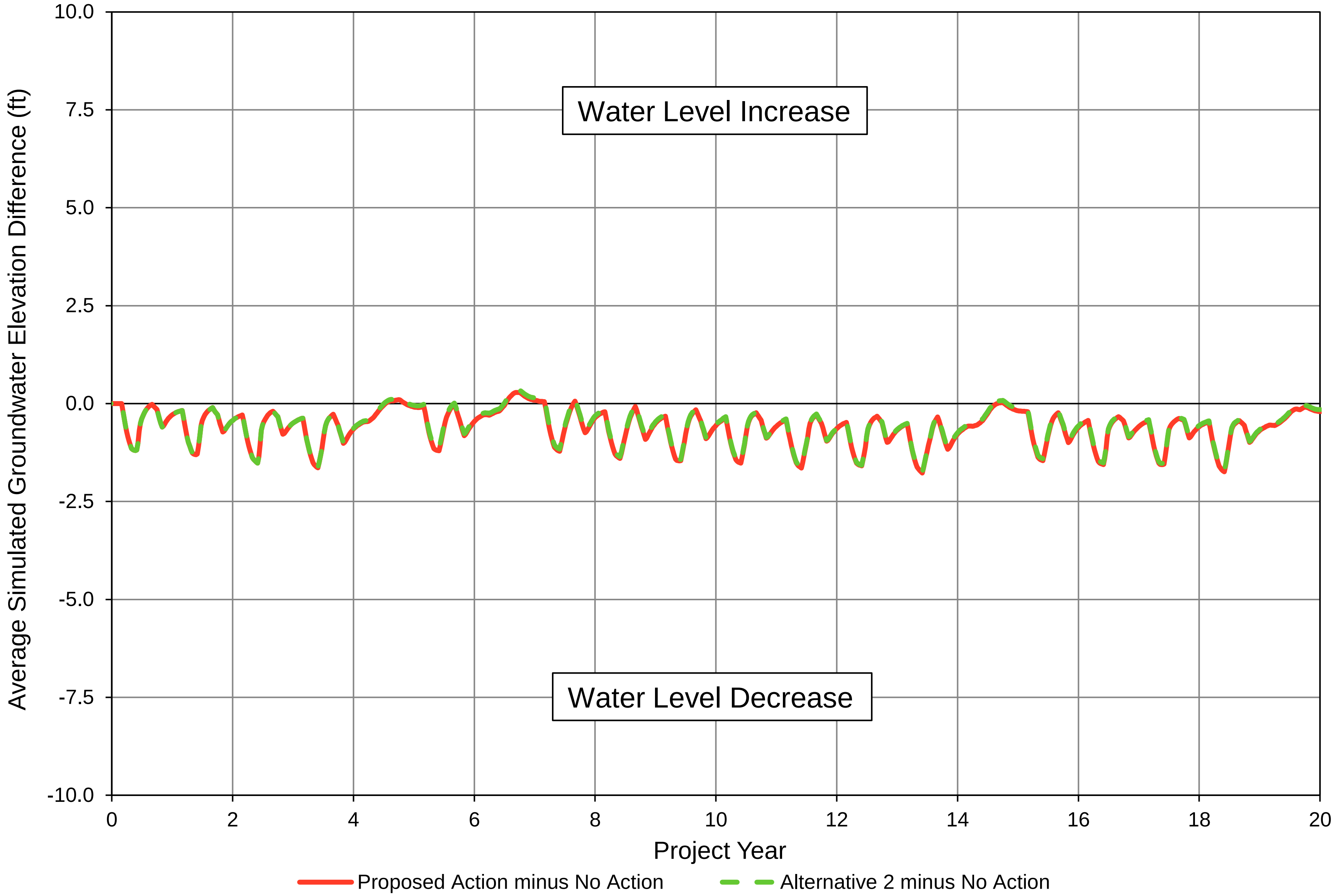

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Figure 9-29
Difference in Average Simulated Groundwater Elevation
In the Primary Study Area, Lower Aquifer (Cumulative Impacts)
Mendota Pool Group EIS/EIR

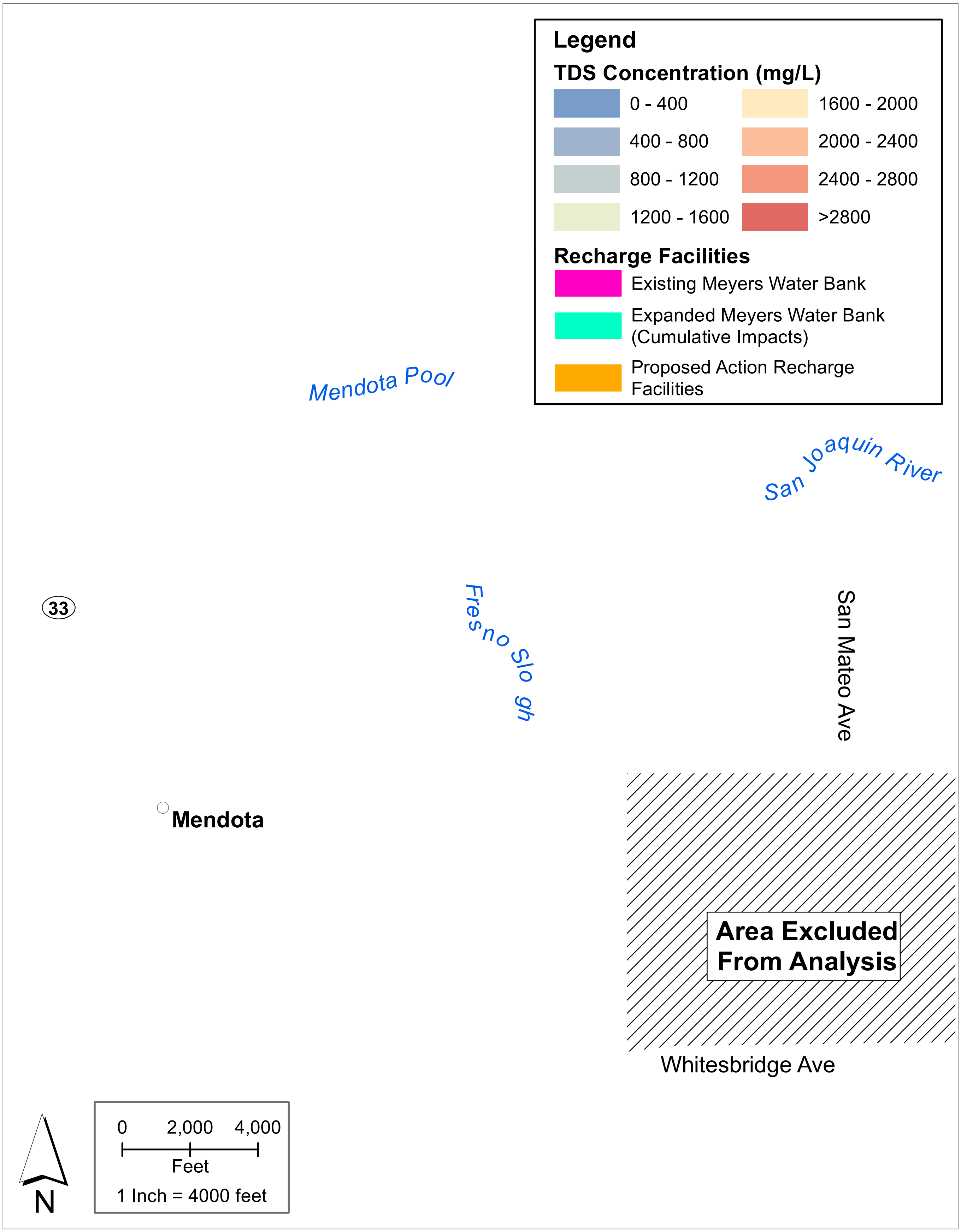

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Figure 9-30
Proposed Action Simulated TDS Concentration Shallow Zone, Year 20 (Cumulative Impacts)

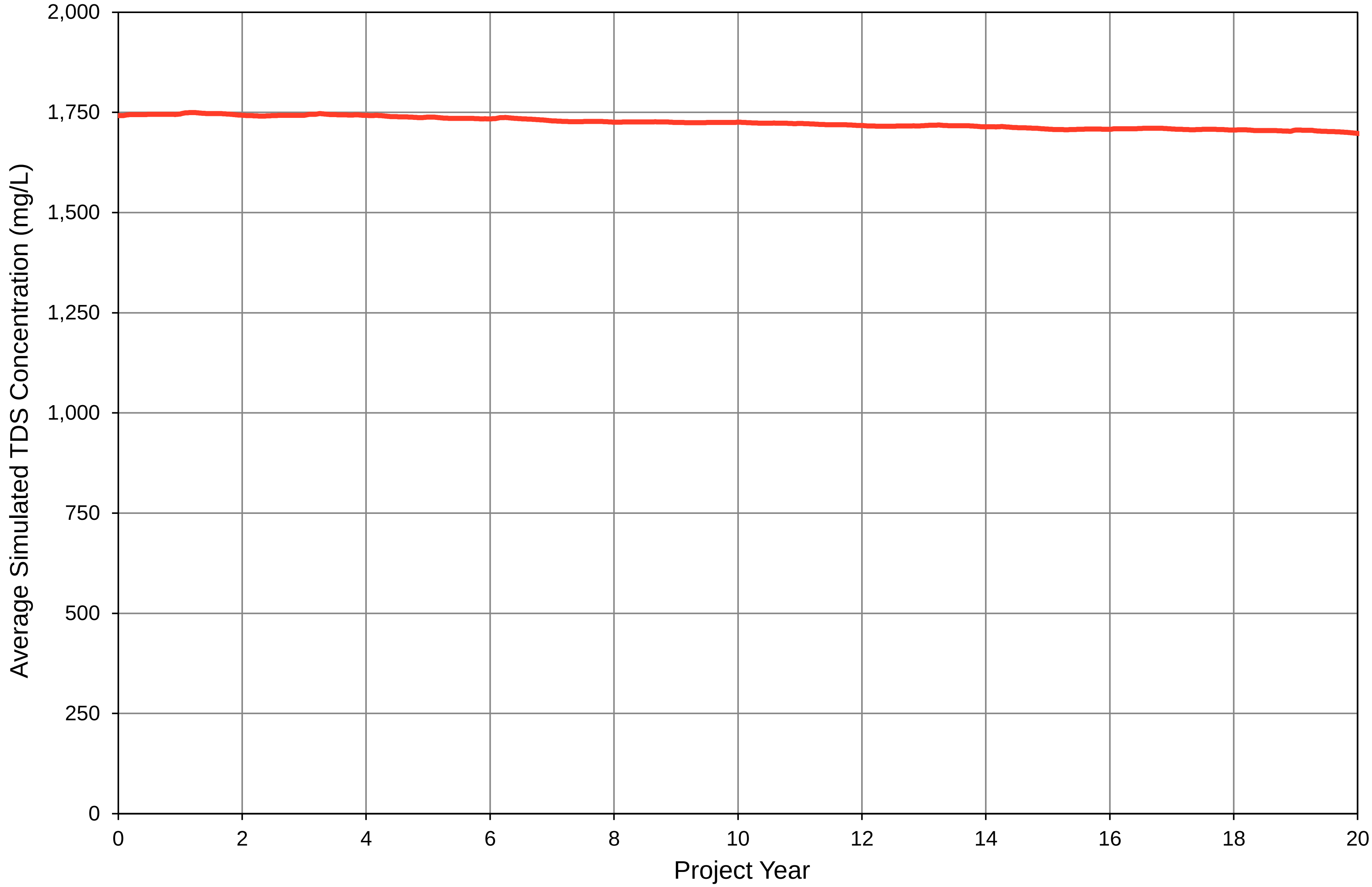

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Figure 9-31
Proposed Action Average Simulated TDS Concentration
In the Primary Study Area, Shallow Zone (Cumulative Impacts)
Mendota Pool Group EIS/EIR

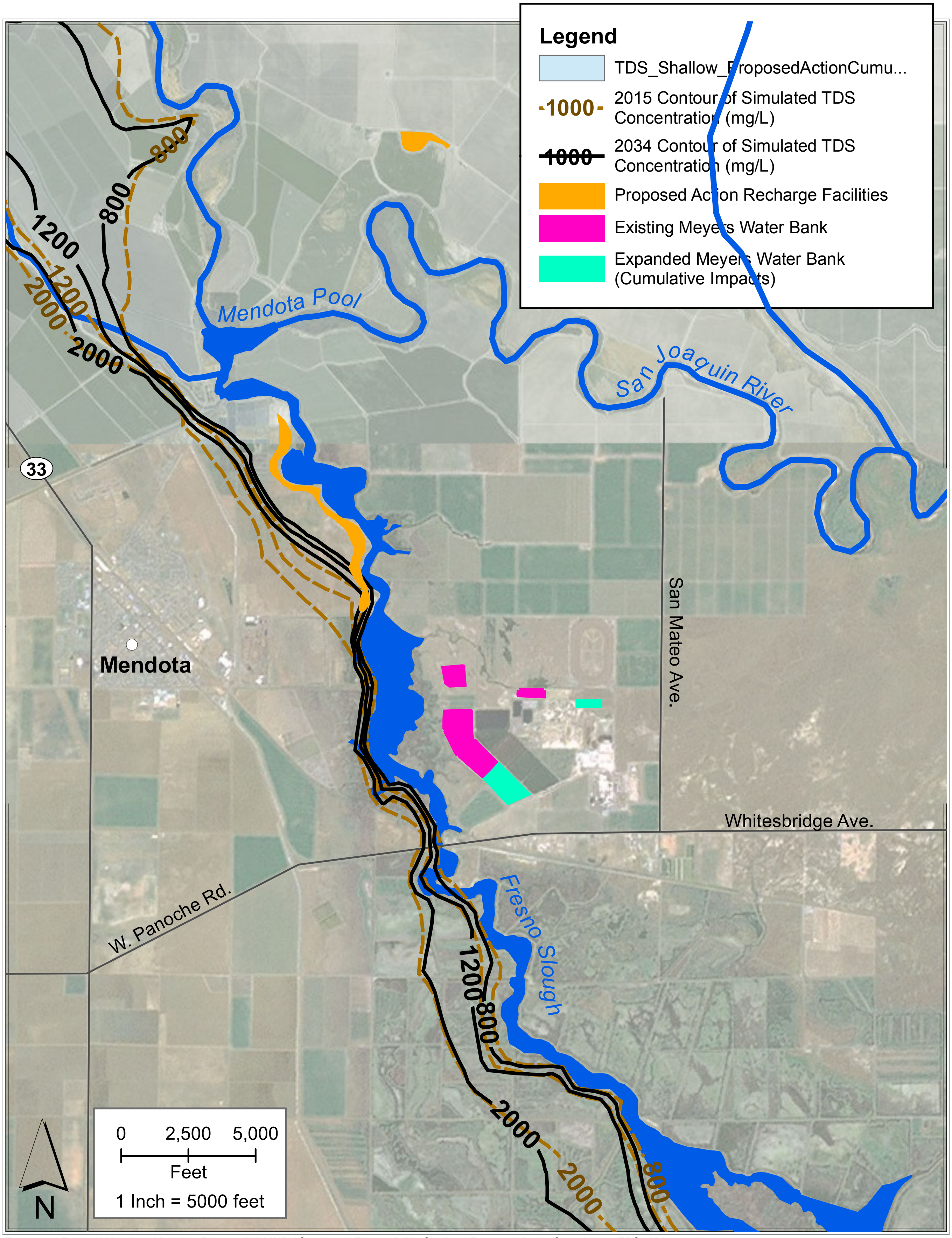

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Figure 9-32
Proposed Action Contours of Equal Simulated TDS Concentration Shallow Zone, Year 20 (Cumulative Impacts)

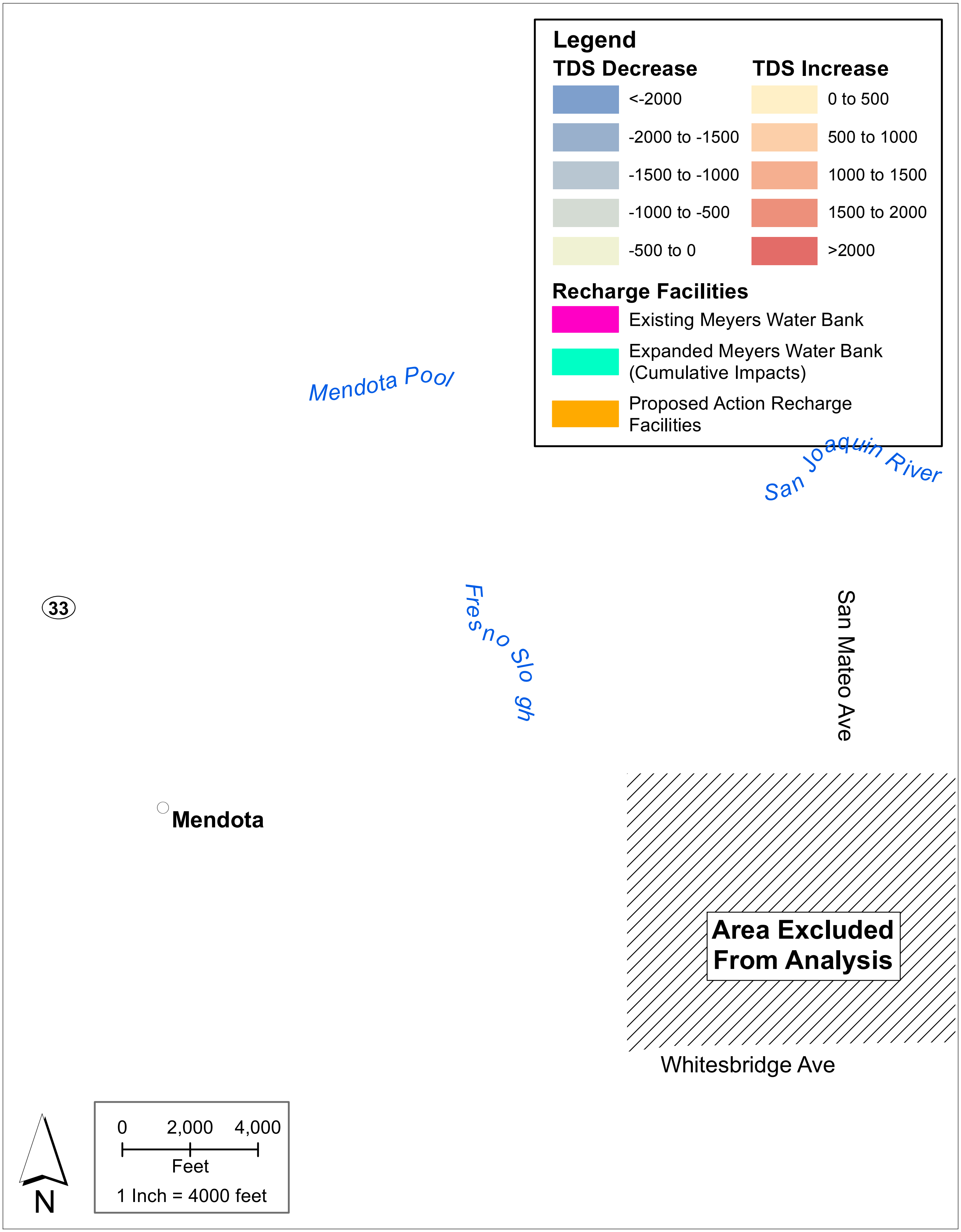

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Figure 9-33
Proposed Action Simulated Change in TDS Concentration from Year 1 to Year 20 Shallow Zone (Cumulative Impacts)

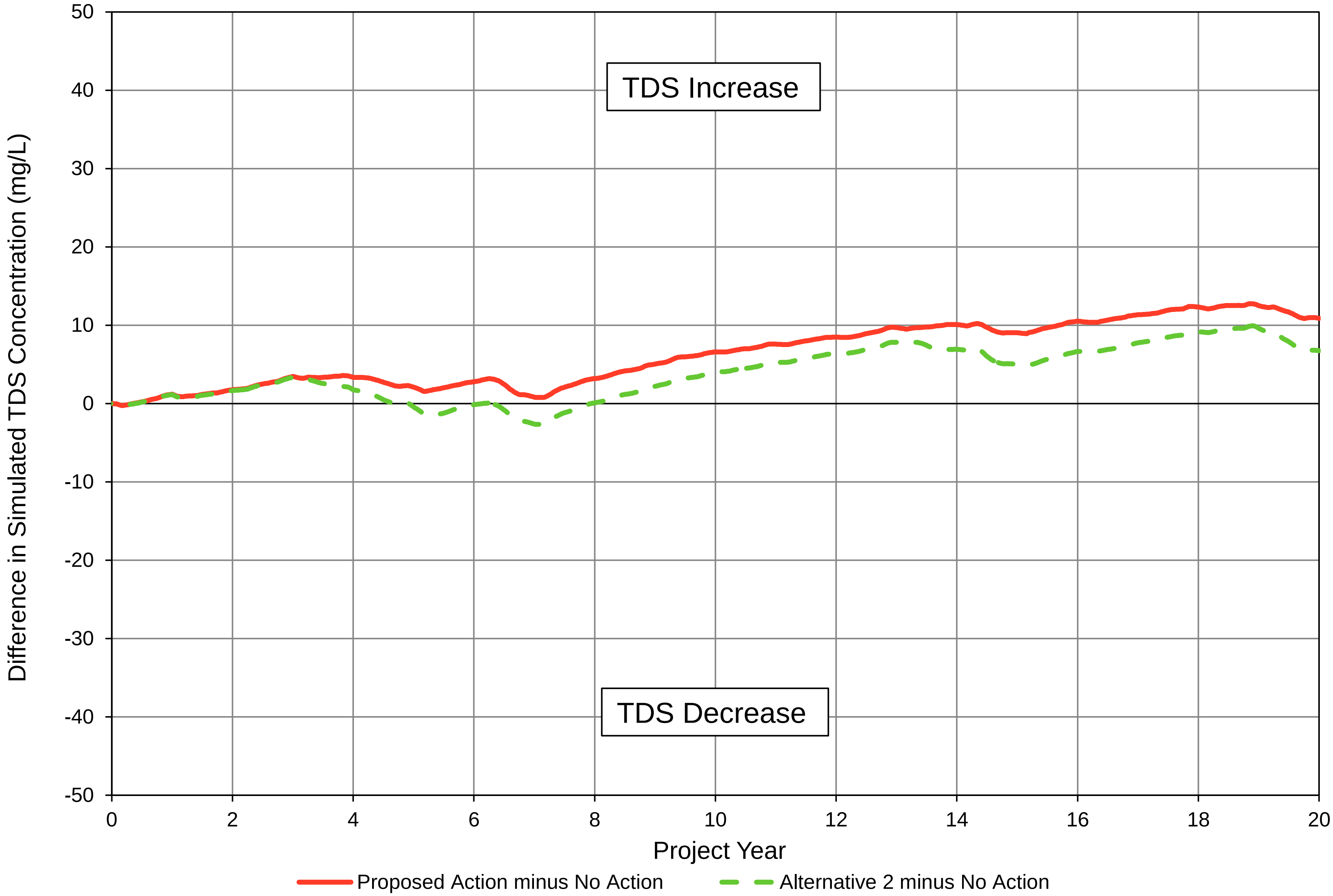

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Figure 9-34
Difference in Average Simulated TDS Concentrations
In the Primary Study Area, Shallow Zone (Cumulative Impacts)
Mendota Pool Group EIS/EIR

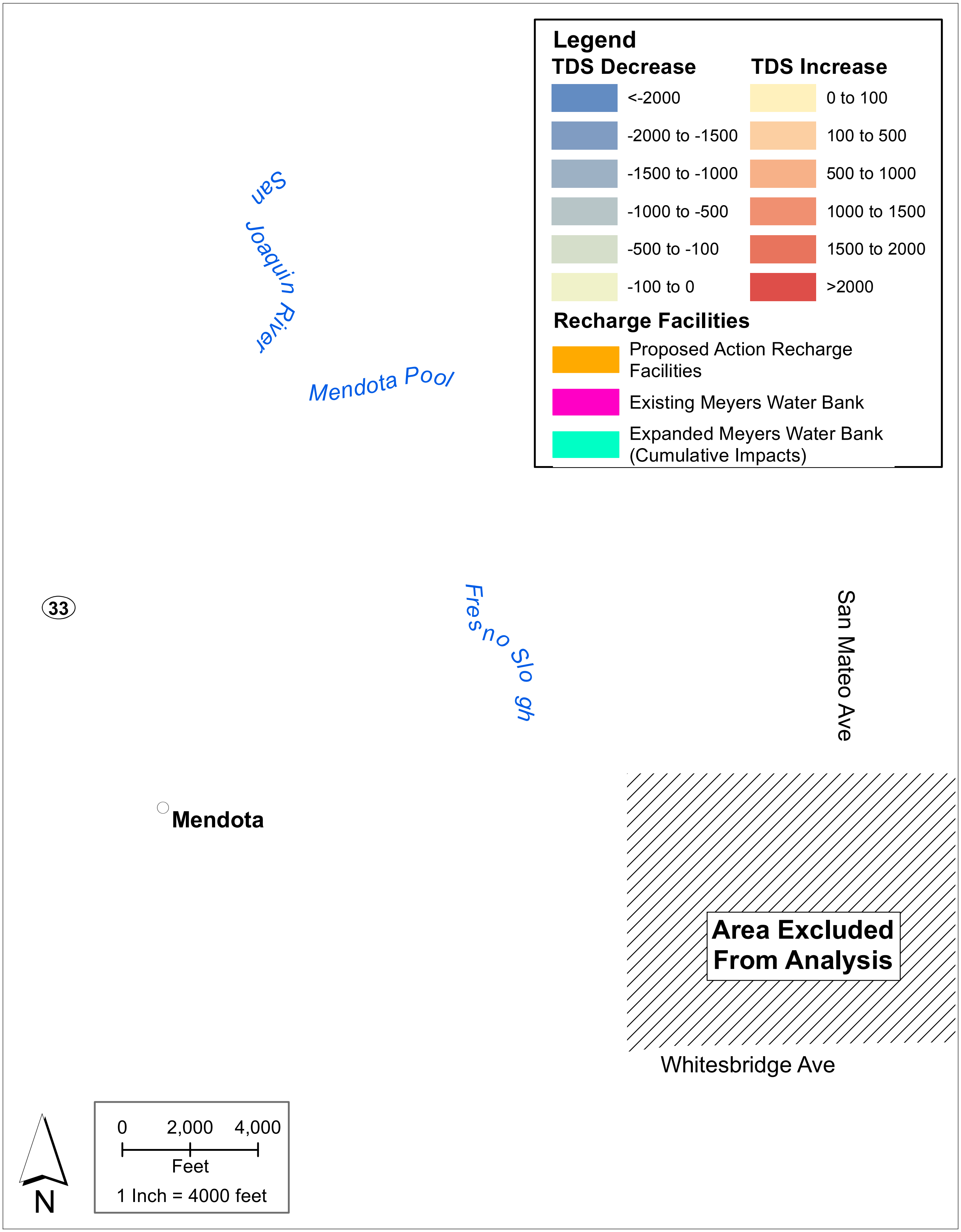

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Figure 9-35
Simulated TDS Difference by Year 20
Proposed Action minus No Action
Shallow Zone (Cumulative Impacts)

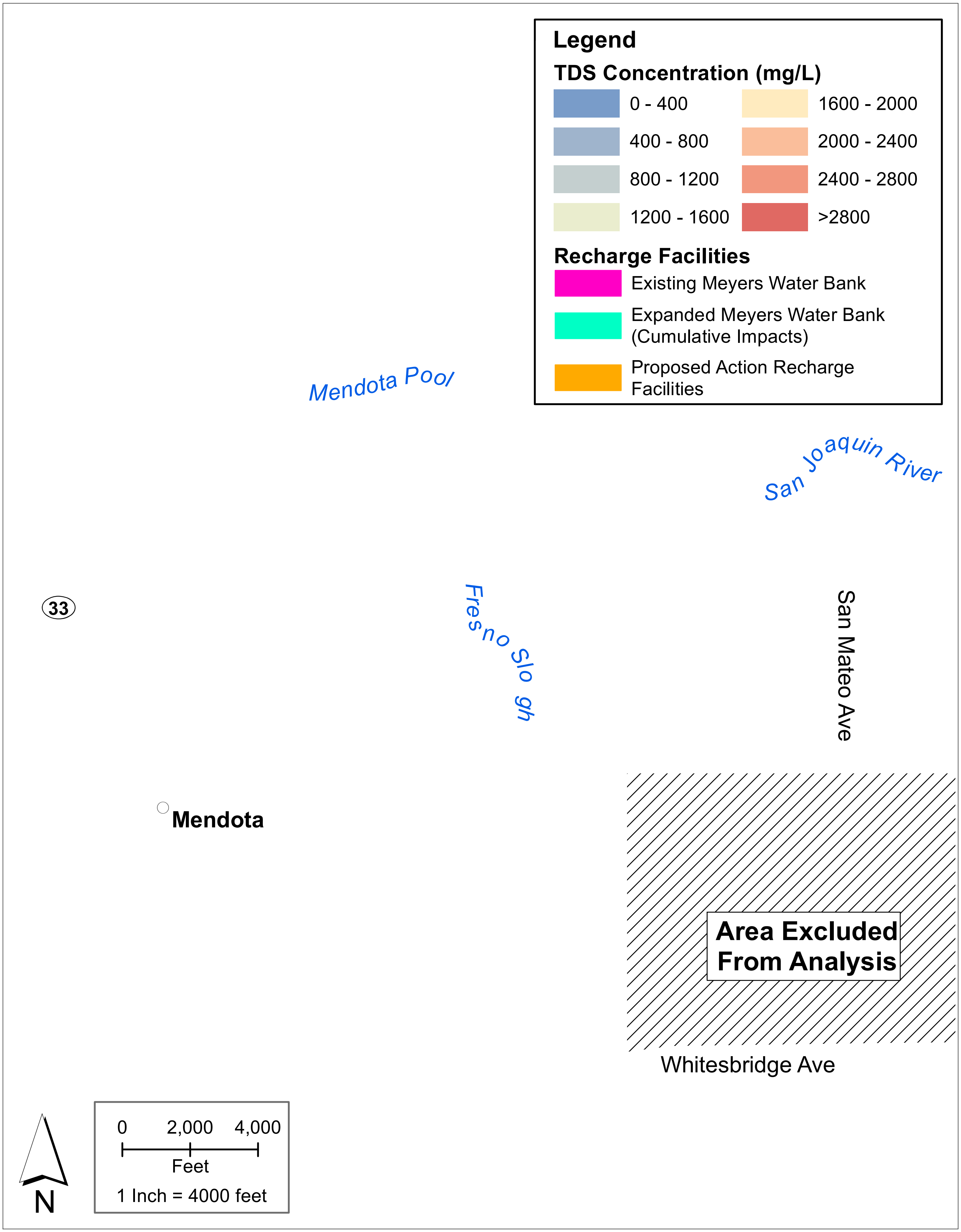

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Figure 9-36
Proposed Action Simulated
TDS Concentration
Deep Zone, Year 20 (Cumulative Impacts)

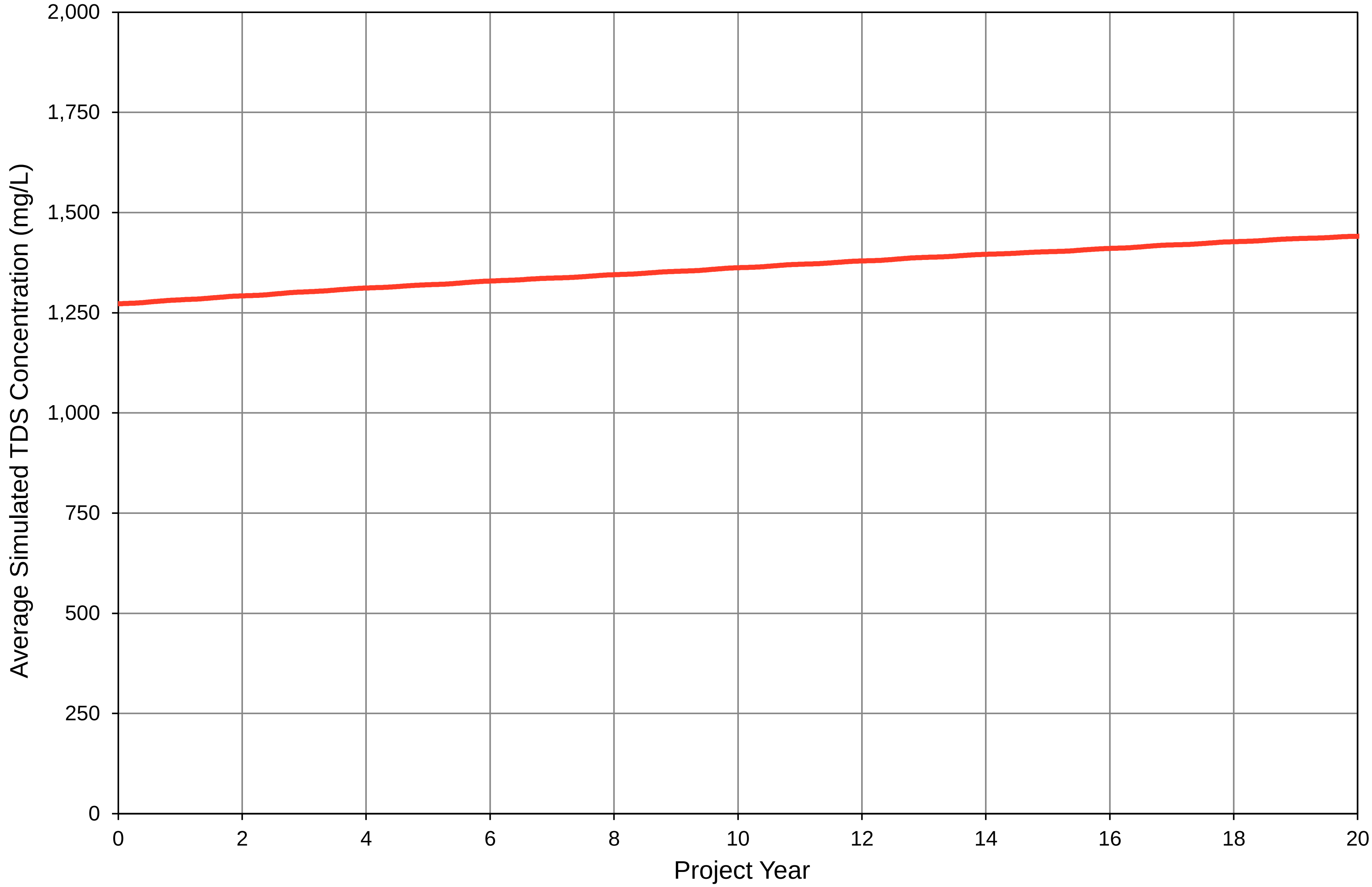

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Figure 9-37
Proposed Action Average Simulated TDS Concentration
In the Primary Study Area, Deep Zone (Cumulative Impacts)
Mendota Pool Group EIS/EIR

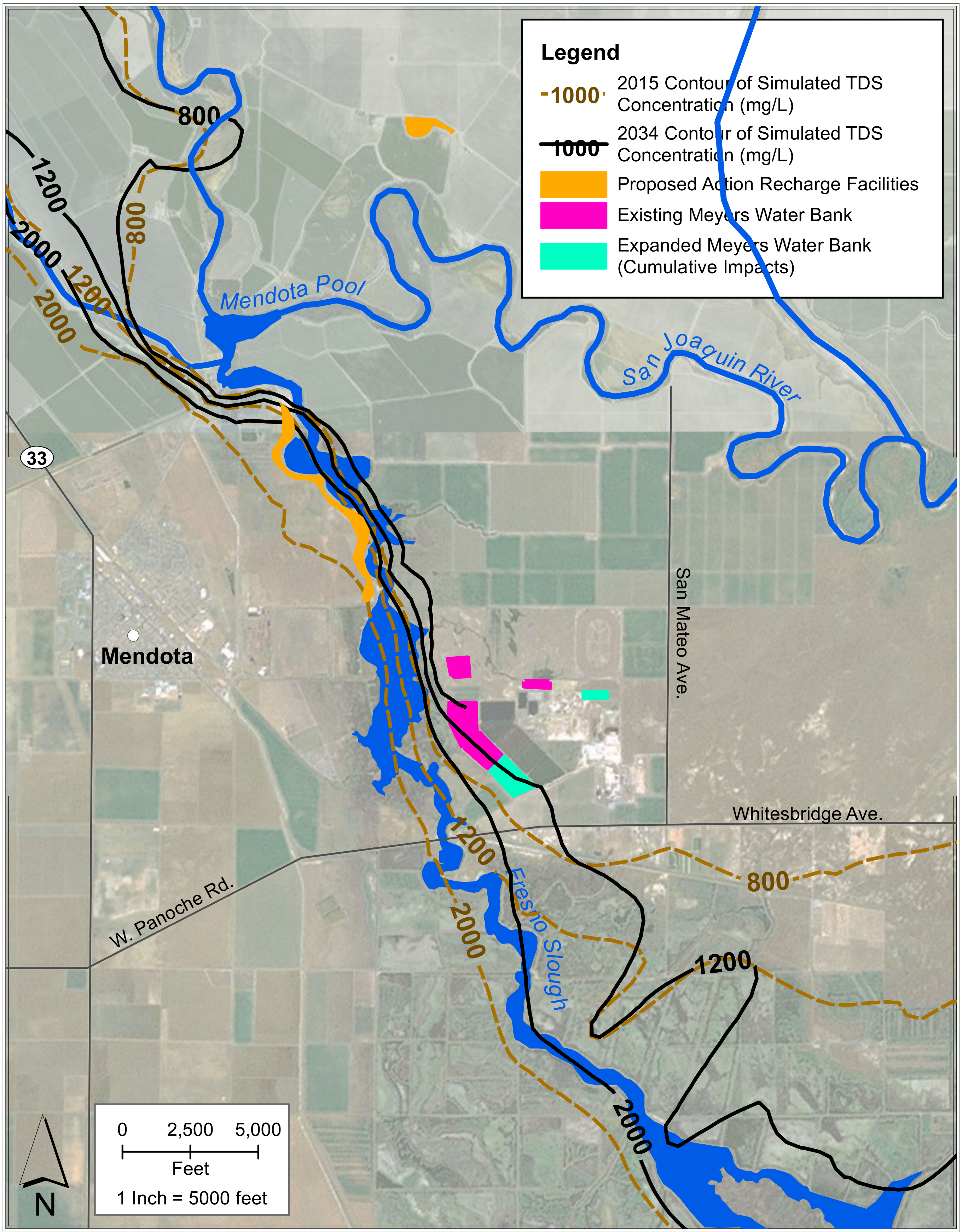

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Figure 9-38
Proposed Action Contours of Equal Simulated TDS Concentration Deep Zone, Year 20 (Cumulative Impacts)

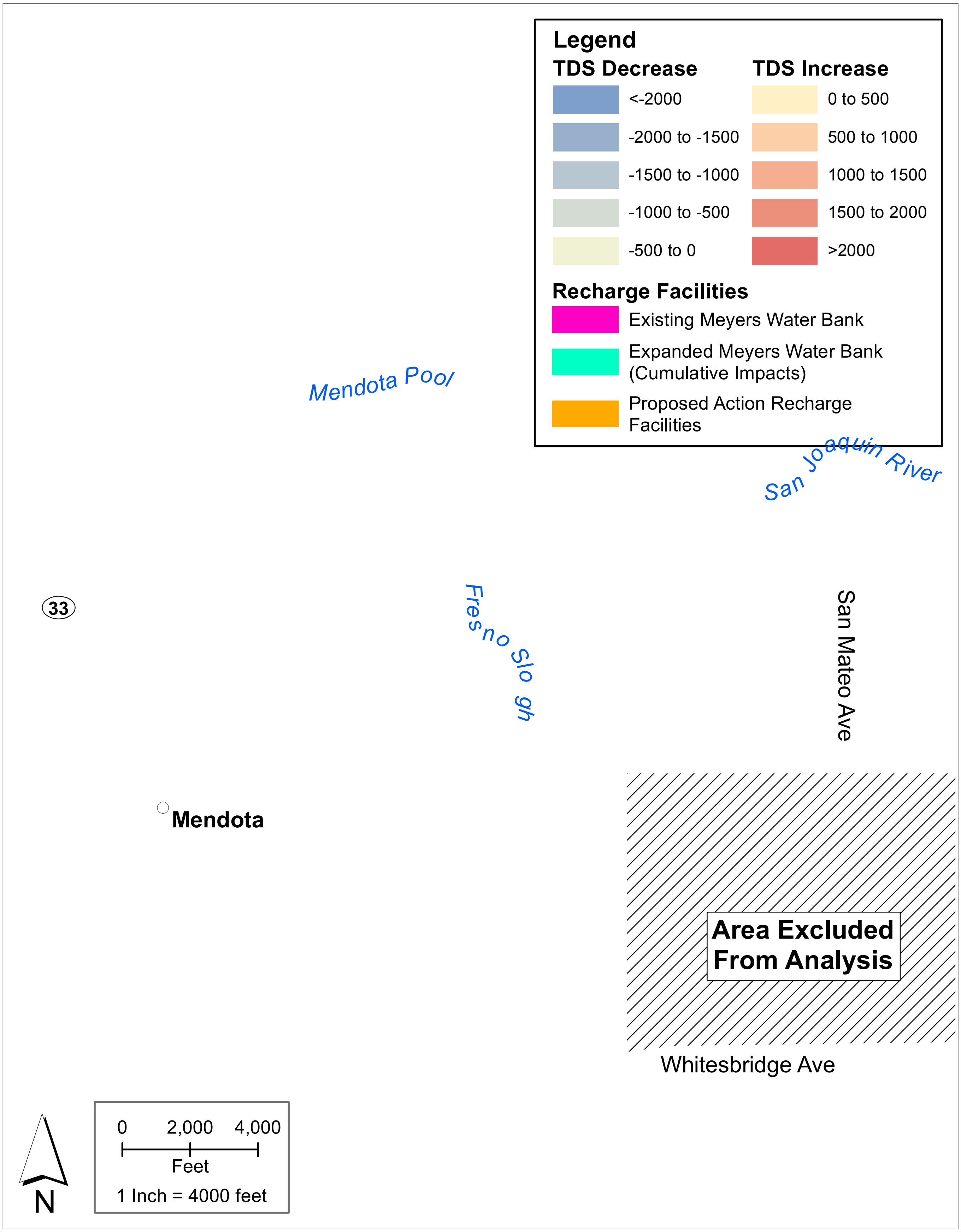

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Figure 9-39
Proposed Action Simulated Change in TDS Concentration from Year 1 to Year 20 Deep Zone (Cumulative Impacts)

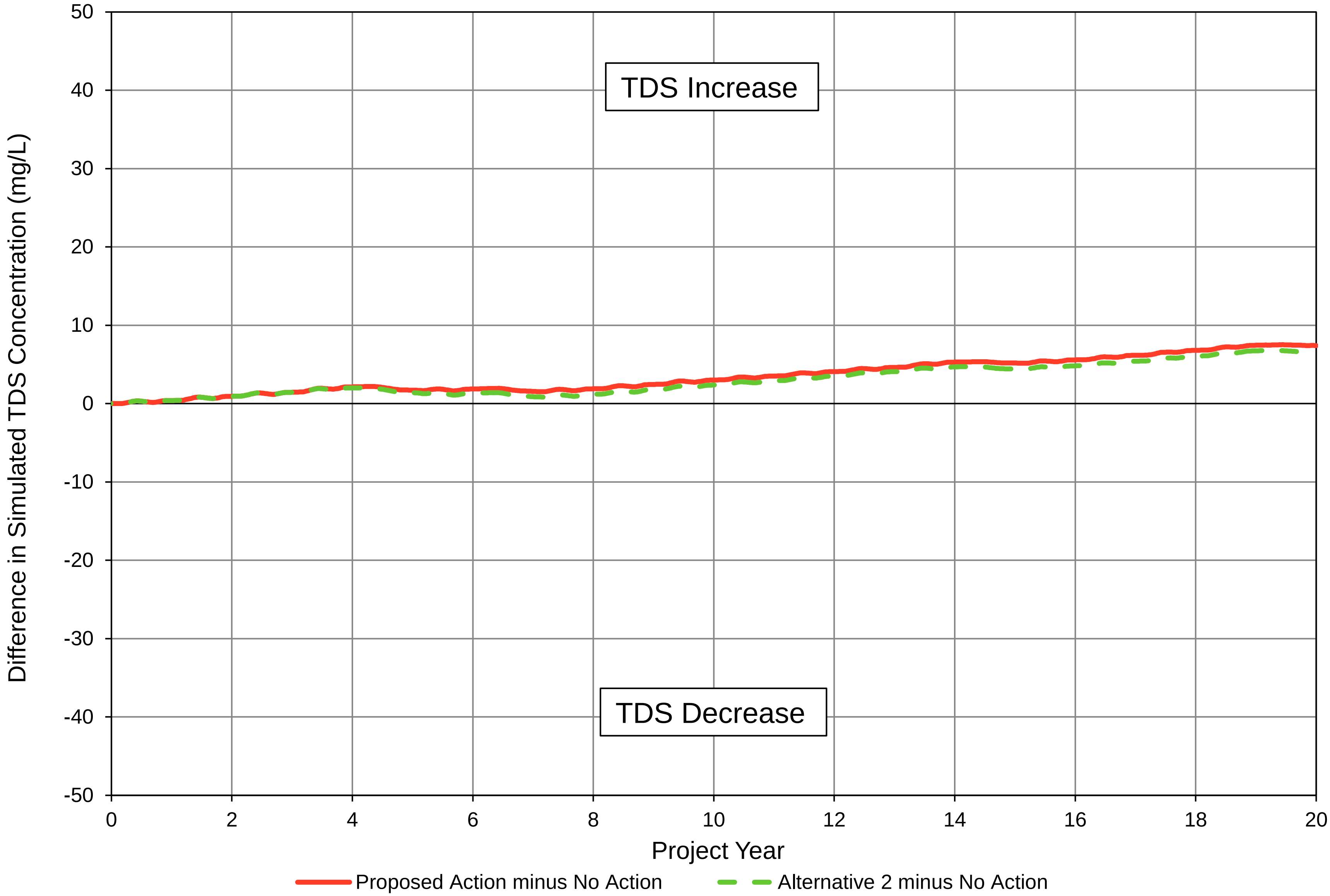

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Figure 9-40
Difference in Average Simulated TDS Concentrations
In the Primary Study Area, Deep Zone (Cumulative Impacts)
Mendota Pool Group EIS/EIR

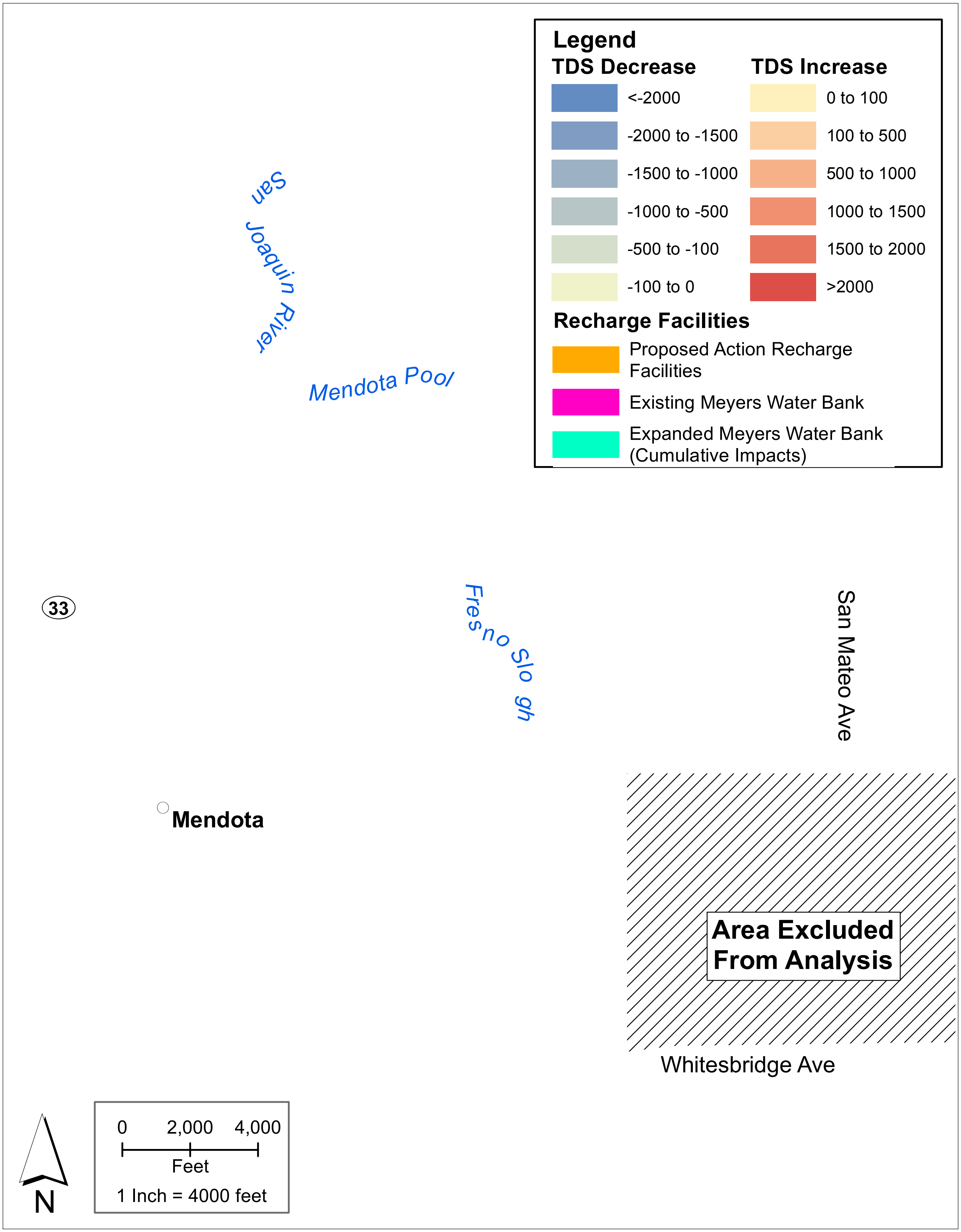

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Figure 9-41
Simulated TDS Difference by Year 20
Proposed Action minus No Action
Deep Zone (Cumulative Impacts)

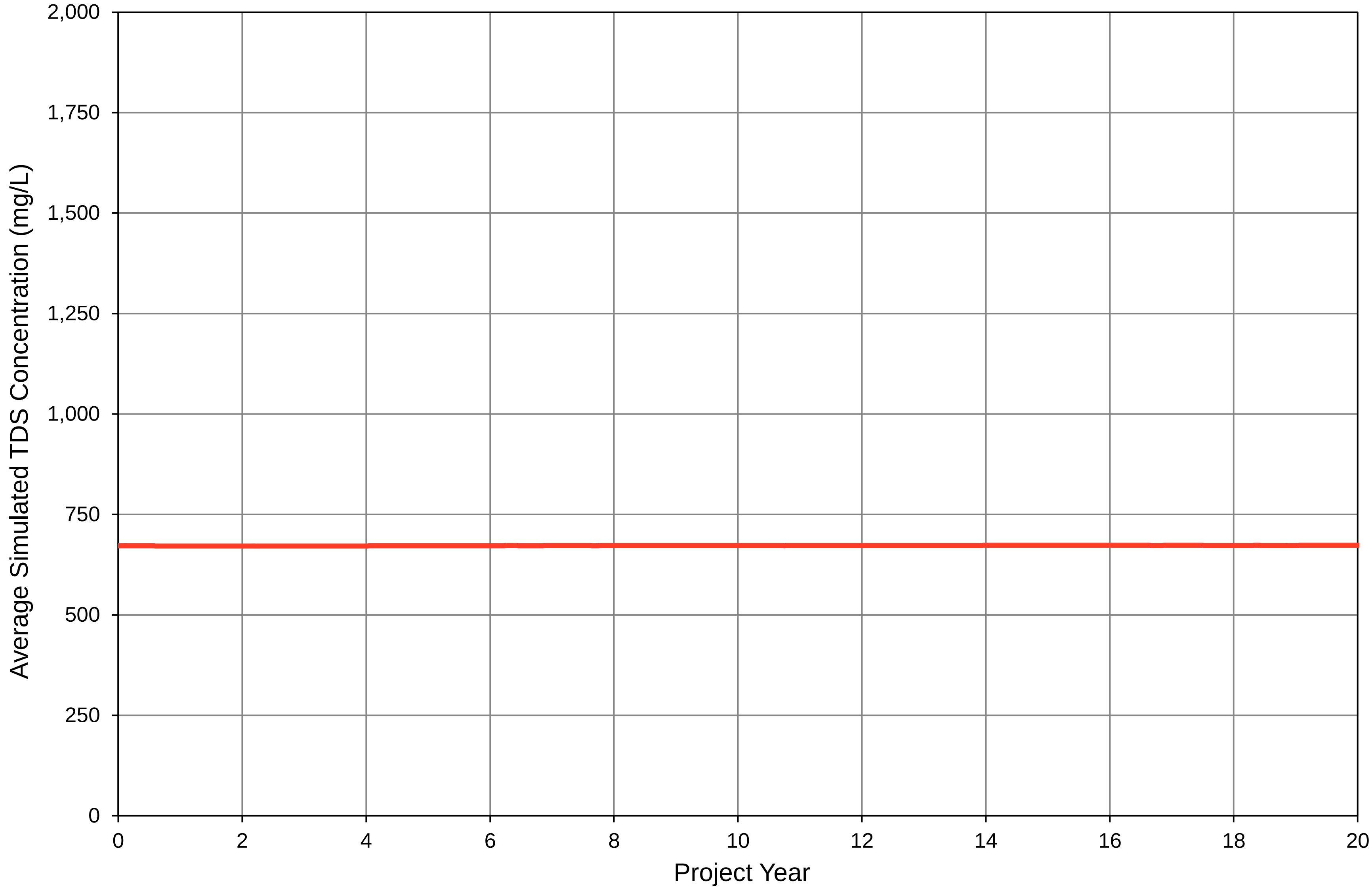

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Figure 9-42
Proposed Action Average Simulated TDS Concentration
In the Primary Study Area, Lower Aquifer (Cumulative Impacts)
Mendota Pool Group EIS/EIR

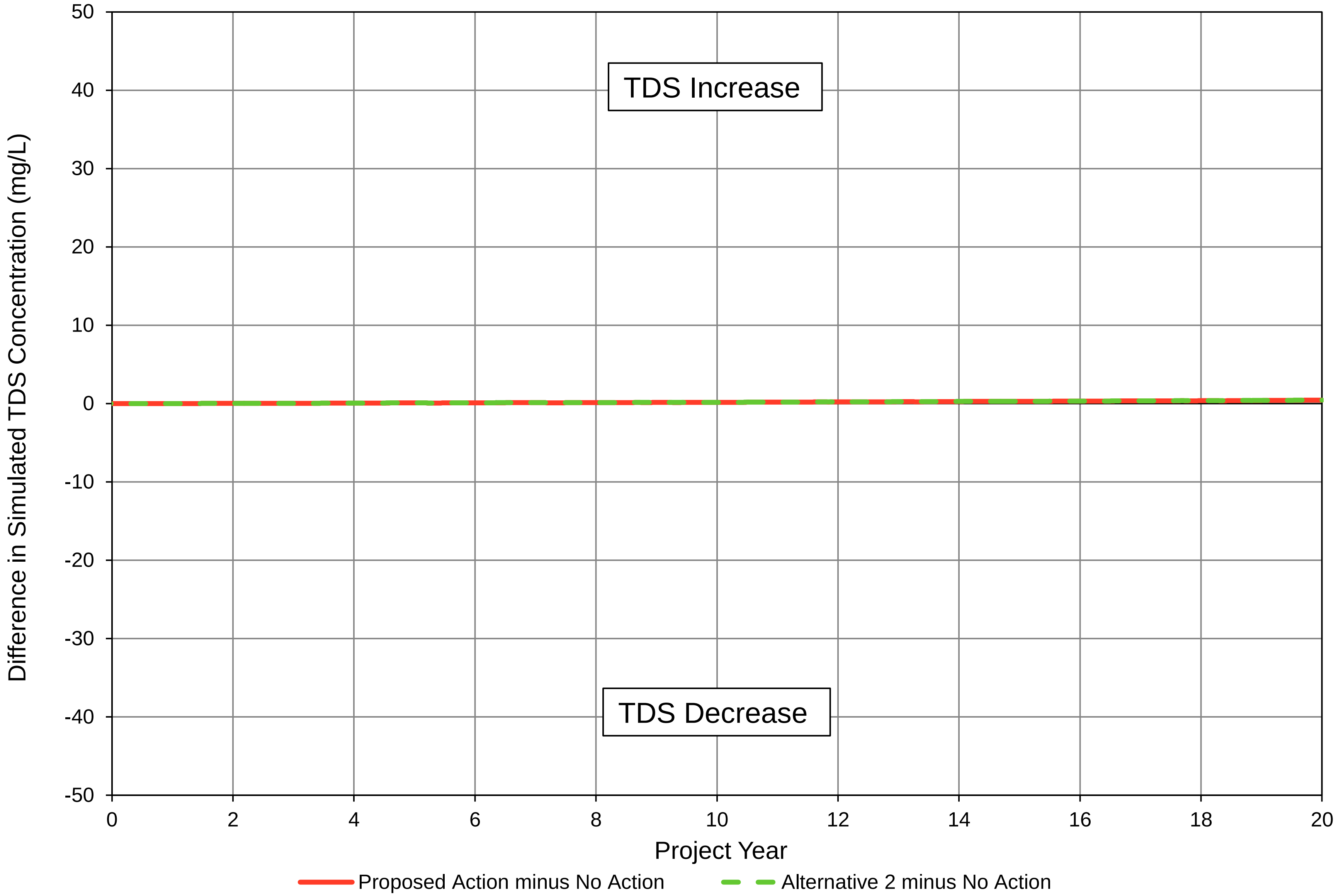

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Figure 9-43
Difference in Average Simulated TDS Concentrations
In the Primary Study Area, Lower Aquifer (Cumulative Impacts)
Mendota Pool Group EIS/EIR

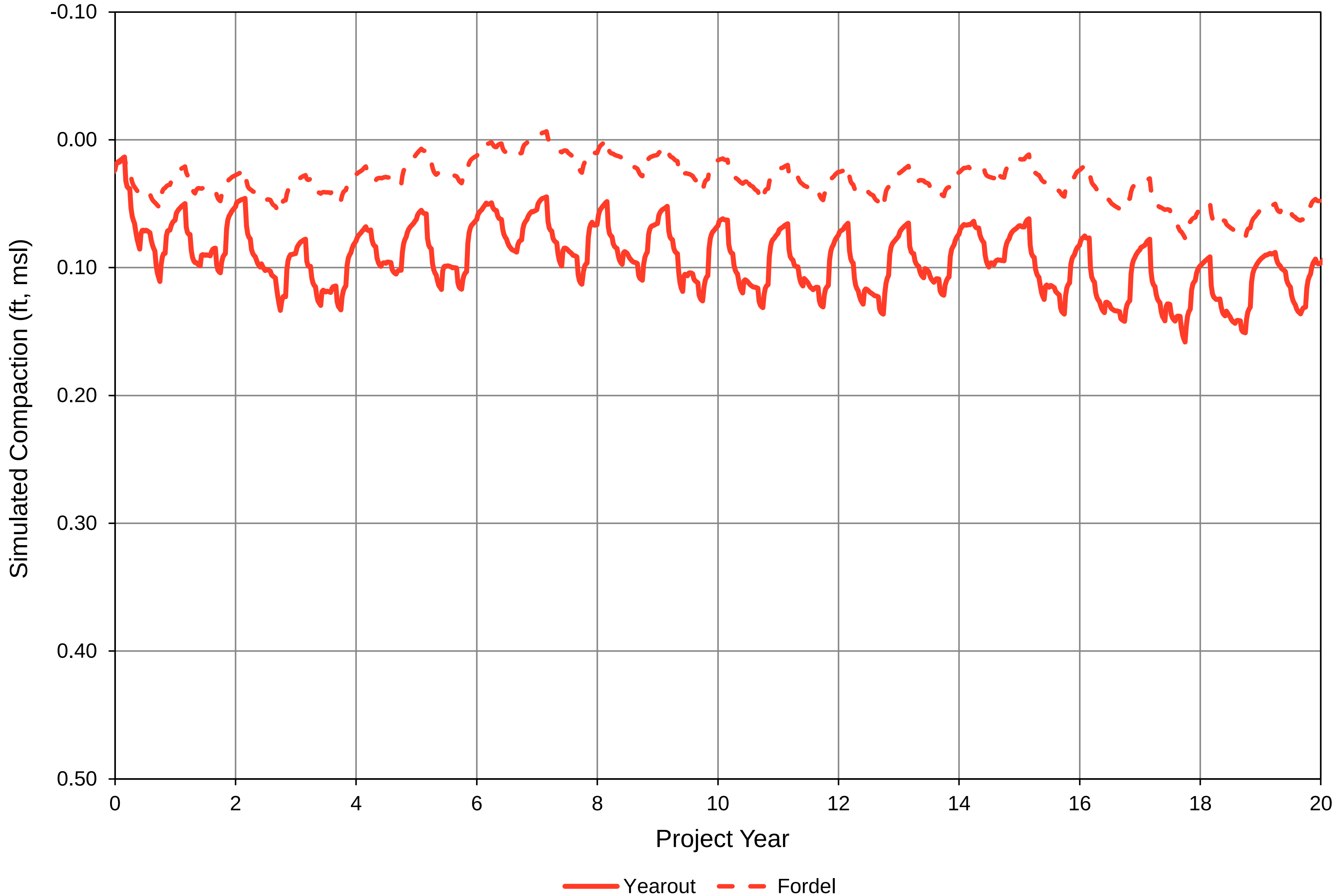

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Figure 9-44
No Action Simulated Compaction Above the Corcoran Clay (Cumulative Impacts)
Mendota Pool Group EIS/EIR

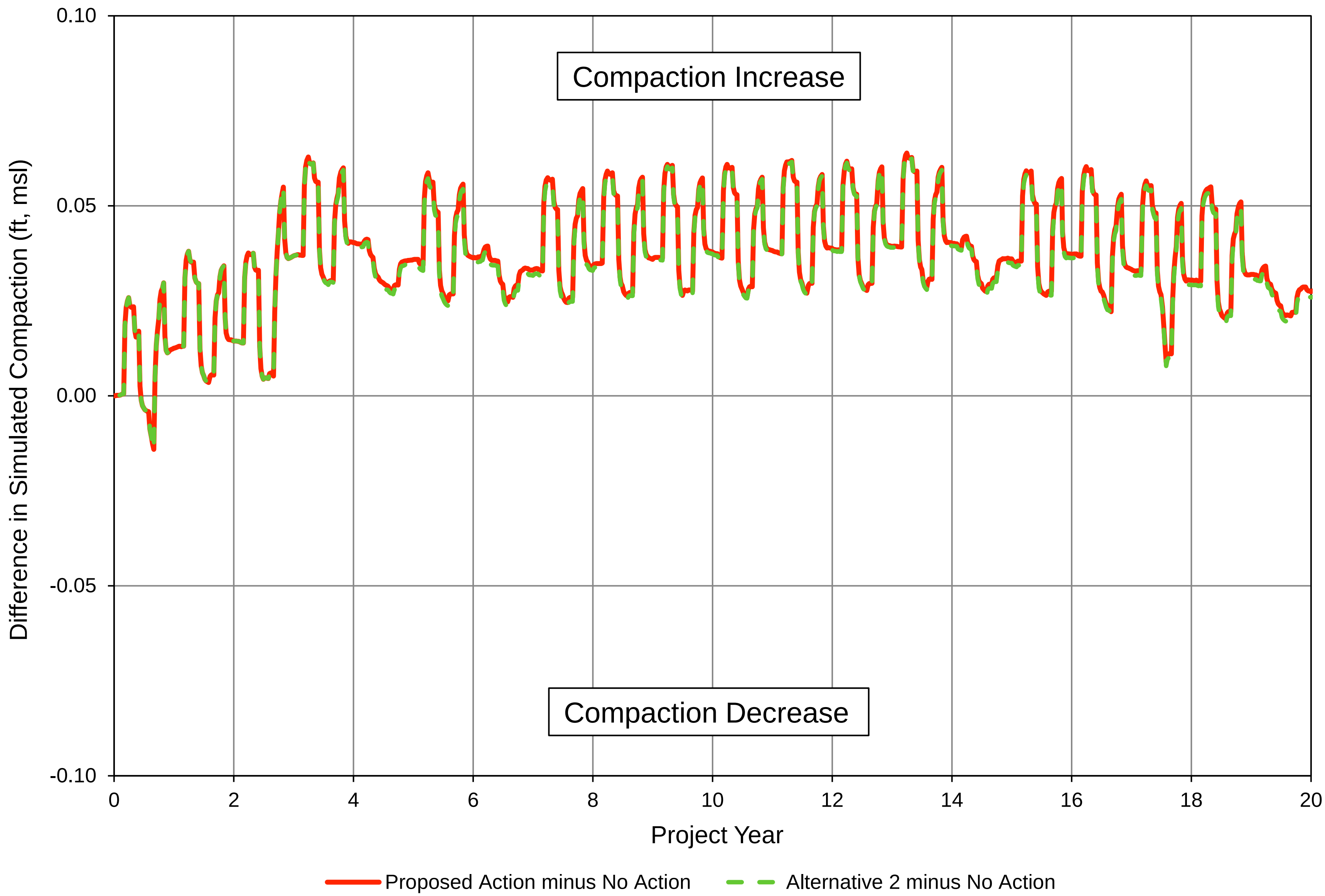

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Figure 9-45
Difference in Simulated Compaction Above the Corcoran Clay at Yearout (Cumulative Impacts)
Mendota Pool Group EIS/EIR

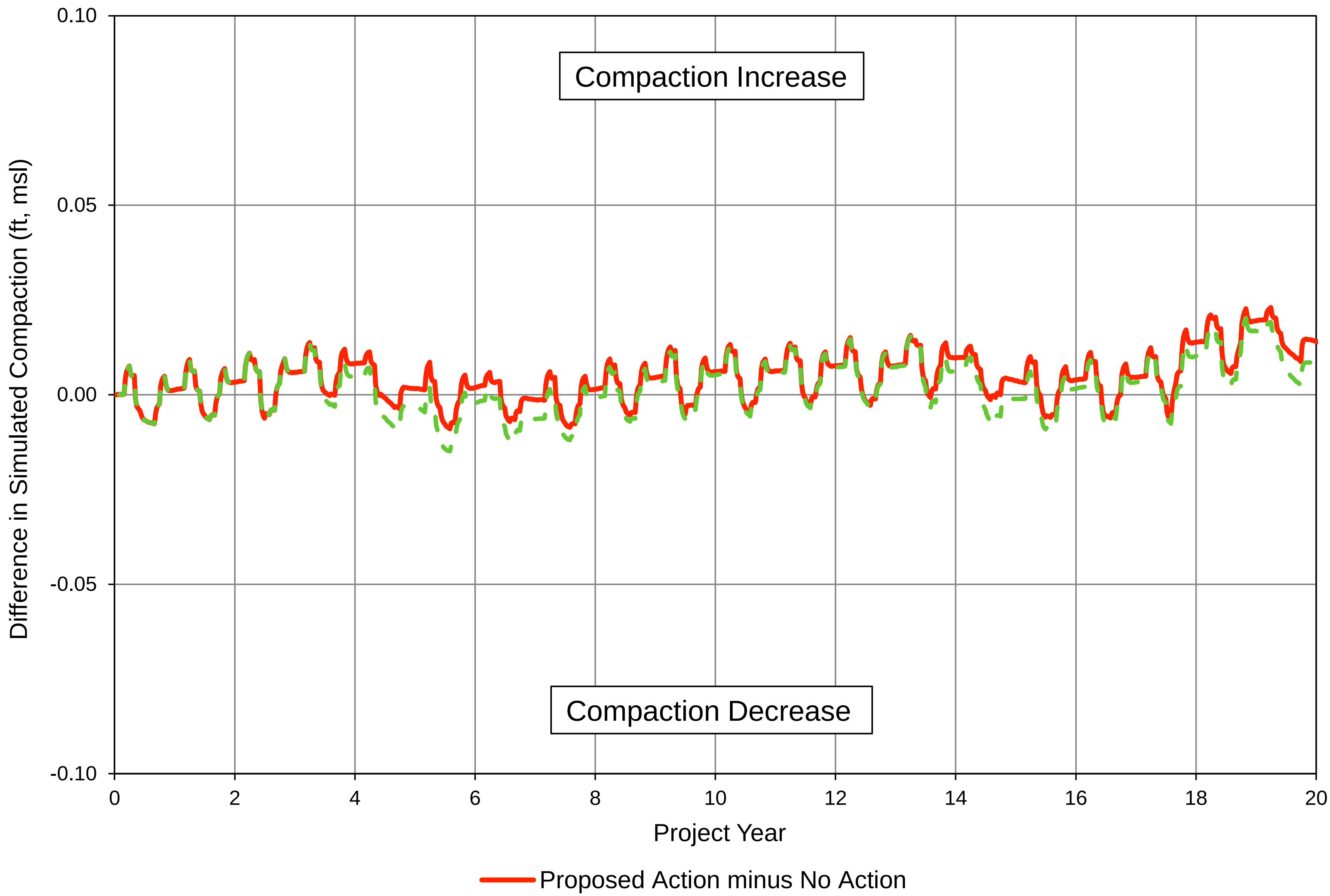

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Figure 9-46
Difference in Simulated Compaction Above the Corcoran Clay at Fordel (Cumulative Impacts)
Mendota Pool Group EIS/EIR

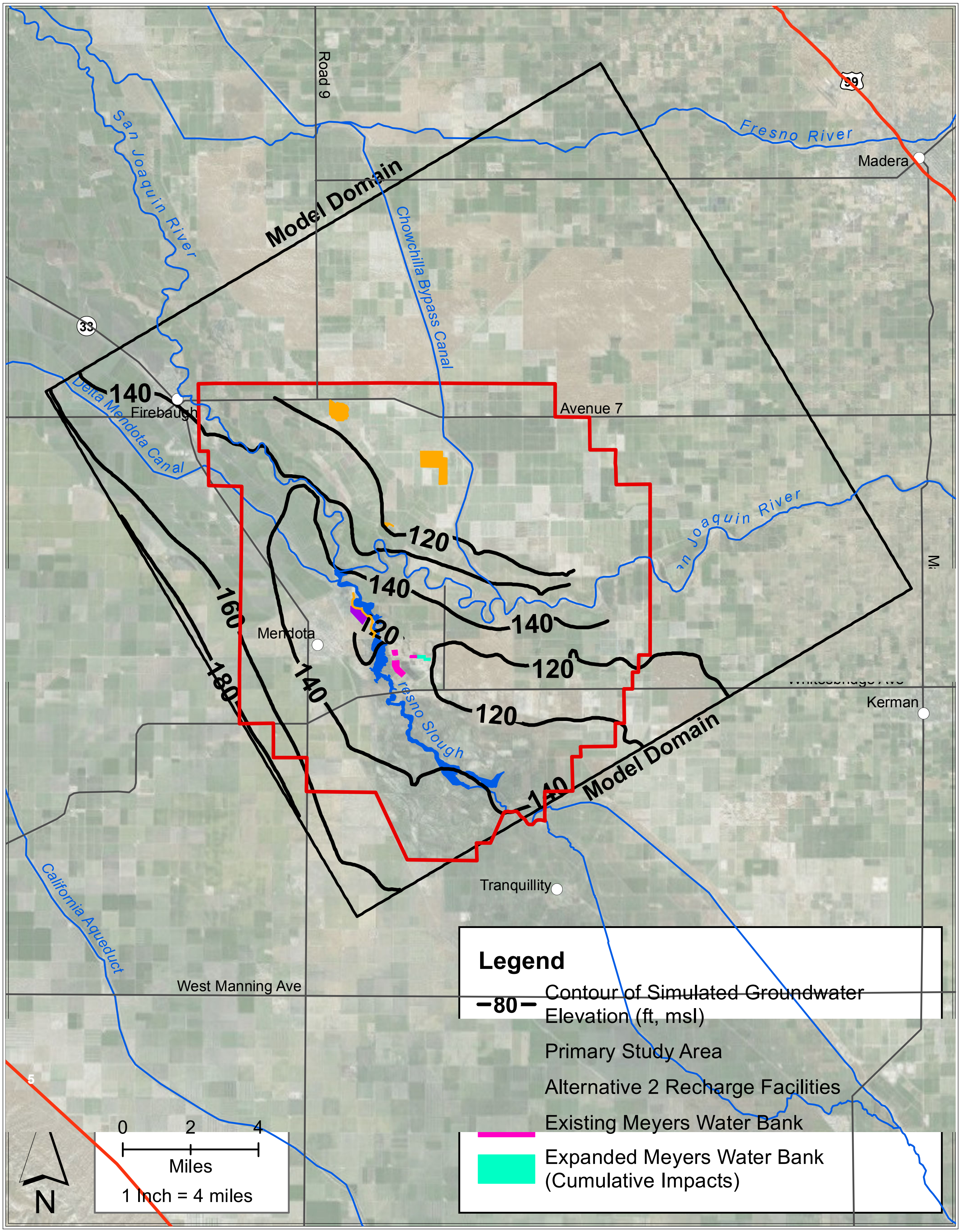

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Figure 9-47
Alternative 2 Contours of Equal Simulated Groundwater Elevation Shallow Zone, Year 20 (Cumulative Impacts)

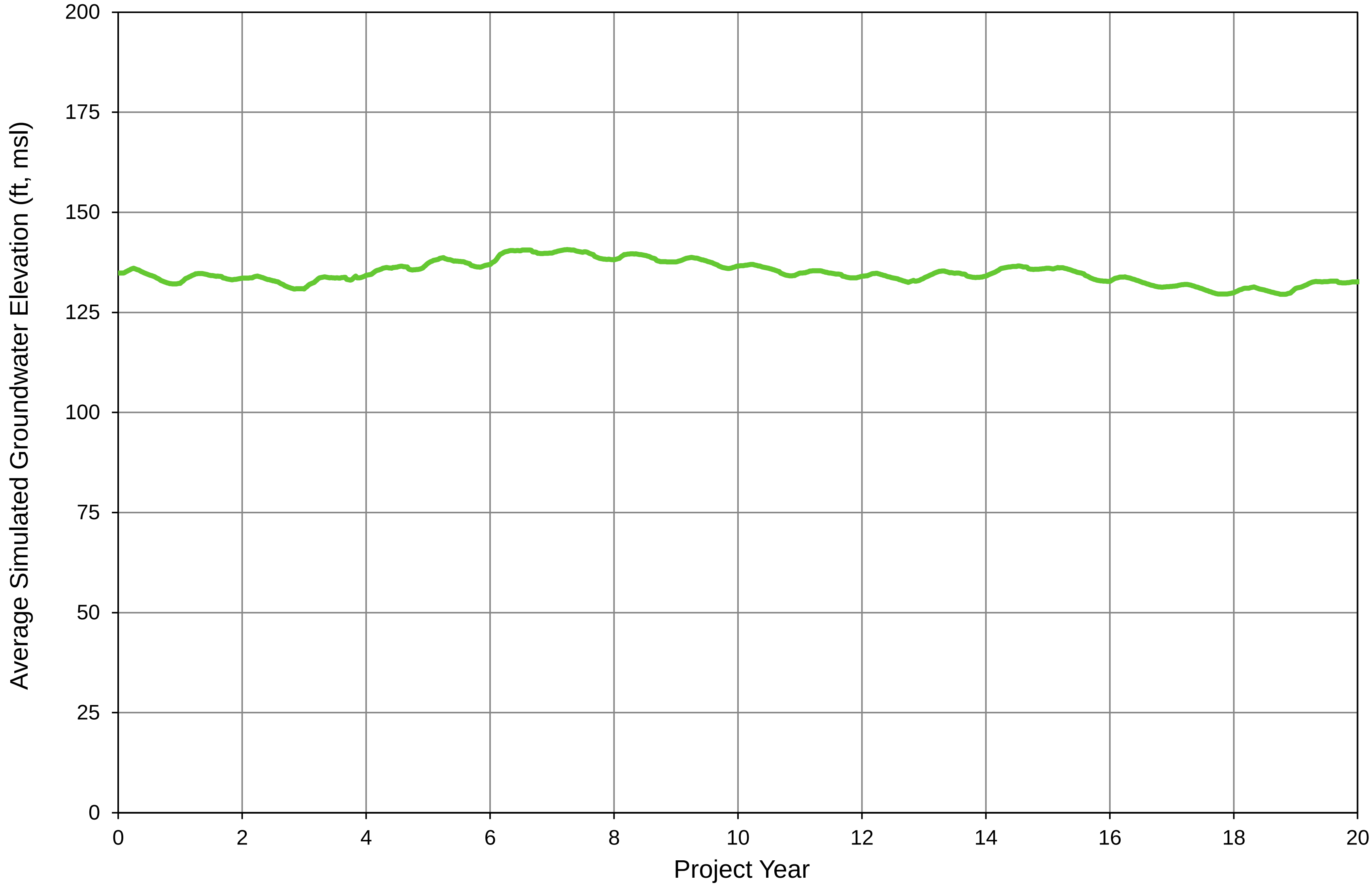

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Figure 9-48
Alternative 2 Average Simulated Groundwater Elevation
In the Primary Study Area, Shallow Zone (Cumulative Impacts)
Mendota Pool Group EIS/EIR

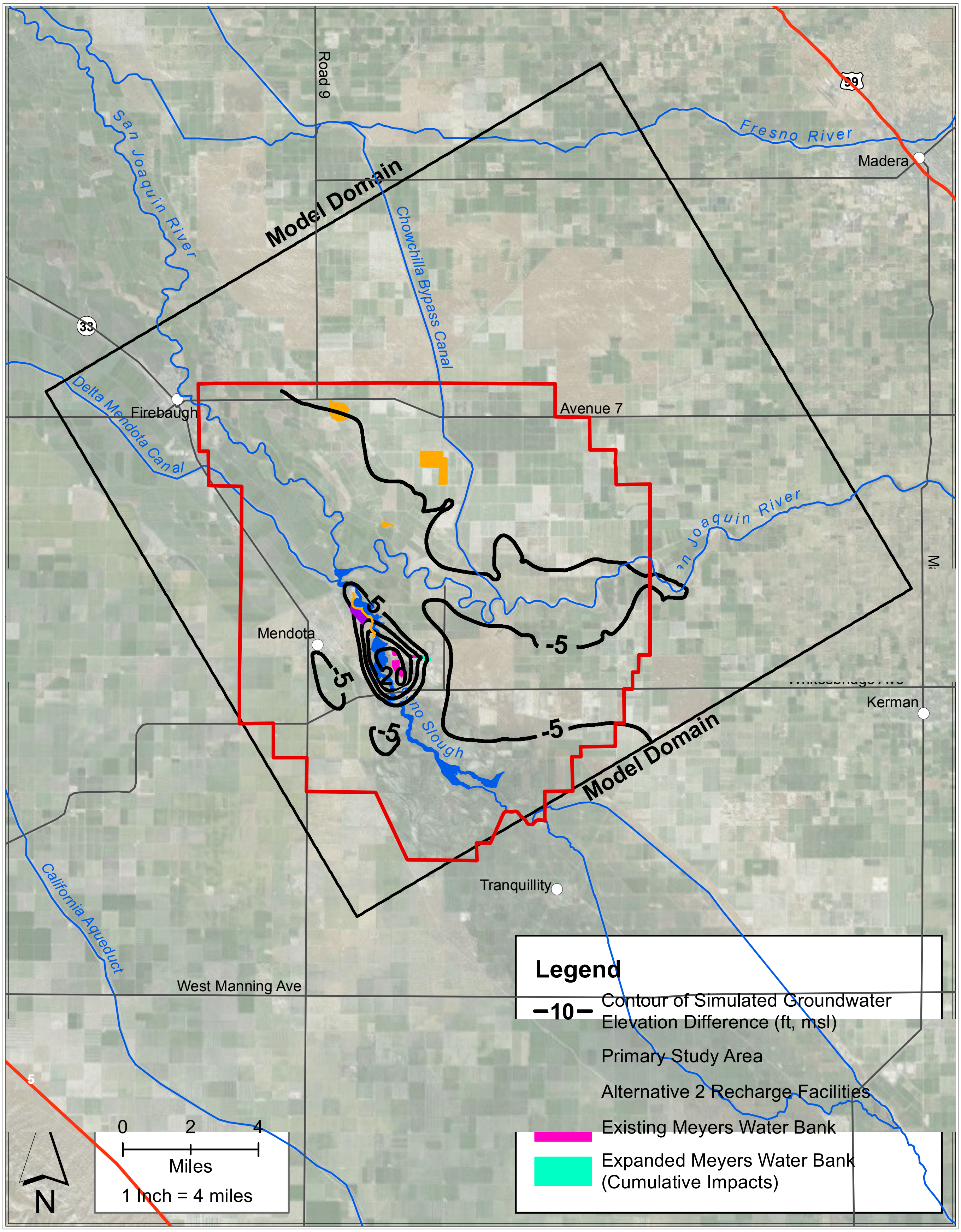

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Figure 9-49
Alternative 2 Contours of Equal Simulated Change in Groundwater Elevation Shallow Zone, Year 1 to Year 20 (Cumulative Impacts)

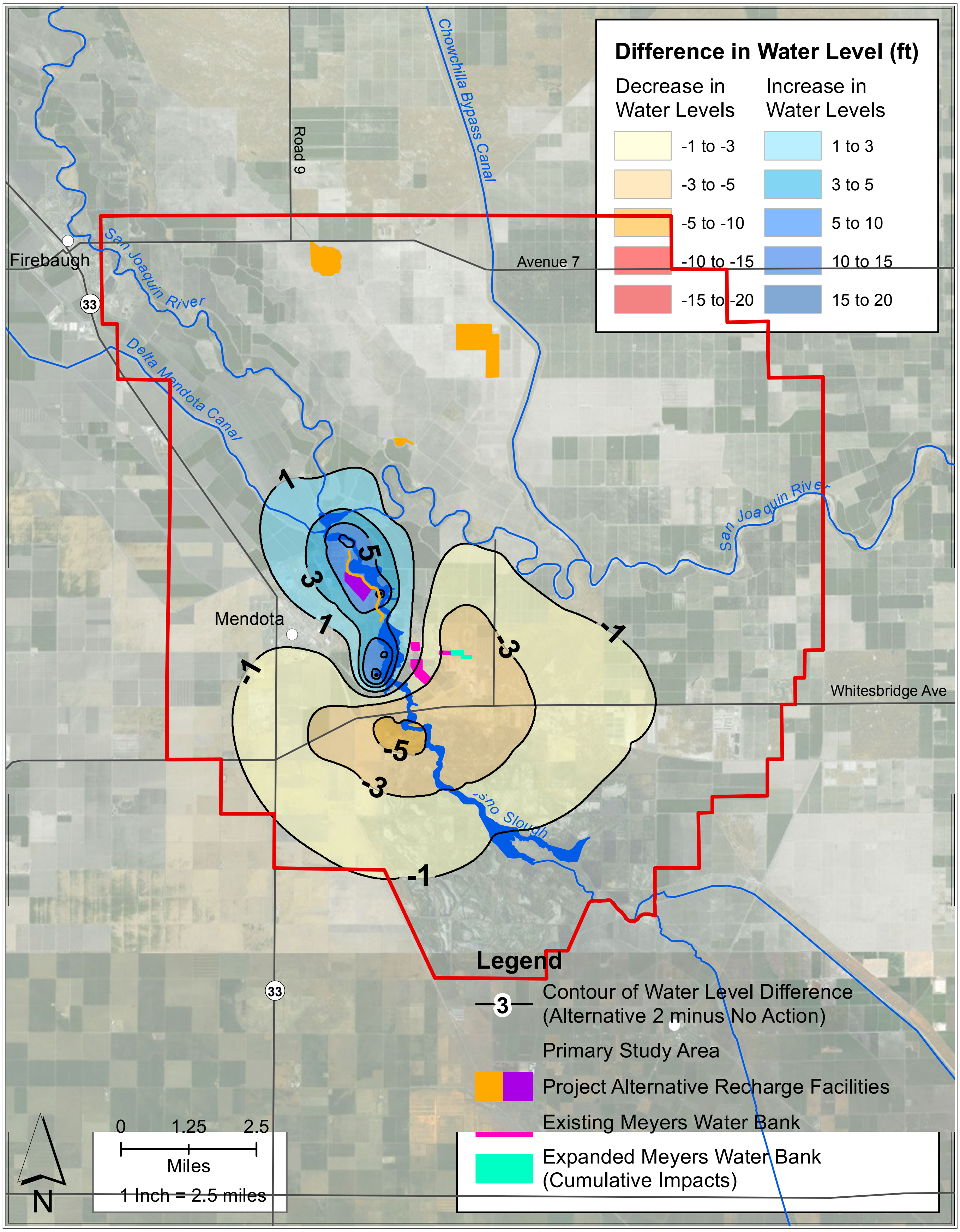

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Figure 9-50
Alternative 2 Contours of Equal Simulated Groundwater Elevation Difference Shallow Zone, Year 20 (Cumulative Impacts)

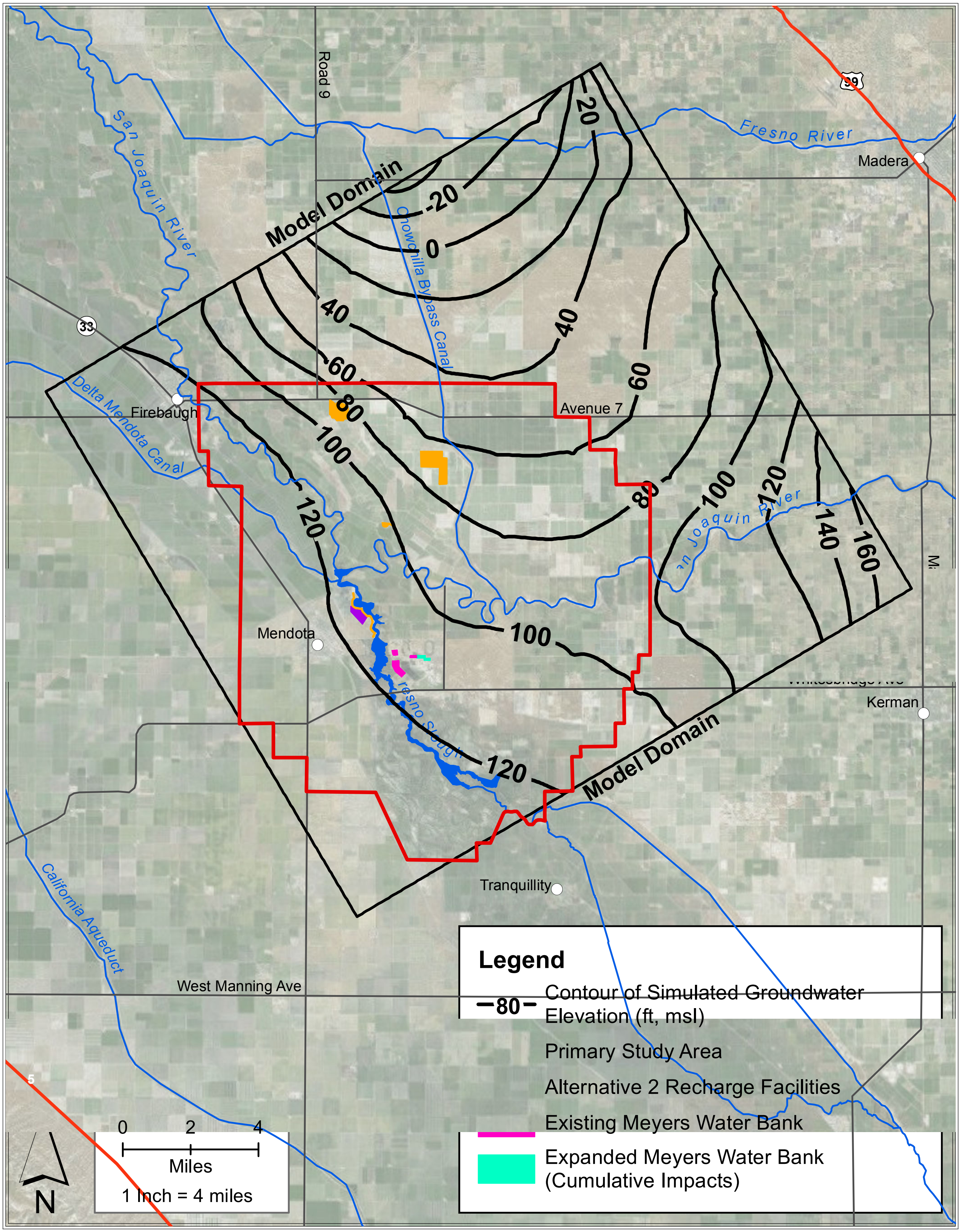

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Figure 9-51
Alternative 2 Contours of Equal Simulated Groundwater Elevation Deep Zone, Year 20 (Cumulative Impacts)

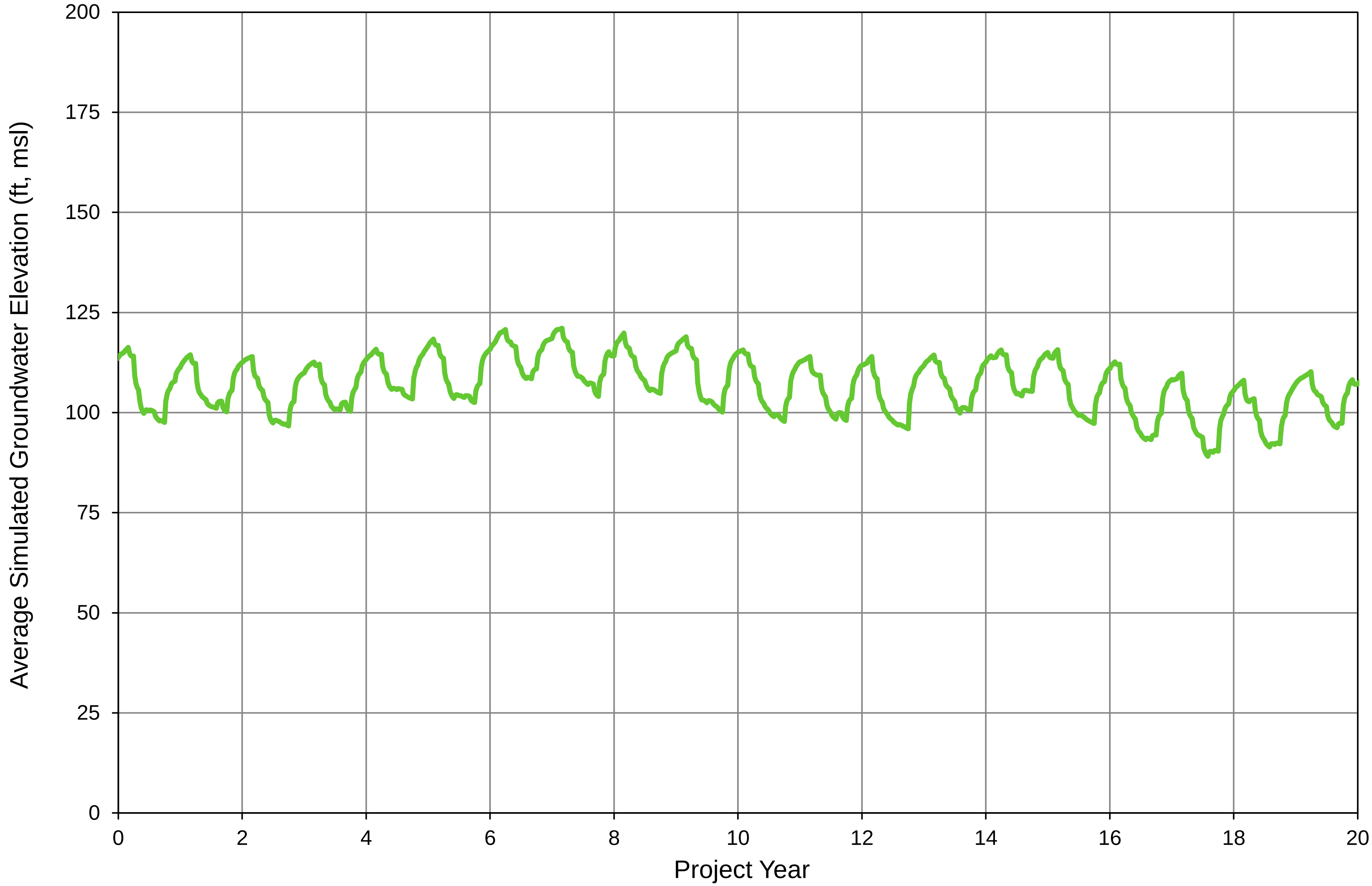

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Figure 9-52
Alternative 2 Average Simulated Groundwater Elevation
In the Primary Study Area, Deep Zone (Cumulative Impacts)
Mendota Pool Group EIS/EIR

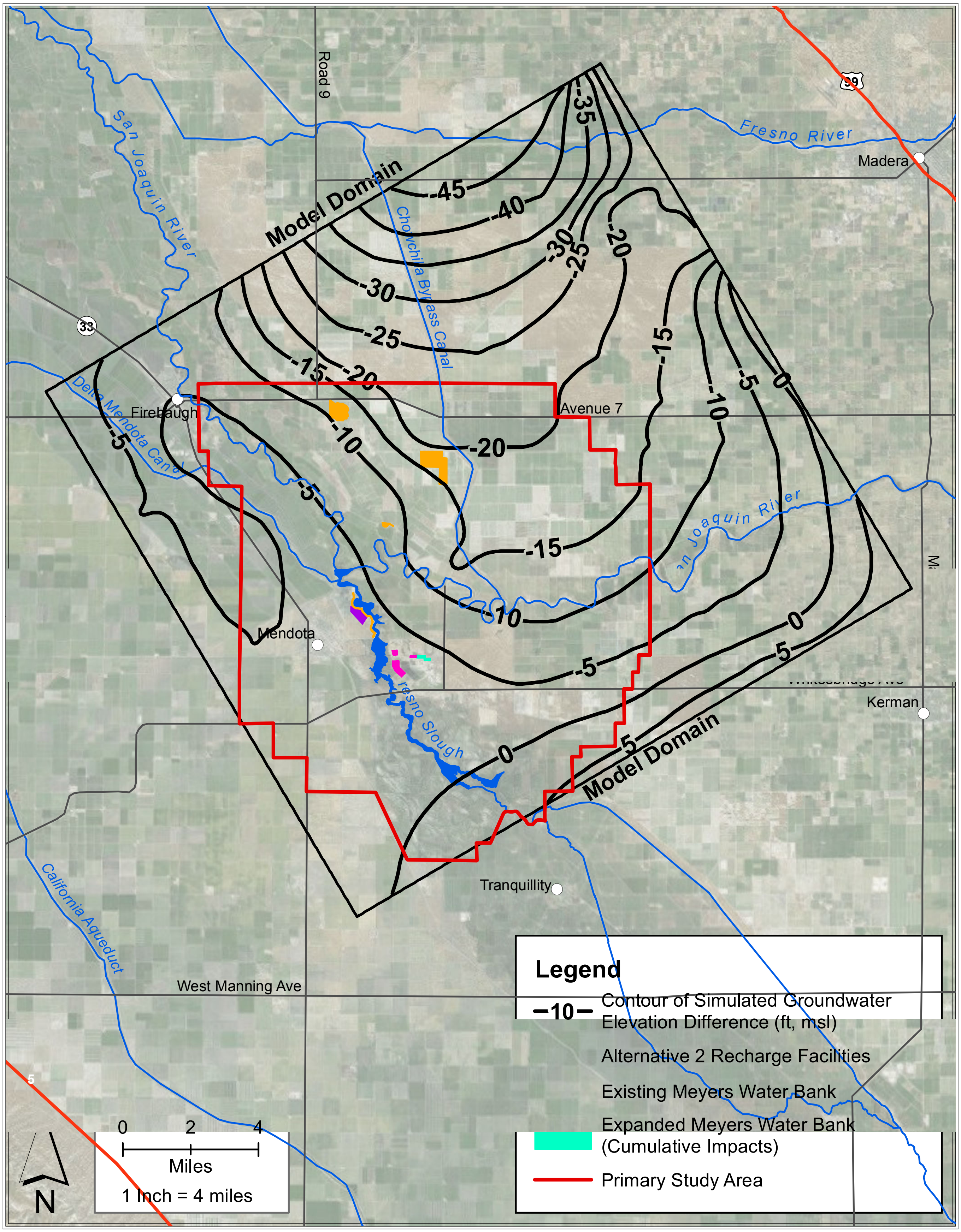

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Figure 9-53
Alternative 2 Contours of Equal Simulated Change in Groundwater Elevation Shallow Zone, Year 1 to Year 20 (Cumulative Impacts)

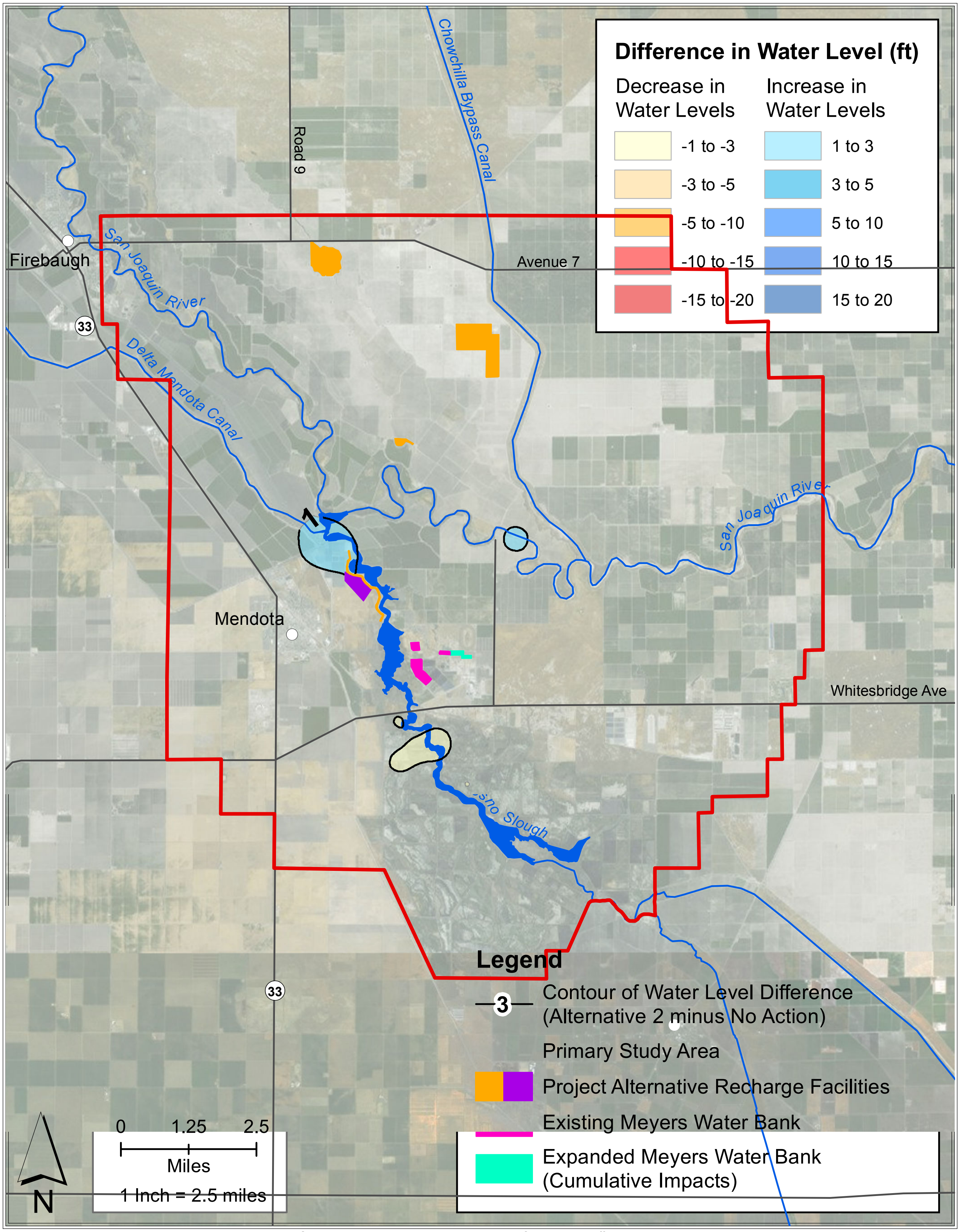

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Figure 9-54
Alternative 2 Contours of Equal Simulated Groundwater Elevation Difference Deep Zone, Year 20 (Cumulative Impacts)

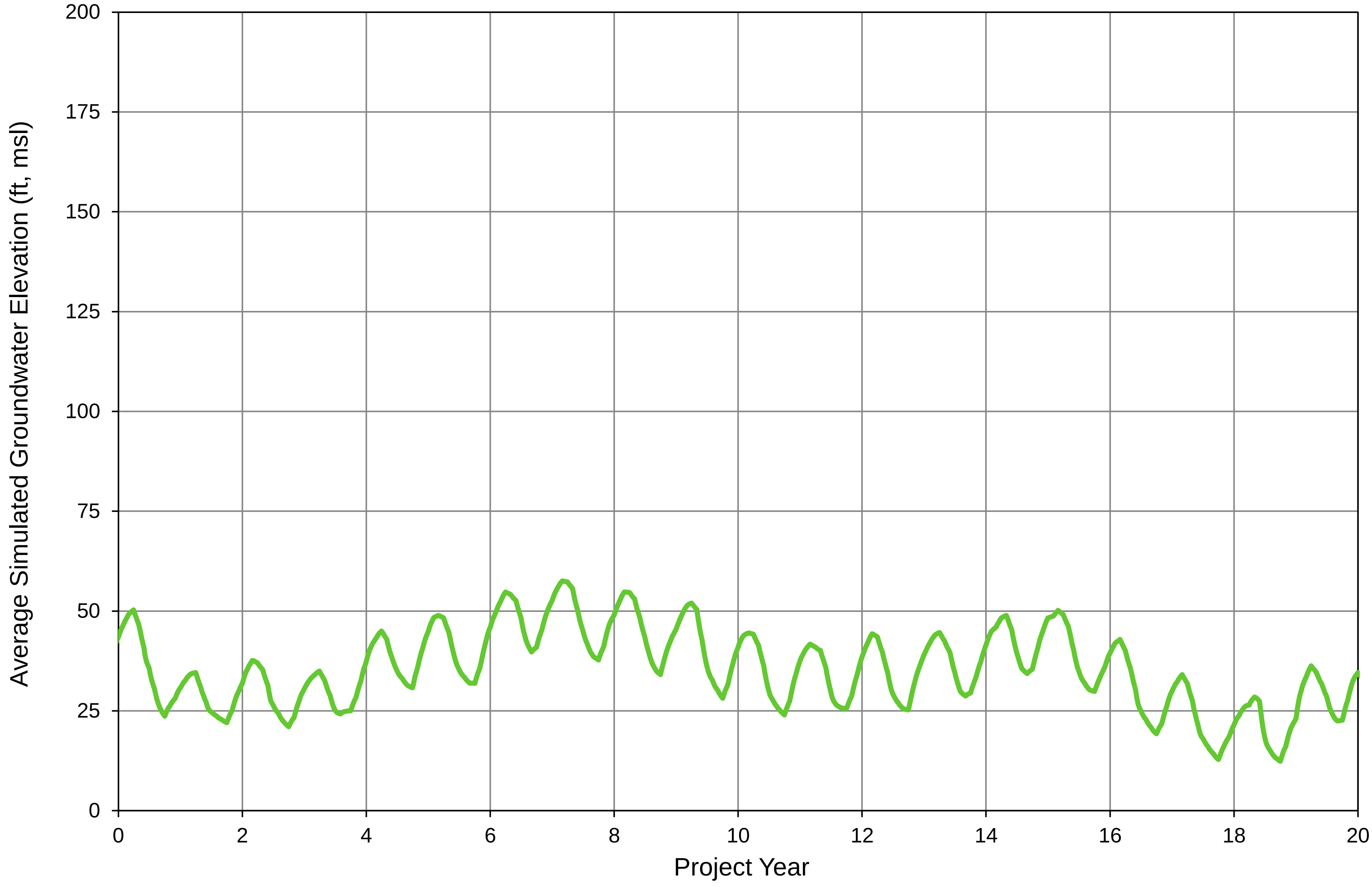

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Figure 9-55
Alternative 2 Average Simulated Groundwater Elevation
In the Primary Study Area, Lower Aquifer (Cumulative Impacts)
Mendota Pool Group EIS/EIR

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Figure 9-56
Alternative 2 Simulated TDS Concentration
Shallow Zone, Year 20 (Cumulative Impacts)

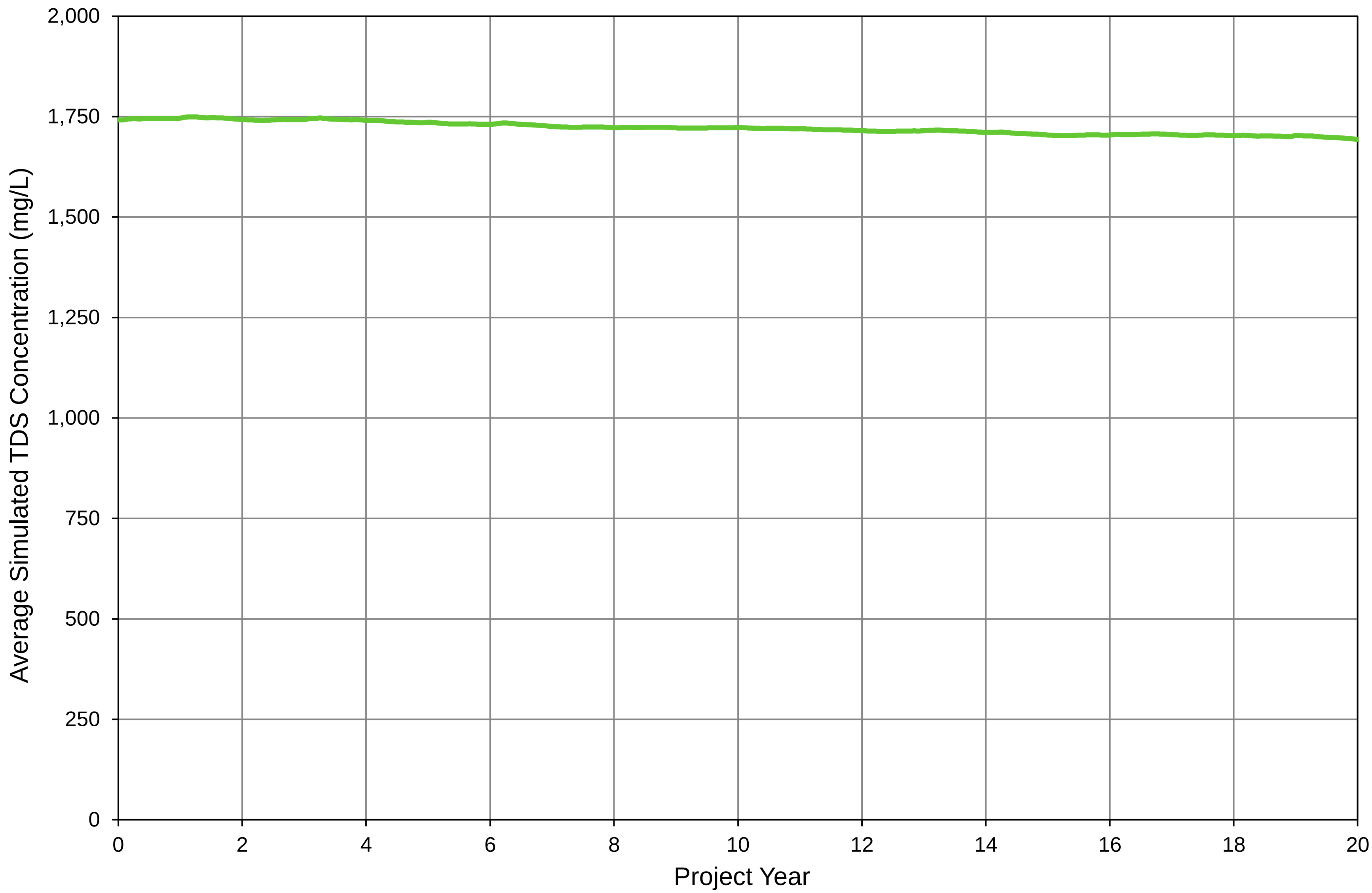

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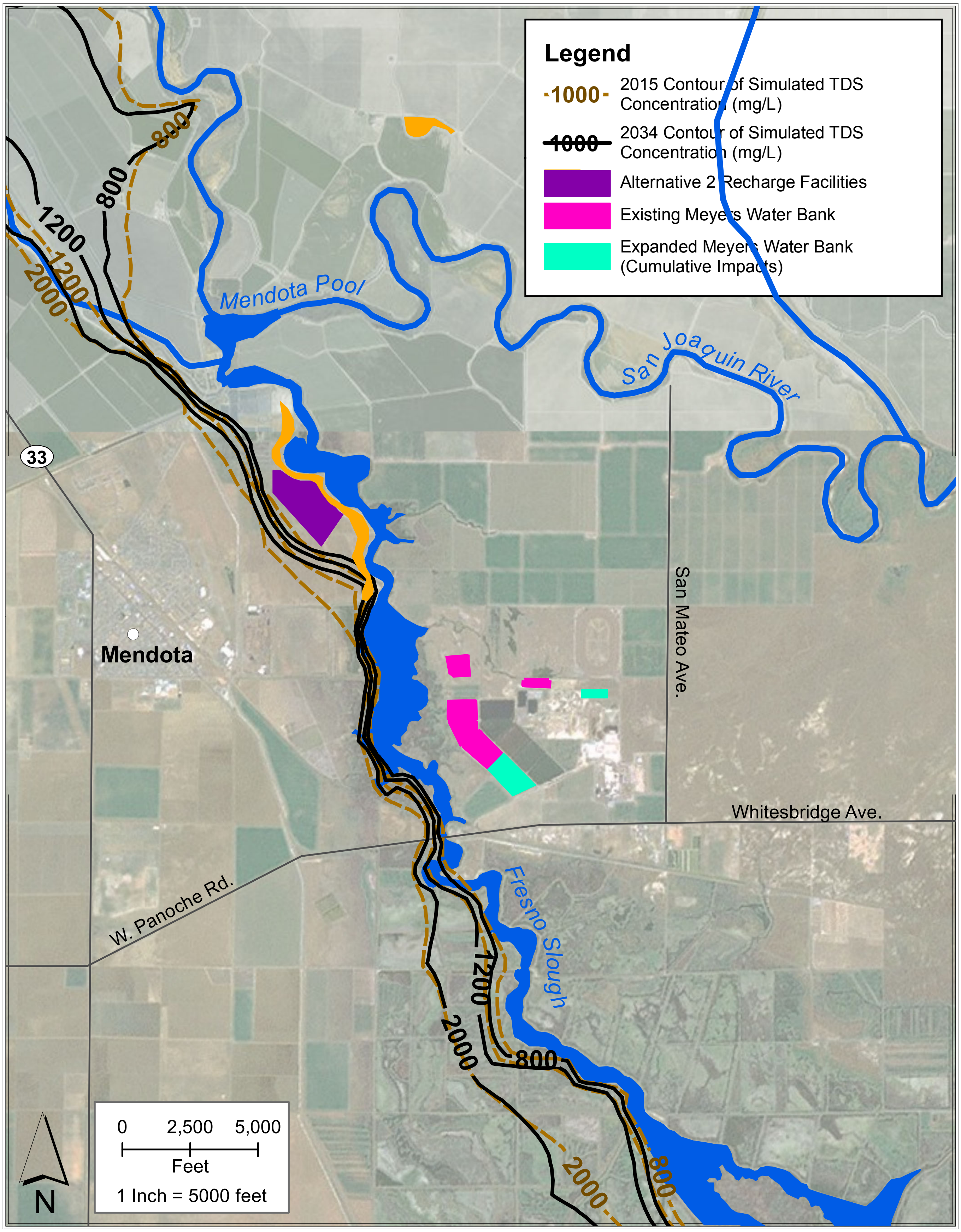
Figure 9-57
Alternative 2 Average Simulated TDS Concentration
In the Primary Study Area, Shallow Zone (Cumulative Impacts)
Mendota Pool Group EIS/EIR



Document Path: J:\Mendota\ModelingFigures_V3\MXDs\Section_9\Figure_9-58_Shallow_Alternative2Cumulative_TDS_2034.mxd

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Figure 9-58
Alternative 2 Contours of Equal Simulated TDS Concentration Shallow Zone, Year 20 (Cumulative Impacts)

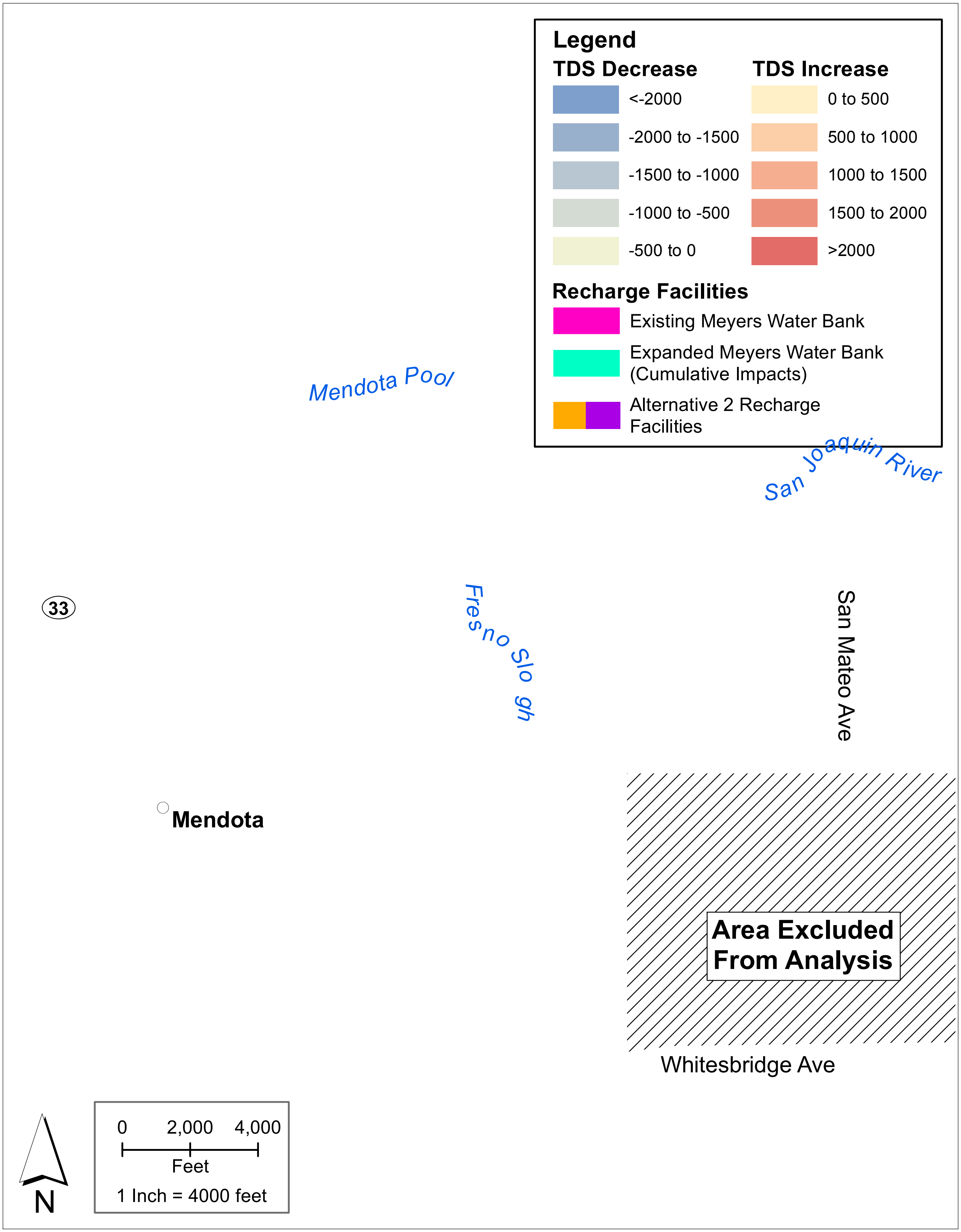

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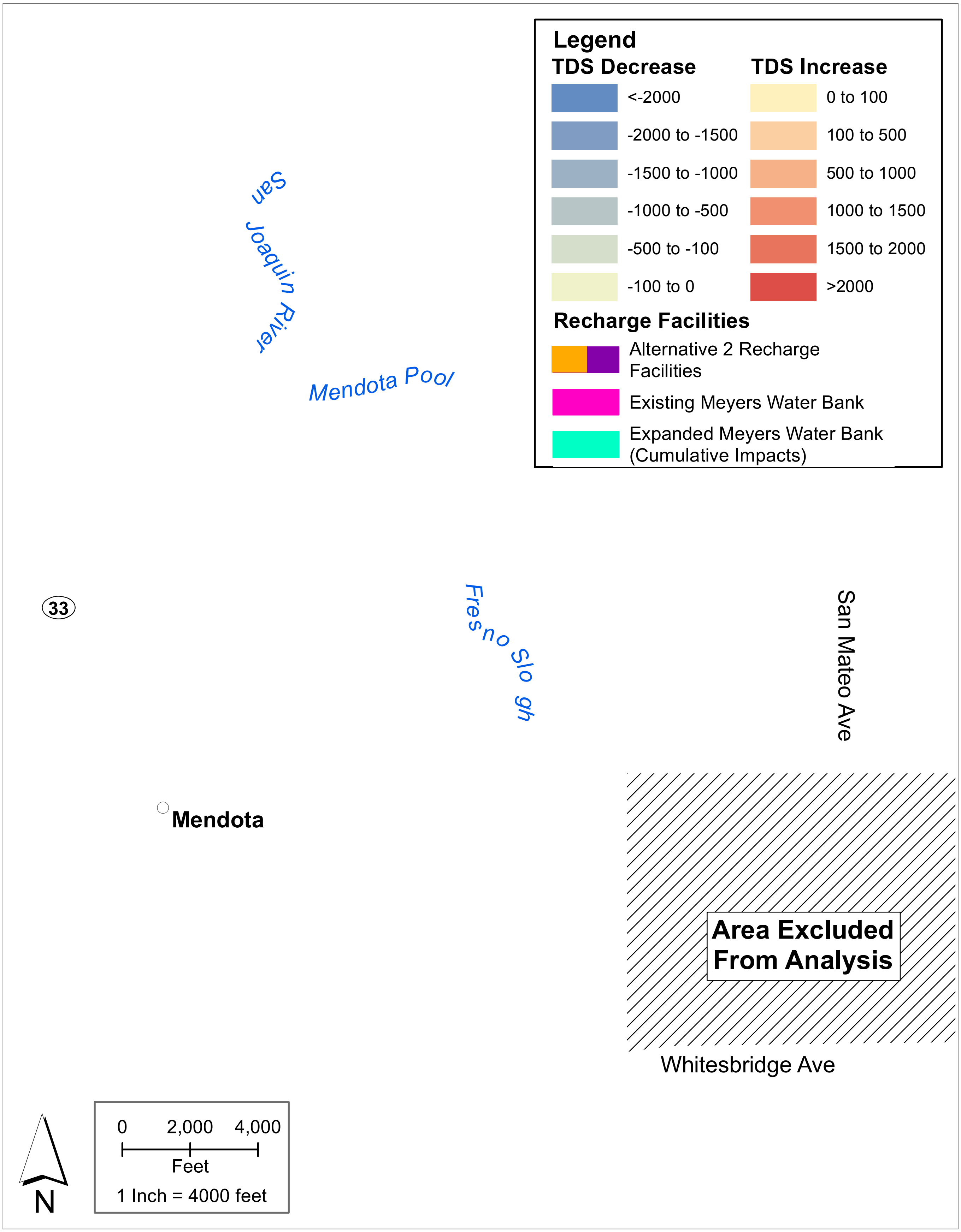
Figure 9-59
Alternative 2 Simulated Change in TDS Concentration from Year 1 to Year 20 Shallow Zone (Cumulative Impacts)



Document Path: J:\Mendota\ModelingFigures_V3\MXDs\Section_9\Figure_9-60_Shallow_Difference_Flood_Alternative2.mxd

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Figure 9-60
Simulated TDS Difference by Year 20
Alternative 2 minus No Action
Shallow Zone (Cumulative Impacts)

Document Path: J:\Mendota\ModelingFigures_V3\MXDs\Section_9\Figure_9-61_Deep_Flood_Alternative2Cumulative.mxd

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Figure 9-61
Alternative 2 Simulated TDS Concentration
Deep Zone, Year 20 (Cumulative Impacts)

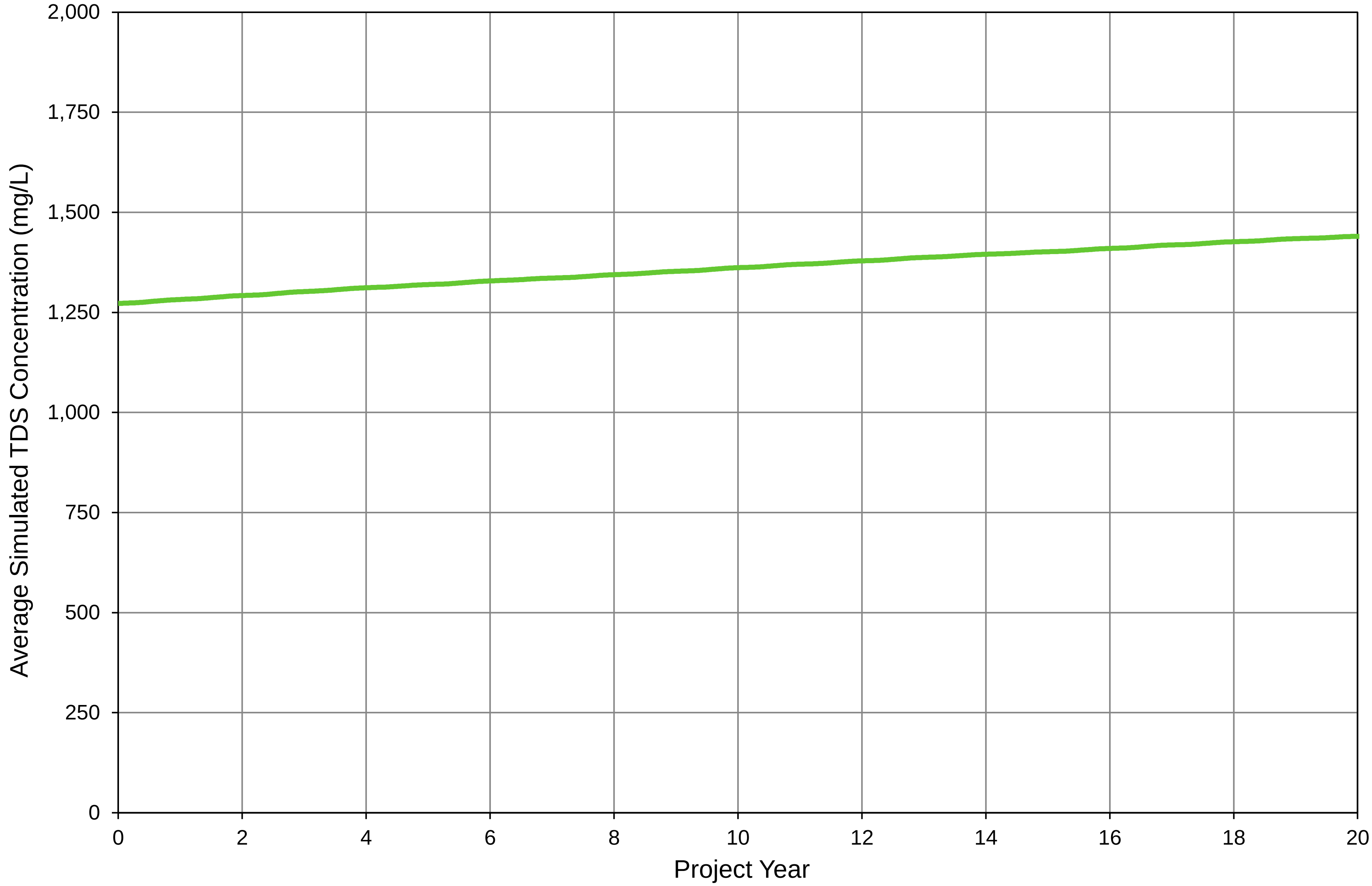

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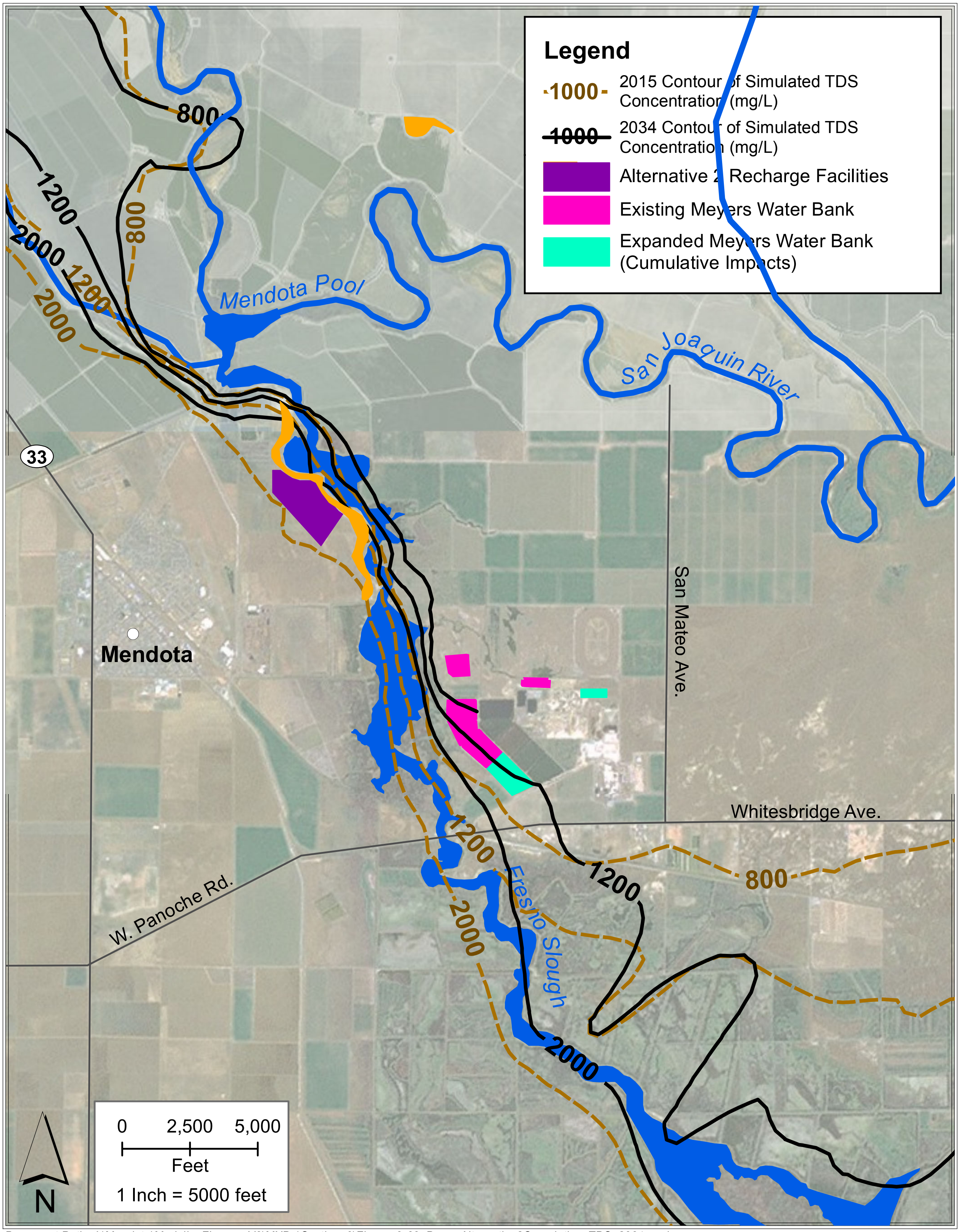
Figure 9-62
Alternative 2 Average Simulated TDS Concentration
In the Primary Study Area, Deep Zone (Cumulative Impacts)
Mendota Pool Group EIS/EIR



Document Path: J:\Mendota\ModelingFigures_V3\MXDs\Section_9\Figure_9-63_Deep_Alternative2Cumulative_TDS_2034.mxd

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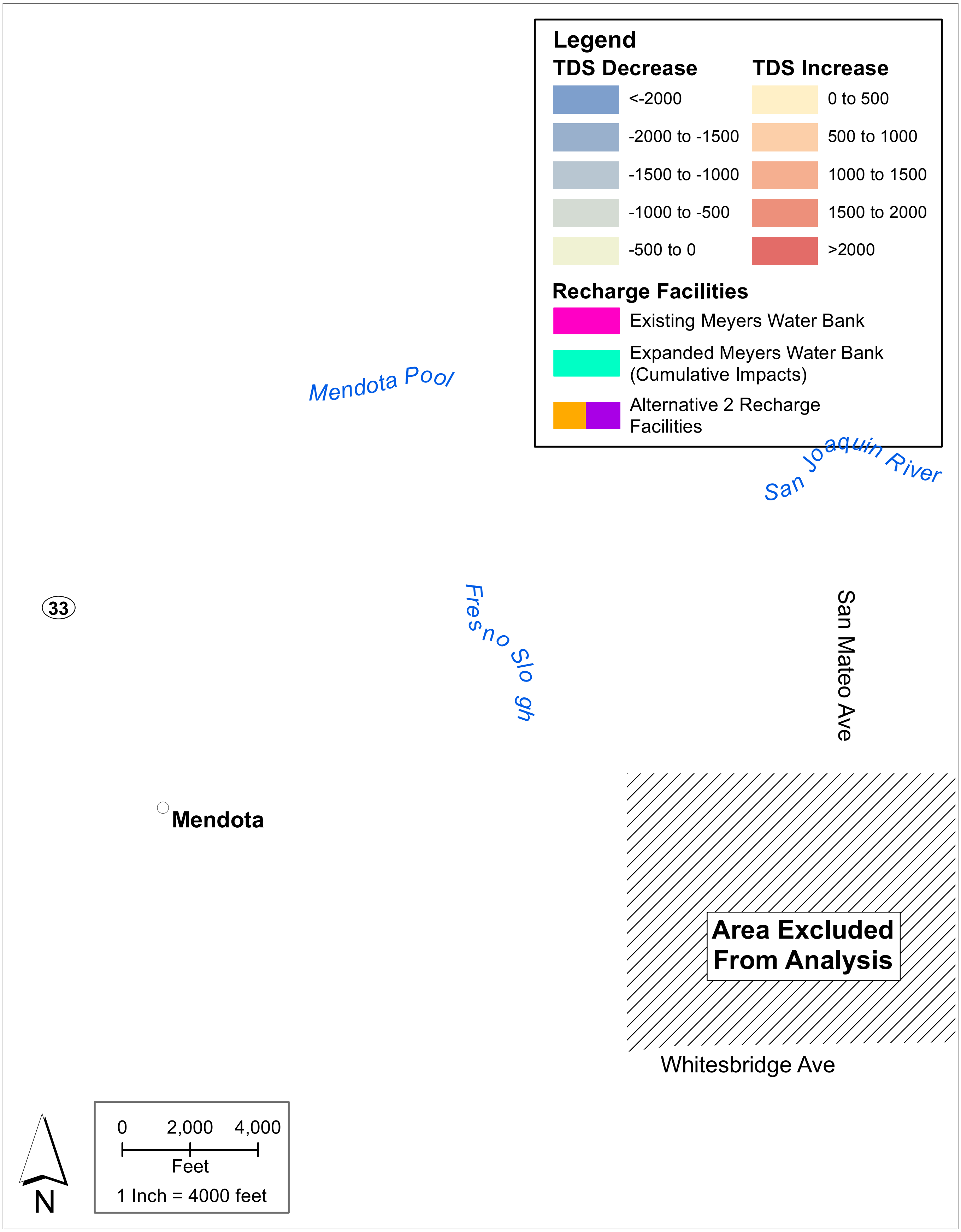
Figure 9-63
Alternative 2 Contours of Equal Simulated TDS Concentration Deep Zone, Year 20 (Cumulative Impacts)



Document Path: J:\Mendota\ModelingFigures_V3\MXDs\Section_9\Figure_9-64_Deep_Difference_Flood_Alternative2Cumulative.mxd

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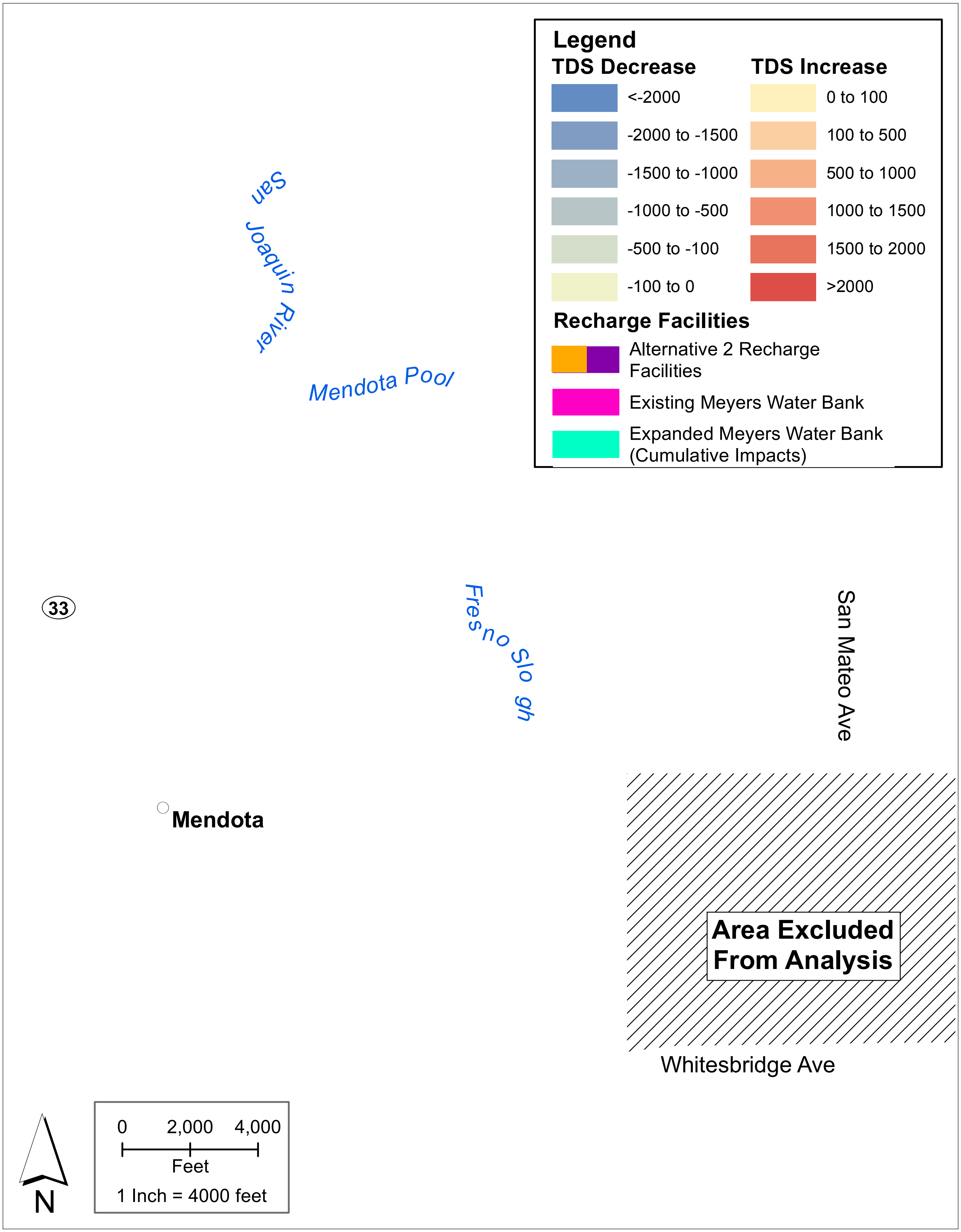
Figure 9-64
Alternative 2 Simulated Change in TDS Concentration from Year 1 to Year 20 Deep Zone (Cumulative Impacts)



Document Path: J:\Mendota\ModelingFigures_V3\MXDs\Section_9\Figure_9-65_Shallow_Difference_Flood_Alternative2.mxd

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Figure 9-65
Simulated TDS Difference by Year 20
Alternative 2 minus No Action
Deep Zone (Cumulative Impacts)

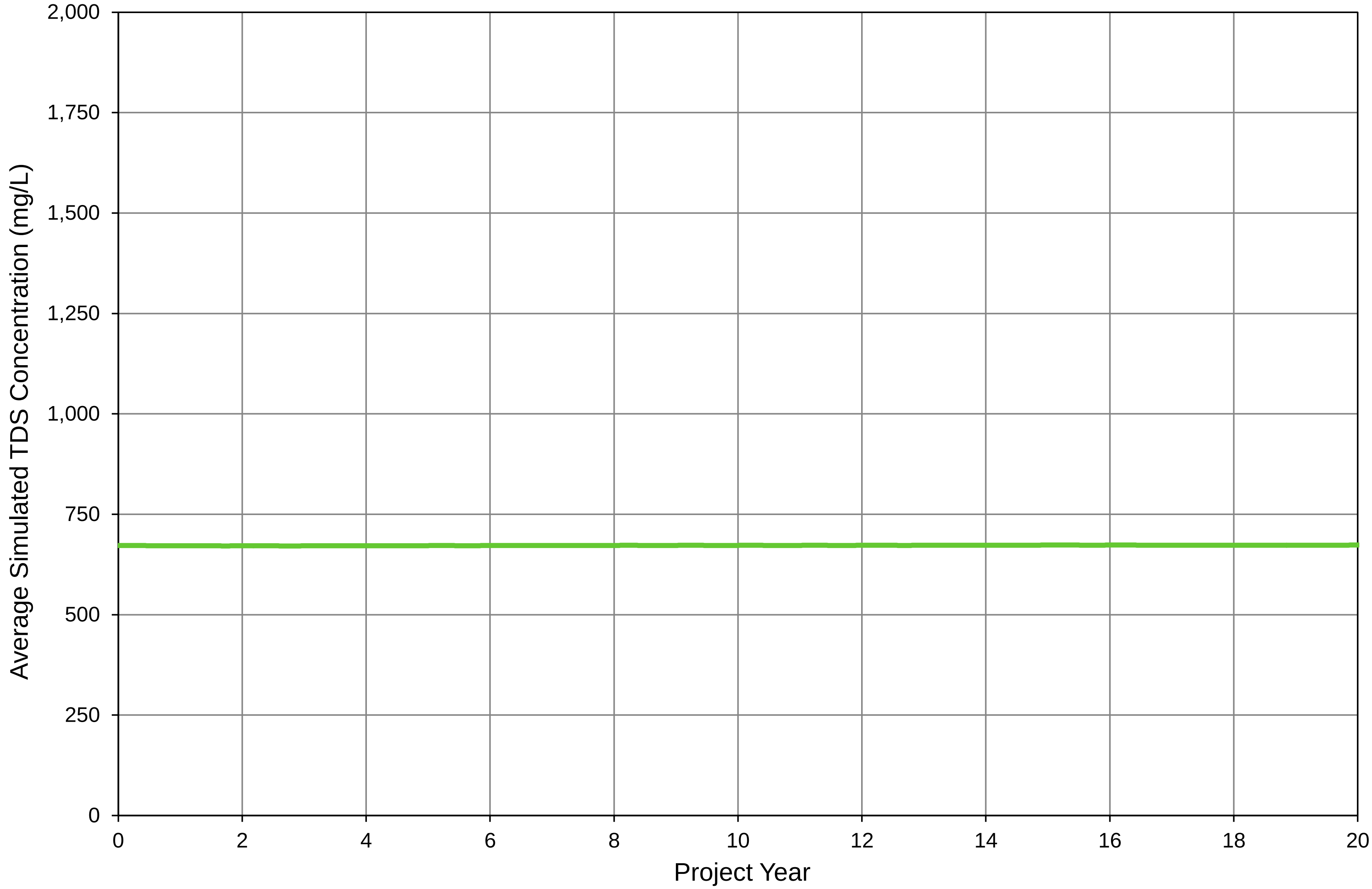

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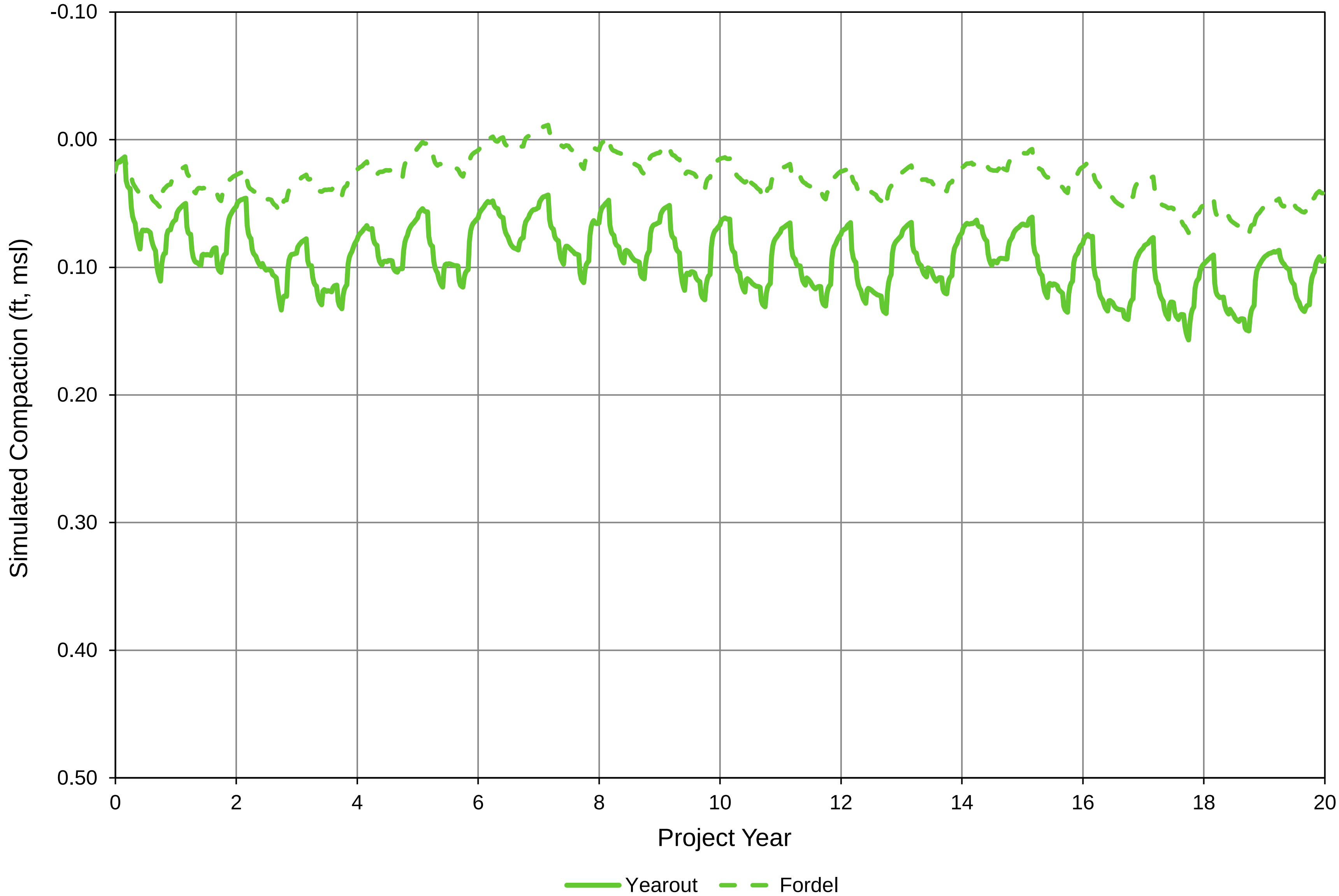
Figure 9-66
Alternative 2 Average Simulated TDS Concentration
In the Primary Study Area, Lower Aquifer (Cumulative Impacts)
Mendota Pool Group EIS/EIR



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Consulting Engineers

Figure 9-67
Alternative 2 Simulated Compaction Above the Corcoran Clay (Cumulative Impacts)
Mendota Pool Group EIS/EIR

10 SUMMARY OF PROJECT IMPACTS

The effect of the Project scenarios on groundwater and surface water features are summarized below utilizing the data and information presented in chapters 7, 8, and 9. The summary of the impacts from the No Action, Proposed Action, and Alternative 2 are organized into effects on groundwater levels, groundwater quality, subsidence in the form of compaction above the Corcoran Clay, and surface water quality at the Mendota Dam and the MWA. The three scenarios run under the Existing Conditions exhibited a greater amount of groundwater level declines, groundwater quality degradation (primarily in the shallow zone), and subsidence than those run under the Cumulative Impacts.

10.1 Groundwater Levels

The effect on groundwater levels from the Project scenarios (No Action, Proposed Action, and Alternative 2) are greater under the Existing Condition compared to the Cumulative Impacts. All three Project scenarios in the Existing Condition result in groundwater levels in the shallow and deep zones declining over the project period in varying degrees in the PSA. In the Existing Condition, the decline in groundwater levels over the project period in all the scenarios is caused by a number of factors including combined pumping of groundwater resources by all the various non-MPG and MPG landowners in the model domain and PSA along with regional influences on groundwater levels from groundwater pumping occurring outside the model domain. The average decline and variation in groundwater levels in the shallow and deep zones in the PSA is similar among the three scenarios which indicates that the MPG exchange program contributes very little to the overall long term decline in groundwater levels in the PSA and model domain during the simulation period. The overall decline in groundwater levels over the simulation period in all three scenarios (with or without the MPG exchange program) is about 5 ft in the shallow zone and about 10 ft in the deep zone. In the lower aquifer, impacts on groundwater levels are also similar between the three scenarios. The magnitude of the long term simulated declines in the lower aquifer are larger than those in the shallow and deep zones. However, this may be related to the assigned trends in groundwater levels at the boundaries of the model domain that reflect regional (and not PSA) conditions over the 20-year project period. Overall decline in the Cumulative Impacts was generally smaller than in the Existing Conditions, though relative impacts between scenarios were largely similar between the two. The projected long term declines in groundwater levels in all three aquifer zones will likely need to be addressed as part of a larger regional effort by groundwater sustainability agencies (GSAs) to comply with the Sustainable Groundwater Management Act (SGMA) in the Delta-Mendota subbasin and other adjacent subbasins.

The magnitude and spatial distribution of declines in shallow zone groundwater levels over the project simulation period are similar among the three Project scenarios both in the PSA as a whole and among the subregions within the PSA. Recharge in MPG facilities west of the Fresno Slough lead to relative increases in water levels in the shallow zone in the Proposed Action and Alternative 2. However, impacts (particularly in the Proposed Action) are generally limited to the area surrounding the recharge facilities and do not significantly carry over to subsequent years. This is likely a result of the frequency of Kings River flood flows available for recharge purposes simulated in the Proposed Action and

Alternative 2 scenarios. In some subregions, especially those in the vicinity of the Pool, there is a greater amount of water level increases and decreases over time in the Proposed Action and Alternative 2 compared to the No Action. However, on a long term annual average basis these variations result in average changes in water levels that are similar to No Action average results on a subregion basis.

The magnitude and spatial distribution of Project (from all three scenarios) impacts on deep zone groundwater levels are also similar among all three Project scenarios within the PSA as a whole and also among each of the subregions. The influence of artificial recharge from the MPG recharge facilities simulated in the Proposed Action and Alternative 2 scenarios is not as pronounced in the deep zone as in the shallow zone. In some subregions, especially those in the vicinity of the Pool, there is a greater amount of water level increases and decreases over time in the Proposed Action and Alternative 2 compared to the No Action. However, on a long term annual average basis these variations result in average changes in water levels that are similar to No Action average results on a subregion basis.

10.2 Groundwater Quality

Groundwater quality in the PSA is similar among all three scenarios (No Action, Proposed Action, and Alternative 2) over the project simulation period. This indicates that MPG exchange pumping is generally projected to have little influence on regional groundwater quality in the model domain and PSA in general. However, more significant impacts are simulated on the subregional scale – mostly in the shallow zone west of the Fresno Slough, and deep zone east of the Fresno Slough.

The similarity in the magnitude of long-term average annual changes in groundwater quality over the project period among all the scenarios is caused by a number of factors including pumping of groundwater resources by all the various non-MPG and MPG landowners in the model domain and PSA along with regional influences from groundwater pumping occurring outside the model domain. The average change in groundwater quality in the shallow zone, deep zone, and lower aquifer in the PSA varies little among the three scenarios which indicates that the MPG exchange program as simulated in the Proposed Action and Alternative 2 runs will contribute very little to changes in groundwater quality in the PSA during the simulation period.

When evaluating groundwater quality by zone, all three scenarios result in a small improvement in shallow zone groundwater quality in the form of TDS concentrations under both Existing Conditions and Cumulative Impacts. This improvement is slightly greater under Cumulative Impacts Conditions (about 45 to 55 mg/L over 20 years) than under the Existing Conditions (20 to 30 mg/L over 20 years). In the deep zone, all three scenarios cause similar levels of degradation (increase in average TDS concentrations) over the 20-year project period. The magnitude of degradation as expressed by average TDS concentrations is slightly greater under the Existing Conditions scenarios (200 to 210 mg/L) compared to the Cumulative Impacts scenarios (about 160 to 170 mg/L).

When evaluating groundwater quality on a subregion basis within the PSA, there are more pronounced differences in simulated groundwater quality between scenarios in both the shallow and deep zones. These differences are most pronounced west and east of the Fresno Slough and in the MWA in the form of average concentrations and in relative differences between Proposed Action and No Action and between Alternative 2 and No Action. Other subregions show little difference in either long-term (over the proposed project period) average TDS concentrations or relative differences between the No Action and the other two scenarios.

The subregion west of the Fresno Slough exhibits an increase in TDS concentrations in the shallow zone in the Proposed Action compared to the No Action with an average TDS increase of about 90 mg/L over the project period compared to 40 mg/L in the No Action. The net increase of 50 mg/L is similar in the Cumulative Impacts. However, the Alternative 2 scenario with the addition of the River Ranch North recharge facility limits the net increase in TDS concentrations in the shallow zone from 50 mg/L to about 20 mg/L over No Action concentrations (**Table 8-7**). In addition, the relative difference in shallow zone TDS concentrations in this subregion is dramatically higher and lower than No Action concentrations (**Table 8-7**). The large relative differences observed between the Proposed Action and Alternative 2 versus the No Action in the West of the Fresno Slough subregion reflects localized variations which, when averaged together, do not result in a large difference on a subregion basis between the Proposed Action and Alternative 2 runs versus the No Action. In the East of the Fresno Slough and the MWA subregions, there is little difference in long-term average concentrations in the shallow zone between all three scenarios under both Existing Conditions and Cumulative Impacts conditions. However, in localized areas within each of those two subregions there are large variations in TDS concentrations in the Proposed Action and Alternative 2 scenarios compared to the No Action. The magnitude of the relative differences are less than those simulated in the West of the Fresno Slough subregion. However, similar to the subregions west of the Pool, these relative differences, when averaged together, do not result in large differences in average concentrations between the Proposed Action and No Action and the Alternative 2 and No Action scenarios

In the deep zone, there is a similar pattern as the shallow zone TDS concentrations when evaluating Project scenarios on a subregion basis. In the subregion East of the Fresno Slough, deep zone TDS concentrations are slightly higher on average in the Proposed Action and Alternative 2 as compared to the No Action (about 50 mg/L higher TDS concentrations). When comparing relative differences in TDS concentrations over the project period between the Proposed Action and Alternative 2 to No Action, there is a large difference of up to 1,500 mg/L increase in TDS to a decrease of almost 200 mg/L TDS in areas within this subregion. However, on an average basis over the project period these relative differences do not result in a large change in the scenarios run under either Existing Conditions or Cumulative Impacts. The subregions West of the Fresno Slough and the MWA, average concentrations are similar between the three scenarios, however, the relative differences between the Proposed Action and No Action and Alternative 2 and No Action are slightly less than observed in the East of the Fresno Slough subregion.

In summary, outside of the shallow zone west of the Fresno Slough and the deep zone east of the Fresno Slough, there is little difference in long term average TDS concentrations between the three scenarios on groundwater quality. The primary and most significant influences on changes to groundwater quality over the 20 year simulation period is not the MPG exchange project but non-MPG influences both within the PSA and model domain and also regionally. The projected long term declines in groundwater quality in the deep zone will likely need to be addressed as part of a larger regional effort by groundwater sustainability agencies (GSAs) to comply with the Sustainable Groundwater Management Act (SGMA) in the Delta-Mendota subbasin and other adjacent subbasins.

10.3 Subsidence

The effect of the MPG exchange program on subsidence in the form of compaction of sediments overlying the Corcoran Clay is extremely small over the 20-year simulation period. The estimated amount of compaction attributed to MPG exchange pumping is equal to or less than current monitoring criteria of 0.005 ft per year on a long term average annual basis. There is a larger amount of compaction associated with non-MPG pumping in all three scenarios.

The amount of compaction that was simulated is extremely small in comparison to historical data on total subsidence which includes compaction occurring below the Corcoran Clay. The effect on infrastructure, such as irrigation canals and the Mendota Dam, from the small amount of compaction associated with MPG exchange pumping in the Proposed Action and Alternative 2 scenarios compared to the total amount of compaction that results without MPG exchange pumping is not known.

The effect of increased groundwater pumping in WWD in the absence of the exchange pumping program is anticipated to result in an incremental increase in subsidence in WWD that is relatively small (less than 5 inches or less than 0.05 ft per year over 20 years) in relation to subsidence resulting from baseline levels of pumping (up to 0.5 ft per year). The qualitative analysis of the influence the additional pumping may have on groundwater conditions in WWD, especially in the form of subsidence, is based on a number of assumptions. These assumptions assume the following:

- Groundwater levels in WWD where MPG wells are located will exceed historic low groundwater levels during the 20-year project period;
- An extended dry period spanning 7 years will occur during the project period during which subsidence will occur;
- Management actions by WWD to address subsidence under SGMA will not be implemented to address subsidence; and
- Wells used to replace the exchanged water are constructed in areas in WWD that are susceptible to subsidence.

10.4 Surface Water Quality

The analysis of surface water quality at the Mendota Dam and at the MWA utilizing project scenario data from the No Action, Proposed Action, and Alternative 2 did not result in producing TDS concentrations at the MWA above the current monthly and annual concentration thresholds, assuming discharge groundwater quality criteria of 1,200 and 1,600 mg/L TDS thresholds and other assumptions of southerly flow and DMC inflows utilized in the analysis do not change. The influence of MPG pumping on TDS concentrations at the Mendota Dam was extremely small and insignificant.

The analysis of surface water quality at the MWA utilizing average and dry year annual conditions over the 20-year project period did not yield results that were dramatically different. The analysis of MWA water quality under low southerly flow conditions representative of some dry year conditions resulted in slightly higher TDS concentrations at the MWA compared to average year conditions. Similar to the average year conditions, the dry year simulation resulted in TDS concentrations at the MWA that were below the existing monthly and annual TDS concentration criteria that is currently in place.

The results of the surface water quality analyses are dependent on many factors that impact the quantity and quality of southerly flow in the Pool to the MWA. These factors are outside the control of the MPG and include DMC water quality, demands for southerly flow through the Pool and into the MWA, and water quality of non-MPG discharges into the Pool and various areas in the MWA.

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